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Assimilation impact from satellite wind observations filling the gap at high latitudes

L. Garand, J. Feng, Y. Rochon, S. Heilliette,
Environment Canada, and A. P. Trishchenko,
Canada Center for Remote Sensing

5h WMO Workshop on the Impact of Various Observing Systems on NWP
Sedona, AZ, 22-25 May 2012

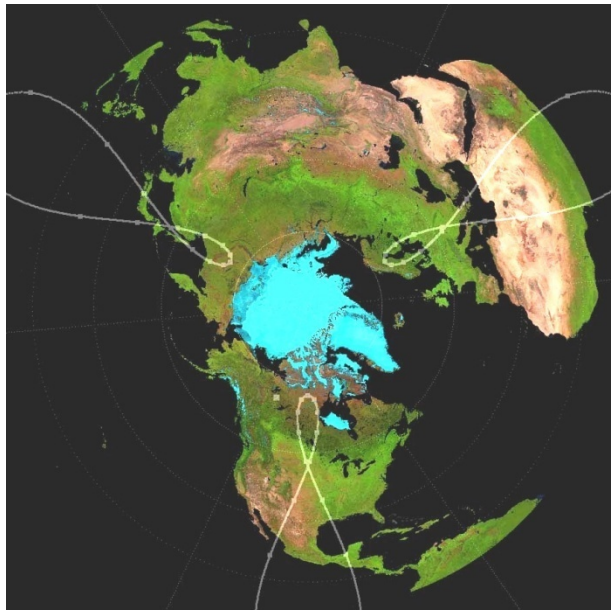
Outline

- Advantage of Highly Elliptical Orbit for polar regions
- Motivation for a specific AMV impact study
- OSE AMV impact in Canadian data assimilation system
- OSSE definition
- Results
- Conclusion

Polar Communications and Weather (PCW) mission in a few words

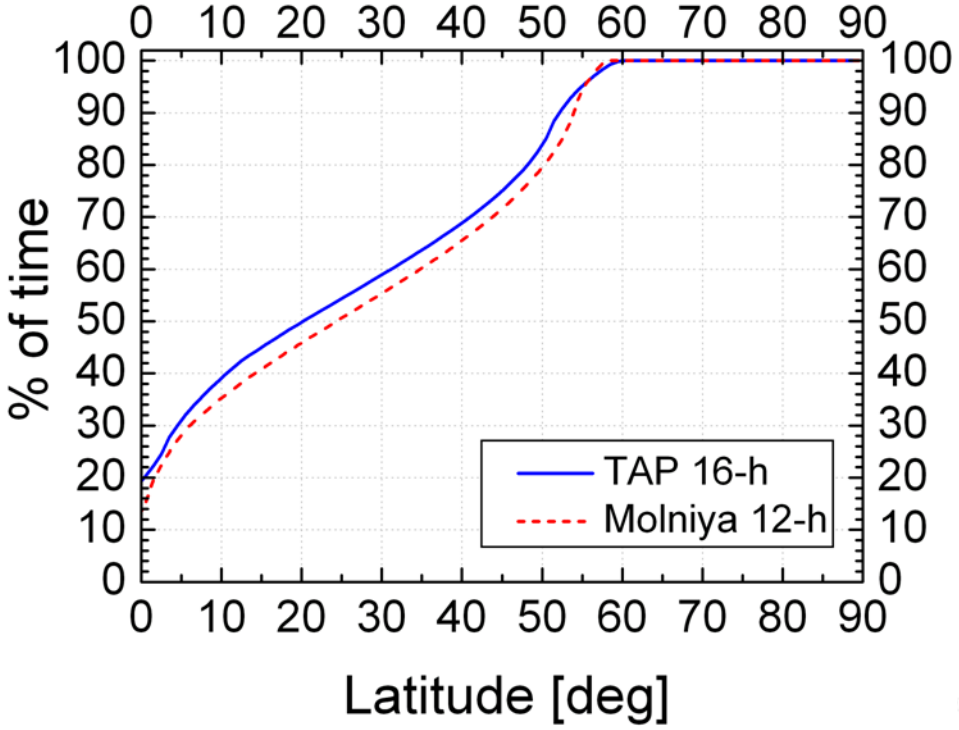
- 2-satellite constellation in highly elliptical orbit planned for 2018
- Core meteo instrument similar to ABI (GOES-R)
- Extends GEO applications to the pole, 15 min imagery

16-h 3-apogee (TAP) ground track



Apogee 43,000 km, at 30 N, 30,000 km

spatio-temporal coverage vs latitude



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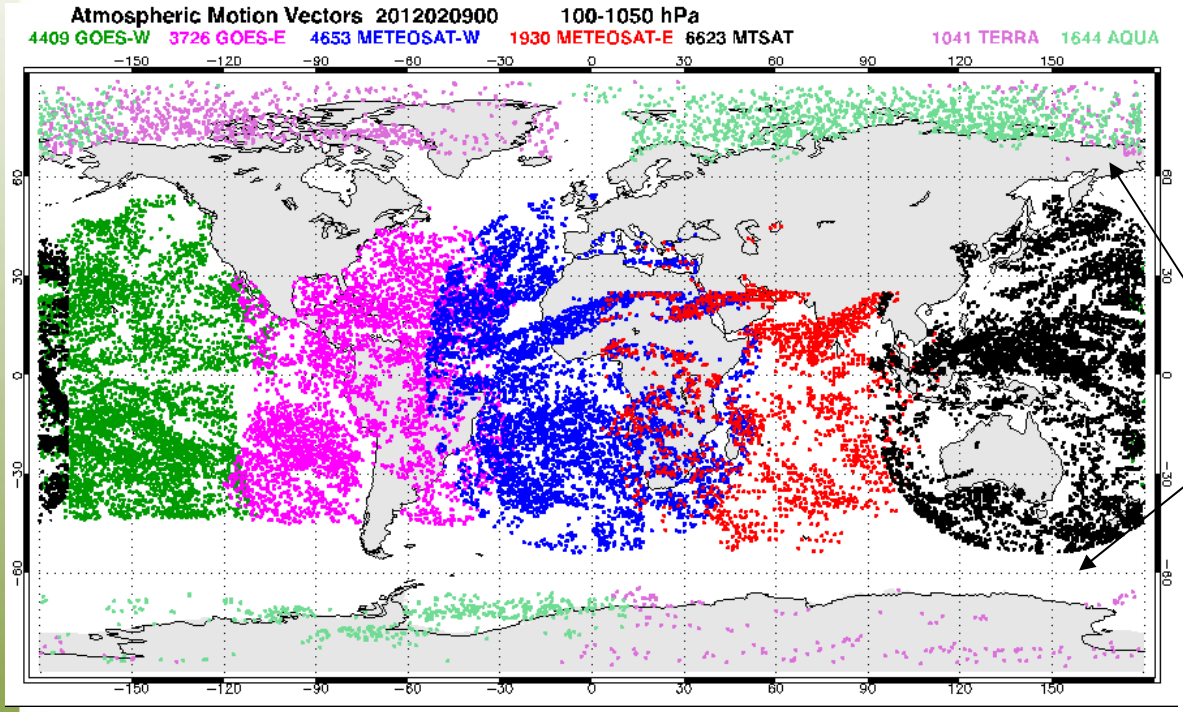
Motivation here: impact on NWP of filling the AMV gap in the northern polar region



