Assessing the Impact of a Potential Degradation in the Satellites Constellation on NOAA NWP

Afternoon Orbit Gap & Tropics-Only COSMIC2 Coverage

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Briefing Agenda

1. **GOS Expected Evolution, Motivation and Scope of Study**
2. OSEs Experiments design
3. Overall forecast performance statistics
4. Main points and conclusions

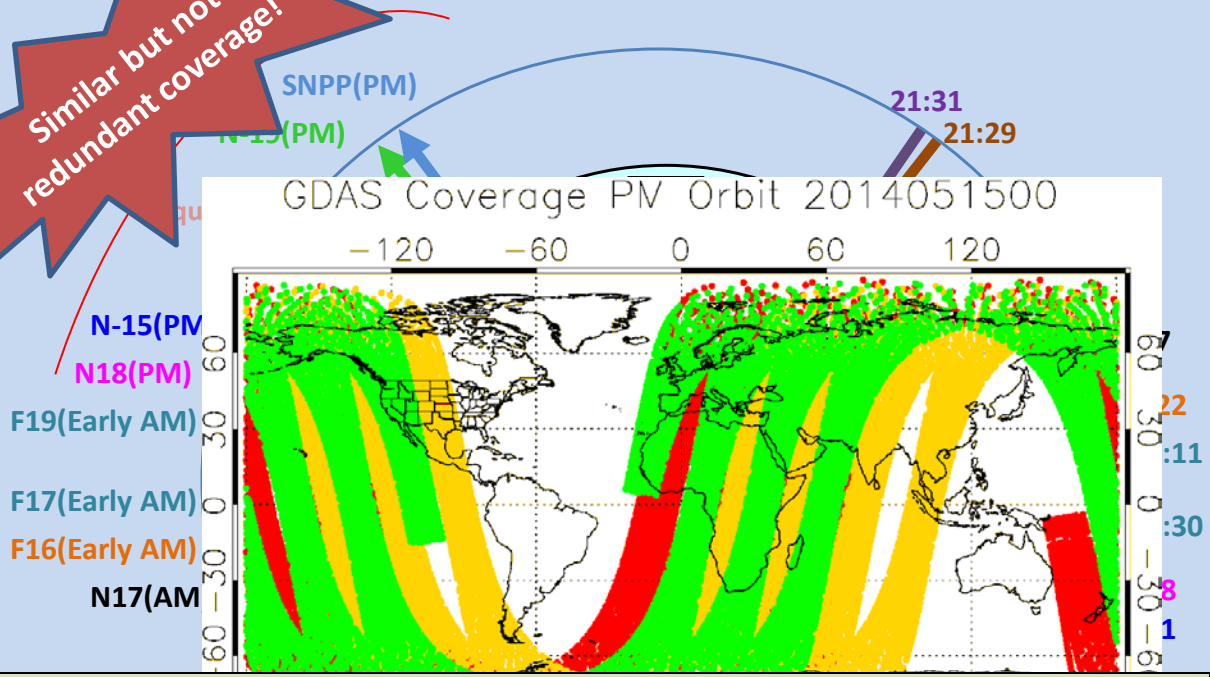
Motivation #1: Evolution of the Polar-orbiting Satellite Constellation

What is the *worst case* future of the GOS Polar-orbiting satellite constellation?

Polar-orbiting satellite constellation coverage in 1 or more PRIMARY orbits is lost

Complete set of unique observations is lost

Similar but not redundant coverage!

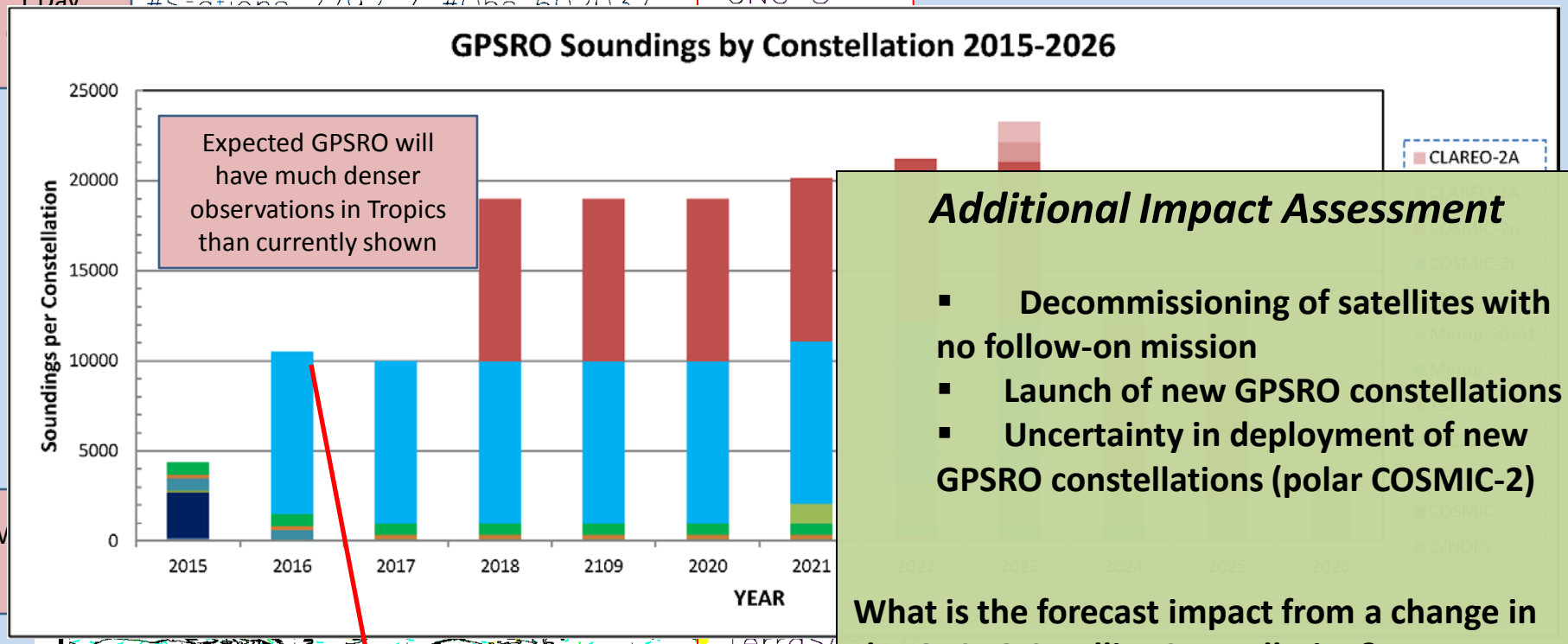


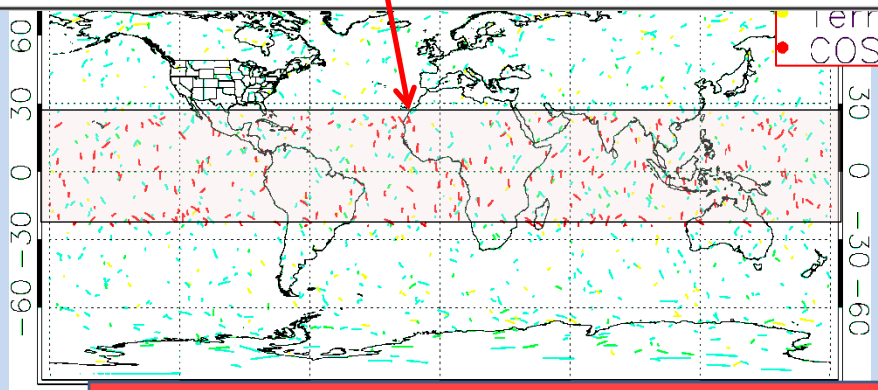
Overarching Motivation

Assess impact of potential JPSS data gap on global NWP forecast performance.

Establish a baseline to assess added value of the data gap mitigation strategies being implemented by the JCSDA (e.g. AMVs, new sensors, cloudy radiance assimilation, Geo DA).

Motivation#2: COSMIC-2 Plan





Additional Impact Assessment

- **Decommissioning of satellites with no follow-on mission**
- **Launch of new GPSRO constellations**
- **Uncertainty in deployment of new GPSRO constellations (polar COSMIC-2)**

What is the forecast impact from a change in the GPSRO Satellite Constellation?

Removal of missions with no successor, redundancy, and COSMIC extratropical GPSRO observations

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Experiment Design
What System?

Data Assimilation and Forecast System

Configure matches current NOAA operational model suite implemented in January 2015.

- NOAA Global Data Assimilation System (GDAS) with Hybrid 3DVar/EnKF
  - Resolution: T574 (30km) for both analysis and 80-member ensemble analyses
- NOAA Global Forecast System (GFS)
  - Resolution: T1534 (13 km), semi-Lagrangian

High Performance Computing

- All experiments are run on JCSDA S4 Supercomputer
- Post-processing, porting, synchronization – leveraged from the JCSDA O2R effort

Experiment Design
What Season?

- Experiment period: May 15, 2014 – August 7, 2014.
  - Summer season capturing Hurricane Arthur case
- Assessment period: May 25, 2014 – August 7, 2014.
  - Allow for a 10 day spin-up
- GFS 168 hour forecast run at 00Z only
- Caveats
  - Single season
  - 00Z forecast cycle only

OSE impacts may differ for other seasons, forecast cycles

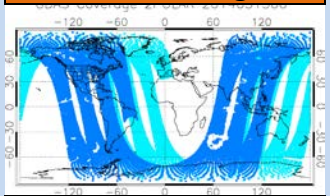
Experiment Design
What Satellite Data?

3PGPS

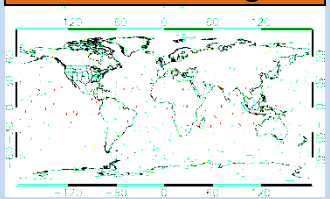
Remove quasi-redundant satellite data.

Remove GPSRO data with no future mission or uncertain funding.

