Ocean model, Interconnections within the climate model

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Interaction between atmosphere and ocean plays important role for many processes in both medium.

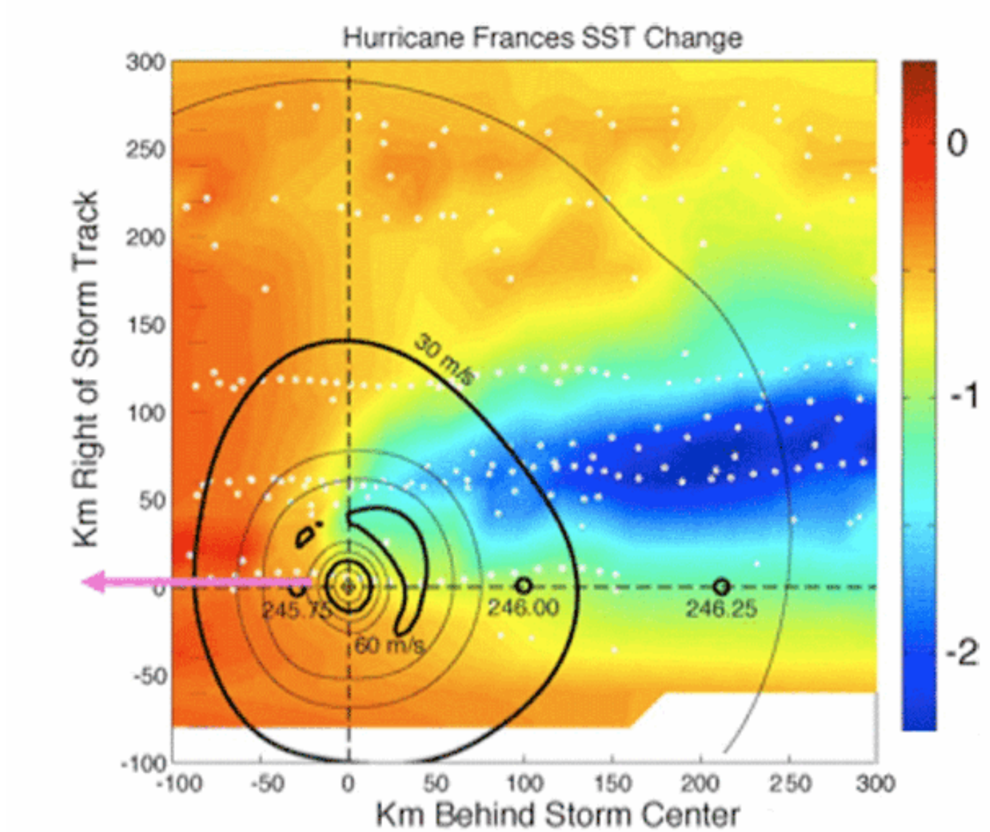
Interaction happens on all possible spatial and time scales.

spatial scales:

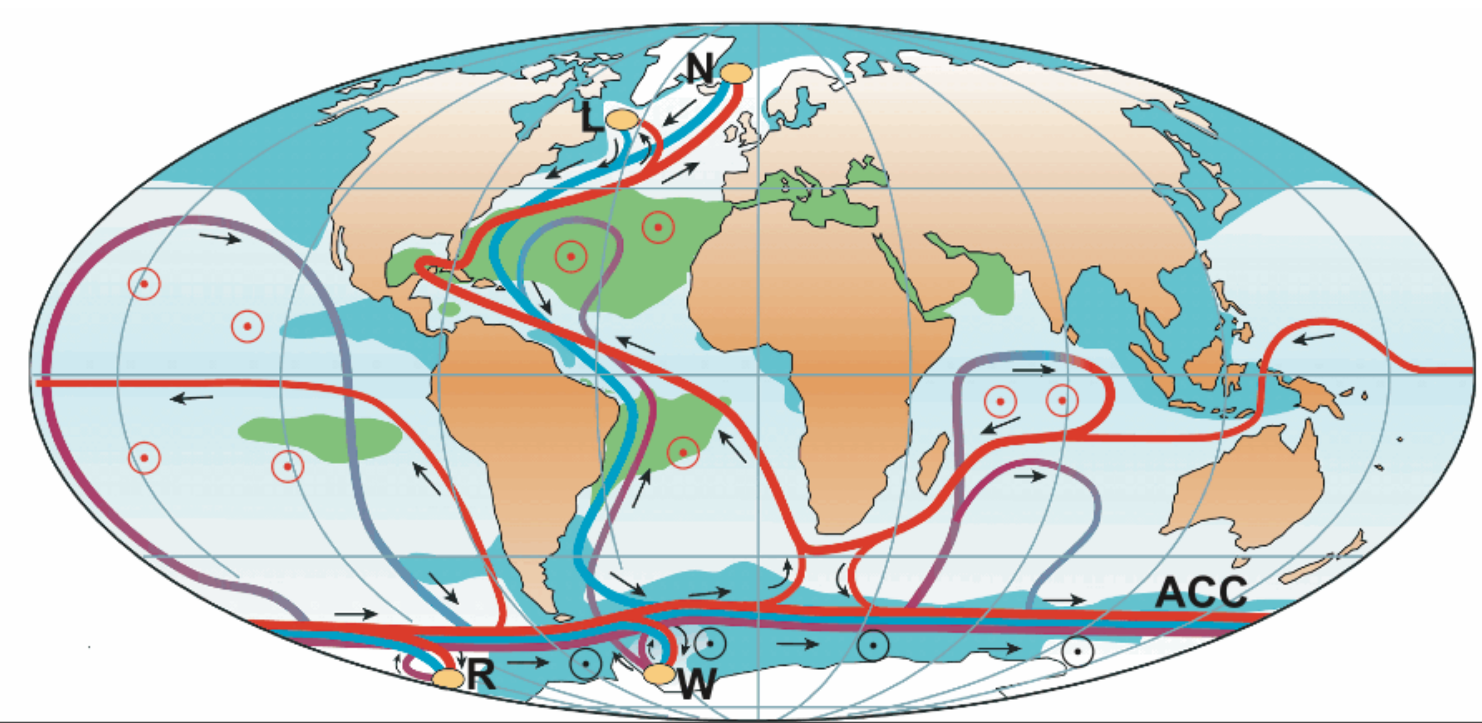
- meters - ocean surface ocean waves
- planetary - ENSO, thermohaline circulation

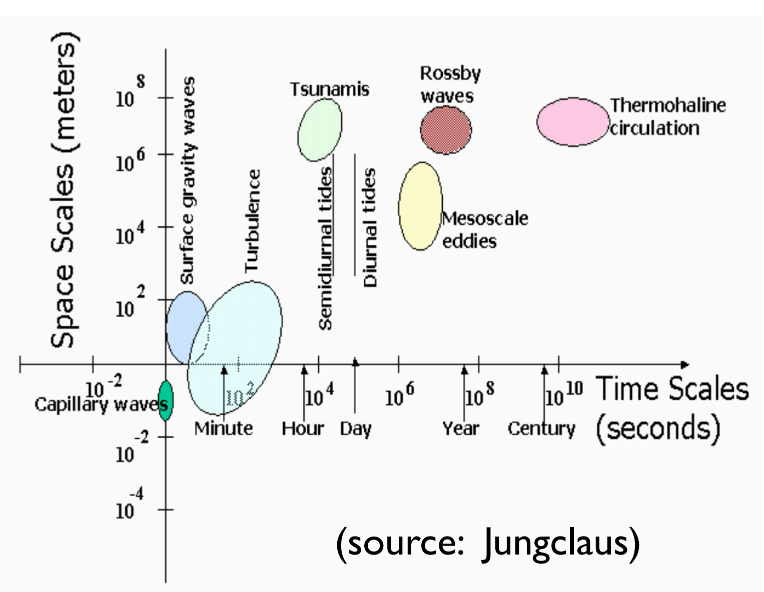
time scales:

