Opportunities to Leverage Aircraft-Derived Atmospheric Observation Data

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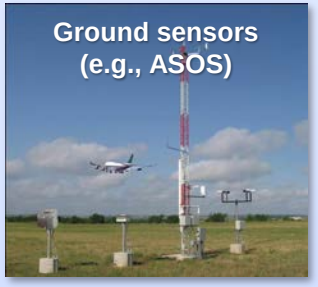
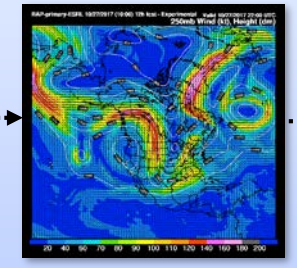
Motivation

Atmospheric observations are critical to aviation activities

Sample Observation Systems



Strategic Activities



Weather Models

Sample applications

Flight Planning

Traffic Management

Tactical Activities

Real-time Tools

Sample applications

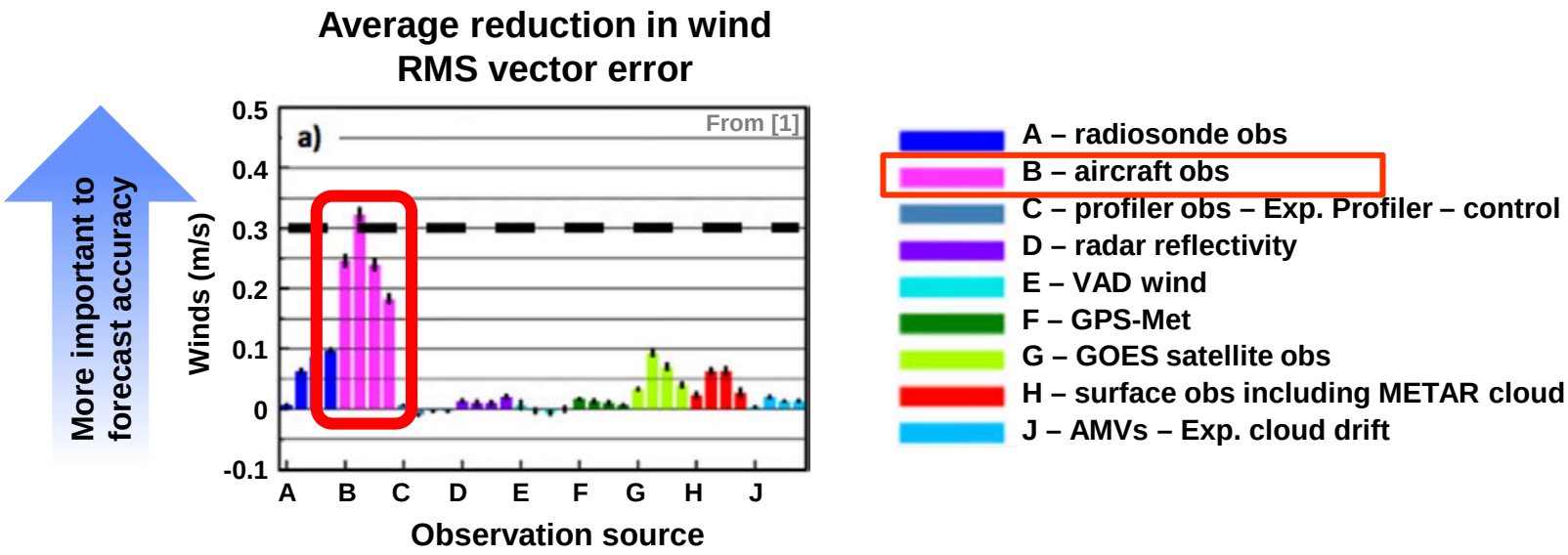
ATC Decision-Making

Pilot Decision-Making

ASOS = Airport Surface Observation System

Aircraft-Derived Observation Usage in Forecasts

Atmospheric observations used to best represent initial conditions in the forecast volume above the surface

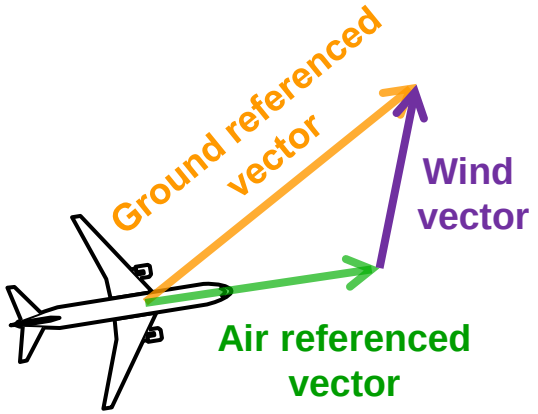


Aircraft-derived weather observations are the most important input in wind and temperature forecast accuracy

[1] James, E., and S. Benjamin, 2017: Observation system experiments with the hourly-updating Rapid Refresh model using GSI hybrid ensemble/variational data assimilation. Mon. Wea. Rev. doi:10.1175/MWR-D-16-0398.1, in press.

Aircraft-Derived Observations

- **Aircraft measurements can be used for atmospheric observations**
- **Meteorological Data Collection & Reporting System (MDCRS) is current airborne source**
- **"ADS-B Weather out" could enable greater access to aircraft-based observations, but not for foreseeable future**
- **Mode S Enhanced Surveillance (EHS) widely available now**
  - **Can act as near-term surrogate for ADS-B Wx Out**



ADS-B = Automated Dependent Surveillance – Broadcast

Observation System Comparisons

Observation Source	Horizontal Coverage	Vertical Range	Update Period	Latency	Comment
ASOS	900 sites many at airports	Surface only	20 mins/ 1 min	<1 min	Used primarily for airport operations
Radiosondes	69 sites in CONUS	Ground to >100 kft	12 hours	< 2 hrs	Used primarily for forecast input data
MDCRS	Limited fleet coverage (~20% current US fleet)	Ground to typical cruise altitudes	6 secs ground, 1 min ascent/ descent 7 mins cruise	7-60+ mins, Average is 17 mins	Used primarily for forecast input data
Mode S EHS	Growing fleet coverage (>50% current US fleet)	Ground to typical cruise altitudes	4.8-12 secs	Seconds	Useful for forecast & real-time operations
ADS-B Wx Out (future)	None now, could be meaningful % in future	Ground to typical cruise altitudes	~10 secs	Seconds	Specifications not planned until at least 2019

Aircraft-Derived Observations

Opportunity to assess enhanced aircraft-derived observations via Mode S EHS to guide development of future applications and ADS-B Weather specifications

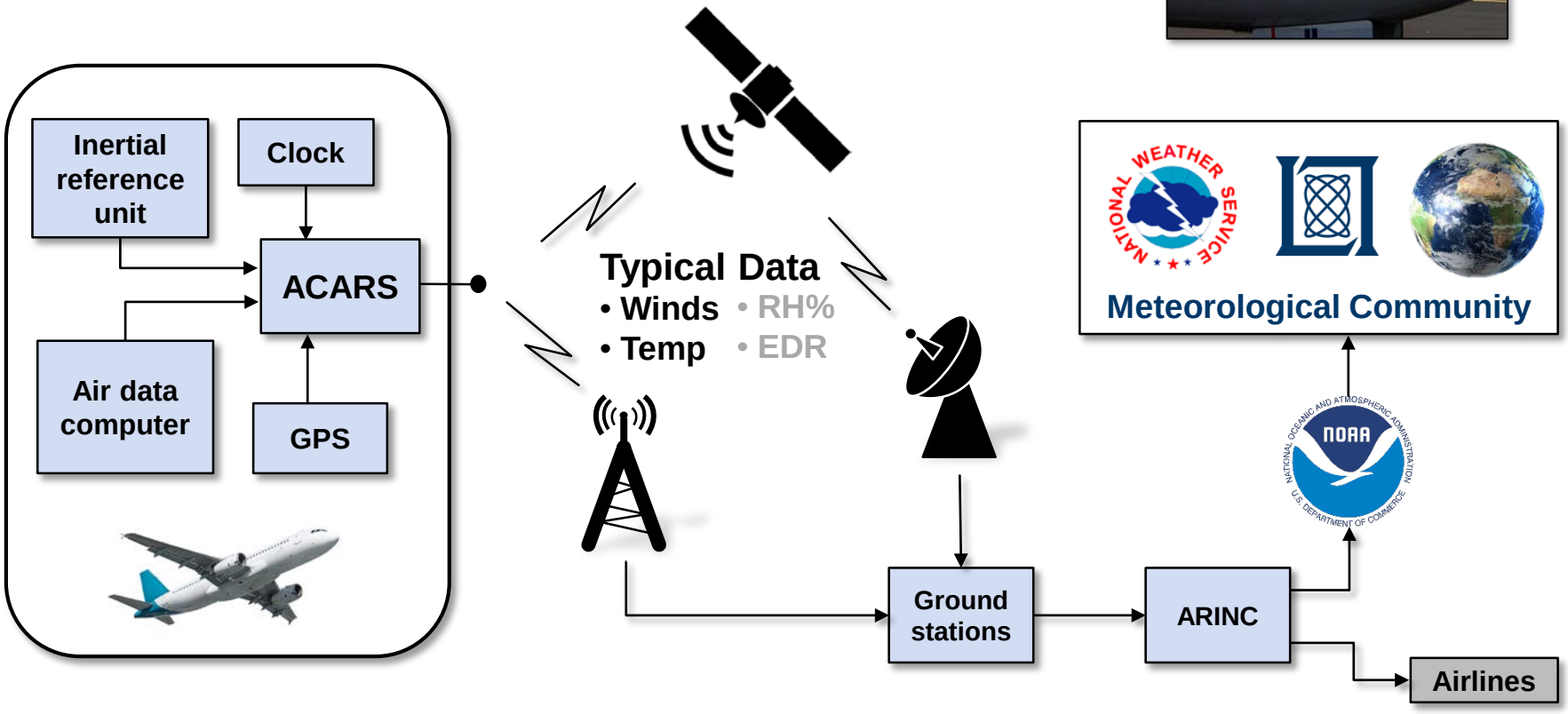
ASOS = Airport Surface Observation System
MDCRS = Meteorological Data Collection & Reporting System
Mode S EHS = Mode S Enhanced Surveillance

