NOAA/NWS Aircraft-Based Observations Program

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Office of Observations
National Weather Service

National Academy Sciences
Space Studies Board
“Contrails Committee”
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Aircraft Based Observations

- Let's first tackle acronym soup
  - **ACARS** (**A**ircraft **C**ommunications, **A**ddressing, and **R**eporting **S**ystem): VHF comms/Datalink service provided by Aeronautical Radio Inc (now Collins Aerospace in Annapolis) that sends information between aircraft and ground stations.
  - **MDCRS** (**M**eteorological **D**ata, **C**ollection and **R**eporting **S**ystem): Weather portion of the ACARS data stream.
  - **AMDAR** (**A**ircraft **M**eteorological **DA**ta **R**eport): Preferred term by the World Meteorological Organization (WMO). Wind and temperature reports from commercial aircraft WMO and NWS have adopted Aircraft Based Observations as the newest term as a not to emerging "alternative" aircraft data. AMDAR are enabled by onboard avionics and software installed on factory floor at Boeing and Airbus
  - **TAMDAR** (**T**ropospheric **AMDAR**) is provided by a private company, Panasonic Aeronautics, using regional commercial air carriers and specially installed equipment.
  - **AFIRS-AMDAR** (**A**utomated **F**light **I**nformation **S**ystem-**AMDAR**)
  - **WVSS** (**W**ater **V**apor **S**ensing **S**ystem): A subset of 135 of the 3500 USA AMDAR aircraft (all on UPS and Southwest) providing an addition profile of humidity/water vapor. WVSS is a post-factory install of a sensor on AMDAR-enabled aircraft.

Some History

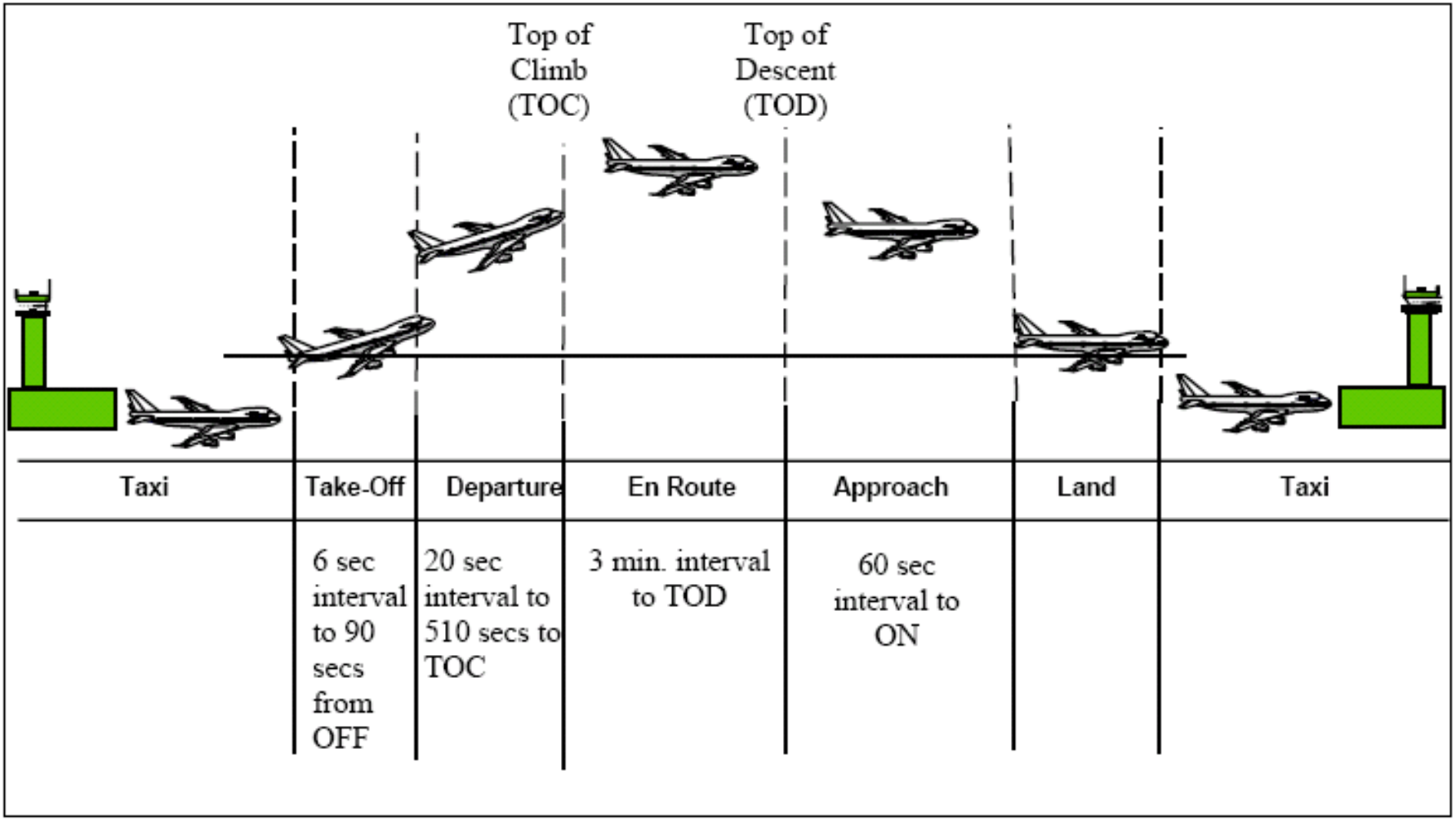
- In-situ meteorological observations from aircraft pre-date the rawinsonde by 2 decades, but it wasn't until the 1990s that developments in automated comms allowed the weather community to tap this inexpensive and ubiquitous source of data, and the airlines agreed to share it.
- From the late 1990s until 2016, the FAA held the legacy contract with Collins for procurement of AMDAR data, with reimbursable support from NWS. NWS has always held the contract for WVSS.
- In 2014, with a large infusion of "Sandy Supp" funds, NWS awarded a contract to Collins that doubled the AMDAR pie, with about ½ over the CONUS and ½ elsewhere, plus en-route data over the oceans. This included for the first time a large component of AMDAR data over South America from LATAM airlines, and en-route data ("ADS-C") on transoceanic flights at cruise altitude
- In 2017, NWS and FAA agreed NWS would combine its "Sandy Supp" contract and the FAA legacy contract into one vehicle to be awarded by NWS
- As of today, the US ABO program procures and provides via the GTS about three million AMDAR soundings per year worldwide

