EUMETNET
The Network of European Meteorological Services

E-AMDAR (Aircraft Meteorological DAta Relay)

AEMET, Madrid,

27 de Mayo de 2016

Steve Stringer, E-AMDAR Programme Manager

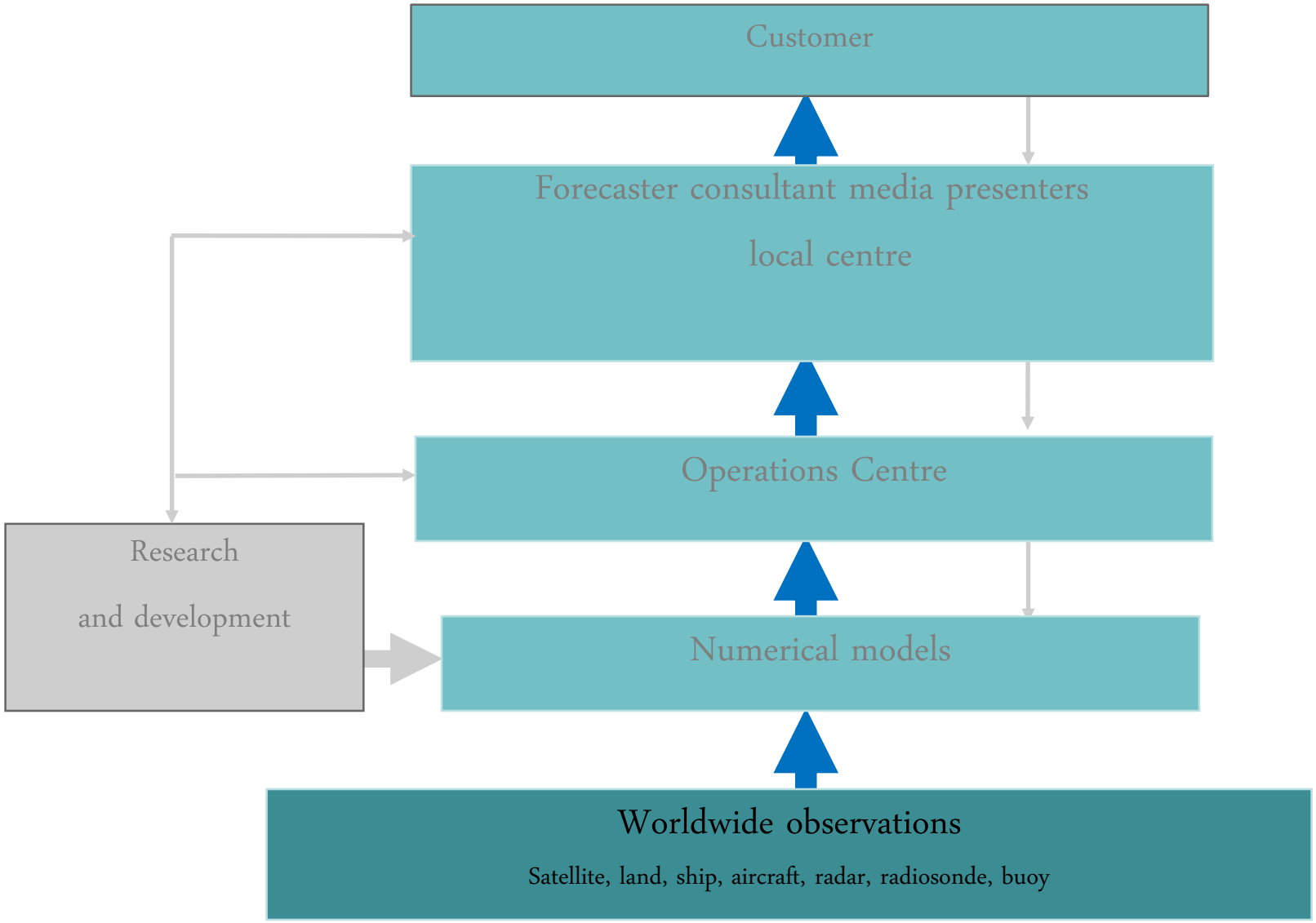
Content of Presentation

- 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

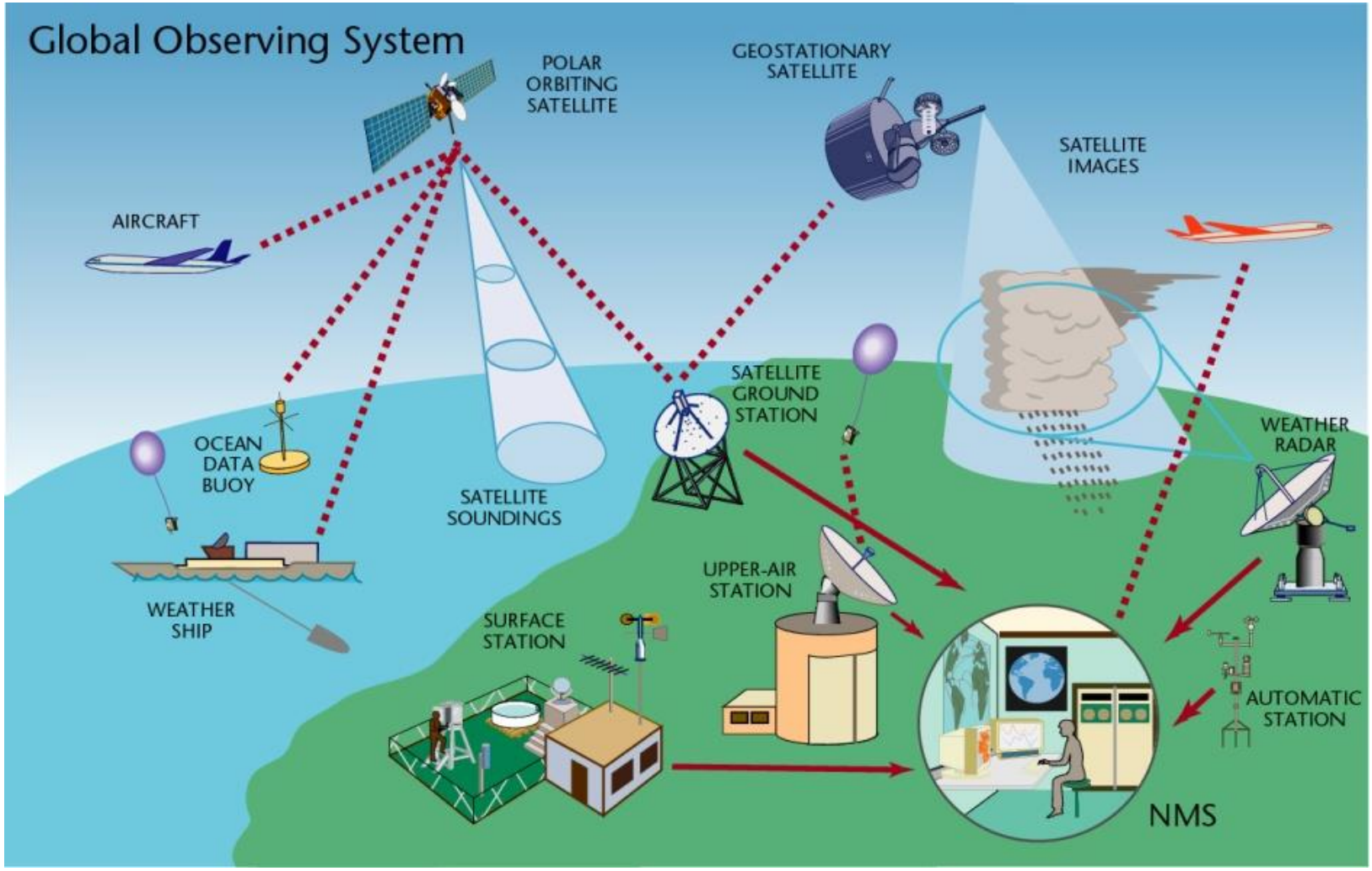
Why do we need aircraft data?

What are benefits to meteorology and to the aviation Industry?

Forecasting the weather

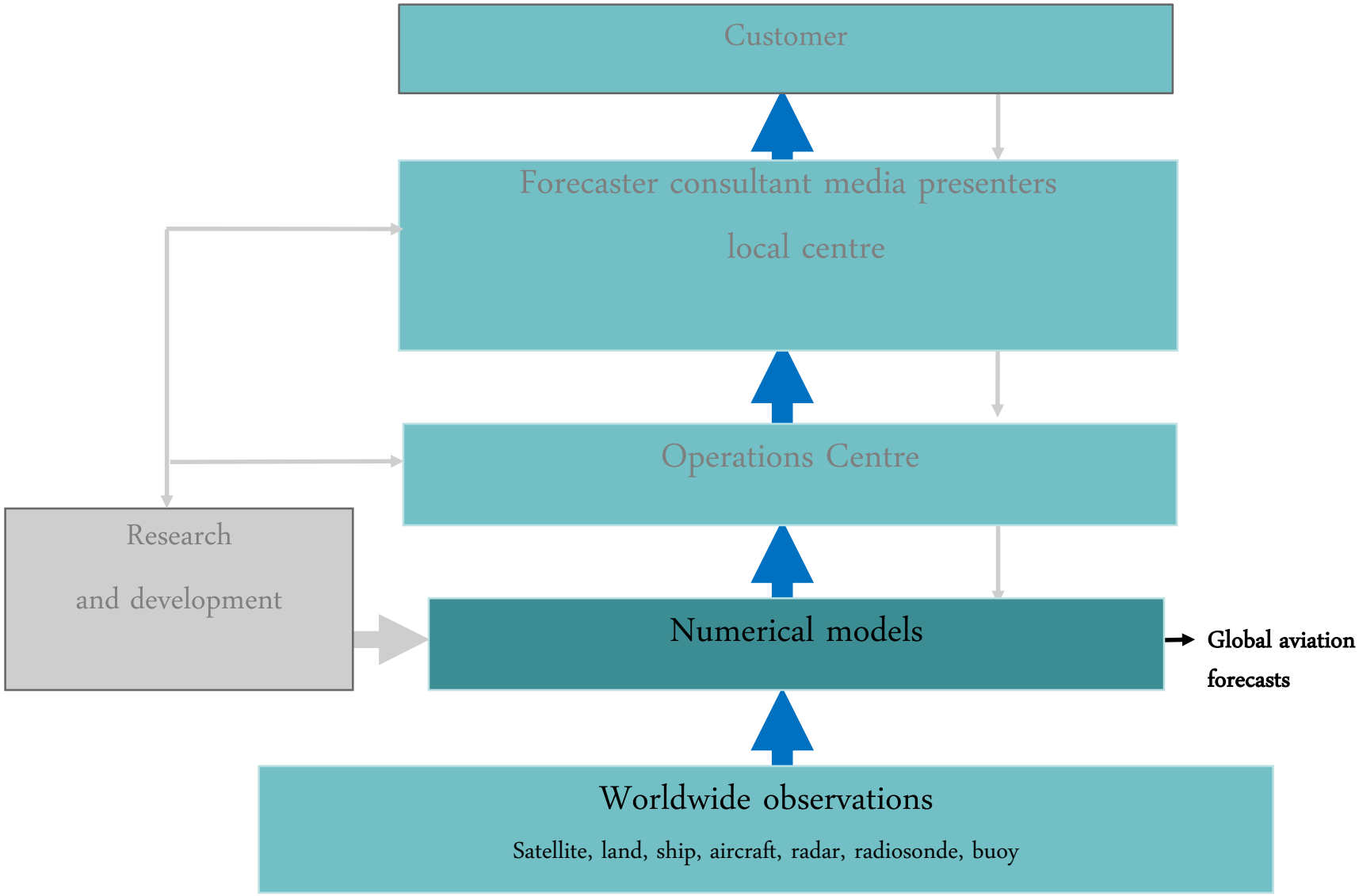


WMO Global Observing System



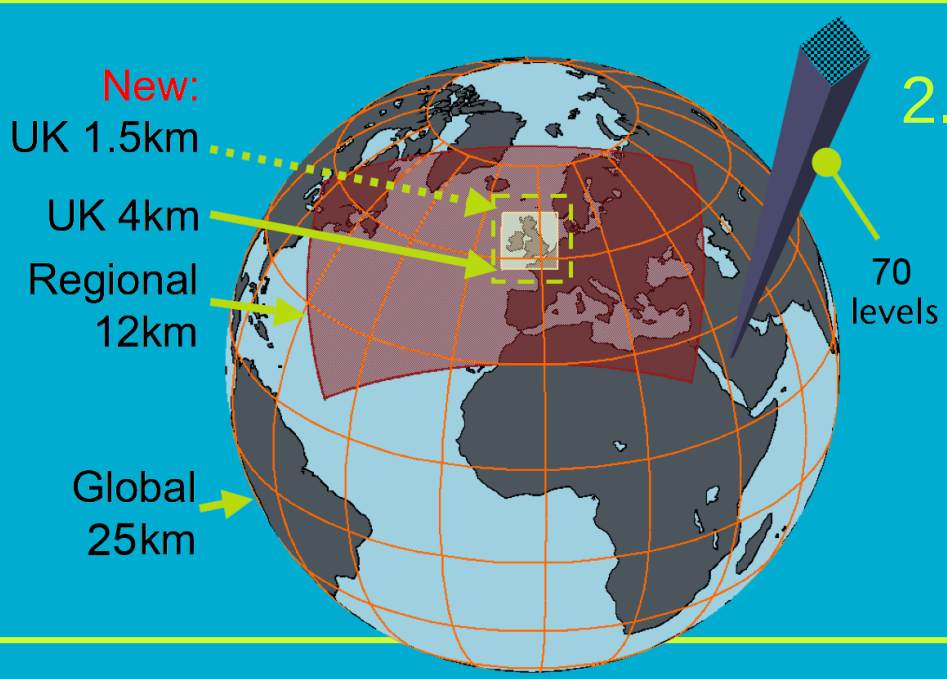
WMO – World Meteorological Organization (http://www.wmo.int)

