P4.8

VERIFICATION OF OCEANIC WEATHER DIAGNOSES AND FORECASTS FOR AVIATION WEATHER ELEMENTS

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1. Introduction

The Oceanic Weather Product Development Team (OWPDT), sponsored by the FAA's Aviation Weather Research Program (AWRP) is addressing oceanic weather needs for aviation. The OWPDT is developing intelligent weather forecasting systems that generate timely information on convective weather, convection-induced or clear air turbulence, high-resolution wind, cloud-top height, volcanic ash, and in-flight icing. Also, techniques for quick product generation and methods for timely dissemination to the end users such as aircraft en-route over the oceans are being explored.

The greatest challenge associated with creating accurate and timely oceanic/remote weather hazard information is the lack of data available for algorithm development and verification. To complicate the problem, the observation datasets used for verification should be independent of those used to develop an algorithm. In a data sparse environment, this independence is difficult to achieve. Therefore, it is very important to discover creative approaches for extracting as much information as possible from the limited amount of global data. To this end, the AWRP's Quality Assessment Product Development Team (QAPDT) is investigating creative approaches for developing independent verification methodologies. The observations and approaches being considered are summarized in this paper.

2. Methodology

New verification strategies are being developed that are appropriate for aviation weather in oceanic regions. An initial approach is to focus on the CONUS coastal areas and islands where operational data are available. Also, specific oceanic areas will be explored for which experimental data have been collected (e.g., THORPEX, the Observing-system Research and Predictability Experiment) and where data from the Tropical Rainfall Measuring Mission (TRMM) are available. Verification techniques developed using the variety of observations will be compared. The most reliable methods will be implemented into verification systems and used for long-term evaluation of the oceanic weather forecasts. Figure 1 shows the THORPEX 2003 project operation area in the Pacific. It includes the Hawaiian Islands where surface and upper-air observations as well as Doppler radar and satellite data are available in addition to the experimental data sets. Thus, in this area verification methods can be developed using standard observations as well as experimental sounding and/or dropsonde observations.

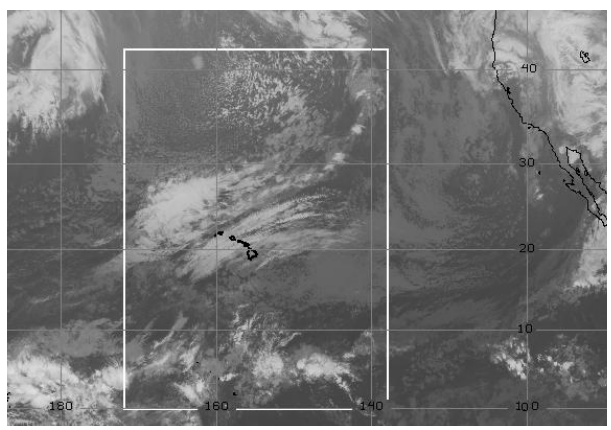

Figure 1: THORPEX 2003 project operation area.

Advanced aircraft measurements are also expected to be employed for verification. The wind observations and the eddy dissipation rate (EDR) from ACARS reports, as well as wind gust data from AMDARs may play an important role for high-resolution wind and turbulence verification. All of

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these observations will be used in combination with more standard ship and buoy-based data such as are available through the World Meteorological Organization (WMO) World Weather Watch (WWW) program. These and other data sources are described more fully in the following section.

3. Observations and Forecasts

The creation of a properly matched set of forecasts and observations can be one of the most difficult aspects of forecast verification. This process is particularly difficult when verifying aviation weather forecasts, where the observations frequently are non-standard. This is especially true over data-sparse regions like the Pacific Ocean. To fully reach the objectives of verification, all possible information should be collected in and around this huge area.

3.1. *Available data from all existing sources for verification over oceanic regions*

The WWW, which is a core program of the WMO, combines observing systems, telecommunication facilities and data-processing centers operated by member states to make available meteorological information needed to provide efficient services in all countries. Since most of the available meteorological information around the world goes through the WWW Global Telecommunication System (GTS), the first step to find data for oceanic weather verification is to look for them on the GTS.

