Scientific recommendations Ocean - Atmosphere

Y. Desaubies, A. Bentamy (Ifremer)
and MERSEA participants

Do not forget Land – Ocean !

- River input into coastal seas and beyond
  - Temperature, salinity
  - Chemical inorganic (polutants, nutrients) and organic
  - Particulate (sediments) and dissolved
  - Important component of carbon cycle
  - Poorly known, data access difficult
- Coastal erosion
- Sea level change
- No HALO contribution on those topics

Baltic sea catchment area is four times the sea's area

Ocean – Atmosphere interactions

- Intimately coupled systems
- Atmosphere forcing on the ocean (forecasts)
  - Wind (and fluxes)
- Sea surface temperature and upper ocean heat content
- Seasonal forecasting
- Carbon cycle
- Effect of currents on surface waves

Forcing fields

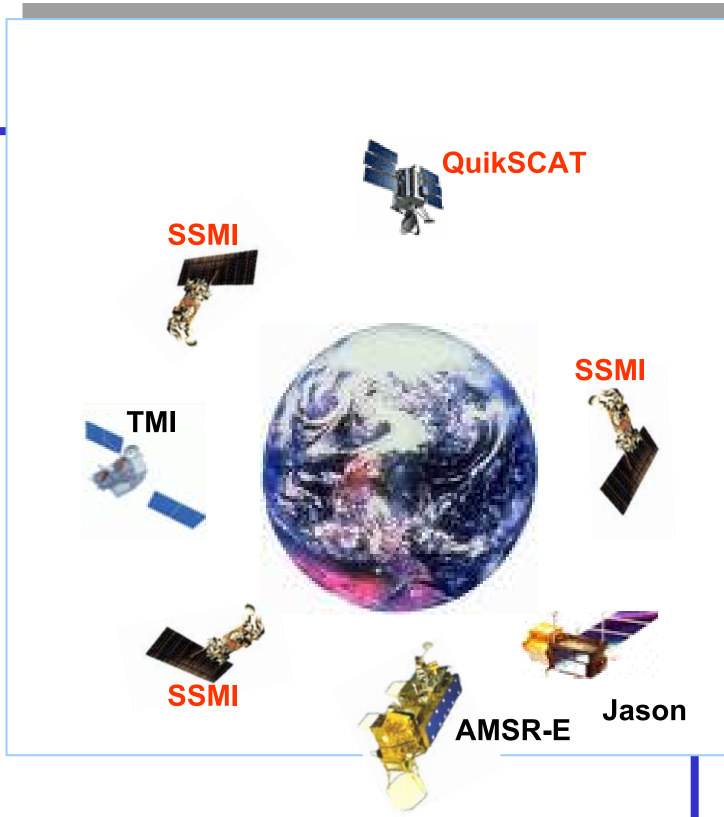
- To do forecasts, the ocean systems need forecasts of forcing fields
  - Obtained from ECMWF (or Met Office, HIRLAM)
  - Wind and radiative fluxes used as such
  - Different approaches for latent and sensible heat fluxes
  - Resolution always a requirement
- Re-analysis are also very valuable (ERA- 40)
- Issue : data policy for marine agencies

Wind fields :
blended satellite & ECMWF fields

Near real time (24 hrs delay), ***high resolution***

Bentamy and Ayina

Near Real Time Blended Surface Fluxes



Method : Objective OI

$$U_a^i = U_b^i + \lambda'(U_o - U_{bo})$$

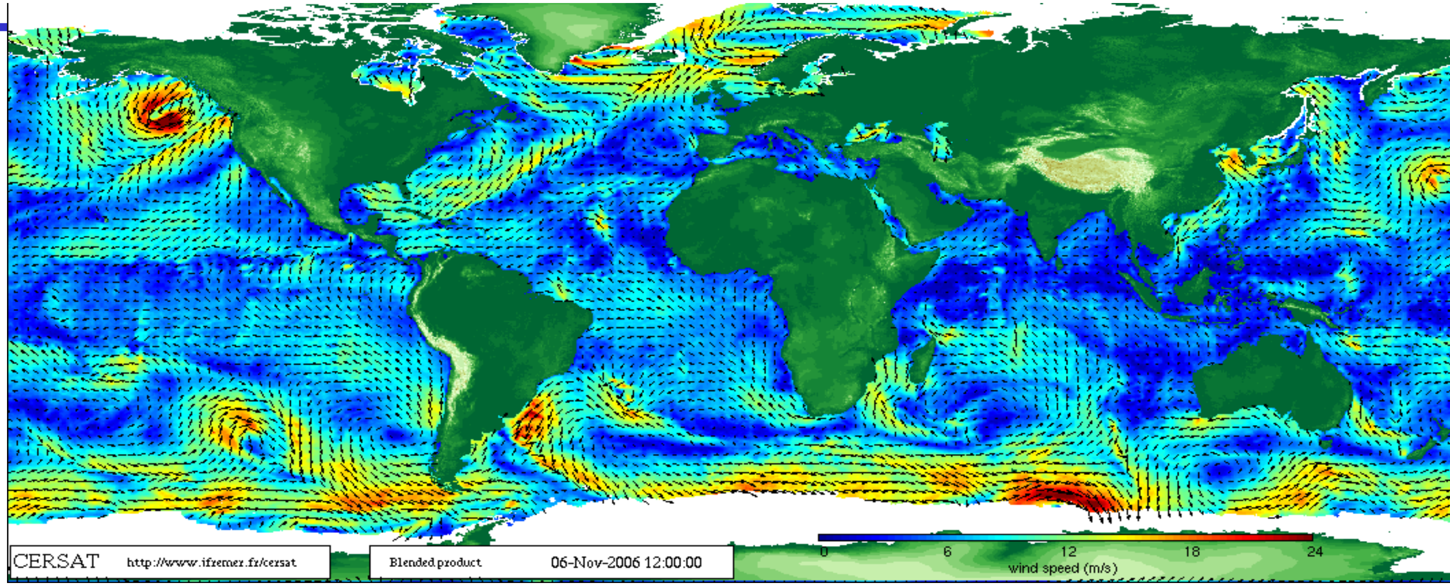
- U_b is the background (ECMWF); U_o is the satellite observations (Scatterometers, Altimeters; SSM/I), U_{bo} is the background at observation location, and λ are the weights.

6-hourly global wind vector and wind stress 0.25°×0.25°

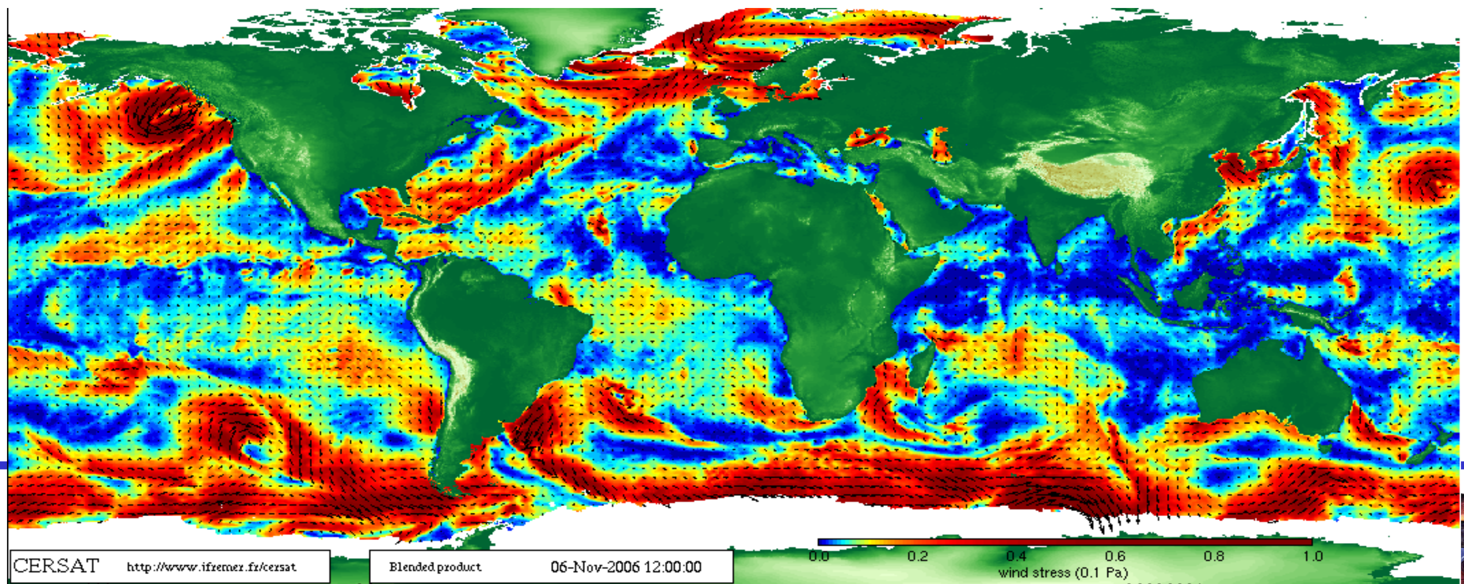
Daily Global latent and sensible heat fluxes : 0.50°×0.50°

Examples of Blended Wind Fields: 6th November 2006 12h:00

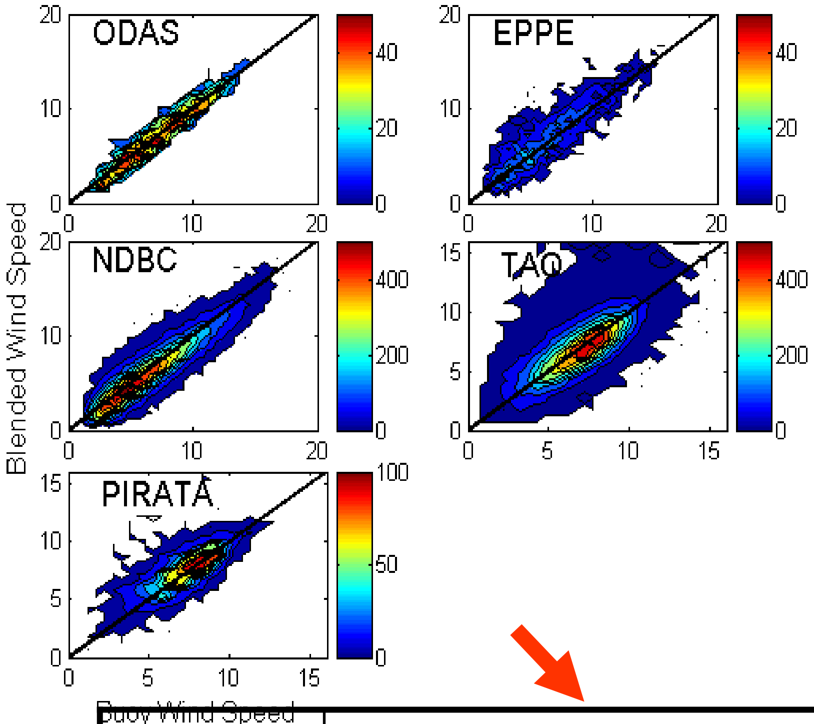
Wind Vector

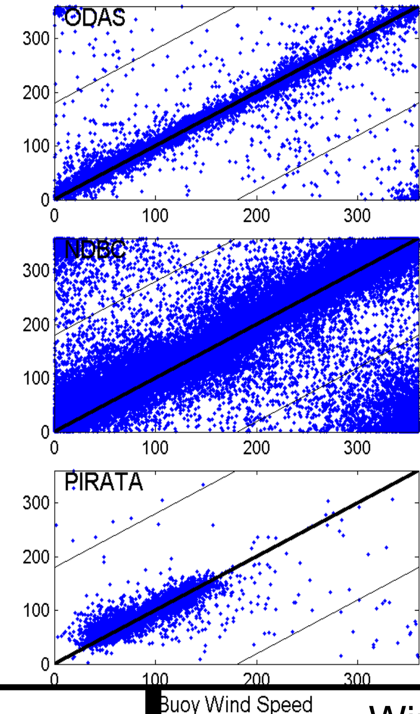


Wind Stress



Accuracy of Blended Wind Fields :
Comparisons to Buoy 6-hourly Wind Estimates





	Wind Speed			Wind Direction		
	Bias	Std	Cor	Bias	Std	Cor
Blended	-0.47(-0.10)	1.23(0.47)	0.80(0.96)	-2(0)	20(5)	1.48(1.75)
ECMWF	0.42(0.62)	1.19(1.16)	0.87(0.78)	-1(1)	16(13)	1.54(1.36)

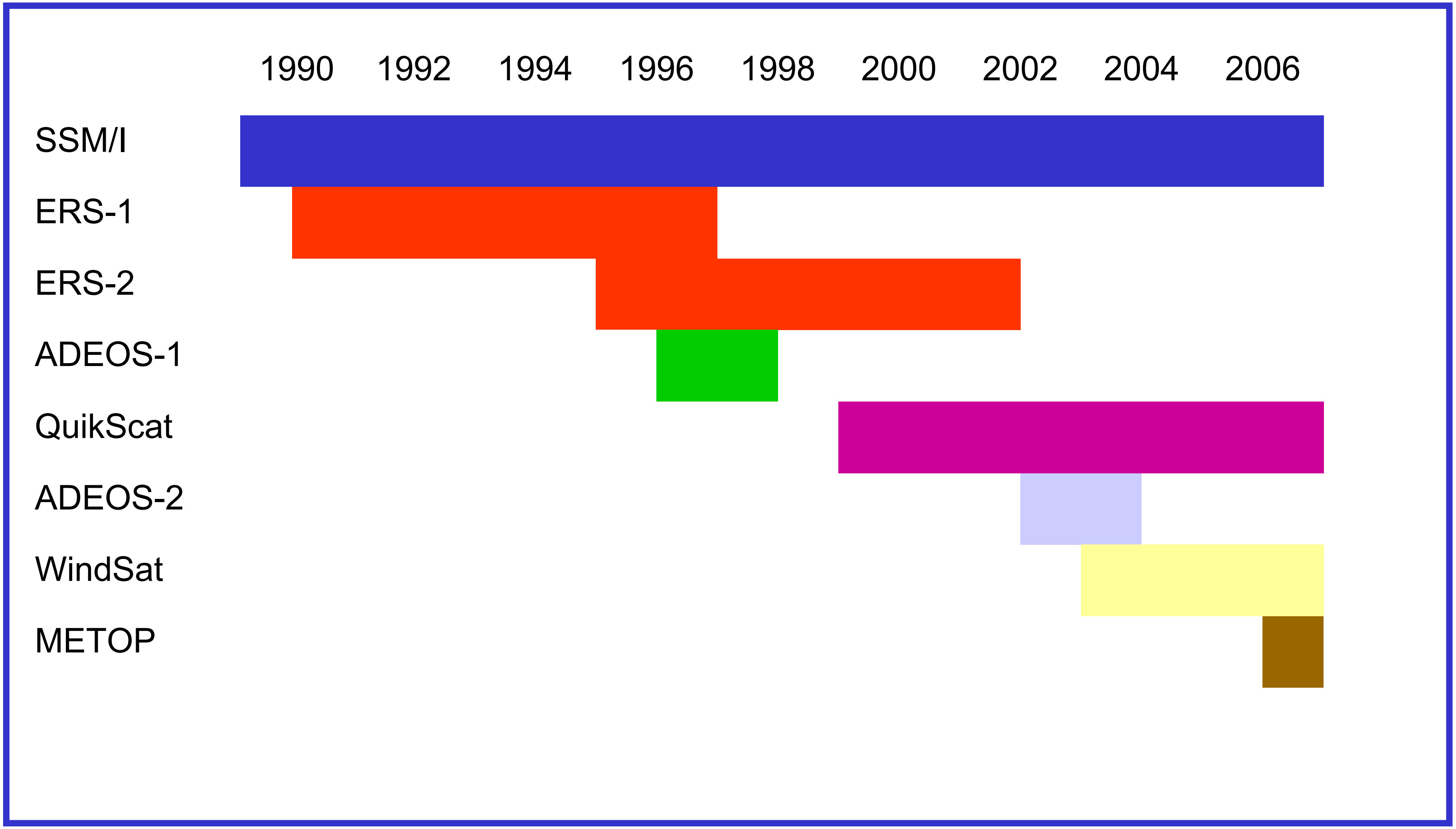
Satellite-Derived Fluxes and Comparisons with NWP Data

Momentum and latent and sensible heat fluxes derived only from satellite data.

