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OSSE to infer the impact of Arctic AMVs extracted from highly elliptical orbit imagery

L. Garand[1]

Y. Rochon[1], S. Heilliette[1],

J. Feng[1], A.P. Trishchenko[2]

[1]Environment Canada, [2]Canada Center for Remote Sensing

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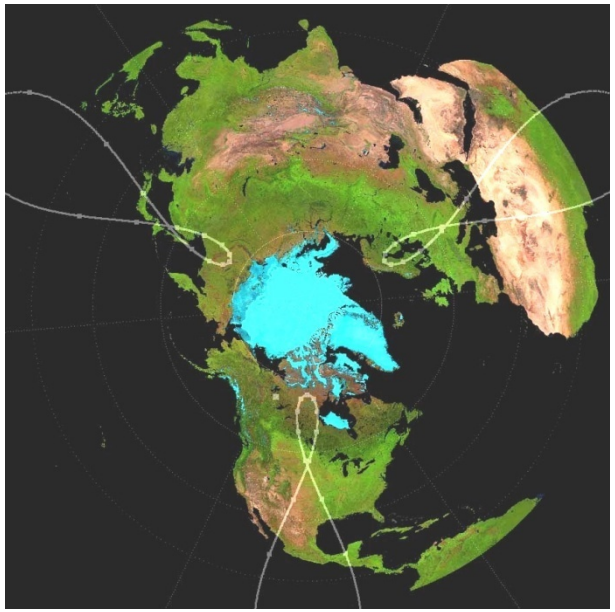
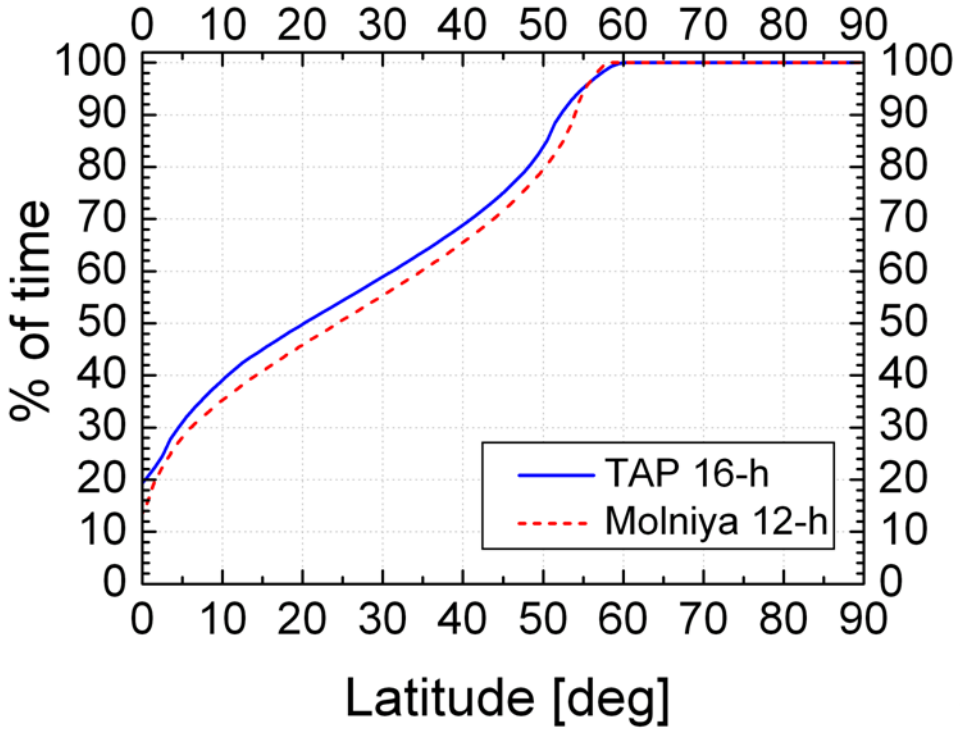
Polar Communications and Weather (PCW) mission in a few words

- 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

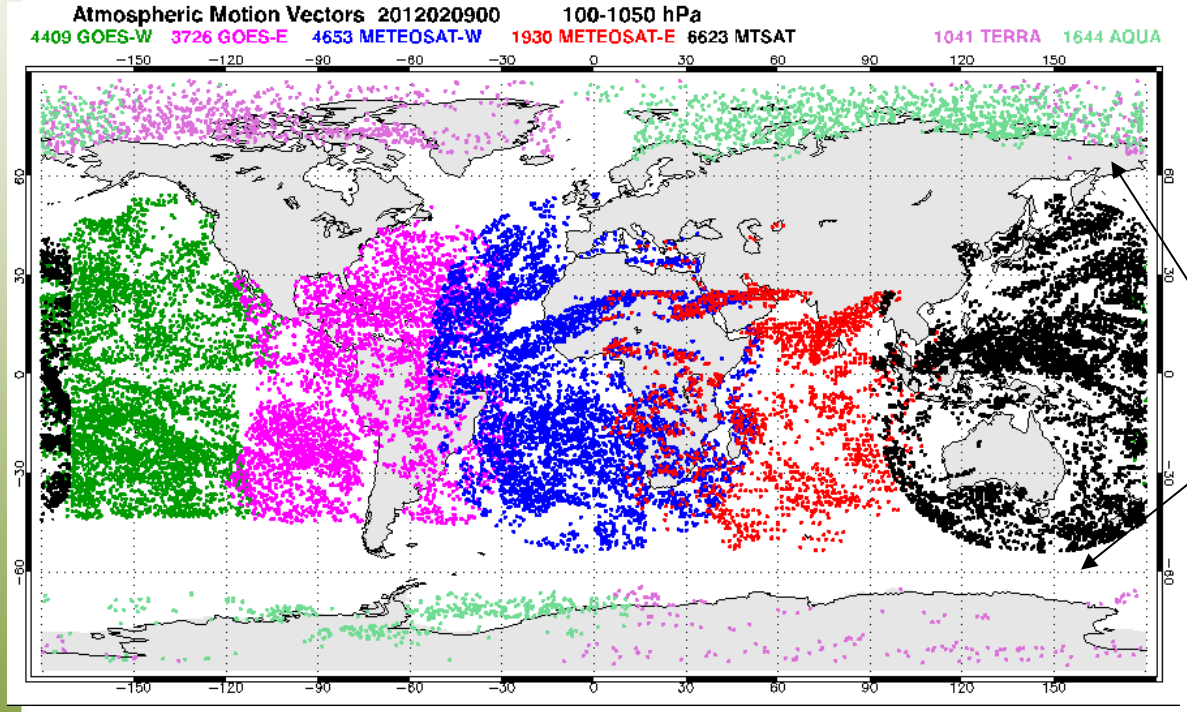
16-h 3-apogee (TAP) ground track



spatio-temporal coverage vs latitude



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

Other questions of interest for current AMV assimilation:

- To what extent can we assimilate AMV over land?
- Sensitivity to observation error

Nature RUN "truth" for OSSE

- Nature Run:
  - provided by ECMWF as contribution to the international Joint OSSE program (e.g. Reale et al., 2007; Masutani et al., 2008; http://www.emc.ncep.noaa.gov/research/JointOSSEs)
  - ECMWF (Cy31r1 cycle) free forecast run at triangular 511 spectral truncation (~40 km) and 91 eta levels with the top at 0.02 hPa (~80km)
  - Model details are provided at http://www.ecmwf.int/research/ifsdocs/CY31r1

Control observation sets

- 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).

