

# Observation Denial Trials in the UKV.

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EWGLAM, 2020

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With thanks to : Robert Tubbs, Bruce Macpherson, Adam Maycock





# Motivation

- Impact from Observation Network components
- Work in Progress



# UKV model configuration – key features

- Variable Grid with 1.5km interior resolution
- Hourly 4D-Var on 4.5km grid
- ‘OS43’ Science (=current Operational)
- Observation Cutoff = 45 minutes (=80 on 11 & 23Z cycles to capture sondes)
- Latent Heat Nudging
- Adaptive Variable Grid
- Climatological covariances – lagged NMC method



# Observational Denial Trials

- **Control** = OS43 (current) Science Configuration
- 2 Seasons (Summer and Winter)
- Approximately 2 months in each season



# Denial Observation Sets

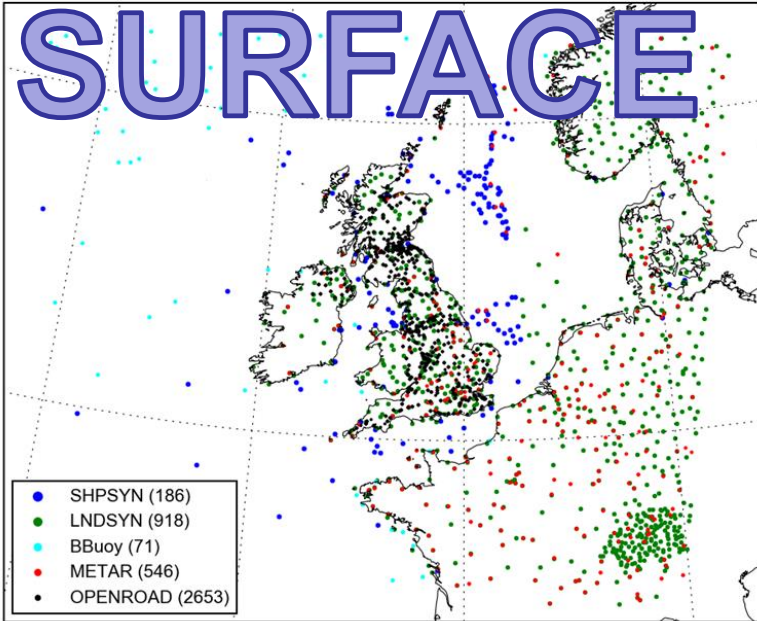
	Near-surface Sets	Abbn	Obs Denied
1	All land-surface	LAND	= SYNOP + METAR + Roadside
2	All land-surface except roadside	LANDxROAD	= SYNOP + METAR
3	Roadside Only	ROAD	=Roadside
4	All land T/RH	T/RH	=SYNOP + METAR + Roadside T/RH
5	All land MSLP	MSLP	=SYNOP + METAR MSLP
	<b>SYNOP:</b> T <sub>2m</sub> , RH <sub>2m</sub> , Wind <sub>10m</sub> , Vis <sub>2m</sub> , MSLP, Cloud <b>METAR:</b> T <sub>2m</sub> , RH <sub>2m</sub> , Wind <sub>10m</sub> , Vis <sub>2m</sub> , MSLP <b>ROADSIDE:</b> T <sub>2m</sub> , RH <sub>2m</sub> , Vis <sub>2m</sub>		
	Upper-Air Sets	Abbn	Obs Denied
6	All Upper-Air Conventional	UPAIR *	=Sondes, Profilers & Aircraft (AIRREP, AMDAR & Mode-S)
7	All AMDAR & AIREP	AMDAR	=AMDAR & AIREP T,RH & Wind
8	All Mode-S	MODES	=MODES Wind
9	Radar	RADAR	=LHN + Doppler Winds
10	GroundGPS	GNSS	=GroundGPS
11	GeoCloud	GEOCLOUD	=Satellite cloud fraction profile
12	All Satellite Radiances	SATRAD *	=All Satellite Radiances



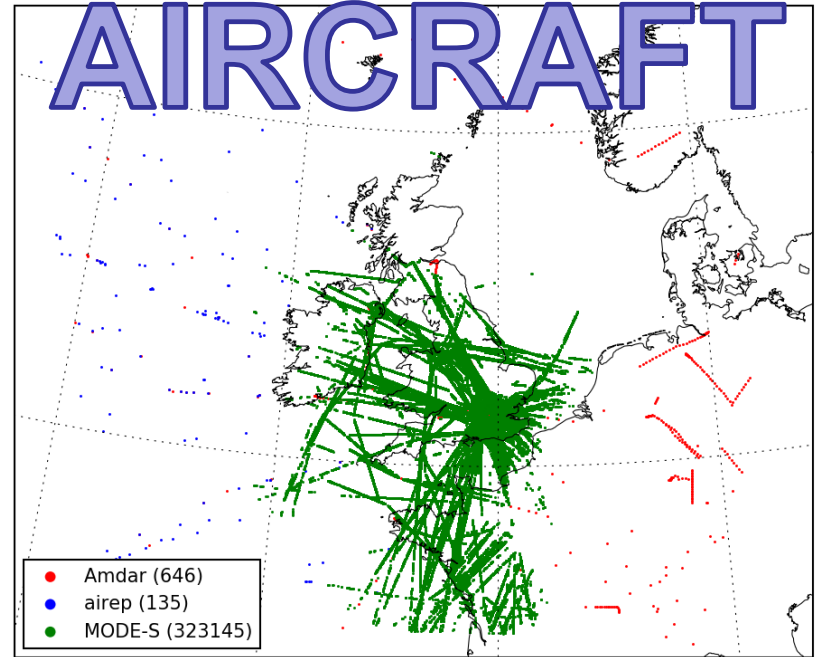
All surface for 2019092816



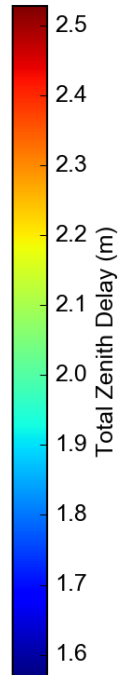
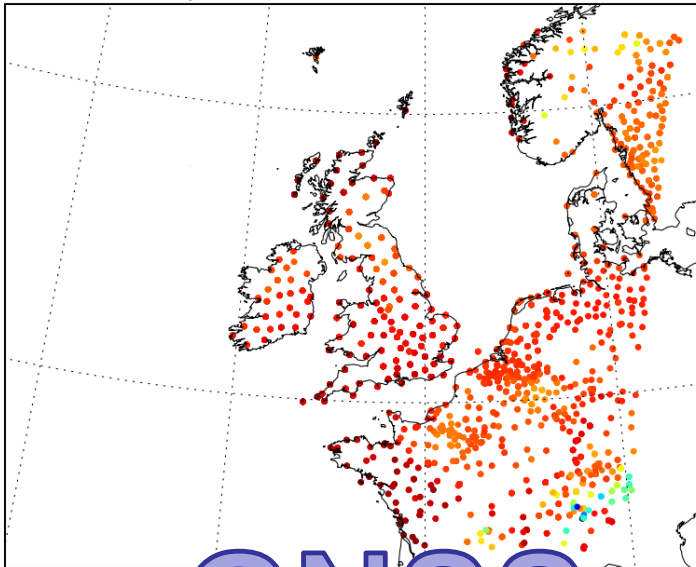
# SURFACE



# AIRCRAFT

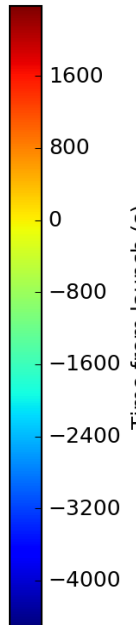
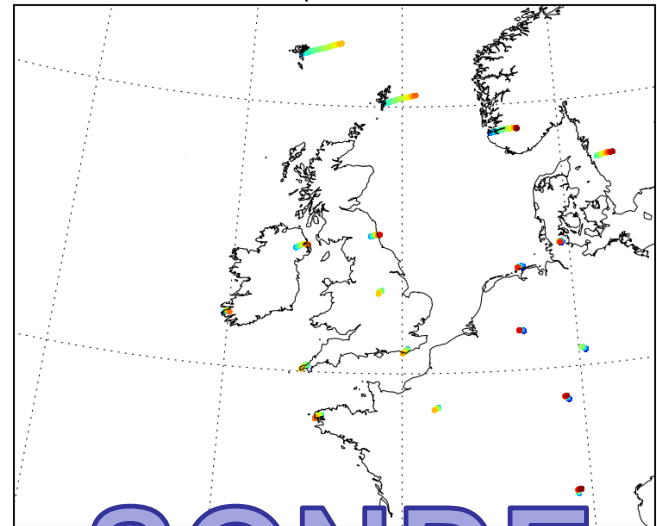


Obs plot for 2020092201 : 5395 obs



# GNSS

BUFR sonde reports with drift (35)



# SONDE





# Verification vs Observations

- **‘Sensible Weather’** – mainly vs SYNOP (03) observations
- $T_{2m}$ ,  $RH_{2m}$ ,  $Vis_{2m}$ ,  $Wind_{10m}$ , Ppn, Cloud Cover, Cloud Base Height, MSLP

- **Upper-Air** – vs SONDE profile observations

- Temperature, RH, Wind

- **Important Note**

.....as we also assimilate SYNOP & SONDE obs, impacts from these obs types likely to be exaggerated relative to other obs types



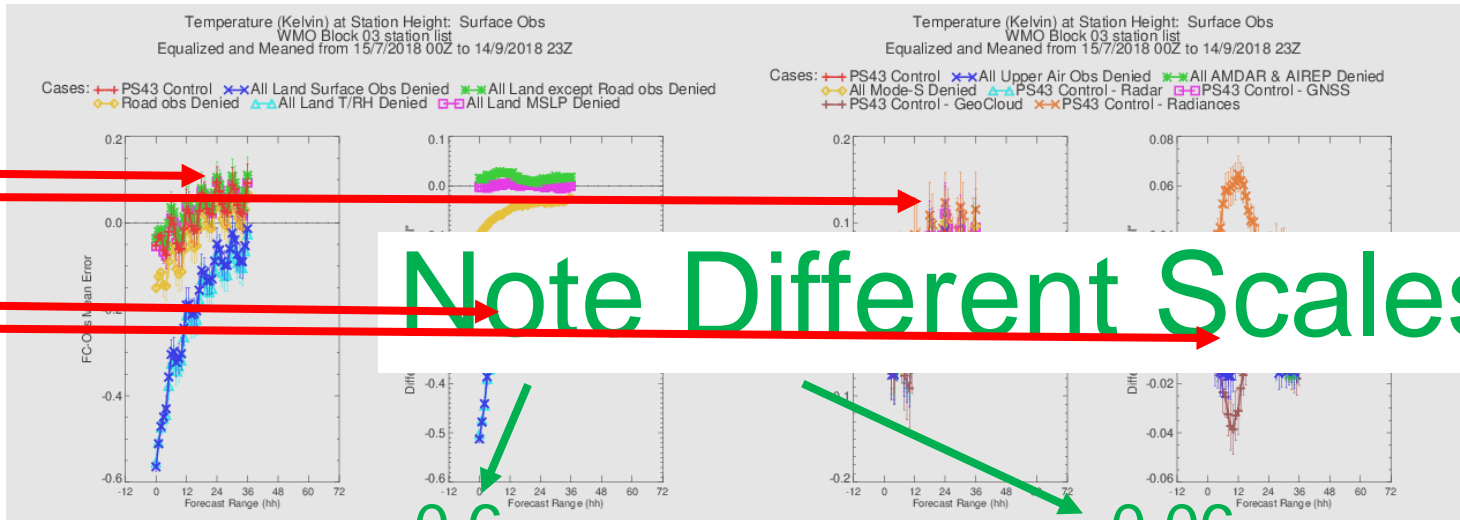
# T<sub>2m</sub> Summer

Summer Impacts Summary vs Surface Obs

Met Office	PS43	PS43 Control	PS43 Control - Radar	PS43 Control - GNSS	PS43 Control - GeoCloud	PS43 Control - Radiances	All Land Surface Obs Denied	All Land except Road obs Denied	All Land MSLP Denied	All Upper Air Obs Denied	All AMDAR & AIREP Denied	All Mode-S Denied	Road obs Denied	All Land T/RH Denied
PS43	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control - Radar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control - GNSS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control - GeoCloud	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control - Radiances	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Land Surface Obs Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Land except Road obs Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Land MSLP Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Upper Air Obs Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All AMDAR & AIREP Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Mode-S Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Road obs Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Land T/RH Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

**Bias**

Diff from Control



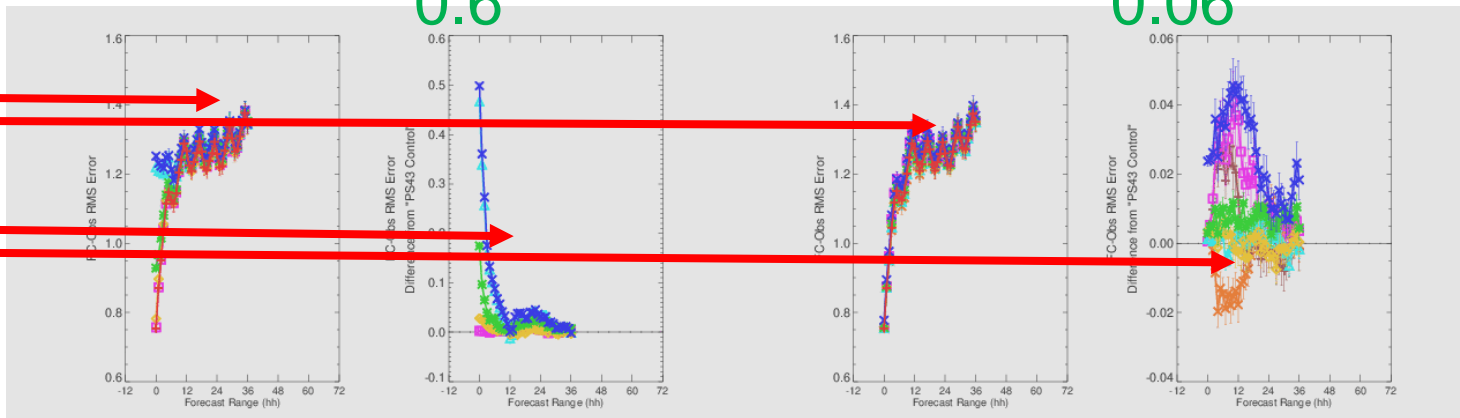
Note Different Scales

0.6

0.06

**RMS**

Diff from Control



Surface

'Upper-Air'



