Royal Netherlands
Meteorological Institute
*Ministry of Infrastructure and the Environment*

# EMADDC

## towards operational collection of Mode-S EHS observations in Europe

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KNMI

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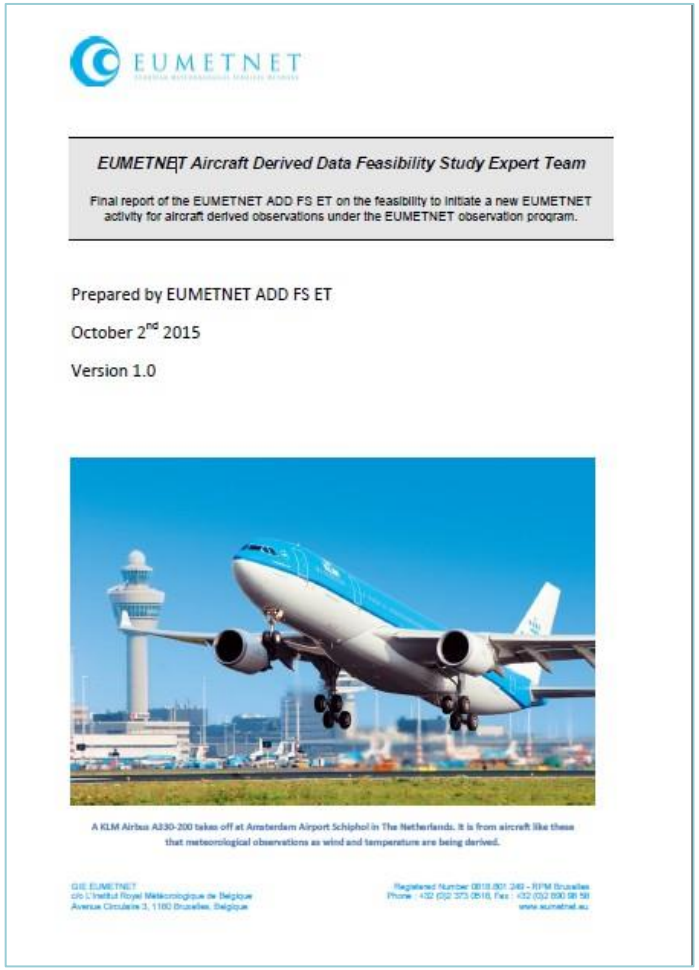
EUMETNET

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Final report of the EUMETNET ADD FS ET on the feasibility to initiate a new EUMETNET activity for aircraft derived observations under the EUMETNET observation program.

Prepared by EUMETNET ADD FS ET

October 2nd 2015

Version 1.0

A KLM Airbus A330-200 takes off at Amsterdam Airport Schiphol in The Netherlands. It is from aircraft like these that meteorological observations as wind and temperature are being derived.

# EMADDC

EMADDC: European Meteorological Aircraft Derived Data Center

Objective: to obtain as many high quality meteorological upper air observations for Europe at large for as little cost as possible

by installing an operational service for collecting, processing and disseminating Mode-S EHS derived, quality controlled meteorological data.

Rationale: new air traffic control surveillance technologies present opportunities to obtain or derive observations for:

- Wind direction
- Wind speed
- Temperature

# EMADDC Deliverables

- Continuous data flow of near-real time quality controlled upper air observations (wind direction, wind speed, temperature) for an expanding geographical area in Europe
  - NMHS e.g. vertical profiles for forecasters
  - Aviation e.g. time based separation operations
  - General public

observations

- To assimilate in rapid update cycles of numerical weather prediction models, impact up to 15 hours in KNMI Hirlam model
  - NMHS e.g. warning function
  - Aviation e.g nowcast and trajectory prediction systems

nowcasts
forecasts

# Mode-S EHS Enhanced Surveillance

Start in 2007 with research on the use of Mode-S EHS data

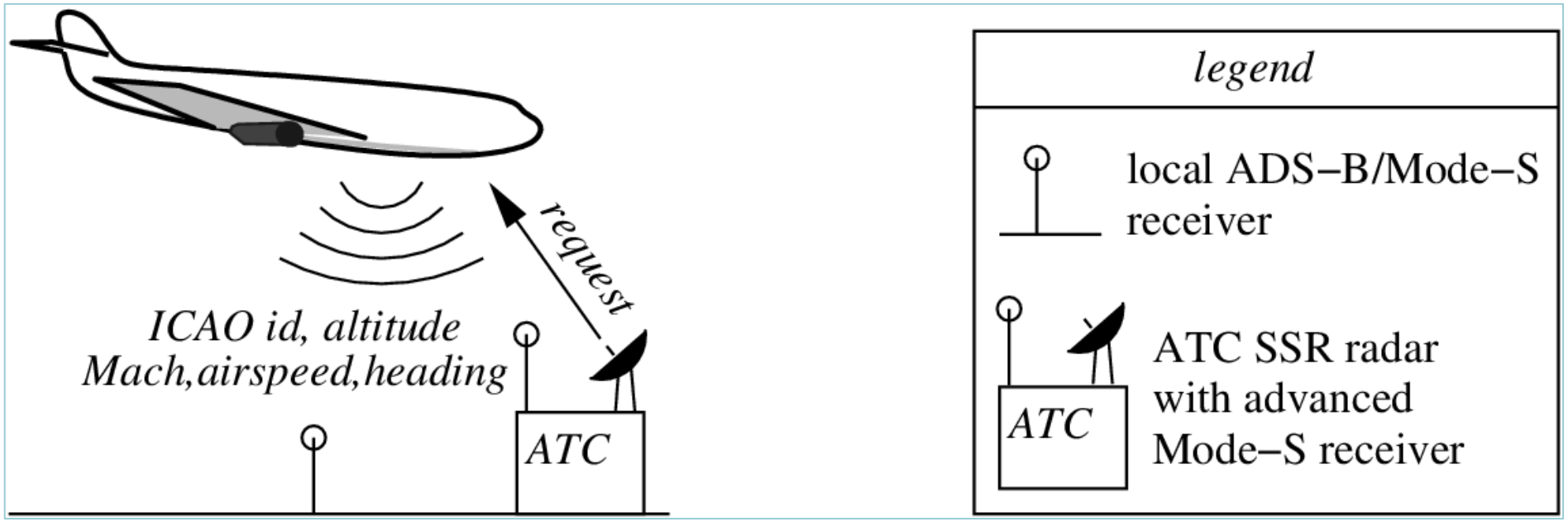
Secondary Surveillance Radar data used by Air Traffic Management to obtain situation information from aircraft.