Sources of meteorological observations to be assimilated, excluding radiances

Observing network	Atmospheric Variables	Applied resolution and or coverage (after thinning)	Approximate number of observations per 6h
Radiosondes/dropsondes	U, V, T, (T-Td), Ps	28 vertical levels	~750 stations (<1000) usually for 00 and 12UTC
Surface reports (ground stations, ships and buoys)	T, (T-Td), Ps, U and V over water	1 report / 6h	~6 000
Wind profilers (NOAA network of UHF radars)	U, V	0.5 km to 16 km vert. range with a 750 m vert. resol.	35 sites
Aircrafts	U, V, T, humidity	1° x1° x 50 hPa covers 100 - 1025 hPa	~14 000 to 22 000
GPS RO micro satellites (COSMIC (6), GRACE, METOP, CHAMP)	T, humidity	~1 km to 40 km vert. range with a 830 m vert. resol.	~600 profiles
Scatterometer winds from the SeaWinds microwave radar (13.4GHz) on the Quikscat polar-orbiter	Ocean surface U,V	–	~10 000
AMVs from MODIS on TERRA and AQUA (polar orbiting)	U,V over water (+land in tropics)	~180km for polar winds 550-700hPa range	~2 500
AMVs from 5 GEO sats	U,V over water (+ land in tropics)	1.5° x1.5° 400-700 hPa range	~14 000 to 26 000

Radiance observations

Instrument	Platform	Number (one typical day)	Orbit	Channels used	Target variable
AMSU-A (ATOVS)	NOAA-15	338 000	Polar	Ch. 3-14 over ocean Ch. 6-14 over land	T
	NOAA-18	472 000			
	AQUA	332 000			
AMSU-B (ATOVS)	NOAA-15	41 000		Ch. 2-5 over ocean Ch. 3-4 over land	q
	NOAA-16	84 000			
	NOAA-17	93 000			
MHS	NOAA-18	96 000			
SSMI	DMSP-13	61 000		Ch. 1-7 for *cloud-free* regions over the ocean	q and surface wind
SSMIS	DMSP-16	39 000			
AIRS	AQUA	660 000		87 channels with peak below 150 hPa (650-2100 cm^{-1}) - cloud-free pixels	T, q, surface and clouds
IASI	METOP-2	501 000		62 channels with peak below 150hPa (650-770 cm^{-1}) - cloud-free pixesl	T, surface and clouds
GOES imagers	GOES-11	35 000	Geo-stationary (GEORAD)	One channel per instrument in the 6.2 to 6.8 microns range -Cloud-free pixels	q
	GOES-12	42 000			
MVIRI	METEOSAT-7	69 000			
SEVIRI	METEOSAT-9 (MSG-2)	42 000			
MTSAT-01	METSAT-1R	21 000			

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

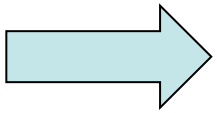
Applied observation perturbations: Standard deviation scaling factors

Observation family		Scaling factor
Upper air data		0.92
Aircraft		0.56
Wind profilers		0.58
Surface observations		0.51
Cloud drift winds (AMVs)		0.28
GPS-RO		*1.0*
SBUV/2 and MLS ozone		*0.6*
IASI	METOP-2	0.77
AIRS	AQUA	0.31
AMSU-A	AQUA	0.44
	NOAA15	0.34
	NOAA16	0.34
	NOAA18	0.41
AMSU-B	NOAA15	0.60
	NOAA16	1.25
	NOAA17	0.36
MHS	NOAA18	0.30
SSMI	DMSP13	0.32
SSMIS	DMSP16	0.21
GOES	GOES11	0.08
SEVIRI	METEOSAT9	0.21
MVIRI	METEOSAT7	0.19
GMSMTSAT	MTSAT-01	0.23

Perturbation level is less than assigned obs error, the latter being inflated in assimilation

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



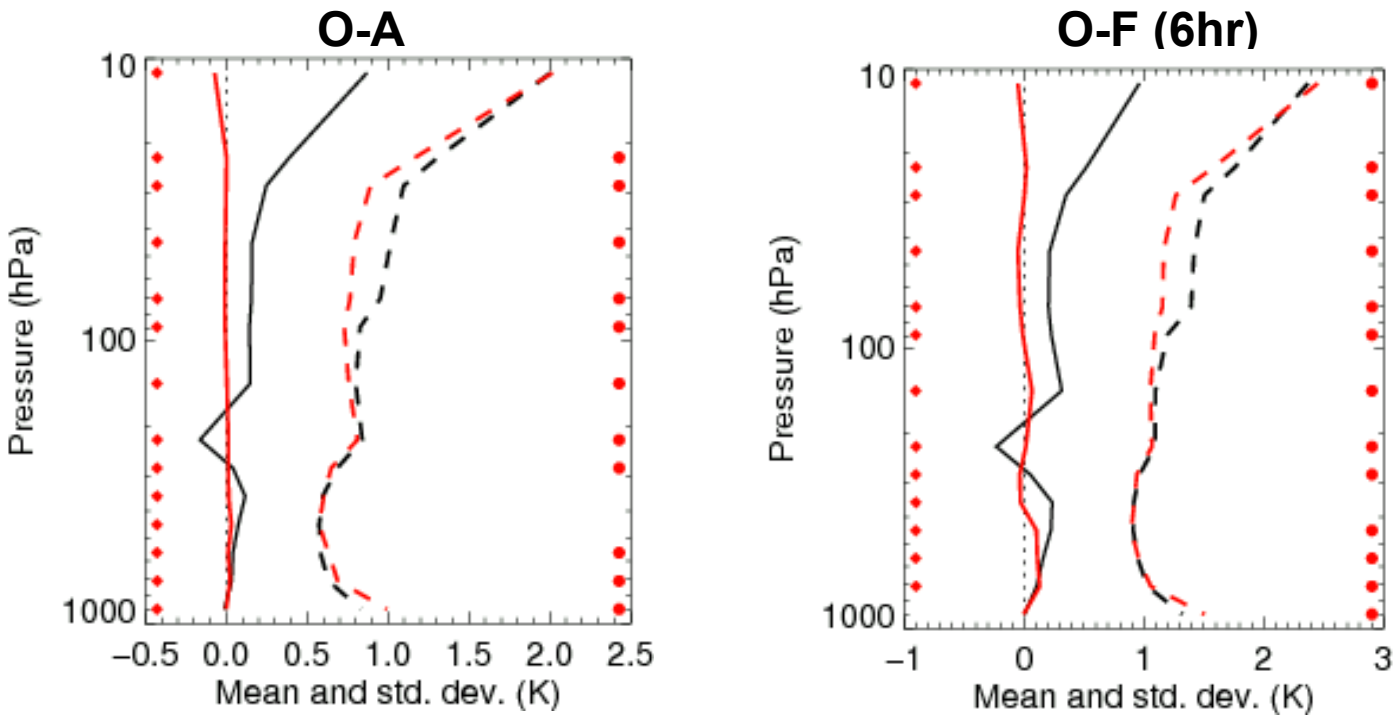
- AMV error inflated in relation to (O-F)
- polar MDV lower than extratropics MVD
- perturbation is 0.28 AMV obs error

Comparisons of *calibrated* control to real obs. assimilations: Comparisons to radiosondes (January)