For oceanic weather verification the usable data from the GTS are as follows:

- AIREP - Aircraft Weather Report
- AMDAR - Aircraft Meteorological Data Acquisition and Relay
- DRIBU - Drifting buoys
- METAR - Aviation routine weather report
- PILOT - Fixed land
- PILOT SHIP - Ship
- Profiler - in BUFR code
- SHIP - Ship synoptic
- SIGMET - Significant Meteorological Information
- SPECI - Aviation Selected Special Weather Report
- SYNOP - Surface synoptic
- TEMP - Rawinsonde – fixed land
- TEMP SHIP - Rawinsonde – ship.

Reports of surface observations are usually recorded at synoptic land stations and then sent to the GTS. They typically include elements like present/past weather, wind direction and speed, wind gust, precipitation, visibility, amount/height of cloud, height of cloud base, air temperature, relative humidity or dew point temperature, atmospheric pressure, sea level pressure, pressure tendency, extreme temperature, state of ground, special phenomena, sea surface temperature, and marine data.

In general, surface observations are made every hour, although the time needed to send the reports to the collecting stations varies for different types of stations. Data from surface land stations are available every 3 or 6 hours, while ships provide data every hour, but usually with some delay. At times this delay can be one or more hours. An example of the spatial distribution of observing stations can be seen in Figure 2.

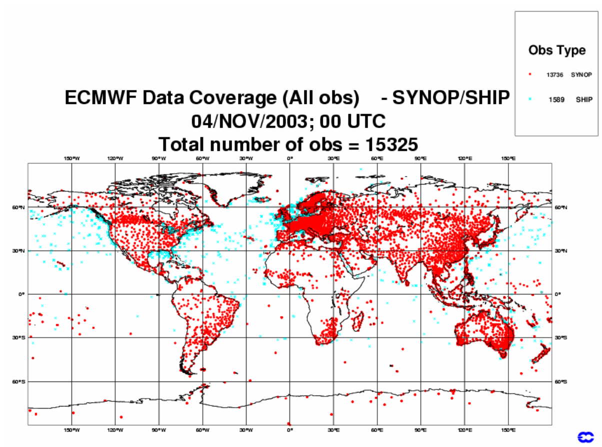

Figure 2: Distribution of surface synoptic stations over the globe.

Automatic synoptic stations and buoys send messages automatically immediately after the observation. The spatial distribution of buoys is shown in Figure 3. Additional buoy data can be obtained from the National Data Buoy Center (C-man stations, drifting buoys, and moored buoys) for locations or platforms different from those on the GTS.

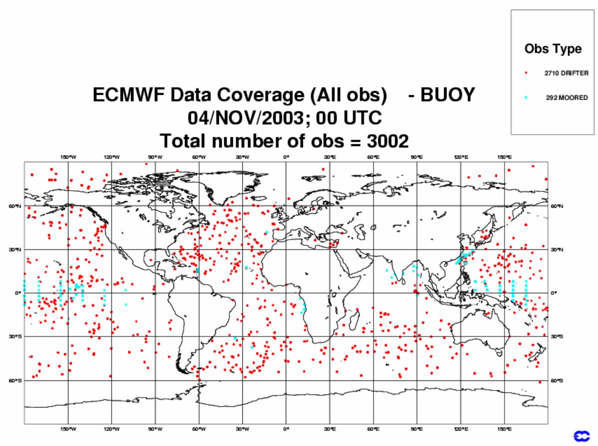

Figure 3: Distributions of buoys over the globe.

Upper air measurements are typically made every 6 hours (00, 06, 12, 18 UTC), although some rawinsonde stations provide data only once or twice per day. The spatial distribution of upper air measuring stations is shown in Figure 4.

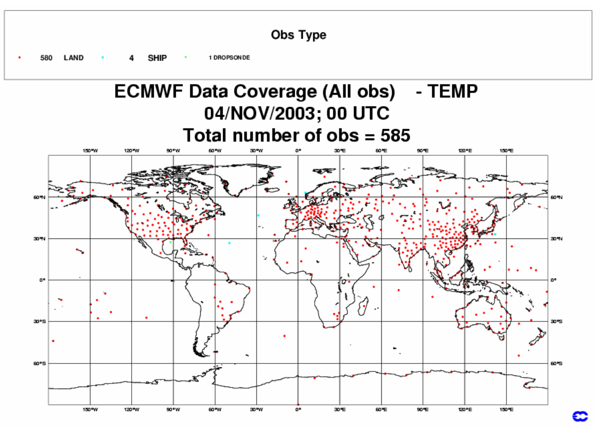

Figure 4: Distribution of rawinsonde stations over the globe.

