Impact studies with satellite observations at the Met Office

John Eyre Met Office, UK

WMO Impact Studies Workshop; Sedona, Arizona, USA; 22-26 May 2012

Impact studies with satellite observations at the Met Office

- Operational use of satellite data at the Met Office – summary

- Some specific assimilation studies:
  - AIRS + IASI cloudy radiances
  - IASI radiances over land
  - GPS radio occultation (RO) bending angles
  - GPS total zenith delay (ZTD)
  - A problem with humidity analysis in the UK 1.5 km model
  - Forecast sensitivity to observations (FSO)
  - Impact of AMVS and scatterometer observations

Met Office

Acknowledgements

Ed Pavelin
Mike Rennie
Gemma Bennitt
Tom Levick
Mary Forsythe
James Cotton
Robert Tubbs
Richard Marriott
Sangwon Joo

… and many others for the underlying work

Satellite data used in NWP (1)

May 2012

Observation type	Satellites	NWP models *
AMSU/MHS radiances	4 NOAA + Metop	G, R
HIRS clear radiances	2 NOAA + Metop	G, R
IASI and AIRS clear+cloudy radiances	Metop + Aqua	G, R
SSMIS radiances	1 DMSP	G, R
Geo imager clear IR radiances	MSG, GOES	G, R, UK
GPS RO bending angles	5 COSMIC, Metop/GRAS, GRACE-A, TerraSAR-X	G, R
GPS ZTDs	~350 European stations	G, R, UK

* G=global, R=regional=N.Atlantic+Europe, UK=UK area

Satellite data used in NWP (2)

May 2012

Observation type	Satellites	NWP models *
AMVs – geo	5 geo satellites	G, R, UK
AMVs – MODIS and AVHRR	Aqua, Terra, NOAA, Metop	G, R
Scatt. sea-surface winds: ASCAT	Metop	G, R, UK
MW imager sea-surface winds: Windsat	Coriolis	G, R
SEVIRI cloud height/amount	MSG	R, UK
SSTs: AVHRR, AATSR, AMSR-E…	NOAA, Metop, ENVISAT, Aqua	G, R, UK
Soil moisture: ASCAT	Metop	G, R, UK
Sea ice: SSM/I, SSMIS	DMSP	G, R
Snow cover	various	G, R

Assimilation of cloud-affected AIRS and IASI radiances

Assimilation of cloud-affected AIRS and IASI radiances

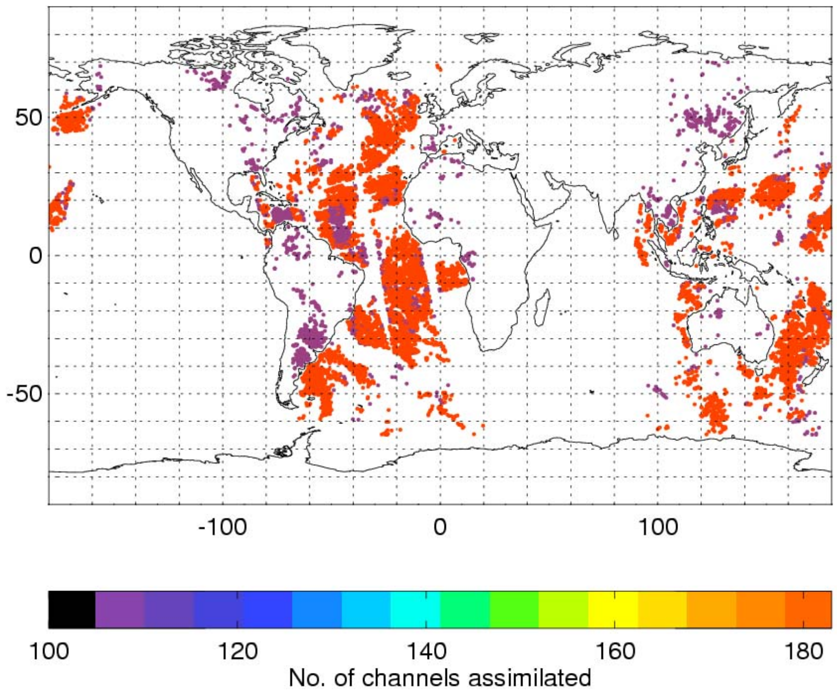
Met Office approach:

- 1D-Var cloud analysis
  - retrieve cloud-top pressure and cloud fraction
  - … assuming single-level “grey-body” cloud
- Select channels peaking above retrieved cloud top
  - … to minimise errors due to simplistic cloud model
- Assimilate cloudy radiances in 4D-Var
  - Using 1D-Var retrievals of cloud variables as fixed inputs to radiative transfer calculations

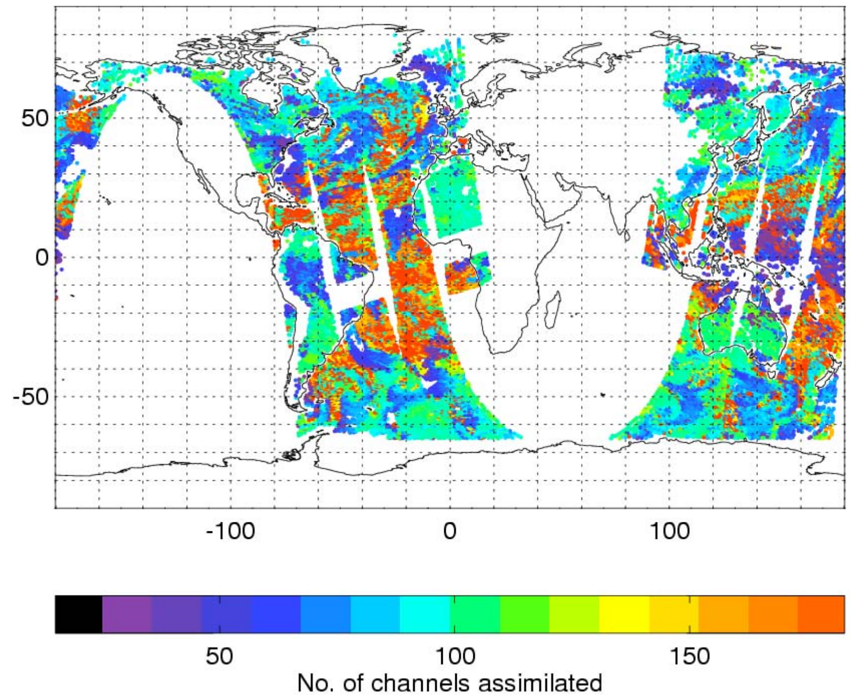
IASI assimilation - coverage:

Number of IASI channels passing 1D-Var qc

"Clear" IASI

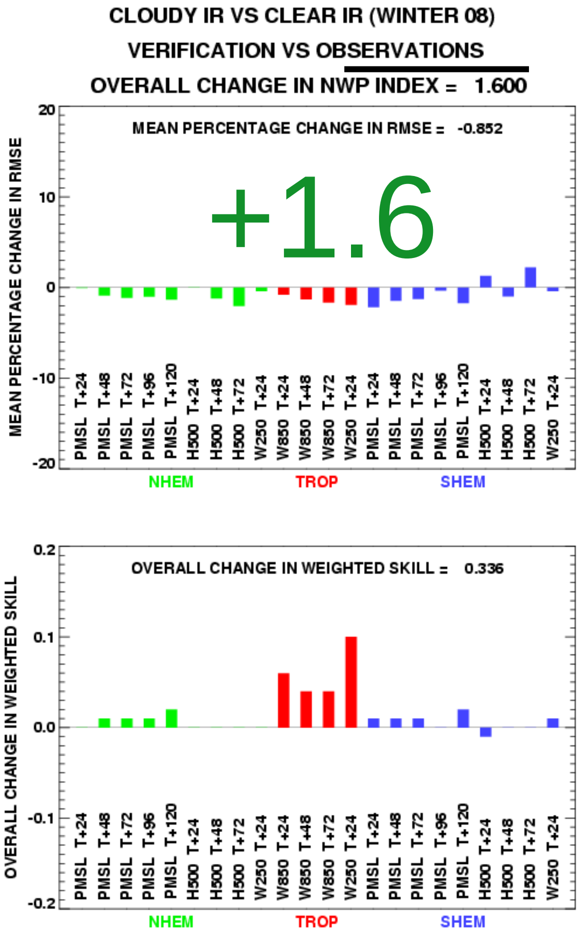


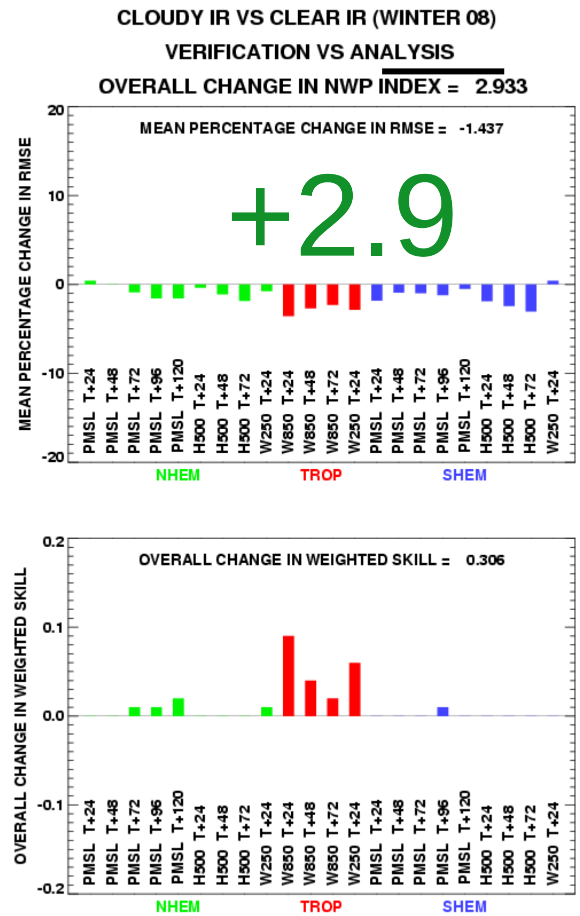
"Cloudy" IASI



Cloudy AIRS+IASI: NWP index impact (Winter 2008)

