P1.12

Assessment of space based DWL in Joint OSSE

http://www.emc.ncep.noaa.gov/research/JointOSSEs

Fourth Symposium on
Lidar Atmospheric Applications
Phoenix, AZ 11-15 January 2009

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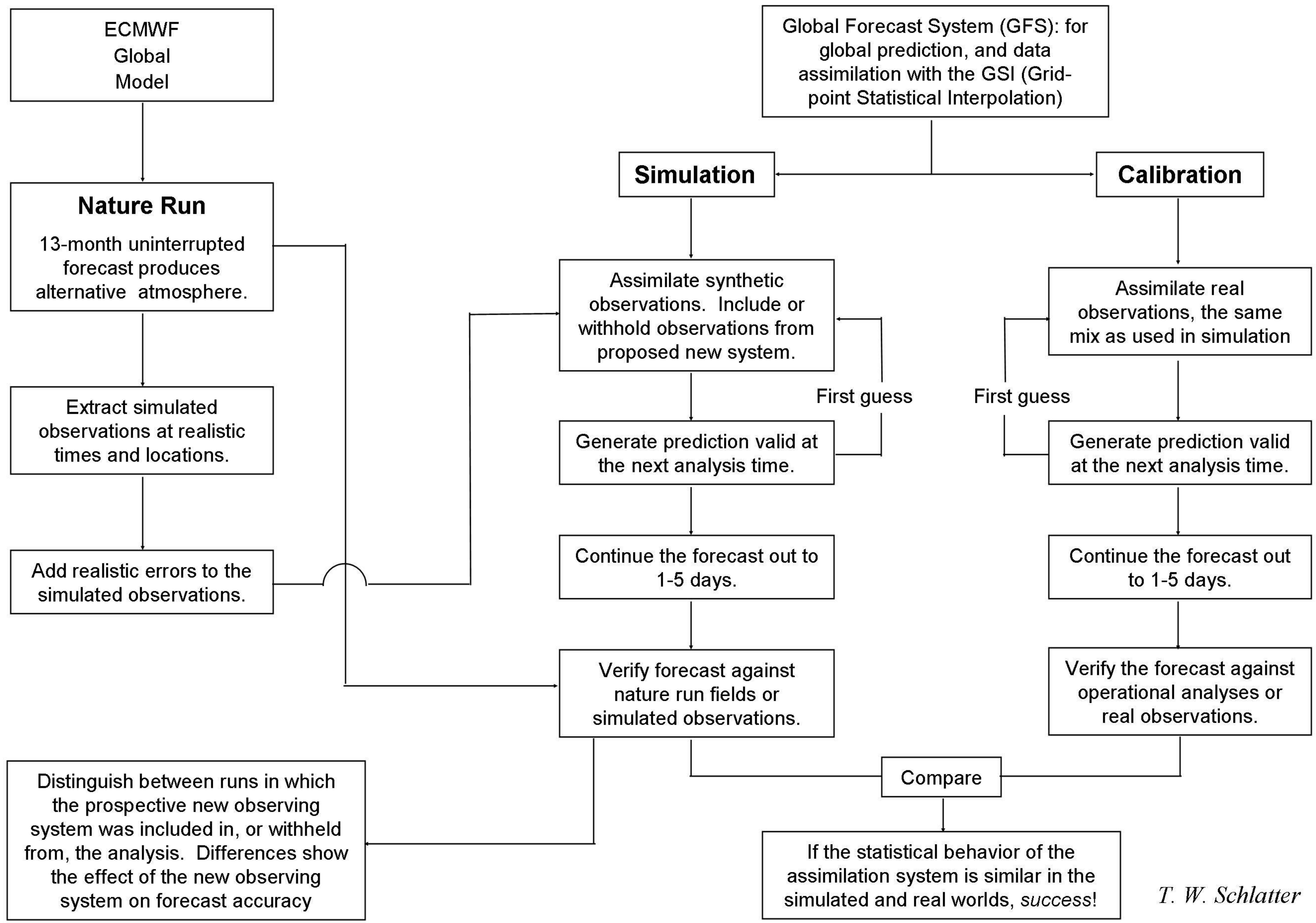
OSSEs: Observing Systems Simulation Experiments

A Global OSSE



T. W. Schlatter

Need for OSSEs

♦Quantitatively–based decisions on the design and implementation of future observing systems

♦ Evaluate possible future instruments without the costs of developing, maintaining & using observing systems.

If we cannot simulate observations, how could we assimilate observations?

Benefit of OSSEs

- OSSEs help in understanding and formulating observational errors
- DA (Data Assimilation) system will be prepared for the new data
- Enable data formatting and handling in advance of “live” instrument
- OSSE results also showed that theoretical explanations will not be satisfactory when designing future observing systems.

Need for collaboration

Need one good new Nature Run which will be used by many OSSEs, including regional data assimilation.

Share the simulated data to compare the OSSE results from various DA systems to gain confidence in results.

OSSEs require many experts and require a wide range of resources.

Extensive international collaboration within the Meteorological community is essential for timely and reliable OSSEs to influence decisions.

New Nature Run by ECMWF

Based on discussion with
JCSDA, NCEP, GMAO, GLA, SIVO, SWA, NESDIS, ESRL, and ECMWF

Low Resolution Nature Run

Spectral resolution : T511
Vertical levels: L91
3 hourly dump
Initial conditions: 12Z May 1st, 2005
Ends at: 0Z Jun 1,2006
Daily SST and ICE: provided by NCEP
Model: Version cy31r1

Two High Resolution Nature Runs

35 days long
Hurricane season: Starting at 12z September 27,2005,
Convective precipitation over US: starting at 12Z April 10, 2006
T799 resolution, 91 levels, one hourly dump
Get initial conditions from T511 NR

Note: This data must not be used for commercial purposes and re-distribution rights are not given. User lists are maintained by Michiko Masutani and ECMWF

Archive and Distribution

To be archived in the MARS system on the THORPEX server at ECMWF
Accessed by external users. Currently available internally as expver=etwu

Copies for US are available to designated users for research purpose& users known to ECMWF
Saved at NCEP, ESRL, and NASA/GSFC
Complete data available from portal at NASA/GSFC
Conctact:Michiko Masutani (michiko.masutani@noaa.gov), Harper.Pryor@nasa.gov
Gradsdods access is available for T511 NR. The data can be down loaded in grib1, NetCDF, binary. The data can be retrieved globally or selected region.
Provide IP number to :Arlindo da Silva (Arlindo.Dasilva@nasa.gov)

Supplemental low resolution regular lat lon data

1degx1deg for T511 NR, 0.5degx0.5deg for T799 NR

Pressure level data: 31 levels,
Potential temperature level data: 315,330,350,370,530K
Selected surface data for T511 NR: Convective precip, Large scale precip, MSLP,T2m,TD2m, U10,V10, HCC, LCC, MCC, TCC, Sfc Skin Temp
Complete surface data for T799 NR
T511 verification data is posted from NCAR CISL Research Data Archive. Data set ID ds621.0. *Currently NCAR account is required for access*.
T799 verification data are available from NASA/GSFC portal
(Contact Harper.Pryor@nasa.gov)
(Also available from NCEP hpss, ESRL, NCAR/MMM, NRL/MRY, Univ. of Utah, JMA,Mississippi State Univ.)

