Improving 7-Day Forecast Skill by Assimilation of Retrieved AIRS Temperature Profiles

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Background

Last year I gave a presentation entitled "Improving Forecast Skill by Assimilation of AIRS Cloud Cleared Radiances R_i^{CC}"

The objective of that research was to assess the degree of improvement in seven day forecast skill achieved by assimilating values of AIRS R_i^{CC} in place of AIRS observed radiances R_i, as done by GMAO, everything else being done the same.

7-day forecast results were shown covering the period Sept. 10, 2014 – Oct. 31, 2014 based on Data Assimilation studies using GEOS-5.

Assimilations were done and presented using the GMAO operational procedure as a control run, as well as using five other assimilations performed differently all assimilating either AIRS R_i or Quality Controlled (QC'd) AIRS $R_i^{CC.}$

We also performed one additional study using GEOS-5 in which we assimilated AIRS QC'd retrieved values of $T(p)$. $T(p)$ retrievals are presented to the analysis as if they were radiosonde reports.

The following 5 charts were shown at last year's presentation.

First Set of Forecast Impact Tests

All experiments use MERRA2 with the GEOS DAS. We ran forecasts with a resolution of 0.25° x 0.25° and analyses with 0.5° x 0.5°.
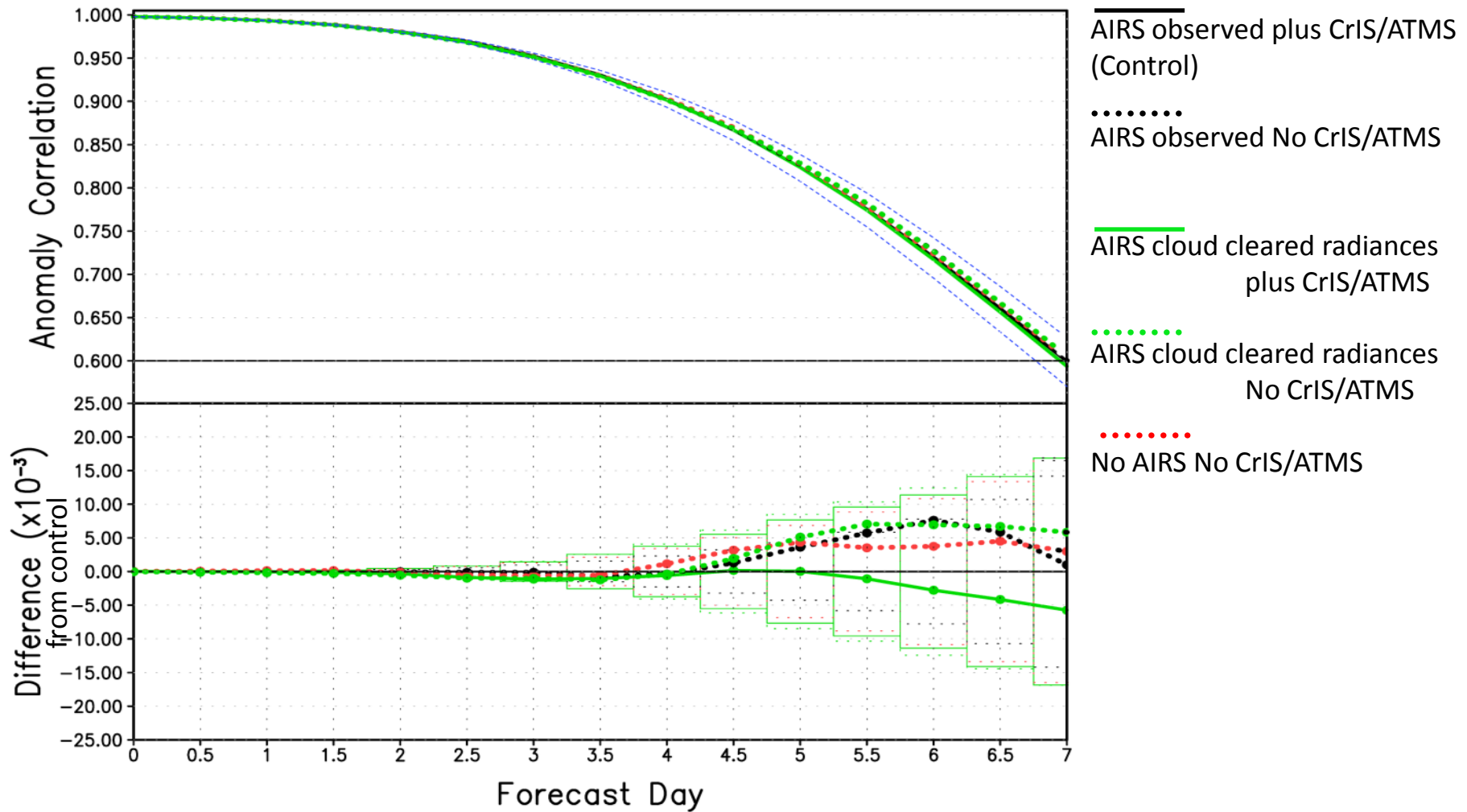
Data period covers September 1, 2014 – October 31, 2014.