Current AMV coverage
After quality control
and thinning

4 HEO satellites would
Be needed to fill both
N and S gaps

AMVs would be produced from 15 min imagery
At latitudes 45^{o}-90^{o}

HEO (2-sats) vs LEO (2, 4, 7 sats) coverage

based on May 2011 average

Single images

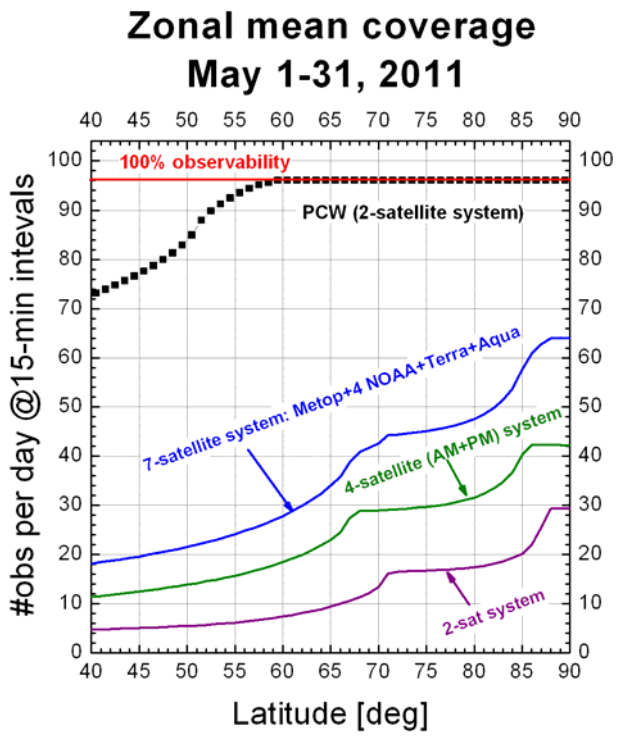


Image pairs

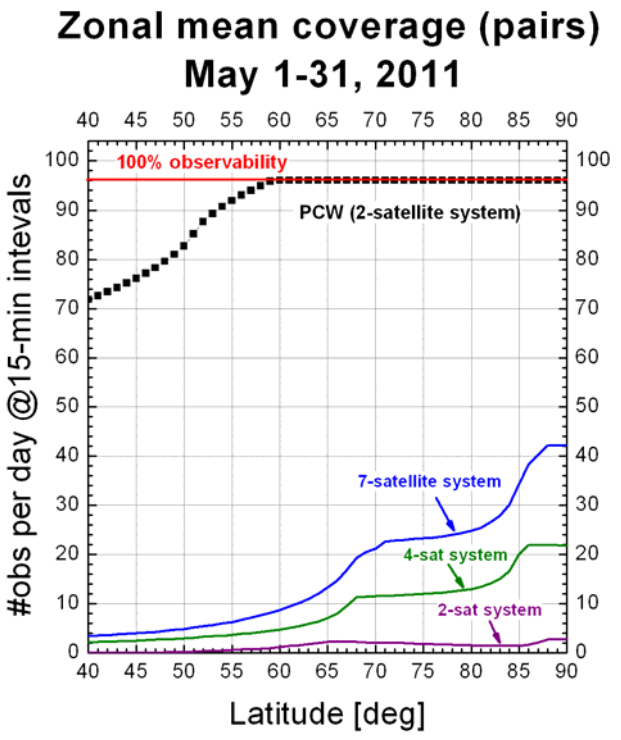
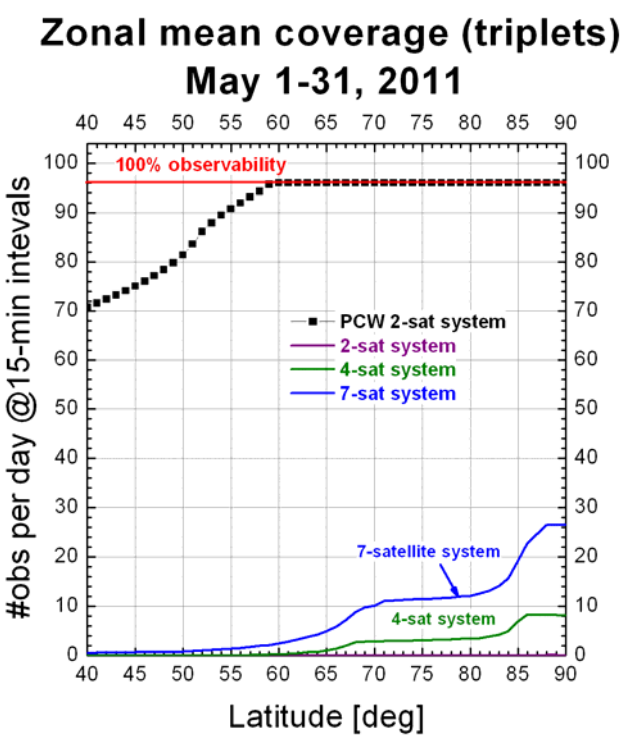


Image triplets



Ref: Trishchenko and Garand, 2012, Canadian J. Remose Sensing

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Start with real AMV observations

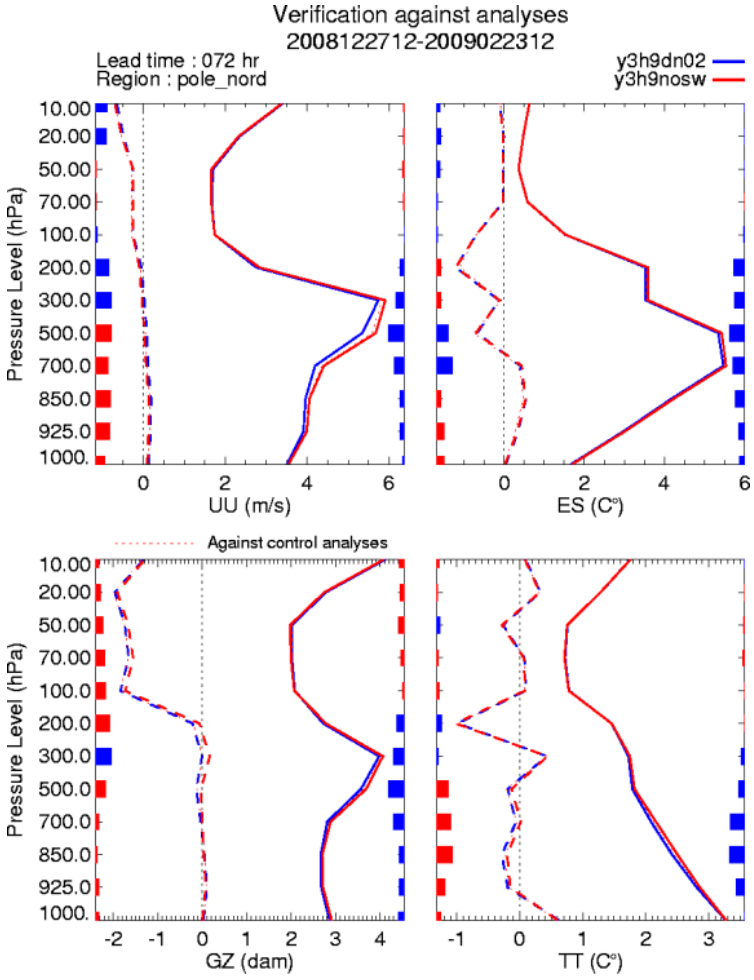
OSE:

- OPE system: includes GEO and MODIS AMVs
- NO-AMV: OPE, but without AMVs
- 3D-Var FGAT
- 2 months 27 Dec 2008 to 23 Feb 2009

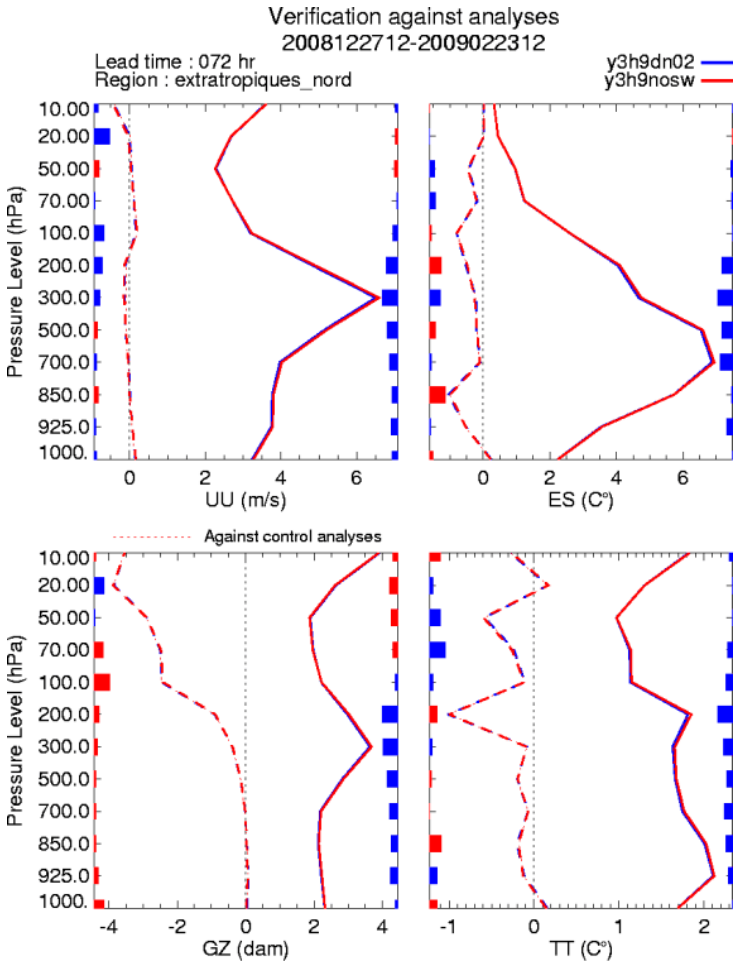
- Goal:
  - reassessing AMV impact globally and by region
  - will allow evaluating the realism of OSSE

