

# Current TOPAZ developments

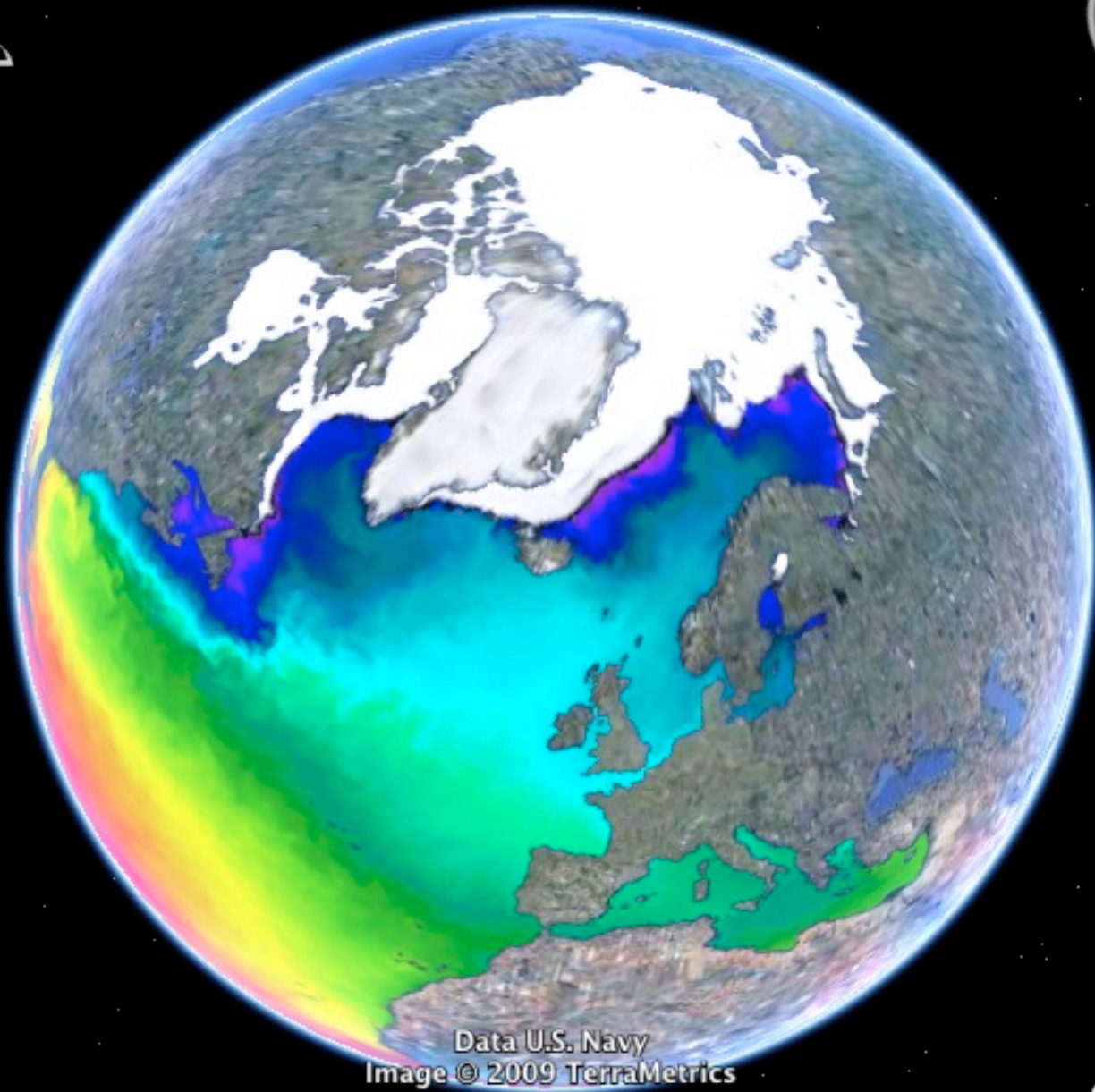
L. Bertino, F. Counillon

Mohn-Sverdrup Center/NERSC



*Opnet workshop, Geilo, 27<sup>th</sup> May 2009*





Data U.S. Navy  
Image © 2009 TerraMetrics

©2009 Google



op Center  
nal Oceanography



65°21'50.89" N 17°02'39.44" W

Eye alt 5947.31 mi



# 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



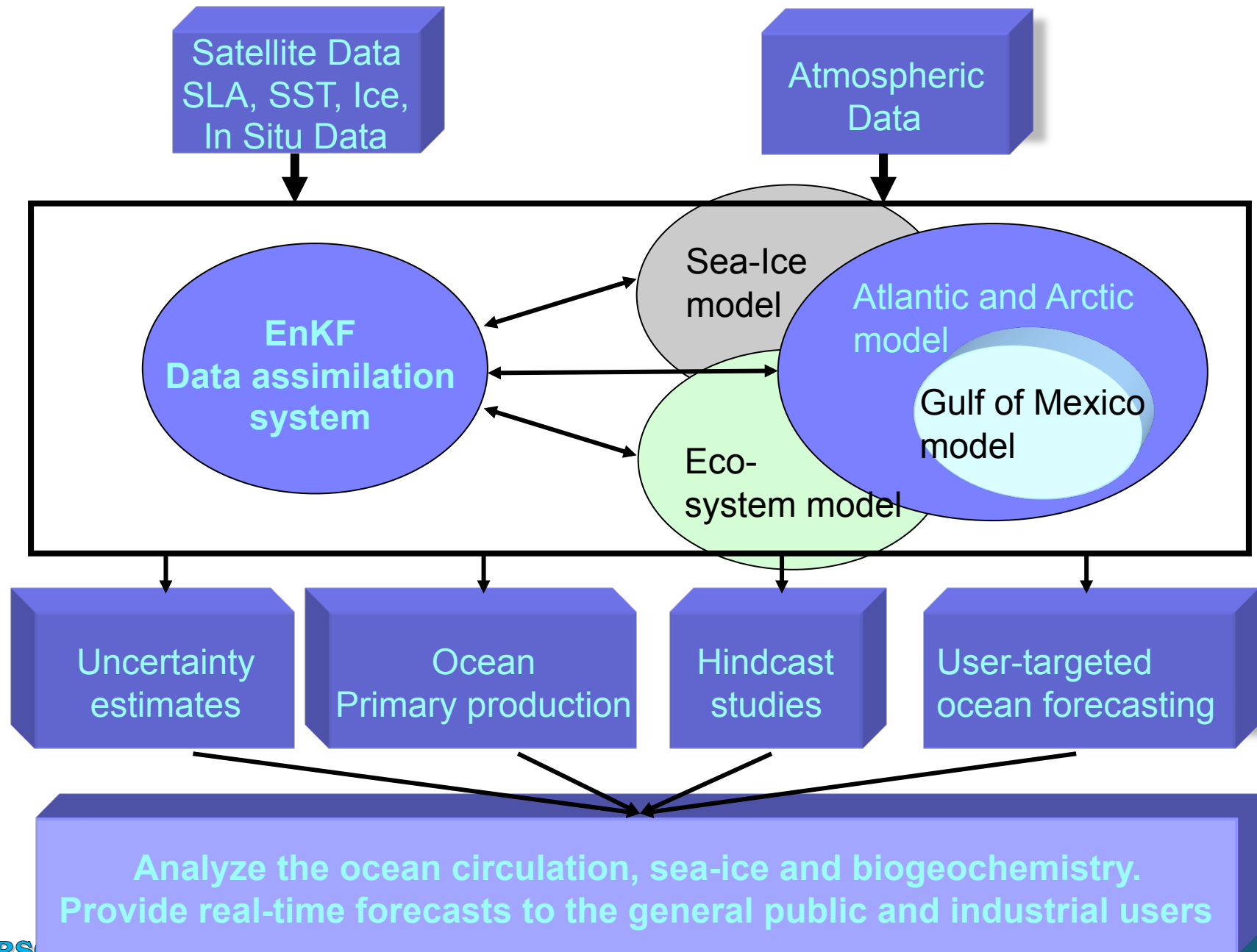
# Motivation

- 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





# The TOPAZ model system

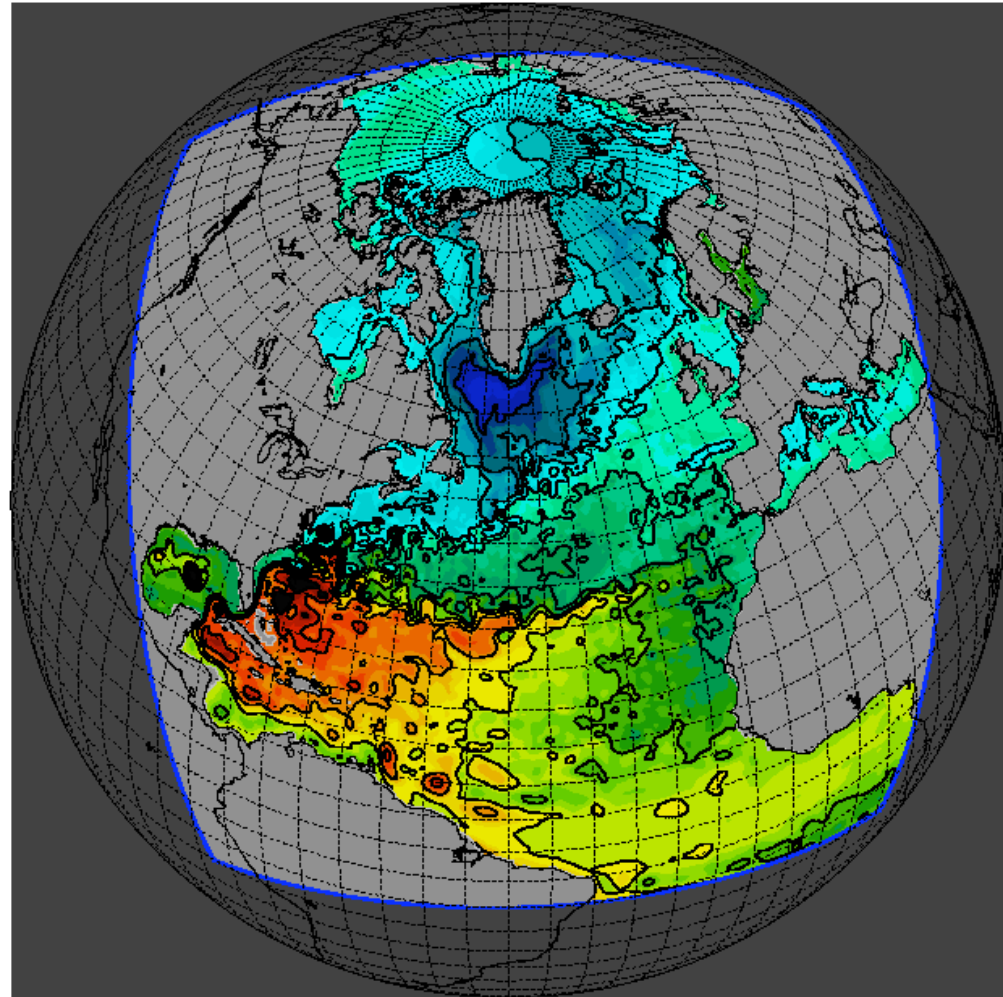
- TOPAZ3: Atlantic and Arctic
  - HYCOM + EVP sea-ice model
  - 11- 16 km horizontal resolution
  - 22 hybrid layers
- EnKF
  - 100 members
- Observations
  - Sea Level Anomalies (CLS)
  - Sea Surface Temperatures (NOAA)
  - **Sea Ice Concentr. (AMSR, NSIDC)**
  - Sea ice drift (CERSAT)
  - **Argo T/S profiles (Coriolis)**
- Runs weekly, 10 days forecasts
  - ECMWF forcing

NERSC



<http://topaz.nersc.no/thredds>

■ <http://thredds.met.no> (MERSEA...)



