DAO Office Note 96-14

Office Note Series on Global Modeling and Data Assimilation

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Requirements for DAO's On-Line Monitoring System (*DOLMS*) Version 1.00

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June 1996

Abstract

One of the main goals of the DAO is to develop a system with careful attention to needs of users, in particular the EOS instrument teams and the Earth Science applications community at large. This demand requires a comprehensive quality assurance effort encompassing the input observing system and the output global gridded fields, on time scales ranging from hours to decades. The purpose of this document is to establish the requirements for an *on-line* monitoring system capable of providing real-time information about the performance of several DAO systems.

We describe several of the DAO's modes of operation, including its planned 1998 real-time and near real-time systems. The main components of DAO's On-Line Monitoring System ($\mathcal{DOLMS}$) are discussed, including observing system and climate diagnostic monitoring. Section 3 provides an overview of the requirements for a Web-based on-line monitoring system which is described in greater detail in the Appendix.

An on-line version of this document can be obtained from

`ftp://niteroi.gsfc.nasa.gov/www/dolms/dolms.html`

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1 Introduction

The central mission of the Data Assimilation Office (DAO) is to develop a state-of-the-art Data Assimilation System capable of assimilating relevant remotely-sensed data from the Earth Observing System (EOS) platforms, as well as global atmospheric data from the other observing systems. One of the main goals of the DAO is to develop a system with careful attention to needs of users, in particular the EOS instrument teams and the Earth Science applications community at large. This demand requires a comprehensive quality assurance effort encompassing the input observing system and output global gridded fields, on time scales ranging from hours to decades. The purpose of this document is to establish the requirements for an *on-line* monitoring system capable of providing real-time information about the performance of several DAO systems. Such a monitoring system is a component of the *DAO Quality Assurance Plan* being developed (Schubert 1996), but in itself does not define the overall validation strategy.

Throughout this document, we shall refer to the *DAO On-Line Monitoring System* ($\mathcal{DOLMS}$) as an information system whose primary function is to provide relevant system statistics, produced automatically on a routine basis, with the intent of diagnosing the quality of the input observational data and assimilation output. The specific algorithms for statistical quality control of observations, physical parameterizations and recent assessment of the DAO's assimilated data products dictates the choice of parameters to be monitored, but these algorithms are not described here[1]. This document focuses on the specification of minimum requirements for continuous monitoring of the data assimilation system performance. Additional tools for troubleshooting and diagnostics of specific features will undoubtedly be necessary, but their specification is beyond the scope of this document. Furthermore, the staffing and plan of action for an effective monitoring activity will be documented elsewhere.

The requirements for a monitoring system are largely dependent on the frequency the assimilation system is run, and on the input/output data volume. For example, an operational data assimilation system run in real-time can produce monitoring diagnostics for inspection of quality control statistics at each synoptic time. However, when performing a multi-year assimilation ("re-analysis") with a turn-around of 1 month of assimilation per day, monitoring diagnostics need to be conveniently summarized to allow timely inspection by the monitoring staff. Stobie (1996) identifies the following DAO modes of operation for 1998:

[1] A description of the current data pre-processing procedures can be found in Lamich *et al.* (1996), while Pfaendtner *et al.* (1995) documents Version 1 of the Goddard EOS Data Assimilation System (GEOS-1/DAS). The Atmospheric General Circulation Model component of GEOS-1/DAS is documented in Takacs *et al.* (1994) and Suarez and Takacs (1995). Schubert *et al.* (1995a) provide an overview of the main results of GEOS-1 multi-year assimilation. The proceedings of the *Workshop on the GEOS-1 Five-year Assimilation* (Schubert *et al.* 1995b) provides a good summary of the strengths and weaknesses of the data set. Most of these documents are available on-line from DAO's Home Page (`http://dao.gsfc.nasa.gov`).

First Look Assimilation: Operational support to EOS will have three components. The first is a first-look analysis that runs 12 to 24 hours after observation time, and uses primarily non-EOS data. This run provides background information to the AM-1 instrument retrieval algorithms, and analyses are produced 4 times a day at 0, 6, 12 and 18 GMT. The second component is a ten-day forecast, produced once a day following the first-look analysis. It is primarily used to support NASA field experiments.

Final Platform Assimilation: The third component is the final platform analysis which runs several months after data time and will use all the same data as the first look plus data from the AM-1 instruments. Final platform analyses may include standard GEOS DAS assimilations and off-line analyses (*e.g.*, constituent analyses).

Multi-year Assimilations ("Re-analyses"): Reanalysis is the process of running a long-term assimilation using historical data and a "frozen" assimilation system. Typically, the DAO will run a complete 20-year reanalysis about once every 4 years. This will be done to take advantage of advances in the assimilation system as well as the use of previously unanalyzed data.

New System Validation: From time to time, a new version of the Data Assimilation System will undergo a comprehensive validation against the most recent frozen system. This validation will typically consist of season long runs, with a turn-around time similar to the multi-year assimilations.

The specification of requirements described below takes into consideration these different modes of operation.

The organization of this document is as follows. Section 2 describes the general requirements for an on-line monitoring system, and identifies the 3 main components of $\mathcal{DOLMS}$: 1) observing system monitoring, 2) current analysis and forecast monitoring and 3) climate diagnostic monitoring. Section 3 provides an overview of the requirements (in terms of the statistics to be produced) for an initial Web-based on-line monitoring system which are described in greater detail in Appendices A—C. An outline of the Quality Control (QC) activities at DAO appears in Appendix D; a list of acronyms is also included.

2 General Requirements for a Monitoring System

The primary goal of $\mathcal{DOLMS}$ is to ensure overall system quality and stability through early detection and correction of problems. The stability of the data assimilation system is a fundamental requirement for several EOS instrument teams, as DAO first look fields will be used as first guess for retrieval algorithms. The stability of the

assimilation climate is also of primary importance for the earth science applications community, as is forecast accuracy for NASA missions support. Therefore, an effective monitoring system shall have 3 main components:

Observing System Monitoring: This component shall perform routine monitoring of the following:

- observations and residuals from forecast and analysis
- data counts and quality control (QC) decisions
- goodness-of-fit assessment of error covariance models used in the analysis, and results of bias correction algorithms

The system shall detect calibration and other instrumentation problems, and flag the inadequacy of the statistical models assumed in the analysis system. The system shall also monitor new (passive) data types (see subsection 2.1 for the definition of a *passive data type*).

Current Analysis and Forecast Monitoring: This component shall perform routine monitoring of the following:

- gridded assimilation data products
- forecast skill

The system shall detect abrupt changes in quality of analysis and accuracy of forecasts. Comparison with analysis and forecasts by at least one other operational center shall be included.

Climate Diagnostic Monitoring: This component shall perform routine monitoring of several *monthly mean* quantities, including

- prognostic and diagnostic quantities
- boundary conditions

with the intent of detecting climate drifts in the assimilation system.

