Monitoring and Assessing Regional Climate change in High latitudes and the Arctic

by

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Abstract

Climate change can only be understood through improved knowledge of the coupling between the dynamic processes in the atmosphere, the solid Earth, the hydrosphere, the cryosphere, the biosphere and the anthroposphere. These components are interlinked by forcing and feedback mechanisms at a broad range of temporal and spatial scales, and usually with distinct regional characteristics. The Arctic and northern hemisphere high latitude regions, in particular, are susceptible to climatic and environmental change. Rapid decreases in Arctic Sea ice concentration (Drobot et al., 2008; Johannessen, 2008) and decreases in sea surface carbonate saturation caused by human-produced CO2 (Orr et al., 2005) are two striking examples. Quantitative uncertainties in changes in high latitude and Arctic sea level, permafrost and surface albedo are other examples. The European citizen has a right to know the consequences of such changes for Europe. However, this cannot adequately be provided today. The scientific rationale, uniqueness and timeliness of the MONARCH-A project must be seen in this perspective.

The ultimate goal of MONARCH-A is consequently to generate a dedicated information package tailored to a subset of multidisciplinary Essential Climate Variables (ECVs) and their mutual forcing and feedback mechanisms associated with changes in terrestrial carbon and water fluxes, sea level and ocean circulation and the marine carbon cycle in the high latitude and Arctic regions.

Adopting an Earth system approach MONARCH-A will execute systematic provision of tailored information and products to assist climate change research and generate and make avaiable reliable, up-to-date scientific input for the elaboratio and implementation of European and international policies and strategies on climate change and society. The information package will be based on generation of time series of observation datasets and reanalyses of past observational data enabling adequate descriptions of the status and evolution of the high latitude and Arctic region Earth system components.

Work programme, Methodology and milestones

The MONARCH-A approach (Figure 1) will be organized around four main activities, notably: (i) changes in carbon-water interaction; (ii) changes in sea level and ocean circulation; (iii) changes in marine carbon cycle; and (iv) synthesis and interaction with the scientific community on climate change research. 11 multidisciplinary Essential Climate Variables (ECVs) relevant for high latitude and Arctic regions will be generated and made available in the information package. Arranged according to the GCOS ECVs domain they include:

- Terrestrial: river discharge, snow cover, ice sheet mass balance and permafrost;
- Oceanic: sea ice drift and sea ice volume, sea level, current, ocean color and CO2 partial pressure;
- Atmospheric: near surface wind field