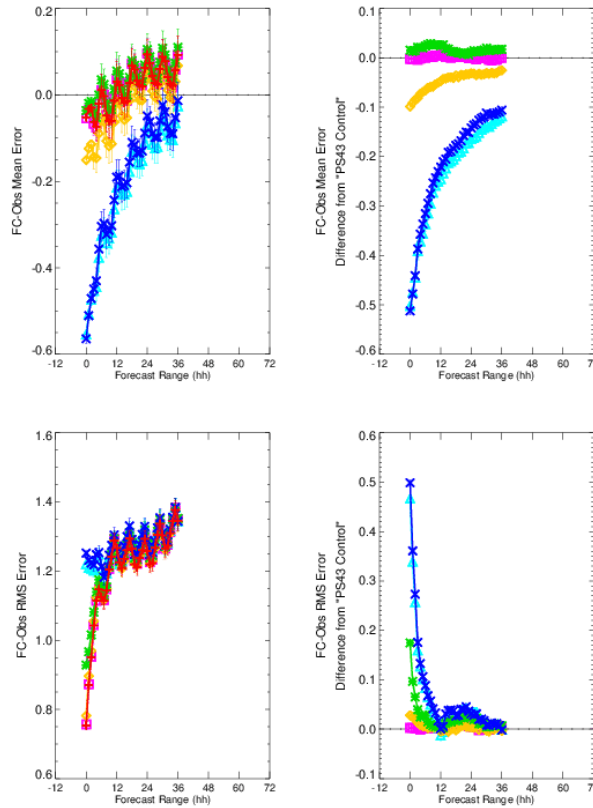
# T<sub>2m</sub> Summer

Summer Impacts Summary vs Surface Obs												
Met Office	LAND	LANDxROAD	ROAD	T/RH	MSLP	UPAIR	AMDAR	MODES	RADAR	GNSS	GEOCLOUD	SATRAD
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	T <sub>2m</sub>
LAND	✓✓
LANDxROAD	✓
ROAD	✓
T/RH	✓✓
MSLP	
UPAIR	✓
AMDAR	
MODES	
RADAR	
GNSS	✓
GEOCLOUD	✓
SATRAD	x

Temperature (Kelvin) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

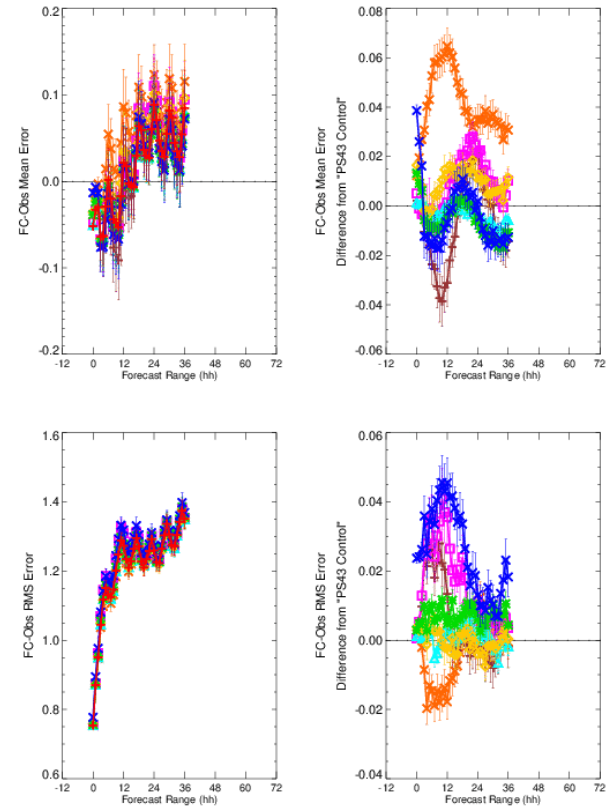
Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, All Land T/RH Denied, All Land MSLP Denied



Surface

Temperature (Kelvin) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode-S Denied, PS43 Control - Radar, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



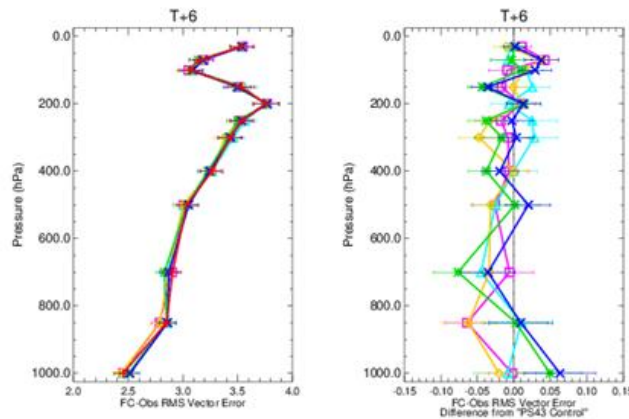
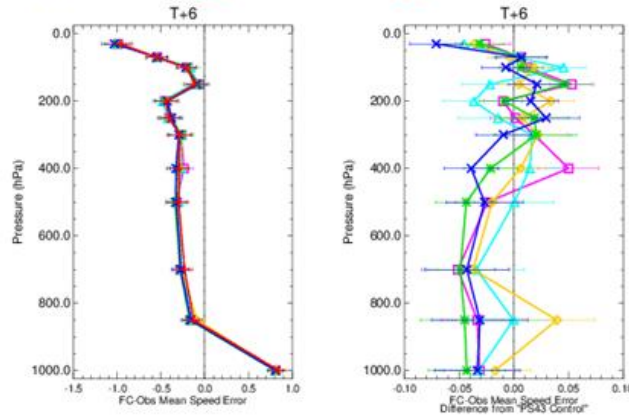
'Upper-Air'

# Upper-air Wind Summer

	Wind
LAND	
LANDxROAD	
ROAD	
T/RH	
MSLP	
UPAIR	✓✓
AMDAR	
MODES	✓✓
RADAR	
GNSS	
GEOCLOUD	
SATRAD	

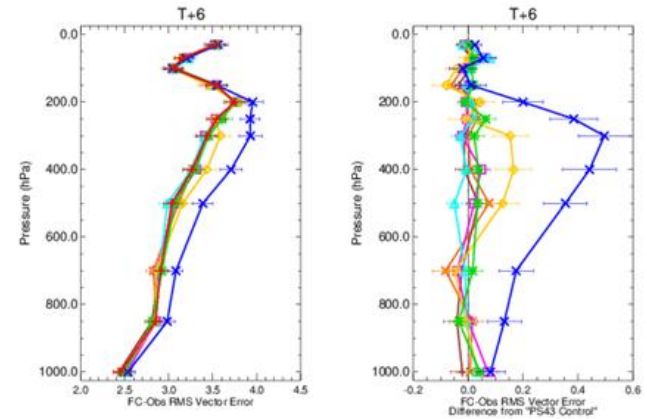
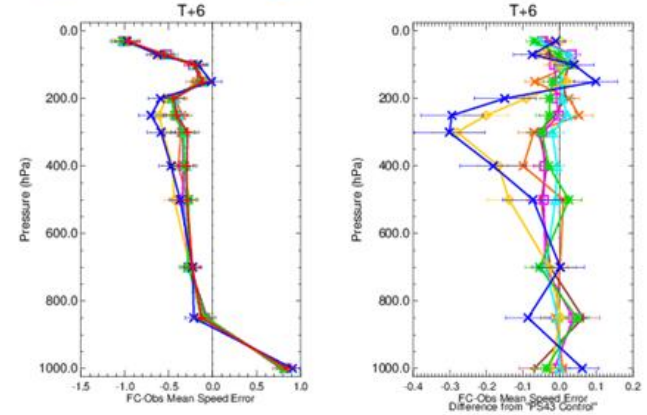
Wind (m/s): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, All Land T/RH Denied, All Land MSLP Denied



Wind (m/s): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode-S Denied, PS43 Control - ROBH GNSS, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



Surface

‘Upper-Air’



# Summer Impacts Summary vs Surface Obs

	<u>T<sub>2m</sub></u>	<u>RH<sub>2m</sub></u>	<u>Vis<sub>2m</sub></u>	<u>Wind<sub>10m</sub></u>	<u>Ppn</u>	<u>Cloud Cover</u>	<u>Cloud Base Height</u>	<u>MSLP</u>
LAND	✓✓	✓✓	✓	✓✓	✓✓	✓		✓✓
LANDxROAD	✓	✓✓	✓✓	✓✓				✓✓
ROAD	✓		(✓)					
T/RH	✓✓	✓✓		✓	✓✓	✓	(✓)	✓✓
MSLP								✓✓
UPAIR	✓	✓		✓		✓		✓
AMDAR								
MODES					✓			
RADAR					✓			
GNSS	✓	✓	✓		✓	xx	x	
GEOCLOUD	✓	✓				✓		
SATRAD	x							x

✓ = benefit  
x = harm



# Winter Impacts Summary vs Surface Obs

	<u>T<sub>2m</sub></u>	<u>RH<sub>2m</sub></u>	<u>Vis<sub>2m</sub></u>	<u>Wind<sub>10m</sub></u>	<u>Ppn</u>	<u>Cloud Cover</u>	<u>Cloud Base Height</u>	<u>MSLP</u>
LAND	✓✓	✓✓	✓✓	✓✓	✓✓	✓	(✓)	✓✓
LANDxROAD	✓	✓	✓✓	✓✓	✓			✓✓
ROAD	✓							
T/RH	✓✓	✓✓	✓	✓	✓✓	✓	✓	✓
MSLP					✓			✓✓
UPAIR	(✓)	✓		✓	✓✓		(✓)	✓
AMDAR								
MODES				(✓)				
RADAR	(x)				✓✓			x
GNSS	x	x			✓✓	xx	xx	
GEOCLOUD		(✓)				(✓)		
SATRAD						(✓)		

✓ = benefit  
x = harm

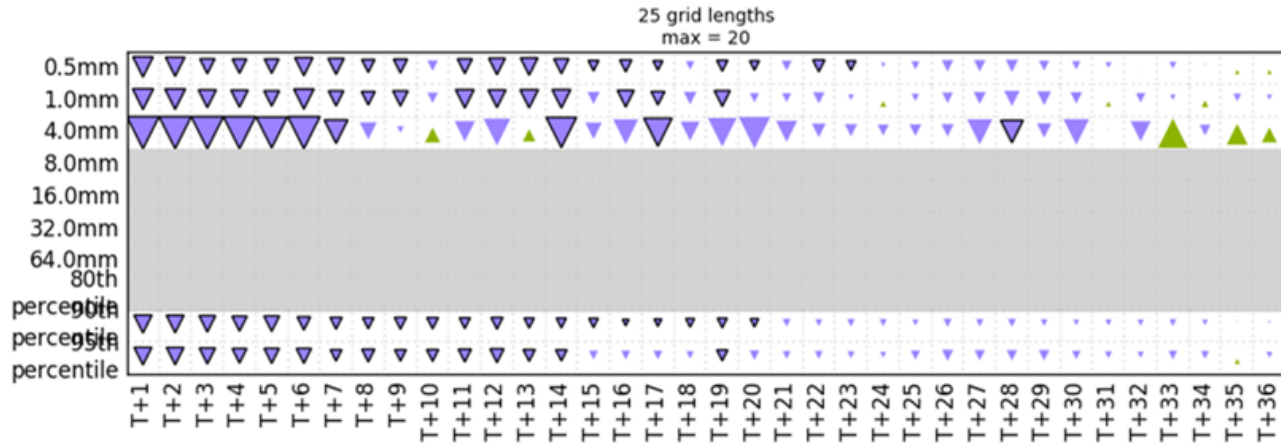


# Impacts Summary vs Upper-Air Obs

	LAND	LANDxROAD	ROAD	T/RH	MSLP	UPAIR	AMDAR	MODES	RADAR	GNSS	GEOCLOUD	SATRAD
<b>SUMMER</b>												
<u>Temperature</u>	✓✓ (below 700mb)			✓✓ (below 700mb)		✓✓	(✓)					
<u>Relative Humidity</u>						✓				✓	x	✓
<u>Wind</u>						✓✓		✓✓				
<b>WINTER</b>												
<u>Temperature</u>	✓✓ (below 850mb)			✓✓ (below 850mb)		✓✓	✓					
<u>Relative Humidity</u>						✓✓	✓			✓✓	✓	✓✓
<u>Wind</u>						✓✓	(✓)	✓				

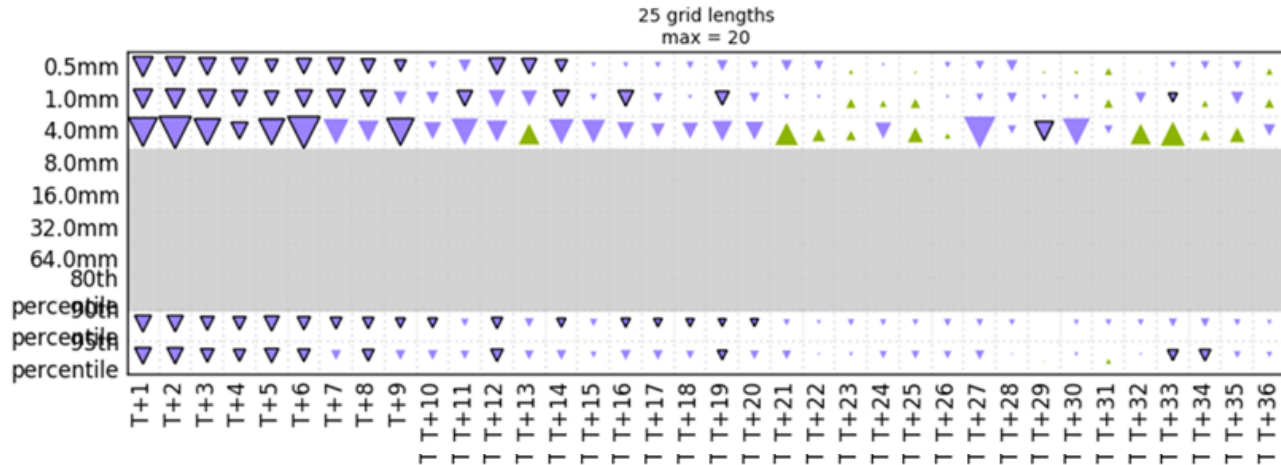
# Impacts on Ppn from Land Surface Obs (FSS)

% Difference (AllLandSurfDen vs. PS43Control), 1hr Precipitation Accumulation (mm), Analysis



**LAND  
Denial**

% Difference (AllLandTRHDen vs. PS43Control), 1hr Precipitation Accumulation (mm), Analysis