compared with clear AIRS+IASI





Operational: AIRS from June 2008, IASI from Feb 2010

Assimilation IASI radiances over land

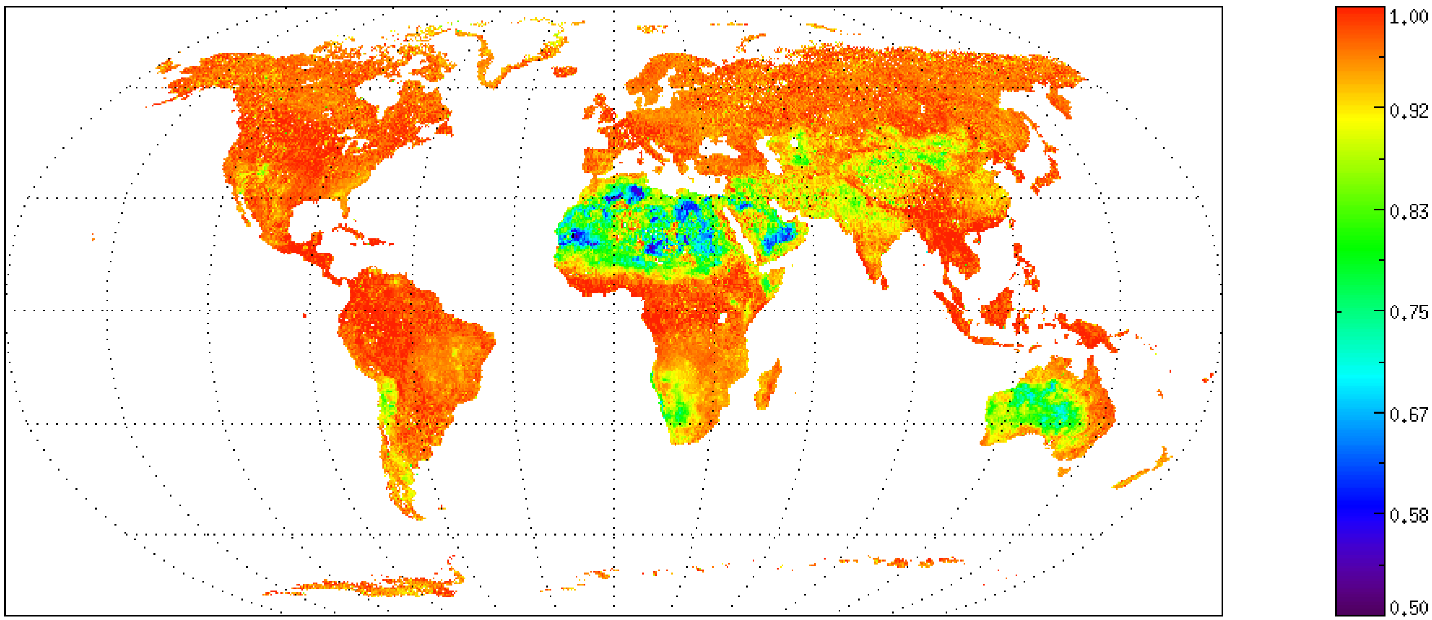
Assimilation of IASI radiances over land

Met Office approach:

- Surface emissivity treated similarly to cloud:
  - retrieve emissivity simultaneously with other variables in 1D-Var
  - pass retrieved emissivity, along with radiances, to 4D-Var
- Emissivity spectrum represented by 12 leading eigenvectors computed from library of laboratory data for diverse surfaces
- !st-guess emissivity from CIMSS atlas – spatially based on MODIS, spectrally based on laboratory data

Land surface emissivity (8.5μm)

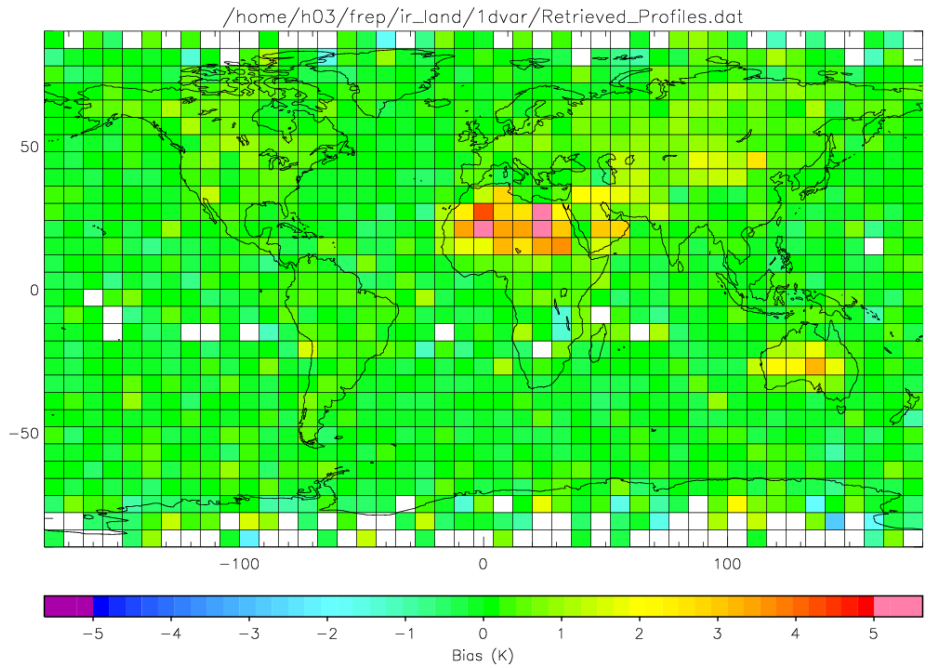
from NASA AIRS product, June-August 2008

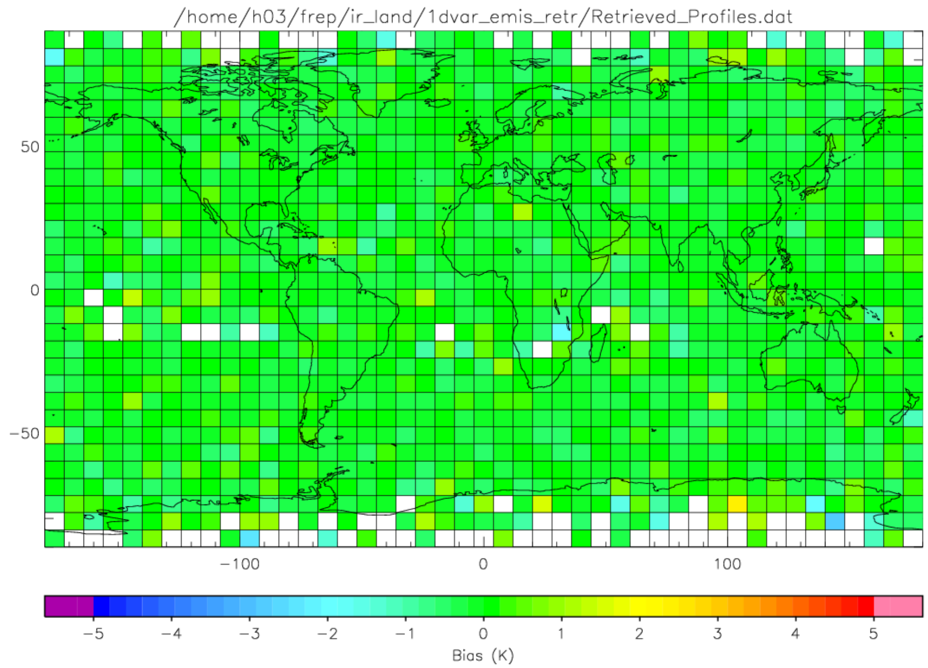


Before July 2011:

- assumed infra-red land surface emissivity = 0.98
- channels peaking below ~400hPa not used

