

Impact of upper-air and near-surface observations on short-range forecasts from NOAA hourly assimilation cycles (RUC and Rapid Refresh)

- aircraft
- profiler
- VAD winds
- rawinsonde
- GPS precipitable water
- METARs
- radar reflectivity
- AMVs

Stan Benjamin

Eric James

Haidao Lin

Steve Weygandt

Susan Sahm

Bill Moninger

*NOAA Earth System
Research Laboratory,
Boulder, CO*

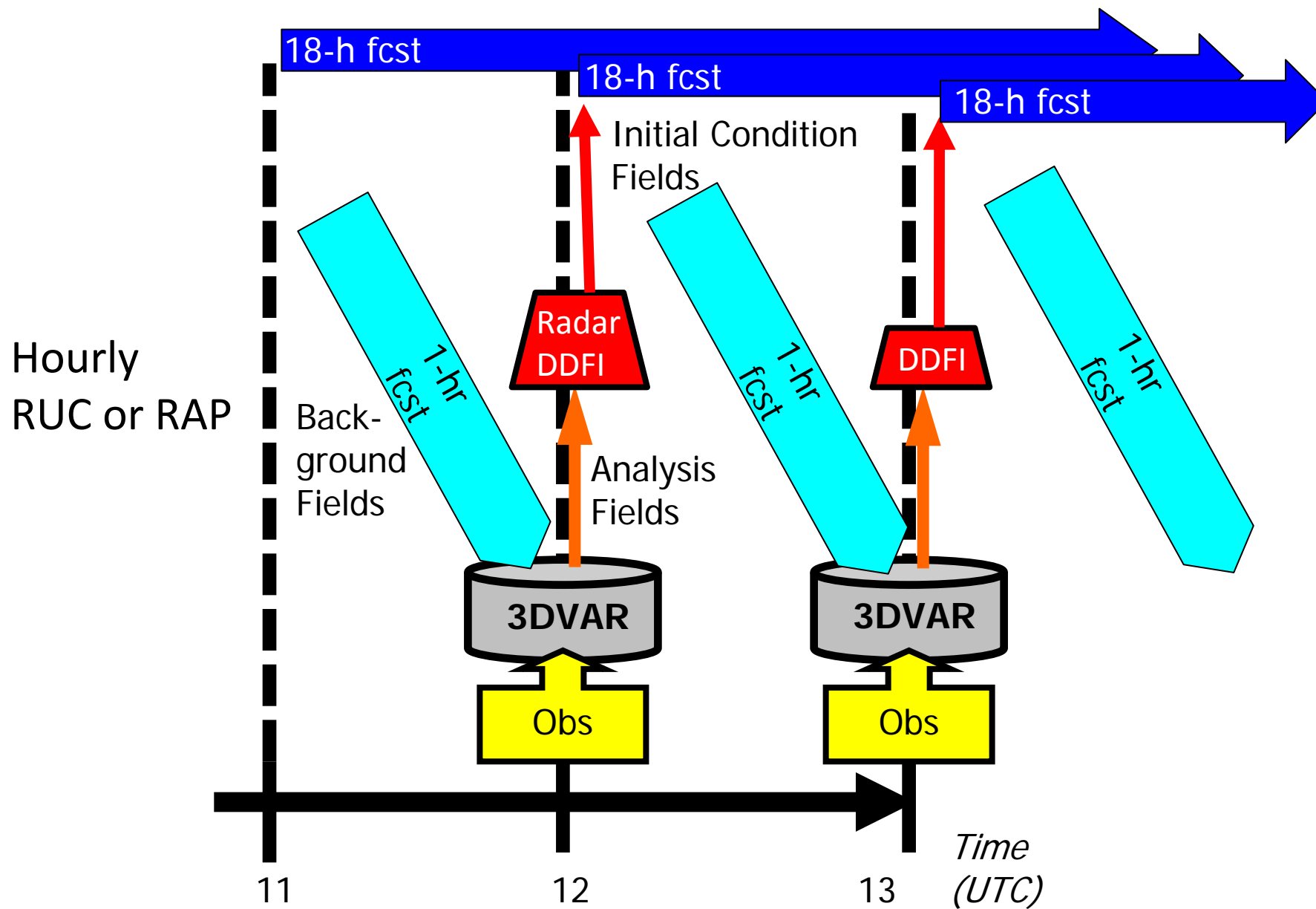


Earth System Research Laboratory
SCIENCE, SERVICE & STEWARDSHIP

**Wed 23 May 2012
WMO Workshop on
Impact of Obs on NWP**

<http://rapidrefresh.noaa.gov>

RUC / RAP hourly cycling



Hourly Updated NOAA NWP Models

Rapid Refresh (RAP)

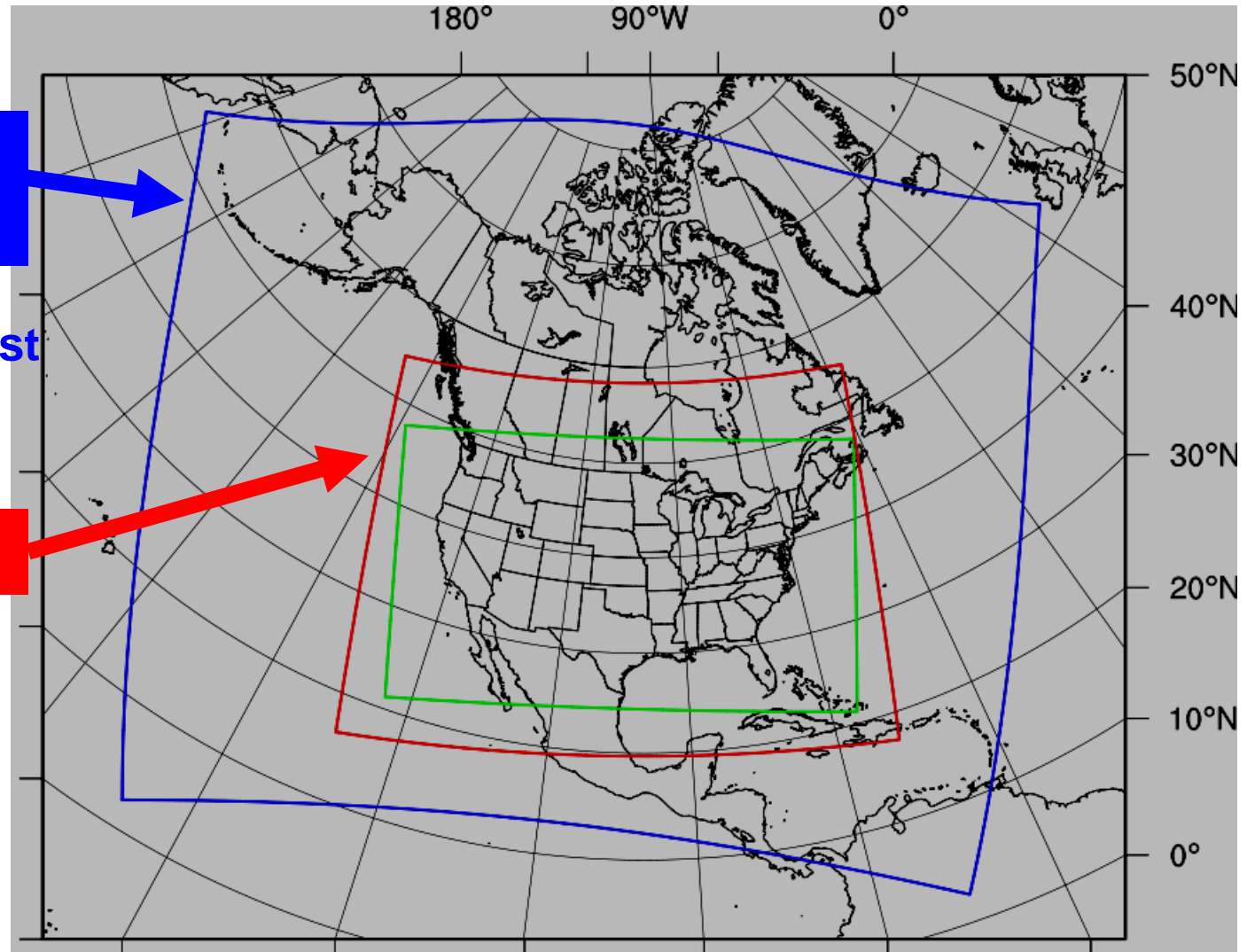
replaced RUC at NCEP 1 May 12
Uses WRF, GSI with RUC features

13km Rapid Refresh

new operational
model, new 18h fcst
every hour

13km RUC

prior operational
model, new 18h fcst
every hour



NOAA hourly updated models from RUC to Rapid Refresh RAP

Community-based advanced model and analysis in RAP

- **WRF-ARW**: advanced numerics, non-hydrostatic
- **GSI**: advanced satellite data assimilation

Model	Domain	Grid Points	Grid Spacing	Vertical Levels	Vertical Coordinate	Pressure Top	Boundary Conditions
RUC	CONUS	451 x 337	13 km	50	Sigma/ Isentropic	~50 mb	NAM
RAP	North America	758 x 567	13 km	50	Sigma	10 mb	GFS

Model	Assimilation	DFI	Cloud Analysis	Cloud micro-physics	Radiation LW/SW	Conv param	PBL	LSM
RUC	RUC-3DVAR	Yes w/radar	Yes	Thompson (2003) – 5 species	RRTM/ Dudhia	Grell-Devenyi	Burk Thompson	RUC 2003
RAP	GSI w/ radiance	Yes w/radar	Yes	Thompson (2008) – 6 species	RRTM/ Goddard	Grell-3d	MYJ	RUC 2010

Topic of this presentation:

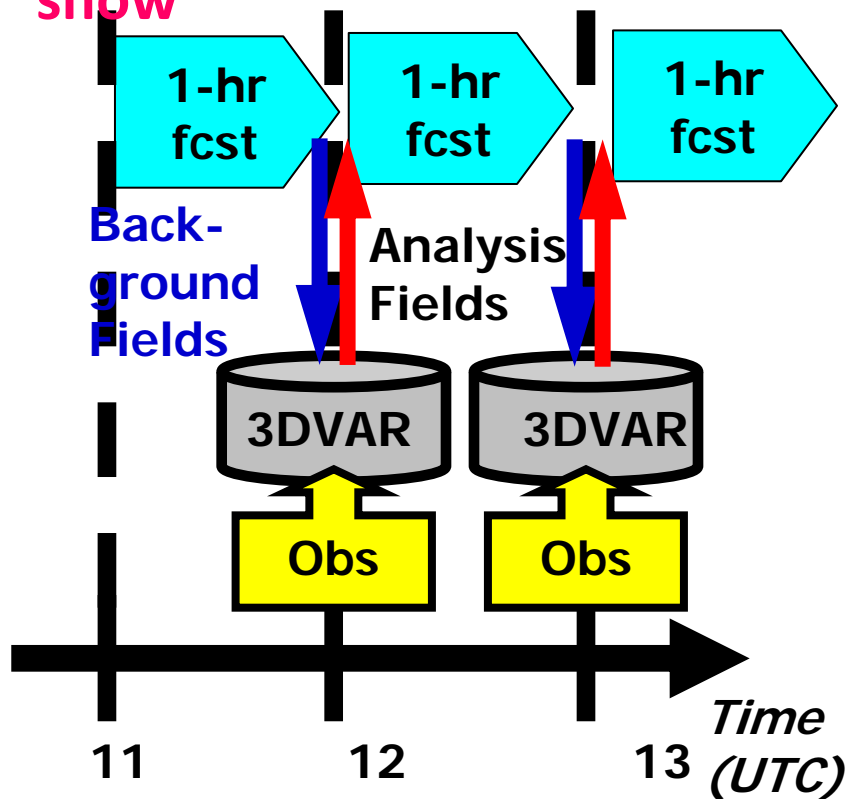
3 sets of regional observation denial experiments with NOAA hourly assimilation cycles

- **Rapid Update Cycle experiments**
 - Cold-season – Nov-Dec 2006 – 11 days
 - Warm-season – August 2007 – 10 days
 - Experiments used 2009 version of RUC
- **Rapid Refresh**
 - Warm-season – May-June 2011 – 14 days
 - Experiments used 2012 version of experimental RAP (ESRL version)

RUC/Rapid Refresh

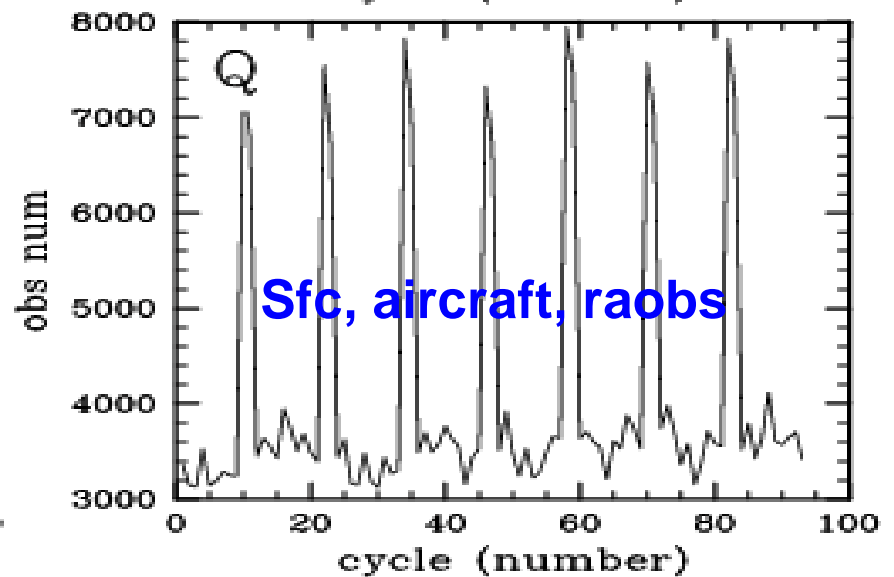
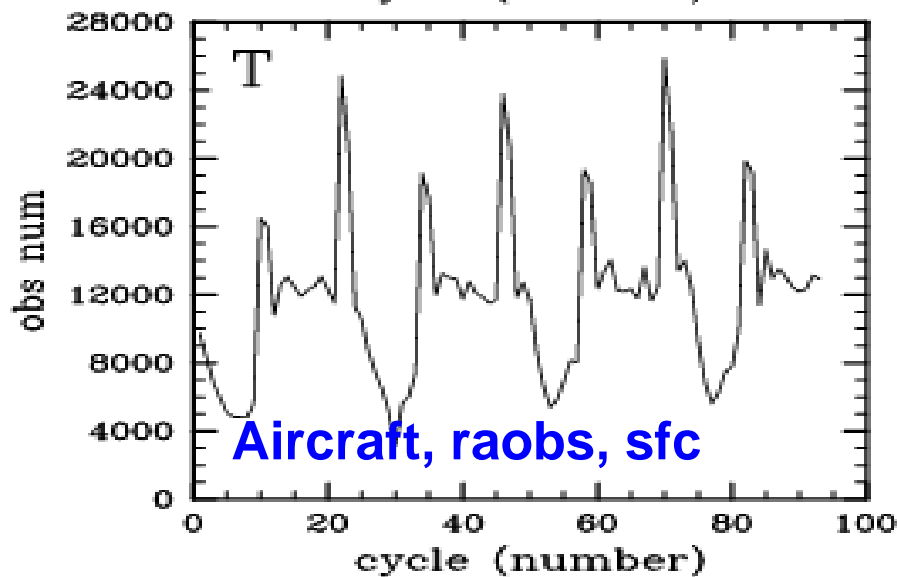
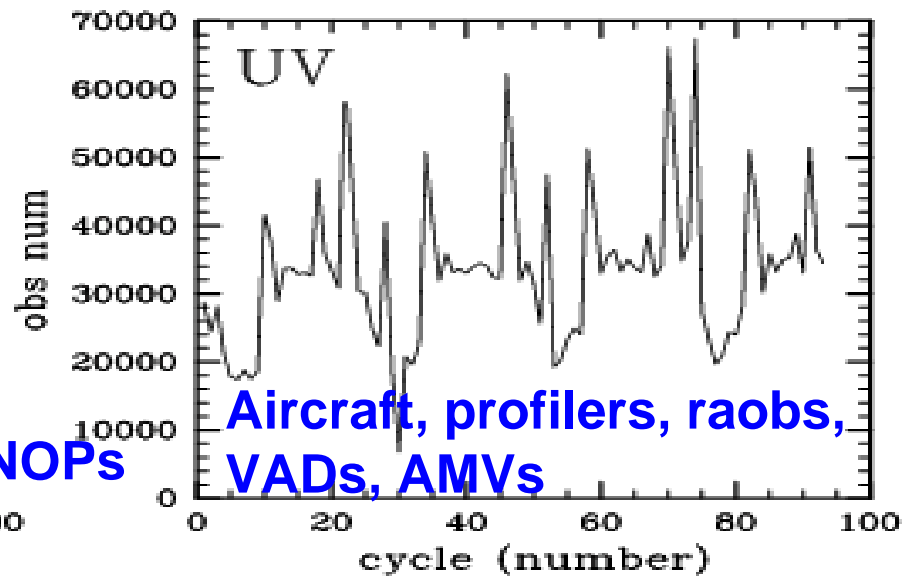
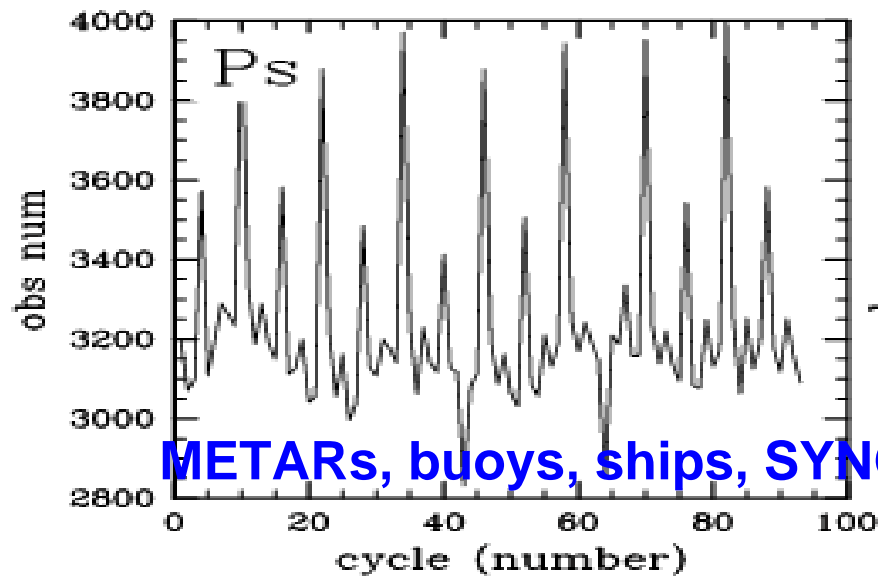
Hourly assimilation cycle