Evaluation of the Nature run

Cloud Cover

Comparison between the ECMWF T511 Nature Run against climatology

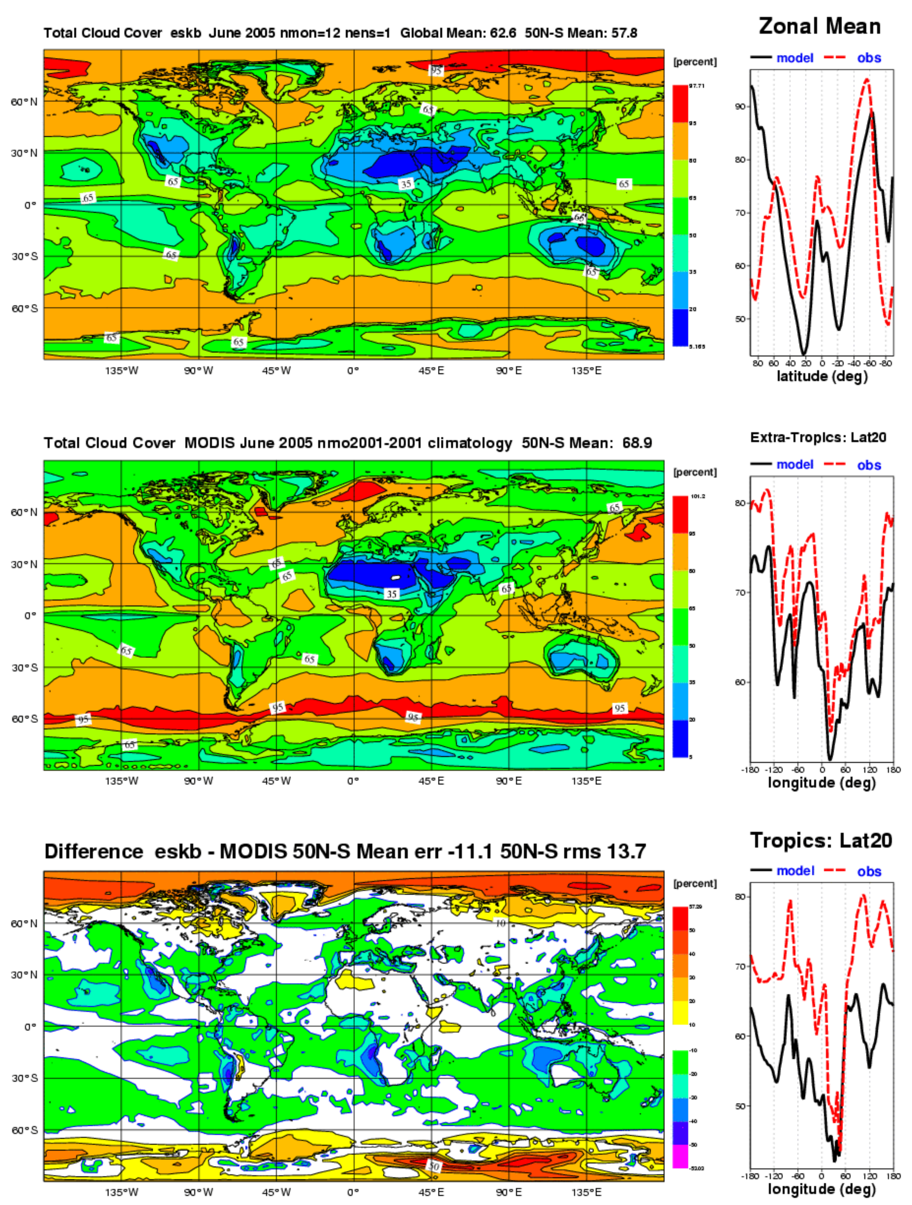
20050601-20060531, exp=eskb, cycle=31r1

Adrian Tompkins, ECMWF

NR

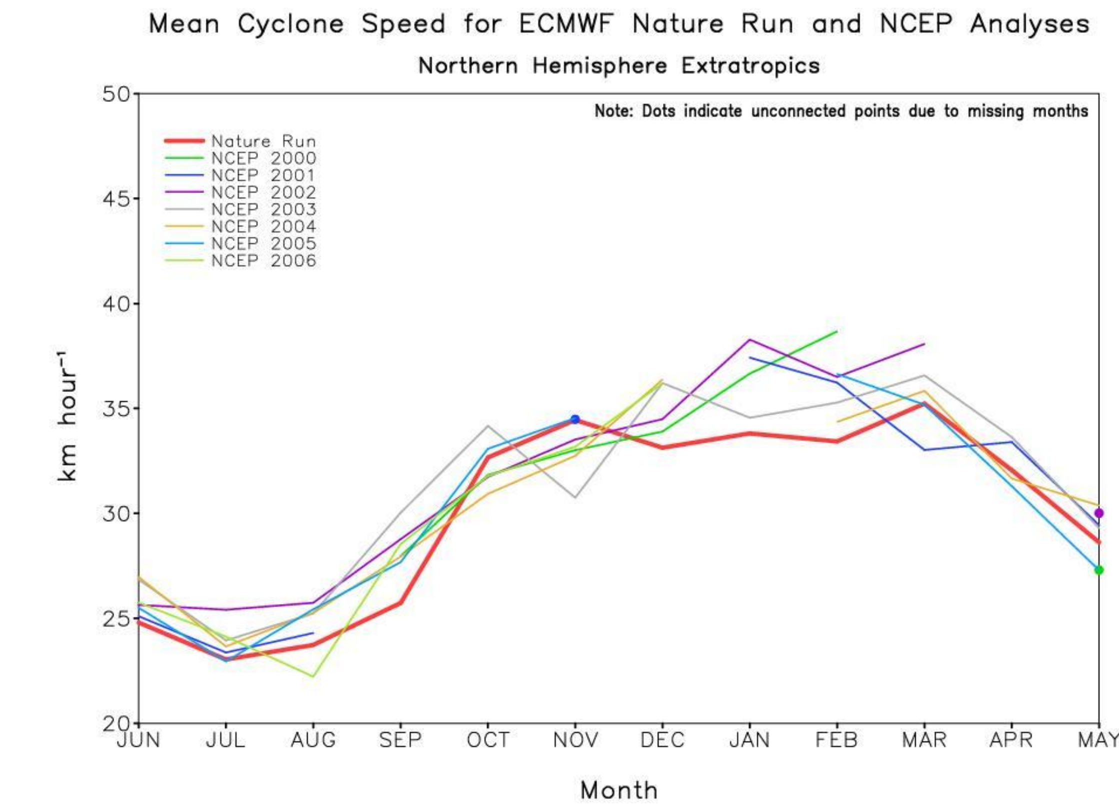
MODIS

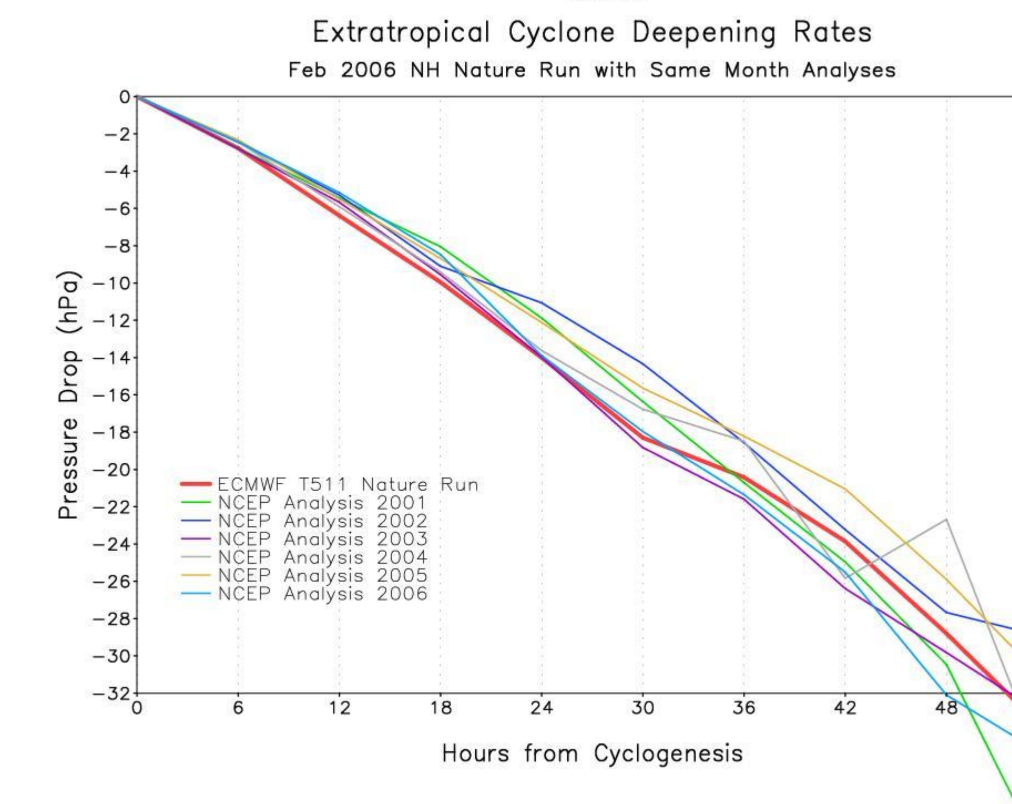
NR-MODIS



Utilize Goddard's cyclone tracking software (*Terry and Atlas, AMS conf, Aug 1996*):

