Optimal distribution of polar-orbiting sounding missions

John Eyre Met Office, UK

CGMS-40; Lugano, Switzerland;5-9 Nov 2012

Optimal distribution of polar-orbiting sounding missions

- Background
- Previous studies in Europe
- A new theoretical study:
  - the impact of temporal spacing of observations on analysis accuracy
- Conclusions

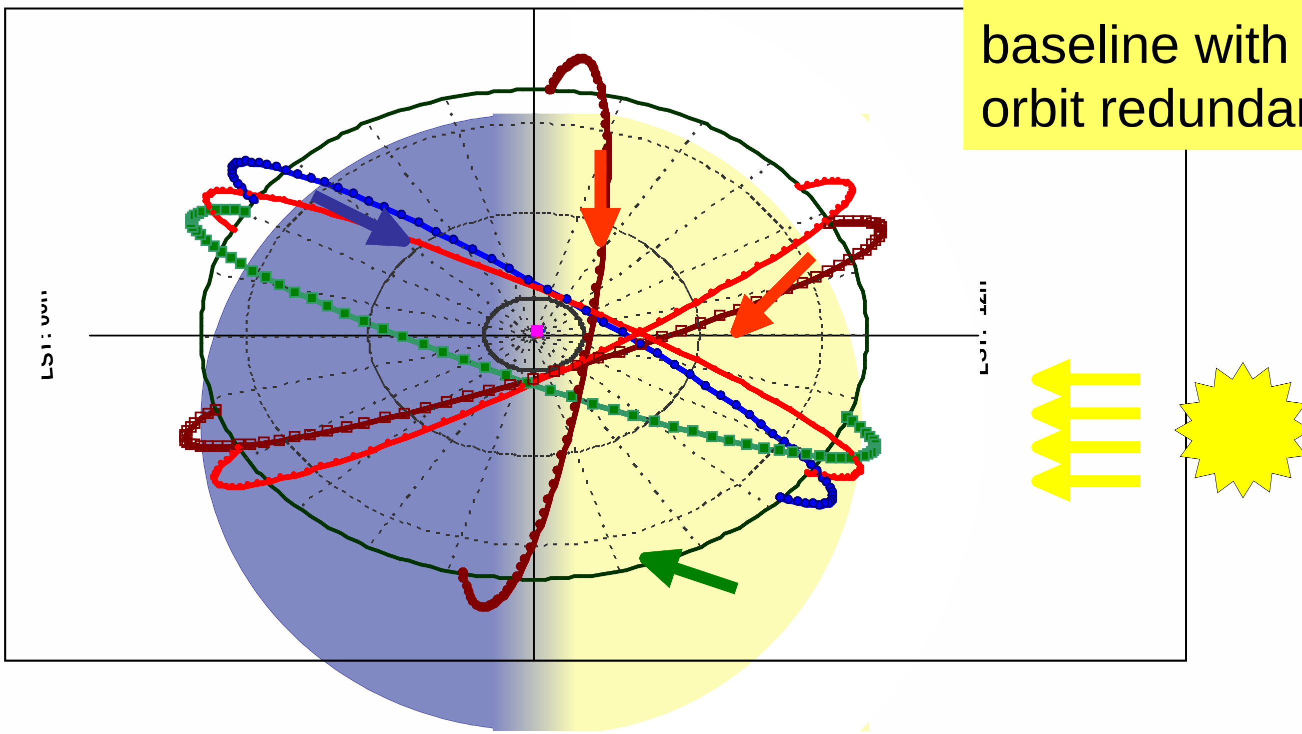
Acknowledgements

Enza Di Tomaso (ECMWF)
Niels Bormann (ECMWF)

Peter Weston (Met Office)

Background:
WMO Vision for the GOS in 2025

Recommended baseline with in-orbit redundancy



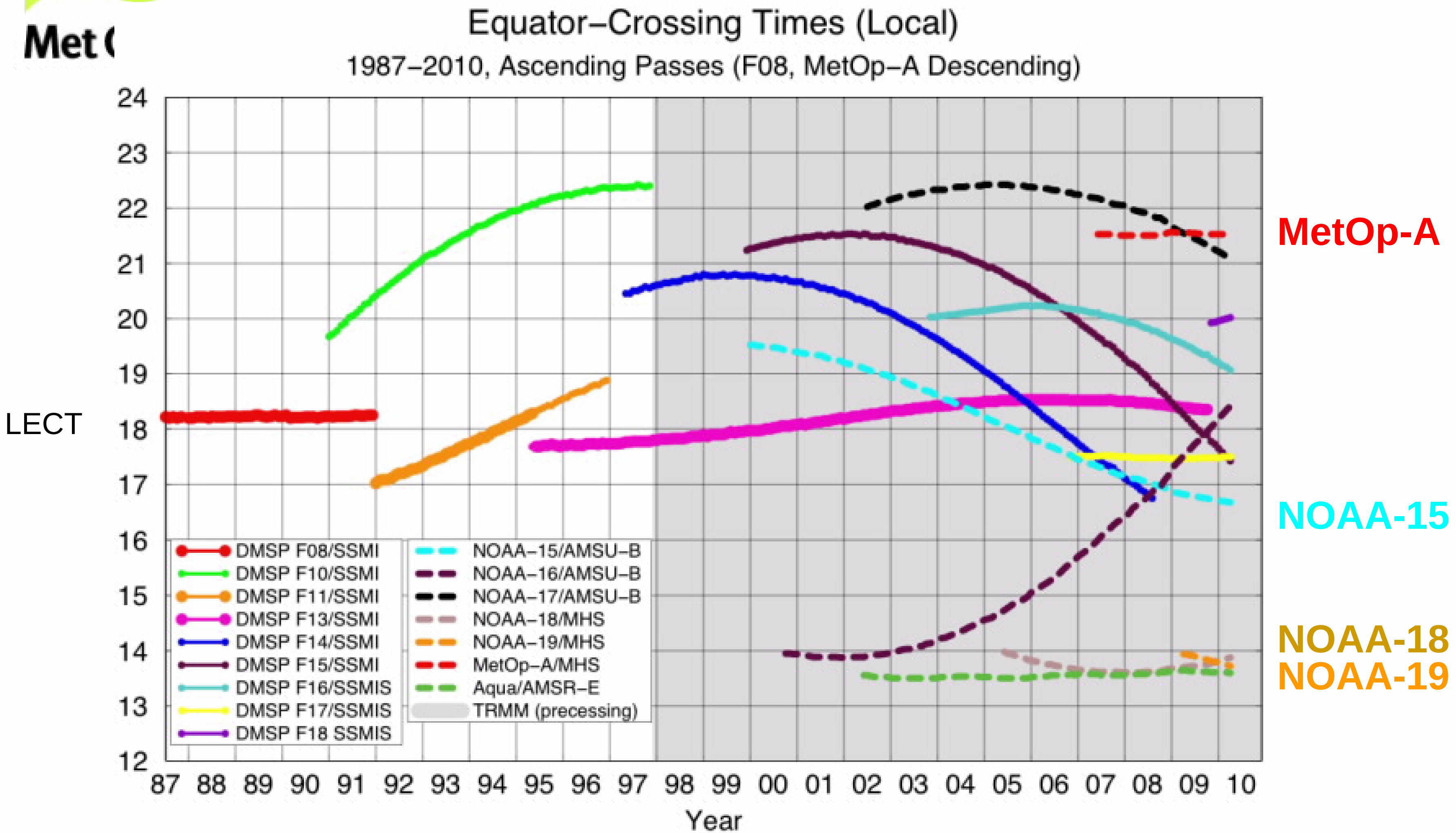
approved by WMO-EC, 2009

Previous studies in Europe

Assimilation of ATOVS radiances at ECMWF.
E. Di Tomaso and N.Bormann.
EUMETSAT/ECMWF Fellowship Programme Res. Rep. 22