- daily - hurricanes, sea-land breeze
- decade to century - global ocean circulation,
- The Atlantic Meridional Overturning Circulation



(source: Large 2008)





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(source: Jungclaus)

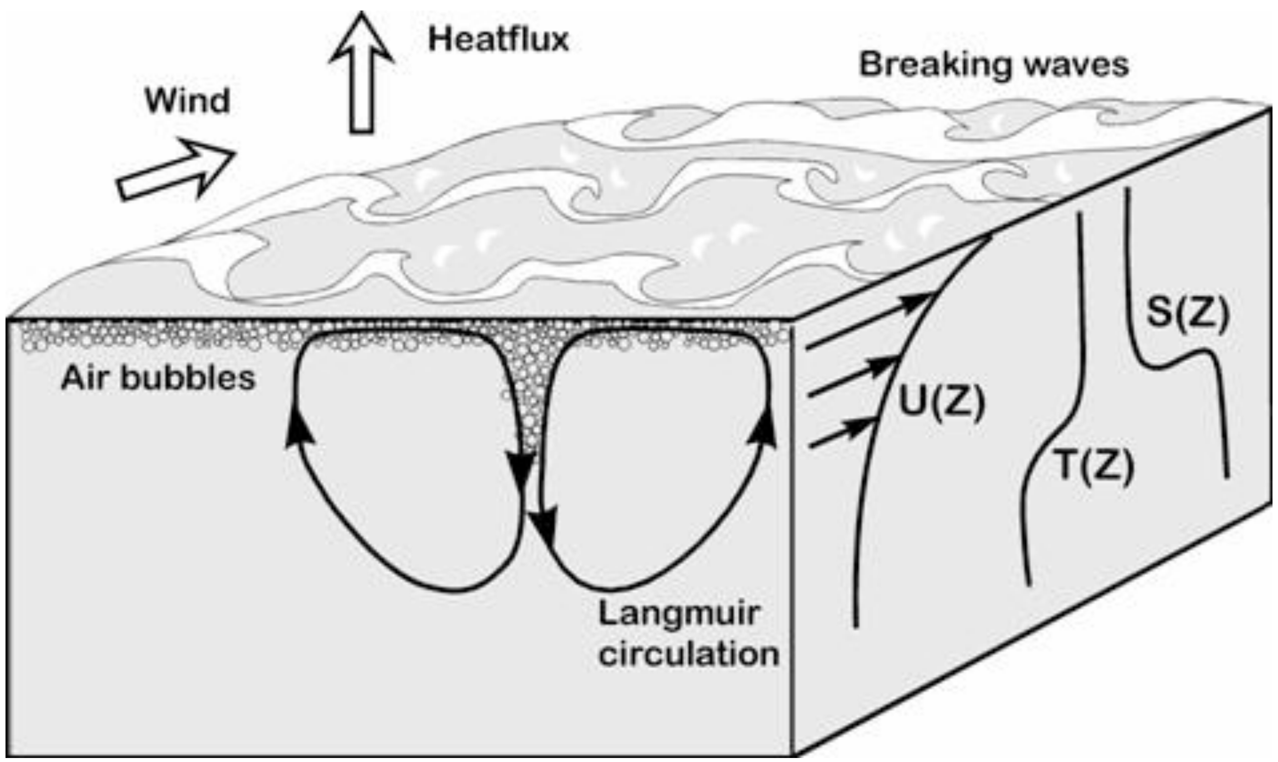
Exchanges between atmosphere and ocean:

momentum exchange
  formation of ocean currents

heat exchange, turbulent and radiation fluxes
  mixed layer

mass exchange
  fresh water flux

gases and chemical exchange
  CO_2 uptake, deposition of minerals in atmospheric aerosols



(source: http://www.oceanclimate.se/research_atmosphere_ocean_interaction.htm)

Approaches for ocean modeling and coupling

Q-flux, mixed layer model or slab ocean models

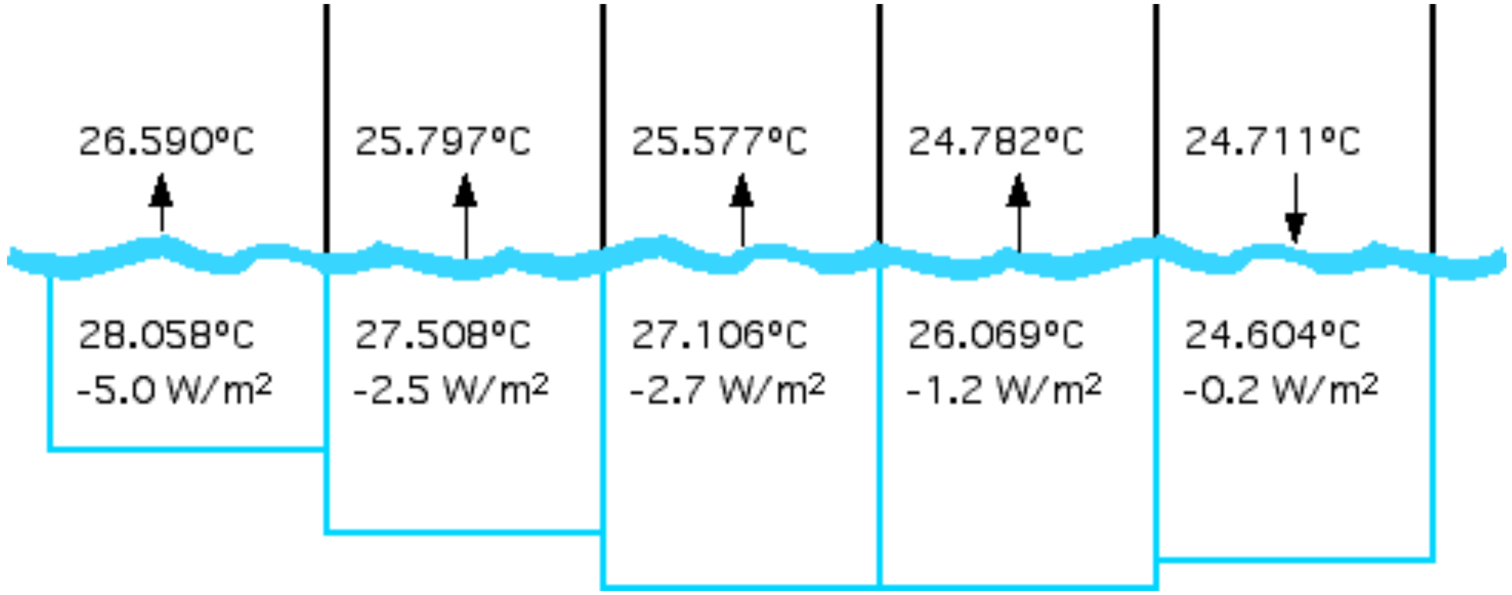
•model without ocean dynamics
•each grid cell in the ocean is given a temperature and a depth for the mixed layer
•energy convergence (divergence) at each grid cell is calculated based on the heat storage capacity of the surface ocean and the vertical energy fluxes at the air/sea interface
•allows the ocean to adjust to the surface air temperature

advantages:

simple for implementation
suitable for different climate experiments
CPU efficient

disadvantages:

no ocean dynamics
training run - fluxes are derived from specified SST control runs where the specified SSTs are from climatology



