3.9 / P1.19 THE FAA AWRP OCEANIC WEATHER PROGRAM DEVELOPMENT TEAM

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1.0 Introduction

Remote, oceanic regions have few, if any, high resolution weather products that indicate the current or future locations of aviation hazards such as volcanic ash, convection, turbulence, icing or adverse headwinds. Moreover, oceanic regions present unique challenges due to severely limited data availability, the long duration of transoceanic flights and the difficulty of transmitting critical information into the cockpit. In 2001, the Oceanic Weather Program Development Team (OWPDT; Herzegh et al. 2002) was organized within the Federal Aviation Administration (FAA) Aviation Weather Research Program (AWRP) to focus on resourceful methods for overcoming these limitations through the use of a diverse range of satellite observations, global model results and satellite-based communications. Resulting products focus on the needs of pilots, dispatchers, air traffic managers and forecasters within the oceanic aviation community. The team is a leader in the inflight display of weather products and will continue to develop new displays as products become available.

Hazards to oceanic flight impact the safety, efficiency and economic viability of aircraft operations. For example, aircraft incursion into volcanic ash clouds is a safety concern that causes \$10M/year[1] in damage to engines, avionics and airframes and impacts efficiency costs by \$1.4M/year[1]. Hazardous convection produces turbulence, icing and lightning and necessitates aircraft rerouting while inflight, leading to higher fuel costs and delays. Turbulence, from convection and clear air, causes \$5M/year[1] in safety costs due to injuries and aircraft damage and \$46.3M/year[1] in efficiency costs. Enhanced inflight winds, a critical need to maintain horizontal and vertical separation of oceanic aircraft within the Advanced Technologies and Oceanic Procedures (ATOP) system, are expected to lead to fuel savings of up to \$0.3M/year[1].

2.0 Methodology

Developing aviation weather products for remote, oceanic regions is challenging. Geostationary satellite imagery is a primary data source and is used to cover the large domains in the Pacific, Atlantic and Gulf of Mexico. The National Center for Environmental Prediction (NCEP) Global Forecasting System (GFS) model provides numerical weather prediction guidance.

For the oceanic convective nowcasting product, the turbulence products (for clear air and convectively-induced conditions) and the icing products, a technology transfer of continental U.S. (CONUS) methodologies, as developed by the Convective

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[1] Taken from a study done by MCR Federal LLC. that examined NTSB incident reports for oceanic flights from 1992-2002.

Weather (Wolfson and Mueller, 2006), Turbulence (Sharman et al., 2006), and InFlight Icing (Politovich, 2006) PDTs, respectively, are underway or planned. Oceanic data sources require that significant modifications be made during the transfer. Regardless, leveraging product development from other PDTs is an efficient and effective strategy for the OWPDT. Seamless boundaries between products for the CONUS and for oceanic regions are planned.

2.1. *Volcanic Ash*

Volcanic ash clouds are a particular hazard for oceanic flights that occur near the Pacific Ring of Fire, in the Caribbean and in other regions having volcanic activity. Frequently, ash clouds are indistinguishable from water- or ice-based clouds and they cannot be seen at night. The OWPDT is developing a suite of automated volcanic ash analysis and forecast capabilities. When complete, these automated capabilities will approximate a '*virtual analyst*', essentially a 24/7 assistant and ally to the analysis staff who carry the monitoring and warning responsibilities of the Volcanic Ash Advisory Centers (VAAC) and National Weather Service (NWS) watch offices. The virtual analyst will operate in conjunction with the FAA/NWS Volcanic Ash Coordination Tool (VACT; Rodgers et al., 2004)

The VACT focuses on capabilities that enable improved real-time interaction and collaboration among analysts. Those capabilities include access to critical datasets (e.g., GOES, POES and others), flexible presentation of the data across networked workstations, tools for real-time interaction with the data, and tools for analyst-to-analyst communication centered on data displays and data interactions. The VACT is further addressing the generation of automated first-guess ash advisories, impact statements and other messages.