Polar Coverage



GPSRO Coverage



Current Operational	Type	Orbit	3polar	2polar (PM Gap)	3pgps (Expected RO)
F16 (SSMI/S)	MW	Early-AM			
F17 (SSMI/S)	MW	Early-AM			
F18 (SSMI/S)	MW	Early-AM			
N15 (AMSU)	MW	Late PM			
N18 (AMSU/MHS)	MW	PM			
N19 (AMSU/MHS)	MW	PM			
SNPP (ATMS/CrIS)	MW/IR	PM			
Metop-A (AMSU/MHS/IASI/HIRS)	MW/IR	Mid-AM			
Metop-B (AMSU/MHS/IASI)	MW/IR	Mid-AM			
Aqua MODIS IR Winds	IR	PM			
Aqua AIRS	IR	PM			
Aqua MODIS WV Winds	IR	PM			
Terra MODIS IR/WV Winds	IR	AM			
WindSat		Early-AM			
GOES Sounder, AMVs	IR	GEO			
JMA AMVs	IR	GEO			
METEOSAT AMVs	IR	GEO			
COSMIC	RO	n/a			Poleward 24° Latitude
Metop-A (GRAS)	RO	n/a			Poleward 24° Latitude
Metop-B (GRAS)	RO	n/a			
TerraSAR-X	RO	n/a			
GRACE	RO	n/a			
C/NOFS	RO	n/a			Poleward 24° Latitude
SAC-D	RO	n/a			Poleward 24° Latitude

***MODIS IR winds are a proxy for SNPP VIIRS**

Assimilated

Denied

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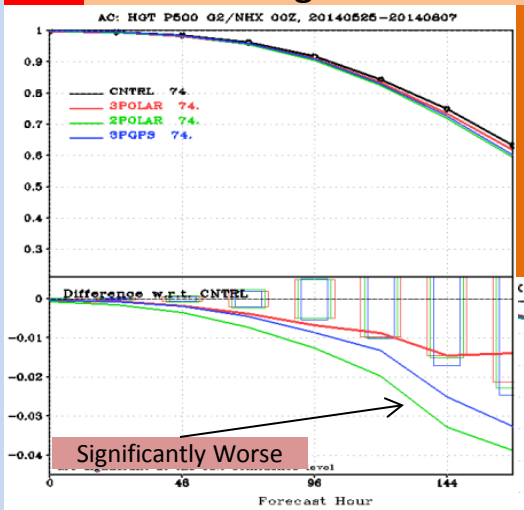
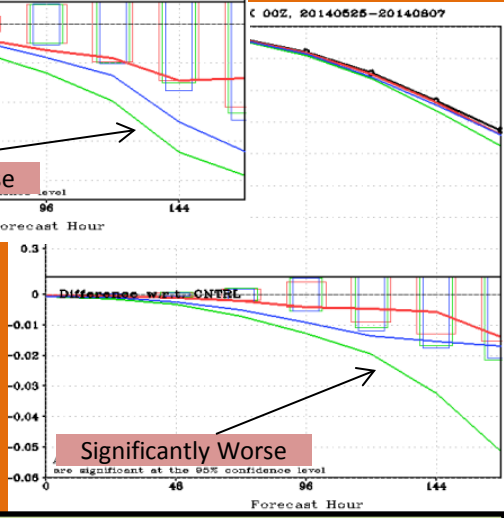
500 mb Height Forecast Anomaly Correlation (vs CNTRL)

MEAN AC SCORE	CNTRL	3POLAR	2POLAR	3PGPS
NH (top)	0.843	0.835	0.824	0.830
SH (bottom)	0.854	0.850	0.835	0.841

500mb Height AC vs Forecast Time

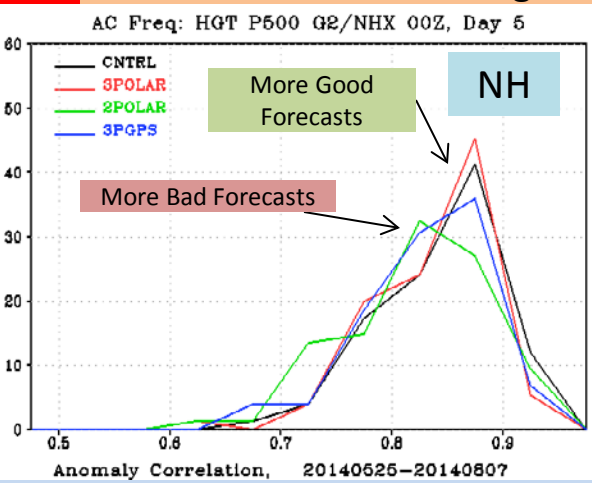


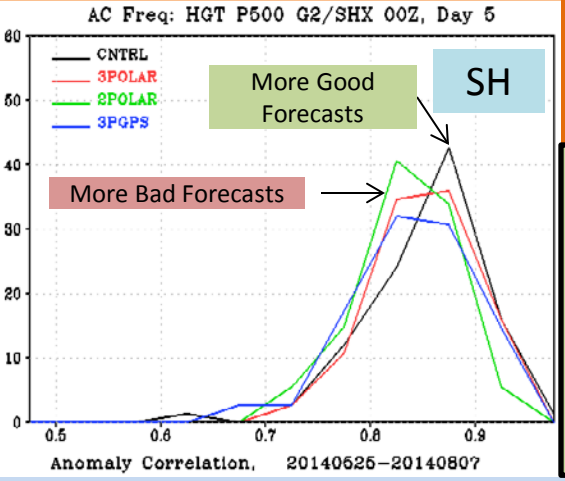
Northern Hemisphere Dieoff (left)



Southern Hemisphere Dieoff (right)

Distribution of DAY 5 Height 500mb Anomaly Correlation





Impacts on 500 mb Height Forecast Anomaly Correlation (Day 5)

- Timeseries of AC shows few dropouts for all experiments, with 2POLAR having much lower mean AC than other experiments.
- 3POLAR slightly degraded AC in NH, neutral in SH.
- 3PGPS significantly degraded in NH and slightly at Day 3-4 in SH
- 2POLAR significantly degraded in NH and SH for Day 1-7 forecast.
- 2POLAR exhibits more frequent low AC score.

200 mb Wind- tropics and Extra Tropics

(vs CNTRL)

Tropics

vs CNTRL

MEAN RMSE (m/s)	CNTRL	3POLAR	2POLAR	3PGPS
DAY 1 (top)	4.52	4.84	4.94	4.82
DAY 3 (bottom)	7.03	7.12	7.22	7.12

Impacts on 200 mb Wind Forecast (RMSE) vs CNTRL

- Significant degradation of forecast tropical upper-level wind field at Day 1, and slightly degraded at Day 3.
- 2POLAR is slightly worse than 3POLAR and 3PGPS relative to CNTRL.
- 3PGPS expected impact low due to unchanged coverage in Tropics.

Southern hemisphere

MEAN RMSE (m/s)	CNTRL	3POLAR	2POLAR	3PGPS
DAY 3 v CNTRL (top)	6.94	7.17	7.48	7.31
DAY 3 v ECMWF (bottom)	7.01	7.23	7.55	7.38

Impacts on Day 3 200mb SH Wind Forecast (RMSE)

- Day 3 wind forecast impact is neutral for 3POLAR, and slightly negative for 2POLAR and 3PGPS compared to CNTRL analysis.
- Day 3 wind forecast impact is negative for 3POLAR, more significantly negative for 3PGPS, and most significantly negative for 2POLAR compared to ECMWF.
- Impacts similar, for NH Day 3 200 mb Wind Forecast.

Scorecard
Reference: CNTRL Analysis

3PGPS vs CNTRL

3POLAR configuration with loss of GPSRO coverage

Polar Quasi - redundancy lost and extra-tropical GSPRO degraded

Significance for NWP

- Day 1-3 forecast remains degraded for all parameters (99.9% sig.)
- Day 5-6 forecast has significant degradation (95-99.9% sig.)
- Impact is global (affecting both hemispheres)

			Globe						N. Hemisphere						S. Hemisphere						Tropics					
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
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Cumulative Forecast Score

Overall forecast quality based on multiple forecast parameters and forecast accuracy metrics

$$CFS = \alpha * C_{AC} + \beta * C_{RMSE}$$

Where CFS is the weighted average between Cumulative Anomaly Correlation (C_{AC}) score and Cumulative Root Mean Square Error score (C_{RMSE}). The weights α and β are set to 0.5 and,

$$C_{AC} = \sum_{i=1}^{np} \sum_{j=1}^{nlev} \sum_{k=1}^{nhr} \frac{(ac_{i,j,k} - \min_k)}{(\max_k - \min_k)}$$

$$C_{RMSE} = \sum_{i=1}^{np} \sum_{j=1}^{nlev} \sum_{k=1}^{nhr} 1 - \frac{(rmse_{i,j,k} - \min_k)}{(\max_k - \min_k)}$$

Where,

max = maximum score at forecast time *k*, and **min =** minimum score at forecast time *k*, to account for degrading forecast skill at longer lead times.

The parameters included are:

np

Parameters
- Height
- Temperature
- Vector Wind

nlev

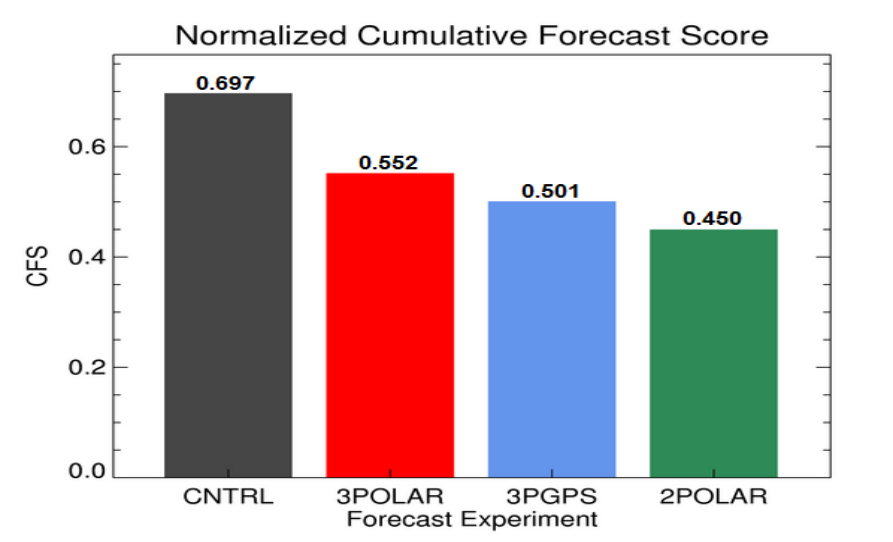
Levels (mb)
- 250
- 500
- 700
- 850

nhr

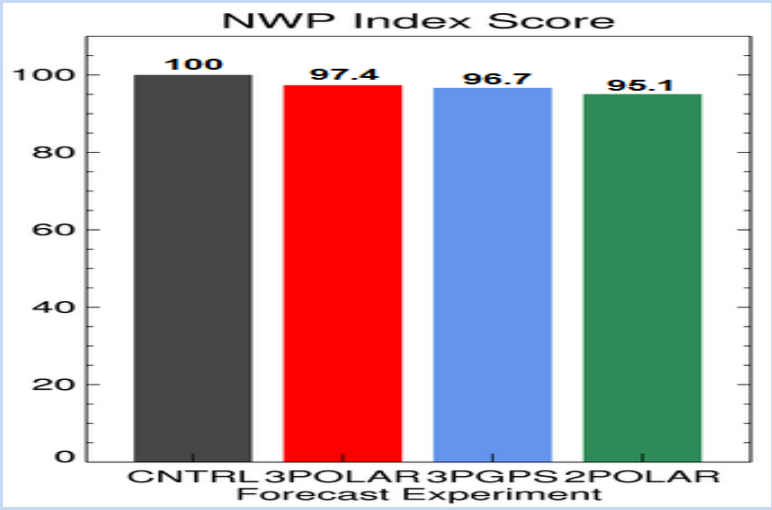
Forecast (hr)
- 24
- 48
- 72
- 96
- 120
- 144
- 168

Overall Forecast Score
Reference: CNTRL Analysis

OFS



UKMO Index: The UK Met Office NWP Index is based on global model forecast RMSE of mean sea level pressure, along with height and wind fields at selected atmospheric layers for leads times up to Day 5, normalized by the RMSE of the persistence forecast.



