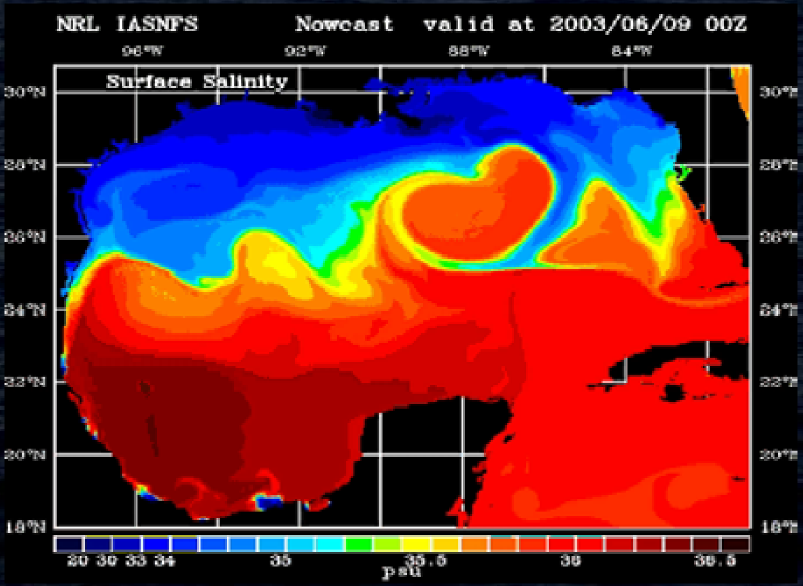
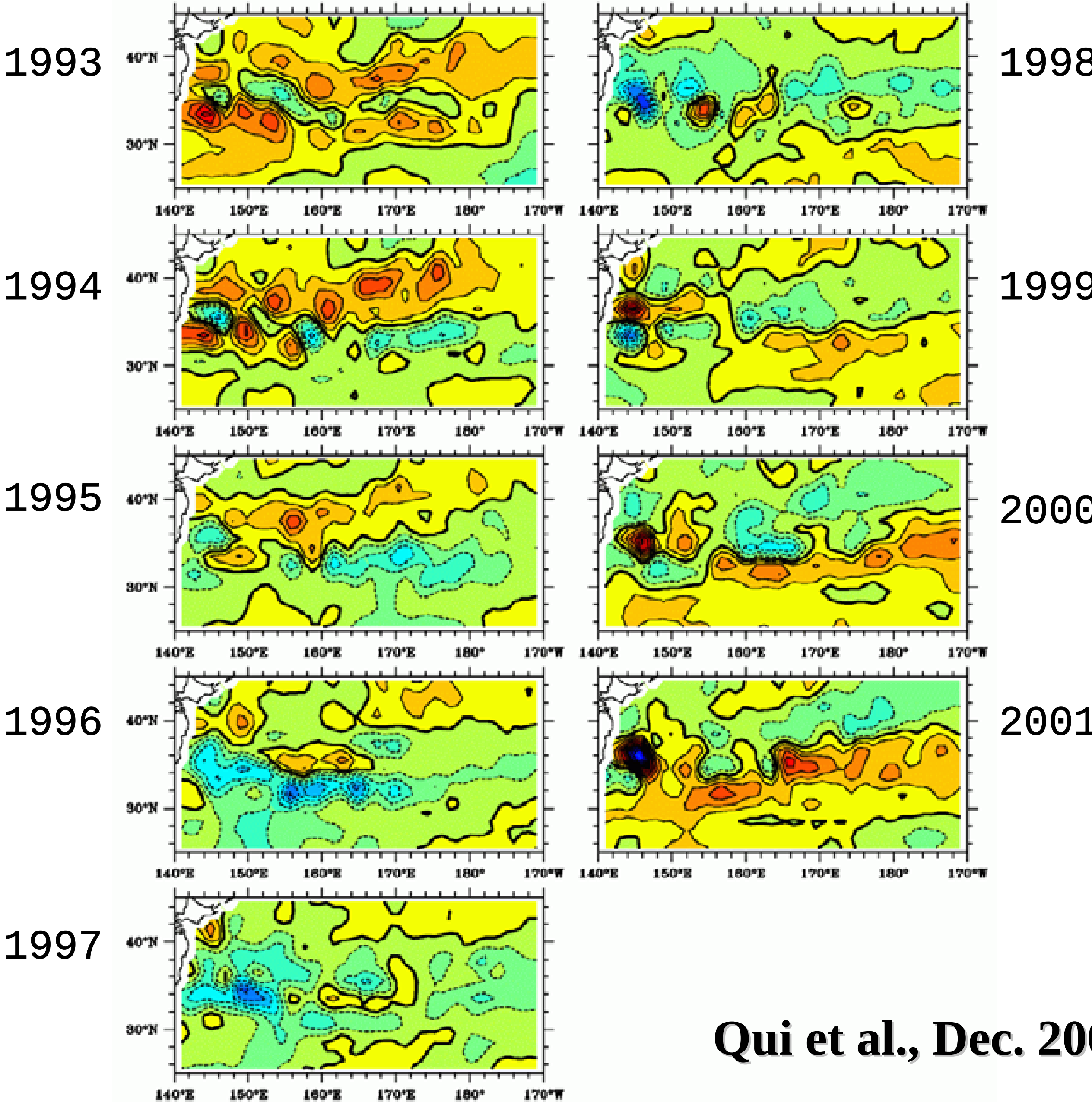
Mesoscale

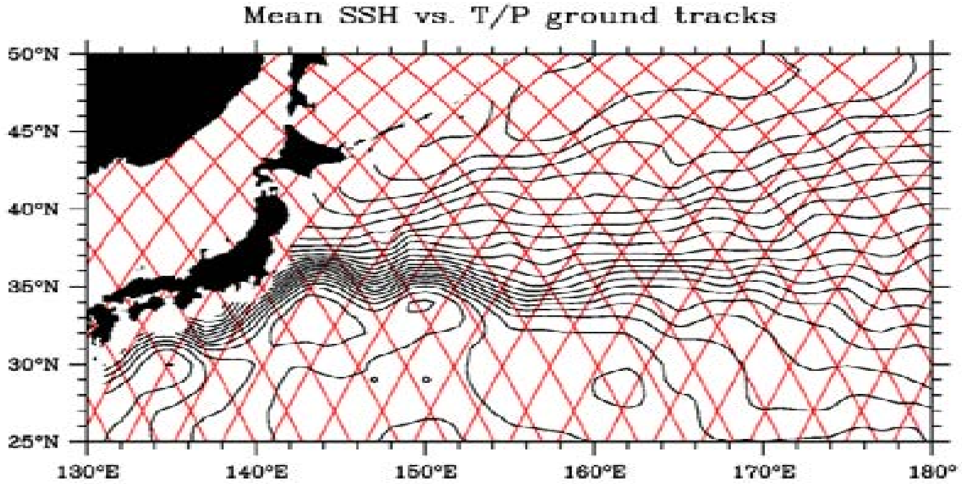
- Climate change
- Synoptic dynamics
- Subsurface inference
- Dynamic accuracy
- Future directions for systems and applications

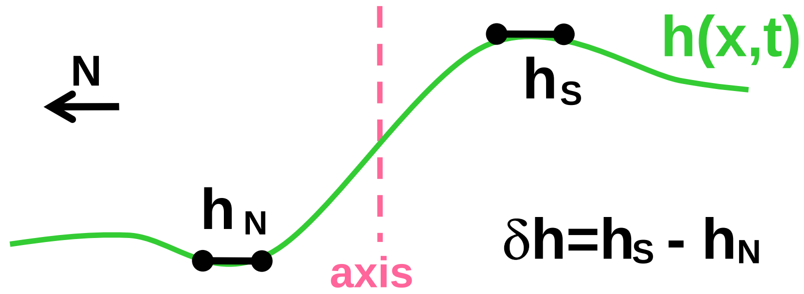


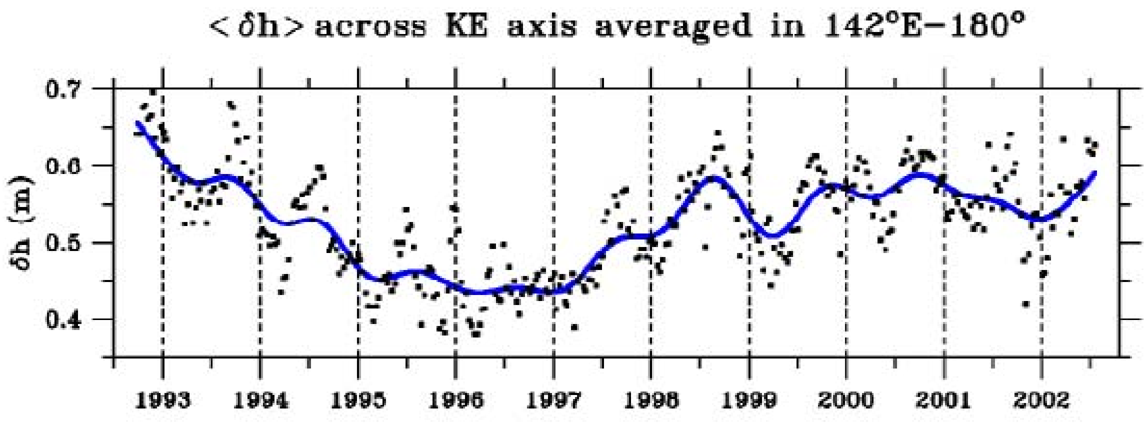
T/P yearly SSHA fields



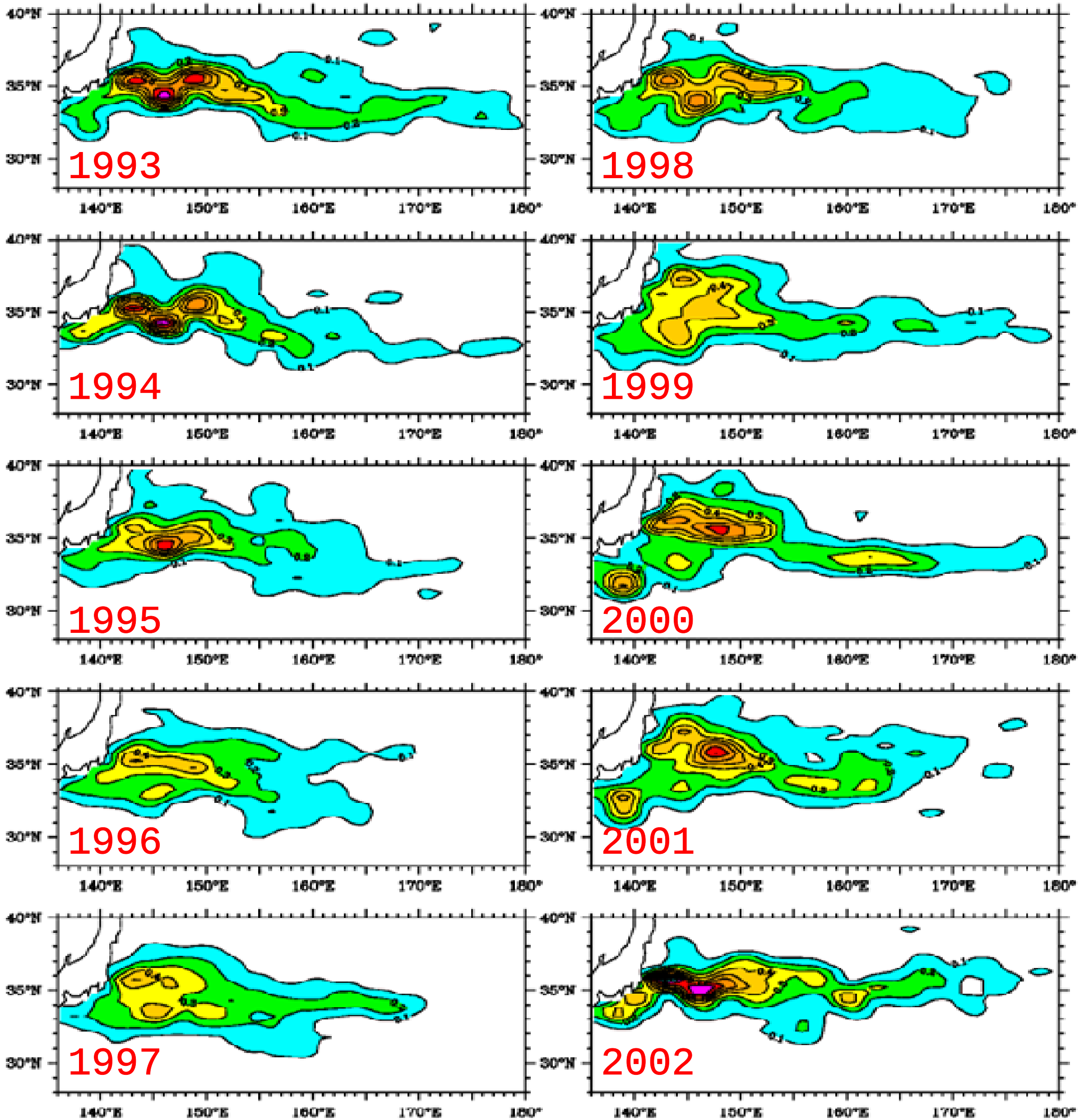
Qui et al., Dec. 2003


Mean SSH vs. T/P ground tracks
50°N
45°N
40°N
35°N
30°N
25°N
130°E
140°E
150°E
160°E
170°E
180°


h(x,t)
N
h_S
h_N
axis
$\delta h = h_S - h_N$

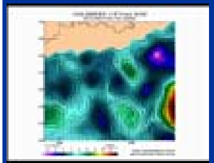

< δh> across KE axis averaged in 142°E−180°
δh (m)
0.7
0.6
0.5
0.4
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002

