

Ocean model, Interconnections within the climate model

Vladimir Djurdjevic and Bora Rajkovic

EXPERT WORKSHOP “SEE RESEARCH FRAMEWORK IN REGIONAL CLIMATE MODELING FOR 2012-2017”
Belgrade, Serbia, April 11-13, 2011

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

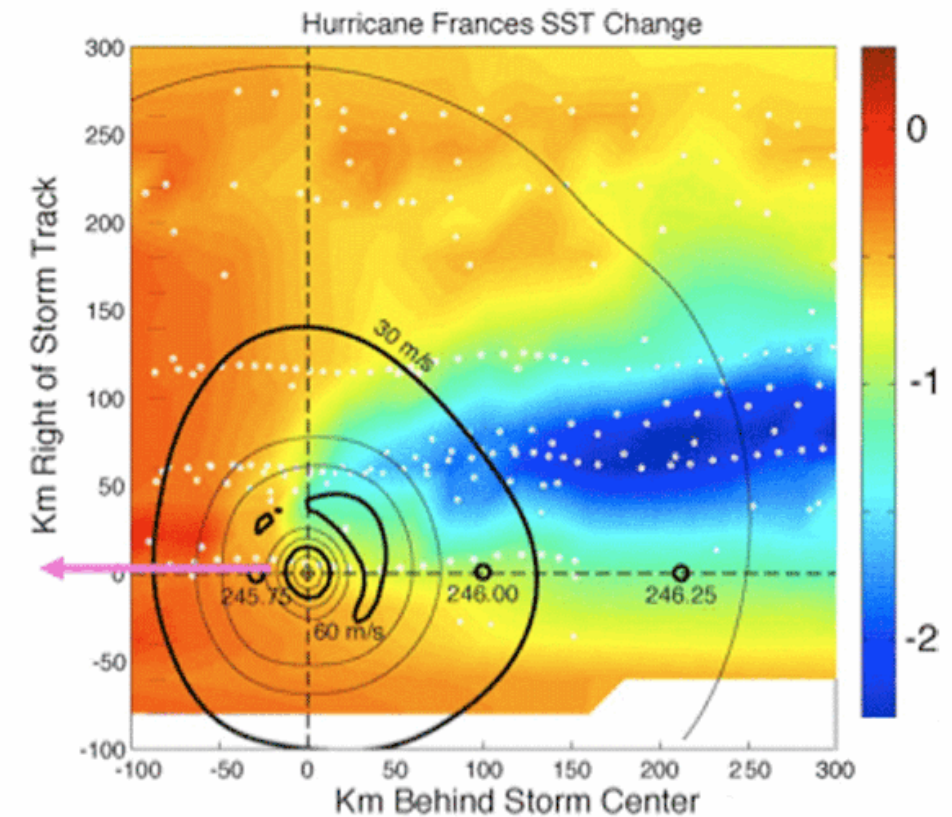
planetary - ENSO, thermohaline circulation

time scales:

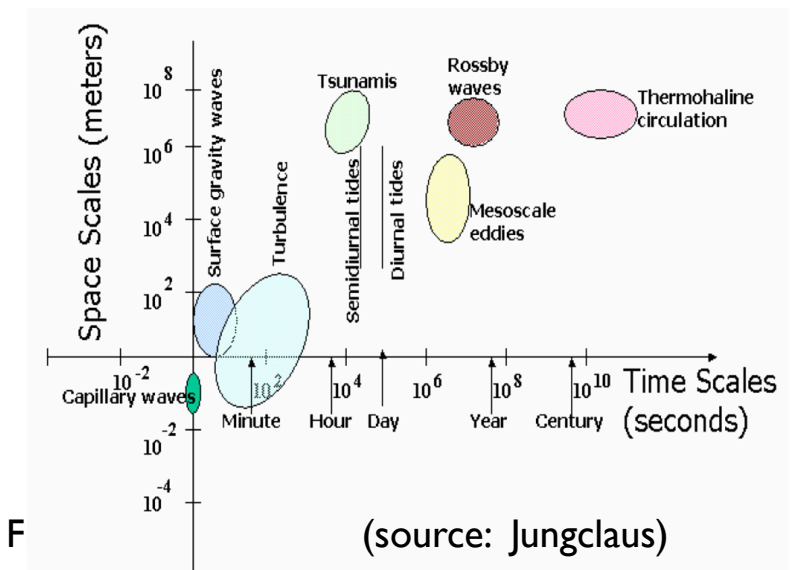
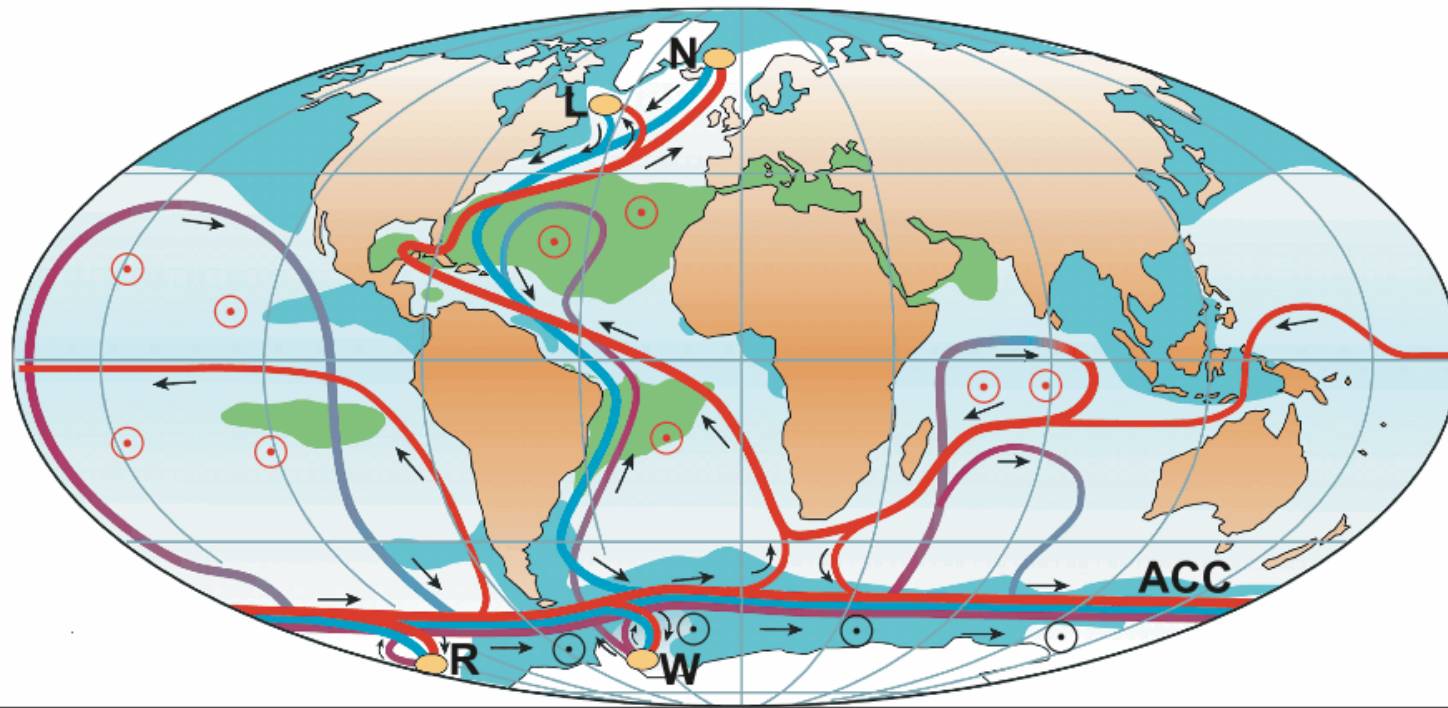
daily - hurricanes, sea-land breeze