1D-Var simulation study: 920 hPa temperature bias

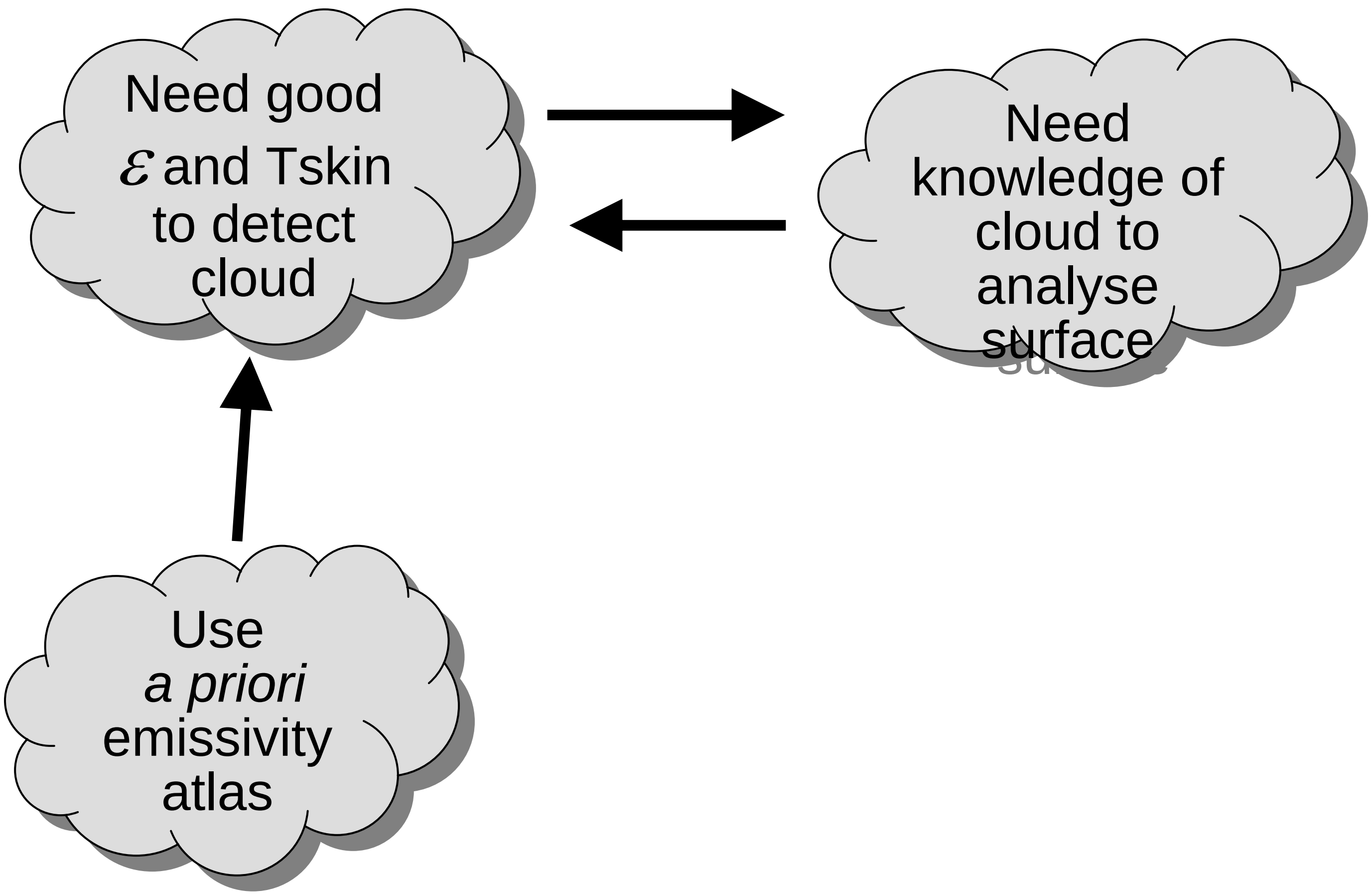




without emissivity retrieval

with emissivity retrieval

Promising results from simulations… … but what to do about cloud?



Global NWP trials

Bottom line: modest impact on Met Office "global NWP index"

- Winter: +0.0 v. observations, -0.1 v. analysis
- Summer: +0.1 v. observations, +0.3 v. analysis

Sufficiently positive to include in operations, July 2011

BUT:

- Problems with model T_{skin} biases during daytime
- At present data included night-time only, and only IASI

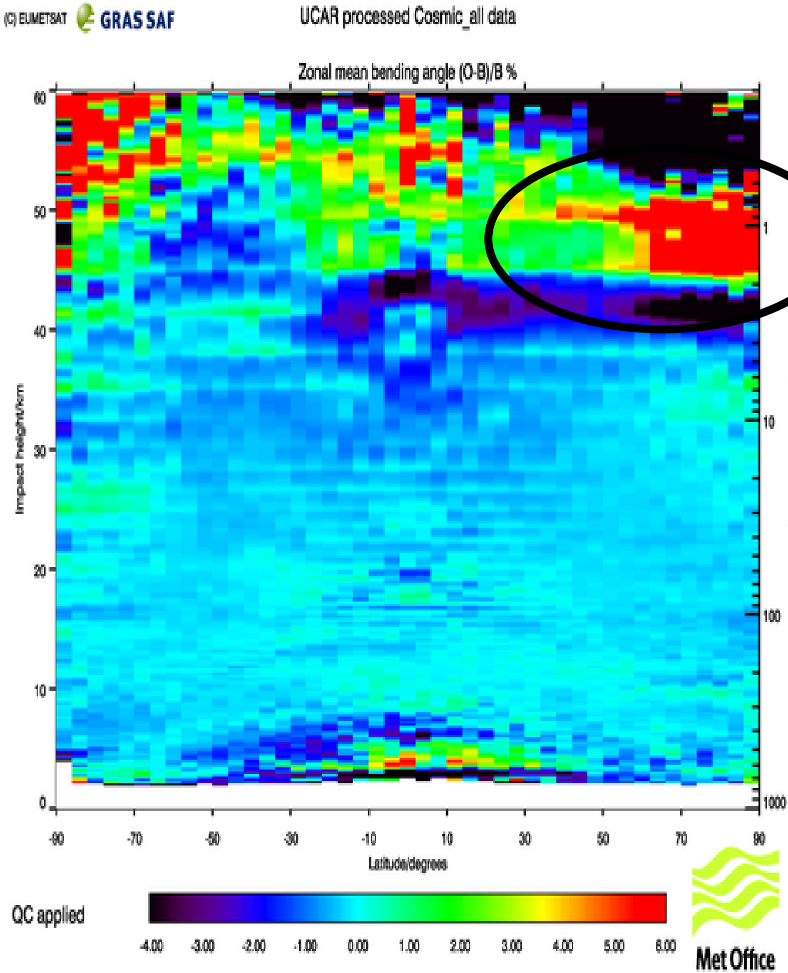
This is first step – further improvements expected

Extending assimilation of GPS-RO bending angles

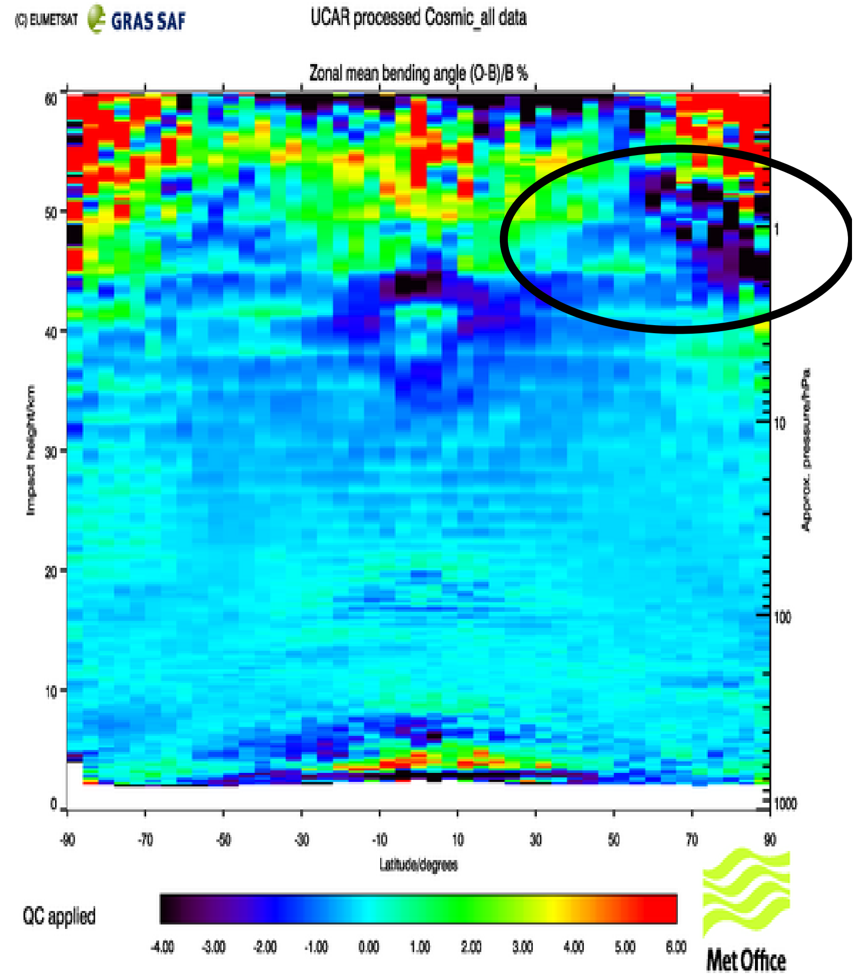
solving problems caused by raising the model top into the mesosphere

