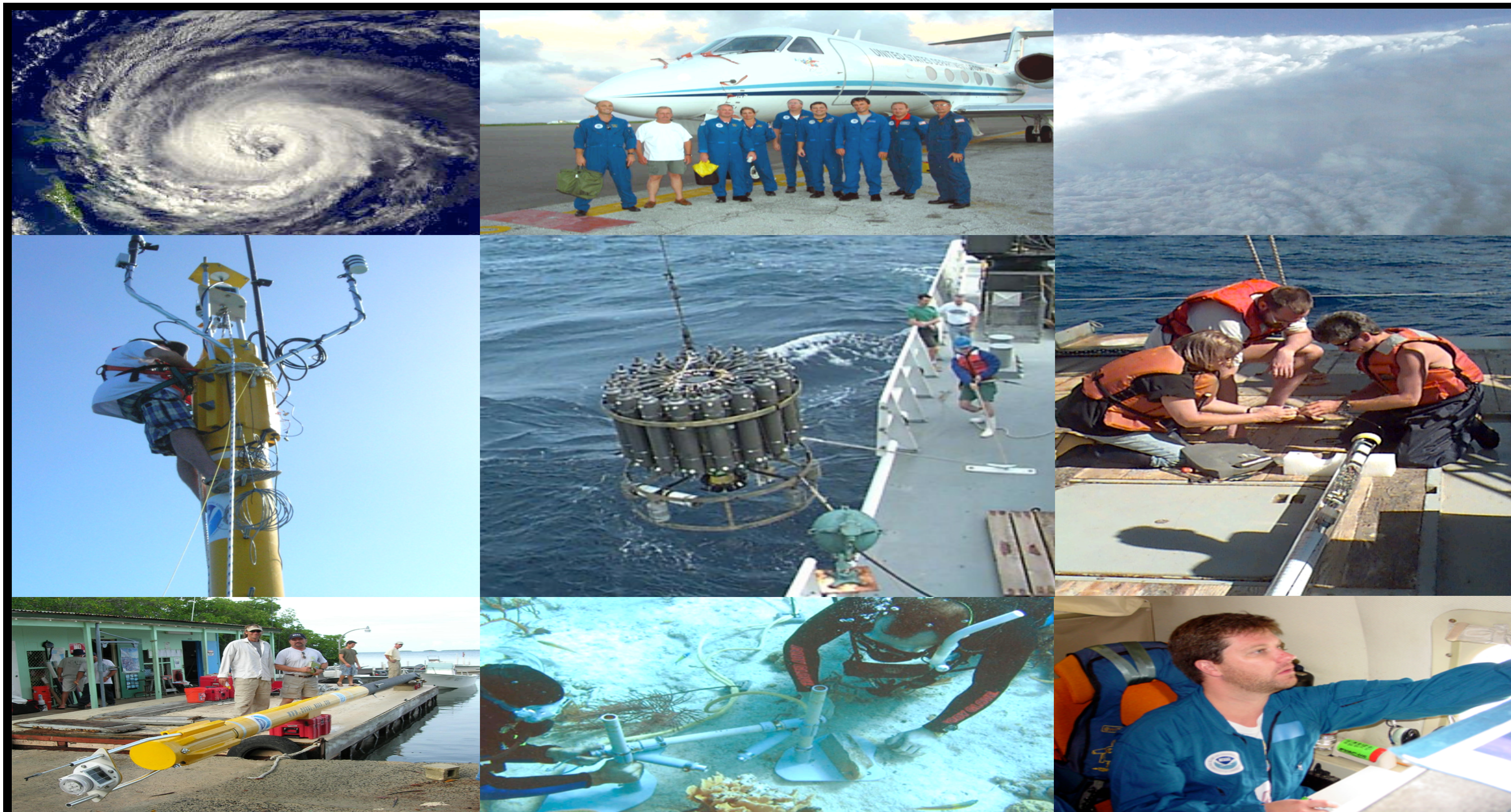
Atlantic Oceanographic and Meteorological Laboratory

Modeling and Data Assimilation at NOAA AOML and Potential Requirements/ Applications of CIB

Robert Atlas



Atlantic Oceanographic and Meteorological Laboratory

Dr. Robert M. Atlas, Director

The Atlantic Oceanographic and Meteorological Laboratory conducts a basic and applied research program that seeks to understand the physical, chemical, and biological characteristics and processes of the ocean and atmosphere, both separately and as a coupled system. The principal focus of these investigations is to provide knowledge that will ultimately lead to improved prediction and forecasting of severe storms, better utilization and management of marine resources, better understanding of the factors affecting both climate and environmental quality, and improved ocean and weather services for the nation.