(source: http://forums.edgcm.columbia.edu/showthread.php?p=315)

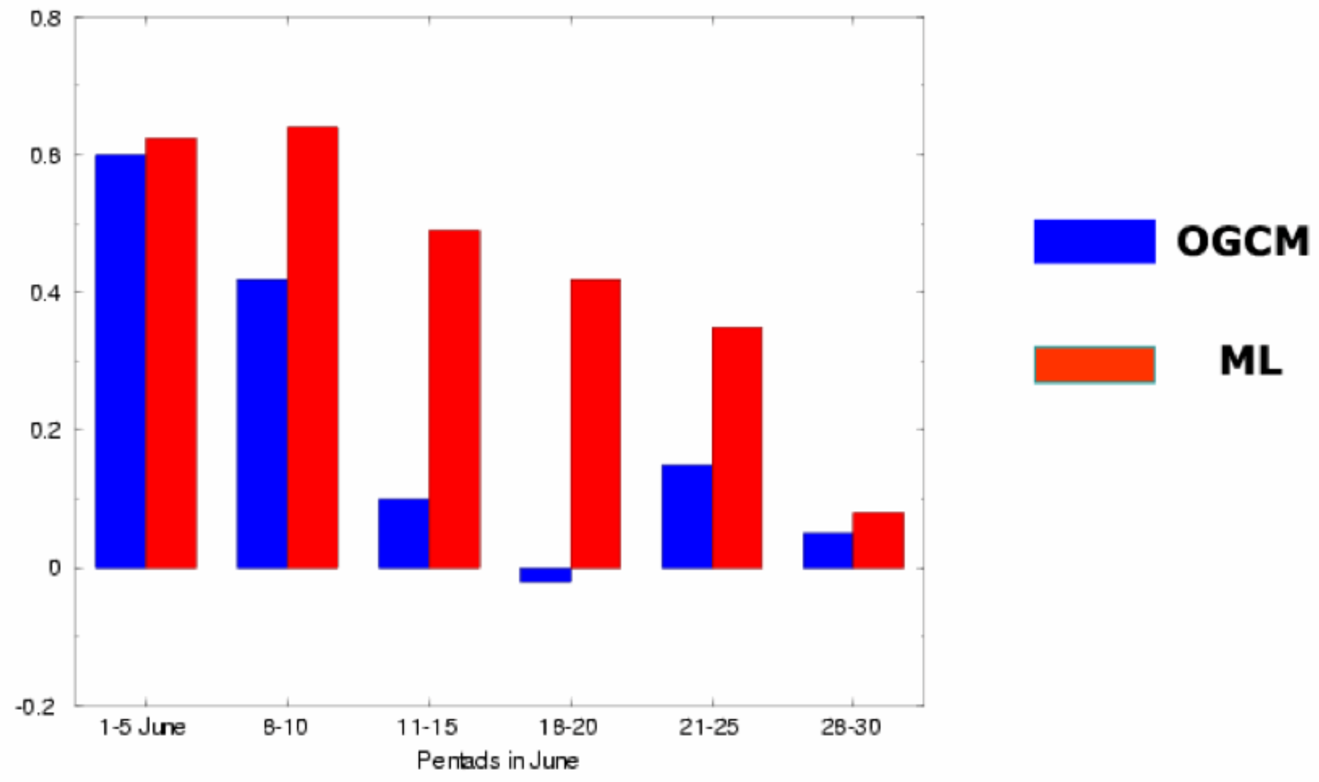
Approaches for ocean modeling and coupling

K Profile Parameterization (KPP) mixed-layer ocean model

Example from seasonal forecast in ECMWF (Vitart, 2008):

•mixed layer model is based on the KPP scheme (Large et al., 1994).
•vertical domain of 200 m with 29 vertical levels
•vertical grid is stretched so that the top model level is 1.4 meter thick with 16 levels in the top 20 meters.
•model includes penetrative short wave radiation using the double exponential of (Paulson and Simpson 1977) for Jerlov water type IB (Jerlov, 1976)
•the mixed layer domain extends to +/- 44o of latitude

(source: Vitart, 2008)



Linear correlation between the inter annual variability of precipitation from Indian station data averaged over pentads in June from 1991 to 2007 and the ensemble mean precipitation predicted by OGCM (blue) and ML (red)

Approaches for ocean modeling and coupling

OGCMs - Ocean General Circulation Model

solve the primitive equations for global incompressible fluid flow analogous to the ideal-gas primitive equations solved by atmospheric GCMs

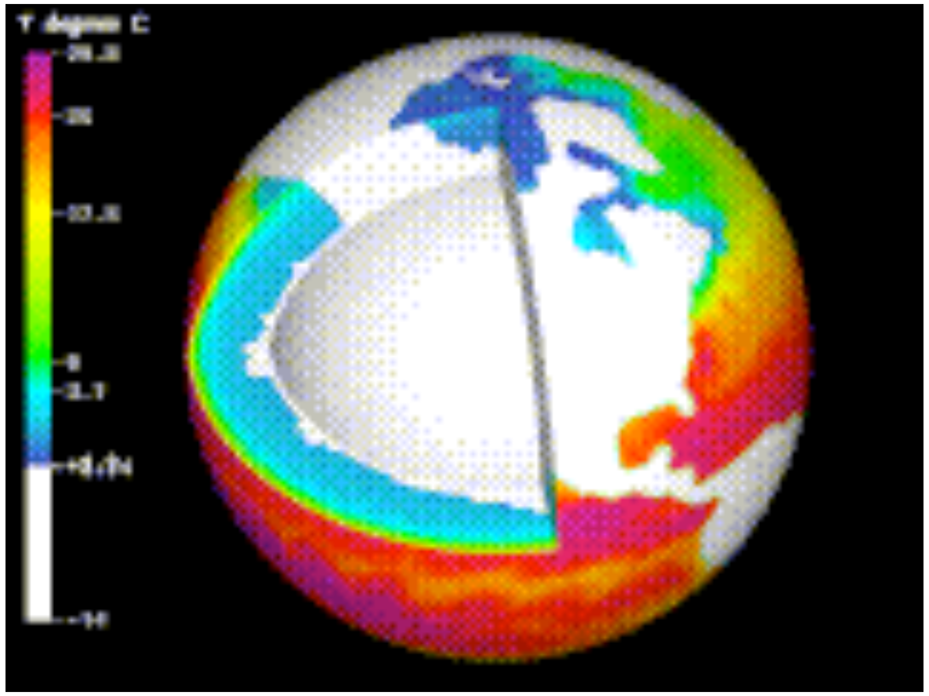
ocean dynamics is important on centuries scales, and all ‘modern’ AOGCM have OGCM

an explicit representation of the sea surface height is being used in many models, and real freshwater flux is used to force those models instead of a ‘virtual’ salt flux

between IPCC TAR and AR4:
most AOGCMs no longer use **flux adjustments**, which were previously required to maintain a stable climate