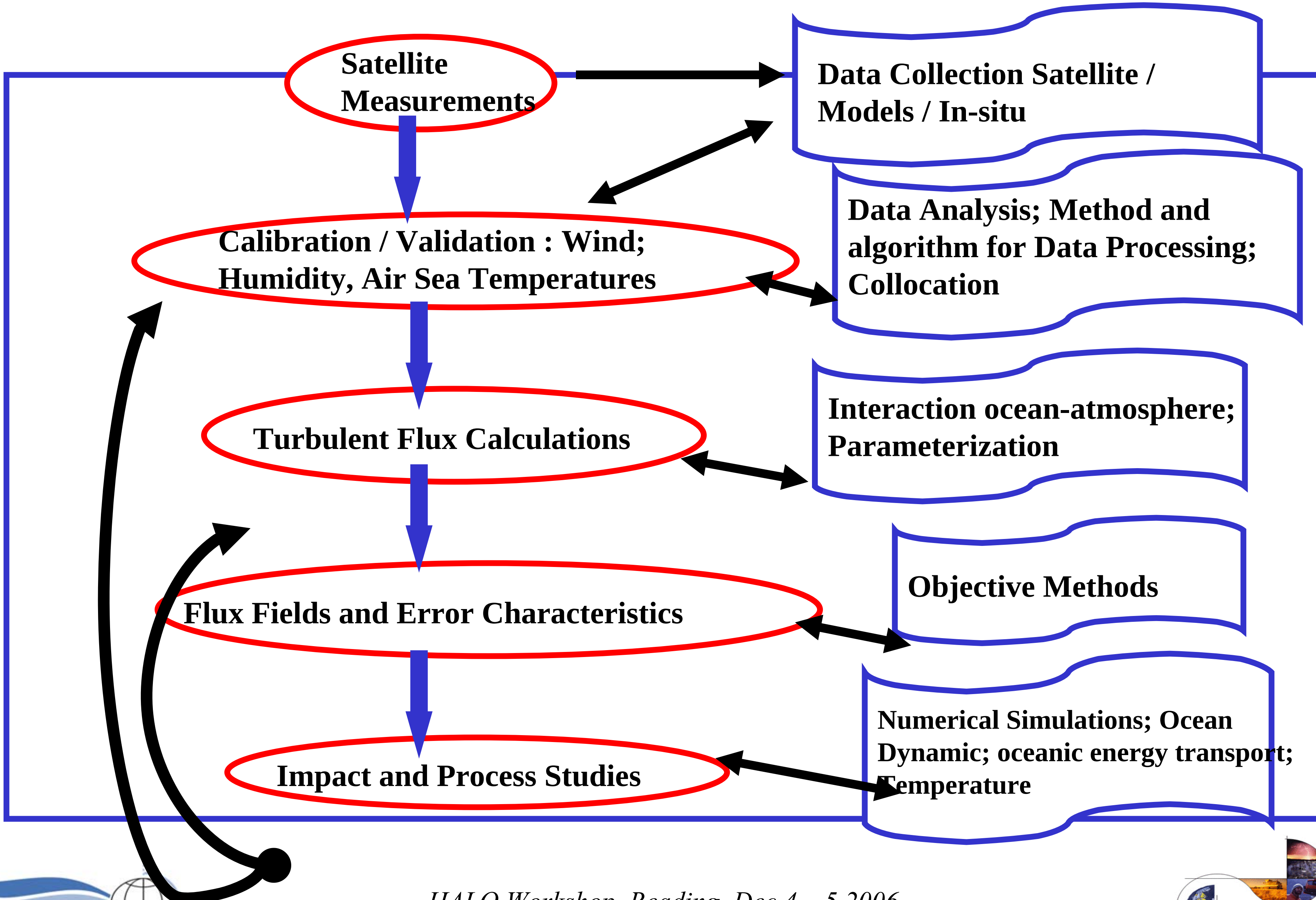
Calculation of Blended Products

Bentamy, Ayina, et al.

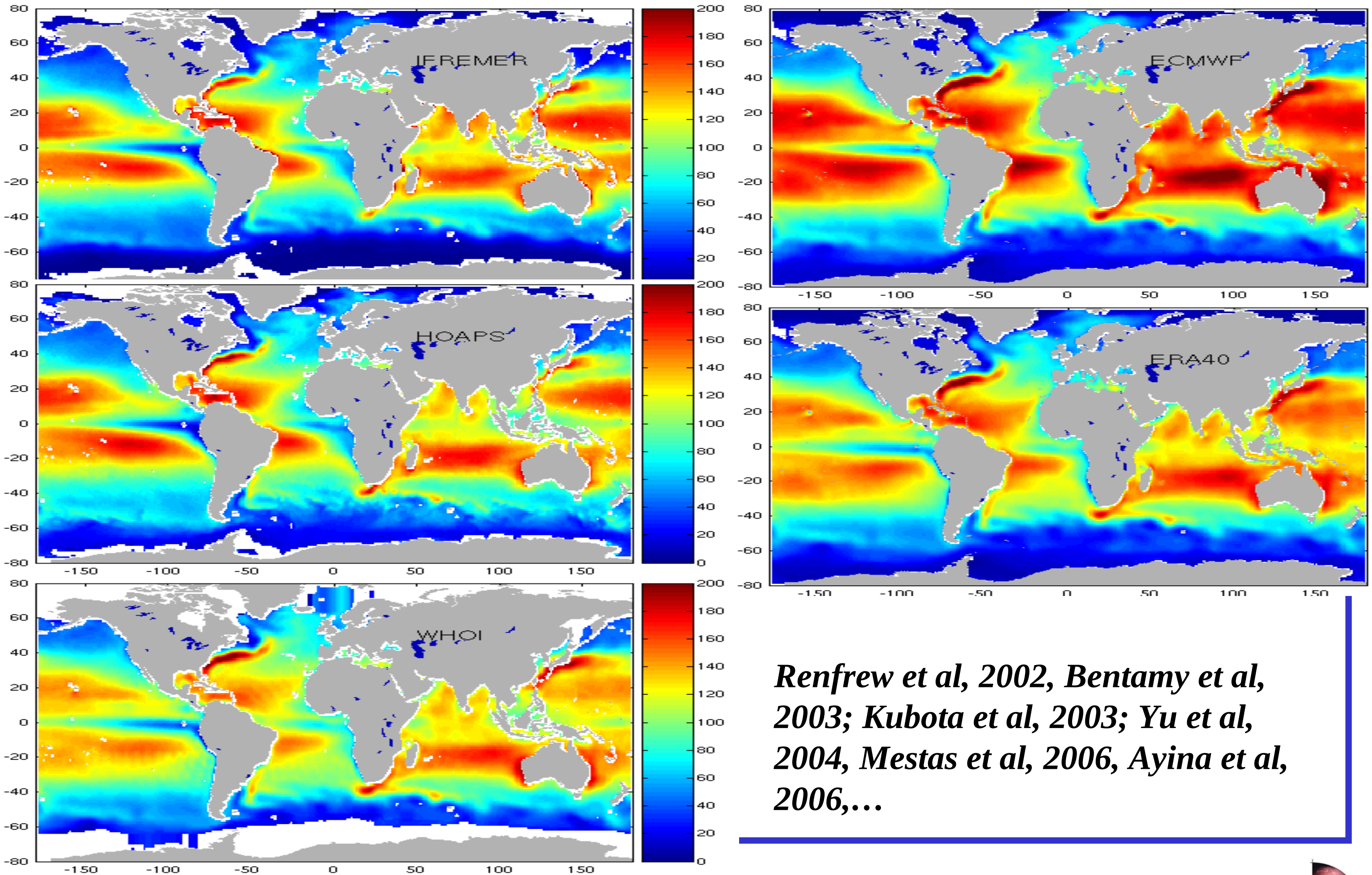
Satellite Data



Satellite Processing Scheme

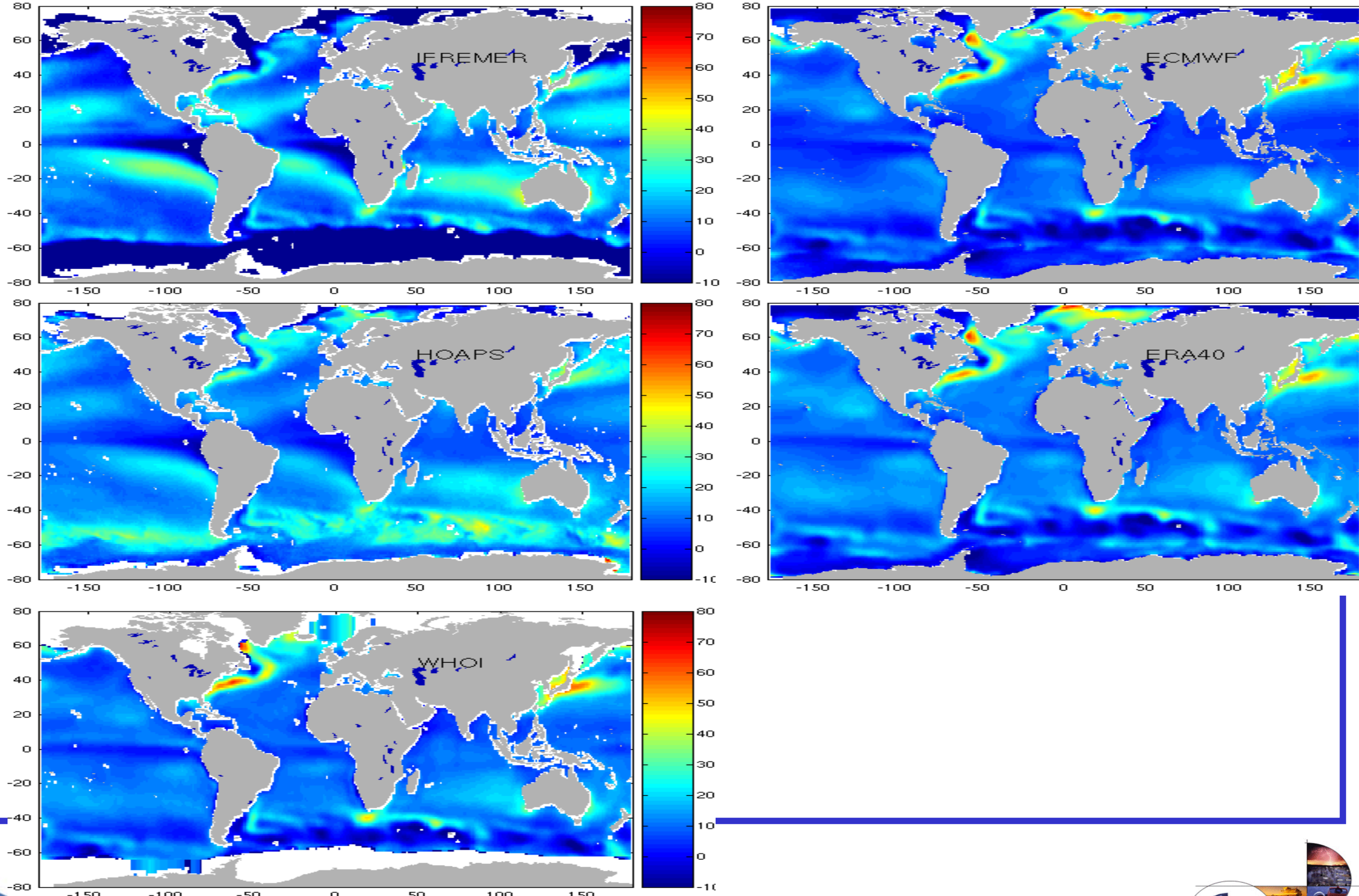


Latent Heat Flux : 1995 - 2000



Renfrew et al, 2002, Bentamy et al, 2003; Kubota et al, 2003; Yu et al, 2004, Mestas et al, 2006, Ayina et al, 2006,…

