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Current Knowledge about Observed Impacts of Climate Change on the Natural and Human Environment

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Dr. Cynthia Rosenzweig is a Senior Research Scientist at the NASA Goddard Institute for Space Studies located at Columbia University. Her primary research involves the development of interdisciplinary methodologies by which to assess the potential impacts of and adaptations to global environmental change. Recognizing that the complex interactions engendered by global environmental change can best be understood by coordinated teams of experts, Dr. Rosenzweig has organized and led large-scale interdisciplinary, national, and international studies of climate change impacts and adaptation. She co-led the Metropolitan East Coast Regional Assessment of the U.S. National Assessment of the Potential Consequences of Climate Variability and Change, sponsored by the U.S. Global Change Research Program. She is a recipient of the Guggenheim Fellowship and is a Fellow of both the American Association for the Advancement of Science and the American Society of Agronomy. She leads the Climate Impacts Research Group at the Goddard Institute of Space Studies, whose mission is to investigate the interactions of climate variability and change on systems and sectors important to human well-being. For the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC), she is the Co-Coordinating Lead Author for Chapter One, Assessment of Observed Changes and Responses in Natural and Managed Systems, of Working Group II on Impacts, Adaptation, and Vulnerability.

Dr. Cynthia Rosenzweig is entering into testimony Section B of the Working Group II Contribution to the Intergovernmental Panel on Climate Change, Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability Approved Summary for Policymakers.

Current knowledge about observed impacts of climate change on the natural and human environment

A full consideration of observed climate change is provided in the IPCC Working Group I Fourth Assessment. This part of the Summary concerns the relationship between observed climate change and recent observed changes in the natural and human environment.

The statements presented here are based largely on data sets that cover the period since 1970. The number of studies of observed trends in the physical and biological environment and their relationship to regional climate changes has increased greatly since the Third Assessment in 2001. The quality of the data sets has also improved. There is, however, a notable lack of geographic balance in data and literature on observed changes, with marked scarcity in developing countries.

These studies have allowed a broader and more confident assessment of the relationship between observed warming and impacts than was made in the Third Assessment. That Assessment concluded that "there is high confidence[1] that recent regional changes in temperature have had discernible impacts on many physical and biological systems".

From the current Assessment we conclude the following.

Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.

With regard to changes in snow, ice and frozen ground (including permafrost)[2], there is high confidence that natural systems are affected. Examples are:

- enlargement and increased numbers of glacial lakes [1.3];
- increasing ground instability in permafrost regions, and rock avalanches in mountain regions [1.3];
- changes in some Arctic and Antarctic ecosystems, including those in sea-ice biomes, and also predators high in the food chain [1.3, 4.4, 15.4].

Based on growing evidence, there is high confidence that the following types of hydrological systems are being affected around the world:

- increased run-off and earlier spring peak discharge in many glacier- and snow-fed rivers [1.3];
- warming of lakes and rivers in many regions, with effects on thermal structure and water quality [1.3].

[1] See Endbox 2.
[2] See IPCC Working Group I Fourth Assessment Report Summary for Policymakers.

There is very high confidence, based on more evidence from a wider range of species, that recent warming is strongly affecting terrestrial biological systems, including such changes as:

- earlier timing of spring events, such as leaf-unfolding, bird migration and egg-laying [1.3];
- poleward and upward shifts in ranges in plant and animal species [1.3, 8.2, 14.2].

Based on satellite observations since the early 1980s, there is high confidence that there has been a trend in many regions towards earlier 'greening'[3] of vegetation in the spring linked to longer thermal growing seasons due to recent warming. [1.3, 14.2]

There is high confidence, based on substantial new evidence, that observed changes in marine and freshwater biological systems are associated with rising water temperatures, as well as related changes in ice cover, salinity, oxygen levels and circulation [1.3]. These include:

- shifts in ranges and changes in algal, plankton and fish abundance in high-latitude oceans [1.3];
- increases in algal and zooplankton abundance in high-latitude and high-altitude lakes [1.3];
- range changes and earlier migrations of fish in rivers [1.3].

The uptake of anthropogenic carbon since 1750 has led to the ocean becoming more acidic with an average decrease in pH of 0.1 units [IPCC Working Group I Fourth Assessment]. However, the effects of observed ocean acidification on the marine biosphere are as yet undocumented. [1.3]

A global assessment of data since 1970 has shown it is likely[4] that anthropogenic warming has had a discernible influence on many physical and biological systems.

