E-AMDAR (Aircraft Meteorological Data Relay)
AEMET, Madrid,
27 de Mayo de 2016
Steve Stringer, E-AMDAR Programme Manager
Content of Presentation

• Why do we need aircraft observation data?
  - Impacts & benefits

• What is AMDAR?
  - What and when does it measure?
  - Who is involved?

• E-AMDAR Programme
  - Requirements, Objectives & Priorities
  - Status and plans
Why do we need aircraft data?

What are benefits to meteorology and to the aviation Industry?
Forecasting the weather

Customer

Forecaster consultant media presenters
  local centre

Operations Centre

Numerical models

Worldwide observations
  Satellite, land, ship, aircraft, radar, radiosonde, buoy

Research and development
WMO Global Observing System

WMO – World Meteorological Organization (http://www.wmo.int)
Forecasting the weather

Customer

Forecaster consultant media presenters
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Operations Centre

Numerical models

Worldwide observations
  Satellite, land, ship, aircraft, radar, radiosonde, buoy

Research and development

Global aviation forecasts
Forecasts

The process

2. We use numerical computer models and supercomputers to forecast weather.

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AMDAR Impact on Weather Prediction (NWP)

• Provides both better accuracy than satellites
• and higher temporal coverage than radiosondes
• With improved horizontal coverage and water vapour – Impacts will be even greater.

Note that both Research (~20%) and Operational (~80%) Satellite Sensors contribute

When used together, AMDAR Wind and Temperature observations have the fourth largest impact of any observation type.
Forecasting the weather

Customer

Forecaster consultant media presenters
local centre

Operations Centre

Numerical models

Worldwide observations
Satellite, land, ship, aircraft, radar, radiosonde, buoy

Research and development

International Emergency/Severe Weather Warnings
Defence
Civil Aviation

Global aviation forecasts
Forecasting the weather
Ops Centre
Benefits of Aircraft Data (to Meteorology and to the Aviation Industry)

Data Use

- Use in Numerical Weather Prediction Models
- Use in Forecast Applications
- Use in Climate Applications
- Use in Verification of Forecast Products

Benefit to Airline Operations

- Impact of Improved Weather Forecast Skill on Airline Operations
- Improved Flight Operations
- Improved Safety
- Operational Cost Savings
- Aircraft Sensor and System Monitoring
Benefits to Aviation


- Improved and more accurate weather forecasts, products and diagnostics and aircraft sensor performance monitoring for the aviation industry ultimately lead to significant cost savings to airlines and safer flight operations.
Benefits: Aviation Industry

A recent Study by South African Airways shows the benefits of using AMDAR data:

1. Pre-departure Dynamic Fuel Planning - Use latest possible weather information and forecasts for determination of fuel load.

2. Pre-departure Flight Planning – Use latest possible forecasts (Flight Plan/Winds Aloft) for latest possible adjustment of flight plan.

3. In-flight Planning – Request and use updated forecasts for in-flight adjustment and optimisation.
Benefits: Aviation Industry

Findings below are based on SAA’s 24 wide body aircraft (A330 and A340) fleets.

- Financial results of using Dynamic Fuel Planning: *Savings over a 1 year period, utilising actual Zero Fuel Weight and using prevailing weather conditions: Between 2 and 3 million dollars.*

- Cost of fuel saved through use of pre-flight and in-flight planning: > $600,000
What is AMDAR?

**AMDAR (Aircraft Meteorological Data Relay)**

- Automated collection and transmission of various parameters using existing aircraft sensors and airline infrastructure:
  - Height (pressure derived)
  - Temperature
  - Wind speed
  - Wind direction

Additional parameters potential
- Turbulence
- Icing
- Humidity
Aircraft Meteorological DData Relay (AMDAR)

- AMDAR is a collaborative programme between Airlines and National Meteorological Services
- From aircraft systems, meteorological parameters are provided in real time via ACARS (Aircraft Communications Addressing and Reporting System):
AMDAR observations

• TAT probes (temperature)

• Pitot-static tubes (pressure)
AMDAR observations

- AMDAR data can be reported in all phases of flight - series of observations at a height, latitude and longitude forming a profile, similar to a radiosonde.

