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 July 2014 – 30 September 2014

On behalf of
The Cooperative Institute for Meteorological Satellite Studies (CIMSS)
Space Science and Engineering Center (SSEC)
at the University of Wisconsin-Madison
1225 West Dayton Street
Madison, Wisconsin 53706
608/262-0544

David Santek
Principal Investigator
dave.santek@ssec.wisc.edu

Ralph Peterson
Co-Investigator
ralph.petersen@ssec.wisc.edu

Sandy Supplemental Grant Recipient Quarterly Progress Report
Quality Control and Impact Assessment of Aircraft Observations in the GDAS/GFS

Table of Contents

Sandy Supplemental Grant Recipient Quarterly Progress Report
Quality Control and Impact Assessment of Aircraft Observations in the GDAS/GFS

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 July 2014 – 30 September 2014

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

Three areas were investigated during this quarter:

1. the geographic and vertical coverage of the aircraft observations as compared to radiosondes,

2. the impact of the aircraft moisture observations on the global analysis, and

3. the impact of the aircraft observations and radiosondes (with and without aircraft data) on the analysis.

These are preliminary results based on a 10-day control and experiment for late October 2013 using the GDAS/GFS at T670 resolution on zeus. The experiment assimilated the aircraft moisture data using the same quality control and error settings as used in the North American Model (NAM).

Geographic and vertical coverage of aircraft data as compared to radiosondes

To evaluate the aircraft data coverage as compared to radiosondes, assimilated moisture observations in the GDAS from aircraft and radiosondes were used. An example is shown in Figure 1 for 25 October 2013 at the 0000, 0600, 1200, 1800 UTC analysis times. The upper panel in Figure 1 depicts the radiosonde locations over North America; the lower panel the aircraft moisture observations that were assimilated. The aircraft observations spread out from the airport sites, showing the takeoff and landing patterns, resulting in increased spatial coverage over radiosondes. This is especially evident in the eastern half and southwest US.

However, the aircraft increased spatial coverage is not at all levels. Complementing Figure 1, Figure 2 presents the vertical coverage of radiosonde and aircraft data distributed over the US using a 1°x1° grid. The vertical coverage is defined as the number of levels where data are assimilated, binning the vertical into 11 levels between 1000 and 300 hPa. As expected, the top panel in Figure 2 shows that the radiosonde moisture data has a very good vertical coverage, mostly over 80% of the previously defined vertical levels. Aircraft data present a lower vertical coverage, on average, due to ascent and descent crossing into nearby 1° boxes. Therefore, this implies the aircraft moisture observations complement those from radiosondes, by providing additional vertical and spatial coverage. Also, the temporal coverage is increased using aircraft data as radiosondes are typically launched at only 0000 and 1200 UTC.