Result: it is possible to derive wind and temperature observations of good quality.

| BDS Register | Basic DAP Set (if track Angle Rate is available) | Alternative DAP Set (if Track Angle Rate is not available) |
|---|---|---|
| BDS 4,0 | Selected Altitude | Selected Altitude |
| BDS 5,0 | Roll Angle | Roll Angle |
| | Track Angle Rate | |
| | True Track Angle | True Track Angle |
| | Ground Speed | Ground Speed |
| | | True Airspeed (provided if Track Angle Rate is not available) |
| BDS 6,0 | Magnetic Heading | Magnetic Heading |
| | Indicated Airspeed (IAS) / Mach no. (Note: IAS and Mach no. are considered as 1 DAP (even if technically they are 2 separate ARINC labels). If the aircraft can provide both, it must do so). | Indicated Airspeed (IAS) / Mach no. (Note: IAS and Mach no. are considered as 1 DAP (even if technically they are 2 separate ARINC labels). If the aircraft can provide both, it must do so). |
| | Vertical Rate (Barometric rate of climb/descend or baro inertial) | Vertical Rate (Barometric rate of climb/descend or baro inertial) |

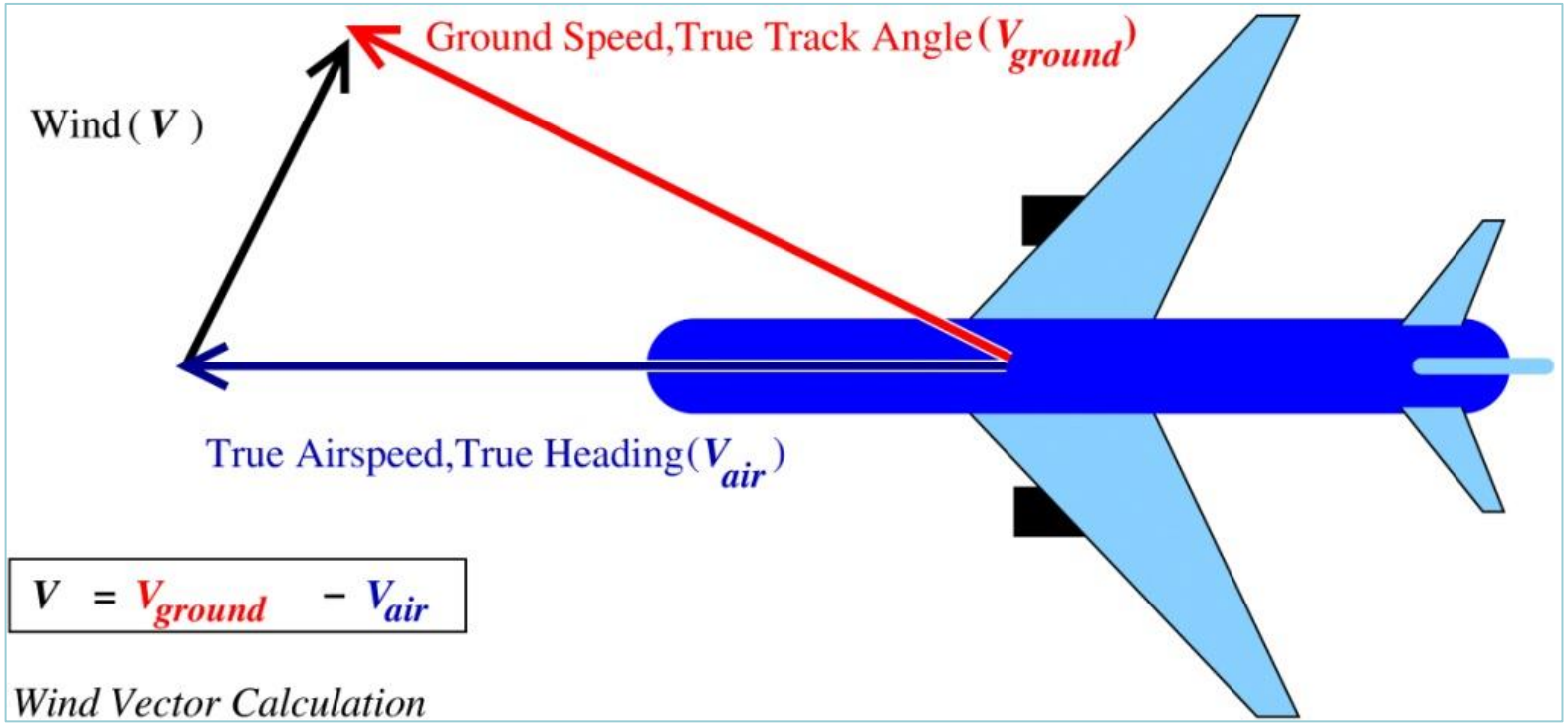
Mode-S EHS downlink aircraft parameters (DAPs).
Fixed wing aircraft that can provide the list of 8 DAPs displayed in this table are considered to be Mode-S EHS capable. Where the parameter 'Track Angle Rate' cannot be provided 'True Air Speed' should be used instead. Source: EUROCONTROL.

# Method Mode-S EHS




- Requires active interrogation from Air Traffic Control radar
- Aircraft responds with providing data
- Frequency dependent on radar (~4 – 20 sec)

# Method Mode-S EHS Wind




Schematic representation of wind derivation from aircraft flight information

The wind vector (black) is deduced from the difference between the ground track vector (red) and the orientation (heading) and speed of the aircraft relative to the air (dark blue). The ground track vector is constructed by ground speed and true track angle.

Note that both heading and ground track angle are defined with respect to true north.

