CHAPTER 2. HOW ECA'S CLIMATE HAS CHANGED AND IS LIKELY TO CHANGE FURTHER[20]

The world is becoming a warmer, wetter place and one where the frequency and magnitude of extreme events is increasing. As the Intergovernmental Panel on Climate Change's Fourth Assessment report states: "Warming of the climate system is unequivocal" (IPCC 2007b).

Adaptation is unavoidable. This is because past emissions are causing warming that will continue for decades: even if the world stopped producing greenhouse gases (GHGs), average temperatures would continue to increase by a total of about 0.6ºC over the rest of the century (IPCC 2007b). Continued GHG emissions at or above current rates will induce further changes in the climate system, changes that are likely to be much larger than those experienced in the past century. Thus, mitigation will not substitute for adaptation; but the extent of adaptation needed will depend on how much mitigation does in fact occur.

ECA's climate is already changing

While there is a good deal of inter-annual variation in temperature, a significant increasing trend in year-to-year temperature can be seen for many sub-regions, particularly the Baltics, Central Asia, and the Caucasus, as well as the northern and eastern parts of Russia (Westphal 2008). Comparing the mean value for annual temperature in 1901–1920 to 1980–2002, warming has varied from 0.5ºC (Southeastern Europe) to 1.6ºC (South Siberia) across ECA, and the results are statistically significant for all sub-regions.

There has also been a significant increasing trend in year-to-year precipitation over most of Russia, with the exception of the Central and Volga sub-regions and Baltic Russia, while there have been no significant trends in year-to-year precipitation for the rest of ECA.

The change has already shown itself in increased weather-related natural disasters, which have a large economic impact on the ECA region. Both the number of climate-related natural disasters and the economic losses associated with them have increased, with the vast majority of disasters concentrated in the last two decades (Figure 2.1). During this period, there has also been a marked increase in drought conditions over much of ECA, even in regions experiencing increased mean annual precipitation.

Many locations within ECA are in the top three deciles of the global distribution of economic losses per GDP for climate-related natural disasters (Dilley et al. 2005). The potential economic loss from natural disasters is particularly severe for the Caucasus and parts of Central Asia (Tajikistan), where it is upwards of 70 percent of GDP (Pusch 2004).

The two sub-regions are especially vulnerable to drought for geographic reasons (high inter-annual rainfall variability, dependence on snowmelt) and structural reasons (economies heavily dependent on agriculture, inadequate hydrometeorological monitoring, and poor water management planning). The 2000–2001 drought in the region was estimated to have cost Georgia and Tajikistan 6 and 5 percent of their respective GDPs (World Bank 2006).

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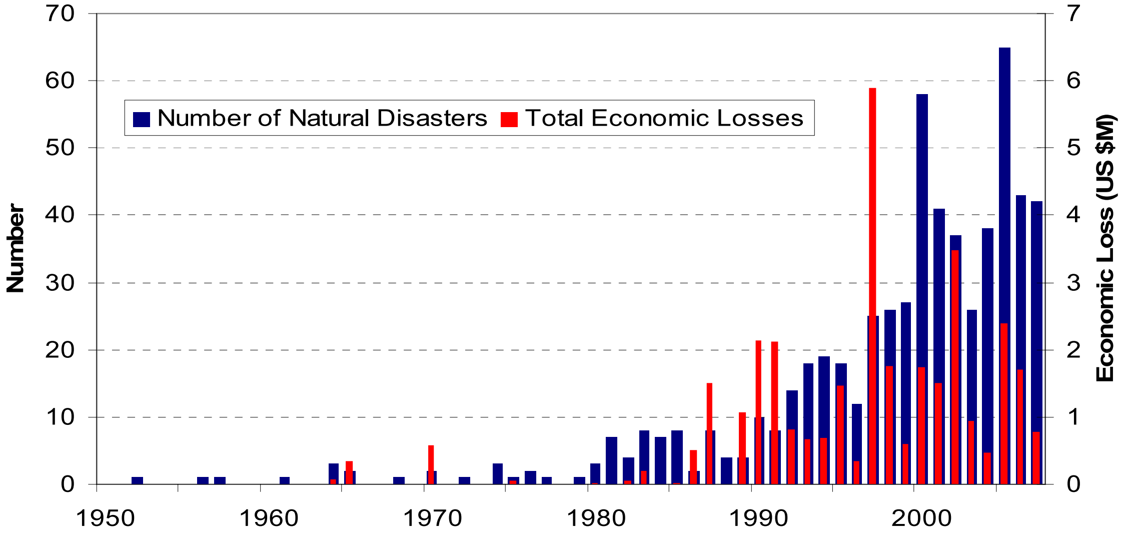
[20] This chapter is based on "Summary of the Climate Science in the Europe and Central Asia Region: Historical Trends and Future Projections" by Michael Westphal, a background paper commissioned for this report.