GPS-RO: COSMIC bending angles
zonal mean of (O-B)/B

Operations: 10-19 Oct 2010
GPSRO used up to 40 km

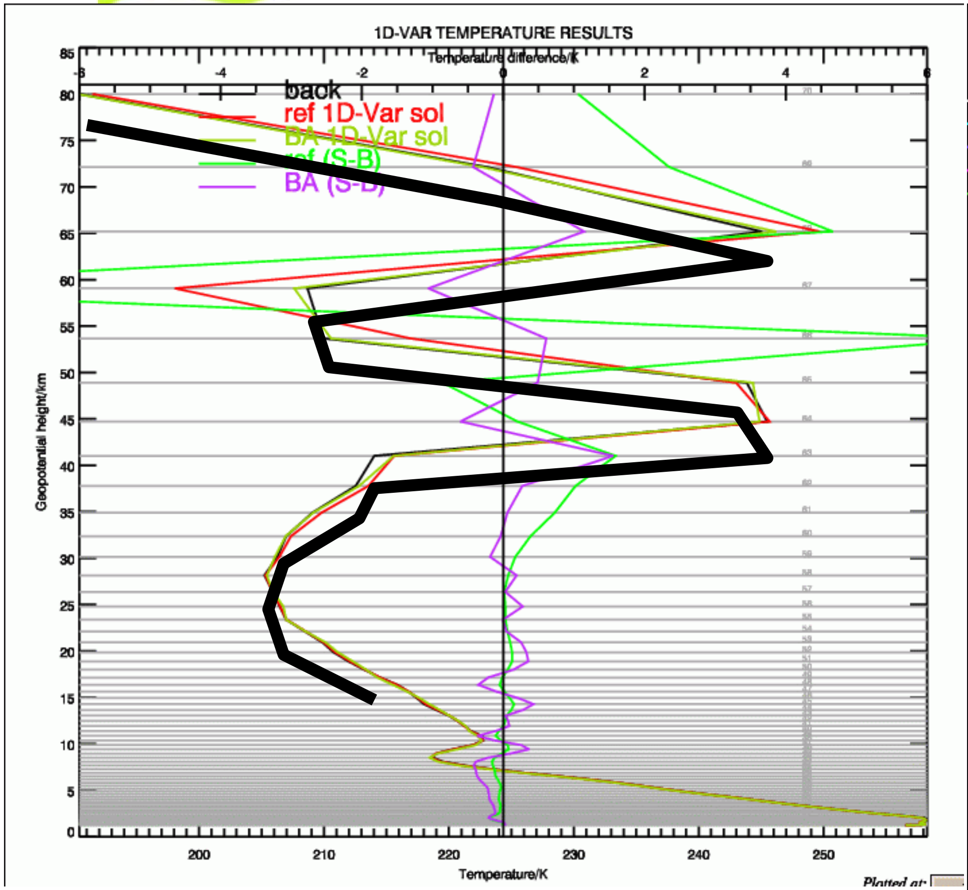


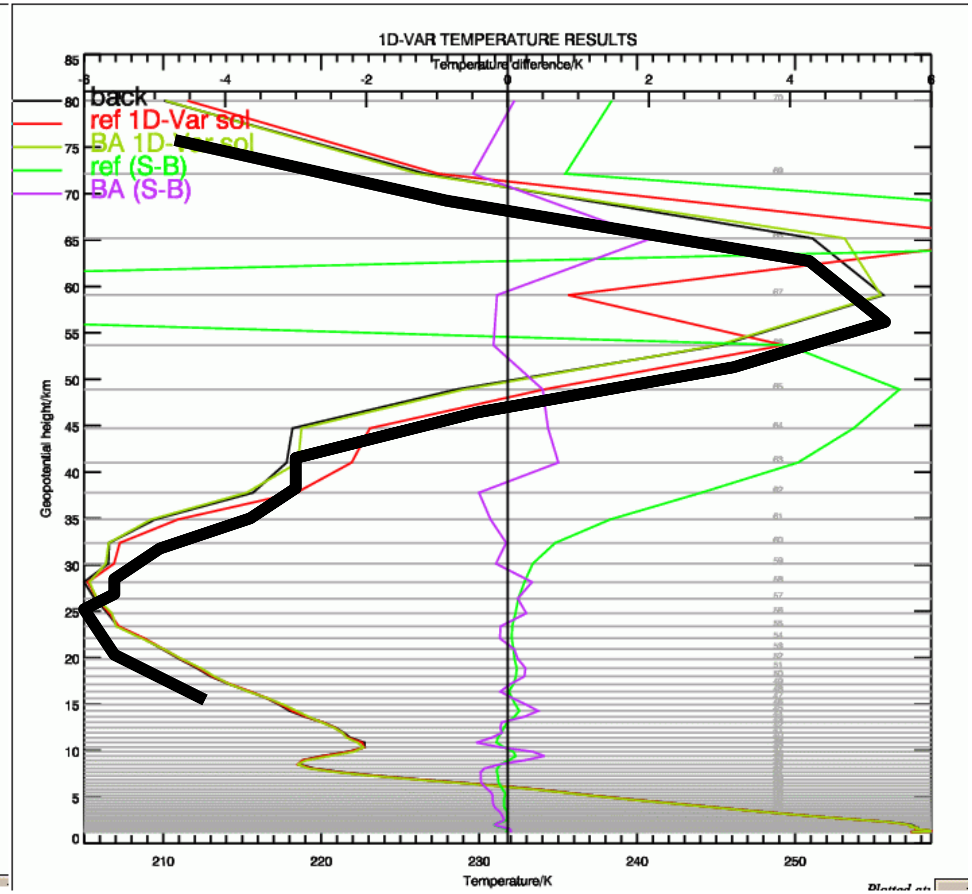
PS25: 10-19 Oct 2010
GPSRO used up to 60 km



Single profile: N. Greenland, 19 Oct 2010

Operations PS25





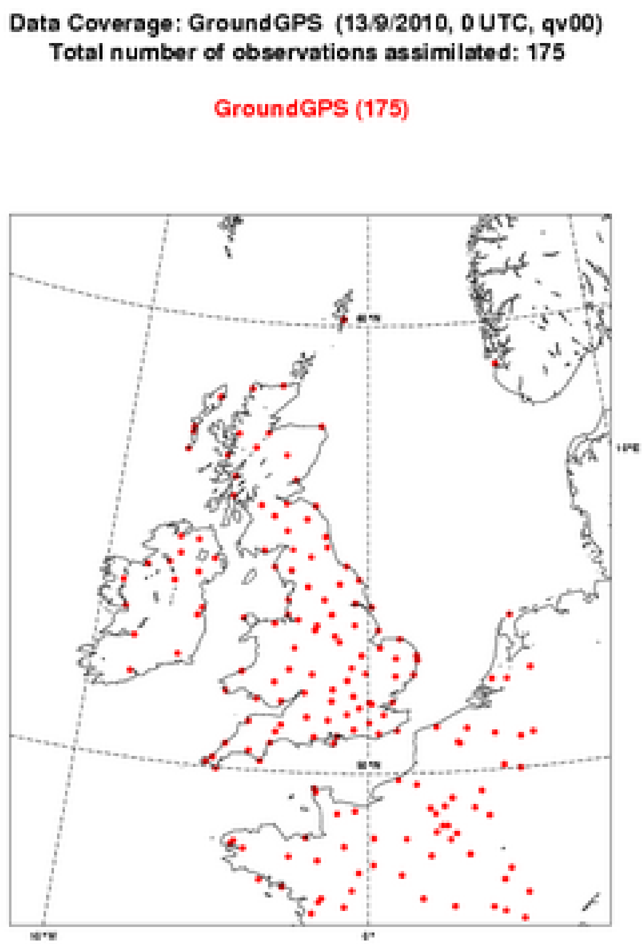
More realistic stratopause in PS25. Combination of:

- GPS-RO data assimilation up to 60 km
- New background error covariances
- SSMIS UAS channels assimilated earlier in PS25 (taken out on 7 Oct 2010)

Assimilation of GPS total zenith delay in the UK 4km model

GPS-ZTD assimilation

Met Office

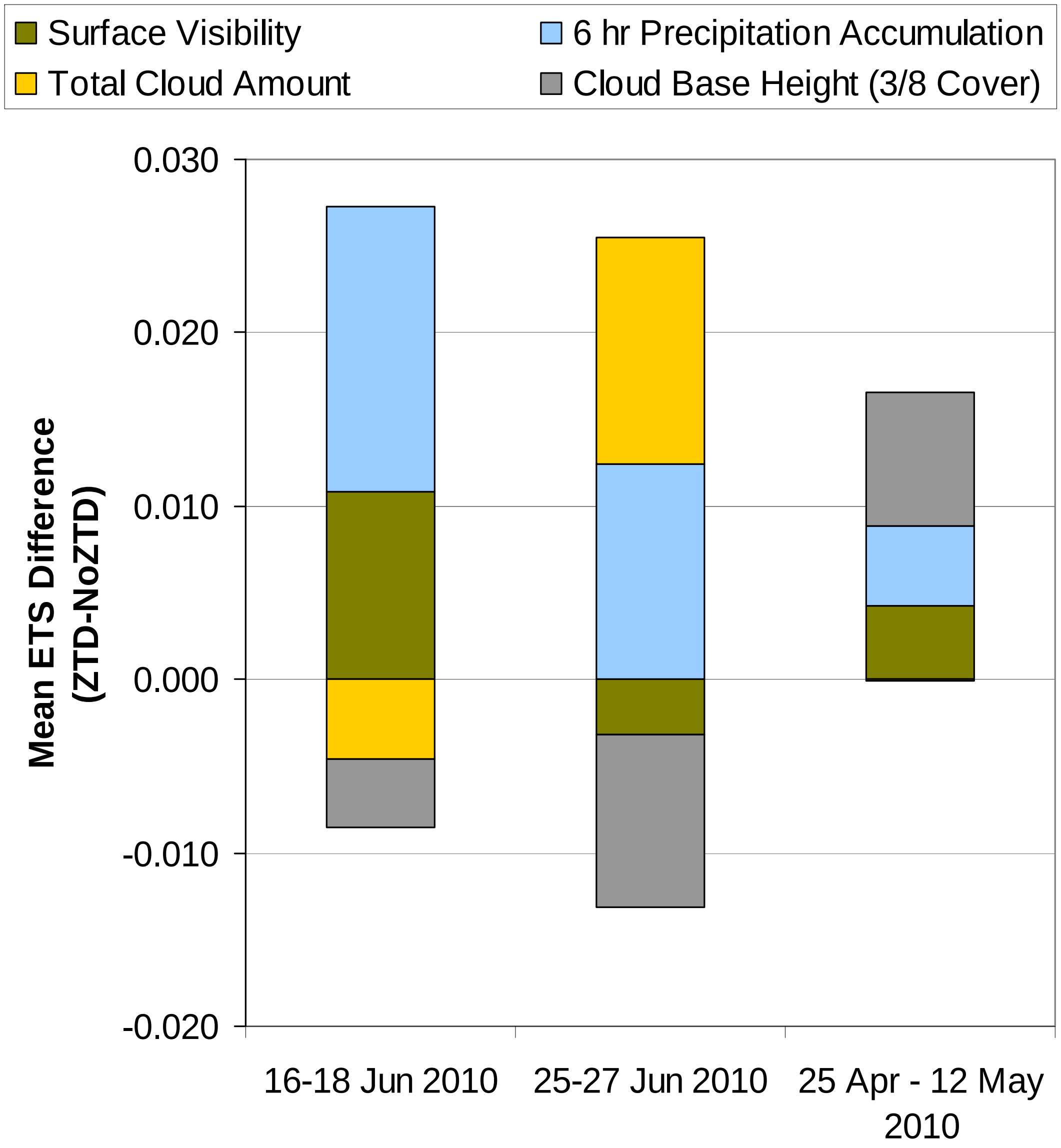


New impact trials

with UK4 model

Trial periods	Reduction in forecast temperature RMS error
16-20 Nov 2009	0.2%
16-18 Jun 2010	1.4%
25-27 Jun 2010	0.4%
25 Apr- 12 May 2010	0.4%

