U.S. Naval Operational Oceanography

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Naval Operational Oceanography

Major Points

- TRANSFORMATION
  - Net-Centric Littoral Warfare Teams
  - Inside the Warfighter's Decision Loop
  - Emphasize Ocean-Related Warfare Disciplines
- TRANSLATION
  - Applying Oceanographic Knowledge to Warfighter Questions
- GODAE Role
  - Important, Though Not Primary,
    Given Littoral Focus of the U.S. Navy

Naval Operational Oceanography

What is Operational Oceanography?

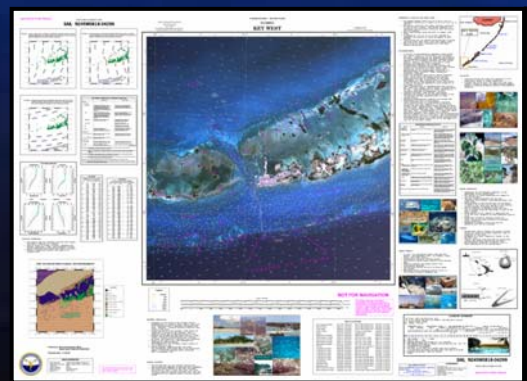
"Relevant" Oceanographic Knowledge to the Warfighter

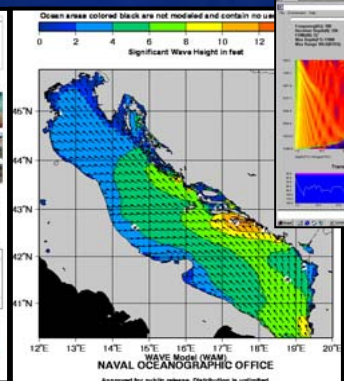
Via

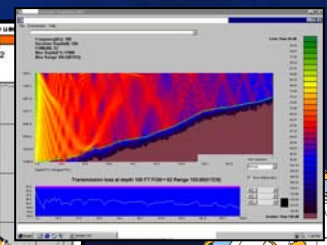
Smart Collection,

Focused Analysis,

Responsive Delivery







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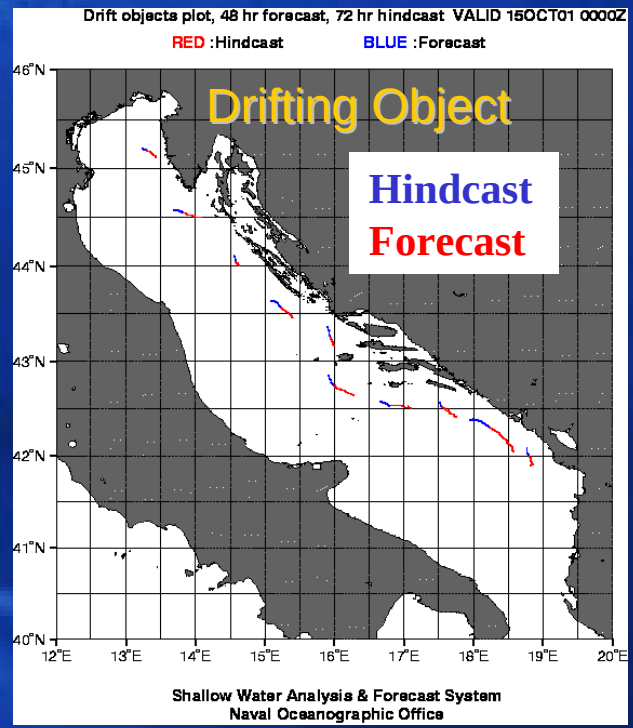
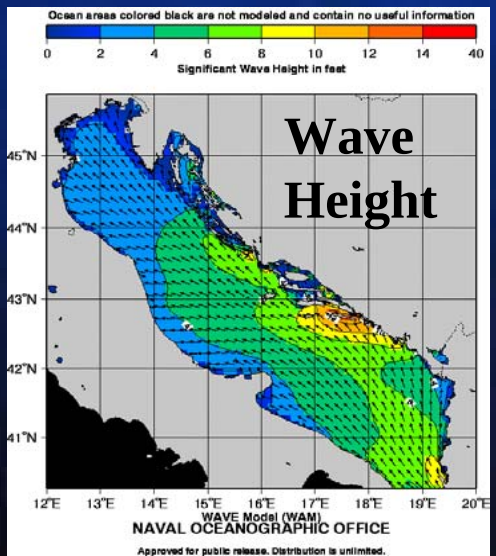
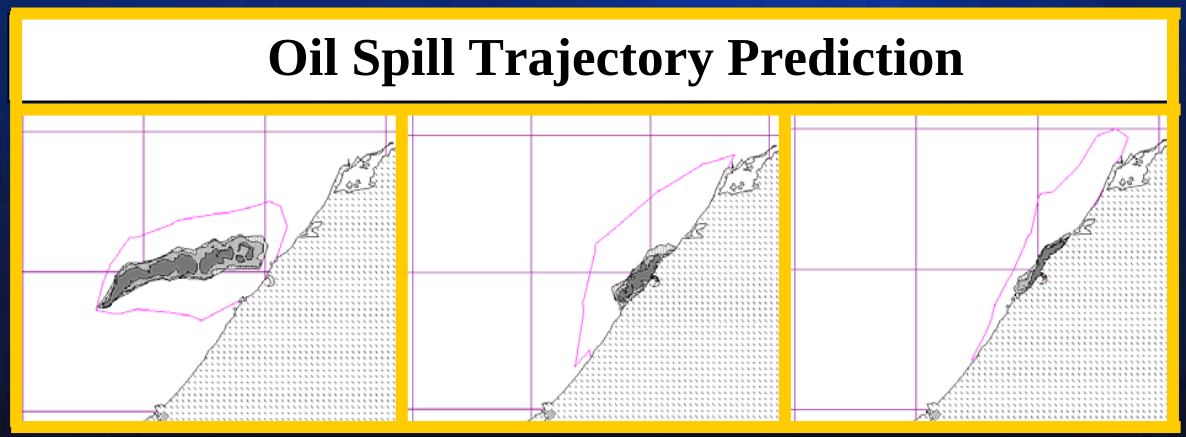
Distinctions from R&D Oceanography

- Defined Customer Base (Fleet User)
- Products support real operations/ exercises
- Reliability (Fleet expects timely, useful products)
- Customer Support (product requests)
- Operational vs. Research Quality Data
- Operational vs. Research Evaluation
- Systematic Monitoring/Assessment of Product Performance







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The Customer

What are the warfighter questions operational oceanography can address?

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Example Warfighter Questions

-When & where will coastal currents indicate a benefit, hindrance or no-go for a swimmer (SOF, NSCT) or AUV operation?

-When & where will water level and/or near-shore wave/surf cause my amphibious assault (JLOTS, NEO) operation to be go/no go?

-How do I best search for an adversary's submarine? What are my detection ranges?

-When & where will solitons cause my SDV/submarine to broach?

-Will the presence or lack of bioluminescence make my SOF vulnerable or make an adversary's SOF operations less likely?

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Additional Example Warfighter Questions

-Will wave conditions and/or current shear abort my planned UNREP operations?

-Will I encounter drifting mines (oil, toxic substance) during my operations this week at location X?

-What type of assault vehicle is best for the given beach trafficability, water depth,current and tide window combination?

-Will salinity and temperature changes impede use of marine mammals?

-Will biologics/plants (e.g., jellyfish or kelp) hinder conventional vessel performance by clogging intakes or control surfaces? How about Swimmer OPS?

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Navy METOC Today: Where are the Navy METOC specialists?

Not Shown: 4 Facilities, 31 Detachments, 9 Mobile Environmental Teams, 1 Special Center

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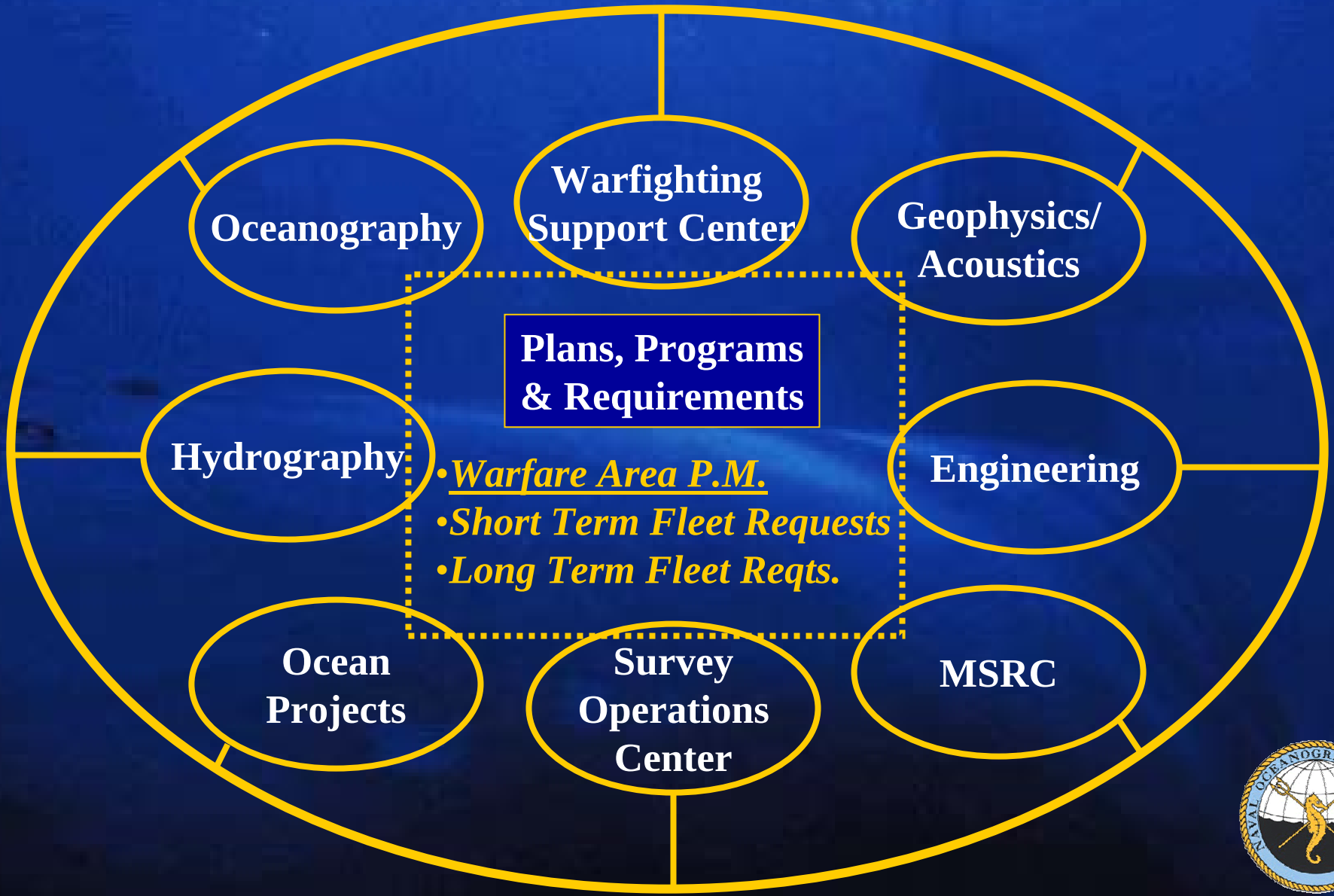
NAVOCEANO production of "relevant" oceanographic knowledge



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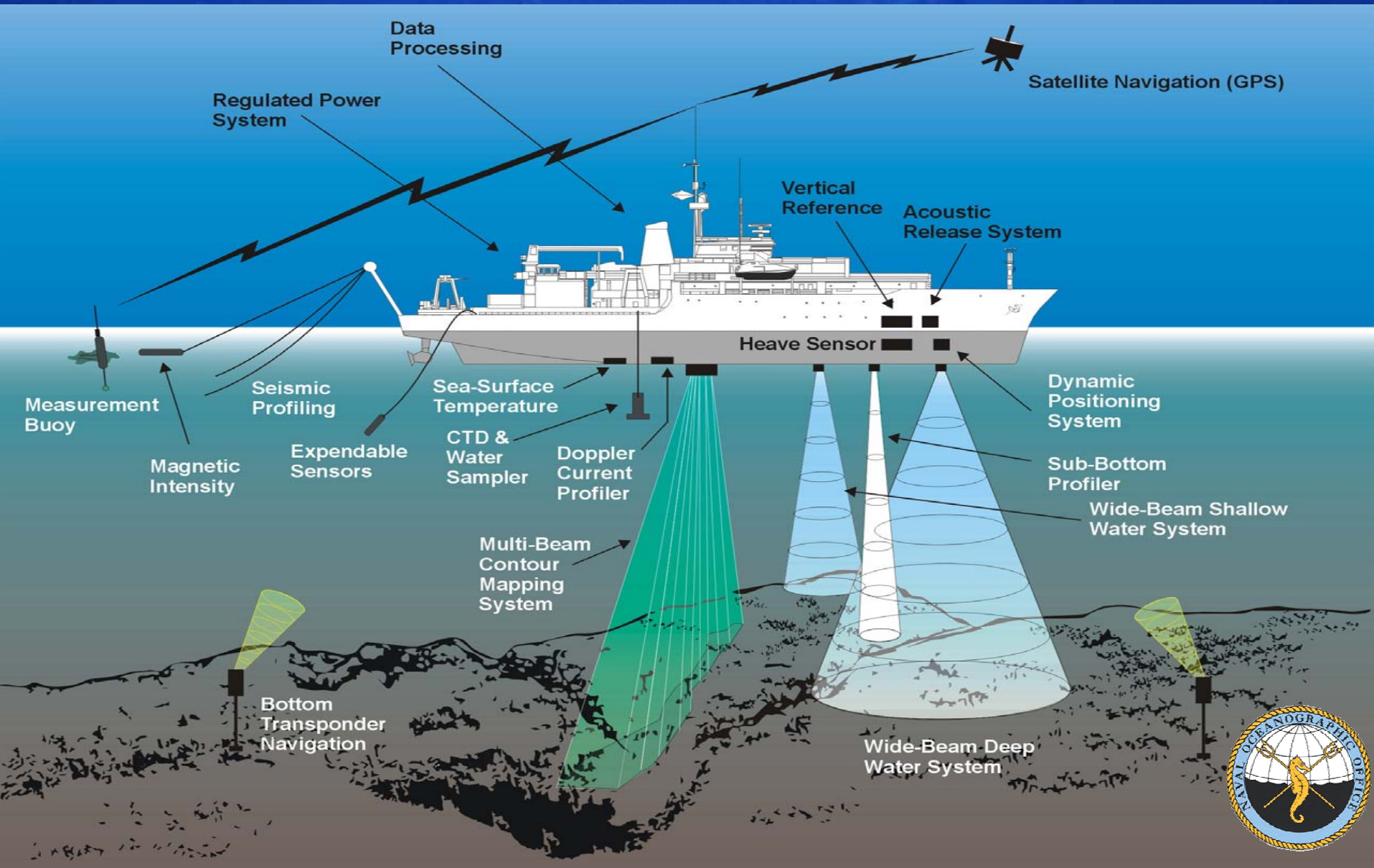
Hydrography Department Example



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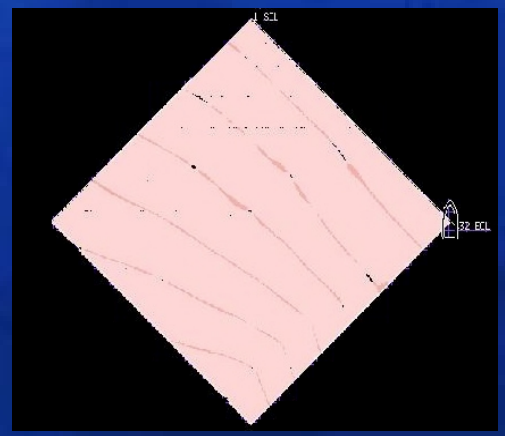
Engineering Department Sample

AutoSurvey

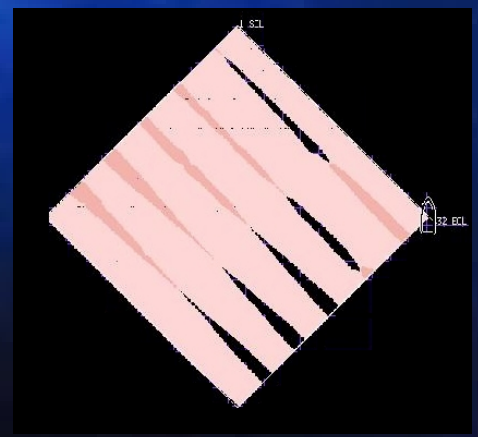
Purpose: Minimize deployment time with swath sensors while ensuring 100% sensor coverage*

100% sensor coverage



WANT THIS

Approach: Adapt vessel navigation based on actual versus predicted sensor coverage, which varies significantly with conditions



NOT THIS

* Or operator specified percent coverage from 20-200%

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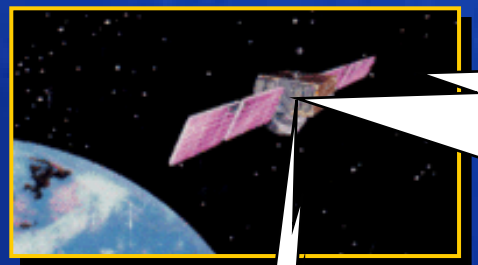
Survey Operations Department Sample



Survey Operations Center

Raw Data

Processing Codes

Internal Users

Data Warehouse

External Users

Scientific Expertise

Technical Expertise

Additional Data

(Future)

(Future)

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Acoustics/Geophysics Department Sample

Acoustic Transmission Loss Measurements

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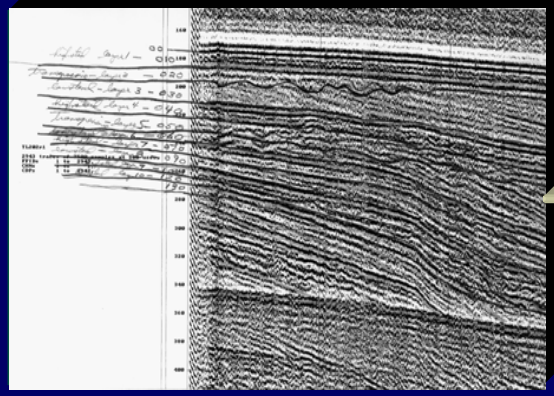
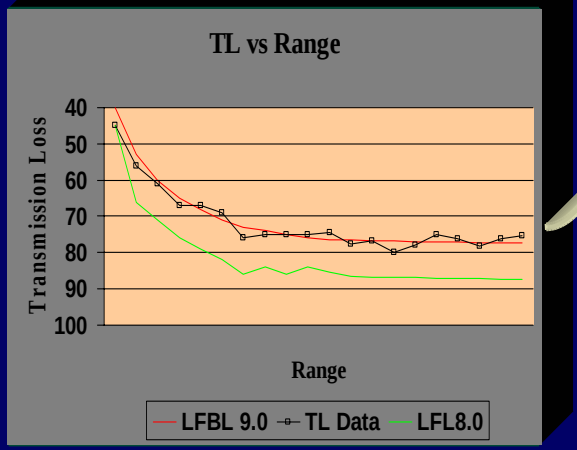
Acoustics/Geophysics Department Sample

Collected Seismic



Collected TL Data



PE 5.0 Transmisson Loss Model

Good TL Match?