Forecasting the weather



Forecasts

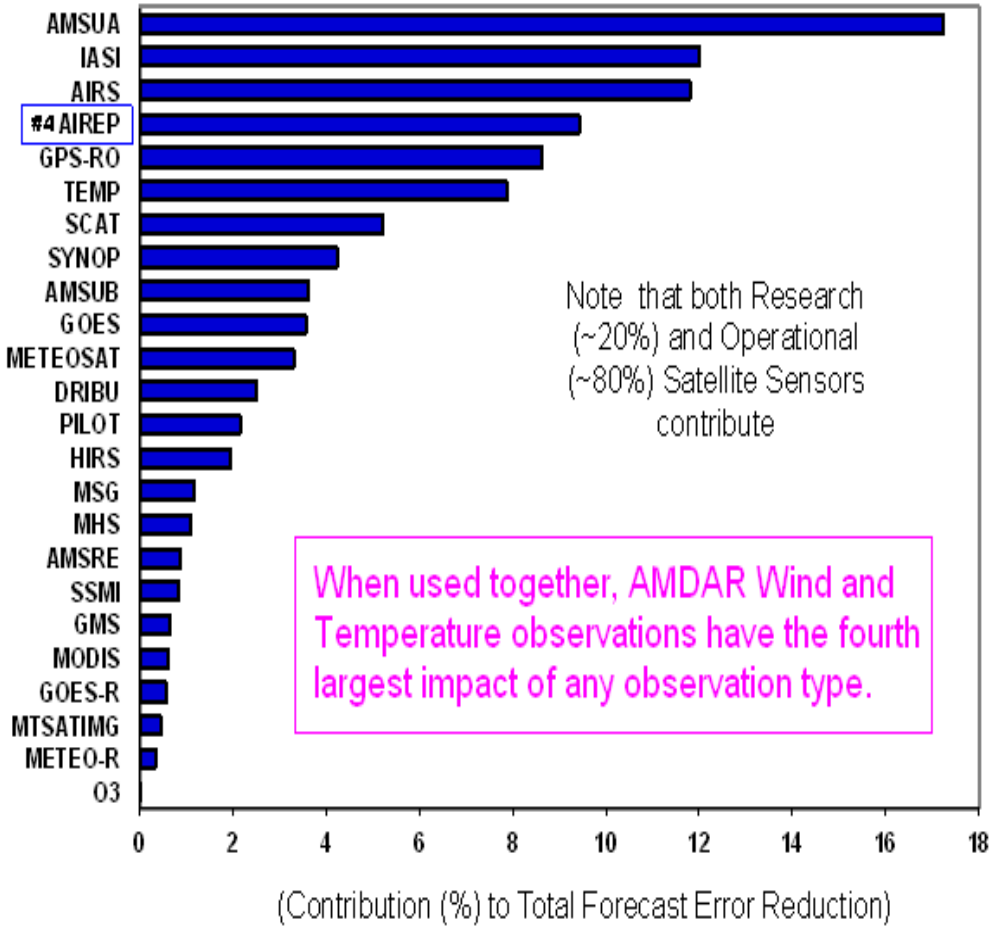
The process



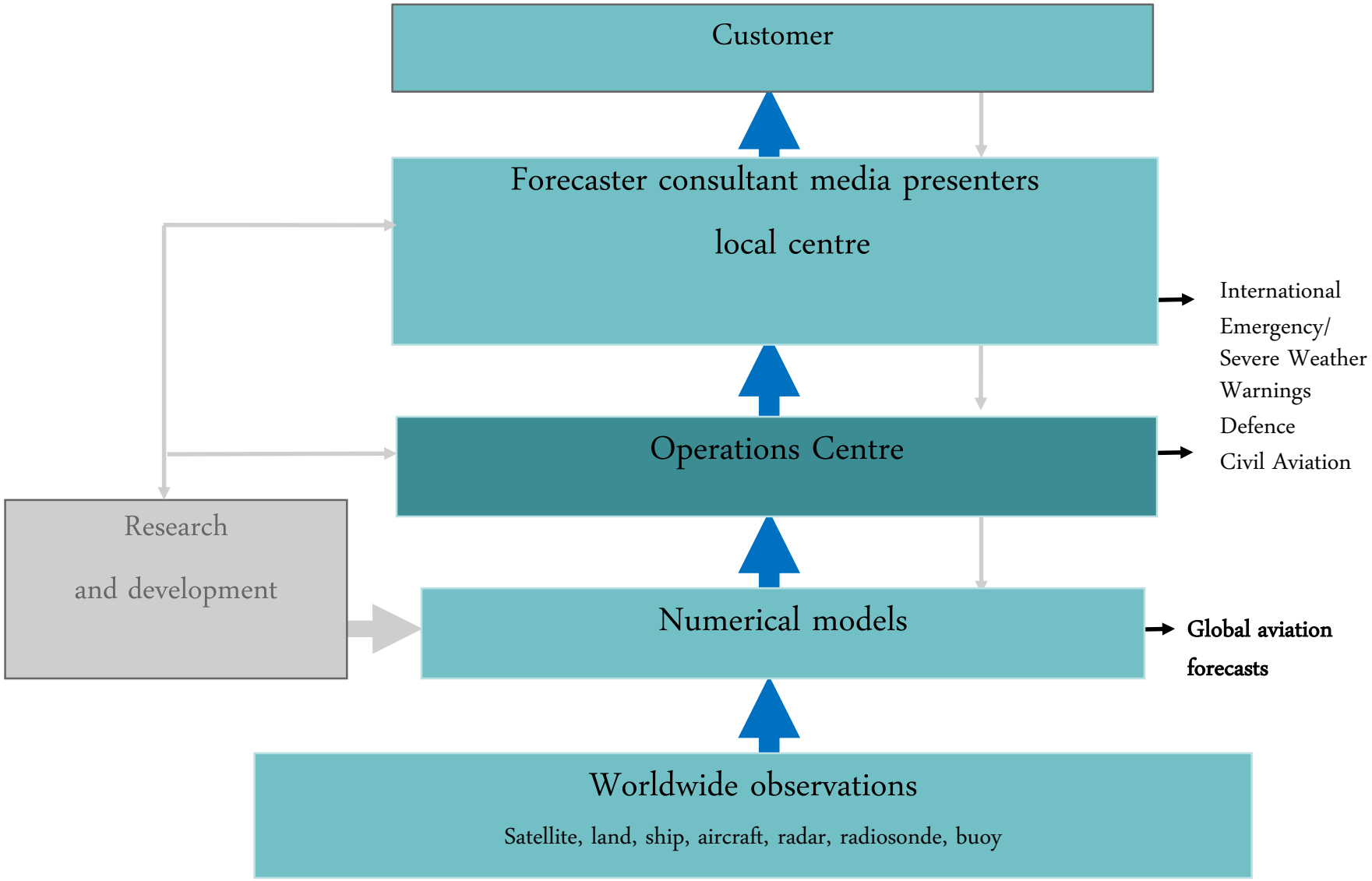
2. We use numerical computer models and supercomputers to forecast weather

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.

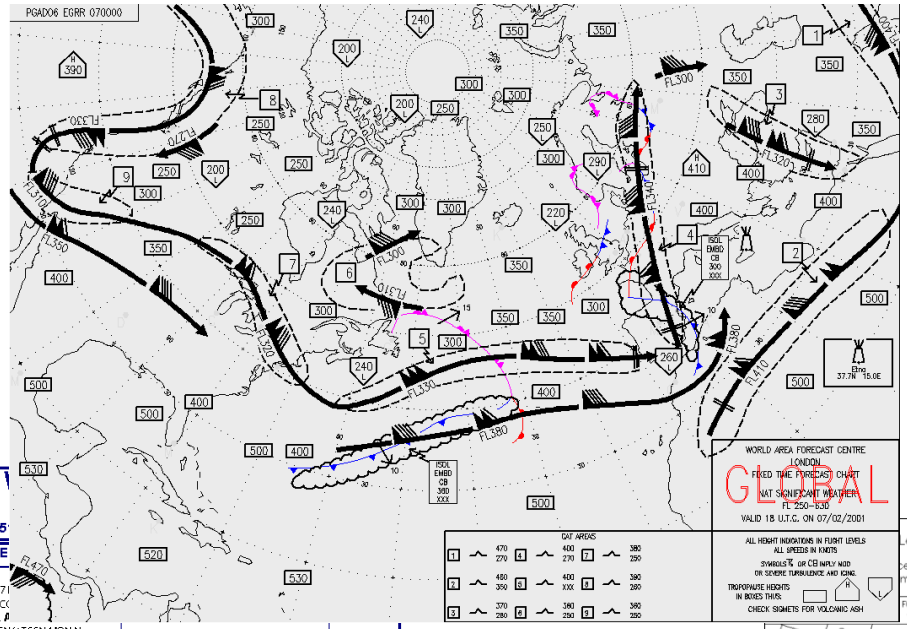


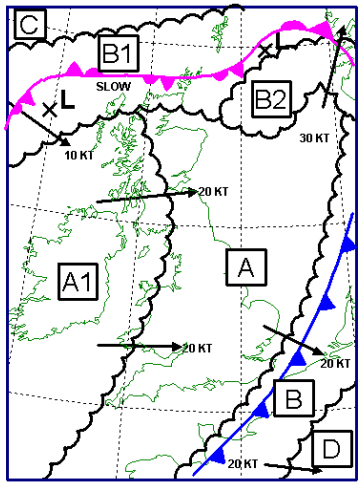
Forecasting the weather



Forecasting the weather

Ops Centre



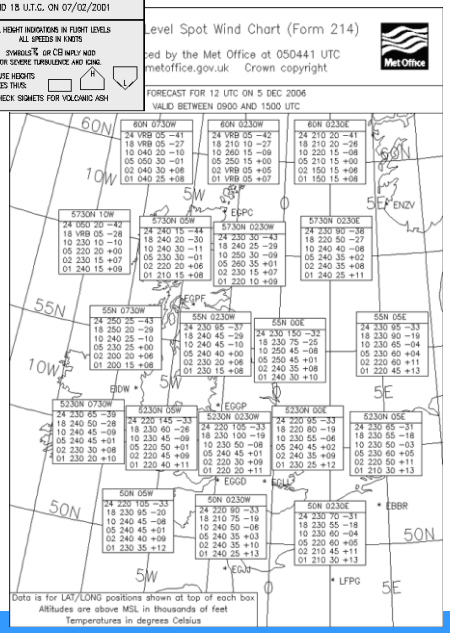


Forecast

Valid 050800 to 05

AREA	SURFACE		
A	30 KM NIL ISOL (OCNL **A1**) 7 ISOL (OCNL SEA C ... +SHRA/+TSRA LOC 500 M +SHSN/+TSSN MON N OCNL ⅄ (ISOL ⅄ SW) ISOL HILL FG		
B	15 KM NIL/-RA WDSPR 7 KM RA OCNL 3000 M RADZ ISOL 3000 M +RA FRONTS (+TSRA **B1**) ⅄ (OCNL ⅄ E OF COLD FRONT ... ... AND **B2**) OCNL HILL FG	BKN/OVC CU SC AC ψ ⅄ 015-020 / XXX ISOL EMBD CB 015 / XXX **B1** BKN/OVC ST 005-010 / 015	070-080
C	30 KM NIL ISOL 10 KM-SHRA ISOL ⅄ FARW	SCT/BKN CU AC ψ ⅄ 020-030 / 080-XXX	025 W 035 E
D	20 KM NIL ISOL 7 KM-RADZ ⅄ (ISOL ⅄) ISOL HILL FG	AREAS BKN AC ψ ⅄ 080 / XXX BKN SC ψ ⅄ 020-030 / 060-080 SCT/BKN ST 010-015 / 020	080

Outlook Until: 060000 Z
Occlusion moving back into NW Scotland. OCNL showers affecting most sea areas and windward coasts, (ISOL inland and Southern North Sea).



Benefits of Aircraft Data (to Meteorology and to the Aviation Industry)

Data Use

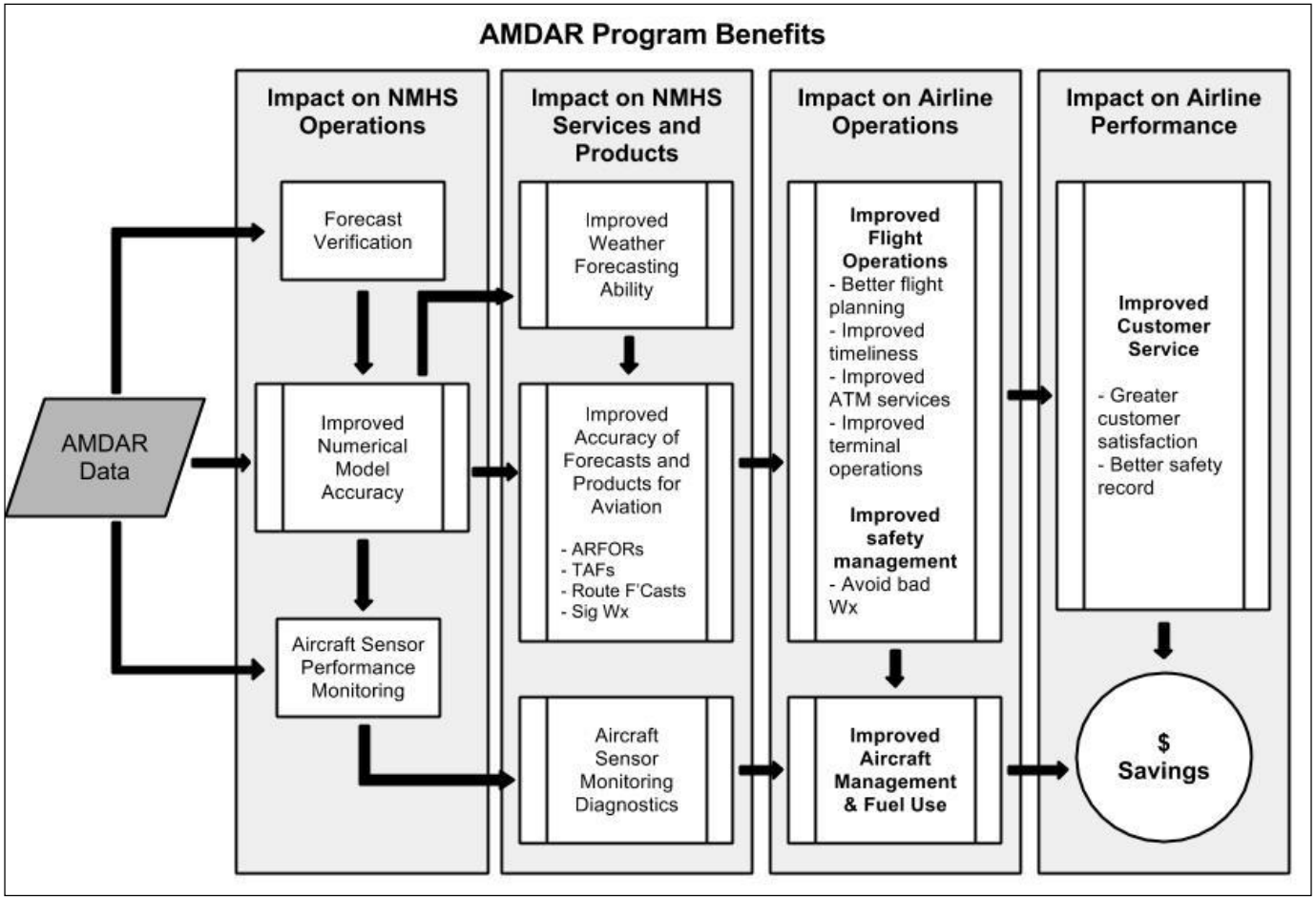
- Use in Numerical Weather Prediction Models
- Use in Forecast Applications
- Use in Climate Applications
- Use in Verification of Forecast Products

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

(http://www.wmo.int/pages/prog/www/GOS/ABO/AMDAR/publications/Benefit_of_AMDAR_Data_to_Meteorology_and_Aviation.pdf)



- **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:

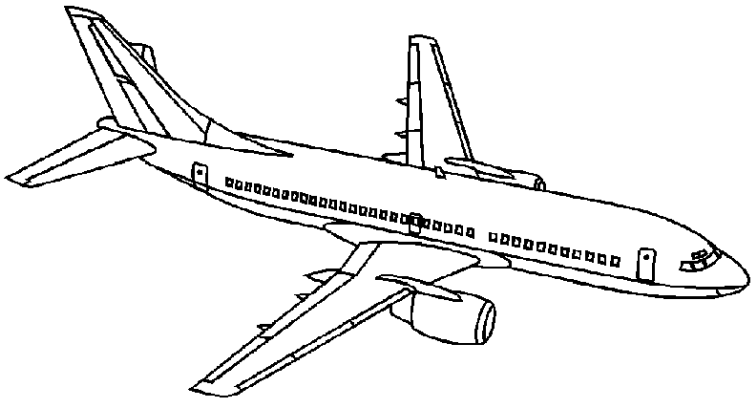
  Savings over a 1 year period, utilising actual Zero Fuel Weight and using prevailing weather conditions: ***Between 2 and 3 million dollars***.
- Cost of fuel saved through use of pre-flight and in-flight planning: **> $600,000**

What is AMDAR ?