Other, mainly remotely sensed data types are:

- NEXRAD data,
- Visible and infrared satellite imagery,
- Other satellite-derived information such as water vapor-derived winds, cloud-type classification, etc.

Experimental data have special interest for oceanic weather forecast verification because they are not used to formulate the forecast products. Examples of some research programs that are of particular interest include:

- THORPEX 2003 Pacific test (http://www-angler.larc.nasa.gov/thorpex/),
- THORPEX 2003 Atlantic test (http://www.wmo.ch/web/arep/wwrp/THORPEX/atlantic_ob_system.htm)
- AIRS-II (Alliance Icing Research Study-II) (http://www.airsicing.org/AIRS_II/AIRS_II.htm)

In some cases (e.g., Atlantic THORPEX, AIRS-II) it may be possible to "piggy-back" the collection of some special verification observations (e.g., cloud-top height) along with the collection of research data.

The TRMM (http://trmm.gsfc.nasa.gov/) satellite provides radar and lightning data, and visible and infrared satellite imagery for tropical regions between 35°N and 35°S. Because the TRMM satellite is not geostationary, it is an ideal resource for verification of the oceanic weather forecasts, since its observations currently are not used by any of the forecast systems.

One of the newest types of automated observations becoming available is in-situ measurement of eddy dissipation rate (EDR). The EDR observations are based on a transformation of the aircraft-observed vertical acceleration to obtain a measurement of atmospheric turbulence that is independent of aircraft characteristics and motions (Cornman et al. 1995). The maximum and average EDR values can be obtained from ACARS for certain aircraft. Wind speed and direction, as well as temperature values are also included in these reports.

The QAPDT has begun to investigate the use of the *in-situ* EDR observations for verification. We expect that these measurements will be suitable for turbulence verification after more aircraft have the *in-situ* measuring system installed and the EDR values have been verified and compared to PIREPs. Unfortunately, these observations are not currently available over the oceans so the network of aircraft included in the system will also need to be expanded.

Wind speed and direction data that are also available from ACARS and AMDARs might be used for verification of improved 3-D wind products. The results of comparisons of observations from ACARS and rawinsondes have indicated that these observations are quite accurate (Schwartz and Benjamin, 1995).

3.2. *Oceanic weather forecast products*

Operational aviation forecasts are prepared for points (local forecasts or grid point forecasts), areas, and routes and can be given in text, coded and graphical formats. They are usually issued for certain times of the day and are valid for 6, 12, or 18 hours. However, if it is necessary, forecasts are amended, corrected, and delayed, identified by *AMD*, *COR* and *RTD*.

For oceanic weather, operational forecasts include U. S. Offshore Significant Meteorological Advisories (SIGMETs), Oceanic IFR SIGMETs, and International SIGMETs. The size of the operational forecast area is usually at least 3000 mi^2. However, if the total area covered by a forecast is very large, it could be that only a small portion of this total area would be affected by significant weather at any one time during the forecast valid period. Over oceanic areas, the international SIGMETs give information to pilots regarding the occurrence, or expected occurrence, of en-route weather phenomena, which may affect the safety of aircraft operations. Operational en-route forecasts includes the area forecasts (FA), TWEB (transcribed weather broadcast) for more than 200 routes and local vicinities over the contiguous U. S., and low- and high-level significant weather chart (SIGWXs). The route forecasts are for a 50-nautical-mile wide corridor along a line connecting the end points of the route.

The experimental forecast products being developed by the OWPDT include oceanic Graphical Turbulence Guidance (GTG), Cloud-top height (CTH), 3-D winds, and convective diagnosis. These products are usually given in gridded form and are typically valid at a particular point in time. Operational forecasts can serve as a reasonable standard-of-comparison for experimental forecasts. However, comparisons between the operational and advanced forecasts can be difficult due to their different characteristics.

