The Joint Center for Satellite Data Assimilation

Coastal Ocean Data Assimilation Workshop
3 – 5 April 2007
Joint Center for Satellite Data Assimilation

PARTNERS

NASA/Goddard
Global Modeling & Assimilation Office

US Navy
Oceanographer of the Navy, Office of Naval Research (NRL)

NOAA/NESDIS
Center for Satellite Applications and Research

NOAA/NCEP
Environmental Modeling Center

NOAA/OAR
Office of Weather and Air Quality

US Air Force
AF Director of Weather AF Weather Agency
JCSDA Mission

• Mission: Accelerate and improve the quantitative use of research and operational satellite data in weather, climate and environmental analysis and prediction models
The Challenge: Satellite Systems/Global Measurements

- Aqua
- Terra
- TRMM
- SORCE
- SeaWiFS
- Aura
- Meteor/SAGE
- GRACE
- CALIPSO
- GIFTS
- Cloudsat
- Landsat
- Jason
- CALIPSO
- Cloudsat
- Jason
- GRACE
- SSMIS
- TOPEX
- NOAA/POES
- SSMIS
- NOAA/POES
- GOES-R
- SeaWiFS
- GOES-R
- ICESat
- WindSAT
- WindSAT
- GOES-R
- NPP
- Aura
- NOSS
- NPOESS
- METOP
- Windsat
- GOESDMSP

5-Order Magnitude Increase in Satellite Data Over 10 Years
JCSDA Data Assimilation Opportunities

**ATMOSPHERE**
- Global NWP
- Regional NWP

**OCEAN**
- Global near-real time
- Coastal near-real time

**SPACE**
- Ionospheric DA

**COUPLED**
- Near-real time
- Climate

**ATmospheric Chemistry**
- Air Quality

**ECOSYSTEMS**
Priorities and Goals

RESEARCH AND DEVELOPMENT PRIORITIES
• Improve radiative transfer models
• Prepare for use of advanced instruments with enhanced capabilities
• Advance techniques for assimilating cloud and precipitation observations
• Advance techniques for assimilating land surface observations
• Advance techniques for assimilating ocean observations
• Advance techniques for assimilating atmospheric chemistry observations

GOALS
• Increase uses of current and future satellite data in Numerical Weather and Climate Analysis and Prediction models
• Develop the hardware/software systems needed to assimilate data from the advanced satellite sensors
• Advance common numerical models and data assimilation infrastructure
• Develop a common fast radiative transfer system (CRTM)
• Assess impacts of data from advanced satellite sensors on weather, climate, and environmental analysis and forecasts (OSEs, OSSEs)
• Reduce the average time for operational implementations of new satellite technology from two years to one
JCSDA Ocean Data Assimilation Challenges

• **Satellites**
  – *Exploit satellite investment and ensure continuity*
  – Prepare data streams, evaluate quality/impact
  – Current
    • GOES, POES, METOP, DMSP, Jason
  – Future
    • NPOESS, GOES-R, Aquarius, METOP, DMSP, Jason-2

• **Infrastructure**
  – *Optimize assimilation for efficiency, accuracy, and uncertainty*
  – Expand ocean computational capacity
  – Develop ocean OSE capability
  – Develop ocean OSSE capability
  – Support IOOS national backbone for modeling and data assimilation

• **Applications**
  – *Maximize use of satellite ocean data*
  – Atmospheric modeling
    • Global & regional
  – Coupled modeling
    • Climate & near-real time
  – Ocean modeling
    • Near-real time global & regional
  – Coastal modeling
  – Ecosystem modeling
Key contributions sought in JCSDA collaborations:

- **Estimation of observational error characteristics** for satellite data used in ocean state estimation (surface altimetry, microwave and IR SST retrievals), specifically, covariances, biases, correlated errors, and errors of representativeness; e.g.:
  - altimeter significant wave height corrections from buoy match-ups;
  - altimeter sea-surface height corrections for removal of inverse barometer and barotropic signals;
  - identification of diurnal warming and skin affects in the satellite SST data.

- **Assimilating satellite data products** to improve forecasts of the ocean mesoscale or seasonal climate anomalies; e.g.,
  - Improving the current methods for assimilating altimetry, possibly identifying a ‘community-based approach’;
  - Direct radiance assimilation

- **Expanding the current operational system capabilities** to include preparation for the assimilation of remotely-sensed **surface salinity**, assimilation of **sea-ice**, time-varying **ocean color**, GRACE, GPS data, or other satellite observations.