The OWPDT virtual analyst will draw upon important infrastructure provided by the VACT (such as real-time access to datasets), but will work toward automation in monitoring and analysis applications that are not addressed by VACT-supported collaboration. These applications include the monitoring of targeted volcanoes, pre-processing of satellite imagery to optimize detection of volcanic ash, simulations of ash trajectories to aid in recognition of the eruption and preparation of the first-guess forecast, and to automatically alert analysis staff that an eruption has commenced.

Improved techniques and improved 24/7 automation (not increases in monitoring staff) must be the mechanism for improved readiness and more immediate warning of a volcanic event that threatens aviation. The well-known (but distant) goal of a much-shortened 5 minute time gap between a detectable eruption and issuance of a corresponding warning can only be met if next-generation automation of data access, processing and analyst support tasks is accomplished. A long-term goal is to uplink automated warning messages

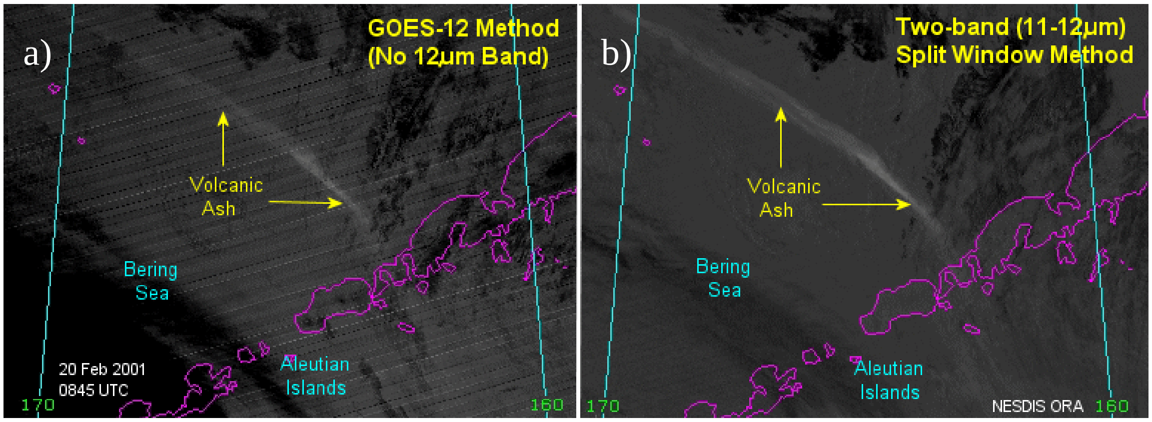

Figure 1. A comparison of two ash detection techniques is shown. In a), the three-band method using IR channels available on GOES-12 is compared to the b) traditional two-band method based on 11-12 µm IR. Images were derived from Terra MODIS at 0845 UTC, February 20, 2001. Striping in left hand image is from MODIS 13.3 µm IR band.