Cycle hydrometeors
 Cycle soil temp., moisture,
 snow



Hourly observations (stations for raobs/profiles)	RUC 2006-7 CONUS	RAP 2011 N.Amer
Rawinsonde (T,V,RH)	85	120
Profiler – NOAA Network (V)	30	21
Profiler – 915 MHz (V, Tv)	flagged	25
Radar – VAD (V)	120	125
Radar reflectivity - CONUS	2km	2km
Lightning (proxy reflectivity)	-	NLDN
Aircraft (V,T)	1.4-7K	2-15K
Aircraft - WVSS (RH)	-	0-800
Aircraft – TAMDAR (V,T,RH)	0-1800	0-50
Surface/METAR (T,Td,V,ps,cloud, vis, wx)	1800- 2000	2200- 2500
Buoys/ships (V, ps)	100-200	200-400
Mesonet (T, Td, V, ps)	4500	flagged
GOES AMVs (V)	1000- 2500	2000- 4000
AMSU/HIRS radiances	-	Used
GOES cloud-top pressure/temp	13km	13km
WindSat scatterometer	-	2-10K

Rapid Refresh obs counts (not counting radar reflectivity, GOES cloud, polar sat radiances)

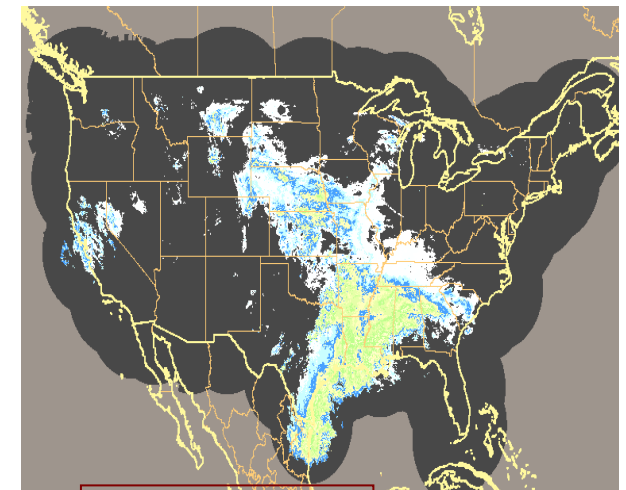
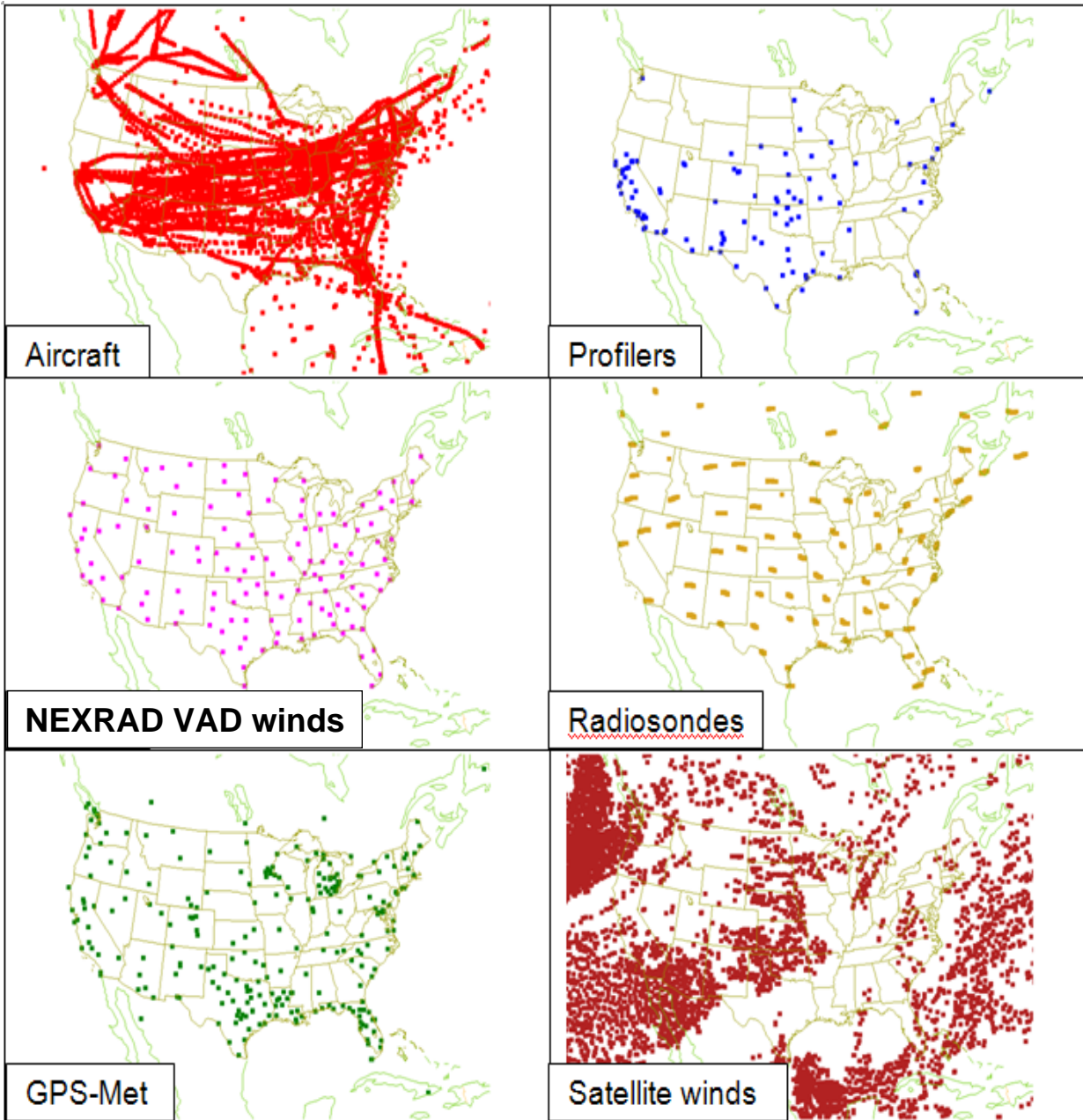


RUC/RAP

observation denial experiments

Experiments with observations denied	Aircraft	Profilers	VAD winds	RAOBs	Surface (w/ METAR clouds)	GPS prec water	Mesonet	Atmos motion vectors	Radar reflectivity
RUC - Winter 2006	✓	✓	✓	✓	✓	✓	✓	✓	
RUC – Summer 2007	✓	✓	✓	✓	✓	✓			
RAP – Summer 2011	✓	✓	✓	✓	✓	✓		✓	✓

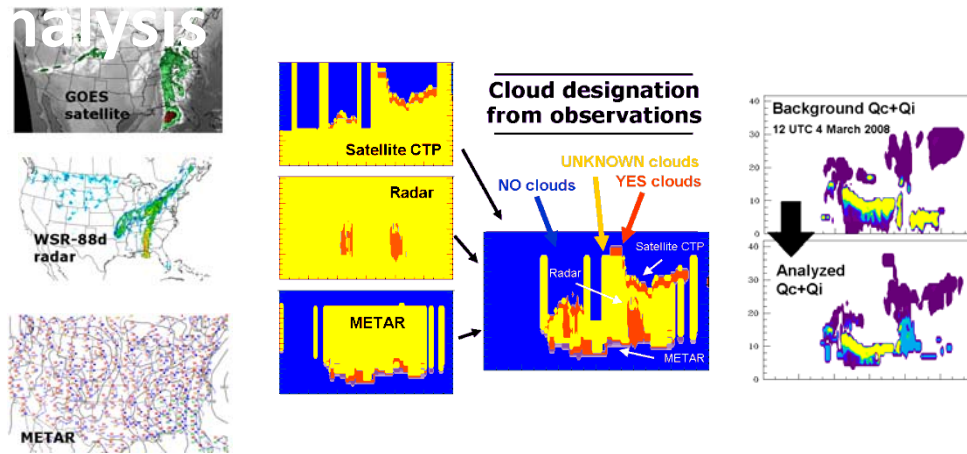
Observations assimilated in hourly update models (RUC, Rapid Refresh)



Radar reflectivity

RUC/RAP – specific analysis features

Cloud and hydrometeor



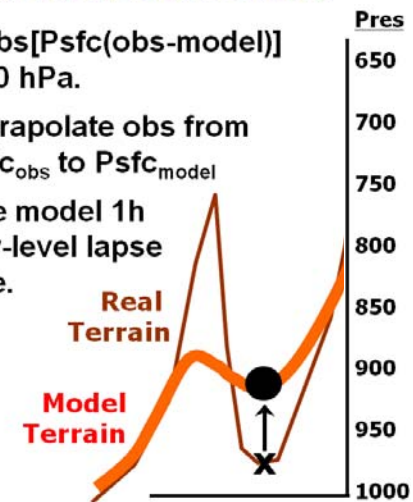
Special treatments for surface observations

Elevation correction

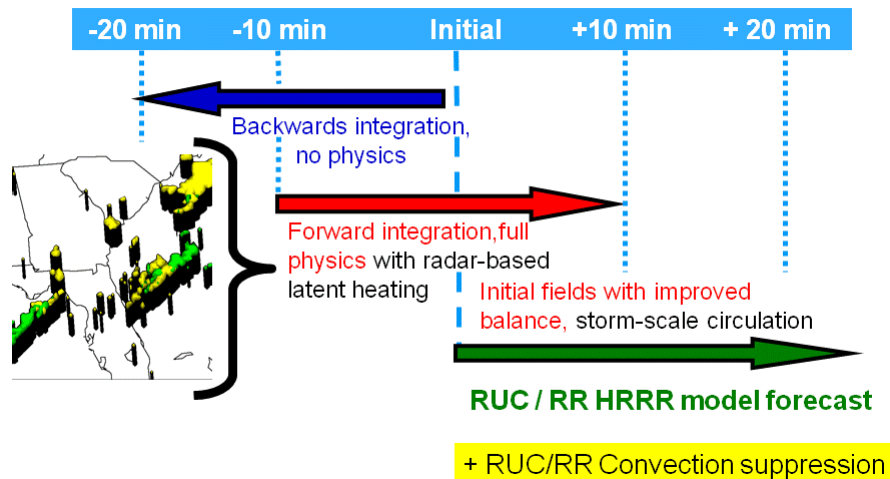
If $\text{abs}[\text{Psfc}(\text{obs}-\text{model})] < 70 \text{ hPa}$.

Extrapolate obs from Psfc_{obs} to $\text{Psfc}_{\text{model}}$

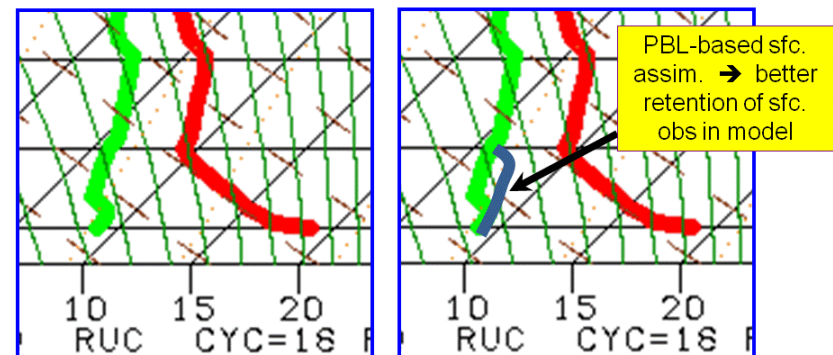
Use model 1h low-level lapse rate.



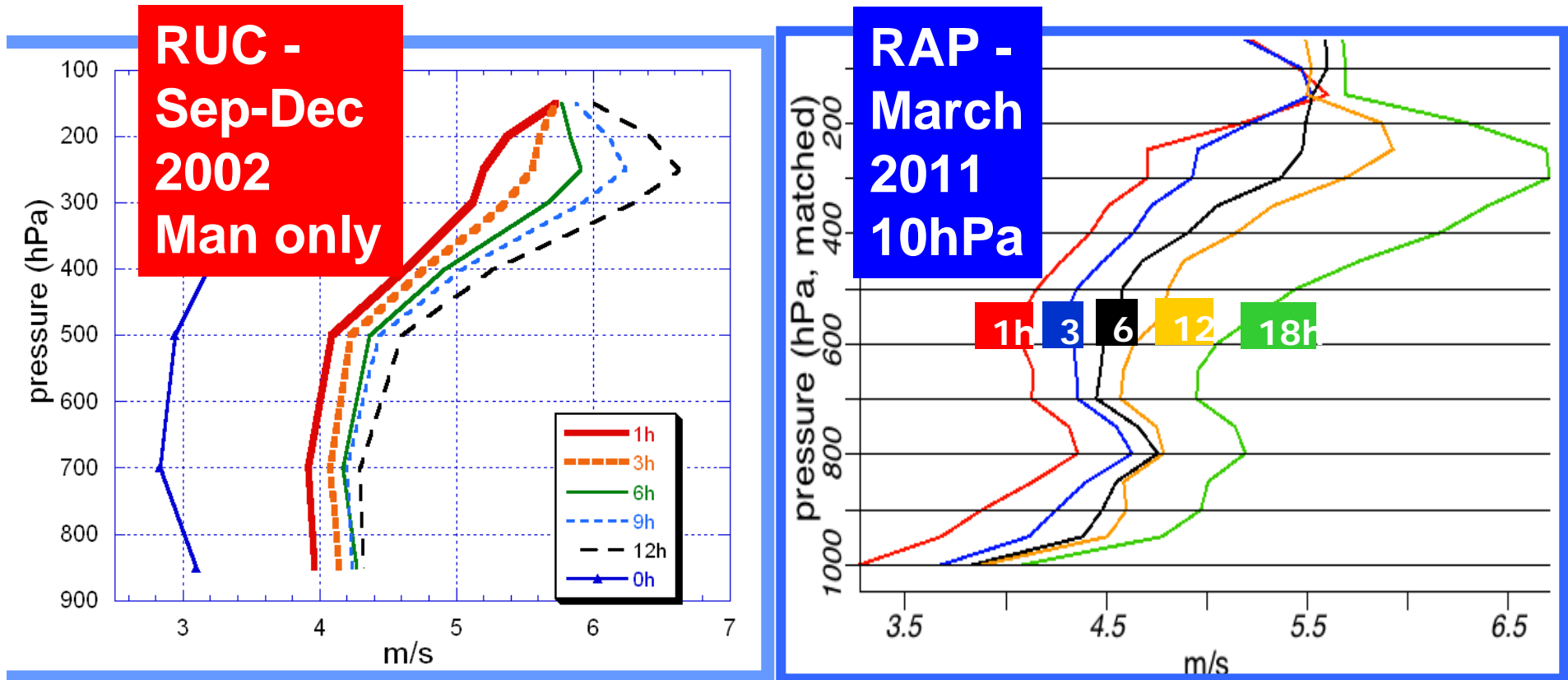
Digital filter-based reflectivity assimilation



PBL-based pseudo-observations

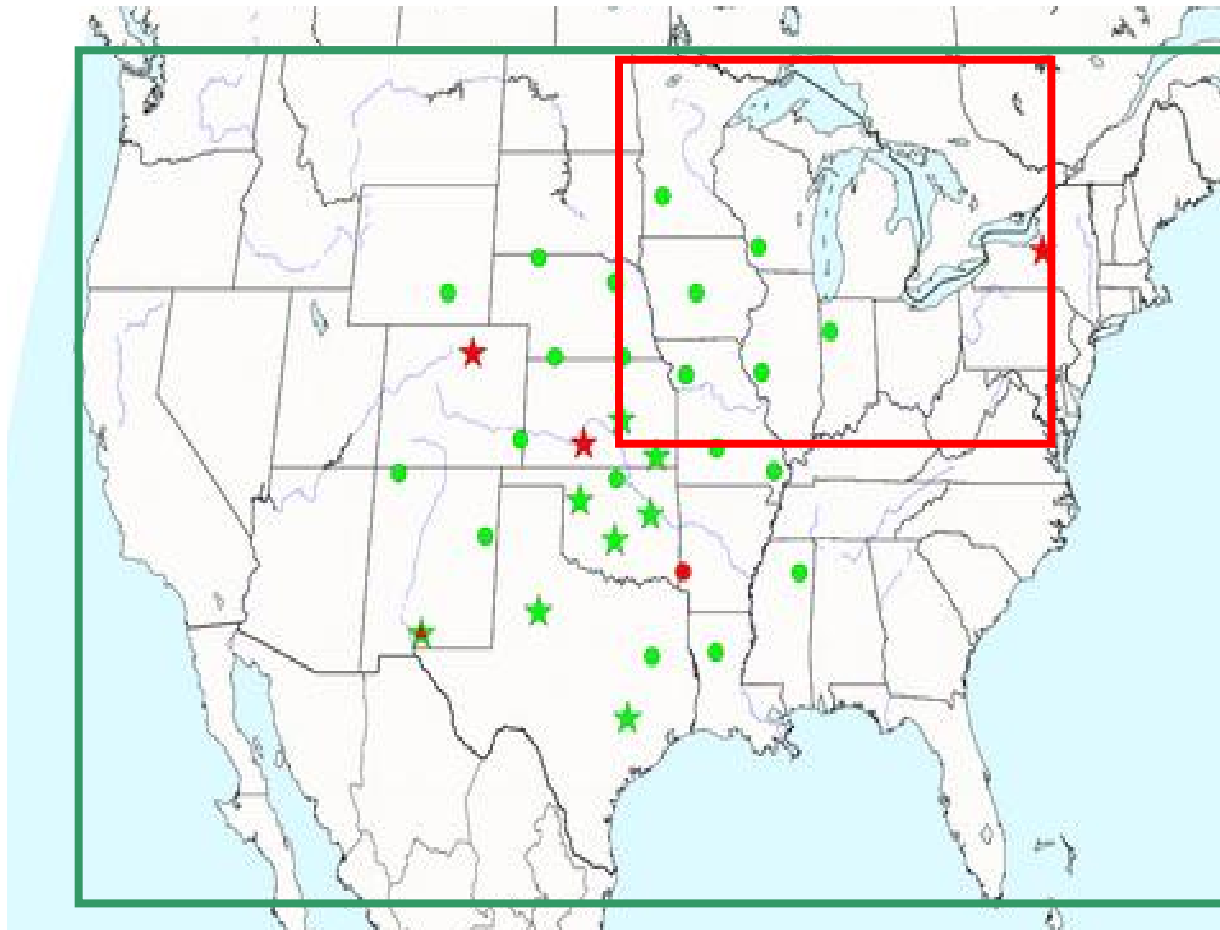


RAOB verification – every 10 hPa (Moninger et al. WAF 2010)



Verification against rawinsonde data over CONUS domain
RMS vector difference (forecast vs. obs)

RUC and RAP are able to use recent obs to improve forecast skill down to 1-h projection for winds



Location for 3 verification domains

Region 0 - National

Region 1 - Eastern

Region 2 - Midwest / Great Lakes

Diurnal dependencies for observations

- **Aircraft**
 - minimum in commercial traffic at night (06z-11z) over N.America
- **Profiler, VAD winds –**
 - vulnerable to bird migration contamination at night in spring/fall
- **Surface –**
 - Winds/temperature/dewpoint obs representative over deeper boundary layer in daytime

Breakdown for RUC/RAP OSE results

- **7-9 experiments (control, 6-8 obs denial experiments)**
- **2 Regions**
 - **US National (data rich)**
 - **Midwest (very data rich)**
- **4 layers**
 - **1000-100 hPa (full depth)**
 - **1000-800 hPa (near surface) or 1000-600 (lower trop)**
 - **800-400 hPa (mid-troposphere)**
 - **400-100 hPa (upper troposphere, lower stratosphere)**
- **2 seasons**
 - **winter**
 - **summer**
- **Forecast duration**
 - **3h, 6h, 9h, 12h**
- **Valid time of day**
 - **00z, 12z**

5 dimensions!