Of course, a natural disaster is a function of both a natural hazard (climatic event) and inherent vulnerability. The increase in climate-related natural disasters in ECA shows an adaptation deficit in regard to current climate variability.

FIGURE 2.1 CLIMATE-RELATED NATURAL DISASTERS IN THE ECA REGION



Notes: Natural disasters include floods, droughts, landslides, extreme temperatures, wind storms, and wildfires. A disaster is defined as an episode: leading to 10 or more deaths, affecting 100 or more people, resulting in a declaration of a state of emergency, and/or leading to a call for international assistance. *Source*: EM-DAT (www.emdat.be).

More change is certain—the question is where and how

Adaptation requires an understanding of the potential impacts of climate change on human, economic, and ecological systems. Yet, any attempt to estimate such impacts means dealing with a cascade of uncertainties (Schneider and Kuntz-Duriseti 2002).

Uncertainty starts with the selection of an underlying emission scenario, which is determined by economic and population growth, and by energy-use choices. Will the world grow rapidly or slowly? Will developing-country populations soon adopt the consumption habits of high-income countries? And what kind of energy future are we to look forward to?

To account for these questions, the IPCC has developed six socio-economic scenarios that project possible trajectories of population and economic growth and the degree of adoption of clean technologies. However, no preferred scenario has emerged; nor is there any probability distribution associated with the scenarios. They are simply different options for the future that imply different carbon emission levels.

There is also uncertainty in the carbon cycle response and the global climate sensitivity, or how the earth's system will respond to the increasing global carbon dioxide (CO_2) level. Climate models work to capture the highly complex interaction of many different influences (ocean, atmosphere, cryosphere, etc.) on the weather. As a result they differ in their projections. The IPCC uses a set (ensemble) of global climate models instead of relying on a single one. The variation of results across models gives an estimate of uncertainty.

Local climate change is also affected by local features, such as mountains, which are not well represented in global models because of their coarse resolution. Capturing local characteristics requires downscaled models (see box 2.1). Regional climate models (RCMs) provide projections at a much finer scale (typically using cells measuring 50 km by 50 km as opposed to 300 km to 500 km for global climate models) for limited areas, taking their input from global climate models at their boundaries. However, greater precision does not guarantee greater reliability.

BOX 2.1 GENERAL CIRCULATION MODELS AND CLIMATE DOWNSCALING

Most of the data presented in this report are from General Circulation Models (GCMs). GCMs are spatially explicit, dynamic models that simulate the three-dimensional climate system using as first principles the laws of thermodynamics, momentum, conservation of energy, and the ideal gas law. GCMs divide the world into a grid, and each equation is solved at each grid cell across the entire globe, at a fixed time interval (usually 10–30 minutes), and for several layers of the atmosphere. Due to the computational burden, GCMs typically have spatial resolutions of 1–4 degrees (~100–400 km^2). The coarseness of the spatial resolution means that aspects of those climate dynamics that have smaller spatial scales—such as topography, clouds, and storms—are imperfectly incorporated and averaged over the entire grid cell, (Wilby et al., in press). Generally, climate models perform better in projecting temperature than precipitation, and mean changes rather than extreme events (IPCC 2007d).

The term climate downscaling in regard to climate change projections is an umbrella term that includes two approaches for enhancing precision but not necessarily improving accuracy. ”Dynamic downscaling” generates Regional Climate Models (RCMs) while “empirical downscaling” relies on locally observed statistical relationships (Wilby et al., in press). Because both rely on data and boundary conditions from GCMs, it is pointless to downscale where there is limited confidence in the GCMs (Schiermeier 2004). Downscaling should only be undertaken in regions where the GCMs are in general agreement, which signals greater reliability.

RCMs simulate climate dynamically at very fine scales (10–50km). The atmospheric fields simulated by a GCM (surface pressure, temperature, winds, water vapor) are entered as boundary conditions for the RCM, and the “nested” RCM then simulates the smaller-scale climate. RCMs have been shown to realistically simulate regional climate features, such as precipitation, extreme climate events, and regional scale climate anomalies, such as those associated with the El Niño Southern Oscillation (Wang et al. 2004). However, RCMs are sensitive to the errors of the “mother” GCM models, which specify the boundary conditions and the choice of initial conditions (e.g., soil moisture).