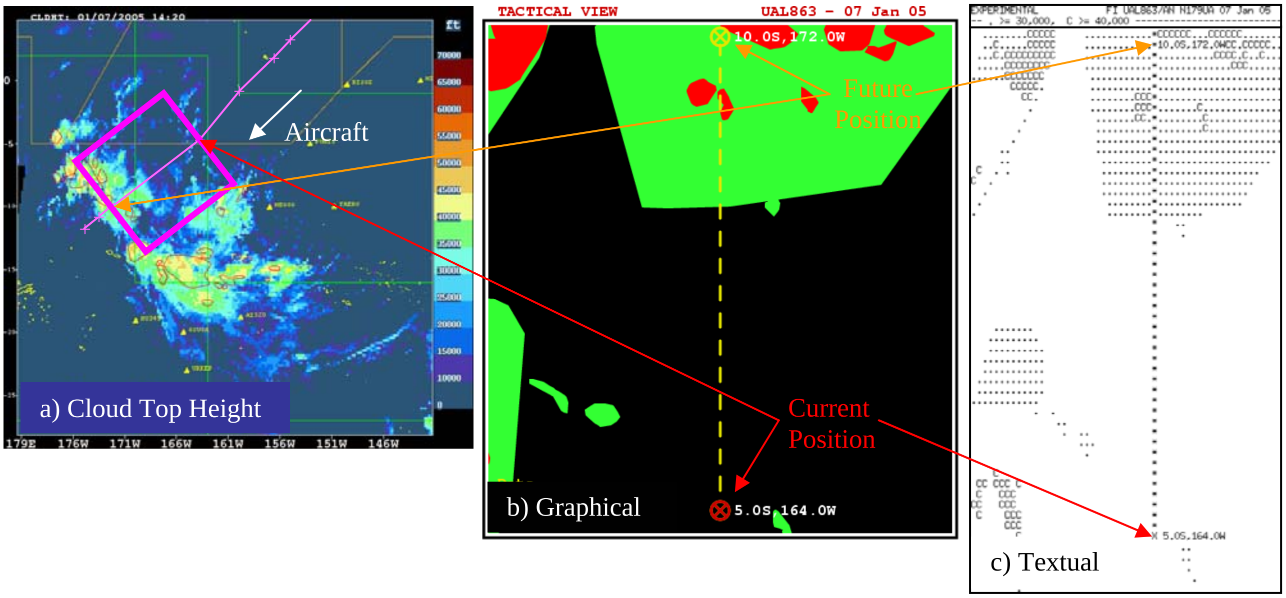

Figure 2. An example of the cockpit display of the cloud top height product is shown. In a), the cloud top height product is shown, with altitudes contoured at 5Kft intervals. The aircraft track is shown by the purple line with the purple box indicating the region contained within the b) color graphical display and c) the ASCII display. In b) and c), the heights are contoured at 30-40Kft (green and ".") and at >40Kft (red and "C"). The aircraft's current position is indicated in b) and c) as is the position of the next way point, assuming no deviation in the flight track.

to aircraft flying near volcanic ash clouds and will utilize the cockpit display discussed below.

Volcanic ash efforts to date have concentrated on case study analysis to refine satellite detection techniques. Using archived MODIS data, two detection techniques for the airborne volcanic ash cloud from the Mt. Cleveland, Alaska eruption of February 2001 have been evaluated using the equivalent wavelengths as are available on the GOES-12 for Infrared (IR) channels 2, 4, and 6. The GOES-12 method (using IR bands centered near 3.9, 10.7, and 13.3 µm) clearly shows the ash over the Bering Sea (Fig. 1a), although the classic two-band "split window" approach (using a longwave IR channel no longer available on GOES-12) was slightly more effective (Fig. 1b).

2.2. Enhanced Inflight Winds

Enhancing the fidelity of inflight winds used within the FAA Oceanic and Offshore Integrated Product Team (IPT) Advanced Technologies and Oceanic Procedures (ATOP) system and the Dynamic Ocean Track System (DOTS) Plus for oceanic traffic management and route planning is another area of endeavor. Ingesting hourly satellite-tracked wind fields into these systems, in a similar method as is currently done for aircraft winds, will enhance the quality of the resulting wind field and support optimum flight tracks and aircraft separation.

2.3. Inflight Display of Cloud Top Height

The depiction of the cloud top height has been the first product developed by the OWPDT. This product, called Cloud TOP height (CTOP; Miller et al., 2005), maps the IR brightness temperature from GOES channel 4 to flight level altitudes by matching the brightness temperature to a Global Forecasting System (GFS) pressure level. The pressure level is then converted to flight altitude using the standard atmosphere approximation. This is the same methodology used by the aviation community to convert altimeter settings to flight altitudes. An example is shown in Fig. 2a.

