



A Comparison of Forecast Skills among GFS Four Cycles in the Past Ten Years -- Justification for the 06Z and 18Z Runs

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December 13, 2012

- This presentation is based on the talk I gave at the 2012 NCEP Production Suite Review at NCWCP on December 4-6, 2012. Bill Lapenta asked me to review the GFS 06Z and 18Z forecast skills.
- Additional slides are added to the present talk to address some of the questions and comments I received during and after the production review.

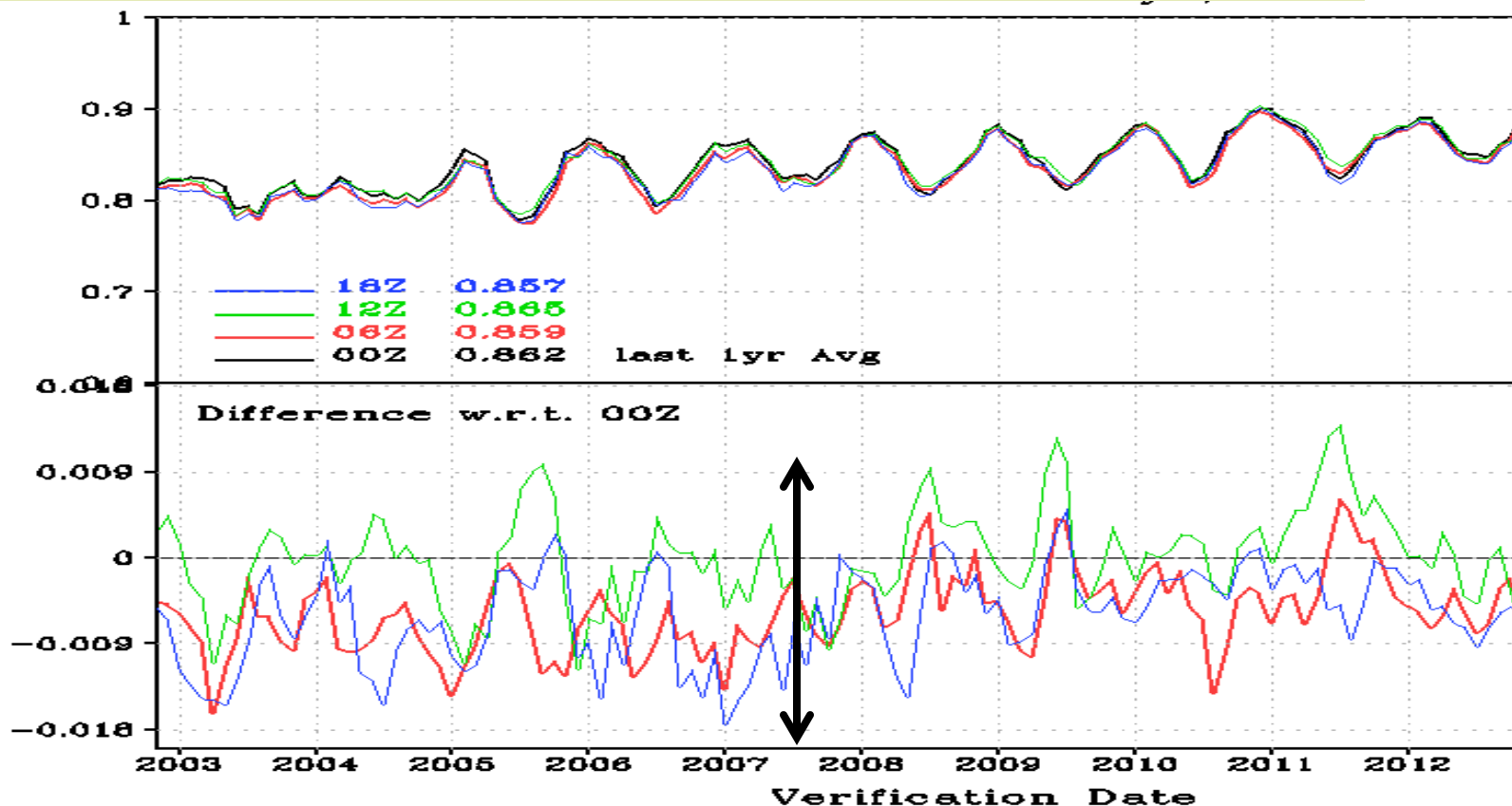
Acknowledgments

1. I wish to thank Krishna Kumar, Russ Treadon, Daryl Kleist, and Xiujuan Su for their assistance in locating conventional and satellite data counts used in this presentation.
2. I thank John Derber, Richard Pasch, Bill Lapenta, Geoff DiMego, and Shrivinas Moorthi for helpful discussion and comments.

Outline

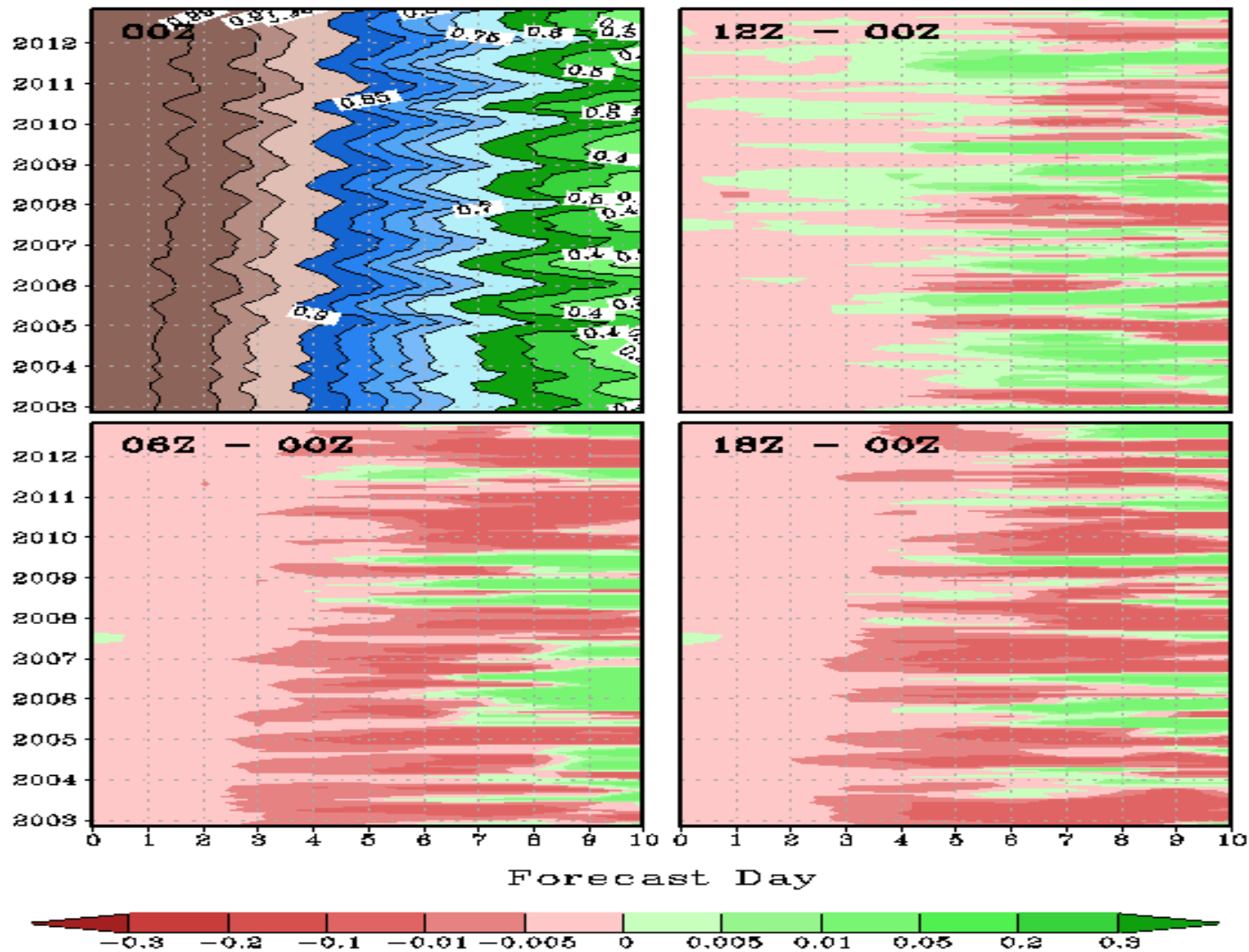
- 1. The forecast skills of GFS four cycles (00Z, 06Z, 12Z and 18Z) for the past 10 years from November 2002 to October 2012 are compared. All forecasts are verified against GFS's own analyses.**
- 2. Conventional and satellite data assimilated in the GFS forecast system are analyzed to understand some of the skill differences among the four cycles.**
- 3. NCEP runs GFS for four cycles per day, while most other centers only run global NWP forecasts for two cycles per day. The usefulness of the GFS 06Z and 18Z cycles is assessed.**
- 4. The difference between the ECMWF 00Z and 12Z cycles is also reviewed.**

GFS NH 500-hPa HGT Monthly Mean Day-5 Anomaly Correlation



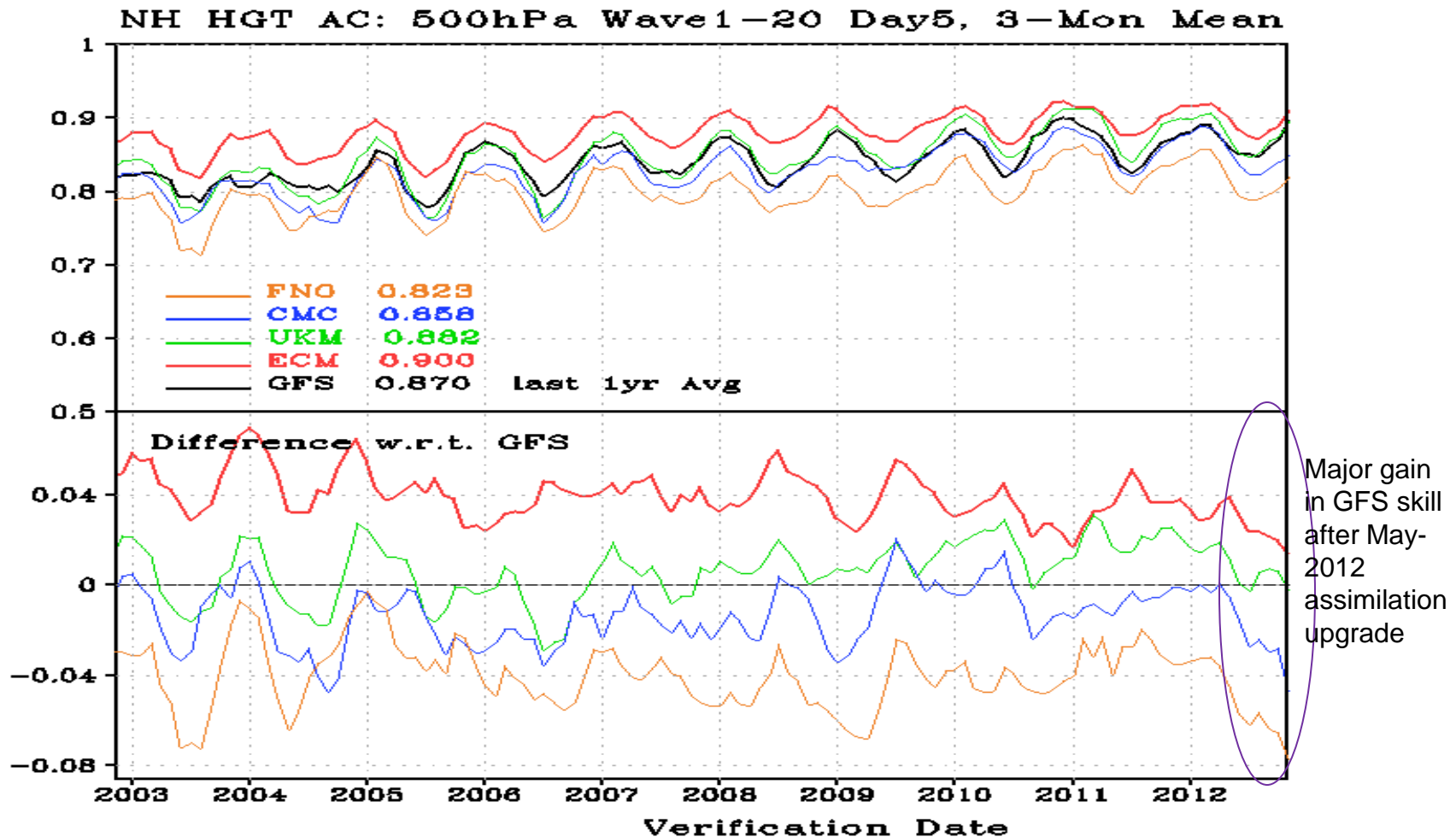
- All cycles have been improved in the past 10 years.
- 12Z cycle is comparable to 00Z cycle.
- 06Z and 18Z cycles are consistently slightly worse than the other two cycles. However, since mid-2007 the gap has been reduced. The GFS was upgraded from sigma to sigma-p vertical coordinate and from SSI to GSI data assimilation technique in May 2007.

GFS NH 500-hPa HGT AC for all forecast hours



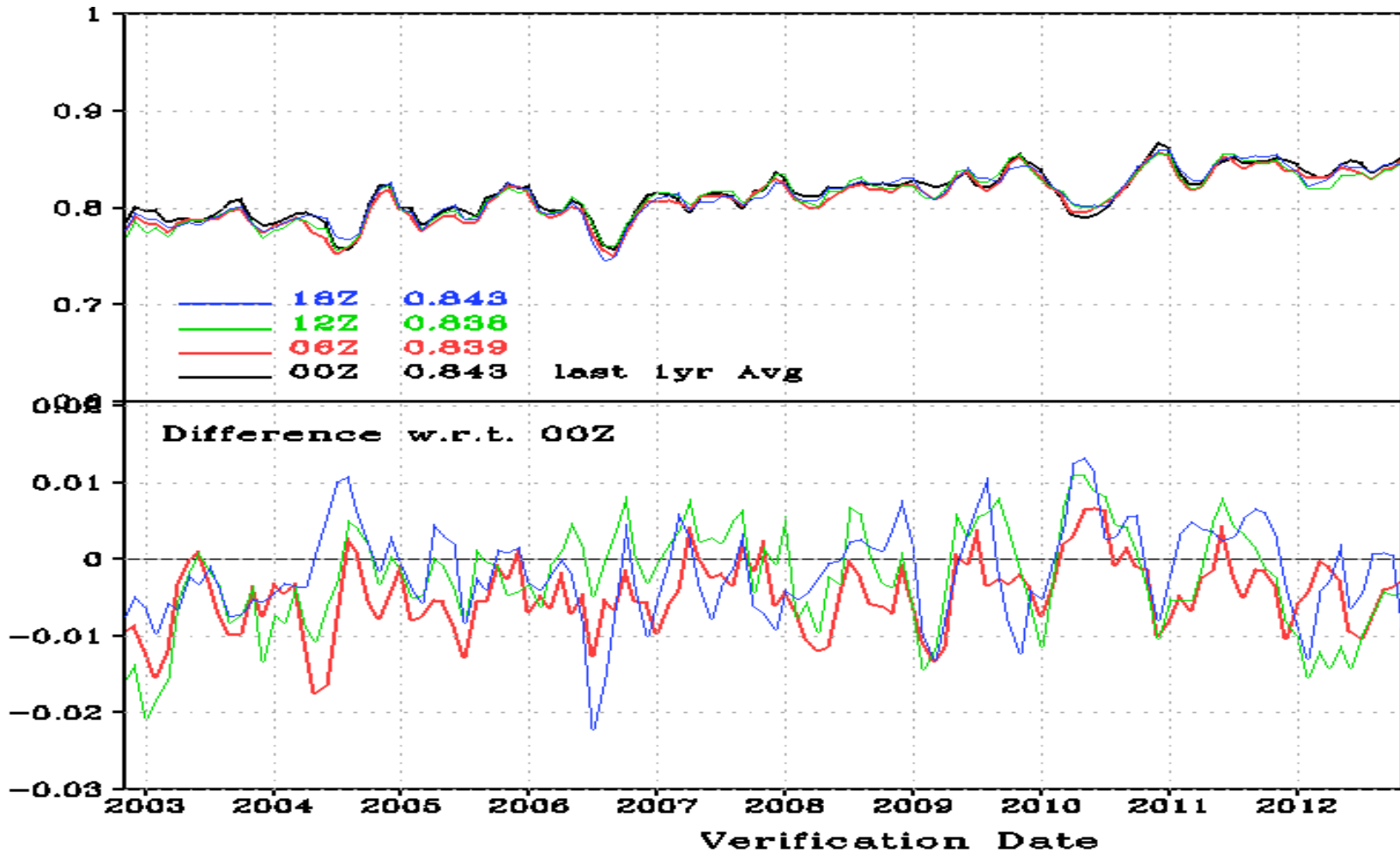
- 12Z and 00Z cycles are comparable.
- 06Z and 18Z cycles are worse than the 00Z and 12Z cycles for all forecast hours

