NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

NCEP

WHERE AMERICA'S CLIMATE AND WEATHER SERVICES BEGIN

Global OSSE using the NCEP Data Assimilation System

Michiko Masutani. John C. Woollen,
Stephen J. Lord, John C. Derber
G. David Emmitt, Sidney A. Wood, Steven Greco
Joseph Terry, Robert Atlas,
Thomas J. Kleespies, Haibing Sun

August 2002

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

Participating Scientists

NOAA/NWS/NCEP/EMC
Steve Lord , Michiko Masutani
Jack Woollen, John Derber
Robert Kistler
NOAA/NWS/NCEP/NCO
Wayman Baker

NASA/GSFC/DAO
Bob Atlas, Joe Terry
Genia Brin, Steve Bloom

Simpson Weather Associates
Dave Emmitt, Sid Wood
Steve Greco, Chris O'Handley

NOAA/NESDIS/ORA
Tom Kleespies, Haibing Sun
Mitch Goldberg
Walter Wolf, Jim Yoe
Chris Velden

Sponsored by

NOAA/NESDIS
NOAA/OAR
NPOESS/IPO

Advisory Panel

D. Norquist	AFWA
T. Krishnamurti	FSU
E. Eloranta	U. Wisconsin
A. Kasahara	NCAR
G. Mandt	NWS/OS
J. Paegle	U. Utah

Advised by
Roger Daley
Eugenia Kalnay

Acknowledgment

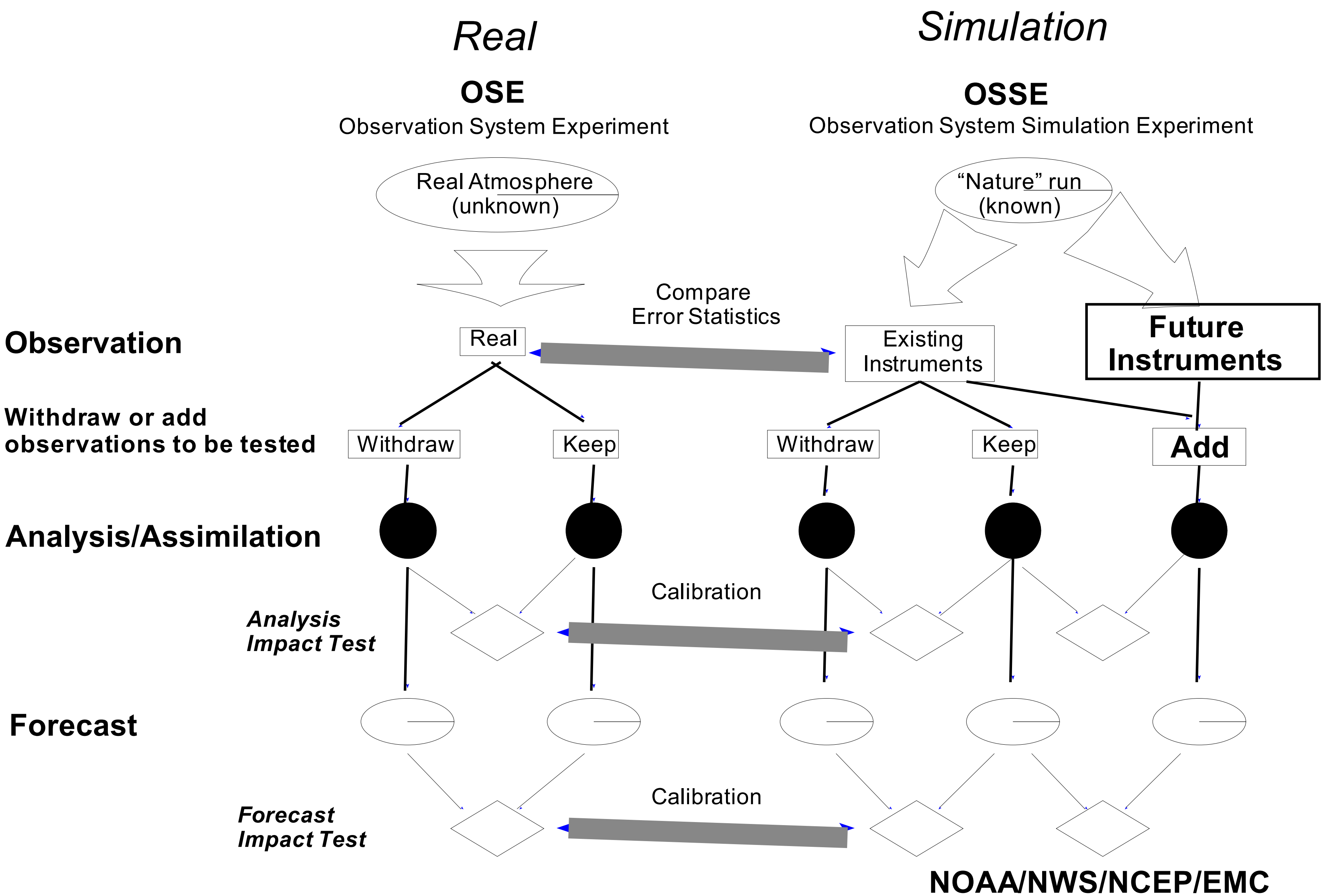
Wei yu Yang, Russ Treadon, Ken Campana, S.-K. Yang, Wan Shu Wu, Yuejian Zhu, , Bert Katz, Jim Purser, Dave Parrish, Bill Collins, Mark Iredell, Dennis Keyser, Zoltan Toth, Song- You Hong, Wesley Ebisuzaki, George Vendenberg, Steve Tracton, Hua-Lu Pan (NCEP)

Dick P. Dee, and N. Wolfson (DAO),

Lin Wood (SWA)

Larry Stowe, Andrew Heidinger , Po Li , Vaisali Kapoor(NESDIS)

Christian Jakob, Roger Saunders, Keith Felding, Tony Hollingsworth Data support section (ECMWF)



Real
Simulation
OSE
Observation System Experiment
OSSE
Observation System Simulation Experiment
Real Atmosphere (unknown)
"Nature" run (known)
Observation
Real
Compare Error Statistics
Existing Instruments
Future Instruments
Withdraw or add observations to be tested
Withdraw
Keep
Withdraw
Keep
Add
Analysis/Assimilation
Analysis Impact Test
Calibration
Forecast
Forecast Impact Test
Calibration
NOAA/NWS/NCEP/EMC

The NCEP OSSE data assimilation system

Operational data assimilation system-March 99 version.
Spectral Statistical Interpolation (SSI)
Use TOVS level 1B data
T62/ 28 level

Parrish and Derber (1992)

Observation

Use distribution of real observations in February 1993
RAOB and other conventional data
ACARS (1993 distribution)
HIRS and MSU level 1B data from NOAA-11, NOAA- 12
Satellite cloud track wind

Nature Run

ECMWF reanalysis model
Resolution T213 (about 60 km), 31 levels
06Z 5 February 1993 to 00Z 7 March 1993
Near normal condition
Good agreement in synoptic activities

FGVCM Nature run proposed by NASA/DAO
After OSSE by ECMWF NR is exploited

Benefits (beyond instrument evaluation)

-Prepare for real data
(formats, data flow, analysis development)
-Some prior experience for new instrument
- Data impact tests with known truth will reveal negative impacts of some data sources.