rotated and three pole horizontal grids are adopted to avoid problem North Pole coordinate singularity

increased horizontal resolution in tropics



Approaches for ocean modeling and coupling

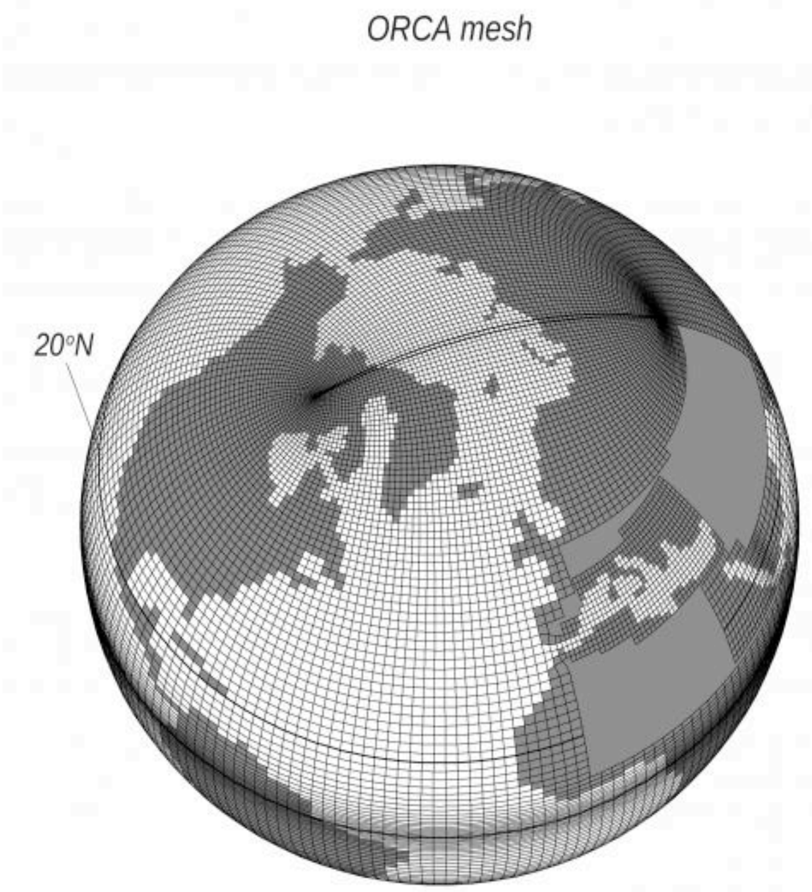
Examples of OGCM:

NEMO:

4 major components

- the blue ocean (ocean dynamics, NEMO-OPA)
- the white ocean (sea-ice, NEMO-LIM)
- the green ocean (biogeochemistry, NEMO-TOP)
- the adaptive mesh refinement software (AGRIF)

incorporated in Met-Office models HadGEM3 family (climate research) and GloSea4 (seasonal forecast)



Approaches for ocean modeling and coupling

Examples of OGCM:

HOPE (Hamburg Ocean Primitive Equation model):

full primitive equation, free surface model, E-grid formulation, sea ice model

The ocean model has a variable resolution going from about 0.3 degrees of latitude at the equator to about 1.4 degrees in the extratropics by about 1.4 degrees in longitude everywhere

incorporated in System 3 (ECMWF seasonal forecast)

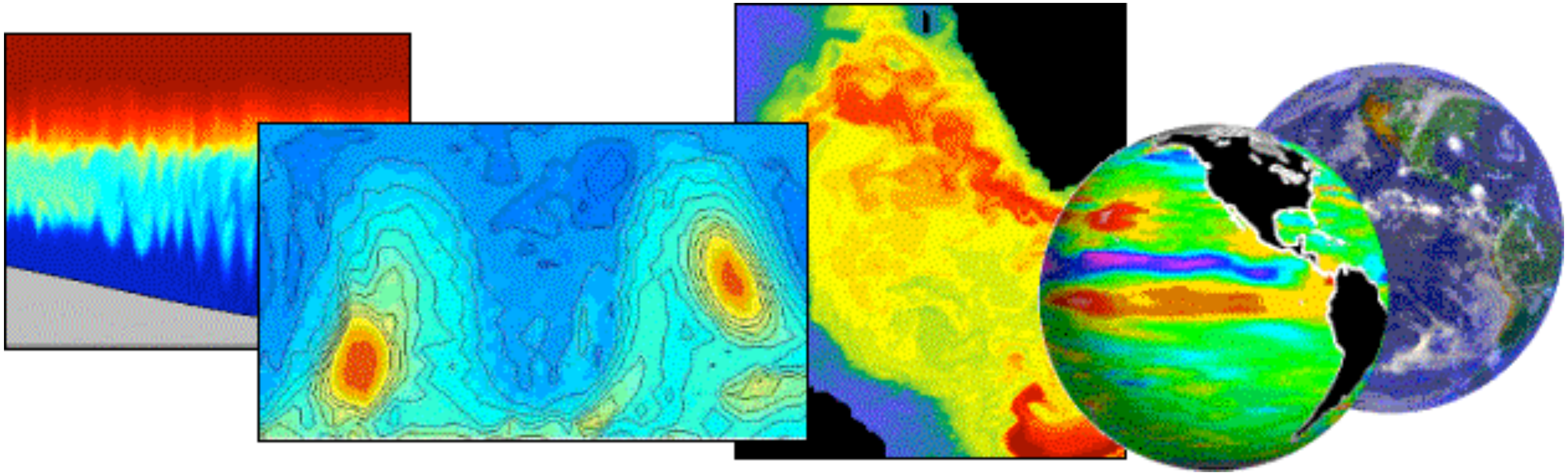
Approaches for ocean modeling and coupling

Examples of OGCM:

MITgcm (MIT General Circulation Model):

•has a non-hydrostatic capability
•supports horizontal orthogonal curvilinear coordinates

incorporated in PROTHEUS (ENEA), for regional climate studies in Euro-Mediterranean region.



