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PROJECTS, PLANNING AND WORK PROGRAMME

Enhancement of AMDAR Observing System Coverage

Water Vapour Sensing

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SUMMARY AND PURPOSE OF DOCUMENT

Presents progress made on the development and implementation of water vapour sensing, including WVSS-II validation, operational implementation, and future plans and strategy.

ACTION PROPOSED

1. The Panel is invited to note the information contained in the document.

1. WVSS-II Validation

1.1. Research Aircraft BAe 146 of FAAM (Facility for Airborne Atmospheric Measurements, UK):

Two units of the humidity sensor are permanently flown in a piggy-back mode. The parallel use of two systems is done because they have different intake and outlet configurations. Besides of the conventional flush mount “Air Sampler” on one instrument a total-air-temperature (TAT) housing is used on the other system unit to achieve the ram air heating to get far enough apart from unwanted condensation effects.

In the range from 10 g/kg down to 0.5 g/kg the two sensors show a good congruence with the reference values based on a chilled mirror system. Below that range a systematic tendency can be seen in the relative deviation of the conventionally equipped WVSS-II unit. It is a trend going up to +20 %. To separate this effect of a possibly existing physical tendency from that of individual sensor biases the two WVSS-II units are planned to be swapped. The piggy-back operation of the two units continues.

1.2. DENCHAR (Development and Evaluation of New Compact Hygrometers for Airborne Research):

DWD got the opportunity to provide two units of WVSS-II Version 3 for this flight test campaign. In the frame of EUFAR (European Facility for Airborne Research, an EU FP7 programme) this experiment has been set up for several highly sophisticated scientific humidity instruments to be exposed to a large spread of conditions in the troposphere as well as in the lower stratosphere.

The WVSS-II units were mounted on different locations on the aircraft. The WVSS-II unit having been coupled to a common inlet system with its intake beyond the fuselage’s boundary layer shows a good congruence with the reference signal down to about 50 ppmv (0.03 g/kg). The WVSS-II unit coupled to the conventional Air Sampler did not come below 100 ppmv (0.06 g/kg). This behaviour can have several reasons. One of them could be a small leak in the pressurized cabin anywhere in the upstream region of the Air Sampler. An intake orifice beyond the fuselage’s boundary layer would completely elude this problematic possibility.

DENCHAR is planned to be continued. A second test flight campaign is envisaged for 2013.

1.3. Impacts on NWP

The impact of the humidity measurements on NWP has been shown of the 5th WMO workshop on Impact of Observations, May 2012. Even with the amount of only 60 aircraft their impact on the the GFS exceeds that of the radiosondes. Even more impact can be seen in NOAA’s Rapid Refresh Models (RAP).

2. WVSS-II Operational Implementation Status

2.1. 2012 U.S. WVSS-II Progress/Activity Report

2.1.1. A new water vapour sensing contract with ARINC was signed in September 2012. This and a Supplemental Type Certification (STC) granted for the B737-700 series will allow for WVSS-II installations on an additional 55 Southwest Airlines (SWA) aircraft.

a. The FAA STC for WVSS-II on the B737-700 aircraft was completed in June of 2012. The first B737-700 aircraft went into operation on August 23, 2012.

b. The inclusion of the B737-700 airframe as a WVSS-II platform, opens the door for approximately 600 aircraft among the fleets of current AMDAR participating airlines. With approximately 1,400 Boeing B737-700 aircraft worldwide, there are many opportunities for further international expansion of the water vapor observation network via AMDAR.

c. Additionally, this contract will initiate arrangements with Alaska Airlines to begin the process for equipping their aircraft with WVSS-II.

d. A new BUFR file will be created which will contain, among other data, real-time WVSS-II observations. This data will not have distribution restrictions and will be available to research and commercial interests.

2.1.2. The updated installation schedule from ARINC and SWA has an average of 6 new units being installed monthly starting in October 2012. At this rate, the 55 aircraft should be outfitted in about 9 months, or in the June/July 2013 time frame.