The results of OSSE influenced the upgrade of NCEP data assimilation system

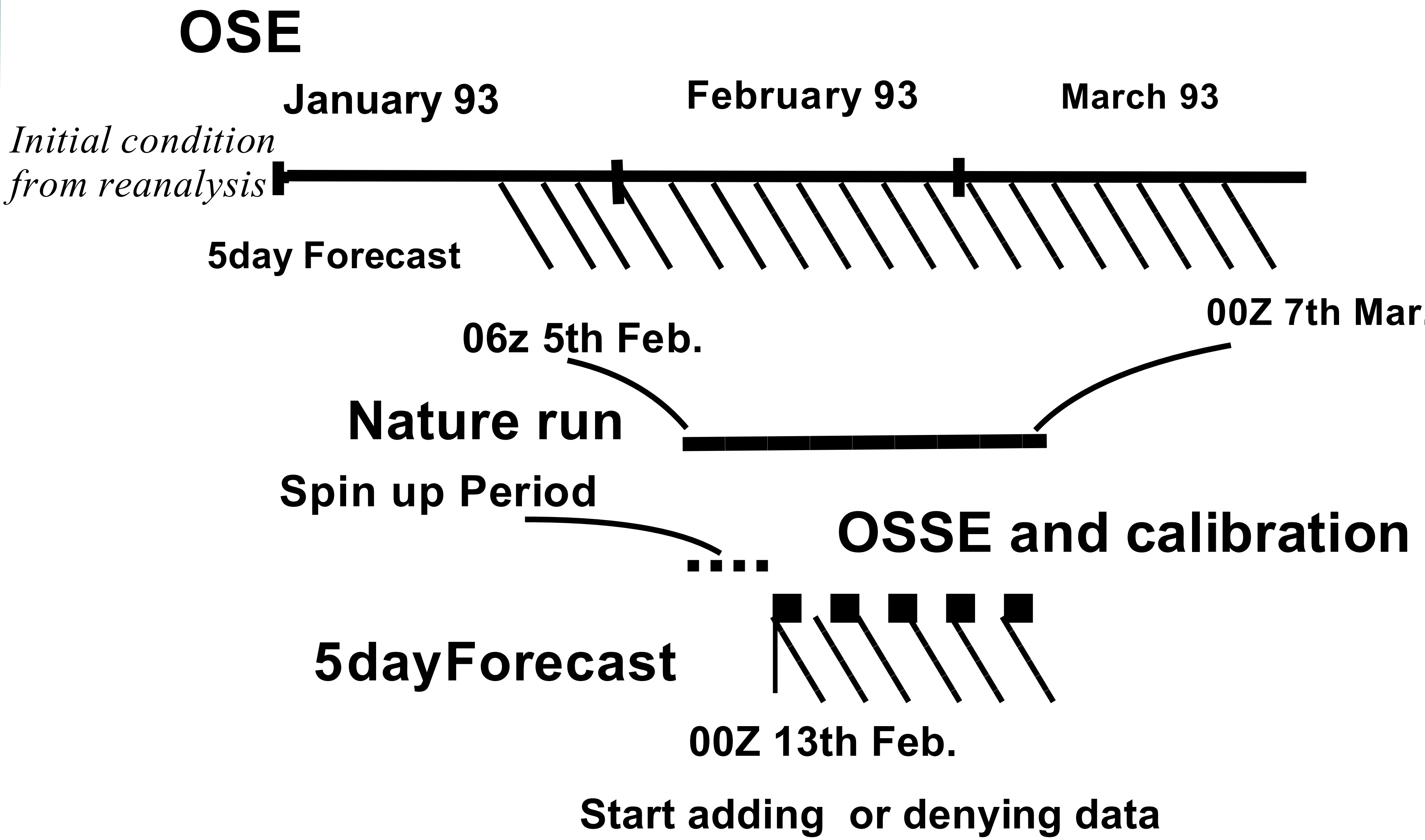
Procedure for Calibration Experiments

- Start data assimilation on 1 January 1993
  Take initial conditions from reanalysis
  Use TOVS 1B radiance
  Use same model and data assimilation system
  for OSSEs

- Spin up of assimilation with simulated data
  from 06Z 5 February

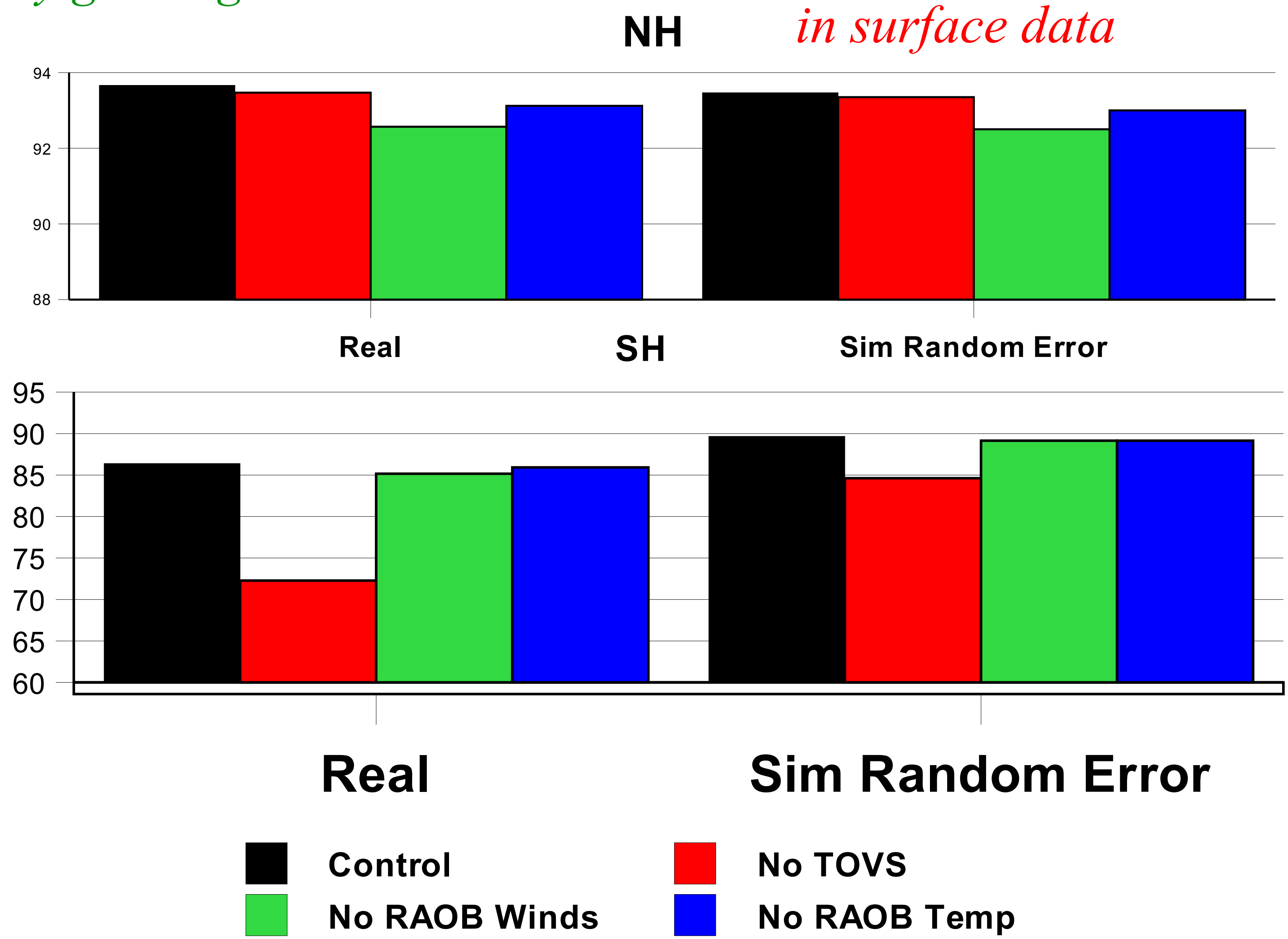
- Add or deny runs starting from 00Z 13 February
  Both real and simulated
  Total 24 days for calibration and OSSE

- Three kinds of errors has been tested
  to simulated conventional data
  - Random error
  - Use obs.- analysis from real assimilation as error.
  - No error (Use interpolated values as they are.)


OSE
January 93
February 93
March 93
Initial condition
from reanalysis
5day Forecast
06z 5th Feb.
00Z 7th Mar.
Nature run
Spin up Period
OSSE and calibration
5dayForecast
00Z 13th Feb.
Start adding or denying data

Generally good agreement

We need to work on error in surface data



Anomaly correlation between control analysis and 72 hour forecasts for 500 hPa height.

Comparison of impact in Real and Simulated analysis

- In general, there is consistency between real and simulated data impacts.

- RAOB winds have more impact compared to RAOB temperatures globally in both simulation and real.