Approaches for ocean modeling and coupling

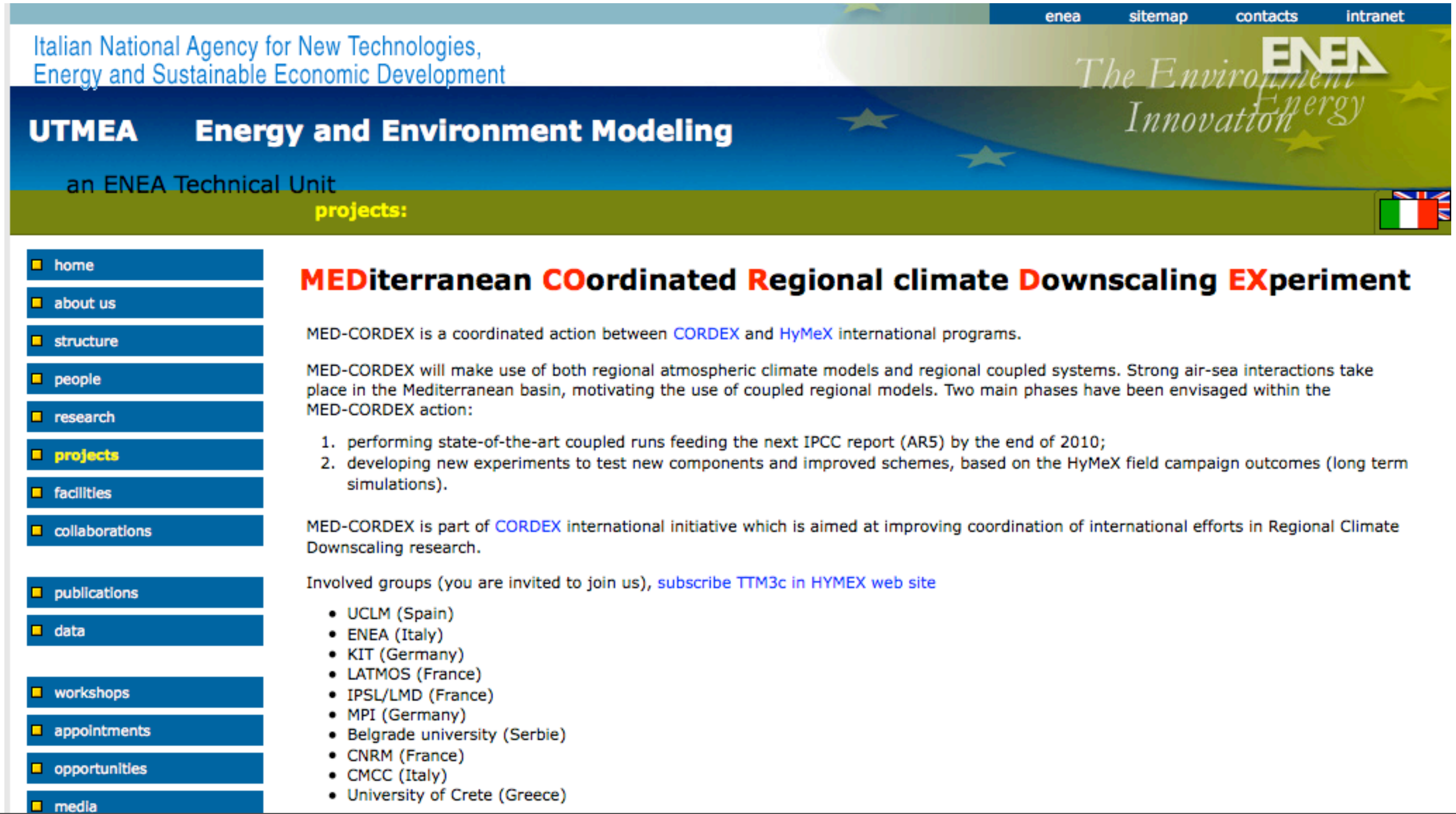
Examples of coupled regional climate model

stretched ARPEGE-Climate or the LAM ALADIN-Climate with OPAMED8 and now NEMOMED8

PROTHEUS system, RegCM3 with MITgcm

EBU-POM, Eta/NCEP with POM (Princeton ocean model)

