RUSSIAN GEOGRAPHICAL SOCIETY

FACULTY OF GEOGRAPHY,
M.V. LOMONOSOV MOSCOW STATE UNIVERSITY

INSTITUTE OF GEOGRAPHY,
RUSSIAN ACADEMY OF SCIENCES

No. 01 [03]
2010

GEOGRAPHY ENVIRONMENT SUSTAINABILITY

EDITORIAL BOARD

CONTENT

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HISTORY OF FORMATION PALAEODELTAS OF LOWER VOLGA DELTAS

ABSTRACT

The palaeo-Volga River valley existed within the present-day Lower Volga region during the last 600–700 ka. Its lower parts periodically transformed into a long and deep ingressional estuary with the apex location controlled by the amplitude of the Caspian Sea level rise. Between the Early Khvalinian highstand of +50 m and the Early Holocene Mangyshlak lowstand at –100 m, the apex of the Volga Delta has wandered 700 km alongstream. The estuarine-marine and alluvial environments in the ingressional estuary in the area between the present-day cities of Volgograd and Astrakhan, were changing throughout the entire Late Pleistocene and Holocene. The associated succession reflects a complex history of the Caspian Sea level oscillations. Only over the last 16 ka, there have been six marine (estuarine) phases within the Volga-Akhtuba valley correspondent to the Late Khvalinian and Novocaspian transgressions. The transgressions alternated with regressive phases associated with the dominance of alluvial environments in the Lower Volga valley. There are pronounced traces of three transgressive-regressive phase alternations of the Late Khvalinian and Novocaspian ages in the modern Volga-Akhtuba floodplain topography, that correlate with four generations of ancient floodplain and delta surfaces distinguished in this study. Surfaces of different age generations differ in absolute and relative heights, morphological types of floodplain topography, and present-day vegetation.

KEYWORDS: Volga-Akhtuba valley, palaeodelta, ancient floodplain, bay-head delta

INTRODUCTION

The Volga-Akhtuba part of the Volga River valley (downstream from the Volgograd city) is geomorphically different from its upstream parts largely occupied by reservoirs. It is characterized by a well-developed wide floodplain, lack of prominent terraces and a symmetric box-like cross-section shape. The adjacent interfluvial areas of the Early Khvalinian marine accumulation plain have a monotonous even surface with dendritic network of flat-bottomed hollows. Within the Late Khvalinian plain areas, aeolian landforms and Baer's mounds are very widespread characteristic landforms.

Long existence of a complex multi-thread channel system of the Lower Volga River determined the formation of two main surface types within the valley bottom that differ in height, location, morphology and age. These clearly distinguished surface types are: i) *ancient (central) floodplain* and ii) *modern floodplains of the Volga River main channel and the Akhtuba branch;* they can be further subdivided into different generations of local floodplain surface types.

The Lower Volga region is located within the Pricaspian tectonic depression – the largest and deepest within the Russian platform with a folding structure of the Karpinskiy anticline in its far southern part. According to geophysical data, pre-Palaeozoic crystalline basement of the depression is found at depths exceeding 15 km. It is fractured into separated blocks at different elevations. The rocks that compose crystalline basement of the depression mainly belong to the Archaean-Proterozoic metamorphic type and are overlain by sedimentary rocks of the Russian platform mantle that consists of undersalt, oversalt, and superficial structural levels. The undersalt structural level is composed of the terrigenous-carbonate rocks of the Late Palaeozoic that form relatively large platform structures broken by fracture dislocations.

Salt domes are the main structural elements of the Pricaspian tectonic depression sedimentary mantle. They were formed as a result of plastic dislocations of enormous masses of the Kungurian stage (Lower Permian) evaporites which initial strata had a thickness exceeding 4 km. The Lower Volga region has large underground salt bodies that form extensive salt ridges or gigantic domes – Enotaevskiy, Soleno-Zaymichenskiy, etc. The height of salt stocks in such domes reaches 6 to 8 km; they are overlain by Mesozoic or even Neogenic rocks. In the brocken salt domes, such as Inder or Elton, some stocks are open on the surface. The oversalt structural level consists of the Upper Permian and Pleistocene sedimentary rock which is strongly deformed on limbs of salt domes and eroded on top.

The modern valley of the Lower Volga River inherited negative tectonic structures developed at least since the beginning of the Quaternary. The valley section between the Kamyshin and Volgograd cities follows the Volzhsko-Ergeninskiy fracture zone. Its southwestern strike direction coincides with that of the Volgograd flexure and the Bolshoy Volgograd fault. A sharp bend of the valley nearby the Volgograd city – to almost 90° – is associated with the Akhtubinskiy fault of the southeastern strike direction. The Volga-Akhtuba part of the Lower Volga River valley is formed along the two large linear depression structures. In the northern part, it follows the Arzgirskiy depression (down to the Cherniy Yar settlement), farther southward – the Nizhne-Volzhskiy depression. Both of these structures coincide with the deep fracture zone which remained active until the Holocene. Tectonic depressions are superimposed with halokinesis structures such as salt domes Beketovskiy nearby the Volgograd city, Verkhne-Akhtubinskiy at the Akhtuba branch inlet, Kamennoyarskiy, etc. These and other similar active structures cause local deviations of the Lower Volga River valley from its general southern direction and formation of narrowed valley sections. Such influence is often reflected in local characteristics of the Volga River channel morphology and morphometry [Lower Volga River..., 2002; Nikolaev, 1962]. Thus, the Lower Volga River valley formation, geomorphic structure, and channel morphology are largely controlled by tectonic structures and dislocations of the Pricaspian depression crystalline basement. For example, the valley width upstream of Volgograd does not exceed 3–8 km, whereas farther downstream it increases to 30–35 km with local relatively narrower sections up to 12–15 km wide (Fig. 1).

The upper part of the Paleozoic-Cenozoic sedimentary mantle is mainly composed of unconsolidated Upper Pliocene – Quaternary deposits few hundred meters thick. Most of these deposits were formed as marine sediments during the Akchagylian and Apsheronian transgressions. These deposits are dominated by relatively fine sediments (clays and silts) with layers of sand or, less often, marls with basal clays. The Akchagylian and Apsheronian deposits are distinctively characterized by specific macro- and microfossil communities.

The sedimentary mantle is topped with a heterogeneous layer of Quaternary deposits

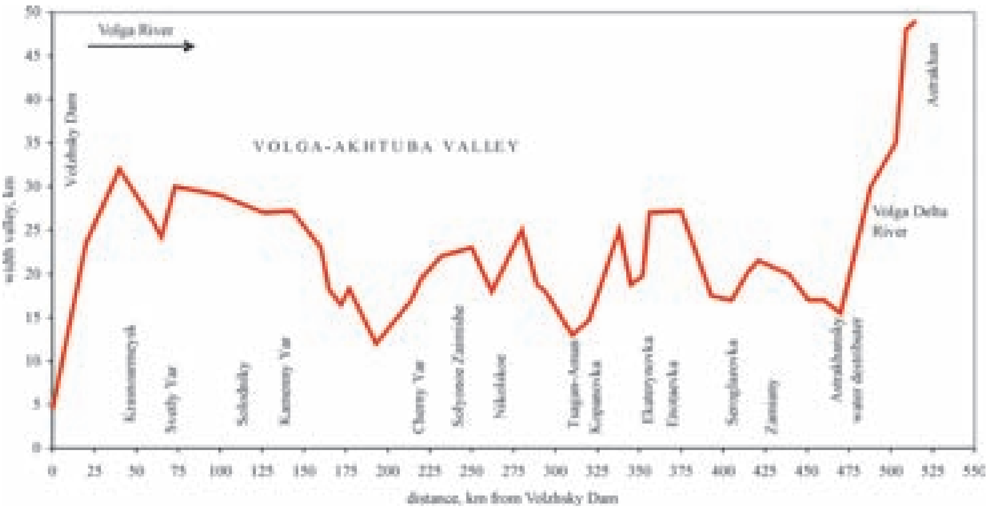

Figure. 1. Width Variability of the Volga-Akhtuba Valley.

exceeding 100 m in thickness. Within this layer, all major subdivisions of the Quaternary system (Lower, Middle, Upper Pleistocene, and Holocene) can be distinguished[1]. Quaternary deposits are dominated by marine sediments formed during the Baku, Lower and Upper Khazarian, Lower and Upper Khvalinian, and Novocaspian transgressions. Significant part of the geological section is represented by heterogeneous non-marine aquatic sediments, i.e., fluvial, lacustrine, lagoon deposits. Aeolian deposits are the most widespread within sediments of non-aquatic environments, though alluvial fan deposits and some other types are also present. For a long period of geological time, the study area has been a territory of continuous migration of the sea-land interaction zone and the Volga River mouth. Such conditions determine the widespread presence of complex origin sediments: fluvial-marine (deltaic), lacustrine-marine (lagoons, *limans, kultuks*), and fluvial-lacustrine (oxbow lakes, *ilmens*). Such deposits often consist of numerous different facies that alternate in both lateral and vertical directions.

The history of the Volga River palaeodeltas formation is closely connected with a general history of the Lower Volga River valley, and, in particular, the Volga-Akhtuba floodplain formation. This complex and long-term process was primarily controlled by river flow variations, the Caspian Sea level oscillation, and tectonic activity.

The aforementioned history of the development of the Volga River valley suggests that a large river system comparable to the present-day valley existed in the Lower Volga region during the entire Late Cenozoic. This system had a continuously migrating mouth and specific landform complexes that have partly remained prominent up to the present time. Review of previously published data [Goretsky, 1966; Rychagov, 1977; Svitoch et. al., 2000, 2004] allowed us to conclude with a high degree of confidence that the Volga River has been draining into the Caspian Sea at least since the Late Neogene (N_2^{ap}). The buried Volga palaeovalleys of the Venedy (Q_1^{vd}), Solikamsk (Q_1^{sk}) and Early Krivichi (Q_2^{kr}) ages have been discovered to the east from the modern Volga valley. The Planforms of these palaeovalleys generally resemble the modern valleys. However, their widths are usually four to five times larger than the widths of modern valleys. This fact suggests that in the past, the palaeo-Volga

[1] In this paper, authors use the Russian stratigraphic subdivisions. Lower and Middle Pleistocene of the Russian scale correspond to Middle Pleistocene of the International stratigraphic scale.

River discharges were significantly greater compared to the present. As it was already stated above, a relatively poor preservation of old alluvial successions in geological sections, does not permit a detailed determination of palaeodelta locations. The task becomes even more difficult when one takes into account their active migration up- and downstream the palaeo-Volga valleys following the sea level oscillations.

One of characteristic features of the Volga River mouth dynamics during the Late Pleistocene and Holocene is a poor preservation of palaeodeltas due to sea regressions. Traces of such palaeodeltas were discovered in the Caspian Sea shelf geological structure by M.Yu. Lohin and E.G. Maev [1990]. These paleodeltas are represented by wedge-shaped depositional bodies located at depths of 40–25 m and

dated to the (Q_3^{at}) and Enotaevsk (Q_3^{en}) ages. Palaeodeltas of later ages, for example those that correlated with the Mangyshlak regression, have not been discovered so far. This may be the consequence of an important geomorphic event correlated with the Late Khvalinian Sea existence – formation of the abovementioned specific landforms – sandy ridges that form the basis of the Baer's mounds landscape formation. The Baer's mounds landscape is traced on both sides of the modern Volga-Akhtuba valley from the coastline remnants near the Nikolskoe settlement correlated with maximum stage of the Late Khvalinian transgression, to almost the seaward edge of the modern Volga River delta.

PLEISTOCENE HISTORY OF THE VOLGA RIVER PALAEODELTAS

First geological traces of the palaeo-Volga valley found in the North Pricaspian region are dated to the Middle Pliocene. Deep coring program discovered a large buried palaeovalley incised 300–500 m into the Cretaceous-Palaeogene bedrock to the east from the modern Volga River valley. It is partially infilled with the gravels, pebbles, sands and clays of the Kushumskaya succession and is traced from western slopes of the Obshiy Syrt upland to the Baskunchak Lake and farther south. All researchers correlate the Kushum succession deposits with the Kinel succession deposits found in similar buried valleys of the Middle Volga region. The ancient drainage network of this region and associated deposits identified as the Kinel succession, were first distinguished and described by A.N. Mazarovich in 1936 and have been by now studied in details. It has been suggested that the Akchagylian (Kinel) age palaeo-Volga delta was located far to the south from the modern delta within the Caspian depression and flowed into a closed water body – the Balakhany Basin.

Numerous evidence of existence of a few palaeo-Volga valley incisions has been found in the Pleistocene deposits of the Lower Volga region. Deep coring carried out by the Hydroproject Institute [3] and geological sections of the modern Volga River valley [Goretsky, 1966] allowed to distinguish the abovementioned deposits of the Venedy, Singil, Lower Krivichi successions, and succession of the Cherniy Yar sands and Atel age deposits. These deposits are represented by a variety of freshwater sediments that contain shells of the freshwater mollusks *Lithoglyphus caspicus, L. naticoides, Dreissena polymorpha, Valvata piscinalis, Viviparus duboisianus, V.viviparus, Unio tumidus, U. pictorum, Pisidium amnicum, Sphaerium rivicola, Sph.corneum, Planorbis planorbis etc.* The deposits are dominated by material of the active channel alluvial facies, proving the existence of the large palaeo-Volga River valley during the Pleistocene. However, almost no traces of deltas corresponding to these river systems have been found there. On the other hand, within the geological section of the modern Volga delta there are no ancient alluvial deposits older than Atel age sands. Thus, it is possible that the Venedy and Cherniy Yar valley deltas were located upstream from the Astrakhan city.

The palaeo-Volga mouth may have been submerged and had landscapes morphologically similar to the modern Dnieper-Bug and Dunay limanes during the Singil (past-Baku) and Early Krivichi (pre-Early Khazarian) ages. The Singil age deposits are widespread within the Lower Volga River valley and Western Pricaspian region. They contain abundant remnants of vegetation (*Selaginella selaginoides, Azolla interglacialica, Salvinia patens*) and freshwater mollusks (Unio *cf. pictorum, Viviparus duboisianus, Pisidium amnicum, Sphaerium rivicola, Valvata piscinalis, Planorbis planorbis, Theodoxus sp., Dreissena polymorpha etc.*). These data suggest that the formation of these deposits occurred under conditions of slow sedimentation in tranquil waters of vast stagnant or semi-flowing water bodies. The Early Krivichi age alluvial sands overlay the Singil age deposits, proving a deepening regression of the Caspian Sea during that period. There is no reliable information on the spatial pattern of the Krivichi age drainage network in the Lower Volga region. As suggested by G.I. Goretskiy [1966], the palaeodelta of that time was located to the west from the modern Volga River valley, near the present-day Ergeni upland. However, most likely the location of the Krivichi age delta during the deep pre-Khazarian regression of the Caspian Sea was at the southern margin of the North Caspian.

In the Volga River valley section between the Raigorod and Nikolskoe settlement, polyfacial alluvial deposits of the Cherniy Yar succession are widespread. They overlie the erosional unconformity of the Lower Khazarian or Singil deposits. The stratotype of the Cherniy Yar succession has been described in the Cherniy Yar – Nizhnee Zaimishe geological section. Lithologically it is mainly represented by active cross-stratified channel sands, containing numerous bone remnants of large mammals of the Khazarian palaeofauna. Its age is usually attributed to the middle part of the Middle Pleistocene. The stratigraphic position and altitude of the Cherniy Yar succession sands, characteristic fauna remnants, and lithological properties suggest that these deposits were formed in a large river channel during the middle-end of the Middle Pleistocene. The palaeoriver mean low-water level coincided with that of the modern Volga River, or was slightly higher.

Another generation of the palaeo-Volga River delta existed in the Lower Volga region during the Middle Pleistocene. This statement is supported by analysis of the geological section near the Seroglazovka settlement, where alluvial sands of the Cherniy Yar succession change laterally into deltaic deposits correlated with the Late Khazarian Sea level (deposits with Didacna surachanica). The Cherniy Yar and Singil succession alluvial and deltaic deposits of the palaeo-Volga River are correlated with relatively low-amplitude “warm” transgressions of the Caspian Sea (the Late Khazarian and Urundzhik, respectively). These deposits are characterized by diverse palaeontological findings, including freshwater mollusk shells (*Unio pictorum, Viviparus duboisianus, Valvata piscinalis, Lithoglyphus cf. naticoides, Bithynia tentaculata, Planorbis planorbis, Theodoxus sp., Dreissena polymorpha, etc.*), which proves the presence of clear warm flowing water bodies within palaeovalleys at that time.

The existence of the Atel age palaeo-Volga valley is proven by delta deposits of the same age discovered along the boundary between the Northern and Southern Caspian Sea. Later, during the Early Khvalinian transgression maximum, the sea covered the entire territory of the Pricaspian lowland to the north from the Kamyshin city. The submerged palaeo-Volga valley of that period was represented by a narrow and long estuary stretched to approximately 500 km, as far upstream as to the Samarskaya Luka. It was filled with relatively cold slightly saline waters. The depth of the estuary exceeded 40 m. The so-called “chocolate” clays with rare molluscs of the slightly brackish type fauna (Monodacna caspia, Hypanis plicatus) were deposited in its relatively stagnant waters, mainly from suspended sediment delivered by the river. It is believed that the coarser material represented by the palaeo-Volga bedload sediment was deposited farther to the north.

The Early Khvalinian Sea regression was marked by high-amplitude sea-level fluctuations that resulted in the formation of the stadial terraces at altitudes of 20–22 m, 14–16 m and 4–6 m. Following the retreating sea, the palaeo-Volga River inherited not only its pre-Khvalinian valley. The Sarpinskaya and Davan depressions that formed at the same time are still prominent in the modern topography.

During the Enotaevsk regression, the Lower Khvalinian deposits were subject to intensive erosion. Incision took place both within the Pricaspian lowland and in the land areas to the south which are, at present, occupied by the Caspian Sea. The period of erosion is evident from the sharp and uneven upper boundary of the "chocolate" clays observed in cores taken from the present-day Caspian Sea bottom. Erosional dissection of the

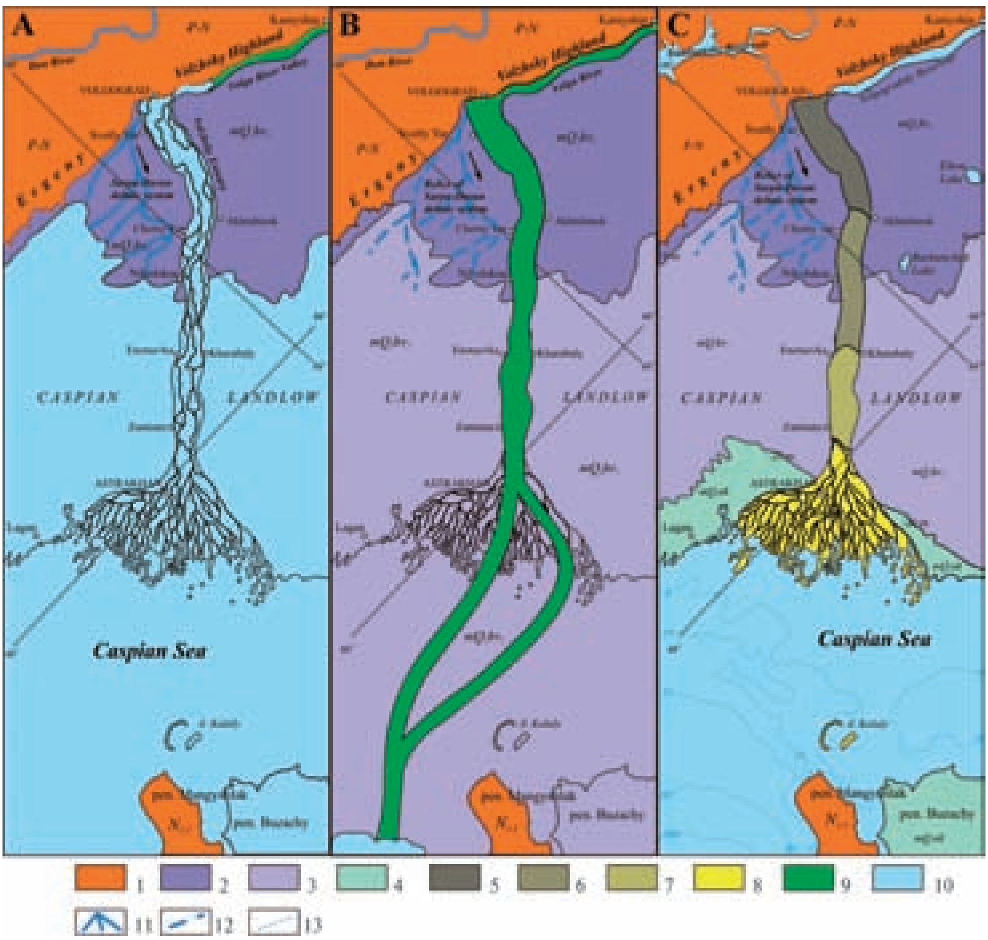

Figure 2. The history of the Lower Volga palaeodeltas formation and their position in the Volga-Akhtuba Valley. A – Maximum stage of the Late Khvalinian transgression (0 m BSL), B – Maximum stage of the Mangyshlak regression (-100 m BSL (i.e, Baltic System Level). C – Recent stage of formation the Volga Delta. 1 – Highland accumulative-denudation, 2 – Marine accumulative plane of Early Khvalinian, 3 – Marine accumulative plane of Late Khvalinian, 4 – Marine accumulative plane of Novocaspian, 5 – Floodplane Makhachkala of Late Khvalinian (17–12 ka, –3–(–9) m BSL), 6 – Floodplane Turali of Novocaspian (9–5 ka, –9–(–18) m BSL), 7 – Floodplane Ulluchay of Novocaspian (4–1,5 ka, –18–(–23) m BSL), 8 – Recent Volga Delta and marine islands (less 1 ka, –25–(–27) m BSL), 9 – Volga Channel of the Late Khvalinian, 10 – water surface, 11 – river systems, 12 – relict river systems, 13 – isobaths.

Early Khvalyn plain during the Enotaevsk regression determined the complicated coastline configuration of the Late Khvalinian Sea.

During the Late Khvalinian transgression maximum, there was a funnel-shaped bay in the palaeo-Caspian Sea at the Sarpa-Davan depression mouth (Fig. 2-A). The Ural River flowed into the estuary. Bays also existed in the mouths of the Bolshoy and Maliy Uzen, Uil, Sagiz, and Emba rivers. In the Volga River valley, the Late Khvalinian Sea bay apical part was located between the present-day Kamyshin and Volgograd cities. Such a planform of the sea coastline determined specific hydrodynamic conditions in the coastal zone. The interaction of oppositely directed hydraulic and surge currents favoured the formation of accumulative underwater landforms in the coastal zone of the Late Khvalinian Sea. These landforms were similar to sand ridges widespread on shelves of many present-day seas. Another condition necessary for the development of such landforms was a substantial amount of sediment delivered by rivers as a result of erosion of the older marine deposits. Such sandy ridges commonly develop at bay and gulf outlets, along open coastlines with significant tidal amplitude, in shallow marginal seas, and in river deltas and estuaries. We suggest that these depositional landforms (i.e., sandy ridges) formed a basis for the modern Baer's mounds landscape topography. Despite certain discrepancies in the Baer's mounds distribution areas distinguished by different authors, one fact is undisputable: all such landforms are located within the territory that was subject to the Late Khvalinian transgression. Moreover, they are mostly associated with the zones of palaeodeltas and estuaries of the rivers flowing into the Late Khvalinian Sea [Kroonenberg et. Al., 1997, 2008; Rychagov, 1977; Varushchenko et. Al., 1987].

The Early Khvalinian marine plain experienced substantial relief transformations during the Late Khvalinian Sea transgression. The Sarpinskaya depression was once again filled with a river flow. The interfluves between the Volga valley and Sarpinskaya depression and areas to the east from the present-day Volga-Akhtuba valley were dissected by a system of incised deltas. The latter are still prominent in the modern relief. Similarly to the Early Khvalinian period, the Late Khvalinian Sea retreat was interrupted by relatively limited transgressive phases. These events resulted in formation of coastlines which remnants can be traced on altitudes of –5–(–6) m (Kuma phase), –11–(–12) m (Sartassk phase), –16–(–18) m (Dagestan phase), and –30–(–32) m (Samur phase).

HOLOCENE BAY-HEAD PALAEODELTAS OF THE VOLGA-AKHTUBA VALLEY

The beginning of the Late Khvalinian Sea regression corresponds to the formation of the first terrace (Sarpa terrace, 14–17 ka) that currently exists in the modern Volga River valley (Fig. 2-B). Although this terrace is not prominent in the modern topography, its fragments can be observed near the Vyazovka and Staritsa settlements on the right side of the Volga-Akhtuba, as well as near the Leninsk city, Sokrutovka settlement, and in some other locations on the left side of the valley. It is probable that the Lower Volga River channel dichotomy formation also took place at that period of time. Two quasi-independent watercourses (the Volga main channel and Akhtuba branch) have most likely inherited two main branches of the Late Khvalinian estuary infill (Volgograd) delta. The larger and most active right branch gave rise to the modern Volga River main channel, while the left branch that followed the Akhtubinskiy fault structure, later developed into the Akhtuba branch. The geological structure of the Volga-Akhtuba valley (closely connected with the Volgogradskiy fault and the Verkhne-Akhtubinskaya anticline) is an example of tectonic control over the valley's direction. The tectonic structure has also determined the bifurcation of the Volga River channel, specifically, the anticline represented by a crest-like fold of the Maikop age clays [Goretsky, 1966]. Within ancient deltas

(Akhtubinskaya and younger), these two main branches remained closely interconnected by numerous secondary channels. However, as deltas gradually migrated downstream following the retreating sea, the branches became more and more separated. This process remained relatively continuous along many stages of the Astrakhan-Volgograd estuary infill and eventually gave rise to the modern anastomosing pattern of the Lower Volga River channel. The Volga-Akhtuba floodplain was formed by geomorphic activity of both the Volga River main channel and the Akhtuba branch.

An analysis of available aerial and satellite images, and topographic and geological data allowed us to reconstruct the last stages of the Astrakhan-Volgograd ingressional estuary infill by the Volga River sediment, which took place during the Late Pleistocene and Holocene since the Late Khvalinian transgression. The geomorphological structure of the Volga-Akhtuba floodplain is not uniform. As discussed above, it consists of: i) the modern floodplains of the Volga main channel and the Akhtuba branch; and ii) the ancient floodplain represented by sections of four different generations consecutively alternating downstream (Fig. 2-C). The modern floodplain is stretched along the Volga and Akhtuba channels. It is characterized by depression-island (the Volga main channel) or segmented-ridge (the Akhtuba channel) primary topography. Different generations of the ancient floodplain located between the Volga main channel and the Akhtuba branch occupy more than 80% of the entire Volga-Akhtuba floodplain area. These elements can be distinguished by their structure and morphology. Both modern and ancient floodplain surfaces have similar relative elevations over the mean low-water level. However, it must be noted that overlain levees of the modern floodplain are commonly about 1 m higher than surfaces of ancient floodplain generations [Bolikhovskaya, 1990; Estuarine-deltaic systems of Russia and China..., 2007; Geology of the Volga River Delta, 1951; Korotaev, and Chernov, 2000, 2001; Li C.X. et. al., 2004; Lower Volga River..., 2002; Nikolaev, 1962].

Alternation of the estuarine-marine and alluvial environments has taken place in the

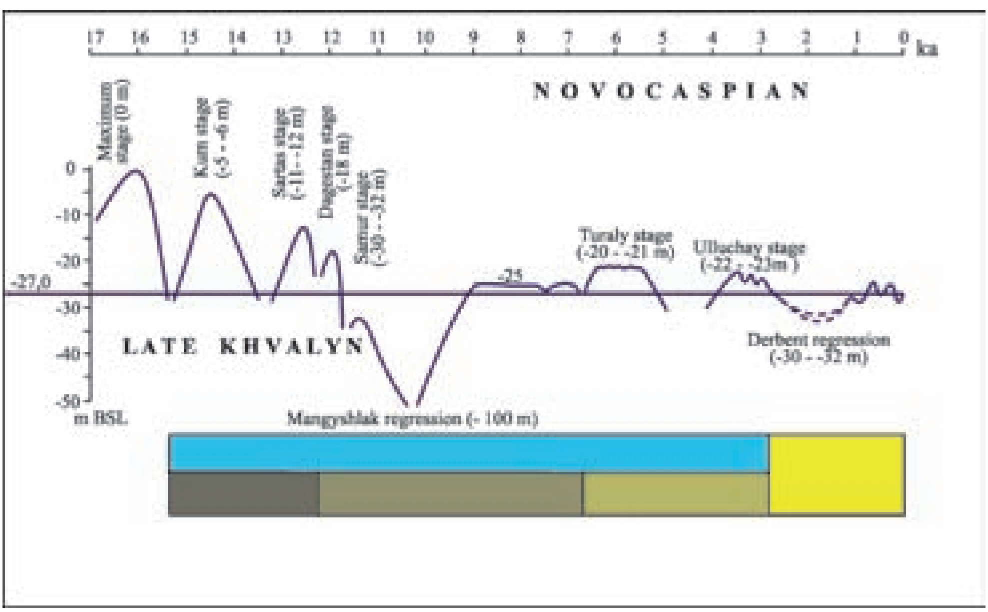

Figure 3. The diagram of changes in the Caspian Sea-level during Late Pleistocene – Holocene and the main period of formation of the Volga-Akhtuba floodplain [after G.I. Ruchagov, 1977]

ingressional estuary between the present-day Volgograd and Astrakhan cities during the entire Late Pleistocene and Holocene. This succession reflected a complex history of the Caspian Sea level oscillations. Only over the last 16 ka, there were six marine (estuarine) phases within the Volga-Akhtuba valley correspondent to transgressive phases of the Late Khvalinian and Novocaspian ages (Fig. 3). These events alternated with regressive phases associated with the dominance of alluvial environments in the Lower Volga valley.

The Late Khvalinian transgression was followed by the Mangyshlak regression when the sea level retreated to about –100 m BSL. The Volga River delta was then located at the boundary between the northern and central parts of the modern Caspian Sea. As a result, the Volga River channel incised deeply and partly eroded the Khvalinian transgression deposits forming two main channels at the location of the present-day Volga River delta. The entire post-Khvalinian time, Volga River discharge was passing through these two branches.

The beginning of the Novocaspian transgression was accompanied with the depositional infill of deep Volga River incisions formed during the Mangyshlak regression and simultaneous erosion of the Baer's mounds by wave action. The Caspian Sea level grew to –25 m BSL during the first phase of the Novocaspian transgression and further reached –20 m BSL during the maximum phase (the Turali stage). A relatively small marine bay existed in the Volga River valley to the north from the present-day location of the Astrakhan City during the Turali stage of the Novocaspian transgression. At the same time, the Novocaspian transgression deposits filled the depressions between the Baer's mounds and the Mangyshlak regression incisions at the present location of the Volga River delta downstream from the Astrakhan City. The formation of the Zamyanskiy section of the Volga-Akhtuba floodplain and the bifurcation of the main channel at the present outlet of the Buzan branch took place at that time. The Turali stage of the Novocaspian transgression was followed by a relatively prolonged but limited in amplitude regression. During that period, both the Volga main channel and the Akhtuba branch returned into the incisions formed during the Mangyshlak regression.