Q: HOW TO SUMMARIZE?

A: Composite plots

1st Breakdown for RUC OSE results

- 7-9 experiments (control, 6-8 obs denial experiments)
- 2 Regions
 - US National (data rich)
 - Midwest (very data rich)
- 4 layers
 - 1000-100 hPa (full depth)
 - 1000-800 hPa (near surface)
 - 800-400 hPa (mid- troposphere)
 - 400-100 hPa (upper troposphere, lower stratosphere)
- 2 seasons
 - winter
 - summer
- Forecast duration
 - 3h, 6h, 12h
- Valid time of day
 - 00z, 12z

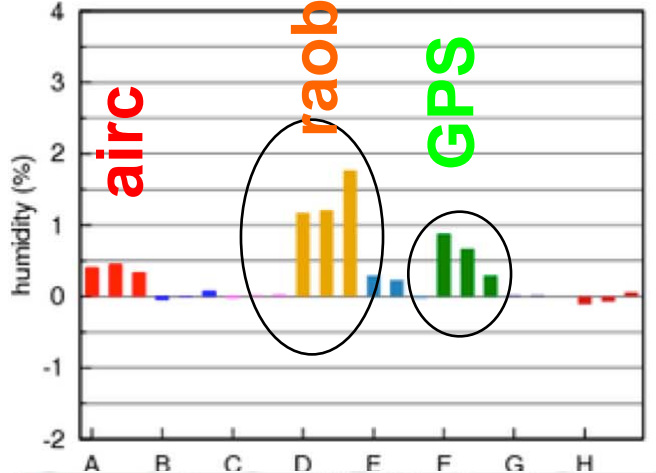
6 dimensions!

Q: HOW TO SUMMARIZE?

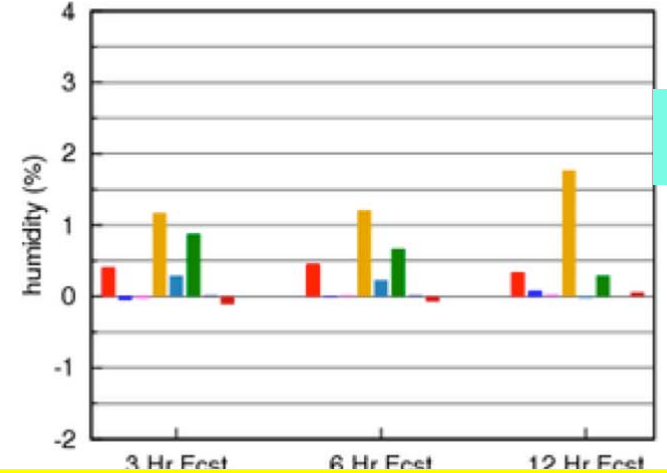
A: Composite plots

WINTER

Natl region, humidity averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-400 mb)



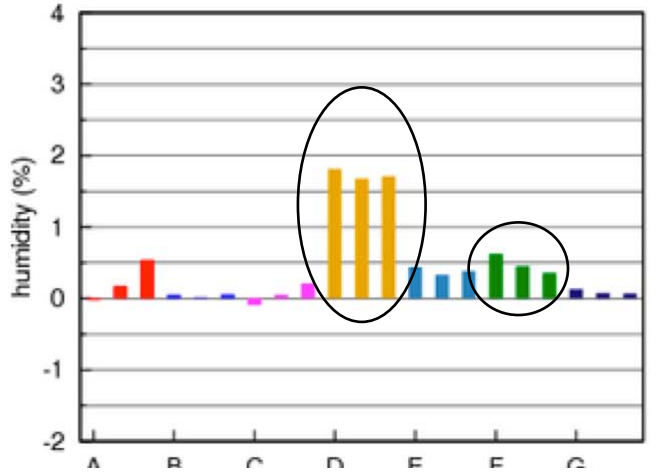
Natl region, humidity averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-400 mb)



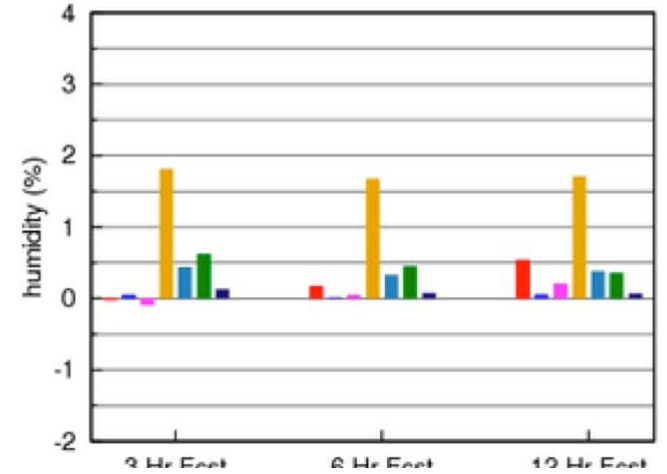
- A - No-aircraft - control
- B - No-profiler - control
- C - No-VAD - control
- D - No-RAOB - control
- E - No-surface - control
- F - No-GPS-PW - control
- G - No-mesonet - control
- H - No-AMV - control

RH - national - 1000-400 hPa
#1 obs type = Raobs
#2 = GPS-PW

Natl region, humidity averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-400 mb)



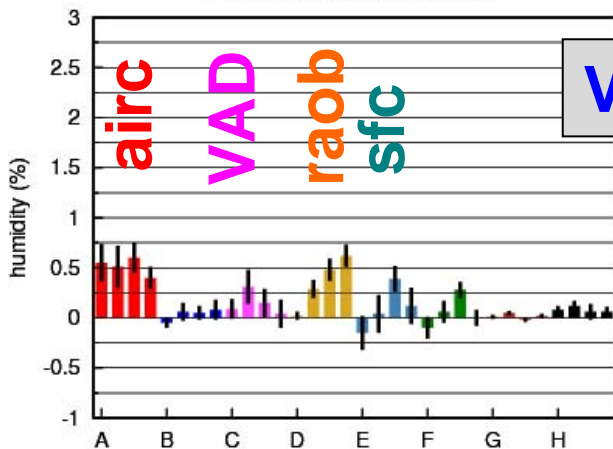
Natl region, humidity averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-400 mb)



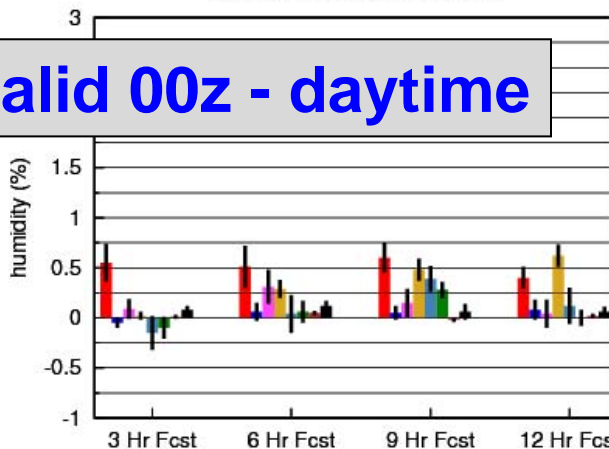
SUMMER

Natl region, humidity averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-400 mb)
Forecasts valid at 00 UTC

Natl region, humidity averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-400 mb)
Forecasts valid at 00 UTC

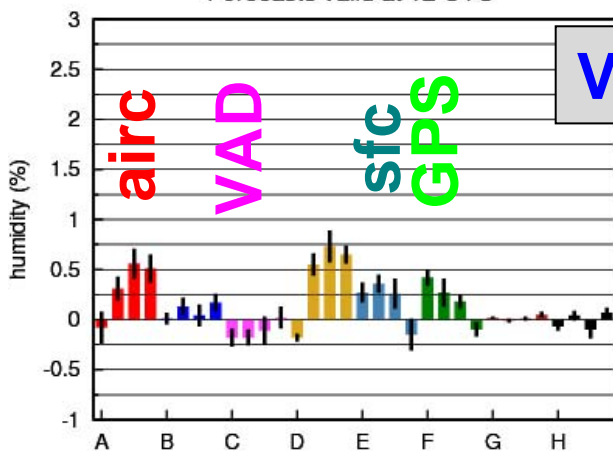


Valid 00z - daytime

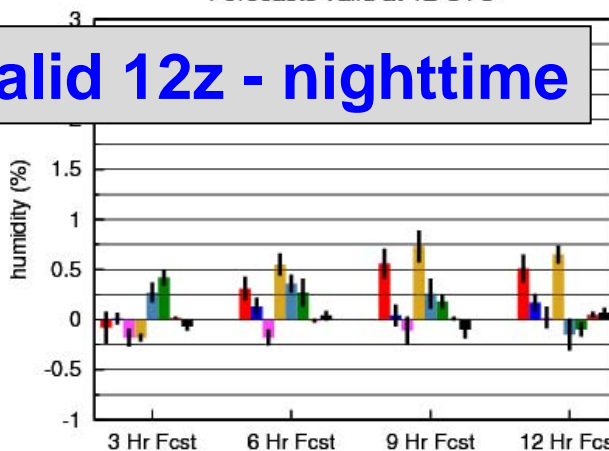


Natl region, humidity averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-400 mb)
Forecasts valid at 12 UTC

Natl region, humidity averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-400 mb)
Forecasts valid at 12 UTC



Valid 12z - nighttime



- A - withhold aircraft obs - Exp v6 - control
- B - withhold all profiler obs - Exp v7 - control
- C - withhold VAD winds - Exp v11 - control
- D - withhold rawinsonde obs - Exp. v5 - control
- E - withhold surface obs incl METAR cloud - Exp v9 - control
- F - withhold GPS-Met PW obs - Exp v12 - control
- G - withhold AMVs - Exp v10 - control
- H - withhold radar refl- Exp v8 - control

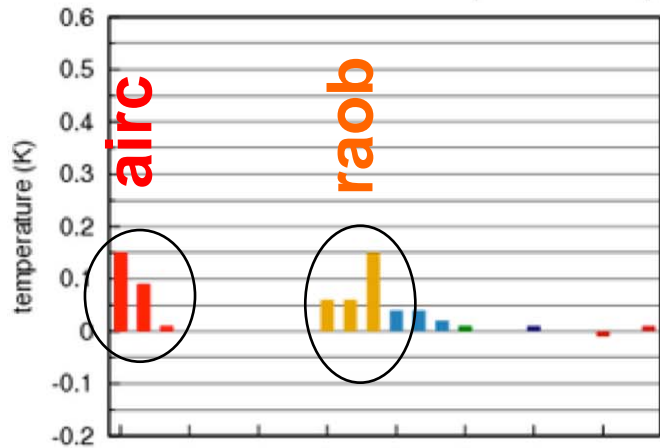
RH - national - 1000-400 hPa

- #1 obs type = Raobs**
- Close #2 = aircraft**
- #3 - GPS at night**
 - VAD in day
 - sfc - day/night

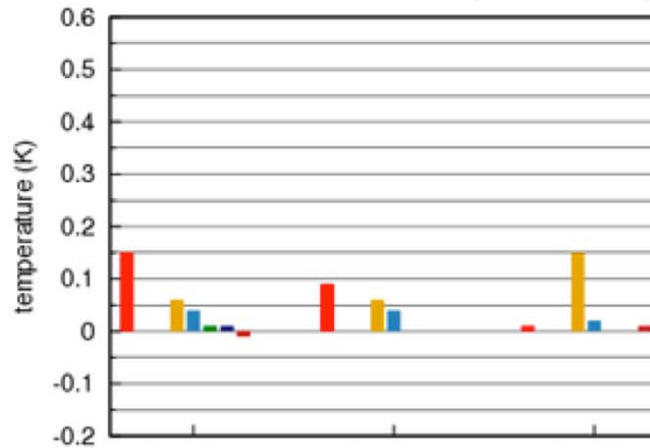
More cross-covariance effect w/ GSI/RAP for wind-moisture than w/ RUC

WINTER

Natl region, temperature averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-100 mb)



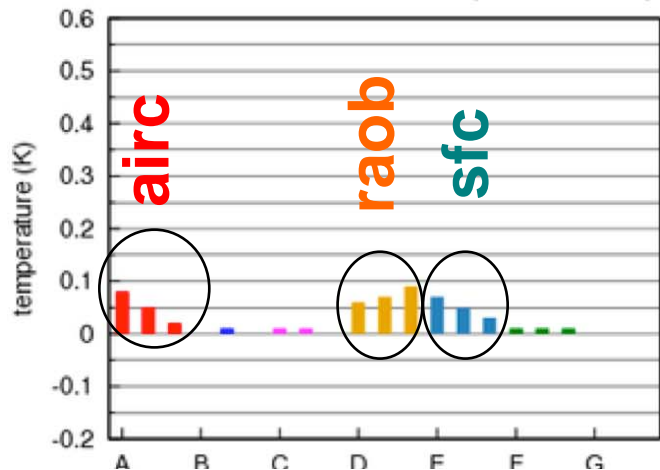
Natl region, temperature averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-100 mb)



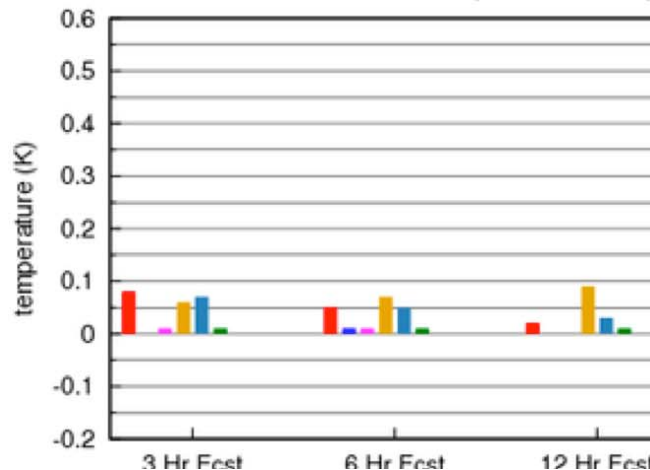
- A - No-aircraft - control
- B - No-profiler - control
- C - No-VAD - control
- D - No-RAOB - control
- E - No-surface - control
- F - No-GPS-PW - control
- G - No-mesonet - control
- H - No-AMV - control

Temp - national - 1000-100 hPa
 Tie for #1 = Aircraft, RAOBs
 Aircraft more at 3h, RAOB-12h
 Sfc ~ aircraft, RAOB in summer(!)