Cumulative Forecast Scores

1). The loss of a quasi-redundant polar satellite constellation (3POLAR) results in a significant degradation of overall forecast quality.

2). Both removal of PM polar satellite data and GPSRO extratropical data lower forecast scores further degrades forecast quality from 3POLAR.

3). Removal of the PM polar satellite data has the largest negative impact.

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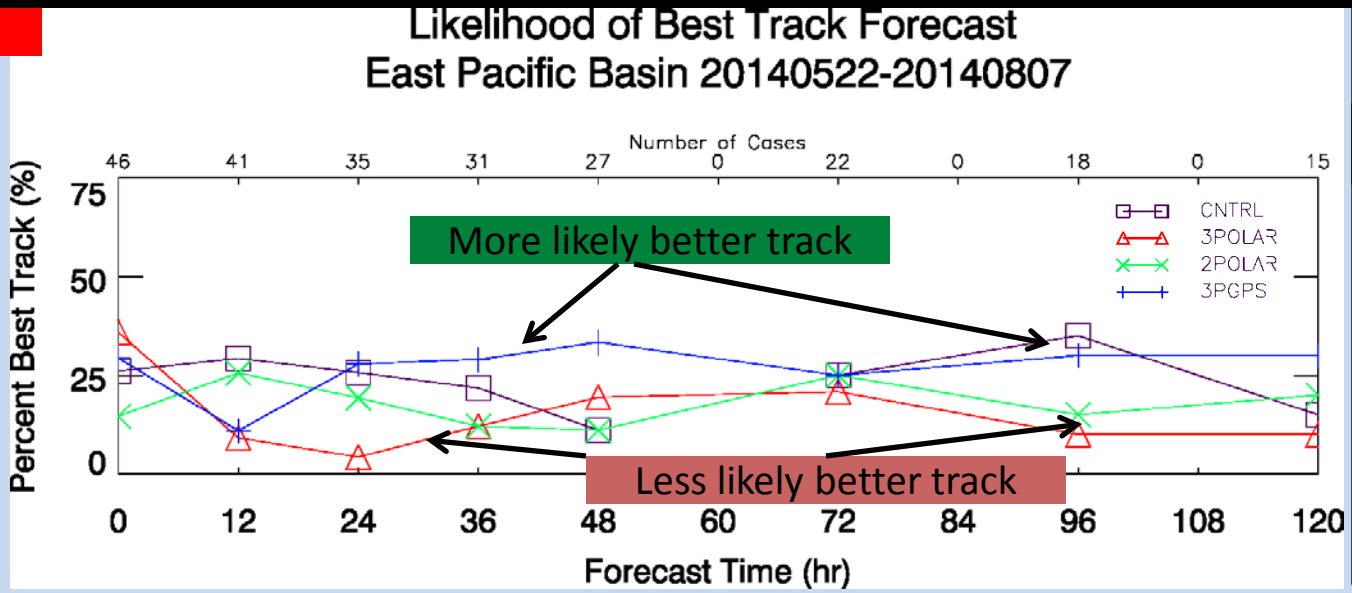
Main Points

- Overall forecast quality is degraded significantly when secondary polar data is removed (only 1 satellite in each Primary orbit).
- Overall forecast quality is further degraded when PM polar data are removed.
- Overall forecast quality is also degraded (but not as significantly) when the GPSRO coverage is altered (removal of extratropical observations).
- Tropical Cyclone track forecasts vary widely on a case by case basis (not shown) so statistical robustness is critical before interpreting results. Results suggest loss of redundancy and loss of PM orbit could lead to degraded performances.
- Caution should be exercised when deciding on removal of so called ‘secondary’ sensors (orbits are not redundant), as this will lead to degraded global performances
- Global forecast performance skills are more degraded from loss of the afternoon polar orbiting satellite than from the polar-coverage of COSMIC
- Future Work:
  - Extend period to obtain more robust Hurricane statistics
  - Investigate further the degradation due to removing secondary sensors

Backup

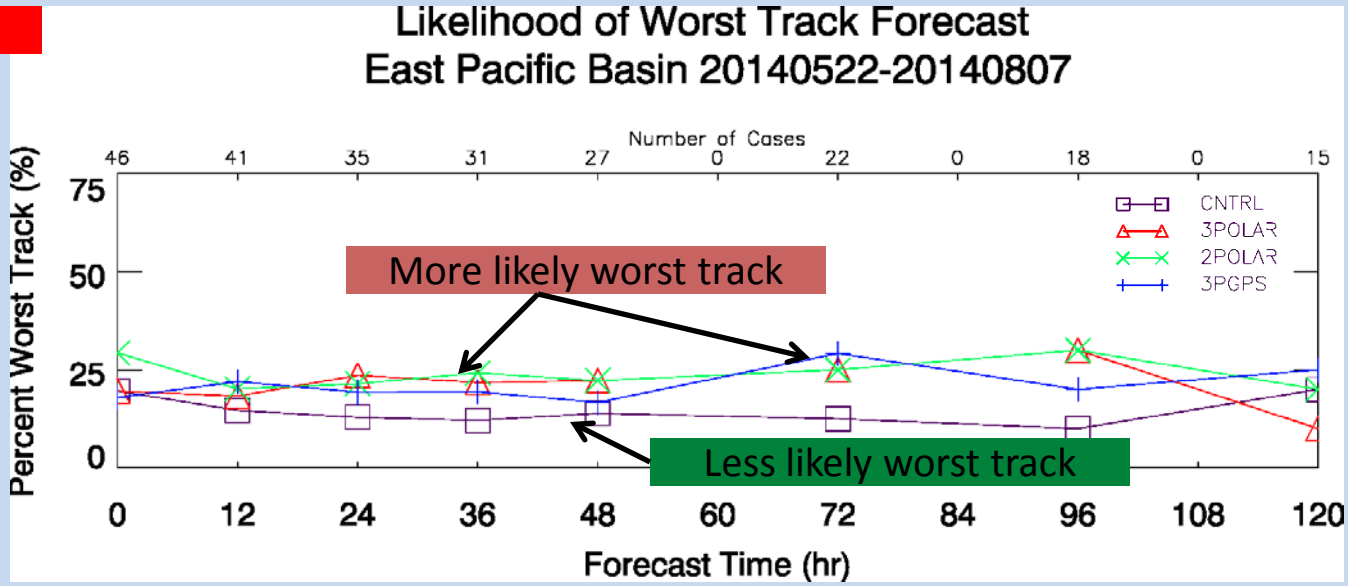
Mission	Launch	End of Life	Number of Satellites	Coverage	Obs per Day
Operational					
C/NOFS (CORISS)	2008-04-16	>2015	1	Tropical (13°)	200
COSMIC	2006-04-14	>2015	1x6	LEO (72°)	2500
GRACE (blackjack)	2002-03-17	>2015	1x2	LEO (89°)	150
Metop-A (GRAS)	2006-10-19	>2015	1	Polar	650
SAC-D (ROSA)	2011-06-10	>2016	1	Polar	650
Metop-B (GRAS)	2012-09-17	>2018	1	Polar	650
TerraSAR-X (IGOR)	2007-06-15	>2024	1	Polar	200
Not Used					
Megha-Tropiques (ROSA)	2011-10-12	> 2016	1	Tropical (10°)	650
OceanSat-2 (ROSA)	2009-09-23	> 2015	1	Polar	250
TanDEM-X (IGOR)	2010-06-21	> 2015	1	Polar	200
Planned					
SEOSAR (ROHPP)	≥ 2015	≥ 2020	1	Polar	250
COSMIC-2	≥ 2016	≥ 2023	2x6	Tropical (24°)	9000
GRACE-FO (Tri-G)	≥ 2017	≥ 2022	1x2	LEO (89°)	150
TSX-NG (IGOR)	≥ 2017	≥ 2024	1	Polar	200
COSMIC-2	≥ 2018	≥ 2025	2x6	LEO (72°)	9000
Metop-C (GRAS)	≥ 2018	≥ 2024	1	Polar	650
Metop-SG-A1 (RO)	≥ 2021	≥ 2043	1	Polar	1100
Metop-SG-B1 (RO)	≥ 2022	≥ 2043	1	Polar	1100
CLARREO-1A	> 2023	≥ 2028	1	Polar	1100
CLARREO-2A	> 2023	≥ 2028	1	Polar	1100

Tier 2: Likelihood Best/Worst Track Forecast



How often does the experiment produce the best track forecast?

- ***CNTRL and 3PGPS are more likely*** to forecast better Tropical Cyclone track at all forecast lead times
- ***3POLAR and 2POLAR are less likely*** to forecast better Tropical Cyclone track at all forecast lead times

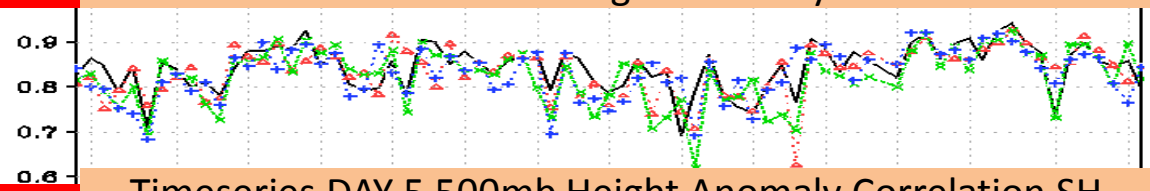


How often does the experiment produce the worst track forecast?