Outline

- **Background**
- **Current Aircraft-Derived Observation Systems**
- **Comparison of MDCRS & Mode S EHS Aircraft-Derived Observation Data**
- **Recommended Next Steps**

Current System Characterization

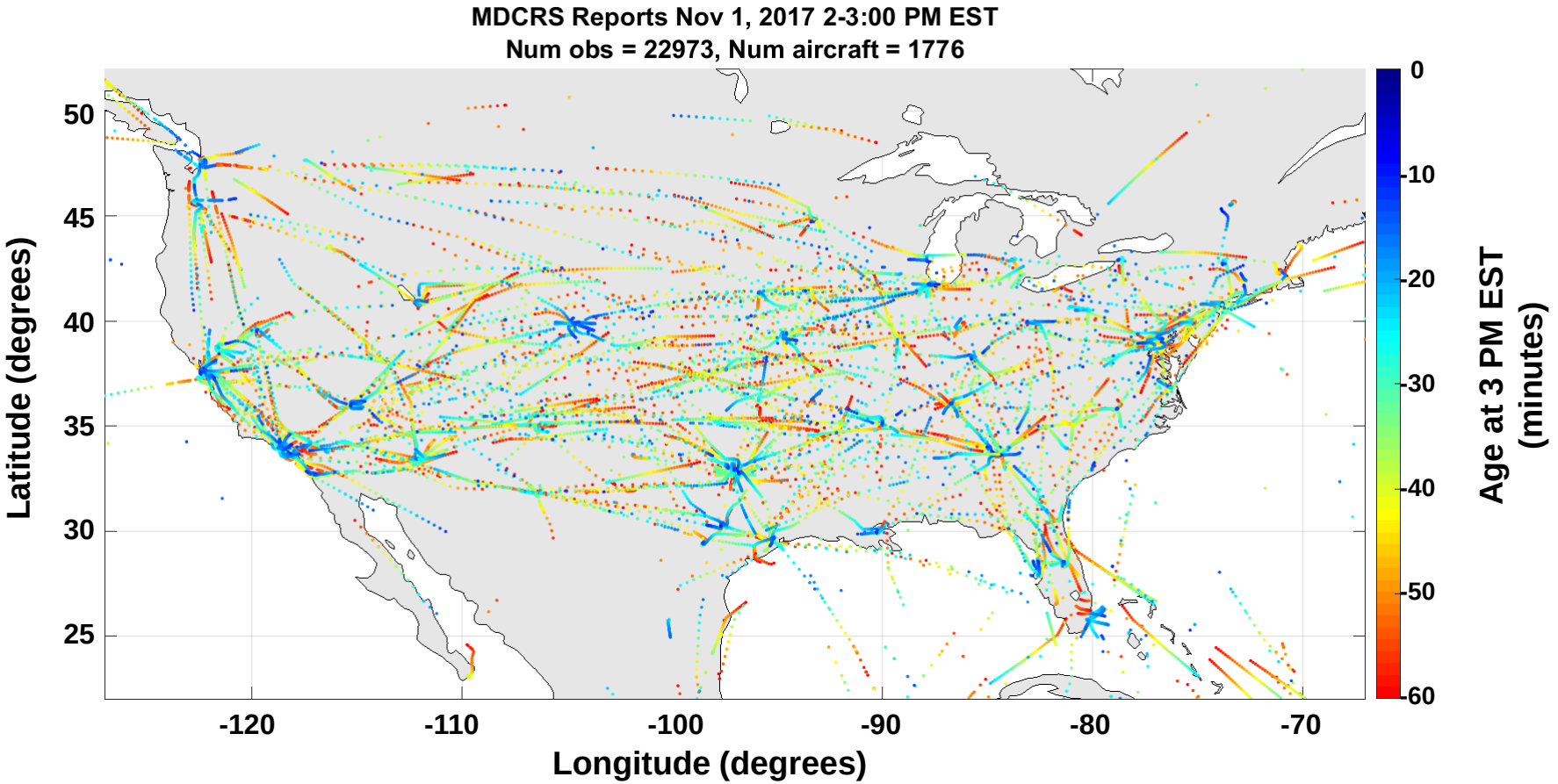
- MDCRS: North American, 11 airlines reporting
- E-AMDAR: Europe, 14 airlines reporting



E-AMDAR = European Aircraft Meteorological Data Relay
ACARS = Aircraft Communications Addressing and Reporting System
RH = Relative Humidity EDR = Eddy Dissipation Rate

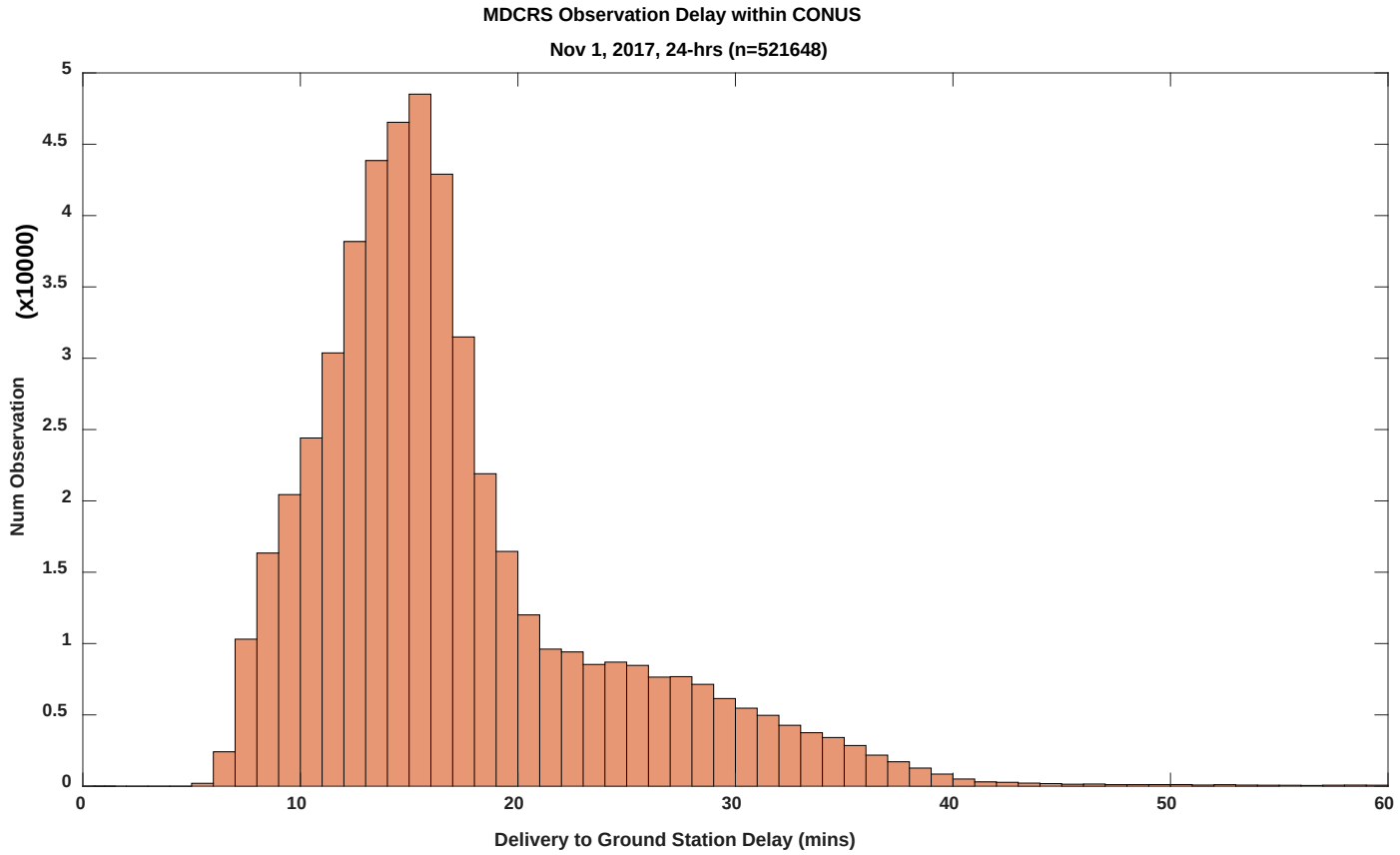
MDCRS Spatial/Temporal Coverage

- **Current sampling across country is varied and limited to a small percentage of commercial flights/routes**



