DWL Operations within a Sensor Web Modeling and Data Assimilation System:Recent Results

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SENSOR WEB

A model-driven sensor web is an Earth observing system that uses information derived from data assimilation systems and numerical weather prediction models to drive targeted observations made from earth-orbiting spacecraft as well as from atmospheric- and ground-based observing systems.

Project Goals

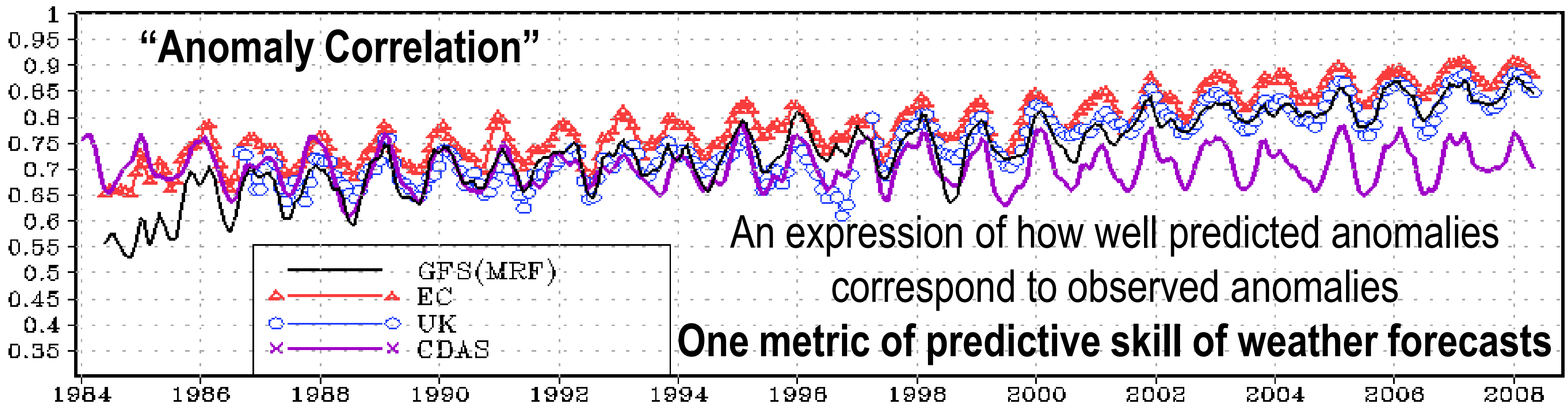
Demonstrate the value of implementing sensor web concepts for meteorological use cases

Quantify cost savings to missions
Quantify improvement in achieving science goals

Design and Build an integrated simulator with functional elements that will allow multiple “what if” scenarios in which different configurations of sensors, communication networks, numerical models, data analysis systems, and targeting techniques may be tested

Evolution of Weather Forecast Predictive Skill

TIME SERIES of monthly mean anomaly correlations for 5-day forecasts of 500hPa heights for various operational models (CDAS frozen as of 1995) - Northern Hemisphere



Improvements in predictive skill over the past several decades have been gradual; the sensor web provides an opportunity for a "revolutionary" impact

Source: Fanglin Yang, Environmental Modeling Center, National Centers for Environmental Prediction, NOAA

Example: Societal Impact and Predictive Skill

Errors in temperature forecasts lead to errors in the prediction of electrical loads for large utilities