# Method Mode-S EHS

Data processing contains quality control and **aircraft specific** heading, air speed and temperature corrections

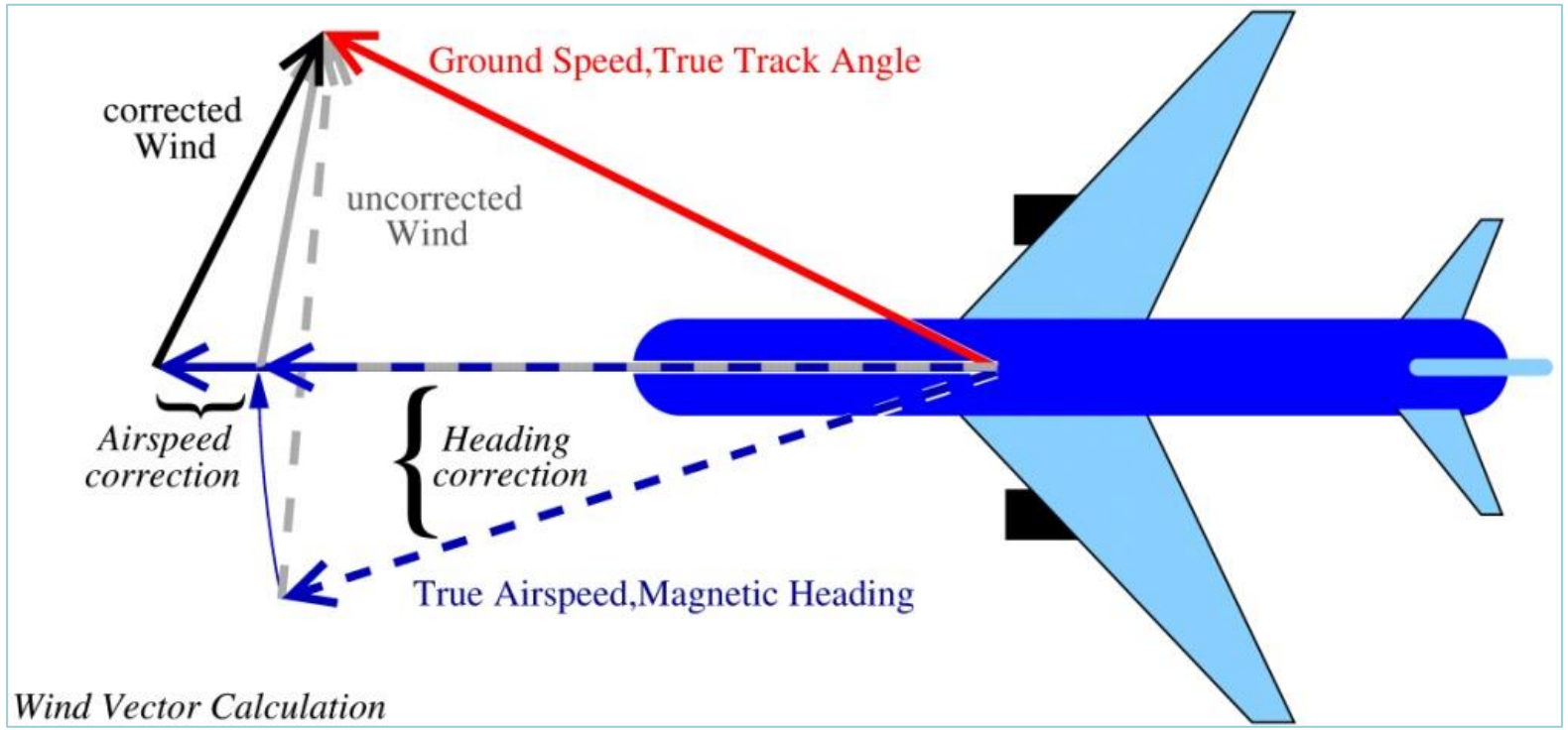
Two methods to determine heading corrections

1) Aircraft regularly landing at Schiphol Airport
   - using known direction of runway
   - only aircraft that land regularly at Schiphol Airport can be used

2) Using external wind information from NWP, assuming the wind factor is perfect
   - after 30 days with minimum of 15 days observation of aircraft
   - corrections available for much more aircraft
   - dynamic aircraft database, updated every day

The acquired quality is equal for both methods (KNMI position)

# Method Mode-S EHS Wind




Schematic representation of wind derivation from aircraft flight information including individual aircraft corrections

The dashed white-blue vector (uncorrected vector) is constructed using aircraft downlink information of magnetic heading and true airspeed. The dashed grey-blue vector is the result of the proper heading correction being applied to correct for heading offsets and to convert to true heading. The solid blue vector denotes the air vector after heading and airspeed correction. In black is the resulting wind after corrections and in grey are the intermediate wind estimates - in dashed gray without any corrections and solid grey with only heading correction applied. The ground track is assumed to be correct.

# Method Mode-S EHS Temperature

Observed:

- Mach-number (M)
- Speed of Sound depends on Temperature (T)
  - $c = (C/\rho)^{1/2}$, $C$ = constant en $\rho$ airdensity
  - $\rho = p/(R\,T)$, $R$ = constant

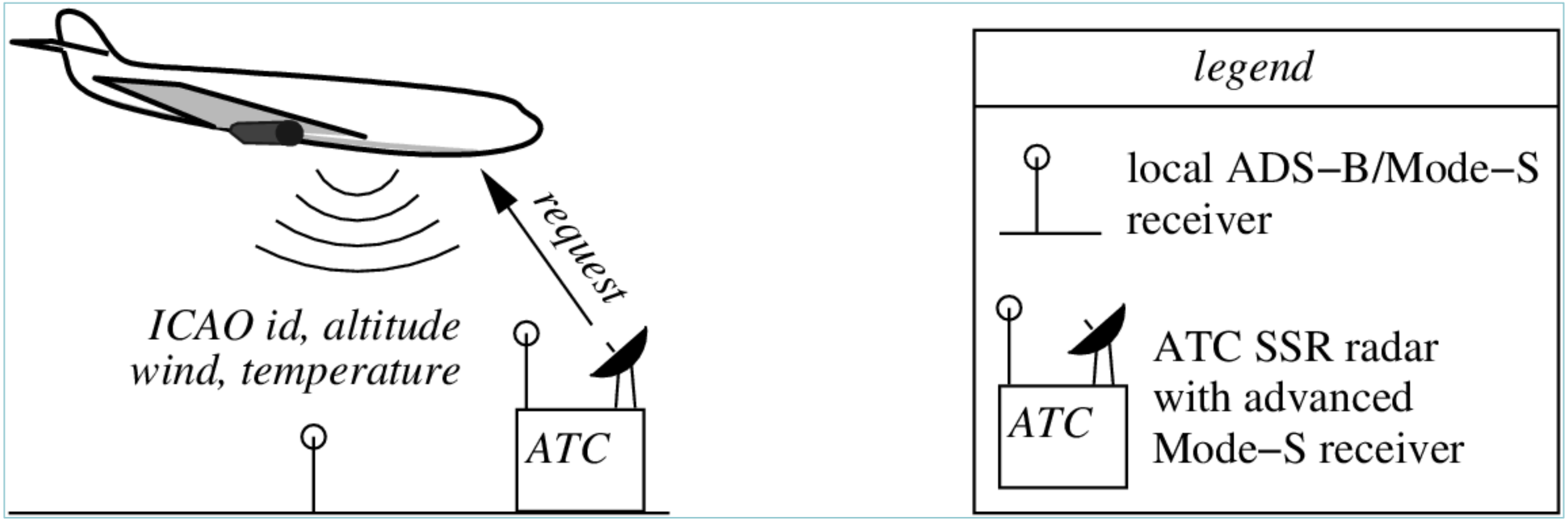
Thus: $V_{true} = K\,M\,T^{1/2}$ with $K$ constant