MDCRS Latency

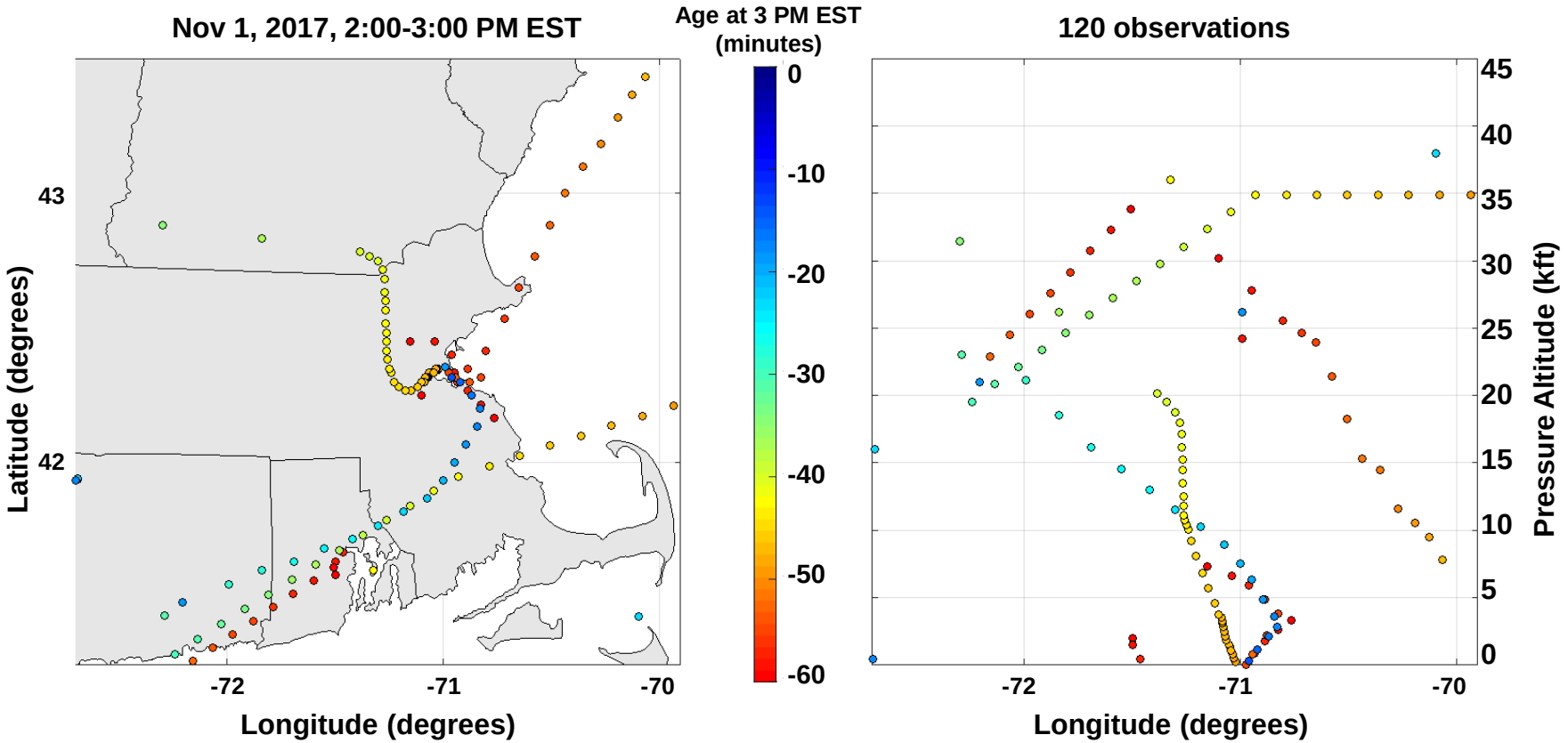
- **MDCRS data are delayed due to batching before transmitting**
  - **Average observation delay = 17 minutes**



Not appropriate for near real-time applications

Sample MDCRS Coverage Around Boston

At BOS, about 5% of scheduled flights report MDCRS data



Limited MDCRS data available for forecasting and real-time applications: opportunity to leverage Mode S EHS observations

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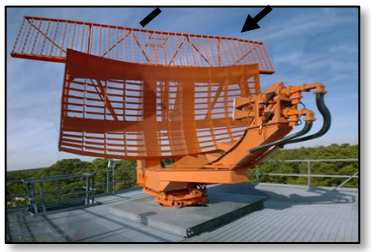
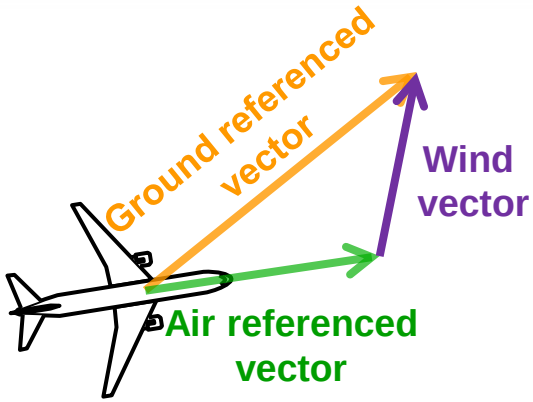
Mode S EHS Based Observation System



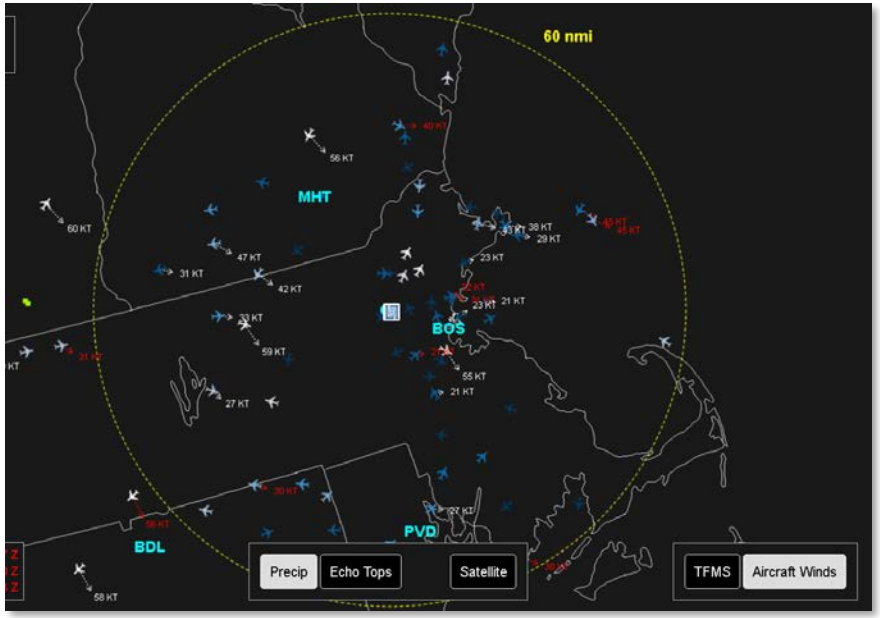
4.8 or 12 secs update rate



Register	Content	Comment
0x50	• Ground speed • True air speed • Roll angle • Track angle	Used to estimate • Wind speed • Wind direction • Temperature
0x60	• Mag heading • Mach • Altitude rate	
0x44	• Wind speed/dir • Temperature	Only 5% of EHS A/C populate