ABO Program Structure

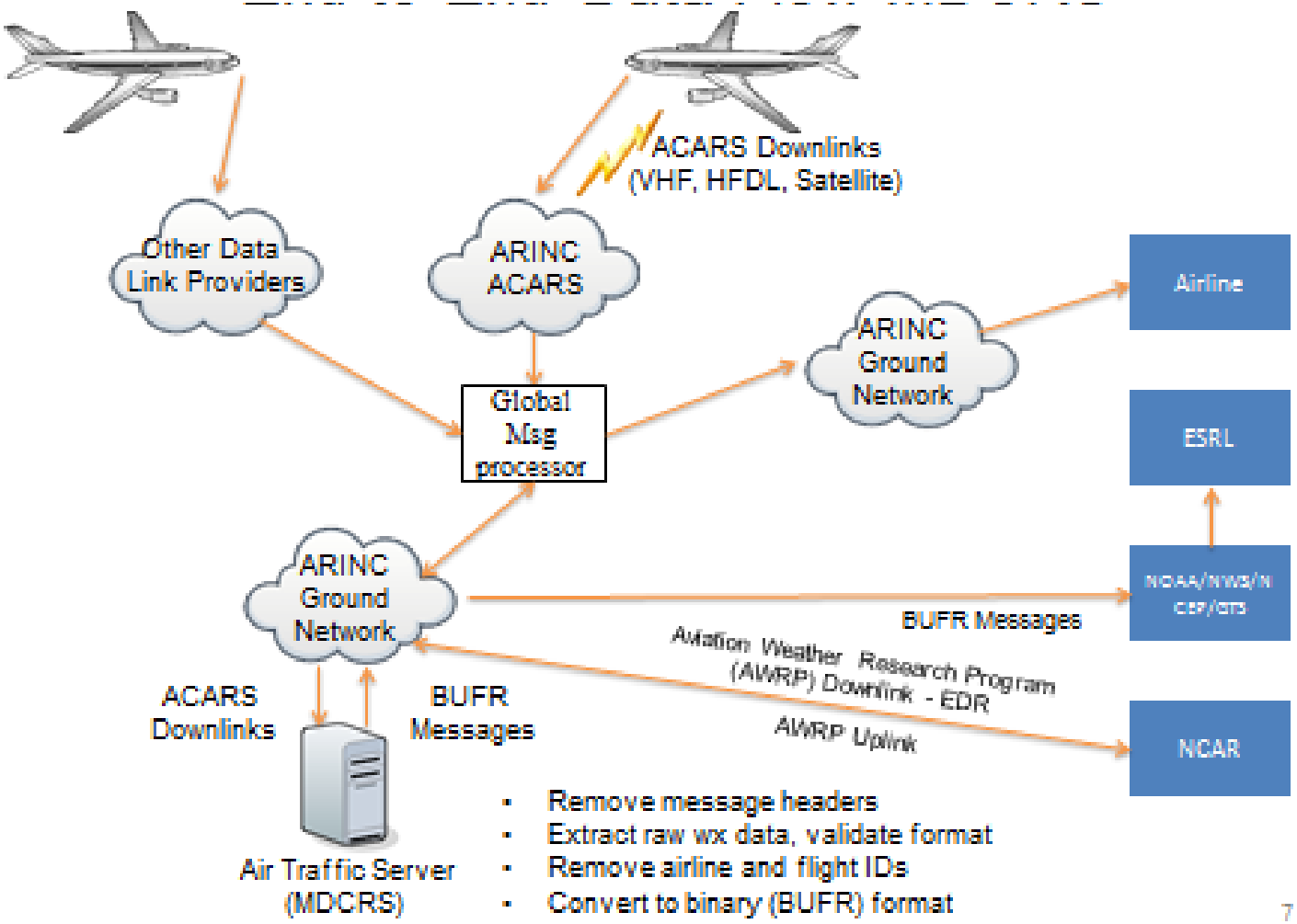
- Two main components to the ABO Program: AMDAR/MDCRS and WVSS
  - 3500 aircraft across most major US commercial airlines provide wind and temperature reports
  - A subset of 135 of the 3500 on UPS and Southwest are WVSS-equipped

- Collins Aerospace (aka ARINC) holds contracts for AMDAR and WVSS with NWS
  - Collins is the ACARS comms provider for almost all US Commercial Airlines. They own lock, stock, and barrel the comms system (VHF towers, ground networks, and related onboard avionics and software)
  - ACARS/VHF is one way commercial aircraft have air-to-ground communications with airline flight operations, ATC, and other components in the National Airspace and civil aviation system
  - Weather elements are part of each ACARS broadcast
  - Collins has subcontracting relationships with the airlines
  - At their operations center in Annapolis, ACARS messages are ingested, weather elements for AMDAR and WVSS parsed, formatted into BUFR, and transmitted to MADIS/NCO and from there into downstream NWS systems

ABO Basics


Top of Climb (TOC)
Top of Descent (TOD)
Taxi
Take-Off
Departure
En Route
Approach
Land
Taxi
6 sec interval to 90 secs from OFF
20 sec interval to 510 secs to TOC
3 min. interval to TOD
60 sec interval to ON

ABO Basics


ACARS Downlinks
(VHF, HFDL, Satellite)
Other Data Link Providers
ARINC ACARS
ARINC Ground Network
Airline
Global Msg processor
ESRL
ARINC Ground Network
NOAA/NWS/NCEP/GTS
BUFR Messages
Aviation Weather Research Program (AWRP) Downlink - EDR
AWRP Uplink
ACARS Downlinks
BUFR Messages
NCAR
Air Traffic Server (MDCRS)
Remove message headers
Extract raw wx data, validate format
Remove airline and flight IDs
Convert to binary (BUFR) format

MDCRS

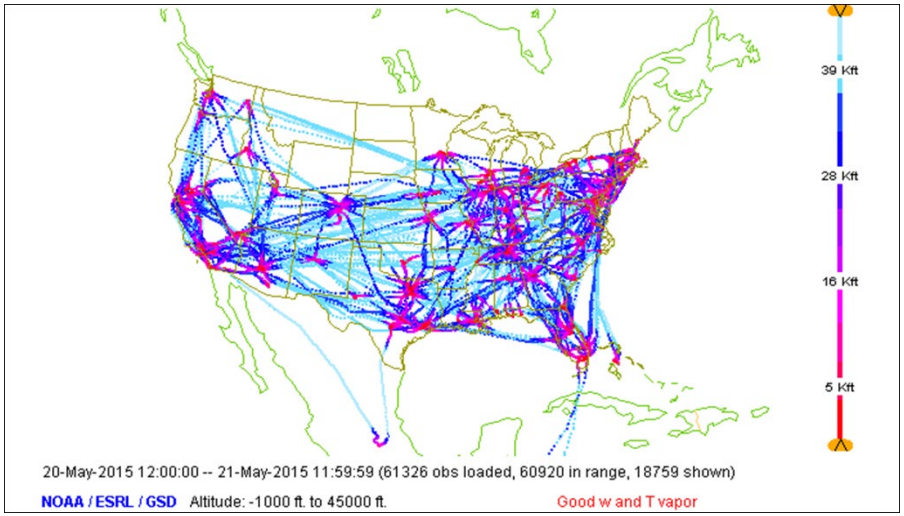
- FAA and NWS share funding of operation of MDCRS for the US-base.
- Collins (Formerly ARINC) has provided the service since 1991 for the MDCRS shared funding contract, with periodic open competitions. Data is not shared in real time with others outside of the airlines, FAA and NOAA, and other WMO member states (NMHSs).
- Additionally NWS supports procurement of OCONUS and ADS-C data via Collins on the MDCRS contract – “Expansion Contract” since 2014.
- Up to 3.2M wind and temperature “soundings” per year worldwide

