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AUTOMATED ATMOSPHERIC OBSERVATIONS FROM MILITARY AIRCRAFT

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1. INTRODUCTION

Many military operations are weather dependent and will succeed only if meteorological conditions are favorable. Therefore, accurate weather forecasts for the battlespace environment are often of critical importance. However, conventional meteorological observations in and near the battlespace may not be available as governments seek to deny the observations to their enemies and as commercial aviation and the observations made from these aircraft are suspended. If the decrease in conventional observations presented to a data assimilation system is severe, the accuracy of the ensuing numerical forecasts will likely also suffer.

This paper reports on preliminary work at the Naval Research Laboratory—Monterey (NRL) to utilize automated observations from military aircraft in data assimilation. These observations are expected to have the same general characteristics as those from commercial aircraft, and therefore the same potential for improving forecast accuracy. Two separate but related efforts are included here, using data from the Predator Unmanned Aeronautical Vehicle (UAV) (Fig. 1) and data from United States Air Force (USAF) transport aircraft.

Figure 1: Predator in flight. [From http:/www.af.mil/photos/factsheet_photos.asp?fsID=122]

2. PREDATOR OBSERVATIONS

The RQ-1 Predator is a long-endurance medium-altitude UAV flown by the USAF and others. The Predator A, the current aircraft being used for atmospheric observations, is twenty-seven feet long with a wingspan of forty-eight feet (Office of the Secretary of the Air Force 2005). It can fly for up to forty hours on a Rotax four cylinder engine. On board the aircraft are a pressure altimeter, an air speed sensor, and a temperature sensor in the "alpha" probe protruding from the front of the fuselage. The winds are computed as the vector difference of the true airspeed vector from the groundspeed vector.

The Predator is not an autonomous aircraft, but rather is flown by pilots at the Ground Control Station (GCS). There are both line-of-sight (4.5 Mbs) and satellite links (T1) for controlling the aircraft and receiving information from the aircraft sensors. The portion of the communications containing non-imagery information (including meteorological parameters) is called the Exploitation Support Data (ESD). It is possible to send the ESD out through a port on the GCS.

The Intelligence, Surveillance, and Reconnaissance (ISR) office of the Space and Naval Warfare Systems Command's Operational Effects Program has developed the capability to read the Predator ESD using a personal computer and build an aircraft weather observation in the World Meteorological Organization (WMO) Aircraft Meteorological Data Relay (AMDAR) format, also referred to as FM-42 (World Meteorological Organization 1995). This allows the Predator to do double duty as both an ISR platform and a weather-observing platform in areas of interest.

The AMDAR encoding software reads the ESD, finds the weather data, strips it out, and builds the AMDAR message. The observation frequency and

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averaging period comply with ARINC 620, the widely used specification that governs meteorological observations taken from commercial aircraft (World Meteorological Organization 2003). Every thirty minutes, a file containing the formatted observations is delivered via File Transfer Protocol (FTP) at the NRL and copied from there to Fleet Numerical Meteorology and Oceanography Center (FNMOC) .

A Predator AMDAR message includes the aircraft identifier, observation time (to the nearest minute), pressure altitude (to the nearest hundred feet), latitude and longitude (to the nearest minute), air temperature (to the nearest 0.1°C), wind direction and speed (to the nearest degree/knot), and flight phase, all encoded according to the FM-42 standard (World Meteorological Organization 1995). In addition, the aircraft roll and pitch angles are included at the end of each message following "555"—the indicator used in certain WMO alphanumeric formats to mark the beginning of a section containing nationally developed groups. Since the Predator data are not widely distributed at present, this variation on the format was deemed to be a reasonable way to include the non-standard information. Wind accuracy can suffer at large roll angles, so AMDAR winds from commercial aircraft are flagged as bad whenever the roll angle exceeds 5°. Having actual roll and pitch angles available will allow an examination of this threshold to determine whether larger roll angles are permissible and whether pitch angles affect wind accuracy.

Predator AMDAR reports are generated at an interval of approximately 1000 ft (300 m) during ascents and descents, which can lead to more than one report per minute. In level flight, a sampling interval of approximately 5 min is used.