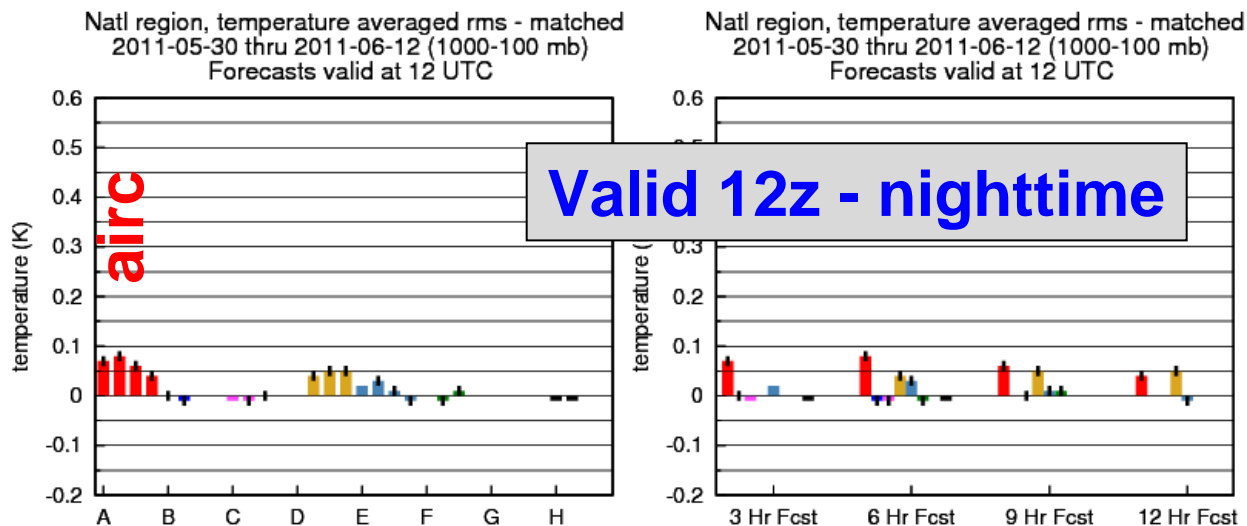
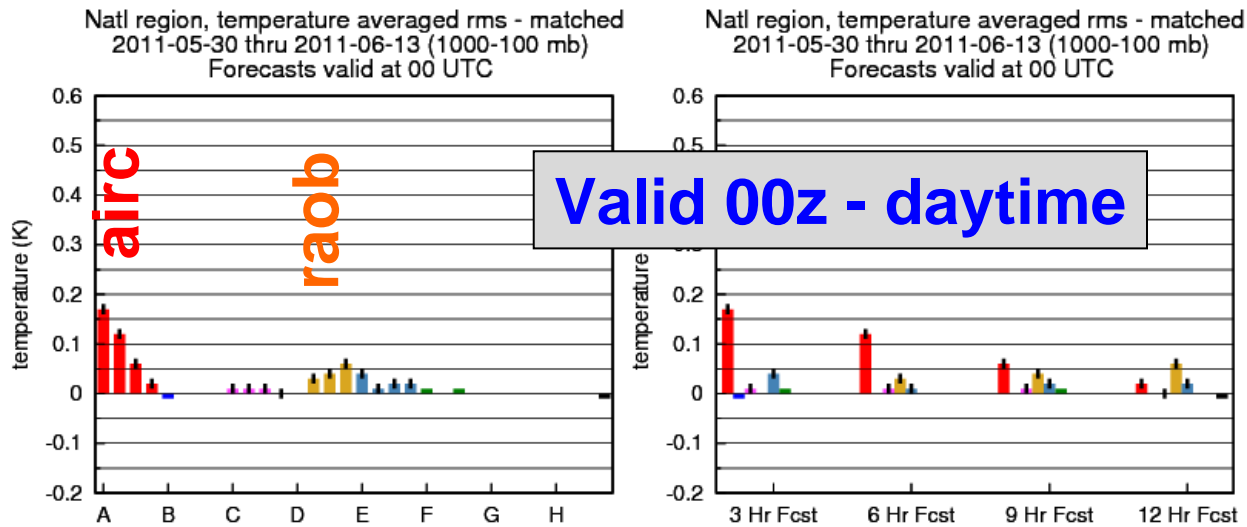
Natl region, temperature averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-100 mb)



Natl region, temperature averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-100 mb)



SUMMER

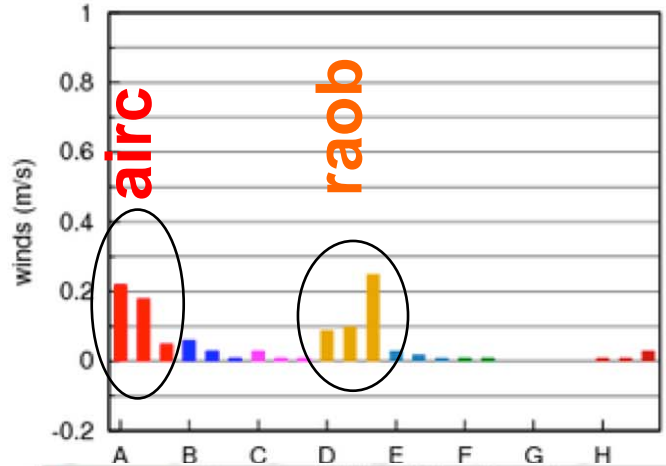


Temp - national -
1000-100 hPa
#1 = Aircraft
#2 = RAOBs
Aircraft more at 3h,
RAOB-12h

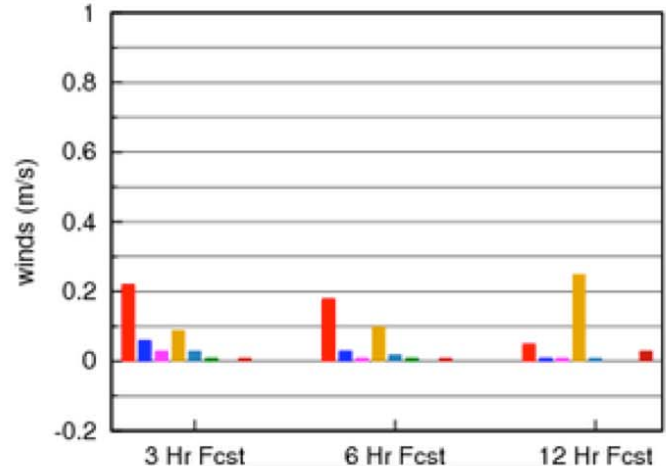
- A - withhold aircraft obs - Exp v6 - control
- B - withhold all profiler obs - Exp v7 - control
- C - withhold VAD winds - Exp v11 - control
- D - withhold rawinsonde obs - Exp. v5 - control
- E - withhold surface obs incl METAR cloud - Exp v9 - control
- F - withhold GPS-Met PW obs - Exp v12 - control
- G - withhold AMVs - Exp v10 - control
- H - withhold radar refl- Exp v8 - control

WINTER

Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-100 mb)



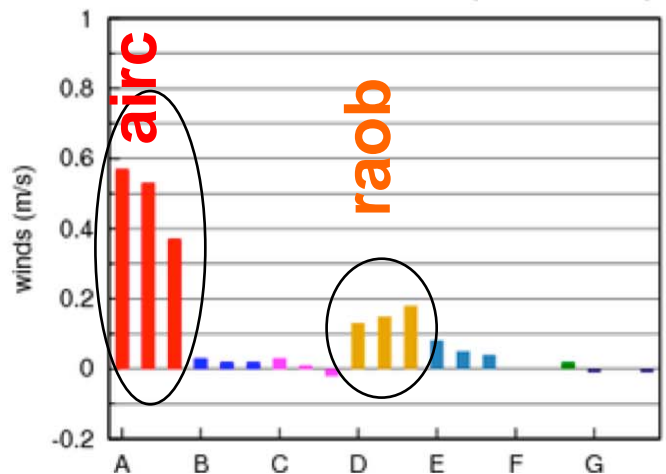
Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-100 mb)



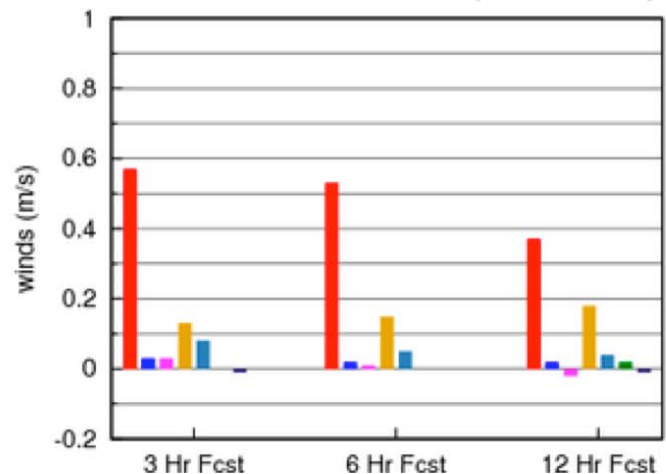
- █ A - No-aircraft - control
- █ B - No-profiler - control
- █ C - No-VAD - control
- █ D - No-RAOB - control
- █ E - No-surface - control
- █ F - No-GPS-PW - control
- █ G - No-mesonet - control
- █ H - No-AMV - control

Wind - national - 1000-100 hPa
#1 = Aircraft
#2 = RAOBs

Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-100 mb)



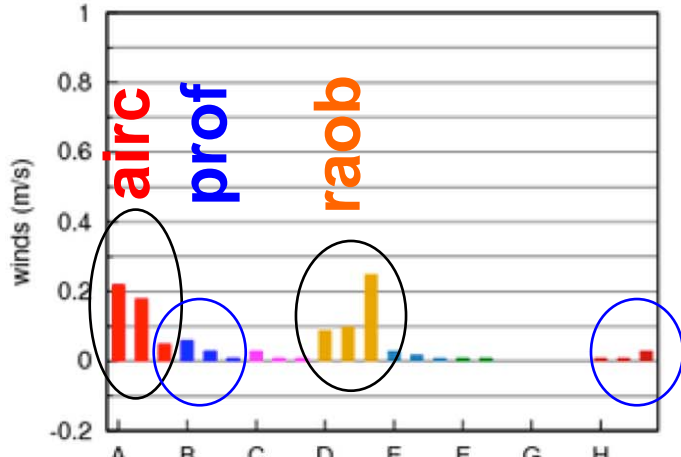
Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-100 mb)



SUMMER

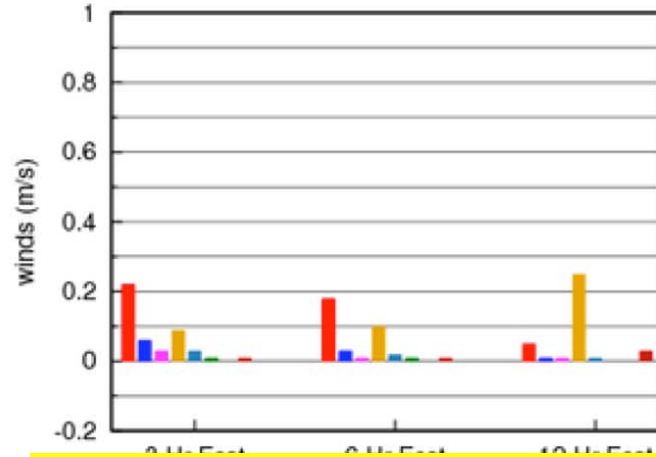
WINTER

Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-100 mb)



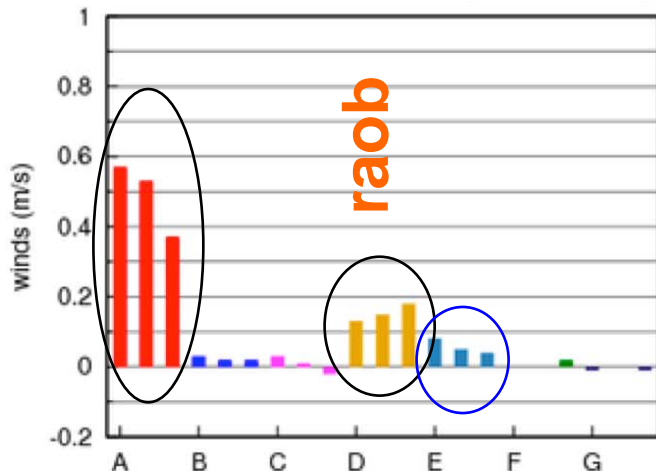
- A - No-aircraft - control
- B - No-profiler - control
- C - No-VAD - control
- D - No-RAOB - control
- E - No-surface - control
- F - No-GPS-PW - control
- G - No-mesonet - control
- H - No-AMV - control

Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-100 mb)

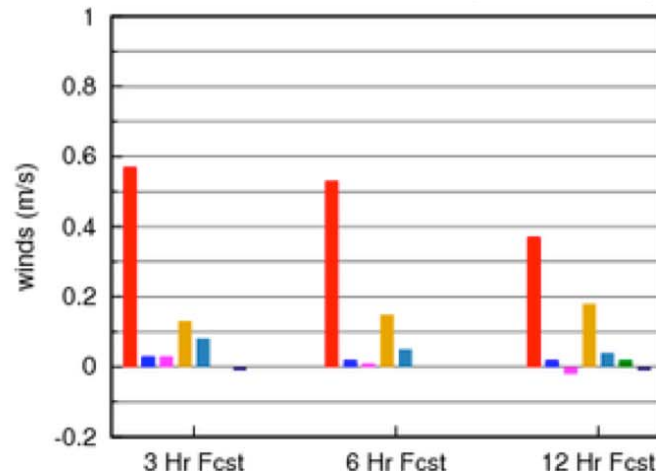


Wind - national - 1000-100 hPa
#1 = Aircraft
#2 = RAOBs
Smaller players: prof, AMV, sfc

Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-100 mb)



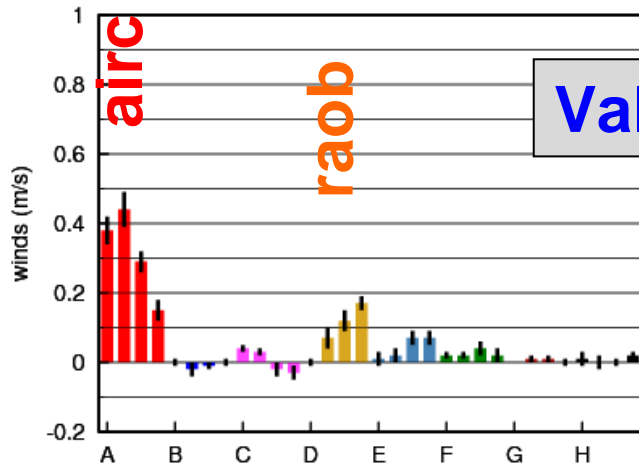
Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-100 mb)



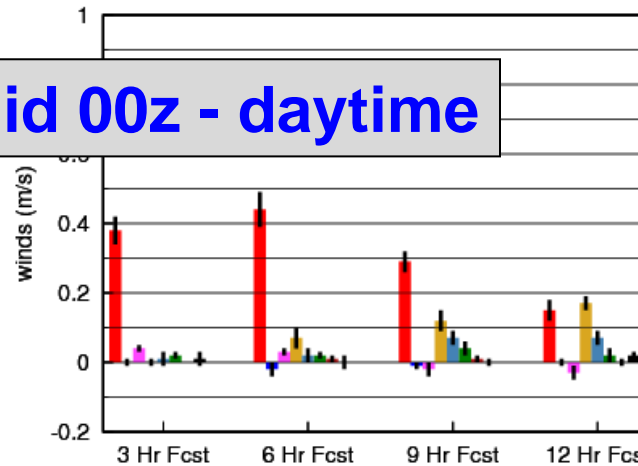
SUMMER

Natl region, winds averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-100 mb)
Forecasts valid at 00 UTC

Natl region, winds averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-100 mb)
Forecasts valid at 00 UTC

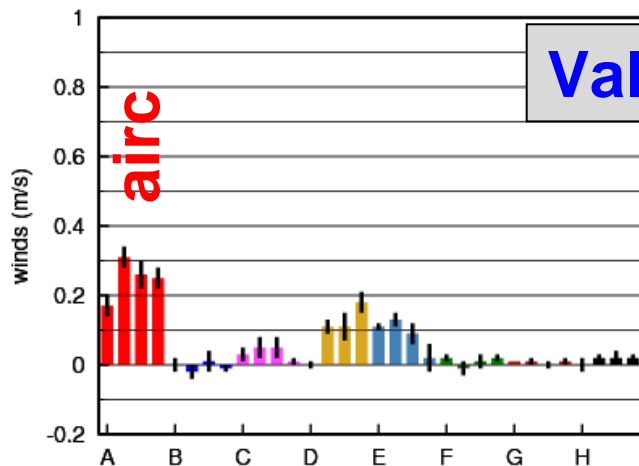


Valid 00z - daytime

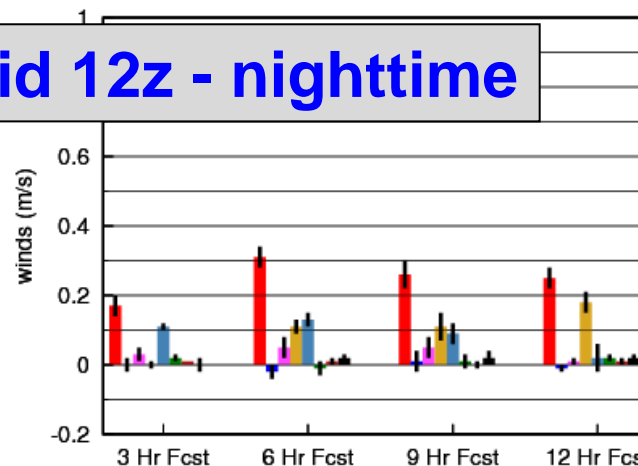


Natl region, winds averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-100 mb)
Forecasts valid at 12 UTC

Natl region, winds averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-100 mb)
Forecasts valid at 12 UTC



Valid 12z - nighttime



Wind - national - 1000-100 hPa

#1 = Aircraft

#2 = RAOBs

#3 = surface

**Smaller players:
sfc, VADs**

- █ A - withhold aircraft obs - Exp v6 - control
- █ B - withhold all profiler obs - Exp v7 - control
- █ C - withhold VAD winds - Exp v11 - control
- █ D - withhold rawinsonde obs - Exp. v5 - control
- █ E - withhold surface obs incl METAR cloud - Exp v9 - control
- █ F - withhold GPS-Met PW obs - Exp v12 - control
- █ G - withhold AMVs - Exp v10 - control
- █ H - withhold radar refl- Exp v8 - control

2nd Breakdown for RUC OSE results

- 7 experiments (control, 6 obs denial experiments)

- 2 Regions

- US National (data rich)

- Midwest (very data rich)

- 4 layers

- 1000-100 hPa (full depth)

- 1000-800 hPa (near surface)

- 800-400 hPa (mid-troposphere)

- 400-100 hPa (upper troposphere, lower stratosphere)

