United Nations
Educational, Scientific and
Cultural Organization

Organisation
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International Experts Meeting

Climate Change
and Arctic Sustainable Development :
scientific, social, cultural and educational challenges

3-6 March 2009, Monaco

ABSTRACT: OCEANS, ICE AND ATMOSPHERE

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Climate change: Consequences for the Arctic physical environment.
Average air temperature over the globe in the year 2008 took 10^{th} place in top 100 warm year's list. In the year of 1988 air temperature reached its highest point and became more or less fixed, experiencing insignificant decrease since then.

Average surface temperature in the Arctic appears to have increased during most of the 20th century. The trend between 1966 and 2008 over the Arctic was 0.4ºC/decade, approximately four times greater than the average for the century (0.09ºC/decade). It is very probable that Arctic air has warmed faster than in any other region on planet since 1966, and is greater than temperature increase in 30^{th} and 40^{th}. Climate projections suggest continuation of the strong warming trend of recent decades in the Arctic, with the significant changes coming during winter months.

Severe Arctic ozone depletion events were observed in the majority of the last ten springs (up to 45% below normal in 1997). Although depletion of stratospheric ozone was expected to increase UV radiation at the earth's surface, actual correlations have become visible only now taking into consideration the short period of instrumental UV measurement.

UV radiation has a variety of harmful impacts on humans, flora and fauna. It certainly influences inanimate objects.

Long-term variation of sea ice extent is a good indicator of climate change in the Arctic. Satellite observations show a steady downward trend in sea ice for the last three decades. From the start of monitoring in 1979 the minimum seasonal sea ice area observed in September every year has been decreasing by 9% per decade. In 2007 the surface of sea ice had the lowest minimum value ever recorded, 4.3 million km2. However, the northward shift of the ice boundary did not occur everywhere. In the eastern sector of the Russian Arctic the boundary of multi-year ice shifted southward by 300 km on average relative to the previous two decades.

We have insufficient information about depth measurements of the sea ice thickness. Within the Arctic Ocean several occasional surveys of sea ice were measured with sonar from nuclear submarines since 1958. According to measured data average ice thickness lowered from 3,1 m to 1,8 m in the period 1958-1999, and overall volume decreased by 30%.

Ice surface of the Arctic influences marine economic activity. Along the Northern Sea Route at the end of the warm season (August - September) its condition became substantially more favorable for navigation in high latitudes, namely, to the north from the Arctic archipelagos Franz-Josef Land, Severnaya Zemlya and New Siberian Islands. However, the increased occurrence of icebergs amplifies risks for marine transport and fishery. Climate changes have also negatively affected coasts of the northern seas (erosion intensification) and their infrastructure.

In the last quarter of the 20th century, temperature amplification of the upper ground layer was observed at many sites of the permafrost zone, and the increase in depth of seasonal thawing took place in some regions. Annual surface temperature increased by 0.8-1.0°C at many sites of the permafrost zone. Enhancement of seasonal thawing of permafrost, especially near its southern boundary, poses a threat to infrastructure installations (houses and engineering blocks and communication lines, including oil and gas pipelines).

Changes in the permafrost enhance methane emissions from wetlands into atmosphere. However, in the 21st century the expected increase in emissions of methane from wetlands of Arctic permafrost regions will not have a remarkable influence on the global climate.

The annual runoff of Arctic rivers rose by 20–30% since 1978 relative to 1946–1977, basically due to winter flow increase. Freshening of the Arctic Ocean by increased precipitation and runoffs is likely to reduce the formation of cold deep water, thereby slowing the meridional overturn circulation. It is likely that meridional circulation slowdown would lead to a rapid rise of global sea level and exert chilling influence on the Arctic as Gulf Stream heat transport is reduced.

The risk of dangerous floods on rivers in the season of snow melt will grow in those regions where ice jams accompany runoff peaks.

The Arctic is an important part of the global climate system. It both affects and is affected by global climate change. For example, reduction or loss of snow and ice has the effect of increasing the warming trend as reflective snow and ice surfaces are replaced by darker land and water surfaces that absorb more solar radiation. Arctic exploration features the key value to a great number of climatic problems.

Recommendations:

- Observational database for the Arctic is quite limited, with few long-term stations and a paucity of observations in general, making it difficult to distinguish with confidence between the signals of climate variability and change. Steps to be taken now are to fill in observational gaps across the Arctic including oceans, land, ice and atmosphere.
- The Sustained Arctic Observing Networks (SAON) is seen as a means of addressing several of these problems, and improving the situation through involving all relevant partners (see http://www.arcticobserving.org for the details). UNESCO has the opportunity to significantly contribute to SAON, specifically, in the framework of establishing the development of a portal for archiving data and metadata, publishing of dataset and derived products.
- It is evident that further research is still needed. For example, models differ considerably in their estimates of the strength of different feedbacks in the

climate system, particularly cloud feedbacks, oceanic heat uptake and carbon cycle feedbacks. UNESCO has the capacity to push scientific research of Arctic climate in the framework of the World Climate Research Programme and IHP, IOC and MAB.

- Further evaluation of adaptation potential is required for the whole Arctic and its individual regions. Adaptation can reduce vulnerability, both in the short and the long term. Special attention should also be given to the development of early warning systems and techniques for prediction of extreme events leading to serious negative socio-economical and ecological consequences.