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Hurricane Assimilation/Forecast Experiments

- The Hurricane Research Division of AOML is the primary developer of the HWRF-X Model, and an EnKF DAS designed to run with this model.
- We currently perform model and DAS developmental research and forecasting experiments using these systems on a Linux cluster at AOML, and also limited research and forecasting experiments using the Finite volume icosahedral model (FIM) on the Njet computer in Boulder.
- We look to CIB to expand our ability to run other models and to provide differing boundary conditions for HWRF-X, and to augment our computational capabilities for higher resolution.

Observing System Experiments (OSEs)

- As a member of the NASA OVWST and AIRS Team, my colleagues and I perform data assimilation/forecast experiments designed to evaluate and improve the utilization of these data, using GEOS-5, GFS, FIM, and WRF on NASA and NOAA computers.
- We look to CIB to enable us to run the OSEs more efficiently. This is especially true for the GFS runs.

Observing System Simulation Experiments (OSSEs)

- AOML is leading the development of new OSSE testbeds in NOAA. This will include OSSEs for hurricanes, oceans, and climate using both global and regional models and DAS.
- We currently are running a prototype Regional Ocean OSSE system for the Gulf of Mexico on Univ. of Miami computers, and are developing a Global Ocean OSSE system for climate.
- We have also been running Quick OSSEs to evaluate new sensors for hurricane analysis and forecasting on our Linix cluster.
- We look to CIB to provide additional models and DAS for the USWRP regional OSSE testbed that we are developing.

Climate Modeling Experiments

- The hurricane and climate group at AOML is running two coupled ocean-atmosphere models: (1) NCAR CCSM3.5 and (2) GFDL CM2.1; and also HYCOM for ocean studies.
- Currently, we run the models on the NOAA Boulder computers.
- After finishing the runs, we download the model outputs and analyze at AOML.
- We look to CIB to enable us to run similar experiments using other models at potentially higher resolution and to have more control of the computing process.

Backup Slides

OBSERVING SYSTEM SIMULATION EXPERIMENTS

OBJECTIVES:

1. To provide a QUANTITATIVE assessment of the potential impact of proposed observing systems on Earth system science, data assimilation, and numerical prediction.

2. To evaluate new methodologies for the processing and assimilation of remotely sensed data.

3. To evaluate tradeoffs in the design and configuration of proposed observing systems (e.g., coverage, resolution, accuracy, and data redundancy).

4. Can also be used to determine the ability of an existing observing system to detect climatic trends and to optimize the global observing system for climate monitoring and other applications.

Previous OSSEs

1. EVALUATED THE RELATIVE IMPACT OF TEMPERATURE, WIND, AND MOISTURE DATA - These experiments showed wind data to be more effective than mass data in correcting analysis errors and indicated significant potential for space-based wind profile data to improve weather prediction. The impact on average statistical scores for the northern hemisphere was modest, but in approximately 10% of the cases a significant improvement in the prediction of weather systems over the United States was observed.
2. EVALUATED THE RELATIVE IMPORTANCE OF UPPER AND LOWER LEVEL WIND DATA - These experiments showed that the wind profile data from 500hpa and higher provided most of the impact on numerical forecasting.
3. EVALUATED DIFFERENT ORBITAL CONFIGURATIONS AND THE EFFECT OF REDUCED POWER FOR A SPACE-BASED LASER WIND SOUNDER (LAWS) - These experiments showed the quantitative reduction in impact that would result from proposed degradation of the LAWS instrument.
4. DETERMINED DRAFT DATA REQUIREMENTS OF SPACE-BASED LIDAR WINDS - These experiments evaluated different coverages, resolutions, and accuracies for lidar wind measurements to estimate both research and operational requirements for the Global Tropospheric Wind Sounder (GTWS) Mission.

Previous OSSEs (continued)

5. DEVELOPED AND TESTED IMPROVED METHODOLOGY FOR ASSIMILATING SATELLITE SCATTEROMETER DATA. - Applying this methodology resulted in the demonstration of the first significant positive impact of real scatterometer data in 1983.

6. DEVELOPED AND TESTED DIFFERENT METHODS FOR ASSIMILATING SATELLITE SURFACE WIND SPEED DATA.- This led to assimilation of SSM/I wind speed data to improve ocean surface wind analyses.