- 2 seasons

- winter

- summer

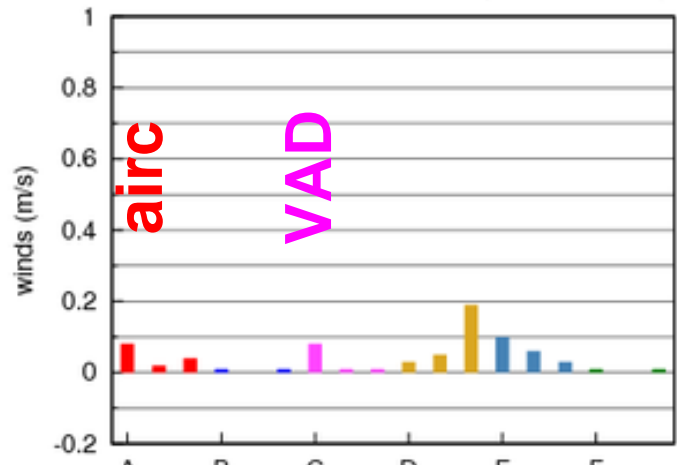
- Forecast duration

- 3h, 6h, 12h

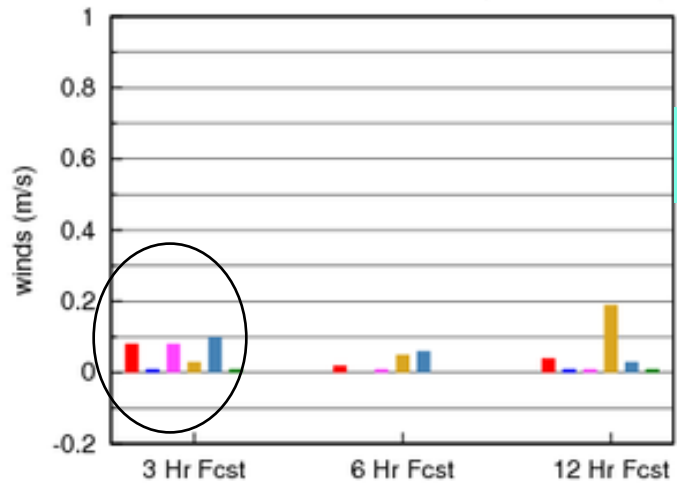
Wind only

WINTER

Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (800-1000 mb)



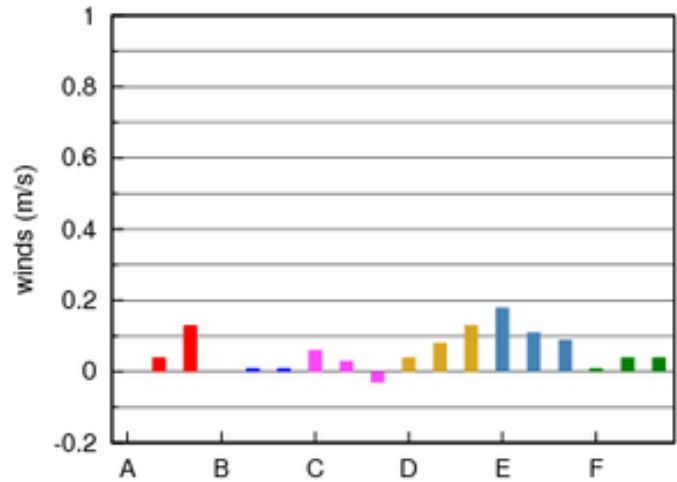
Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (800-1000 mb)



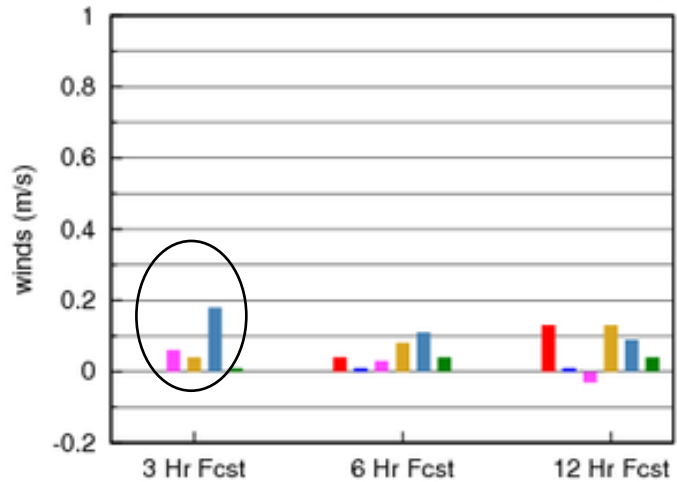
- █ A: No-aircraft - control
- █ B: No-profiler - control
- █ C: No-VAD - control
- █ D: No-RAOB - control
- █ E: No-surface - control
- █ F: No-GPS-PW - control

Wind - national - 1000-800 hPa
Aircraft, VAD, sfc - 3h - winter
Sfc - 3h - summer

Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (800-1000 mb)



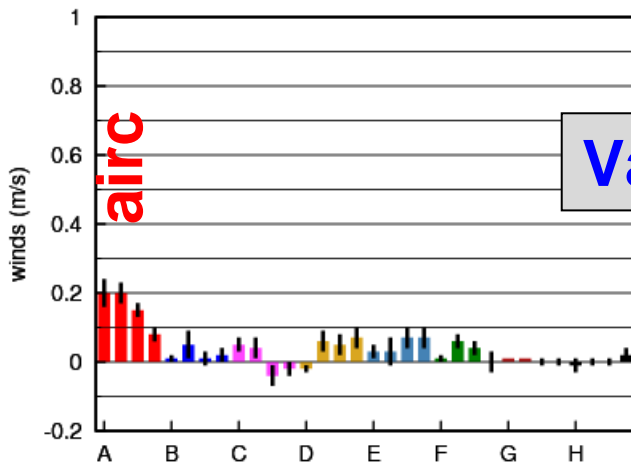
Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (800-1000 mb)



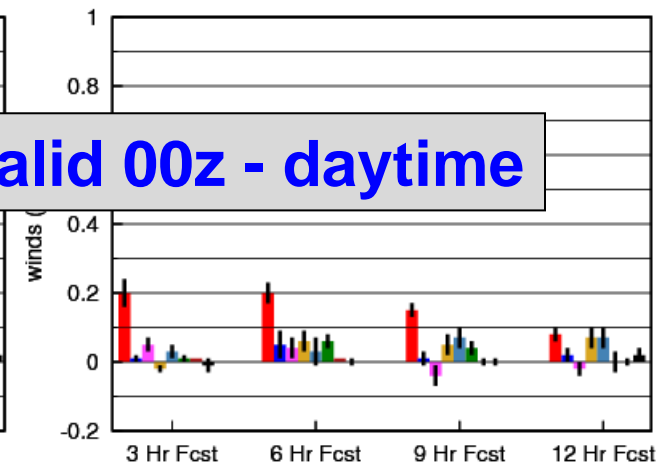
SUMMER

Natl region, winds averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-600 mb)
Forecasts valid at 00 UTC

Natl region, winds averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-600 mb)
Forecasts valid at 00 UTC

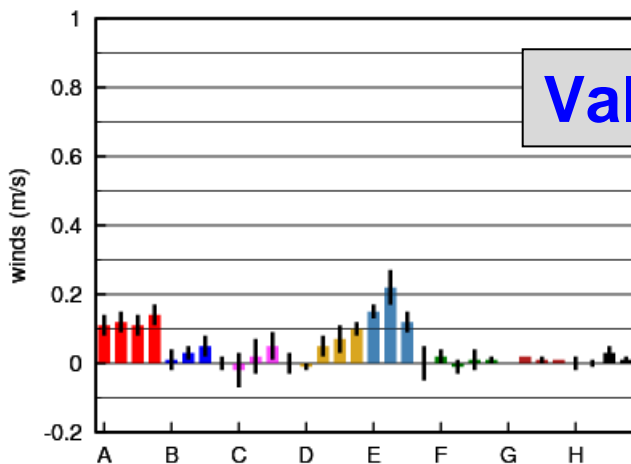


Valid 00z - daytime

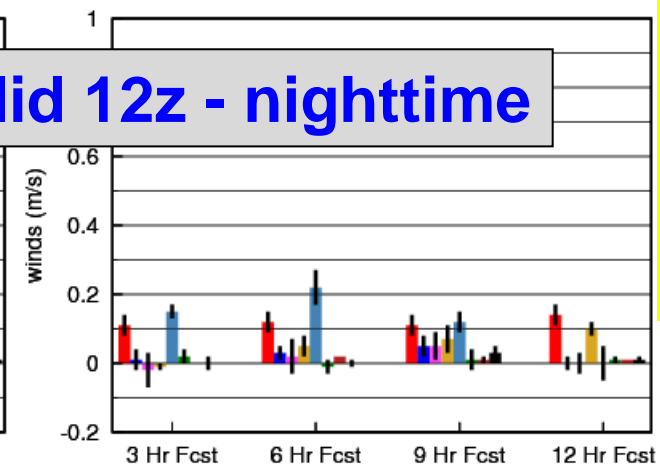


Natl region, winds averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-600 mb)
Forecasts valid at 12 UTC

Natl region, winds averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-600 mb)
Forecasts valid at 12 UTC



Valid 12z - nighttime

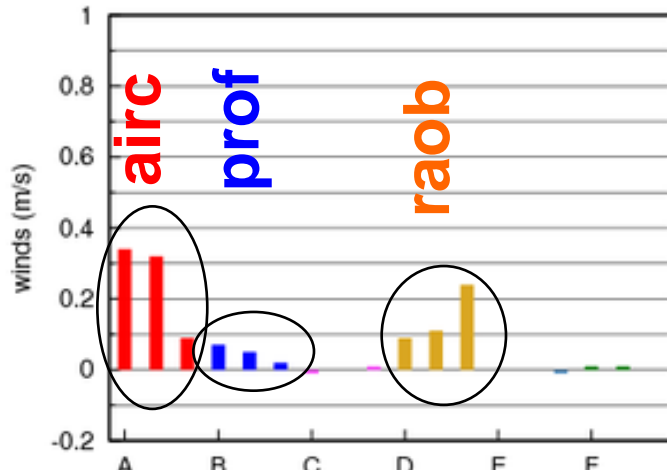


Wind - national -
1000-600 hPa
#1 = Aircraft
#2 = sfc (esp.night)
#3 = raob, prof

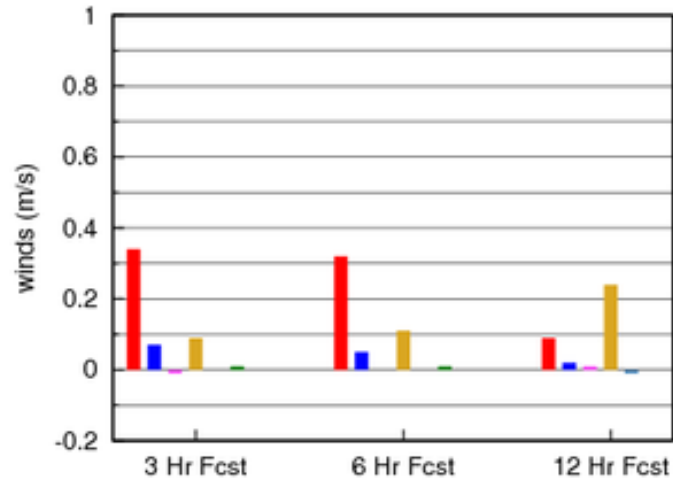
- A - withhold aircraft obs - Exp v6 - control
- B - withhold all profiler obs - Exp v7 - control
- C - withhold VAD winds - Exp v11 - control
- D - withhold rawinsonde obs - Exp. v5 - control
- E - withhold surface obs incl METAR cloud - Exp v9 - control
- F - withhold GPS-Met PW obs - Exp v12 - control
- G - withhold AMVs - Exp v10 - control
- H - withhold radar refl- Exp v8 - control

WINTER

Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (100-400 mb)



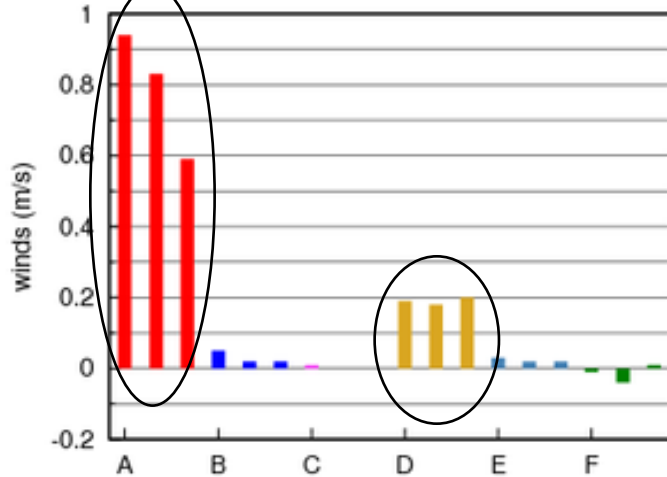
Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (100-400 mb)



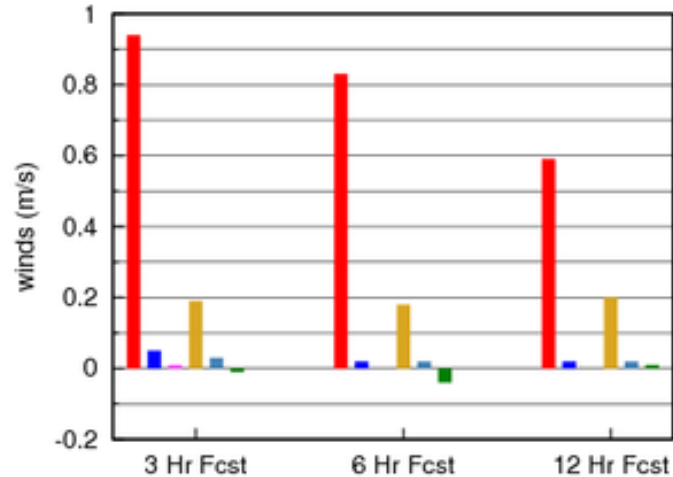
- █ A: No-aircraft - control
- █ B: No-profiler - control
- █ C: No-VAD - control
- █ D: No-RAOB - control
- █ E: No-surface - control
- █ F: No-GPS-PW - control

Wind - national - 400-100 hPa
#1 overall - Aircraft, by far
#2 - RAOBS, distant #3- profiler

Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (100-400 mb)



Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (100-400 mb)



SUMMER

3rd Breakdown for RUC OSE results

- 7 experiments (control, 6 obs denial experiments)

- 2 Regions

- US National (data rich)

- *Midwest (very data rich)*

- 4 layers

- 1000-100 hPa (full depth)

- 1000-800 hPa (near surface)

- 800-400 hPa (mid-troposphere)

- 400-100 hPa (upper troposphere, lower stratosphere)

- 2 seasons

- winter

- summer

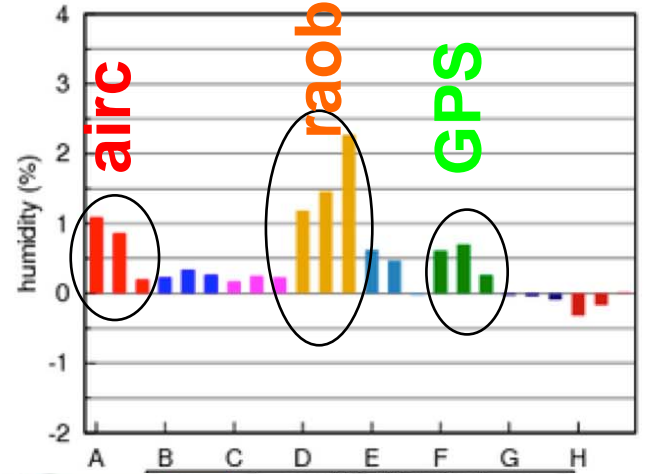
- Forecast duration

- 3h, 6h, 12h

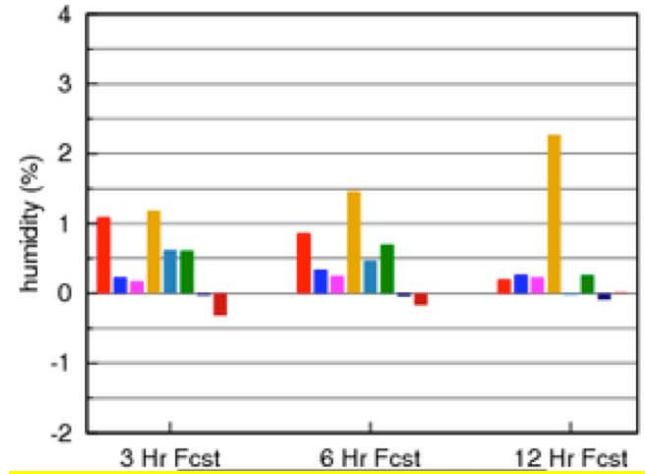
First, look at RH

WINTER

GtLk region, humidity averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-400 mb)



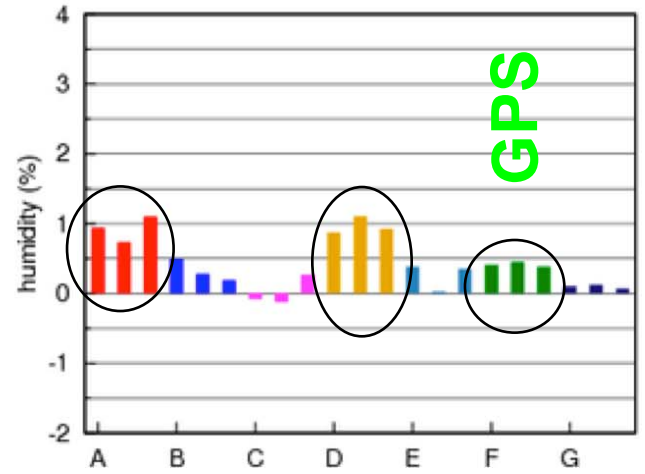
GtLk region, humidity averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-400 mb)