YES

NO

Optimal Geo-Acoustic Parameters **(Attenuation, density and sound speed)**

GENETIC ALGORITHM Search Engine: iteration through geo-acoustic possibilities

Low Frequency Bottom Loss Database

TDA

Inversion For Geo-Acoustic Bottom Parameters

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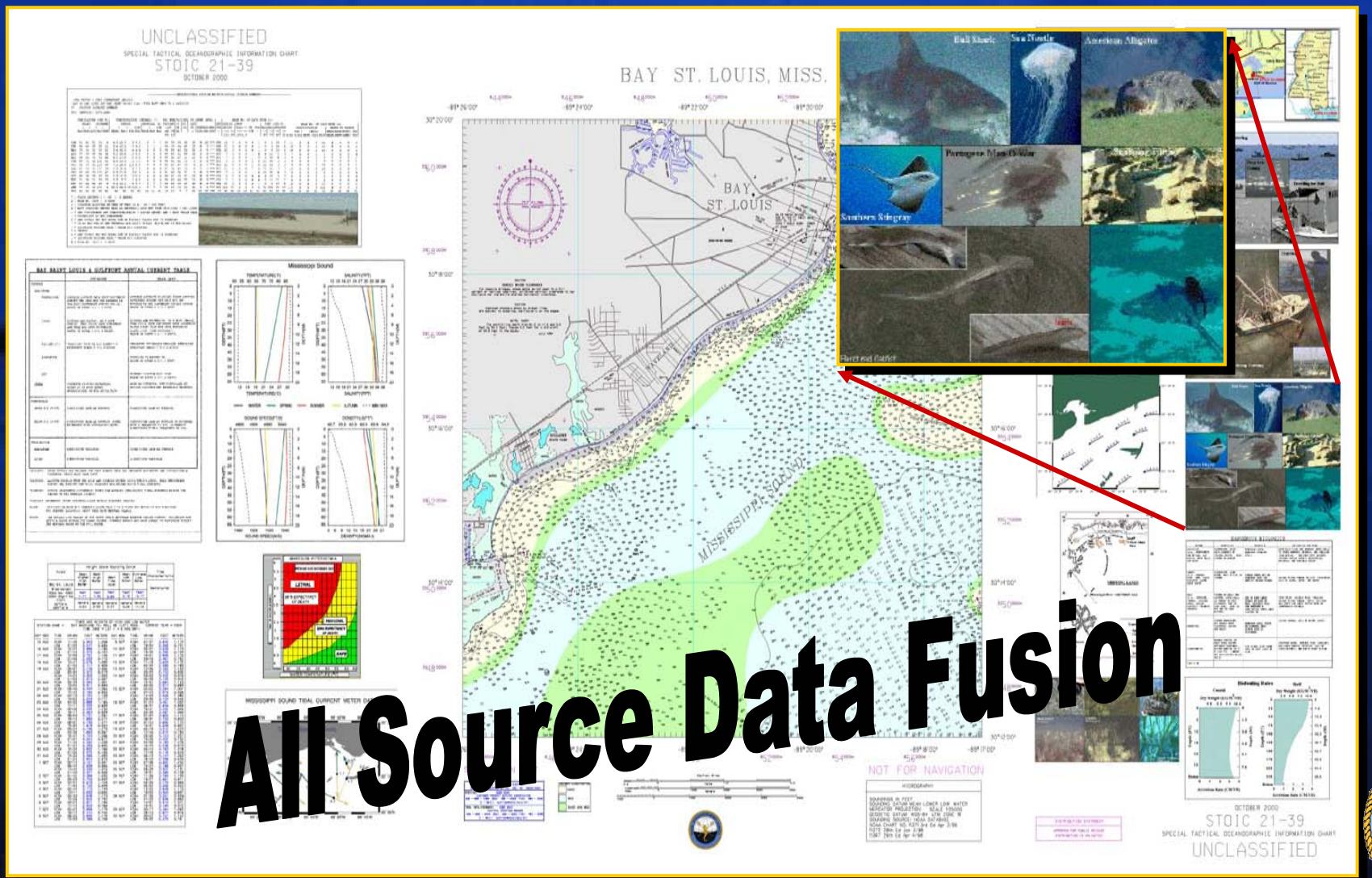
Warfighting Support Center Sample



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Major Shared Resource Center

One of the most capable HPC environments in the world today serving a nationwide user community of over 4,000 scientists and engineers.

- Department of Defense R&D Asset, 15% available for Operations
- World-class terascale HPC systems, (Regularly ranks in Top 10)
- Multi-gigabit LAN/WAN network capability
- High-end scientific visualization
- Massive, petabyte-scalable hierarchical storage
- Strong intellectual component with leading academic affiliates
- Proactive user support & computational technology area expertise

IBM Power 4+

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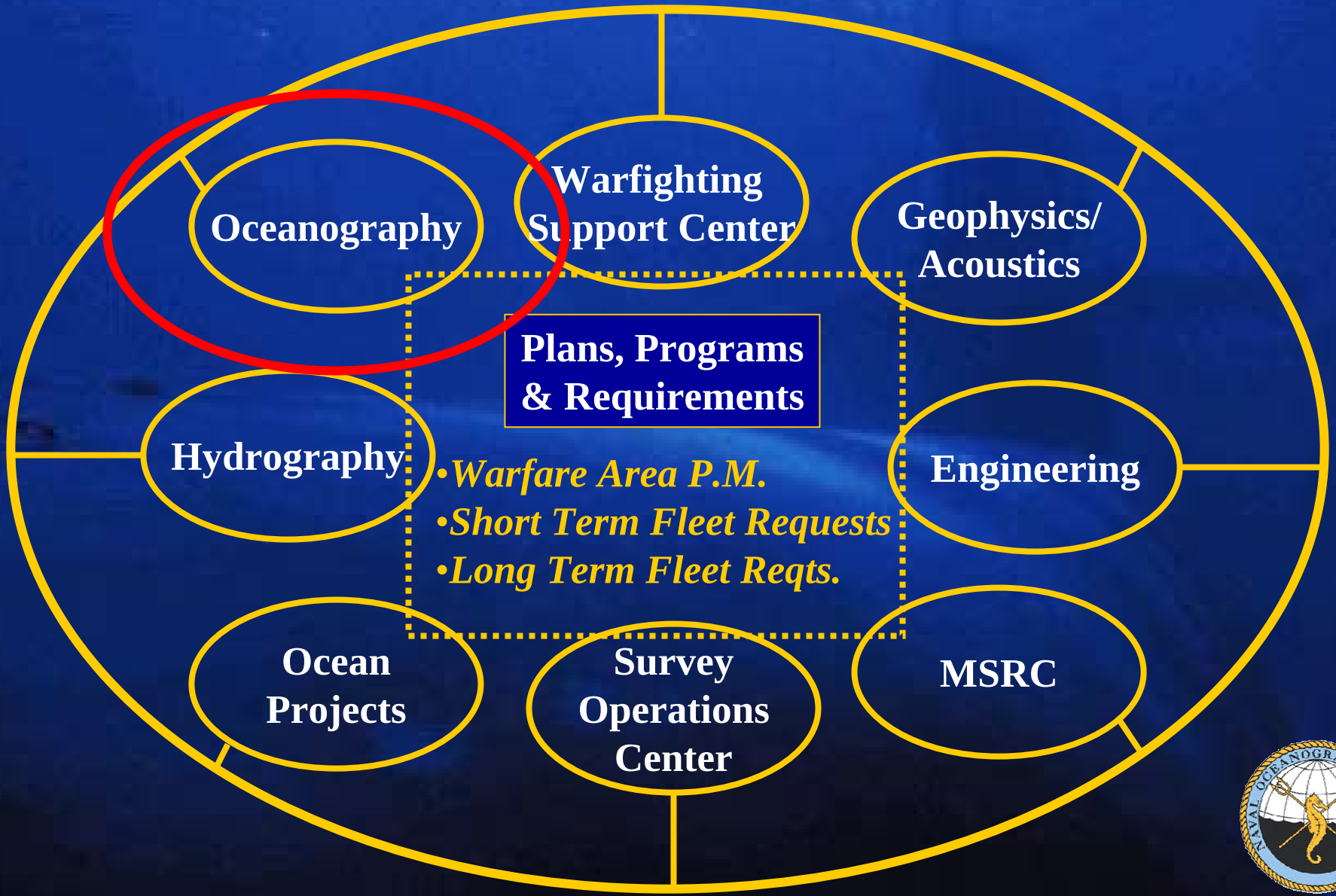
NAVOCEANO Oceanography Department Role



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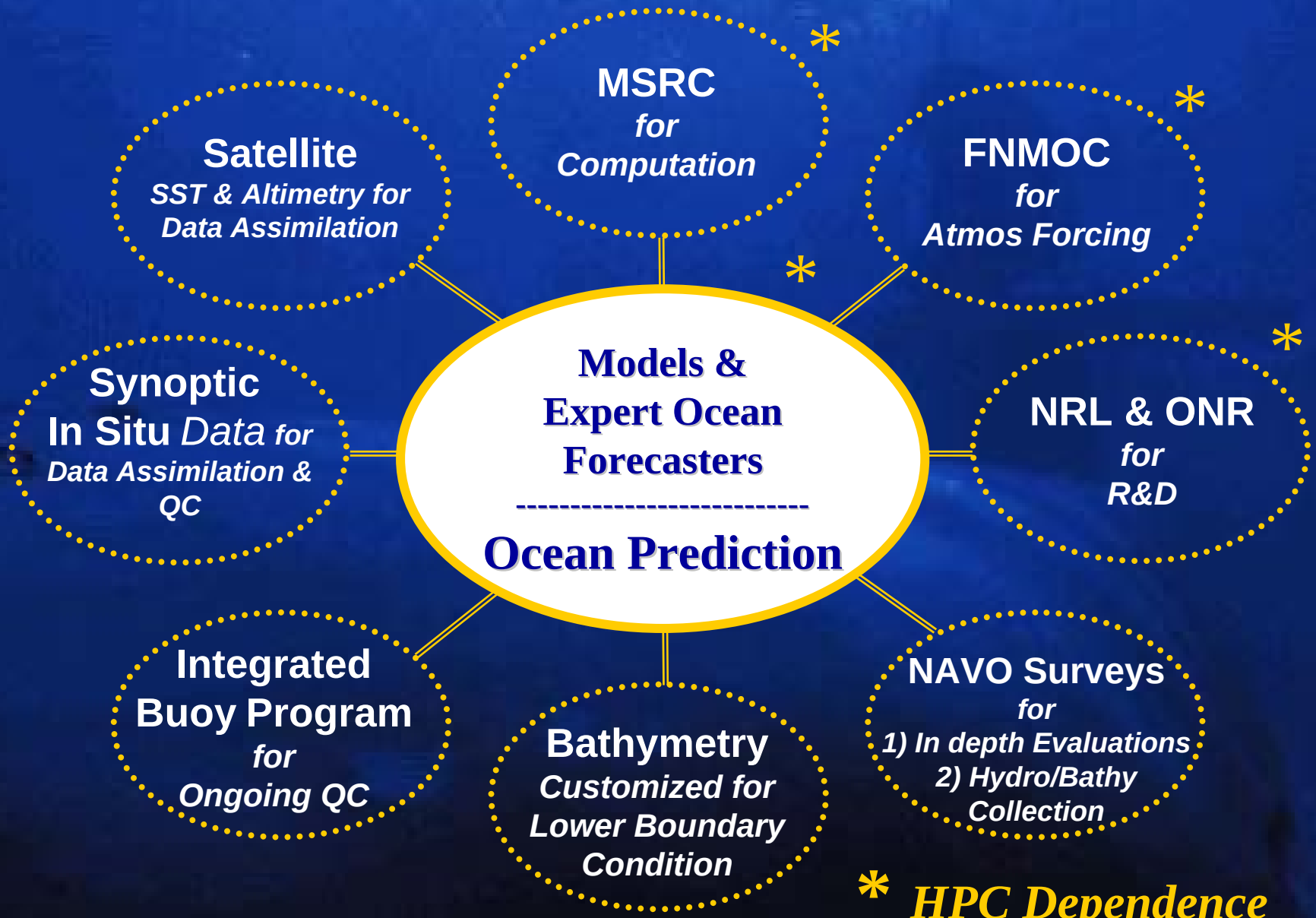
Ocean Prediction Dependencies



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Oceanographic Data Collection

Survey

--CTD --ADCP
--XBT --Current meter
--AC9

Real Time/ Remote In Situ

--Air Nat'l Guard MOA
--MiniMet, WOCE, APEX, Davis, Profilers

ARGO Program
BTs, CTDs, Moorings/ADCPs

Real Time/ Satellite

--Polar Orbiters
--Geostationary

Altimeters
--Navy GFO
--NASA Jason
--ESA Envisat
Comm'l Imagers
--SeaWiFS
NASA Imagers
--MODIS

Climatologies/Databases,
Synoptic Analyses,
Model Assimilation/Eval/QC

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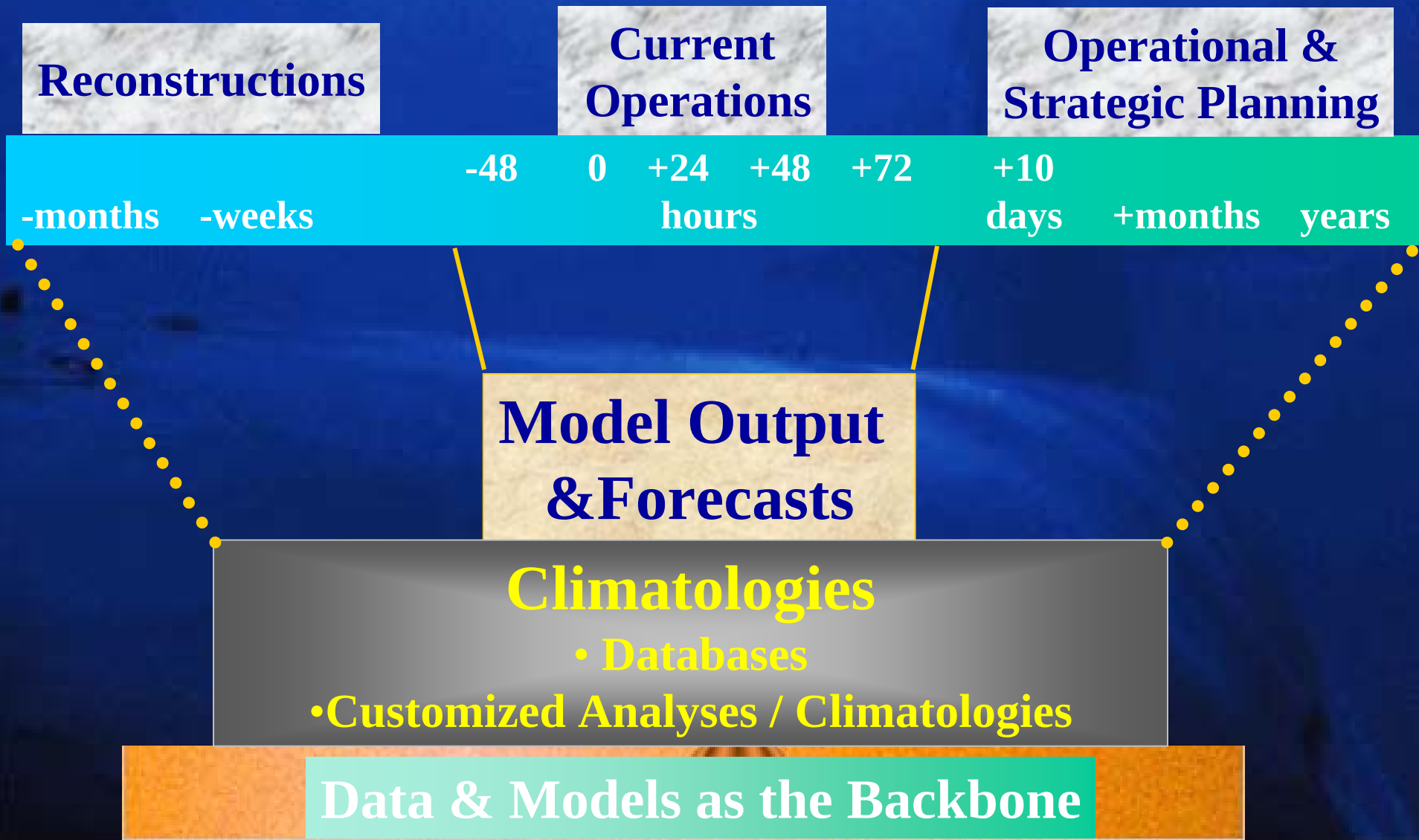
TREND: Less Data Base Production/ More Real-Time Production



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Trends in NAVOCEANO Oceanography

- Surge effort for Warfare Area Support
  - ASW, SOW, MIW, …
- Rapid Response Capability for Current Prediction (data, models, oceanographers)
- Forecasters to interpret models/ generate products

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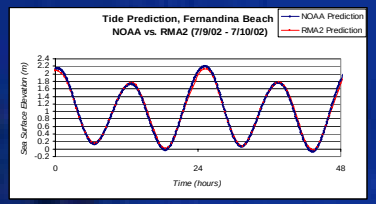
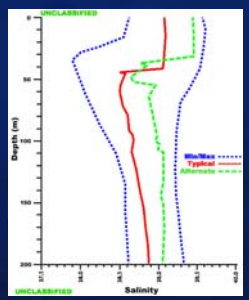
Operational Forecasting

Real-time data



Historical Observations



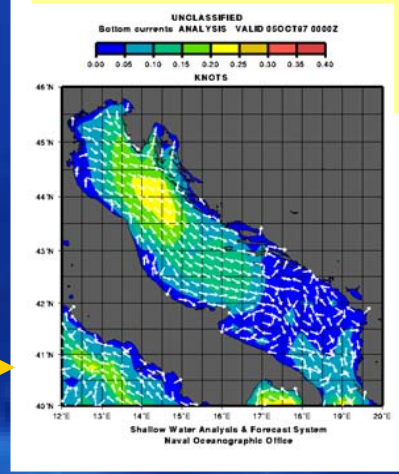
Ocean Climatologies

Bathymetry, Imagery

Data Processing & Assimilation

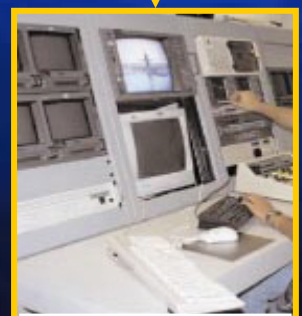
Ocean Models

Oceanographic Predictions



- Graphics
- Data Fields
- Information

Tactical Product



Ocean Forecaster

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Translating Ocean Processes to Answer Warfighter Needs

	Temperature/ Salinity	Currents	Optics	Waves
• MIW	✓	✓	✓	✓
• ASW	✓	✓	✓	✓
• USW	✓	✓	✓	✓
• SPECWAR	✓	✓	✓	✓
• AMPHIB		✓		✓

Naval Operational Oceanography

Naval Applications of Ocean Models

- Diver, Swimmer Mission Windows
- Underwater Vehicle Operations
- Mine Drift Prediction
- Mine Scour Prediction
- SOF Small Boat/ Amphibious Ops (tides, waves)
- Oil / Contaminant Spill Prediction
- Helicopter Navigation for Towed Sleds
- Sound Speed for Mine and Submarine Detection
- Other (SAR, UNREP, JLOTS…)

