Observing System Simulation Experiments

G. D. Emmitt
Simpson Weather Associates
Charlottesville, Virginia

Applications of Remotely Sensed Observations in Data Assimilation

Workshop lecture series
University of Maryland
9 August 2007

Outline

- OSSE general definition
- OSSE objectives
- OSSE “rules”
- OSSE framework
  - Nature Run
  - Realism check
  - Simulated observations
  - Validation/calibration (OSEs)
  - Forecasting experiments
  - Impact assessment (impact metrics)
- Examples
  - NCEP adaptive targeting OSSEs for Doppler Wind Lidar
  - GSFC hurricane forecasting OSSEs for Doppler Wind Lidar

Basic OSSE definition

- Numerical model based experiment designed to test hypothesized impacts of future observing systems on numerical weather prediction (NWP).
- By comparison, Observing System Experiments (OSEs) are performed with only existing observation platforms. Sometimes called “data denial” experiments.

OSSE Objectives (1)

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

OSSE Objectives (2)

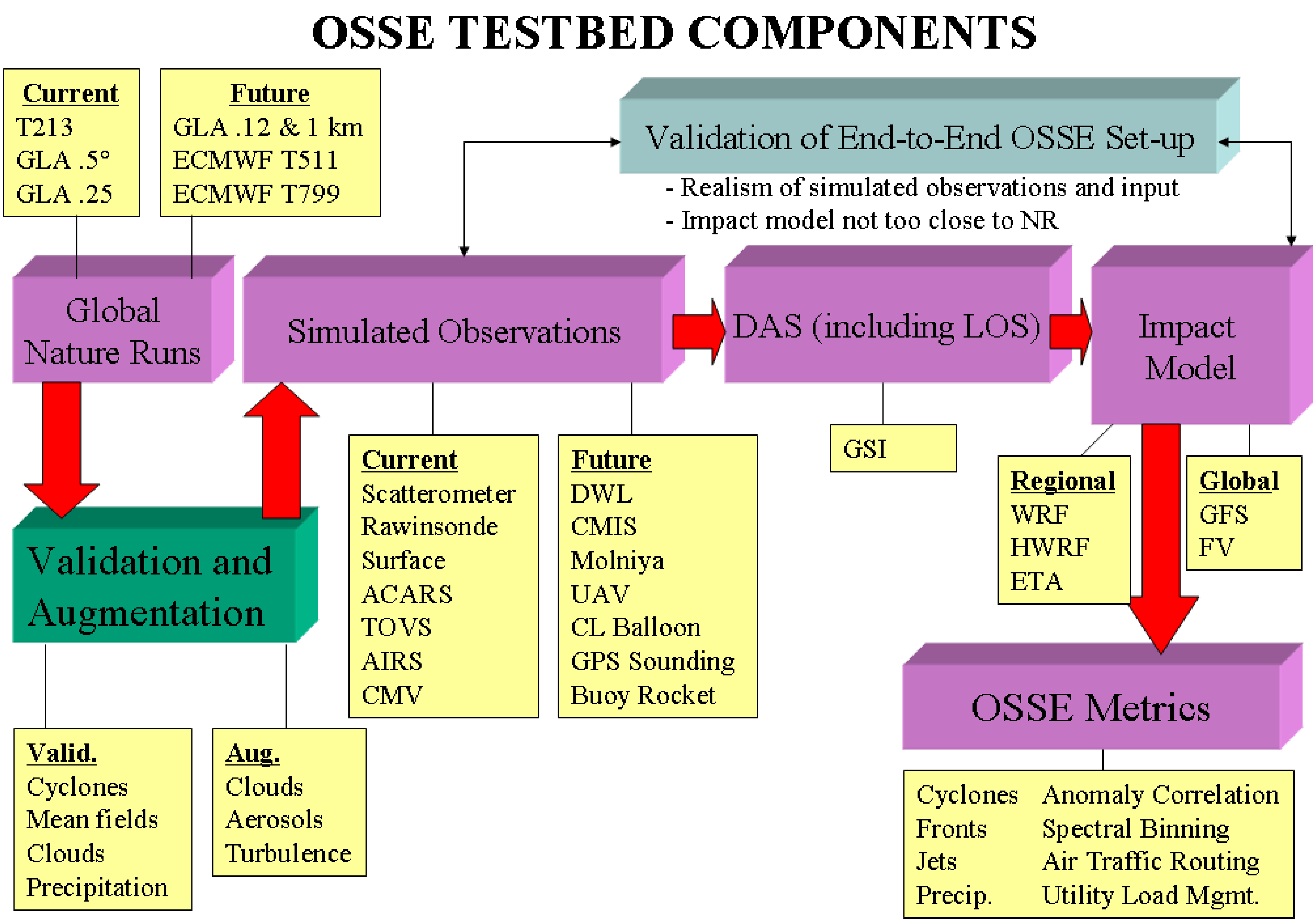
- Accelerate the transition of observations from newly developed instruments to operational use
  - Enables the JCSDA to develop data processing and assimilation software prior to the launch of the new instrument
  - Provide the operational community early insight to synergisms with other instruments

Definitions & Hierarchy

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

OSSE Rules

- Formal OSSE rules were first discussed in WMO and USWRP meetings in the early ’80s
- Best documented by Atlas, Kalnay, Susskind, Baker and Halem (1985)
- Fraternal Twin vs. Identical Twin models
- Realism checks
- Calibration checks
- Simulation of existing sensors
- Simulation of proposed sensors


OSSE TESTBED COMPONENTS
Current
T213
GLA .5°
GLA .25
Future
GLA .12 & 1 km
ECMWF T511
ECMWF T799
Validation of End-to-End OSSE Set-up
- Realism of simulated observations and input
- Impact model not too close to NR
Global Nature Runs
Simulated Observations
DAS (including LOS)
Impact Model
Validation and Augmentation
Current
Scatterometer
Rawinsonde
Surface
ACARS
TOVS
AIRS
CMV
Future
DWL
CMIS
Molniya
UAV
CL Balloon
GPS Sounding
Buoy Rocket
GSI
Regional
WRF
HWRF
ETA
Global
GFS
FV
OSSE Metrics
Valid.
Cyclones
Mean fields
Clouds
Precipitation
Aug.
Clouds
Aerosols
Turbulence
Cyclones
Fronts
Jets
Precip.
Anomaly Correlation
Spectral Binning
Air Traffic Routing
Utility Load Mgmt.

Nature Run

- Needs to be the best (resolution and physics) model available.
- Should have best physics to support forward models used in simulating observations.
- May be a research model not yet used operationally.

Realism Check

- Assessing the NR for its realistic representation of the atmospsphere over the entire length of the model integration
- Key areas for assessment
  - Clouds
  - Fronts
  - Cyclones
  - Precipitation

Nature Run Assessment (Example)

- Clouds
  - Cloud coverage realism changes with model scale: New Nature Runs need reassessment
  - Clouds need to be realistic for simulating passive remote sensor products such as those from AIRS
  - Cloud realism is critical for simulating active optical remote sensors such as wind lidars

Objectives

- Evaluate the ECMWF Nature Run (T511 - 1 degree test) cloud type and amounts
- If necessary, provide modification algorithms
- Recommend techniques for deriving cloud optical properties, CMV targets and radiative transfer model inputs

Process

- Use month of August 2005 from T511 NR
- 1 X 1 degree test data set
- Use reported NR values of total, high, middle and low cloud cover.
  - Derive zonal average values for 10 degree latitudinal bands
  - Derive global cloud coverage
  - Concerned with effects of cloud overlap functions

Process (2)

- Compare NR statistics with those based upon the following:
  - ISCCP monthly cloud climatologies (August)
  - MODIS based cloud climatology
  - UW/HIRS based climatology (August)
  - GLAS and CALIOP cloud statistics (October)
  - WWMCA (Nephanalyses) (August, 2005)
- Develop cloud statistics from NR using individual layer data
  - Invoke contiguous/random overlap function

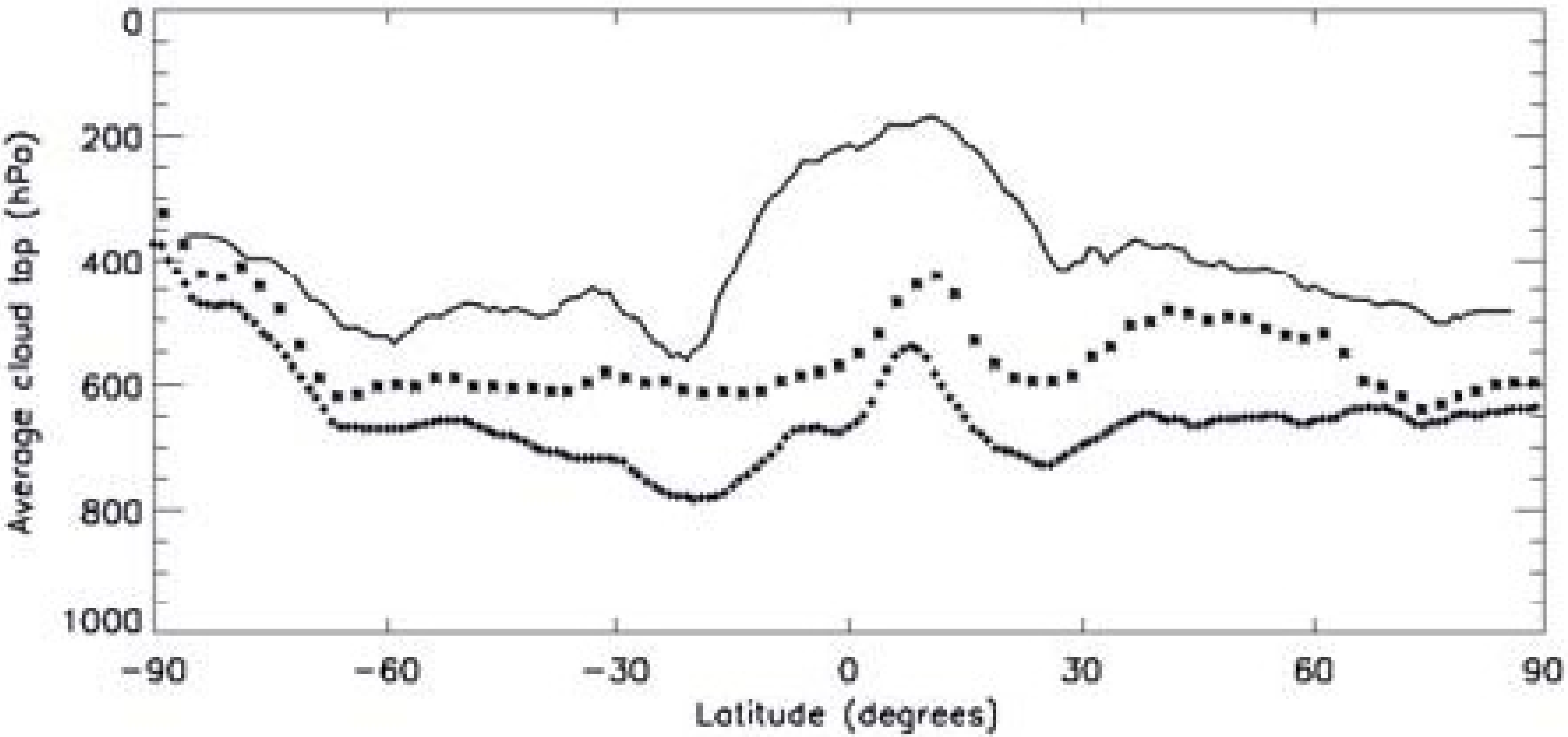
Process (3)

- Investigate enhanced thin cirrus algorithm for T511 NR
- Using the NASA/NOAA/DoD Doppler Lidar Simulation Model (DLSM), simulate GLAS and CALIOP observations within T511 Nature Run using derived optical properties.

Summary

- The T511 cloud distributions (vertical and horizontal), in general, compare best with the HIRS cloud climatology.
- The NR understates the presence of thin cirrus as detected by GLAS and CALILOP.
- Lidar data shows high cloud is often higher than passive sensor based assignments.
- An algorithm to adjust the NR ice cloud coverage yields better comparisons with the GLAS and CALIOP findings.

GLAS/CALIOP View

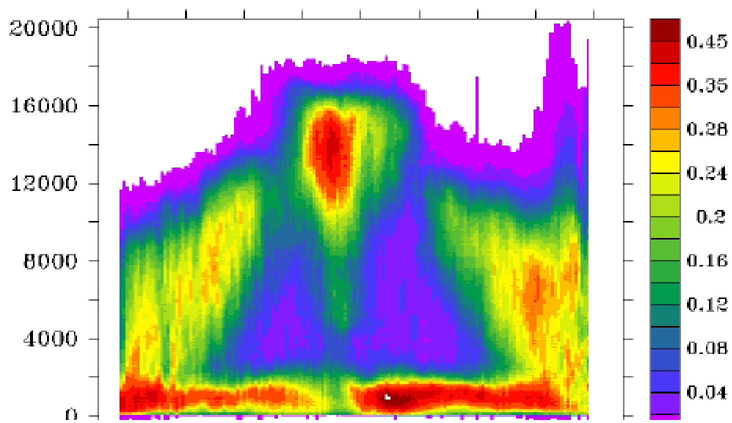


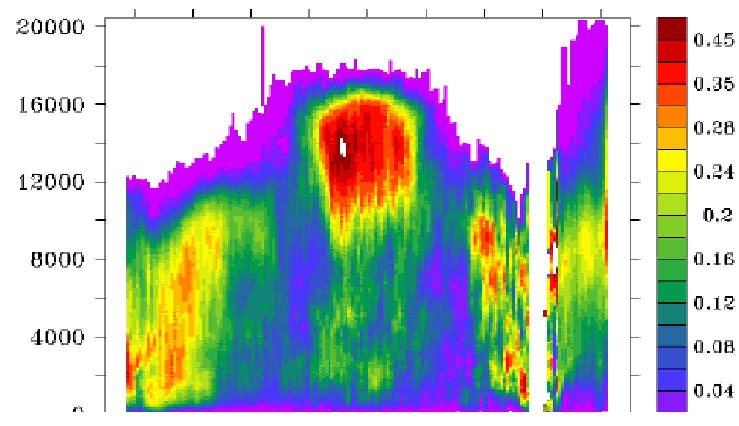
Zonal average cloud top for GLAS,ISCCP, and MODIS for October, 2003.

Taken from: William D. Hart*, Stephen P. Palm, James D. Spinhirne and Dennis L. Hlavka Global and polar cloud cover from the Geoscience Laser Altimeter System, observations and implications

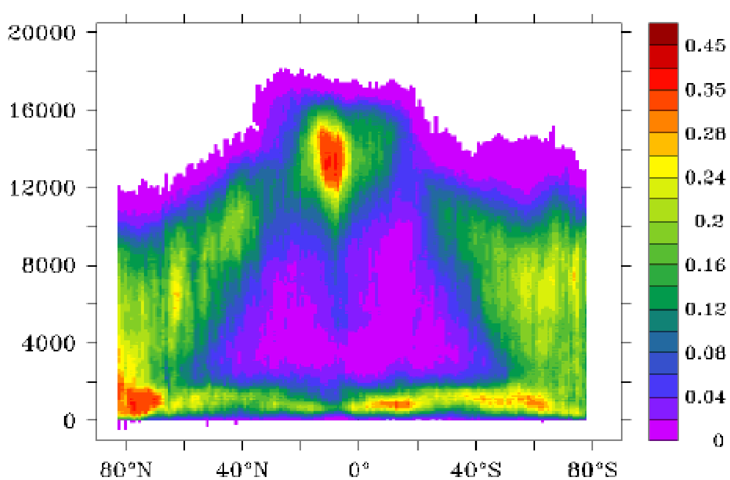
WHAT IS OBTAINED From CALIOP/CALIPSO October 2006

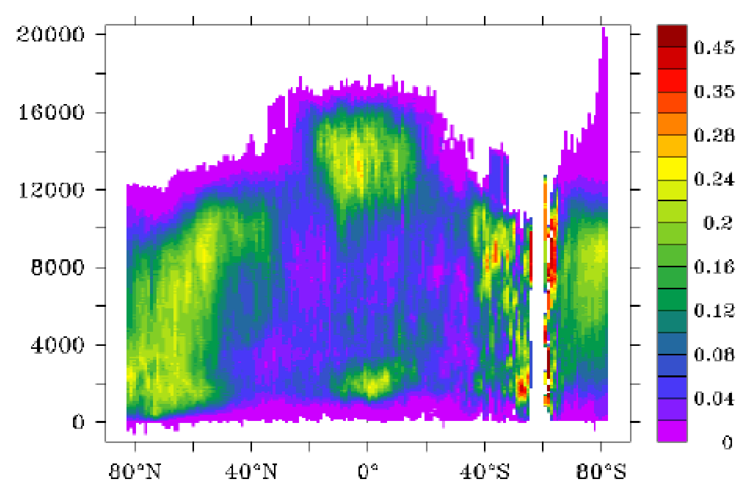
Night Ocean Land





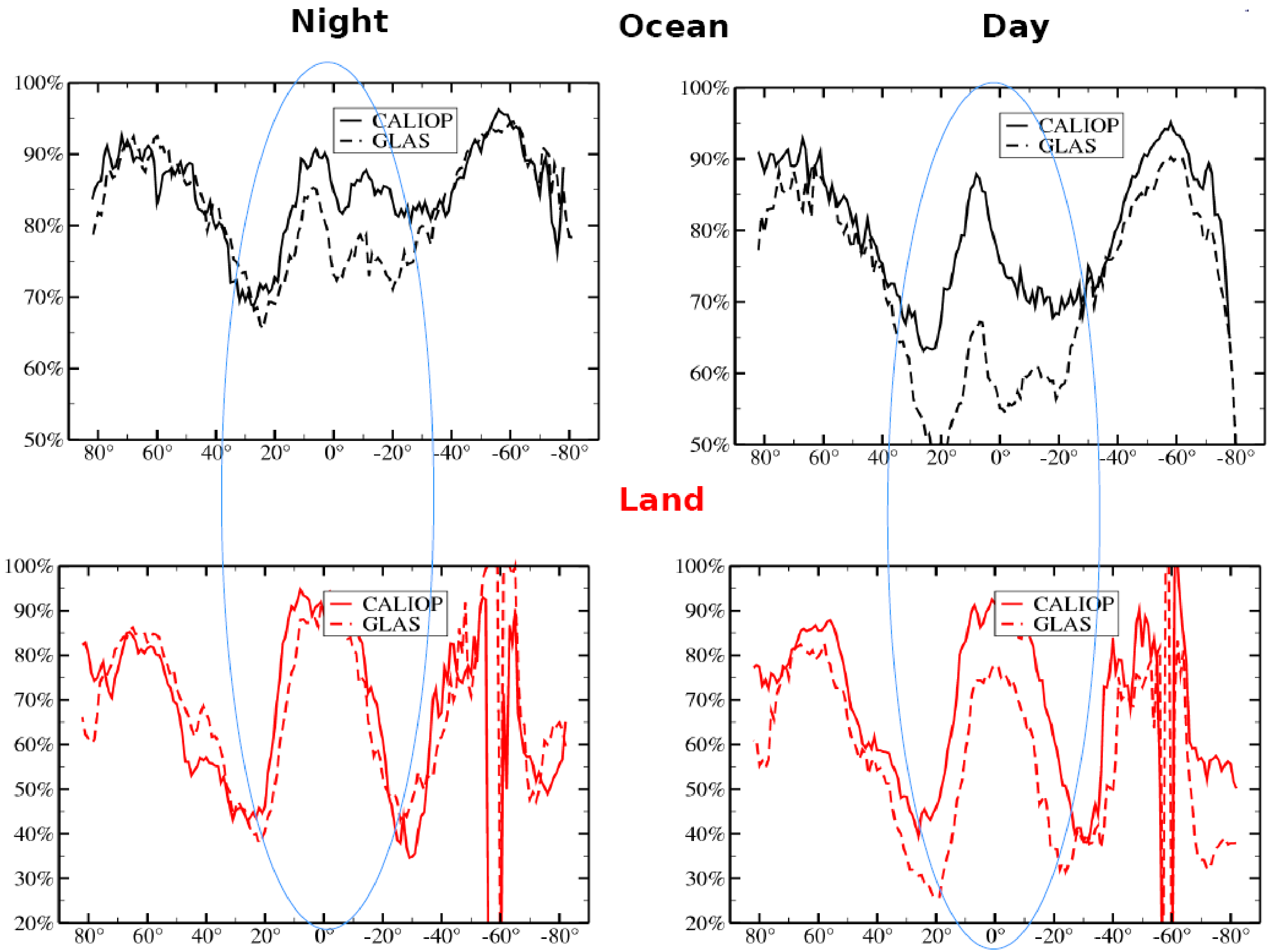
Day Calipso data v1.10





Earthcare workshop, ESTEC, 8 May 2007

Seze, Pelon, Flamant, Vaughn, Trepte and Winker



GLAS october 2003 – CALIOP october 2006

Earthcare Workshop, ESTEC, 8 May 2007

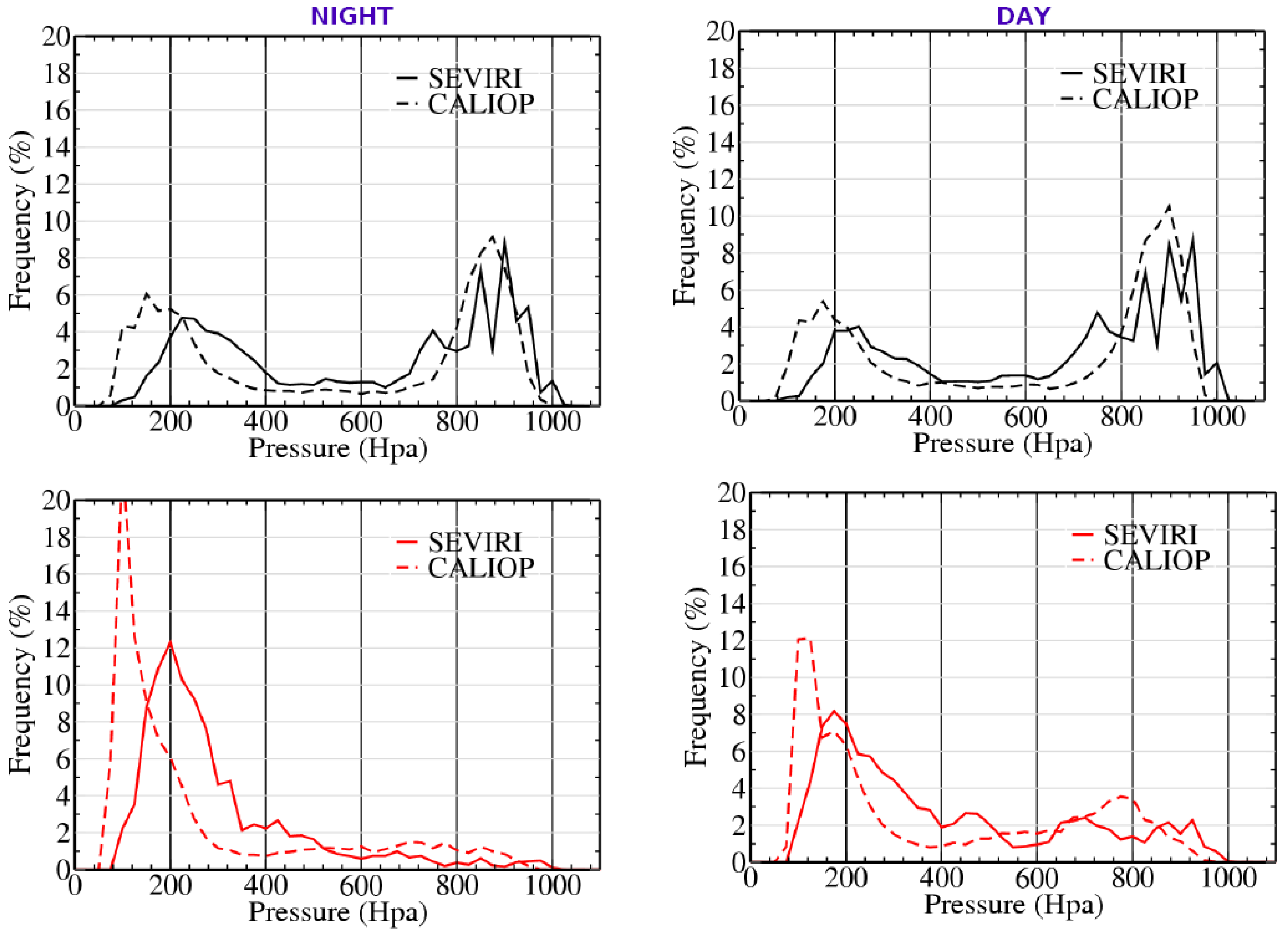
Night and day cloud cover

GLAS 50 days during the 2003 fall, CALIOP August and October 2006

	Night				Day		
	GLAS	CALIPSO			GLAS	CALIPSO	
	2003	*Oct*	*Aug*		*2003*	*Oct*	*Aug*
Total cloud cover	78%	79%	76%		65%	75%	78%
high cloud	21%	23%	29%		20%	23%	20%
middle cloud	19%	12%	11%		23%	13%	15%
high + middle	10%	11%	13%		8%	12%	11%
low cloud	30%	34%	29%		37%	35%	36%
low cloud with other	20%	20%	18%		11%	17%	18%

Low < 700 hPa **Middle : 700-400 hPa** **High > 400 hPa**

CALIOP OCEAN - LAND October 2006

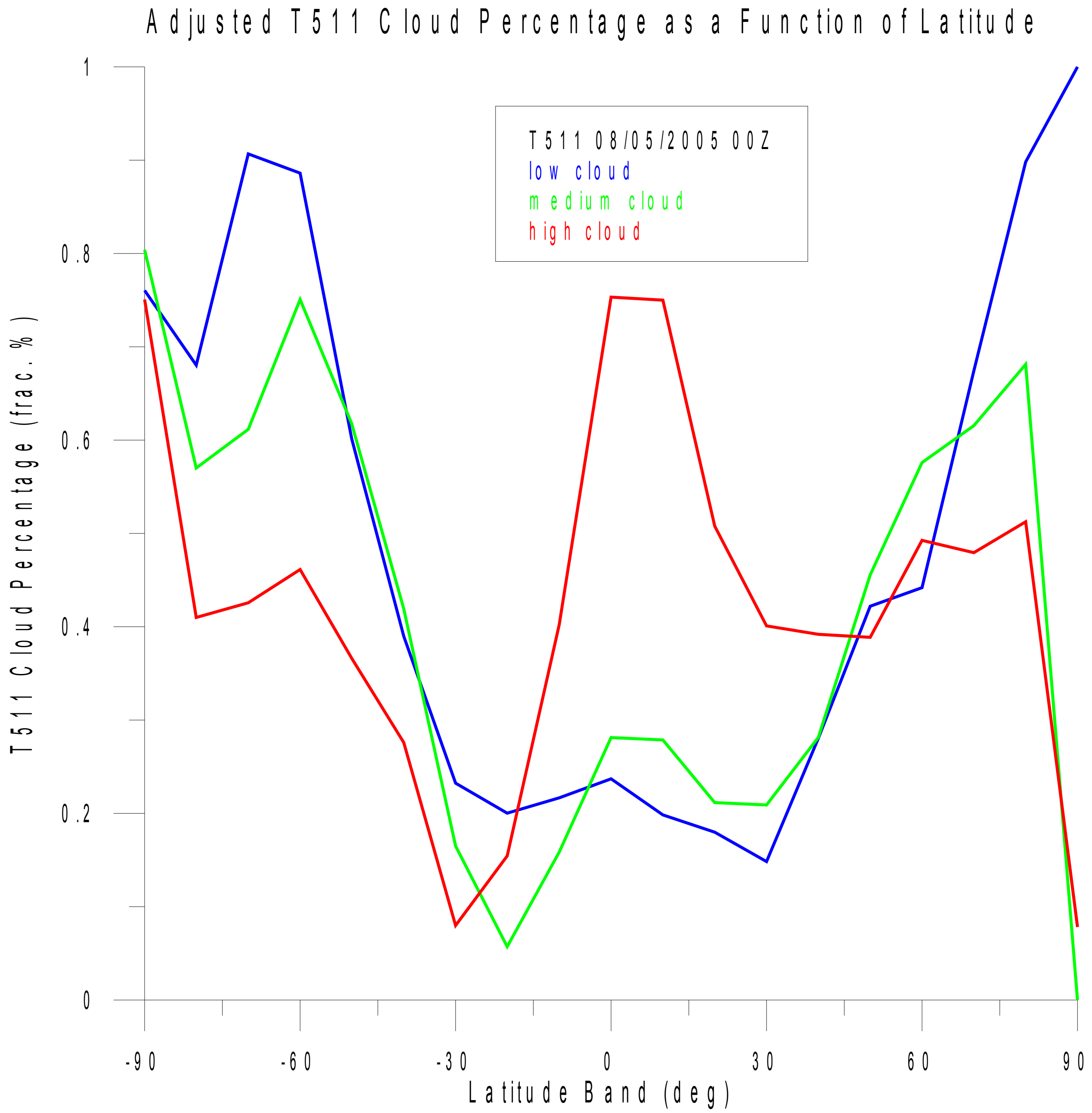


Heads up from CALIPSO

………. the ice cloud formation in the models
need to include the presence of the highly frequent thin ice clouds
with tiny amount of ice water content.

Conversation with CALIPSO team member (June, 2007)

NR cloud distributions using individual layer cloud types and amounts



Adjusted T511 Cloud Percentage as a Function of Latitude
T511 08/05/2005 00Z
low cloud
medium cloud
high cloud
T511 Cloud Percentage (frac. %)
Latitude Band (deg)
0
0.2
0.4
0.6
0.8
1
-90
-60
-30
0
30
60
90

Observation simulations (existing)

- Using the NR simulate data from existing observing systems (e.g. RAOBs, ACARS, SatWinds, OVWs, AIRS)
  - Use forward models used in DA
  - Add errors
    - Random
    - Systematic (correlated)
- Major challenge is proper accounting for clouds and aerosols plus sub-grid scale variance in observed properties

Validation/calibration

- Focus shifts to the realism of the simulated observations and there impact on analyses and forecast errors.
  - Simulated observations tend to be “too good”
  - Representativeness is hard to add in
- OSEs can be used to evaluate the realism of the simulated obs.

