Global OSSE
using the NCEP
Data Assimilation System

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

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Schematic Diagram of OSSE

http://www.emc.ncep.noaa.gov/research/osse/ossedoc/OSSEDIAG.gif

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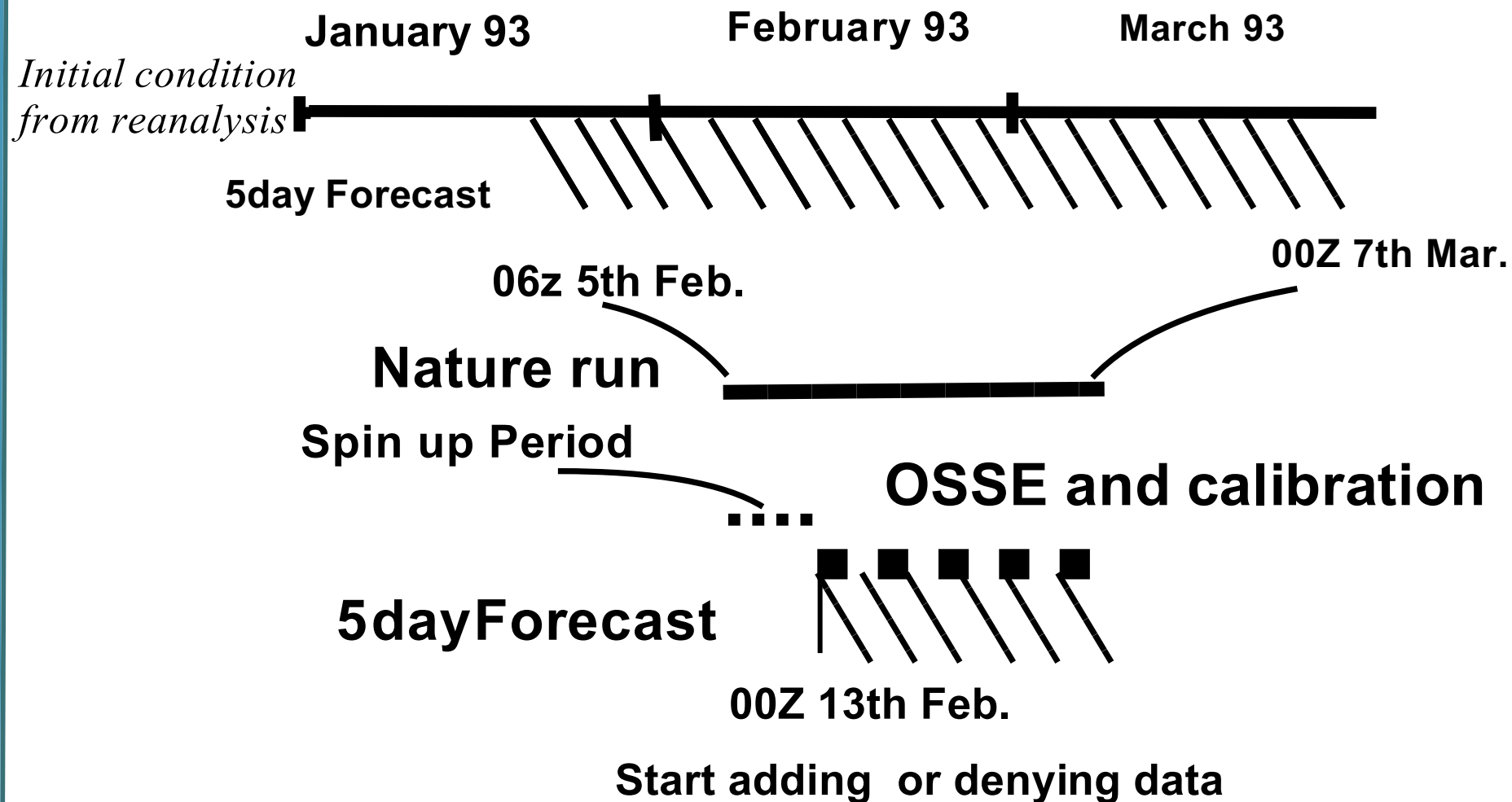
Benefits (beyond instrument evaluation)
 -Prepare for real data
 (formats, data flow, analysis development)
 -Some prior experience for new instrument
 - Data impact tests with known truth will
 reveal negative impacts of some
 data sources.