Yearly kinetic energy maps

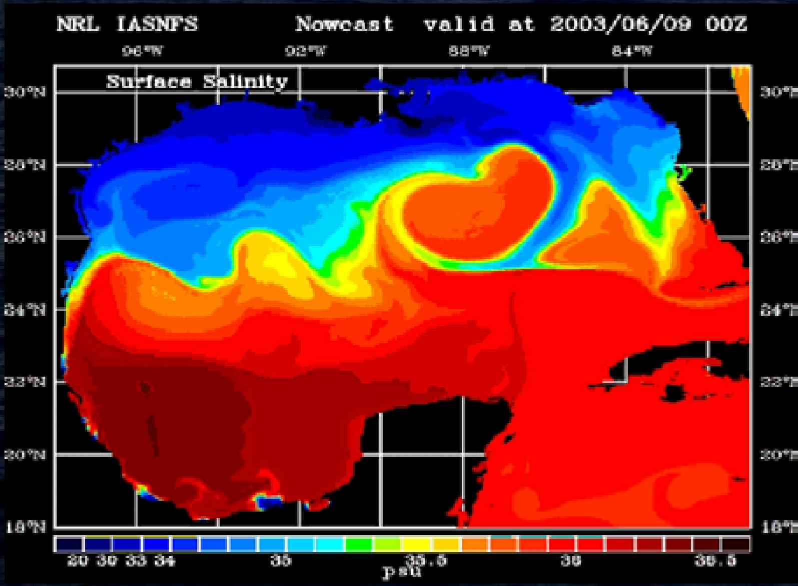


Mesoscale

Climate change



Synoptic dynamics



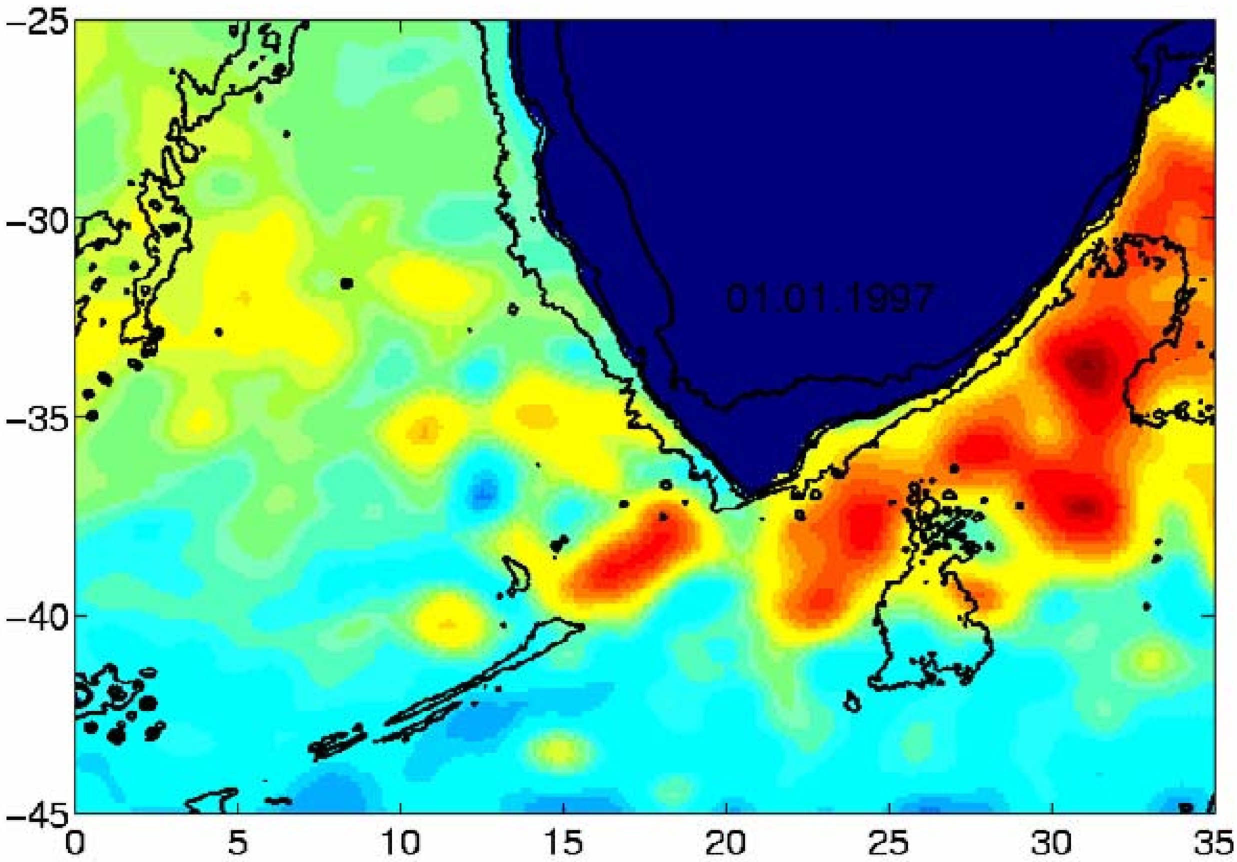
Subsurface inference

Dynamic accuracy

Future potential systems and applications

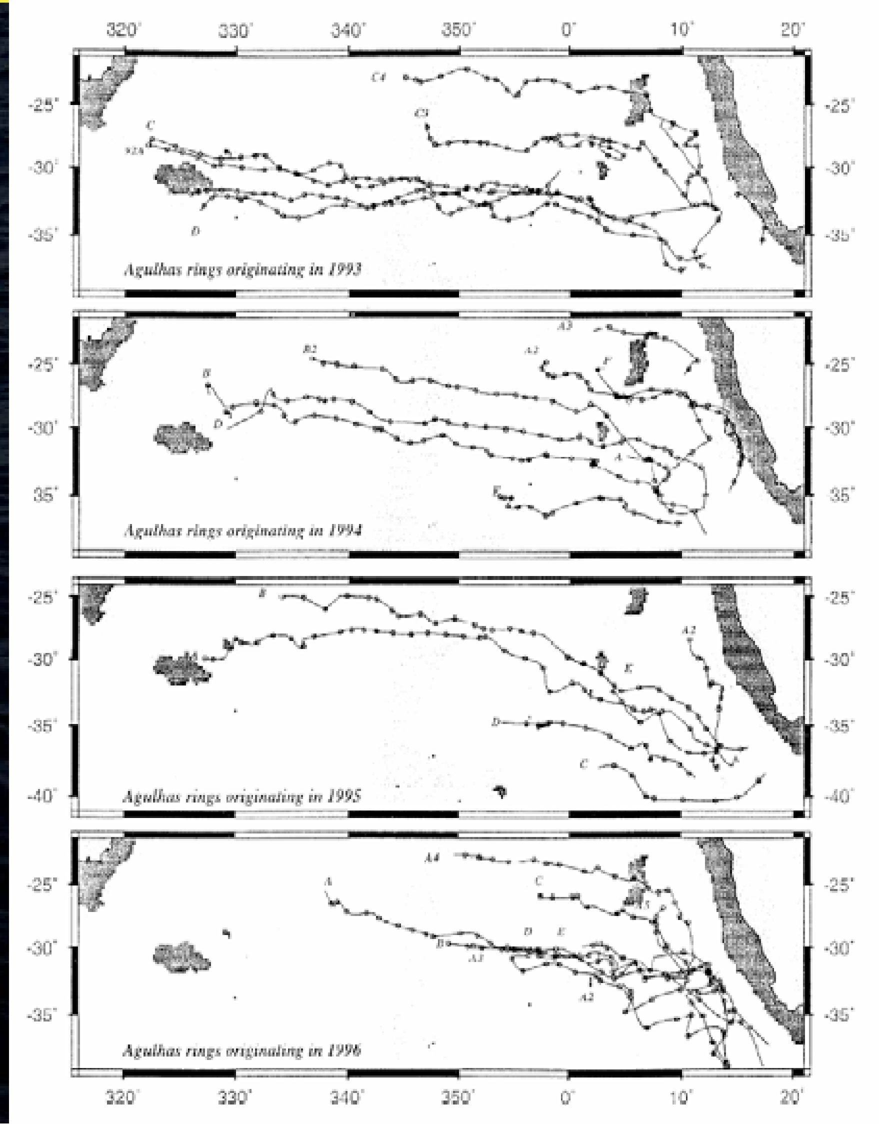
Agulhas

Boebel, O. and C. Barron, 2003.



Observing Mesoscale

Mesoscale Agulhas ring position observations.



1993

1994

1995

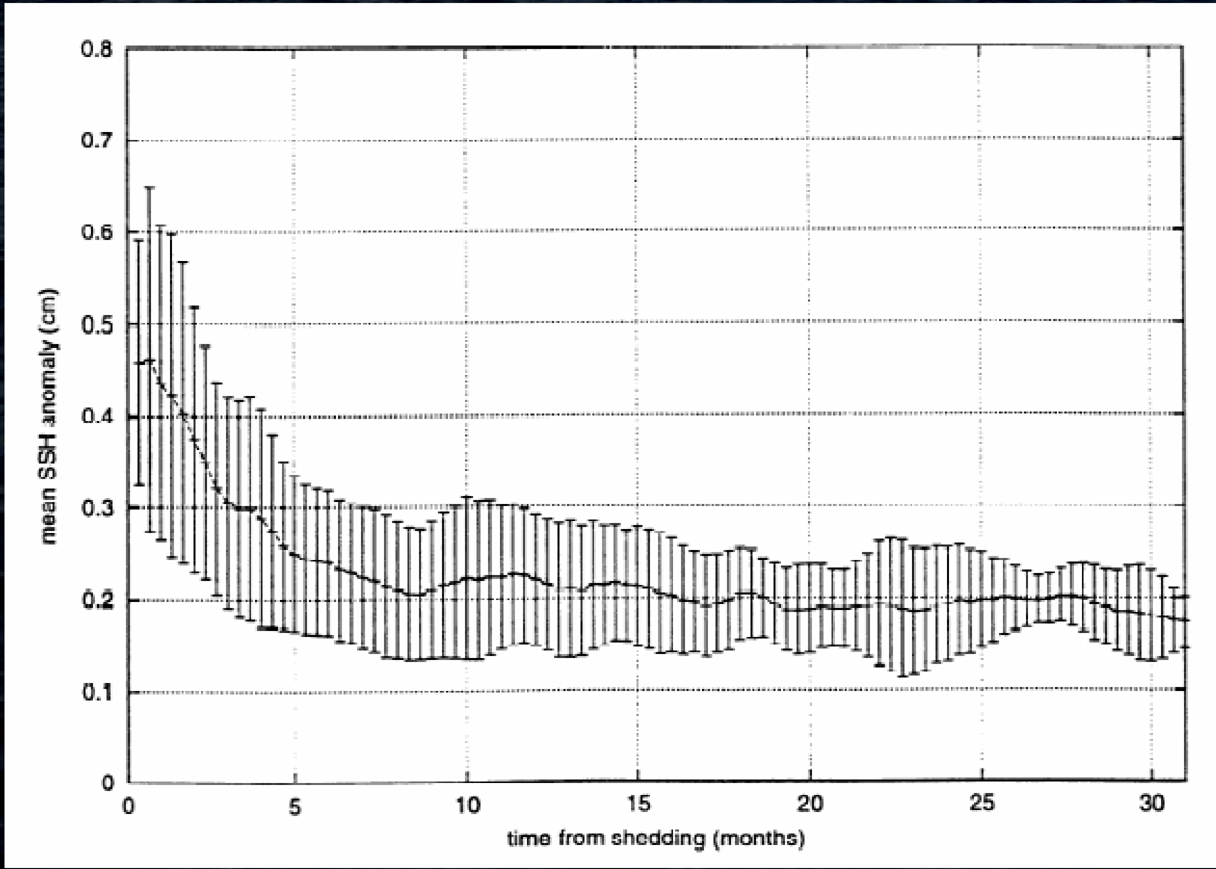
1996

Schouten et al., JGR 2000.