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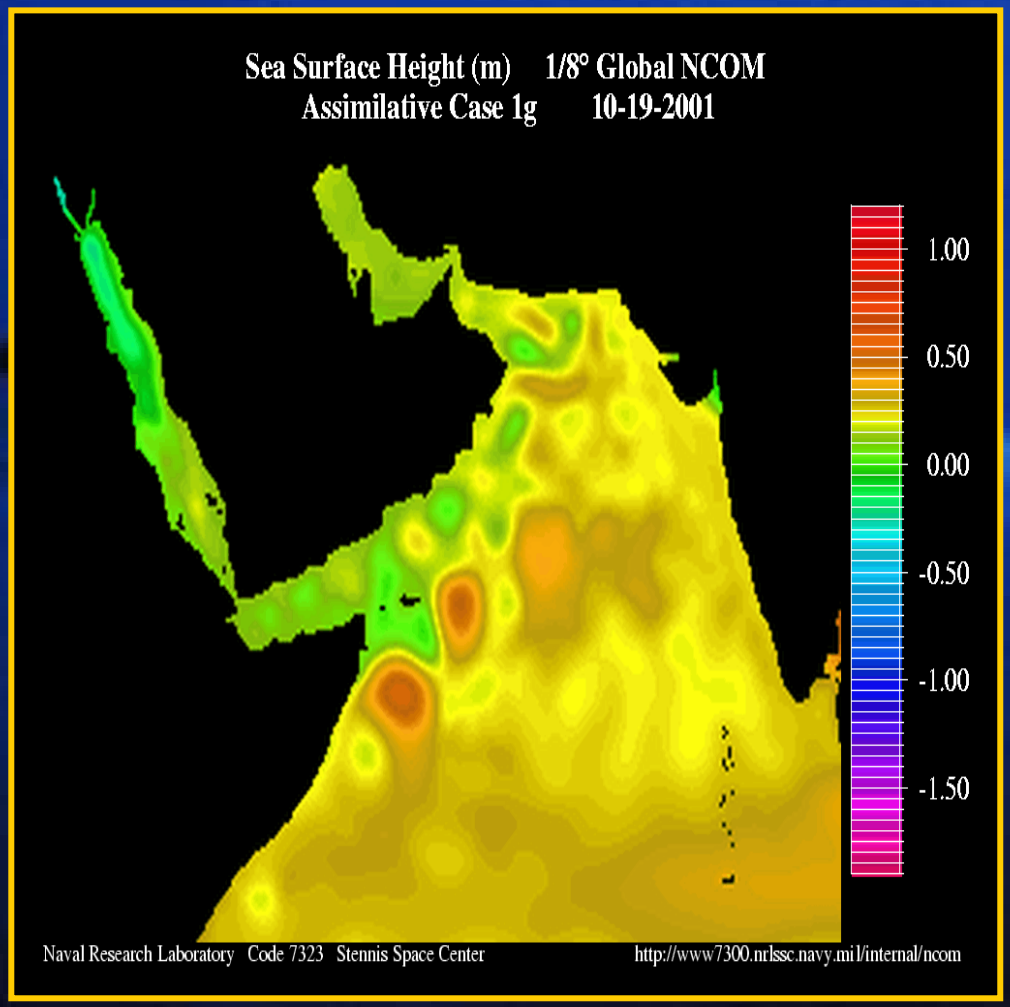
Shallow Water Analysis Forecast System (SWAFS) & NRL Coastal Ocean Model (NCOM)



- *POM-type codes in wide use around the world for coastal & harbor applications*
- *Full primitive equation ocean circulation model*
- *Sigma coordinate in vertical (NCOM hybrid sigma/z)*
- *Includes river runoff, tidal forcing, and tracer capability*
- *NCOM both global and integrated into COAMPS*
- *NCOM efficient scalable, portable code (Wallcraft, Martin)*

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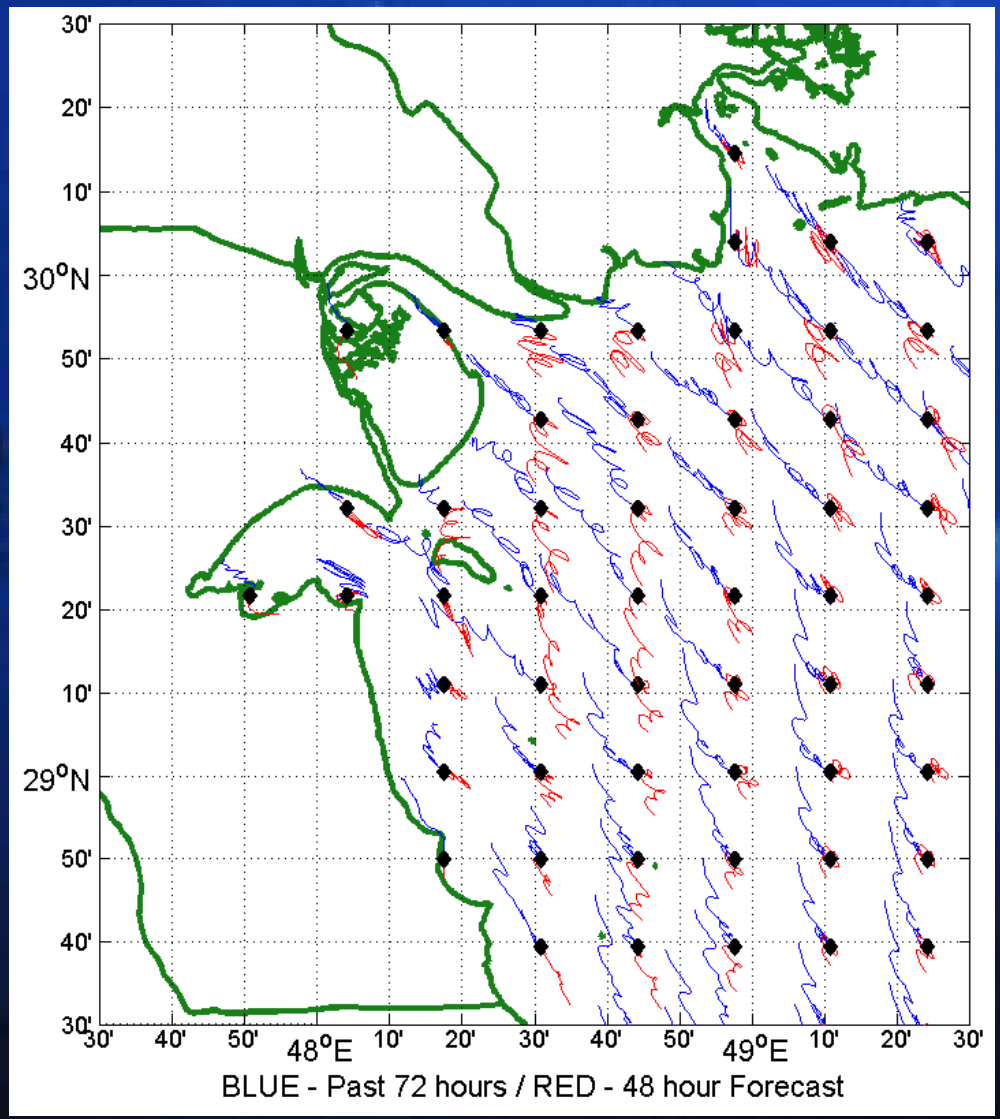
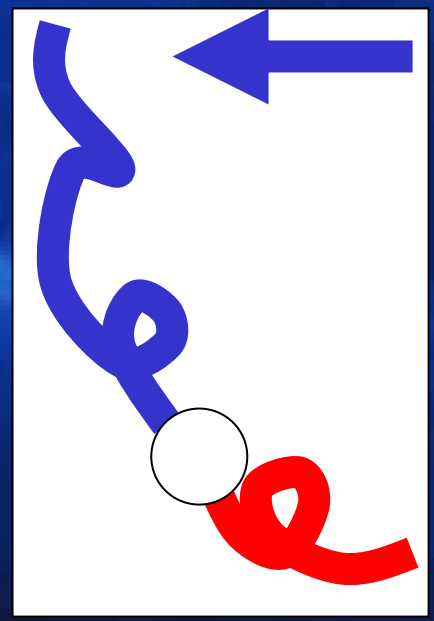
Drift/ Oil Spill Concerns



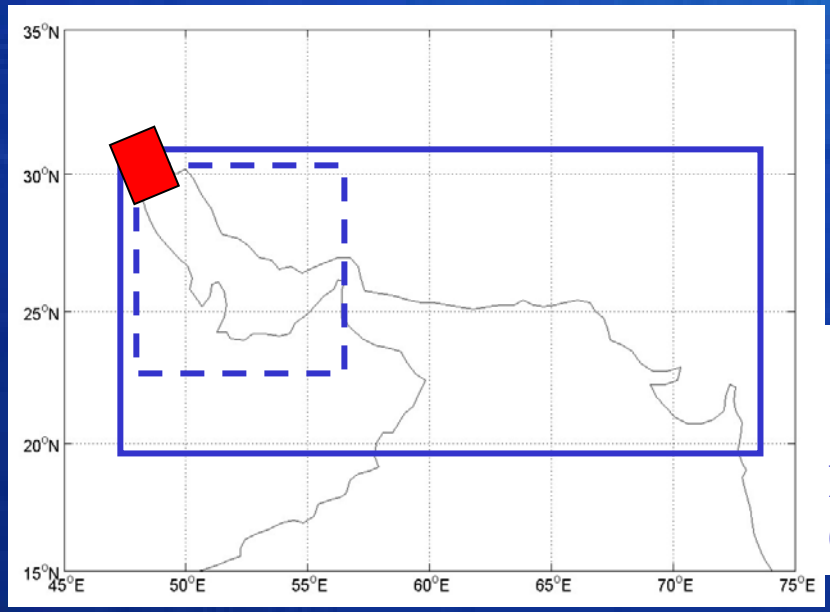
NAG Drift Simulation



If a suspected source region is here, then blue is simulated track over last 72 hr, red is forecast track for next 48 hours

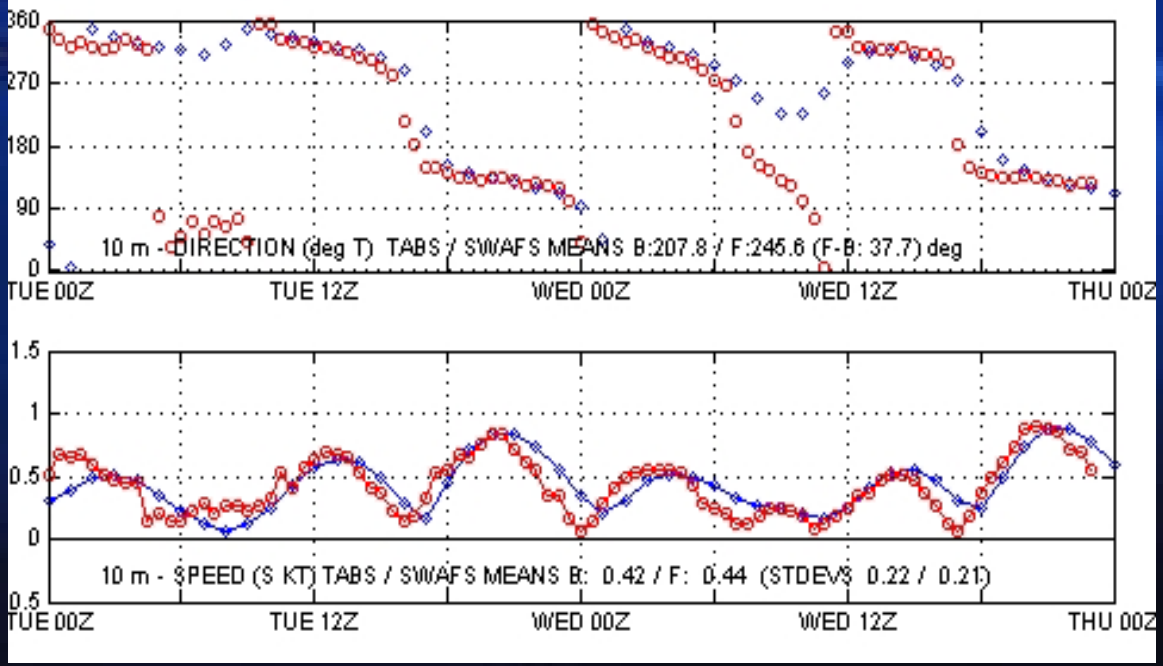
If an object is found at the dot, then blue may point to the source region

Model Domains and Data Comparisons



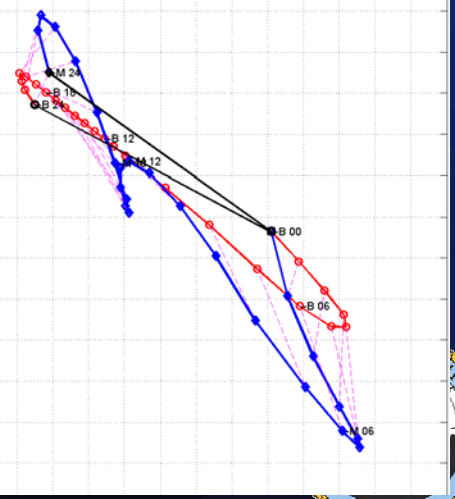
SWAFS 2 km (U)
SWAFS 0.8km (C)
RMA2 Riverine (2 domains)
GNOME (NOAA Oil Spill)

TABS vs SWAFS



Davis vs SWAFS

(24 hr forecast)



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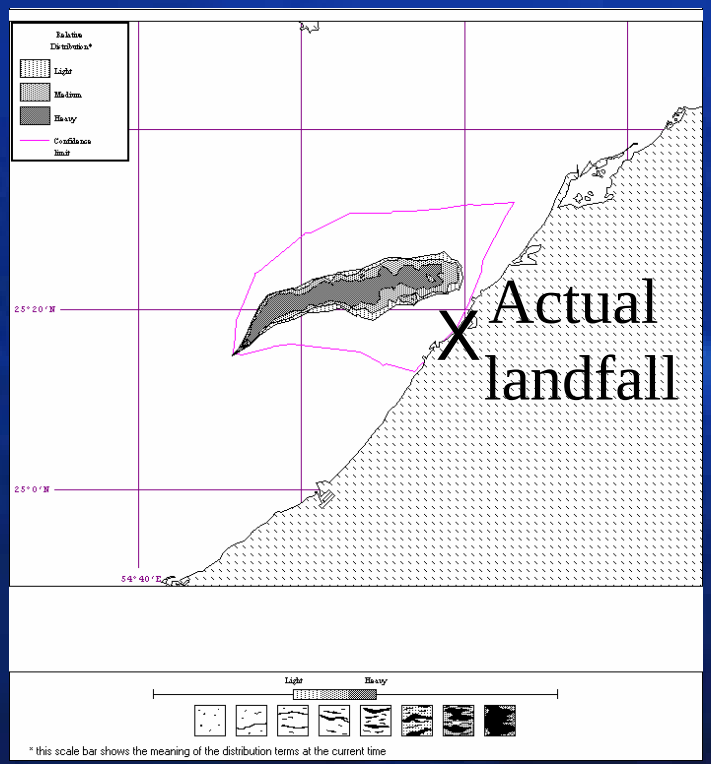
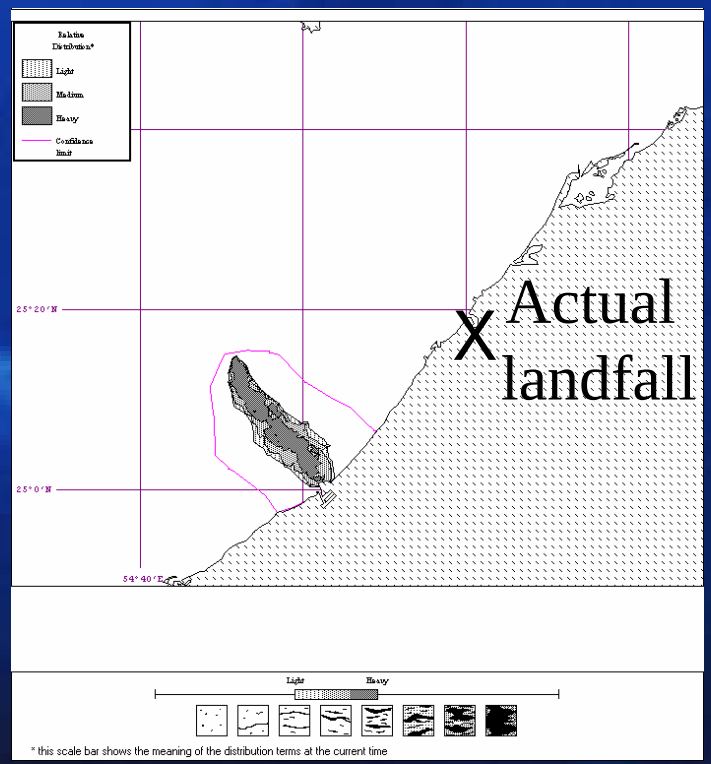
NAVO SWAFS / NOAA GNOME

(example from actual spill during Desert Storm)





SWAFS-COAMPS (best estimate)

Climatology (educated guess)

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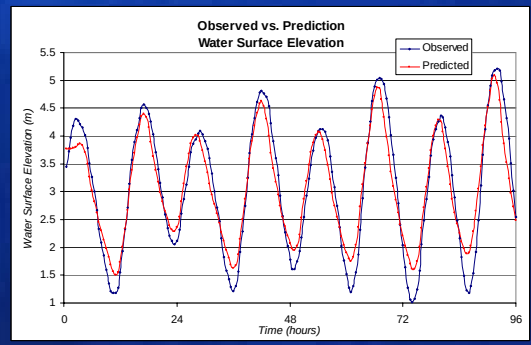
RMA2 River Model Validation (NAVO/ERDC)

Near Um-Qsar

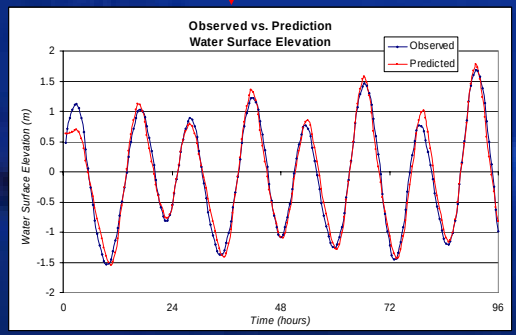
Observation Point

Height



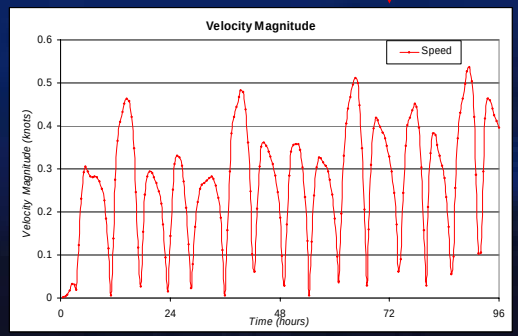
Time

Height

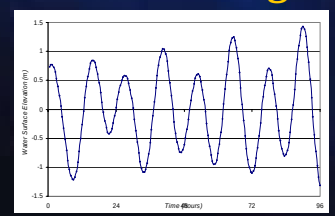


Time

Speed



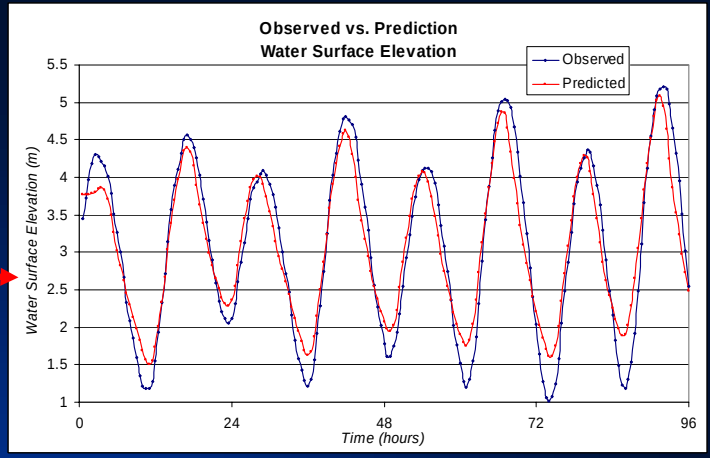
Tidal Forcing



Blue - Observed

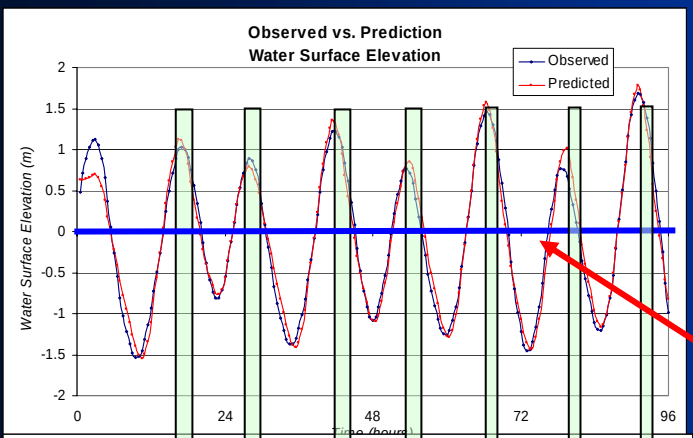
Red - Model

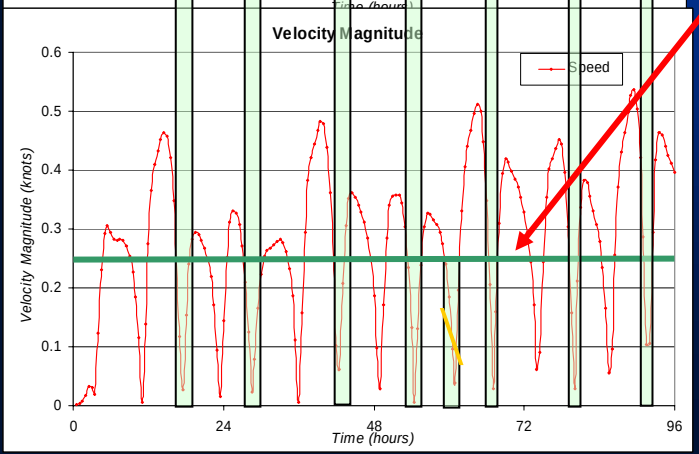
Warfighter Question: When are dive windows where speed low and water level high?



