Assimilating EMADDC Mode-S Aircraft Observations in the Navy's Numerical Weather Models

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Objective

Aircraft provide some of the most impactful observations used in numerical weather prediction. (James and Benjamin 2017)

Aircraft data providers and data transmission standards continue to evolve.

The European Meteorological Aircraft Derived Data Center, EMADDC, processes air traffic reports from Mode-S Enhanced Surveillance (EHS) to derive atmospheric information from aircraft flying over Europe.

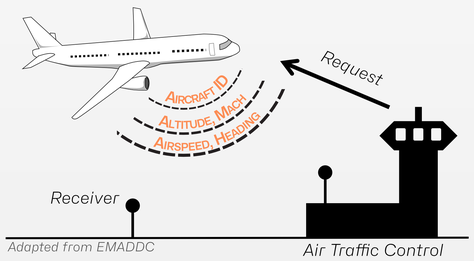
Atmospheric information derived from Mode-S provides an unprecedented volume of data from aircraft.

Mode-S will eventually become the primary source of meteorological aircraft observations in Europe. To prepare for this transition, we developed the capability to assimilate these observations into the Navy's NWP models and evaluated their impact on forecasts.

Mode-S Aircraft Data

Mode-S EHS reports are collected from aircraft by air traffic control receivers as often as every 4-20 seconds. EMADDC collects that data and derives calibrated and quality-controlled observations of wind and temperature. They then disseminate that data every 15 minutes with 15-30 minute latency.

Data quality is comparable to AMDAR. Wind speed bias is ~0.5 m/s and temperature bias is ~0.1 K when compared to models and radiosonde. (WMO Newsletter Volume 24)



Adapted from EMADDC

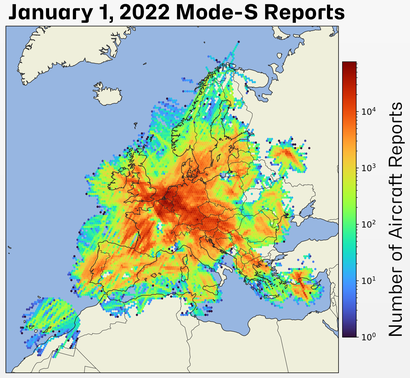
Wind Speed & Direction

Derived from ground speed, track angle, air speed, and magnetic heading with aircraft-specific corrections.

Air Temperature

Derived from Mach number and true air speed with aircraft-specific corrections.

January 1, 2022 Mode-S Reports



▲ *Number of observations derived from Mode-S reports on January 1, 2022 in Europe.*

For a full description, visit https://emaddc.com/

Data Preparation

Preparing Mode-S observations for assimilation required substantial data reduction due to the exceptional volume of data.

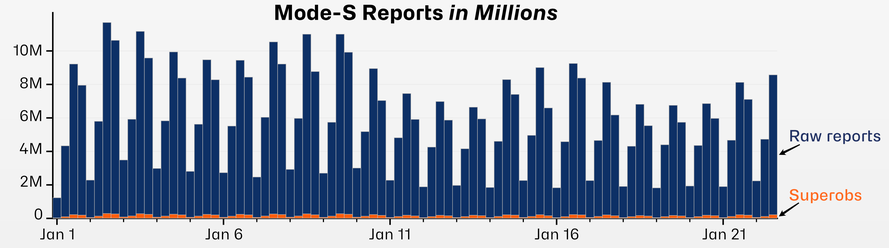
We reduced the amount of data using the superobservation technique; observations close in time and space are averaged together to form a *superobservation*.

Making superobservations reduced the data volume to *~2.5%* of the original data volume.

Superob bin size
- Horizontal: 56 km (~0.5°)
- Vertical: 100 m
- Time: 30 minutes

Due to a constraint in the current COAMPS system that limits the number of data that can be assimilated, we only assimilated 8,000 randomly sampled Mode-S superobs each cycle.

Mode-S Reports *in Millions*



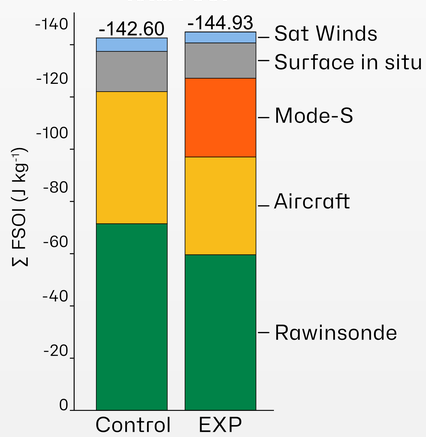
▲ *Number of Mode-S reports for each 6-h window (blue) and number of superobbed samples (orange).*

Impact on Forecasts

The impact of each observation was measured by ***Forecast Sensitivity Observation Impact*** (FSOI).