Mesoscale Characteristics

Decay rate over time (following each individual eddy).

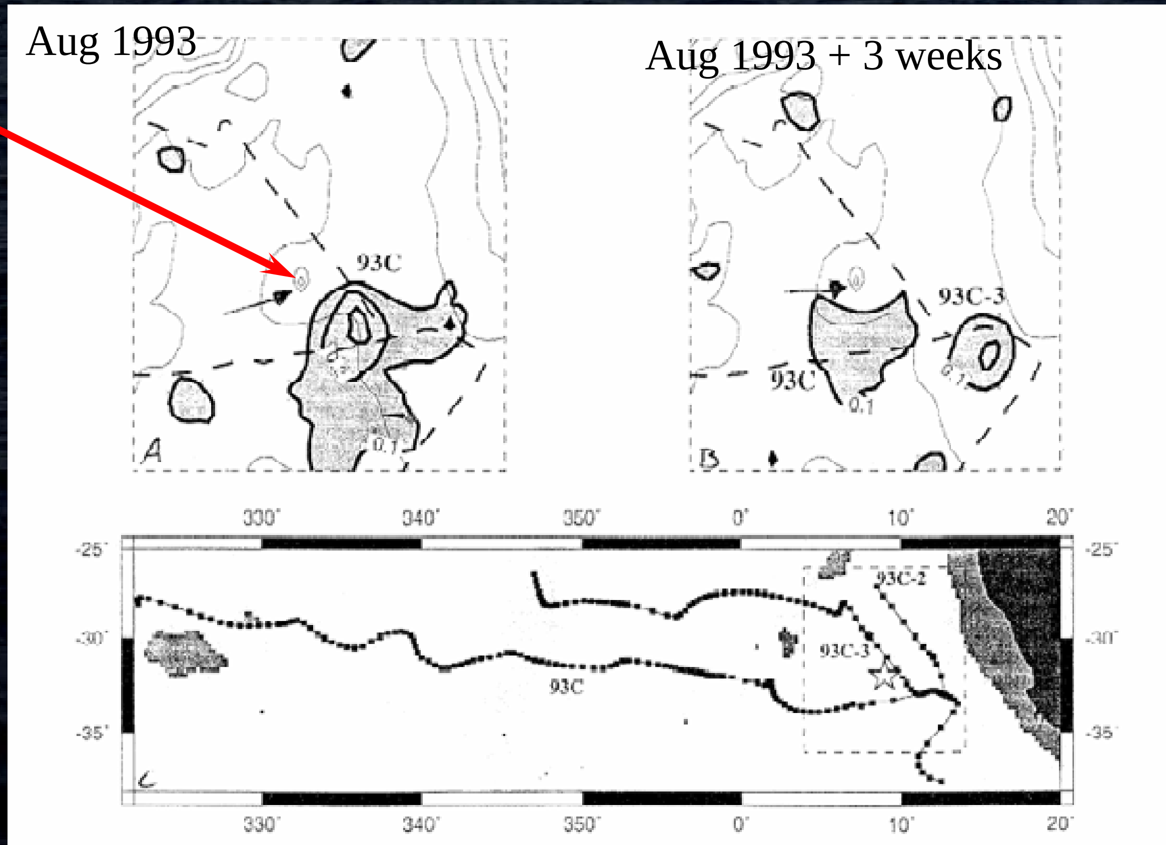
Ring energy from theory is proposed to decrease rapidly during first 5 months due to Rossby wave radiation (Beismann et al., 1999), and then stabilize afterward. Observations confirm this theory.



Schouten et al., JGR 2000.

Mesoscale Evolution

Eddy splitting over Vema Seamount.

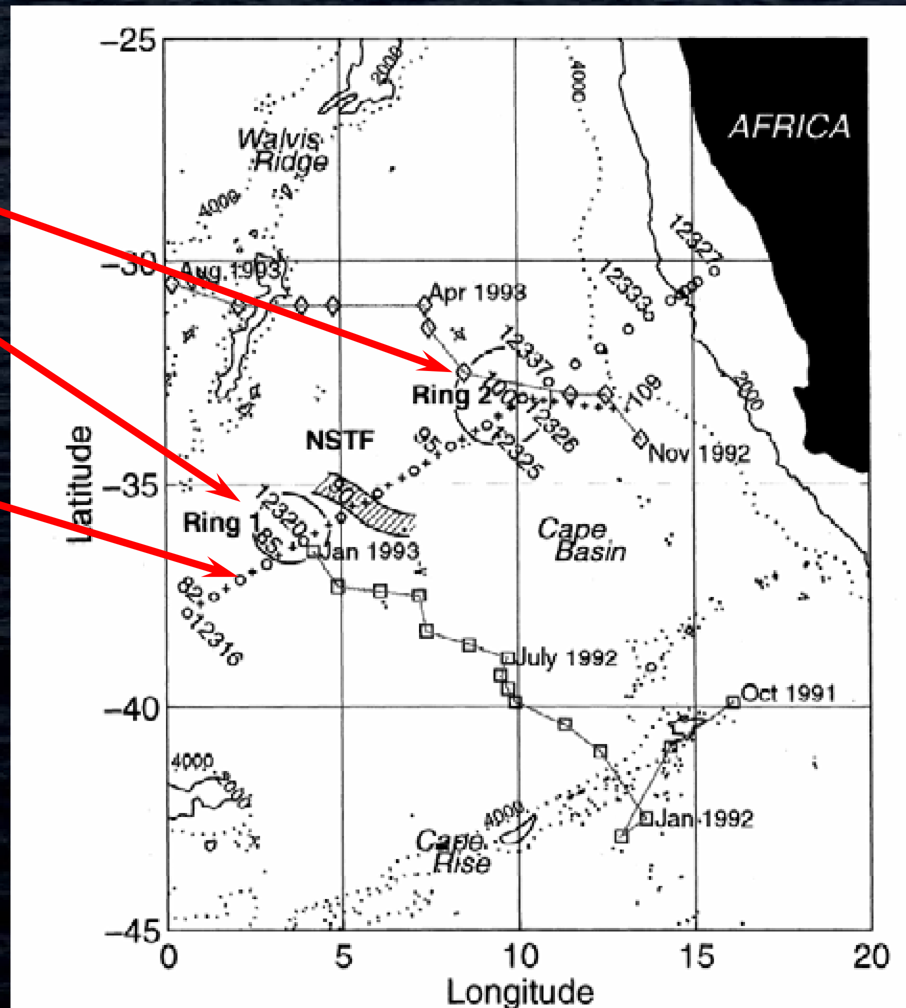


Schouten et al., JGR 2000.

Mesoscale Observations

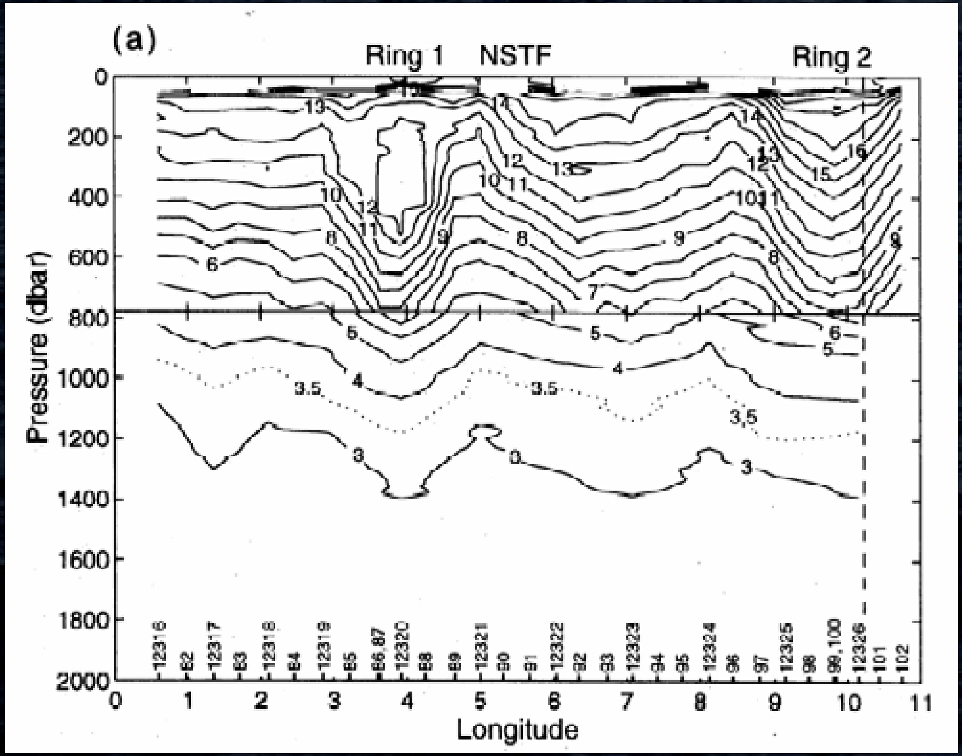
Agulhas rings

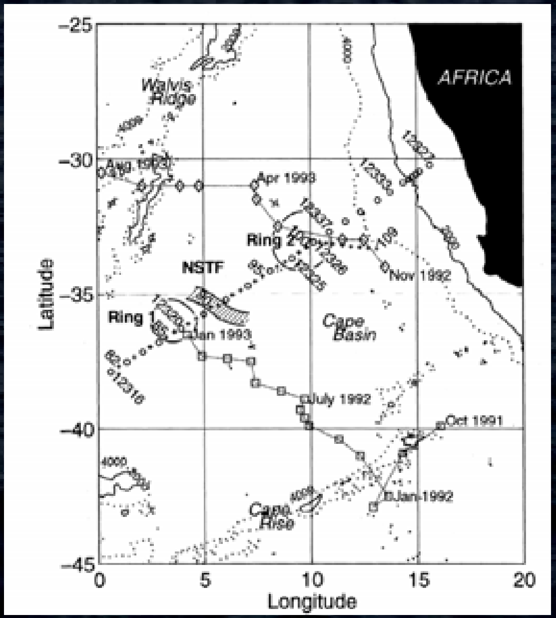
Ship transect



McDonaugh, et al., JGR 1999.

Mesoscale Observations





Potential temperature (°C)

Based on observed T&S profiles and geostrophic velocity, heat and salinity fluxes are estimated.

McDonaugh, et al., JGR 1999.

Mesoscale Observations

Observed propagation speeds of Rings 1 and 2:
2.8 and 6.5 cm/s

Theoretical self-induced speeds due to β effect:

Table 3. Limits of Westward Velocities Induced by the β Effect for Rings 1 and 2

	Nof [1981]		Cushman-Roisin *et al.* [1990]	
	$^{1}/_{3}\beta R_D^2$	$^{2}/_{3}\beta R_D^2$	$\beta g'(h_\infty+dh)/2f^2$	$\beta g' h_\infty/f^2$
Ring 1	0.4	0.7	•	0.8
Ring 2	0.4	0.9	1.4	1.5

Velocities are in centimeters per second. R_D is radius of deformation, g' is acceleration of gravity; h_∞ is depth of the 10°C isotherm outside of the ring; and f is the Coriolis parameter.

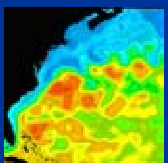
Therefore advection is a significant effect on eddy propagation.

McDonaugh, et al., JGR 1999.

