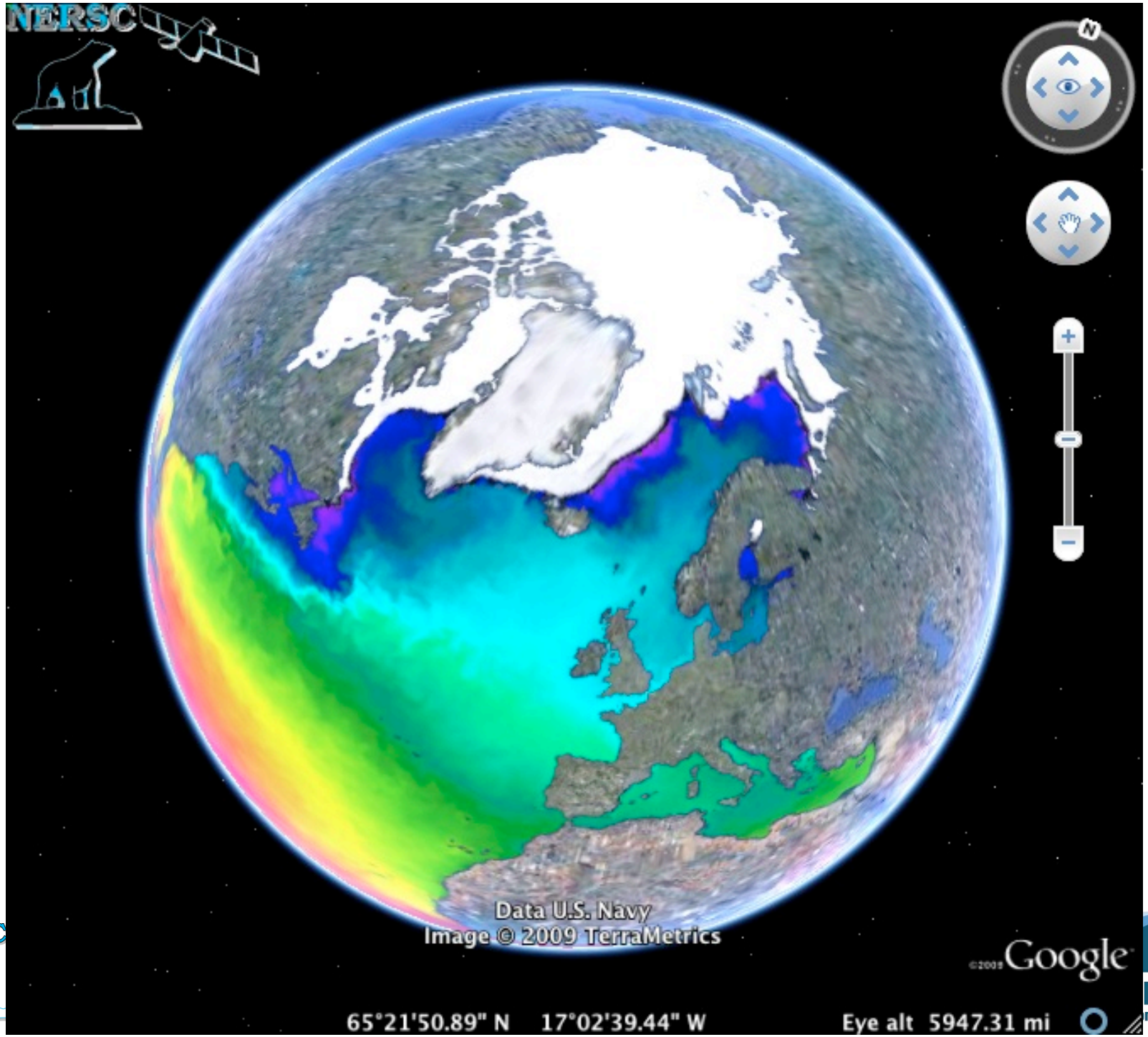
Current TOPAZ developments

L. Bertino, F. Counillon

Mohn-Sverdrup Center/NERSC

Opnet workshop, Geilo, 27th May 2009



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Collaborative Projects overview

- MyOcean WP5 (Arctic MFC) (2009-2012) ~25 MNOK
  - Large scale ocean – sea-ice forecasting/reanalysis service
  - NERSC, met.no, IMR, NIERSC
- eVITA-EnKF (2007-2011) 20 MNOK
  - Data assimilation developments, multidisciplinary
  - NERSC, met.no, Storm, NHH, StatoilHydro, Ecole des Mines
- PRECOC (2005-2008) 2 MNOK
  - Coastal data assimilation, methodology, OSSE
  - NERSC, NIVA, Ifremer, Actimar, Ecole des Mines
- I-NORD (2009-2013?) ? MNOK
  - Observations and Forecasting service (?)
  - Sintef, met.no, IMR, NIVA, NERSC, NPI (?)
- FFI Gliders (2009) 0.25 MNOK
  - OSSE Assimilation of gliders in TOPAZ
  - Met.no, NERSC

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Motivation

- Ocean modelling is undergoing a transition
  - From research to operational services
- Ocean models are based on dynamical principles:
  - Are applicable to the whole world oceans
  - From surface to bottom, where observations are sparse
  - From open ocean to coastal seas
- With data assimilation methods
  - Improves the **timing** of ocean processes
    - In short-term forecast mode (*Ocean weather* forecast)
    - In reanalysis mode
- A new capability available to the public at large

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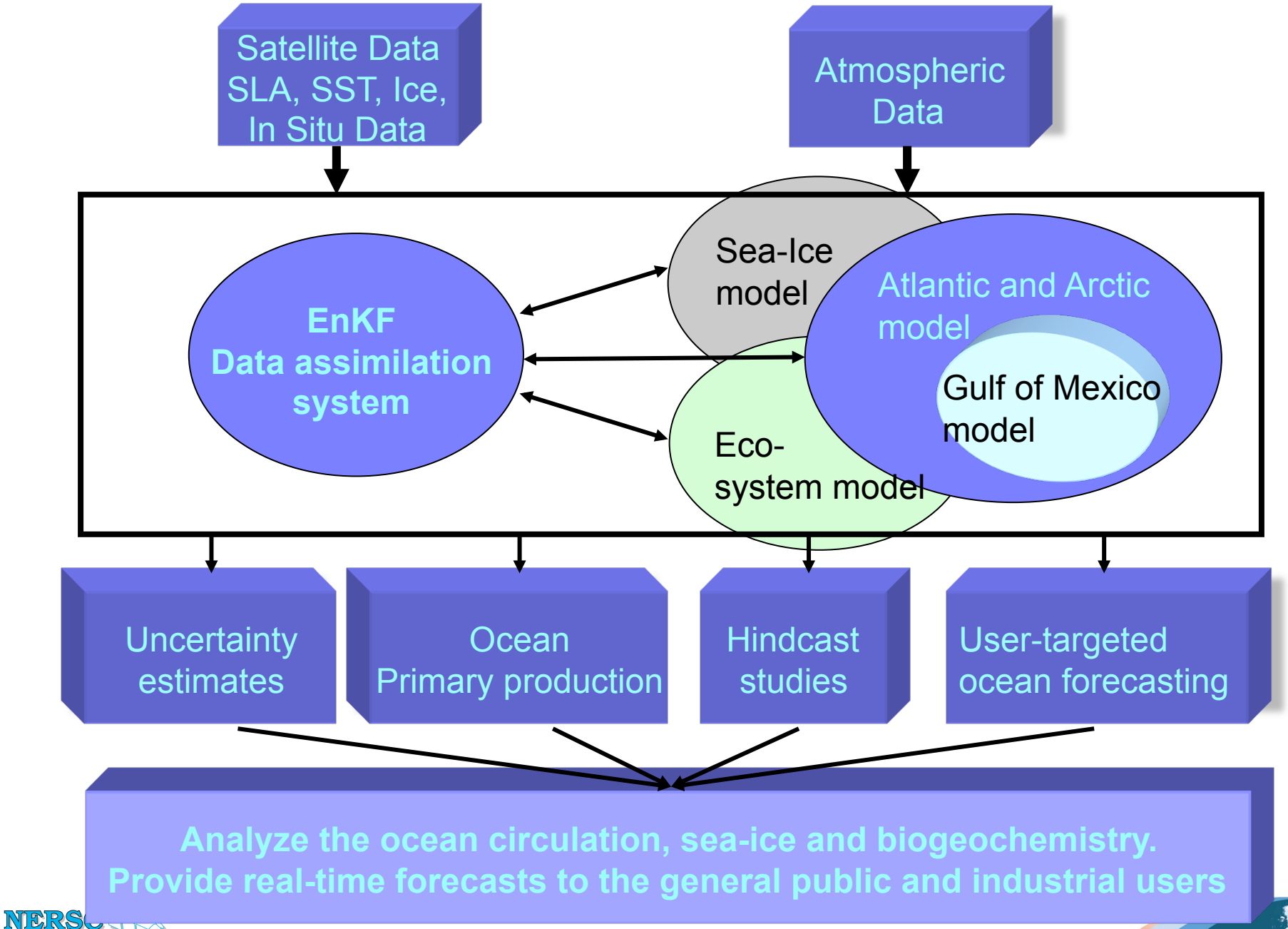

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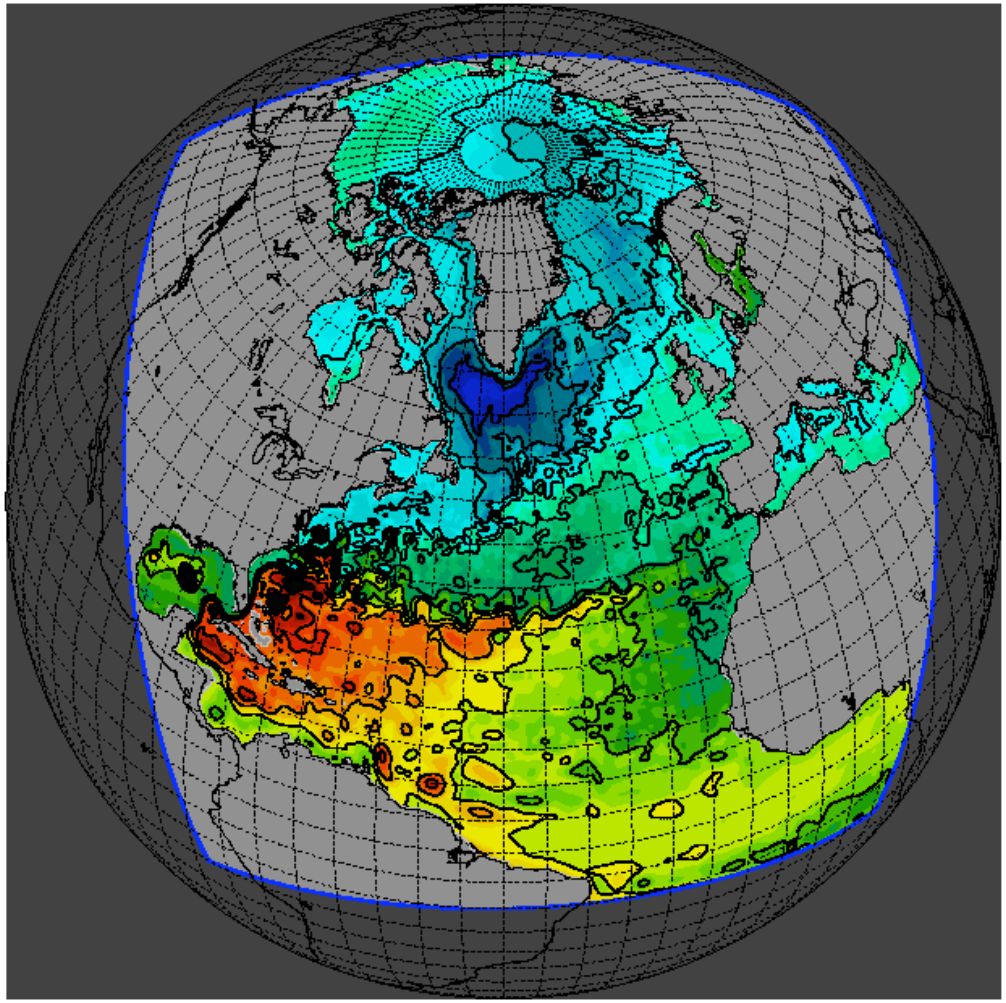
The TOPAZ model system

- TOPAZ3: Atlantic and Arctic
  - HYCOM + EVP sea-ice model
  - 11- 16 km horizontal resolution
  - 22 hybrid layers
- EnKF
  - 100 members
- Observations
  - Sea Level Anomalies (CLS)
  - Sea Surface Temperatures (NOAA)
  - **Sea Ice Concentr. (AMSR, NSIDC)**
  - Sea ice drift (CERSAT)
  - **Argo T/S profiles (Coriolis)**
- Runs weekly, 10 days forecasts
  - ECMWF forcing
  - http://topaz.nersc.no/thredds
  - http://thredds.met.no (MERSEA…)



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TOPAZ System overview

The HYCOM model upgrade

Validation of TOPAZ

Coordination with TOPAZ@met.no

Data Assimilation

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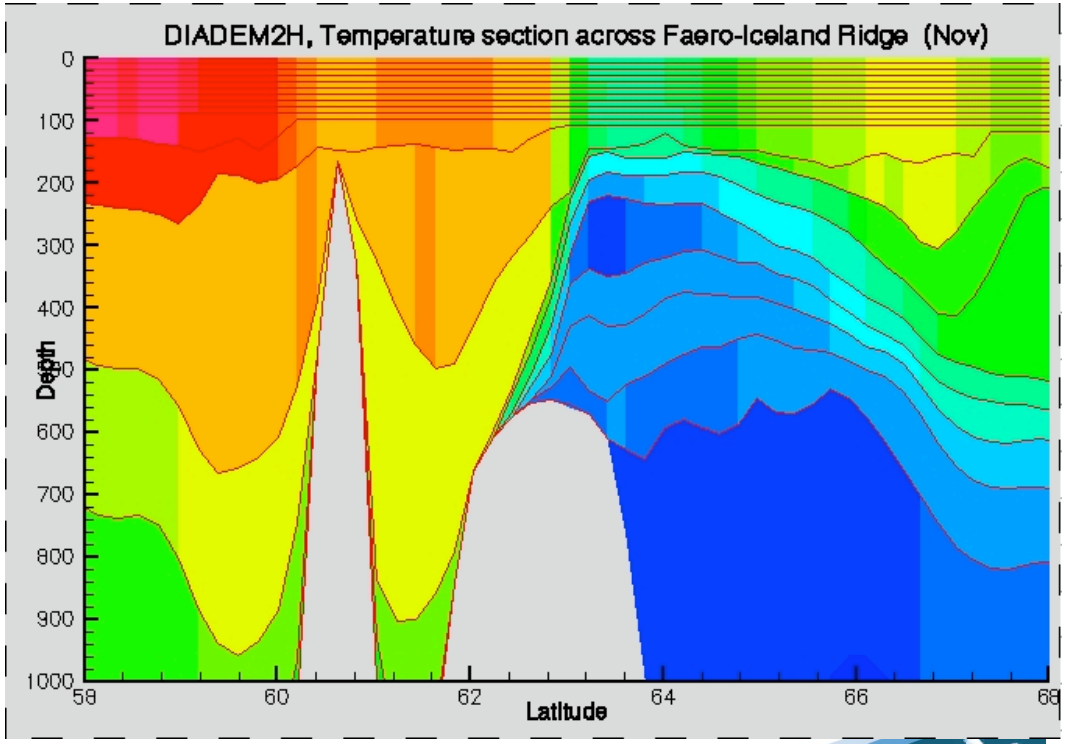
The HYCOM model