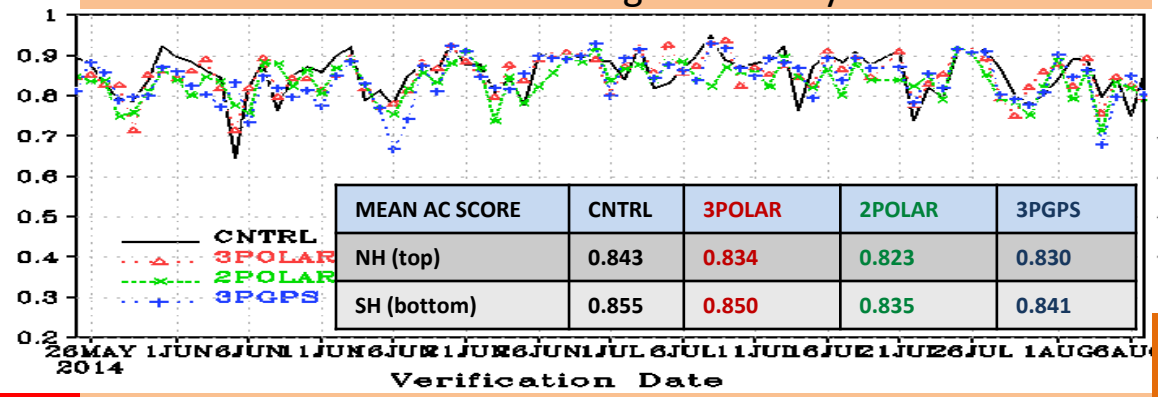
- ***CNTRL is less likely*** to forecast worse Tropical Cyclone track at all forecast lead times
- ***3POLAR, 2POLAR, and 3PGPS are more likely*** to forecast worse Tropical Cyclone track at all forecast lead times

Tier 2: 500 mb Height Forecast Anomaly Correlation (vs ECMWF)

Timeseries DAY 5 500mb Height Anomaly Correlation NH



Timeseries DAY 5 500mb Height Anomaly Correlation SH



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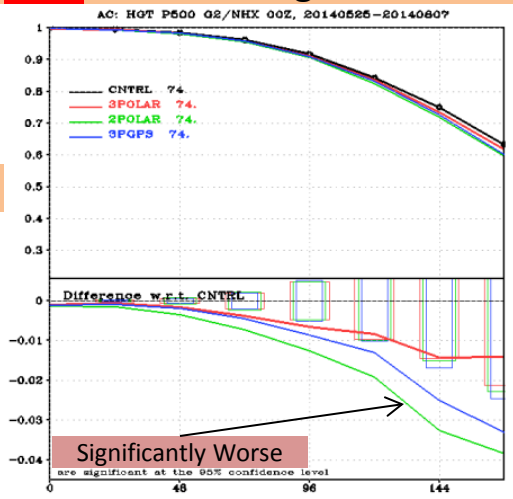

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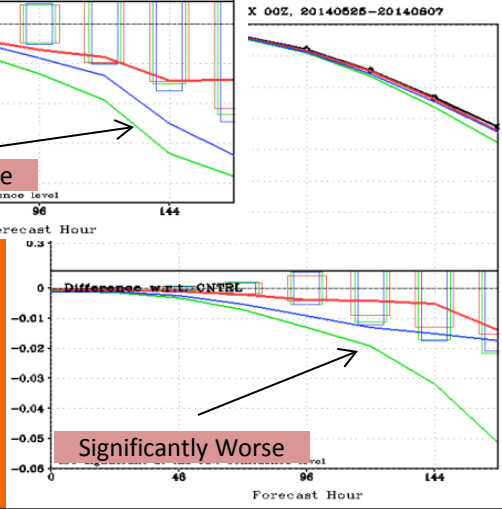
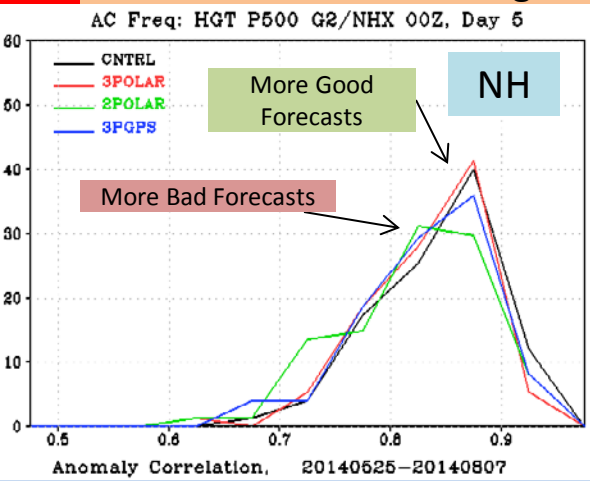
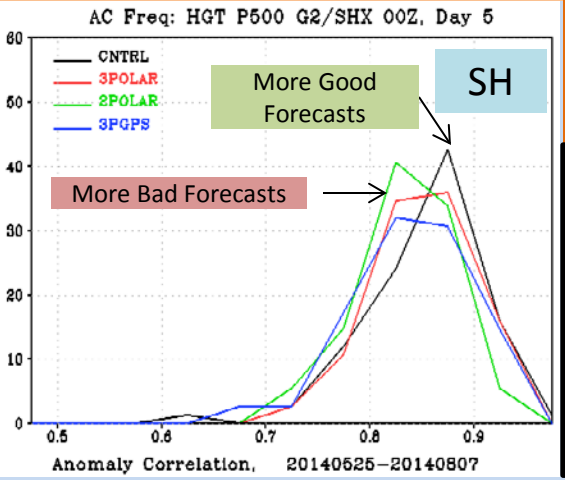


Southern Hemisphere Dieoff (right)

Distribution of DAY 5 Height 500mb Anomaly Correlation





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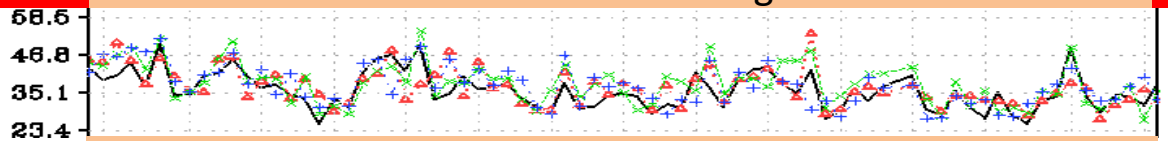
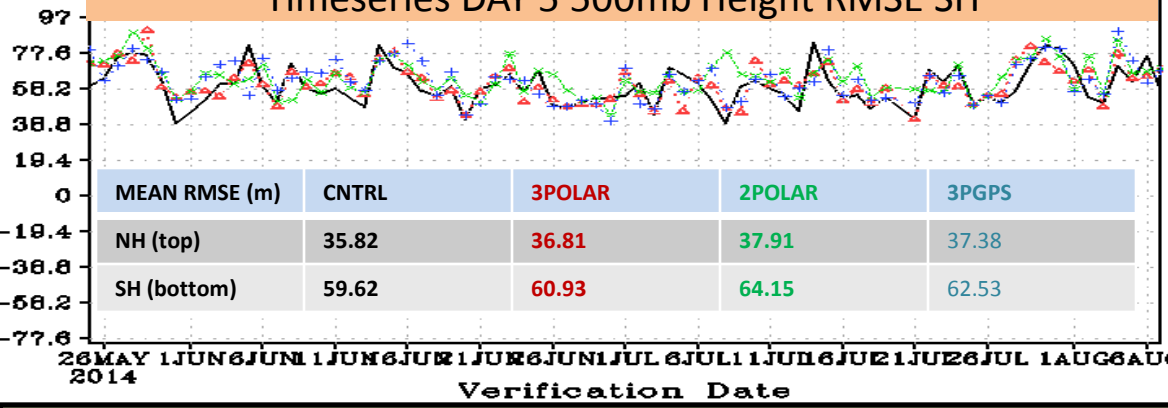
- 3PGPS significantly degraded in NH and slightly at Day 3-4 in SH
- 2POLAR significantly degraded in NH and SH for Day 1-7 forecast.
- 2POLAR exhibits more frequent low AC score.

Tier 2: 500mb Height Forecast RMSE (vs ECMWF)

Timeseries DAY 5 500mb Height RMSE NH

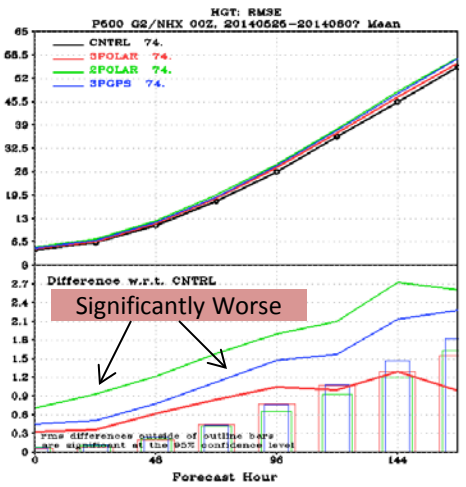


Timeseries DAY 5 500mb Height RMSE SH

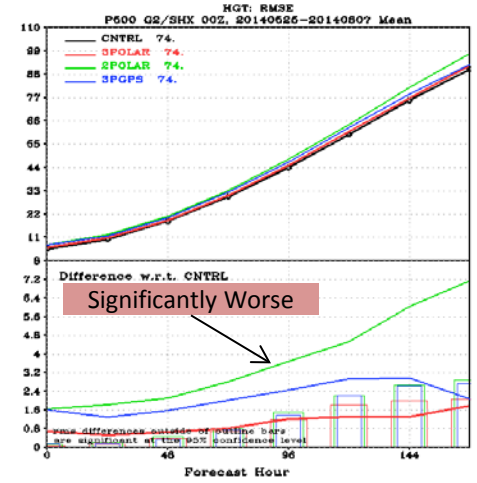


MEAN RMSE (m)	CNTRL	3POLAR	2POLAR	3PGPS
NH (top)	35.82	36.81	37.91	37.38
SH (bottom)	59.62	60.93	64.15	62.53

500mb Height RMSE vs Forecast Time



Northern Hemisphere Dieoff (left)



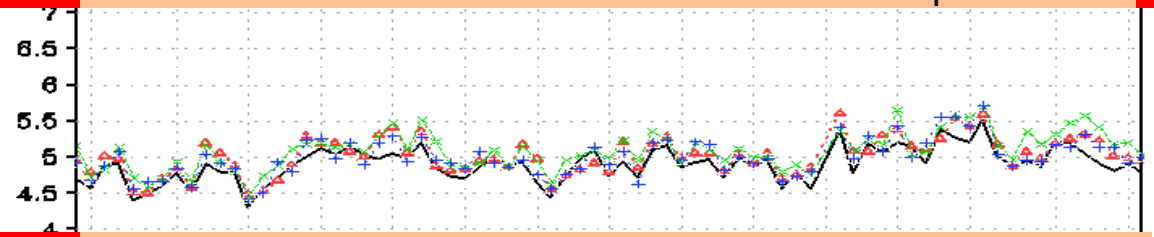
Southern Hemisphere Dieoff (right)