7. EVALUATED THE QUANTITATIVE AND RELATIVE IMPACT OF ERS AND NSCAT YEARS PRIOR TO THEIR LAUNCH.- These results were confirmed after the launch of both instruments.

8. EVALUATED THE QUANTITATIVE IMPACT OF AIRS SOUNDING DATA AND THE IMPORTANCE OF CLOUD-CLEARING. These results were also confirmed by later data impact experiments with real AIRS data.

Development of a USWRP Observing System Simulation Experiment (OSSE) Test Bed

Primary Objective
To establish a numerical test bed that would enable a hierarchy of experiments to:

(1)determine the potential impact of proposed space-based, sub-orbital, and in situ observing systems on analyses and forecasts,

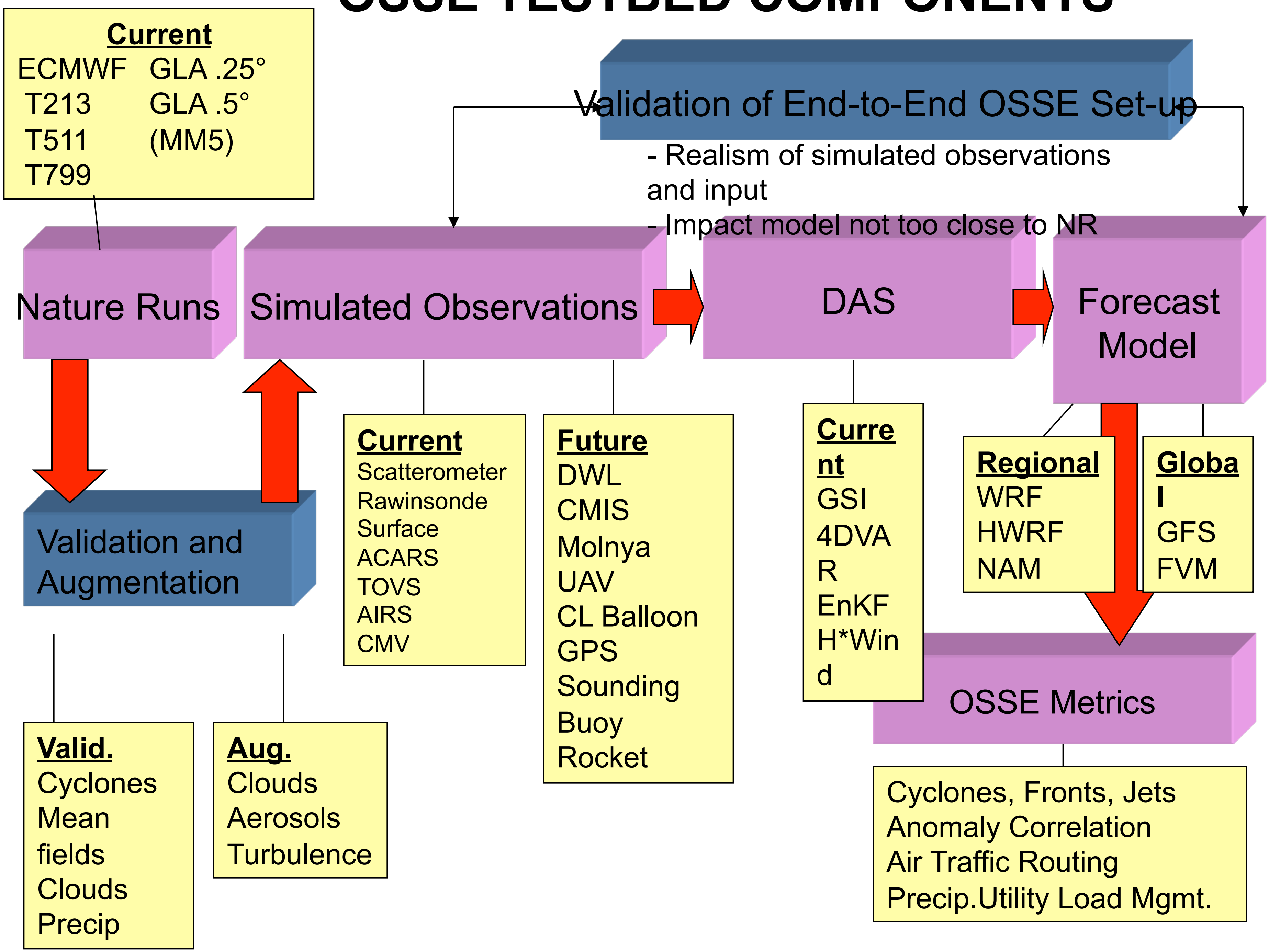
(2)evaluate trade-offs in observing system design, and

(3)assess proposed methodology for assimilating new observations in coordination with the Joint Center for Satellite Data Assimilation (JCSDA).

