Observing System Simulation Experiments (OSSE) to estimate the potential of future observations

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Full OSSEs at NCEP and Internationally collaborative Joint OSSEs

Full OSSE

There are many types of simulation experiments. We have to call our OSSE a 'Full OSSE' to avoid confusion.

- A Nature Run (NR, proxy true atmosphere) is produced from a free forecast run using the highest resolution operational model.
- Calibration to compare data impacts between real and simulated data will be performed.
- Data impact on analysis and forecast will be evaluated.
- A Full OSSE can provide detailed quantitative evaluations of the configuration of observing systems.
- A Full OSSE can use an existing operational system and help the development of an operational system

Full OSSE at NCEP

Main Contributors

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Plus many people in NOAA/NWS/NCEP, NASA/GSFC, NOAA/NESDIS and ECMWF. Forward program for LOS was prepared by J. Derber. We would like to acknowledge contributions from W. Yang, W. Baker of NCEP, R. Atlas, G. Brin, S. Bloom of NASA/GSFC, and V. Kapoor, P. Li, W. Wolf, J. Yoe, M. Goldberg of NOAA/NESDIS. We would like to thank Anthony Hollingsworth, Roger Saunder and the ECMWF data support section for the T213 Nature Run.

Main components of NCEP OSSE with ECMWF T213 Nature Run

Nature Run (Becker et al. 1996)

- Wintertime Nature run (1 month, Feb5-Mar.7,1993)
- Produced by ECMWF model T213 (~0.5 deg)
- 1993 data distribution for calibration

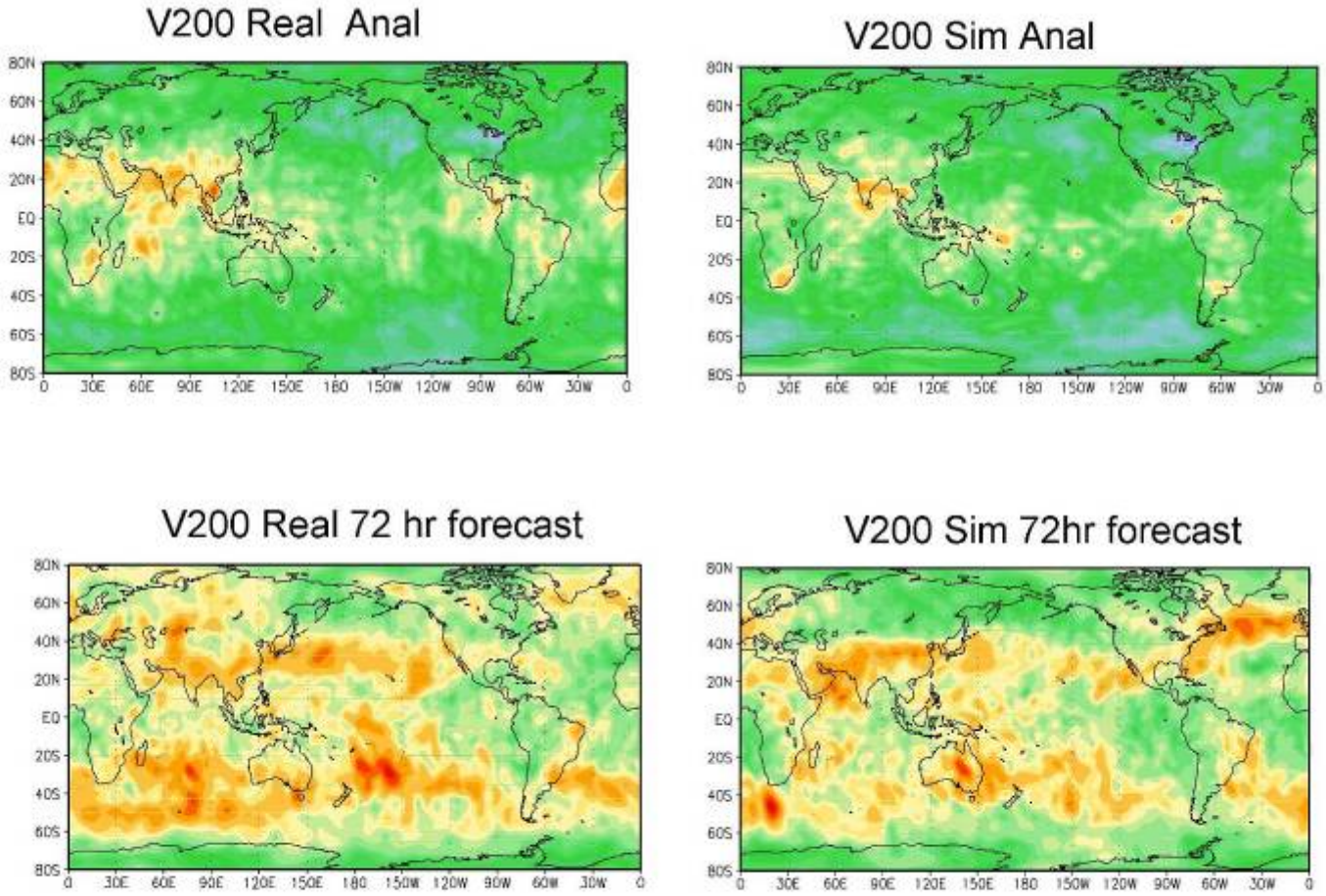
Data Assimilation System

- NCEP DA (SSI) withT62 ~ 2.5 deg, 300km and T170 ~1 deg, 110km
- Simulate and assimilate level1B radiance
  - Different method than using interpolated temperature as retrieval
- Use line-of- sight (LOS) wind for DWL
  - not u and v components
- Calibration performed
- Effects of observational error tested
- Nature Run clouds are evaluated and adjusted

OSSE Calibration

- Real data sensitivity compared to sensitivity with simulated data

Impact of withdrawing RAOB winds



Results from OSSEs for Doppler Wind Lidar (DWL)

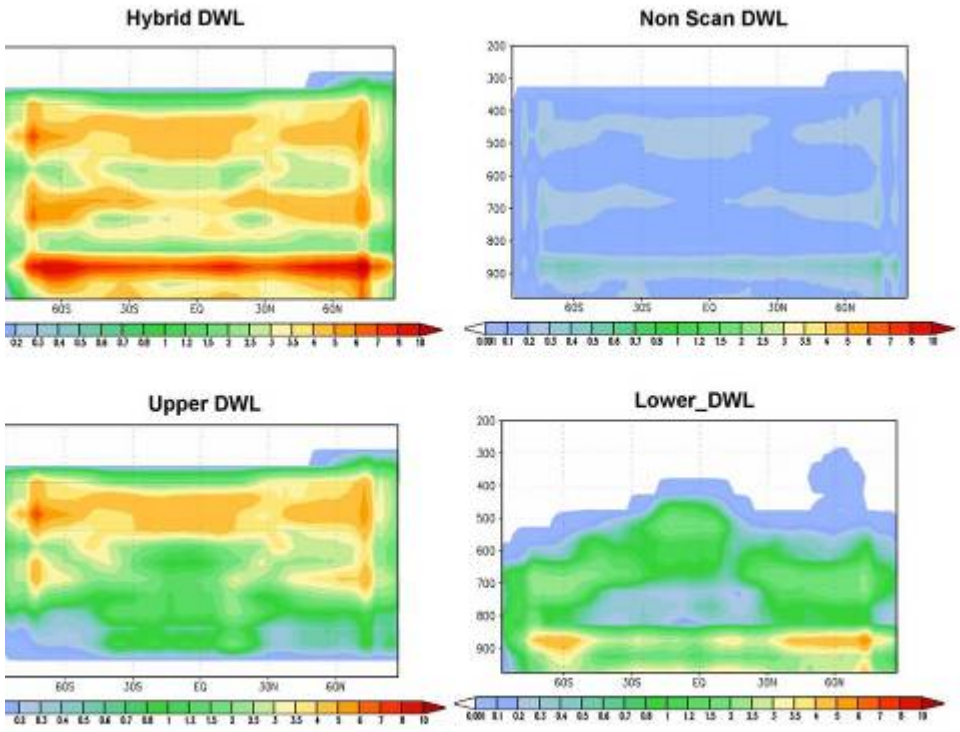
Hybrid-DWL: Ultimate DWL that provides full tropospheric LOS soundings, clouds permitting.