AMV impact from real data
(72-h, std/bias vs own analysis, OPE-NOAMV

North Pole 70-90 N



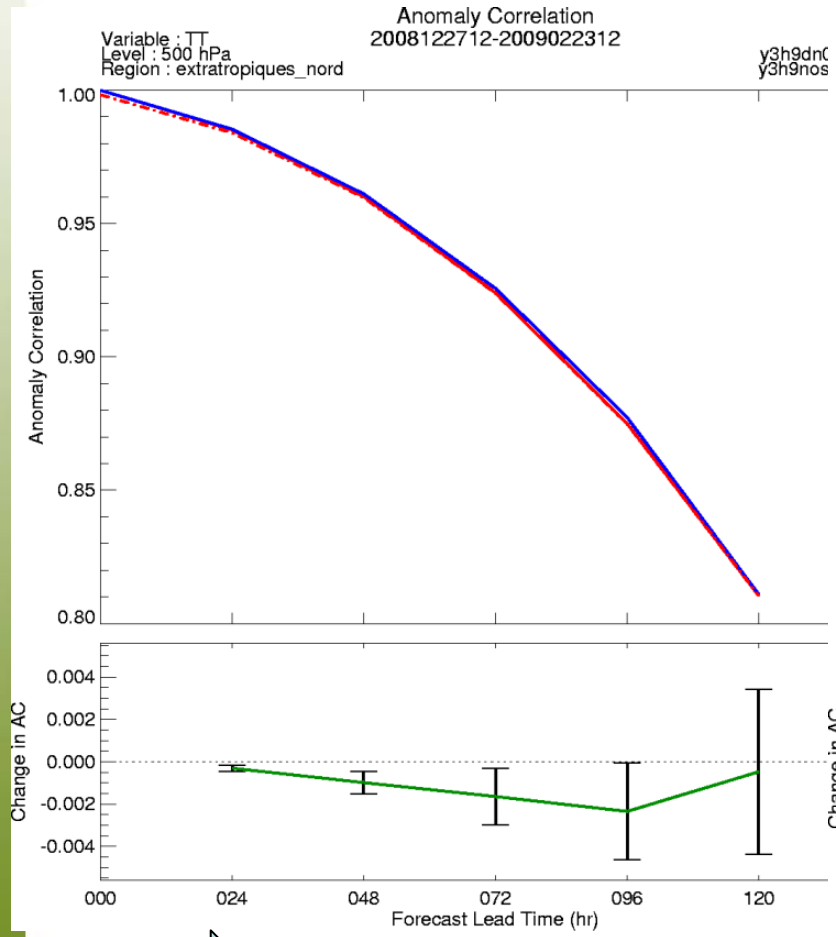
Extra-tropics North 20-70 N



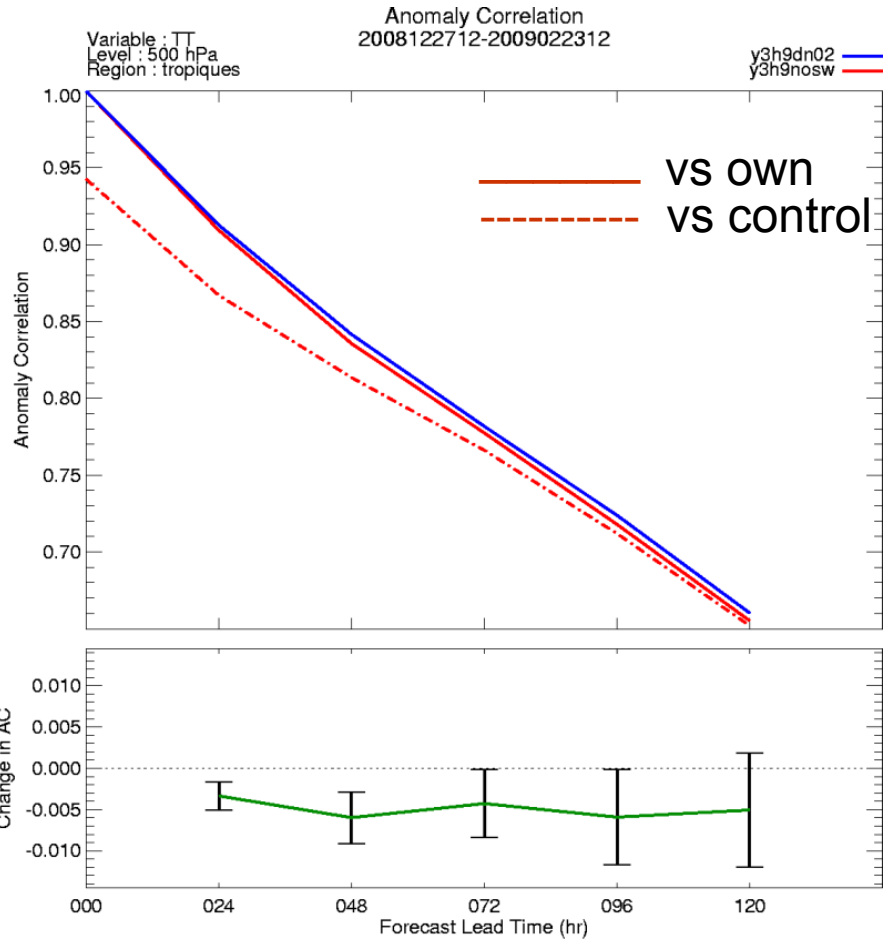
Impact of real AMV: 500 hPa TT ano-cor

OPE-NOAMV

Extra-tropics North 20-70 N



Tropics 20 N – 20 S

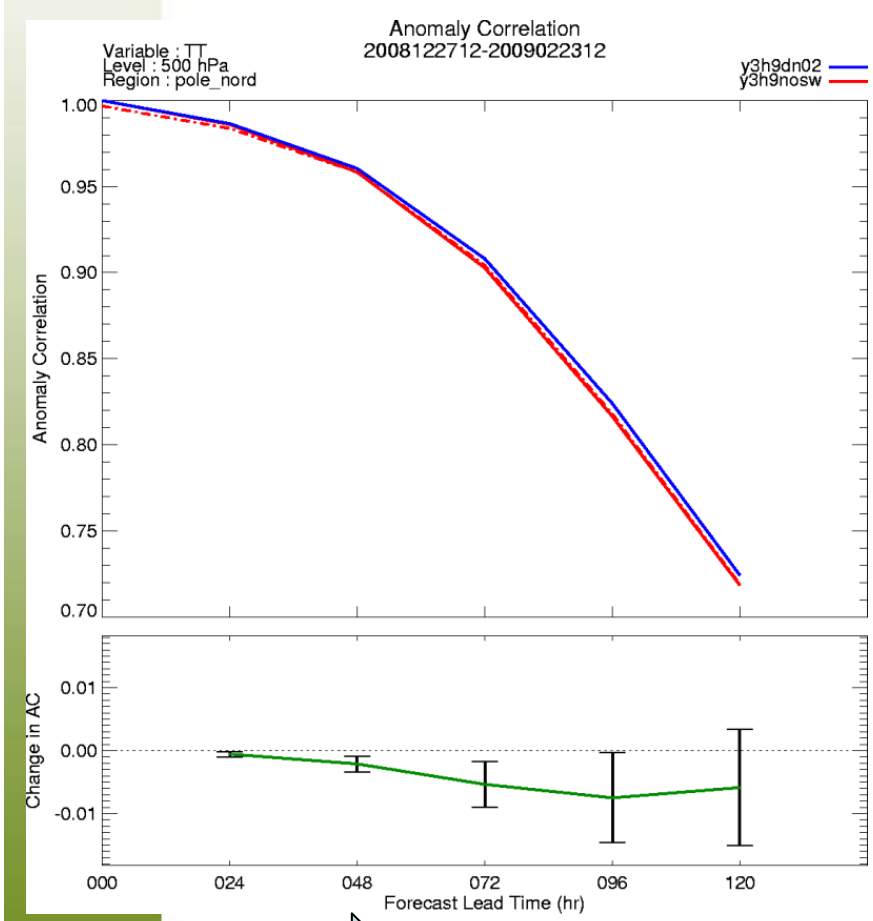


Modest but significant positive impact up to day 4

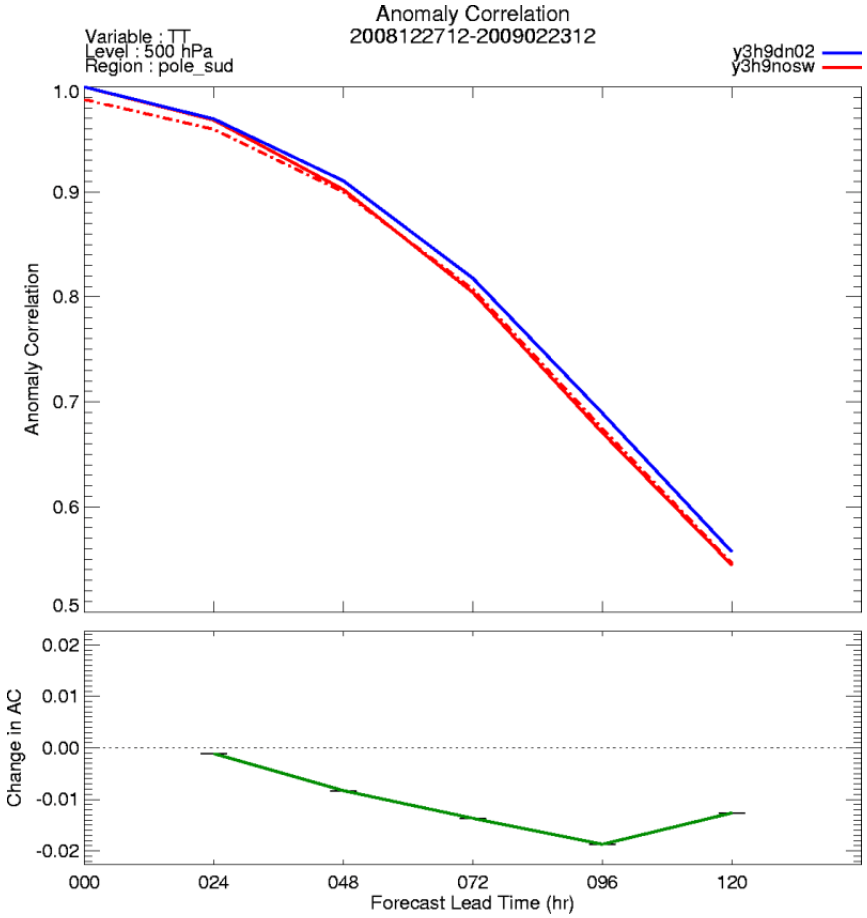
Impact of real AMV in polar areas

OPE-NOAMV 500 hPa TT ano-cor

North Pole 70-90 N



South Pole 70-90 S



Good impact from MODIS AMVs near the poles

OSSE definition

- Period covered in test cycles (2.5 months):
  - 15 December 2005 to 28 February 2006
- Simulated from NR all data types assimilated. Positions are those at the same dates in 2008-2009, to include recent types (GPSRO, IASI) not available in 2005-2006.
- All-sky (cloudy) IR radiances were simulated from NR. Clear radiances were selected as done operationally (residual cloud contamination is possible).
- Background check done once for all (same data assimilated in all cycles).