MET perspective ☺
- Mach resolution to low
- TAS resolution to low

Temperature derivation from aircraft flight information including individual aircraft corrections

Note: $V_{true}$ = TAS

# Mode-S MRAR




- MRAR = Mode-S Meteorological Routine Air Report
- Requires active interrogation of register BDS 4.4 by ATC radar
- Good quality Wind and Temperature measured/calculated by the aircraft
- Little aircraft equipped, little interrogation by ATC (bandwidth issues)

# EUMETNET

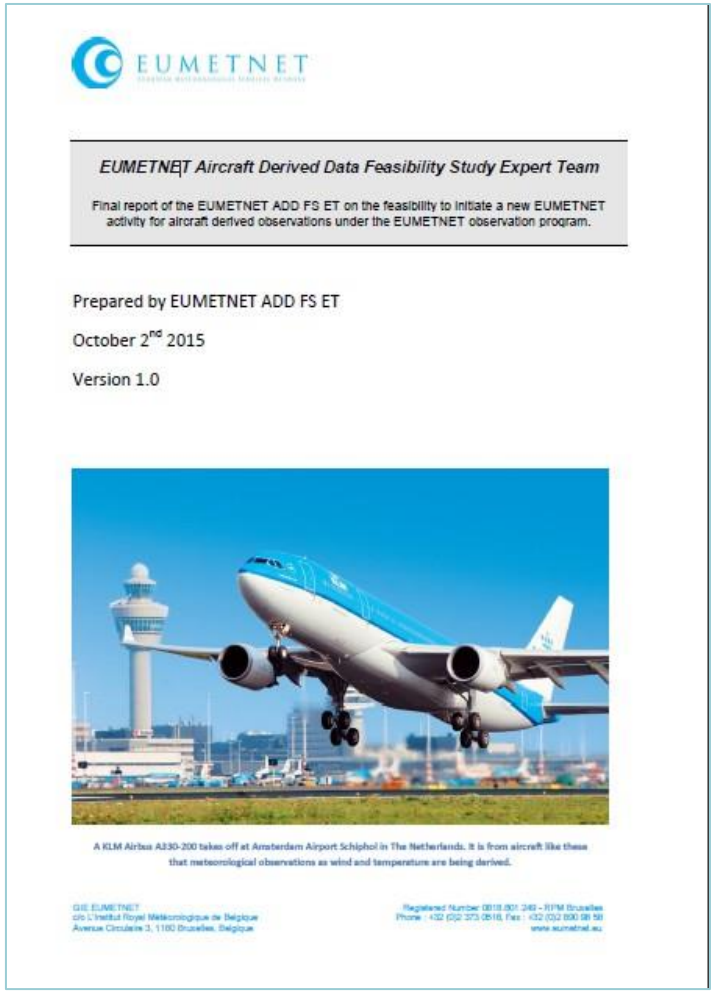
2015: EUMETNET Aircraft Derived Data Feasibility Study

Investigated usage of different aircraft derived data types for meteorological purposes

Conclusion: focus primarily on Mode-S EHS data and Mode-S Meteorological Routine Air Report (MRAR)

Intention for EMADDC to become a EUMETNET observations programme as of 2021

www.eumetnet.eu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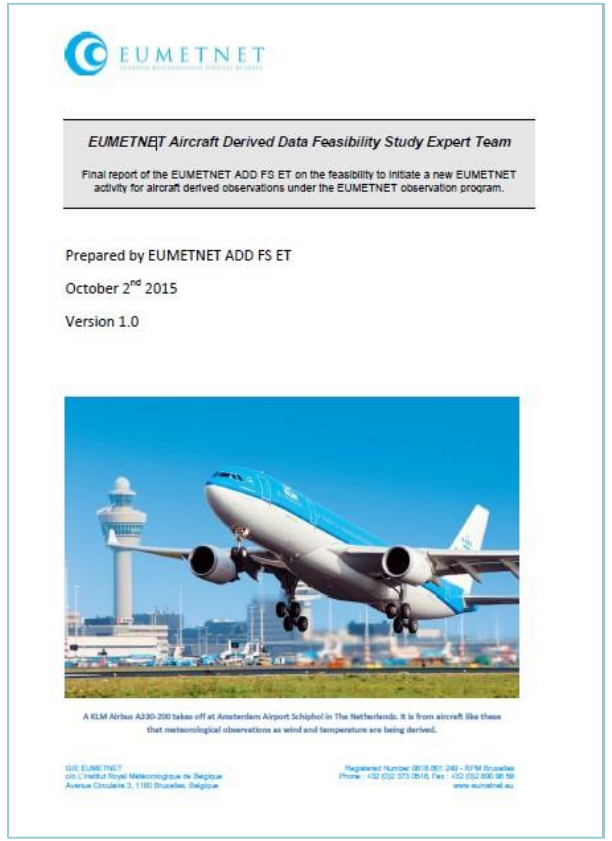
# EUMETNET