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

Lower-DWL: An instrument that provides wind observations only 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.
(ADM-Aeolus like DWL)

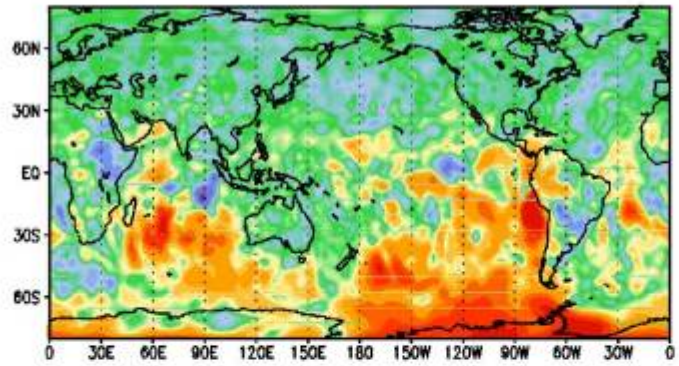
Estimate impact of real DWL from combination.



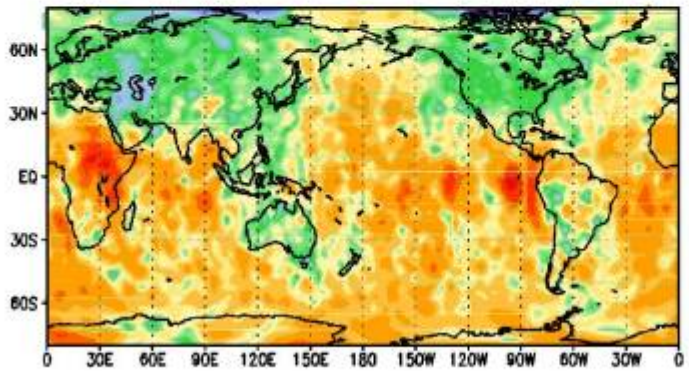
Zonally and time averaged number of DWL measurements in a 2.5 degree grid box with 50km thickness for 6 hours. Numbers are divided by 1000. Note that the 2.5 degree boxes are smaller in size at higher latitudes.

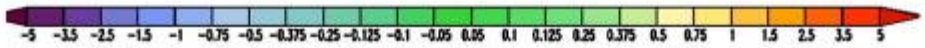
V 200hPa Analysis

Impact of Radiance



Impact of Hybrid DWL
CTL including Radiance





Maximum over tropics

Difference in RMSE from the Nature Run for 200hPa meridional wind. Analysis using 2004 NCEP DAS with T62 model. Top: reduction in RMSE from the inclusion of TOVS data. Bottom: reduction in RMSE from the addition of Hybrid_DWL to the CTL run. Averaged between Feb13 and Feb28, with twice daily sampling.

Doppler Wind Lidar (DWL) Impact without TOVS (using 1999 DAS)

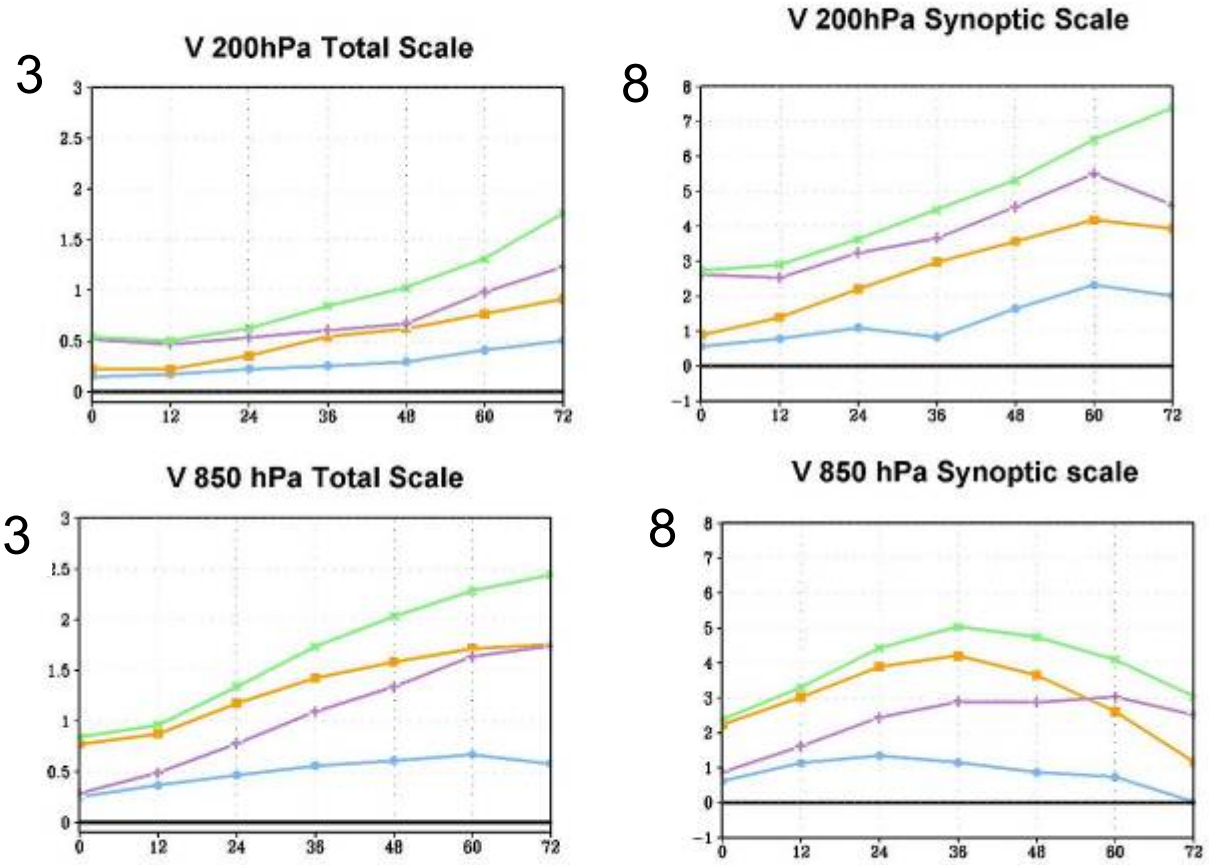
Hybrid_DWL

DWL_upper

DWL_Lower

Non_scan_DWL

No Lidar (Conventional + radiance)



Time averaged anomaly correlations between forecast and Nature Run for meridional wind (V) fields at 200 hPa and 850 hPa. Experiments are done with 1999 NCEP DAS withT62 model. CTL assimilates conventional data only.

Doppler Wind Lidar (DWL) Impact With TOVS (using 2004 DAS)