- In tropics, simulations show bias related to RAOB temperature and moisture.

- OSSE data impact depends on error formulation for simulated observations. Random error is easy to produce but it is not challenging enough for data assimilation systems. Need to include systematic large scale errors.

Surface data

The error in real surface data is much larger than simulated surface data. Therefore, impact of other data, particularly satellite data including DWL, may be underestimated in simulation.

⬇

Need to add more realistic error to surface data

Impact Assessment of a DWL

Simulation of DWL wind

EXP 1(Best) : Ultimate DWL that provides full tropospheric LOS soundings, clouds permitting.

EXP 2 (PBL+cloud): An instrument that provides only wind observations from clouds and the PBL.

EXP 3 (Upper): An instrument that provides mid and upper tropospheric winds only down to the levels of significant cloud coverage.

Exp 4 (Non-Scan): A non-scanning instrument that provides full tropospheric LOS soundings, clouds permitting, along a single line that parallels the ground track.

Clustered: Data product is based upon averaging the observations of shots clustered within a very small area compared to the base area of the TRV.

Distributed: Data product is based upon averaging the observations of shots distributed throughout the TRV as would result from continuous conical scanning

Data products based upon ***clustered*** and ***distributed*** shots are generated for each experiment except for the reference experiment.

No measurement error is assigned.

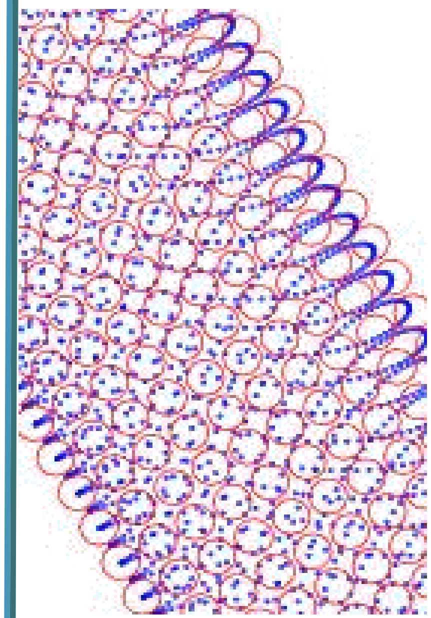
Targeted Resolution Volume (TRV)
200Kmx200KmxT
T: Thickness of the TRV
0.25 Km if z<2 Km, 1 Km if z> 2 Km, 0.25 Km for cloud return

Swath Width: 2000 Km

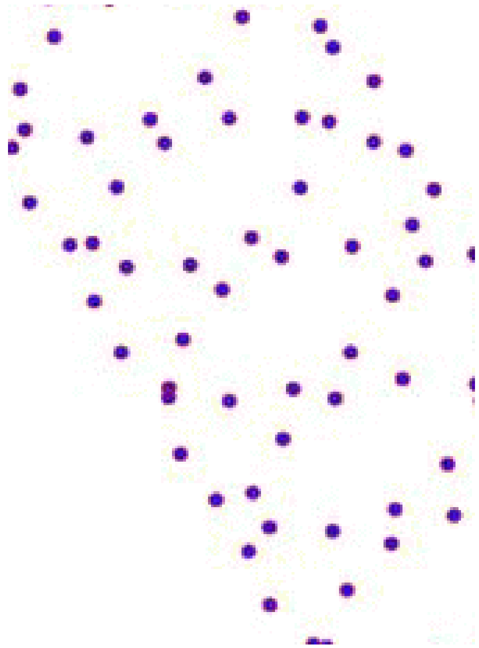
Representativeness error, 1, 2, 7 m/s, are tested.

Scan
swath width: 2000 km

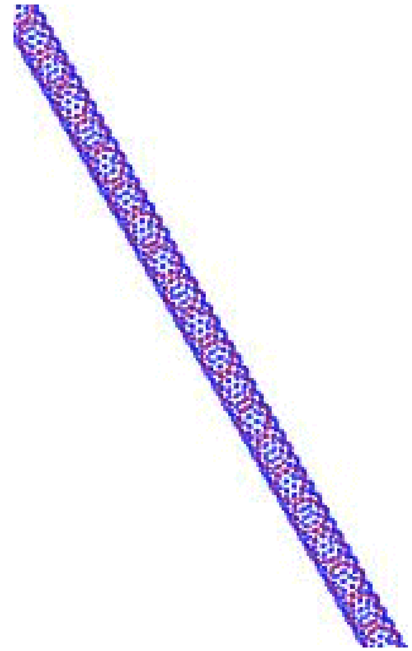
Non-Scan



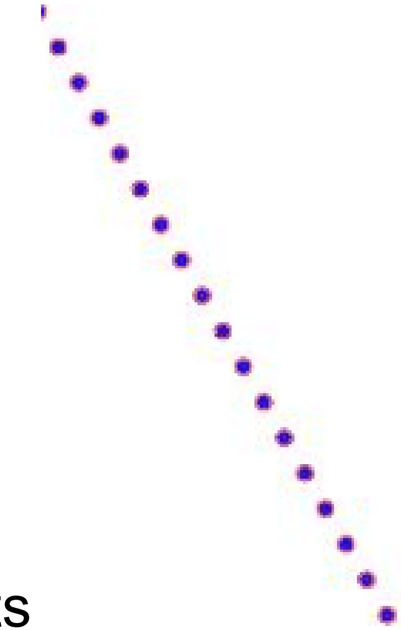
Distributed Shots



Clustered Shots



Distributed Shots



Clustered Shots

Red: measurement, Blue: Shots

One measurement is an average of many shots (LOS)
Distributed shot has smoothing effect
Distributed shot for non-scan scenario is to test the effect of small scale structures.

Note: "Scan clust." and "Non scan Dist." require similar numbers of shots.

In this experiment r=7 is used for clustered shots. This means one shot (LOS) is used to produce one measurement.

In order to produce r=1 measurement 49 $\approx$ 50 times more shots (LOS) are required compared to r=7 measurements.

Scanning requires about 50 times the measurements compared to non scan.

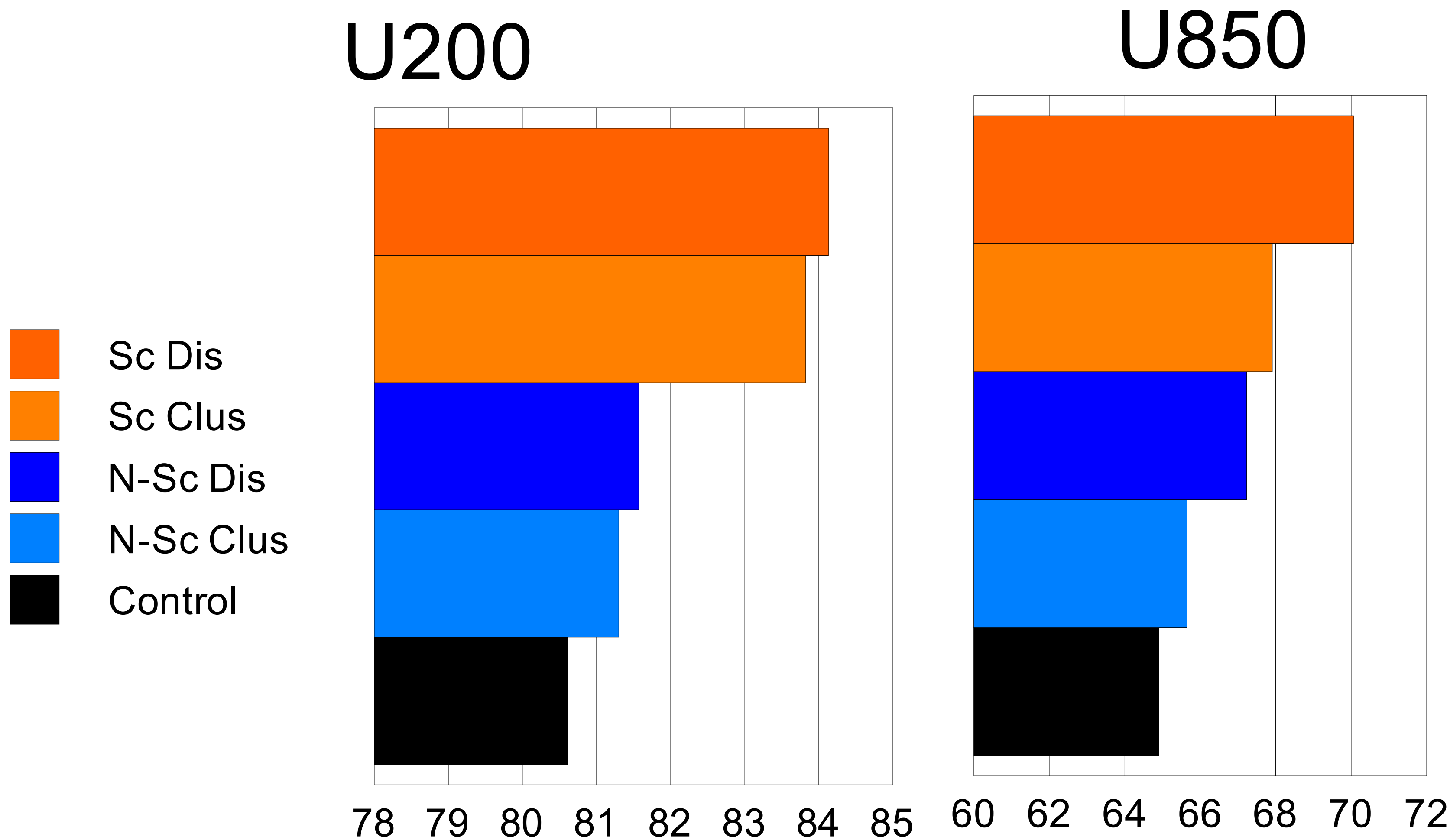
Therefore, non scan distributed shots with r=1 and scanned clustered shots with r=7 require similar numbers of shots (LOS), i.e. power