- AMDAR reporting can be triggered by time or pressure – dependant on software/avionics platforms installed on the airlines.

- Reported observation resolution can be configured to meet specific requirements (i.e. cost saving or Continuous Descent Approach).
AMDAAR Observations – Brief History:

- First system developed by the Australian Bureau of Meteorology in the mid1980s:
  - 1985 Ansett
  - 1990 Qantas
- Other National Met Services/Airlines soon followed:
  - 1992 New Zealand & USA (Delta, Northwest, United & UPS)
  - 1993 KLM
  - 1995 Air France
  - 1998 British Airways & SAS
  - 1999 Lufthansa (inc. LHCityline, LHCargo & Germanwings)
  - 2000+ Canada, Saudi, South Africa and since
  - 2005+ Hong Kong, China, Japan, Korea and also the SAS Hosted airlines Blue1, Novair & ThomasCook Scandinavia
  - 2010 Finnair and easyJet
  - 2013 Austrian Airlines
  - 2016+ SATA (Azores) , Aer Lingus + others?
AMDAR data coverage: Global
Global aircraft observations

Aircraft Observations - Smoothed Monthly Average of Daily Report Totals

Solid lines on Left Axis, Dashed lines on Right Axis

Based on reports received by the Canadian Meteorological Centre

GIE/EIG EUMETNET, Registered Number 0818.801.249 - RPM Bruxelles
## Participating Airlines - by Programme

<table>
<thead>
<tr>
<th>Programme</th>
<th>Number</th>
<th>Airlines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>6</td>
<td>Qantas Airways, JetConnect (Qantas), Jetstar Airways, Jetstar Asia, SkyTraders, Air Vanuatu</td>
</tr>
<tr>
<td>Canada</td>
<td>2</td>
<td>Air Canada Jazz, NAV Canada</td>
</tr>
<tr>
<td>China</td>
<td>2</td>
<td>China Southern Airlines, Shandong Airlines</td>
</tr>
<tr>
<td>E-AMDAR</td>
<td>14</td>
<td>Air France, Austrian Airlines, KLM, Lufthansa Passage, Lufthansa CityLine, Lufthansa Cargo, British Airways, Finnair, Scandinavian Airlines, Blue1, easyJet, Novair, Thomas Cook Scandinavia, GermanWings</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>1</td>
<td>Cathay Pacific</td>
</tr>
<tr>
<td>China</td>
<td>1</td>
<td>Cathay Pacific</td>
</tr>
<tr>
<td>Japan</td>
<td>2</td>
<td>Air Nippon Airways, Japan Airlines</td>
</tr>
<tr>
<td>New Zealand</td>
<td>1</td>
<td>Air New Zealand</td>
</tr>
<tr>
<td>Korea</td>
<td>2</td>
<td>Korean Air, Asiana Airlines</td>
</tr>
<tr>
<td>South Africa</td>
<td>1</td>
<td>South African Airways</td>
</tr>
<tr>
<td>USA</td>
<td>9</td>
<td>Alaska Airlines, American Airlines, Continental, Delta Airlines, Northwest Airlines, Federal Express, United Airlines, United Parcel Service (UPS), Southwest Airlines</td>
</tr>
</tbody>
</table>
EUMETNET

- **31 Members**: National Met. & Hydro. Services (NMHS)
- **3 Programmes**
  - Observations
  - Forecasting
  - Climate
- **Obs Programme**
  - E-AMDAR *(aircraft)*
  - E-ASAP *(ship Wx balloon)*
  - E-GVAP *(GNSS humidity)*
  - E-PROFILE (+ lidar)
  - E-SURFMAR *(ship, buoy)*
  - OPERA *(radar)*

Economic Interest Grouping, EIG EUMETNET: provides a framework to organise co-operative programmes between its Members in the various fields of basic meteorological activities.  [www.eumetnet.eu](http://www.eumetnet.eu)
Requirements

Regional requirements
EUCOS area: 70°W to 40°E; 10°N to 90°N
Observations: Spatial resolution: 250km
Temporal resolution: 3 hours

Quality: maximum temperature RMSE should not exceed 1.5 K
maximum wind RMSVD should not exceed 5 m/s.