Impact trials with UK4 model



A problem with humidity analysis in the UK 1.5 km model

A problem with humidity analysis in the UK 1.5 km model

Met Office

Problem:

- Static anticyclonic conditions → little advection from boundaries
- Assimilation of cloud info from geo images raises humidity in PBL
- GPS-ZTD observations constrain total column water vapour
- No humidity observations assimilated in upper troposphere
  - No geo WV radiances assimilated over low cloud
  - No polar WV radiances assimilated
- Analysed humidity in upper troposphere → zero/negative

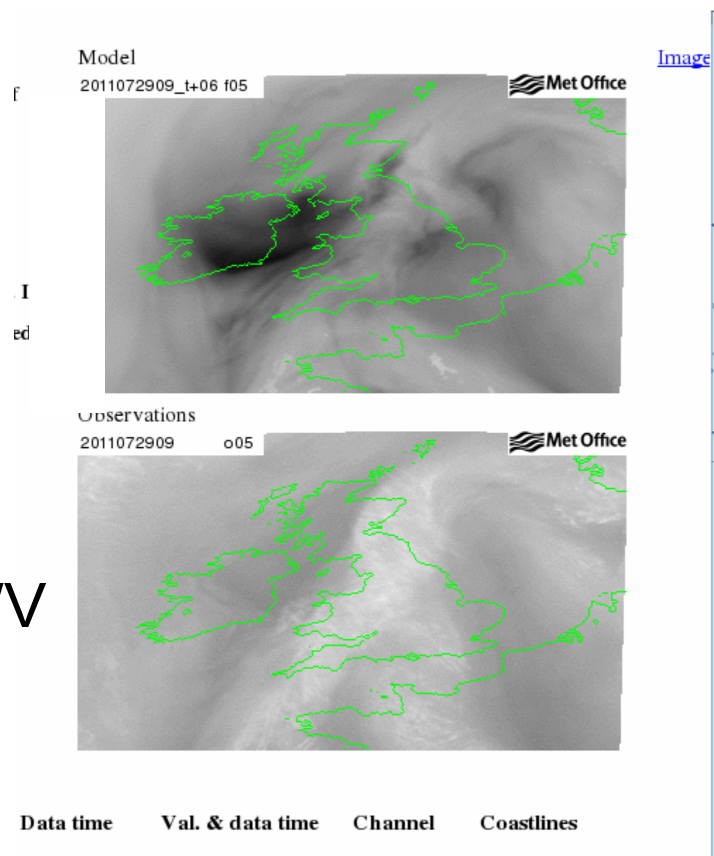
Solution:

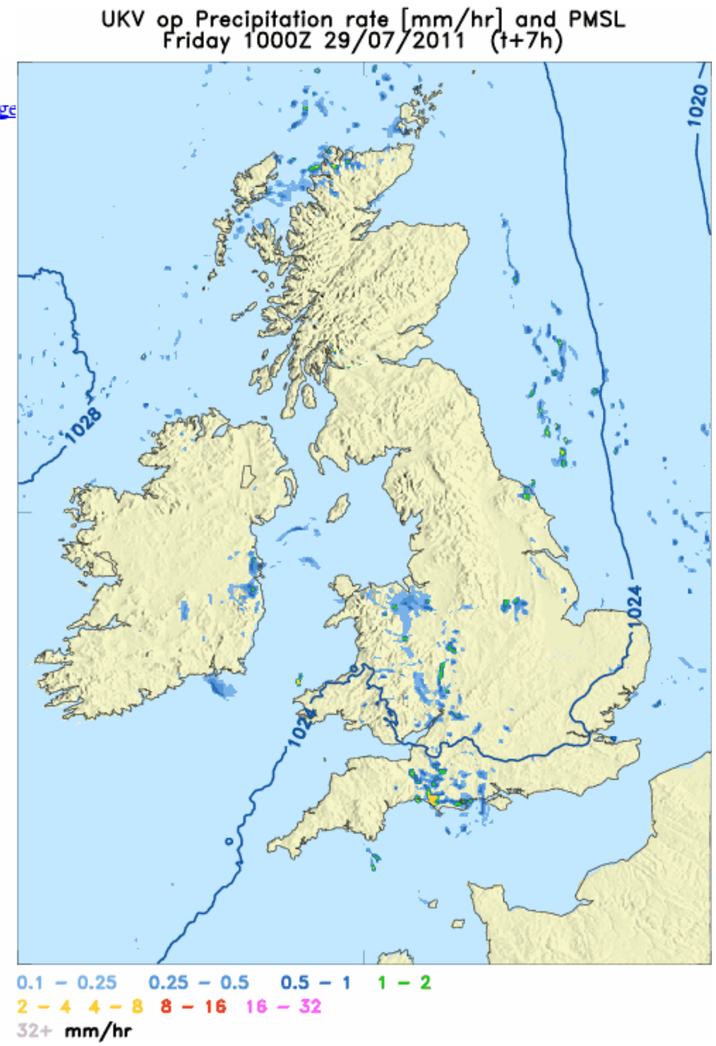
- Assimilate MSG/SEVIRI WV channels and/or AMSU-B/MHS

Example of humidity/cloud problems

Model

SEVIRI WV radiances





Associated with spurious precipitation on 29/07/11

13 Feb 2012, 03Z

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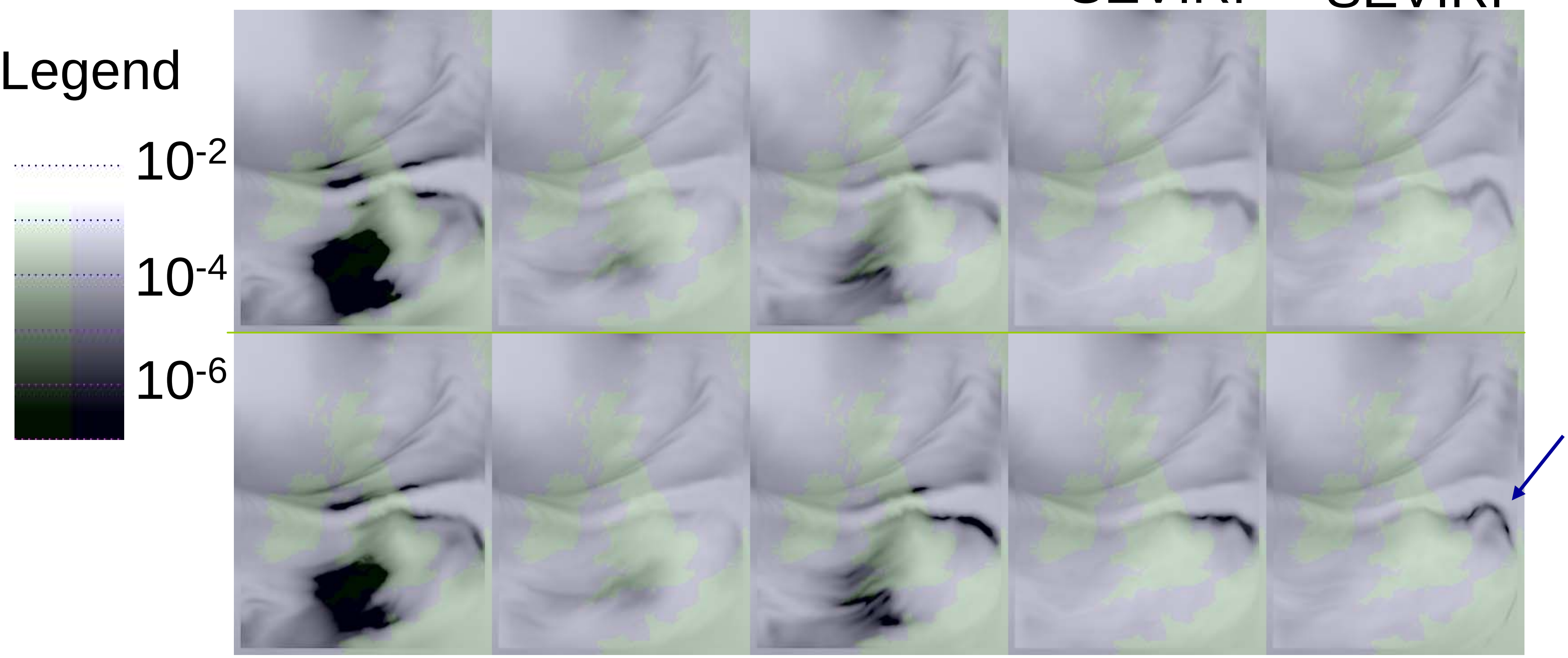
UK4 level 45 specific humidity on a log scale

