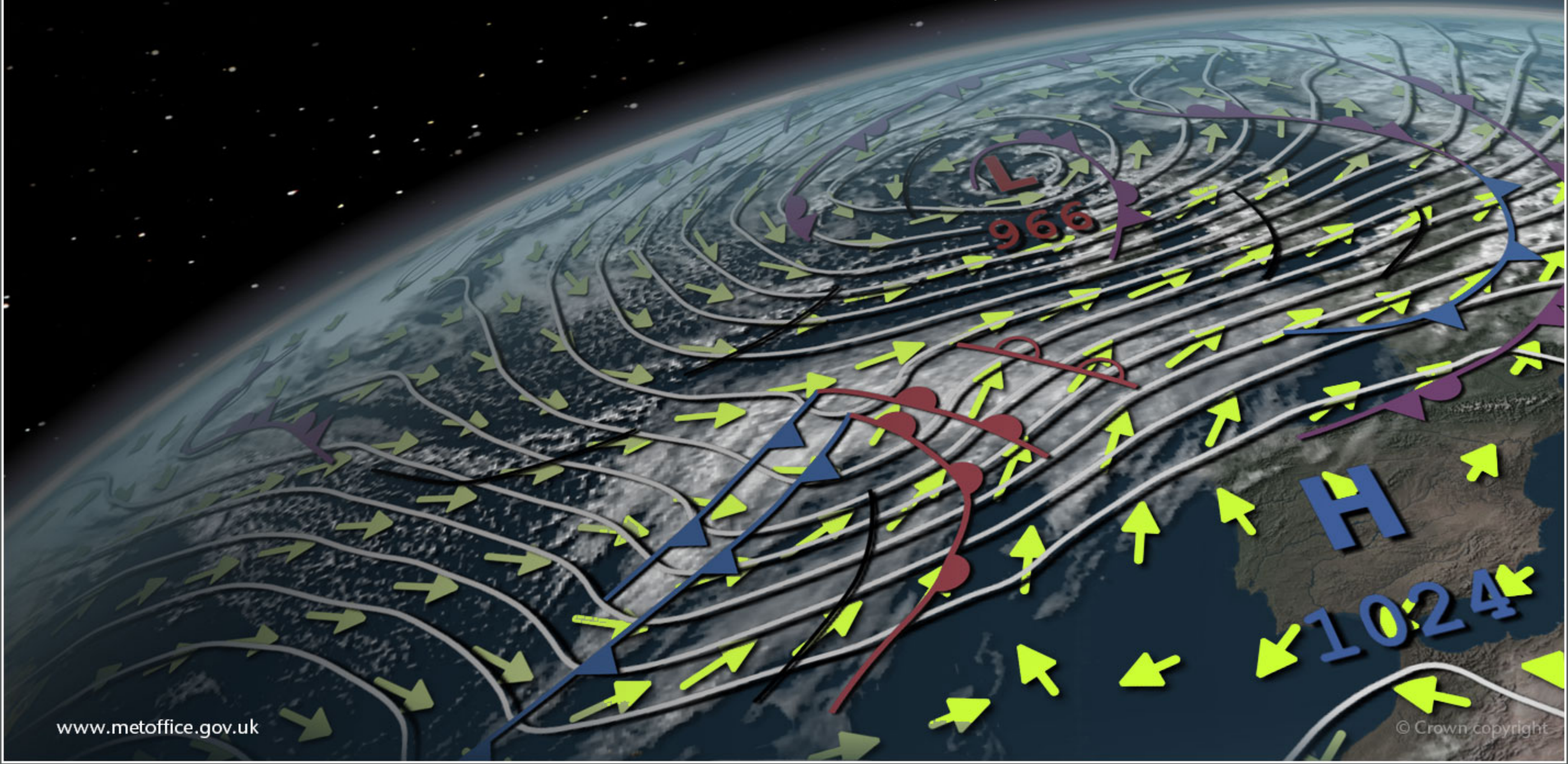
Towards improved height assignment and quality control of AMVs in Met Office NWP

James Cotton, Mary Forsythe, Francis Warrick

International Winds Workshop, Monterey, 28 June 2016



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- Motivation
- QC in Model Dry Layers
- Low Level Inversion Correction
- Global Impact Experiments

Met Office

Motivation

Height assignment (HA) remains dominant source of error in AMV derivation

Observation operator: single-level point observation of wind

Current approach to HA errors:

1) *a-priori* blacklist of problem areas with large systematic errors
2) down-weight through situation-dependent obs. errors
3) bias correction of mean height errors (regional NWP)

Project Aim

Can we use model forecast profiles to further improve handling of HA errors?

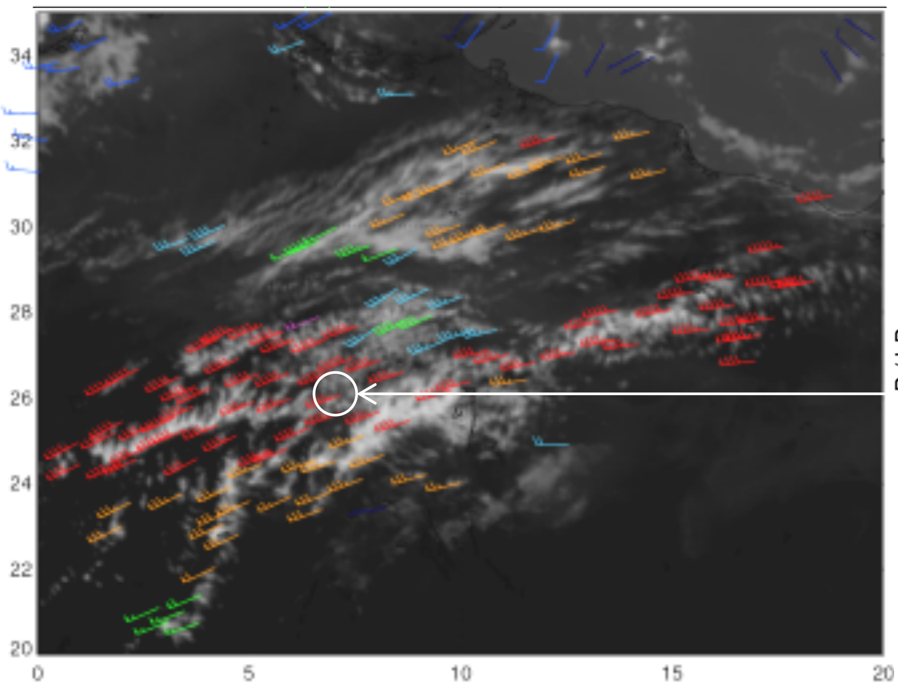
- AMVs derived from tracking cloud/WV features - investigate quality control of AMVs assigned in *dry layers* of model
- Height correction in presence of inversions

QC in Model Dry Layers

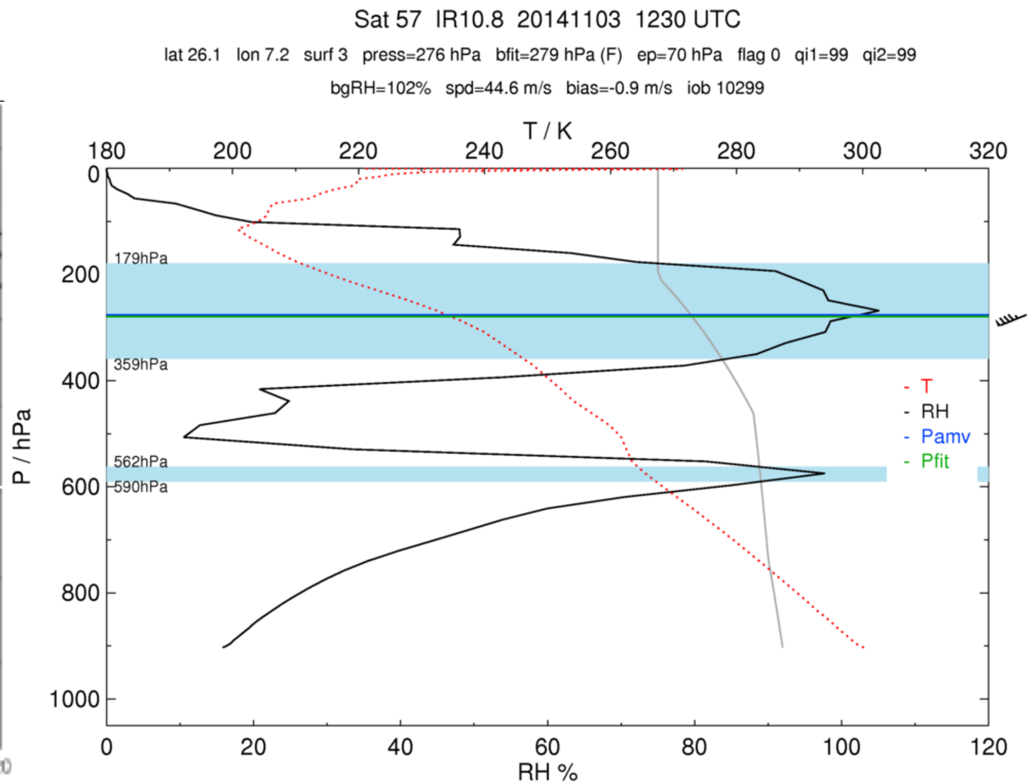
Case study 1. North Africa

MSG IR10.8 AMVs at 12:30 UTC, 3 Nov 2014

AMV Speed



QI2 > 80



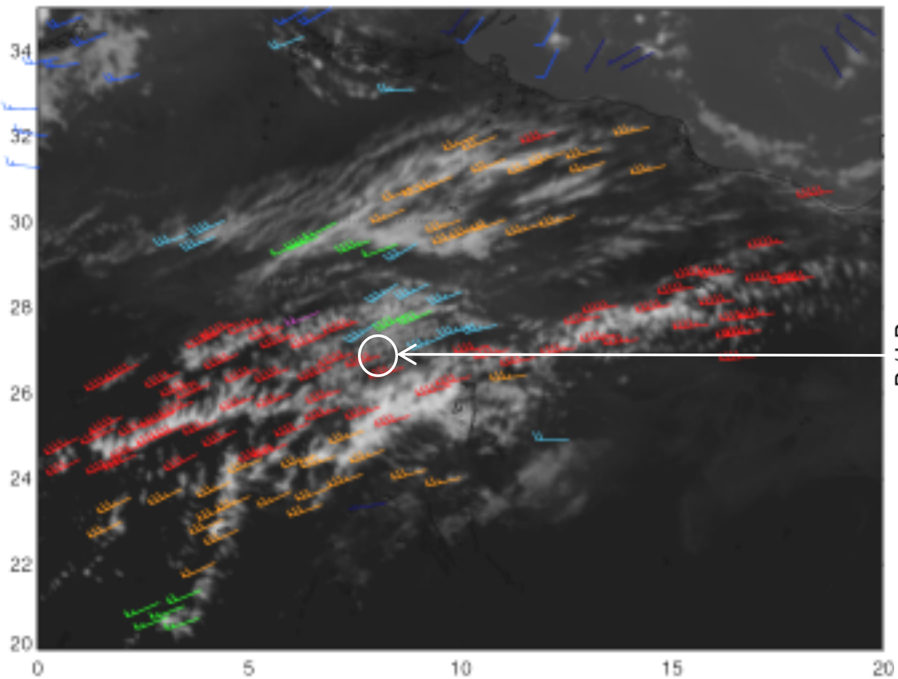
P=276 hPa, V=45 m/s, O-B=-0.9 m/s, BgRH=102%