About 4M obs simulated & assimilated
(all those of the operational system)

- Conventional
  - radiosondes & dropsondes, aircrafts
  - surface reports, buoys, ships
  - wind profilers
- Satellite
  - AMVs from Modis Terra/Aqua, 5 GEOs
  - scatterometrer surface ocean winds
  - AMSU-A/B, MHS from 8 satellites
  - hyperspectral IR from AIRS & IASI
  - GEO water vapor channel from 5 satellites
  - GPSRO refractivity from 9 satellites

Simulation and assimilation setups

- Assimilation model and system:
  - Operational Global Environmental Multi-scale model (GEM)
    - 801x600 (~35 km), 80 levels, top 0.1 hPa
  - 3D-VAR assimilation, FGAT (First Guess at Appropriate Time)
  - Cycle starts from 5-day forecast from NR

- ECMWF NR interpolated to GEM grid for validation purposes

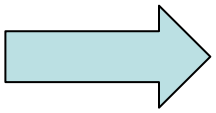
Observation perturbations

- Perturbations applied to the simulated observations using Gaussian-distributed random errors
- No applied spatial or inter-channel error correlations.
- No applied biases
- Calibration of OSSE:
  - Perturbation is simple multiplier of assigned observation error STD for each data type to get (O-A), (O-F) statistics similar to real corresponding statistics

Ref: Rochon et al., 2012, this conference

Wind errors assigned in assimilation in comparison to AMV MVD errors

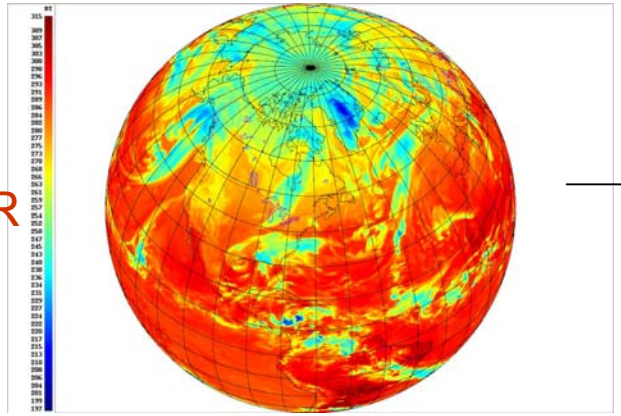
Level hPa	Raob m/s	AMDAR m/s	AMV m/s	(O-F) AMV MVD 60-90N	20-60N (m/s)
1000	1.6	2.6	3.0	----	---
925	1.7	2.6	3.0	----	1.8
850	1.7	2.6	3.0	----	1.8
700	1.8	2.6	3.5	2.7	3.2
500	2.0	2.6	4.5	2.7	3.2
400	2.2	3.1	5.0	3.2	3.2
300	2.6	3.1	5.5	3.2	3.6
250	2.6	3.1	6.0	3.2	3.6
200	2.3	3.1	6.0	3.2	3.6
150	2.1	3.1	6.0	3.2	3.6
100	1.9	3.1	6.0	3.2	3.6

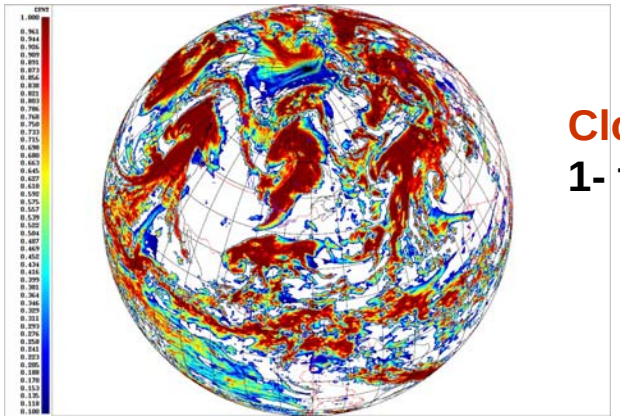


- AMV error inflated in relation to (O-F)
- polar MDV lower than extratropics MVD
- perturbation is 0.28 AMV obs error

Simulated AMV: NR wind at NR cloud top

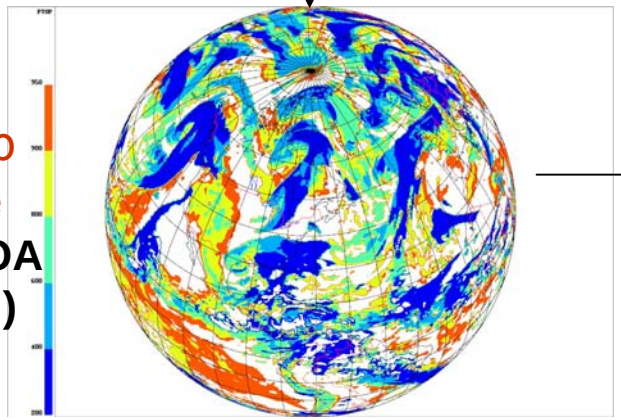
11m BT
From NR

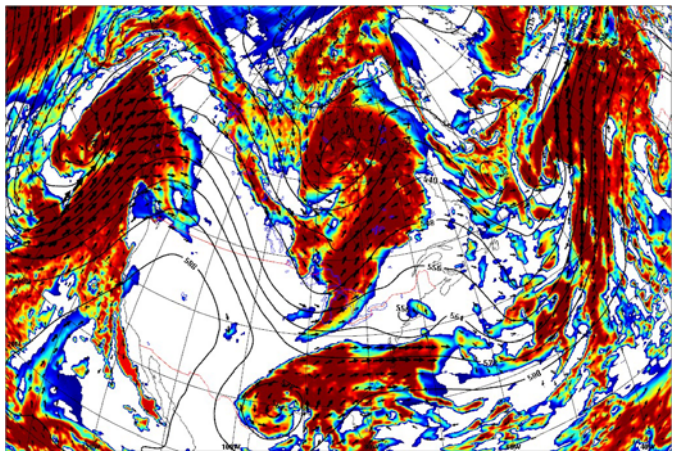




Cloud fraction
1- tau(cloud)

Cloud top
Pressure
Where TOA
tau(cloud)
=0.9





AMV
NR wind
At cloud
top

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Ref: Garand et al, Atmosphere-Ocean, 2011.

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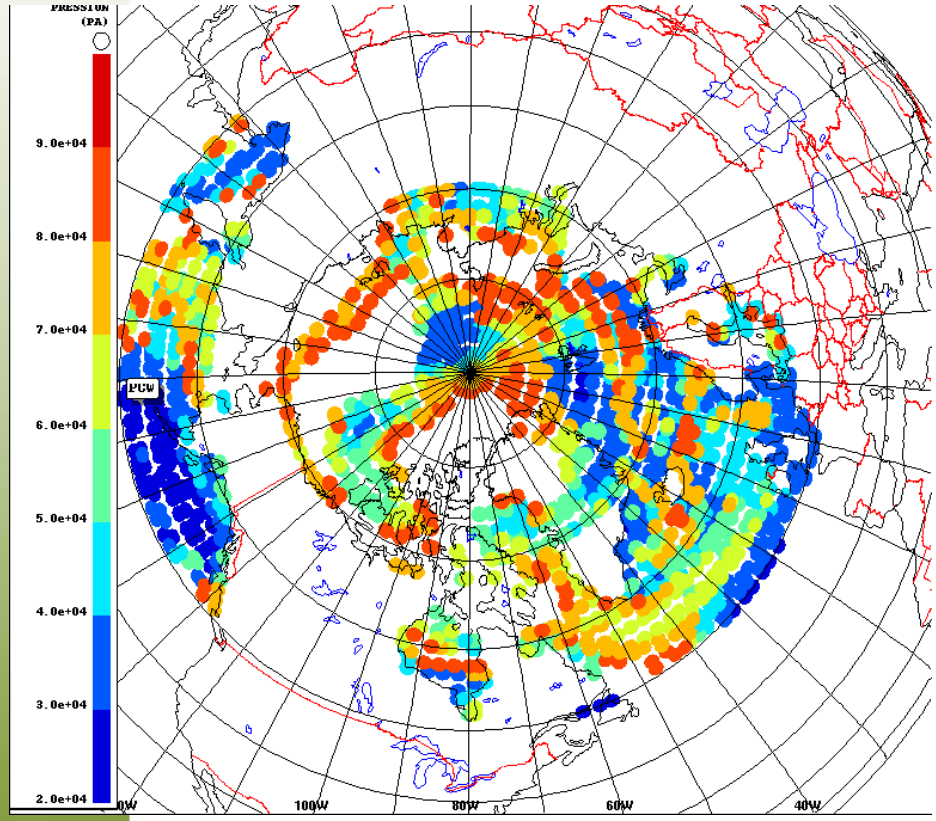
PCW AMV used in assimilation