- **Observing system experiments** to help define the requirements for remotely sensed **surface salinity** and accuracy requirements for **improved sea surface temperature**;

- **Validation** of ocean assimilation products and ocean forecasts with satellite products.
**JCSDA 2006 Ocean Projects**

- **WindSat Assimilation**
  - Evaluate WindSat wind vectors/improve algorithms relative to other marine winds, and their impact on global forecasts
  - Develop forward models of ocean surface emission and radiative transfer; develop physically-based retrieval algorithms for wind vector, SST, integrated water vapor and cloud liquid water

- **SST Assimilation**
  - Continue to improve physical SST retrievals based on Variational Technique; improve Real-Time Global SST analysis; use additional instruments in physical retrieval algorithms as appropriate
  - Perform validation studies to test and improve the assimilation of satellite derived SST into real-time Navy ocean prediction systems. Specifically, the systems includes MODAS, NCODA, NLOM, NCOM and HYCOM. The research supports the assimilation algorithms
  - Incorporate the NPOESS observations that affect the upper ocean layer into operational systems. These observations include heat fluxes and surface temperature from infrared (IR) and passive microwave.

- **Altimetry**
  - Transition assimilation of altimeter SWH observations for the Navy’s global WW3 forecast model.
  - Perform validation studies to test and improve the assimilation of Altimetric SSH into real-time Navy ocean prediction systems. Specifically, the systems includes ALPS, MODAS, NCODA, NLOM, NCOM and HYCOM.
  - Integrate the NPOESS altimeter (ALT) sensor observations into the automated processing system at NAVOCEANO, perform quality control on the data, ensure that corrections for atmosphere and electron content are accurate, and provide appropriate spatial and temporal covariance functions for numerical model assimilation systems. Use of the NPOESS ALT will allow nowcast and prediction of the ocean mesoscale currents and impact on temperature and salinity through assimilation into numerical ocean models both globally and regionally nested.

- **Sea Ice**
  - Perform validation tests of assimilation of SSMI ice concentration data into the new PIPS 3.0 system based on the Los Alamos CICE model.

- **Assimilation Methodology**
  - Develop and test algorithms for a 3-D MVOI methodology for ocean data assimilation. This research is based on the NCODA system and is coordinated with atmospheric data assimilation algorithm development for a planned upgrade to a 3D-VAR (NAVDAS).
  - Develop and test algorithms for 4DVAR assimilation of ocean data (SSH, SST, in-situ T, S, U, and V) into ocean models using model adjoints.
JCSDA Grants Program

• **Special attention paid to clearly identified paths from research to operations and coordination with PIs working in similar research areas**
  – Particularly useful to have an identified JCSDA partner / collaborator / mentor / contact to integrate the research output into the operational program

• Supports projects with longer-term goals, i.e. potential evaluation for operations within 3 – 5 years

• Annual Announcements of Opportunity ~ July/August
  – Average grant: $100K/Yr for 1 to 3 years
  – 21 grants in place
Education and Outreach

- JCSDA recognizes the scarcity of trained and qualified data assimilation scientists
- Newsletter
- Web Page
- Seminar Series
- Workshops
Recent JCSDA Research

- **Improved Physical Retrieval Technique for SST** (Xu Li and John Derber, NCEP/EMC)
  - Analyze SST by assimilating satellite radiances directly with GSI
    - 6-hourly skin temperature analysis
  - Aerosol Effect
    - Radiance increment dependency on Navy aerosol optical depth
  - Incorporation of oceanic components in GSI
    - Diurnal warming and sub-layer cooling model (in development)
    - Oceanic model in GFS and coupling?

- **AVHRR Radiance Bias Correction** (Andrew Harris, Jonathan Mittaz, CICS/UMD)
  - Pursue physically-based methodologies to provide:
    - Techniques to identify instrument calibration and characterization post-launch
    - Improved AVHRR SST retrieval capability (inc. diurnal)
    - Feed back results to improve forward modeling
  - **Bayesian cloud detection** a promising method for assigning quantitative errors to individual pixels

- **Improving analysis of tropical upper ocean conditions for forecasting** (Jim Carton, UMD)
  - Forecast bias correction implemented in NCEP’s GODAS

- **Use of Wavenumber Spectrum of Sea Surface Height for constructing error models in ocean data assimilation** (Alexey Kaplan, LDEO)
Recent JCSDA Research

• **Collaborations on SST:**
  - Use of aerosol data - collaboration with Clark Weaver (and A. da Silva) on aerosol products
  - Detection and correction of aerosol contamination in infrared SST retrievals (Jim Cummings, NRL/Monterey; Andrew Harris, NESDIS)
  - Inclusion of emissivity/reflectance model in forward model in NCEP radiance assimilation (Nalli)
  - Inclusion of ocean mixed-layer model (Li, Harris, Rienecker)

• **Collaborations on Assimilation Methodology:**
  - Bias estimation (Carton, Keppenne)
  - Methods to assimilate altimetry - noise models (Kaplan, GMAO)
  - Ensemble generation (Kaplan, GMAO)
Priorities