Temperature

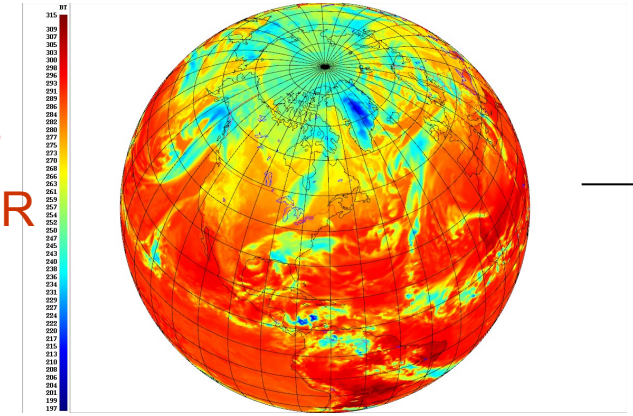
Black: real obs.
Red: OSSE control

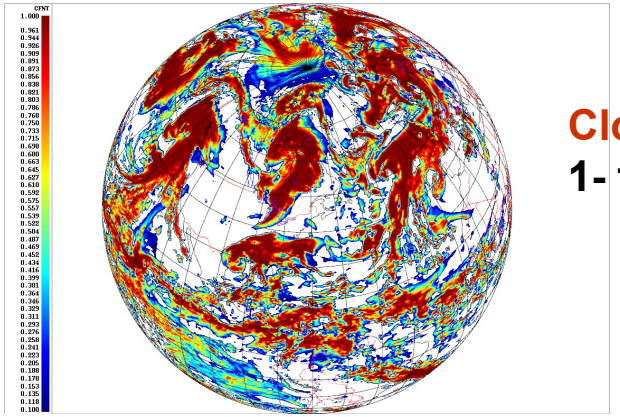
mean diff.: solid
std. dev.: dashed



Simulated AMV: NR wind at NR cloud top

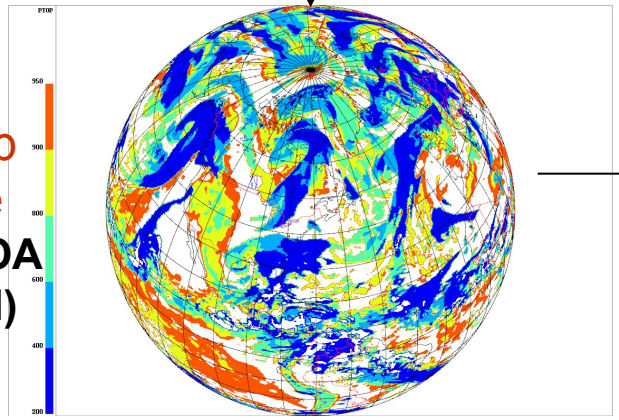
11m BT
From NR

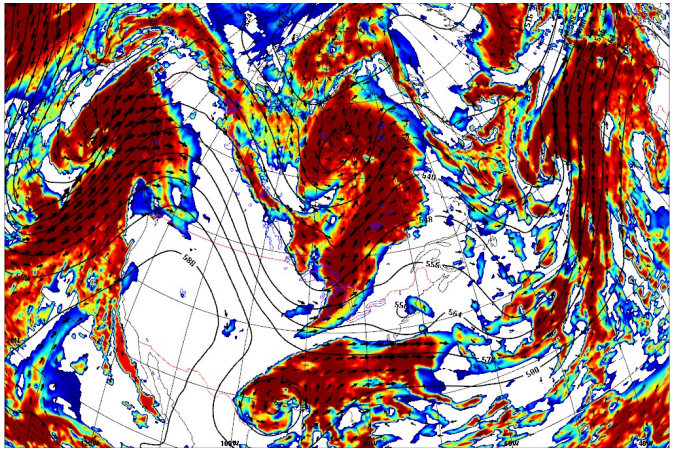




Cloud fraction
1- tau(cloud)

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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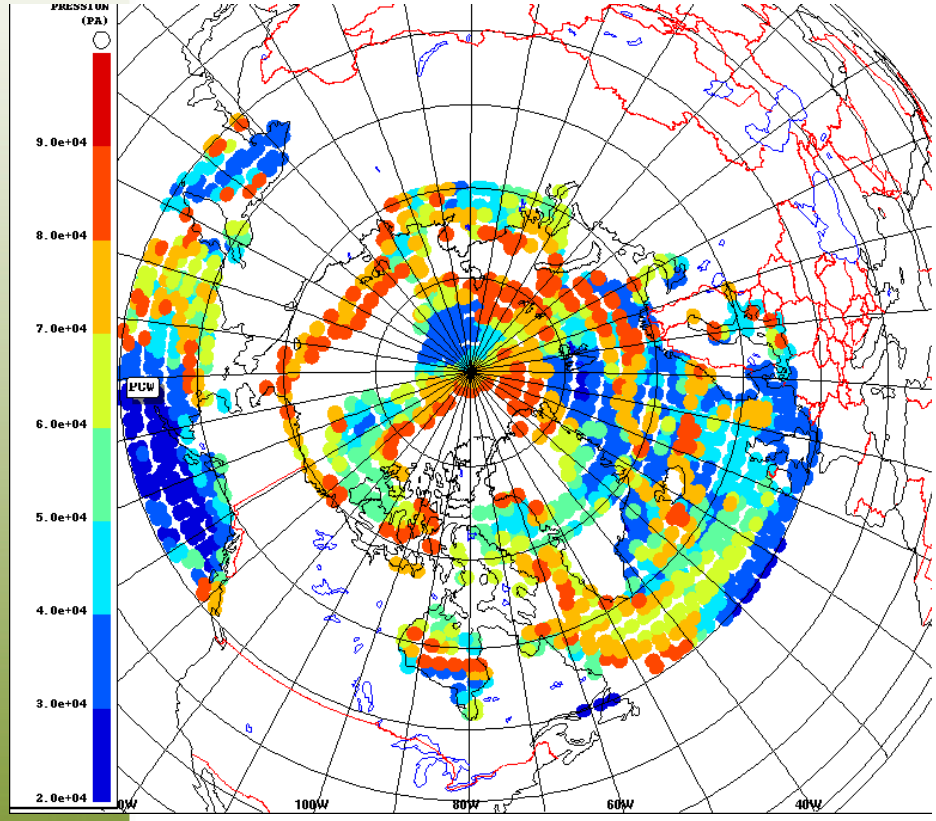
PCW AMV used in assimilation



- thinning at 180 km
- 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

- EXP1: no AMV, all other data types assimilated
- EXP2: EXP1 + PCW AMVs (50-90 N)
- EXP3: EXP2 with AMV error reduced (x 0.7)
- PR10: mimics OPE system

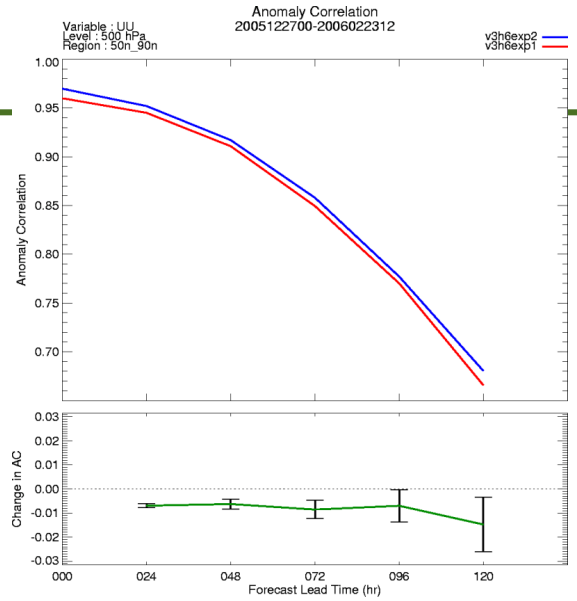
- Later: cycles with/without real AMVs to confirm realism on impact magnitude

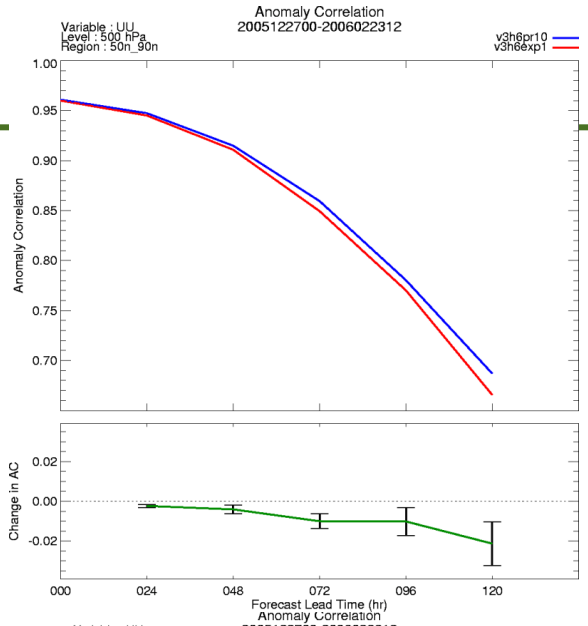
500 hPa UU anomaly correlation (vs NR)

