Observing Systems Simulation Experiments using the NCEP Data Assimilation System

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

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Observing Systems Simulation Experiments

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

Topics Covered

Calibration of OSSEs

Formulation of simulated observation errors

Synoptic assessment (case study) of Doppler Wind Lidar impact

Observation used for initial OSSEs

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
Surface observations

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

Other NR will be introduced
after OSSE by ECMWF NR is exploited

The data assimilation system

Operational NCEP data assimilation system
March 99 version.
T62/ 28 level

Getting ready to move on to the current operational SSI

Further Plans

- 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

New features in operational (2002) SSI

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

- New version of radiative transfer model (OPTRAN)
- Improved treatment in bias correction for radiance data.
- Upgraded background error covariance
- 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
- Accommodate satellite instruments recent instruments
  HIRS, AMSU, TRMM, SSM/I Precipitation products,
  SBUV (ozone), AIRS, DWL

Benefits of running OSSEs

(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 some data sources.

- Design advanced strategies of observing systems and
  data assimilation (e.g. THORPEX)

Calibration of OSSE

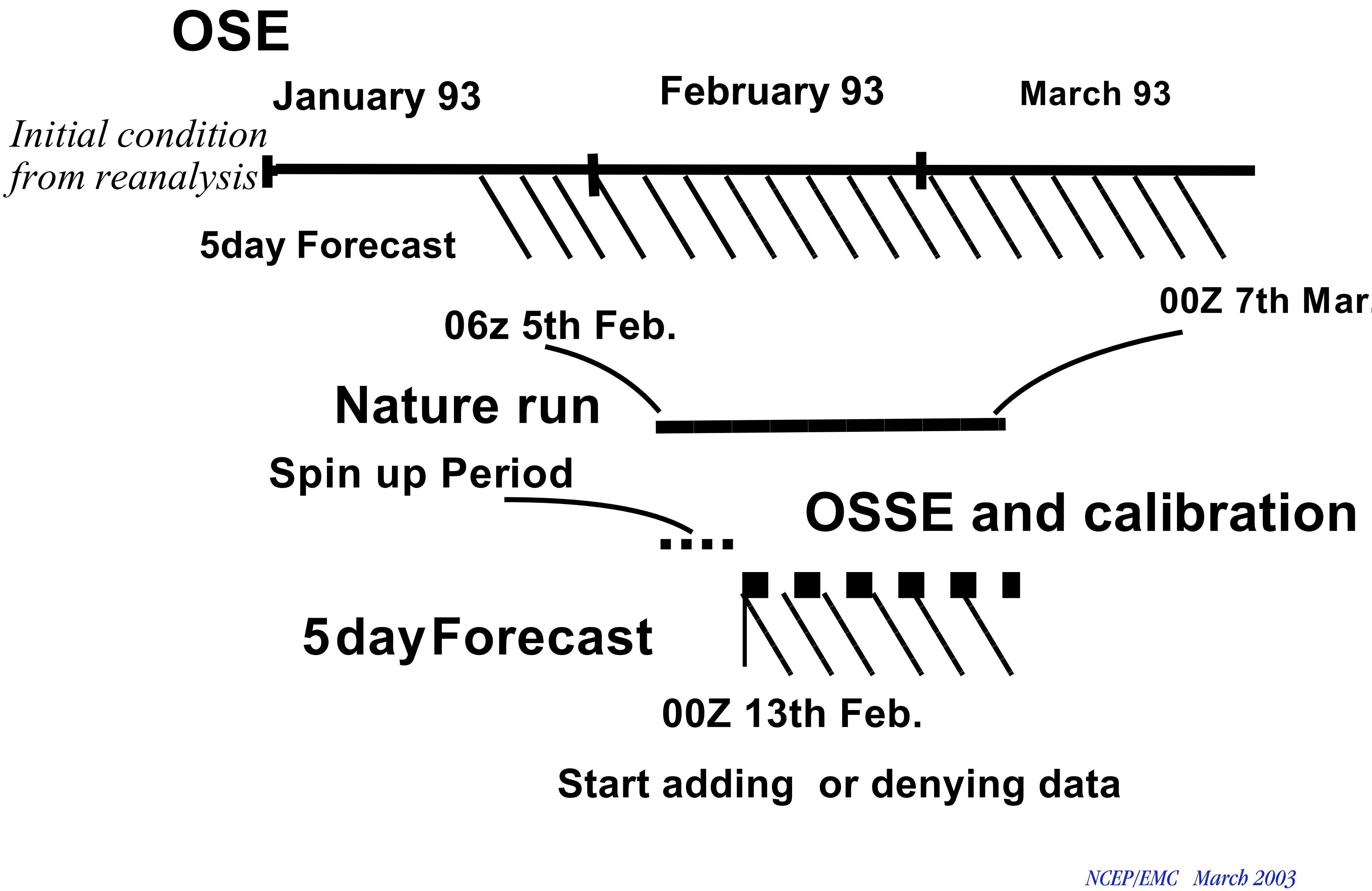
Using existing data test if the data impact of real and simulated systems are similar

Procedure for Calibration Experiments

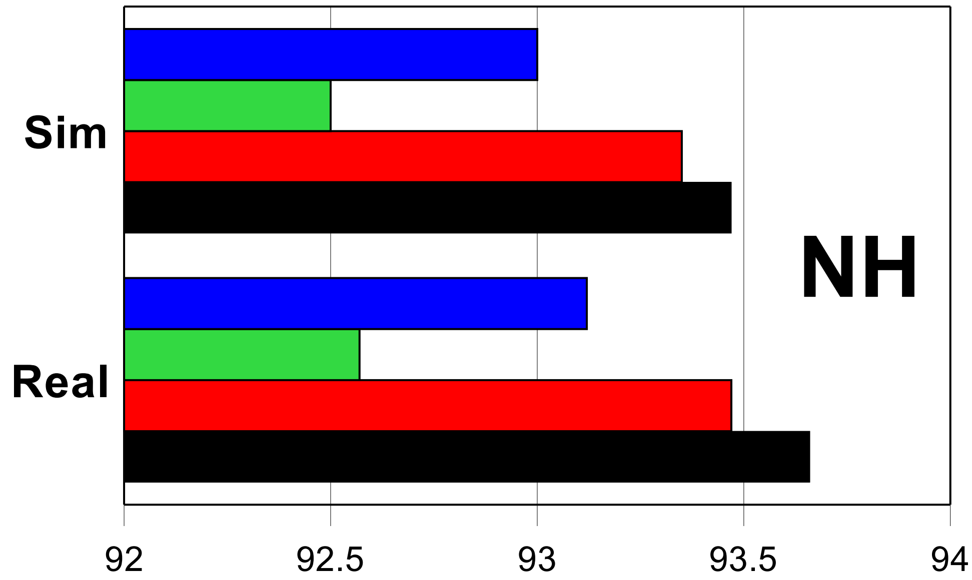
- Spin up data assimilation system beginning 1 January 1993
  - Take initial conditions from reanalysis
  - Use TOVS 1B radiance
  - Use same model and data assimilation system for OSSEs

- 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


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
NCEP/EMC March 2003

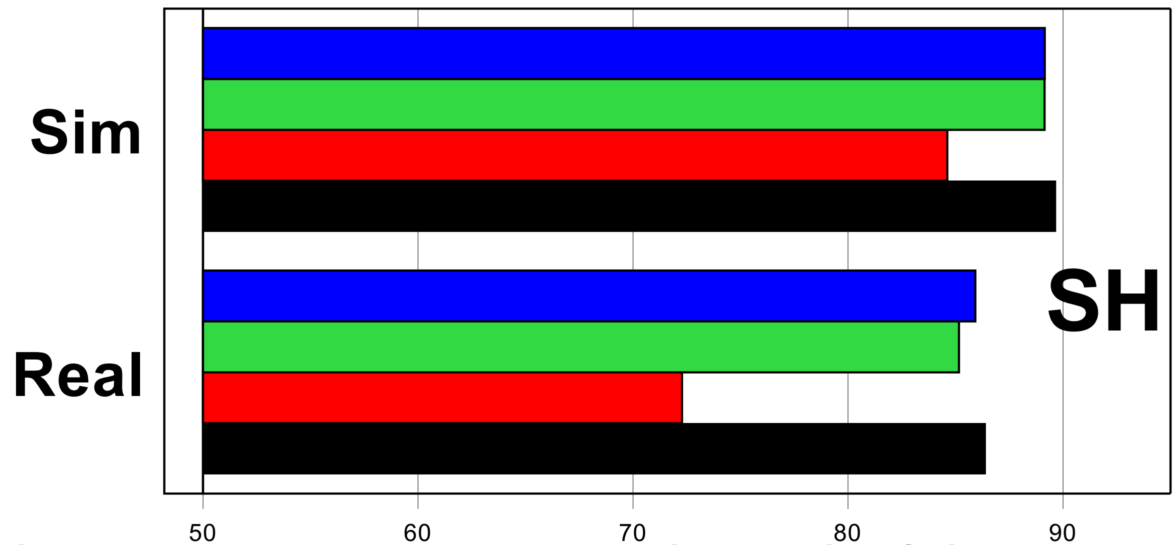
RAOB winds have more impact compared to RAOB temperatures globally in both simulation and real.