The results of OSSE influenced the upgrade
of NCEP data assimilation system
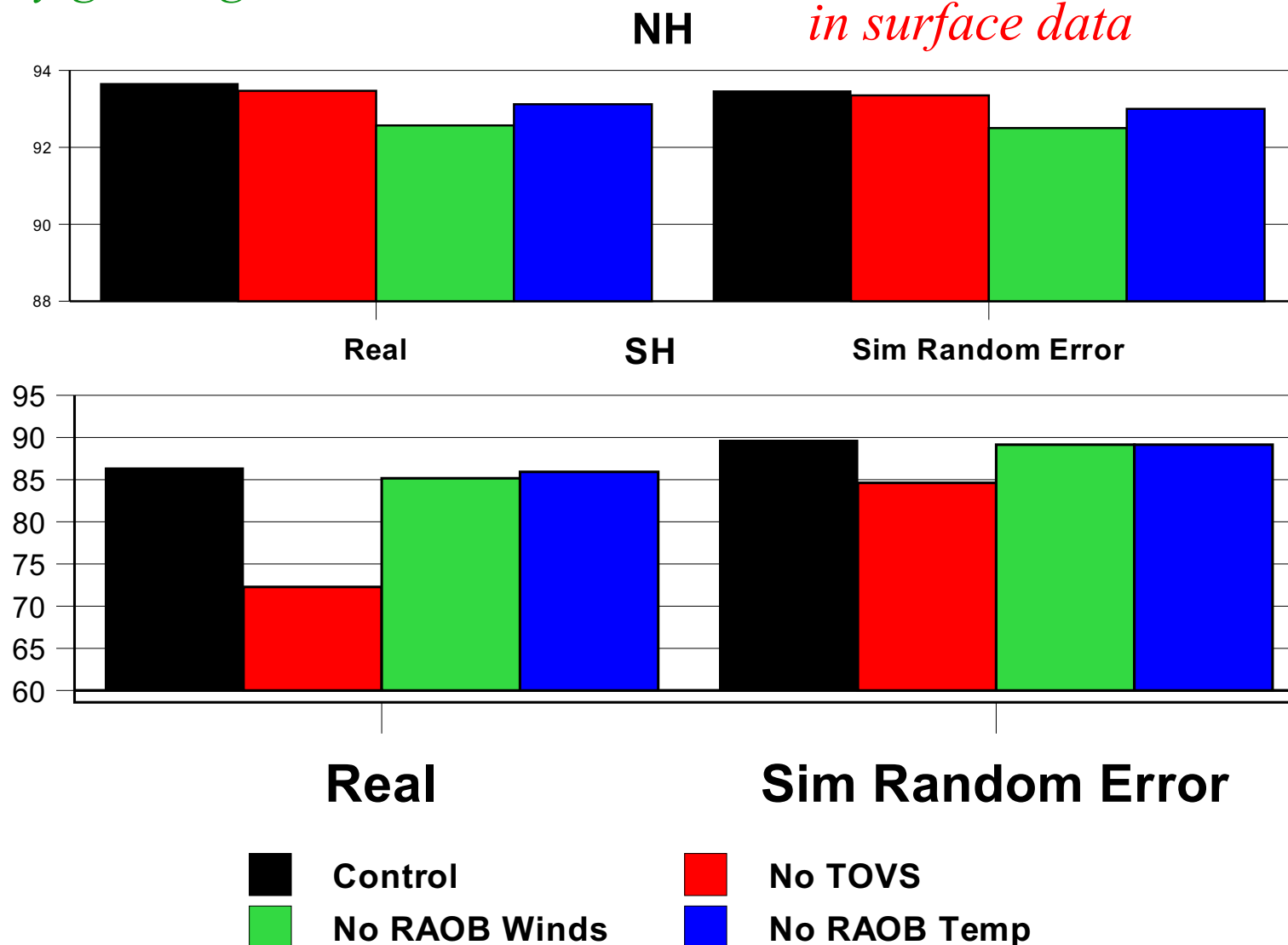
Procedure for Calibration Experiments

•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

00Z 7th Mar.

06z 5th Feb.

Nature run

Spin up Period

OSSE and calibration

....

5dayForecast

00Z 13th Feb.

Start adding or denying 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.

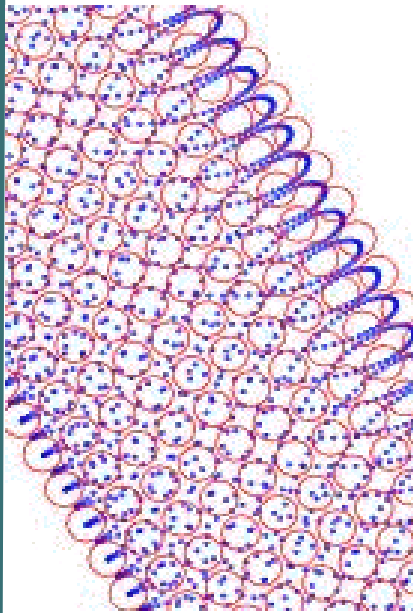**Targeted Resolution Volume** (TRV)
200Kmx200KmxT
T: Thickness of the TRV
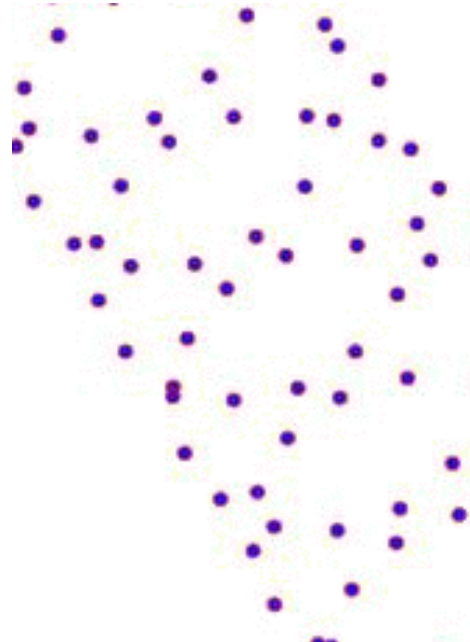0.25 Km if z<2 Km, 1 Km if z> 2 Km, 0.25 Km for cloud return

Swath Width: 2000 Km

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

Scan
swath width: 2000 km

Non-Scan
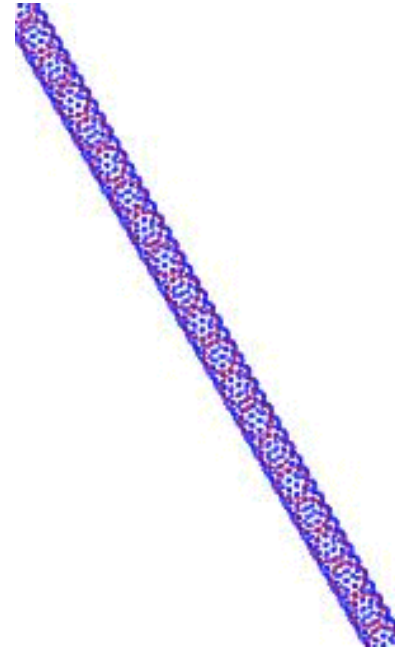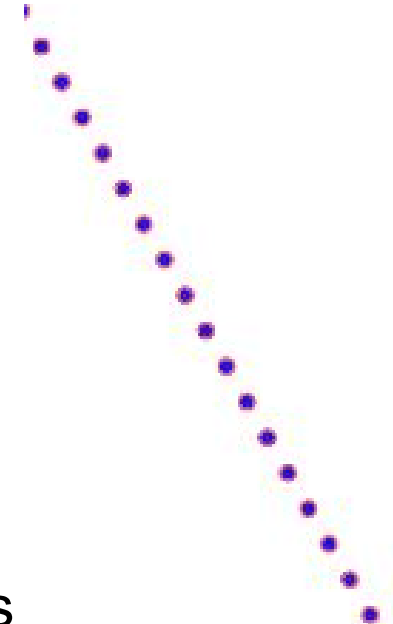

Distributed Shots

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.

