Atlantic Oceanographic and Meteorological Laboratory

Development of an Observing System Simulation Experiment (OSSE) test bed

Robert Atlas

May 3, 2012

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

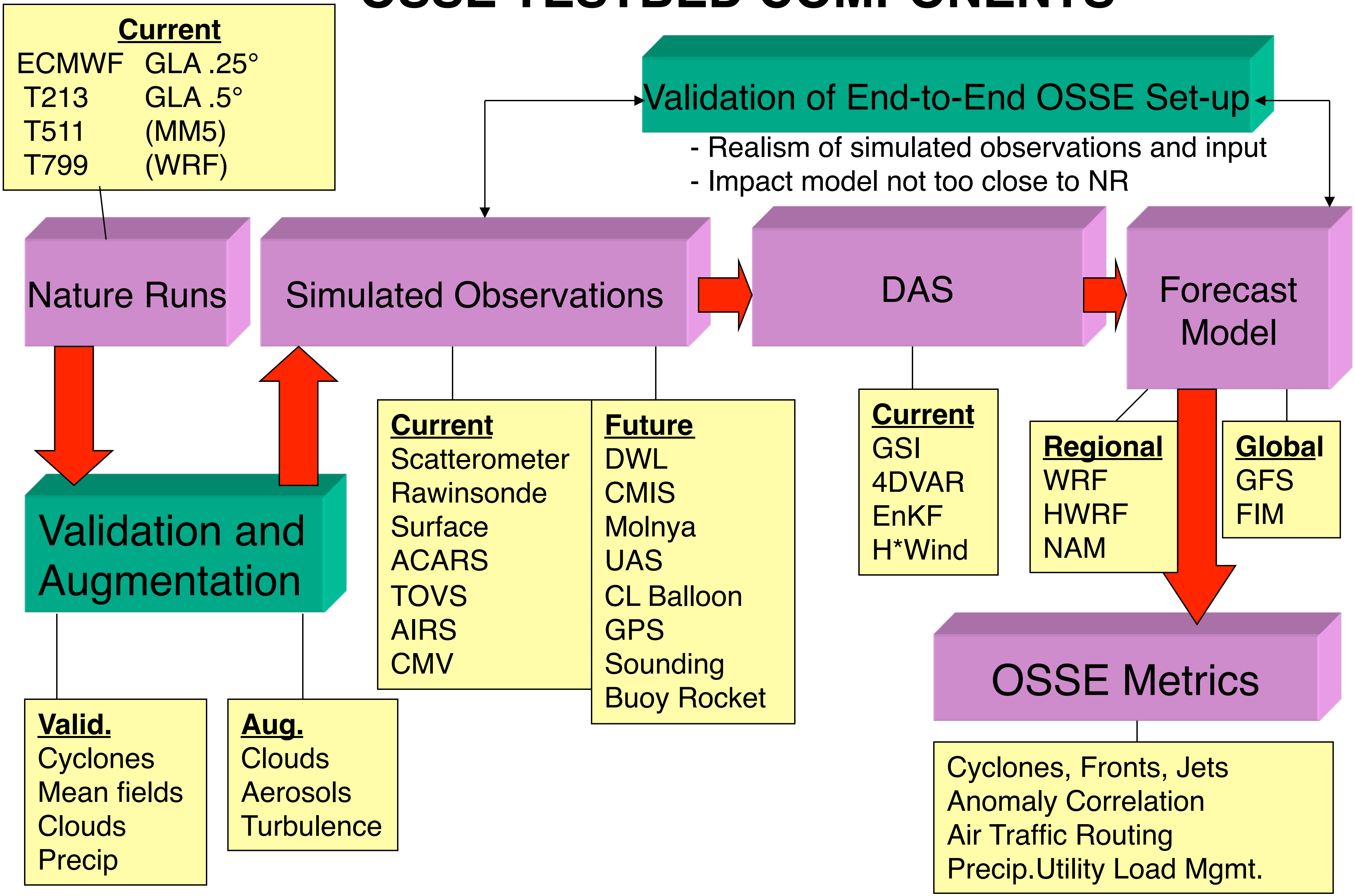
(3)assess proposed methodology for assimilating new observations in coordination with the Joint Center for Satellite Data Assimilation (JCSDA).

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



Summary for 2011

During FY 11, the OSSE Testbed:

1. provided expertise on OSSEs to NOAA and JCSDA partners and academia, and evaluated the global OSSE system and the experiments being performed.