decade to century - global ocean circulation,

The Atlantic Meridional Overturning Circulation



(source: Large 2008)



F

(source: Jungclaus)

Exchanges between atmosphere and ocean:

momentum exchange

formation of ocean currents

heat exchange, turbulent and radiation fluxes

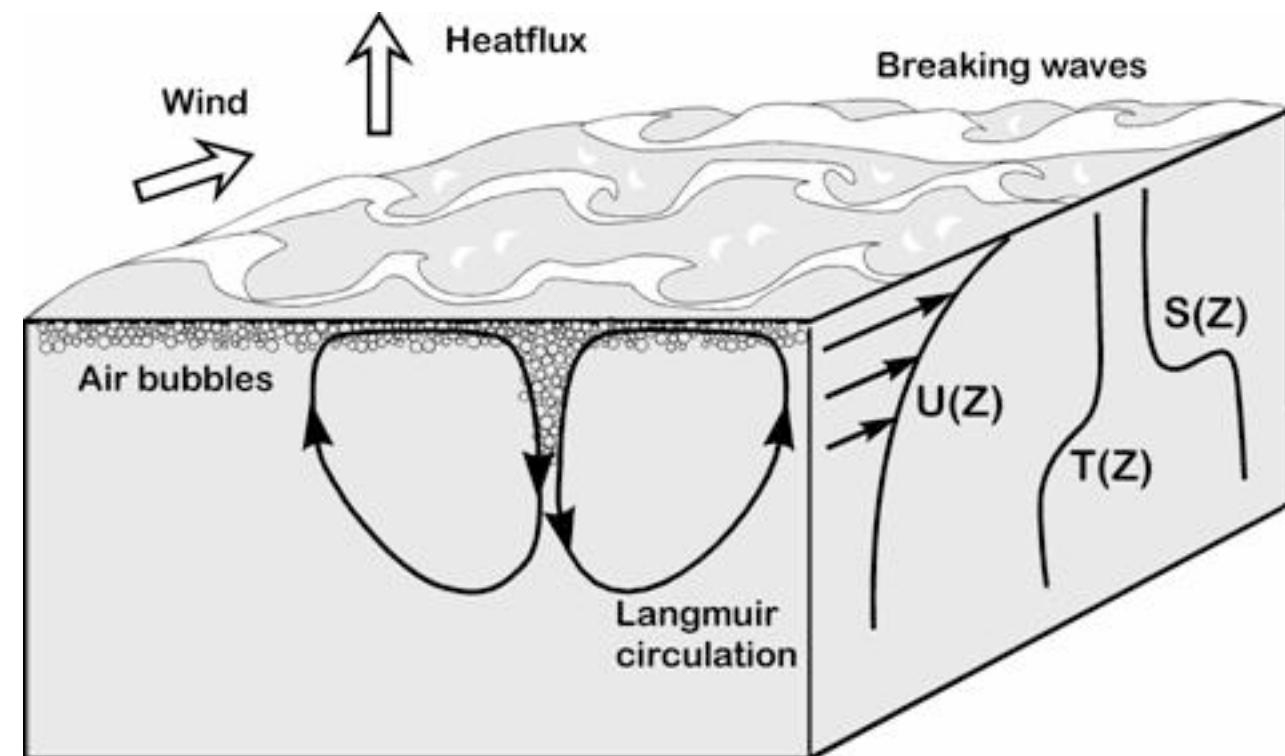
mixed layer

mass exchange

fresh water flux

gases and chemical exchange

CO₂ 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

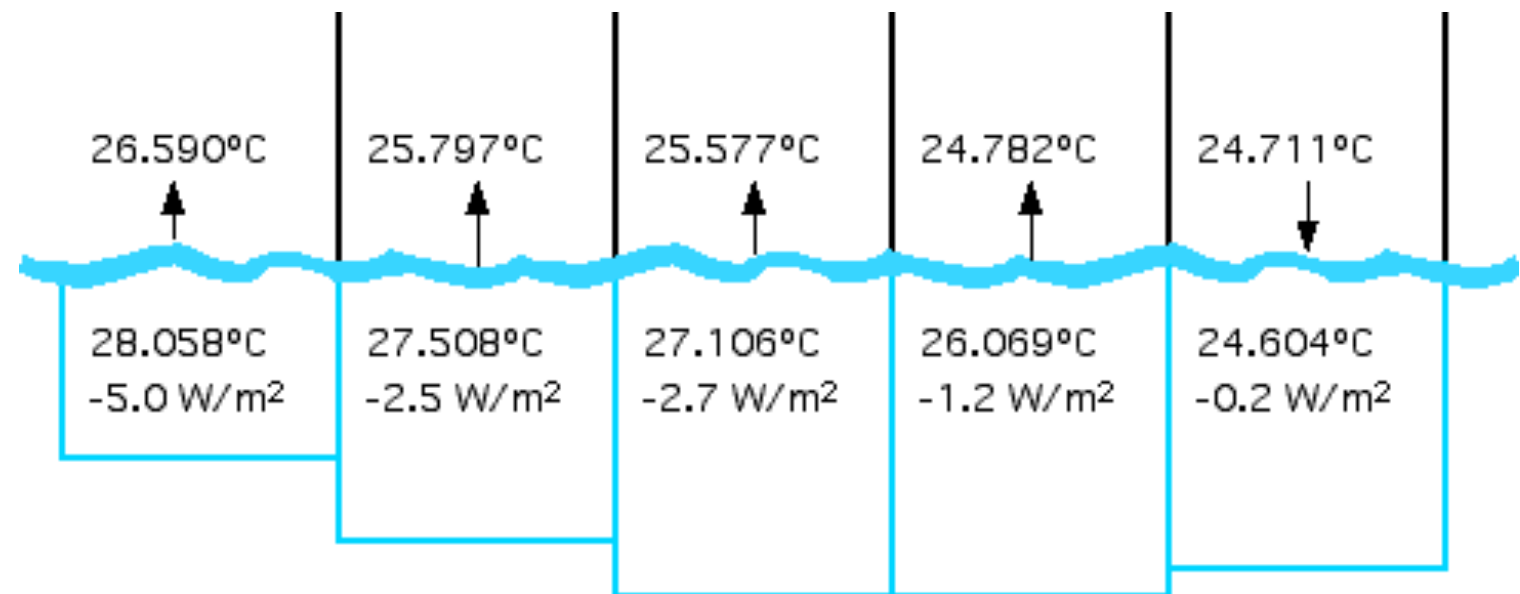
- model without ocean dynamics