Simulations for new instrument

- Most challenging since there is no heritage data to assess realistic performance.
  - Room for exaggerated performance
  - Need for neutral oversight
- DASs not optimized for new data
  - May tend to understate impacts

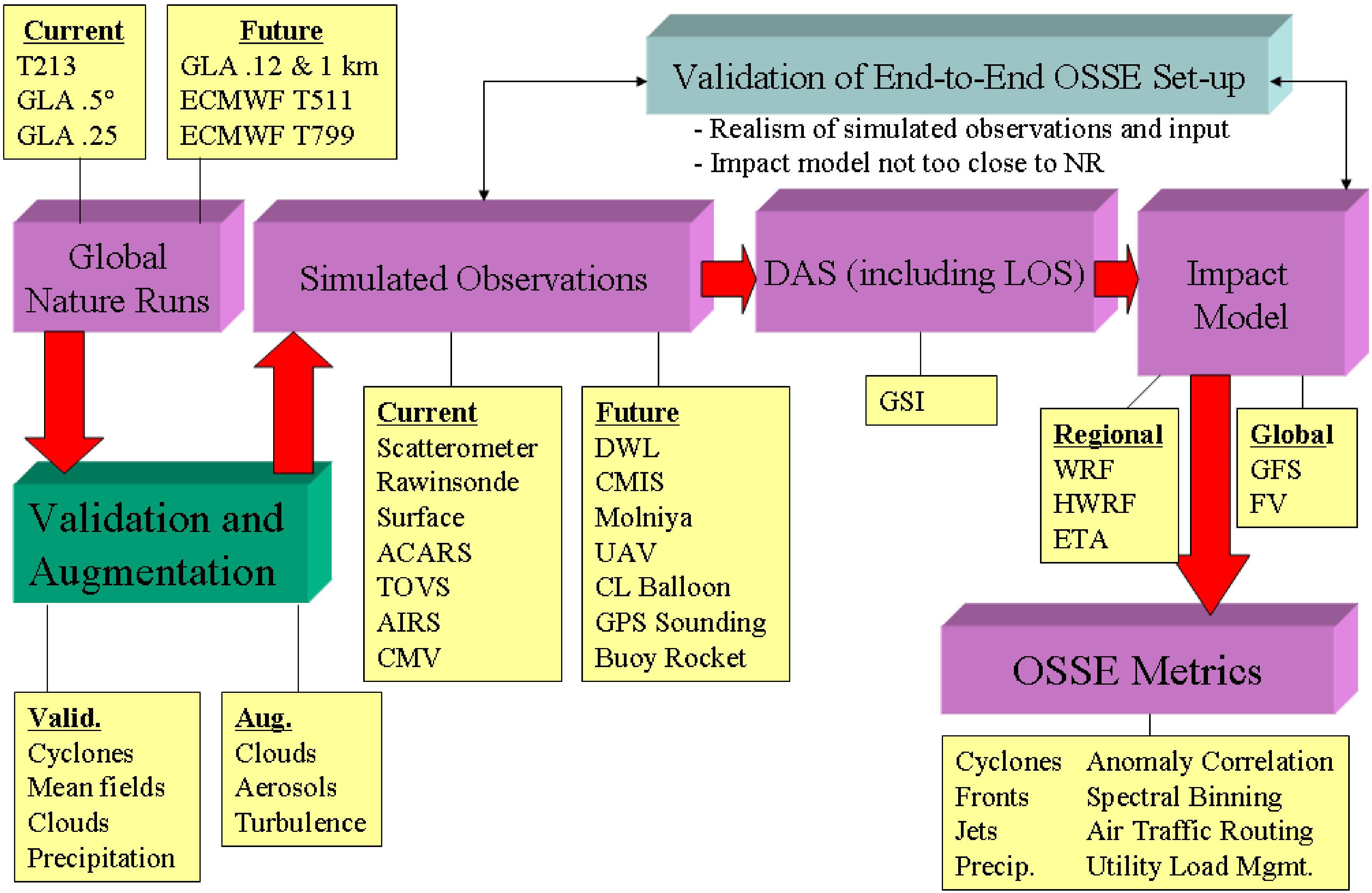
Forecast Runs

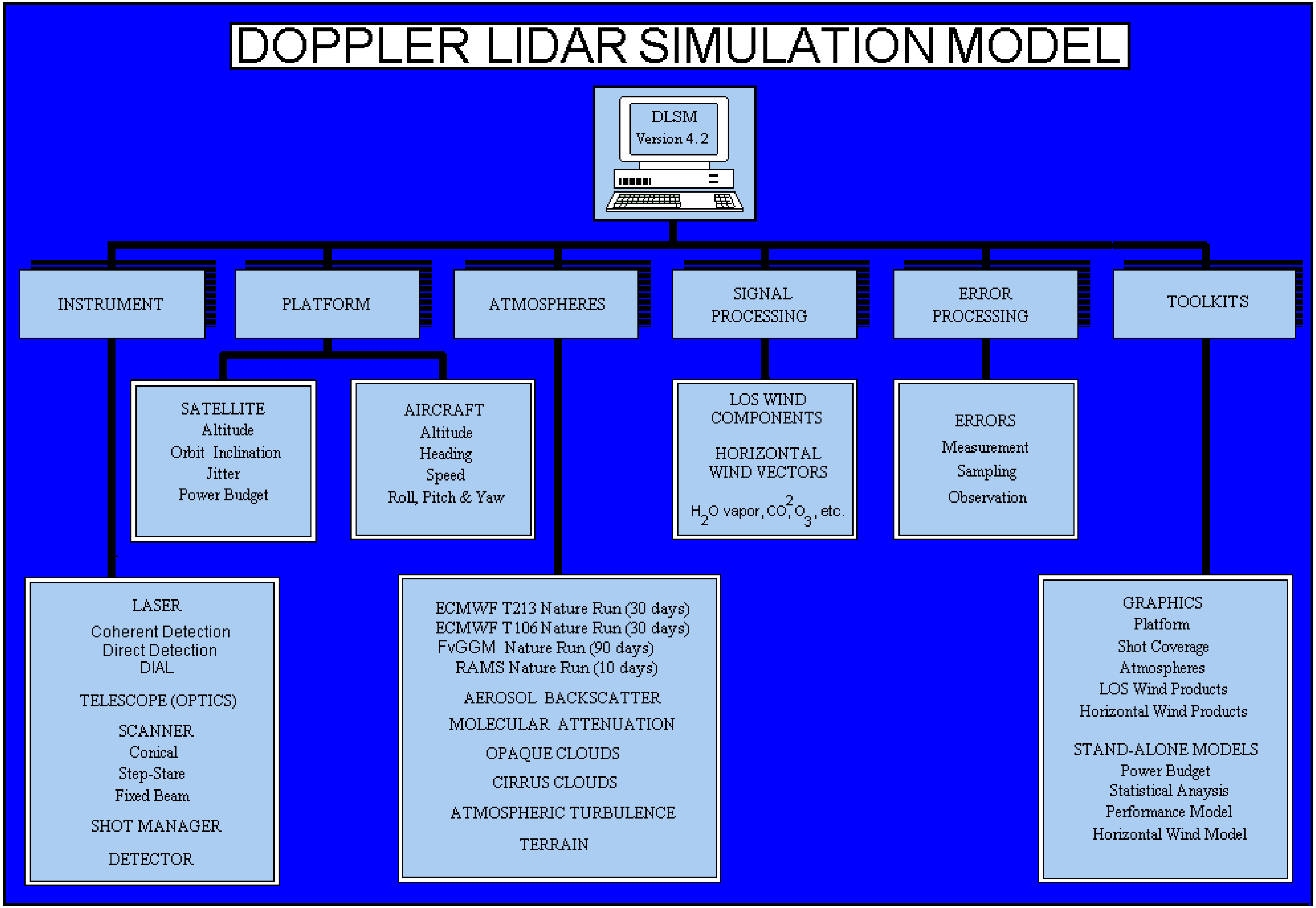
- Use a model different than the model used to create the Nature Run.
  - Physics should be different
  - Resolution should be lower
- Run the forecasting experiments for many cycles and forecast periods (with and without the new instrument data)
  - Compile statistics for differences between Nature Run and predictions.

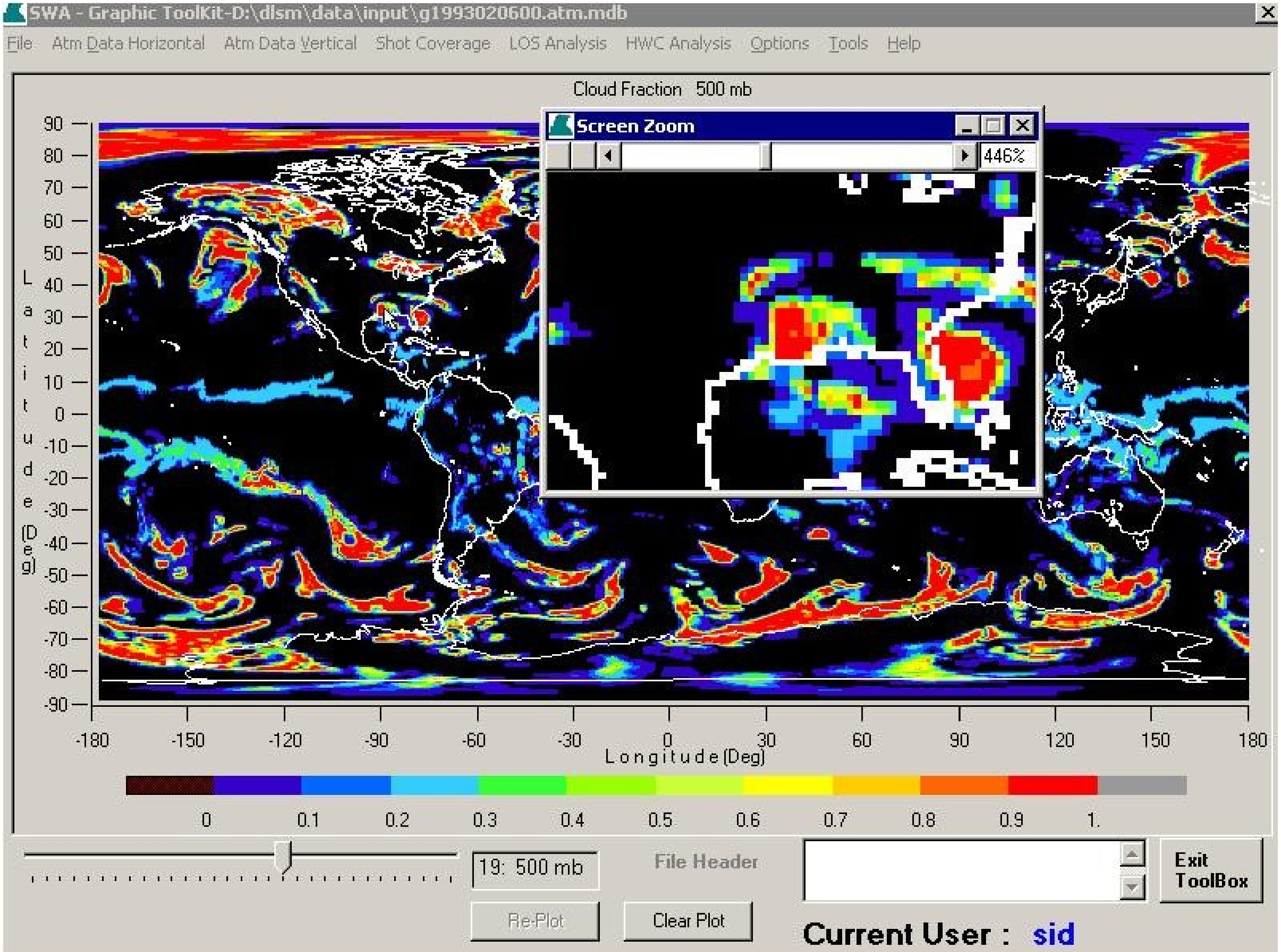
Impact Assessment

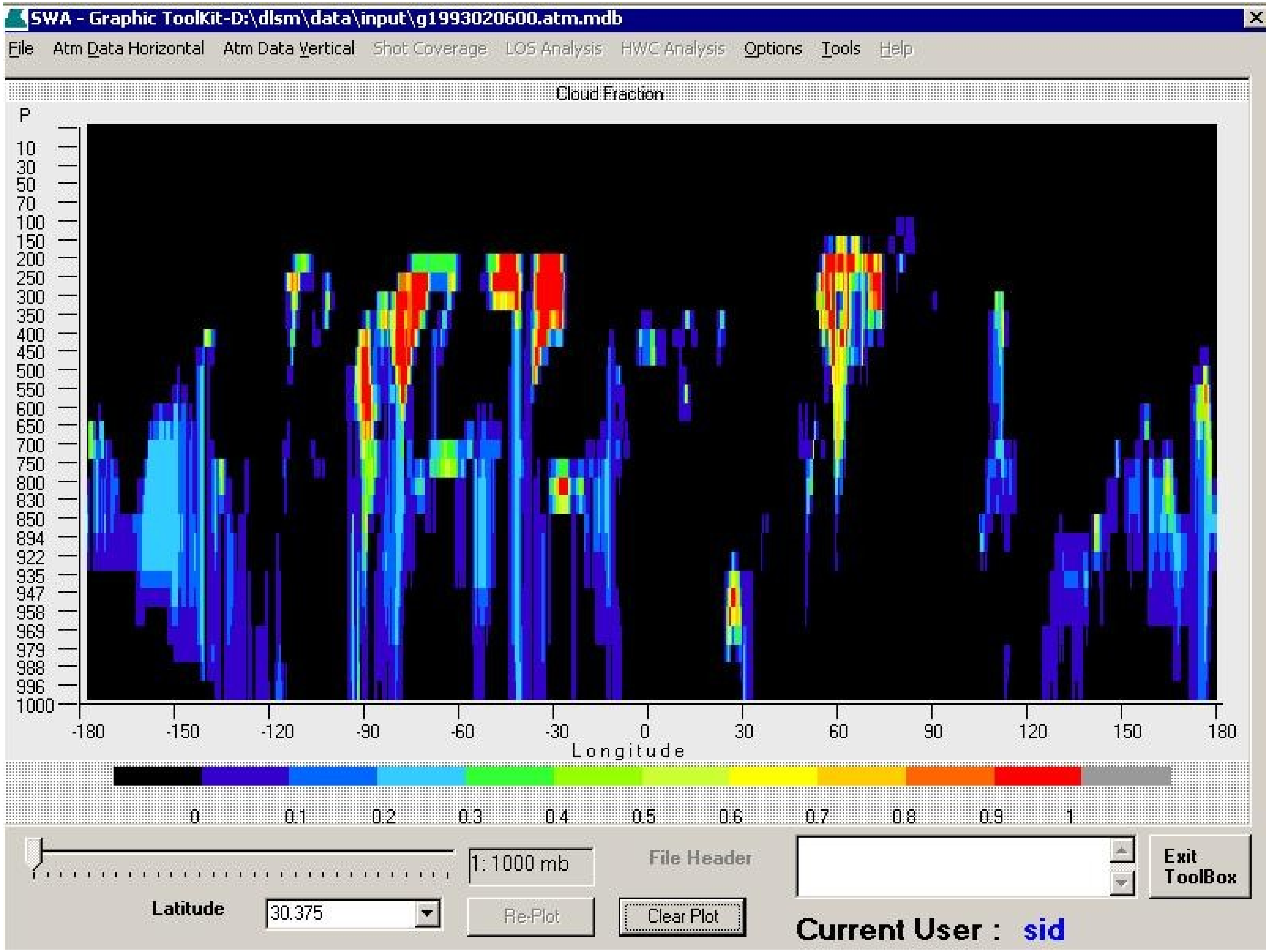
- Should define a set of impact metrics prior to running OSSEs
- Metrics should not be limited to anomaly correlations
  - Cyclone intensity
  - Magnitude of jet core speeds
  - Precipitation patterns
  - Storm tracks

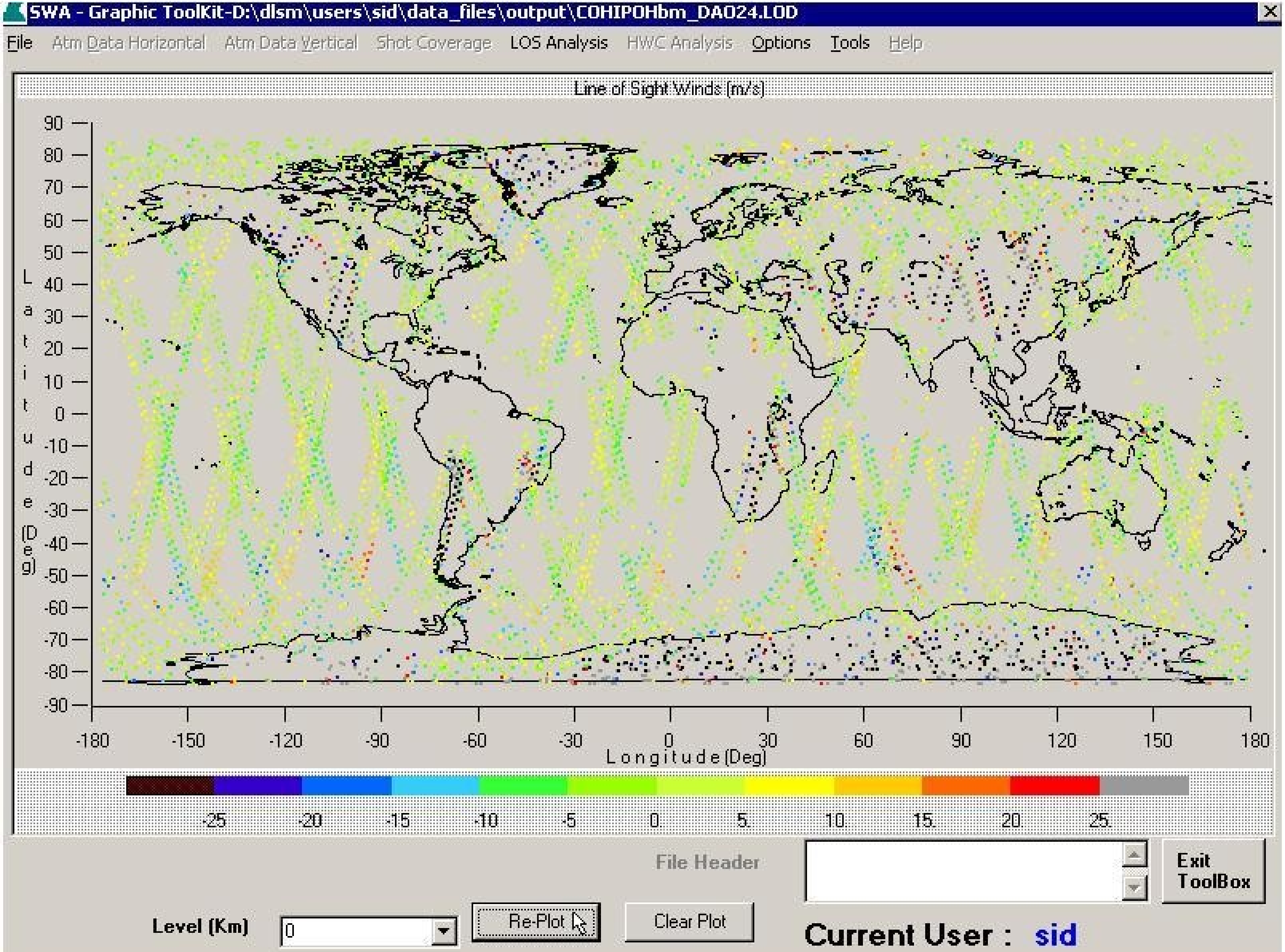
OSSE TESTBED COMPONENTS

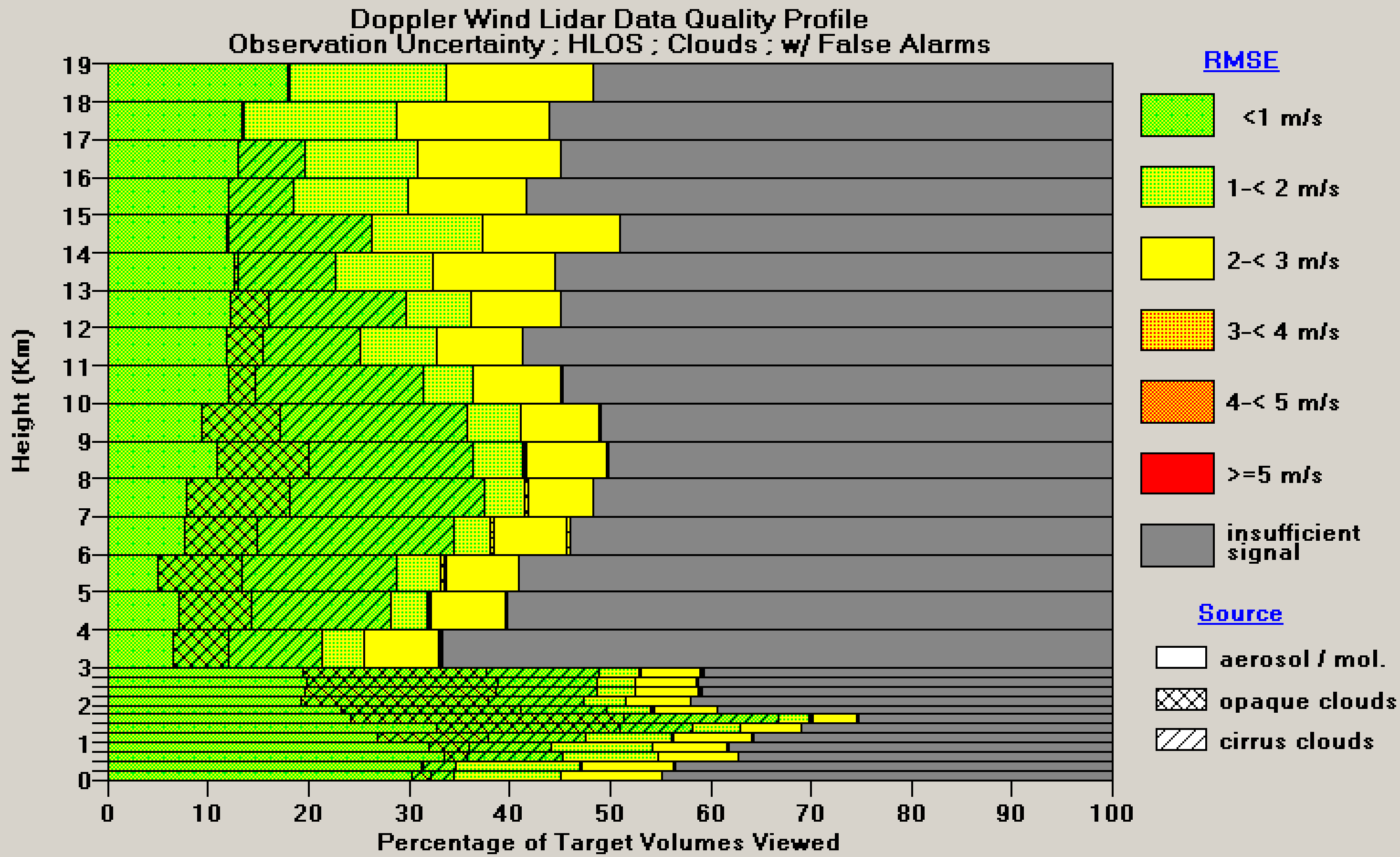



DOPPLER LIDAR SIMULATION MODEL
DLSM
Version 4.2
INSTRUMENT
PLATFORM
ATMOSPHERES
SIGNAL PROCESSING
ERROR PROCESSING
TOOLKITS
SATELLITE
Altitude
Orbit Inclination
Jitter
Power Budget
AIRCRAFT
Altitude
Heading
Speed
Roll, Pitch & Yaw
LOS WIND COMPONENTS
HORIZONTAL WIND VECTORS
H2O vapor, CO2, O3, etc.
ERRORS
Measurement
Sampling
Observation
LASER
Coherent Detection
Direct Detection
DIAL
TELESCOPE (OPTICS)
SCANNER
Conical
Step-Stare
Fixed Beam
SHOT MANAGER
DETECTOR
ECMWF T213 Nature Run (30 days)
ECMWF T106 Nature Run (30 days)
FvGGM Nature Run (90 days)
RAMS Nature Run (10 days)
AEROSOL BACKSCATTER
MOLECULAR ATTENUATION
OPAQUE CLOUDS
CIRRUS CLOUDS
ATMOSPHERIC TURBULENCE
TERRAIN
GRAPHICS
Platform
Shot Coverage
Atmospheres
LOS Wind Products
Horizontal Wind Products
STAND-ALONE MODELS
Power Budget
Statistical Anaysis
Performance Model
Horizontal Wind Model


SWA - Graphic ToolKit-D:\dlsm\data\input\g1993020600.atm.mdb
File
Atm Data Horizontal
Atm Data Vertical
Shot Coverage
LOS Analysis
HWC Analysis
Options
Tools
Help
Cloud Fraction 500 mb
Screen Zoom
446%
Latitude (Deg)
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90
-180 -150 -120 -90 -60 -30 0 30 60 90 120 150 180
Longitude (Deg)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.
19: 500 mb
File Header
Exit ToolBox
Re-Plot
Clear Plot
Current User : sid


SWA - Graphic ToolKit-D:\dlsm\data\input\g1993020600.atm.mdb
File
Atm Data Horizontal
Atm Data Vertical
Shot Coverage
LOS Analysis
HWC Analysis
Options
Tools
Help
Cloud Fraction
P
10 30 50 70 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 830 850 894 922 935 947 958 969 979 988 996 1000
-180 -150 -120 -90 -60 -30 0 30 60 90 120 150 180
Longitude
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
1: 1000 mb
File Header
Exit ToolBox
Latitude
30.375
Re-Plot
Clear Plot
Current User : sid


SWA - Graphic ToolKit-D:\dlsm\users\sid\data_files\output\COHIPOHbm_DA024.LOD
File
Atm Data Horizontal
Atm Data Vertical
Shot Coverage
LOS Analysis
HWC Analysis
Options
Tools
Help
Line of Sight Winds (m/s)
Latitude (Deg)
Longitude (Deg)
-25 -20 -15 -10 -5 0 5 10 15 20 25
File Header
Exit ToolBox
Level (Km)
0
Re-Plot
Clear Plot
Current User : sid



RUN: 2/6/1993 0001 Z (1 hr sim.) Global
TARGET ATM.: background- log normal variability
ALTITUDE: 400 Km ORBIT INC: 98 deg
VERTICAL INT. >PBL: 1. Km <=PBL: 0.25 Km

DETECTION: Coherent SCAN: Step_Stare
WAVELENGTH: 2.052 um NADIR: 45. deg
ENERGY: 0.5 J APERTURE: 0.5 m PLT PWR: 75. W
PRF: 12. Hz ACCUM. TIME: 5 s BETA THR.: 50.%

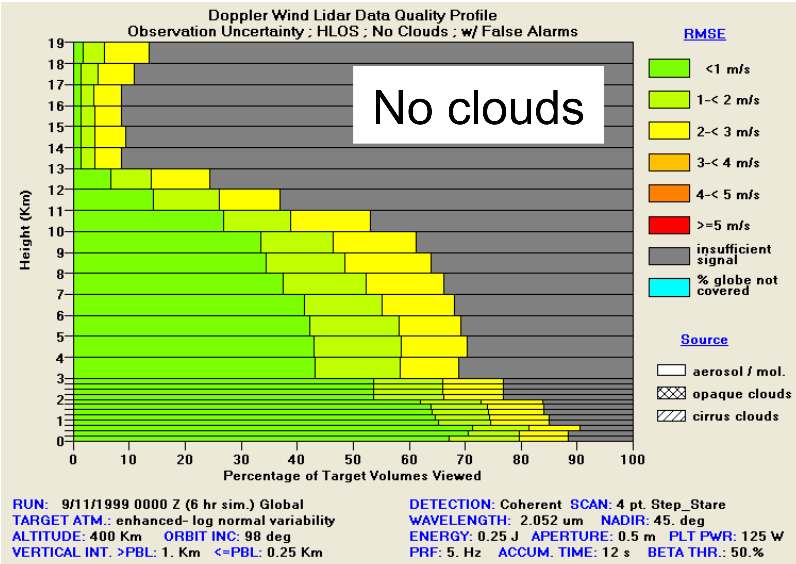
Lidar design issues

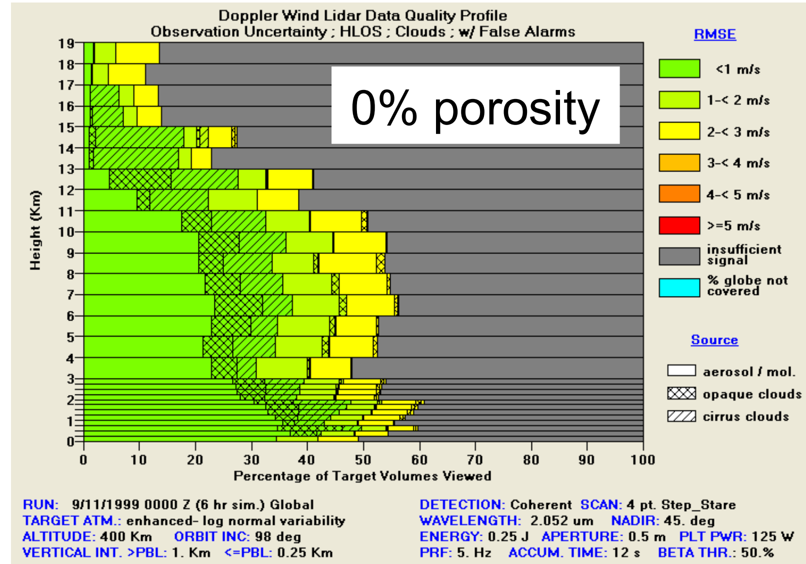
- The instrument accuracy of direct detection lidars for Doppler and DIAL are proportional to the number of photons detected. For molecular lidars, clouds are a source of error. If “integration on a chip” is employed, individual cloud returns contaminate the entire integration interval.
- Coherent detection lidars have the properties of threshold accuracy (i.e. instrument accuracy does not change much above some threshold of detected coherent photoelectrons). Sensitivity, however, is a function of the total number of PEs.
- For both detection techniques, the total observation error is dependent on the number and spacing of the samples.
  - Total error = Sqrt(instrument error^2 + representative error ^{2})

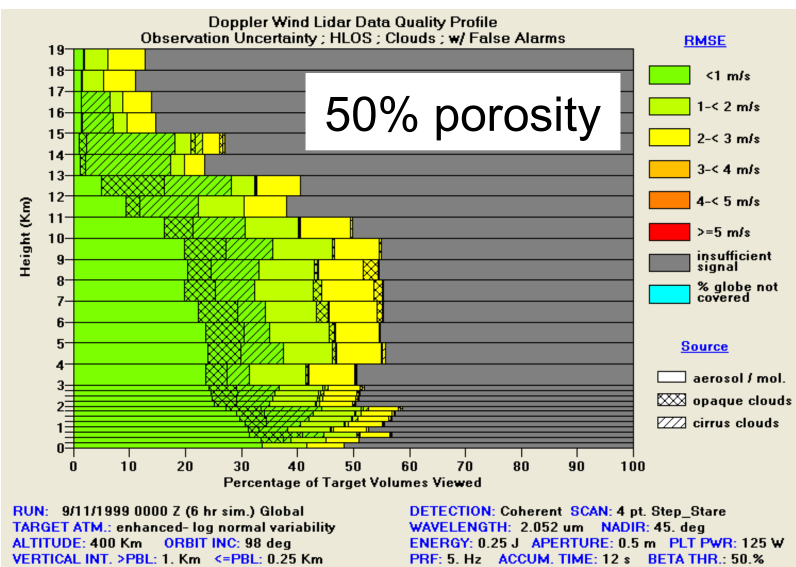
Performance modeling

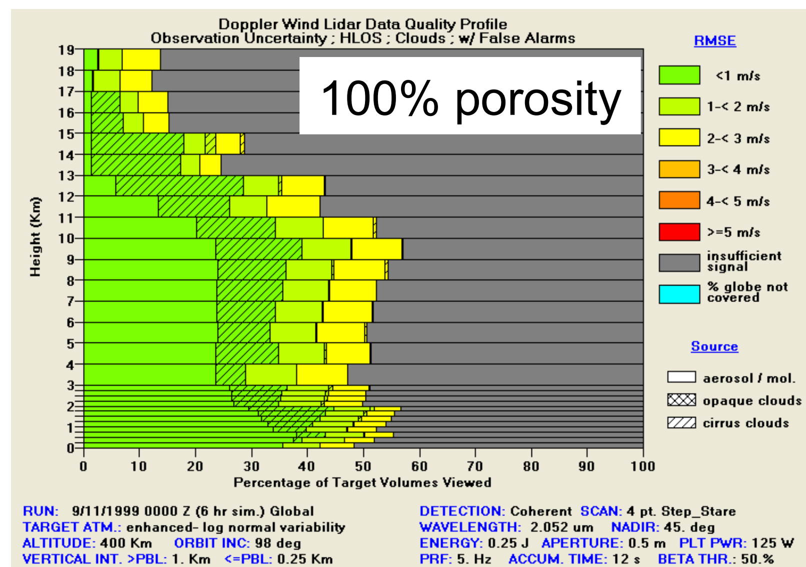
- The DWL community has available tools for simulating future DWL instrument and mission concepts
  - Doppler Lidar Simulation Model (DLSM/SWA)
  - Observing System Simulation Experiments (OSSEs by NOAA, NASA & DoD; NPOESS/IPO major funding)
    - Nature Runs are used as truth
- Performance profiles
  - Generated by running DLSM on Nature Runs
  - Summarizes vertical coverage of the simulated DWL data products and their accuracy
  - Uses “background” and “enhanced” aerosol distributions to bracket performance
  - Much emphasis on clouds

Cloud Porosity









Porosity Summary

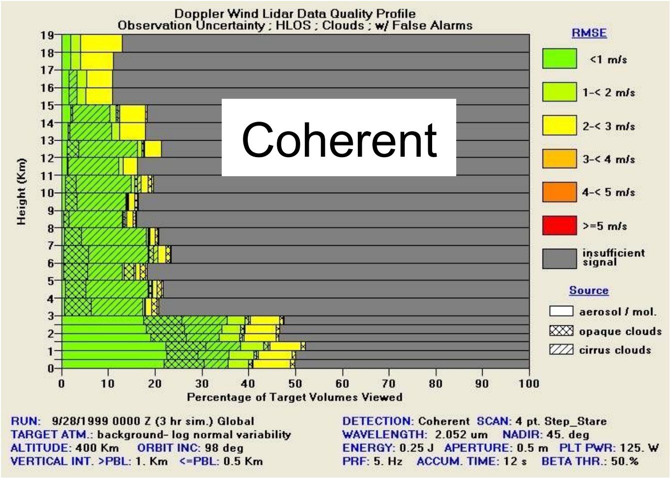
- For the coherent subsystem of the hybrid DWL, the vertical coverage of the data products meeting the requirements are reasonably “cloud proof ”.
- A remaining issue is how the utility of cloud returns (actual horizontal motion of the cloud particles) differs from those from the adjacent aerosols.