Main Points

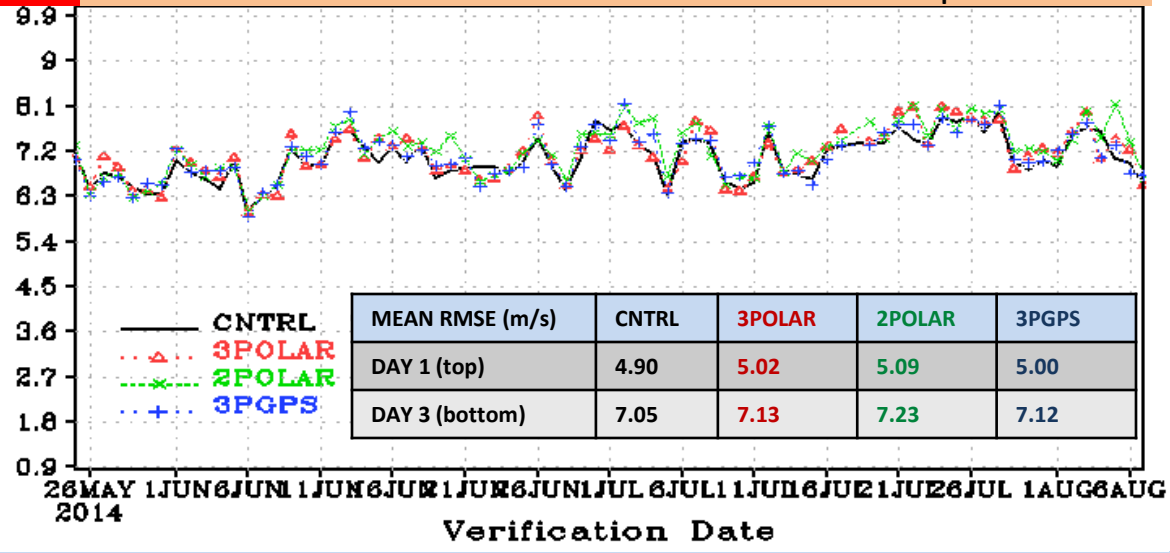
- Impacts vs ECMWF are similar to impacts vs CNTRL analysis
- 3POLAR impact mostly neutral except for NH Day 3/4
- 2POLAR 500mb Height forecast shows significant degradation for NH/SH (Day 5 average RMSE: 2.1m/3.5m worse than CNTRL forecast)
- 3PGPS shows significant degradation for NH/SH, but less negative impact than 2POLAR (Day 5 average RMSE 1.5m/2.9m worse than CNTRL forecast)

Tier 2: 200 mb Tropical Wind (vs ECMWF)

Timeseries DAY 1 200mb WIND RMSE Tropics

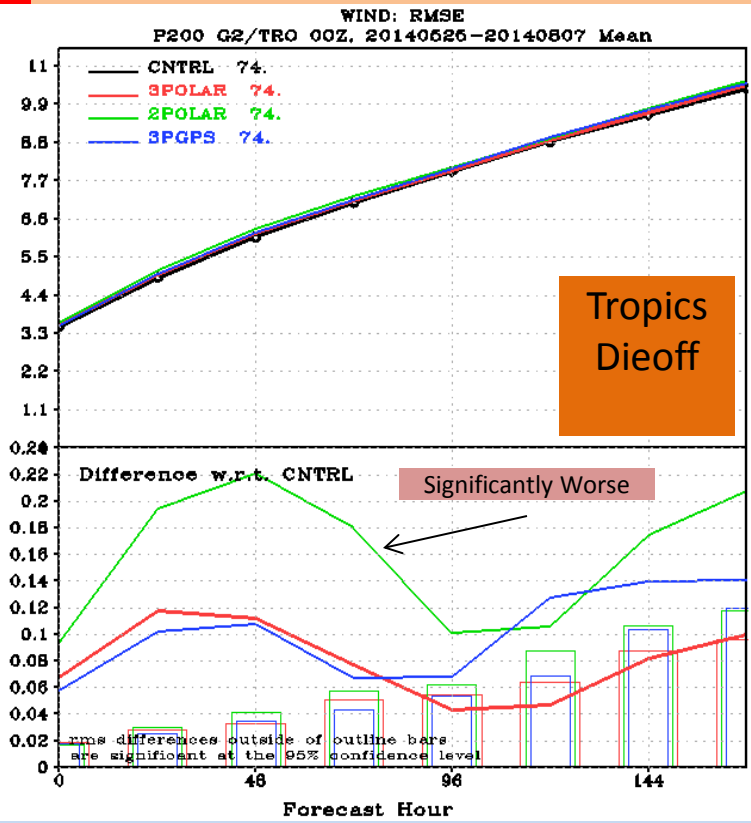


Timeseries DAY 3 200mb WIND RMSE Tropics



MEAN RMSE (m/s)	CNTRL	3POLAR	2POLAR	3PGPS
DAY 1 (top)	4.90	5.02	5.09	5.00
DAY 3 (bottom)	7.05	7.13	7.23	7.12

200mb WIND RMSE vs Forecast Time



Impacts on 200 mb Wind Forecast (RMSE) vs ECMWF

- Small but significant degradation of forecast tropical upper-level wind field at Day 1, and slightly degraded at Day 3.
- 2POLAR is slightly worse than 3POLAR and 3PGPS with respect to CNTRL.
- 3PGPS shows further degradation at longer lead times than 3POLAR.

What Results Will be Shown

Tiered Forecast Impact Analysis

Message: What is the "event driven" forecast implication for loss of satellite data?

High Level Forecast Performance Assessment — Tier 1

Parameters	Metrics	References
Summary of Statistics	*Scorecard*	*CNTRL Analysis*
Overall Forecast Quality	*Cumulative Forecast Scores*	*ECMWF Analysis*
		Ground Truth

Detailed Statistical Performance Assessment — Tier 2

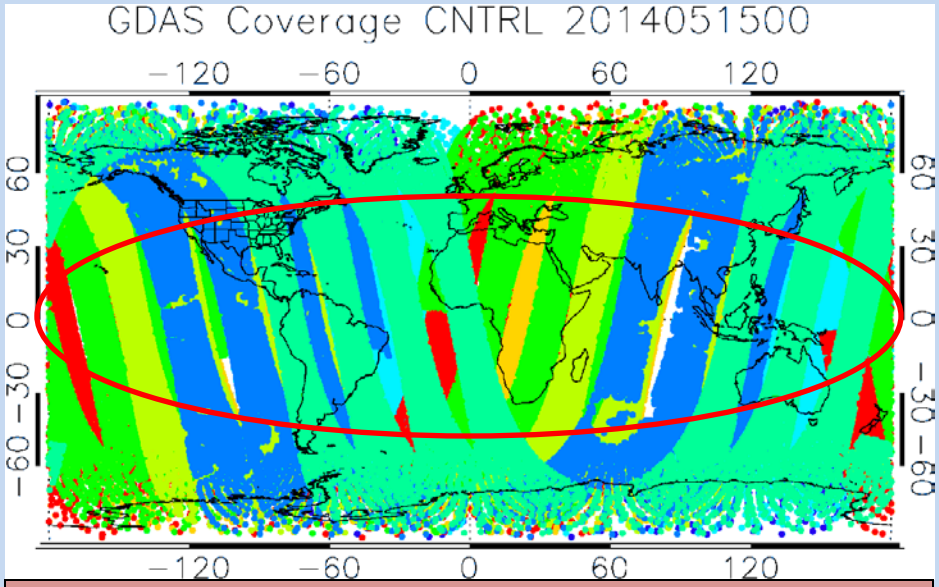
Parameters	Metrics	References
Geopotential Height	*Anomaly Correlation*	*CNTRL Analysis*
Temperature, Humidity, Wind	*RMSE, Bias*	*ECMWF Analysis*
CONUS Precipitation	*Threat Scores*	*Ground Truth*
Tropical Cyclones	*Track/Intensity Error*	

Case Studies — Tier 3

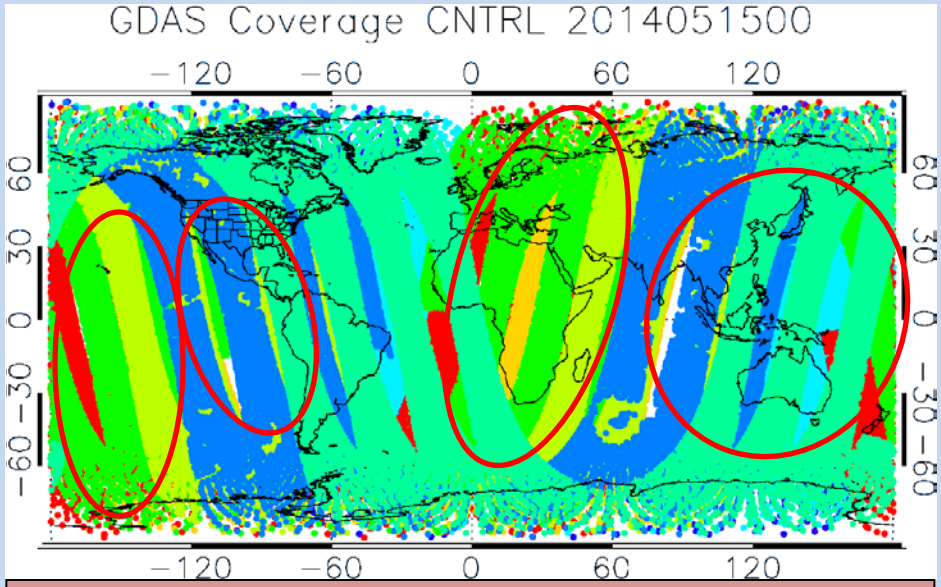
Parameters	Metrics	References
Tropical Cyclone	*Track Error, MSLP*	*CNTRL Analysis*
High Intensity Mid-Latitude Cyclones	*Displacement, Heights,*	*ECMWF Analysis*
	Precipitation	*Ground Truth*

Motivation for Observing System Experiments (part I)