• **Assimilating Data Streams**
  – Exploiting existing ocean data streams
    • SST:  
      – Infrared: GOES, MODIS
      – Microwave: TMI, WindSat, AMSR-E
    • SSH: GFO, Jason-1
    • Ocean Vector Winds: QuikScat, WindSat
    • Sea ice: AMSR-E, WindSat, QuikScat, SAR
    • In-situ: Argo floats, oceanographic monitoring stations (e.g., ADCP)
    • Ships of opportunity
  – Preparing for continuity operational data streams
    • SST: MetOp, NPP, GOES-R, NPOESS
    • SSH: Jason-2
    • Ocean Vector Winds: ASCAT
    • Sea ice: ASCAT
    • In-situ:
  – Preparing for new operational data streams
    • HF radar
    • SSS: SMOS, Aquarius
    • Ocean color: NPP, GOES-R, NPOESS
    • Ocean vector winds: Synthetic Aperture Radar (SAR); ASAR, ALOS, Radarsat
    • Sea ice: Synthetic Aperture Radar (SAR); ASAR, ALOS, Radarsat
    • IOOS data
Priorities

• Modeling Assimilation
  – Techniques / methodologies
    • Community-based approaches
  – Application
    • Coupled/active ocean modeling for atmospheric modeling
      – Hurricane WRF, GFS
    • Ocean modeling
      – RTOFS, GODAS, Wavewatch-3
    • Estuary, Great Lakes, and Coastal modeling
      – Regional
      – High-resolution
    • Climate modeling
      – Seasonal-interannual predictions
      – Decadal projections
    • Ecosystem Modeling
      – Data assimilation via coupling with physical/hydrodynamic models
      – Direct assimilation
Satellite Data used in NOAA NWP

- HIRS sounder radiances
- AMSU-A sounder radiances
- AMSU-B sounder radiances
- GOES sounder radiances
- GOES, Meteosat, GMS winds
- GOES precipitation rate
- SSM/I precipitation rates
- TRMM precipitation rates
- SSM/I ocean surface wind speeds
- ERS-2 ocean surface wind vectors
- Quikscat ocean surface wind vectors
- AVHRR SST
- AVHRR vegetation fraction
- AVHRR surface type
- Multi-satellite snow cover
- Multi-satellite sea ice (DMSP, AMSR-E)
- SBUV/2 ozone profile and total ozone
- Altimeter sea level observations (ocean data assimilation)
- AIRS
- Current Upgrade adds; MODIS Winds...
ATMOSPHERE

COUPLED

- Near-real time (global, regional, hurricane)
  - Expand data streams & parameters
  - SST, altimetry, ocean vector winds, sea ice
  - Active ocean
  - 2-way coupling
- Climate
  - Ocean color
  - Salinity
  - Sea ice

OCEAN

- Global near-real time
  - Expand operationally assimilated data streams & parameters
  - SST, altimetry, ocean vector winds, sea ice
  - Spectral assimilation for waves (Wavewatch-3)
  - Enhance assimilation into sea-ice models
  - Salinity

- Coastal near-real time
  - Implement research & operational assimilation
  - Expand data streams & parameters
    - SST, altimetry, ocean vector winds, sea ice
  - Explore synthetic aperture radar data assimilation

ECOSYSTEMS

- Implement research & operational assimilation
  - Harmful Algal Blooms (HABs)
  - Ocean color / primary productivity
  - Storm surge
  - Particle trajectories
NASA-NOAA-DOD
JCSDA
AMSR, GOES, AIRS, JASON, WindSat, MODIS
Advanced ODA Techniques

Observations

Satellite
(AVHRR, JASON, QuikSCAT)

In situ
(ARGO, Buoys, Ships)

Data Cutoff

CFS: 2 week data cutoff
RTOFS: 24 hour data cutoff

OCEAN DATA ASSIMILATION
CLIMATE FORECAST

CFS-GODAS
NCO/ODA
EMC
NOPP-JPL (ECCO)

RT-OFS-GODAE
NOPP
EMC

Shared history, coding, and data processing

MOM-3 → MOM-4 → HOME

OPNL OCEAN FORECASTS

Climate Forecast System

Real-Time Ocean Forecast System

http://cfs.ncep.noaa.gov/
http://polar.ncep.noaa.gov/ofsf/
Seasonal to Interannual Prediction at NCEP

- **MOMv3**
- **Climate Forecast System (CFS)**
- **GFS**

**GODAS**
- 3DVAR
- XBT
- TAO etc
- Argo
- Salinity (syn.)
- (TOPEX/Jason-1)

**Reanalysis-2**
- 3DVAR
- T62L28
- update of the NCEP-NCAR R1
Seasonal to Interannual Forecasting at NCEP

Global Ocean Data Assimilation System (GODAS)

- Altimeter
- Argo
- SST
- XBT
- TAO

Coupled Ocean Atmosphere Forecast System (CFS03)

- Ocean Initial Conditions
- SST Anomaly

SST Anomaly

- IRI
- CCA, CA Markov

Seasonal Forecasts

- IRI
- CCA, OCN MR, ENSO

Surface Temperature & Rainfall Anomalies

Official SST Forecast

Official Probabilistic Surface Temperature & Rainfall Forecasts

Forecasters

Stress

Heat Fluxes

Scatterometer

E-P
OBJECTIVE: Maximized satellite data assimilation into operational models, with minimized errors and uncertainty

