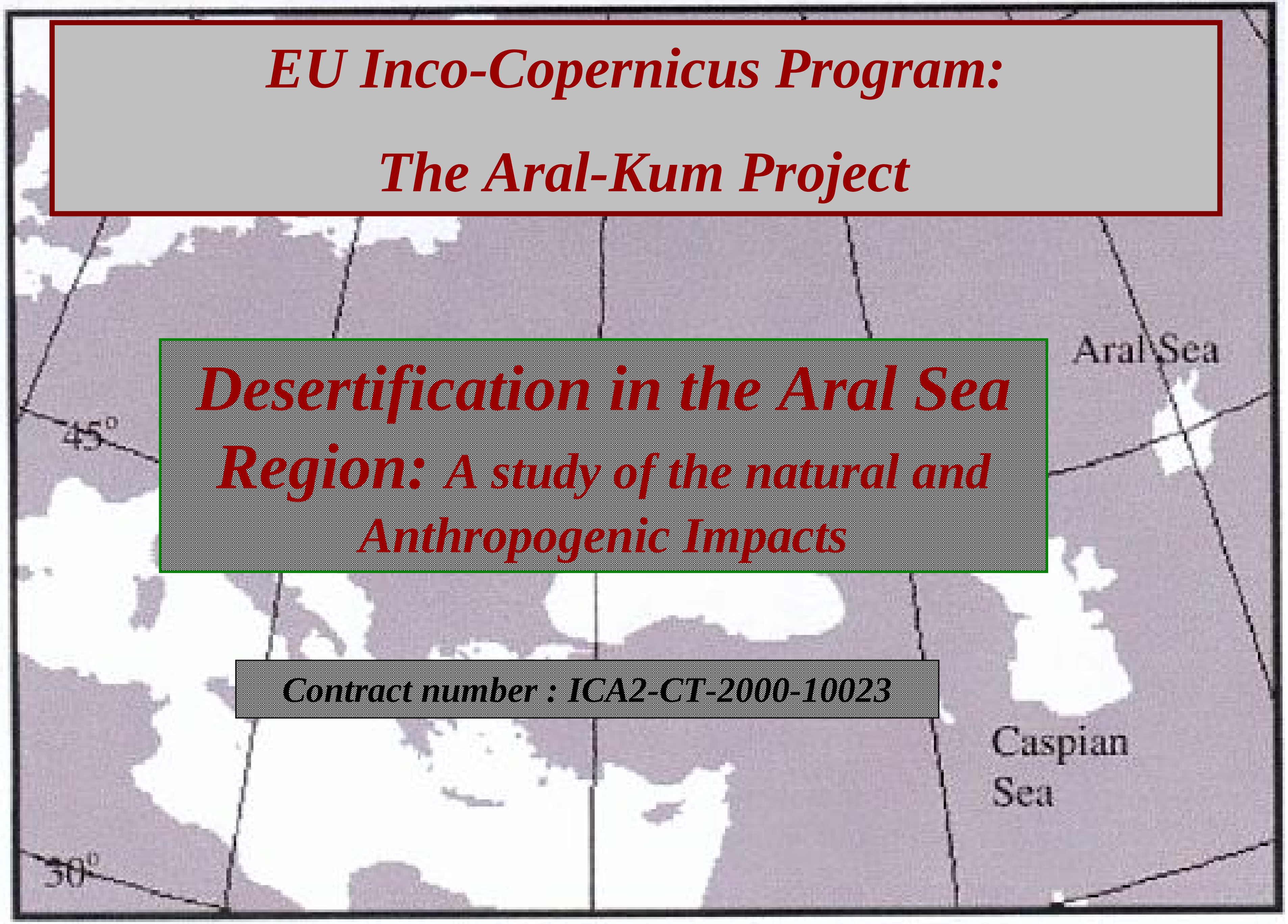
EU Inco-Copernicus Program:

The Aral-Kum Project

Desertification in the Aral Sea Region: A study of the natural and Anthropogenic Impacts

Contract number : ICA2-CT-2000-10023



Final objective of the project :

"Develop a mechanism of basin-scale / regional integrated management of the Aral Sea region based on an identification of linkages between socio-economic human dimensions and air-sea-land interaction aspects of the climate system, to prevent or mitigate the effects of ongoing desertification."

Practically : **Establishment of an international Aral Sea data and Information System (ASIS)**

Development of an integrated mathematical modeling tool for a sound environmental management of the basin.

For: **Rational identification of environmental control criteria**
Formulation of recommendations to combat desertification.

Public Access : **scientists, politicians, water resource managers and decision-makers**

Influence of the Aral Sea negative water balance on its seasonal circulation patterns: use of a 3D hydrodynamic model.

GHER
GeoHydrodynamics and Environment Research

ULg
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Aral Sea

Caspian Sea

45°

EU INCO Project ARAL-KUM:

"Desertification in the Aral Sea Region: A study of the Natural and Anthropogenic Impacts", Contract IAC2-CT-2000-10023.

3D simulation of the Aral Sea hydrodynamism

Objective

Studying the impacts of drying process on the Aral Sea hydrodynamism by the seasonal simulation of the 3D circulation, temperature, salinity and water mixing fields.

Forcings

Seasonal fluctuations of wind fields, precipitation, evaporation, water discharge and salinity of the Amu Darya and Syr Darya rivers, cloud cover, air temperature and humidity.

Model Description

Adaptation of 3-dimensional, baroclinic, mathematical model, with a robust turbulent closure, designed to address specifically the macroscale processes.

A 100*130 grid is chosen to cover the whole Aral Sea (longitude*latitude), with grid size of 2,9*2,9 km

10 layers → vertical coordinates 'sigma'

Parallel Program

Identification of periods of interest for seasonnal modelisation

According to:

- **<u>data availability (forcing and validation)</u>**
- **years of particular interest :**

in the drying process with particular river discharge, water body separation (1961, 1969, 1985, 1990, 1992)

from a biological point of vue (seasonnal and local critical salinity conditions, temporal drying of shallow habitat: suggestions?)

from hydrodynamical point of vue (change in the mixing induced by ice cover formation with the increasing salinity around 1984)

others… ?

Database compilation

- **Fastiduous collection of complete data set in order to cover the forcing and validation needs of the model since 1950 until today.**
- **Selection of particular years for seasonal 3D hydrodynamic modelisation as best compromise between data availability and years of particular interest in the drying process :**

  - **1956-1960: Original Aral Sea seasonal hydrodynamism: period of relative stability of the water balance, before the beginning of the drying process.**
  - **1981-1985: Consequences of the drying process: low river flow period.**

Validation of the model: mean seasonal salinity and temperature fields from Russian Hydrological and Meteorological Institute and sea surface.