Observation Point

Observation Point



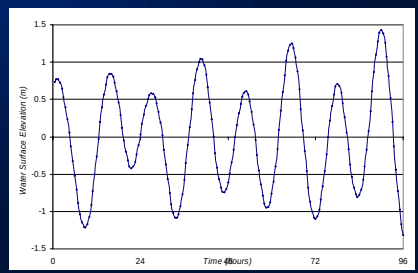


Depths > mean &
Speeds < 1/2 kt

Feedback from MIW Squadron

- Without RMA2 predictions for dive windows, MCM ops would have been extended from 2 months to 3 months
- AMCM Pilots routinely used NAVO graphics on flash cards in cockpit during missions.

Tidal Forcing Input



Naval Operational Oceanography

<u>The Bigger Picture</u>:

The U.S. Navy Has Global Responsibility.

Different Geographic Areas can have
Different Dominant Ocean Dynamics
That Impact the Warfighter.

Where GODAE Fits In.

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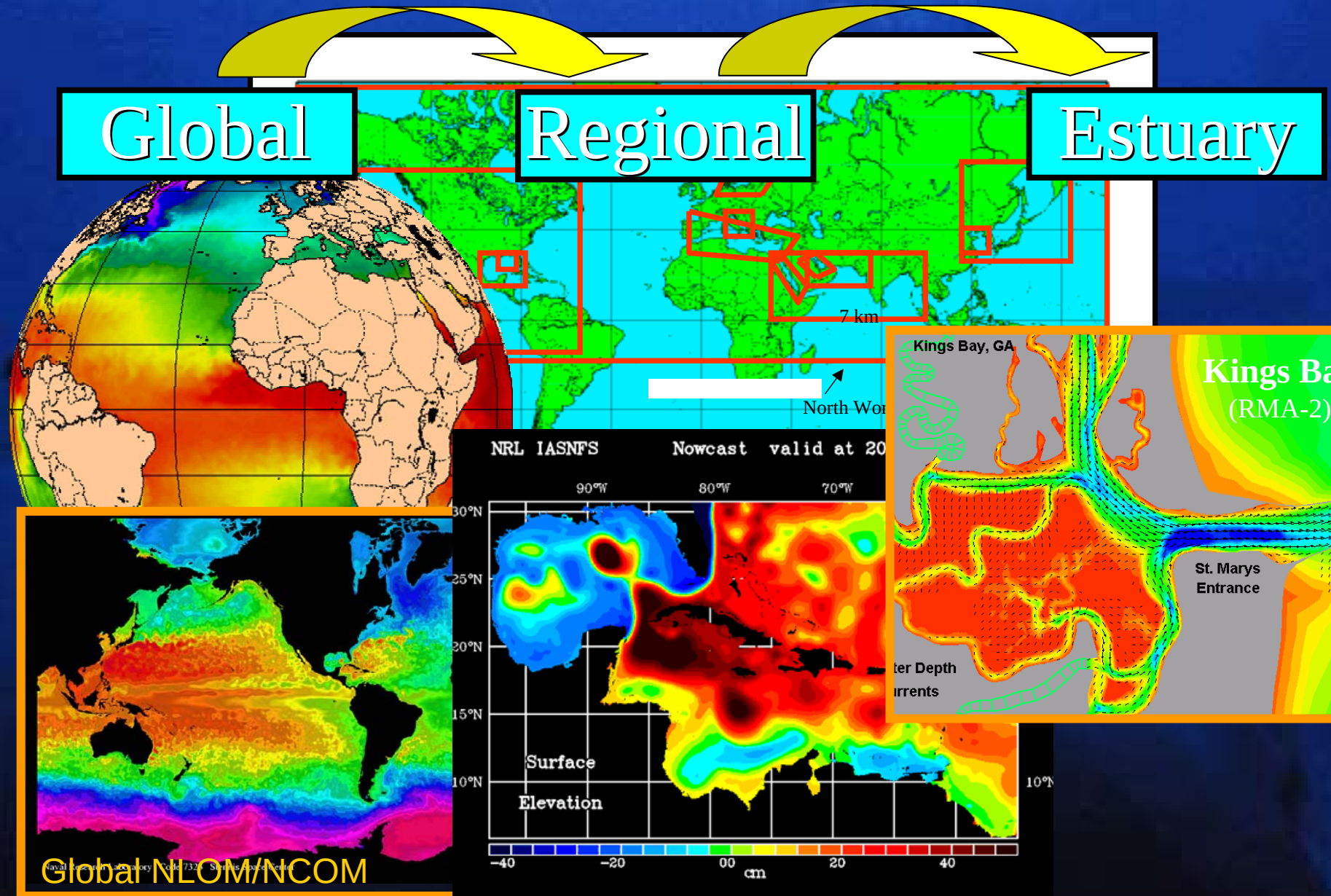
Nesting Approach in Ocean Prediction (Coastal Emphasis)



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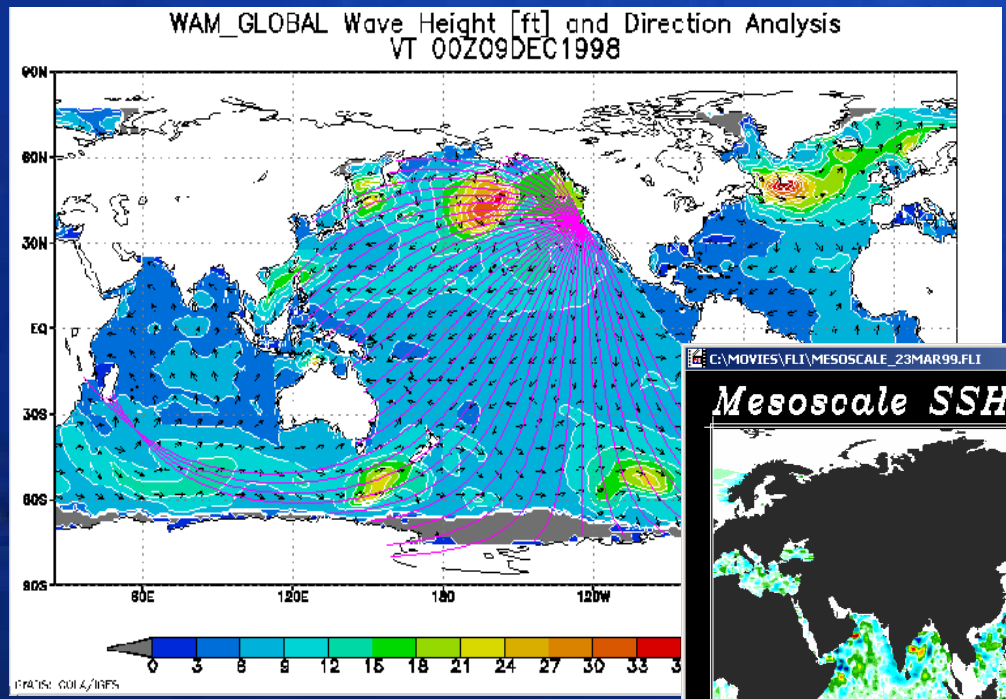
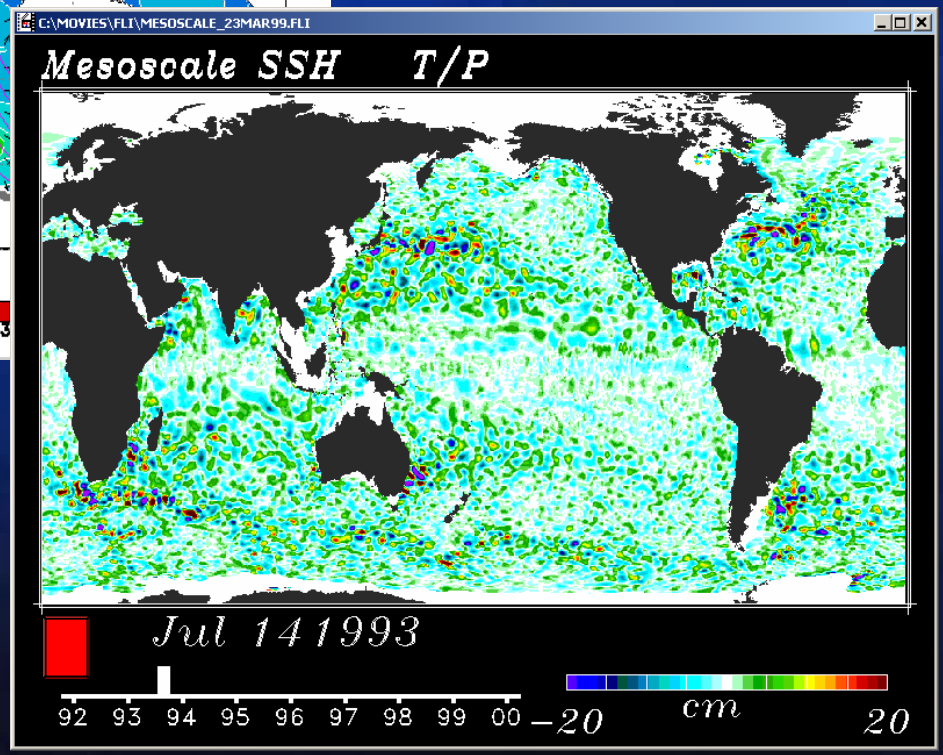
Importance of "Global" View in Littoral Ocean Prediction



Surface Swell Propagation Example



Mesoscale Dynamics Example

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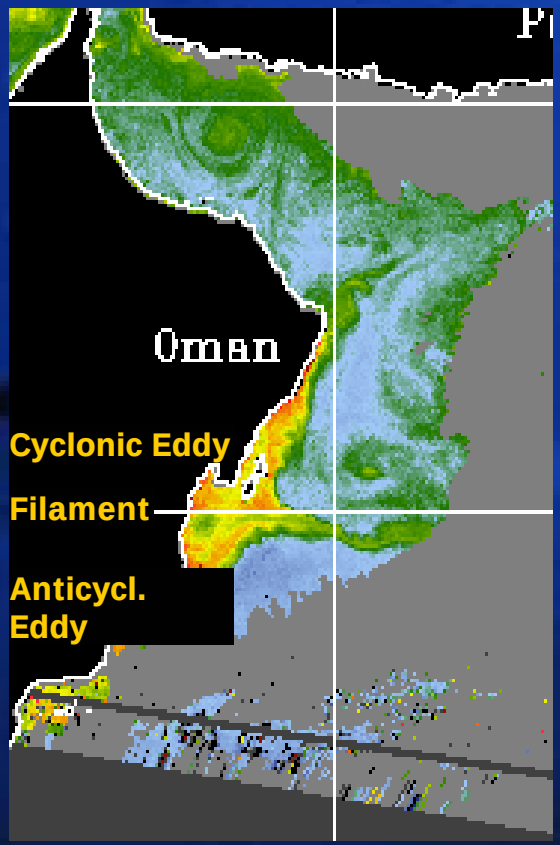
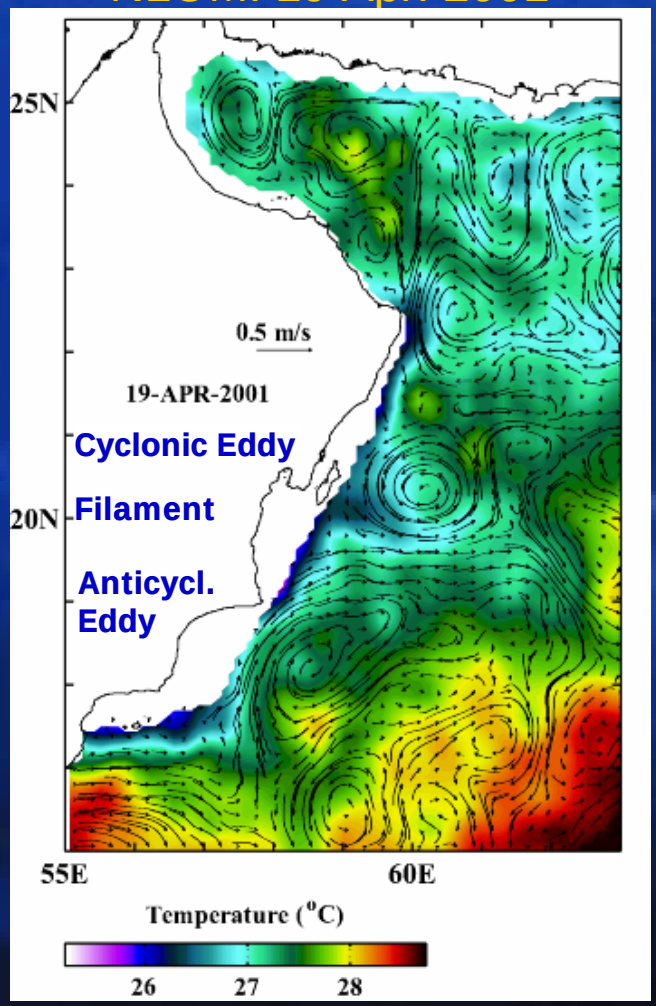
SeaWIFS relative to NLOM/NCOM - Oman Coastal Filaments