GOAL
More accurate environmental forecasts through optimal use of Satellite Data

GODAS (seasonal-interannual ocean: MOM)
CFS (seasonal-interannual, coupled ocean-atm: MOM)

Ocean Color
NPP VIIRS Ocean color
NPOESS VIIRS Ocean color

SSH
ERS-2 SSH
GFO SSH
Jason-1 SSH
Jason-2 SSH

Sea Ice
Climatological sea ice (MOM4)
Interactive sea ice field
Assimilated sea ice data

SST
Non-NOAA SST (MODIS, AATS, MTSAT, MSG, InSat, FY2C, …)
Microwave SST (AMSR-E, WindSat, TMI)

AVHRR
GOES-12/13 Imager SST op preps/OSE
GOES-O Imager SST op preps/OSE
GOES-P Imager SST op preps/OSE
NPP VIIRS SST op preps/OSE
NPOESS VIIRS SST Op preps/OSE

MetOp-1 AVHRR SST OSE
MetOp-2 AVHRR SST prep/OSE
NOAA N’ AVHRR SST prep/OSE
NOAA-18 AVHRR SST OSE

Add bio-physical feedback mechanism
Add dynamic topography with heat content signal
Add sea ice; improve temporal & spatial resolution
Increased coverage
Increased coverage; confirmation
Increased spatial resolution; GOES continuity
Increased temporal resolution; GOES SST continuity
AVHRR replacement; VIIRS SST continuity
AVHRR SST continuity; Increased resolution

Planned
Potential

NOW
NCEP
Real-time Ocean Forecast System (RTOFS)

Data:
- SST
- SSH
- T & S
  (AVHRR, GOES, ARGO, JASON, Buoys, ships)

Data Assimilation:
Daily update of
T, S & SSH
(3DVAR)

Forcing:
- Air-sea fluxes
  (GDAS & GFS)
- River outflow
  (USGS, RIVDIS)
- Tide
  (TPX.03)

For open boundaries:
T, S & transport climatology
(historical data, MDT [Rio5])

Ocean Dynamical Model
Hybrid layer model
(HYCOM)

Product:
- Now-cast
- 5-day Forecast
- Temperature
- Salinity
- Currents
- Sea surface
- Elevation

Service:
- Initial & Boundary
  Data for Regional Ocean
  and Atmospheric Models;

Support:
- Marine Safety,
  Management of Hazards,
  Ecosystems;
- Exploration & Exploitation
**NOAA**

**Real-Time Ocean Forecast System (RTOFS)**

**GOAL**

More accurate environmental forecasts through optimal use of Satellite Data

**OBJECTIVE:**

Maximized satellite data assimilation into operational models, with minimized errors and uncertainty

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**RTOFS** (near-real time: HYCOM)

**Sea Ice**

- Aqua AMSR-E sea ice via auto MW ice product
- Active radar sea ice (scatterometer)
- WindSat sea ice

**SSH**

- ERS-2 SSH
- Jason-1 SSH
- Jason-2 SSH

**Winds**

- MetOp-1 ASCAT winds OSE
- MetOp-2 ASCAT winds prep/OSE
- MetOp-3 ASCAT winds prep/OSE

**SST**

- Microwave SST (AMSR-E, WindSat, TMI)
- GOES-R ABI SST OSSE/op preps/OSE
- GOES-12/13 Imager SST op preps/OSE
- GOES-12/13 Imager SST op preps/OSE
- GOES-P Imager SST op preps/OSE
- NPP VIIRS SST OP preps/OSE
- NPOESS VIIRS SST OP preps/OSE
- NOAA-18 AVHRR SST OSE
- NOAA AVHRR SST prep/OSE
- NOAA N’ AVHRR SST prep/OSE

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**Planned**

**Potential**

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**Improved sea ice temporal coverage & spatial resolution: augment SSMI**

**Add dynamic topography with heat content signal**

**Operational ocean vector winds via regional atm forcing model; scatterometry continuity**

**Increased coverage**

**Increased coverage; verification**

**Increased spatial resolution; GOES continuity**

**Increased temporal resolution; GOES SST continuity**

**AVHRR replacement; VIIRS SST continuity**

**AVHRR SST continuity; Increased resolution**
GOAL
More accurate environmental forecasts through optimal use of Satellite Data

OBJECTIVE:
Maximized satellite data assimilation into operational models, with minimized errors and uncertainty

WW-III (near-real time global waves)

- Evolve altimetry assimilation methodology
- Assimilate altimetry data based on spectral content
- Increase temporal & spatial resolution

SAR

- Envisat ASAR swell spectral data
- Increase information content
- Improved sea ice temporal coverage & spatial resolution: augment SSMI

Sea Ice

- Aqua AMSR-E sea ice via auto MW ice product
- Active radar sea ice (scatterometer)

Sea Ice

- WindSat sea ice

SSH

- Envisat altimeter significant wave height
- Jason-1 significant wave height
- Jason-2 significant wave height
- GFO significant wave height
- Increase temporal & spatial resolution

NOW

Planned
Potential

NOW

NOW

NOW

NOW

NOW

NOW

Near-real-time Coupled Modeling

**HURRICANE FORECASTING**

- For 2007 hurricane season, NOAA intends to implement a coupled forecasting system:
  - Global Forecast System (GFS); global atmospheric model
  - Hurricane – Weather and Research Forecast (HWRF) model; regional atmospheric model
  - Real-time Ocean Forecast System (RTOFS); Atlantic regional ocean model
  - WaveWatch3; global surface wave model

- Planned operational computing system upgrade (FY2007) to provide sufficient computing to run fully-coupled HWRF and wave models.