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

SST was kept constant for NR. This will affect the data impact. (TOVS is important larger SST variability)

No RAOB Temp
No RAOB Winds
No TOVS
Control



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

Systematic Errors

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.

Skill may be sensitive to systematic error added to the upper air data.

Errors in 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.

Adding the effect of representativeness error

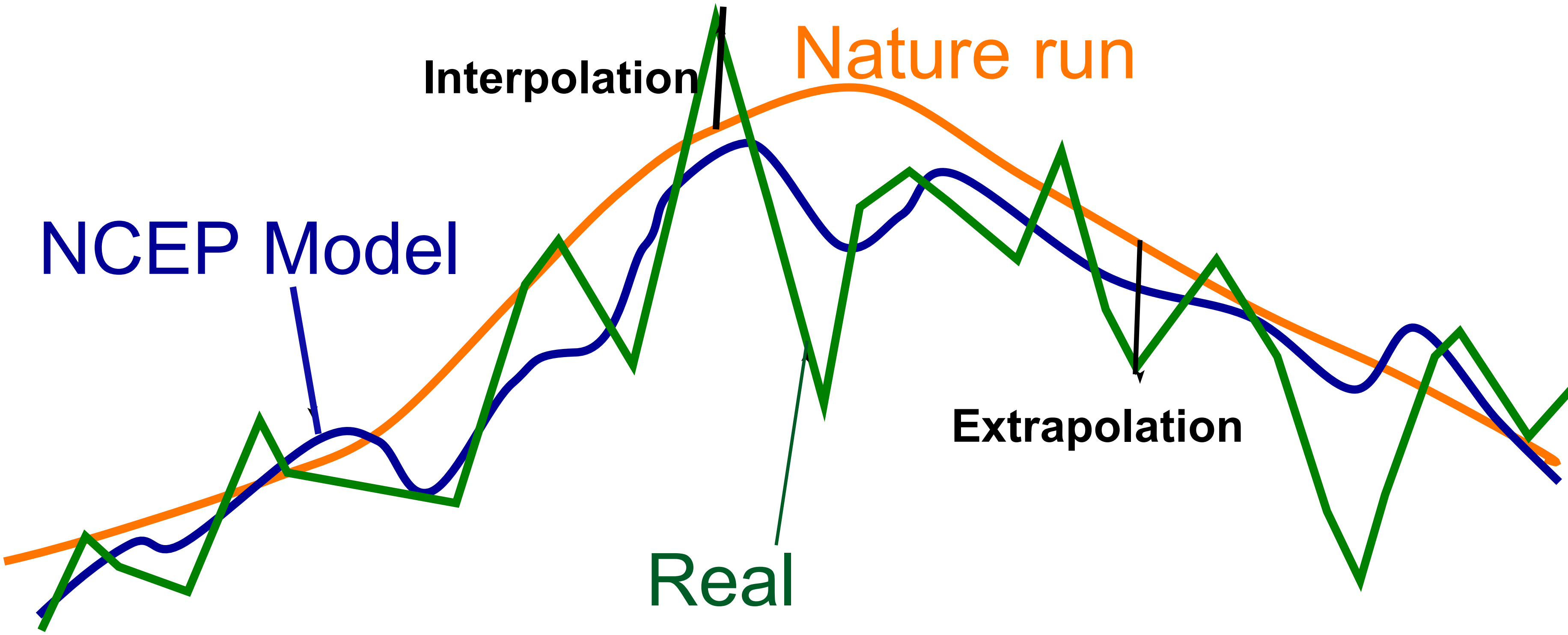
Observational error
- Instrument (random and bias)

Representativeness
- Due to the fact measurement may not represent average grid point value
- Nature produces all time and space scale whereas model is discretized
- A major source of error is topography.

Problem - How to create representativeness error from the NR
- NR is a model
- Unrepresentativeness already removed.

Unrepresentativeness is included in
-(Observation - analysis) at every obs point at every time
-depends on meteorology

Extremely difficult to model meteorological dependence



Surface observation can be simulated either at the NR orography (orange line) or extrapolated or interpolated to the real (green line). Surface observation simulated at the NR orography will produce much smooth and easier to assimilated.

Error Adjustment Technique

Adjust error based on Obs-analysis (o-a) from real data to add systematic errors

Random error proportional to Reresentativeness error

Add different error for each observation type

The adjusted data presented in this paper

Surface synoptic: Random error+1.0*(o-a)
Ship data: 1.0*(o-a)
Upper air synoptic data:
Adj: 0.5*(o-a),   Adj_2: 2.0*(o-a)

Test impact of removal of surface data with various error assignments

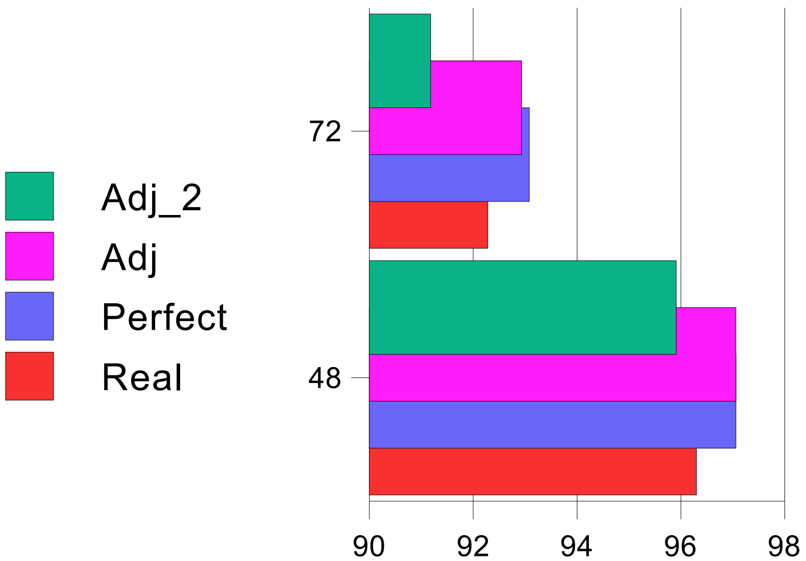
Impact of error added to the surface data was a lot smaller than that to the upper air data.