- **Possibility of simulation for few particular years (91-93), after the drying of Berg's strait → temporal rehabilitation of the hydrology and ecosystem of the northern sea.**

Selected Dataset

ECMWF simulated data: wind and total cloud cover fields

Temporal resolution: 24 h

Spatial resolution: 6 grid nodes over the Aral Sea allowing direct linear interpolation by the model to the final grid.

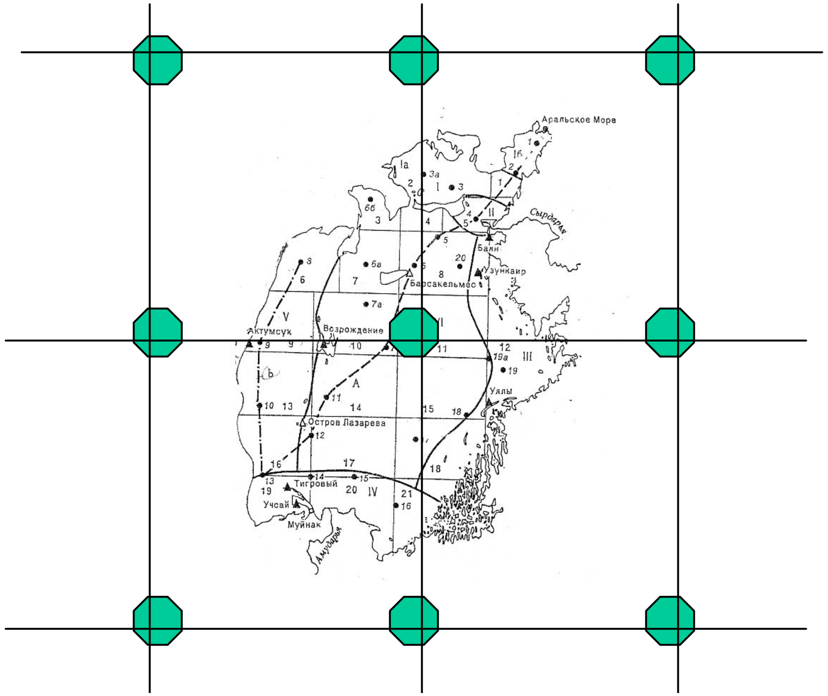
Common Data of period 1981 to 1985 for both stable and drying simulation periods.

Simplify interpretations

Further improvements with atmospheric model results?

ECMWF grid : 2.5 deg.

(latitude and longitude)

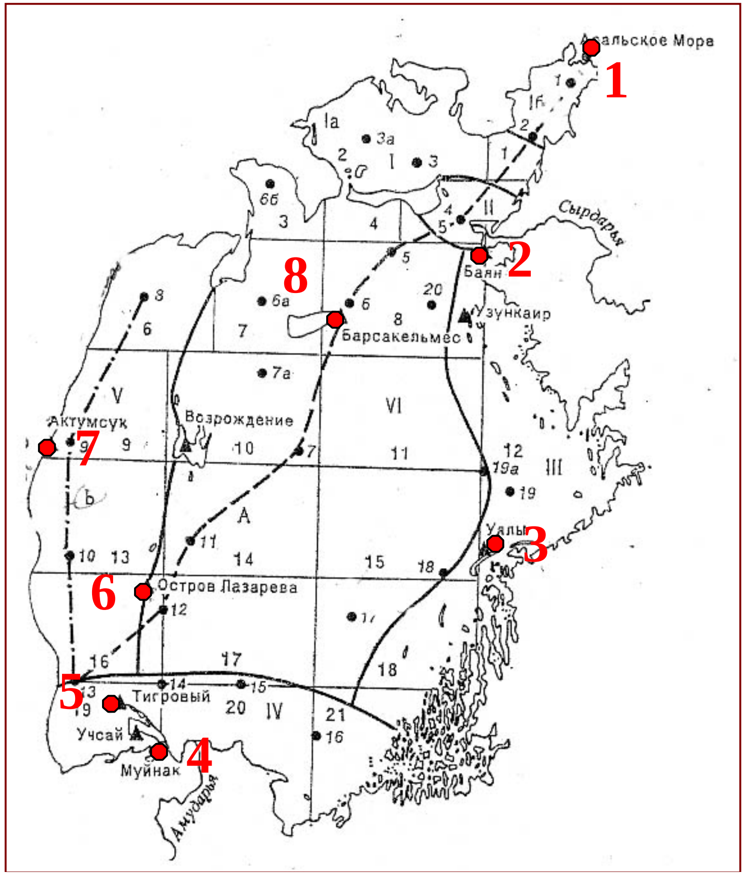


<u>Russian Hydrology and Meteorology Institute (RHMI)</u> measured data:

<u>Air temperature, Air humidity and Precipitation</u>

Temporal resolution: 1 month; mean seasonal cycle for the periods 1951-1960 and 1981-1985.

Spatial resolution: data measured in 6 to 8 meteorological stations according to parameter and period:



Period / Parameter	Precip	Air T	Air H
1951-1960	6	8	7
1981-1985	6	6	6

1	Aralsk
2	Bayan
3	Uyaly
4	Muinak
5	Tigrovy
6	Ostrov Lazareva
7	Aktumsuk
8	Barsakelmes

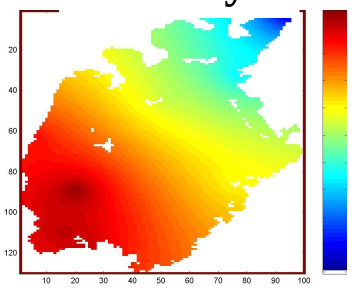
Automatised interpolation of the 72 fields (3*12*2) to the final grid by computing inverse distance numerical code with Matlab software (wp = 1; smoothing factor = 10)

Mean Air Temperature fields for the period 1951-1960:

Max & Min spatial ranges: 5 degree C in November; 1 degree C in July

Total annual ranges: -10 to 25.5 degree C

January



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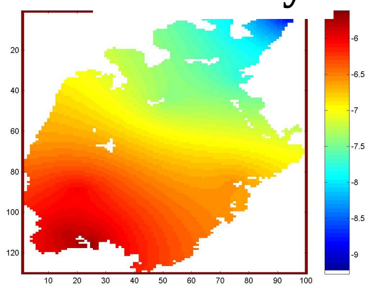

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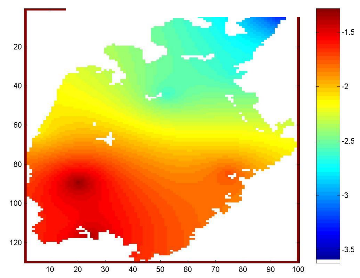