# ADD data types

| Type | Sub-type | Direct meteorological information | Derived meteorological information | Remarks |
|---|---|---|---|---|
| Automatic Dependent Surveillance (ADS) | ADS-B | ✗ | ✓ | - Only wind<br>- Small number<br>- Poor quality |
| | ADS-B ES | ✗ | ✓ | - Small number<br>- Poor quality |
| | ADS-C | ✓ | ✓ | - Only small portion of messages<br>- Good quality<br>- Data only via ATC or airlines<br>- Data communication costs |
| Secondary Surveillance Radar (SSR) Mode-S | Mode-S ELS | ✗ | ✗ | - |
| | Mode-S EHS | ✗ | ✓ | - Specific dynamic aircraft corrections and quality control required<br>- Good quality wind<br>- Lower quality of temperature<br>- Exceptionally large amounts of observations<br>- Data distribution costs still to be negotiated with ATM community |
| | Mode-S MRAR | ✓ | ✗ | - Small number<br>- Good quality |
| | Mode-S MET Hazard Report | ✗ | ✗ | - |
| E-AMDAR (for comparison) | E-AMDAR | ✓ | ✗ | - Requires on-board AMDAR software<br>- Contract with airlines<br>- Data communication costs<br>- Good quality |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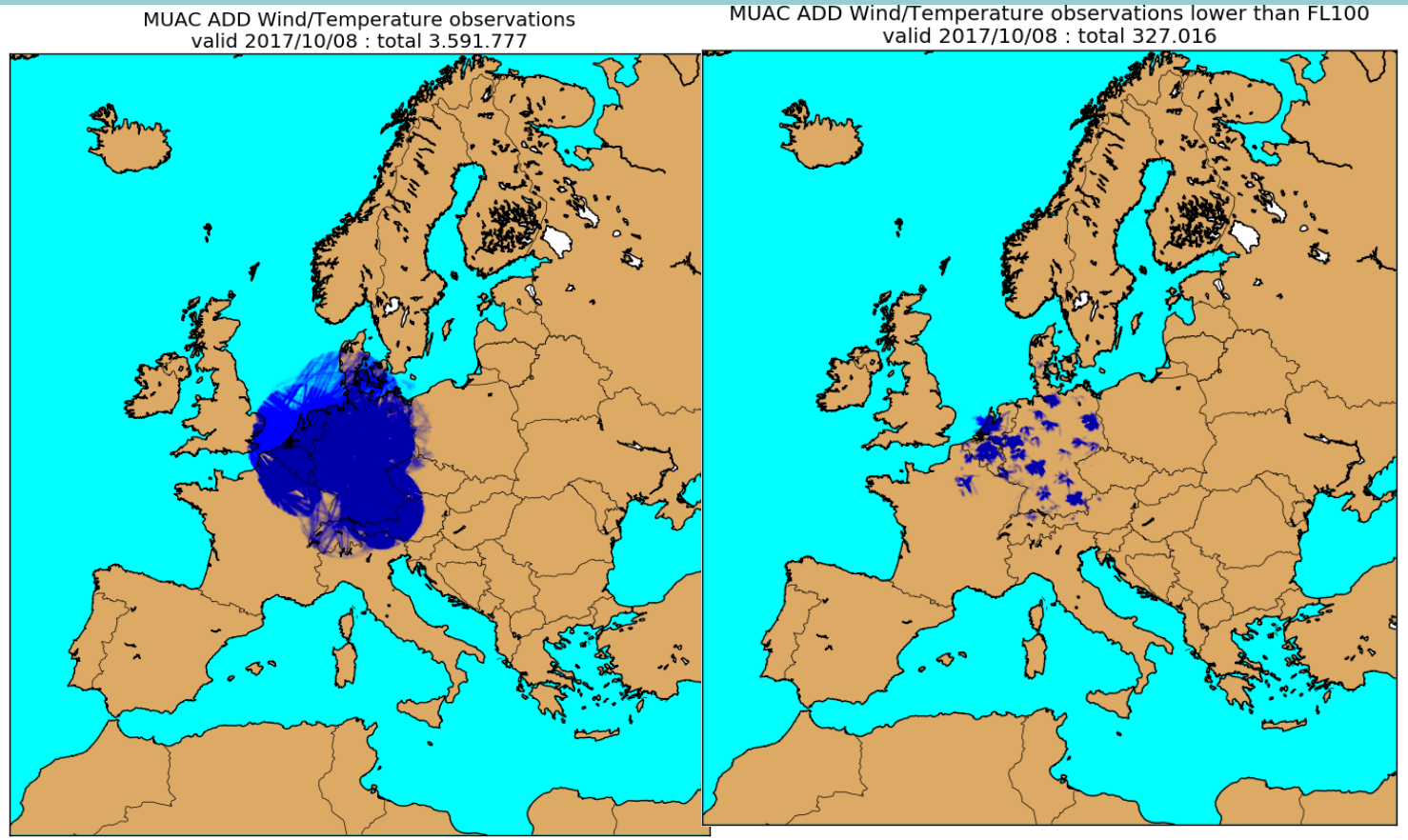
A KLM Airbus A330-200 takes off at Amsterdam Airport Schiphol in The Netherlands. It is from aircraft like these that meteorological observations as wind and temperature are being derived.

