**Sandy Supplemental Grant Recipient Quarterly Progress Report**

# Quality Control and Impact Assessment of Aircraft Observations in the GDAS/GFS

**Award Number: NA13NWS4830022**

The National Oceanic and Atmospheric Administration
National Environmental Satellite Data and Information Service
Center for SaTellite Applications and Research (STAR)

For the Period
1 January 2015 – 31 March 2015

On behalf of
The Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Space Science and Engineering Center (SSEC)
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## I. Introduction

### Cooperative Institute Description

The Cooperative Institute for Meteorological Satellite Studies (CIMSS) is a collaborative relationship between the National Oceanic and Atmospheric Administration (NOAA) and the University of Wisconsin-Madison (UW-Madison). This partnership has and continues to provide outstanding benefits to the atmospheric science community and to the nation through improved use of remote sensing measurements for weather forecasting, climate analysis and monitoring environmental conditions. Under the auspices of CIMSS, scientists from NOAA/NESDIS and the UW-Madison Space Science and Engineering Center (SSEC) have a formal basis for ongoing collaborative research efforts. CIMSS scientists work closely with the NOAA/NESDIS Advanced Satellite Product Branch (ASPB) stationed at the UW-Madison campus. This collaboration includes a scientist from the National Climate Data Center (NCDC), who joined the NOAA NESDIS employees stationed at CIMSS.

CIMSS conducts a broad array of research and education activities, many of which are projects funded through this Cooperative Agreement with NOAA. This Cooperative Agreement identifies four CIMSS themes:

1. Satellite Meteorology Research and Applications, to support weather analysis and forecasting through participation in NESDIS product assurance and risk reduction programs and the associated transitioning of research progress into NOAA operations,
2. Satellite Sensors and Techniques, to conduct instrument trade studies and sensor performance analysis supporting NOAA's future satellite needs as well as assisting in the long term calibration and validation of remote sensing data and derived products,
3. Environmental Models and Data Assimilation, to work with the Joint Center for Satellite Data Assimilation (JCSDA) on improving satellite data assimilation techniques in operational weather forecast models, and
4. Outreach and Education, to engage the workforce of the future in understanding and using environmental satellite observations for the benefit of an informed society.

### CI Management and Organizational Structure

CIMSS resides as an integral part of the Space Science and Engineering Center (SSEC). CIMSS is led by its Director, Dr. Steven Ackerman, who is also a faculty member within the UW-Madison Department of Atmospheric and Oceanic Sciences. Executive Director Wayne Feltz provides day-to-day oversight of the CIMSS staff, science programs, and facilities. The education and outreach activities at CIMSS are coordinated by Senior Outreach Specialist Margaret Mooney. The individual science projects are led by University Principal Investigators (PIs) in conjunction with a strong and diverse support staff who provide additional expertise to the research programs. CIMSS is advised by a Board of Directors and a Science Advisory Council.

The CIMSS administrative home is within the Space Science and Engineering Center (SSEC), a research and development center within the UW–Madison's Office of the Vice Chancellor of Research. The independent CIMSS 5-year review panel for administration wrote that they were "…impressed by the people, systems and processes in place." The SSEC mission focuses on geophysical research and technology to enhance understanding of the Earth, other planets in the Solar System, and the cosmos. To conduct its science mission on the UW-Madison campus, SSEC has developed a strong administrative and programmatic infrastructure. This infrastructure serves all SSEC/CIMSS staff.

The CIMSS mission includes three goals:

- Foster collaborative research among NOAA, NASA, and the University in those aspects of atmospheric and earth system science that exploit the use of satellite technology;
- Serve as a center at which scientists and engineers working on problems of mutual interest can focus on satellite-related research in atmospheric and earth system science;
- Stimulate the training of scientists and engineers in the disciplines involved in atmospheric and earth sciences.