F18	F17	MetB	MetA	N19	N15	N18	NPP



Loss of data in satellite orbit gaps



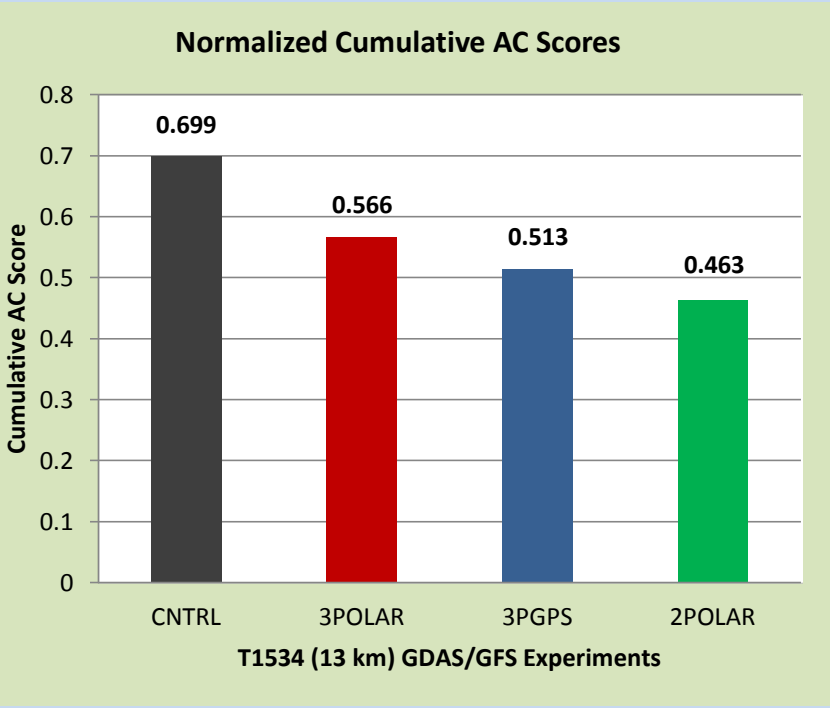
Loss of global coverage and orbit gaps

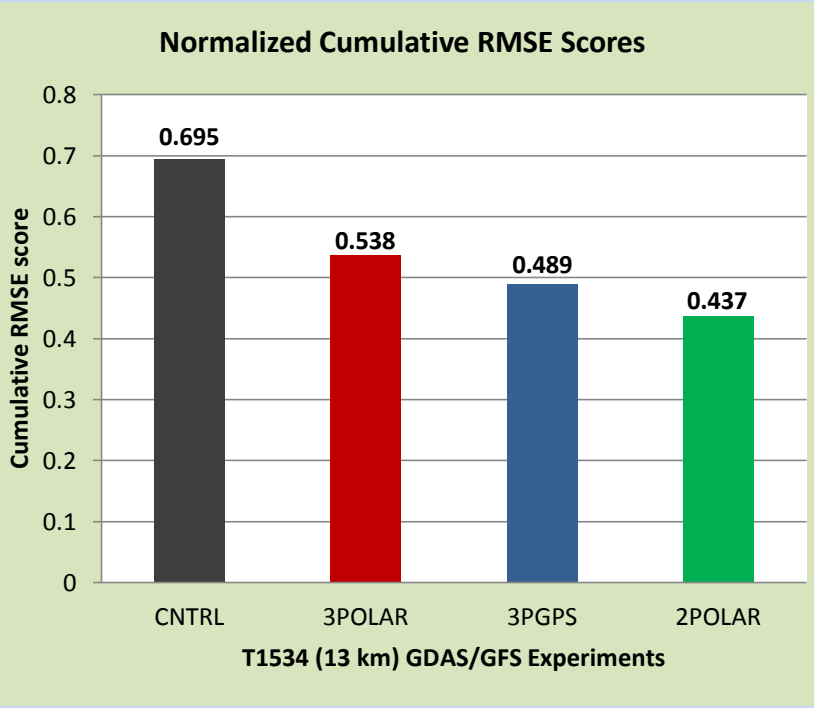
Overarching Motivation

Assess impact of potential JPSS data gap on global NWP forecast performance.

Establish a baseline to assess added value of the data gap mitigation strategies being implemented by the JCSDA (e.g. AMVs, new sensors, cloudy radiance assimilation, Geo DA).

Cumulative Forecast Score Reference: CNTRL Analysis





Cumulative Anomaly Correlation Scores

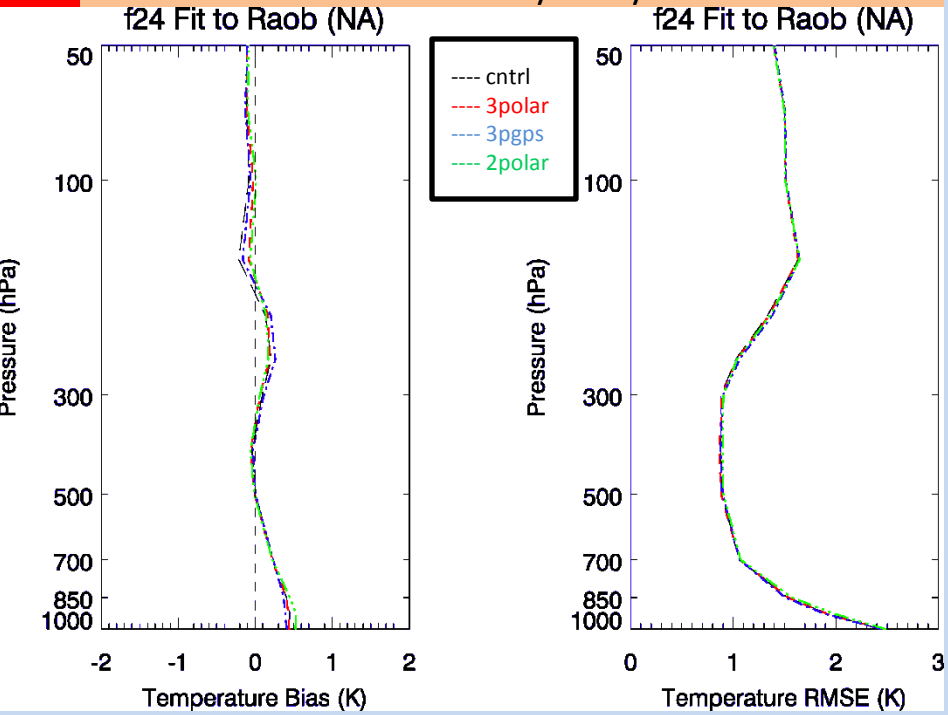
- 3POLAR – Removal of quasi-redundant polar data results in reduction of C_{AC}
- 3PGPS – Removal of quasi-redundant polar data plus additional loss of polar GPSRO further degrades C_{AC}
- 2POLAR - Removal of quasi-redundant polar data plus additional loss of PM polar data results in more significant degradation of C_{AC} than loss of GPSRO

Cumulative RMSE Scores

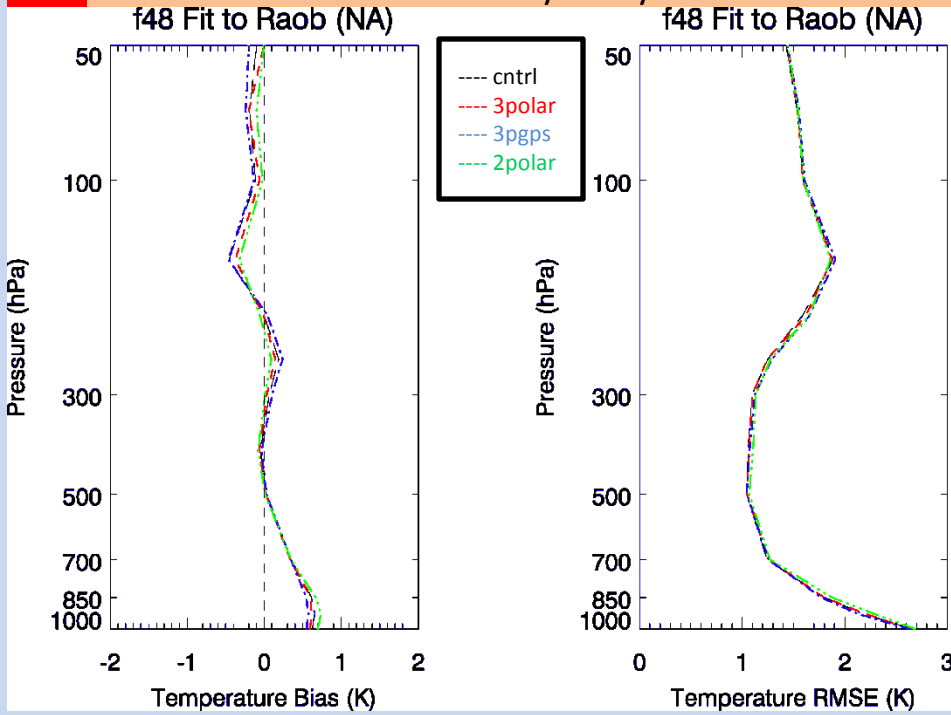
- 3POLAR – Removal of quasi-redundant polar data results in significant reduction of C_{RMSE}
- 3PGPS / 2POLAR – Further removal of the GPSRO observations or the afternoon polar observations has similar degradation as shown with C_{AC} score.