# TOPAZ System overview

The HYCOM model upgrade

Validation of TOPAZ

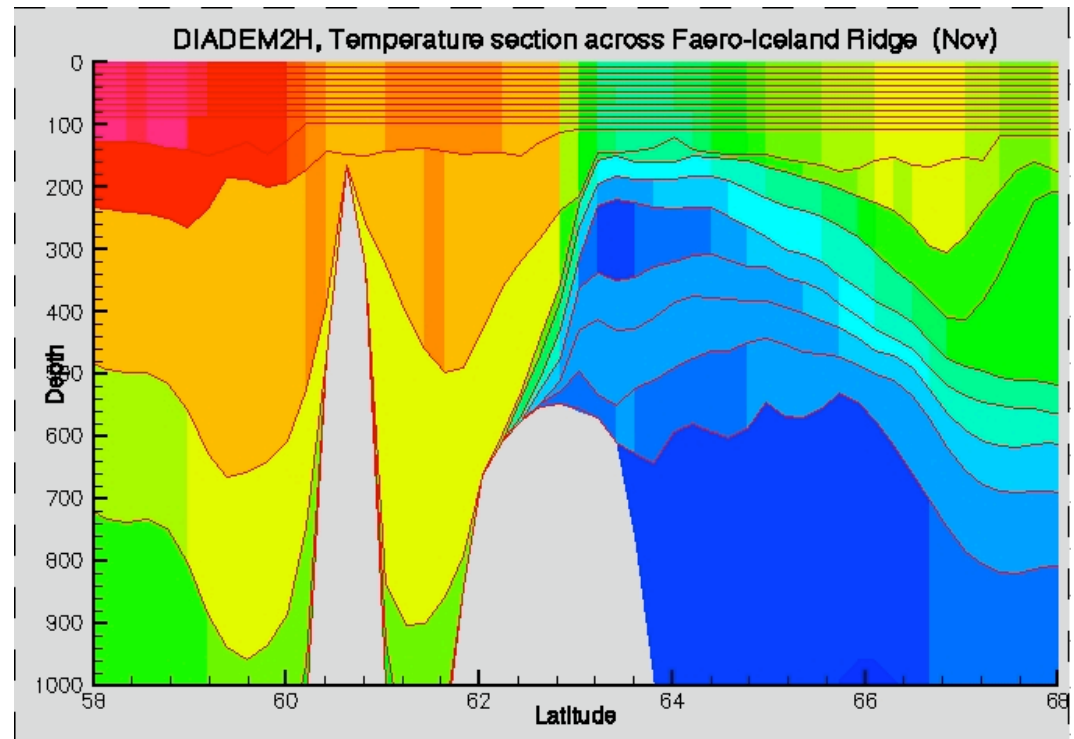
Coordination with TOPAZ@met.no

Data Assimilation



# 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



NERSC Ecosystem models

- Large community (<http://www.hycom.org>)



# 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)



# 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

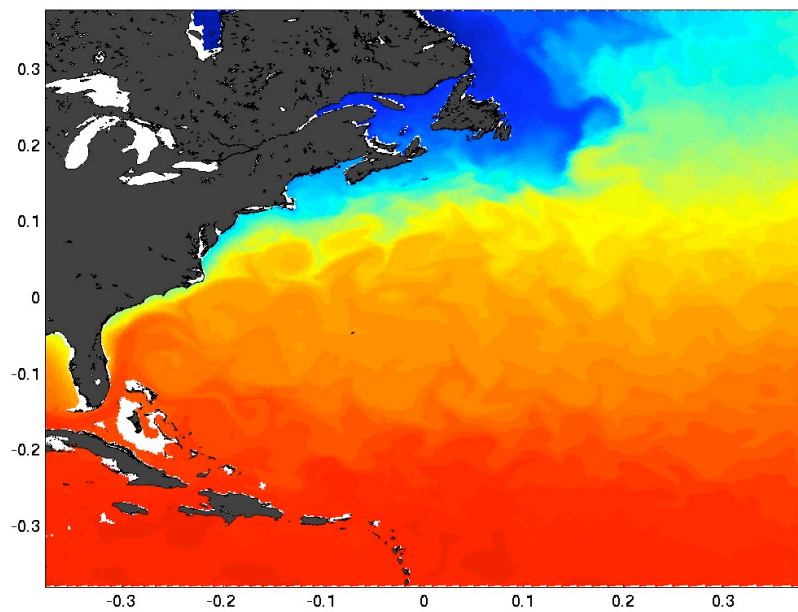
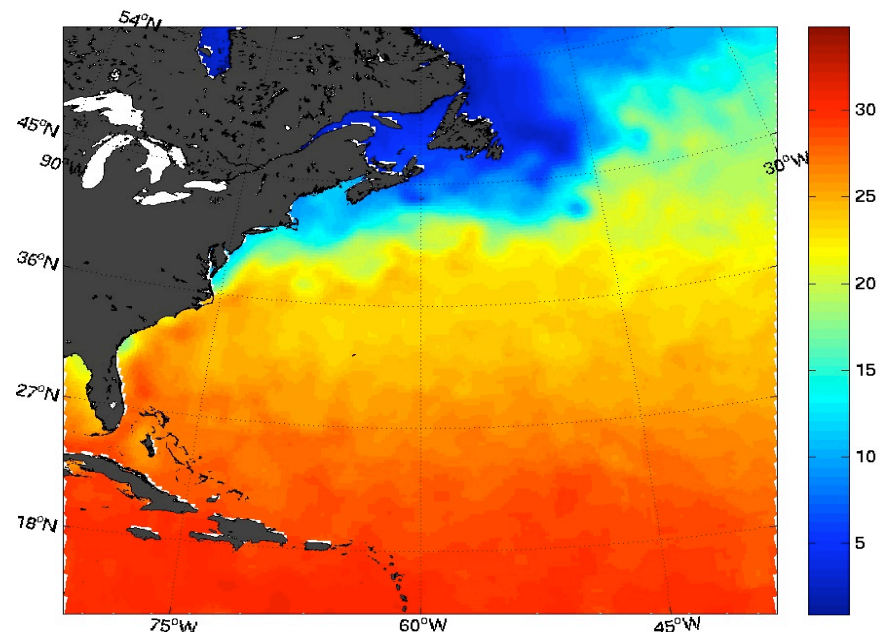


# Effect of the upgrade

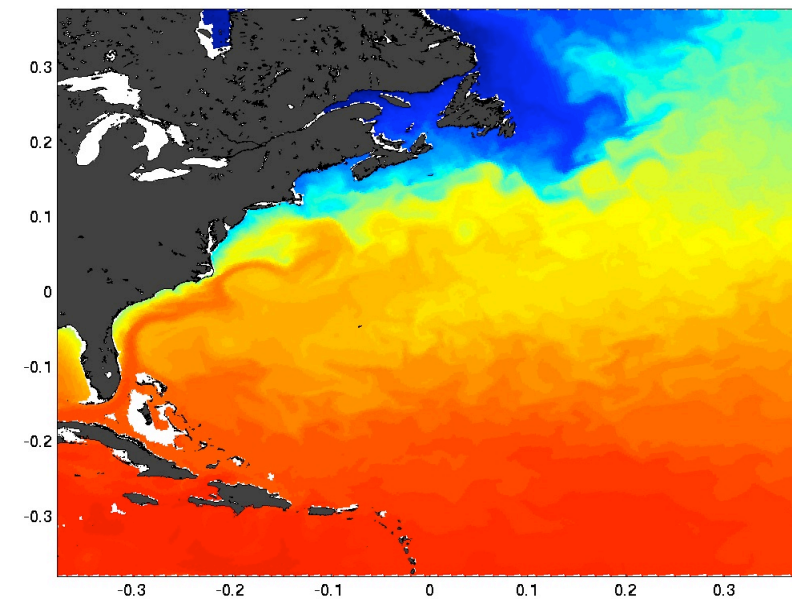
*Weekly SST in Dec. 1999, free run*

AVHRR

L4 SST



TOPAZ3



TOPAZ4

**Mohn-Sverdrup Center**  
Global Ocean Studies - Operational Oceanography

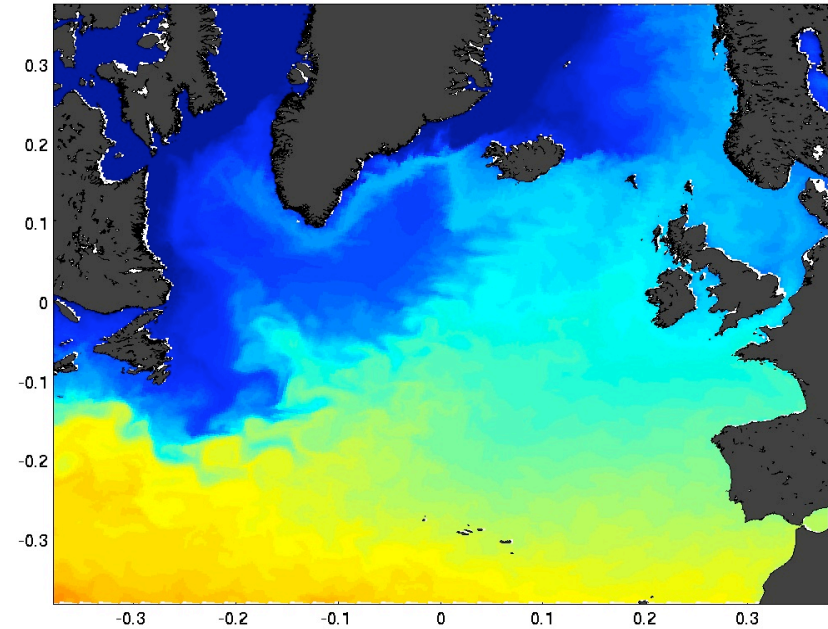
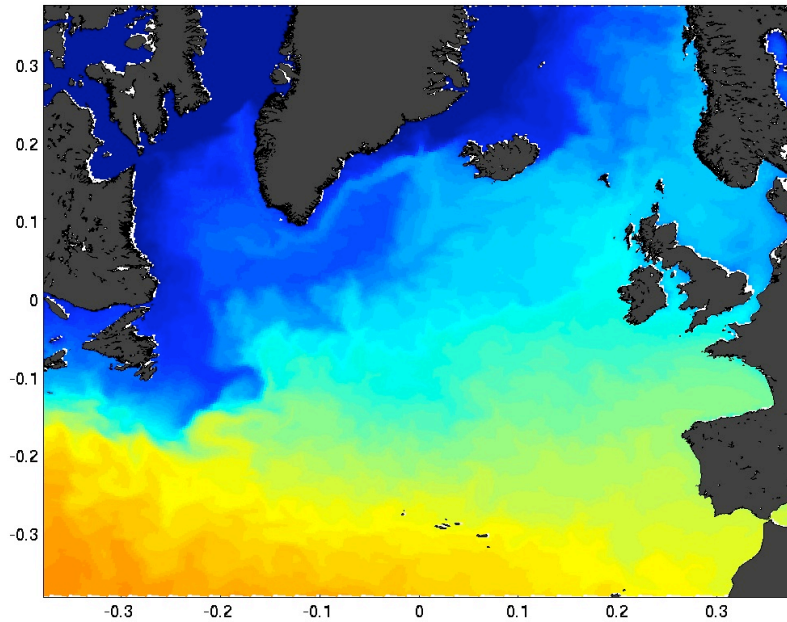
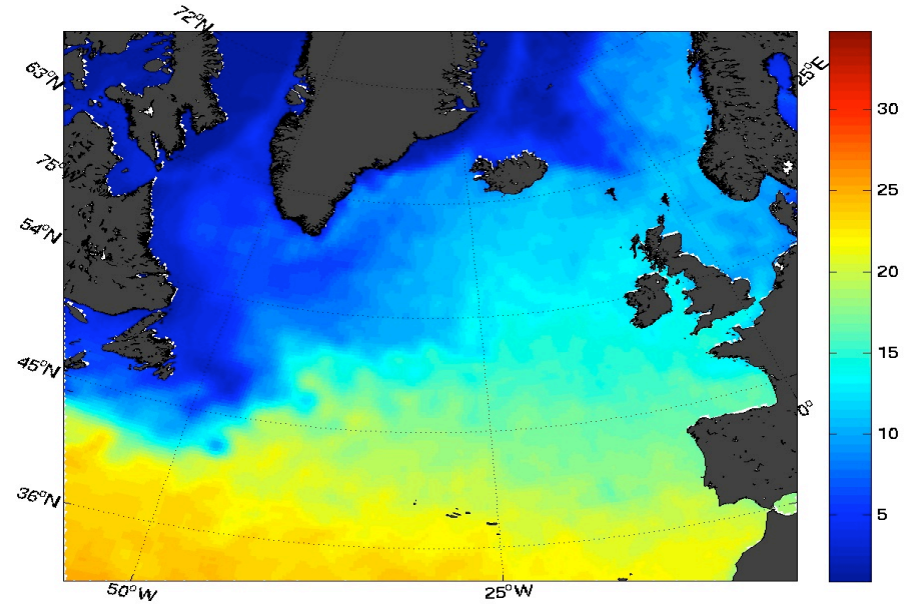