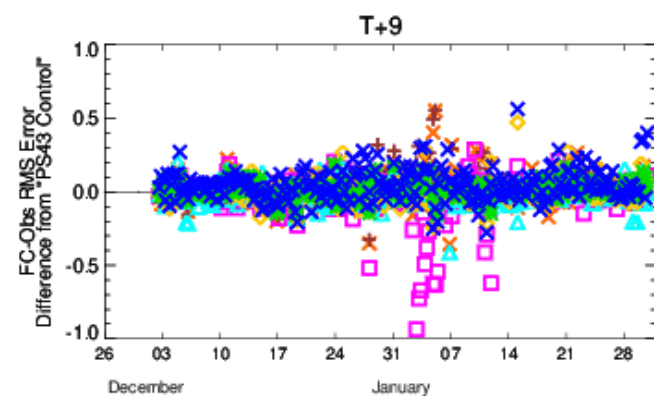
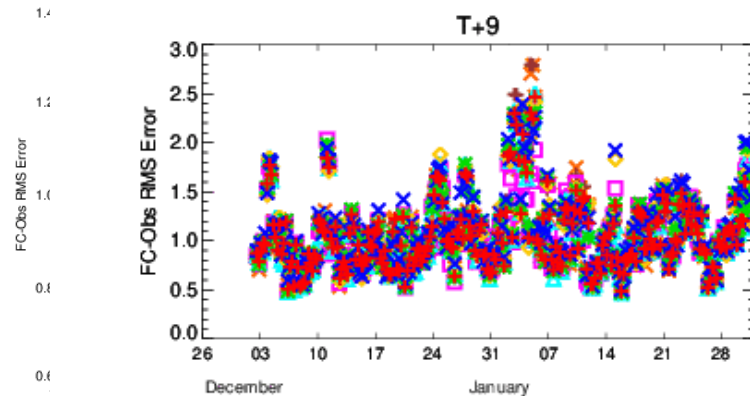
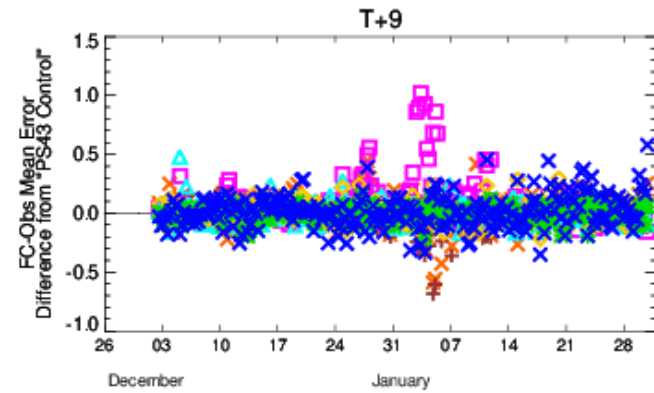
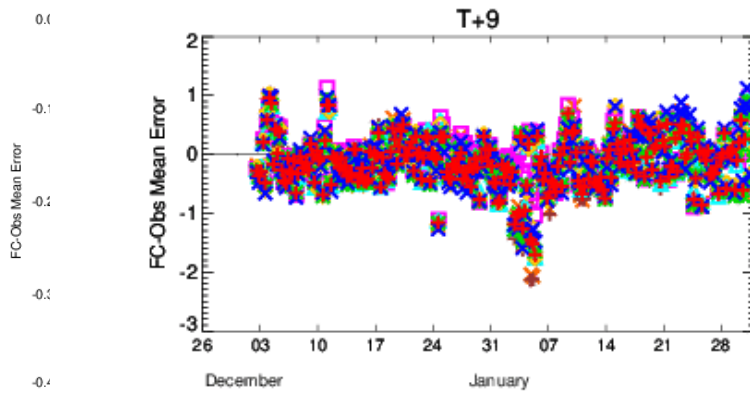
**T/RH  
RADA  
Denial**



# GNSS QC ?

Temperature (Kelvin) at Station Height: Surface Obs  
WMO Block 03 station list

Cases:   
 PS43 Control (red square) All Upper Air Obs Denied (blue cross) All AMDAR & AIREP Denied (green asterisk) All Mode-S Denied (yellow diamond)   
 PS43 Control - Radar (cyan triangle) PS43 Control - GNSS (magenta square) PS43 Control - GeoCloud (orange cross) PS43 Control - Radiances (red cross)





# Conclusions

- Redundancy in Surface Network
- ‘All-rounder’  $T_{2m}/RH_{2m}$  observations – benefits also for  $Wind_{10m}$  & ppn predictions
- Some episodic negative Impacts from GNSS (QC issues)
- Radar Impacts restricted to ‘Nowcasting’ range
- Mode-S dominating Upper-Air Wind Impacts from Aircraft
- Relatively small impacts from satellite radiances

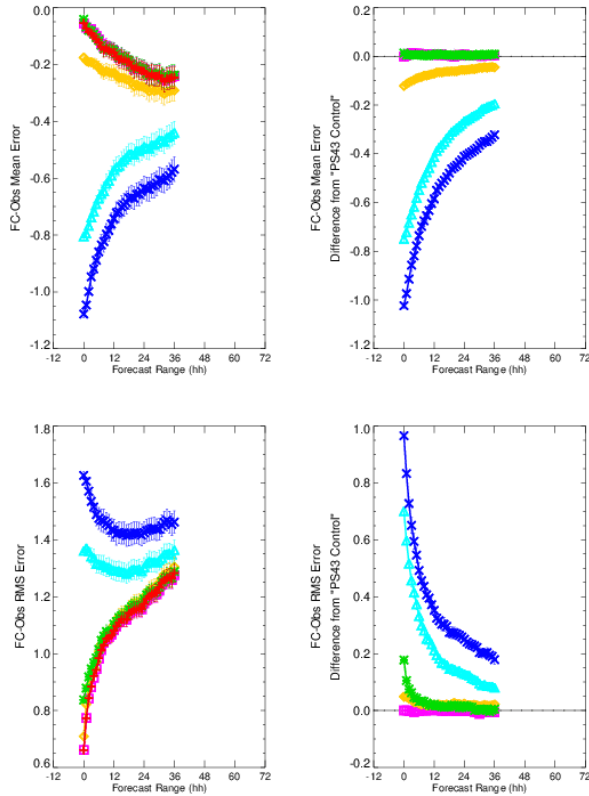


# T<sub>2m</sub> Winter

Winter Impacts Summary vs Surface Obs														
Met Office	LAND	SEA	ICE	SNOW	PERM	URBAN	COAST	PLANT	WATER	GLACI	SWAMP	WETL	HEATH	MOOR
✓ 1 hour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ 3 hour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ 6 hour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ 12 hour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ 24 hour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ 48 hour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
✓ 72 hour	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Temperature (Kelvin) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

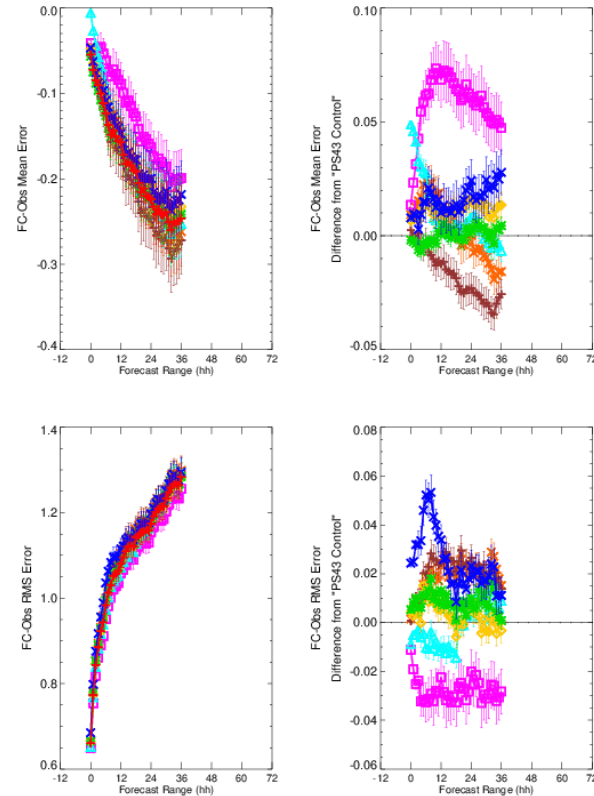
- Cases: + PS43 Control x All Land Surface Obs Denied x All Land except Road obs Denied  
o Road obs Denied Δ Land T/RH Denied □ Land MSLP Denied



Surface

Temperature (Kelvin) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

- Cases: + PS43 Control x All Upper Air Obs Denied x All AMDAR & AIREP Denied  
o All Mode-S Denied Δ PS43 Control - Radar □ PS43 Control - GNSS  
+ PS43 Control - GeoCloud x PS43 Control - Radiances



'Upper-Air'



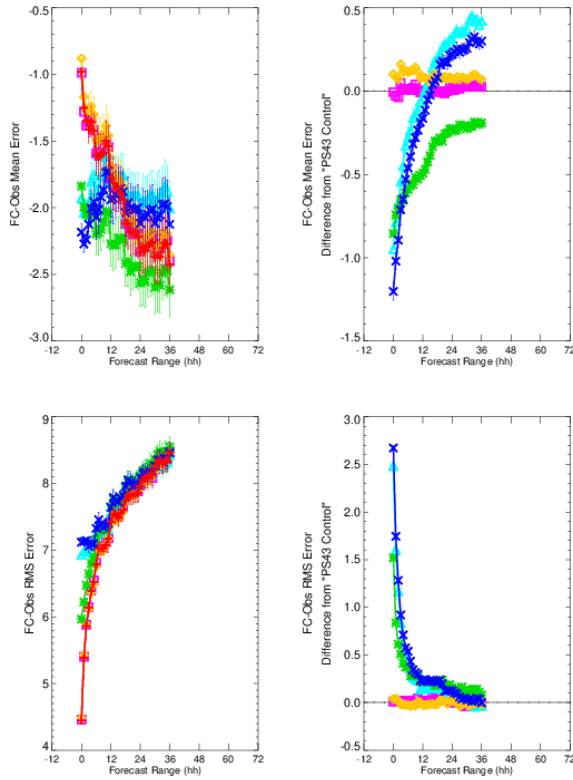
# RH<sub>2m</sub> Summer

Summer Impacts Summary vs Surface Obs

Met Office	UK	Europe	North America	South America	Asia	Africa	Oceania	Antarctica	Global
LAND	✓	✓	✓	✓	✓	✓	✓	✓	✓
LAND/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
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NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
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NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓
NO/NO	✓	✓	✓	✓	✓	✓	✓	✓	✓

Relative humidity (%) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

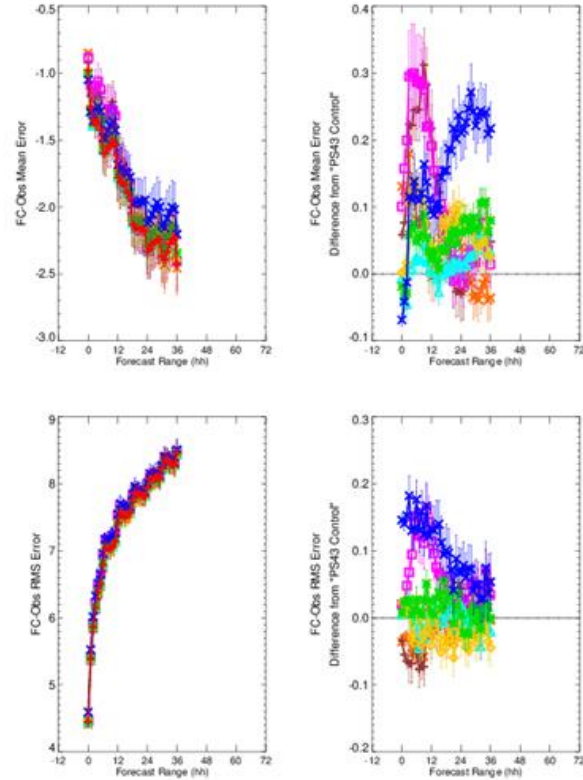
- Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, All Land T/RH Denied, All Land MSLP Denied



Surface

Relative humidity (%) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

- Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode-S Denied, PS43 Control - Radar, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



'Upper-Air'

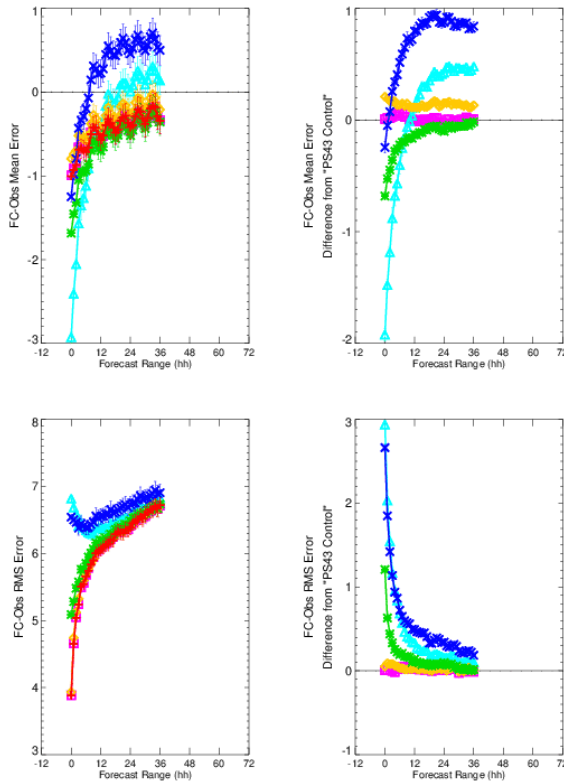
# RH<sub>2m</sub> Winter

Winter Impacts Summary vs Surface Obs

Met Office	UK	France	Germany	Spain	Italy	Portugal	Belgium	Switzerland	Austria	Poland	Czech	Slovakia	Hungary	Romania	Bulgaria	Greece	Turkey	Malta	W.M.E.P.
LAND																			
UNKNOW																			
PS43																			
Mode-S																			
AMDA																			
GNSS																			
GeoCloud																			
Radiances																			

Relative humidity (%) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

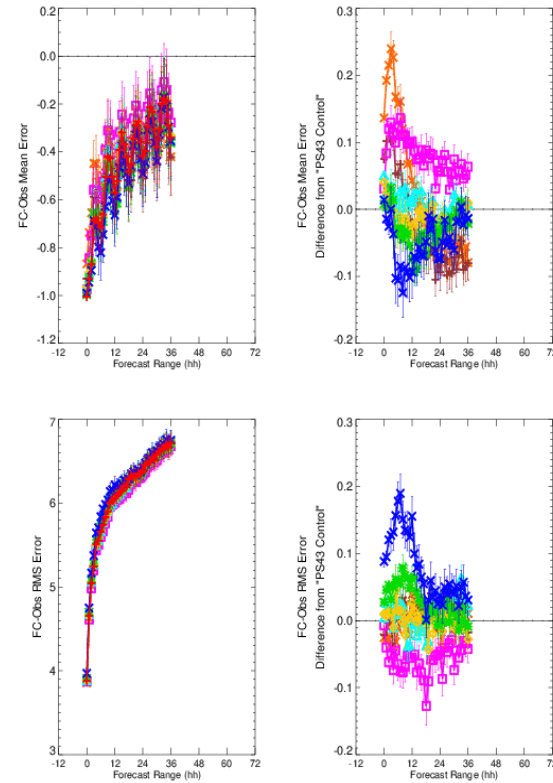
Cases: PS43 Control (red line), All Land Surface Obs Denied (blue 'x'), All Land except Road obs Denied (green 'x'), Road obs Denied (yellow diamond), Land T/RH Denied (cyan triangle), Land MSLP Denied (magenta square)



Surface

Relative humidity (%) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

Cases: PS43 Control (red line), All Upper Air Obs Denied (blue 'x'), All AMDAR & AIREP Denied (green 'x'), All Mode-S Denied (yellow diamond), PS43 Control - Radar (cyan triangle), PS43 Control - GNSS (magenta square), PS43 Control - GeoCloud (brown line), PS43 Control - Radiances (orange 'x')



'Upper-Air'

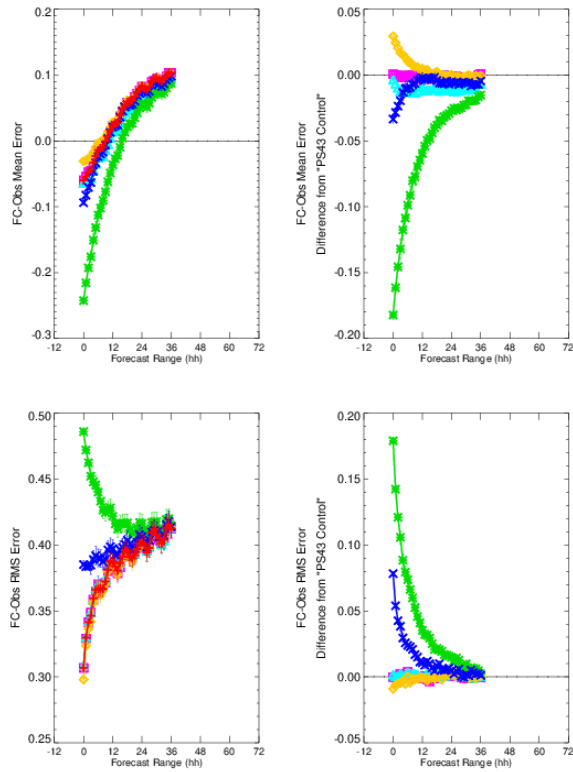


# Vis<sub>2m</sub> Summer

Summer Impacts Summary vs Surface Obs													
Met Office	1	2	3	4	5	6	7	8	9	10	11	12	13
1. 1km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2. 3km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3. 6km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4. 12km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5. 25km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6. 50km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7. 100km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8. 200km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9. 400km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10. 800km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11. 1600km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12. 3200km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
13. 6400km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
14. 12800km	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Log(10) Visibility (m) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