Most of the information above shall be available on-line on the World Wide Web, both in graphical form and as data files for allowing further inspection by the users. In addition, a text based *system log* shall be maintained, where a summary of run-time anomalies, problems and corrective actions shall be recorded.

Each of the main components of $\mathcal{DOLMS}$ are further discussed below.

2.1 Observing System Monitoring

One of the essential ingredients for the Physical-space Statistical Analysis System (PSAS, da Silva *et al.* 1995) is the specification of covariance models for the forecast and observation errors, along with effective bias removal procedures. Current error covariance modeling methodology (Dee *et al.* 1996) requires the availability of innovations (O-F residuals) for statistically deriving such models, and for physically based bias removal. Therefore, before an observation can be used for assimilation O-F residuals need to be available. One possibility is to have this data type go through GEOS/DAS as a *passive* data type. A passive data is neither quality controlled nor used in the analysis, but is included in the assimilation *Observational Data Stream* (ODS) output (see Appendix D). For historical data types, ODS files can be created by combining pre-existing 6 hour forecasts with observational data. In any event, bias corrections and random error characterization are generally developed off-line based on ODS files.

Once error covariance models and bias correction schemes are developed and the new-data type is actively used in GEOS/DAS, post-analysis ODS files need to be constantly monitored to assess the goodness-of-fit of the assumed statistical models, and to adaptively re-tune model parameters. As instruments are replaced, or calibration characteristics change over time, an automated system capable of detecting and correcting such problems is an essential requirement. This is a crucial step for the overall stability of the data assimilation system.

At a minimum, the Observation System Monitoring sub-system shall include:

Innovations (O-F): time-mean, standard deviations and time evolution. The goal is to detect abrupt changes, assess the realism of the statistical models in PSAS, and the effectiveness of the bias correction procedures.

Observation minus Analysis (O-A) residuals: time-mean, standard deviations and time evolution. The goal is to detect abrupt changes, and the existence of time-mean biases in the analysis. O-A residuals are also useful to diagnose the performance of the analysis, in particular whether the observations are being used efficiently by the analysis system (Hollingsworth and Lönnberg 1989).

QC statistics: recent history of data counts, rejects and re-acceptance. An outline of the Quality Control procedures currently used at DAO and planned for 1998 is given in Appendix D.

The above statistics shall be monitored for each major instrument, with observations spatially averaged over key regions (*e.g.*, North America, Europe, etc.). For real-time/near real-time systems, a global map of QC decisions shall be produced. Global maps of O-F and O-A at key levels shall also be produced (on a synoptic time basis for real-time systems, on a monthly mean basis otherwise).

A detailed plan for goodness-of-fit assessment and re-tuning of error covariance and bias correction parameters will be described elsewhere.

2.2 Current Analysis and Forecast Monitoring

There currently exist several Web sites on the INTERNET providing a number of weather maps and forecast products (*e.g.*, the *Purdue Weather Processor* at `http://thunder.atms.purdue.edu/`). Typically, these sites produce standard DIFAX-like weather maps based on analysis and forecasts, along with current meteograms and MOS (model output statistics). Generally these sites focus on North America.

A minimum monitoring system shall include a basic weather map capability, portraiting analysis and forecasts. In addition to global maps, a regional (zoomed) version should be produced for the Northern Hemisphere and for another *floater* region which should be dictated by the specific NASA mission being supported. The monitoring system shall also maintain a number of forecast skill scores.

2.3 Climate Diagnostic Monitoring

One of the main goals of the DAO is to produce research quality data sets for earth science applications. Therefore, a continuous monitoring of climate diagnostics is mandatory. A minimum set of requirements must include monthly means of the following:

- Zonal mean of prognostic variables (winds, temperature, height and moisture) both from analysis and assimilation[2].
- Zonal mean of analysis increments
- Global maps of prognostic variables at key levels for both analysis and assimilation.
- Global maps of analysis increments at key levels.
- Global maps of selected diagnostic variables at key levels, such as
  - Precipitation and evaporation
  - Short- and long-wave radiation fluxes both at the surface and at the top of the atmosphere.

[2]By *analysis* is meant the output of the Physical-space Statistical Analysis System (PSAS). The *assimilation* fields are sampled from a model run forced by IAU increments. For more information on IAU and DAO data products, consult Schubert *et al.* (1993), Pfaendtner *et al.* (1995) and Bloom *et al.* (1996).

- Surface wind stress
- Surface net heat fluxes
- Boundary layer depth, etc.

2.4 Tailoring $\mathcal{DOLMS}$ for each "mode of operation"

For real-time operations (*first look system*[3]), the monitoring system shall provide on-line access to recent analyses and forecasts, as well as details of the quality control process for each synoptic time, and its evolution in the last 30 days. In addition, a number of climate diagnostics shall be continuously monitored to detect artificial climate drifts and other spurious signals introduced by the data assimilation system.

The *final platform* monitoring system will share most of the components with the real-time system, with the addition of statistics for several new data types. The system shall be able to monitor not only the new data types used in the final platform analysis, as well as *passive* data types which are not used in the analysis.

Typically, in *multi-year assimilation* mode, the system will process 1 month of data on single day, and detailed inspection of statistics on a synoptic time basis is not feasible. Therefore, the monitoring system shall concentrate on time series at key locations or regional averages, and on a comprehensive collection of climate diagnostics. If forecasts are issued on regular intervals or for case studies, these forecasts shall be monitored in a way similar to the first look system.

The monitoring system for *system validation* shall again concentrate on monthly time series and climate diagnostics. However, the monitoring system shall differ from the previous modes of operation in one particular aspect: it must simultaneously depict the performance of the new system compared to the control system.

3 Specification of Requirements: Overview

This section presents an overview of the requirements for an initial implementation of the DAO's On-Line Monitoring System. In order to promote the widest possible distribution within DAO and to outside users of our data products (*e.g.*, EOS instrument teams) the system shall be implemented as a World Wide Web document and available on the INTERNET[4]. However, the system shall be capable of automatically producing hardcopy of pre-selected pages for posting on bulletin boards and/or in-

[3]The DAO mode of operation are described in section 1; see also Stobie (1996).

[4]Some portions of the system, such as the pages relating to *Systems Validation* may have restricted access to outside users.

clusion on regular *Monitoring Reports*. In addition to graphical output, the original data files used by $\mathcal{DOLMS}$ shall be made available on *anonymous ftp*.

The requirements below focus on the observing system currently handled by GEOS/DAS which consists primarily of radiosondes, NESDIS/TOVS retrievals, Cloud-track winds, aircraft reports and ship/buoy surface marine observations. As new data types become available, these requirements shall be updated to reflect the new observing system.