- 3D numerical ocean model
  - Hybrid Coordinate Ocean model, HYCOM (U. Miami)
  - US Navy global forecasts
- Hybrid coordinate
  - Isopycnal in the interior
  - Z-coordinate at the surface
  - Terrain following (sigma)
- **Nesting capability**
- **Coupled**
  - Sea-ice model
  - Ecosystem models
- Large community (http://www.hycom.org)



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HYCOM upgrade (v2.2.12)

- Choice of different mixing schemes
  - KPP, MY2.5, Canuto (GISS), ...
- Hybrid grid generator:
  - 3(4) different vertical interpolation methods (PCM, PLM, PPM,WENO)
- Improved treatment of rivers
  - Mass fluxes
- Bottom boundary layer (inverse KPP)
  - Shallow seas, Gibraltar Strait, Red Sea outflow.
- More stable in shallow waters (Morel et al. 2008)

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Other upgrades

TESTED

- Vertical resolution
  - 28 layers instead of 22
  - Thicker z-levels for deep mixed layers
- Sea.ice model
  - Advection scheme (WENO)
  - Snow distribution
  - Tuning of P* (ice strength)
- River fluxes from hydrologic model (TRIP), Oki and Sud (1998)
- Bering Strait fluxes from Pacific

ONGOING

- Forcing fields: ERA-Interim (to be tested)
- Assimilation of ocean colour in HYCOM-NORWECOM
- MIZ sea-ice rheology (TOTAL)

PLANNED

- Sea-level altimeters tracks
- Ferrybox data (Svalbard)
- Gliders (FFI-met.no)
- Rio05 MDT
- HR SST (Ostia/Odyssea)
- New satellites
  - GOCE, SMOS, CryoSAT

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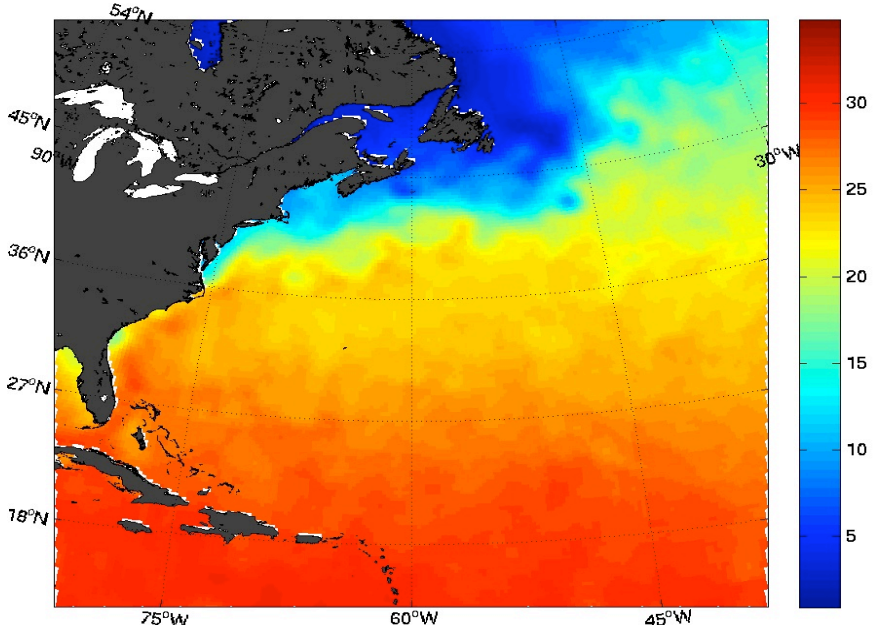
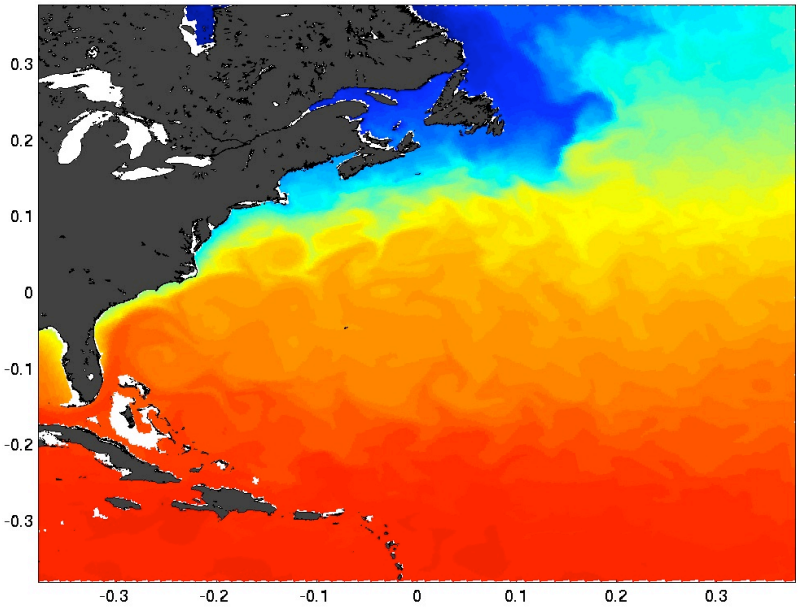
Effect of the upgrade

Weekly SST in Dec. 1999, free run

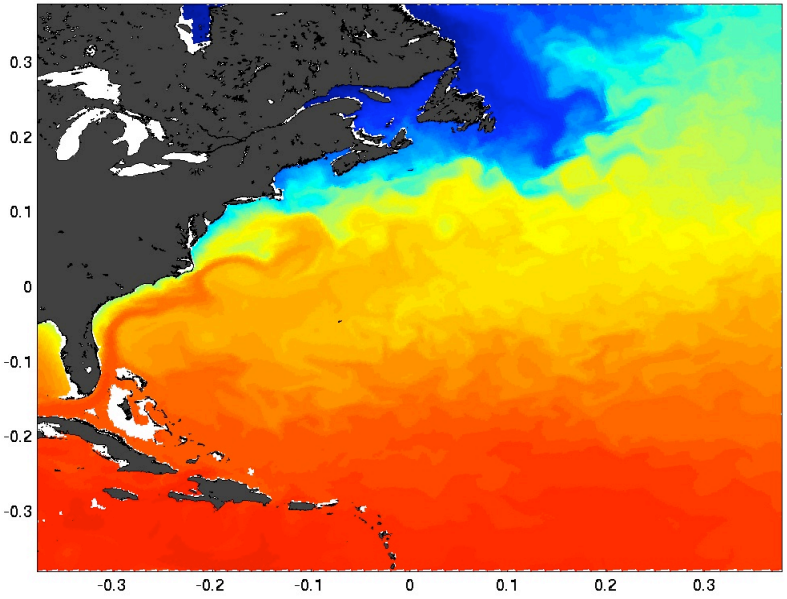
AVHRR

L4 SST





TOPAZ3



TOPAZ4

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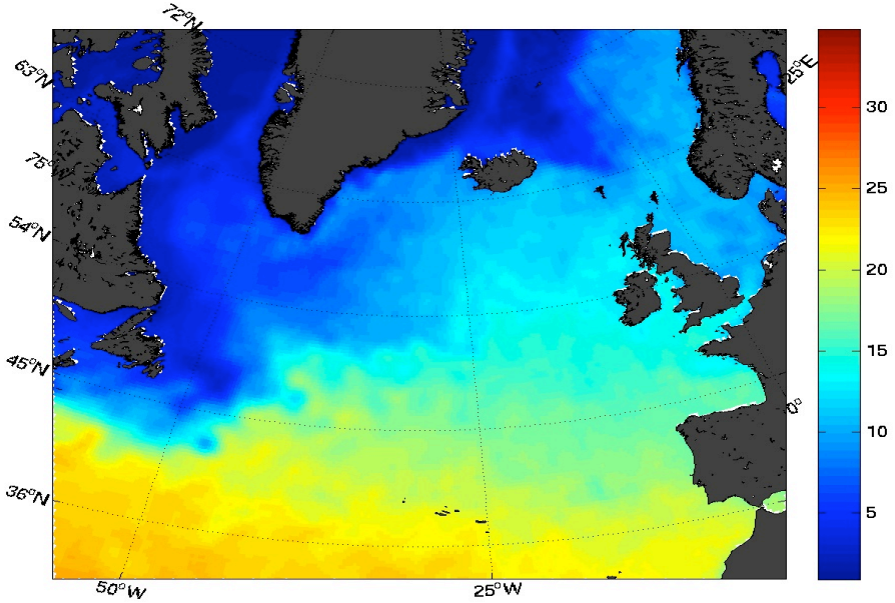
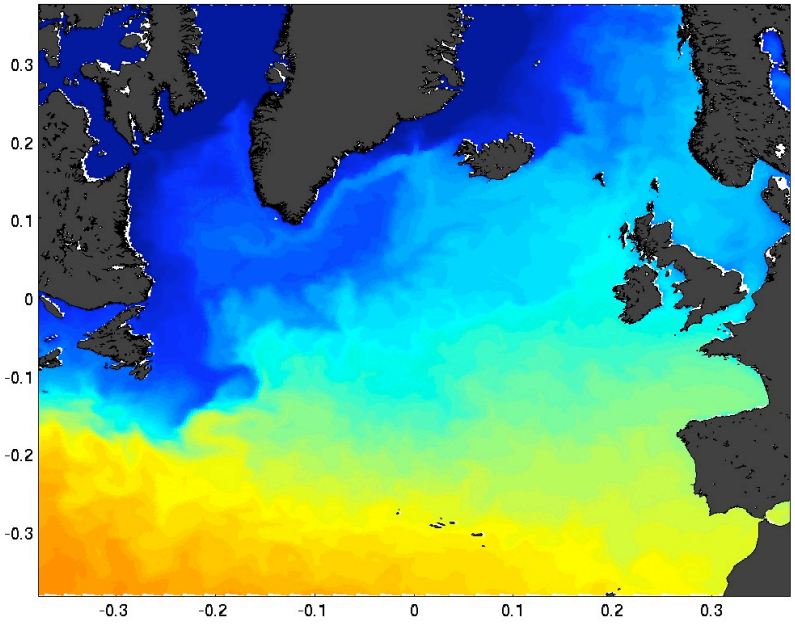
Effect of the upgrade