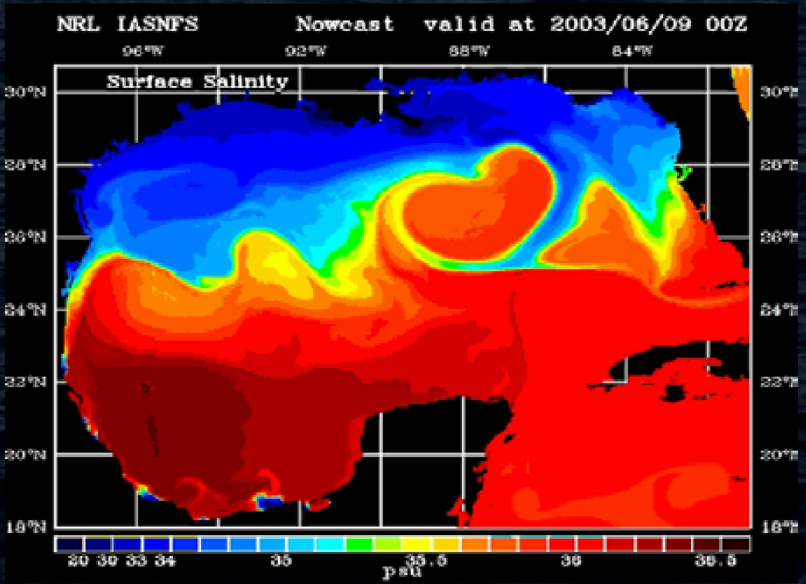
Mesoscale

Climate change

Synoptic dynamics



Subsurface inference

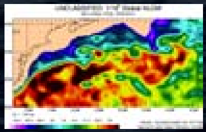


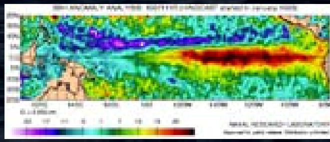
Dynamic accuracy

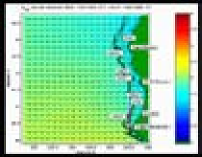
Future potential systems and applications

Purpose for Ocean Assimilation

- Non-deterministic features require continuous observation. Predictive time scales are order of 1-2 weeks for atmosphere and 15-30 days for ocean.
    - Mesoscale eddies
    - El Nino
- Correction of forcing fields
    - Wind-driven circulation
    - Wind-driven wave field
    - Heat-driven steric variability
    - Boundary conditions for high resolution local models (tides for example)
- Correction of inaccurate dynamics
    - Tides errors due to bathymetry inaccuracies (part of dynamical equations)
    - Vertical turbulence closure inaccuracies leads to errors in vertical density distribution
    - Assimilation should not be a replacement for accurate dynamics
    - A system MUST represent the dynamics contained in the input data







Need for Observations

An accurate numerical model should reproduce realistic statistics without assimilation

- Mean flow, position of currents
- Eddy variability
- Eddy statistics (size, speed, energy, …)

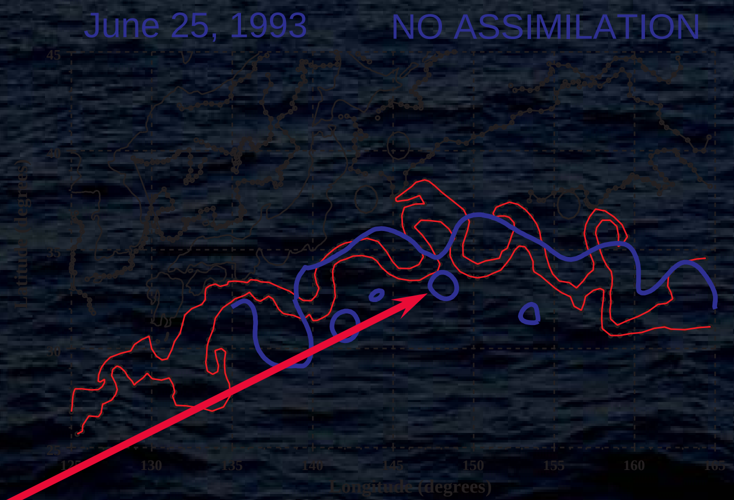
Without assimilation, modeled mesoscale features do not match synoptic reality.

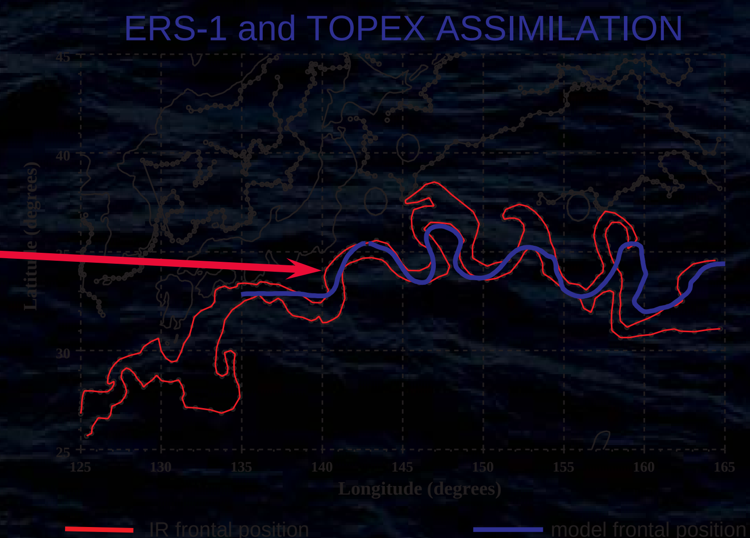
With assimilation, modeled mesoscale features match synoptic reality.

Observed IR position

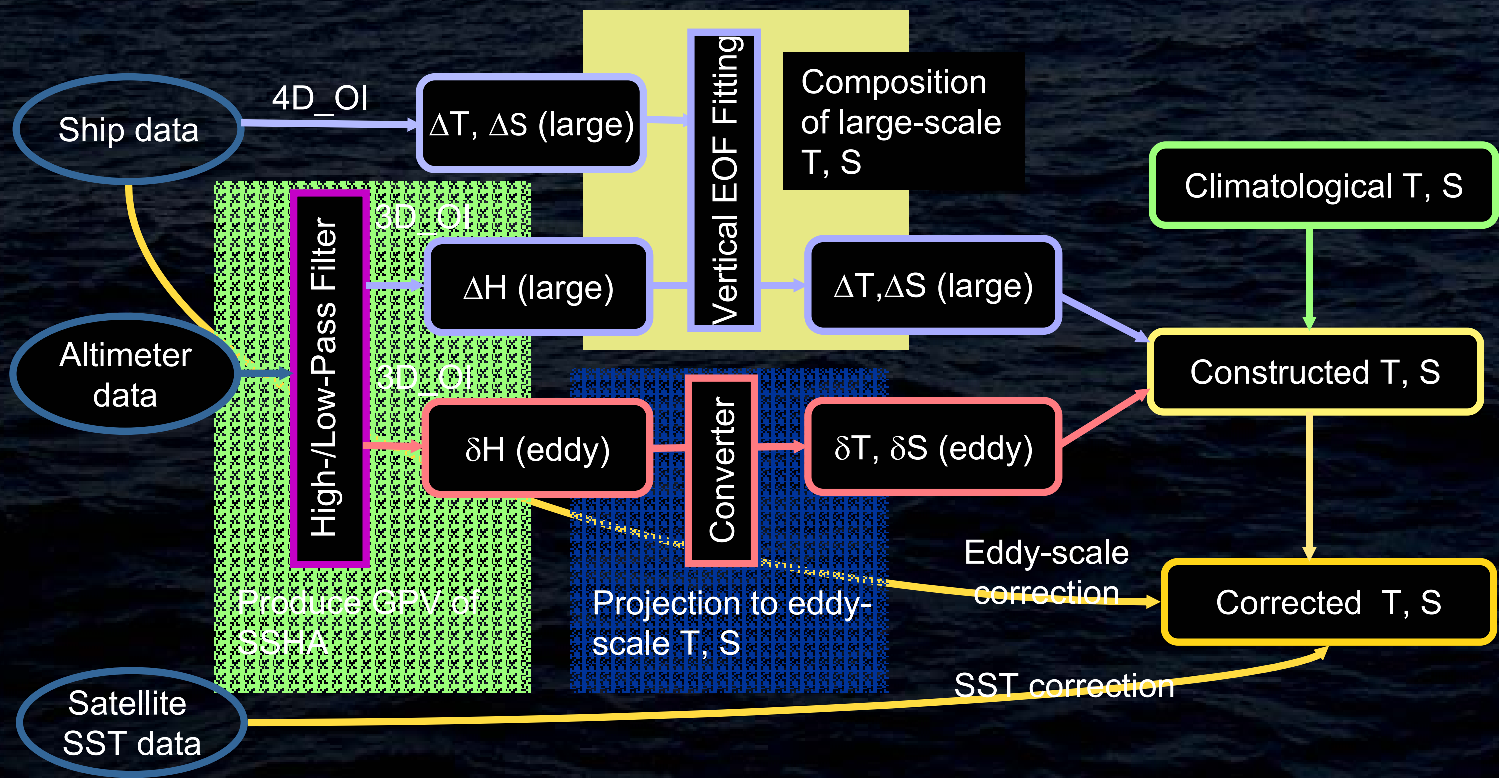
Model position

Smedstad et al., 1998





Japan Met Agency Analysis Cycle (Kuragano)



4D_OI: space(3D)-time(1D) optimum interpolation. 3D_OI: space(2D for horizon)-time(1D). Converter: statistical regression method. Vertical EOF fitting: linear composite of EOF modes to fit OI analysis.

Indirect Observations (Surface Connection to Subsurface)

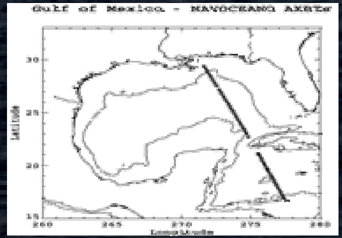
The deep ocean mesoscale variability is due primarily to displacement of waters of different density.

It is possible (through historical in situ observations) to relate surface height and temperature to subsurface temperature and salinity (and thus density).

Assimilation of only surface data leads to a very slow convergence of the model to observations.

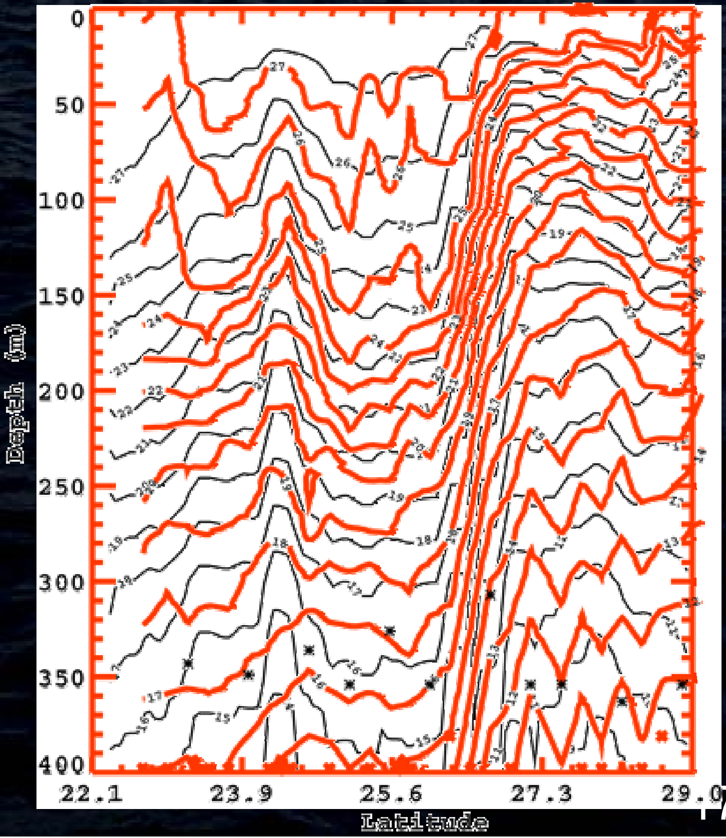
This "synthetic observation" is valuable information to extend the surface observations below the surface rapidly in the assimilation system.

Another way to view this is that we are applying all our knowledge to the problem including historical observations and statistics.



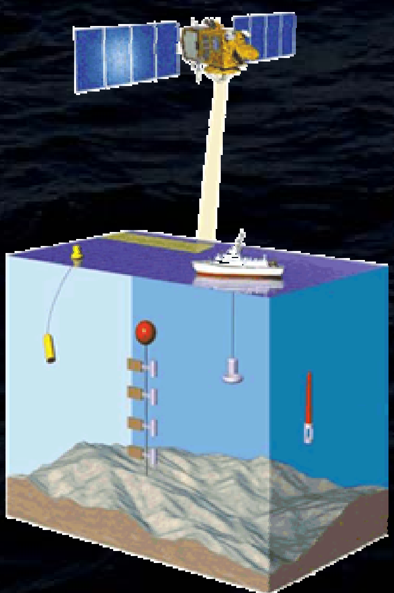
AXBT survey during May 1999

AXBT vs. MODAS/GFO



Data Combination (Le Traon)

1. vertical projection of altimetry + SST
2. Combination of the synthetic profile and in-situ



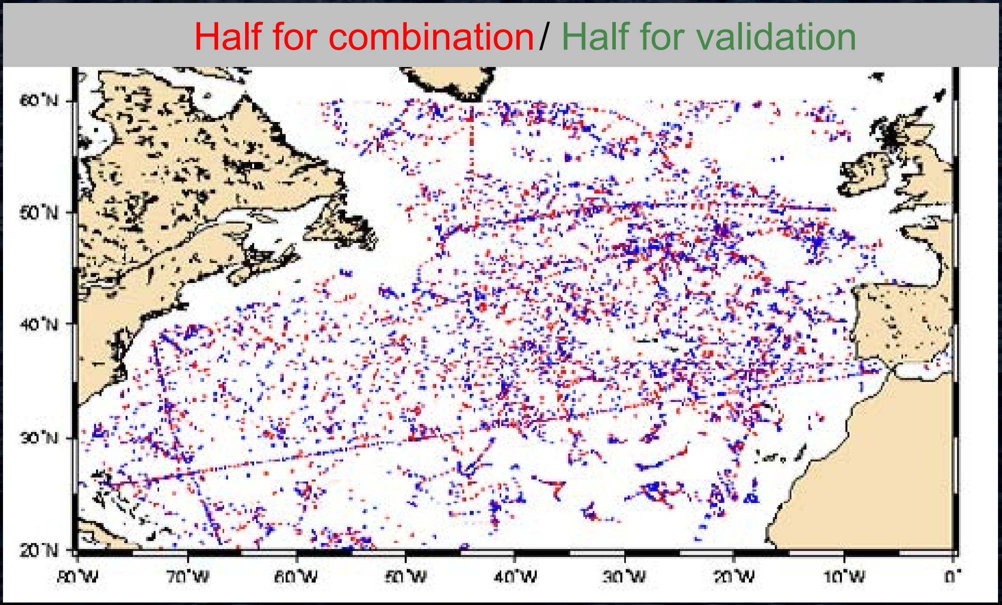
altimetry, SST → (1) Linear regression → synthetic profiles $T_{syn}(z)$, $S_{syn}(z)$