Next, we present a summary of the requirements for each of the DAO's modes of operation described in section 1. Within each mode of operation, requirements are listed for *Observing System Monitoring*, *Current Analysis and Forecast Monitoring* and *Climate Diagnostic Monitoring*. At this stage, requirements are briefly described, *e.g.*

- O-F Time-series at Selected Levels (Region Averaged)
- O-F Time-mean and Standard Deviation (Region Averaged)
- O-F Global Maps (Each Synoptic Time)
- O-F Global Maps (Running Monthly Means)

Each of these bullets are further described in Appendices A–C, where levels, variables and instruments are fully specified. These Appendices are organized as *Generic Web Pages* for each of the main components of $\mathcal{DOLMS}$ described in section 2.

Welcome to $\mathcal{DOLMS}$

The Data Assimilation Office's On-line Monitoring System ($\mathcal{DOLMS}$) provides real-time information about the performance of several DAO systems.

1. **Real-time/Near Real-time Systems**

   (a) *Observing System Monitoring*

      i. O-F Time-series at Selected Levels (Region Averaged)
      ii. O-F Time-mean and Standard Deviation (Region Averaged)
      iii. O-F Global Maps (Each Synoptic Time)
      iv. O-F Global Maps (Running Monthly Means)
      v. O-A Time-series at Selected Levels (Region Averaged)
      vi. O-A Time-mean and Standard Deviation (Region Averaged)
      vii. O-A Global Maps (Each Synoptic Time)
      viii. O-A Global Maps (Running Monthly Means)
      ix. QC Time-series at Selected Levels (Region Averaged)
      x. QC Means for All Levels (Running Monthly Means)
      xi. QC Global Maps (Each Synoptic Time)
      xii. QC Global Maps (Running Monthly Means)

   (b) *Current Analysis and Forecast Monitoring*

      i. Prognostic quantities from *analysis* at selected levels (comparison with other centers)
      ii. Analysis increments at selected levels
      iii. Forecast verification (prognostic quantities)
      iv. Anomaly correlations at selected levels (each synoptic time)
      v. Anomaly correlations at selected levels (running monthly means)

   (c) *Climate Diagnostic Monitoring (Running Monthly Means)*

      i. Zonal means of prognostic quantities from *analysis*
      ii. Zonal means of prognostic quantities from *assimilation*
      iii. Zonal means of analysis increments
      iv. Prognostic quantities from *analysis* at selected levels
      v. Prognostic quantities from *assimilation* at selected levels
      vi. Analysis increments at selected levels
      vii. Surface diagnostics from *assimilation*
      viii. Top-of-atmosphere diagnostics from *assimilation*
      ix. Boundary conditions

(d) *System Log*

2. **Multi-year Assimilation**

   (a) *Observing System Monitoring*

      i. O-F Time-series at Selected Levels (Region Averaged)
      ii. O-F Time-Mean and Standard Deviation (Region Averaged)
      iii. O-F Global Maps (Running Monthly Means)
      iv. O-A Time-series at Selected Levels (Region Averaged)
      v. O-A Time-Mean and Standard Deviation (Region Averaged)
      vi. O-A Global Maps (Running Monthly Means)
      vii. QC Time-series at Selected Levels (Region Averaged)
      viii. QC Means for All Levels (Running Monthly Means)
      ix. QC Global Maps (Running Monthly Means)

   (b) *Current Analysis and Forecast Monitoring*

   A few key events shall be chosen for a detailed inspection on a synoptic time basis. In this case the system shall monitor:

      i. Prognostic quantities from *analysis* at selected levels (comparison with other centers)
      ii. Analysis increments at selected levels
      iii. Forecast verification (prognostic quantities)
      iv. Anomaly correlations at selected levels (each synoptic time)
      v. Anomaly correlations at selected levels (running monthly means)

   (c) *Climate Diagnostic Monitoring (Running Monthly Means)*

      i. Zonal means of prognostic quantities from *analysis*
      ii. Zonal means of prognostic quantities from *assimilation*
      iii. Zonal means of analysis increments
      iv. Prognostic quantities from *analysis* at selected levels
      v. Prognostic quantities from *assimilation* at selected levels
      vi. Analysis increments at selected levels
      vii. Surface diagnostics from *assimilation*
      viii. Top-of-atmosphere diagnostics from *assimilation*
      ix. Boundary conditions

   (d) *System Log*

3. **System Validation**

   In this mode of operation the system shall include information about the system being validated as well as information about a *control* system. For time-series (line) plots, an additional curve for the control shall be included. For contour maps, each figure shall contain 3 panels:

Top panel: monthly mean obtained with system being validated

Middle panel: monthly mean obtained with the control system

Bottom panel: difference between top and middle panel.

(a) *Observing System Monitoring*

i. O-F Time-series at Selected Levels (Region Averaged)
ii. O-F Time-Mean and Standard Deviation (Region Averaged)
iii. O-F Global Maps (Running Monthly Means)
iv. O-A Time-series at Selected Levels (Region Averaged)
v. O-A Time-Mean and Standard Deviation (Region Averaged)
vi. O-A Global Maps (Running Monthly Means)
vii. QC Time-series at Selected Levels (Region Averaged)
viii. QC Means for All Levels (Running Monthly Means)
ix. QC Global Maps (Running Monthly Means)

(b) *Current Analysis and Forecast Monitoring*

A few key events shall be chosen for a detailed inspection on a synoptic time basis. In this case the system shall monitor:

i. Prognostic quantities from *analysis* at selected levels (comparison with other centers)
ii. analysis increments at selected levels
iii. Forecast verification (prognostic quantities)
iv. Anomaly correlations at selected levels (each synoptic time)
v. Anomaly correlations at selected levels (running monthly means)

(c) *Climate Diagnostic Monitoring (Running Monthly Means)*

i. Zonal means of prognostic quantities from *analysis*
ii. Zonal means of prognostic quantities from *assimilation*
iii. Zonal means of analysis increments
iv. Prognostic quantities from *analysis* at selected levels
v. Prognostic quantities from *assimilation* at selected levels
vi. Analysis increments at selected levels
vii. Surface diagnostics from *assimilation*
viii. Top-of-atmosphere diagnostics from *assimilation*
ix. Boundary conditions

(d) *System Log*

Acknowledgments

A formal technical review of this document was conducted on June 4, 1996 at the Data Assimilation Office. We would like to thank Jim Stobie (review leader), Dick Dee, Sieg Schubert and Juan-Carlos Jusem (reviewers) for valuable suggestions.

Appendix

Requirements for a Web-based Monitoring System

These pages shall present several relevant information aimed at monitoring the behavior of the different observing platforms, their impact on the assimilation system, and the adequacy of observation and forecast errors assumed by the statistical interpolation algorithm. These are *generic* Web Page, and not all statistics appearing here may be available for given mode of operation. See section 3 for a list of statistics for each of the DAO modes of operation.