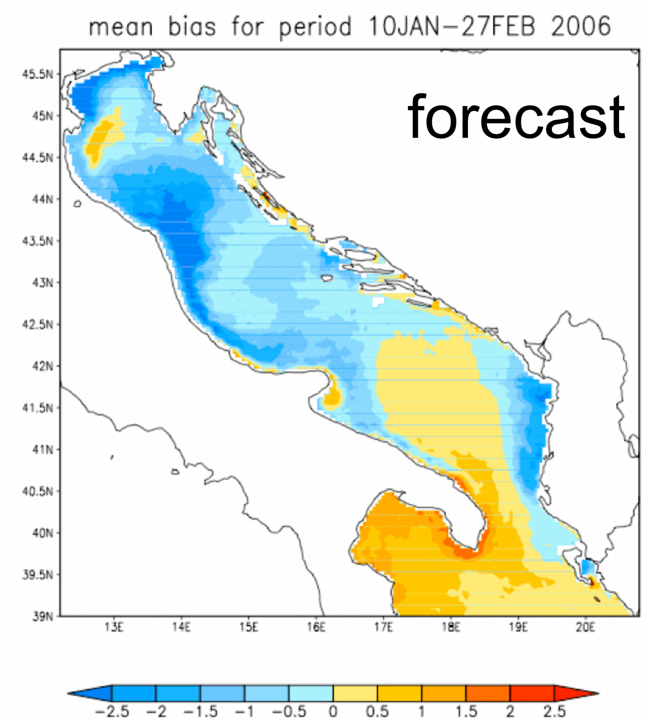
MED-CORDEX

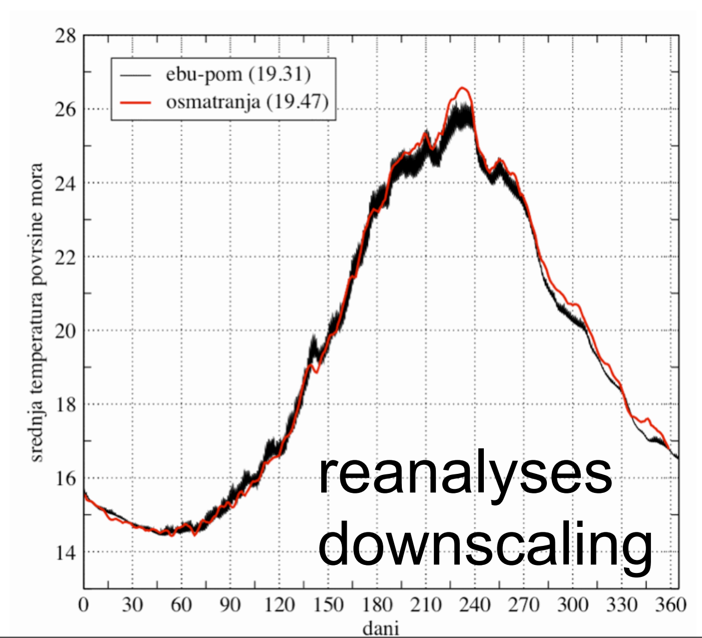


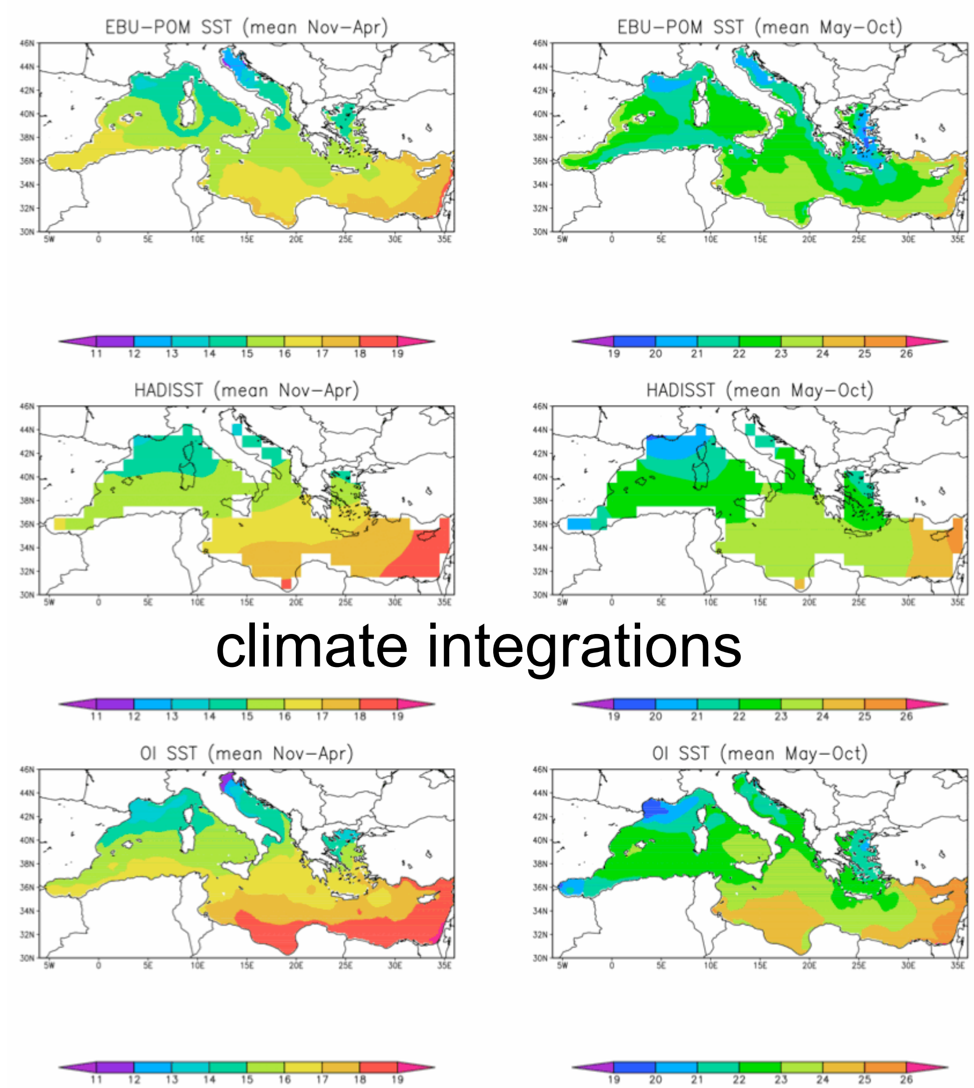
Approaches for ocean modeling and coupling

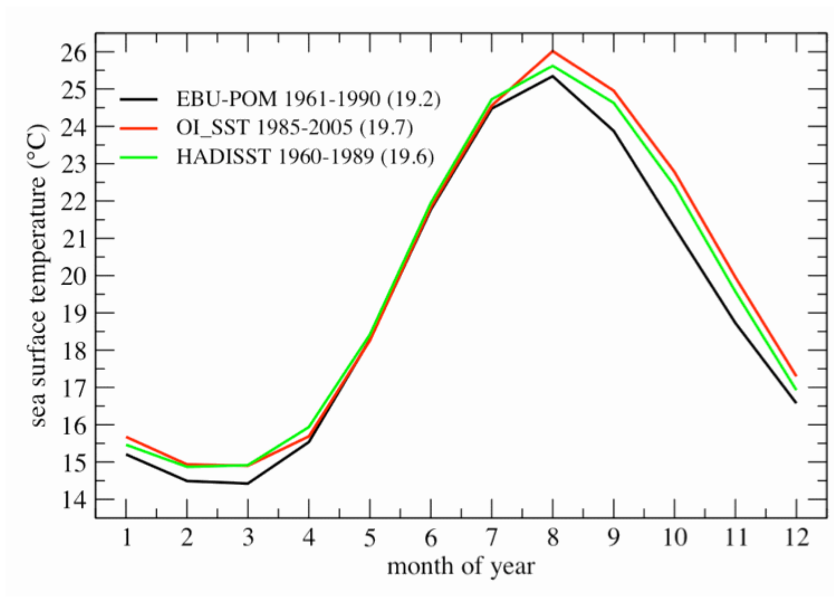
Belgrade experience: EBU-POM/CRM-SEEVCCC

Different aplications:
-medium range forecast
-climate change experiments
-seasonal forecast