In-situ profiles T(z), S(z) → (2) Combination using optimal interpolation

→ 3D [T(z), S(z)]

Validation of synthetic and in situ profiles (Le Traon)

Validation with independent data for 2002 year



Methodology

- weekly combination of synthetic and in-situ profiles
- interpolation to the space/time location of independent profiles
- interpolation of independent profiles on the standard Levitus levels
- calculation of the differences between in-situ and combined profiles

- Statistics…to characterize the spatial and vertical structure of the error associated to the 3D combined products

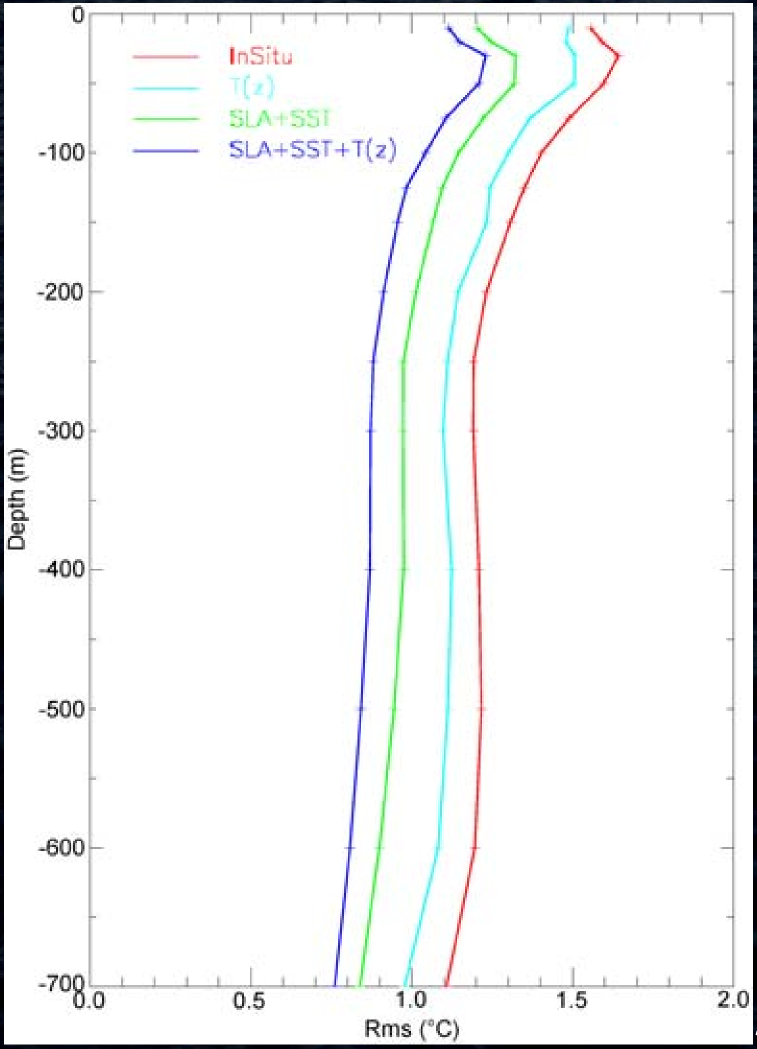
Vertical estimation error (Le Traon)

Satellite data [SLA+SST] + Argo[T(z)]

Combined [SLA+SST+T(z)]

Argo only [T(z)]

Levitus monthly climatology

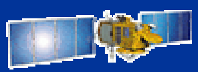


Mesoscale

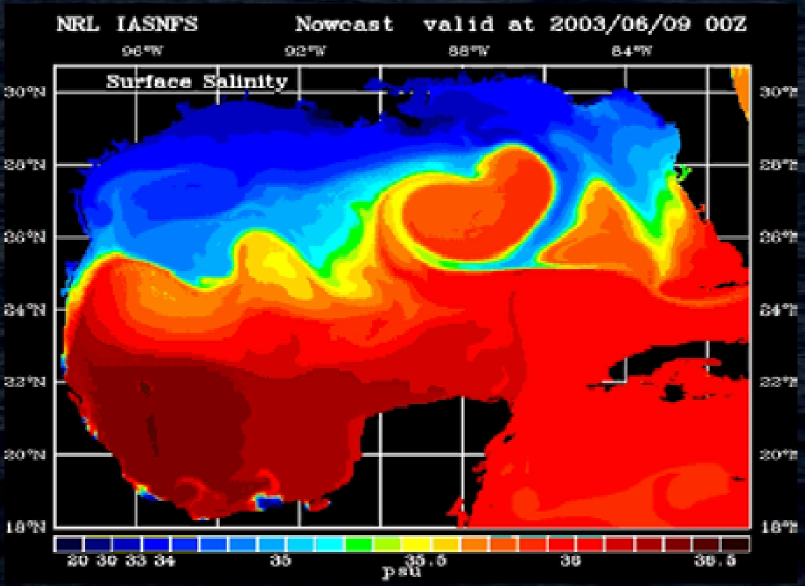
Climate change

Synoptic dynamics

Subsurface inference



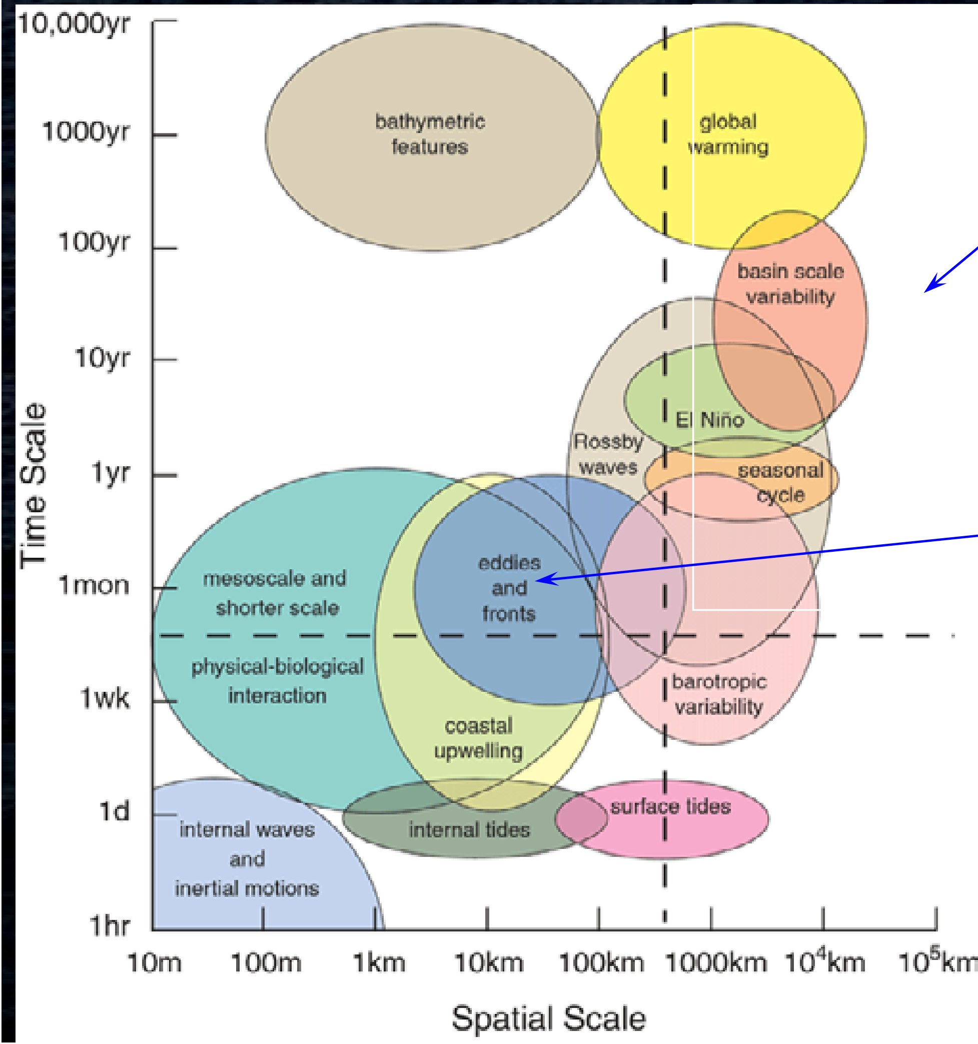
Dynamic accuracy



Future potential systems and applications

What is resolvable?

Chelton et al., High Resolution Ocean Topography Report, 2001

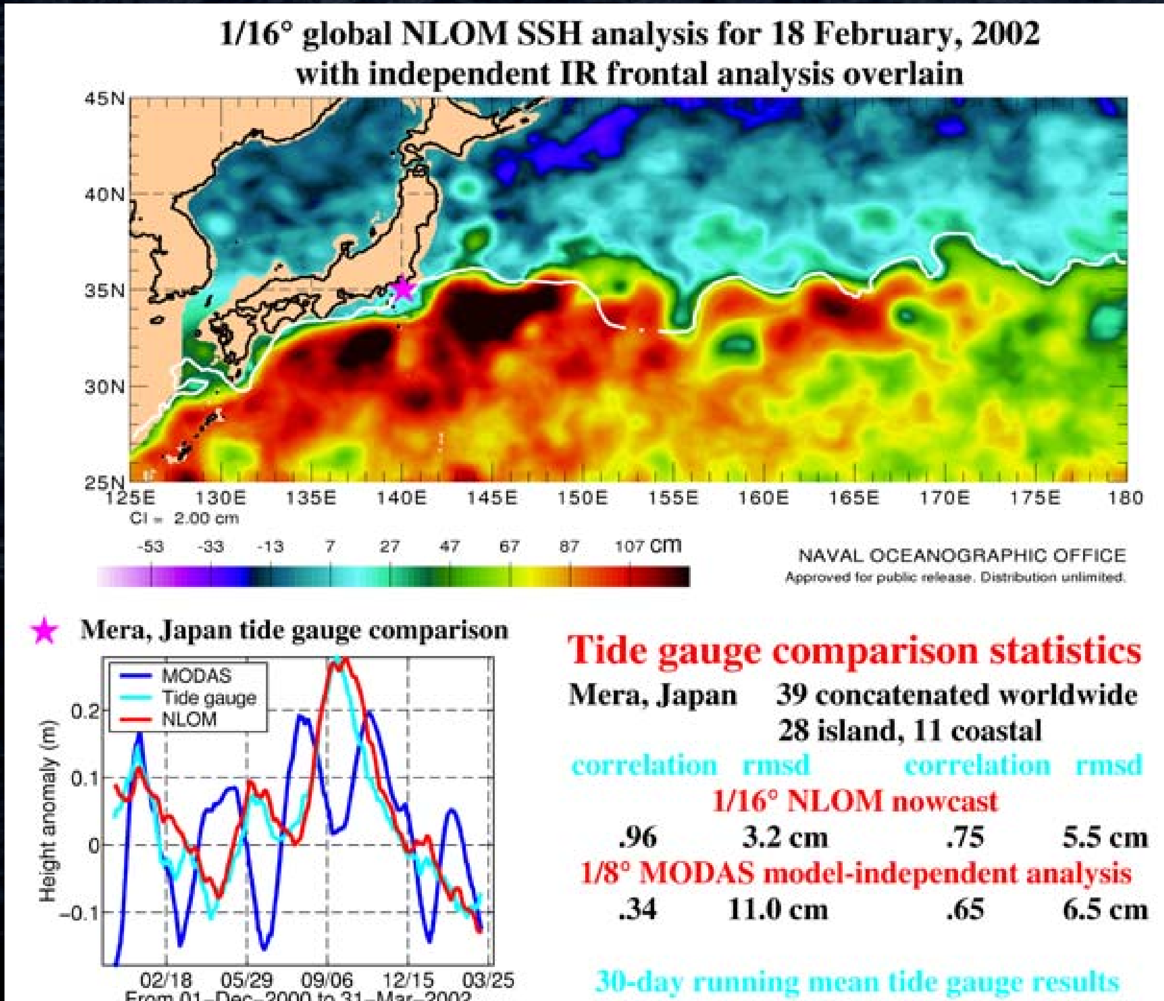


Resolvable area of Topex/Poseidon or Jason-1

A single nadir altimeter can not resolve the mesoscale.