Empirical downscaling relies on determining statistical relationships between large-scale atmospheric variables (e.g., strength of airflow, humidity) with local response variables, such as daily precipitation. Changes in those large-scale variables under climate change (as simulated by GCMs) can be translated into changes in local predictor variables and thus outcomes.

A plethora of downscaling software is available; however, access to data on predictor variables for calibration presents a major impediment to their use. Empirical downscaling relies on having good observational data and accurate predictions of the relationship of the local variables to large-scale forcing, as well as knowledge of how that relationship may be altered by climate change. In one global study of daily precipitation, empirical downscaling performed relatively poorly in near-equatorial and tropical locations, but adequately reproduced seasonal precipitation and the phase of daily precipitation in mid-latitude locations (Cavazos and Hewitson 2005).

Source: Westphal 2008.

Finally, uncertainty is magnified when we attempt to estimate impacts (on ecosystems, health, agriculture, housing, the economy, etc.), since this requires developing another set of models that include sectoral information and socio-economic behavior, and making assumptions as to people and systems' capacity for adaptation (EEA 2007).

But uncertainty is no excuse for inaction. As indicated in chapter 1, countries must develop adaptive capacity rather than seek to adapt to one particular outcome. As the next section shows, there is no doubt that change is coming. And while it is a good idea to improve and refine projections, it would be a very poor strategy to do nothing until projections become "more precise," however that is defined.

Climate projections: how is ECA likely to be affected?

There is consensus about broad climate trends over the twenty-first century, particularly if we limit ourselves to general qualitative assessments (milder winters, hotter summers).

This report, however, goes a step further: the IPCC ensemble of models was used to generate projections for the period 2030 to 2049 (the more relevant one for adaptation policy) assuming a world of rapid economic growth, slow population growth, and very high, but cleaner, energy use (otherwise known as the A1B scenario).[21]

Given ECA's tremendous climate diversity (from polar to Mediterranean), the region was divided into 6 sub-regions plus Russia, itself divided into another 7, for a total of 13 sub-regions based on agro-ecological zones (map 2.1). A regional summary is presented here, but climate summary sheets are available for each of the 13 sub-regions in the background paper (Westphal 2008).

Warmer everywhere: fewer frost days, more heat waves

The ensemble of General Circulation Models (GCMs) projects continued *warming everywhere*, with *fewer frost days* and *more heat waves.* There is *complete model concordance* on the direction of these changes (box 2.2).

Map 2.2 summarizes the projections: the projected increase in mean annual temperature in ECA ranges from 1.6ºC to 2.6ºC by the middle of this century, with a gradient of increasing temperature change with more northern latitudes; the northern parts of the region will have greater temperature changes in the winter, while the more southerly parts of the region will show greater warming in the summer months; the number of frost days is projected to decrease by 14–30 days, with the greatest decrease occurring in the Baltic sub-region. Furthermore, the number of hot days is projected to increase by 22–37 days per year by 2030–2049, and the greatest increases in heat wave duration are expected in the North Caucasus.[22] In general, daily minimum temperatures are projected to increase faster than daily maximum temperatures, narrowing intra-daily temperature ranges (IPCC 2007c).

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[21] Of the four "pillar" emission scenarios (A1, A2, A1B, B2) (IPCC 2007d), only projections for the mid-range A1B scenario are shown. There are no significant differences across scenarios in their warming projections until 2030; moreover, even by mid-century, the variation between climate models for a given emission scenario tends to be greater than the variation between model means calculated across the emission scenarios. For a full discussion of the methodology and model used, see Westphal 2008.

[22] This is a relative measure of the number of consecutive days that have a daily maximum temperature at least 5ºC greater than the historical normal daily maximum temperature.

BOX 2.2 THE SKILL OF MODELS IN SIMULATING PRESENT CLIMATE IN ECA

The credibility, or reliability, of climate models can be tested by comparing model-generated climate simulations for the current period against currently observed climate. Such an exercise reveals that regional climate models perform better generally than global climate models, but that performance varies across ECA sub-regions, with Central Asia most poorly served.