A Generic Observing System Monitoring Web Pages

For conciseness, statistics of observation minus 6 hour forecast (O-F) residuals and observation minus analysis (O-A) residuals are *spatially* averaged over several geographic areas:

- Global (ALL)
- North America (NAM)
- South America (SAM)
- Australia (AUS)
- Europe (EUR)
- Africa (AFR)
- Asia (ASI)
- Northern oceans (NOC)
- Tropical oceans (TOC)
- Southern oceans (SOC)
- Arctic (ARC)
- Antarctica (ANT)

A map of these regions is shown in Figure 1. In addition, the system shall comply with the following requirements:

1. Ship and buoy statistics shall only be produced at the ocean surface (regions: ALL, NOC, TOC & SOC).

2. Radiosonde statistics shall only be produced over land (all regions, except NOC, TOC & SOC).

3. Cloud-track wind statistics shall only be produced at 2 "vertical levels": below 500 hPa and above 500 hPa.

4. Aircraft data statistics shall be vertically integrated.

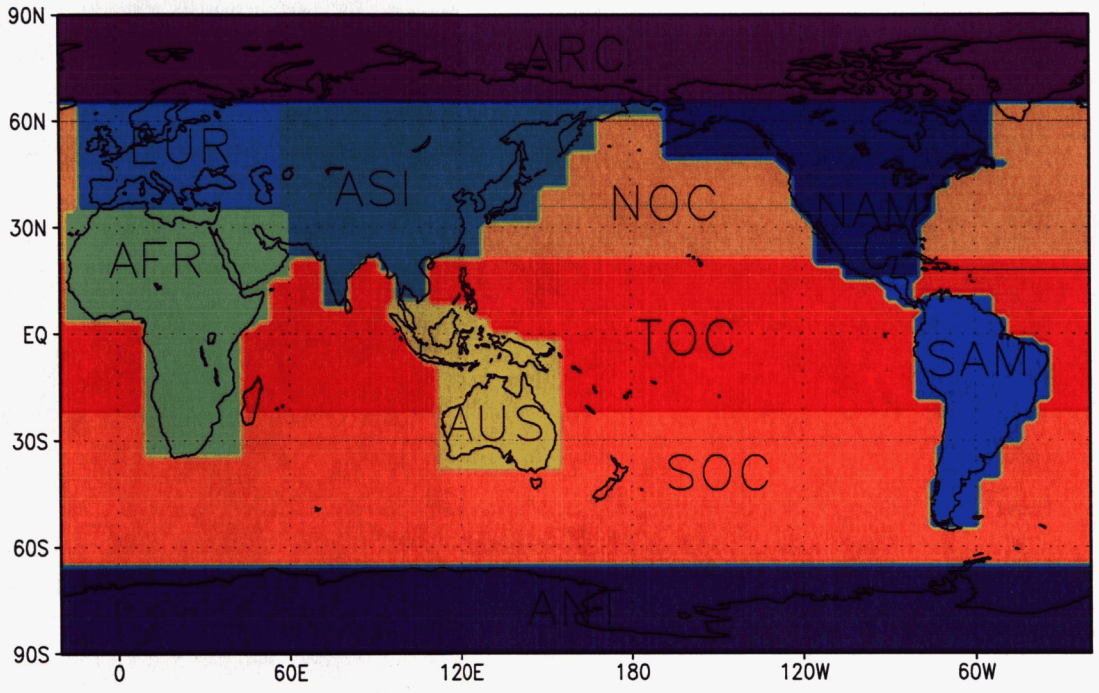

Figure 1: Region boundaries. See text for details.

O-F Time-series at Selected Levels (surface, 700 hPa, 500 hPa, 200 hPa, 50 hPa & 20 hPa)

These pages shall include *region averaged* statistics (last 30 days) of observation minus 6 hour forecast (O-F) residuals at selected vertical levels.

- Ship sea level pressure (hPa)
- Ship u-wind (m/s)
- Ship v-wind (m/s)

- Buoy sea level pressure (hPa)
- Buoy u-wind (m/s)
- Buoy v-wind (m/s)
- Radiosonde sea level pressure (hPa)
- Radiosonde geopotential heights (m)
- Radiosonde u-wind (m/s)
- Radiosonde v-wind (m/s)
- Radiosonde moisture
- TOVS height retrievals (m)
- Cloud-track u-wind (m/s)
- Cloud-track v-wind (m/s)
- Aircraft u-wind (m/s)
- Aircraft v-wind (m/s)

O-F Time-Mean and Standard Deviation (Running Monthly Means)

These pages shall include vertical profiles (all observing levels) of running monthly mean and standard deviations of observation minus 6 hour forecast (O-F) residuals. Single level instruments are excluded, as this information is provided with the time-series above. The system shall also depict the O-F standard deviation used in the statistical interpolation algorithm.

- Radiosonde geopotential heights (m)
- Radiosonde u-wind (m/s)
- Radiosonde v-wind (m/s)
- Radiosonde moisture
- TOVS height retrievals (m)

O-F Global Maps: Each Synoptic Time (surface, 700 hPa, 500 hPa, 200 hPa, 50 hPa & 20 hPa)

For each instrument/quantity listed below, O-F residuals shall be binned at the analysis grid-boxes and a global map shall be produced at each synoptic time, with the color of each grid-box reflecting the box mean O-F value.

- Radiosonde sea level pressure (hPa)
- Radiosonde geopotential heights (m)
- Radiosonde u-wind (m/s)
- Radiosonde v-wind (m/s)
- Radiosonde moisture
- TOVS height retrievals (m)
- Cloud-track u-wind (m/s)
- Cloud-track v-wind (m/s)
- Aircraft u-wind (m/s)
- Aircraft v-wind (m/s)

O-F Global Maps: Running Monthly Means (surface, 700 hPa, 500 hPa, 200 hPa, 50 hPa & 20 hPa)

For each instrument/quantity listed below, running monthly mean O-F residuals shall be binned at the analysis grid-boxes and a global map shall be produced, with the color of each grid-box reflecting the time/box mean O-F value.