<table>
<thead>
<tr>
<th>Performance Targets for E-AMDAR</th>
<th>2016</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of airports in EUCOS area observed daily</td>
<td>129</td>
<td>171</td>
<td>180</td>
<td>186</td>
</tr>
<tr>
<td>Number of 3 hourly observed airports</td>
<td>37</td>
<td>54</td>
<td>63</td>
<td>69</td>
</tr>
<tr>
<td>Total daily number of profiles within EUCOS area</td>
<td>718</td>
<td>1012</td>
<td>1122</td>
<td>1118</td>
</tr>
<tr>
<td>World Weather Watch contribution</td>
<td>11%</td>
<td>9.91%</td>
<td>16.52%</td>
<td>16.74%</td>
</tr>
<tr>
<td>Total number of observations</td>
<td>-</td>
<td>1.49M</td>
<td>1.55M</td>
<td>1.66M</td>
</tr>
<tr>
<td>Annual number of E-AMDAR funded observations</td>
<td>11M</td>
<td>1.34M</td>
<td>1.35M</td>
<td>1.47M</td>
</tr>
<tr>
<td>Timeliness T + 50</td>
<td>90%</td>
<td>97.14</td>
<td>92.55</td>
<td>91.81</td>
</tr>
<tr>
<td>Timeliness T + 100</td>
<td>95%</td>
<td>99.23</td>
<td>99.63</td>
<td>99.65</td>
</tr>
</tbody>
</table>
Requirements

Regional requirements
EUCOS area: 70°W to 40°E; 10°N to 90°N
Observations: Spatial resolution: 250km
Temporal resolution: 3 hours
Quality: maximum temperature RMSE should not exceed 1.5 K
maximum wind RMSVD should not exceed 5 m/s.

In addition now have
National & Short Range NWP requirements
Observations: Spatial resolution: <100km
Temporal resolution: 1 hour
Timeliness: T+15 mins
Temp rmse goal: 1.0K
Wind rmsvd goal: 3.5m/s
E-AMDAR Programme Objectives

- Continued, sustainable access to high quality upper air observations from commercial aircraft;
- Delivery of the humidity trial and a business case setting out the investment options and related costs for an extension of capability to include humidity data;
- Increased number of airports providing 3-hourly observations;
- Increased horizontal coverage in data sparse areas;
- Flexibility to facilitate additional data required by individual NMSs.
Global AMDAR observation coverage

31-Mar-2016 00:00:00 -- 31-Mar-2016 23:59:58 (753170 obs loaded, 689802 in range, 21752 shown)

**NOAA / ESRL / GSD**  Altitude: -1000 ft. to 45000 ft.  Good w and T
E-AMDAR Global observation coverage
E-AMDAR EUCOS domain coverage
E-AMDAR airport coverage
E-AMDAAR Iberia Coverage
Wind profile Diagram (Airport: MADRID/BARAJAS)

Wind profiles in knots (Airport: MADRID/BARAJAS) Date: 20160520
Current status of airport coverage over Europe

Commercial airport coverage in Europe:

- airports currently flown to/from by current E-AMDAR airlines
- potentially E-AMDAR airports if further, suitable airlines participate.

Appr. 250km grids:

- no E-AMDAR airport coverage but at least one ‘international commercial’ airport
- no airport and no possibility of E-AMDAR profile coverage.
Priorities for expansion

1) Efficiencies – to save budget
   - Optimisation - reduces duplication
   - Supplementary data – Mode-S, ADS-C

2) Gap filling /Uniform coverage in EUCOS area – New airlines

3) Humidity Network
   - 8(9) WVSS sensors operational with DLH
   - Identifying other airlines
   - Business case for investment – external sourcing

4) Turbulence & Icing reporting

5) National programmes (currently France, Germany, Netherlands, Scandinavia & UK)
Why measure humidity?