WVSS-II

Photos courtesy of FlightAware.com

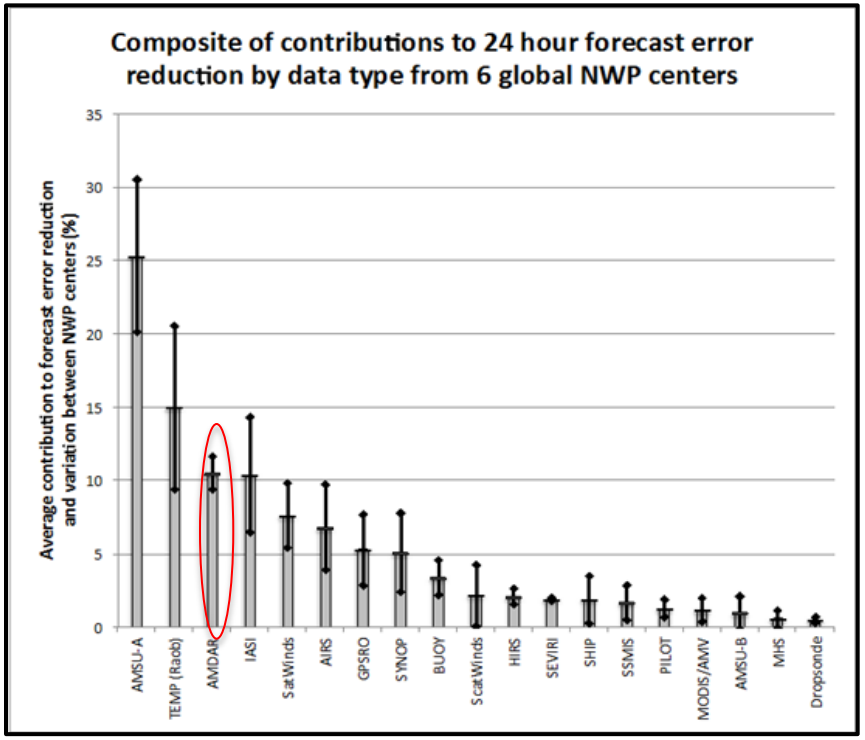
WVSS Basics

- Studies in the 1990s showed that relative humidity measurements from commercial aircraft were feasible and accurate for meteorological applications
- In a partnership between NWS and industry, a sensor called the "**W**ater **V**apor **S**ensing **S**ystem" (**WVSS**) using a tunable diode laser was developed in the early 2000s with technology repurposed from the oil and gas pipelines industry
- From 2007 – 2012 NWS worked with Collins, Southwest, UPS, and the FAA to address regulatory issues and install 135 WVSS sensors on Southwest and UPS
- NWS continues to buy the data from Collins and most of the sensors continue to function with low maintenance, providing high quality data.



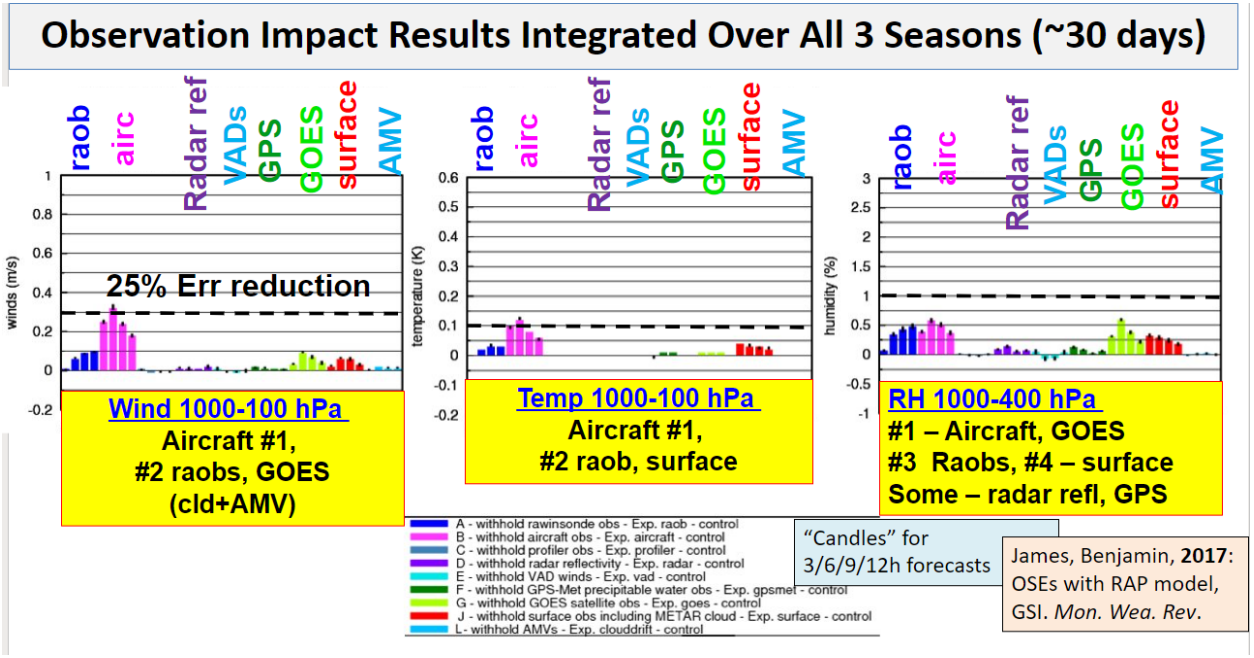
Importance to Global NWP

- WMO in partnership with the world's major global NWP centers showed that when averaged across global modeling at UK Met Office, NCEP, ECMWF, Meteo France and the NASA Global Modeling and Assimilation Office, and using a pan-variable energy metric, AMDAR is the 3rd most important contributor to global model forecast skill.