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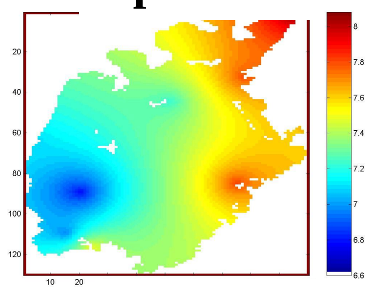

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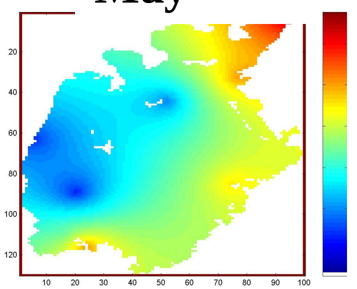

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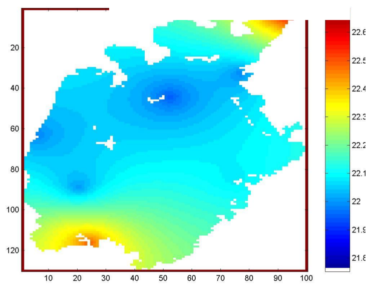
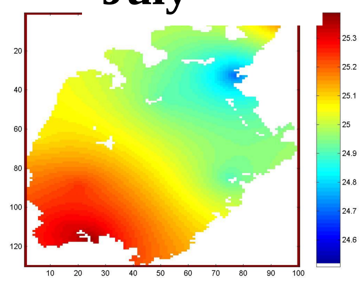


July



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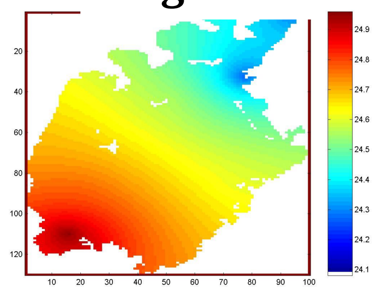

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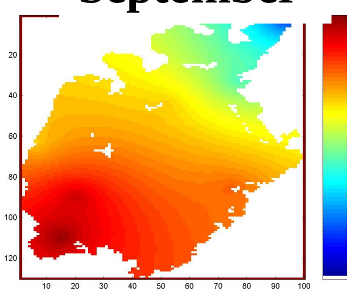

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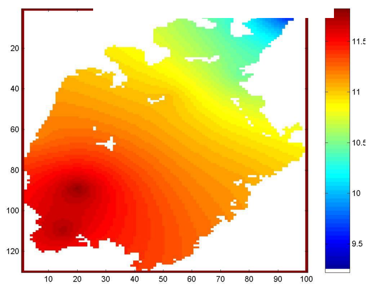
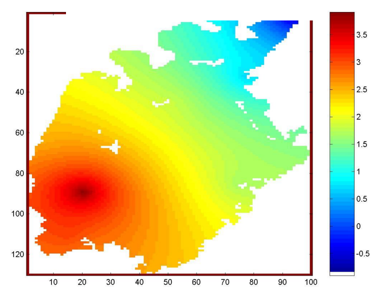


November



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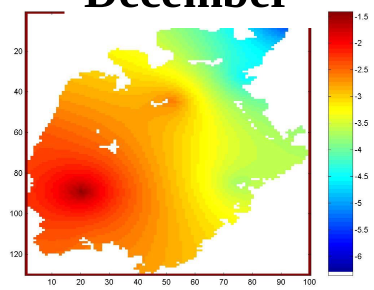
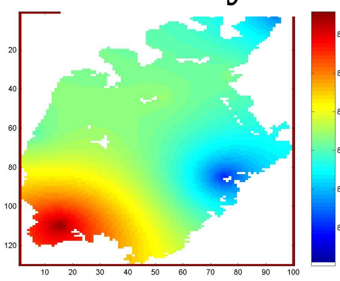


Mean Air Saturation fields for the period 1951-1960:

Max & Min spatial ranges: 2 % in February and November; 13 % in June
Total annual ranges: 50 to 85 %

January



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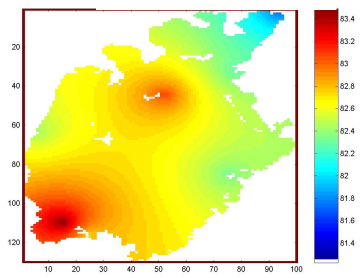

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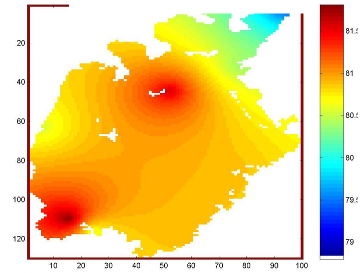

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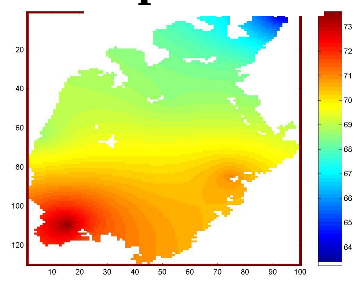
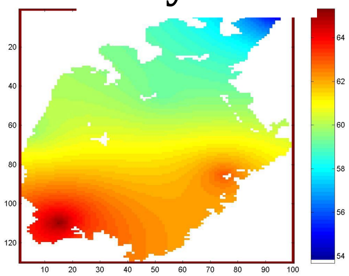
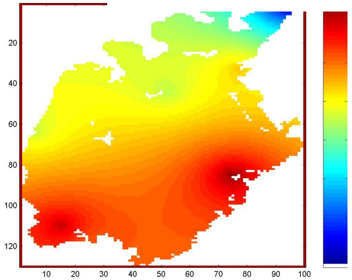


May



June



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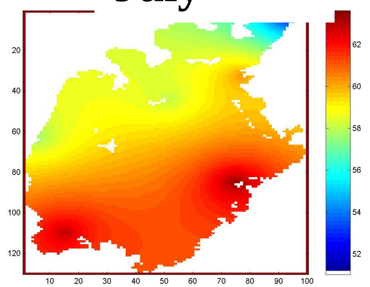

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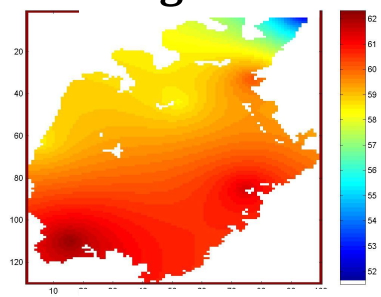

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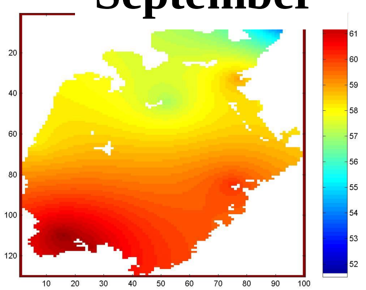