In this experiment, FSOI measured how each observation reduced the 12-h forecast dry energy norm for the area of the inner-nest and lowest 48 model levels. Note that negative FSOI indicates *beneficial* impact.

Total FSOI

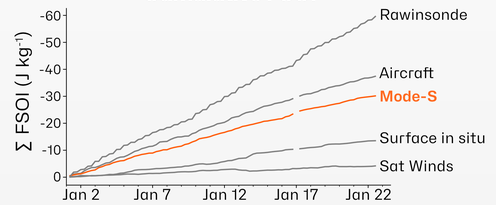


▲ *Total FSOI for each observation group over 22 days (88 model cycles). Compared to a control experiment that did not assimilate Mode-S observations, Mode-S appears to "steal" impact from other observation types, but the overall total impact is slightly larger with the additional data.*

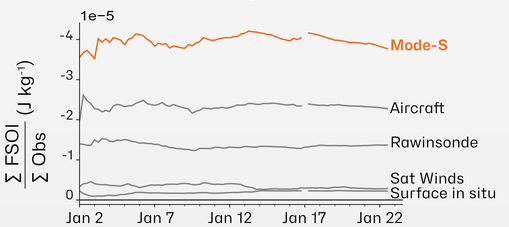
Even when assimilating a small subset of the available Mode-S observations:

- **Mode-S was the 3rd most beneficial observation type.**
- **Mode-S "impact per observation" was nearly double any other observation type.**

Cumulative FSOI



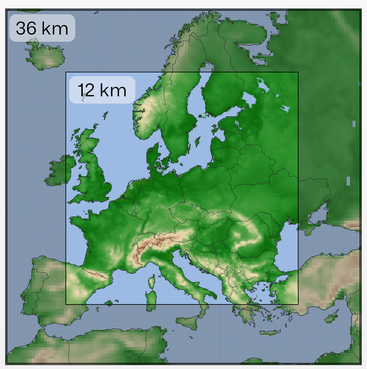
Cumulative FSOI per Observation



▲ *Timeseries of cumulative FSOI (top) and cumulative FSOI per observation (bottom) for each observation group.*

COAMPS Experiment

COAMPS® is the Navy's regional model. We ran a COAMPS simulation for a 22-day period starting on January 1, 2022, and assimilated all operationally available datasets in addition to a sample of superobbed Mode-S reports.



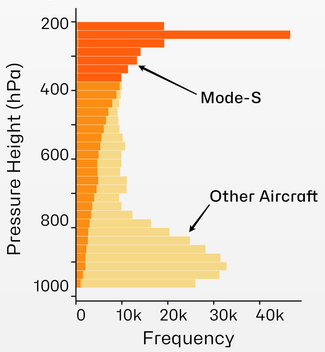
▲ *COAMPS domain and model terrain.*

Specifications: NAVGEM boundary conditions • 60 vertical levels COMAPS-AR 4D-Var data assimilation • Cycled every 6 hours. FSOI was evaluated for the area in the inner-most domain and lowest 48 model levels.

Temperature Quality

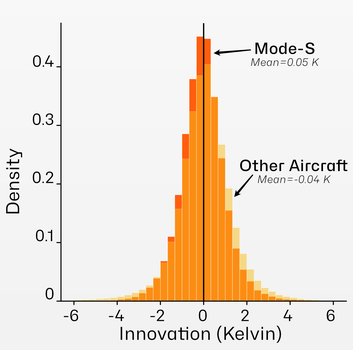
Aircraft temperatures measured at flight level have historically been excluded from data assimilation in the Navy models due to a known temperature bias (other NWP centers apply bias correction techniques). Mode-S derived measurements are not subject to the same temperature bias. One major advantage in using Mode-S observations is the ability to assimilate good quality temperature data at upper levels without the need for bias correction.

Temperature Observation Count



▲ *Number of aircraft temperature data assimilated binned by pressure level. Notice that temperatures from other aircraft are not assimilated at upper levels.*

Temperature Innovations



▲ *Distribution of aircraft temperature innovations (observed value minus model background). There is virtually no difference between other aircraft data and Mode-S.*

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