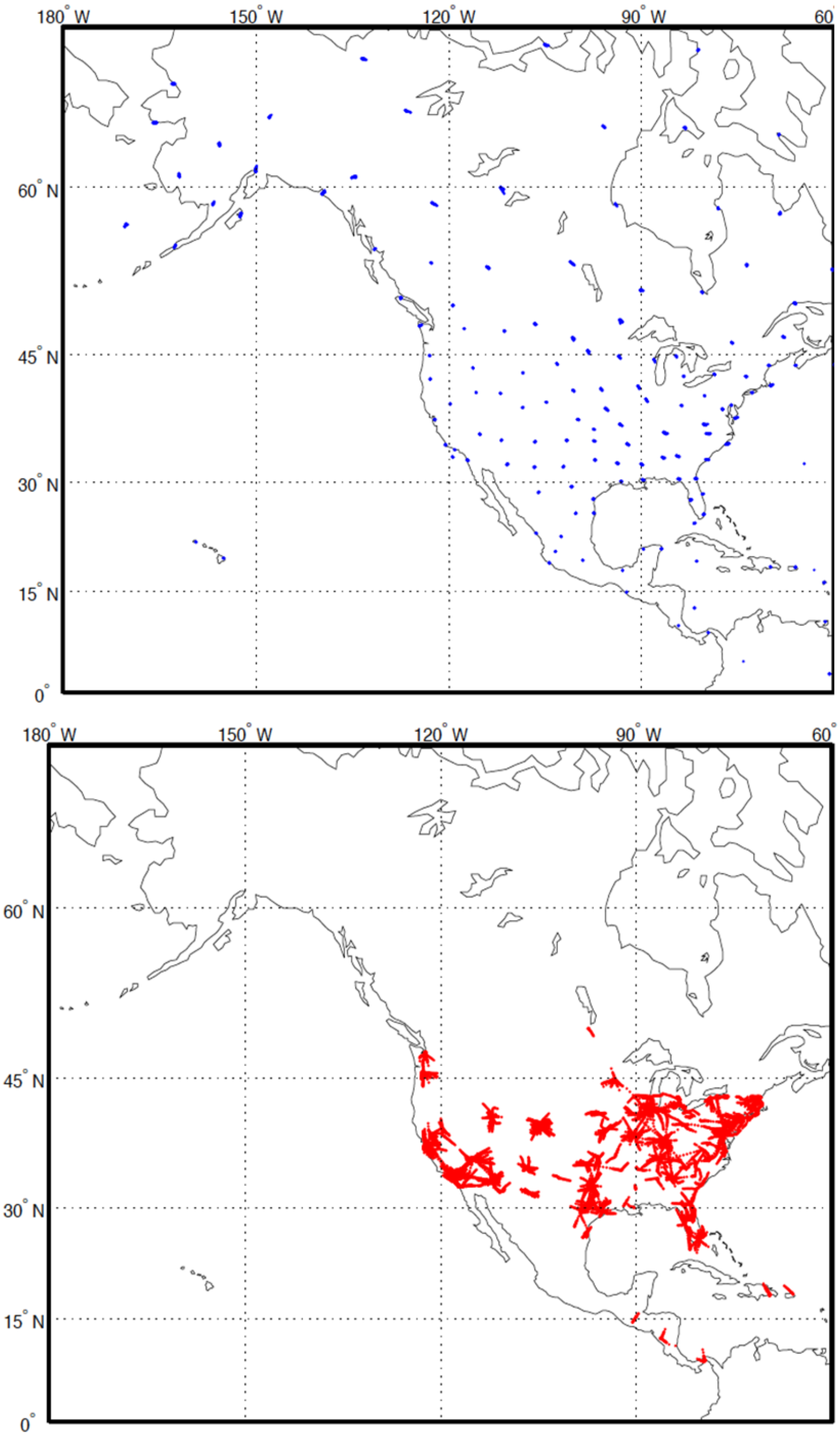
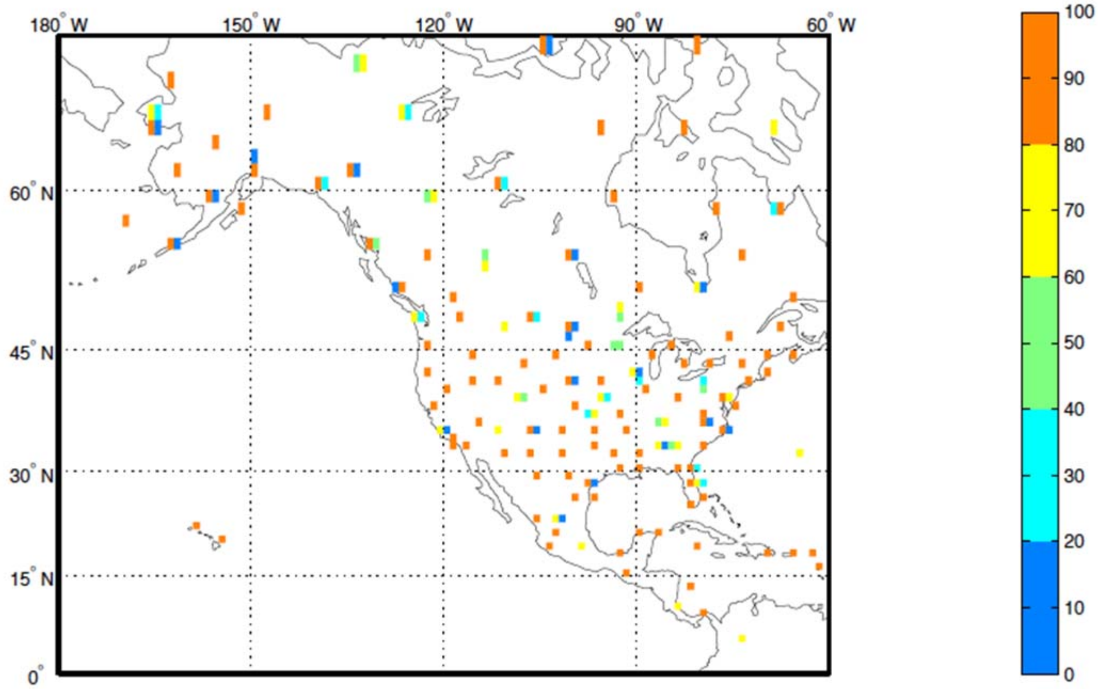