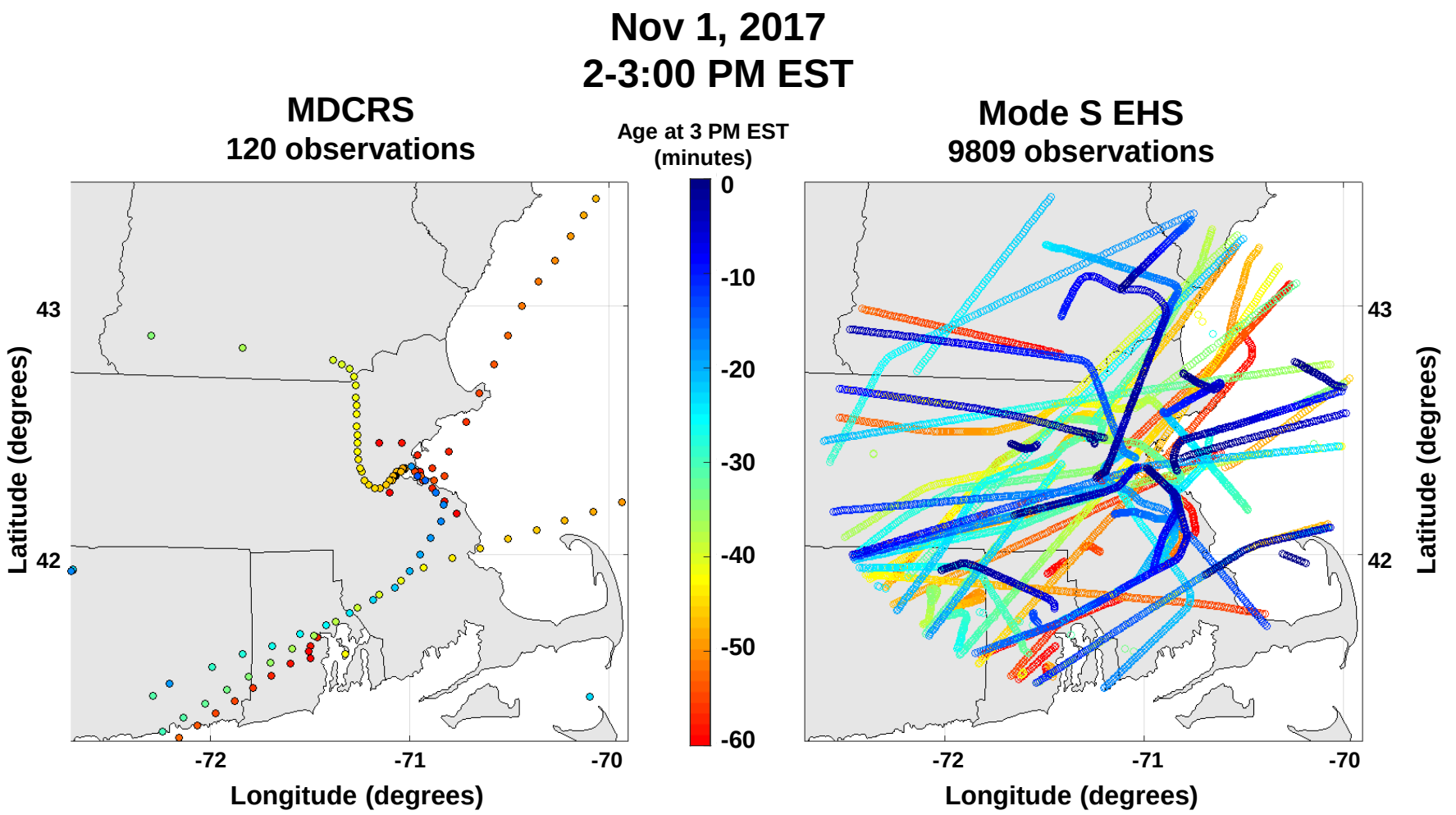
Lincoln Mode S EHS Aircraft-Derived Observation Evaluation

- **FAA Mode S radars do not currently interrogate relevant registers***
  - **Could do so with simple adaptation modifications**
- **Lincoln MODSEF has been adapted to interrogate aircraft within range (60 nmi radius)**
  - **Data streaming started March 8, 2017**



*FAA's Fremont Valley BI6 radar at Edward's AFB, which feeds High Desert TRACON (E10), conducts EHS interrogations

Comparison of MDCRS & Mode S EHS Observations Around KBED/KBOS



>80x increase in atmospheric observations with Mode S EHS vs MDCRS in this case

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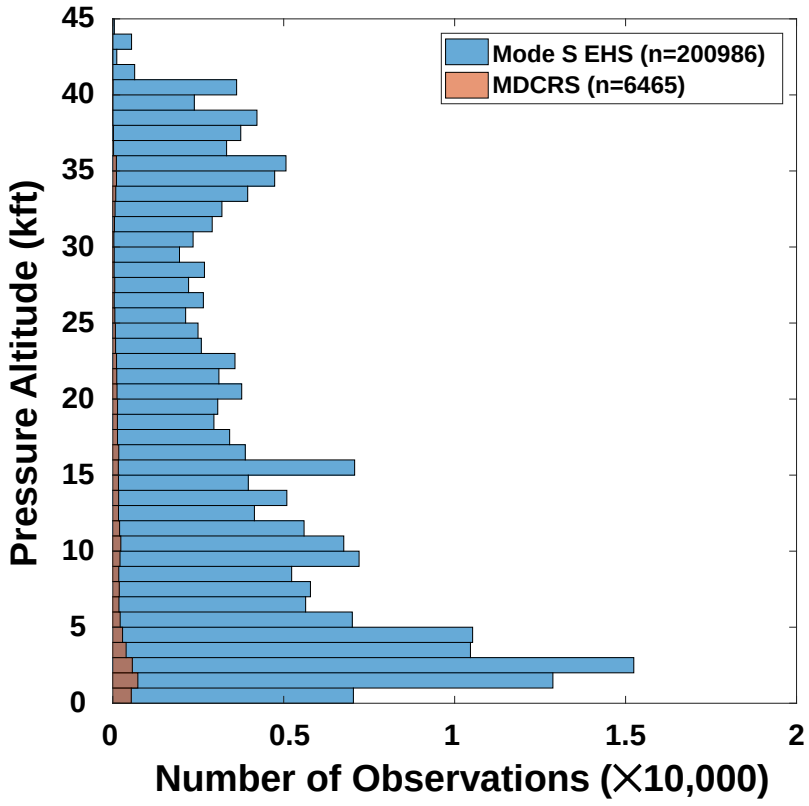
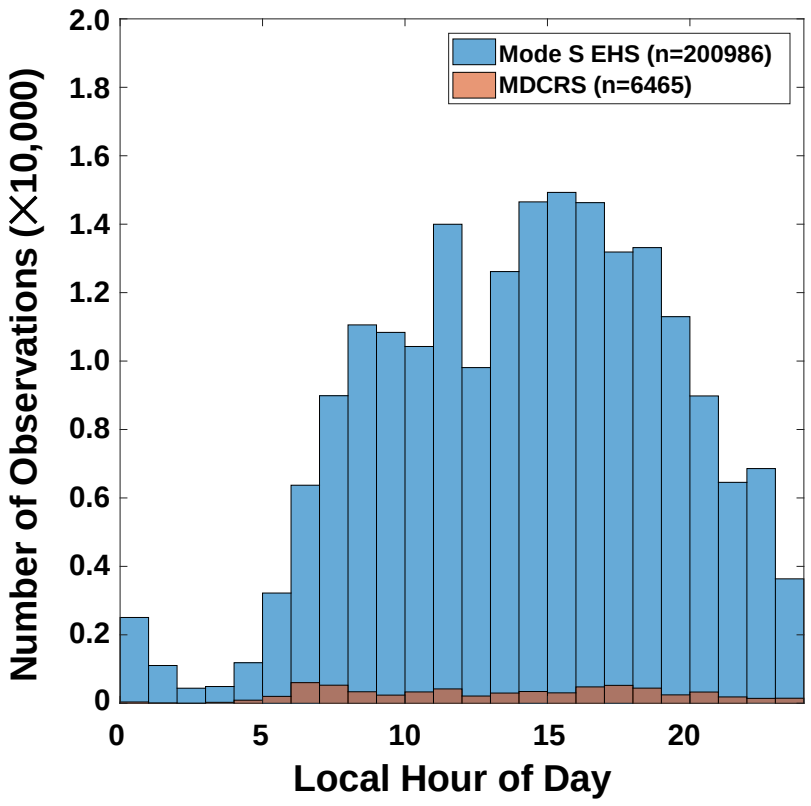
Comparison of MDCRS & Mode S EHS Observations Around KBED/KBOS