- each grid cell in the ocean is given a temperature and a depth for the mixed layer
- energy convergence (divergence) at each grid cell is calculated based on the heat storage capacity of the surface ocean and the vertical energy fluxes at the air/sea interface
- allows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

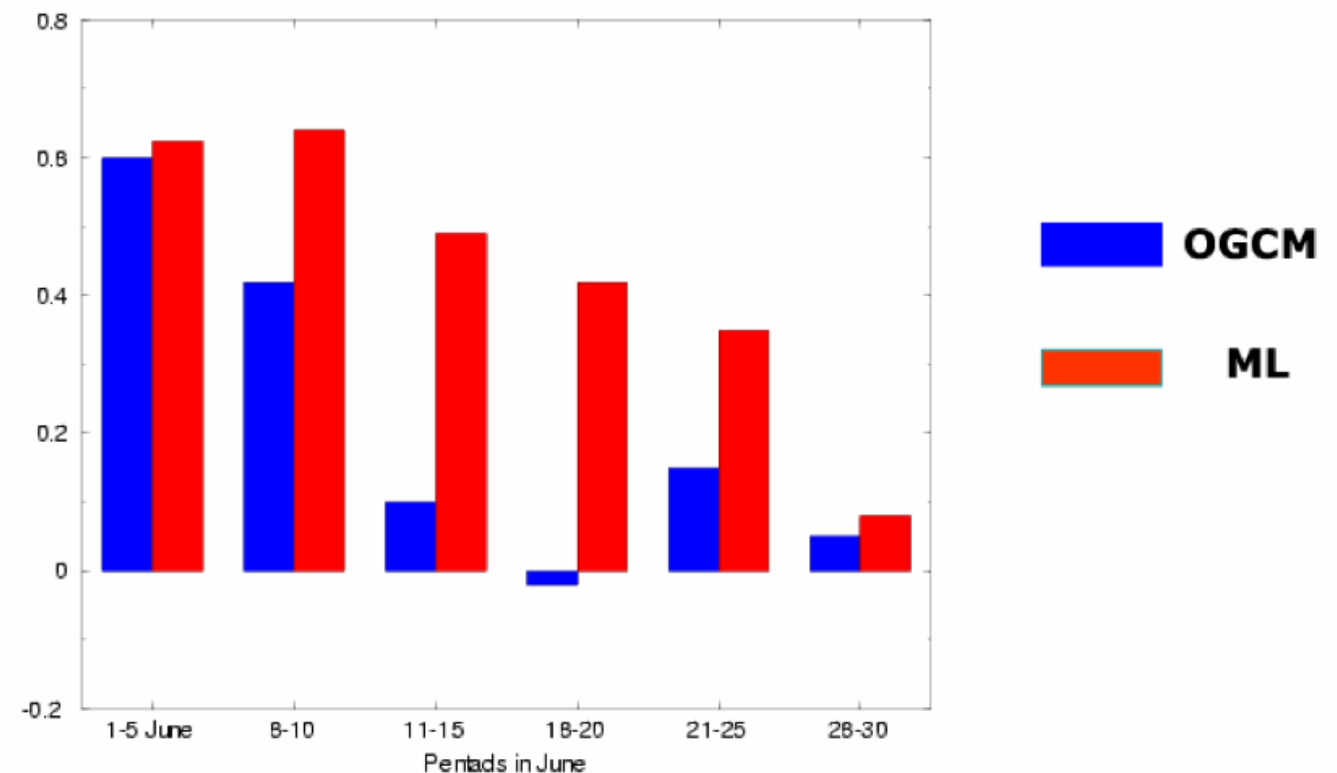
Approaches for ocean modeling and coupling

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 +/- 44° 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