SeaWIFS: 19 Apr. 01

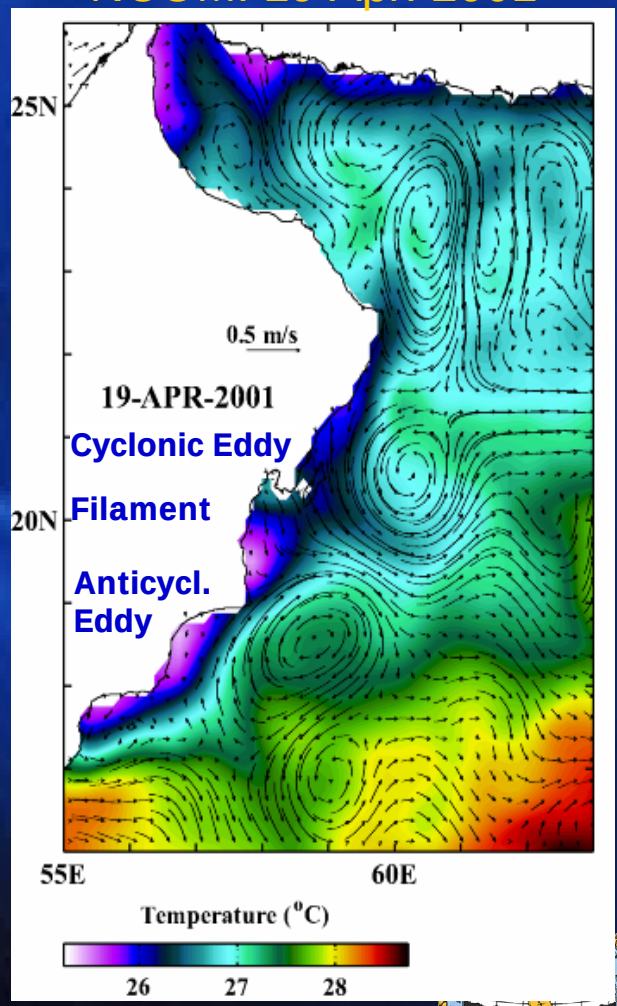


Chlorophyl from SeaWIFS

NLOM: 19 Apr. 2001



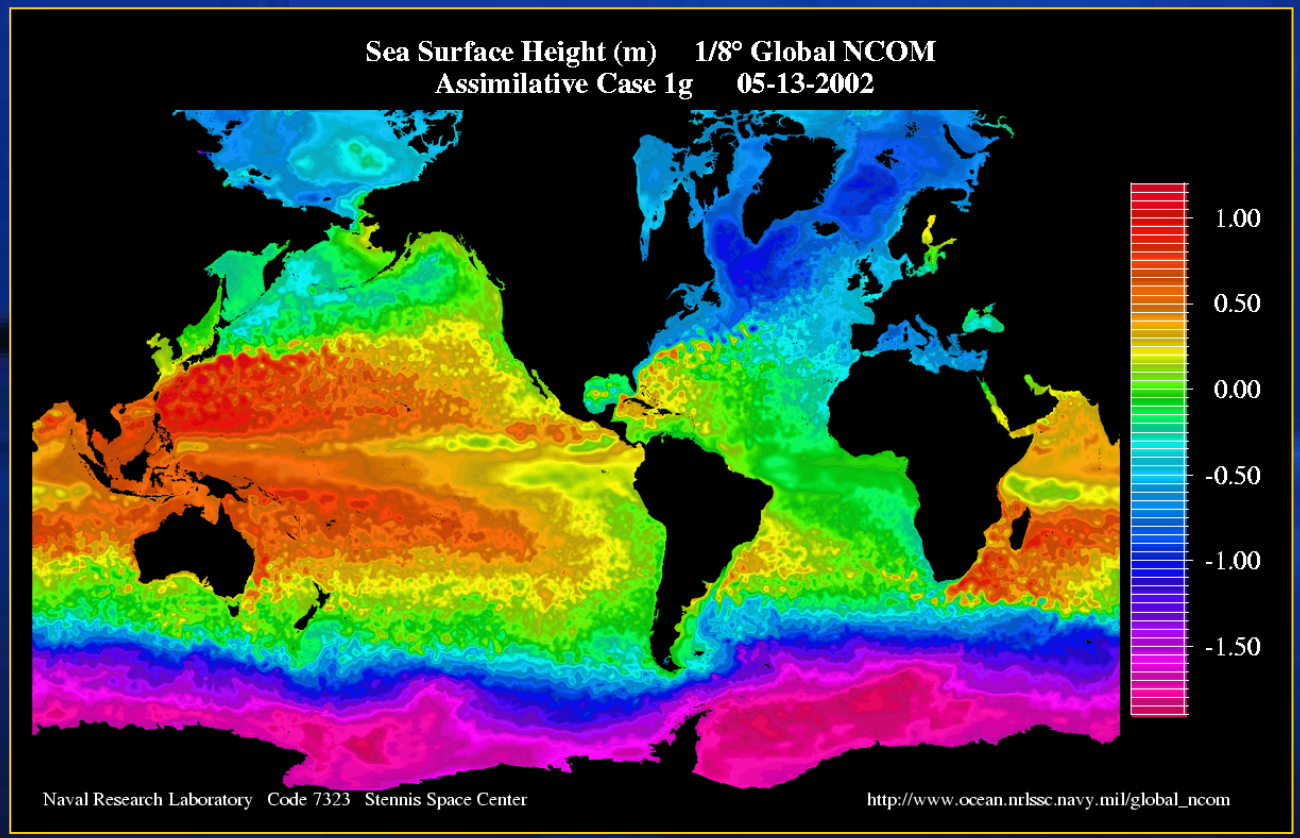
NCOM: 19 Apr. 2001



Model SST and Surface Currents

Naval Operational Oceanography

Importance of "Global" View in Littoral Ocean Prediction



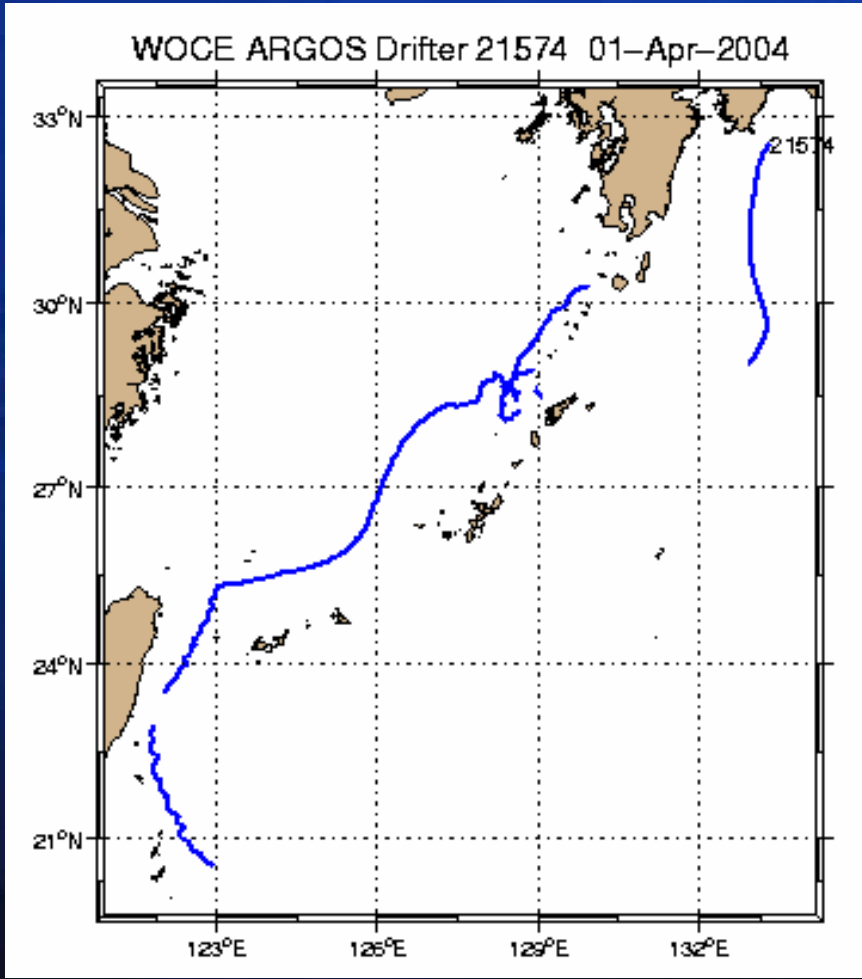
Boundary Conditions For Regional Models

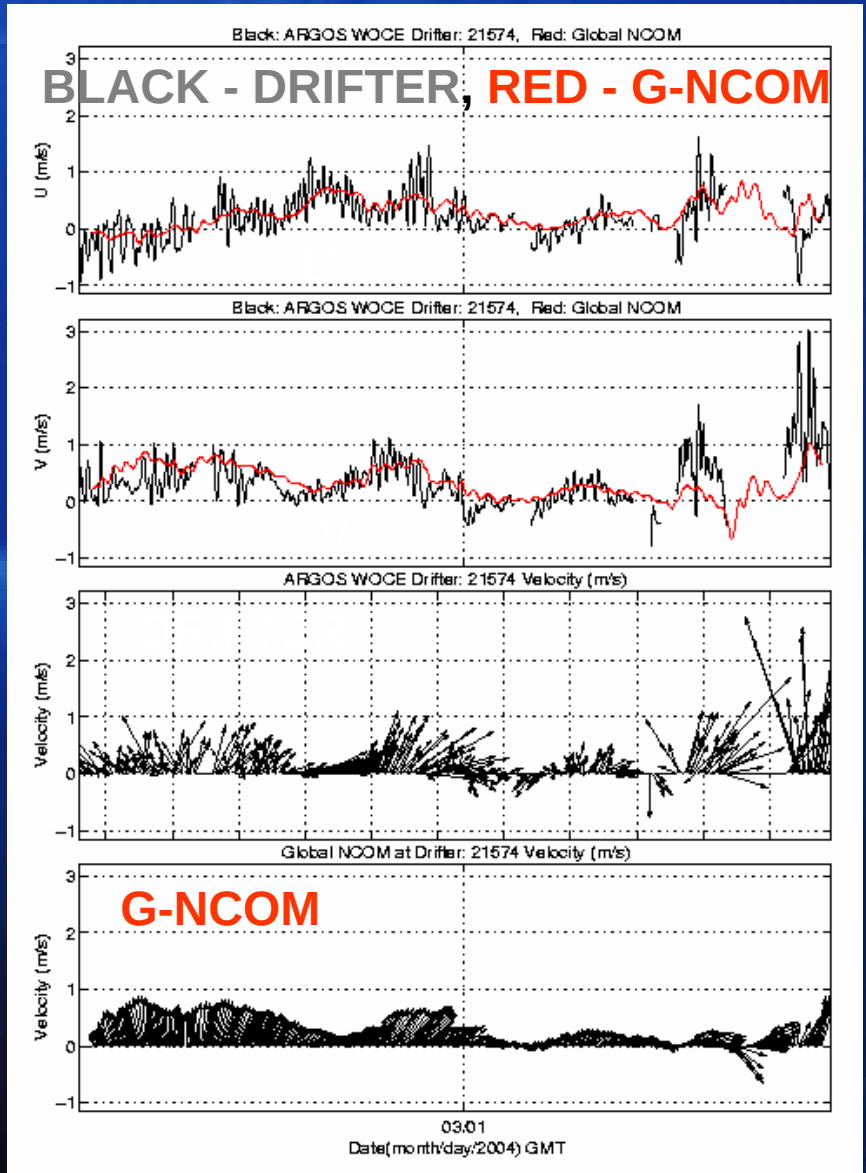
Shallow Water Coastally-Trapped Wave & Surge Guidance When Regional Model Not Available

Naval Operational Oceanography

Global NCOM – Potential for Search & Rescue, Object Drift Tracking

Courtesy: M. Carnes- NAVO)



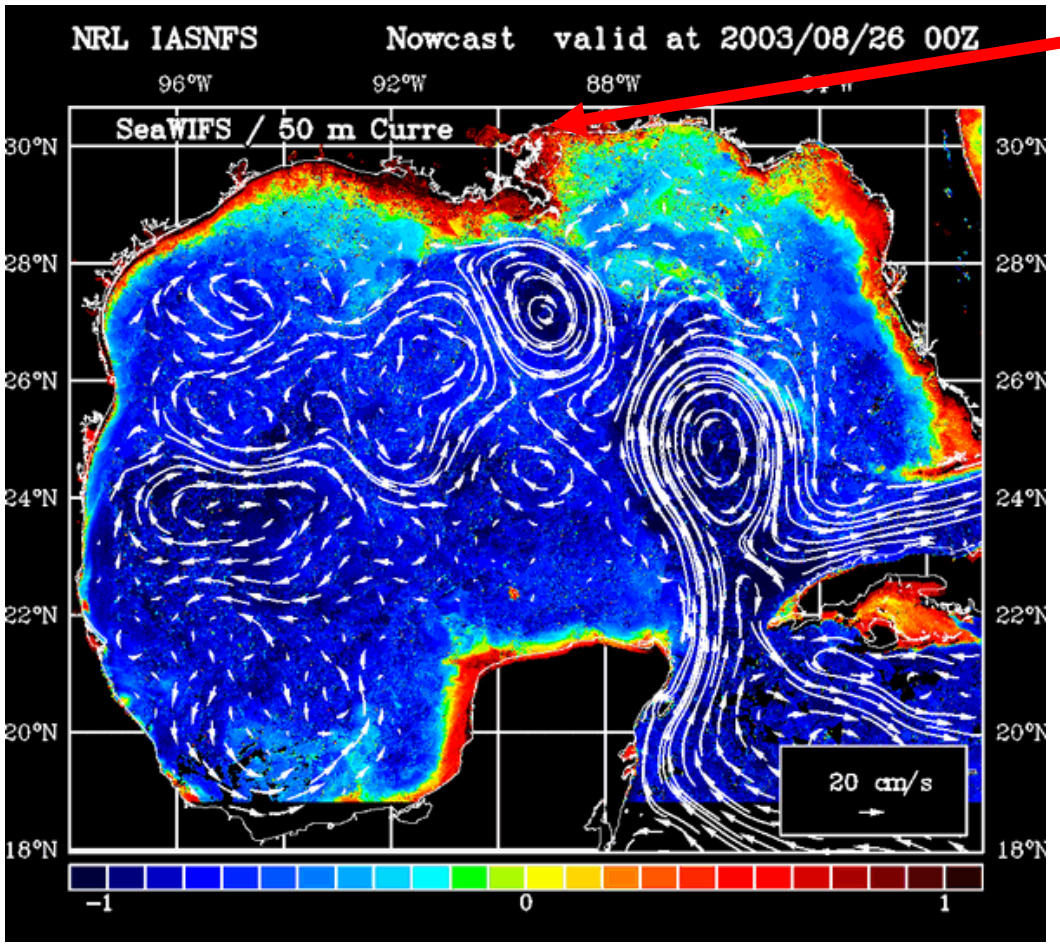


Naval Operational Oceanography

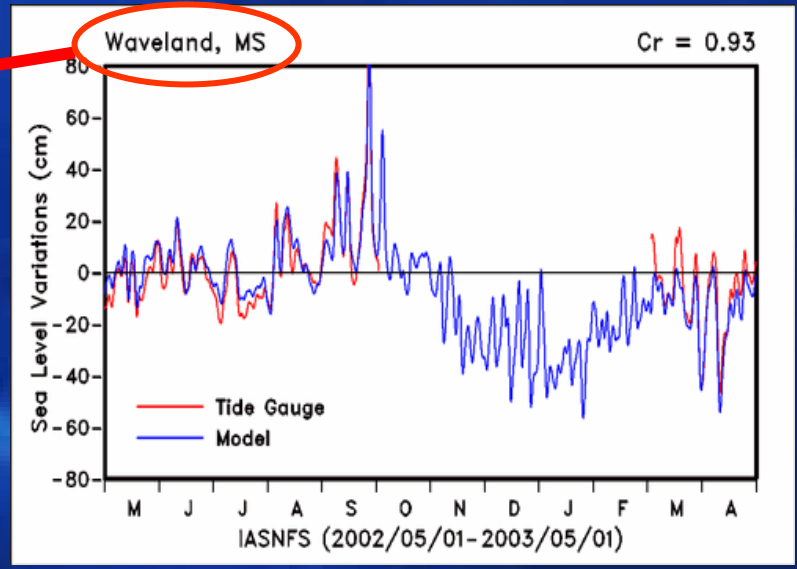
Gulf of Mexico Extract from NRL Intra-Americas Seas NCOM

(Regional Nest in Global NCOM)

IAS Currents over SeaWIFS color imagery



Seasonal & Synoptic Variability



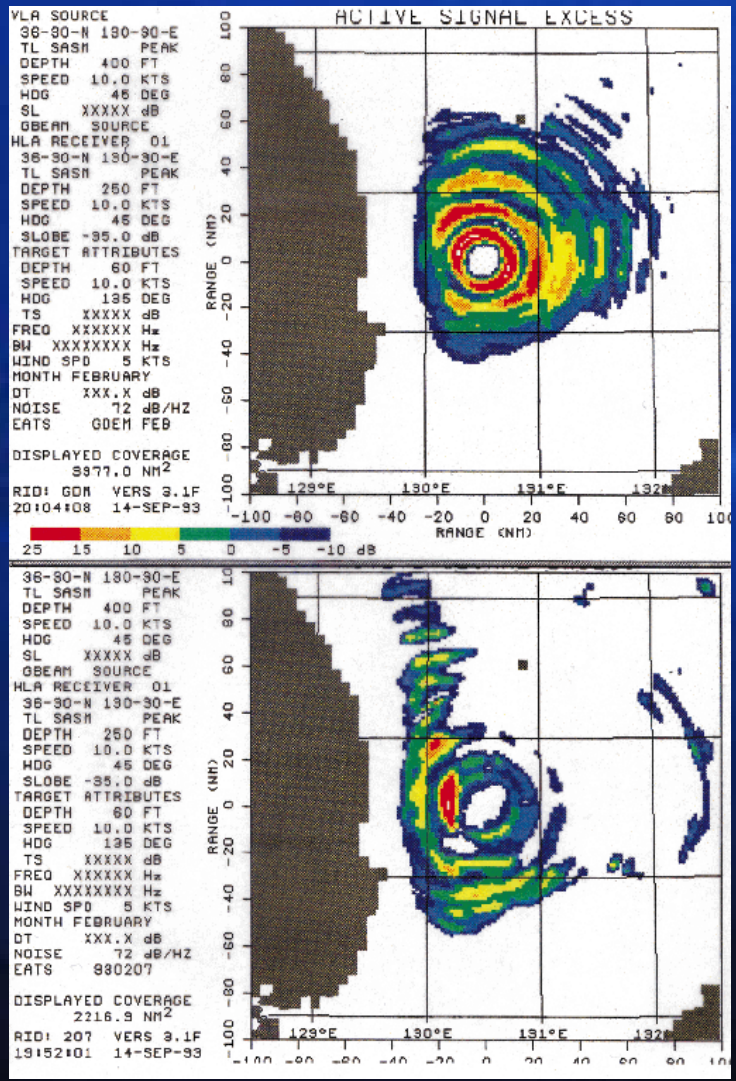
Courtesy: Dong Shan Ko, NRL

www.ocean.nrlssc.navy.mil

Naval Operational Oceanography

Returning to Warfighter Questions & Impact of the Environment

Acoustic Active Signal Excess in the Sea of Japan



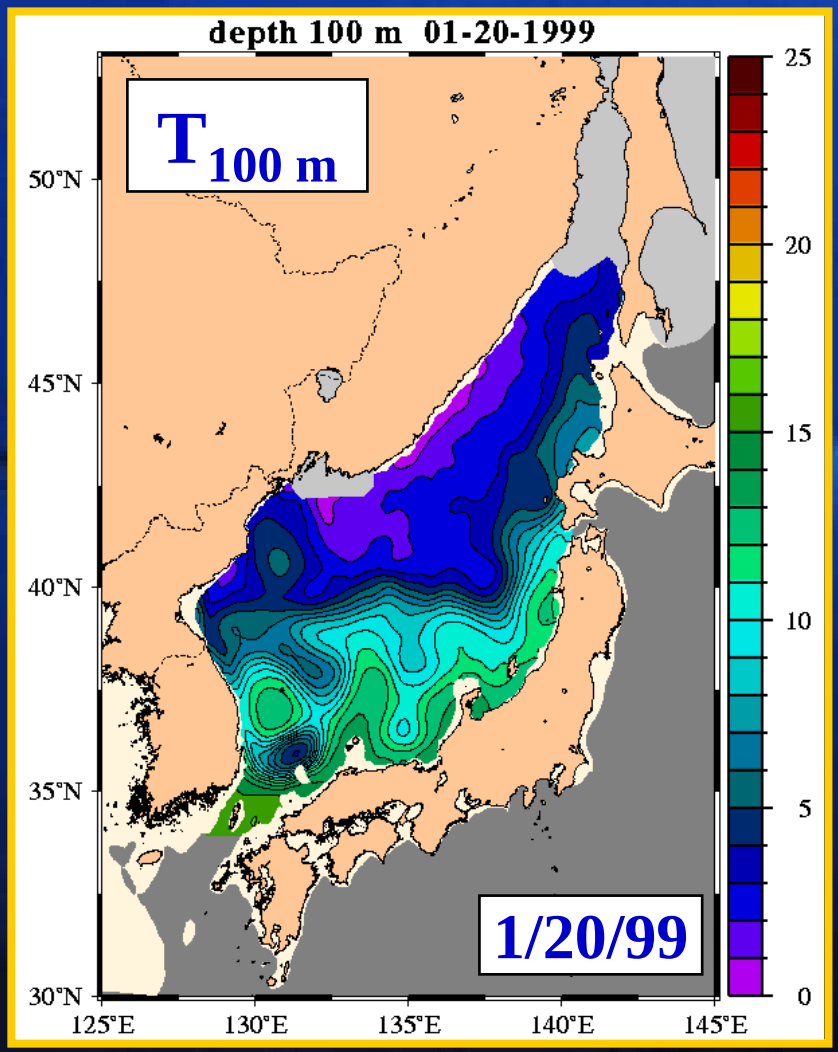
From <u>climatological</u> density (GDEM)

- ***The ocean state at any time contains large deviations from climatology***
- ***Monitoring and predicting the environment is vital***

From <u>measured</u> density

Naval Operational Oceanography

Modular Ocean Data Assimilation System (MODAS)

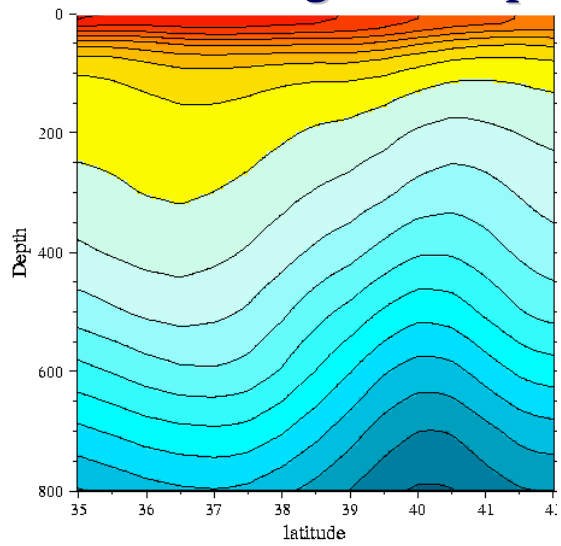


- *Ocean thermal data assimilation toolbox*
  - *Seasonal Climatology*
  - *Synthetic Profiles*
  - *MODAS 2D*
  - *MODAS 3D (synthetics only & full)*
- *Combine climatology, altimetry, MCSST, and on-scene data to produce 3D ocean thermal structure nowcasts*
- *Operational global & relocateable, regional implementations*
- *Optimum Interpolation based*

