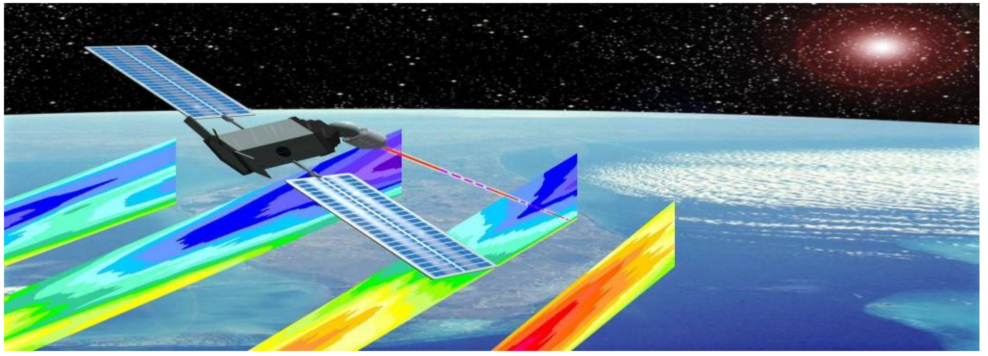
Potential Impacts of a Space-based Doppler Wind Lidar



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20-24 January 2008

Outline

- Description of a proposed Doppler Wind Lidar to meet need for global wind soundings
- Brief overview of OSSEs in general
- Summary of some past DWL OSSE results
  - Global
  - Regional
- Current simulations for planned OSSEs

Motivation

- The NWP communities and the NPOESS program have identified 3D global tropospheric (and stratospheric) winds as having the highest priority as a new observing capability. ***Global tropospheric winds are NPOESS's #1 unaccomodated EDR.***

- The NRC Weather Panel determined that a Hybrid Doppler Wind Lidar (DWL) in low Earth orbit could make a **transformational** impact on global tropospheric wind analyses.

- Computer modeling studies at NCEP, NASA and ESA have shown that 3D tropospheric ***wind profiles are critical to advancing operational forecasting skills***.

- Cost benefit studies show that global 3D wind observations would have ***significant cost/safety impacts*** on aviation (> $100M$/yr), severe weather preparation (evacuation cost avoidance > 100M$/yr) and military operations (>15M$/yr).

Global Wind Observing Sounder (GWOS)

- Space-borne **hybrid** Doppler Wind Lidar
  - Includes both aerosol **coherent** (lower troposphere) and molecular **direct detection** (mid- and upper troposphere) measurement systems

- First space-borne Doppler Wind Lidar to provide true vector winds
  - ADM/Aeolus provides LOS winds for one direction only
  - Several independent simulation studies have shown vector wind information to be more useful for data assimilation

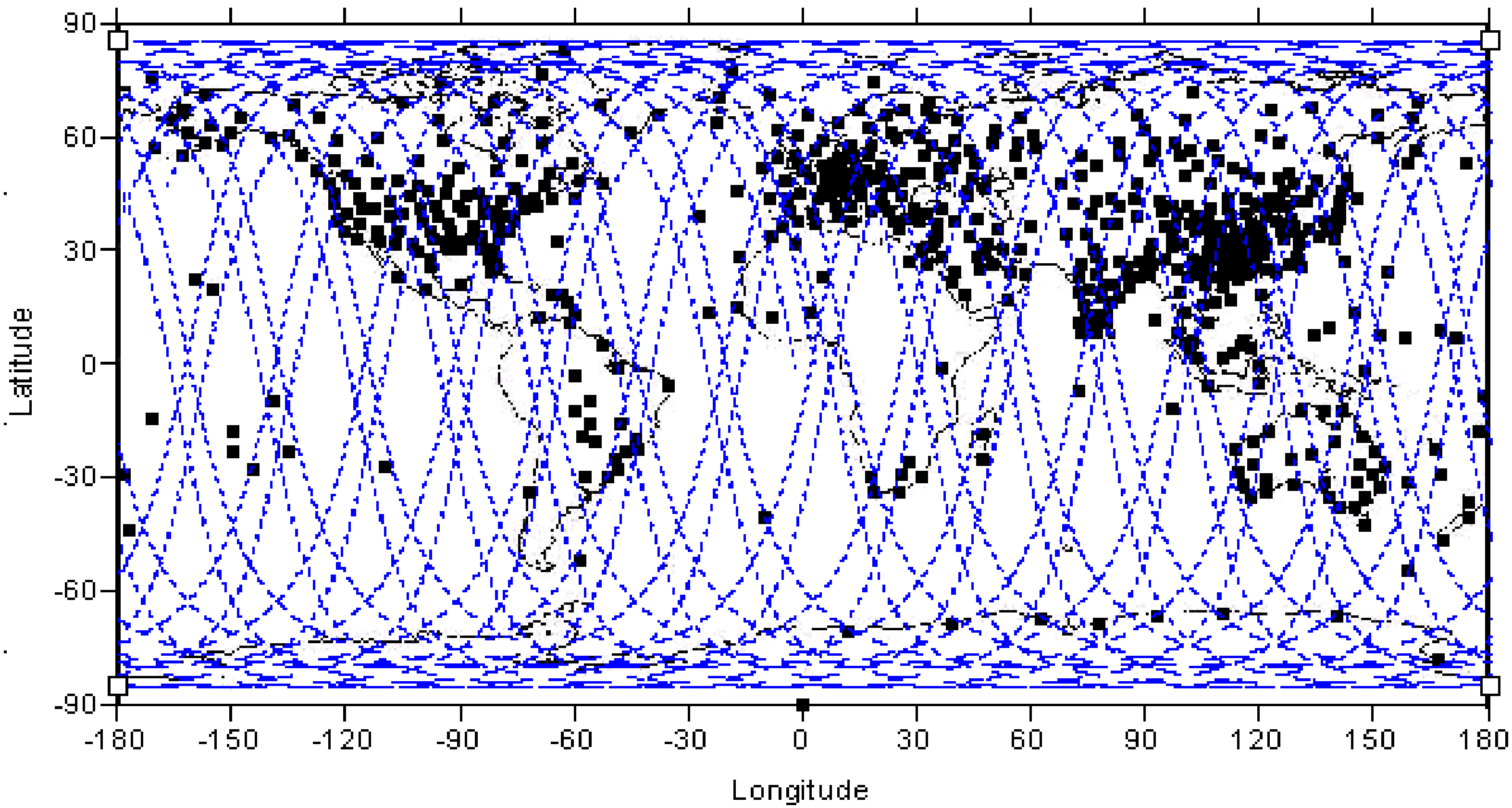
Proposed Initial DWL Mission Concept

- Demonstrate instrument architecture
  - Hybrid DWL
    - Direct detection for molecular backscatter
    - Coherent detection for aerosol backscatter
  - 2 tracks, bi-perspective
  - < 3 m/s HLOS accuracy throughout troposphere
  - 0-20 km altitude (higher with more averaging)
- Employ adaptive targeting (optional)
  - < 100% duty cycle to reduce platform power requirements and extend laser lifetimes
  - Select high NWP impact targets

GWOS Coverage

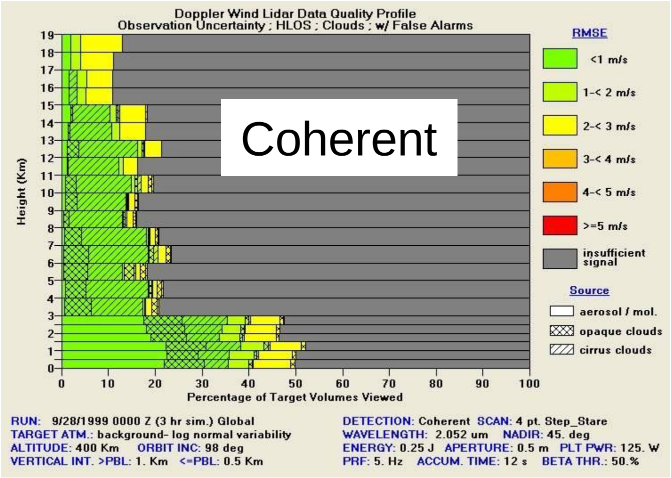
• **Around 600 radiosonde stations (black) provide data every 12 h**

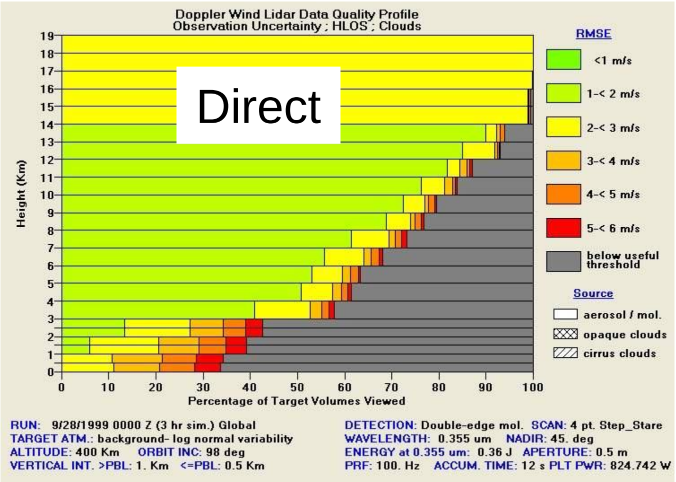
• **GWOS (blue) would provide ~3200 profiles per day**