# Effect of the upgrade

*Weekly SST in Dec. 1999,  
free run*

AVHRR

L4 SST



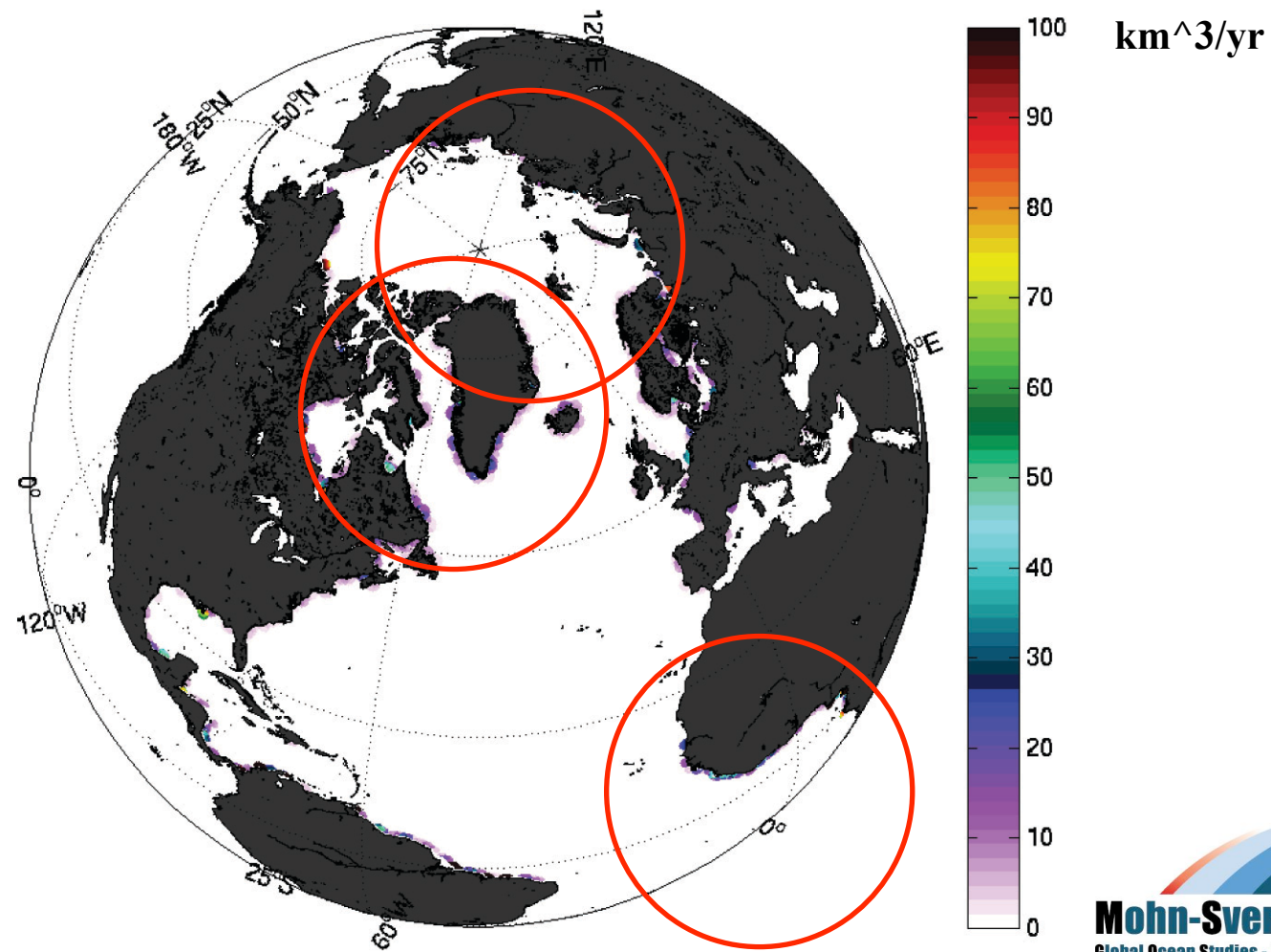
TOPAZ3

TOPAZ4 Mohn-Sverdrup Center  
Global Ocean Studies - Operational Oceanography



# River run-offs: diagnosed from ECMWF data

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



# 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:
  - $(f_{ice}, h_{ice}, temp\_profile * nb\_ice\_layers) * n\_categories + albedo, q_{brine}$

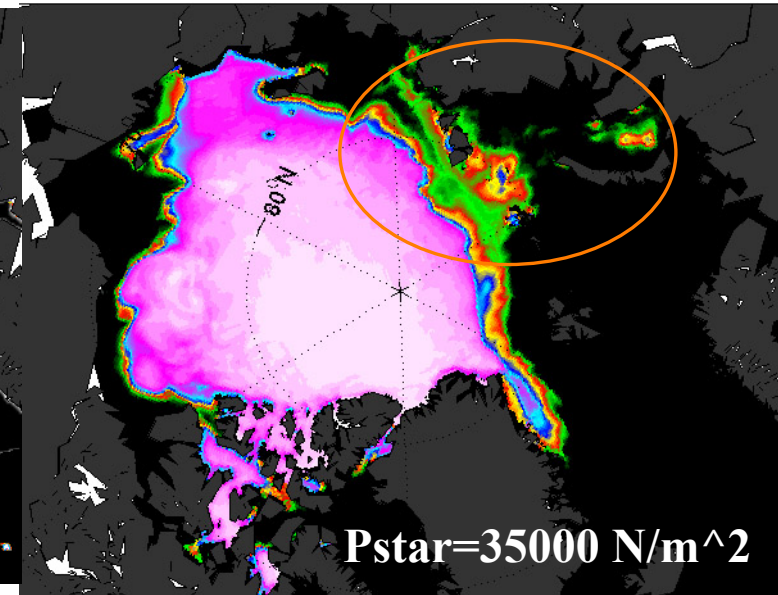
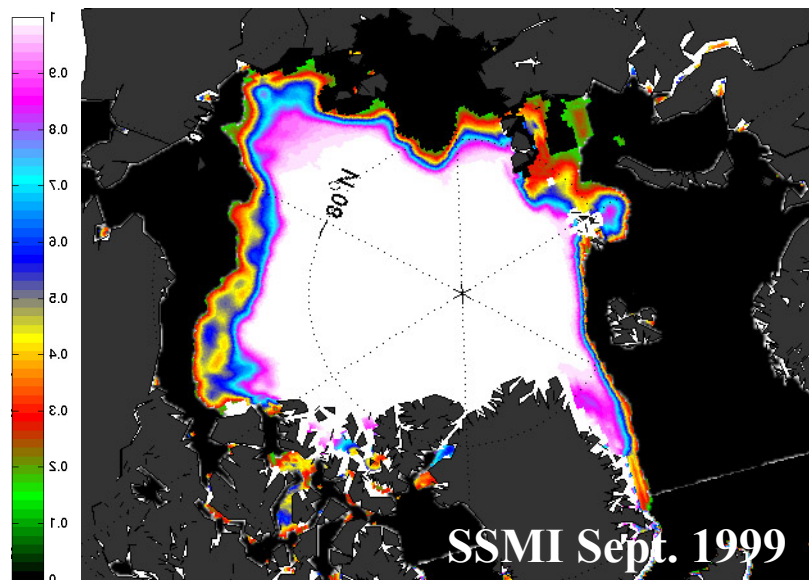
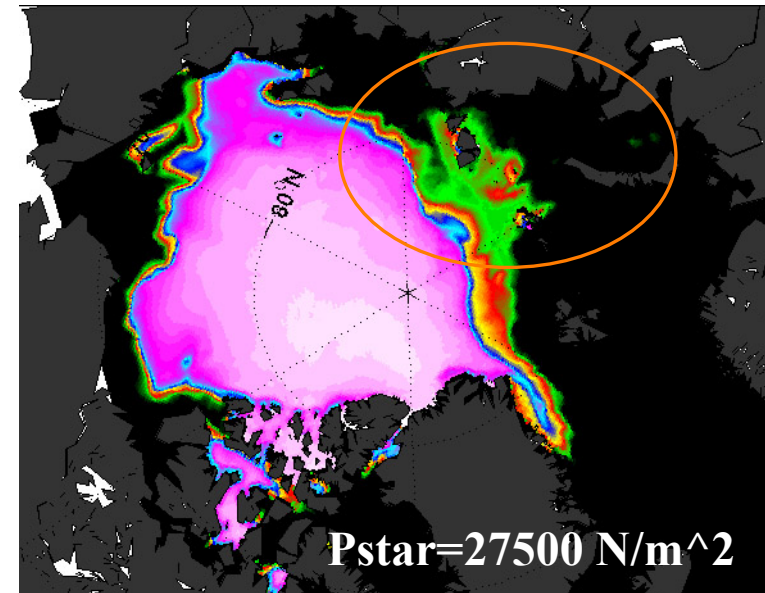


# Sensitivity to Sea ice strength ( $p^*$ )

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

Test: Free run

- little difference in winter
- ice holds longer in summer with larger  $P_{star}$