The second stage of the modern Volga River delta formation and its geomorphic evolution was associated with the Ulluchay phase of the Novocaspian transgression (3,0–2,5 ka BP) when the Caspian Sea level rose up to –23–(–24) m BSL and Active deposition of the *kultuk-ilmen* (lacustrine-marine and fluvial-lacustrine) sediment facies took place. Currently, these deposits are widespread over the entire area of the modern Volga River delta. Predominantly fine silt-clay sediment composition and numerous findings of freshwater mollusks remnants (*Planorbis planorbis, Unio tumidus, Valvata piscinalis, Dreissena polymorpha*) indicate that sedimentation occurred mainly in fresh (or less frequently brackish) stagnant water bodies with calm and stable sedimentary conditions. Lithological characteristics of the *kultuk-ilmen* deposits are substantially different from those of the avandelta (distal part of a delta submerged by shallow sea waters up to 15 m deep) deposits. However, no prominent traces of sedimentation discontinuity are observed between these parts of the delta. It can therefore be concluded that the regression separating the two peaks of the Novocaspian transgression was limited in amplitude and did not cause significant incision of the deltaic watercourses. The main branches of the present-day Volga-Akhtuba valley – the Volga main channel, and Buzan, Bushma, Kigach, and Akhtuba – have already existed in the delta upper part during that period of time. They inherited existing incisions and separated the deltaic plain into large lowland islands. Thus, the second stage of the Novocaspian transgression was characterized by the continuing development of the estuary infilling delta and the onset of the formation of advancing delta.

The Ulluchay stage of the multiphase Novocaspian transgression was followed by the Derbent regression when the Caspian Sea level fell to –32 m BSL. This event triggered a new stage of the Volga River delta evolution, specifically, the onset of the advancing delta formation beyond the area of Baer's mounds development. Later on, insignificant sea level fluctuations caused a number of changes of the delta planform and patterns of its branches. Nevertheless, traces of two large palaeo-branches occupying the main incisions formed during the Mangyshlak regression remained prominent in the Volga River delta topography until the early 20th century as the Sinee Mortso Bay (at the ancient Buzan branch location) and the Zelenginskiy Bay (at the ancient Bushma branch and the Belinskiy bank location). After the Derbent regression the Caspian Sea level has never risen above –25 m BS.

The modern stage of the Volga River delta evolution generally coincides with the history of the regional geomorphological development that has been marked by greater contribution of fluvial processes that formed channel-floodplain landform complexes (floodplain, channel, natural levees, etc.). They were controlled by hydrological regime which played a dominant role in the delta morphology transformations. As a result, the alluvial-deltaic sedimentation regime now prevails over most of the delta, while the *kultuk-ilmen* (lacustrine-marine and fluvial-lacustrine) and avandelta sedimentation regimes are limited to only distal parts of the delta.

CONCLUSION

There is sufficient evidence that the palaeo-Volga River valley existed within the present-day Lower Volga region during the last 600–700 ka. Its lower parts were periodically transforming into a long and deep ingressional estuary with the apex location controlled by the amplitude of the Caspian Sea level rise.

There are pronounced traces of four transgressive-regressive phases of the Late Khvalinian and Novocaspian ages in the modern Volga-Akhtuba floodplain topography that correlate with three generations of ancient floodplain and delta surface types identified in this study. The surfaces of different age generations vary in absolute and relative heights, morphological type of floodplain topography, and modern vegetation.

During the transgressive phases, the lower parts of the valley located below the arisen sea level became filled with slightly saline waters, flowing slowly seaward. Relatively gradual and continuous sedimentation occurred on the estuary bottom under such limane-like conditions. This finer sediment became settled by marine fauna. During the regressive phases, the palaeo-Volga followed the falling sea level, incising into previously deposited layers of marine and lagoon sediment. This sediment was later reworked and redeposited as alluvial material usually separated into active channel and floodplain facies during floodplain formation. The depth of the palaeo-Volga channel incision during the Caspian Sea regressions did not exceed 20–25 m. A very shallow coastal zone with extremely low seaward gradients did not favor the development of deeper incisions. Under such conditions, the base level drop cannot be followed by a substantial channel incision. That is why only remnants of the oldest alluvial successions lying deeper than 20–25 m under the present-day Volga River mean low-water level, are preserved in geological sections of the modern Volga-Akhtuba floodplain. These remnants are overlain by the Holocene alluvial sediment which underwent multiple reworking during the past Caspian Sea regressions.

ACKNOWLEDGEMENTS

This research work was supported by the Russian Foundation for Fundamental Research (Grant no. 07-05-00525). ■

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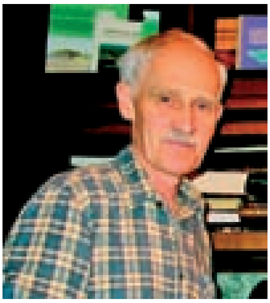

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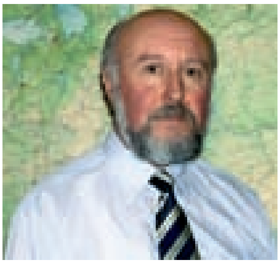

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CLIMATOLOGY OF THE BRUNT-VÄISÄLÄ FREQUENCY OVER MILAN, ITALY

ABSTRACT

In this paper we investigate the spatial and temporal variability of *N* over the city of Milan, using the historical record of soundings in the period 1991–2007, using 00GMT and 12GMT soundings and performing evaluations at intervals 300–700 m, 800–1800 m, 1500–2500 m, (00GMT only) and 2500–3500 m, 3000–4000 m, 4000–5000 m, 7000–8000 m (both 00GMT and 12GMT).

The values obtained reveal that the Brunt-Väisälä frequency is subject to a moderate change with height over the entire observation period, and once the height is fixed shows only weak seasonal changes. At the height interval 1500–2500 m, the maximal values of *N* are observed between December and January, whereas from April to September smaller values of *N* represent a flat plateau. These variations generally decrease with increasing height. They are still recognizable in the interval 2500–3500 m, and fully diminish at 7000–8000 m.

KEY WORDS: Brunt-Väisälä frequency, free atmosphere, static stability

INTRODUCTION

The Brunt-Väisälä frequency, *N*, defined as $N^2 = \frac{g}{\theta_v}\frac{\partial \theta_v}{\partial z}$ (where z the height, θ_v the virtual potential temperature, and u_* the friction velocity), quantifies the static stability of the atmosphere.

This paper investigates the time variation of the Brunt-Väisälä frequency over the area of Milan on period 1991–2007, for which easily accessible low-resolution soundings are available.

The types of time variation addressed are the average seasonal change referred to the whole period considered, and changes in yearly average.

Provisions have been taken to prevent and avoid, in the limits possible, perturbations due to PBL dynamics.

DATA AND METHOD

Data used in this work are low resolution soundings taken at the Linate airport (16080 LIML, lat. 45°27'N, lon. 9°16'E, 4 km E of Milan), as available from the Wyoming University download facility.

The time period considered spans 1991 to 2007. In this interval, sounding are available at standard hours 00GMT, 06GMT, 12GMT and 18GMT. Of these, profiles 06GMT and 18GMT are not always present and have then not been considered. At site longitude, 00GMT is always nighttime, and 12GMT daytime.

Direct use of sounding data to estimate the Brunt-Väisälä frequency is not possible due to measurement errors and other perturbations. Then, individual profiles have been fitted by monotonic cubic splines whose value has been sampled at the ends of a family of height intervals (300–700 m, 800–1800 m, 1500–2500 m, 2500–3500 m, 3000–4000 m, 4000–5000 m, 7000–8000 m). Interval Brunt-Väisälä frequency has then been estimated from these samples using the first order difference approximation $N^2 = \frac{g}{\theta_v}\frac{\Delta\theta_v(z)}{\Delta z}$.

On 12GMT, estimates of the Brunt-Väisälä from height intervals 300–700 m, 800–1800 m and 1500–2500 m have been excluded to prevent contamination from PBL dynamics. On 00GMT data from intervals 300–700 m and 800–1800 m have been used for checking purposes and not used to draw conclusions, as their value is likely to reflect PBL dynamic properties inherited through the residual layer.

The actual cubic spline fitting has been done using the routine CUBGCV [Hutchinson, 1986], which per se does not guarantee the monotonicity of the fitting function. Individual fitted profiles have then been evaluated in the useful range (300 m to 8000 m) and any non-monotonic item has been removed. This approach is actually more severe than imposing monotonicity constraint during spline identification, and has been used to reduce the opportunity of ill-behaved profiles to contaminate the statistics. Of the 20135 total profiles considered, 5049 yielded non-monotonic splines and have been consequently discarded.

The surviving profiles have then been evaluated at experimental height levels, and the absolute difference between experimental and estimated temperature values have been inspected.

At end of these computing, a data set containing values of *N* relative to the height intervals mentioned has been constituted, with contamination from PBL dynamics reduced as possible. Data in set are time stamped with date and time (00 and 12GMT), allowing separation of nocturnal and diurnal estimates.

Various time averages have then been formed starting from the data set, namely:

- Whole data set and yearly average and standard deviation of *N* data with same reference hour (00 or 12GMT)
- Bootstrap estimate of the 95% confidence limits on period and yearly averages of *N* data with same reference hour (00 or 12GMT)
- "Typical year" of *N* data with same reference hour (00 or 12GMT) from the whole data set.

RESULTS

The averages of mean and maximum absolute difference between experimental and estimated temperature have been found respectively equal to 0.59 and 1.76 K for profiles at 00GMT and 0.56 and 1.70 K at 12GMT. The corresponding empirical density functions at 00GMT are shown in figure 1.

The average absolute residual is close to the 0.5 K error selected when performing the data interpolation, even after the non-monotonic profiles have been excluded from the data set. If per-radiosounding maxima of absolute residuals are considered, the value of their average does not exceed 2 K. Both mean and maximum absolute deviations are small respect to the typical temperature variation along the height range 300-8000m, and suggest a good visual adaptation of the smooth reconstructed profiles to the experimental data.

In figure 2, two specific examples of reconstructed profiles are shown along with the corresponding experimental radio sounding points. The good adaptation suggested by residuals is confirmed by visual inspection; the problem with low resolution radio soundings available for public download is also evident, the number and position of experimental data points being remarkably non-uniform from sounding to sounding, and widely spaced

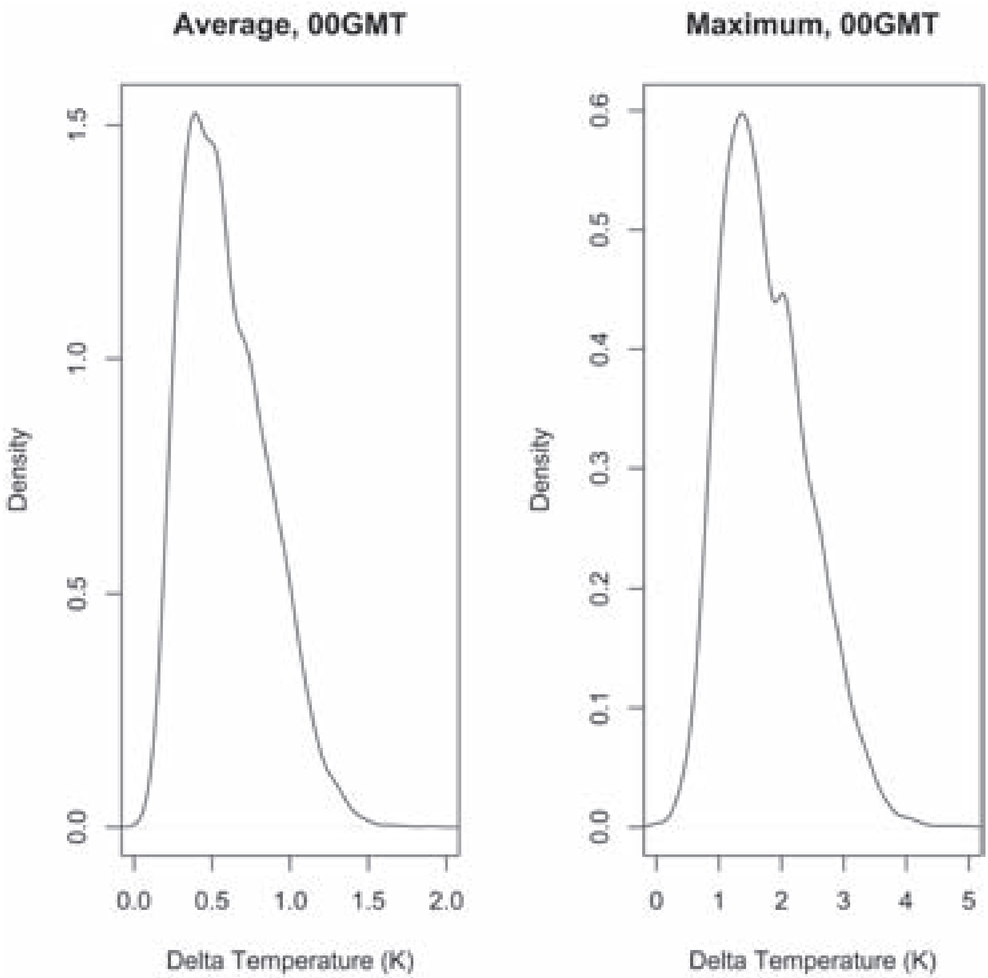

Figure 1: Empirical densities of average and maximum absolute residuals on 00GMT

along the vertical even close to ground in some instances. This may make difficult using directly these data for further more detailed analyses, namely detecting by visual means the height of the PBL to exclude boundary-layer affected evaluation in a more sophisticated manner.

Table 1 presents the period average of the Brunt-Väisälä frequency at different height intervals. The error values represent the maximum deviation of the average from lower and upper limits of the respective 95% confidence interval, obtained using bootstrap method. Individual standard deviations are also shown, to present the overall variability of the data set.

Table 2 shows the yearly average and standard deviation of Brunt-Väisälä frequency for the height intervals 1500–2500, 2500–3500 and 7000–8000 meters. All averages and standard deviations are computed using only 00GMT soundings. Averages are given with error values defined as the maximum shifts from the lower and upper limits of 95% confidence limits obtained using the bootstrap method.

Figures 3 and 4 illustrate the seasonal changes in the Brunt-Väisälä frequency, using the 00GMT soundings over the entire observational period. Figure 3 presents the 1500–2500 m data via a box-plot summarizing the monthly empirical distributions; and

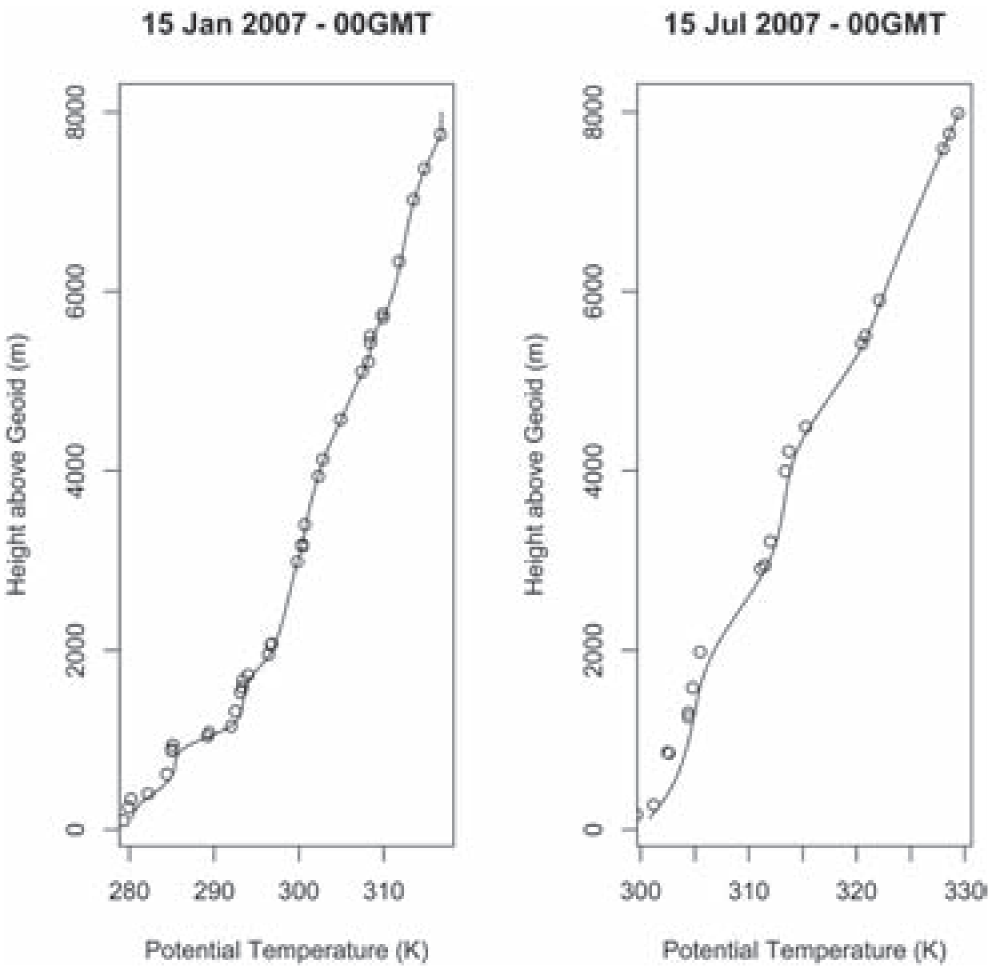

Figure 2: Example of vertical profiles of temperature

figure 4 compares the monthly means from the two height intervals 1500–2500 and 7000–8000 m; the variation bars in figure 4 represent the monthly standard deviations over the whole data period (1991–2007).

DISCUSSION

The data presented show a modest tendency of the period-averaged *N* to decrease with increasing height (for convenience, the height is attributed to the lower limit of each interval). The pattern observed is

Table 1: Period averages of the Brunt-Väisälä frequency

$\overline{N}$	00GMT		12GMT	
	Mean	Standard deviation	Mean	Standard deviation
300–700 m	0.0136 ± 0.0002	0.0041	n/a	n/a
800–1800 m	0.0105 ± 0.0001	0.0036	n/a	n/a
1500–2500 m	0.0110 ± 0.0001	0.0035	n/a	n/a
2500–3500 m	0.0109 ± 0.0001	0.0031	0.0116 ± 0.0001	0.0029
3000–4000 m	0.0111 ± 0.0001	0.0030	0.0115 ± 0.0001	0.0026
4000–5000 m	0.0111 ± 0.0001	0.0028	0.0108 ± 0.0001	0.0028
7000–8000 m	0.0089 ± 0.0002	0.0043	0.0087 ± 0.0002	0.0056

Table 2: Yearly $\overline{N}$ at 00GMT

Year	1500–2500 m		2500–3500 m		7000–8000 m	
	Mean	Std. dev	Mean	Std. dev	Mean	Std.
1991	0.0115 ± 0.0005	0.0034	0.0112 ± 0.0003	0.0030	0.0088 ± 0.0003	0.0025
1992	0.0115 ± 0.0005	0.0033	0.0111 ± 0.0003	0.0029	0.0084 ± 0.0003	0.0023
1993	0.0113 ± 0.0004	0.0035	0.0108 ± 0.0003	0.0030	0.0089 ± 0.0003	0.0029
1994	0.0111 ± 0.0004	0.0031	0.0106 ± 0.0004	0.0031	0.0092 ± 0.0006	0.0058
1995	0.0110 ± 0.0004	0.0033	0.0109 ± 0.0003	0.0031	0.0090 ± 0.0004	0.0033
1996	0.0113 ± 0.0004	0.0036	0.0113 ± 0.0003	0.0031	0.0087 ± 0.0003	0.0027
1997	0.0112 ± 0.0004	0.0031	0.0108 ± 0.0003	0.0027	0.0093 ± 0.0007	0.0050
1998	0.0110 ± 0.0003	0.0031	0.0112 ± 0.0003	0.0029	0.0099 ± 0.0013	0.0068
1999	0.0107 ± 0.0004	0.0032	0.0107 ± 0.0003	0.0028	0.0096 ± 0.0010	0.0062
2000	0.0109 ± 0.0003	0.0030	0.0110 ± 0.0003	0.0029	0.0089 ± 0.0005	0.0045
2001	0.0107 ± 0.0004	0.0033	0.0110 ± 0.0003	0.0028	0.0089 ± 0.0004	0.0044
2002	0.0107 ± 0.0003	0.0030	0.0109 ± 0.0003	0.0026	0.0081 ± 0.0005	0.0030
2003	0.0105 ± 0.0005	0.0033	0.0108 ± 0.0003	0.0031	0.0089 ± 0.0005	0.0047
2004	0.0107 ± 0.0004	0.0033	0.0106 ± 0.0004	0.0026	0.0088 ± 0.0004	0.0033
2005	0.0112 ± 0.0006	0.0058	0.0109 ± 0.0005	0.0057	0.0091 ± 0.0006	0.0059
2006	0.0108 ± 0.0004	0.0034	0.0107 ± 0.0003	0.0027	0.0079 ± 0.0006	0.0029
2007	0.0106 ± 0.0004	0.0032	0.0107 ± 0.0003	0.0028	0.0083 ± 0.0003	0.0025

independent on the choice of the sounding hour (00GMT or 12GMT).

By analyzing the yearly averages of *N* it can be noticed that the changes are small. At 1500 m the minimum value occurred in the year 2003, characterized in Northern Italy by the warmer summer in the whole period considered. However, the relation between *N* and the yearly average surface temperature in Linate has not been investigated, and may be the subject of future work.

Comparing the yearly variation of *N*at 1500m to other altitudes, it can be noticed the latter's present a smoother behavior, with fluctuations on a longer time scale. The minimum Brunt-Väisälä frequency at 2500 m (respectively 7000 m) occurred on 2005 (respectively 2007).

The monthly variation in the Brunt-Väisälä frequency at 00GMT exhibit a seasonal dynamics (figure 3), characterized by a maximum in December and January waning out to a lower plateau from April to August.

This dynamics, still evident at 2500–3500 m, is not evident at 7000–8000 m (figure 4), where an almost constant behavior manifests.

At all altitudes investigated, however, the seasonal variation of monthly values taken at 00GMT is in the same order of magnitude of monthly variation. In figure 3 the bands from 25th to 75th percentiles shows a strong variability in monthly data. The variation bars in figure 4 further confirm this. In order to clarify this point in a definitive manner, analysis of 00GMT high resolution sounding data on a longer period may be necessary.

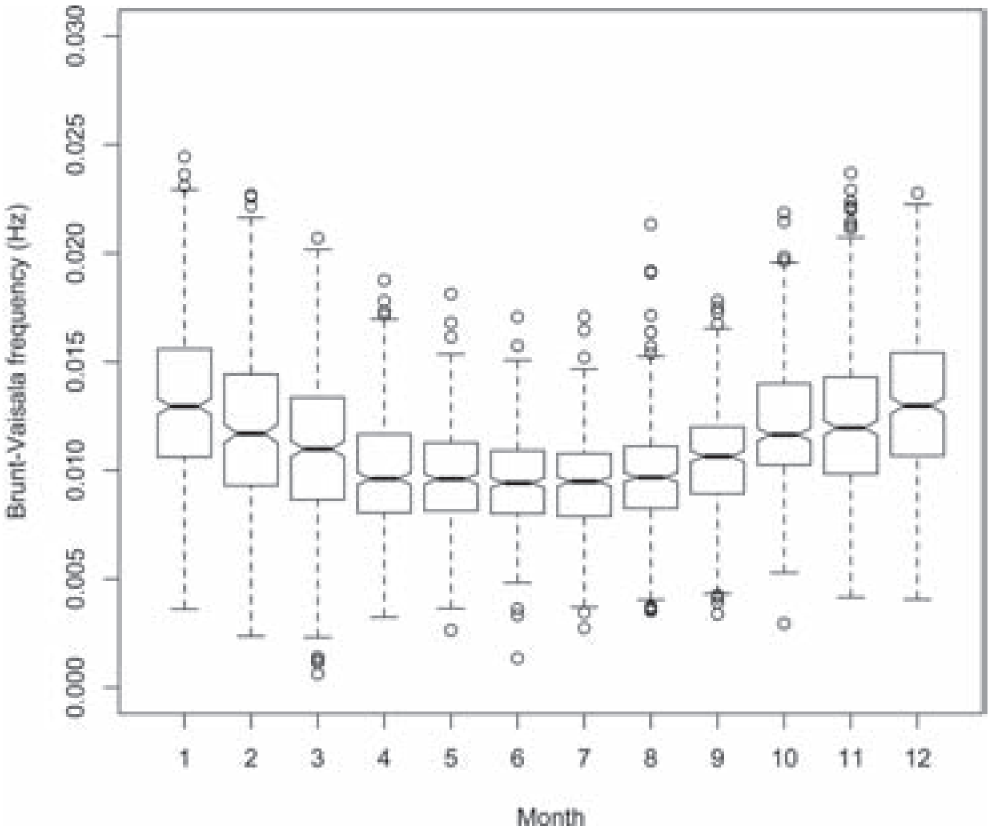

Figure 3: Typical year of Brunt–Väisälä frequency between 1500 and 2500 m (00 GMT)

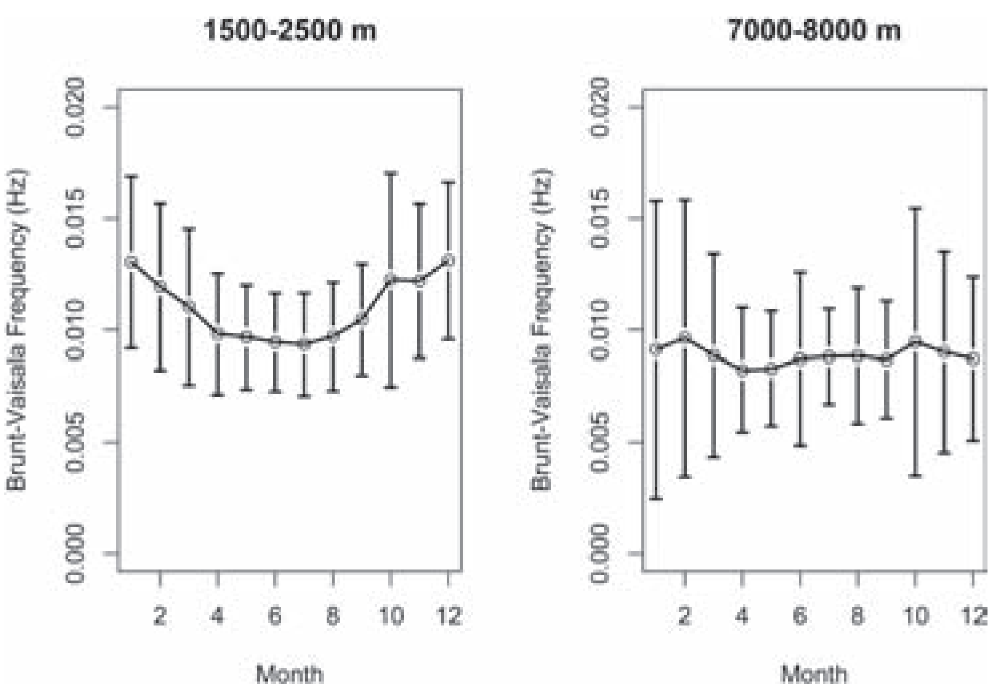

Figure 4: Comparison between typical year of Brunt–Väisälä frequency at different altitudes (00GMT)

CONCLUSIONS

The method used yielded estimates of the Brunt-Väisälä frequency made from the automatic processing of publicly available radio sounding data, and providing values compatible with typical value of 0.01.

The estimates permitted to constitute a data set spanning a 17 years time period and various reference altitudes, from which a climatology of the Brunt-Väisälä frequency has been obtained. Key elements of this climatology are:

- A relative constancy of yearly averages, with minor variations possibly correlated to other climatological indicators;
- The existence of a seasonal variation, more evident at low altitudes, superposed to a strong variability.

All findings described in this paper are by their very nature local, and their extension to other sites is not automatic. In particular, a relation between the kind and amplitude of seasonal variation with latitude is likely to occur, and an extension of this study to other sites is currently planned by the authors.

The climatology of the Brunt-Väisälä frequency described in this work is suitable of improvement, at the cost of using more advanced data and processing options. In particular:

- Use of high resolution radio soundings would allow the visual detection of anomalies, such as residual layers, allowing the precise removal of the part of profiles directly affected by PBL dynamics;
- High resolution soundings would also allow the direct detection of convective PBL, allowing its removal and so improving the value of data at 12GMT, currently underused;
- Explicit imposition of monotonicity on the temperature fitting cubic splines, although less conservative than the non-monotonic profile removal adopted, would allow a more efficient use of the data available – this change would be of even higher value when the more "nervous" high resolution data are used.

Addressing these items would allow to explore the behavior of the Brunt-Väisälä frequency at altitudes lower than the ones taken into account in this work, with possible practical implications. These extensions are currently under evaluation by the authors, and may constitute the subject of a future work.

ACKNOWLEDGEMENTS

This work has been performed in the framework of the ENEA project "ATMOSFERA©®" where the neural network approach has been used to predict air pollution in cities. The PBL height is an input parameter in the ATMOSFERA©® Neural Network Model. ■

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He coordinates the scientific activities and collaborates with Italian (Rome, Salento) and foreign universities (ASU, FMI, RSHU, Helsinki) to characterize the micro-meteorological state of the atmosphere into the PBL and develop new technologies and scientific tools oriented to the air quality control.
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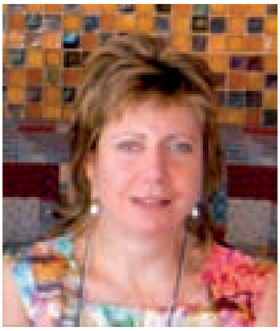

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LONG-TERM FLUCTUATIONS OF THE NORTHERN HEMISPHERE ATMOSPHERIC CIRCULATION ACCORDING TO DZERDZEEVSKII'S CLASSIFICATION

ABSTRACT

The long-term series of fluctuation of monthly and annual Northern Hemisphere atmospheric circulation in non-tropical latitudes from 1899 to 2008 according to Dzerdzeevskii classification have been discussed. The differences in atmospheric circulation between circulation epochs have been identified. The circulation and climatic characteristics of extreme decades of circulation epochs in the Northern Hemisphere and its six sectors – Atlantic, European, Siberian, Far East, Pacific, and American – have been given. The recent, the 1981–2008 period, is characterized by the increase in frequency (number of cases) and duration (number of days) of the southern meridional circulation group

KEY WORDS. Macro-circulation processes, atmospheric circulation fluctuations, circulation epoch, climate fluctuations, Northern Hemisphere, Russia

INTRODUCTION

Atmospheric circulation is one of the most dynamic components of the climate system. Its changes may be quantitatively assessed with the help of the classification of global atmospheric circulation. In the Institute of Geography RAS, the elementary circulation mechanism classification according to B.L. Dzerdzeevskii [Dzerdzeevskii, 1975; Dzerdzeevskii, 1962; Dzerdzeevskii, Kurganskaya, Vitvitskaya, 1946] has been applied. The important feature of this classification is that it characterizes the entire Northern Hemisphere and the trajectories of cyclones and anticyclones over specific regions. Therefore, this classification has been used to study solar – earth relationships [Chernavskaya, Kononova, Val`chuk, 2006]; global and regional changes of climate [Rubinshtein, Polozova, 1966.]; fluctuations of atmosphere – ocean system [Byshev, Kononova, Neiman, Romanov. 2004; Byshev, Nejman, Romanov, 2006], water, snow and ice regimes [Kononova,2003; The Nature of Long-Term Fluctuations of River Discharge, 1976; Titkova, Kononova, 2006] and natural hazardous events in different regions of the Northern Hemisphere [Kononova, 2007; Kononova, Malneva, 2003; Kononova, Malneva, 2007; Kononova, Mokrov, Seliverstov, Tareeva,. 2005].

At the present time, the analysis of long-term fluctuations of atmospheric circulation is lacking proper attention. However, without studying these fluctuations it is impossible to explain alternation of the periods of increase and decrease in air temperatures and total precipitation in isolated regions and the entire Northern Hemisphere; it is also impossible to explain global and regional distinctions in warming of the 1920s–1940s and the last warming.

Studies of long-term air temperature and precipitation fluctuations in different sectors of the Northern Hemisphere have shown their correlation with fluctuations of atmospheric circulation.