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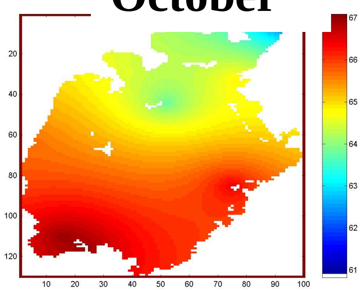

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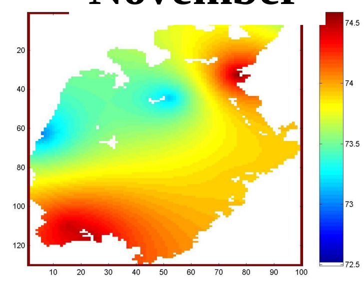

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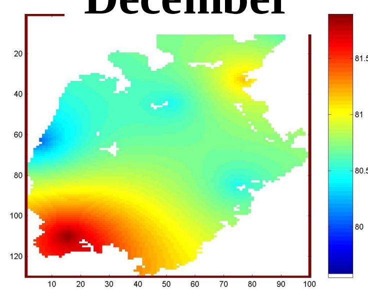
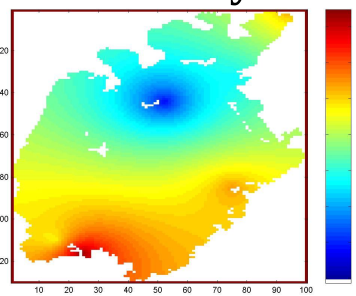


Mean Precipitation fields for the period 1951-1960:

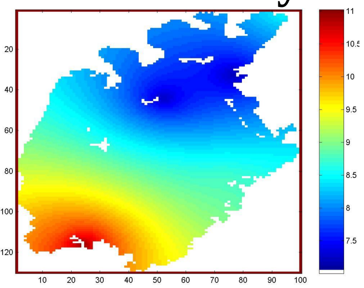
Max & Min spatial ranges: 1 mm/month in January; 6 mm/month in February, May and October

Total annual ranges: 3 to 17 mm/month

January



February



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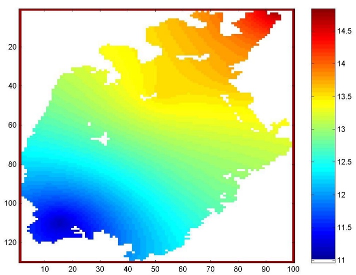

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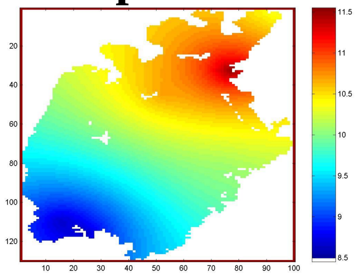
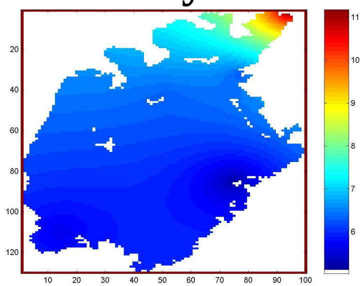


May



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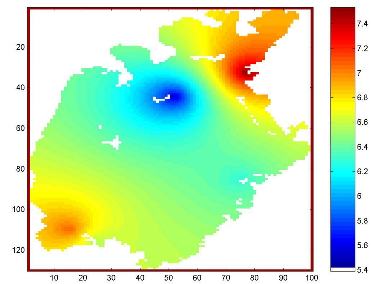

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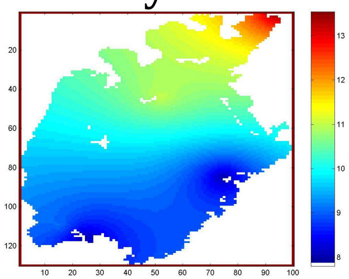
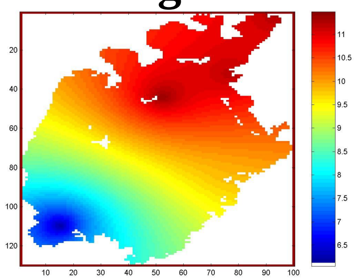


August



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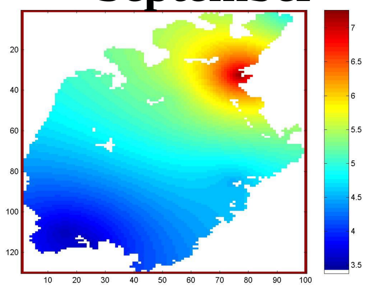

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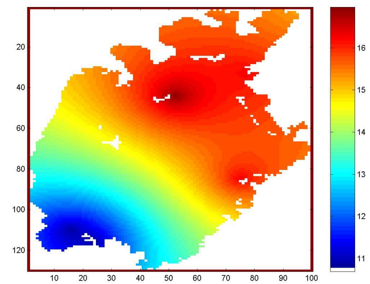

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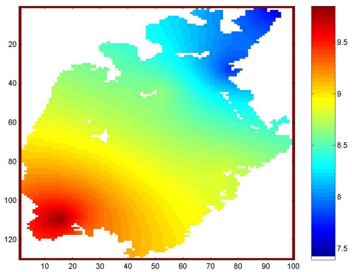

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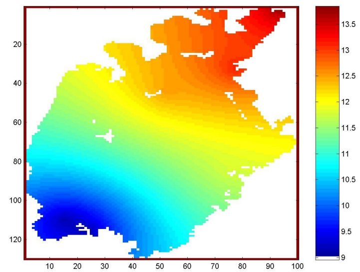