**FY09-13**

- Improved data assimilation of altimetry for sea surface height
  - Critical to the determination of the energy available in the upper ocean
    - Given appropriate atmospheric conditions, the intensification of a hurricane is driven largely by the upper-ocean available energy
Data Assimilation Gaps

• **Optimal exploitation of existing data streams**
  - Unused data streams:
    • SST (GOES, microwave)
    • Sea ice (scatterometry, synthetic aperture radar, passive polarimetry)
    • Ocean vector winds (passive polarimetry)
    • Ocean color

• **Ocean/coastal assimilation methodology development**

• **Implementation capacity**
  - Quadrupled NOAA operational satellite ocean parameters
  - Ocean data assimilation computational capacity
    • Research and development
    • Operational

• **Continuity of NOAA operational data streams**
  - SSH
  - Ocean vector winds (scatterometry)
  - Synthetic aperture radar (sea ice)

• **Coastal and ecosystem operational data assimilation**
# NOAA IOOS PROGRAM: Integrate Data

<table>
<thead>
<tr>
<th>Problem</th>
<th>Need</th>
<th>Core Variables</th>
<th>Decision Tools</th>
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<tbody>
<tr>
<td>Global climate system not well understood</td>
<td>• Characterize the state of the global climate system and its variability</td>
<td>Temperature, Salinity, Sea Level, Surface currents, Ocean color, Bathymetry, Surface waves, Ice distribution, Contaminants, Dissolved nutrients, Fish species, Fish abundance, Zooplankton species, Optical properties, Heat flux, Bottom character, Pathogens, Dissolved ( O_2 ), Phytoplankton species, Zooplankton abundance</td>
<td>Hurricane Intensity Model, Coastal Inundation Model, Harmful Algal Bloom Model, Integrated Ecosystem Assessment</td>
</tr>
<tr>
<td>Coastal populations at risk, including coastal hazards and coastal development and urbanization</td>
<td>• Improved models (e.g., coastal inundation, hurricane intensity, and harmful algal bloom model)</td>
<td>Integration: Long-term data series, coordinated in space and time</td>
<td></td>
</tr>
<tr>
<td>Ocean, coastal, and Great Lakes ecosystems at risk, including the hydrological and biogeochemical cycles, and ecosystem health and productivity</td>
<td>• Improved ecosystem assessments and models</td>
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<td></td>
</tr>
</tbody>
</table>
NOAA IOOS PROGRAM: Decision Tools – Integrated Core Variables for Models

**Process Flow**

- Evaluate NOAA models that impact highest-priority problems
- Integrate variables needed to achieve benchmarked improvements
- Quantify progress toward defined modeling improvements
- Identify additional source(s) of error within model
- Identify remaining IOOS core variables needed to reduce error
- Select next set of priority core variables based on impacts to NOAA products
- None?

### CORE VARIABLES | NOAA MODELS | Current State | MODELING IMPROVEMENTS (future state)
--- | --- | --- | ---
- Temperature | Hurricane Intensity Model | Non real-time and interpolated temperature data used to inform model | Integration of real-time, temperature = increased accuracy of hurricane intensity predictions
- Sea Level | Coastal Inundation Model | Sea level data (various sources and formats) integrated on site-by-site basis for use in model | Expedited development of coastal inundation forecasts for Southeast and Gulf
- Surface currents | Harmful Algal Bloom Model | Wind data and marine forecasts used as proxy to determine currents | Improved bloom trajectory forecast
- Ocean Color | | | Enable development of national HAB forecast with integrated currents
- Salinity | | | Assess current conditions
- Temperature | Integrated Ecosystem Assessment | NOAA compiles and integrates suite of data required for each assessment | Forecast ecological health based on existing management strategies
- Salinity | | | Evaluate impacts of alternate management strategies
- Ocean Color | | |
**NOAA IOOS Program:**
*Data Integration Framework – Initial Operating Capability*

**Months 0-12**
Integration of 5 Core Variables

**Month 18**
Integrated variable ingest for following products

**Month 24**
Test & Evaluation

**Month 36**
Benchmarked product improvements for operational use

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**NOAA 5 Core Variables**
- Temperature
- Salinity
- Sea Level
- Currents
- Color

**Systems Engineer**
- Standards

**NOAA IOOS Integrated Data Framework**

**External sources of 5 Core Variables**
(consistent with NOAA standards)

**PRIORITY 1**
- Systems Engineering: Standards

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**Hurricane Intensity Model**
- Integrated Ecosystem Assessment