## Executive Summary of CI Banner Research Activities

CIMSS is a collaboration between NOAA and UW–Madison that has increased the effectiveness of research and the quality of education in the environmental sciences. In a *Space Policy* article in 1986, William Bishop, former acting Director of NESDIS, noted, "Remote sensing from space can only thrive as a series of partnerships." He used CIMSS as a positive working example of the government-academia partnership, noting "The Institute pioneered the computation of wind speeds at cloud heights by tracking cloud features from image to image. These are now a stable product provided from the satellites to the global models at the National Meteorological Center." CIMSS continues to be a leader in the measurement of winds from satellite observations and leads the way in many other research endeavors as outlined above. There is great value to NOAA and UW-Madison in this long-term collaboration known as CIMSS.

## II. Funded Project

**Award Number: NA13NWS4830022**

**Project Title: Quality Control and Impact Assessment of Aircraft Observations in the GDAS/GFS**

**PI: Dr. David Santek**

**NOAA Sponsor: Andrew Collard and Stephen Lord**

**NOAA Sponsoring Organization: NOAA NWS/EMC**

**Reporting Period: 1 January 2015 – 31 March 2015**

### Description of Task I Activities

Primarily activity involves quarter reporting.

### NOAA Strategic Goal(s)

### NOAA Mission Goals

1. Climate Adaptation and Mitigation: An informed society anticipating and responding to climate and its impacts
2. Weather-Ready Nation: Society is prepared for and responds to weather-related events

### NOAA Strategic Plan-Mission Goals

1. Serve society's needs for weather and water
2. Understand climate variability and change to enhance society's ability to plan and respond
3. Provide critical support for the NOAA mission

## III. Research Progress

A GDAS/GFS parallel experiment and control were initialized on 25 March 2014, and forecast statistics began being collected starting on 05 April 2014 through 29 May 2014. The experiment is identical to the control, except that the experiment assimilates AMDAR moisture observations using an error-table identical to that used to assimilate these observations in the NAM model. No additional quality control is introduced for these observations.

### a) Ob-minus-background (OMB) for radiosondes and collocated AMDAR observations

Observed and 4D-interpolated model first-guess (“background”) moisture are available as routine output from the GDAS. Statistics are available for 126 0000 UTC and 1200 UTC analysis periods for both radiosonde observations and AMDAR observations. In order to compare OMB values between the two observation types, only AMDAR observations deemed collocated to radiosondes are included for analysis; an AMDAR observation is deemed collocated if it exists within 0.5 degrees of a radiosonde observation and was collected within 60 minutes of the radiosonde observation. A total of 2458 profiles are found where there were at least some radiosonde and collocated AMDAR observations, and the mean OMB statistics are computed within 25 equally-spaced pressure layers between the surface and 300 hPa.

Mean profiles of OMB for radiosondes shows that the radiosondes express a dry-bias relative to the model first-guess from near-surface through the depth of the troposphere (Fig. 1 blue profile), but OMB for these same radiosondes is reduced when AMDAR observations are assimilatd (Fig. 1, red profile). The difference between the radiosonde profiles with/without AMDAR observations is statistically significant to 95% confidence from near surface to ~900 hPa and between 600-700 hPa. The OMB of AMDAR observations themselves is less than that of radiosondes.

The OMB can be interpreted as a fit of the model 6-hr forecast to the observations, since the model first-guess is a 6-hr forecast from a previous analysis. OMB profiles from radiosondes indicate that there is an improved fit-to-observations for the model 6-hr forecast when AMDAR observations are assimilated, representing analysis-improvement. A similar analysis was performed on radiances derived from NOAA-18, NOAA-19, and METOP-A microwave humidity sounder (MHS), but no significant differences in OMB were observed (not shown).

### b) Forecast impact of AMDAR observations

While forecast impact is often measured for hemispheric scores of geopotential height, temperature, and wind for forecasts extending out to seven days, the expectation is that AMDAR moisture observations will have no significant impact on these scores. While improvement is not expected, it is still important to monitor how the experiment changes these scores as a sanity check.