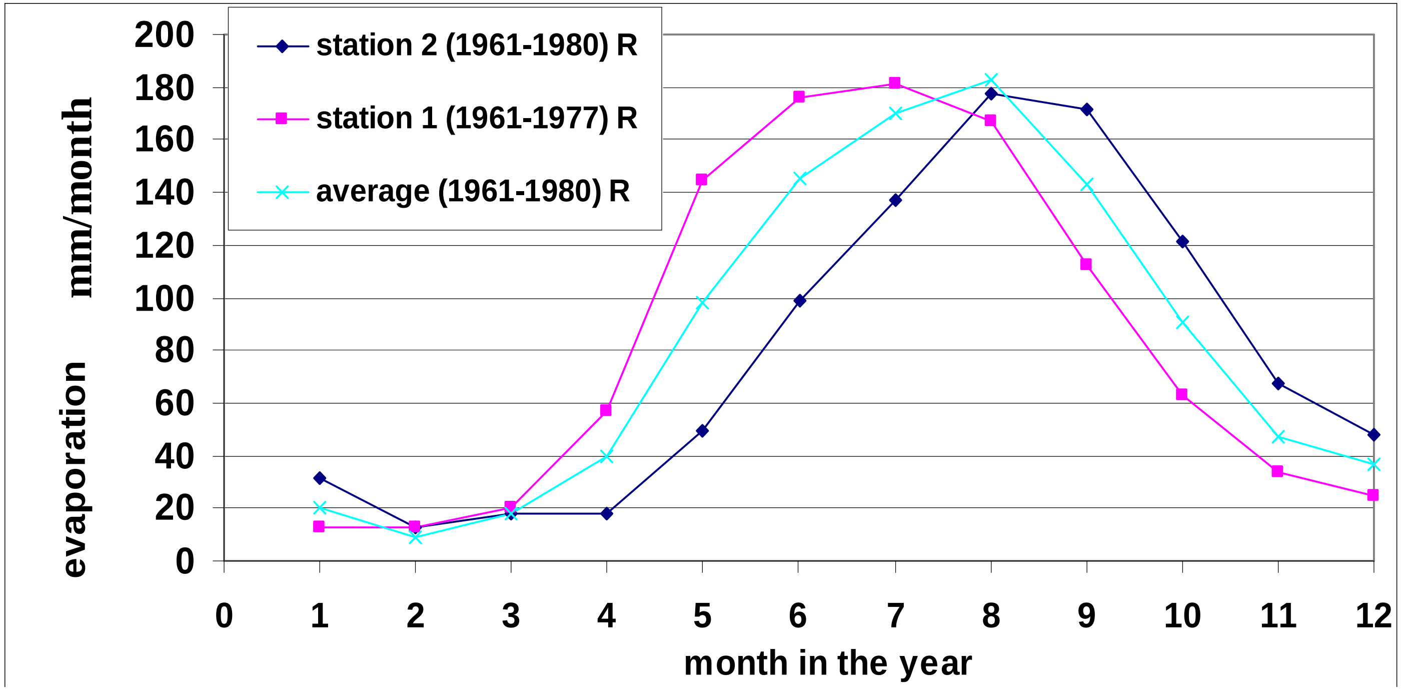
Evaporation

Temporal resolution: 1 month; mean seasonal cycle for the period 1960-1980.

Total annual evaporation:
- **1951-1960: set as respecting water mass conservation**
- **1981-1985: mean annual evaporation from RHMI**

Spatial resolution: homogeneous

? Improved with
- **simple north-south gradient**
- **atmospheric model results**
- **gradient computation from previous meteo fields (Wind, Air Temperature and Humidity fields)**



Station 1:

Uyaly

Station 2:

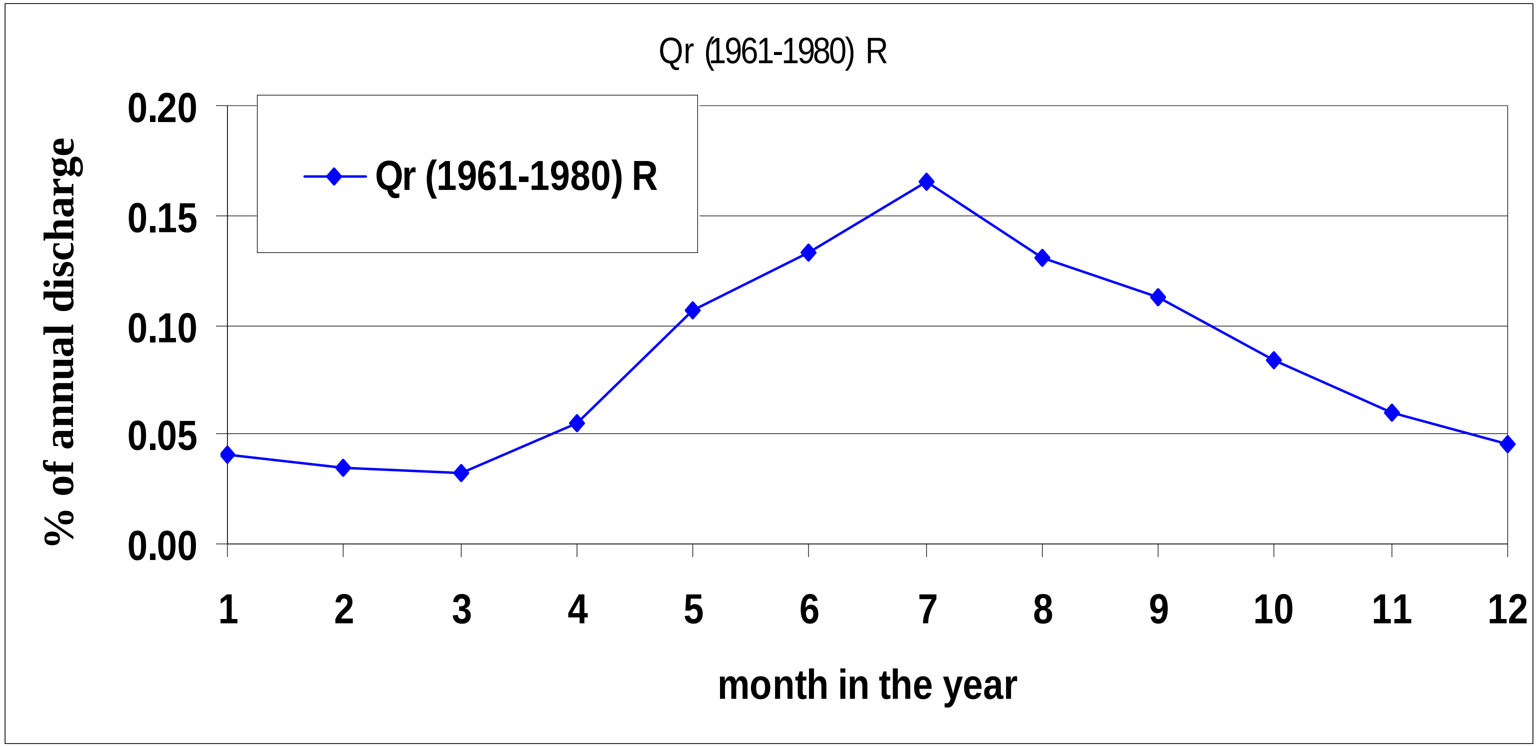
Ostrov Lazareva

River discharge (Amu Darya and Syr Darya)

Water flow

Temporal resolution: 1 month; mean seasonal cycle for the period 1960-1980.