Optimum amount of error to add to the upper air data is between 0.5*(o-a) and 2.0*(o-a)

Impact of Surface data

Anomaly correlation for z500

No sfc data verif. vs. anl with sfc



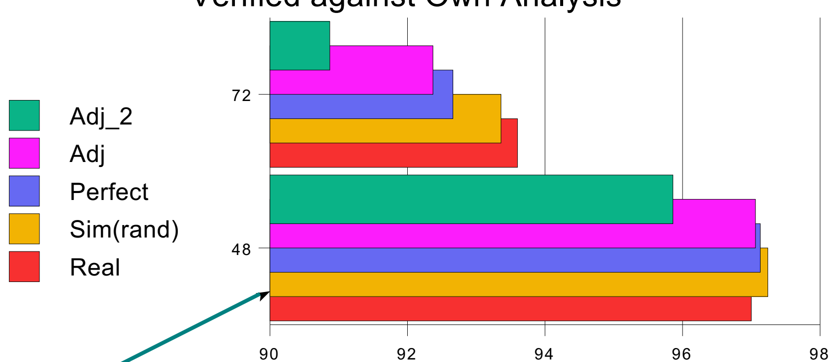
1.0*(obs-anl)+Random for surface and 2.0*(obs-anl) for upper air data

1.0*(obs-anl)+Random for surface and 0.5*(obs-anl) for upper air data

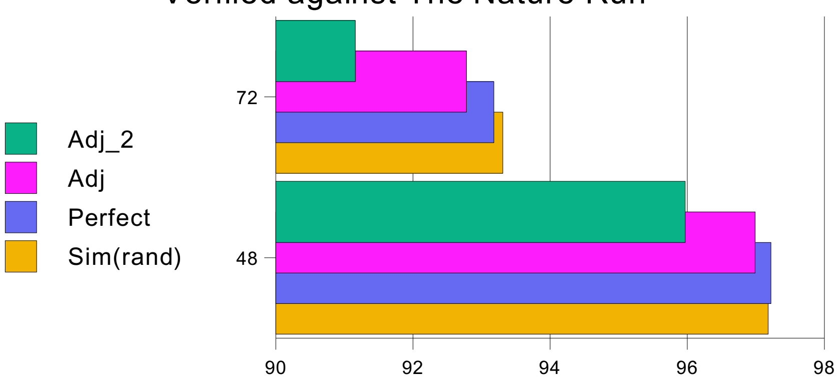
Perfect data with surface data at real surface

Real

Verified against Own Analysis



Verified against The Nature Run



Simulated with Random error with surface data at NR topography. Used for Experiments with DWL.

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Impact Assessment of a DWL

Simulation of DWL wind

All levels (Best-DWL): Ultimate DWL that provides full tropospheric LOS soundings, clouds permitting.

DWL-Upper: An instrument that provides mid and upper tropospheric winds only down to the levels of significant cloud coverage.

DWL-PBL: An instrument that provides only wind observations from clouds and the PBL.

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

One measurement is an average of many shots (LOS)
(Between 50 to 200)

Targeted Resolution Volume (TRV)
200Km x 200Km x T (Km)
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

The original simulated data without adjustment is used for the DWL impact test presented today.

Impact of DWL in forecast skill

Anomaly correlations are computed for:

NH: U,V,T,Z at 200, 500, 850 hPa
ω at 500hPa, Z at 1000hPa

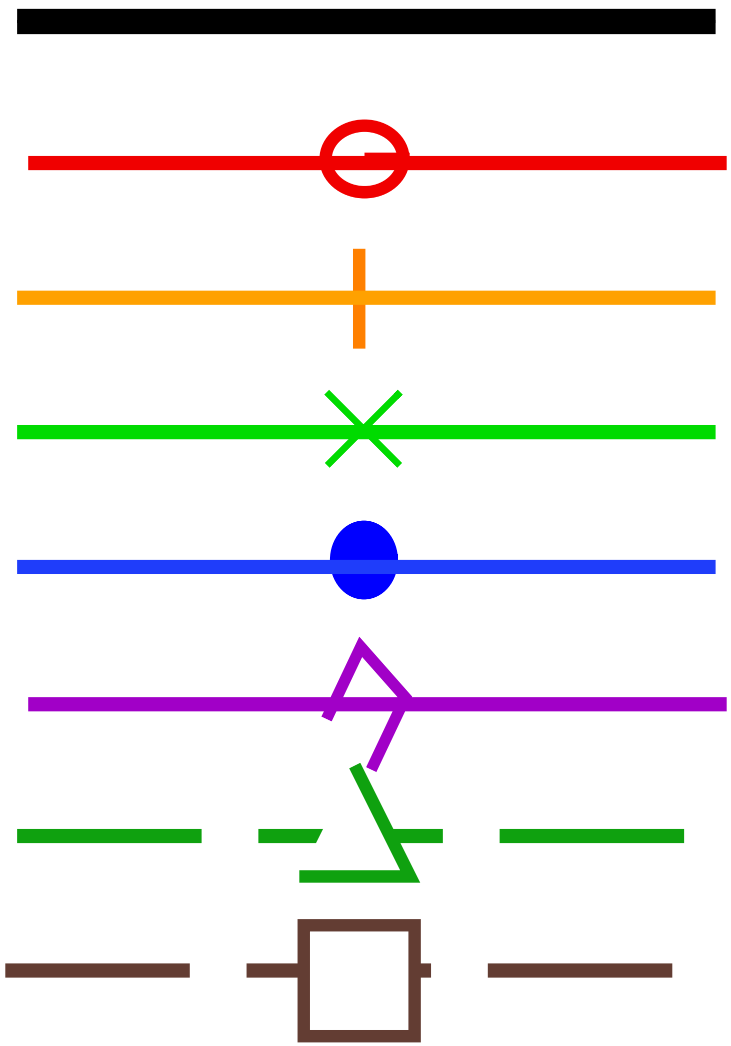
SH: U ,V,T, ω at 500hPa
Z at 1000hPa and 500hPa

Tropics: U and V at 200hPa and 850hPa

Anomaly correlation for zonal wave number 1-3, 4-10, 10-20, and 1-20 components are compared.

Attention to the combined impact of DWL and TOVS

There is a great deal of variability in the time series. However it is still possible to assess the relative impact. All DWL show positive impact in all variables, levels and scales. TOVS have negative impact sometime.



Conv Only

Conv. + TOVS

Conv +DWL(Best)

Conv + DWL(PBL)

Conv + DWL(Upper)

Conv + DWL(non-scan)

Conv + TOVS + DWL(best)

Conv + TOVS + DWL(non-scan)

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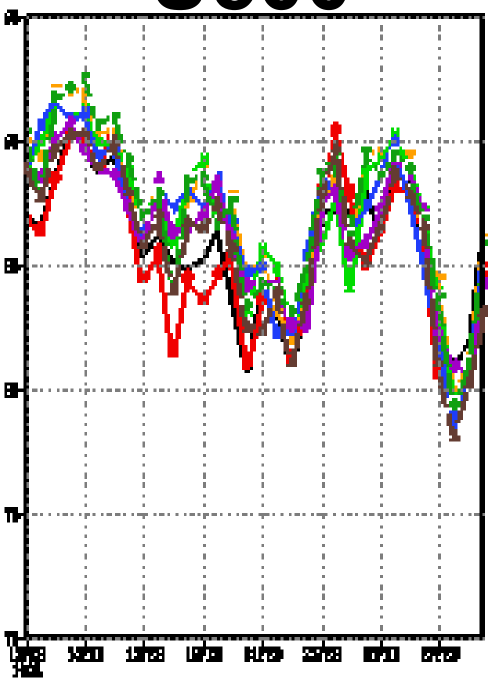
Anomaly Correlation NH Extratropics (20N-80N) 48 hour fcst