3. USAF AMC ACARS OBSERVATIONS

The USAF Air Mobility Command (AMC) operates tanker, transport, and VIP aircraft (including Air Force One), in missions that span the globe often operating in civil-controlled airspace. In order to take advantage of planned improvements in civilian air traffic control technology (the Communication, Navigation, and Surveillance/Air Traffic Management initiative or CNS/ATM), AMC aircraft, including C17s, KC135s, C5s, C130s, and KC10s, are being fitted/retrofitted with CNS/ATM compliant avionics under the Department of Defense's Global Air Traffic Management (GATM) program (United States Air Force 2003). The purpose of the CNS/ATM initiative is to increase capacity in congested airspace by decreasing aircraft separation, which requires more precise knowledge of aircraft location in that airspace. This in turn requires improvements in aircraft navigation and communication through upgraded avionics. As part of the avionics upgrade, AMC aircraft will have ACARS (Aircraft Communications, Addressing, and Reporting System) datalink capability, which among other tasks will be used to automatically generate and transmit position reports (Raab 2001). These position reports also include observations of flight-level air temperature and winds, similar to the ACARS and AMDAR reports from commercial aircraft that are currently used in data assimilation.

As of October 2005, 109 C17s, 99 KC135s, and 5 C5s are ACARS-equipped, with 4-5 aircraft per month being retrofitted (Maj. J. Peterson, personal communication). Retrofits for C130s and KC10s are scheduled to begin within 3-4 years. Eventually, over 1000 AMC aircraft will be ACARS equipped.

Position reports are automatically generated on board equipped aircraft at fifteen-minute intervals regardless of flight phase and transmitted to the Tanker Airlift Control Center (TACC) at Scott Air Force Base, IL. The raw reports are sent from there to FNMOC via FTP and include aircraft identifier, latitude (to the nearest 0.1 min), longitude (to the nearest minute), observation time (to the nearest minute), pressure altitude (to the nearest hundred feet), air temperature (to the nearest degree), wind direction and speed (to the nearest degree/knot), true airspeed (to the nearest knot), and other quantities not of interest to the current research.

4. PROCESSING MILITARY AIRCRAFT DATA

Once the data are received at FNMOC, they are decoded and then encoded in another format used internally at FNMOC and placed in a "tfile"—the file of conventional observations used by the data assimilation system. Corresponding routines were developed at NRL to read the Predator and AMC ACARS data from the tfile, perform quality control using the same software as for data from commercial aircraft (AMDAR, MDCRS, and AIREP), and present the data to the Navy Atmospheric Variational Data Assimilation System (NAVDAS).

NAVDAS is a three-dimensional variational (3DVAR) data assimilation system developed at NRL and in operational use at FNMOC since 1 October 2003 for the U.S. Navy's global model, the Navy Operational Global Atmospheric Prediction System (NOGAPS). NAVDAS differs from other operational 3DVAR systems in that it is formulated in observation space rather than in grid space (Daley and Barker 2001). Consequently, it uses profile information very efficiently. At present, the only aircraft profiles that are used in NAVDAS are ascent profiles. Given that a profile is sufficiently vertical and has a sufficient number of points, it is assigned an average position rather than using the reported position at each point and used in NAVDAS in the same way as a rawinsonde profile.

After NAVDAS has read the observations, the next step in the process is to interpolate the model background fields (here from a six-hour NOGAPS forecast) to the observation locations in both time and space. The "innovation" is then defined as the observation minus the interpolated background value. NAVDAS then processes the innovations through its 3DVAR algorithm to generate corrections that are applied to the background field to produce the analysis. The analysis is then used as the initial conditions for the next forecast run, which produces the background for the next analysis (Fig. 2). The "residual" is defined as the observation minus the analysis value interpolated to the observation location.

In this preliminary evaluation, Predator data from training flights out of Creech AFB (near Indian Springs, Nevada) will be compared to NOGAPS background fields, to rawinsonde data from nearby Mercury/Desert Rock (WMO station number 72387), and to commercial aircraft ascents/descents at Las Vegas/McCarran International Airport. Data from approximately 20 flights between 9 June and 5 August 2005 were available. Flights began typically between 1430 and 1800 UTC and lasted 1.5 to 4 hr. For some cases, the data were processed after NAVDAS had been run, allowing only innovations to be examined. For other cases, the data were processed during the NAVDAS run, allowing both innovations and residuals to be examined.