Mean annual river discharge for the periods 1951-1960 and 1981-1985 (data source selected trough validation of water balance model)

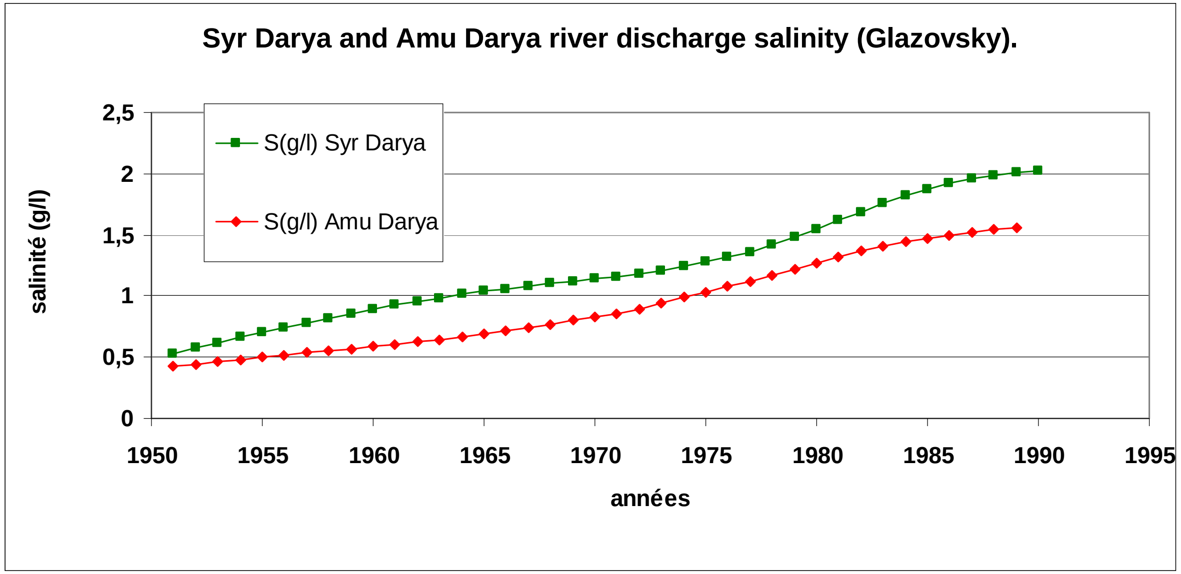


River discharge (Amu Darya and Syr Darya)

Water salinity of each river

Temporal resolution: one year; mean salinity for each simulated period.

no seasonal fluctuation considered



River water temperature

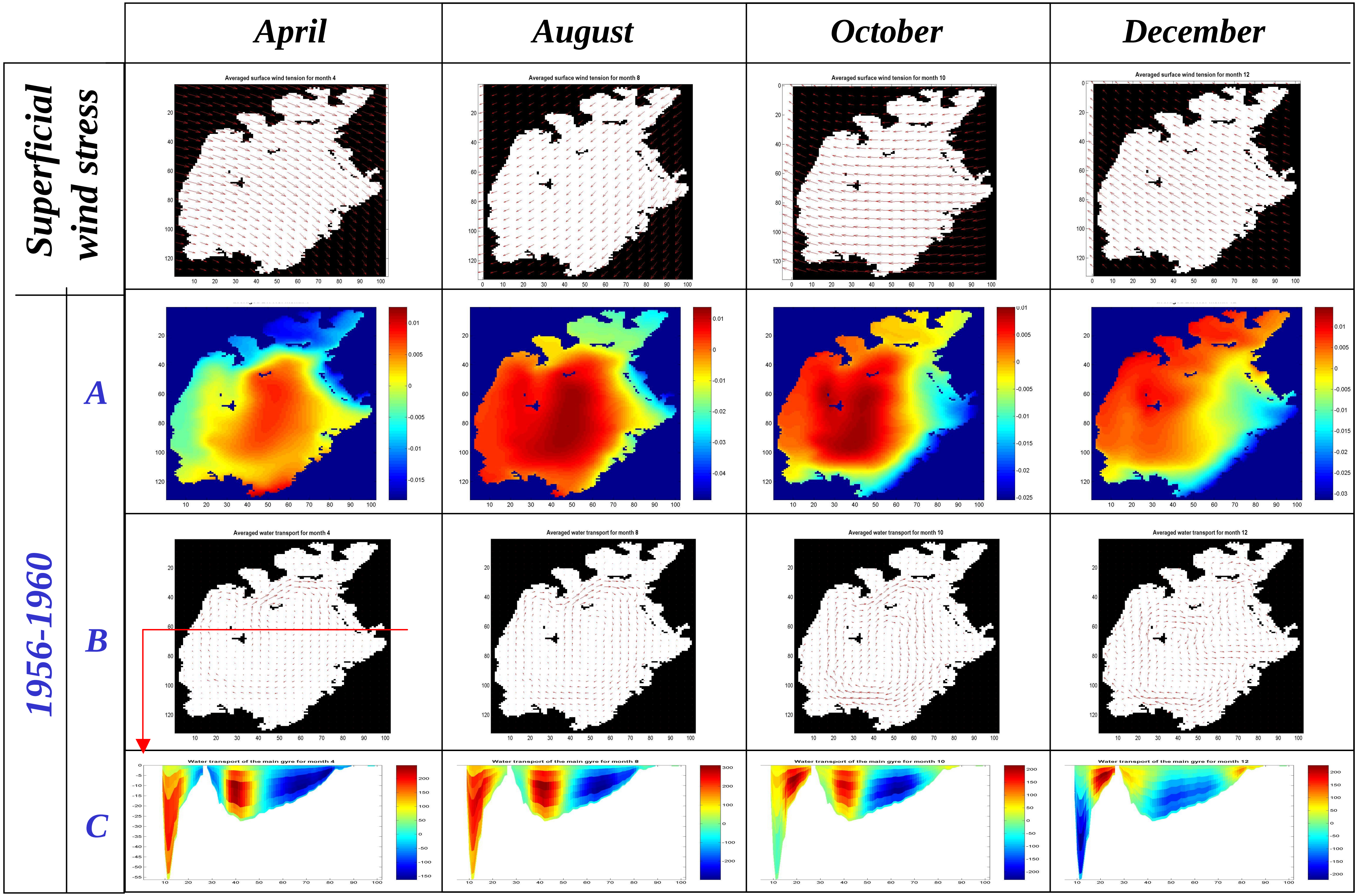
Temporal resolution: one month.