The purpose of this paper is to present the results of studies of long-term fluctuations of atmospheric circulation during the 1899–2008 period based on the classification by B.L. Dzerdzeevskii and co-authors and to demonstrate how these fluctuations are reflected in the climate of the Northern Hemisphere and different regions of Russia.

METHODS AND DATA

Analyses of synoptic daily maps allow one to isolate 41 elementary circulation mechanisms (ECM). They differ in direction and quantity of blocking and of southern cyclone outlets. The important feature of ECM is that they are seasonal in nature. Each ECM has a unique cyclone and anticyclone trajectory scheme and description [Dzerdzeevskii, 1968; Dzerdzeevskii, Kurganskaya, Vitvitskaya, 1946], maps of see level pressure and temperature, height of AT 500 and temperatures at AT 500 for 1970–1978 [Savina, Khmelevskaya, 1984], annual series and long-term series of fluctuation for 1899–2008 [Kononova, 2009].

ECM have been grouped in 13 types, and 4 groups (Table 1, Figure 1). The first group is the *zonal* (types 1 and 2: anticyclone on the North Pole, 2–4 of southern cyclone

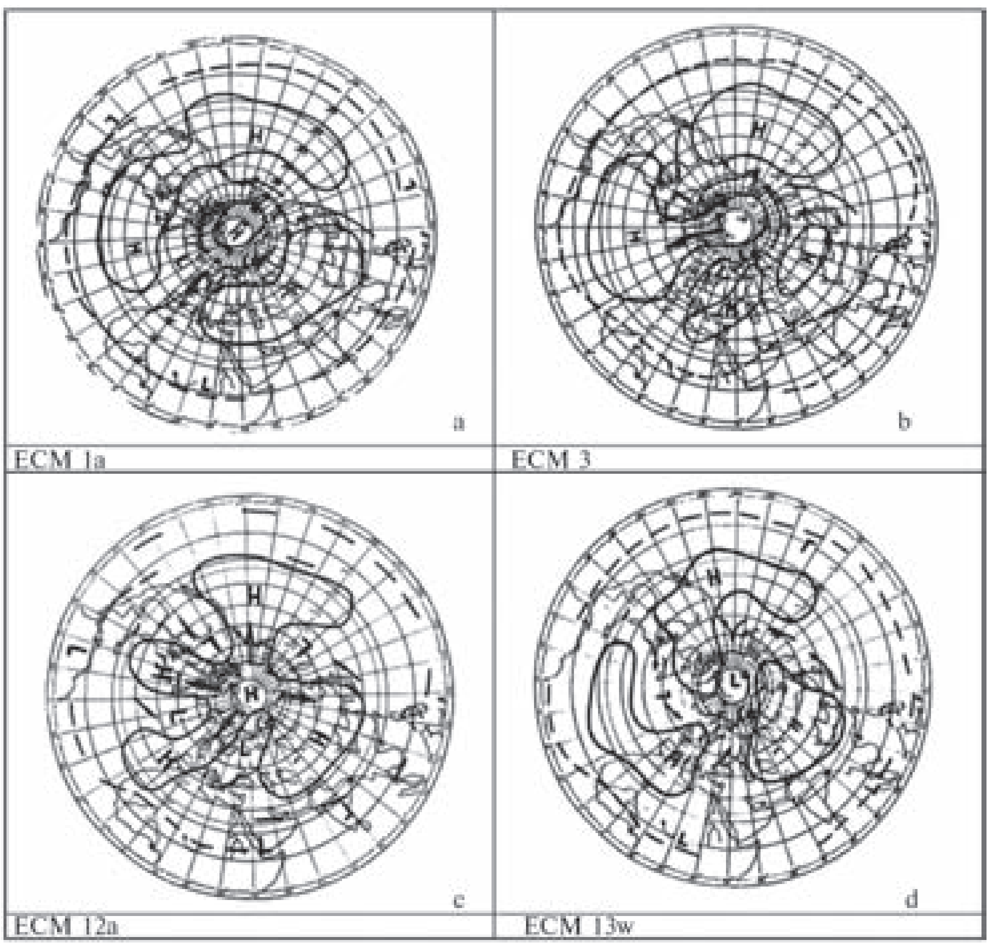


Figure 1. Examples of dynamic schemes of elementary circulation mechanisms (ECM) of different circulation groups according to Dzerdzeevskii: a) zonal, ECM 1a; b) disturbance of zonal circulation, ECM 3; c) northern meridional, ECM 12a; d) southern meridional, ECM 13w. (See also Table 1). Arrows show the cyclonic tracks (dark) and anticyclonic tracks (light). Letters "H" and "L" denote high atmosphere pressure (anticyclone) and low one (cyclone), respectively

Table 1. Characteristic of elementary circulation mechanisms groups according to classification of the Northern Hemisphere extra tropical atmospheric processes [10]

Group of elementary circulation mechanisms	Elementary circulation mechanisms (ECM)	Atmospheric pressure at the Arctic region	Amount of simultaneous blocking processes	Amount of southern cyclones outlets	Example
Zonal	1a*–2b	High	0	2–3	Fig. 1a
Disturbance of zonal circulation	3–7bs	High	1	2–3	Fig. 1b
Northern meridi-onal	8a–12g	High	2-4	2–4	Fig. 1c
Southern meridi-onal	13s**–13w	Low	0	3–4	Fig. 1d

* Numbers of ECM (1 to 13) are labeled by letters "a", "b", "c", "d" according to geographical locations of blocking processes and southern cyclones outlets.
** Letters "s" and "w" indicate summer and winter seasons correspondingly

outlets in 2–4 sectors without blocking). The second group is the zonal disturbance (types 3 through 7: high pressure on the Pole, one blocking over the Hemisphere). The third group is the *northern meridional*, (types 8 through 12: high pressure in the Arctic, 2–4 blockings and 2–4 southern cyclone outlets). The fourth group is the *southern meridional* (type 13) that is characterized by cyclone circulation over the Arctic as a result of cyclonic action on the arctic front especially the regeneration of southern cyclones. Such processes occur during all seasons, but more often in summer: there are only 3 southern cyclone outlets over the Hemisphere in winter, while 4 outlets happen in summer)

The History of alternation of ECM has been given for the entire period beginning in 1899. First, the see level pressure maps [Historical weather maps, 1899–1948] were used and then, the entire collection of maps of Hydrometcentre Synoptic Bulletin (from 1997 – in electronic format).

The History of alternations of ECM has been first developed at by B.L. Dzerdzeevskii and his colleagues, and, then, by his colleagues. The History of alternations of ECM has been published for the period 1899–2008 [Kononova, 2009]. The results obtained using this classification (background material, archives, most recent publications, list of all publication where this classification was used) for the period 1899–2008 are placed on the website www.atmosphertc-circulation.ru.

FLUCTUATION OF ATMOSPHERIC CIRCULATION

The basic purpose of the classification of the atmospheric circulation over the Northern Hemisphere is the analysis of long-term climatic fluctuations and forecast. To address this goal, ECM were grouped in different categories using the History of the alternation of ECM and the ECM duration was calculated on a monthly, circulation season, and yearly basis for the entire period beginning in 1899 (Table 1). These data are also placed on the website www.atmospheric-circulation.ru.

First results of research efforts to study multi-year atmospheric circulation over the Northern Hemisphere based on the History of alternation of ECM, have been published in 1956 [Dzerdzeevskii, 1956]. At that time, the first representations of generalized (composite) circulation groups (i.e., the zonal (the zonal itself and disturbances of the zonal) and the meridional (the northern and southern)) and circulation epochs (i.e., periods with positive or negative deviations of the zonal circulation from its long-term average duration value) were made.

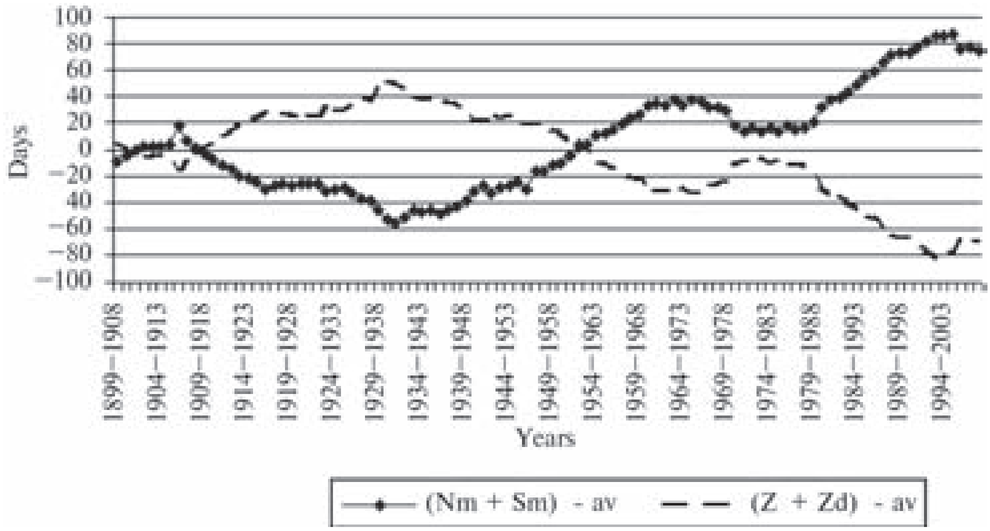


Figure 2. Deviations of the total annual duration of the generalized zonal and meridional circulation groups from corresponding average values (10-year moving average)

There were 3 alternations in circulation epochs form 1899 to 2008 (Fig. 2): 2 meridional (form 1899 to 1915 and form 1957 to the present time) and one zonal (1916–1956). During the modern, the meridional epoch, the duration of the meridional ECM is greater than during the first epoch, as it has been previously suggested by B.L. Dzerdzeevskii [Dzerdzeevskii,. 1968]. The maximal total duration of all meridional ECM was 319 days per year on average in 1997–

Table 2. Summary annual circulation groups duration (dais) in extreme decades of circulation epochs

Period	Duration.	Circulation groups					
		N.m.	Z.d.	S.m.	Z.	N.m.+S.m.	Z.+Z.d.
1899–2007	Average	196	95	45	29	241	124
	Max., year	274 (1915)	163 (1945)	201 (1989)	86 (1938)	346 (2000)	230 (1932)
1906–1915	Average	246	97	4	18	250	115
	Max., year	274 (1915)	116 (1910)	7 (1910)	30 (1913)	278 (1915)	140 (1913)
1930–1939	Average	168	135	13	49	181	184
	Max., year	206 (1933)	159 (1931)	45 (1937)	86 (1938)	209 (1933)	230 (1932)
1960–1969	Average	216	71	52	26	268	97
	Max., year	268 (1969)	93 (1964)	94 (1964)	53 (1962)	314 (1969)	130 (1962)
1988–1997	Average	155	42	149	19	304	61
	Max., year	215 (1995)	57 (1995)	201 (1989)	63 (1992)	338 (1993)	98 (1992)
1998–2007	Average	197	42	119	7	316	49
	Max., year	241 (2007)	59 (1998)	143 (2000)	21 (2004)	346 (2000)	74 (1998)

Note: N.m. – north meridional, Z.d. – zonal disturbance, S.m. – south meridional, Z. – zonal.

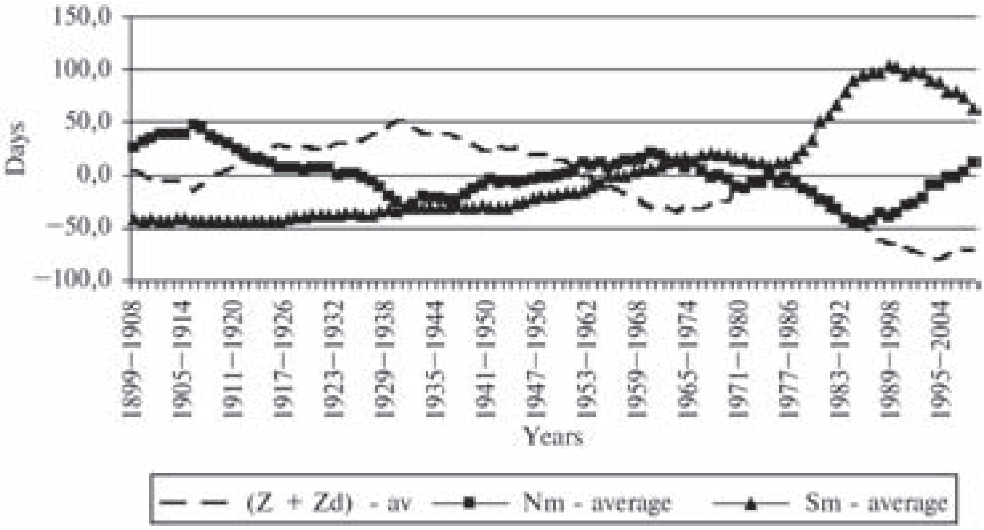


Figure 3. Deviations of the total annual duration of the generalized zonal group, northern meridional and southern meridional groups of circulation from their long-term average values for 1899–2008 (10-year moving average)

2006 (Figure 2) with the absolute maximum in 2000 (346 days, Table 2).

Differences between the first and modern meridional epochs are also associated with the duration of northern and southern ECM (Figure 3).

There were almost no meridional southern processes in the beginning of XX century (Fig. 3). Their duration started to increase in 1920s; only in 1963, it reached the mean value for the 1899–2008. Beginning in 1980s, it grew fast and now, the duration of the meridional southern circulation is over one-third of the year with weather patterns determined by alternations in meridional northern and southern processes.

Figure 4 shows the structure of circulation epochs and the annual duration of each ECM

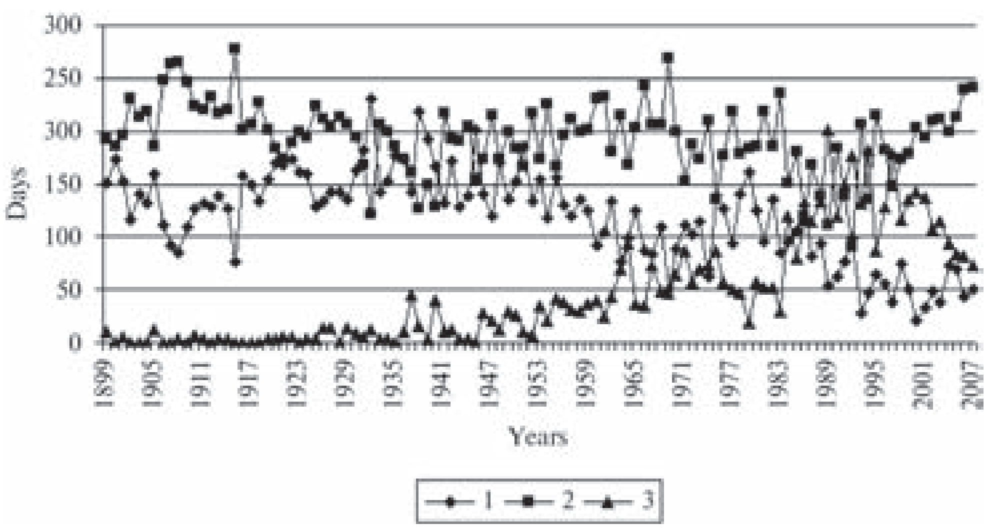


Figure 4. A long-term change in the total annual duration of the generalized zonal circulation and disturbance of zonal circulation and northern meridional and southern meridional circulation groups in 1899–2008

group. The meridional northern circulation group prevails practically during the entire period (the average duration of 193 days per year). The years 1932, 1938, 1939, 1940, 1945, 1951 and 1975 represent the exception. During these years, the zonal circulation was longer in duration than the meridional northern. All years, except for 1975, can be referred to the zonal epoch. In 1989, 1991, 1992, 1994 и 1997, the meridional southern circulation was the longest.

During the meridional epoch, the duration of northern processes was the longest (246 days per year on average, with a 274 days maximum in 1915 (Table 2)). During the zonal epoch and especially in the period from 1932 to 1951, years with the prevalence of the meridional northern circulation alternated with years when the zonal circulation prevailed. A new increase in the duration of the meridional northern circulation that started in 1957 led to its absolute dominance in 1969 (268 days per year with a further decrease to a 91 days per year minimum in 1992 (Figure 4). By that time, the duration of meridional southern processes increased significantly while the duration of the zonal processes reached even greater minimum than in the beginning of XX century. As a result, during the period from 1965 to 1977, the durations of the zonal and meridional southern processes were almost similar. In 1977–1985, at an absolute dominance of the meridional northern circulation, the duration of zonal processes increased and took over the meridional southern processes. From 1986 to 1977, the durations of the meridional northern and southern circulation groups was about the same and exceeded substantially the duration of the zonal group. The duration of the southern group more than by a factor of three exceeded the mean value. This situation determined an extremely instability of atmospheric circulation that has not been seen during the entire previous period. A sharp alternation in atmospheric processes became a reason for a fast growth in re-occurrence of meteorological extremes and hazardous natural events resulting from these meteorological conditions [Kononova, 2007]. In 1997, the duration of the meridional northern processes was 147 days per year compared to 196 days on average for 1899–2008; the duration of the meridional southern processes was 179 days per year compared to 45 days on average for the entire period, i.e., it was four times greater than the long-term average value. From 1998, the duration of meridional southern processes started to decrease, while the duration of the northern processes grew (Figure 4).

From 1998 to the present time, there is a decrease in the duration of the meridional southern circulation with the dominance and a new increase in the duration of the meridional northern circulation and minimal duration of the zonal group. In 2007, the

Table 3. Borders of circulation epoch and the periods inside them

Circulation epoch	Years	The periods inside epoch	Years
Northern meridional	1899–1915		
Zonal	1916–1956		
southern meridional	1957 to present	Simultaneous increase of northern and southern meridional processes duration	1957–1969
		The increase of zonal processes duration	1970–1980
		Fast growth of southern meridional processes duration	1981–1997
		Decrease of meridional southern and growth of meridional northern processes duration	1998–2007

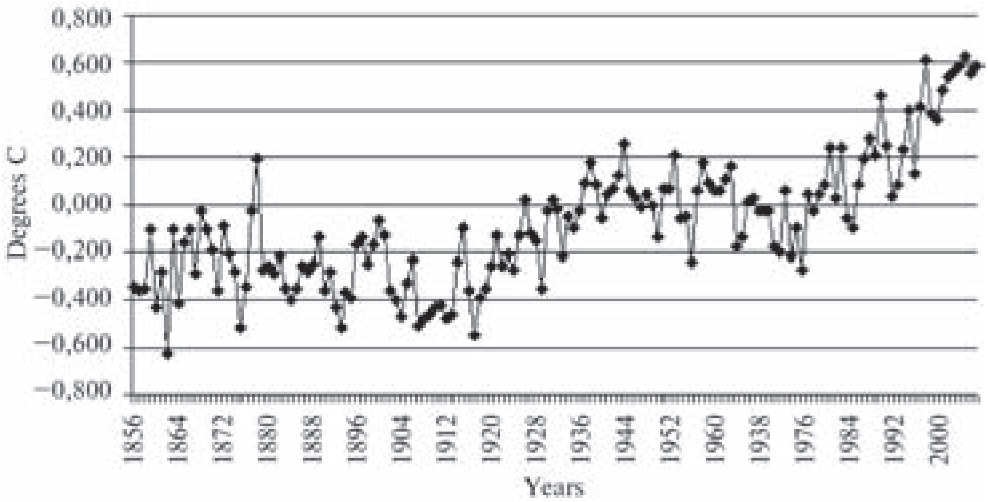


Figure 5. Deviations of the average annual air temperature over the Northern Hemisphere for 1856–2008 from average for 1961–1990 [28]

meridional southern circulation still remained 1,6 times longer than the average (73 days at the average value of 45 days), but was 106 days shorter than in 1997.

Thus, while the meridional northern and zonal epochs were relatively uniform, the meridional southern epoch can be subdivided into 4 periods with different combinations of the circulation group durations (Table 3). Table 2 presents the durations of circulation groups in extreme decades of circulation epochs and specific periods of the third epoch, including the last decade.

FLUCTUATIONS OF CLIMATE OF THE NORTHERN HEMISPHERE

Fluctuations of climate during the period under consideration agree well with fluctuations of atmospheric circulation in the Northern Hemisphere. The data [http://www.cru.uea.ac.uk/cru/data/temperature/] were used to analyze air temperatures of the Northern Hemisphere and fluctuations of atmospheric circulation.

The first epoch over the Northern Hemisphere was cold (Fig. 5). There were negative deviations of average annual air temperature over the Northern Hemisphere for 1899–1915 from the average value for 1961–1990. The years 1917 and 1913 were the coldest for the entire 1899–2008 period with the deviations of –0,542°C and –0,53°, respectively.

Increase in duration of zonal processes in 1920th–1940th was accompanied by the rise in temperatures that was referred in history to as "warming of Arctic regions." There were positive deviations of average annual air temperature over the Northern Hemisphere in 1931, 1937–1941, 1943, 1944 from the average for 1961–1990. The warmest, for this zonal epoch, was the year 1944, with the deviations of 0,163°C.

During the period of decrease in zonal and increase in northern meridional ECM during modern epoch (1957–1985, Fig. 4), there was some decrease in temperature over the Northern Hemisphere (Fig. 5). The year 1976 was the coldest for this period with the deviations of –0,294°C. The last negative deviation (–0,134°C) was noted in 1985.

The period from 1986 to 1997 when there was maximal duration of the meridional southern ECM, was marked with a warming (Fig. 5). A sharp increase in the duration of southern meridional processes correlated to climatic changes in the system "ocean – atmosphere" [Byshev, Kononova, Neiman, Romanov, 2004]. The tropical zone of the Pacific Ocean and the Mediterranean are the basic generators of the southern cyclones that move far north along almost meridional trajectories and bring southern heat and precipitation to high latitudes.

The year 2005 was the warmest for the meridional southern epoch over the Northern Hemisphere with the deviation of 0,625°C. However, in the last 11 years, anomaly of the annual average air temperature over the Northern Hemisphere of approximately 0,6° occurred in four years (0,608°, in 1998, 0,586° in 2004, 0,625° in 2005, and 0,590° in 2007); in other years, the anomalies varied from 0,36° to 0,55°. Thus, in comparison with the previous decade, warming has slowed down.

Now, the system "ocean – atmosphere" is changing [Byshev, Nejman, Romanov, 2006]. There is a decrease in water temperature in the top 600-m layer of the ocean. The Atlantic Ocean is cooling faster than Pacific.

The character of the modern atmospheric circulation is determined by a change in the duration of northern and southern ECM (Table 4). At the present time, the duration of ECM of type 12 (3 to 4 blocking processes and 3 to 4 southern cyclones outlets) is maximal (106 and 122 days in 2001 and 2006, respectively). There were approximately 7 more transitions from type 12a to type 13 during 1993–2002 compared to 1924–1954 (based on the data from [Chaplygina, 1961], and there were 11 times more reverse transitions from type 13 to type 12a. No such alternations happened in 1899–1923. Alternation in ECM types 12 and 13 provides for the best conditions for deepening of atmospheric fronts that leads to increase in re-occurrence of meteorological and ecological extremes registered in recent years.

CIRCULATION EPOCHS IN SECTORS OF THE NORTHERN HEMISPHERE

The elementary circulation mechanism that acts as a uniform and complete mechanism of macro-circulation exchange manifests itself in different ways depending on the location in the Northern Hemisphere: while there may be blocking in one area, a southern cyclone outlet or zonal circulation are possible in another. To study these processes, the Northern Hemisphere was subdivided into six sectors [Dzerdzeevskii, 1968; Dzerdzeevskii, 1970] with their boundaries drawn considering positions of the continents and oceans that determine seasonal character of development of atmospheric circulation. These boundaries are as follows: Atlantic –60°W–0°; European

Table 4. Frequency of change (%) ECM 12a, 13w and 13s in 1899–1954 and 1993–2002 [22]

ECM	PERIODS	ECM			
		12a	13w	13s	Type 13
12a	1899–1923				—
	1924–1954				4
	1993–2002		9	18	27
Type 13	1899–1923	–			
	1924–1954	2			
13w	1993–2002	10		1,5	
13s		12	1,7		
Type 13		22			

–0°–60°E.; Siberian –60°E–120°E; Far East –120°E–170° E; Pacific –170°E–120°W; American –120°W–60°W.

Circulation epochs in different sectors during the same Hemisphere epoch appear to also differ due to features discussed previously.

Relative prevalence of the duration of the zonal or meridional processes in a sector serves as a criterion for defining the circulation epochs in the sector and for the Hemisphere in general. However in this case, the terms "zonal" and "meridional" are applied to circulation processes for the entire Hemisphere, while, in individual sectors, the terms "latitudinal" and "longitudinal" are used. The principles of isolation of latitudinal and longitudinal circulation in individual sector have been developed by B.L. Dzerdzeevskii [Dzerdzeevskii, 1968; Dzerdzeevskii, 1970]. The direction of the air stream in the atmosphere over the sector was used as a criterion to describe a character of circulation. Trajectories of cyclones and anticyclones from weather maps and the direction of the air stream from maps AT 500 were used as input data. Breaking ECM into groups with similar circulation patterns in each of the six sectors of the Northern Hemisphere is presented in [Dzerdzeevskii, 1968; Dzerdzeevskii, 1970]. Additional groups, compared to the ECM grouping in the Northern Hemisphere as a whole, were isolated to characterize, for example, such a poison when Arctic intrusion is displaced to one of the boundaries of the sector. In this case, there may be a penetration of a southern cyclone far north within the rest of the sector, or the latitudinal circulation may be maintained. For such cases, combined definitions of circulation processes over the sector, i.e., "longitudinal northern and longitudinal southern" or "longitudinal northern and latitudinal western" were applied. Similar to these instances, there can be various descriptions of a direction of the air stream in the northern and southern parts of the sector. For example, when there is an intrusion of the air from the north into a stationary anticyclone located in the middle latitudes, the group "longitudinal northern and stationary position" is defined. When there is interfluence of a southern cyclone with cyclones formed on the Arctic front, the term "latitudinal western and longitudinal southern" is used. The maximal number of groups in one sector is 9 (American) and the minimal is 5 (Far East).

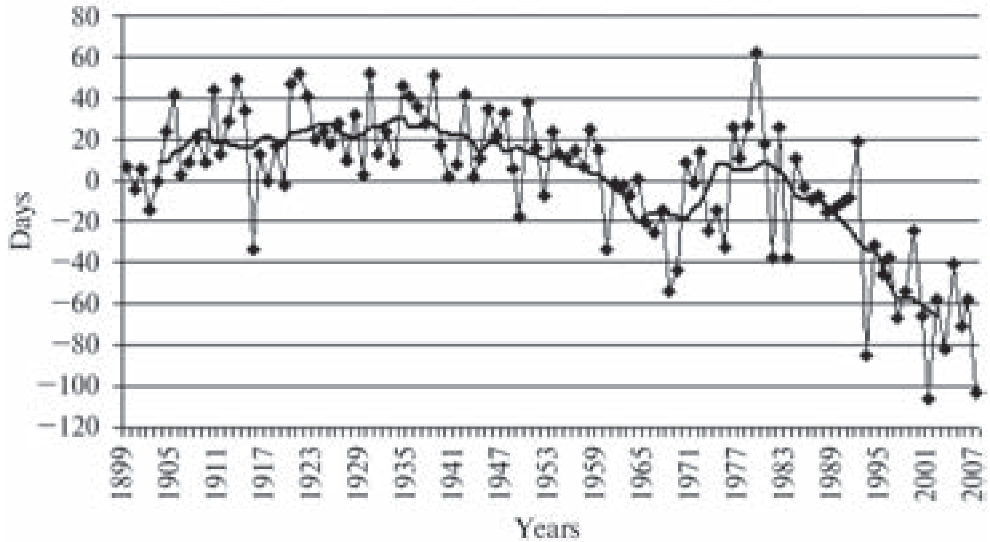
To solve some problems (e.g., establishment of boundaries of circulation epochs in different sectors and defining their seasonal character) it is necessary to use, as in the case of the Northern Hemisphere, only two generalized groups: latitudinal which includes all ECM when latitudinal trajectories of cyclones and anticyclones prevail over the sector, and longitudinal. The generalized latitudinal group includes 3 groups: (1) latitudinal western, (2) latitudinal western and longitudinal southern and (3) latitudinal western and stationary position. All others groups form the generalized longitudinal group. The long-term variations in the duration of the generalized latitudinal groups in each of the six sectors are presented in Fig. 6.

Comparison of these graphs with the graphs for the zonal circulation for the entire Northern Hemisphere showed a shift in the boundaries of the circulation epochs in each sector relative to their boundaries within the Hemisphere.

The boundaries of the circulation epochs in the sectors are presented in Table 5. Analysis of this table indicates that the changes in relative prevalence of zonal over meridional processes and vice versa, occur in oceanic sectors earlier, than in continental.

Besides, the circulation epochs in different sectors during the same Hemisphere epoch, are different in character: they may be zonal in one sector and meridional in another. We will address a character of the circulation epochs of the Northern Hemisphere in each of its six sectors in more details.