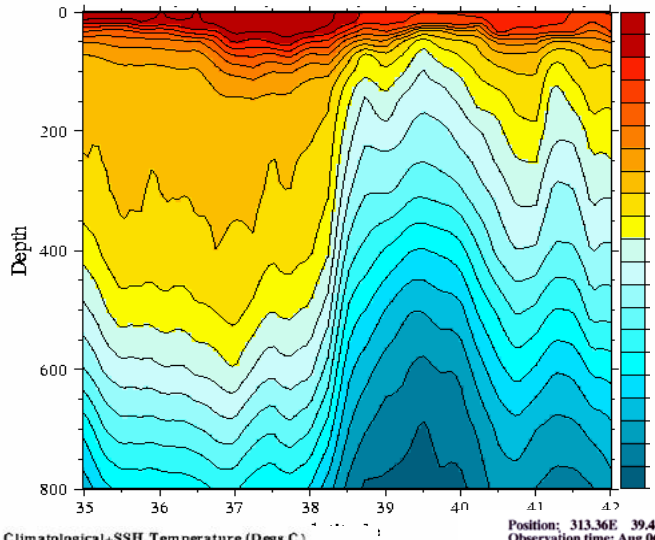
Naval Operational Oceanography

MODAS synthetic profiles

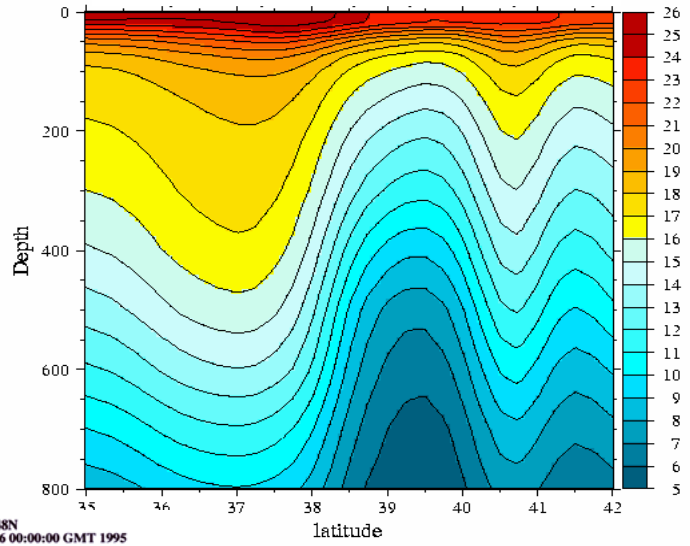
Climatological Temp

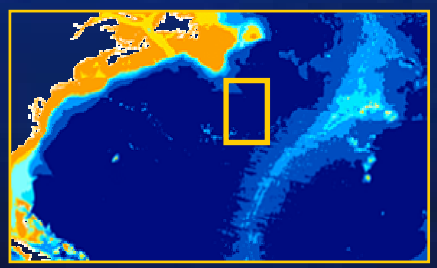


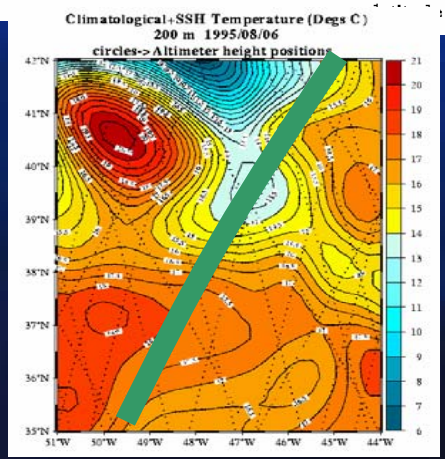
Actual AXBT Temp



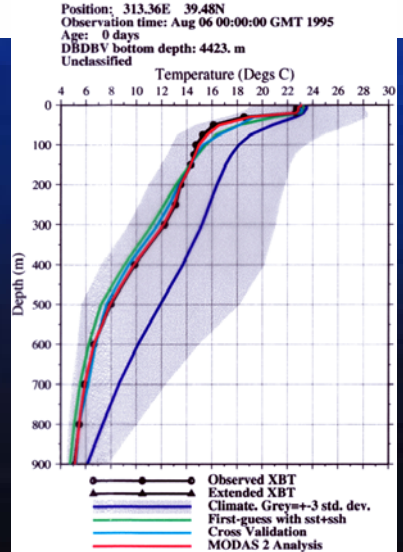
SSH + SST + Clim







MODAS Temperature at 200m



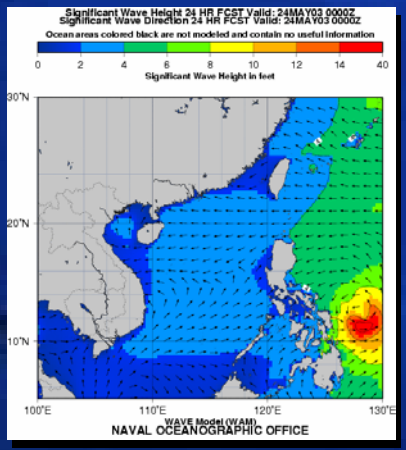
This used as first guess field to blend in any local data.

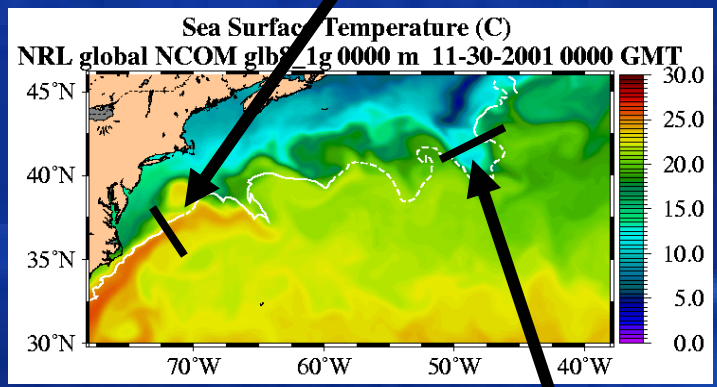
Naval Operational Oceanography

Environmental Effects on Operations

Wave and Current affect:

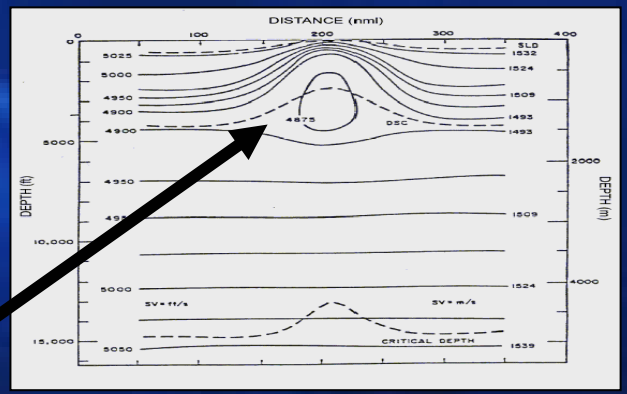
1. Layer depth
2. Ambient Noise
3. Sonabouy dispersion

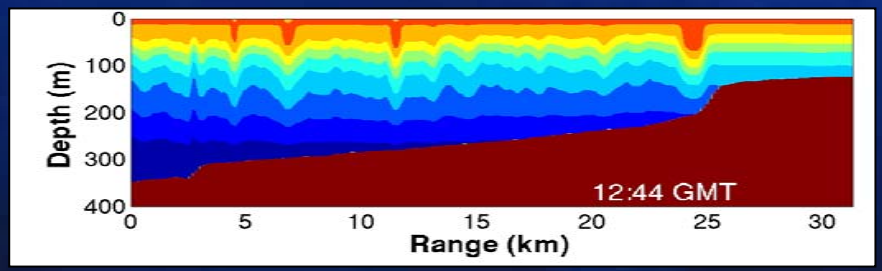




Frontal boundaries affect:

1. Shadow zones
2. Bottom grazing
3. Bottom loss





Internal waves:

1. Vary layer depth
2. Affects transmission loss

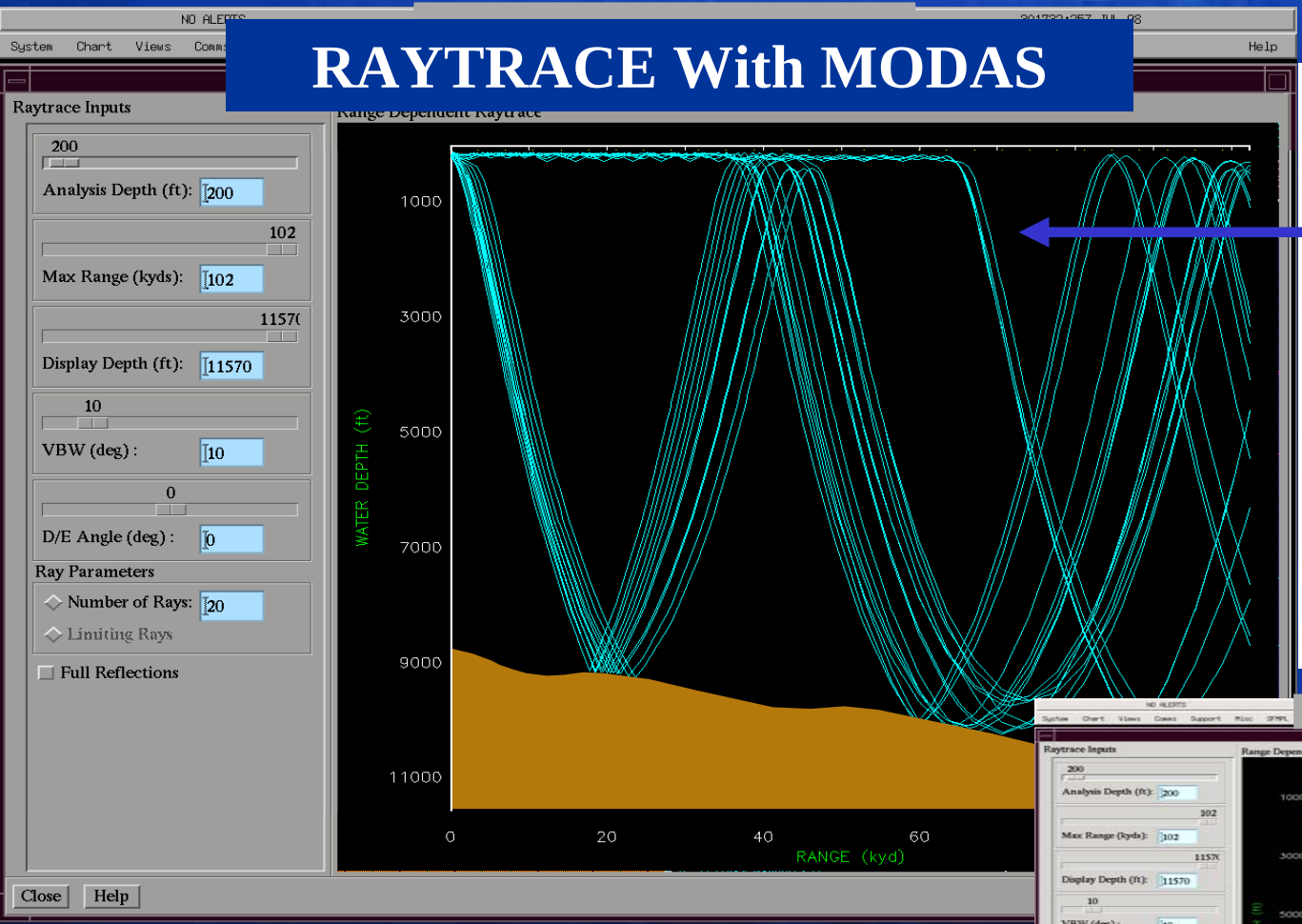
Eddies:

1. Change SSP quickly
2. Influence surface and subsurface drift

Naval Operational Oceanography

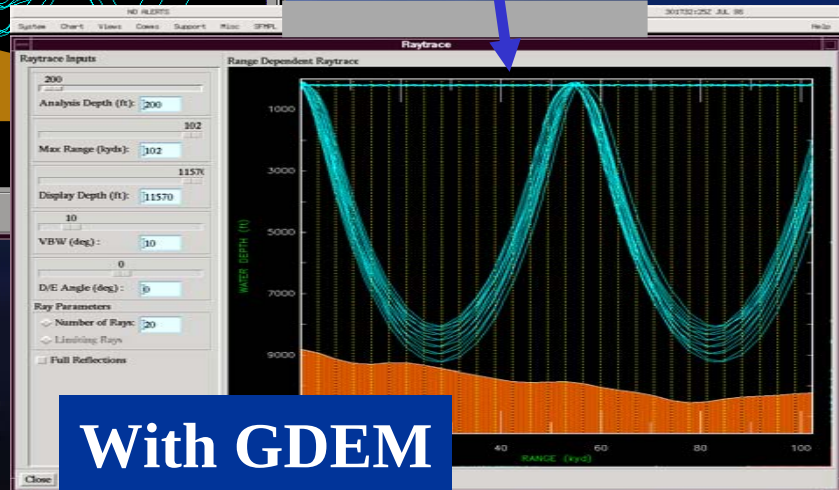
Environmental Effects on Operations

RAYTRACE With MODAS



MODAS correctly shows complex bottom bounce paths with a shallow sound channel that converts to a bottom bounce path as it crosses the Gulf Stream

Historical (GDEM) indicated CZ with a constant shallow sound channel



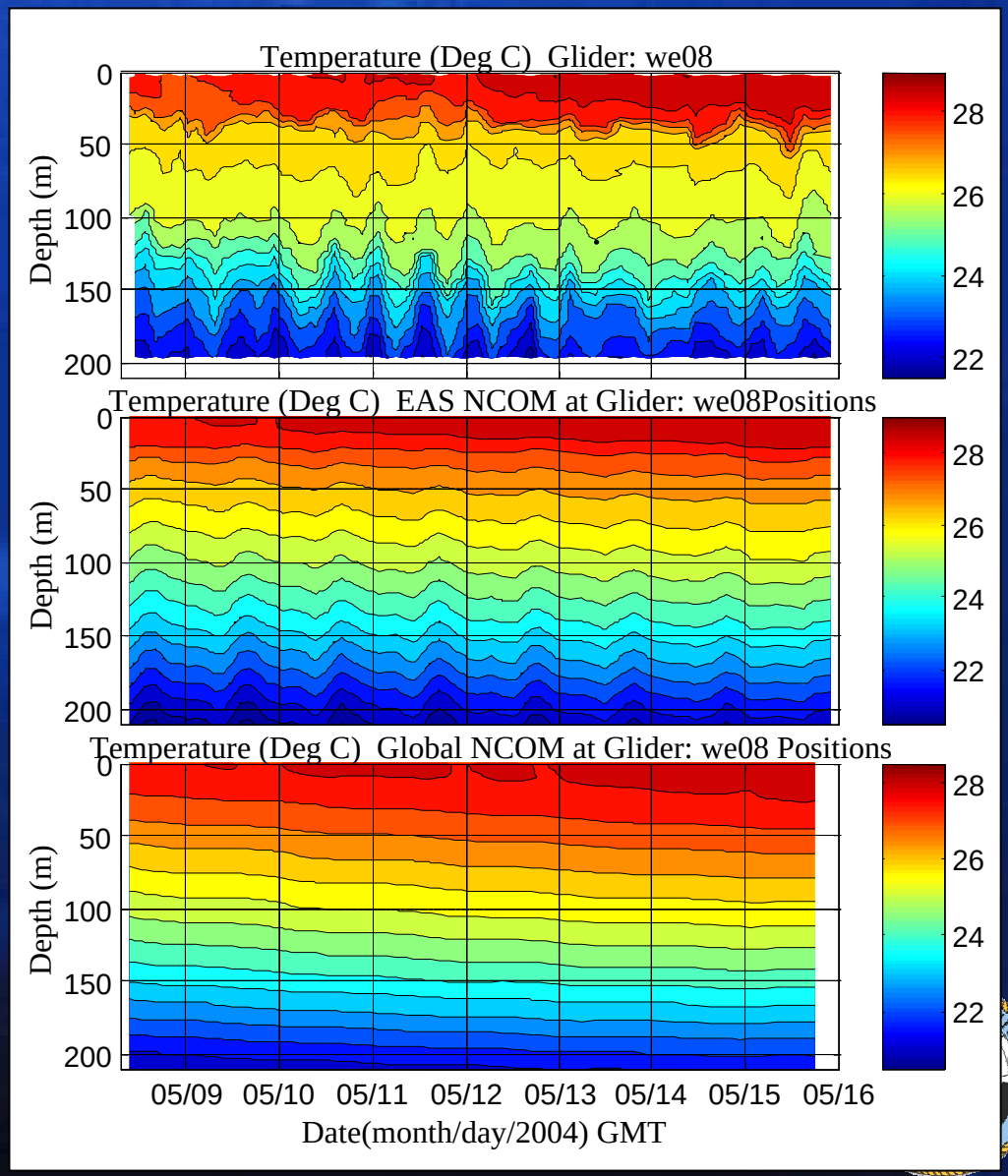
With GDEM

Courtesy: CDR Van Gurley,
SUBLANT Oceanographer (1999)

Naval Operational Oceanography

Environmental Effects on Operations – Science Windfalls

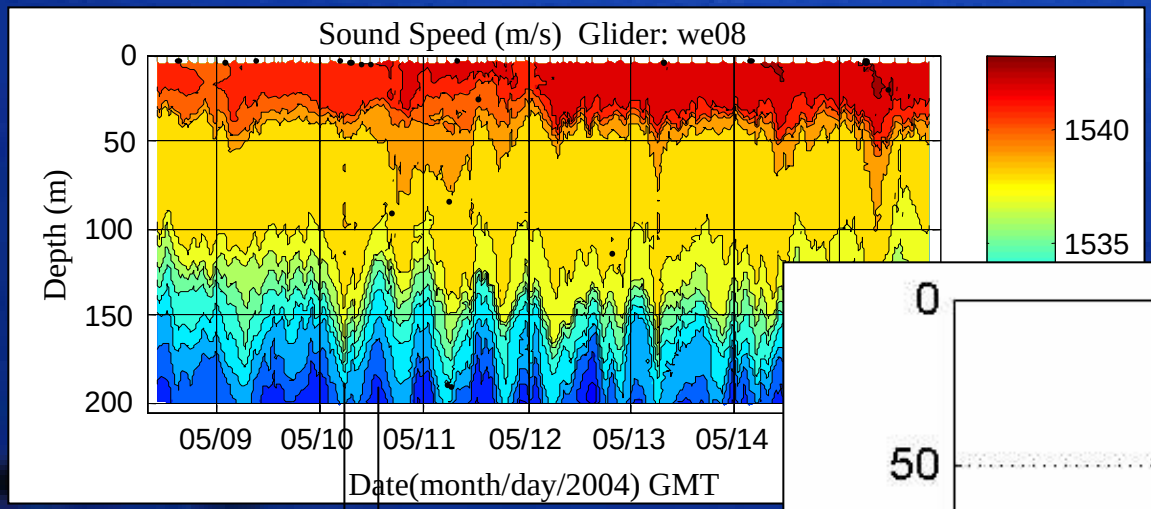
- Glider data shows variability in temperature and salinity isopleths that appear, in part, due to internal tides.
- East Asian Seas NCOM resolves tide signal, but amplitude of signal is suppressed. Gliders provide data that will enable adjustment and tuning of 3D forecast models.
- Global NCOM does not include tides, hence no internal tide signal, but shows some skill in resolving the vertical temperature structure.
- This level of skill is available now without profile data assimilation.



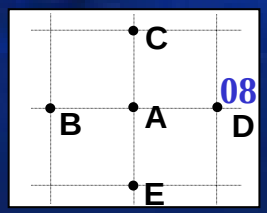
Naval Operational Oceanography

Environmental Effects on Operations – Science Windfalls

X

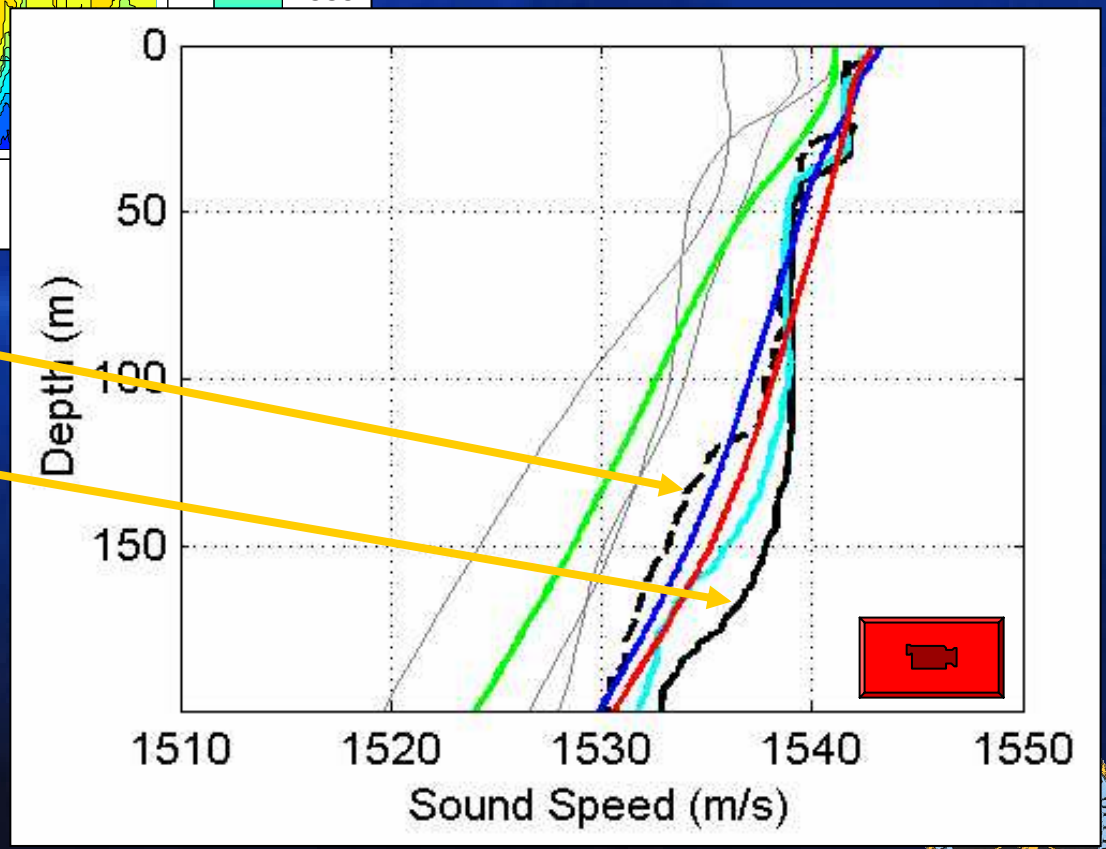


Range independent runs, assume internal tide is isotropic for at least 20 km from observation.