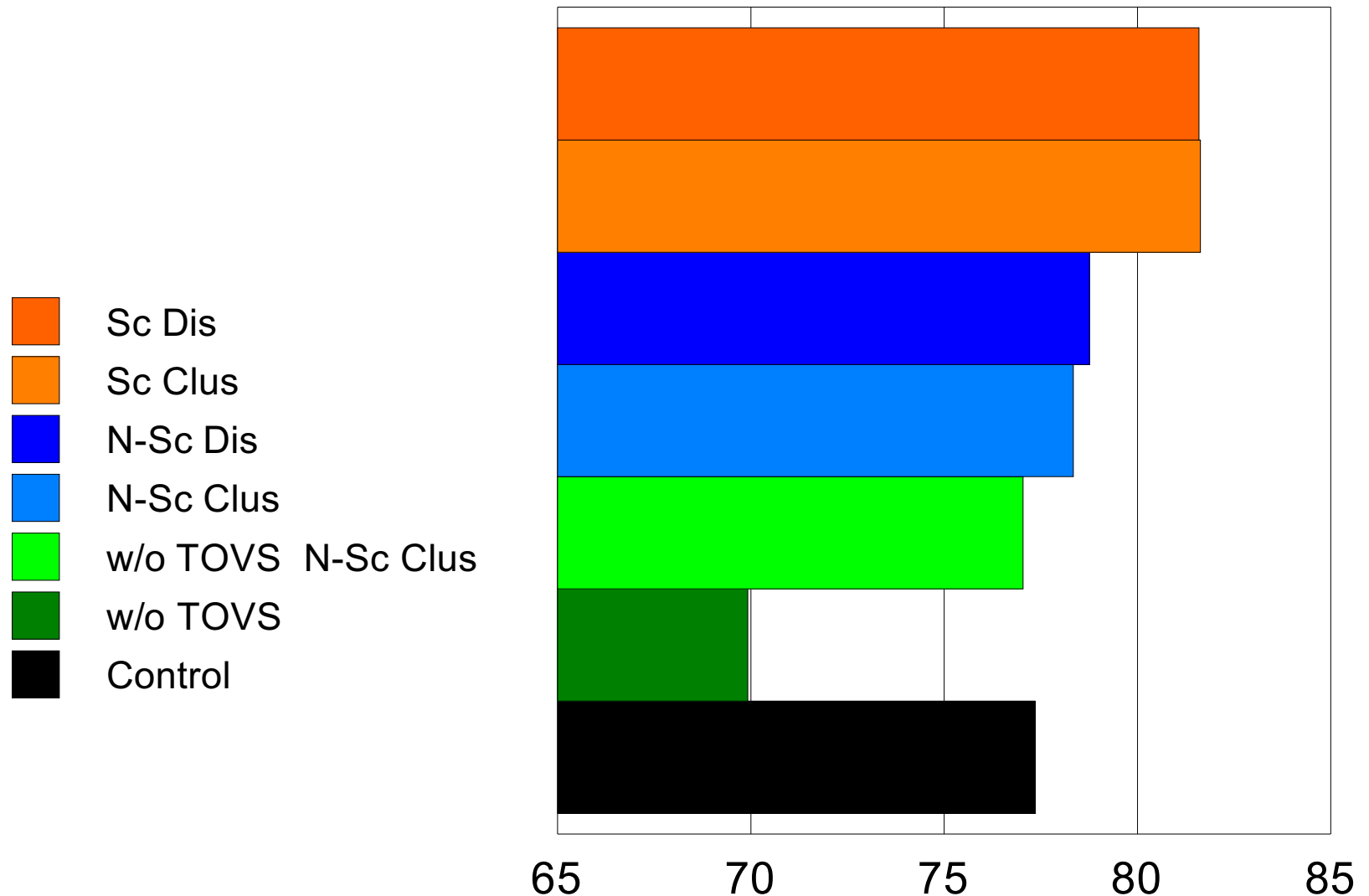If shots are distributed in 200Kmx200Km there are better chances to find holes in clouds.