- thinning at 180 km
- no data where cloud free
- 50-90 N coverage
- allowed range 250-850 hPa
- every 6-h
- ocean only 50-70 N
- same obs error for all AMVs

Conditions similar to operational AMVs except +-3-h window for OPE and range 100-700 hPa

Definition of OSSE cycles (3dvar)

OSSE cycles

Comparing current OPE with OPE+ PCW AMV:

- PR10: mimics complete OPE system
  includes GOES and MODIS AMVs
- PCWS: PR10 + PCW AMVs

Comparing NOAMV to adding PCW AMV:

- EXP1: PR10 without AMV (no IR radiances by mistake)
- EXP2: EXP1 + PCW AMVs (no other AMVs)
- EXP3: EXP2 with AMV obs error X 0.7

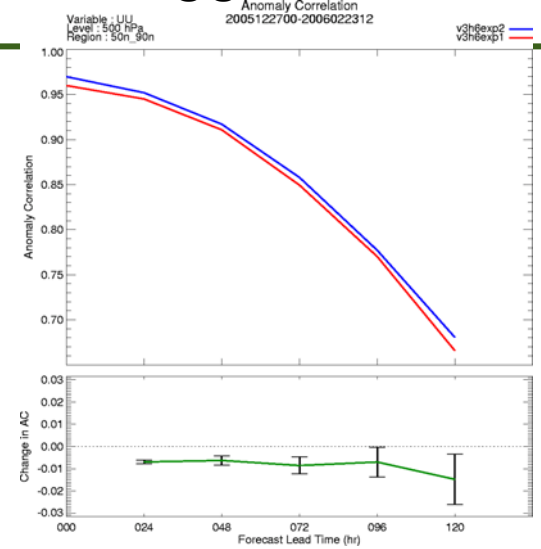
* EXP1 to be redone with IR radiances assimilated for comparison to PR10 and equivalent denial experiences done with real data

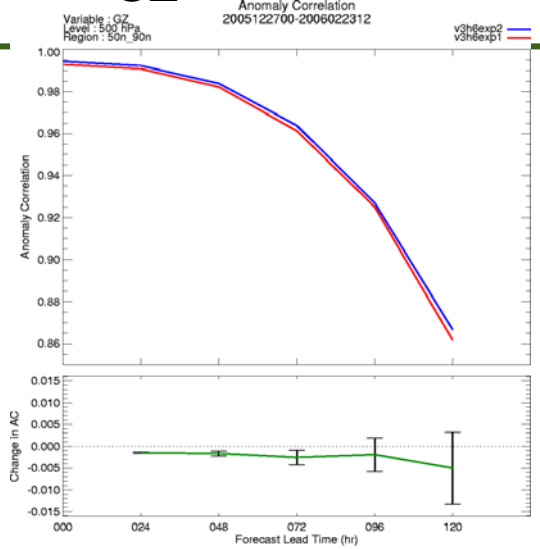
500 hPa anomaly correlation (vs NR)

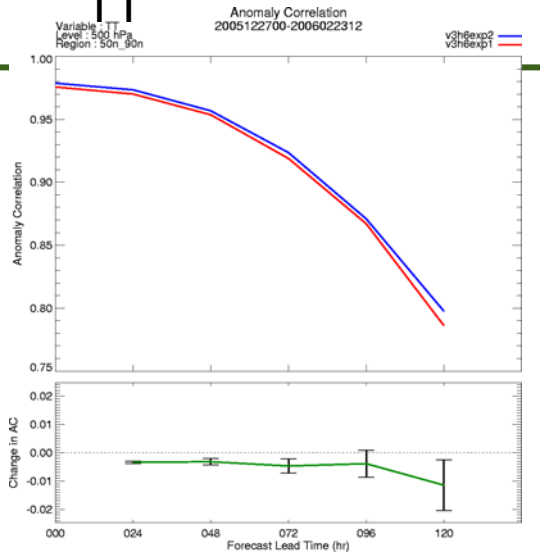
No-AMV PCW-AMV

UU GZ TT

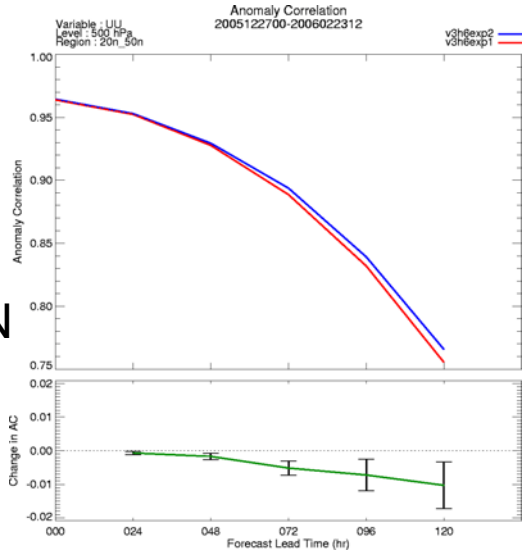
50-90 N

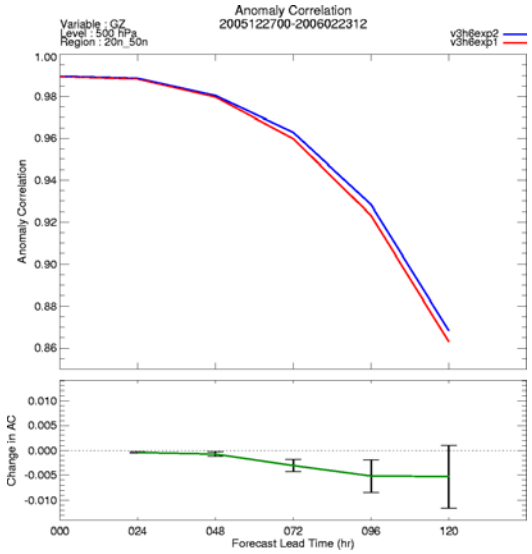


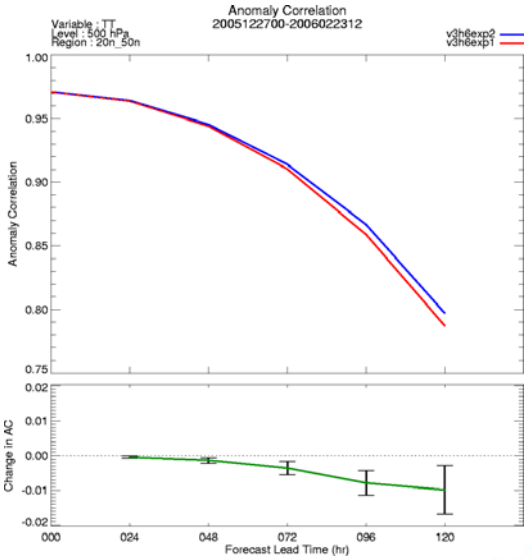




20-50 N







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Impact extends to 20-50N region!