Importance to Regional and Local NWP

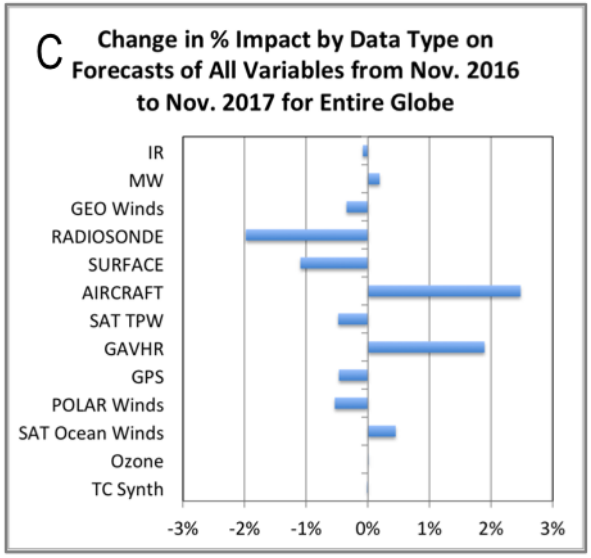
- James and Benjamin (2017) showed that aircraft obs, when benchmarked against the other primary observing systems used as inputs for these models (radar, weather balloons, ground-based GPS water vapor, surface observations, and satellites of various bandwidths and orbits), are unambiguously the most important source of data for improving model skill and reducing forecast error for all three of the primary meteorological variables of NWP: temperature, wind, and humidity. Their results hold across all seasons, over a long duration, and over the depth of the troposphere.

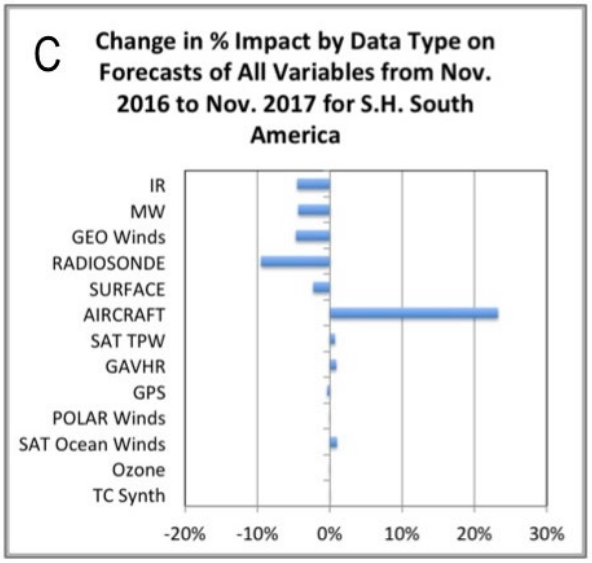


Impact of Additional AMDAR

- Pauley and Petersen (2017), using the Navy's Fleet Numerical Meteorology and Oceanography Center global model provided a clean illustration of the high impact of this data on the skill of global NWP. Running the model for one month before the provision of LATAM, and the same calendar month one year later (which bracketed a time with no other significant changes to the overall observing system or the FNMOC global NWP model), we see that the pan-variable impact globally was +2.5%, appreciable for any addition of observations to the overall global suite. But when examined for the Southern Hemisphere, model impact increased by an astounding 25%.

- Small investment, huge return



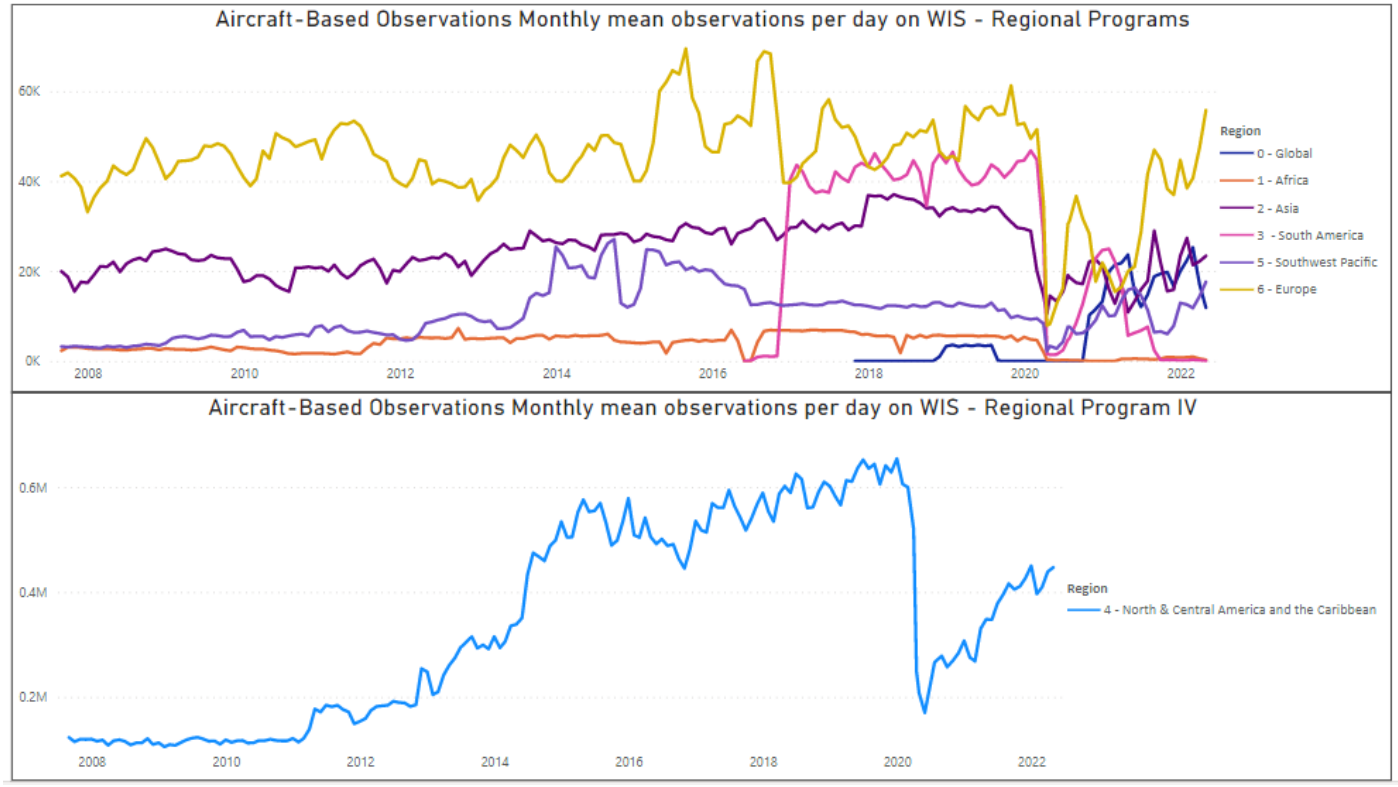


Importance to NWP: Summary

- ABO are a high ranking source of observational data for the skill of Global NWP;
- ABO are the most important source of observations for the skill of high resolution, regional and local NWP;
- As the global volume of ABO grows, their impact on model skill grows: we have not reached the point of diminishing returns;
- Strategic addition of ABO in data void regions of the globe can have outsized and astonishing impacts on model forecast skill.