Hybrid_DWL

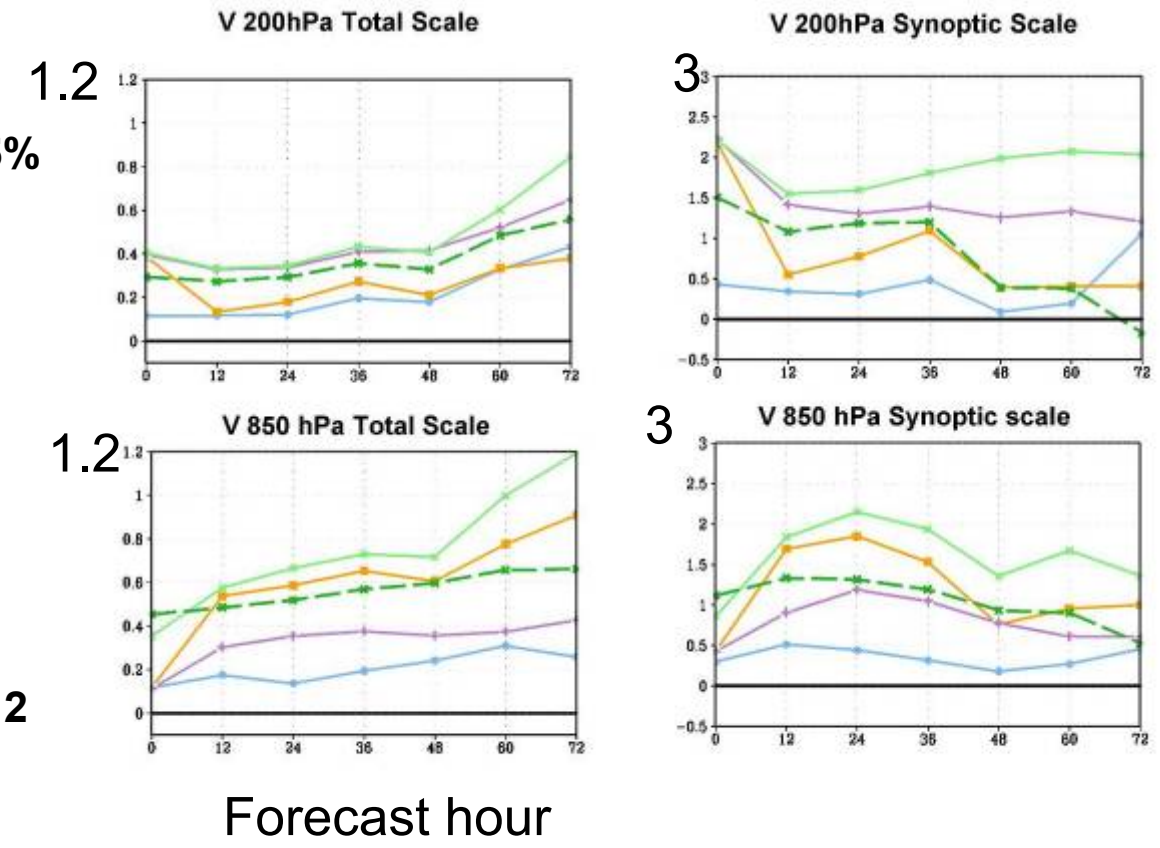
Hybrid DWL Uniformly thinned to 5%

Scan DWL_upper

Scan DWL_Lower

Non-scan_DWL

No Lidar (Conventional + NOAA11 and NOAA12 TOVS)



Dashed green line is for scan DWL with 20 times less data to make the observation counts similar to non-scan DWL. This experiment is done with 2004 NCEP DAS with T62 model.

Data Impact of scan DWL
1999 DAS vs. 2004 DAS

Impact of 2004 DAS

2004 DAS CTL - 1999 DAS CTL
(Conventional + TOVS)

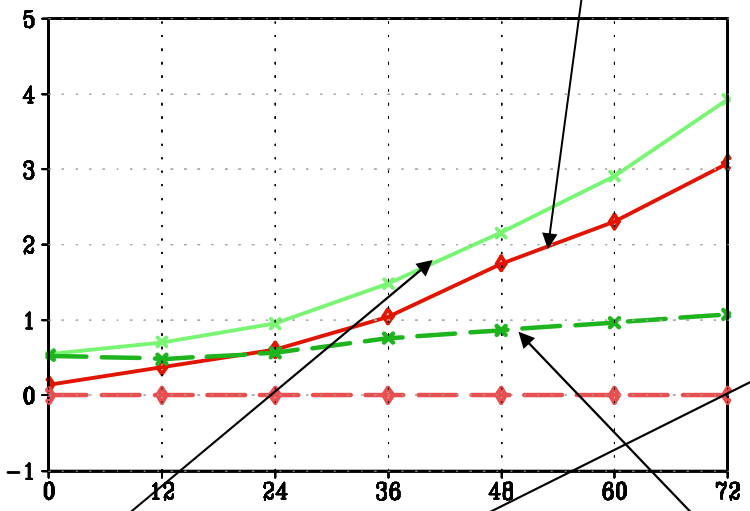
2004 DAS Hybrid DWL
- CTL (99)

1999 DAS CTL
- CTL (99)

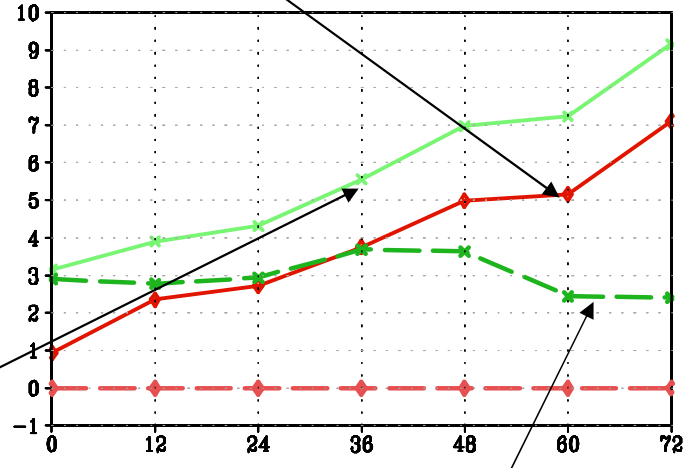
1999 DAS Hybrid DWL
- CTL (99)

200 mb V

Total scale



Synoptic Scale



Differences in anomaly correlation

Impact of DWL + better DAS

Impact of DWL

These experiments are done with T62 model with SSI.

Data Impact of scan DWL vs. Model Resolution

Impact of DWL + T170

Differences in anom correlation for 200hPa V

T62 CTL (reference)
(Conventional data only)

T62 CTL with Hybrid DWL
- CTL (T62)

T170 CTL
- CTL (T62)

T170 CTL with Hybrid DWL
- CTL (T62)

◊ CTL

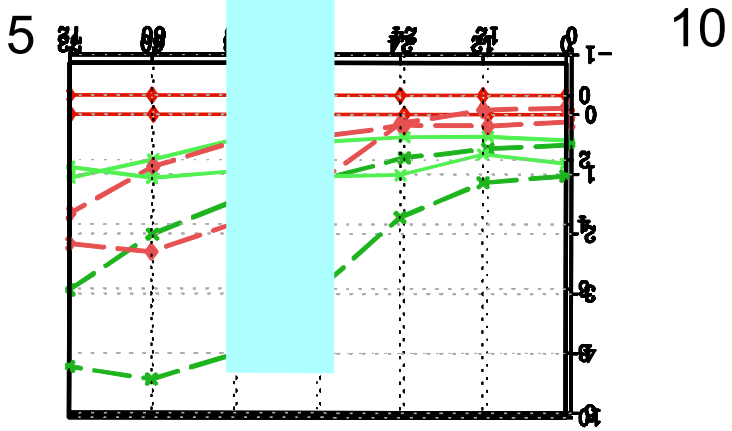
X CTL+Hybrid DWL

Tropical Scale

Synoptic Scale

Impact of DWL

Impact of T170 model

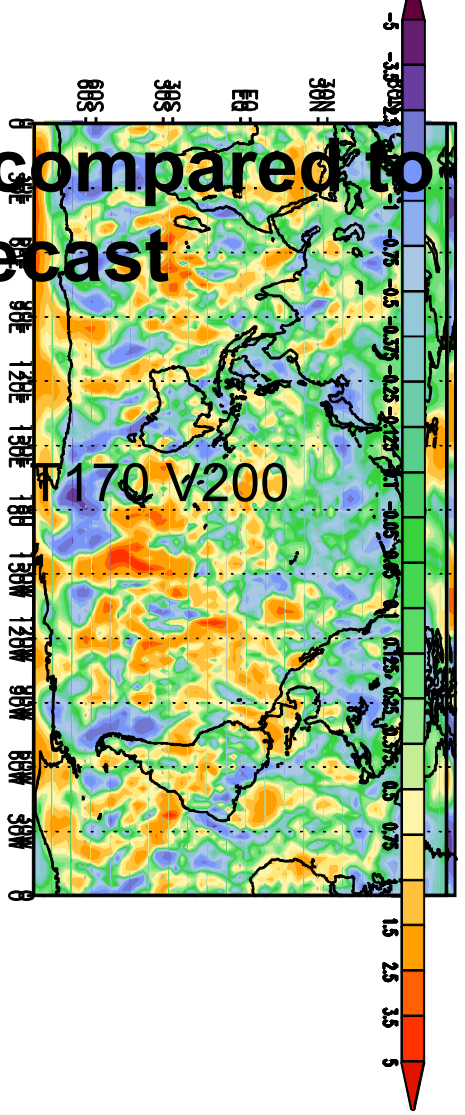


Adding Hybrid lidar has large impact on analysis but increasing the resolution has more impact on forecast after one or two days.