Nov 1, 2017
Observations across 24 hours

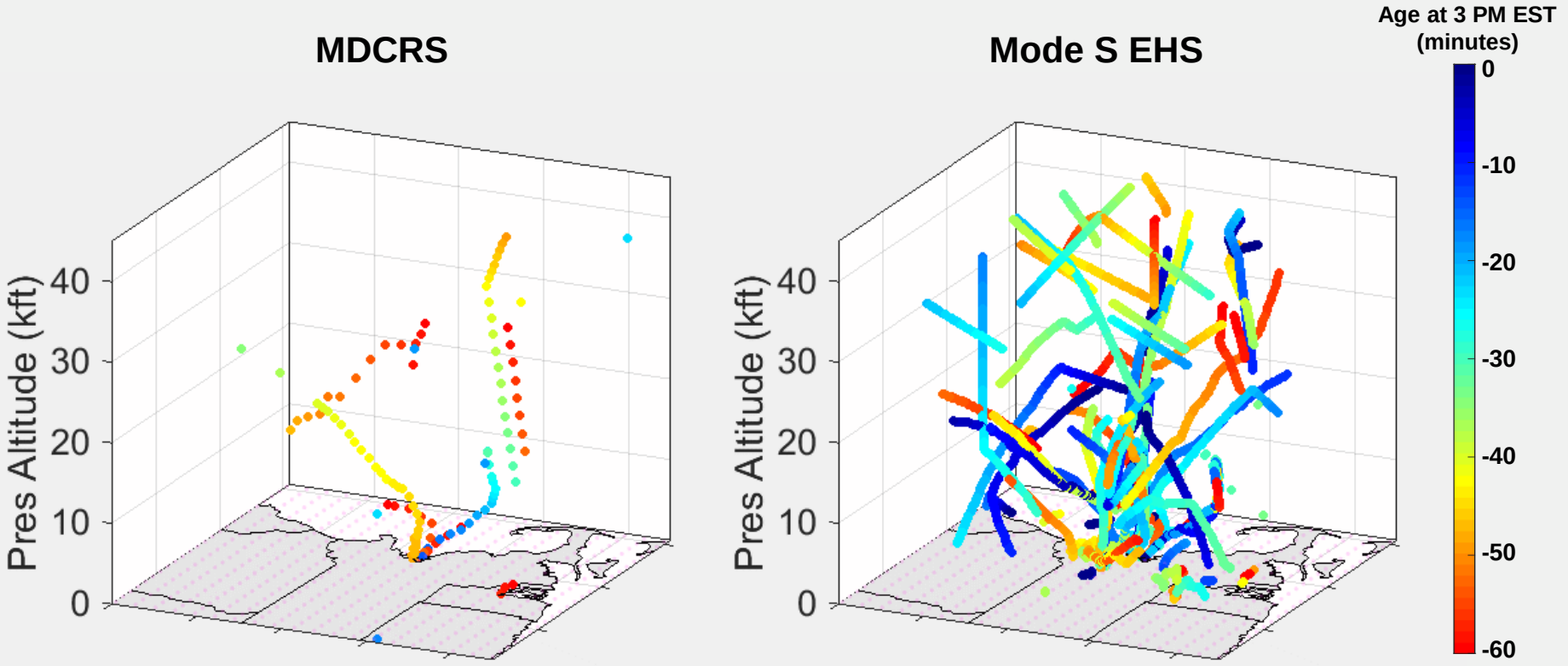




Significantly increased time and altitude coverage with Mode S EHS

MDCRS & MODSEF Observations Around KBED/KBOS

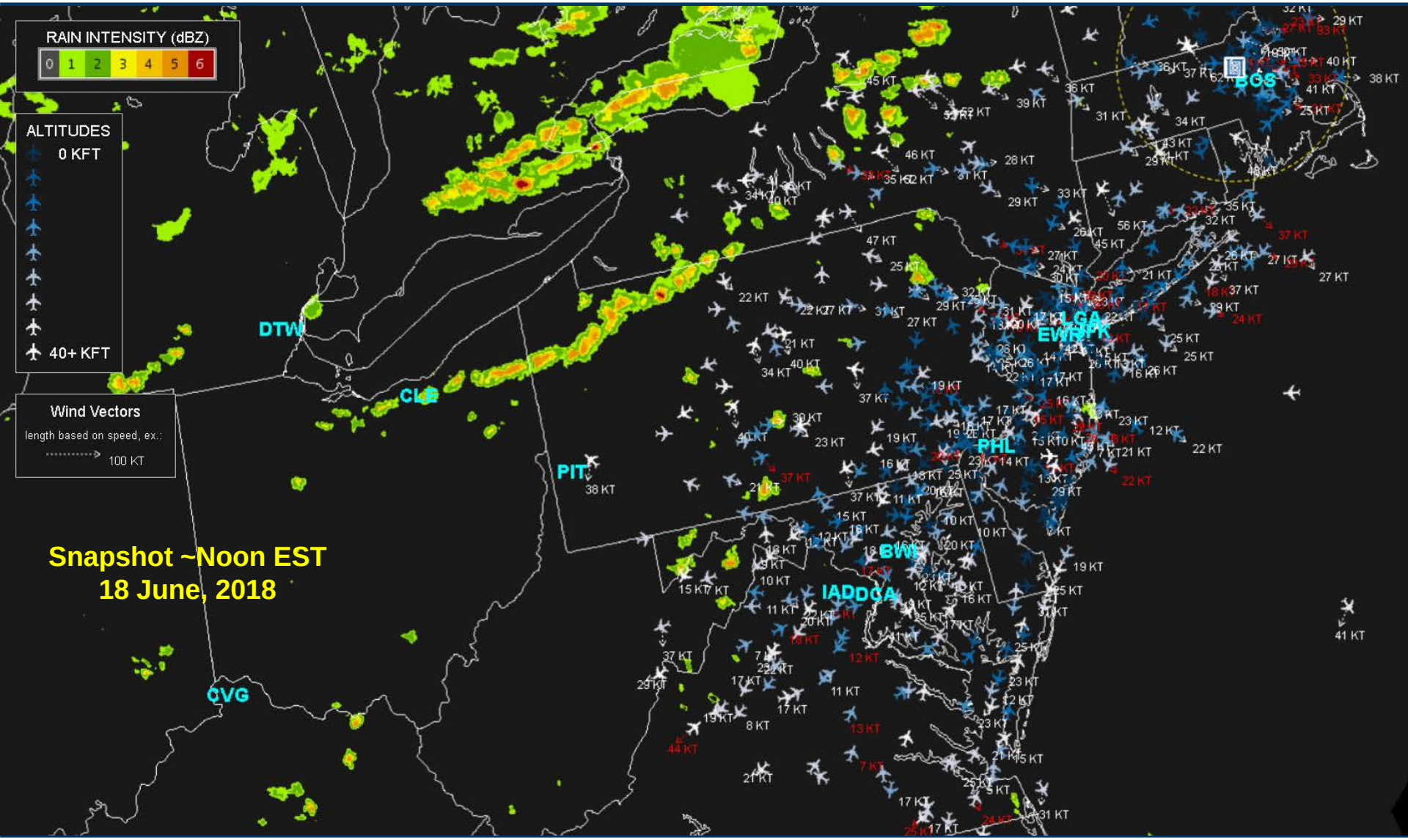
Magenta points in figures are RAP model grid points initialized from observation data



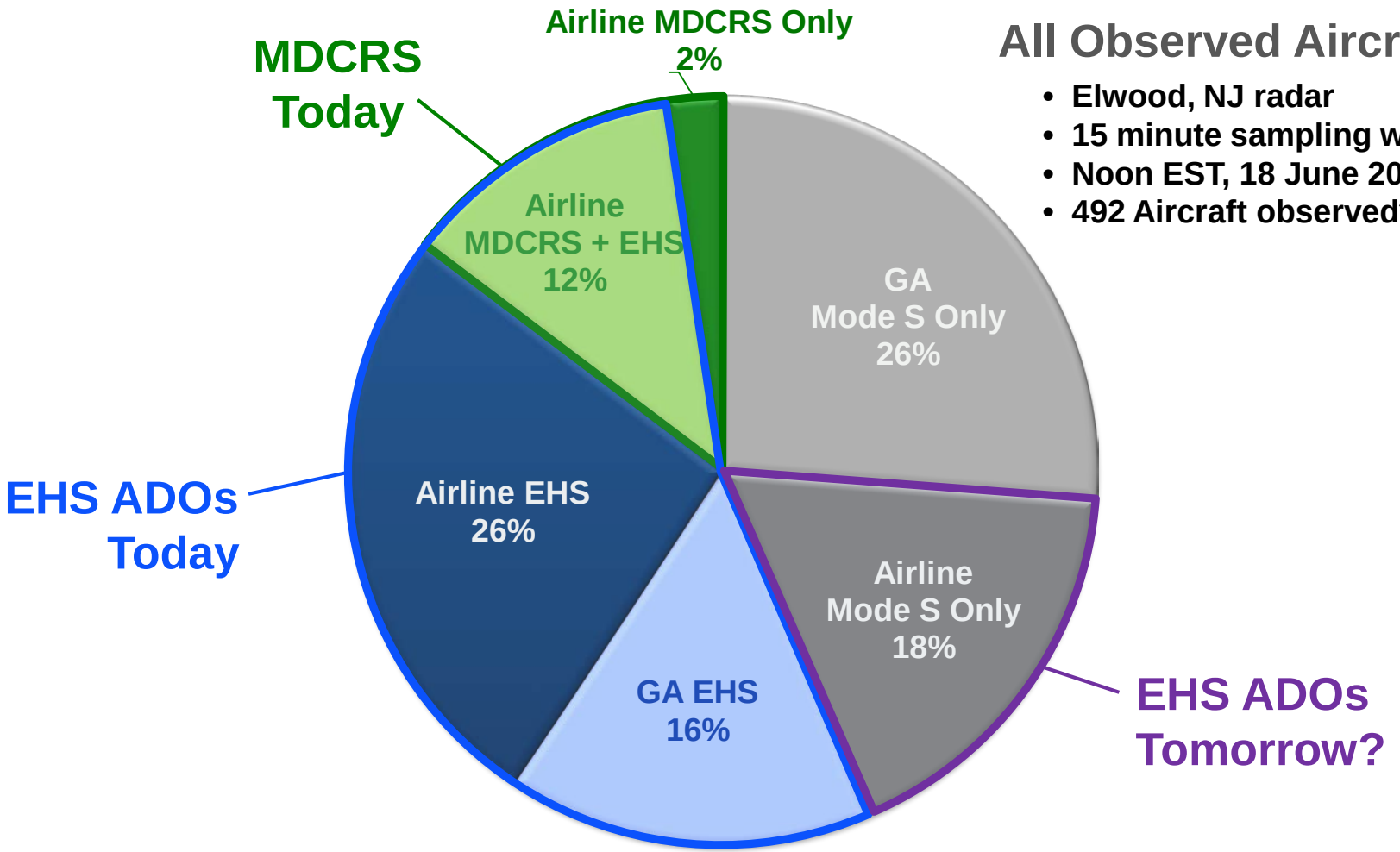
Opportunity for forecast models to assimilate higher quantities of more recent data