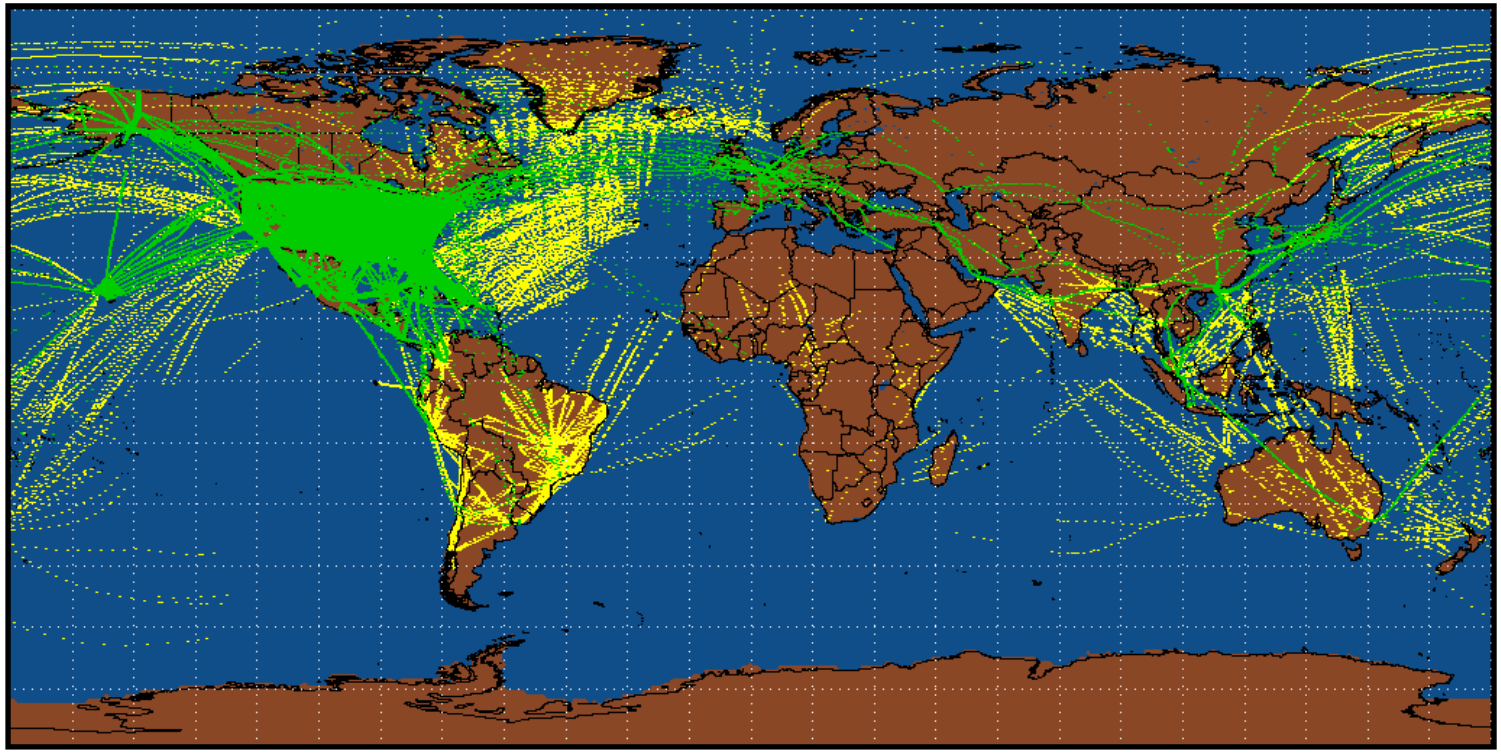
Worldwide Growth of ABO

Beginning in 2014, with disaster supplemental funds from Hurricane Sandy, NOAA effectively began doubling the amount of AMDAR reports it had provided until then.



OCONUS Grwoth

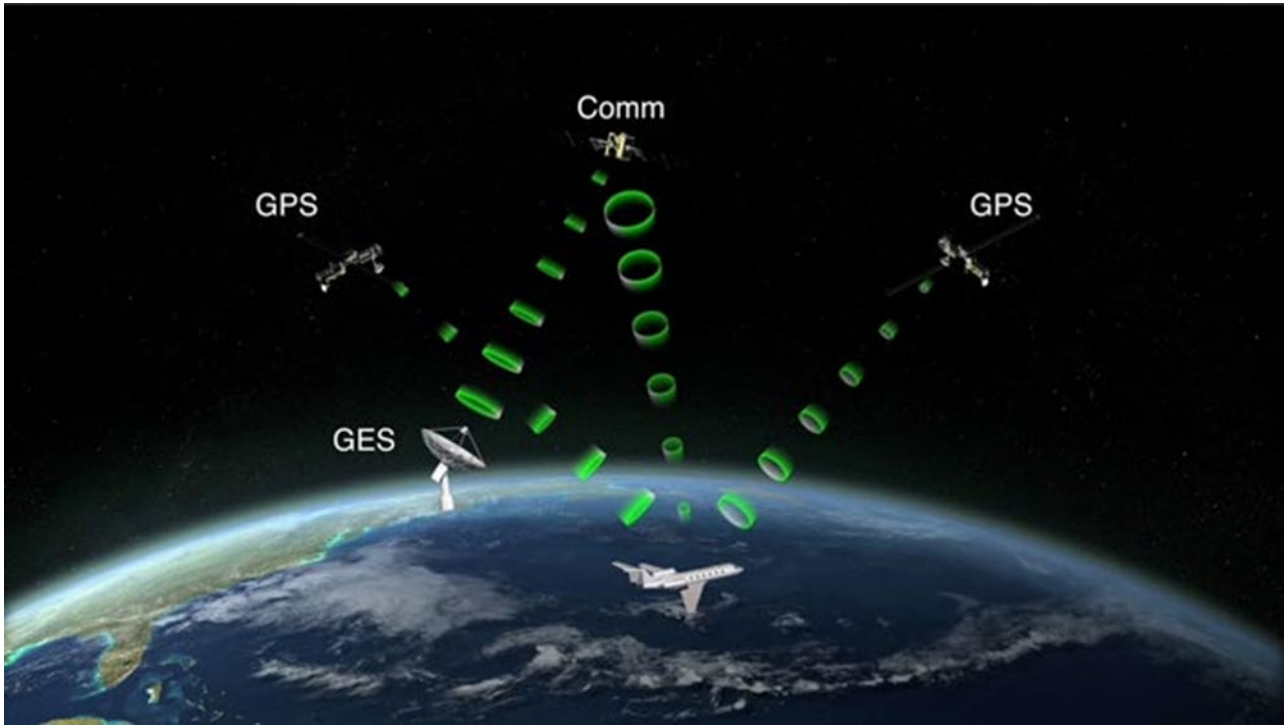
In 2016, this came to include LATAM over South America (up to 1000 profiles daily). These funds were intended to expire after 3 years but NOAA has managed (until now) to continue providing the resources.