Five data assimilation experiments were run:

1) "AIRS radiance" assimilates all data GMAO used operationally at that time, including R_i of AIRS/AMSU, CrIS/ATMS, and IASI/AMSU.

2) "AIRS R_i^{CC}" uses the same data but with AIRS R_i^{CC} in place of AIRS R_i.

3) "No AIRS" uses otherwise the same data but uses no AIRS data at all.

4) "AIRS radiance, no CrIS/ATMS" is like "AIRS radiance" but uses no CrIS/ATMS data.

5) "AIRS R_i^{CC}, no CrIS/ATMS" is like "AIRS R_i^{CC}", but uses no CrIS/ATMS.

52 independent 7-day forecasts were run from each 0Z analysis starting September 10. Forecasts are verified against the concurrent NCEP analysis.

Forecast 500 mb Height/Anomaly Correlation Coefficients
September 10 to October 31, 2014   Global

Legend:
- **AIRS observed plus CrIS/ATMS (Control)** — black solid line
- **AIRS observed No CrIS/ATMS** — black dotted line
- **AIRS cloud cleared radiances plus CrIS/ATMS** — green solid line
- **AIRS cloud cleared radiances No CrIS/ATMS** — green dotted line
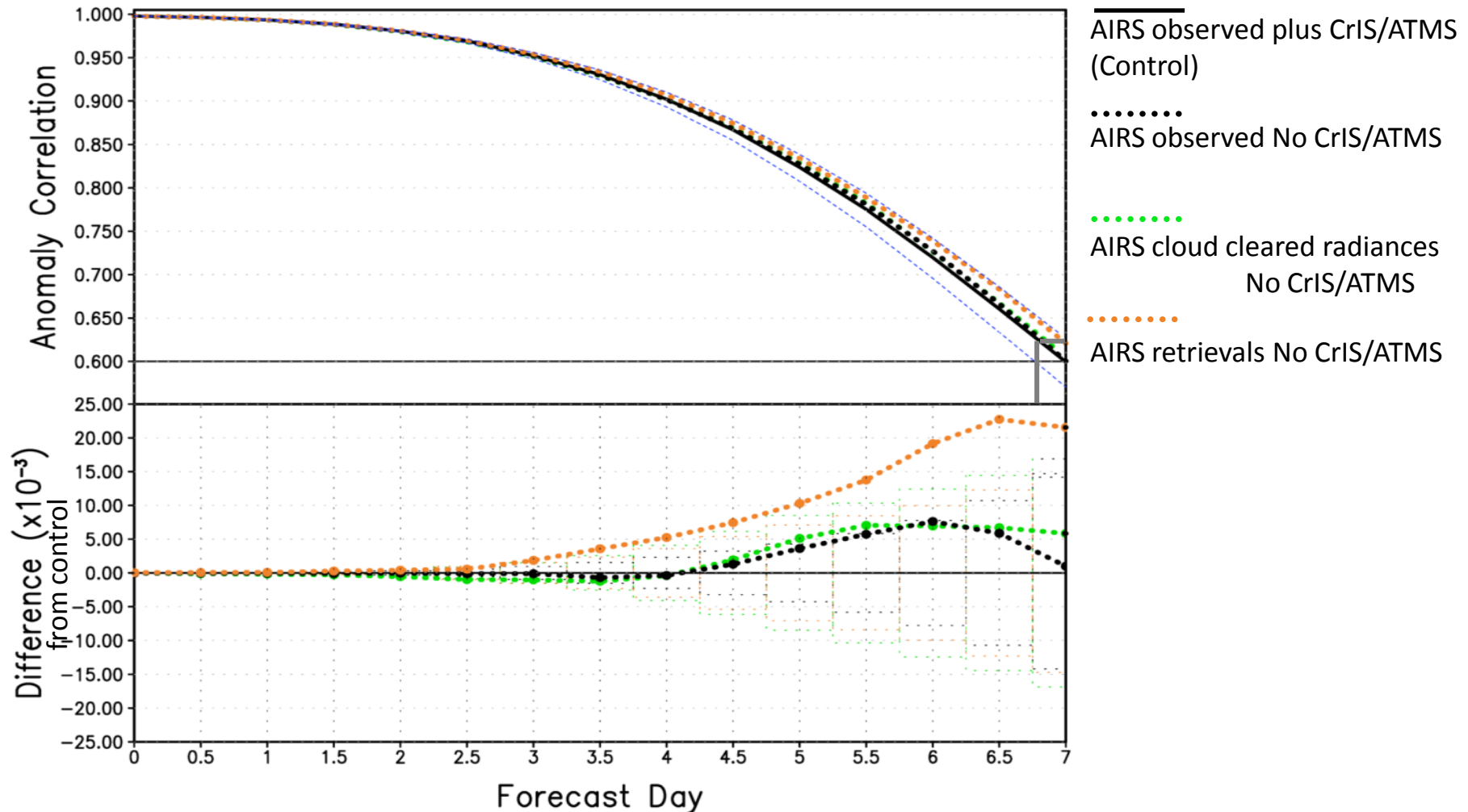- **No AIRS No CrIS/ATMS** — red dotted line

Assimilation of CrIS/ATMS (solid lines) degrades global forecast skill when used with AIRS. The best global 7-day forecast skill is obtained assimilating AIRS R_i^{CC} with no CrIS/ATMS.