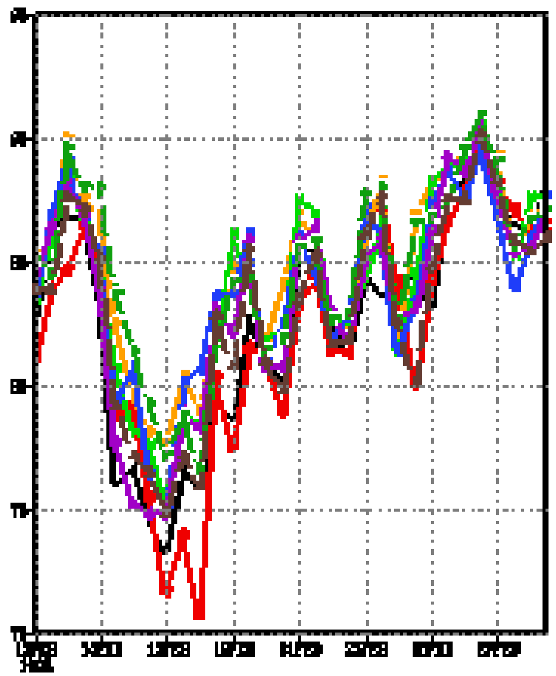
U500



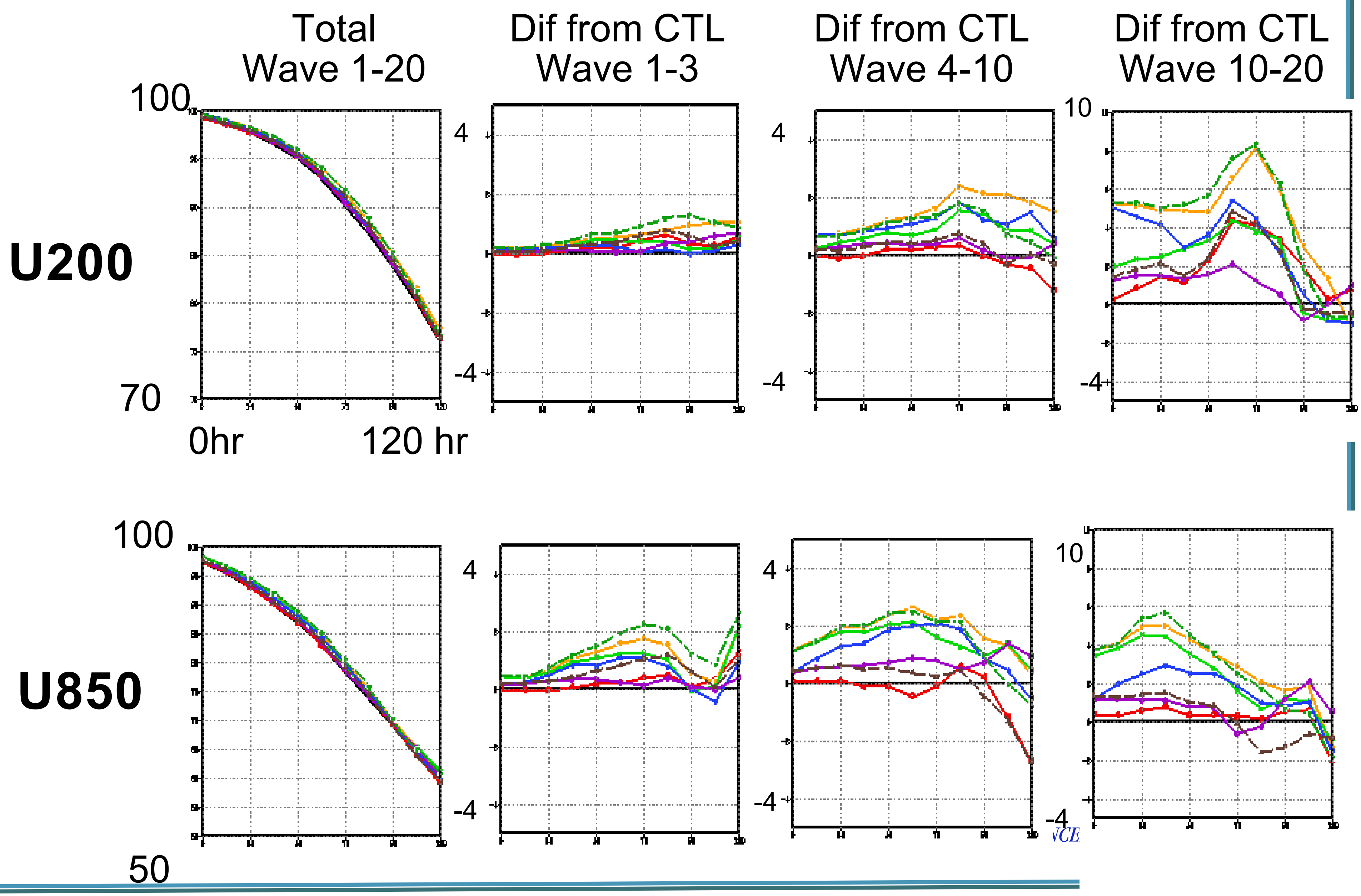
Feb13, 1993 Feb28, 1993

Anomaly Correlation NH Extratropics (20N- 80N) 48 hour fcst

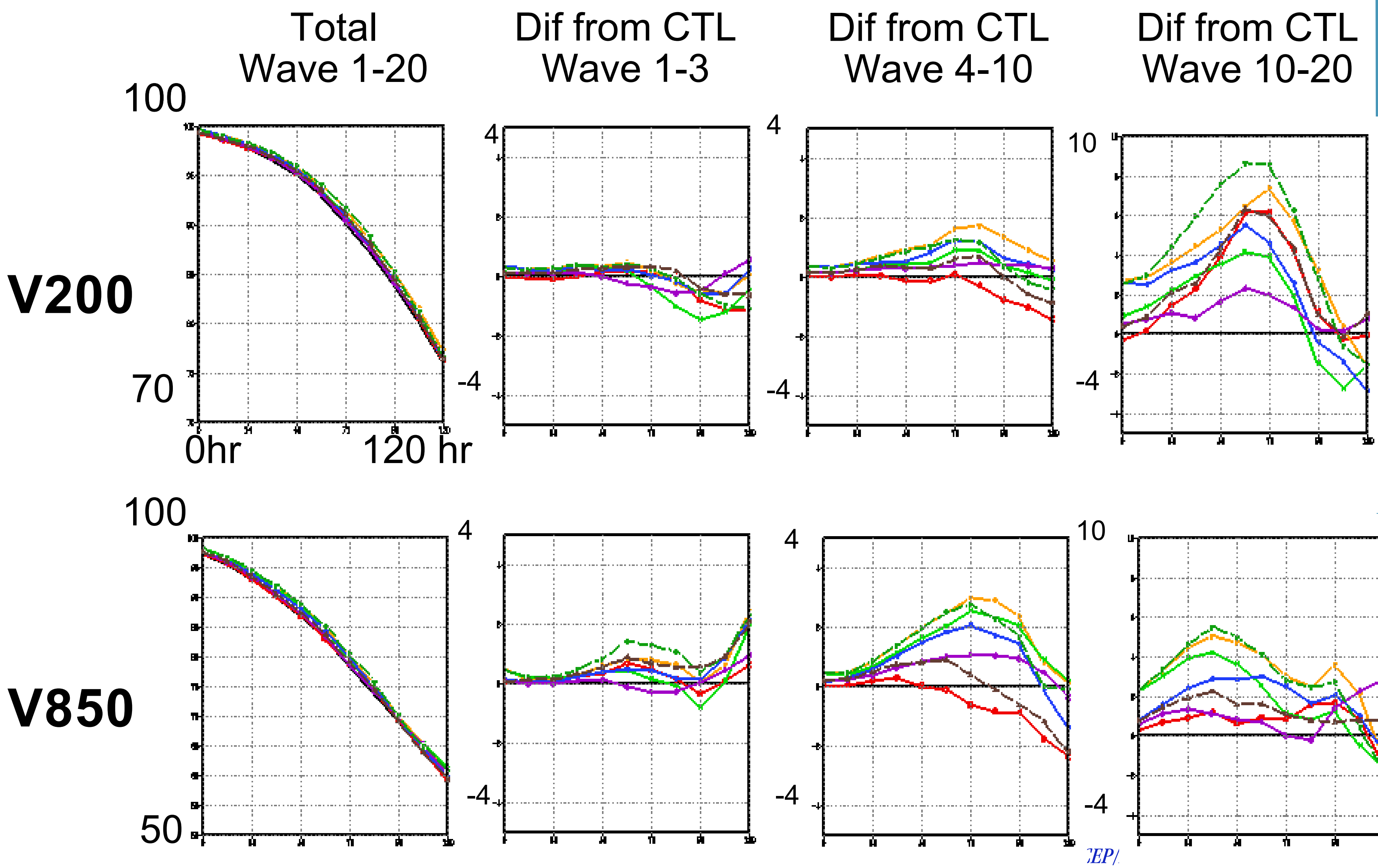
V500



Anomaly correlation in NH extratropics (20N-80N)



Anomaly correlation in NH extratropics (20N-80N)