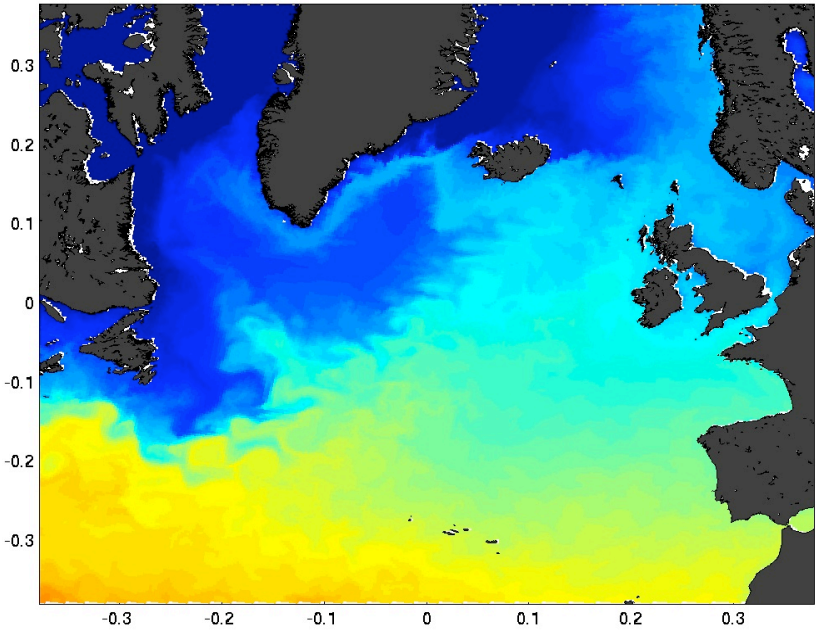
Weekly SST in Dec. 1999, free run

AVHRR

L4 SST







TOPAZ3

TOPAZ4

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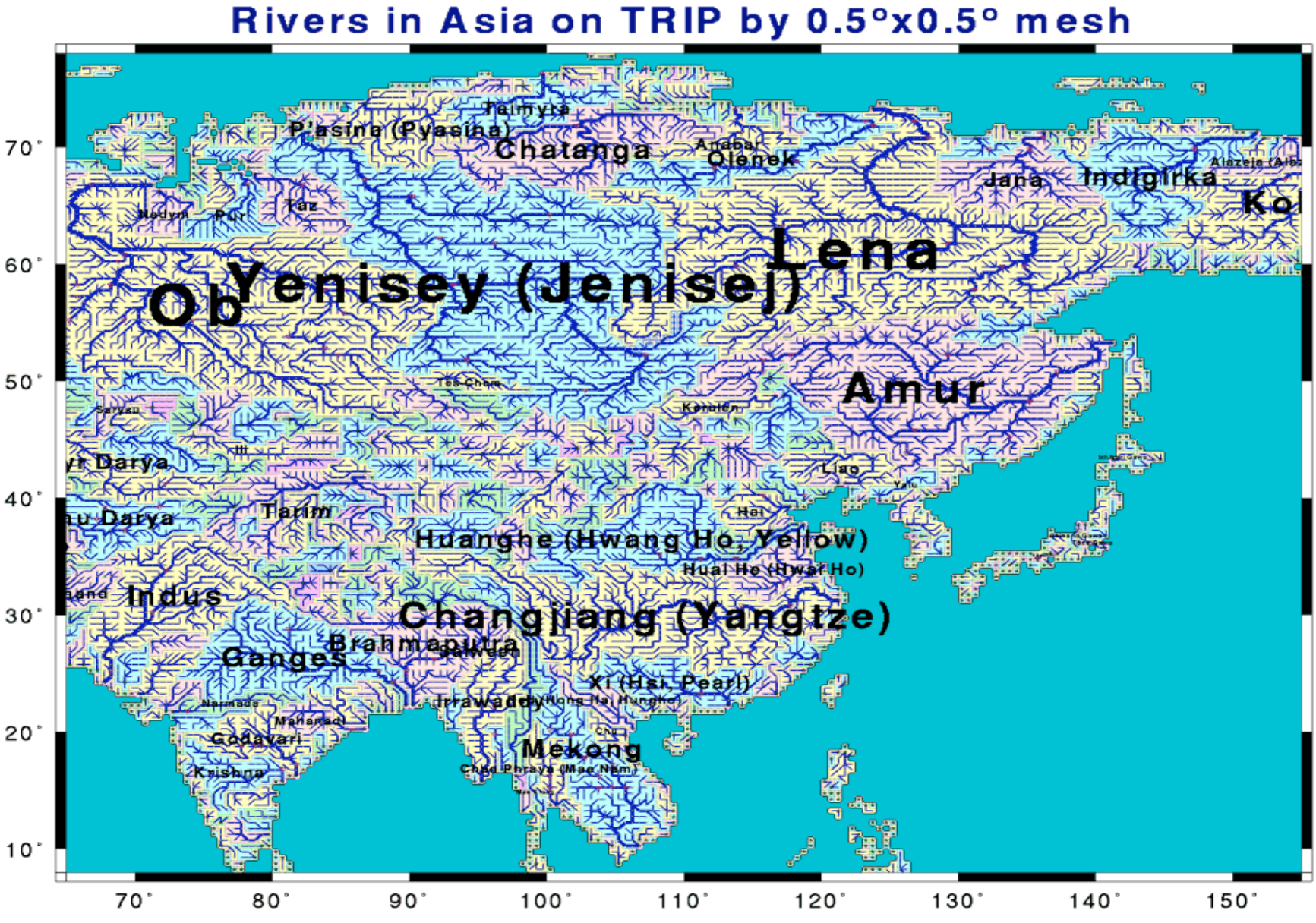
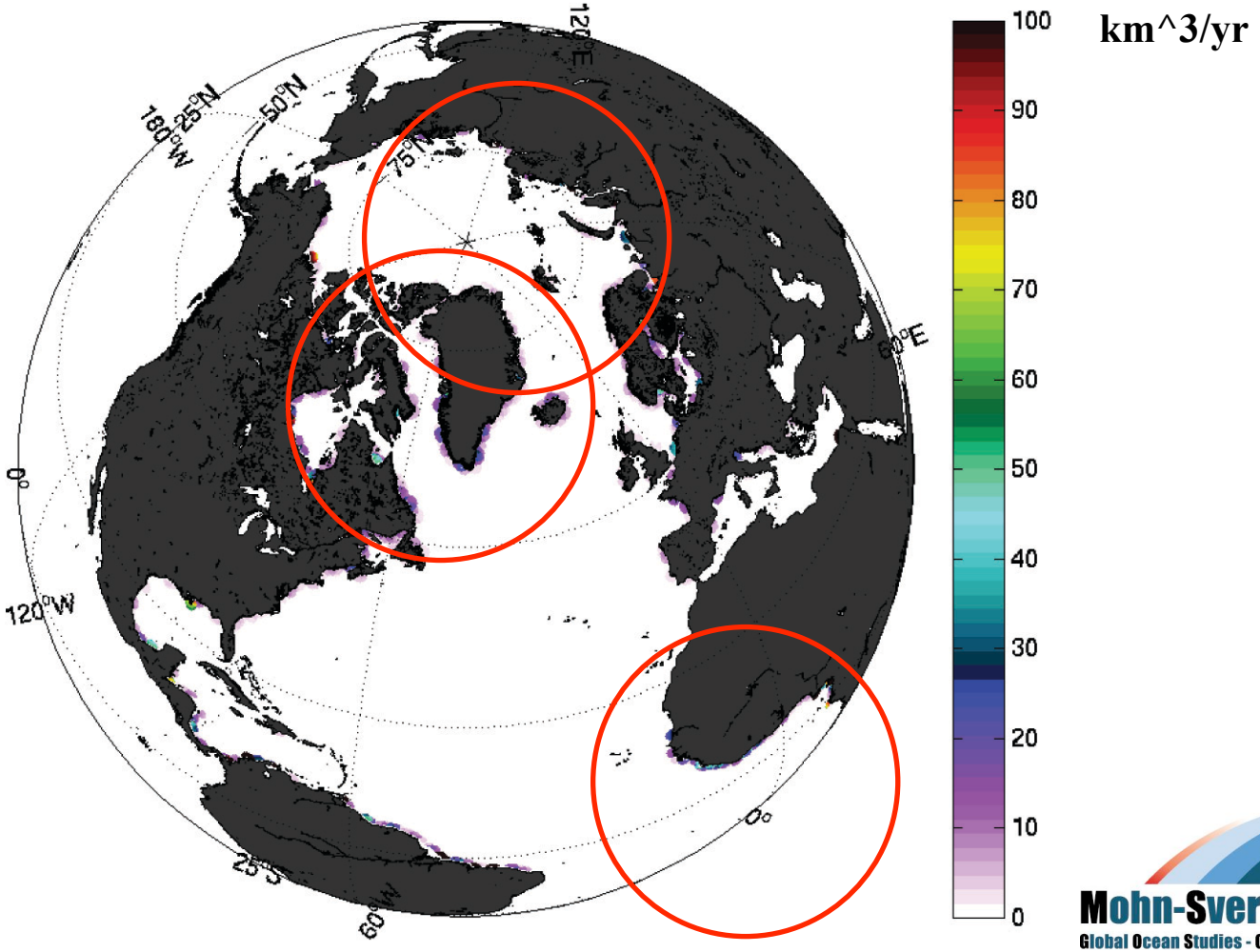
River forcing - TRIP



River run-offs: diagnosed from ECMWF data

ISLSCP2 data-base in combination with ERA-interim run off



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Sea-Ice model developments

- New advection scheme (WENO)
  - Reduces numerical noise in Ice fields
  - Leads to more ice in average.
- Plan for MyOcean@met.no: CICE model (Los Alamos)
  - HYCOM 2.2 includes coupling to ESMF (and CICE)
- Data-assimilation in the multi-category ice model:
  - Many more prognostic variables:
  - (fice, hice, temp_profile*nb_ice_layers)*n_categories + albedo, qbrine
- More variables to check!

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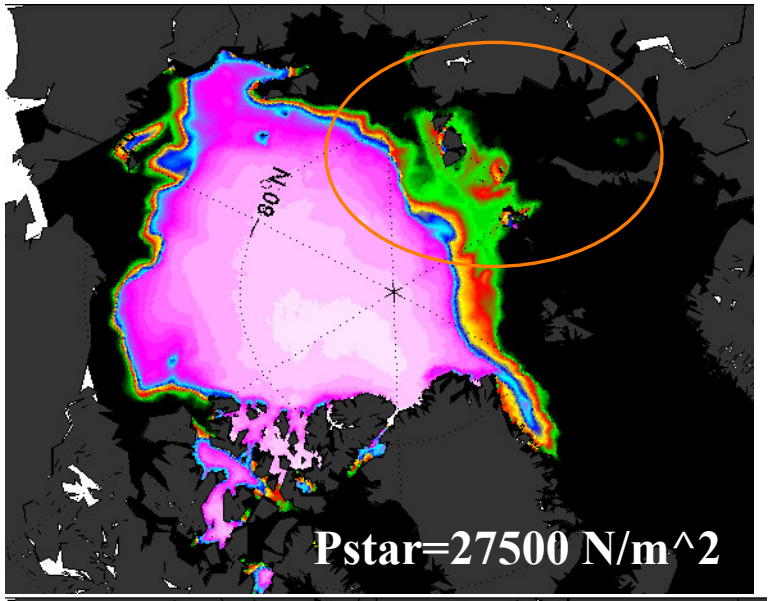
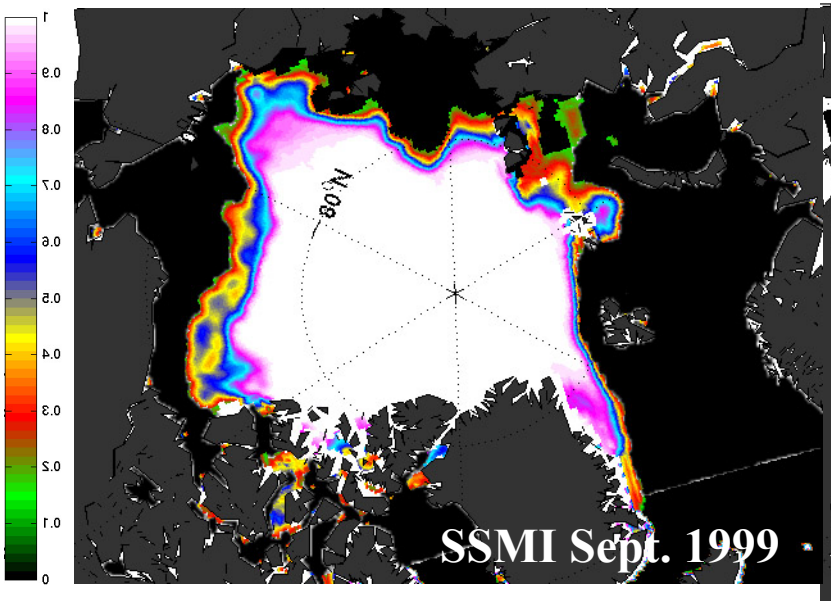
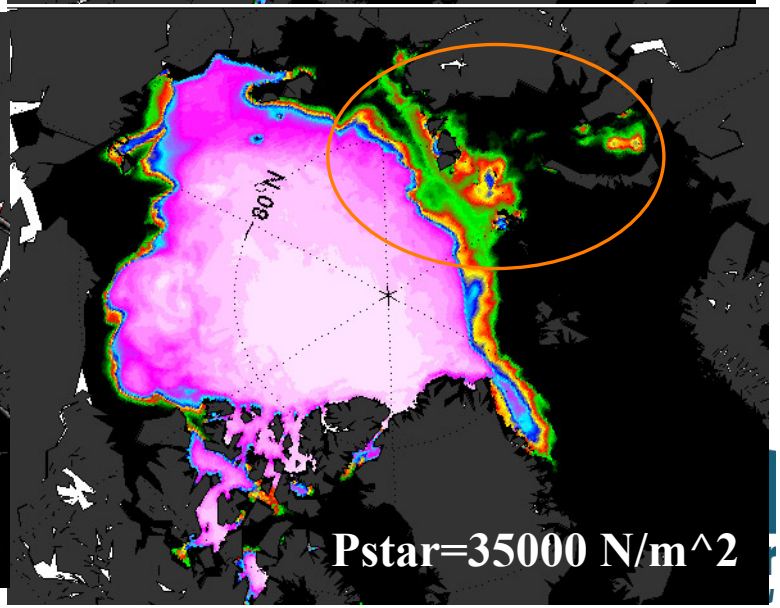
Sensitivity to Sea ice strength (p*)

p* has high uncertainties,
depends on the model resolution.

Test: Free run
- **little difference in winter**
- **ice holds longer in summer with larger Pstar**







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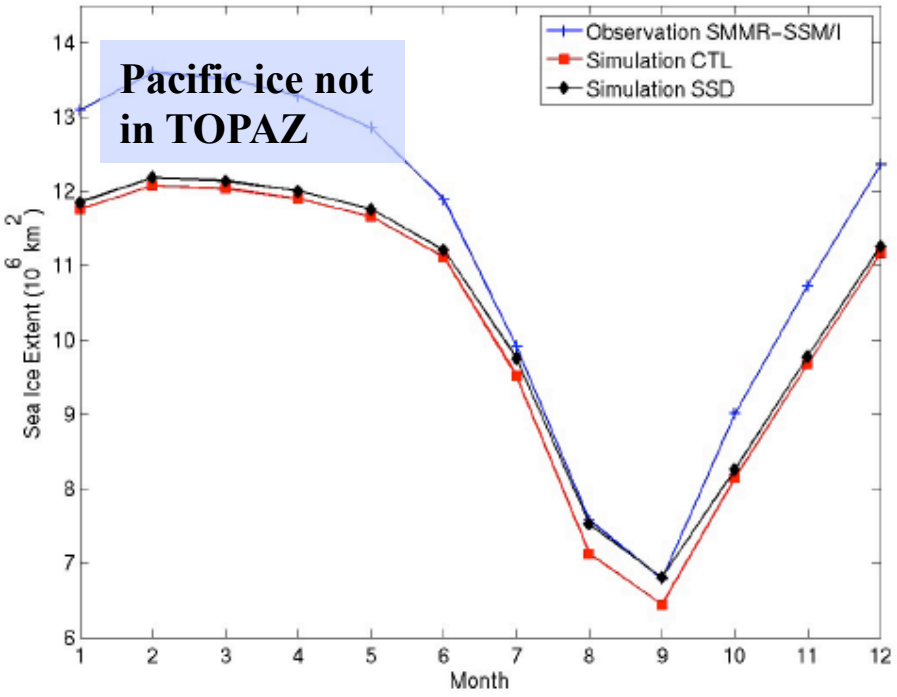
Snow module

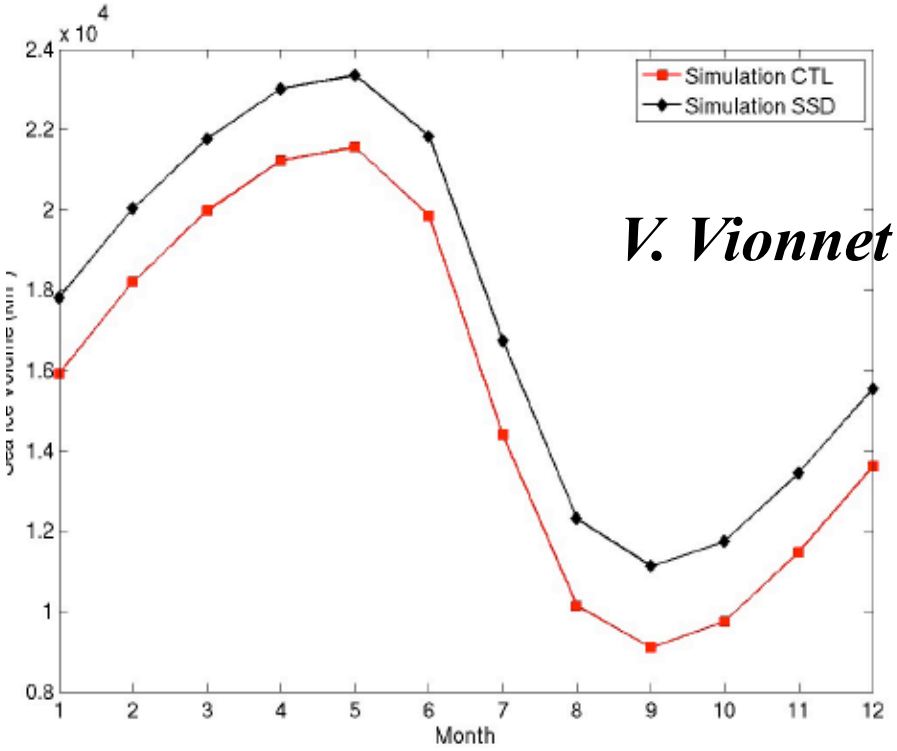
- Two effects:
  - Snow increases the albedo
  - Isolates the ice