Distributed shots penetrate better than clustered shots.

If shots are distributed in 200Kmx200Km there are better chances to find holes in clouds.

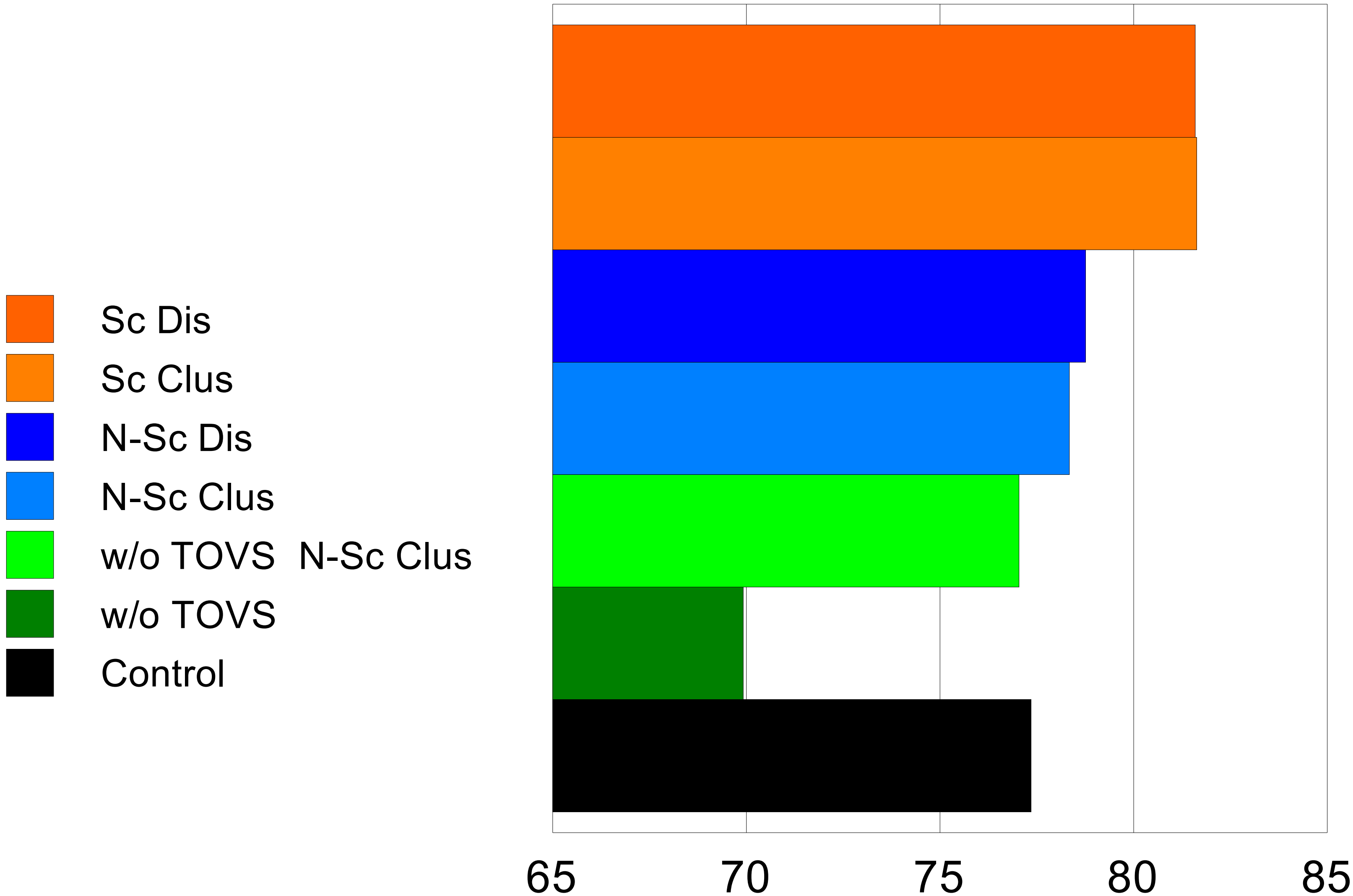
Representativeness error (r) should be a function of number of shots actually used in meausrement. Resolution of the model and scale of error covariance affect "r" as well.
(Future work)

DWL Impact on Tropical Wind (72 hr fcst)



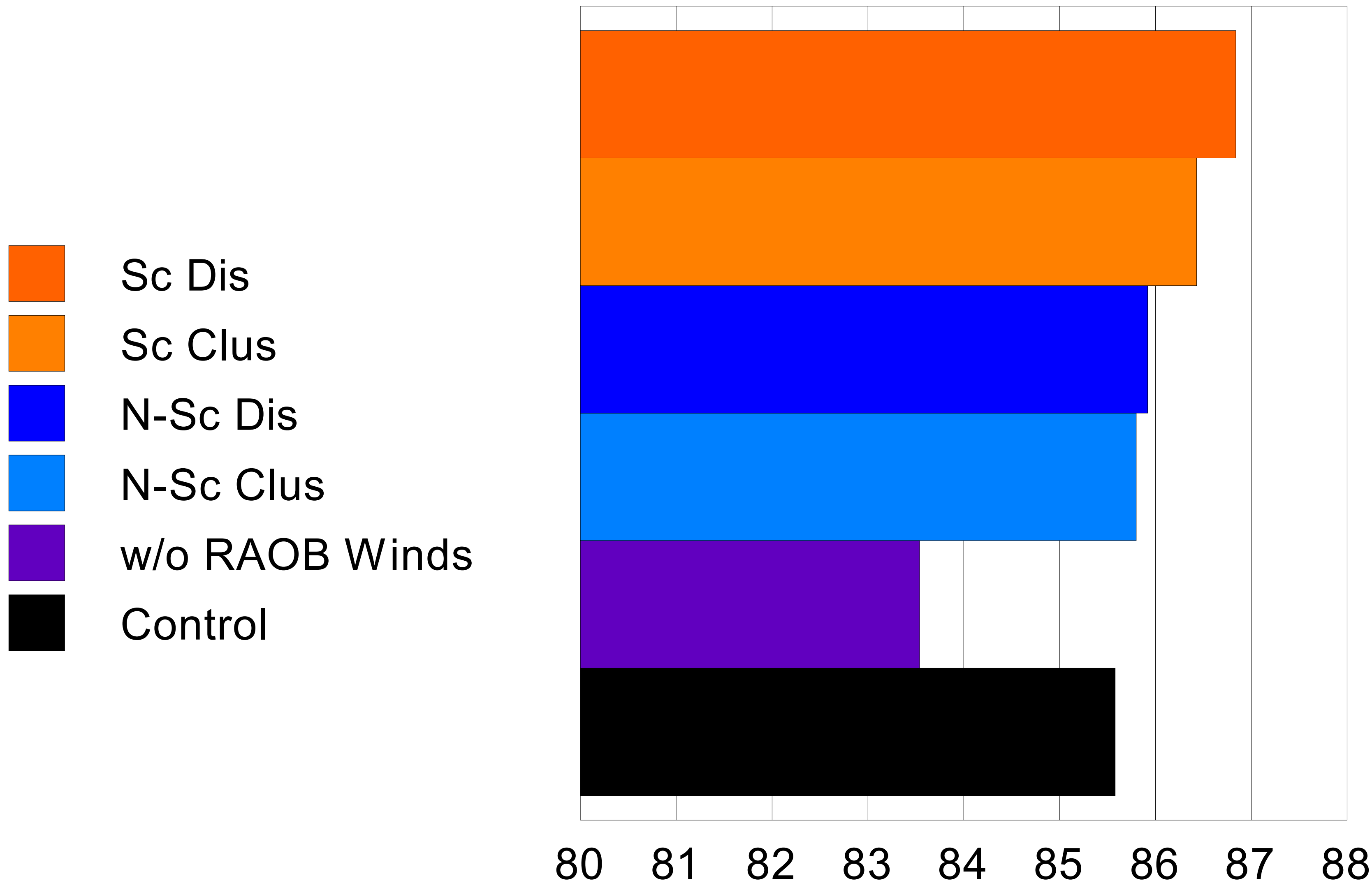
Anomaly correlation with the Nature run (%). The skill is computed from12 hourly forecasts from Feb14 to Feb28, 1993.

