The Remote Oceanic Meteorology Information Operational (ROMIO) Demonstration

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Introduction

The Federal Aviation Administration (FAA) Next Generation (NextGen) Weather Technology in the Cockpit (WTIC) program is sponsoring an operational demonstration to evaluate the feasibility to uplink convective storm products to commercial aircraft flying routes over remote, oceanic regions for display on an electronic flight bag (EFB). The effort is called the Remote Oceanic Meteorology Information Operational (ROMIO) demonstration and is a collaborative effort between the FAA, the weather research community, the airlines, and airlines inflight entertainment and connectivity (IFEC) providers. The ROMIO Demonstration project will develop and demonstrate operational strategies for the use of rapidly updated Cloud Top Height (CTH) and Convective Diagnosis Oceanic (CDO) products on the flight deck, in the Oceanic Air Route Traffic Control Centers (ARTCC) and as part of Airline Operations Center (AOC) flight dispatch operations. Participating airlines include Delta Air Lines, United Airlines and American Airlines. The domain for storm product creation is contained by the scanning area of the Geostationary Operational Environmental Satellite (GOES) East and West satellites. Routes to be flown are between the continental United States (CONUS) and South America, Caribbean, Australia, and South Africa, among others. A select number of online pilots will participate in the demonstration. The ROMIO demonstration will begin in the fall of 2017 and be conducted for a year. During the demonstration, feedback from pilots, AOC dispatchers and Oceanic ARTCC will be solicited to ascertain the costs and benefits associated with providing realtime, rapidly updated graphical information on convective structure to them.

The purpose of the WTIC Program ROMIO Demonstration Project

The operational demonstration will “exercise” the Aeronautical Information (AI) / Meteorological (MET) Data Link System infrastructure (DO-340, Concept of Use for Aeronautical Information Services and MET Data Link Services). Its purpose is to data link information to the flight deck and ingest that information using near-operational formats, links, and flight deck information transfer. The ability to display the same or similar graphical and textual information on the cockpit EFB as well as in ATC / AOC will be “exercised” to evaluate costs and benefits to the ATC / AOC functions.
Goal of the ROMIO Demonstration Project

The overall goal of this RE&D project is to conduct a flight demonstration that will identify and validate the minimum MET information services required for safe and efficient flight in oceanic and remote airspace. In addition, identify MET information gaps that are not fully resolved by providing CTH / CDO information in the cockpit.

The objectives of the ROMIO Demonstration

1. Identify those decisions pilots make in the current environment without updates, and elicit pilot decisions that can be facilitated with more-frequent weather updates while enroute. This and findings described below will be solicited from aircrews either by direct observation or post-flight, on-line questionnaire.
   a. How does updated weather information affect timing of altitude and/or route deviation requests from the aircrew?
   b. How does the updated information enhance operational safety? That is, does the availability of more frequent weather information (in addition to that provided by the airborne radar) decrease the flight’s potential for a hazardous weather encounter?
   c. Does a timely weather update result in a reduction of flight time, workload, and/or fuel burn?
   d. How does the passive uplink of CTH / CDO updates affect the volume of pilot communications with dispatch and with air traffic control?
   e. How can frequently updated information induce timelier cabin management strategies by the flight crew (cabin and cockpit)?

2. Obtain initial AOC and/or Flight Dispatch Subject Matter Experts’ feedback on convective weather information needs and display concepts. Specifically:
   a. Does the increased potential for information transfer offered by a graphic display in the AOC provide additional efficiency and safety benefit?
   b. To optimize benefits, how frequent are CTH / CDO updates needed for the AOC display? On the EFB? and are other weather information uplinks needed?

3. Obtain initial flight crew feedback on convective weather information needs and display concepts. Specifically:
   a. Does the increased potential for information transfer offered by a EFB display provide an additional efficiency and safety benefit?
   b. To optimize benefits, how frequent would the flight crew like to obtain updates on CTH / CDO? How frequent is too frequent? How frequent is not enough?

4. Identify situations where collaborative decisions between air traffic controllers, dispatch, and aircrews using common, updated weather information can benefit flight operations. What are the benefits? At what costs (e.g., satellite communications)?
Satellite Data Coverage, Latency and Mosaic process

The GOES-East satellite is located above -75 degrees’ longitude and 0 degrees’ latitude. The GOES-West satellite is located above -135 degrees’ longitude and 0 degrees’ latitude. Each day, each satellite covers a particular sequence of sub-domains in a pre-determined scanning strategy (Figure 1). Each scan starts at the North Pole and progresses southward toward the South Pole.

Figure 1. Scanning regions of the GOES-West (left panel) and GOES-East (right panel) geostationary satellites.

NOAA National Environmental Satellite, Data, and Information Service controls the scanning of each satellite. The GOES-East and GOES-West satellites scan the full disk at 3 hr intervals (Figure 2). In addition, the GOES-East satellite scans three sub-domains: CONUS, Northern Hemisphere extended and Southern Hemisphere (Figure 3). And the GOES-West has four sub-domains: Sub-CONUS, PACUS, Northern Hemisphere and the Southern Hemisphere (Figure 4). Figures 2-4 shows the sector scan domains with the infrared (IR) 10.8-micron brightness temperature field.
Figure 2. GOES-West (left) and GOES-East (right) full disk scans are shown for the 10.8 micron IR brightness temperature (°C).
The National Center for Atmospheric Research (NCAR) Research Applications Laboratory (RAL) has a SeaSpace Terascan satellite receiver and receives the data directly after transmission from the GOES-East and GOES-West satellites. The data latency between satellite transmission, data reception by Terascan and conversion into the NCAR internal Mdv format is on the order of 1-2 minutes.