Probabilistic snow distribution:



Ice area

Leads to more ice



Ice volume

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TOPAZ System overview

The HYCOM model

Validation

Coordination with TOPAZ@met.no

Data Assimilation

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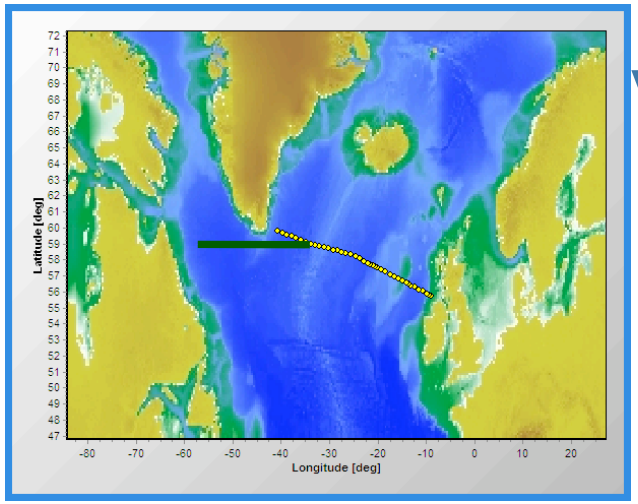
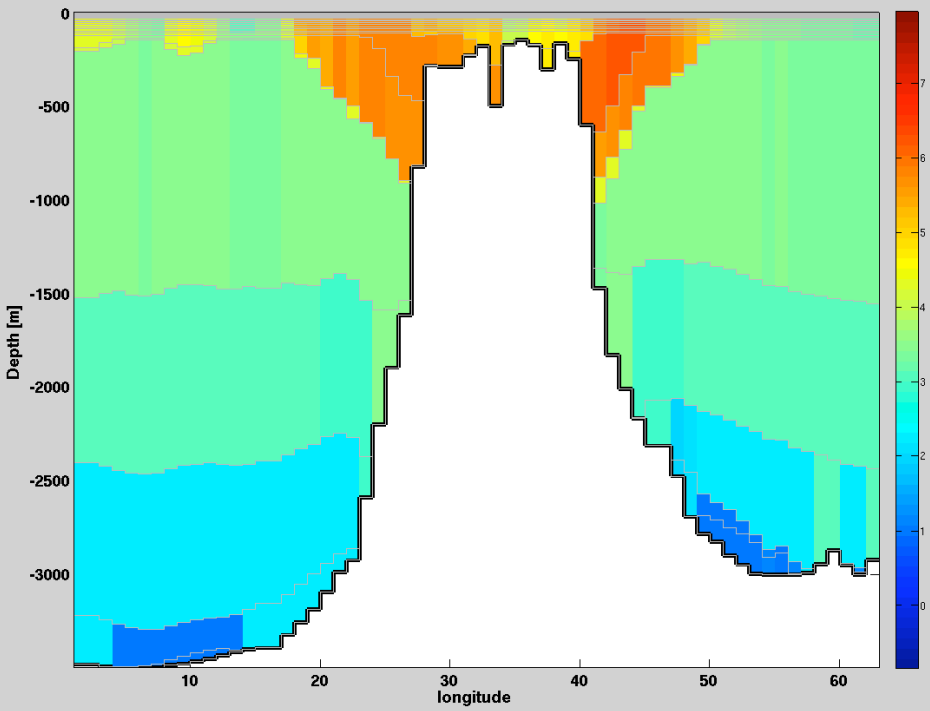


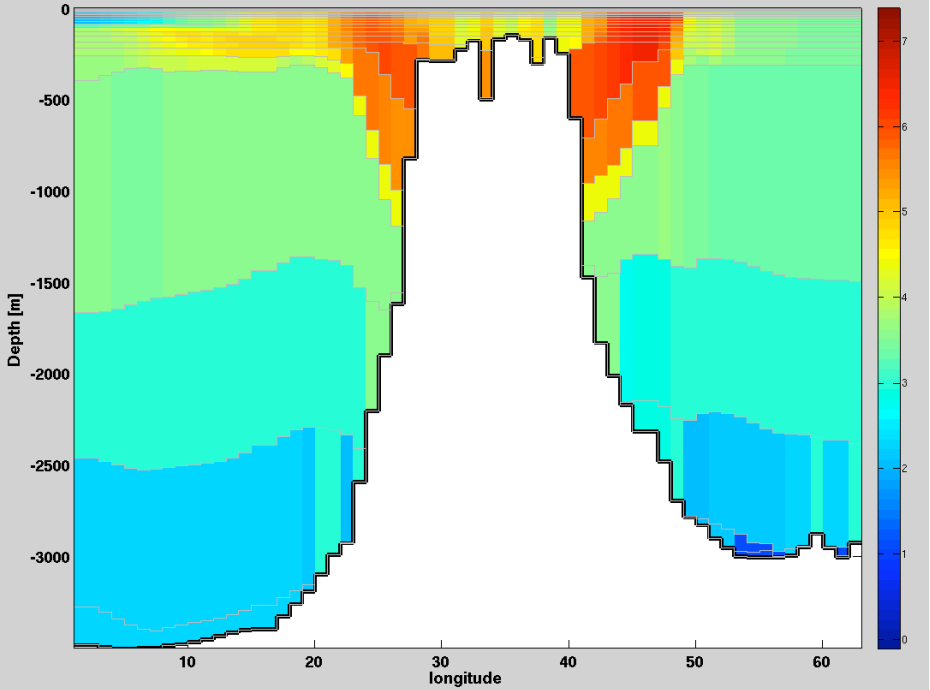
Vertical resolution

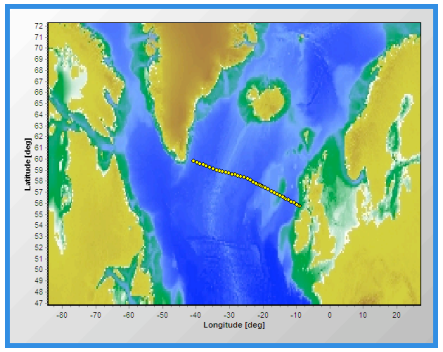
thicker z-levels

Thin z-levels



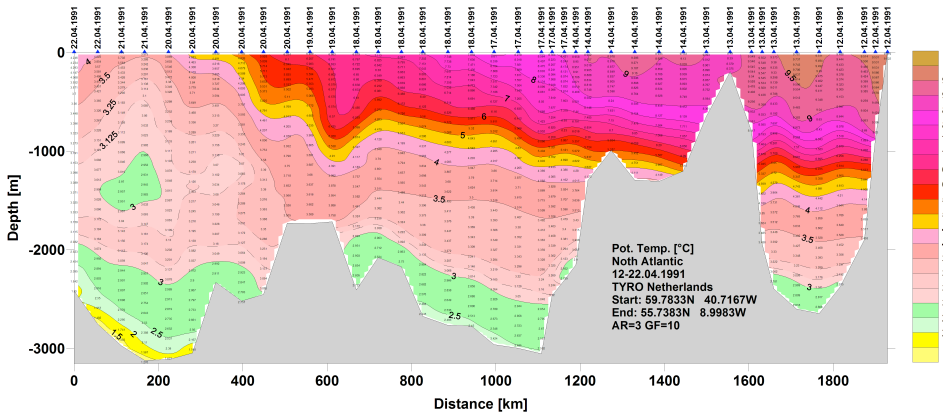
Thick z-levels

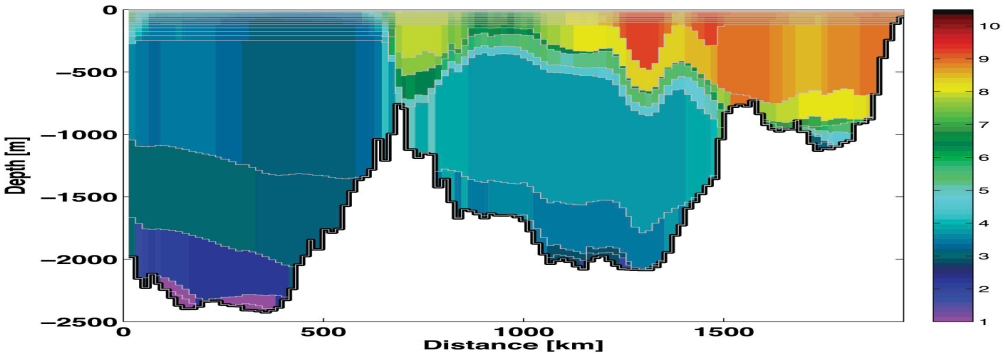




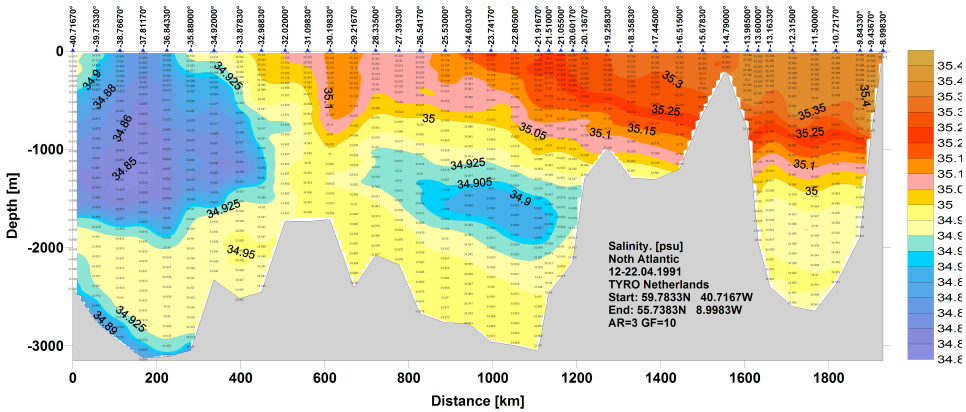
TOPAZ4 Validation
"North Atlantic"

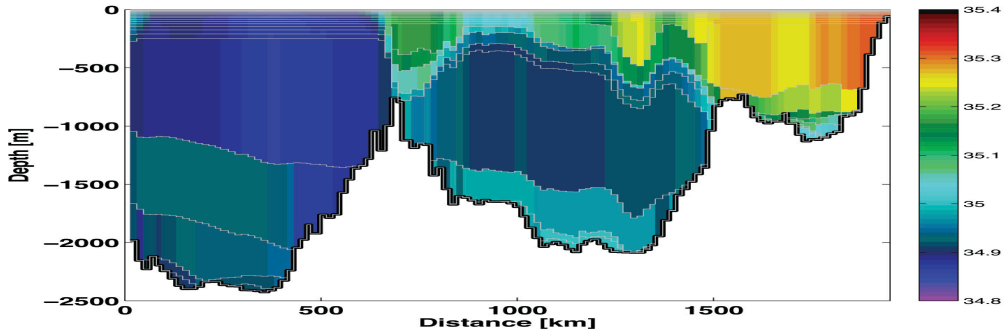
TEM





SAL





INTAS-Nansen-AARI database

CourtesyA. Korablev

TOPAZ4

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TOPAZ4-TOPAZ3

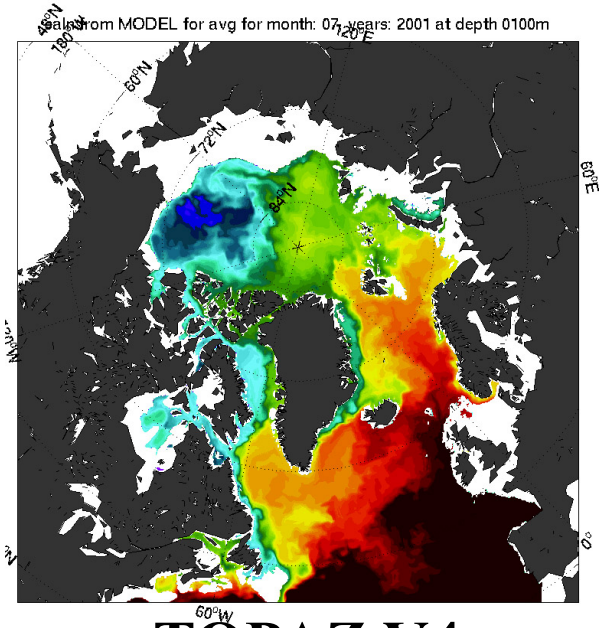
Surface Salinity, July

- **Improved transport of Atlantic Water**
- **Freshwater flux in Bering Strait (1.2 Sv)**
- **Corrected the saline bias in the Arctic,**
  - **But: Slight fresh bias**
  - **Too saline in the Labrador Sea**

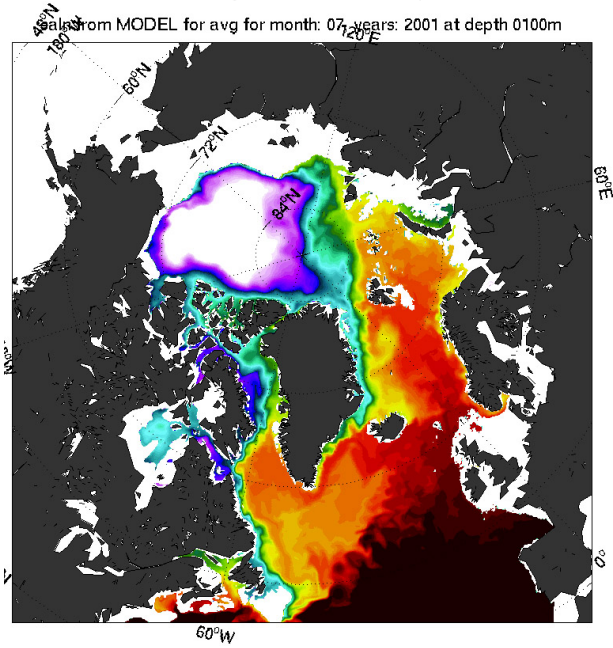
Solution:

- **reduce the flux in Bering Strait (0.8 Sv)**

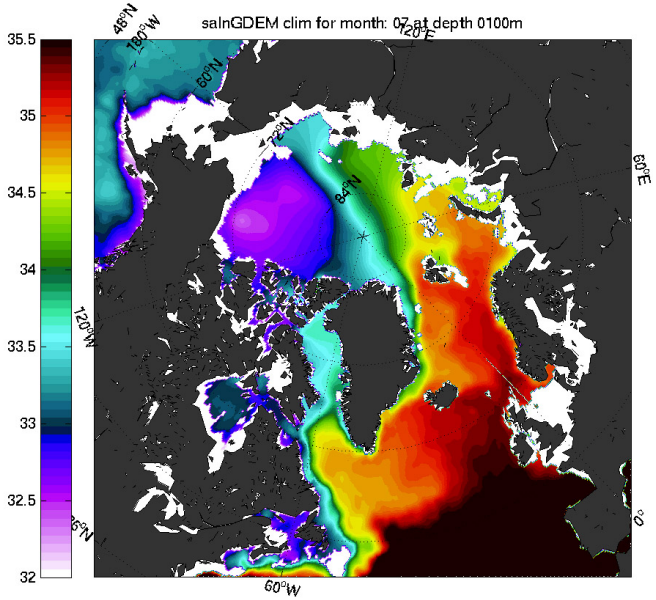
TOPAZ V3

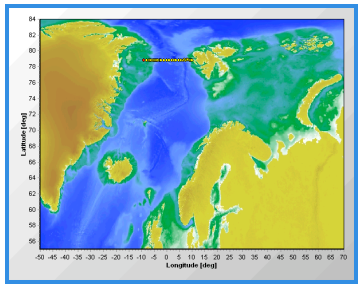


TOPAZ V4

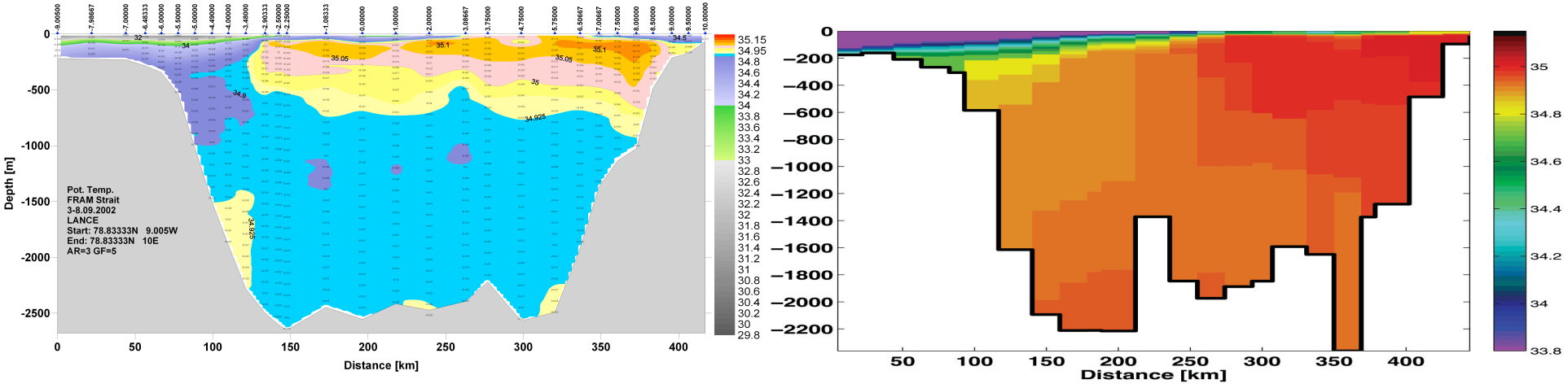


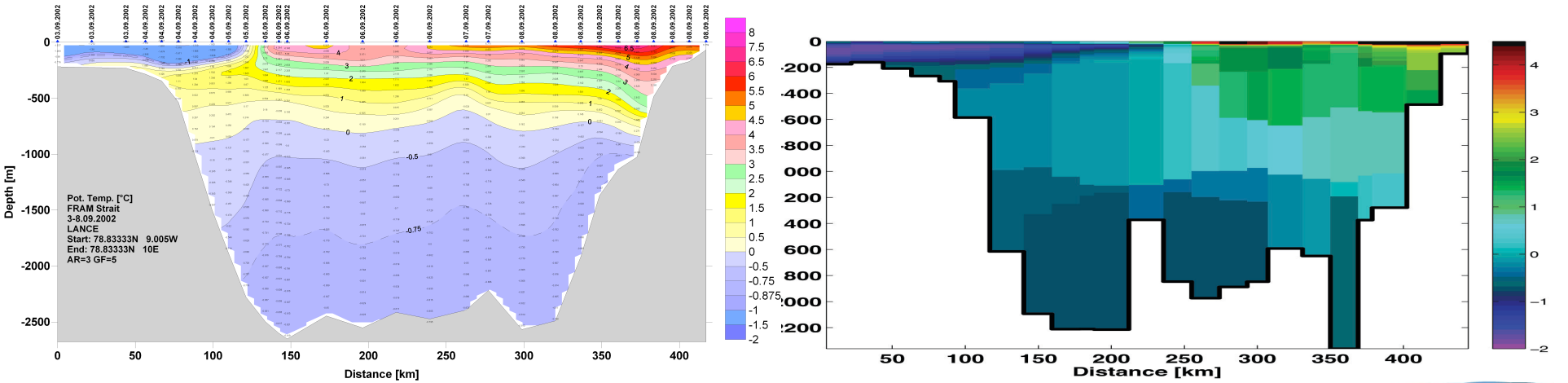
GDEM July





TOPAZ Validation
"Fram Straits"





INTAS-Nansen-AARI database
Courtesy A. Korablev

TOPAZ4

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TOPAZ4-TOPAZ3

Transport estimates

	TOPAZ3	TOPAZ4	Observed value	Positive is
Fram Straits (Net)	0.69 Sv	2.0 Sv	~2 Sv	Southwards
Bear Island (Net)	0.85 Sv	2.19 Sv	2.2-2.5 Sv	Eastwards
Nordic Sea **(Northwards)** (Iceland-Færoe-Shetland-Scotland)	7.68 Sv	7.76 Sv	7-8 Sv	Northwards

Improvement of the "critically important fluxes"

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TOPAZ System overview

The HYCOM model

Validation

Coordination with TOPAZ@met.no

Data Assimilation

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Things to share

- Visualisation
  - Comparisons TOPAZ@NERSC and TOPAZ@met.no
  - THREDDS/OPeNDAP clients
- Performance statistics
- Code:
  - concurrent upgrades, documentation
- User:
  - ECMWF operational wave forecast

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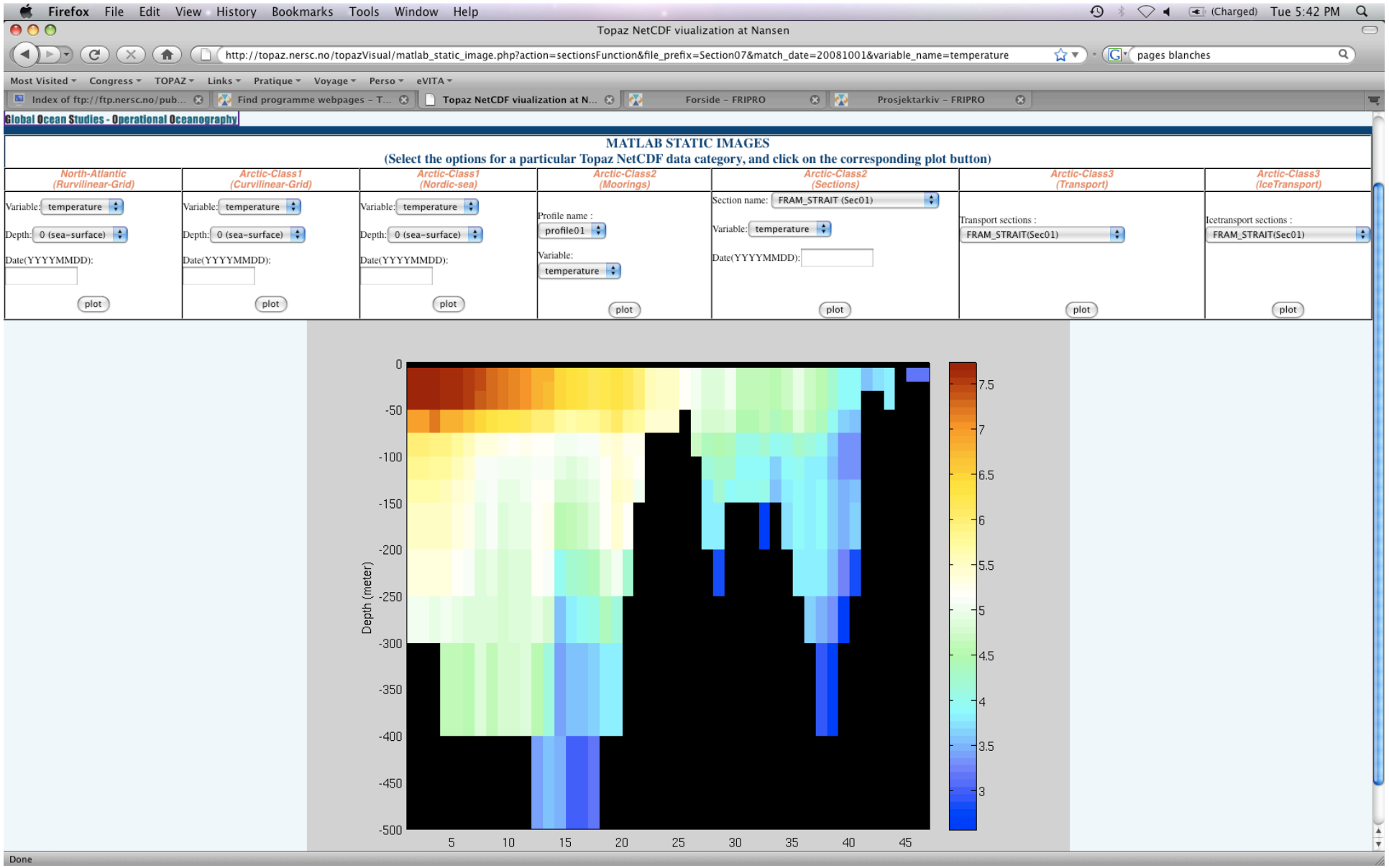
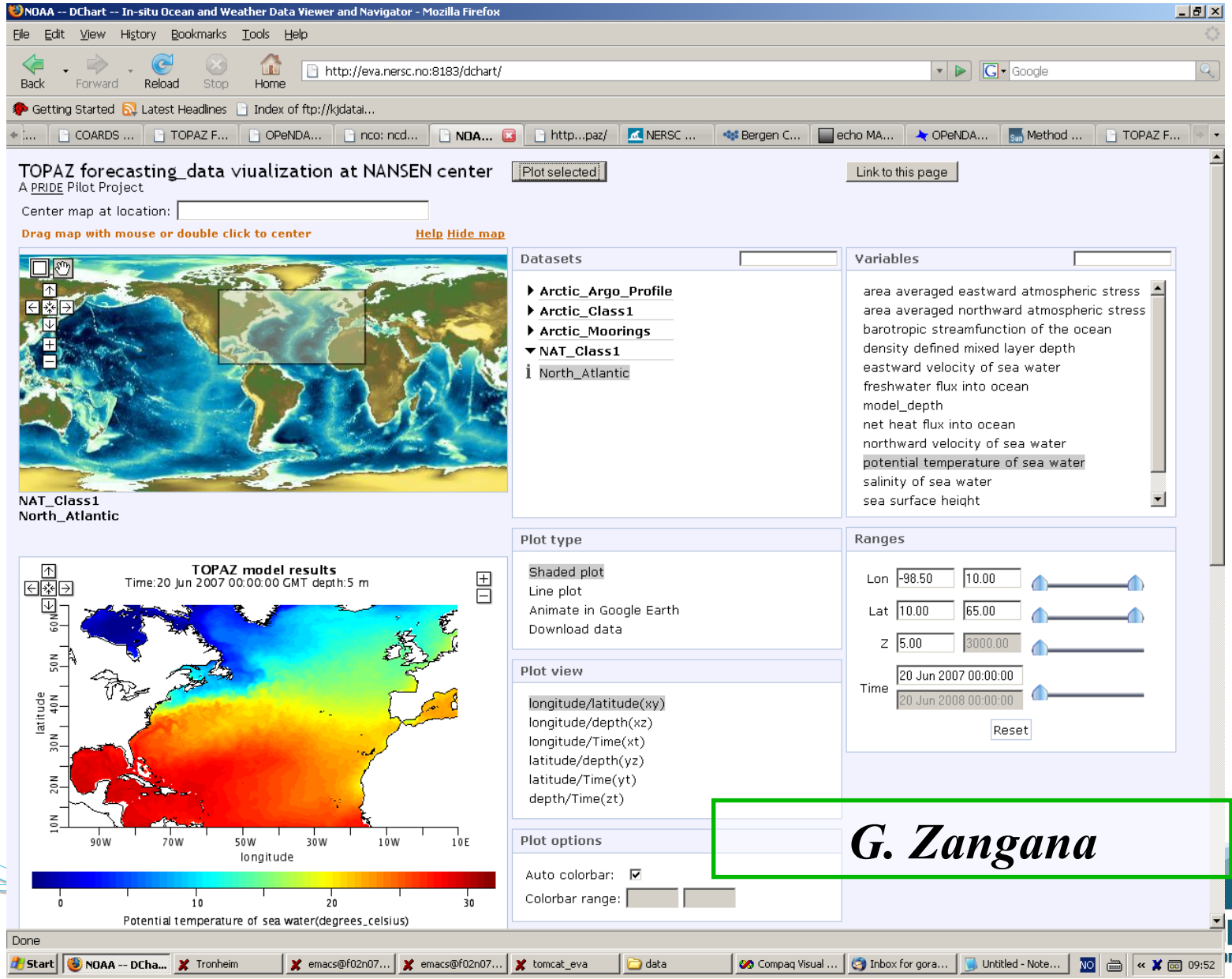
Visualization

http://topaz.nersc.no/topazVisual



OPeNDAP clients: DAPPER



G. Zangana

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Vertical Salinity and temperature profiles from TOPAZ