Also presented in CGMS-38 EUM-WP-41

Orbits of current satellites



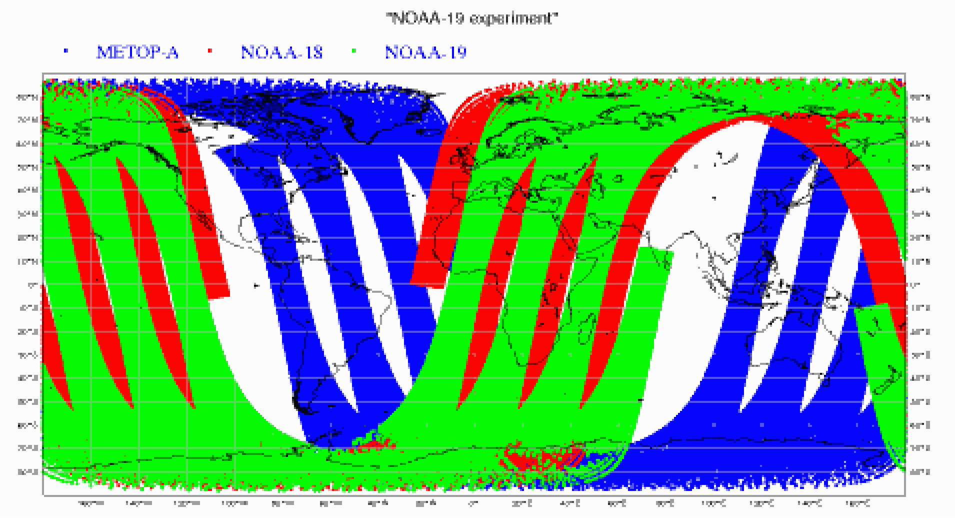
Thickest lines denote GPCP calibrator.

Image by Eric Nelkin (SSAI), 19 April 2010, NASA/Goddard Space Flight Center, Greenbelt, MD.

Data coverage

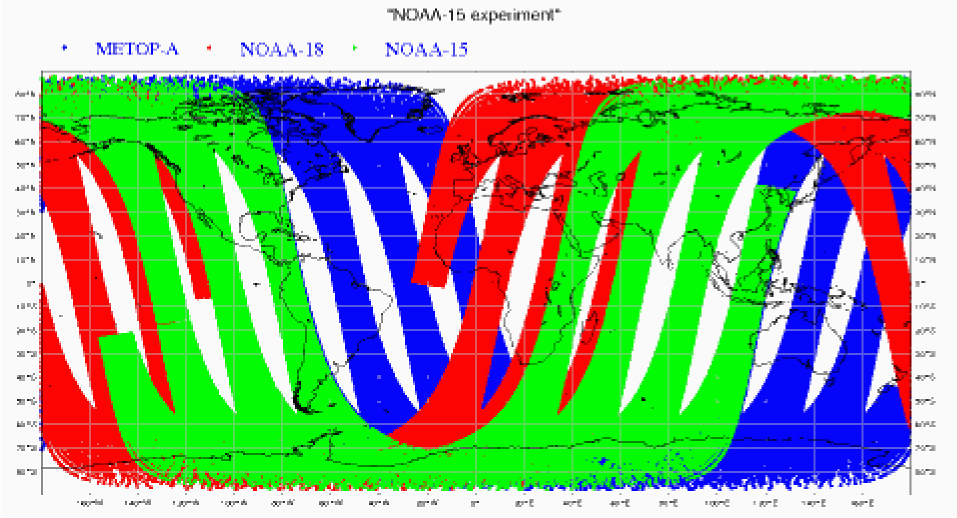
“NOAA-19 experiment”

* MetOp-A * NOAA-18 * NOAA-19



“NOAA-15 experiment”

* MetOp-A * NOAA-18 * NOAA-15



Sample coverage from a 6-hour period around 00Z

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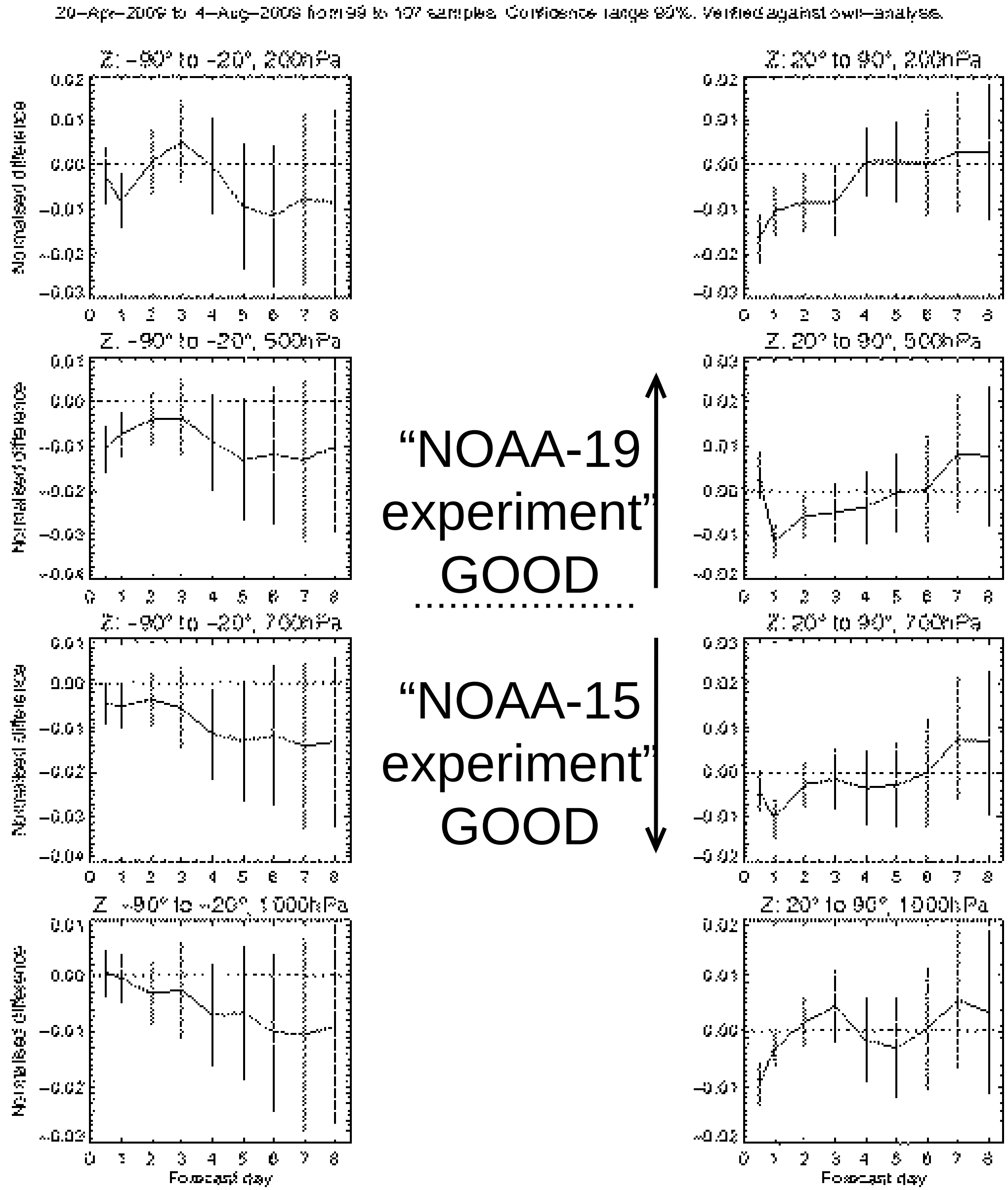
Forecast impact of ATOVS