6.7km

Control | SEVIRI | MHS | MHS + SEVIRI | AMVs + MHS + SEVIRI

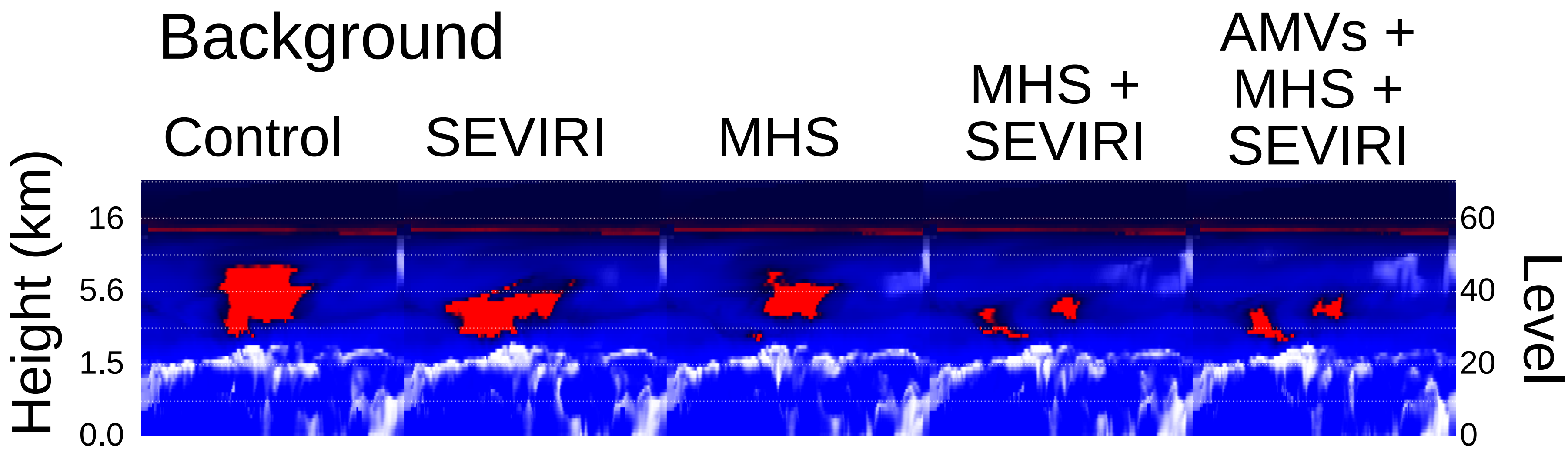
Legend



13 Feb 2012, 03Z

Log specific humidity in blue, with red where humidity is extremely low

Cloud water superimposed in white

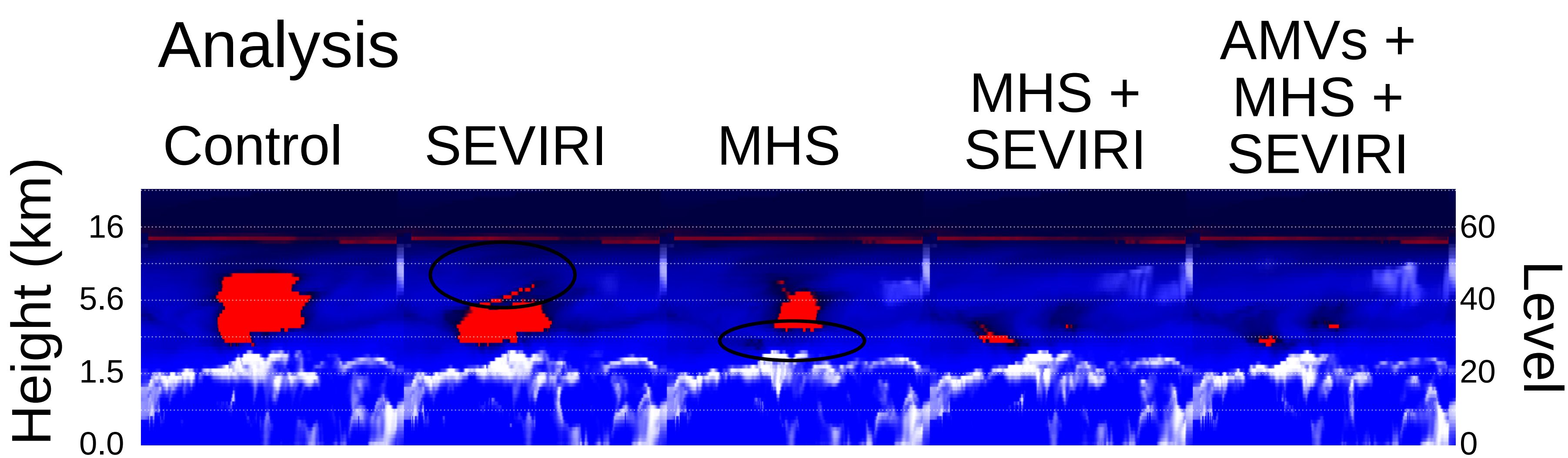


13 Feb 2012, 03Z

SEVIRI data improves the humidity in the upper troposphere

MHS data improves the humidity just above the cloud top

They complement each other in this case



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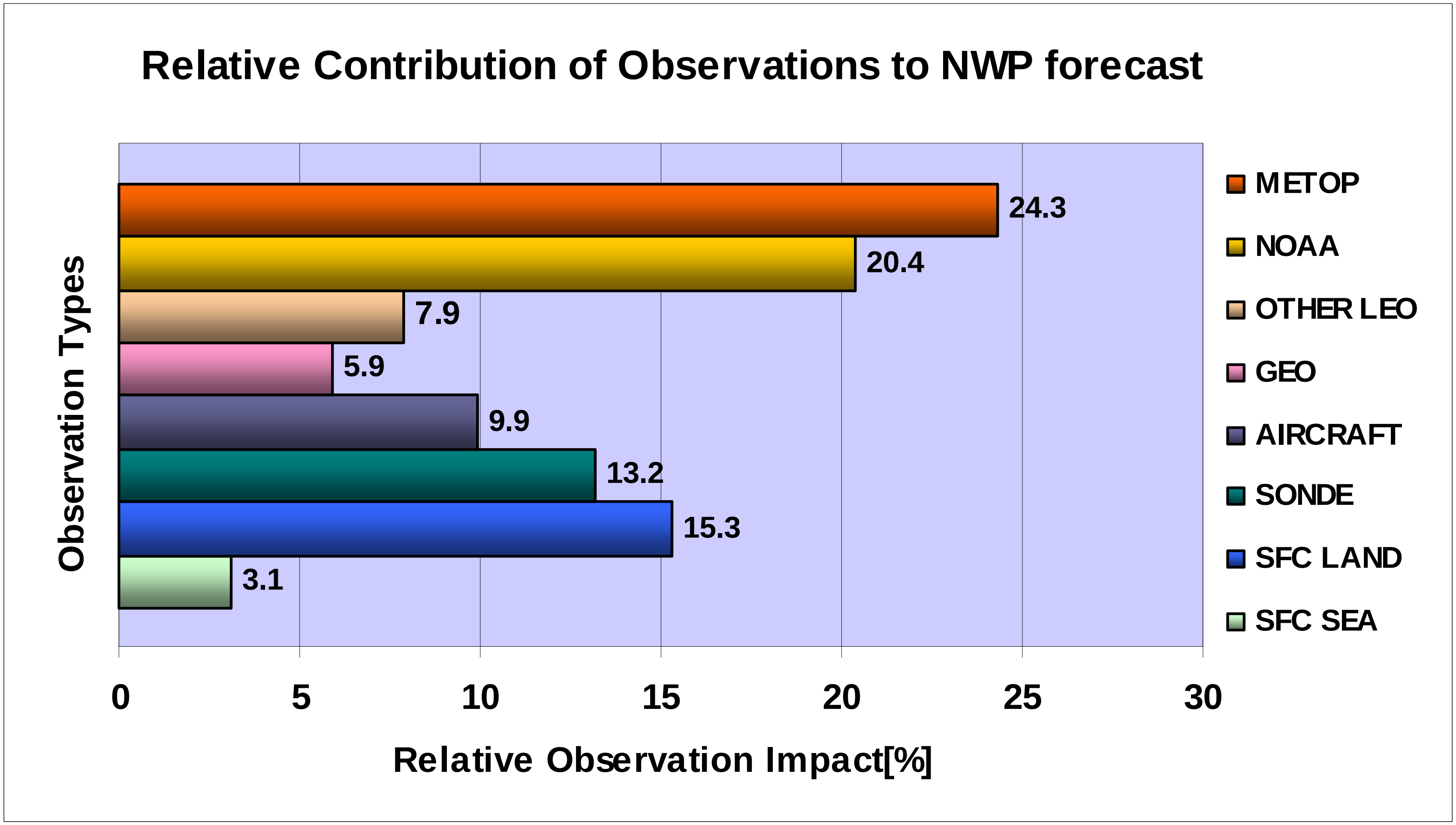
New monitoring tools: forecast sensitivity to observations (FSO)