International NWP Models, NH 500-hPa HGT Monthly Mean Day-5 AC



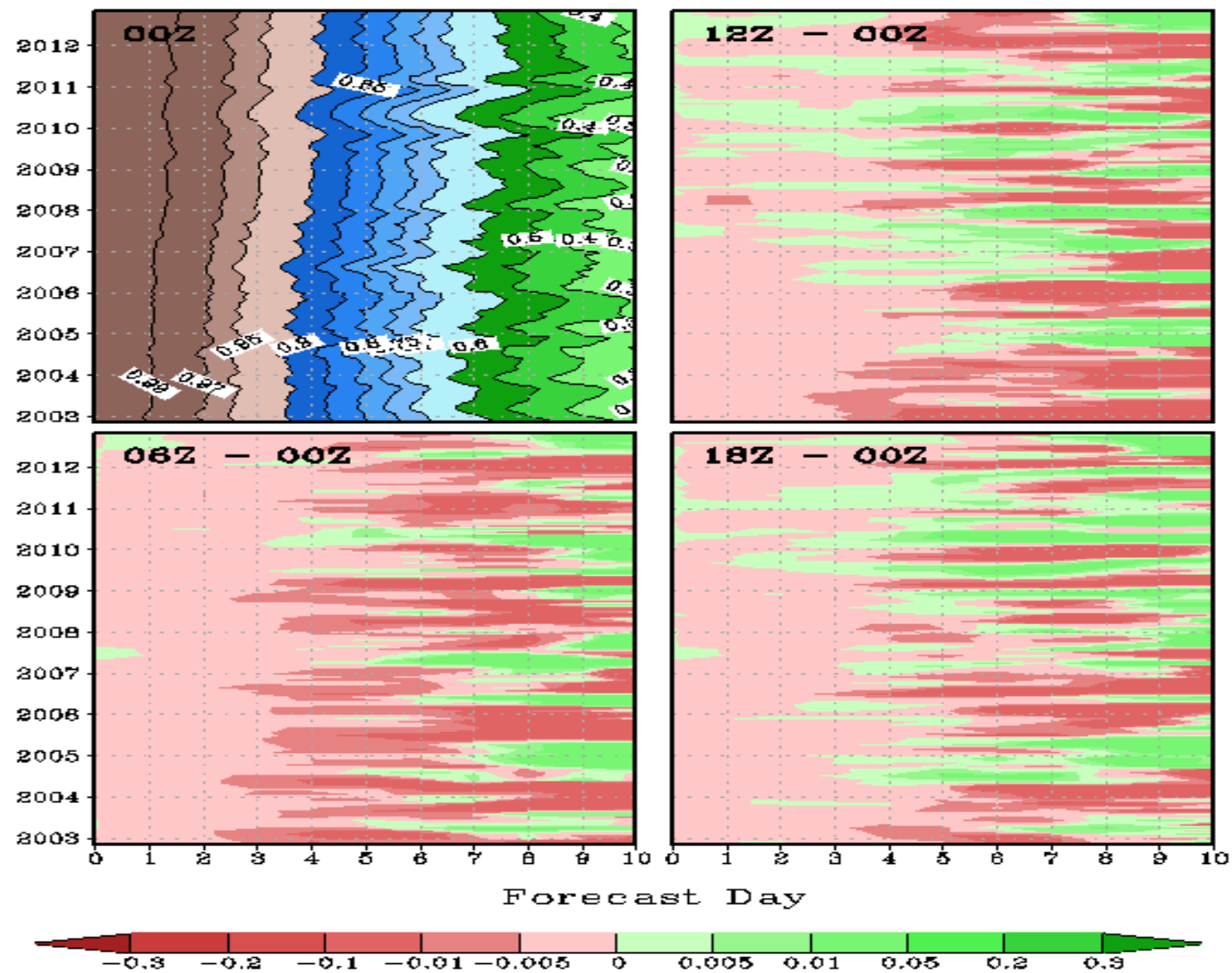
The differences among the GFS four cycles [-0.018 to 0.009] are much smaller (five times) than that among different NWP models [-0.08 to 0.05].

SH 500-hPa HGT Monthly Mean Day-5 AC



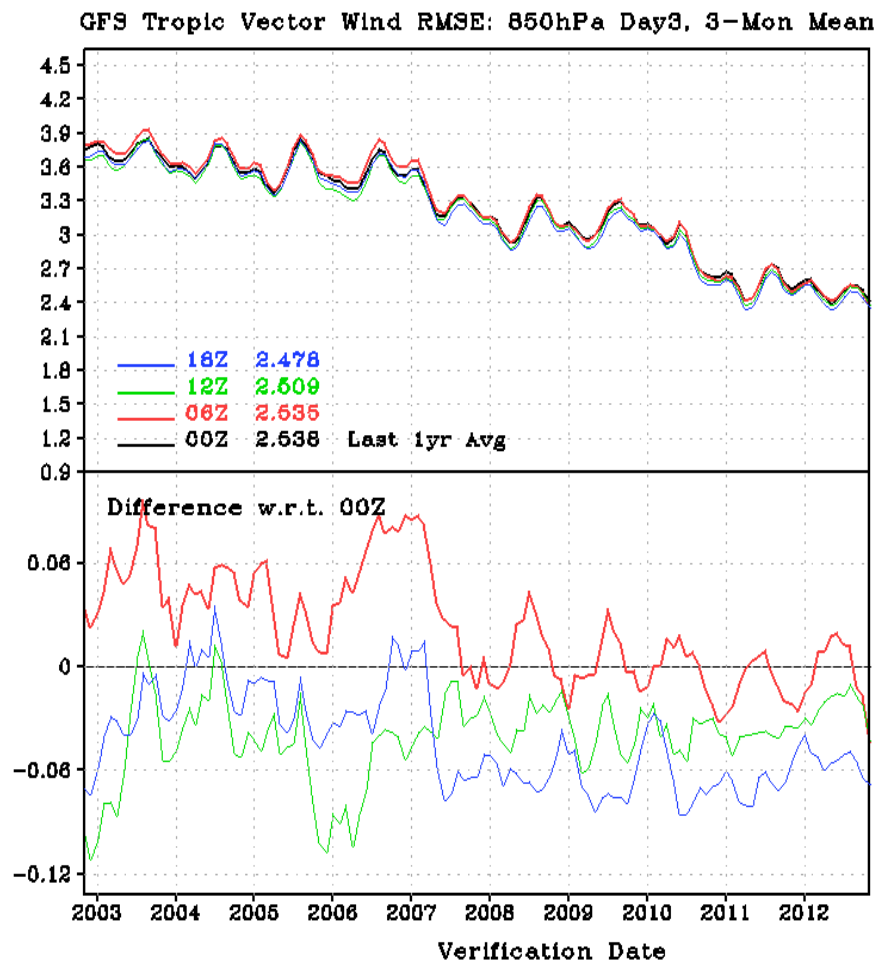
- All cycles have been improved in the past 10 years.
- The 06Z, 12Z and 18Z cycles are slightly worse than the 00Z cycle for most of the time.

SH 500-hPa HGT AC for all forecast hours

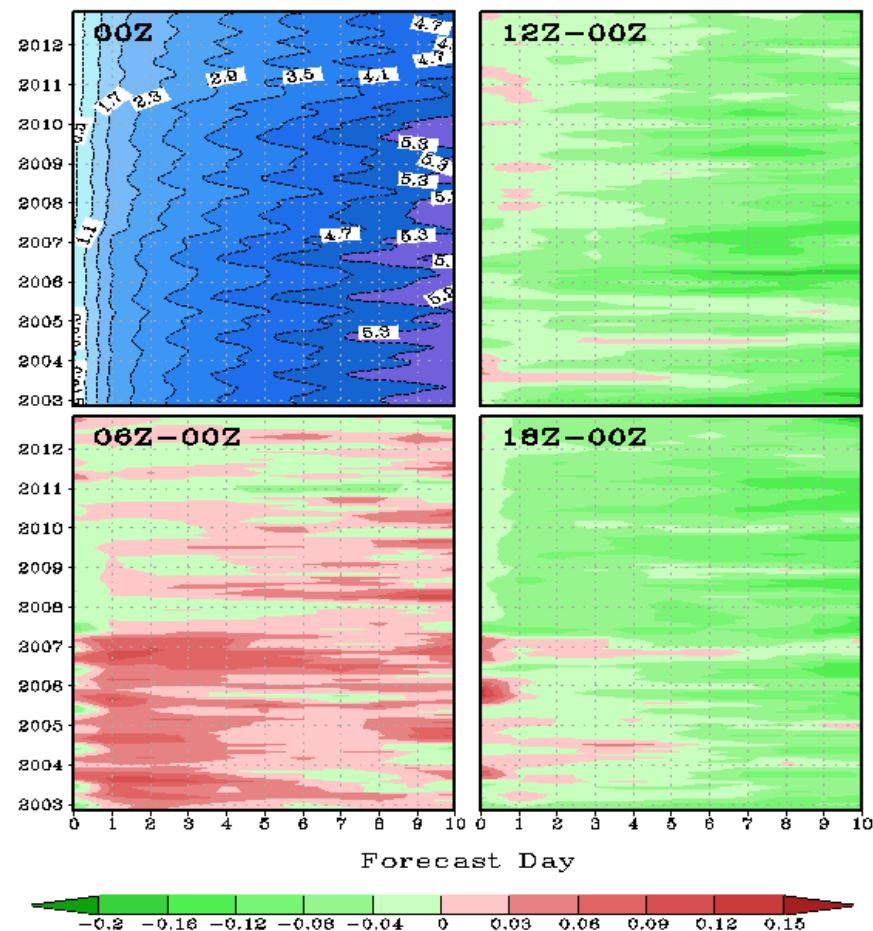


- **00Z the best, 06Z the least skillful**

Tropical Wind RMSE, 850 hPa



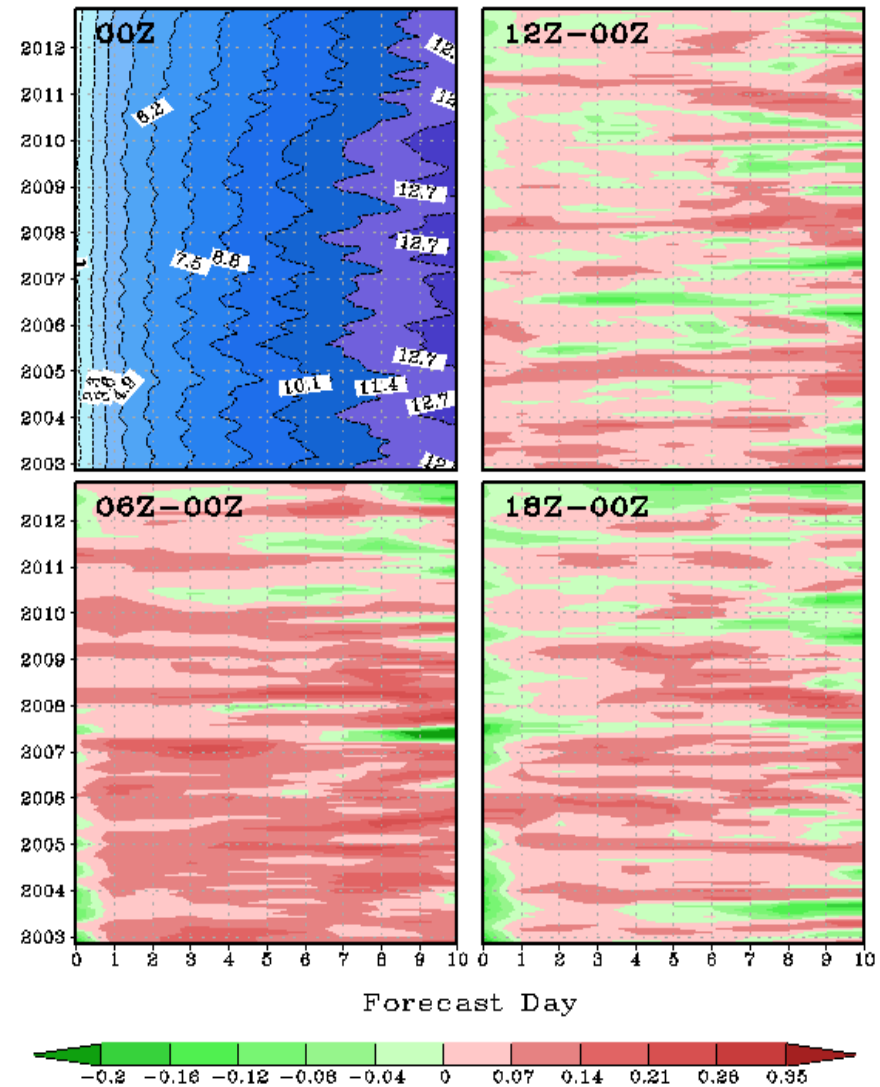
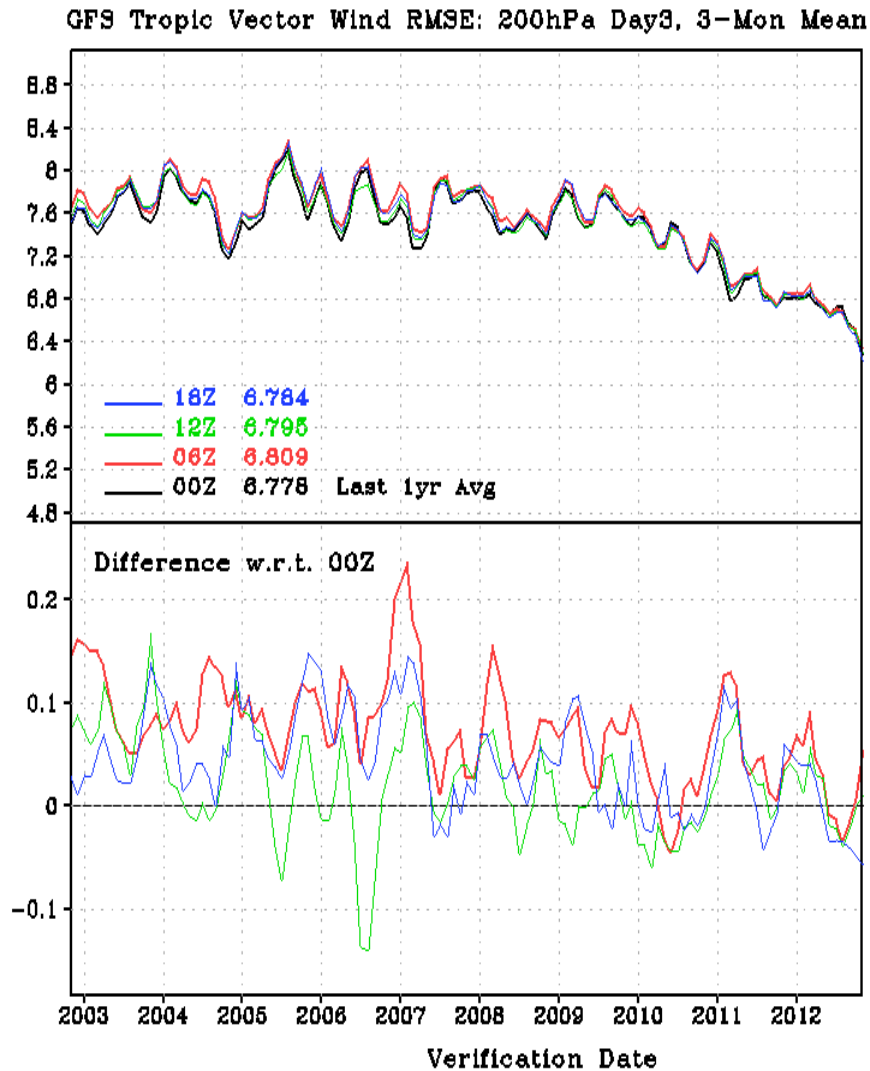
GFS Tropic 850hPa Vector Wind RMSE, 3-Mon Mean



- 06Z cycle was much worse than the other three cycles before 2007, and has been greatly improved since the May-2007 model upgrade (GSI & hybrid coordinate).
- 12Z and 18Z cycles are better than 00Z cycle (for reasons unknown).