Figure 1: Spatial coverage of radiosonde (upper panel) and aircraft (lower panel) data for 25 October 2013, sum of 0000, 0600, 1200 and 1800 UTC.

a) Radiosondes – 25 October 2013



b) Aircraft – 25 October 2013

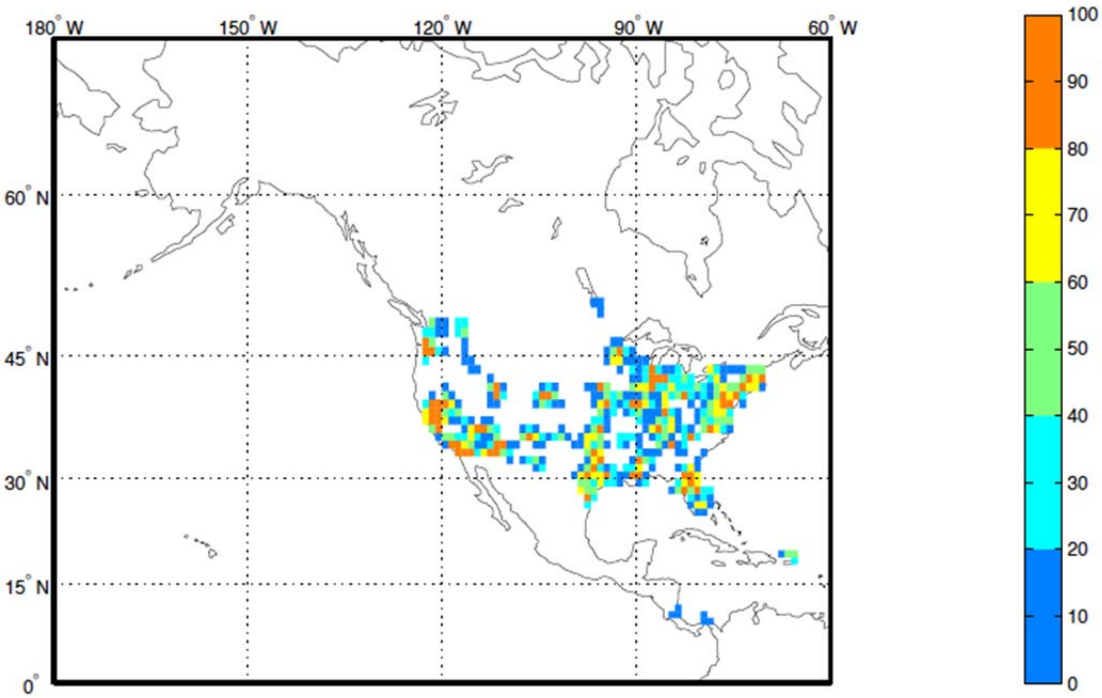


Figure 2: Vertical coverage (%) for (a) radiosonde and (b) aircraft datasets for 25 October 2013 distributed on a 1°x 1° degree grid.

Impact of the aircraft moisture observations on the global analysis

Figure 3 depicts the mean impact for a 10-day period of aircraft moisture observations on the global analysis of the low-level relative humidity (RH) and cloud cover. The RMSD between the experiment and control is used as the metric, to identify regions of largest impact, regardless if it is an increase or decrease in the parameter.