http://topaz.nersc.no/Knut/Test/profiles.php

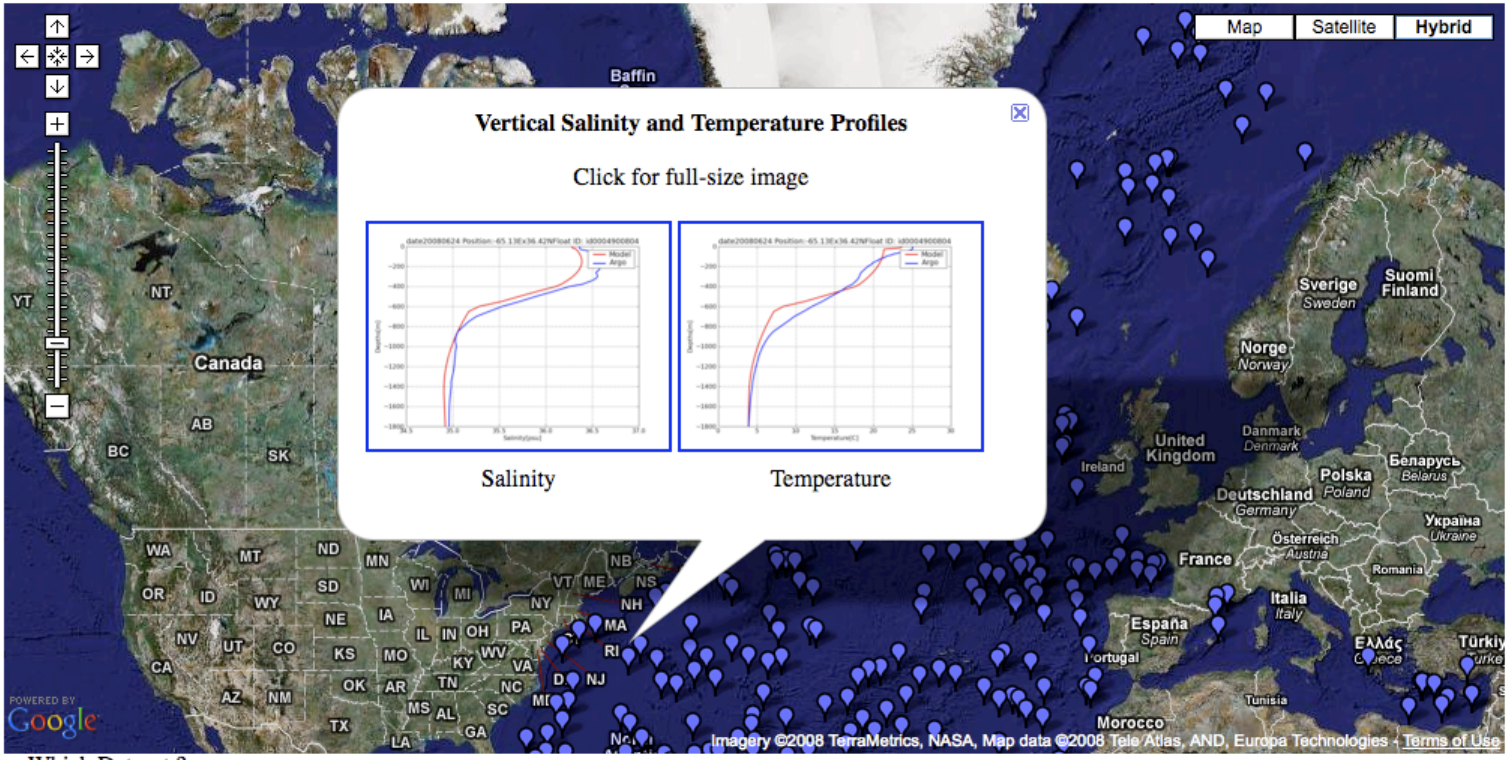
screenshot mac

Most Visited Radios Blogs Kultur Bands Pratique Copains Bank

Vertical Salinity and temperatur... Taking Screenshots in Mac OS ...

Vertical temperature and salinity profiles from TOPAZ

Profiles are based on model data from the TOPAZ model system and from in situ profiles of salinity and temperature acquired from Coriolis. Click on the place mark in the map to get images of the profiles. Map is powered by Google Maps.



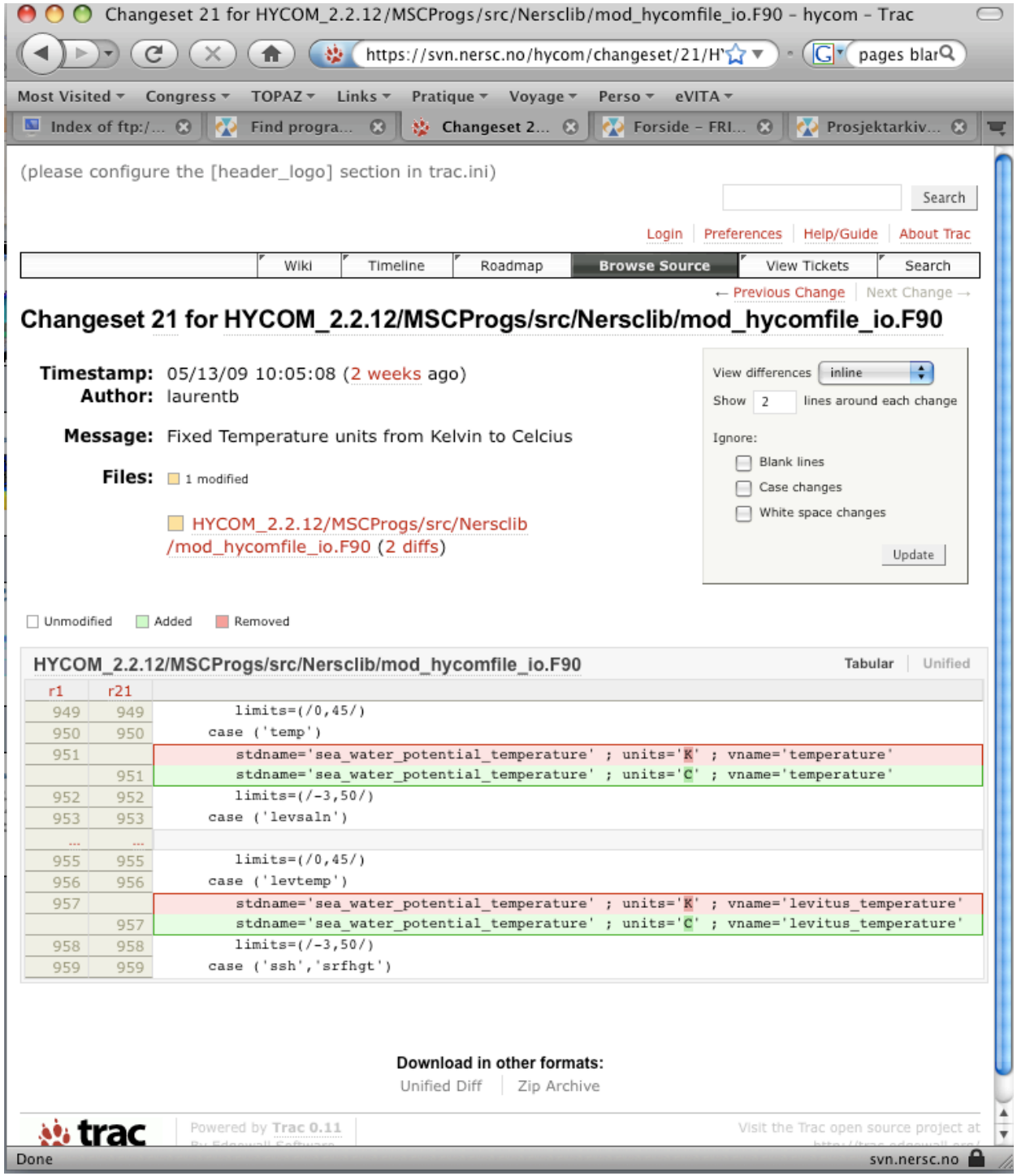
Which Dataset ?

- TOPAZ3_20080618
- TOPAZ3_20080625
- TOPAZ3_20080702
- TOPAZ3_20080709
- TOPAZ3_20080716
- TOPAZ3_20080723
- TOPAZ3_20080730
- TOPAZ3_20080806
- TOPAZ3_20080813
- TOPAZ3_20080820
- TOPAZ3_20080827

Online comparison to Argo profiles

Subversion:

HYCOM code sharing



Wave modelling at ECMWF
(J. Bidlot)

- TOPAZ surface currents in ECMWF wave model
  - Hs: Small improvement of scatter index
  - Larger improvement for peak periods
  - But biases are slightly more negative
- ECMWF has decided to use TOPAZ for operations
- One output script to pass to met.no

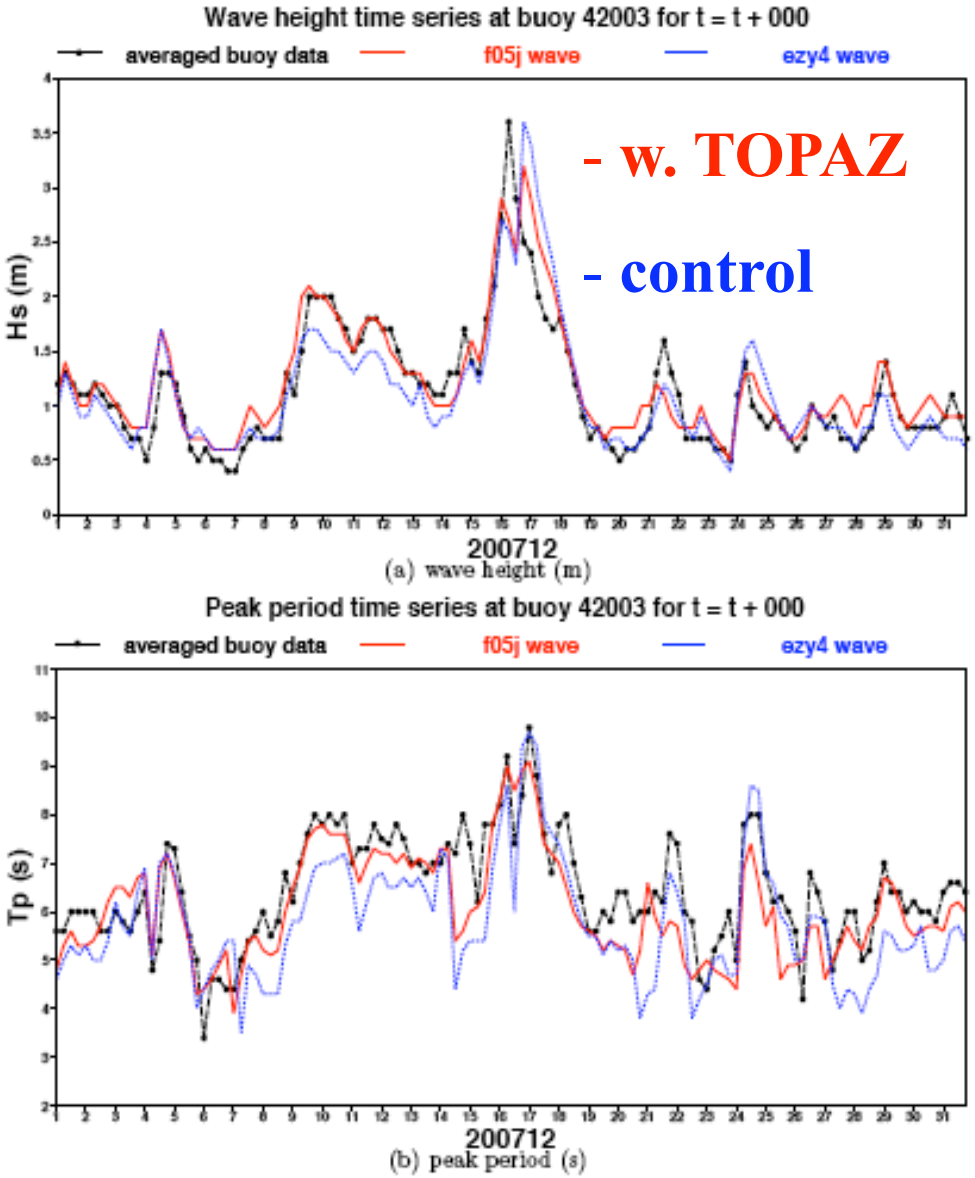


Figure 6: Wave height and peak period time series at buoy 42003 (East Gulf) for December 2007. The solid red line (f05j) is the run with currents and the dash blue line (ezy4) is the reference experiment.

TOPAZ System overview

The HYCOM model

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Data Assimilation

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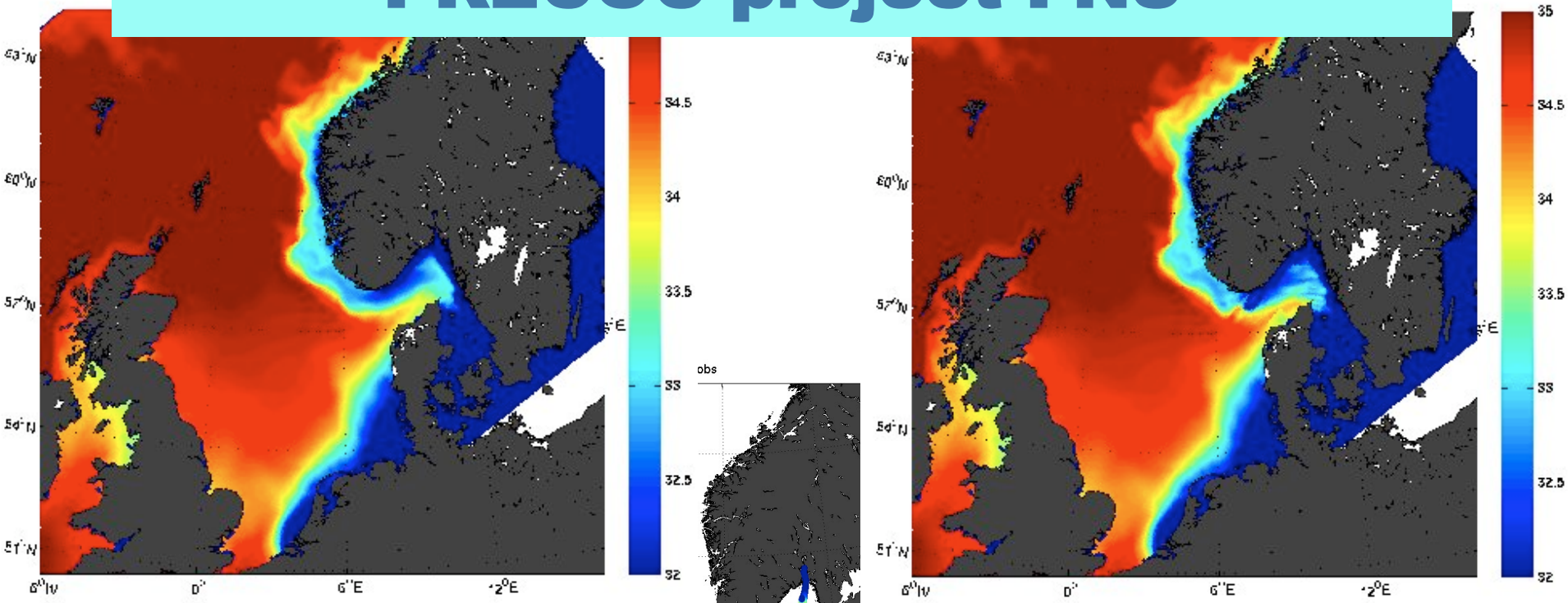
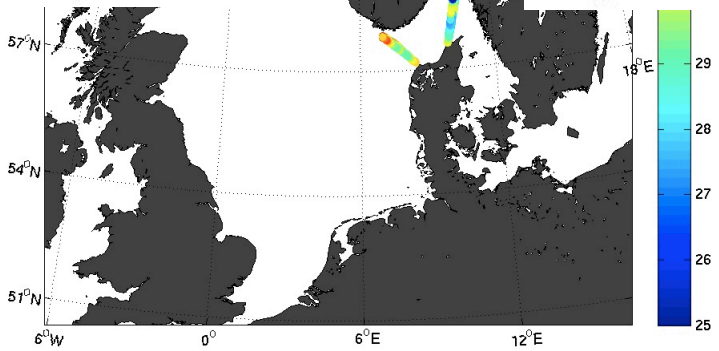
Assimilation of Ferrybox data
PRECOC project FNS