Temperature Profile vs Radiosonde

24 hr ForecastFit to radiosonde over North America: 5/25-8/7 2014



48 hr ForecastFit to radiosonde over North America: 5/25-8/7 2014

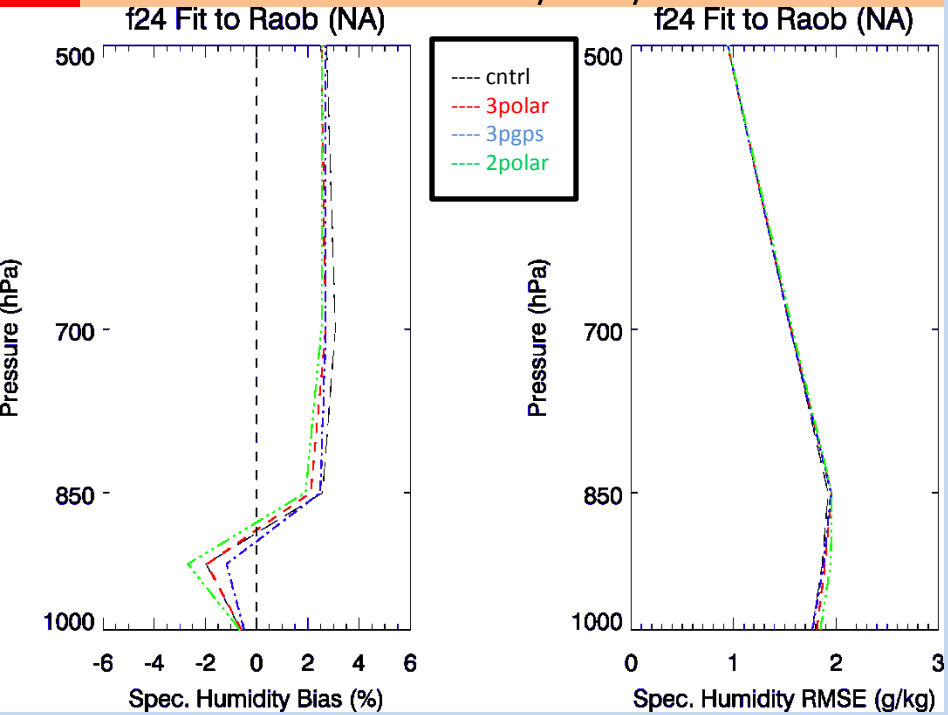


Impacts on Day 1-2 Temperature Forecasts

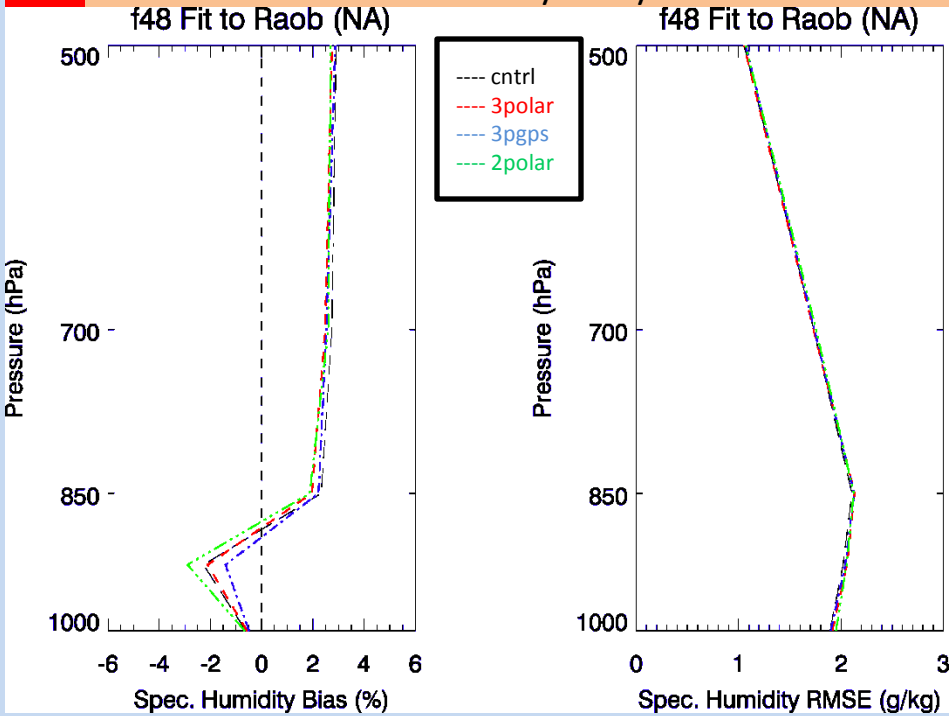
- No impact on temperature forecast when compared to radiosonde over North America for any level of Global Observing System degradation.
- Statistics are similar on a global scale.

Water Vapor Profile vs Radiosonde

24 hr ForecastFit to radiosonde over North America: 5/25-8/7 2014



48 hr ForecastFit to radiosonde over North America: 5/25-8/7 2014

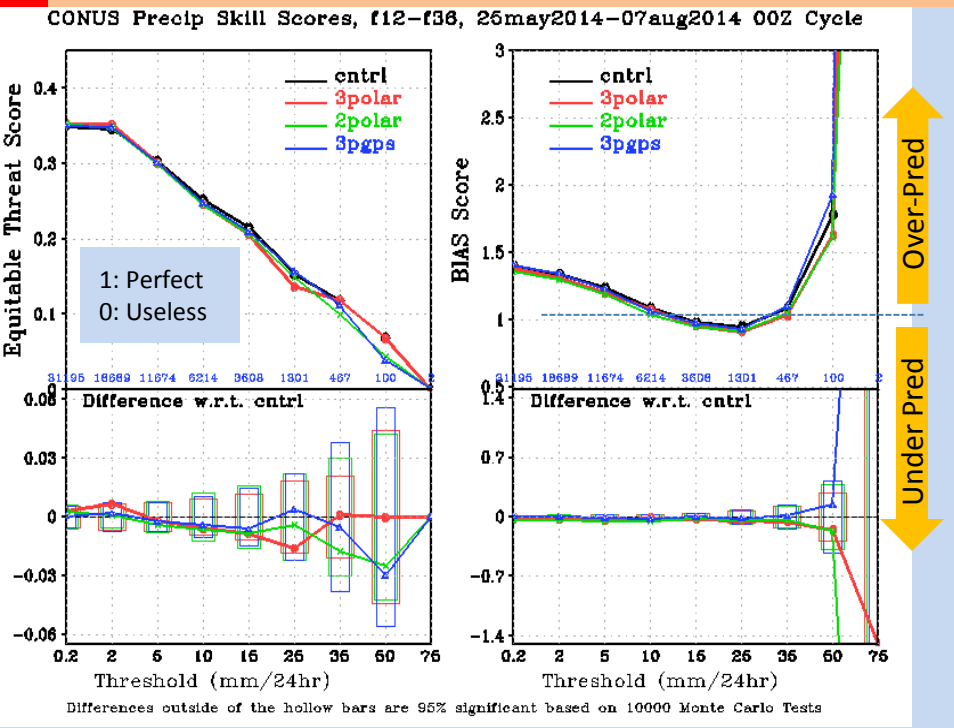


Impacts on Day 1-2 Specific Humidity Forecasts

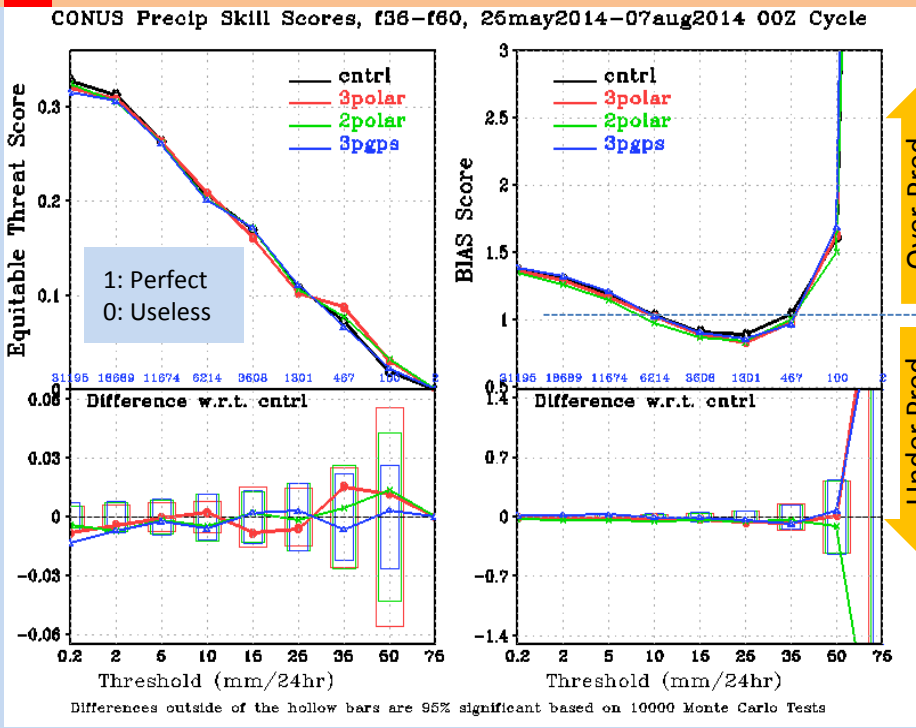
- Small negative impact (increased negative bias) for 2POLAR and 3POLAR specific humidity forecasts (1%) in lower troposphere over North America.
- Statistics are neutral on a global scale.

CONUS Precipitation Scores
Reference: Rain Gauge/Radar

Equitable Threat and Bias Scores 12-36hr Forecast



Equitable Threat and Bias Scores 36-60hr Forecast



12-36 hr Forecast Impact

- Equitable Threat Score shows no significant impact with loss of Polar/GPSRO coverage for precipitation events < 75 mm/24hr.
- Bias Score shows no significant impact with loss of Polar/GPSRO coverage for precipitation events < 75 mm/24hr.

36-60 hr Forecast Impact

- Equitable Threat Score shows slightly less predictability with loss of Polar/GPSRO coverage for precipitation events < 2 mm/24hr.
- Bias Score shows slight under-prediction of precipitation event intensity around 10-15 mm/24hr for 2POLAR, but not significant.

Met Office new global NWP index

- Skill score:
- $S = 1 - r_f^2 / r_p^2$
  - r_f = rms forecast error
  - r_p = rms persistence error
- Weighted as table → S_{mean}
- $N = (1 - S_{mean})^{-½}$
- Index = 100 x N / N_0
- N_0 = value on 31 March 2012

- *April 2013 value = 101.49*
- 1% reduction in r.m.s. error → 1% increase in Index

Weights		Forecast period	
		T+12 – T+72	T+96 & T+120
NH	PMSL	3.2	6.4
	H500	1.2	2.4
	W250	1.2	2.4
TR	W850	1.0	2.0
	W250	0.6	1.2
SH	PMSL	1.6	3.2
	H500	0.6	1.2
	W250	0.6	1.2

The UK Met Office NWP Index is based on global model forecast RMSE of mean sea level pressure, along with height and wind fields at selected atmospheric layers for leads times up to Day 5, normalized by the RMSE of the persistence forecast. The forecast skill score for particular parameters or regions can be weighted depending on their importance: In this case they are equally weighted.

Scorecard
Reference: ECMWF Analysis

3PGPS vs CNTRL

3POLAR configuration with loss of GPSRO coverage

Polar Quasi - redundancy lost and extra-tropical GSPRO degraded

Significance for NWP

- Day 1-3 forecast remains degraded for most parameters (99.9% sig.)
- Day 5-6 forecast has significant degradation (95-99.9% sig.)
- Impact is global (affecting both hemispheres)

			Globe						N. Hemisphere						S. Hemisphere						Tropics					
			Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10	Day 1	Day 3	Day 5	Day 6	Day 8	Day 10
Anomaly Correlation	Heights	250hPa	▼	▼	▾				▼	▼		▾			▼	▼					Not Relevant					
		500hPa	▼	▼	▾				▼	▼		▾			▼	▼										
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	Vector Wind	250hPa	▼	▼	▼	▼			▼	▼					▼	▼		▾								
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	MSLP	MSL		▼						▼		▾			▼	▼										
RMSE	Heights	10hPa	▼	▼	▼	▼			▼	▼	▼	▼			▼	▼	▼	▼			▼	▼	▼	▼		
		20hPa	▼	▼	▼	▼			▼	▼	▼	▼			▼	▼	▼	▼				▼	▼	▼		
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	Vector Wind	10hPa	▼	▼	▼	▼			▼		▼	▼			▼	▼	▼	▼			▼	▼	▼			
		20hPa	▼	▼	▼	▾			▼						▼	▼	▼	▾			▼					
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		20hPa	▼	▼	▼	▼			▼						▼	▼	▼	▼			▼	▼	▼	▼		
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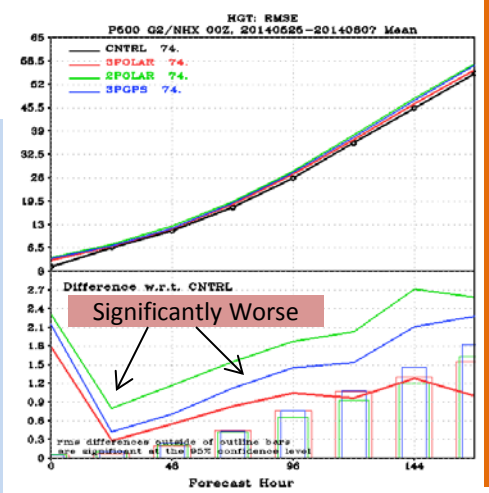
		1000hPa	▼	▼	▼	▾			▾	▾					▼	▼	▾				▼	▼	▼	▼		