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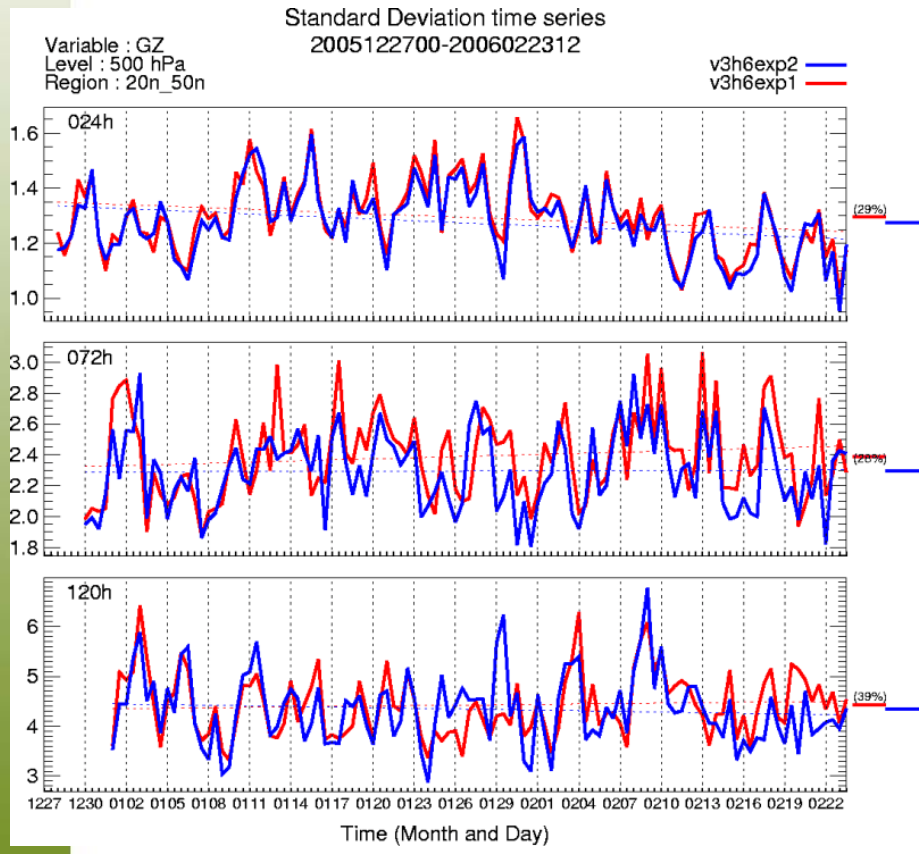
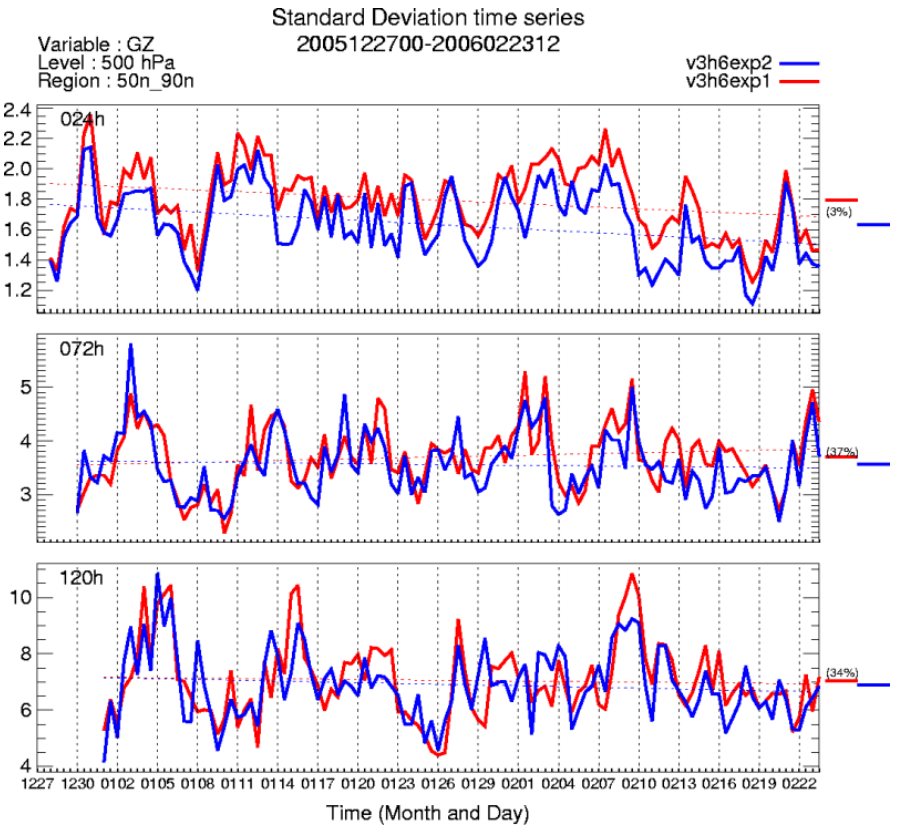
Time series of 500 hPa GZ STD vs Nature Run

NO-AMV PCW-AMV

20-50 N



50-90 N



Impact as strong in 20-50 N region than 50-90 N 72h-120h

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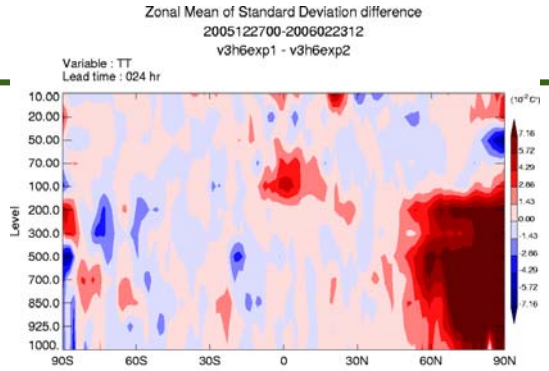
Zonal mean of std difference for temperature

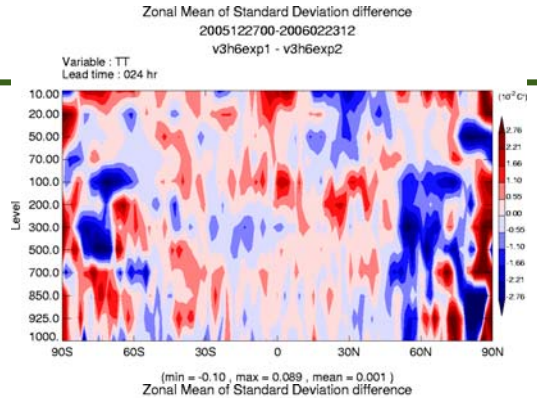
No-AMV - PCW-AMV

Vs Nature run

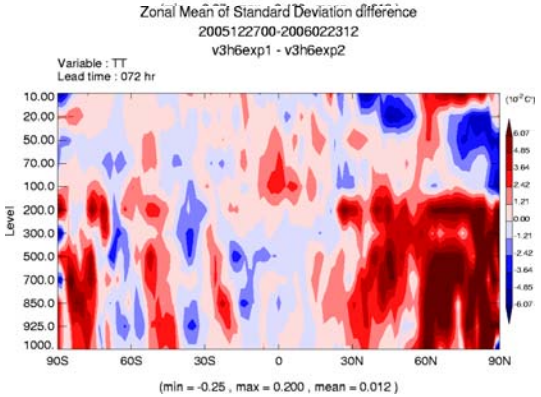
vs own analysis

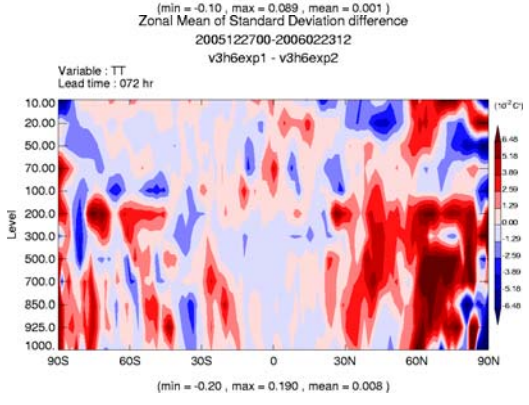
24-h



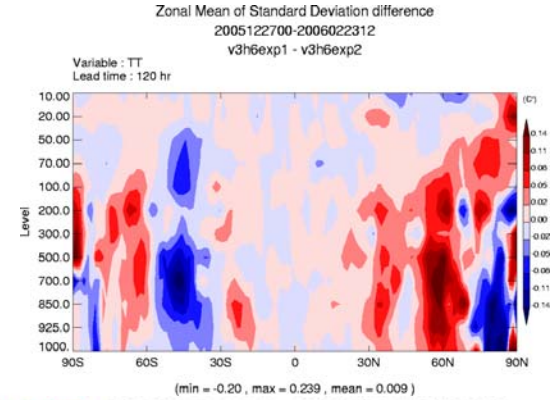


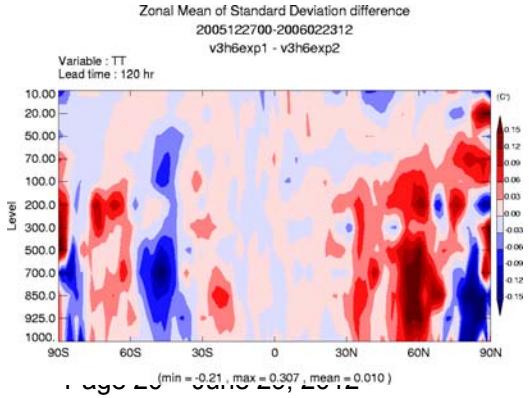
72-h





120-h





Results differ significanly early In forecast

Results get much closer with time

Positive impact spreads to lower latitudes (red)

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Comparing results vs own analysis and vs NR (50-90 N)

NO_AMV-PCW_AMV

VS OWN ANALYSIS

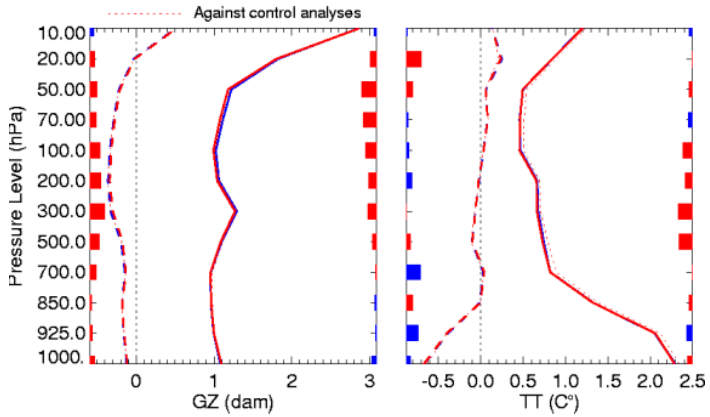
Verification against analyses
2005122700-2006022312