AMDAR (**A**ircraft **M**eteorological **DA**ta **R**elay)

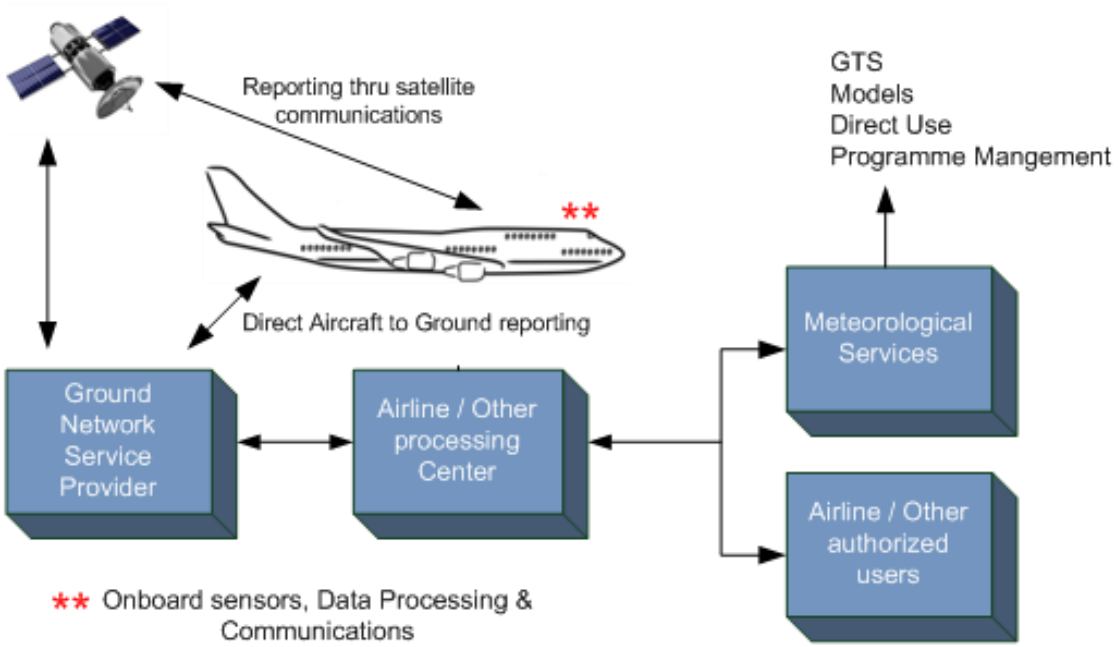
- Automated collection and transmission of various parameters using existing aircraft sensors and airline infrastructure:
  - Height (pressure derived)
  - Temperature
  - Wind speed
  - Wind direction

Additional parameters potential
  - Turbulence
  - Icing
  - Humidity



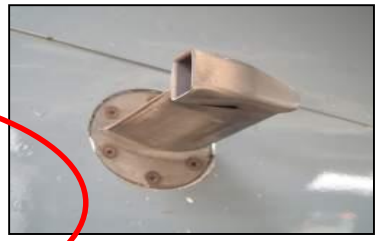
Aircraft Meteorological DAta Relay (AMDAR)

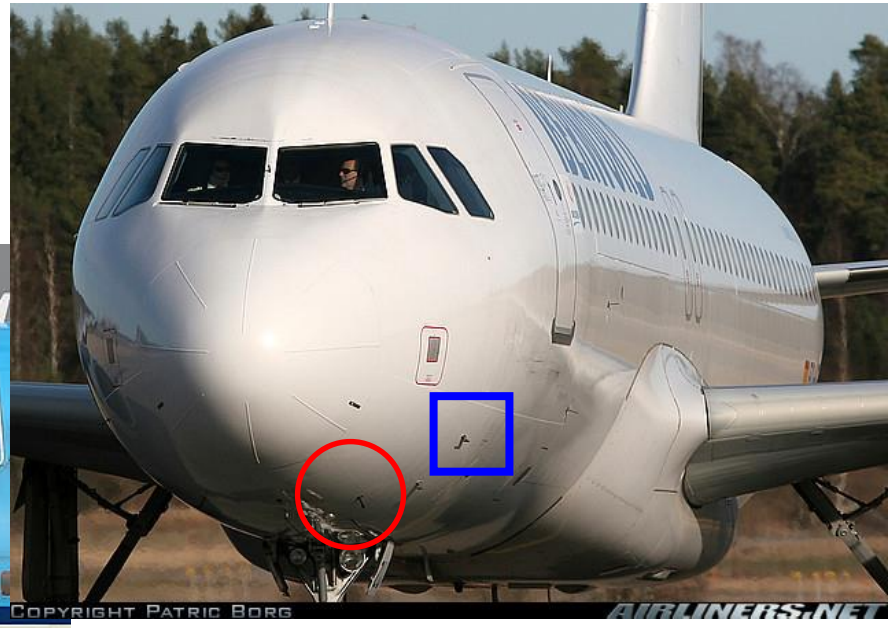
- AMDAR is a collaborative programme between Airlines and National Meteorological Services
- From aircraft systems, meteorological parameters are provided in real time via ACARS (**A**ircraft **C**ommunications **A**ddressing and **R**eporting **S**ystem):



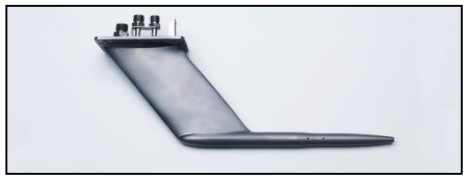
AMDAR observations

- TAT probes (temperature)



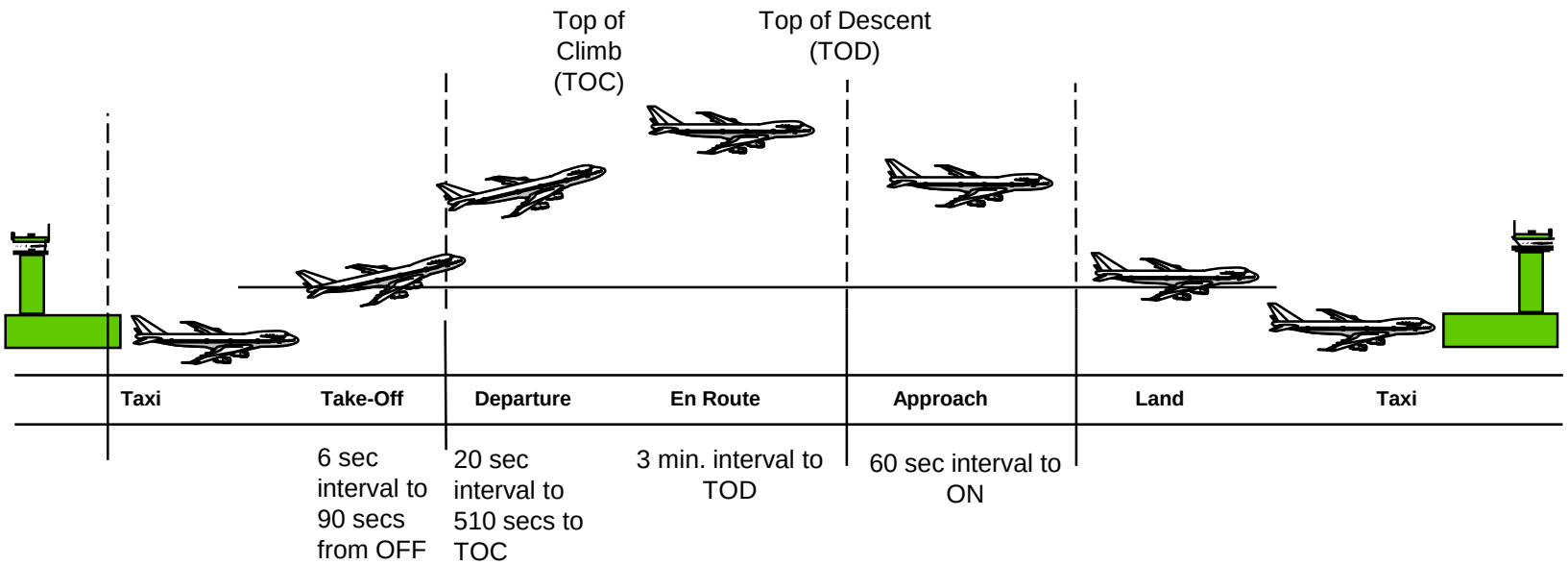


- Pitot-static tubes (pressure)



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



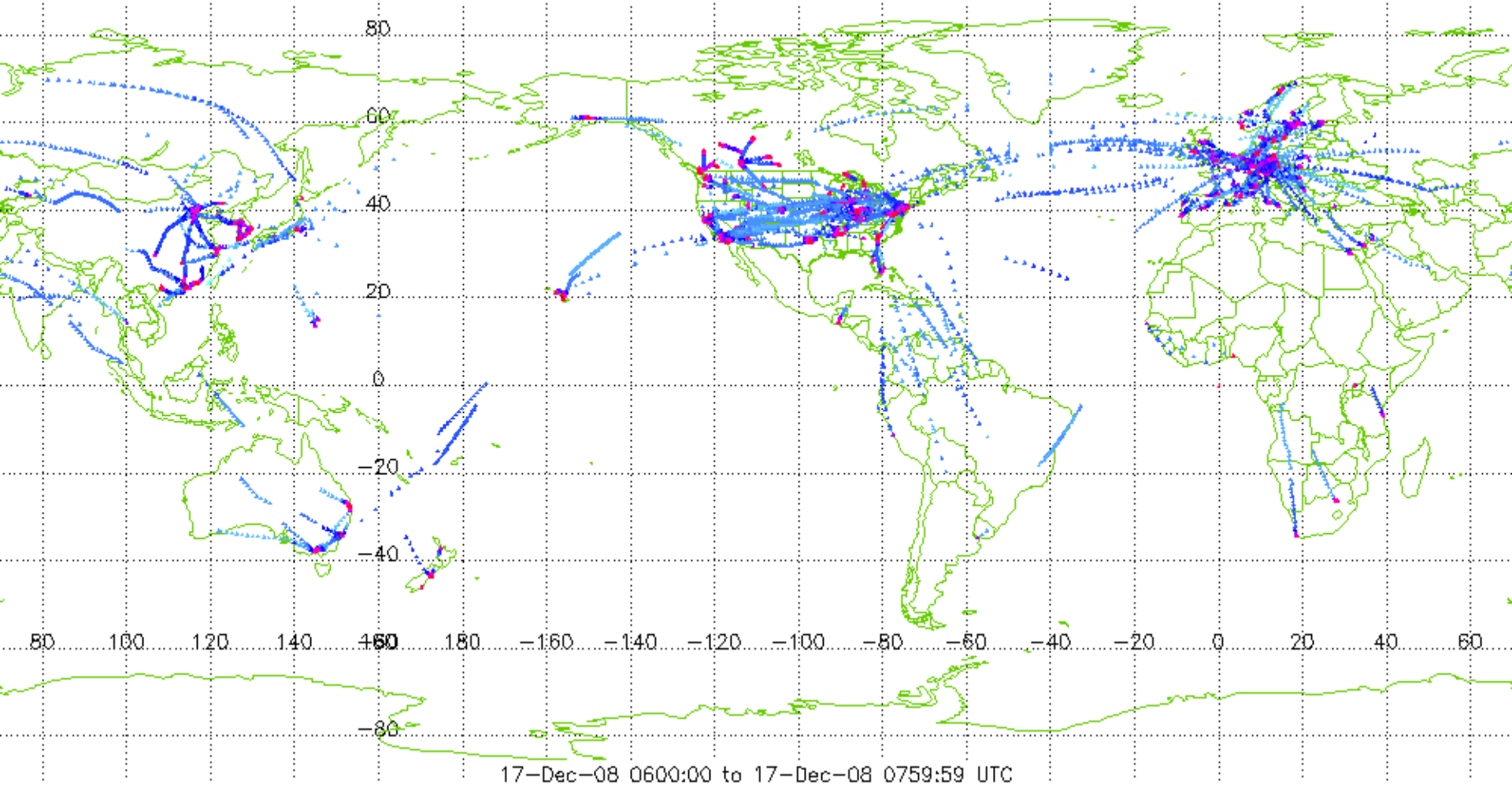
- AMDAR reporting can be triggered by time or pressure – dependant on software/avionics platforms installed on the airlines

- Reported observation resolution can be configured to meet specific requirements (i.e. cost saving or **C**ontinuous **D**escent **A**pproach)