CONMAN SSS Before assimilation



Ferrybox SSS

CONMAN SSS After assimilation

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Assimilation of Ocean Color in HYCOM-NORWECOM

Data:

Satellite Ocean Color (SeaWIFS)

Coupled Model:

HYCOM-NORWECOM

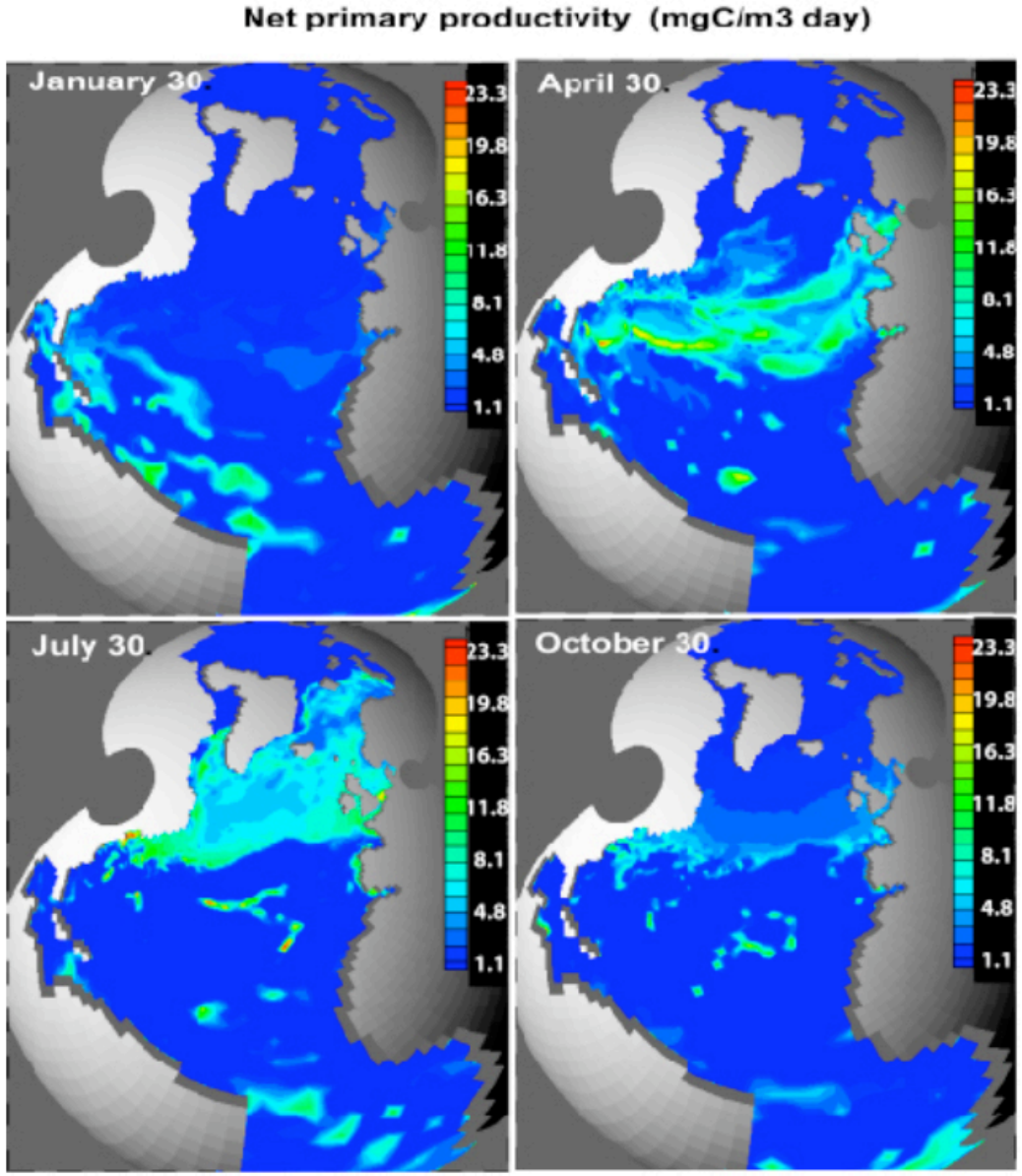
(7 compartments)

Problems:

- Coupled 3-dimensional physical-biological model.
- High-dimension.
- Non-Gaussian variables.

Perspectives:

- Environment monitoring.
- Fisheries.
- Methodological developments for future coastal HR systems.

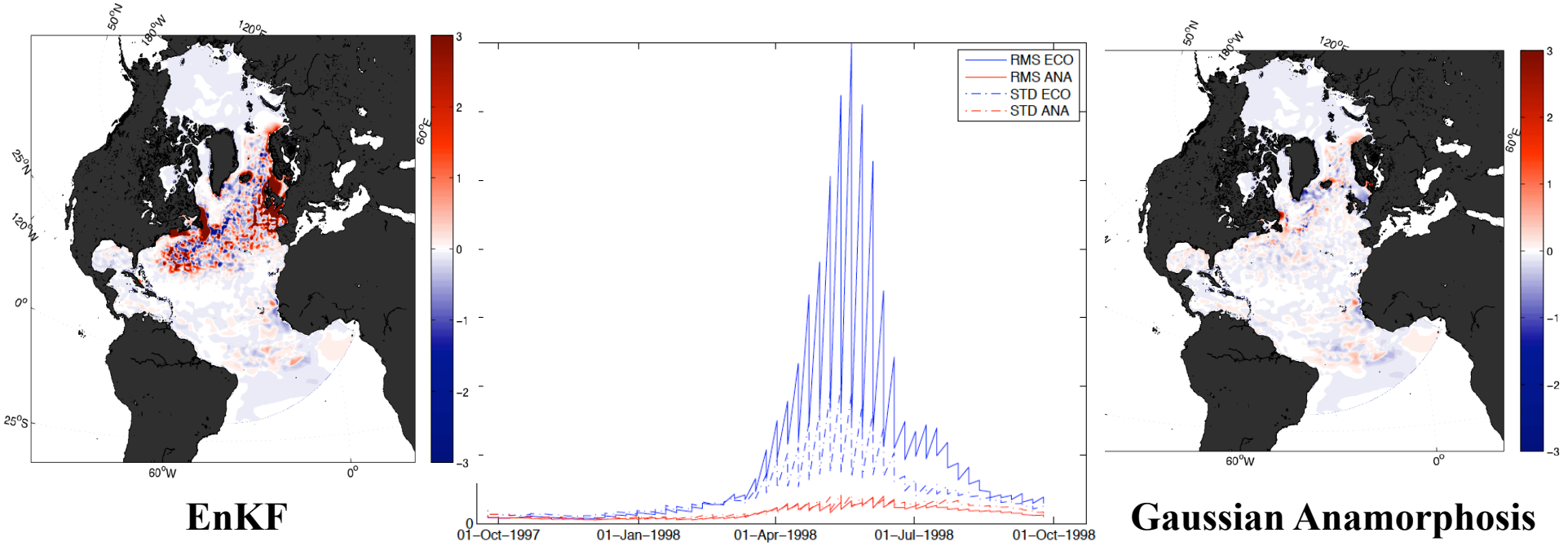


Gaussian anamorphosis with the EnKF

Anamorphosis: prior transformation of the variables in a Gaussian space (*Bertino et al. 2003*)

Twin experiments (surface chlorophyll-a synthetic observations)

Surface CHLa RMS error



EnKF
Cut-off of neg. values

Gaussian Anamorphosis
EnKF

Simon &Bertino (OSD, 2009)

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Conclusion

- First runs of TOPAZ4 showed some improvements (ice, inflow of Atlantic Water, front sharpness) but can take some more tuning
- A 20 year reanalysis of TOPAZ4 is underway, with (EnKF) assimilation of satellite and in-situ data (INTAS database)
- Assimilation of Ocean Color = encouraging, tested in a realistic application.
- Collaborative developments of TOPAZ:
  - Avoid code divergence with Subversion repository
  - Re-organize the code and auxiliaries with HYCOM2.2
- Similar systems are getting set up for China, India, South Africa

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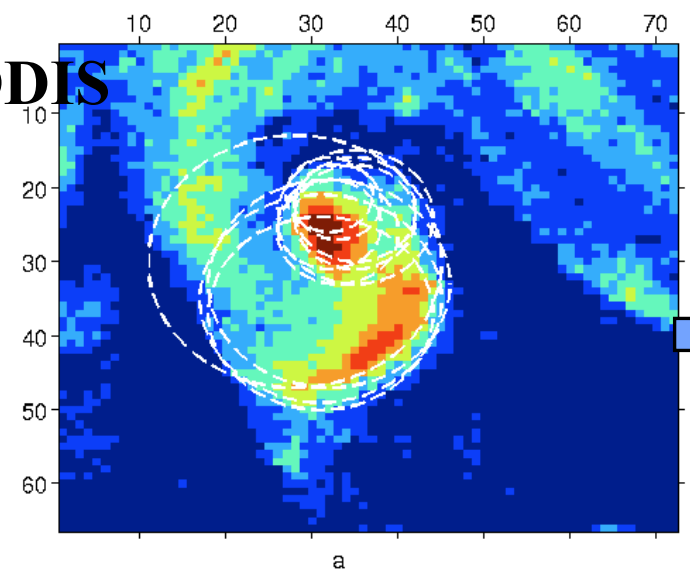
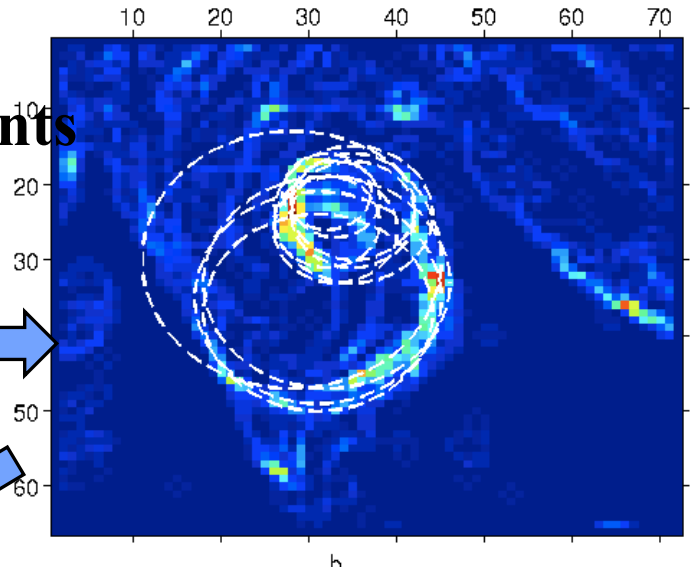
Circlets: eddy detection

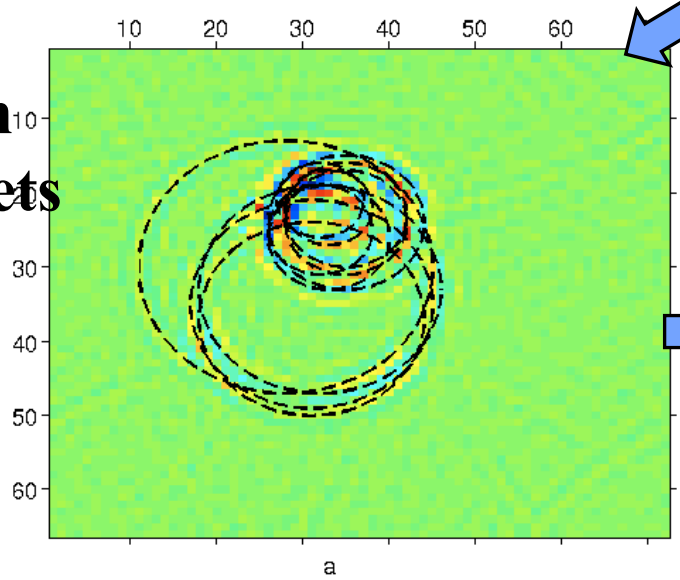
MODIS OC



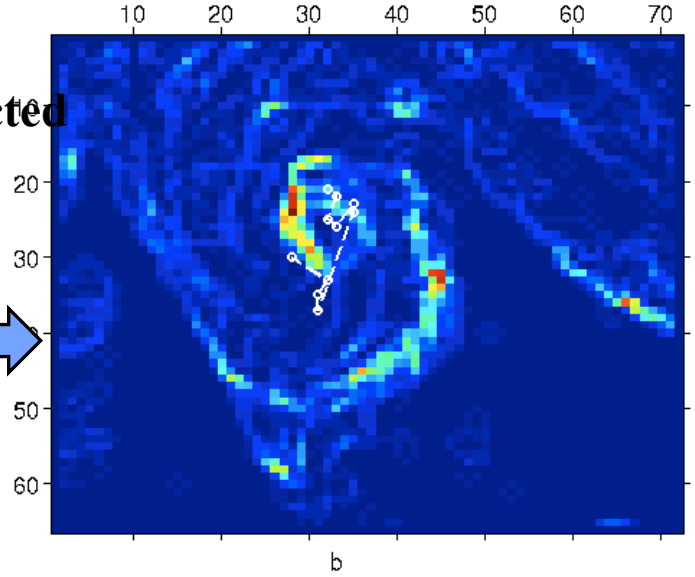
Gradients



Main circlets



Reconstructed gradients



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MyOcean

European project 2009-2012

Lead by Mercator Ocean

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Market Segmentation

- MyOcean will *"provide the common denominator data for **all users in the marine sector**, in other words the information for existing & new downstream services."*

Area 1
« MARINE SAFETY »
(marine operations, oil spill combat, ship routing, defense, search & rescue, …)

Area 3
« MARINE AND COASTAL ENVIRONMENT »
(water quality, pollution, coastal activities, …)

Area 2
« MARINE RESOURCES »
(fish stock management, ICES, FAO, …)

Area 4
« CLIMATE & SEASONAL FORECASTING »
(climate monitoring, ice, seasonal forecasting, ..)