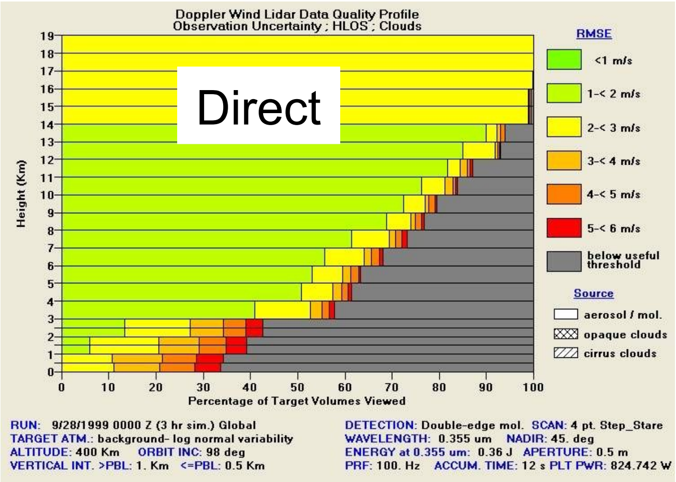
Adaptive Targeting Mission for NPOESS Hybrid DWL: NCEP OSSE

- **Coherent detection sub-system (wedge scanner or HOE)**
  - **100% duty cycle**
  - **65W, 2.05microns**
  - **Lower tropospheric and enhanced aerosol/cloud winds**
  - **CMV height assignment**
    - **Reduce DAS observation error by ~2-3 m/s (per Chris Velden)**
  - **Depth of PBL**
  - **ICAT for direct detection + target identification by LEKF (e.g.)**
- **Direct detection (molecular) sub-system (HOE)**
  - **10-15% duty cycle (aperiodic, i.e. adaptively targeted)**
  - **850W peak, 0.355 microns**
  - **Cloud free mid-upper tropospheric/ lower stratospheric winds**

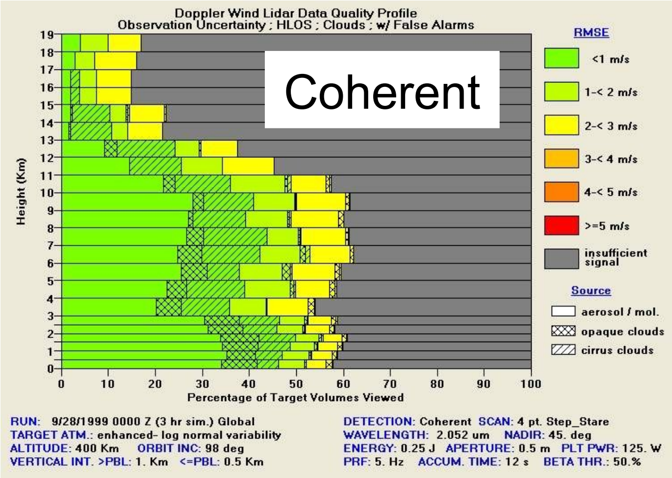
Vertical Distribution of GWOS LOS Observations

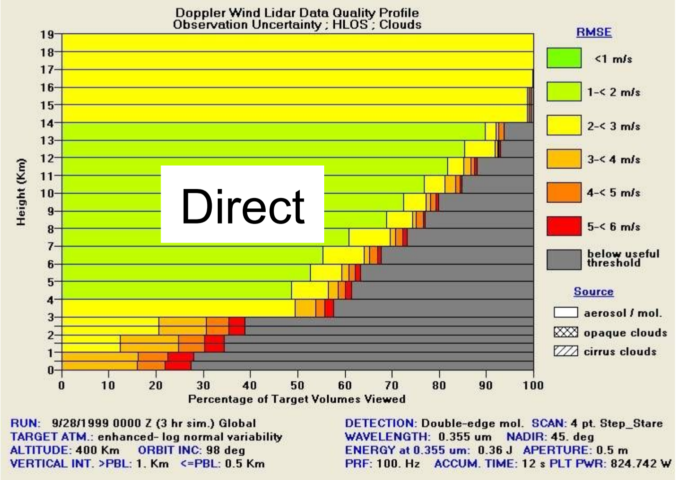
GWOS with background aerosol mode





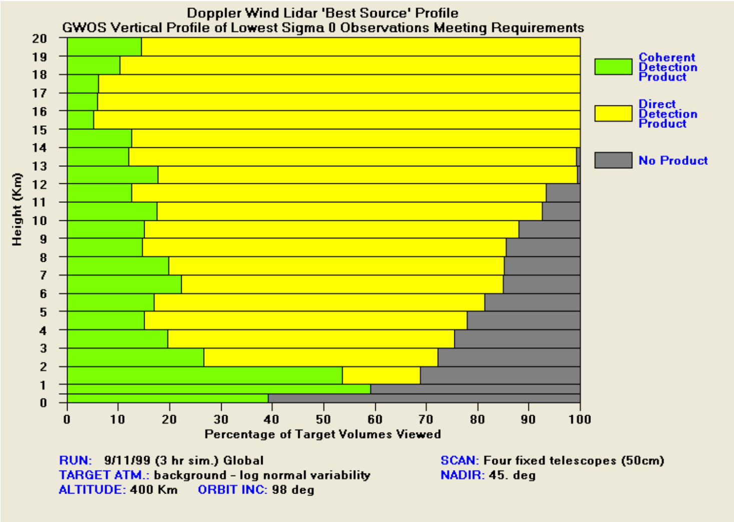
GWOS with enhanced aerosol mode





Vertical Distribution of “Best choice” LOS Observations

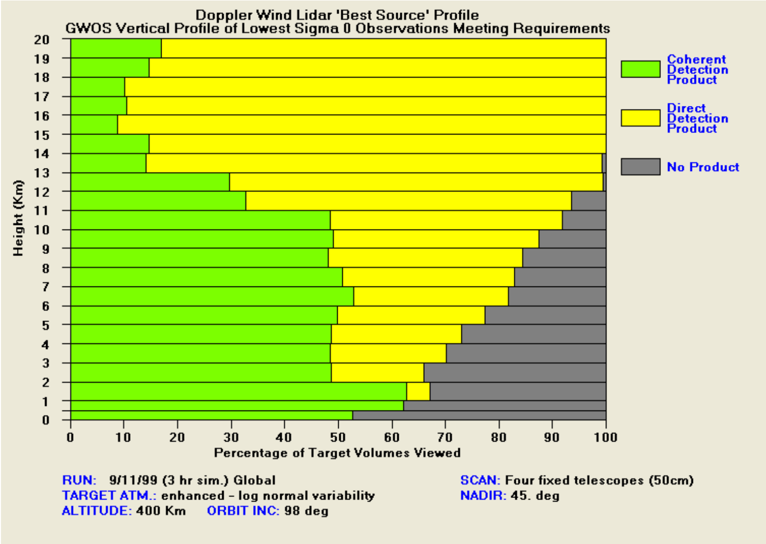
GWOS with background aerosol mode



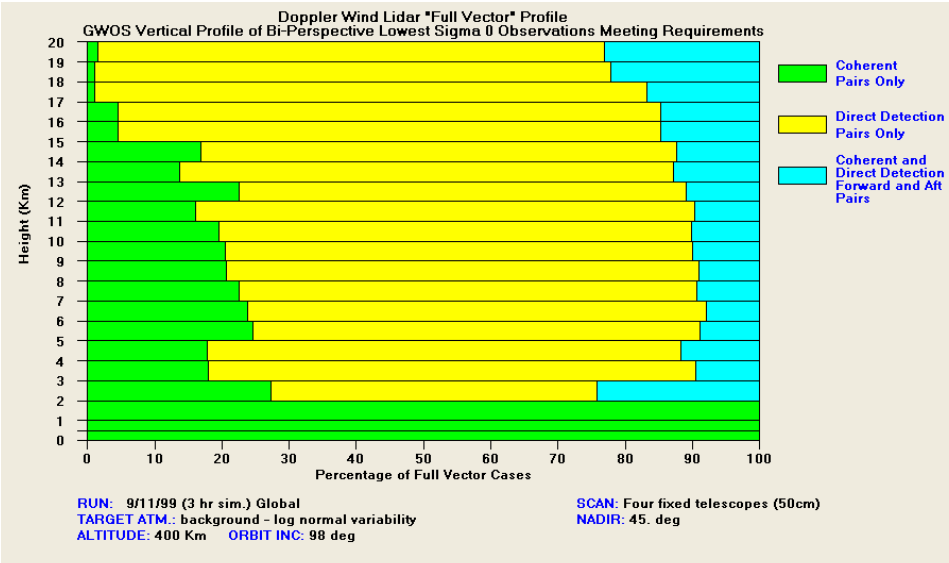
Dual sampling with the coherent and direct detection molecular Global Wind Observing Sounder (GWOS)

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

GWOS with enhanced aerosol mode



GWOS Synergistic Vector Wind Profiles*



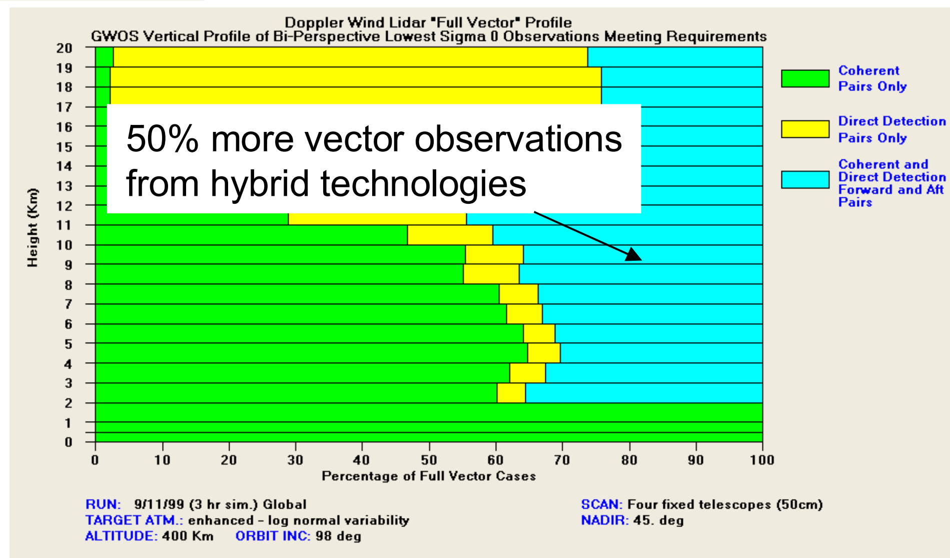
Green: both perspectives from coherent system

Yellow: both perspectives from direct molecular

Blue: one perspective coherent; one perspective direct

Background aerosol mode

Enhanced aerosol mode

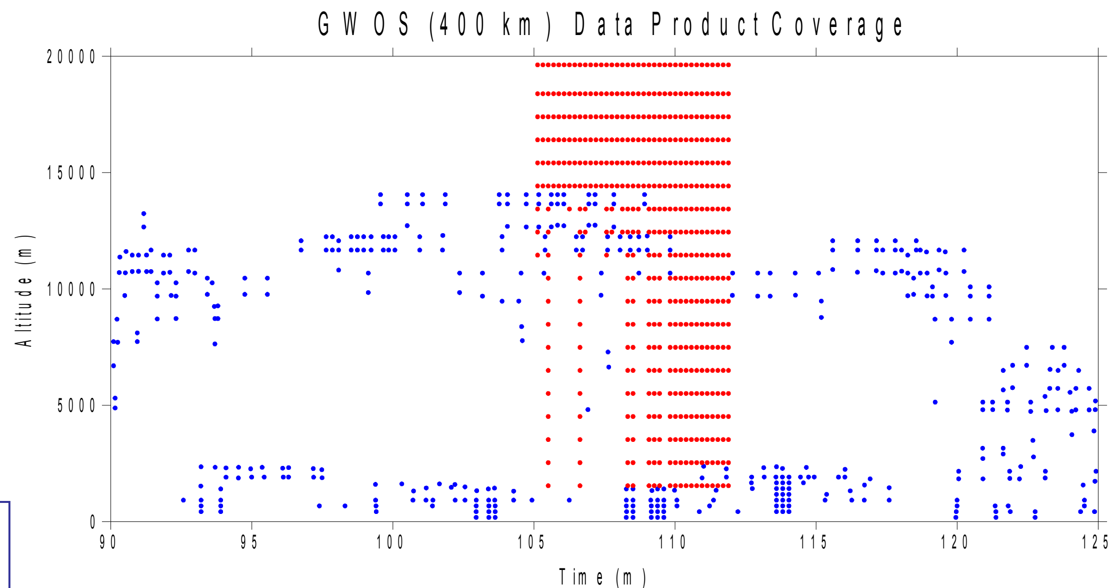


Coherent aerosol and direct detection molecular channels work together to produce optimum vertical coverage of bi-perspective wind measurement

* When two perspectives are possible

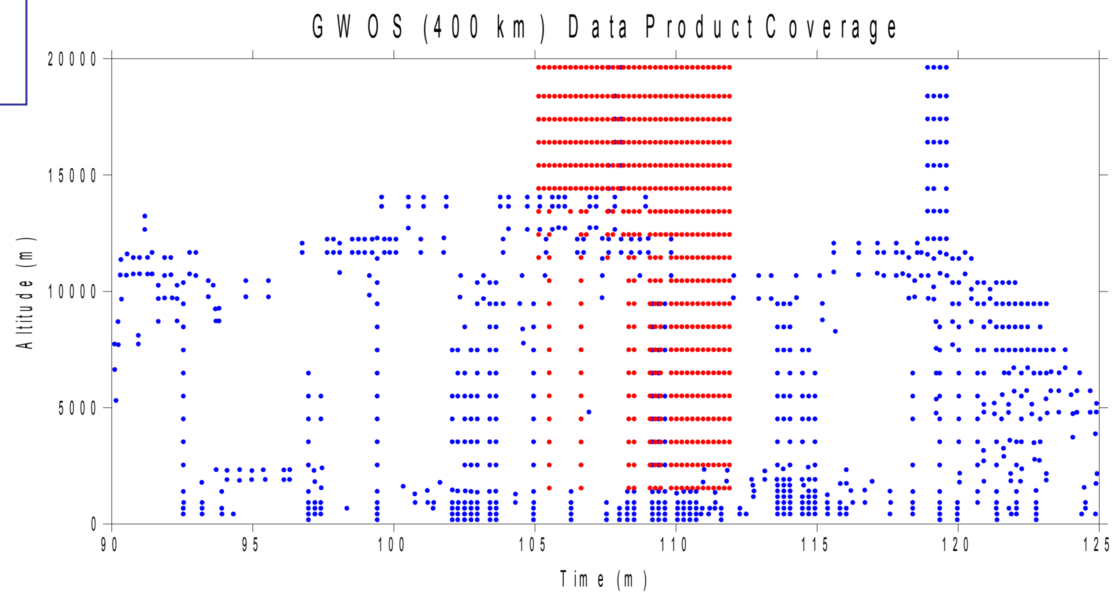
10 % duty cycle coverage

With background aerosol concentrations



Observation source and errors
Blue: coherent w/ < 1.5 m/s
Red: direct w/ < 3.0 m/s

With enhanced aerosol concentrations

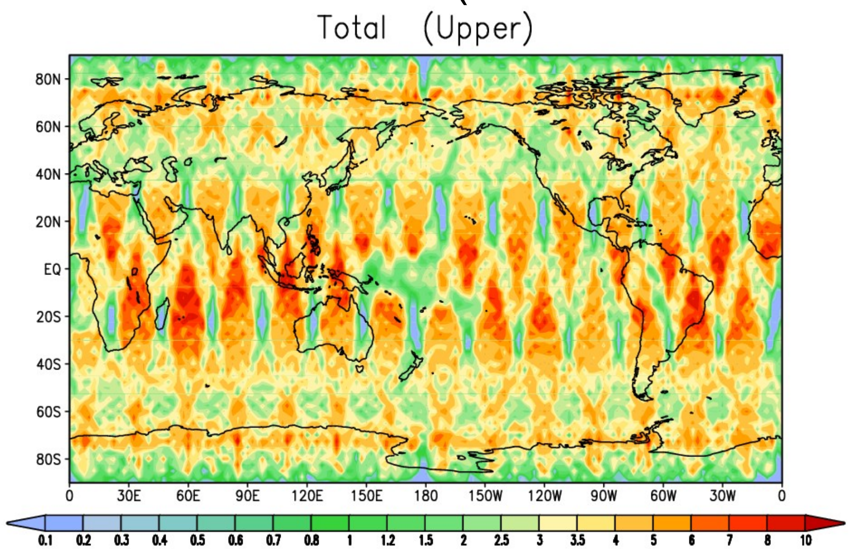


Doppler Wind Lidar experiments

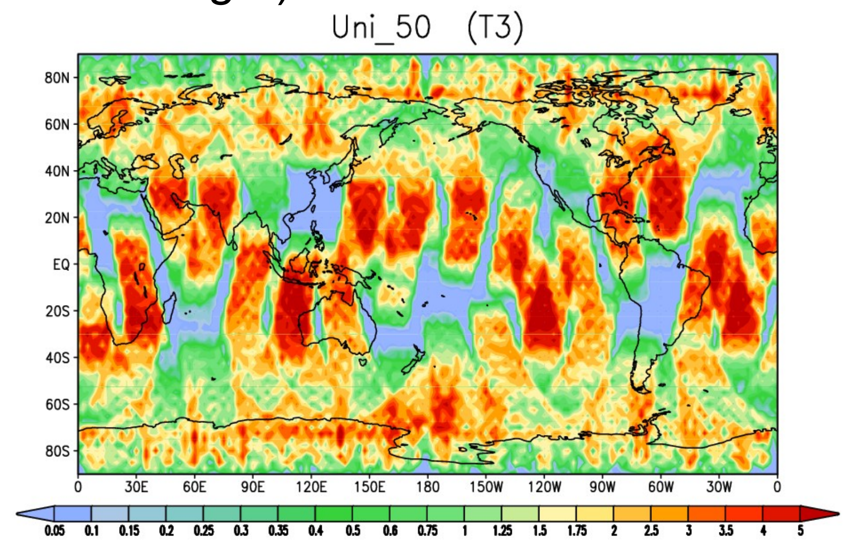
- The 90/10 rule implied a variety of choices, but which one is better?
- How to design the targeting strategy so that the direct detection can be optimized?
- The design of the direction detection has to keep NWP operations in mind
- We have conducted 8 adaptive targeting experiments

Data selection Cases

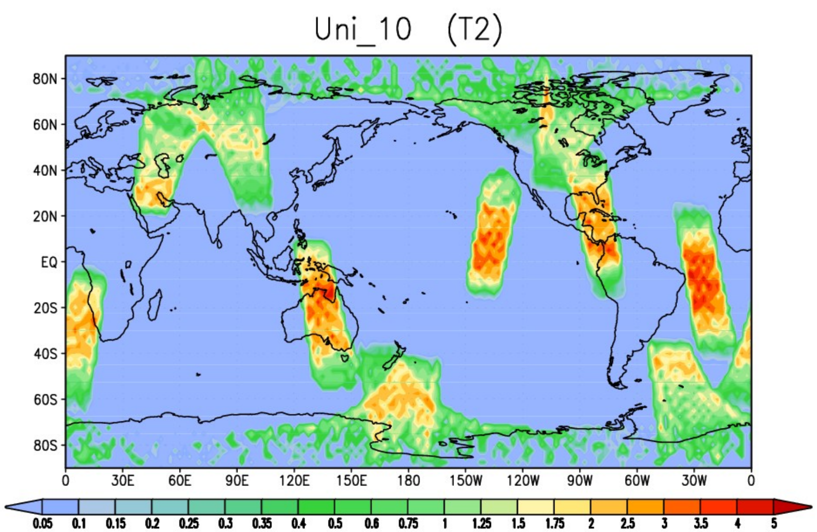
(200mb Feb13 - Mar 6 average)



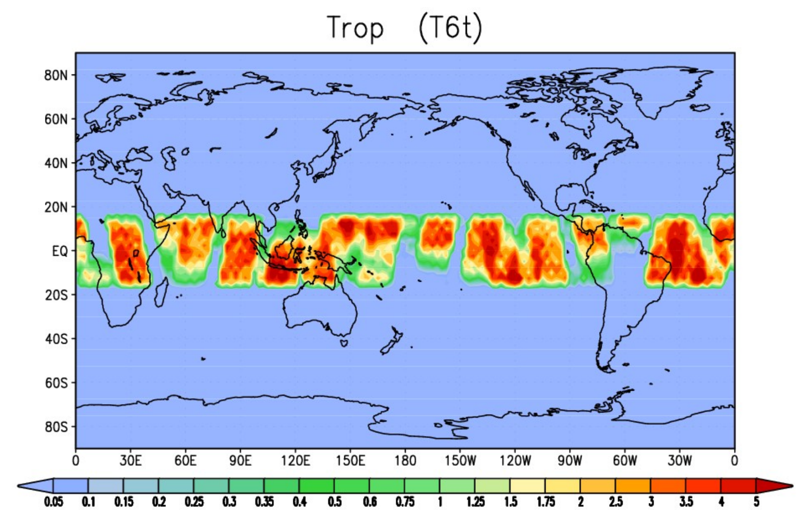
100% Upper Level



50% Upper Level regular sampling

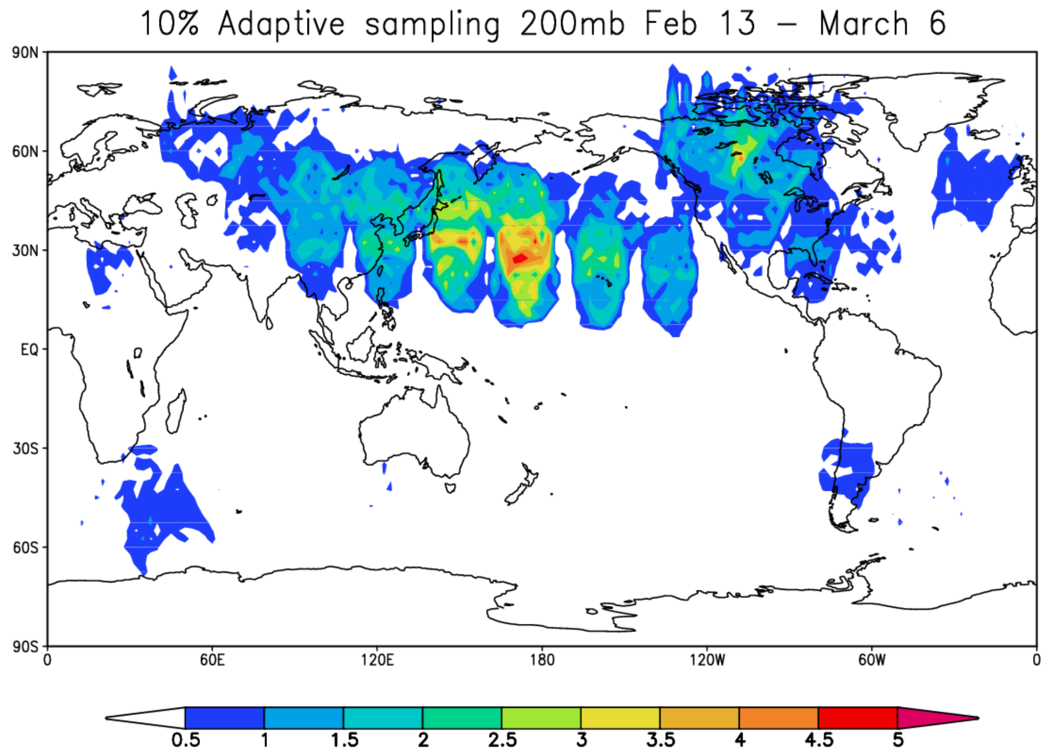


10% Upper Level



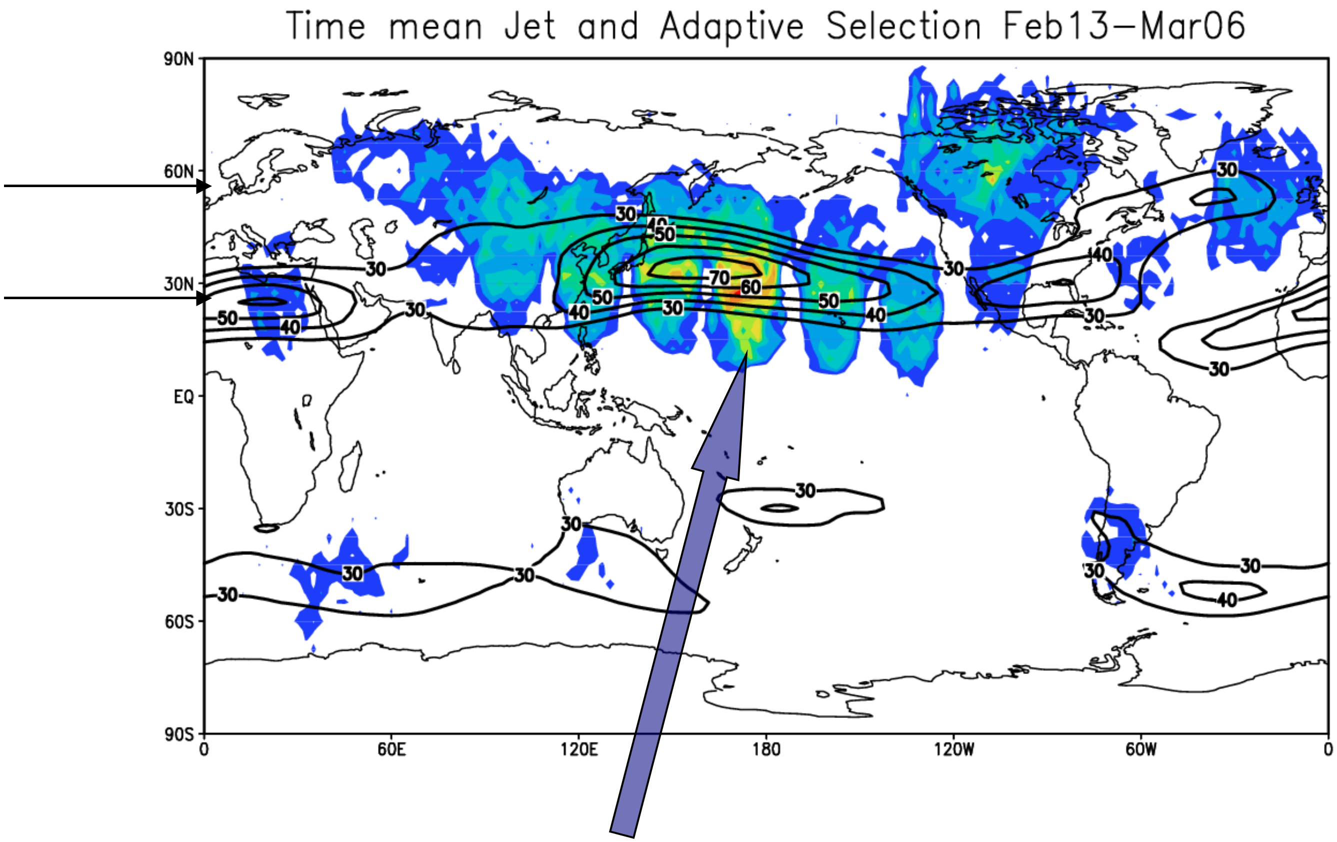
10% Upper Level tropics

Adaptive sampling based on error level



The values are number of selected data within a 2.5 by 2.5 degree box

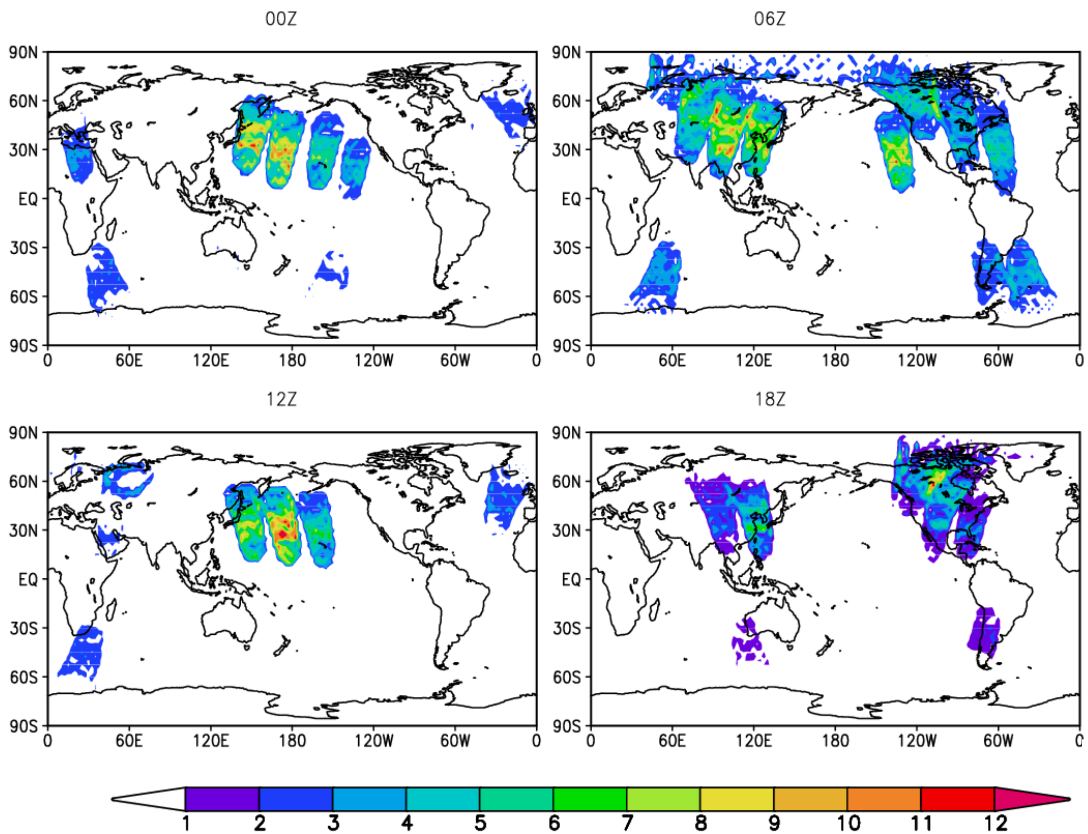
Position of jet stream and adaptive sampling region