Forecast sensitivity to observations (FSO): importance of Metop data



Assimilation of AMV and scatterometer observations

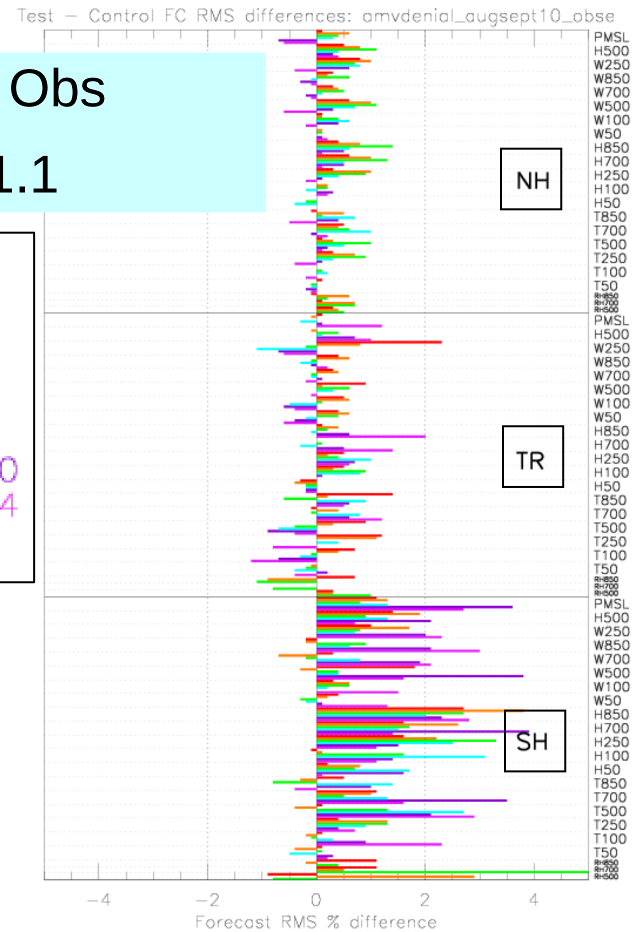
AMV impact

Collaborative IWWG impact study – 2 seasons of 6 weeks

NWP index scores for 2010 N.Atlantic hurricane season

v. Obs

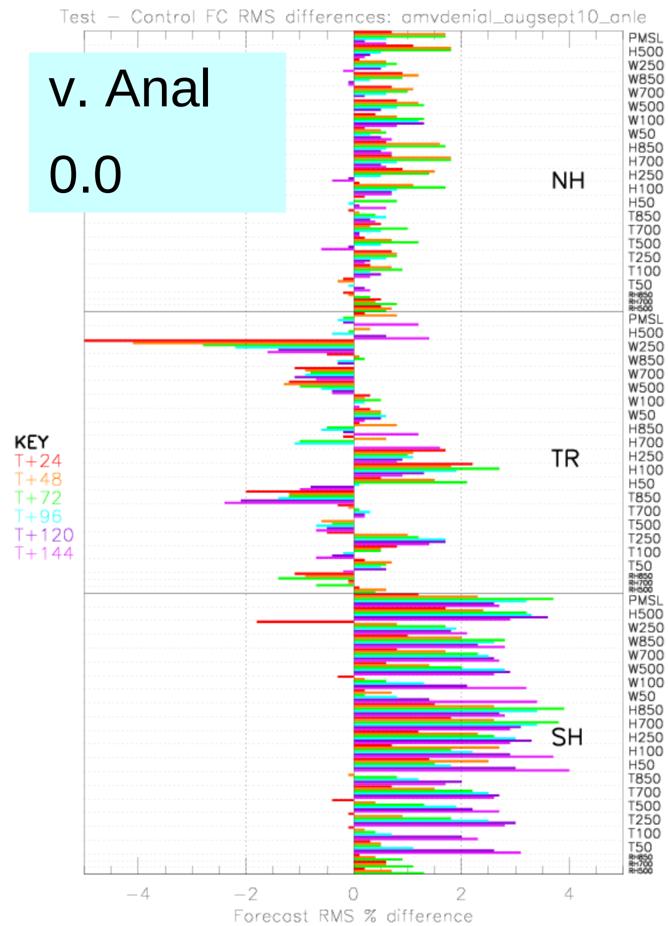
-1.1



KEY
T+24
T+48
T+72
T+96
T+120
T+144

v. Anal

0.0



AMV denial - control

Positive impact

Positive impact

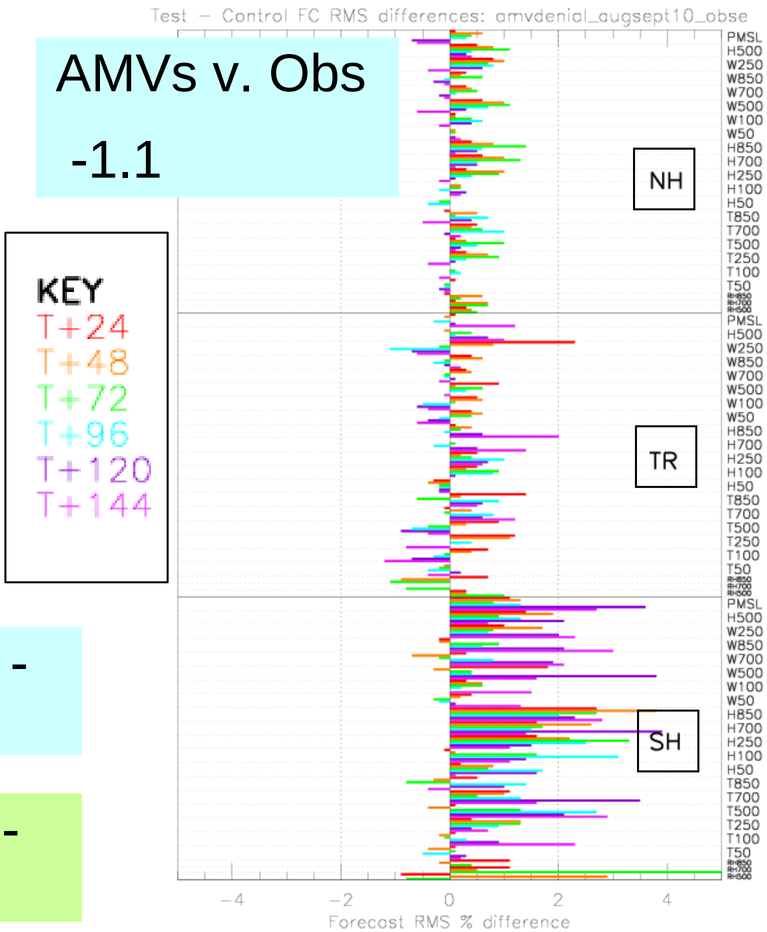
AMV and Scatterometer impact

Collaborative IWWG impact study – 2 seasons of 6 weeks

NWP index scores for 2010 N.Atlantic hurricane season

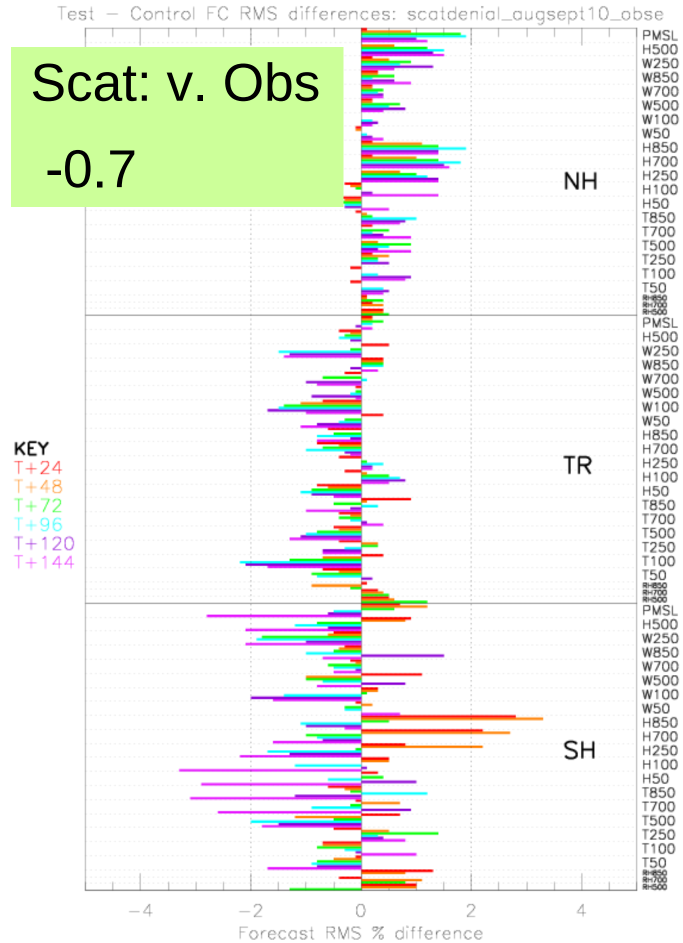
AMVs v. Obs

-1.1



Scat: v. Obs

-0.7



AMV denial - control

Scat denial - control

Positive impact

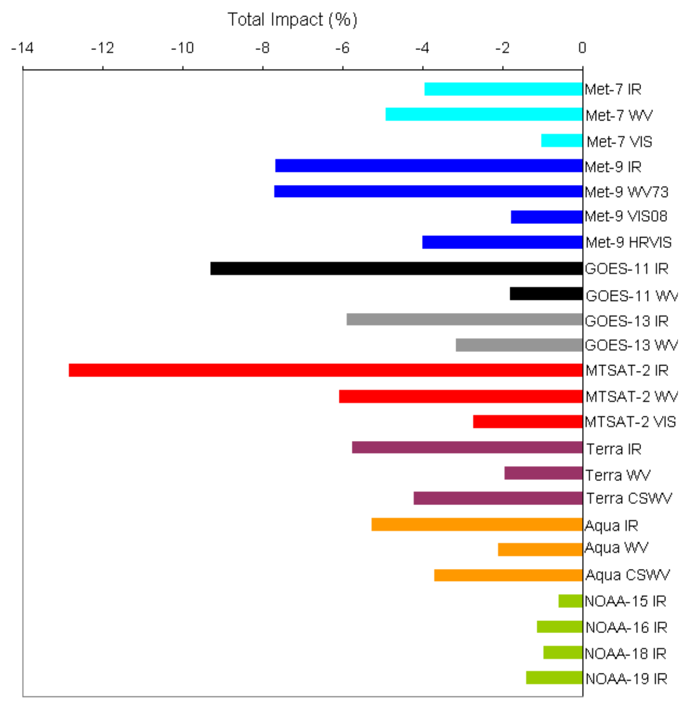
Positive impact

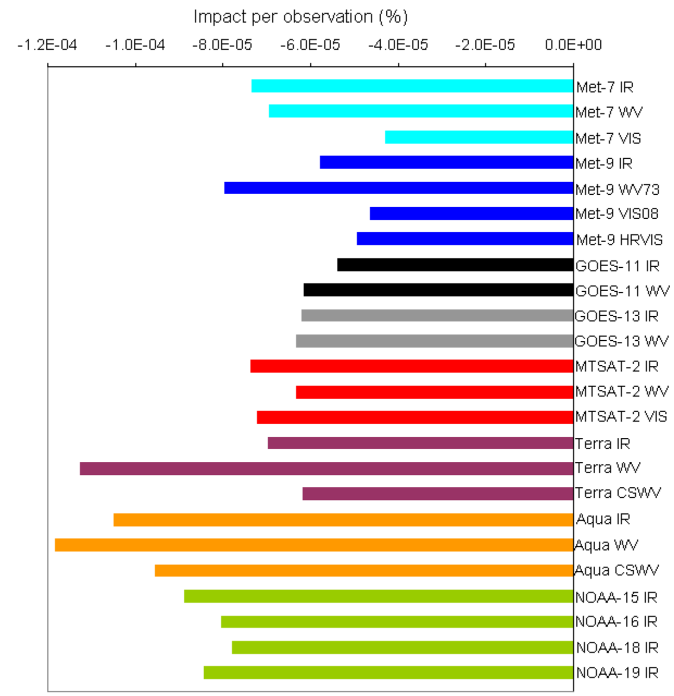
AMV impact

Forecast Sensitivity to Observations (FSO)