AMV coincident with middle of moist layer and best-fit pressure

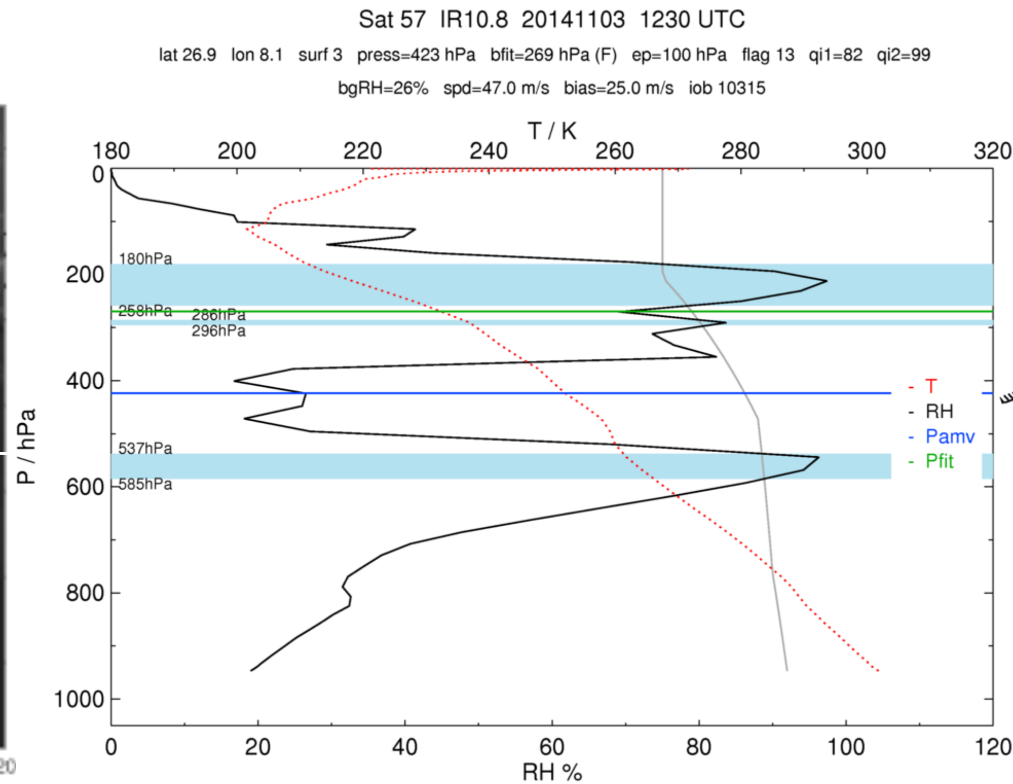
Case study 1. North Africa

MSG IR10.8 AMVs at 12:30 UTC, 3 Nov 2014

AMV Speed



QI2 > 80



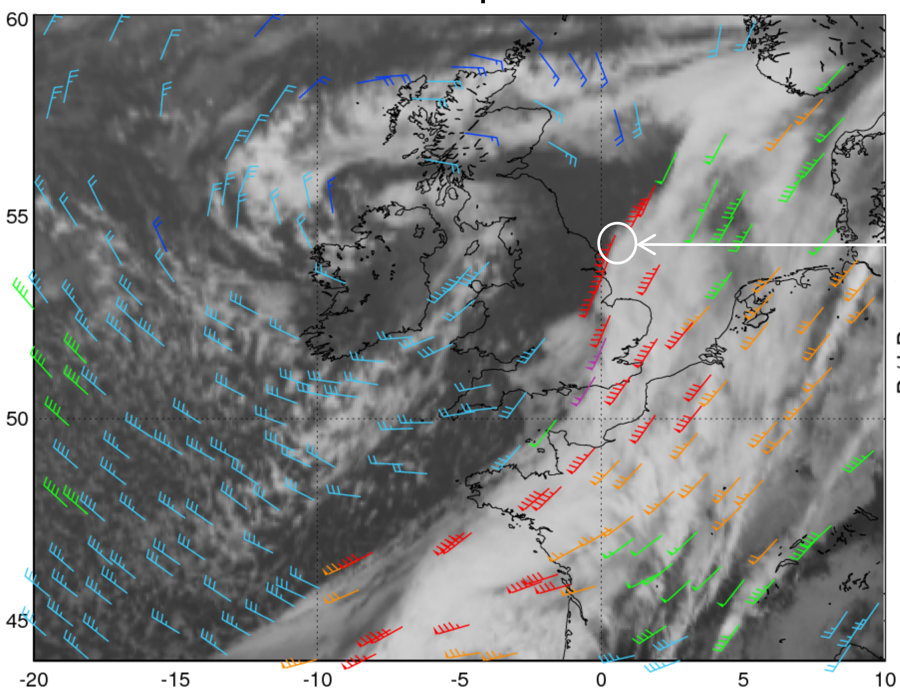
P=423 hPa, V=47 m/s, O-B=+25 m/s, BgRH=26%

AMV assigned in dry slot between 2 moist layers. Large speed bias

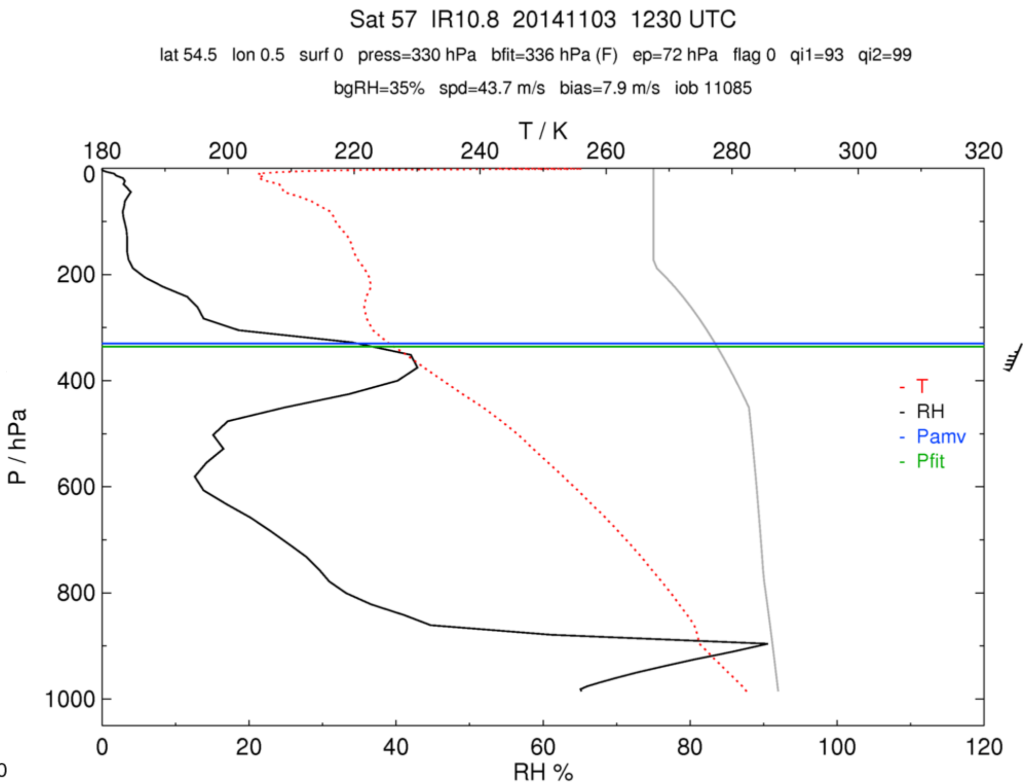
Case study 2. NW Europe

MSG IR10.8 AMVs at 12:30 UTC, 3 Nov 2014

AMV Speed



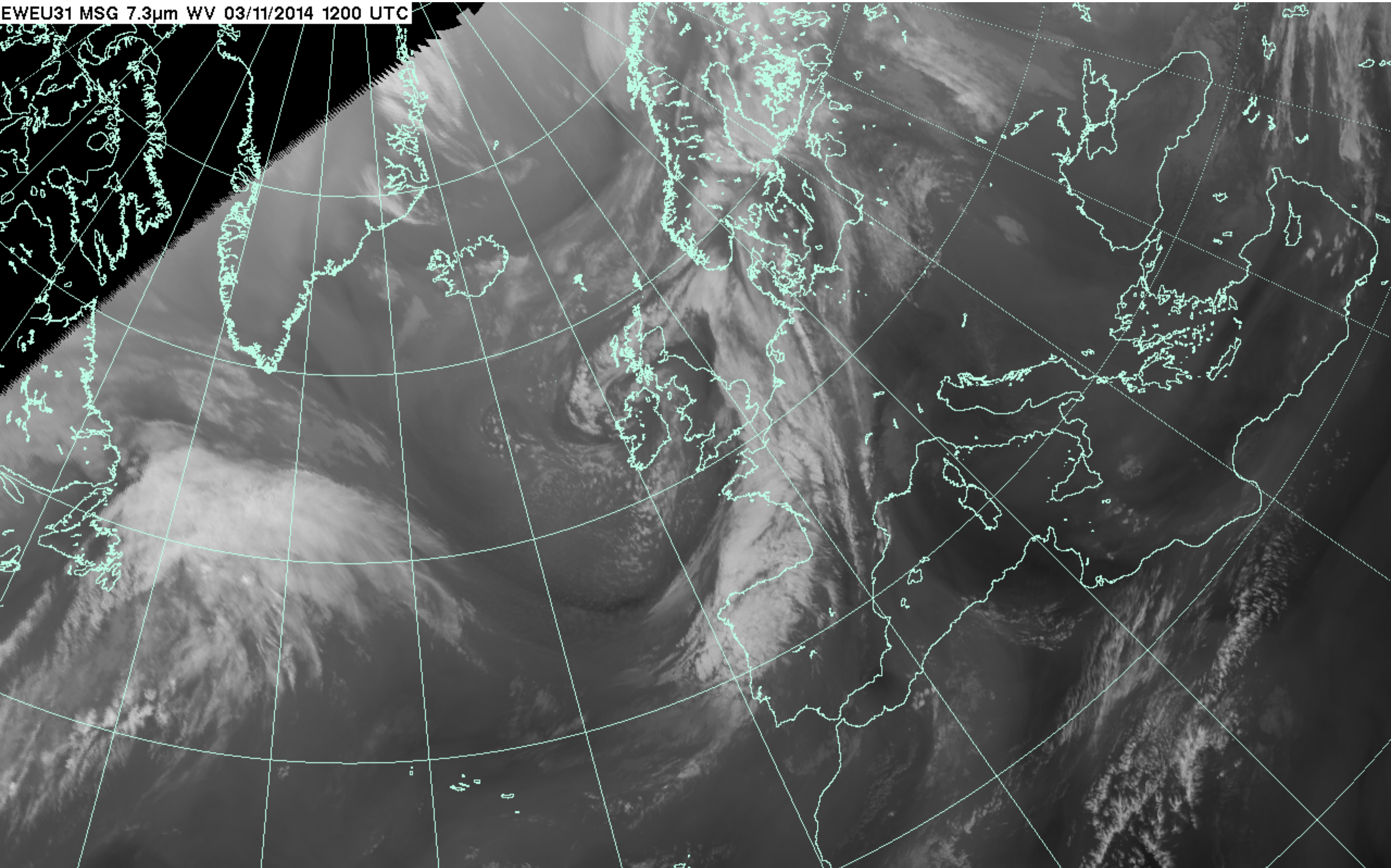
QI2 > 80



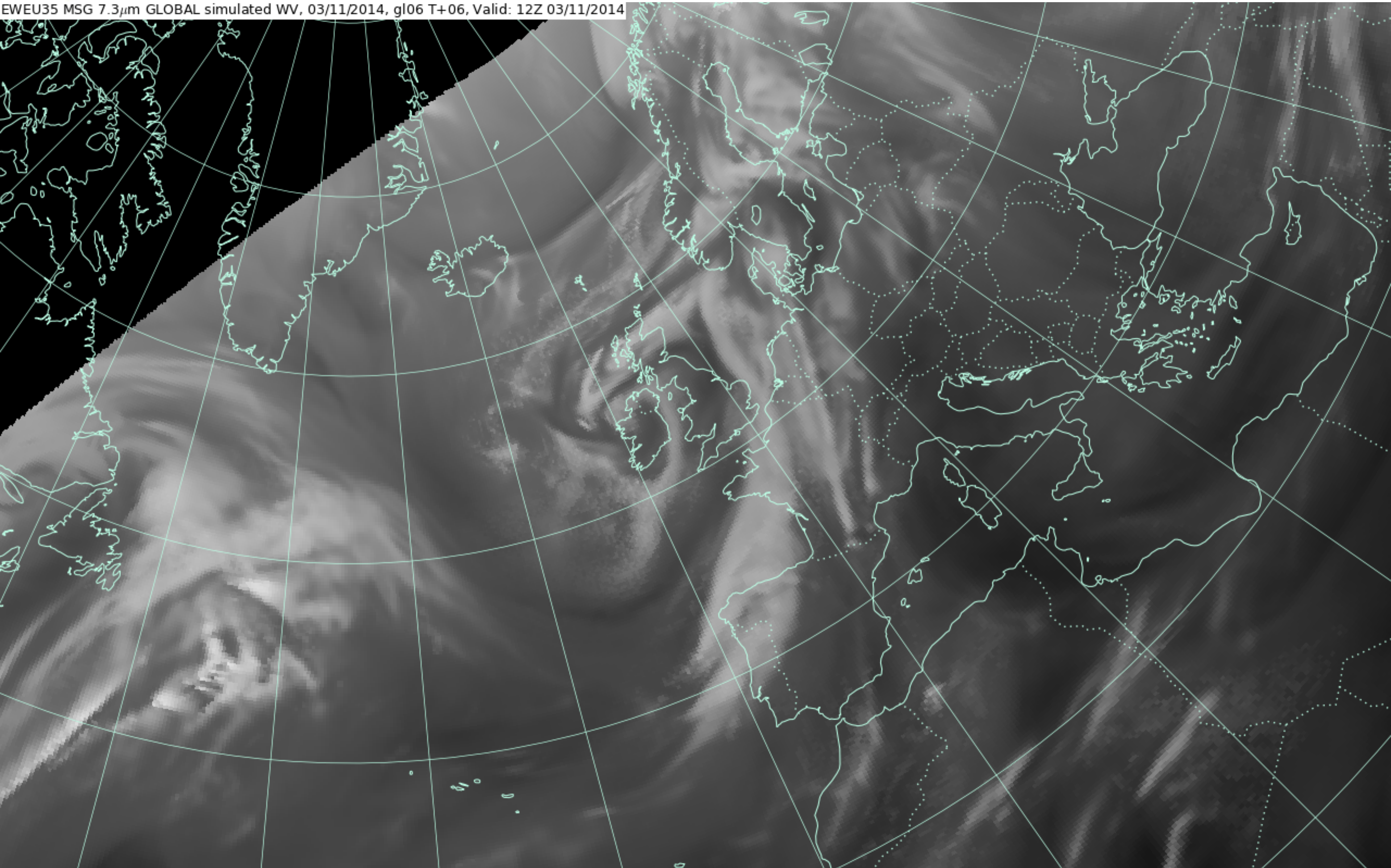
P=330 hPa, V=44 m/s, O-B=+8 m/s, BgRH=35%

AMV assimilated, consistent with imagery. Bg RH only 35% - model error?