Impact of DWL in NH

U,V, T, Z at 200 500, and 850hPa. ω at500hPa, Z at 1000hPa

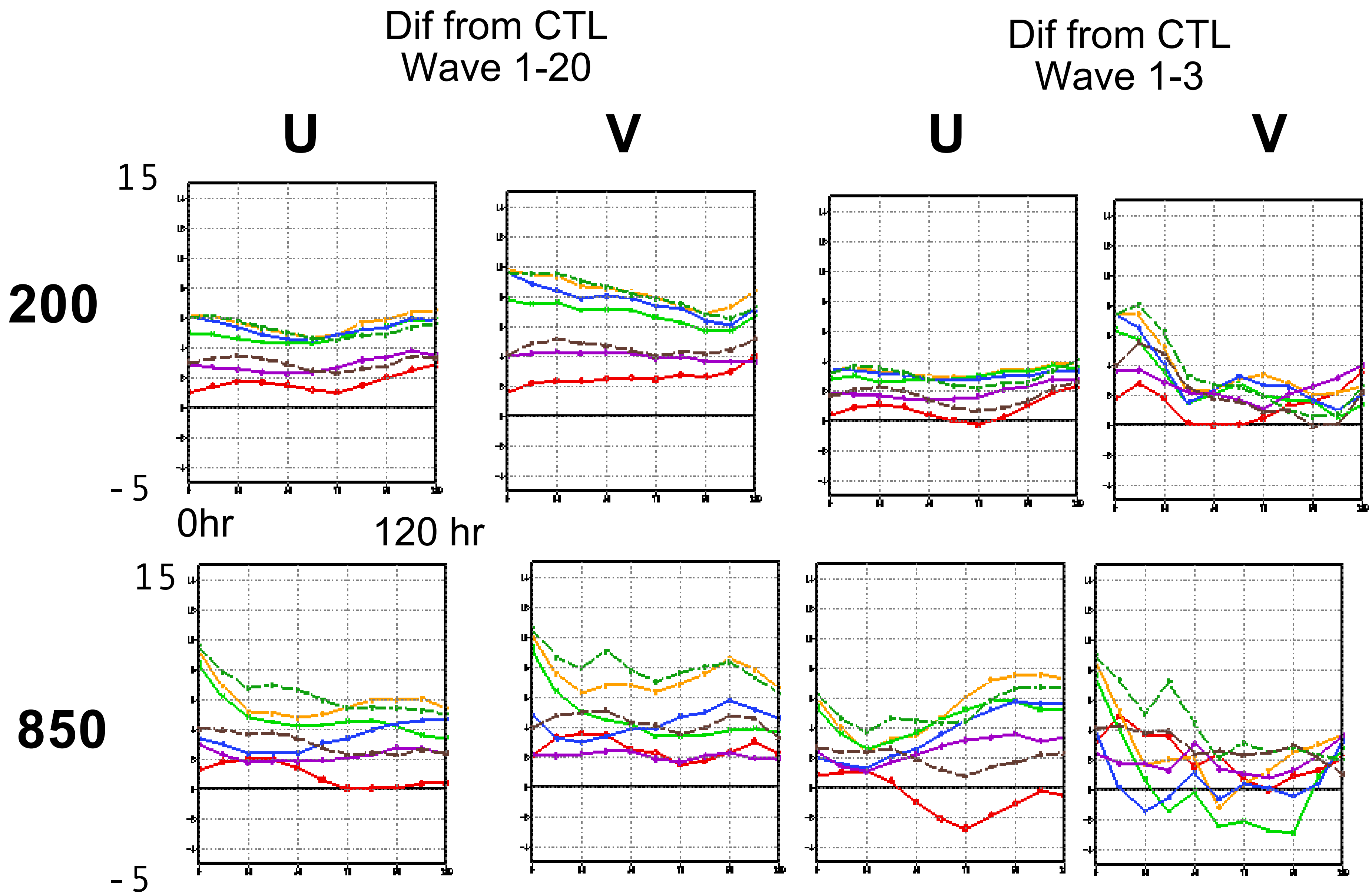
Impact of DWL at smaller scales is most significant. More impact on V than U or T.

At 200hPa and 850hPa both TOVS and DWL have positive impact. TOVS increase skill with DWL for wave numbers 1-3 and 10-20, but often decrease the skill for wave numbers 4-10. However, skill of TOVS +DWL is greater than TOVS only, even for non-scan DWL.

At 500hPa, bothTOVS and DWL show positive impact most of the time. The combined impact increases up to 24 hour forecast then become less than DWL only. However, it is still greated than skill with TOVS only.

At 850hPa, skill of DWL-PBL starts off better than DWL-upper, but after 48-72 hour forecast with DWL-upper becomes better.

Anomaly correlation in Tropics (20S-20N)



Impact of DWL in Tropics

U and V at 200hPa and 850hPa are studied.

Both TOVS and DWL show positive impact in most of the cases. Even non-scan DWL has more impact than TOVS.

Large positive impact with best DWL in analysis is reduced to half after 72 hour forecast.

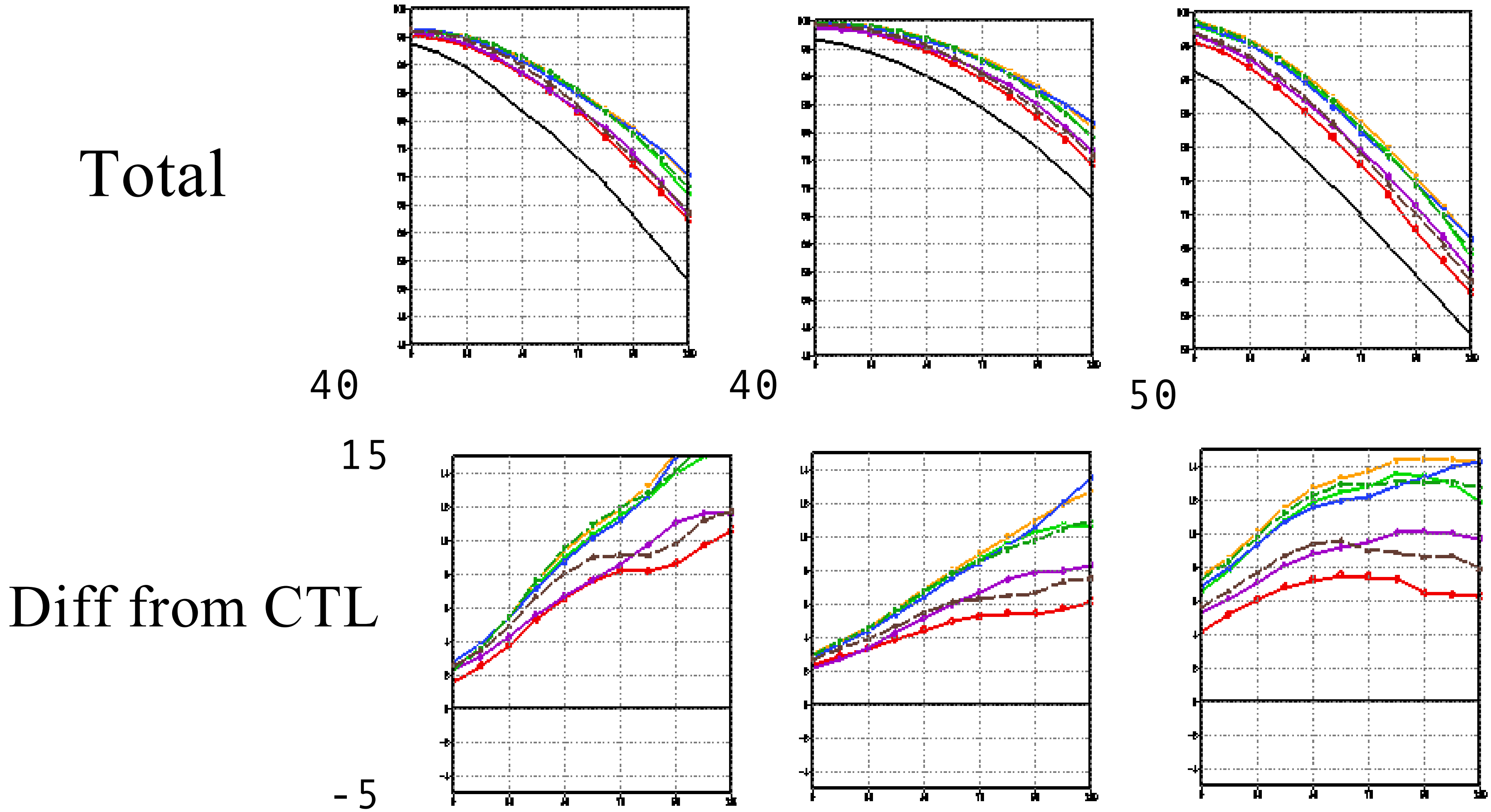
With non-scan DWL, TOVS significantly increases skill. However, with best DWL skill often decreases slightly, particularly after 48 hour forecast

After 48 hour forecast significant negative data impact were found for wave numbers 1-3 at 850hPa. TOVS has significant negativs impact in U: DWL-PBL has significant negative impact in V.