**Coastal Inundation Model**
- Harmful Algal Bloom Model

**Verification & Validation**
- Test & Evaluation
- Product Enhancement

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**Enhanced decision support through:**
- Integrated information services for NOAA programs
- Identify observation gaps
- Validated enhanced data products
- NOAA’s Data Integration Framework

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**NOAA MISSION OBJECTIVES**
Oceanic satellite data assimilation is a core JCSDA mandate

JCSDA’s ocean component is poised for growth

Infrastructure issues need to be addressed
  • computational resources
  • implementation of operational ocean/coastal and coupled models
  • funding wedge to support the assimilation of expanding observations

Work in progress
  • funded research and development
    • assimilation techniques
  • operational satellite data assimilation implementation
    • SST
    • altimetry
    • sea ice
    • ocean vector winds

Notable opportunities exist, in particular for coastal data assimilation.
BACKUP SLIDES
**Joint Center for Satellite Data Assimilation**

**Global Forecast System (GFS)**

**GOAL**
More accurate environmental forecasts through optimal use of Satellite Data

**OBJECTIVE:**
Maximized satellite data assimilation into operational models, with minimized errors and uncertainty

**GFS** (atmosphere model, ocean component)

**DRAFT**

**Sea Ice**
- SSM/I
  - Active radar sea ice (scatterometer)
  - WindSat sea ice
  - Aqua AMSR-E sea ice via auto MW ice product

**Wind**
- QuikScat, SSM/I
  - MetOp-A ASCAT winds OSE
  - MetOp-B ASCAT winds prep/OSE
  - MetOp-C ASCAT winds prep/OSE

**SST**
- AVHRR
  - Microwave SST (AMSR-E, WindSat, TMI)
  - GOES-12/13 Imager SST op prep/OSSE
  - GOES-O Imager SST op prep/OSSE
  - GOES-P Imager SST op prep/OSSE
  - NPP VIIRS SST OSSE/op prep/OSSE
  - NPOESS VIIRS SST Op prep/OSSE
  - MetOp-A AVHRR SST OSE
  - MetOp-B AVHRR SST prep/OSSE
  - NOAA N' AVHRR SST prep/OSSE

**Now**

- Microwave SST (AMSR-E, WindSat, TMI)
- GOES-12/13 Imager SST op prep/OSSE
- GOES-O Imager SST op prep/OSSE
- GOES-P Imager SST op prep/OSSE
- NPP VIIRS SST OSSE/op prep/OSSE
- NPOESS VIIRS SST Op prep/OSSE
- MetOp-A AVHRR SST OSE
- MetOp-B AVHRR SST prep/OSSE
- NOAA N' AVHRR SST prep/OSSE
Global Forecast System (GFS)

**Now**
- **SST:**
  - Uses weekly NCEP SST analysis (“Reynolds” SST)
  - Uses data in Gridpoint Statistical Interpolation (GSI) system
    - AVHRR
    - HIRS
- **Sea ice:**
  - Uses automated microwave sea ice product based on SSMI data
- **Ocean winds**
  - Assimilates QuikScat scatterometry ocean vector winds

**Planned**
- Adding active ocean: ~ Sep 06 (1-D mixed-layer model on atmospheric grid)
- **SST**
  - Adding MetOp AVHRR 4km data: FY07
- **Sea ice**
  - Adding AMSR-E to automated microwave product: ~ Jun 07

**Potential**
- **SST**
  - GOES Imager SST data (already in GSI)
  - International geostationary SST data: MTSAT, MSG, InSat, FY2C
  - Polar-orbiting SST data: Envisat AATSR, MODIS
  - Microwave data: AMSR-E, Windsat, TMI
- **Sea ice**
  - Passive: Windsat
  - Active: QuikScat, ASCAT, Envisat ASAR), JAXA ALOS
- **Ocean Winds**
  - MetOp ASCAT scatterometry ocean vector winds
  - Windsat passive polarimetry ocean vector winds
**GOAL**

More accurate environmental forecasts through optimal use of Satellite Data

**OBJECTIVE:**
Maximized satellite data assimilation into operational models, with minimized errors and uncertainty

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**WRF (atmosphere model, ocean component)**

- **GOES-R ABI SST**
- **OSSE/op preps/OSE**
- **Microwave SST (AMSR-E, WindSat, TMI)**
- **MetOp-1 ASCAT winds OSE**
- **MetOp-2 ASCAT winds prep/OSE**
- **MetOp-3 ASCAT winds prep/OSE**

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**Wind**

- QuikScat ASCAT winds OSE
- MetOp-1 ASCAT winds OSE
- MetOp-2 ASCAT winds prep/OSE
- MetOp-3 ASCAT winds prep/OSE

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**Sea Ice**

- **SSM/I**
- **Aqua AMSR-E sea ice via auto MW ice product**
- **SAR sea ice (Envisat ASAR)**
- **WindSat sea ice (passive polarimetry)**