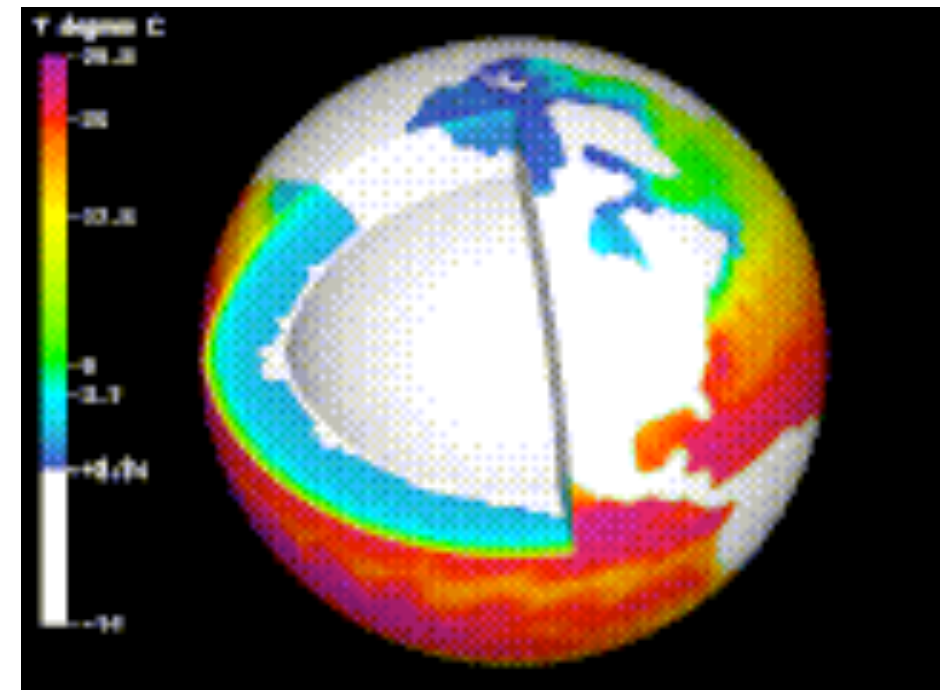
an explicit representation of the sea surface height is being used in many models, and real freshwater flux is used to force those models instead of a 'virtual' salt flux

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

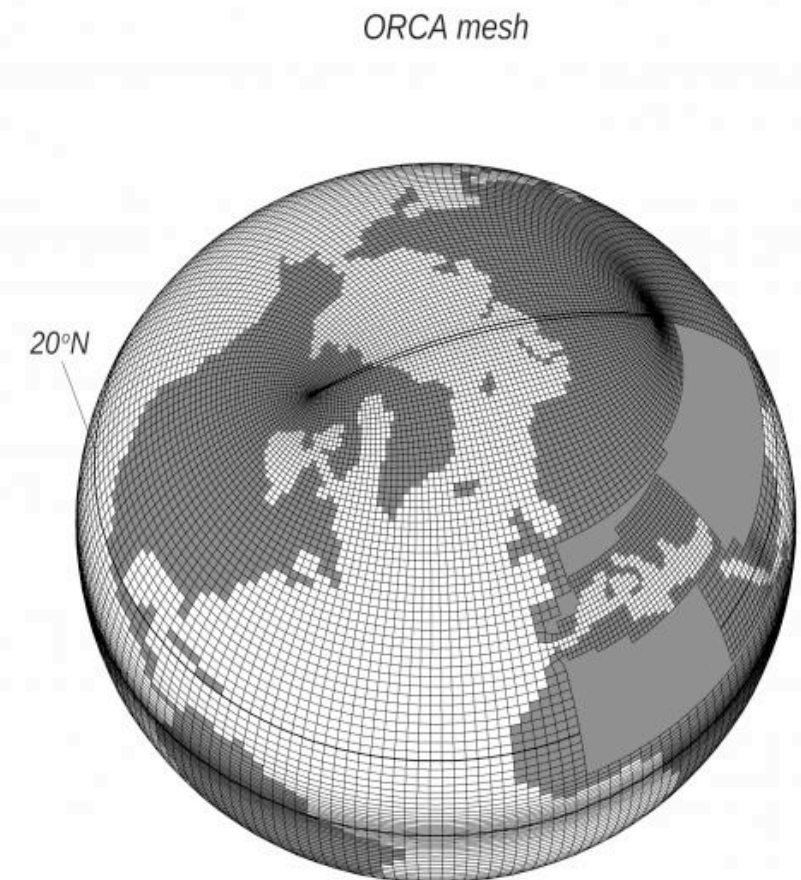
Examples of OGCM:

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)

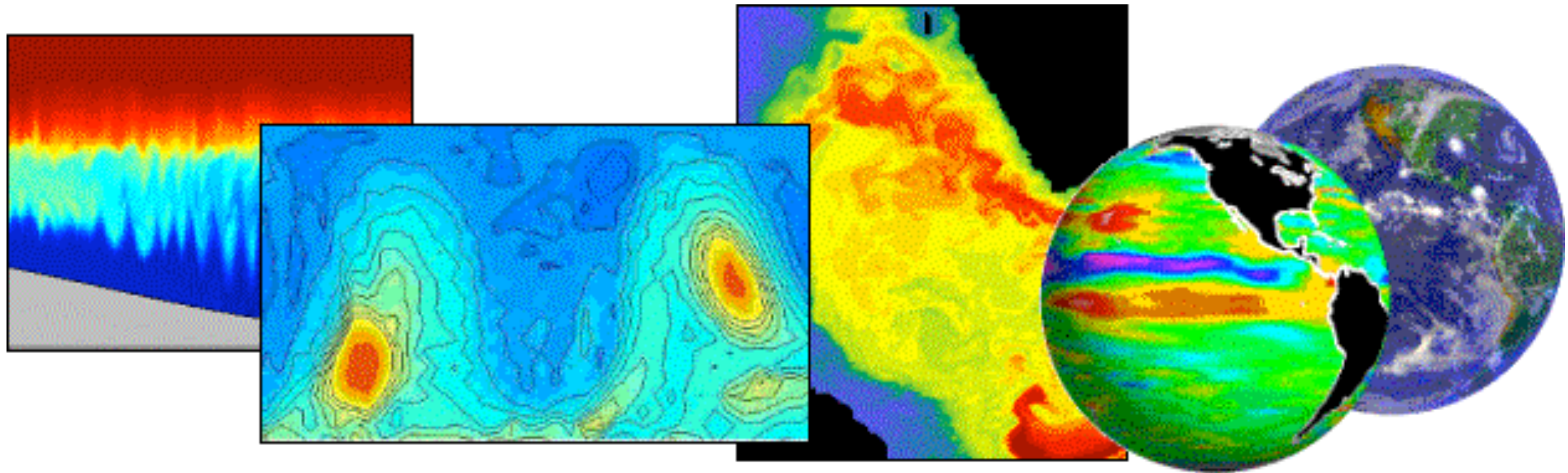
Approaches for ocean modeling and coupling

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

Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

enea sitemap contacts intranet

UTMEA Energy and Environment Modeling
an ENEA Technical Unit

projects:

MEDiterranean COordinated Regional climate Downscaling EXperiment

MED-CORDEX is a coordinated action between [CORDEX](#) and [HyMeX](#) international programs.