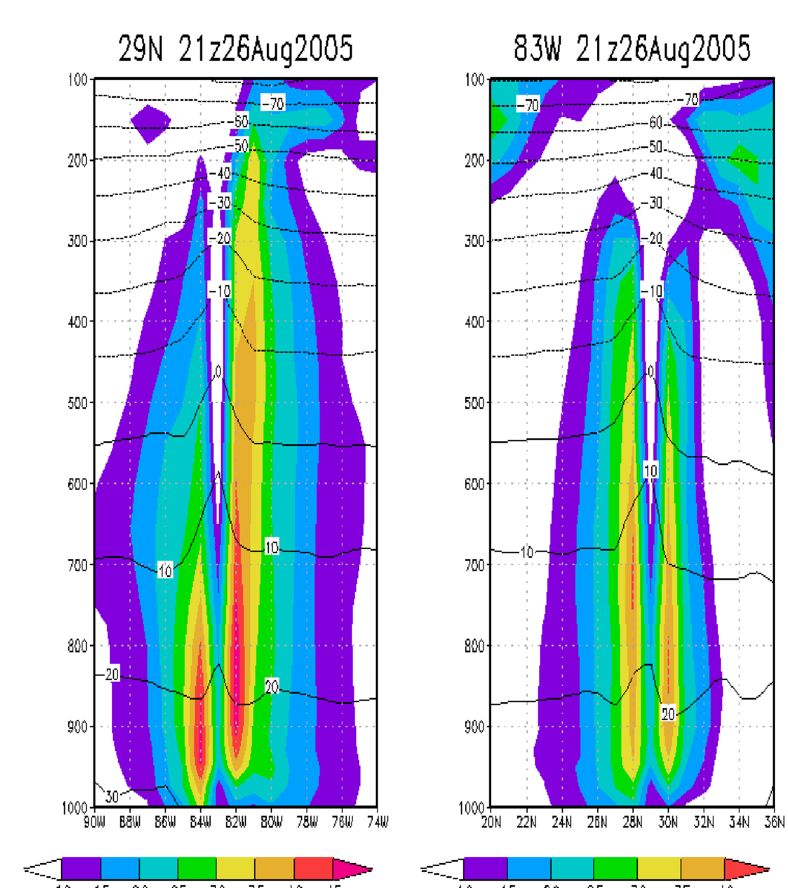
- Identifies and tracks mostly extratropical cyclones (cutoff at 20 deg N/S latitude)
- Interfaces with GrADS contouring algorithm
- Uses SLP field at 4hPa contour interval
- Finds centroid of inner-most closed isobar
- Tracks the centers using extrapolation and 500hPa steering





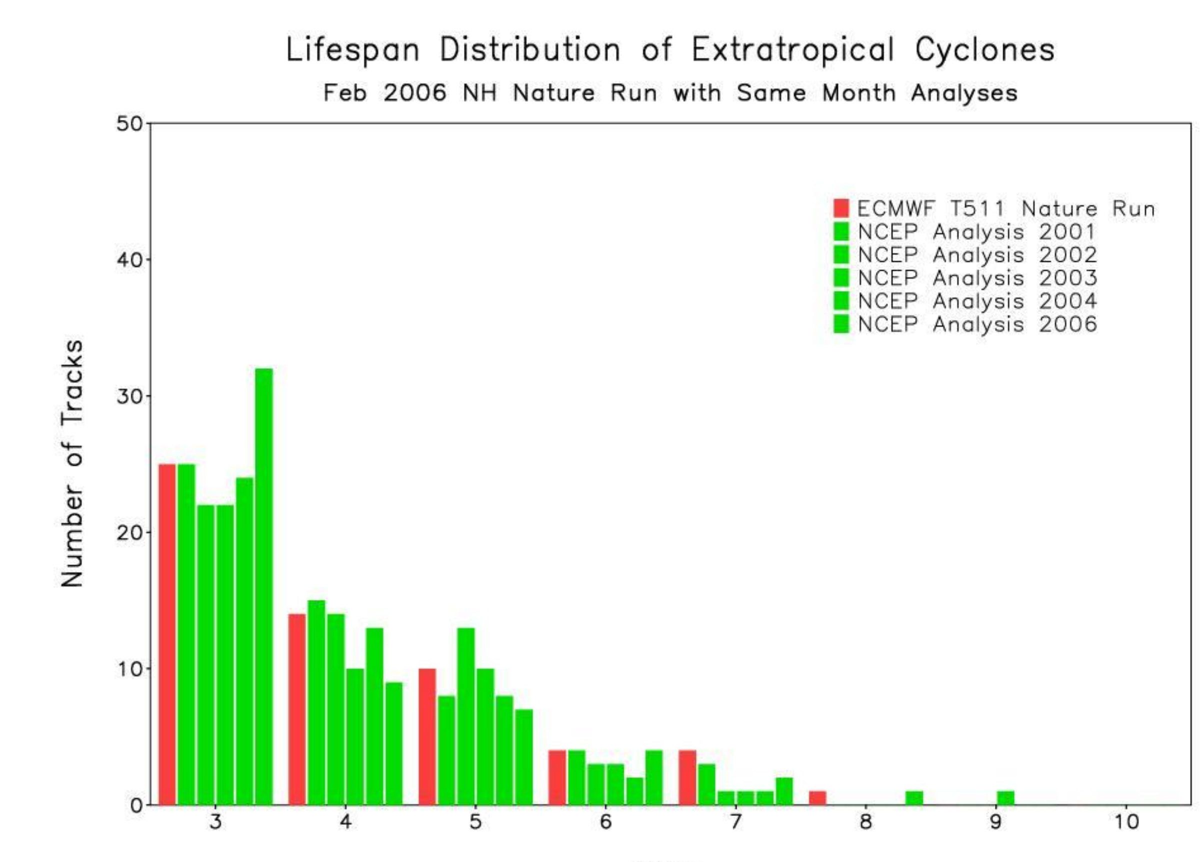
Tropics
Oreste Reale (NASA/GSFC/GLA)