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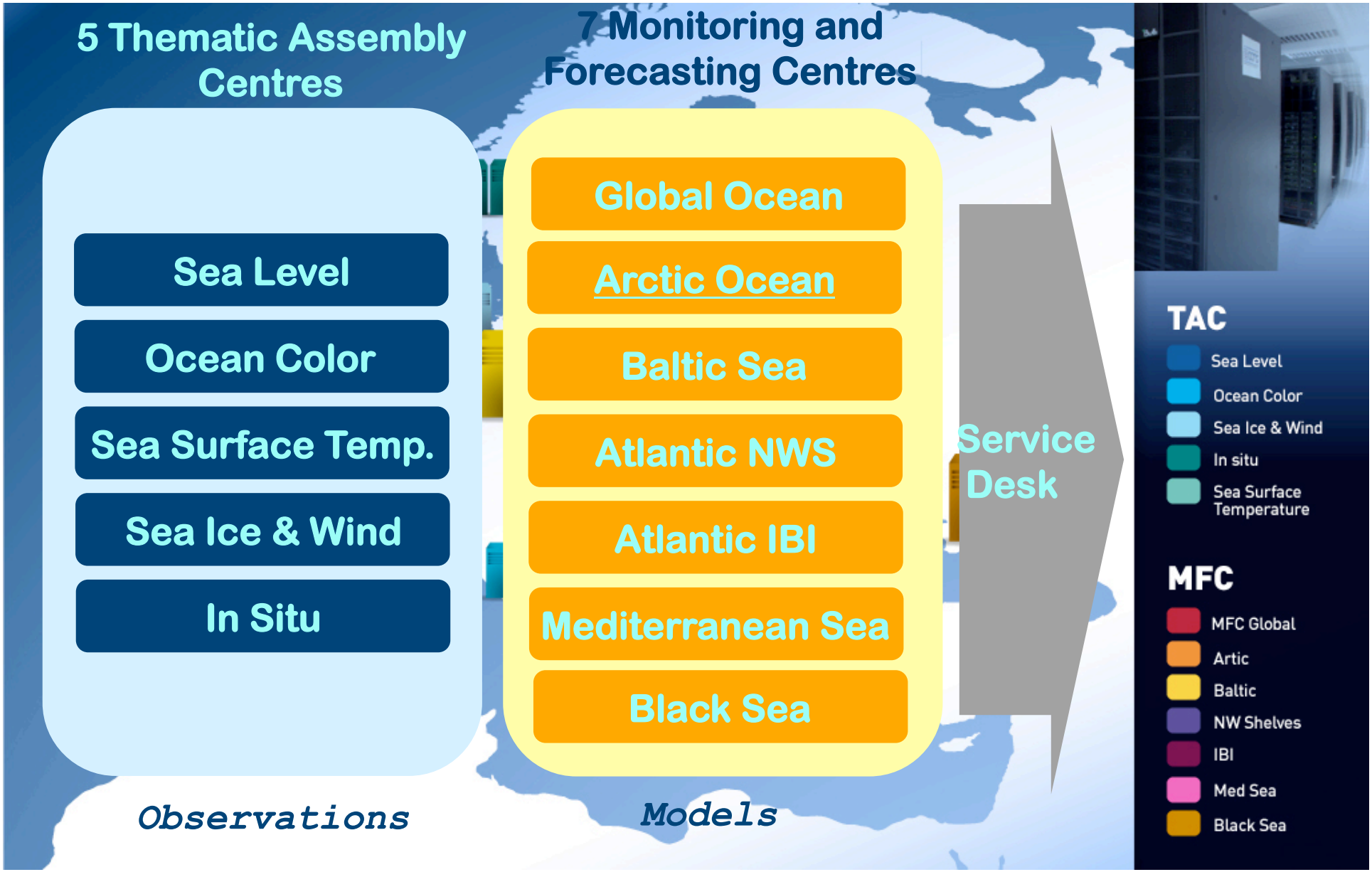
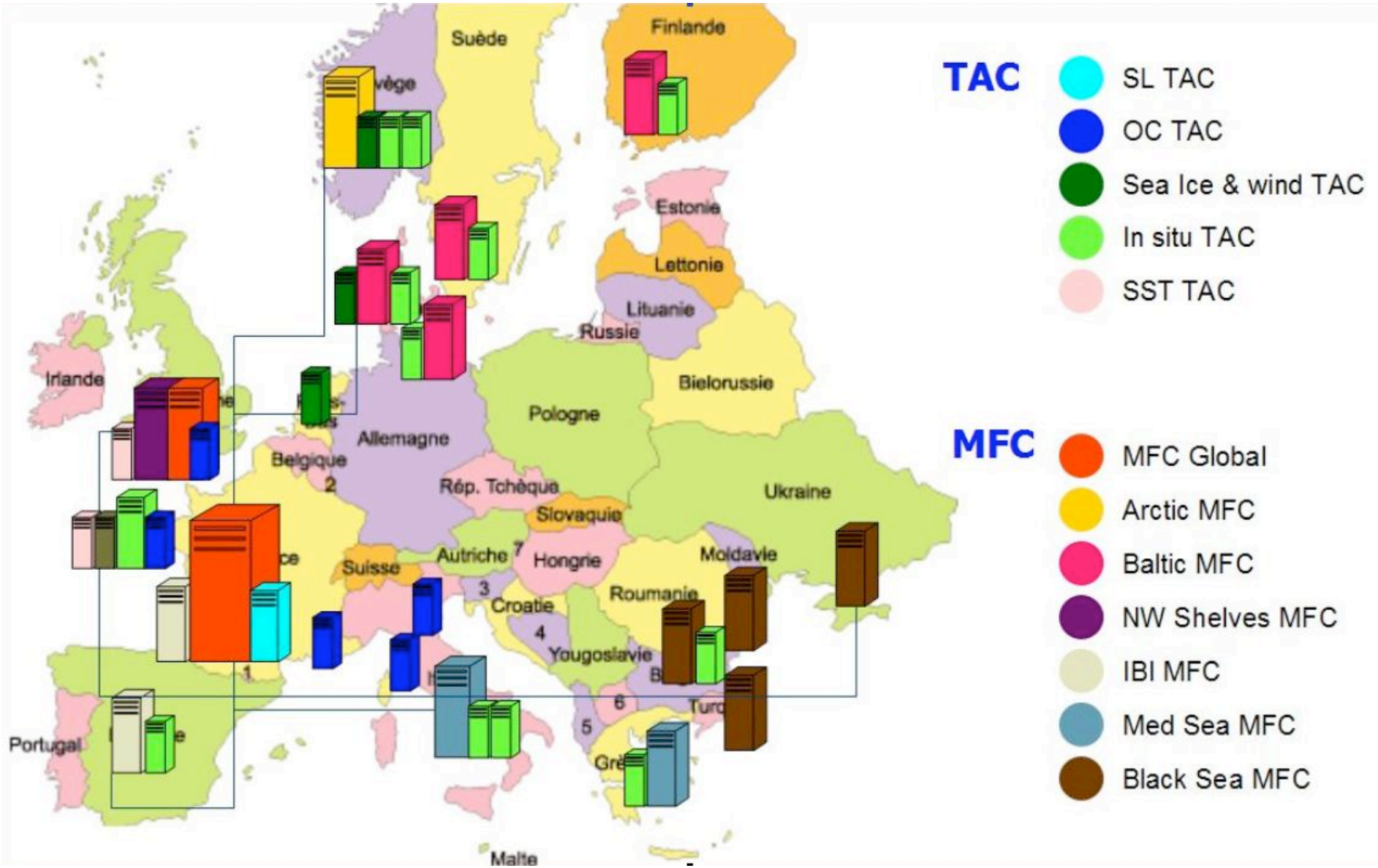
The Production Units

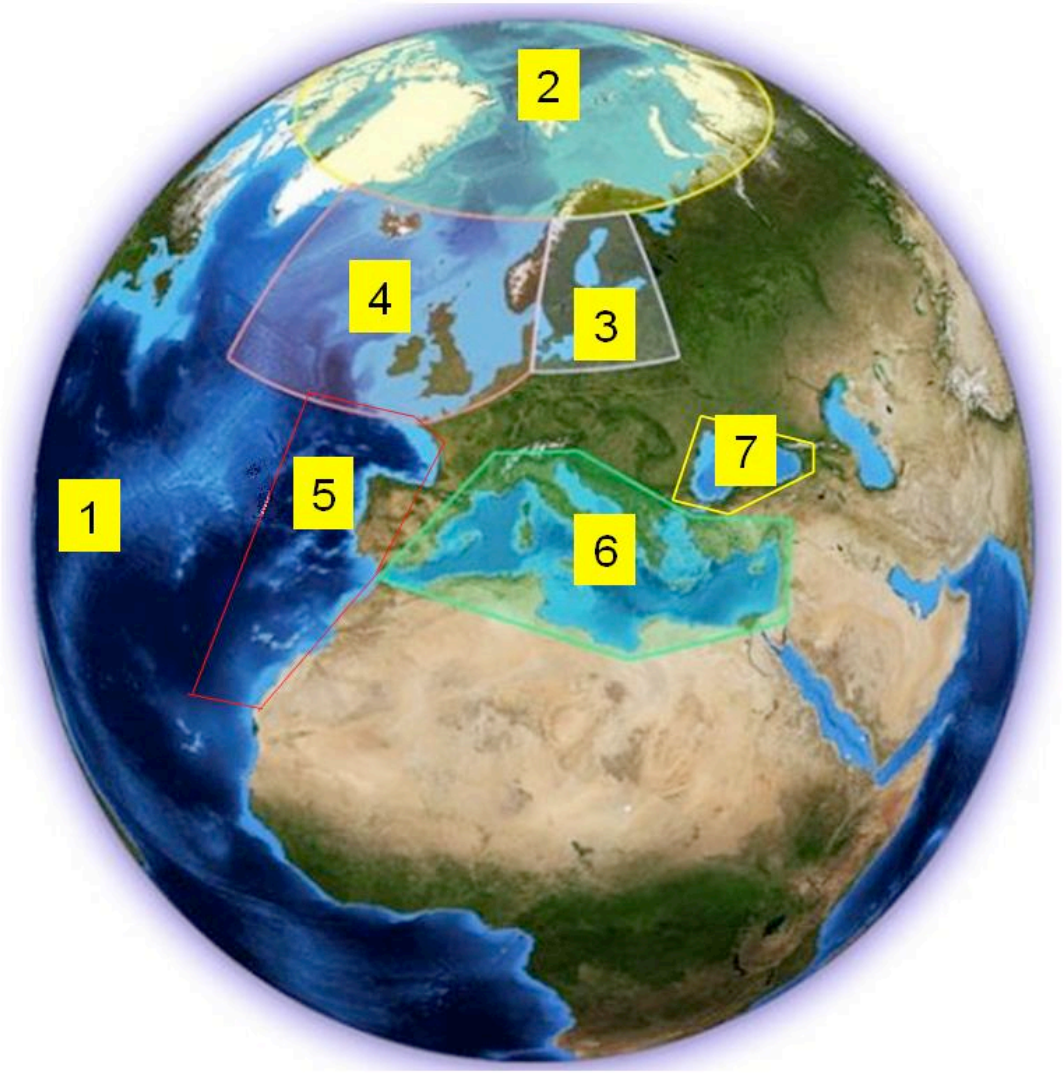


System organization
12 production units



The MyOcean value

6 European Seas + Global Ocean



- 1. Global
- 2. Arctic
- 3. Baltic
- 4. NWS
- 5. IBI
- 6. Med Sea
- 7. Black Sea

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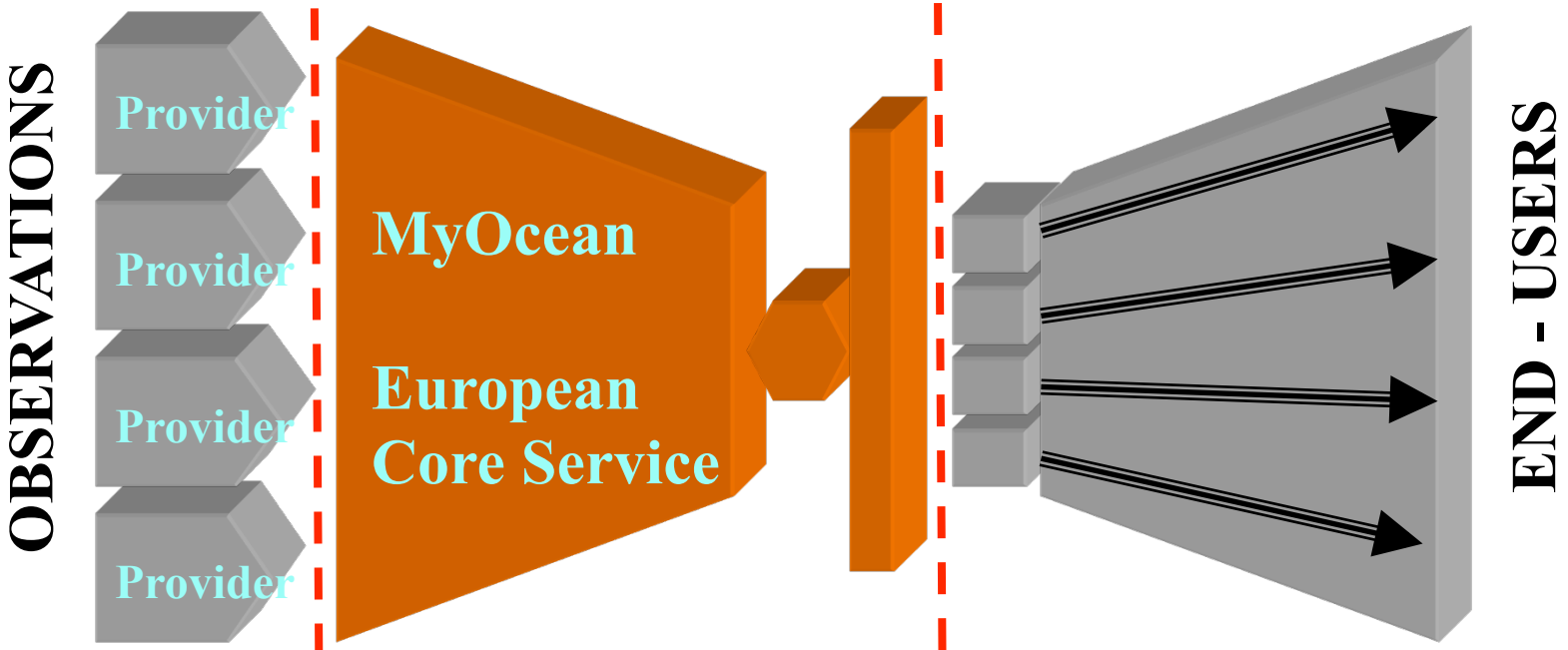
Scope of responsibility



The upstream cut-off

The downstream cut-off

upstream to our service

... is done (duty) by an observation agency or center (raw data)
Example : Eumetsat SAF
or the ESA PAC

Data, Model
European added-value

downstream to our service:
... is done (duty), or will be better done (skill) by a specialized agency, a European agency or a national center ; usually already in place
Example : COASTAL SYSTEMS