At 850hPa, skill of DWL-PBL starts off better than DWL-upper, but after 48-72 hour forecast with DWL-upper becomes better.

Anomaly correlation in SH extratropics (80S-20S)

Z1000 (Wave 1- 20)	Z500 (Wave:1-20)	U500 (Wave:1-20)



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Impact of DWL in SH

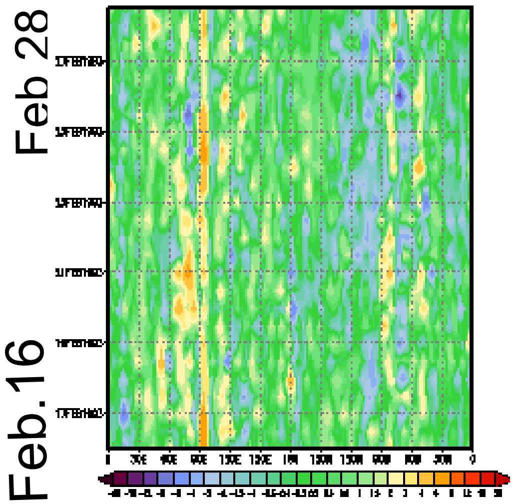
U ,V,T, ω at 500hPa, Z at 1000hPa and 500hPa are studied.

All DWL and TOVS increase the skill significantly. With best DWL skill in SH become similar to skill in NH.

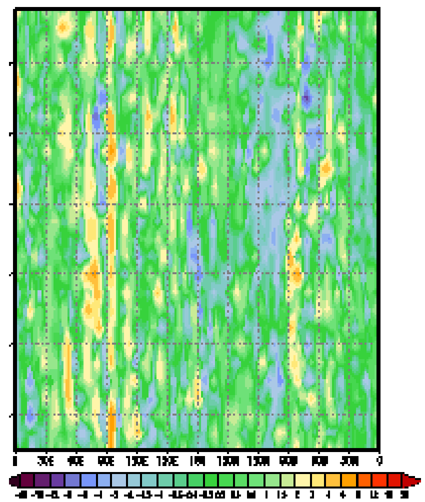
Even non-scan DWL shows more positive impact than TOVS in almost all cases.

TOVS adds skill to non-scan DWL up to 48 hours forecasts, but slightly reduce the skill from best DWL.

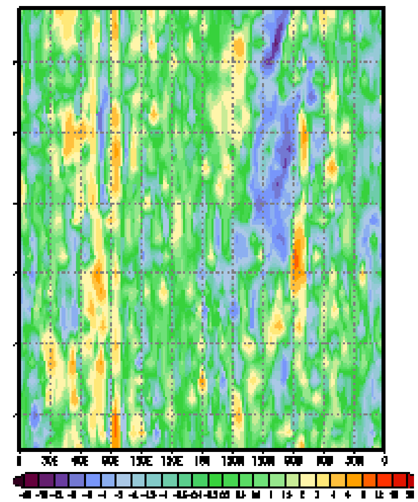
DWL (Best)



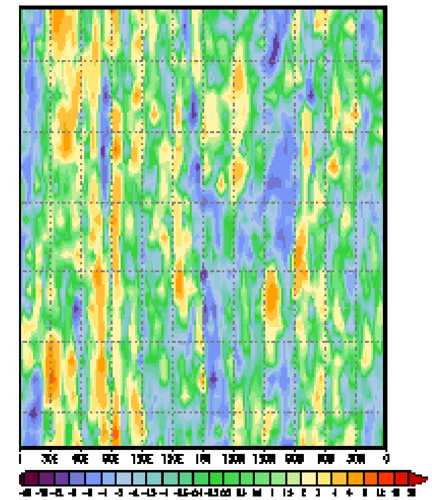
DWL Upper

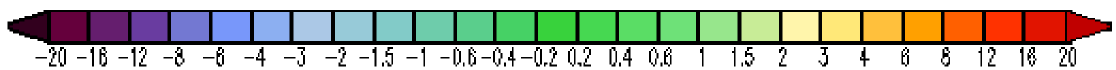


DWL PBL

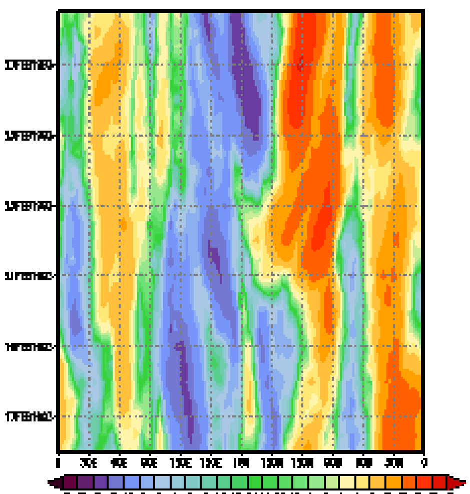


DWL non Scan





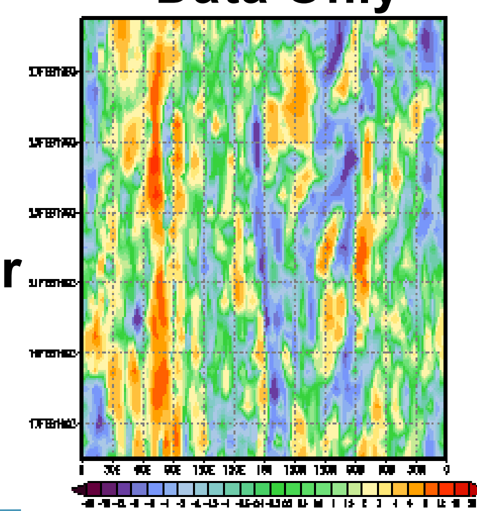
Nature run (Total Fields)