The Aviation Weather Technology Transfer (AWTT) board approved the CTOP product for experimental status in 2005. The CTOP is now appearing on the experimental Aviation Digital Data Service (ADDS) web site. During the

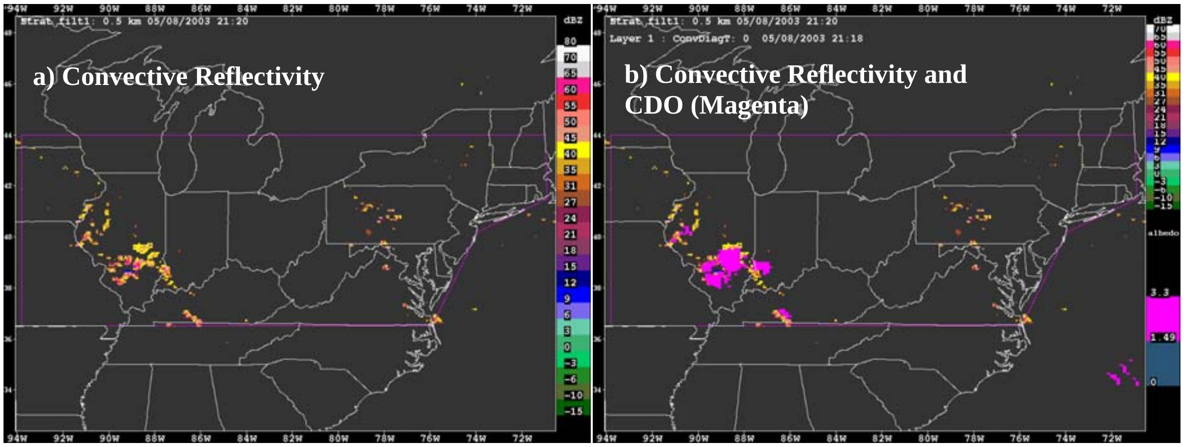

Figure 3. An example of the Convective Diagnosis Oceanic (CDO) product is compared to the convective partition of the national reflectivity mosaic on 8 May 2003 at 2120 UTC. Fields shown are a) the convective reflectivity field (dBZ) and the b) convective reflectivity field overlaid with the CDO shapes plotted in magenta. Good agreement between the two is seen in Illinois and Indiana.

approval process, the Quality Assessment PDT (QAPDT) independently verified CTOP (Holland et al., 2006; Madine et al., 2006; Wolff et al., 2006) and showed that it gave valid results, particularly for deep convection.

A cockpit display of the CTOP has been developed that depicts cloud top heights between 30-40kft and above 40kft. An ASCII display (Fig. 2c) is generated and uplinked for printing after an aircraft position report is sent. Capability for color graphical display (Fig. 2b) exists but only for a limited number of aircraft types. The cloud top height product was uplinked for display during one United Airlines flight in 2005. This innovation will lead to the inflight display of other products such as volcanic ash and turbulence.

2.4. Convection Diagnosis and Nowcasting

Three satellite-based techniques are used to detect oceanic, deep convective clouds. These techniques include the CTOP product, the Global Convective Diagnosis (GCD) product (Mosher, 2002), and the Cloud Classification (CC) algorithm (Tag et al., 2000). Donovan et al. (2006) provides details on the methodologies of each of these techniques and shows the results of a study that compares these algorithm outputs to the reflectivity structures measured by the Precipitation Radar (PR) on the Tropical Rainfall Measuring Mission (TRMM) satellite.

The Convective Diagnosis Oceanic (CDO) product combines the results from these three algorithms in a fuzzy logic scheme to define the locations of convection. A CDO example is shown in Fig. 3 for a region over the CONUS. The corresponding convective reflectivity field, taken from the CWPDT National Convective Weather Forecasting (NCWF) product, is shown for comparison purposes. Verification of oceanic products is a difficult problem due to the lack of independent data sources such as ground-based radar. For this reason, computation and display of oceanic products over the CONUS provides a means to examine product performance. As Fig. 3 shows, good agreement between the CDO and the convective reflectivity is obtained in Illinois and Indiana. Convection within Pennsylvania is not detected by the CDO because it is less mature and has a lower cloud top height, as indicated by the GCD and the CTOP products (not shown).