RAP = Rapid Refresh forecast model

Observation From Tech Center Radar



Available Wx Observations

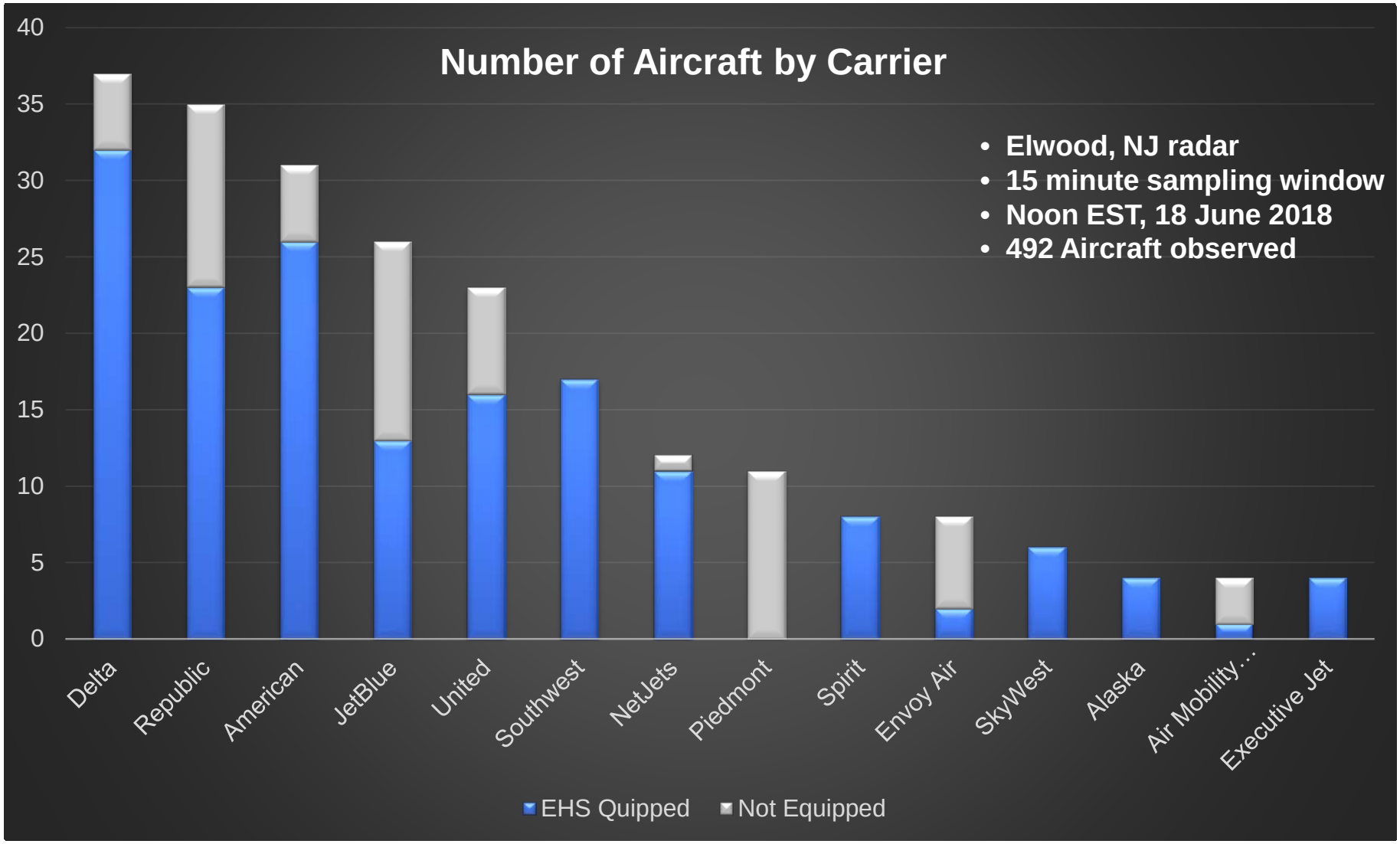


All Observed Aircraft

- Elwood, NJ radar
- 15 minute sampling window
- Noon EST, 18 June 2018
- 492 Aircraft observed*

* Observed aircraft with Mode A and Mode C transponders not included in count

Observed Equipage
Mode S & Mode S EHS



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Recommended Next Steps

- **FAA**
  - **Operational considerations**
    - **Identify and develop operational procedures to take advantage of real-time aircraft-derived observations, inc. to ground and cockpit systems**
  - **Policy considerations**
    - **Leverage knowledge gained through near-term Mode S EHS assessment to inform ADS-B Out weather requirements**
  - **Architectural considerations**
    - **Conduct analysis on means to collect and disseminate aircraft-derived observations from Mode S EHS to end users, inc. spectrum analysis**

- **NOAA/FAA**
  - **Perform benefits analysis on forecast improvements if large quantities of aircraft-derived observations were available, e.g., for high resolution terminal area wind forecasts**

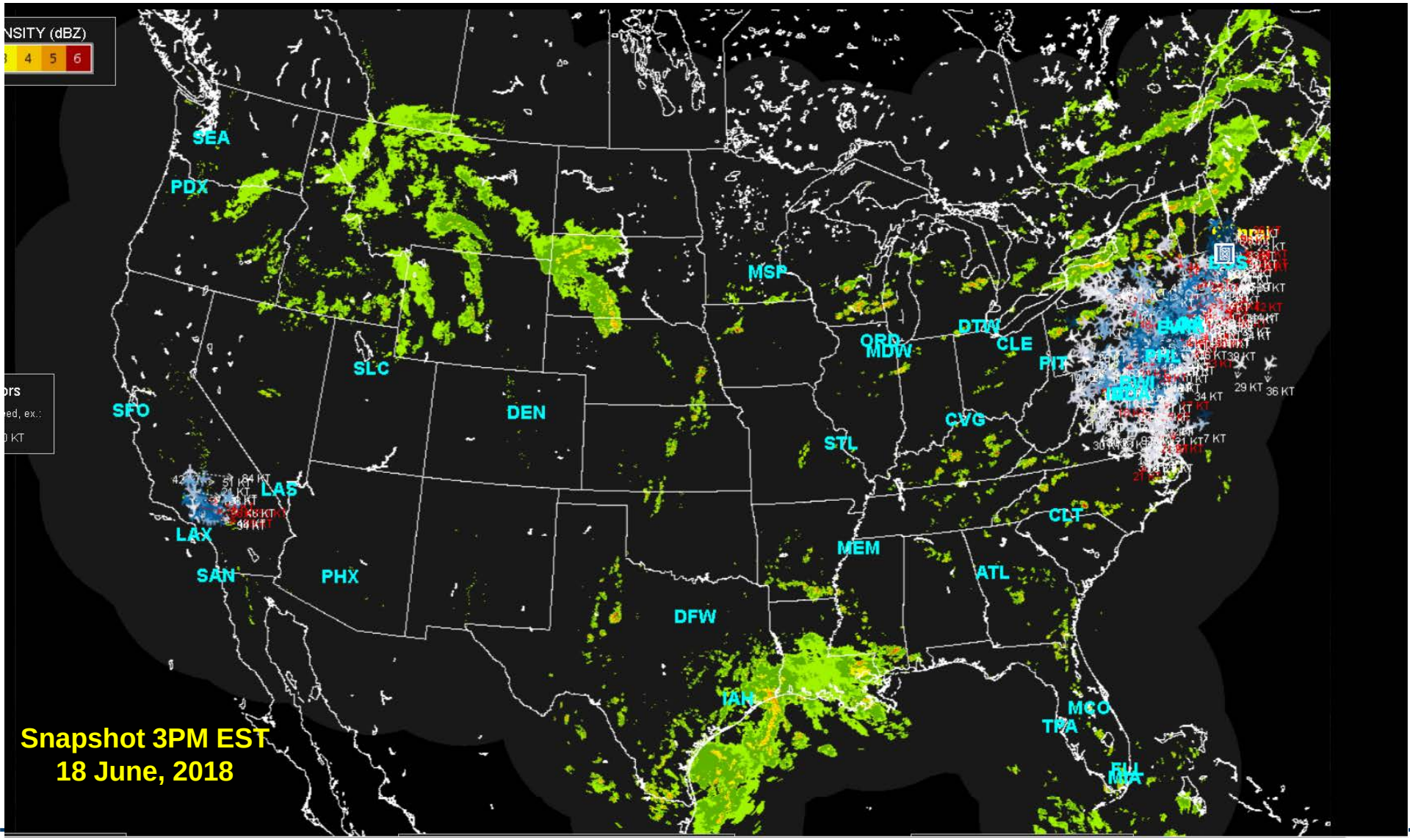
Summary

- **Leveraging aircraft-derived operations holds significant promise for improving weather forecasting and real-time operations**