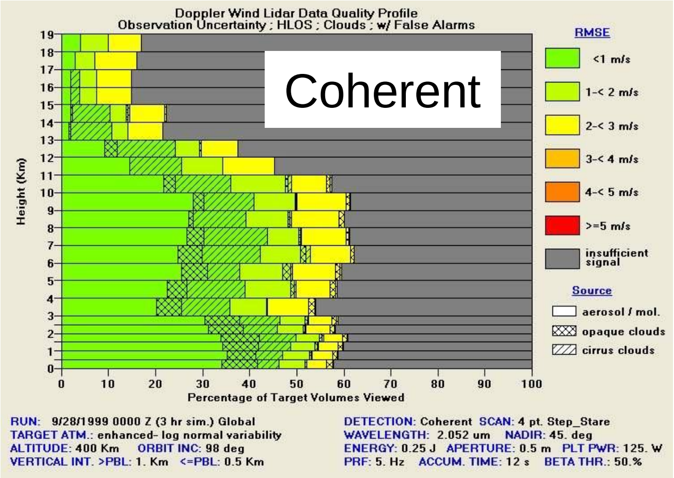
Vertical Distribution of GWOS LOS Observations

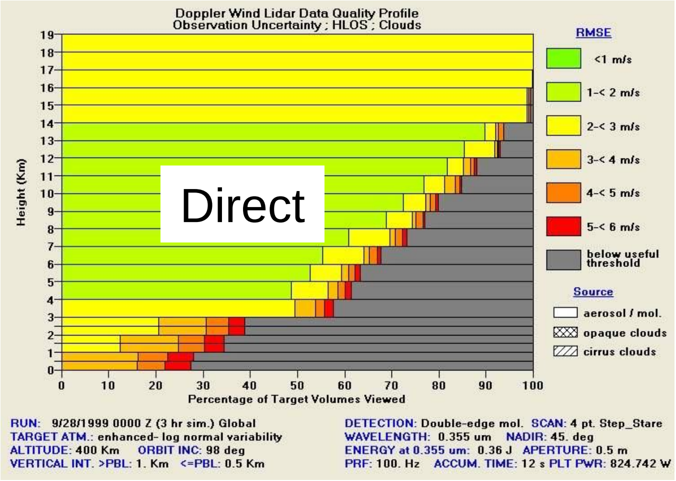
GWOS with background aerosol mode





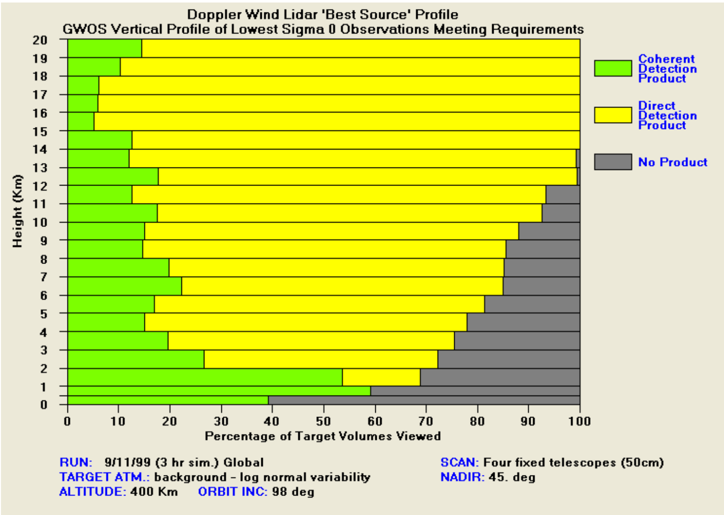
GWOS with enhanced aerosol mode





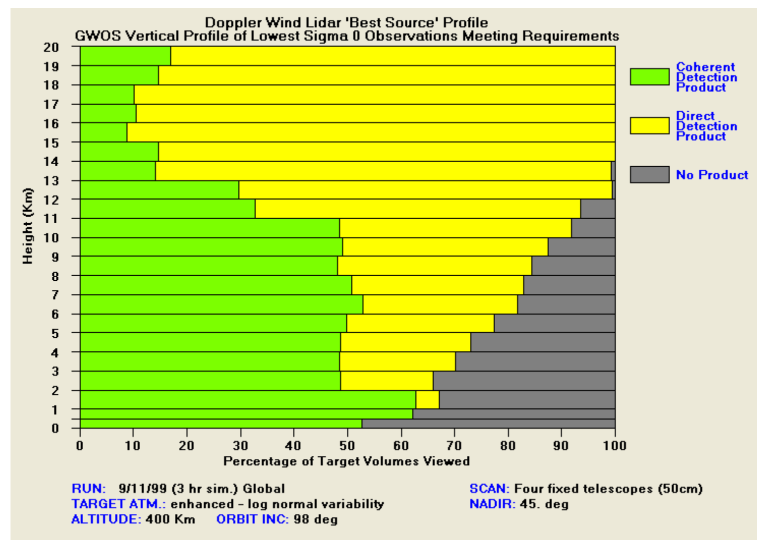
Vertical Distribution of “Best choice” LOS Observations

GWOS with background aerosol mode



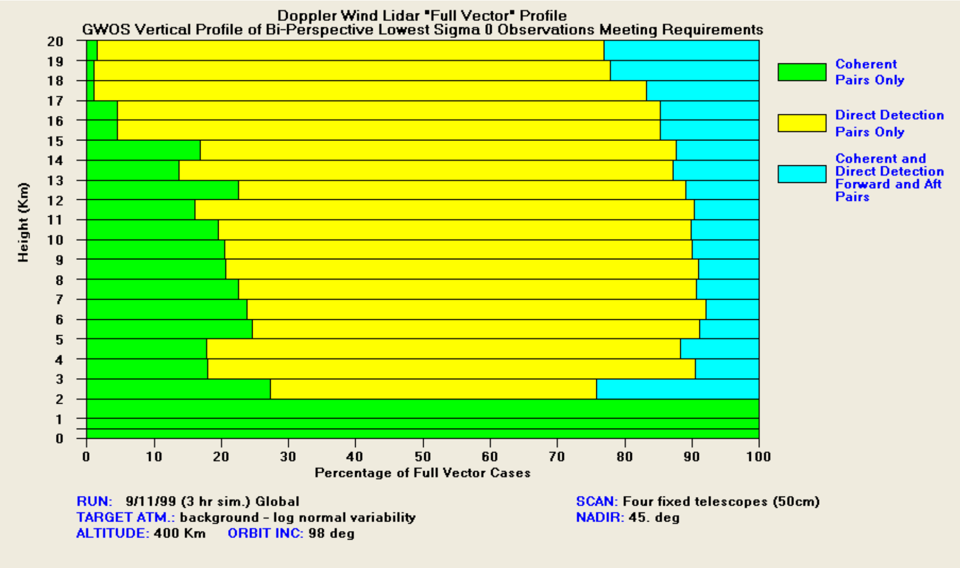
Dual sampling with the coherent and direct detection molecular Global Wind Observing Sounder (GWOS)

GWOS with enhanced aerosol mode



Green represents percentage of sampled volumes when coherent subsystem provides the most accurate LOS measurement; **Yellow** is for direct detection; **Gray** is when neither system provides an observation that meets data requirements due to signal strength or cloud obscuration

GWOS Synergistic Vector Wind Profiles*



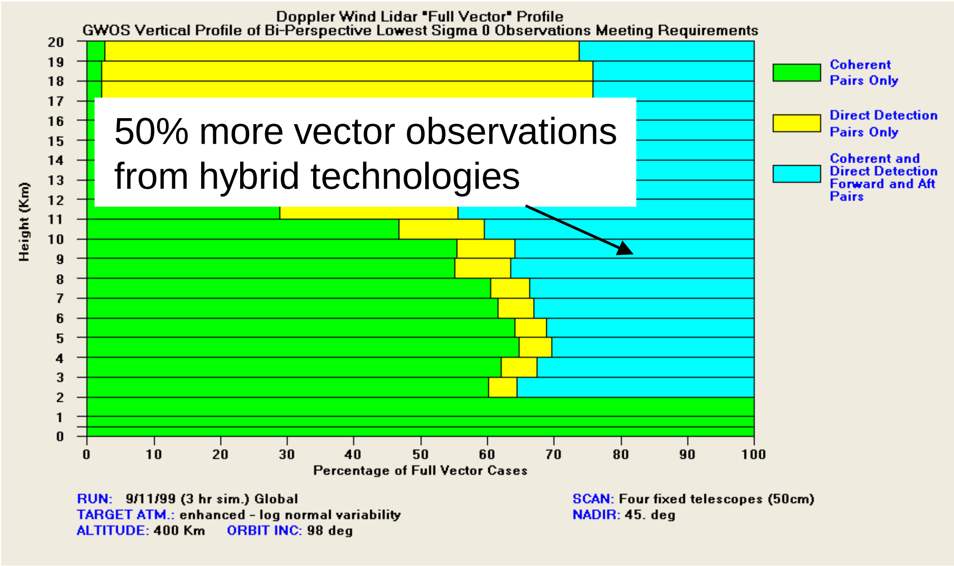
Green: both perspectives from coherent system

Yellow: both perspectives from direct molecular

Blue: one perspective coherent; one perspective direct

Enhanced aerosol mode

Background aerosol mode



Coherent aerosol and direct detection molecular channels work together to produce optimum vertical coverage of bi-perspective wind measurement

* When two perspectives are possible

Observing System Simulation Experiments (OSSEs)

Basic OSSE definition

- Model based experiments designed to test hypothesized impacts of future observing systems on numerical weather prediction (NWP).