2.1.3. These new 55 aircraft will be added to the current 57 WVSS-II fleet (25 UPS B757-200PFs, 31 SWA B737-300 and 1 SWA B737-700) bringing the total of equipped aircraft to 112.

2.1.4. This fleet will produce about 1200 profiles (approximately 25,000 moisture observations) of the atmosphere daily.

2.1.5. Each aircraft will average around 470 mixing ratio reports daily. Therefore, with 6 installations expected monthly, moisture measurements are scheduled to increase by about 86,000 observations per month into July 2013.

2.1.6. The completion of the 55 WVSS-II installations is expected to add nearly 790,000 moisture observations per month. This will be a 26% increase to the approximately 3,000,000 reports currently being made.

Southwest Airlines / AirTran Airways Destinations

2.2. E-AMDAR Progress/ Activity Report

As hitherto 3 humidity sensors type WVSS-II, version 2 are flown on Lufthansa aircraft of the Airbus A320 family. For the year 2013 the units are planned to be exchanged against instruments of the version 3. The appropriate contracts with Lufthansa and the instrument's manufacturer SpectraSensors Inc. are fixed.

The usability of the WVSS-II integration's engineering bulletin as an STC or something being equivalent to that is not yet decided.

2.3. Australia Progress/Activity Report

Since 2010 the Bureau has been encouraging our major airline partner, Qantas, to consider collaborating with us in adding water vapour to the suite of AMDAR observations. Qantas have consistently indicated their in-principle support of such a project, and in early 2012 they indicated their readiness to proceed in practice. Accordingly, the Bureau ordered three SpectraSensors WVSS-II ver.3 systems, which arrived in May 2012. We also ordered the recently FAA approved installation hardware specific for the 737-700 airframe, on the basis that this would likely prove a good starting point in determining the installation hardware requirements for the very similar 737-800 airframe. A non-disclosure agreement has been executed between Qantas and SpectraSensors which has facilitated the sharing with Qantas of significant engineering and technical certification information. The Bureau, Qantas and SpectraSensors are still in the process of planning and costing a project to deliver STC certification and installation of the WVSS-II on 1-3 Qantas 737-800 aircraft, in the first instance. The STC certification process seems likely to be more expensive than the installation itself.

The Bureau is conscious that the 737-800 is one of the most common commercial passenger jet in the world (second only to the A320), with 2610 deliveries to date and a further 1450 on order, totalling 4060, (figures current at August 8, 2012). FAA STC certification of the first WVSS-II install on this airframe opens up the entire 4000+ aircraft to WVSS-II installation. It is less than optimal that there is no coordinated approach in place to amortise the significant cost of the 737-800 airframe STC certification across all of the AMDAR programs who will clearly benefit from it. The Bureau encourages the Panel to address this issue.

3. International Implementation Plan for Water Vapour Sensing Capability for AMDAR

An implementation plan for water vapour measurement (WVM) on commercial aircraft platforms is outlined (see Appendix I). It starts with a request for the definition of the physical and aeronautical frame conditions. These conditions give a first view on the necessity of reasonable standardisations on the aviation side.

To enlarge the instruments' range of meteorologically useful performance, even to extremely cold parts of the upper troposphere, it is recommended to continue with research and development for the sensors and inlet systems.

The possibilities for implementation processes on commercial aircraft divide into three pathways:

(1) The AMDAR functionality plus WVM is installed as a retrofit on already existing aircraft models. It is the obvious solution to achieve a first realization and verification of the measurement principle and strategy. This kind of instrument's integration on the carrier system always needs another step of engineering and airworthiness certification for each different type or even sub-type of aircraft. Direct or indirect contracts between NMHSs and airlines are needed. Strategies for project activities are recommended.

(2) An NMHS or regional AMDAR program should contemplate the approach directly to aircraft manufacturers. Some kind of preparation of aircraft production series for a cheap sensor integration on demand should be negotiated by support of WMO. A contract between NMHS or regional program and the manufacturer will have to be targeted. An appropriate model of payment coupled to each AMDAR activated aircraft will have to be created.