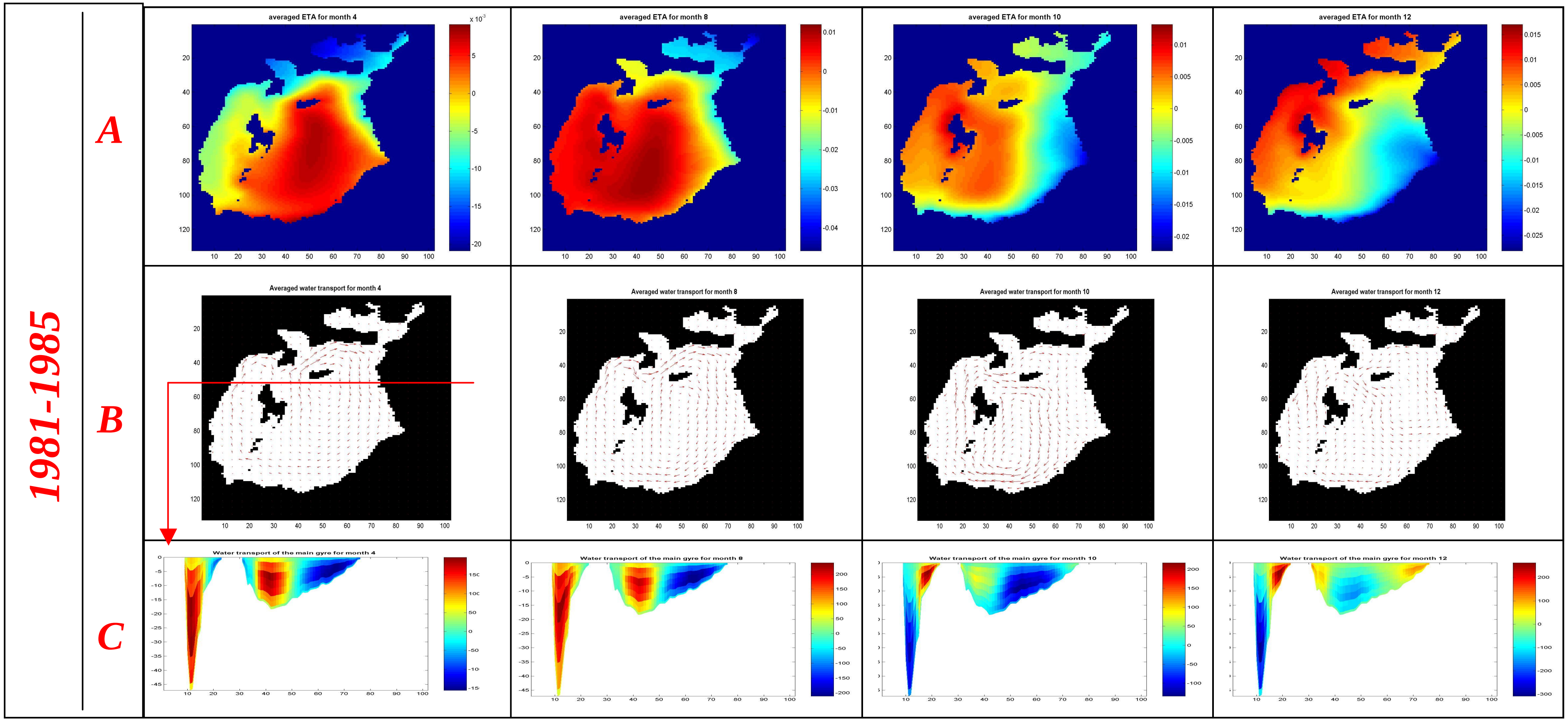
Sinusoidal cycle estimated by minimum of 0 degreC in end of January and maximum of 20 degree in end of July.

Identical for both rivers, and both periods

First Results

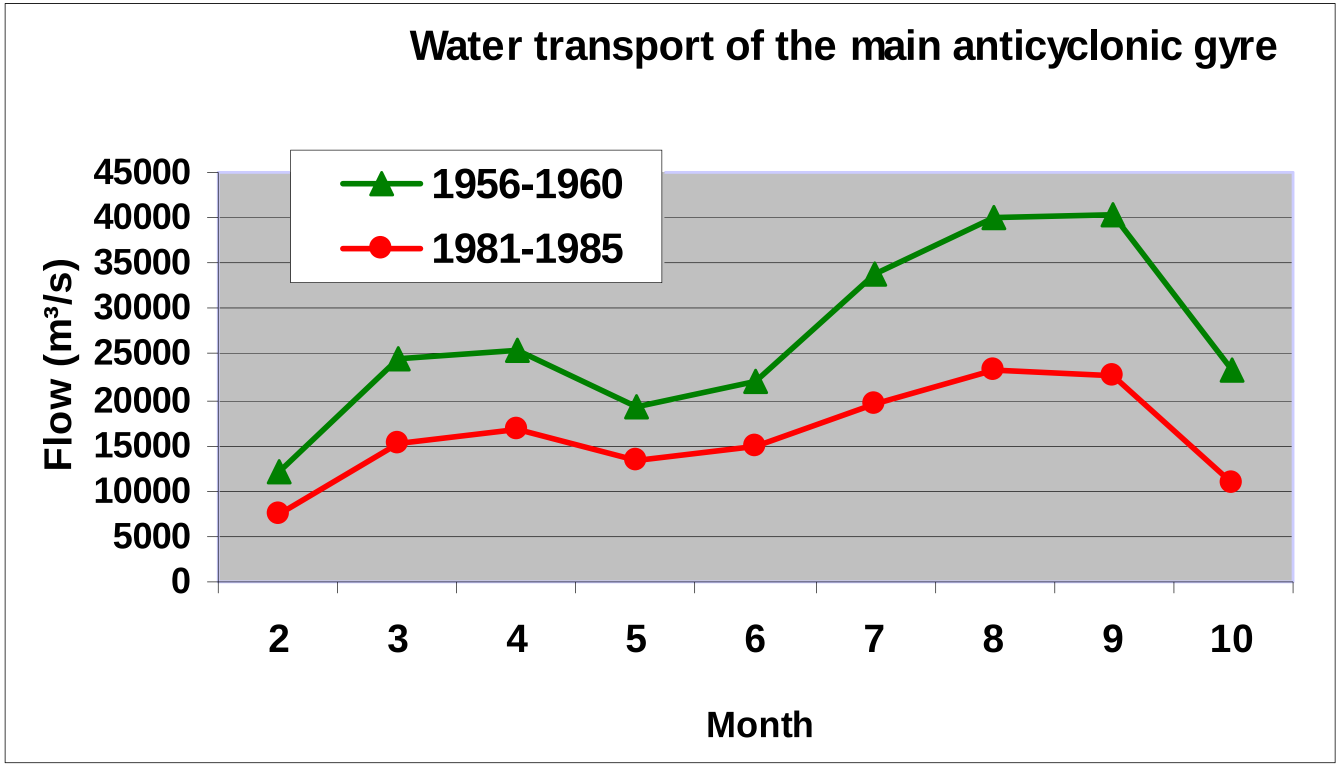
A: sea surface elevation (m), B: circulation (m²/s), and C: horizontal flow across a longitudinal section centred on the main gyre (m³/s).





Consequently to the 10 meter sea level drop **observed between the two periods considered:**

1) the 1981-1985 simulation suggests an *intensification of* described *seasonal changes*



Consequently to the 10 meter sea level drop **observed between the two periods considered:**

2) total water transport of the main gyre was lowered by a minimum of 30% in May, and up to 54% in September.