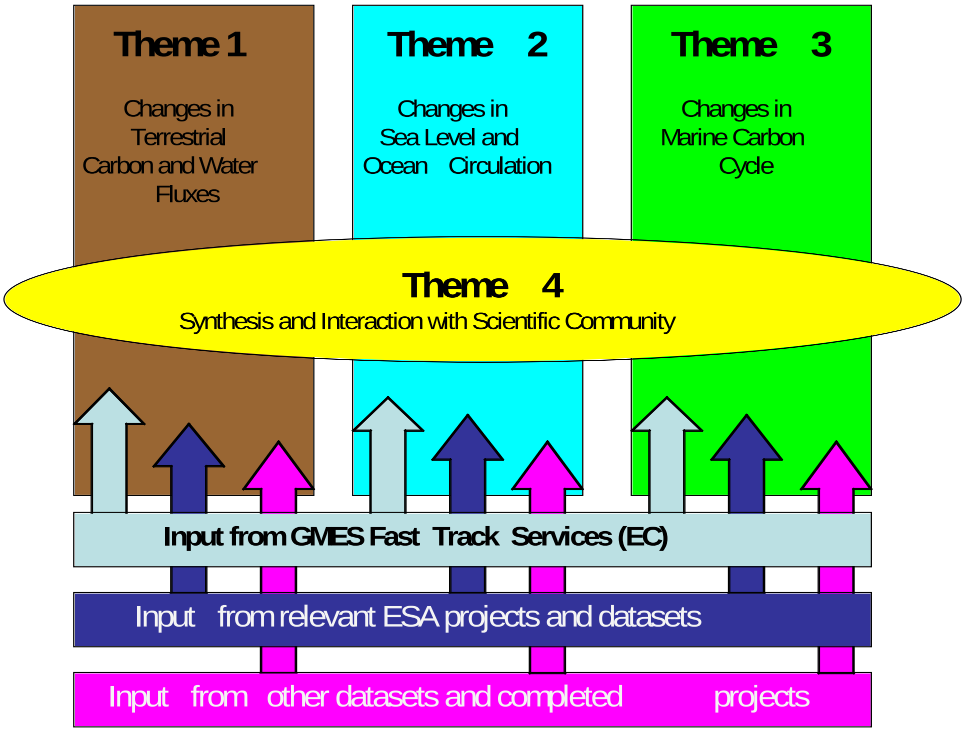

Figure 1. Illustration of project structure with the three (vertical) themes focusing on generating selected multidisciplinary Earth system ECV while the fourth (horizontal) cross-cutting theme will include synthesis and interaction with the user community. Products from major information platforms including the GMES Fast Track Services, ESA relevant projects and data archives and other national and international datasets and projects will be pulled in as marked by the arrows (Copyright MONARCH-A).

Quantifying and reducing the uncertainty in climate predictions is a critical element in IPCC considerations, in order that society can use the predictions to take informed decisions on mitigation and adaptation strategies. This presents a major challenge in climate modeling and prediction. Quality control of the model fields through regular and consistent validation and inter-comparison against independent observations is therefore mandatory, as is implementation of realistic initial conditions. Cox and Stephenson (2007) have shown that the major element of uncertainty in predictions up to 30 years is the lack of adequate information on initial conditions – i.e. lack of quality observations. In order to reduce the uncertainty in climate predictions over such a multi-decadal period, the primary need is for more and better observations, scientific research, feedback mechanisms and process understanding as also emphasized by IPCC (2007) and Hawkins and Sutton (2009).

Partnerships collaborations

The MONARCH-A project consortium collectively constitute advanced experience and knowledge as briefly indicated below**.**

Partner	**Expertise, Experience and Knowledge**
P1-NERSC	Developing multi-satellite ocean and sea ice remote sensing algorithms. Developing coupled ocean – sea ice models, data assimilation system (TOPAZ) and reanalyzes.
P2-USFD	Developing terrestrial carbon and water models, and analyzing satellite data for land surface processes and exploiting them in Dynamic Vegetation Models. Innovative data assimilation methods in terrestrial carbon and water models.
P3-UHAM	Developing reanalyzes in coupled ocean-sea ice models; developing and running ocean and coupled assimilation experiments; analyzing the quality of ocean and climate models; developing ocean and sea ice remote sensing algorithm.
P4-CNRS	Applying space techniques to study solid Earth and surface fluid envelopes; large-scale continental hydrology, sea level variations at global and regional scales, gravitational field and temporal gravity variations.
P5-NIERSC	Expertise in understanding behaviour of aquatic ecosystems in response to global change; bio-optical retrieval algorithms; monitoring of harmful algae bloom events; primary production assessment for ocean and inland waters .
P6-UiB	World class expertise in analyzing inorganic carbon in the ocean and synthesizing global carbon and other relevant data sets obtained from different measuring platforms. Delivered state of art system for measuring sources and sinks of carbon in the ocean.
P7-DTU	Expertise in the field of geodesy and developing Earth observation methodology for both marine and arctic GMES services. Strong focus on climate changes in Greenland on sea level, the ice sheet mass balance and the sea ice extent.
P8-IFREMER	The CERSAT repository at IFREMER offer expertise in retrieval algorithm developments, calibration/validation of satellite sensors, data analysis and merging techniques. Also developed a fast and flexible reprocessing capability.