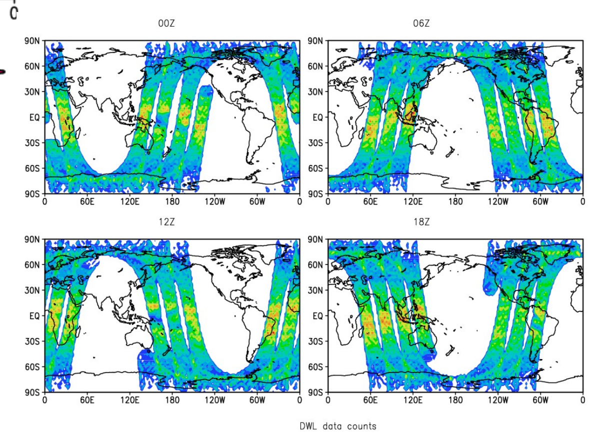


The maximum sampling region located in the jet core

Diurnal cycle of the adaptive sampling region

(Feb 13 ~ Mar 6 average)

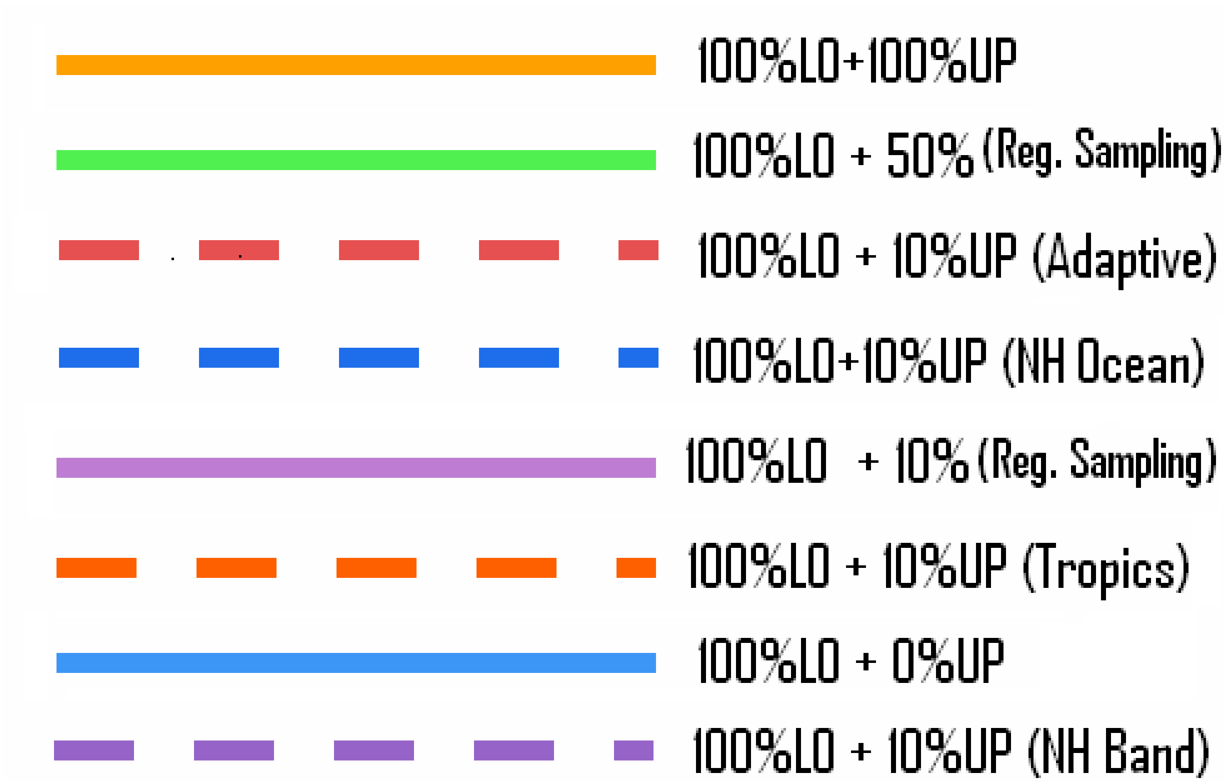




There has to be a match between satellite tracks and max error level regions

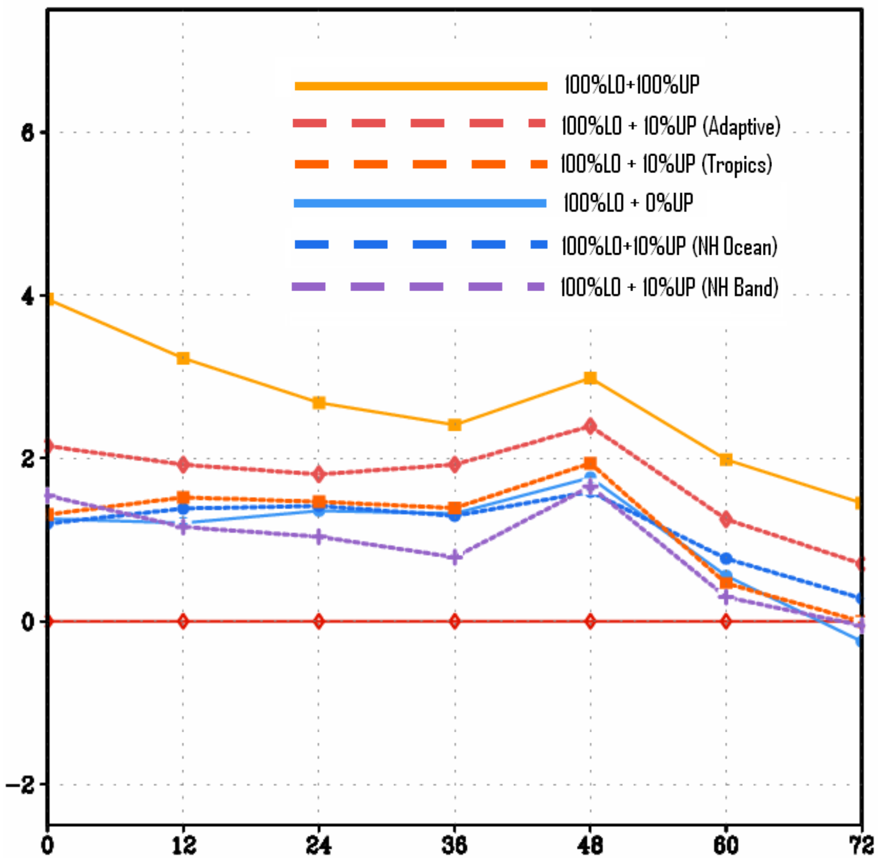
Anomaly Correlation results
(8 experiments)

- D2D3
- D2D3T3
- JW1
- T4
- D2D3T2
- T6t
- D2
- T6n

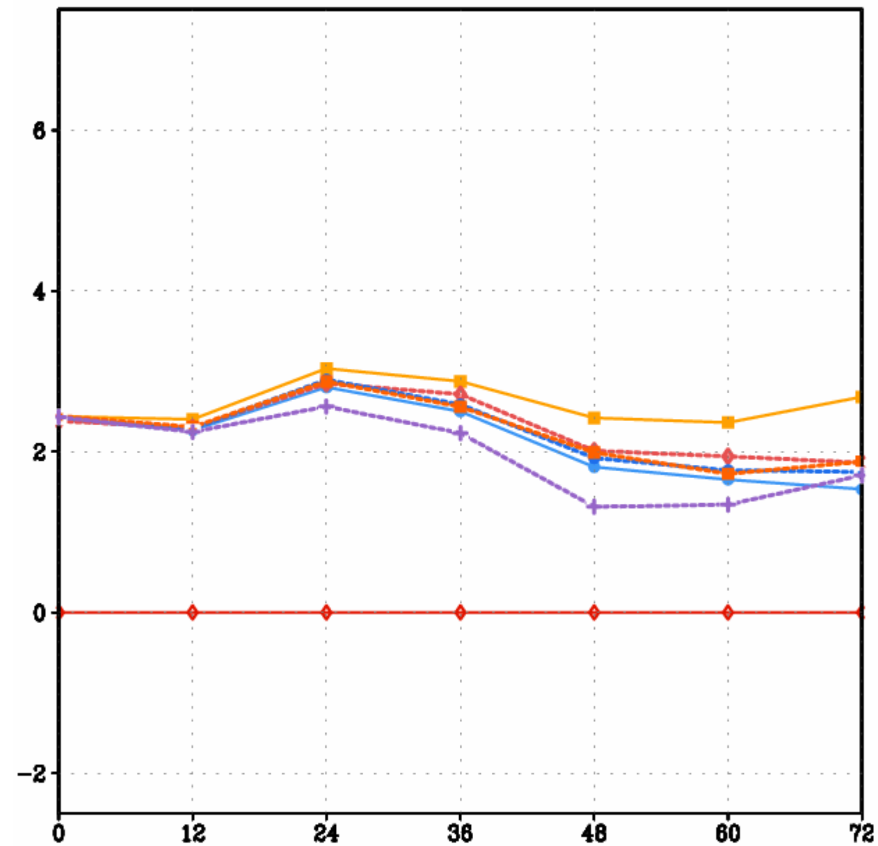


Anomaly correlation difference in NH from CTL (No DWL) Synoptic scale Meridional wind (U)

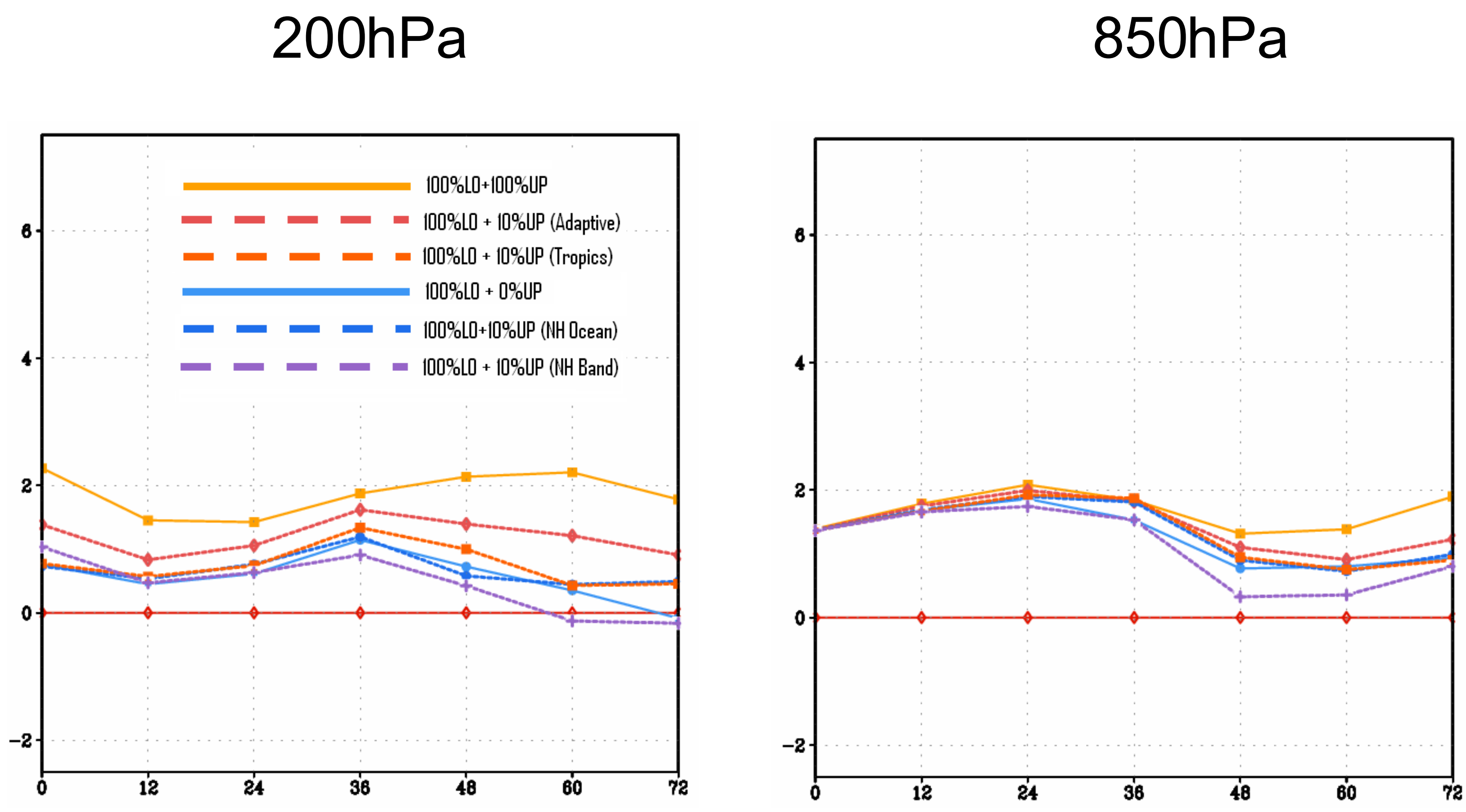
200hPa



850hPa

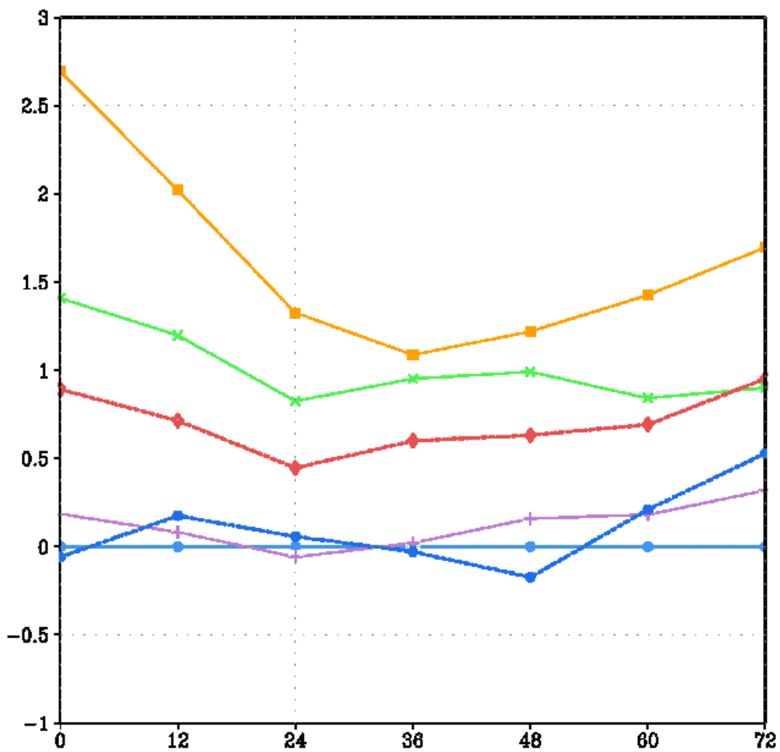


Anomaly correlation at NH
Difference from CTL (No DWL)
Synoptic scale Meridional wind (V)

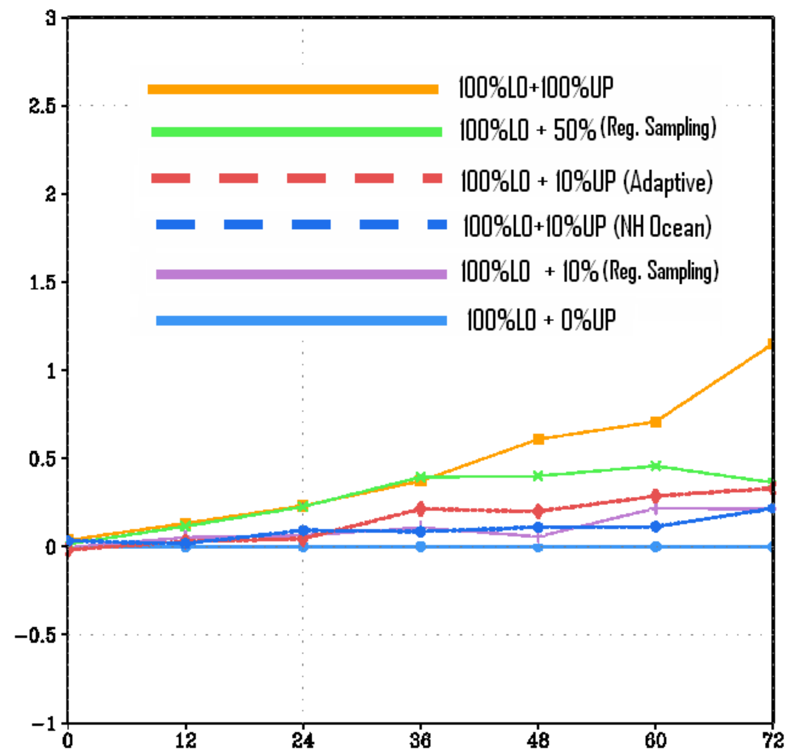


Anomaly correlation at NH
Difference from D2 (100%LO)
Synoptic scale Zonal wind (U)

200hPa

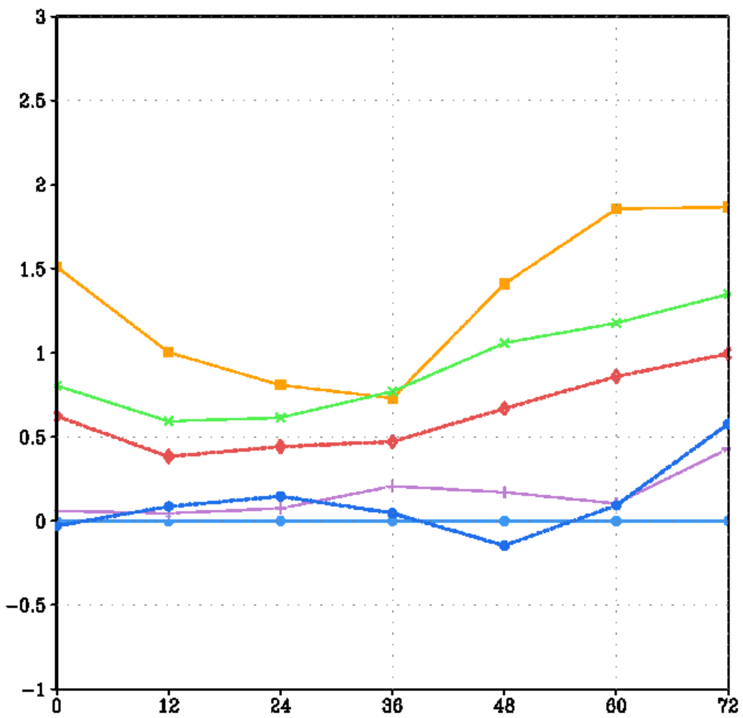


850hPa

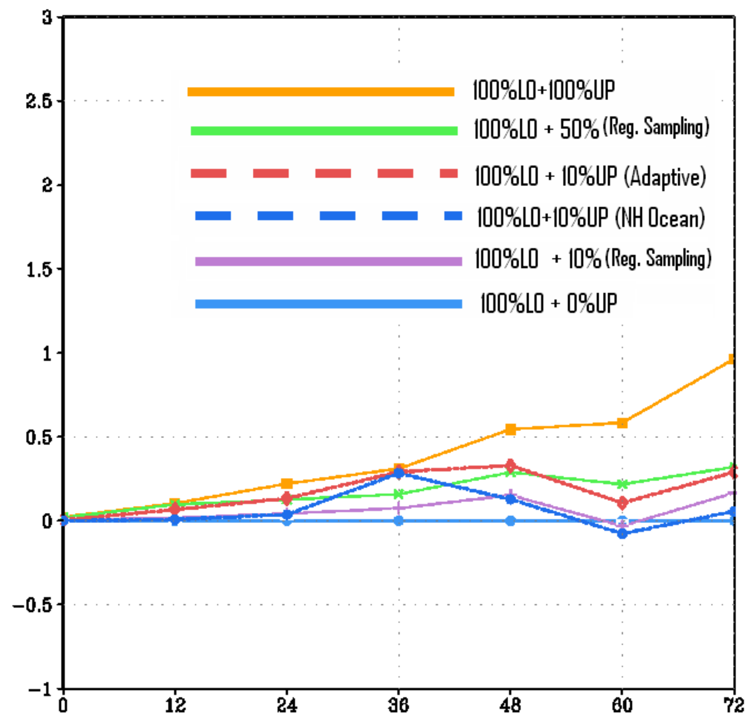


Anomaly correlation at NH
Difference from D2
Synoptic scale Meridional wind (V)

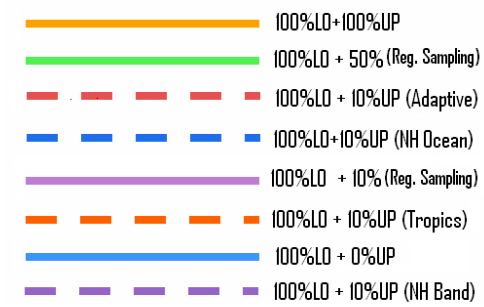
200hPa

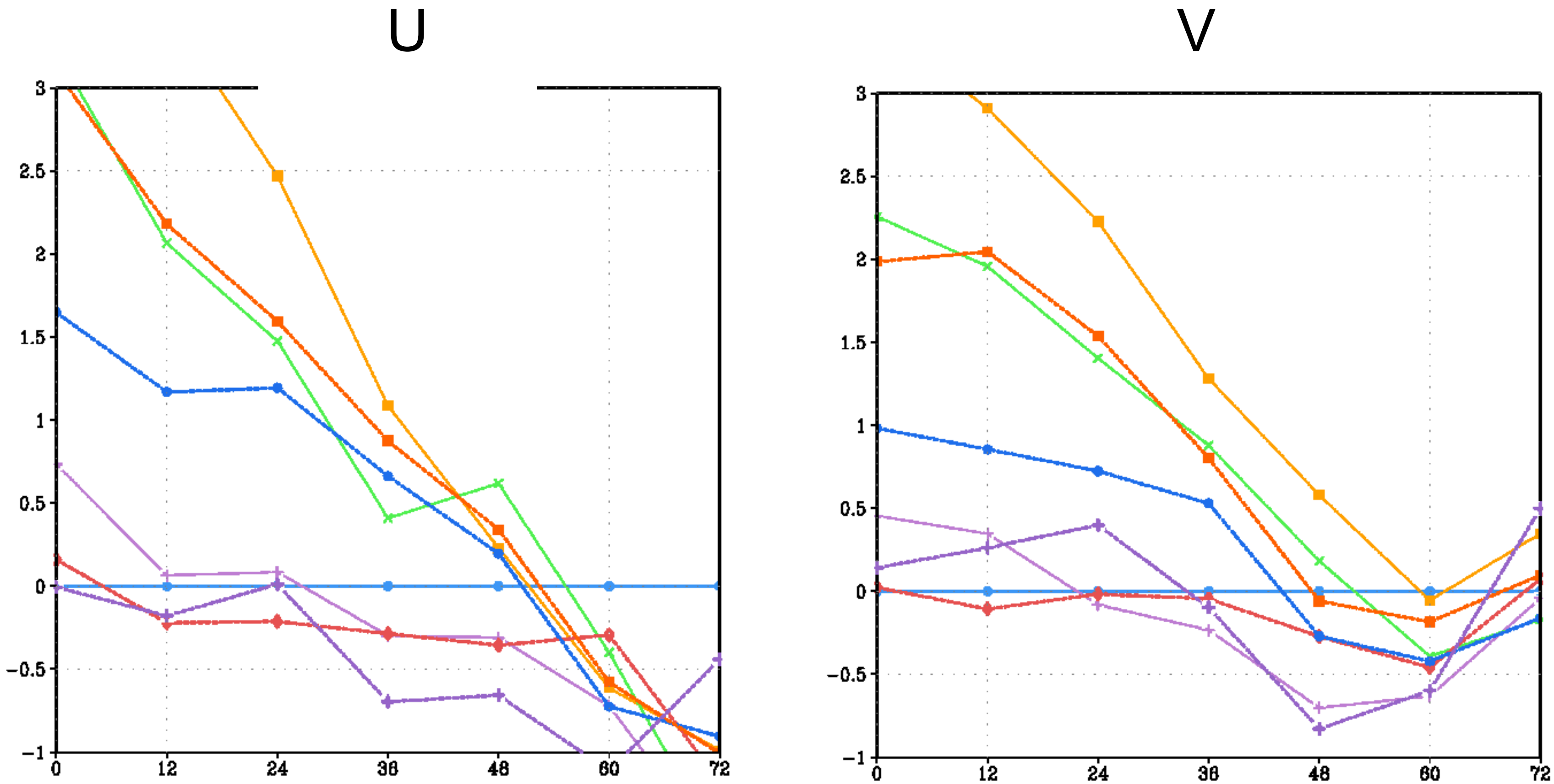


850hPa



Anomaly correlation over tropics
Difference from D2
Synoptic scale wind 200mb





Summary for DWL experiments

- 10% Upper DWL without targeting does not produce much impact (**requires at least 50%)**
- A simple adaptive targeted DWL showed significantly better impact
- Target regions correspond well with Northern Hemisphere jet stream
- Adaptive DWL targeting is better than targeting NH Ocean (data sparse area) only
- 10% DWL direct detection improve low level wind forecast after 48 hrs

OSSEs at GSFC for DWL impact on hurricane forecasting

SIMULATION STUDIES CONDUCTED AT GSFC

- DEMONSTRATED THE POTENTIAL FOR SPACE-BASED WIND PROFILES TO IMPROVE GLOBAL ANALYSIS AND PREDICTION.

- DETERMINED THE RELATIVE IMPORTANCE OF UPPER AND LOWER LEVEL WIND DATA.

- EVALUATED THE RELATIVE IMPACT OF TEMPERATURE, WIND AND MOISTURE DATA.

- TESTED DIFFERENT METHODS FOR ASSIMILATING SATELLITE SURFACE WIND SPEED DATA, AND THE RELATIVE IMPORTANCE OF SSM/I, ERS-1 AND NSCAT.

- EVALUATED DIFFERENT ORBITAL CONFIGURATIONS AND THE EFFECT OF REDUCED POWER FOR LAWS.

- DETERMINED DATA REQUIREMENTS OF SPACE-BASED LIDAR WINDS.