Mode-S EHS can be collected with low cost receivers

# KNMI Mode-S EHS





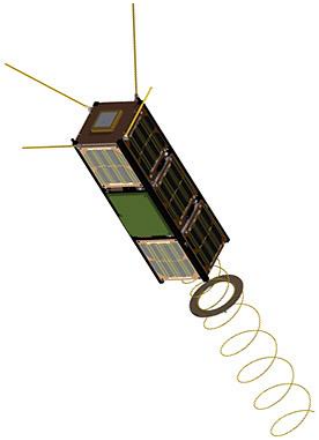


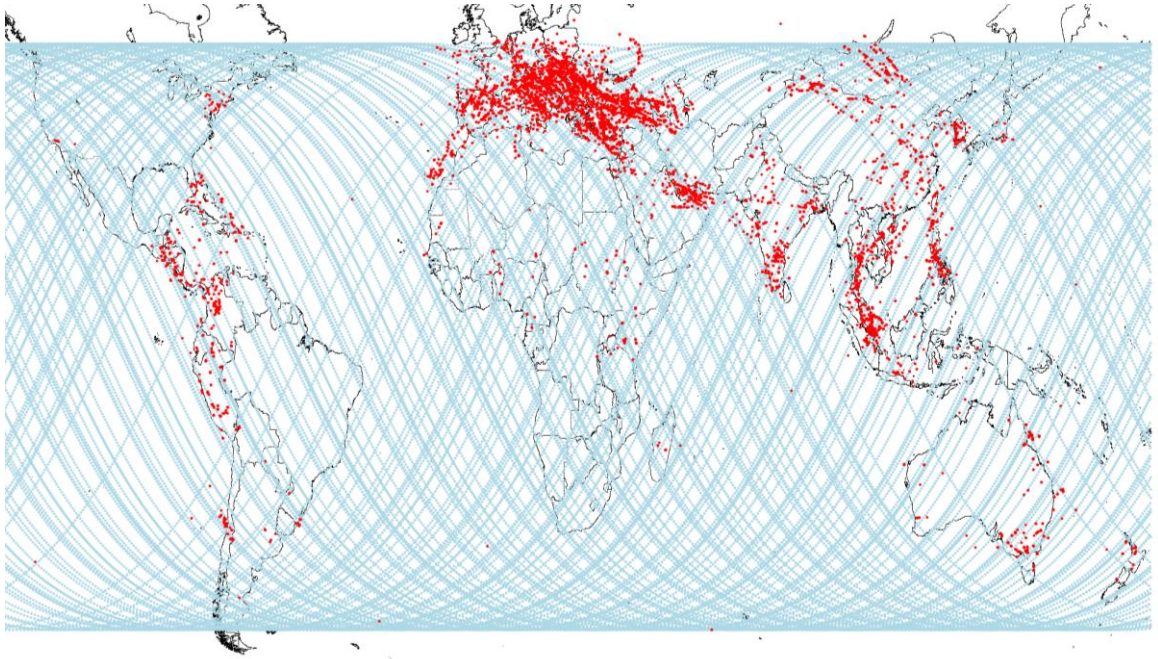
For the MUAC area alone 20 Million+ raw observations per day

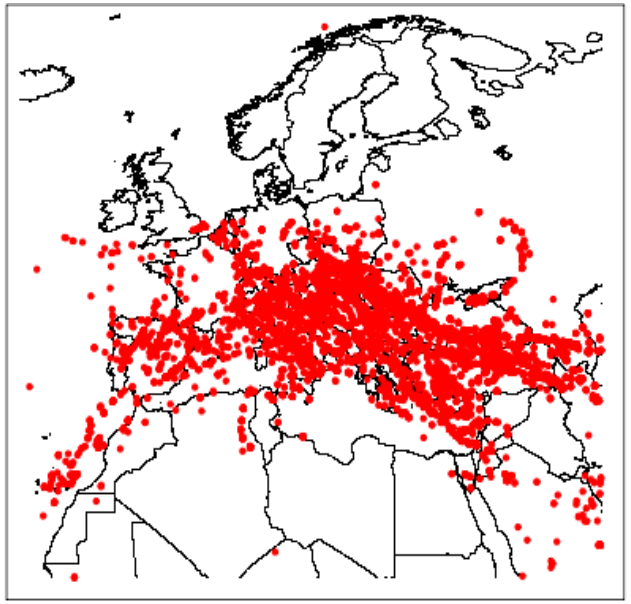
Resulting in 3,5 Million quality controlled observations per day

Current coverage of Mode-S EHS derived and quality controlled wind and temperature observations available at KNMI. The example shows the observations for the 8th of October 2017 over western Europe. Source: EUROCONTROL MUAC in ASTERIX Cat 48 format, processed by KNMI.

# Global applicability







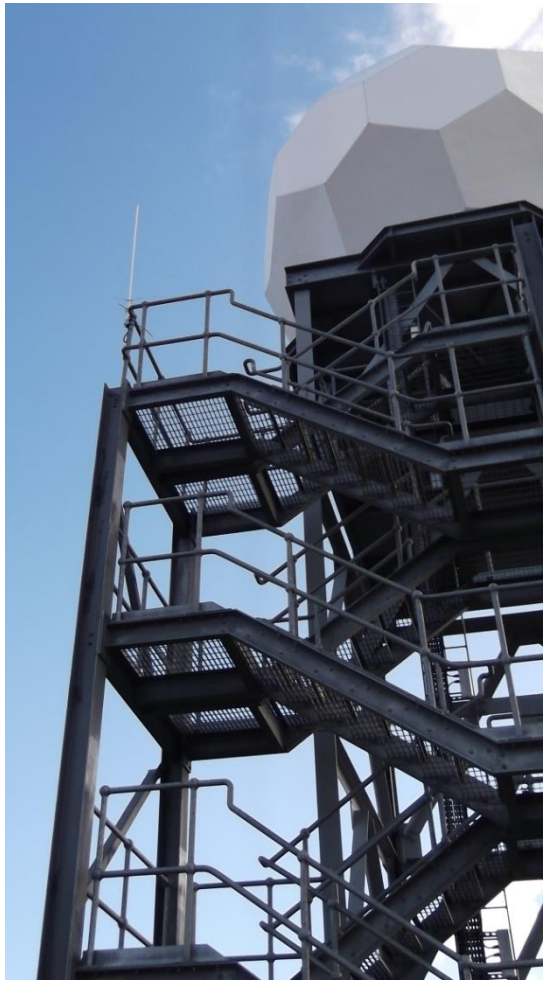
Location of derived wind and temperature observations from Mode-S EHS observations (red dots), globally and over Europe, collected by the GomX-3 Cube Satellite.
Data was collected for a two week period during August 2016 with an orbital period of 90 minutes. The blue lines show the path of the satellite during the data collection period.
The limited coverage towards the north is due to the orbit not passing high enough North.

https://blog.metoffice.gov.uk/2016/11/30/can-space-tech-help-measure-the-weather/

# UK Met Office

R&D Network – current state

- 5 receivers across the UK (+1 in the Channel Islands)
- 5 are located at Weather Radar Sites, and one at Met Office HQ in Exeter
- Tuned antenna with amplifier using a Mode-S beast decoder
- Real time system using a Raspberry Pi