Tropical Wind RMSE, 200 hPa

GFS Tropic 200hPa Vector Wind RMSE, 3-Mon Mean



- 00Z cycle is better than all other cycles. 06Z cycle is less skillful

Findings

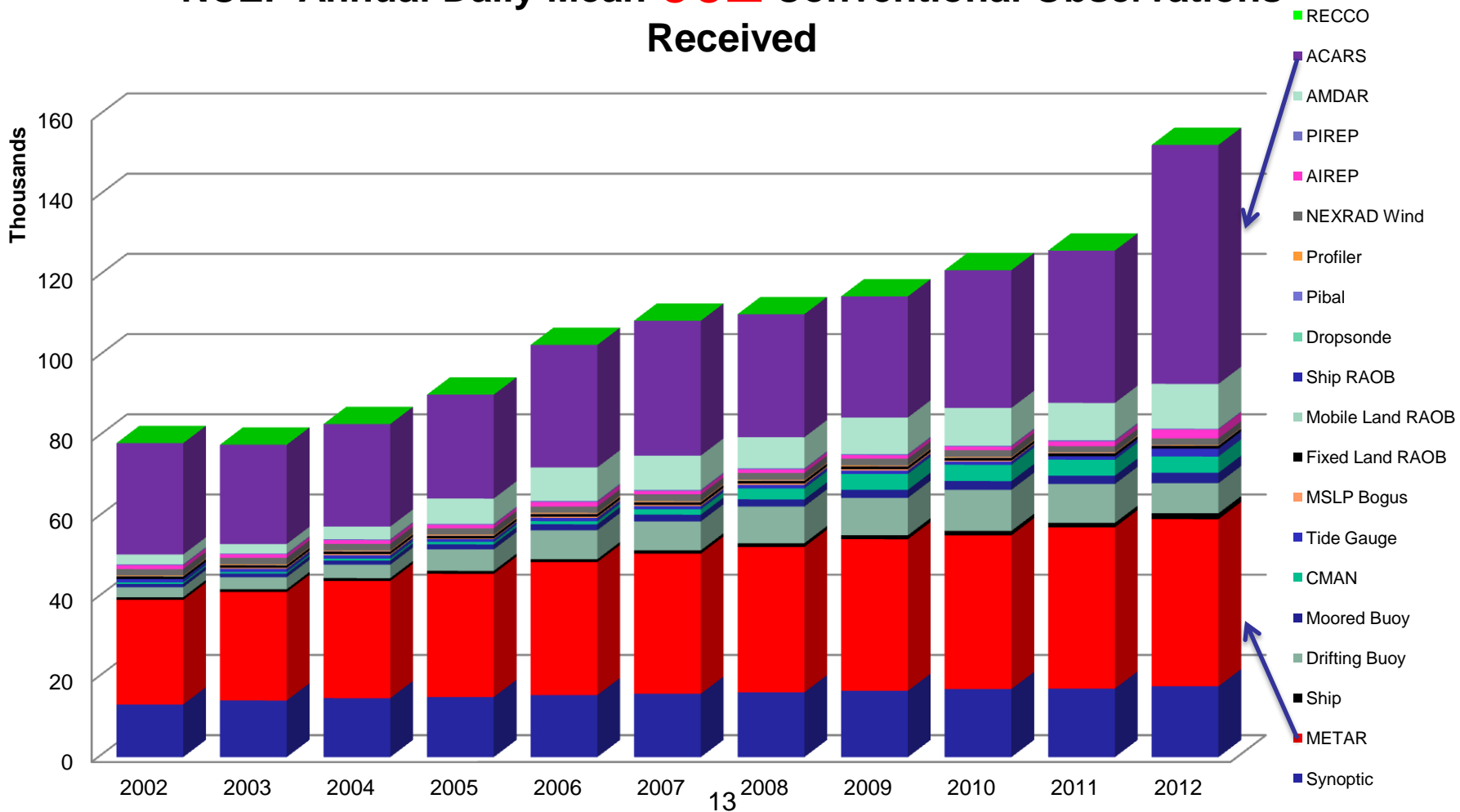
- **Overall, the difference in forecast skills among the GFS four cycles is much smaller than that among different NWP models.**
- **GFS 00Z cycle is the best in all category except for tropical wind in the lower troposphere.**
- **GFS 06Z cycle seems to be the least skillful cycle. 18Z cycle is also slightly worse than 00Z and 12Z cycles.**

Questions

- 1. Are the differences in forecast skills correlated to the number of observations ingested in the data assimilation system?**
- 2. Since the forecast skills of 06Z and 18Z cycles are not as good as the 00Z and 12Z cycles, what is the benefit for running these two extra cycles?**
- 3. Why the 00Z cycle has worse tropical wind in the lower troposphere than the other cycles ?**

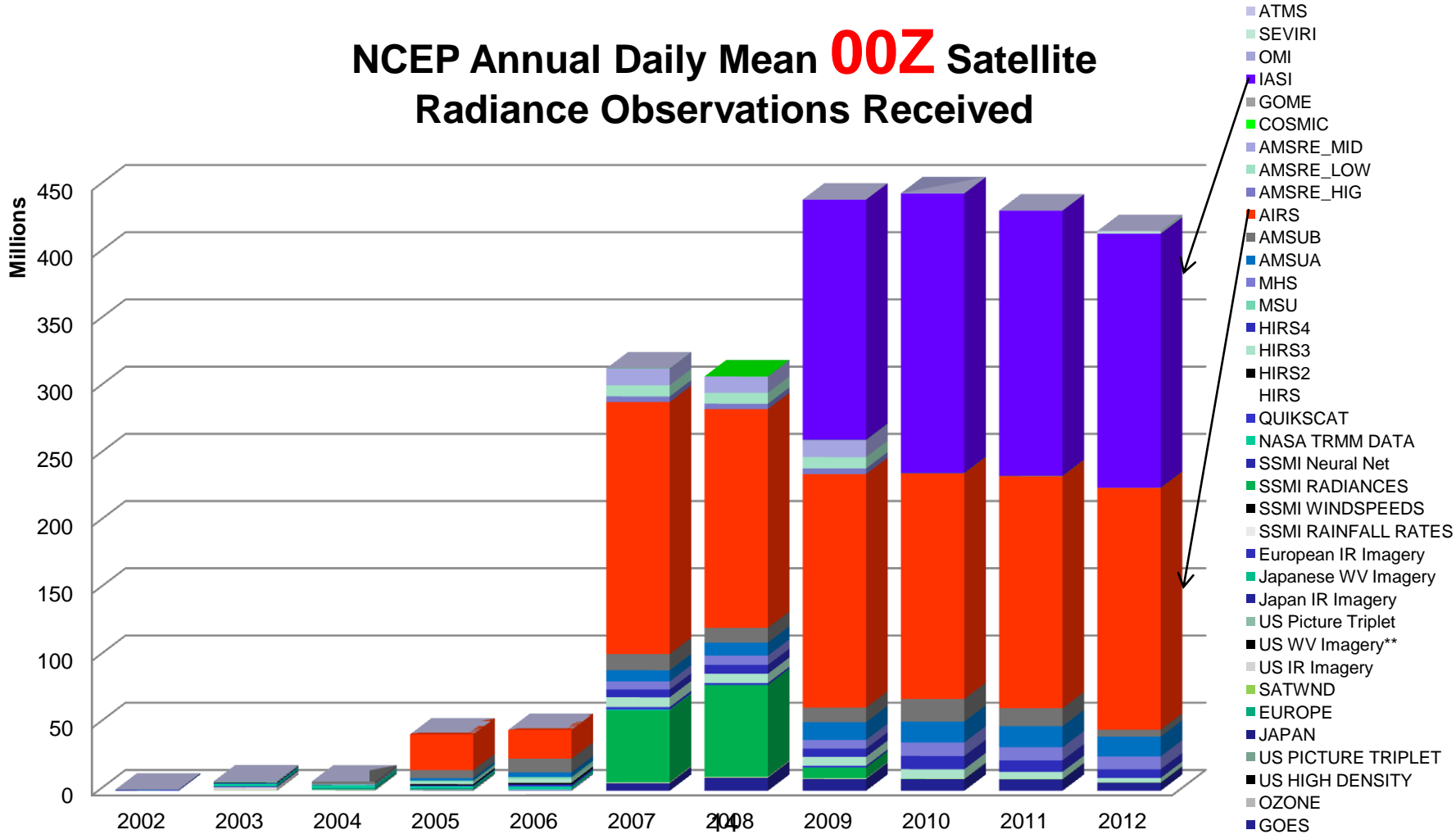
Conventional Data Received

NCEP Annual Daily Mean **00Z** Conventional Observations Received



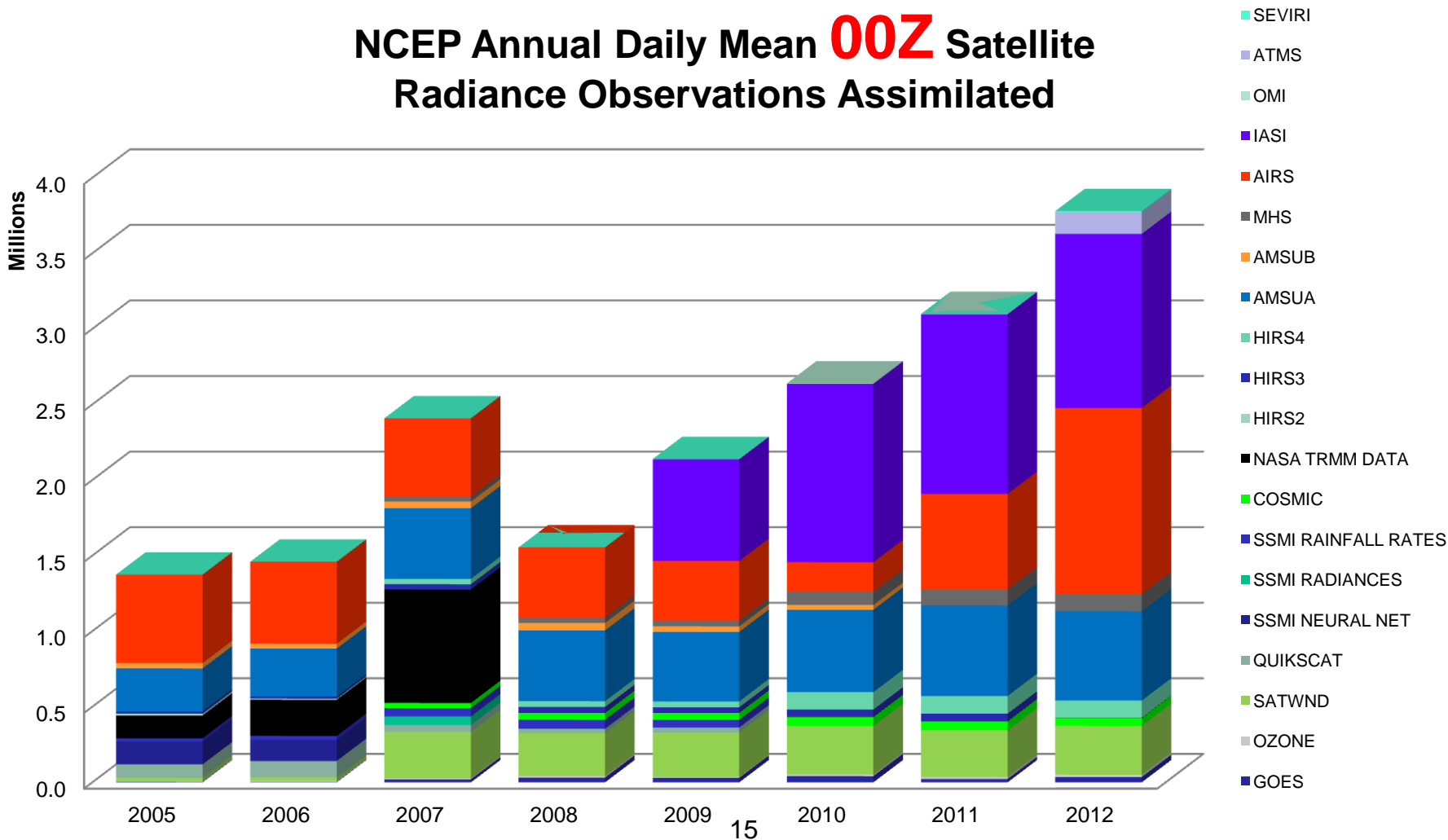
Non-Conventional Data Received

NCEP Annual Daily Mean **00Z** Satellite Radiance Observations Received

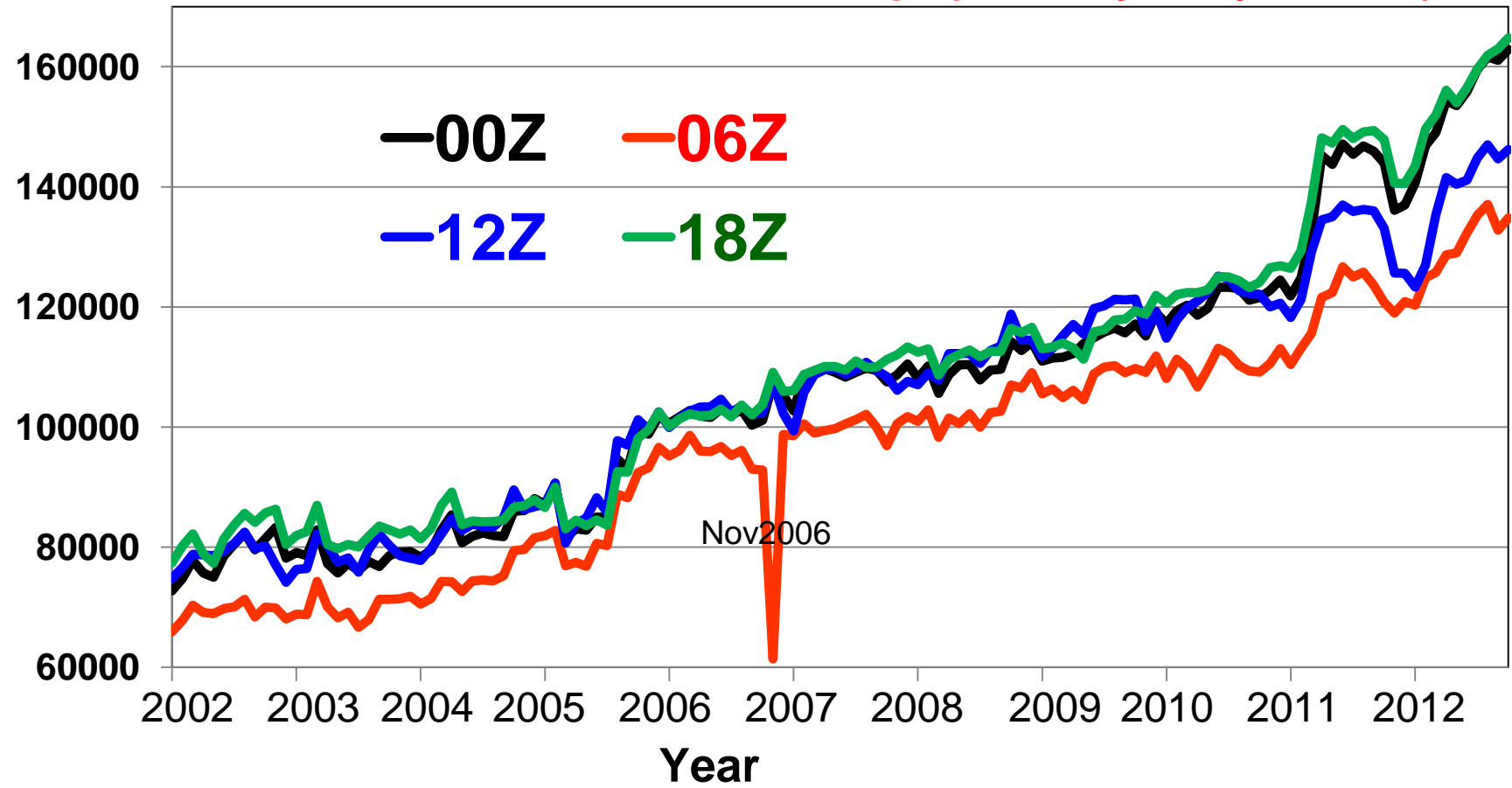


Non-Conventional Assimilated Data

NCEP Annual Daily Mean **00Z** Satellite Radiance Observations Assimilated

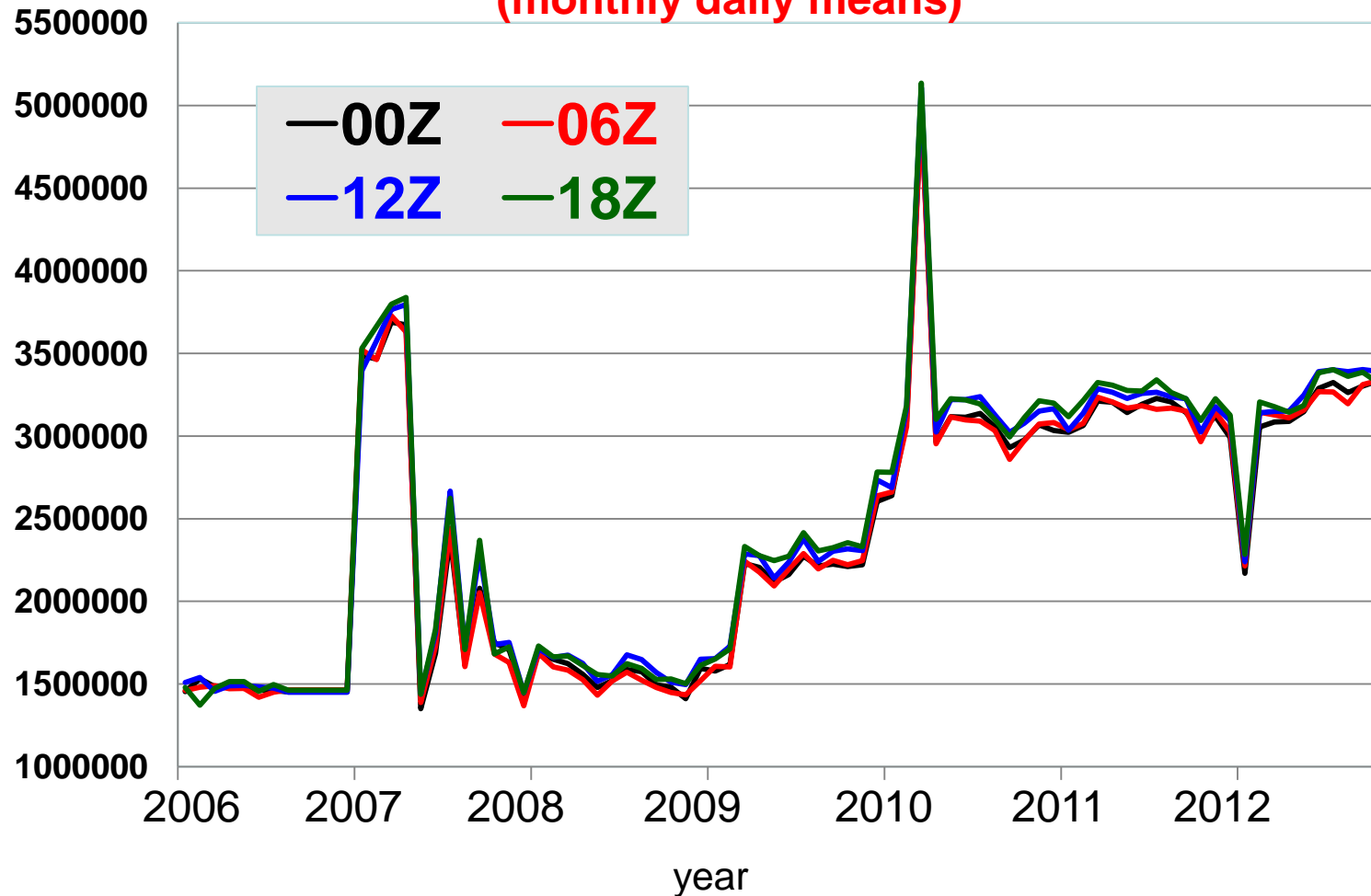


Counts of Conventional Data Received in NCEP GDAS Data Dump (monthly daily means)



- **06Z data count is always about 10% less (primarily ACARS) than other cycles.**
- **The counts for 00Z , 12Z and 18Z are similar except that after March 2011 the 12Z count started to deviate from the 00Z and 18Z cycles.**

Count of Satellite Data Received in NCEP GDAS (monthly daily means)



- **No significant difference in the number of satellite data assimilated in the GFS forecast system among the four cycles.**

Question 1

Are the differences in forecast skills correlated to the number of observations ingested in data assimilation?