MED-CORDEX will make use of both regional atmospheric climate models and regional coupled systems. Strong air-sea interactions take place in the Mediterranean basin, motivating the use of coupled regional models. Two main phases have been envisaged within the MED-CORDEX action:

1. performing state-of-the-art coupled runs feeding the next IPCC report (AR5) by the end of 2010;
2. developing new experiments to test new components and improved schemes, based on the HyMeX field campaign outcomes (long term simulations).

MED-CORDEX is part of [CORDEX](#) international initiative which is aimed at improving coordination of international efforts in Regional Climate Downscaling research.

Involved groups (you are invited to join us), [subscribe TTM3c in HYMEX web site](#)

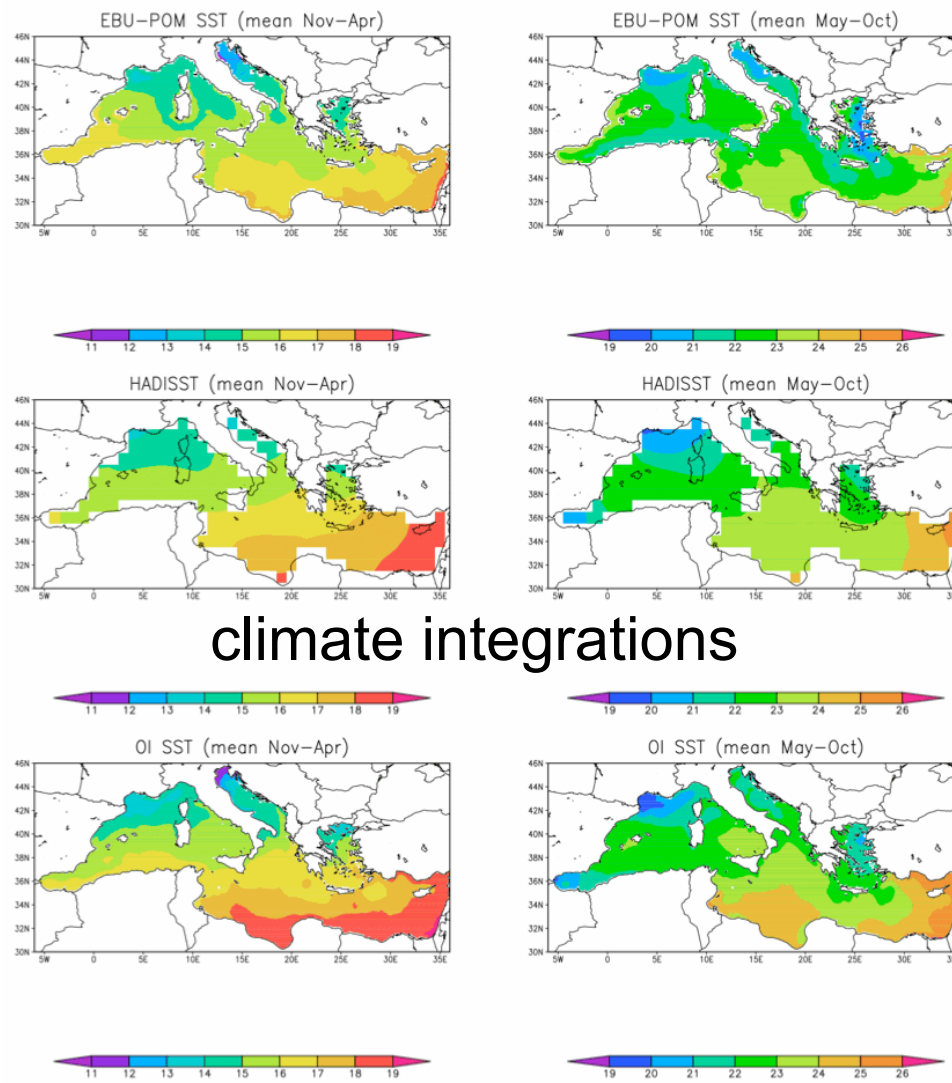
- UCLM (Spain)
- ENEA (Italy)
- KIT (Germany)
- LATMOS (France)
- IPSL/LMD (France)
- MPI (Germany)
- Belgrade university (Serbie)
- CNRM (France)
- CMCC (Italy)
- University of Crete (Greece)

Approaches for ocean modeling and coupling

Belgrade experience: EBU-POM/CRM-SEEVCCC

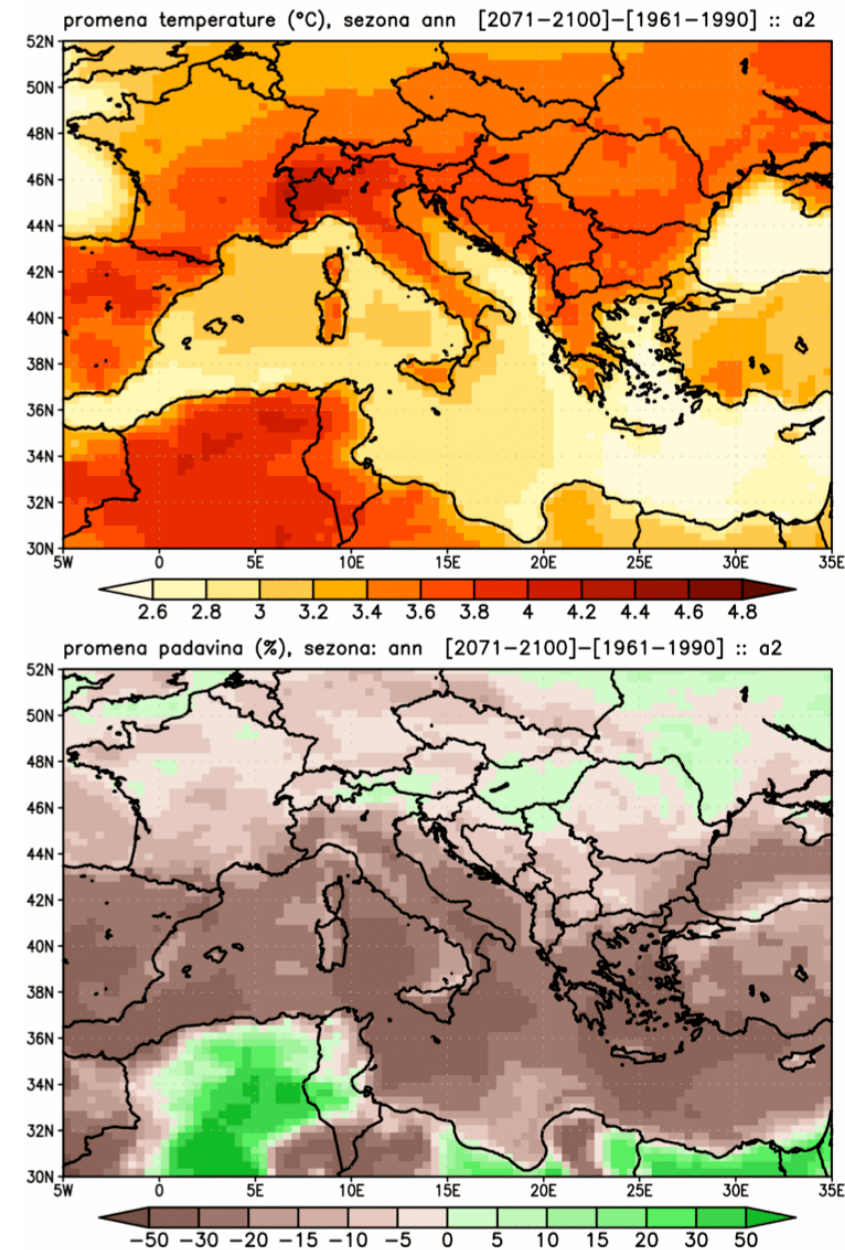
Different applications:

- medium range forecast
- climate change experiments
- seasonal forecast

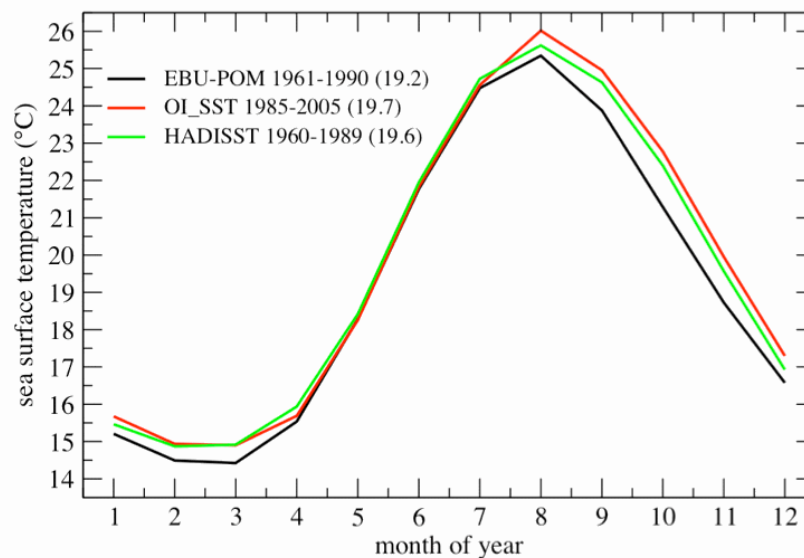
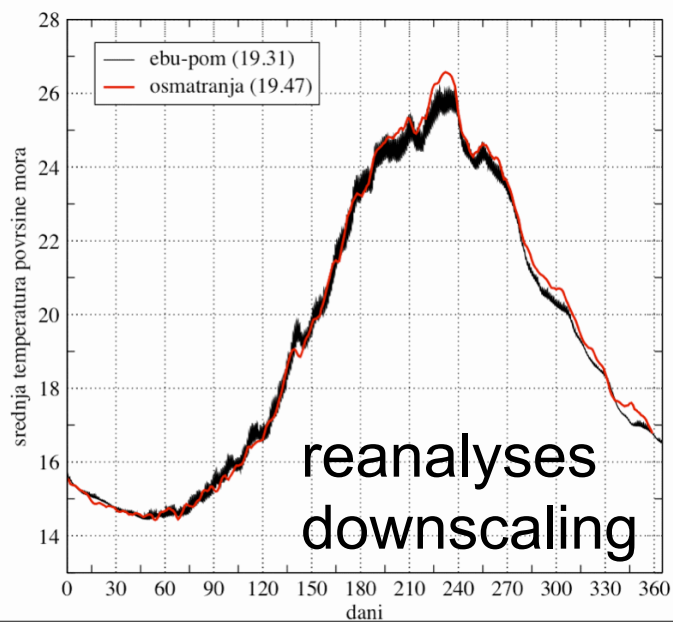
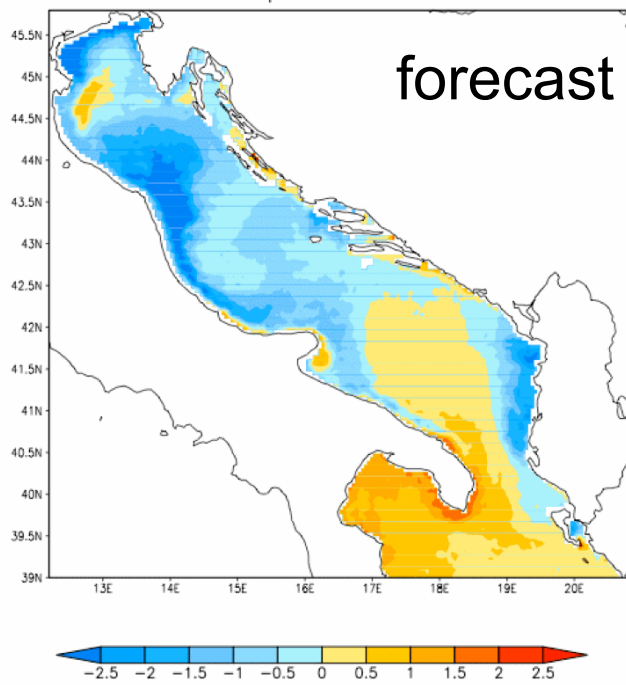