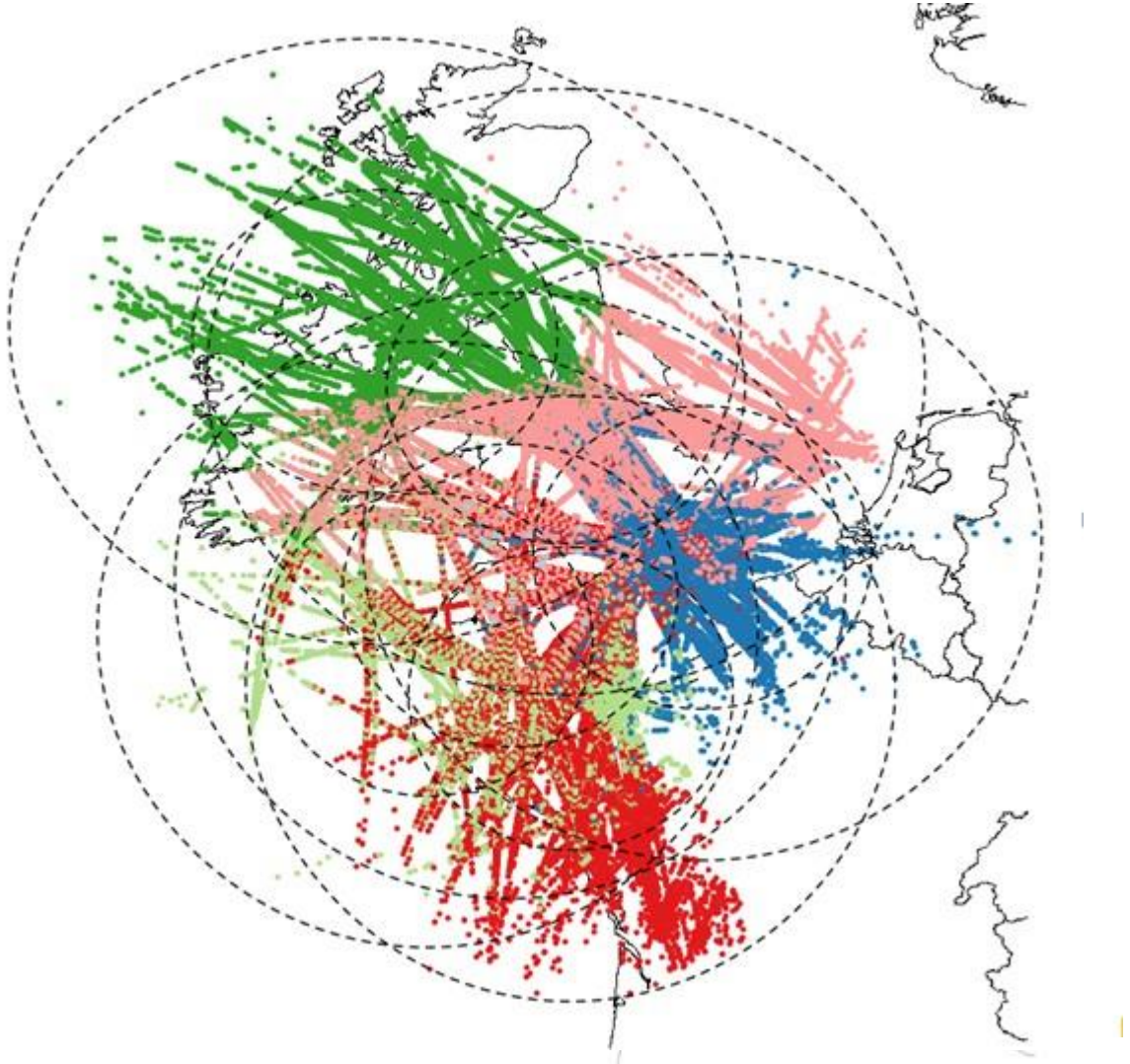


# UK Met Office

R&D Network – current state

- One hour of data
- Maximum number of observations for one day for this area was 8.1 Million of wind observations and 8.1 Million temperature observations
- Due to the fact that several radars interrogate the same aircraft every 4 to 20 seconds

| Name | Cod |
|---|---|
| Exeter | m00 |
| Thurnham | m02 |
| Predannack | m03 |
| Castor Bay | m04 |
| Hameldon Hill | m05 |
| Channel Islands | m06 |



# EMADDC output

Mode-S EHS ADD is available from 01/01/2013 till present for the MUAC air space

- in batches of 15 minutes
- with a latency of approximately 10 minutes

With the content

- Position (latitude/longitude/flight level)
- (anonymized) aircraft identifier
- Wind speed and direction
- Temperature

With the (estimated) absolute quality

- For wind speed : 1 - 1.5 m/s
- For wind direction: 5 – 10 degrees
- For temperature: 0,5 - 2 K