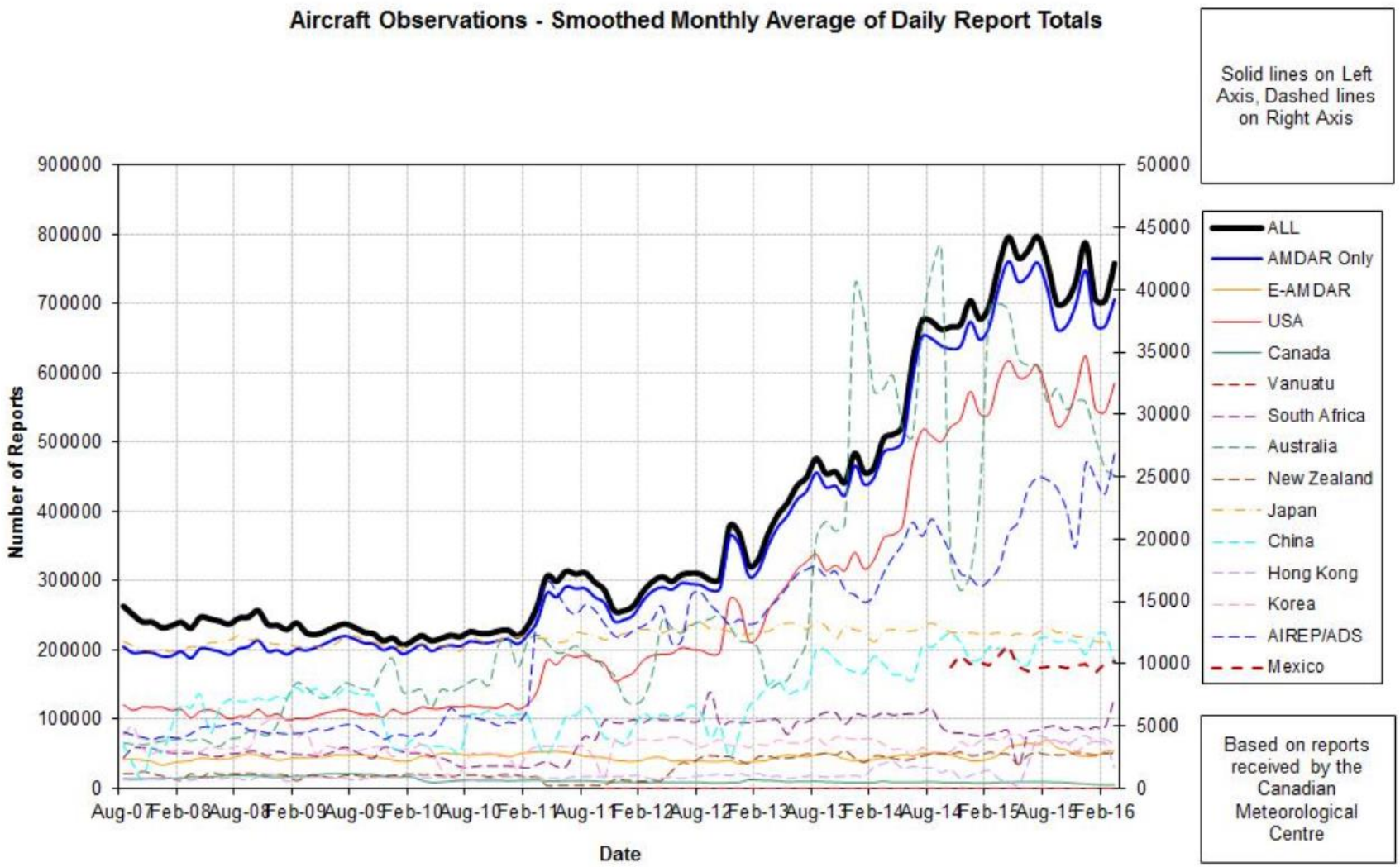
AMDAR Observations – Brief History:

- 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

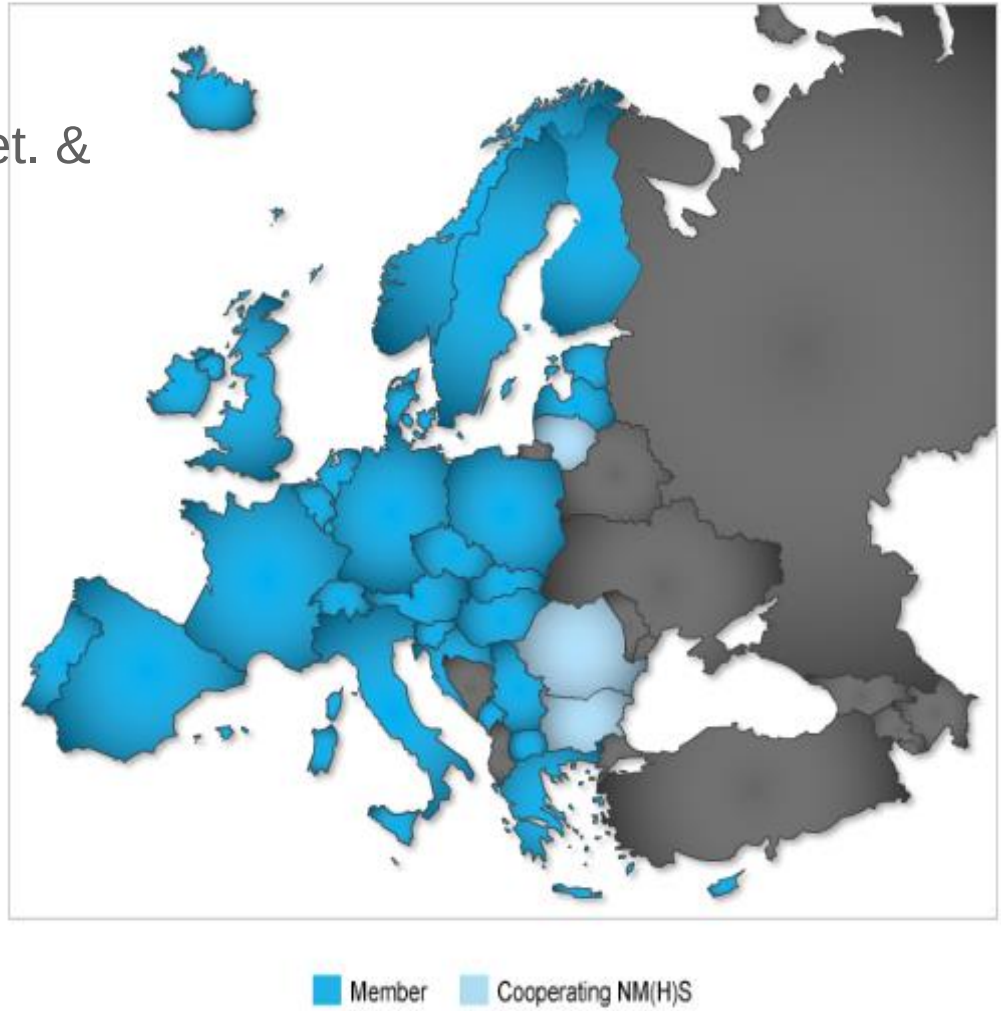


Participating Airlines - by Programme

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

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

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.

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

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

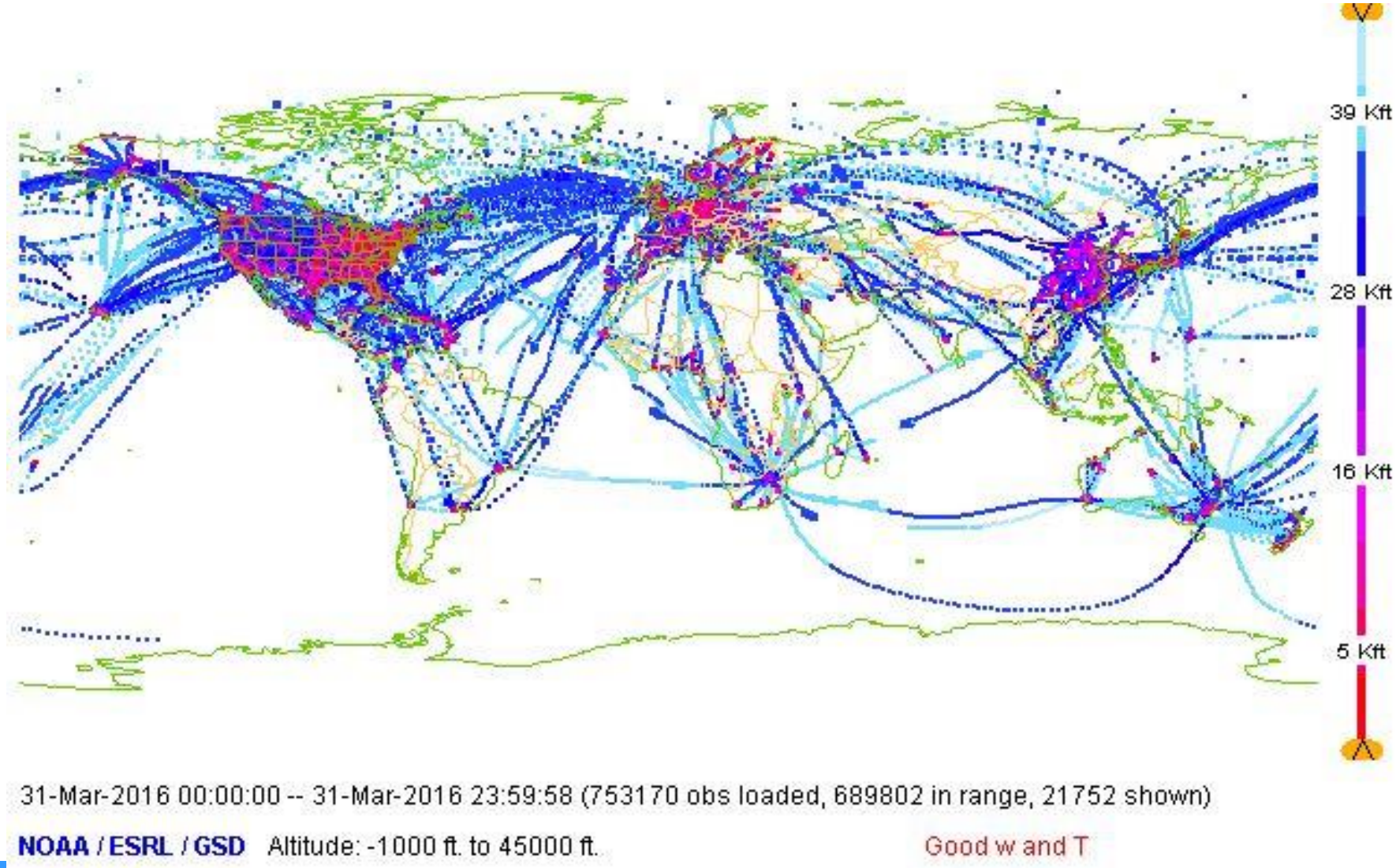
National & Short Range NWP requirements

Observations: Spatial resolution: <100km
Temporal resolution: 1 hour
Timeliness: T+15 mins
Temp rmse goal: 1.0K
Wind rmsvd goal: 3.5m/s