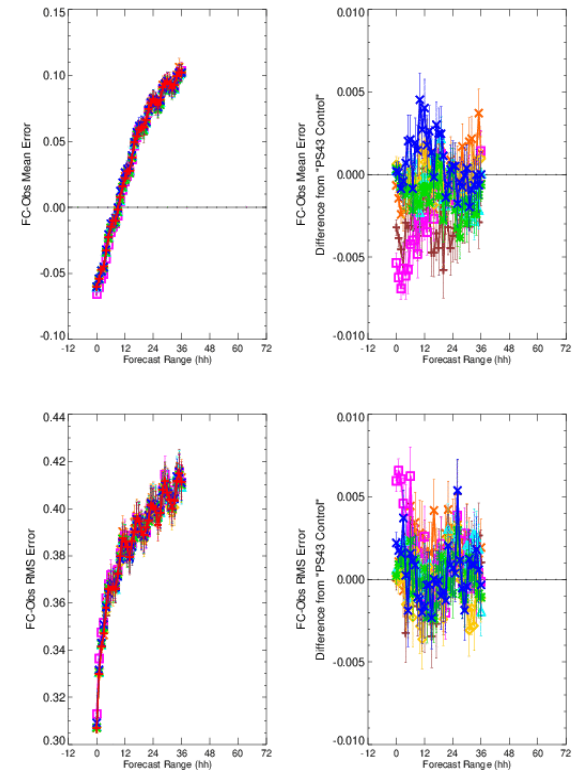
- Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, All Land T/RH Denied, All Land MSLP Denied



Surface

Log(10) Visibility (m) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

- Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode-S Denied, PS43 Control - ROB GNSS, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



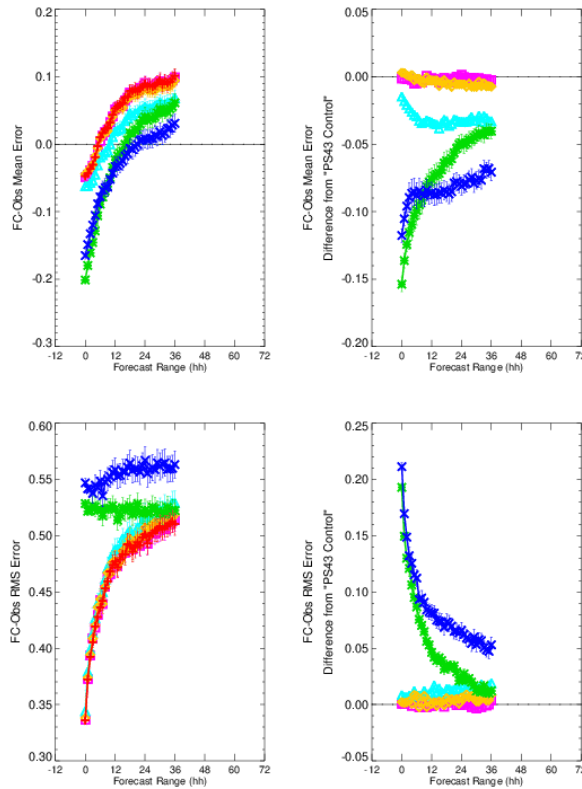
'Upper-Air'



# Vis<sub>2m</sub> Winter

Log(10) Visibility (m) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

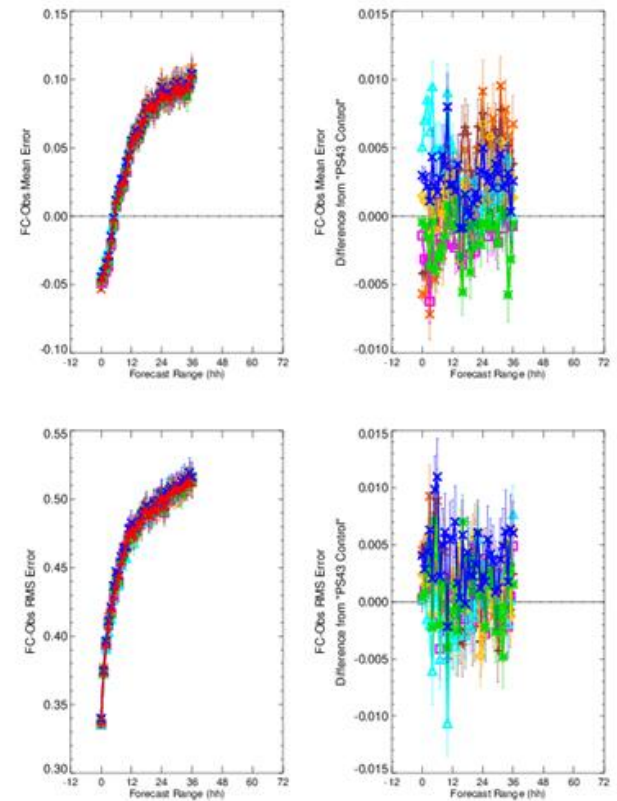
- Cases: + PS43 Control    x All Land Surface Obs Denied    \* All Land except Road obs Denied  
o Road obs Denied    ^ Land T/RH Denied    □ Land MSLP Denied



Surface

Log(10) Visibility (m) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

- Cases: + PS43 Control    x All Upper Air Obs Denied    \* All AMDAR & AIREP Denied  
o All Mode-S Denied    ^ PS43 Control - Radar    □ PS43 Control - GNSS  
+ PS43 Control - GeoCloud    x PS43 Control - Radiances



'Upper-Air'



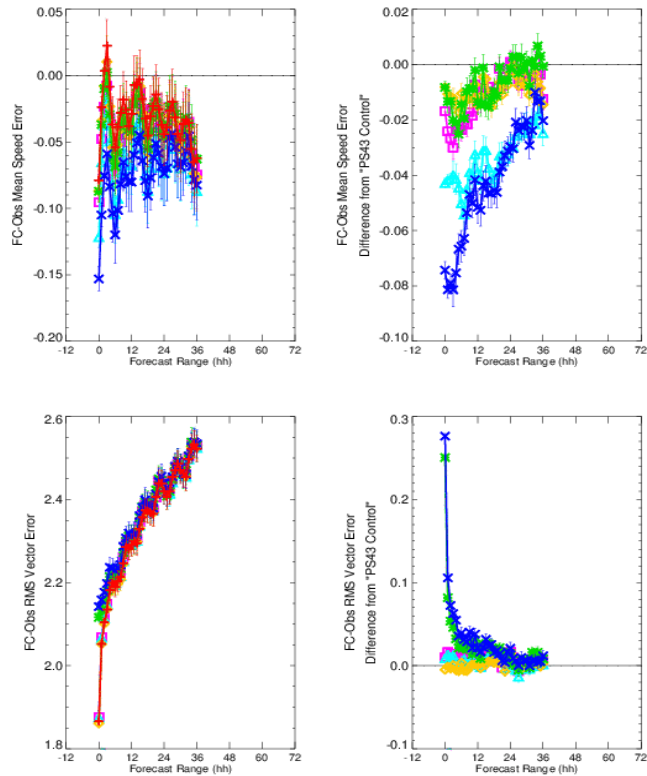
# Wind<sub>10m</sub> Summer

Summer Impacts Summary vs Surface Obs

Met Office	UK	Europe	North America	South America	Asia	Africa	Oceania	Antarctica	Global
UK	✓	✓	✓	✓	✓	✓	✓	✓	✓
Europe	✓	✓	✓	✓	✓	✓	✓	✓	✓
North America	✓	✓	✓	✓	✓	✓	✓	✓	✓
South America	✓	✓	✓	✓	✓	✓	✓	✓	✓
Asia	✓	✓	✓	✓	✓	✓	✓	✓	✓
Africa	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oceania	✓	✓	✓	✓	✓	✓	✓	✓	✓
Antarctica	✓	✓	✓	✓	✓	✓	✓	✓	✓
Global	✓	✓	✓	✓	✓	✓	✓	✓	✓

Wind (m/s) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

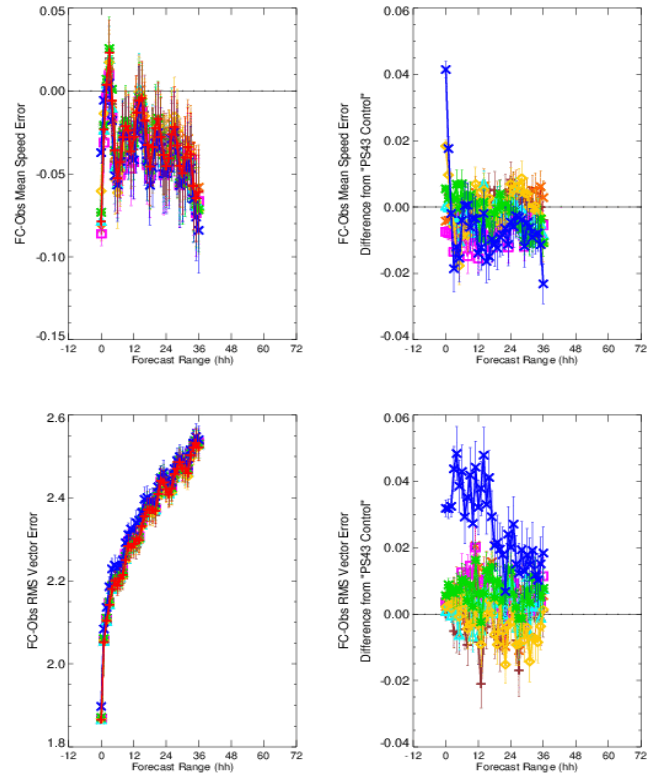
- Cases: + PS43 Control x All Land Surface Obs Denied x All Land except Road obs Denied  
o Road obs Denied △ All Land T/RH Denied □ All Land MSLP Denied



Surface

Wind (m/s) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

- Cases: + PS43 Control x All Upper Air Obs Denied x All AMDAR & AIREP Denied  
o All Mode-S Denied △ PS43 Control - ROBH GNSS □ PS43 Control - GNSS  
+ PS43 Control - GeoCloud x PS43 Control - Radiances



'Upper-Air'

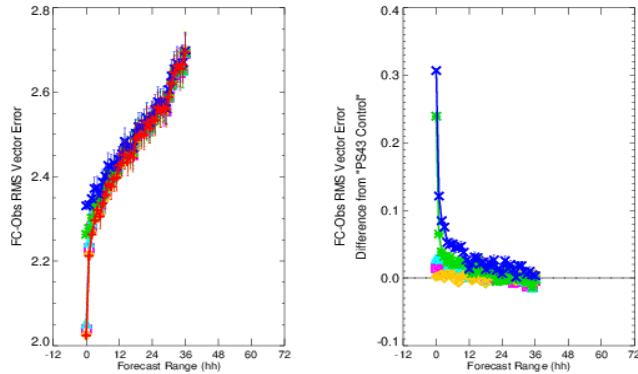
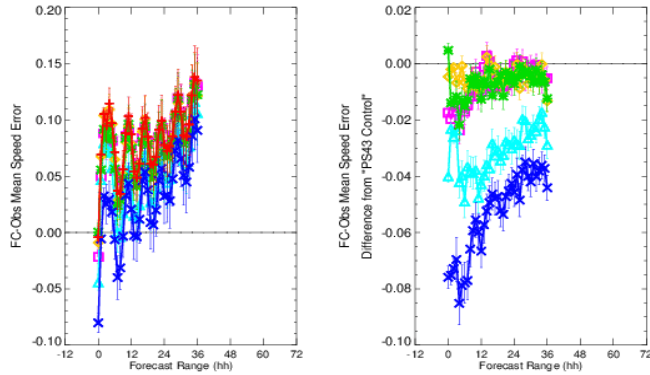


# Wind<sub>10m</sub> Winter

Met Office	UK	France	Germany	Spain	Italy	Portugal	Poland	Czech	Slovak	Austria	Switzerland	Belgium	Netherlands	Denmark	Sweden	Norway	Finland	Latvia	Lithuania	Poland	Czech	Slovak	Austria	Switzerland	Belgium	Netherlands	Denmark	Sweden	Norway	Finland	Latvia	Lithuania							
UK	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						
France	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					
Germany	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
Spain	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Italy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Portugal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Poland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
Czech	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Slovak	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Austria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Switzerland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Belgium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Netherlands	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Denmark	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sweden	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Norway	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Finland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Latvia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lithuania	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Wind (m/s) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

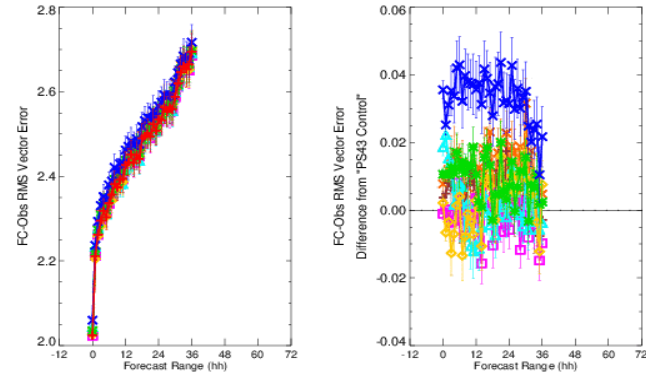
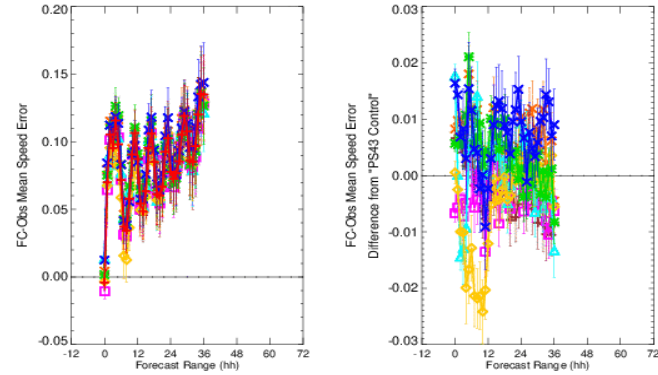
- Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, Land T/RH Denied, Land MSLP Denied



Surface

Wind (m/s) at Station Height: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

- Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode-S Denied, PS43 Control - Radar, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



'Upper-Air'