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**SST**

- **AVHRR SST**
- **GOES SST**
- **QuikScat SSM/I**
- **SSM/I**
- **NOAA N’ AVHRR SST OSE**
- **NPP VIIRS SST Op preps/OSE**
- **NPOESS VIIRS SST Op preps/OSE**
- **MetOp-1 AVHRR SST OSE**
- **MetOp-2 AVHRR SST prep/OSE**
- **MetOp-3 AVHRR SST prep/OSE**
- **NOAA-18 AVHRR SST OSE**
- **NOAA N’ AVHRR SST prep/OSE**

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**Currently Resourced**

- **NOW**

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**Planned**

- **Potential**
- **Not Resourced**

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**Microwave SST (AMSR-E, WindSat, TMI)**

- Increased coverage;
- Increased spatial resolution;
- GOES SST continuity

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**Non-NOAA SST (MODIS, AATSR, MTSAT, MSG, InSat, FY2C, …)**

- Improved sea ice temporal coverage & spatial resolution: augment SSM/I
- Increased coverage
- Increased coverage; confirmation
- Increased spatial resolution; GOES SST continuity
- Increased temporal resolution; GOES SST continuity
- AVHRR replacement; VIIRS SST continuity
- AVHRR SST continuity
- AVHRR SST continuity
- Operational ocean vector winds; scatterometry continuity

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**SAR sea ice (Envisat ASAR)**

- Improved sea ice temporal coverage & spatial resolution: augment SSM/I
- Increased coverage
- Increased coverage; confirmation
- Increased spatial resolution; GOES SST continuity
- Increased temporal resolution; GOES SST continuity
- AVHRR replacement; VIIRS SST continuity
- AVHRR SST continuity
- AVHRR SST continuity

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**QuikScat**

- **AVHRR SST**
- **GOES SST**
- **QuikScat SSM/I**
- **SSM/I**
- **NOAA N’ AVHRR SST OSE**
- **NPP VIIRS SST Op preps/OSE**
- **NPOESS VIIRS SST Op preps/OSE**
- **MetOp-1 AVHRR SST OSE**
- **MetOp-2 AVHRR SST prep/OSE**
- **MetOp-3 AVHRR SST prep/OSE**
- **NOAA-18 AVHRR SST OSE**
- **NOAA N’ AVHRR SST prep/OSE**

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**NOW**

- **NOW**
- **NOW**
- **NOW**
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- **NOW**
- **NOW**
- **NOW**
- **NOW**
- **NOW**
- **NOW**

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**During the planning period:**

- Improved sea ice temporal coverage & spatial resolution: augment SSM/I
- Increased coverage
- Increased coverage; confirmation
- Increased spatial resolution; GOES SST continuity
- Increased temporal resolution; GOES SST continuity
- AVHRR replacement; VIIRS SST continuity
- AVHRR SST continuity
- AVHRR SST continuity
- Operational ocean vector winds; scatterometry continuity

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**DRAFT**

- Improved sea ice temporal coverage & spatial resolution: augment SSM/I
- Increased coverage
- Increased coverage; confirmation
- Increased spatial resolution; GOES SST continuity
- Increased temporal resolution; GOES SST continuity
- AVHRR replacement; VIIRS SST continuity
- AVHRR SST continuity
- AVHRR SST continuity
- Operational ocean vector winds; scatterometry continuity

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**SST (atmosphere model, ocean component)**

- Improved sea ice temporal coverage & spatial resolution: augment SSM/I
- Increased coverage
- Increased coverage; confirmation
- Increased spatial resolution; GOES SST continuity
- Increased temporal resolution; GOES SST continuity
- AVHRR replacement; VIIRS SST continuity
- AVHRR SST continuity
- AVHRR SST continuity
- Operational ocean vector winds; scatterometry continuity

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**Joint Center for Satellite Data Assimilation**

- **Regional Forecast System**
- More accurate environmental forecasts through optimal use of Satellite Data
Regional / Mesoscale

**Now:** Weather Research and Forecast (WRF) model
- SST
  - Daily SST analysis (NCEP Marine Modeling Branch): AVHRR + GOES for NW Atlantic
- Sea ice
  - WRF uses NCEP automated microwave sea ice product
- Ocean winds
  - WRF assimilates SSMI (wind speed only), QuikScat (vector winds), ERS (when data useable)
- Short-Range Ensemble Forecast (SREF)
  - Regional Spectral Model (RSM)
  - Eta North American model
    - SST
    - Uses the NESDIS Interactive Multi-sensor Snow/ice (IMS) product, incorporates a National Ice Center (NIC) analysis from multiple sensors
    - Assimilates SSMI (wind speed only)

**Planned**
- SST
  - Changing from NCEP weekly analysis (Reynolds SST) to Pathfinder SST for relaxation climatology?
- Sea ice
  - Adding AMSR-E to automated microwave product: ~ Jun 07
  - NIC will provide QuikScat GIS layer: ~ Dec 06
- Ocean winds: WindSat, MetOp ASCAT