Forecast 500 mb Height/Anomaly Correlation Coefficients
September 10 to October 31, 2014   Northern Hemisphere Extra-tropics
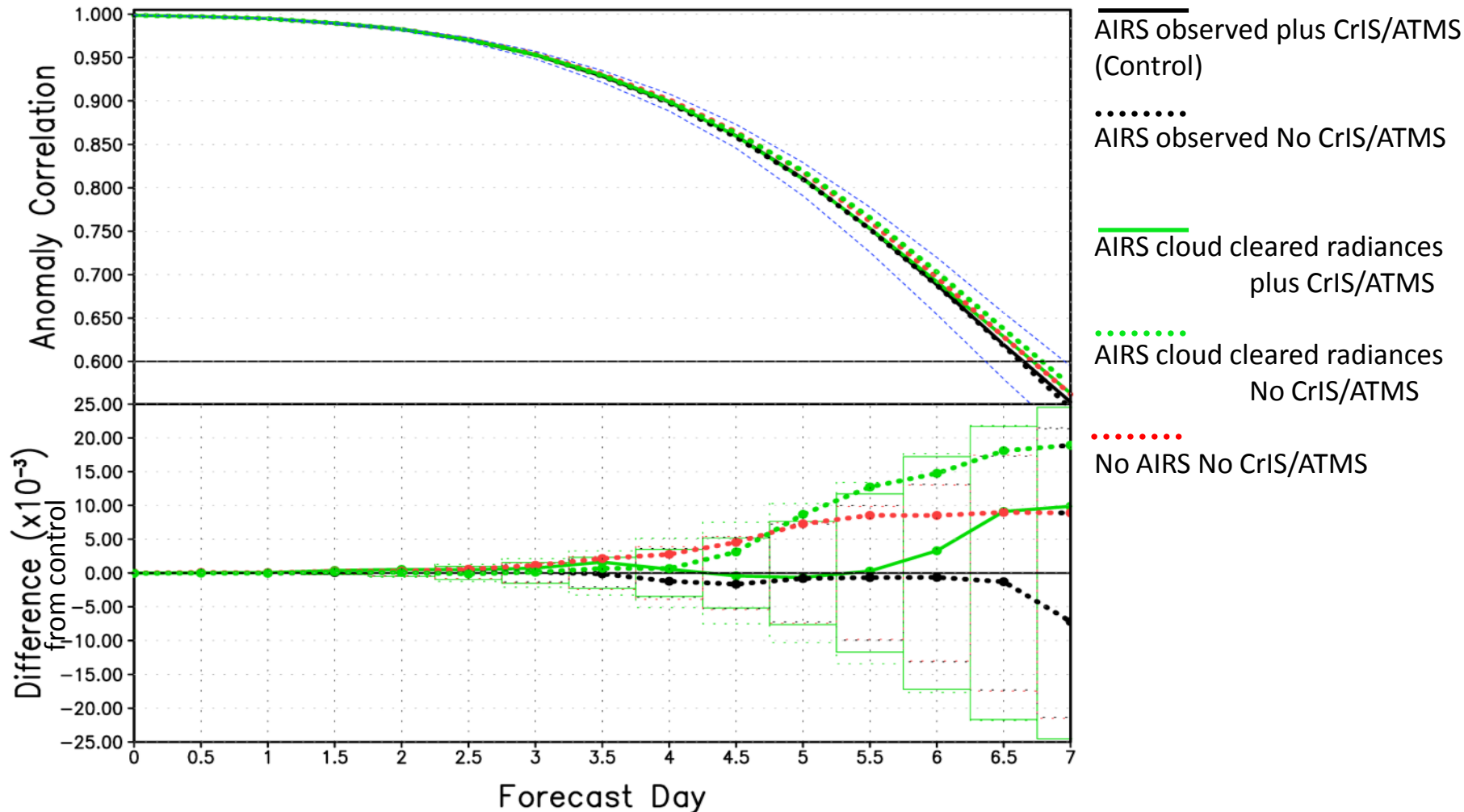
Considerable improvement in Northern Hemisphere 7-day forecast skill as compared to the control is obtained by assimilating AIRS R_i^{CC} with no CrIS/ATMS.

Forecast 500 mb Height/Anomaly Correlation Coefficients
September 10 to October 31, 2014   Global

AIRS observed plus CrIS/ATMS (Control)

AIRS observed No CrIS/ATMS

AIRS cloud cleared radiances No CrIS/ATMS

AIRS retrievals No CrIS/ATMS

Global Mean 500 mb height anomaly correlation coefficients assimilating QC'd *T(p)* are better than those of all other experiments at all time scales. Global mean 7-day forecast skill is improved by 6 hours as compared to the control.

More Recent Data Assimilation Research

Our most recent data assimilation research has concentrated on further improvements in 7-day forecast skill by assimilation of AIRS Version-6 retrieval values of $T(p)$ passing Data Assimilation QC. Retrieved values of $T(p)$ are presented to the GEOS DAS as if they were radiosonde reports.