- **Mode S EHS is a currently-available technology enabling immediate access to aircraft-derived observations**
  - **Inform standards and opportunities for ADS-B Weather Out**
  - **Potential to enhance forecasting performance**
  - **Potential to enhance real-time operations**

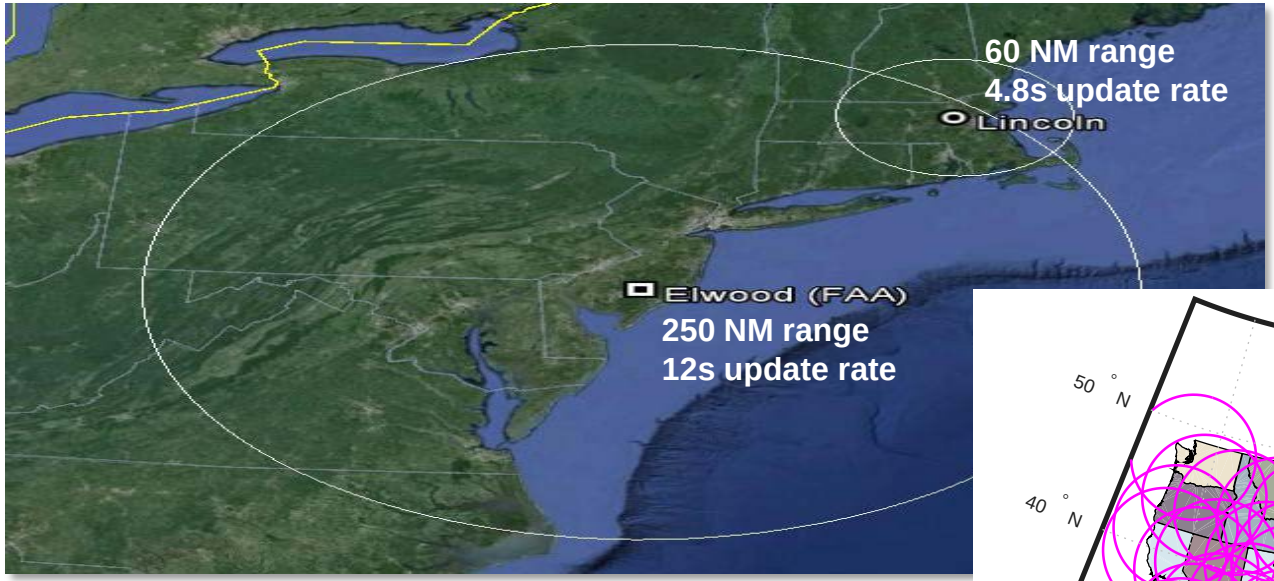
Backup

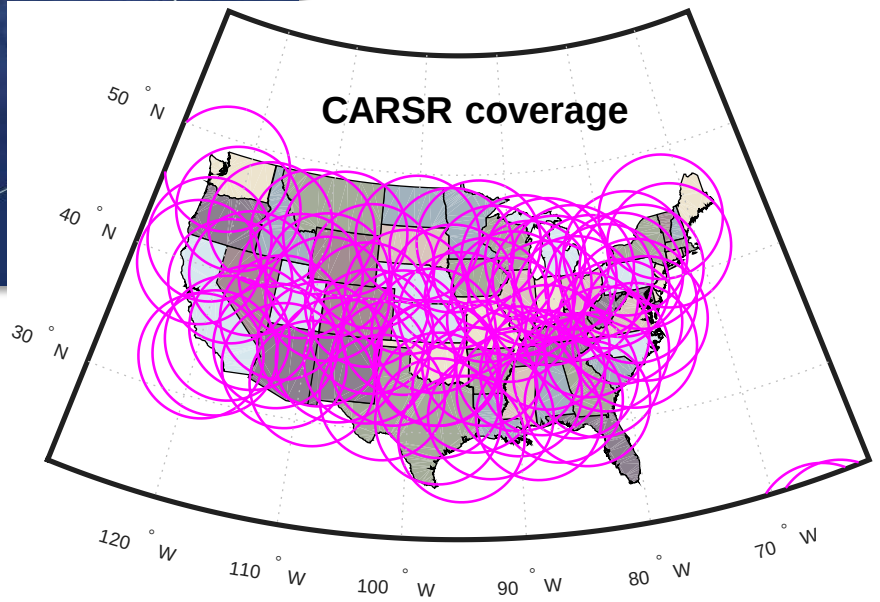
Fremont Valley, CA, Elwood, NJ, Lexington, MA Mode S EHS Radars



Expanding Mode S EHS Aircraft-Derived Observation Analysis

- **Incorporated FAA Elwood ARSR-4 for broader coverage (NYC, PHL and DC operations)**