There are a different number of circulation epochs in different sectors for the period


80
60
40
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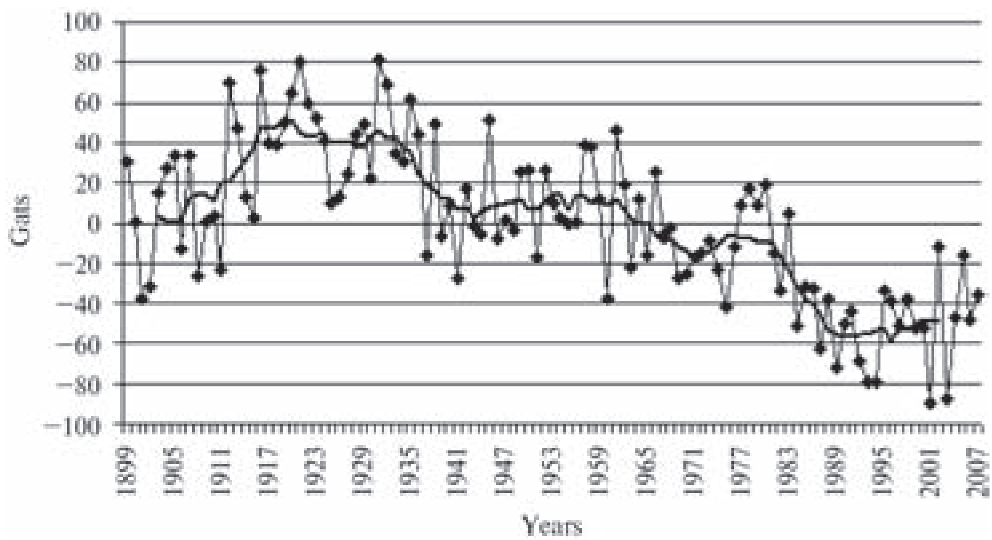
Days
1899 1905 1911 1917 1923 1929 1935 1941 1947 1953 1959 1965 1971 1977 1983 1989 1995 2001 2007
Years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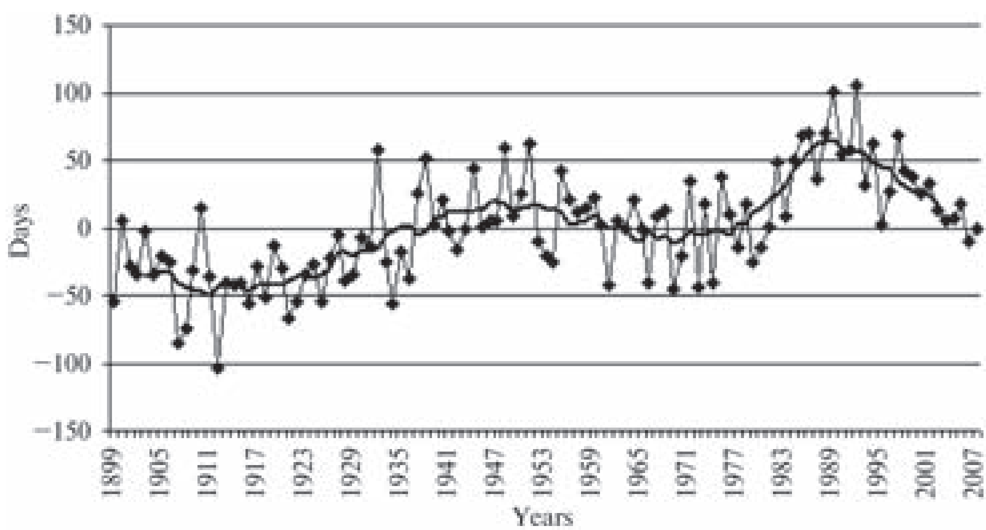
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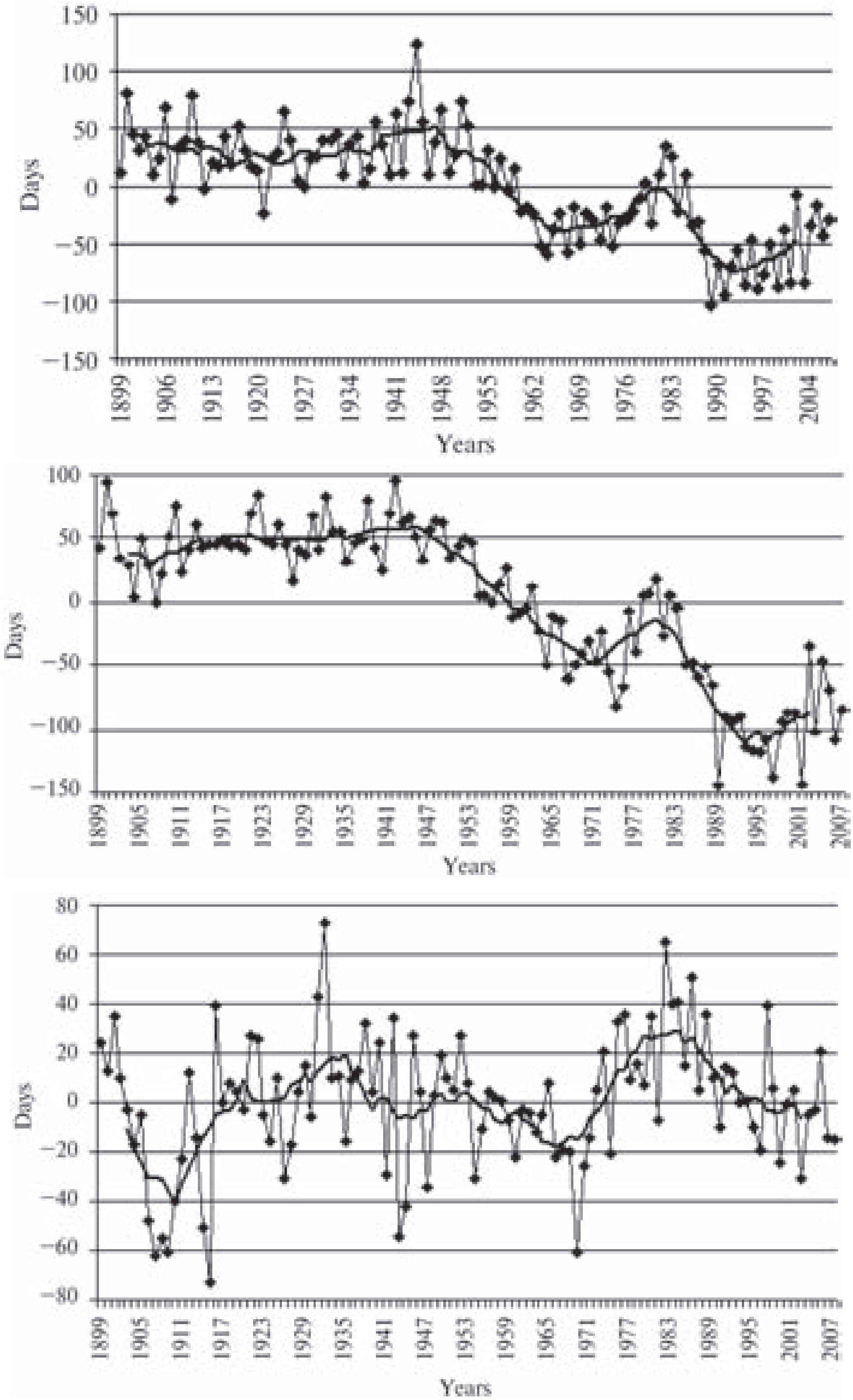

Figure 6. Deviations of the total annual duration of the generalized latitudinal circulation group in sectors of the Northern Hemisphere from the average for 1899–2008:
a – Atlantic, b – European, c – Siberian, d – Far East, e – Pacific, f – American

Table 5. Borders of circulating epoch in sectors of northern hemisphere in 1899–2007

Sector	Circulating epoch							
	I		II		III		IV	
	Borders	character	Borders	character	Borders	character	Borders	character
Atlantic	1899–1959	Zonal	1960–1975	Meridi-onal	1976–1984	Zonal	1985 to present	Meridion
Euro-pean	1899–1966	Zonal	1967 to prezent	Meridi-onal	–	–	–	–
Sibe-rian	1899–1931	Meridion	1932–1980	Fluctua-tion near average	1981 to present	Zonal	–	–
Far East	1899–1958	Zonal	1959 to present	Meridi-onal	–	–	–	–
Pacific	1899–1962	Zonal	1963 to present	Meridi-onal	–	–	–	–
Ameri-can.	1899–1915	Meridion	1916–1942	Zonal	1943–1971	Meridion	1972 to present	Zonal

of 1899-2008. As shown in Table 5 and Fig 6, there are 2 circulation epochs in the European, Far-East, and Pacific sectors: (1) zonal and (2) meridional; as it was noticed above, these sectors, since the second half of XX century to the present time, represent the generators of the southern cyclones.

In the Siberian sector, there are 3 circulating epochs: (1) meridional, (2) one without a clear prevalence of either latitudinal or longitudinal processes, and (3) zonal, with a substantial role of southern cyclones, i.e., the circulation group "latitudinal western in combination with longitudinal southern."

In the Atlantic and American sectors, there are 4 opposite in sign circulation epochs: during a zonal epoch in the Atlantic sector there is a meridional in the American.

Thus, the first, meridional, epoch in the Northern Hemisphere characterized by the development of the blocking processes in the Siberian and American sectors, has manifested itself in the meridional epochs specifically in these sectors. The zonal epochs in the very beginning of XX century occurred in the oceanic (the Atlantic and Pacific) and their dependant European and Far-East sectors. The epochs that coincide in time with the third, i.e., the meridional southern, Hemisphere epoch, reflect periods in its development presented in Table 3. At the present time, the Pacific, Far-East, and European sectors are experiencing the bulk of re-occurring southern cyclones [Byshev, Kononova, Neiman, Romanov, 2004].

Characteristic periods of fluctuations of the latitudinal circulation in all sectors may be identified from data presented in Fig. 7. Thus, from 1899 to 1934–1943, the duration of the latitudinal circulation differed significantly between individual sectors. From 1934–1943 to 1969–1978, it varied about the mean in all sectors, with the exception of the Far-East and Pacific sectors where it was above the average till 1954–1963, with a decrease in the future years. Beginning in 1970–1979 till the present time, the duration of the latitudinal circulation between individual sectors differed even to a greater degree then in the beginning of the century. The greatest differences in the duration of the latitudinal circulation are between individual sectors in 1989–1998. Therefore, during the periods of maximal development of the meridional Hemisphere circulation (both northern and southern) there are the maximal differences in the durations of latitudinal circulation between individual sectors.

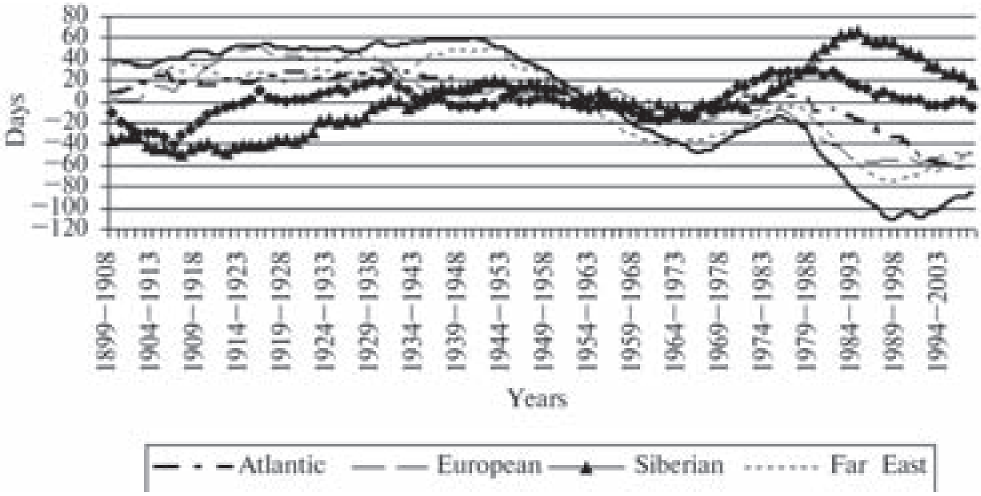

Figure 7. Deviations of the total annual duration of the generalized zonal circulation group from the average value in six Northern Hemisphere sectors (10-year moving average)

Analysis of fluctuations of the durations of all circulation groups in each sector indicated the maximal increase in the outlets of the southern cyclones and the maximal negative deviations in the latitudinal circulation group in the Pacific, Far-East, and European sectors in 1989–1998.

Changes in the duration of the latitudinal and longitudinal circulations impact the sectors' climate and meteorological extremes. Thus, under the same ECM in the Siberian and European sectors there are opposite in sign air streams. This leads to the formation of temperature extremes different in signs. For example, the winter of 1906/07 in Siberia was warm, while in Western Europe (based on [Easton, 1928], it was cold. The winter of 1911/12 was cold and snow free in Siberia but warm and with significant snow in Western Europe. A. Kosiba [Kosiba, 1962.] has noticed a decrease in summer temperature in Eastern Europe during the entire 1939–1959 period.

B.L. Dzerdzeevskii [Dzerdzeevskii, 1969] thought it was necessary to have a set of climatic data for each circulation epoch because just a mean value for the entire period alone can not be used to characterize modern climate. This thesis is especially important now when many regions are experiencing extreme weather evens with a low probability of occurrence of one in 20, 50, and even 100 years.

REGIONAL FEATURES OF ECM

Within each sector, individual ECM are characterized by different circulation modes in different parts of the sector. Often, within latitudinal ECM, in northern areas there is movement of cyclones, while anticyclones move or stationary within southern sectors. In longitudinal ECM, blockings in western sectors are accompanied by outlets of southern cyclones in their eastern parts. In order to describe circulation and climatic properties of individual territories within the sectors, each sector has to be broken into areas based on cyclonic or anticyclonic nature of ECM. This procedure has been applied to the territory of Russia [Kononova, 2005].

Using the Black Sea coast of Krasnodar region and the western steppe region of the Altai region as examples, we will demonstrate the relationships between circulation and climatic characteristics.

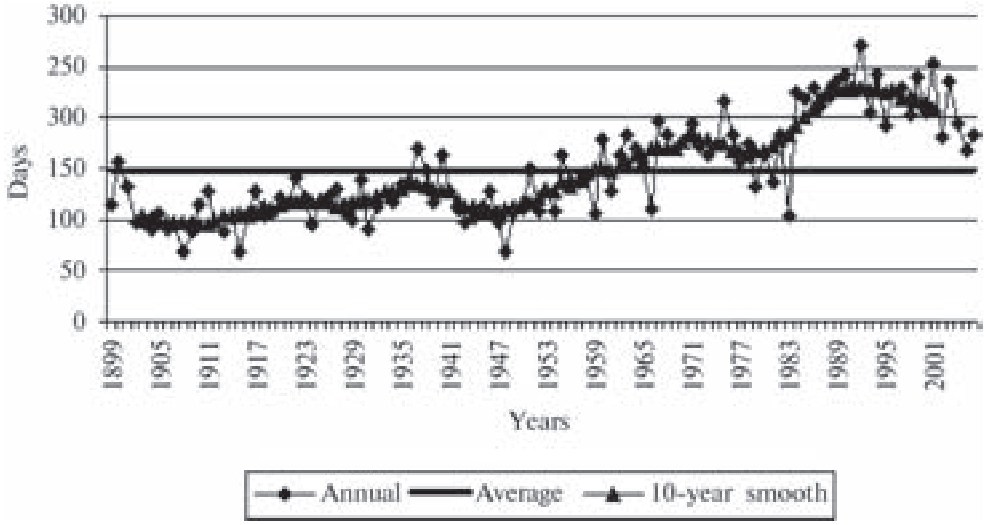

Figure 8. Fluctuation of the total annual duration of cyclonic circulation over the Black Sea coast of Krasnodarsky region

As shown in Fig. 8–11, fluctuations of annual precipitation sums in these regions are consistent with variations in the duration of their cyclonic circulation. This is important for the analysis of hazardous natural processes that occur due to meteorological conditions (mudflows, landslides, avalanches, etc.), for which monitoring is conducted from time to time. According to known data on hazardous natural processes for particular regions, there is a connection with certain ECM. Data on fluctuations of the duration of these ECM for 1899–2008 may be used to establish a degree of hazard from increased activity of analyzed processes in the present and near future.

CONCLUSIONS

Three circulation epochs with different ratios of the durations of the circulation groups were identified based on the analysis

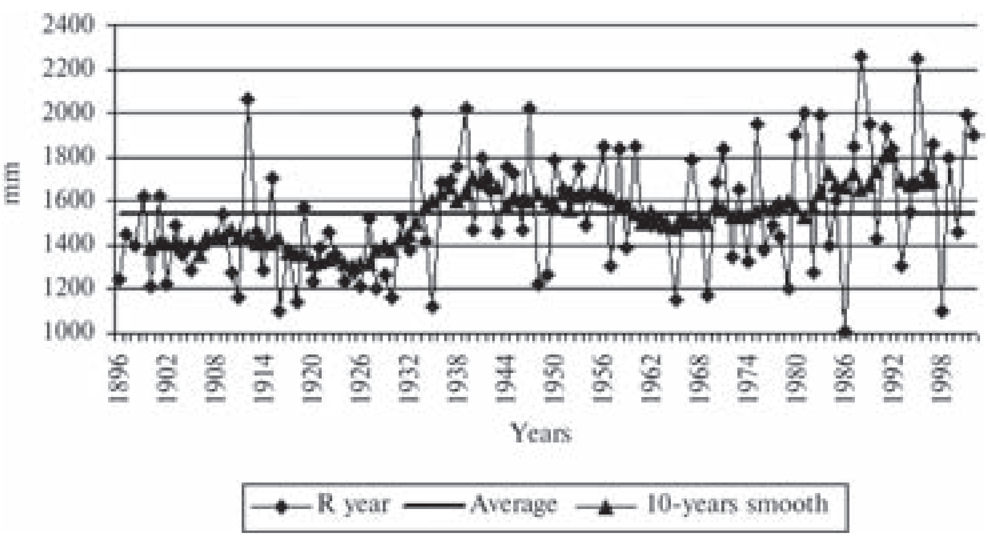

Figure 9. Fluctuation of the total annual precipitation in Sochi

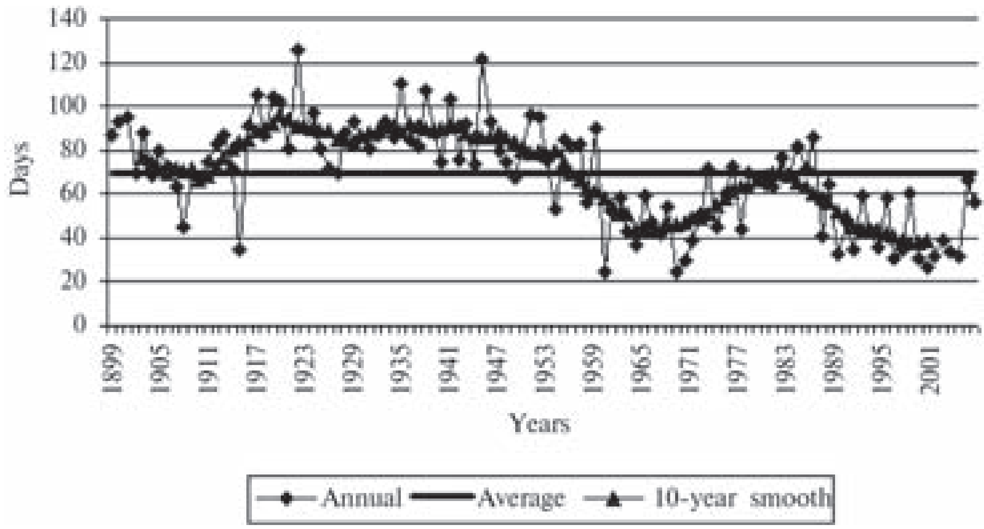

Figure 10. Fluctuation of the total annual duration of the cyclonic circulation over the Altai region

of long-term fluctuations of atmospheric circulation over the Northern Hemisphere; these epochs have determine the climate of the larger circulation epoch from 1899 to the present time.

The first circulation epoch (1899–1915) was marked by the deviation of the total annual duration of the meridional northern processes (types 8 through 12) from the average for the entire period (1899–2008). The average annual air temperature over the Northern Hemisphere during this period was lower than the average temperature for the period 1961–1990 accepted by WMO as the standard period.

The second circulation epoch (1916–1956) was marked by long deviations of the total annual duration of the zonal circulation from the 1899–2008 average. The average annual air temperature over the Northern Hemisphere during this period was above the average for 1961–1990. Especially significant

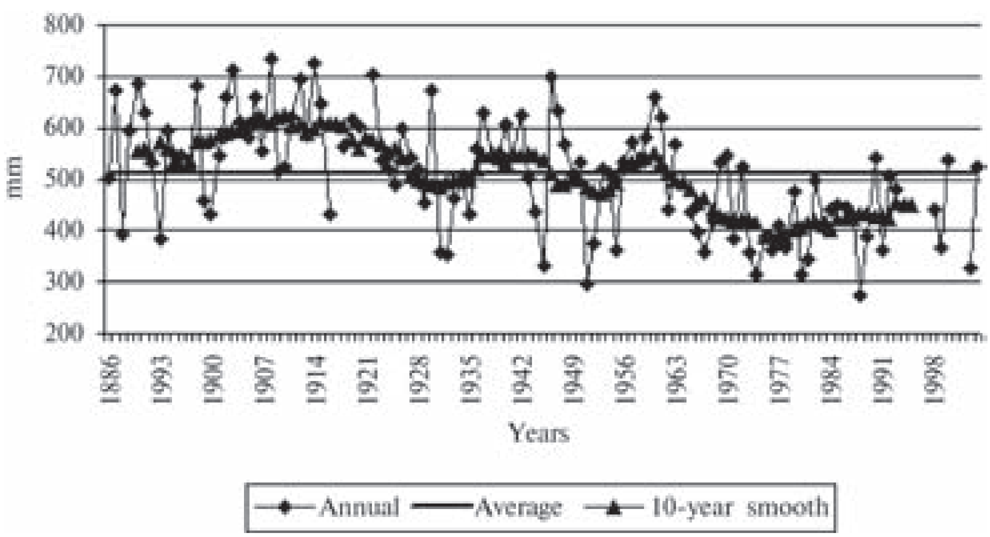

Figure 11. Fluctuation of the total annual precipitation in Barnaul

rise in temperatures was observed over high latitudes and this period was referred to in history as "warming of the Arctic."

During the third circulating epoch (1957 – present time), there were positive deviations of the total annual duration of the meridional southern processes (type 13), when cyclone circulation over the Northern Hemisphere was supported by three to four southern cyclone outlets in different sectors of the Hemisphere. During 1981–1997 of this epoch, there was the greatest increase in the annual duration of the southern processes with a simultaneous substantial increase in the average annual air temperature over the Northern Hemisphere. The greatest positive deviations of the average annual temperature over the Northern Hemisphere from the average for 1961–1990 were in 1998 (0,608°C) and in 2005 (0,625°C).

All processes have intensified during the extreme decade of 1906–1915 of the meridional northern circulation epoch, when in the Northern Hemisphere, the duration of the total annual meridional northern processes was the longest (274 days/year) with the most significant negative deviations from the average annual air temperatures (–0,523°C in 1907 and –0,542°C in 1917).

In the extreme decade of the zonal circulation epoch (1930–1939), there was the longest total annual duration of the generalized zonal group of circulations: 230 days/year. The greatest positive deviation of the average annual air temperature over the Northern Hemisphere during this decade was 0,141°C (1938). The year 1944 was the warmest with the deviation of 0,163°C.

The modern meridional circulation epoch is the most unstable. It has three extreme decades with the maximal duration of the meridional processes: northern (1960–1969), southern (1988–1997), and northern-southern (1997–2006).

In 1960–1969, the total annual duration of the meridional northern processes was comparable to the level for 1906–1915 (268 and 274 days/year, respectively). The duration of the meridional southern processes in 1963 reached its average long-term value for 1899–2008 and continued to grow. The average annual air temperature over the Northern Hemisphere decreased with the deviations of –0,222°C in 1964 and –0,294°C in 1976. The average annual total precipitation over the northern Hemisphere increased as a result of the development of atmospheric fronts.

In 1988–1997, the maximal total annual duration of the meridional southern processes was noted, with the maximum of 201 days in 1989. The maximal positive deviation of air temperatures in XX century occurred immediately after this decade (in 1998, 0,608°C).

In 1998–2008, the total annual duration of the meridional southern processed decreased with the increase in the duration of the meridional northern processes; as a result, the duration of the meridional processes on average for the decade was 319 days and has reached its maximal value in 2000 (i.e., 346 days/year). That year was marked with decrease in the average annual temperature of the Northern Hemisphere with the deviation of 0,357°C. This decade had the maximal (for the entire observation period) positive deviation of 0,625°C in 2005. Similar to the period 1960–1969, there was an increase in the annual total precipitation on average for the Northern Hemisphere.

The fluctuations of the duration of the atmospheric circulation processes of the Northern Hemisphere cause fluctuations of the air temperatures, precipitation, and, as a result, the increase in reoccurrence of the hazardous natural events in different regions of the northern Hemisphere.

It is important to consider the character of circulation epochs in modeling efforts that target circulation of atmosphere and climate because alternations of circulation epochs impact fluctuations of air temperatures and precipitation over the Northern Hemisphere.

ACKNOWLEDGEMENT.

This research was funded by the Russian Foundation for Basic Research (RFBR), project 08-05-00475. ■

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POST-SUBURBIA: GROWTH MACHINE AND THE EMERGENCE OF "EDGE CITY" IN THE METROPOLITAN CONTEXT OF MOSCOW

ABSTRACT

To what extent do the ideas of "edge city", "post-suburbia" and associated models of urban growth apply in the transition economy case? The paper considers urban development and place-making on the periphery of Moscow, based on the case of Khimki, a former off-limits "satellite city" and more recently a fast-growing area. The forces and ideologies driving the growth on the edge of Moscow and the relationship between different actors are considered. The paper argues that while the Russian case shares some commonalities with the Western models of "edge city" and "growth machine", growth in Khimki is fuelled by opportunistic profit-making initiatives that are disconnected from "local" city. It is yet to be seen whether a growing demand for new infrastructure, as well as emerging residents' movements will restructure the modes of governing urban growth more in line with proactive place-focused post-suburban politics.

KEYWORDS: suburbanization; satellite city; Khimki; Moscow city-region.

INTRODUCTION

While the processes of "post-suburban" patterns of urbanisation have been identified in a number of Western contexts (Western Europe and North America), spaces beyond these regions remain fairly absent from associated research. Little is known, for example, how easily the ideas of "edge city" [Garreau, 1991], "post-suburbia" [Kling et al, 1995] and associated models of urban growth may travel to the transition economy case. The interest of this paper is therefore to establish some considerations in this respect specifically focusing on the metropolitan context of Moscow, based on the case study of Khimki.

While the logic of socialist urbanization produced a somewhat different type of the city from the Western regimes, the introduction of the market economy resulted in a flood of new urban processes changing the function and morphology of cities. Larger cities, such as Moscow, and especially their inner areas were first to accommodate post-industrial transformation, tertiarization and commercialization [Bater et al., 1998]. However, eventually the processes of change have fallen upon the cities further down the urban hierarchy, as well as peripheries of the larger cities. To what extent this centrifugal momentum of growth and attendant urban change is predetermined by certain "structural" forces and to what extent it is driven by purposeful strategies of economic and political agency can be investigated by looking more closely at local contingency and the local combination of different forces.

In this paper we consider the politics and practice of development and place-making of urban areas at the periphery of Moscow, based on the case study of Khimki and drawing on material collected during our fieldwork in summer/autumn 2008, which involved almost 50 semi-structured interviews with local officers in Khimki, planning bodies at the Moscow Oblast level, Federal authorities, private developers, chambers of commerce, academic experts, as well as representatives of local environmental groups.

URBAN PROCESSES ON THE PERIPHERY OF MOSCOW

In the US literature both inner-city regeneration and transformations on metropolitan edges are sometimes opposed to suburbanization in the previous decades. In Russia, the processes of urban transformation have been unfolding as a rapid explosion. Due to suburbanisation the "built-up" land use had grown twice in the 1990s and still in parallel central urban areas have been renovated and increasingly colonized by the new rich – a recognizable pattern of gentrification [Badyina and Golubchikov, 2005]. Furthermore, what looks familiar has much local specificity. For example, "suburbanisation" in Moscow has taken a form of second-home developments rather than permanent residences, although more "permanent" residential suburbanisation is also increasingly taking place [Makhrova et al., 2008].

Along with quasi-suburbanisation, the fringe of Moscow metropolitan area is now experiencing some patterns of intensified growth. Initially at least, this was driven by the development of shopping malls along the Moscow Orbital Motorway (which for the most art corresponds to the administrative border between the City of Moscow and Moscow Oblast – a separate administrative region surrounding Moscow), as well the development of warehouses along the major motorways running from Moscow. But, increasingly, more complex forms of development, such as major modern office-based employments, including back-offices, emerge in the nearest cities of Moscow [e.g. Rudolph and Brade, 2005; Makhrova and Molodikova, 2007]. These forms of development are also paralleled by intensified residential construction around the Russian capital.

Khimki was one of the first cities in Moscow Oblast to experience the combination of these processes. Khimki is often seen as having a favourable location. Firstly, it is adjacent to Moscow and is well connected with it. Secondly, there are Russia's major transport links crossing Khimki, including the Moscow-St Petersburg motorway (known as Leningrad Motorway) and Moscow-St Petersburg railway. Thirdly, Khimki is located near and on the main route from Moscow to Russia's major international airport Sheremetyevo, which also now administratively belongs to the territory of Khimki. Fourthly, the city is located in an environmentally favourable zone to the west of Moscow (for the socio-economic performance of Khimki see Table 1).

Khimki was traditionally considered as one of "satellite cities" of Moscow in its "near belt", although it administratively belongs to Moscow Oblast. Historically, the city has been a centre of a larger district with a few other

Table 1. Main socio-economic indicators for Khimki

	2001	2002	2003	2004	2005	2006	2007
Population, 1,000s	176.5	176.9	177.6	178.7	179.7	180.1	181.0
Migration, ‰	11.1	12.2	13.7	11.8	9.0	12.5	19.8
Employee (excl. small enterprises), 1,000s	53.3	43.5	47.4	52.2	55.2	61.4	65.6
Average salary, RR (excl. small enterprises)	5,764	7,616	9,716	11,846	15,471	18,898	22,919
Retail turnover, RR per capita	21,144	33,007	32,743	65,669	81,175	11,1447	185,370
Paid services, RR per capita	6,970	8,246	11,120	13,966	18,747	55,559	68,686
Existing housing, sq. m per capita	26.4	25.8	26.5	26.8	27.5	29.1	31.3
New housing completed sq. m. per capita	0.42	0.76	0.84	0.44	0.72	1.75	1.24
Capital investment, RR per capita (excl. small enterprises)	9,988	10,075	32,877	34,661	36,396	37,094	81,830
Accumulated foreign investment, million US dollars	187.3	262.6	552.1	787.1	1,226.7	2,129.9	3,424.7

Source: Mosoblkomstat (2000–2007)a, Mosoblkomstat (2000–2007)b.

settlements and the countryside. In 1984, the Council of Ministers of Soviet Russia handed over a large part of the territory of the Khimki District to Moscow. This is because Khimki was an off-limits city, based on defence; hence Moscow grew around the city rather than incorporating it into its borders. As a result, the Khimki District became divided into two parts, separated by the territory under Moscow's jurisdiction. As one of our interviewees noted: "it's a very complicated city as it is all interpenetrated by Moscow territory, Federal transport junctions and motorways" (Ladygina[1]). In January 2006, due to a municipal reform, the Khimki District changed its status and the whole district area which used to consist of several urban and rural parts became amalgamated as the unified "Urban District of Khimki" with the total population of about 180 thousand.

POST-SOCIALIST GROWTH MACHINE?

No one who travels to and from Moscow to the Sherymetyvo airport within Khimki district can avoid making superficial comparisons with the edge city environment of the US. The heavy congestion on the stretch of road allows one ample time to gaze out onto what is a rather chaotic mix of office and apartment blocks and retail outlets that, until very recently, were being built at very rapid rates (Figure 1).

It is tempting therefore to consider this suburban nodal point of car based accessibility being subject to the sorts of private sector forces apparent in the US. Growth in the peripheries of major cities in post-socialist countries has prompted Kulscar and Domokos (2005) to invoke the term post-socialist growth machine – making use of Molotch's (1976) classic description of the politics of US urban development. The conjoining of the term growth machine is testimony to the concepts ability to travel, but it may actually conceal more than it reveals. As Kulscar and Domokos (2005: 560) acknowledge "The nature of the pro growth agenda is primarily political in the post-socialist case. The power core is the local administration and this strongly influences the composition of the growth machine". Development activity is also almost entirely unimpeded by civil society.

[1] Interview with Olga Ladygina, Deputy Head of the Project Studio for Suburban Zone of Moscow and Moscow Oblast, Research and Development Institute for the General Plan of the City of Moscow, Moscow, 26 August 2008.