Much more evidence has accumulated over the past five years to indicate that changes in many physical and biological systems are linked to anthropogenic warming. There are four sets of evidence which, taken together, support this conclusion:

1. The Working Group I Fourth Assessment concluded that most of the observed increase in the globally averaged temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.
2. Of the more than 29,000 observational data series5, from 75 studies, that show significant change in many physical and biological systems, more than 89% are consistent with the direction of change expected as a response to warming. (Figure SPM-1) [1.4]
3. A global synthesis of studies in this Assessment strongly demonstrates that the spatial agreement between regions of significant warming across the globe and the locations of significant observed changes in many systems consistent with warming is very unlikely

[3] Measured by the Normalised Difference Vegetation Index, which is a relative measure of the amount of green vegetation in an area based on satellite images.
[4] See Endbox 2.
[5] A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) Ending in 1990 or later; (2) spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies.

to be due solely to natural variability of temperatures or natural variability of the systems.(see Figure SPM-1) [1.4]

4. Finally, there have been several modelling studies that have linked responses in some physical and biological systems to anthropogenic warming by comparing observed responses in these systems with modelled responses in which the natural forcings (solar activity and volcanoes) and anthropogenic forcings (greenhouse gases and aerosols) are explicitly separated. Models with combined natural and anthropogenic forcings simulate observed responses significantly better than models with natural forcing only. [1.4]

Limitations and gaps prevent more complete attribution of the causes of observed system responses to anthropogenic warming. First, the available analyses are limited in the number of systems and locations considered. Second, natural temperature variability is larger at the regional than the global scale, thus affecting identification of changes due to external forcing. Finally, at the regional scale other factors (such as land-use change, pollution, and invasive species) are influential. [1.4]

Nevertheless, the consistency between observed and modelled changes in several studies and the spatial agreement between significant regional warming and consistent impacts at the global scale is sufficient to conclude with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems. [1.4]

Other effects of regional climate changes on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.

Effects of temperature increases have been documented in the following systems (medium confidence):

- effects on agricultural and forestry management at Northern Hemisphere higher latitudes, such as earlier spring planting of crops, and alterations in disturbance regimes of forests due to fires and pests [1.3];
- some aspects of human health, such as heat-related mortality in Europe, infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes [1.3, 8.2, 8.ES];
- some human activities in the Arctic (e.g., hunting and travel over snow and ice) and in lower elevation alpine areas (such as mountain sports). [1.3]

Recent climate changes and climate variations are beginning to have effects on many other natural and human systems. However, based on the published literature, the impacts have not yet become established trends. Examples include:

- Settlements in mountain regions are at enhanced risk to glacier lake outburst floods caused by melting glaciers. Governmental institutions in some places have begun to respond by building dams and drainage works. [1.3]
- In the Sahelian region of Africa, warmer and drier conditions have led to a reduced length of growing season with detrimental effects on crops. In southern Africa, longer dry seasons and more uncertain rainfall are prompting adaptation measures. [1.3]

- Sea-level rise and human development are together contributing to losses of coastal wetlands and mangroves and increasing damage from coastal flooding in many areas. [1.3]