San Francisco, May 28, 2003

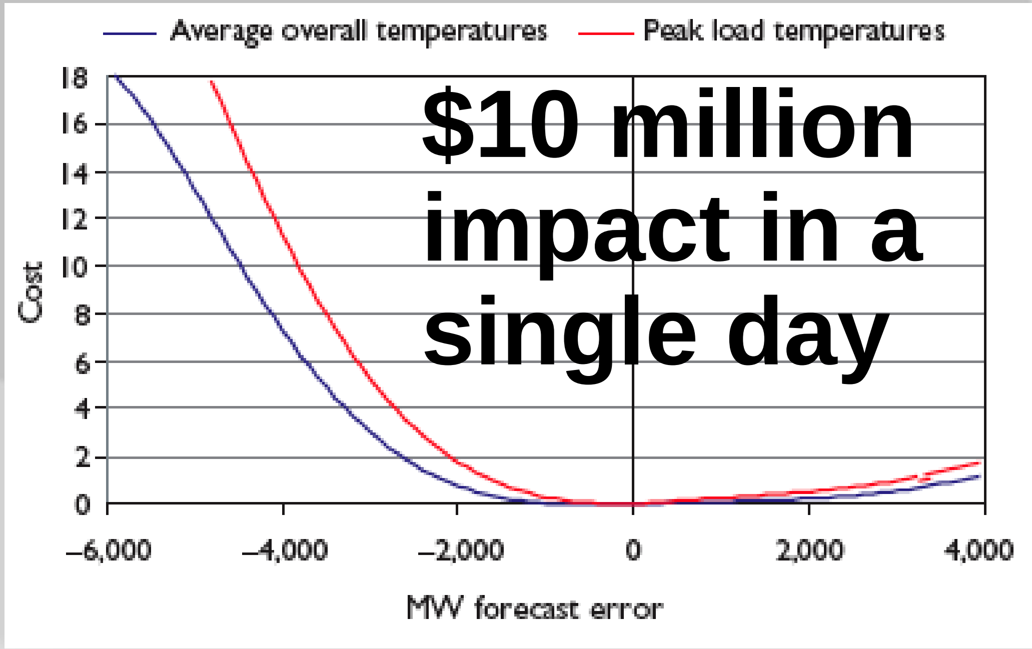
Temperature forecast error of about 5ºC

↓

Electrical load underestimated by 4.8GW

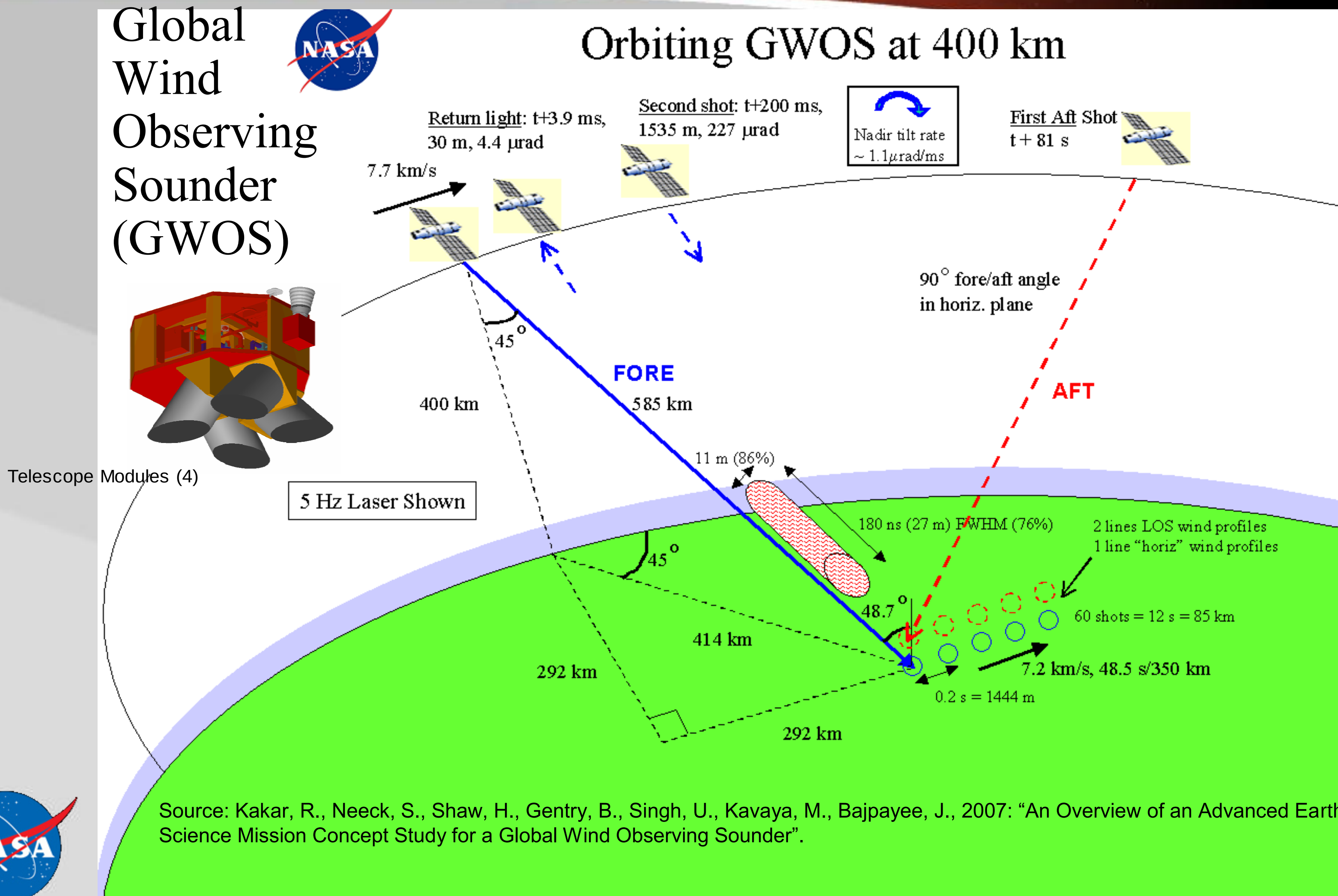
↓

"On the spot" energy purchase required



Source: Mary G. Altalo (SAIC, Inc) and Leonard A. Smith (London School of Economics): "Using Ensemble Weather Forecasts to Manage Utilities Risk", *Environmental Finance*, October 2004