MSG WV7.3 Observed



MSG WV7.3 Simulated T+6

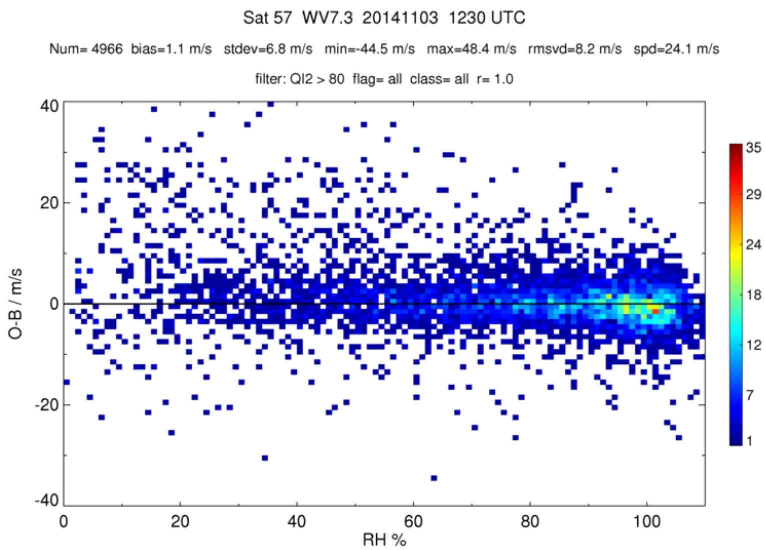


Bg RH as Quality Indicator

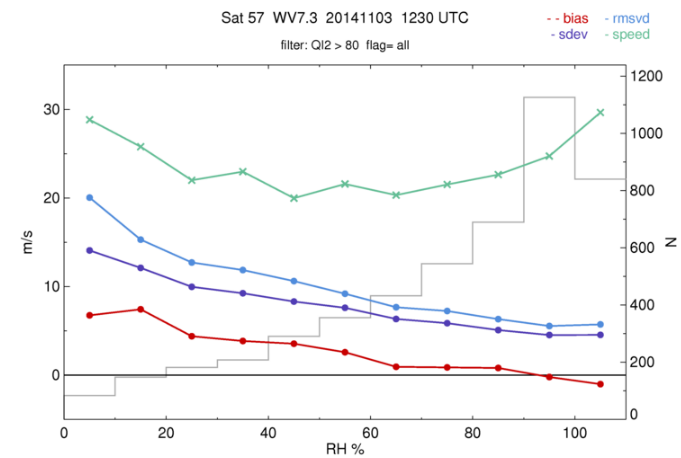
MSG

Background RH a good quality indicator for the **IR** and **WV** winds, less so for visible

Met-10 WV7.3

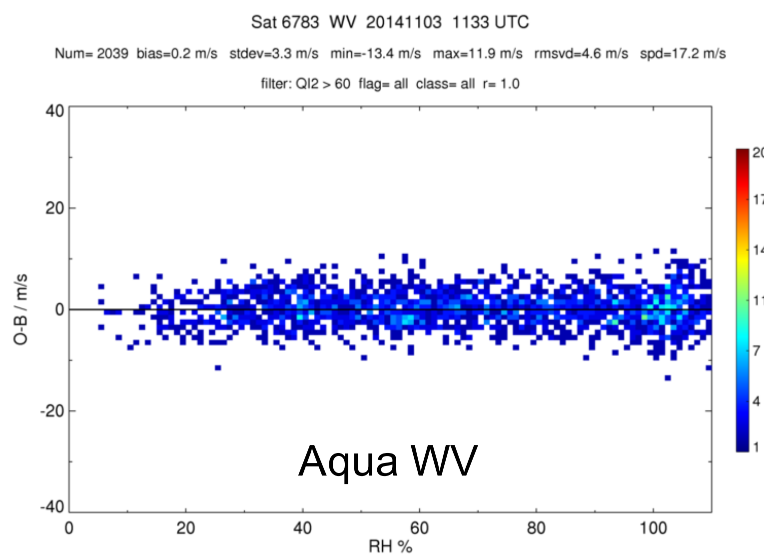


Met-10 WV7.3

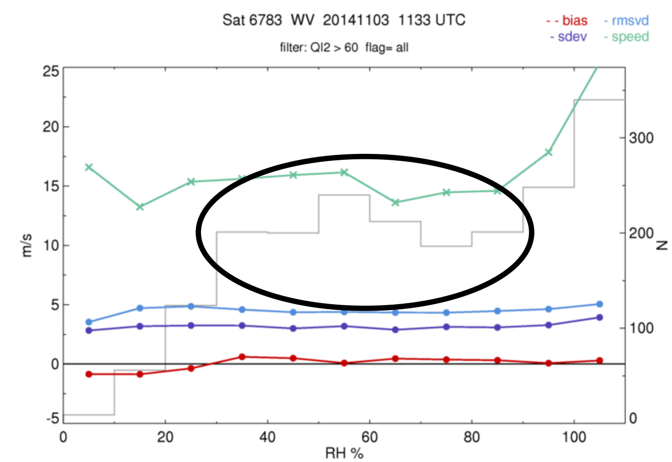


Polar

IR show some increase in RMSVD at low RH. **WV** and **CSWV** have very different distribution



Aqua WV

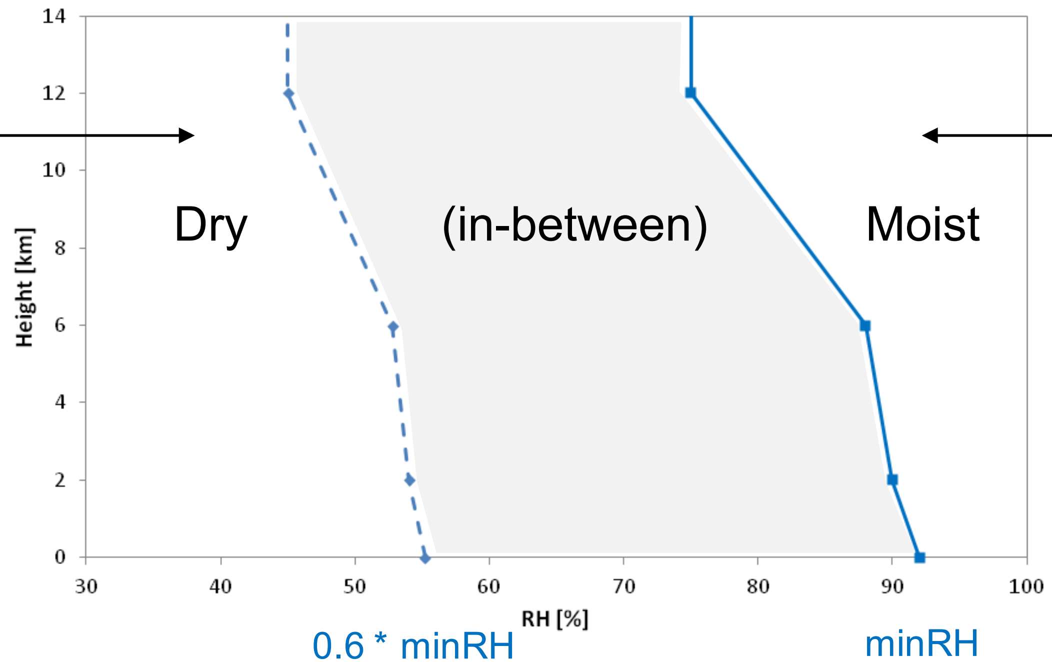


Classification Dry/Moist

Diagnose “moist” and “dry” layers by interpolating RH on 70 NWP model levels

Diagnose “dry” if RH less than Zhang profile x 0.6

(from sensitivity to number and quality of AMVs classed as dry)



Diagnose “moist” if RH exceeds thresholds from Zhang et al. (2010)

Hence classify AMVs as “moist” or “dry”, or in-between

Zhang et al. (2010), Analysis of cloud layer structure in Shouxian, China, using RS92 radiosonde aided by 95 GHz cloud radar, *J. Geophys. Res.*,**115**

Reject Dry Layer AMVs

Met Office

Jan 2015:

QI2 > 80 for Geo

QI2 > 60 for polar

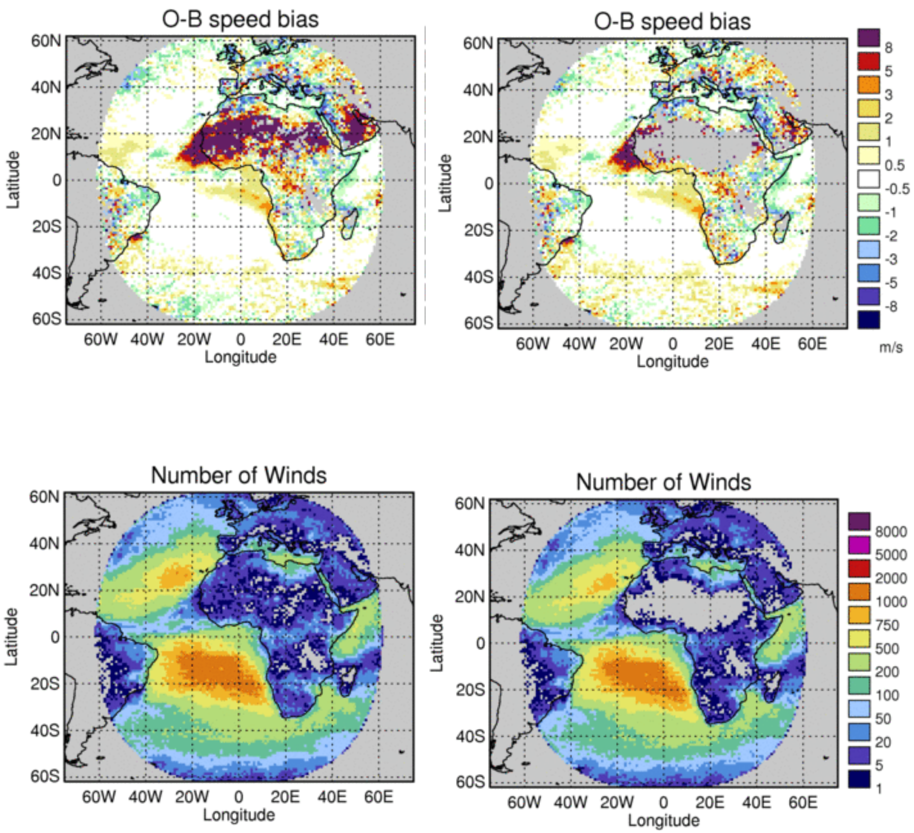
Satellite	Channel	Reference N	Reference RMSVD	Dry Layer N	Dry Layer % Reject	Dry Layer RMSVD	Dry Layer % Diff
Met-7	IR	498918	7.6	412947	17.2	6.2	**-18.4**
	VIS	340190	3.7	323319	5.0	3.4	-8.1
	WV	1043885	8.7	837290	19.8	7.1	**-18.4**
Met-10	IR10.8	5440650	6.5	4713189	13.4	5.5	**-15.4**
	VIS0.8	1477934	3.3	1382028	6.5	3.0	-9.1
	HRVIS	4309987	3.7	4092704	5.0	3.4	-8.1
	WV7.3	3648984	9.4	2845035	22.0	6.9	**-26.6**
	WV6.2	2438393	7.8	2091766	14.2	6.9	**-11.5**
	CSWV7.3	996805	10.3	126602	**87.3**	9.7	-5.8
	CSWV6.2	544026	10.2	95621	**82.4**	9.3	-8.8
MTSAT	IR	4485905	5.4	4203799	6.3	4.6	**-14.8**
	VIS	725620	2.7	720813	0.7	2.6	-3.7
	WV	2308404	7.0	2016684	12.6	6.2	**-11.4**
	CSWV	1413296	11.6	530477	**62.5**	6.9	-40.5
GOES-13	IR	5274881	4.0	4775800	9.5	3.8	-5.0
	VIS	3770951	2.8	3580127	5.1	2.7	-3.6
	WV	2494480	5.1	2177994	12.7	4.9	-3.9
	CSWV	1109413	5.5	372954	**66.4**	5.0	-9.1
GOES-15	IR	4715622	4.0	4341161	7.9	3.8	-5.0
	VIS	3209339	2.6	3063279	4.6	2.5	-3.8
	WV	2659188	5.1	2354476	11.5	4.9	-3.9
	CSWV	924142	5.7	259792	**71.9**	4.9	-14.0
MODIS Aqua	IR	348657	4.7	290458	16.7	4.8	2.1
	WV	168448	6.2	138032	18.1	6.4	3.2
	CSWV	668023	4.3	484535	**27.5**	4.3	0.0
NOAA-19	IR	222740	4.3	189079	15.1	4.2	-2.3
EUM Metop-B	IR10.8	2176144	5.6	1882163	13.5	5.6	0.0
LeoGeo	IR	1830837	4.2	1666527	9.0	4.0	-4.8
		59245862		49968651	**15.7**		**-16.2**