Sensible Heat Flux : 1995 - 2000



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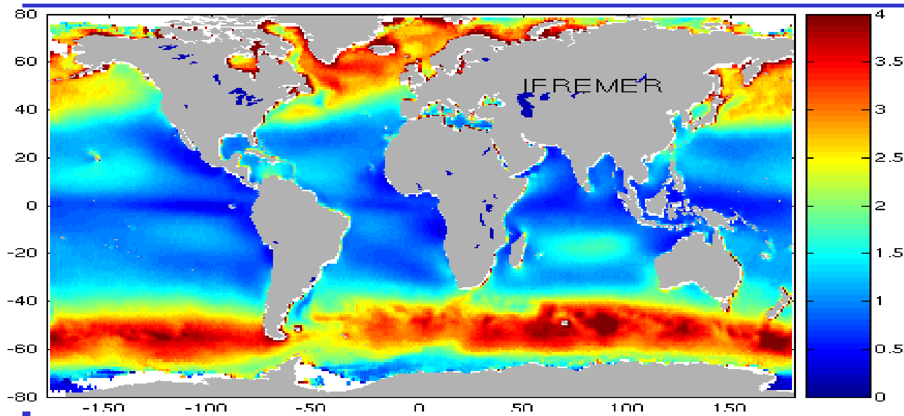
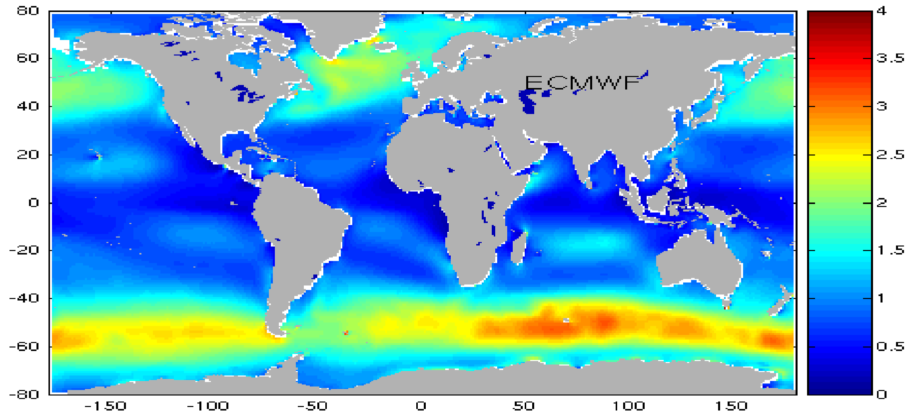
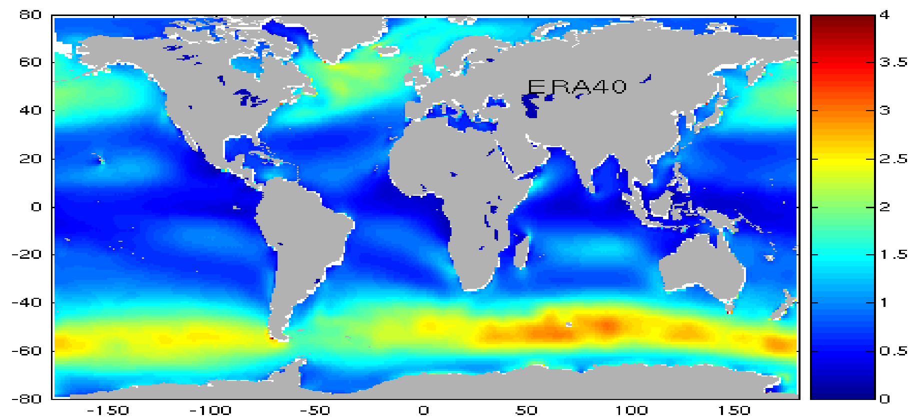
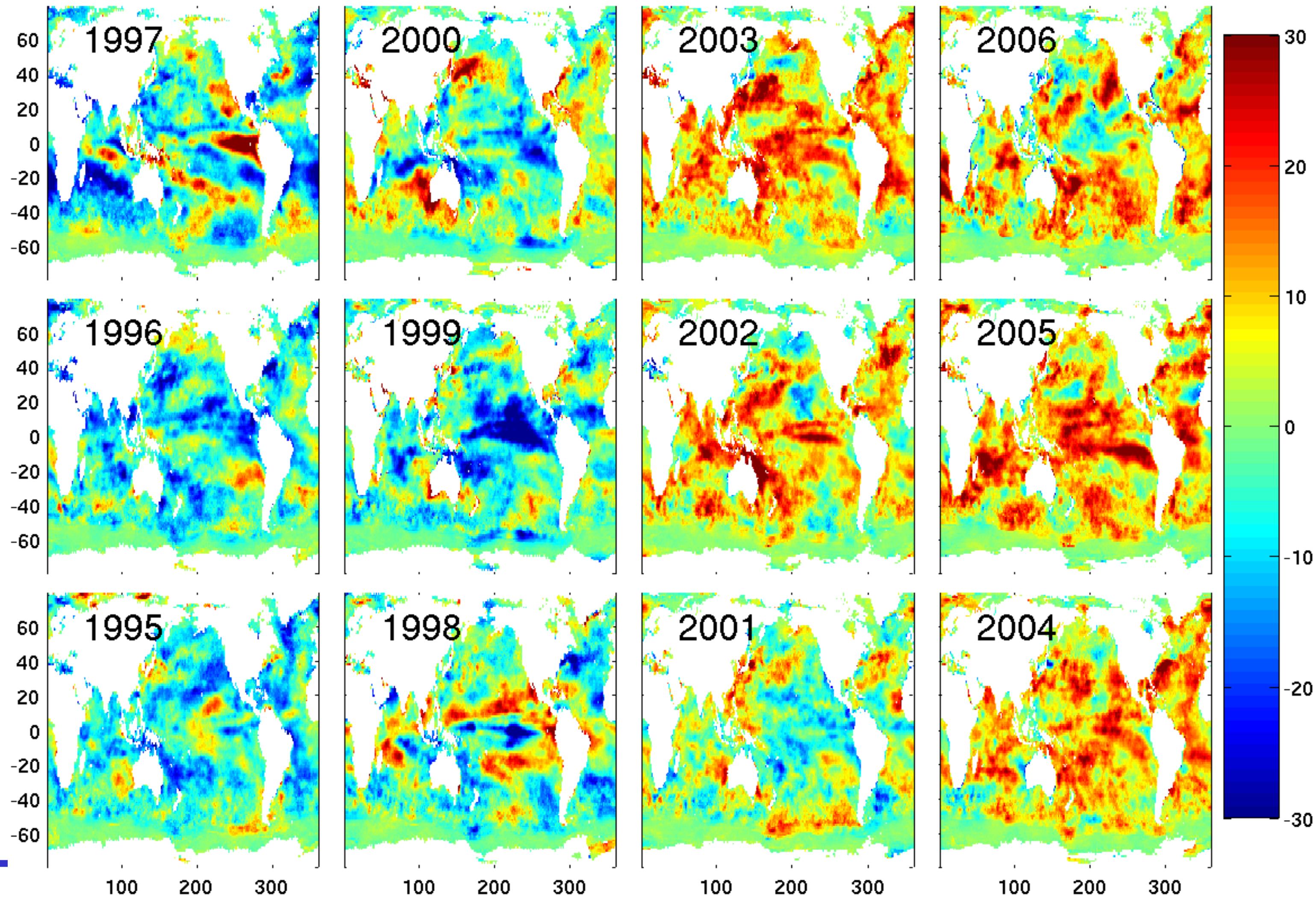
Wind Stress : 1995 - 2000



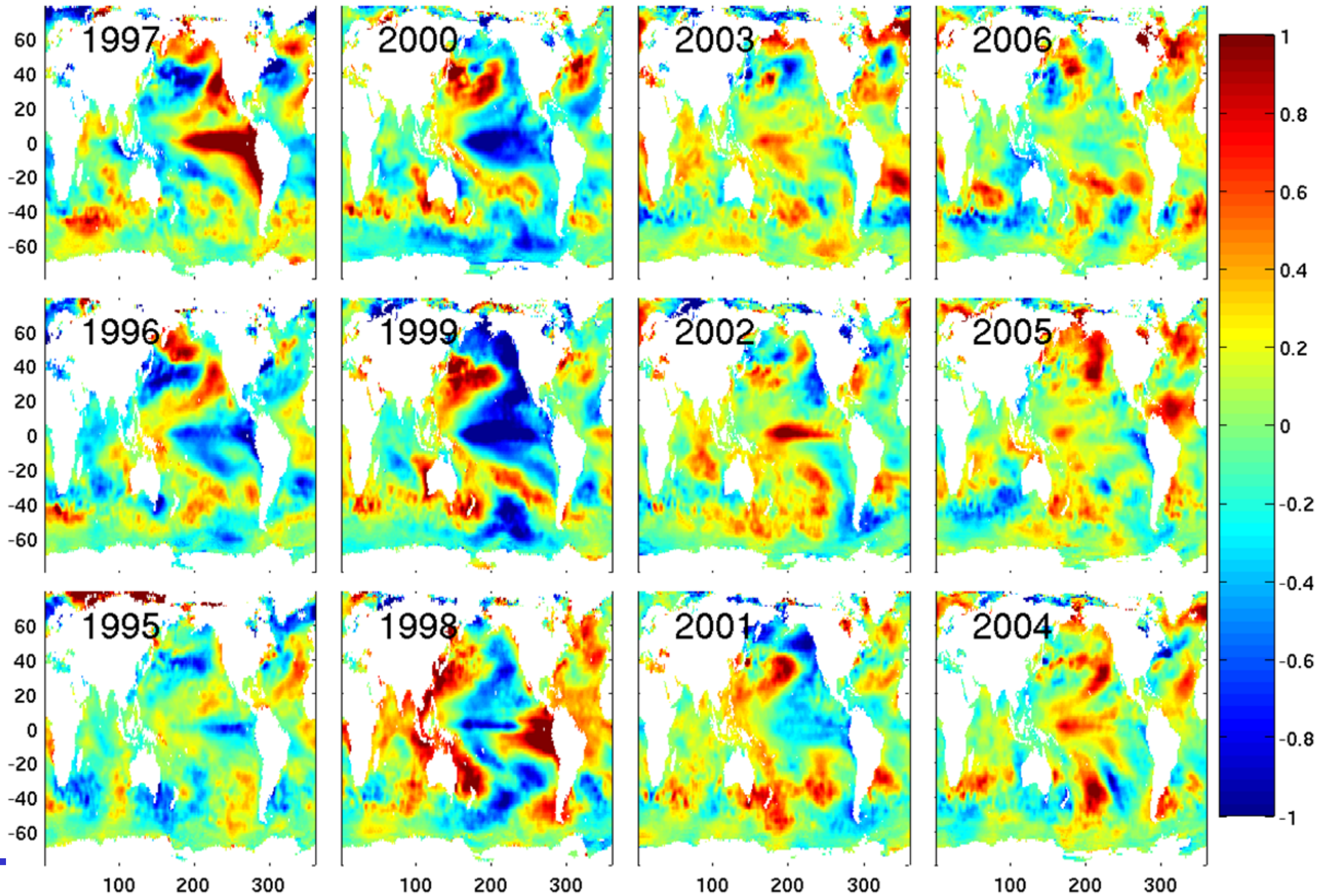




Heat Flux Anomaly



SST Anomaly



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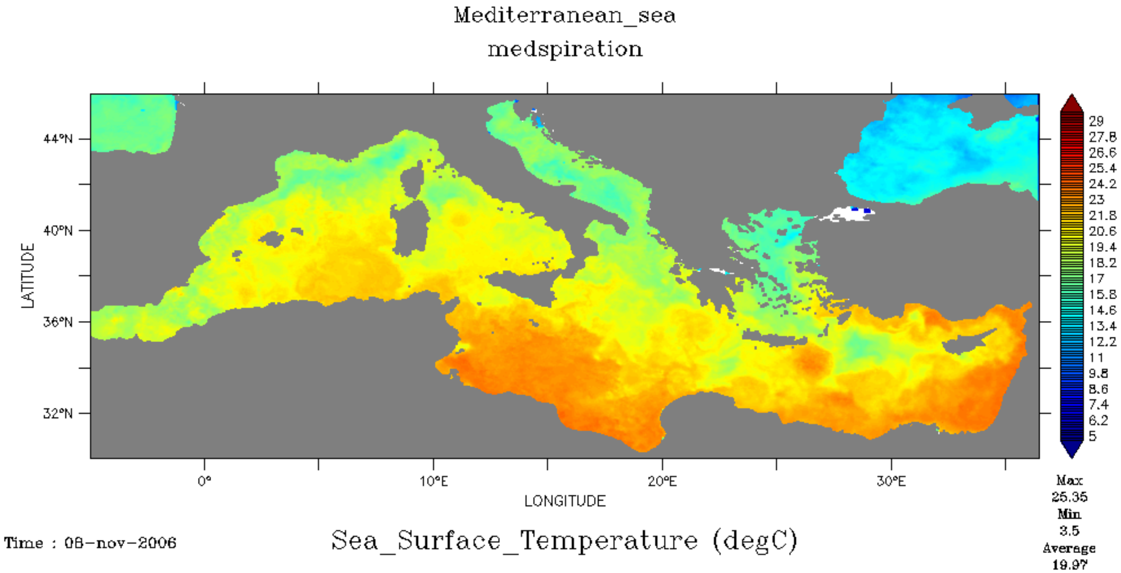
Sea surface temperature and upper ocean heat content