3.3. *Matching forecasts and observations*

Due to the scarcity, non-systematic nature, and general non-uniformity of most oceanic weather observations, the approach for matching forecasts and observations by necessity must be “driven” by the observations in most cases. That is, the forecasts can only be verified at locations where there are observations. For each valid time, a search will need to be conducted to determine what observations are available for verification, since ships, buoys, and aircraft that report are always changing their position. This approach is consistent with the approach that has been taken in other aviation weather forecast verification studies. For example, forecasts of in-flight icing and turbulence can only be verified at locations where there are PIREPs or other observations (e.g., Brown et al. 1997). This approach limits the statistics that can be computed (Brown and Young 2000), but does allow computation of a variety of meaningful statistics that can be used to compare different types of forecasts. In some cases where observations are more dense or systematic (e.g., island rawinsondes stations) it will be possible to match forecasts and observations in a more consistent way and to compute the full range of verification statistics.

4. Verification approaches

Diagnostic forecast verification approaches will be applied as much as possible for the evaluation of the oceanic weather products. The evaluation of oceanic GTG will be based on aircraft observations, including determining relationships between PIREP-reported turbulence intensities, EDR values from ACARS, and wind gust data from AMDARs. For verification of convective diagnoses, at least yes/no observations can be obtained using “present and/or past weather” from PIREPs and ship-synoptic reports, as well as lightning data. Note that due to the lack of detailed data, severity cannot be taken into account in all cases.

Verification of cloud top heights and 3-D winds will be somewhat more problematic. Cloud-top heights are observed visually by aircraft (PIREPs). As noted earlier, direct measurements of cloud-top heights (via pressure altimeter reading) may be obtained through “piggy-back” observations collected in coordination with research programs such as THORPEX and AIRS-II. These observations may serve as reference points for evaluating cloud top pressure estimates through remote sensing techniques applied to polar orbital satellite data. 3-D wind observations may be obtained from soundings but these data are mostly lacking over oceanic regions, except for a few stations located on islands and over coastal areas. We will be forced to use these in spite of the fact that they will not be relevant in all cases. Observations from ACARS will also be very valuable for evaluating 3-D wind fields.

In addition to the “piggy-back” observations, cloud-top heights will be determined from rawinsonde and dropsonde data from all possible sources using a method based on Wang and Rossow’s (1995) work. The method is simple and easily understandable as illustrated in Figure 5.

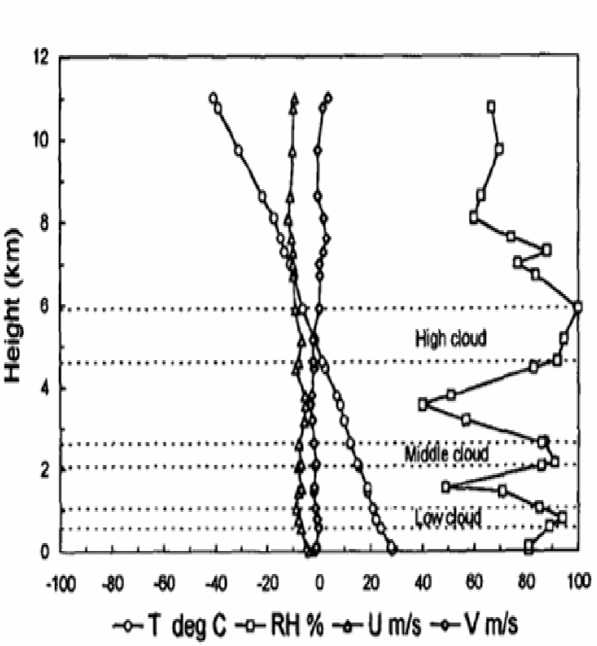

Figure 5: A profile of temperature (T), relative humidity (RH), and wind speed (U and V). Three cloud layers are marked corresponding to the RH profile. (Wang and Rossow, 1995)

Verification of turbulence and 3-D wind products might be improved after studying ACARS and AMDAR data. Preliminary results are promising as more and more EDR, wind gust and wind data become available for verification.

In some cases, visual verification will be performed. This approach can provide meaningful results in spite of the fact that it is labor intensive, not quantitative and subjective (Ebert, 2002). These case studies might give us some experience in using climatology. That is, studies verification over regions that are not data sparse (e.g. CONUS) may be extended to oceanic areas through knowledge of the cimatological differences between the two regions.

In addition to standard verification approaches, new and advanced verification methods will be necessary to verify the new gridded forecast products. Some examples include object-oriented, entity-based, event-oriented, and scale decomposition methods and techniques (e.g., Brown et al. 2002). These approaches allow more diagnostic evaluation of forecast errors than can be obtained from standard verification methods.