Spatial Distribution

Jan 2015: QI2 > 80

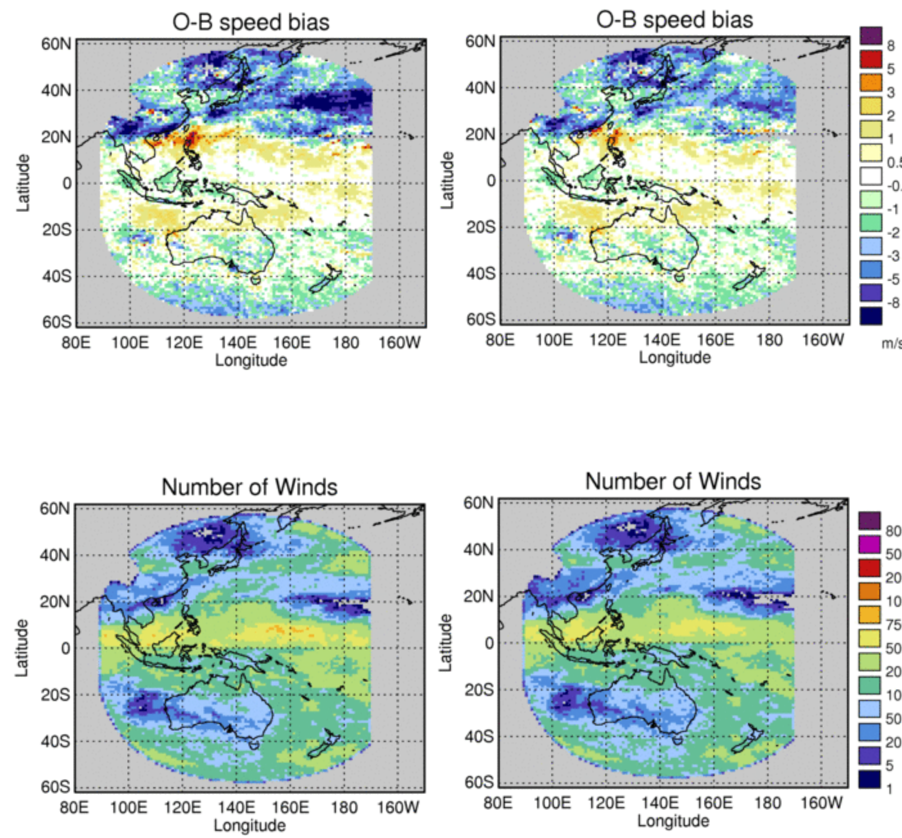
Met Office

QI2 > 80 | + Dry Layer Flag



MSG IR10.8 below 700 hPa

QI2 > 80 | + Dry Layer Flag



MTSAT-2 IR above 400 hPa

Low Level Inversion Correction

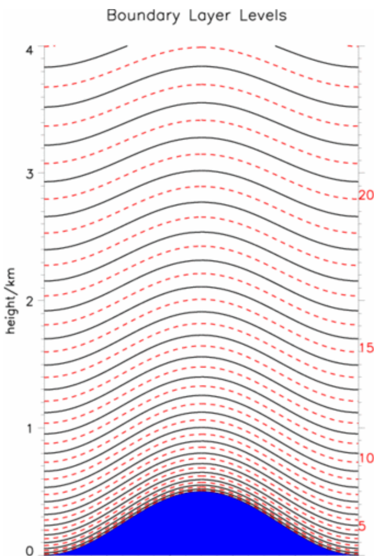
Why an Inversion Correction?

From IWW3 Schmetz et al. (1996)

- Important that low level winds are assigned within boundary layer as directional variations can increase rapidly above the capping inversion.
- (Low) clouds travel with wind at cloud-base which is usually within atmospheric boundary layer (ABL)

Most GEO AMVs already account for inversion situations, but there remain potential benefits to doing within NWP

- Full vertical model resolution (more levels within ABL to resolve inversion)
- Highest temporal resolution and update frequency (e.g. 3-hrly x4 /day, rather than 6-hrly x2 /day)
- Consistent with model characteristics

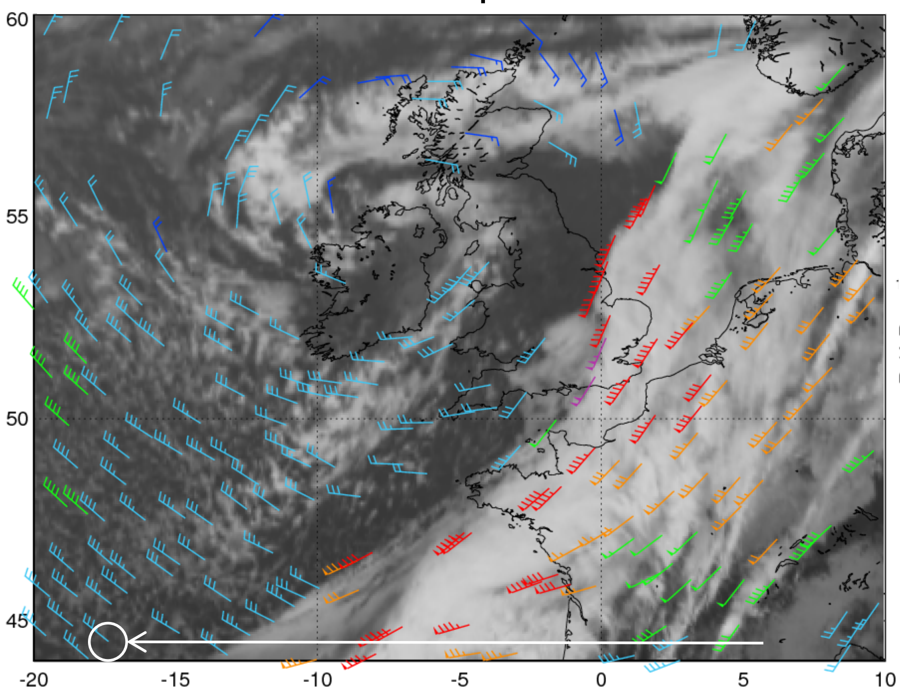


Schmetz et al. (1996), Low-Level Winds from High-Resolution Visible Imagery, *Proceedings of Third International Winds Workshop*, 1996.

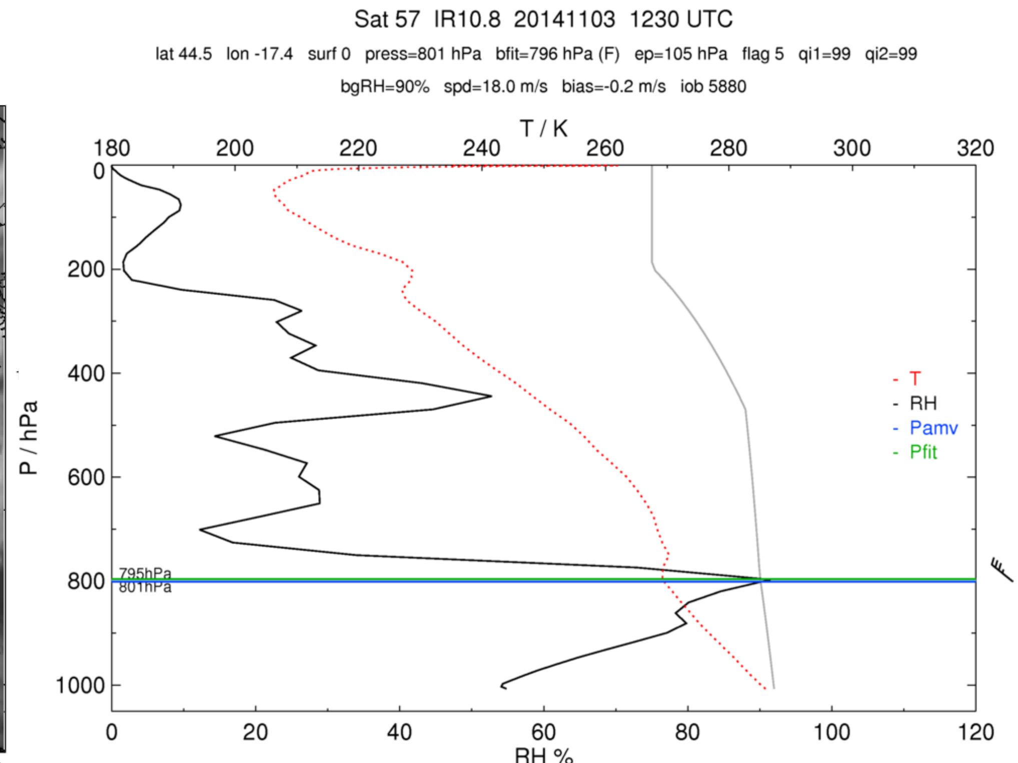
Case study 3. NW Europe

MSG IR10.8 AMVs at 12:30 UTC, 3 Nov 2014

AMV Speed



QI2 > 80



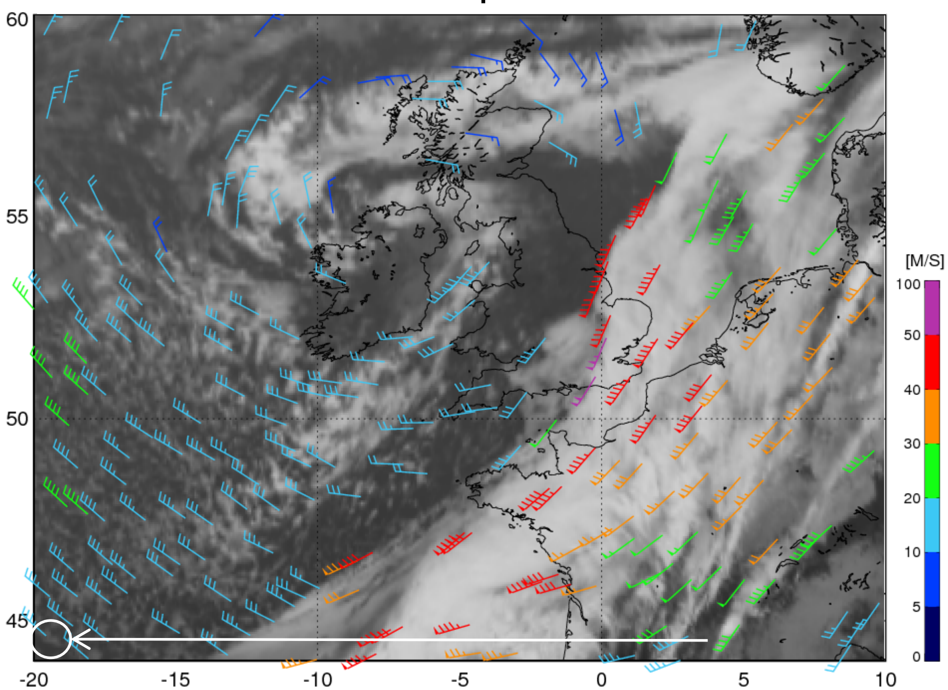
P=801 hPa, V=18 m/s, O-B=-0.2 m/s, BgRH=90%

Base of temperature inversion, zero bias

Case study 3. NW Europe

MSG IR10.8 AMVs at 12:30 UTC, 3 Nov 2014

AMV Speed

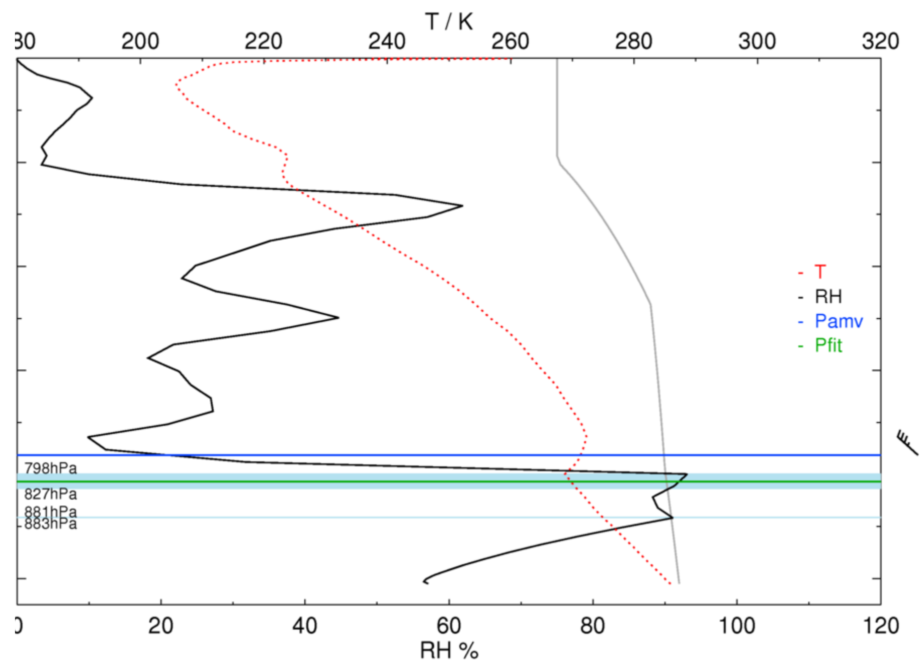


QI2 > 80

Sat 57 IR10.8 20141103 1230 UTC

lat 44.6 lon -19.6 surf 0 press=762 hPa bfit=813 hPa (F) ep=116 hPa flag 5 qi1=93 qi2=99

bgRH=21% spd=18.1 m/s bias=-8.9 m/s iob 5883



P=762 hPa, V=18 m/s, O-B=-9 m/s, BgRH=21%

Assigned ½ way up from inversion base. Same speed, large bias, bg RH 21%.