- Remote sensing
- In situ observations
- Model (with assimilation) output

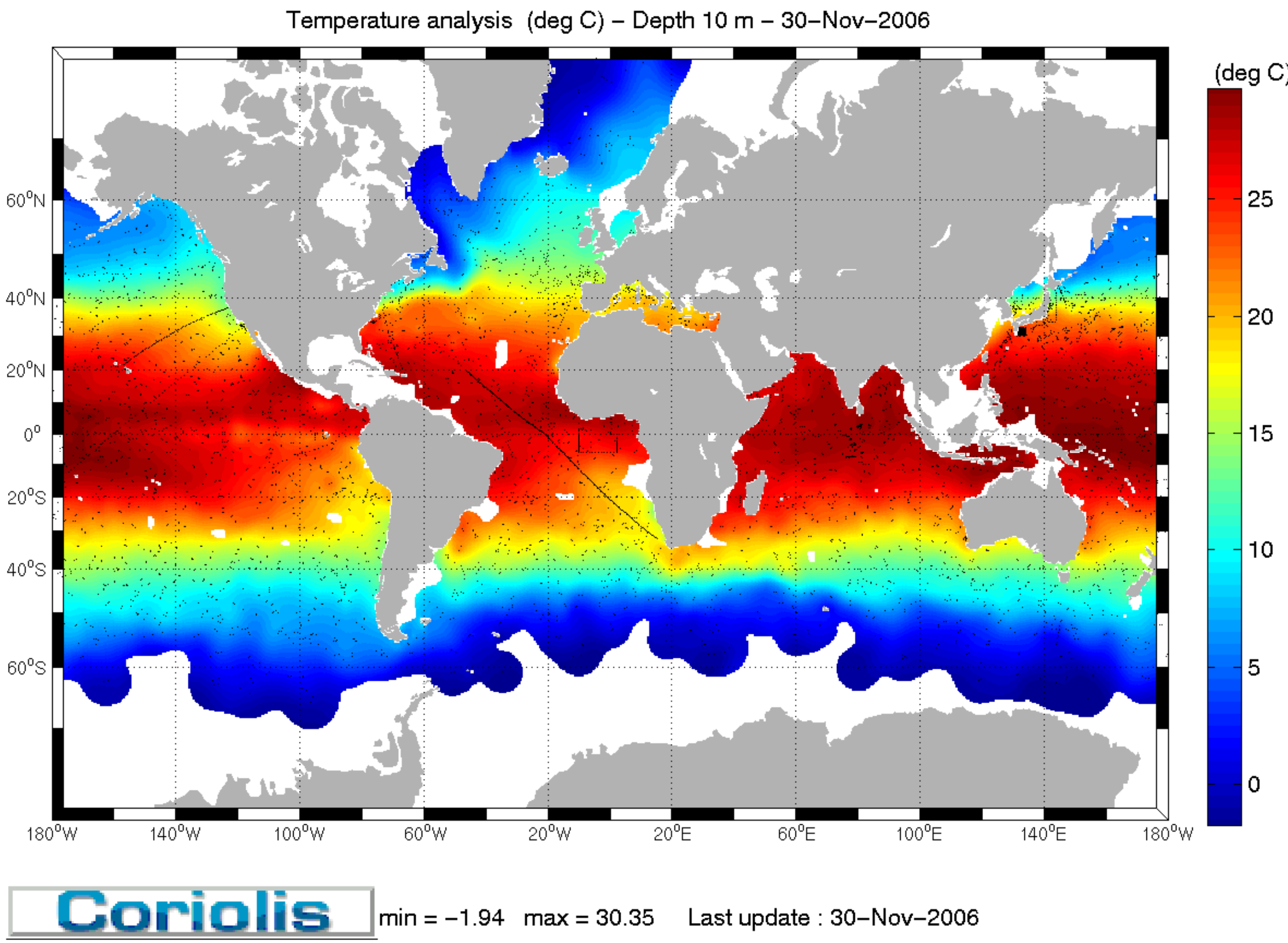
Sea Surface Temperature

- Thematic assembly centre derived from expertise of Global High Resolution SST – Pilot Project and ESA's Medspiration
  - ➢ Global : 5 to 10 km resolution
  - ➢ Regional : 2 km



~ SST (@ 10 m !) from in situ obs.

Weekly maps



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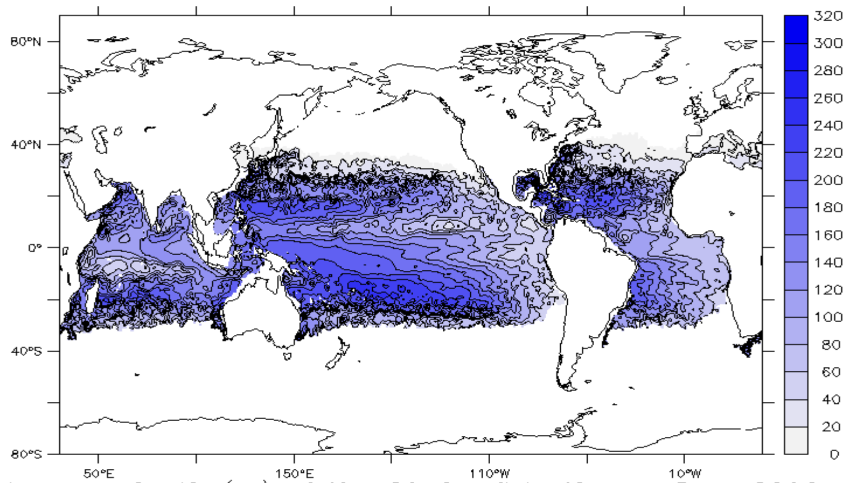
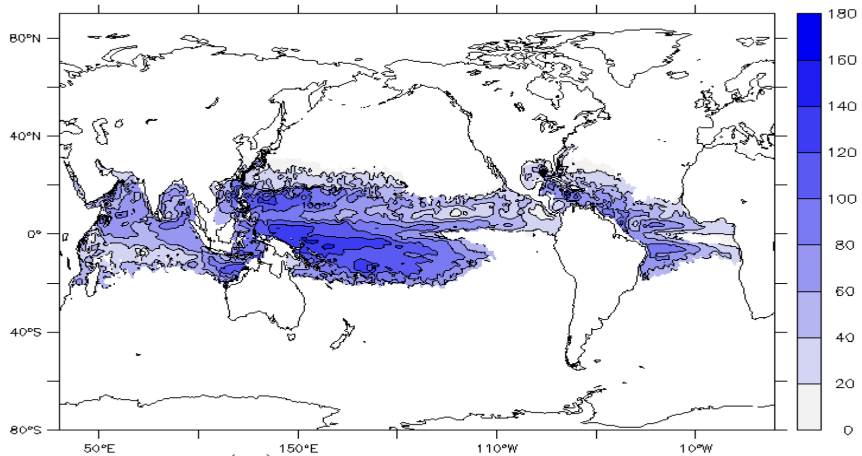
Upper ocean heat content :
Global Monthly maps of D20 and D26



Average depth (m) of the 20 deg.C isotherm, June 2006

D20 = Depth of 20°C isotherm jun06



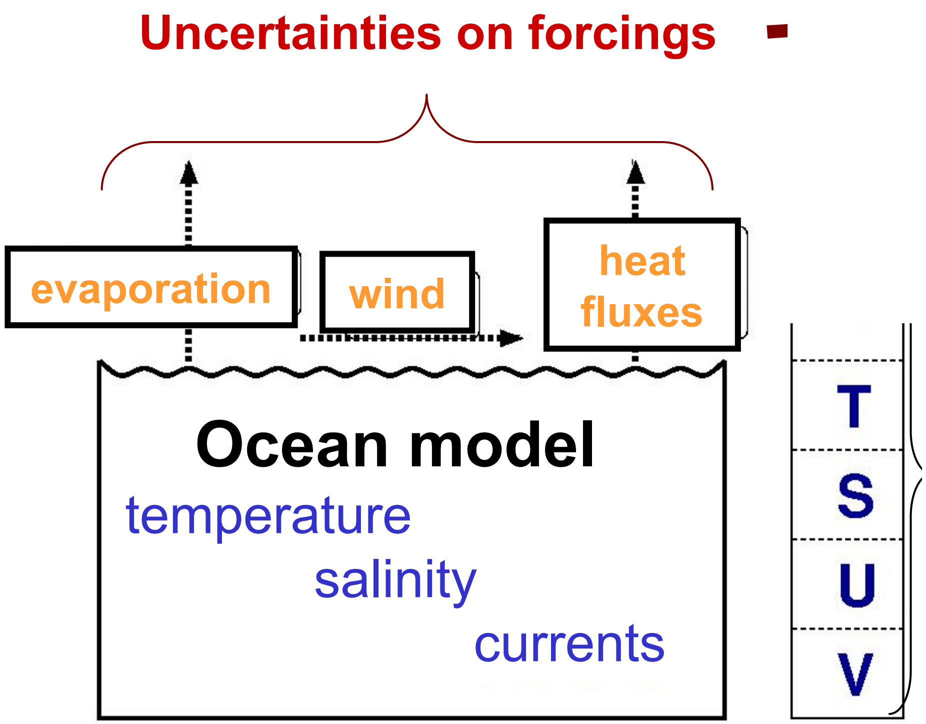
Average depth (m) of the 26 deg.C isotherm, June 2006

D26 = Depth of 26°C isotherm jun06

Surface fluxes estimated by ocean data assimilation

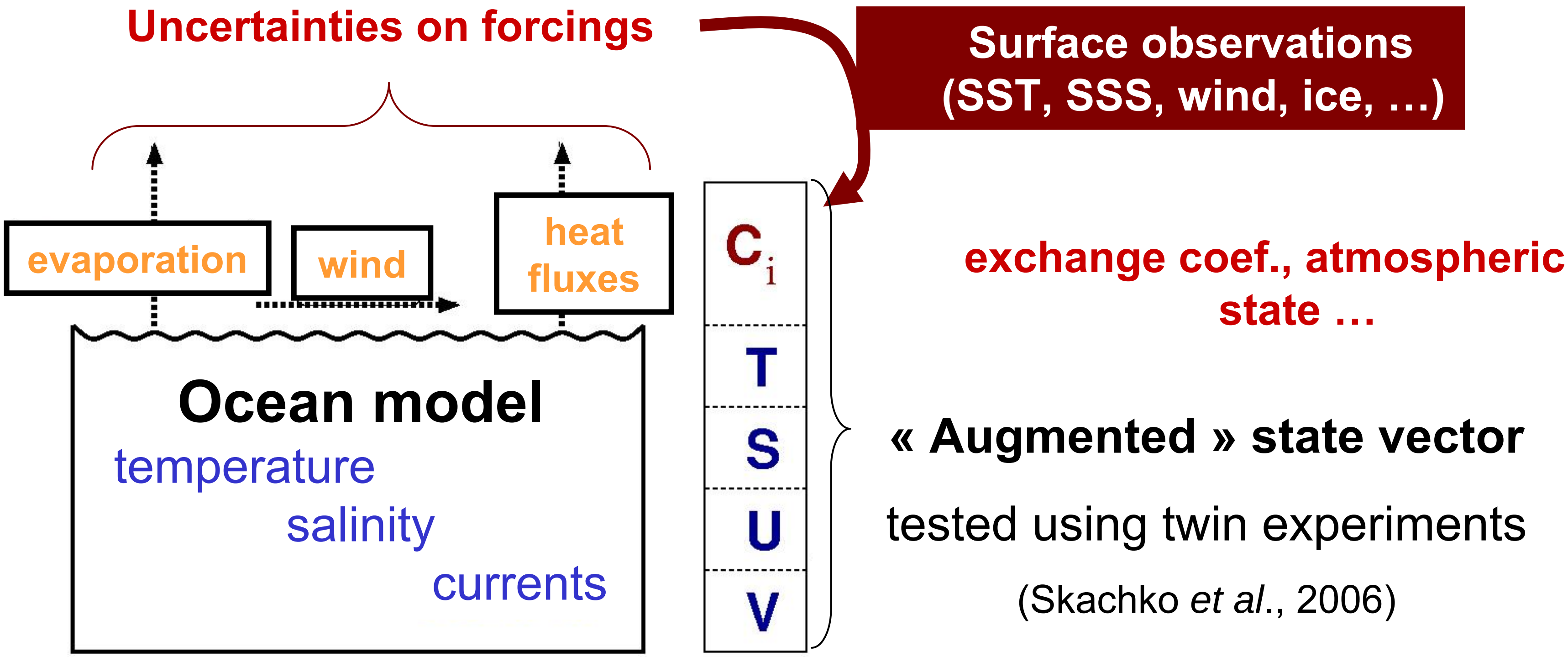
Skachko *et al*., 2006)

Control of air-sea fluxes : « Augmented » state vector estimation



(Skachko *et al*., 2006)

Control of air-sea fluxes : « Augmented » state vector estimation



« Augmented » state vector

tested using twin experiments

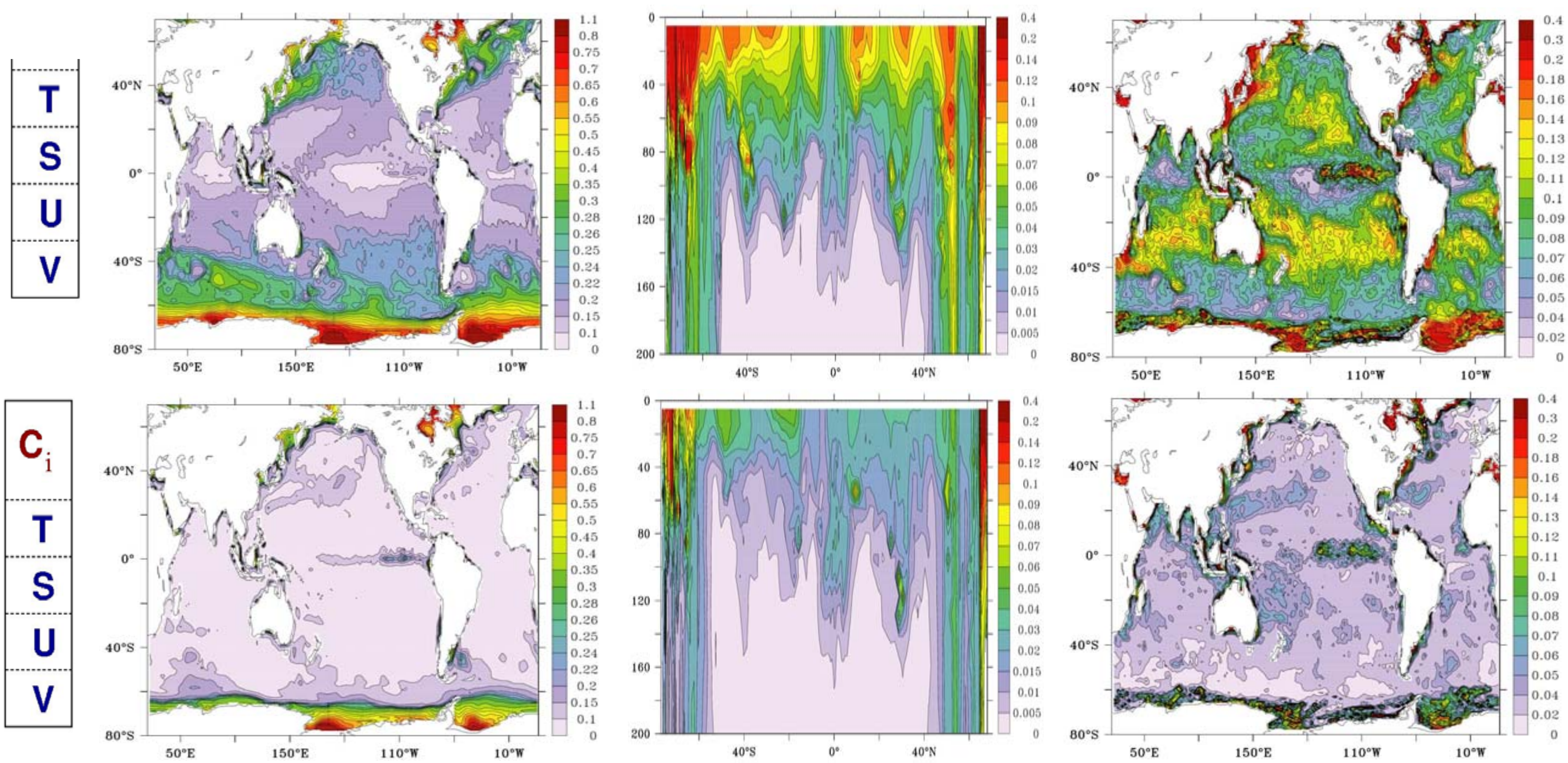
(Skachko *et al.*, 2006)