DWL impact on SH U500 (72 hr fcst)



Anomaly correlation with the Nature run (%). The skill is computed from12 hourly forecasts from Feb14 to Feb28, 1993.

DWL Impact on NH U500 (72 hr fcst)



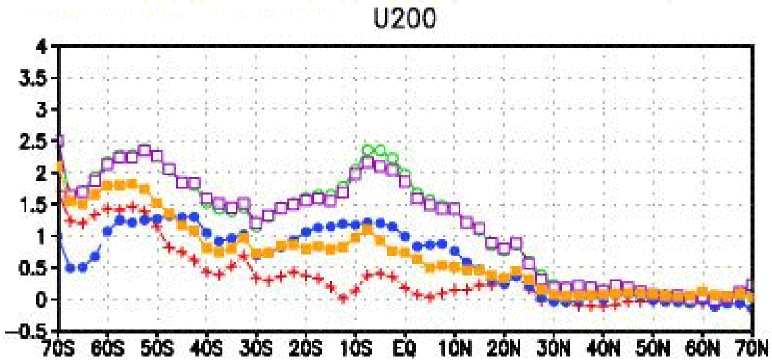
Anomaly correlation with the Nature run (%). The skill is computed from12 hourly forecasts from Feb14 to Feb28, 1993.

Control:Conventional obs only

Red(Cross):1B TOVS 1B

Blue(Closed circle):EXP2_Dist_r=1 EXP2: PBL

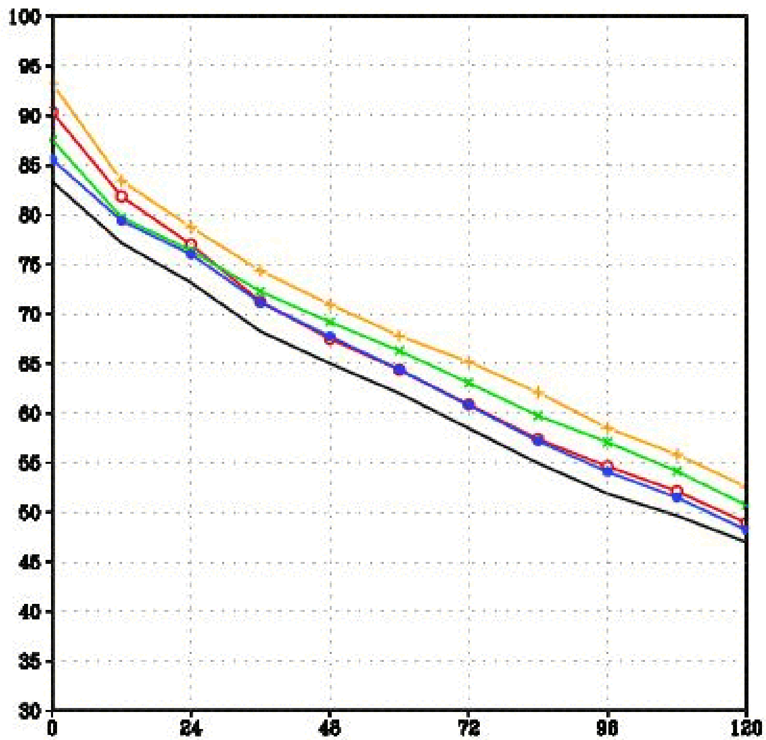
Orange(Closed square):EXP4_Dist_r=1 EXP4 non scan