Use Case: Decadal Survey Mission 3D Wind Lidar

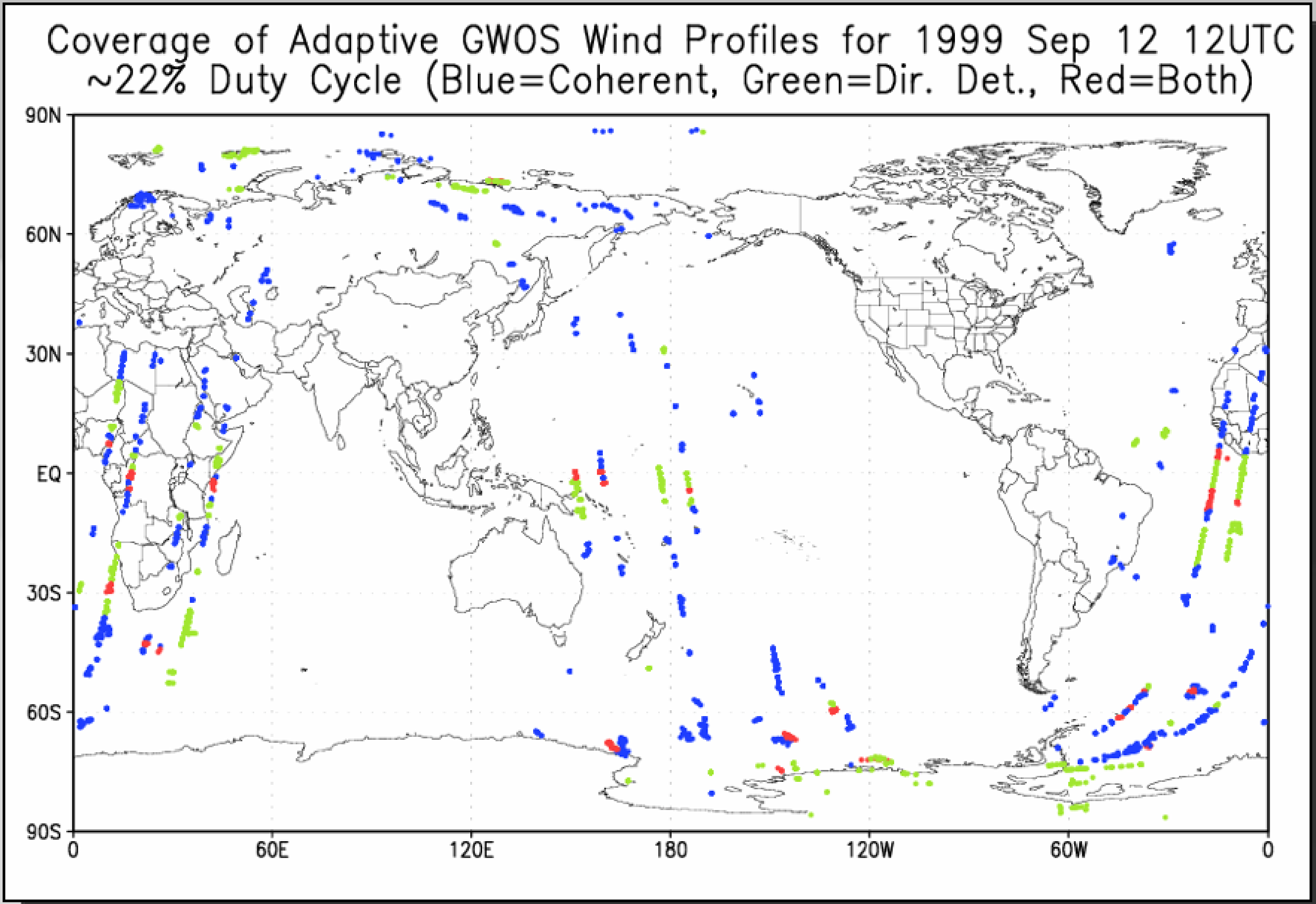


Source: Kakar, R., Neeck, S., Shaw, H., Gentry, B., Singh, U., Kavaya, M., Bajpayee, J., 2007: "An Overview of an Advanced Earth Science Mission Concept Study for a Global Wind Observing Sounder".

Application of Sensor Web Concepts

- **Simulation 1: <u>Extend Mission Life</u> via Power Modulation**
- Conserve power / extend instrument life by using aft shots only when there is “significant” disagreement between model first guess line-of-sight winds and winds measured by fore shots
  - Lidar engineers have recently suggested reduced duty cycles may increase laser lifetimes
  - Duty cycles that are on the order of 10 minutes “on” and 80 minutes “off” may be very beneficial to mission lifetime
- Will require model’s first guess fields be made available on board the spacecraft -- requires engineering trades be performed for on-board processing, storage, power, weight, communications