5. Summary

This paper has presented the first steps in planning and preparing verification of oceanic weather diagnoses and forecasts of aviation weather elements. It has described the efforts that are underway to identify data sources that match as closely as possible the events being predicted. The first product to be evaluated is CTH. For this weather element, all available real-time and experimental data will be utilized, including the valuable data that will be obtained through “piggy-back” observation collection programs. Similar processes will be applied to convective diagnoses. Turbulence and 3-D wind products will be verified using additional advanced aircraft observations.

6. Acknowledgements

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References

Brown, B.G., and G.S. Young, 2000: Verification of icing and turbulence forecasts: Why some verification statistics can't be computed using PIREPs. *Preprints, 9th Conference on Aviation, Range, and Aerospace Meteorology*, Orlando, FL, 11-15 September, American Meteorological Society (Boston), 393-398.

Brown, B.G., J.L. Mahoney, C.A. Davis, R. Bullock, and C.K. Mueller, 2002: Improved approaches for measuring the quality of convective weather forecasts, *Preprints, 16th Conference on Probability and Statistics in the Atmospheric Sciences*. Orlando, 13-17 January, American Meteorological Society (Boston), 20-25.

Brown, B.G., G. Thompson, R.T. Bruintjes, R. Bullock, and T. Kane, 1997: Intercomparison of in-flight icing algorithms. Part II: Statistical verification results. *Wea. Forecasting*, **12,** 890-914.

Cornman, L.B., C.S. Morse, and G. Cunning, 1995: Real-time estimation of atmospheric turbulence severity from *in-situ* aircraft measurements. *Journal of Aircraft*, **32**, 171-177.

Ebert, E.E., 2002: Verification of spatial forecasts. *Workshop on Making Verification More Meaningful.* Boulder, CO, 30 July - 1 August.

Schwartz, B.E., and S. C. Benjamin, 1995: A comparison of temperature and wind measurements from ACARS-equipped aircraft and rawinsondes. *Weather and Forecasting,* **10**, 528-544.

Wang, J., and W.B. Rossow, 1995: Determination of cloud vertical structure from upper-air observations. *Journal of Applied Meteorology,* **34**, 2243-2258.

2003 Pacific THORPEX Observing System Test

THORPEX: a Global Atmospheric Research Program

Honolulu, Hawaii February 18 - March 13, 2003

[Home] [Objectives] [Mission Ops] [Participants] [Weather] [Satellite] [Data]

- **Schedule Changes, Notices, & Updates** **Directions to Air Services Hawaii**
- **2003 Pacific TOST Test Plan: PDF or MSdoc** ***Updated on 14 Feb 2003***
- **THORPEX Project Overview (PDF file)** ***by Shapiro & Thorpe***

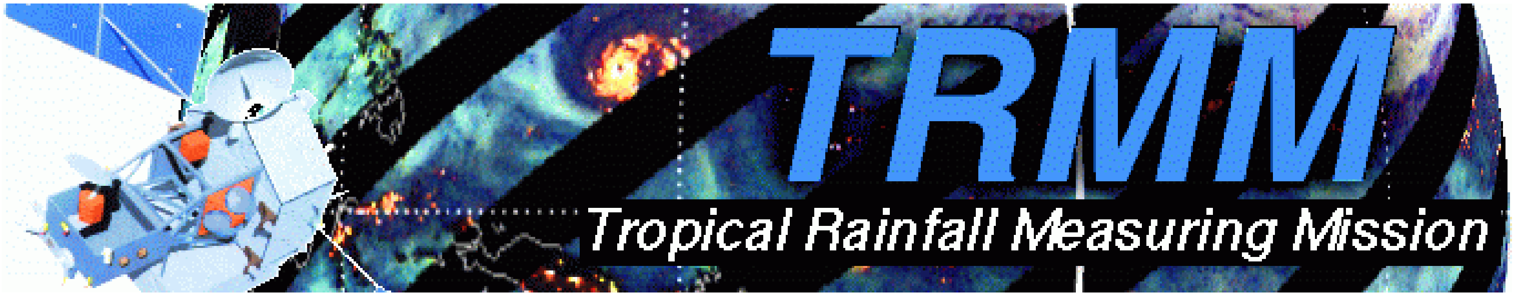
The 2003 Pacific THORPEX Observing System Test is the first in a series of Pacific and Atlantic observation campaigns in support of the WWRP/USRP THORPEX Program. THORPEX - a Global Atmospheric Research Program, is a 10 year international research program under the auspices of the World Meteorological Organization/World Weather Research Program (WMO/WWRP) to accelerate improvements in short range (up to 3 days), medium range (3-7 days) and extended range (two week) weather predictions and the societal value of advanced forecast products. THORPEX will examine predictability and observing system issues, and establish the potential to produce significant statistically-verifiable improvements in forecasts of high impact weather. The program builds upon and coordinates advances being made in the operational forecasting and basic research communities.