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)
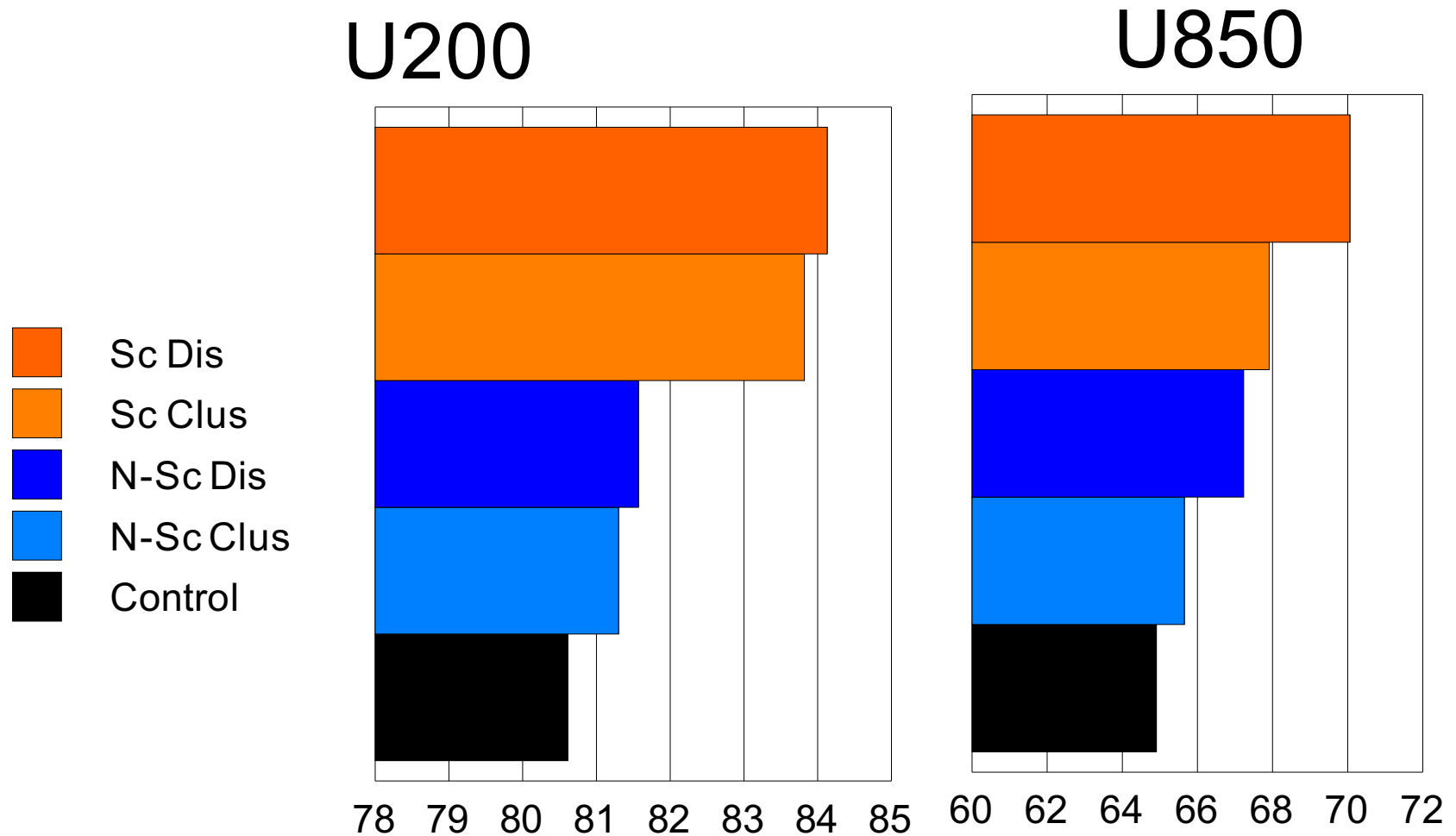
U200

U850

Sc Dis
Sc Clus
N-Sc Dis
N-Sc Clus
Control

78 79 80 81 82 83 84 85

60 62 64 66 68 70 72

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)

Legend:
- **Sc Dis** (orange-red)
- **Sc Clus** (orange)
- **N-Sc Dis** (blue)
- **N-Sc Clus** (light blue)
- **w/o TOVS N-Sc Clus** (green)
- **w/o TOVS** (dark green)
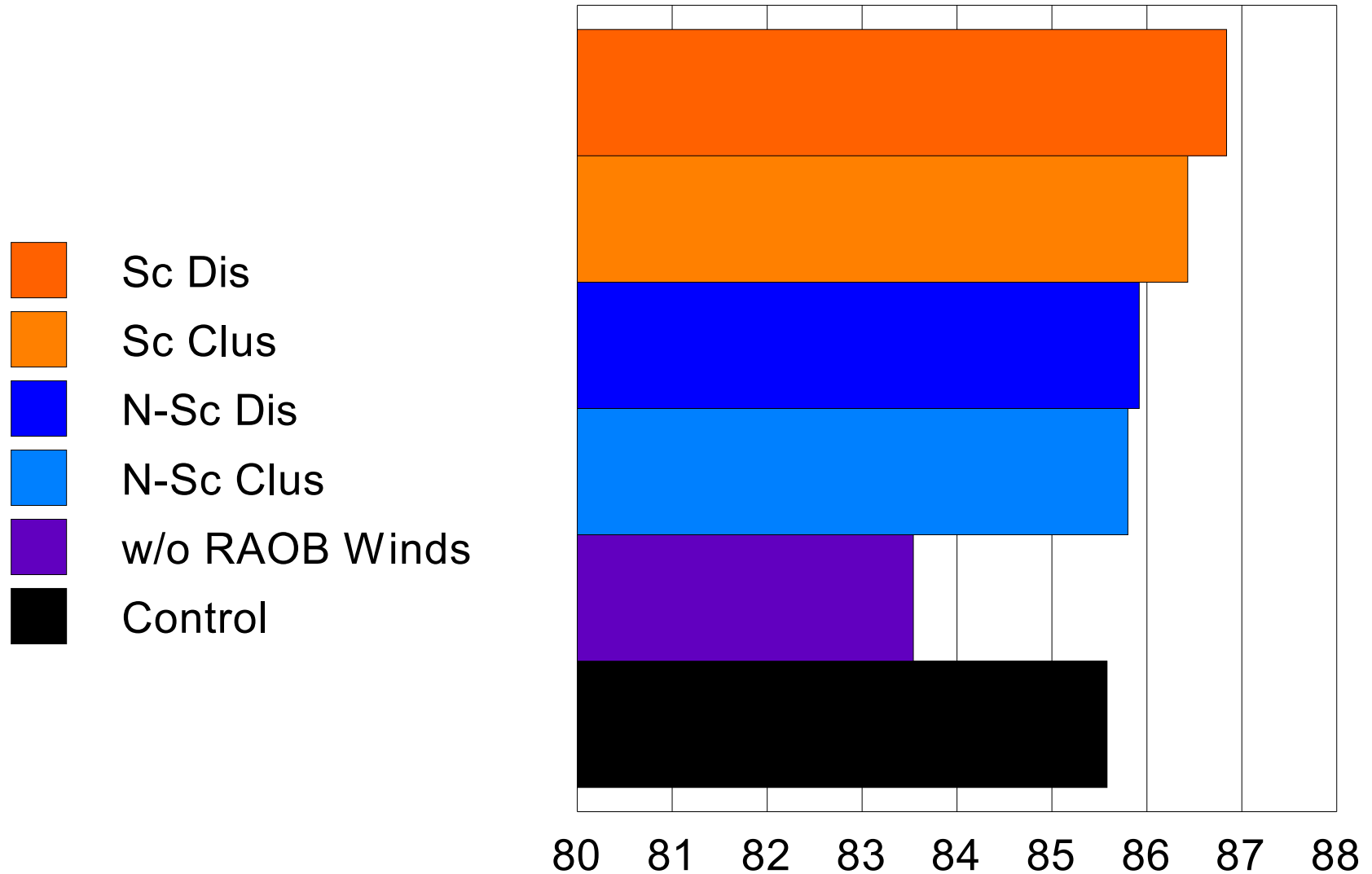- **Control** (black)