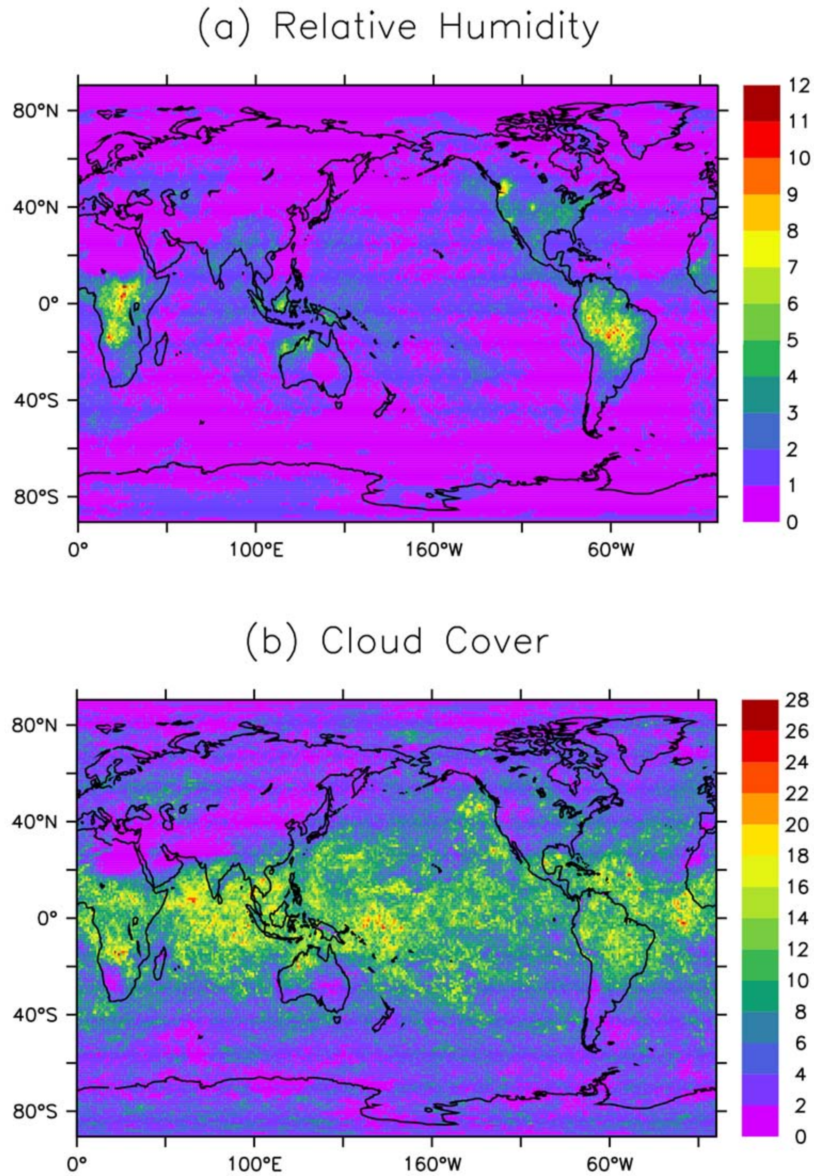


Figure 3: Root-mean-squared-difference (RMSD) for (a) 975 hPa relative humidity (percent; global mean is 1.11%) and (b) total atmospheric column cloud cover (percent; global mean is 5.65%) between the experiment and control runs. RMSD was first derived for each analysis-period and then averaged across all analysis-periods from 21 - 31 October 2013.

The top panel in Figure 3 shows a RMSD of several percent over the US, where the aircraft observations are most numerous (similar to the pattern in Figure 2b). However, the largest impact in the 975 hPa RH analysis is over South America and portions of Africa, which is likely due to a model adjustment with the new data being assimilated. Similarly, the RMSD of cloud cover (Figure 3b) varies widely throughout the tropical regions, but without any correlation to the additional moisture observations over the US.

Observation-space analysis impact of AMDAR and RAOB moisture observations

In a simplified framework, one can assume that an assimilated observation imposes an impact on the analysis-state defined by the following measure of analysis impact *a*:

$$a = \frac{\alpha^2 - \beta^2}{\varepsilon_o^2}$$

Which relates the difference between "ob-minus-analysis" (α) and "ob-minus-background" (β) relative to the assumed observation error (ε_o). For any observation, the analysis pulled closer to that observation if $a < 0$, while the analysis pulled away from any observation with $a > 0$.