Changes in physical and biological systems and surface temperature 1970-2004

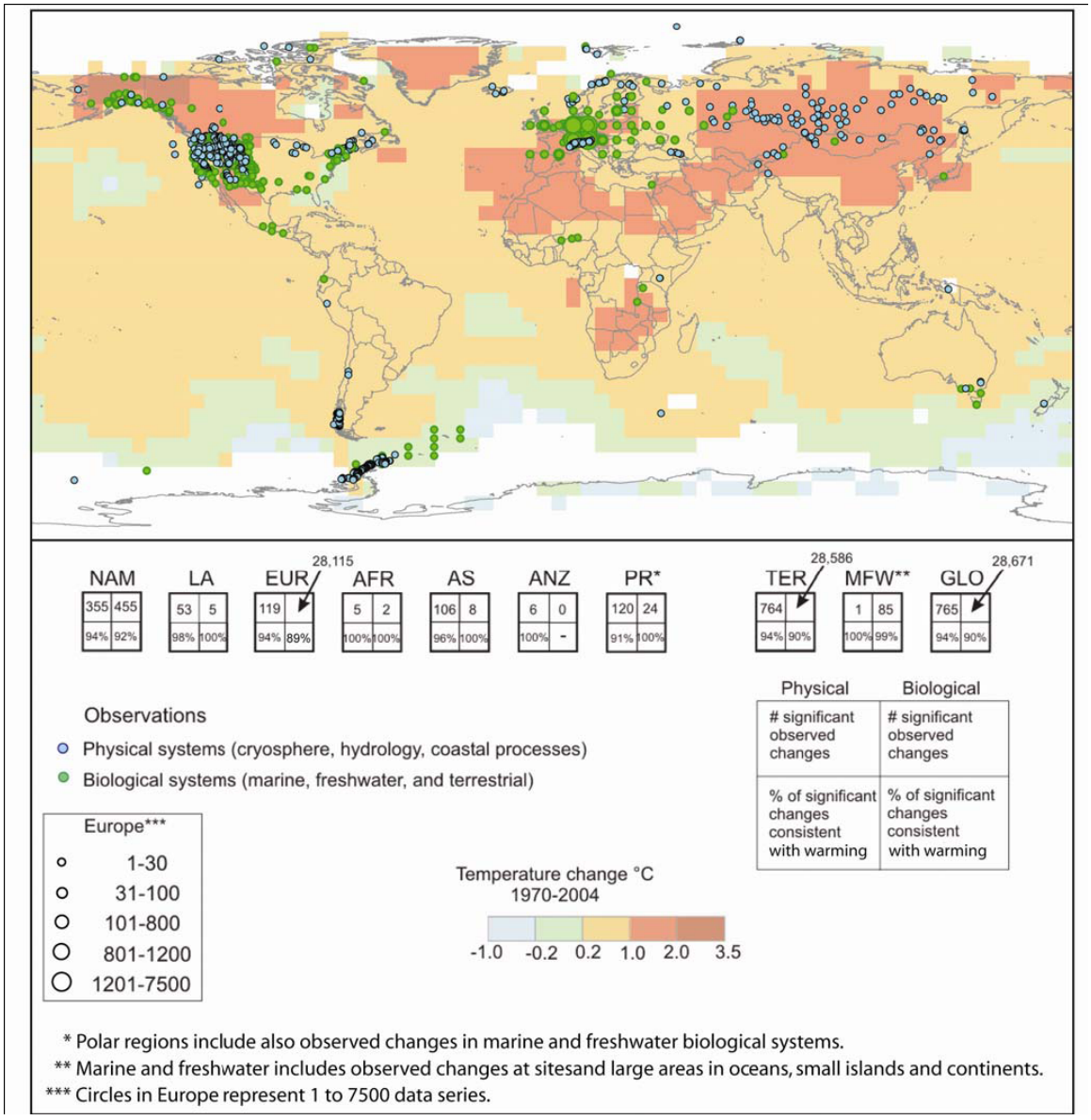

Figure SPM-1. Locations of significant changes in observations of physical systems (snow, ice and frozen ground; hydrology; and coastal processes) and biological systems (terrestrial, marine, and freshwater biological systems), are shown together with surface air temperature changes over the period 1970-2004. A subset of about 29,000 data series was selected from about 80,000 data series from 577 studies. These met the following criteria: (1) Ending in 1990 or later; (2) spanning a period of at least 20 years; and (3) showing a significant change in either direction, as assessed in individual studies. These data series are from about 75 studies (of which ~70 are new

since the Third Assessment) and contain about 29,000 data series, of which about 28,000 are from European studies. White areas do not contain sufficient observational climate data to estimate a temperature trend. The 2 x 2 boxes show the total number of data series with significant changes (top row) and the percentage of those consistent with warming (bottom row) for (i) continental regions:
North America (NAM), Latin America (LA), Europe (EUR), Africa (AFR), Asia (AS), Australia and New Zealand (ANZ), and Polar Regions (PR) and (ii) global-scale: Terrestrial (TER), Marine and Freshwater (MFW), and Global (GLO). The numbers of studies from the seven regional boxes (NAM, …, PR) do not add up to the global (GLO) totals because numbers from regions except Polar do not include the numbers related to Marine and Freshwater (MFR) systems. [F1.8, F1.9; Working Group I Fourth Assessment F3.9b]

Endbox 2. Likelihood and confidence language

In this Summary for Policymakers, the following terms have been used to indicate: the assessed likelihood of an outcome or a result:
Virtually certain > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Very unlikely* < 10%, *Extremely unlikely* < 5%.

The following terms have been used to express confidence in a statement:
Very high confidence At least a 9 out of 10 chance of being correct, *High confidence* About an 8 out of 10 chance, *Medium confidence* About a 5 out of 10 chance, *Low confidence* About a 2 out of 10 chance, *Very low confidence* Less than a 1 out of 10 chance.