- Ship sea level pressure (hPa)
- Ship u-wind (m/s)
- Ship v-wind (m/s)
- Buoy sea level pressure (hPa)
- Buoy u-wind (m/s)
- Buoy v-wind (m/s)
- Radiosonde sea level pressure (hPa)

- Radiosonde geopotential heights (m)
- Radiosonde u-wind (m/s)
- Radiosonde v-wind (m/s)
- Radiosonde moisture
- TOVS height retrievals (m)
- Cloud-track u-wind (m/s)
- Cloud-track v-wind (m/s)
- Aircraft u-wind (m/s)
- Aircraft v-wind (m/s)

QC Time-series at Selected Levels (surface, 700 hPa, 500 hPa, 200 hPa, 50 hPa & 20 hPa)

This page shall include *region averaged* time-series (last 30 days), at selected vertical levels, of the number of observations that were

- Marked as suspicious by the off-line QC system
- Marked as suspicious by the *gross-limit* check
- Re-accepted by the *buddy-check*

for the following quantities/observing systems:

- Ship sea level pressure (hPa)
- Ship u-wind (m/s)
- Ship v-wind (m/s)
- Buoy sea level pressure (hPa)
- Buoy u-wind (m/s)
- Buoy v-wind (m/s)
- Radiosonde sea level pressure (hPa)
- Radiosonde geopotential heights (m)
- Radiosonde u-wind (m/s)

- Radiosonde v-wind (m/s)
- Radiosonde moisture
- TOVS height retrievals (m)
- Cloud-track u-wind (m/s)
- Cloud-track v-wind (m/s)
- Aircraft u-wind (m/s)
- Aircraft v-wind (m/s)

QC Running Monthly Means for All Levels

This page shall present running monthly means of the total number of observations that were

- Marked as suspicious by the off-line QC system
- Marked as suspicious by the *gross-limit* check
- Re-accepted by the *buddy-check*

for the following quantities/observing systems:

- Radiosonde geopotential heights (m)
- Radiosonde u-wind (m/s)
- Radiosonde v-wind (m/s)
- Radiosonde moisture
- TOVS height retrievals (m)

QC Global Maps (Each Synoptic Time) (surface, 700 hPa, 500 hPa, 200 hPa, 50 hPa & 20 hPa)

A global map shall be produced with a dot for each observation marked by the QC system, as follows:

Top panel: observations marked as suspicious by the off-line QC system (red dots), and observations marked as suspicious by the *gross-limit* check (blue dots)

Bottom panel: observations re-accepted by the *buddy-check*

for each instrument/quantity listed below:

- Radiosonde sea level pressure (hPa)
- Radiosonde geopotential heights (m)
- Radiosonde u-wind (m/s)
- Radiosonde v-wind (m/s)
- Radiosonde moisture
- TOVS height retrievals (m)
- Cloud-track u-wind (m/s)
- Cloud-track v-wind (m/s)
- Aircraft u-wind (m/s)
- Aircraft v-wind (m/s)

QC Global Maps (Monthly Means)
(surface, 700 hPa, 500 hPa, 200 hPa, 50 hPa & 20 hPa)

The total number of observations flagged by the QC system in the last 30 days shall be binned in the analysis grid-boxes, and global maps shall be produced with the following:

Top panel: number of observations marked as suspicious by the off-line QC system

Middle panel: number of observations marked as suspicious by the *gross-limit* check (blue dots)

Bottom panel: number of observations re-accepted by the *buddy-check*

These maps shall be produced at selected vertical levels for each instrument/quantity listed below.

- Ship sea level pressure (hPa)
- Ship u-wind (m/s)
- Ship v-wind (m/s)

- Buoy sea level pressure (hPa)
- Buoy u-wind (m/s)
- Buoy v-wind (m/s)
- Radiosonde sea level pressure (hPa)
- Radiosonde geopotential heights (m)
- Radiosonde u-wind (m/s)
- Radiosonde v-wind (m/s)
- Radiosonde moisture
- TOVS height retrievals (m)
- Cloud-track u-wind (m/s)
- Cloud-track v-wind (m/s)
- Aircraft u-wind (m/s)
- Aircraft v-wind (m/s)

B Generic Current Analysis and Forecast Web Pages

These pages shall monitor basic prognostic quantities from analysis and forecasts on a synoptic time basis. It shall include comparison with analysis by other centers, and forecast verification against our own analysis.

Prognostic Variables at Selected Levels from Analysis ("Uninitialized")

This page shall present DAO's current analysis along with analysis by other centers (initially only the analysis by the National Centers for Environmental Prediction [NCEP]) on the same figure. It shall consist of global maps, a stereographic Northern Hemisphere map, and possibly another floater region in support of a specific NASA mission.

- Sea level pressure (hPa)
- 1000 hPa u-wind (m/s)
- 1000 hPa v-wind (m/s)
- 1000 hPa temperature (m/s)
- 1000 hPa specific humidity (m/s)
- 700 hPa geopotential heights (m)
- 700 hPa u-wind (m/s)
- 700 hPa v-wind (m/s)
- 700 hPa temperature (m/s)
- 700 hPa specific humidity (m/s)
- 500 hPa geopotential heights (m)
- 500 hPa u-wind (m/s)
- 500 hPa v-wind (m/s)
- 500 hPa temperature (m/s)
- 500 hPa specific humidity (m/s)
- 200 hPa geopotential heights (m)
- 200 hPa u-wind (m/s)

- 200 hPa v-wind (m/s)
- 200 hPa temperature (m/s)
- 200 hPa specific humidity (m/s)
- 50 hPa geopotential heights (m)
- 50 hPa u-wind (m/s)
- 50 hPa v-wind (m/s)
- 50 hPa temperature (m/s)
- 20 hPa geopotential heights (m)
- 20 hPa u-wind (m/s)
- 20 hPa v-wind (m/s)
- 20 hPa temperature (m/s)

Analysis Increments at Selected Levels

This page shall present analysis increments (difference between analysis and first guess) at selected vertical levels. It shall consist of global maps, and possibly another floater region in support of a specific NASA mission.

- Sea level pressure (hPa)
- 1000 hPa u-wind (m/s)
- 1000 hPa v-wind (m/s)
- 1000 hPa temperature (m/s)
- 1000 hPa specific humidity (m/s)
- 700 hPa geopotential heights (m)
- 700 hPa u-wind (m/s)
- 700 hPa v-wind (m/s)
- 700 hPa temperature (m/s)
- 700 hPa specific humidity (m/s)
- 500 hPa geopotential heights (m)
- 500 hPa u-wind (m/s)

- 500 hPa v-wind (m/s)
- 500 hPa temperature (m/s)
- 500 hPa specific humidity (m/s)
- 200 hPa geopotential heights (m)
- 200 hPa u-wind (m/s)
- 200 hPa v-wind (m/s)
- 200 hPa temperature (m/s)
- 50 hPa geopotential heights (m)
- 50 hPa u-wind (m/s)
- 50 hPa v-wind (m/s)
- 50 hPa temperature (m/s)
- 20 hPa geopotential heights (m)
- 20 hPa u-wind (m/s)
- 20 hPa v-wind (m/s)
- 20 hPa temperature (m/s)

Forecast Verification of Prognostic Variables at Selected Levels

This page shall present the verification of DAO's 1-day, 2-day, 3-day, 6-day and 10-day forecasts by DAO's current analysis. It shall consist of global maps, a stereographic Northern Hemisphere map, and possibly another floater region in support of a specific NASA mission. Each figure will show the verifying analysis along with the several forecasts verifying at the same time.