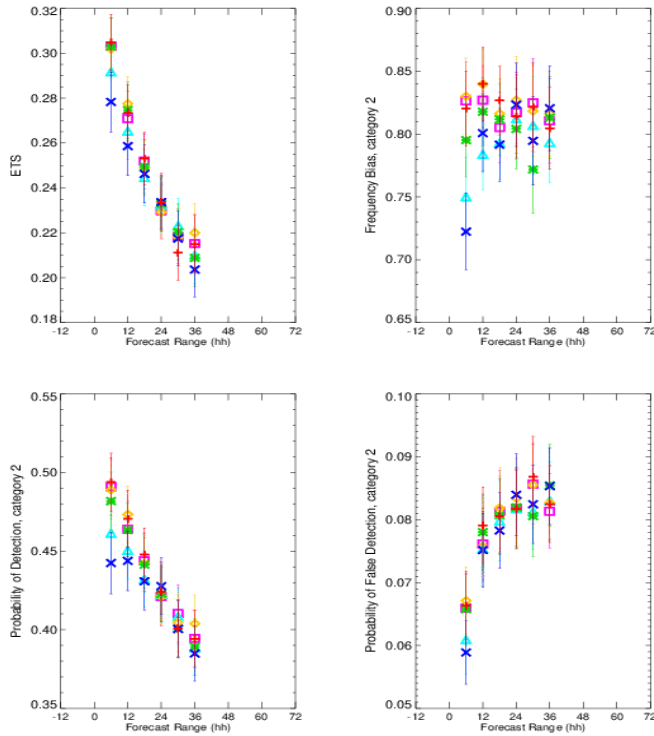
# Ppn (1mm/6 hour) Summer

Summer Impacts Summary vs Surface Obs

Model	UK	EU	NA	AS	SA	AF	OC	Global	Current	Future	MSLP
UKMO	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ECMWF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
NOAA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CMAP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AMDA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CMCC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ECMWF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ECMWF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ECMWF	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

6hr Precip Accumulation (mm)(1.0): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

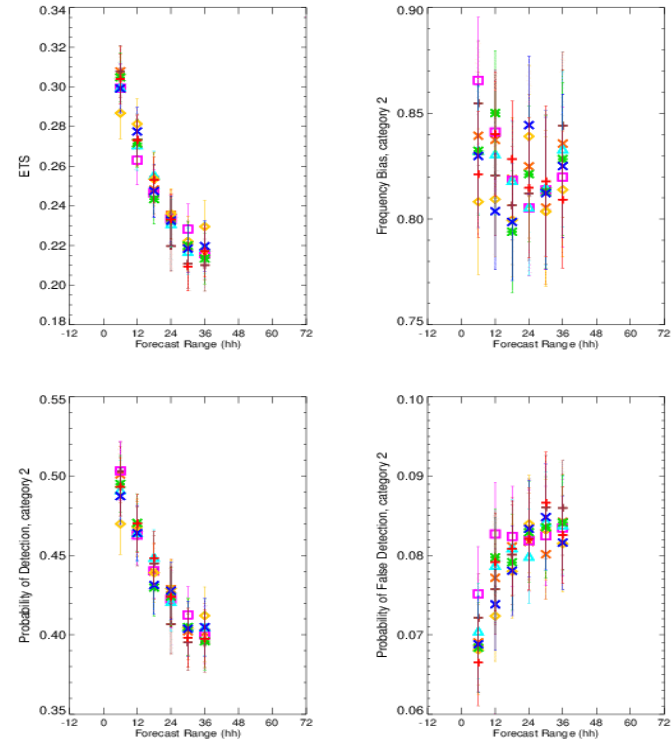
Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, All Land T/RH Denied, All Land MSLP Denied



Surface

6hr Precip Accumulation (mm)(1.0): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode-S Denied, PS43 Control - Radar, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



'Upper-Air'

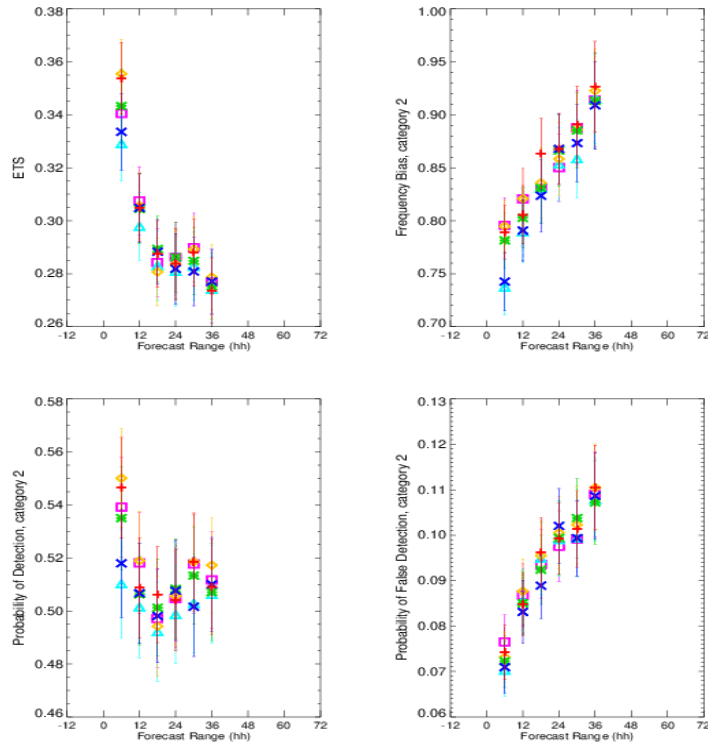


# Ppn (1mm/6 hour) Winter

	Land	Sea	Urban	Road	MSLP	Upper Air	AMSAR	AMSAR	AMSAR	AMSAR	AMSAR	AMSAR	AMSAR	AMSAR	AMSAR
PS43 Control	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Land Surface Obs Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Land except Road obs Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Mode-S Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
All Mode-S Denied	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control - Radar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control - GNSS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control - GeoCloud	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
PS43 Control - Radiances	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

6hr Precip Accumulation (mm)(1.0): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

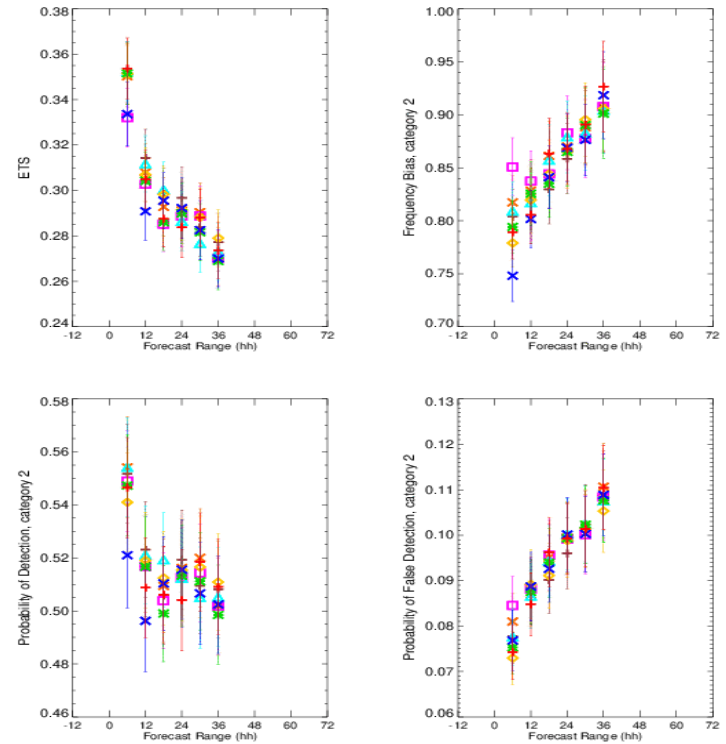
- Cases:   
 - PS43 Control (red line with square)   
 - All Land Surface Obs Denied (blue line with 'x')   
 - All Land except Road obs Denied (green line with asterisk)   
 - Road obs Denied (orange line with diamond)   
 - Land T/RH Denied (cyan line with triangle)   
 - Land MSLP Denied (magenta line with square)



Surface

6hr Precip Accumulation (mm)(1.0): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

- Cases:   
 - PS43 Control (red line with square)   
 - All Upper Air Obs Denied (blue line with 'x')   
 - All AMSAR & AIREP Denied (green line with asterisk)   
 - All Mode-S Denied (orange line with diamond)   
 - PS43 Control - Radar (cyan line with triangle)   
 - PS43 Control - GNSS (magenta line with square)   
 - PS43 Control - GeoCloud (brown line with circle)   
 - PS43 Control - Radiances (black line with cross)



'Upper-Air'

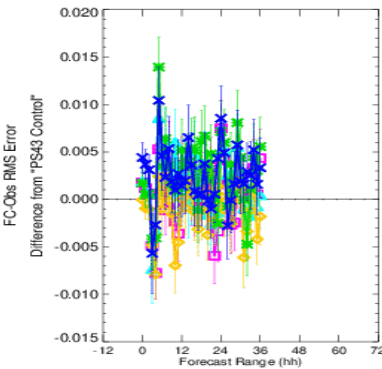
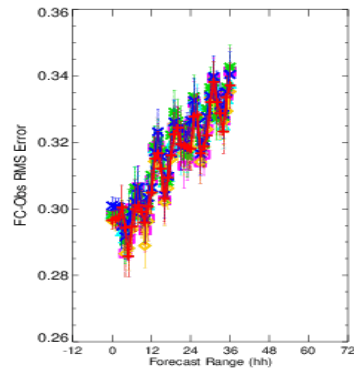
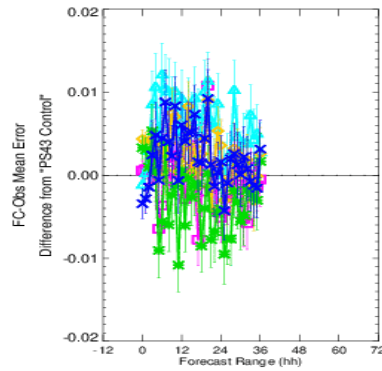
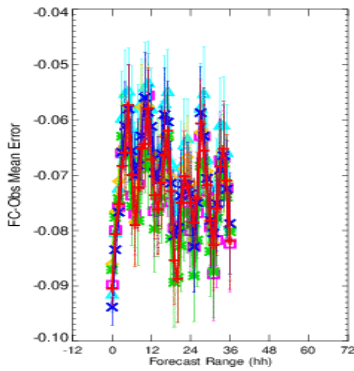
# Cloud Cover Summer

Summer Impacts Summary vs Surface Obs

Met Office	UK	France	Spain	Italy	Germany	Poland	Sweden	Denmark	Finland	Latvia	Lithuania	Belgium	Netherlands	Portugal	Spain	Italy	France	UK
UK	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
France	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spain	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Italy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Germany	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Sweden	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Denmark	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Finland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Latvia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lithuania	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Belgium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Netherlands	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Portugal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spain	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Italy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
France	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UK	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Ceilometer cloud amount: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

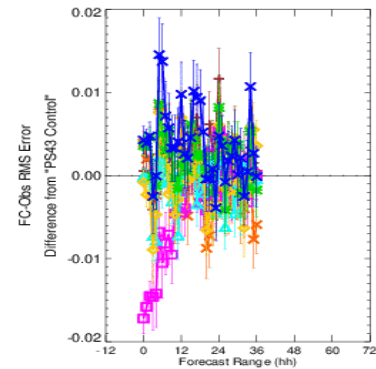
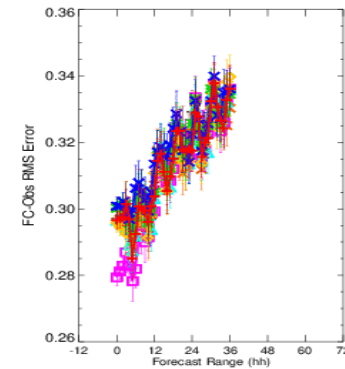
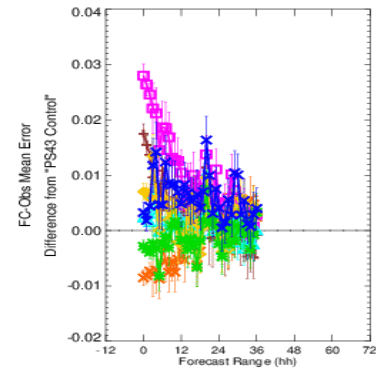
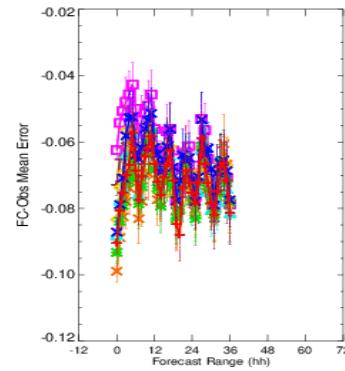
- Cases:   
 - PS43 Control (red line with dots)   
 - All Land Surface Obs Denied (blue line with crosses)   
 - All Land except Road obs Denied (green line with asterisks)   
 - Road obs Denied (orange line with diamonds)   
 - All Land T/RH Denied (cyan line with triangles)   
 - All Land MSLP Denied (magenta line with squares)



Surface

Ceilometer cloud amount: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

- Cases:   
 - PS43 Control (red line with dots)   
 - All Upper Air Obs Denied (blue line with crosses)   
 - All AMDAR & AIREP Denied (green line with asterisks)   
 - All Mode-S Denied (orange line with diamonds)   
 - PS43 Control - Radar (cyan line with triangles)   
 - PS43 Control - GNSS (magenta line with squares)   
 - PS43 Control - GeoCloud (brown line with crosses)   
 - PS43 Control - Radiances (yellow line with asterisks)



'Upper-Air'

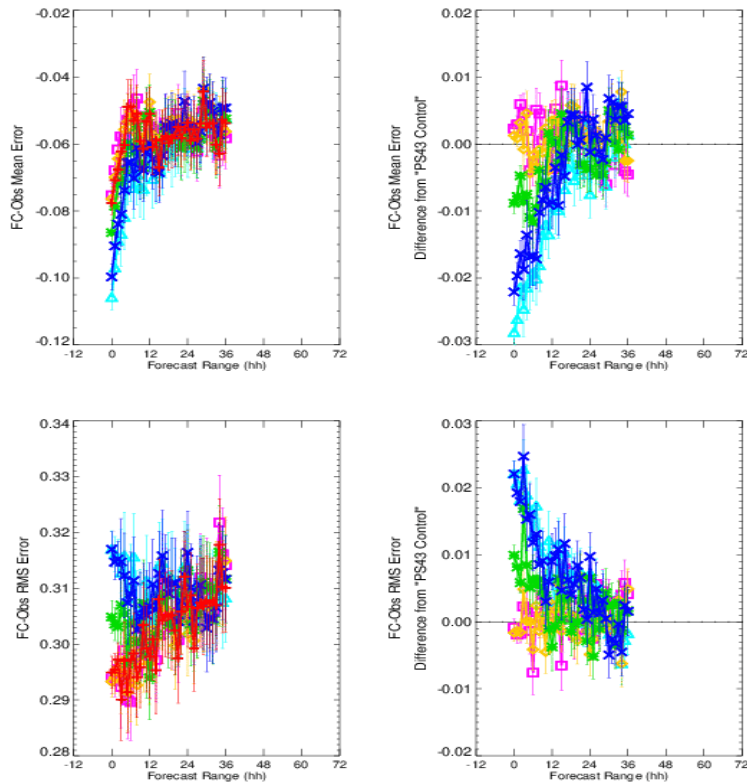


# Cloud Cover Winter

Winter Impacts Summary vs Surface Obs												
Met Office	UK	EU	NA	SA	AS	OC	AM	AN	AR	AT	AW	AX
LAND	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
UNKNOW	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ROAD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TOT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MSLP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AMODAR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
MODE-S	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GEOS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GNSS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
GEOSRAD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SATRAD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Ceilometer cloud amount: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