Criteria for Correction

Met Office

AMV heights corrected if following criteria are met:

- IR and VIS channels only
- Inversion detected (only consider inversion layer closest to surface)
- inversion strength >= 2K to be significant
- Observed pressure > 700 hPa
- AMV assigned above height of inversion base
- Check that inversion top is located in dry layer (capping inversion)
- Only apply to Geostationary AMVs, with surface type = land or sea
- MSG apply only over sea

Not considered for polar winds due to different characteristics of inversion profiles (non-capping, nr-surface inversions)

Met Office

Apply Inversion Correction

Jan 2015, QI2 > 80, inversion corrected data only

Satellite	Channel	N low level corrected	% low level corrected	RMSVD at original height	RMSVD at corr. height	% Diff
Met-7	IR	29226	18.3	4.5	4.3	-4.4
	VIS	45481	13.4	4.0	3.3	**-17.5**
Met-10	IR10.8	197064	7.9	6.0	6.0	0.0
	VIS0.8	101842	6.9	4.4	4.2	-4.5
	HRVIS	195329	4.5	5.8	5.9	1.7
MTSAT	IR	288812	11.5	3.8	3.5	-7.9
	VIS	125356	17.0	3.2	2.0	**-37.5**
GOES-13	IR	284189	12.6	2.3	1.9	**-17.4**
	IR3.8	1143015	14.0	2.6	2.1	**-19.2**
	VIS	604504	16.9	2.8	1.9	**-32.1**
GOES-15	IR	181680	9.1	2.2	2.0	-9.1
	VIS	354990	11.4	2.8	2.0	**-28.6**
		3551488	11.4			**-16.2**

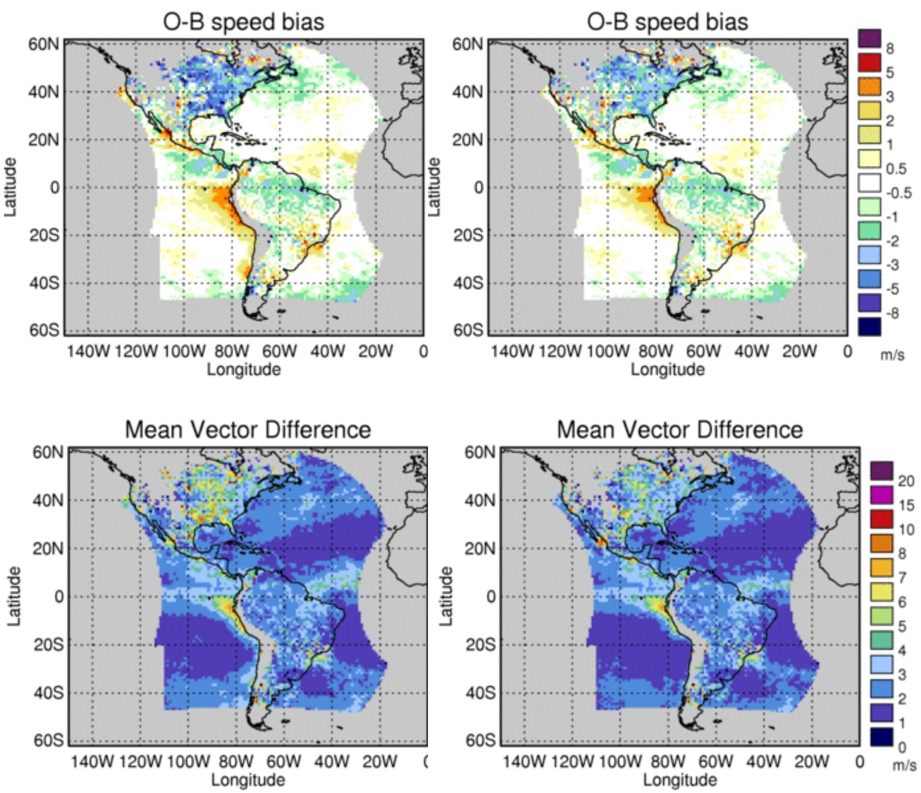
11% of low level winds have correction applied

RMSVD reduced by 16% on average (over 30% for GOES VIS)

Spatial Distribution

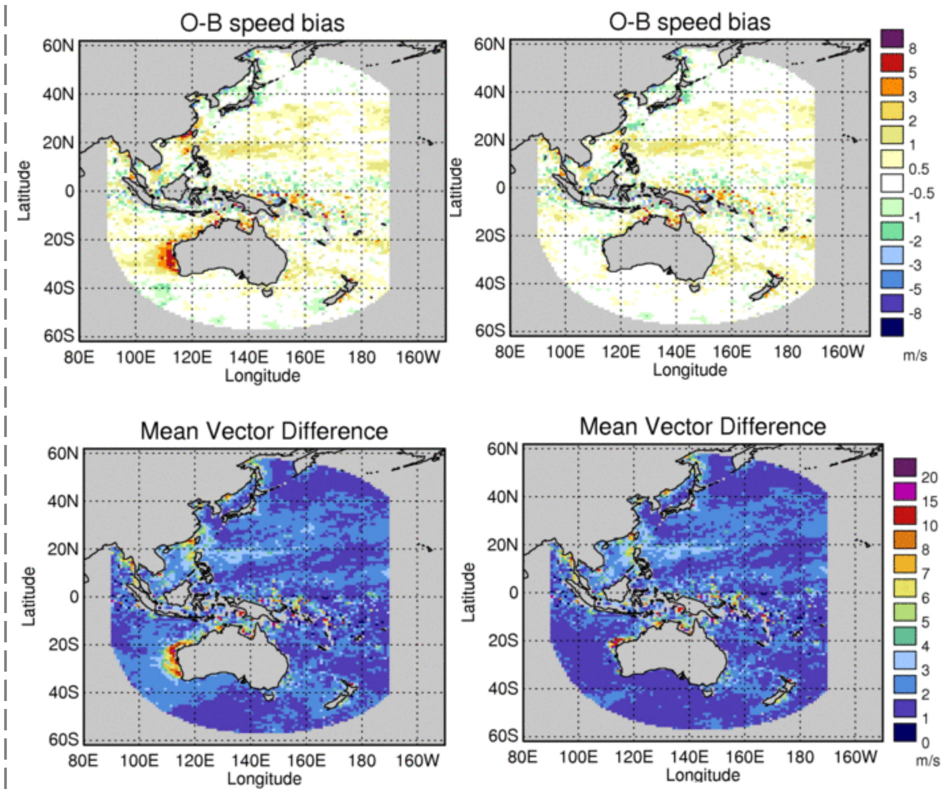
Jan 2015: QI2 > 80

QI2 > 80 | + Inversion



GOES-13 VIS below 700 hPa

QI2 > 80 | + Inversion



MTSAT-2 VIS below 700 hPa

Impact Experiments

Experiments

Test inversion correction + dry layer QC, in combination*

- Inversion applied 1st, then QC
- Two seasons. Summer: 20150622 – 20150815 (55 days),
  Winter : 20151112 – 20160115 (65 days)
- PS37 baseline, 4D-Var, N320, 70 levels, uncoupled, hybrid VAR N108/N216

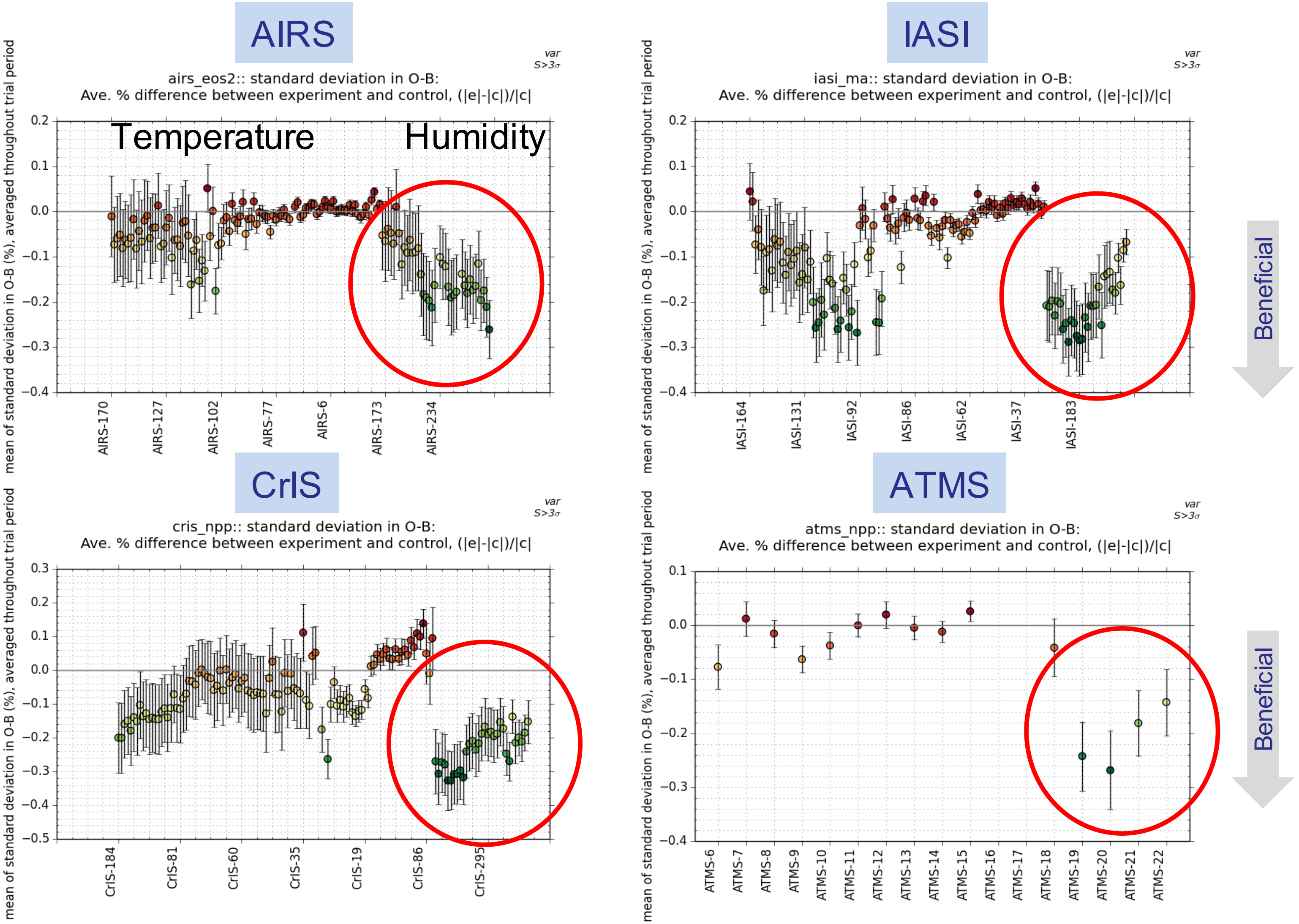
VAR Statistics

- AMV counts reduced by 10% per cycle
- AMV initial penalty reduced by ~17% ✔
- AMV RMS U-wind/V-wind component reduced by 6% / 5% ✔
- Small improved background (T+6) fit to humidity sounding channels ✔