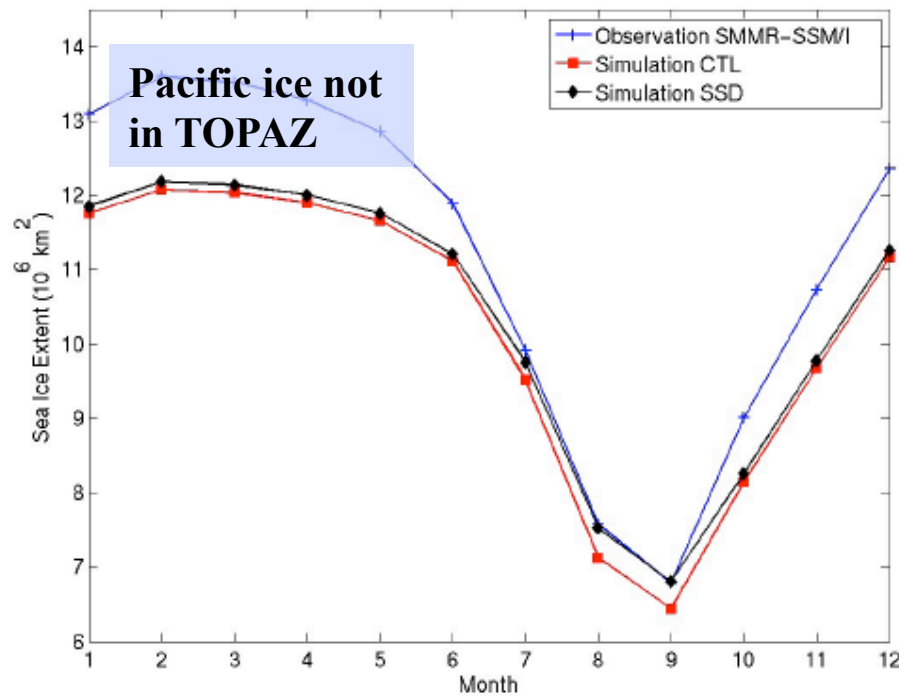




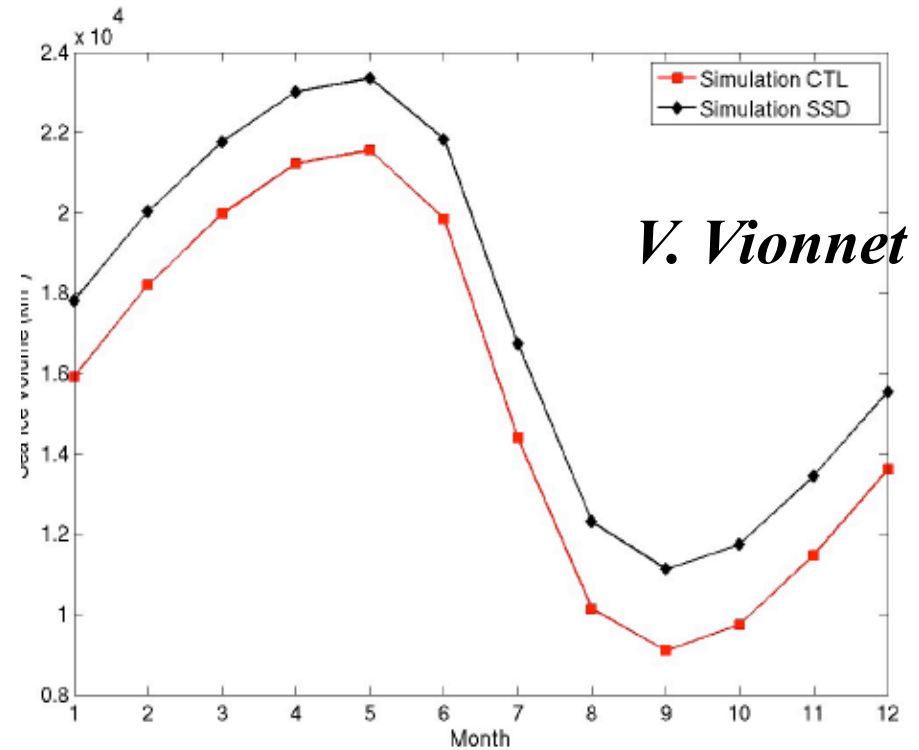
# Snow module

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

## Probabilistic snow distribution:



## Leads to more ice



Ice area

Ice volume

# TOPAZ System overview

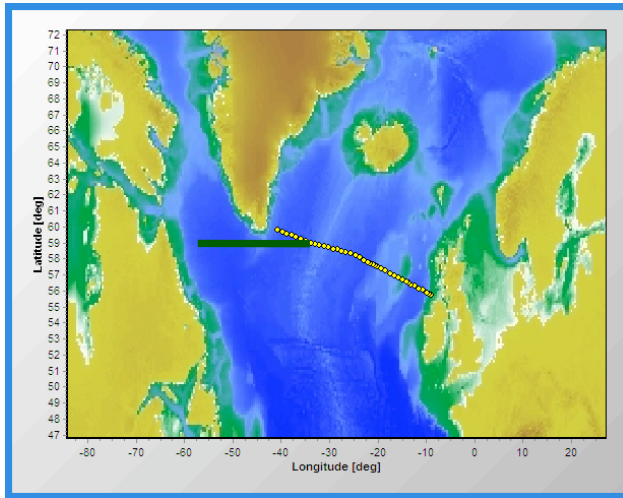
The HYCOM model

Validation

Coordination with TOPAZ@met.no

Data Assimilation



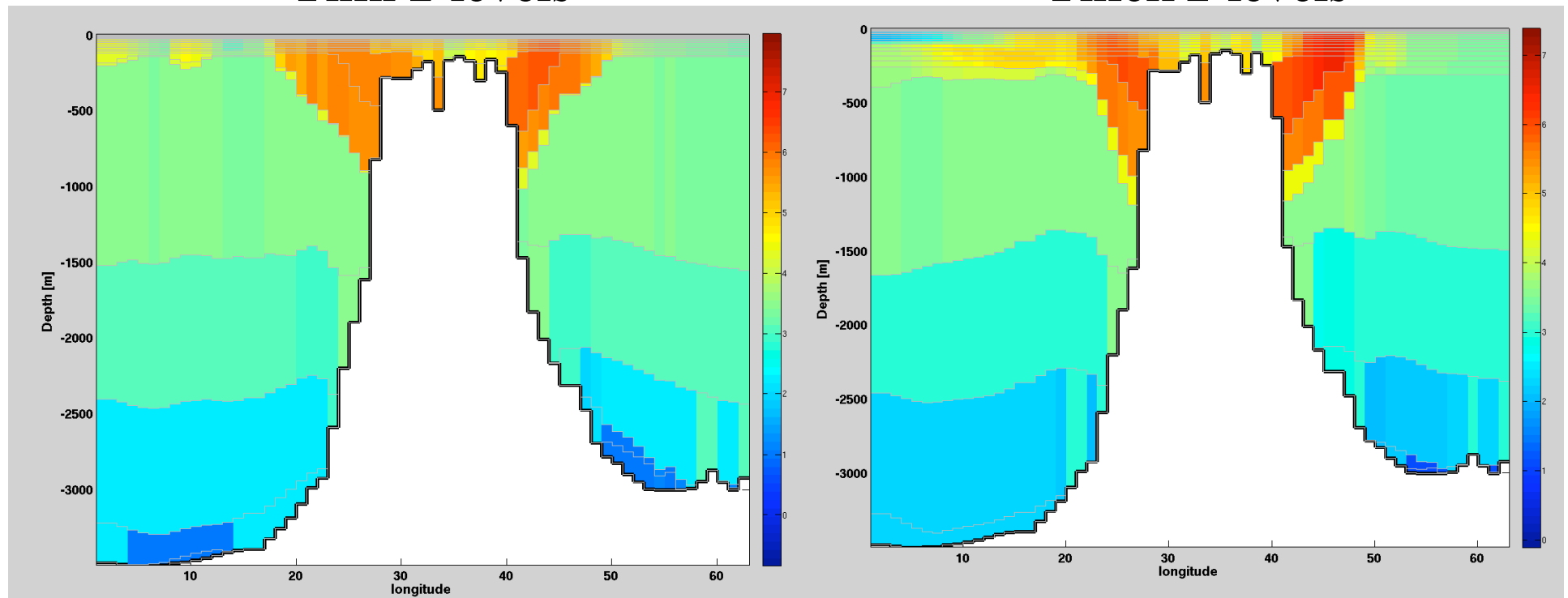


# Vertical resolution

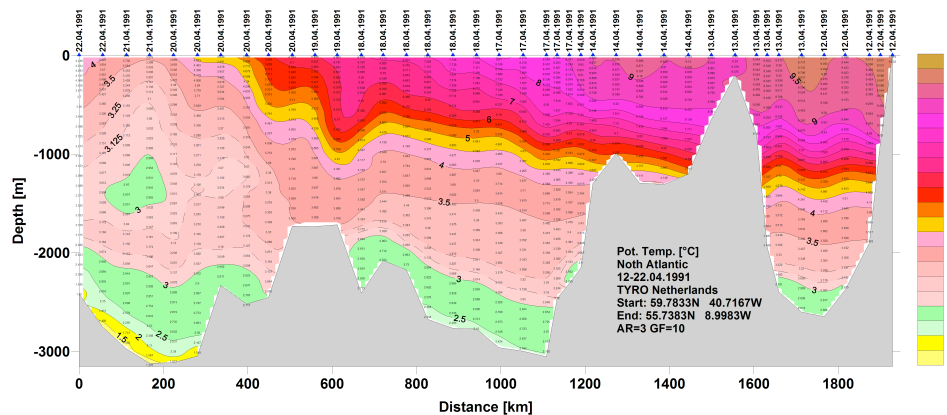
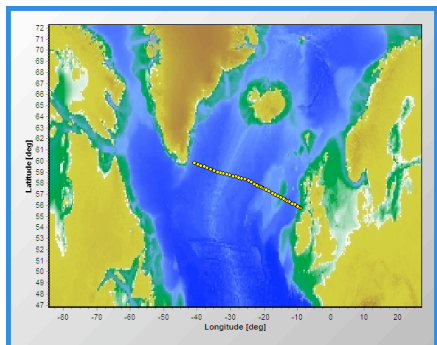
## *thicker z-levels*

### Thin z-levels

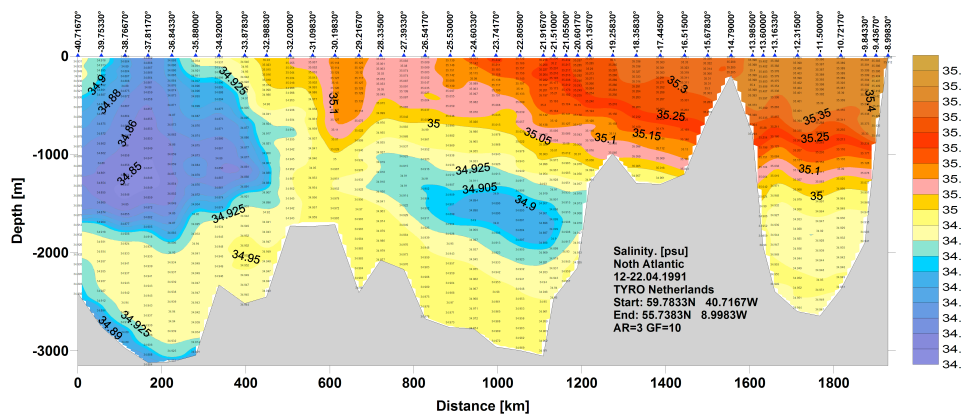
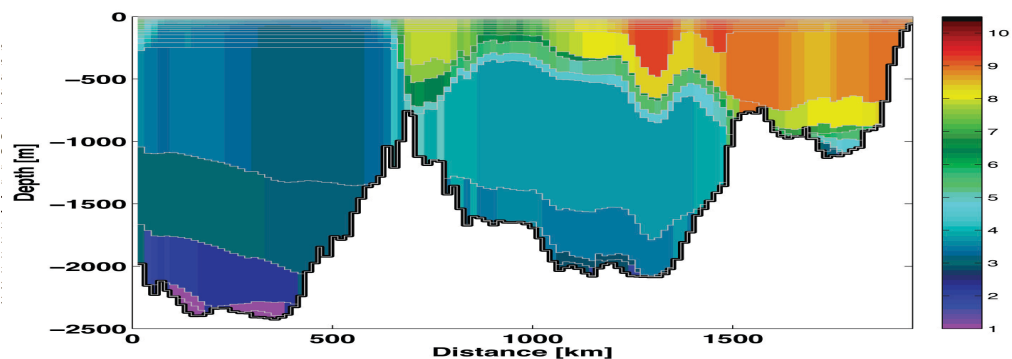
### Thick z-levels



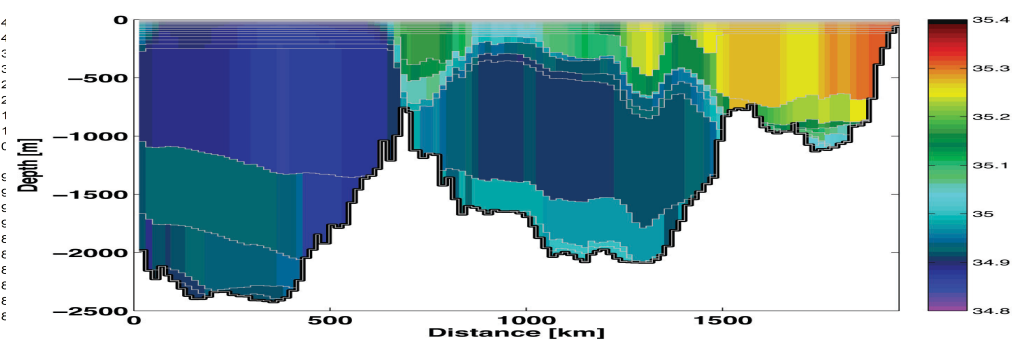
# TOPAZ4 Validation "North Atlantic"



TEM



SAL



INTAS-Nansen-AARI database  
Courtesy A. Korabely

TOPAZ4  
Mohn-Sverdrup Center  
Global Ocean Studies - Operational Oceanography

# TOPAZ4-TOPAZ3

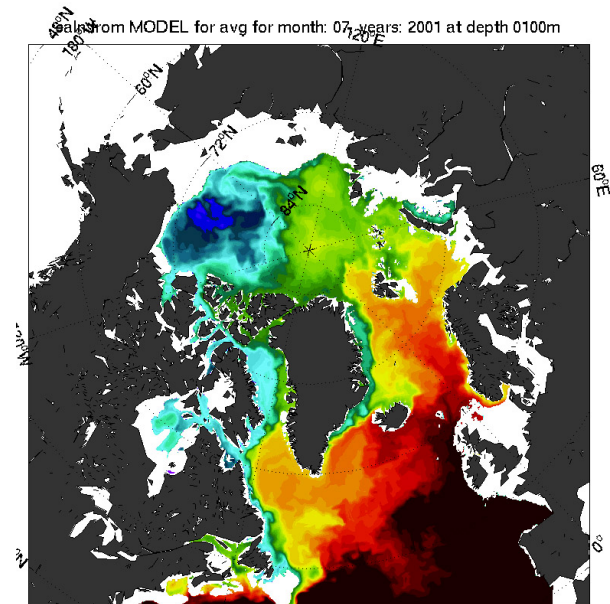
## Surface Salinity, July

- 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

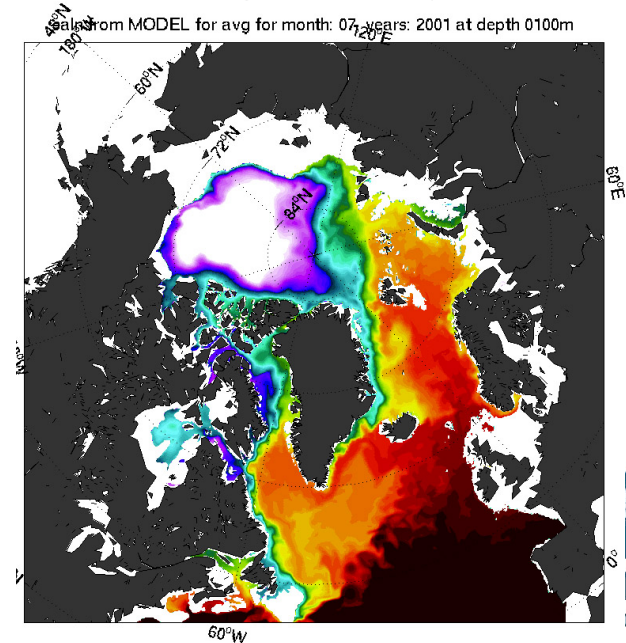
Solution:

- reduce the flux in Bering Strait (0.8 Sv)