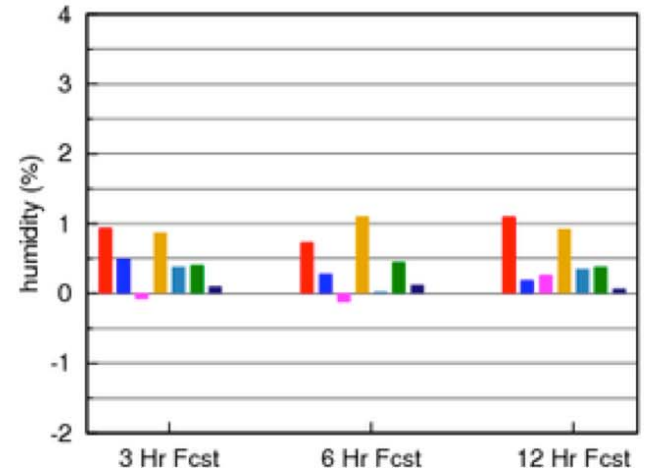
- A - No-aircraft - control
- B - No-profiler - control
- C - No-VAD - control
- D - No-RAOB - control
- E - No-surface - control
- F - No-GPS-PW - control
- G - No-mesonet - control
- H - No-AMV - control

RH - MIDWEST – 1000-400 hPa
#1 obs type = Raobs, aircraft
Closely followed GPS-PW
TAMDAR – strong RH effect

GtLk region, humidity averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-400 mb)



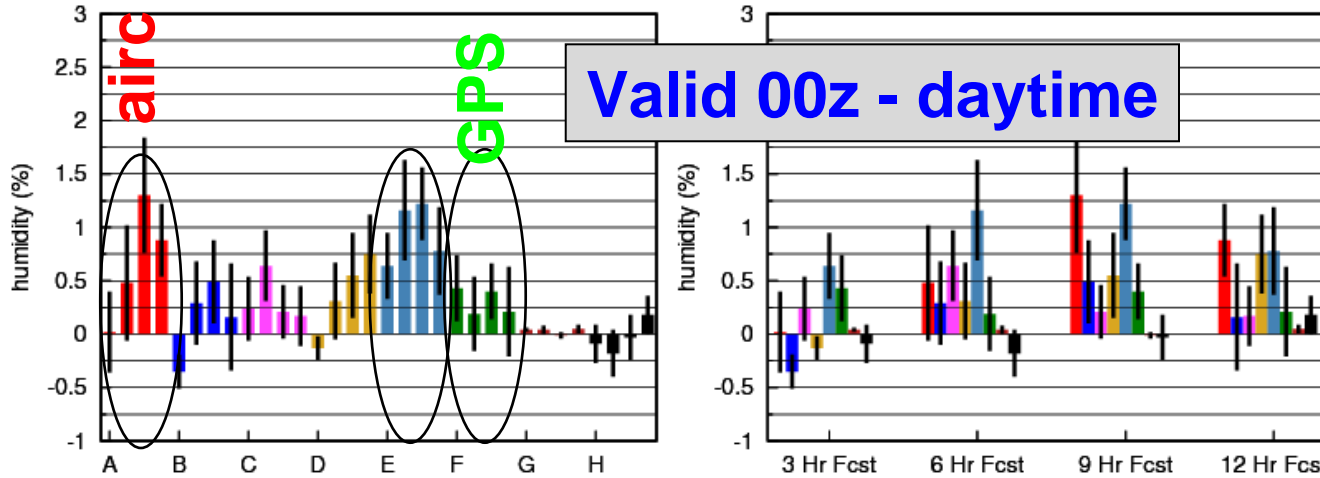
2007-08-15 thru 2007-08-25 (1000-400 mb)



SUMMER

GtLk region, humidity averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-600 mb)
Forecasts valid at 00 UTC

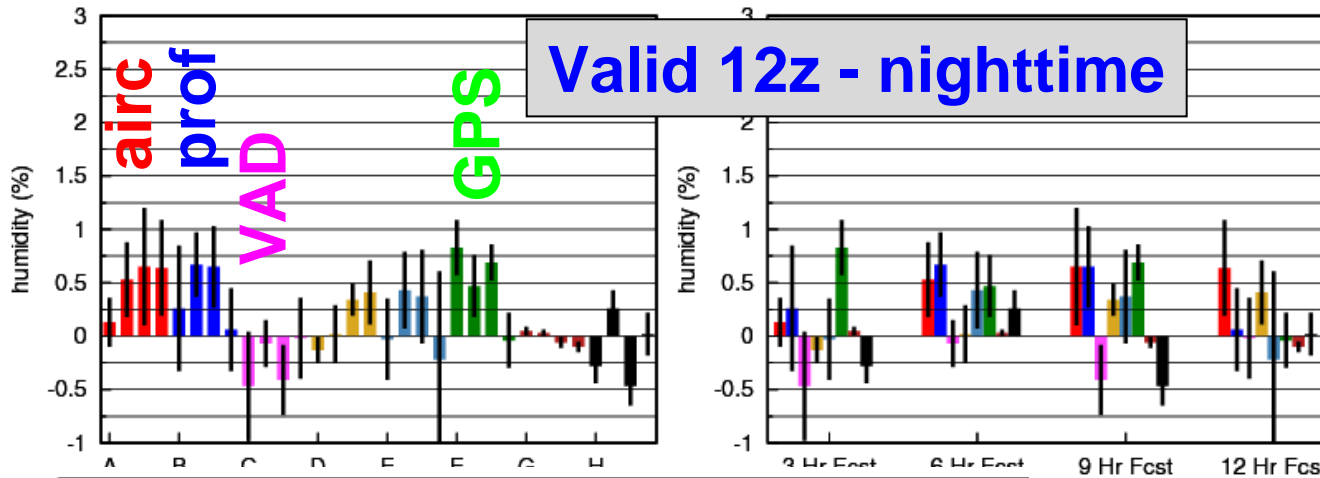
GtLk region, humidity averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-600 mb)
Forecasts valid at 00 UTC



Valid 00z - daytime

GtLk region, humidity averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-600 mb)
Forecasts valid at 12 UTC

GtLk region, humidity averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-600 mb)
Forecasts valid at 12 UTC



Valid 12z - nighttime

- A - withhold aircraft obs - Exp v6 - control
- B - withhold all profiler obs - Exp v7 - control
- C - withhold VAD winds - Exp v11 - control
- D - withhold rawinsonde obs - Exp. v5 - control
- E - withhold surface obs incl METAR cloud - Exp v9 - control
- F - withhold GPS-Met PW obs - Exp v12 - control
- G - withhold AMVs - Exp v10 - control
- H - withhold radar refl- Exp v8 - control

RH - MIDWEST -
1000-600 hPa
Daytime
#1 = sfc, aircraft
#3 = GPS

Nighttime
Aircraft, prof, GPS

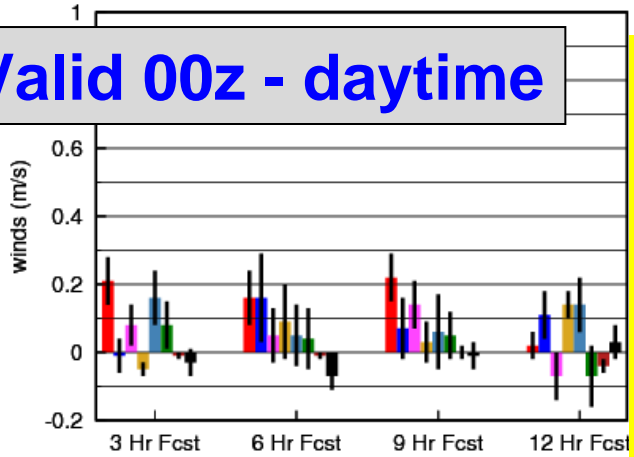
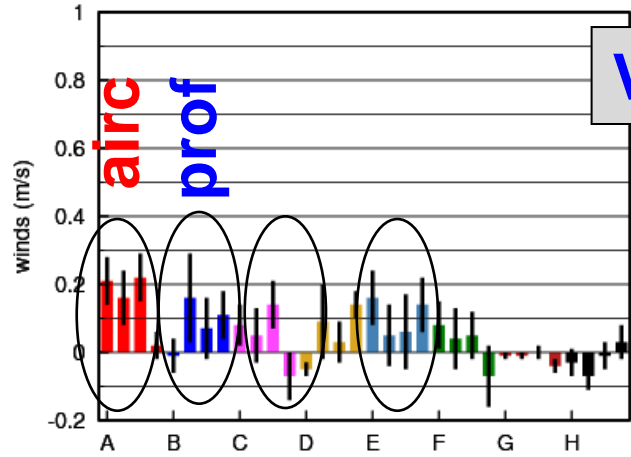
Negative impact
- VAD at night
(bird migration?)
- Radar refl

GtLk region, winds averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-600 mb)
Forecasts valid at 00 UTC

GtLk region, winds averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-600 mb)
Forecasts valid at 00 UTC

**Wind - GtLakes –
1000-600 hPa
Day- Aircraft, prof,
VAD, sfc
Night – Sfc, VAD,
aircraft, prof, GPS**

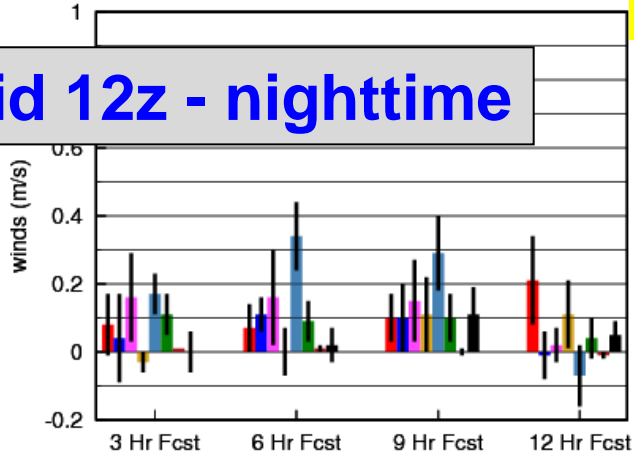
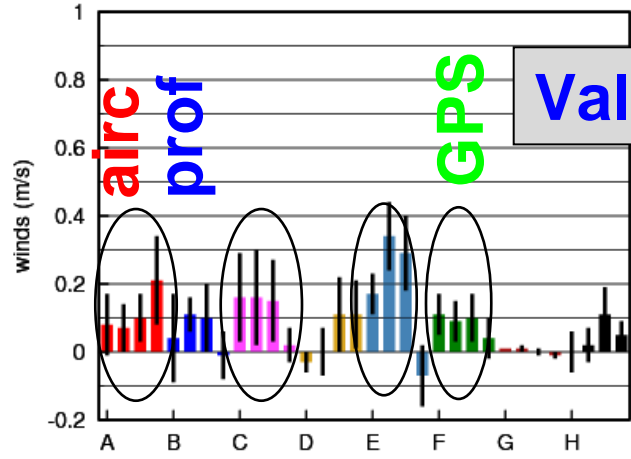
Valid 00z - daytime



GtLk region, winds averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-600 mb)
Forecasts valid at 12 UTC

GtLk region, winds averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-600 mb)
Forecasts valid at 12 UTC

Valid 12z - nighttime



- A - withhold aircraft obs - Exp v6 - control
- B - withhold all profiler obs - Exp v7 - control
- C - withhold VAD winds - Exp v11 - control
- D - withhold rawinsonde obs - Exp. v5 - control
- E - withhold surface obs incl METAR cloud - Exp v9 - control
- F - withhold GPS-Met PW obs - Exp v12 - control
- G - withhold AMVs - Exp v10 - control
- H - withhold radar refl- Exp v8 - control

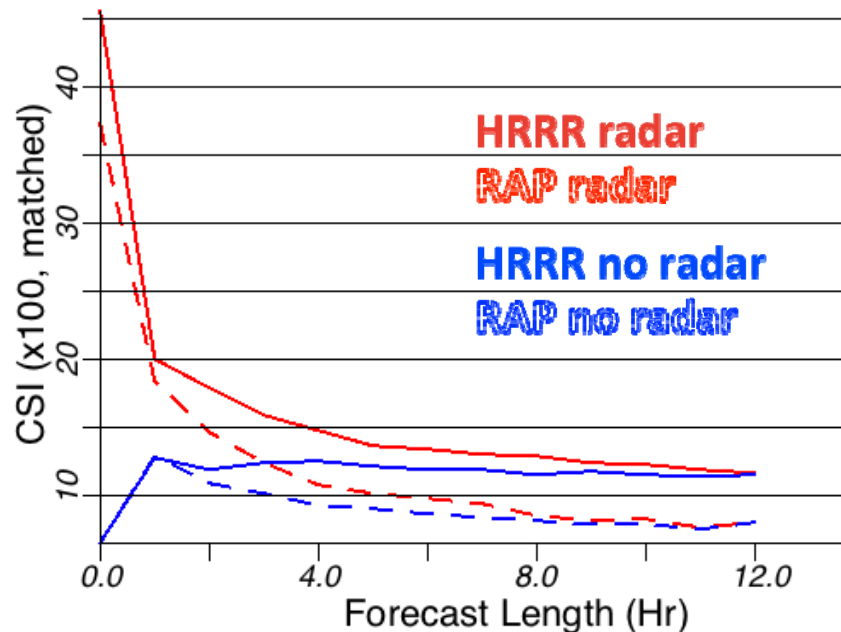
Other RAP-related OSE studies

- **PBL profilers for improved 50-100m wind forecasts**
 - Dept. of Energy funded Wind Forecast Improvement Project (WFIP)
- **Radar reflectivity assimilation**
 - Critical for 3km hourly updated High-Resolution Rapid Refresh (HRRR) experimental forecasts in US for aviation, severe weather, renewable energy
- **AIRS radiance / retrieval assimilation**
 - NESDIS-funded, GOES-R, goal: improve hourly assimilation impact for short-range RAP/HRRR forecasts

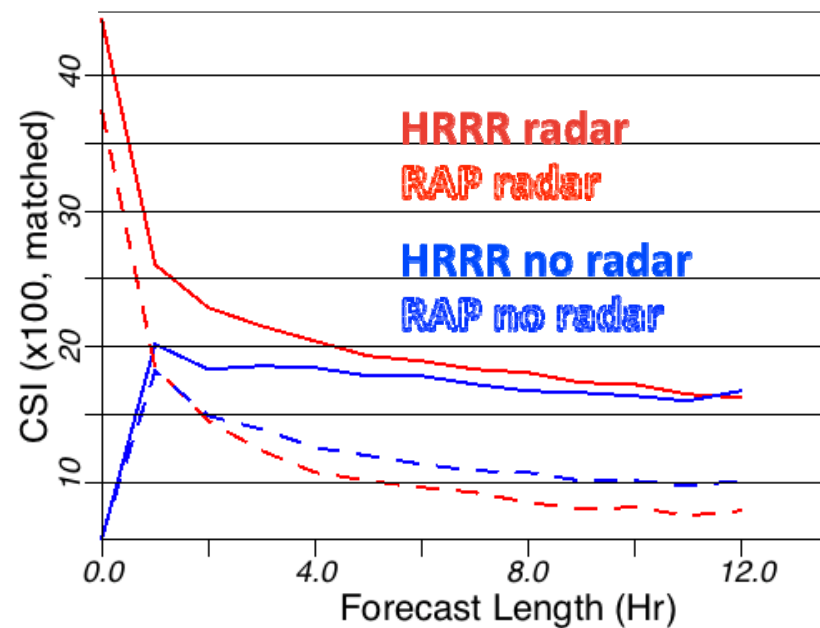
RAP/HRRR Reflectivity Verification

Eastern US, Reflectivity > 25 dBZ
11-21 August 2011

CSI 13 km

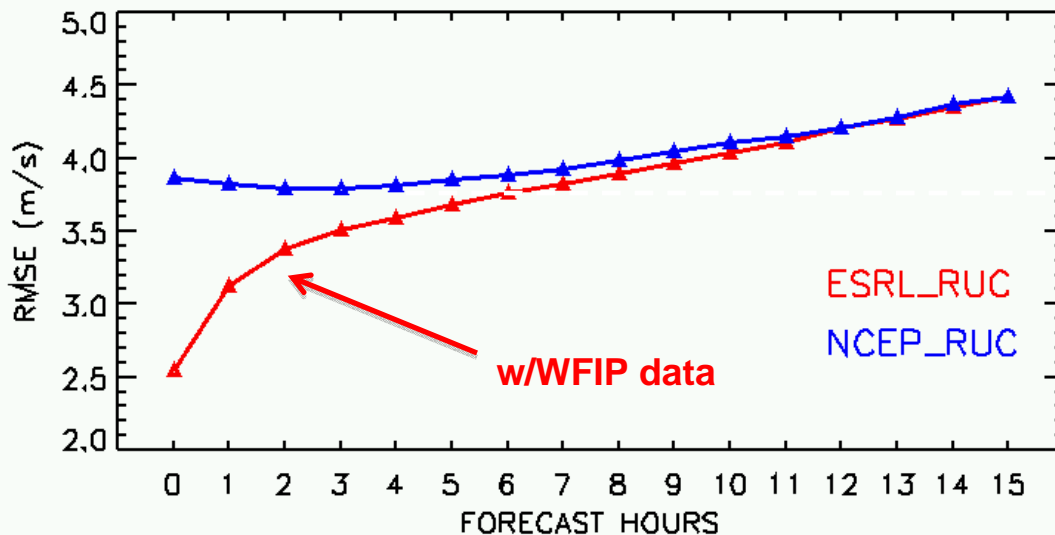
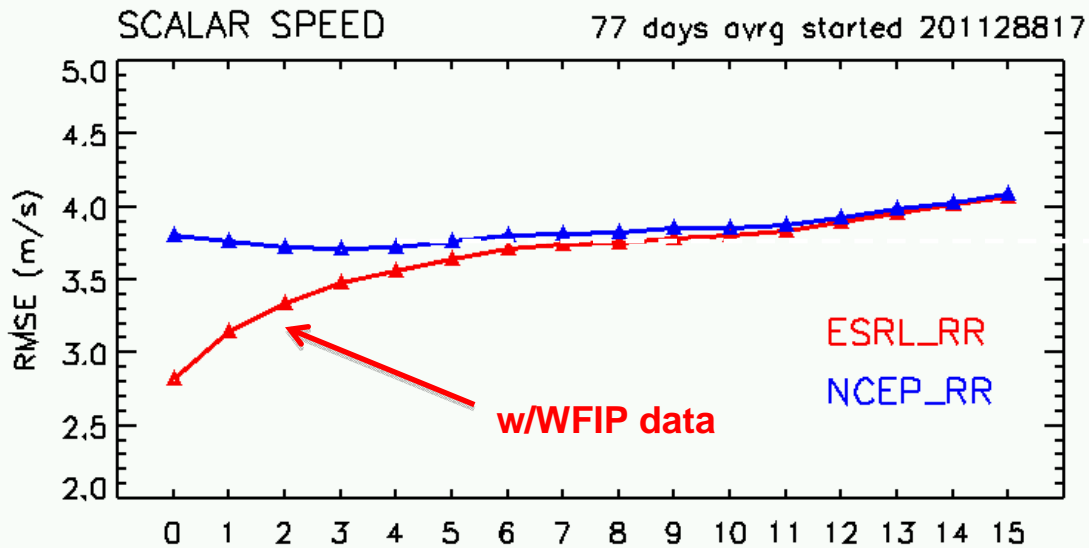