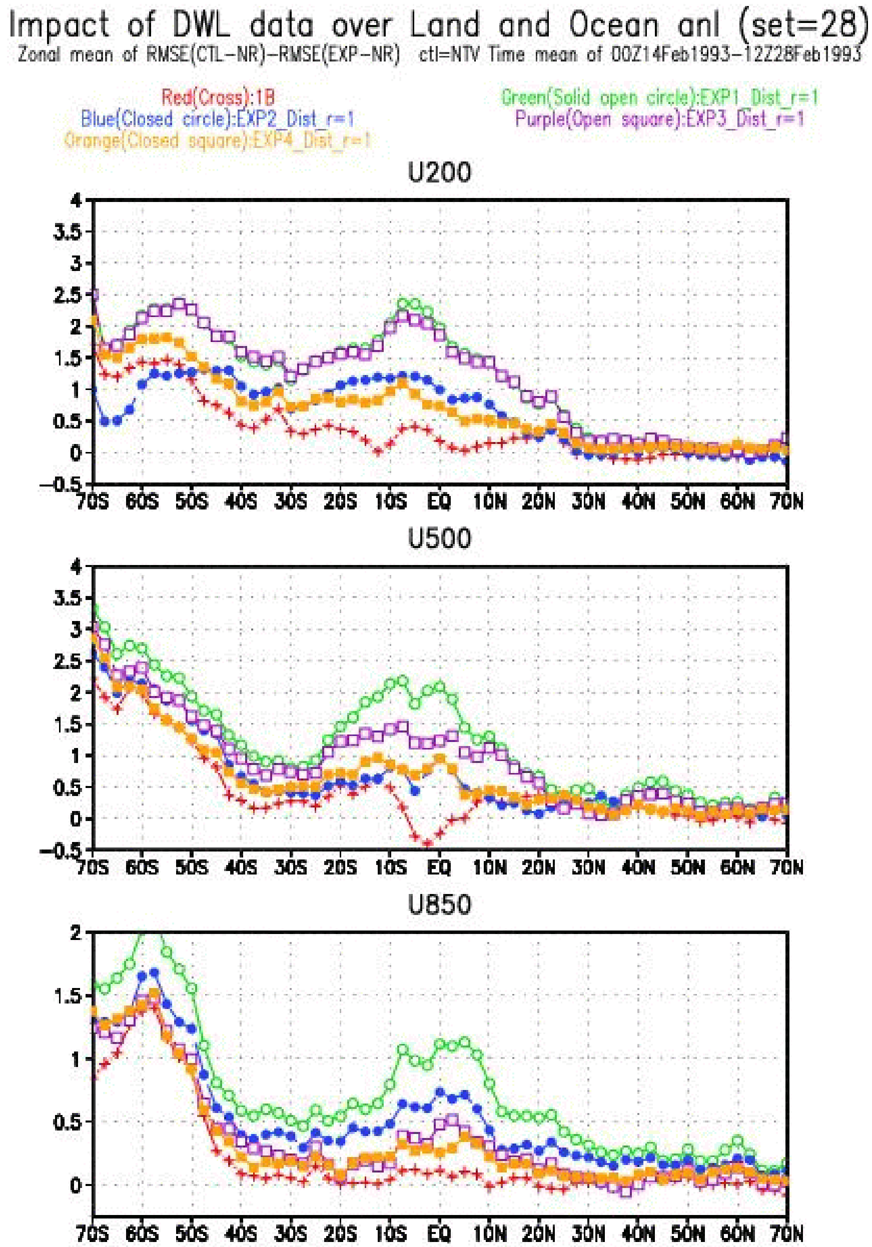


Green(Solid open circle):EXP1_Dist_r=1 EXP1: Hybrid

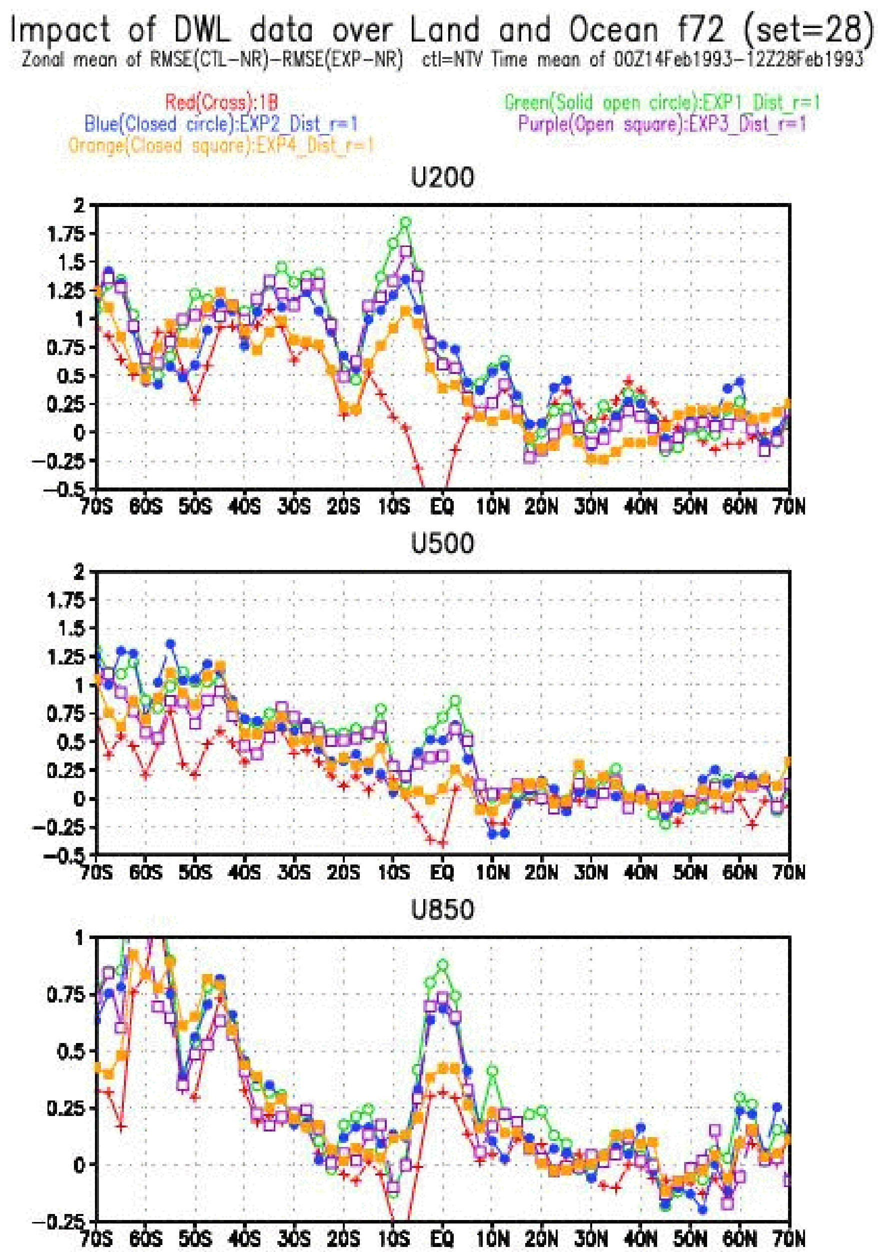
Purple(Open square):EXP3_Dist_r=1 EXP3 Upper

Anomaly correlation
850mb V,   Tropics
Black: No 1B
Yellow : EXP1, Red: EXP2,
Green: EXP3, Blue: EXP4





Impact of DWL data over Land and Ocean anl (set=28)
Zonal mean of RMSE(CTL-NR)-RMSE(EXP-NR) ctl=NTV Time mean of 00Z14Feb1993-12Z28Feb1993
Red(Cross):1B
Blue(Closed circle):EXP2_Dist_r=1
Orange(Closed square):EXP4_Dist_r=1
Green(Solid open circle):EXP1_Dist_r=1
Purple(Open square):EXP3_Dist_r=1
U200
U500
U850
70S 60S 50S 40S 30S 20S 10S EQ 10N 20N 30N 40N 50N 60N 70N

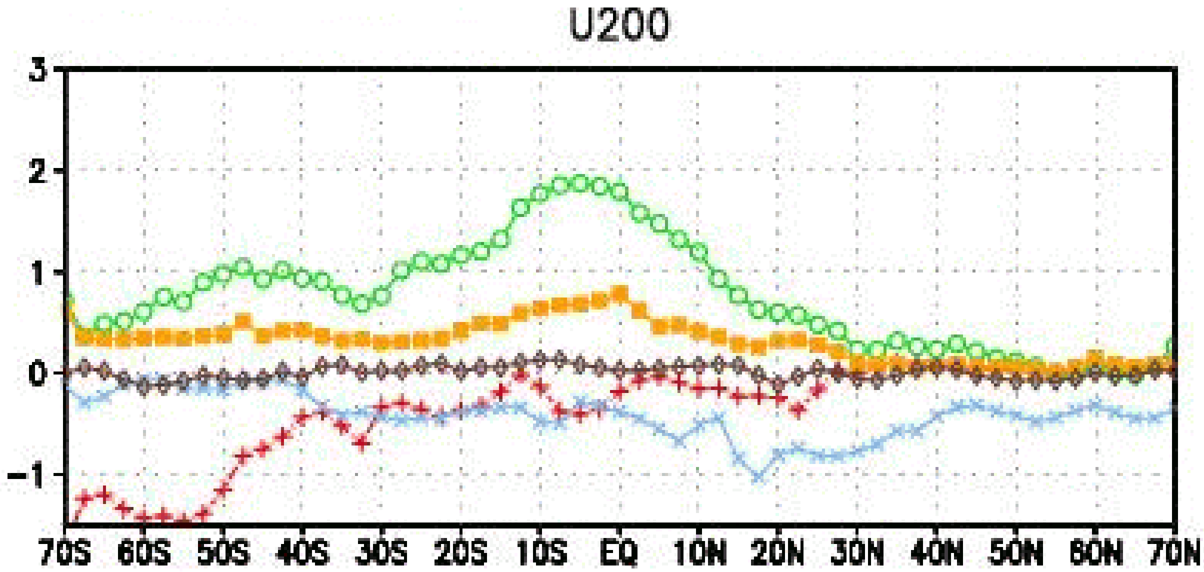

Impact of DWL data over Land and Ocean f72 (set=28)
Zonal mean of RMSE(CTL-NR)-RMSE(EXP-NR) ctl=NTV Time mean of 00Z14Feb1993-12Z28Feb1993
Red(Cross):1B
Green(Solid open circle):EXP1_Dist_r=1
Blue(Closed circle):EXP2_Dist_r=1
Purple(Open square):EXP3_Dist_r=1
Orange(Closed square):EXP4_Dist_r=1
U200
U500
U850
70S 60S 50S 40S 30S 20S 10S EQ 10N 20N 30N 40N 50N 60N 70N