Vertical structure of a HL vortex shows, even at the degraded resolution of 1 deg, a distinct eye-like feature and a very prominent warm core. Structure even more impressive than the system observed in August. Low-level wind speed exceeds 55 m/s



Cyclone tracks generated:

- Nature run at one degree for Jun 2005 to May 2006 (each month and season)
- NCEP operational analysis at one degree for 2000 to 2006 (each month, 68 of 84 months were available)



Simulation of Observation

GMAO Observation Simulator for Joint OSSE

- Software for generating conventional obs (Observation type included in NCEP .prepbufr file)

The codes are set up for raobs, aircraft, ships, vad winds, wind profilers, surface station data, SSMI and Quick scat surface winds, Cloud Motion Vector (CMV)

- Software for simulating radiances

Code to simulate HIRS2/3, AMSUA/B, AIRS, MSU has been set up. Community Radiative Transfer Model (CRTM) is used for forward model.

- Software for generating random obs. error

Observations are generated without errors but software to simulate error is provided.

The output of the data is saved in BUFR format which can be read by the Gridpoint Statistical Interpolation (GSI). GSI is a DAS used at NCEP, GMAO and ESRL. The codes are flexible and include many tunable parameters.

Contact: GMAO (Ronald Errico: ronald.m.errico@nasa.gov)
Joint OSSE (Michiko Masutani: michiko.masutani@noaa.gov).

OBS91L Nature Run Model level profiles for simulating radiance obs

Jack Woollen (EMC)

For development purposes, 91-level ML variables are processed at NCEP and interpolated to observational locations with all the information need to simulate radiance data (OBS91L).

The OBS91L are also available for development of a Radiative Transfer Model (RTM) for development of other forward model.

Conventional data, AMSUA, AMSUB, GOES datahas been simulated for entire T511 NR period.

Considerations
Data distribution depends on atmospheric conditions
Cloud and Jet location, Surface orography, RAOB drift

Cloud Motion Vectors SWA, GMAO and NCEP

- Advised by Chris Velden -

Sat wind was included to provide reasonable fields for SH
Radiation data are not included.
Initial data will have no error added and quality control is not necessary.

Radiance Simulation System for Joint OSSE

Ron Errico, Runhua Yang, Emily Liu, Meta Sienkiewicz, (NASA/GSFC/GMAO)
Tong Zhu, Tom Kleespies,Haibing Sun, Fuzhong Weng, (NOAA/NESDIS)
Jack Woollen, Michiko Masutani(NOAA/NCEP)
Lars Peter Riishojgaard (JCSDA)

Other possible resources and/or advisors *David Groff , Paul Van Delst (NCEP) Yong Han, Walter Wolf, Cris Bernet, Mark Liu, M.-J. Kim,* (NESDIS)*, Erik Andersson (ECMWF); Roger Saunders (Met Office)*

Initially, CRTM is used for simulation and assimilation.

CRTM: Community Radiative Transfer Model

Algorithm for determining cloud-cleared observation locations used at GMAO

For each grid box where a satellite observation is given, use the cloud fraction to specify probability that it is a clear spot. Then use random number to specify whether pixel is clear. Use a functional relationship between probability and cloud fraction that we can tune to get a reasonable distribution.

Calibration for Joint OSSEs

Calibration using the adjoint technique has been conducted at GMAO
Calibration using data denial experiments at ESRL, NCEP, and NESDIS

The GMAO simulation software was successfully installed at NCEP and initial simulation AIRS, HIRS2 and HIRS3 radiance data were completed for the entire period of T511 NR. GMAO software is also versatile to simulate other observing systems.

AMSUA, AMSUB GOES data have been simulated using OBS91L at NESDIS and NCEP for entire period of T511NR

Alternative software to simulate radiance data using the Stand-alone AIRS Radiative Transfer Algorithm (SARTA) as well as the CRTM is also being developed at NESDIS. NESDIS software includes results from various research. This will be important to evaluate CRTM in Joint OSSEs.

Discussion forum for observational errors

Extensive discussion on simulation of observational error particularly representativeness error.
Published in "Data assimilation: Making sense of observation" (Springer)

Calibration for Joint OSSEs at NASA/GMAO

Estimation of Impacts of Observations

1. The Energy Norm

$$E = \frac{1}{2A}\int\left[u'^2 + v'^2 + \frac{C_p}{T_r}T'^2 + \frac{RT_r}{p_{sr}^2}p_s'^2\right]\, dA\, d\sigma$$

2. Consider an analysis $\mathbf{x}_a = \mathbf{x}_b + \mathbf{K}\delta\mathbf{y}$ and forecasts $\mathbf{x}_f = \mathbf{M}(\mathbf{x})$
3. Consider the change in E between 2 forecasts

$$\Delta E \;=\; E(\mathbf{x}_a^f) \;-\; E(\mathbf{x}_b^f)$$

4. Consider the approximation for a subset of observations S_j

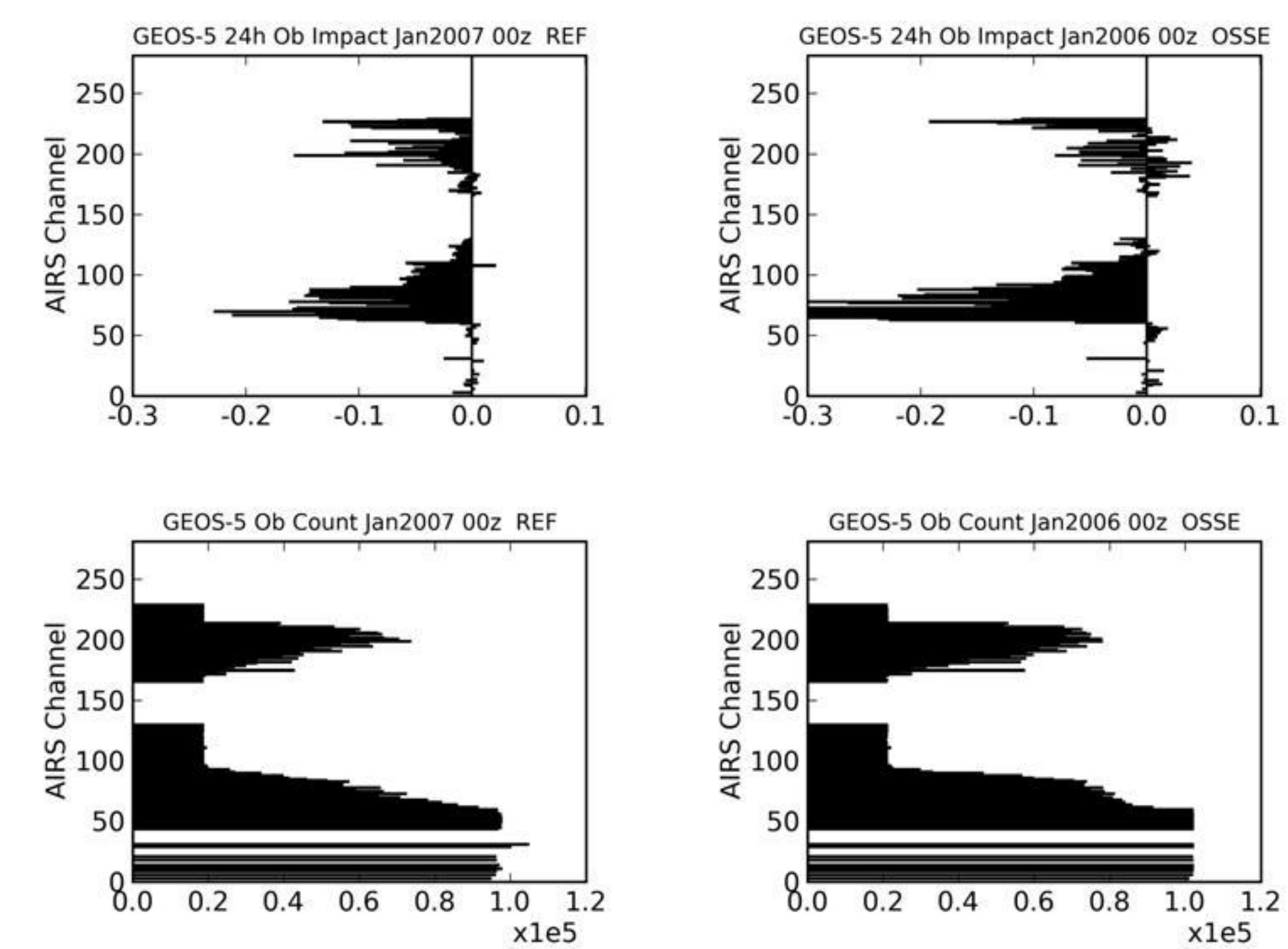
$$\delta_3 E_j \;=\; \sum_{i\in S_j} \delta y_i \; g_i$$