"Base" MDCRS with appropriated funds (primarily North America)

Reports added with "Sandy" funds

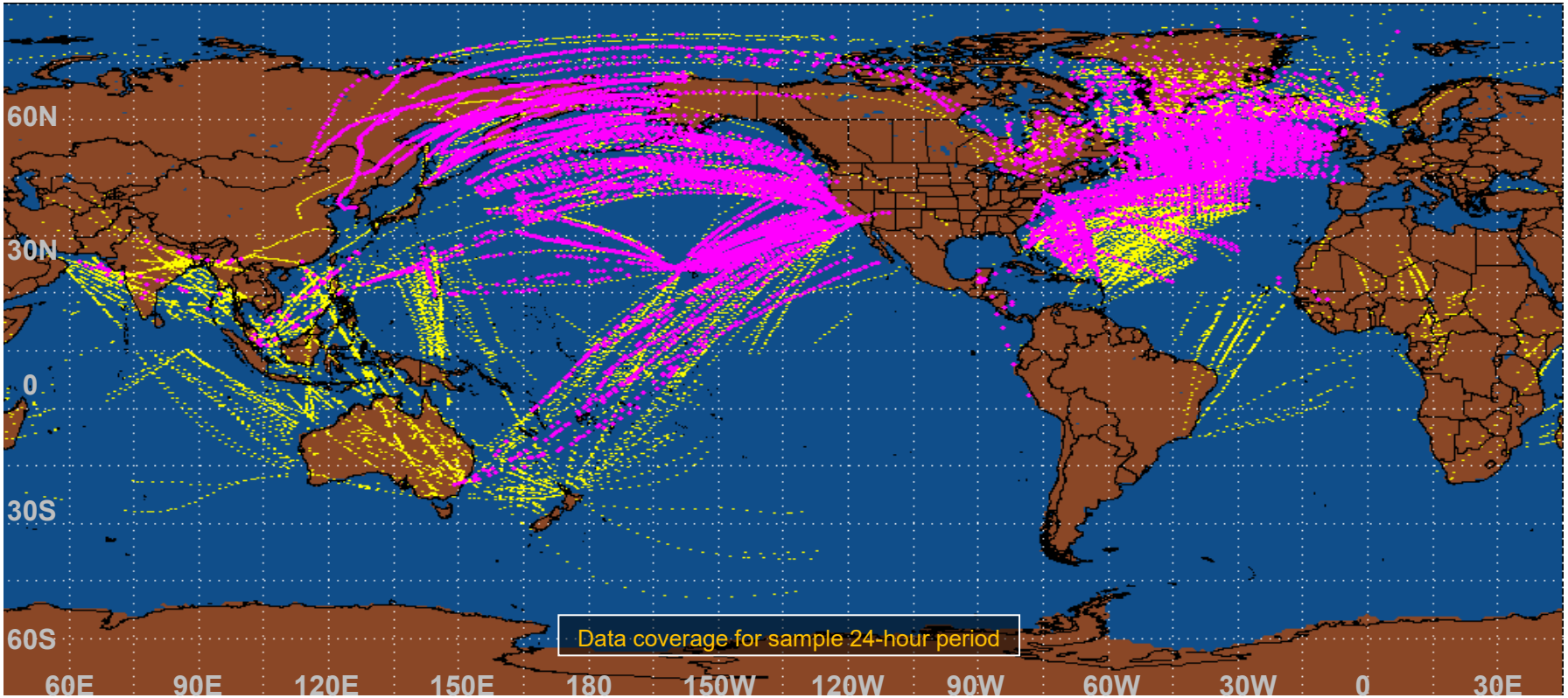
ADS-C



ADS-C messages provide aircraft positional information and meteorological data such as flight level environmental air temperature and winds

ADS-C

At about the same time NOAA began provision of ADS-C subject to its partner airlines and data quality.



ADS-C data originating from U.S. commercial carrier aircraft

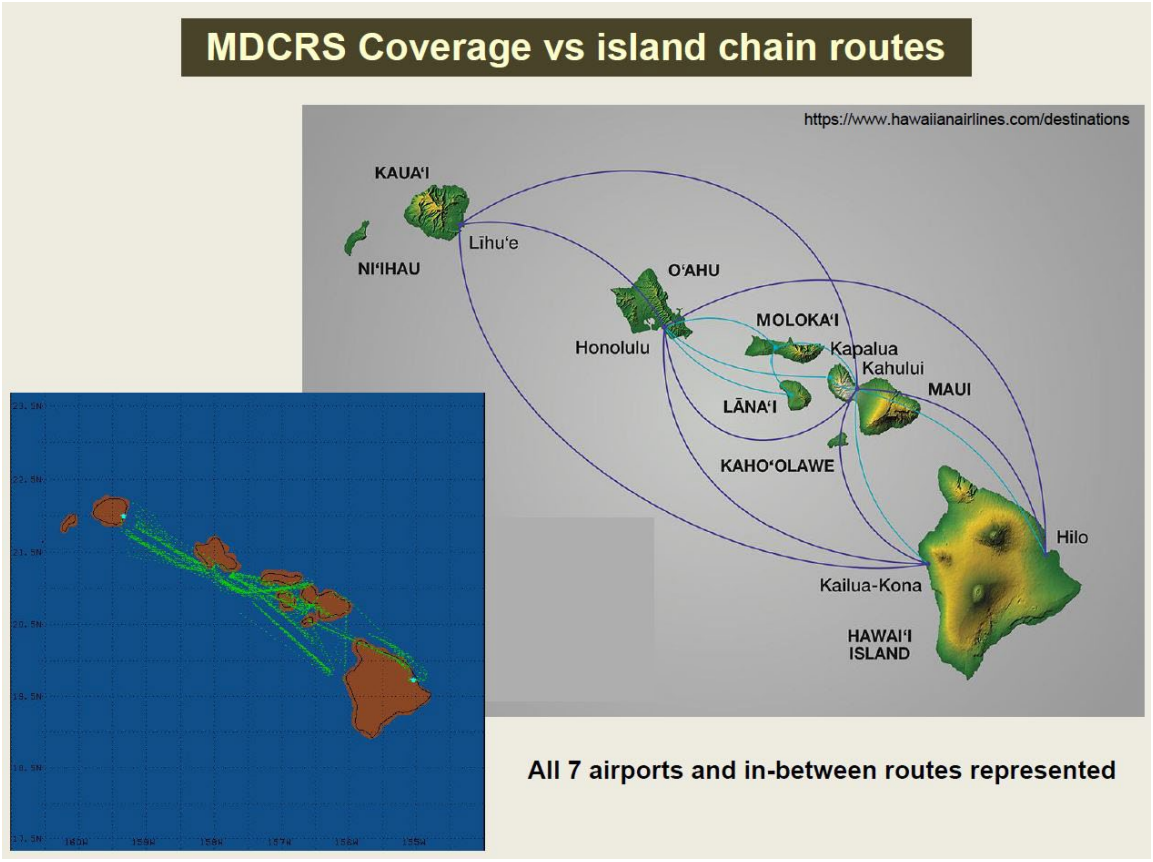
ADS-C data originating from non-U.S. commercial carrier aircraft

AeroMexico (Supported by USA)