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)

Sc Dis

Sc Clus

N-Sc Dis

N-Sc Clus

w/o RAOB Winds

Control

80 81 82 83 84 85 86 87 88

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

Control:Conventional obs only
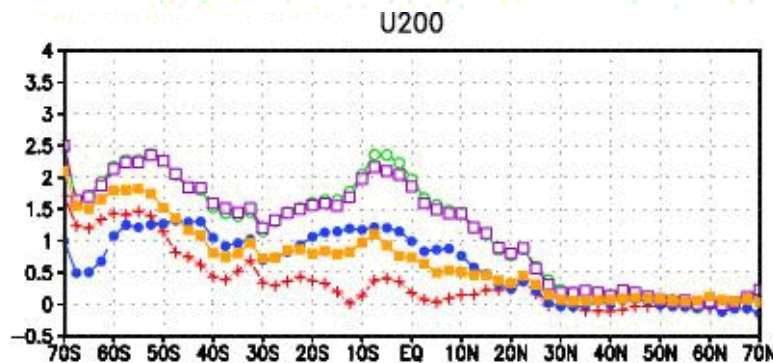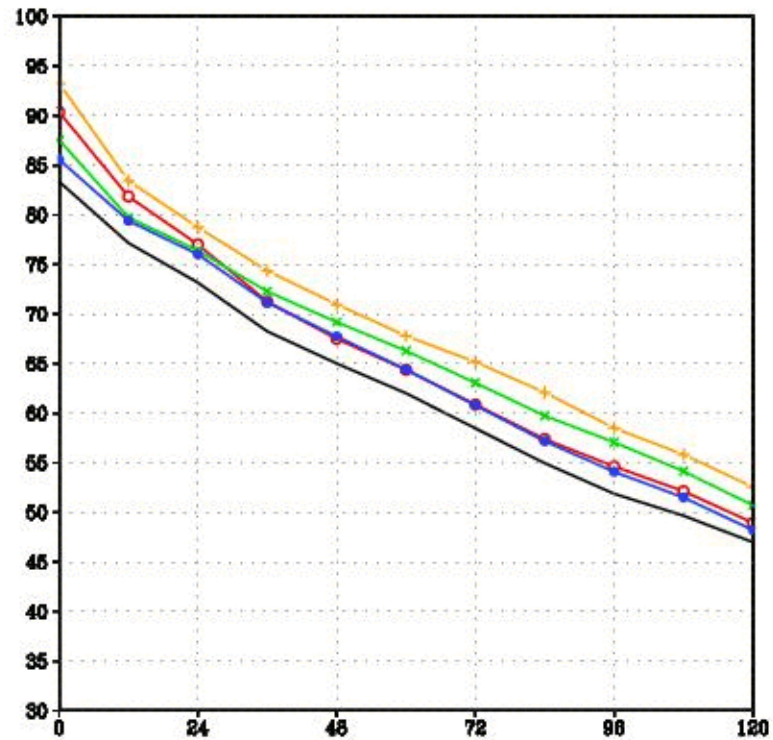
Red(Cross):1B — TOVS 1B

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

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

U200

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   Green(Solid open circle):EXP1_Dist_r=1
Blue(Closed circle):EXP2_Dist_r=1   Purple(Open square):EXP3_Dist_r=1
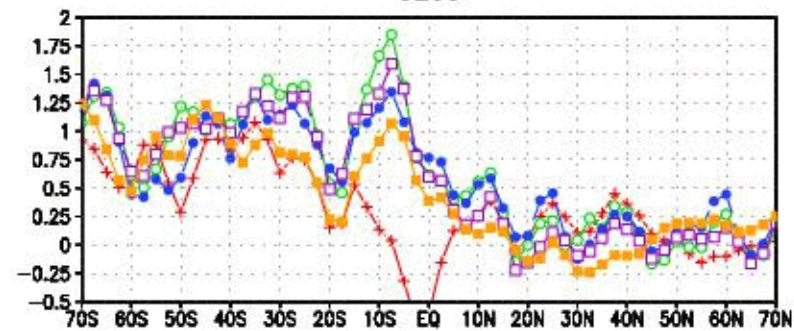Orange(Closed square):EXP4_Dist_r=1
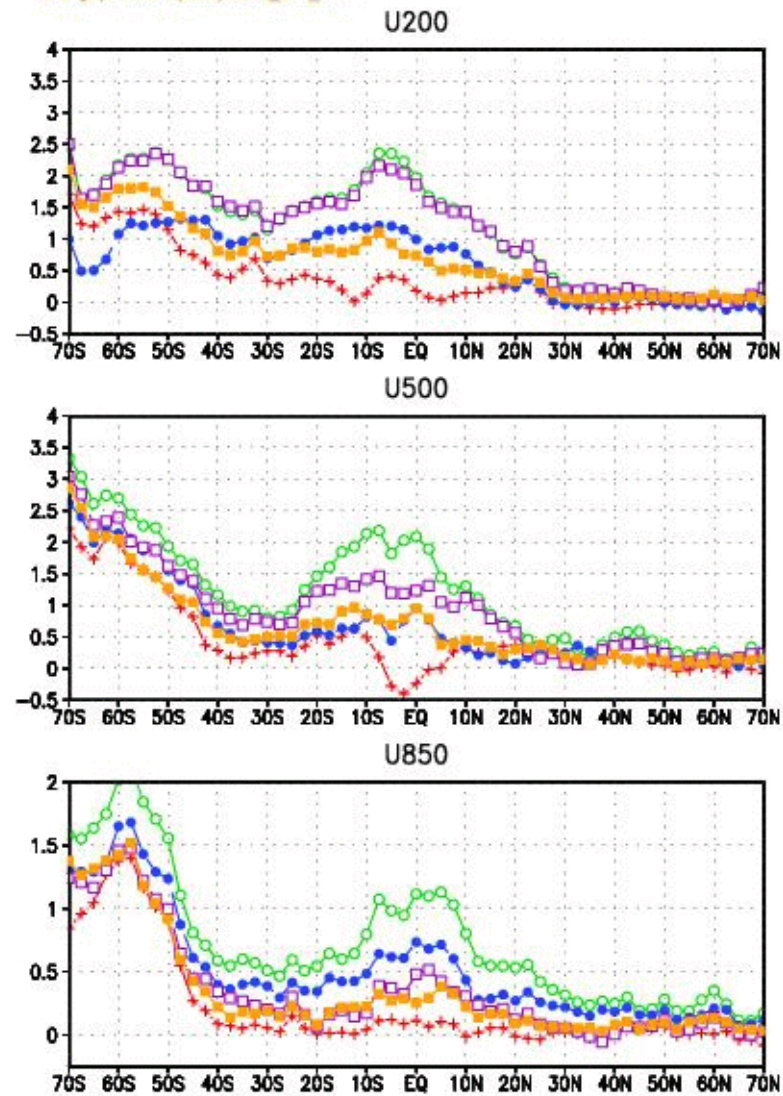
Impact of DWL data over Land and Ocean f72 (set=28)
Zonal mean of RMSE(CTL−NR)−RMSE(EXP−NR)   ctl=NTV Time mean of 00Z14Feb1993−12Z28Feb1993