climate integrations

climate change scenarios



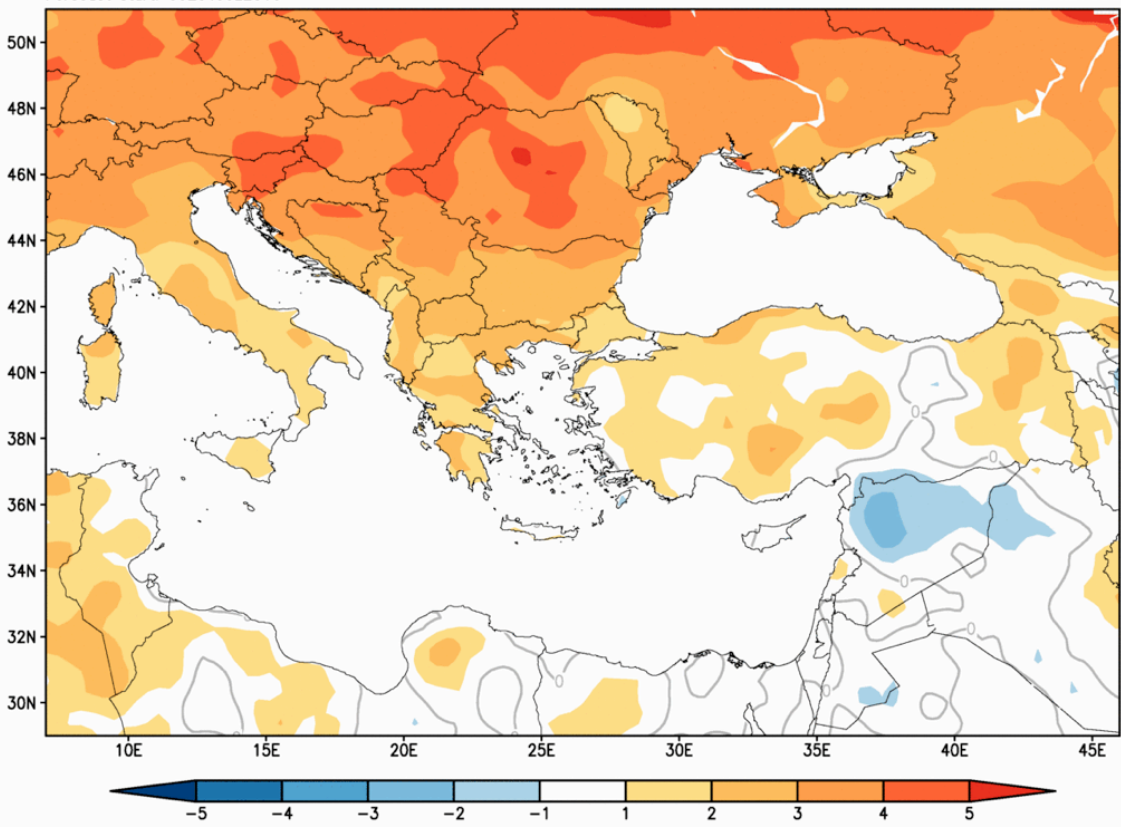
mean bias for period 10JAN-27FEB 2006



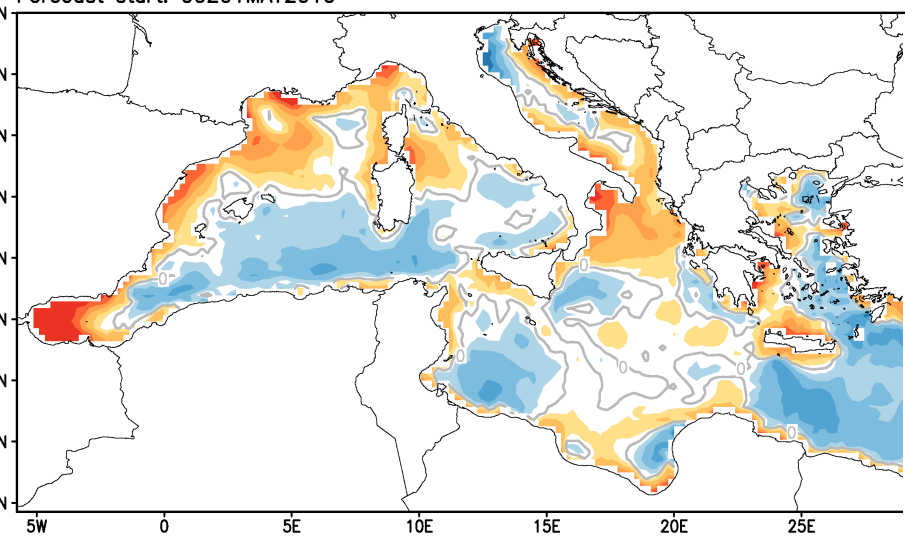
Approaches for ocean modeling and coupling