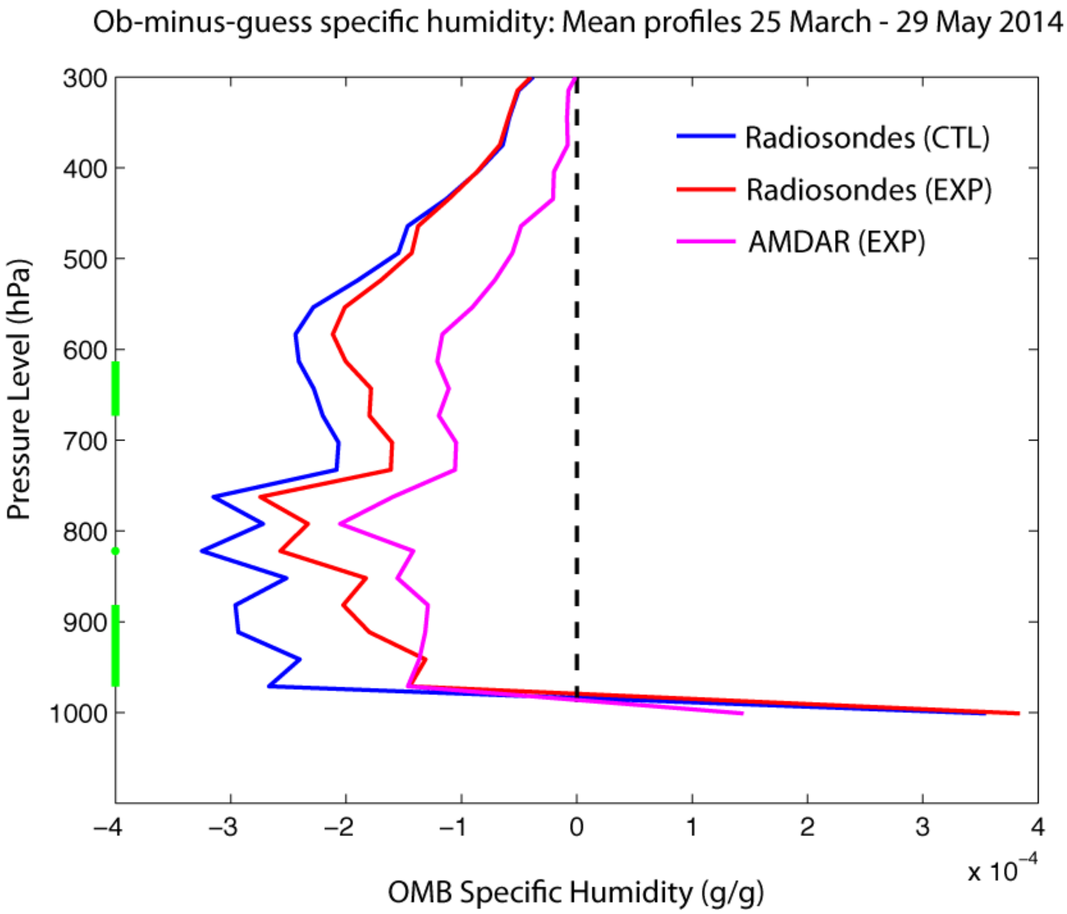


**Figure 1**. Ob-minus-background (OMB) of specific humidity for radiosondes with no AMDAR assimilated (blue), radiosondes with AMDAR assimilated (red), and assimilated AMDAR observations collocated to radiosonde locations (magenta). The difference between red and blue profiles is statistically significant to 95% confidence on vertical levels indicated by a green highlight along the ordinate.

Scores are computed for the period 05 April – 29 May 2014.