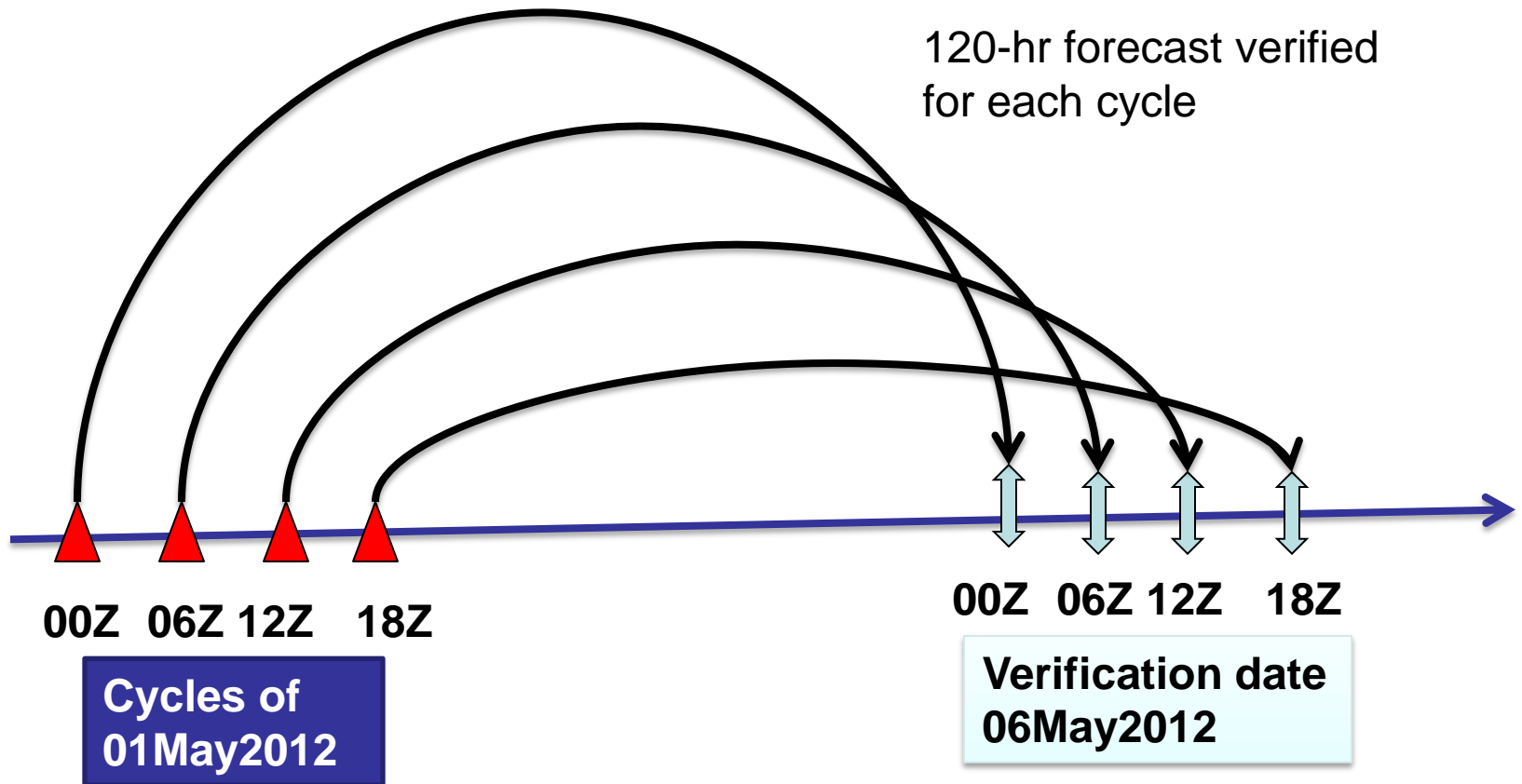
Answer

- **The relatively worse skill of the 06Z cycle can be explained in part by lower data count of conventional observations (primarily ACARS).**
- ***Conventional data are important.***
- **The importance of conventional data can be better quantified by carrying out data denial experiments.**

Questions:

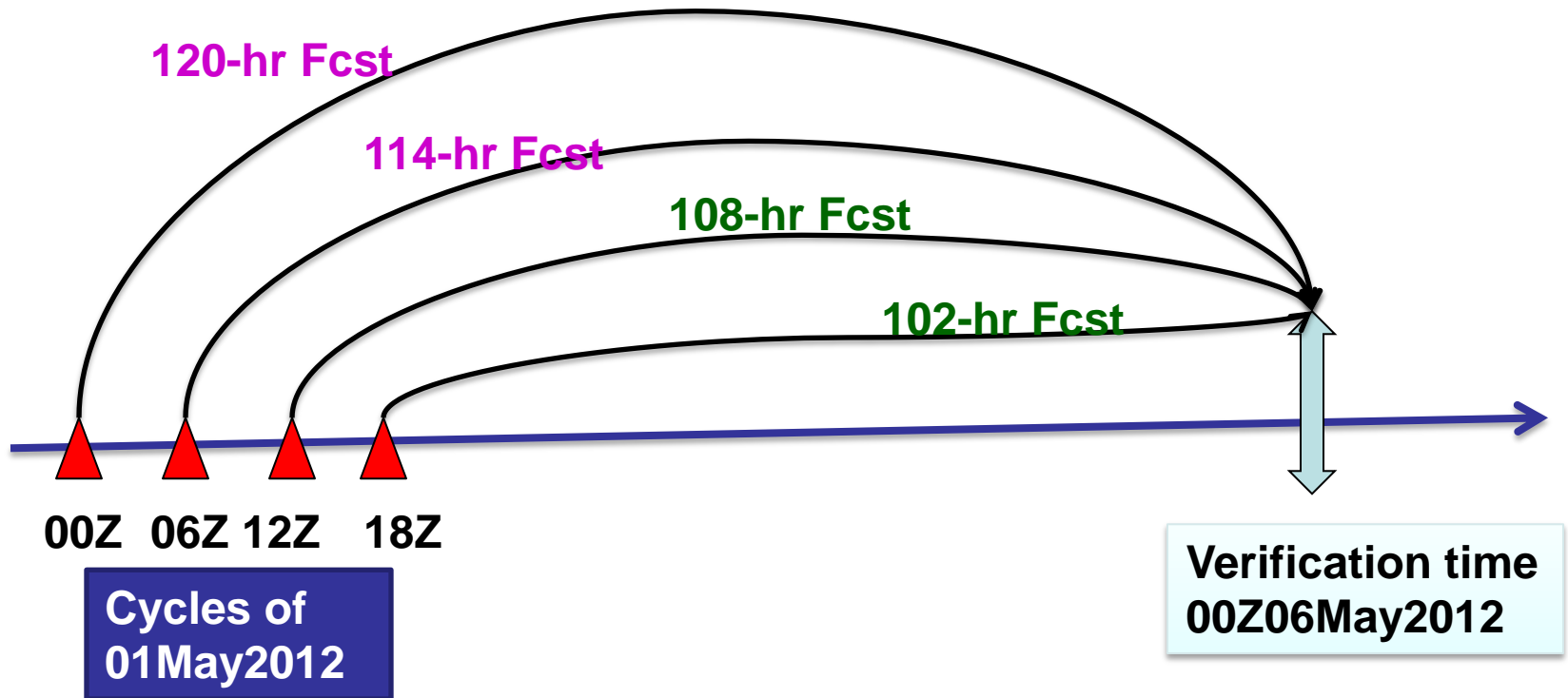
1. Are the differences in forecast skills correlated to the number of observations ingested in the data assimilation system?
- 2. Since the forecast skills of 06Z and 18Z cycles are not as good as the 00Z and 12Z cycles, what is the benefit for running these two extra cycles?**
3. Why the 00Z cycle has worse tropical wind in the lower troposphere than the other cycles ?

NCEP EMC Routine Verification



- Equal forecast length verification, fair for all cycles.
- Forecast output at 24-hour interval are used for verification.

Amended Verification Statistics



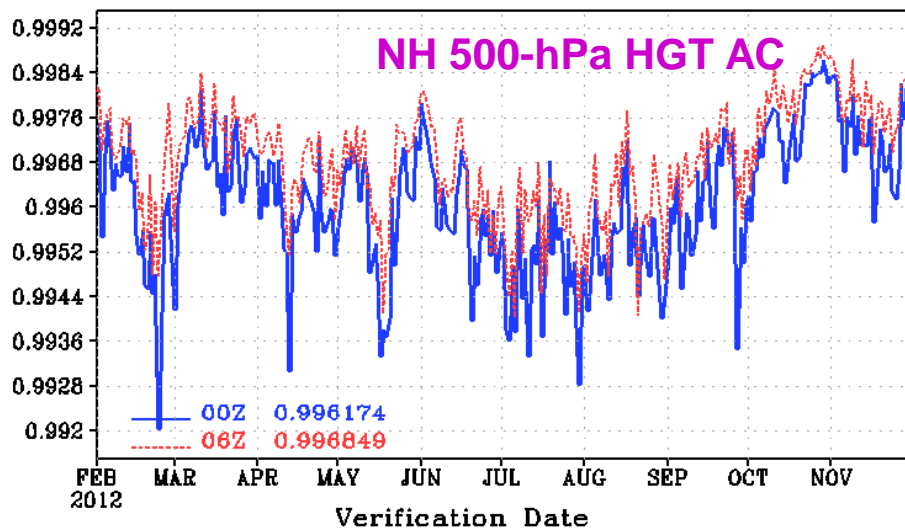
Q: Is the 06Z 114-hr forecast better than the 00Z 120-hr forecast?

Q: Is 18Z 102-hr forecast better than the 12Z 108-hr forecast?

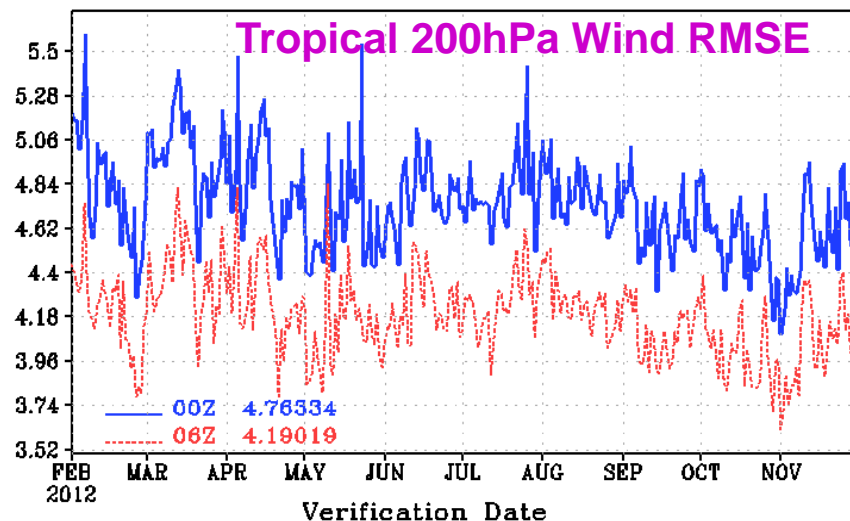
In the following, verification stats computed for every 6-hour forecasts for the period from 01 February 2012 to 30 November 2012 are used to address this question.

day-1: The 06Z 18-hr fcst is **always better** than the 00Z 24-hr fcst.

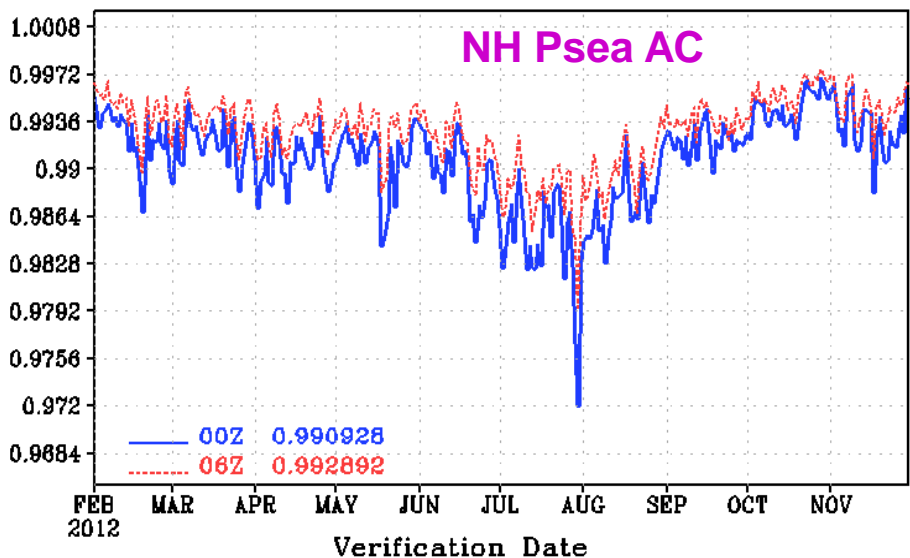
GFS NHX 500-hPa HGT Anomaly Correlation
06Z Cycle 18hr Fcst v.s. 00Z Cycle 24hr Fcst



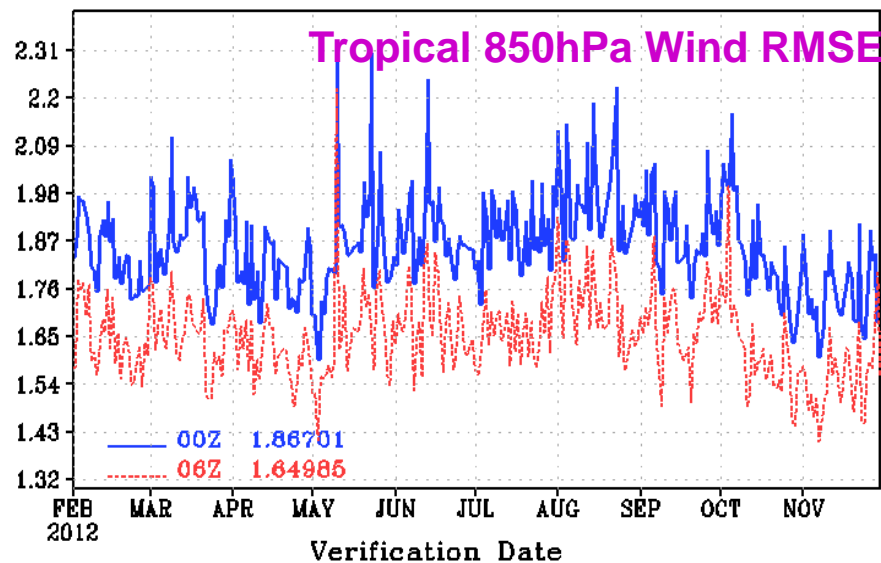
GFS Tropical 200-hPa Vector Wind RMSE (m/s)
06Z Cycle 18hr Fcst v.s. 00Z Cycle 24hr Fcst



GFS NHX Sea-Level Pressure Anomaly Correlation
06Z Cycle 18hr Fcst v.s. 00Z Cycle 24hr Fcst

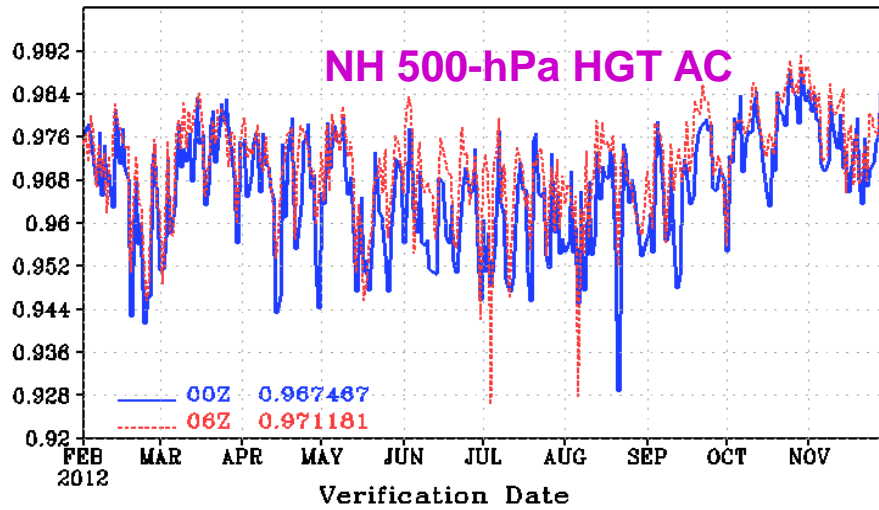


GFS Tropical 850-hPa Vector Wind RMSE (m/s)
06Z Cycle 18hr Fcst v.s. 00Z Cycle 24hr Fcst

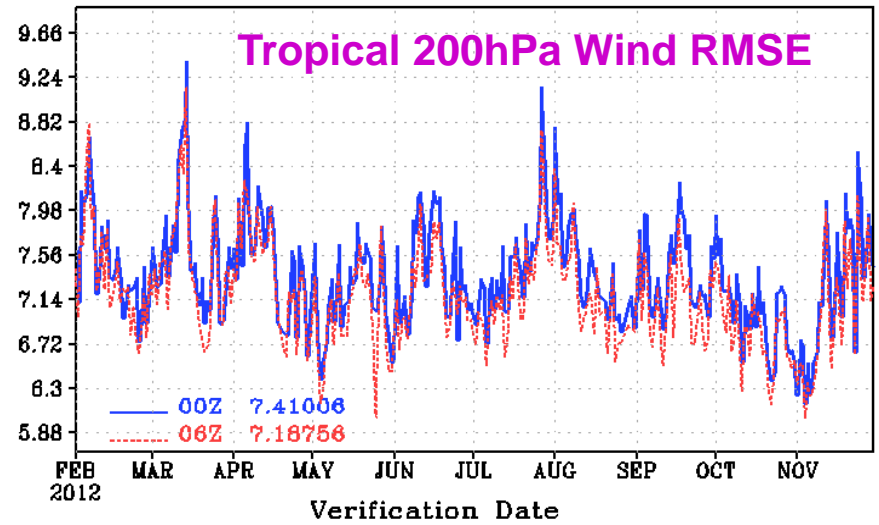


day-3: The 06Z 68-hr fcst is **mostly better** than the 00Z 72-hr fcst.