* also trialed as separate components

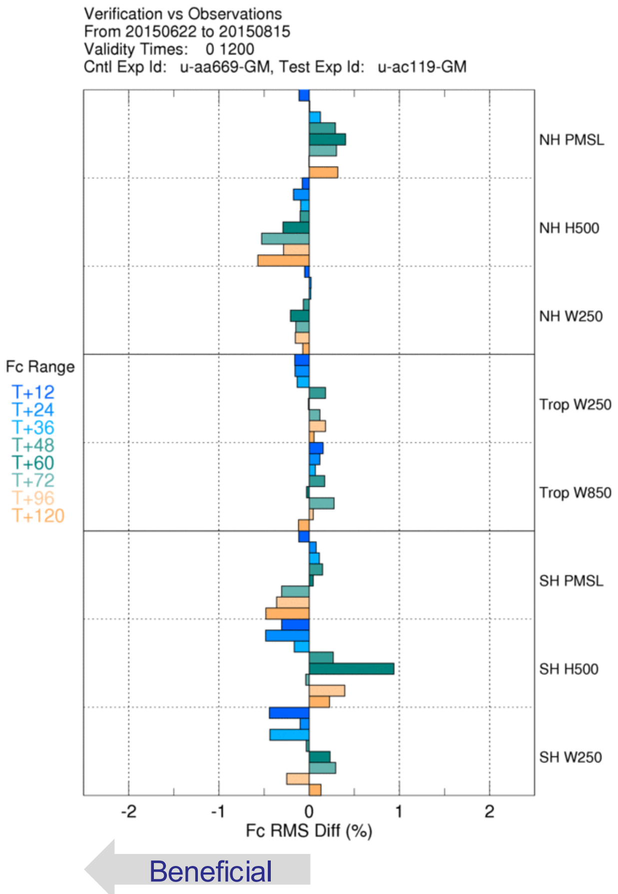
Background Fits to Adv IR and MW Sounders

Small benefit for 'humidity' sounding channels

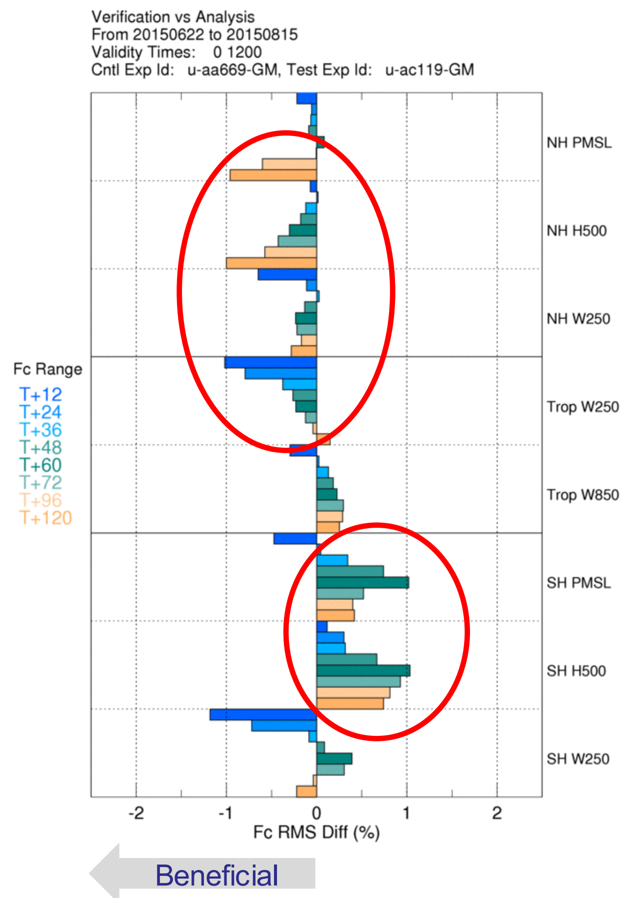


Change in Forecast RMS (I)

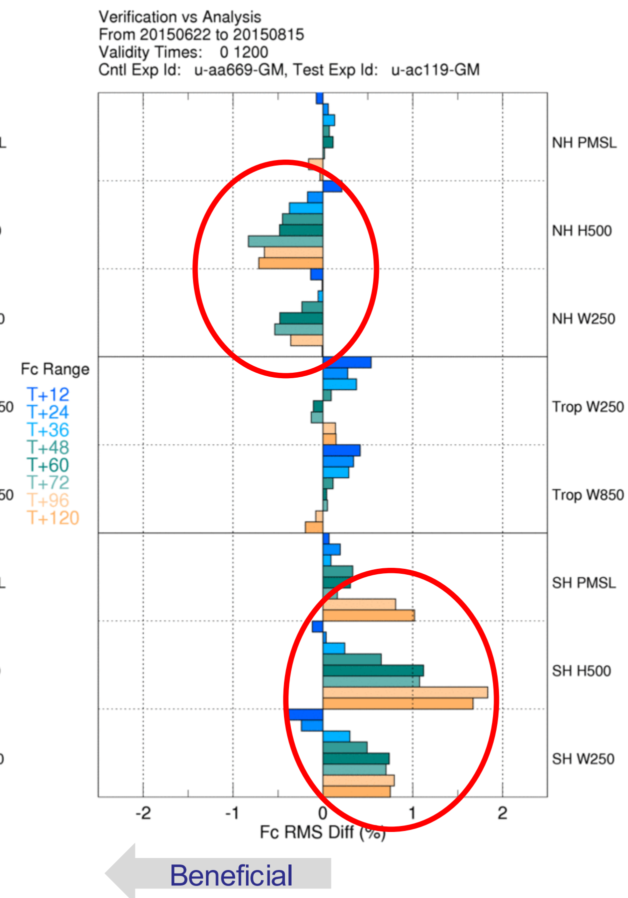
Summer: June – Aug 2015



Observations



Analysis

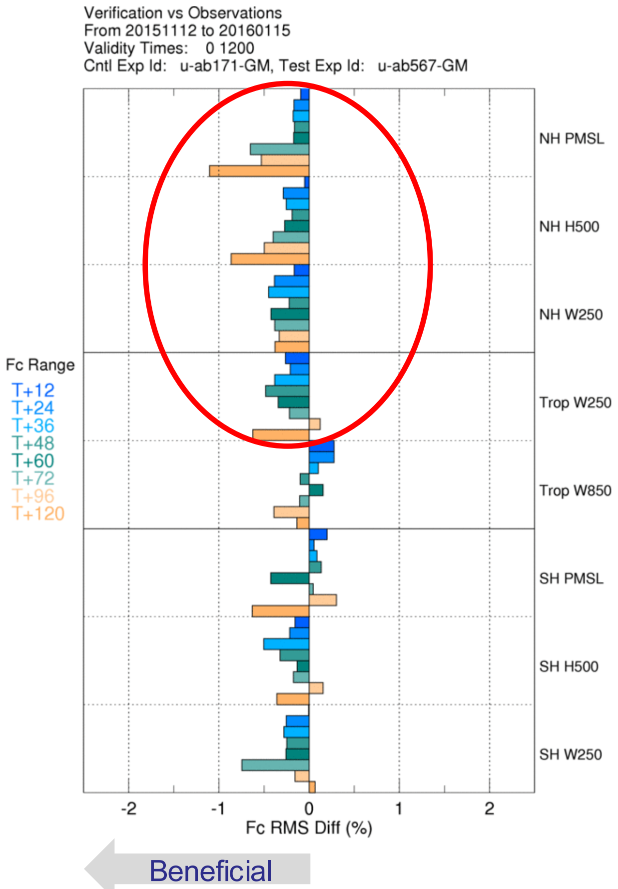


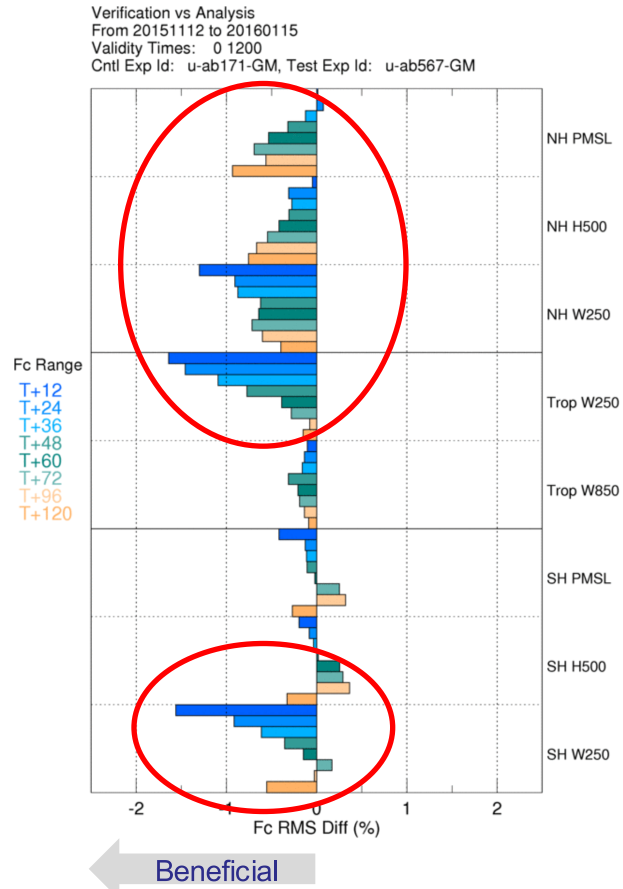
EC Analysis

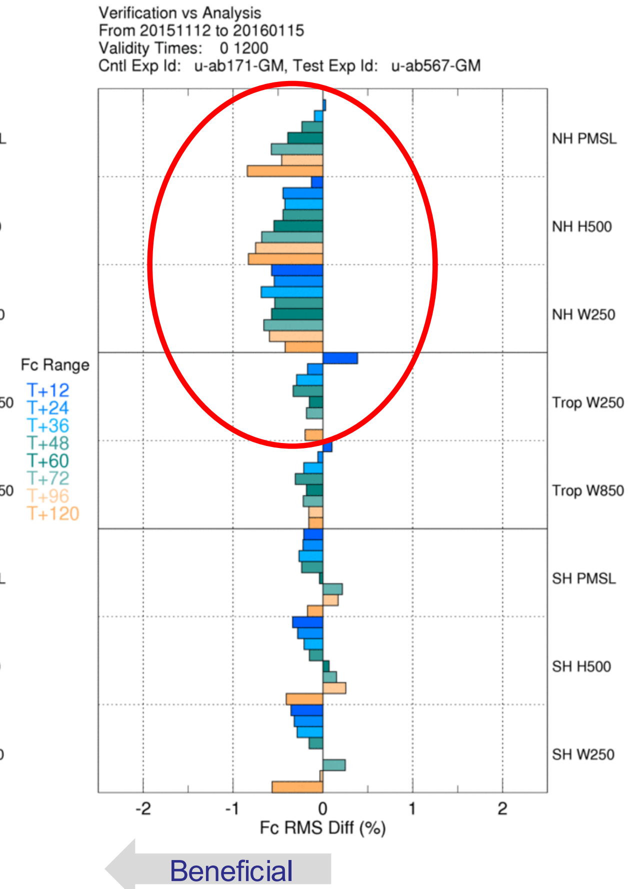
	Observations	Analysis	EC Analysis
Global NWP Index:	+0.09	+0.31	-0.06

Change in Forecast RMS (II)

Winter: Nov 2015 – Jan 2016







	Observations	Analysis	EC Analysis
Global NWP Index:	+0.42	+0.63	+0.36

Conclusions

Met Office

- Background RH a good quality indicator for Geo IR and WV winds, less helpful for polar winds
- Applying a height-dependent RH threshold we can reject AMVs assigned to dry layers of the model (sensitive to model errors)
    - Main benefit is for Geo data, particularly MSG (25% reduction in RMSVD for WV 7.3) and MTSAT-2
    - Little impact on polar winds, very high reject-rate for Geo clear-sky WV
- Applying an inversion height correction for 11% of low level winds
    - Large benefit for GOES-13 over both land and sea, including the Sc region, particularly for VIS (30% reduction in RMSVD)
    - Not applying over land for MSG
- Impact experiments combining inversion correction and dry layer QC
    - Number of AMVs assimilated reduced by 10%, background RMS fit improved ~5%
    - Small improvement in background fit to microwave and advanced IR sounders humidity channels
    - Positive impact on Fc RMS errors in NH winter season, some degradation in SH vs analysis in summer season
- Currently being tested as part of PS38 – due operational Sept 2016

Thank you for listening

Questions?