For oceanic convection nowcasting, a technology transfer of methodologies developed by the Convective Weather PDT is underway. Oceanic data sources require that significant modifications be made during the transfer. The Convective Nowcasting Oceanic (CNO) product for 0-2 hr predictions is the first product being developed. Other predictive products will be developed for the 2-6 hr period and for the 6-15 hr period.

Using the Lighting Imaging System (LIS) on the TRMM satellite, a 7-year, climatological data base

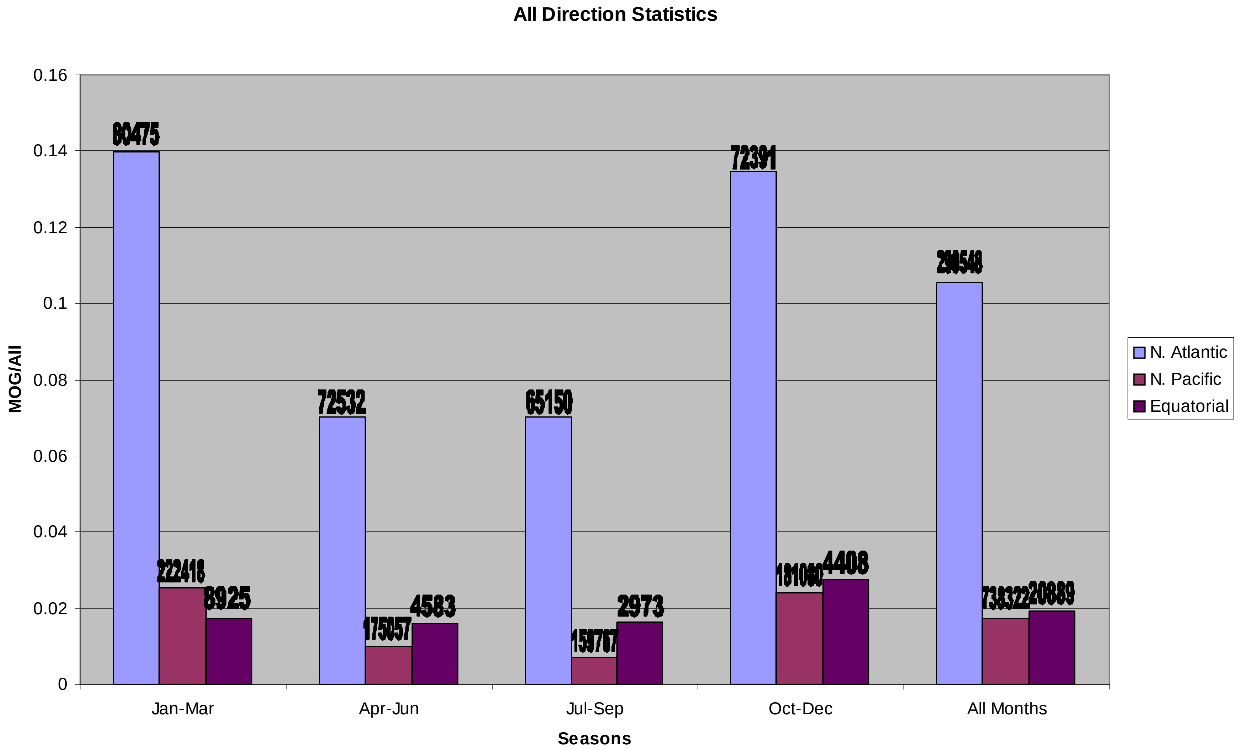

Figure 4. This plot shows the frequency of moderate- or-greater (MOG) turbulence incidents on a seasonal basis. The number of oceanic aireps indicating MOG turbulence is divided by the total number of aireps. Results are complied by location: the north Atlantic, the north Pacific and the Equatorial regions.

that shows the location of lighting strikes has been developed as a proxy for the location of hazardous convection (not shown). These results are partitioned by seasons for use within the CNO.