- Sea level pressure (hPa)
- 1000 hPa u-wind (m/s)
- 1000 hPa v-wind (m/s)
- 1000 hPa temperature (m/s)
- 1000 hPa specific humidity (m/s)
- 700 hPa geopotential heights (m)

- 700 hPa u-wind (m/s)
- 700 hPa v-wind (m/s)
- 700 hPa temperature (m/s)
- 700 hPa specific humidity (m/s)
- 500 hPa geopotential heights (m)
- 500 hPa u-wind (m/s)
- 500 hPa v-wind (m/s)
- 500 hPa temperature (m/s)
- 500 hPa specific humidity (m/s)
- 200 hPa geopotential heights (m)
- 200 hPa u-wind (m/s)
- 200 hPa v-wind (m/s)
- 200 hPa temperature (m/s)
- 200 hPa specific humidity (m/s)
- 50 hPa geopotential heights (m)
- 50 hPa u-wind (m/s)
- 50 hPa v-wind (m/s)
- 50 hPa temperature (m/s)
- 20 hPa geopotential heights (m)
- 20 hPa u-wind (m/s)
- 20 hPa v-wind (m/s)
- 20 hPa temperature (m/s)

Anomaly Correlations (Each Synoptic Time) at Selected Levels

This page shall present (forecast minus analysis) *anomaly correlations* for the Northern hemisphere extra-tropics (north of 20N), Southern Hemisphere extra-tropics (south of 20S) and tropics (within 20S—20N). Anomaly correlations shall be computed every synoptic time, with forecast lags from 1-day to 10-days, for the following quantities:

- Sea level pressure
- 700 hPa geopotential heights
- 500 hPa geopotential heights
- 200 hPa geopotential heights
- 50 hPa geopotential heights
- 20 hPa geopotential heights

Anomaly Correlations (Running Monthly Means) at Selected Levels

This page shall present (forecast minus analysis) *anomaly correlations* for the Northern hemisphere extra-tropics (north of 20N), Southern Hemisphere extra-tropics (south of 20S) and tropics (within 20S—20N). The "monthly mean" anomaly correlation shall be computed from the one-month sample anomaly co-variance. Anomaly correlations shall be computed for forecasts with lags from 1-day to 10-days, for the following quantities:

- Sea level pressure
- 700 hPa geopotential heights
- 500 hPa geopotential heights
- 200 hPa geopotential heights
- 50 hPa geopotential heights
- 20 hPa geopotential heights

C Generic Climate Monitoring Web Pages

These pages shall present (running) monthly means of several prognostic and diagnostic quantities. Only global contour maps shall be produced.

Zonal Means of Prognostic Quantities from Analysis ("Uninitialized")

- zonal mean u-wind (m/s)
- zonal mean v-wind (m/s)
- zonal mean temperature (C)
- zonal mean specific humidity (g/kg)
- zonal mean vertical velocity ω (hPa/day)

Zonal Means of Analysis Increments

- zonal mean u-wind (m/s)
- zonal mean v-wind (m/s)
- zonal mean temperature (C)
- zonal mean specific humidity (g/kg)

Zonal Means of Prognostic Quantities from Assimilation

- zonal mean u-wind (m/s)
- zonal mean v-wind (m/s)
- zonal mean temperature (C)
- zonal mean specific humidity (g/kg)
- zonal mean vertical velocity ω (hPa/day)

Prognostic Variables at Selected Levels from Analysis ("Uninitialized")

- Sea level pressure (hPa)
- 1000 hPa u-wind (m/s)
- 1000 hPa v-wind (m/s)
- 1000 hPa temperature (m/s)
- 1000 hPa specific humidity (m/s)
- 700 hPa geopotential heights (m)
- 700 hPa u-wind (m/s)
- 700 hPa v-wind (m/s)
- 700 hPa temperature (m/s)
- 700 hPa specific humidity (m/s)
- 500 hPa geopotential heights (m)
- 500 hPa u-wind (m/s)
- 500 hPa v-wind (m/s)
- 500 hPa temperature (m/s)
- 500 hPa specific humidity (m/s)
- 200 hPa geopotential heights (m)
- 200 hPa u-wind (m/s)
- 200 hPa v-wind (m/s)
- 200 hPa temperature (m/s)
- 200 hPa specific humidity (m/s)
- 50 hPa geopotential heights (m)
- 50 hPa u-wind (m/s)
- 50 hPa v-wind (m/s)
- 50 hPa temperature (m/s)
- 20 hPa geopotential heights (m)
- 20 hPa u-wind (m/s)
- 20 hPa v-wind (m/s)

- 20 hPa temperature (m/s)

Analysis Increments at Selected Levels

- Sea level pressure (hPa)
- 1000 hPa u-wind (m/s)
- 1000 hPa v-wind (m/s)
- 1000 hPa temperature (m/s)
- 1000 hPa specific humidity (m/s)
- 700 hPa geopotential heights (m)
- 700 hPa u-wind (m/s)
- 700 hPa v-wind (m/s)
- 700 hPa temperature (m/s)
- 700 hPa specific humidity (m/s)
- 500 hPa geopotential heights (m)
- 500 hPa u-wind (m/s)
- 500 hPa v-wind (m/s)
- 500 hPa temperature (m/s)
- 500 hPa specific humidity (m/s)
- 200 hPa geopotential heights (m)
- 200 hPa u-wind (m/s)
- 200 hPa v-wind (m/s)
- 200 hPa temperature (m/s)
- 50 hPa geopotential heights (m)
- 50 hPa u-wind (m/s)
- 50 hPa v-wind (m/s)
- 50 hPa temperature (m/s)
- 20 hPa geopotential heights (m)

- 20 hPa u-wind (m/s)
- 20 hPa v-wind (m/s)
- 20 hPa temperature (m/s)

Prognostic Variables at Selected Levels from Assimilation

- Sea level pressure (hPa)
- 1000 hPa u-wind (m/s)
- 1000 hPa v-wind (m/s)
- 1000 hPa temperature (m/s)
- 1000 hPa specific humidity (m/s)
- 700 hPa geopotential heights (m)
- 700 hPa u-wind (m/s)
- 700 hPa v-wind (m/s)
- 700 hPa temperature (m/s)
- 700 hPa specific humidity (m/s)
- 700 hPa vertical velocity ω (hPa/day)
- 500 hPa geopotential heights (m)
- 500 hPa u-wind (m/s)
- 500 hPa v-wind (m/s)
- 500 hPa temperature (m/s)
- 500 hPa specific humidity (m/s)
- 500 hPa vertical velocity ω (hPa/day)
- 200 hPa geopotential heights (m)
- 200 hPa u-wind (m/s)
- 200 hPa v-wind (m/s)
- 200 hPa temperature (m/s)

- 200 hPa specific humidity (m/s)
- 200 hPa vertical velocity ω (hPa/day)
- 50 hPa geopotential heights (m)
- 50 hPa u-wind (m/s)
- 50 hPa v-wind (m/s)
- 50 hPa temperature (m/s)
- 50 hPa vertical velocity ω (hPa/day)
- 20 hPa geopotential heights (m)
- 20 hPa u-wind (m/s)
- 20 hPa v-wind (m/s)
- 20 hPa temperature (m/s)
- 20 hPa vertical velocity ω (hPa/day)