OSSE Objectives (1)

- Provide quantitative basis for defining the optimal mix of sensors for NWP
  - Assess potential analyses/forecast impacts of new observing systems under consideration for deployment
  - Provide feedback to the instrument developers including rationale for descoping

OSSE Objectives (2)

- Accelerate transition of observations from newly developed instruments to operational use
  - Enables the JCSDA to develop data processing and assimilation software prior to the launch of the new instrument
  - Provide the operational community early insight to synergisms with other instruments

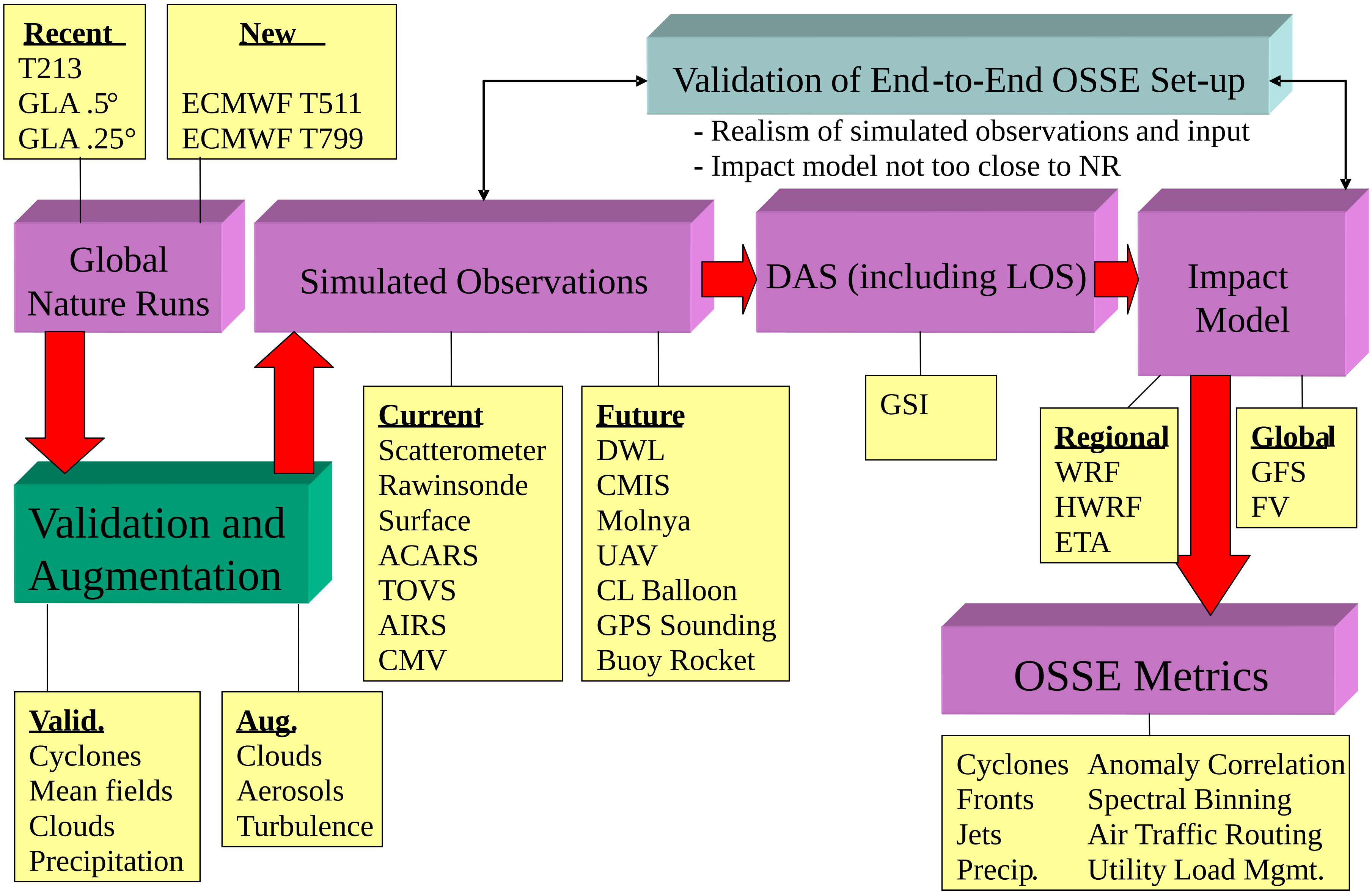
OSSE Rules

- Proposed by Kalney, Halem and Atlas (1986)
- Fraternal Twin vs. Identical Twin models
- Realism checks
- Calibration checks
- Simulation of existing sensors
- Simulation of imagined sensors

Definitions & Hierarchy

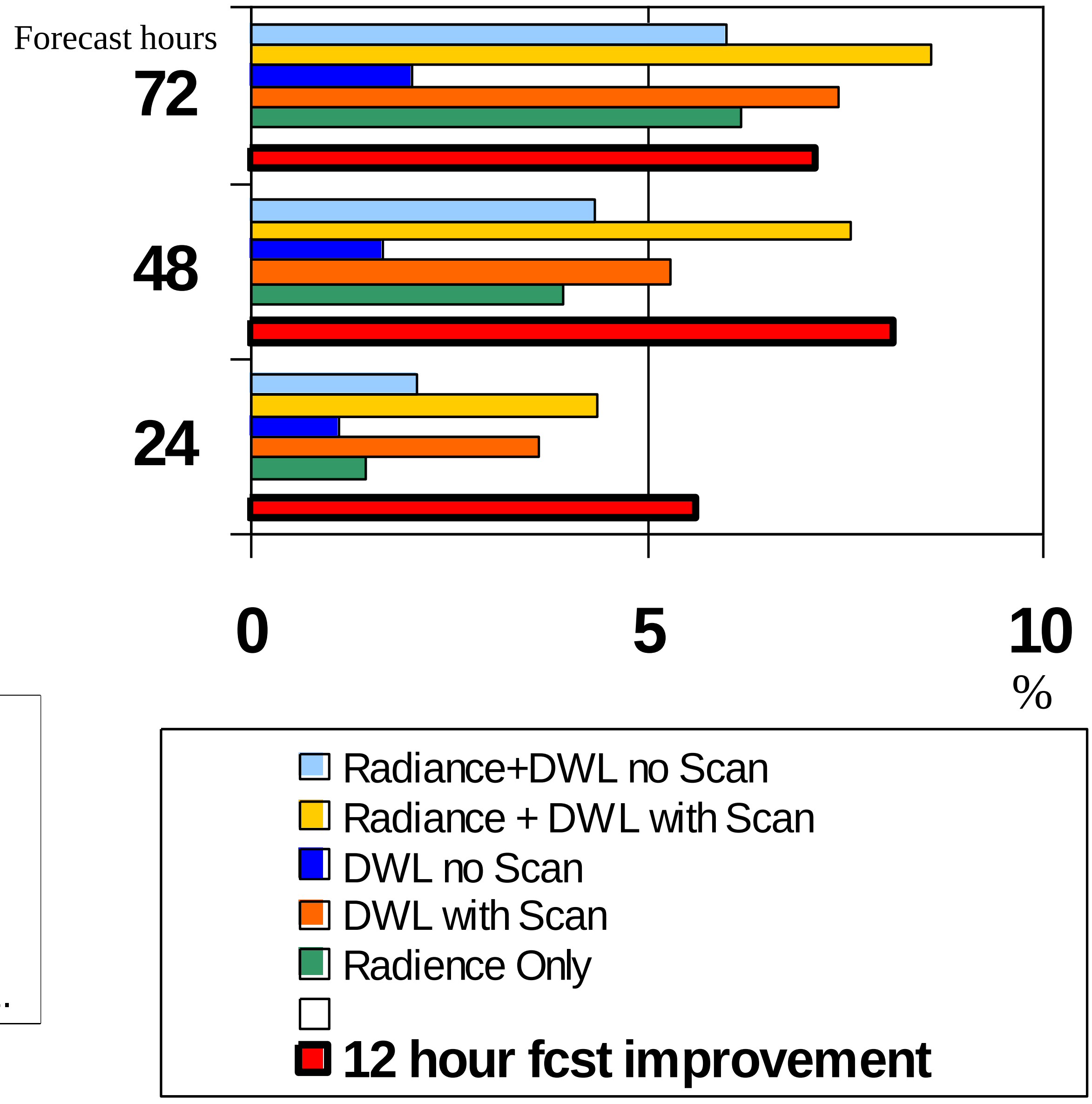
- Observing System Simulation Experiment (OSSE)
- Observing System Experiment (OSE)
- OSSE-Like Experiments
  - Rapid Observing System Simulation Experiments (ROSSEs)
  - Quick OSSEs (QOSSEs)
  - Simple OSSEs (SOSSEs)
  - Partial OSSES (POSSEs)