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
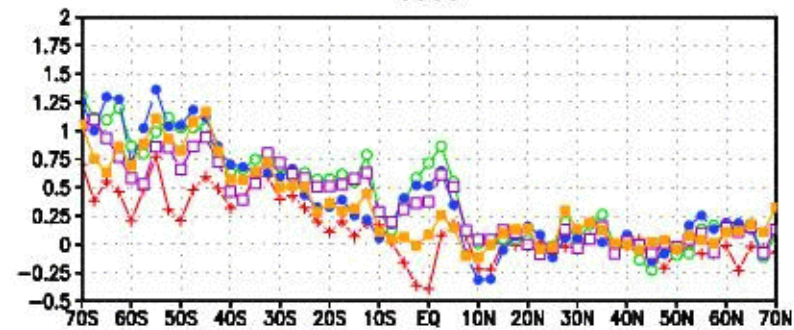
U850
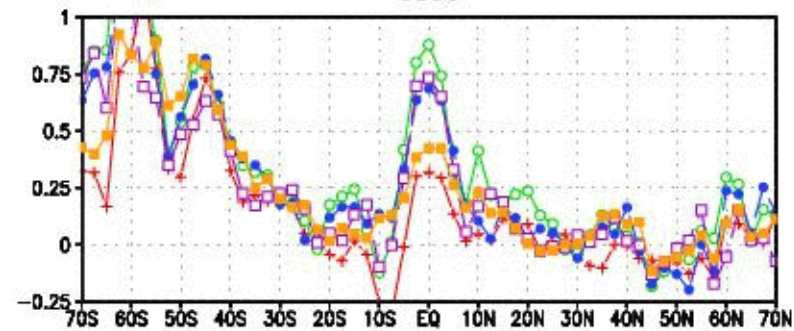
Control: 1B + conventional obs

Red(Cross):No_1B
Orange(Closed square):1B_DWL_noscan_r
Brown(Diamond):1B_No_RAOB_TMP

No1B no DWL
1B+DWL(exp4: non scan)
1B no RAOB Temp

U200

Green(Solid open circle):1B_DWL_scan_r=1
Light Blue(x):1B_No_RAOB_WIND

1B+DWL(exp1, best)
1B no RAOB_wind
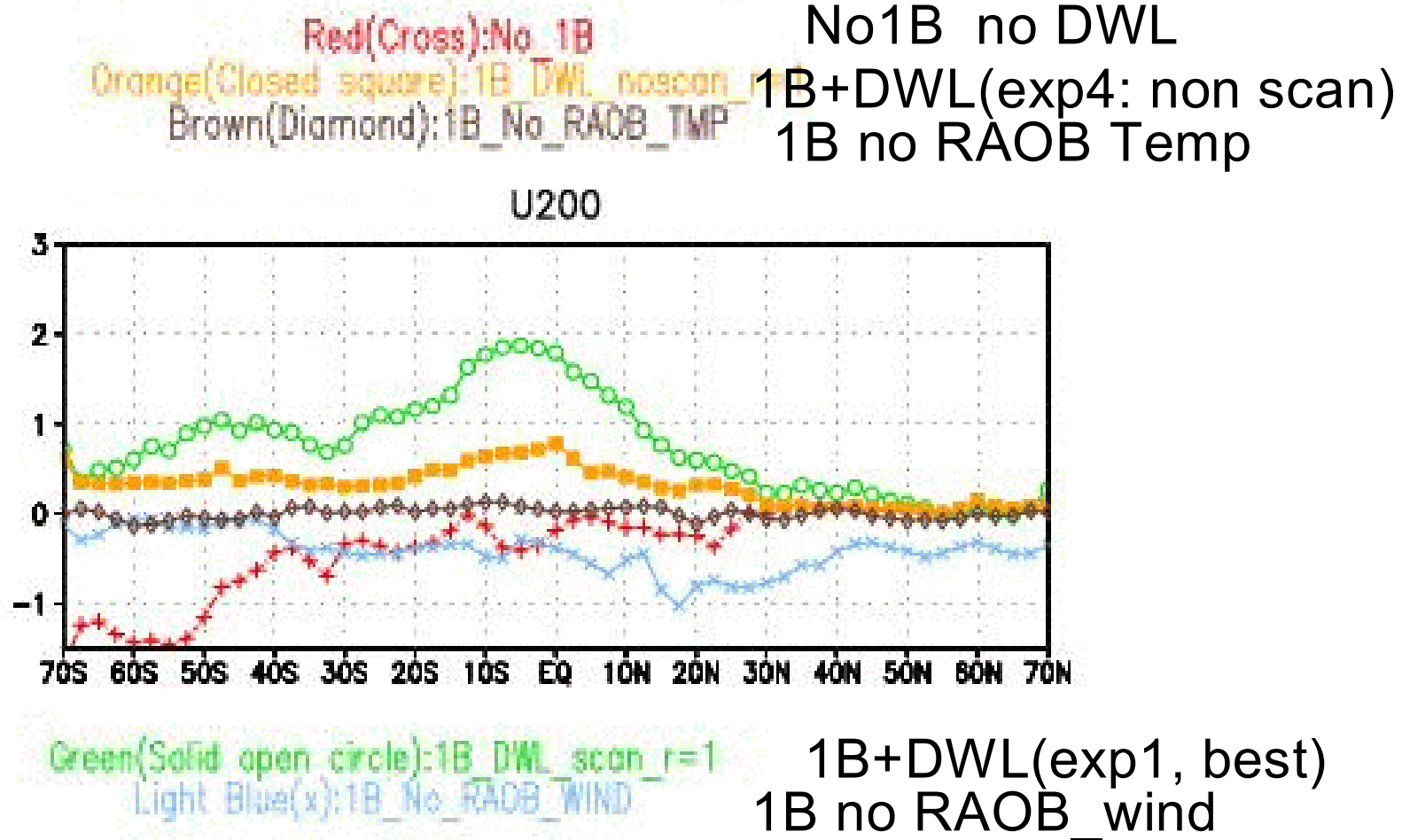
Impact of DWL data over Land and Ocean anl (set=24)