2. finalized regional OSSE nature runs (NR) at 3 and 1km resolution. This required an exhaustive number of iterations of the WRF model embedded within an ECMWF global nature run and confirmed the validity (strongpoints and weaknesses) of both the 3km and 1km nature runs over a 13 day period. A comprehensive evaluation of the NR and twelve initial experiments using this system are planned are currently underway.

3. completed the first phase of a global OSSE for UAS and completed a report and one refereed article from this OSSE.

4. established an external advisory committee for the OSSE Testbed, as requested by the NUEC.

Planned Work for 2012

The work planned for 2012 and the expanded development of the OSSE Testbed is designed to be consistent with the NOAA Annual Guidance Memorandum (AGM), the NOAA (OAR) Goal for Holistic Understanding, and discussions with the OAR DAA for LCI, and the Assistant Secretary for Observations and Prediction.

In support of the specific objectives for OSSEs in the aforementioned documents, we propose to continue the development of an OSSE testbed for use by USWRP partners and academia in collaboration with NESDIS/STAR, NOAA EMC and the Joint Center for Satellite Data Assimilation. This testbed will be applicable to analysis/forecast impact studies, observing system design, instrument trade studies, future instrument constellation planning, and data utility investigations.

During 2012, we will support the AGM OSSE goals and the NOSC by completing the following tasks:

1. Survey all line offices and take stock of existing OSE and OSSE capabilities across NOAA. This will include the capabilities and expertise of each organization and the ability of each organization to perform and/or analyze experiments.

2. Determine through the NOSC the most critical observing system questions to be addressed and their priority.

3. Coordinate global and regional OSEs and OSSEs to be performed, the resources that need to be utilized and the role of each organization.

4. Continue to provide expertise on OSSEs to NOAA and JCSDA partners and academia.

5. Conduct global and regional OSSEs for NOAA's UAS program and HFIP, perform OSSE relating to the polar orbiting satellite program, and experiments relating to wind lidar.

6. Continue work to develop the framework for the full OSSE testbed.

Current work and plans for Ocean OSSEs

- AOML has a prototype ocean OSSE Systems for
  - GoM OSSEs
    - Evaluate the impact of current and new observing systems
      - Gliders
      - Coastal high-frequency radar
      - Targeted airborne observations to improve ocean and hurricane forecasts
  - Global Ocean Climate OSSEs
    - Perform observing system design studies for monitoring changes in the Atlantic and Global Overturning Circulation
    - Expand these studies to other critical ocean climate problems (e.g. tropical Atlantic variability)
- Develop the capability at AOML to perform OSSEs for a broad range of oceanographic problems on relatively short notice
  - Develop a library of regional and global validated nature runs
  - Develop capability to set up relocatable regional domains on short notice

Personnel and their role

Dr. R. Atlas, NOAA/AOML: Lead development of testbed, evaluate global OSSEs, conduct mesoscale OSSEs for hurricanes, and coordinate with the JCSDA.

Dr. Yuanfu Xie, NOAA/ESRL/GSD: Lead global OSSEs using ECMWF T511 nature run and participate in regional OSSEs for UAS and HFIP.

Dr. Ross Hoffman, AER: Chair of External Advisory Group

Dr. G.D. Emmitt, SWA: Simulation of Wind lidar and other observing systems

Backup slides

Observing System Simulation Experiments to Assess the Potential Impact of New Observing Systems on Weather Prediction:

Methodology and Background

Robert Atlas

National Oceanic and Atmospheric Administration
Atlantic Oceanographic and Meteorological Laboratory

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 weather prediction.

2. To evaluate new methodology 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 existing observing system to detect climatic trends and to optimize the global observing system for climate monitoring and other applications.