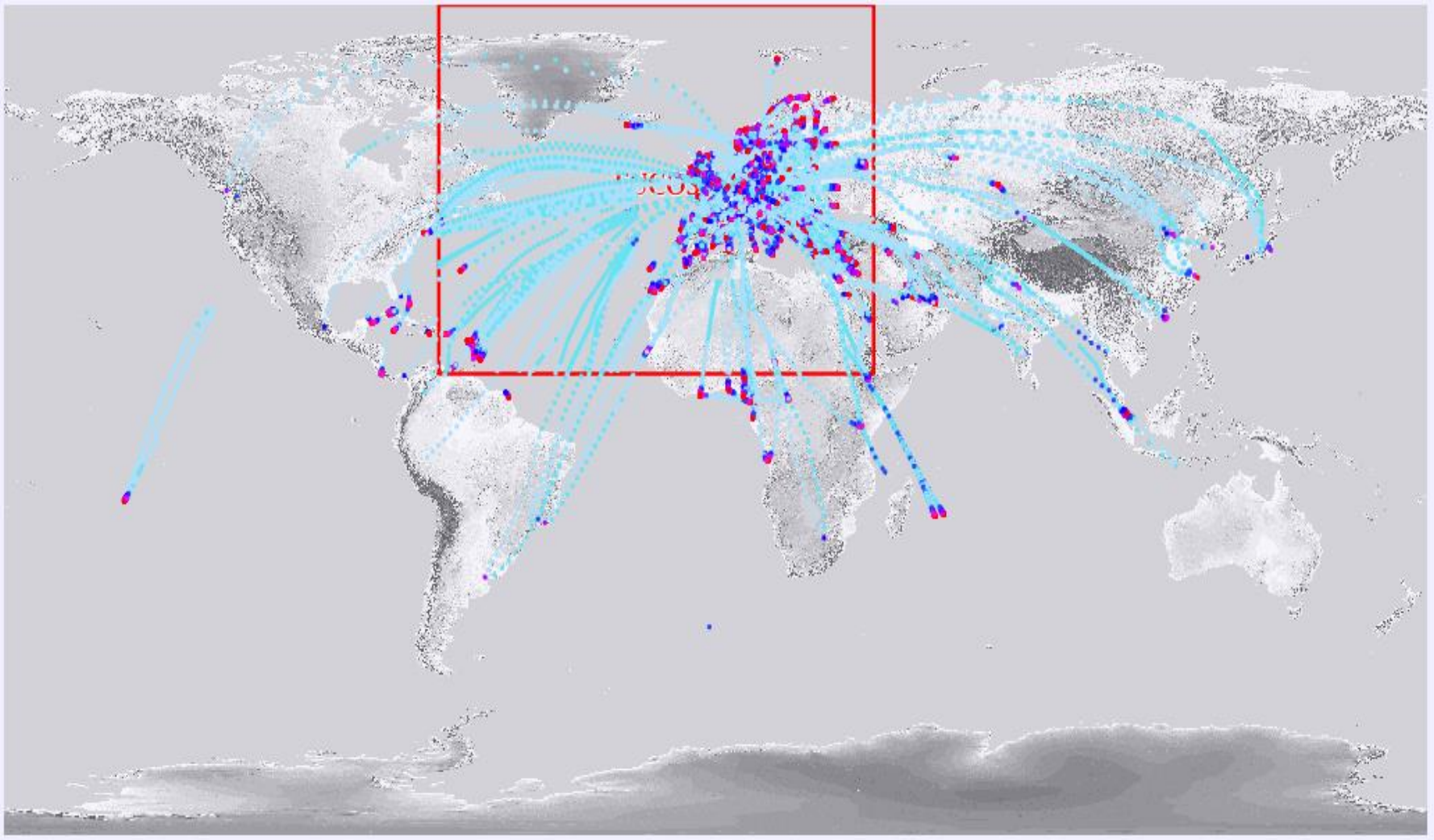
E-AMDAR Programme Objectives

- 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

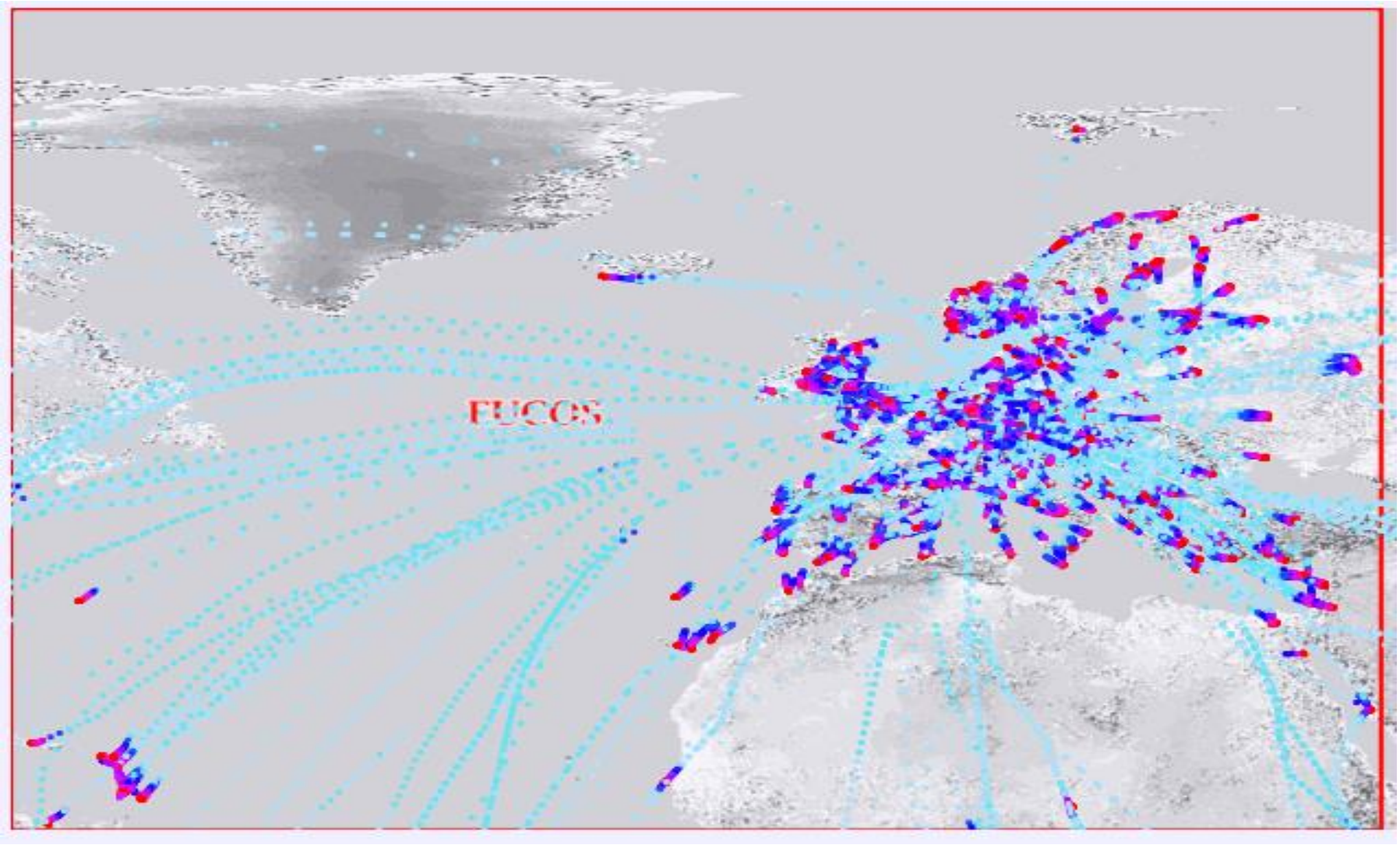
Global AMDAR observation coverage



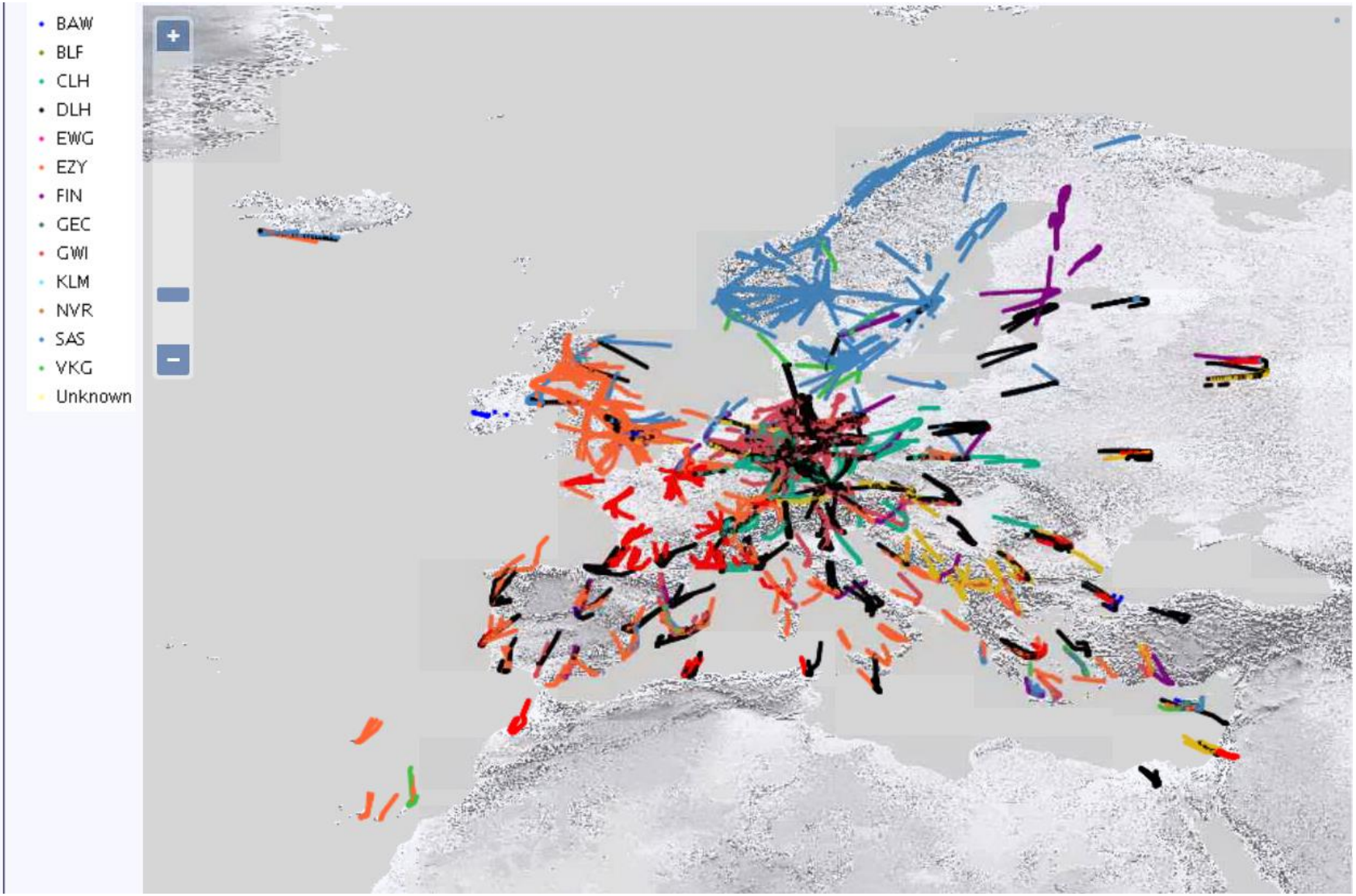
E-AMDAR Global observation coverage



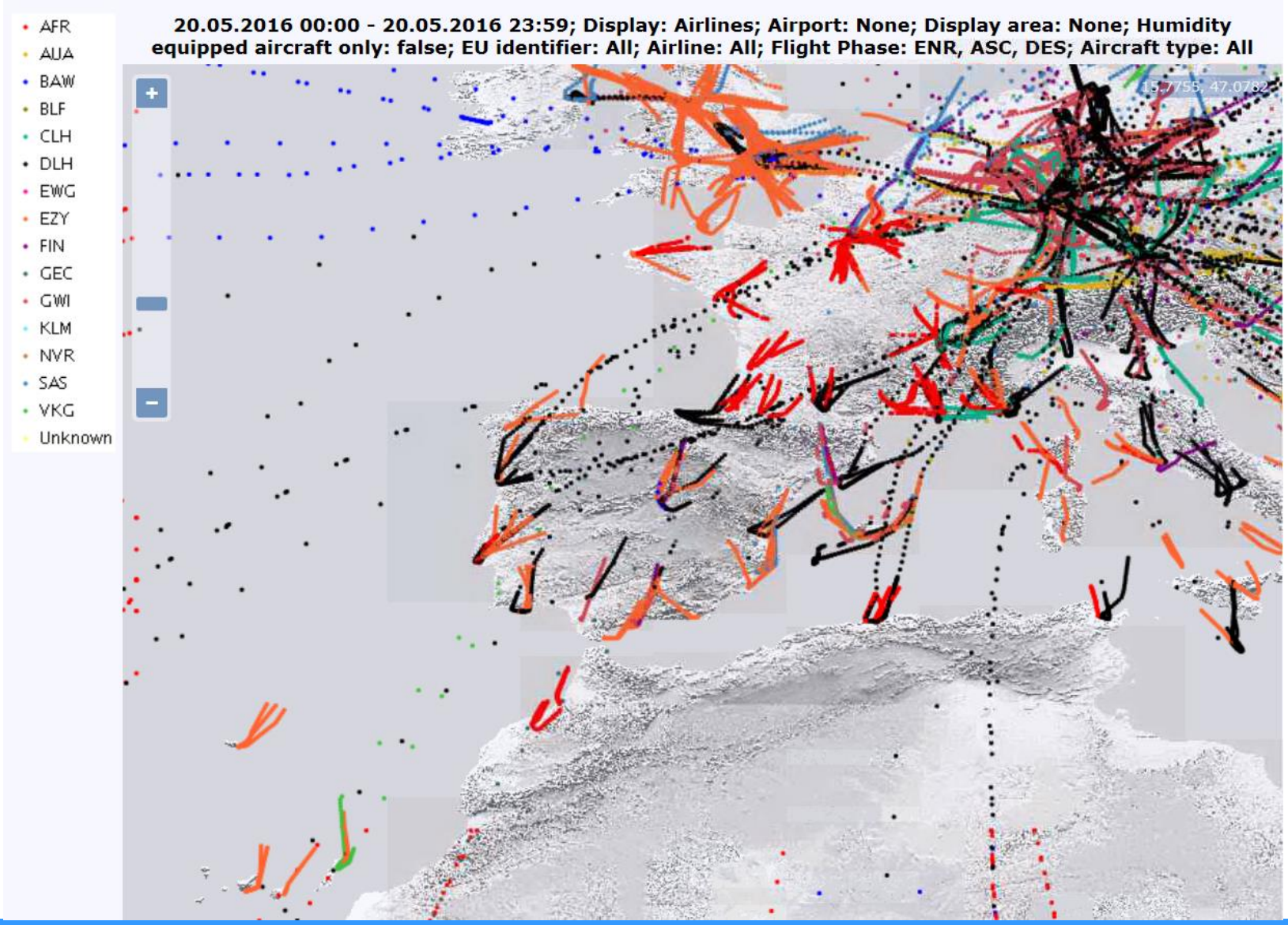
E-AMDAR EUCOS domain coverage



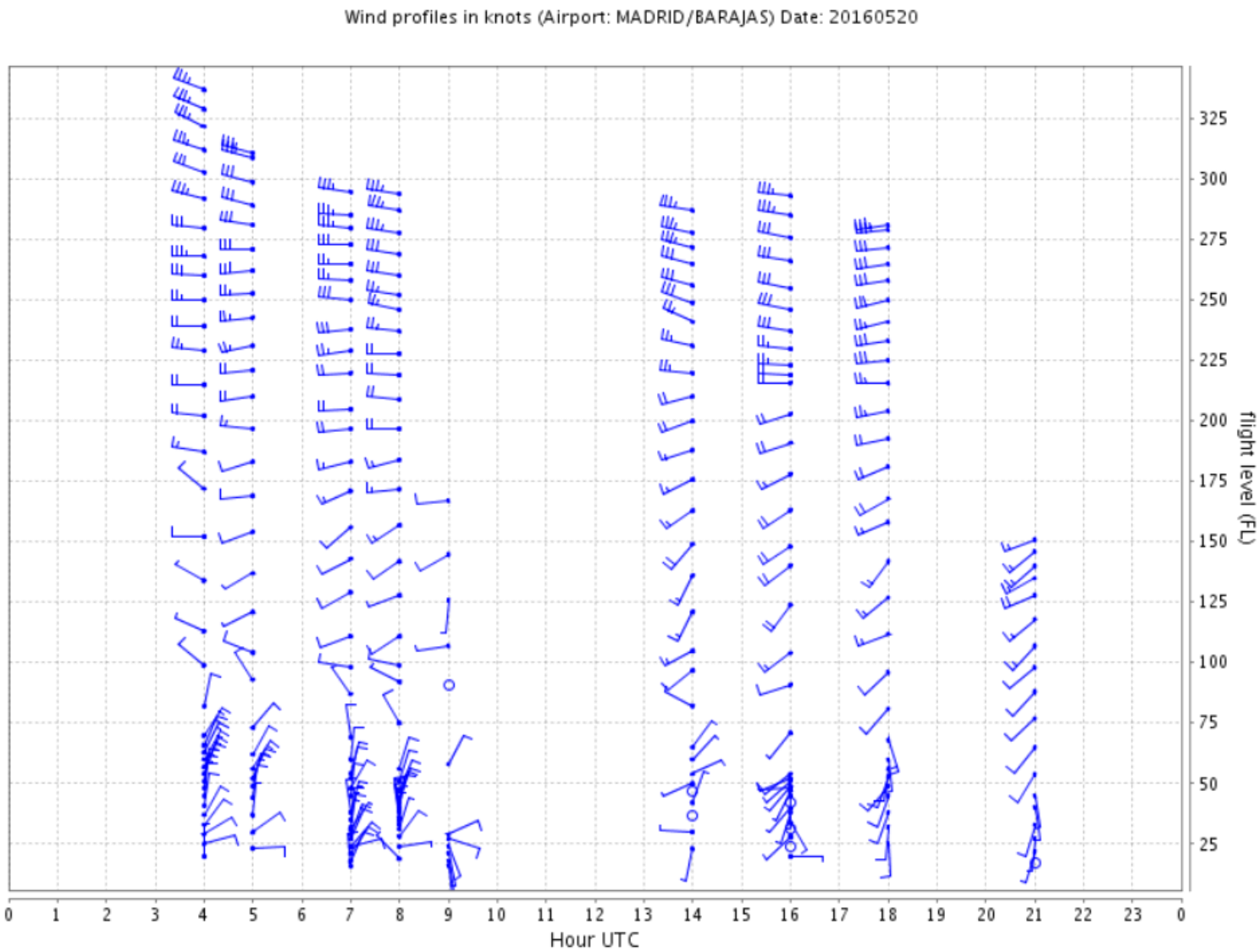
E-AMDAR airport coverage



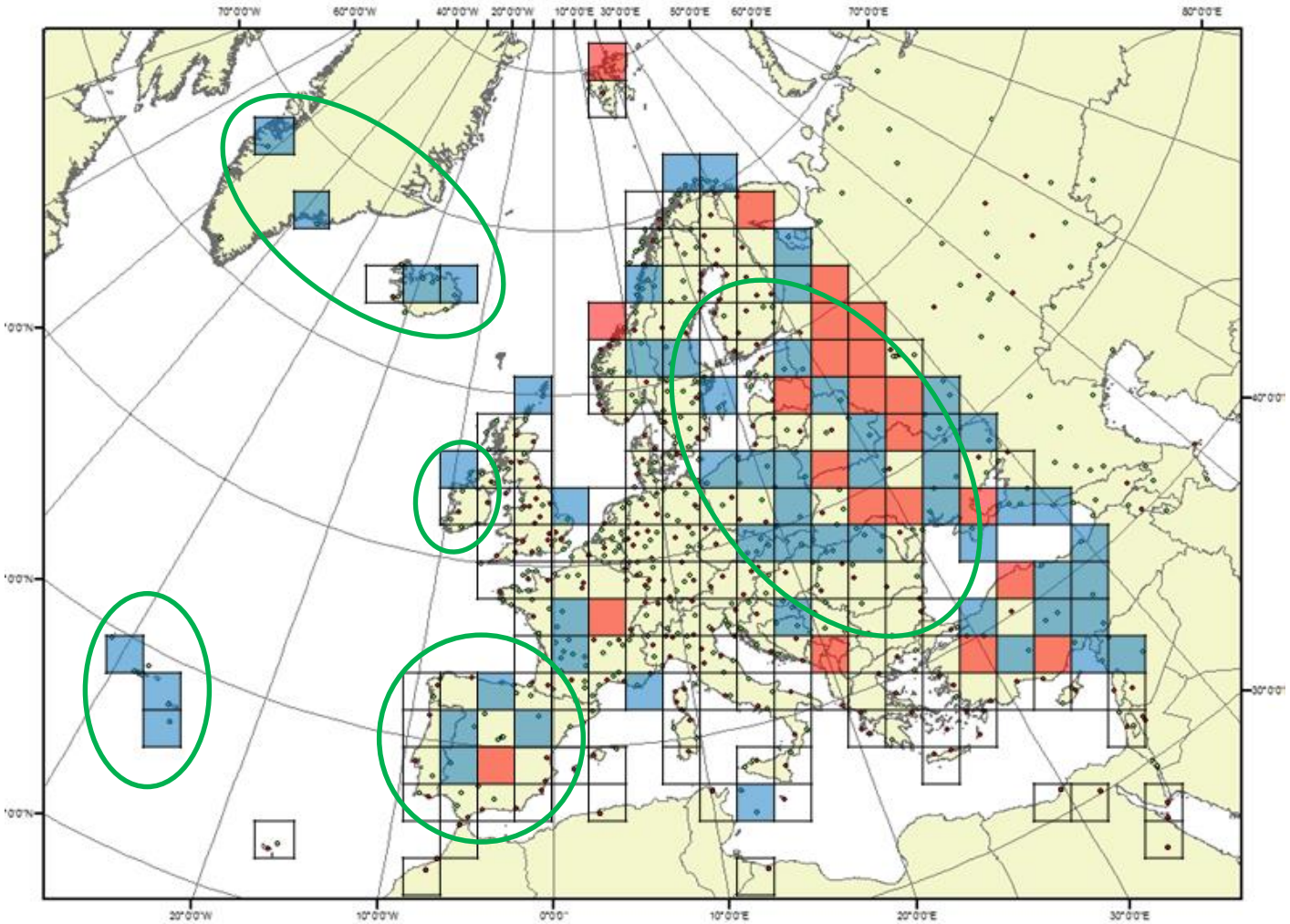
E-AMDAR Iberia Coverage



Wind profile Diagram (Airport: MADRID/BARAJAS



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.