NASA/GODDARD NATURE RUN

- Model

- FVCCM (Finite-Volume Community Climate Model)

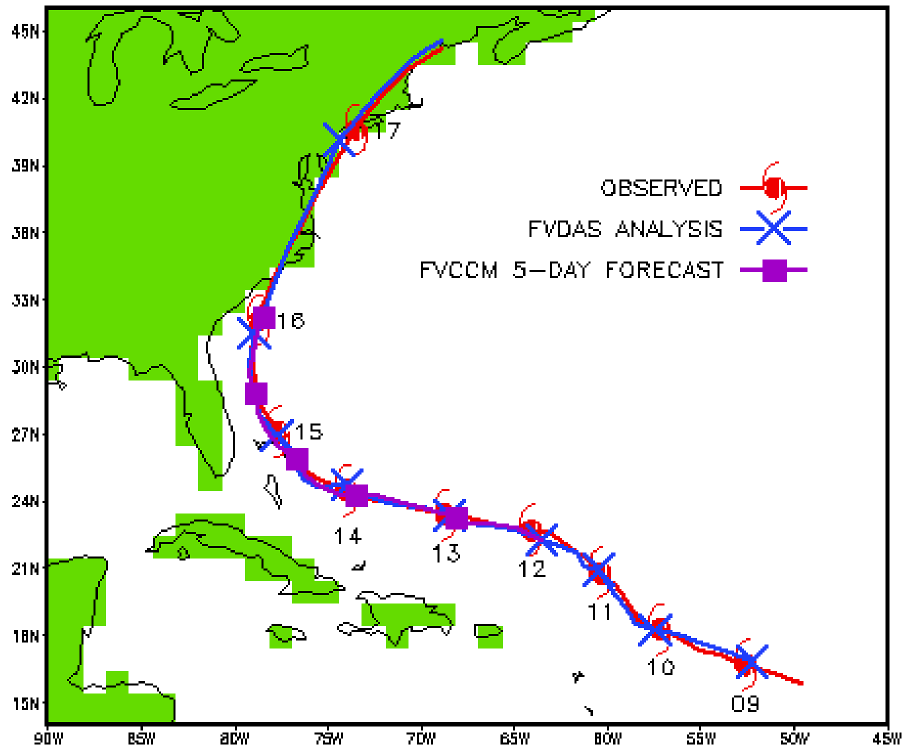
- Resolution
-
- Horizontal: 0.5° lat x 0.625° lon (regular grid)
- Vertical: Surface + 35 pressure levels
- (1000 Hpa to 0.4 Hpa)

- Time Period

- 1999 Sept. 11 00Z to 1999 December 31 18Z

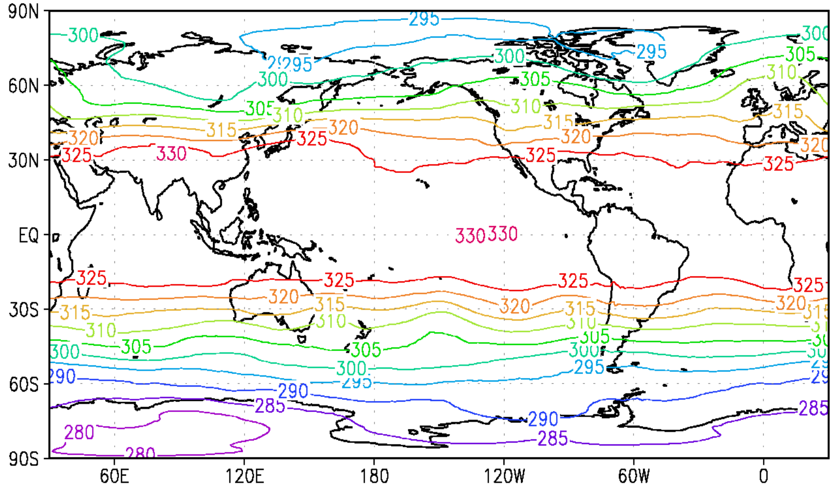
- Every 6 hours.

fvDAS ASSIMILATION AND FORECAST OF HURRICANE FLOYD

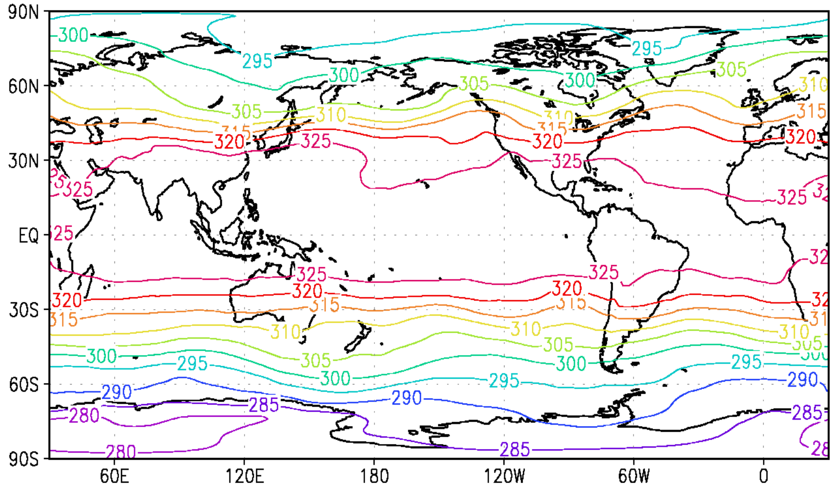


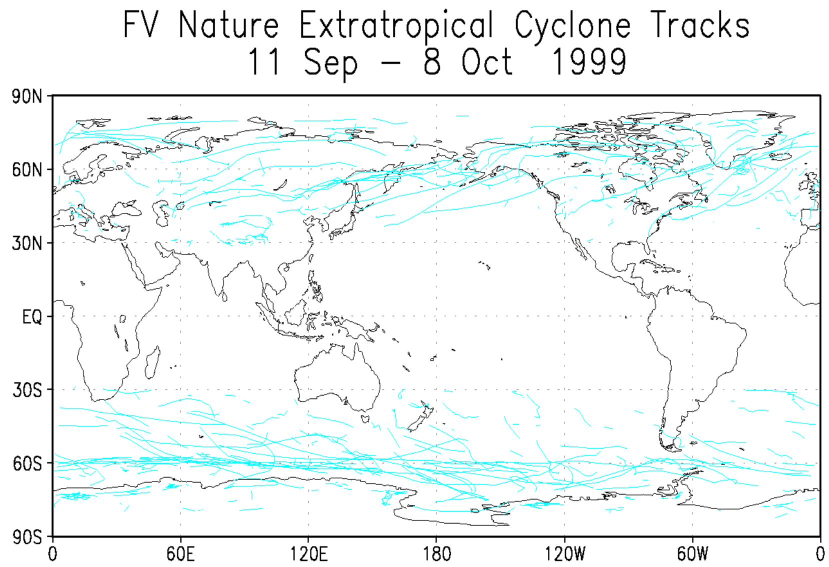
Hurricane Floyd tracks form National Hurricane Center observed best track, NASA DAO Finite Volume Data Assimilation System (FVDAS) 1^{o} X 1.25^{o} analysis, and FVCCM model 5-day forecast starting at 0000 UTC 12 September 1999.

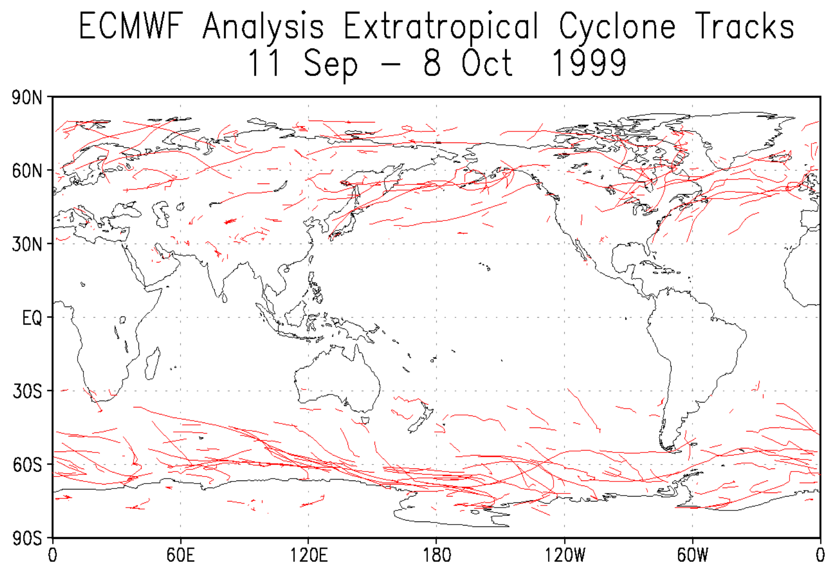
FV Nature 500 mb Potential Temperature (K)
11 Sep – 8 Oct 1999



ECMWF Analysis 500 mb Potential Temperature (K)
11 Sep – 8 Oct 1999




FV Nature Extratropical Cyclone Tracks
11 Sep – 8 Oct 1999
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0


ECMWF Analysis Extratropical Cyclone Tracks
11 Sep – 8 Oct 1999
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0

Cyclone Verification for September through December 1999

	Global		Southern Hemisphere Extratropics		Northern Hemisphere Extratropics	
	ECMWF Analysis	FVCCM Nature Run	ECMWF Analysis	FVCCM Nature Run	ECMWF Analysis	FVCCM Nature Run
Avg number of cyclone centers per synoptic time	24.3	28.8	10.7	13.6	12.9	14.5
Avg number of genesis cases per synoptic time	7.3	9.5	2.8	3.9	4.0	5.1
Avg number of lysis cases per synoptic time	7.2	9.5	2.8	3.9	4.0	5.0
Mean central pressure (hPa)	987.9	986.7	975.7	976.6	997.4	995.2
Mean cyclone direction	90°	90°	111°	110°	68°	69°
Mean cyclone speed (km/h)	36	35	37	35	35	36

SUMMARY OF OSSEs USING FVCCM NATURE RUN

GLOBAL DATA ASSIMILATION SYSTEM USED:

GEOS-3,	1 X 1 deg horizontal resolution
FVDAS,	1 x 1.25 deg horizontal resolution
SPINUP:	35 days

PERIOD OF ASSIMILATION: Sept. 11 - Oct. 31, 1999

CALIBRATION EXPERIMENTS (REAL and SIMULATED):

CTRL (Conventional Data + TOVS + CTW + QSCAT)

CTRL-ALL SAT (Conventional Data only)

CTRL-SAT TEMP (Conventional Data + CTW + QSCAT)

CTRL-QSCAT (Conventional Data + TOVS + CTW)

SIMULATED DATA EXPERIMENTS:

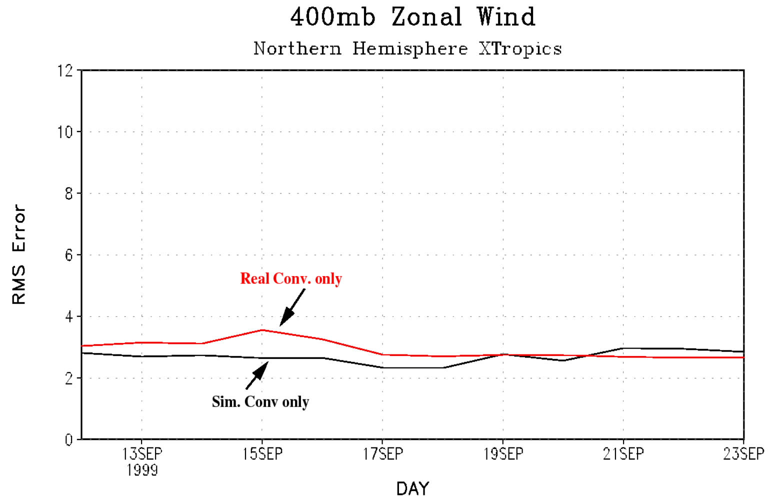
CTRL + Lidar Winds (with varying coverage)

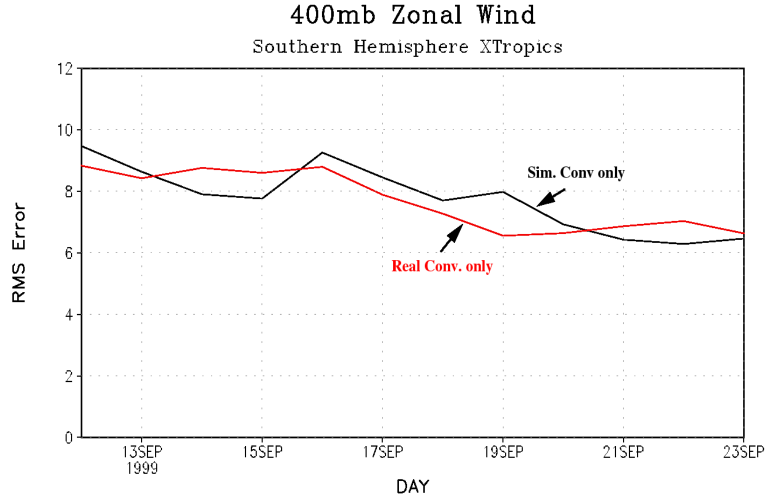
AIRS (Conventional Data + Airs + CTW + QSCAT)

AIRS + Lidar winds

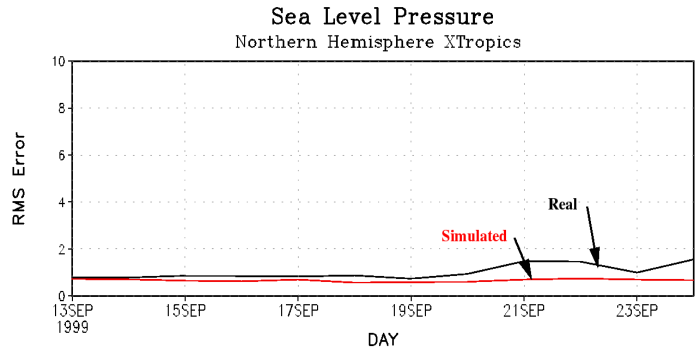
CTRL + SeaWinds (from ADEOS 2)

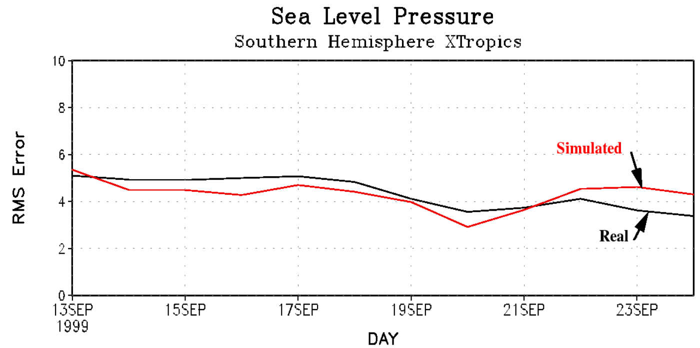
Comparison of Real and Simulated Conventional Data Only Assimilations

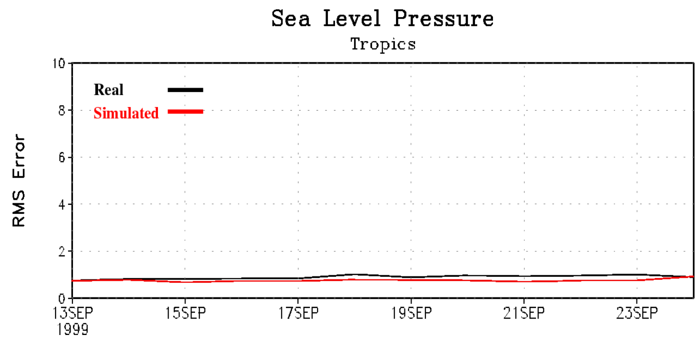




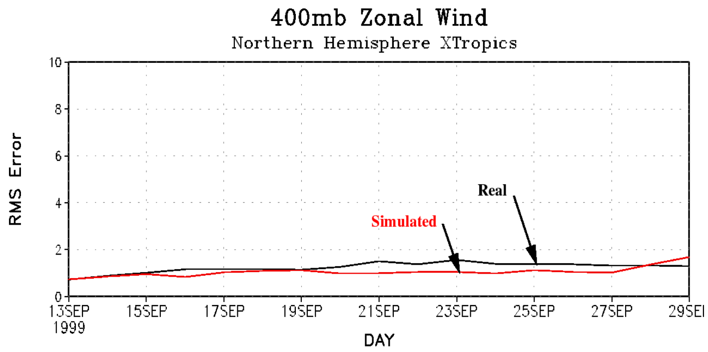
Impact of All Existing Satellite Data

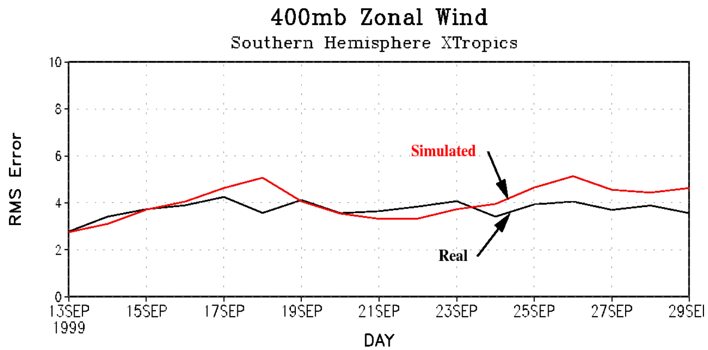


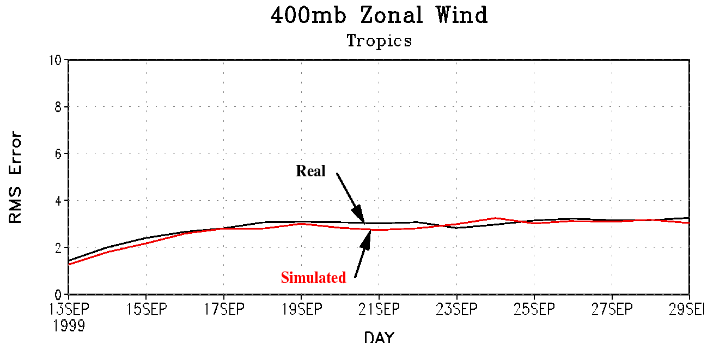




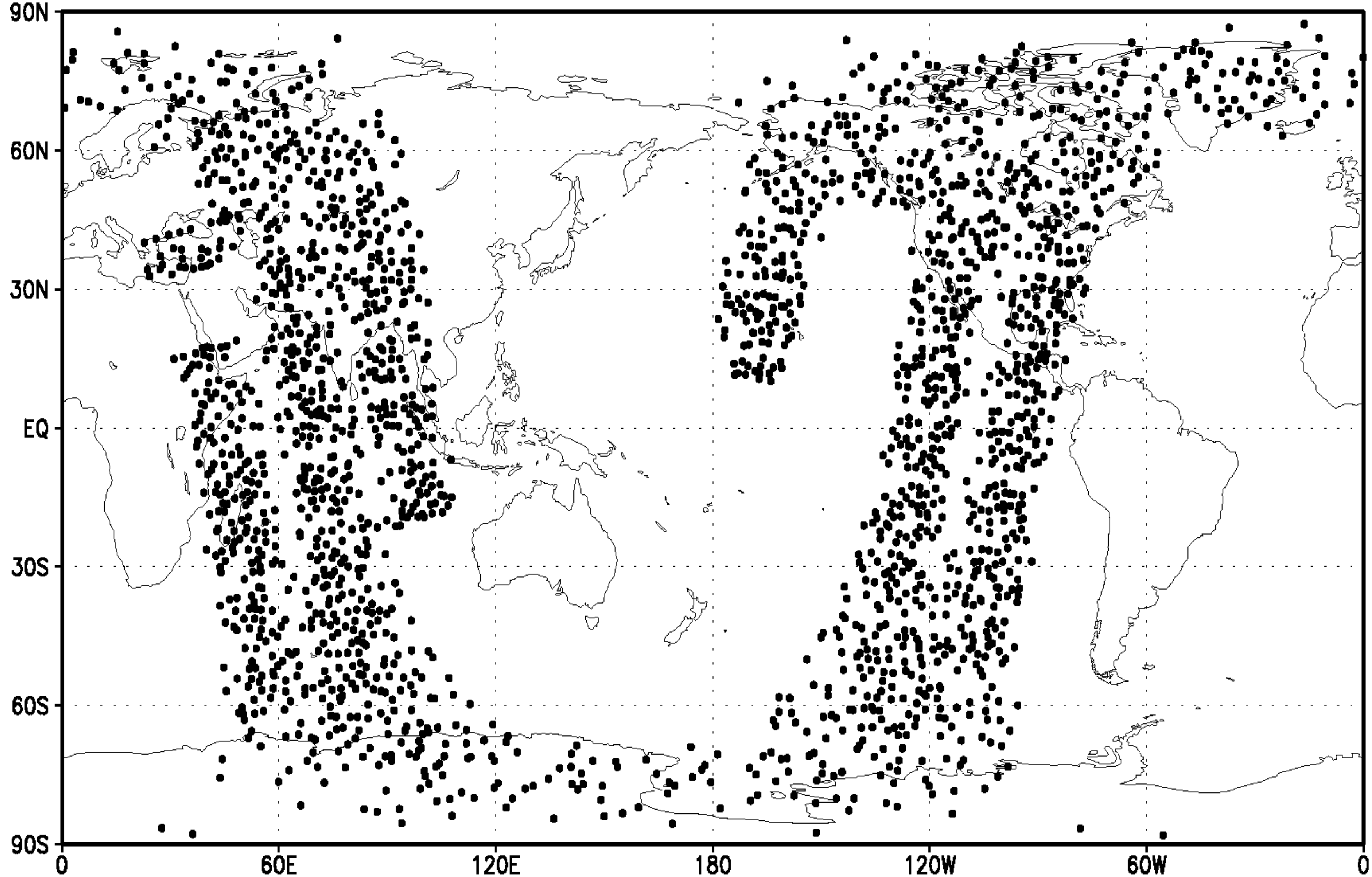
Impact of QSCAT



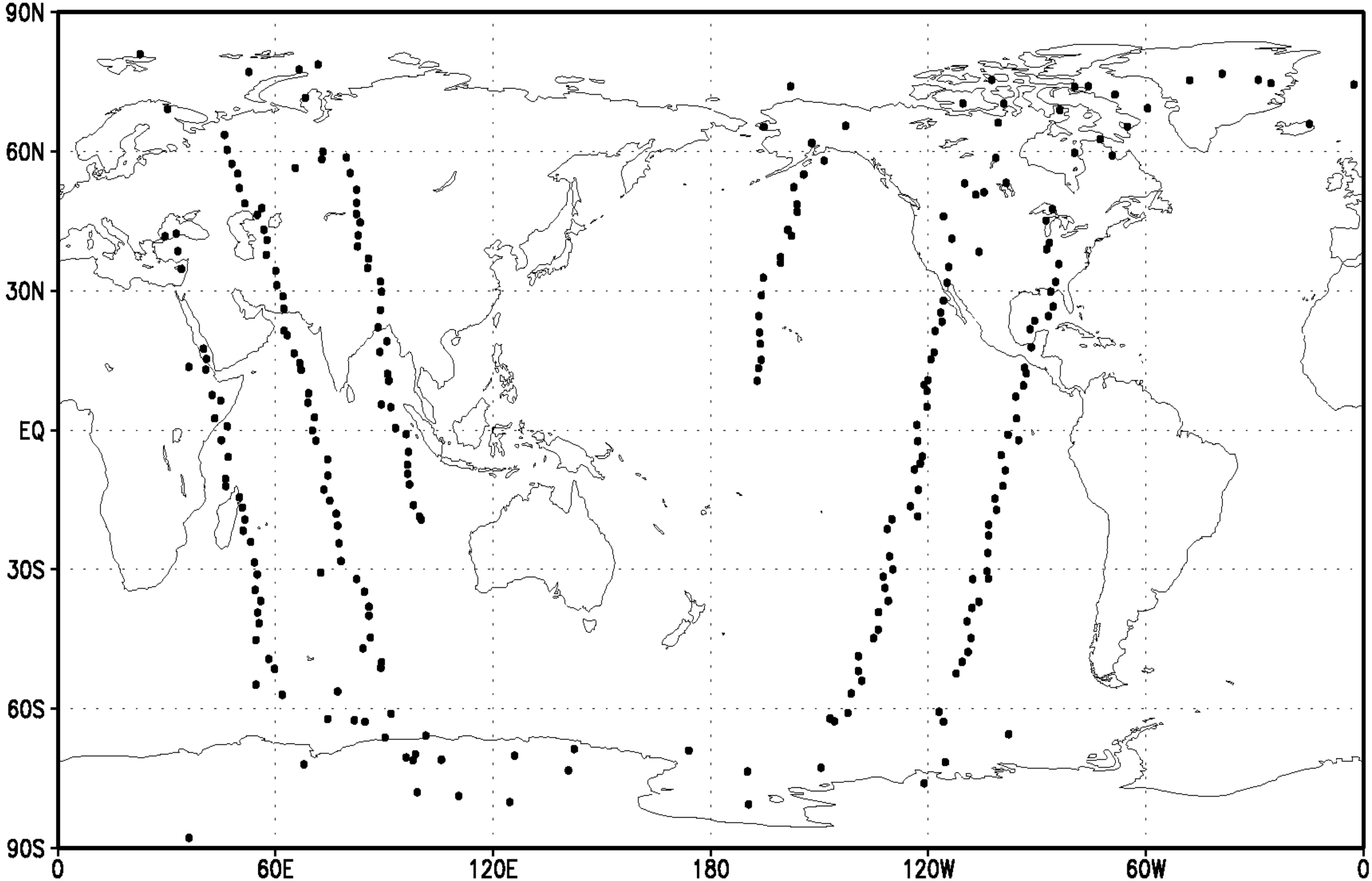




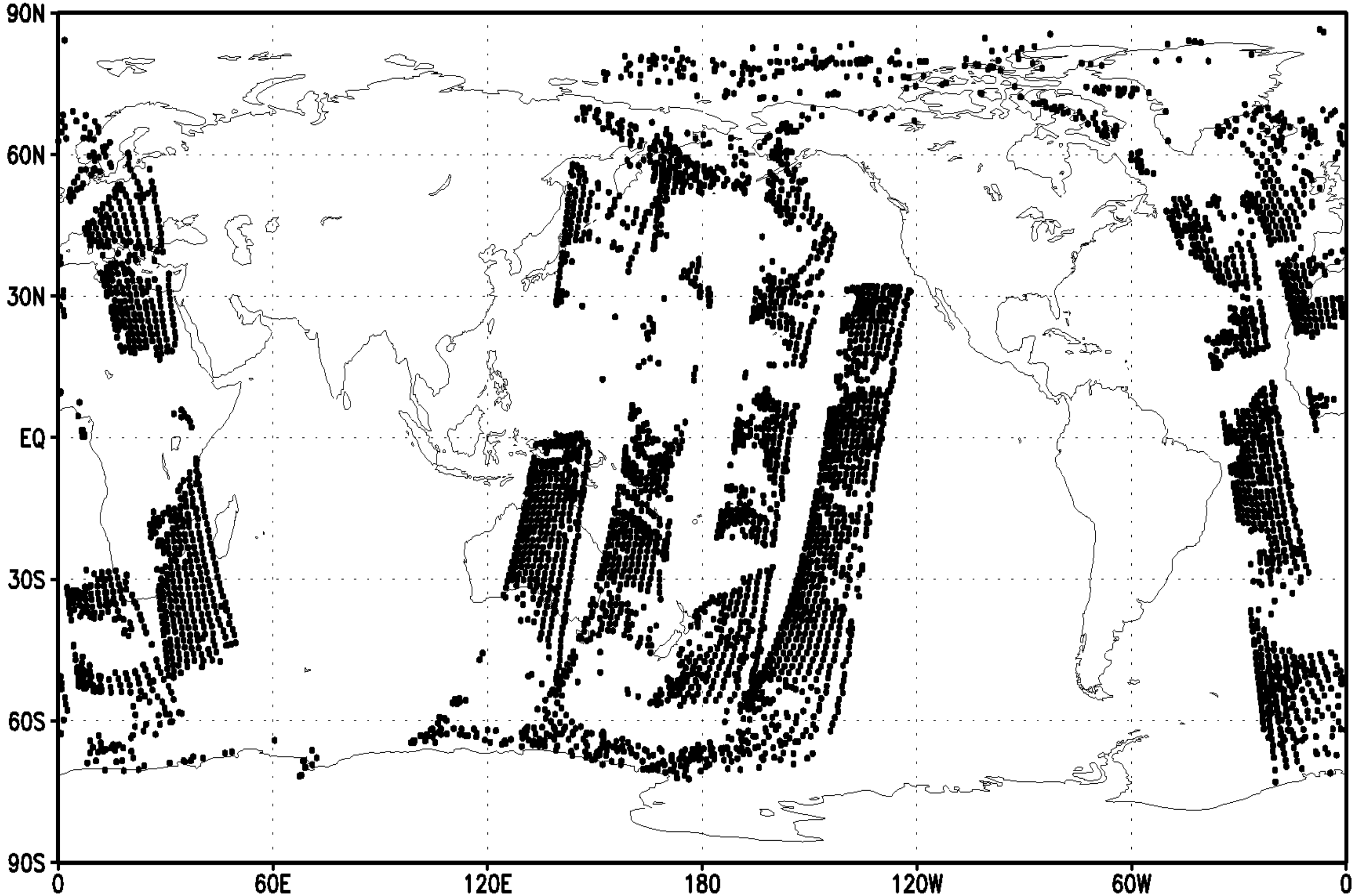
Simulated Full Swath LIDAR locations
1999 Sep 11 12Z