No-AMV PCW-AMV

No-AMV OPE-AMV

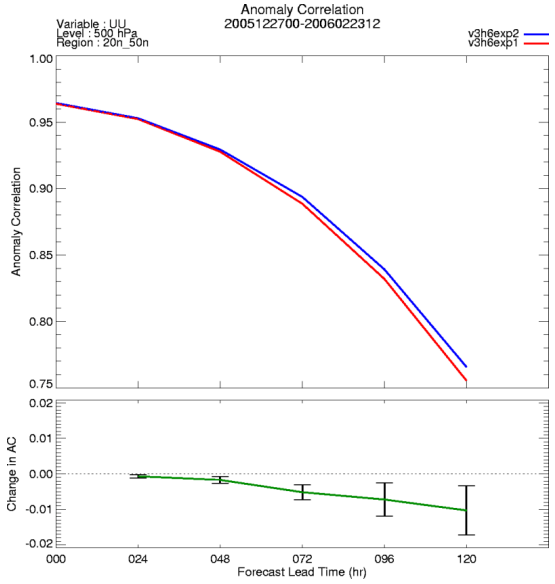
50-90 N

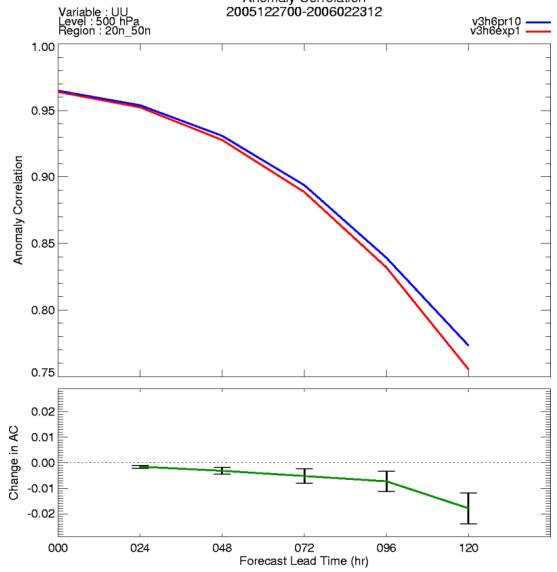




Impact of PCW better early OPE better days 4-5

20-50 N



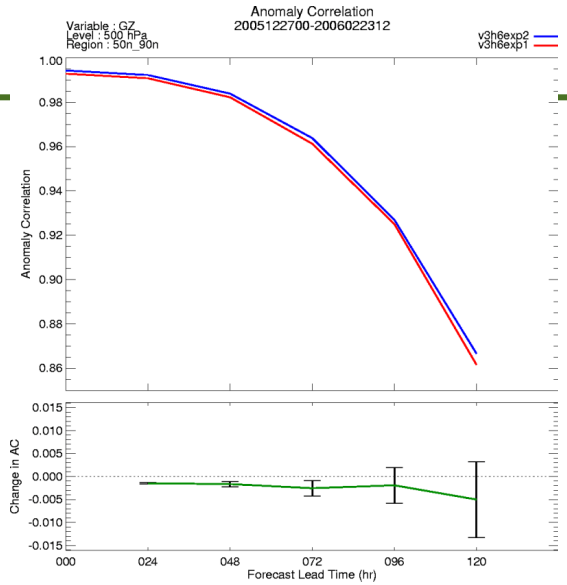


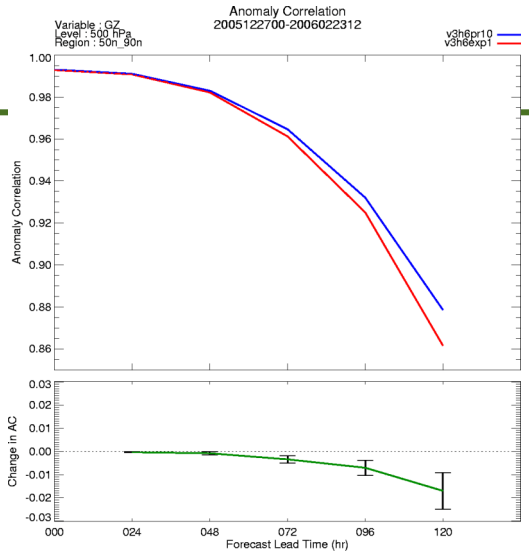
Impact of PCW stronger than OPE up to 96-h

500 hPa GZ anomaly correlation

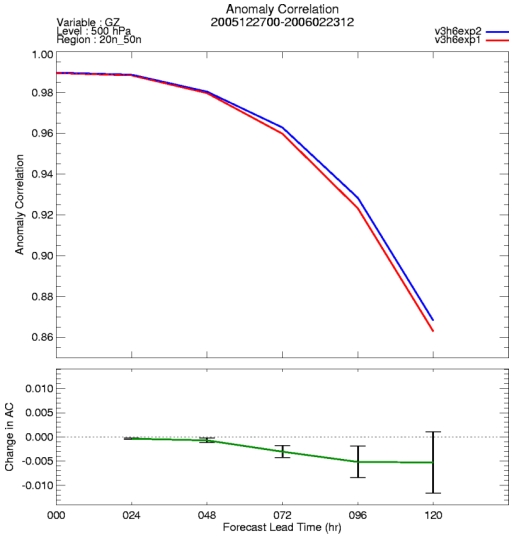
No-AMV PCW-AMV | **No-AMV OPE-AMV**

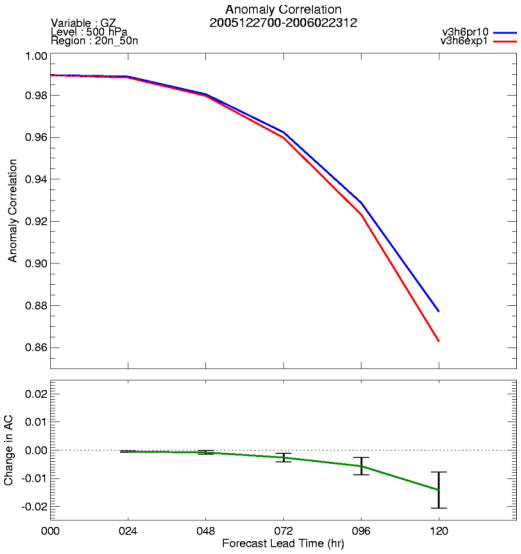
50-90N





20-50 N





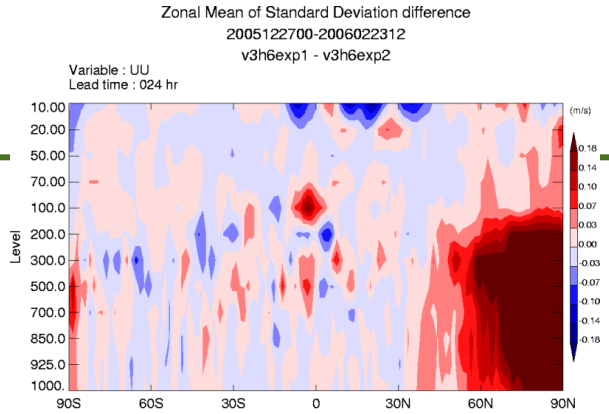
PCW has larger impact in mid-lats than in polar region!

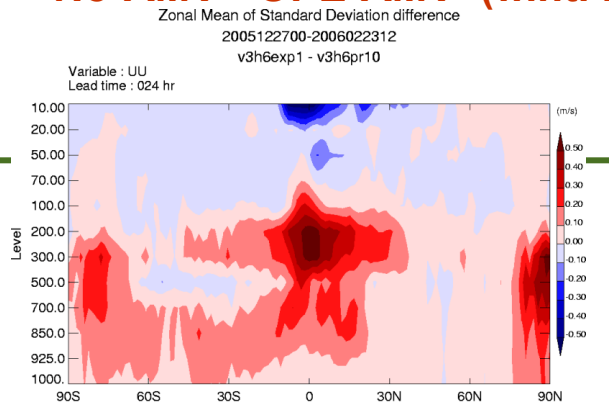
Zonal mean of std difference for meridional wind component

No-AMV - PCW-AMV

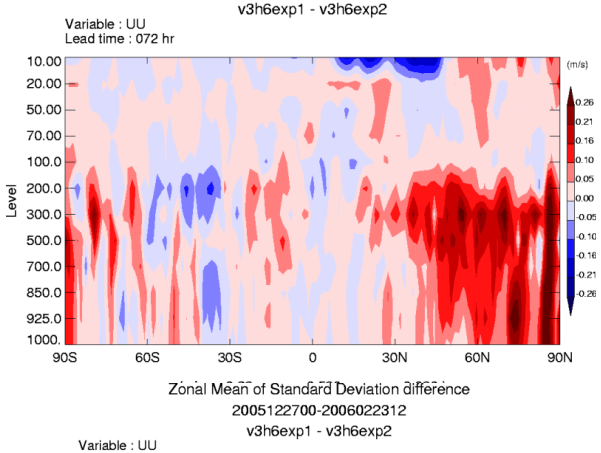
No-AMV - OPE-AMV (w.r.t. NR)