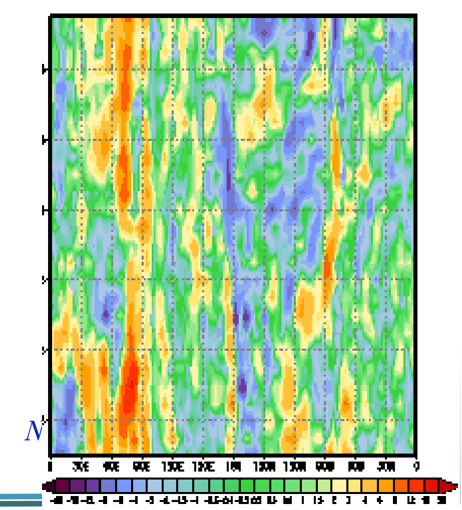
U 200 Analysis fields

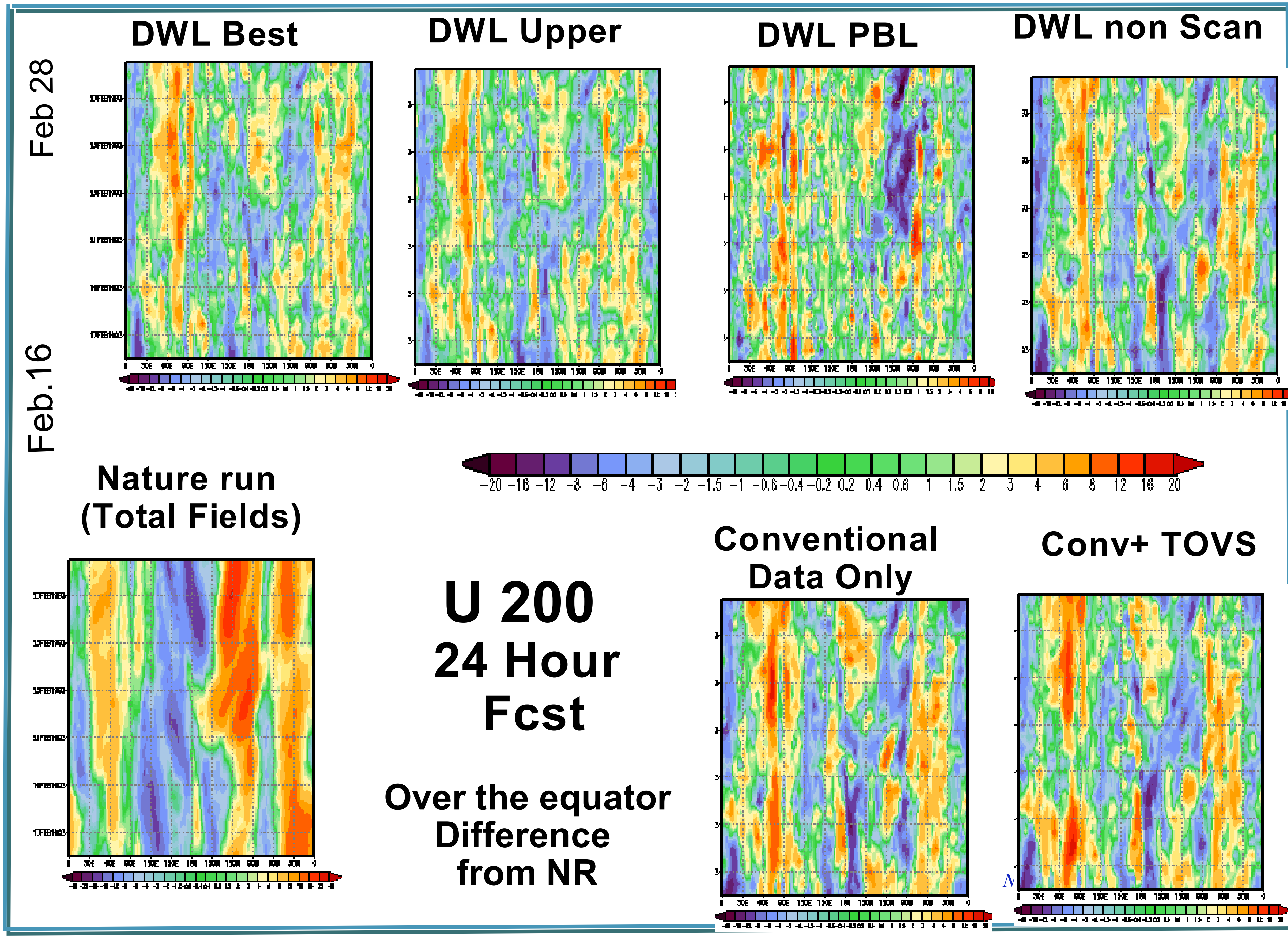
Over the equator Difference from NR

Conventional Data Only

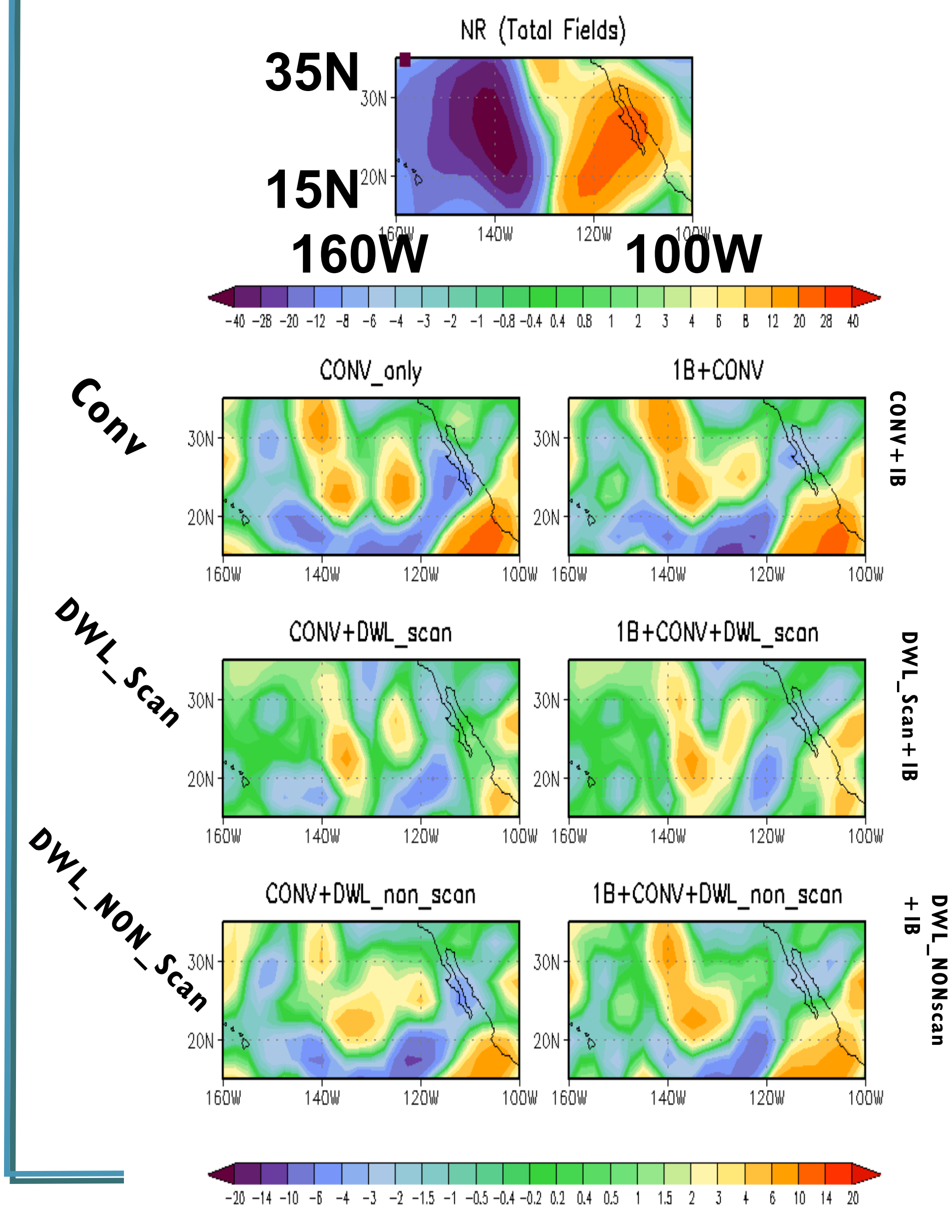


Conv+ TOVS

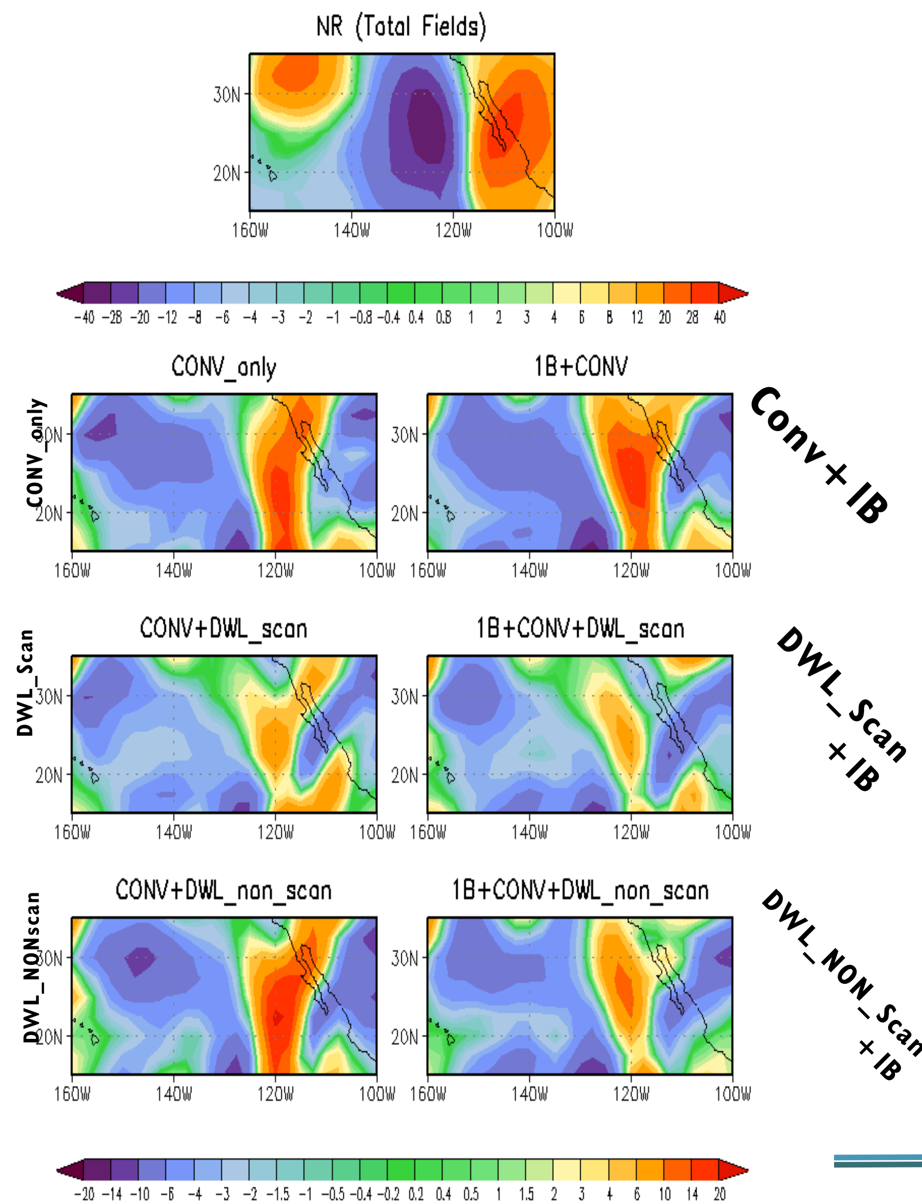



DWL Best
DWL Upper
DWL PBL
DWL non Scan
Feb 28
Feb.16
Nature run
(Total Fields)
-20 -16 -12 -8 -6 -4 -3 -2 -1.5 -1 -0.6 -0.4 -0.2 0.2 0.4 0.6 1 1.5 2 3 4 6 8 12 16 20
U 200
24 Hour
Fcst
Over the equator
Difference
from NR
Conventional
Data Only
Conv+ TOVS

V 200 Analysis fields on 00Z Feb. 26 Difference from NR



V 200 48hr fcst fields on 00Z Feb. 28 Difference from NR



Impact seen in synoptic events

In NH, scanning is important to analyse sharp gradient of the winds. That will affect the forecasts.

In NH, within the time scale of the NR, the impact of DWL is not significant in planetary scale such as U fields.

In tropics, more analysis impacts in area with large gradient of wind. It is also seen in larger scale fields.

In Tropics, due to the large difference between NCEP model and NR, forecast impact be much smaller than analysis impact.

It is more important to have less quality observation through out troposphere than best observation in PBL.

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. May increase 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. 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.

Comments (cont.)