Related Links: [CPL] [SHIS] [NAST] [DRIFTSONDE] [MAS] [CIMSS] [LaRC Cloud & Radiation]

Responsible NASA Official: John Murray **Web Curator**: Louis Nguyen

Website address: http://www-angler.larc.nasa.gov/thorpex **Last Update**: June 02, 2003

Field Operations Center Phone Number: 1-808-840-1858



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The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the National Space Development Agency (NASDA) of Japan designed to monitor and study tropical rainfall. For more detailed information on the TRMM mission or the satellite, click on "Mission Overview".

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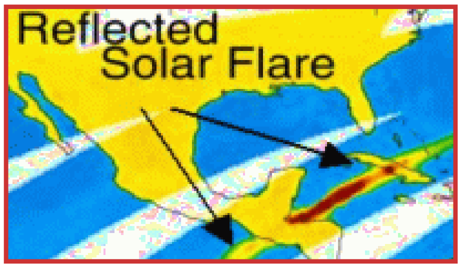

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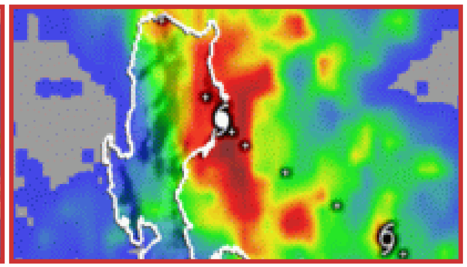

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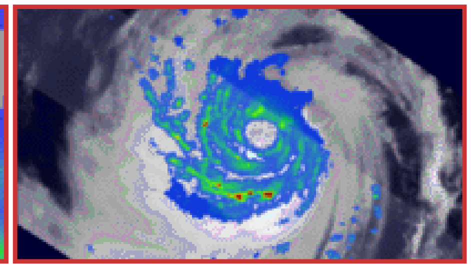