" Averaged over extra-Tropics, impact of NOAA-15 experiment versus NOAA-19 experiment is neutral to slightly positive "

Note: AIRS and IASI not assimilated in these experiments



"NOAA-15 exp" RMSE – "NOAA-19 exp" RMSE

New theoretical study: the impact of temporal spacing of observations on analysis accuracy

Outline of theoretical study

- Very simple DA system
  - one variable in space
  - observations distributed in time
- Observations inserted in 12-hour cycle
  - to simulate 1, 2, 3 or 4 satellites
  - with temporal spacing to simulate 3 orbital planes
- Results found to be very sensitive to assumed rates of forecast error growth
  - different rates of doubling time for forecast error variance used:
  - 12 hours, 6 hours, 3 hours
- See CGMS-40 WMO-WP-19 for theory and details

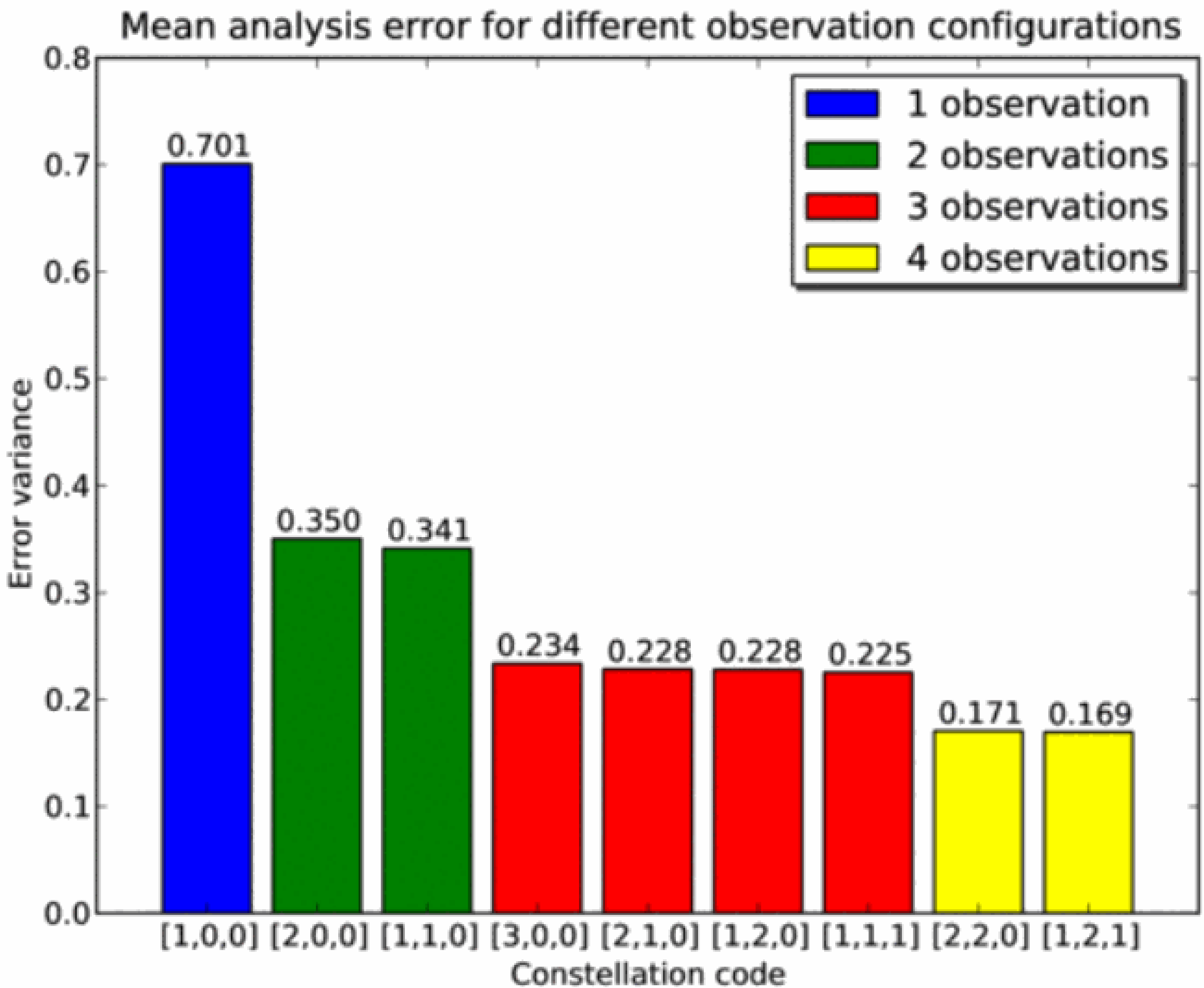
The experiments:

different numbers of observations and different observation spacings

relative observation time (hours) →			0	1	2	3	4	5	6	7	8	9	10	11
experiment number	**number of observations**	**constellation code**												
1	1	[1,0,0]	1											
2	2	[2,0,0]	2											
3	2	[1,1,0]	1				1							
4	3	[3,0,0]	3											
5	3	[2,1,0]	2				1							
6	3	[1,2,0]	1				2							
7	3	[1,1,1]	1				1				1			
8	4	[2,2,0]	2				2							
9	4	[1,2,1]	1				2				1			

Average analysis error variance:

forecast error variance doubling time = 12 hours



Average analysis error variance:

forecast error variance doubling time = 6 hours

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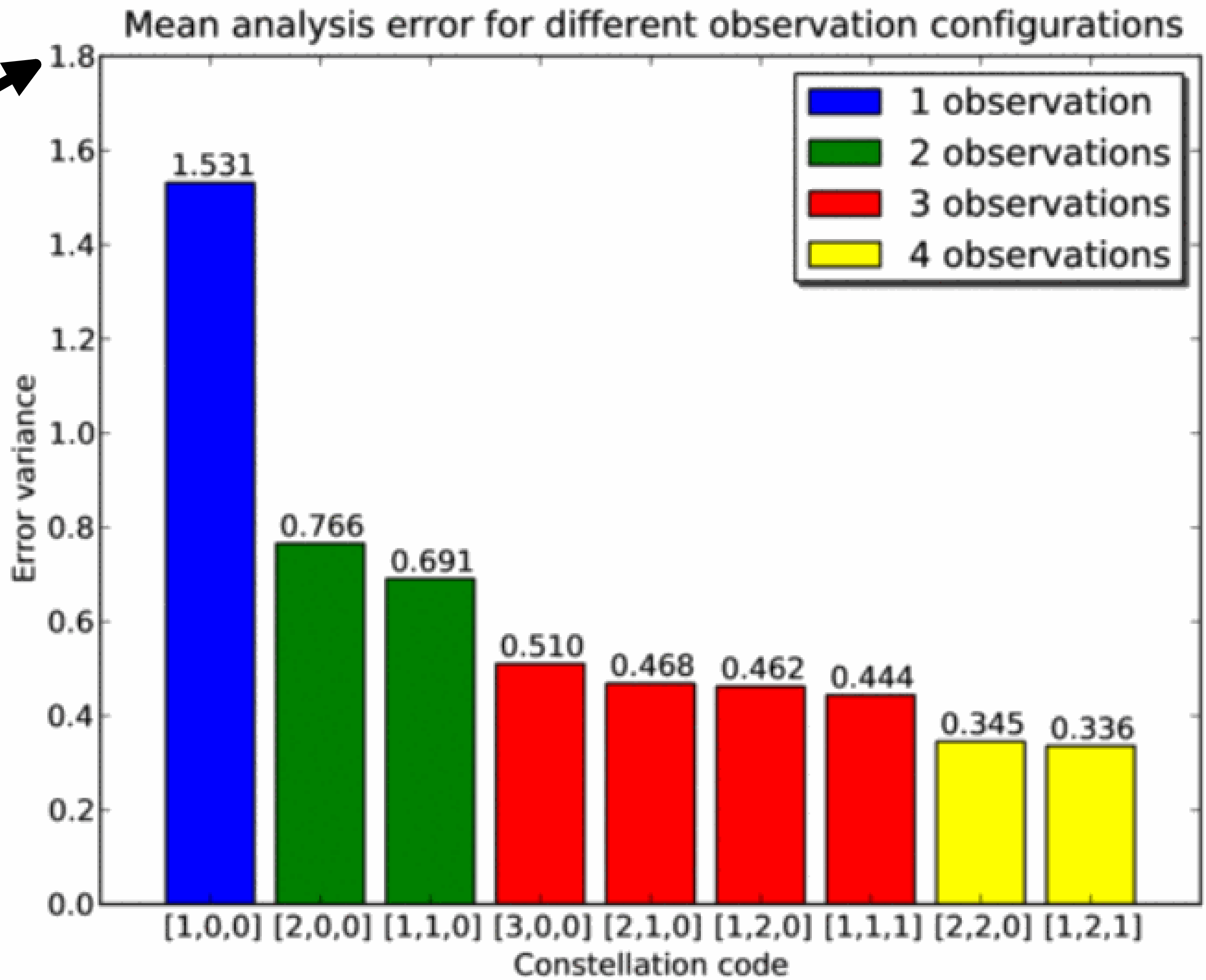
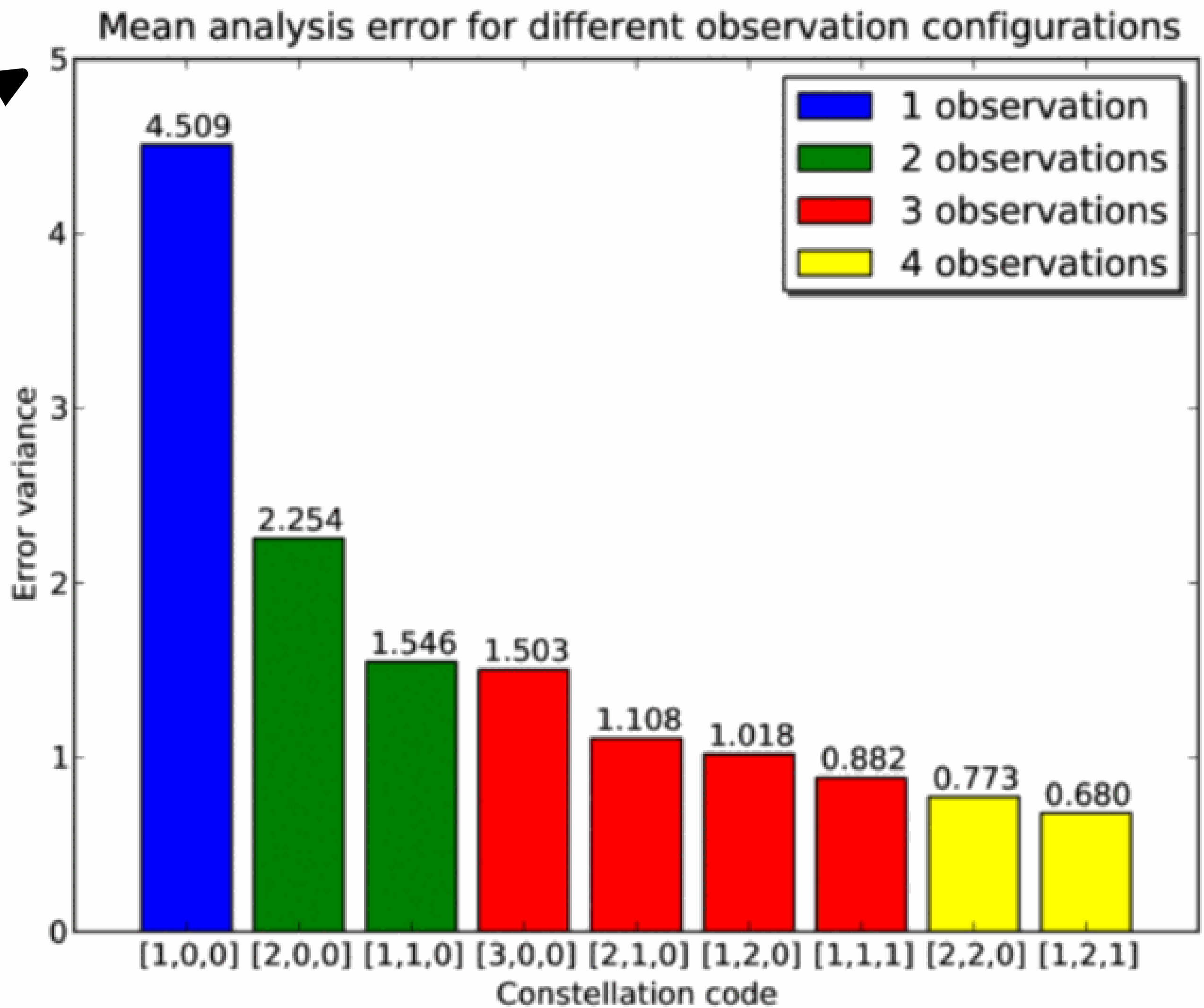
note change of scale