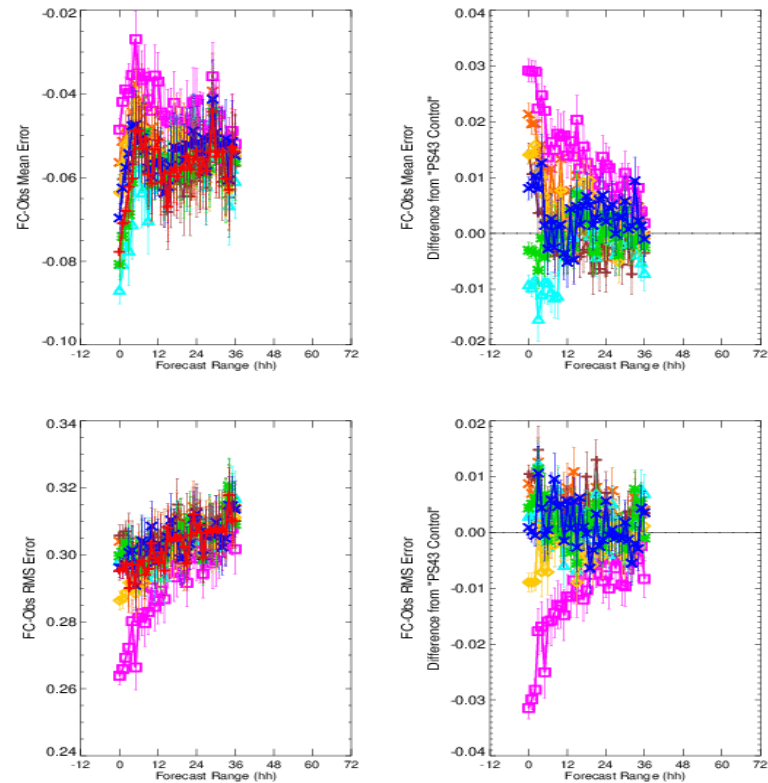
- Cases: PS43 Control (red line), All Land Surface Obs Denied (blue 'x'), All Land except Road obs Denied (green asterisk), Road obs Denied (orange diamond), Land T/RH Denied (cyan triangle), Land MSLP Denied (magenta square)



Surface

Ceilometer cloud amount: Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

- Cases: PS43 Control (red line), All Upper Air Obs Denied (blue 'x'), All AMDAR & AIREP Denied (green asterisk), All Mode-S Denied (orange diamond), PS43 Control - Radar (cyan triangle), PS43 Control - GNSS (magenta square), PS43 Control - GeoCloud (brown line), PS43 Control - Radiances (orange 'x')



'Upper-Air'

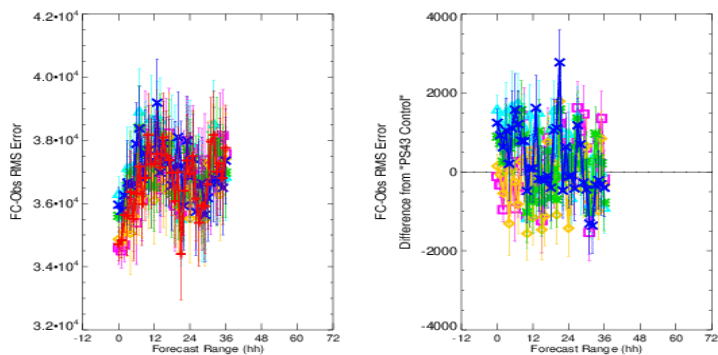
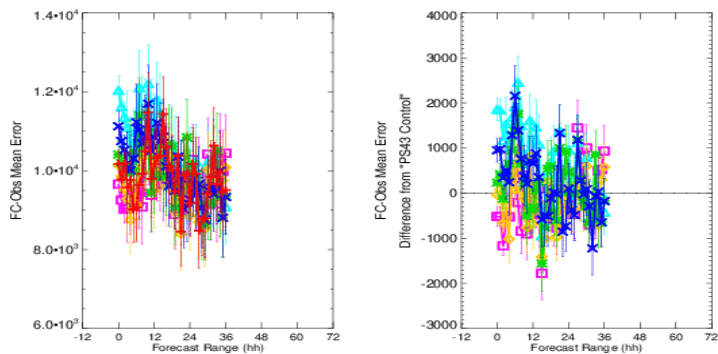
# Cloud Base Height Winter

Winter Impacts Summary vs Surface Obs

		0-6h	6-12h	12-18h	18-24h	24-30h	30-36h	36-48h	48-72h	WMO	UK	EU	NA	AS	AF	SA	AU	AN
LAND	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
ROAD	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
TSR	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
MSLP	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
MODE	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
AMDAR	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
RADAR	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
GNSS	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
GEOSCLD	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓
SURFAD	UNKNOWN	✓	✓	✓	✓	✓	✓	✓	✓	PS	✓	✓	✓	✓	✓	✓	✓	✓

Cloud Base Height Given 3/8th Cover (m): Surface Obs  
 WMO Block 03 station list  
 Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

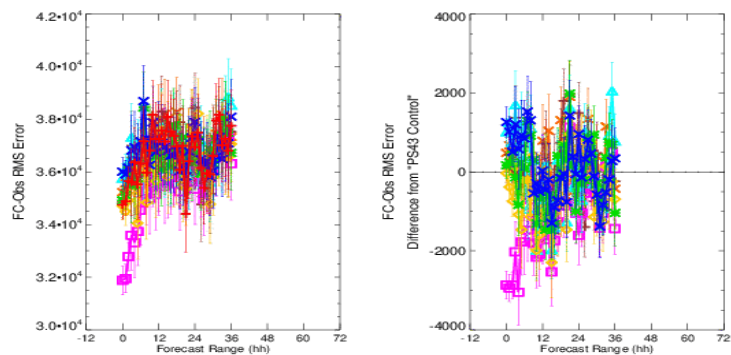
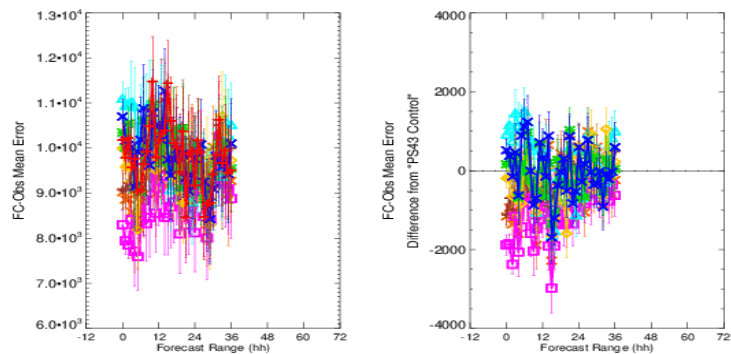
Cases: + PS43 Control x All Land Surface Obs Denied \* All Land except Road obs Denied  
◇ Road obs Denied △ Land T/RH Denied □ Land MSLP Denied



Surface

Cloud Base Height Given 3/8th Cover (m): Surface Obs  
 WMO Block 03 station list  
 Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

Cases: + PS43 Control x All Upper Air Obs Denied \* All AMDAR & AIREP Denied  
◇ All Mode-S Denied △ PS43 Control - Radar □ PS43 Control - GNSS  
+ PS43 Control - GeoCloud x PS43 Control - Radiances



'Upper-Air'

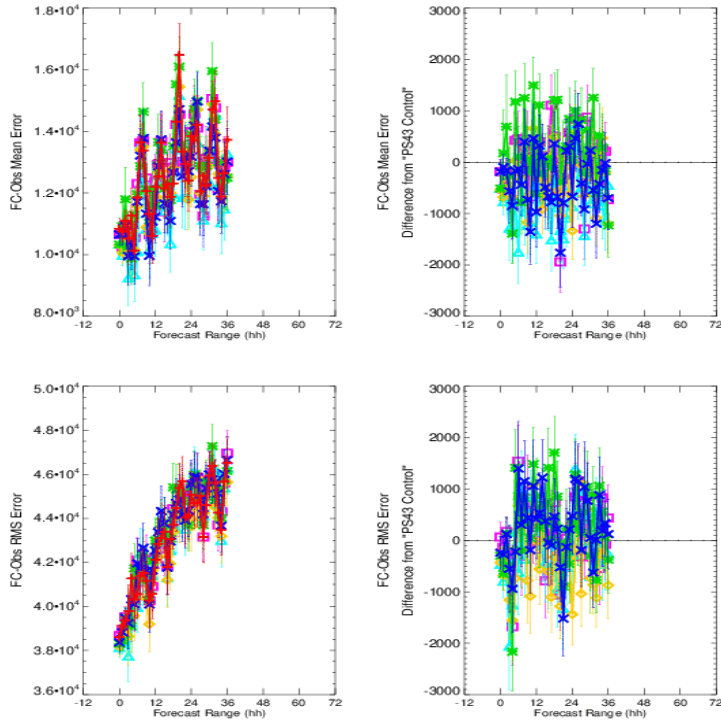


# Cloud Base Height Summer

Summer Impacts Summary vs Surface Obs												
Met Office	1	2	3	4	5	6	7	8	9	10	11	12
LANE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANDROD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BRIS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
TRU	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SHIP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AMDR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BRIS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SHIP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BRIS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANDROD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SHIP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BRIS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANDROD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SHIP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BRIS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANDROD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SHIP	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
BRIS	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LANDROD	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Cloud Base Height Given 3/8th Cover (m): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

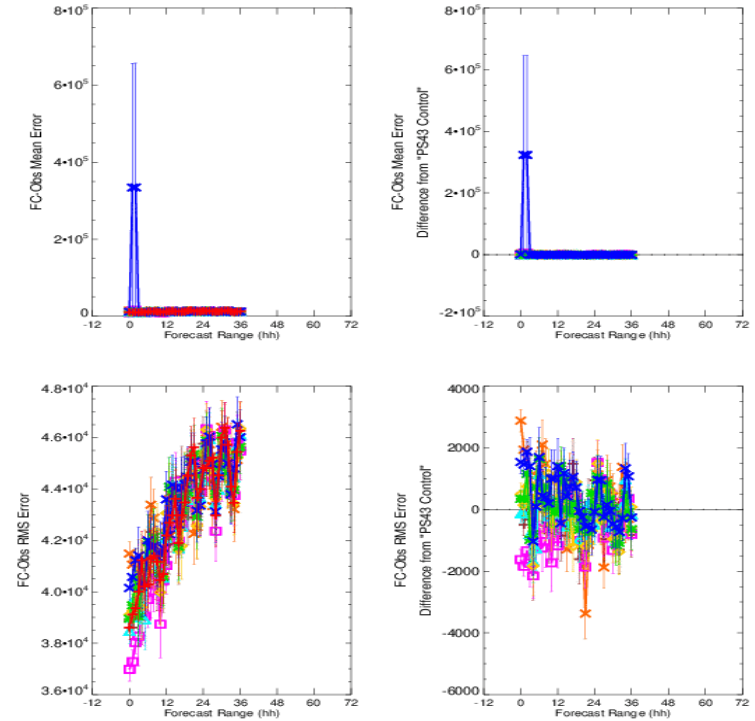
- Cases: + PS43 Control x All Land Surface Obs Denied \* All Land except Road obs Denied  
o Road obs Denied ^ All Land T/RH Denied □ All Land MSLP Denied



Surface

Cloud Base Height Given 3/8th Cover (m): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

- Cases: + PS43 Control x All Upper Air Obs Denied \* All AMDAR & AIREP Denied  
o All Mode-S Denied ^ PS43 Control - Radar □ PS43 Control - GNSS  
+ PS43 Control - GeoCloud x PS43 Control - Radiances



'Upper-Air'



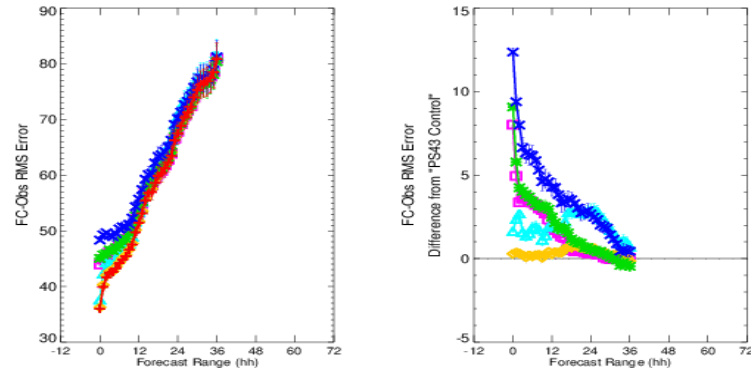
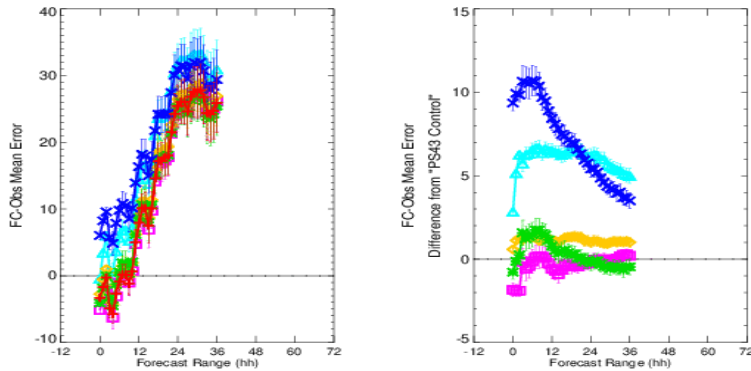
# MSLP Summer

Summer Impacts Summary vs Surface Obs

Met Office	UK	Europe	North Africa	North America	South America	Asia	Australia	Antarctica	Other	Global
UK	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Europe	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
North Africa	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
North America	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
South America	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Asia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Australia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Antarctica	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Other	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Global	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Mean Sea Level Pressure (Pa): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

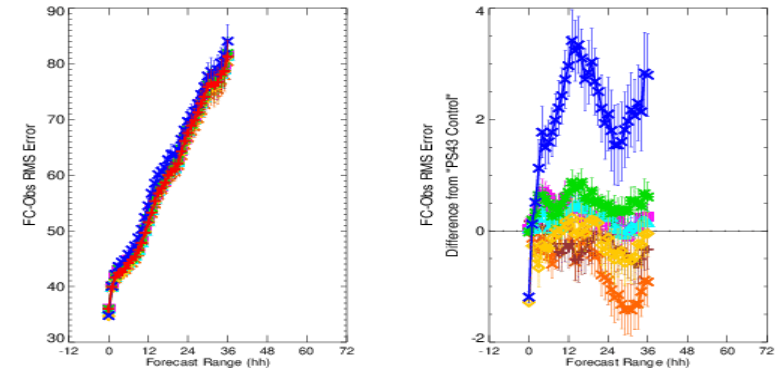
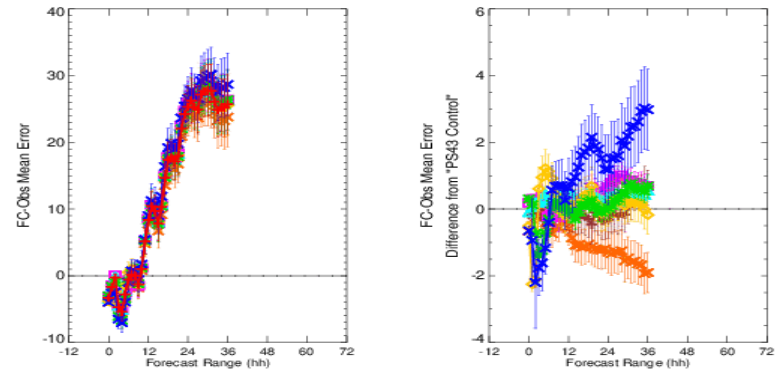
- Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, All Land T/RH Denied, All Land MSLP Denied