Belgrade experience: Seasonal forecast with regional coupled model

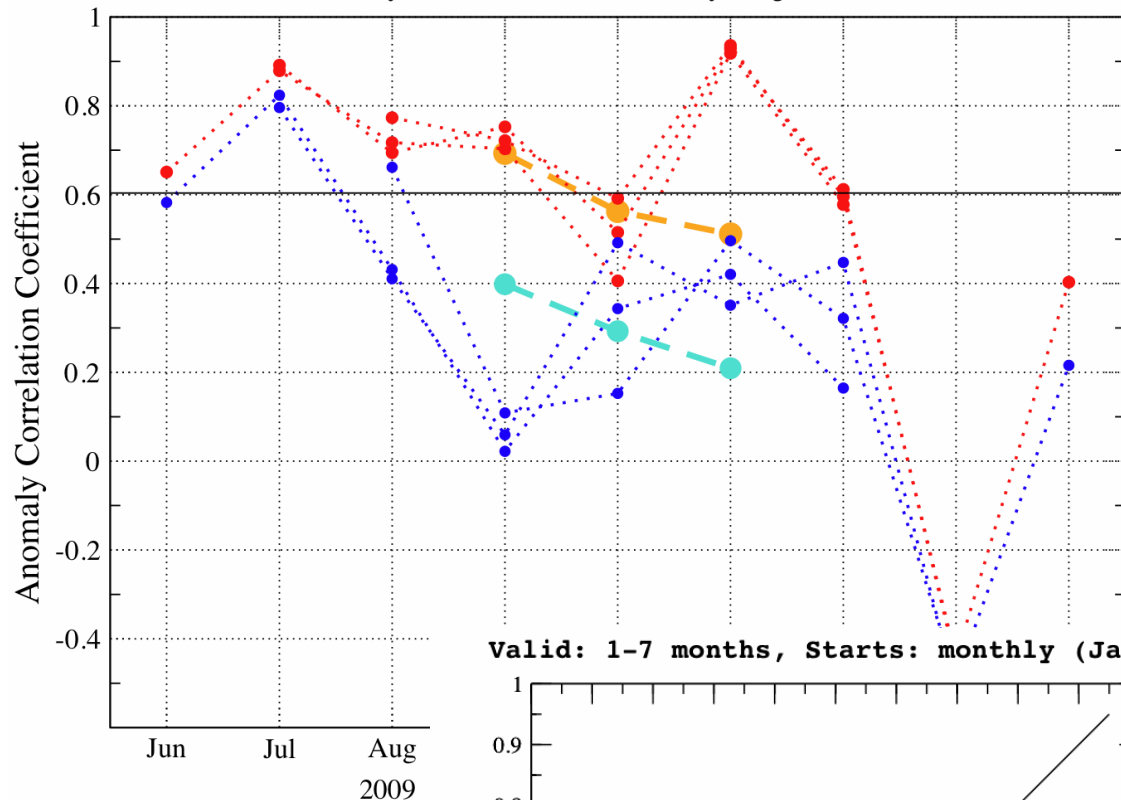
RCM-SEEVCCC: Mean 2m temperature anomaly (°C) for JUL 2010
Forecast start: 00Z01JUL2010



RCM-SEEVCCC: Sea surface temp. anom. (°C) for season JUN-JUL-AUG 2010
Forecast start: 00Z01MAY2010

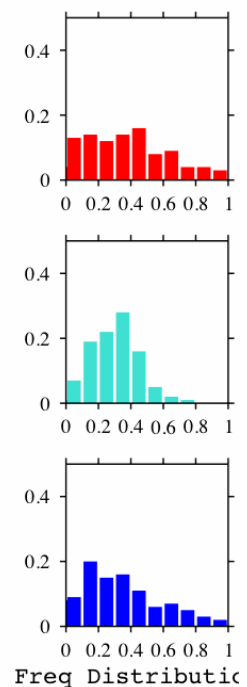
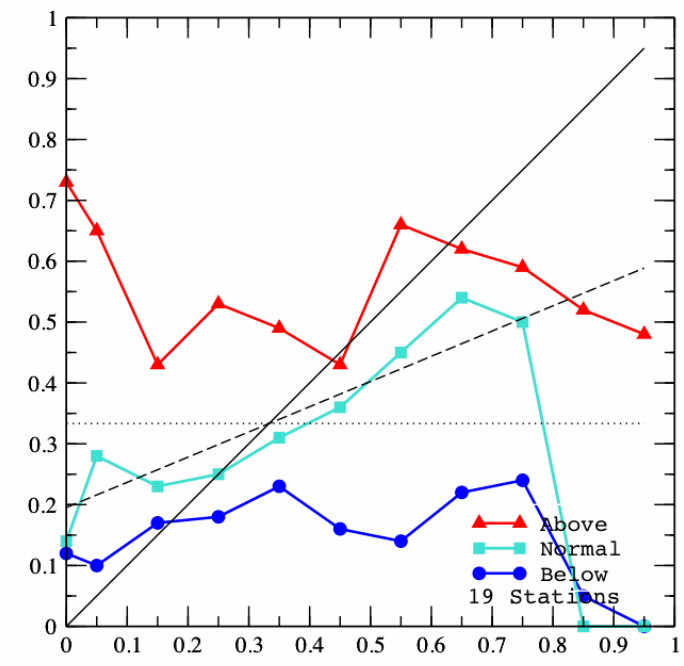
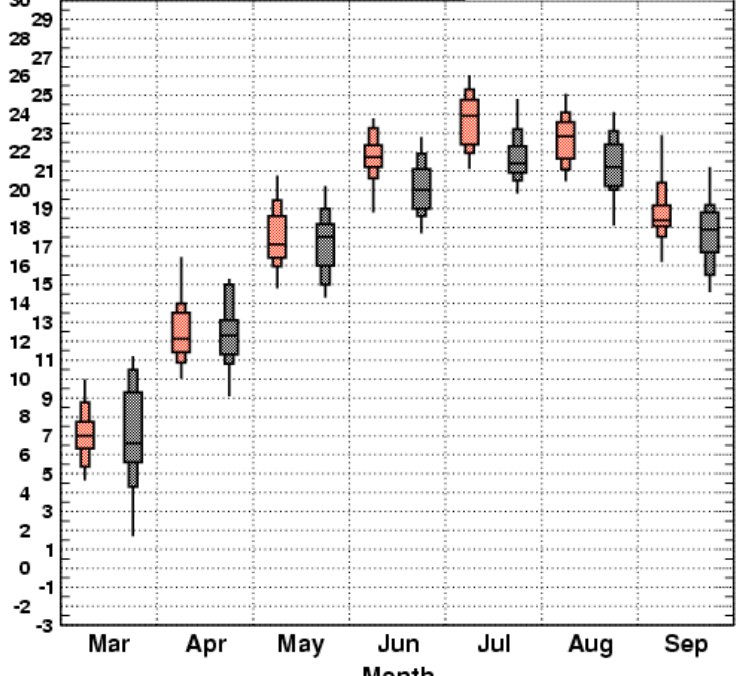


- RCM-SEEVCCC 7 months mean acc
- ECMWF 7 months mean acc
- RCM-SEEVCCC monthly acc, forecast start: Jun, July, August 2009
- ECMWF monthly acc, forecast start: Jun, July, August 2009



Valid: 1-7 months, Starts: monthly (Jan-June 2010)

Monthly mean temperature
Forecast start at: 01-03-2010
Station: BELGRADE



	Brier Score(LCSkill)	Reliability	Resolution	Uncertainty
A	+0.34 (-1.04)	+0.10 (+0.37)	+0.01 (+0.95)	+0.25
N	+0.21 (-0.27)	+0.01 (+0.95)	+0.00 (+0.97)	+0.21
B	+0.22 (-0.29)	+0.08 (+0.53)	+0.00 (+0.99)	+0.14

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](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