These experiments are done with 2004 T62 DAS with SSI.

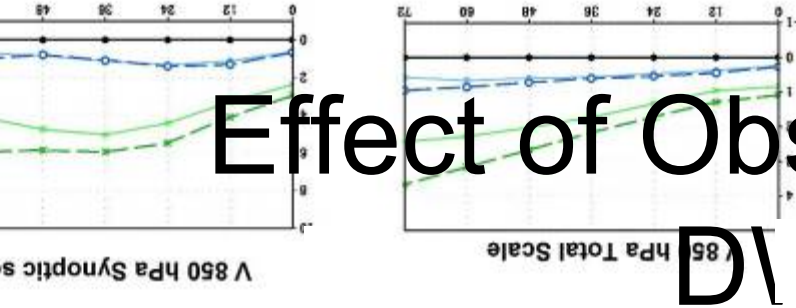
Reduction in RMSE from NR compared to control in 72 hour forecast

T62 V200



More consistent improvement with T170 model

Effect of Observational Error on D_ L Impact



- Percent improvement over Control Forecast (without DWL)

3 8

- Open circles: RAOBs simulated with systematic representation error

3 8

- Closed circles: RAOBs simulated with random errors

- Green: Best DWL
  Blue: Non-Scan DWL

Time averaged anomaly correlations between forecast and NR for meridional wind (V) fields at 200 hPa and 850 hPa. Experiments are done with 1999 DAS with T62 model. CTL assimilates conventional data only.

Targeted DWL experiments

(Technologically possible scenarios)

Combination of two lidars

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

Operates only 10% (possibly up to 20%) of the time. Switched on

des wind

observations from only clouds and the PBL.

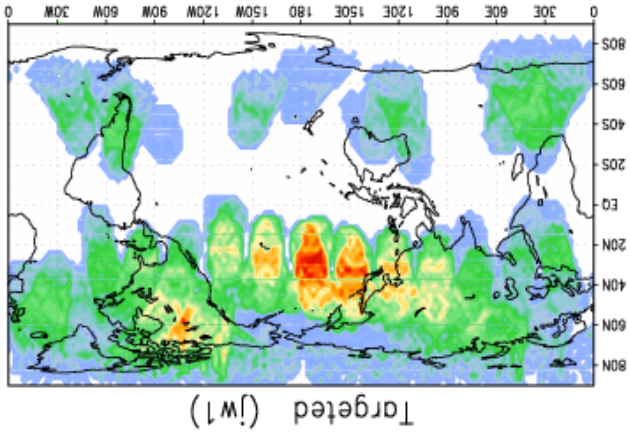
Operates 100% of the time and keeps the instruments warm as well as measuring low level wind

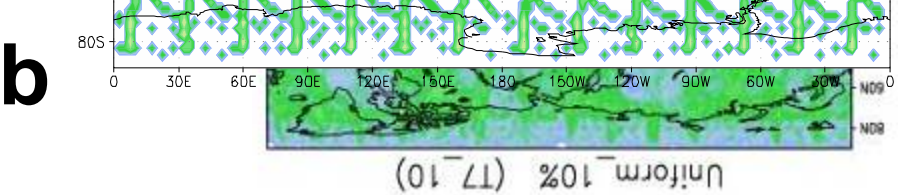
DWL-NonScan: DWL covers all levels without scanning

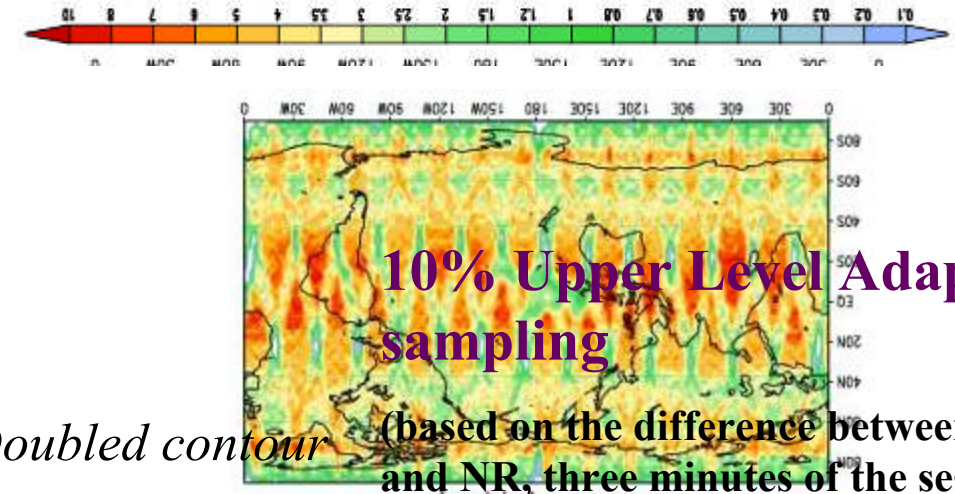
(ADM mission type DWL)

200mb

(Feb13 - Mar 6 average)







Doubled contour

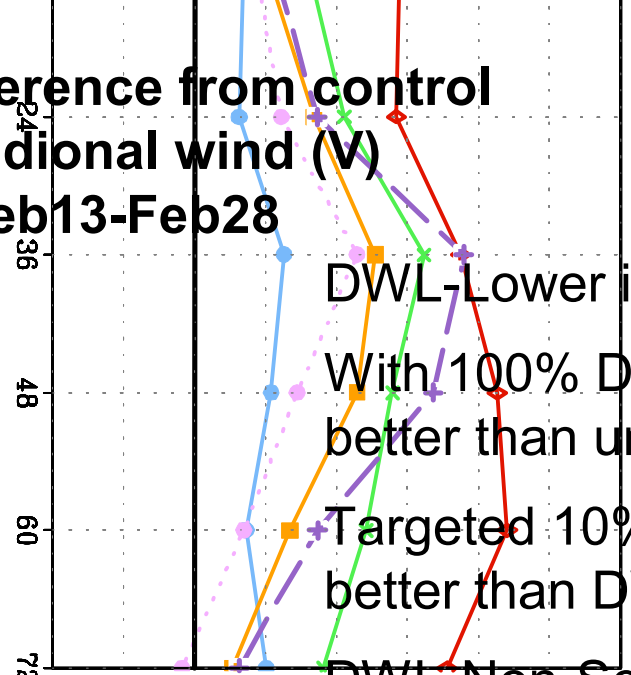
10% Upper Level Adaptive sampling

(based on the difference between first guess and NR, three minutes of the segments are chosen – the other 81 min are discarded)

10% Uniform DWL Upper

Non-Scan DWL

Anomaly correlation difference from control
Synoptic scale Meridional wind (V)
200hpa NH Feb13-Feb28



DWL-Lower is better than DWL-Non-Scan only

With 100% DWL-Lower, DWL-Non-Scan is better than uniform 10% DWL-Upper

Targeted 10% DWL-Upper performs somewhat better than DWL-Non-Scan in the analysis

DWL-Non-Scan performs somewhat better than Targeted 10% DWL-Upper in 36-48 hour forecast