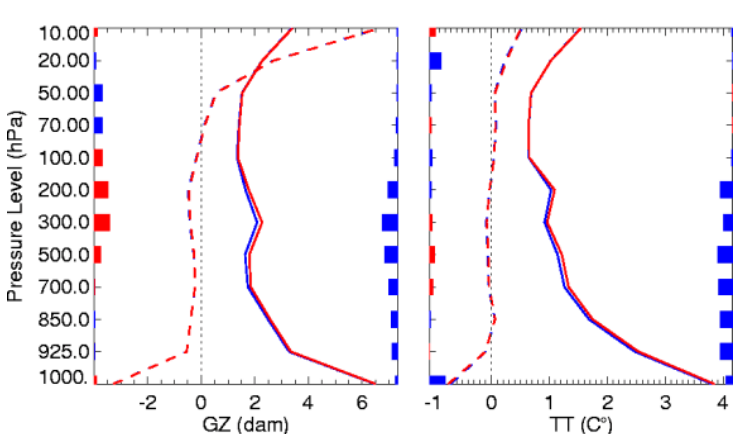
VS NR ANALYSIS

Lead time : 024 hr
Region : 50n_90n

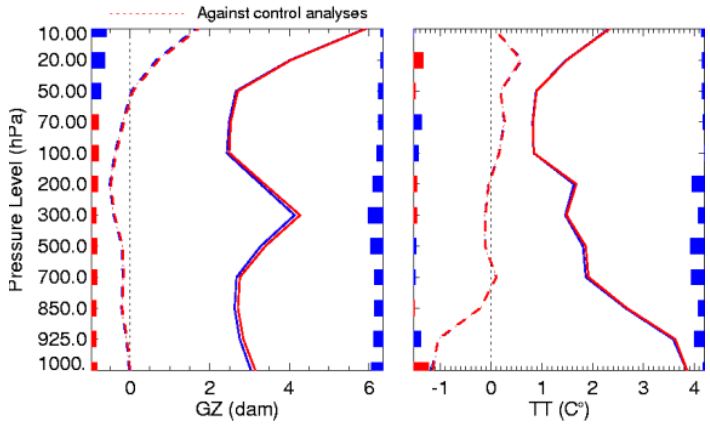
v3h6exp2
v3h6exp1

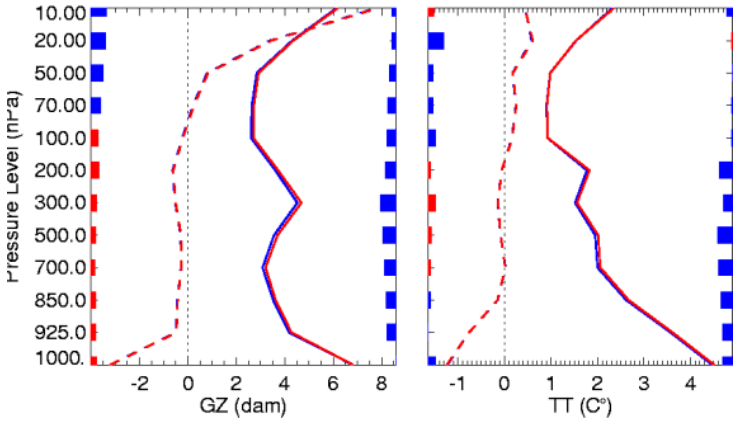
24-h





72-h

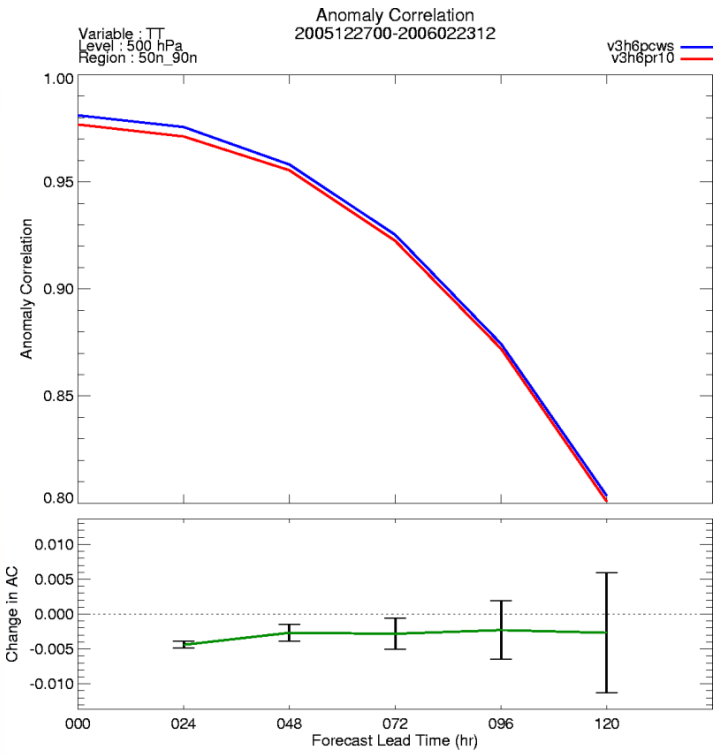




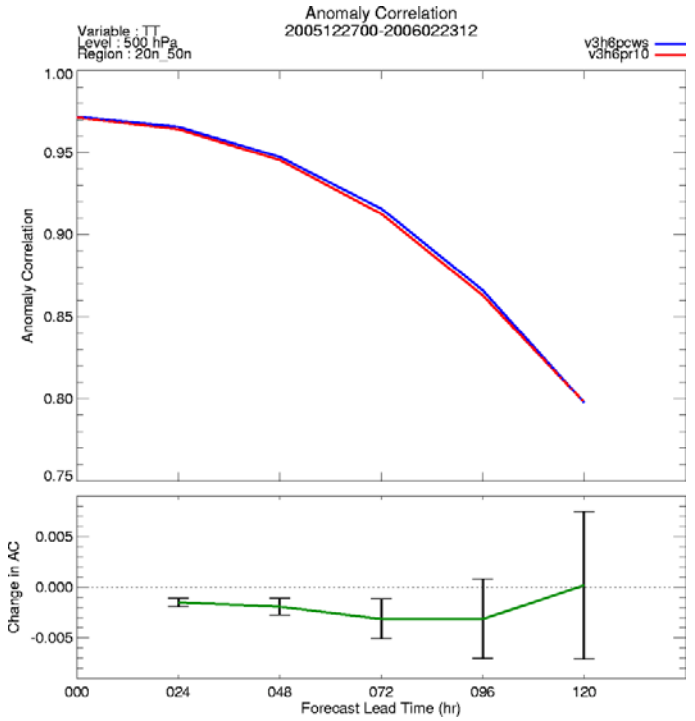
Comparing Simulated OPE to OPE+PCW_AMV

(against NR)

50-90 N



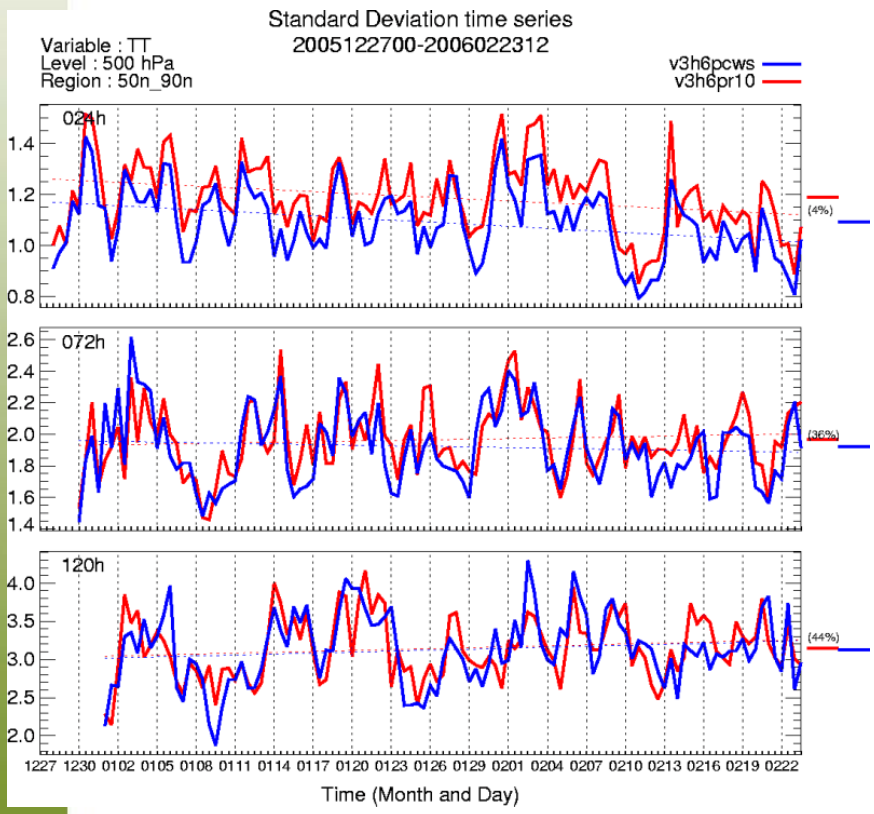
20-50 N



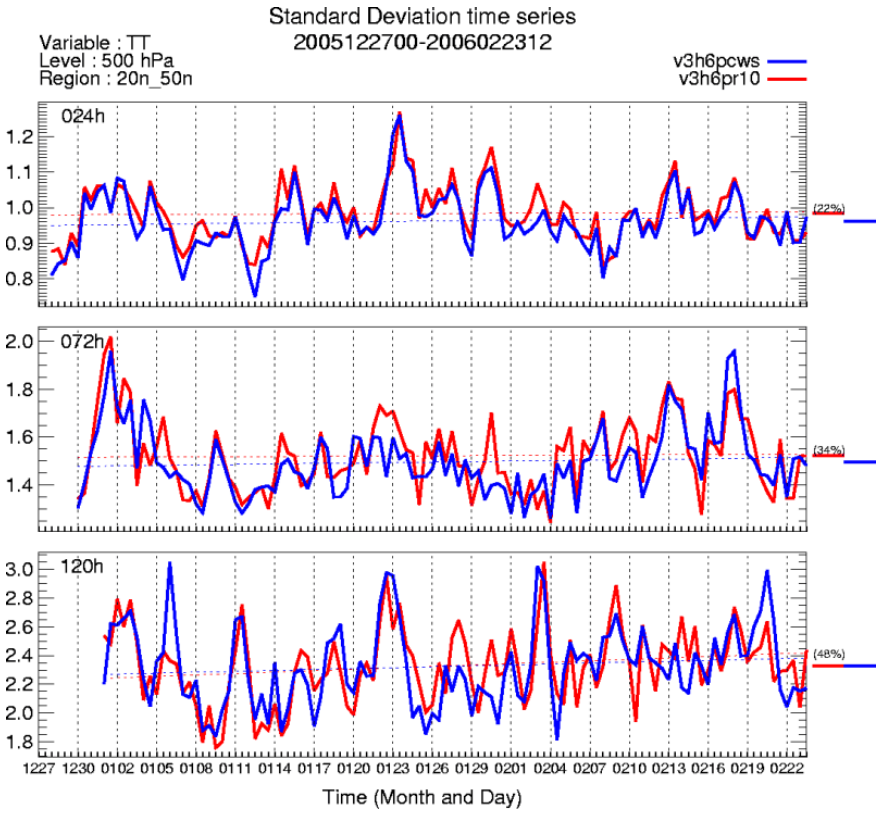
Significant gain up to day 3 of ~2h in both regions