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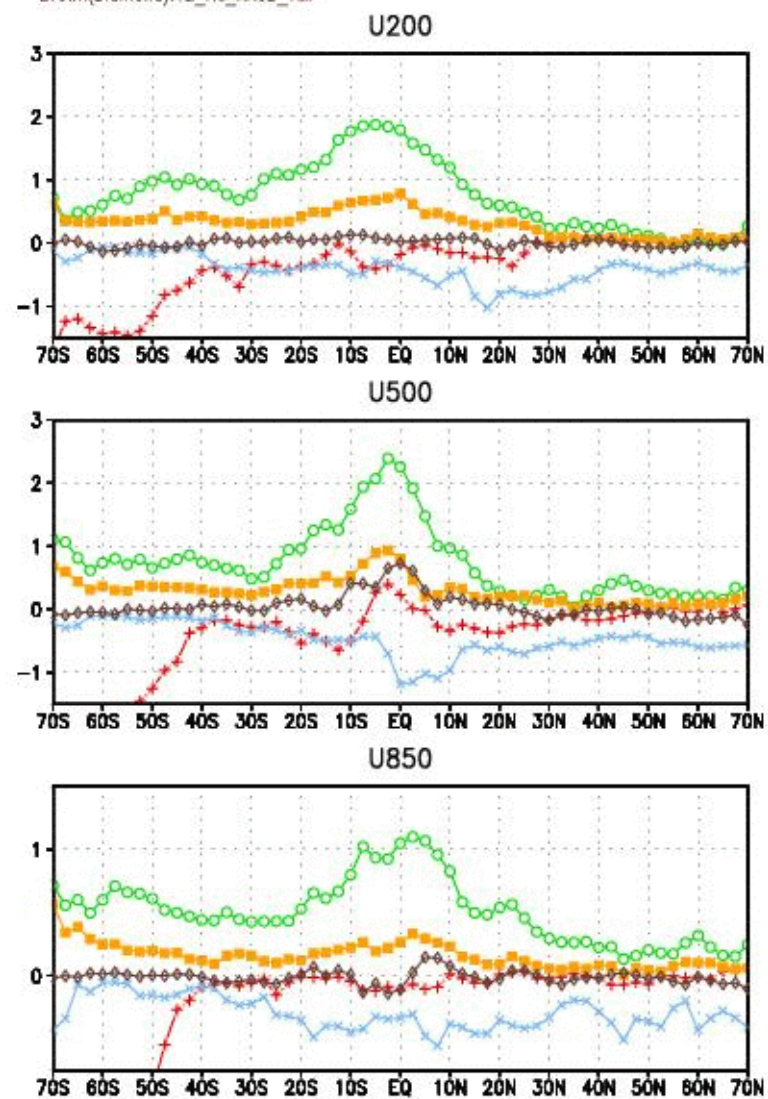
Impact of DWL data over Land and Ocean f72 (set=24)

Zonal mean of RMSE(CTL−NR)−RMSE(EXP−NR)   ctl=1B_no_DWL Time mean of 00Z14Feb1993−12Z28Feb1993
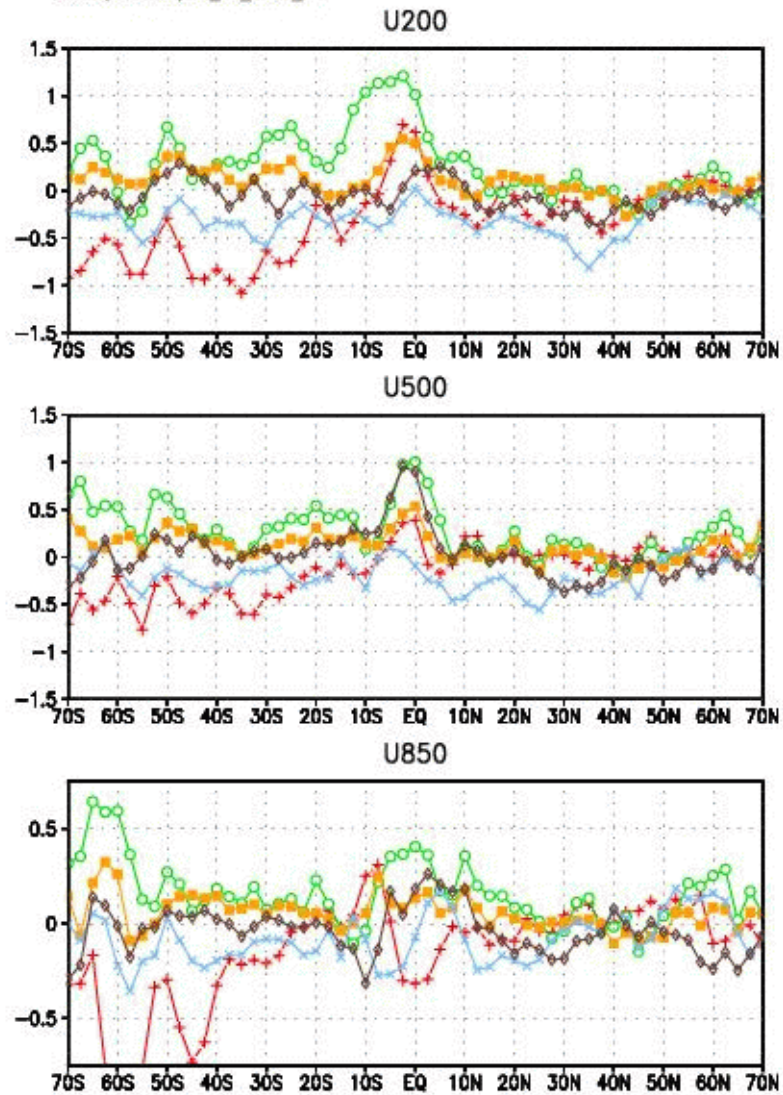
Red(Cross):No_1B   Green(Solid open circle):1B_DWL_scan_r=1
Orange(Closed square):1B_DWL_noscan_r=1   Light Blue(x):1B_No_RAOB_WIND
Brown(Diamond):1B_No_RAOB_TMP