• Humidity – is one of the most significant parameters for weather evolution. Highly variable in time & space.
• Improvements to aviation meteorological products can be expected in the areas of:
  - Convection, precipitation and fog (forming/clearance) forecasts
  - Reliability of short and long term weather prognoses
  - Nowcasting procedures for fog and icing prognoses.
• The improvements to aviation meteorological products will have affects on:
  - Flight safety
  - Airport operations/flow control (optimisation of the start/landing frequency)
Humidity Sensor hardware (WVSS-II)

- Near-Infrared Absorption Spectrometer based on Tunable Diode Laser
- Heated Inlet Hose
- Output: Water Vapor Mass Mixing Ratio
AMDACR Humidity Current Coverage

WVSS-II coverage over 14 day period with 8 sensors
AM DAR Humidity: Atmospheric Profiles

AM DAR Profile 19.05.2016 12:47:37 UTC (ASC) Aircraft: EU084 Airport: LONDON/HEATHROW (STUEVE)

*Dewpoint calculation Buck approach: Wagner & Prüß above freezing point, Murphy & Koop below freezing point*
Humidity: TAMDAR

- Part of NASA’s Aviation Weather Safety Program initiative.
- AirDat (now Panasonic Weather Solutions) designed a low cost airborne instrument to measure temperature, moisture, pressure, wind, ice accretion and turbulence.
- TAMDAR sensors initially installed on prop-jet aircraft that serve small and medium size regional airports.
- Now certified for Boeing aircraft e.g. Icelandair B757
TAMDAR Coverage in Europe

Plot of TAMDAR and E-AMDAR WVSS aircraft for same day…composite network potential if price is affordable!!
Aircraft Based Observing with Mode-S Enhanced Surveillance (EHS)

- Huge potential to supplement E-AMDAR data at some airport locations.
- Met Office and KNMI conducting studies into the data.
- Recently formed Expert Team - Aircraft Derived Data (ET-ADD) reported in Oct’15 in favour of operational network
# Mode-S EHS Variables

<table>
<thead>
<tr>
<th>Data type</th>
<th>BDS</th>
<th>Resolution</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode-A slant position (range)</td>
<td>4</td>
<td>1/256</td>
<td>Nm</td>
</tr>
<tr>
<td>Mode-A slant position (azimuth)</td>
<td>5</td>
<td>360/2^16</td>
<td>Degrees</td>
</tr>
<tr>
<td>Position from ADS-B</td>
<td>6</td>
<td>~5</td>
<td>M</td>
</tr>
<tr>
<td>MCP/FCU selected altitude; roll angle;</td>
<td>6</td>
<td>16</td>
<td>Feet</td>
</tr>
<tr>
<td>true track angle; ground speed; magnetic heading;</td>
<td>6</td>
<td>2</td>
<td>Knots</td>
</tr>
<tr>
<td>indicated airspeed (IAS)</td>
<td>6</td>
<td>1</td>
<td>Knots</td>
</tr>
<tr>
<td>Mach number (iso. IAS);</td>
<td>6</td>
<td>2.048/512</td>
<td>[-]</td>
</tr>
<tr>
<td>vertical rate (barometric or baro-inertial);</td>
<td>6</td>
<td>32</td>
<td>Feet per minute</td>
</tr>
<tr>
<td>barometric pressure setting (minus 800 hPa);</td>
<td>6</td>
<td>0.1</td>
<td>Millibar</td>
</tr>
<tr>
<td>track angle rate (TAR)</td>
<td>6</td>
<td>8/256</td>
<td>Degrees per second</td>
</tr>
<tr>
<td>true airspeed (iso. TAR)</td>
<td>6</td>
<td>2</td>
<td>Knots</td>
</tr>
</tbody>
</table>
UK Network – current state.