Control: 1B + conventional obs

Red(Cross):No_1B — No1B no DWL

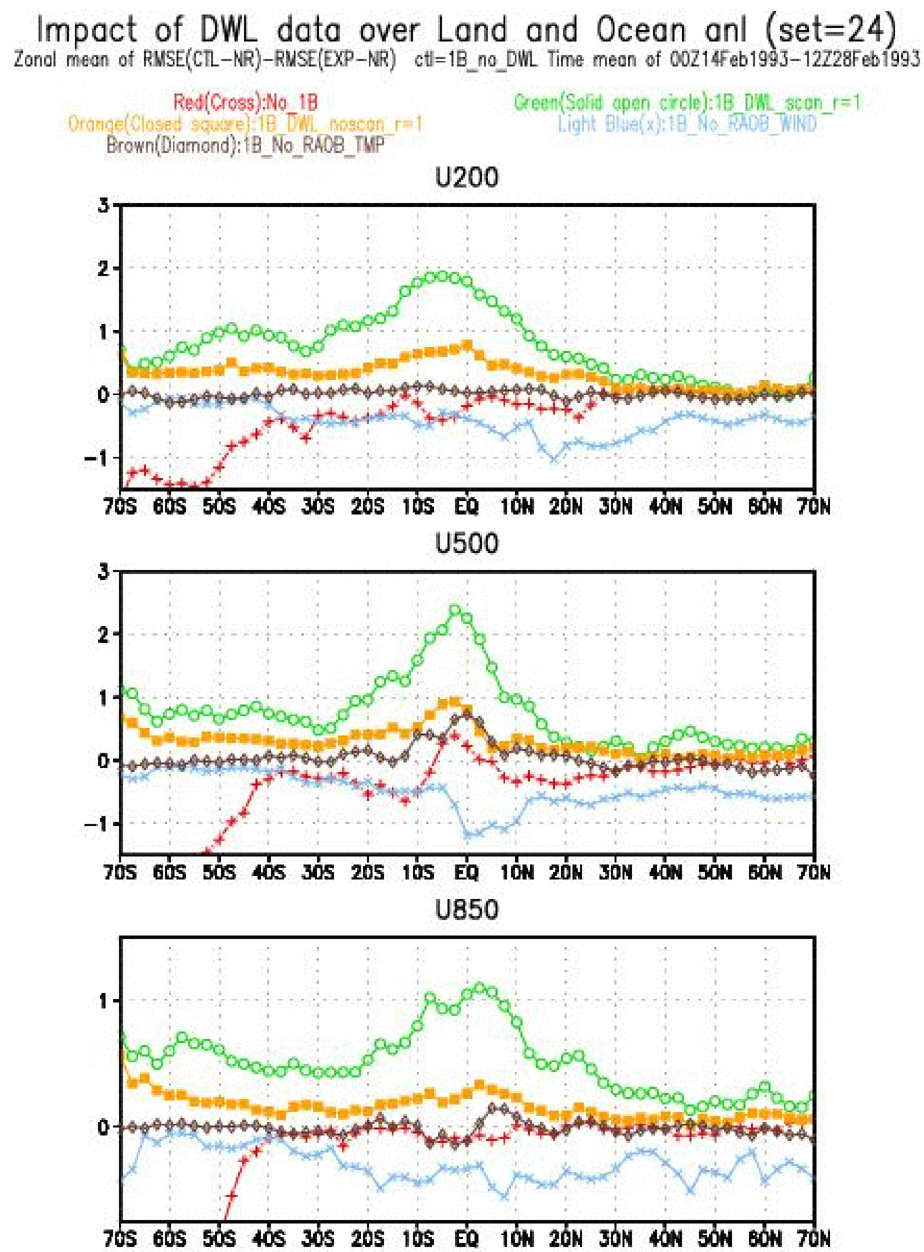
Orange(Closed square):1B_DWL_noscan_r=1 — 1B+DWL(exp4: non scan)

Brown(Diamond):1B_No_RAOB_TMP — 1B no RAOB Temp



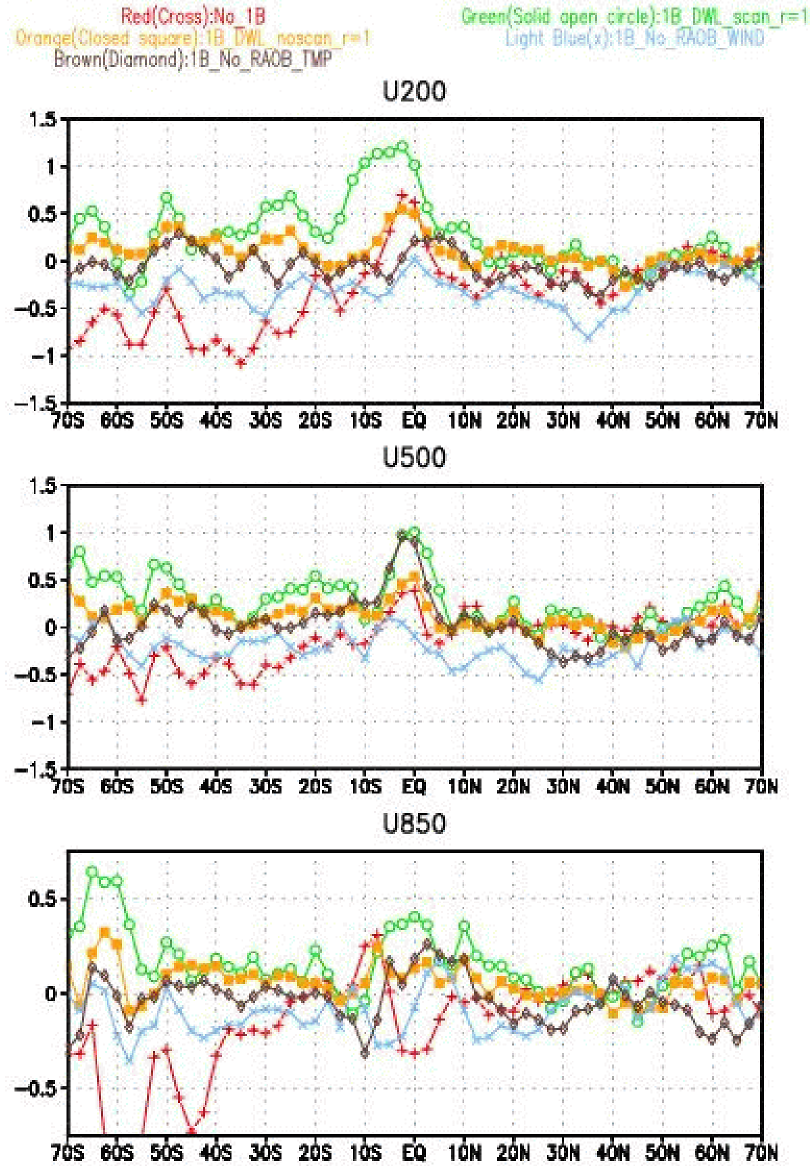
Green(Solid open circle):1B_DWL_scan_r=1 — 1B+DWL(exp1, best)

Light Blue(x):1B_No_RAOB_WIND — 1B no RAOB_wind


Impact of DWL data over Land and Ocean anl (set=24)
Zonal mean of RMSE(CTL-NR)-RMSE(EXP-NR) ctl=1B_no_DWL Time mean of 00Z14Feb1993-12Z28Feb1993
Red(Cross):No_1B
Orange(Closed square):1B_DWL_noscan_r=1
Brown(Diamond):1B_No_RAOB_TMP
Green(Solid open circle):1B_DWL_scan_r=1
Light Blue(x):1B_No_RAOB_WIND
U200
U500
U850
70S 60S 50S 40S 30S 20S 10S EQ 10N 20N 30N 40N 50N 60N 70N

Impact of DWL data over Land and Ocean f72 (set=24)

Zonal mean of RMSE(CTL-NR)-RMSE(EXP-NR) ctl=1B_no_DWL Time mean of 00Z14Feb1993-12Z28Feb1993



Summary

•DWL increases skill in all cases globally.