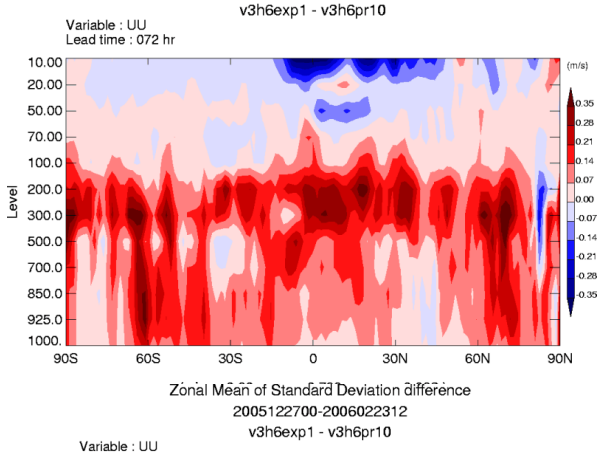
24-h



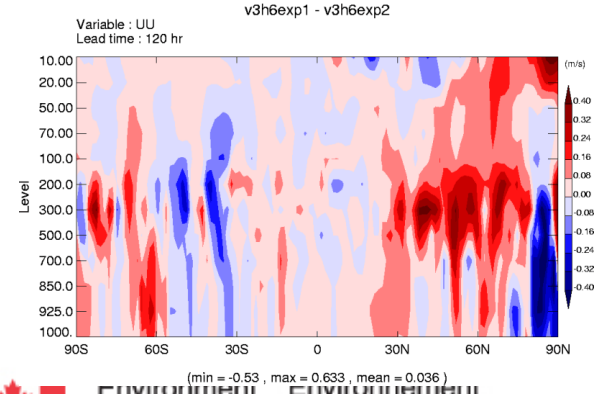


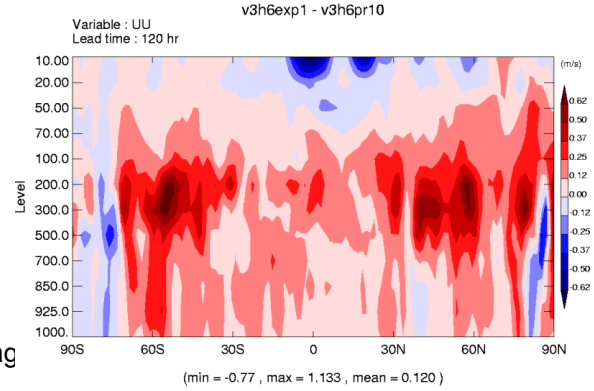
72-h





120-h





Impact of PCW AMV extends to 20 N

OPE impacts Good at all Latitudes

Largest impact of AMVs is in layer 200-500 hPa

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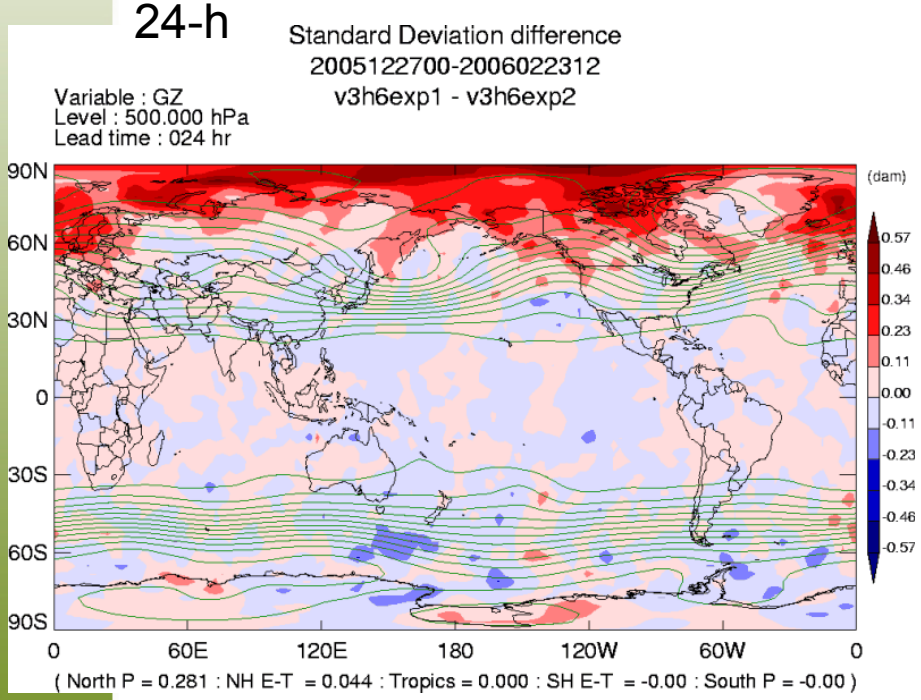
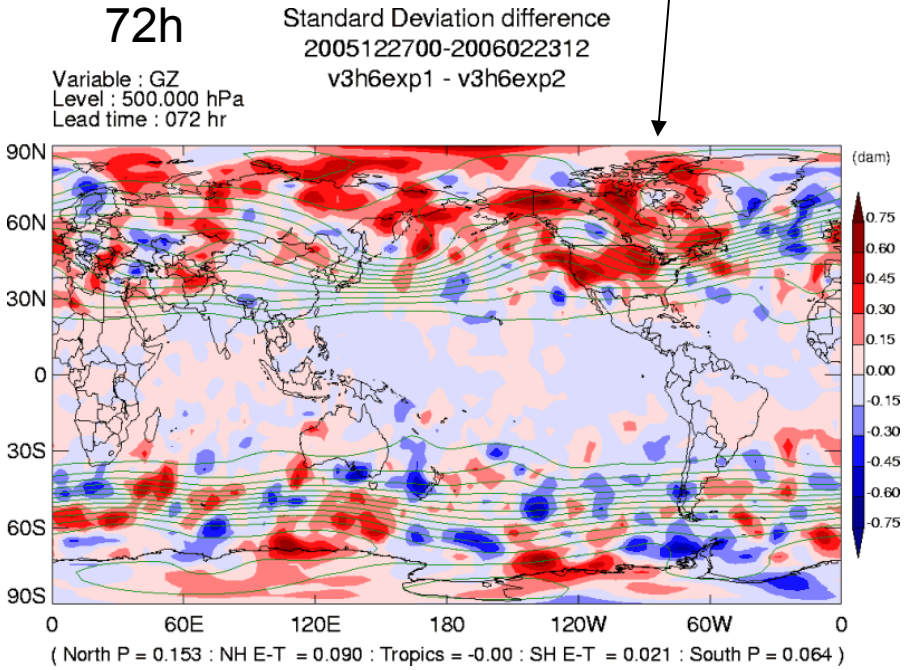
STD differences: No-AMV minus PCW-AMV (vs NR)
GZ 500 hPa