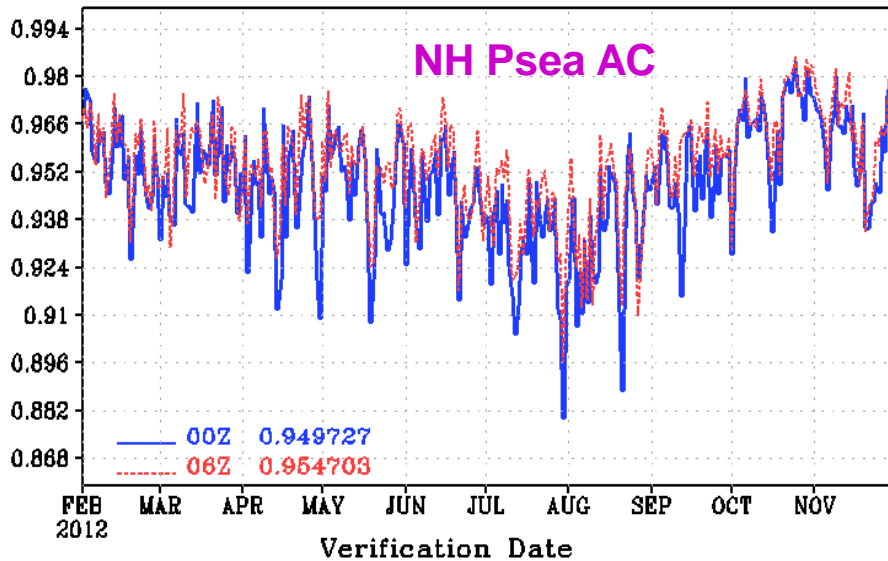
GFS NHX 500-hPa HGT Anomaly Correlation
06Z Cycle 68hr Fcst v.s. 00Z Cycle 72hr Fcst



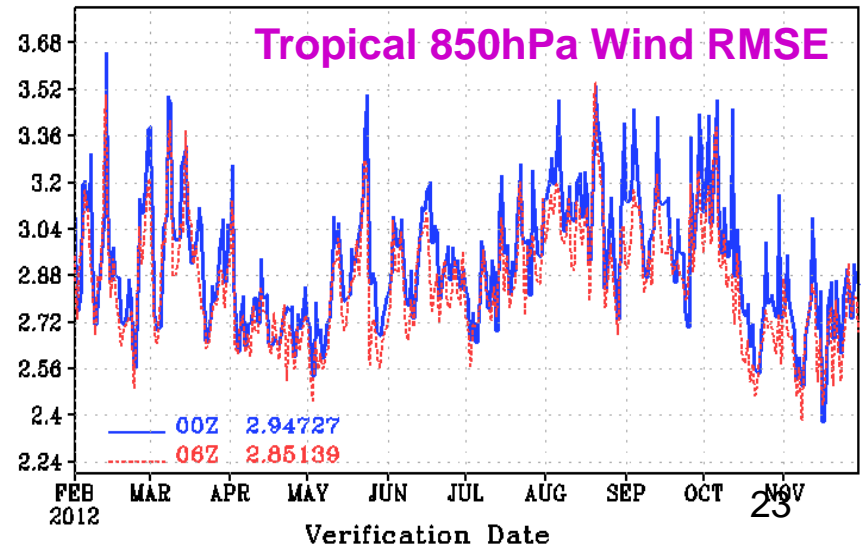
GFS Tropical 200-hPa Vector Wind RMSE (m/s)
06Z Cycle 68hr Fcst v.s. 00Z Cycle 72hr Fcst



GFS NHX Sea-Level Pressure Anomaly Correlation
06Z Cycle 68hr Fcst v.s. 00Z Cycle 72hr Fcst

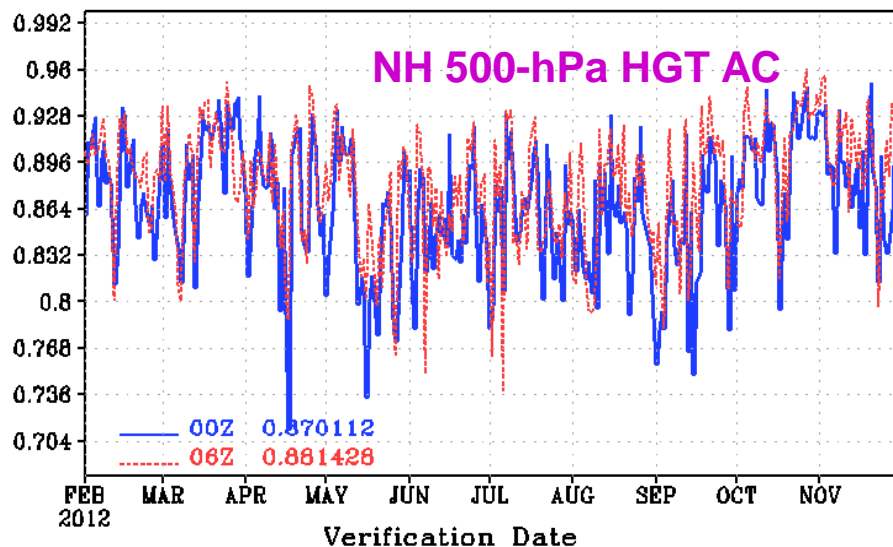


GFS Tropical 850-hPa Vector Wind RMSE (m/s)
06Z Cycle 68hr Fcst v.s. 00Z Cycle 72hr Fcst

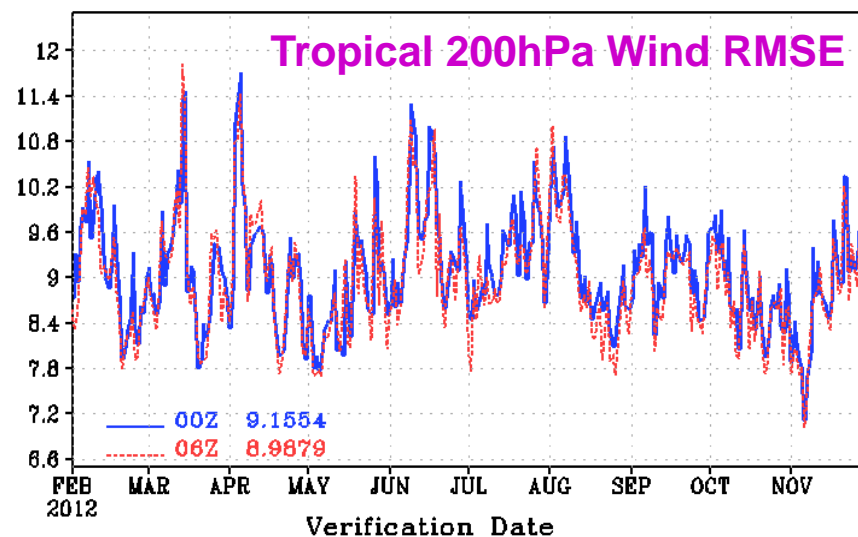


day-5: 06Z 114-hr fcst is **equally better or worse** than 00Z 120-hr fcst.

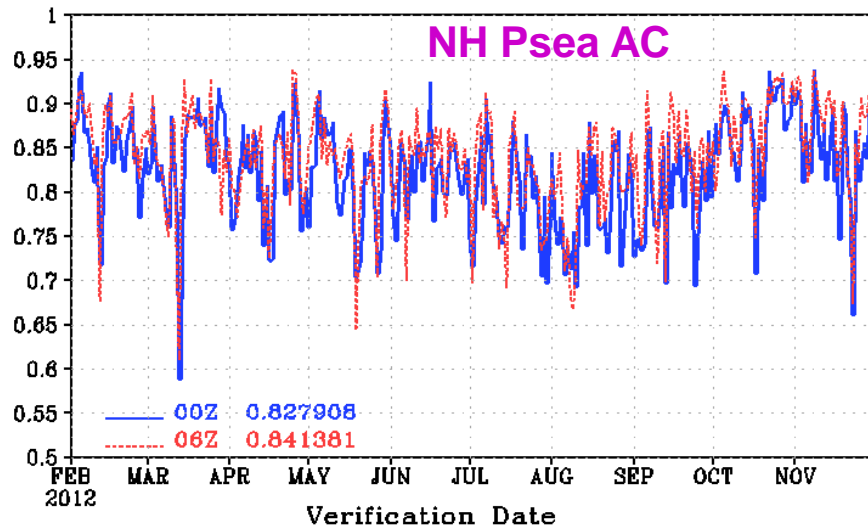
GFS NHX 500-hPa HGT Anomaly Correlation
06Z Cycle 114hr Fcst v.s. 00Z Cycle 120hr Fcst



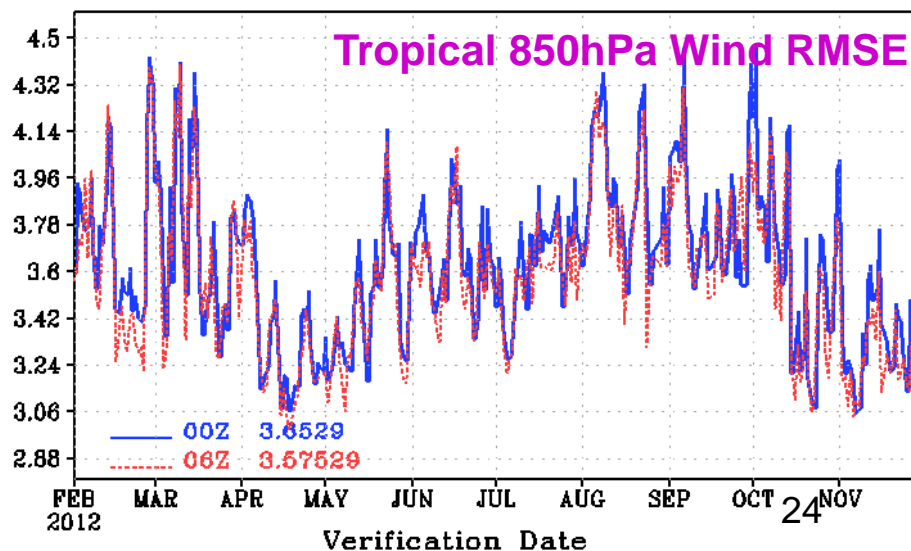
GFS Tropical 200-hPa Vector Wind RMSE (m/s)
06Z Cycle 114hr Fcst v.s. 00Z Cycle 120hr Fcst



GFS NHX Sea-Level Pressure Anomaly Correlation
06Z Cycle 114hr Fcst v.s. 00Z Cycle 120hr Fcst

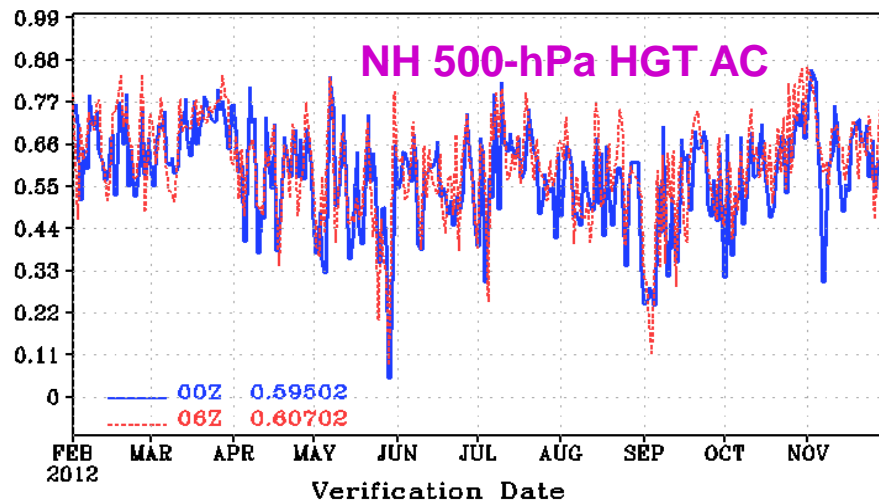


GFS Tropical 850-hPa Vector Wind RMSE (m/s)
06Z Cycle 114hr Fcst v.s. 00Z Cycle 120hr Fcst

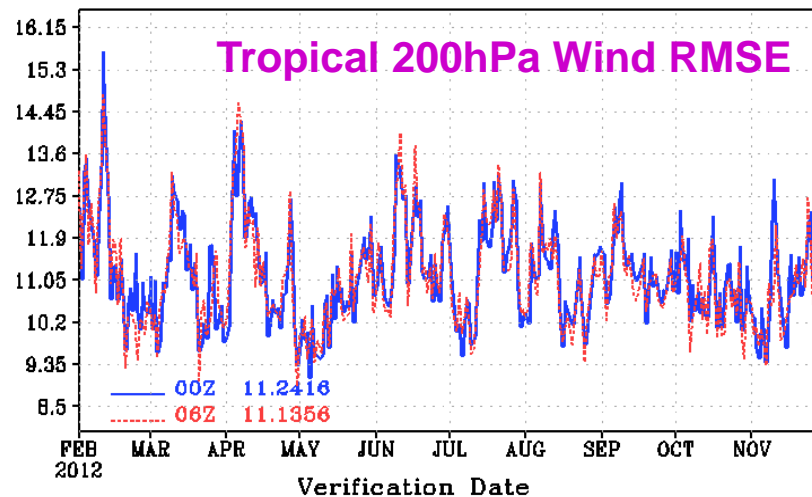


day-8: 06Z 186-hr fcst is **not different from** 00Z 192-hr fcst.