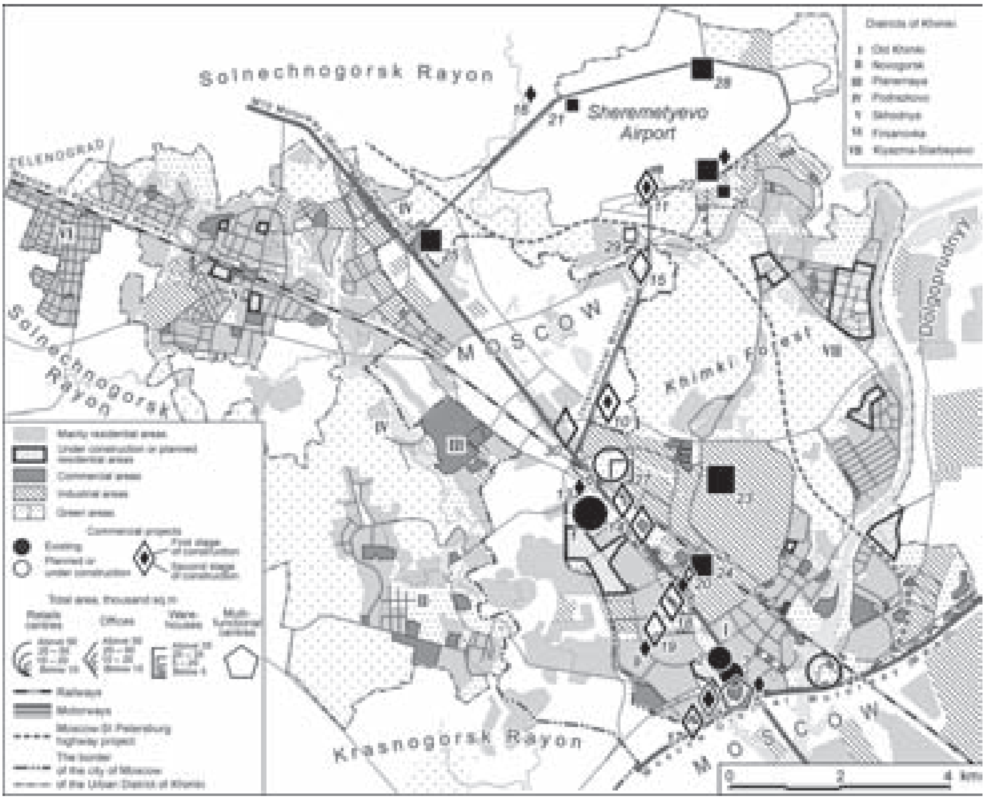

Figure 1. The spatial structure and new development projects in Khimki. Development projects shown on the map: 1. Mega-Khimki. 2. Liga. 3. Ramstor. 4. Levoberezhnyy shopping and entertainment centre. 5. Khimki City. 6. Big Boxes. 7. Country Park. 8. Office centre, Moskovskaya Ul. 21. 9. Office centre, Yubileynyy Prospect, 60a. 10. Mercedes Benz Club. 11. Sheremetyevskiy Business Centre. 12. Sherrizone. 13. Business park, Mashkinskoye Shosse, build. 1. 14. Khimki Business Park. 15. Aeroport Komplex. 16. Aeroplaza. 17. Khimki Gate. 18. Khimki Plaza. 19. Business park, Lavochkina Ul. 16. 20. Olympus. 21. Aeroshare Express. 22. Sheremetyevo Cargo. 23. National Logistic Company Khimki. 24. Khimki Praedium. 25. Sheremetyevo Warehouse Complex. 26. Sheremetyevo Industrial Park. 27. Terminal Europe. 28. Vesna-M. 29. Vega-Khimki

Both of which leads Kulcsar and Domokos to suggest that post-socialist constellations of pro-growth interests would exist in the absence of growth, as their motivations centre on the exercise of power and control of the communities.

Some similarities to patterns and processes of urban development in the US do exist. These revolve around the speed of development and allied to this the motivation of development in terms of exchange values. Certainly, the initiative, as in the US, does tend to come from the private sector as one interviewee from a commercial property brokerage described:

As for the government, there is no one good well thought-out strategy of developing this or that Moscow Region suburb or district or Moscow Region. It is stimulated by developers. Developers come to the government and ask for permissions. IKEA, for instance, was built without any permission for construction. They just came out on the land and started to build and got the permissions in process. (DTZ[2]).

Here, government and its planning and regulatory systems at all level and especially the municipal level in Russia responds to

[2] Interview with DTZ property consultants, Moscow, 20 August 2008 (in English).

a newly created market system which was ushered in, albeit in a rather incomplete way, in the early 1990s. Legislation in the early 1990s provided for private property rights, and although incomplete, released a huge suppressed demand for housing from individuals and commercial premises from established and new financial and business services, retail and distribution businesses (including foreign direct investment). This time, until new legislation effectively completing the market system in more recent years, was considered as period of 'wild capitalism' by one informed interviewee (Gaige[3]) as implied in the description of the IKEA development in Khimki above (Figure 2).

In this respect, post-socialist processes of urban development may well be a mutation of the US growth machine. However, once we move on to consider how the development process relates to a politics of place, major dissimilarities appear. In Molotch's original formulation and in subsequent elaborations [Logan and Molotch, 1987], the mutual interests of municipal politicians and officials and private sector, usually land based business interests, are place-based due to what Cox and Mair (1988) have further elaborated as local dependency on both parties. The joint actions of the private and public sectors coalesce over the profits and revenues that attend the development patterns centred on uplifts in the exchange value of land and property within a particular jurisdiction. As such municipal economic development strategies, and planning policies become a focal point for coalitions of public and private sector interests. And here dissimilarities become pronounced. In the next section, we will start exploring these dissimilarities by firstly discussing why planning policies play a rather different role in the context of Russia.

THE ROLE OF THE PLANNING SYSTEM

The Soviet model of urban planning was inscribed into a centralized institutional setting and land development was part of social and economic regulation. Social infrastructure, including housing, services and green spaces, was allocated according to some norms based on the needs of production. The implication of this top-down planning process was that it was largely "sectoral", while urban plans were to integrate different sectors by the virtue of their location in one place.

With the emergence of market reforms and political and economic liberalization, Russian urban planning fell into a state of crisis, as the new requirements made many inherited principles of Soviet planning for administrative-led development ineffective [Golubchikov, 2004]. A series of reforms in relation to the institution of urban planning have, however, not solved this problem but instead considerably emasculated the institution of planning without providing a really workable alternative. Importantly, the 2004 Urban Development Code of Russia stresses the role of legal zoning, thus re-orientating the accent of the Russian town planning from a more comprehensive concept of planning to that of land use zoning underpinned by narrower development rights interests. Planning in modern Russia has increasingly taken development-led and opportunistic forms, which are familiar to many other post-socialist cities in Europe [e.g. Tasan-Kok, 2006].

This combination of the legacy of sector-based planning and pro-development zoning results in a lack of a comprehensive and purposeful approach to make coherent places. When asked whether there were any visions at local or regional governments how individual cities in Moscow Oblast should look like in 20–30 years, the head of Moscow Oblast Planning Board argued that such "visions" were not according to the market regime: "people who will live in those places in 20 or 30 years time will have their own vision about how they want those places to look like and we don't have the right to impose our

[3] Interview with Gerald Gaige, Partner, Ernst and Young, Moscow, 28 October 2008 (in English).

Figure 2. The IKEA centre was one of the signature development projects for Khimki in the previous decade and has become one of its landmarks

views on their wishes" (Frolov[4]). It may be paradoxical to hear such a discourse from those responsible for planning. However, this reflects the uneasy combination of the neoliberal ideology with the tradition of considering urban plans not as the instruments of "making places", but rather as the tools of providing the basic functionality to the places, mostly in terms of transport infrastructure as in Soviet times. Thus, the centralized sector-based planning of the Soviet era continues to have an important legacy in that there remains little appreciation of the value of territorial planning at the municipal scale among political leaders and local officials.

Furthermore, the capacity for municipalities to integrate aspects of planning for their jurisdictions is also significantly compromised by planning responsibilities and financing that remain fragmented between Federal, regional and municipal levels. The situation contrast, for example, with China where the State is seen as a coordinator and promoter of development as part of place building at national, provincial and local level. Russian local state has rather become an unpredictable holder and releaser of developable land. It is here that we should turn to considering in more details the power relations between different interests in the development process based on an analysis of our case study city.

THE INTERPLAY AND BALANCE OF URBAN DEVELOPMENT INTERESTS IN KHIMKI

For some, at least, aspirations to improve territorial planning at municipal level do exist. There is some suggestion that Khimki's mayor has been resistant to powerful real estate company interests with designs on

[4] Interview with Alexandr Frolov, Head of the Main Department for Architecture and Urban Planning of Moscow Oblast, Moscow, 29 October 2008.

his municiaplity (Pozdnev[5]). Nevertheless it seems that these companies are able to realize development opportunities on the vast land banks they have acquired at the outset of liberalization in Russia by capitalising on their political connections at the regional or Federal political levels. The clash between local plans and financial interests, with clear dominance of the latter, is exemplified by the development of a previously vacant prime location at the entrance of Khimki from Moscow by the Leningrad Motorway and next to the municipality's first class A office development – Country Park. The site was originally earmarked in the general plan for a new commercial and community centre. However, the plot was suddenly granted planning permission for large residential development by the developer PIK. The interviews with both local administration and neighbouring businesses reveal the discontent about this outcome, which is considered to disrupt what could have been a compatible cluster of office and retail land use. But the pressure for development seems to be not only restricted to the lack or availability of money, but with vested interest involving both large development groups with strong backing. As deputy mayor put it:

The problem is related to the investment attractiveness of the city. There are people coming here who we cannot actually turn down. It happens that we are forced to take decisions that contradict with the policy we have. It happens very often (Pozdnev).

One might assume that a municipality like Khimki experiencing such rapid development ought to have a healthy fiscal capacity. In fact due to the tax system in Russia all municipalities are in a relatively weak position relative to the regions in which they sit. As a result, some of the chief possibilities for place making that are evident at the municipal level have come from the planning gain extracted from developers. For residential developments, the planning gain extracted has been quite significant with 20% (and up to 25%) of all units of flats constructed in Khimki being handed over to the municipality in the form of municipal housing. Beyond this, one would have to say that the planning gain extracted so far is modest and far from guaranteed. It has extended so far to the provision or refurbishment of public spaces and parks and the building of kindergartens and schools (Maximov[6]). Even so, the present financial crisis promises to affect the planning gain extracted from even the largest of developers who according to one interviewee are now struggling to finance the amenities and services promised for major residential developments in Khimki (Figure 3).

For a number of reinforcing reasons, local officials and politicians operate in a context in which as yet there is little understanding or concern for issues such as rising social inequalities and the costs of rapid urban development. The enormous pent up demand for housing that exists in Moscow coupled with a celebration of unbridled economic growth and the personal wealth that it offers mean that there is little or no popular discourse, and hardly any major grass-roots or civic group action, relating to, for instance, issues of rising social and spatial inequalities, or of the costs of growth. Yet, in some respects this coupled with Khimki's accessibility to Moscow may make politics rather more active in Khimki than many other localities. As one interviewee suggested, "Taking into account that Khimki is very near Moscow, it's a very politicized city." (Mikhaylov[7]). What was being described here was less a genuine conflict of developer and preservationist interests than the fabrication of such conflicts by different development interests, as highlighted by environmental activists:

[5] Interview with Dmitriy Pozdnev, Deputy Mayor for Building, Architecture and Land Use, Khimki Administration, 30 October 2008.

[6] Interview with Yuriy Maximov, Head of the Committee for the Economy, Khimki Administration, 30 October 2008

[7] Interview with Valeriy Mikhaylov, Chief Architect of the Urban District of Khimki, Khimki Administration, Khimki, 30 October 2008.

Figure 3. Some of many new residential complexes built in Khimki before 2009

On the one hand, there are those people who want to live in suburbs and they need a normal environment... On the other hand, there are the interests that want to pump up the economy of these zones and make them means for money-mining. This means maximum destruction to these green zones and maybe at the cost of residents but with some development of the infrastructure that will bring money... (Mikhail[8])

There is some evidence to suggest that the comparatively highly educated population of Khimki has exerted some influence on the municipality. One interviewee commented that the population did have rising expectations of the municipality in terms of improvements to the exiting housing stock (Pozdnev) and another that the public have been vocal at planning meetings (Mikhaylov). Yet, this is rather limited evidence that business and civic groups are becoming engaged in any political economy of place with any substantial degree of impact. There is, for example, little sign of business interests having become organized to any significant degree and no real evidence of lobbying government regarding the need for transport improvements, as would be the case in the US and Europe. Indeed, the only organized action regarding transport issues actually relates to environmental and civic group opposition to a by-pass proposed by the Federal government in order to relieve this bottleneck. A small but tenacious group of people have been trying to raise awareness of the potential destruction of a major forest area and part of Moscow's greenbelt that lies in the eastern part of Khimki which they suspect is driven by the new development opportunities that it would present.

As yet there is little indication that municipal level politicians are evolving distinctive agendas across the greater Moscow area. The problem is the system of politics that prevails at present is one in which local political leaders are constrained by patronage

[8] Interview with Mikhail and Evgeniya Chirikova, Khimki Forest Defence Movement, Moscow, 21 August, 2008

relationships with the regional governor. Thus "opportunities" for the building of a sense of place are often allocated by political leadership at a higher tier of government. As Rudolph and Brade's (2005: 139) argue "the districts of Moscow Oblast have relatively little influence on local economic development, because major economic actors operate at the level of the governor". Whilst Khmki has one of the largest municipal budgets in the Oblast, of more importance in this respect is that Khimki is considered, according to one interviewee, to be the 'locomotive for Moscow Oblast' (Maximov). The close relationship of the Khimki administration and its leadership to the Oblast government and its political leadership has ensured some significant flagship capital investments such as a new basketball and football stadium. However, to one observer from a major company operating in Khimki this relationship between municipal and regional government had provided little in the way of any place-shaping strategy:

Khimki administration work quite closely with the Moscow Oblast and Moscow Oblast needs to take a long-term grip but so far they have done little cosmetics for the citizens to see that the parks are greener and nicer and that the football stadium is a bit better and so on. I think they try with the funds they have. But what really will make a difference is the long term strategy (Gewert[9])

There are also obstacles for the territorial planning which are beyond the control of local or even regional administration. Khimki was originally built as a location for key state enterprises related to missiles and aerospace. As many of these enterprises are still controlled by the Ministry of Defence, the insertion of these state enterprises into municipalities represent a freezing in time of industry location, with only some urban adjustment to industrial expansion in the post-Socialist era. Furthermore, as Khimki has a complicated border and is inter-penetrated by the territory of Moscow. There is still a lack of inter-regional planning in Russia, while Moscow in particular is not keen to cooperate with federal government or its neighbour on such issues, as a number of interviewees indicated (e.g. Vorona[10]). The new general plan for Khimki, which is expected to come into force in 2009, and related land use zoning documentation leave considerable strips of the territory "in the middle" uncovered.

CONCLUSIONS

Patterns of suburbanisation and the development of satellite towns around Moscow embodied something of the ambiguities that were apparent in the planning ideals during much of the early Soviet era [French, 1995]. The ambiguous position of suburban and satellite settlements remains and has often been amplified in the post-Soviet era. Rudolph and Brade (2005), while making it clear that contemporary urbanisation at the periphery of Moscow can be described as a new phase, suggest that development at the periphery displays hybrid elements [Rudolph and Brade, 2005: 148]. Notable in this regard is a strengthening of processes of social polarisation that have become visible at the periphery. Perhaps as a corollary to this, as they argue, is that the economics of transition have become less powerful as a defining force in peripheral urbanisation and that "Rather, universal economic mechanisms and strategies with global effects are starting to shape the Moscow periphery" [Rudolph and Brade, 2005:148]. What we have described above tends to question the diminishing importance of transition.

While the case of Khimki may share some facets and controversies as depicted by the concepts of "edge city" and "(surburban) growth machine", it is still distinctive from these. Particularly, it is "placelessness" that must be added to the conceptualisation

[9] Interview with Herman Gewert, Vice-President, Director of Operations and Marketing, IKEA Real Estate Russia and Ukraine, Khimki, 6 November 2008 (in English)

[10] Interview with Galina Vorona, Ministry for Regional Development, Russian Federation, Moscow, 1 September 2008

of rapid urban growth in the context of post-Soviet Khimki. The placelessness, or the lack of purposeful place-making strategies by the growth coalitions, arises from a number of reinforcing reasons, including highly speculative development practices, a little interest of local businesses to influence the shape of wider urban development beyond their immediate control, and local government's retreat to standardised planning requirements and to a capricious allocation of developable land as opposed to visionary urban planning and development strategies. This model of growth destroys Khimki's Soviet-era industrial identity as a self-contained city and makes the city into an increasingly fragmented place which may well be hardly distinguished as one city, but rather as several peripheral dormitory districts of the city of Moscow proper. In this respect, Khimki may be considered as actually reverted from being a self-centred (moreover, "closed") city to more of a suburb.

However, Khimki does have a separate local government, which complicates the political structuration of development interests. Rather than being considered a peripheral and less well-off district of Moscow, Khimki finds itself in the position of being a "special" district of Moscow Oblast, effectively one of its wealthiest and investment-attractive. This territorial configuration circumscribes to some degree a place-focused element and creates prerequisites for Khimki remaining a separate place. It remains to be seen, however, whether a growing demand for new urban infrastructure and emerging residents' movements will further re-structure the modes of governing developments in Khimki more in line with what is believed to be proactive place-focused post-suburban politics.

ACKNOWLEDGEMENTS

This research was supported by the UK Economic and Social Research Council (ESRC). ■

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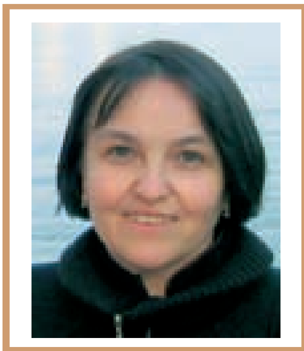

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"STRONG" AND "WEAK" GLOBAL ENVIRONMENTAL PHENOMENAS

Abstract Many global environmental issues being subject of ambitious international environmental politics could look very different in terms of scientific justification. This was revealed during interviews made by the author with some leading American environmental scientists. All interviewed American scientists granted minor confidence to three environmental issues – deforestation, desertification and biodiversity loss, while two issues – the ozone depletion and climate change – were deserved high degree of confidence. The striking difference in evaluation of the global concepts of environmental issues is discussed in the context of the classical epistemological problem of coexistence of "strong" and "weak" theories in modern science. The normative character of epistemology suggests that some ways of raising scientific credibility of the backward environmental concepts can be proposed. Better justification of these global environmental issues can help to move forward the environmental politics which have shown mere stagnation during the last years.

Key words: Global environmental issues, Precautionary principle, Demarcation, Scientific credibility, Epistemology, Environmental policy

INTRODUCTION

More than 200 multilateral environmental agreements (MEAs) now exist, forming a central part of the framework for global environmental governance. Most have appeared within the last 20 years. Today no one person or small group of specialists can master the body of knowledge and skills required to address global environmental problems comprehensively. Moreover, beyond the challenges of strictly scientific considerations are questions that rest squarely in the realm of public values and thus in the domain of political decision: our responsibility to future generations, even to the biosphere generally; the extent to which we trade future costs and benefits against present ones; aesthetic considerations; and opportunity costs associated with the allocation of resources to address environmental issues versus other issues as poverty, health or education.

With respect to strictly scientific issues the key question is: how can the public properly assess the credibility of a particular scientific concept? For example, in the face of disagreement within the scientific community, should politicians take actions against only modestly substantiated threats or should they wait for more conclusive and consolidated scientific consensus? In their turn could the scientists undertake targeted efforts to raise credibility of their concepts?

Many policy makers and environmentalists refer to the so called Precautionary Principle that sanctions preventative measures in condition of great uncertainty. But others want to test credibility of particular claims first in order to avoid wasting resources to address poorly substantiated hypothetical dangers. This paper investigates reasons for such testing on the example of key global environmental issues.

The idea for this paper came to one of the authors[1] as he was preparing a series of lectures on global environmental issues. During preparation of the course the author observed that theories of the global environmental issues differ greatly with respect to their level of scientific confirmation. The arguments supporting climate change, for example, looked to the author much more solidly grounded than those supporting "desertification".

Subsequently, the author visited the US spending several months as a Fulbright fellow at New York University (NYU). There he met several prominent American environmental scientists from different academic institutions. With them, in a series of short interviews the author discussed their views as to the level of confirmation of key global environmental issues – climate change, depletion of the ozone layer, desertification, deforestation, biodiversity loss.

These discussions brought two surprises. The first was the absence of any substantial difference among the views of those interviewed. Despite differences in expertise and background, the researchers (among them, biologists, hydrologists, climatologists, philosophers) were in agreement that only few concepts of global environmental issues deserve a high degree of confidence. The second surprise came with realizing that their position is very close to the author's one which he then believed was too radical to be shared by so many experts.

HOW CONFIDENT WE ARE ABOUT GLOBAL ENVIRONMENTAL THREATS?

This section is based on discussions of global issues with professors from several American universities and on their assessment of the level of confirmation of claims made with regard to those issues. The interviews lasted no longer than 30–40 minutes and focused on the comparison of five issues – ozone depletion, climate change, desertification, deforestation and biodiversity loss – that are widely seen as global threats to sustainable development of humankind in this century. All have been on the political agenda for many years and command considerable commitment of resources on the part of the national governments. It is therefore important to be sure that these five issues are analyzed in terms of genuinely "strong theories."

Specifically, the following five claims were offered for the experts to comment and rank them as to level of substantiation:

Ozone depletion has been driven by human production of CFCs;

Global warming is anthropogenically driven process threatening major damage to humans and their environments;

Desertification is taking place on a global scale;

Deforestation is taking place on a global scale;

We have entered, or are entering, a period of mass extinction of species of considerable importance to human welfare.

The author's own ranging of the five issues in terms of their scientific credibility coincided with the order they are presented above. However, in the author's view, the space on which the claims are ranked is not evenly partitioned with respect to the five issues: there is a large break between ozone depletion and climate change, on the one hand, and the three remaining issues on the other. The American experts interviewed showed surprising consensus despite differences in backgrounds and expertise. In general the scheme drawn by the author

[1] Nikolay M.Dronin.

was confirmed with single exception: the most experts place "desertification" issue on the one step down preferring to see "deforestation" on the third position. As the author the experts consider the two top issues as much more fully confirmed than all the others. The expert's comments concerning difference in credibility of the issues were valuable and interesting. Some news ideas emerged during the discussion. One was related to the criteria of "credibility" of an environmental concept. The author deliberately avoided to define strongly term of "credibility of concept" or "justification" during the discussion because one of the goals of the interviews was to ascertain whether diverse criteria come into play in evaluating concepts.

All the experts regard the "ozone depletion" concept as firmly established. However, it is important to note that for the most part the experts have no research experience with respect to the ozone problem. The only one to have such experience was cautious in his evaluation of the concept, stressing that some elements remain unclear. However, he also had no hesitation in placing this issue at the top of the list. Evidently, most of the experts see some confirmatory advantage in the existence of a clear mechanism that accounts for the phenomenon in question and in solid empirical verification of the process obtained, for example, during experimental airborne measurements of the stratospheric ozone over Antarctica in 1987. Thus two criteria emerge for the high ranking of ozone depletion: a theoretically clear mechanism of anthropogenic origin for the environmental issue and empirical confirmation of this causality.

All the experts ranked "climate change" second in terms of scientific confirmation. They stressed that theoretically the concept of human-induced change in the global climate is being well developed and looks plausible but empirical confirmation of the hypothesis about the causal link of observable warming and greenhouses emissions is less compelling because of the much more complex character of the phenomenon as compared with "the ozone depletion." The experts differed in relation to question how close the concept of climate change might be placed to that of "ozone depletion". Some regard the claims more or less equal in terms of substantiation while others find the evidence for anthropogenic climate change less persuasive. The first consider that existing models of climate change can be empirically tested by retrospective data or by observations of climate conditions in coming decade when the influence of solar activity can be controlled. Those who are less convinced point to the presence of noise in climate change data resulting from the multiplicity of factors capable of exercising influence (especially with respect to precipitation) and judge that changes in radiation change caused by increasing presence of greenhouses gases is too slight to be captured by direct observation. In view of these scientists, conclusions with respect to the anthropogenic character of climate change will rely on modeling efforts rather than observation. Despite this difference the scientists concurred in their "belief" in both ozone depletion and anthropogenic climate change. In relation to the three remaining environmental issues, such wording was never used.

The majority of the experts ranked deforestation third, well behind ozone depletion and climate change. Opinions of the experts varied very much concerning the weak elements of the concept. Some experts question empirical data on deforestation, regarding existent statistics on decrease of area of forests as unreliable and, certainly, exaggerated for tropical regions. Others regard deforestation as "simply fact." There was a decisive split among the experts (50:50) as to the very definition of "deforestation" as a global environmental issue. One group sees no problem in taking deforestation simply as the reduction of forested area globally or in some region of the world (say, South America or Central America). When invited to replace this conventional definition with a more "theoretical" one, these experts declined. However, the second group rejected the conventional definition as excessive simplification and stressed the need to define deforestation with respect to the essential role of forests in biosphere stability. According to this group a decrease of forest area should be regarded as a global environmental issue only at the threshold where normal function of the biosphere (including global climate) is disturbed. Thus some scientists question the reality of deforestation grounds that empirical evidence indicating unprecedented rates of forest reduction is missing while others do so on the ground of oversimplified definition of the issue. The net result is that only very few experts grant even moderate confidence to the issue.

The experts place the "desertification" in the fourth position in terms of scientific credibility. However, in this case the fourth position says very little about negligible credibility granted to the concept of "desertification". Actually 100 percent of interviewed scientists definitely said the issue was non-existent. The wording "it's tricky thing" occurred frequently. Most importantly, the scientists pointed to the absence of any empirical evidence confirming a steadily unfolding "desertification" in the regions of the world. Secondly, they pointed to the lack of clarity in the use of the term desertification which varies in thrust across policy documents and publications (from mismanagement of farming in semi-arid zone to the advance of great deserts). If we regard desertification as a global change caused by anthropogenic factors, then we must recognize the absence of any plausible theoretical explanation as to how human activity might cause desertification (aridization) globally. The experts pointed out that precipitation variability is ruled by caprices of global atmospheric circulation and all great droughts began and ended abruptly due to the change of circulation. It is worth noting that the credibility of desertification is rejected on three parameters: empirical evidence, theoretical explanation and confusion in the term itself.

Finally, the experts (with one exception) grant no credibility to the concept of the "biodiversity loss" and rank this issue as the least tenable. Biodiversity loss issue can be broadly defined as unprecedented decline, caused by human activity, in number of extant species, in their genetic (population) diversity, and in the variety of ecosystems. Among the most skeptically minded experts were biologists who stressed the extremely complex character of "biodiversity". They pointed out that as many classical theoretical problems of biology (for example, the problem of species borders) are not resolved, they cannot represent publicly the "biodiversity loss" issue with any confidence. The total number of species of any part of the world is still unknown (presumably 90%). The experts definitely rejected the hypothesis of observable mass extinction at present. All experts stressed the difficulty of gathering empirical evidence supporting the notion of loss of biodiversity. There are two ways to measure the rate of extinction of species. One is based on direct evidence of loss of known species. In this case the rate is not high when compared with the historical average. The second is based on an assumed correlation between the fraction of habitat destroyed by human activity and the fraction of species lost therein. When applied to the total number of species presumably resident in the area before human invasion, this correlation yields a fantastically high rate of loss of species. The method is obviously speculative because the total number of existing species is still poorly approximated and the correlation between number of species and areas of their habitats is not established. Perhaps, it would be more reasonable to suggest that it is not the diversity of species generally but the diversity within single species that is more affected by habitat loss. In summary the experts see no reliable way to obtain empirical evidence supporting mass extinction, find only weak theoretical substantiation (How could it happen?) and excessively broad definitions (from genes to ecosystems). Some experts think that the issue of loss of species should be addressed on the basis of cultural and quality-of-life considerations rather than from that of mass extinction.

CRITERIA OF SCIENTIFIC CREDIBILITY

There are still be few works suggesting criteria of credibility of environmental concepts. One of most original comes from Weiss [2006] who proposes a complementary twelve-point scale of certainty, based on a hierarchy of standards of proof used in various branches of US law in specific legal situations, and have assigned arbitrary but plausible quantitative probabilities (borrowed from so-called Bayesian statistics) to each point of the scale. It shows that even at low levels of certainty (10–20% in Bayesian terms) adoption of some serious actions may be called for (in legal practice the action can be as serious as "stop and frisk for weapons"). At very low levels of certainty (less than 1%) no actions are sanctioned ("does not justify stop and frisk"). The scale captures the thrust of the Precautionary Principal: action may be taken in the absence of near certainty to avert harm. According to Weiss [2006] this scale "could be the basis for a clear and understandable expression of uncertainty for policy makers".[2]

The proposed scheme, however, provides no basis for assigning particular events to particular points of the scale. Should biodiversity loss, for example, be assigned "reasonable suspicion" (1–10%), "reasonable belief" (20–33%) or "substantial and credible evidence" (67–80%)? Evidently, a special set of criteria is required to construct a "credibility index." In the absence of agreed instructions, assignments are arbitrary.

Popular view regards a "credible" scientific theory as having been confirmed by multiple observations. An account which empirical observation contradicts lacks credibility. Weiss, apparently, uses the term in this sense. An expert is expected to decide whether an outcome enjoys 10% or 80% confidence, given the strength of empirical evidence favoring it. However, this is a simplification of science. As seen from summary of the interviews, scientists use a variety of criteria to establish the credibility of any claim or account. The anthropogenic hypothesis of ozone depletion is credible because it offers a transparent and coherent account of the observation and because it has been confirmed by the correlation of ozone loss and the presence of anthropogenic substances in the stratosphere. From the point of view of scientists climate change, and its possible anthropogenic origin, is difficult to confirm by empirical observation because the climate is a complex system with many feedback loops and considerable noise. However, the concept earns a high degree of confidence due to the existence of a clear and theoretically plausible mechanism in the form of greenhouse gas emissions which drives the process. An account of low credibility lacks just such a mechanism to explain the observation and the empirical evidence to support it. Moreover, an account loses in credibility when subject to multiple and ambiguous readings (desertification) or excessively broad definition of terms (biodiversity loss). Such flaws not only prevent empirical testing but self-evidently undermine theoretical formulation.

LINKING EPISTEMOLOGY AND ENVIRONMENTAL STUDIES

Perhaps, evaluation of the credibility of concepts should be dealt within epistemology which has practiced a complex (holistic) approach to science. We may regard science as an enterprise that while constructing theories and seeking their empirical confirmation is shaped by social and political values and personal limitations. This is a classical problem of critical rationalism, namely the demarcation

[2] Other authors as well have seen the analogy between the precautionary principle and legal process. Peter Saunders said: "Moreover, like the legal principle, the precautionary principle does not demand absolute proof. A jury is not supposed to convict only on the balance of probabilities – the standard used in civil actions – but it does not need absolute proof that the defendant is guilty. It must only be convinced "beyond reasonable doubt" (Saunders 2000).

between strong and weak theory (or pseudo-theory) addressed by Karl Popper (in 1934), who advanced the notion of falsification as a criterion. Among those who followed Popper – Thomas S. Kuhn, Imre Lakatos, and Paul R. Thagard, each held his own position on the ways to demarcate "sound" science.

The views of the scientists in the interviews concerning assessment of credibility of global issues was improvisation on their part but their improvisations show the complex character of the problem which corresponds to classical epistemology. However, the experts did not explicitly raise any epistemological questions and, when directly asked about the relevance of Popper's notion or those of the post-positivists, they were skeptical. This is remarkable given that most of the scientists in my sample hold to the distinction between weak and strong theories. A few experts (with philosophical backgrounds) said that if they were to decide to write on the subject they would certainly take an epistemological approach. Philosophers of science and environmentalists share rather little. Maureen Christie [2000], a philosopher of science who analyzes the history of our understanding of ozone depletion with reference to Popper, is unusual in her concern with epistemological aspects of environmental studies.

However, there is benefit in referring our interviews to classical epistemology. The striking results of the interviews might be dismissed by reference to the subjectivity of the exercise. The selection of interviewees was anecdotal (although based on their professional records). The scientists are all specialists in particular areas and cannot know the ins and outs of other areas. Their opinions might be ill-founded. Nor were they in full agreement on some issues, as when in the evaluation of deforestation some questioned its empirical validation while others stressed only improper definition of the issue. Their responses do not conform to the dominant views found in official international reports.[3]

The experts proposed quite different criteria which do not lend themselves to easy systematization in a single scale such as that of Weiss. However, relocating this exercise in philosophical context reveals striking differences in credibility and confirms the epistemological opposition of "weak" and "strong" theories in modern science.

It is also important to recall that epistemology is a normative discipline and its final aim is to improve science. We think it wrong to reject any concept as totally unscientific. Weak concepts can be reformulated and improved to allow testing and assessment with respect to other demarcation criteria. Proponents of particular concepts must be willing to rework them so that they comply with the demands of scientific discourse. Recall that Popper [1978] changed his mind about the testability and logical status of the Darwinian theory of natural selection. As he wrote: "I am glad to have an opportunity to make a recantation. ... The theory of natural selection *may be so formulated* that it is far from tautological". By "may be so formulated" Popper believed that a theory that looked suspect to him for many years could be reformulated to allow empirical testing.