Positive impact expanding to midlatitudes

24-h



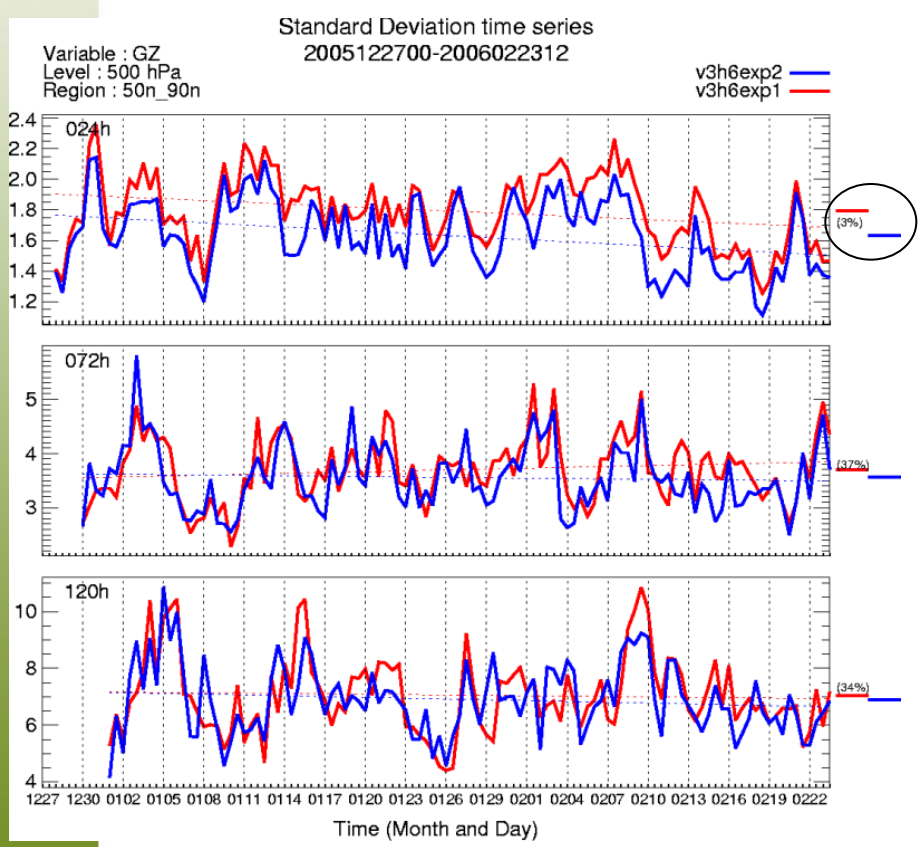
72h



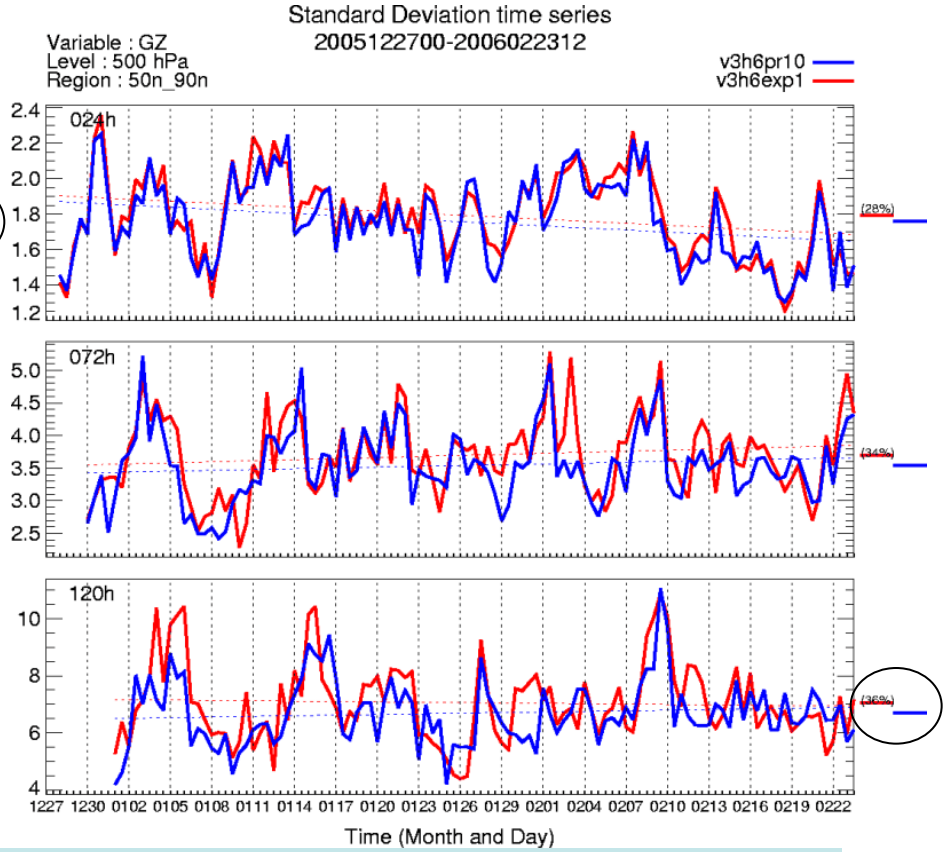
Time series of 500 hPa GZ STD vs Nature Run

50-90 N region

NO-AMV PCW-AMV



NO-AMV OPE-AMV

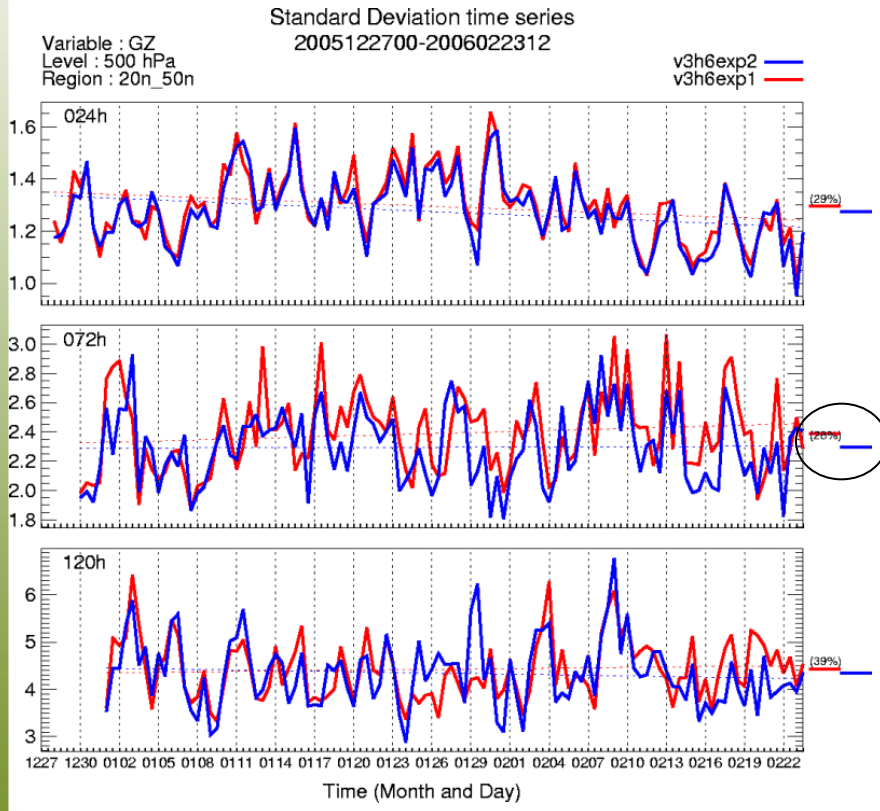


PCW impact large early in forecast, OPE (MODIS+GEO) better at 120-h

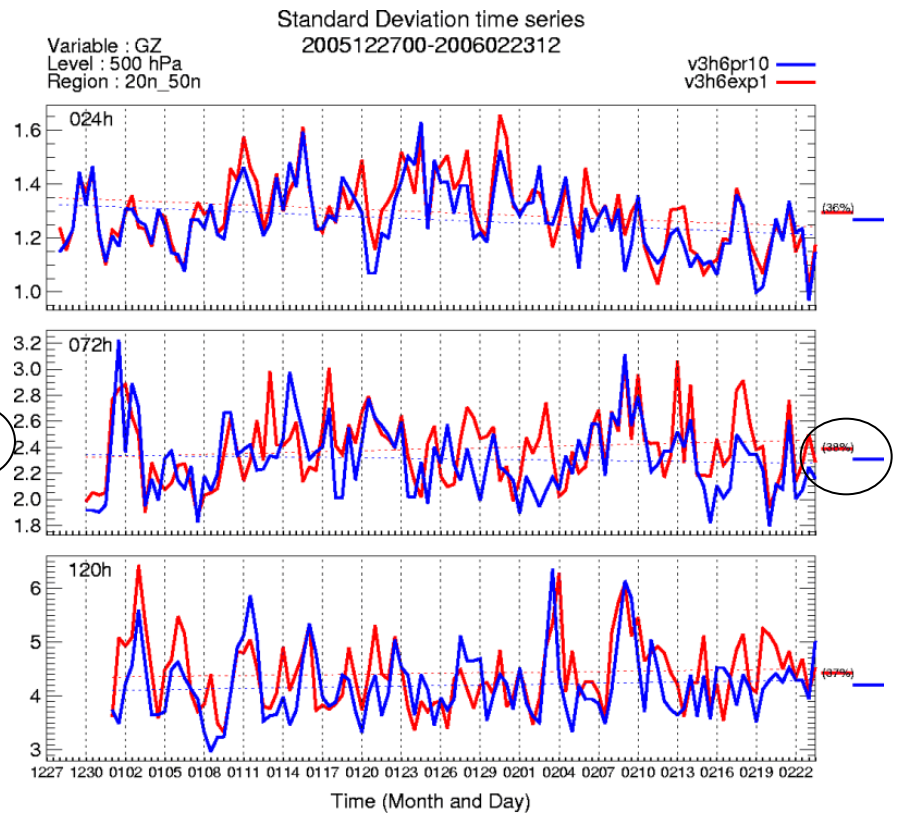
Time series of 500 hPa GZ STD vs Nature Run

20-50 N region

NO-AMV PCW-AMV



NO-AMV OPE-AMV



Impact of PCW AMV as large as OPE at 72-h

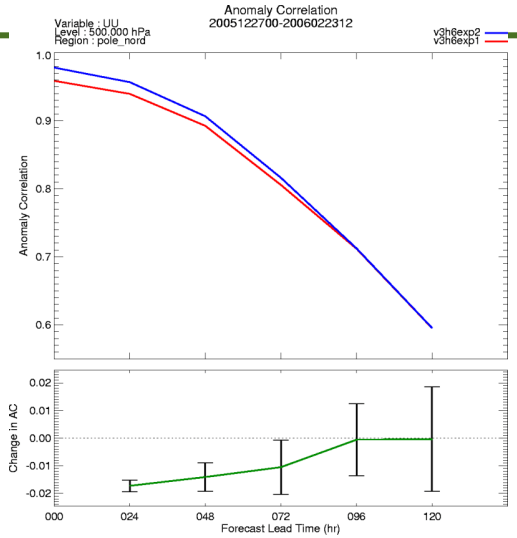
Impact of reducing AMV observation error (500 hPa UU anom-corr)