Bad Okay Best

Better Dynamics, Better Results…

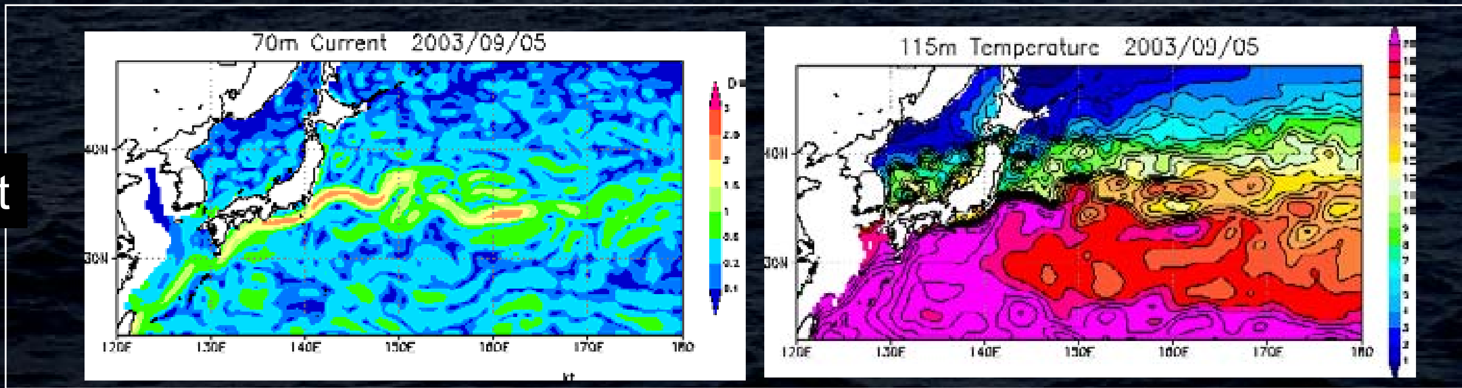


NLOM assimilates altimeter track data using the model as a first guess

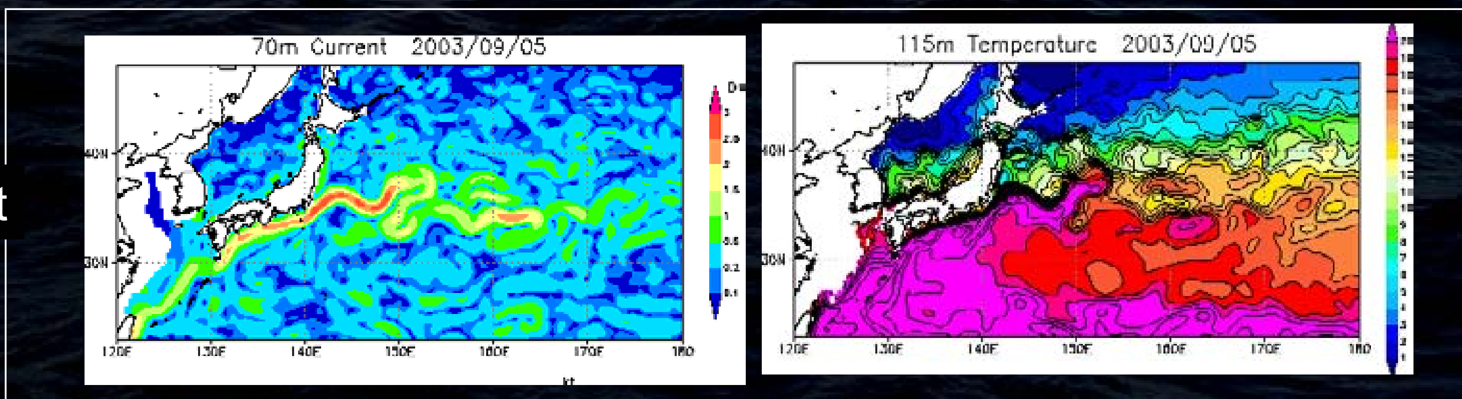
Need for Accurate Model

Japan Met Agency Analysis Cycle (Kuragano)

Forecast



Nowcast

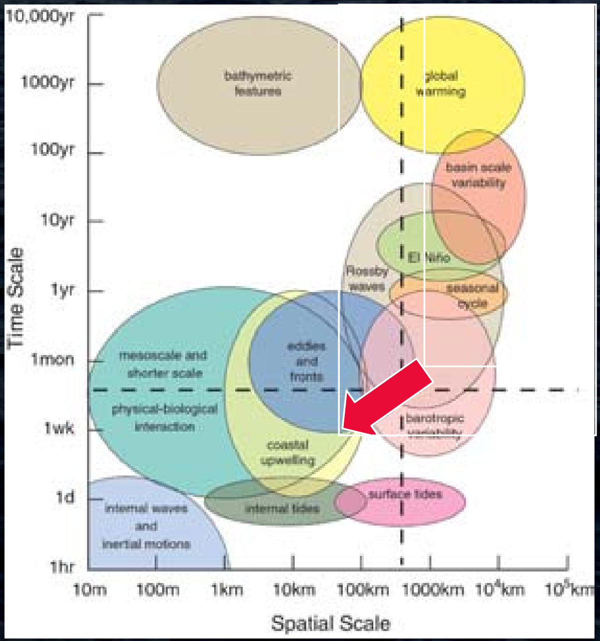


Larger meander at Kuroshio Extension in Nowcast run than that in Assimilation run

But we don't learn anything new

By assimilation (OI, data insertion, EnKF, 4-D Var, …) we force the solution to match the specified dynamics (to some degree depending on covariance errors).

But we don't learn anything new regarding the dynamics.



To learn anything beyond our present dynamical representations we need

- Independent observations
- Sufficient observations to outweigh our present dynamical understanding
- Assimilation systems to demonstrate we have learned something new

Mesoscale

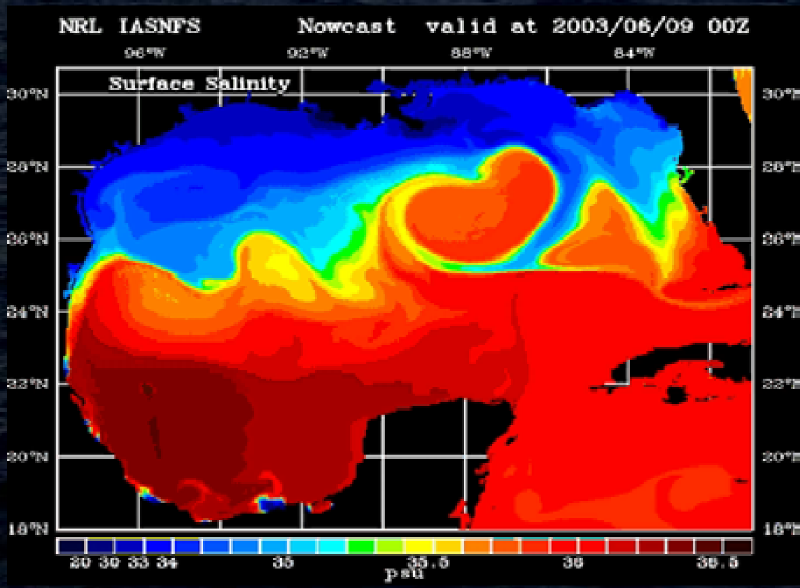
Climate change

Synoptic dynamics

Subsurface inference

Dynamic accuracy

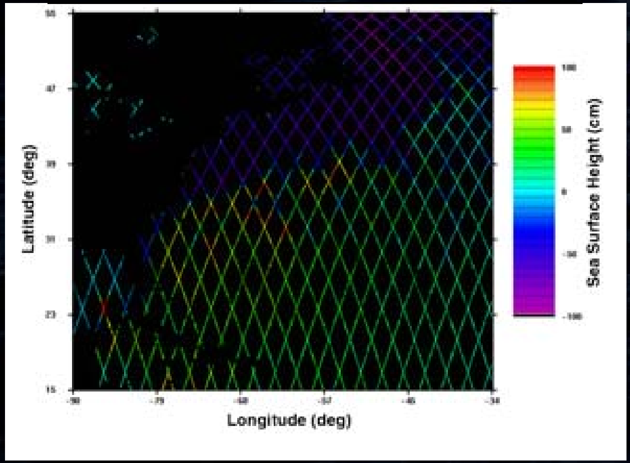
Future potential systems and applications