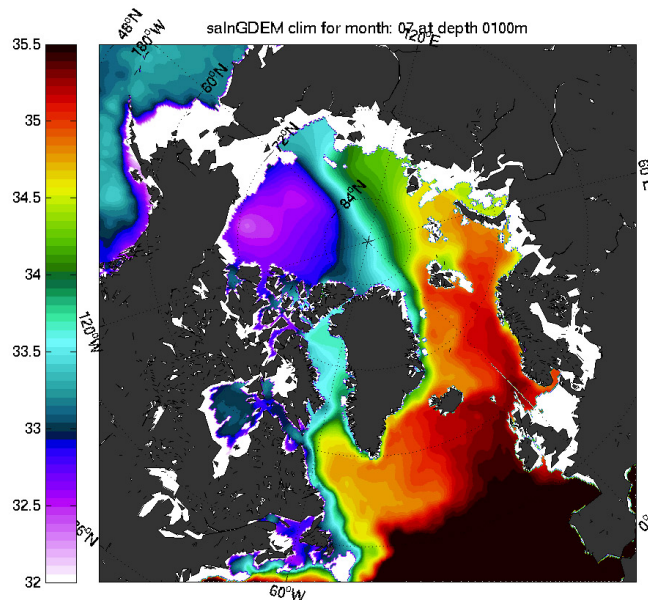
## TOPAZ V3



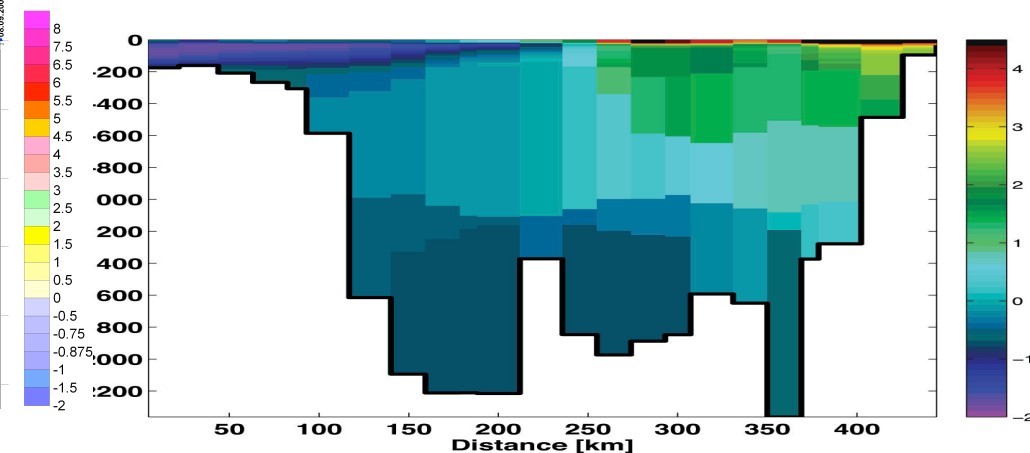
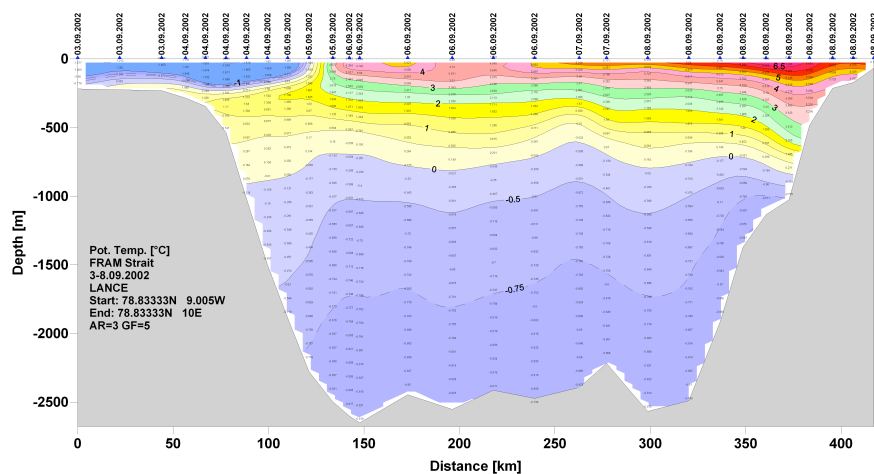
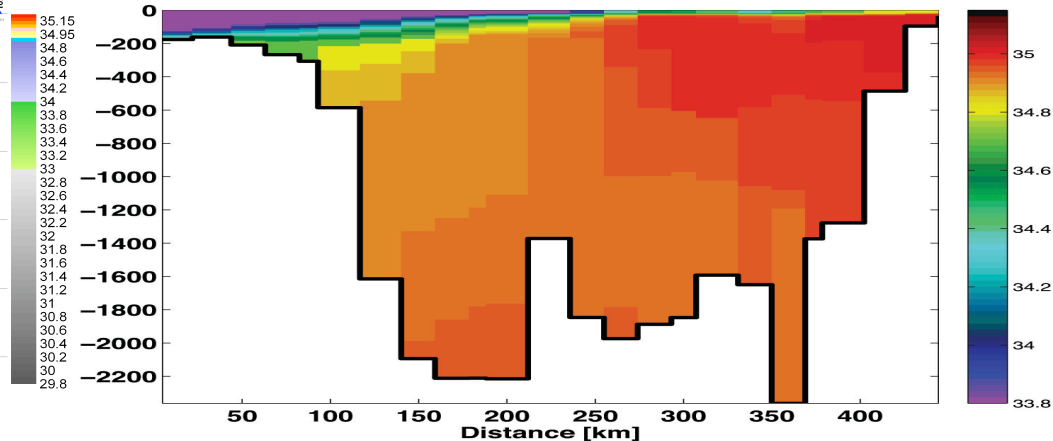
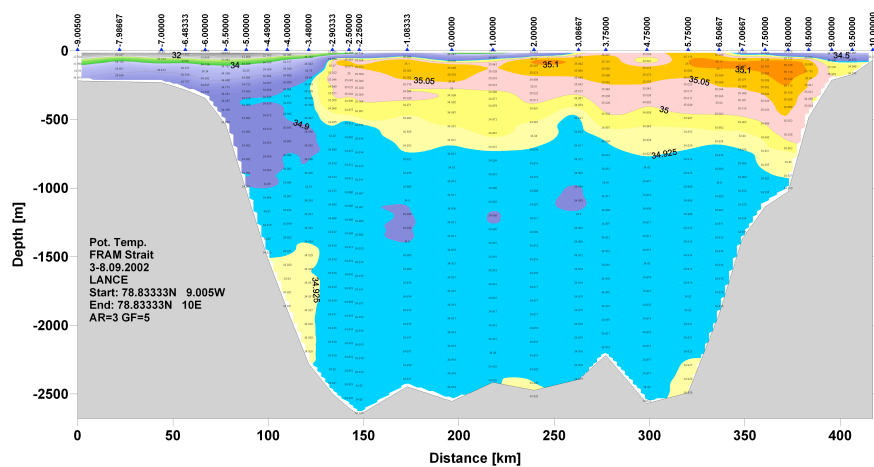
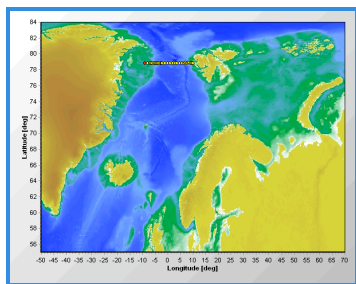
## TOPAZ V4



## GDEM July



# TOPAZ Validation "Fram Straits"



# 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 ( <b>Northwards</b> ) (Iceland-Færoe-Shetland-Scotland)	7.68 Sv	7.76 Sv	7-8 Sv	Northwards



Improvement of the  
“critically important fluxes”



# TOPAZ System overview

The HYCOM model

Validation

Coordination with [TOPAZ@met.no](mailto:TOPAZ@met.no)

Data Assimilation





# Things to share

- Visualisation
  - Comparisons TOPAZ@NERSC and [TOPAZ@met.no](mailto:TOPAZ@met.no)
  - THREDDS/OPeNDAP clients
- Performance statistics
- Code:
  - concurrent upgrades, documentation
- User:

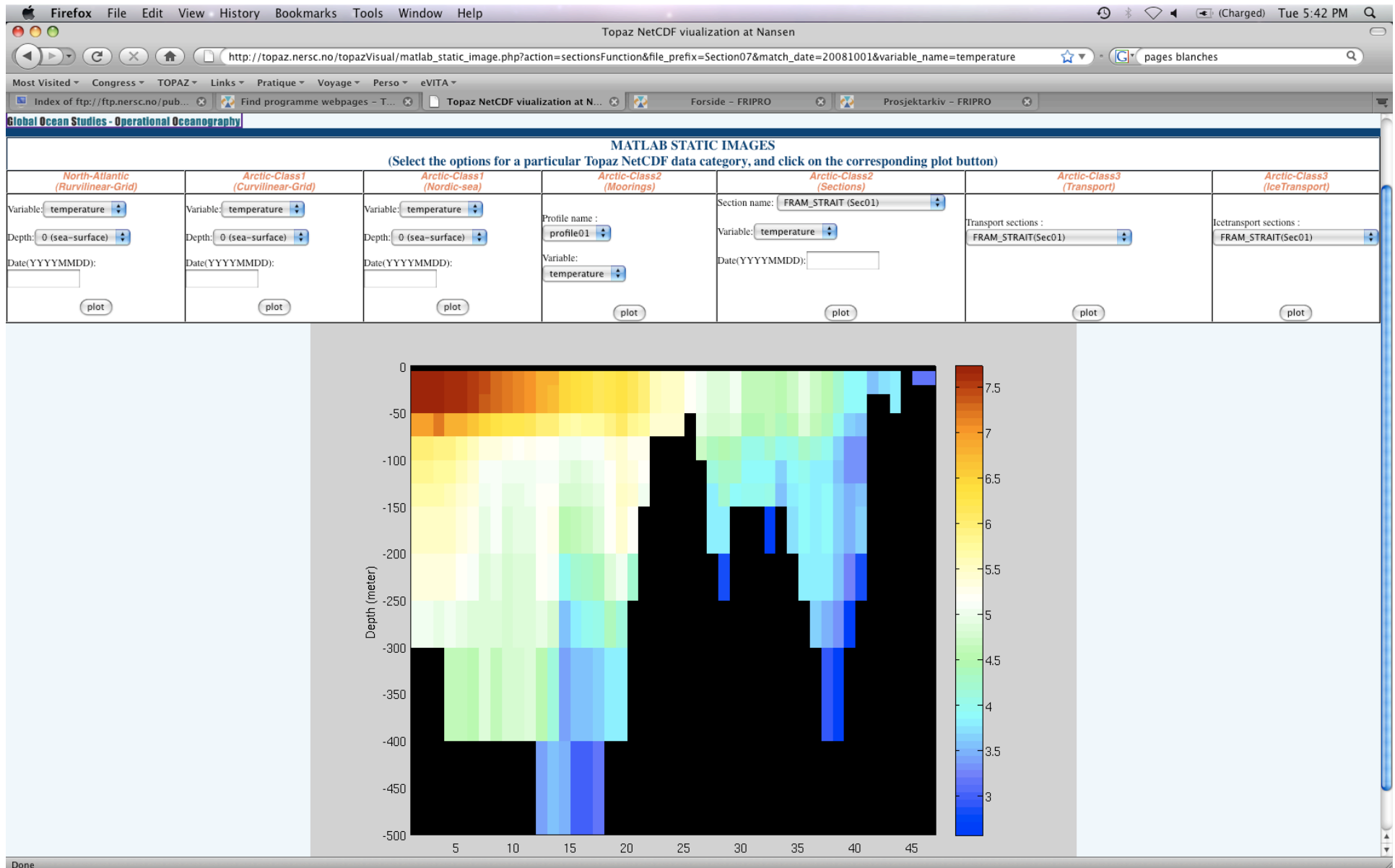


■ ECMWF operational wave forecast



# Visualization

<http://topaz.nersc.no/topazVisual>



# OPeNDAP clients: DAPPER

The screenshot displays the NOAA DChart web interface in a Mozilla Firefox browser. The page title is "TOPAZ forecasting\_data viualization at NANSEN center" (note the typo "viualization"). The interface includes a search bar for "Center map at location:", a "Plot selected:" dropdown menu, and a "Link to this page" button. The main content area is divided into several panels:

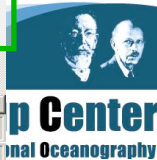
- Map Panel:** A satellite-style map of the North Atlantic region with a zoomed-in view of the area around 40°N, 40°W. The map is labeled "NAT\_Class1" and "North\_Atlantic".
- Variables Panel:** A list of variables including "area averaged eastward atmospheric stress", "area averaged northward atmospheric stress", "barotropic streamfunction of the ocean", "density defined mixed layer depth", "eastward velocity of sea water", "freshwater flux into ocean", "model\_depth", "net heat flux into ocean", "northward velocity of sea water", "potential temperature of sea water", "salinity of sea water", and "sea surface height".
- Plot type Panel:** Options for "Shaded plot", "Line plot", "Animate in Google Earth", and "Download data".
- Plot view Panel:** A list of plot views such as "longitude/latitude(xy)", "longitude/depth(xz)", "longitude/Time(xt)", "latitude/depth(yz)", "latitude/Time(yt)", and "depth/Time(zt)".
- Plot options Panel:** Includes "Auto colorbar" (checked) and "Colorbar range" input fields.
- Ranges Panel:** Sliders for "Lon" (ranging from -98.50 to 10.00), "Lat" (ranging from 10.00 to 65.00), "z" (ranging from 5.00 to 3000.00), and "Time" (ranging from 20 Jun 2007 00:00:00 to 20 Jun 2008 00:00:00).