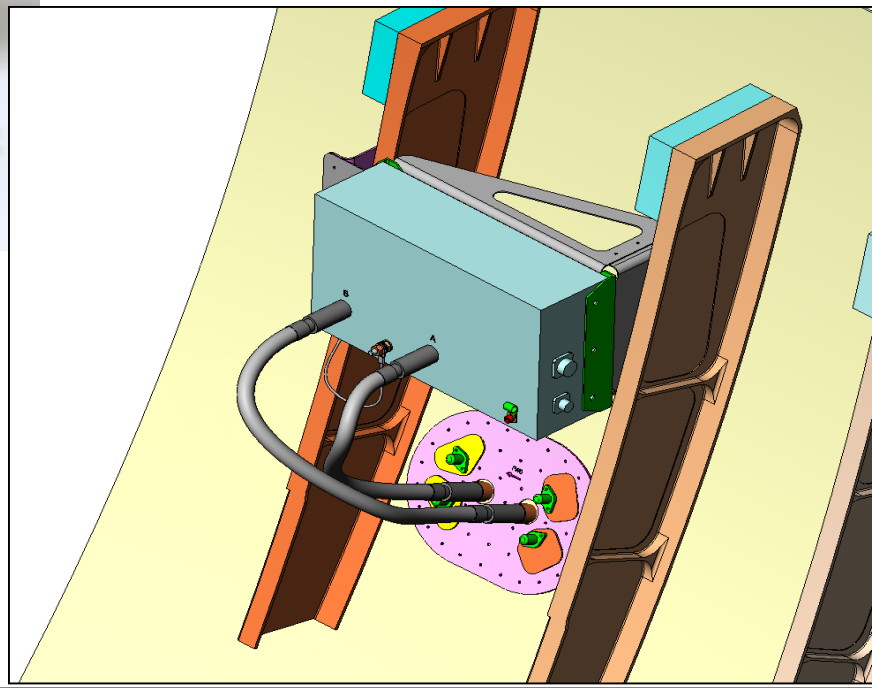
Priorities for expansion

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?

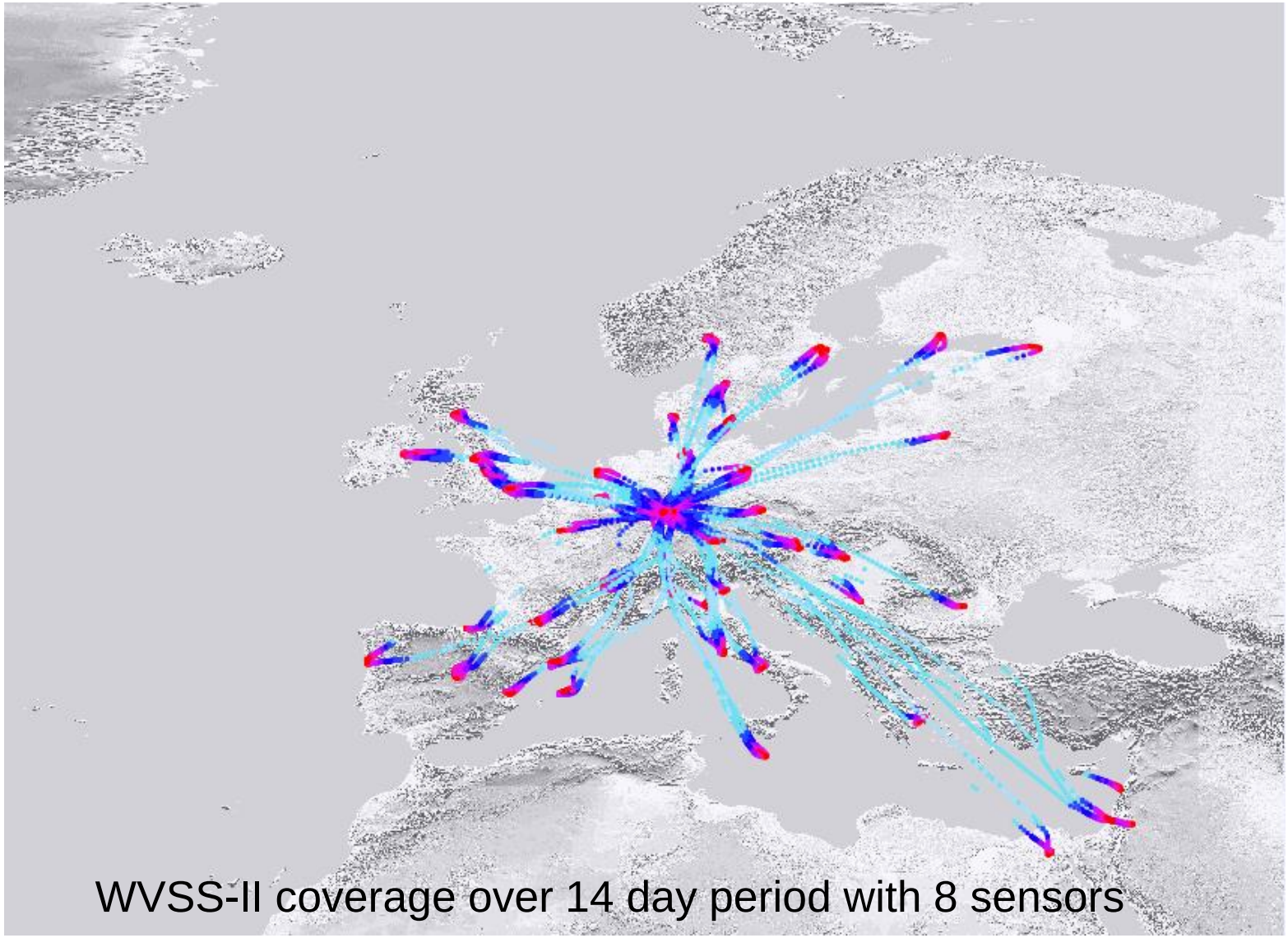
- Humidity – is one of the most significant parameters for weather evolution. Highly variable in time & space.
- Improvements to aviation meteorological products can be expected in the areas of:
  - Convection, precipitation and fog (forming/clearance) forecasts
  - Reliability of short and long term 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)



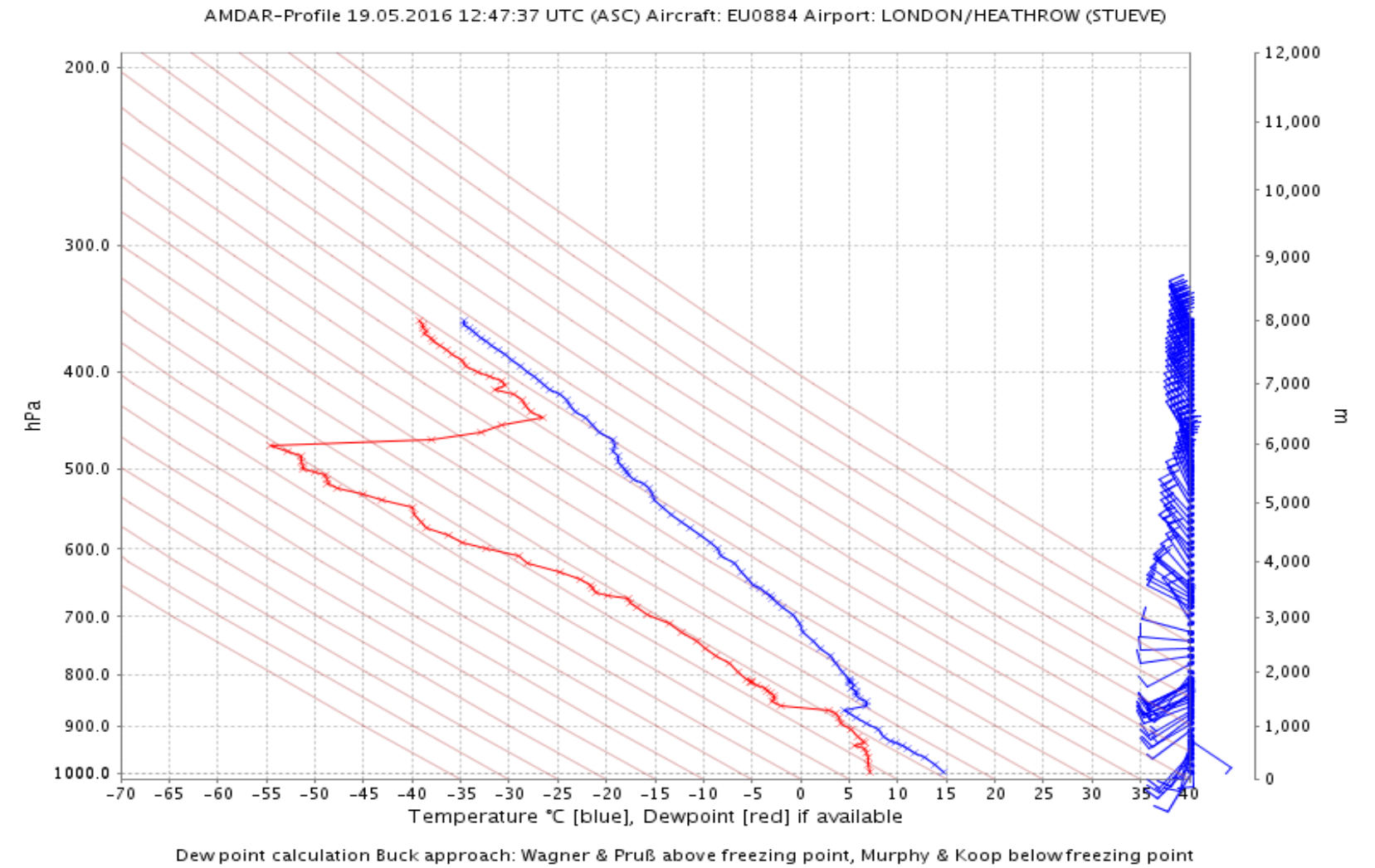
- **Near-Infrared Absorption Spectrometer based on Tunable Diode Laser**
- **Heated Inlet Hose**
- **Output: Water Vapor Mass Mixing Ratio**