Mexico

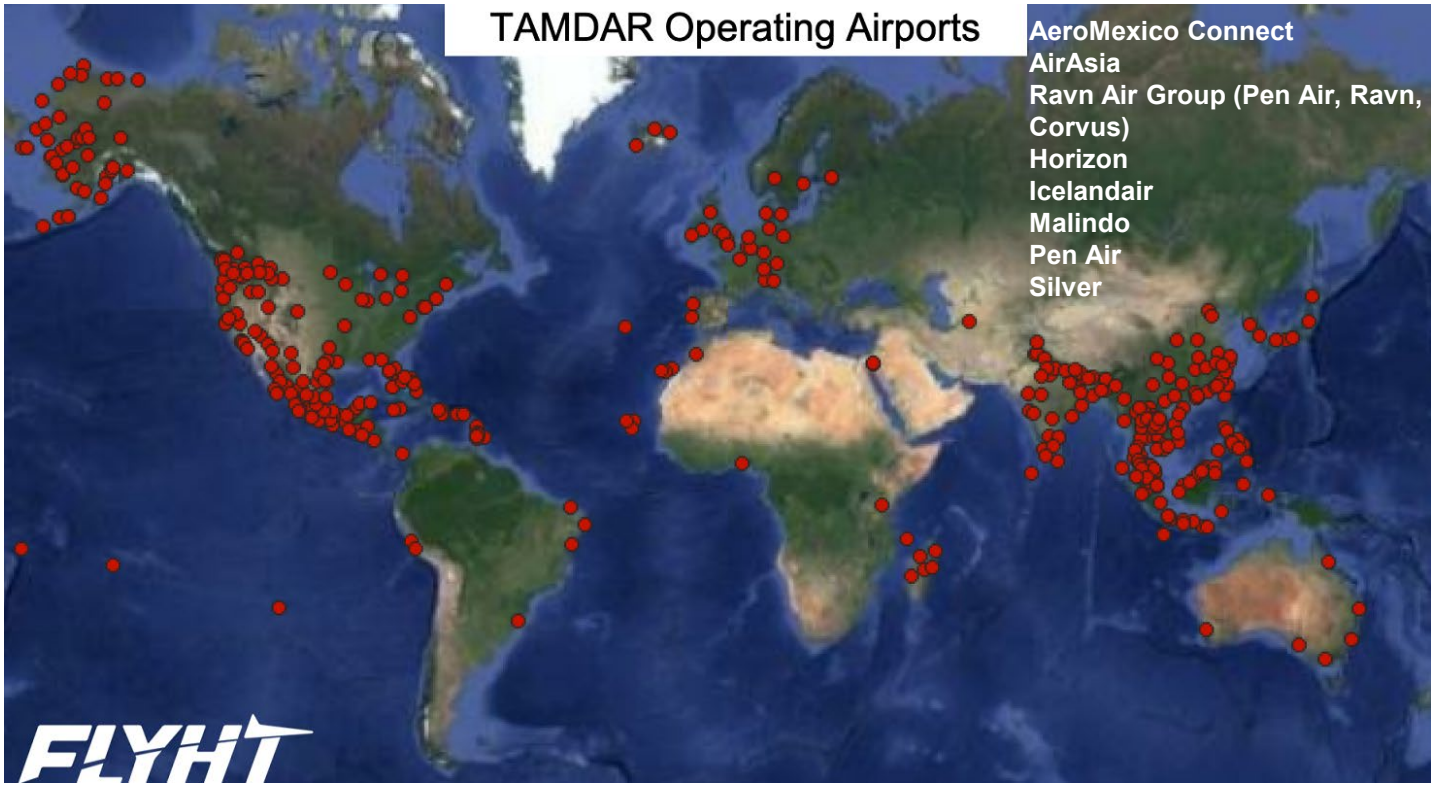
Hawaiian Airlines

Later, these funds were used to sustain the provision of AeroMexico, and add Hawaiian Airlines which provides ~300 profiles per day around all islands and airports. Not much data but highly valuable given data void.



National Mesonet Program ABO

Third Party Data: TAMDAR. Beginning in 2016 the USA (again) began to obtain TAMDAR via contract, but subject to NOAA-only data rights. In 2020, after FLYHT acquired TAMDAR from Panasonic, and motivated by COVID-19, these data were provided to all NMHSs. Now we have secured the funds to continue this provision for the foreseeable future.



National Mesonet Program ABO

Third Party Data: AFIRS-AMDAR. Subsequent to the 2018 WMO-sponsored pilot with Air New Guinea, and in light of COVID-19, FLYHT made all AFIRS-AMDAR free and open for one year, and then NOAA provided the resources to continue that provision to all NMHSs for the foreseeable future.

Figure 2: AFIRS global coverage for September 2021. The image clearly
over Canada, eastern Europe, Asia and Africa (court