Simulation 1 Results

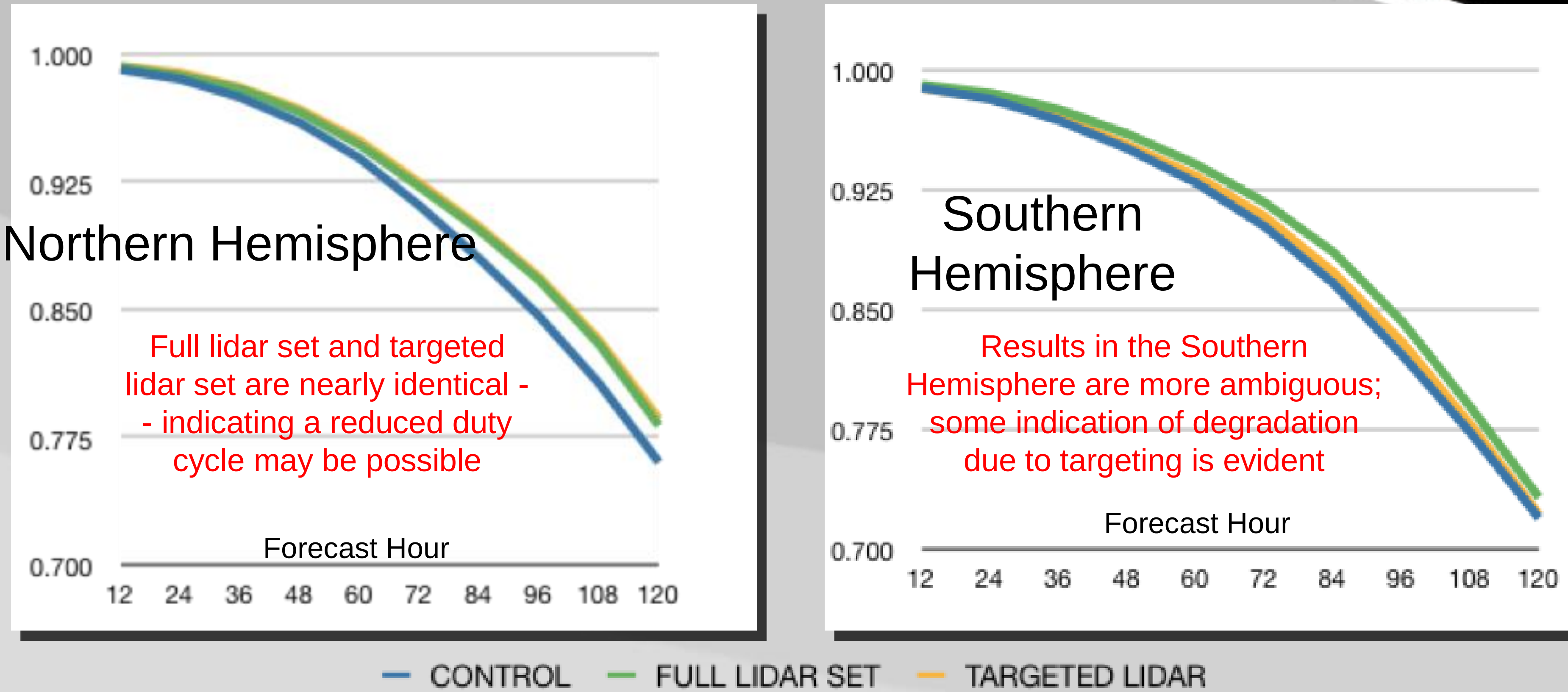


Lidar data deleted when there is "adequate" agreement with the numerical model's first guess wind fields

Designed to simulate suppression of the aft shot of the lidar

Result: Nearly 30% of the lidar's duty cycle may be reduced -- IF there is no discernible impact to forecast skill!

Simulation 1 Results



Impact of duty cycle reduction on forecast skill, 20 day assimilation with 5-day forecasts launched at 00z each day. Results represent an aggregate over all forecasts