Data Assimilation experiments were conducted over the time period December 15, 2015 through February 29, 2016. Sixty 7-day forecasts from each experiment were made each day at 0Z over the period January 1, 2016 through February 29, 2016, and verified every 12 hours against the current NCEP analysis.

Our experience in these experiments indicates that the GEOS DAS analysis does not perform as well, from the 7-day forecast skill perspective, when a large number of values of $T(p)$ are assimilated, especially when they come from different sources, in neighboring locations, that may (will) have different error characteristics.

Experiments Involving Assimilation of *T(p)* from Different Sources

We have conducted the following tests in conjunction with AIRS *T(p)*

1) Assimilate AIRS *T(p)* but do not assimilate radiosonde *T(p),* while still assimilating radiosonde *q(p)* and radiosonde winds. This significantly improves 7-day forecast skill.

2) Assimilate AIRS *T(p)* but do not assimilate radiosonde *T(p)*, *q(p)*, or winds. This significantly degrades 7-day forecast skill.

WE STILL NEED RADIOSONDES

3) Assimilate AIRS *T(p)* but do not assimilate radiosonde *T(p)* or aircraft temperatures. This produces the best results at this time.

The next charts show 7-day forecast skill for four experiments:

1) Control; 2) AIRS R_i^{CC} with no CrIS/ATMS; 3) AIRS *T(p)*, no CrIS/ATMS, no radiosonde *T(p)*; and 4) AIRS *T(p)*, no CrIS/ATMS, no radiosonde *T(p)*, and no aircraft temperatures.
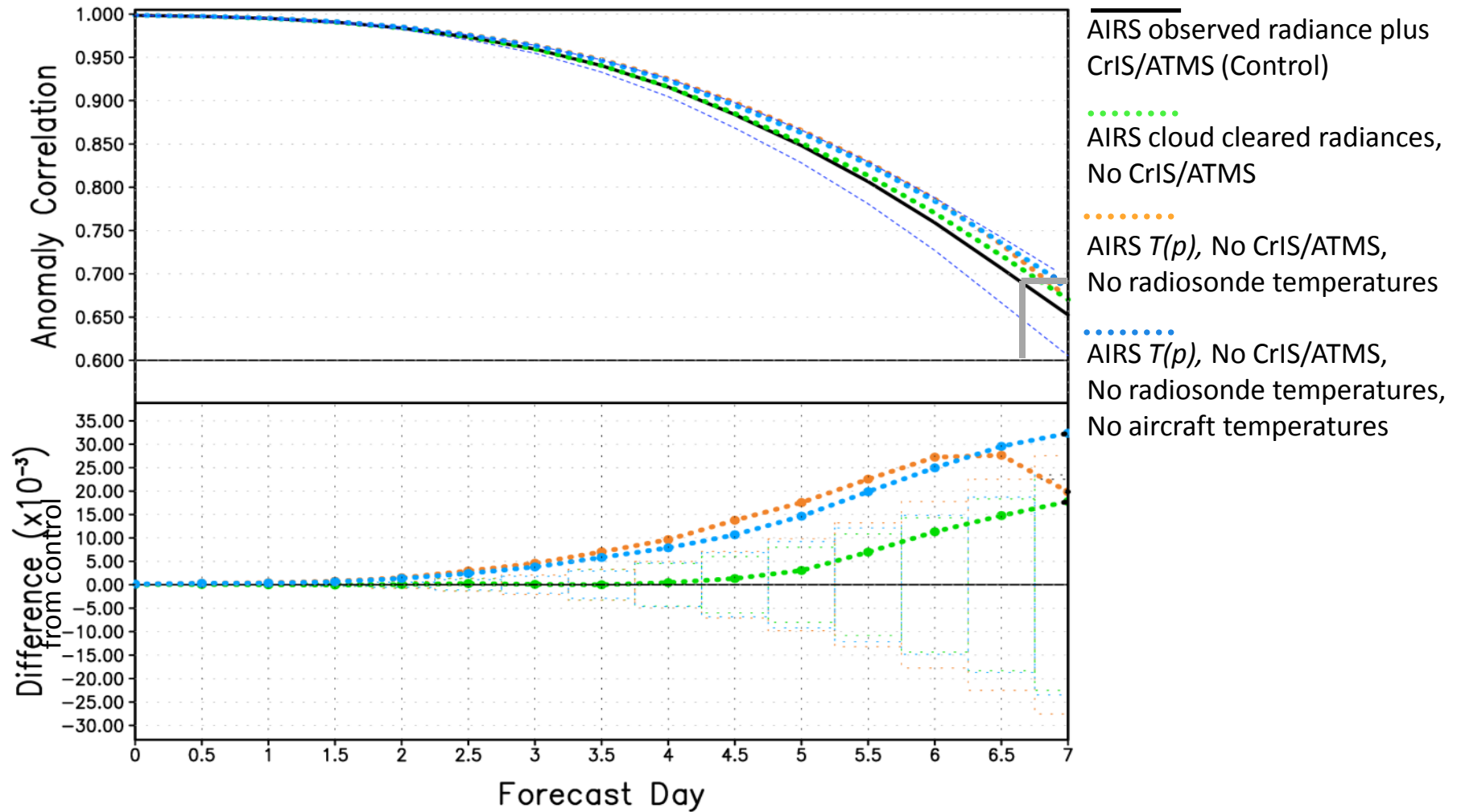
Forecast 500 mb Height/Anomaly Correlation Coefficients
January 1 to February 29, 2016   Global
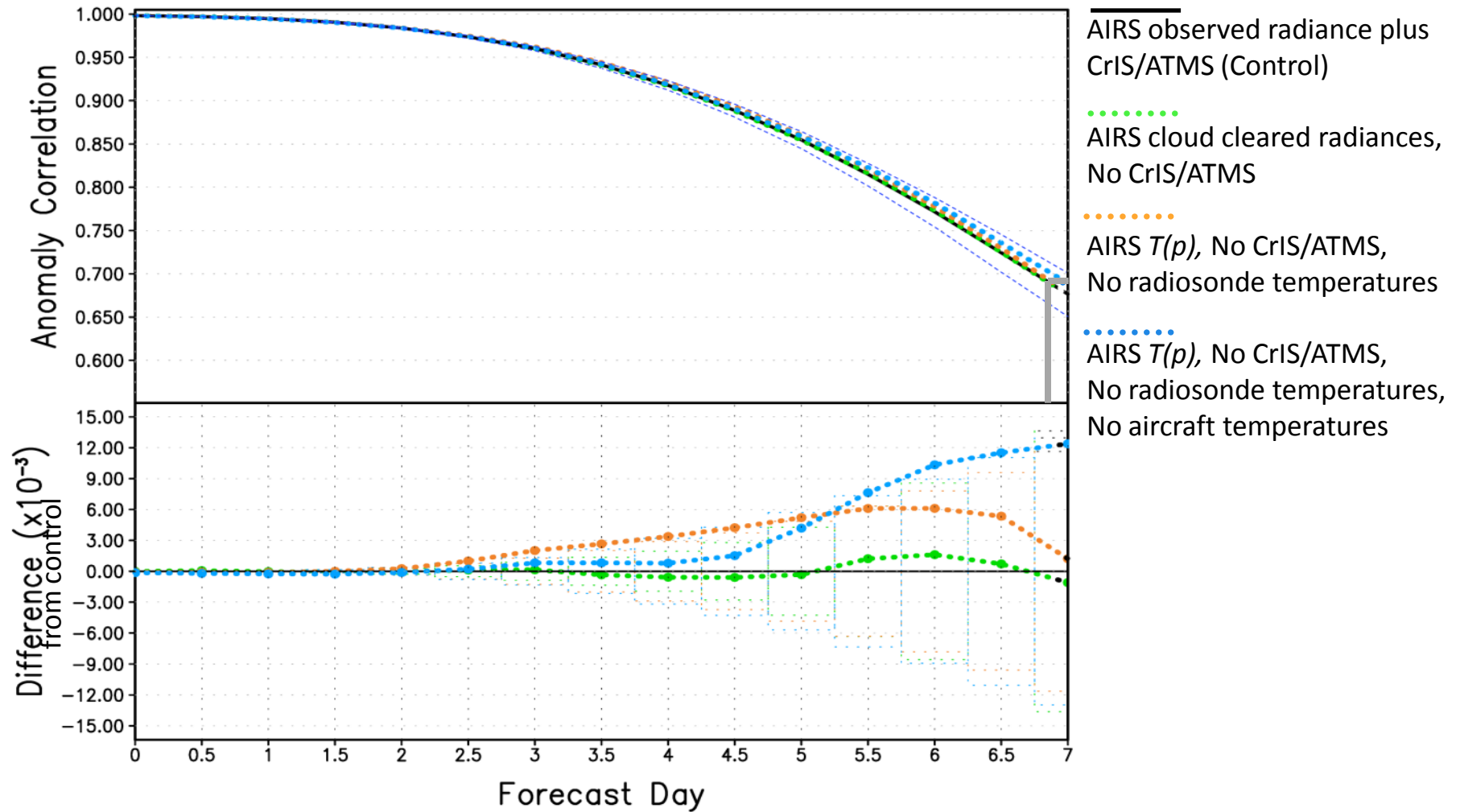
Global mean 7-day forecast skill is improved over the Control by four hours by assimilation of AIRS QC'd values of *T(p)* without radiosonde or aircraft temperatures.