TO RAISE CREDIBILITY OF ENVIRONMENTAL CONCEPTS

MORE COMPETITION, MORE CREDIBILITY

The main indicator of a "strong theory" is that it faces acute competition from alternative theorizing. The alternative theory appears in the wake of the dominant theory as a reaction to its difficulties. The dominant theory has already made great strides

[3] For example, a survey of emerging issues carried out among scientists for *GEO 2000* listed the top three environmental threats (from the total number 36) as climate change (51%), scarcity of fresh water resources (29%), and deforestation/desertification (28%) (Global Environment Outlook 1999). However, according to the experts' evaluation the "desertification" as well "deforestation" issues are not deserved significant level of scientific confidence yet.

accompanied by extensive search for facts that confirm the theory but in this way new facts that challenge the dominant theory have inevitably accumulated. Although the dominant theory could settle the situation via the elaboration of additional hypotheses, not all scientists are happy and eventually propose a new theory to cover old (confirming) and new (discrepant) facts. The alternative theory plays the important role of external critic whose aim is to falsify the dominant theory as Popper wanted "real science" to do.

With environmental studies competition between concepts typically arises between two accounts of origin – anthropogenic and natural. The dominant concept of climate change suggests that observable and predicted global warming results from the anthropogenic increase of greenhouse gases in the atmosphere. The alternative concept argues that global warming is taking place due to the astronomically driven transition of the Earth from past-glacial to mid-glacial eras. Existence of two competing camps concerning climate change needs no demonstration as we find estimates about fraction of scientists from each camp in current literature. The dominant theory of ozone depletion asserts that the anthropogenic substance CFCs being accumulated in the stratosphere are the principal cause of formation of "the ozone hole". An alternative theory suggests that "the ozone hole" could be the result of upwelling of ozone poor troposphere air because of a climate shift. Yet another account pointed to an increase in solar activity between 1976 and 1984. Christie [2000] investigates the collision of alternatives in detail.

In contrast, "the weak theory" is too thinly formulated to give birth anomalies. The weak theory changes little over the years and reiterates the same formulations and arguments. Despite stagnation, as the theory seems self-evident, it can have many adherents. Difference in views among its proponents may exist, but rather than compete, they simply coexist. Little work is done to settle these differences. It is close to Kuhn's characterization of pre-paradigmatic science where the difference of views of scientists often concerns basic definitions. At least three concepts of global environmental issues – desertification, deforestation and loss of biodiversity – correspond to this stage of the development.

Remarkable differences in the meaning of the term "desertification" provide a useful illustration. The French botanist Aubréville, who first proposed the term in 1949, took desertification to be a negative change in semi-humid (but not semi-arid!) regions manifesting a decline of soil fertility, erosion, and thinning vegetation [Dregne 1986]. Today this meaning has all but been abandoned in favor of usage with strong geographic localization to semi-arid areas. "Desertification" has also been understood as the spreading of major world deserts into neighboring areas[4]. Many experts speak of the expansion of deserts and cite figures for the rate of this expansion. However, other experts consider desertification to be a desert-like transformation of lands in semi-arid zones caused by mismanagement, namely overgrazing and excessive tilling. This understanding prevails in modern conventions on desertification. According to more sophisticated concepts, human activity in semi-arid zone changes local climate for drier ones as a result of weaker convection in the atmosphere that causes aridization of the area [Charney et al. 1977]. These meanings coexist rather than compete. Little is done to clarify this difference and no competing arguments in favor of any meaning are found in the current literature. To move forward with clarification of the concept of "desertification" different meanings of the term must be settled first.

[4] "...the idea that the Sahara was a vast sand field advancing in great waves like the incoming tide of a sea became attractive to numerous writers on desertification that it now represents a common view on the subject" (Cloudsley-Thompson 1974). There apparently is something fascinating about the idea of an expanding desert threatening mankind. Encroachment of moving sand dunes on desert oases and transportation routes is an aspect of desertification that is of small areal extent but is locally important and highly visible" (Dregne 1986).

MORE THEORY, MORE CREDIBILITY

It is also essential for environmental concepts to offer a distinction between mechanisms (*what a phenomenon is it by itself?*) and evaluation of potential dangers (*what danger is posed to humankind?*). A clear distinction indicates conceptual maturity. Concepts of climate change and depletion of the ozone layer clearly distinguish these two aspects. Theory ascribes atmospheric warming to increasing concentrations of greenhouse gases (CO_2, most importantly). Other research models the possible impact (danger) of a much warmer climate on agricultural productivity, frequency of extreme weather events, health, disease, etc. Stratospheric chemistry investigates depletion of the ozone layer in relation to reactions between ozone and anthropogenic substances while impact evaluations explore the potential dangers of increasing radiation for human health and ecosystems.

For such global issues as deforestation, biodiversity loss, and desertification, the distinction between mechanism and impact receives scant attention. Factually the conceptual treatment of these issues is limited to declarations about their negative impact which figures as self-evident. Deforestation is bad because it results decline of forests. Such tautologies are a trap for environmental studies. Some of the scientists in our panel suggested that notion deforestation should not be limited to a narrow focus on the decline of forested area. There is no theoretical issue in the decline of forested area. Rather the notion should extend to the global function (service) of forests in the biosphere including global climate (some experts particularly stress the climate aspect). Such an extension would be the basis for a new definition of deforestation.

It is evident that global biodiversity loss is a serious concern for Earth and its population. To take this issue seriously is to move beyond this observation to search out the mechanisms that drive it. Some observers consider that the current situation is comparable to the largest geological catastrophes of the past. Surprisingly, no theory of this assumed mass extinction has been elaborated. Rather, it has been suggested in the literature of the last 30 years that current large-scale extinction of species results from the reduction of natural habitats. All estimates about current rates of extinction are based on this assumption with different variations. For example, O.E. Wilson, assumes that loss of 90% in the area of natural habitat is accompanied by a 50% loss in species [Habitat Loss and Biodiversity 2002]. Similarly WWF biologist T. Lovejoy projected loss of biodiversity at one-third as a result of suggested loss of 50% of tropical forests by 2000 [Lovejoy 1980]. The loss of species globally (based on such assumptions) varies between 33% and 50% which is comparable to the extinction rates associated with largest catastrophes in the geological history of the planet. None of the experts in the interviews took it seriously. The total number of species on the Earth and in any particular region (including the rainforests) is unknown.

At the same time the situation with "desertification" looks more advanced due to attempts to propose a theory of mechanism (and it gives the author ground to place this issue at higher position than "deforestation" in his ranging of the issues). Charney has suggested that the presence of more dust from degraded lands might decrease atmospheric convection with the result of less rain and diminished cloud formation in semi-arid areas [Charney et al. 1977]. This conjecture stimulated research into the origin of dust in areas neighboring the Sahara desert but remained unconfirmed [N'Tchayi et al. 1997]. This demonstrates nonetheless that Charney's theory can be empirically tested (and thus falsified) by observation. However, these attempts are scarce and are not at the focus of research devoted to desertification. More common are studies in which experts discuss potential danger for local populations and countries at risk. Differences in the meaning of the basic term mentioned above are typical.

Theoretical development of global environmental concepts must be priority for their proponents.

CONCLUDING REMARKS

With the exception of ozone depletion, which rose to prominence in 1987, the global issues considered in this paper came to world attention at Rio World Summit at 1992. At that summit only conventions on climate change and biodiversity loss were adopted. Two others – deforestation and desertification – were framed in convention format only significantly later. In the 17 years since the Forum, the state of environmental policy with respect to the five issues has changed remarkably. In terms of effective policy, the ozone depletion issue has been a resounding success. Forward movement on climate change ranks second. After some suspension associated with the slowing of environmental policy in the USA, the convention and associated Protocol promise to move much faster in the coming years. There is little doubt that results will be achieved soon.

Far more problematic is the development of policies in relation to the other three issues. Desertification was the subject for international policy many years before the Rio Conference. The problem was first put at the policy agenda at 1977 at a special UN conference on desertification. However, at the Rio Forum negotiations on the convention failed. One of the reasons was uncertainty as to the definition of the subject. Four years later (1996) the convention came into force due to enormous efforts at mediation by the UN. However by 2007 less than one-third of all countries had presented a plan of action while financing for convention efforts was on hold.

Although deforestation has been subject of international policy considerations since the end of 1970s, this issue is bogged down to an even greater extent as no convention has yet been adopted. The problem is subject to different interpretations. At the Rio Conference, some countries insisted that forests are a global ecological resource a view not shared by countries which export timber. A special UN Forest Forum worked from 2000–2005 to establish shared understanding for a convention but failed.

The Biodiversity convention somehow gained more support from parties at Rio in 1992 but progress has been modest. As of 2008, 189 countries had ratified the convention, but only a fraction of these have developed a Biodiversity Action Plan (BAP) which should provide a full inventory of individual species, with emphasis upon the population distribution and conservation status. The most common characterization of BAP is that it is a "daunting task" as only an estimated ten percent of the world's species are believed to have been described, mostly plants and lower animals. Moreover, such plans come with heavy associated costs.

Difficulties in the development of the environmental policies can be explained in part by the existence of different interests of the parties involved. Still, the role of scientific status of the issues under scrutiny should be not overlooked. The struggle to achieve agreement on international environmental issues is waged on highly competitive ground where political and economic interests are frequently deeply conflicted. In this struggle only claims which enjoy high credibility will overcome the subrational self-interest of all parties.

ACKNOWLEDGEMENTS

The research was done in the frame of Fulbright fellowship granted to Nikolay Dronin and the author appreciates R. Wagner School of Public Management, New York University for warmly hosting, and Professor Dennis Smith for being encouraging academic advisor. We also thank Dr. Renee Richer from Weill Cornell Medical College in Qatar, for her kind regarding and commenting the paper.

We thank as well all the panelists: Professor Stephen Pacala, Director of Princeton

Environmental Institute, Professor Michael Oppenheimer, Director of the Program in Science, Technology and Environmental Policy at the Woodrow Wilson School, Princeton University, Professor Simon Levin, Director of Center for BioComplexity, Princeton University, Professor Dale Jamieson, Director of Environmental Studies at New York University, Dr. Tyler Volk, Associate Professor of Biology, New York University, Dr. David Holland, Director of the Center for Atmosphere Ocean Science, New York University, Dr. Andrew Robertson, Research Scientist, International Research Institute for Climate Prediction of the Earth Institute of Columbia University, Dr. Richard Seager, Senior Research Scientist, Lamont Doherty Earth Observatory of Columbia University, Dr. Michael Hill, Professor, Department of Earth System Science and Policy, University of North Dakota, Dr. Rebecca Romsdahl, Assistant Professor, Department of Earth Systems Science and Policy, University of North Dakota. ■

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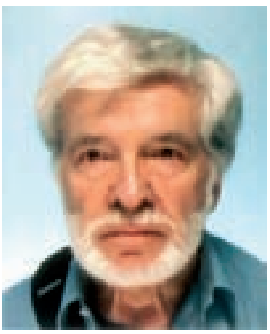

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MATHEMATICAL MODELLING OF SPATIAL-ECOLOGICAL COMPLEX SYSTEMS: AN EVALUATION

ABSTRACT

Assessing the complexity of landscapes is one of the top research priorities for Physical Geography and Ecology.

This paper aims at a methodological evaluation of the discrete and analytical mathematical models hitherto available for quantitative assessments of spatial ecological complex systems.

These models are derived from cellular automata and nonlinear dynamics. They describe complex features and processes in landscapes, such as spatial ecological nonlinear interactions, unpredictability and chaos, self-organization and pattern formation.

Beginning with a distinction between two basic types of spatial ecological complexity (structural, functional), and after reviewing the quantitative methods so far available to assess it, the areas where the major challenges (and hence, difficulties) for future research arise are identified. These are: a) to develop measures of structural spatial-ecological complexity, b) to find Lyapunov functions for dynamical systems describing spatial interactions on the landscape (and related attractors), and c) to combine discrete time and continuous spatial data and models.

Key-words: Geographical Modelling, Nonlinear Dynamical Systems, Complex Geo-Systems, Lyapunov functions, Cellular Automata

INTRODUCTION

Various research efforts undertaken over the last years aimed to evaluate how complex a landscape may be. If successful, such methods would have been useful for the theory of landscape ecological analysis, as well as for the practice of landscape management. Geomorphology does not appear to have any widely accepted tool or method to evaluate landscape complexity, while Landscape Ecology presents studies in which assessments of landscape complexity are made by using various (and, to a certain extent, subjective) combinations of already known landscape-ecological indices.

To date, neither of these disciplines possesses a set of general methods to measure landscape complexity. Consequently, a number of questions rise: Why is this so difficult? What are the main analytical models for calculating how complex a landscape is? How far have we advanced in modelling landscape complexity by using analytical methods? These questions are tackled theoretically in this paper.

Landscape complexity is a key research priority in Landscape Ecology according to Wu & Hobbs [2002] and several studies have appeared over the last years in the literature, related to quantitative assessments of landscape complexity [e.g. Gabriel et al, 2005; Kolasa, 2005; Herzon & O'Hara, 2006]. Research has produced evidence of non-linear interactions in the landscape [Pahl-Wostl, 1995] and findings related to complexity observed from within landscape dynamics [Turchin & Taylor, 1992].

In Geomorphology also, there is evidence of complexity in landforms [Werner, 1999] and landform formation processes [Fonstad, 2006] and it was also suggested that landscape complexity should be one of the highest research priorities in Geomorphology [Murray & Fonstad, 2007].

The objectives of the paper are: a) to present a state-of-the-art account of the discrete and analytical mathematical methods used to model landscape complexity (particularly functional landscape complexity, which seems more difficult to decipher) and b) to present an effort to shed light on the fields in which ambiguities or difficulties arise, related to modelling and computation of landscape complexity with such methods.

TWO TYPES OF LANDSCAPE COMPLEXITY

Despite the recognition of the importance of the subject, there are however difficulties in the classification of types of landscape complexity. For instance, Loehle [2004] suggested, that there are five types of "ecological complexity", aside of spatial ecological complexity: temporal (population dynamics etc), structural (referring to relationships within the ecosystem), process (i.e. steps and compounds), behavioural (i.e. adaptation) and geometric. The latter might be considered as yet another form of spatial complexity, with emphasis on the third dimension and the particular shapes of ecological objects. Yet, this is one classification only, available from the domain of Ecology. There is no widely accepted typology of ecological complexity however, nor any classification from the domain of Landscape Ecology. In line with previous publications, in this paper it is suggested that landscape complexity may be of two basic types: structural and functional, which can both change with time and hence can be "dynamic" (in the sense of [May & Oster, 1976]). The words "structure" and "function" have precise meanings in Landscape Ecology and the reader is referred to any classic text of landscape ecology [Forman & Godron, 1986] for their explanation.

The *structural* landscape complexity can be computed in various ways, i.e. through the study of a landscape's map or a landscape's satellite image or aerial photograph. In this case, the computation of landscape complexity is equivalent to the calculation of spatial complexity from the landscape's land use, land cover, soil and vegetation maps. Hence, a landscape's structural complexity is higher than another's, if it has higher diversity of land cover types and longer boundary length of its patches. The main problem here is that we do not have a general algorithm providing us with these characteristics in a unifying way.

The computation of *functional* landscape complexity is more elaborate than that of structural landscape complexity, due to the non-spatial characteristics of landscape functions. Such functional characteristics (i.e. species interactions, water flows, soil movements, trophic chains) render the calculation of landscape complexity particularly difficult, because quantitative assessments of the relationships among the landscapes' constituents (plant and animal species, soil and non-biota) are much more complex than the landscapes' structural components are.

What mathematical tools do we need to model structural and functional landscape complexity?

Ecological modelling entails a diverse array of mathematical methods. But, two main categories of mathematical methods prevail: discrete and analytical. Given that ecosystems are ususally described as populations, we often use analytical mathematical methods (i.e. differential equations models). These equations are modelling the change of a population species *X* with time: *dX/dt*. They are typically nonlinear and therefore describe how different populations (i.e. pray *X* and predator *Y*) interact. These interactions are shown by "nonlinear" terms in these equations (terms such as X^2 and *XY)*.

Yet, when we need to explore the spatial components of ecological changes, the analytical mathematical models are very difficult to handle, because solving differential equations in space and time per grid cell is a painstaking undertaking, due to the many mathematical difficulties arising (boudnary conditions etc). It is for this reason that researchers have turned their attention to non-analytic models also, such as cellular automata. With cellular automata, we have the possibility to explore changes over a geographical space with relatively simple rules, without solving any complicated equations, as we do with differential equations models.

COMPLEX SYSTEMS AND SELF-ORGANIZATION

"Complex Systems Theory" entails a very wide spectrum of applications, in many disciplines, such as economics, physics, physiology, astronomy, materials science etc. We most often use this term to signify precisely what is understood by the layman as "complex" and to explore how some system becomes complex, why, by what processes, and, once it becomes, how does it evolve in time.

Complex Systems Theory usually focuses on processes and behaviours that lead to "complex behaviour". As such, we often mean behaviours difficult to decipher, difficult to predict, difficult to quantify. Such behaviours can thus be unpredictable or chaotic. A major discovery of Complex Systems Theory is that unpredictability and chaos may also emerge from purely deterministic systems. In fact, as will be seen in the next chapters, it may emerge from even simple differential equations systems.

As there is a variety of features of complexity aside of pattern formation in an observed system (i.e. connectivity of elements, stabilization and resilience, emergence of new properties), the mathematical methods, that can be used to model complexity in any system vary immensely and they can range from methods of discrete mathematics to calculus. But it is the mathematical analysis of nonlinear systems that occupies the foremost and central tool we possess to tackle issues of complexity in any system. In fact, the major part of Complex Systems Theory uses analytical methods for tackling complexity. And landscapes are no exception to this. Furthermore, analysing the role of time in the spatial evolution of ecosystems constitutes a central theme in landscape ecological analysis. It is precisely in this respect, that cases of "self-organisation" (or "pattern formation"), observed on a landscape are hallmarks of complexity and complex behaviour. It is also at this point that models using analytic approaches (differential equations) are most valuable and preferred at the expense of any other mathematical approaches.

Self-organization in ecosystems may be spatial and non-spatial. For instance, when spatial units interact and, after some time, result in a "permanent" spatial allocation, we may call this process a self-organization. Also, when populations interact and, after some time stabilize, this is also a (*sensu lato*) self-organization process. Examples of purely spatial self-organization can be seen from cellular automata, and examples of "functional" self-organization occur in the case of species interactions, such as those described by Lotka-Volterra models (with certain values of their parameters only).

WHY IS LANDSCAPE COMPLEXITY DIFFERENT THAN LANDSCAPE HETEROGENEITY

Clearly, the "complexity" of a landscape is different than its "heterogeneity" and the latter concept is simply a sub-concept of the former. A highly heterogeneous landscape is also highly complex. But a highly complex landscape may not be such because of the complexity of its heterogeneity only. It can also be complex due to the complexity of its functions. So high heterogeneity may imply high complexity, but the reverse does not always hold. Further, a less heterogeneous landscape and with lower functional complexity, may develop a more complex dynamic behaviour than another more heterogeneous landscape, and this complex behaviour may lead to the creation of patterns or self-organisation, which, as stated earlier, constitute a key difference between complexity and its components, such as heterogeneity. In fact, considering the context of the word "complexity" (as understood in the domain of Complex Systems Theory) is enough to reveal its difference with "heterogeneity": in Complex Systems Theory, complexity is perceived as a condition *in between order and randomness*, where self-organization appears and spatial patterns emerge (fig. 1).

Following these methodological concerns, the computation of each one of the two types of landscape complexity previously referred to presents distinct challenges. We therefore have both discrete and continuous approaches to it. Discrete (algorithmic) methods are mainly used to assess structural landscape complexity, while continuous (analytical) approaches are more suitable for problems of functional landscape complexity, without precluding the possibility of using analytic methods for both types. Also, both methods are used for describing temporal changes in landscape complexity (either structural or functional).

MODELLING STRUCTURAL LANDSCAPE COMPLEXITY

Discrete models for structural landscape complexity are mainly based on cellular automata. These are automatic evolutionary processes depending on a set of "states" S_1, S_2, ..., S_n and a set of "transition rules" T_1, T_2, ..., T_m, acting on these states. Each cell is found in one state only and its state is determined by the rules and the states of the surrounding cells. Consequently, at each time $t + 1$, the state of each cell, S_{t+1}, is determined from the transition rule T_i acting on the state of the cell at time t:

Fig. 1. According to Complex Systems Theory, complexity is a condition in between order and chaos, so neither landscape A (ordered) nor landscape C are "complex", because A is completely ordered and C is completely random. But landscape B is complex, because it is in between the two states of order and randomness and displays distinct patterns (such as the dark area in the middle) (Fivos Papadimitriou. 2009).

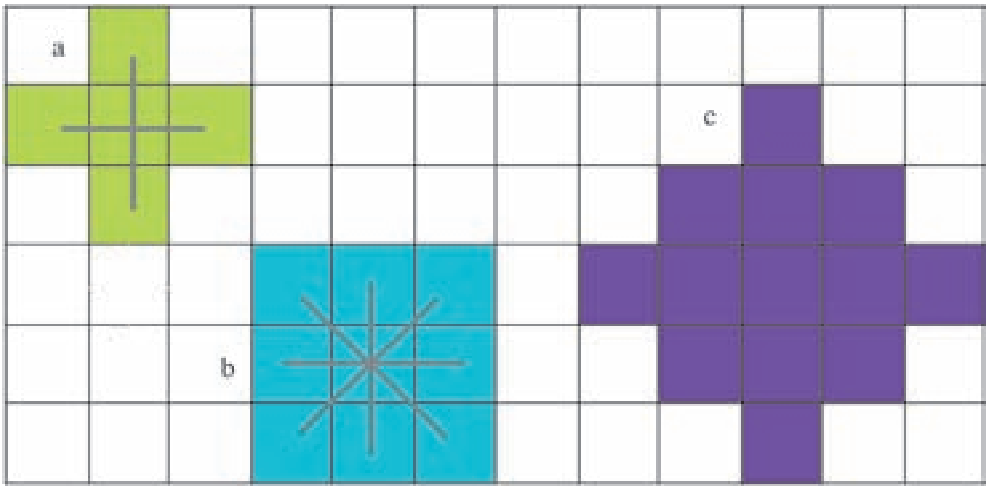

Fig. 2. Elementary cellular automata: in "rook's case" (a), the central cell interacts only with four surrounding cells, while in "king's case" (b) it interacts with all nine surrounding cells. In a 5-cell von Neumann neighbourhood (c), the central cell interacts with 12 cells around it (Fivos Papadimitriou. 2009)

$$S_t \xrightarrow{T_i} S_{t+1}$$

The "rules" are simple algorithms acting on landscape cells in two dimensions (fig. 2), that can interact with their neighbouring cells, either in the "rook" sense or in the "king" sense (as the rook's or the king's movements in chess) in cases "a" or "b" respectively. The former is also called a "3X3 von Neumann neighbourhood", while the latter is also called a "9-cell Moore neighbourhood".

There are other possibilities for constructing cellular automata with longer interactions than in the 9 cells surrounding the immediate neighbourhood of the central cell. One such is the "5X5 Von Neumann neighbourhood" (case c).

The simulation usually needs object-oriented languages, such as Java, C++ and Delphi.

Cellular automata have been applied to explain complexity in a number of cases in Landscape research, ranging from the possibility to establish general algorithmic ecological laws, to the exploration of ecological processes such as niches, industrial ecologies, interspecies competition, latitudinal gradients and species diversity [Rohde, 2005; Baynes, 2009].

Also, they have been applied in Geography to model the expansion of urbanization in the course of time [Barredo et al, 2003; Guermond et al, 2004], geomorphological processes (i.e. run-off and soil erosion) in basins [Guermond, et al, 2004; D'Ambrosio et al, 2001], and overall landscape evolution [Matsuba & Namatame, 2003; Sprott et al, 2002].

With cellular automata, we can simulate the ways by which landscapes change with the spatial propagation of fire [Green et al, 1990; Duarte,1997], we can even explore the complexity of spatial synchronization processes [Satulovsky, 1997], as well as phenomena of self-organization in landscapes [Manrubia & Sole, 1996; Malamud & Turcotte, 1999].

It must be noticed however, that cellular automata are useful to *simulate* the spatial mechanisms of complexity of some geographical processes, but they do not help us measure landscape complexity. This is because with cellular automata we simulate landscape changes over time and observe pattern formation and self-organization, which are signs of complexity (fig. 3), but they are not particularly enlightening as computational measures of spatial

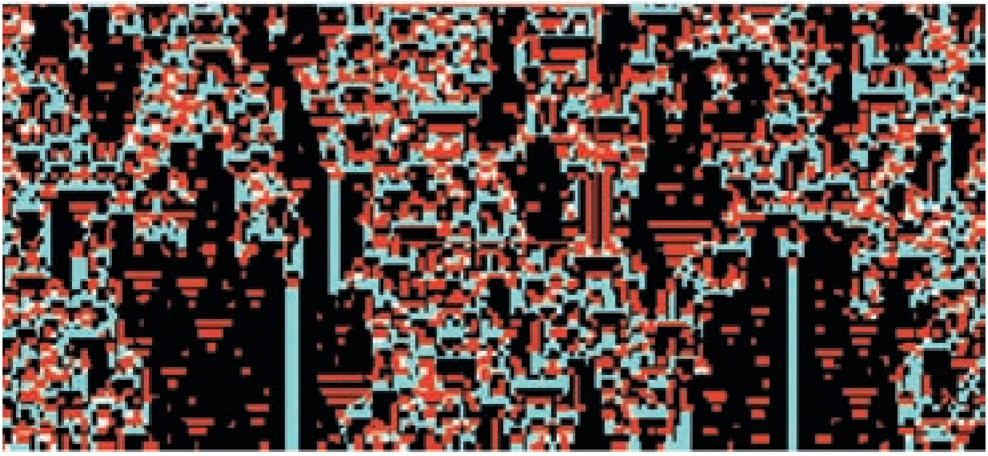

Fig. 3 An example landscape covered by a cellular automaton with 4 interacting "land cover" types, which has evolved after 100 time steps and begun from a random initial spatial distribution of its four land cover. After this number of time steps, it now shows areas of "self-organization" (areas of homogeneity, i.e. down-left and down-right), even some linear features (the vertical lines in the lower half of the landscape) (Fivos Papadimitriou. 2009)

complexity (*describing* a complex process as it evolves with time is different than actually *measuring* it).

Furthermore, in cellular automata the transitions between landscape states are given by rules and not by equations, so we cannot apply analytic mathematical methods for studying the evolutionary processes they describe. In a way, with cellular automata we trade realism with ignorance. In other words, the more realistic our representations are, the more ignorant we are about the analytic details behind the processes we model.

MODELLING FUNCTIONAL LANDSCAPE COMPLEXITY

SINGLE SPECIES MODELS

One of the major discoveries in Complex Systems Theory was that complex phenomena, such as bifurcations and chaos may appear from even simple nonlinear dynamical systems. A typical such case is the logistic differential equation:

$$\frac{dX}{dt} = aX(1 - X)$$

which displays periodicity for $a = 3.2$, whilst for other values such as $a = 3.75$ for which it is plotted here, it displays stable and chaotic orbits (fig 4).

In its discrete and recurrent form

$$X_{n+1} = aX_n(1 - X_n)$$

it holds for $a \leqslant 4$ (otherwise $X \rightarrow -\infty$) and it displays another interesting complex behavior, which is bifurcations (fig 5), for iterative values of X_n (plotted for $X_0 = 0.5$ here).

Interestingly, when a > acritical = 3.569945, the solutions become very complex and fluctuate wildly. Thus, even simple ecological models can display very complex dynamic behavior and this discovery has been one of the cornerstones of Complex Systems Theory, as it reveals that even simple deterministic systems are difficult to predict, because they are "infinitely sensitive" to initial conditions.

Another single-species model which has attracted much attention is the *Levins* model [Levins, 1969], because it aims at exploring analytically the spatial inhomogeneities of a population.

Defining with X the fraction of patches occupied at a given time, the model considers that each occupied patch may

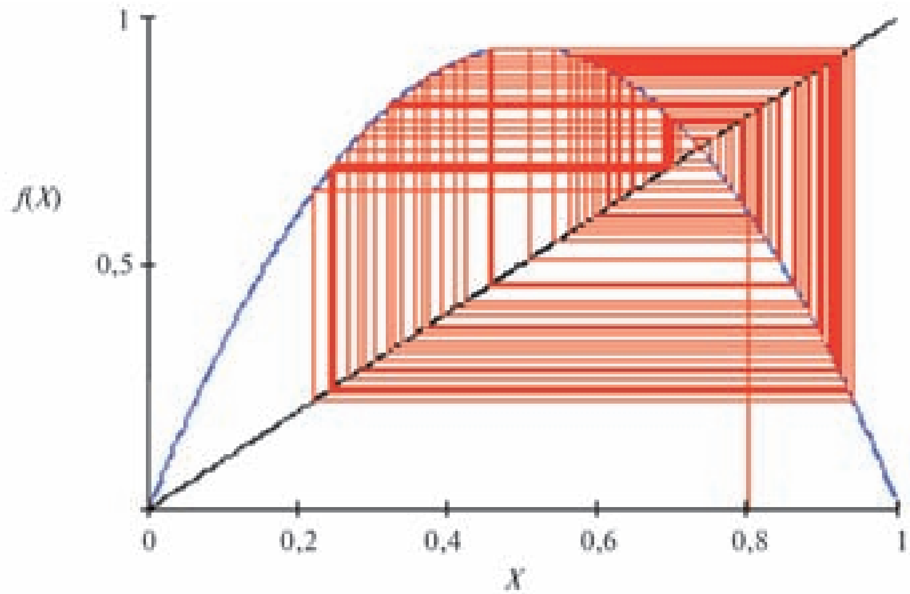

Fig. 4 "Chaotic orbits" generated in the logistic function for values of *a* = 3.75 (Fivos Papadimitriou. 2009)

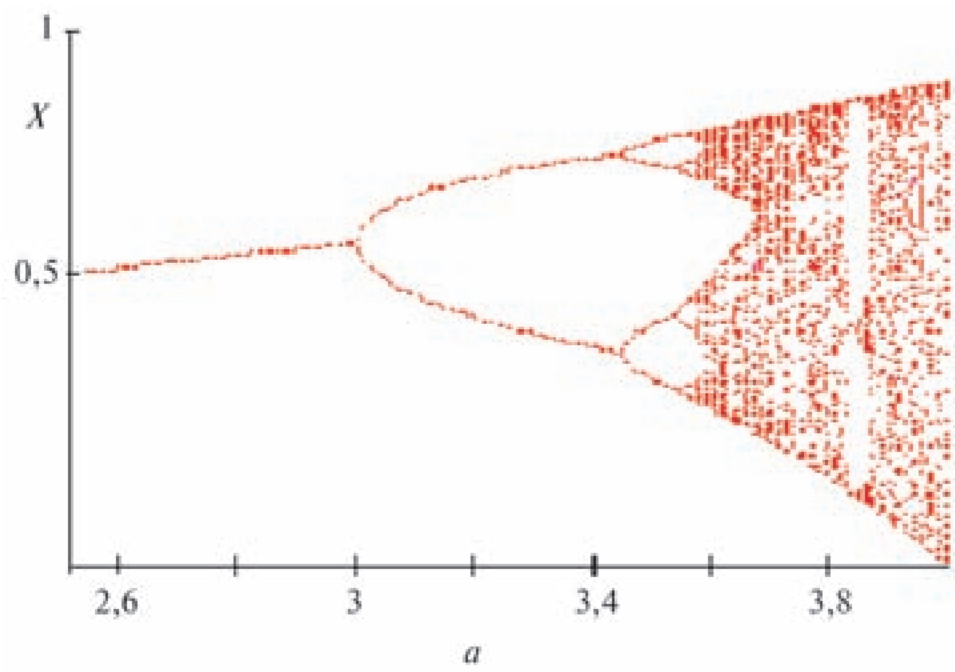

Fig. 5 Bifurcations generated in the logistic function for values of *X*=0.5 (Fivos Papadimitriou. 2009)

become unoccupied after some time *t*, with probability *m*. Hence, 1 – *X* is the proportion of unoccupied patches (which nevertheless remaining subject to colonization). Letting *c* be a constant rate of propagule generation for each of the *X* occupied patches, the probability for each unoccupied patch to be colonized is *cX*. Consequently, the change in the proportion of occupied patches, *dX/dt*, is:

$$\frac{dX}{dt} = cX(1 - X) - mX$$

Setting dX/dt equal to zero, gives either $X = 0$ or

$$X = 1 - \frac{m}{c}$$

The latter relationship implies that $X \leqslant 1$, so some fraction of a species habitat will always remain unoccupied.