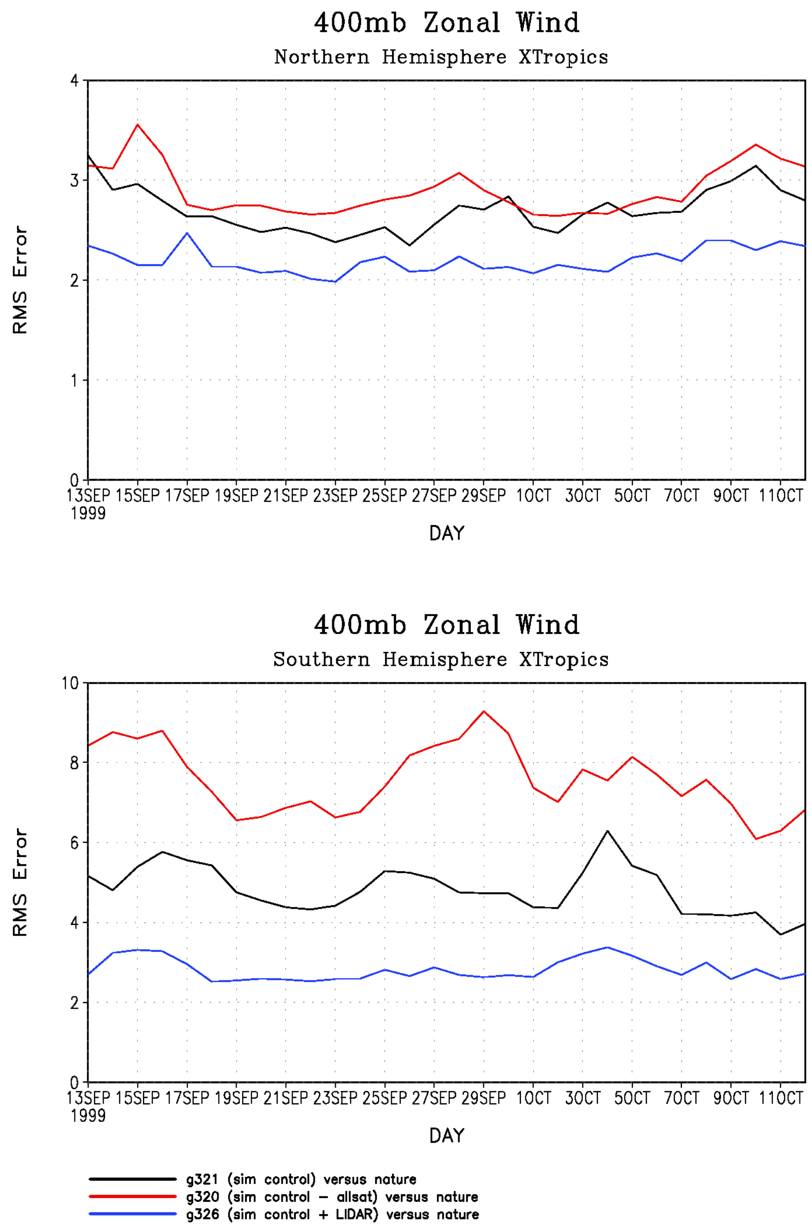


Simulated Non-scan LIDAR locations
1999 Sep 11 12Z

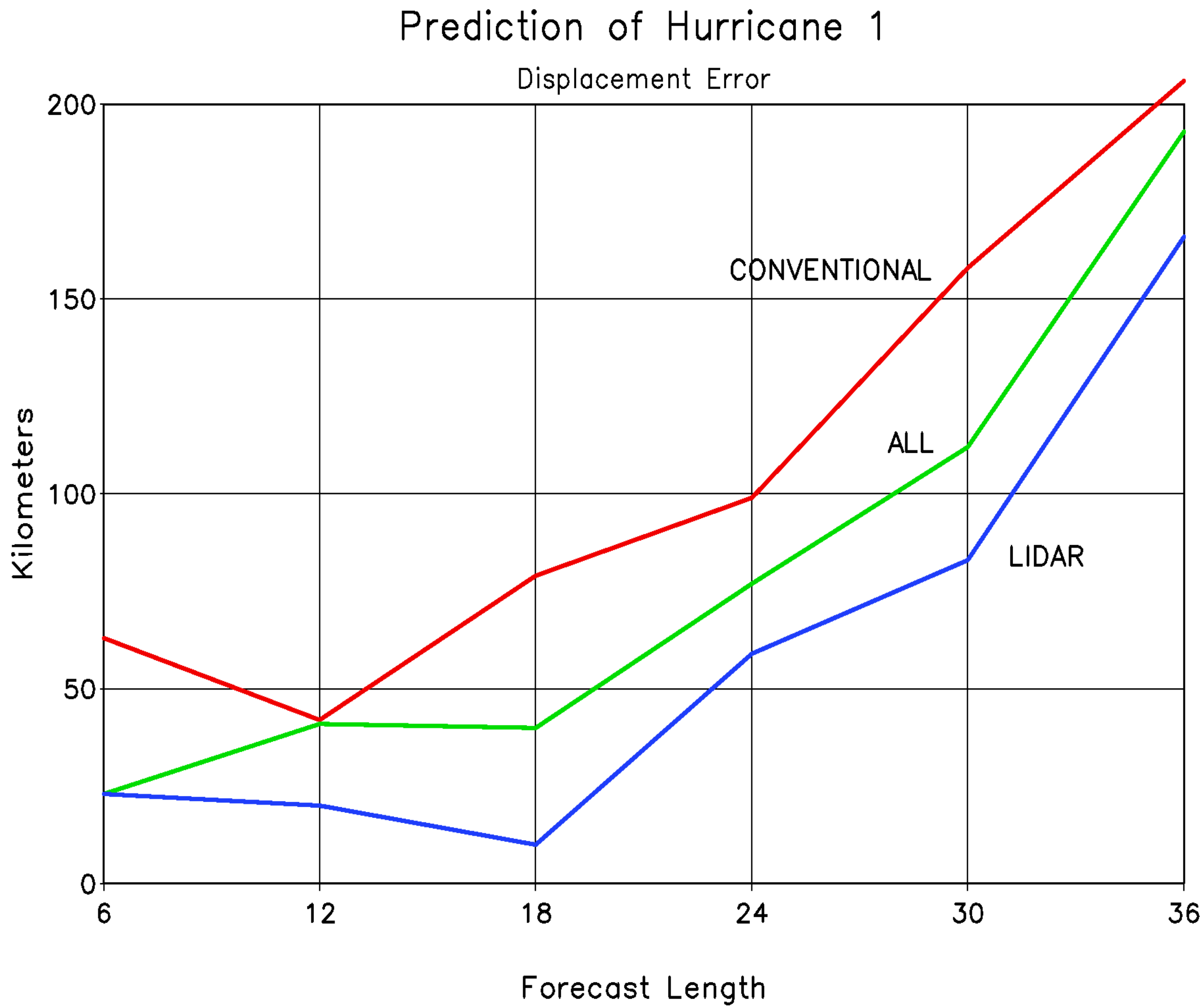


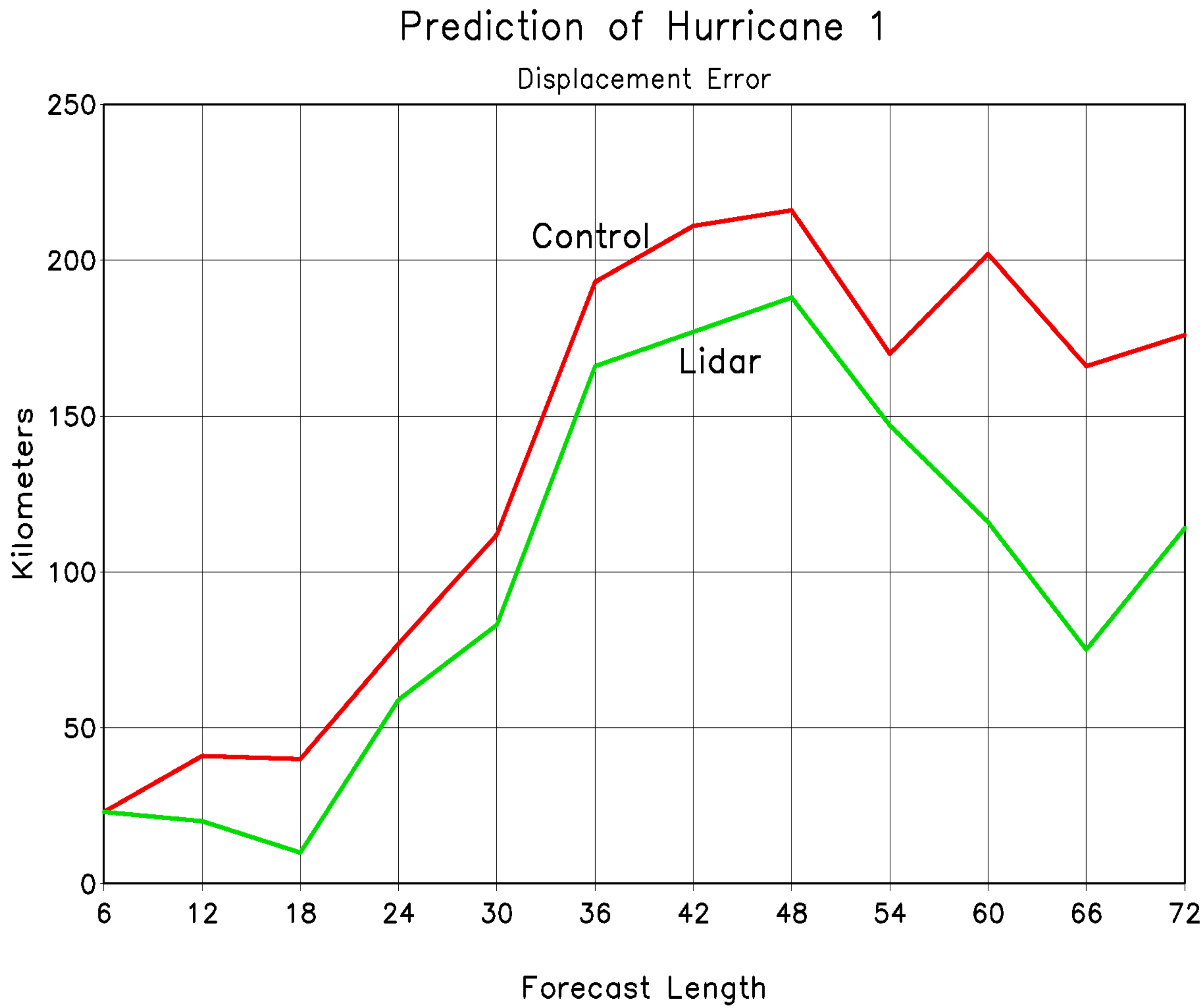
Simulated SWA Best 900 hPa LIDAR locations (Distributed)
1999 Sep 13 00Z





400mb Zonal Wind
Northern Hemisphere XTropics
RMS Error
DAY
13SEP 1999
15SEP
17SEP
19SEP
21SEP
23SEP
25SEP
27SEP
29SEP
1OCT
3OCT
5OCT
7OCT
9OCT
11OCT
400mb Zonal Wind
Southern Hemisphere XTropics
RMS Error
DAY
g321 (sim control) versus nature
g320 (sim control – allsat) versus nature
g326 (sim control + LIDAR) versus nature


Prediction of Hurricane 1
Displacement Error
Kilometers
Forecast Length
200
150
100
50
0
6
12
18
24
30
36
CONVENTIONAL
ALL
LIDAR


Prediction of Hurricane 1
Displacement Error
Control
Lidar
Kilometers
0
50
100
150
200
250
6
12
18
24
30
36
42
48
54
60
66
72
Forecast Length

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

Based on OSSEs at NASA Data Assimilation Office

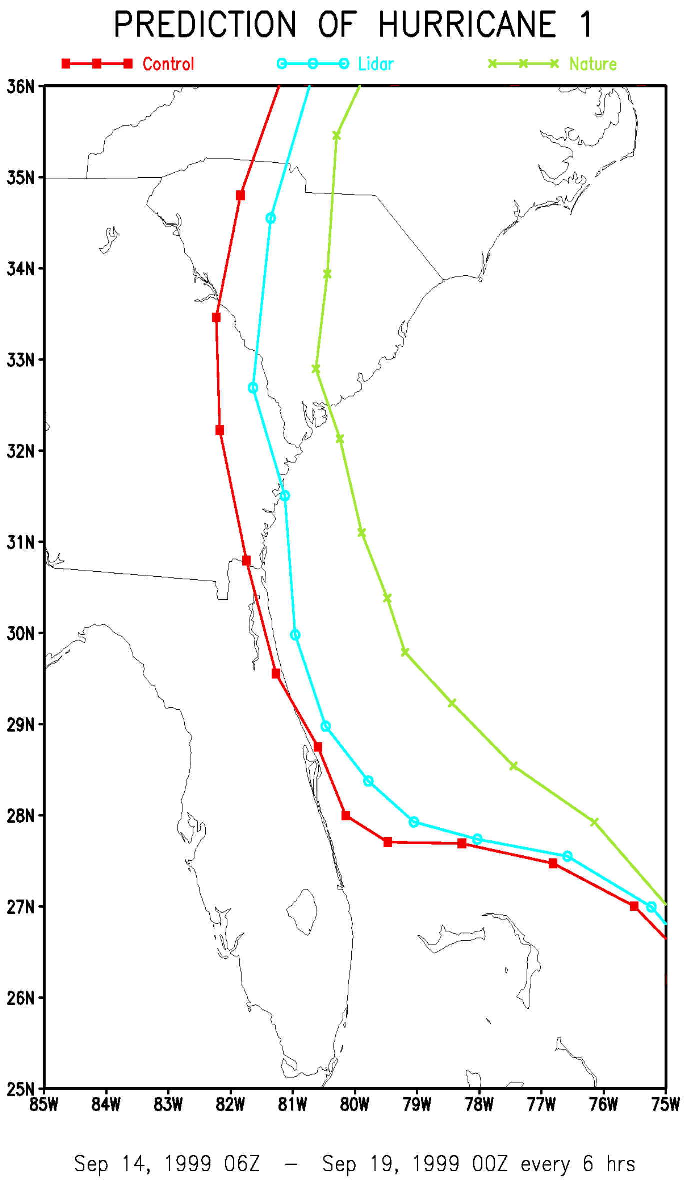
Tracks

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

Save ~ $1M/mile per hurricane for improved landfall forecast

Lidar in this one case

- Reduces landfall prediction error by 66%
- Potentially save > $165M



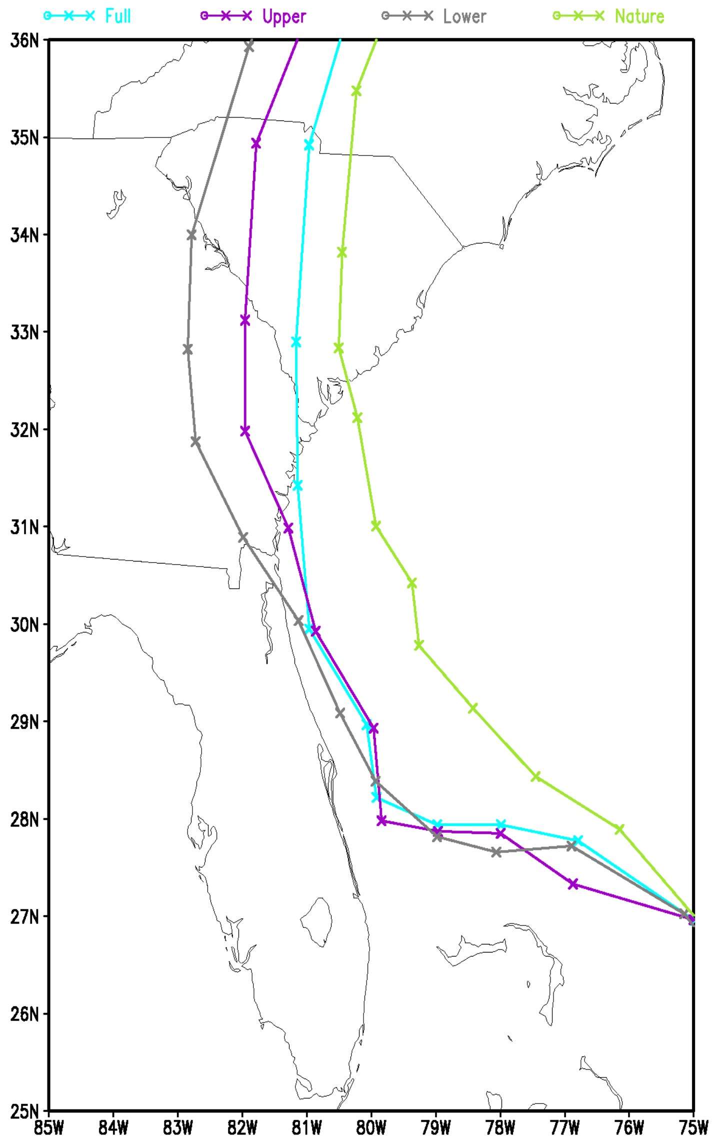
SUMMARY OF LIDAR WIND EXPERIMENTS USED IN THE HURRICANE 1 CASE STUDY

PERIOD OF ASSIMILATION: Sept. 11 - Sept. 14, 1999
FIVE DAY FORECASTS: From Sept. 14, 1999

LIDAR WIND EXPERIMENTS:

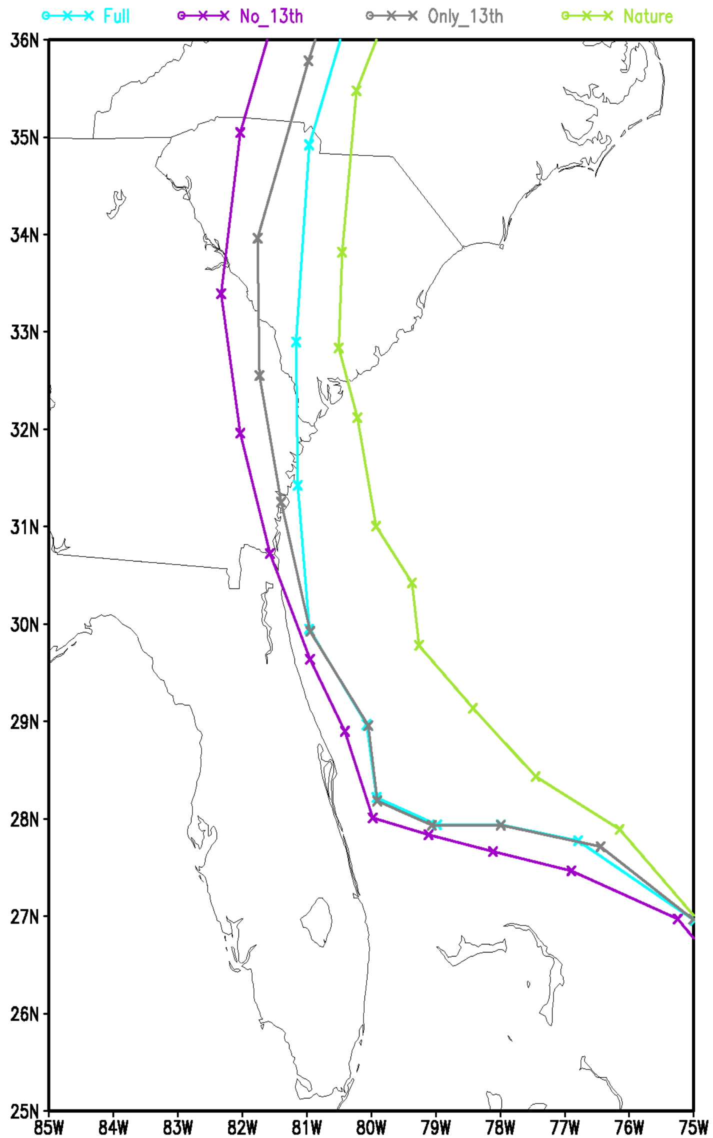
CTRL + Full Lidar (complete profile and + / - 1100 km swath)
CTRL + Full Lidar (no data after Sept. 13, 1999, 0.0z)
CTRL + Full Lidar (no data before Sept. 13, 1999, 0.0z)
CTRL + Upper Lidar 1 (500mb and above)
CTRL + Upper Lidar 2 (300mb and above)
CTRL + Mid and Upper Lidar (700mb and above)
CTRL + Lidar 850mb and above
CTRL + Lower Lidar (1000 - 700mb)

PREDICTION OF HURRICANE 1

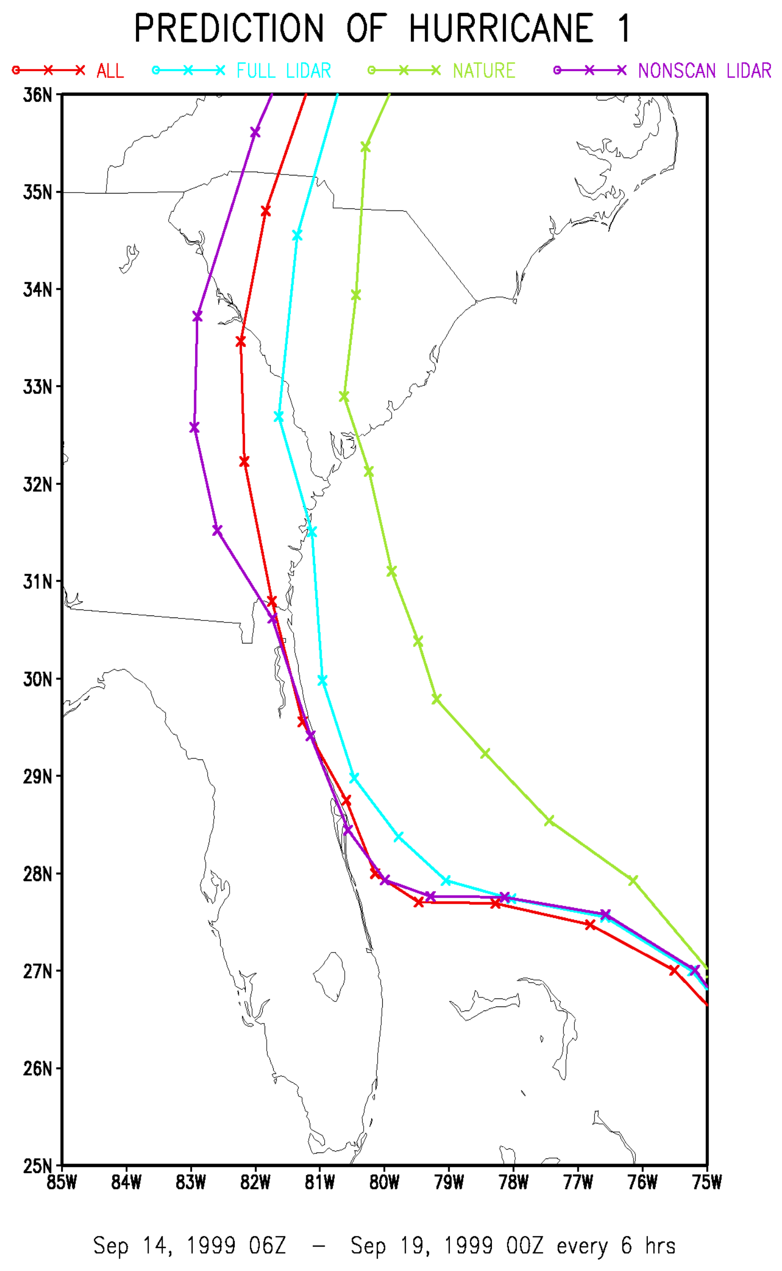


Sep 14, 1999 06Z — Sep 19, 1999 00Z every 6 hrs

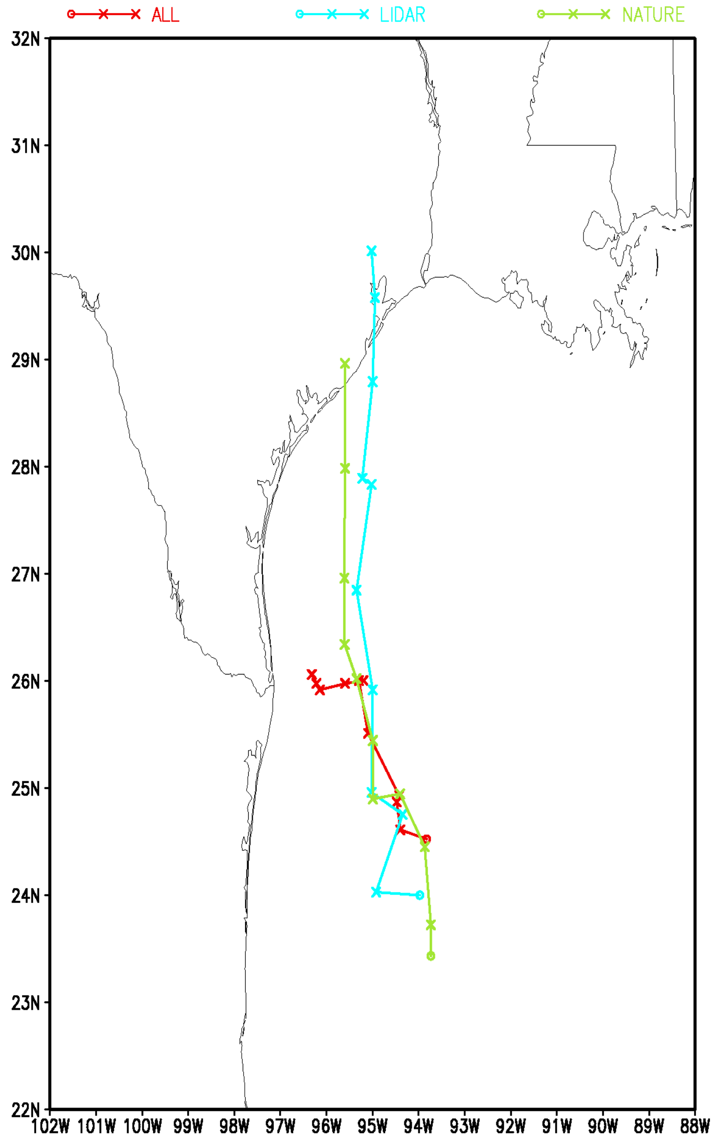
PREDICTION OF HURRICANE 1



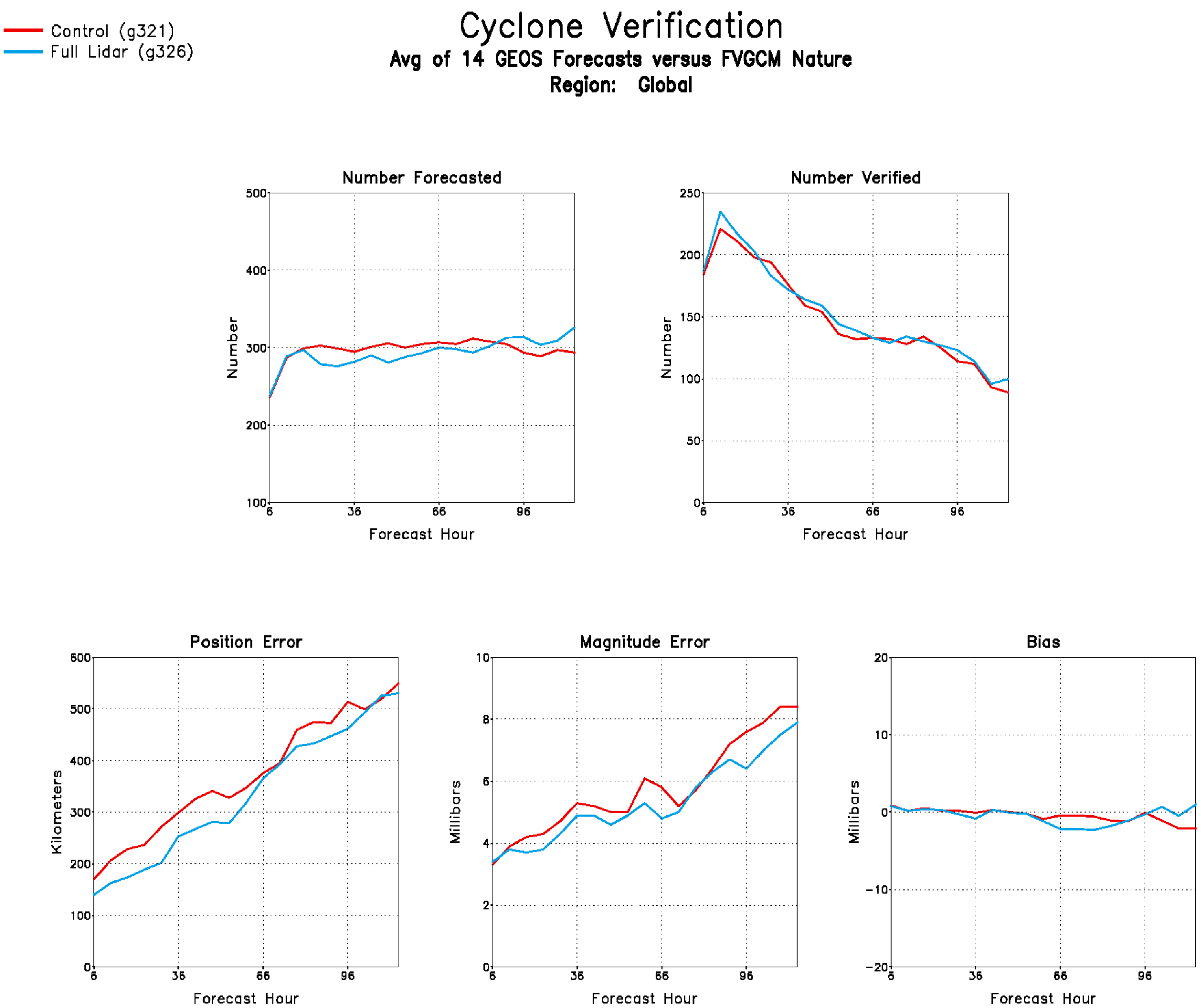
Sep 14, 1999 06Z – Sep 19, 1999 00Z every 6 hrs


PREDICTION OF HURRICANE 1
ALL
FULL LIDAR
NATURE
NONSCAN LIDAR
36N
35N
34N
33N
32N
31N
30N
29N
28N
27N
26N
25N
85W
84W
83W
82W
81W
80W
79W
78W
77W
76W
75W
Sep 14, 1999 06Z – Sep 19, 1999 00Z every 6 hrs