OSSE TESTBED COMPONENTS



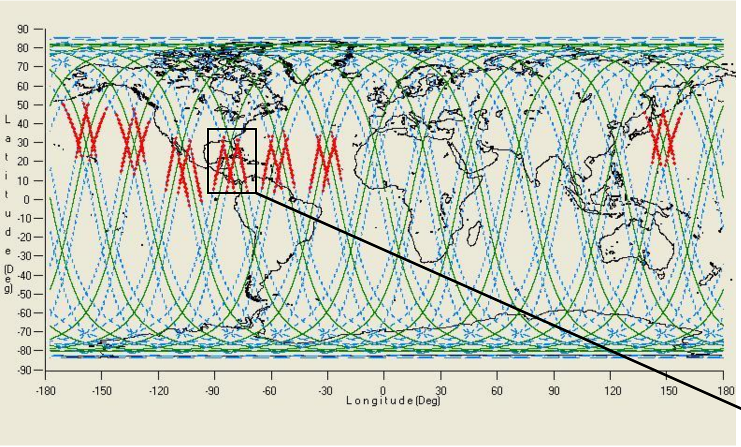
Highlight of the Results from DWL OSSEs

- Scanning significantly increases the impact
- In NH, DWL with scanning is required to produce additional skill over existing data
- Non-scan DWL may produce significant impacts in NH with radiance data



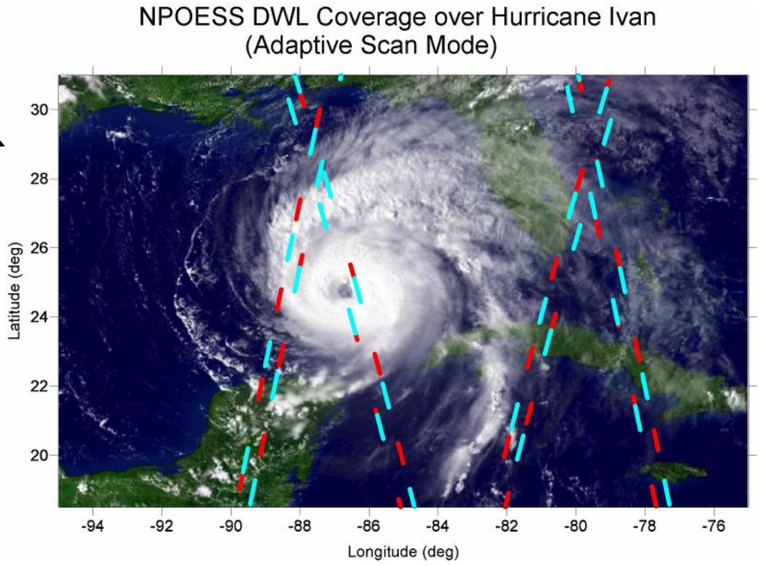
The diagram is anomaly correlations with nature run for 200mb V. Improvement in forecast skill with respect to forecasts with RAOB and surface data only. Skill for Northern Hemisphere synoptic scale events are presented. The resolution of DA is T62.

Adaptive Targeting

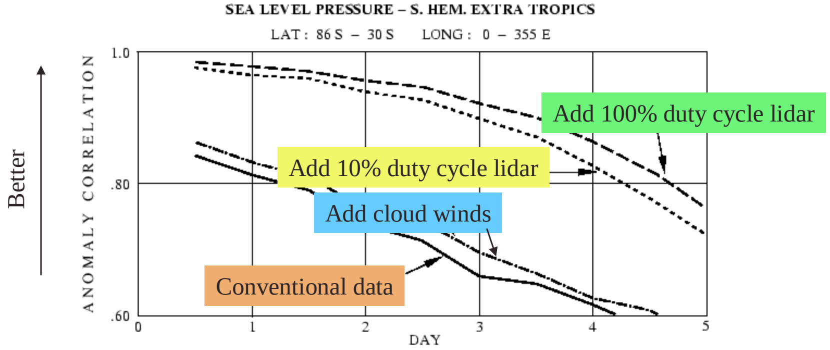


Adaptive targeting with emphasis on CONUS interests

(Blue is coherent coverage
Red is both coherent and direct)



Adaptive Targeting Experiments



Model: GEOS-2 Recon.
Verification: ECMWF Nature Run

Control:	- Conventional Data + Perfect TOVS
CTW	- Control + Cloud Tracked Winds
1 m/s Wind	- Control + Doppler Wind Lidar (RMSE = 1 m/s)
Adaptive Targeting	- Control + Adaptive Targeting of DWL Observations (~10% duty cycle)

Example of targeting a hurricane as it approaches the Gulf coast. (blue segments: forward looks; Red segments: aft looks; Blue plus red Provide full horizontal wind vector)

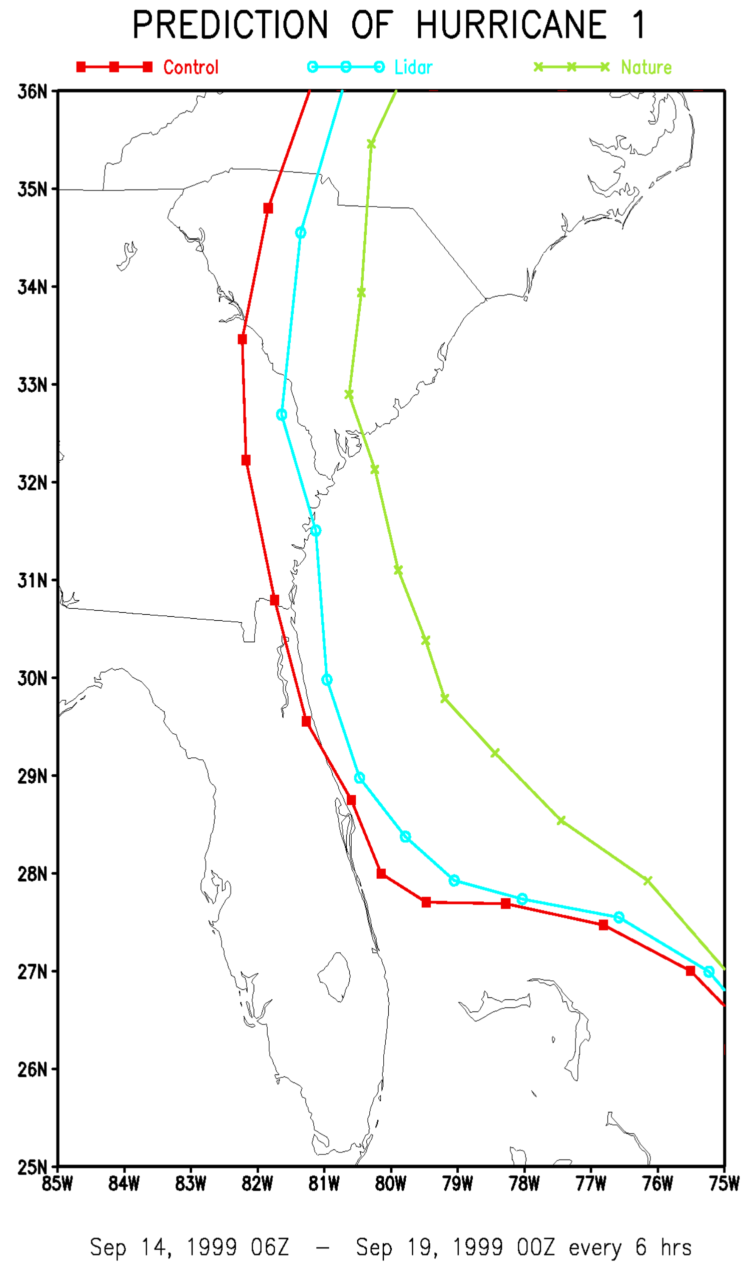
DWLs greatly improve hurricane track predictions