Surface

Mean Sea Level Pressure (Pa): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

- Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode-S Denied, PS43 Control - Radar, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



'Upper-Air'

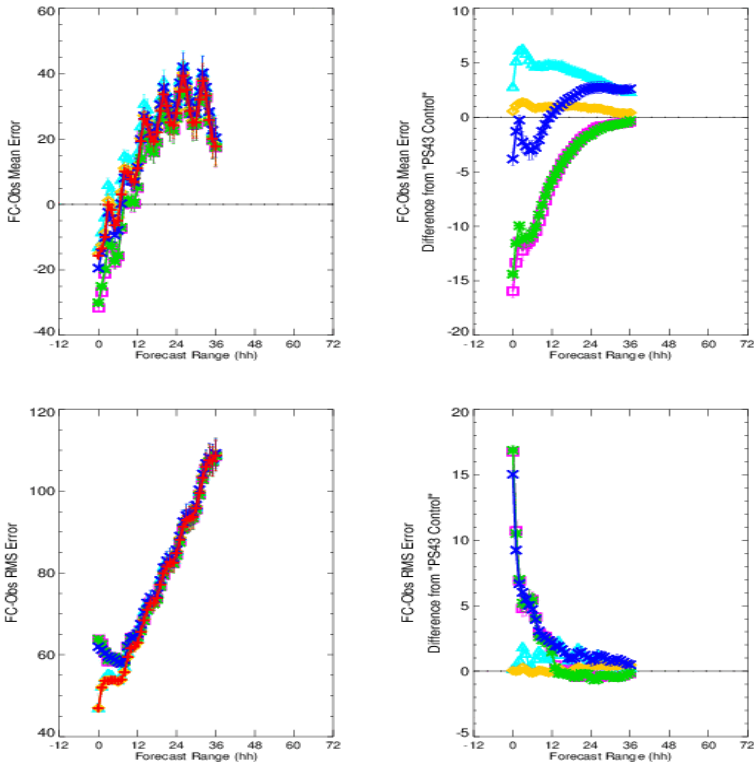


# MSLP Winter

Met Office	UK	France	Germany	Spain	Italy	Portugal	Benelux	Switzerland	Austria	Poland	Czech	Slovakia	Hungary	Slovenia	Croatia	Serbia	Bulgaria	Romania	Greece	Turkey	North Africa	Middle East	India	China	Japan	SE Asia	Australia	South America	USA	Canada
UK	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
France	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Germany	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Spain	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Italy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Portugal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Benelux	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Switzerland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Austria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Poland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Czech	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Slovakia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hungary	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Slovenia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Croatia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Serbia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Bulgaria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Romania	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Greece	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Turkey	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
North Africa	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Middle East	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
India	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
China	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Japan	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
SE Asia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Australia	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
South America	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
USA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Canada	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Mean Sea Level Pressure (Pa): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

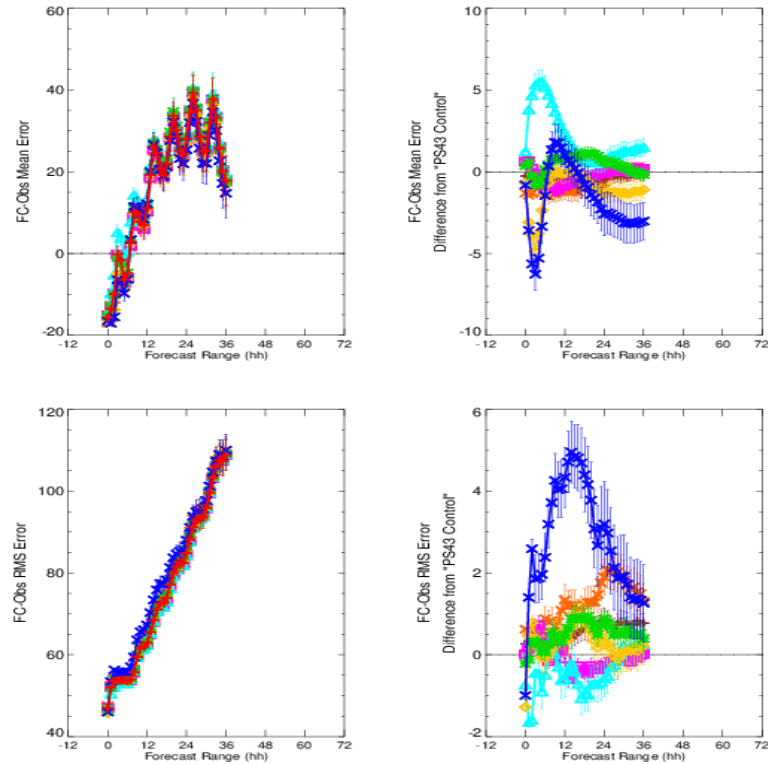
- Cases: + PS43 Control x All Land Surface Obs Denied x All Land except Road obs Denied o Road obs Denied ^ Land T/RH Denied □ Land MSLP Denied



Surface

Mean Sea Level Pressure (Pa): Surface Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

- Cases: + PS43 Control x All Upper Air Obs Denied x All AMDAR & AIREP Denied o All Mode-S Denied ^ PS43 Control - Radar □ PS43 Control - GNSS + PS43 Control - GeoCloud x PS43 Control - Radiances

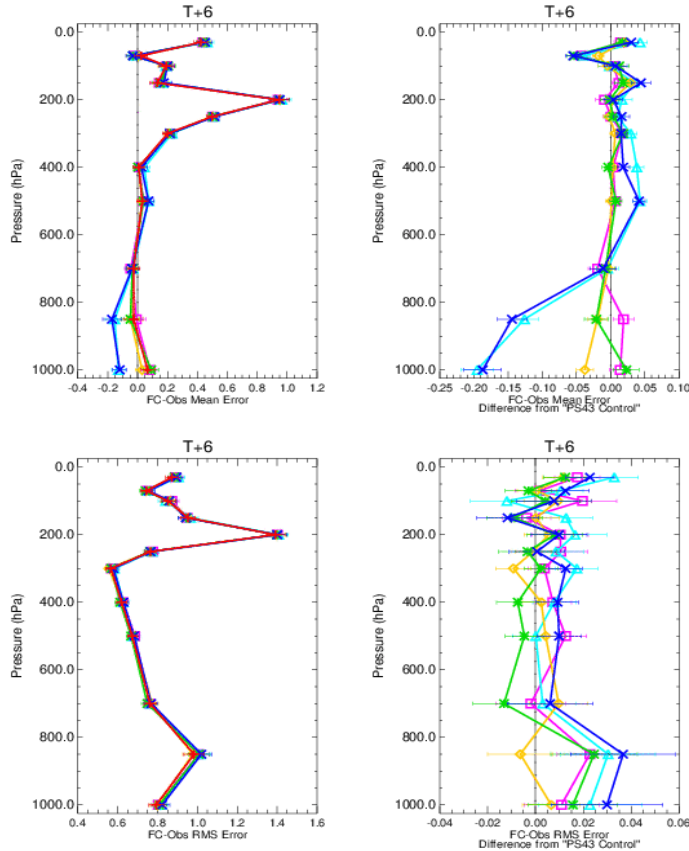


'Upper-Air'

# Upper-air Temperature Summer

Temperature (Kelvin): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

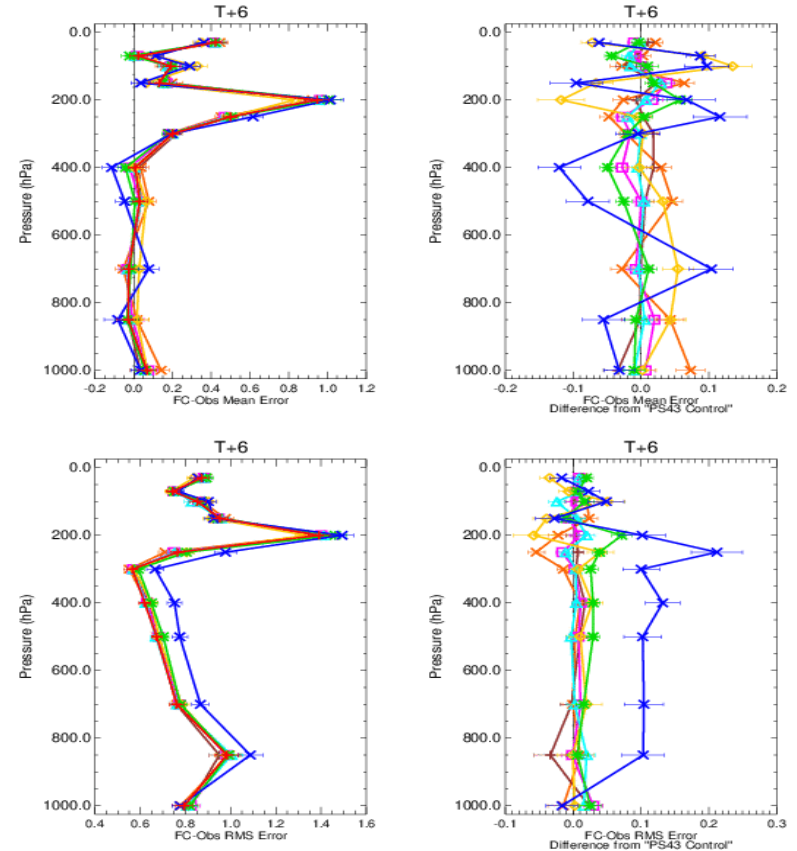
Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, All Land T/RH Denied, All Land MSLP Denied



Surface

Temperature (Kelvin): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode S Denied, PS43 Control - ROBH GNSS, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



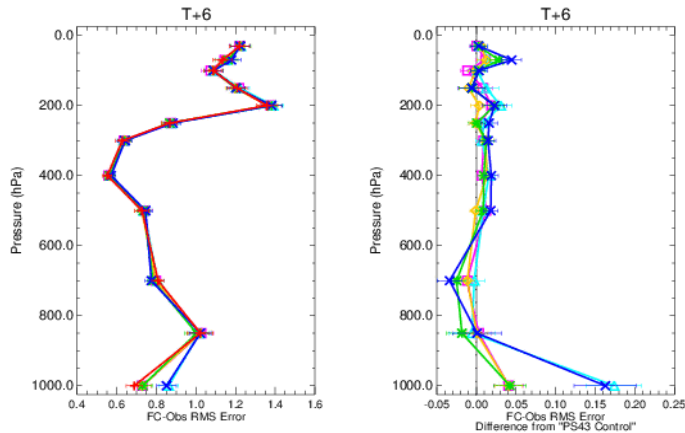
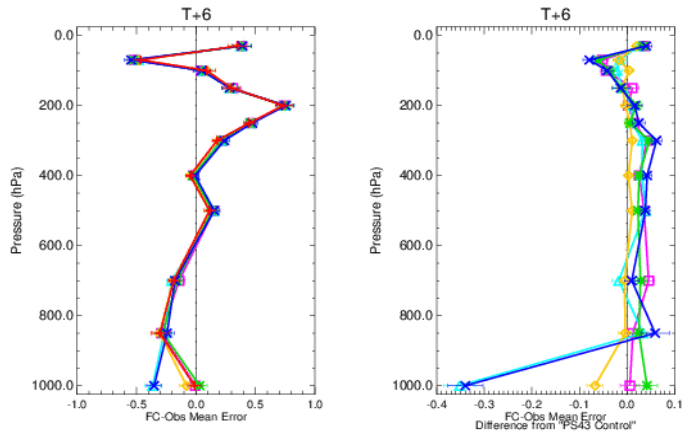
'Upper-Air'



# Upper-air Temperature Winter

Temperature (Kelvin): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

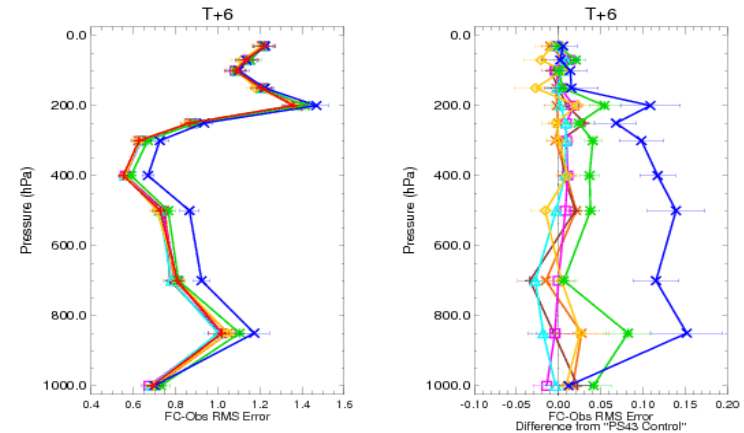
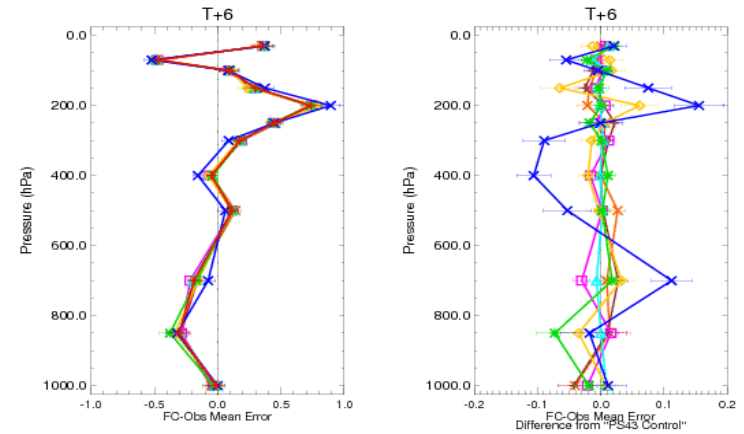
Cases: + PS43 Control x All Land Surface Obs Denied \* All Land except Road obs Denied  
o Road obs Denied ^ Land T/RH Denied □ Land MSLP Denied



Surface

Temperature (Kelvin): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

Cases: + PS43 Control x All Upper Air Obs Denied \* All AMDAR & AIREP Denied  
o All Mode-S Denied ^ PS43 Control - ROBH GNSS □ PS43 Control - GNSS  
+ PS43 Control - GeoCloud x PS43 Control - Radiances



'Upper-Air'