Because the sub-domains are scanned at varying intervals for each satellite, a merger process is used to fill the satellite grid domain with the latest data from any sub-domain at each grid point. Data from each satellite have the parallax correction applied. Next, a satellite mosaic merges the GOES-East and GOES-West satellite scans. The mosaicking process creates a
weighted value based on the satellite zenith angle at each grid point. For example, the data from GOES-West are weighted at unity over its equator position (where its zenith angle is zero degrees), while the GOES-East data contribute less at that position because its zenith angle is 60 degrees.

**National Oceanic and Atmospheric Administration (NOAA) Global Forecast System (GFS) numerical model data**

The NOAA National Center for Environmental Prediction GFS numerical model is used within the CTH algorithm to provide the vertical soundings used to map the satellite IR brightness temperature to a pressure level. The model is run four times per day. The model produces forecasts at 3 hr intervals. Forecasts out to 12 hrs are converted to the NCAR internal Mdv format for input into the CTH algorithm. A recent upgrade to the model by NOAA has increased the horizontal resolution from 0.5° latitude/longitude to 0.25° latitude/longitude and has increased the number of vertical levels.

**Algorithm outputs for uplink to aircraft display**

Two algorithm outputs are used to define the convective hazard area: the CTH and the CDO. The CTH is used to define the entire area of the convective anvil and to give the aircrew information on the storm cloud heights. The CDO defines the region surrounding the convective updrafts where the hazard level can be expected to be high.

**CTH**

The CTH is computed by: 1) converting the satellite 10.8 micron IR brightness temperature to pressure by comparison to the GFS model sounding and then 2) converting the pressure to a flight level through the standard atmosphere equation (Miller et al. 2005). An example is illustrated in Figure 5. The IR brightness temperature only measures the temperature of the tops of deep convection and cannot resolve internal structures. The anvil clouds typically can have a much larger area than the convective region. Polygons of the CTH flight levels are for flight levels at FL300, FL350, FL400, FL450 and FL500 currently being made in XML format.

![Image of IR Brightness Temperature and Cloud Top Height](image.png)

*Figure 5. The 10.8 micron IR brightness temperature data (left panel) are used to compute the CTH field (Kft; right panel).*
Four algorithmic inputs are used to calculate the CDO and include the CTH, the Global Convective Diagnosis (GCD), the Overshooting Tops Detection algorithm (OTops) and the combined lightning strike interest field. They are described below.

GCD is computed by subtracting the brightness temperature of the IR channel from the brightness temperature of the water vapor channel (Mosher, 2002). The GCD indicates the location of mature updrafts when the difference is near zero. The GOES-R OTops Algorithm is computed following Bedka et al. (2010) and shows the locations of OTops. Combined Lightning Interest is computed by accumulating the EarthNetworks lightning strike data into 15 min, 30 min and 60 min accumulation fields. They are combined in a fuzzy logic framework to produce an interest map called “combined lightning”. The algorithmic inputs, described above, are scaled using membership functions to be between zero and unity (and called “interest fields”), where unity is a positive indicator for convection. Once scaled, the interest fields are weighted and summed. The selected weights are unity for the CTH, the GCD and the OTops interest fields. The combined lightning field is weighted a value of three. This means that the lightning contribution is equal to the contribution from the other three algorithms. This is important as the lightning is the best indicator of the presence of convective hazards. The CDO interest field has values between zero and six, with values >2 indicating the likelihood of convection and values >3 indicating an increased level of hazard due to the presence of lightning and/or overshooting tops. XML polygons are made for the CDO interest values of 2, 3, 4, and 5.

**Polygon creation for uplink display**

The CTH and the CDO outputs are created on a gridded field and used to define storm characteristics. The Thunderstorm Initiation, Tracking and Nowcasting algorithm (Dixon and Wiener, 1993), an object tracking algorithm that correlates identified storms over time, is used to minimize uplink bandwidth.

**ROMIO Demonstration System**

NCAR will distribute the data in XML format utilizing technology being implemented by the FAA’s NextGen Common Support Services – Weather (CSS-Wx) Program.

The Embry-Riddle Aeronautical University NextGen Aircraft Access to System Wide Information Management (SWIM) (AAtS) Testbed is part of the FAA NEXTGEN system architecture that provides access to FAA data using SWIM’s Service Oriented Architecture interface.

Basic Commerce and Industries (BCI) will provide data management services (DMS) and perform processing primarily to minimize bandwidth requirements during transfer. DMS will utilize web services technologies to transfer data to participating IFEC broadband providers.

BCI will also create a web display application for use by stakeholders categorized as Internet users at the AOCs and OCCs. Weather content of these web displays will match what is being displayed for the aircrew.

The ROMIO demonstration will utilize Gogo and Panasonic Avionics IFEC to transfer the DMS data to EFB for presentation to the aircrew. Figure 6 is the ROMIO Demonstration System and figure 7 is the aircrew CTH / CDO Viewer. Pilots may also enter feedback on the ROMIO
demonstration using the EFB devices. The feedback data will be sent via the IFEC back to DMS for collection.

Figure 6. ROMIO Demonstration System.
9 References


RTCA DO-340, Concept of Use for Aeronautical Information Services (AIS) and Meteorological (MET) Data Link Services.

RTCA DO-364, Minimum Aviation System Performance Standards (MASPS), AIS/MET