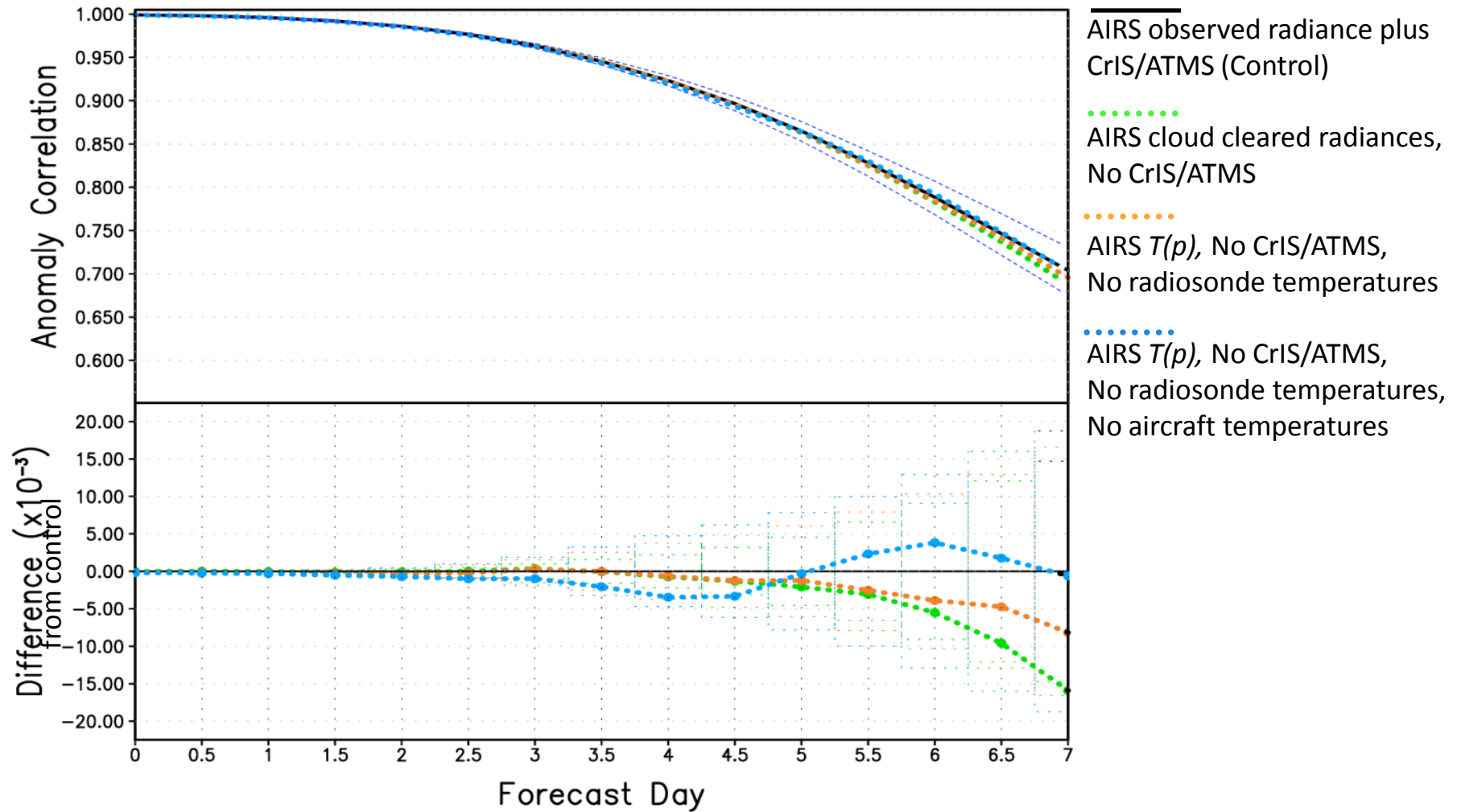# Forecast 500 mb Height/Anomaly Correlation Coefficients
January 1 to February 29, 2016   Southern Hemisphere Extra-tropics