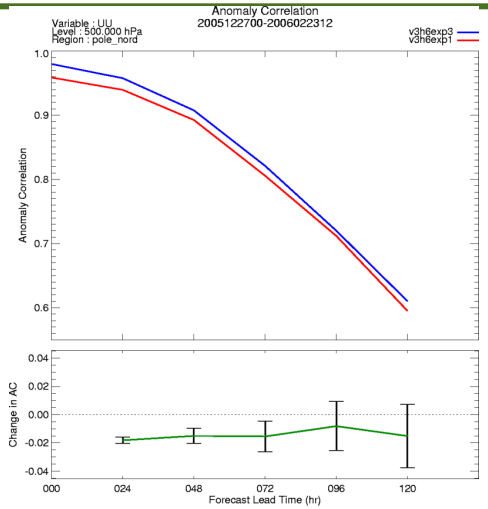
Nominal AMV error

AMV error x 0.7

NO-AMV PCW-AMV

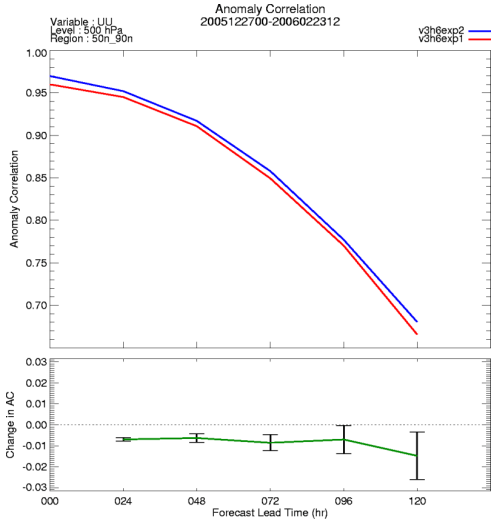
70-90 N

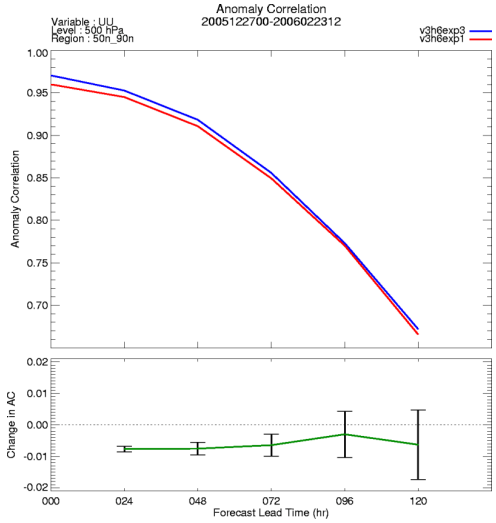




Lower AMV error improves score

50-90 N





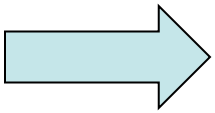
Lower AMV error degrades score

Impact of assigned obs error requires further study

Conclusion

- A comprehensive OSSE setup was developed
- PCW-AMV has stronger impact than OPE-AMV in region 50-90 N up to 48-h. OPE-AMV is better at longer lead times.
- PCW-AMV impact is as large as OPE impact in region 20-50 N up to 72-h.
- Polar AMV improves forecast in midlatitudes. Conversely GEO AMVs improves scores in polar area.
- Overall conclusion is that filling AMV gap in region 50-70 N, a key baroclinic area, is very beneficial for whole region 20-90 N, this even with data not assimilated over land below 70 N.

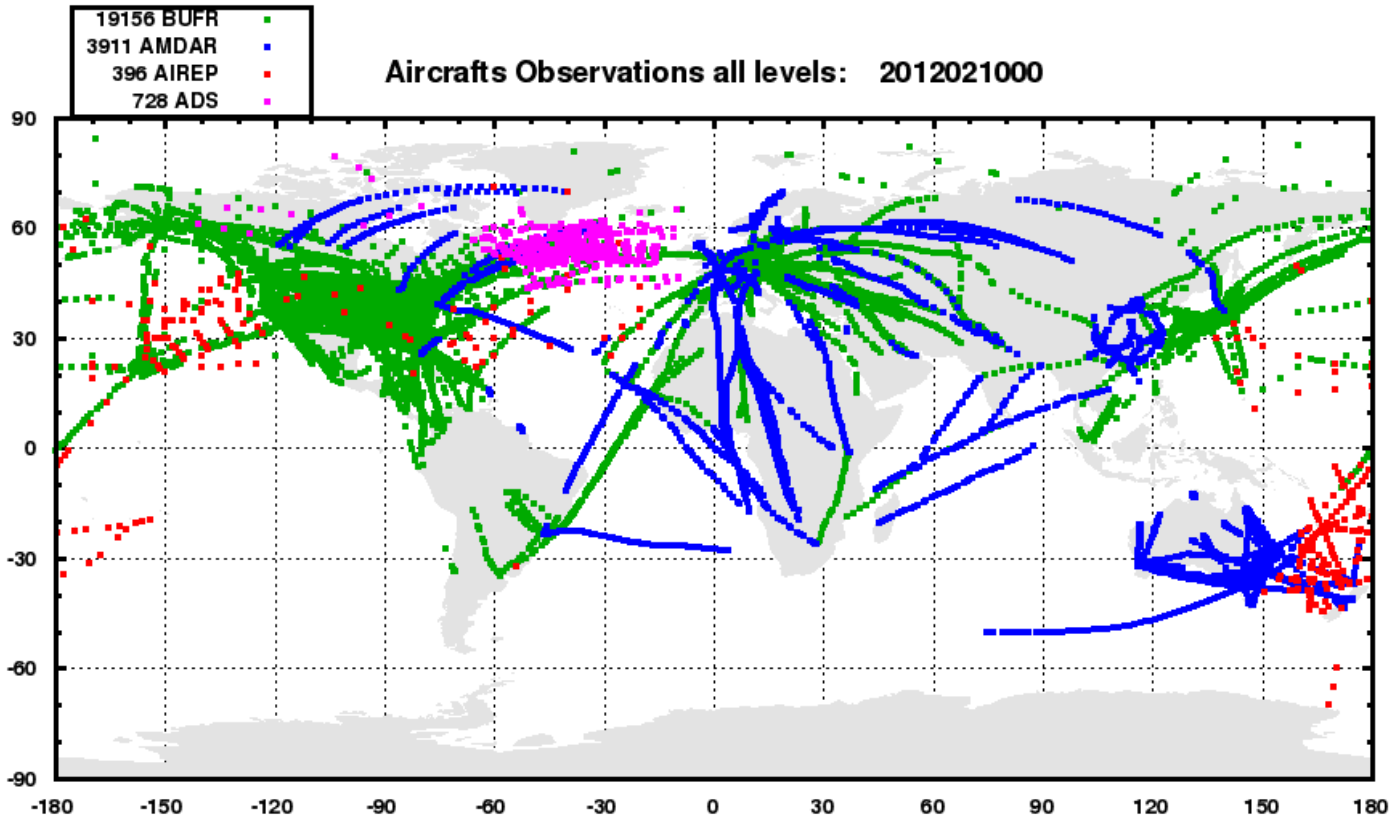
- Issues include:
  - extent of AMV assimilation over land
  - fine tuning of observation error and perturbation level
  - test impact in 4D-var
  - futher comparisons of simulated vs real data impact



Covering AMV gap area 50-70 N has large impact on forecasts!