Surface Diagnostics from Assimilation

- Total precipitation (mm/day)
- Convective precipitation (mm/day)
- Evaporation (mm/day)
- Vertically integrated moisture divergence (mm/day)
- Total precipitable water
- Net shortwave radiation (Watts/m^2)
- Net longwave radiation (Watts/m^2)
- Surface Shortwave cloud forcing: all-sky minus clear-sky (Watts/m^2)
- Surface Longwave cloud forcing: all-sky minus clear-sky (Watts/m^2)
- Net latent heat flux (Watts/m^2)
- Net sensible heat flux (Watts/m^2)
- Wind stress (N/m^2)

- Planetary Boundary Layer depth (m)

Top of the Atmosphere Diagnostics from Assimilation

- Net shortwave radiation (Watts/m^2)
- Net longwave radiation (Watts/m^2)
- Shortwave cloud forcing: all-sky minus clear-sky (Watts/m^2)
- Longwave cloud forcing: all-sky minus clear-sky (Watts/m^2)

Boundary Conditions

- Surface ground temperature
- Surface ground wetness
- Surface roughness
- Surface type
- Surface albedo
- Snow cover flag

D Quality Control at DAO: Background

This appendix outlines the main characteristics of the data pre-processing and quality control (QC) at DAO. For additional information consult Lamich *et al.* (1996) and Dee and Trenholm (1996). We also describe the Observational Data Stream (ODS), a new file format for observational data being implemented at DAO.

D.1 Data pre-processing at DAO

Traditionally, all observational data received at DAO are first archived with a consistent home-grown format known as UNPACK. UNPACK files hold all observational data we receive, including such data that never make it to the assimilation process. In preparation for assimilation, a pre-processing system referred to as REPACK selects data from UNPACK files, performs a few simple quality checks and corrections (such as the hydrostatic check), producing an output file which is read by GEOS/DAS. Details of the UNPACK/REPACK systems and file formats can be found in Lamich *et al.* (1996).

At the moment, DAO obtains its observational data through a link to the National Centers for Environmental Predictions (NCEP, formerly the U.S. National Meteorological Center) in Camp Springs, Maryland. By obtaining the data at a later stage of NCEP's pre-processing, we have been able to take advantage of several aspects of NCEP's data screening and quality control, such as the Complex Quality Control (CQC) of Collins and Gandin (1990), NCEP's radiation correction (Julian 1991), and radiosonde *black-listing.* Recent changes in the NMC data stream have forced us to add to REPACK the capability of reading BUFR, a WMO format used internally at NCEP. Although DAO has plans to strengthen its collaboration with NCEP in this area, steps are being taken to ensure that internal changes at NCEP do not impact operations at DAO. The overall approach is to obtain the raw data at a earlier stage in the NCEP pre-processing, and implement at DAO the Complex Quality Control and other relevant software. This arrangement will also allow us to adapt this software to address issues specific to the DAO mission. The general strategy in this area is discussed by Dee and Trenholme (1996).

D.2 The on-line QC system

The on-line QC system consist of data screening procedures which depend on the model first guess and are therefore performed during the assimilation cycle. The input observations produced by the REPACK system have quality marks with 2 possible values: *good* or *suspicious.* A gross-check is performed on the innovations (O-F, the difference between the observation and the 6 hour forecast), and observations

which fail the gross-check are added to the list of suspicious observations provided by the REPACK. A *buddy* check is then performed on all suspicious observations, in which nearby *good* observations are used to determine whether any of the suspicious observations are to be re-accepted. For details on the current quality control consult Pfaendtner *et al.* (1995). Dee and Trenholme (1996) discusses future plans for DAO's QC system.

Table 1: List of mandatory data attributes for a post-analysis ODS file. See da Silva and Redder (1995) for description of attributes.

Variable name	*Description*	*Units*
kt	Data type index	
kx	Data source index	
ks	Sounding index	
km	Metadata index	
lat	Latitude	degrees north
lon	Longitude	degrees east
level	Level or channel	hPa/none
julian	Julian day	
time	Time stamp	minutes
obs	Observation value	depends on *kt*
qc_flag	Quality control flag	
mod_flag	Modification flag	
omf	Observation minus 6h forecast	depends on *kt*
oma	Observation minus analysis	depends on *kt*
sigO	Observation error standard deviation	depends on *kt*
sigF	Forecast error standard deviation	depends on *kt*

D.3 The Observation Data Stream (ODS)

Useful by-products of the assimilation system are the innovations (O-F) and the differences between the observation and the analysis (O-A), along with the quality control marks assigned by GEOS/DAS. In order to provide easy access to all relevant information about observations during its life-cycle, a new Observation Data Stream file format has been designed (da Silva and Redder 1995). These HDF compliant files are intended to serve as input and output for GEOS/DAS, and unify the old REPACK and del-files used at DAO.

Table 1 lists all the attributes available for each observation stored on a (post-analysis) ODS file. The data type index *kt* identifies the observed quantity (wind, temperature, etc.) while the data source index *kx* identifies the instrument (radiosonde, aircraft,

etc.). Of particular relevance for the monitoring system are the QC and modification flags:

Quality control flag (*qc_flag*). This flag contains the result of the several quality control tests performed on the observation. A list of these tests is given in Table 2; see Pfaendtner *et al.* (1995) and Lamich *et al.* (1996) for additional information on the GEOS-1/DAS quality control and data pre-processing procedures. This flag is currently stored on the ODS file using 2 bytes, with bitwise encoding of the result of the several quality control tests performed. For most tests, a "0" means that the observation passed the test OR that the test has not been performed; a bit of value "1" means that the observation failed the test. For some tests, *e.g.*, the off-line subjective test, the observation can fail (bit values 11), pass (bit values 00), or be marked as suspicious (bit values 01). The *off-line* tests listed in Table 2 are performed prior to the assimilation cycle, at the "REPACK" level. The *on-line* tests are those performed inside the GEOS Data Assimilation System and for the most part make use of the model first guess (currently, a 6 hour forecast). For a summary of these QC tests see Appendix D of da Silva and Redder (1995).

Table 2: Conventions for the quality control flag (*qc_flag*). See text for details.

Bit Position	*Test Description*	*Possible Values*
1	Off-line gross limit check	0 or 1
2	Off-line climatological check	0 or 1
3	Off-line hydrostatic check	0 or 1
4	Off-line sea level pressure check	0 or 1
5	Off-line integrity test	0 or 1
6	Off-line black-list mark	0 or 1
7–8	Off-line Complex QC test	00 or 01 or 11
9–10	Off-line subjective test	00 or 01 or 11
11	On-line gross limit check	0 or 1
12	On-line *buddy* check	0 or 1
13	On-line final QC decision	0 or 1
14	On-line passive data type mark	0 or 1
15–16	Bits currently not used	00

Modification flag (*mod_flag*). In addition to simple pass/fail tests, both on- and off-line quality control systems can alter the value of an observation to remove known biases, correct for transmission errors, or simply to combine several observations into a single, "average" super-observation. Other observations, such as dew-point temperature, are derived from reported quantities. The *mod_flag* attribute keeps a record of the changes made to the observations during the

assimilation process. This flag is stored using 1 byte, with bitwise encoding of the different modifying processes (Table 3).