100% Lower + 100% Upper
100% Lower + 10% Targeted Upper
100% Lower + Non-Scan
100% Lower + 10% Uniform Upper
100% Lower
Non-Scan only
No Lidar (Conventional + NOAA11 and NOAA12 TOVS)
CTL

ata and model resolution

OSSEs th Uniform Da

More d or a better mo

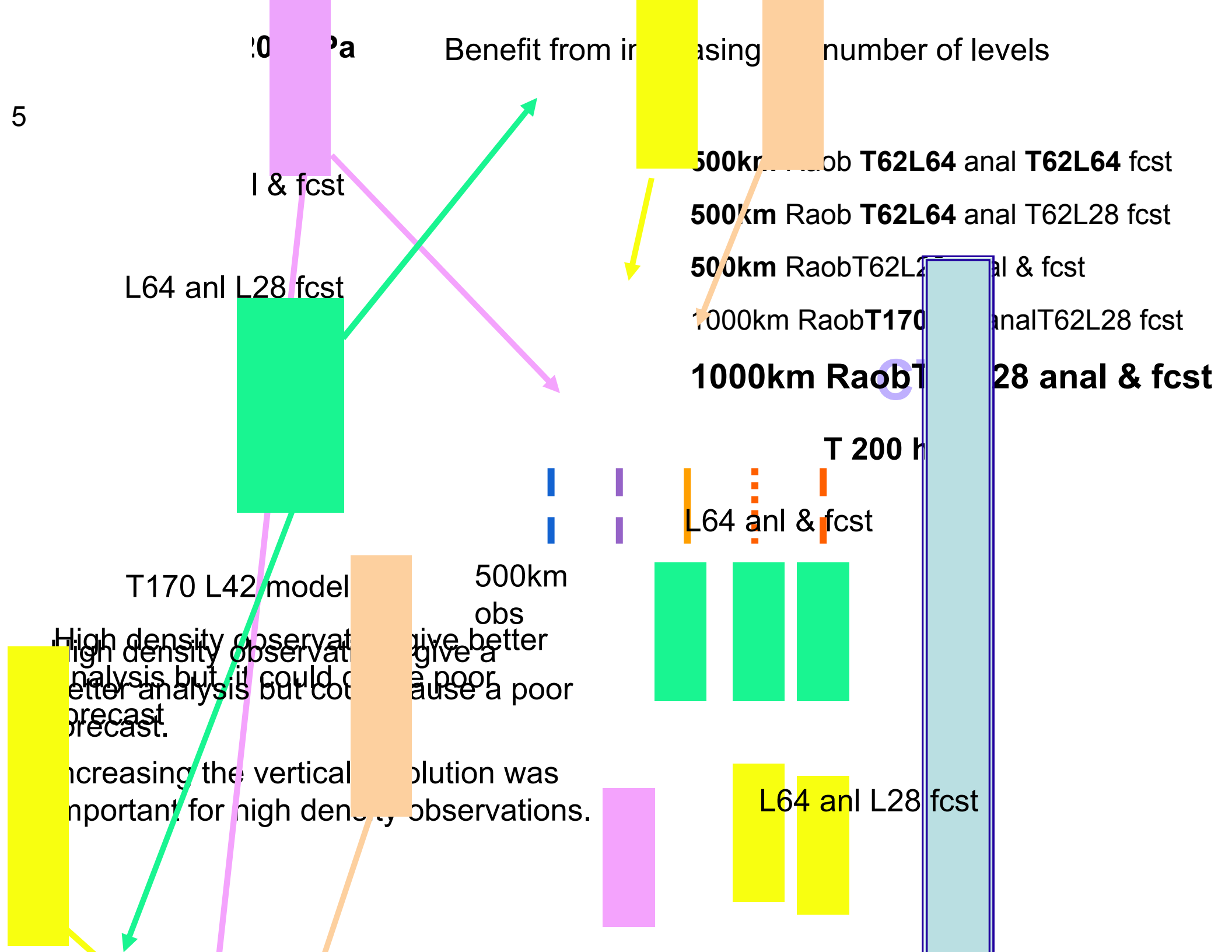
F acci Grid used in the uniform data c e OSSE

40 levels of equally-spaced data
100km, 500km, 200km are tested

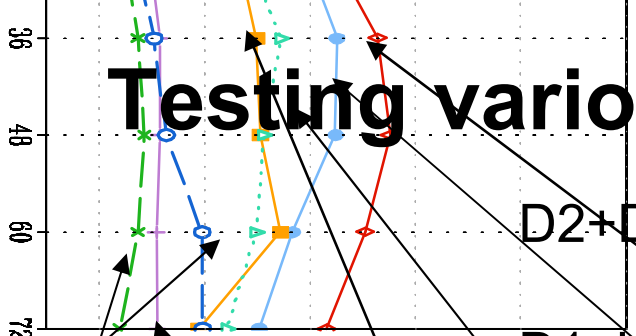
Skill is presented as Anomaly Correlation %
The differences from selected CTL are presented

Time averaged from Feb13-Feb28
12-hour sampling
200mb U and 200mb T are presented

- Yucheng Song


Benefit from increasing number of levels
5
500km Raob T62L64 anal T62L64 fcst
500km Raob T62L64 anal T62L28 fcst
500km RaobT62L28 anal & fcst
1000km RaobT170 anal T62L28 fcst
1000km RaobT62L28 anal & fcst
L64 anl L28 fcst
T 200 h
L64 anl & fcst
T170 L42 model
500km obs
High density observations give better analysis but could cause a poor forecast.
Increasing the vertical resolution was important for high density observations.
L64 anl L28 fcst

Testing various scenarios



NH V500
Zonal wave number
10-20

D2+D3: Red: upperDWL + L WL

D1: Light Blue closed circle: DWL (D1) with scan, rep error 1m/s

R45: Cyan dotted line triangl
D1 with rep error 4. .5x4.5≈20)

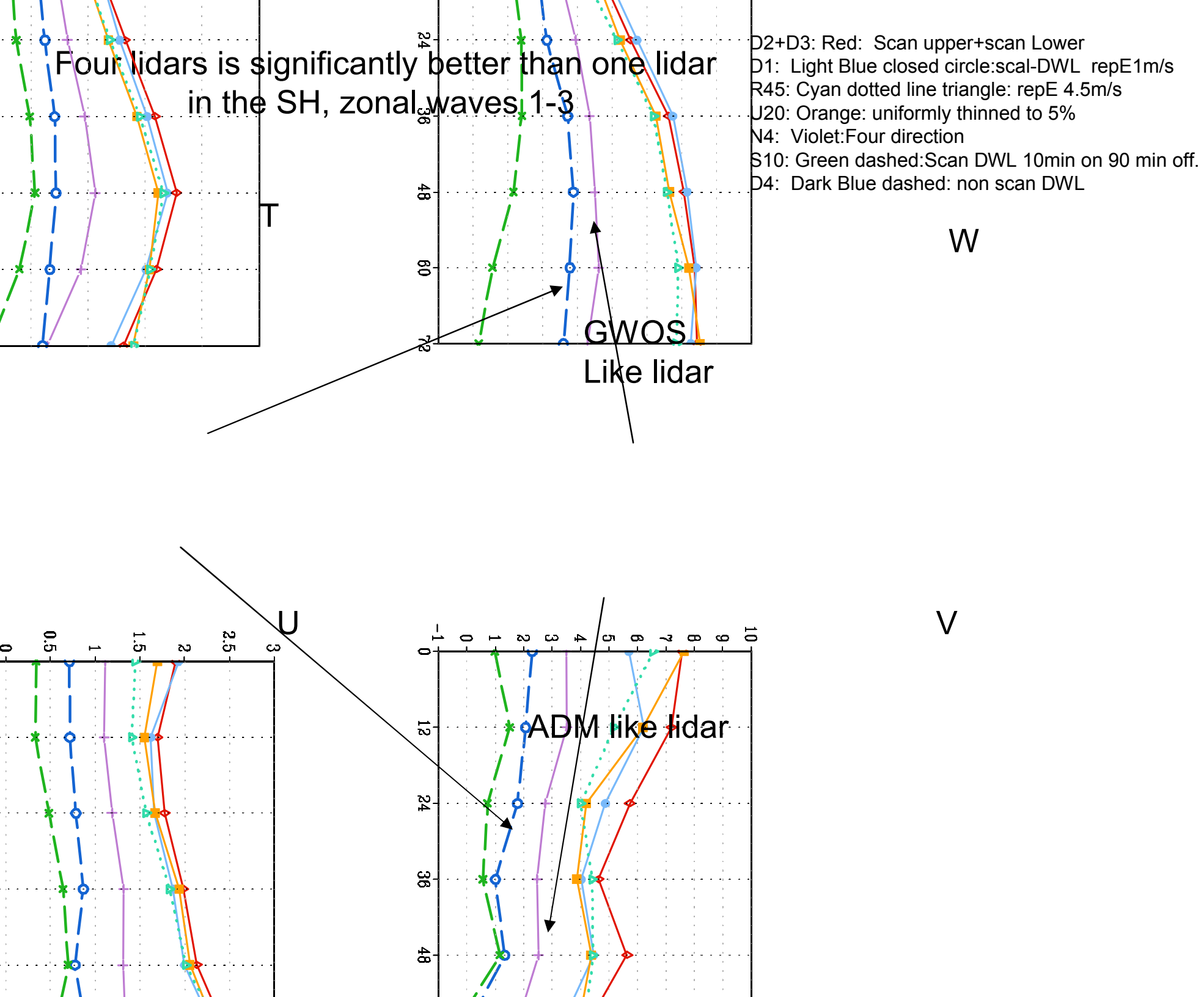
U20: Orange: D1 uniformly t for factor 20
(Note this is technologicall lt)