Legend:
- **AIRS observed radiance plus CrIS/ATMS (Control)** — solid black line
- **AIRS cloud cleared radiances, No CrIS/ATMS** — green dotted line
- **AIRS *T(p)*, No CrIS/ATMS, No radiosonde temperatures** — orange dotted line
- **AIRS *T(p)*, No CrIS/ATMS, No radiosonde temperatures, No aircraft temperatures** — blue dotted line

All experiments improve the Southern Hemisphere Extra-tropics forecast skill significantly compared to the Control. The largest improvement in 7-day forecast skill (10) hours is obtained when AIRS *T(p)* is assimilated without radiosonde or aircraft temperatures.

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Forecast 500 mb Height/Anomaly Correlation Coefficients
January 1 to February 29, 2016 Northern Hemisphere Extra-tropics

Legend:
- **AIRS observed radiance plus CrIS/ATMS (Control)**
- **AIRS cloud cleared radiances, No CrIS/ATMS**
- **AIRS T(p), No CrIS/ATMS, No radiosonde temperatures**
- **AIRS T(p), No CrIS/ATMS, No radiosonde temperatures, No aircraft temperatures**

Assimilation of AIRS *T(p)* without radiosonde or aircraft temperatures is the only experiment that does not degrade the Control in the Northern Hemisphere Extra-tropics.

Summary

We conducted a new set of Data Assimilation Experiments covering the period January 1 to February 29, 2016 using the GEOS-5 DAS.

Our experiments assimilate all data used operationally by GMAO (Control) with some modifications.

Significant improvement in Global and Southern Hemisphere Extra-tropical 7-day forecast skill was obtained when:

> We assimilated AIRS Quality Controlled temperature profiles in place of observed AIRS radiances, and also did not assimilate CrIS/ATMS radiances, nor did we assimilate radiosonde temperature profiles or aircraft temperatures.

This new methodology did not improve or degrade 7-day Northern Hemispheric Extra-tropical forecast skill. We are conducting experiments aimed at further improving of Northern Hemisphere Extra-tropical forecast skill.