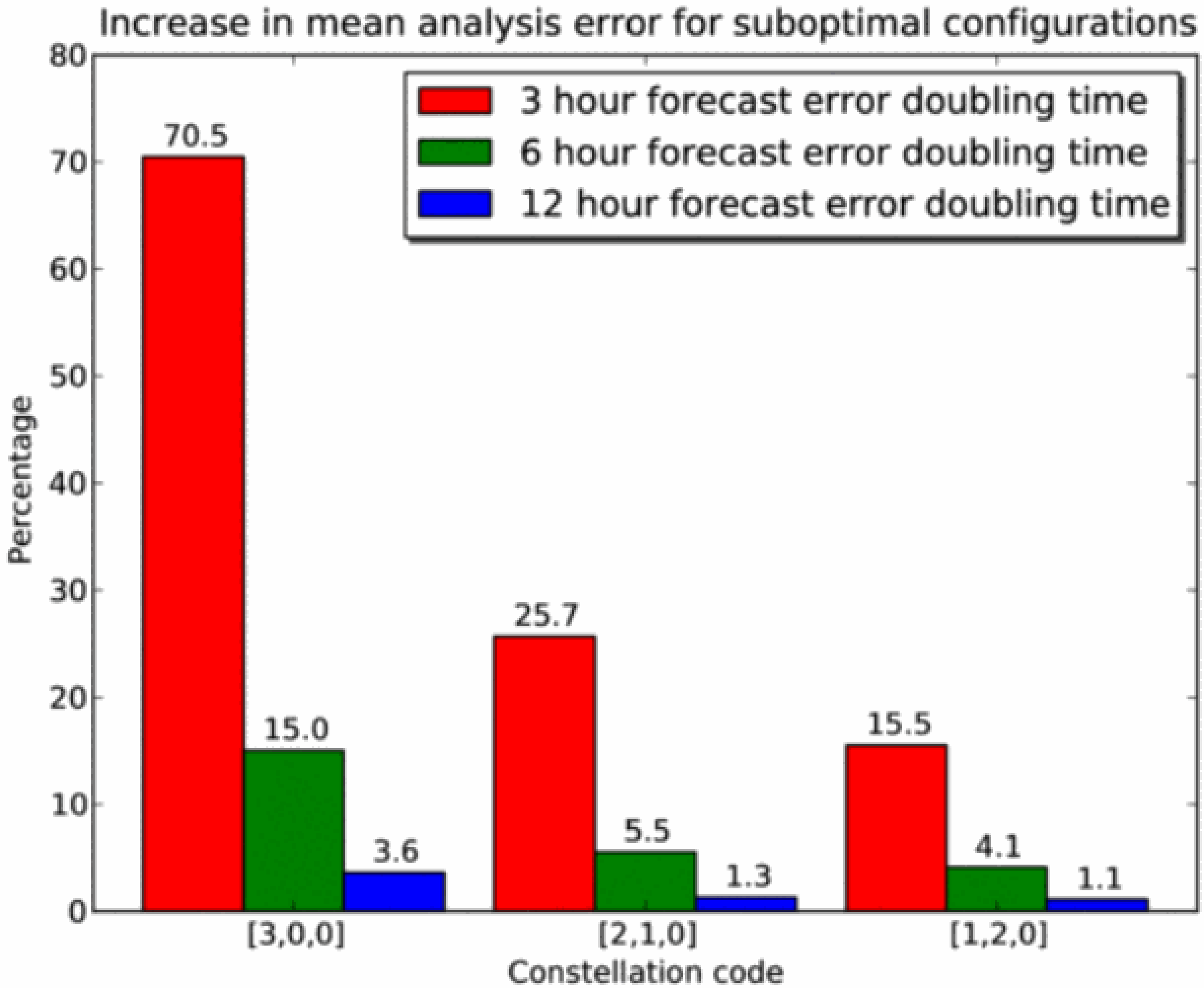
Average analysis error variance:

forecast error variance doubling time = 3 hours

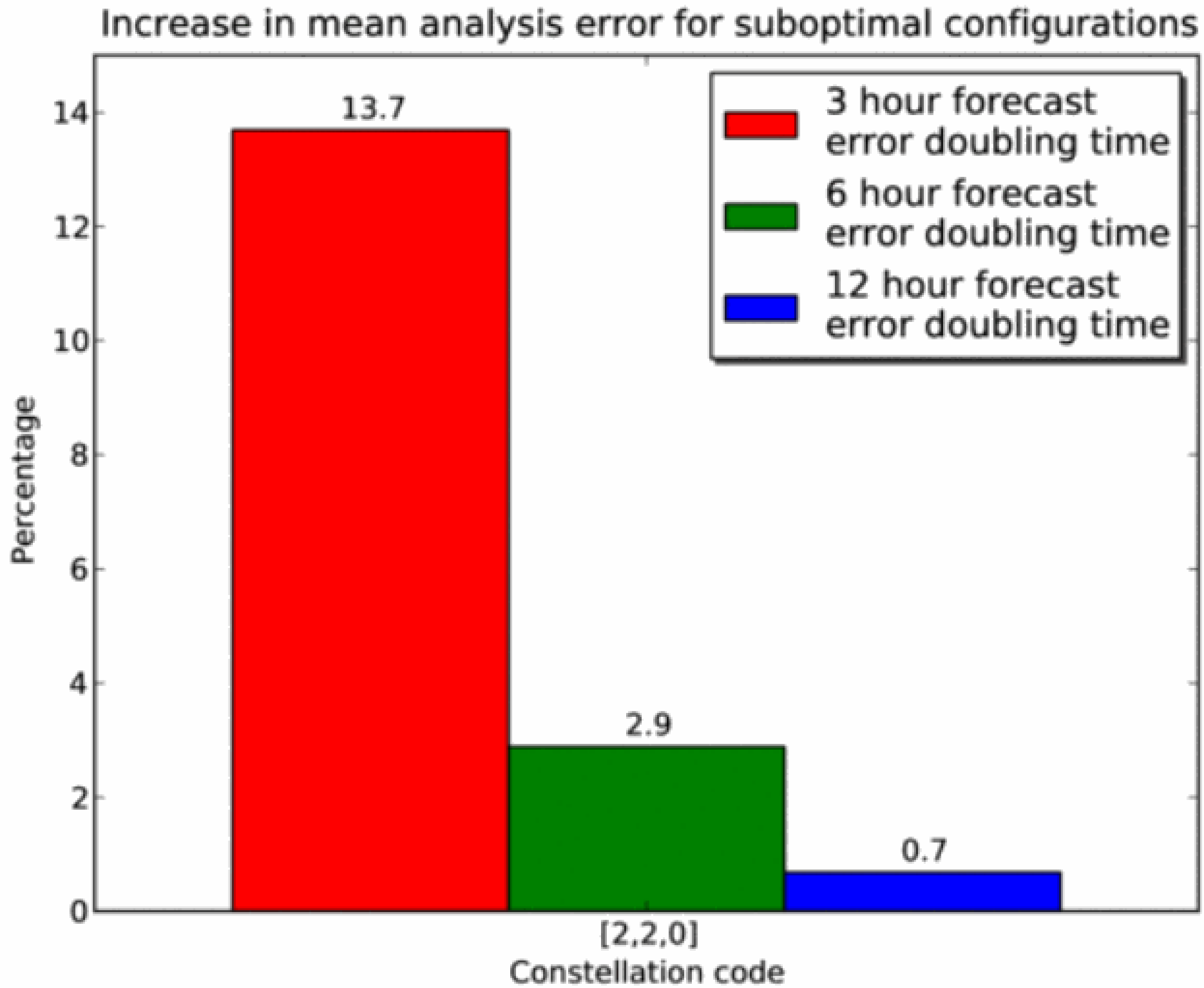
note change of scale



For 3-satellite constellations: percentage increases in analysis error variance relative to [1,1,1]