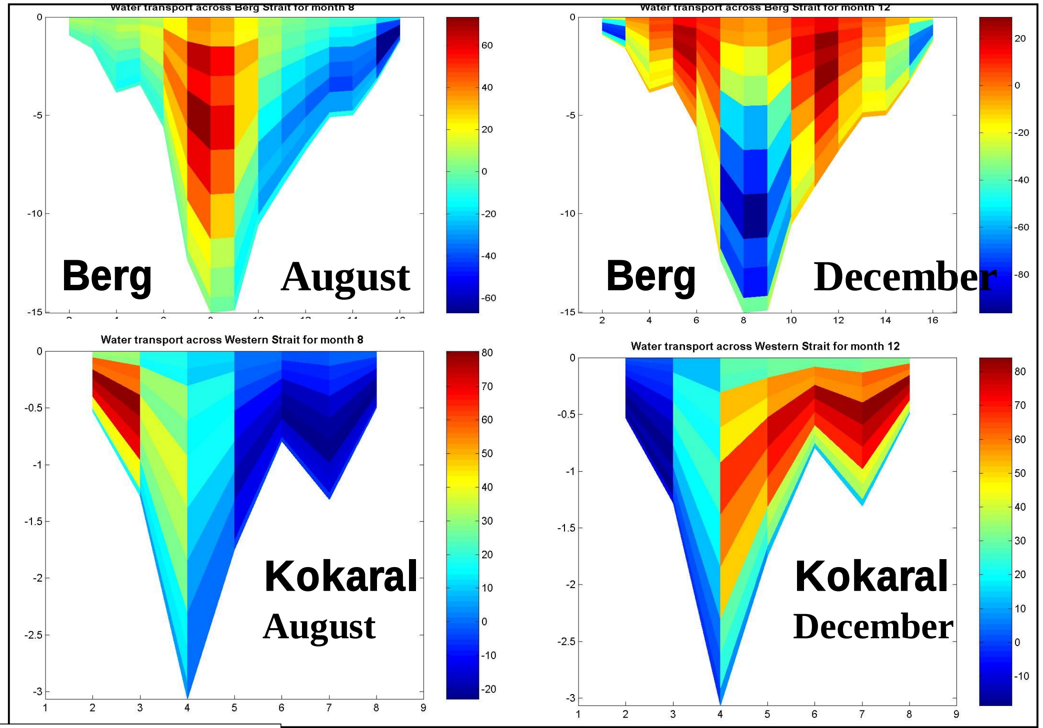
Flows between the Small and the Large Sea

1956-1960: flows through Berg and Kokaral straits

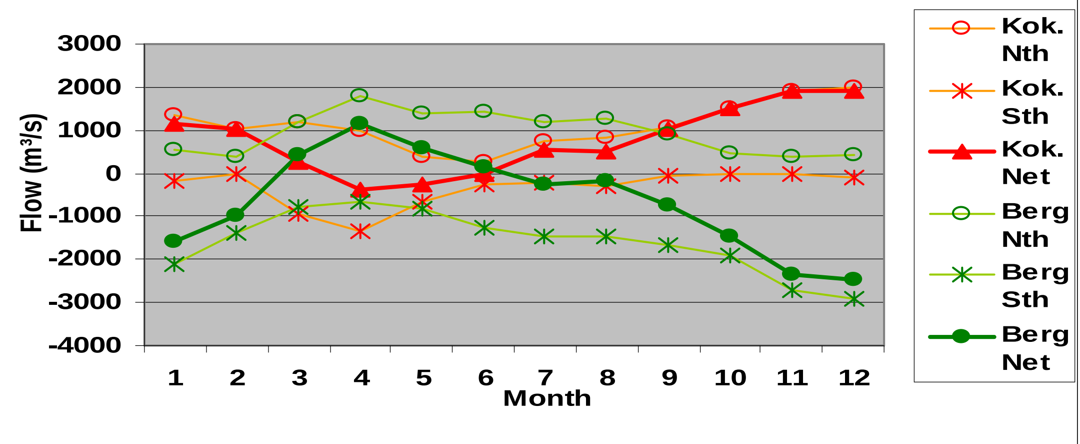
In fall and winter, important net transports leads to a mean exchange of about ***1200 m³/s***.

In summer, net flows through the straits are low and the water exchange occurs by local circulation at the scale of each strait.

Horizontal flow across Berg and Kokaral straits for the months of August and December 1956-1960 (m³/s).



Monthly net flows (and components) through Berg and Kokaral Straits.



This exchange flow contribute to force an anti-cyclonic circulation in the Small Sea, resulting even in a larger gyre around Kokaral Island in December.

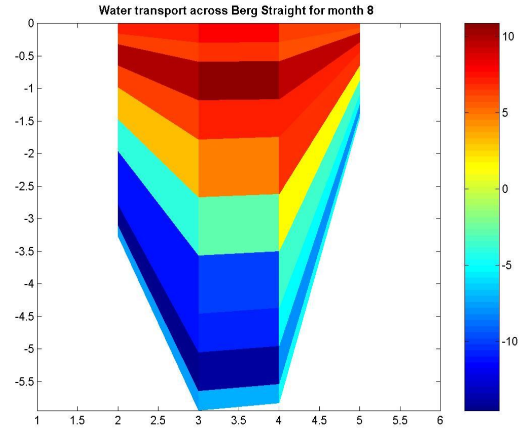
Net flows are only shortly reversed in spring.

1981-1985: flows through Berg straits

After about 20 years of negative water balance, the western Kokaral strait was dryed up and depth of Berg strait was reduced from 15 to 5 m.

Simulation indicated a quasi nul net transport, except at the occasion of the seasonal modification of circulation pattern, in February and October.

A limited but stable water exchange of about *100 m³/s* remains throughout the year, as a result of permanent superposition of opposite currents.



Typical horizontal flow across Berg strait for August 1981-1985 (m³/s).

Foreseen realisations and applications :

Validation of the 3D hydrodynamic model **with in-situ data (mean seasonal salinity and temperature fields are available for the 2 simulated periods) and satellite data (seasonal level and coastline changes, sea surface temperature).**

Realisation of sensitivity analysis **to all forcings used in order to evaluate the** ***distinct impacts of climate and hydrological changes*** **of the region on the Aral Sea water body.**

Design and coupling of a synthetic ecosystem model **in order to study the impact of drying process and consequent hydrodynamic changes on the Aral Sea biogeochemistry and on the relative importance of pelagic to benthic primary production. As first step, vertical profiles of turbulent kinetic energy will be derived to force a 1D biogeochemical model designed for the Aral Sea.**

Consideration of ground fluxes **for simulations of the recent, present or future and hydrodynamics situations, as their relative contribution to the water balance probably grew as sea level dropped and as river discharge vanished.**