(3) The ideal way to integrate the WVM is given by a conglomerate of NMHSs / WMO, airlines, ATM, environmental control and aircraft manufacturers. The flight operation will profit not only by better NWP but far more by using the humidity signal individually on each aircraft for an improved icing warning, economic de-icing control and improved prevention of engine icing. By additional use of particle sensors ISSRs (ice super saturated regions) will get identifiable. ATM could contribute to the avoidance of contrails keeping these regions free of air traffic.

Finally a ranking and an appropriate assortment of WMO activities is given.

APPENDIX I

DRAFT IMPLEMENTATION PLAN FOR WATER VAPOUR SENSING CAPABILITY FOR AMDAR

1. Background

Since the eighties of the last century airlines began to equip their fleets with systems enabling the aircraft to transmit flight operational data to their headquarters via a worldwide communication network. One component of this data flow consists of meteorological data like pressure, temperature and wind. Specific software puts these communication systems in the ability to transmit those data to an NMHS or directly into the GTS. This kind of in-situ measurement method yields an effective worldwide coverage with vertical profiles and en-route data series.

The assimilation processes of the NWP models are well attuned on AMDAR. To catch up with the parameter range of radiosondes AMDAR has to be completed with water vapour measurement (WVM). Then, these instrument platforms will be an economic and efficient complementation of the radiosondes. In some places and time slots the comparatively expensive radiosonde launches could be conserved.

Up to now, AMDAR just benefits of an instrumentation already existing on each aircraft because of immediate flight operational reasons. The equipment of the aircraft with humidity sensors needs to become a standard process.

2. Aims and Goals

2.1. Worldwide, the water vapor measurement shall coincide with temperature, pressure and wind measurement on a component (ideally all AMDAR aircraft) of the AMDAR fleet that provides optimal coverage for water vapour measurement based on the requirements of the WMO Integrated Global Observing System (WIGOS) and of WMO Member NMHSs.

2.2. The accuracy of the water vapor measurement shall meet or approach the requirements as specified in the WMO Guide to Instruments and Methods of Observation:

- ± 5 to 3 % of relative humidity over the whole measurement range,
- measurement range between 5 % RH at -75 °C in 200 hPa
  and 100 % RH at +35 °C in 1050 hPa.
- ability to measure supersaturation (i.e. in ISSRs).

2.3. Ideally, the water vapor measurement sensor shall be a standard component of commercial aircraft and integrated with AMDAR software, standard avionics and communication systems like ACARS or successor systems.

3. Justification

The addition of water vapor measurements leads to the most complete usefulness of the infrastructure of already existing airborne measurement platforms. AMDAR could be used as a system being an equivalent complementation and replacement for radiosondes.

4. Benefits

- AMDAR is a productive measurement data source for NWP.
- Radiosonde launches can be conserved.

- Airline's use of humidity data at their own internal meteorological centres, as practiced in the USA, such as support for fog warnings on airports).
- Improvement in met applications (see business case BoM).
- Improved NWP for clouds, icing, fog, precipitation.
- "Green" aircraft for airline's advertising.

5. Detailed Activities and Tasks

The WMO approach to the implementation of a water vapour measurement (WVM) capacity to AMDAR shall be undertaken in cooperation with operational AMDAR Programme Managers and shall incorporate the following major activities:

5.1. Definition of general necessities and frame conditions

5.1.1. Physical requirements for WVM implementation

A universal specification for inlet and outlet device has to be created. It has to cover the features outlined in the following subitems:

5.1.1.1. Location and orientation on the airframe

A set of rules has to be stated to be able to determine the best or even the only possible zones on the fuselage for WVM system's location:

- The upstream's path of the sampling air over the fuselage shall be as short as possible
- The depth of the boundary layer shall be either
  - as small as possible

  or
  - smaller than the intake's distance to the fuselage.