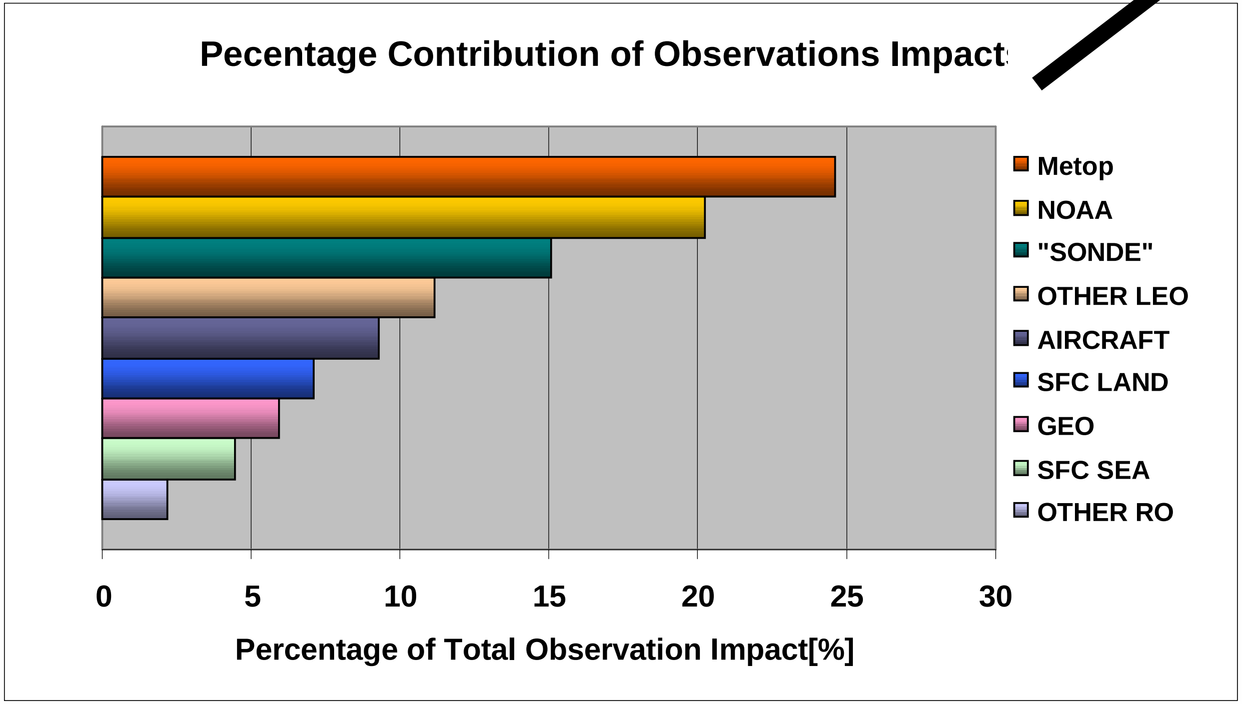


For 4-satellite constellations: percentage increases in analysis error: [2,2,0] relative to [1,2,1]



Relevance of theoretical results to real world?

Forecast sensitivity to observations (FSO) in global NWP:
(Joo, Eyre and Marriott. Met Office FR Tech. Rep. No.562, 2012. Also submitted to MWR.)



~64% of impact comes from satellite observations

…

of which ~90% from polar sounding data

…

higher for mid-latitude oceans

Theoretical study – Conclusions

- Mean analysis error variance is most relevant metric when assessing impact of temporal spacing of observations on global NWP performance

- Dependence of mean analysis error variance on observation spacing is very sensitive to assumed rate of forecast error growth:
  - for a 12-hour doubling time of forecast error variance, dependence on observation spacing is significant but small,
  - for a 3-hour doubling time reaching ~25% increase in variance for plausible 3-satellite constellations, and ~8% increase for 4-satellite constellations.

- These simple experiments are relevant to real NWP systems, particularly for rapidly-developing storms over mid-latitude oceans.

- Results support assumptions guiding the WMO Vision: that polar-orbiting satellites should be equally space in time, as far as is practicable.

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Overall conclusions

Overall conclusions

- OSE and theoretical study results support guidance that observations should be roughly equally spaced in time
- Impact of observation spacing on NWP is greatest when forecast error growth rates are high, as likely in rapidly-developing storms
- → At least one set of IR+MW sounding instruments in an early morning orbit is highly desirable
- More important to optimise the temporal spacing than to hit specific absolute LECTs

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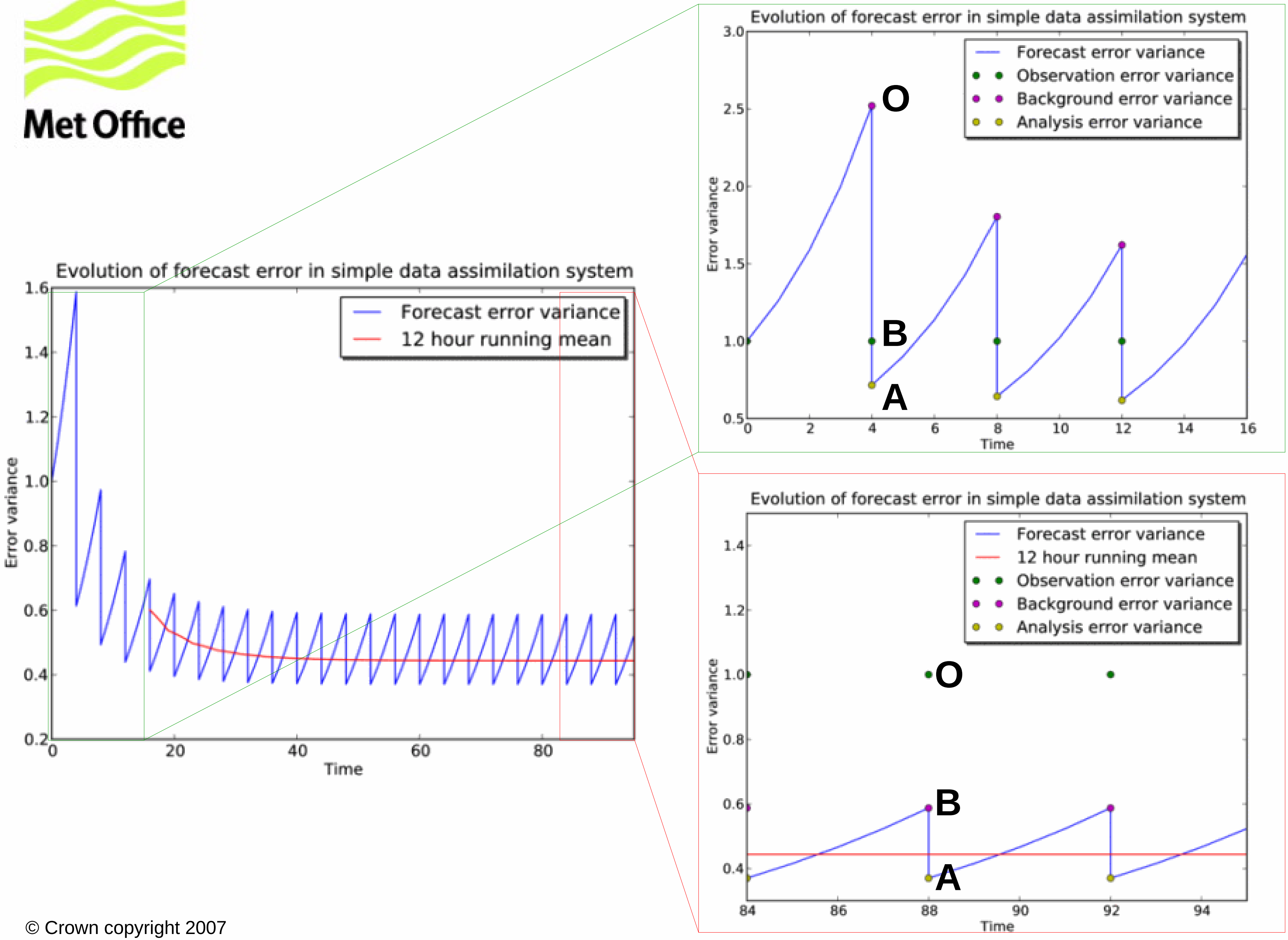
Thank you! Questions?