AMDAR Humidity Current Coverage



WVSS-II coverage over 14 day period with 8 sensors

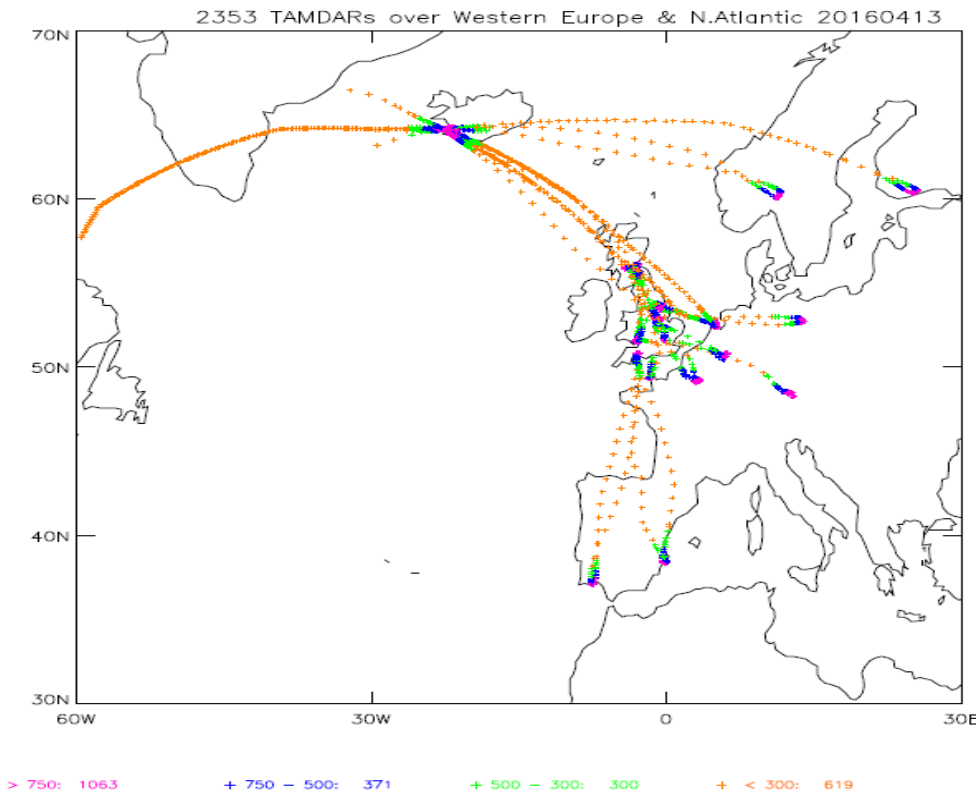
AMDAR Humidity: Atmospheric Profiles

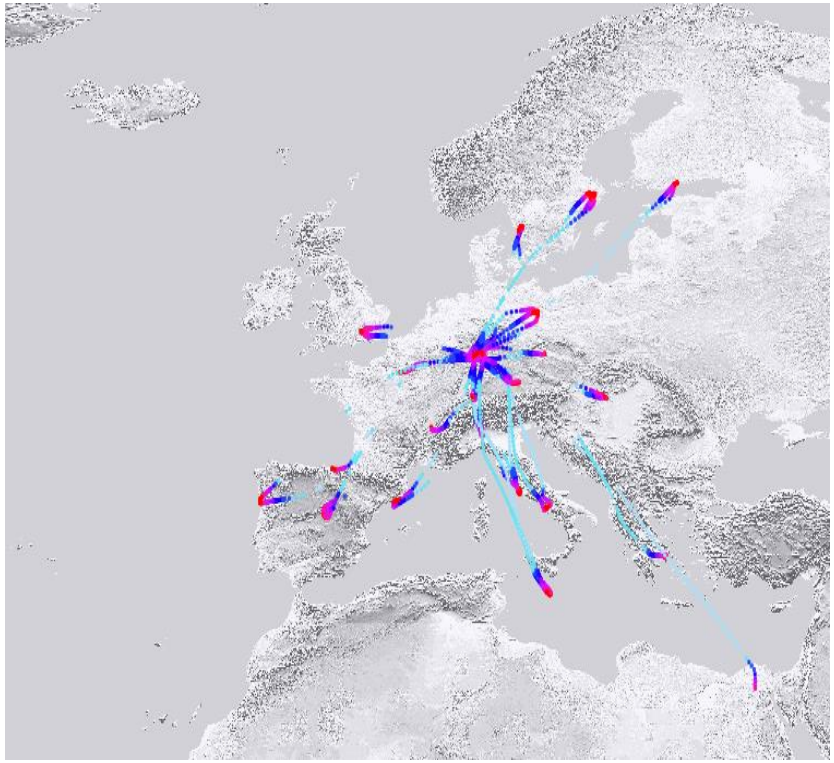


Humidity: TAMDAR

- 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

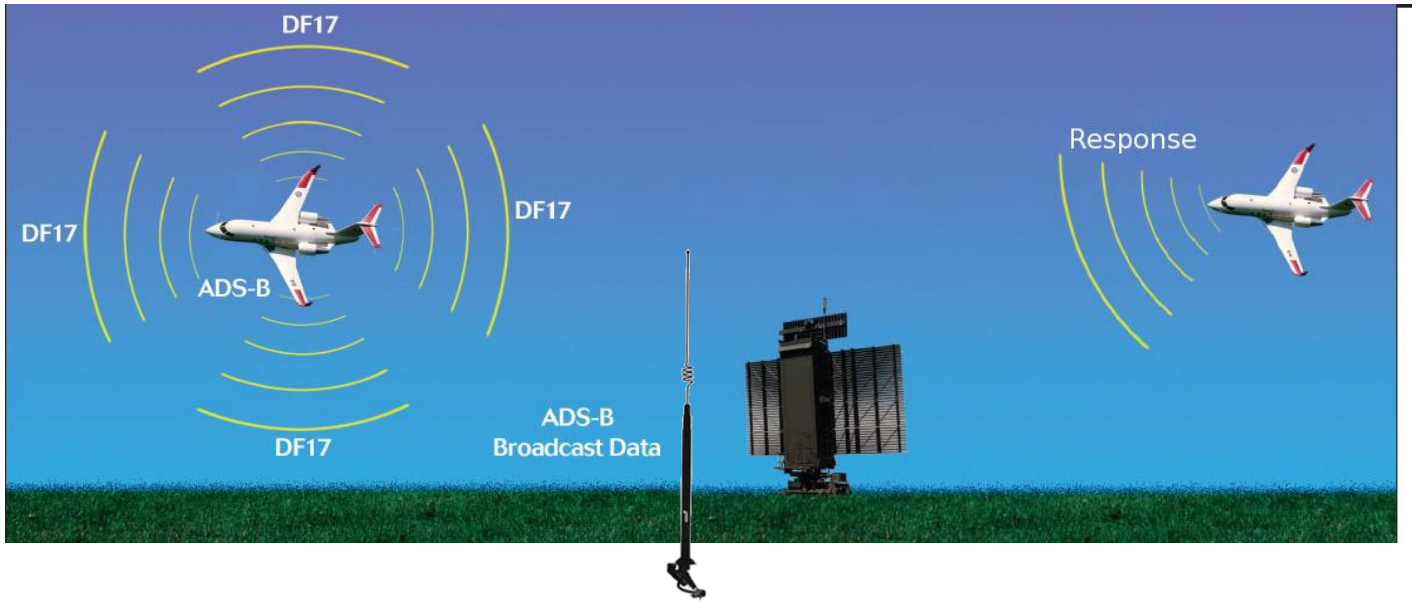
TAMDAR Coverage in Europe





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

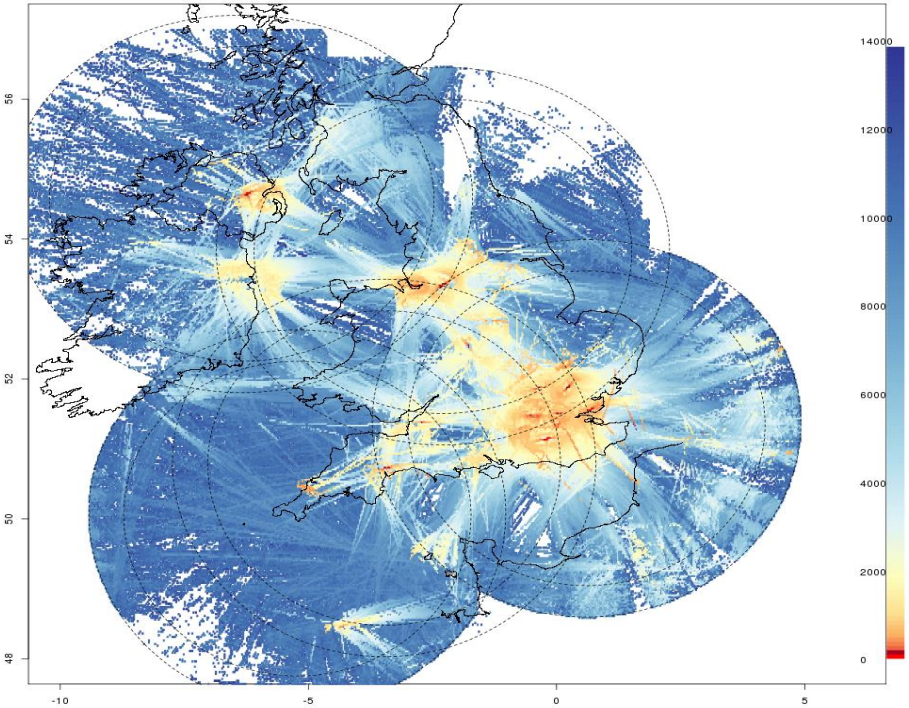
Data type	BDS	Resolution	Unit
Mode-A slant position (range)		1/256	Nm
Mode-A slant position (azimuth)		$360/2^{16}$	Degrees
Position from ADS-B	-	~5	M
MCP/FCU selected altitude;	4,0	16	Feet
roll angle;	5,0	45/512	Degrees
true track angle;	5,0	90/512	Degrees
ground speed;	5,0	2	Knots
magnetic heading;	6,0	90/512	Degrees
indicated airspeed (IAS)	6,0	1	Knots
Mach number (iso. IAS);	6,0	2.048/512	[-]
vertical rate (barometric or baro-inertial);	6,0	32	Feet per minute
barometric pressure setting (minus 800 hPa);	6,0	0.1	Millibar
track angle rate (TAR)	6,0	8/256	Degrees per second
true airspeed (iso. TAR)	6,0	2	Knots

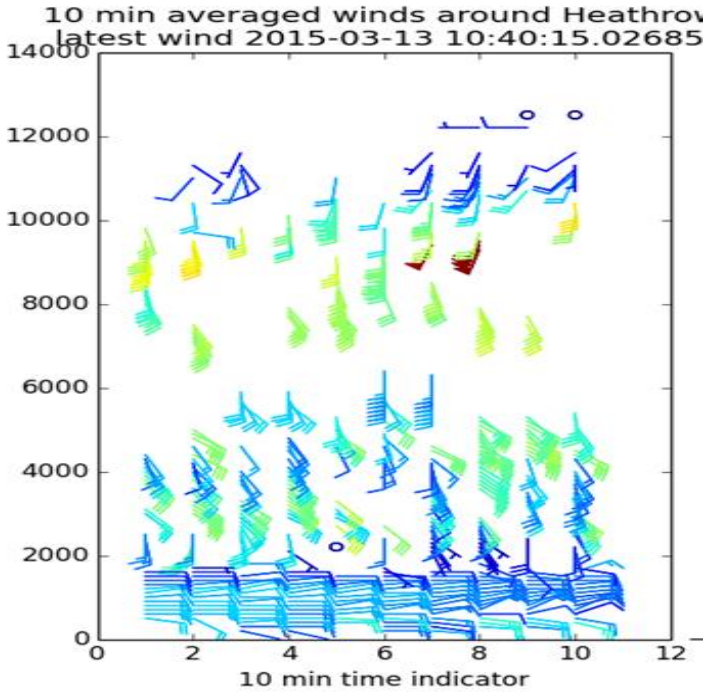
UK Network – current state.

- 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)

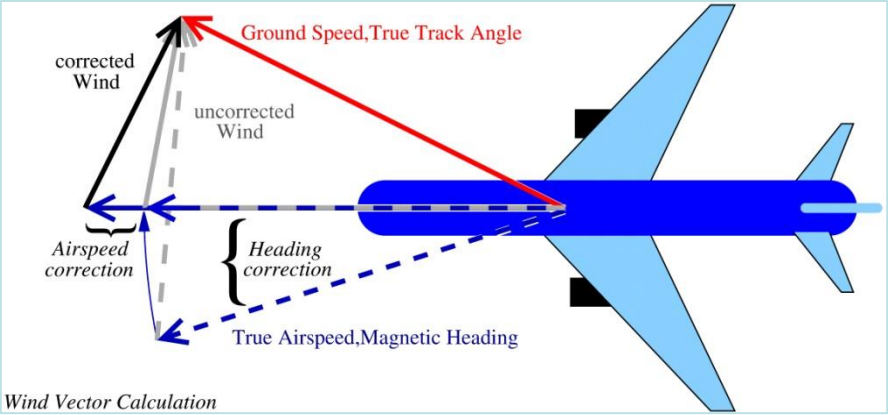
- Huge potential to supplement E-AMDAR data at some airport locations.
- Met Office and KNMI conducting studies into the data.
- Recently formed Expert Team Aircraft Derived Data (ET-ADD)– Reported in Oct'15.



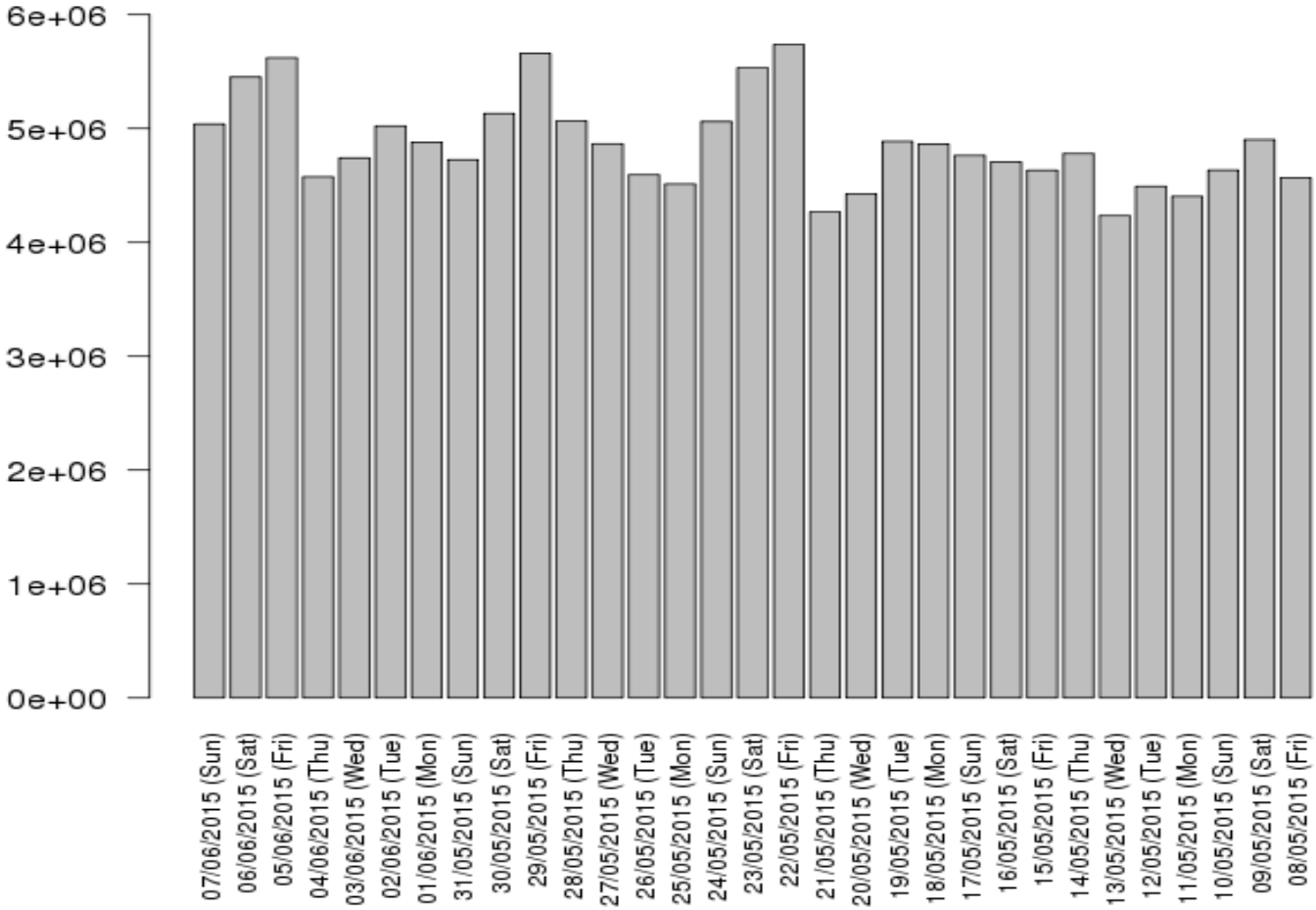


Quality of derived meteorological parameters from Mode-S EHS after quality control and corrections