Potential Impact of new space-based observations on Hurricane Track Prediction

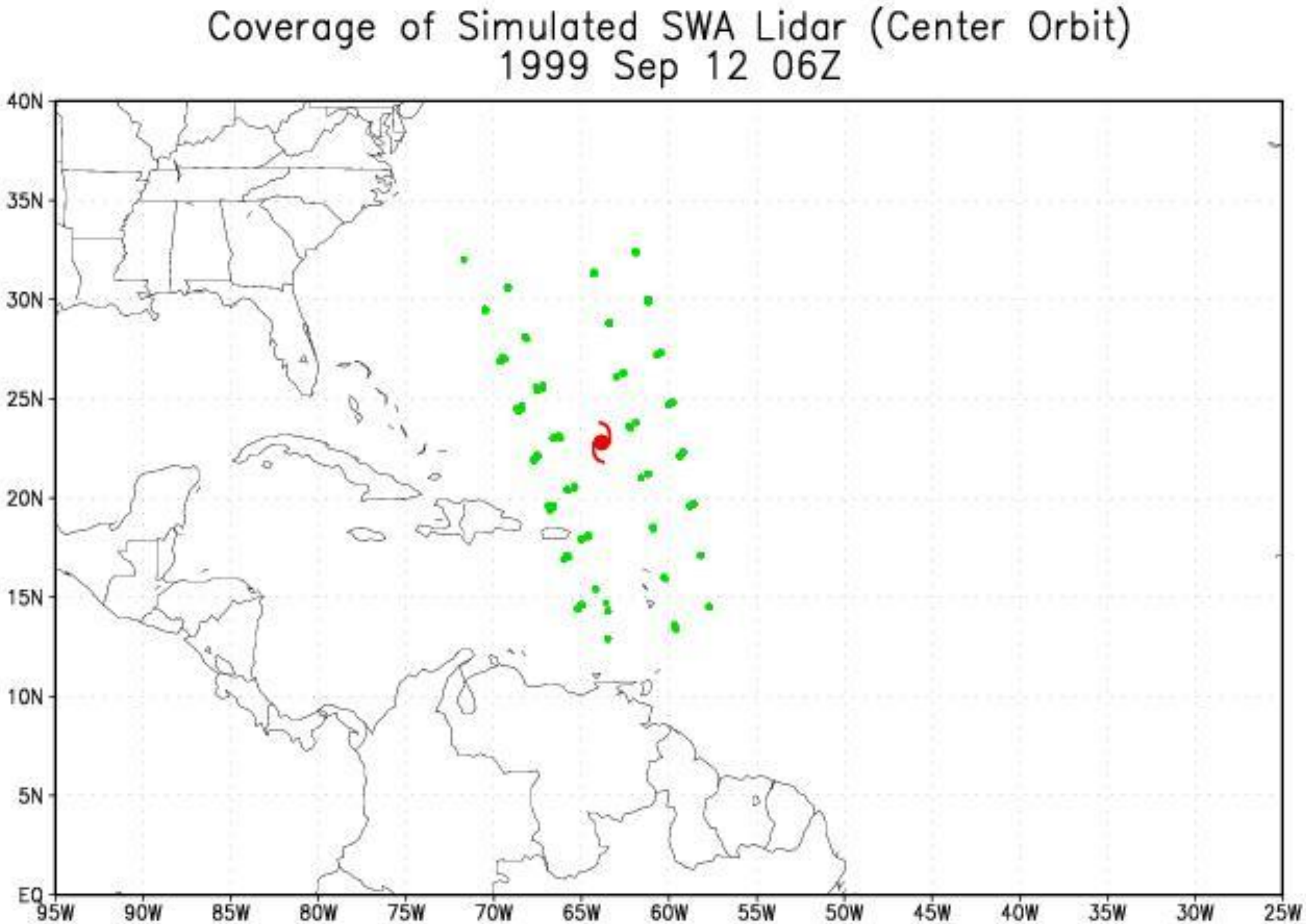
Based on OSSEs at NASA Laboratory for Atmospheres

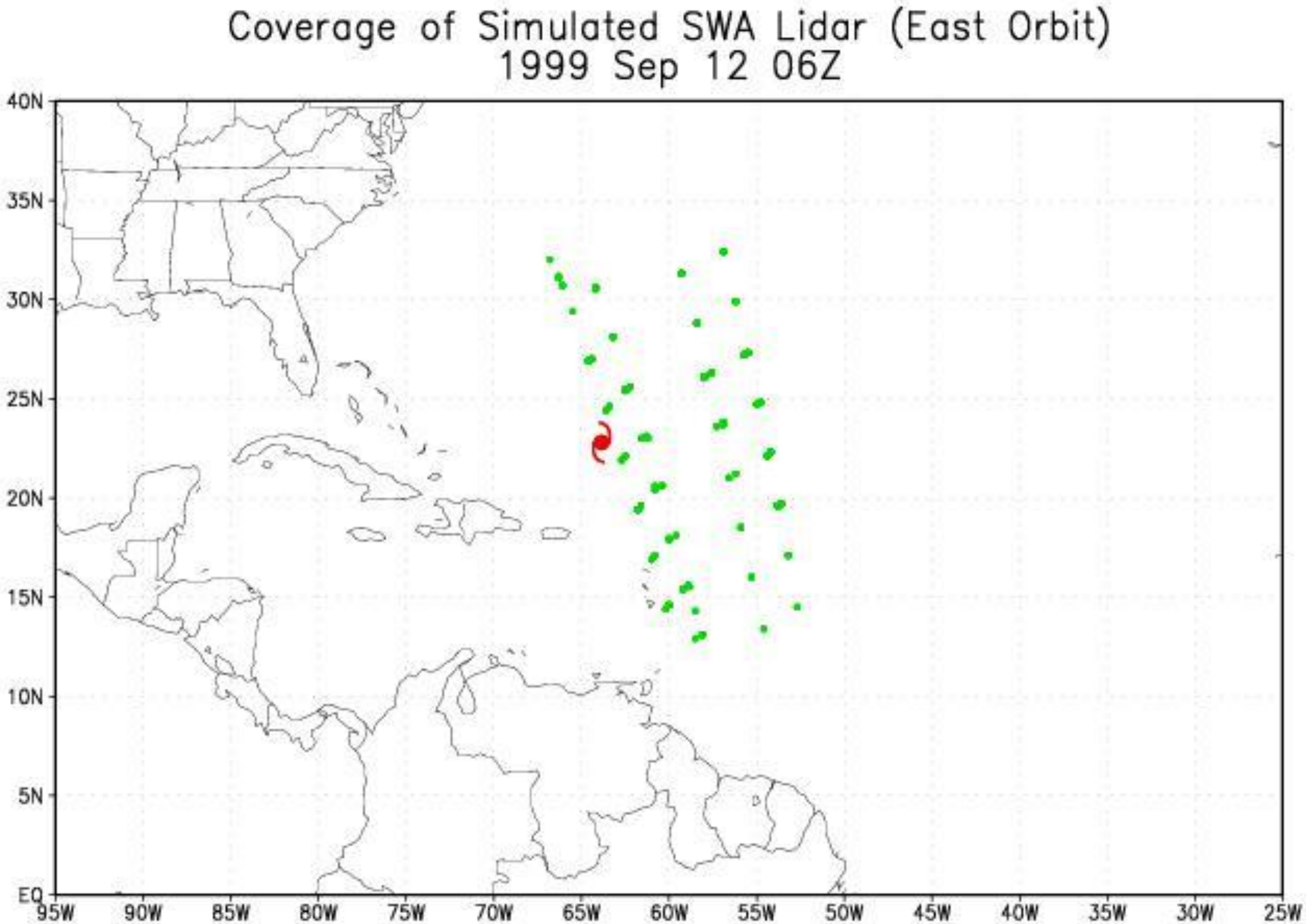
- Tracks
  - Green: actual track
  - Red: forecast beginning 63 hours before landfall with current data
  - Blue: improved forecast for same time period with simulated wind lidar