EARLY SIMULATION STUDIES

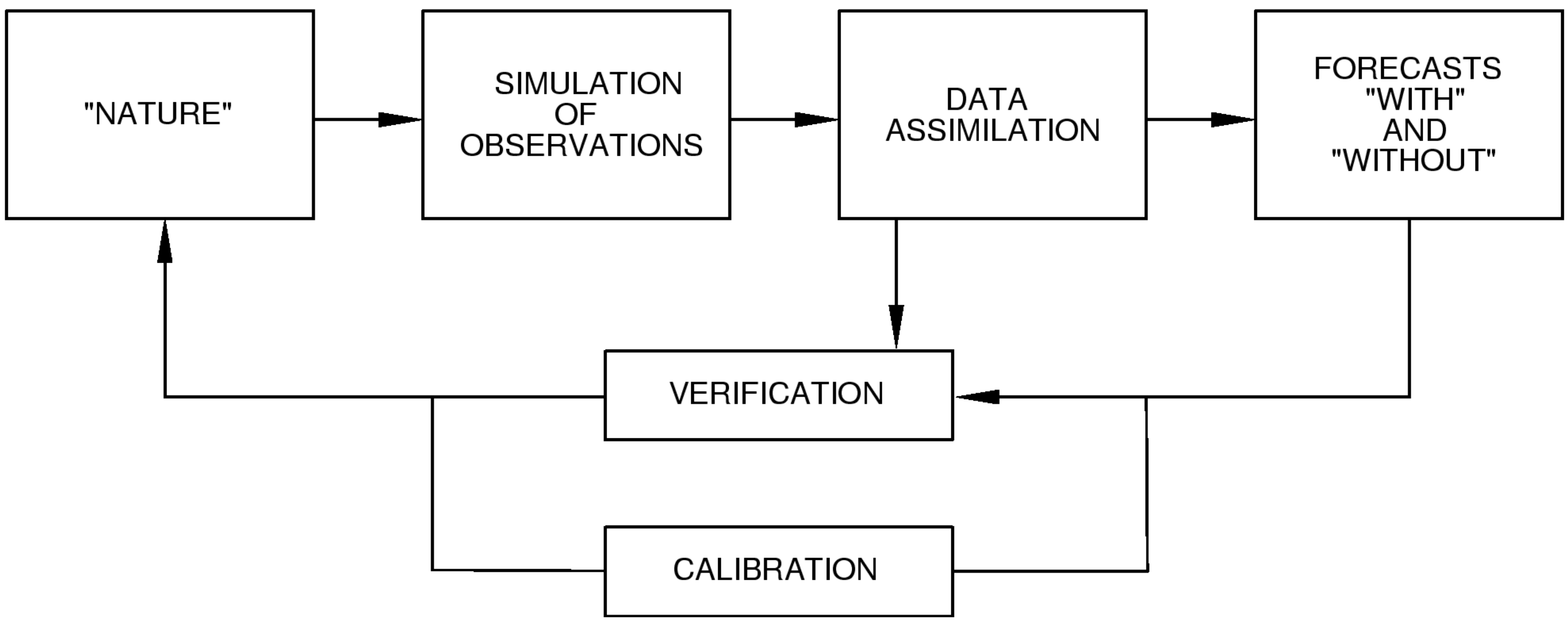
1. PROVIDED AN ANALYSIS OF
   - GARP DATA REQUIREMENTS
   - “USEFUL” RANGE OF PREDICTABILITY
   - NEED FOR REFERENCE LEVEL DATA
   - RELATIVE USEFULNESS OF ASYNOPTIC vs SYNOPTIC DATA ASSIMILATION

2. INDICATED THAT
   - ALL THREE OF THE PRIMARY VARIABLES (TEMPERATURE, MOISTURE, WIND) COULD BE DETERMINED IF A CONTINUOUS TIME HISTORY OF ANY ONE OF THESE VARIABLES WERE INSERTED INTO A GENERAL CIRCULATION MODEL. (“CHARNEY CONJECTURE”)