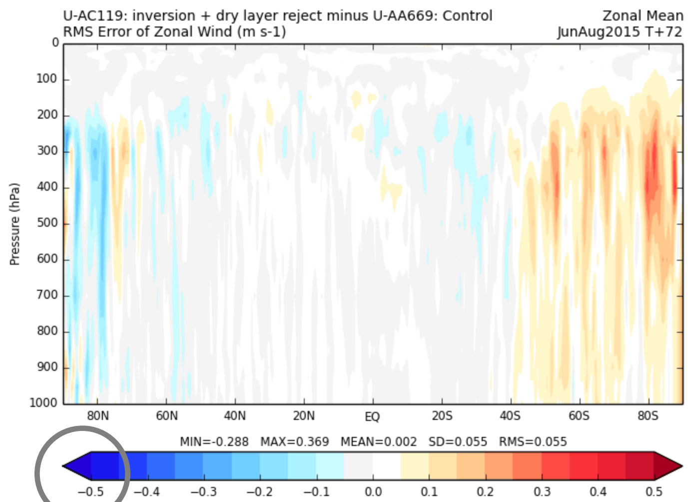
Spare Slides

Day 3 RMS Error Difference

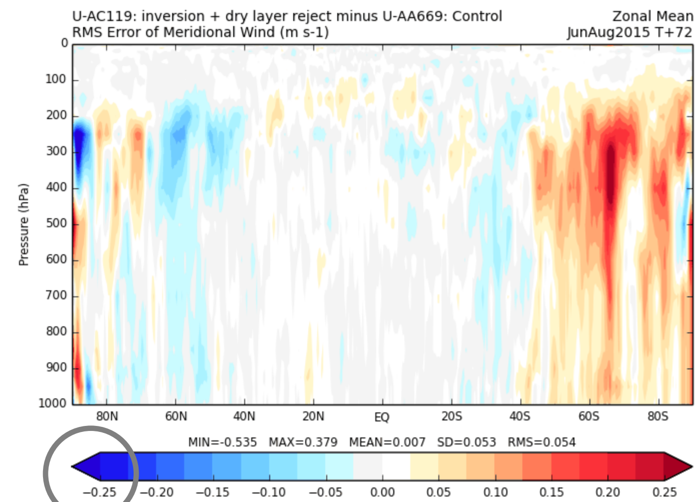
Summer: June – Aug 2015

Scales!

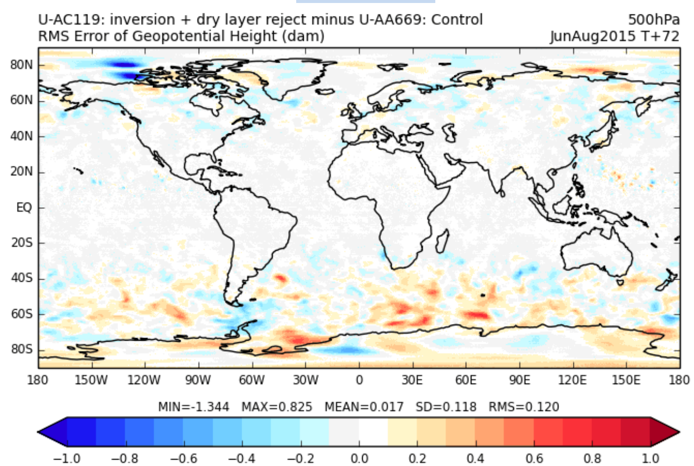
U-wind



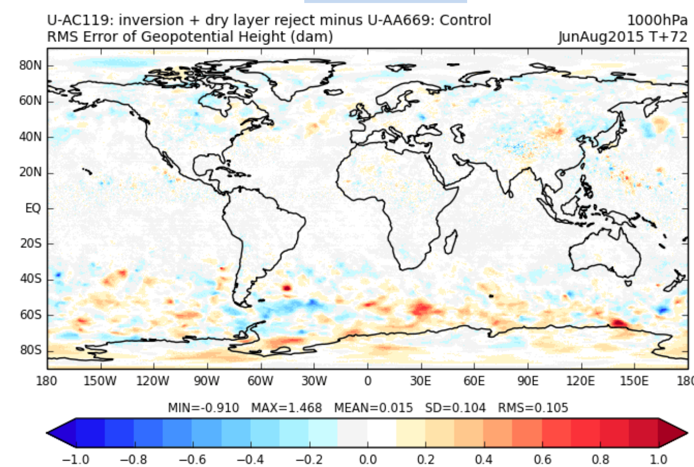
V-wind



Z500



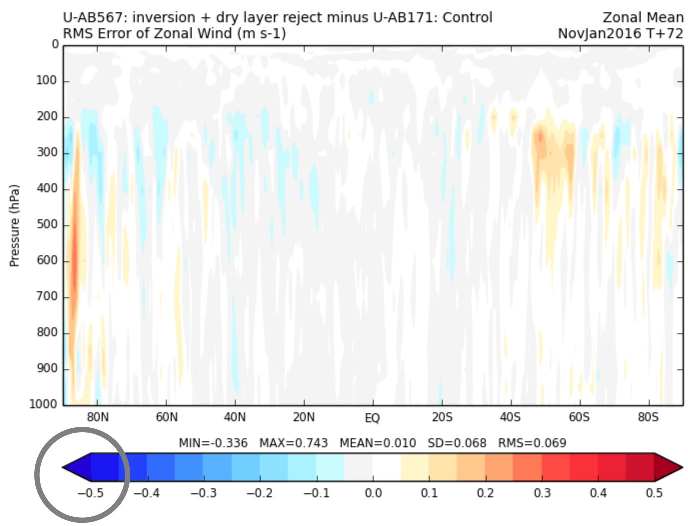
Z1000



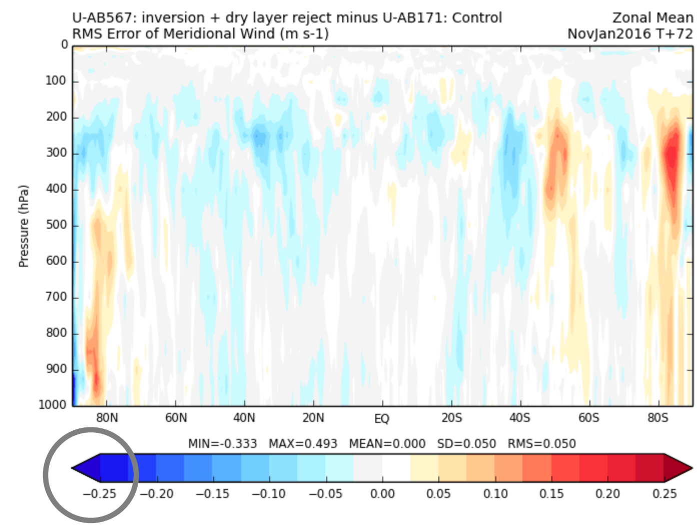
Day 3 RMS Error Difference

Winter: Nov 2015 – Jan 2016

U-wind

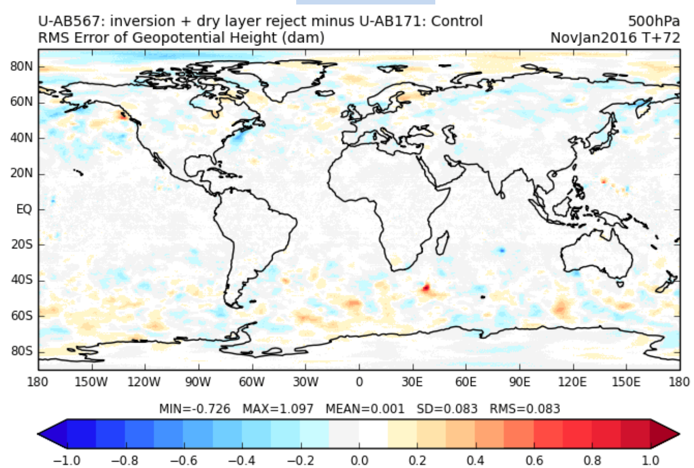


V-wind



Scales!

Z500



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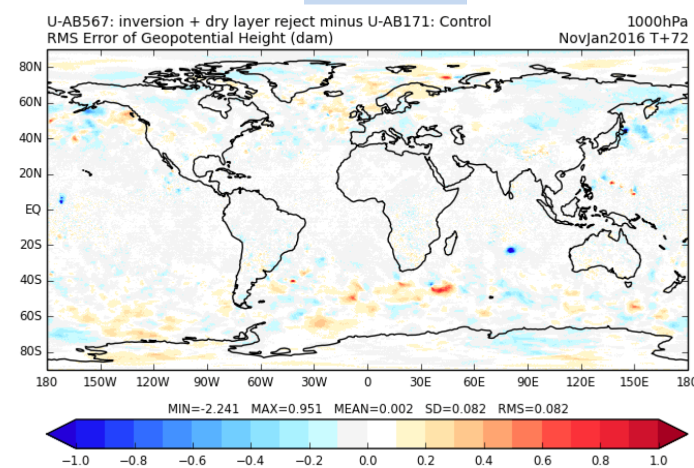


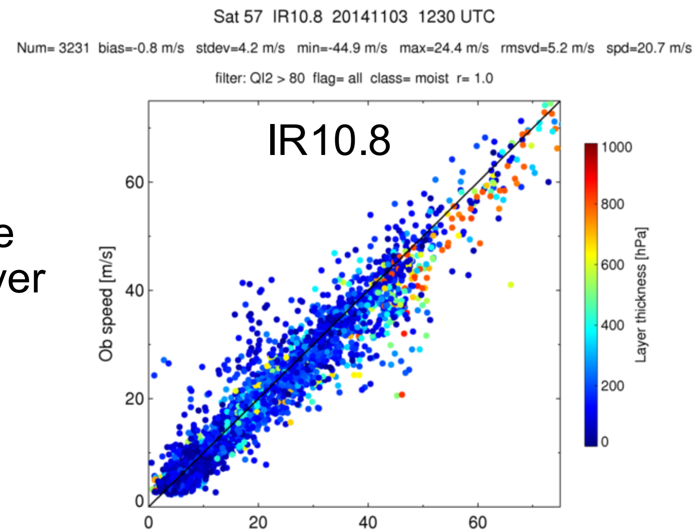
Met Office

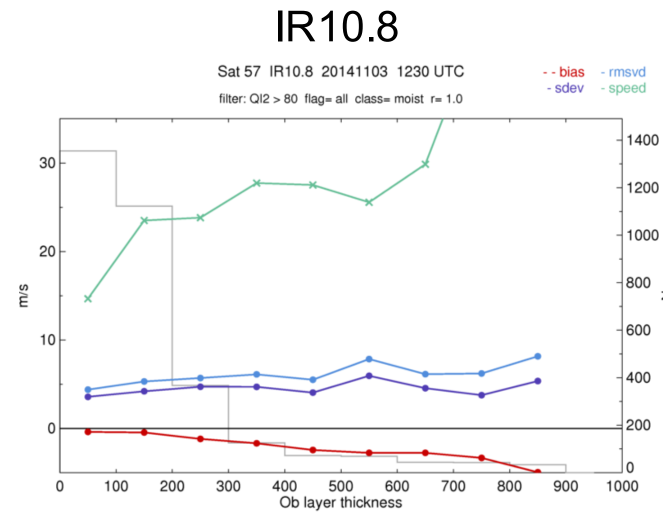
Moist Layer Thickness

MSG IR and **WV**:

Increasing negative speed bias with layer thickness

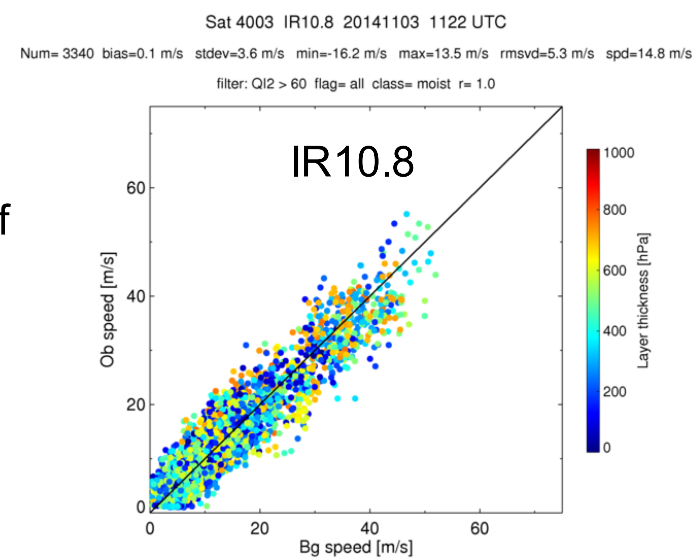
Deeper layers also associated with fastest AMVs

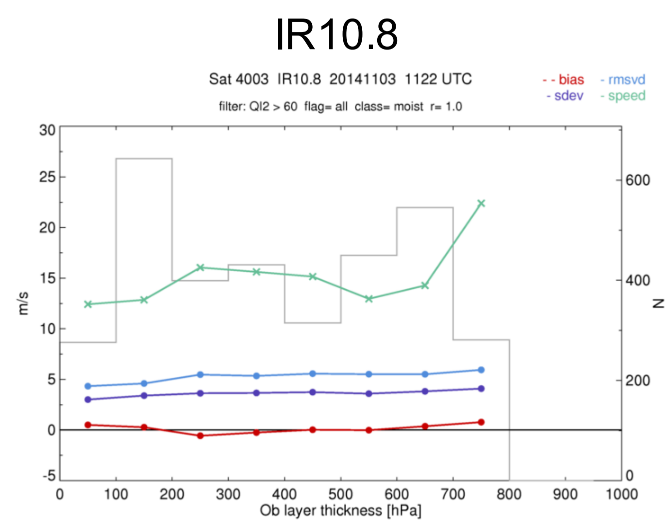




EUM Metop-B IR:

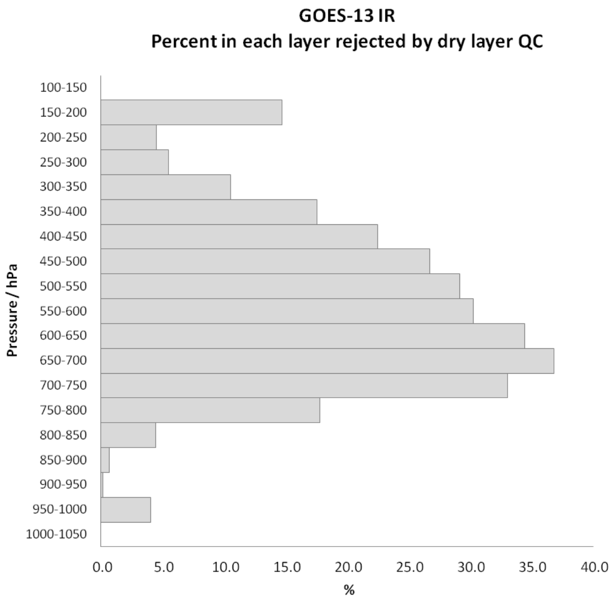
Far greater prop of thicker layers compared to MSG

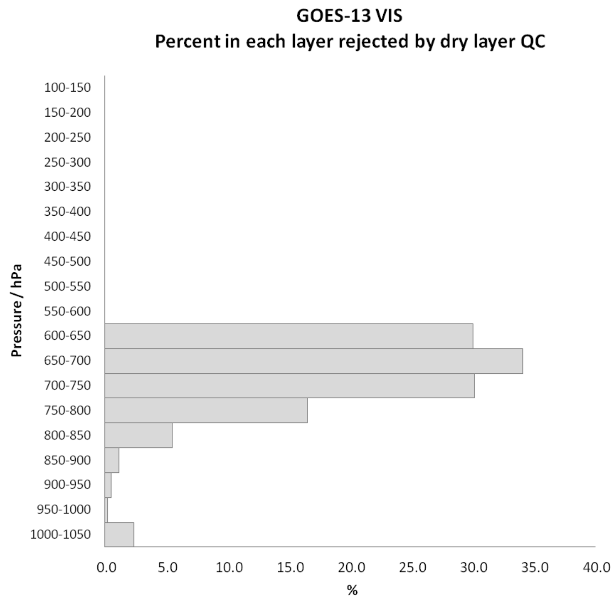


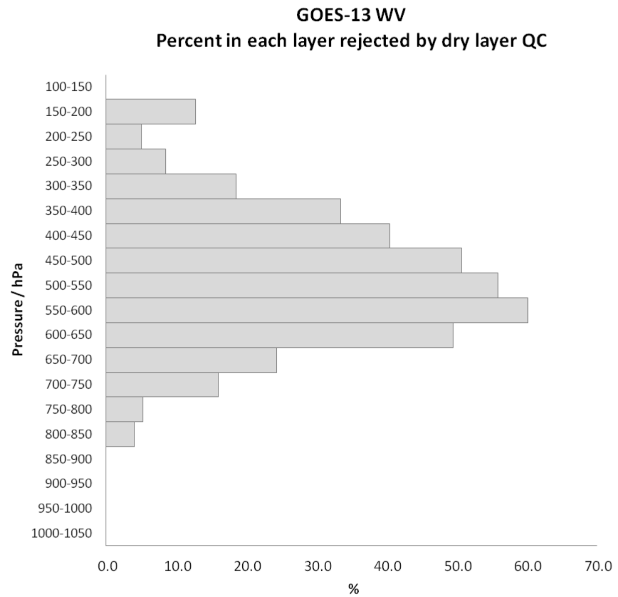


Reject Dry Layer AMVs

Percent of data rejected in each 50 hPa layer





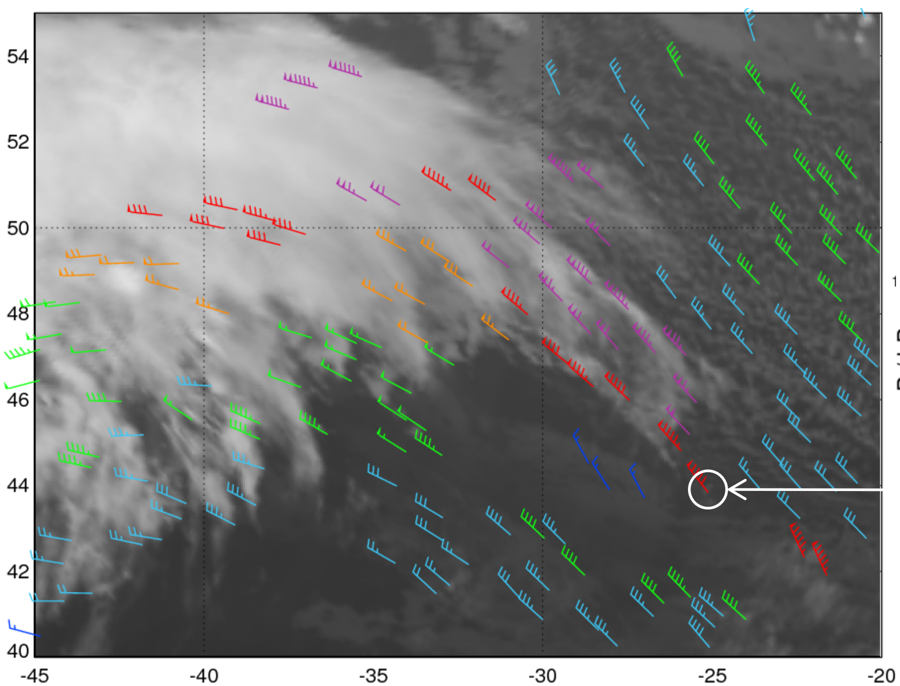


Highest proportion of data rejected at mid-level

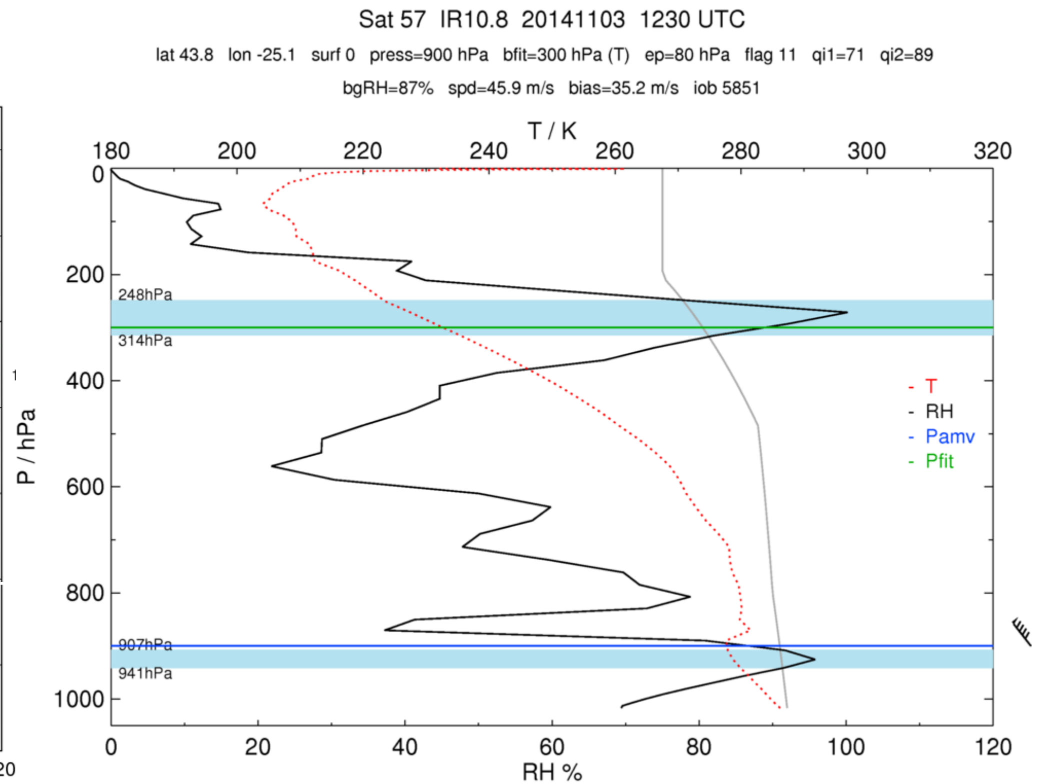
Case study 3. North Atlantic

MSG IR10.8 AMVs at 12:30 UTC, 3 Nov 2014

AMV speed



QI2 > 80



P=900 hPa, V=46 m/s, O-B=+35 m/s, BgRH=87%

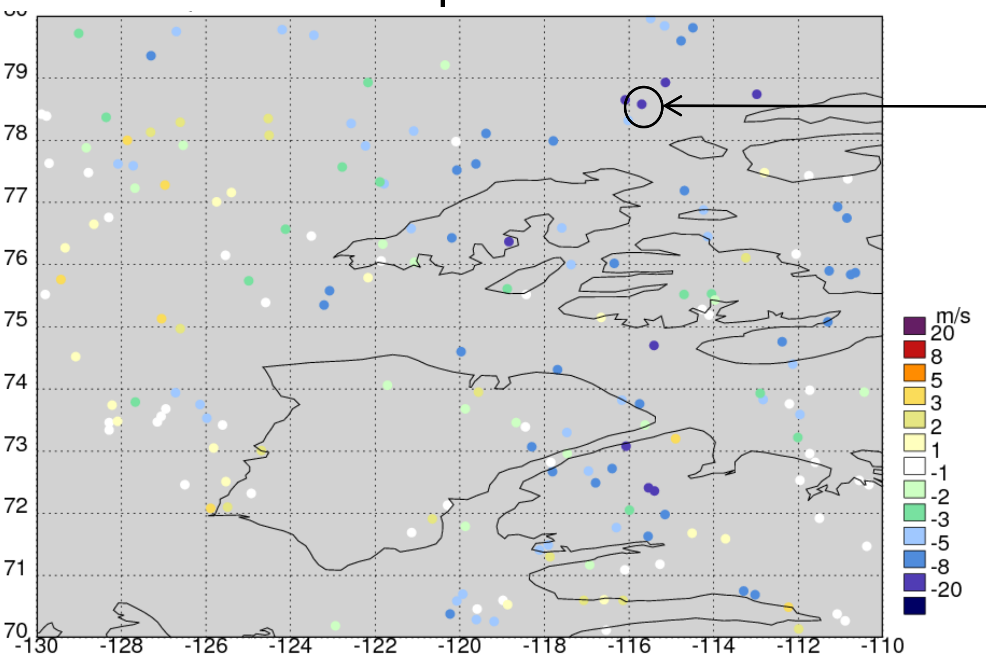
AMV tracking high level, assigned to low level (Bg RH 87%)

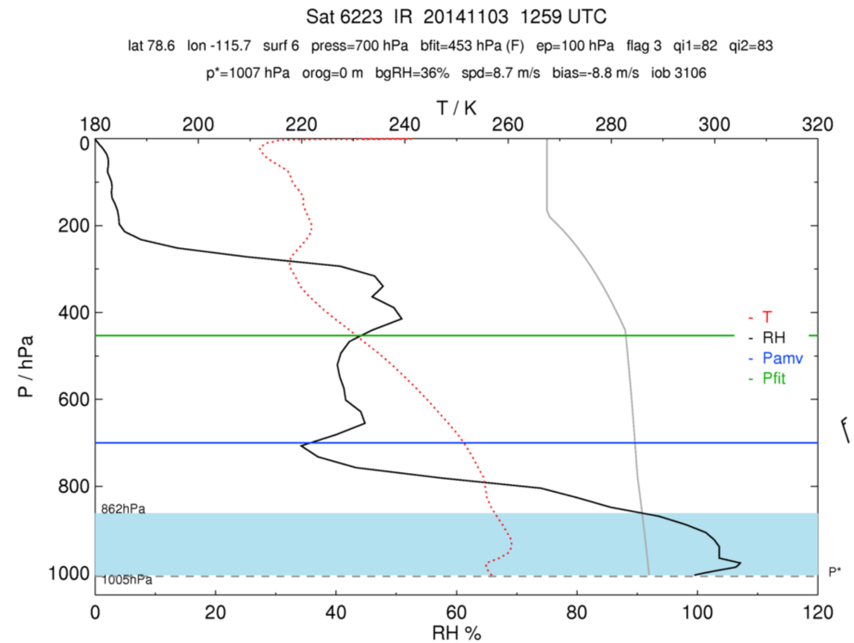
Case study 4. Canadian Arctic

NOAA-19 AMVs at 11:21-12:59 UTC, 3 Nov 2014

Met Office

O-B speed





Surface = Sea ice.

Inversion near the surface. Stays moist well above inversion top