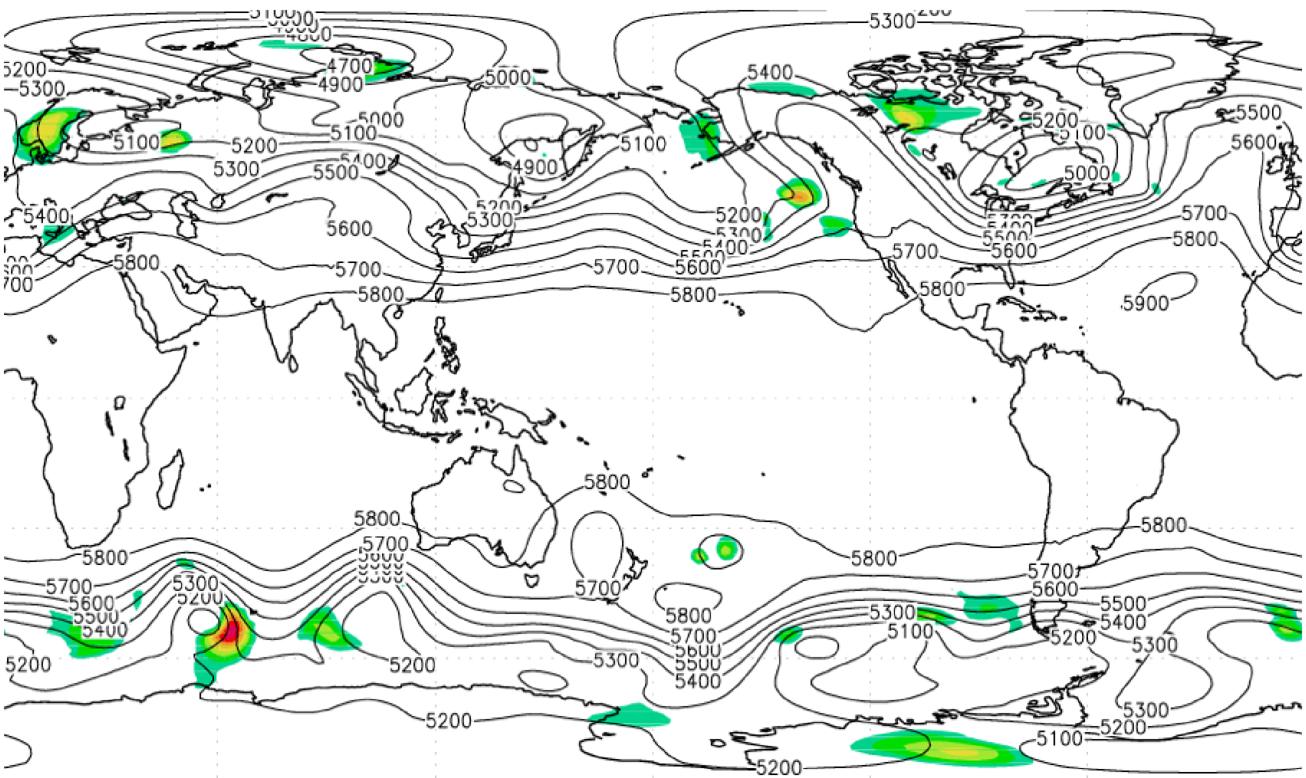
Application of Sensor Web Concepts

- **Simulation 2: <u>Better Science</u> via Targeted Observations**
- Goal is to target two types of features to help improve predictive skill:
  - "Sensitive regions" of the atmosphere: those regions where the forecast is highly responsive to analysis errors
  - Features of interest that may lie outside of the instrument's nadir view
    - Tropical cyclones
    - Jet streaks
    - Rapidly changing atmospheric conditions
- Would require slewing
- Would require optimization to choose between multiple targets
- Studies have shown that targeted observations can improve predictive skill (difficult to implement operationally)

Source: D. Emmitt and Z. Toth, 2001: Adaptive targeting of wind observations: The climate research and weather forecasting perspectives. Preprints, 5th Symposium on Integrated Observing Systems, AMS.

Calculating "Sensitive Regions"

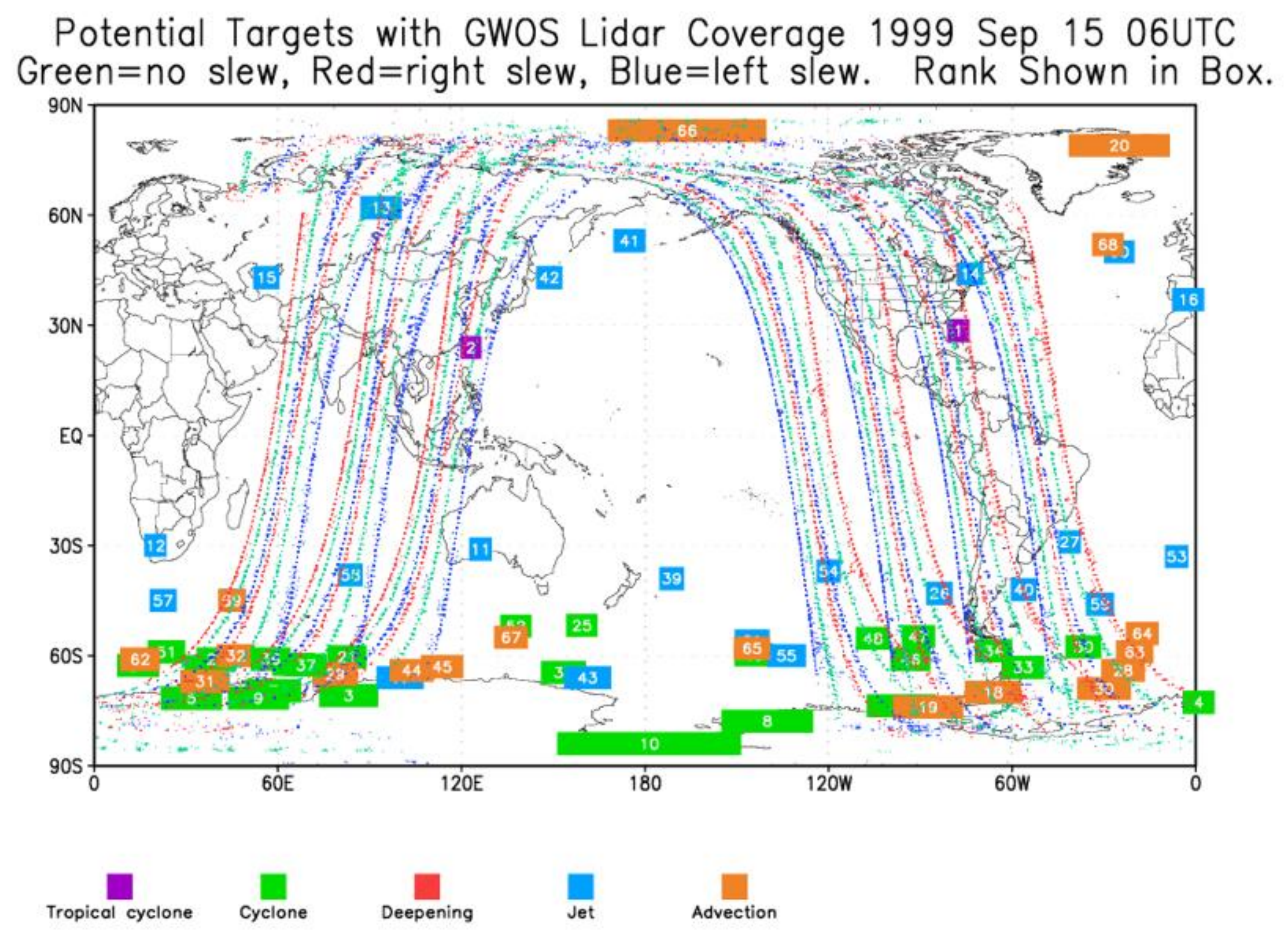
Differences between two forecasts launched 72 hours apart and valid at the same forecast hour. Largest differences ("sensitive regions") depicted in colored shading.