Sub-objectives
(1)To define both the advantages and limitations of a hierarchy of OSSEs that includes rapid prototyping of instrument or data assimilation concepts, as well as the more rigorous "full" OSSEs.

(2) To generate an OSSE/OSE process that invites participation by the broad community of agency planners, research scientists and operational centers.

OSSE TESTBED COMPONENTS

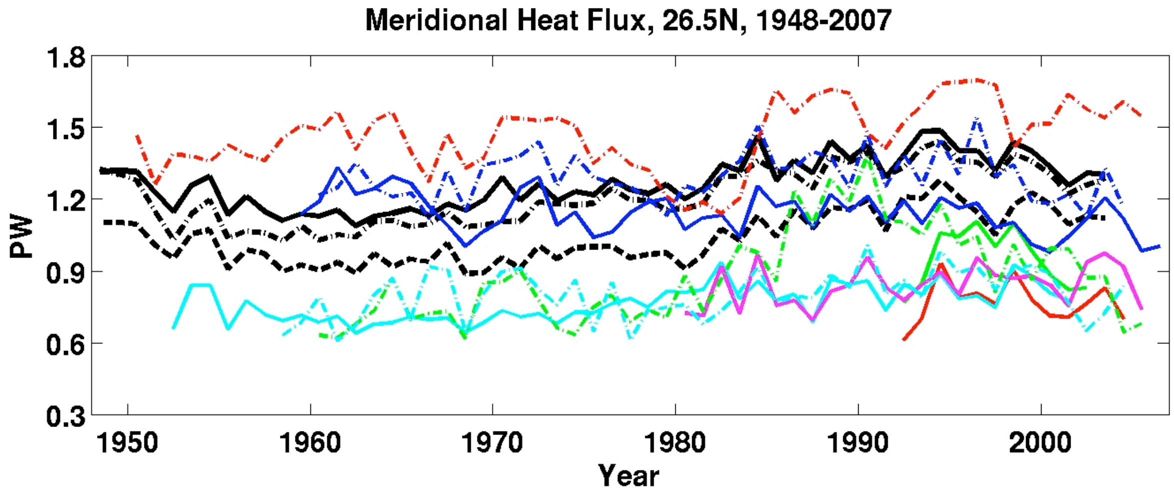


Development of Virginia Key Ocean OSSE/OSE System

- **Initial Applications**
  - Atlantic Meridional Overturning Circulation (AMOC)
    - Design monitoring strategies
  - Initialization of ocean models for hurricane forecasting
    - Improve performance of coupled forecast models
  - Regional/coastal ocean modeling
    - Observing system design for northern Gulf of Mexico

- **Initial Strategy**
  - "Fraternal twin" approach
    - HYbrid Coordinate Ocean Model (HYCOM)
      - Different configurations mimic different ocean model types
        - » Vertical coordinate discretization (isopycnic, level, terrain-following)
        - » Multiple choices of numerical algorithms and model parameterizations
      - Use two different HYCOM configurations for the "nature run" and the data-assimilative "operational" models
        - » Choice of four data assimilation schemes in HYCOM

Figure: Meridional heat flux in Petawatts associated with the AMOC revealed by 12 different ocean models. The black lines show HYCOM simulations while colored lines are from other ocean models.



- AMOC: The fraternal twin approach appears to be feasible
  - Two HYCOM configurations will be used
    - Standard hybrid vertical coordinates (solid black curve above)
    - Fixed hybrid mix of level coordinates (open ocean) and terrain-following (coastal) (dashed black curve above)
  - Uncertainties in the AMOC (mass transport and the associated meridional heat flux) must be determined by models.
    - RMS differences of heat flux among models exceeds 0.35 PW (30%)
  - Differences in mass transport and meridional heat flux produced by the two HYCOM configurations is roughly equal to the AMOC uncertainties among all present-day ocean models.