At the bottom of the interface, there is a "TOPAZ model results" plot showing "Potential temperature of sea water(degrees\_celsius)" for "Time: 20 Jun 2007 00:00:00 GMT depth: 5 m". The plot shows a color gradient from blue (0°C) to red (30°C) across the North Atlantic. A colorbar at the bottom of the plot indicates the temperature scale.

The browser's taskbar at the bottom shows several open applications, including "NOAA -- DCha...", "Trondheim", "emacs@f02n07...", "tomcat\_eva", "data", "Compaq Visual ...", "Inbox for gora...", "Untitled - Note...", and "NO". The system clock shows "09:52".

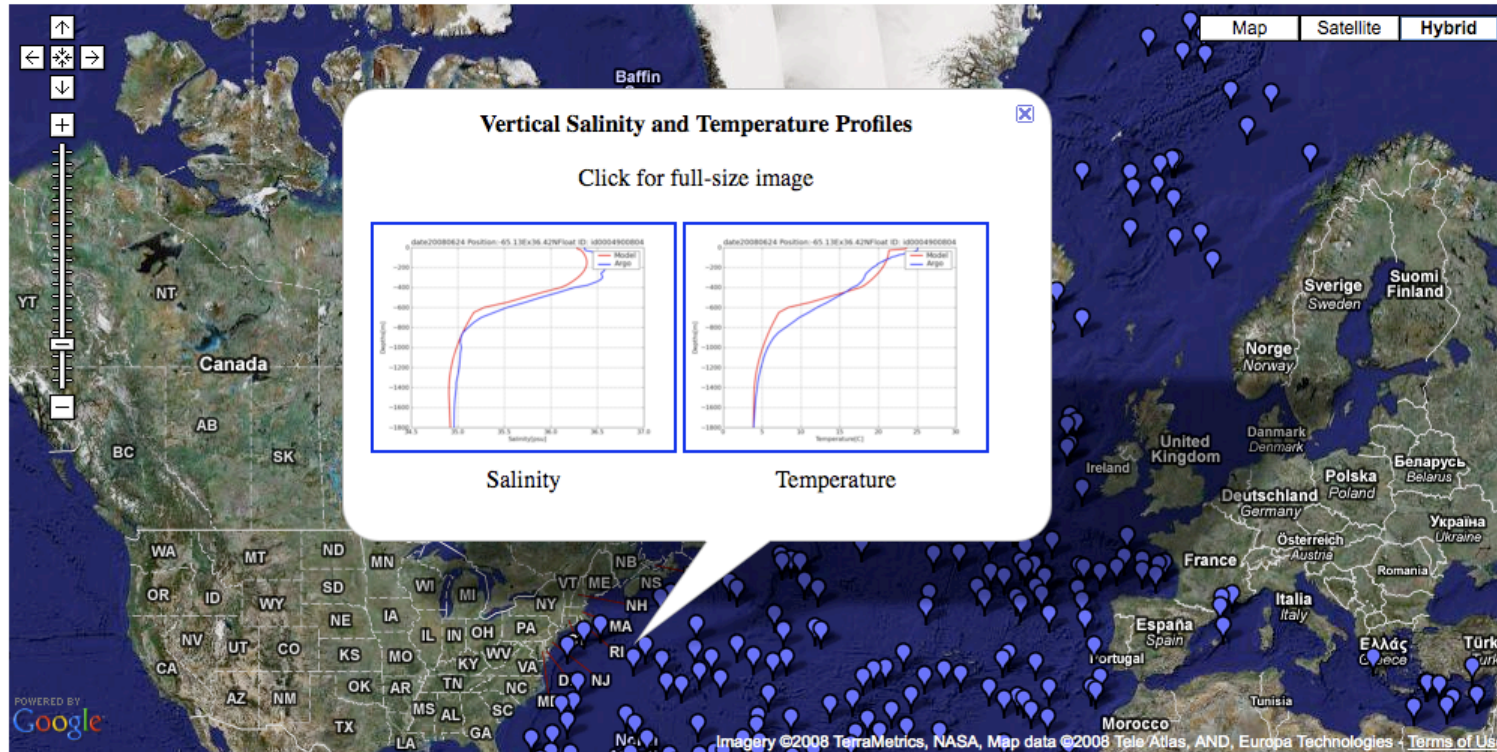


G. Zangana



## 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
- TOPAZ3\_20080902

# Online comparison to Argo profiles

# Subversion:

# HYCOM code sharing



Changeset 21 for HYCOM\_2.2.12/MSCProgs/src/Nersclib/mod\_hycomfile\_io.F90 - hycom - Trac

https://svn.nersc.no/hycom/changeset/21/H/

Index of ftp/... Find progra... Changeset 2... Forside - FRI... Prosjektarkiv...

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← [Previous Change](#) | [Next Change](#) →

## Changeset 21 for HYCOM\_2.2.12/MSCProgs/src/Nersclib/mod\_hycomfile\_io.F90

**Timestamp:** 05/13/09 10:05:08 (2 weeks ago)  
**Author:** laurentb  
**Message:** Fixed Temperature units from Kelvin to Celcius  
**Files:** 1 modified

- HYCOM\_2.2.12/MSCProgs/src/Nersclib/mod\_hycomfile\_io.F90 (2 diffs)

View differences: inline  
Show 2 lines around each change  
Ignore:  
 Blank lines  
 Case changes  
 White space changes  
Update

Unmodified  Added  Removed

### HYCOM\_2.2.12/MSCProgs/src/Nersclib/mod\_hycomfile\_io.F90

Tabular | Unified

r1	r21	
949	949	limits=(/0,45/)
950	950	case ('temp')
951		stdname='sea_water_potential_temperature' ; units='K' ; vname='temperature'
	951	stdname='sea_water_potential_temperature' ; units='C' ; vname='temperature'
952	952	limits=(/-3,50/)
953	953	case ('levsaln')
...	...	
955	955	limits=(/0,45/)
956	956	case ('levtemp')
957		stdname='sea_water_potential_temperature' ; units='K' ; vname='levitus_temperature'
	957	stdname='sea_water_potential_temperature' ; units='C' ; vname='levitus_temperature'
958	958	limits=(/-3,50/)
959	959	case ('ssh', 'srfhgt')

Download in other formats:  
[Unified Diff](#) | [Zip Archive](#)

Powered by **trac** 0.11  
Visit the Trac open source project at <http://trac.edgewall.org/>

Done | svn.nersc.no

# 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

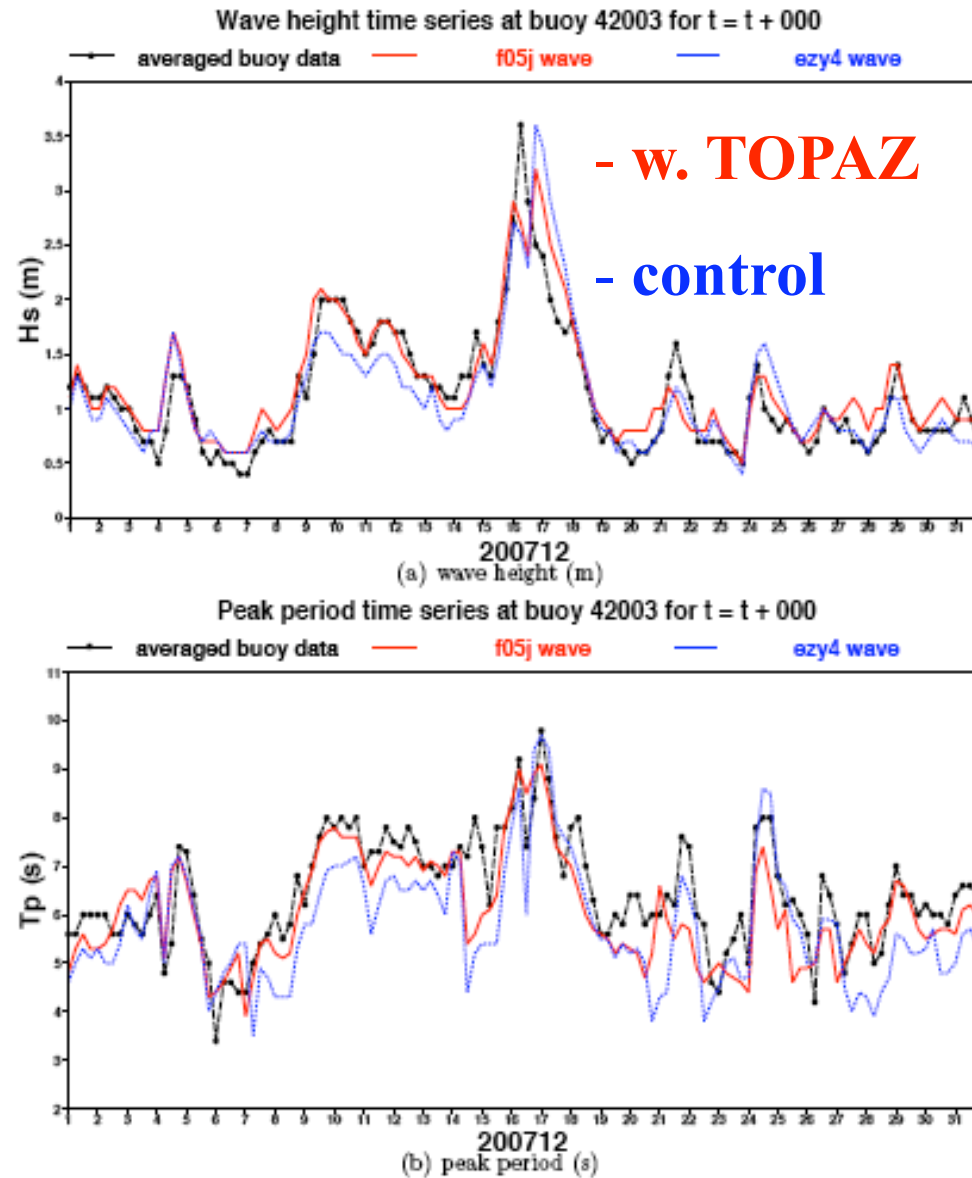


Figure 6: Wave height and peak period time series at buoy 42003 (East Gulf) for December 2007. The solid red line (f05j) is the run with currents and the dash blue line (ezy4) is the reference experiment.