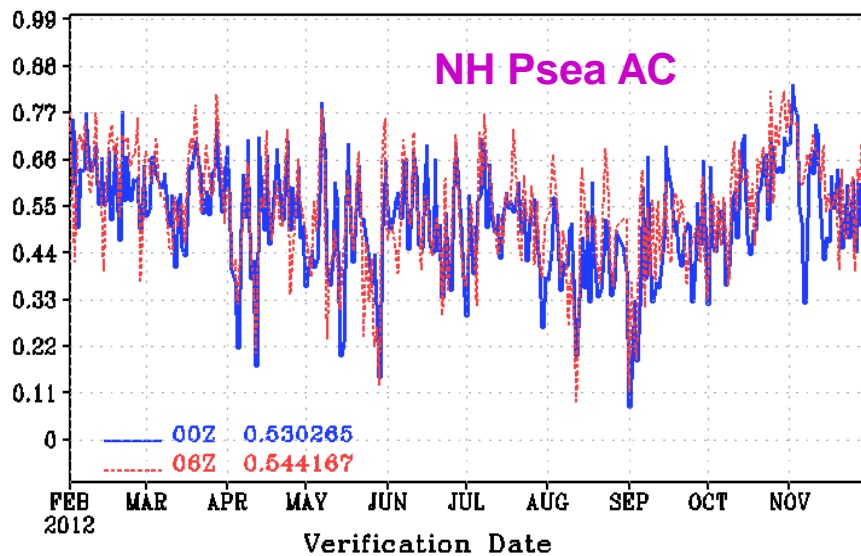
GFS NHX 500-hPa HGT Anomaly Correlation
06Z Cycle 186hr Fcst v.s. 00Z Cycle 192hr Fcst



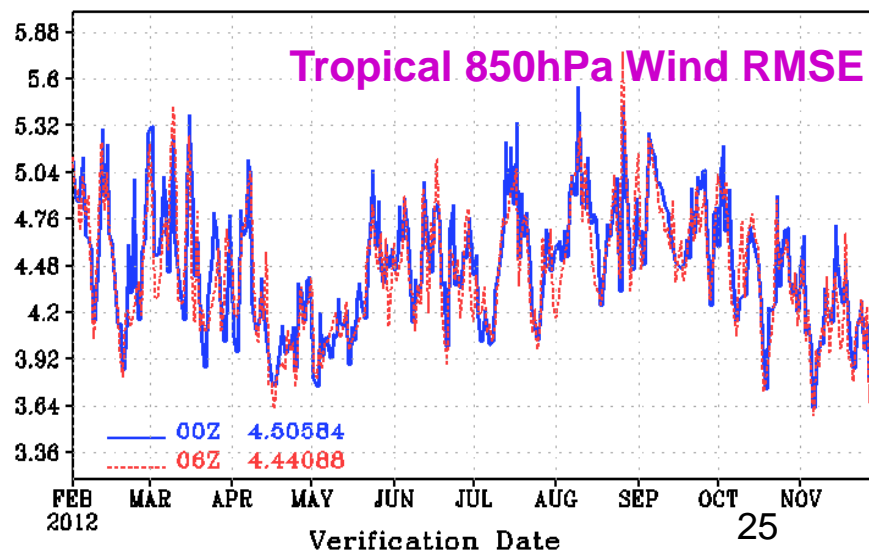
GFS Tropical 200-hPa Vector Wind RMSE (m/s)
06Z Cycle 186hr Fcst v.s. 00Z Cycle 192hr Fcst



GFS NHX Sea-Level Pressure Anomaly Correlation
06Z Cycle 186hr Fcst v.s. 00Z Cycle 192hr Fcst



GFS Tropical 850-hPa Vector Wind RMSE (m/s)
06Z Cycle 186hr Fcst v.s. 00Z Cycle 192hr Fcst



Question 2

Since the forecast skills of 06Z and 18Z cycles are not as good as the 00Z and 12Z cycles, what is the benefit for running these two extra cycles?

Answer

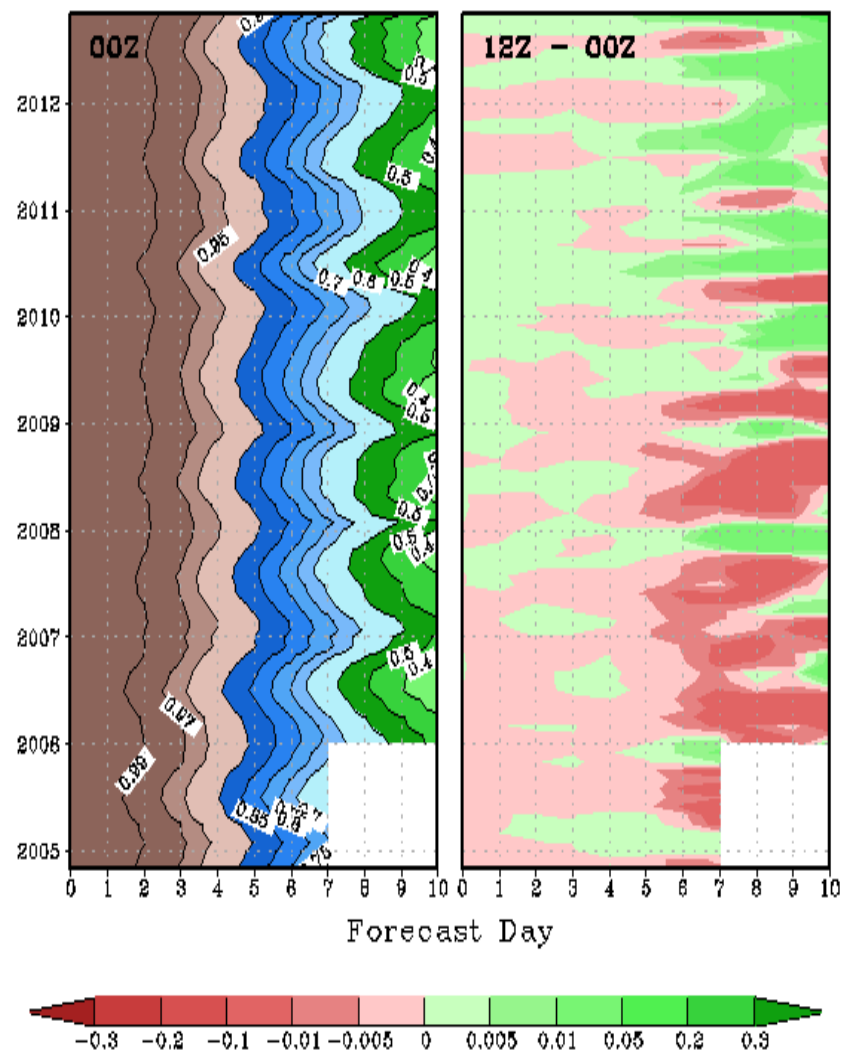
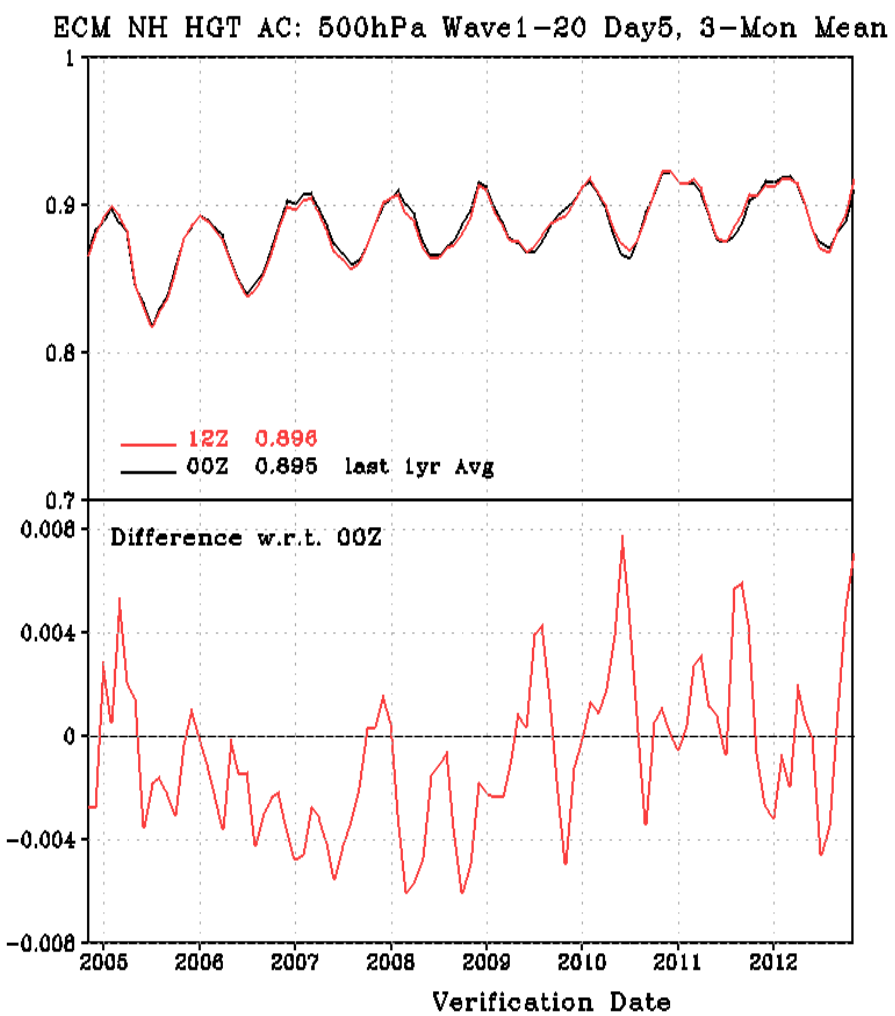
- 1. For short-range forecast (~ 3 days), the later 06Z cycle does show better forecast skills than the earlier 00Z cycle when both are validated at the same verification time.**
- 2. For medium and longer range forecast, the later 06Z cycle is not significantly different from the earlier 00Z cycle.**
- 3. Similarly, the 18Z cycle is better than the 12Z cycle for short-range forecast, but not significantly different from the 12Z cycle for medium and longer range forecast.**

See backup slides for the comparison between the 18Z and 12Z cycles.

Questions:

1. Are the differences in forecast skills correlated to the number of observations ingested in the data assimilation system?
2. Since the forecast skills of 06Z and 18Z cycles are worse than the 00Z and 12Z cycles, what is the benefit for running these two extra cycles?
3. **Why the 00Z cycle has worse tropical wind in the lower troposphere than the other cycles ?**

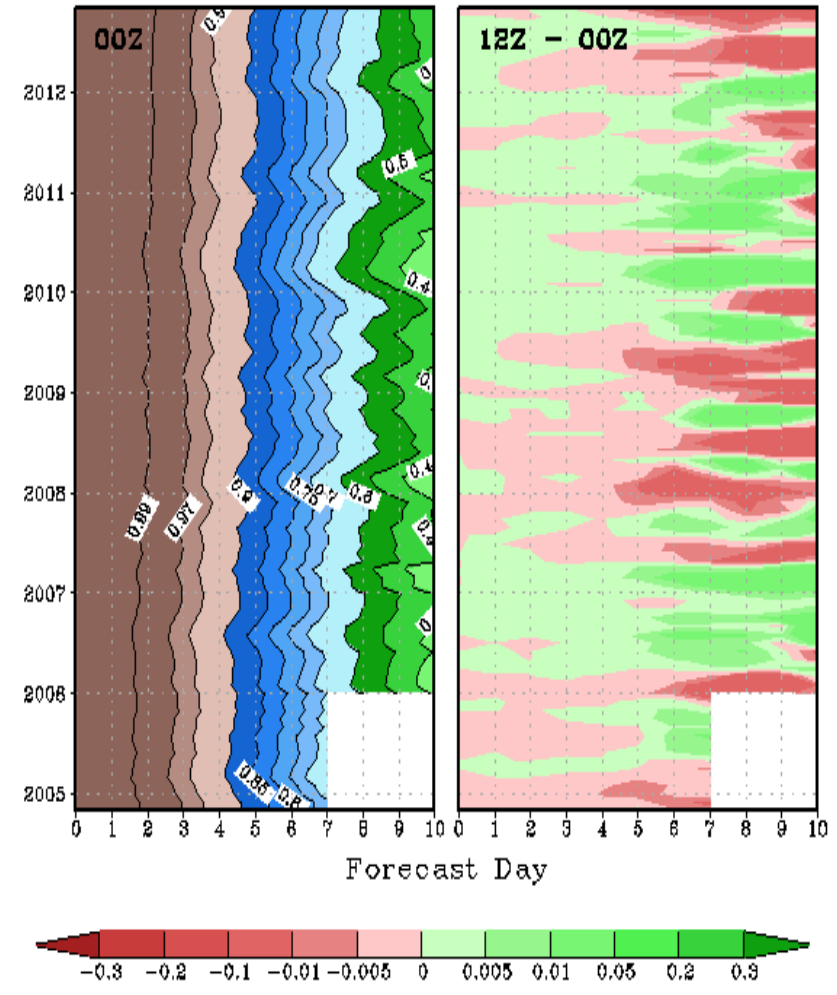
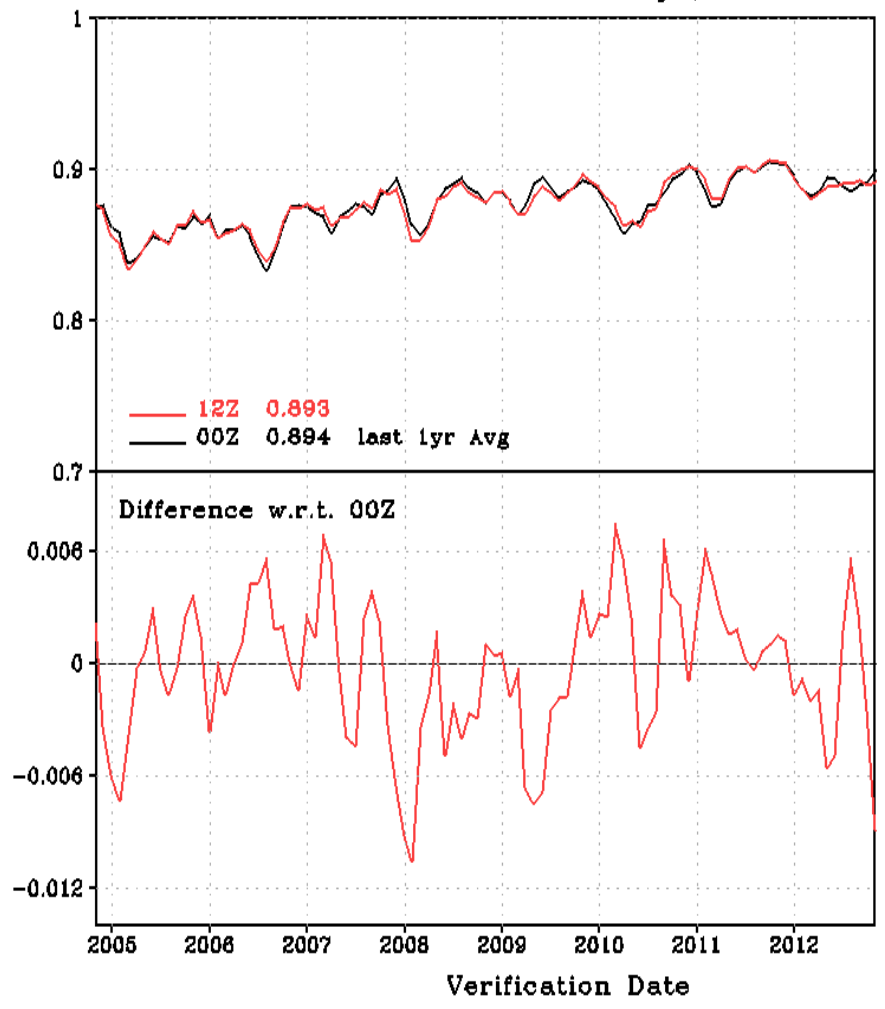
ECM HGT AC: NH 500hPa Wave1-20, 3-Mon Mean



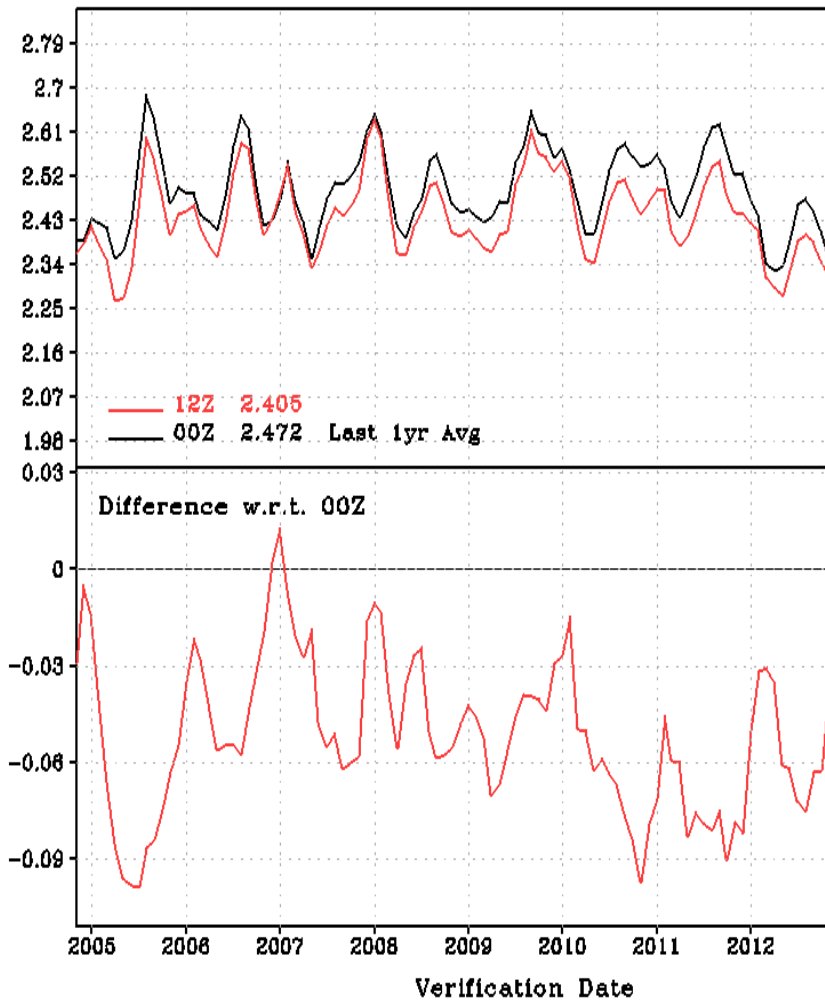
- 00Z is better than 12Z before 2009

ECM HGT AC: SH 500hPa Wave1-20, 3-Mon Mean

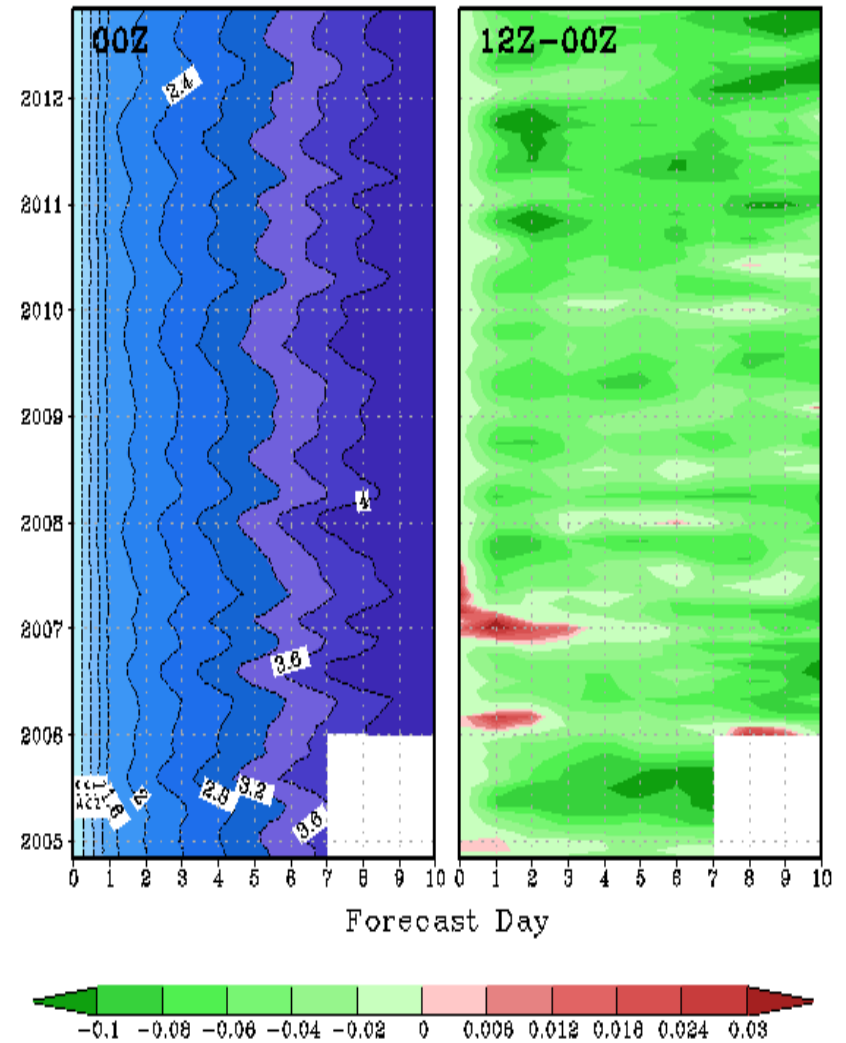
ECM SH HGT AC: 500hPa Wave1-20 Day5, 3-Mon Mean