OSSEs in the Gulf of Mexico – *model setting*

Model Configuration:

• Hybrid Coordinate Ocean Model 1/25 degree, 26 vertical layers
• Atmospheric forcing: COAMPS (27 km, 3h)
• IC: NCODA simulation run at NRL(altimetry, SSH and in-situ data assimilated)
• BC: climatology from 4 years of Hycom Atlantic simulation
• Planned study period: 2004-2008

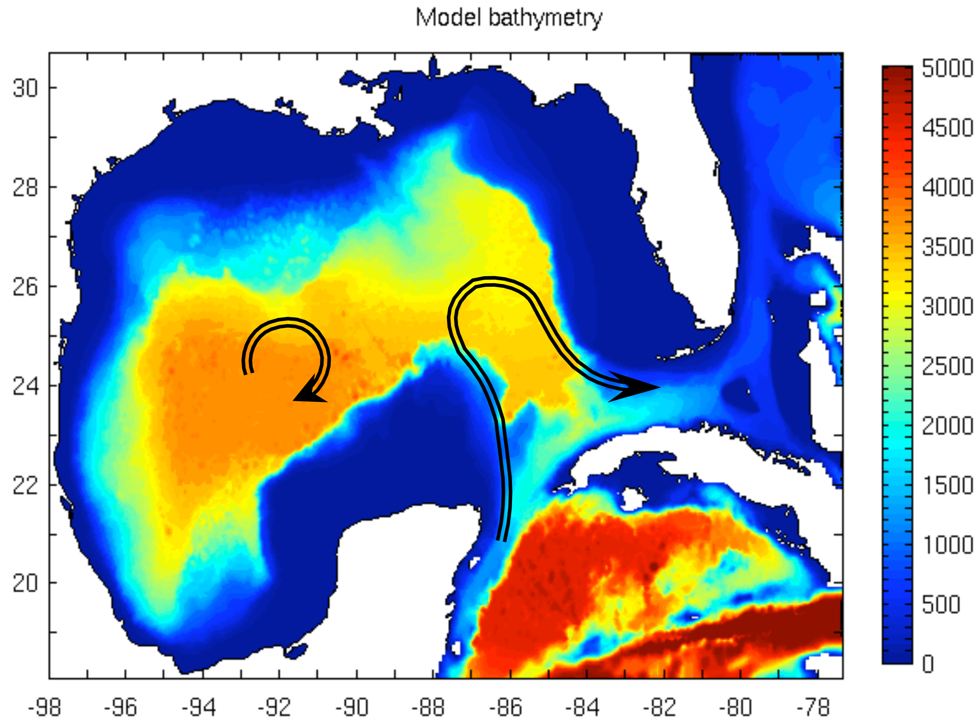


Figure 1: Model bathymetry (m) with examples of dynamical features (LC and eddy)

Objectives:

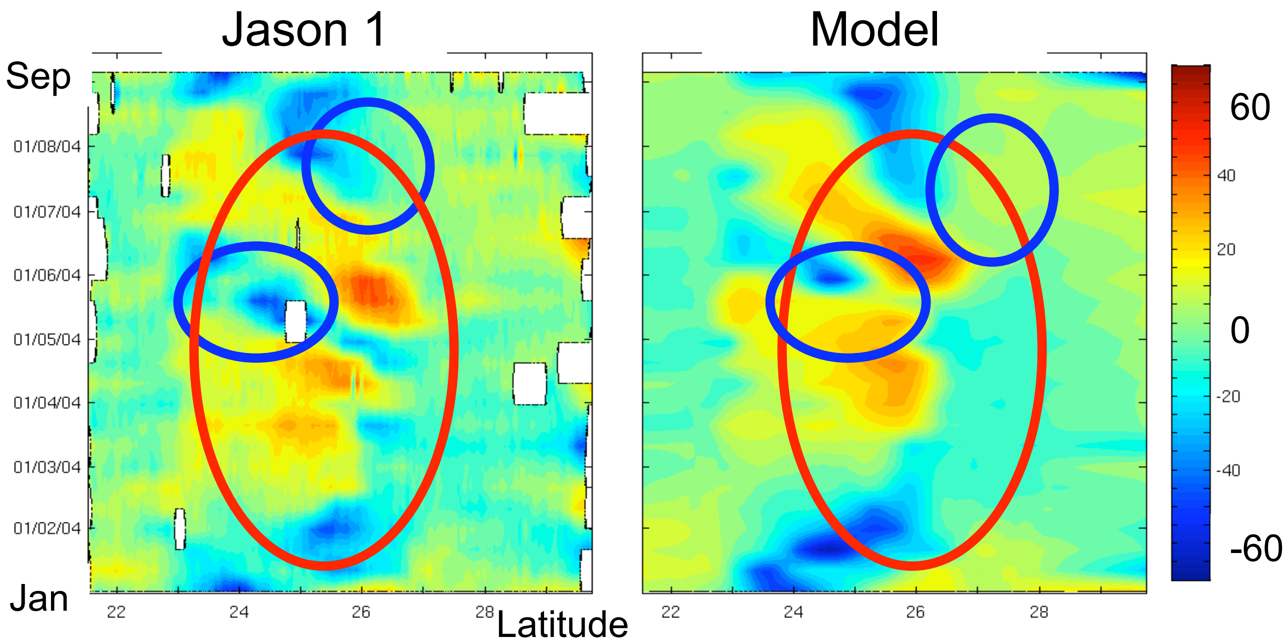
• Study the variability of the LC and the associated connectivity, as well as the model errors associated with the LC
• Perform OSSEs to test various data assimilation schemes and assess the performance of observation networks dedicated to the LC monitoring