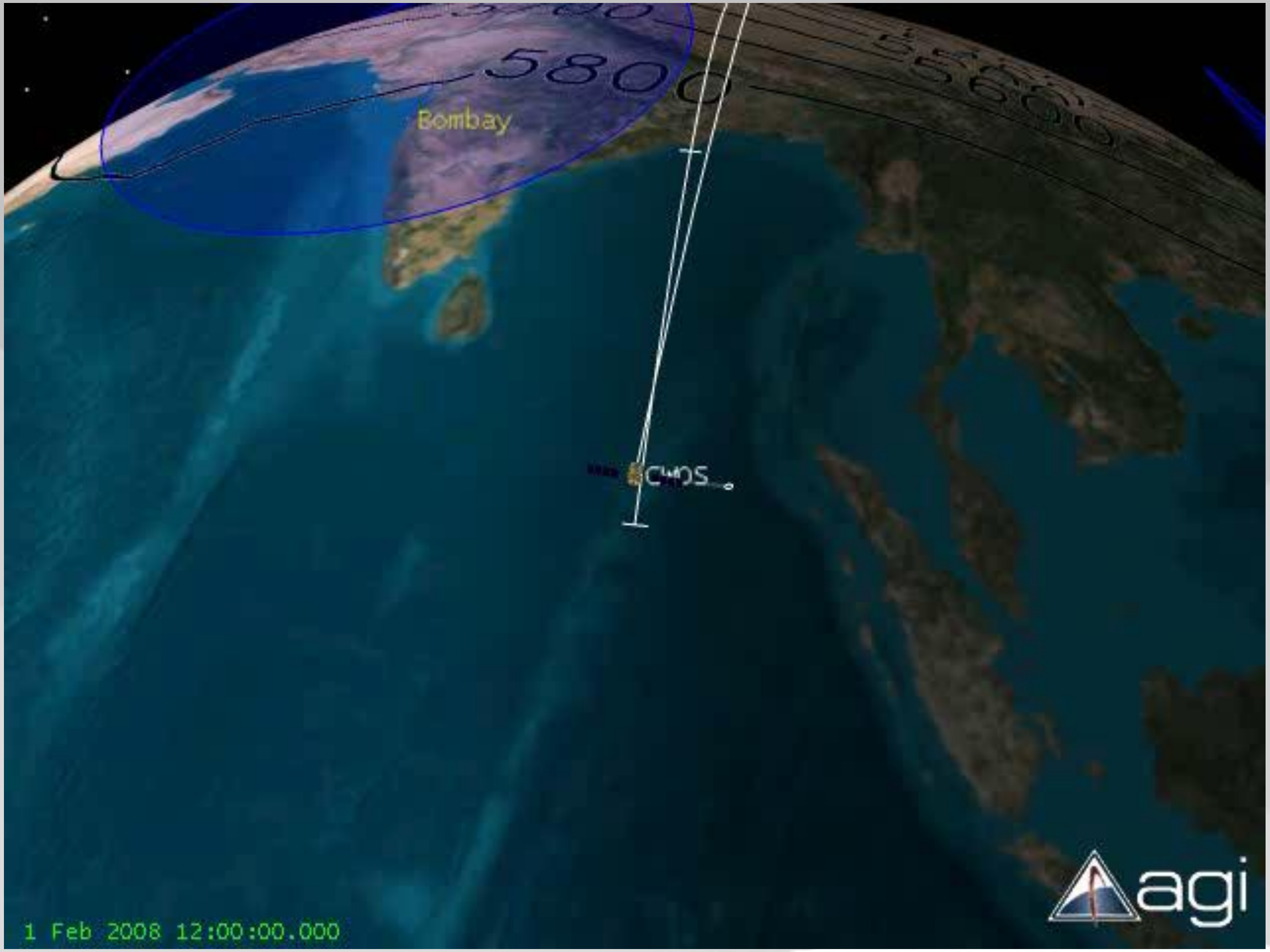
Studies have shown the adjoint technique to be effective for adaptive targeting†. Testing with this technique will occur during years 2-3 in coordination with NASA's Global Modeling & Assimilation Office.