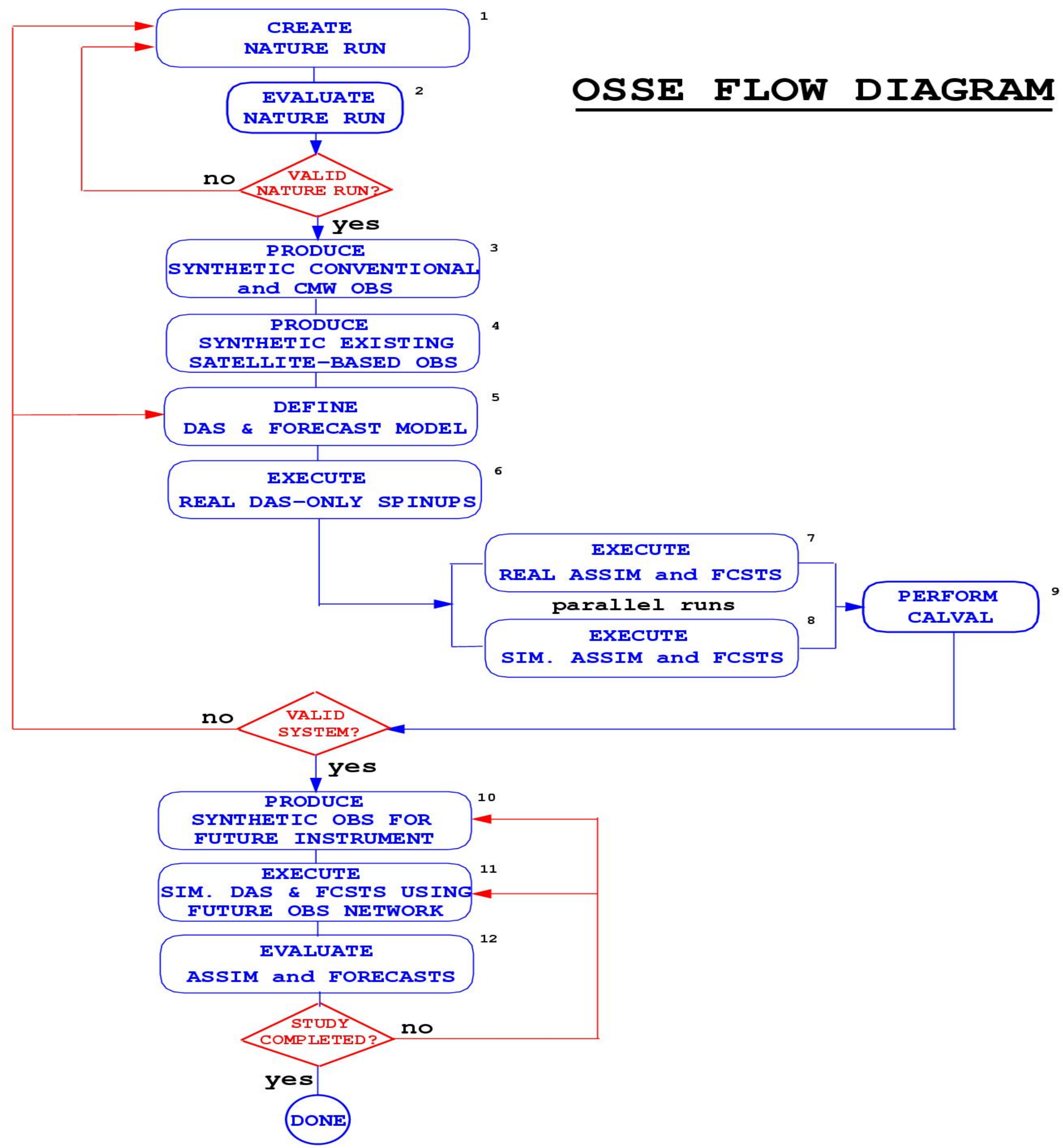
LIMITATIONS OF EARLY STUDIES

- MOST IMPORTANT IS THE USE OF THE SAME MODEL FOR NATURE AND ASSIMILATION / FORECASTING "IDENTICAL TWIN EXPERIMENTS"
- MODEL DEPENDENCE OF RESULTS
- TREATING OBSERVATIONAL ERRORS AS RANDOM AND UNCORRELATED

OBSERVING SYSTEMS SIMULATIONS



OSSE FLOW DIAGRAM



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.

QuickOSSEs

1. QuickOSSEs follow a similar methodology, but are generally performed for much shorter periods and often as single forecasts after a limited data assimilation.

2. They have the advantages of being cheaper and faster to perform, and can sometimes be used to answer questions relating to a particular storm or to demonstrate potential.

3. There utility is very limited in that they typically cannot be used to establish statistically significant quantitative results.

SUMMARY

1. Observing System Simulation Experiments (OSSEs) provide an effective means to:
   - Evaluate the potential impact of proposed observing systems
   - Determine tradeoffs in their design
   - Evaluate new data assimilation methodology

2. Great care must be taken to ensure the realism of the OSSEs and in the interpretation of OSSE results. (OSSEs are only valid if the limitations of the OSSE system have been determined and the conclusions of the experiment do not go beyond the limitations.)

3. Regional OSSE are needed to study the impact of future instruments on high impact weather forecasting. However regional simulations are very sensitive to boundary conditions and model physics, and the calibration/validation of regional OSSE systems can be challenging.

4. QuickOSSEs are a useful adjunct to rigorous OSSEs, but are limited in their ability to evaluate forecast impact quantitatively.