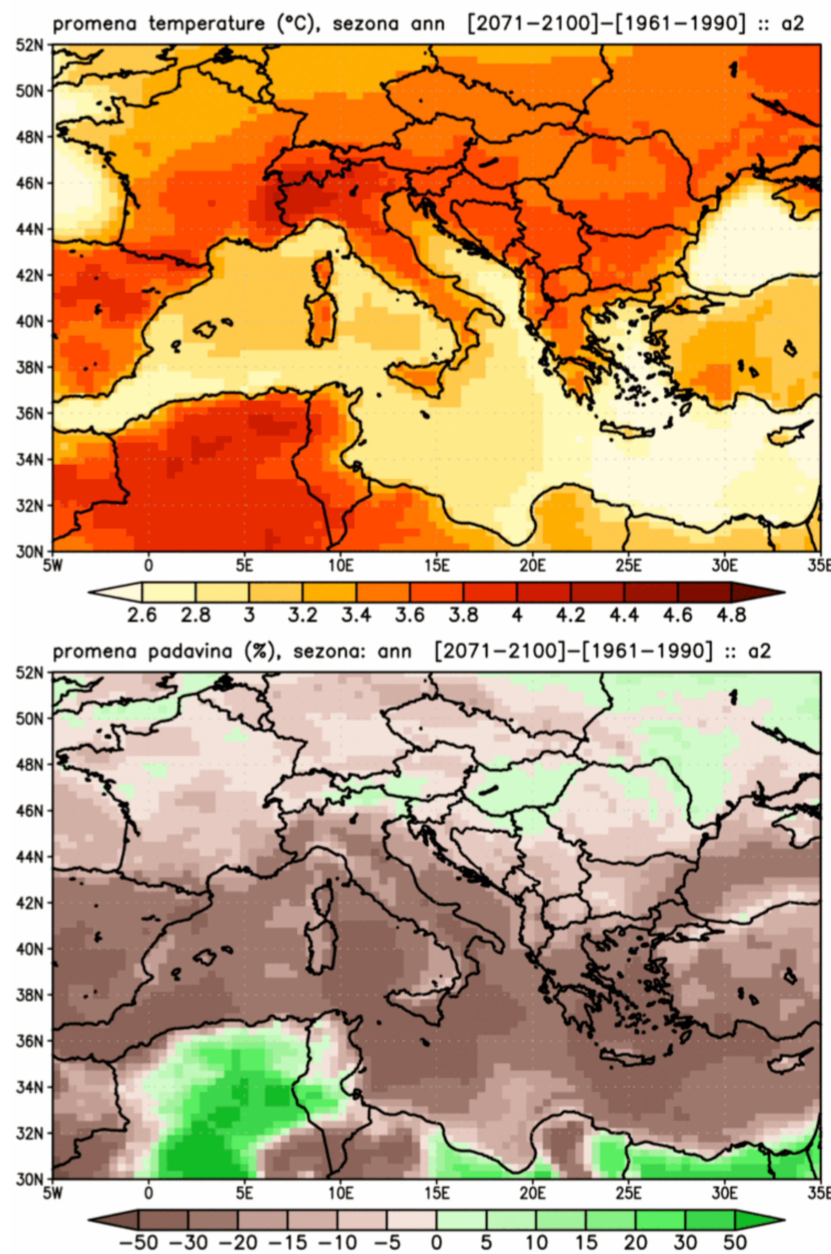






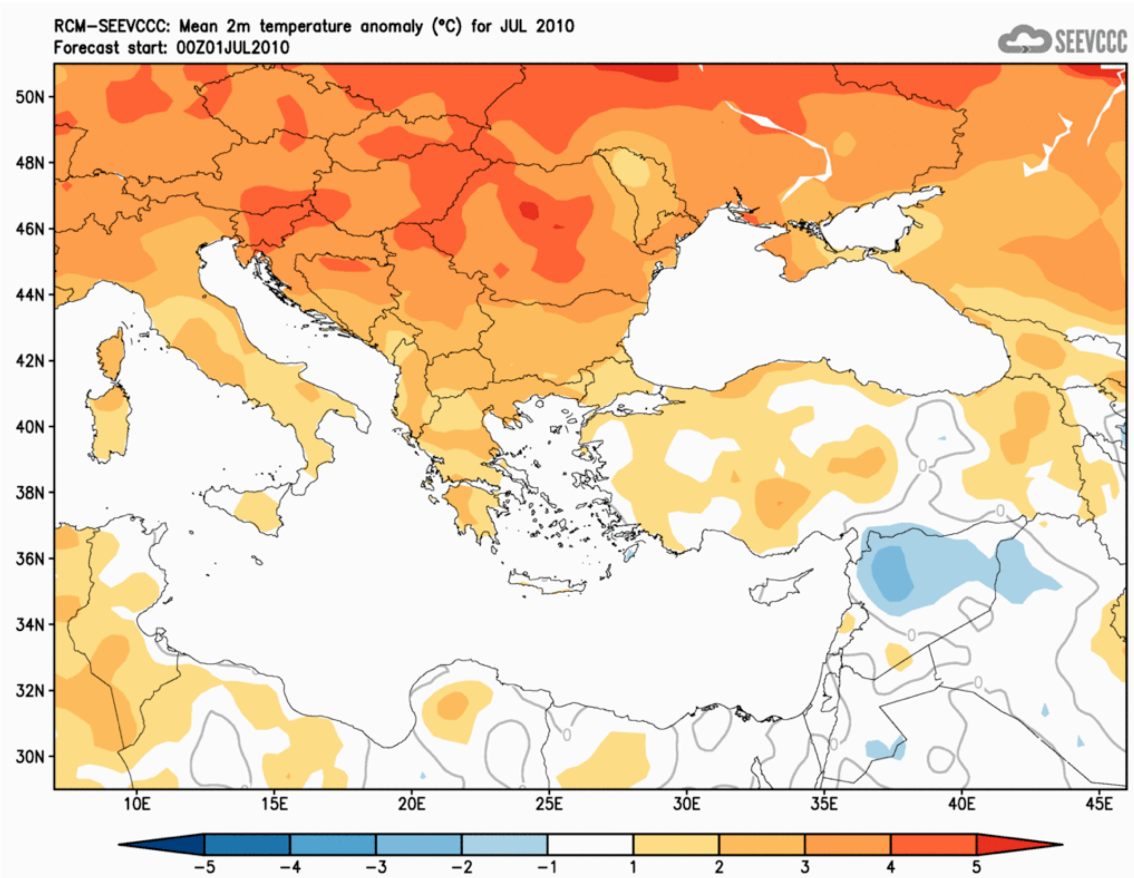


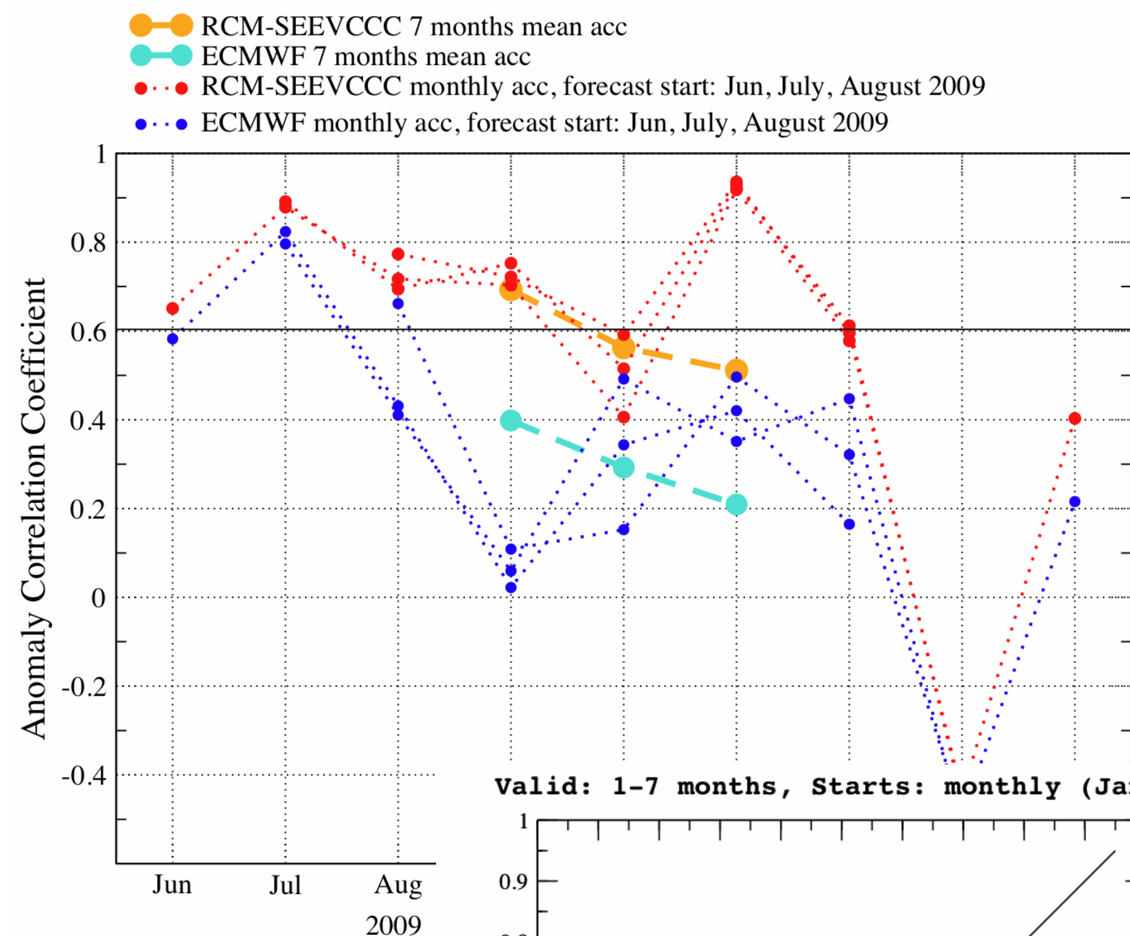
climate change
scenarios

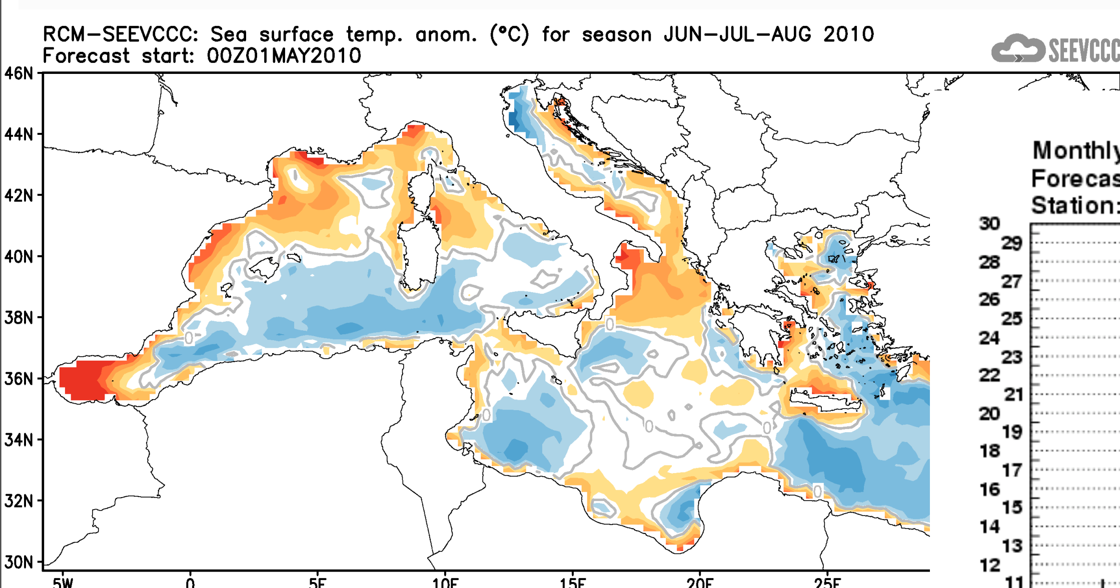


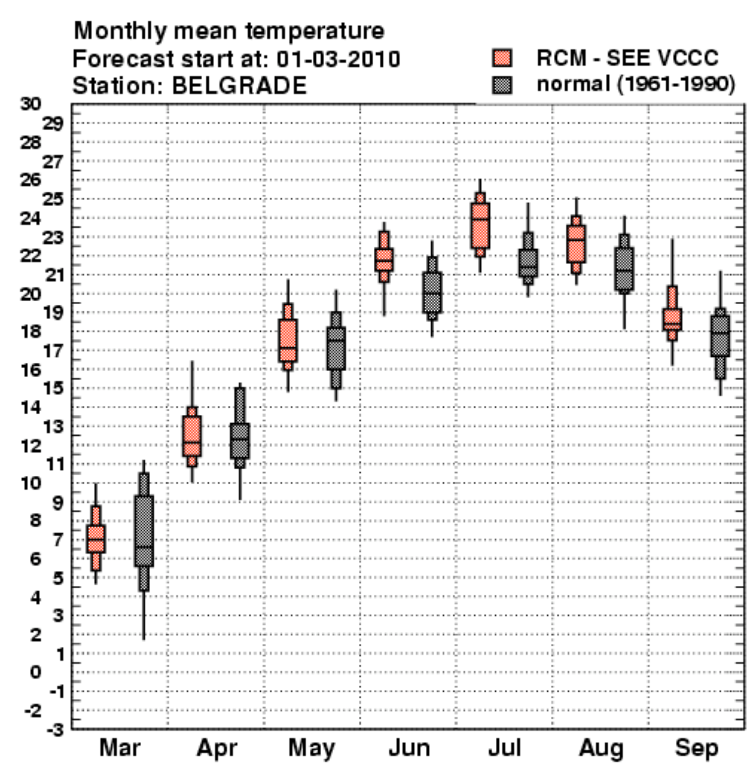
Approaches for ocean modeling and coupling

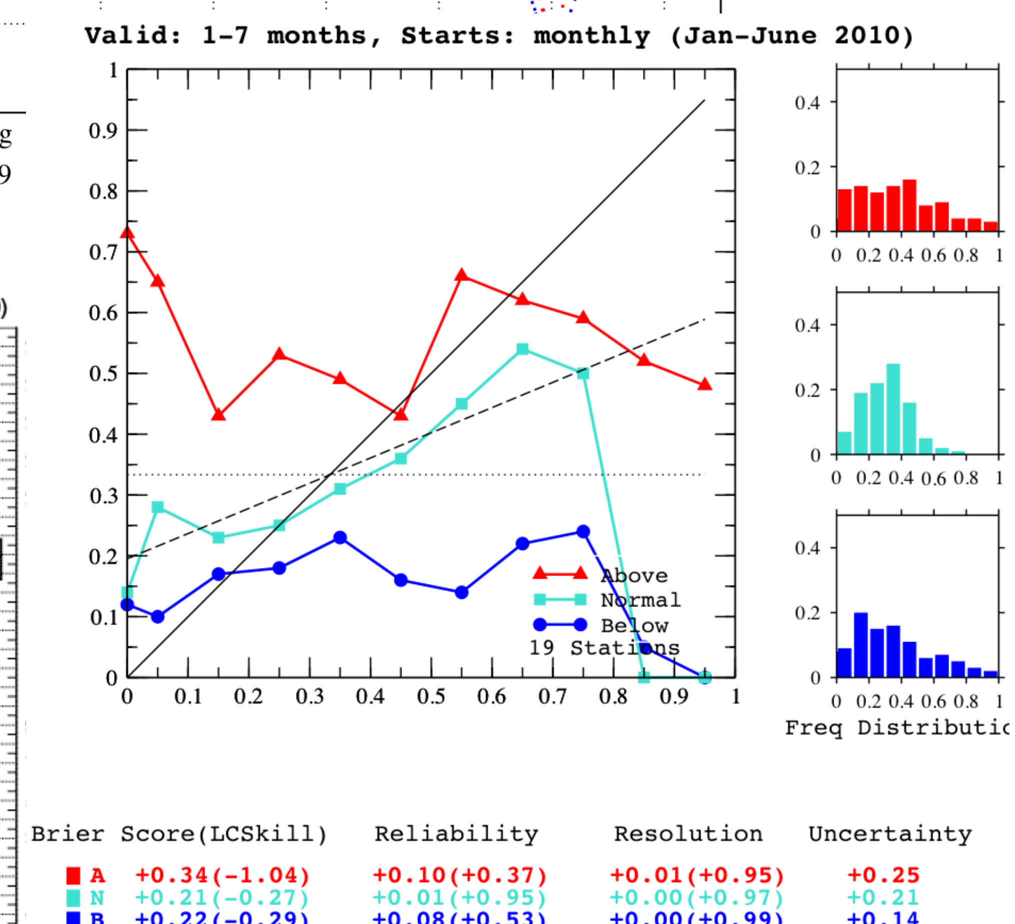
Belgrade experience: Seasonal forecast with regional coupled model











Approaches for ocean modeling and coupling

Coupling strategies (Valcke and Guilyardi, 2008)

Merging of the codes

- information can be exchanged by argument passing or by sharing a common module
- ensures efficient memory exchanges
- must be hard-coded
- own transformations and interpolations
- EBU-POM approach

Direct use of existing communication protocols

- MPI
- CORBA
- Unix pipes
- scientist masters the communication protocol and implements his own transformations
- and interpolations

Approaches for ocean modeling and coupling

Use of a coupling framework

- ESMF (http://www.esmf.ucar.edu)
- adapt the code units to the framework standard data structure and calling interface
- approach is fully flexible (the different units can be easily reused in different
- allows the user to use the different tools offered by the framework (parallelisation, regridding, time management, etc.)
- requires a deeper level of interference in the codes and imposes strict coding rules in order to take full advantage of the framework functionalities
- NMM-B is incorporated already in ESMF

Use of a coupler

- MCT (http://www.mcs.anl.gov/mct)
- PALM (http://www.cerfacs.fr/globc/PALM WEB/index.html)
- OASIS (https://oasistrac.cerfacs.fr/)

- ensures that the original codes will run as separate executables with main characteristics (e.g. internal parallelisation) unchanged with respect to the uncoupled mode
- some cases be less efficient than a more integrated one-executable approach