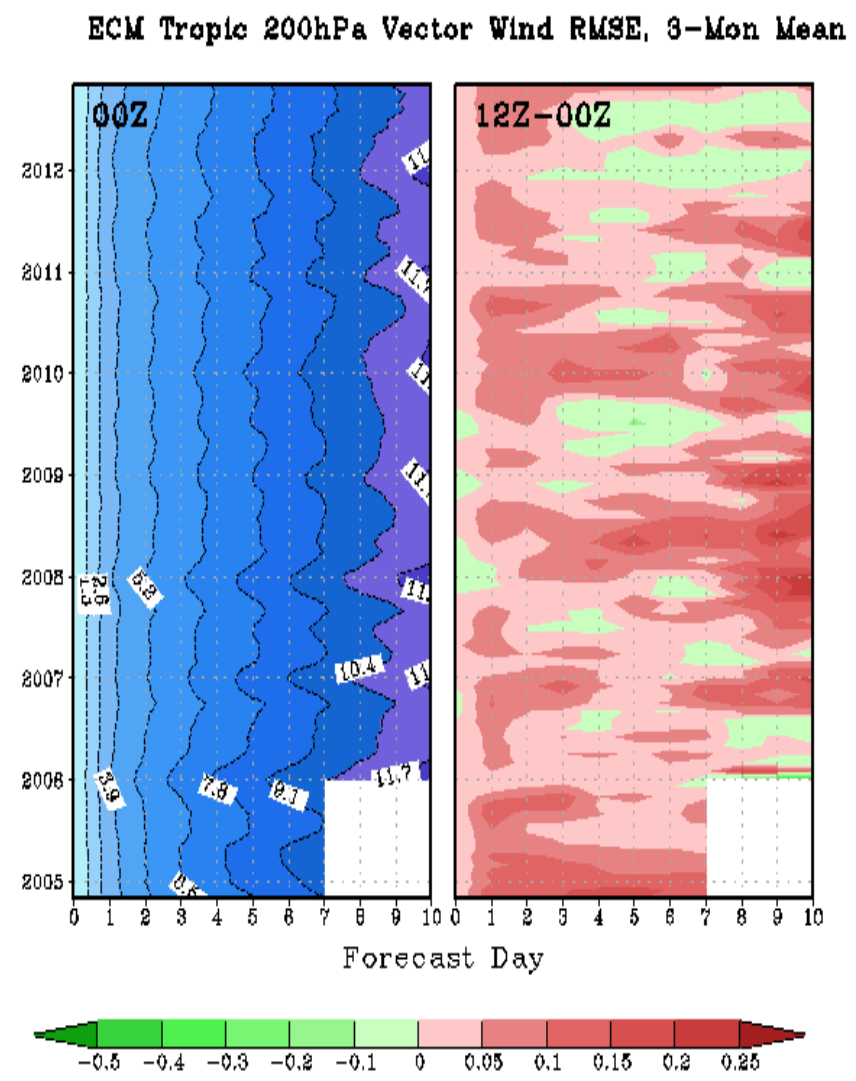
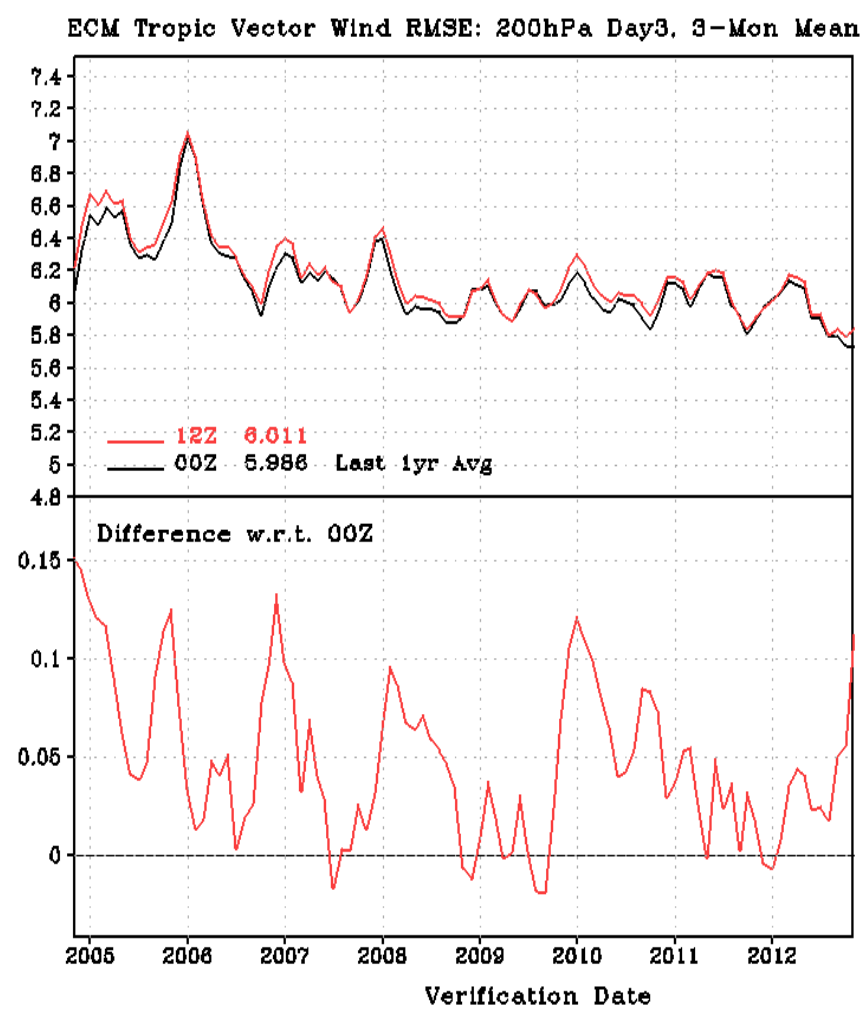
ECM Tropic Vector Wind RMSE: 850hPa Day3, 3-Mon Mean



ECM Tropic 850hPa Vector Wind RMSE, 3-Mon Mean



- 12Z better than 00Z, **same as GFS**



- 12Z worse than 00Z, same as GFS

Question 3:

Why the 00Z cycle has worse tropical wind in the lower troposphere than the other cycles ?

Answer (not really):

- For both the GFS and ECMWF, tropical wind from the 00Z cycle is **worse** (**better**) than that from the 12Z cycle in the **lower** (**upper**) troposphere.

Summary

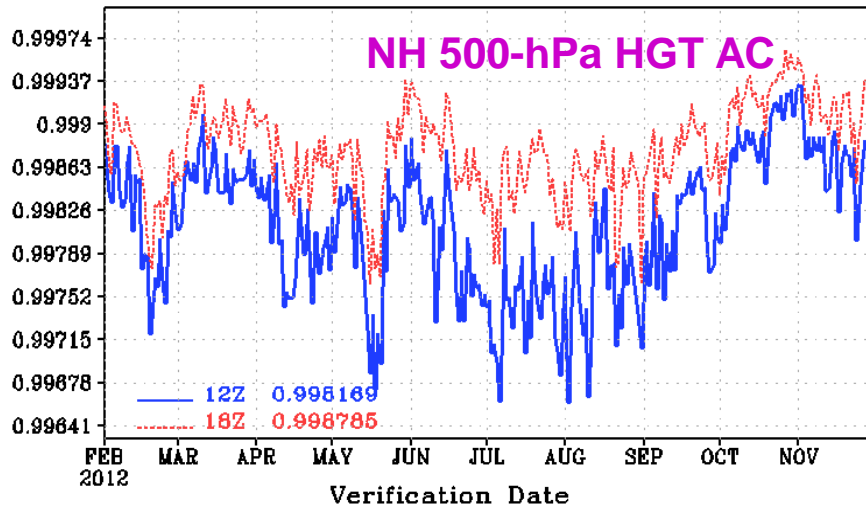
1. The GFS 06Z and 18Z cycles are not as good as the 00Z and 12Z cycles.
2. The 06Z cycle is the least skillful.
3. Conventional data count of the 06Z is consistently less (~10%) than that of the other cycles. No large difference in satellite data count is found among the four cycles.
4. For short-range forecast (~ 3 days), the later 06Z (18Z) cycle does show better forecast skills than the earlier 00Z (12Z) cycle when both are validated at the same verification time.
5. For medium and longer range forecast, the later 06Z (18Z) cycle is not significantly different from the earlier 00Z (12Z) cycle.
--- only run the 06Z and 18Z cycles for short-range forecast?
6. In general, both the GFS and ECMWF have the best (better) forecast skills for the 00Z cycle. However, both model showed worse tropical 850-hPa winds for the 00Z cycle than that of the other cycles.

Caveat: the verification metrics included in this presentation is limited. Other important forecast elements such as precipitation and hurricane tracks should be included for a more comprehensive evaluation of the four cycles.

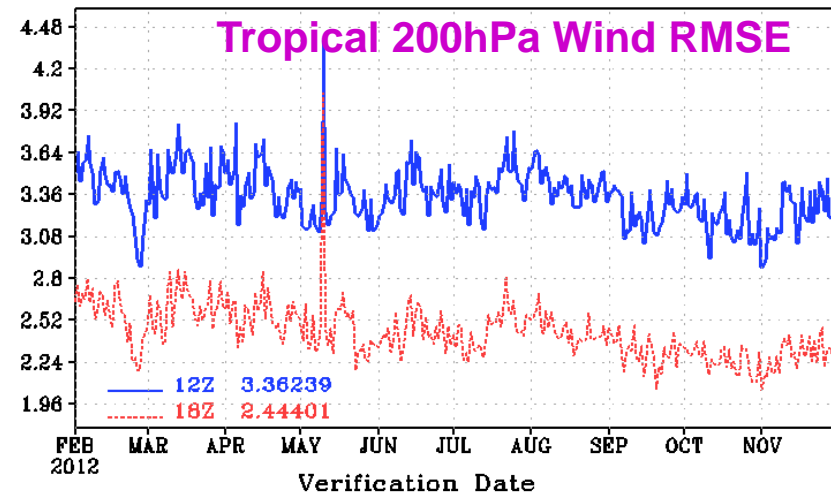
Backup slides

day-1: The 18Z 6-hr fcst is **always better** than the 12Z 12-hr fcst.

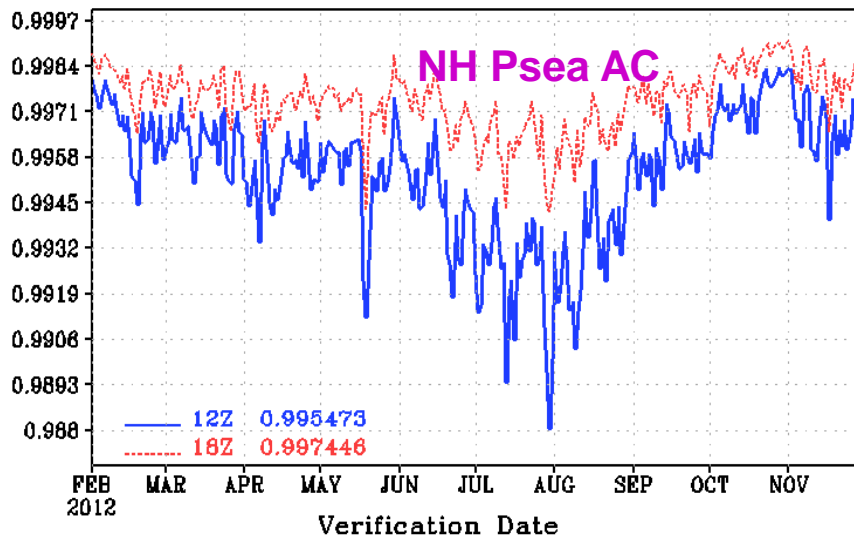
GFS NHX 500-hPa HGT Anomaly Correlation
18Z Cycle 6hr Fcst v.s. 12Z Cycle 12hr Fcst



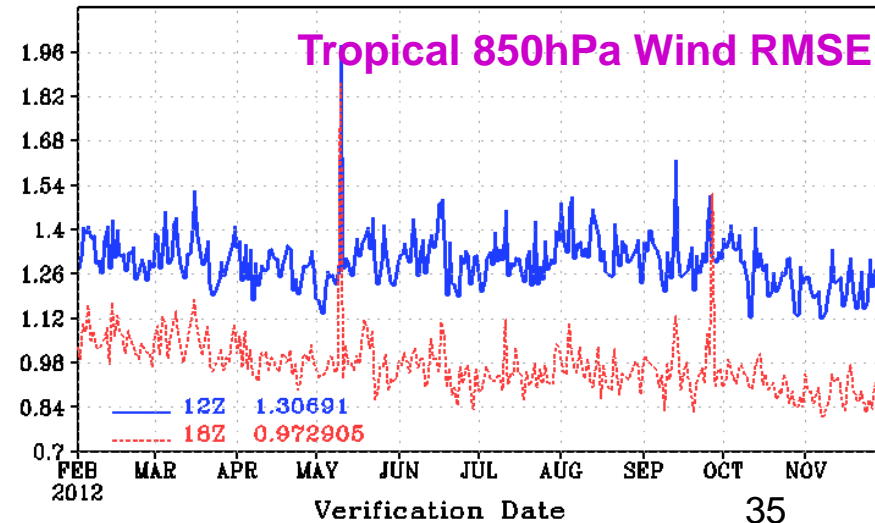
GFS Tropical 200-hPa Vector Wind RMSE (m/s)
18Z Cycle 6hr Fcst v.s. 12Z Cycle 12hr Fcst



GFS NHX Sea-Level Pressure Anomaly Correlation
18Z Cycle 6hr Fcst v.s. 12Z Cycle 12hr Fcst

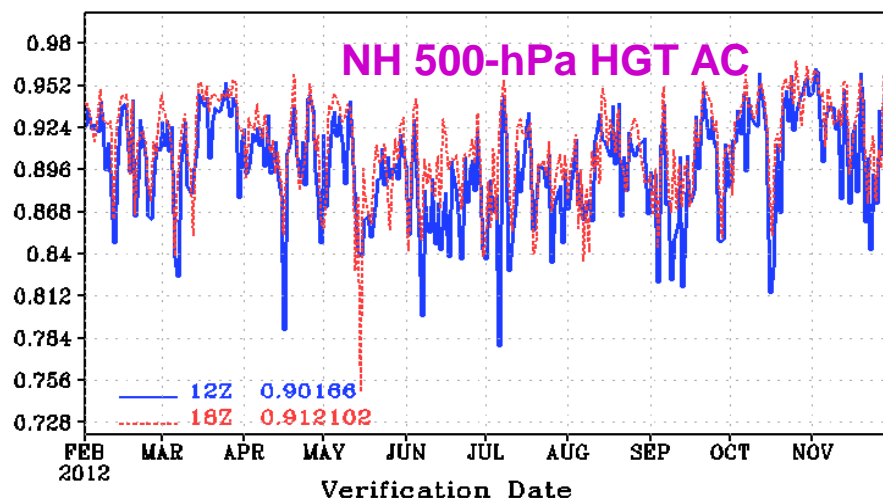


GFS Tropical 850-hPa Vector Wind RMSE (m/s)
18Z Cycle 6hr Fcst v.s. 12Z Cycle 12hr Fcst

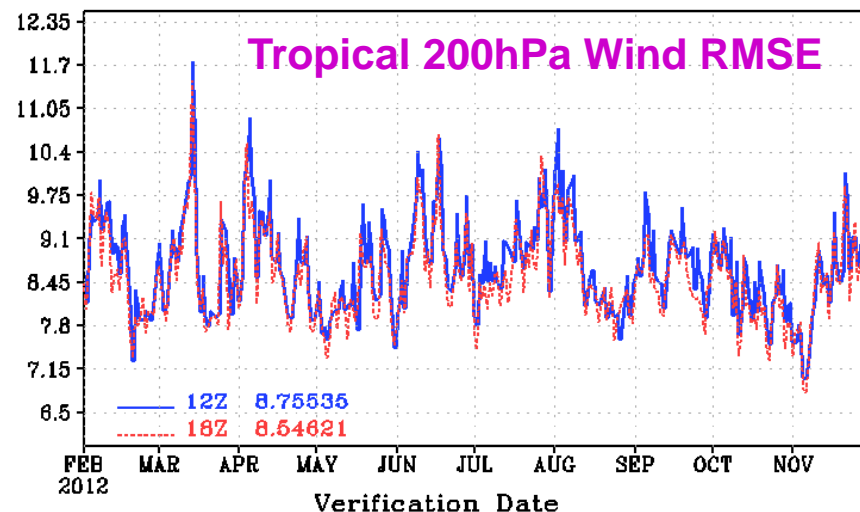


day-5: 18Z 102-hr fcst is not significantly different from 12Z 108-hr fcst.