Europe

Existing GCMs exhibit either positive or negative biases for temperature in the summer, while most have a cold bias in the winter, particularly for northern Europe (meaning that models tend to project colder than actual temperatures in the winter). Biases in temperature vary considerably in Europe, both spatially and temporally. Precipitation biases for Europe are smaller than those of most regions of the world. Most GCMs overestimate rainfall from autumn to spring in northern Europe, but many also overestimate summer rainfall. In the Southern Europe and Mediterranean region, the median simulated annual precipitation is very close to observation, although models differ in the sign of the small bias.

RCMs for Europe capture the geographical variation of temperature and precipitation better than global models but tend to simulate conditions that are too dry and warm in southeastern Europe in summer. Most but not all RCMs also overestimate the inter-annual variability of summer temperatures in southern and central Europe.

Asia

For Russia west of the Urals, most models have negative temperature and positive precipitation biases (i.e., they underestimate temperatures but overestimate precipitation). GCMs typically perform poorly over central Asia due to the topography. Models, even RCMs, tend to overestimate precipitation over arid and semi-arid areas in the northern part of Central Asia. The precipitation biases range from –58 to +24% over the ensemble of models over all seasons. RCMs for Central Asia are much less developed than those for Europe.

Source: Westphal 2008.

Our projections are consistent with the results of downscaled models available for the region. In Europe, a team of 21 European research groups undertook an interdisciplinary project—PRUDENCE (Prediction of Regional scenarios and Uncertainties for Defining EuropeaN Climate change risks and Effects)—to provide high resolution climate change scenarios for Europe at the end of the twenty-first century using Regional Climate Models (RCMs) (Christensen et al. 2007).

In terms of extreme temperature events, the PRUDENCE RCM projections reiterate the patterns seen in the GCM projections presented here. By the end of the twenty-first century, central Europe (roughly corresponding to the same sub-region of this study) is projected to experience the same number of hot days (> 30ºC) as experienced in Spain and Sicily.

An RCM has also been developed for parts of Russia and Central Asia (Shkolnik et al. 2007). In winter, the model projects a decrease in temperature variability and cold extremes, while in the summer, extremely high daily temperatures are projected to increase at a faster rate than the rest of the temperature distribution. As for heat wave duration, the model projects the most severe increases for the Urals and Western Siberia, Kazakhstan, and Central Asia.[23]

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[23] Heat wave duration is defined as the sequence of days with daily maximum temperatures exceeding the local 90th percentile of previous summers' maximum temperature distributions.

The following summarizes expected general trends for the region. Sub-regional trends are summarized in annex table 2.1, while more disaggregated and detailed projections are available in Westphal 2008.

Wetter north and east, drier south

The GCMs project a wetter north and east and a drier south (map 2.3). By mid-century, mean annual precipitation will increase in most of the Russian sub-regions (by 5–11%), with the North Caucasus the only anomaly (–2%). The increase is most pronounced in Siberia and the Far East. In addition, winter precipitation in Russia is projected to increase more substantially than precipitation during the other seasons (9–18%, excluding the North Caucasus).

For all of the Russian sub-regions, there is strong model agreement in mean annual and winter precipitation; the situation for summer precipitation is not consistent, with the exception of South Siberia. However, by the end of the century, there are clear consistent trends for increased precipitation in most of Russia for the summer months (IPCC 2007c, Kattsov 2008). The projections for precipitation changes in Russia agree with the historical trends.

For the rest of ECA, the most consistent trends are: an increase in winter (9%) and spring (5%) precipitation in Kazakhstan by mid-century and a decrease in precipitation in Southeastern Europe (–6% for annual mean). The near-term picture of summer precipitation in Southeastern Europe is inconsistent across models, although end-of-century projections show consistent trends of decreasing precipitation (IPCC 2007c).

There is strong model disagreement for annual and seasonal precipitation on average for Central Asia, Caucasus, Central Europe, and the Baltics.

Finally, the models project that the interval between rainfall events will decrease in the north and east and increase in the south and west, with the greatest magnitude in Southeastern Europe (maximum consecutive dry days [CDD] increasing by five days) and eastern Russia (CDD decreases by four days in South Siberia).

Runoff, a measure of water availability, is projected to decrease everywhere but in Russia (map 2.4). The most dramatic decrease will likely occur in Southeastern Europe (–25%) and result in increased drought conditions (Milly et al. 2005; Milly et al. 2008).

The net impact is less clear in Russia: precipitation and runoff are projected to increase, but so are temperatures and heat waves, speeding evaporation and reducing water availability. Most of the precipitation increase in Russia is expected in the winter, and while low runoff is often used as a proxy for drought, the runoff indicator is an annual average that masks temporal variation.