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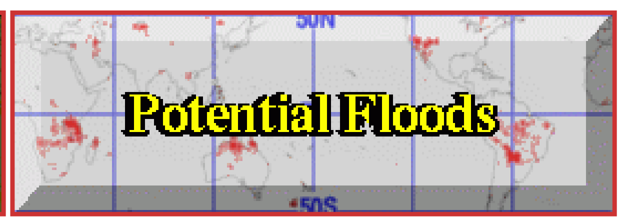
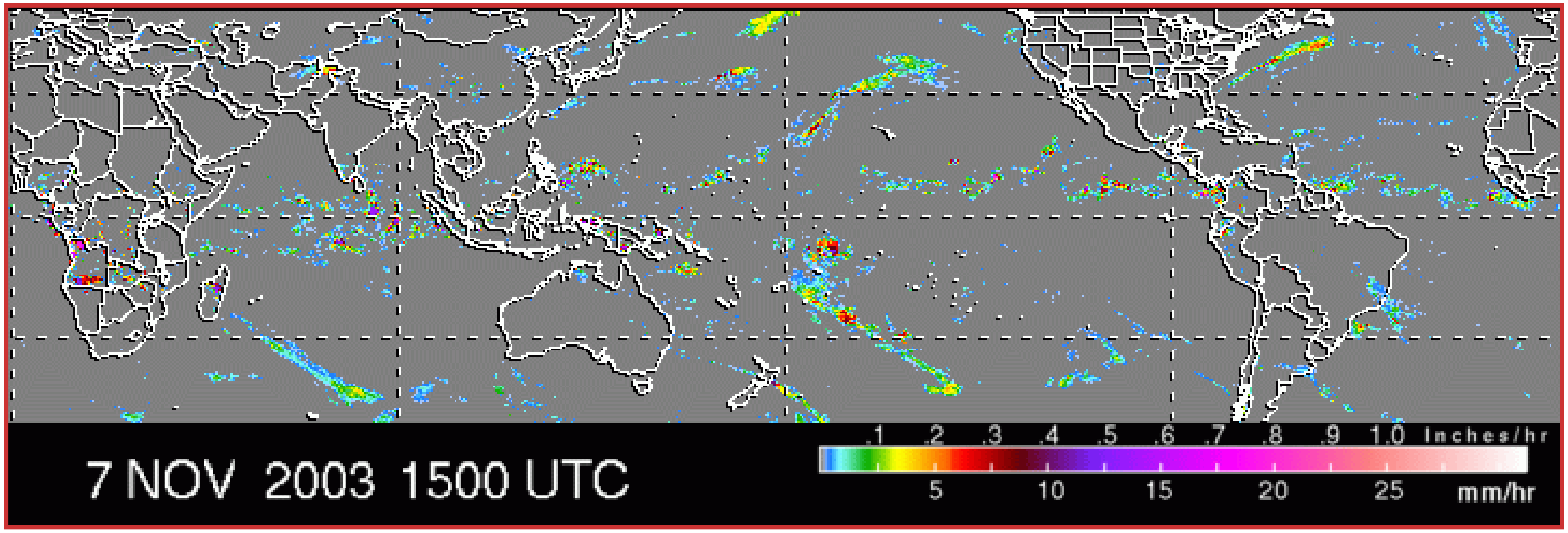
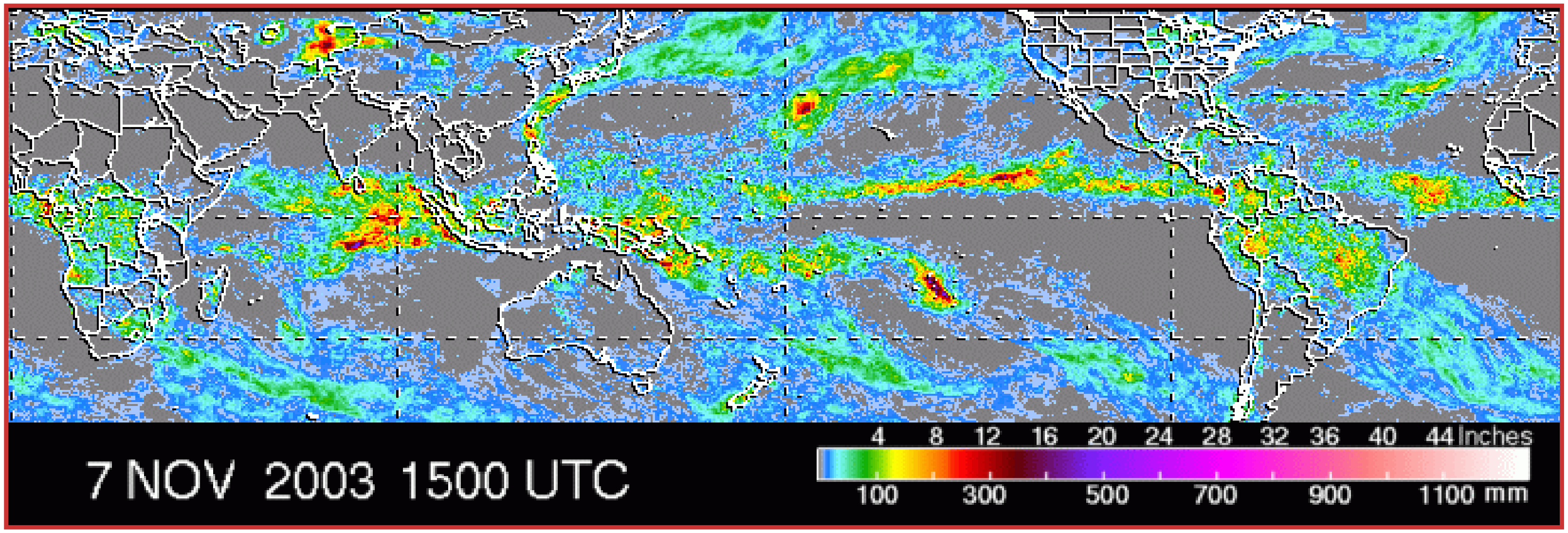




Latest 3 Hourly Global Rainfall _ Click to See a Small [1.6 MB] Animation



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Notice The normally used 3B42 rain estimation product will be be replaced by the 3B40 product when the 3B42 product is unavailable. The 3B40 is a merger of all available SSM/I and TMI *microwave* precipitation estimates. The 3B42 product is a merger of *microwave* plus estimates from *geostationary infrared (IR)* observations.