The orientation of the intake shall be almost parallel to the airflow.

5.1.1.2. Aerodynamics and Thermodynamics

The impact process of the sampled air shall lead to an increased temperature-dew point spread.

5.1.1.3. Sample air pipes

The pipes or hoses need to have the most neutral behaviour in contact to water vapour as well as to liquid or solid water.

5.1.2. Aeronautical requirements

5.1.2.1. Power Adaptor

The interface to the carrier system's power supply has to be compliant to international standards for commercial aircraft (115 VAC, 400 Hz).

5.1.2.2. Mechanical aircraft integration

For maintenance reasons the instrument's mounting has to comply with the aviation standards for avionics components (tray for fast assembly and disassembly).

5.1.2.3. Covering tools

The instrument has to be integrated in the standard procedures for aircraft care on airports. Covering caps with appropriate vanes are to be taken into the aircraft's standard equipment.

5.1.2.4. Maintenance

The instrument's maintenance cycles have to match with those of the aircraft.

5.2. Research & development for WVM

Carry out tasks and activities towards the research, development and testing of existing and developmental WVM sensors. Scientific flight trials such as DENCHAR (Development and Evaluation of Novel Compact Hygrometer for Airborne Research) or the piggy-back test operation of WVM systems on the research aircraft BAe 146 of FAAM (Facility for Airborne Atmospheric Measurements) are examples for appropriate assessments.

5.2.1. Monitor and coordinate requests and trials about

- sample air flow
- sensor performance
- electromagnetic ruggedness of the sensor's raw signal

for

- the existing WVM type WVSS-II,
- other existing WVM system solutions,
- and new WVM techniques.

5.2.2. Undertake performance and quality assessments

Request NWP to carry out investigations for measurements of existing sensors;

- Impact studies
- Quality evaluation against first guess of NWP
- Implement ongoing radiosonde/ WVM co-location comparison reporting.

5.2.3. Request NMHSs to carry out investigations about alternative sensors.

The WVM systems have to be improved to cover also extremely cold conditions in the upper troposphere.

APPENDIX I

5.3. The pathways for capturing commercial aircraft fleets

5.3.1. Retrofitting of AMDAR aircraft with WVM

This activity and its tasks encompasses the process of AMDAR Programme working together with partner airlines to advance the process of retrofitting of existing AMDAR aircraft platforms with a WVM.

5.3.1.1. Ensure that AMDAR including humidity is standardised within existing aviation communication frameworks

The AMDAR on-board software shall follow international standards.

5.3.1.2. Write generic letter from WMO/CBS to existing AMDAR airlines to request participation in the WVM project.

5.3.1.3. Consideration of new aircraft types

In future the aircraft's construction material will change to carbon fibre. Consequences in STCs and/ or in the WVM system's concept have to be envisaged.

5.3.1.4. Survey operational programmes

The airline's flight profiles of different aircraft types are to be chosen appropriately for equipping with WVM systems.

5.3.1.5. Survey airline's fleet planning

The selection of aircraft for humidity instrumentation depends on the perspective on a long-term use of each unit within the airline.

5.3.1.6. Determine target aircraft model and fleets for retrofit:

Selection of platforms

- Aircraft types
  - flight ranges to achieve highest density of profiles,
  - climb rates,
  - suitable measurement system for True Track and True Heading,
- Fleets
  - sufficiently large number of appropriate aircraft,
  - sufficiently large period of aircraft use,
  - communication system ACARS,
- Airlines
  - covered regions,
  - cooperativeness.

5.3.1.7. Coordinate the attainment of supplemental type certificates (STCs)

- Develop a list of STCs to be attained based on target aircraft models
- Develop a process for streamlining initiation of STCs.
- Achieve grants given by CASA, EASA, FAA, JCAB.

5.3.2. Global ex-works implementation of AMDAR including WVM

This activity will encompass activities and tasks related to the process of working with appropriate aviation industry entities to ensure that WVMs are integrated into the standard manufacturing and avionics processes and systems with the ultimate aim of making the humidity measurement a standard component of aircraft platforms upon manufacture and delivery.