†Leutbecher, M., and A. Doerenbecher, 2003: Towards consistent approaches of observation targeting and data assimilation using adjoint techniques. Geophysical Research Abstracts, Vol. 5, 06185, European Geophysical Society.

Selecting Specific Targets



Simulation 2: Adaptive Targeting

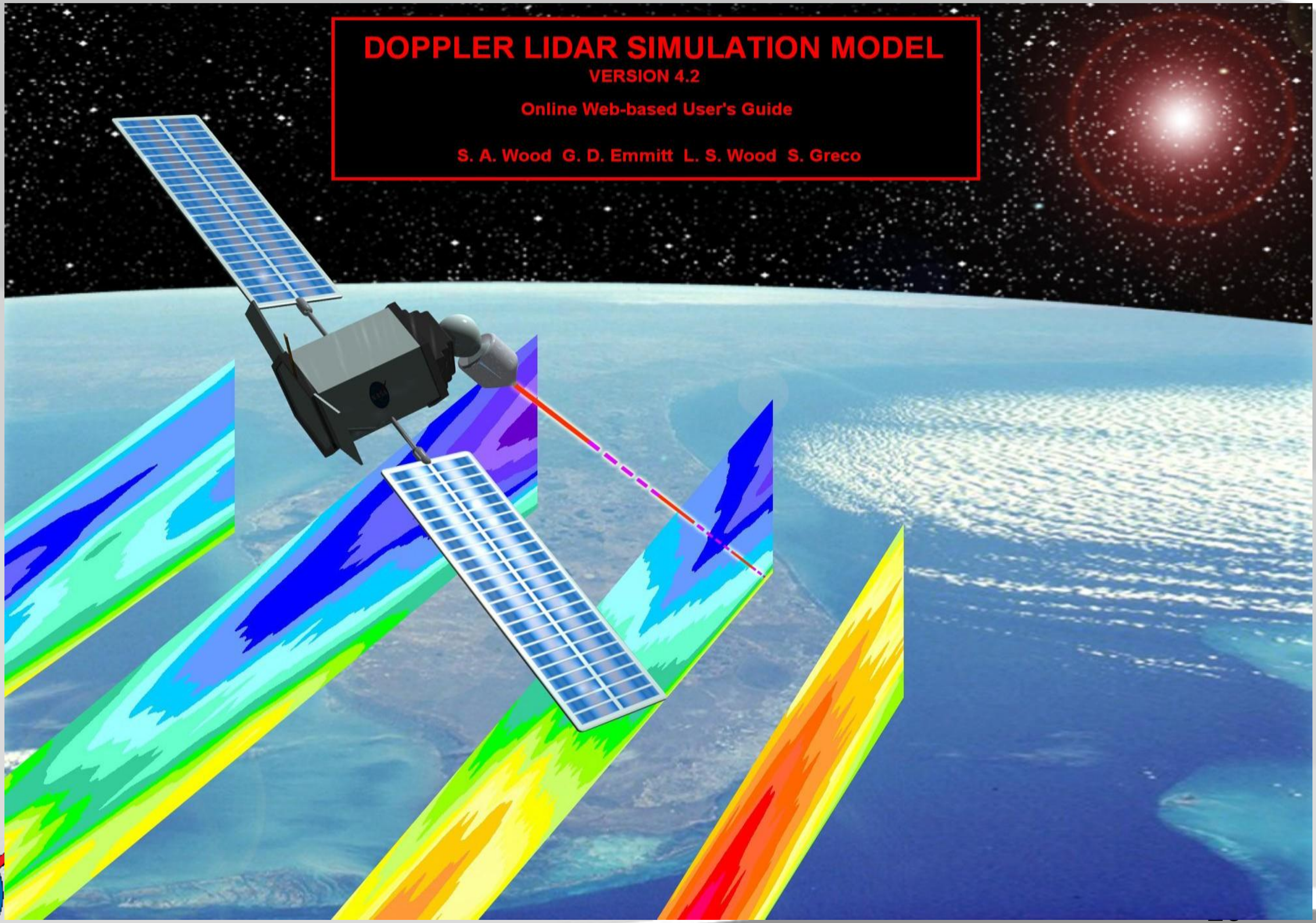


Approach

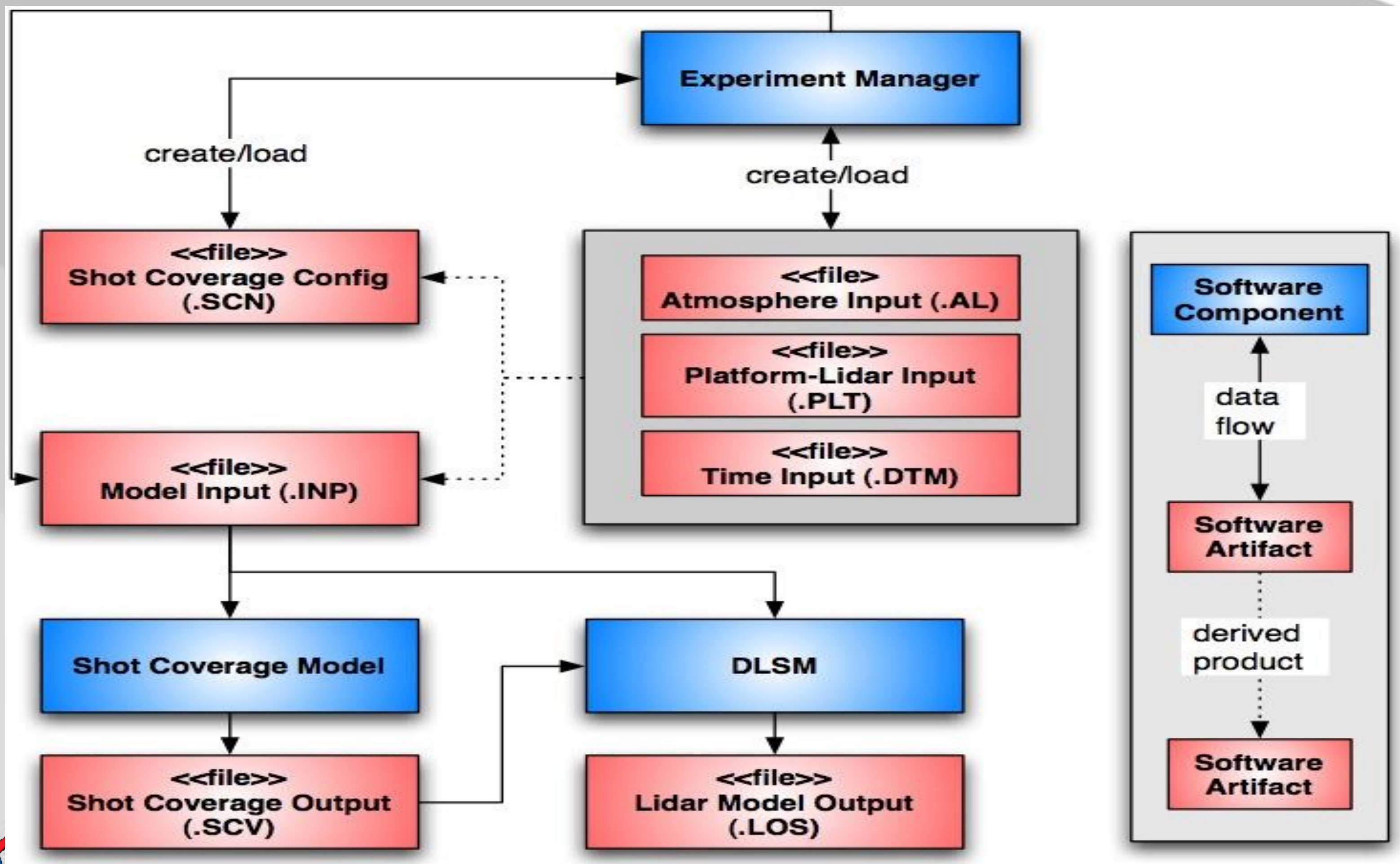
- **Sensor Web Simulator Design**
- During 2007 most elements of the lidar use case (1-5) were executed “by hand” to help aid in the design of the simulator prototype
- Five separate Observing System Simulation Experiments (OSSEs) were conducted that concluded:
  - Under certain situations[1], the lidar duty cycle may be reduced 30% without impacting forecast skill
  - Under certain situations, having the model task the lidar to perform a roll maneuver improves detection of features of interest 30% (tropical cyclones, jet streaks, rapidly changing atmospheric conditions)
- **SIVO Workflow Tool (“NASA Experiment Design”)**
- Selected as the “glueware” to sequentially execute components 1-6 and manage data flow

1 The OSSEs performed were based upon a 20 day assimilation cycle during September 1999. Although the use cases have been examined by GMAO scientists they have not undergone a rigorous scientific review and the results should not be considered scientifically valid. OSSEs presented here are to validate engineering processes of the simulator.

DLSM


DOPPLER LIDAR SIMULATION MODEL
VERSION 4.2
Online Web-based User's Guide
S. A. Wood G. D. Emmitt L. S. Wood S. Greco

MODEL INPUTS



LATEST RESULTS

In Spring, 2008 Simpson Weather Associates, Inc. established the Doppler Lidar Simulation Model version 4.2 onto an Apple dual quad processor computer for the SensorWeb project. SSH, the network protocol that allows data to be exchanged over a secure channel between two computers, was installed and tested. SWA and SIVO were able to test the push/pull and communications functionality successfully. SIVO was able to push DLSM inputs to SWA and request model simulations. The DLSM was successfully executed and SIVO was able to retrieve DWL coverage and DWL line-of-sight wind products for a six hour simulation in less than 2 minutes.

NEAR FUTURE PLANS

- Line of Sight wind operator for the assimlation models
- Integrate Satellite Toolkit into the workflow tool to provide satellite location and attitude inputs
- Establish the T511 and T799 nature runs into DLSM database format including generating aerosol, molecular and cloud optical property databases
- Build the slewing capability into the scanner model
- Integrate into the Sensor Web the SWA cloud motion wind model
- Global OSSEs (maybe mesoscale OSSEs - hurricanes)