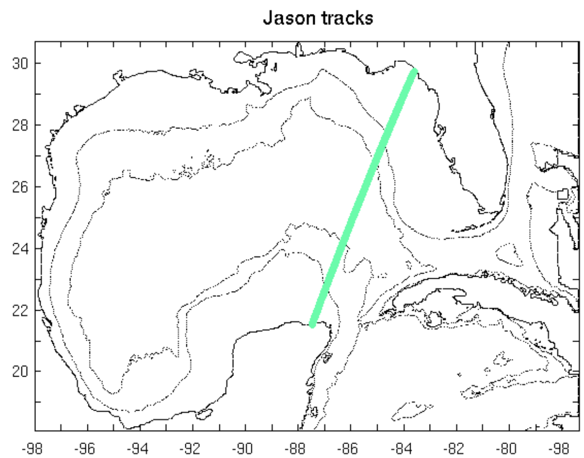
Provided by M. LeHenaff and V. Kourafalou

OSSEs in the Gulf of Mexico – *toward a nature run*

Model evaluation of a free run using altimetry *(Sea Level Anomaly)*

Along-track Jason 1 sea surface height by CTOH (LEGOS, Toulouse, France), treated with X-track (Roblou et al., 2007) to access Sea Level Anomaly





Sea Level Anomaly (cm) along Jason 1 track 91

- realistic development of the LC (timing, amplitude)
- presence of cyclonic features South and North of the LC
- general trend realistic on the West Florida Shelf

Provided by M. LeHenaff and V. Kourafalou

Answers to Questions

- • **What computational and data management barriers do you face?**
- It takes too much time to move model data from the remote server to local (i.e., AOML) disk storage.
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- • **How would you benefit from high-performance computing?**
- Our current research involves running HYCOM, CAM3, CCSM3 on high-performance computers.
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- • **What is your current architecture?**
- We are currently using NOAA high performance computing system (HPCS) at Boulder. The Beowulf cluster system at HPCS, also known as JET system, consists of approximately 2016 CPU nodes using 2.8 GHz Intel Quad-core Xeon processors.
- Each node has 2 GB per processor interconnected using InfiniBand. We are currently using the maximum of 120 CPUs concurrently with the total disk storage space
- of 600 Gbytes.
-
- • **What are your current needs in regional climate modeling and applications?**
- We need to run HYCOM, CAM3, CCSM3, and CM2.1 with an emphasis on Atlantic climate variability.
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- • **Do you require integrated Earth Systems Modeling for impact assessments?**
- Not sure.
-
- • **Do you have sufficient data storage capabilities?**
- We are currently using 15TB storage disk system. This is sufficient for now, but it will be increased in the near future.
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- • **Would you benefit from having access to new datasets, integrated modeling codes (climate and ecosystem models), and formatting standardized to your needs?**
- Yes, we would.
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- • **Would data visualization and analysis tools be beneficial either for research or stakeholder engagement?**
- Yes, it will be beneficial for our research. We are currently using NCL, MATHLAB, and FERRET.

Answers to Questions

- **Model and Data:**
- **• What are the models and data sets that should be available on CIB?**
- We would like to have HYCOM, MOM, CAM3, CM2.1 and CCSM4.
-
- **• What are the tests required for the inclusion of data, research products, and model codes within CIB?**
- Not sure.
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- **Workflow, Scenarios, Datasets, and Tools:**
- **• What workflows would be beneficial?**
- Not sure.
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- **• What are the scenarios, tools, and datasets that should be included?**
- Datasets:
- ERSST3, HADISST, NCEP reanalysis, ERA40, Levitus climatology
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- Scenarios:
- GOGA, TOGA types of experiment sets for AGCM
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- Tools:
- NCL, FERRET, GRADS
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