<u>Expected benefits:</u>

- ❑ **Reduction of uncertainties on oceanic forcings (parameterizations)**
- ❑ **Improved control of mixed layer properties**

« Augmented » state vector estimation including « bulk » coefficients

Assimilation of simulated data (0-200 m) in global OPA 2°x2°



RMS error on latent heat flux coef (x 10^3)

RMS error on temperature

RMS error on SST

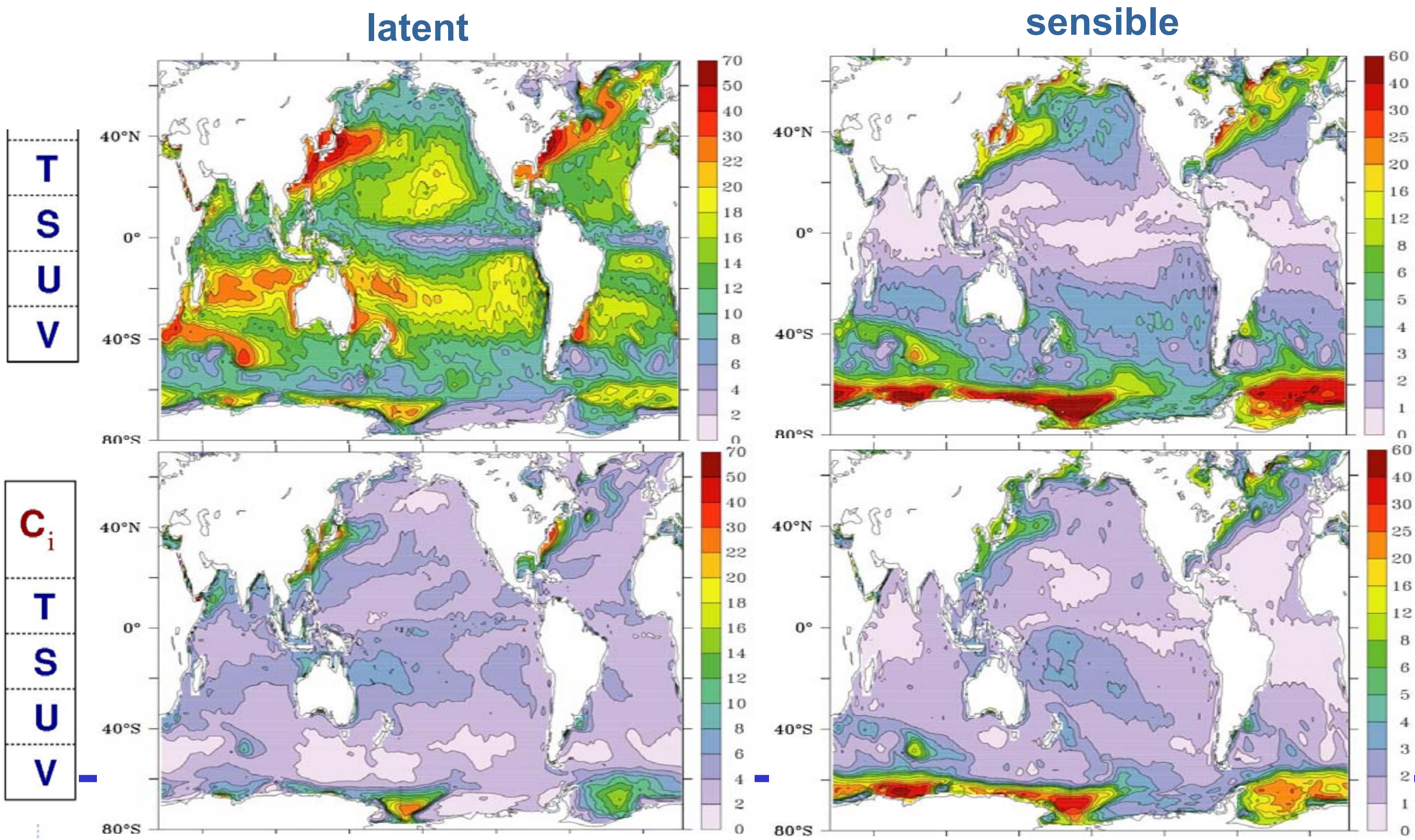
$$Q_{lat} = \rho_{air} L_w C_E W max\left(\mathbf{0}, q_{srf} - q_{air}\right)$$

GMES

Augmented state vector estimation including bulk coefficients

Assimilation of simulated data (0-200 m) in global OPA 2°x2°

RMS error on heat flux (computed *a posteriori*, in W/m2)



❑ Generic approach: to be generalised to other observations at O/A interfaces

The Carbon Cycle

What can operational oceanography contribute ?

Ocean and the Carbon Cycle

- The Ocean : reservoir and damper
  - ~ ½ of exchanges with atmosphere
- Very much a research issue
  - e.g. the CARBOOCEAN Integrated Project
  - Several actions in MERSEA
- The physical pump (~ ¼ of the fluxes)
  - Depends on wind, SST, and pCO_2
  - Production of gas exchange coefficients
- Biological pump
  - Coupled physical and bio-geochemical or ecosystem modelling

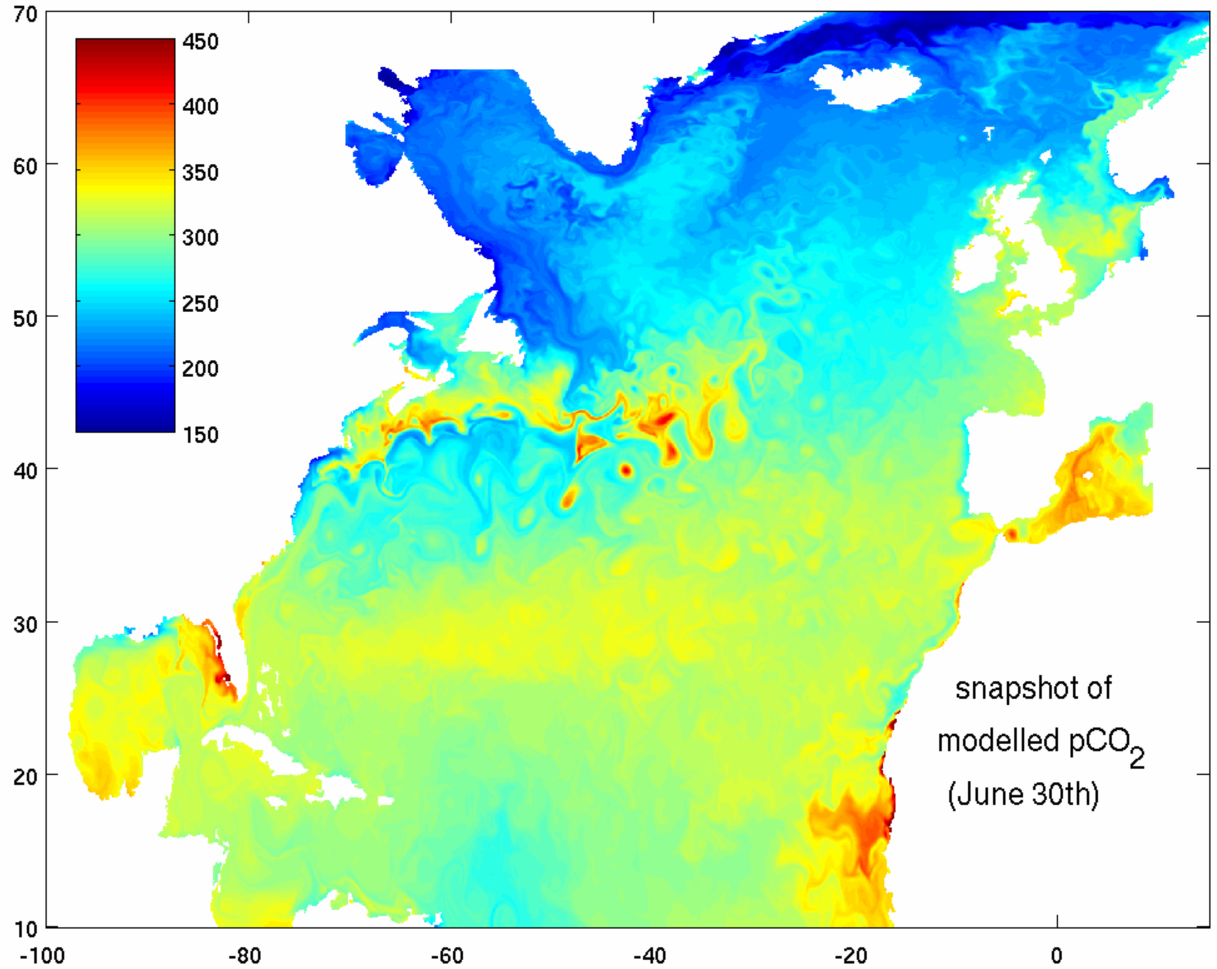
Physical pump

What help can an ocean observing and monitoring system provide for better estimates of sea-surface pCO_2?

Issues

- Synoptic maps of surface pCO_2 critical for better estimates of regional CO_2 fluxes across the ocean surface.
- Still sparse pCO_2 measuring network (mainly VOS lines).
- Need robust interpolation tools.
  - Models
- Direct spatial interpolation difficult because of large spatial and temporal variability of pCO_2.

Snapshot of pCO_2 simulated by a 1/12 degree coupled biogeochemical-circulation model

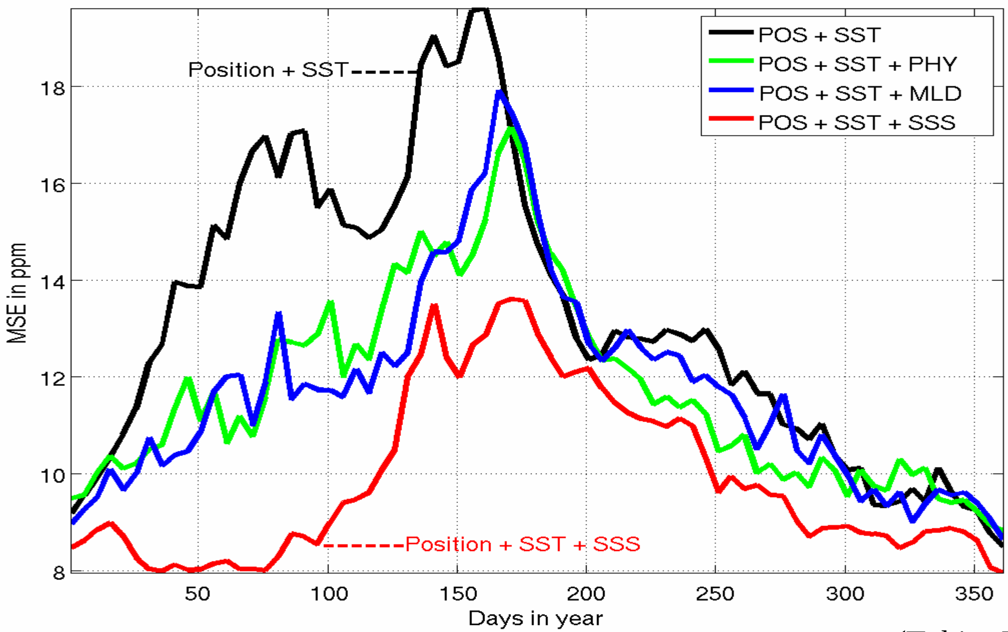


(Tobias Friedrich et al., IFM-GEOMAR)

A pCO_2 mapping approach

- We have:
  - pCO_2 measured along VOS lines
  - Remote sensing of SSH and SST (cloud issues), ocean colour (cloud issues), SSS (?)
  - Analysed SST, SSH, SSS, ocean colour,… fields from operational systems.
- We can:
  - use VOS lines to train neural network that can derive pCO_2 from easier-to-measure/predict surface properties (SST, SSS, chlorophyll, mixed layer depth)
  - use neural network to estimate pCO_2 everywhere where information about these easier-to-measure/predict properties is available.

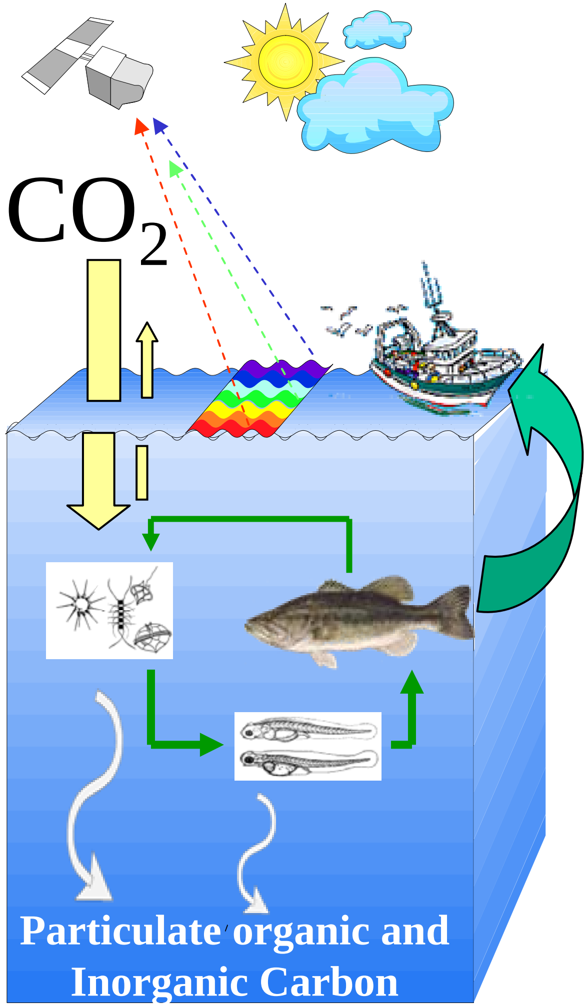
Annual cycle of rms errors in pCO_2 estimated from different input fields



(Tobias Friedrich et al., IFM-GEOMAR)

- ⇒ So far, pCO_2 maps estimated from SST+SSS have lowest errors.
- ⇒ Need good estimates of high-resolution SST and SSS fields (and possibly additional variables like MLD and chlorophyll).
- ⇒ Exploit surface information on properties other than pCO_2, and provided by operational systems, to generate accurate synoptic maps of pCO_2 .