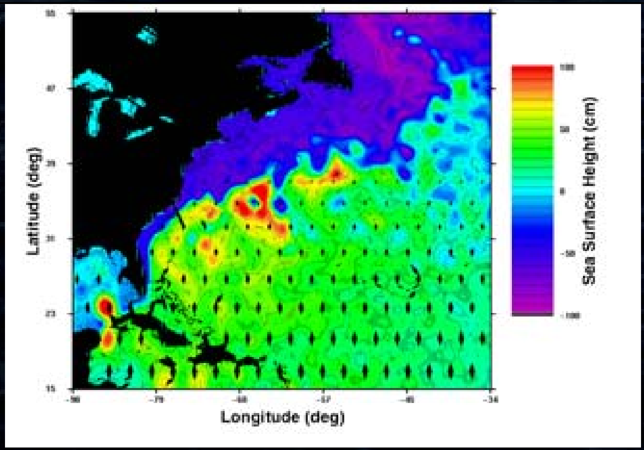
Wide Swath Ocean Altimeter

Ocean Surface Topography Mission

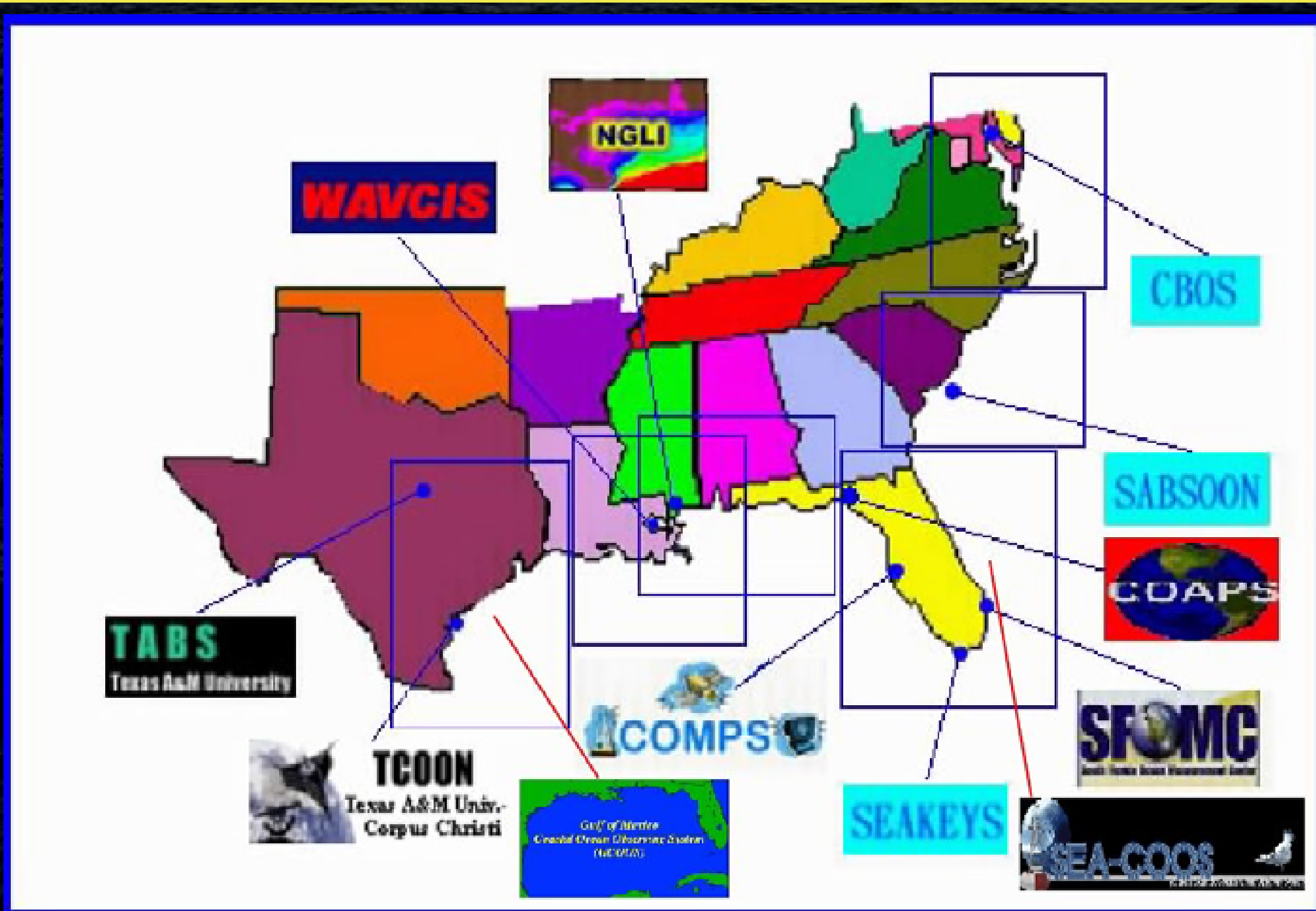
Nadir altimeter



Wide swath altimeter

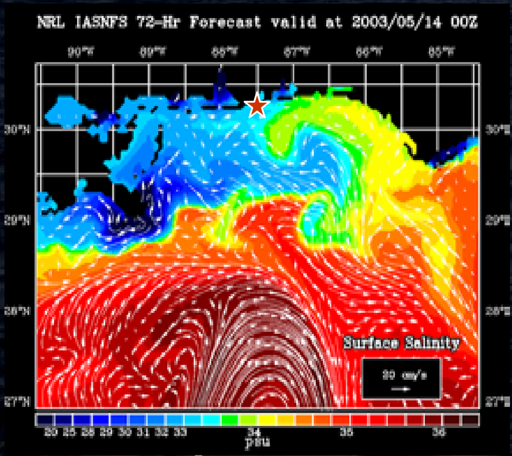


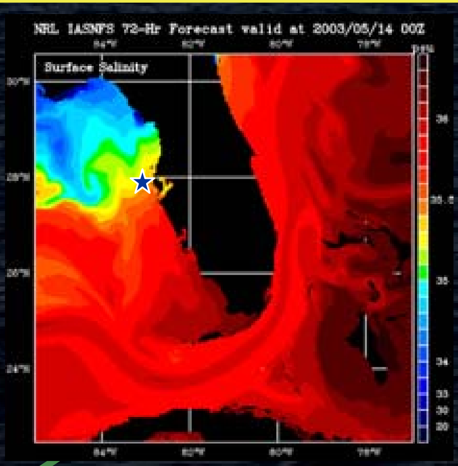
Integrated Ocean Observation System

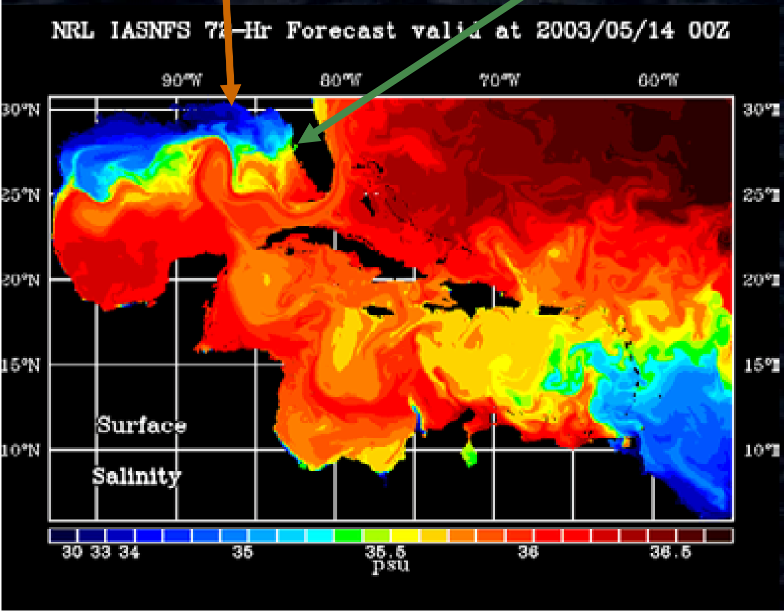


SURA Coastal Ocean Observation System

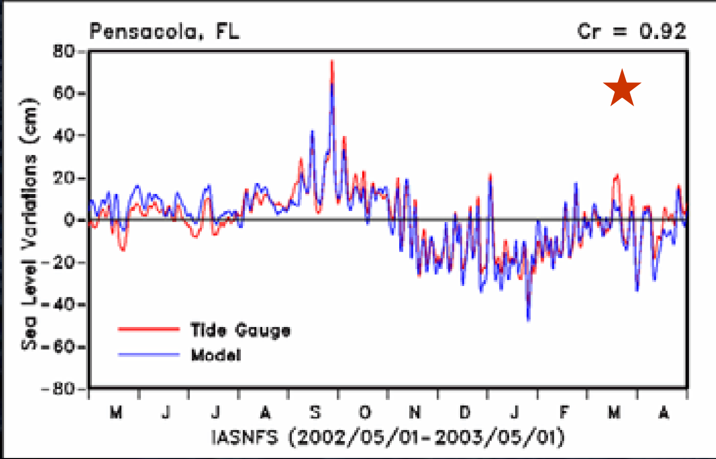
Regional Modeling

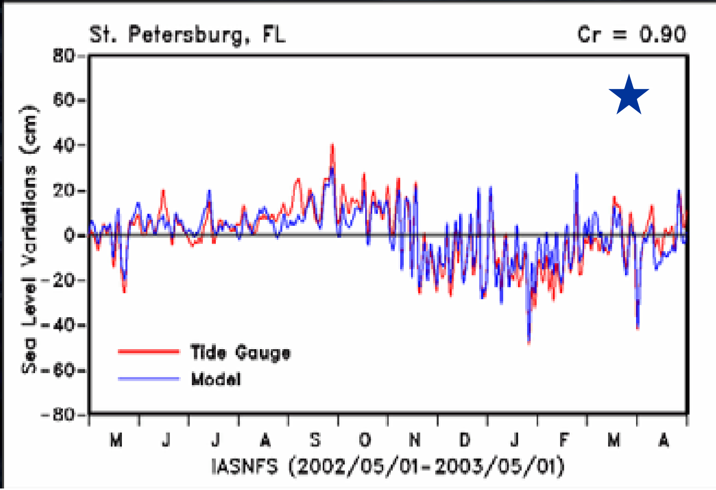




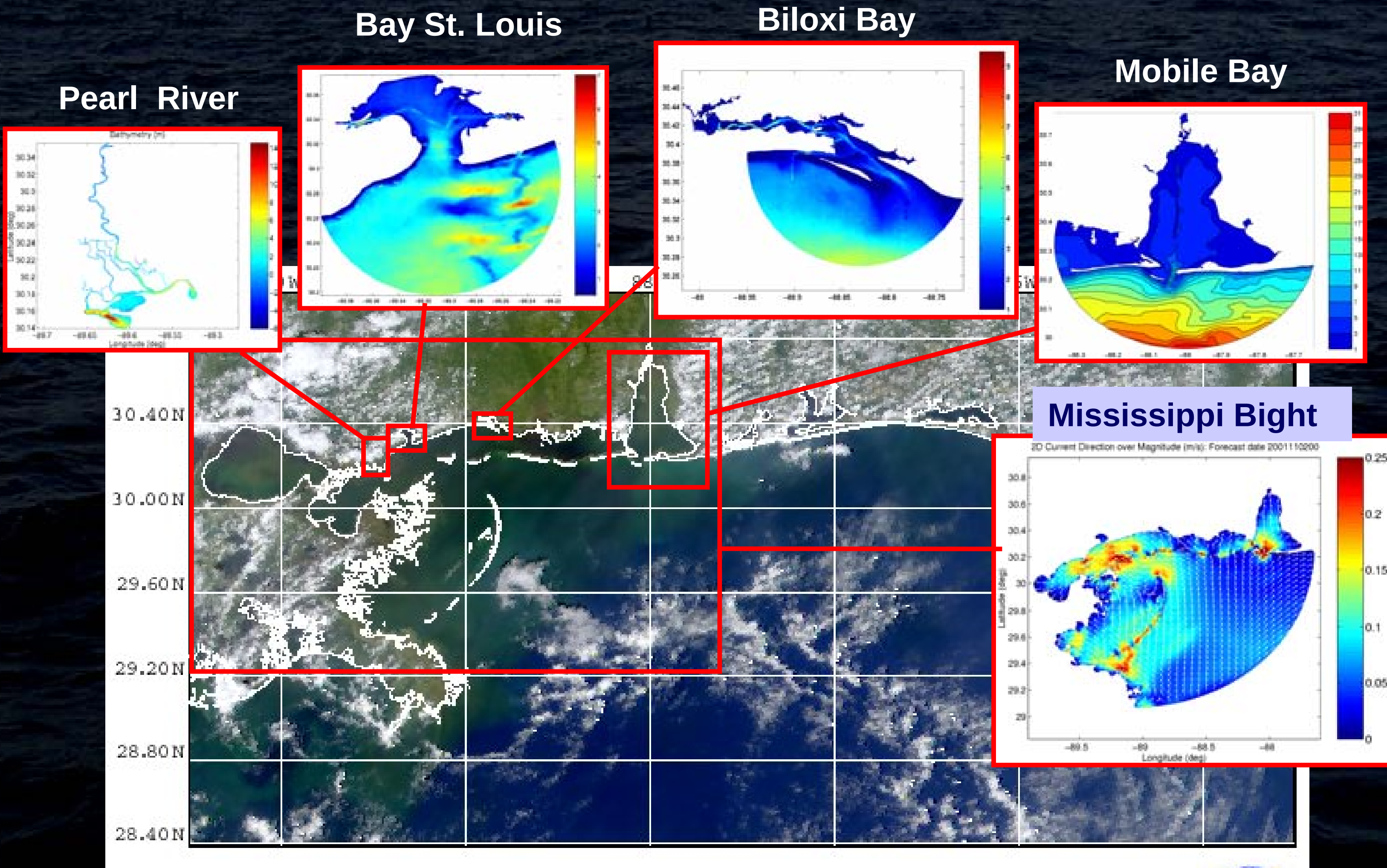


Model/Data Sea Level Comparison

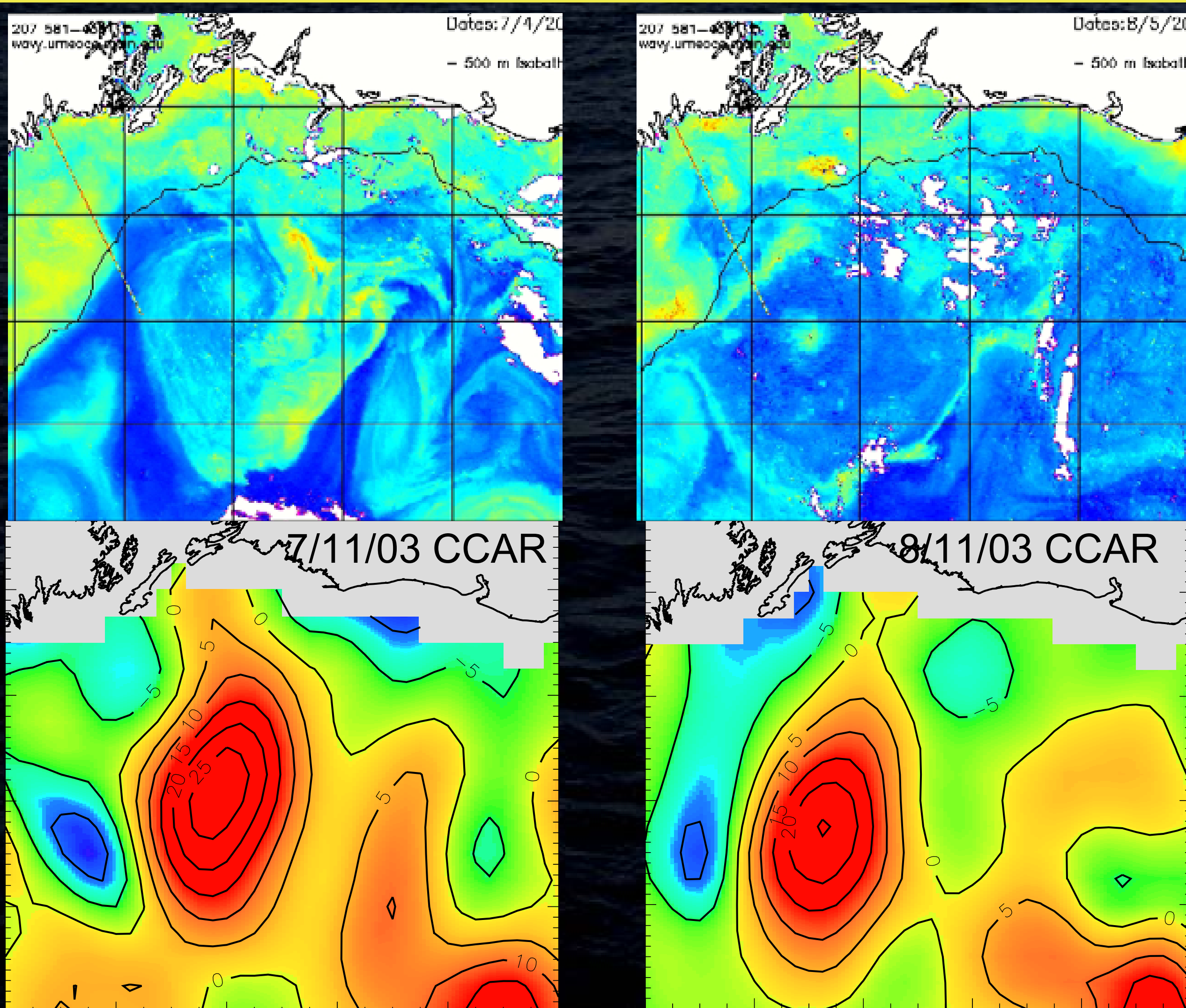




Bay and Estuaries



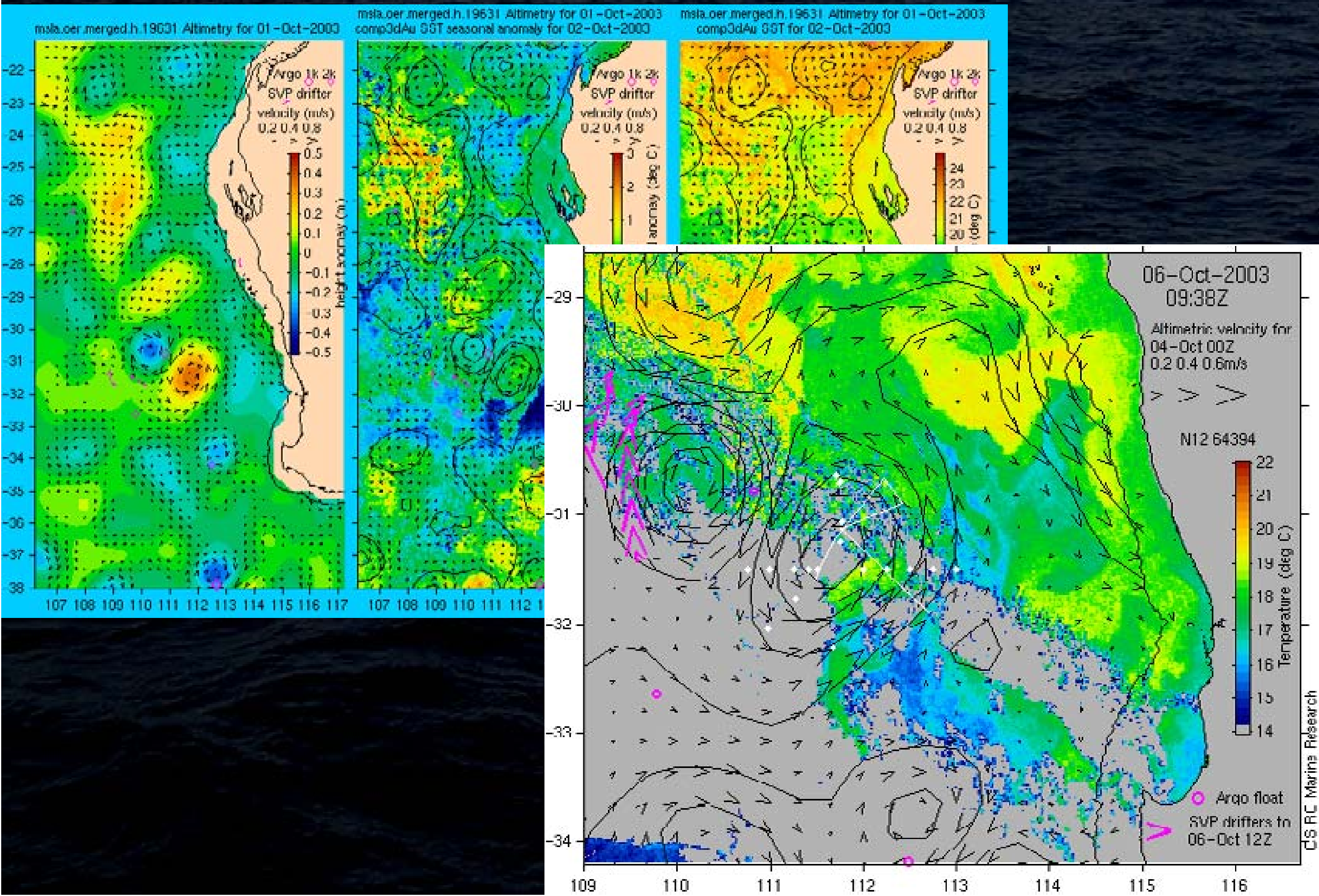
Optical Future (Ted Strub)



SeaWiFS
From
Andrew
Thomas,
U. Maine

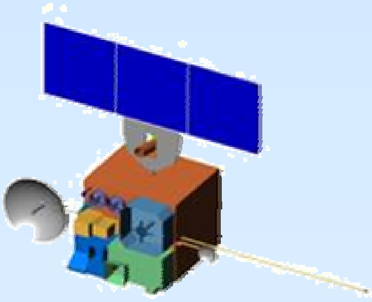
R. Leben

Optical Future (David Griffin)



Next Generation Geostationary Satellite - GOES-R

- Responds to national operational environmental requirements
- Provides higher spatial resolution, enhanced spectral information, improved coverage, and more rapid updates to better predict severe weather
  - Better able to discern details that indicate storm formation and provides more accurate wind tracking for model inputs
  - Improved monitoring of volcanic ash, aviation icing hazards, mid-level moisture tracking, and snow/cloud discrimination
  - Able to monitor severe local storms without impacting global coverage
- Program is based on launch readiness by the start of the next decade



GOES R Observational Requirements*

Preliminary Instrument Allocation

Absorbed Shortwave Radiation	Downward Solar Insolation	Rainfall Potential
Aerosol Detection	Dust/Aerosol	Rainfall Rate/QPE
Aerosol Particle Size	Energetic Heavy Ions	Reflected Solar Insolation
Aircraft Icing Threat	Enhanced "V"/Overshooting Top Detection	Sea & Lake Ice/ Displacement and Direction
Atmospheric Vertical Moisture Profile	Fire / Hot Spot Imagery	Sea & Lake Ice/Age
Atmospheric Vertical Temperature Profile	Flood/Standing Water	Sea & Lake Ice/Concentration
Capping Inversion Information	Geomagnetic Field	Sea & Lake Ice/Extent and Characterization