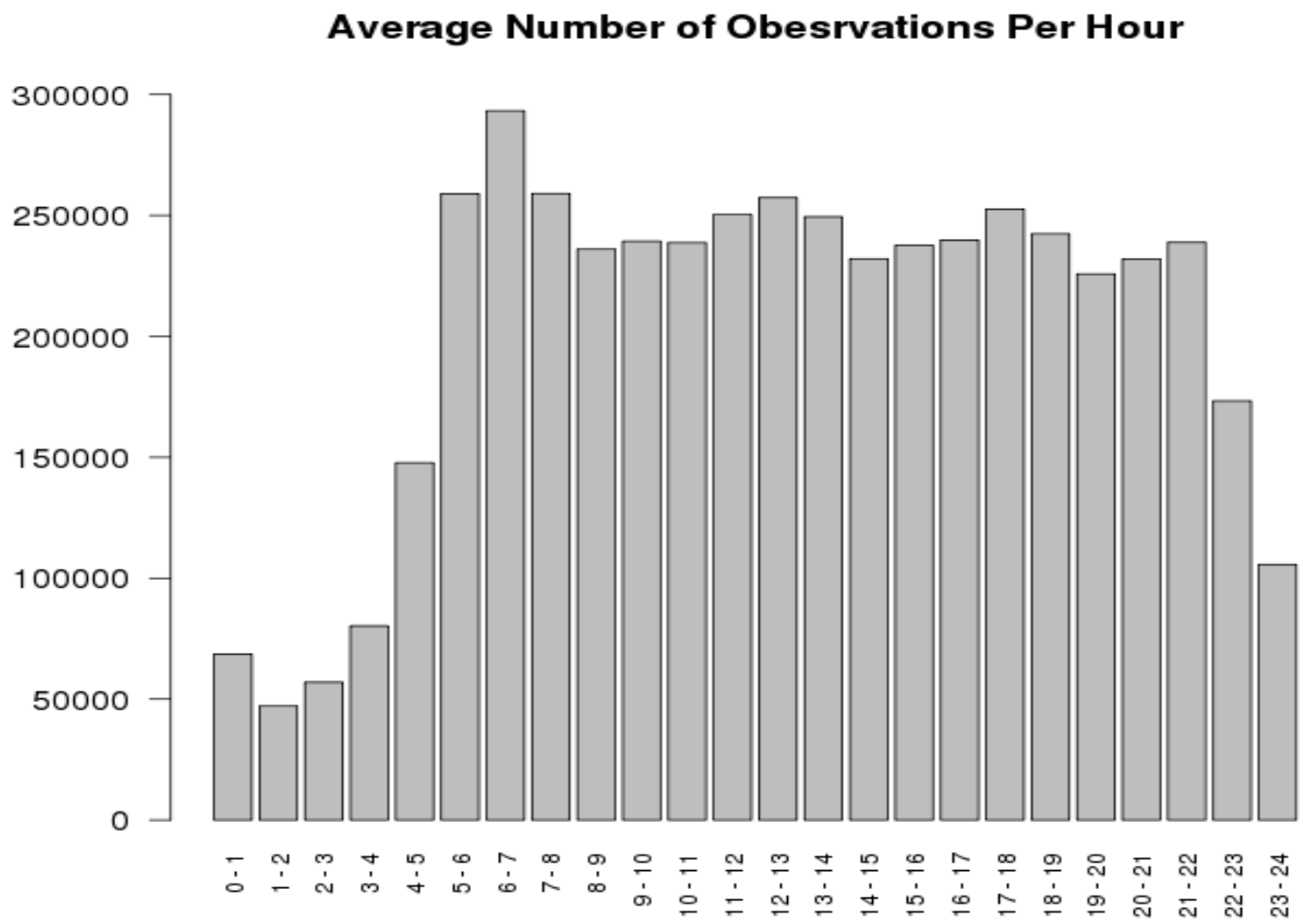
Meteorological parameter	Presence	Observed	Quality	Accuracy wrt. NWP model
Wind speed	Derived	All aircraft	Good	2-2.5 m/s
Wind direction	Derived	All aircraft	Good	10-15 degrees
Temperature	Derived	All aircraft	Moderate	2K



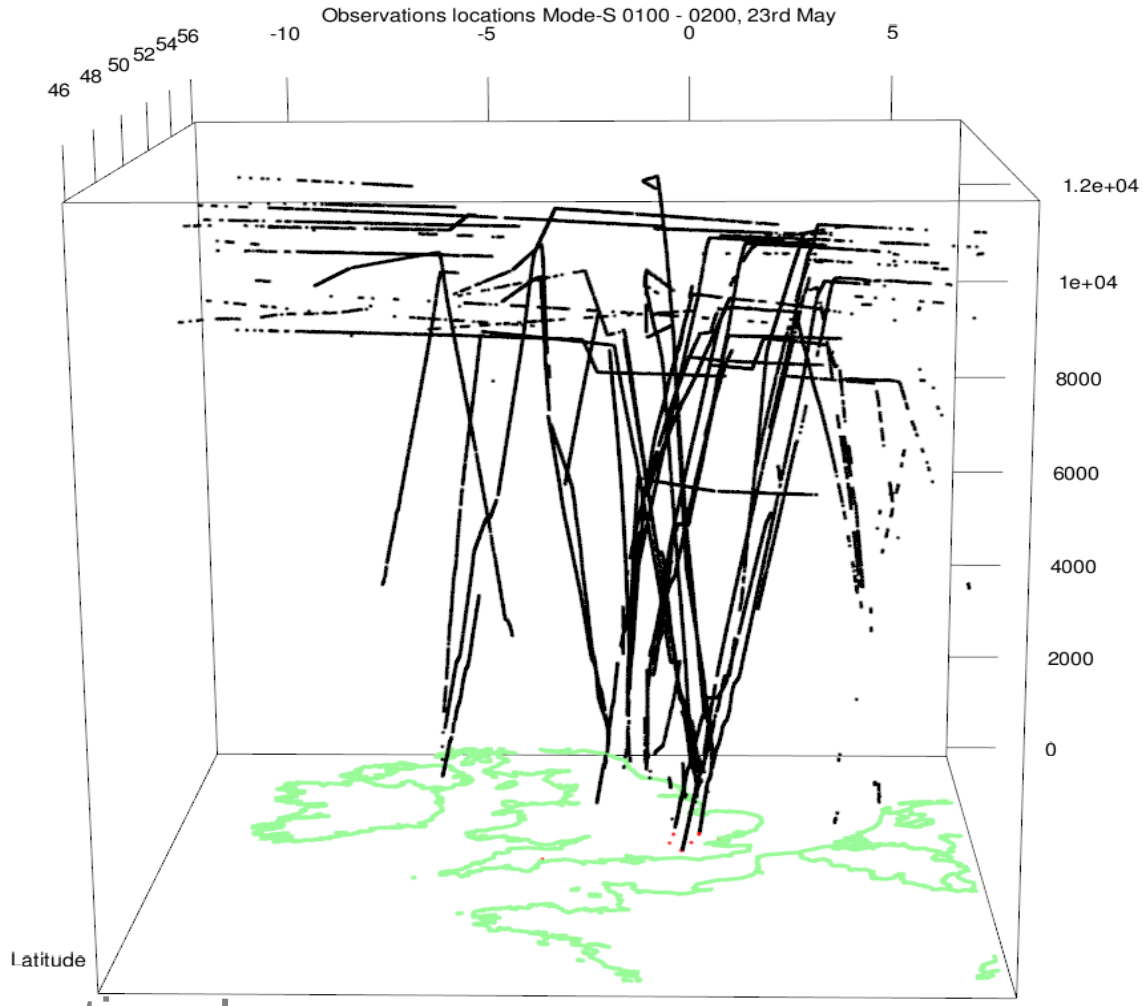
Observations per day



Observations per hour

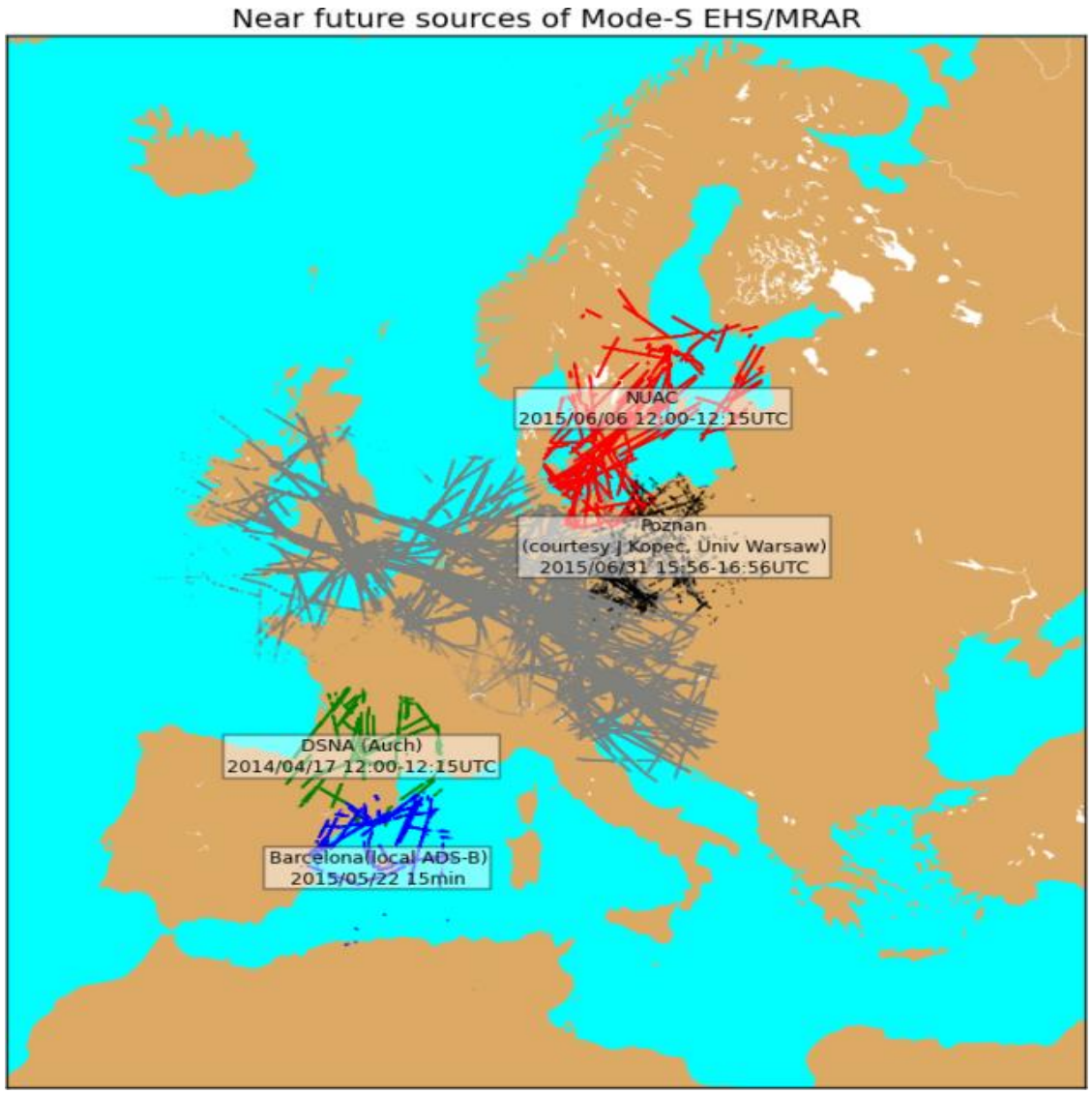


Observations overnight

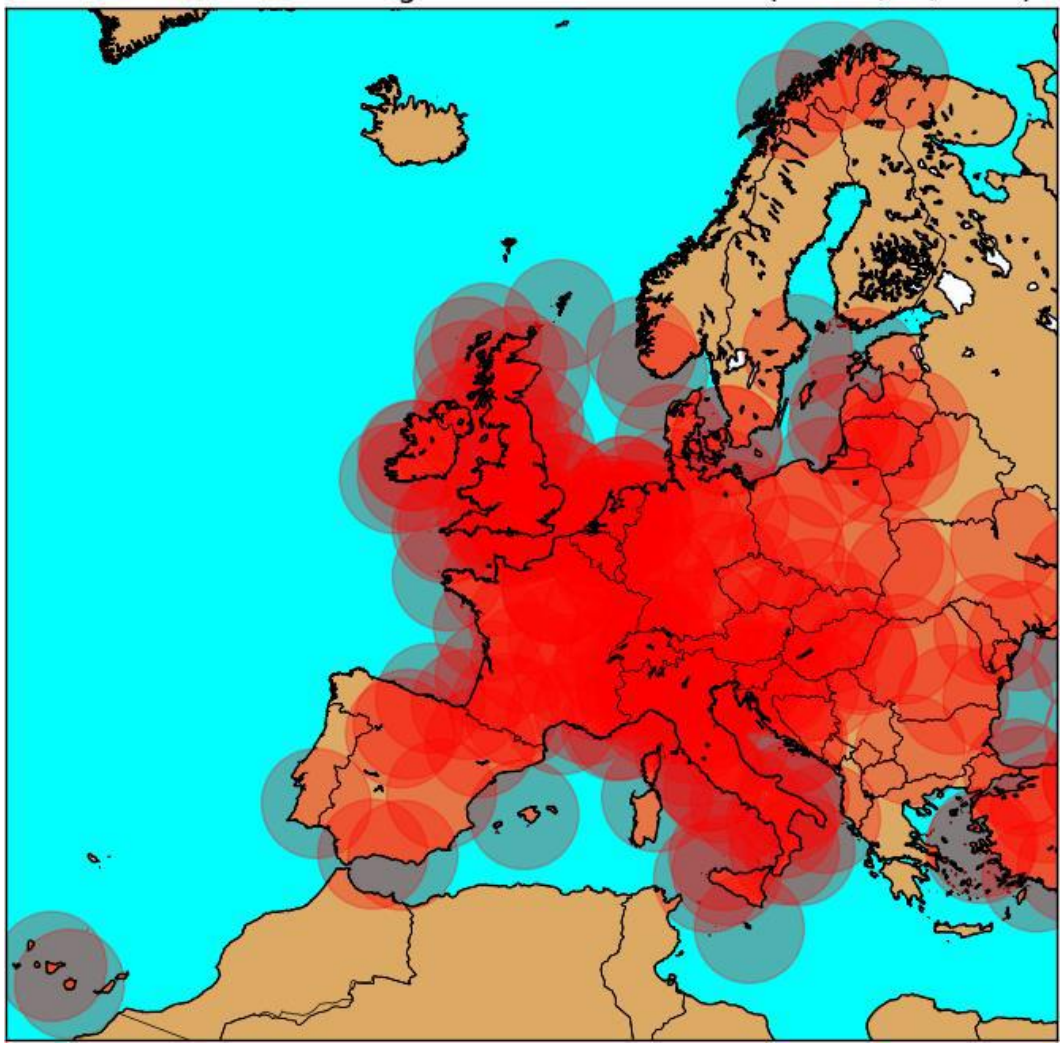


~61000 observations!

Near future sources of Mode-S EHS/MRAR



Current Mode-S Interrogator Code Allocations (dd. 28/08/2015)



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?

Data type	Resolution	Unit
Mode-A slant position (range)	1/256	Nm
Mode-A slant position (azimuth)	$360/2^{16}$	Degrees
Position from ADS-B	~5	m
wind speed	1	Knot
Wind direction	180/256	Degrees
Static air temperature	0.25	°C
Average static pressure	1	hPa
Turbulence	4 levels	nil/light/moderate/severe
Humidity	100/64	%

Meteorological parameter	Presence	Observed	Quality	Accuracy wrt. NWP model
Wind speed	Yes	10% aircraft	Good	2-2.5 m/s
Wind direction	Yes	10% aircraft	Good	10-15 degrees
Temperature	Yes	10% aircraft	Good	1K

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-AMDAR

Any Questions?

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