# TOPAZ System overview

The HYCOM model

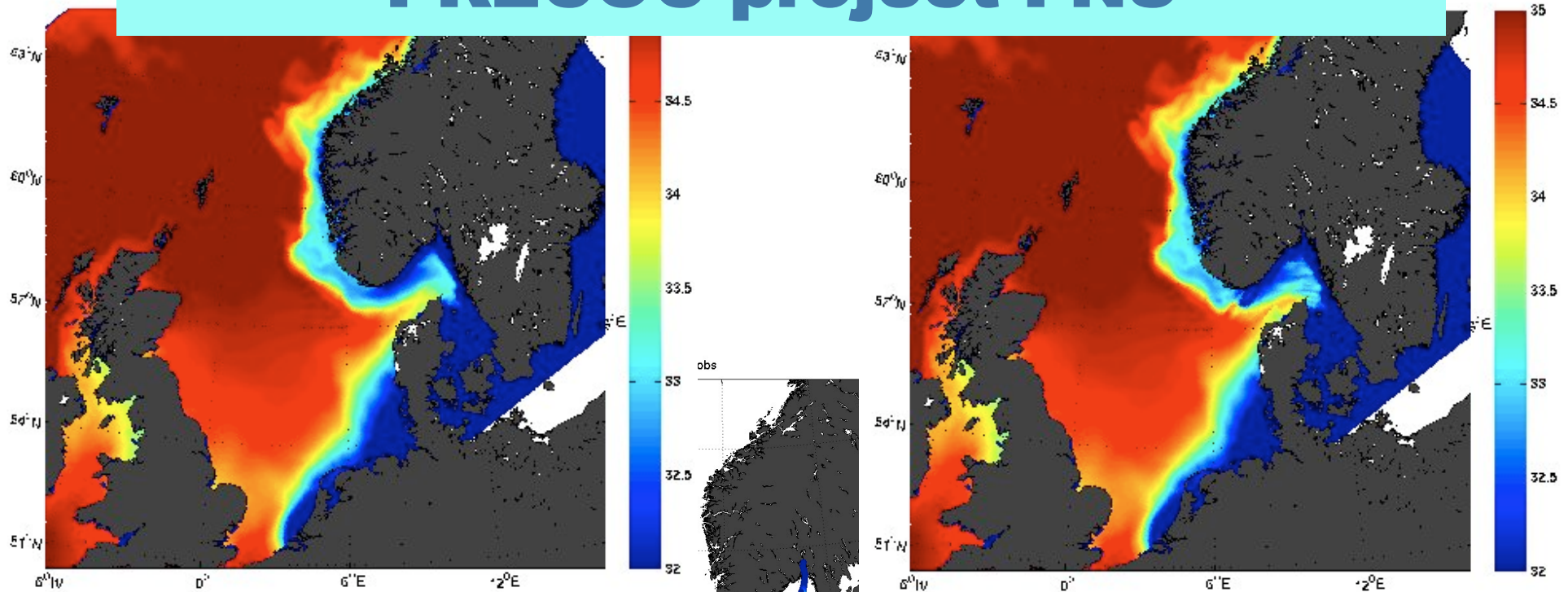
Validation

Coordination with TOPAZ@met.no

Data Assimilation



# Assimilation of Ferrybox data PRECOC project FNS



**CONMAN  
SSS  
Before  
assimilation**

**CONMAN  
SSS  
After  
assimilation**

**Ferrybox SSS**





# Assimilation of Ocean Color in HYCOM-NORWECOM

## Data:

Satellite **Ocean Color (SeaWiFS)**

## Coupled Model:

**HYCOM-NORWECOM**

(7 compartments)

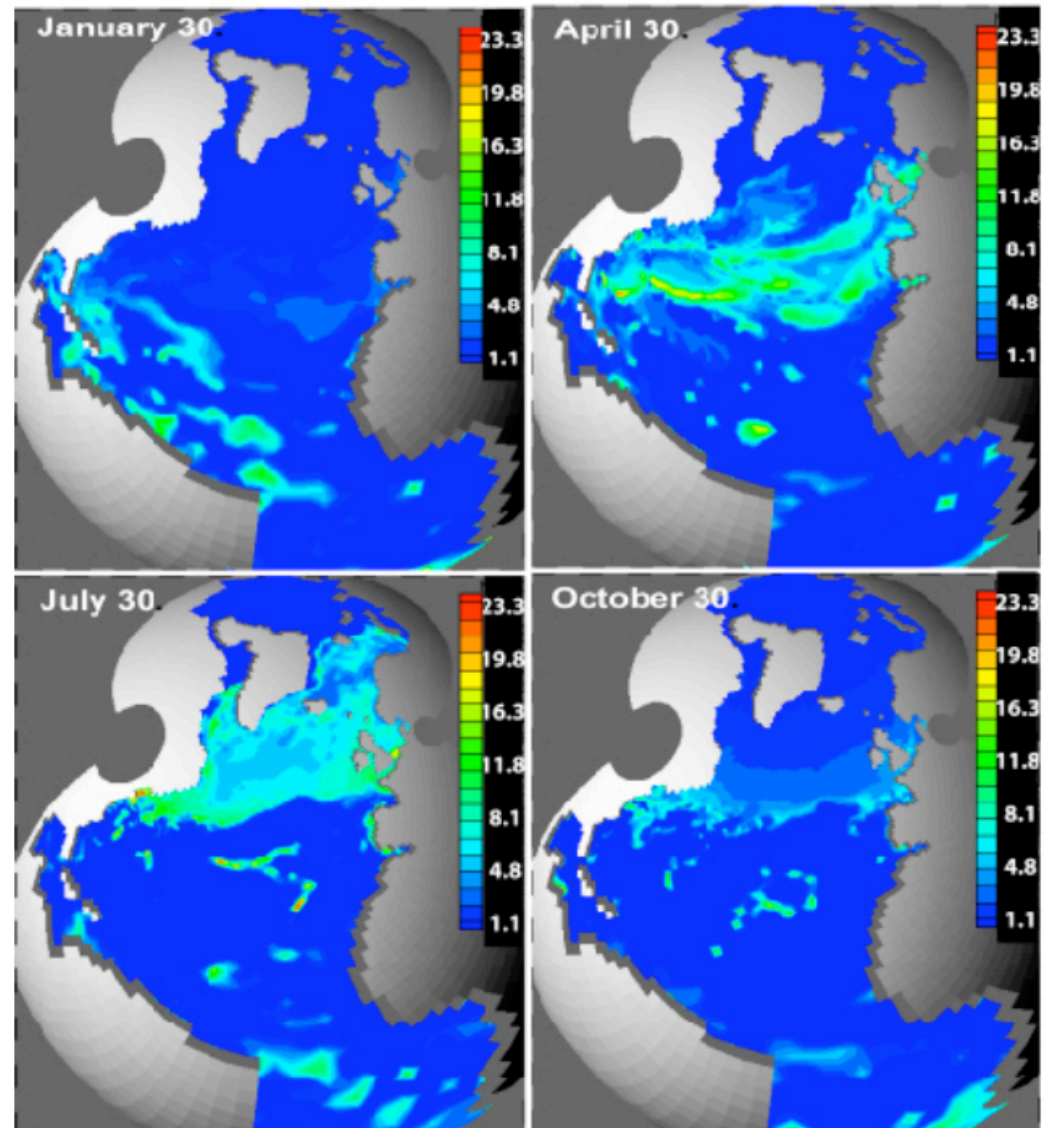
## Problems:

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

## Perspectives:

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

Net primary productivity (mgC/m<sup>3</sup> day)

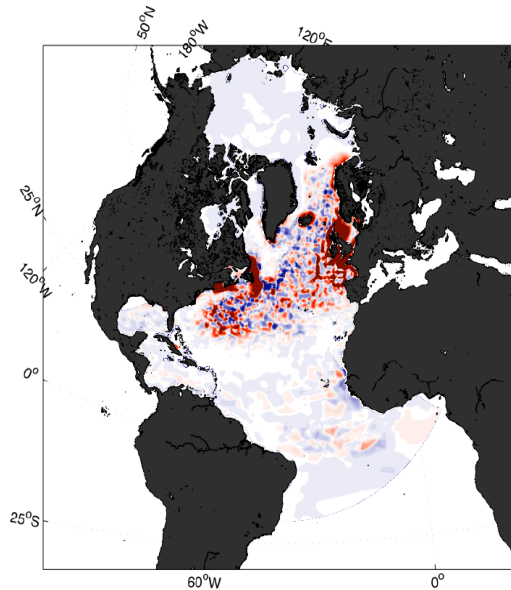


# Gaussian anamorphosis with the EnKF

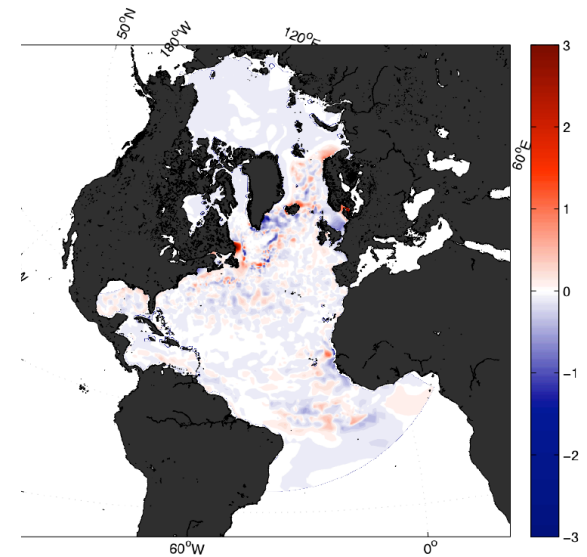
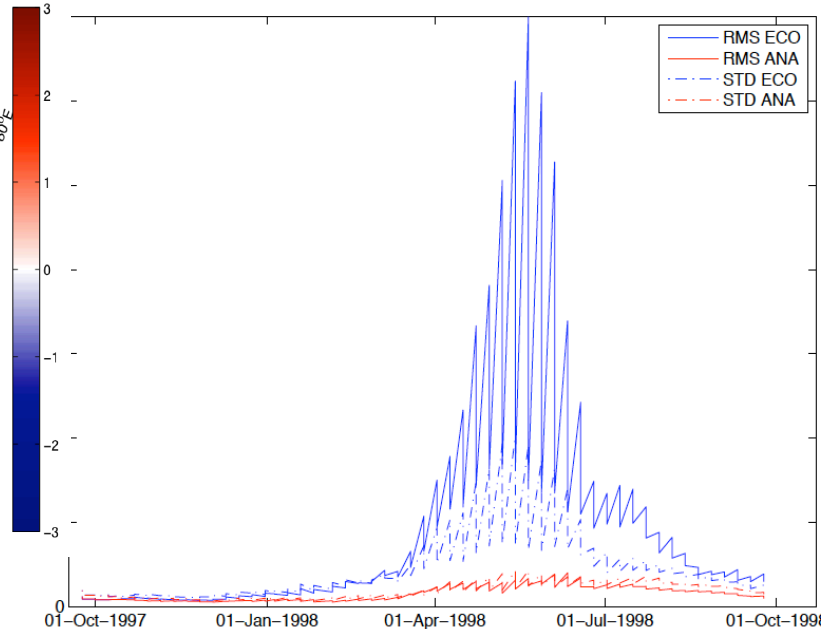
Anamorphosis: prior transformation of the variables in a Gaussian space  
(*Bertino et al. 2003*)

Twin experiments (surface chlorophyll-a synthetic observations)

## Surface CHL<sub>a</sub> RMS error



**EnKF**  
Cut-off of neg. values



**Gaussian Anamorphosis**  
**EnKF**



*Simon & Bertino (OSD, 2009)*

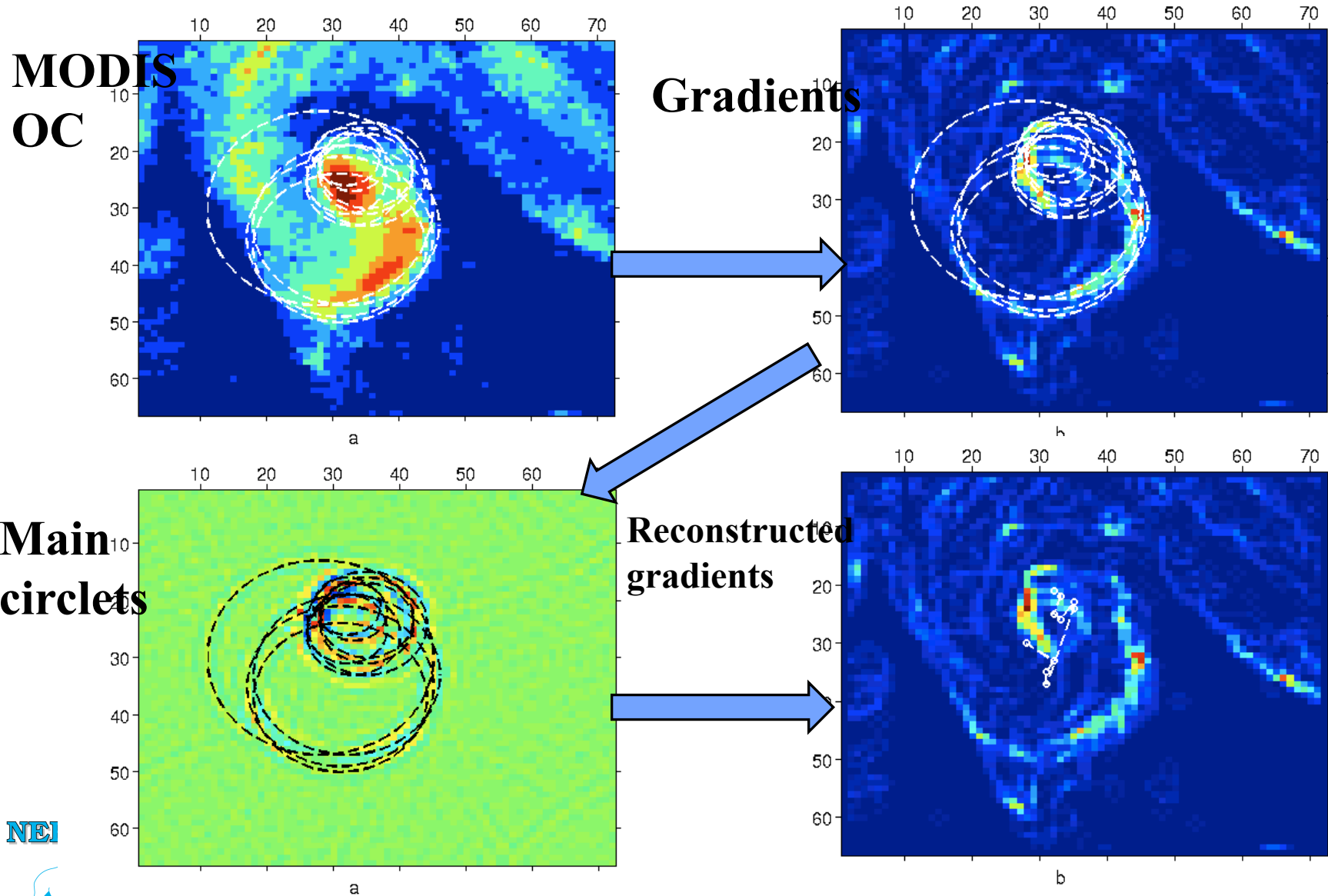


# Conclusion

- 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



# Circlets: eddy detection



NEI



enter

# MyOcean

European project 2009-2012

Lead by Mercator Ocean



# 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, ..)

NER



# The Production Units

## 5 Thematic Assembly Centres

Sea Level

Ocean Color

Sea Surface Temp.