Evolution of forecast error in simple data assimilation system
Forecast error variance
12 hour running mean
Error variance
Time
Evolution of forecast error in simple data assimilation system
Forecast error variance
Observation error variance
Background error variance
Analysis error variance
O
B
A
Error variance
Time
Evolution of forecast error in simple data assimilation system
Forecast error variance
12 hour running mean
Observation error variance
Background error variance
Analysis error variance
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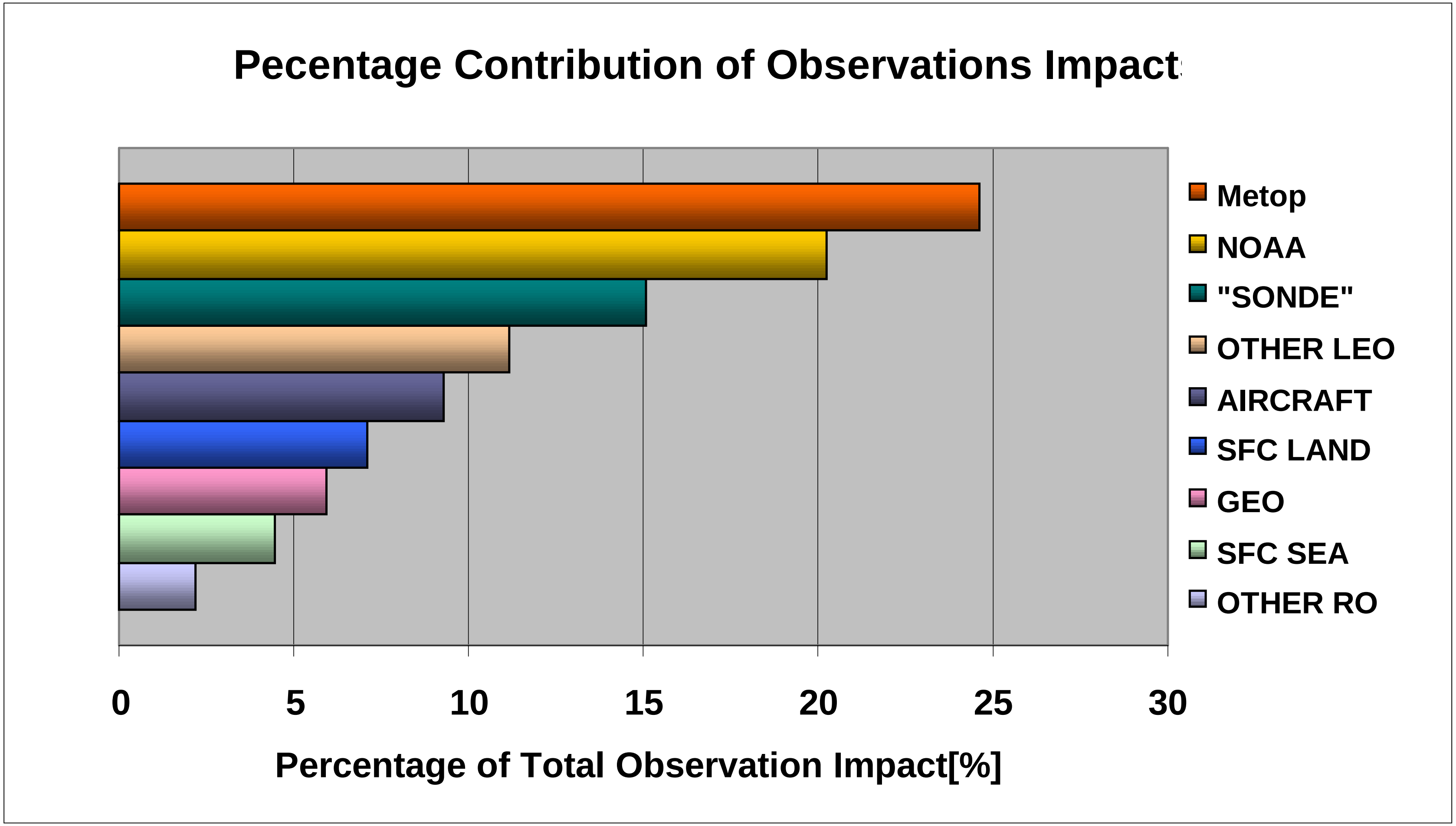
The experiments:

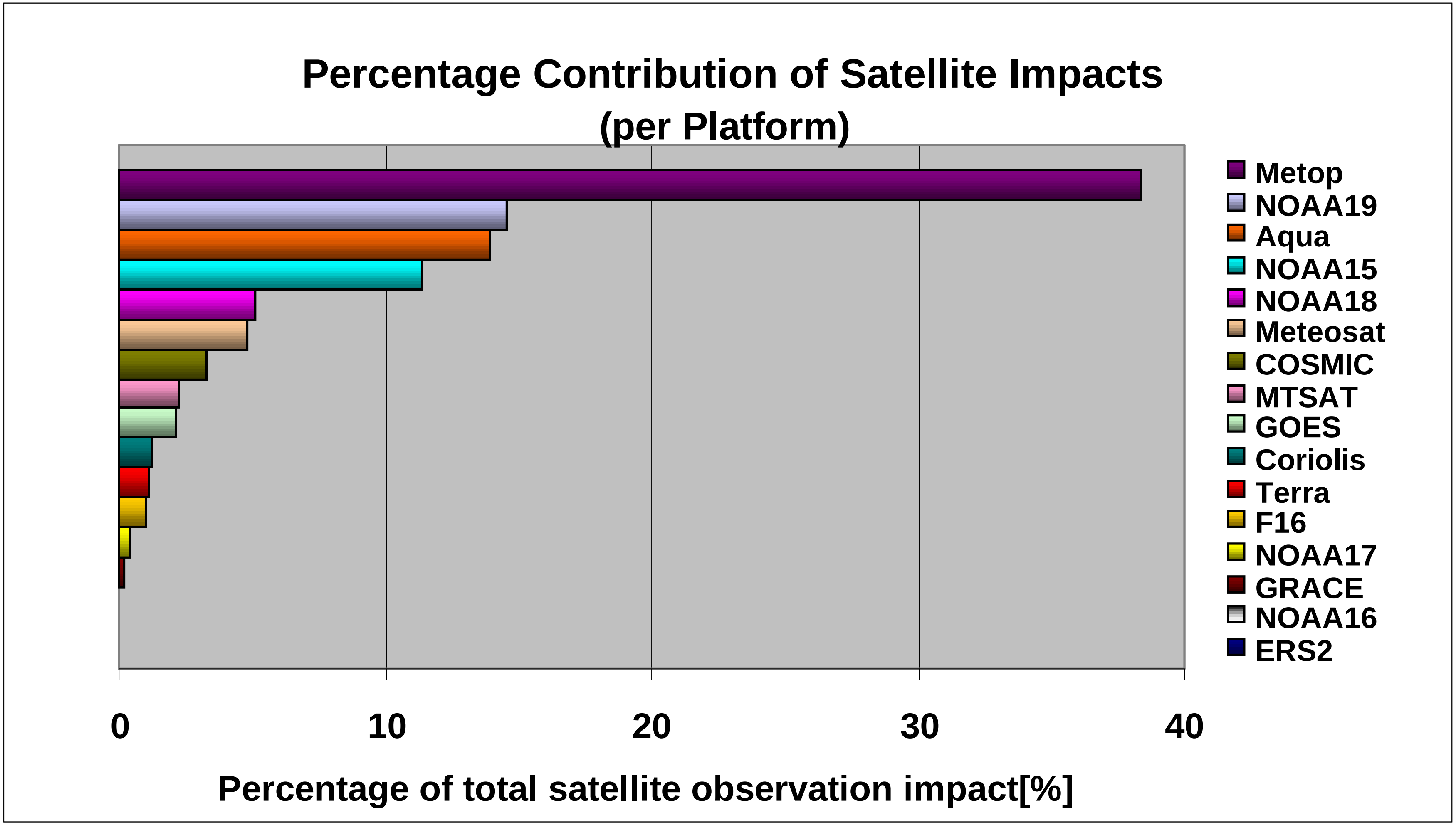
mean analysis accuracies and error variances