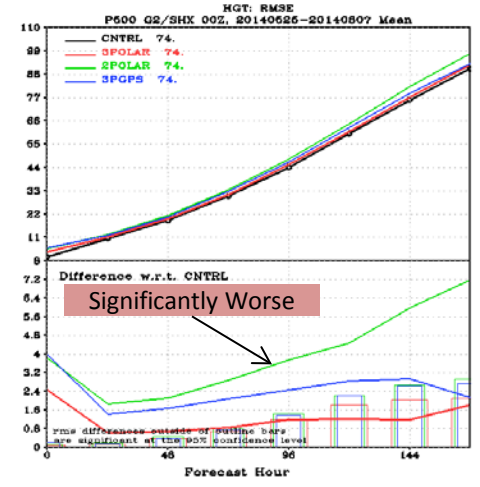
500mb Height Forecast RMSE (vs CNTRL)

MEAN RMSE (m)	CNTRL	3POLAR	2POLAR	3PGPS
NH (top)	35.72	36.68	37.75	37.25
SH (bottom)	59.90	61.11	64.26	62.74

500mb Height RMSE vs Forecast Time



Northern Hemisphere Dieoff (left)

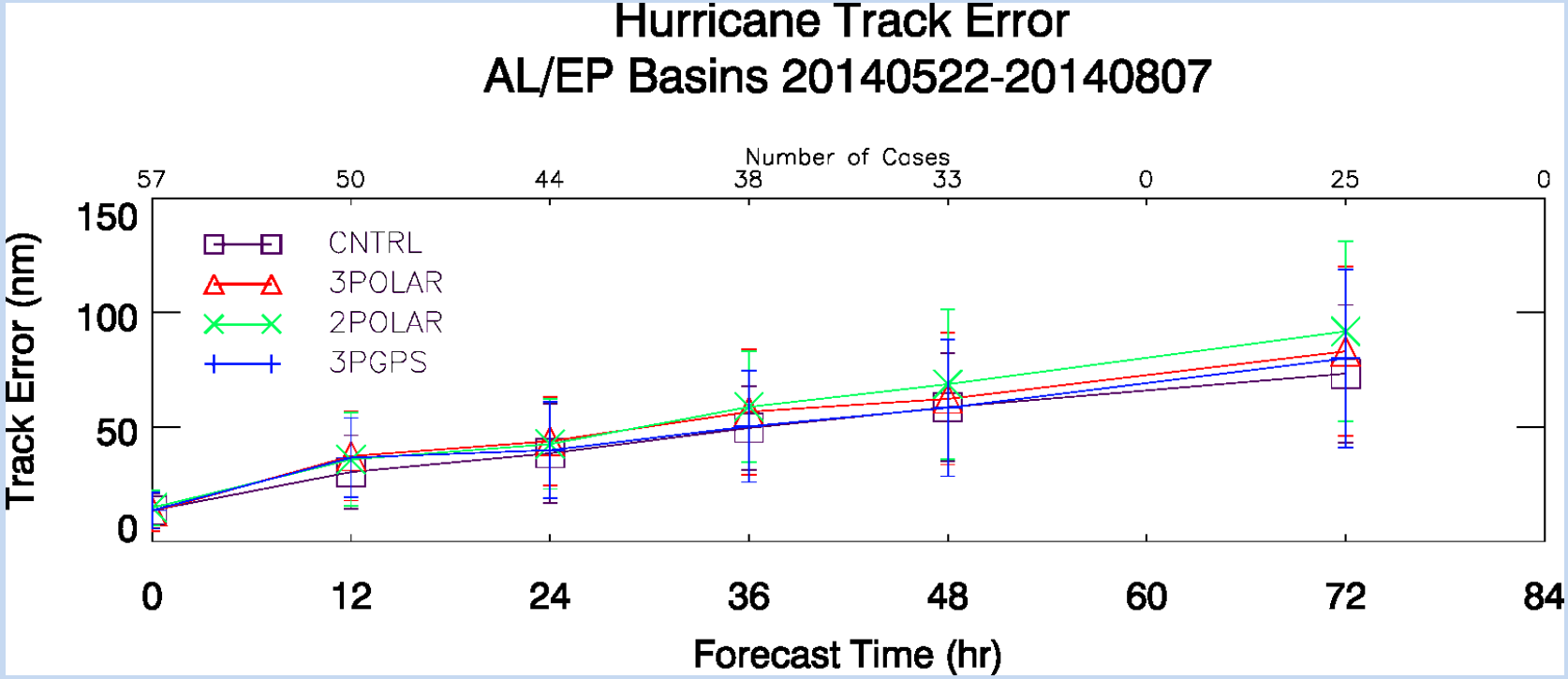


Southern Hemisphere Dieoff (right)

Main Points

- 3POLAR impact mostly neutral except for NH Day 3/4
- 2POLAR 500mb Height forecast shows significant degradation for NH/SH (Day 5 average RMSE: 2m/4.3m worse than CNTRL forecast)
- 3PGPS shows significant degradation for NH/SH, but less negative impact than 2POLAR (Day 5 average RMSE 1.75m/2.8m worse than CNTRL forecast)

Hurricane Statistics
Track Error



East-Pacific Basin Hurricane Stats:

- With respect to the CNTRL track error, **2POLAR** is degraded at 12 hours reaching 10 nm and 18 nm by 48 and 72 hours respectively.
- With respect to the CNTRL track error, **3POLAR** shows similar degradation as 2POLAR up to 36 hours, but is less degraded at 48 and 72 hours.
- 3PGPS performs similar to CNTRL, but is 6 nm degraded at 72 hours.
- Error bars (±1 Standard Deviation) illustrate that degradation from experiments is not statistically significant

More cases needed for Day 4/5 impact

Hurricane Track Performance

Cumulative Track Forecast Score Normalized to the mean CNTRL track error

$$TFS_{Exp} = \frac{\sum_{i=1}^{nfcsts}\sum_{j=1}^{nhr} score_{i,j}}{totalFcsts}$$

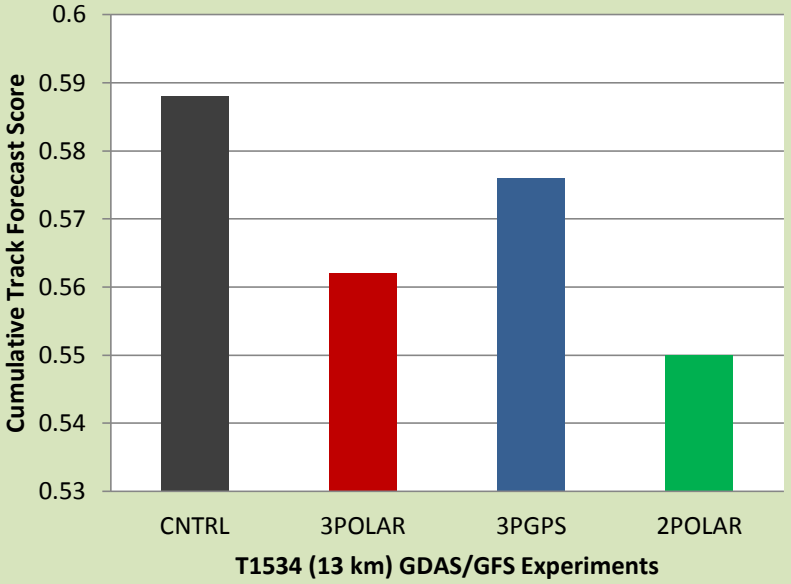
Where *score*$_{i,j}$ is $Score = 0.5 - \frac{(err_{i,j} - mean_j)}{(\max_j - mean_j)} * 0.5$ **for *err*$_{i,j}$ > *mean*$_j$, and**

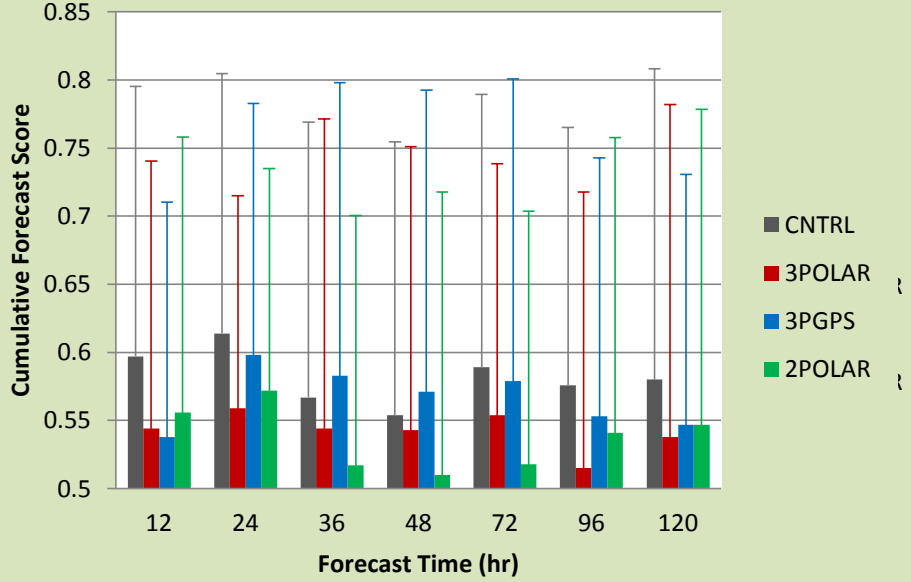
***score*$_{i,j}$ is** $Score = 0.5 + \frac{(mean_j - err_{i,j})}{(mean_j - \min_j)} * 0.5$ **for *err*$_{i,j}$ < *mean*$_j$,**

mean*$_j$** is the mean track error of the CNTRL experiment at lead time ***j; ***err*$_{i,j}$** is the experiment track error for forecast ***i*** at lead time ***j***, and ***min*$_j$** and ***max*$_j$** are the minimum and maximum track error from all experiments at lead time ***j***.

Hurricane Track Performance

Cumulative Track Forecast Score Normalized to the mean CNTRL track error





Cumulative Tropical Cyclone Track Forecast Scores

1). Significant loss of track forecast skill with loss of quasi-redundant polar orbit coverage.
2). Loss of PM Primary (2POLAR) results in further degradation (esp. at 36, 48, 72 hours).
3). Alteration of GPSRO coverage improves track forecasts slightly over 3POLAR.