Top of cycle

Bottom of cycle



- **MOODS**
- **GDEM**
- **GLIDER-08** 10 May @ 0539
- **GLIDER-08** 10 May @ 1337
- **CTD**
- **EAS NCOM**
- **GL NCOM**

Internal wave animation courtesy of Preller & Martin, NRL

Naval Operational Oceanography

R&D NEEDS

1. **Coastal Data Collection, Fusion & Exploitation**
   - e.g. adaptive sampling, use of AUVs & other technologies
2. **Coastal Analysis & Prediction**
   - e.g., improved coastal/nearshore models/assimilation
3. **Global Analysis & Prediction**
   - e.g., improved global/regional models/assimilation
4. **Real-time Evaluation, Visualization & Applications**
   - e.g., rapid, automated data analysis

Naval Operational Oceanography

Major Points

- TRANSFORMATION
  - Net-Centric Littoral Warfare Teams
  - Inside the Warfighter's Decision Loop
  - Emphasize Ocean-Related Warfare Disciplines
- TRANSLATION
  - Applying Oceanographic Knowledge to Warfighter Questions
- GODAE Role
  - Important, Though Not Primary,
    Given Littoral Focus of the U.S. Navy

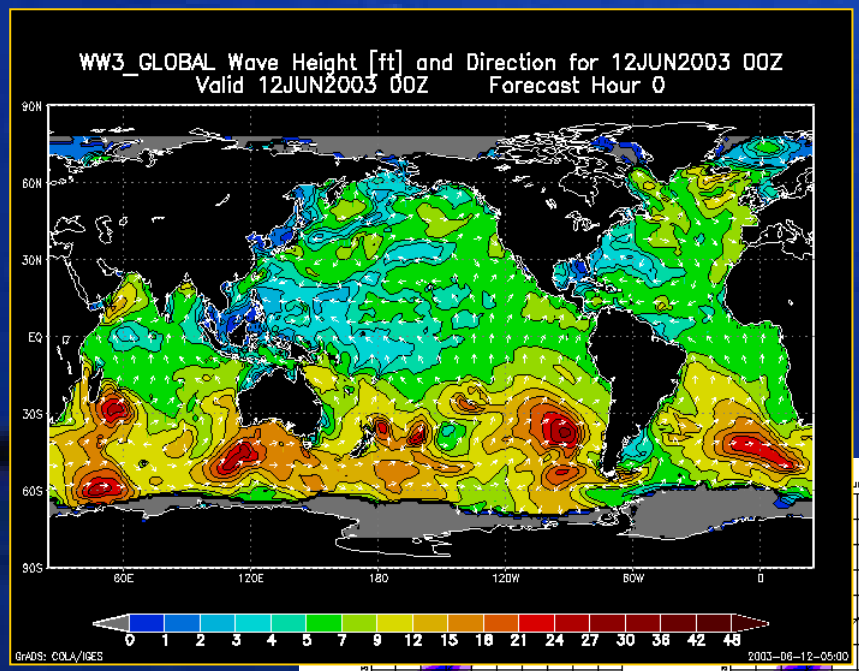
Naval Operational Oceanography

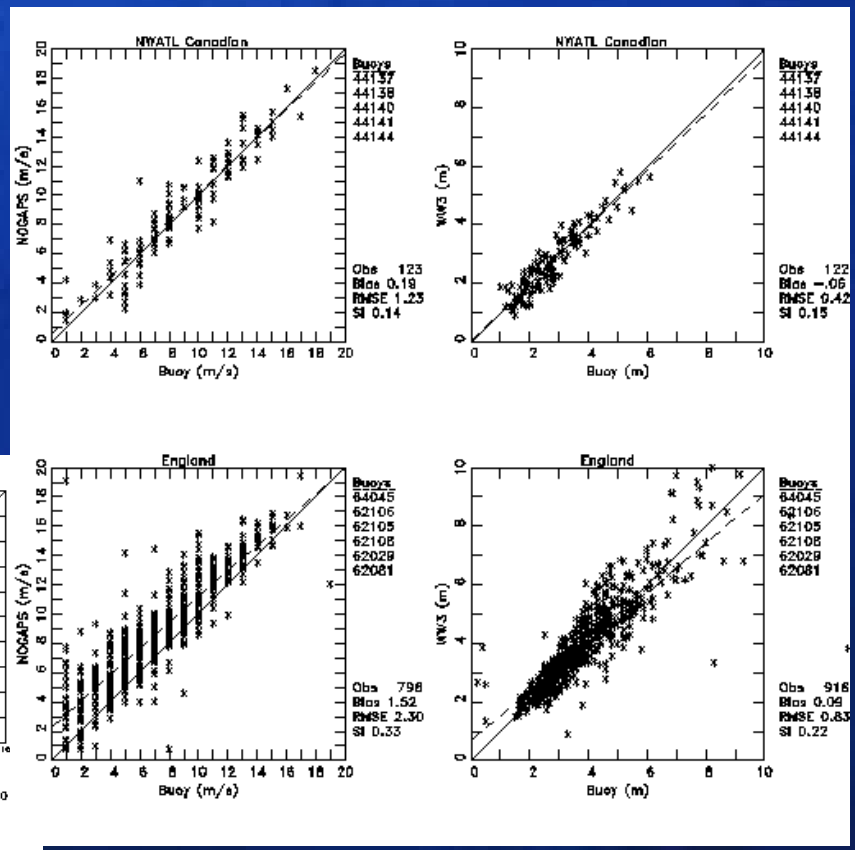
QUESTIONS?

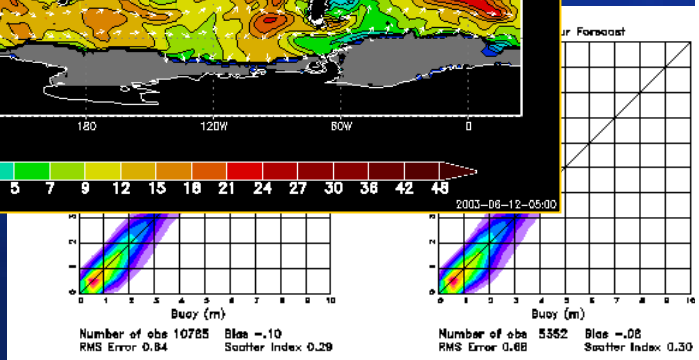

NAVAL OCEANOGRAPHIC OFFICE

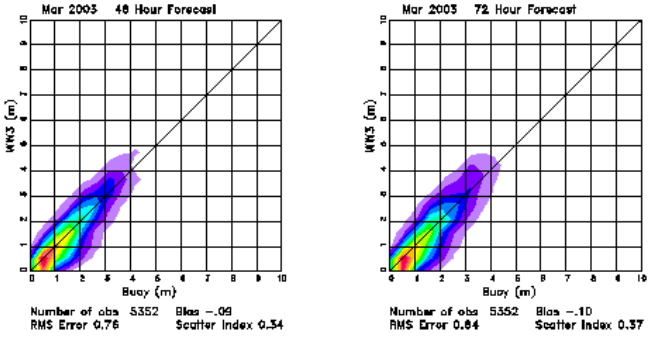
Naval Operational Oceanography

WaveWatch 3 (Global & Mediterranean)







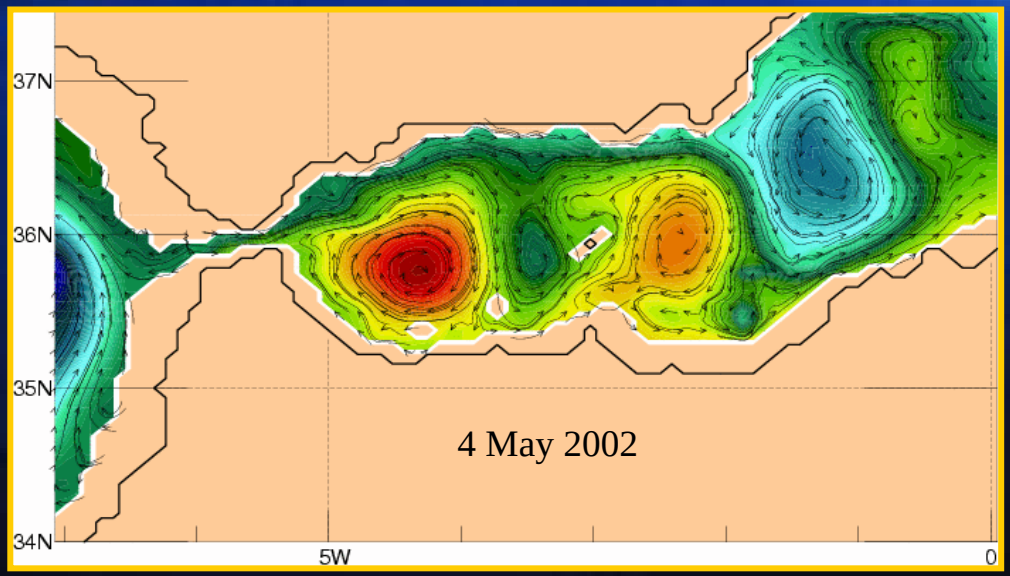


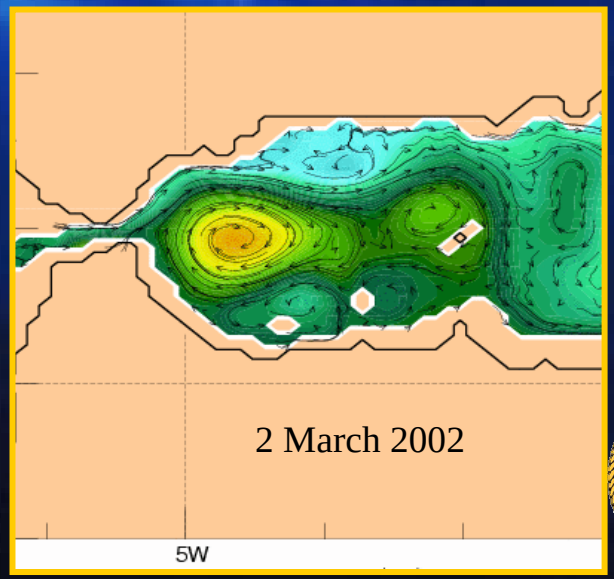
Global Forecast Statistics

NOGAPS & WW3 Atlantic Regional Nowcast Statistics

Naval Operational Oceanography

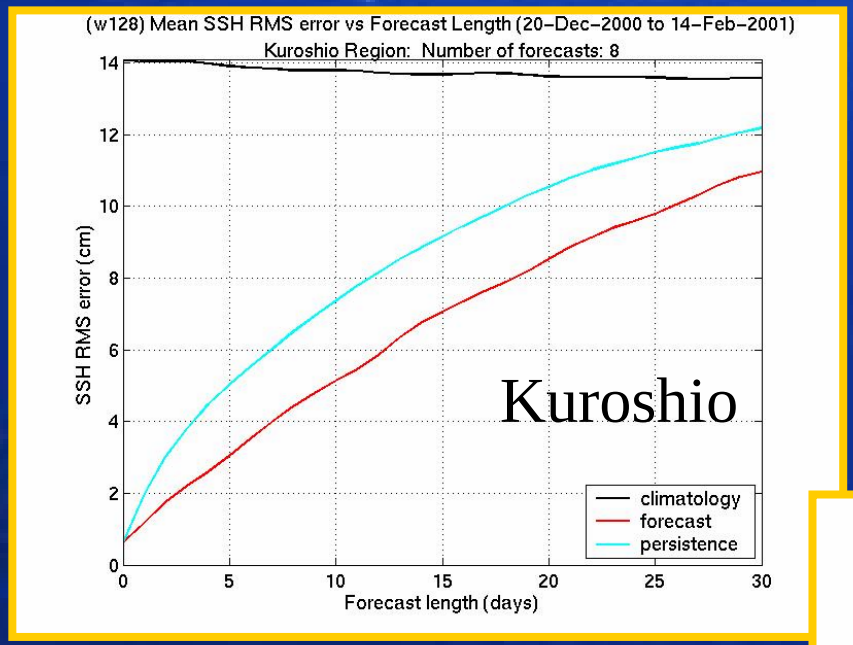
Qualitative Comparison of Ocean Color & NLOM





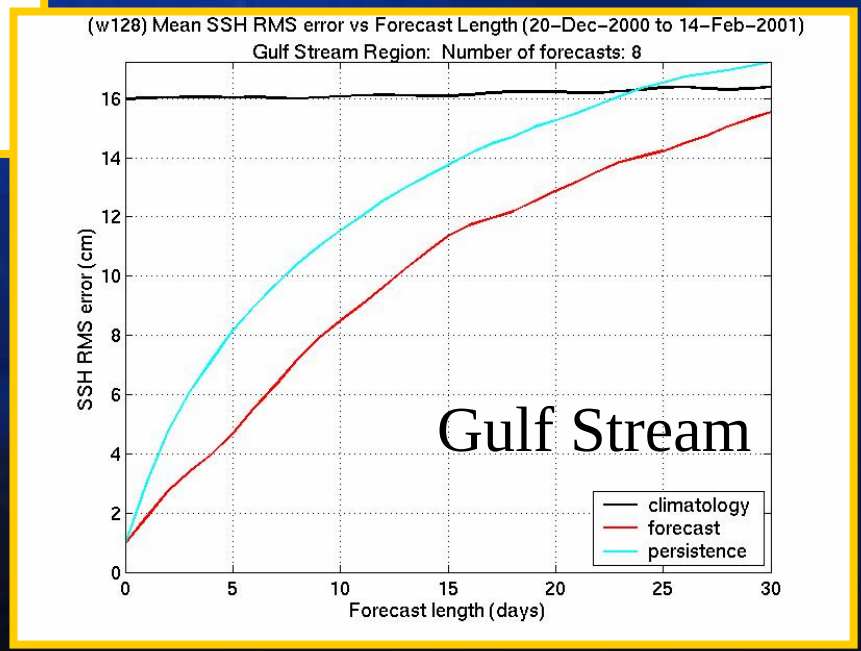
Naval Operational Oceanography

NLOM Quantitative Forecast Performance



Global NLOM RMS SSH Forecast Error:

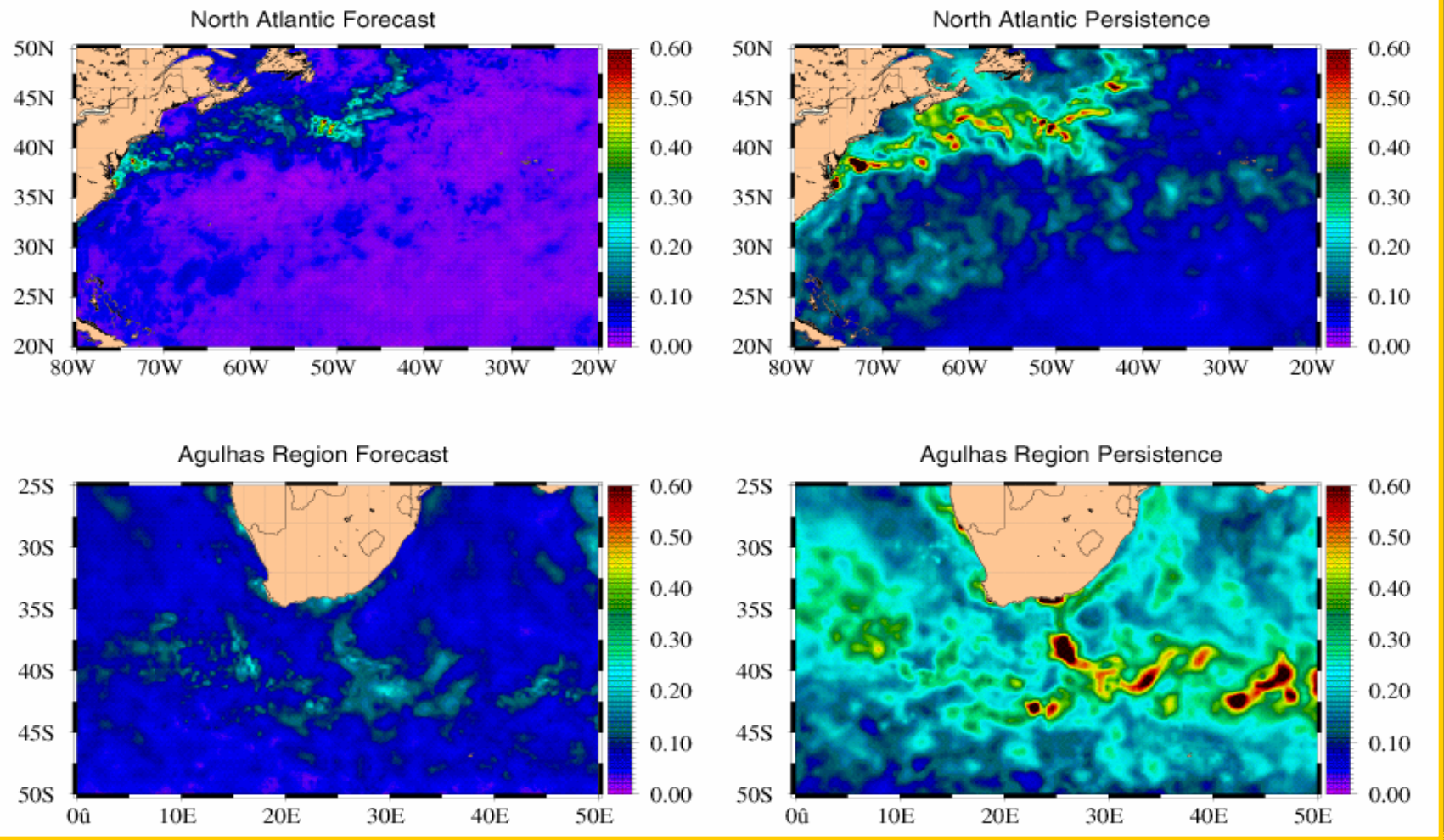
Black - Climatology
Blue - Persistence
Red - Forecast