Formats : BUFR WMO7, NetCDF and ASCII

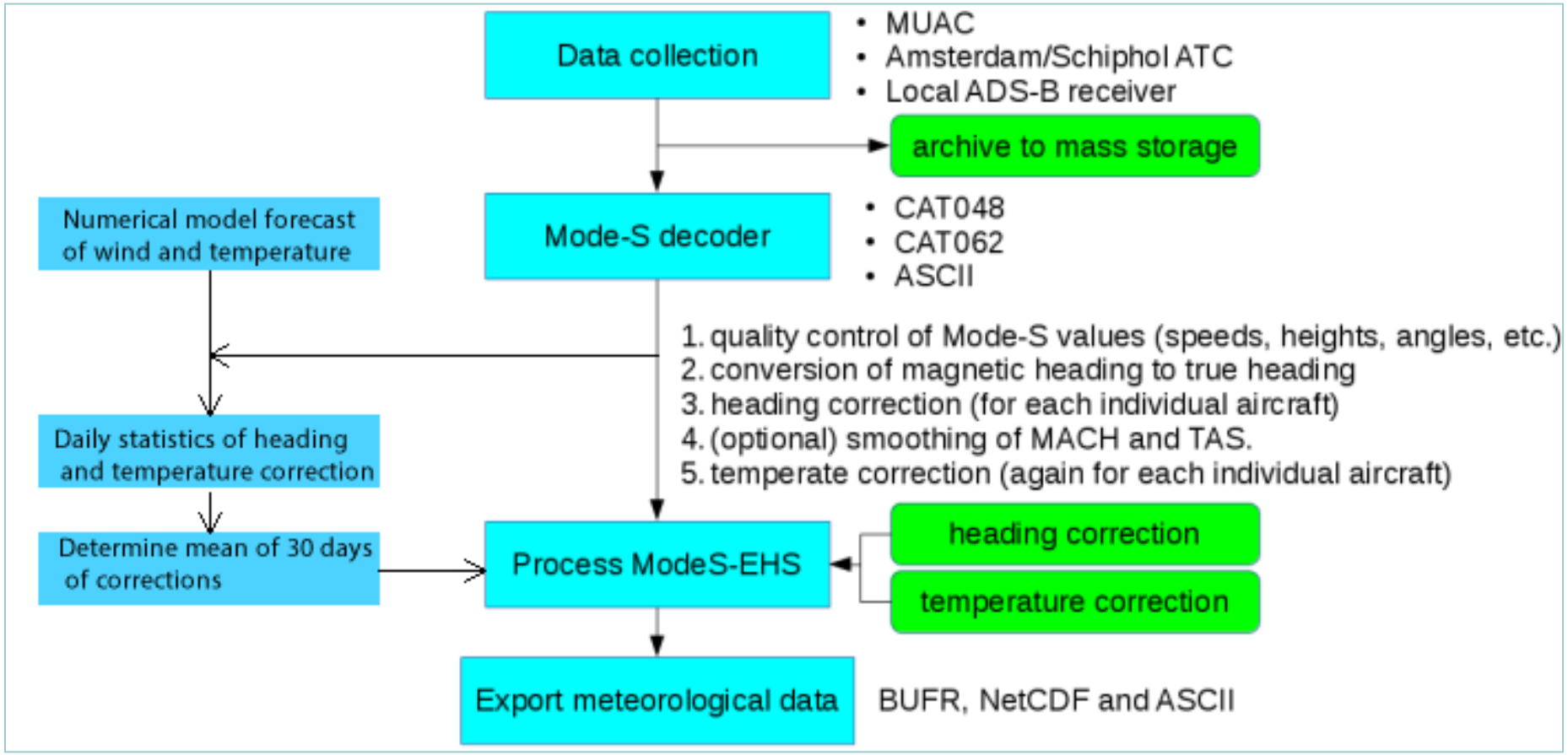
# Status EMADDC

- Funding
  - SESAR Deployment
  - KNMI
  - UK Met Office
- Team
  - Complete as of January 2018
  - 36 months to deliver

Co-financed by the European Union
Connecting Europe Facility

SESAR DEPLOYMENT MANAGER LET'S DELIVER TOGETHER

# Flow of data processing




Current semi-operational KNMI Mode-S EHS processing chain that will be made operational in 2018

# Next steps EMADDC Time Frame 2017-2020

- Integrate current semi-operational ADD-system in the 24x7 controlled environment of KNMI
- Set up of dynamic database, updated daily, for individual aircraft corrections
- Propose new BUFR format to exchange derived data to WMO
- Organise governance (standard contracts, IPR, business model)
- Produce standardized plug-and-play ADS-B/Mode-S receivers and processing software
- Roll out of local ADS-B/Mode-S receivers in the UK
- Expand geographical scope of surveillance data
- Increase towards near-real time processing instead of batch processing

# Further research EMADDC Time Frame 2017-2020

- Improve quality of Mode-S EHS derived temperature
- Improve quality control parameters and algorithms
- Regionalization of magnetic declination correction
- Research other data sets like ADS-C and other sources e.g. direct data from aircraft via wifi or nanosatelites
- Investigate opportunities to utilise ADD to derive e.g. turbulence
- Research NWP dependency on calculating aircraft heading correction

# Partners and acknowledgements

EMADDC knowledge partners, funding or data provided by:

EUROCONTROL

Luchtverkeersleiding Nederland
Air Traffic Control the Netherlands

Met Office

DFS Deutsche Flugsicherung

GOMSPACE

knowledge & development centre
Mainport Schiphol

EUMETNET
EUROPEAN METEOROLOGICAL SERVICES NETWORK

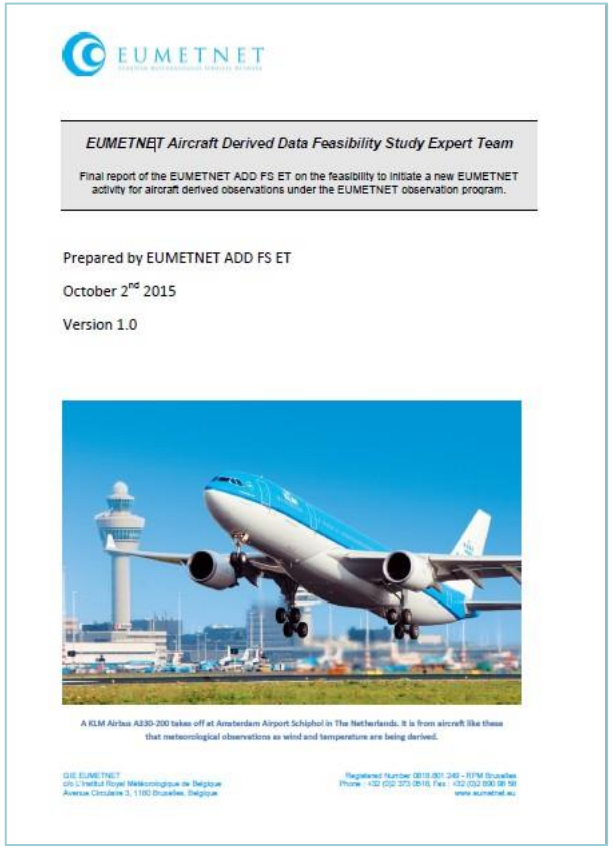
SESAR DEPLOYMENT MANAGER

esa

KLM Royal Dutch Airlines

SKYTEAM

BOEING




The initial research on Mode-S EHS (2007)
has been funded by the Knowledge Development Center
Mainport Schiphol (KDC) http://www.kdc-mainport.nl

Co-financed by the European Union
Connecting Europe Facility

Thank you for your attention.

For more info consult the website mode-s.knmi.nl

To join or participate in the EMADDC programme please contact mode-s@knmi.nl or sondij@knmi.nl