- Lidar in this one case
  - Reduces landfall prediction error by 66%

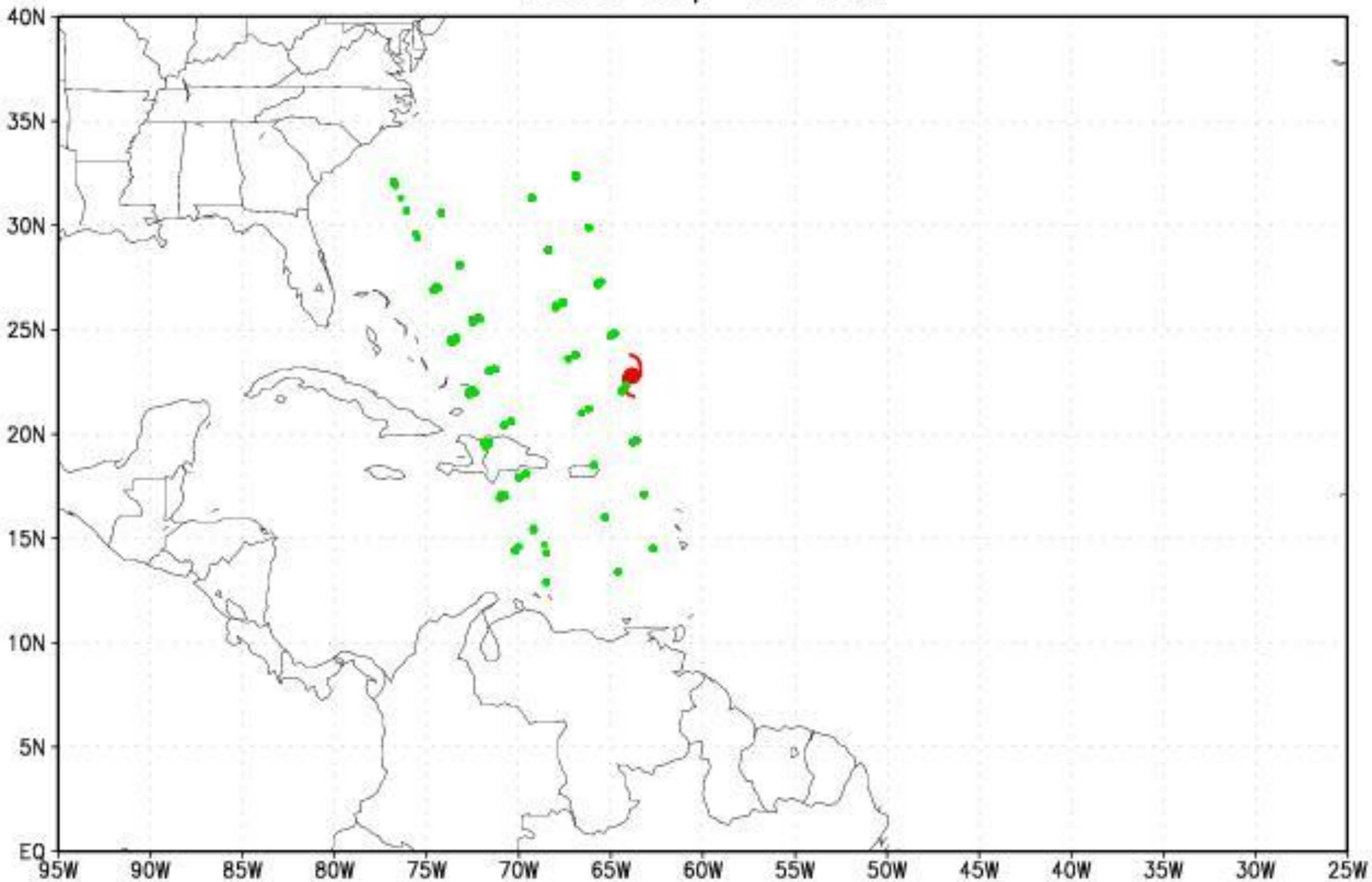


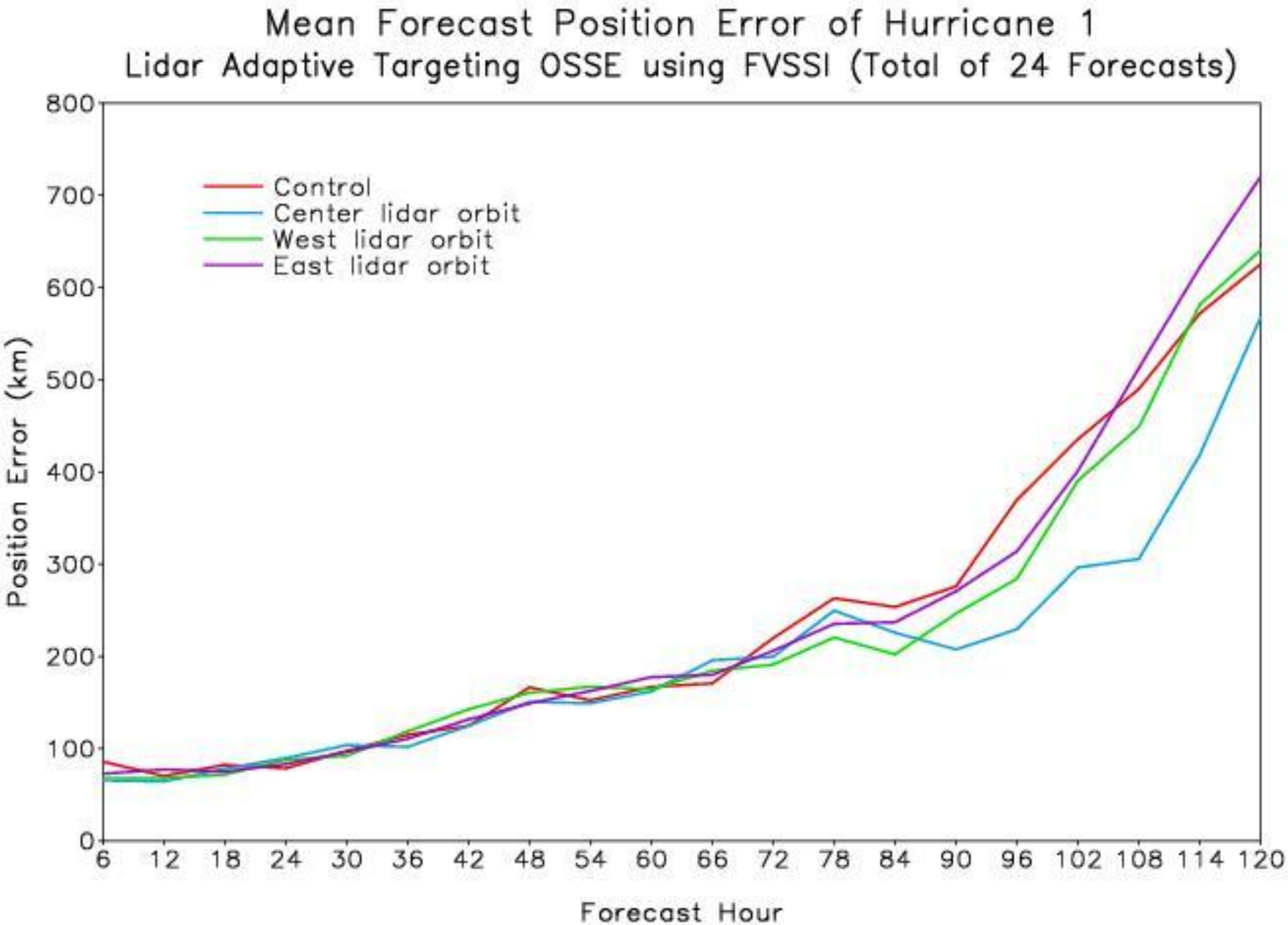
Courtesy R. Atlas

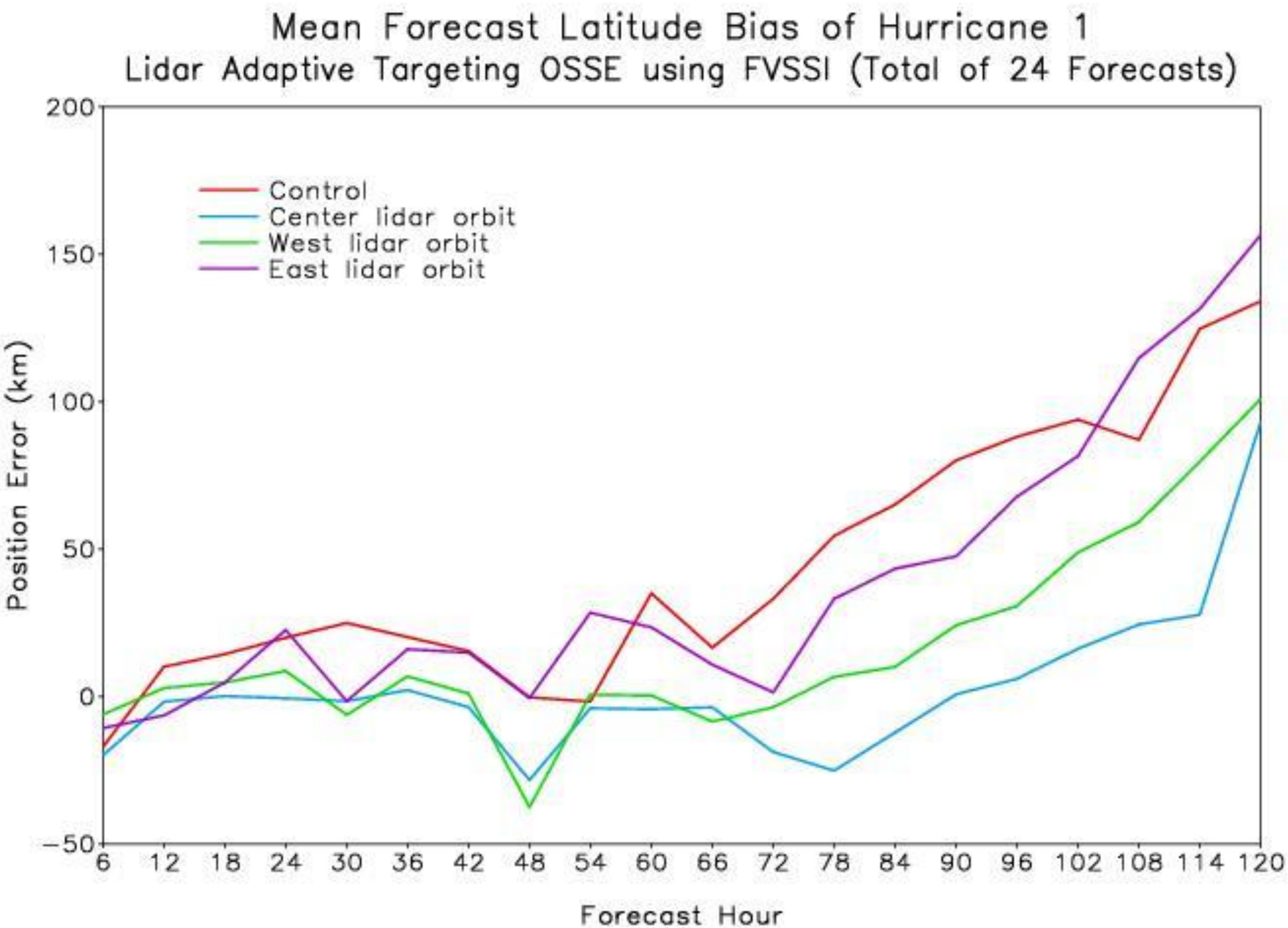

Coverage of Simulated SWA Lidar (Center Orbit)
1999 Sep 12 06Z
40N
35N
30N
25N
20N
15N
10N
5N
EQ
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
45W
40W
35W
30W
25W