All available AMC ACARS data during August and September 2005 were processed during the NAVDAS run, generating both innovations and residuals. Even though equipped AMC aircraft flew at many locations worldwide during this period, the total data volume was relatively small compared to the volume of MDCRS and AMDAR data used in NAVDAS. These data will be compared with the NOGAPS background fields and with nearby data from other aircraft and rawinsondes when available.

5. SUMMARY

This preliminary study demonstrates the feasibility of using military aircraft data in operational numerical weather prediction. Specific examples of the data will be shown at the conference. The relatively low data volume from Predator flights and from ACARS-equipped AMC aircraft makes an exploration of data quality difficult, but some

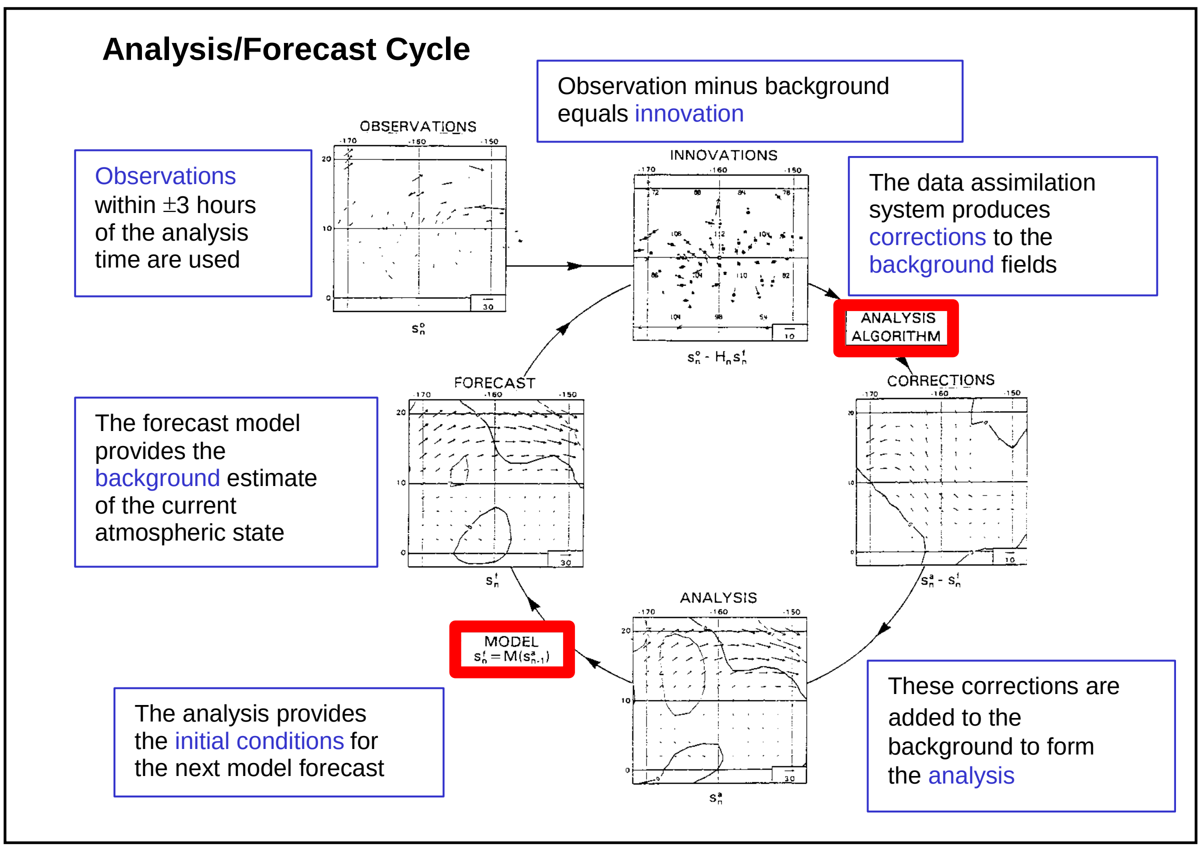

Figure 2: Schematic of the analysis and forecast cycle used in NAVDAS.

preliminary statistics will also be shown at the conference. If the quality of these data is found to be sufficiently good, they will be transitioned to operational use at FNMOC.

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