Sea Ice & Wind

In Situ

*Observations*

## 7 Monitoring and Forecasting Centres

Global Ocean

Arctic Ocean

Baltic Sea

Atlantic NWS

Atlantic IBI

Mediterranean Sea

Black Sea

*Models*

Service Desk

### TAC

- Sea Level
- Ocean Color
- Sea Ice & Wind
- In situ
- Sea Surface Temperature

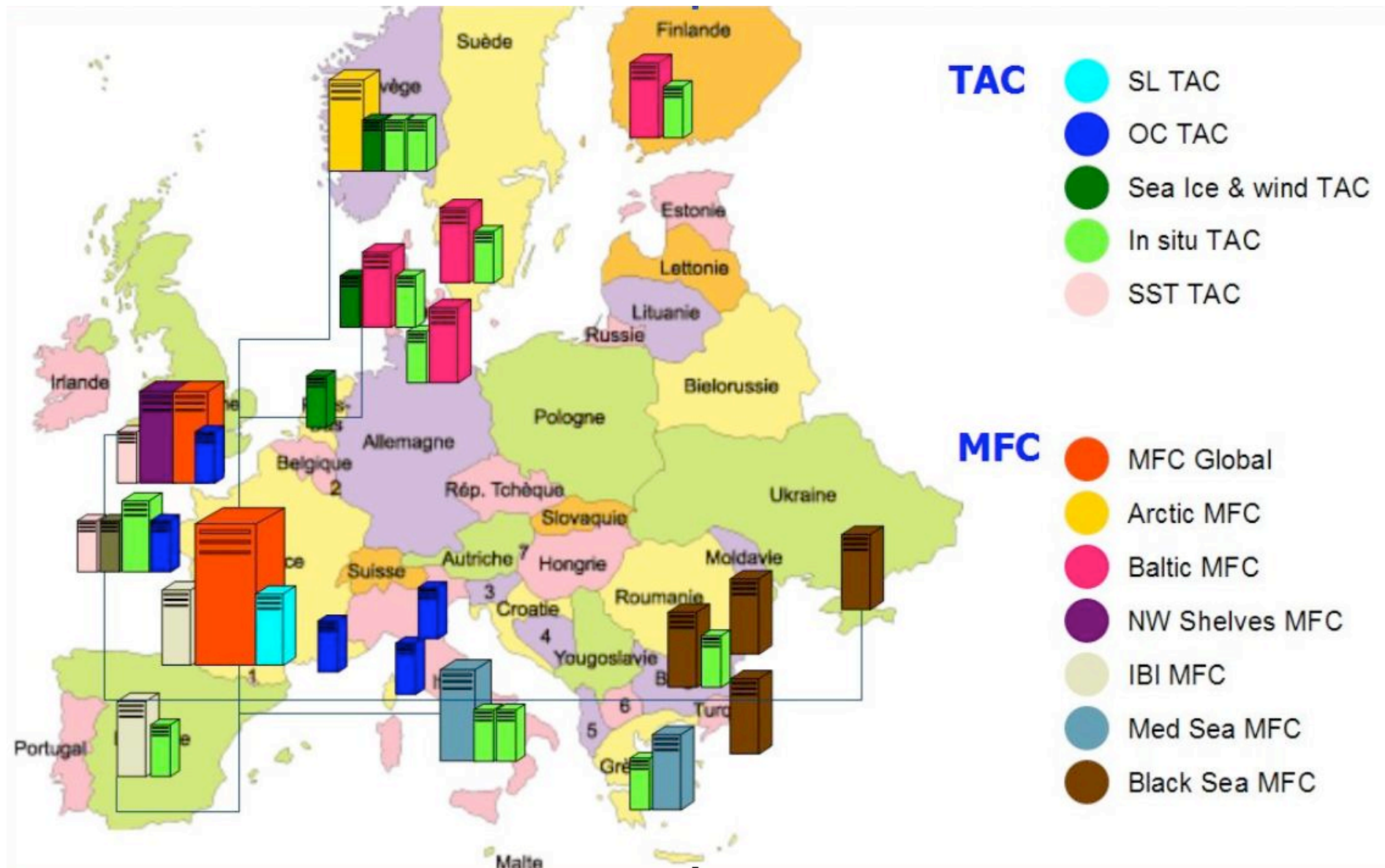
### MFC

- MFC Global
- Arctic
- Baltic
- NW Shelves
- IBI
- Med Sea
- Black Sea



# System organization

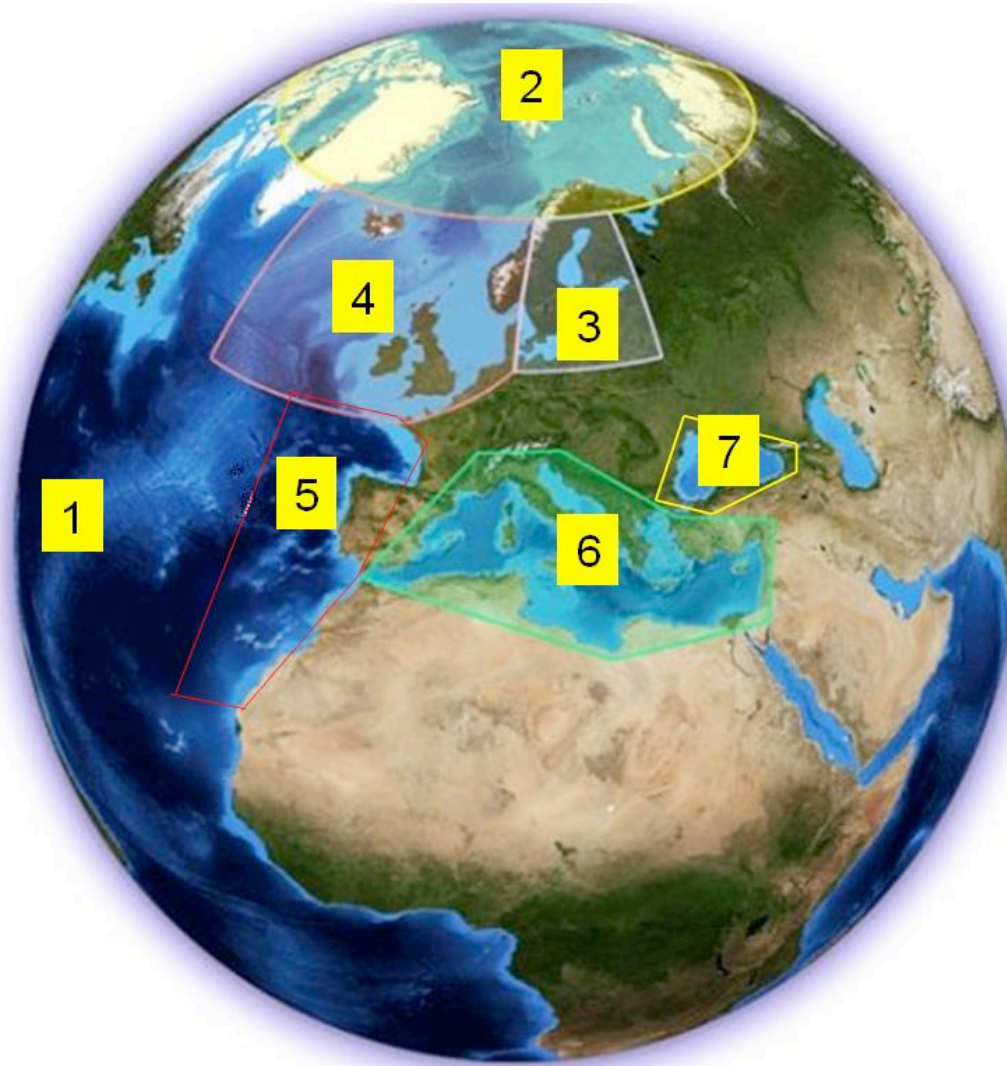
## 12 production units





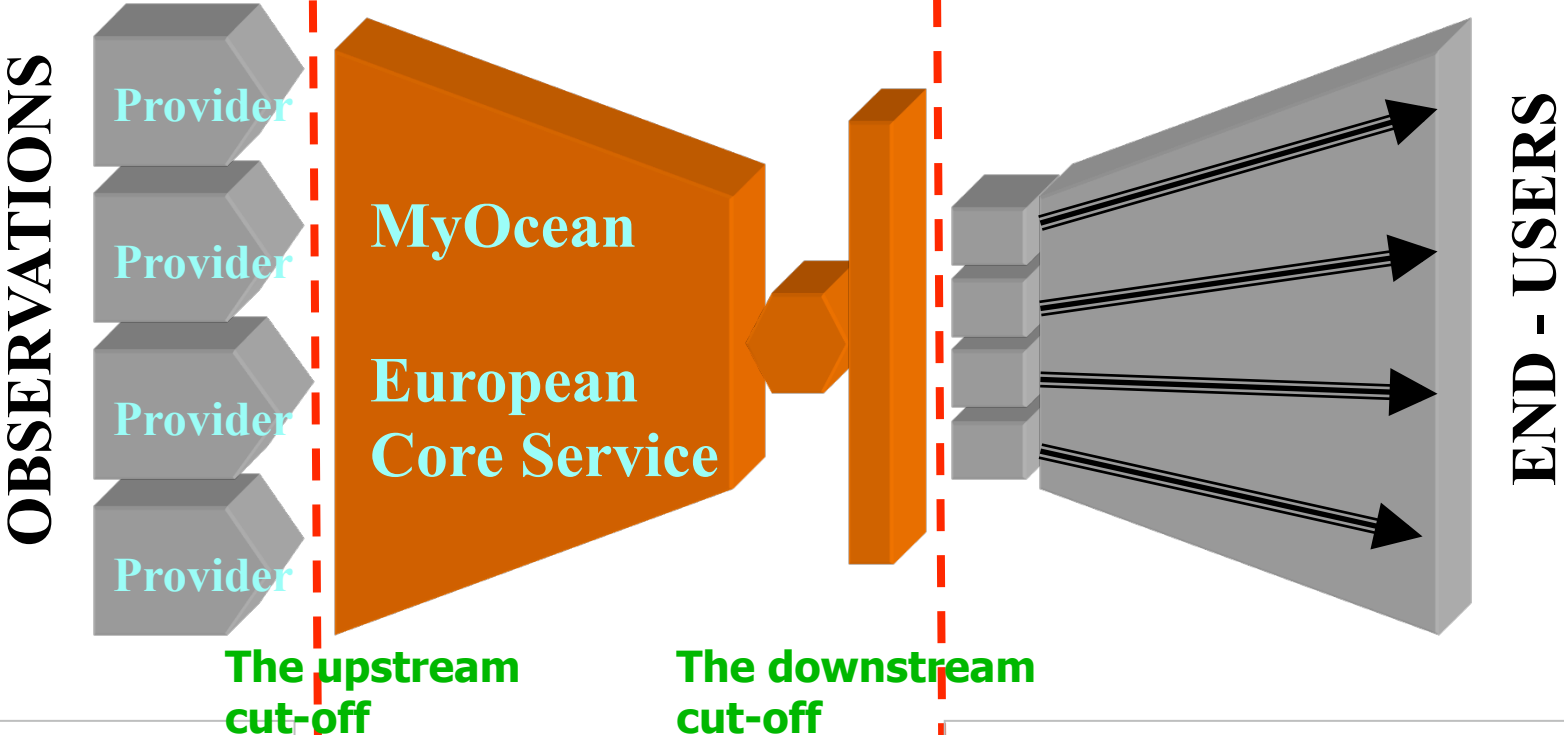
# *The MyOcean value*

## 6 European Seas + Global Ocean



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

# Scope of responsibility



**upstream to our service**

... is done (duty) by an observation agency or center (raw data)

Example : **Eumetsat**



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**