	experiment number	1	2	3	4	5	6	7	8	9
	number of observations	1	2	2	3	3	3	3	4	4
Δt	**constellation code**	[1,0,0]	[2,0,0]	[1,1,0]	[3,0,0]	[2,1,0]	[1,2,0]	[1,1,1]	[2,2,0]	[1,2,1]
12 h	**mean accuracy**	1.485	2.970	2.970	4.454	4.454	4.454	4.454	5.939	5.939
	mean error variance	0.701	0.350	0.341	0.234	0.228	0.228	0.225	0.171	0.169
	% difference	-	+2.7	0	+3.6	+1.3	+1.1	0	+0.7	0
6 h	**mean accuracy**	0.764	1.528	1.528	2.291	2.291	2.291	2.291	3.055	3.055
	mean error variance	1.531	0.766	0.690	0.510	0.468	0.462	0.444	0.345	0.336
	% difference	-	+10.9	0	+15.0	+5.5	+4.1	0	+2.9	0
3 h	**mean accuracy**	0.404	0.808	0.808	1.212	1.212	1.212	1.212	1.616	1.616
	mean error variance	4.509	2.254	1.546	1.503	1.108	1.018	0.882	0.773	0.680
	% difference	-	+45.8	0	+70.5	+25.7	+15.5	0	+13.7	0

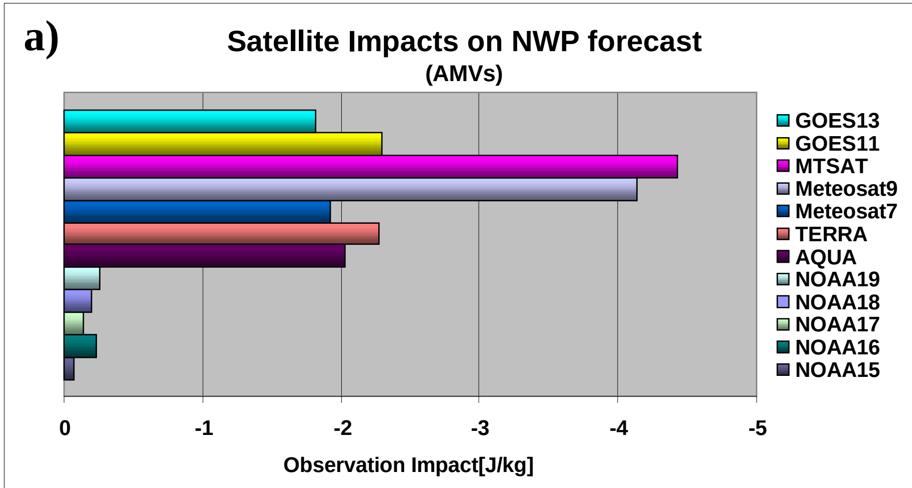
Forecast sensitivity to observations (FSO): importance of Metop data

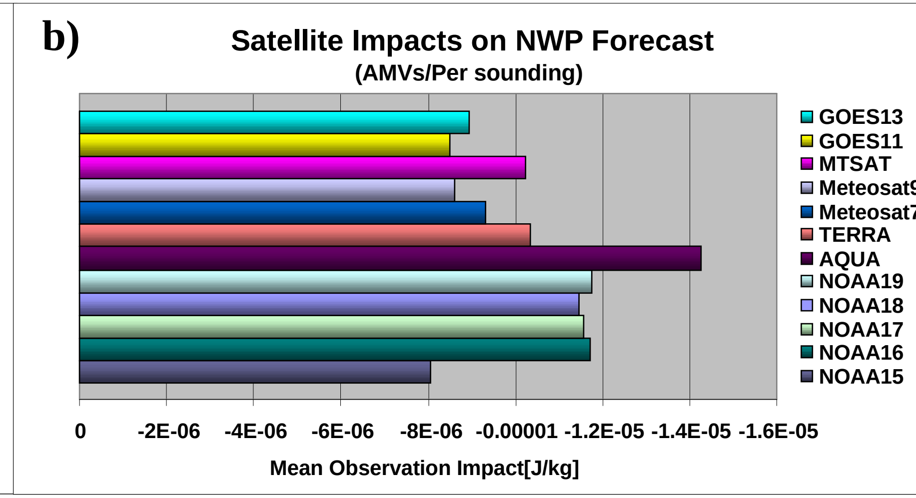


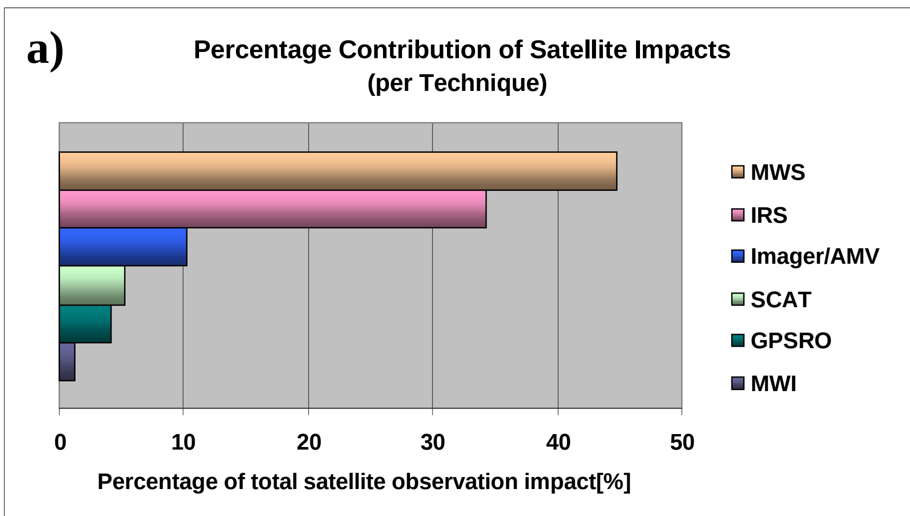
Forecast sensitivity to observations (FSO): importance of Metop data

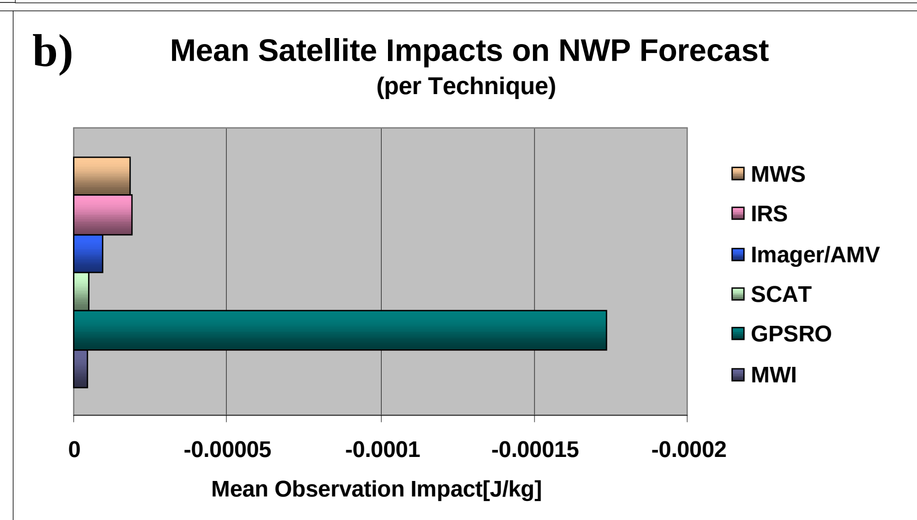


Forecast sensitivity to observations (FSO): importance of Metop data









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