*i) Hemispheric scores*

Root mean square error (RMSE) in the geopotential height field shows slight improvement in the northern hemisphere and slight degradation in the southern hemisphere centered around 400 hPa and beginning at 96-hrs into the model simulation (Fig. 2 a,b). However, these changes to RMSE are small compared to the existing RMSE, constituting less than a 1% change in most regions. An examination of mean 500 hPa geopotential height anomaly correlation scores from days 0-5 shows the same slight improvement over the northern hemisphere and degradation over the southern hemisphere, but significance testing reveals that none of these adjustments are statistically significant (Fig. 2c,d). An investigation of wind speed RMSE at 200 hPa in the tropics reaches a similar conclusion (not shown).

*ii) Precipitation skill score*

The forecast skill for precipitation is computed using the equitable threat score (higher is better) and bias score (lower is better) for 24-hr cumulative precipitation amounts between 0.2 mm to 75

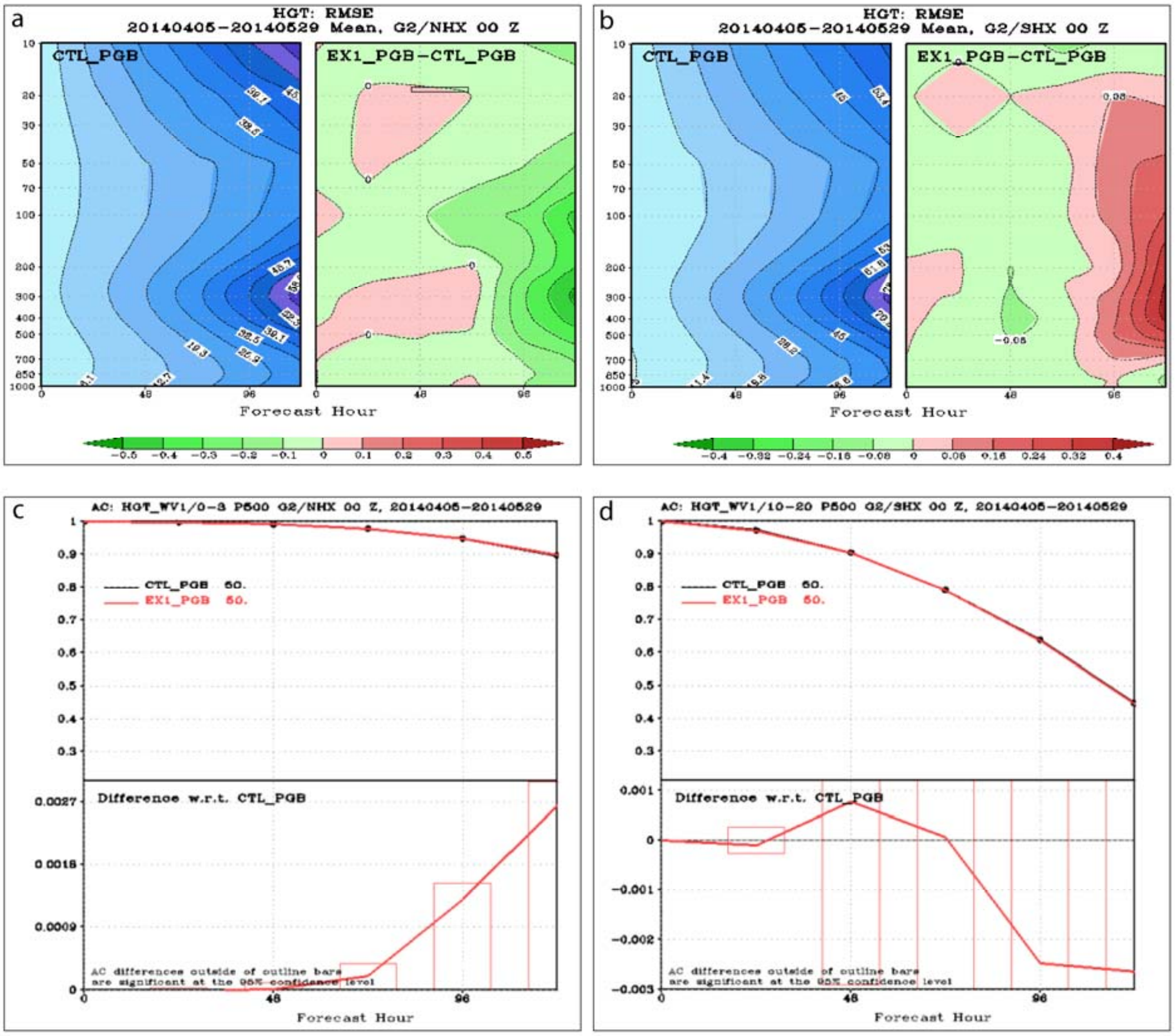


**Figure 2**. (top) Time-pressure plots of mean geopotential height RMSE and change in RMSE for days 0-5 in (a) the northern hemisphere and (b) the southern hemisphere. (bottom) Mean 500 hPa geopotential height anomaly correlation coefficient "dieoff" curves for days 0-5 in (c) the northern hemisphere and (d) the southern hemisphere. Differences between experiment and control are plotted below each curve, with a bar representing the amplitude necessary for statistical significance.

mm, separated into nine bins. Equitable threat scores for 12-36 hour forecasts shows statistically significant improvement for 0.2 mm, 2 mm, and 5 mm bins, coupled with a statistically significant reduction in bias for these categories (Fig. 3). Statistically significant improvement in equitable threat score is also found for the 0.2 mm bin in 36-60 hour forecasts, and statistically significant degradation is observed for the 10 mm bin in 60-84 hour forecasts (not shown), but no other categories for any times experience any statistically significant changes. The largely positive improvement in ETS and bias is evidence of an improved forecast courtesy of a more accurate moisture field in the analysis.