N4: Violet: D1 Thinned for fa but in forward direction 45,135,225,315 (m ng GWOS)

S10: Green dashed: Scan D min on, 90 min off. No other DWL

D4 : Dark Blue dashed: non WL

This experiment is done with 2004 T62 DAS with SSI. Significant changes are expected with newer DAS with higher resolution models.


Four lidars is significantly better than one lidar
in the SH, zonal waves 1-3
D2+D3: Red: Scan upper+scan Lower
D1: Light Blue closed circle:scal-DWL repE1m/s
R45: Cyan dotted line triangle: repE 4.5m/s
U20: Orange: uniformly thinned to 5%
N4: Violet:Four direction
S10: Green dashed:Scan DWL 10min on 90 min off.
D4: Dark Blue dashed: non scan DWL
T
W
GWOS
Like lidar
U
V
ADM like lidar

Hybrid-DWL has much more impact compared to non-scan-DWL with the same amount of data.

If the data is thinned uniformly, 20 times thinned data (U20) produces 50%-90% of impact.

20 times less weighted 100% data (R45) is generally slightly better than U20 (5% of data)

Four lidars directed 90 deg apart (N4) showed significant improvement to D4 only at large scales over SH but is not much better over NH and at synoptic scales.

Without additional scan-DWL,10min on 90 off (S10)sampling is much worse than U20 (5% uniform thinning) with twice as much as data.

The results will be very different with newer assimilation systems and higher resolution model.

NCEP OSSE demonstrated that when using Full OSSE, various experiments can be performed and compared.

OSSE with one month long T213 Nature Run is limited.
Better Nature Runs are needed.

Internationally collaborative Joint OSSE which shares same Nature Runs has emerged.

The results from the NCEP OSSE have to be confirmed by Joint OSSEs with Joint OSSE NRs

Need for collaboration

Need one good new Nature Run which will be used by many OSSEs, including regional data assimilation.

Share the simulated data to compare the OSSE results from various DA systems and gain confidence in results.

OSSEs require many experts and a wide range of resources.

Extensive international collaboration within the Meteorological Community is essential for timely and reliable OSSEs to influence decisions.

International Collaborative Joint OSSE

- Toward reliable and timely assessment of future observing systems -

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

Participating Institutes

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[3]NOAA/ NESDIS/STAR, Camp Springs, MD,
[4]ECMWF, Reading, UK
[5]NOAA/Earth System Research Laboratory (ESRL), Boulder, CO,
[6]SWA, Charlottesville, VA
[7]Royal Dutch Meteorological Institute (KNMI), DeBilt, Netherlands,
[8]Mississippi State University/GRI (MSU), MS,
[9]JCSDA, MD
[10]University of Utah, UT

Other institutes expressing interest

[11]NOAA/OAR/AOML, Miami, FL,
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[13]JMA, Tokyo, Japan, [14]University of Tokyo, Japan, [15]NGC, [16]JAMSTEC, Japan,
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Core members who have been involved from the early stage

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

Meeting summary, Discussion forums, References, FAQ for OSSE, GSI, and CRTM

New Nature Run by ECMWF

Based on discussion with
JCSDA, NCEP, GMAO, GLA, SIVO, SWA, NESDIS, ESRL, and ECMWF

Low Resolution Nature Run

Spectral resolution : T511 , Vertical levels: L91, 3 hourly dump
Initial conditions: 12Z May 1st, 2005 , Ends at: 0Z Jun 1,2006
Daily SST and ICE: provided by NCEP
Model: Version cy31r1

Two High Resolution Nature Runs

35 days long

Hurricane season: Starting at 12z September 27,2005,

Convective precipitation over US: starting at 12Z April 10, 2006

T799 resolution, 91 levels, one hourly dump

Get initial conditions from T511 NR

Note: This data must not be used for commercial purposes and re-dist ot given. User lists are maintained by Michiko Masutani and ECMWF

Archive and Distribution

To be archived in the MARS system at EC
To access T511 NR, set expver = etw

Copies are available to designated users for research ... ses & users known to ECMWF

Saved at NCEP, ESRL, and NASA/GS
Complete data available from portal at NA... SFC
Conctact: Michiko Masutani (michiko.masutani@... .gov),
Harper Pryor (Harper.Pryor@nasa.gov...

Gradsdods access is available for T511 NR. The data can ... nloaded in grib1, NetCDF, or binary. The data can be retrieved glob... for selected regions.

Provide IP number to: Arlindo da Silva (Arlindo.Das... asa.gov)

Supplemental low resolution regular lat lon data

1deg x 1deg for T511 NR

Pressure level data: 31 levels,

Potential temperature level data: 315,330,350,370,530K

Selected surface data for T511 NR: Convective precip, Large scale precip, MSLP,T2m,TD2m, U10,V10, HCC, LCC, MCC, TCC, Sfc Skin Temp

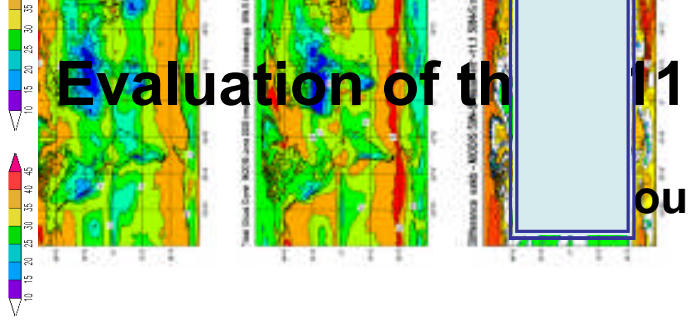
T511 verification data is posted from NCAR CISL Research Data Archive. Data set ID ds621.0. *Currently NCAR account is required for access*.

(Contact Harper.Pryor@nasa.gov)

(Also available from NCEP HPSS, ESRL, NCAR/MMM, NRL/MRY, Univ. of Utah, JMA, Mississippi State Univ.)

Evaluation of th 11 Nature run

oud Cover



Comparison between the ECMWF T511 Nature Run against climatology

20050601-20060531, exp=eskb, cycle=31r1

Adrian Tompkins, ECMWF

NR

MODIS

NR-MODIS

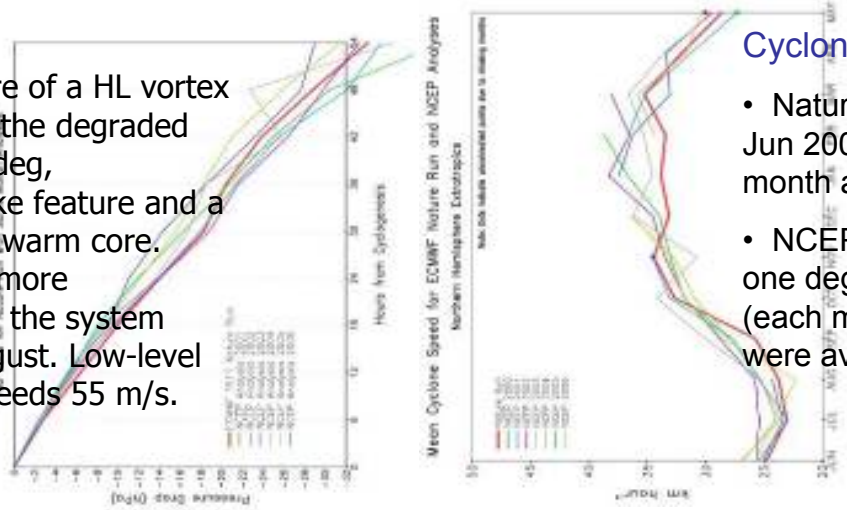
Utilize Goddard's cyclone tracking software (*Terry and Atlas, AMS conf, Aug 1996*):

- Identifies and tracks mostly extratropical cyclones (cutoff at 20 deg N/S latitude)
- Interfaces with GrADS contouring algorithm
- Uses SLP field at 4hPa contour interval
- Finds centroid of inner-most closed isobar
- Tracks the centers using extrapolation and 500hPa steering

Tropics

Oreste Reale (NASA/GSFC/GLA)

Vertical structure of a HL vortex shows, even at the degraded resolution of 1 deg, a distinct eye-like feature and a very prominent warm core. Structure even more impressive than the system observed in August. Low-level wind speed exceeds 55 m/s.