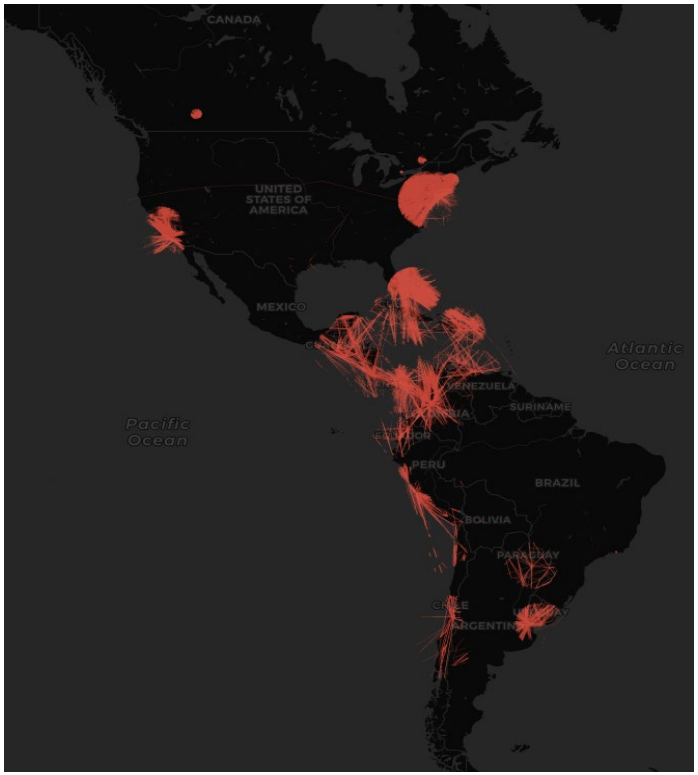
AFIRS-AMDAR (Flyht) a/c and Airlines

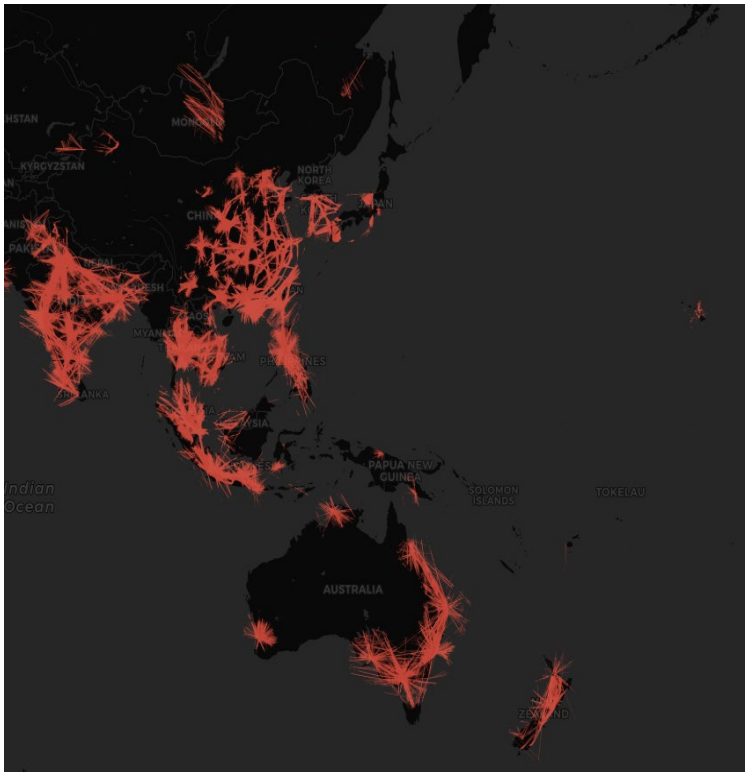
Third Party Data: AFIRS-AMDAR airlines and aircraft

Airline	Number of Aircraft	Aircraft Type	Region
ABX Air	4	B767-300	US, Colombia, Puerto Rico, Germany, UK
AeroContractors	3	B737-500, B737-400	Africa (Nigeria)
Air Astana	4	B757-200	Kazakhstan
Air Niugini	8	B737-800, B737-700, B767-300, F70	New Guinea, Eastern Australia, Phillipines
Air Peace	12	B737-300, B737-500, B737CL	Nigeria
Amerijet International	6	B767-300, B767-200	North America, Central America, Northern S. America
Azur	36	B737NG, B757-200, B767-300, B737-900	Ukraine, Russia
Banco de Mexico	1	CRJ-700	Mexico
Canadian North	10	B737-300	Northern Canada
Cayman	3	B737-300	Cayman Islands
Chengdu Airlines	1	A320	China
China Express	41	CRJ 900	China
DHL	6	B767-200	Saudi Arabia, India
Dow Chemical	2	CRJ-900LR	U.S./Canada
Estafeta Carga Aerea	4	B737-300, B737-400	Mexico
First Air	1	B737-300	Canada
IBOM	3	CRJ 900	Nigeria
Jordan Aviation	5	B737-300, B737-400, A320	Jordan
LIAT	10	ATR 72-600, ATR 42-600	Carribean
Nile Air	7	A320, A321	Egypt
Okay Airways	13	B737-800	China
Omni Air International	15	B767-200, B767-300, B777-200	US, South America, South Korea, Japan, Saudi Arabia, Germany, Ireland, Bulgaria
Pacific Air Express	1	B757-200	Australia
Skytrader	1	A319	Australia
Texel Air	3	B737-300, B737-700	Bahrain
Uganda	4	CRJ 900	Uganda

Commercial Mode-S

- Mode-S? We are in receipt of global feed from FlightAware, and that could be made available to all NMHSs, but need to choreograph next steps with EMADDC and Met Office. Ironically, ubiquitous about the globe with the exception of a few locations CONUS

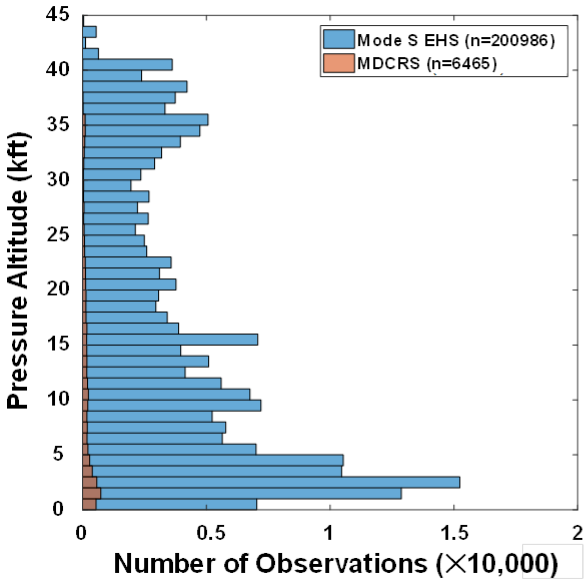


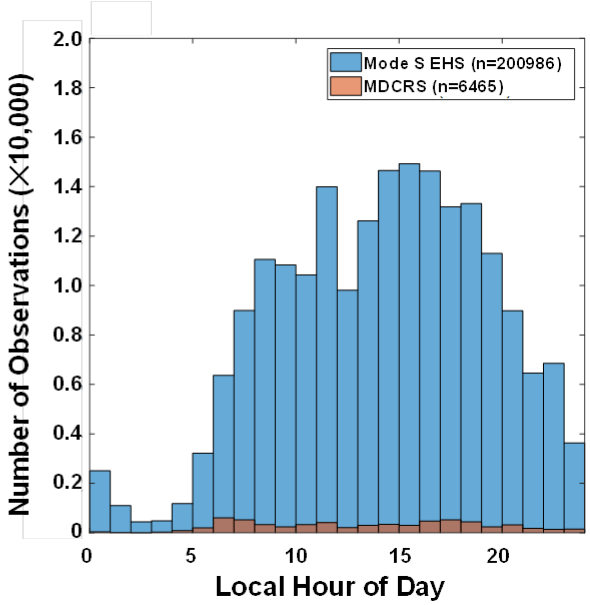


WMO OMM

Mode-S

- Mode-S: but where it exists in the RA-IV, it exceeds AMDAR by an order of magnitude





Nov 1 2017 24 hours of data under MIT MODSEF radar umbrella.

Mode-S

- Mode-S ubiquitous everywhere but RA-IV
- Possible solution?

MIT Lincoln Laboratory Mode S Experimental Facility (MODSEF)

Portable Aircraft-Derived Weather Observation System (PADWOS)

Future Plan

- Consider reallocation of potentially redundant data over CONUS to OCONUS profiles (both USA and non-USA airlines)
- Maintain TAMDAR, maintain and grow AFIRS-AMDAR with availability to all NMHSs
- Few airlines remaining for traditional AMDAR over USA: pursue growth in non-traditional sources
- Pursue growth of WVSS to the benefit of all:
  - New Contract with FLYHT for WVSS installations on AFIRS-AMDAR aircraft (significant congressional attention on this and ABO/commercial obs in general)
  - Watching developments for a new generation sensor to increase precision to <10ppmv
  - Yours truly to be involved in various interagency and international efforts to support contrails prediction and mitigation

FIN

Thank You

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