Langland and Baker 2004
Gelaro et al 2007, G. and Zhu 2008
Errico 2007, Tremolet 2007

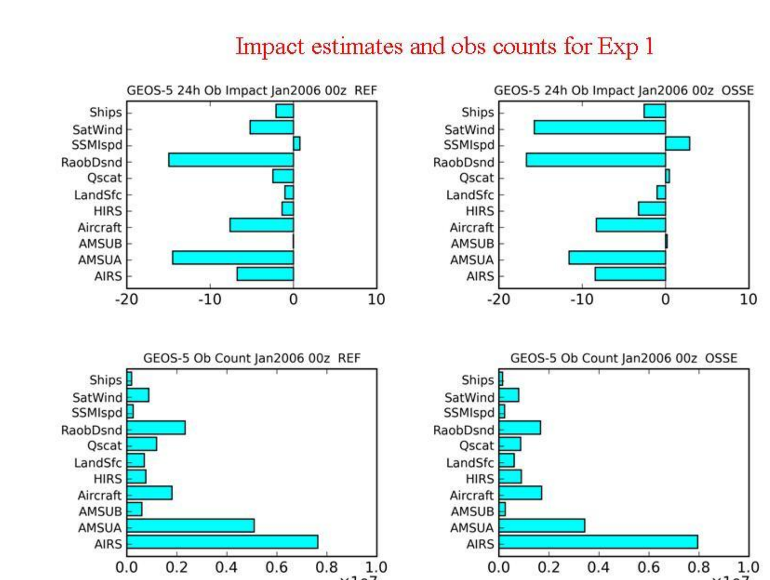
Exp 1 OSSE Calibration for Jan 2006 vs. Jan 2007 Reference

GEOS-5 DAS version and impact calculation **same**

Try 1

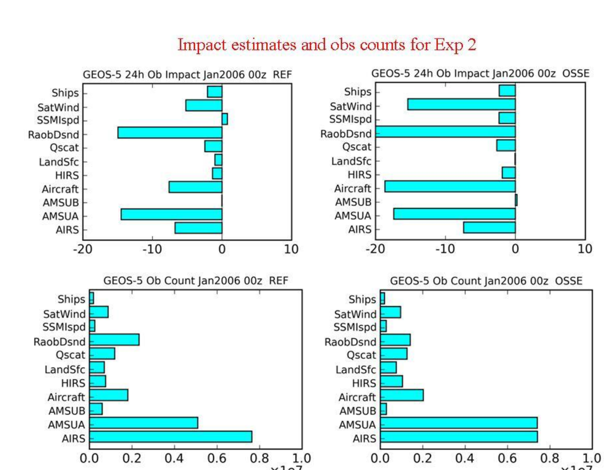


Try 1



REAL OSSE

Try 2



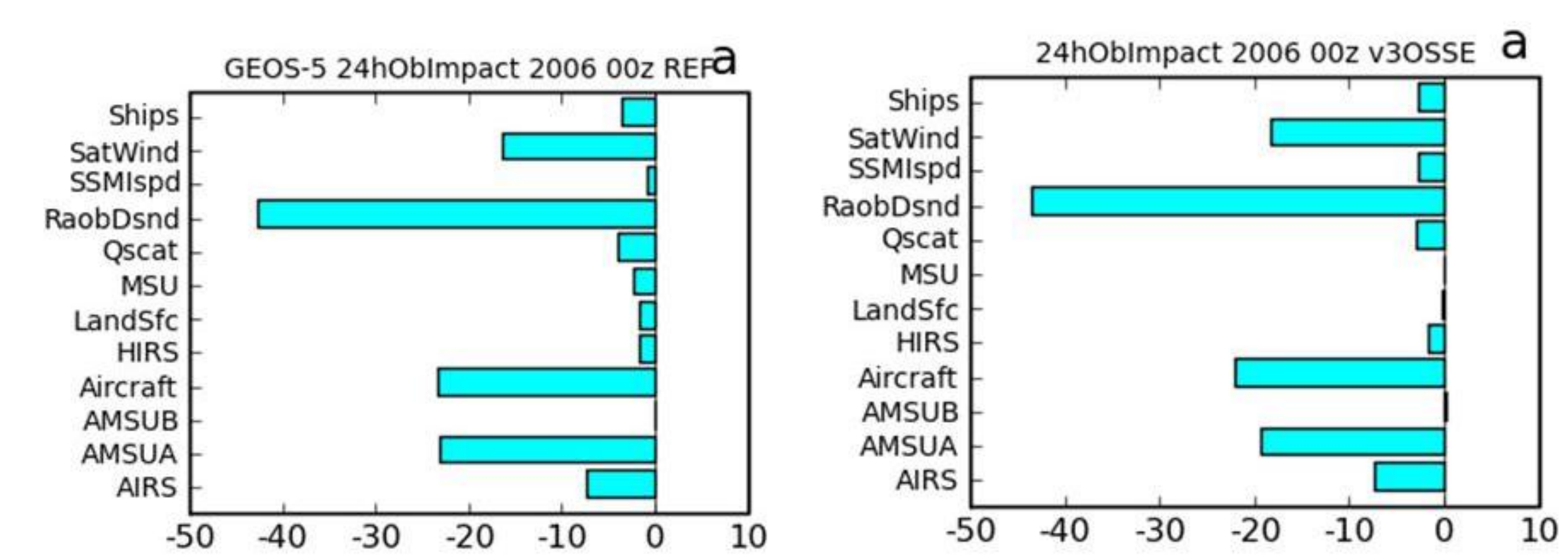
REAL OSSE

Continue working on tuning parameter for cloud clearing

Investigate problem in surface emissivity

Improving simulation of Cloud motion vector. (Need to work with SWA)