•Scanning has larger impact in the upper troposphere than in lower troposphere.

• Distributed shots give significantly better skill in the lower troposphere compared to clustered shots. Note: distributed shots have better penetration.

• In NH, an optimal DWL with scanning can produce comparable impact to RAOB wind.

• In SH, a minimal DWL can produce comparable impact with TOVS radiance.

Comments

The results need to be verified with further test with various observational error assignments.

Further development of the data assimilation will alter the impact.

Situation-dependent background error covariances may be more sensitive to higher density data set such as DWL wind.

Other high density data such as AIRS may improve the skill in a great deal. DWL need to be evaluated with AIRS.

DWL could be useful data to calibrate other data set such as Cloud motion vectors and radiance data.

Impact on temperature is similar but different from the impact on wind.

Small dirfference in impact will change with verification method.

Further Plans for assesement of DWL

- Test with new surface data.
  (Surface data is too optimistic in simulation)
- Test DWL with various distributions of cloud drift winds
- Test DWL with AIRS data.

Possible further assessment

- Further data sampling and density for DWL
- DWL with proposed design.
- Diagnostics of cyclone and jets. (DAO)
  (Strength and position)
- Compare extreme events (DAO)
- Data rejection statistics (NCEP)
- Cost benefit in different application (SWA)
  (e.g., flight planning)
- Data distribution and processing
  (Averaging, Super observation, etc.)
- Error assignment.
  (Test systematic errors)
- Adaptive observing strategies

Plans for OSSE at NCEP in 2002

A. Test various observational error assignments and weight in data assimilation , particularly for the surface data.

(Test with variouis observational error to achieve similar impact of surface data.)

B. Set up OSSE system with upgraded SSI

C. Start OSSE for AIRS
(The first data has been simulated)

D. Continue to evaluate simulation of TOVS
Treatment of cloud
Formulation of observational errors
Easier to do with upgraded SSI

E. Test idealized data set

- Test the importance of divergent winds.
- Impact of extra RAOBs
- Superobbing

F. OSSE with 2002 and future data distributions

Instruments to be tested

(Simulation in progress)

OSE and OSSE

Cloud Motion Vector - *Simulated by SWA and DAO*

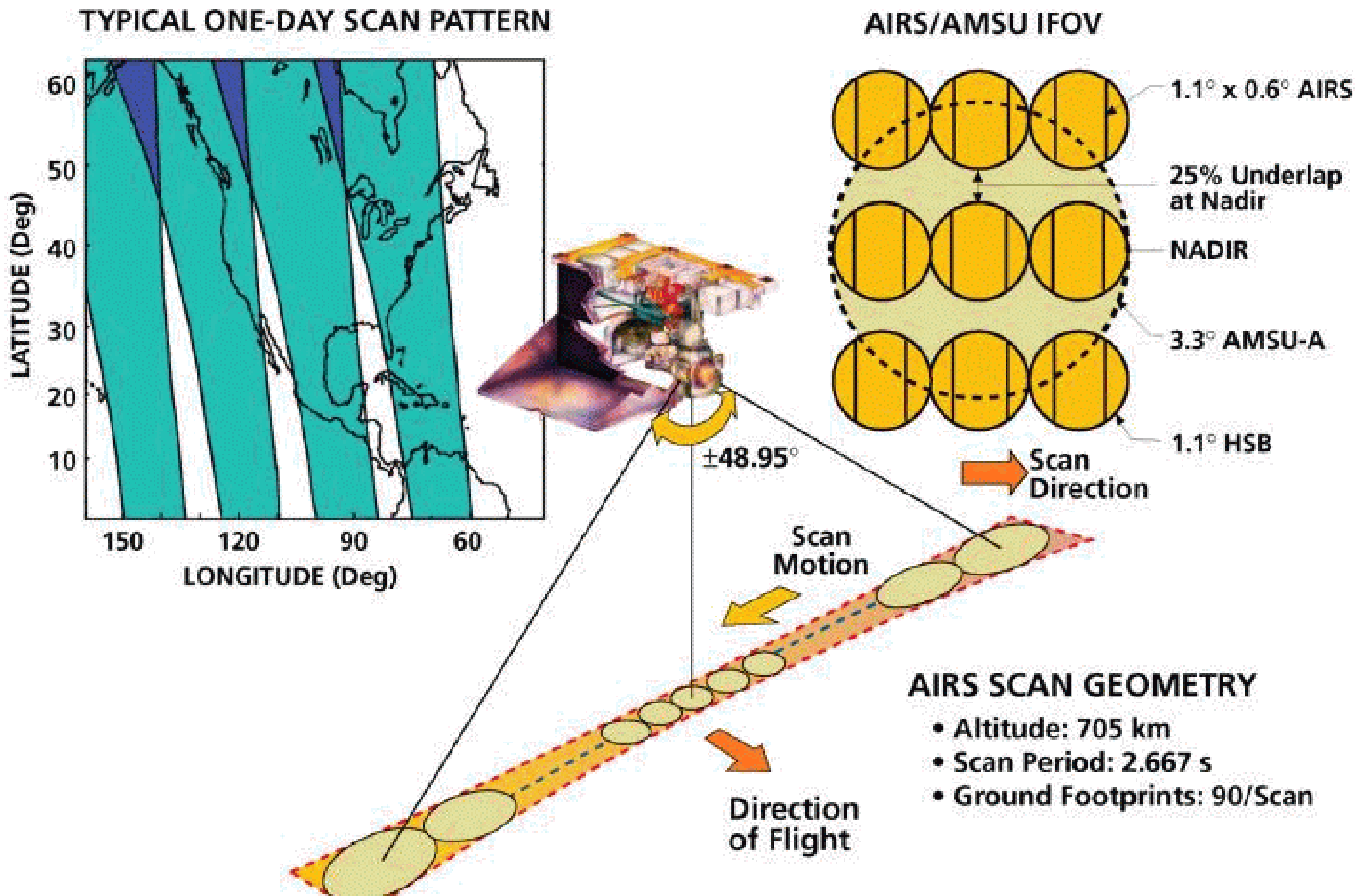
(Possible OSE)

Atmospheric Infrared Sounder (AIRS)- *Simulated by NESDIS*

OSSE

Doppler Wind Lidar (DWL)- *Simulated by SWA and NOAA*

Simulation of AIRS Radiance



NOAA/NESDIS

The Advanced Infrared Radiation Sounder (AIRS)

AIRS is a high spectral resolution spectrometer with 2378 bands in the thermal infrared (3.7 -15.4 μm). These ranges have been specifically selected to allow determination of atmospheric temperature with an accuracy of 1 °C in 1 km layers, and humidity with an accuracy of 20% in 2 km layers in the troposphere.

AIRS is considered to be a high spectrum resolution infrared sounder which will act as a prototype for NPOESS.

AIRS is selected as one of the instruments to be tested in OSSE experiments.

Radiative transfer model

AIRS Fast Forward Model provided by UMBC.This fast transmittance model is based on methods developed and used by Larry McMillan, Joel Susskind, and others. [Larry M. McMillin et al. 1976, 1995].

Hybrid PFAAST/OPTRAN algorithm is developed with kCARTA line by line model.

The Fast Forward Models are developed based on the Pre-launch spectral response function.

AIRS Radiance Simulation

The simulation includes radiances of 281 AIRS channels and microwave radiances for AMSU and HSB.

The simulation result is in BUFR (binary universal form for the representation of meteorological data)

New features in upgraded SSI

http://www.emc.ncep.noaa.gov/gmb/gdas

- New version of radiative transfer model
- Improved treatment in bias correction for radiance data.
- Upgraded background error covariance
- Accommodate more recent instruments
  AMSU, Precipitation, AIRS, DWL
- LOS is added as an observed variable.

(LOS has been included in the test version used for OSSE.)

- Precipitation assimilation is included
- Adjustment for higher resolution models.
- Comprehensive diagnostic tool for radiance assimilation

NCEP Data Assimilation System
Further Plans for 1-2 years

- Development of situation-dependent background error covariances for global and regional systems.

- Bias correction of background field

- Improved moisture background error covariance

- Development of cloud analysis system