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Atlantic THORPEX Observing System Test

13 October - 12 December 2003

The EUMETNET Composite Observing System (EUCOS) Programme and THORPEX share a common goal of testing the hypothesis that the number and size of significant weather forecast errors over Europe and Eastern seaboard of the USA can be reduced by targeting extra observations over oceanic storm-tracks and other remote areas, determined each day from the forecast flow patterns. The Atlantic-THORPEX Observing System Test (Atlantic - TOST) is planned as a field campaign to make a significant contribution towards this common goal. The primary aim of the Atlantic TOST is to test the real-time quasi operational targeting of observations using a number of platforms (including AMDAR, ASAP ships, extra radiosonde ascents, research aircraft and meteorological satellites). To do this, it is necessary to identify suitable cases for targeting, provide information on the location of sensitive areas, and have the facilities to control each observing system at short notice. The Atlantic TOST will be the first time that the real-time adaptive control of such a complex set of observing pratforms has been attempted. It is considered to be an essential preparation or "proof of concept" for future targeting field campaigns. Additional scientific objectives of the Atlantic TOST will contribute to the understanding of the location and predictability of sensitive areas and the impact of targeted observations on forecast performance (and the benefit of potential new observing platforms).

- Project Plan (pdf)
- Operations Plan
- Data exchange and dissemination
- TReC online

Please send questions or comments to
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Last modifed:

Alliance Icing Research Study II

Mirabel Airport, Quebec : Nov 2003 - Mar 2004

On-Line Documents:

- Letter of Intent for AIRS II [PDF]
- AIRS II Science Plan (2003-07-07) [PDF]
- AIRS II Science Plan (2003-01-06) [PDF]
- AIRS II Operations Plan (Draft 7) [.DOC]
- NASA Langley AIRS II Addendum Draft 2 (2003-10-27) [.DOC]
- NASA Langley AIRS II Addendum Draft 1 (2003-10-15) [.DOC]

MSC Data Collection:

- Ontario Region AIRS 2 Website (user/password required at site)
- Ontario Region AIRS 2 FTP Site (user/password required at site)

Operational Objectives:

AIRS II has operational objectives to:

a. develop techniques/systems to remotely detect, diagnose and forecast hazardous winter conditions at airports.
b. improve weather forecasts of aircraft icing conditions.
c. better characterize the aircraft-icing environment.
d. improve our understanding of the icing process and its affect on aircraft.

In order to support the operational objectives, the following science objectives will be addressed to:

a. investigate the conditions associated with supercooled large drop formation.
b. determine conditions governing cloud glaciation.
c. document the spatial distribution of ice crystals and supercooled water and the conditions under which they co-exist.
d. verify the response of remote sensors to various cloud particles, and determine how this can be exploited to remotely determine cloud composition.

It is anticipated that several instrumented research aircraft operating out of Ottawa will be used in AIRS II. These aircraft will fly special flight operations over a network of ground in-situ and remote-sensing meteorological measurement systems, located at Mirabel. Some prototype airport weather forecasting systems, which use satellite and surface-based remote sensors, PIREPS, and numerical forecast models, will be evaluated during the project. The aircraft will also provide data to verify the remote-sensing algorithms, numerical forecast models, and forecast systems, used to detect and predict icing conditions.

AIRS II is an exciting collaborative effort among many scientists and organizations. It will assist in providing the aviation community better tools to avoid aircraft icing, and to improve the efficiency of airport operations. It will also enable some unique basic science objectives to be addressed such as: how supercooled large drops form, how cloud ice forms, and how to better remotely detect cloud properties.

AIRS II Participating Organizations:

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Institute for Aerospace Research of NRC
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Defence Research and Development Canada
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