Bio-geochemical and ecosystem modelling

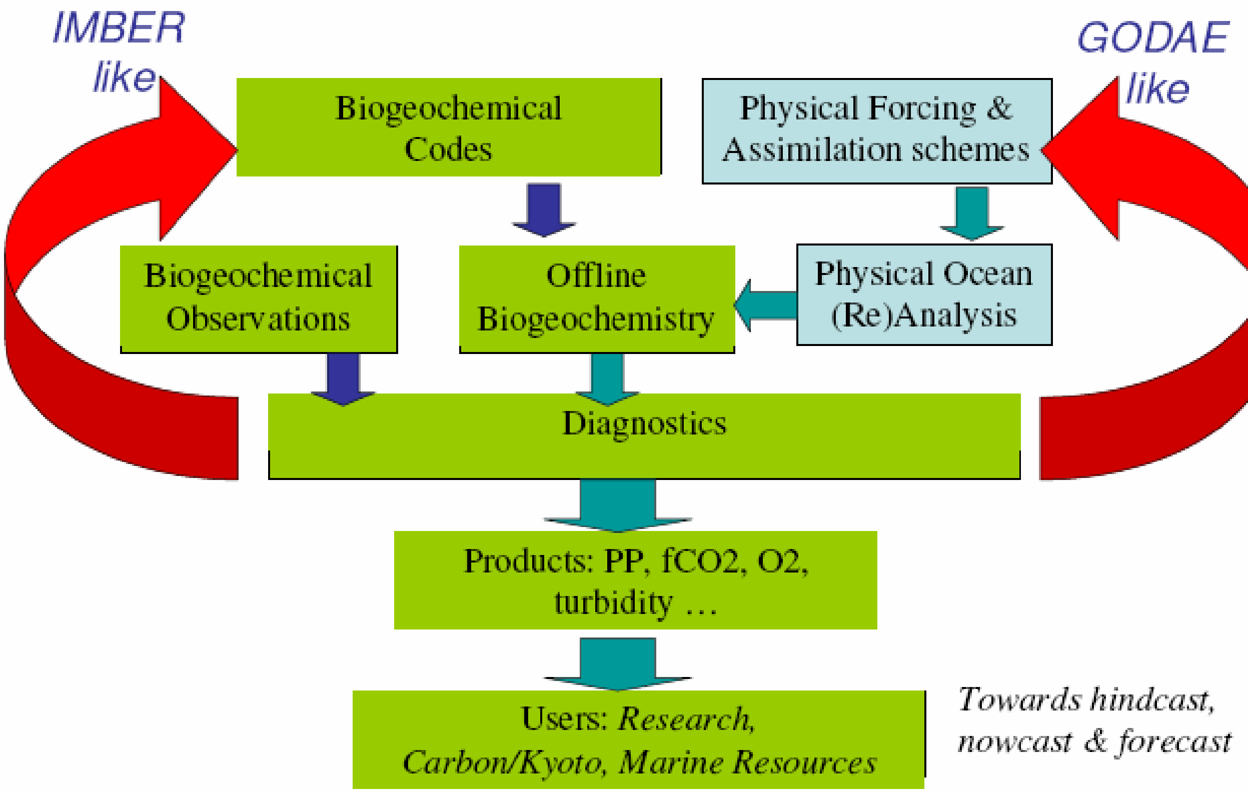


Why monitor ocean primary production ?

The production of organic matter by photosynthesis (Primary Production) controls the **marine food chain**, including the upper trophic levels (fishes) of major importance to society.

Primary reduction of inorganic carbon in the upper layer of the ocean represents the first step in the oceanic removal of the atmospheric carbon dioxide, **the biological pump**.

Biology within operational oceanography:
The double challenge



Considerable challenge !

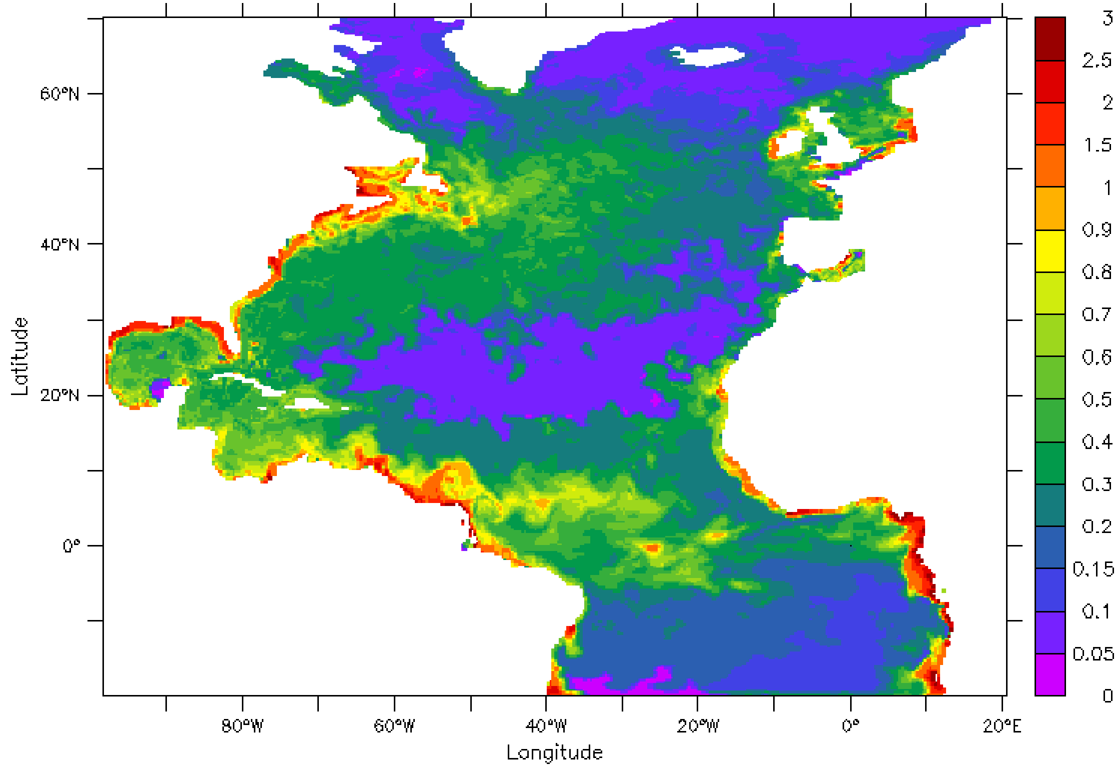
- Complexity of the system
  - Large number of parameters, few of which can be observed
  - Strong coupling with the physics (very small scale processes)
- Several approaches
  - On-line / off-line
  - With or without assimilation (physical and/or bio data)
  - Global to regional to coastal, with increasing levels of complexity, and resolution

Chlorophyll from PISCES model

coupled into 1/3° resolution MERCATOR model

Includes :Nitrates, Silicates, Phosphates, Oxygène, CO_2 , Fe.

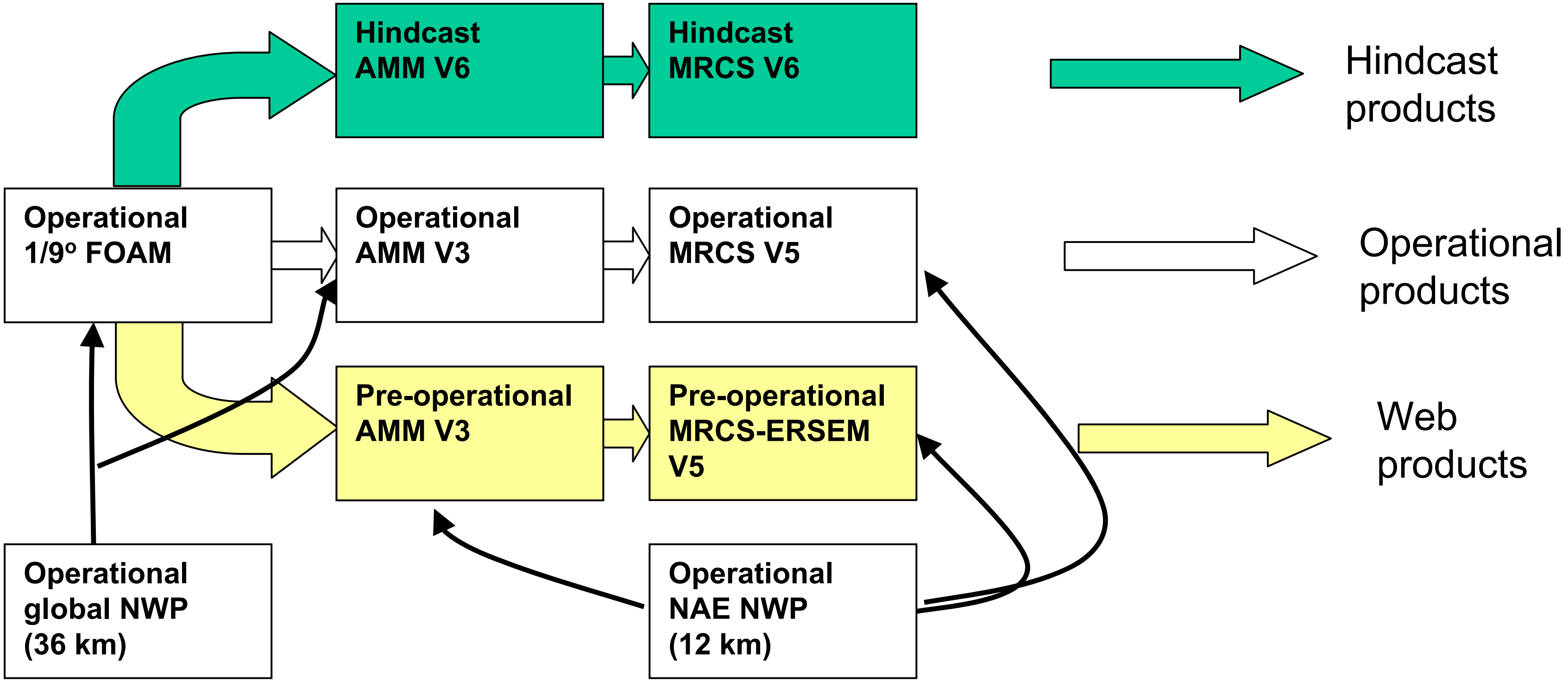
Weekly runs since 2006



PISCES_AN1_20050101

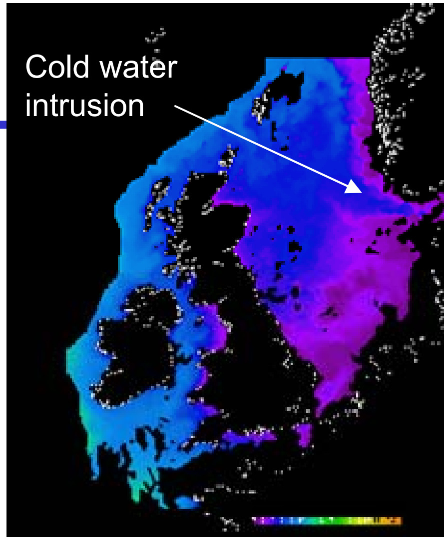
P. Monfray, and the Bionuts Group

Pre-operational Shelf Sea systems: NCOF (Met Office)

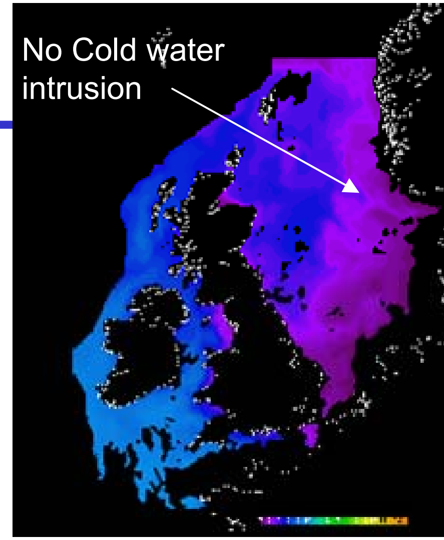


- A period of parallel running starting late October as target
- Full operational implementation in November 2006