U200

U500

U850

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 assesment 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

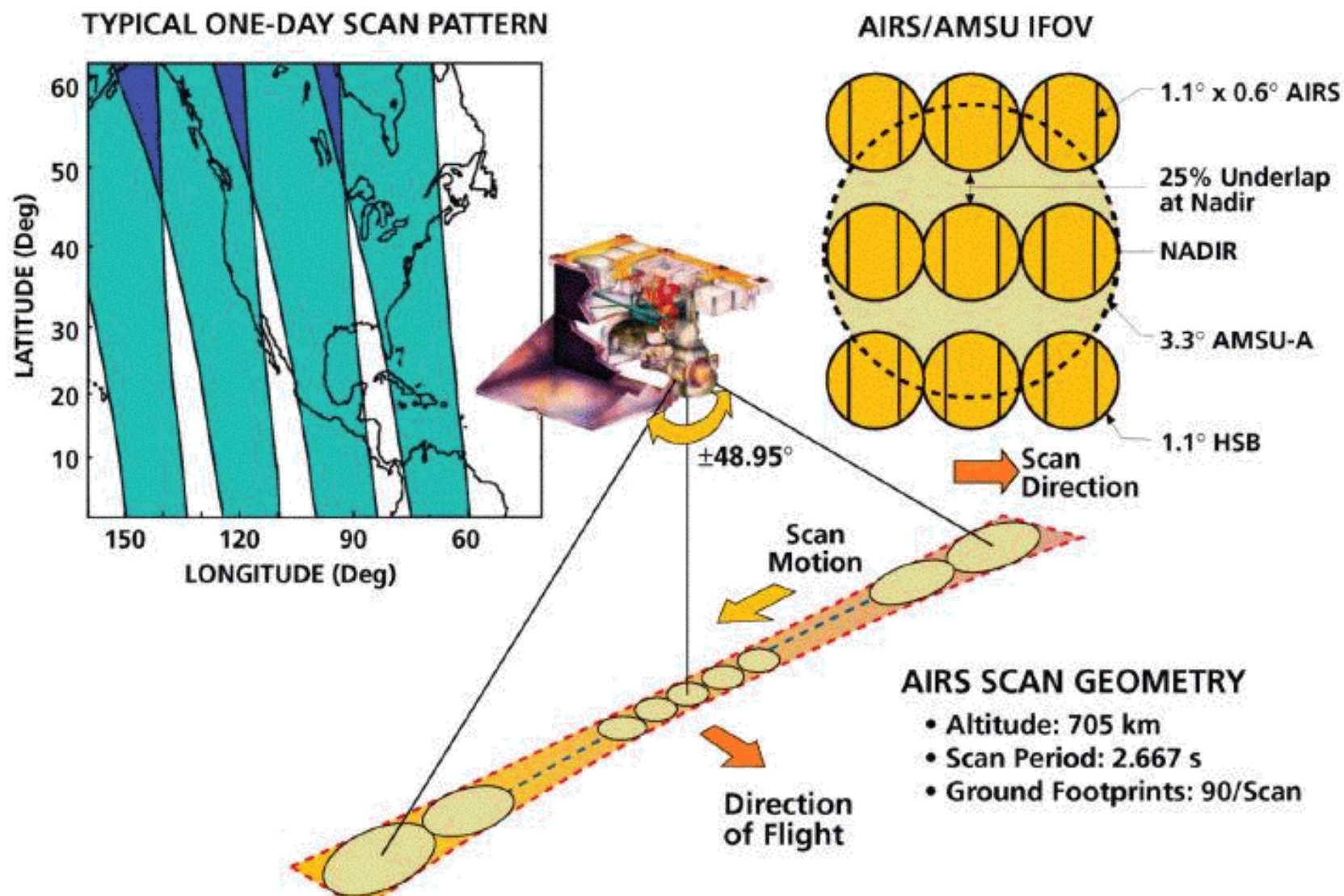Cloud Motion Vector - *Simulated by SWA and DAO*

(Possible OSE)

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

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

Simulation of AIRS Radiance

TYPICAL ONE-DAY SCAN PATTERN

LATITUDE (Deg)
LONGITUDE (Deg)

AIRS/AMSU IFOV

- 1.1° x 0.6° AIRS
- 25% Underlap at Nadir
- NADIR
- 3.3° AMSU-A
- 1.1° HSB

±48.95°

Scan Direction

Scan Motion

Direction of Flight

AIRS SCAN GEOMETRY
- Altitude: 705 km
- Scan Period: 2.667 s
- Ground Footprints: 90/Scan

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/EMC   DWL Wk   Jul2002

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