Latest try



Real Data OSSE

ADM-Aeolus simulation for J-OSSE KNMI plan
G.J. Marseille and Ad Stoffelen

TOGETHER

Towards a Global observing system through collaborative simulation experiments

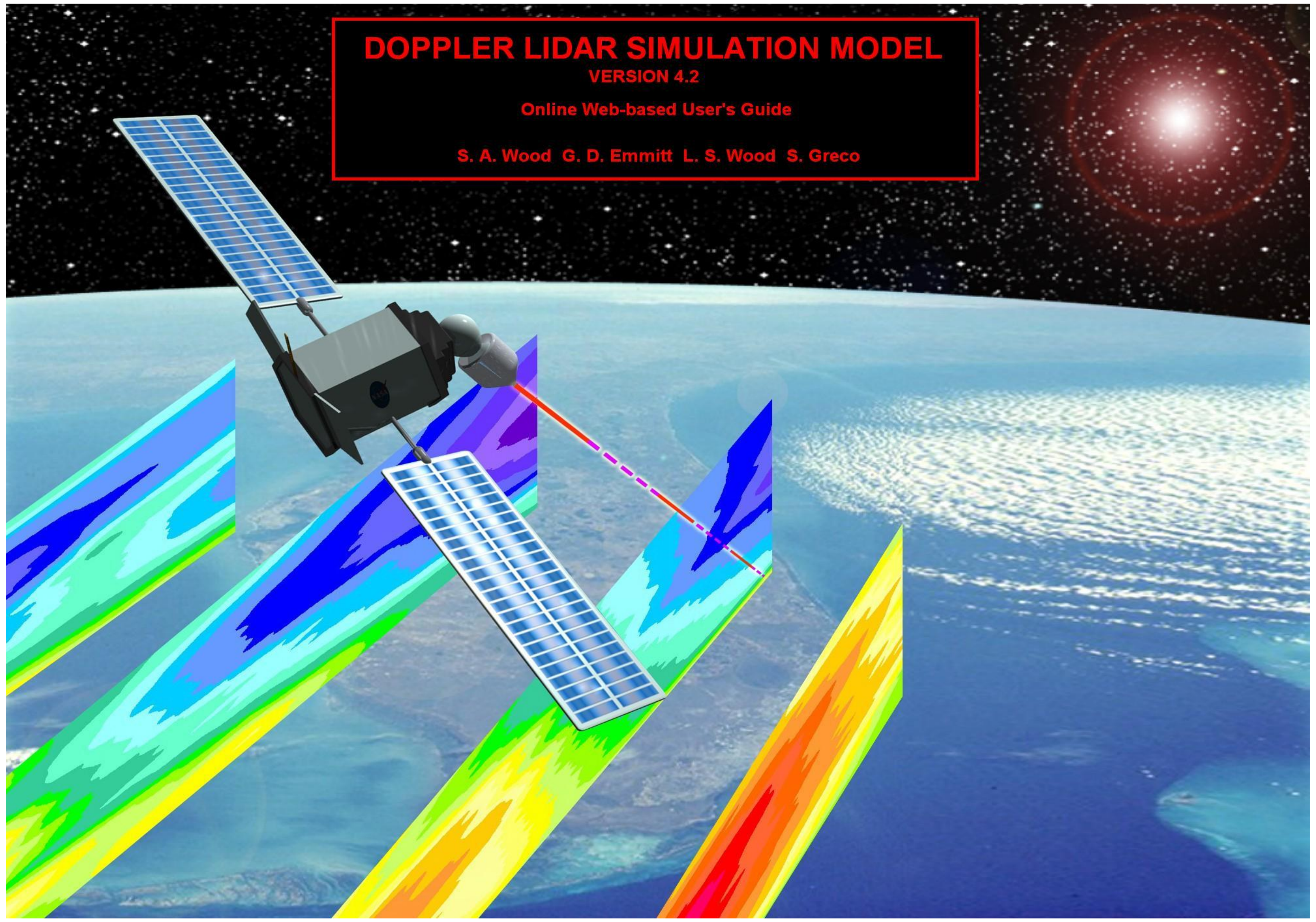
- Spring 2008: ADM Mission Advisory Group (ADMAG) advices ESA to participate in Joint OSSE
- KNMI writes TOGETHER proposal to ESA

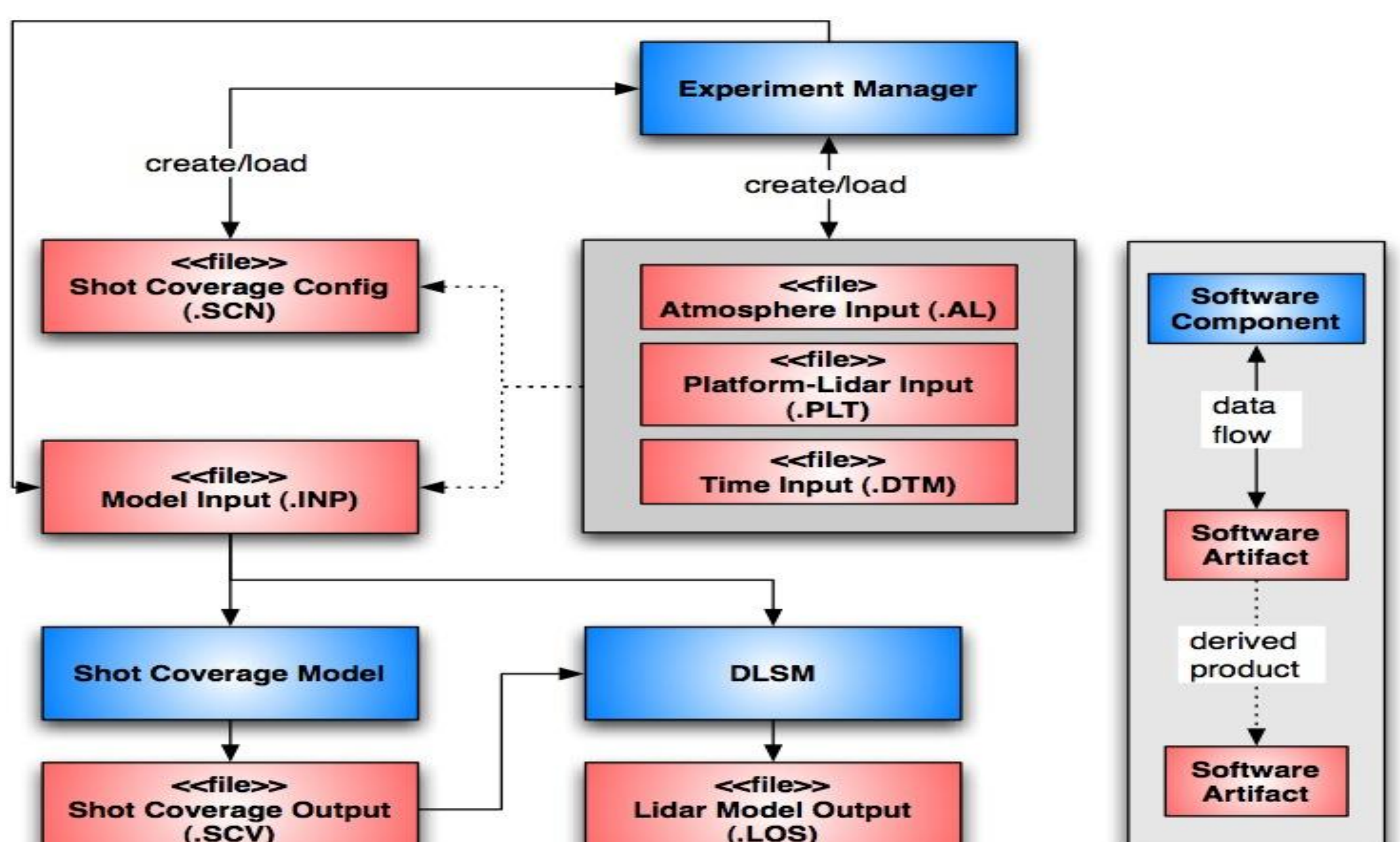
- ADM OSSE heritage, for details see Stoffelen et al., 2006
  http://www.knmi.nl/~marseill/publications/fulltexts/osse.pdf
- Tools for retrieving nature run fields from ECMWF archive
- Orbit simulator
- Interpolation of model fields to ADM location
  - “True” (HLOS) wind
- Instrument error: LIPAS (Lidar Performance Analysis Simulator)
  - For details see Marseille and Stoffelen, 2003
    http://www.knmi.nl/~marseill/publications/fulltexts/dwlsimul.pdf
  - LIPAS is updated and compatible with L2B processor performance
- Representativeness error
  - Unresolved model scales in nature run and ADM sampling determines representativeness error to be added to ADM HLOS wind observation