Coverage of Simulated SWA Lidar (East Orbit)
1999 Sep 12 06Z
40N
35N
30N
25N
20N
15N
10N
5N
EQ
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
45W
40W
35W
30W
25W

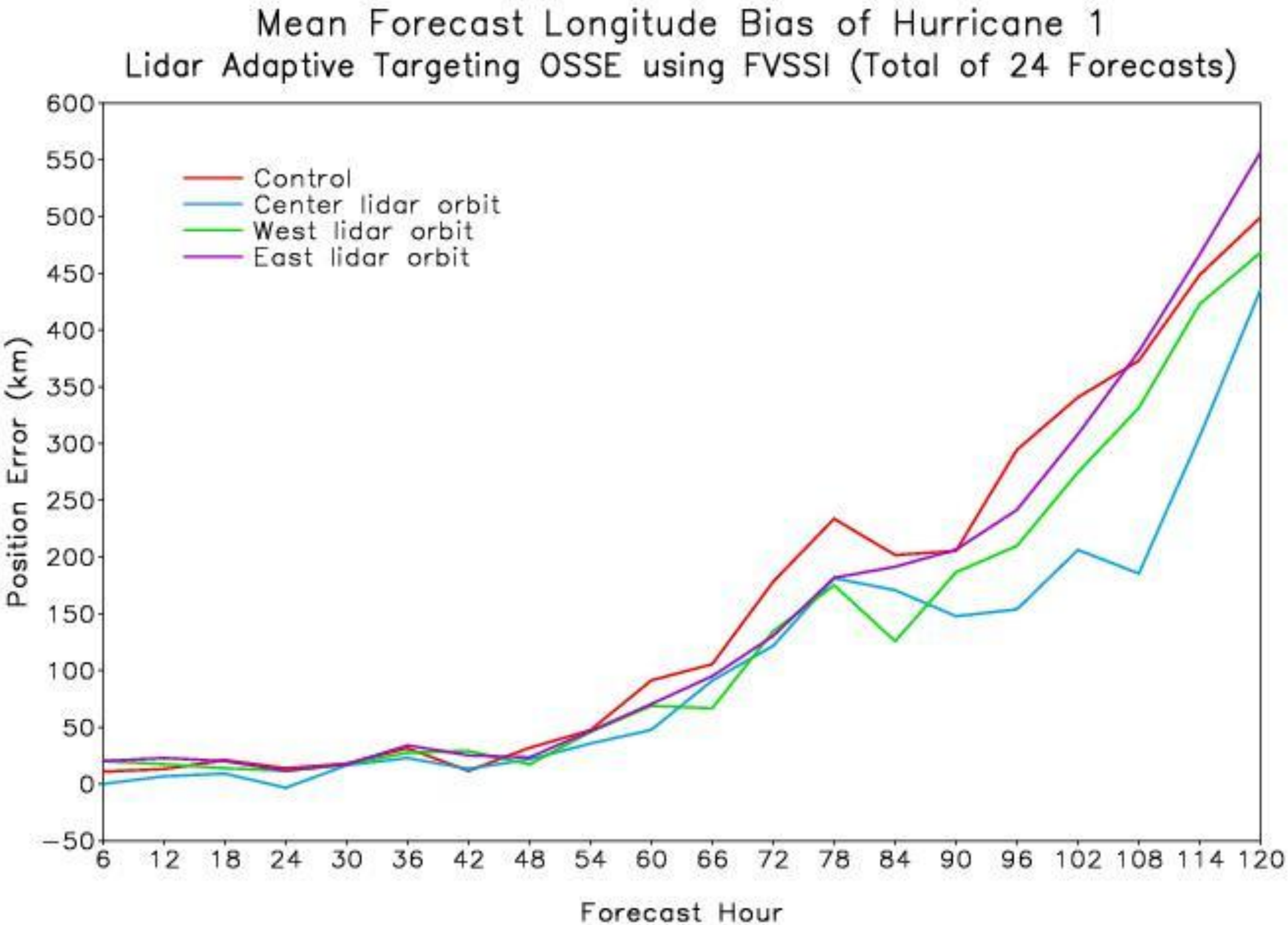
Coverage of Simulated SWA Lidar (West Orbit)
1999 Sep 12 06Z




Mean Forecast Position Error of Hurricane 1
Lidar Adaptive Targeting OSSE using FVSSI (Total of 24 Forecasts)
Control
Center lidar orbit
West lidar orbit
East lidar orbit
Position Error (km)
Forecast Hour
0
100
200
300
400
500
600
700
800
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
102
108
114
120



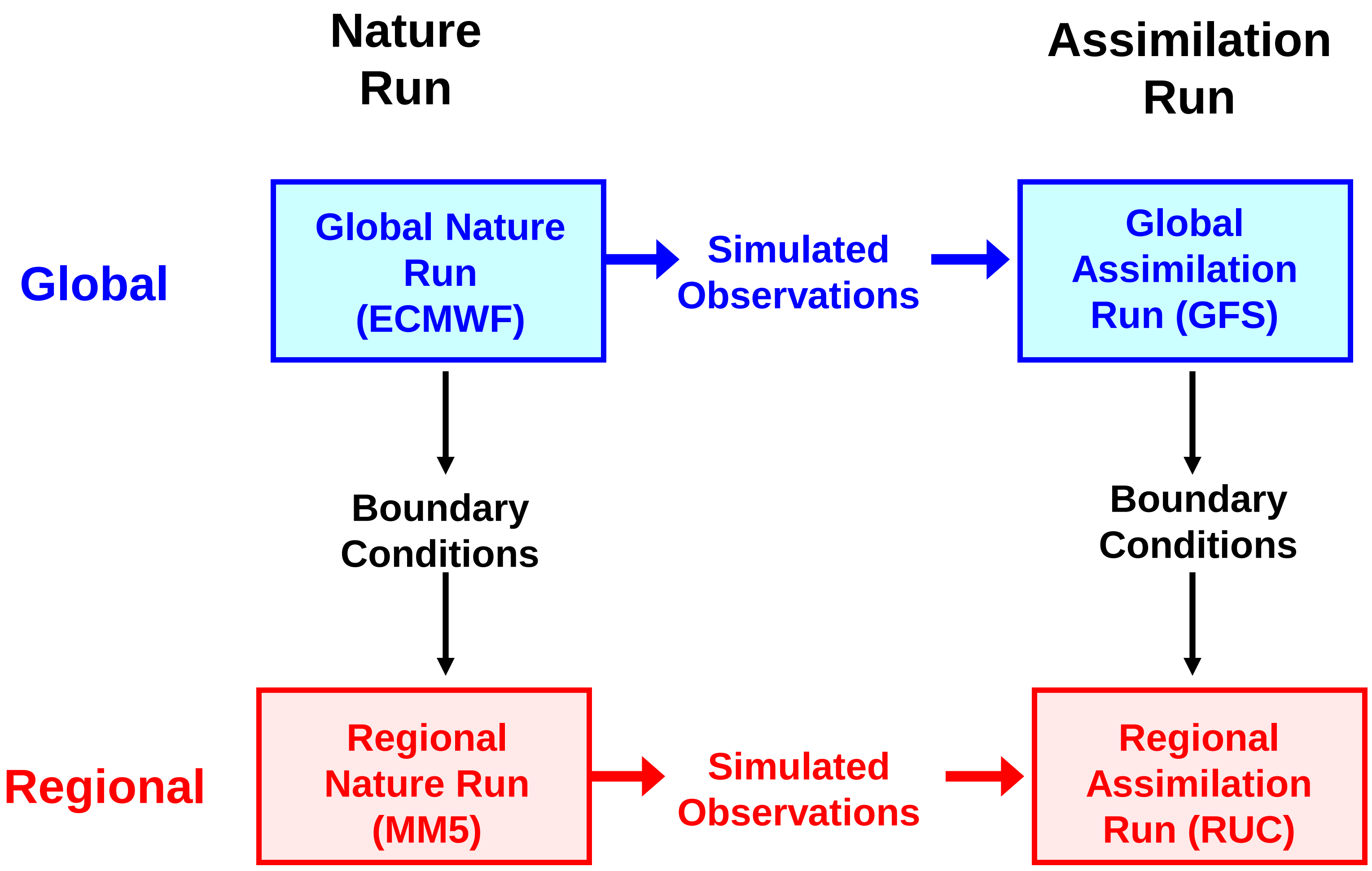
Mean Forecast Latitude Bias of Hurricane 1
Lidar Adaptive Targeting OSSE using FVSSI (Total of 24 Forecasts)
Control
Center lidar orbit
West lidar orbit
East lidar orbit
Position Error (km)
Forecast Hour
200
150
100
50
0
−50
6
12
18
24
30
36
42
48
54
60
66
72
78
84
90
96
102
108
114
120