• 5 receivers across the UK.
• 4 are located at Weather Radar sites. With one at the HQ.
• Tuned antenna with amplifier using a Mode-S beast decoder.
Aircraft Based Observing with Mode-S Enhanced Surveillance (EHS)

- Huge potential to supplement E-AMDAR data at some airport locations.
- Met Office and KNMI conducting studies into the data.
- Recently formed Expert Team Aircraft Derived Data (ET-ADD)–Reported in Oct’15.
Quality of derived meteorological parameters from Mode-S EHS after quality control and corrections

<table>
<thead>
<tr>
<th>Meteorological parameter</th>
<th>Presence</th>
<th>Observed</th>
<th>Quality</th>
<th>Accuracy wrt. NWP model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind speed</td>
<td>Derived</td>
<td>All aircraft</td>
<td>Good</td>
<td>2-2.5 m/s</td>
</tr>
<tr>
<td>Wind direction</td>
<td>Derived</td>
<td>All aircraft</td>
<td>Good</td>
<td>10-15 degrees</td>
</tr>
<tr>
<td>Temperature</td>
<td>Derived</td>
<td>All aircraft</td>
<td>Moderate</td>
<td>2K</td>
</tr>
</tbody>
</table>

![Wind Vector Calculation](image-url)
Observations per day
Observations per hour

Average Number of Observations Per Hour

![Chart showing the average number of observations per hour. The chart has bars representing different time intervals, with the highest observations occurring in the 6-7 hour interval.]
Observations overnight

~61000 observations!
Near future sources of Mode-S EHS/MRAR
Coverage of Mode-S ELS or EHS radars in Europe using a default radius of 200km. As Mode-S ELS and EHS use the same ground infrastructure, this graph shows the enormous future potential for EHS interrogation by ATC. However, updating from ELS to EHS is not trivial for air traffic organizations and results, amongst others, in a significant increase of data load on ATC networks.
Ideally Mode-S MRAR (register 4.4)!

- Mode-S Meteorological Routine Air Report (MRAR) data are transmitted through active interrogation of register BDS 4.4 by a Mode-S radar.
- The frequency of interrogation?

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<td>Position from ADS-B</td>
<td>~5</td>
<td>m</td>
</tr>
<tr>
<td>Wind speed</td>
<td>1</td>
<td>Knot</td>
</tr>
<tr>
<td>Wind direction</td>
<td>180/256</td>
<td>Degrees</td>
</tr>
<tr>
<td>Static air temperature</td>
<td>0.25</td>
<td>°C</td>
</tr>
<tr>
<td>Average static pressure</td>
<td>1</td>
<td>hPa</td>
</tr>
<tr>
<td>Turbulence</td>
<td>4 levels</td>
<td>nil/light/moderate/severe</td>
</tr>
<tr>
<td>Humidity</td>
<td>100/64</td>
<td>%</td>
</tr>
</tbody>
</table>

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<thead>
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<th>Quality</th>
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</thead>
<tbody>
<tr>
<td>Wind speed</td>
<td>Yes</td>
<td>10% aircraft</td>
<td>Good</td>
<td>2-2.5 m/s</td>
</tr>
<tr>
<td>Wind direction</td>
<td>Yes</td>
<td>10% aircraft</td>
<td>Good</td>
<td>10-15 degrees</td>
</tr>
<tr>
<td>Temperature</td>
<td>Yes</td>
<td>10% aircraft</td>
<td>Good</td>
<td>1K</td>
</tr>
</tbody>
</table>
E-AMDAR management

- AMDAR data is entirely third-party derived - we have no control over where the aircraft fly, what sensors they equip, how they are calibrated etc.

- Data flow can be interrupted:
  - Industrial action
  - Airline financial restrictions/removal of operations
  - Airport closures/night curfews
  - Disruptions to flights – weather, volcanic incidents…
  - Changes in airline schedules/destinations and fleets rotation.

- In addition, specific problems of not owning the sensors:
  - Response times to action sensor issues
  - Airlines removing/changing software etc

This all requires a good working relationship with participating airlines – which we have!
E-AMDAAR
Any Questions?
Contact Details

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GIE/EIG EUMETNET

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