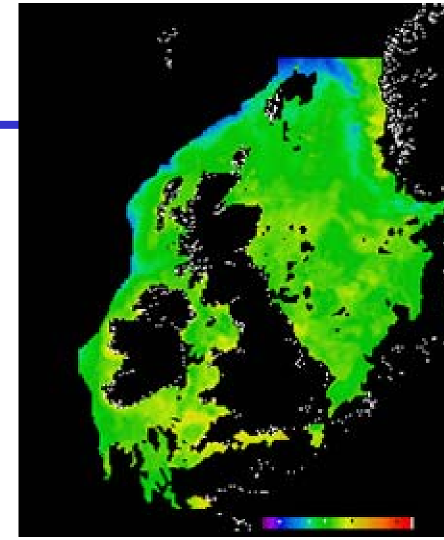
AVHRR SST



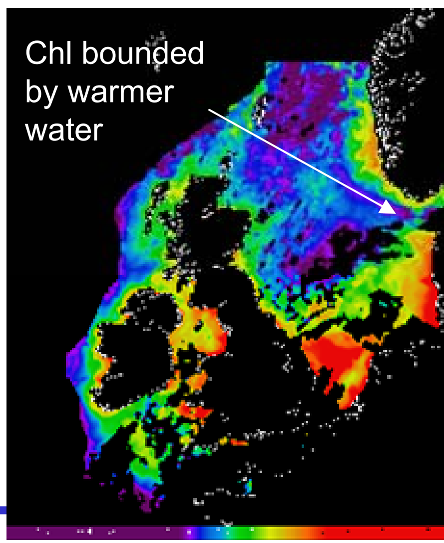
Model SST



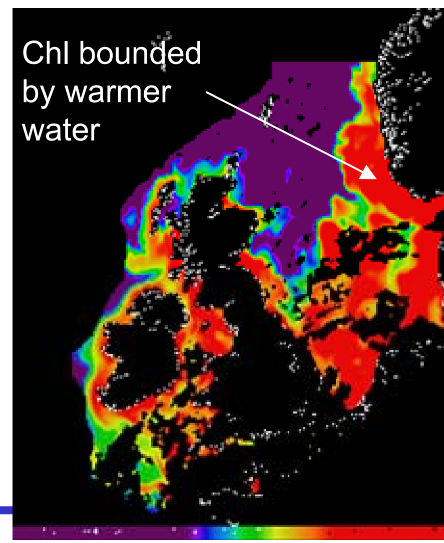
Difference



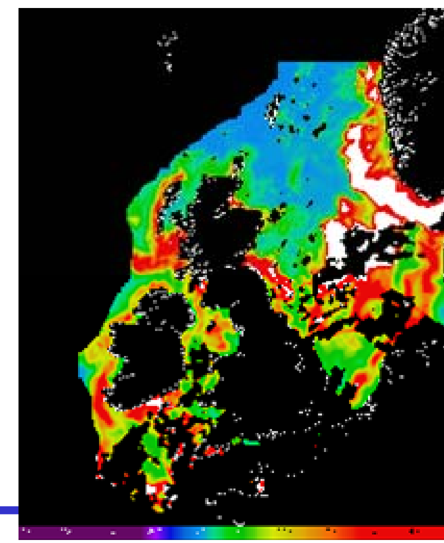
MODIS AQUA Chlorophyll



Model Chlorophyll

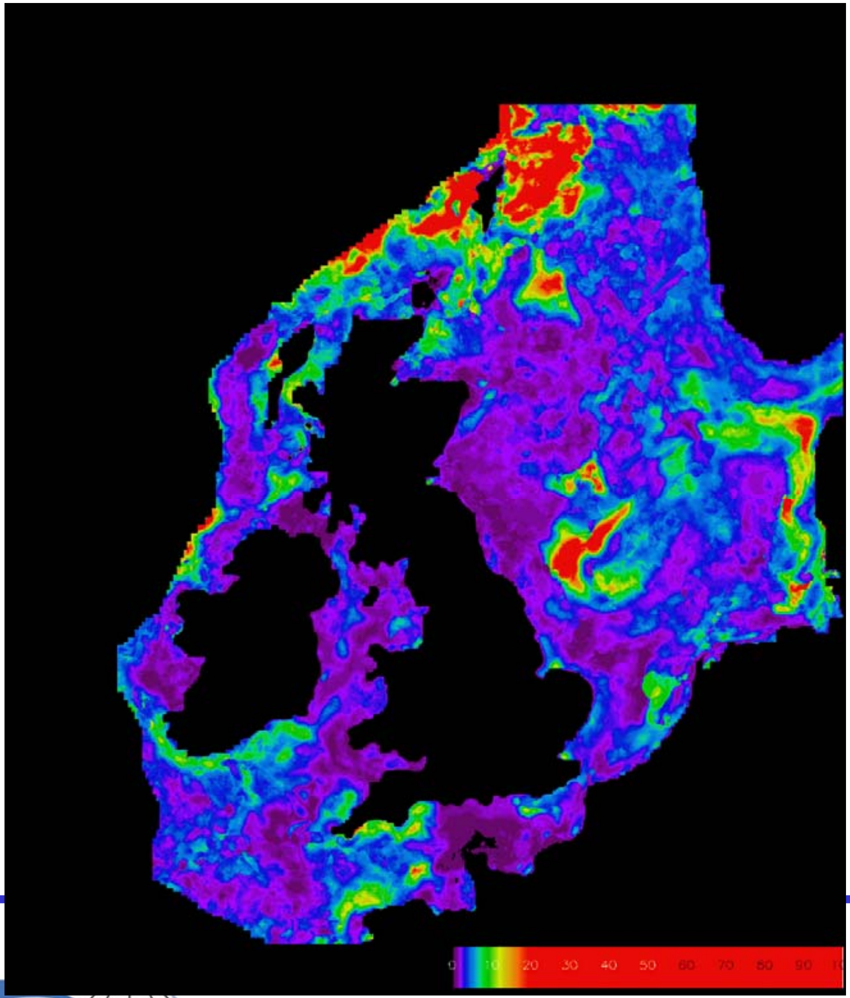


Difference

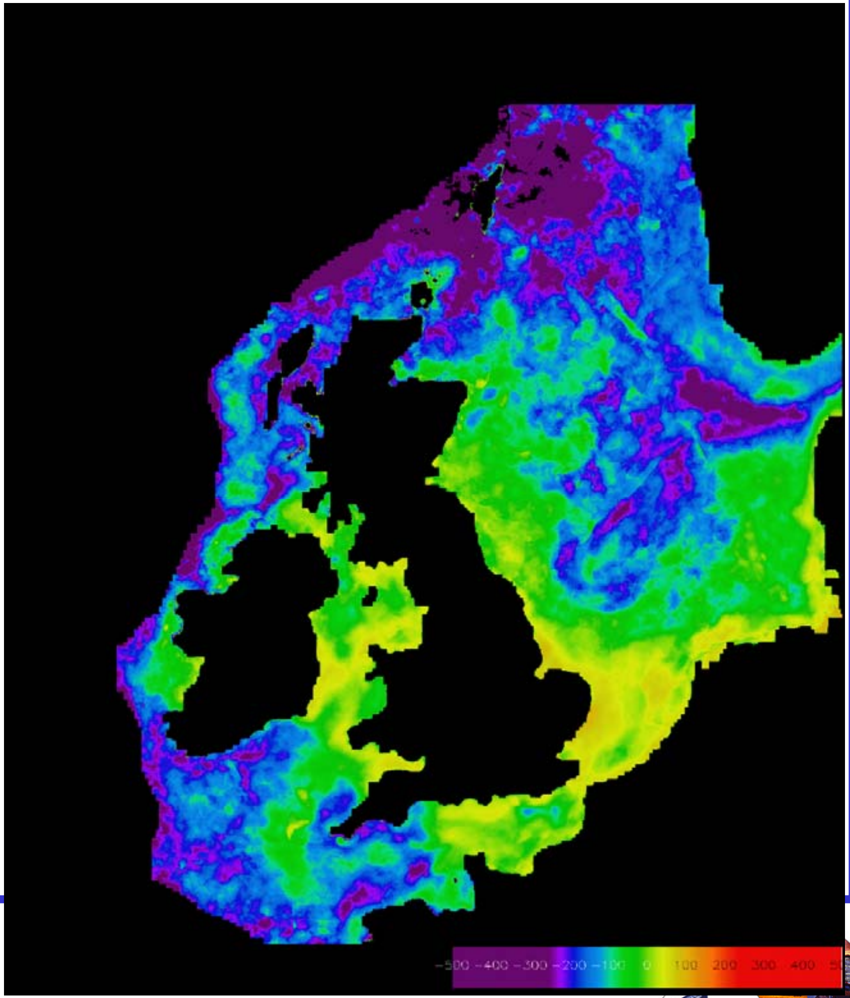


Annual spatial distribution of normalized rms error and model bias: Chlorophyll 2005

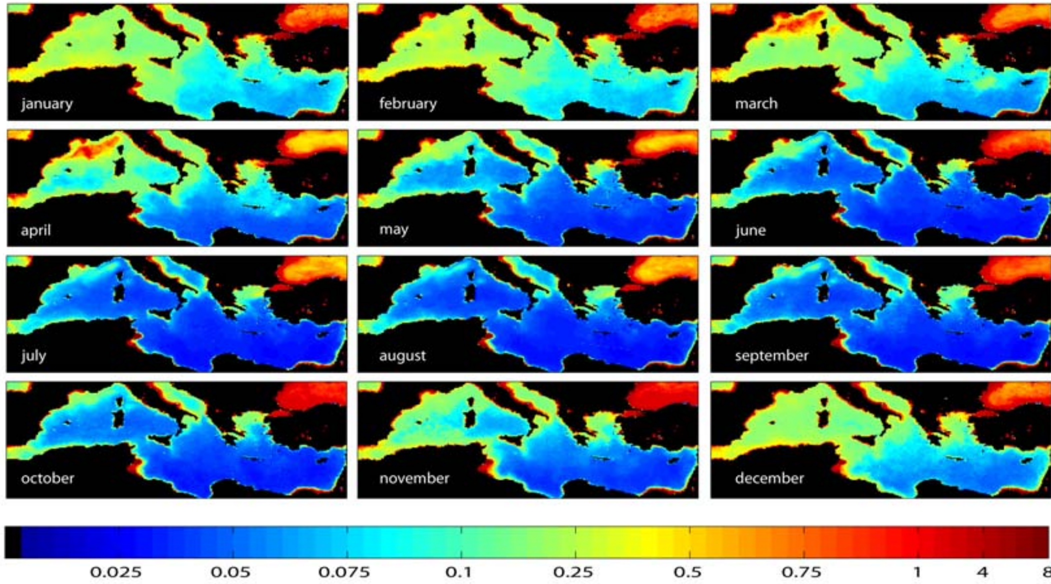
Normalised rms error



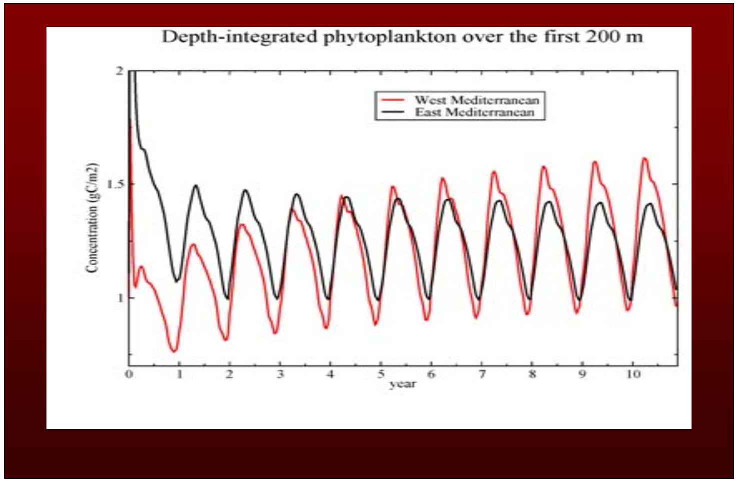
Model Bias

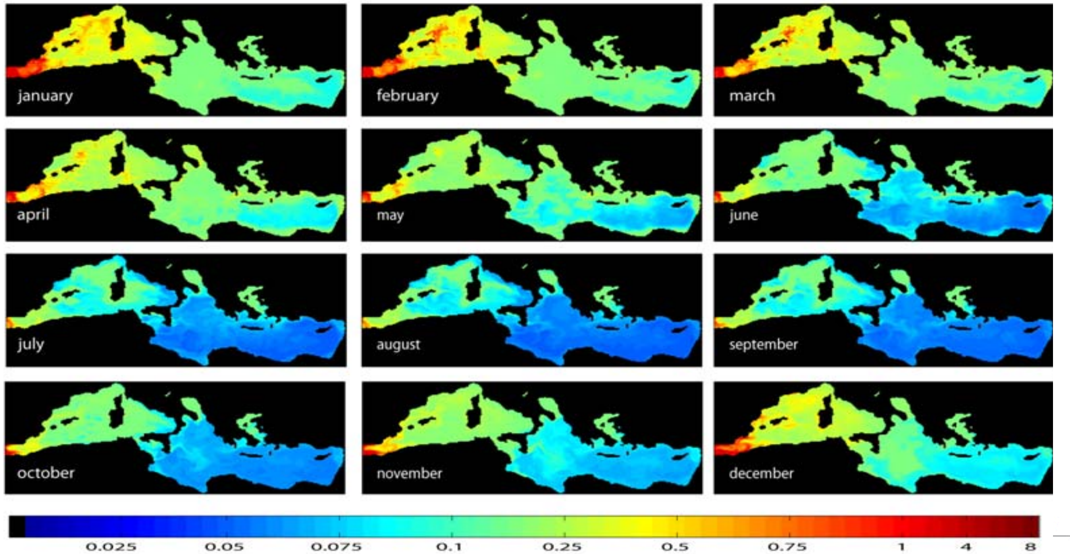


Seasonal cycle of chlorophyll in the first optical layer



Monthly chlorophyll climatology maps derived from SeaWiFS data, processed by GOS-ISAC-CNR, for the year 1997-2004.



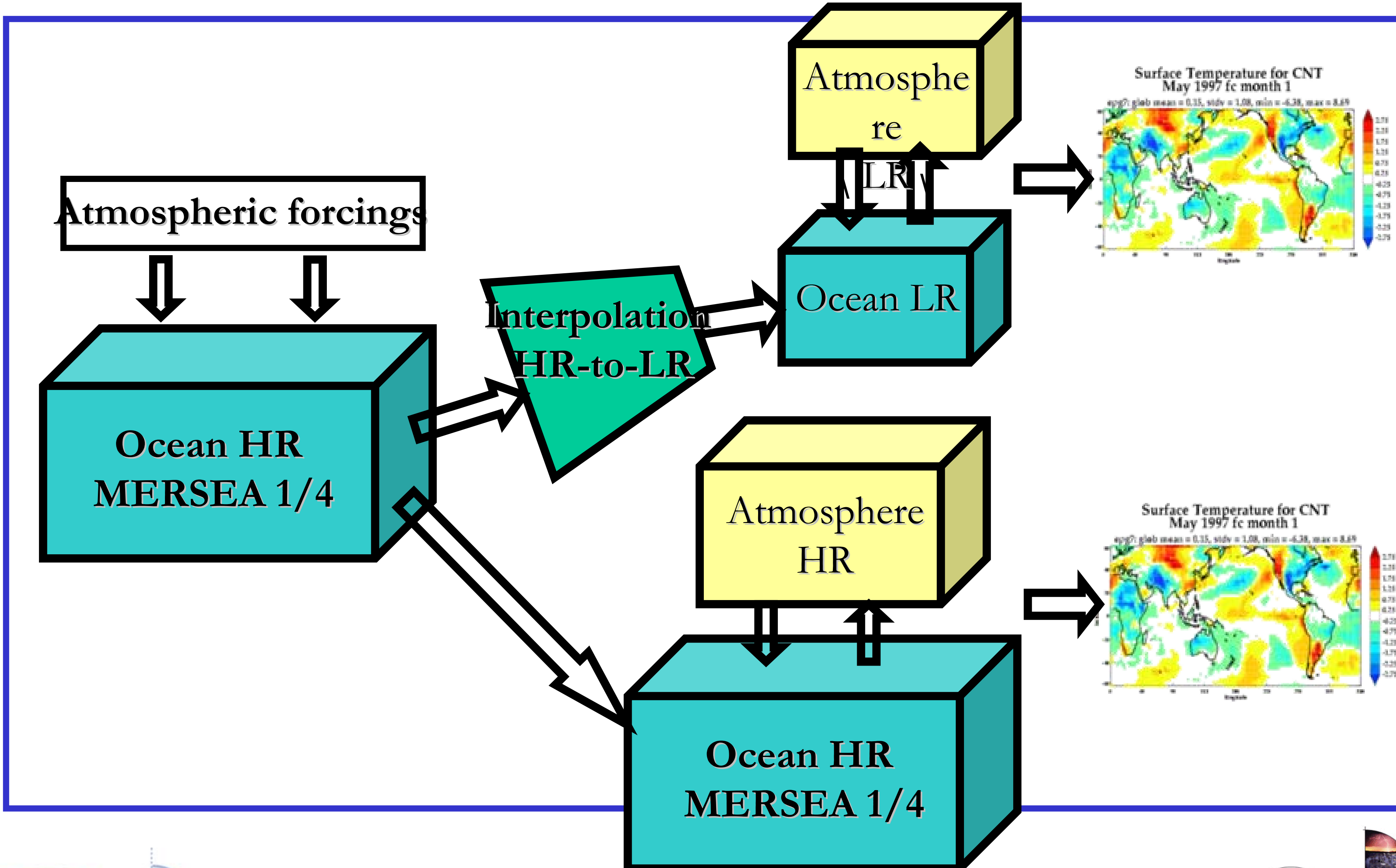


Monthly chlorophyll concentration maps obtained from OGS/OPA transport model after 10y spin-up.