Also, this model predicts that increasing colonization rate leads to increasing numbers of occupied patches, but does not consider the effects of local dispersion (fig. 6).

A variance of the Levins model is the Nee-May model:

$$\frac{dX}{dt} = cX(1 - D - X) - mX$$

where D is the proportion of permanently destroyed habitat areas.

With this spatial model, Nee & May [1992] showed that habitat destruction increases the population of the inferior competitor when two species compete in a non-homogeneously fragmented landscape. This unexpected finding is interpreted as an outcome of the process, whereby the superior competitor suffers greater losses, because of the habitat construction (e.g. due to its lower colonization rate).

TWO-SPECIES MODELS

Yet, we seldom use single species models to model geographically complex sistuations. Our mathematical models in spatial analysis typically use dynamical sytems approaches, based on differential equations models describing systems of species interactions, such as the *Lotka-Volterra*. These systems constitute the "standard" for the analysis of complex nonlinear dynamics. Aside of ecological complexity analysis, Lotka-Volterra systems have been useful in analysing geomorphological landscape evolution (erosion, regeneration and tectonic uplift), by developing models of nonlinear dynamics [Phillips, 1995], from which may emerge new landscape structures through changes of the overall stability regime, described by these differential equations. Phillips [1993] for instance, showed that the landscapes of drylands are inherently unstable, because perturbations tend to grow in these areas.

The basic Lotka-Volterra model of nonlinear ecosystemic dynamics (where X = prey and Y = predator) is:

$$\frac{dX}{dt} = aX - bXY$$
$$\frac{dY}{dt} = -cY + gXY$$

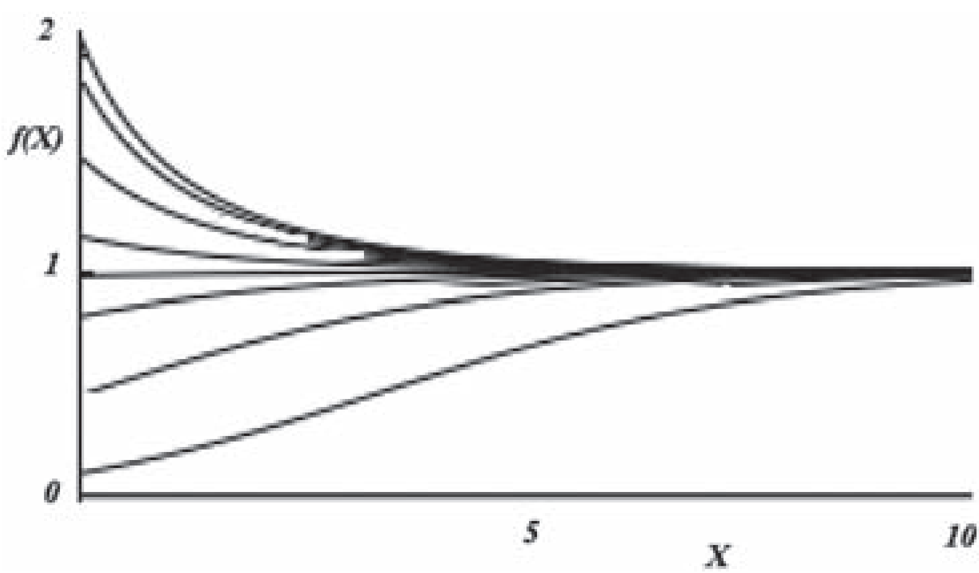

Fig. 6. Graph showing curves of solutions of the Levins model(Fivos Papadimitriou. 2009)

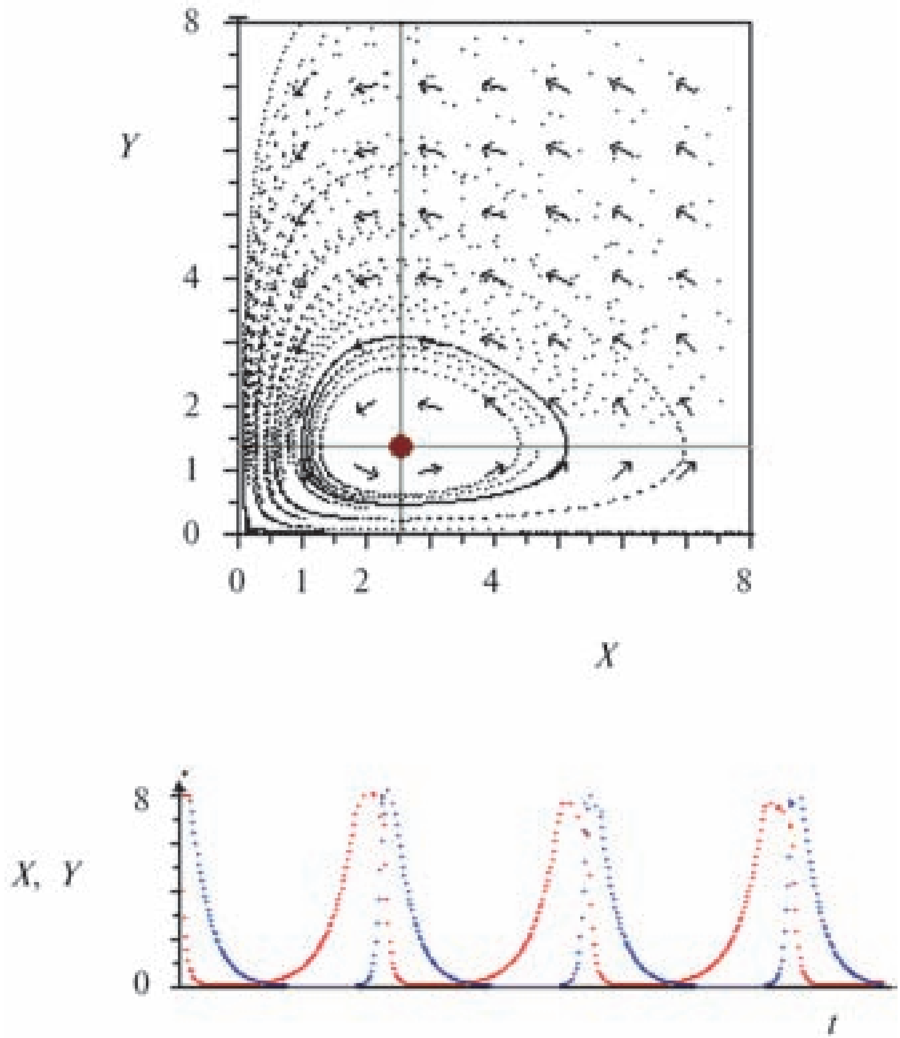

Fig.7. The solutions of a non-linear dynamical Lotka-Volterra system of two species (*X* = prey, *Y* = predator). The attracting region, or "attractor" is shown in the lower left area of the upper diagram (a quasi-ellipsoid area). In the lower diagram, appear the oscillating species populations *X* and *Y* plotted against time. The calculation here is with parameters $a = c = 0.95$, $b = g = 0,7$ and initial values $X_0 = Y_0 = 8$ (Fivos Papadimitriou. 2009)

The prey X has a growth rate *a* and depletes according to a predation rate *b*.

The predator Y has a mortality rate *c* and grows according to the food conversion rate *d*.

An example calculation of this system with $a = c = 0.95$, $b = g = 0,7$ and $X_0 = Y_0 = 8$, is shown in fig. 7, from which a possible long-term evolution of the system's behaviour becomes obvious: the system tends to concentrate to the ellipsoid attractor in the lower left part of the graph, over a range of possible orbits (depicted with arrows).

Lotka-Volterra systems display easily spectacular nonlinear behavior, because the nonzero equilibrium point $(X, Y) = (a/b, c/g)$ is unstable. In ecological analysis at the landscape level, it is remarkable, that spatial heterogeneity can lead to behaviors different than those expected from non-spatial species interaction models, so allowing for the survival of populations at the landscape level, which otherwise would not happen.

THREE-SPECIES MODELS

For three species (X, Y, Z), a well known variant of the Lotka-Volterra model is the *May-Leonard* model [May & Leonard, 1975]:

$$\frac{dX}{dt} = X\{1 - X - aY - bZ\}$$
$$\frac{dY}{dt} = Y(1 - bX - Y - aZ)$$
$$\frac{dZ}{dt} = Z(1 - aX - bY - Z)$$

This model displays a noticeable behavior from the point of view of Complex Systems Theory, because the system's trajectories show pairs of species approaching extinction with closeness to extinction growing with time.

With three species also, the *Hastings-Powell* model is equally suitable for complexity analyses: t represents the functional relationships in a three-species ecosystem, where species X is the resource species, lying at the bottom of the food chain, Y is a species feeding on X and Z is a predator feeding on Y, with a_i, b_i parameters:

$$\frac{dX}{dt} = X(1 - X) - a_1 b_1 \frac{XY}{X_1 + X_0}$$

$$\frac{dY}{dt} = a_1 Y\left[\frac{b_1 X}{X_1 + X_0} - 1\right] - a_2 b_2 \frac{YZ}{Y + Y_0}$$

$$\frac{dZ}{dt} = a_2 Z\left[\frac{b_2 Y}{Y + Y_0} - 1\right]$$

The complexity of interactions among the three species becomes evident when, for certain parameters a_i and b_i, the model displays a chaotic behaviour [Klebanoff & Hastings, 1994].

N-SPECIES MODELS, LYAPUNOV STABILITY AND CHAOS

Both instability and stability are linked with complex systems. A system may be stabilising with time and, by doing so, it may lead to pattern formation and self-organisation. When it destabilises, it may give rise to chaotic and unpredictable behaviors.

A prominent measure of system stability are the Lyapunov exponents. When the Lyapunov exponents are positive, then the system displays diverging orbits with time in its phase space, instability and, possible, chaotic behavior. When the Lyapunov exponents are zero, then a constant distance between orbits is maintained and, when they are negative, the orbits converge to a region of the phase space (or to a point) and the system is stable. Consequently, they are useful in the study of long-term behaviors of complex systems.

Besides Lyapunov exponents, there are "Lyapunov functions", usually symbolized as $V(X(t))$, which characterize the stability of a dynamical system of population species X. These functions must be positive or zero if and only if $X = 0$ and their derivative $\dot{V}(X(t))$ must be negative.

The usefulness of Lyapunov functions is that they can be employed to explore a system's stability without having to calculate its real energy potential (which can be frustratingly difficult in many domains of the natural sciences).

More generally, for n-interacting species, the Lotka-Volterra model is:

$$\frac{dX_i}{dt} = r_i X_i (1 - \sum_{j=1}^{n} a_{ij} X_j)$$

where r_i is the inherent growth rate for X_i and a_{ij} is the interaction matrix.

In other words, the change in the population $\frac{dX_i}{dt}$ of the species X_i is equal to the growth $r_i X_i$ of this species modified by the interactions a_{ij} of this species with all other species present in the same ecosystem: $\sum_{j=1}^{n} a_{ij} X_j$

So for a changing landscape whose dynamics is described by a matrix of nonlinear differential equations, such as:

$$\frac{d\mathfrak{I}}{dt} = \begin{bmatrix} f_1(X_1, X_2, ..., X_n) \\ f_2(X_1, X_2, ..., X_n) \\ ... \\ f_m(X_1, X_2, ..., X_n) \end{bmatrix},$$

the system's divergence or convergence of orbits (repellors or attractors) is given by its Lyapunov exponents (λ). They are as many as the dimensions of the system's states and each one of them gives the rate of convergence or divergence of nearby orbits to the orbits of the system's dynamics. Hence, Lyapunov exponents constitute the prominent measure of stability. Typically, they are defined as:

$$\lambda = \lim_{\substack{t \to \infty \\ \Delta X_{0_t} \to 0}} \frac{1}{t} \ln\left|\frac{\Delta x_i(X_{0_i}, t)}{\Delta X_{0_i}}\right|,$$

where X_i is a variable of the landscape (e.g. species population),

or, alternatively,

$$\lambda = \lim_{N_t \to \infty} \frac{1}{N} \sum_{n=1}^{N} \ln\left|\frac{\partial f(X_n)}{\partial X_n}\right|$$

Thus, the Lyapunov exponents are defined from the iterations $n = 1, 2, ..., N$ and the derivative $\left|\frac{\partial f(X_n)}{\partial X_n}\right|$ measures the speed of divergence of nearby orbits of population changes of species X with time.

When the Lyapunov exponents are positive ($\lambda > 0$), the system is unstable and/or chaotic.

It is precisely at this point that certain interesting challenges to these deterministic nonlinear models of landscape complexity begin to surface.

As is known from Complex Systems Theory, the complexity of such landscape-ecological systems could be described by analytic methods, based on "Lyapunov functions". These functions give descriptions of the overall stability regime of a dynamical system and relate to the "Lyapunov exponents" of the system previously referred to. Consequently, the challenge for landscape analysis is to find attractors in the phase space of the dynamical system (which adequately represents the landscape dynamics) with a (fractal) dimension that would be lower than that of the system considered.

Identifying a low-dimensional attractor from within a deterministic model (such as in the case of the nonlinear differential equations models presented previously) predicts the model's long-term dynamic behavior. This procedure is tantamount to the "shrinking" of the initially hard problem to an easier problem, of lower dimension, and with some easier to describe long-term behavior.

In this respect, it is interesting to notice, that by studying the ecosystem's (and, more generally, the landscape's) dynamics by means of a Lyapunov function, it is possible to derive its long-term (qualitative) dynamics *without* solving numerically the set of equations of the dynamical system [Pykh, 2002]. Although this is theoretically possible, identifying a Lyapunov function for any dynamical system can be a painstaking undertaking, often unsuccessful without some good luck, so we can always attempt to discover Lyapunov functions in order to derive assessments of a landscape's dynamics, but we can not be assured that we will always be able to find them.

CONCLUSIONS

We need to model landscape complexity for both theoretical and practical purposes. Theoretically, we need to be able to model landscape complexity and practically, we need to know whether a landscape is more complex than another and so consider its higher complexity as a potentially additional reason to protect it.

We know that striving to model landscape complexity analytically over the last years has been a particularly difficult undertaking. This study elucidates the causes behind these difficulties, while, at the same time, pointing to possible directions where future research in landscape complexity might focus on.

From the evaluation of these mathematical models, we notice that we do not know whether there exists a numerical algorithm which could compute *both* structural and functional landscape complexity simultaneously. Hence, the difficulties in modelling the two types of landscape complexity pose limitations to modelling "landscape complexity" in its entirety.

To summarize, by evaluating the methods of landscape complexity modelling, we deduce the following:

a) A universally accepted "library" of computer programs for geographical automata is yet to be created. Ideally, this should be a component of a G.I.S. (geographical information system).

b) Cellular automata describe processes of complex behavior in landscapes, but do not constitute measures of landscape complexity themselves. For this reason, we have to explore other computational approaches in order to measure structural landscape complexity.

c) The development of differential equations models of landscape complexity is an uncomplicated procedure, but it is not always possible to find Lyapunov functions for dynamical systems describing spatial interactions on the landscape.

d) Further, it is not always possible to find an attractor from time series of observations of functional landscape changes (even in the case that we may have temporally dense measurements of landscape and/or species population changes, we may encounter difficulties in finding attractors in our data).

e) A central challenge for future research lies in the achievement of combination of discrete-time and continuous-space data and models.

Until the practical and theoretical aspects of landscape complexity are linked together within an overall theoretical framework of quantitative landscape analysis, we need to refine our models of landscape complexity (structural, functional etc), in ways that will gradually provide us the missing links between the hitherto disjoint disciplines of Landscape Ecology and Complex Systems Theory. ■

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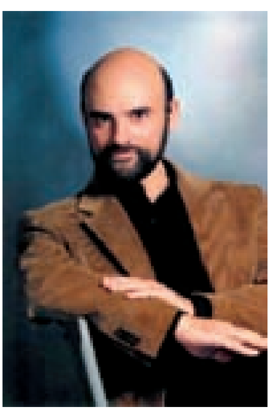

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PROMOTING SUSTAINABILITY THROUGH LAND-USE PLANNING AND TECHNOLOGY

Abstract Although the overall rate of population growth has recently decreased in developed countries, population in their cities continues to grow. Urban and suburban sprawl may threaten the environment necessary to sustain livable communities. Farm and forest land and open space are important components of human life. However, they may be lost to residential and commercial development. It has become important to develop land-use regulation mechanisms that accommodate economic growth and preservation of the environment. In the United States, land-use planning systems have been employed for a long period of time. Many US States have enacted laws that protect land from uncontrolled urban sprawl. Geographic Information Systems (GIS) are used to facilitate the process of land-use regulation. The goal of this paper is to discuss how technology-aided sustainable land-use policies are utilized in the USA at a county and city wide scale.

Key words: sustainable development, land-use planning, zoning, UGB, Oregon, Benton County, GIS.

INTRODUCTION

The world population is projected to reach 7 billion early in 2012 and to exceed 9 billion by 2050 [United Nations, 2009]. Globally, the population *growth rate* has been steadily declining from its peak of 2.19% in 1963, but growth remains high in developing countries. Population in more developed countries may also continue to grow because of the immigration from the developing to developed regions. Industrial and commercial growth resulted in population migration from rural areas to the cities and towns. The UN forecasts that today's urban population of 3.2 billion will rise to nearly 5 billion by 2030, when three out of five people will live in cities [Hunter, 2000].

Urbanization makes it especially important to segregate different land-use practices and protect farm and forest land and open space from commercial development. Residential areas also have to be protected so they continue to sustain housing needs of their residents. These demands are reflected in land-use planning laws that limit specific activities to specific areas. Zoning started in the United States a little after 1910. The first comprehensive zoning law adopted in New York City in 1916 [Toll, 1969] divided the city into different zones according to allowable practices. Other cities soon followed with similar restrictions [Fischler, 1998; Weiss, 1987]. Having started in large cities, zoning quickly spread to small communities and suburban areas [Fischel, 1985; Toll 1969; McKinzeie 1933]. By the late 1920s, most of the nation, with a few exceptions, had developed zoning regulations that met the needs of the communities.

Oregon is the ninth largest state in the USA [U.S. Census Bureau, 2008] with a diverse landscape that transitions from *rainforest* in the Coast Range to barren desert in the southeast. Oregon has an abundance of fertile soils that are the source of a highly successful agricultural sector that is based on production of grain, grass seeds, vegetables, fruit, meat and *dairy* products. Oregon is also one of the major timber producing state in the country.

The Gross Domestic Product (GDP) of Oregon in 2008 was $161.6 billion; it is the 26th wealthiest state in the USA by GDP [Bureau of Economic Analysis, 2009]. Oregon is a home to high-tech industries and services that have been a major employer since the 1970s (e.g., *Tektronix*, *Intel*, Hewlett-Packard, Nike, *TriQuint Semiconductor*, etc.) A number of startup high-tech companies have led to the establishment of the so-called "*Silicon Forest*" in the area [Dodds and Wolner, 1990]. Among other factors that attract these high-tech companies (e.g., highly-qualified labor force, strong infrastructure), development-ready land played an important role in such companies' decision making process. Recently, biotechnology giant *Genentech* has selected Hillsboro (one of the Oregon's cities) for the construction and development of their facility [Genentech, 2010].

Though population of Oregon is the lowest in the US Pacific North West (4 million people in 2008) [U.S. Census Bureau, 2008] (for example, it is an order of magnitude lower than that of California) it continues to increase (Figure 1). From 1990 to 2008, the population of Oregon grew by 33 percent. The population growth demands new land for development; this puts pressure on planning organs to protect agricultural and timber land and recreational open space while allowing economic growth.

Oregon started designing land conservation and development programs in the mid 1970s. These programs targeted economic growth in coming years and preservation of important natural resources. At the initiative of the Republican Governor Tom McCall and with the support from both parties, in 1973, the Land Conservation and Development Commission (LCDC) and the Oregon Planning Program were created by Senate Bill 100 [DLCD, 2008a]. The law directed to develop Statewide Planning Goals. Nineteen Statewide Planning Goals were finally adopted[1]; many of these goals relate to land-use practices. The goals of the Senate Bill 100 were to address the balance between development and conservation. The goals were also to promote high-quality, livable cities and towns by increasing density, improving public transit options, and encouraging affordable housing close to jobs. Redevelopment of existing urban areas was strongly encouraged. In the same year, the legislature also adopted Senate Bill 101 that substantially strengthened land designation for the exclusive farm use. These bills were challenged by the opponents, but the Oregon voters rejected the initiatives to repeal the growth management laws in 1976, 1978 and 1982.

Critics of Senate Bills 100 and 101 and the concept of Urban Growth Boundary (UGB) included in these bills continued to argue that the system infringes on private property rights and may cause rise in property prices by limiting land available for development. In 2000, the land-use system was challenged by Measure 7 that called for overturning of the existing system. Measure 7 maintained that private property owners were unfairly treated by the state's planning programs. As a result, Oregon Constitution was amended with the provision that the government should compensate landowners for losses of property values due to land-use laws. This ballot measure was later struck by the Supreme Court. However, in 2004, property rights groups succeeded in passing of Measure 37. Under this Measure, local governments were required to compensate landowners for their property values lost as a result of application of the land planning system. By 2007, almost 7000 claims were

[1] 1. Citizen Involvement; 2. Land Use Planning; 3. Agricultural Lands; 4. Forest Lands; 5. Natural Resources; Scenic and Historic Areas, and Open Spaces; 6. Air, Water and Land Resources Quality; 7. Areas Subject to Natural Hazards; 8. Recreational Needs; 9. Economic Development; 10. Housing; 11. Public Facilities and Services; 12. Transportation; 13. Energy Conservation; 14. Urbanization; 15. Willamette River Greenway; 16. Estuarine Resources; 17. Coastal Shorelands; 18. Beaches and Dunes; and 19 Ocean Resources.

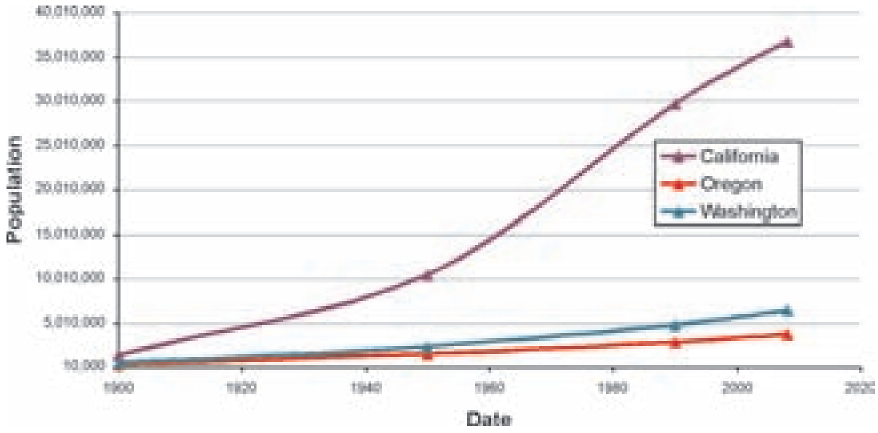

Figure 1. Population Dynamics in the Pacific North West (USA)

filed (for compensations of approximately $20 million) [DLCD, 2008b]. And finally, Measure 49 adopted in 2007 substantially limited the applicability and extent of Measure 37.

Senate Bill 100 did not mandate the adoption of a state plan. Instead it required every city and every county to prepare or amend its own comprehensive plan which included background inventories and technical information (the plan data base), plan policies (policy choices about future land uses) and implementation of measures (zoning ordinances, subdivision control ordinances). Each plan and regulation was required to satisfy all of the applicable Statewide Planning Goals. LCDC was given the responsibility of reviewing all comprehensive plans to determine whether or not they satisfy the Goals. The law provided opportunities for citizens to participate in all phases of the process of implementing the Goals. The Goals are not mandatory and most of them are accompanied by guidelines, which are suggestions on how these goals may be applied

The concept of UGB is one of the most significant outcomes of the reforms enacted by the Oregon land-use planning law in 1973 [DLCD, 2010]. The UGB concept limits development of farm land, forest land, and open space by defining limits for the future urban growth. The UGB controls urban expansion onto farm and forest lands. Inside the UGB, land supports urban services, such as transportation, utility systems, parks, schools, fire protection and police, etc., i.e. all necessary infrastructure for a city to function. The UGB promotes effective use of land and transportation network inside the boundary by limiting availability for involving new land and eliminating the need to build new roads and infrastructure. It motivates to develop and redevelop inside the existing urban settings. Nationwide, UGBs are now mandated in Oregon, Washington, and more recently in Tennessee; localized UGBs exist in over 15 California communities, Boulder (Colorado), and Lexington (Kentucky) [Bollier, 1998]. The UGB limits are set for an extended (e.g., 20 years) period of time to promote serious planning and accommodate changes if such become necessary.

Under the land-use system in Oregon, cities have to prepare and submit their proposal regarding UGBs that address applicable goals to the LCDC. Local governments assess the land required for housing, new business, recreation, and other uses, and make a decision on the area where such activities would be allowed. This boundary is actually a line drawn around this area. New development can occur only within this line. It forces cities to apply more sophisticated approaches to planning to prevent urban sprawl. The boundaries are subject to revisions and new land can be included in the UGB is needed.

LAND-USE LAW IMPLEMENTATION

After the enactment of the land-use law in 1973, Oregon has implemented a strong program for land-use planning. Oregon's land-use policy is achieved through local comprehensive planning. State law requires each city and county (or any local jurisdiction that has responsibilities for land-use regulations) to adopt a comprehensive plan and the zoning and land-division ordinances needed to implement these comprehensive plans. Such local plans have to be consistent with the Statewide Planning Goals. The plans are reviewed for such consistency by the state's LCDC. When LCDC officially approves a local government's plan, the plan is said to be "acknowledged" and becomes the controlling document for land use in the area covered by the plan. Oregon's planning laws apply to local governments and to special districts and state agencies. One of the important features of the law is strong coordination between different jurisdictions and agencies to make the plans and programs consistent with each other and with the Goals [DLCD, 2010].

Benton County[2] is one of the 36 Oregon counties. Value statements of Benton County Comprehensive Plan have specific reference to preservation of farm and forest land. They say, "Agricultural and forest lands provide sustenance for residents of the Willamette Valley. These lands and the larger systems of mountains, valleys, rivers and wetlands of which they are part continue to be highly prized economically, culturally, recreationally, environmentally and aesthetically." They further continue, "The residents of Benton County value the rural character that still exists in much of the county, the distinction that has been maintained between settlement areas and resource land and open paces and the manageable scale of the cities, towns, and rural centers" [Benton County, 2007]. These statements are reflected in the county's zoning map (printed and digital formats) that is available for private citizens, businesses, government officials, and all other interested parties.

The seat of the Benton County government, the city of Corvallis[3], has a similar comprehensive plan. The city of Corvallis is also required by the Oregon land-use program to provide land-use planning for the area within the UGB [City of Corvallis, 2010]. Corvallis Comprehensive Plan was completed as part of the City's periodic review and implemented by the City Council on December 31, 2006. It states, "The Comprehensive Plan of the City of Corvallis is the primary document that guides and controls land-use within the city limits and the Urban Growth Boundary. The Corvallis Comprehensive Plan is intended to reflect the community's current thoughts on land-use planning and to be responsive to the needs and desires of citizens."

The area between the city's limits and the UGB has to be specifically addressed in the county's and city's land-use ordinances because this land may potentially transition from one jurisdiction to another. Currently, this land is under Benton County's jurisdiction, but may be under the city's regulations if it annexed by the city (entirely or in part). Therefore, the county and the city entered into the "Corvallis Urban Fringe Management Agreement" in 1990 [Benton County 2007] that documents this arrangement. The City of Corvallis Comprehensive Plan states, "The process of land annexation allows for the orderly expansion of the City and adequate provision for public facilities and services." The Corvallis Urban Fringe Management Agreement includes a provision of mandatory public hearings jointly set by the county and the city. The City Charter requires voter approval of an annexation unless the annexation is mandated by State law. For example, health hazard annexations are mandated by State law and do not require

[2] There were just over 78 thousand people in Benton County in 2004, approximately 30 thousand households and 18 thousands residing in the county; the population density was 45/km^2 and the average housing was density 18/km^2.

[3] Corvallis is located midway in the Willamette Valley; Corvallis is about 46 miles (74 km) east of Newport and the Oregon Coast. As of the census of 2000 [US Census, 2008], there were 49,322 people, 19,630 households, and 9,972 families residing in the city.

Figure 2. Benton County Open Source GIS Web Application

voter approval. Many times, annexation proposals have been turned down by the voters preventing the proposed annexation lands from being developed to urban densities or perhaps causing them to remain undeveloped[4].

Participation of the public in land-use management process is a crucial element of land development at all levels. The public's involvement is impossible without easily accessible information on land-use issues. Geographic Information System (GIS) technology may significantly facilitate making such information available; this technology is widely employed in Benton county and the city of Corvallis for the purposes of land-use planning. This transparency and information aids regional sustainable development.

GEOGRAPHIC INFORMATION SYSTEMS AND LAND-USE PLANNING

In Benton County and Corvallis, GIS and GIS-compatible data that relate to all issues of land-use are available to planners, general public, and other interested parties. In Benton County GIS is funded through land transaction filing fees (GIS component of the fees is currently $20) and is free of charge to GIS users. An open source GIS application[5] is available on-line via the county's webpage. A variety of maps and GIS-compatible data may be downloaded and used in land availability assessments. Figure 2 provides a "snap-shot" of this open source GIS application webpage utilized in Benton County.

This application may be used to perform inquiries related to many land characteristics. First, a proper maps application must be chosen. The choices include assessment, election, zoning, survey, aerial photos, topographic, and other maps applications. After the selection is made, a user may perform spatial and tabular data overlays and analyses and print maps, if necessary. In Figure 2, the left part of the GIS application (in this case, the *Aerial Photo and Topographic Maps Application*) is the space where a user may choose what data are displayed and what information can be queried. Data choices in *Aerial Photo and Topographic Maps Application* (shown in the Figure 3) include data on surveying, transportation, boundaries, tax assessment, addresses (e.g., building footprints, house points, driveways), topography, water, and aerial photography.

[4] Personal Communication: Bob Richardson, Associate Planner, City of Corvallis

[5] Benton County uses the Easy Land Locator Application Maps (ELLA maps) (http://www.co.linn.or.us/webmap). It was created in 2003 to provide Geographic Information System (GIS) and mapping services to the citizens of Linn County.

The "*Identify*" tool allows a user to identify necessary information using selected layers. After analyses are made, a map may be created and printed at desired scales. This GIS web application is widely used by county employees and the general public. Every day, approximately 20 users employ this application in their work.