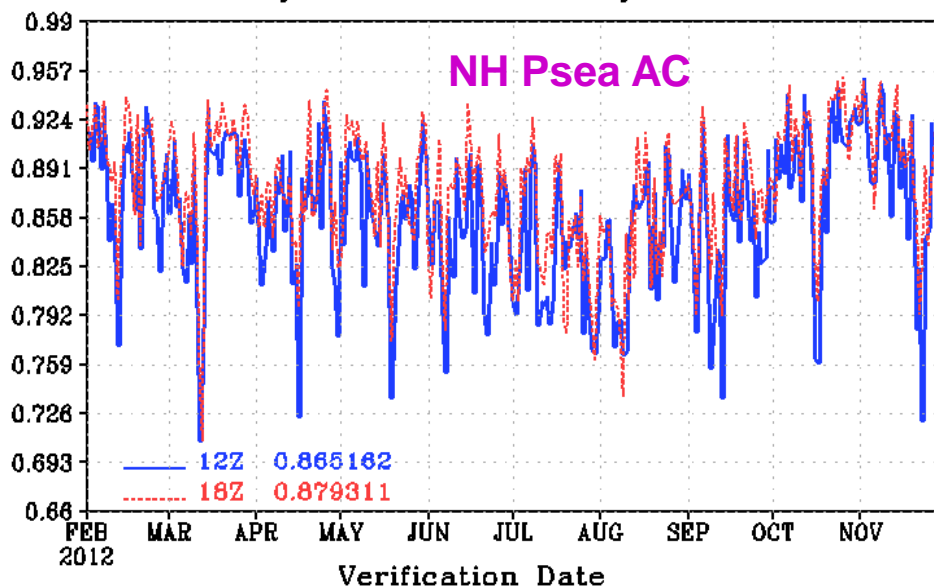
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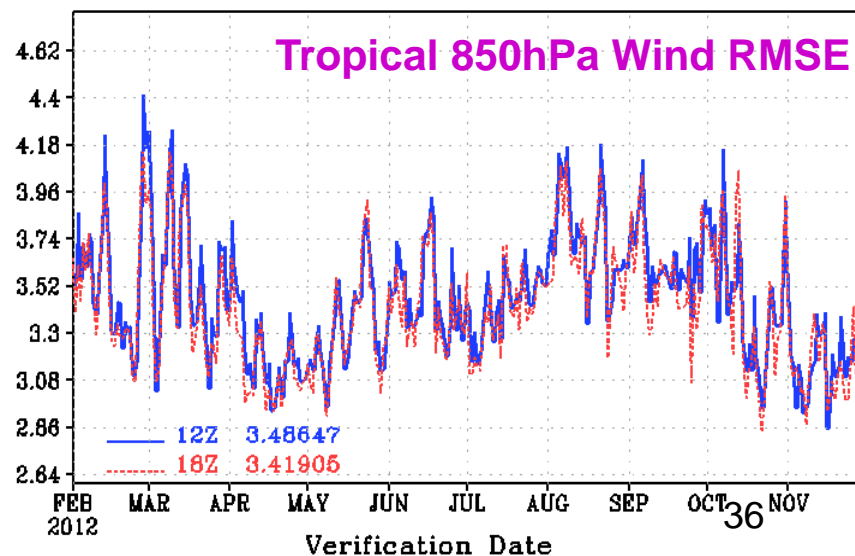
GFS Tropical 200-hPa Vector Wind RMSE (m/s)
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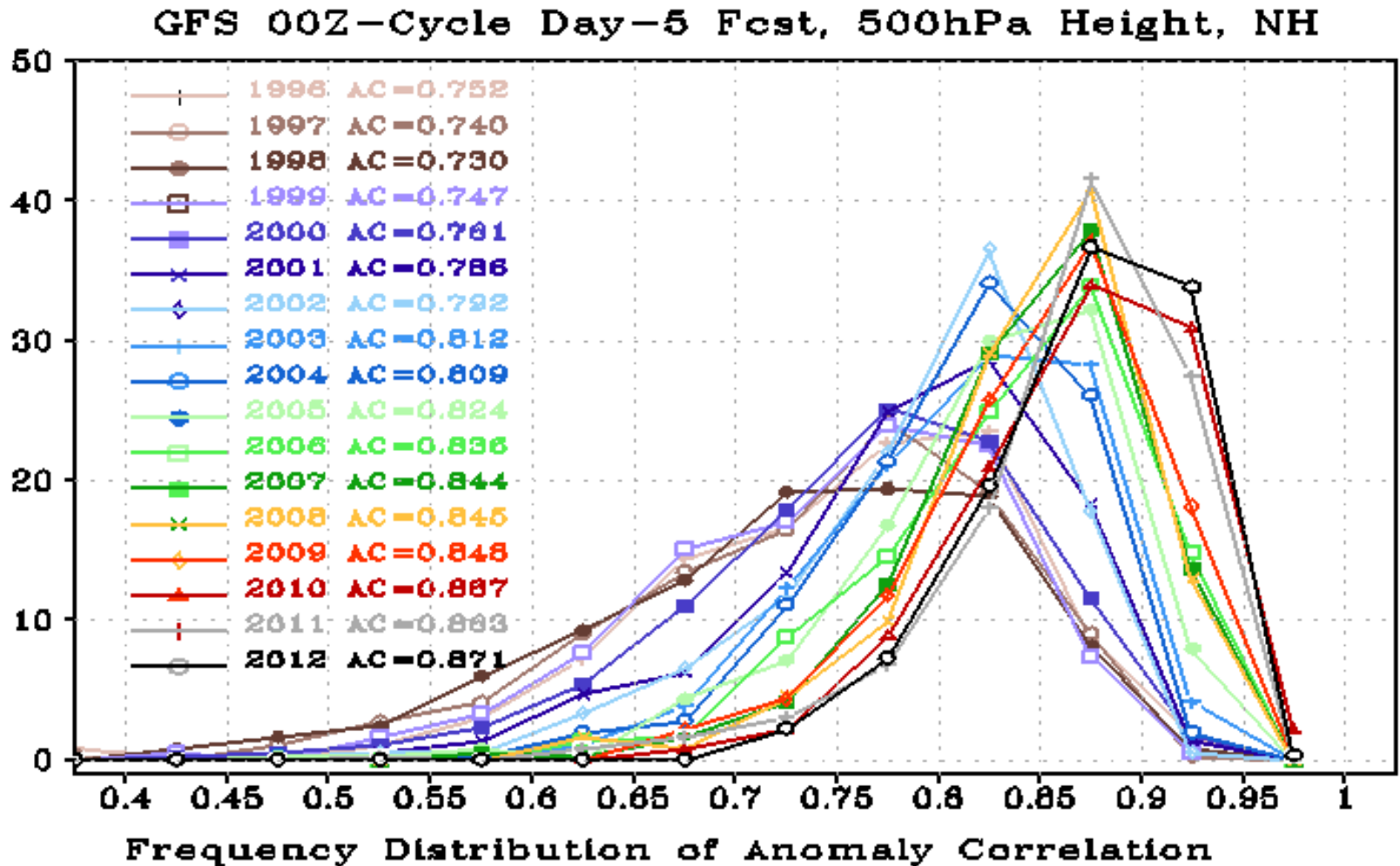
GFS NHX Sea-Level Pressure Anomaly Correlation
18Z Cycle 102hr Fcst v.s. 12Z Cycle 108hr Fcst



GFS Tropical 850-hPa Vector Wind RMSE (m/s)
18Z Cycle 102hr Fcst v.s. 12Z Cycle 108hr Fcst

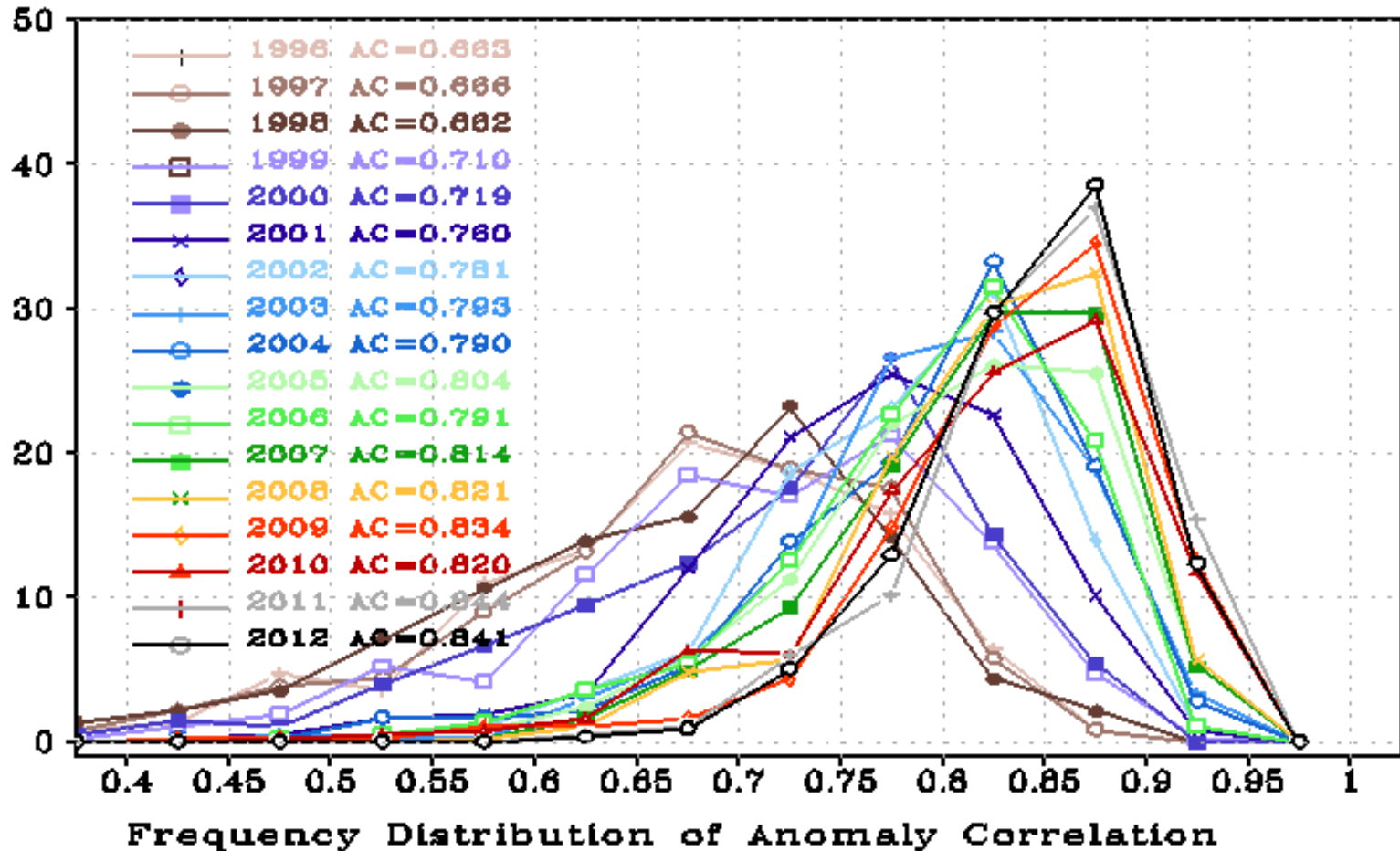


Twenty bins were used to count for the frequency distribution, with the 1st bin centered at 0.025 and the last been centered at 0.975. The width of each bin is 0.05.



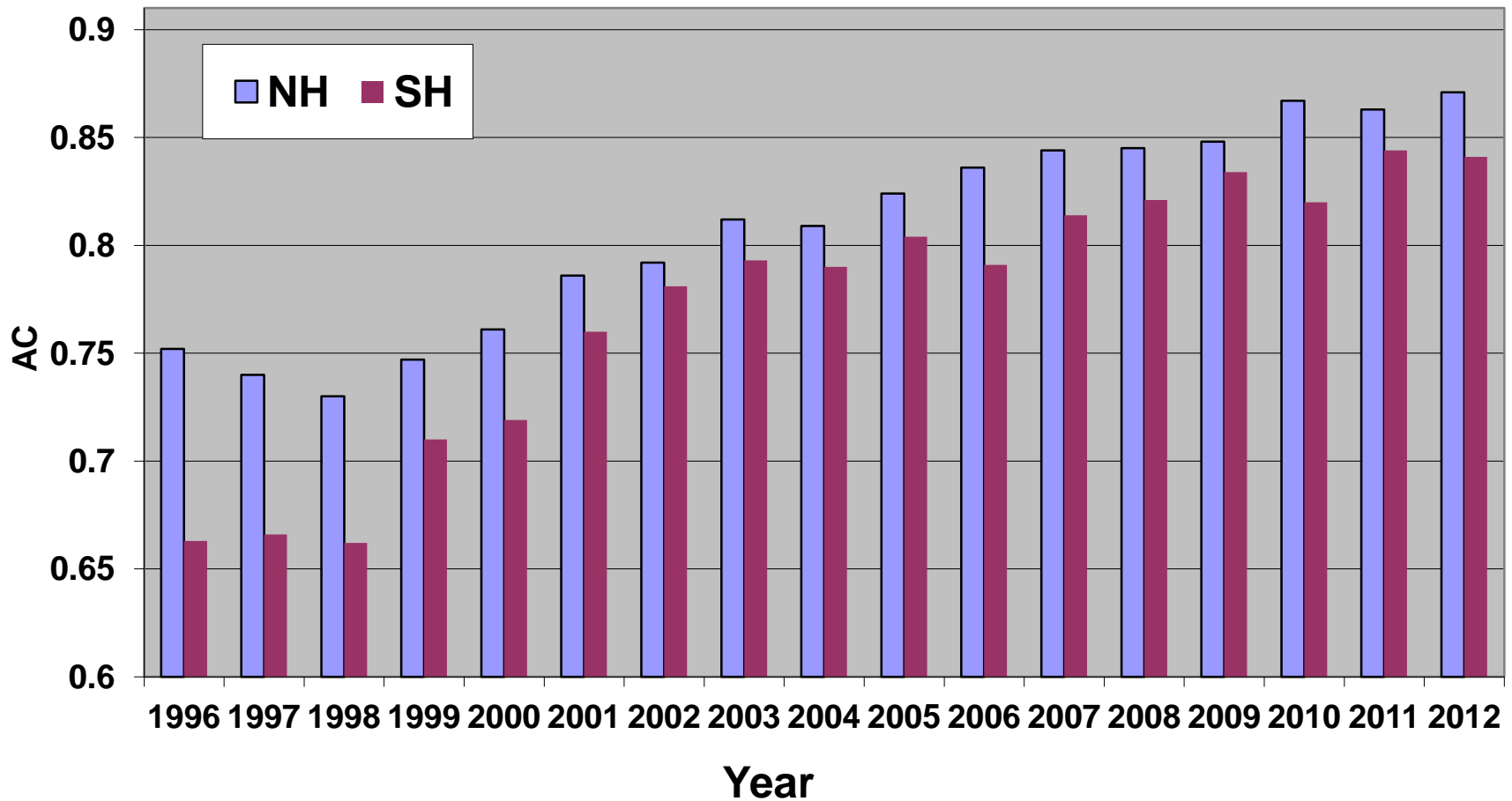
- Jan 2000: T126L28 → T170L42
- May 2001: prognostic cloud
- Oct 2002: T170L42 → T254L64
- May 2005: T254L64 → T382L64;
2-L OSU LSM → 4-L NOHA LSM
- May 2007: SSI → GSI Analysis;
Sigma → sigma-p hybrid coordinate
- July 2010: T382L64 → T574L64; Major Physics Upgrade
- May 2012: Hybrid-Ensemble 3D-VAR Data Assimilation

GFS 00Z-Cycle Day-5 Fcst, 500hPa Height, SH



- Jan 2000: T126L28 → T170L42
- May 2001: prognostic cloud
- Oct 2002: T170L42 → T254L64
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GFS 00Z Cycle Day-5 500hPa Height Anomaly Correlation



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