2.5. *Turbulence*

The climatological occurrence of turbulence, as reported by oceanic aircraft, is important information when devising algorithms to detect or forecast its occurrence. A study was conducted, using 10 years of aireps data taken from U.S. air carriers, to examine of the frequency of moderate-or-greater (MOG) turbulence reports in three oceanic regions: the north Atlantic, the north Pacific, and Equatorial regions. The frequency was calculated as the number of MOG aireps divided by the total number of aireps. Results were calculated on a seasonal basis and on a yearly basis and show (Fig. 4) that the north Atlantic has the highest number of MOG turbulence reports and that the majority of the reports occur during the winter months. This leads to the speculation that clear-air turbulence (CAT) sources or layer clouds associated with mid-latitude synoptic disturbances explain most of the turbulence encounters in the N. Atlantic rather than convective clouds. This is deduced from the fact that convection is probably infrequent over the N. Atlantic and that less convection is expected during the winter compared to summer. Because this study was conducted with U.S. air carriers, the turbulence characteristics in other regions of the globe are not represented.

For oceanic turbulence forecasting, a technology transfer of the Graphical Turbulence Guidance (GTG) methodology (Abernethy and Sharman, 2006) is underway. The oceanic version of the GTG is called the Turbulence Forecasting Oceanic (TFO) product and is being developed for clear air turbulence (CAT) conditions at upper levels of the atmosphere. Currently, the GTG uses the Rapid Update Cycle (RUC) numerical model while the TFO uses the GFS model. The differing resolutions