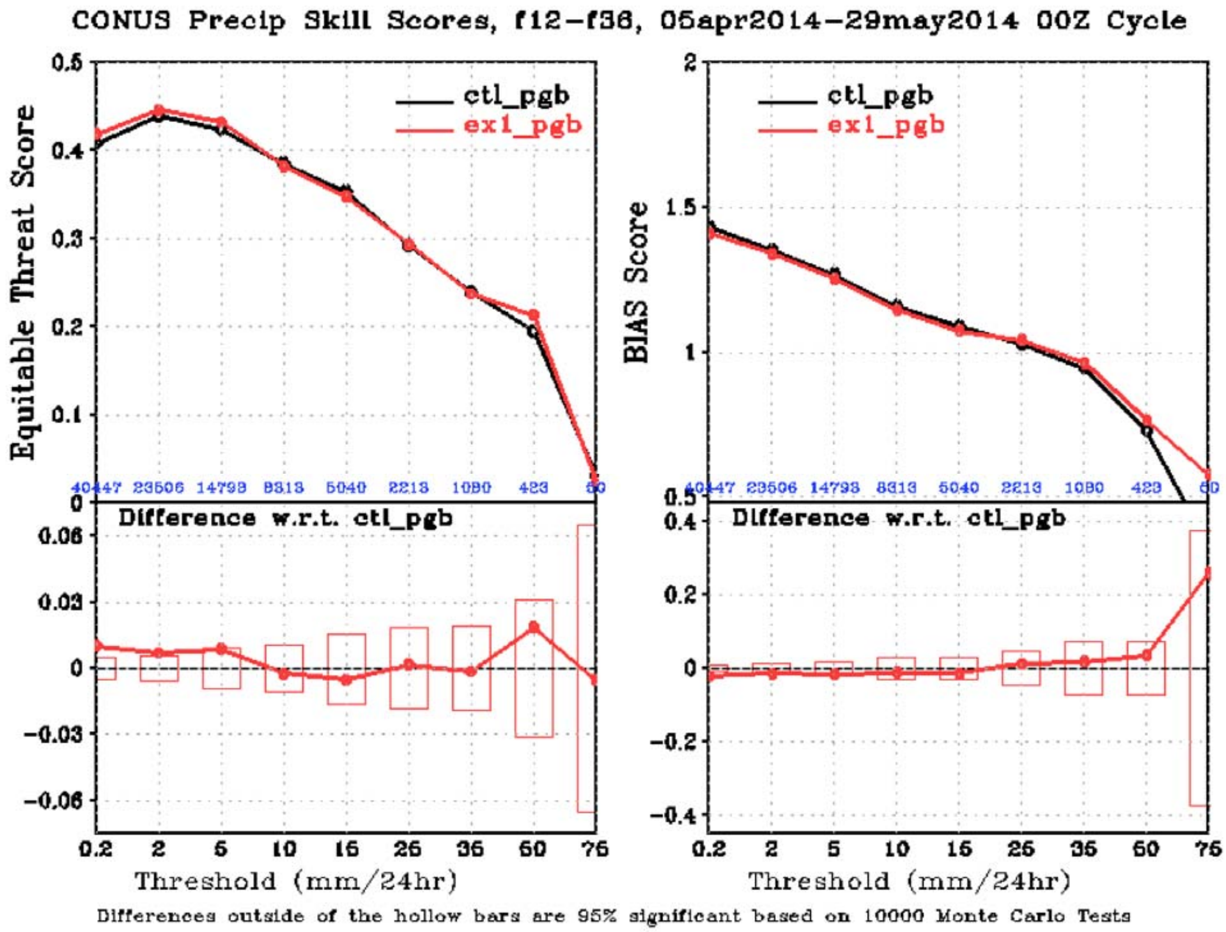


**Figure 3**. Equitable threat score (ETS, left) and bias (right) in precipitation forecasts over the continental US, separated into bins representing 24-hr accumulated rainfall between 0.2 – 75 mm. Differences between experiment and control are plotted below the curves, with bars representing the amplitude necessary for statistical significance.

## c) Future work

We are in the process of running a fit-to-obs of the forecast atmospheric-column precipitable water to GPS radio occultation (GPS-RO) data. This effort is being applied to the first experiment as an additional test of forecast impact.

We are currently in the process of running another 2-month experiment December 2014 – January 2015 in order to examine the impact during the northern hemispheric cold season. In addition, a third experiment is being performed in which AMDAR observations are assimilated over the same April – May 2014 period as the first seasonal experiment, but ten US radiosondes have been selected for deactivation; these sites were found to be the ten radiosonde locations where there exists the most coverage by AMDAR observations in space and time. The ten radiosonde locations are:

| | | | | | | |
|---|---|---|---|---|---|---|