Cyclone tracks generated:

- Nature Run at one degree for Jun 2005 to May 2006 (each month and season)
- NCEP operational analysis at one degree for 2000 to 2006 (each month, 68 of 84 months were available)

T511 Nature Run is found to be representative of the real atmosphere and suitable for conducting reliable OSSEs for midlatitude systems and tropical cyclones. (Note: MJO in T511 Nature Run is still weak.)

There are significant developments in high resolution forecast models at ECMWF since 2006 and a more realistic tropics for T799 Nature Run is expected with a newer version of ECMWF model.

ECMWF agreed to generate a new T799 NR, when the Joint OSSE team has gained enough experience in OSSEs with T511NR and is ready to make the best use of the high resolution Nature Run.

For the time being, the Joint OSSE team will concentrate on OSSEs using T511 Nature Run.

Simulation of Observations for calibration

The output data is saved in BUFR format which can be rea ne Gridpoint Statistical Interpolation (GSI). GSI is a DAS used CEP, GMAO and ESRL. The codes are flexible and include man ble parameters.

Initially observational error will not be added.

GMAO will provide software to add random error.

Simulated observations will be posted from NASA/NCCS p

GMAO will provide calibrated simulated observations.

NCEP-NESDIS will provide additional data which are not si ed by GMAO.

Some calibration will be performed but users are expected perform their own calibrations. Some simulation by GMAO r repeated for the complete period.

Each group will make separate directories for simulated ob ions at the NASA portal.

GMAO Observation Simulator for Joint OSSE

- Software for generating conventional obs (observation type included in NCEP prepbufr file). Surface data are simulated at NR surface height.
- Software for simulating radiances: Code to simulate HIRS2/3, AMSUA/B, AIRS, MSU has been set up. Community Radiative Transfer Model (CRTM) is used for forward model. Random sampling-based uses High, Mid, Low level cloud cover, precipitation to produce a realistic distribution of cloud clear radiance.
- Software for generating random error.
- Calibration is performed using Adjoint technique.

Distribution

Simulated observations will be calibrated by GMAO before becoming available. Limited data are now available for people who contribute to validation and calibration.

Contact:
Ron Errico: ronald.m.errico@nasa.gov

Simulation of radiance data at NCEP and NESDIS

Step 1. Thinning of radiance data based on real use

For development purposes, 91-level ML variables are processed at NCEP and interpolated to observational locations with all the information need to simulate radiance data (DBL91). DWL91 will be posted from NASA portal.

The DBL91 are for quick work and also used for development of CRTM.

GOES and SBUV are simulated as they are missing from GMAO dataset.

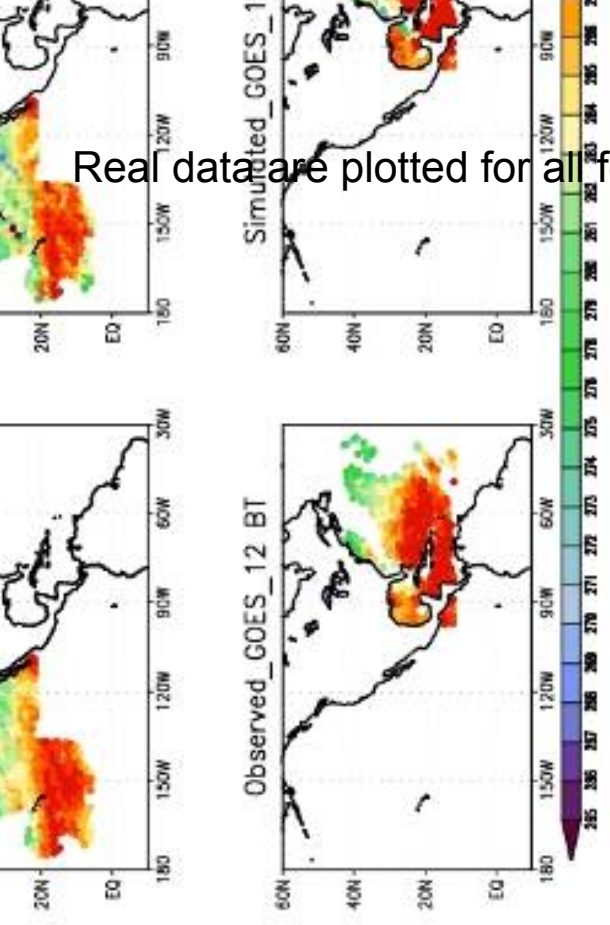
AMSUA, AMSUB, GOES data have been simulated for entire T511 NR period. DBL91 for HIRS2, HIRS3 are also prepared, saved and will be posted. DBL91 for AIRS will not be saved.

Step 2. Simulation of radiance data using cloudy radiance

Cloudy radiance is still under development. Accuracy of GMAO data will be between Step1 and Step2.

GOES May 2 00z

Real data are plotted for all foot prints. Simulated data are plotted for foot prints used at NCEP GDAS.