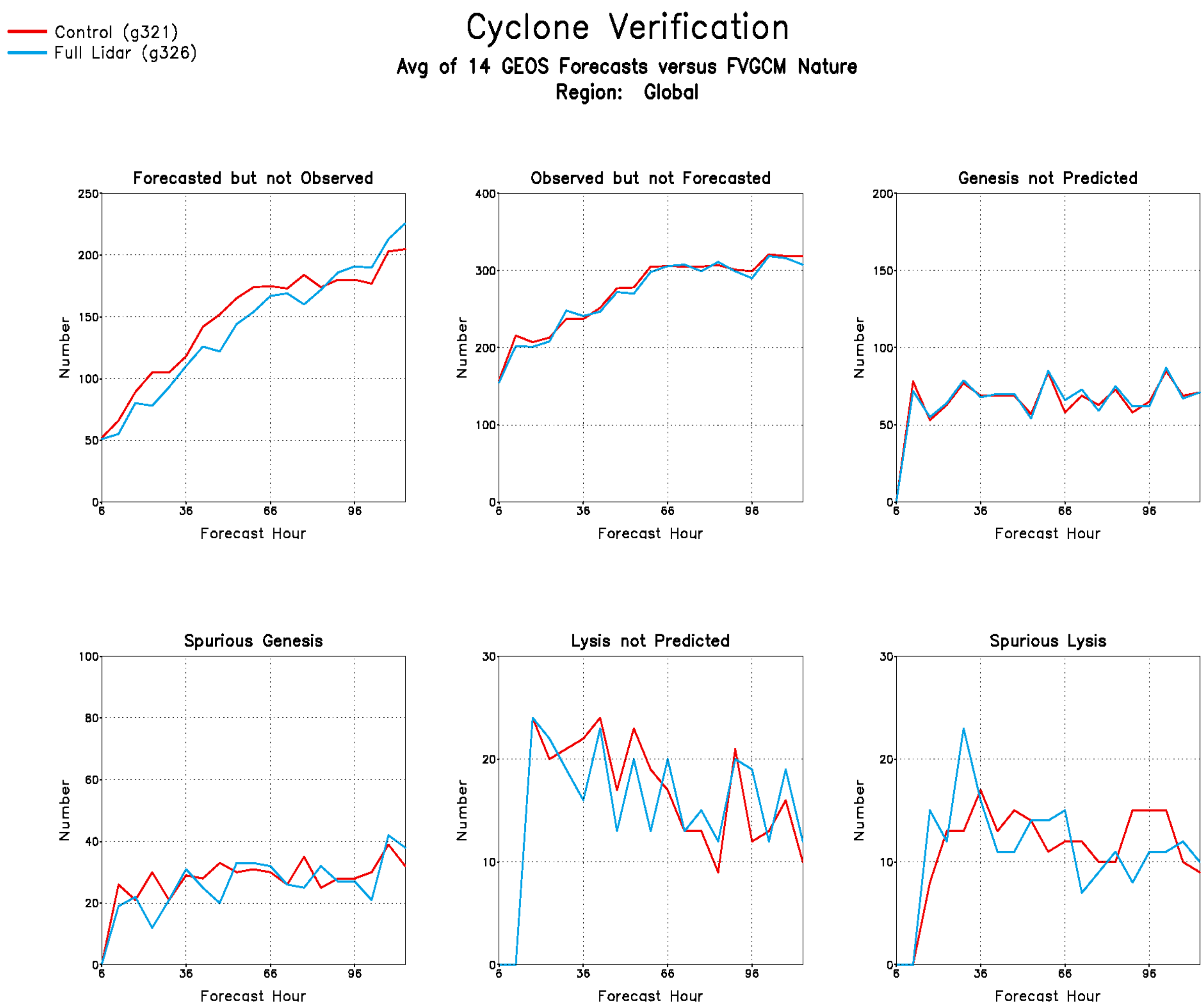
PREDICTION OF HURRICANE 2

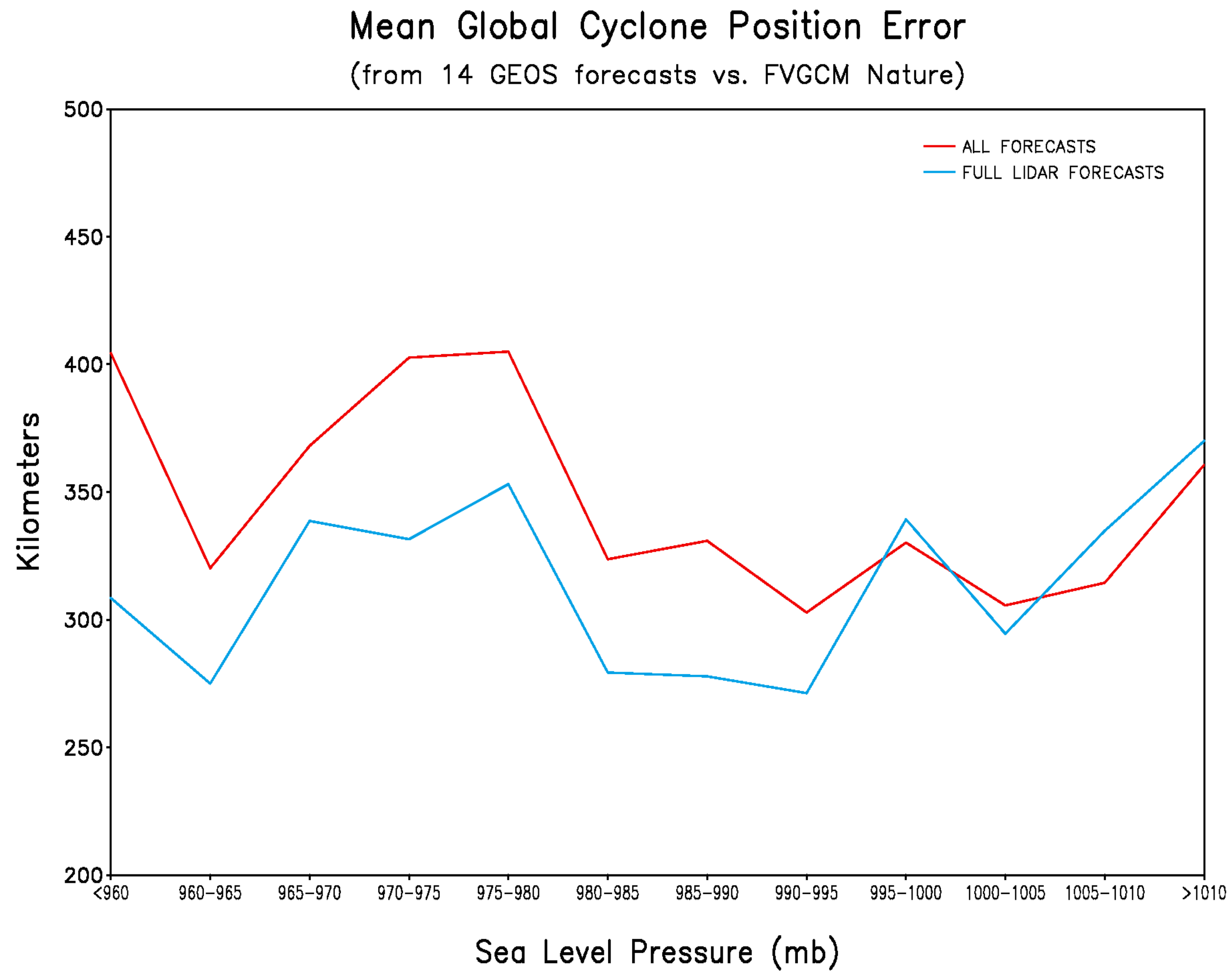


Oct 8, 1999 06Z – Oct 10, 1999 18Z every 6 hrs



Control (g321)
Full Lidar (g326)
Cyclone Verification
Avg of 14 GEOS Forecasts versus FVGCM Nature
Region: Global
Number Forecasted
Number
Forecast Hour
Number Verified
Number
Forecast Hour
Position Error
Kilometers
Forecast Hour
Magnitude Error
Millibars
Forecast Hour
Bias
Millibars
Forecast Hour

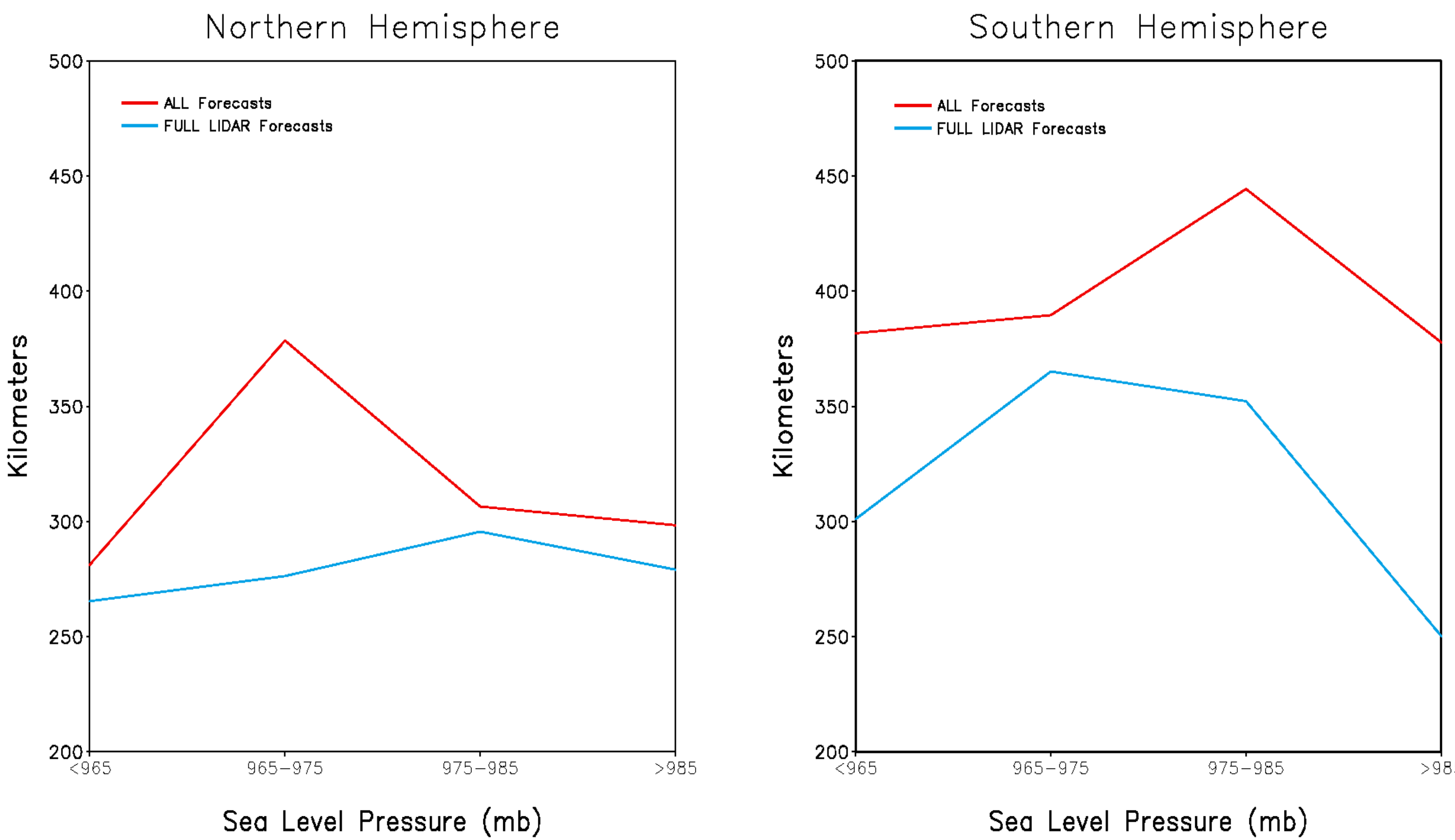

Control (g321)
Full Lidar (g326)
Cyclone Verification
Avg of 14 GEOS Forecasts versus FVGCM Nature
Region: Global
Forecasted but not Observed
Observed but not Forecasted
Genesis not Predicted
Spurious Genesis
Lysis not Predicted
Spurious Lysis
Number
Forecast Hour
6
36
66
96
0
50
100
150
200
250
300
400
10
20
30
40
60
80

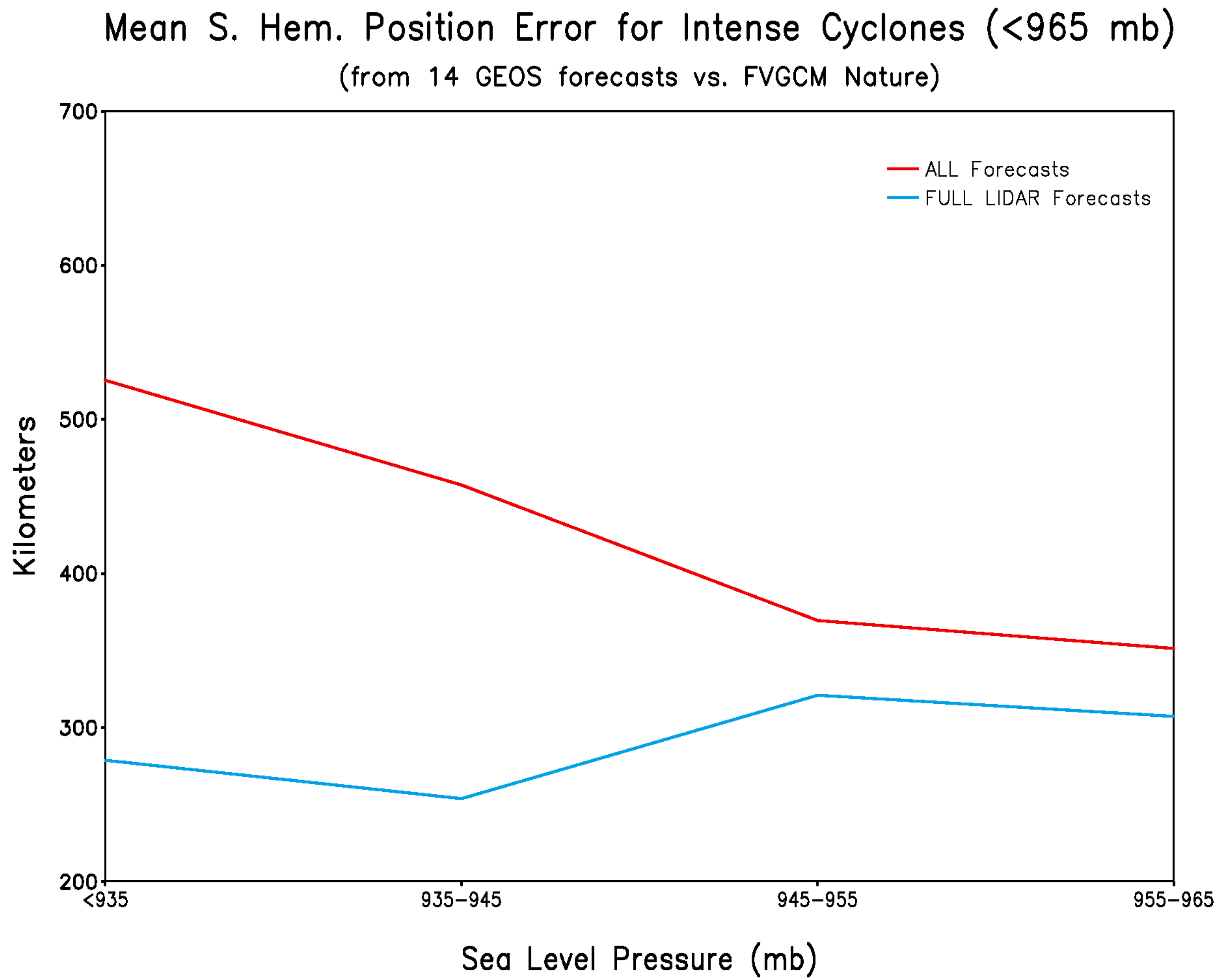


Mean Global Cyclone Position Error
(from 14 GEOS forecasts vs. FVGCM Nature)
ALL FORECASTS
FULL LIDAR FORECASTS
Kilometers
500
450
400
350
300
250
200
<960
960-965
965-970
970-975
975-980
980-985
985-990
990-995
995-1000
1000-1005
1005-1010
>1010
Sea Level Pressure (mb)

Mean Position Error for Intense Cyclones (<995 mb)

(from 14 GEOS forecasts vs. FVGCM Nature)




Mean S. Hem. Position Error for Intense Cyclones (<965 mb)
(from 14 GEOS forecasts vs. FVGCM Nature)
ALL Forecasts
FULL LIDAR Forecasts
Kilometers
700
600
500
400
300
200
<935
935-945
945-955
955-965
Sea Level Pressure (mb)

IMPACT OF LIDAR WINDS ON CYCLONE PREDICTION

5-day Average Reduction in Position Error

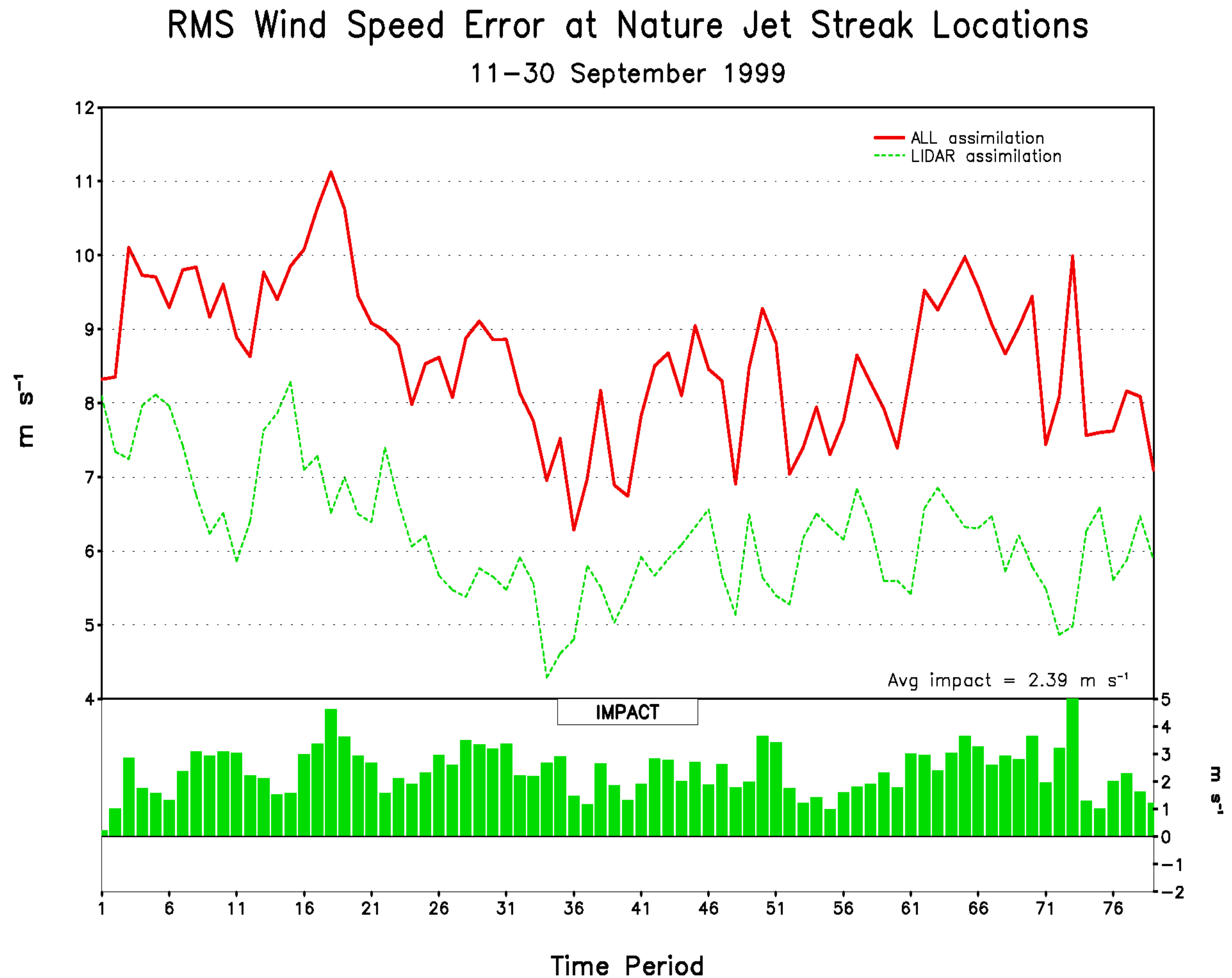
Global:	35 km (10% improvement)
N. America:	48 km (11% improvement)

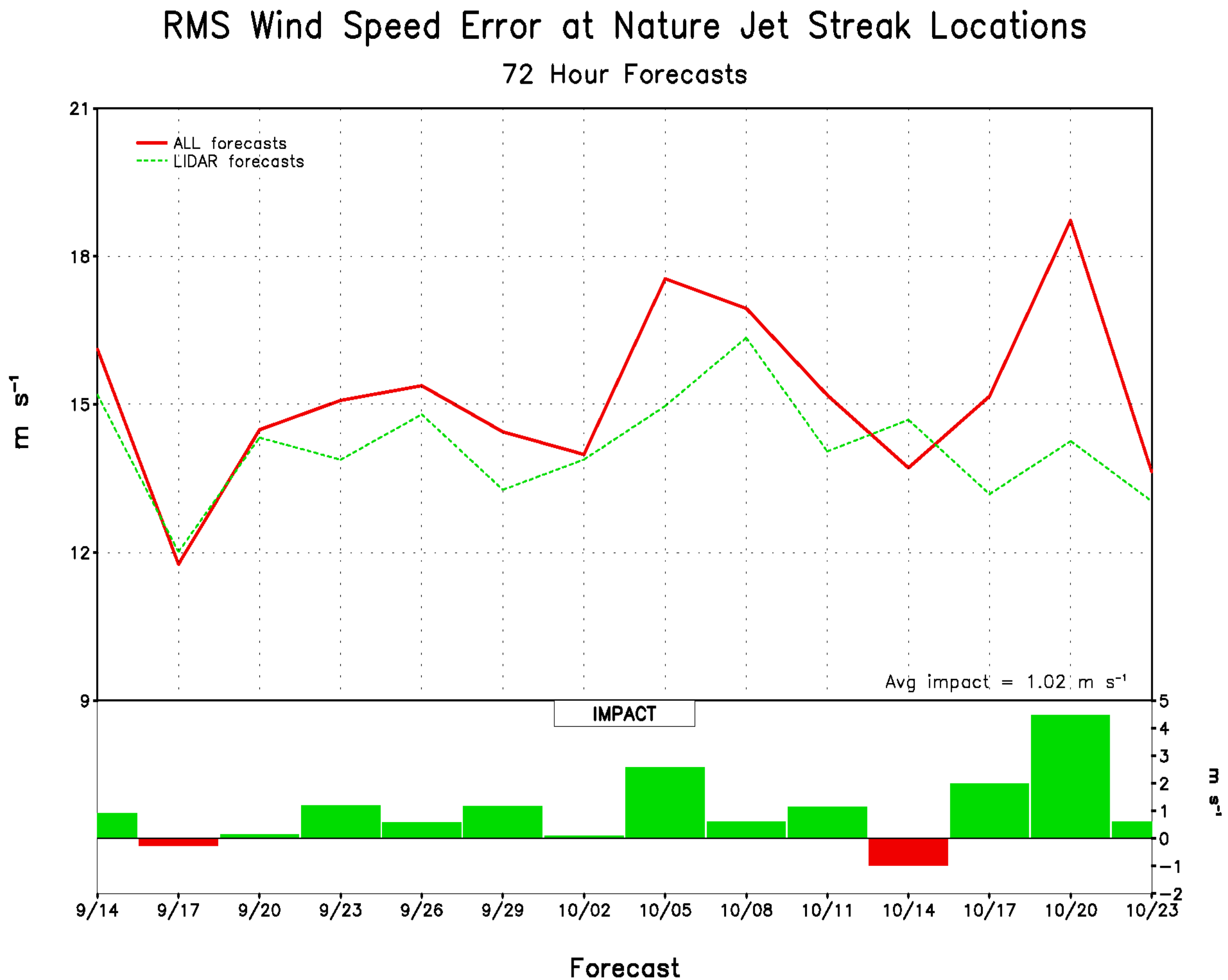
10-day Average Reduction in Position Error

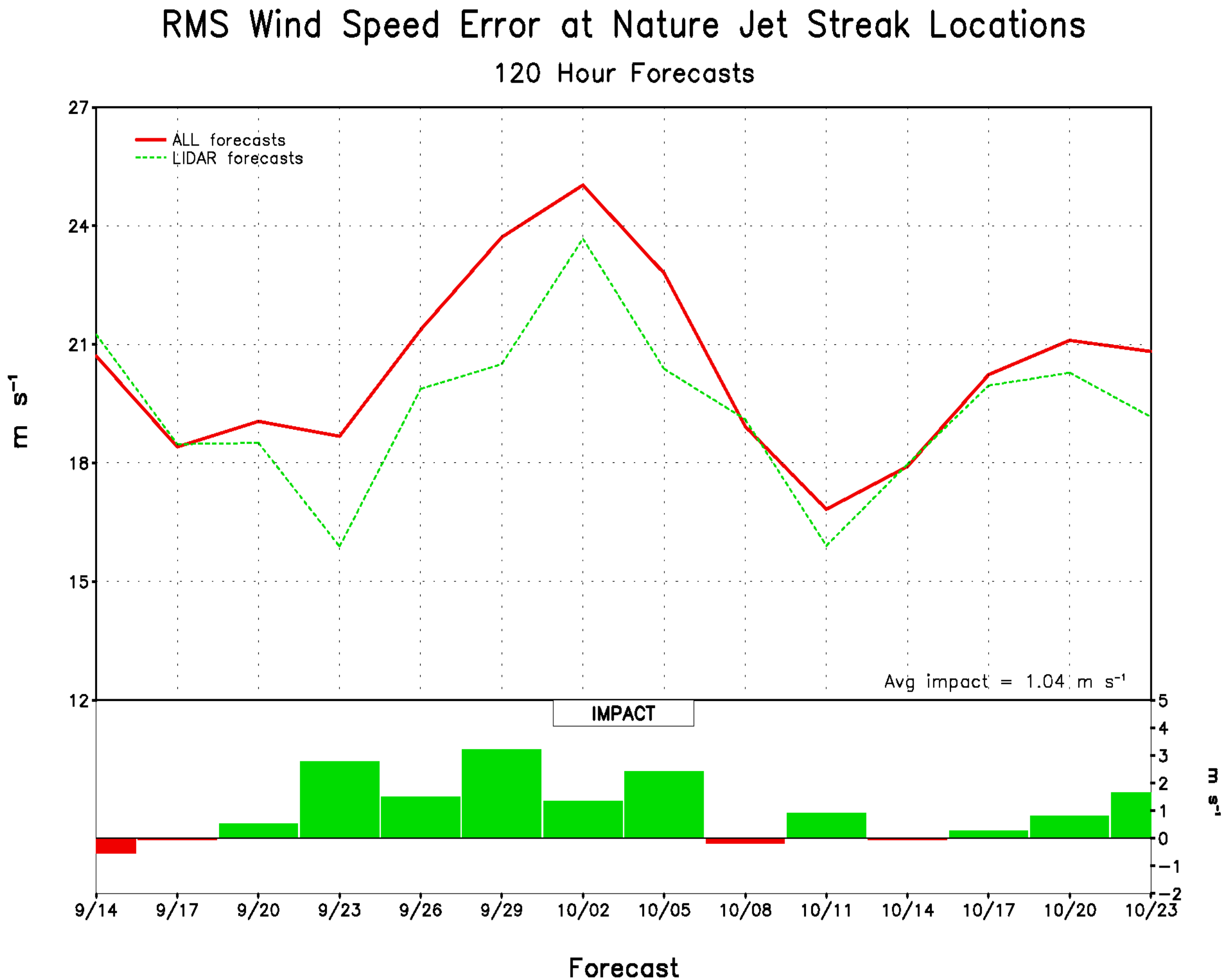
Global;	66 km (17% improvement)
N.H.X.T:	17 km (5% improvement)
S.H.X.T:	48 km (24% improvement)

Reduction in Hurricane Landfall Position Error

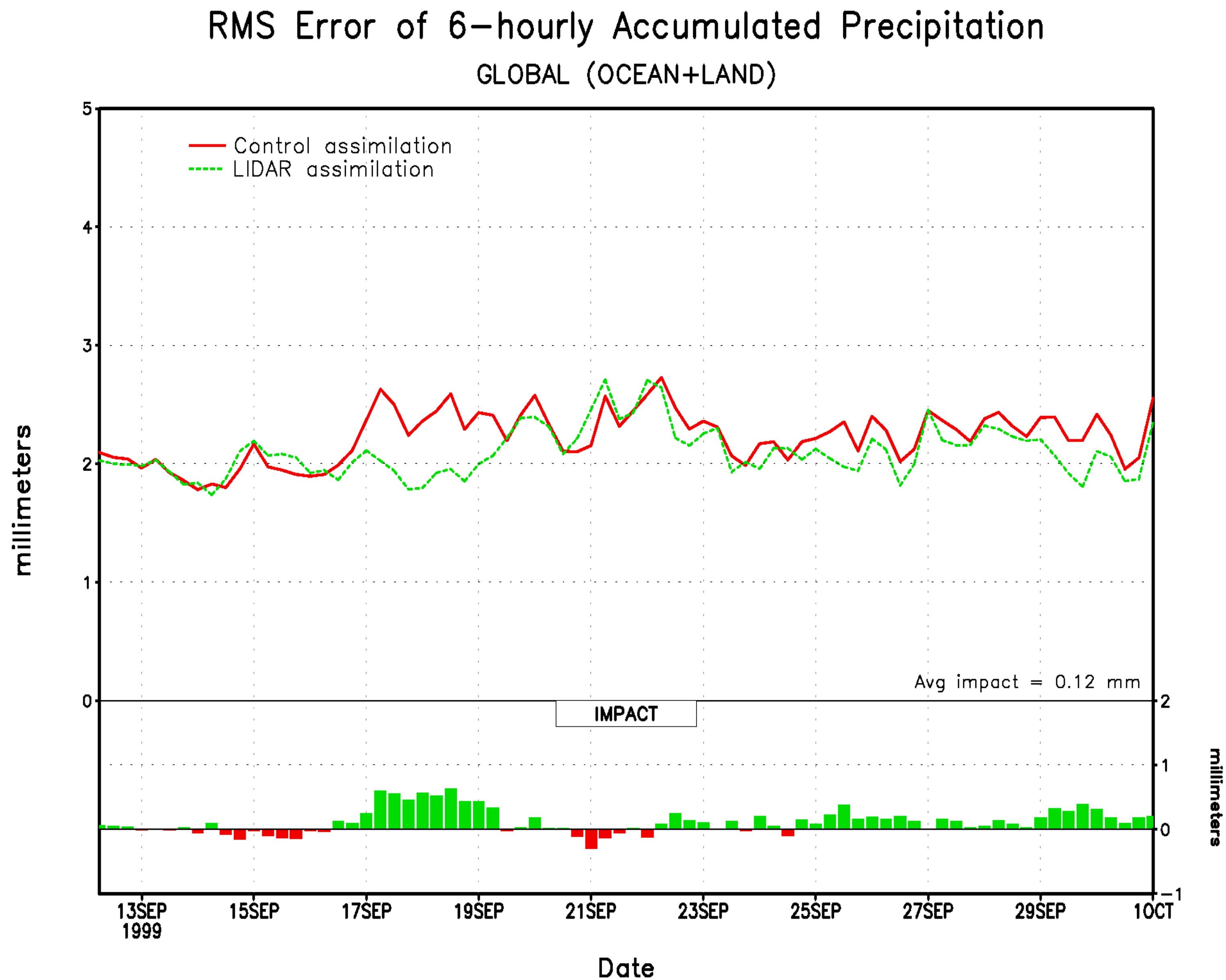
For United States: 239 km (66% improvement) at 63h