Current and planned OSSEs for hurricanes

- OSSEs to determine potential impact of UAS and to optimize sampling strategies. (ESRL, AOML,RSMAS, JCSDA)

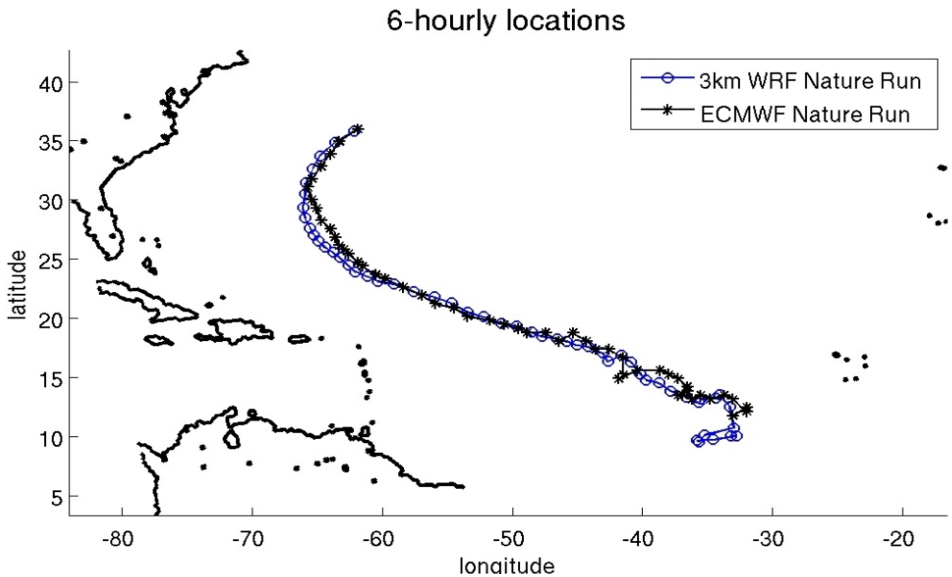
- Sensor Web OSSEs (NASA GSFC, SWA, AOML, RSMAS)

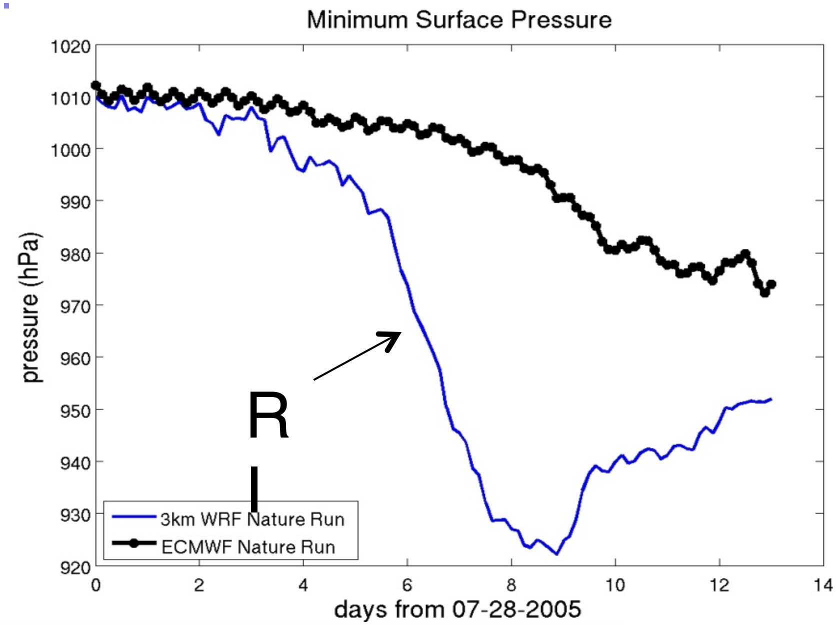
- OSSEs in support of HFIP to evaluate sampling strategies for hurricane reconnaissance, new observing systems, modeling and data assimilation and predictability. (NOAA, Academia)

Current work aimed at developing rigorous regional OSSE system for USWRP OSSE Testbed. (AOML, ESRL, SWA, RSMAS)

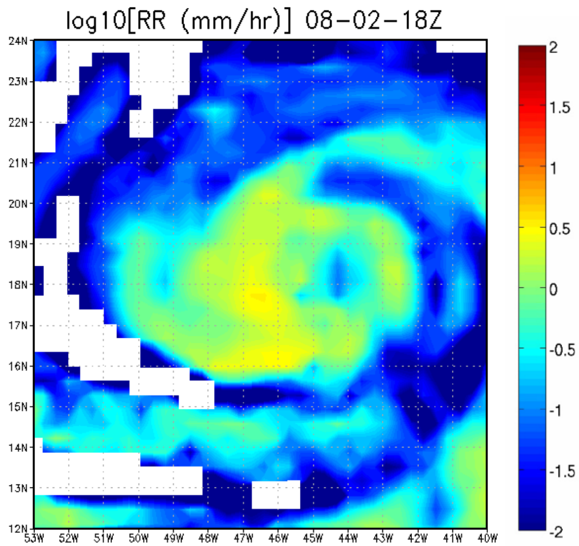
High Resolution Hurricane Nature Run: WRF Simulation Embedded Inside the ECMWF Nature Run