5.3.2.1. Implementation based on WMO/ NMHS requirements only

Cooperation partners: NMHS / WMO and aircraft manufacturers only

- Contact aircraft manufacturers for getting offers about ex-works integration of WVM or at least the provision of mechanical and electrical interfaces. Concept of cost models based on license fees for
  - readily equipped and activated aircraft,
  - aircraft with the appropriate interfaces and quasi STC;
  - aircraft with STC and blocked zones for instruments and wiring
- Re-approach Airbus for refreshment of quotation of 2006.

5.3.2.2. Implementation based on common interest of all aviation partners

- Ensure that the necessity of AMDAR and humidity is represented to the right aviation forums, e.g. AEEC, RTCA, NextGen, SESAR, etc.
- Ensure that AMDAR is standardised within developing and future aviation communications frameworks
- Carry out activities and tasks towards the goal of integration of both AMDAR and WVM sensors into aviation standard procedures, protocols and infrastructure.
- Undertake a study into current and likely future aviation communications developments and possible impact on AMDAR.
- Contact partners like
  - airlines,
  - ATM/ airports,
  - environmental control.
- Build a Business Case for humidity as a standard parameter for flight operations applications
- Commission or undertake research and studies into aviation benefits by cockpit's direct access to humidity for the purpose of:
  - Icing warning.
  - De-icing control (fuel saving by avoiding needless de-icing).

- Control of engine performance (safety) because of the risk of ice accretion as an effect of ambient humidity.
- Contrail avoidance.

- Determine what related research into the above applications is already underway and by whom.
- Contact research institutions who are concerned with impacts of humidity phenomena on flight safety. Example: NASA Glenn Research Centre re engine icing research being carried out and assess relevance to AMDAR and the WV business case.

6. Range of WMO Activities

To meet the goal of a maximal use of airborne meteorological platforms there are three different pathways to be considered. The priorities for WMO should be sorted as follows:

6.1. Top Priority

Comprehensive solution acquiescing a long lapse of time:

Ex-works integration primarily driven by the interest of all the parties of aviation as well as of environmental politics.
AMDAR plus humidity gets to a binding standard for aircraft.

- to be coordinated by WMO
- to be performed by airlines stimulated by economics and environmental control

6.2. Medium Priority

Special solution with efficient impact:

Ex-works integration primarily driven by the interest of NMHSs,
if the solution 6.1 is too long apart:

- to be coordinated by WMO
- to be performed/ contracted by NMHSs and/ or regional programs

6.3. Low Priority

Local, transitory solution:

Integration as retrofit solutions,
if 6.2 is not viable:

- to be promoted by WMO
- to be performed by NMHSs and/ or regional programs
- STCs to be coordinated by WMO

APPENDIX I

7. WMO AMDAR Water Vapour Measurement Project

Bring the current national operational and developmental programs and projects together under the umbrella of an international WMO project with the following activities:

7.1. Develop a simple website promoting the project;

Incorporate and reference AMDAR impact assessment study (Petersen)

7.2. Obtain permission to promote the partner NMHSs and airlines on the website;

7.3. Develop high level project plan with aims, goals, timelines (add to website);

7.4. Develop business cases for AMDAR and WVM (add to website)

7.4.1. Develop a business case for a cooperation between NMHS/ regional program with an airline:

Assign as a collaborative task to an appointed team of AMDAR focal points.

7.4.2. Develop business cases for aviation participation

7.4.2.1. Cooperation between NMHS/ regional program and aircraft manufacturer

Specify and undertake an SSA for the development of the BC.

7.4.2.2. Cooperation between NMHSs/ regional programs with airlines, ATM as well as environmental control

Specify and undertake an SSA for the development of the BC.

7.5. Emphasise all 3 key aspects of the project:

- Research & development,
- Retrofitting of AMDAR aircraft

and

- Aviation integration of AMDAR and WVM.