E**xpected scientific and technological results, positive features, problems encountered**

As the length of existing ECV data records increases, in some cases now to around 20-30 years, and they gradually become of better quality and accuracy, adequate validation and adaptation to better initialization are becoming feasible. In this context, the expected advanced achievements from the Earth system approach undertaken in MONARCH-A, with its focus on high latitude and Arctic regions, will lead to progress beyond the state-of-the-art. In particular the generation of refined and consistent multidisciplinary time series of:

- *Land:* vegetation cover, river discharge and lake levels

- *Cryosphere:* snow cover, permafrost, ice sheet elevation change, sea ice drift and sea ice volume
- *Ocean:* sea level, current and color,
- *Atmosphere:* near surface wind field and CO2 partial pressure

integrated with existing complementary information on land cover, fire, sea ice extent and concentration, sea ice thickness, sea surface temperature and sea level will provide tailored information and products to assist climate change research to incorporate the refined and consistent ECVs. For the ocean carbon cycle, satellite observations constrain primary production – through ocean color and chlorophyll related transfer functions (with the possibility to quantify air-sea gas exchange and detect blooms of specific species), through surface wind-speeds and their variability, sea state/white capping, sea surface temperature and ice cover which influences biological production and gas exchange. There is some hope to obtain new reliable atmospheric CO2 column measurements from space (GOSAT), but not for the surface ocean where one still has to rely on in-situ measurements. For the carbon budget, moreover, the export production rather than the primary production is critical. Though export production can be roughly estimated from primary production, models need to be employed in order to fully account for a correct quantification of the biological carbon pump.

Through re-analyses adequate and consistent description of the status and evolution of the high latitude and Arctic region will be provided in the context of terrestrial carbon and water fluxes, sea level and ocean circulation and marine carbon cycle. It will focus on changes during the last 30 - 50 years. This will ensure new scientific input for the elaboration and implementation of European and international policies and strategies on the environment and society, including climate adaptation strategies addressing European, national, regional and local levels. All in all the outcome of MONARCH-A is therefore anticipated to provide important new quantitative scientific knowledge and information consistent with GCOS -107 (2006) to:

- characterize the state of a subset of dominant multidisciplinary ECVs and their variability in high latitude and Arctic areas;
- monitor the forcing of the high latitude climate system, including natural and anthropogenic contributions, at regional and local scales;
- support the attribution of the causes of high latitude climate change;
- support prediction of high latitude climate change
- enable advanced understanding of the two-way connections between global and regional climate change.

Conclusions

MONARCH-A will contribute to establishing a data archive of systematic observation data related to the climate system, for a continuous record of essential climate variables including river discharges, snow cover, permafrost, ice sheet and glaciers, sea level, current, ocean color, sea ice drift, surface wind, and partial pressure CO2 coherent with UN Framework Convention on Climate Change (UNFCCC) requirements and the ECVs identified in the GCOS 2nd Adequacy Report to UNFCC in 2003. All data and results from MONARCH-A will be subject to a sustainable and transparent access for global climate scientific and operational communities. Elements of the achievements may also be relevant for the IPCC AR5.

The outcome form MONARCH-A is also expected to contribute to improving the structure and coordination of entities involved in the processing and delivery of climate change relevant dataset, in order to avoid dispersion and duplication of activities and to pave the way for a sustainable provision compliant with the requirements of climate analysis communities. Impact will also underpin many of the societal benefit areas as defined by GEOSS, in particular:

- reducing loss of life and property from natural and human induced disasters
- understanding, assessing, predicting, mitigating and adapting to climate variability and change
- improving water resource management through better understanding of the water cycle
- improving the management and prediction of terrestrial, coastal and marine ecosystems

Impact can also lead to socio economic benefits in the following policy areas:

- Europe as a global partner (climate change adaptation, global environment protection, humanitarian response)
- Preservation and management of natural resources (air quality, marine environment, forest ecosystem management, civil protection)
- Sustainable growth (efficient delivery of public services)

Finally it can also be emphasized that the MONARCH-A project and its achievements is expected to have clear relevance vis-à-vis the complementary ESA Climate Change Initiative which started up in 2010 for a period of 6 years.

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