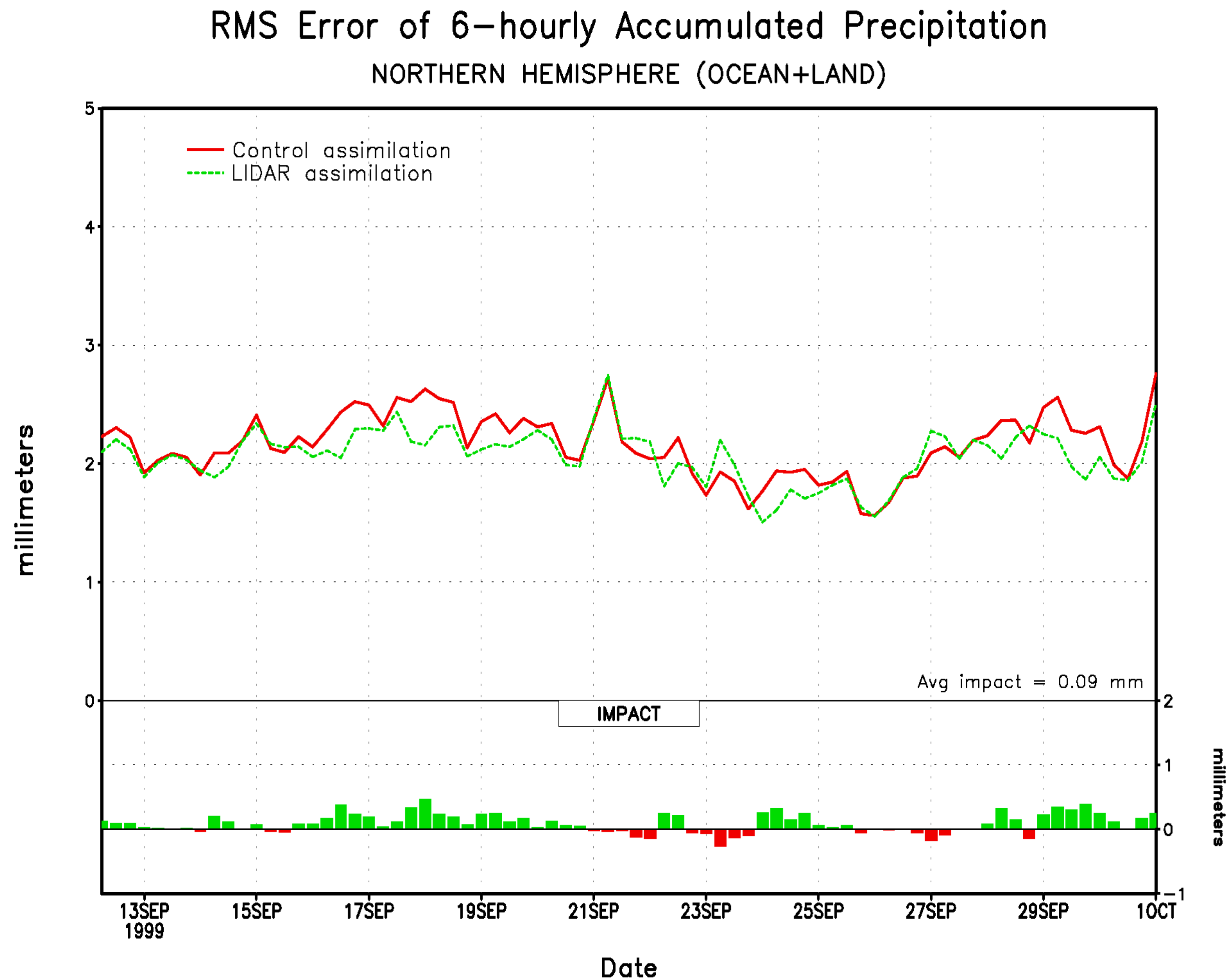

RMS Wind Speed Error at Nature Jet Streak Locations
11–30 September 1999
ALL assimilation
LIDAR assimilation
Avg impact = 2.39 m s⁻¹
IMPACT
m s⁻¹
Time Period
12
11
10
9
8
7
6
5
4
5
4
3
2
1
0
−1
−2
1
6
11
16
21
26
31
36
41
46
51
56
61
66
71
76


RMS Wind Speed Error at Nature Jet Streak Locations
72 Hour Forecasts
ALL forecasts
LIDAR forecasts
m s-1
21
18
15
12
9
Avg impact = 1.02 m s-1
IMPACT
5
4
3
2
1
0
−1
−2
9/14
9/17
9/20
9/23
9/26
9/29
10/02
10/05
10/08
10/11
10/14
10/17
10/20
10/23
Forecast

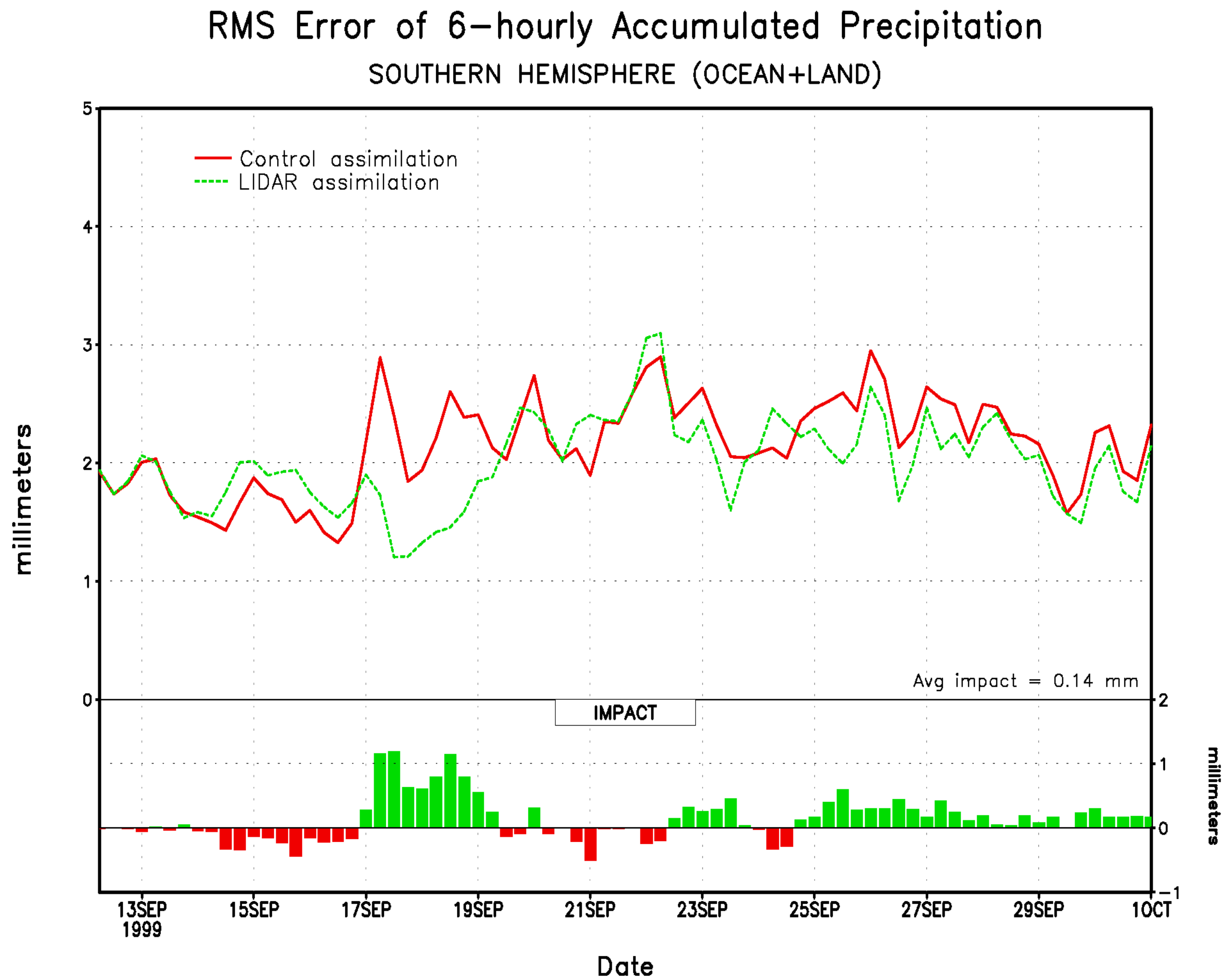


RMS Wind Speed Error at Nature Jet Streak Locations
120 Hour Forecasts
ALL forecasts
LIDAR forecasts
m s⁻¹
27
24
21
18
15
12
Avg impact = 1.04 m s⁻¹
IMPACT
5
4
3
2
1
0
−1
−2
9/14
9/17
9/20
9/23
9/26
9/29
10/02
10/05
10/08
10/11
10/14
10/17
10/20
10/23
Forecast


RMS Error of 6-hourly Accumulated Precipitation
GLOBAL (OCEAN+LAND)
Control assimilation
LIDAR assimilation
millimeters
5
4
3
2
1
0
Avg impact = 0.12 mm
IMPACT
2
1
0
-1
13SEP
1999
15SEP
17SEP
19SEP
21SEP
23SEP
25SEP
27SEP
29SEP
1OCT
Date



RMS Error of 6-hourly Accumulated Precipitation
NORTHERN HEMISPHERE (OCEAN+LAND)
Control assimilation
LIDAR assimilation
Avg impact = 0.09 mm
IMPACT
millimeters
millimeters
0
1
2
3
4
5
2
1
0
-1
13SEP
1999
15SEP
17SEP
19SEP
21SEP
23SEP
25SEP
27SEP
29SEP
1OCT
Date



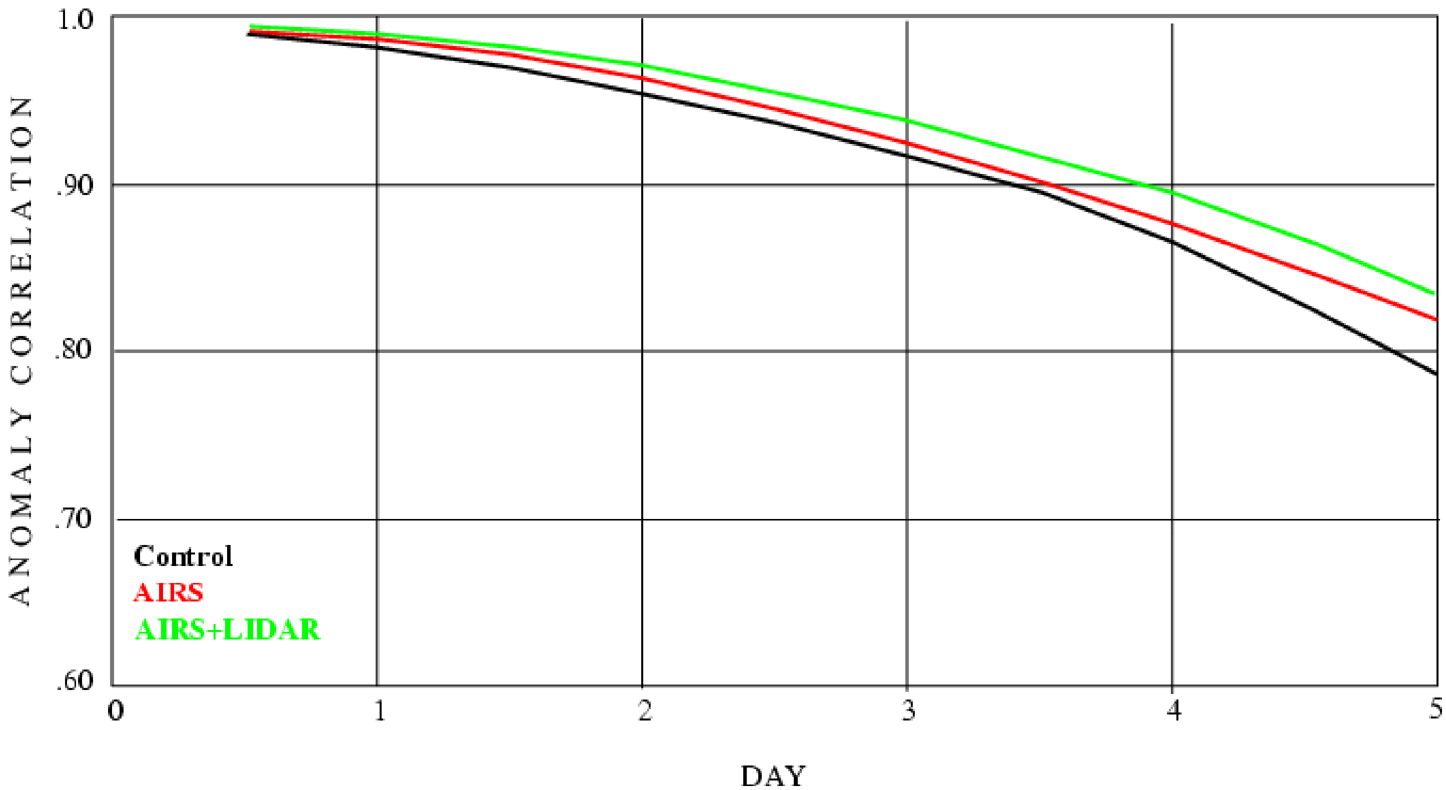
RMS Error of 6-hourly Accumulated Precipitation
SOUTHERN HEMISPHERE (OCEAN+LAND)
Control assimilation
LIDAR assimilation
millimeters
5
4
3
2
1
0
Avg impact = 0.14 mm
IMPACT
2
1
0
-1
millimeters
13SEP
1999
15SEP
17SEP
19SEP
21SEP
23SEP
25SEP
27SEP
29SEP
1OCT
Date

Impact of AIRS on GEOS–3 Forecasts

Average of 14 Five–Day Forecasts

SEA LEVEL PRESSURE – N. HEM. EXTRA TROPICS

LAT : 30 N – 86 N LONG : 0 – 355 E

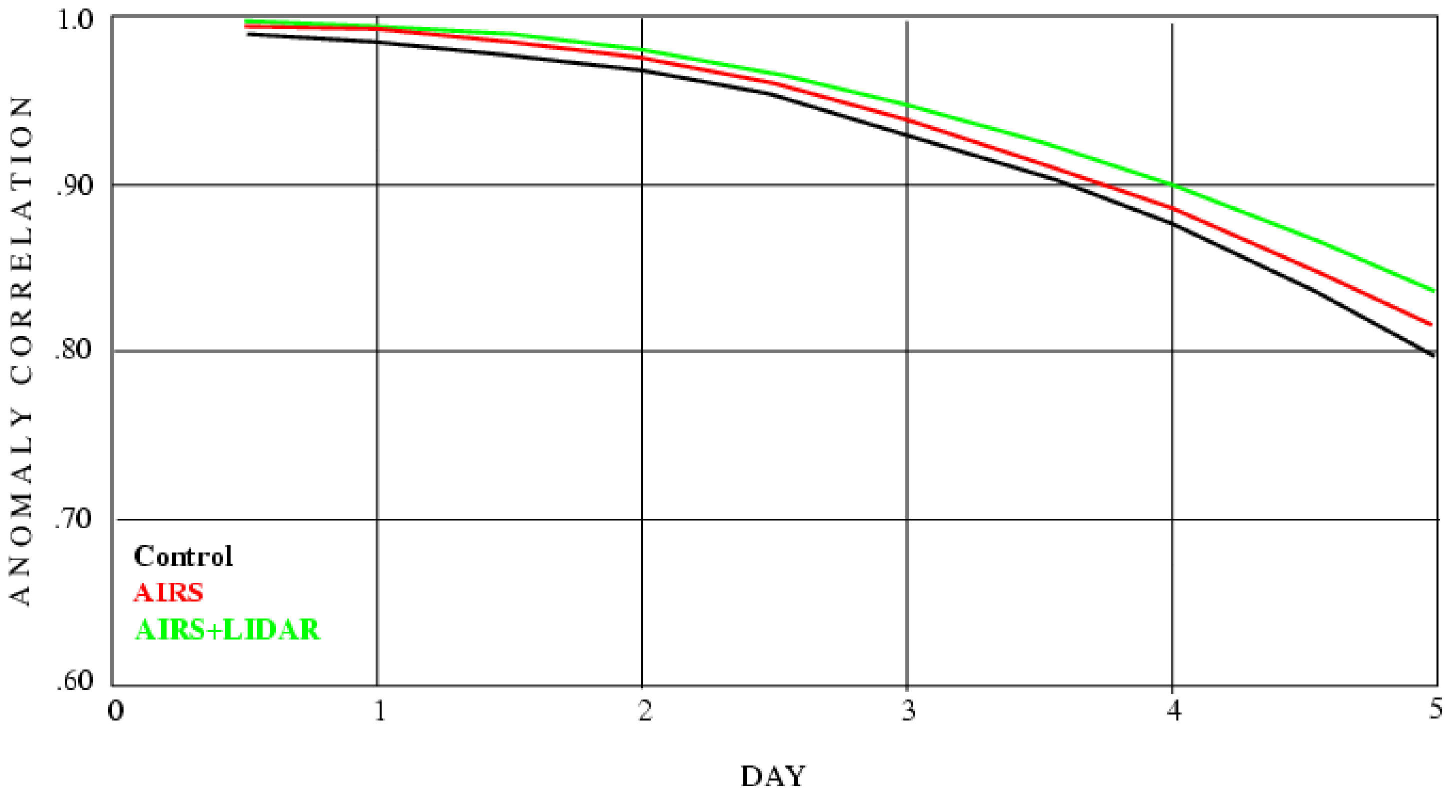


Impact of AIRS on GEOS–3 Forecasts

Average of 14 Five–Day Forecasts

500 MB GEOPOTENTIAL HEIGHTS – N. HEM. EXTRA TROPICS

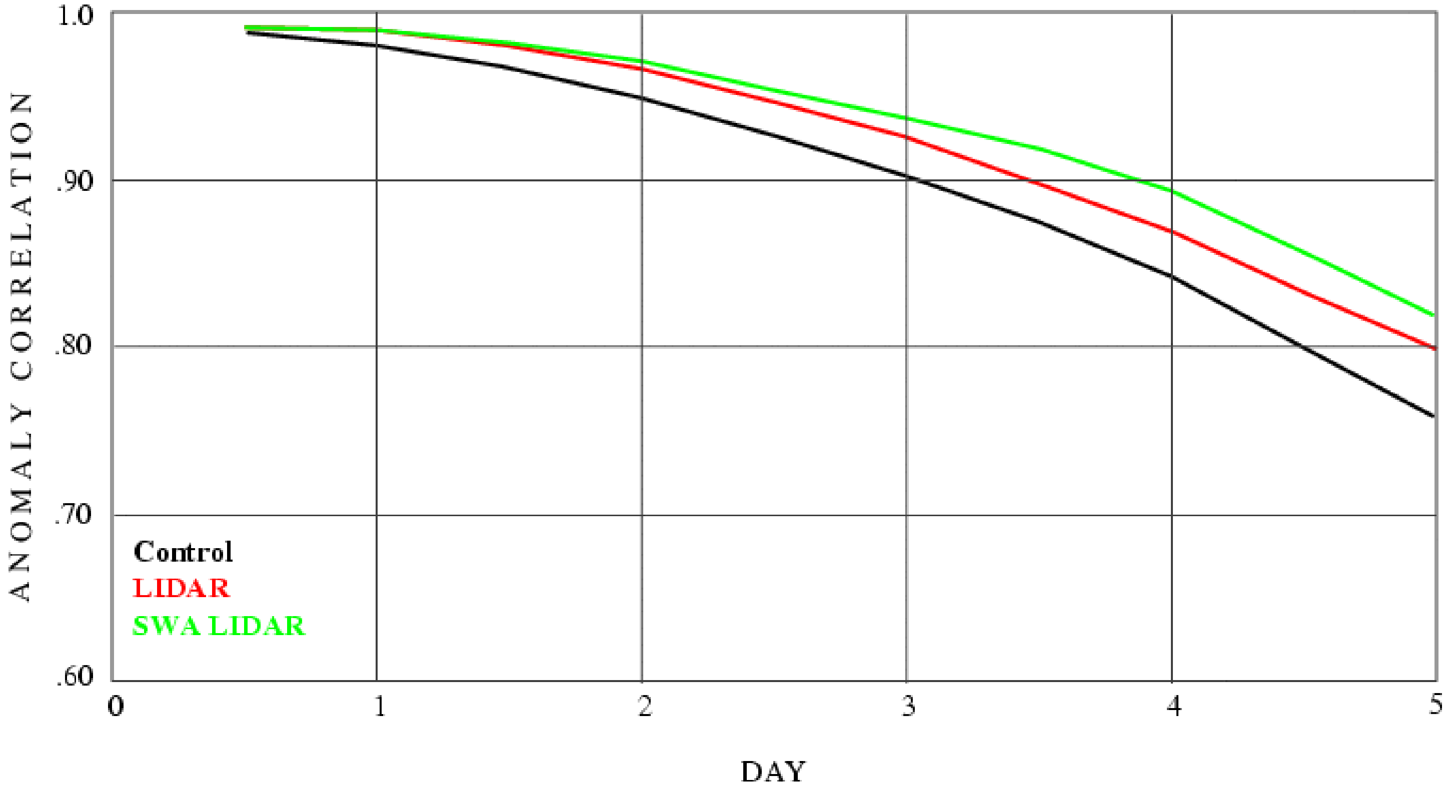
LAT : 30 N – 86 N LONG : 0 – 355 E



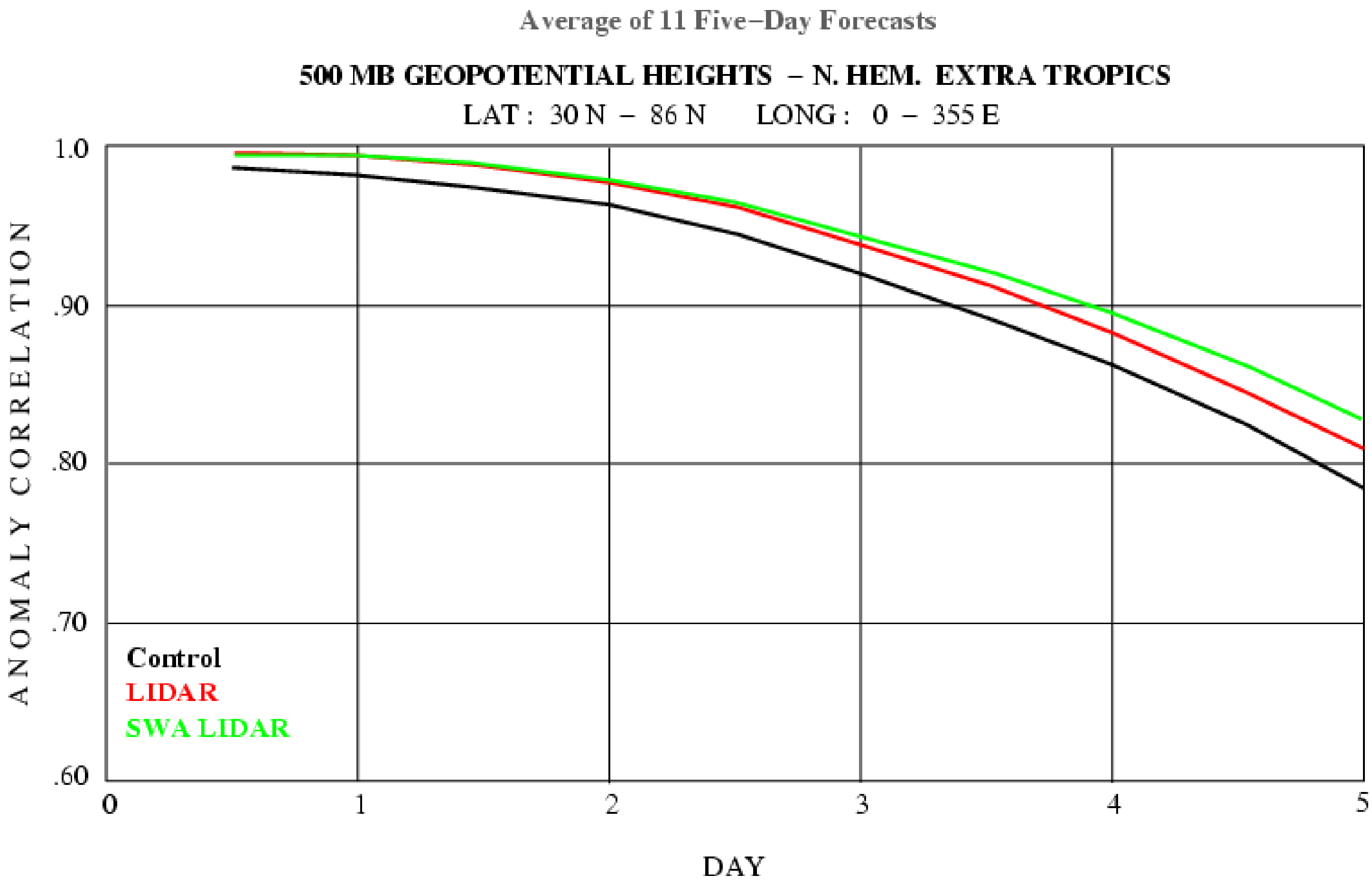
Impact of SWA Best LIDAR on GEOS−3 Forecasts

Average of 11 Five−Day Forecasts

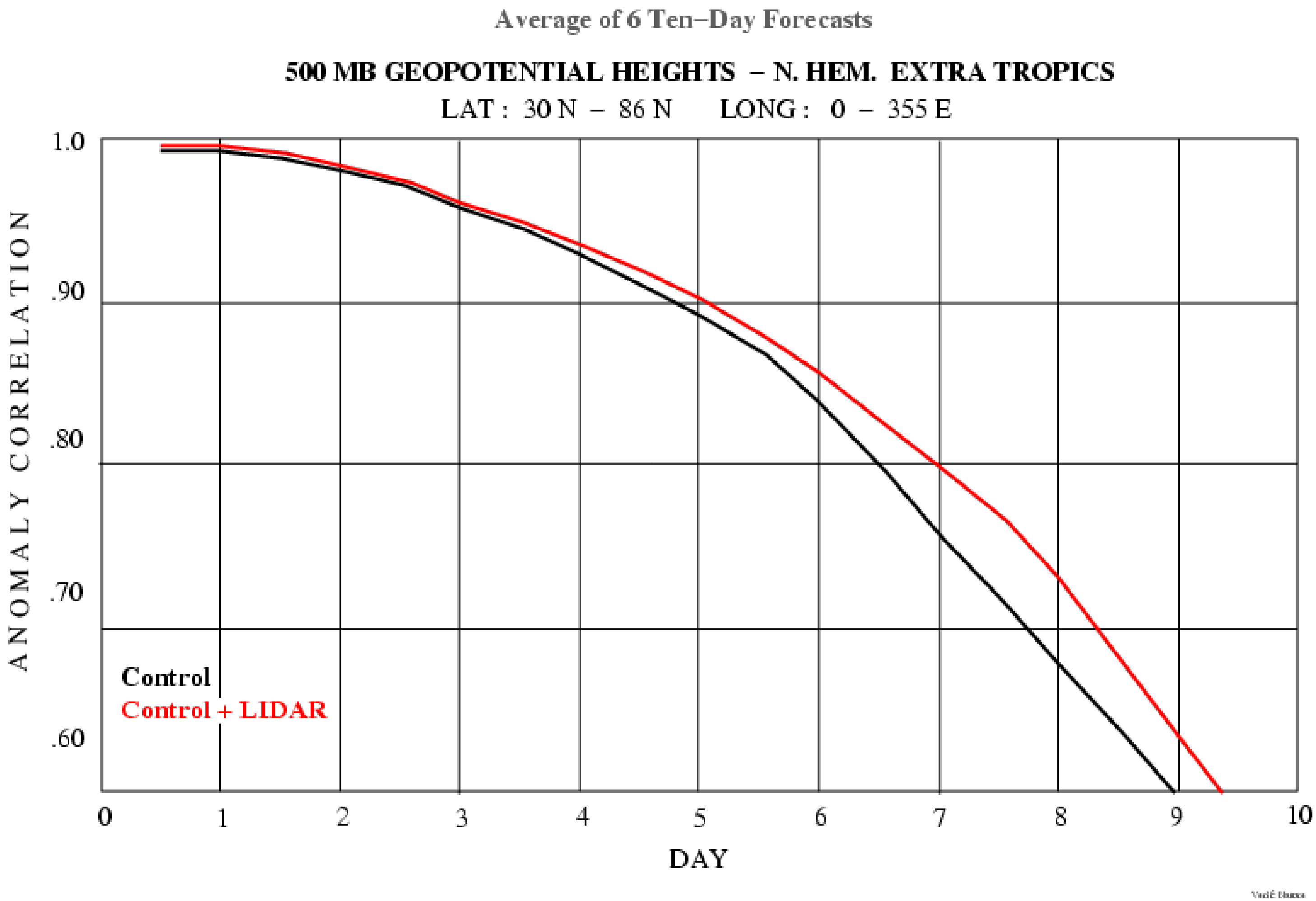
SEA LEVEL PRESSURE − N. HEM. EXTRA TROPICS
LAT : 30 N − 86 N LONG : 0 − 355 E



Impact of SWA Best LIDAR on GEOS-3 Forecasts



Impact of LIDAR Winds on FVGCM Forecasts



CONCLUSIONS

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

- Great care must be taken to ensure the realism of the OSSE's and in the interpretation of OSSE results.

- Previous OSSE's conducted with 4 different data assimilation systems (from 1985-1999) all showed significant potential for space-based lidar wind profiles to improve atmospheric analyses and weather predictions.

- OSSEs are currently being conducted to assess the potential impact of lidar winds in current data assimilation systems.

CONCLUSIONS (CONTINUED)

2. A new nature run that is both longer and more realistic than previous nature runs has been generated.

4. New metrics, which are more directly relevant to local weather, have been developed.

6. Results from the current DAO OSSEs indicate that there would be a substantial impact of space-based lidar winds on weather prediction, if sufficient coverage and accuracy can be achieved from space.

Multi-agency coordinated OSSE/OSE Testbed

March 1 2006

Multi-agency coordinated OSSE/OSE Testbed

- OSSEs require significant funds to set up
  - Best done with “core” support at 1 or 2 centers
  - Nature Run assessment, adjustments, data simulation for current observing systems and checks on realism of the simulated obs on analyses and forecasts are “core” functions
- Individual experiments have much more reasonable incremental costs

Multi-agency coordinated OSSE/OSE Testbed (cont)

- Some redundancy is desirable, but should be by design.
- Need some level of coordination to optimize national investment in OSSEs for instrument design, data utility studies and model development efforts.
- Need recognizable point of contact for academia, industry and government agency inquires into how to access the OSSE testbed.

Some references

- Atlas, Robert, 1997: Atmospheric observations and experiments to assess their usefulness in data assimilation. JMSJ, Vol. 75, pp. 111-130.
- Atlas, R., E. Kalnay, J. Susskind, W. E. Baker and M. Halem, 1985: Simulation studies of the impact of future observing systems on weather prediction. Proc. Seventh Conf. on NWP. 145-151.