**Potential**
- SST
  - MetOp AVHRR 1 km SST data
  - MODIS 1 km SST data (preparation for NPP/NPOESS VIIRS data)
  - Envisat AATSR
  - Geostationary (GOES): need global retrievals, requiring international data; MTSAT, MSG, InSat, FY2C
    - Need smoother data to reduce jumps between subsequent observations
    - Concerns about GOES SST calibration
  - Microwave: Considering AMSR-E; potentially Windsat
- Sea ice
  - Desire Envisat ASAR global monitoring 1km (matches model resolution)
  - JAXA ALOS L-band synthetic aperture radar data; Algorithms and impact assessment required
  - Windsat (passive polarimetric sea ice algorithms needed)
- Ocean winds
  - Envisat ASAR 1-km winds
Global Ocean Data Assimilation System (GODAS) 
Coupled Forecast System (CFS)

- GODAS provides unattached assimilation analysis for the Coupled Forecast System (CFS)
  - Approximately 2 weeks behind present state
  - Ocean model (MOM3) forced by Reanalysis-2 atmosphere
    - Update to MOM4 tied to CFS update
    - Prototype MOM4 expected soon

- **Now**
  - SST
    - Relaxes (5-days) model values to NCEP weekly analysis (Reynolds SST), which incorporates AVHRR data

- **Planned**
  - SST
    - MetOp AVHRR (4 km resolution) in continuity of AVHRR data stream
  - SSH
    - Jason-1 altimetry data: ~ Sep 06
    - Jason-2 altimetry data: ~ FY08
  - Sea ice
    - GODAS(MOM4) will include climatological sea ice
    - Interactive ice field: ~ FY09
    - Assimilated sea ice data: > FY09

- **Potential**
  - SST
    - GOES Imager SST data (already in GSI)
    - International geostationary SST data: MTSAT, MSG, InSat, FY2C
    - Polar-orbiting SST data: Envisat AATSR, MODIS
    - Microwave data: AMSR-E, Windsat, TMI
  - Sea ice
    - Passive: SSMI, AMSR-E, Windsat
    - Active: QuikScat, MetOp ASCAT, Envisat ASAR, JAXA ALOS
  - SSH
    - GFO data currently available
    - ESA ERS-2 data currently available
  - Ocean color
    - SeaWIFS, MODIS, NPP/NPOESS VIIRS for biophysical feedback
Real-Time Ocean Forecast System (RTOFS)

- **Now**
  - Forced by WRF regional model, thereby incorporating the WRF data assimilation
  - SST
    - AVHRR
    - GOES
      - Only using for NW Atlantic
      - Can be turned on everywhere
      - Do not understand biases well; needs/wants NESDIS partner to help
  - Sea ice
    - Uses automated microwave sea ice product based on SSMI data
  - Ocean winds
    - SSMI (wind speed only) via NAM forcing

- **Planned**
  - Global RTOFS (FY07); Pacific Coast RTOFS (mid FY08)
  - SST
    - MetOp AVHRR (4km resolution) in continuity of AVHRR data stream
    - Assimilation of MODIS SST data planned, but not a priority
      - Need instrument statistics
  - Sea ice
  - Adding AMSR-E to automated microwave product: ~ Jun 07
  - SSH
    - Jason-1 and GFO data: imminent implementation; FY06 Q4
    - Jason-2: ~ FY08

- **Potential**
  - SST
    - Desire Envisat AATSR data
  - Sea ice
    - Passive: Windsat
    - Active: QuikScat, MetOp ASCAT, Envisat ASAR, JAXA ALOS
  - Ocean winds
    - Supports best estimate in nowcasts; useful for hindcasts
    - QuikScat, MetOp ASCAT scatterometry ocean vector winds
    - WindSat passive polarimetry ocean vector winds
  - SSH
    - ESA ERS-2 data currently available
  - Ocean color
    - Facilitates resolution of mesoscale features
    - Provides strong signature of mesoscale motion
    - Data on water clarity would help improve other model parameter estimations
    - SeaWiFS, MODIS, NPP/NPOESS VIIRS
WAVEWATCH III

- **Now**
  - SSH
    - ESA ERS-2 altimetry data
  - Sea ice
    - Uses automated microwave sea ice product based on SSMI data

- **Planned**
  - SSH
    - Jason-1 data assimilation implementation imminent: ~ Jul 06
    - Jason-2 data assimilation: ~ FY08
  - Sea ice
    - Adding AMSR-E to automated microwave product: ~ Jun 07

- **Potential**
  - SSH
    - GFO altimetry data (currently received, but not processed)
    - Envisat altimeter (data request pending at ESA)
    - Envisat ASAR data would provide spectral data for swell groups
      - Need ESA to release this data to NCEP
    - JAXA ALOS L-band synthetic aperture radar data
      - Algorithms and impact assessment required
  - Sea ice
    - Passive: Windsat
    - Active: QuikScat, MetOp ASCAT, Envisat ASAR, JAXA ALOS