Backup slides

AMDAR & AIREP coverage (6-h)

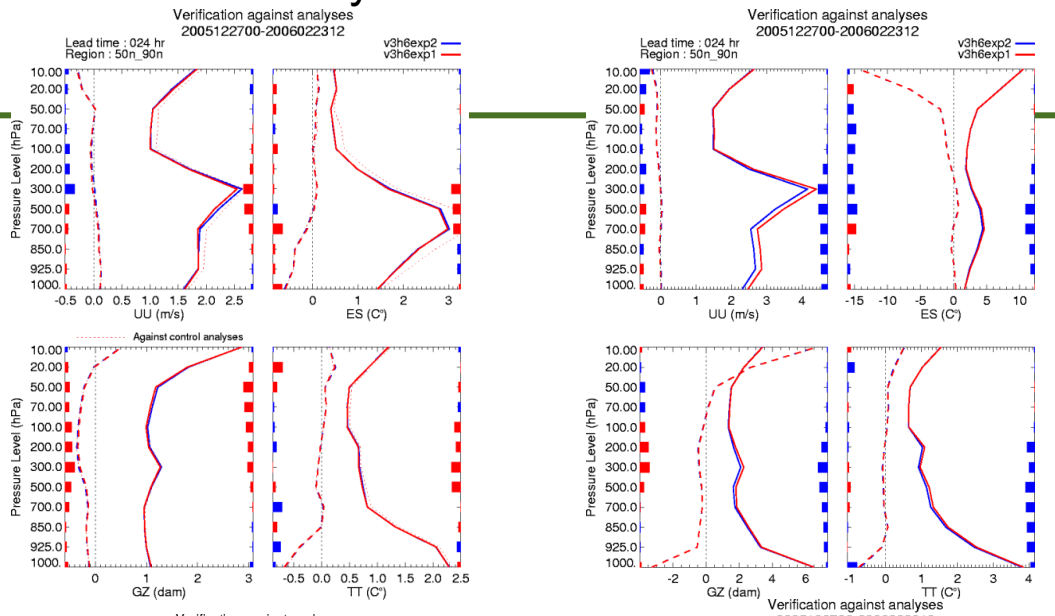


Use this info to define exclusion areas for AMVs?

Comparing errors vs own analysis and vs Nature Run (50-90N)

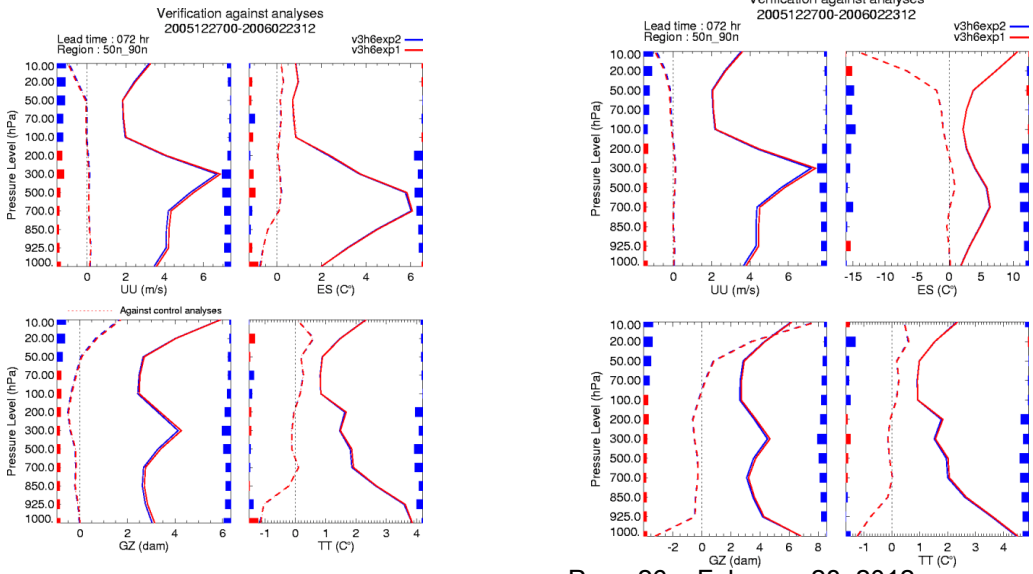
Vs own analysis vs NR NO-AMV PCW-AMV

24-h



Inconsistent results early in forecast

72-h



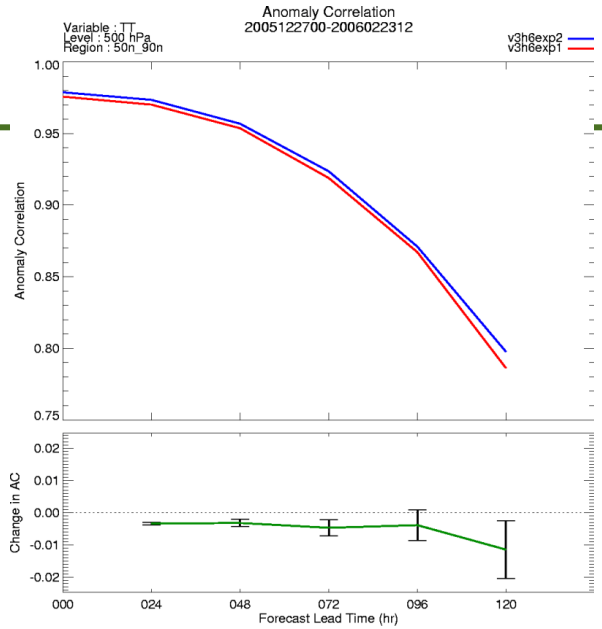
Consistent results further in forecast

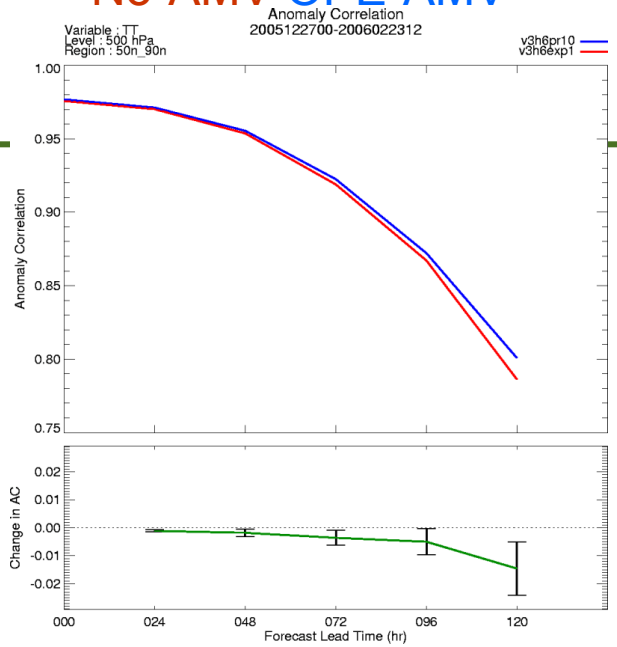
500 hPa TT anomaly correlation

No-AMV PCW-AMV

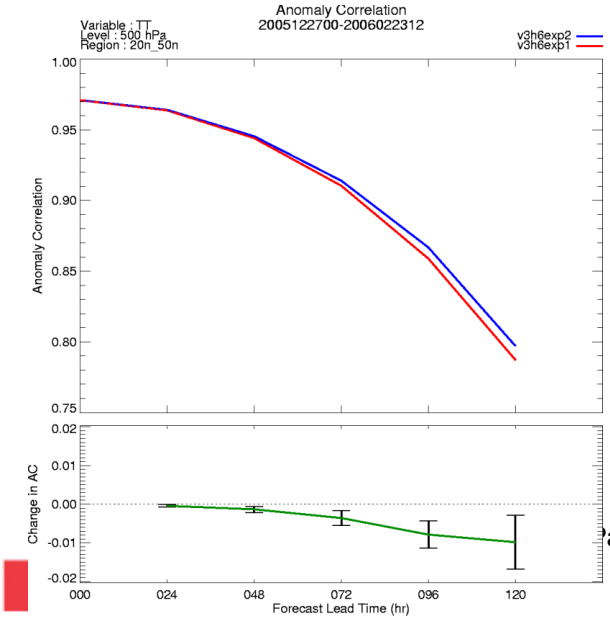
No-AMV OPE-AMV

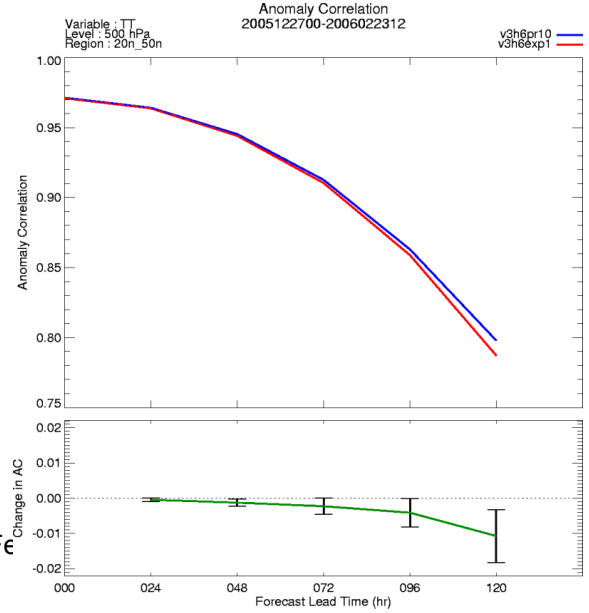
50-90 N





20-50 N





Canada