FSO breakdown by satellite / channel combination

- All AMVs contribute towards a reduction in forecast error
- Highest impact per ob from MODIS and AVHRR polar winds (but lower number used)





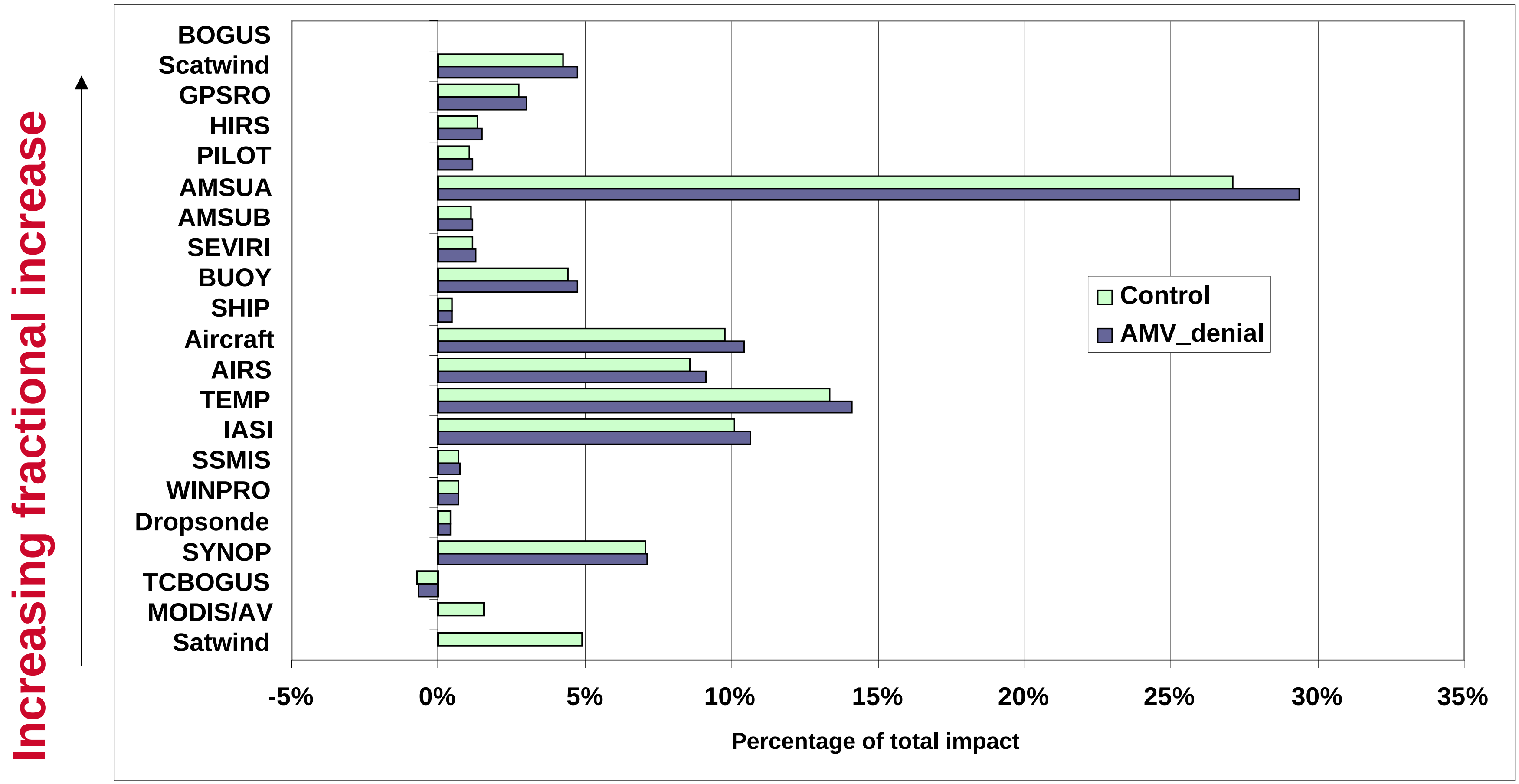
100% = total AMV impact

Total impact

Impact per ob.

AMV impact

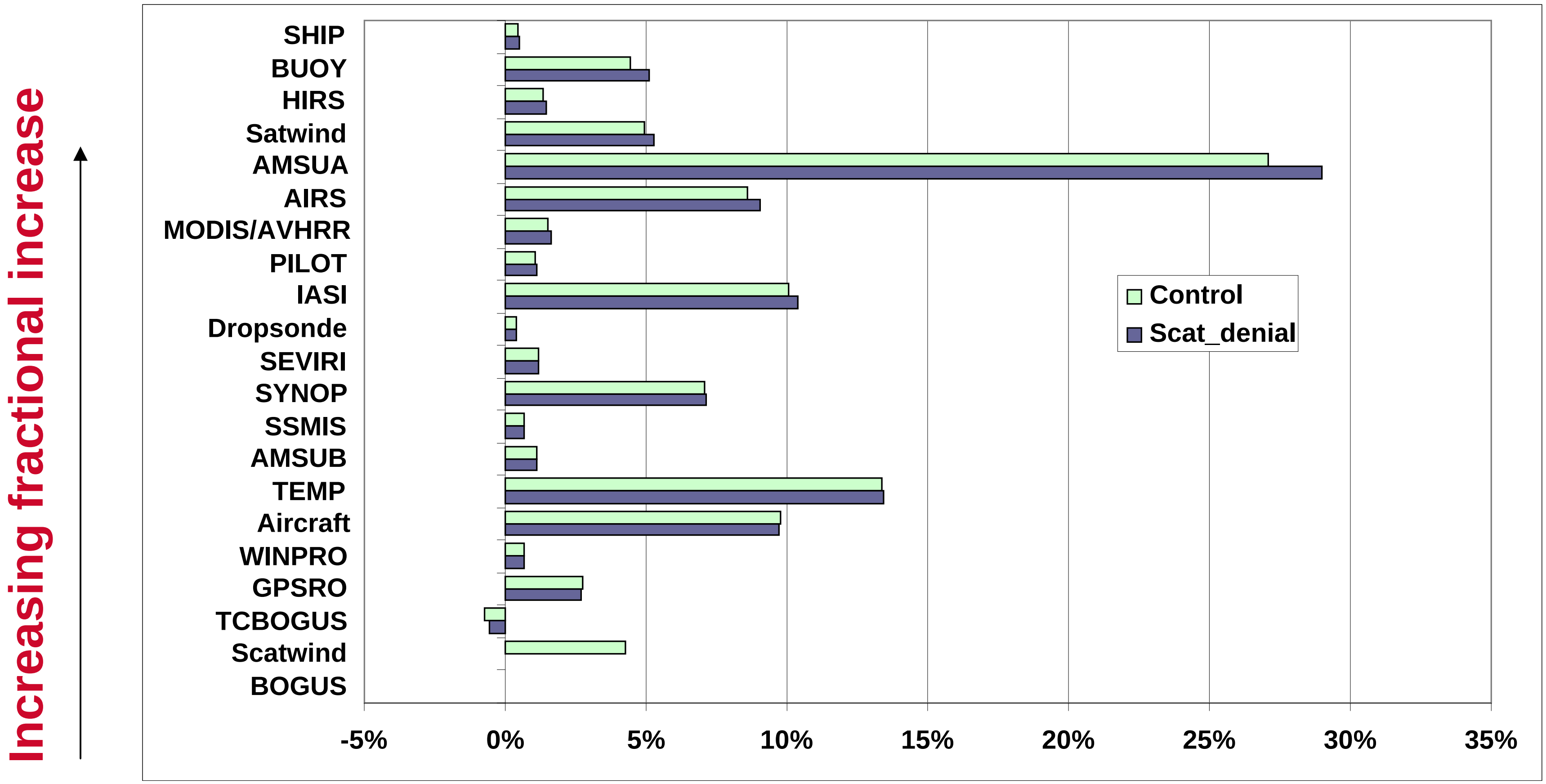
Forecast Sensitivity to Observations (FSO)



When AMVs are denied, scatterometer winds partially compensate

Satellite surface wind impact

Forecast Sensitivity to Observations (FSO)



When ASCAT, ERS-2 and WindSat winds are denied, other surface-marine observations partially compensate

Conclusions

Conclusions

- Good progress on assimilation of IR sounder radiances
  - cloud-affected and over land
  - more progress expected
  - implications for balance of observing system over land
- Dangers of “observation-free zones” in data assimilation
  - examples: mesospheric temperature, upper tropospheric humidity
- GPS-ZTD - significant impact on forecasts of surface variables
- AMV and scatterometer impacts:
  - Positive impact from all AMV types
  - Polar AMV have more impact per ob, but fewer of them
  - FSO statistics show which obs compensate when AMV/scatt denied

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Thank you! Questions?