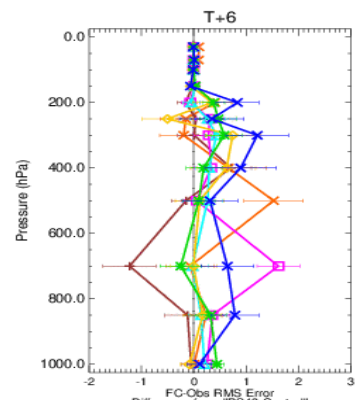
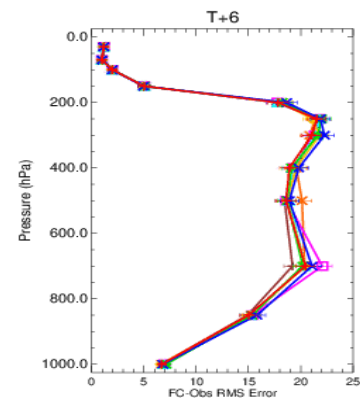
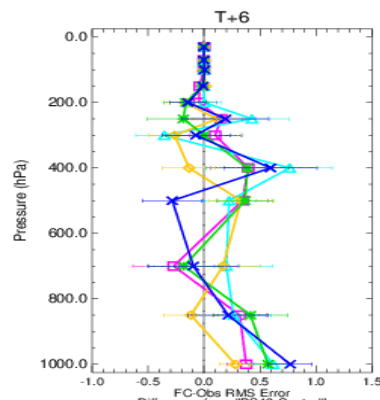
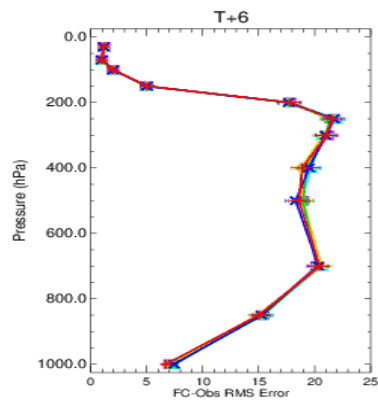
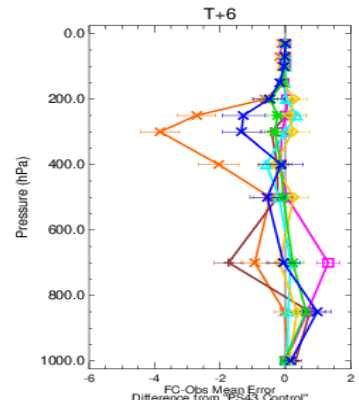
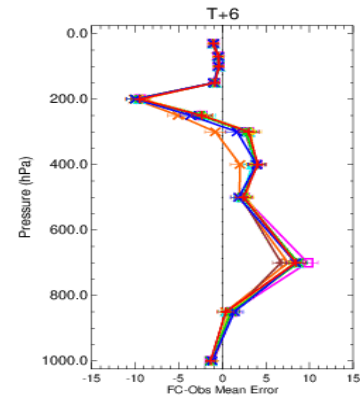
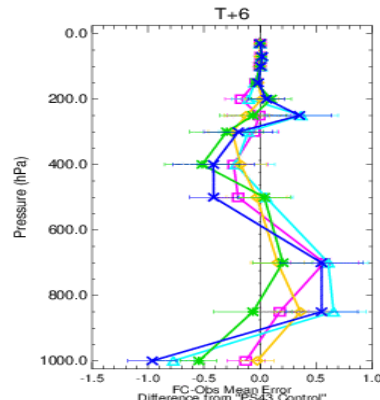
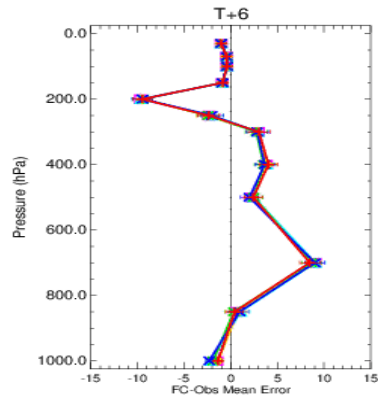
# Upper-air RH Summer

Relative humidity (%): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

Relative humidity (%): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

Cases: PS43 Control (red line with squares), All Land Surface Obs Denied (blue line with crosses), All Land except Road obs Denied (green line with asterisks), Road obs Denied (orange line with diamonds), All Land T/RH Denied (cyan line with triangles), All Land MSLP Denied (magenta line with squares)

Cases: PS43 Control (red line with squares), All Upper Air Obs Denied (blue line with crosses), All AMDAR & AIREP Denied (green line with asterisks), All Mode-S Denied (orange line with diamonds), PS43 Control - ROBH GNSS (cyan line with triangles), PS43 Control - GNSS (magenta line with squares), PS43 Control - GeoCloud (brown line with crosses), PS43 Control - Radiances (yellow line with asterisks)



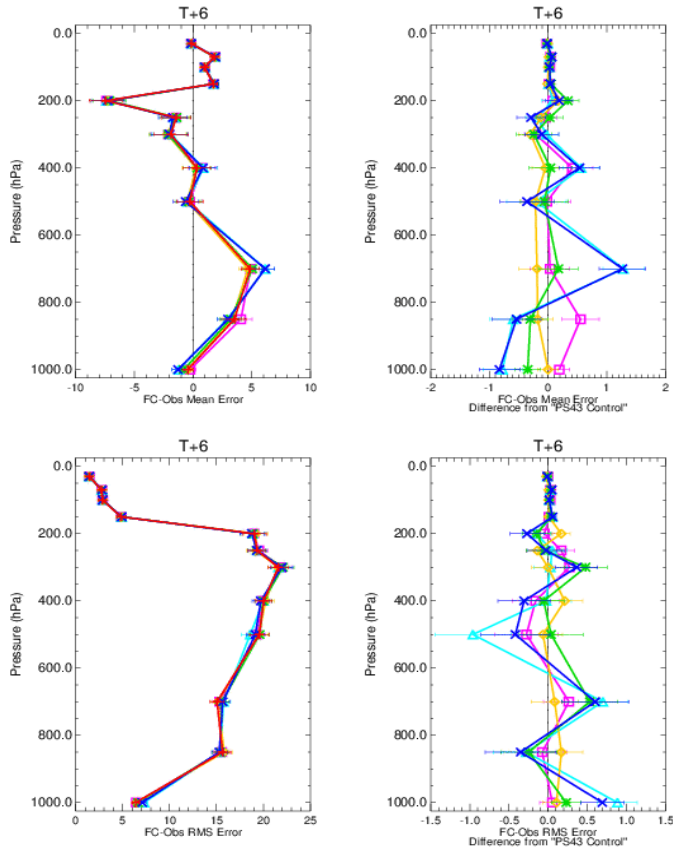
Surface

'Upper-Air'

# Upper-air RH Winter

Relative humidity (%): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

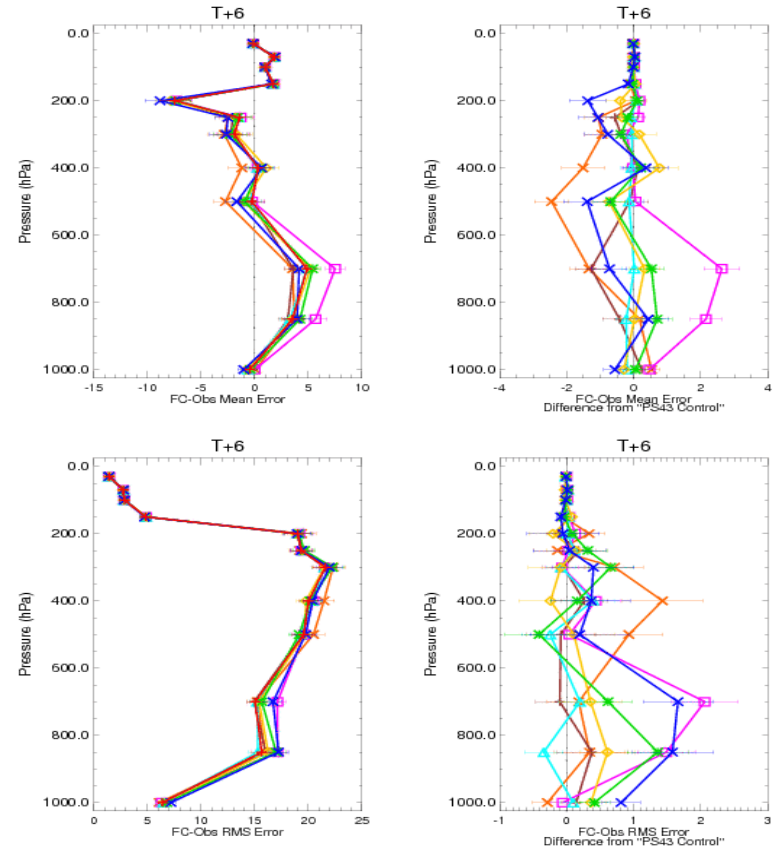
Cases: + PS43 Control x All Land Surface Obs Denied \* All Land except Road obs Denied  
o Road obs Denied ^ Land T/RH Denied □ Land MSLP Denied



Surface

Relative humidity (%): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

Cases: + PS43 Control x All Upper Air Obs Denied \* All AMDAR & AIREP Denied  
o All Mode-S Denied ^ PS43 Control - ROBH GNSS □ PS43 Control - GNSS  
+ PS43 Control - GeoCloud x PS43 Control - Radiances

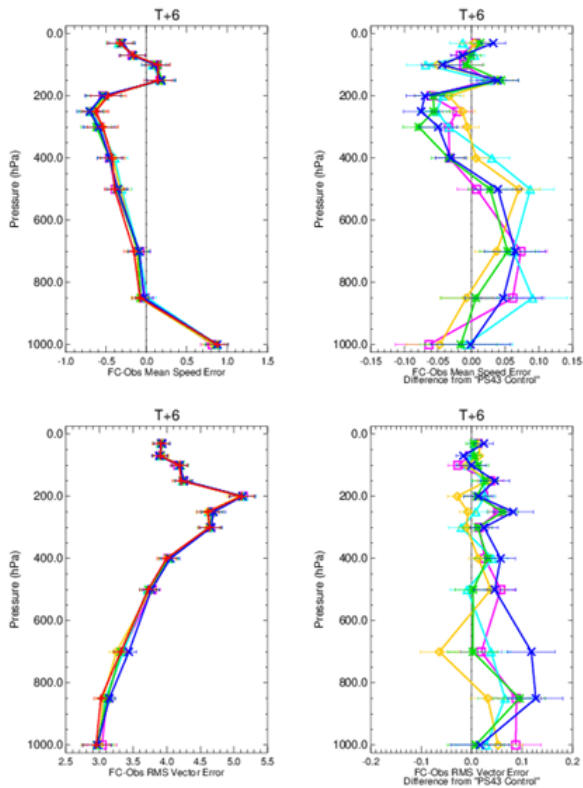


'Upper-Air'

# Upper-air Wind Winter

Wind (m/s): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

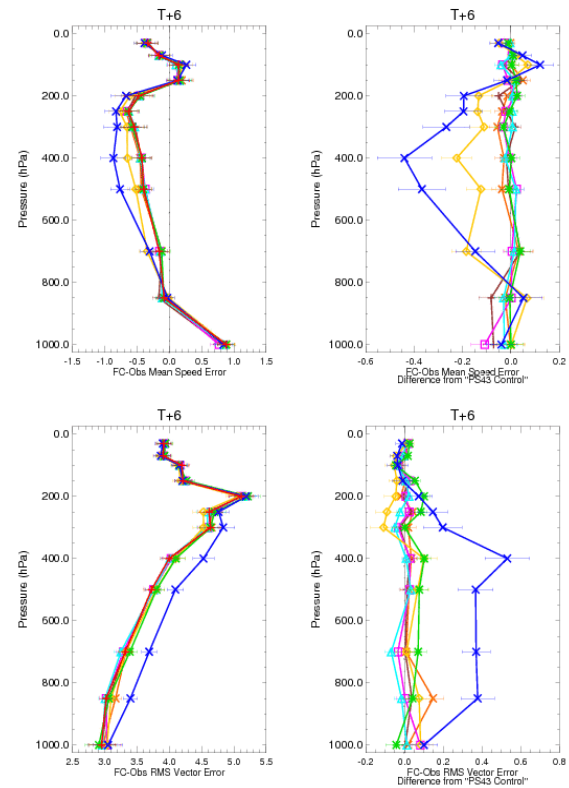
Cases: PS43 Control, All Land Surface Obs Denied, All Land except Road obs Denied, Road obs Denied, Land T/RH Denied, Land MSLP Denied



Surface

Wind (m/s): Sonde Obs  
WMO Block 03 station list  
Equalized and Meaned from 1/12/2018 00Z to 31/1/2019 23Z

Cases: PS43 Control, All Upper Air Obs Denied, All AMDAR & AIREP Denied, All Mode-S Denied, PS43 Control - ROB GNSS, PS43 Control - GNSS, PS43 Control - GeoCloud, PS43 Control - Radiances



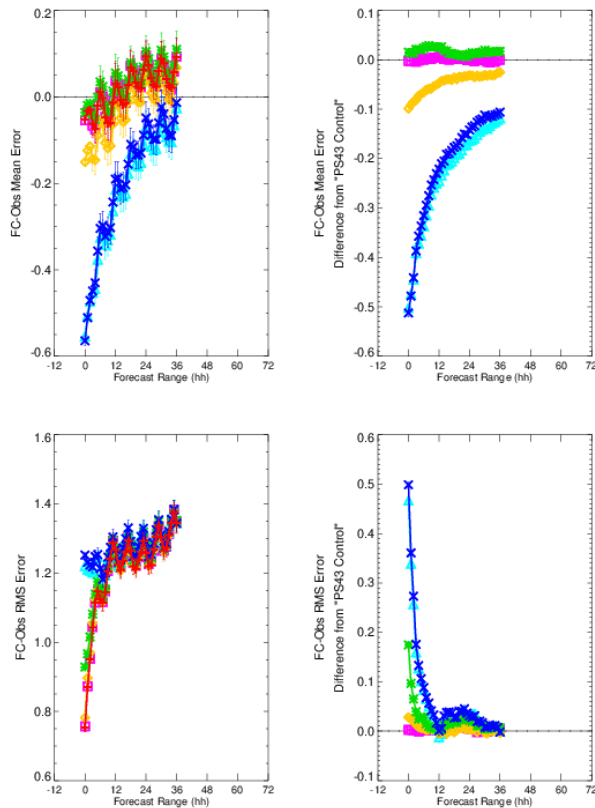
'Upper-Air'



# Vs OpenRoad Obs

Temperature (Kelvin) at Station Height: Surface Obs  
 WMO Block 03 station list  
 Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

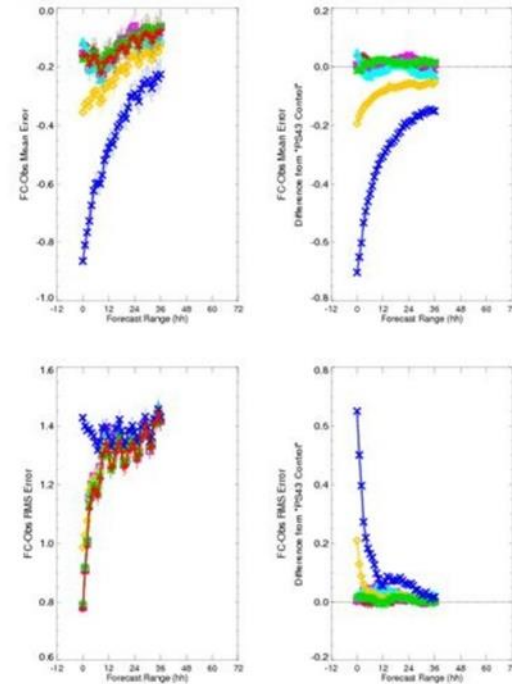
Cases: + PS43 Control x All Land Surface Obs Denied \* All Land except Road obs Denied  
o Road obs Denied △ All Land T/RH Denied □ All Land MSLP Denied



68% error bars calculated using  $S/(n-1)^{1/2}$

Temperature (Kelvin) at Station Height: OPENROAD Obs  
 Reduced UKV 1.5km Model area  
 Equalized and Meaned from 15/7/2018 00Z to 14/9/2018 23Z

Cases: + PS43 Control x All Land Surface Obs Denied \* All Land except Road obs Denied  
o Road obs Denied △ All Upper Air Denied □ GroundGPS Denied  
+ Radar Denied



68% error bars calculated using  $S/(n-1)^{1/2}$