~30-Day Skill from 12/2000 –2/2001

Naval Operational Oceanography

SST – NCOM 48 hr. Forecast Verification



2 Day SST Forecast Verification Statistics

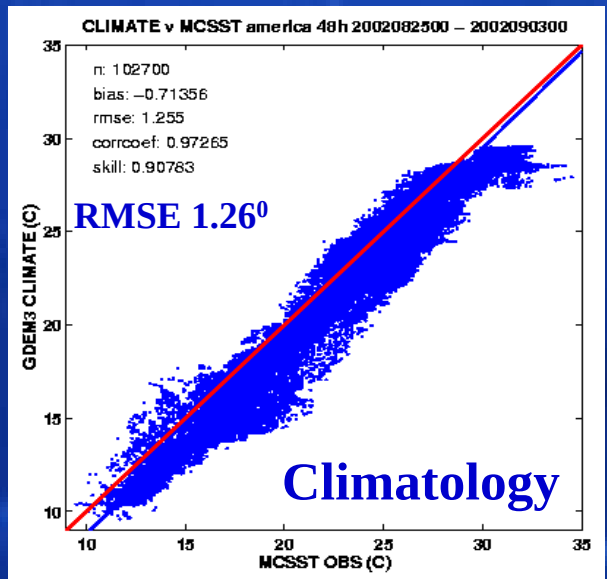
Mean RMS (^{0}C) over 40 forecasts made 4 Jan 2001 – 12 Feb 2001

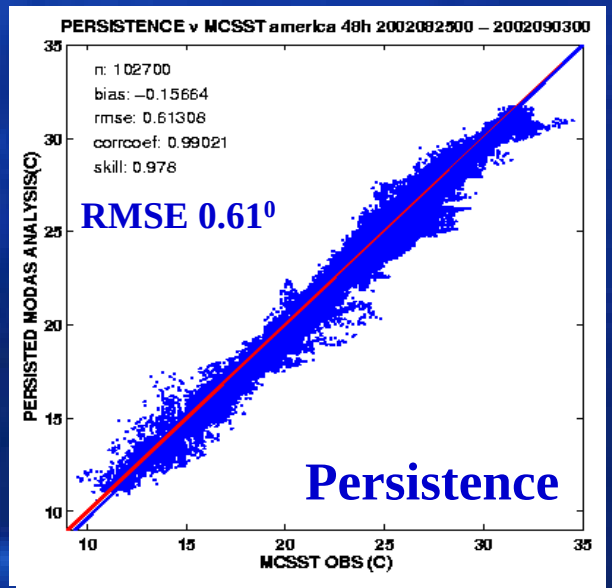
Naval Operational Oceanography

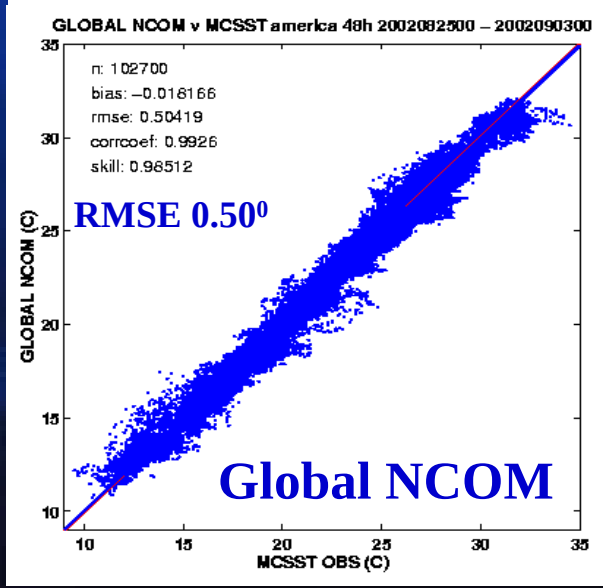
SST – 48 hr. Forecast Verification – 8/25 to 9/03/2002

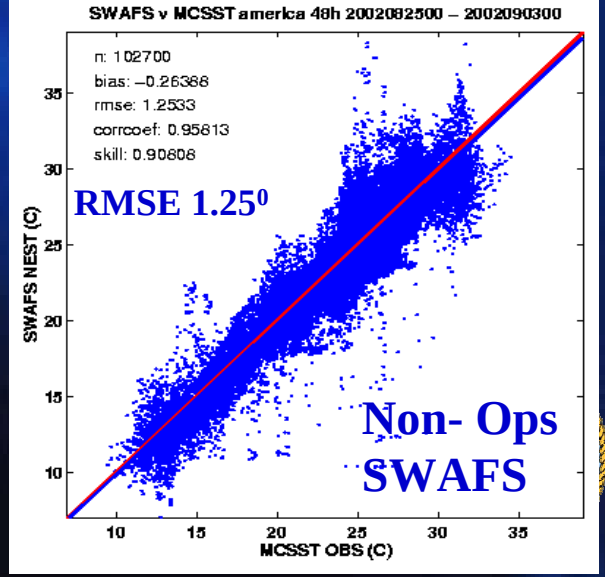
Scatter plot comparisons of MCSST obs. vs. Analysis or Model SST products for Tau 48 (non-operational "SWAFS Americas" domain.)

Example of metric software put together by Clark Rowley to monitor daily performance of various real-time products.



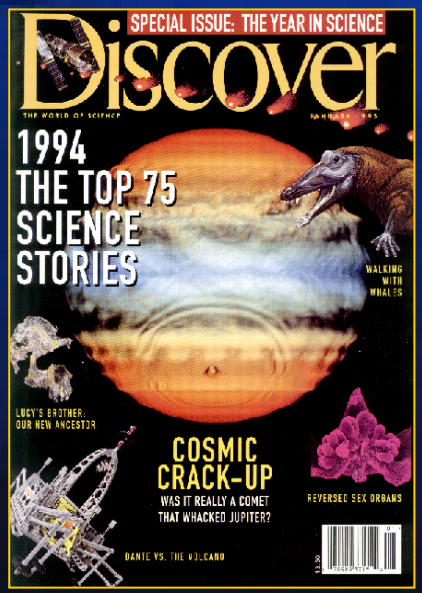






Naval Operational Oceanography

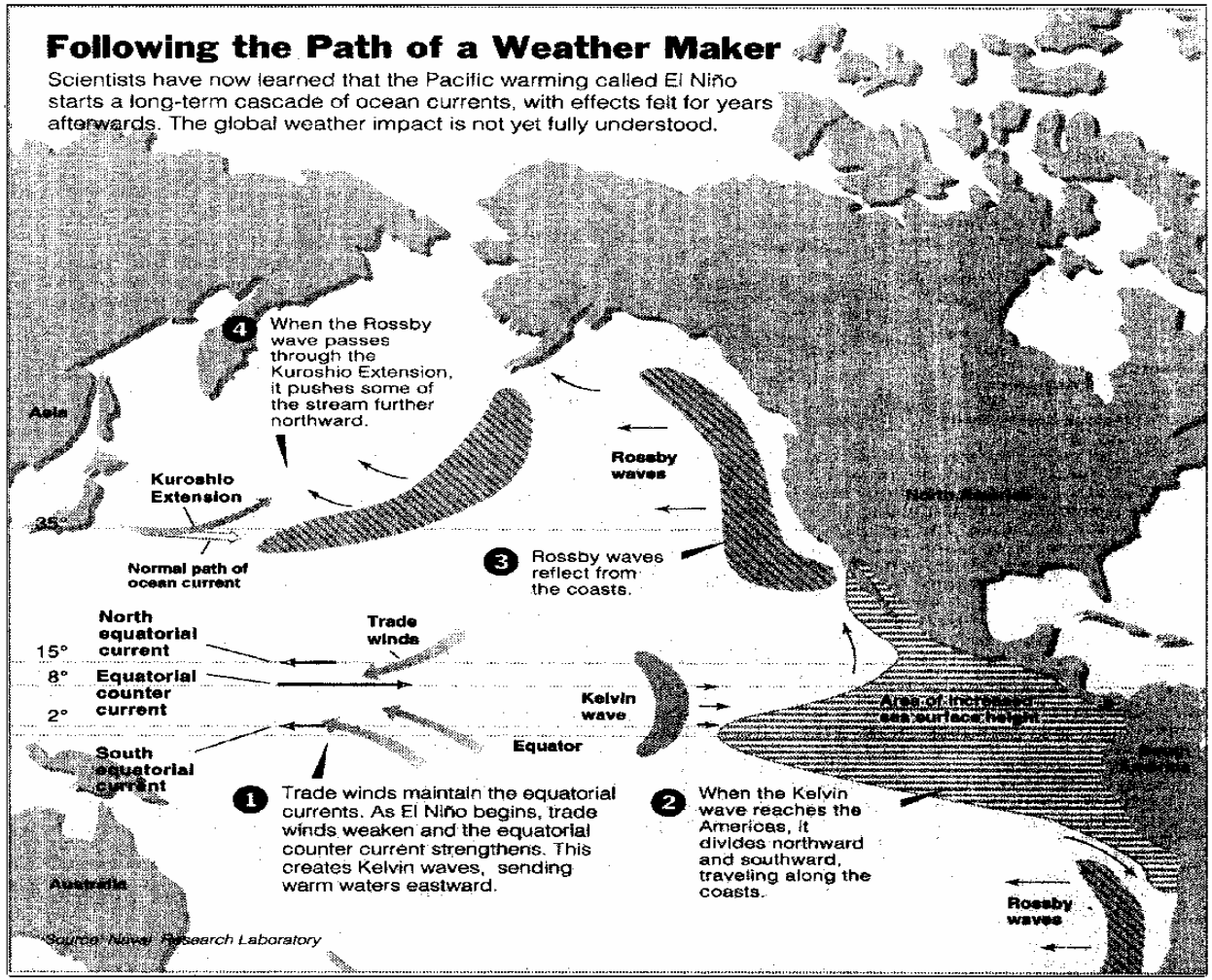
Decadal Impact of El Nino



NEW YORK TIMES **THE ENVIRONMENT** TUESDAY, AUGUST 9, 1994

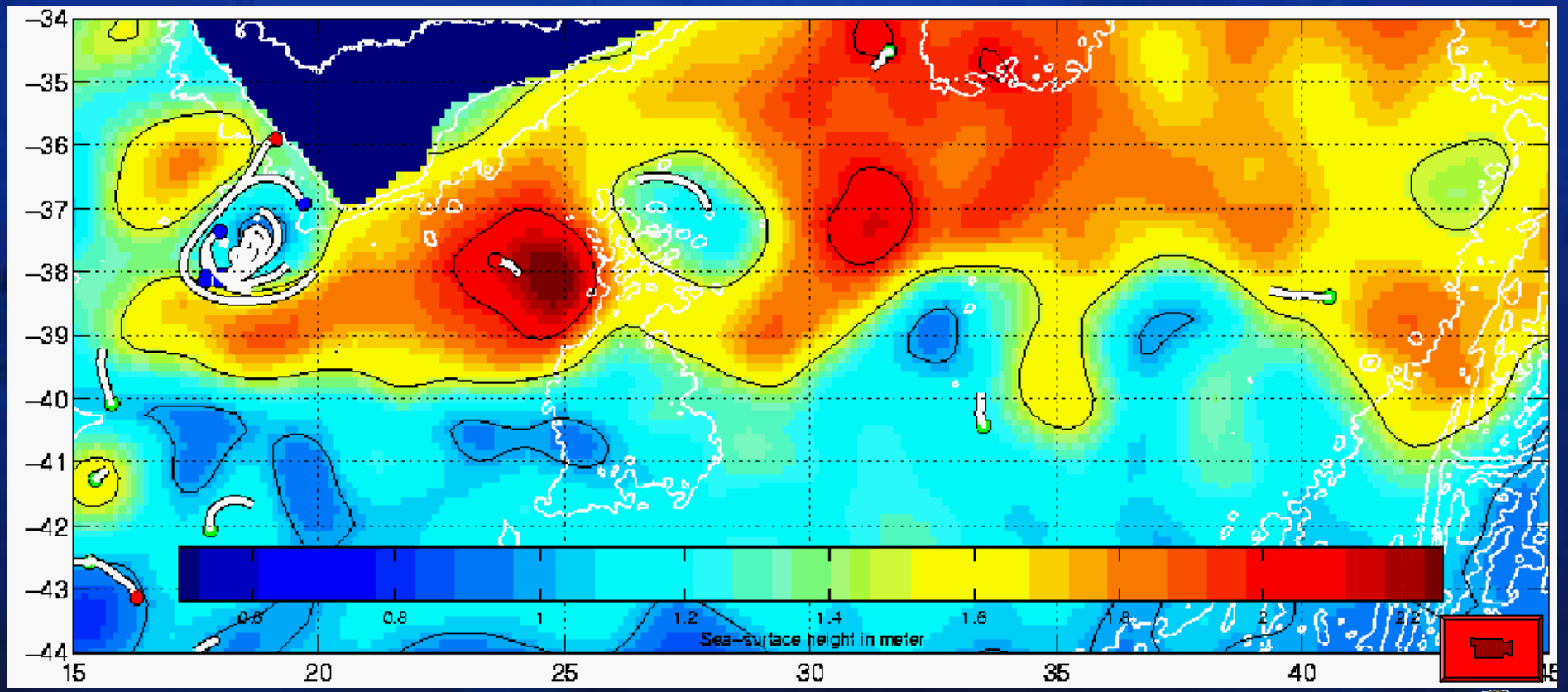
Following the Path of a Weather Maker

Scientists have now learned that the Pacific warming called El Niño starts a long-term cascade of ocean currents, with effects felt for years afterwards. The global weather impact is not yet fully understood.



Naval Operational Oceanography

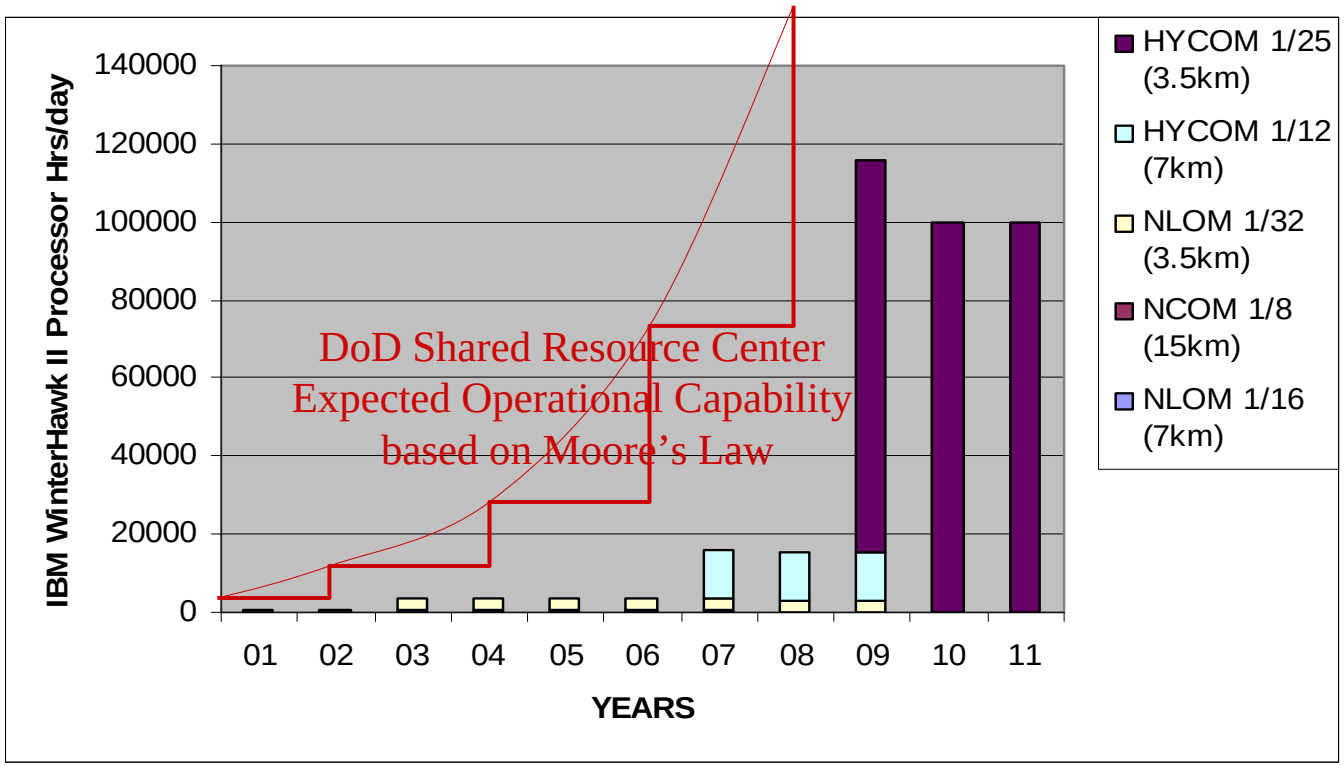
MODAS Height Field Compared to Deep Drifters (1997-99)
(KAPEX Drifter Data & Animation Courtesy of Olaf Boebel at URI)



Note: RAFOS drifters at 800 and 1200 m., drifter tail lengths represent 7 days

NAVO/NRL Interaction

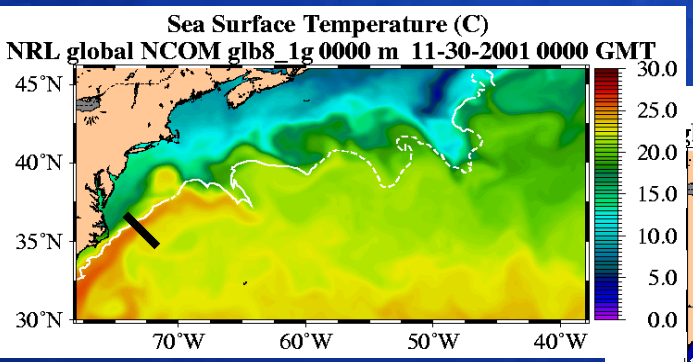
Technical Example – Critical Role of the NAVO MSRC

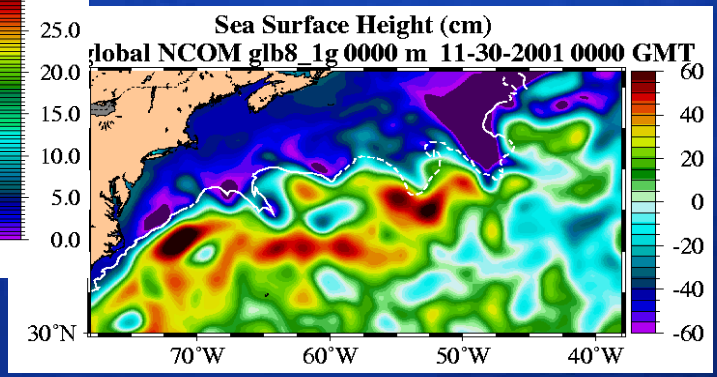


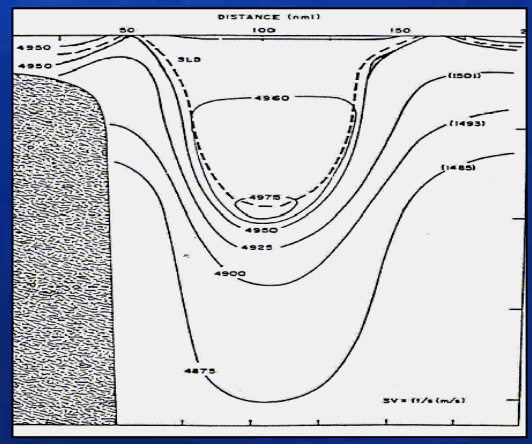
While much of the ocean's mesoscale variability can be forecast, routine global forecasts (at 1/32 degree resolution) remain a Grand Challenge computational goal potentially achievable in 2009 with current level of expenditure.

Naval Operational Oceanography

Environmental Effects on Operations







1. Near-surface sound speed can change by as much as 100 feet/second. This is due to the combined effect of changing temperature and salinity, with temperature usually being the dominant factor. Shallow-water seasonal salinity changes can sometimes dominate.

2. Sonic-Layer Depth (SLD) can change by as much as 1,000 feet from one side of a front to the other during certain seasons.

3. A change of the in-layer and below-layer gradient usually accompanies a change in surface sound speed and SLD.

4. Depth of the Deep Sound Channel Axis (DSCA) can change by as much as 2,500 feet when crossing from one water mass to another.

5. Increased biological activity generally found along a front will increase reverberation and ambient noise.

6. Sea-air interaction along a frontal zone can cause a dramatic change in sea state and thus increase ambient noise levels.

7. Changes in the vertical arrival angle of sound rays as they pass through a front can cause towed-array bearing errors.