Comparing Simulated OPE to OPE+PCW_AMV (against NR) 500 hPa temperature

50-90 N



20-50 N



Gain a 72-h in both regions linked to specific good cases

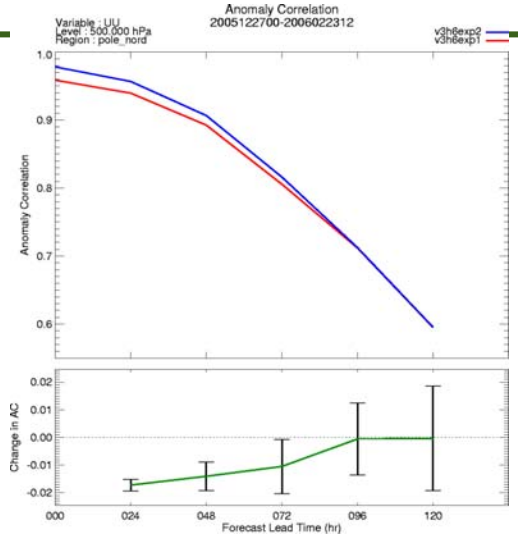
Impact of reducing AMV observation error (500 hPa UU anom-corr)

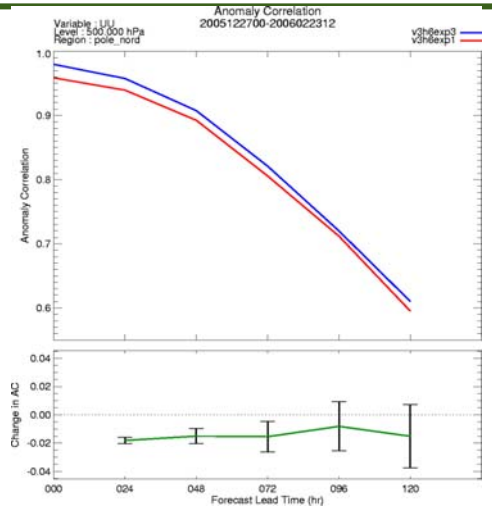
Nominal AMV error

AMV error x 0.7

NO-AMV PCW-AMV

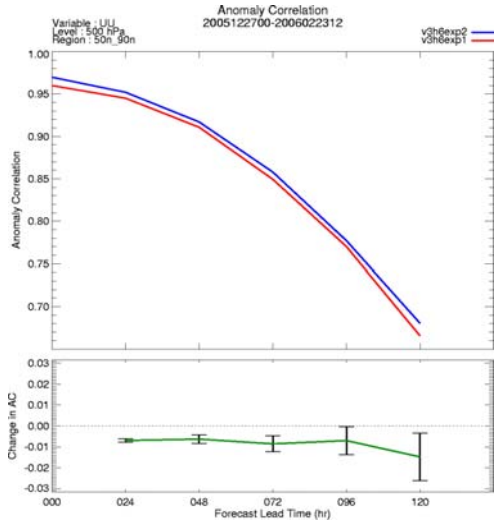
70-90 N

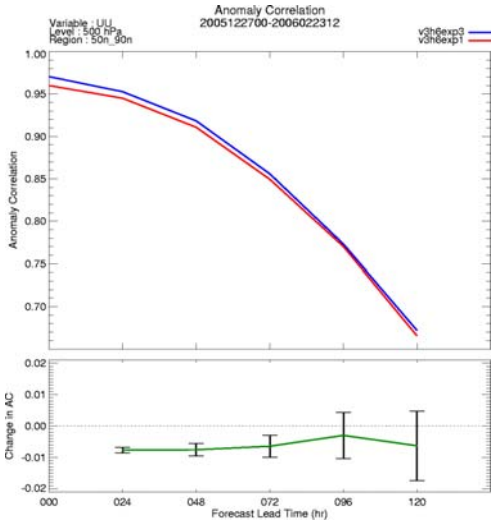




Lower AMV error improves score

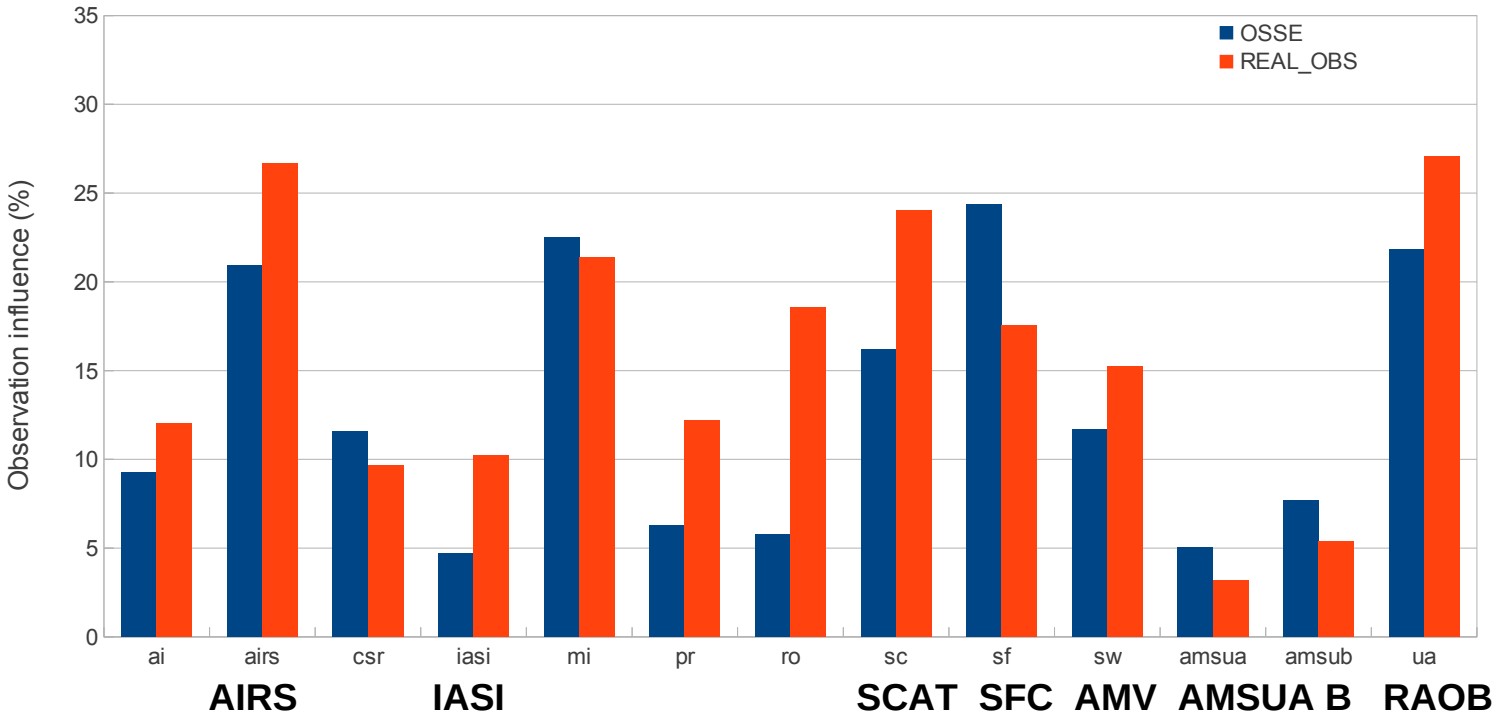
50-90 N





Lower AMV error degrades score

Examination of DFS (% of total per type)



OI (%) = 100 * DFS_k/P_k (Courtesy P. Du, P. Gauthier)

Conclusion

- A comprehensive OSSE setup was developed which proves useful fo infer added value of HEO AMVs
- OSE: Real AMVs have modest but consistent positive impact at all latitudes in OPE system up to day 4.
- OSSE: adding PCW AMVs has a significant positive impact up to day 3, not only in region of PCW data (50-90 N) but in midlatitudes as well (20-50 N).
- Validation vs NR or own analysis consistant after day 2
- Gain of predictability of order 1-3h at day 3 in region 20-90 N.