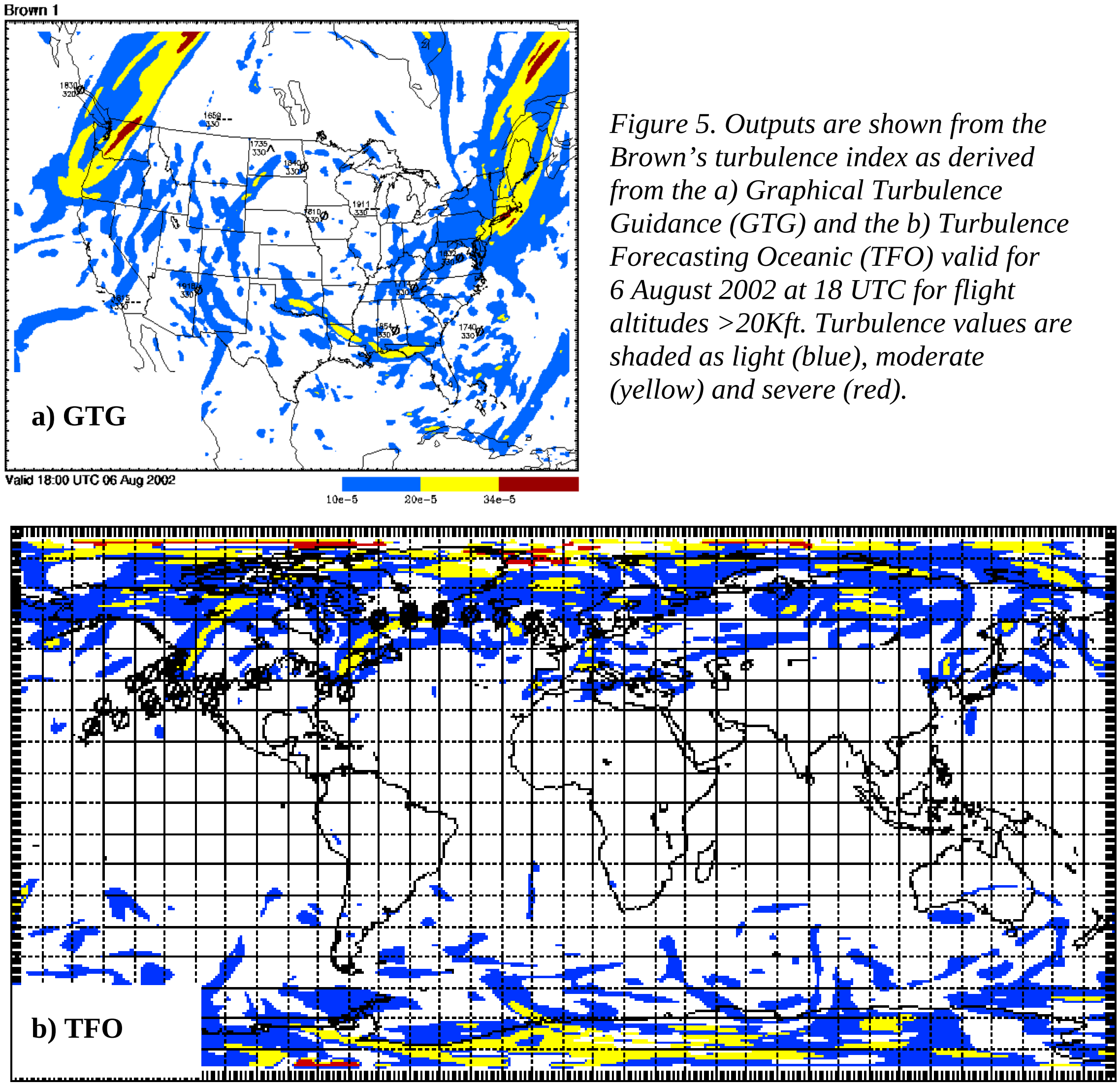

Figure 5. Outputs are shown from the Brown's turbulence index as derived from the a) Graphical Turbulence Guidance (GTG) and the b) Turbulence Forecasting Oceanic (TFO) valid for 6 August 2002 at 18 UTC for flight altitudes >20Kft. Turbulence values are shaded as light (blue), moderate (yellow) and severe (red).

between the RUC (20 km, for the example shown in Fig. 5) and the GFS (one degree latitude/ longitude) means that a significant retuning effort is required to ensure that the TFO produces results consistent with those obtained with the GTG.

Figure 5 shows an example of one of the turbulence indices (i.e., Brown 1) as derived for both the GTG and the TFO for CAT at altitudes >20Kft for 6 August 2002 at 18 UTC. Producing consistent output and seamless boundaries between the GTG and the TFO products is a necessary outcome of this development. As shown in Fig. 5, comparison of the GTG output (Fig. 5a) to the CONUS region of the TFO output (Fig. 5b) shows that both are producing similar results, as seen in the yellow bands of MOG turbulence along both the east and west coasts. The TFO lacks some of the small, detailed regions of turbulence indicated by the GTG within the interior of the CONUS, although increasing the TFO magnification and focusing only on the CONUS might reveal additional agreement.

2.6. Icing

The technology transfer of the CONUS Forecast Icing Potential (FIP; Politovich et al., 2002) product is expected to commence in 2007. Due to the limited oceanic data sources, the technology transfer of the Current Icing Potential (CIP; Politovich et al., 2004) is thought to be a difficult task and, for this reason, will be undertaken after the FIP.

3.0 Collaboration with the NASA ASAP

The OWPDT has been collaborating with the National Aeronautics and Space Administration (NASA) Advanced Satellite Applications Program (ASAP) in our development of oceanic aviation products. The current focus of ASAP research is on volcanic ash detection techniques. This collaboration is invaluable to the OWPDT as research conducted by ASAP scientists will be directly applicable for use within the virtual analyst.

4.0 Summary

A description of the Oceanic Weather Product Development Team has been given. The AWTT milestone schedule of the various OW products for the next few years is, as follows:

1. CTOP: operational status planned for 2007
2. Volcanic Ash Analysis System: experimental status planned for 2008, operational status in 2010
3. TFO: experimental status planned for 2007; operational status in 2009
4. CDO: experimental status planned for 2007 for regions with GOES East coverage and in 2008 for regions with GOES West coverage
5. CNO: experimental status planned for 2011 for the 0-2hr nowcasts; operational status is planned for 2013.

5.0 Acknowledgements

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