Verification against SWA ADM simulation. Simulation consistency needed on

- Clouds
  - Laser beam cloud hit from model grid box cloud cover. Random?
  - Cloud backscatter and extinction from model clouds
  - Maximum overlap between clouds in adjacent (vertical) levels
- Aerosols
  - Backscatter and extinction
  - Horizontal variability
    - along track over 50 km accumulation length
    - between adjacent observations (separated by 150 km)
  - Vertical variability (stratification)
- Dynamics
  - Wind variability over 50 km accumulation length

- ADM continuous mode
  - ESA decision December 2008
  - If continuous mode is selected then more funding will probably become available for additional simulation studies
- Simulation of post-ADM scenarios
  - EUMETSAT funding?





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)

Simulation of DWL in Cloudy conditions at SWA

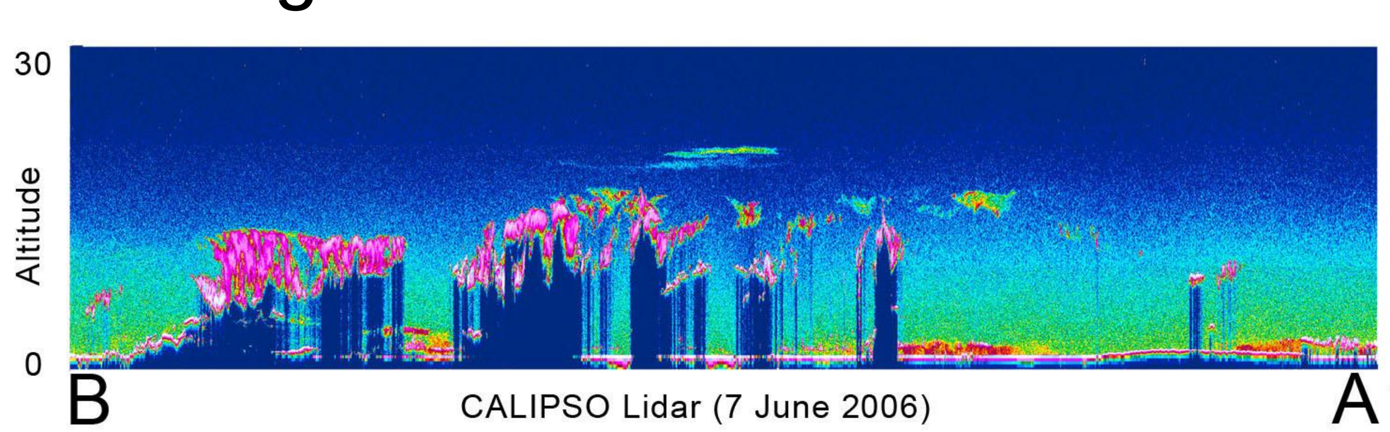
Utility of Doppler Wind Lidars in cloudy conditions

- There are concerns expressed that airborne lidars may be marginally useful in cloudy conditions (same for space-based lidars)
- Airborne and space-based data suggests otherwise.
- An airborne wind lidar combined with dropsondes makes a powerful combination
  - –The DWL can provide direct measure of representativeness of the dropsonde observations enabling dynamic assignment of representativeness in the total observation error (σ_o) assigned for DA.

Current expectations

- From space, current laser technology will detect cloud on 80% of individual laser shots; however, 80% of all laser shots will provide a ground return (i.e. 75% of the shots that intercept cloud will also provide a ground return (based upon analyses of GLAS data).

- Difficult to generalize for airborne lidars since mission objectives could be targeting cloudy phenomena. However, experience by those flying airborne lidars is that laser shots penetrate clouds far more frequently than initially expected. Thus clouds are seen as optically porous at near infrared wavelengths.



Vertical cross section of CALIPSO returns illustrating performance in very Cloudy areas. Note the returns below clouds.

Recommendations

- Recommend hybrid wind lidar for research from high altitude aircraft such as ER2, WB-57, Proteus, Global Hawk..
  - –Hybrid Doppler wind lidar (DWL) includes a molecular subsystem for aerosol weak regions
  - –A coherent sub system for cloudy situations and aerosol rich regions (PBL, elevated dust layers..)
- Co-fly hybrid DWL with dropsondes as will be done in TPARC using the NAVY P3 and the DLR Falcon.