CH_4 Concentration	Hurricane Intensity	Sea & Lake Ice/Surface Temp
Clear Sky Masks	Ice Cover/ Landlocked	Sea Surface Temps
Cloud & Moisture Imagery	Imagery: All-Wx/Day-Nite	Snow Cover
Cloud Base Height	Land Surface (Skin) Temperature	Snow Depth
Cloud Ice Water Path	Leaf Area Index (LAI)	SO_2 Concentration
Cloud Imagery	Lightning Detection	Solar and Galactic Protons
Cloud Layers / Heights and Thickness	Low Cloud and Fog	Solar Flux: EUV
Cloud Liquid Water	Mag Electrons & Protons: Low Energy	Solar Flux: X-Ray
Cloud Optical Depth	Mag Electrons & Protons: Med & High Energy	Solar Imagery
Cloud Particle Size Distribution	Microburst Winds	Surface Albedo
Cloud Phase	Moisture Flux	Surface Emissivity
Cloud Top Height	Ocean Currents	Suspended Matter
Cloud Top Pressure	Ocean Color	Total Precipitable Water
Cloud Top Temperature	Ocean Optical Properties	Total Water Content
Cloud Type	Ocean Turbidity	Turbulence
CO Concentration	Oil Spill Location	Upward Longwave Radiation
CO_2 Concentration	Ozone Layers	Vegetation Fraction
Convection Initiation	Ozone Total	Vegetation Index
Derived Motion Winds	Pressure Profile	Visibility
Derived Stability Indices	Probability of Rainfall	Volcanic Ash
Downward Longwave Radiation	Radiances	

ABI – Advanced Baseline Imager

HES – Hyperspectral Environmental Suite

SEM – Space Environment Monitor

SXI – Solar X-Ray Imager

GLM – GOES Lightning Mapper

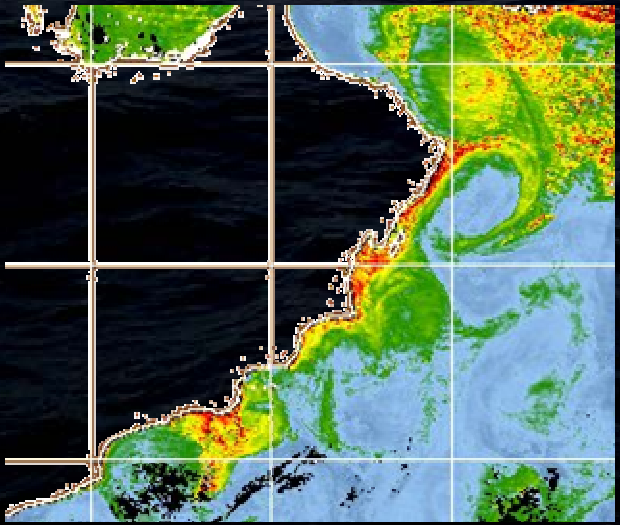
* Does not reflect individual geographic coverage requirements.

Optical Future (John Kindle)

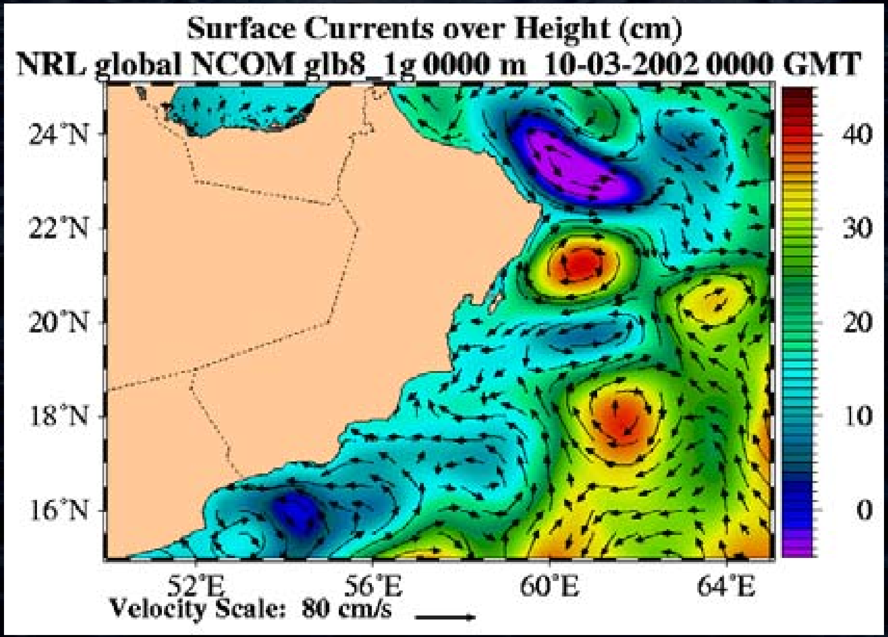
Assimilation of Satellite Imagery and Numerical Models

SeaWIFS composite

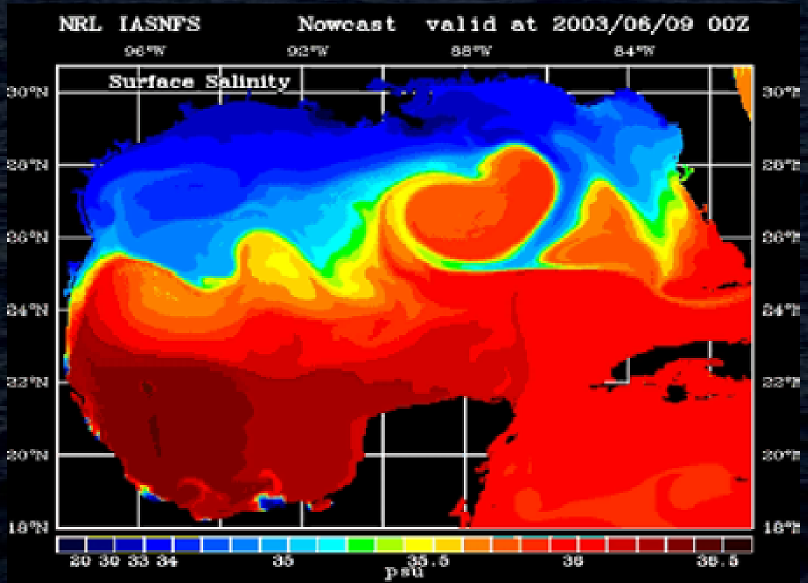
Sep 30-Oct 7 2002



Global NCOM: Oct 3 2002



Conclude



Altimeter observations are essential for understanding the synoptic mesoscale dynamics and fluxes

Mesoscale interacts with coastal region and produces observable effects in non-dynamic observables

Altimeter community, biology, geology, chemistry, … communities need to bring the components together

End