Digital GIS-compatible data provided by the county and the city may be used in other open source or commercial GIS programs. Many Oregon jurisdictions have similar applications. Figure 3 demonstrates how such data may be used in the land-use planning process. The study area was the North Western Corvallis, between the city limits and UGB. In this example, using ArcMap GIS, 9.3®, data on property parcels, UGB, Corvallis city limits, and zoning were overlaid to estimate the number of property parcels that may be currently used for construction of new houses. The parcels in this area are primarily zoned as *Urban Residential* with the minimum acreage per one dwelling of 5 and 10 acres (one hectare = 2.47 acres) (i.e., *UR-5* and *UR-10*, respectively). New construction of houses can only occur on the land parcels that satisfy minimum land requirements in allowable zoning categories (*UR-5* and *UR-10*). It appears, that out of 2632 parcels in the study area zoned *UR-5* and *UR-10*, only 60 (or 9.5 percent) can be potentially developed; the area of these parcels is slightly over one-half of the parcels zoned *UR-5* and *UR-10* in the study area. Many other restrictions

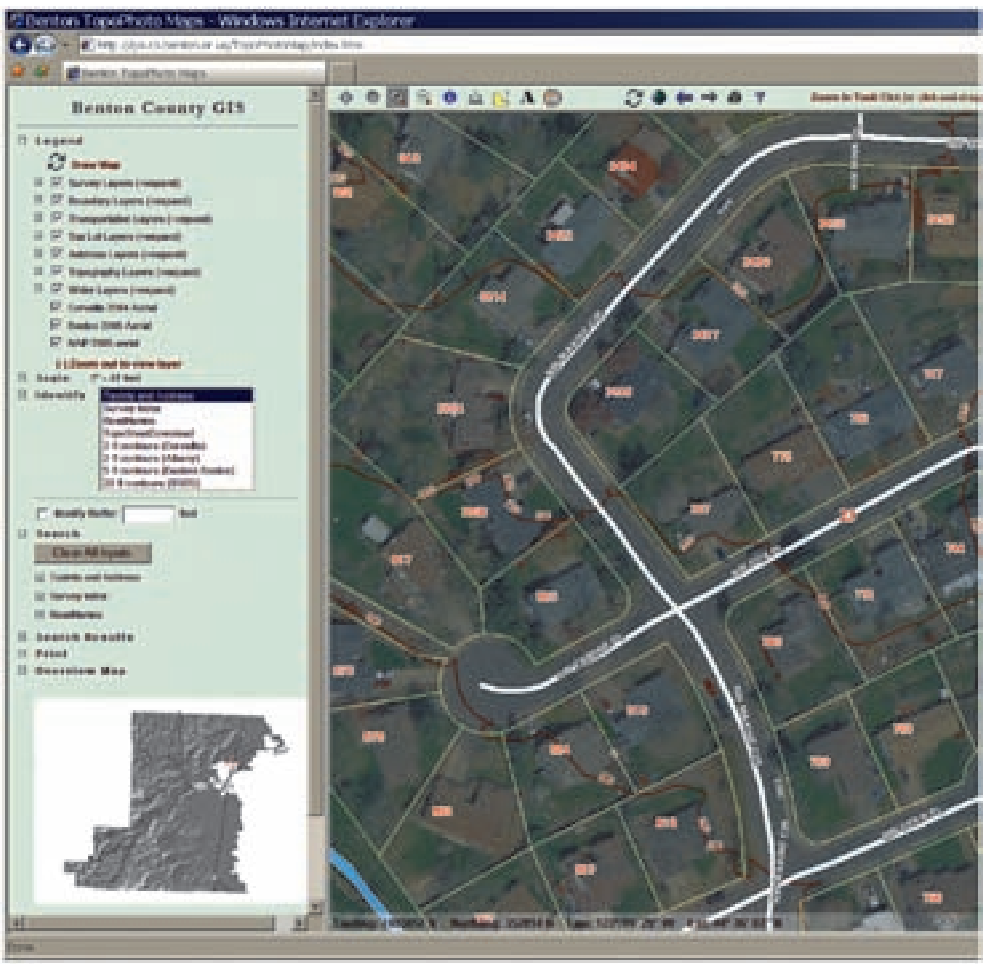

Figure 3. Aerial Photo and Topographic Maps Application

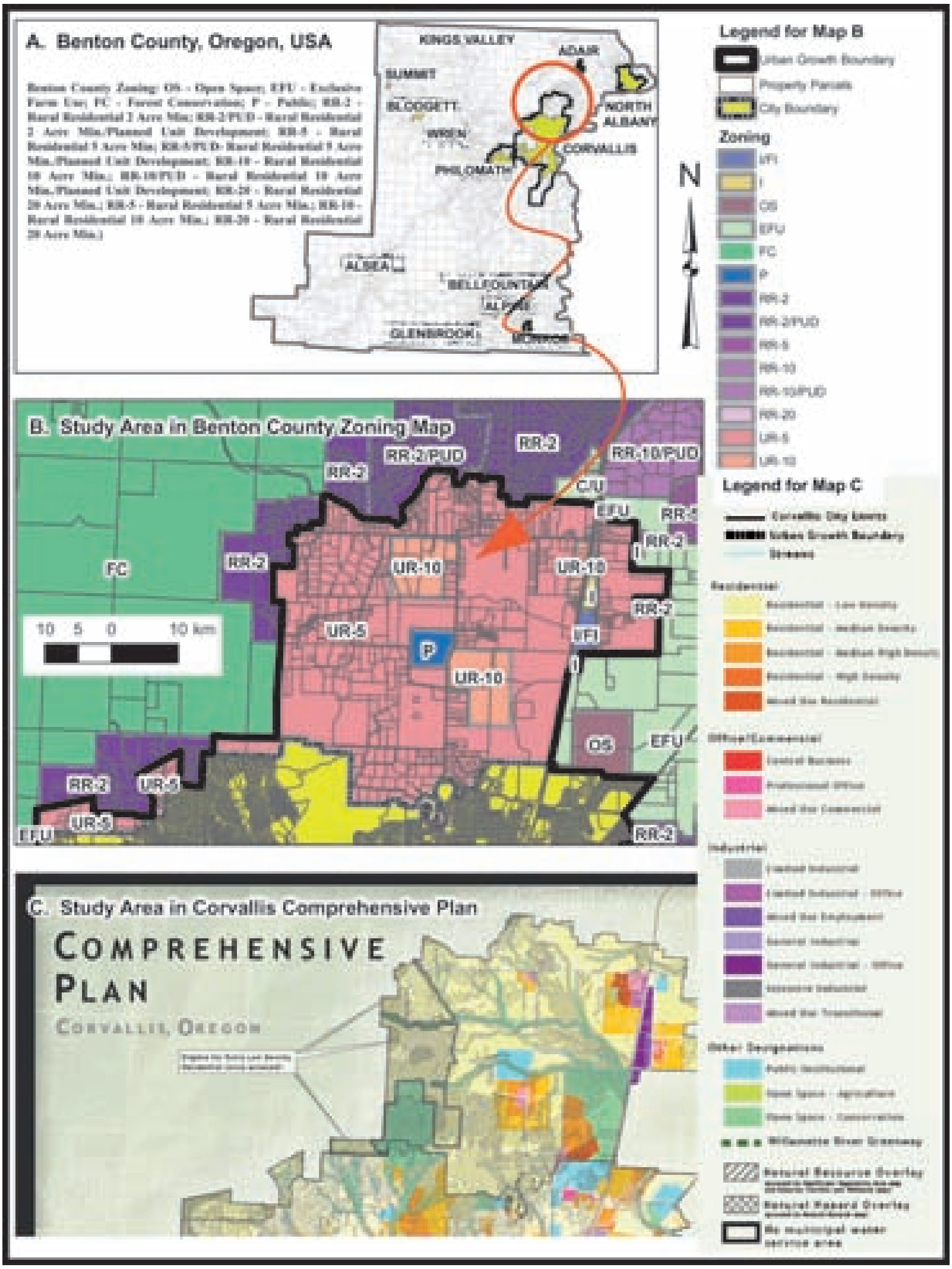

Figure 4. City Limits and Urban Growth Boundary Analysis (Study Area)

may be imposed on the development. Such restrictions include but are not limited to water availability, slope stability, flood or earthquake hazard, etc.

Part C of Figure 3 shows the same area in the City of Corvallis Comprehensive Plan. According to "Corvallis Urban Fringe Management Agreement" this area is currently under Benton County's jurisdiction. If land is annexed into the City of Corvallis, such land will fall under the City of Corvallis jurisdiction and may be developed as shown in Part C of Figure 3. For example, if the western part of the study area that is currently zoned as *UR-10* (i.e., 10 acres min limitation per one dwelling) annexed into the city, it will be zoned as *Extra Low Density Residential* area, which allows more dense residential density compared to the current use.

DISCUSSION AND CONCLUDING COMMENTS

The population of Oregon and its cities (along with the entire nation) continues to grow. The relationships between land-use laws, population dynamics, land values, housing affordability, and attractivity of residential areas are complex and should be considered in land-use analyses. The urban growth boundaries and zoning ordinances create more dense residential development. But "the compact city is not a perfect city"[Abbott, 1997]; "side effects" of more dense urban development that may be more efficient from the standpoint of preservation of rural areas, could include disappearance of existing open local space within city limits. Zoning ordinances may involve shortage of affordable housing and lead to decrease in urban communities' appeal [Abbott, 1997; Joint Center for Housing Studies, 1996]. Population growth could add to the pressure on urban housing caused by land-use planning restrictions.

Though the price of buildable land can rise dramatically while rural real estate may lose its value, there are studies that indicate that in Oregon, land-use planning system has not caused a generalized reduction in land value across rural Oregon; this is consistent with the design of Oregon's land-use planning system [Jaeger and Plantinga, 2007]. Oregon's land-use planning system is flexible enough and is required by law to accommodate a long term supply of vacant land inside UBGs at all times. Oregon's land-use law created desirable urban and rural space for economic and residential growth. This became possible by employing GIS technology to facilitate participation of citizens in land-use management decisions. Many governments in Oregon use GIS applications (commercial and open source) and make them and land-use related data available to all their citizens. The transparent process of making decisions on current or future land-use practices promotes sustainable development of communities. Analyses of land availability for agricultural, forest, residential, commercial, industrial, recreational and other activities can be easily performed at all levels of planning. The transparency mitigates possible conflicts between governments and citizens involving zoning/rezoning, UGBs, annexations, and other land-use related issues. Many jurisdictions in Oregon passed measures through citizens' votes to include GIS fees into their fee- schedules. It created a permanent funding source for GIS implementation and made this technology accessible to anyone who is interested in land-use problems.

ACKNOWLEDGEMENTS

The author expresses sincere thanks to her colleagues at Public Works and Community Development Departments (Benton County) for the encouragement and help in preparation of this article. ■

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THE REPORT ON THE SPECIAL CONGRESS OF THE RUSSIAN GEOGRAPHICAL SOCIETY

A Special Congress of the Russian Geographic Society (RGS) was held on 17–18 November 2009, in Moscow, in the building of Presidium of the Russian Academy of Sciences (RAS). The Congress was held to address urgent organizational issues, specifically, changes in the Charter of the RGS that bring the Charter into compliance with the Russian Federation Law "On Non-Governmental Organizations" and other applicable legal standards, development of new activities, and the election of the RGS President.

In his report, Honorary President of the RGS, Academician of the RAS V.M. Kotlyakov described the current state and prospects of society and nominated Sergei Kuzhugetovich Shoigu for the election as the RGS President on behalf of the RGS Scientific Council. By a secret ballot and with the overwhelming majority, the Congress elected S.K. Shoigu the RGS President. The Congress approved forming the RGS Board of Trustees and approached Prime Minister of the RF V.V. Putin with a proposal to chair the Board.

The RGS is the oldest non-governmental research organization of our country, founded in 1845. It has always played a key role in science, education, and culture of Russia. Because of the socio-economic changes after the collapse of the Soviet Union, the RGS role has become less noticeable. However, the importance of geography itself, environmental and economic-geographical research, and specialized education is constantly rising as it is directly linked to the need of achieving adequate responses to challenges of the time. The State has realized the importance of supporting the organization of associates who share common interests in investigating nature and analyzing the country's state of economy. Now, the RGS that for a long time carried the title of the Imperial Geographic Society is returning to its roots when it was well supported by the State.

Prime Minister of the RF, V.V. Putin, spoke at the Congress. He stressed the importance of the RGS activities and outlined the main prospects of its development: "Several environment protection and ecology initiatives will be launched. The objective is to combat pollution, reclaim land, protect natural resources, and grow tourism industry. Experience and knowledge of scientists and geographers may be used in creation of new educational projects and support for youth organizations. Of course, the work of the RGS implies openness and accessibility, and this could be achieved through the Board on Mass Media within the RGS. Powerful informational and educational realms that embrace public life would enhance and promote geographic science, scientific and environmental tourism, and greatly assist in formation of environmental consciousness of the nation. I am sure that the RGS work will continue to serve the interests of our country."

The RGS President, S.K. Shoigu, also spoke at the Congress. According to his presentation, the RGS task is to develop a new strategy consistent with the spirit of the time while drawing on the experience and tradition of serving Russia. S.K. Shoigu has outlined the main directions of the RGS activities. It is important to disseminate geographical information about Russia and create films, television projects, books, and educational manuals. For this purpose, the RGS must open an information portal that will make scientific discoveries more accessible. Within the RGS, a youth chapter that promotes environmental awareness should be formed. The RGS archives need to be transferred to digital media. In order to attract young scientists, special grants for best projects competition should be allocated. Research work should be pursued; its results should be applied in practice promoting growth of the country's industry, economy, and entrepreneurship, and the ability to forecast natural disasters. Among projects of the nearest future, are projects associated with ecological tourism and development of new tourist routes. According to S.K. Shoigu, the RGS is able and should become a platform for cooperation of scientists, politicians, entrepreneurs and all those engaged in environmental research, and economic and social development of the territories.

The Dean of the Faculty of Geography, Moscow State University, Vice-President of the RGS, Academician of RAS N.S. Kasimov spoke about the present-day problems of modern geography; he emphasized the need to preserve nature and cultural heritage of Russia, and crucial role of concept of education for sustainable development. According to N.S. Kasimov, the task of geography is to provide social validation for ecological, political, and geo-social decision-making process. Greater attention should be paid to the assessment of consequences of global climate change, social geography, regional and strategic planning, and urbanization.

Archival and museum activities illustrate new trends in societal behavior. It is known that a large volume of documents relating to the history of the formation of our country and development of its territories at the time of expeditions of Przewalski, Potanin, Kozlov, and many other researchers, has been accumulated in the RGS headquarters in St. Petersburg. Efforts to preserve this heritage, of course, require certain investments that are finally beginning to emerge.

The RGS intends to pay greater attention to the promotion of geographical knowledge; thematic publications, such as "Proceedings of the Russian Geographical Society", will receive financial support. The RGS plans to increase field exploration that has been considerably essential in the pre-revolution and Soviet Russia. Furthermore, one of the RGS priorities is youth education and immersion in geographical culture aimed at preservation of nature and cultural heritage of our country. Therefore, it is important to support after school club activities and organize thematic Olympiads and children's field trips.

It is hoped that difficulties in RGS activities associated with socio-economic changes in Russia of 1990s, will now be overcome, and the work of this revitalized society actively supported by the State and business community will become more efficient.

Sergey A. Dobrolyubov
Member of the Presidium of the RGS
Corresponding Member of RAS

THE NATIONAL ATLAS OF RUSSIA

In 2009, the National Atlas of Russia has been released.

The National Atlas of Russia (NAR) is a fundamental integrated cartographical product, designed to provide a comprehensive representation of nature, population, economy, ecology, history and culture of Russia; it is the national collection of scientifically processed and reconciled spatial-temporal information, applicable to all branches of the economy, management, education, science, and defense of the country. It is a special kind of cartographical product where the state, in all its aspects and spheres of its existence and development, represents the subject of mapping. The NAR consists of the following volumes: Volume 1 – "General Characteristics of the Territory"; Volume 2 – "Nature. Ecology"; Volume 3 – "Population. Economy"; and Volume 4 – "History. Culture". Being an integral part of the NAR, each volume also stands on its own as independent map work.

Mapping in the NAR is achieved at four spatial-geographical levels: *global and Eurasian* (Russia in the world, Europe and Asia, CIS); *all-Russian* (federal, the Russian Federation as a whole); *regional* (federal districts and members of the Russian Federation, separate regions); *local* (entity oriented, specific cities and industrial units, most interesting in natural, cultural, economic and other conditions territories and sites).

The NAR includes maps, explanatory notes, satellite images with annotations, reference material, indexes of geographic names, etc. The atlas format is 43 × 29,5 cm; each volume has 496 pages.

The atlas has been released in two formats: printed and electronic.

The NAR has been commissioned by the Government of the Russian Federation. The Federal Agency of Geodesy and Cartography of the Ministry of Transport of Russia, as well as the NAR's Main Editorial Board managed and supervised compilation of the Atlas. A big number of organizations and enterprises affiliated with different agencies have been involved in this work.

Volume 1. "General Characteristics of the Territory". Volume 1 of the NAR is an informational-cartographic and scientific-reference publication for experts from different fields of science, industry and culture, employees of the State government, teachers and students of academic institutions, as well as for the broad range of people in this country and abroad.

Volume 1 contains maps and text material grouped into six sections: Introduction; Formation, Exploration and Mapping of the Russian Territory; Federal Structure of Russia; Geographical Regions and Seas Surrounding the Territory of Russia; Reference Data; Index of Geographical Names.

The ***"Introduction"*** section contains information on organizations and individuals who participated in the creation of the Volume, physical map of Russia and political map of the world.

The section ***"Formation, Exploration and Mapping of the Russian Territory"*** describes the formation of the Russian territory from ancient times to our days. The results of exploration by pioneers, industrialists, explorers, scientists, and professionals are reflected in maps of the section. The section is culminated with the chronology of the most important events, which led to changes of the country's territory and level of exploration, most important research activities (field and stationary) and dates of releases of important cartographic products.

The section ***"Federal Structure of Russia"*** reflects the contemporary, as defined by the Constitution of the Russian Federation, federal structure of the Russian Federation and administrative–territorial arrangements of every one of its members through maps, reference data and illustrative material (emblems and flags of the members of the Russian Federation).

The section ***"Geographical Regions and Seas Surrounding the Territory of Russia"*** presents geographical maps of Russia in its entirety, large geographical regions and their finer breakdown, individual local territories, and seas surrounding the Russian territory. The section is opened by a general geographical chart of Russia and consists of three subsections: The European Part of Russia, The Asian Part of Russia, and The Russian Sector of the Arctic. Each subsection contains a general geographical chart of the region at 1:7 500 000 to 1:10 000 000 scales; maps at a 1:2 500 000 scale that cover the entire Russian territory; maps at larger scales (1:1 000 000 and 1:500 000) for individual territories, maps of seas, surrounding the territory of Russia, and satellite images. Satellite images are supplied with annotations and address maps, placed on the same pages with the images.

The section ***"Reference Data"*** includes written material, tables, thematic maps with general information about Russia: physical environment, natural resources, population, economy, science, and culture. Thematic maps of the section characterize physical-geographical zoning of the country, subsurface geology, climate, soils, vegetation, specially protected natural areas, population (number, national and confessional structure), basic types of natural resources (mineral and fuel-energy, land, forest) and the economy.

The ***"Index of Geographical Names"*** presents an alphabetized (Russian language) list of all names of geographical objects that are used on maps of the Volume.

Volume 1 of the NAR has been released in two formats: printed and on a CD-ROM.

Volume 2. "The Nature. Ecology" is intended for wide use in economic, administrative, scientific, educational and other kinds of activities. The physical environment, natural resources and environmental condition of the Russian Federation represent objects of mapping in the volume. The volume contains maps, text and illustrative material grouped into 15 sections: Introduction; Evolution of the Environment; Geological Structure and Subsoil Resources; Relief; Climate; Continental Waters; Snow, Ice, and Permafrost; Seas; Soil Cover and Land Resources; Vegetation; Fauna; Landscapes; State of the Environment; Environment Protection; and Reference data.

The ***"Introduction"*** section contains cartographical and text material reflecting general characteristics of the environment and natural resources of the Russian Federation.

The section ***"Evolution of the Natural Environment"*** describes evolution of the geographical environment of Russia including climatic and hydro-meteorological characteristics and the development of fauna and vegetation for the last 150 thousand years.

The section ***"Geological Structure and Subsoil Resources"*** contains cartographic information on the geological structure of the territory of Russia, hydro-geological and engineering-geological conditions, and location of the basic types of mineral resources. The section includes a number of maps on protection of geological environment and distribution of unique geological sites.

The section ***"Relief"*** presents maps that describe geo-morphologic structure and zoning of the Russian territory and reflect general orography, relief hypsometry, and relief-forming processes.

The section ***"Climate"*** consists of a set of maps and charts that reflect spatial distribution of climatic characteristics over the territory of Russia.

The section ***"Land water"*** contains maps and charts displaying hydrographical network and catchment's basins with the identification of surface and underground water resources.

The section ***"Snow. Ice. Permafrost"*** describes glaciological and geocryological conditions and snow-ice resources. It contains data on the evolution of modern glaciations and permafrost and hazardous snow- ice accumulation.

The section ***"Sea"*** contains information on physical, chemical, and hydrological characteristics of the seas surrounding the territory of Russia. The seas' bio-resources are presented on maps of distribution of phytoplankton, benthos, animal plankton, trade seaweed, and sea animals and fish. The information on ecological conditions of seawater and seacoast is also provided.

The section ***"Top-Soil and Land Resources"*** includes maps and charts on general characteristics of basic soil types and information on land fertility, structure, water and temperature regimes, and process of soil degradation. A special place was designated for Russian chernozem (i.e., black soil) as one the national treasures of Russia.

The section ***"Vegetation"*** has a set of maps reflecting modern vegetative cover. Special attention was given to vegetation resources.

The section ***"Fauna"*** contains information on species diversity of terrestrial and aquatic animals (mammals, fish, amphibians and reptiles) and birds.

The section ***"Landscapes"*** consists of maps and satellite images of modern landscapes with a description of landscape profiles and data on their seasonal rhythms and hydrothermal seasonal phases. Maps of physical-geographical zoning and maps of assessment of natural condition of life of people are also included.

The section ***"State of Environment"*** deals with dynamics of ecological conditions in Russia and has maps on various kinds of anthropogenic impact on the environment, including impacts of different industries (power, mining, processing, transport, agriculture, and forest exploitation).

The section ***"Environment Protection"*** contains maps related to environmental protection and management of natural resources. Specially protected natural areas of international, federal, and regional significance are described in greater details. Maps that show the nature protection system and participation of Russia in international nature protection conventions and agreements are of prime importance.

The final ***"Reference Section"*** includes a dictionary of terms and sources of information (published, cartographical, and statistical).

Volume 3. "Population. Economy" is designed for wide use in management and social, economic, scientific, educational, and other spheres of activity. The objects of mapping in this volume are Russian population and the economy and social-economic systems that they form through interactions. Text material, maps, and illustrations are grouped into five sections: General Description of the Russian Federation; Population and Social Development; Economy and Economic Development; Regions and Regional Development; Reference Section; each of the sections includes a number of subsections.

The section ***"General Description of the Russian Federation"*** provides maps describing modern place that Russia occupy in the world based on various social and economic parameters, as well as changes in its geo-economical and geopolitical situation, territorial aspects of its system, and geographical factors of settlement and the economy.

The section ***"Population and Social Development"*** contains information on population characteristics, its social environment, and development. Accordingly, there are three subsections: Population and Settlement, Social Sphere, and Sociopolitical Development. In the subsection "*Population and Settlement*" thematic subjects are presented as follows: Distribution and composition of the population, its demographic characteristics and resettlement processes, urbanization and cities, labour market and employment, standard of living and population health. The subsection "*Social Sphere*" provides the status and dynamics of its basic segments, as traditionally reflected in geographical atlases (public health services, education, science, culture, and trade) and other areas (living conditions and municipal services, recreation, tourism, and sports). The subsection "*Socio-Political Developmentt*" includes maps showing the level of social development of the regions of Russia.

The section ***"The Economy and Economic Development"*** consists of four subsections. The structure of the section is built on a logical transition from the general characteristics of the economy to a consistent description of its basic spheres: Manufacture – Infrastructure – Investment. Thematic subjects in the subsection "*Industrial Sector*" correspond to the basic branches of the "primary" (agriculture, forestry, and fishing and hunting) and "secondary" (industry and construction) sectors of the economy. This subsection concludes with maps on domestic and foreign trade that allows products produced in different industrial sectors to be sold on domestic and foreign markets. The subsection "*Services Sector*" provides the important information on the conditions of market economy in the services sector, which accounts in modern Russia for about one-half of its gross domestic product. The subsection "*Infrastructure Sector*" describes branches of tertiary and quaternary sectors of the economy. From the traditional themes, the transportation sector is presented and described in the context of transport networks, as well as in the context of its separate branches (railway, automobile, water, etc.). The description of the telecommunication infrastructure, which is crucial to the modern society, has been added to the information on the communication sector. New themes also include maps on the information and market (including bank) infrastructure. The subsection "*Investment Sector*" presents thematic material that describe geography, structure, and dynamics of the investments, major investment programs, and investment climate in the regions (including legal matters).

The section ***"Regions and Regional Development"*** is dedicated to the regional component of the volume. A series of comprehensive social and economic maps reflecting social and economic structure of large geographical areas and the basic features of regional economy is given here. This section is also intended to reflect key long-term issues of Russia's regional development. The section describes basic types of Russian regions (based on social and economic development level and type, presence of troubling issues or stability, long-term prospects for development, level of intervention or assistance from the state, and includes regions within the limits of budgetary federalism).

The final ***"Reference Section"*** includes the dictionary of terms and sources of information (published, cartographical, and statistical).

Volume 4. "History. Culture" is intended for wide use in scientific, educational and other fields. The main objectives are to consistently describe the historical development of Russia since the most ancient times to the present era and provide modern spatial-temporal information on the country's cultural and natural heritage. The material of the volume is grouped into two sections: ***"History"*** and ***"Culture".***

The section ***"History"*** consists of 14 subsections placed in chronological order: *Ancient Cultures*; *Early Iron Age and the Great Migration of People*; *Ancient Russia in IX and the Beginning of XIII Century*; *Mongol-Tatar Invasion*; *Fight for Independence*; *Unification of Russian Lands in XIV – the first half of XV century; Russia in the Second Half XV–XVI Century*; *Russia in XVII Century*; *Russian in the First Half of XVIII Century*; *Russia in the Second Half of XVIII century*; *Russian in the First Half of XIX Century*; *Russian in the Second Half of XIX Century*; *Russia in the Beginning of XX Century*. *Soviet Period*; and *Russia in the Beginning of XXI Century*.

The section ***"Culture"*** consists of two subsections *Cultural and Natural Heritage of Russia* and *Modern Culture*. In the Section, culture is treated both as a public phenomenon and branch of social sphere the growth of which is based on historical events. The section contains aggregated information and data on cultural and natural heritage of Russia; it demonstrates the logic and ways of the spread and development of regional and national cultures, their relationships, and mechanisms of their interactions. The materials of the section may be used in national and regional programs on protection and use of heritage objects, preservation and restoration of historical-cultural and natural environment of Russian people.

Cultural heritage is one of the most important modern resources that determine the social-economic and social-cultural development of Russia in the World. The heritage includes not only cultural treasures, isolated architectural or historical-memorial sites, but also pristine natural environment, historical environment of the cities and rural settlements, special spiritual and material treasures reflected in folklore, trades and handcrafts, art treasures and special forms of live nature and its environment, i.e., everything that reflects the history of the development of nature and culture and is recognized as valuable in scientific, economic, aesthetic, and educational respect and is viewed as national heritage.

Maps *World Heritage Sites within Russian Territory* features objects of the world cultural and natural heritage that are protected by UNESCO. This section is also subdivided into subsections.

The subsection *Cultural and Natural Heritage of Russia* is the largest and contains small and large scale maps that cover the entire Russian territory and its individual sites (including their detailed plans). The section contains maps with sites of architectural historic monuments under federal protection, memorials of war, cult architecture, civil and industrial architecture, monumental art, and estate architecture. The maps also show sites of folk art, trade, and handcraft (wood-, metal-, stone-, glass-, bone-, weaving-, knitting-work, etc.) In addition, this section contains maps *Russia in Works of National Writers* and *Russia in Works of National Painters*.

The subsection "*Modern Culture*" contains maps that reflect the system and type of activities according to the role of cultural establishments: museums, theatres, libraries, archives, and higher educational institutions. The information on cultural communications with foreign countries is also provided. The section is supplemented with data on activities for protection and restoration of objects of heritage with the names of institutions, enterprises, and public organizations engaged in the protection, restoration, and reconstruction of cultural heritage. The section is concluded with the map "Cognitive Tourism and Sightseeing" and reference data: indexes of terms and heritage objects and the chronological table.

Alexander N. Krayukhin,
Vladimir S. Tikunov

INSTRUCTIONS FOR AUTHORS, CONTRIBUTING TO "GEOGRAPHY, ENVIRONMENT, SUSTAINABILITY"

AIMS AND SCOPE OF THE JOURNAL

The scientific English language journal "GEOGRAPHY, ENVIRONMENT, SUSTAINABILITY" aims of informing and covering the results of research and global achievements in the sphere of geography, environmental conservation and sustainable development in the changing world. Publication of the journal will be aimed at foreign and Russian scientists – geographers, ecologists, specialists in environmental conservation, natural resource usage, education for sustainable development, GIS technology, cartography, social and political geography, and also – on field studies in the sphere of environmental science. Publications that are interdisciplinary, theoretical and methodological are particularly welcome.

Among the major sections of the journal will be: basics of geography and environmental science; fundamentals of sustainable development; environmental management; environment and natural resources; human (economic and social) geography; global and regional environmental and climate change; environmental regional planning; sustainable regional development; applied geographical and environmental studies; geo-informatics and environmental mapping; oil and gas exploration and environmental problems; nature conservation and biodiversity; environment and health; education for sustainable development.

I. GENERAL GUIDELINES

1. Authors are encouraged to submit high-quality, original work: scientific papers according to the scope of the Journal, reviews (only invited) and brief articles. Materials earlier published, or accepted to the publication in other editions, are accepted under the decision of the Editorial Board.

2. Papers are accepted in English. Either British or American English spelling and punctuation may be used.

3. All the **authors** of a paper should include their full names, positions, affiliations, postal addresses, telephone and fax numbers and email addresses. One author should be identified as the Corresponding Author. We encourage authors to include theirs photograph and main points of curriculum vitae.

4. The optimum volume of manuscript is 0,2–0,5 of author's sheet (or about 3000–5000 words). On occassion in coordination with edition can be accepted methodological, problem or reviews in volume up to 0,7–1 author's sheet.

II. MANUSCRIPT PREPARATION

1. Manuscript should be compiled in the following **order**: authors names; authors affiliations; title; abstract; key words; main text; acknowledgments; appendixes (as appropriate); references; authors (photo and brief CV).

2. Authors should use word processing software for manuscript preparation.

3. **Figures** should be produced as near to the finished size as possible. Pictures can be represented in formats of programs used for their creation: CorelDraw (up to 9 versions), Adobe Photoshop (up to 6 versions), Adobe Illustrator (up to 9 versions). Raster images should be not less 300 dpi in the natural size. Captions should be given as the separate list.

4. **Tables** should not be too bulky. Each table should have a short title. Tables are to be numbered separately from the illustrations. Each table should be represented as a separate file in an original format MS Word, Excel, etc.

5. **Caption** should follow the reference to figure. The same concerns to names of tables.

6. **References** should be numbered in the alphabetical order, using Arabic numerals. Whenever possible, total number of references should not exceed 10 points. References in the text should be denoted in Harvard (Author, year) system in square brackets, e. g., [Author1, Author2, 2008]. References should be complete in the following style:

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ISSN 2071-9388

SOCIALLY SCIENTIFIC MAGAZINE "GEOGRAPHY, ENVIRONMENT, SUSTAINABILITY"

No. 01(03) 2010

FOUNDERS OF THE MAGAZINE: Faculty of Geography, M.V. Lomonosov Moscow State University and Institute of Geography of the Russian Academy of Sciences

The magazine is registered in Federal service on supervision of observance of the legislation in sphere of mass communications and protection of a cultural heritage. The certificate of registration: ПИ МФС77-29285, 2007, August 30.

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It is sent into print 22.07.2010
Order N 52

Format 32 × 46 cm/2
55 p. sh.
Digital print
Circulation 300 ex.