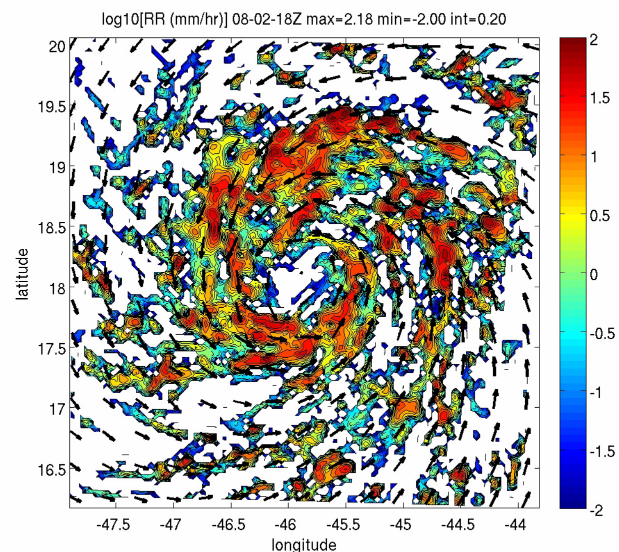
60 levels; 3km resolution; double-moment microphysics; advanced radiation schemes.





ECMWF T511 Nature Run

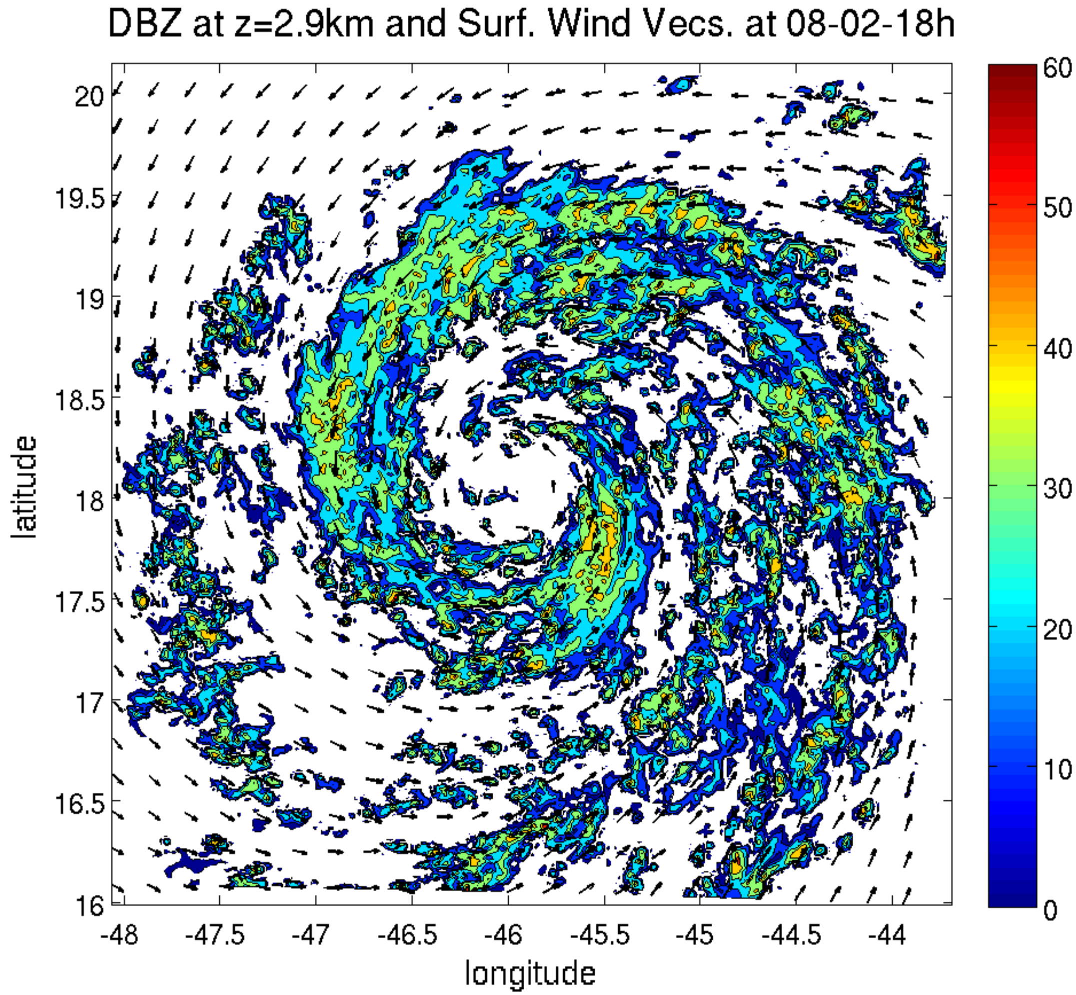




3 km WRF-ARW Nature Run

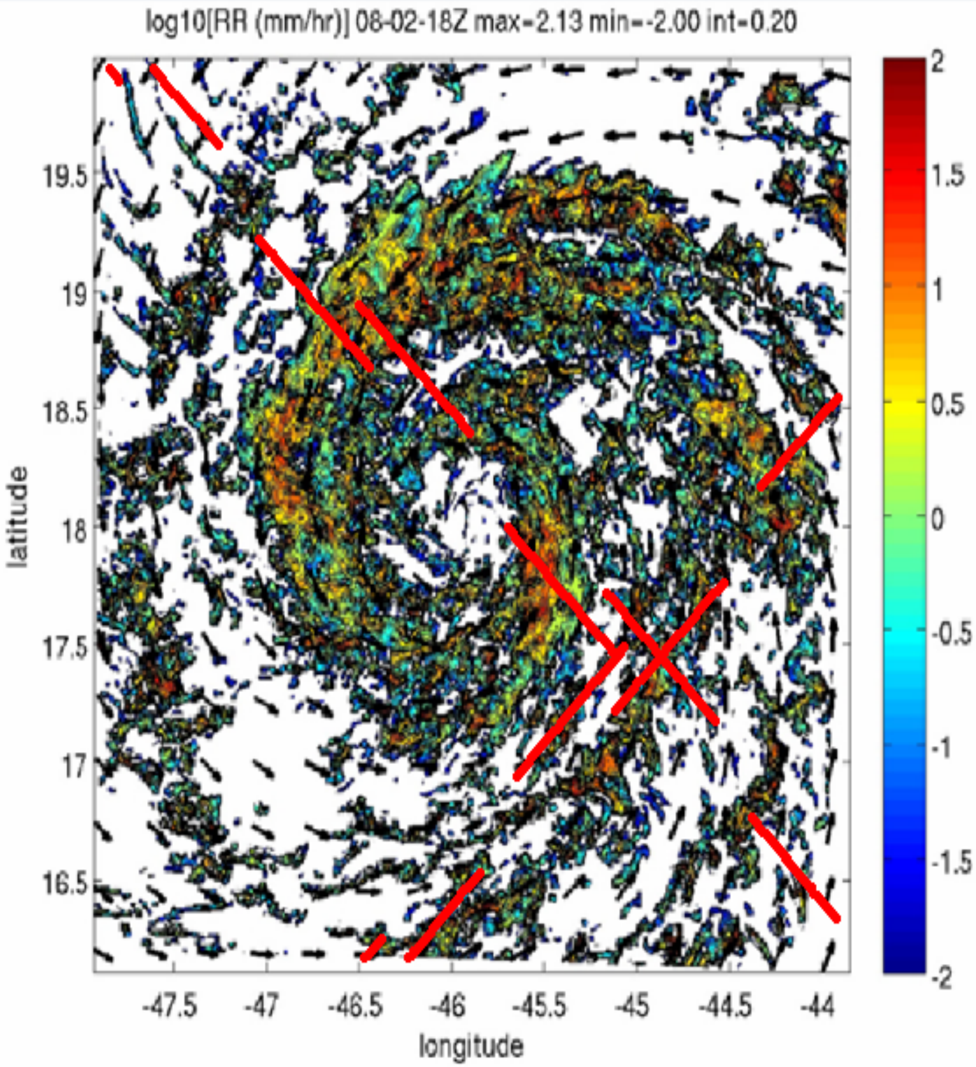
Further improvements expected from 1 km resolution:

3km simulation nested to 1km for 18 hours

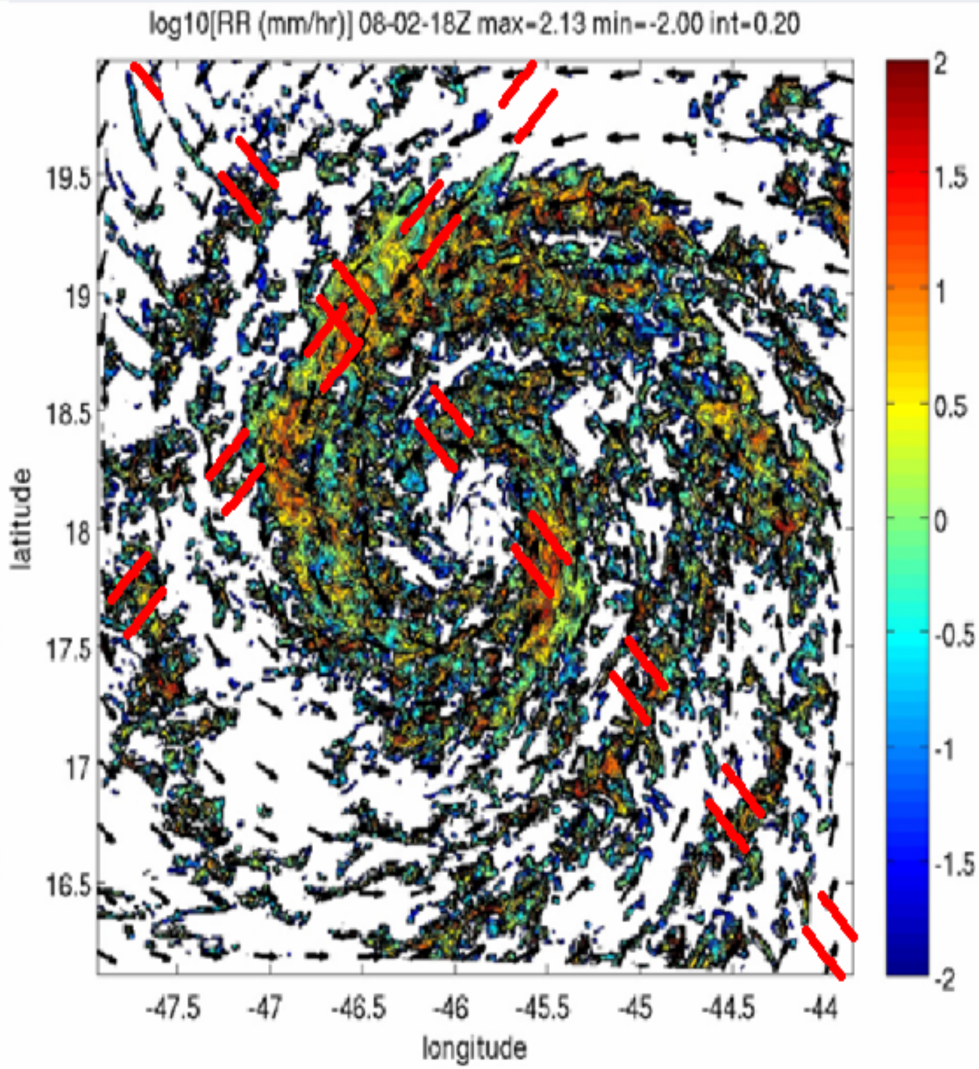


- More realistic distribution of precipitation
- 20 grid points between each arrow shown above

Coverage of Coherent DWL on ISS over WRF-AFW Nature Run Hurricane *



Coherent DWL at 12 sec Dwells



Coherent DWL at 4 sec Dwells

* - R. Atlas (AOML) and L. Bucci (SAIC), 2011

Simpson Weather Associates, Inc., 2011

	Model	Initial Conditions	Boundary Conditions	Nudging	Bogusing	Data Assimilation
1	WRF-ARW	Perfect	Perfect	No		None
2	WRF-ARW	Perfect	GFS	No		None
3	WRF-ARW	Perfect	GFS	Yes		None
4	WRF-ARW	GFS	Perfect	No		None
5	WRF-ARW	GFS	Perfect	Yes		None
6	HWRF3.2	Perfect	Perfect	No		None
7	HWRF3.2	Perfect	Perfect	Yes		None
8	HWRF3.2	GFS	GFS	No		None
9	HWRF3.2	GFS	GFS	Yes		None
10	HWRF3.2	GFS	GFS	No		HEDAS- Standard
11	HWRF3.2	GFS	GFS	Yes		HEDAS- Standard
12	HWRF3.2	GFS	GFS	No		HEDAS-Standard & Experimental Obs
13	HWRF3.2	GFS	GFS	Yes		HEDAS-Standard &