UP to 72 hour forecast Skill in OSSE is meaningful.
Beyond 72 hours similarities between models becomes the problem

In NH, case studies reveal the data impact best

Data impact of SH is affected by constant SST in NR.
Require carefull interpretation

From these experience recommendations for the future NR will be made.

Plans for OSSE at NCEP in 2003

Complete (o-a) tuning.

A. Start OSSE for AIRS
- The data has been simulated
- SSI is need to adapted to OSSE.
- Need to prepare for 1993 data

B. Continue to evaluate simulation of TOVS and AIRS
- Treatment of cloud
- Formulation of observational errors
- Easier to do with upgraded SSI

C. DWL
- Test more realistic DWL under development
- Test DWL with various distributions of cloud drift winds
- Test DWL with AIRS data.

Plans for OSSE at NCEP in 2003 (cont.)

D. Cloud track wind

E. Adaptive observing strategies

F. Test idealized data set

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

G. Plan for OSSE with current and future data distributions

H. New nature run

Instruments to be tested

(Simulation in progress)

OSE and OSSE

Cloud Motion Vector - *Simulated by SWA and DAO*

(Possible OSE)

Atmospheric Infrared Sounder (AIRS) and other instruments

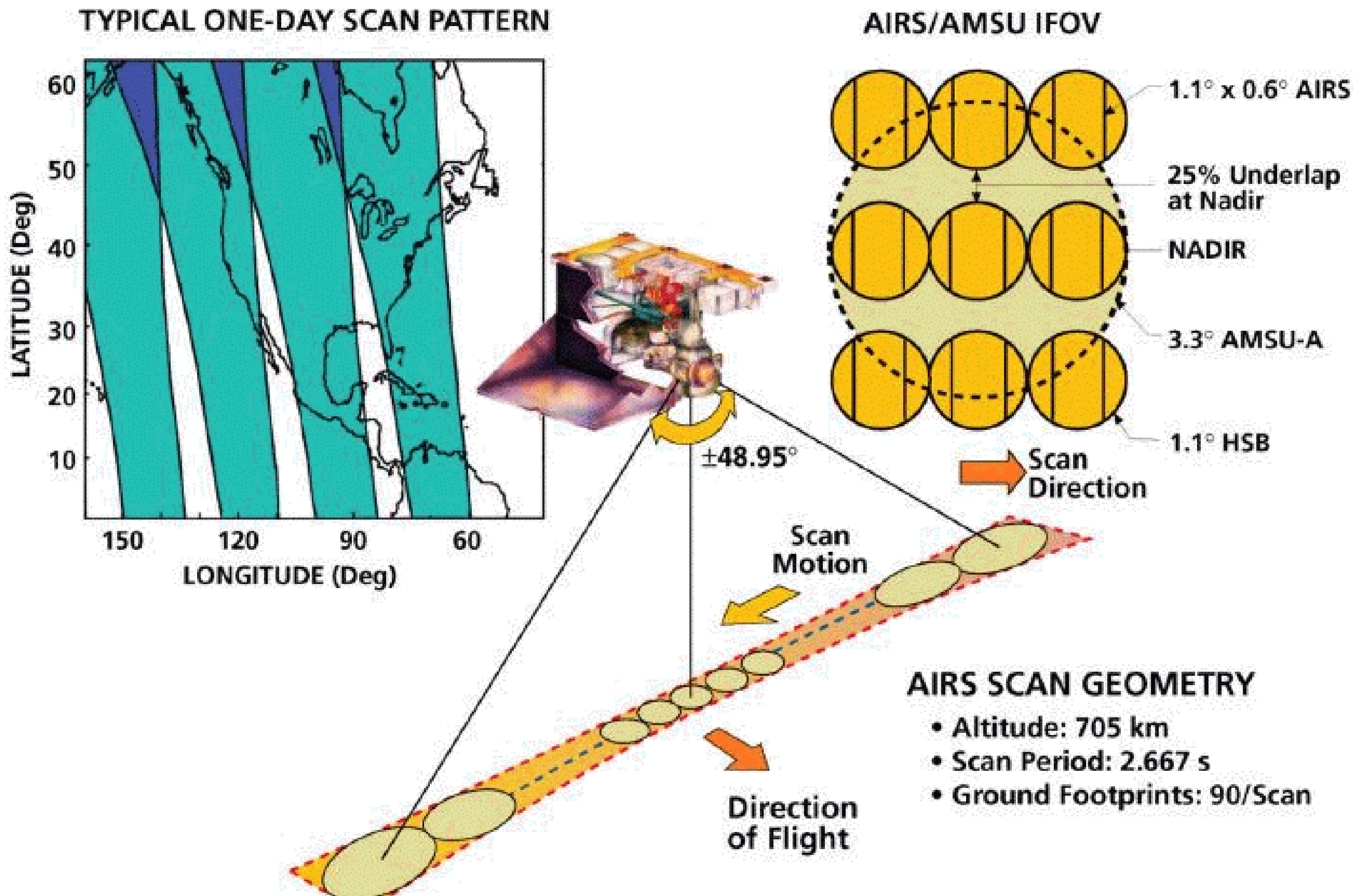
on AQUA -*Simulated by NESDIS*

CrIS

OSSE

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

Simulation of AIRS Radiance



NOAA/NESDIS

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)