Seasonal Forecasting

- Evaluate the impact of high-resolution initial state provided by Mersea system
- Perform different coupled runs
  - ➢ Model resolution (MERSEA ¼ °)
- CEPMMT, Météo-France, INGV, Mercator
- Work under way, high potential impact

Outline of Seasonal Forecast in MERSEA

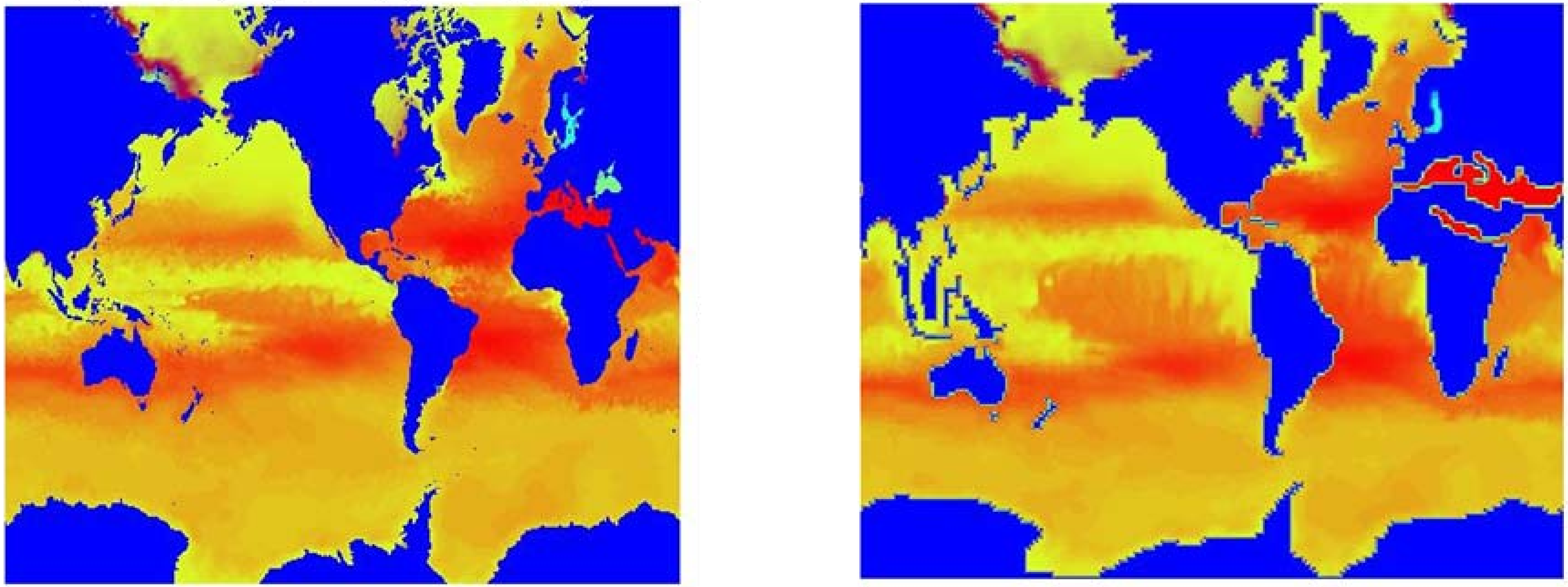


Interpolation MERSEA ¼° → ORCA2

Salinity field

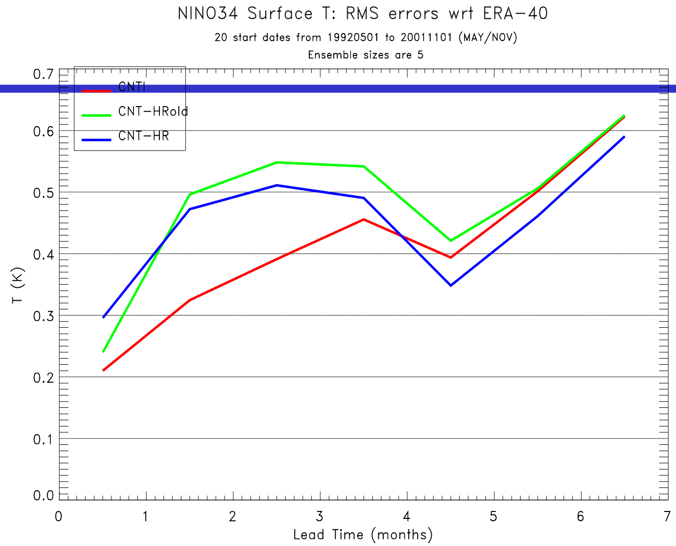
Original field ¼°

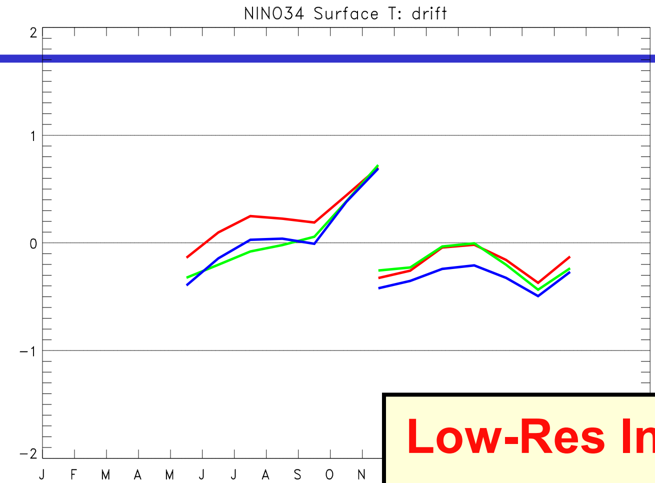
Interpolated field

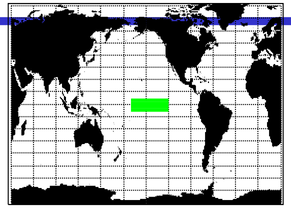


All fields needed for model restart such as T, S, U, V, η and others have been interpolated.

Seasonal Forecasts: summary statistics

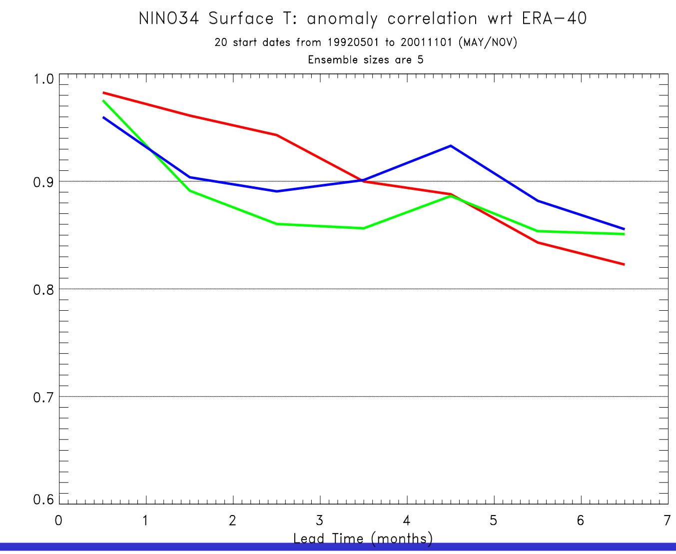


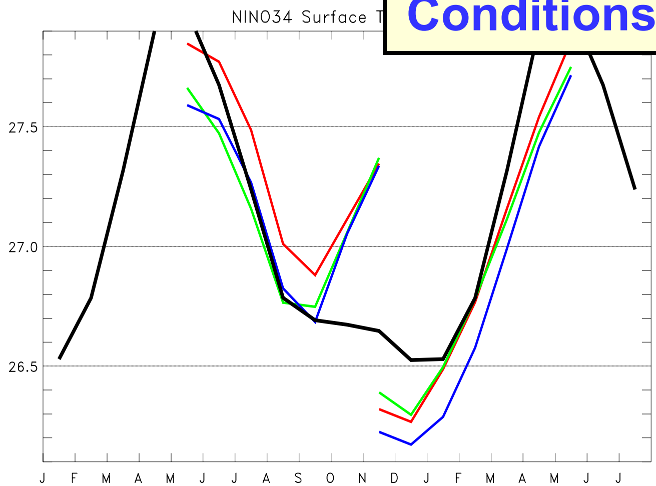




Low-Res Initial Conditions

Interpolated Initial Conditions





MERSEA

GMES

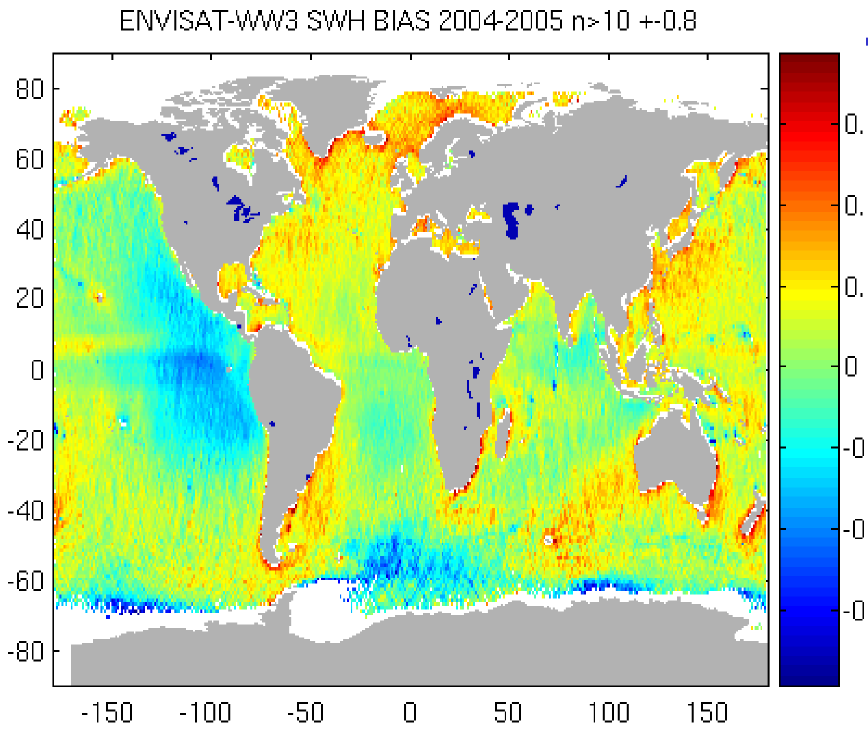
Next steps

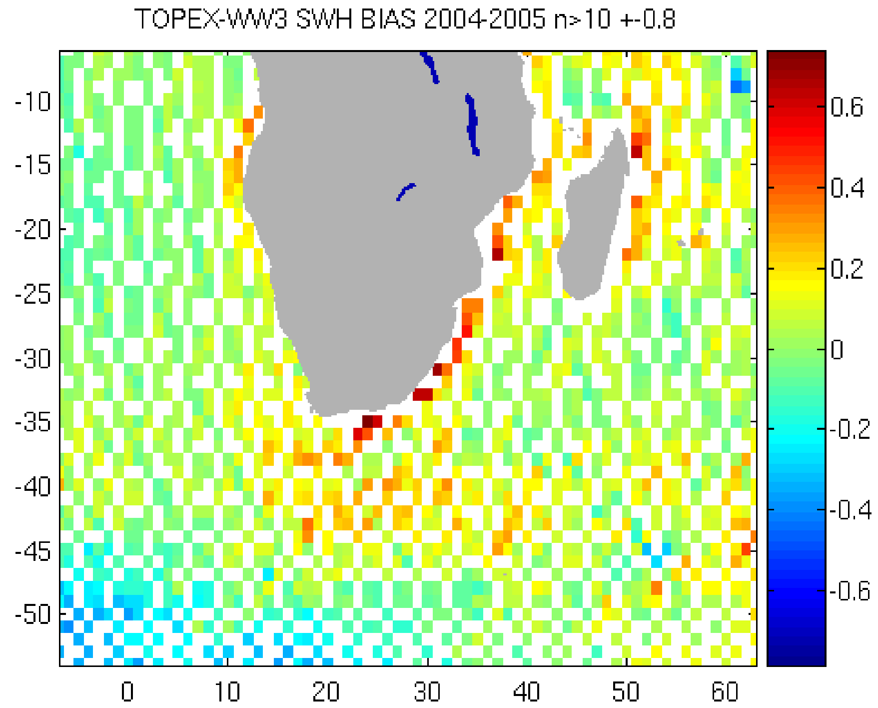
- Seasonal forecasts using Mersea-¼ coupled to high resolution atmospheric models for select cases (e.g. growing phase of El Nino 1997-98).
- Will produce near-real time seasonal forecasts for TOP2 (May 2007 and Sep 2007)
- Also Medium Range with MERSEA ¼ coupled to ECMWF atmospheric model to study select hurricane events

Possible MERSEA follow-up activities

- Continue Seasonal Forecasts with special focus on sea ice modelling and initialisation and on understanding of initial conditions on the first month of integration

Effects of currents on wave forecasts





Comparison of WaveWatch III forecasts and altimetre significant wave height

P. Queffeulou et B. Chapron

Conclusions

- Ocean – Atmosphere interactions are multifarious
- Forcing fields needed for ocean systems
  - Data access is an issue in some cases
- Ocean products being developed
- Wider use of ocean products depends on
  - reliability and operational status
  - full validation
- Some promising and active research areas
  - Carbon cycle, seasonal forecasting, surface fluxes
- Implementation of Marine Core Services will strenthen the links