CSI 40 km



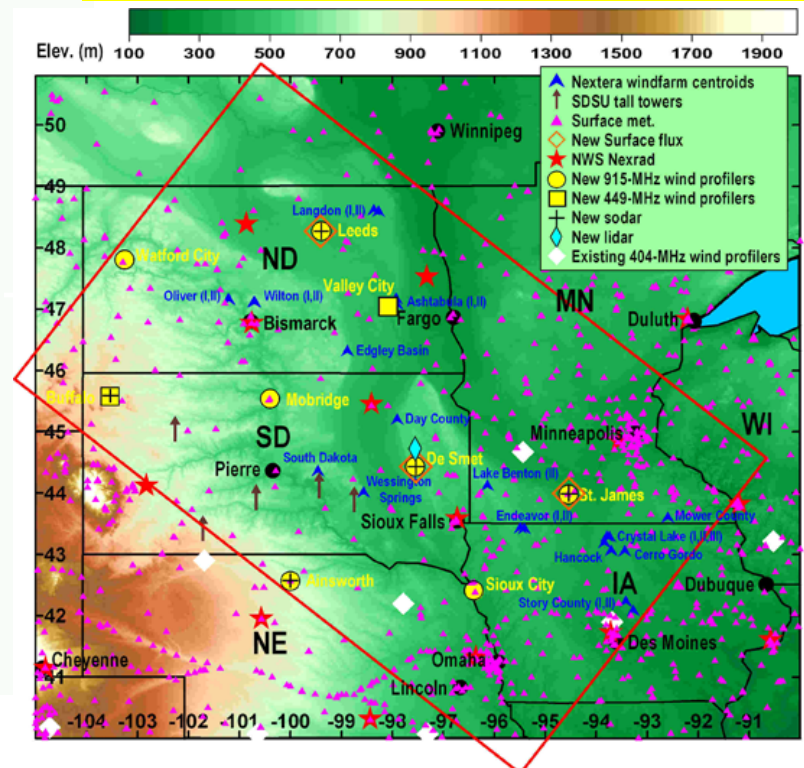
- 3km HRRR forecasts improve upon RAP 13km forecasts, especially at coarser scales → much better upscaled skill
- Radar DDFI adds skill at both 13km and 3km

Wind Forecast Improvement Project vertically averaged wind profiler RMSE



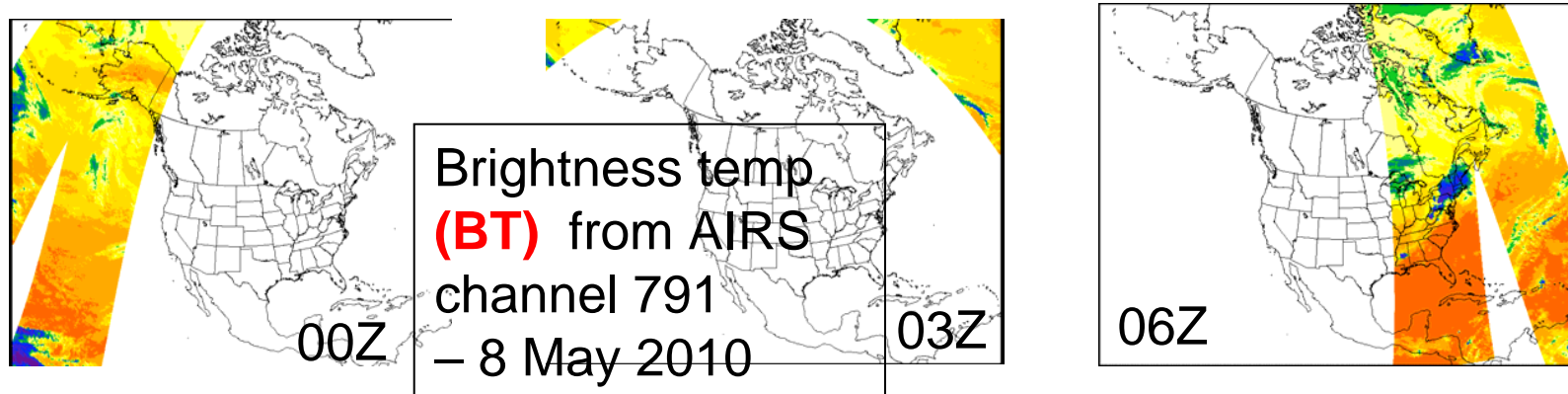
Averaged over 7 sites, 500–2000 meters over the ground

Improvement in 500-2000m wind out to ~8h due to 10 extra 915 MHz wind profiler in n. central US – both in RUC and RAP (RR)

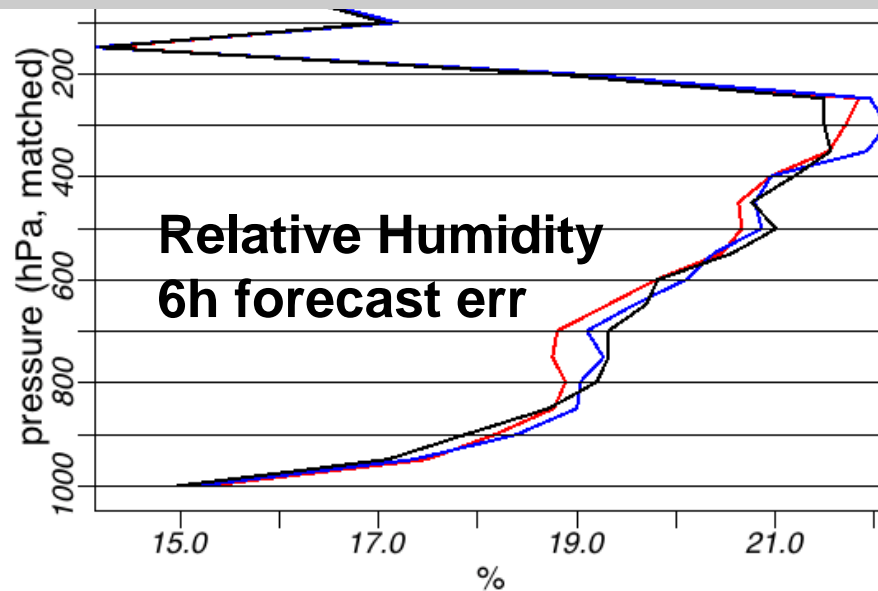


AIRS Radiance Coverage in RAP

- 1.5-h time window (+/- 1.5 h), in 3-h cycle RAP retro run



AIRS Impact Exps with RAP



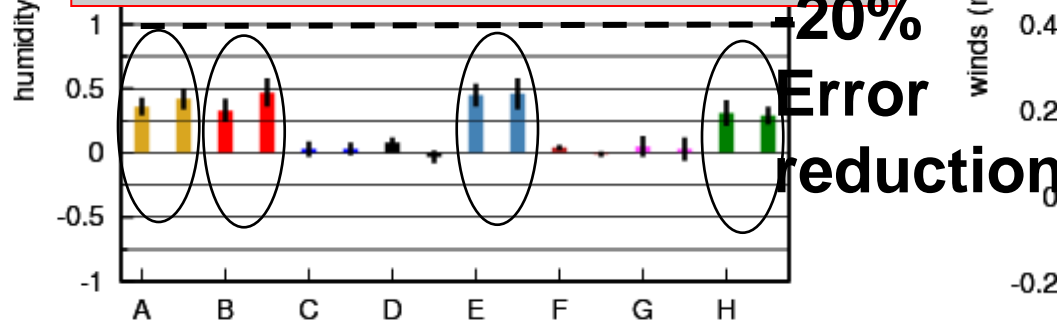
- CNTL
- AIRS Ex. 1 (default 120 channels)
- AIRS Ex. 2 (selected 68 channels)

Haidao Lin,
Steve Weygandt

210 220 230 240 250 260 270 280 290 300 310

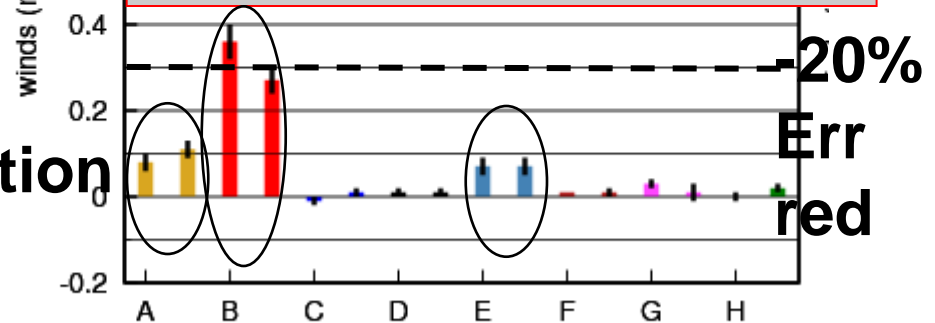
CONUS, 6h/9h only, 12z+00z, RAP

RH 1000-600 –
Similar contribution from sfc, aircraft, raob, GPS

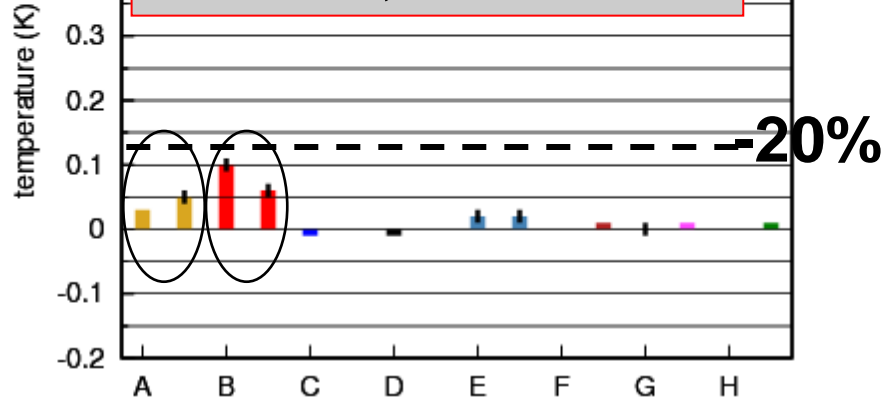


Natl region, temperature averaged rms - matched
 2011-05-29 thru 2011-06-13 (1000-100 mb)
 Forecasts valid at 00 and 12 UTC

Wind 1000-100 –
#1 – aircraft, distant #2 – raob, sfc



Temp 1000-100 –
Aircraft, raob

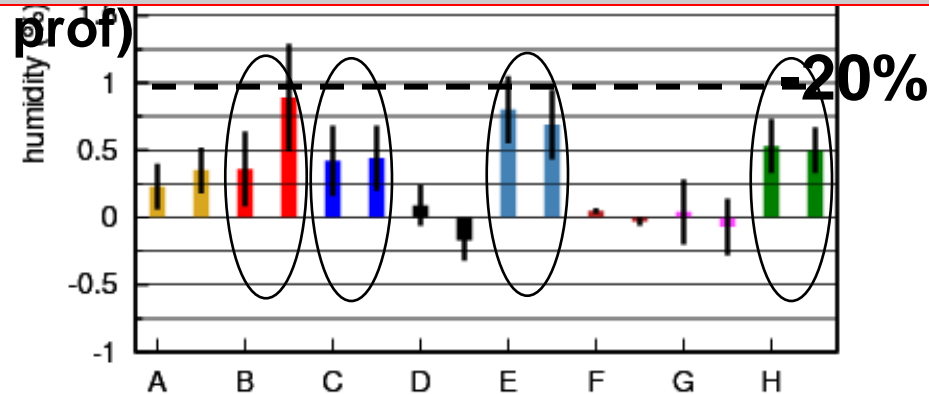


- █ A - withhold aircraft obs - Exp v6 - control
- █ B - withhold all profiler obs - Exp v7 - cont
- █ C - withhold VAD winds - Exp v11 - control
- █ D - withhold rawinsonde obs - Exp. v5 - co
- █ E - withhold surface obs incl METAR cloud
- █ F - withhold GPS-Met PW obs - Exp v12 - c
- █ G - withhold AMVs - Exp v10 - control
- █ H - withhold radar refl- Exp v8 - control

6h F – 0h A for normalizing
V – 1.5 m/s, T – 0.6K
RH – 5%

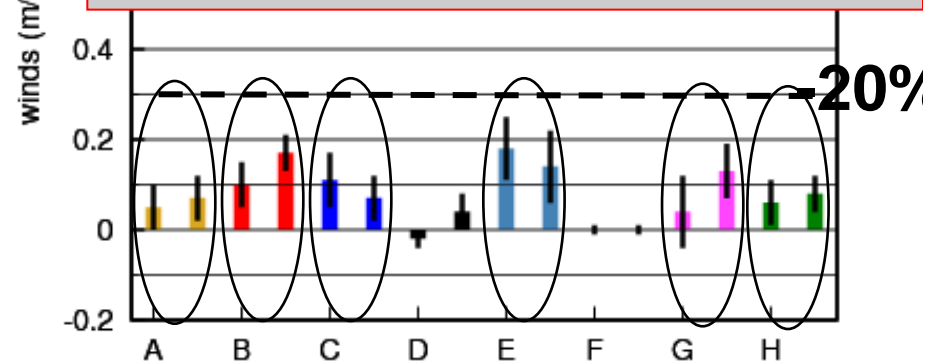
Gt Lakes data-rich area, 12z/0z, 6h/9h only, RAP

RH 1000-600 –
Profiler added (sfc, air, GPS,

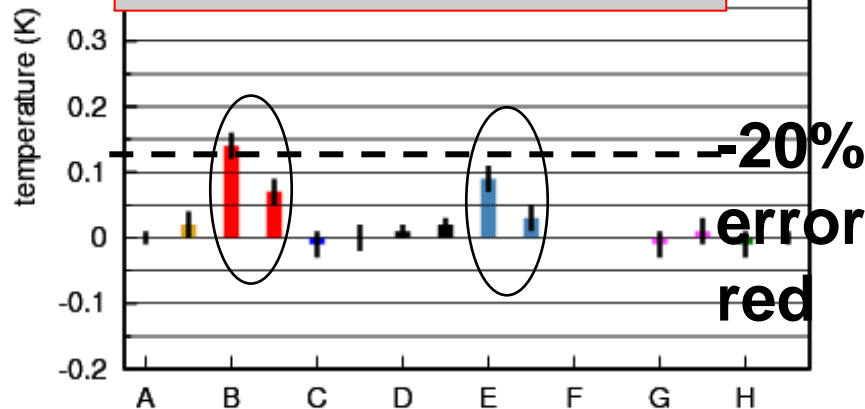


GtLk region, temperature averaged rms - matched
 2011-05-29 thru 2011-06-13 (1000-600 mb)
 Forecasts valid at 00 and 12 UTC

Wind 1000-600 –
Profiler added (sfc, air, prof,
GPS, raob, VAD)



Temp 1000-600 –
Aircraft, sfc



- A - withhold aircraft obs - Exp v6 - control
- B - withhold all profiler obs - Exp v7 - cont
- C - withhold VAD winds - Exp v11 - control
- D - withhold rawinsonde obs - Exp. v5 - co
- E - withhold surface obs incl METAR cloud
- F - withhold GPS-Met PW obs - Exp v12 - c
- G - withhold AMVs - Exp v10 - control
- H - withhold radar refl- Exp v8 - control