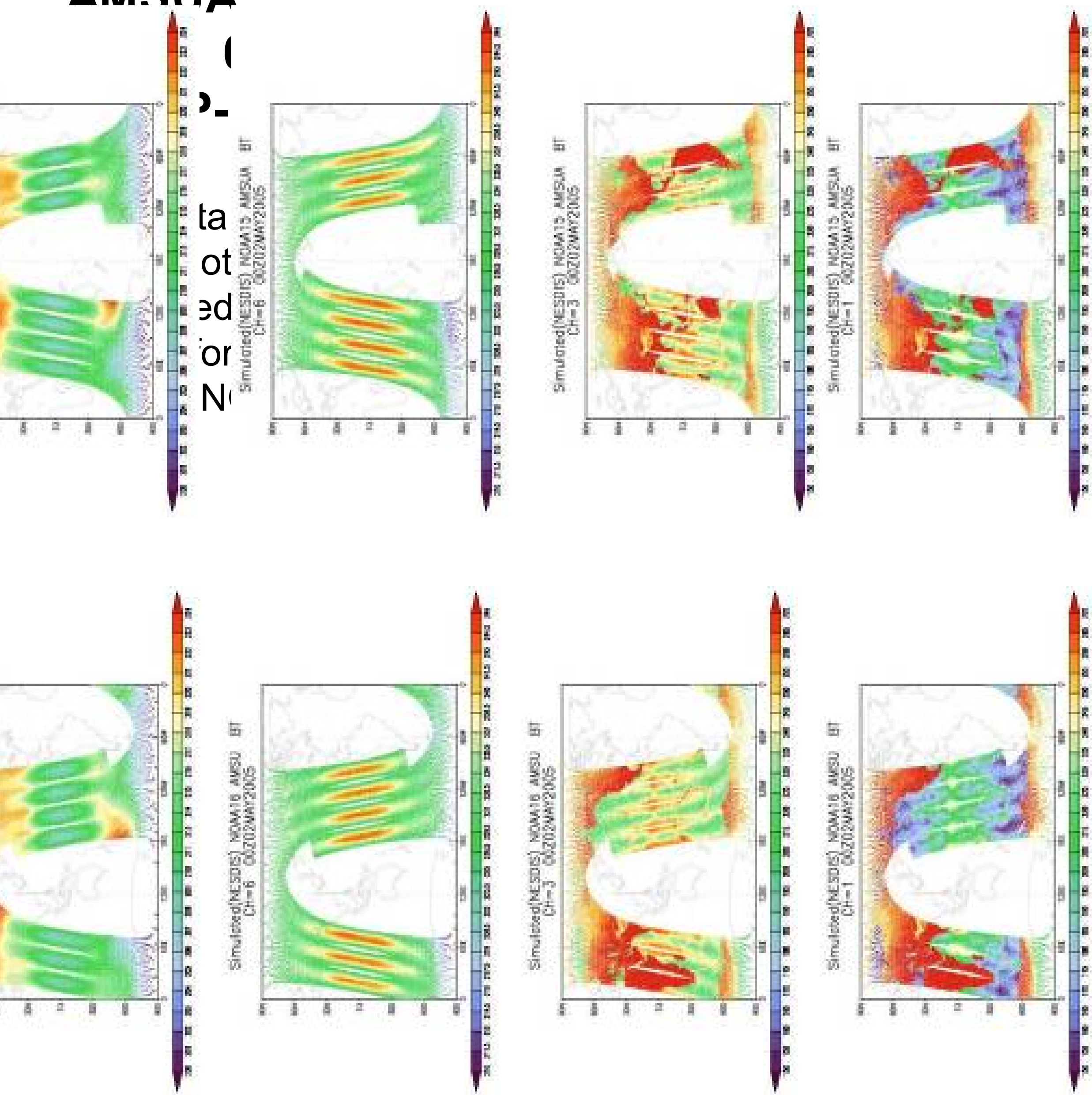


Observed
N15+N16

Simulated NOAA 15

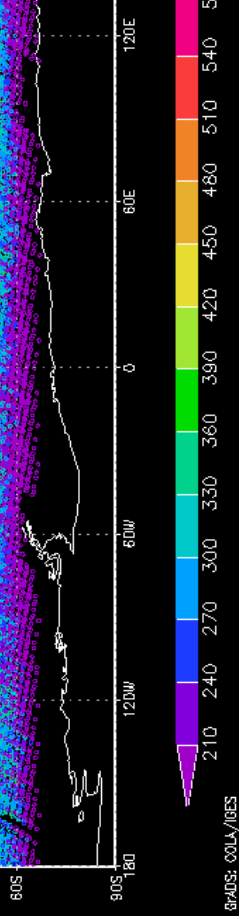
Simulated NOAA 16

AMSUA



Simulation of SBUV ozone data
Jack Woollen (NCEP)

Real



Plot produced by By Jack Woollen

Further Considerations

Data distribution depends on atmospheric conditions.

Aircraft data are heavily affected by Jet Stream location.
Location of Jet in NR must be considered.
Scale of RAOB drift becomes larger than model resolution.
Cloud Motion Vector is based on Nature Run Cloud.

Microwave Radiative Transfer at the Sub-Field-of-View Resolution
(Tom Kleespies and George Gyno)

The ability to integrate high resolution databases within a given field-of-view, and perform multiple radiative transfers within the field of view, weight according to the antenna beam power, and integrate.

Calibration

GMAO is conducting calibration using adjoint method.

Focused on July August 2006 and December 2005-January 2006.

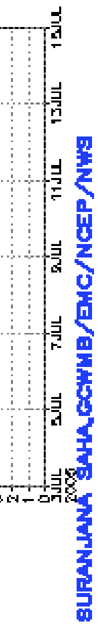
ESRL and NCEP are working on calibration using data denial method.

Using simulated data by GMAO and additional data from NCEP.

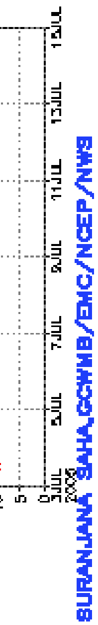
Focused on July-August 2005.

GSI version May 2007.

NCEP is working on upgrading OSSE system to newer GSI to accommodate DWL and flow dependent error covariances. Some calibrations will be repeated.



By Jack Woollen

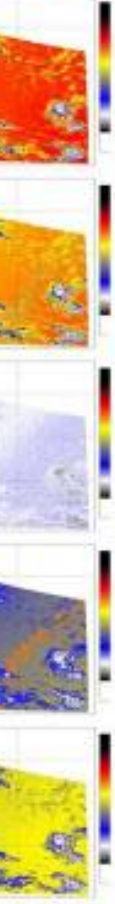


By Jack Woollen

Planned experiments

OSSE for GNSS Radio-Occult (RO) observations
Lidia Cucurull (JCSD

- Several options for a future operational GPS Radio O n system (COSMIC follow-on) regarding orbit configurations, nu satellites, secondary payload vs. dedicated system, etc.
- What is the optimal choice?
- CEOS action WE-07-03 on 'evaluation of the requiren conduct RO OSSEs' given to NOAA/NESDIS.
- These actions have recently been completed:
  - International Joint OSSE project set up;
  - 2-yr full time post-doctoral scientist will conduct.
- Funding made available by NOAA/NESDIS; hire in pr



OSSEs to investigate GOES data usage and prepare for GOES-R

Tong Zhu (CIRA/CSU), Fuzhong Weng (NOAA/NESDIS),
Jack Woollen (NOAA/EMC), Michiko Masutani (NOAA/EMC), Thomas J. Kleespies(NOAA/NESDIS),
Yong Han(NOAA/NESDIS), Quanhua, Liu (QSS), Sid Boukabara (NOAA/NESDIS),Steve Load (NOAA/EMC),

This project involves OSSE to evaluate current usage of GOES data

Simulation of GOES-12 Sounder

Observed GOES-12 Sounder

Nature Run hurricane generated on September 27. At 1200 UTC October 1, it is located at about 43 W, 20N. The high moisture air mass associated with the hurricane is shown clearly.

Observed GOES-12 18 bands on 0230 UTC October 01, 2005 for North Atlantic Ocean section.

by Tong Zhu

Planned experiments (cont.)

OSSE to evaluate UAS

N. Prive(ESRL), Y. Xie(ESRL), et al.

ADM-Aeolus simulation for J-OSSE

G.J. Marseille and Ad Stoffelen (KNMI)

SSEs for THORPEX T-PARC

valuation and development of targeted observation

Toth, Yucheng Song (NCEP) and other THORPEX team members

Simulation of DWL at SWA

G. David Emmitt, Steve Greco, Sid A. Wood,

Regional DWL OSSEs at the University of Utah

Zhaoxia Pu, University of Utah

OSSE to evaluate DWL

M.Masutani(NCEP), L. P Riishojgaard (JCSDA),

NOAA/ESRL, Met Office?

Regional OSSEs to Evaluate ATMS and CrIS Observations

Cris M. Hill, Pat. J. Fitzpatrick, Val. G. Anantharaj GRI- Mississippi State University (MSS)

Lars-Peter Riishojgaard (JCSDA)

Summary

- OSSEs are a cost-effective way to optimize investment in future observing systems
- OSSE capability should be broadly based (multi-agency)
  - Credibility
  - Cost savings
- Joint OSSE collaboration remains only parti[illegible]unded but appears to be headed in right direction
  - GMAO software to calibrate basic data is ready for rele[illegible]
  - Additional software being developed at NCEP, NESDI[illegible]L and GMAO
  - Database and computing resources have been set up for DWL simulation and SWA, KNMI receiving ESA funding for DWL simulations
  - Preliminary versions of some basic datasets have been simulated for entire T511NR period

Using Full OSSE, various experiments can be performed and various verification metrics can be tested to evaluate data impact from future instruments and data distributions.

It was noted that that while OSSEs can be overly optimistic about the impacts of new observations evaluated in the current data assimilation system, advances in data assimilation skill usually allow us to make better use of observations over time. These advances may, to some extent, be an offsetting factor in that they can help achieve greater impact from new observations in the long run. (From Workshop summary)

Theoretical predictions have to be confirmed by full OSSEs. The results are often unexpected. OSSE results also require theoretical back ups.

OSSE capability should be broadly based (multi-agency) to enhance credibility and to save costs.

End