Table 3: Conventions for the modification flag (*mod_flag*). See text for details.

Bit Position	*Description*	*Possible Values*
1	Observation is a super-ob	0 or 1
2	Observation modified by Complex QC system	0 or 1
3	Bias correction applied	0 or 1
4	Derived data type	0 or 1
5–8	Bits currently not used	0000

List of Acronyms

AM-1	*Antemeridiem* 1 (an EOS platform)
ACQC	Aircraft Complex Quality Control
CQC	Complex Quality Control
DOLMS	DAO On-Line Monitoring System
DAO	Data Assimilation Office
DAS	Data Assimilation System
EOS	Earth Observing System
FTP	File Transfer Protocol
GCM	General Circulation Model
GEOS-1 DAS	Goddard EOS-Version 1 Data Assimilation System
GLA	Goddard Laboratory for Atmospheres
IAU	Incremental Analysis Update
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Predictions
NESDIS	National Environmental Satellite, Data, and Information Service
ODS	Observational Data Stream (file format)
OI	Optimal Interpolation
ODS	Observational Metadata Stream (file format)
O-A	Observation minus Analysis Residual
O-F	Observation minus Forecast Residual (innovation)
PBL	Planetary Boundary Layer
PSAS	Physical-space Statistical Analysis System
QC	Quality Control
REPACK	Data pre-processing system for GEOS-1 DAS
TIROS	Television Infrared Observing Satellite
TOVS	TIROS Operational Vertical Sounder
TOVS A	TOVS clear sky retrieval
TOVS B	TOVS partly cloudy sky retrieval
TOVS C	TOVS cloudy sky retrieval
UNPACK	Internal file format for GEOS-1 DAS
WMO	World Meteorological Organization

References

Bloom, S.S., L.L. Takacs, A. M. da Silva, and D. Ledvina, 1996: Data Assimilation Using Incremental Analysis Updates. *Mon. Wea. Rev.*, **124**, 1256–1271.

Collins, W. G. and L. S. Gandin, 1990: Comprehensive hydrostatic quality control at the National Meteorological Center. *Mon. Wea. Rev.*, **18**, 2754–2767.

Dee, D. and A. Trenholme, 1996: GEOS/DAS QC Strategy Document, *DAO Office Note 96-15*, Data Assimilation Office, Goddard Space Flight Center, Greenbelt, MD 20771.

Dee, D., C. Redder and A. da Silva, 1996: Off-line tuning of forecast and observation error covariance parameters. *DAO Office Note 96-??.*. Data Assimilation Office, Goddard Space Flight Center, Greenbelt, MD 20771. *In preparation.*

Hollingsworth, A. and P. Lönnberg, 1989: The verification of objective analyses: diagnostics of analysis system performance, *Meteorol. Atmos. Phys.*, **40**, 3–27.

Julian, P. R., 1991: RADCOR91: The new radiosonde radiation error correction procedure. Office Note No. 374. *National Meteorological Center*, Washington, DC.

Lamich, D., M. Hall, Y. Kondratyeva, R. Govindaraju and E. Hartnett, 1996: Documentation of Observational Data Preparation for the Goddard Earth Observing System (GEOS) Data Assimilation System. NASA Tech. Memorandum 104606, *in preparation.*

Pfaendtner, J., S. Bloom, D. Lamich, M. Seablom, M. Sienkiewicz, J. Stobie, A. da Silva, 1995: Documentation of the Goddard Earth Observing System (GEOS) Data Assimilation System–Version 1. *NASA Tech. Memo. No. 104606*, Vol. **4**, Goddard Space Flight Center, Greenbelt, MD 20771. Available electronically on the World Wide Web as `ftp://dao.gsfc.nasa.gov/pub/tech_memos/volume_4.ps.Z`

Schubert, S.D., R. B. Rood, and J. Pfaendtner, 1993: An assimilated data set for earth science applications. Bul. Amer. Meteor. Soc., 74, 2331-2342.

Schubert, S., C.-K. Park, Chung-Yu Wu, W. Higgins, Y. Kondratyeva, A. Molod, L. Tkacs, M. Seablom, and R. Rood, 1995a: A Multiyear Assimilation with the GEOS-1 System: Overview and Results. NASA Tech. Memo. 104606, Vol. 6. Goddard Space Flight Center, Greenbelt, MD 20771.

Schubert, S. D. and R. Rood, 1995b: Proceedings of the Workshop on the GEOS-1 Five-Year Assimilation. NASA Tech. Memo. 104606, Vol. 7, Goddard Space Flight Center, Greenbelt, MD 20771.

Schubert, S. D., 1996: DAO's Quality Assessment Team: Definition and Planing Document. *DAO Office Note 96-??.*. Data Assimilation Office, Goddard Space Flight Center, Greenbelt, MD 20771. *In preparation.*

da Silva, A. and C. Redder, 1995: Documentation of the GEOS/DAS Observation Data Stream (ODS) Version 1.0. *DAO Office Note 95-01.*. Data Assimilation Office, Goddard Space Flight Center, Greenbelt, MD 20771.

da Silva, A., J. Pfaendtner, J. Guo, M. Sienkiewicz and S. E. Cohn, 1995: Assessing the Effects of Data Selection with DAO's Physical-space Statistical Analysis System. *International Symposium on Assimilation of Observations*, Tokyo, Japan, 133-17 March 1995, 273–278.

Stobie, J, 1996: Data Assimilation Computing and Mass Storage Requirements for 1998. *DAO Office Note 96-16.*. Data Assimilation Office, Goddard Space Flight Center, Greenbelt, MD 20771.

Suarez, M.J. and Takacs, L.L., 1995: Documentation of the Aries-GEOS Dynamical Core: Version 2. NASA Tech. Memo. No. 104606, volume 5, Goddard Space Flight Center, Greenbelt, MD 20771.

Takacs, L.L., A. Molod, and T. Wang, 1994: Documentation of the Goddard Earth Observing System (GEOS) General Circulation Model–Version 1. NASA Tech. Memo. No. 104606, volume 1, Goddard Space Flight Center, Greenbelt, MD 20771.

NOTES:

1. The NASA Tech Memoranda listed above are available by anonymous ftp from

   `ftp://dao.gsfc.nasa.gov/pub/tech_memos`

2. DAO Office Notes listed above are available by anonymous ftp from

   `ftp://dao.gsfc.nasa.gov/pub/office_notes`