| KMFL | 72202 | MIAMI | FL | US | 25.76 | -80.38 |
| KTBW | 72210 | TAMPA | FL | US | 27.71 | -82.40 |
| KFFC | 72215 | ATLANTA | GA | US | 33.36 | -84.57 |
| KFWD | 72249 | FORT WORTH | TX | US | 32.84 | -97.30 |

| | | | | | | |
|---|---|---|---|---|---|---|
| KOHX | 72327 | NASHVILLE | TN | US | 36.25 | -86.56 |
| KVEF | 72388 | LAS VEGAS | NV | US | 36.05 | -115.18 |
| KLWX | 72403 | STERLING | VA | US | 38.98 | -77.49 |
| KDNR | 72469 | DENVER | CO | US | 39.77 | -104.87 |
| KOAK | 72493 | OAKLAND | CA | US | 37.74 | -122.22 |
| KOKX | 72501 | UPTON | NY | US | 40.87 | -72.86 |

The radiosonde sites cover much of the continental US, so it is not expected that the impact will be affected by the removal of a "cluster" of observations in one location. We wish to test the feasibility of the AMDAR observations to make up for the loss of radiosonde observations where AMDAR observations are often collocated.

### Resolved Issues and/or Risks

None.

### New Issues and/or Risks

We have exhausted our monthly allotment of computer-time on Zeus long before the end of the month in April, owing to the running of multiple experiments and controls simultaneously. Further interruption of computing for the rest of the project will severely limit our ability to finish the experiments.