It is still possible for higher summer temperatures to offset precipitation increases and lead to periodic drought conditions in the future. One projection of the Palmer Drought Severity Index shows an increase in drought conditions over the course of the twenty-first century over much of Russia, with the exception of far northeastern Siberia (Dai et al. 2004; Aiguo Dai, *personal communication*). Russia will likely receive more precipitation, but whether this excess can be captured and put to use is uncertain.

When it rains, it pours—everywhere

Throughout the entire ECA Region, the models are *unequivocal:* precipitation intensity will *increase*, ranging from 2–6 percent (map 2.4). While this may not seem significant, these are mean values and depending on local hydrology and topography, this increase in precipitation intensity could have significant repercussions for water storage systems, sanitation, and flood management. With the exception of Southeastern Europe, most models project an increase in precipitation from extreme storm events (2–9% increase in the maximum amount of precipitation over a 5-day period). The PRUDENCE RCMs project heavy winter precipitation increases in Northern and Central Europe and decreases in the south. In the summer, the zone of heavy winter precipitation shifts to Northeast Europe. Extreme wind speeds (winter storms) are projected to increase over Central Europe (Beniston et al. 2007).

The projections for extreme precipitation cannot be translated directly into flood projections; detailed local-scale impact models, incorporating topography and specifics of hydrology, are needed. However, if a region is currently experiencing significant flooding and if no adaptation measures (flood mitigation) are enacted, then one can assume that an increase in extreme precipitation will result in more flooding. Whether this results in more natural disasters depends on whether vulnerability (e.g., land-use planning, the population in the floodplain, the existence of early-warning systems, institutional capacity) remains constant.

ANNEX TABLE 2.1 GENERAL CLIMATE TRENDS IN ECA’S SUB-REGIONS

Sub-region	Current trends and weather related events	Projected temperature rise by 2050	Mean annual precipitation	Runoff	Rainfall intensity and variability	Interval between wet days	Heat waves
Baltics	Warming trend over the past century. Flood damage significant.	1.6ºC, warmer winters, decrease in frost days.	Unclear	South: decrease. North: increase.	Increase		Increase
Central Asia	Warming trend over the past century. Droughts and landslides in some parts.	2.0ºC, decrease in frost days.	Unclear	Decrease	Increase		Increase
Caucasus	Warming trend accelerating in past 20 years. Droughts and landslides in parts.	1.7ºC, warmer summers, decrease in frost days.	Unclear	Decrease	Increased and more variable	Increase	Increase
Central Europe	Warming in the last 20 years but no trends in precipitation.	1.7ºC, decrease in frost days.	Unclear	Decrease (median –13%)	Increased and more variable	Increase	Increase
Kazakhstan	Warming over past century.	2.0ºC	Increasing (4–9%)	Slight increase	Increase	Unclear	Increase
Southeastern Europe	No trends, but vulnerable to floods and drought.	1.8–2.1ºC, decrease in frost days.	Decrease except summer.	Decrease (–25%)	Increase	Increase	Increase

continued

Sub-region	**Current trends and weather related events**	**Projected temperature rise by 2050**	**Mean annual precipitation**	**Runoff**	**Rainfall intensity and variability**	**Interval between wet days**	**Heat waves**
Russian regions:							
Baltic Russia	Flood and landslide damage is significant in some parts.	1.9ºC, decrease in frost days.	Increasing (6%) wetter winter and spring.	Increase (13%)	Increase		Increase
Central & Volga	No trends, flooding significant.	1.9ºC, warmer winters, decrease in frost days.	Winter and spring will be wetter.	Increase (7%)	Increase		Increase
North Caucasus	Increasingly wet over the past century.	1.6ºC, decrease in frost days.	Unclear	Decrease (–12%)	Increased and more variable	Decrease	Increase
Siberia & Far-eastern Russia	Significant warming and wetting in the past century.	2.4ºC, decrease in frost days.	Increase (11%), particularly in winter (17%).	Increase (22%)	Increase	Decrease	Increase
South Siberia	Warming and wetting trend over the past century. Floods and landslides.	2.1ºC	Increasing (8%)	Increase	Increase	Decrease	Unclear
Urals and W. Siberia	Significant wetting in past century. Floods and landslides.	2.2ºC, decrease in frost days.	Annual increase (9%), winter increase (15%).	Increase (10%)	Increase	Unclear	Increase

Source: Derived from climate summary tables (Westphal 2008).