Mean Forecast Longitude Bias of Hurricane 1
Lidar Adaptive Targeting OSSE using FVSSI (Total of 24 Forecasts)
Control
Center lidar orbit
West lidar orbit
East lidar orbit
Position Error (km)
Forecast Hour
600
550
500
450
400
350
300
250
200
150
100
50
0
−50
6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 102 108 114 120

Regional Model OSSEs (conducted at NOAA/FSL)

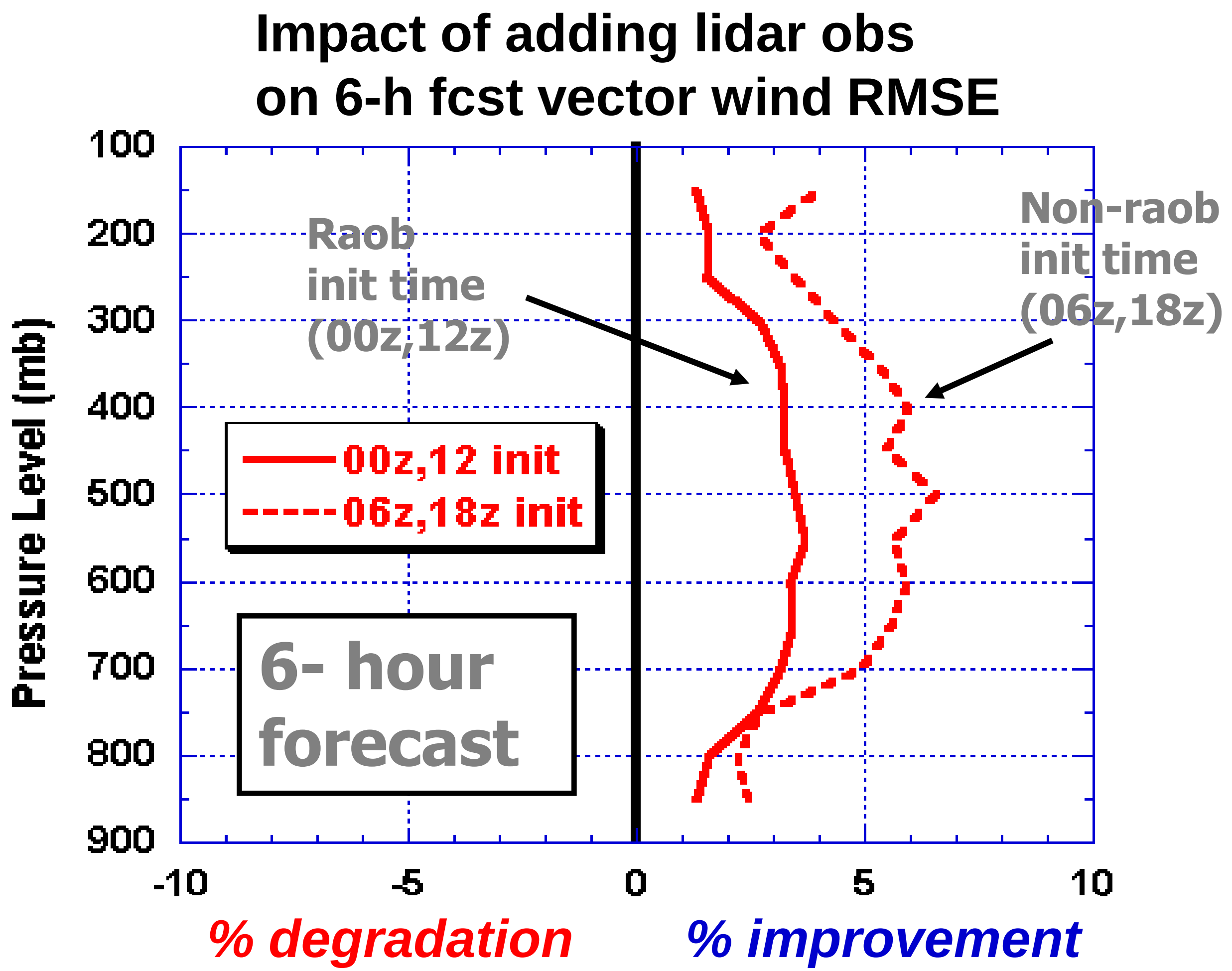
Relationship between Global and Regional OSSEs



Assimilation of lidar observations

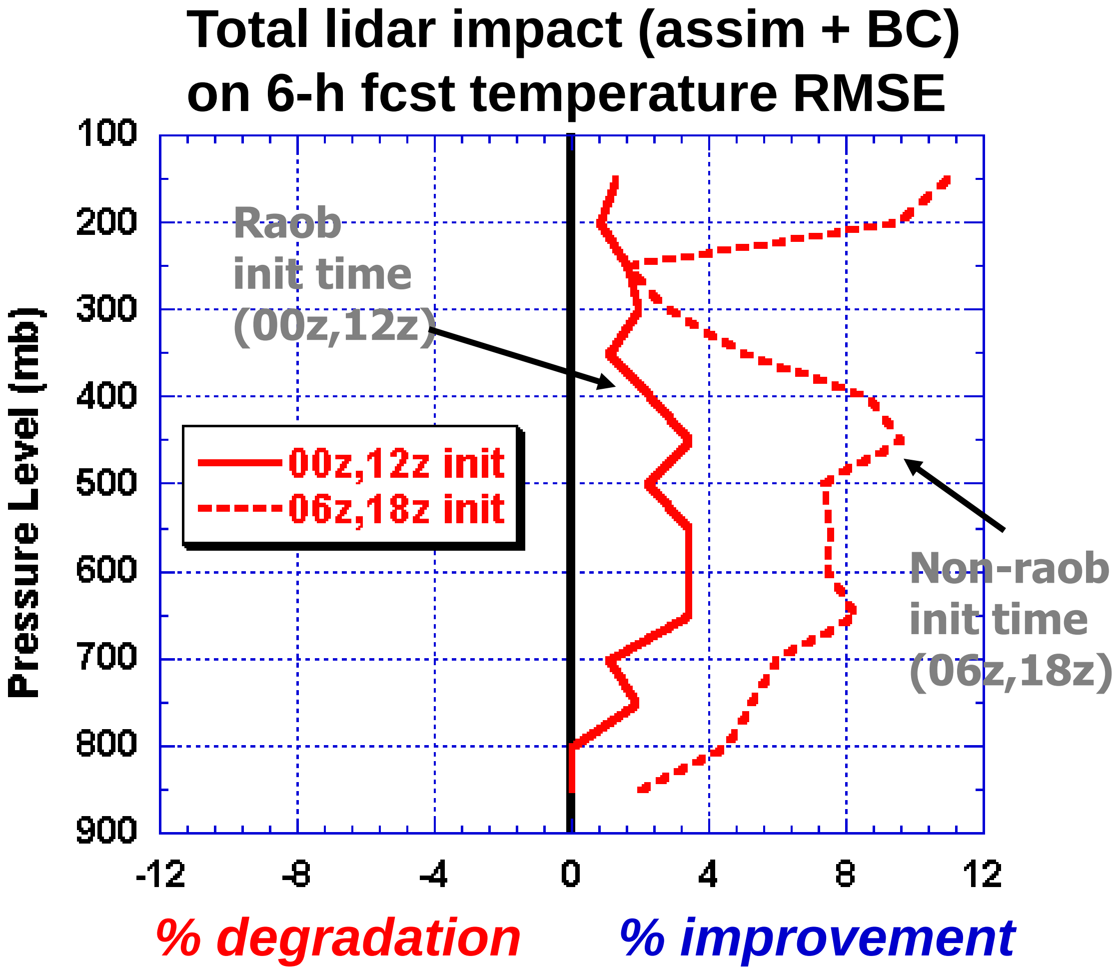
(but no lidar obs in boundary conditions)

- Lidar obs improve fcst more at non-raob init times
- Lidar obs improvement greatest aloft



Assimilation of lidar observations + lidar obs in boundary conditions

- ~8% mid-trop fcst T improvement for non-raob init
- Less improvement near level of max ACARS impact



Recent experience with OSSEs at NCEP and GSFC

- Shifting focus to high impact weather forecasts and events for OSSE metrics
  - Precipitation forecasts
  - Hurricane track
  - Jet stream strength and location
  - Air traffic routing
  - Utility load management
- Adaptive targeting (AT) OSSEs at NCEP (follow–on to earlier GSFC ATOSSE)
- Hurricane lifecycle OSSEs at GSFC in collaboration with NOAA/AOML and GFDL

Summary

- Global wind profiles are recognized as the #1 unmet NWP observational need
- Impact studies over the past 20 years show significant impacts on NWP from a space-based DWL.
- Laser technology is positioned to meet the challenge using hybrid detection technology

Review papers

- Arnold, C. P., Jr. and C. H. Dey, 1986: Observing-systems simulation experiments: Past, present, and future. *Bull. Amer., Meteor. Soc.,* **67**, 687-695.
- Atlas, R. 1997:Atmospheric observation and experiments to assess their usefulness in data assimilation. *J. Meteor. Soc. Japan,* **75**,111-130.