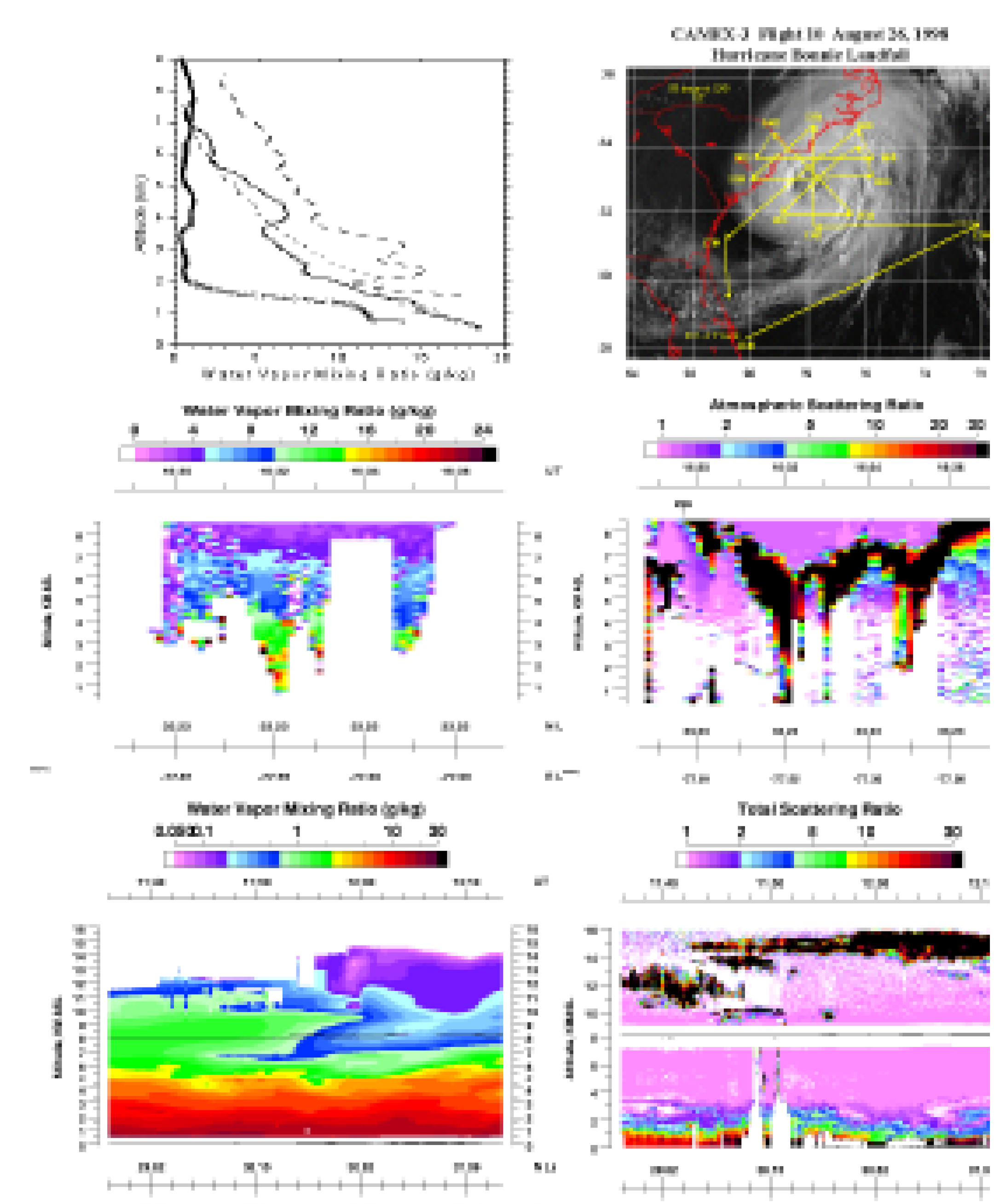


Figure 4. (Top Left) A comparison of LASE measurements of water vapor associated with Hurricane Bonnie: regions of subsidence (diamonds); rainband (solid line), edge of hurricane (dotted line); and eye region (dashed line). (Top Right) GOES image showing DC-8 flight track on August 26, 1998 when Bonnie made landfall. (Middle Left) LASE water vapor measurements in Bonnie's eye. (Middle Right) LASE total scattering ratio measurements in Bonnie's eye. Note that the eye still had considerable cloudiness at this time. (Bottom Left) LASE water vapor measurements acquired southeast of Bonnie. (Bottom Right) LASE total scattering ratio measurements acquired southeast of Bonnie.

Hurricane Bonnie, 1998

Data from an airborne water vapor DIAL flown by NASA

Figure from

LASE Measurements of Water Vapor, Aerosols, and Clouds During the NASA CAMEX-4 Experiment

Edward V. Browell, Principal Investigator

Syed Ismail, Co-Principal Investigator

Richard Ferrare, Co-Investigator

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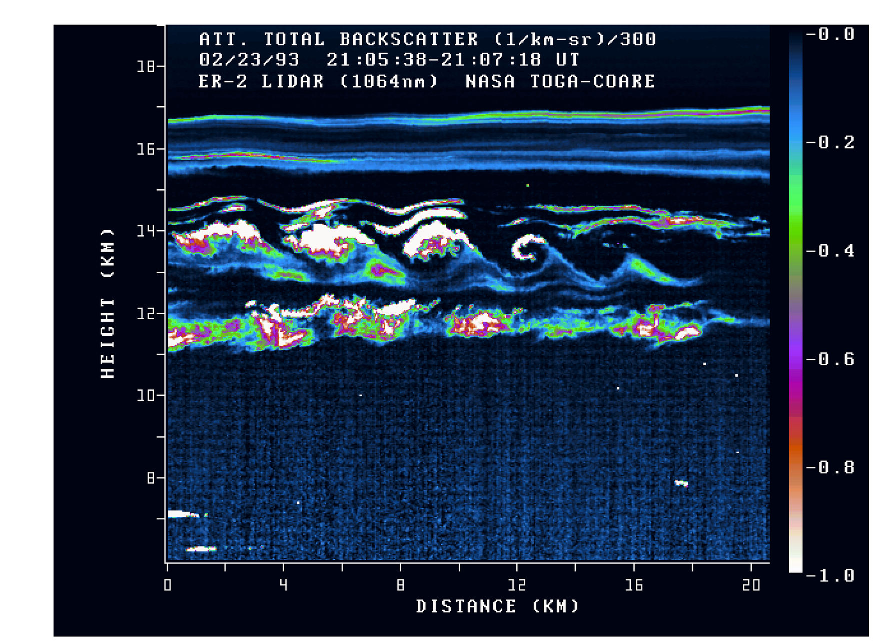
Fax: 757-8647790



Vertical cross section below Cloud Lidar System flown on ER2

- SPOT: Satellite Pour l'Observation de la Terre
- CFLOS: Cloud Free Line of Sight
- TODWL: Twin Otter Doppler Wind Lidar
- HRDL: High Resolution Doppler Lidar
- DIAL: Differential Absorption Lidar
- LITE: Lidar Technology Experiment
- GLAS: Geoscience Laser Altimeter System

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

[2]G. D. Emmitt, [2]S. Greco, [2]S. A. Wood, M. Seablom, [5]E. Brin, [5,6,$]L. P. Riishojgaard

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 Goal

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

- **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)

Adaptive Targeting

Regional OSSEs at the University of Utah

Zhaoxia Pu, University of Utah (Zhaoxia.Pu@utah.edu)

* Use WRF model and NCEP GSI for data assimilation
* Evaluate the global natural runs for regional OSSEs
* Assess the impact of future DWL data on high-impact weather forecasting; focused on the hurricane intensity forecast.
* Investigate the basic problems/challenges, such as boundary conditions and resolution issues in regional OSSEs

Presented at IOAS-AOLS 13.5 Thursday 2:30

Simulation of DWL at NASA/GSFC

Focused on DWL developed at NASA/GSFC

Simulation of aerosol for Joint OSSE Nature Run.
The simulated aerosol will be available for Joint OSSEs

Assimilation of DWL and testing the impact.

NCEP conducted DWL impact test using SSI.

GSI is getting ready for simulation of lidar and being tested and compare with SSI.

Summary

● GMAO Software to calibrated basic data of is ready for release.

● Further development and more software are being developed in NCEP, NESDIS, and ESRL.

● Data base and computing resources has been set up for DWL simulation and SWA

● Limited funding has been allocated to KNMI for DWL OSSEs

● Preliminary version of basic data set has been simulated for entire T511NR period.

- OSSEs are expensive, but can be a cost-effective way to optimize investment in future observing systems
- OSSE capability should be multi-agency, community owned to avoid conflict of interest
- Independent but related data assimilation systems allows us to test robustness of answers
- Joint OSSE collaboration remains only partially funded but appears to be headed in right direction

Presentation about Joint OSSE at IOAS-AOLS 13.2 Thursday 1:30