Profiles of analysis-impact were produced for moisture observations collected by both radiosondes and aircraft at 50 radiosonde locations in the continental US. Observations are discretized into 50 pressure level bins, and average analysis-impact profiles are created for radiosonde observations as well as any aircraft observations taken within roughly 250 km and 1 hour of the radiosonde launch. Analysis-impact from radiosonde observations (blue profiles) is smallest near the surface (Figure 4a), with the analysis state frequently pulling away from the radiosonde below 900 hPa (Figure 4b). When aircraft moisture data is assimilated, analysis-impact of radiosondes changes. Aircraft observations express a larger analysis-impact than radiosondes at most levels (red profile, Figure 4a). The analysis-impact of radiosondes is higher below 900 hPa and above 350 hPa, and lower through the middle troposphere (blue profile, Figure 4c). This enhanced impact below 900 hPa helps mitigate against the analysis pulling away at low levels (magenta profiles, Figure 4b).

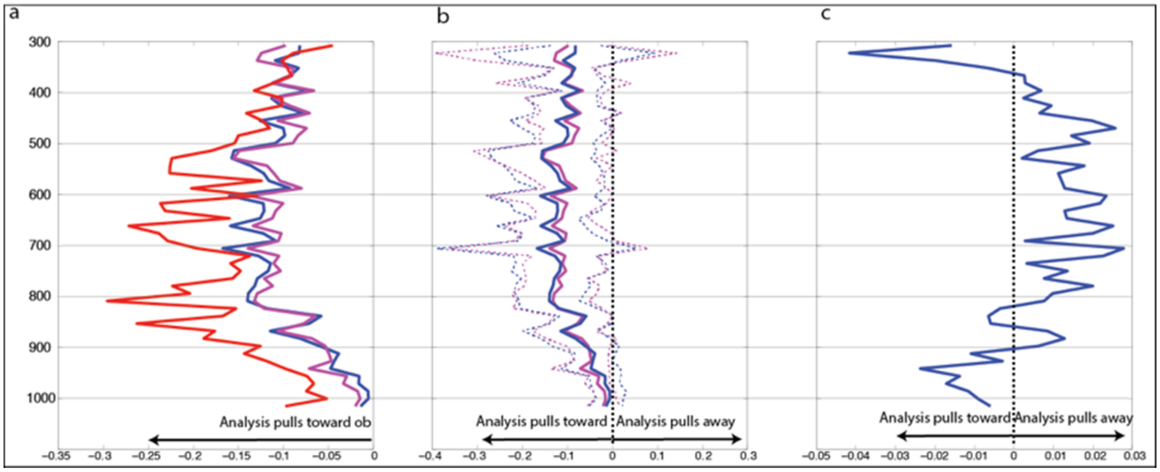


Figure 4: Mean profiles of analysis-impact. (a) Analysis-impact of aircraft moisture observations (red), radiosonde observations without aircraft observations (blue), and radiosondes with aircraft observations assimilated (magenta). (b) Analysis-impact of radiosondes before and after aircraft observation assimilation, with dashed lines representing one standard deviation from the mean. (c) The difference between mean analysis-impact profiles before and after aircraft observation assimilation. Negative (positive) values indicate the analysis pulls closer to (further from) the observation after it is assimilated.

The observed changes to analysis-impact from radiosondes can come from several sources. The model background can be perturbed by the continuous assimilation of aircraft moisture observations, leading to larger changes to β than α. Conversely, the radiosonde observations and collocated aircraft observations can either agree with or oppose each other during minimization, leading to a larger shift in α than β. Either scenario results in a change in analysis-impact.

We plan to use the limited quality control of moisture observations currently existing within the GDAS along with the assumed error-table for aircraft moisture observations already used in the NAM as a baseline to investigate both the model impact of aircraft moisture data, as well as the impact of any proprietary quality control conceived for aircraft moisture data that can be tested in a parallel experiment. Statistics such as the analysis-impact on aircraft moisture as well as radiosondes and other moisture observations will be employed to examine the interaction of the aircraft moisture information with the rest of the observing system, the model background, and the model analysis. Two-month parallel runs are currently in production for this purpose.

Resolved Issues and/or Risks

We are now able to successfully run the T670-resolution GDAS/GFS.

New Issues and/or Risks

None.