6h F – 0h A for normalizing
V – 1.5 m/s, T – 0.6K
RH – 5%

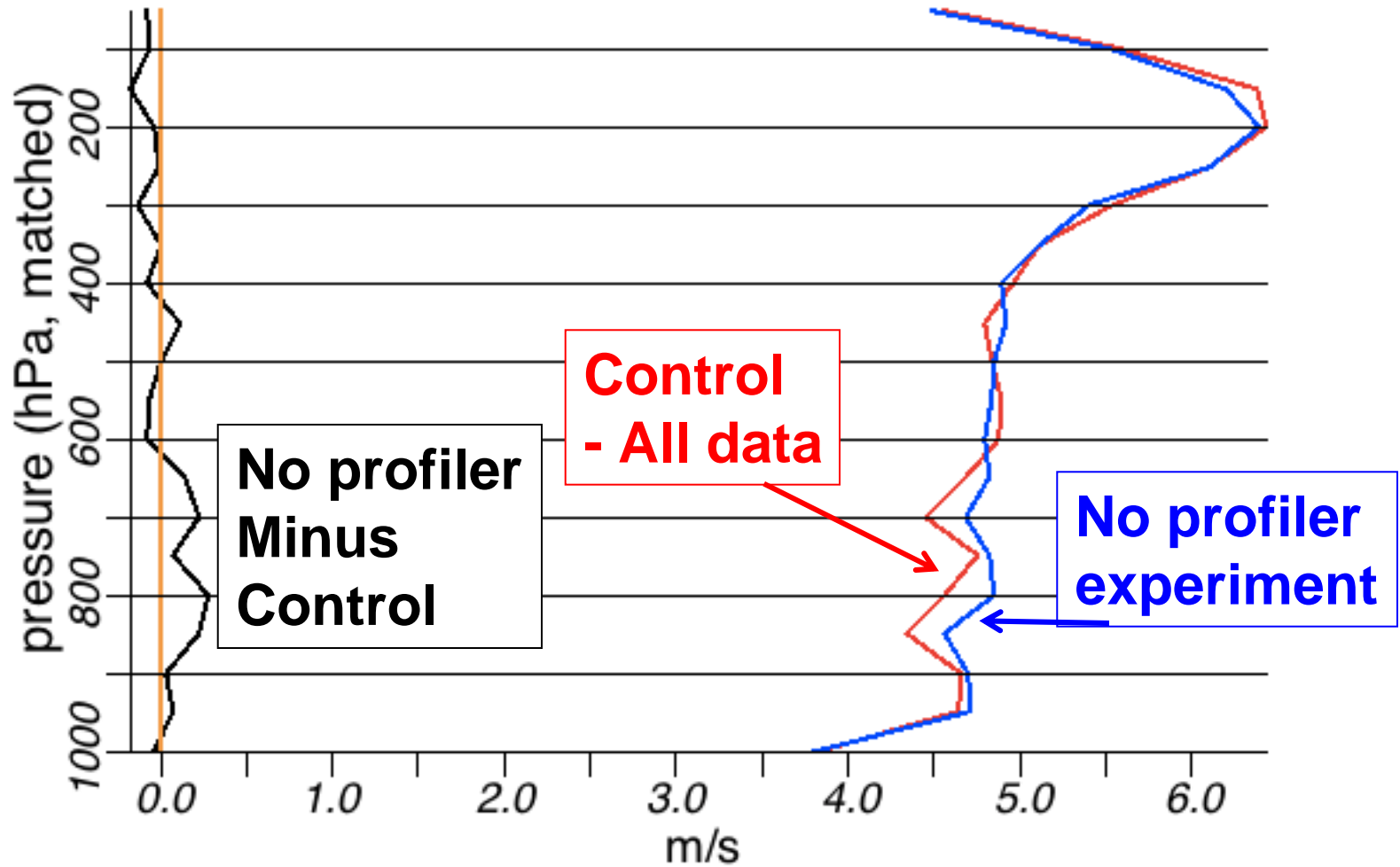
Conclusions – RUC/RAP OSE exps

- Extensive **obs impact study** performed for 1 winter and 2 summer retro periods using **RUC/RAP** for **3-12h forecast impact**
- **Heterogeneous** observing system in US effective for short-range (3-12h) forecasts for tropospheric RH, temp, winds.
 - Stronger wind-moisture cross-covariance with GSI in RAP than with RUC 3dVAR
- **Aircraft data most important observation overall** for short-range fcsts from troposphere-to-sfc (10-20% reduction for 6h fcst err for T/V/RH), **but far from sole key observing system**.
 - For RUC OSEs - **RAOBs** of #2 importance overall
 - For RAP OSEs (w/ GSI) – **broader** contribution evident from different obs systems - **GPS-PW, surface, RAOB**
- Data-rich Great Lakes area –
 - **profiler** provides similar wind/RH impact
 - 6 of 8 systems provide at least 5% err reduction for winds
 - 4 of 8 do same for RH (aircraft, sfc, GPS-PW, profiler)

Conclusions – RUC/RAP OSE exps #2

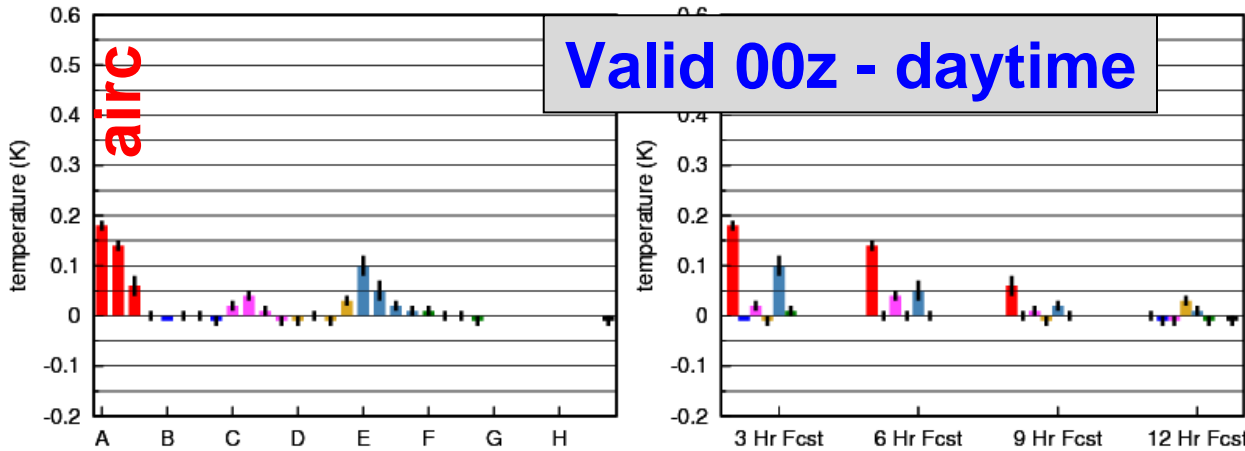
- Results needing follow-up
 - No additional value from [mesonet](#) data in RUC exps.
 - ESRL, NCEP efforts underway to determine station/time/wind direction-dependent biases to improve forward model
 - Test mesonet impact with RAP/GSI
 - Little value added from [AMVs](#) in RUC or RAP experiments
 - high obs error in GSI/RAP?
 - Test U.Wisconsin AMVs
 - [VAD winds](#) also show contribution but nighttime negative impact
 - need better bird migration QC?
 - Other RAP denial experiments needed
 - WindSat, buoy, GOES-cloud
- Add cold-season retrospective impact tests for RAP/GSI
- EnKF/hybrid/GSI efforts – hourly RAP, 6h for NOAA FIM global model
- **RUC-OSEs - MWR article - June 2010 – Benjamin et al.**
 - complements Moninger et al. 2010 W&F paper on TAMDAR impact

- ZERO rgn:GtLk, winds rms 6h fcst 2011-05-29 thru 2011-06-13
- RRret_June_2011_v7-RRret_June_2011_v4 rgn:GtLk, winds rms 6h fcst 2
- RRret_June_2011_v7 rgn:GtLk, winds rms 6h fcst 2011-05-29 thru 2011-0
- RRret_June_2011_v4 rgn:GtLk, winds rms 6h fcst 2011-05-29 thru 2011-0



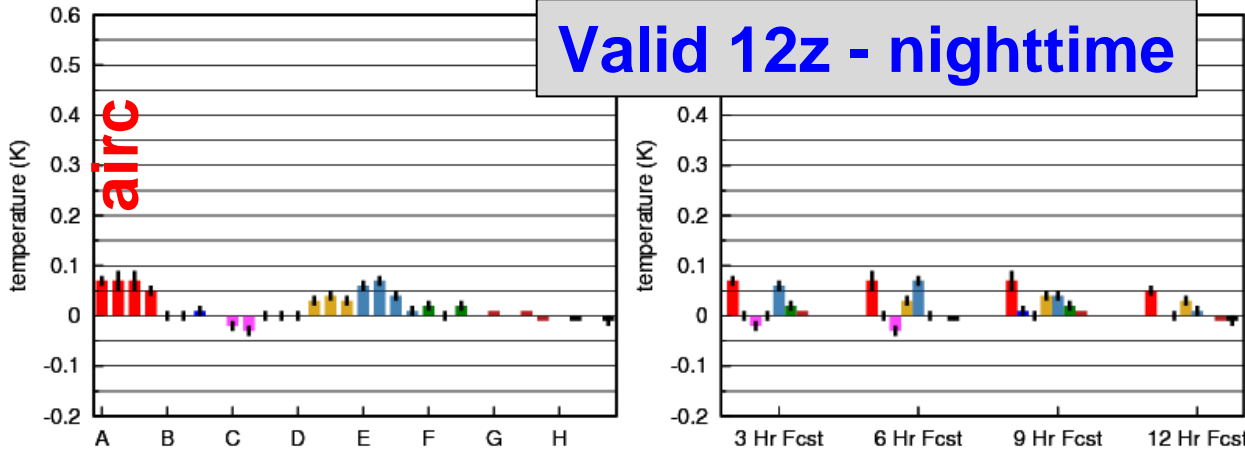
Natl region, temperature averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-600 mb)
Forecasts valid at 00 UTC

Natl region, temperature averaged rms - matched
2011-05-30 thru 2011-06-13 (1000-600 mb)
Forecasts valid at 00 UTC



Natl region, temperature averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-600 mb)
Forecasts valid at 12 UTC

Natl region, temperature averaged rms - matched
2011-05-30 thru 2011-06-12 (1000-600 mb)
Forecasts valid at 12 UTC

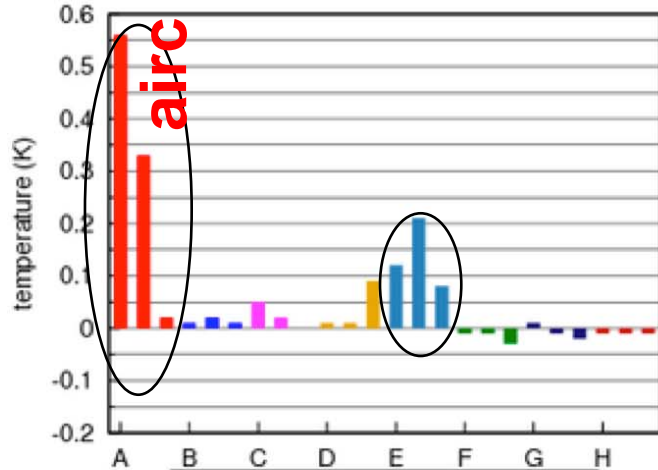


- A - withhold aircraft obs - Exp v6 - control
- B - withhold all profiler obs - Exp v7 - control
- C - withhold VAD winds - Exp v11 - control
- D - withhold rawinsonde obs - Exp. v5 - control
- E - withhold surface obs incl METAR cloud - Exp v9 - control
- F - withhold GPS-Met PW obs - Exp v12 - control
- G - withhold AMVs - Exp v10 - control
- H - withhold radar refl- Exp v8 - control

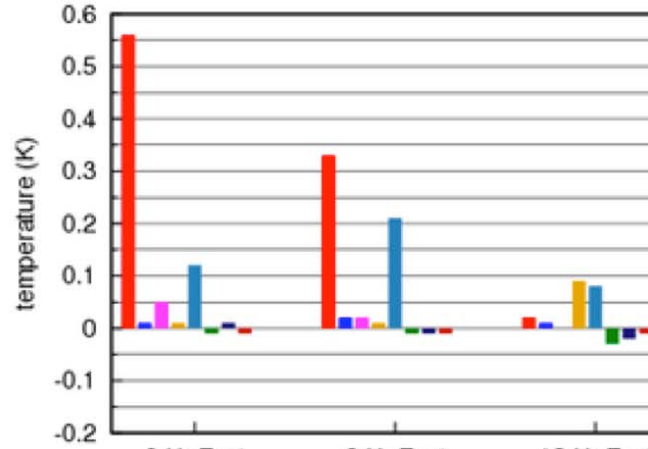
Temp - national -
1000-800 hPa
#1 = Aircraft
#2 = sfc
#3 = raobs (night),
VAD (day)

WINTER

GI Lk region, temperature averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-800 mb)



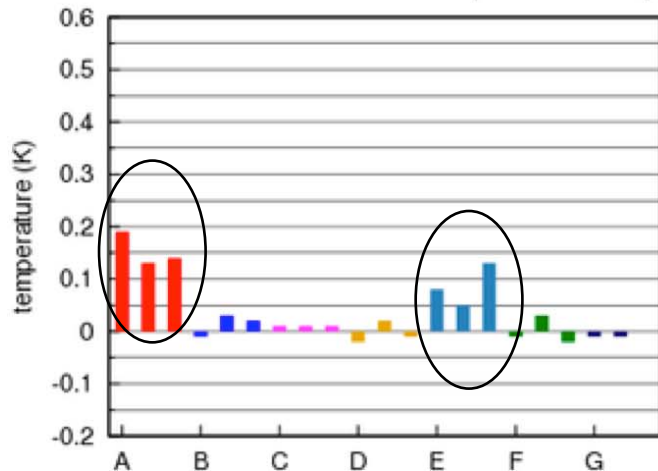
GI Lk region, temperature averaged rms - matched
2006-11-26 thru 2006-12-06 (1000-800 mb)



- █ A - No-aircraft - control
- █ B - No-profiler - control
- █ C - No-VAD - control
- █ D - No-RAOB - control
- █ E - No-surface - control
- █ F - No-GPS-PW - control
- █ G - No-mesonet - control
- █ H - No-AMV - control

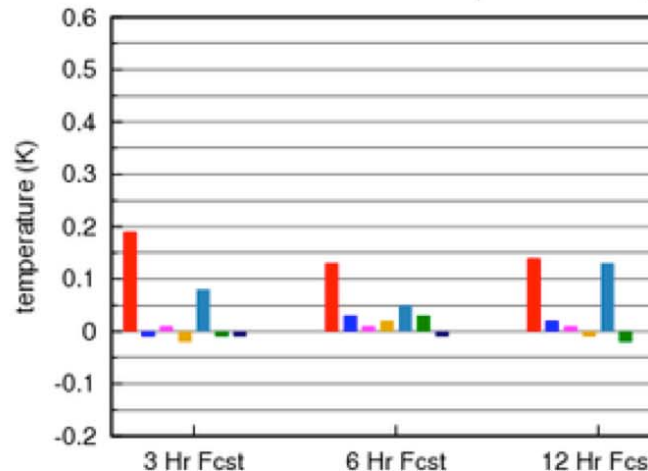
Temp - MIDWEST - 1000-800 hPa
#1 = aircraft (incl. TAMDAR)
#2 = surface (winter and summer)

GI Lk region, temperature averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-800 mb)

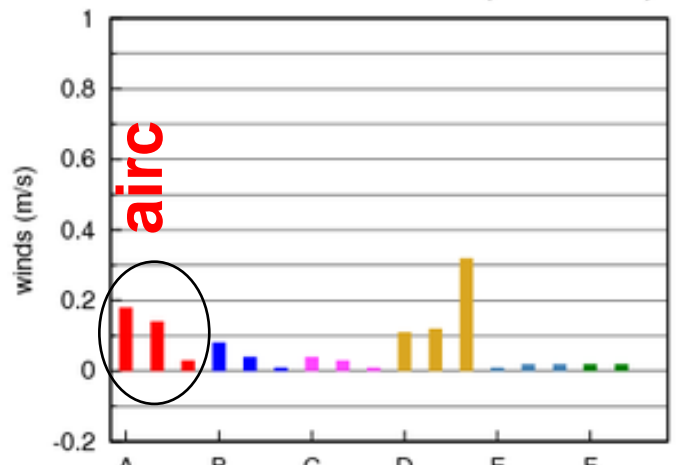


GI Lk region, temperature averaged rms - matched
2007-08-15 thru 2007-08-25 (1000-800 mb)

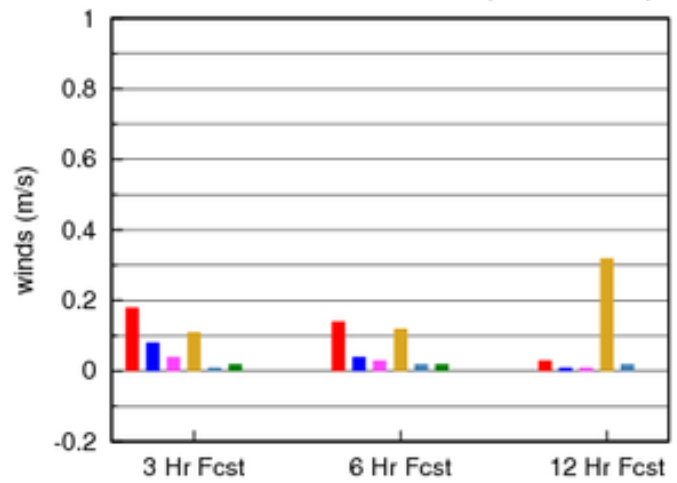
SUMMER



Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (400-800 mb)



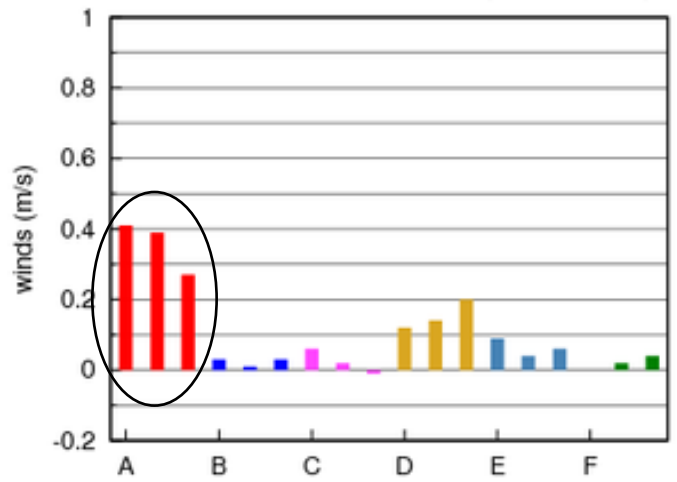
Natl region, winds averaged rms - matched
2006-11-26 thru 2006-12-06 (400-800 mb)



- A: No-aircraft - control
- B: No-profiler - control
- C: No-VAD - control
- D: No-RAOB - control
- E: No-surface - control
- F: No-GPS-PW - control

Wind - national - 800-400 hPa
#1 overall - Aircraft
RAOBs - #1 winter @ 12h

Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (400-800 mb)



Natl region, winds averaged rms - matched
2007-08-15 thru 2007-08-25 (400-800 mb)