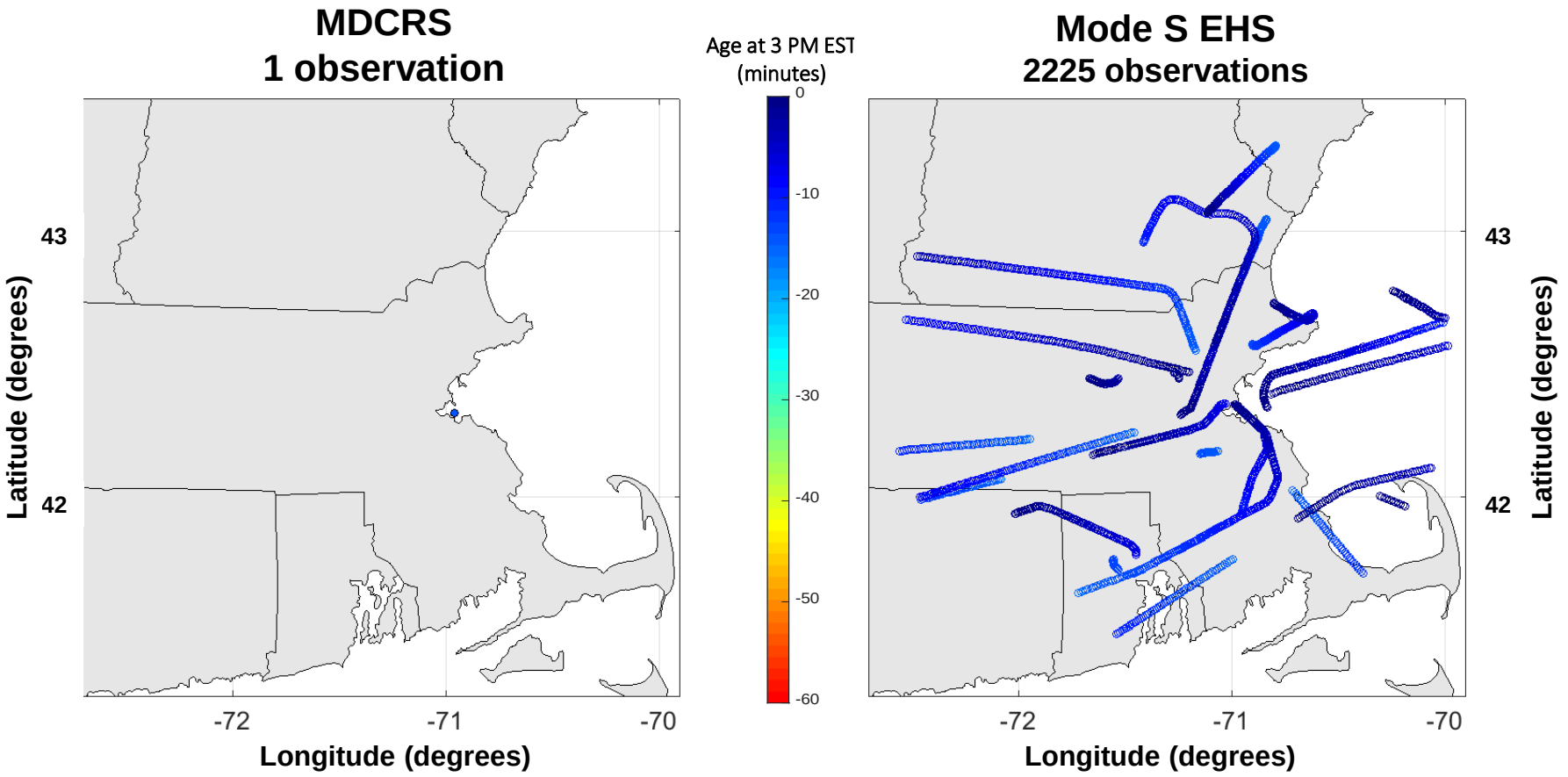




- **Could ultimately expand to all ARSR/ASR radar coverage areas**

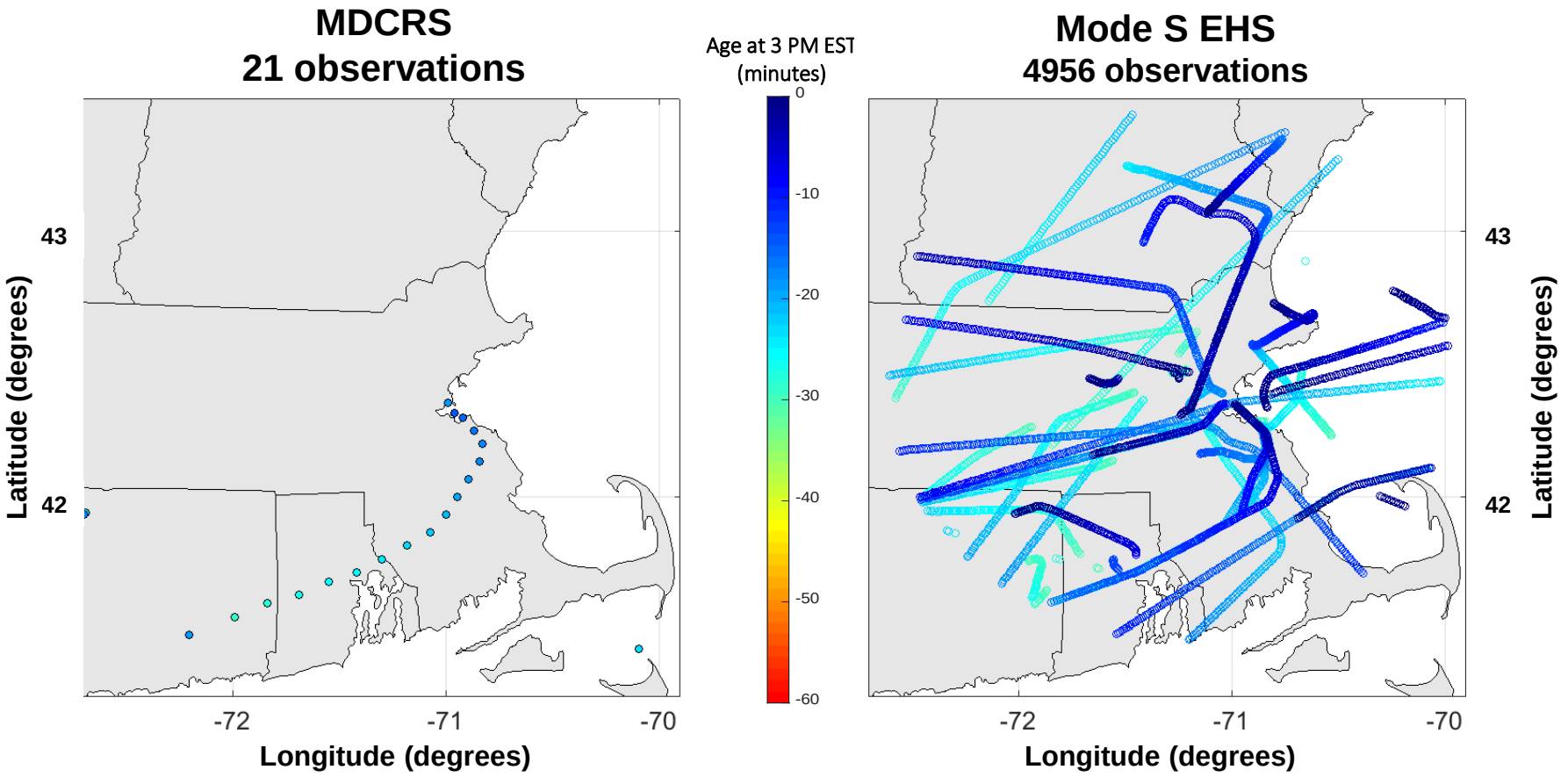
MDCRS & MODSEF Observations Around KBED/KBOS

Nov 1, 2017, 3:00 PM EST forecast assimilation = 15 Minutes



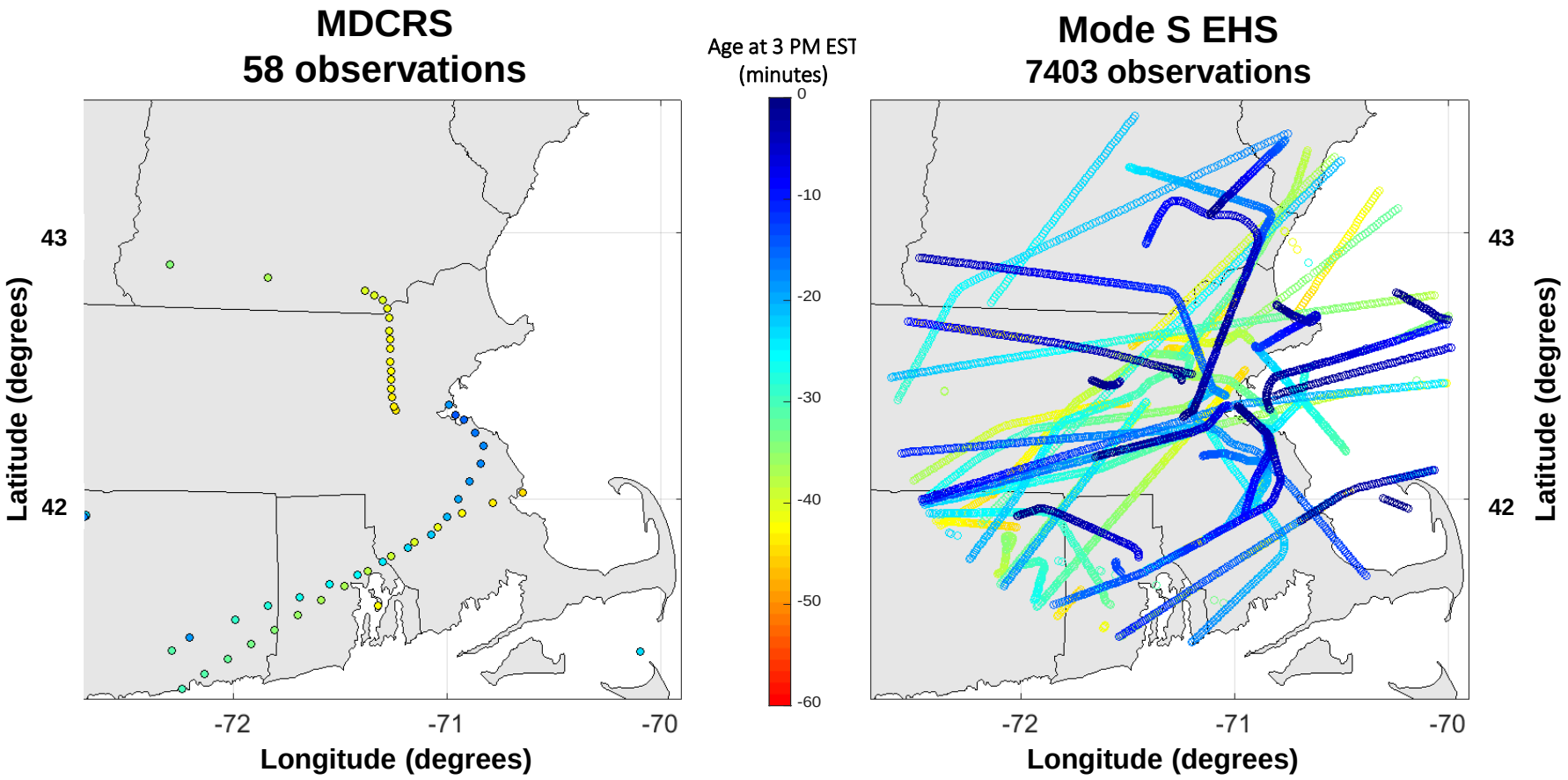
MDCRS & MODSEF Observations Around KBED/KBOS

Nov 1, 2017, 3:00 PM EST forecast assimilation = 30 Minutes



MDCRS & MODSEF Observations Around KBED/KBOS

Nov 1, 2017, 3:00 PM EST forecast assimilation = 45 Minutes



MDCRS & MODSEF Observations Around KBED/KBOS

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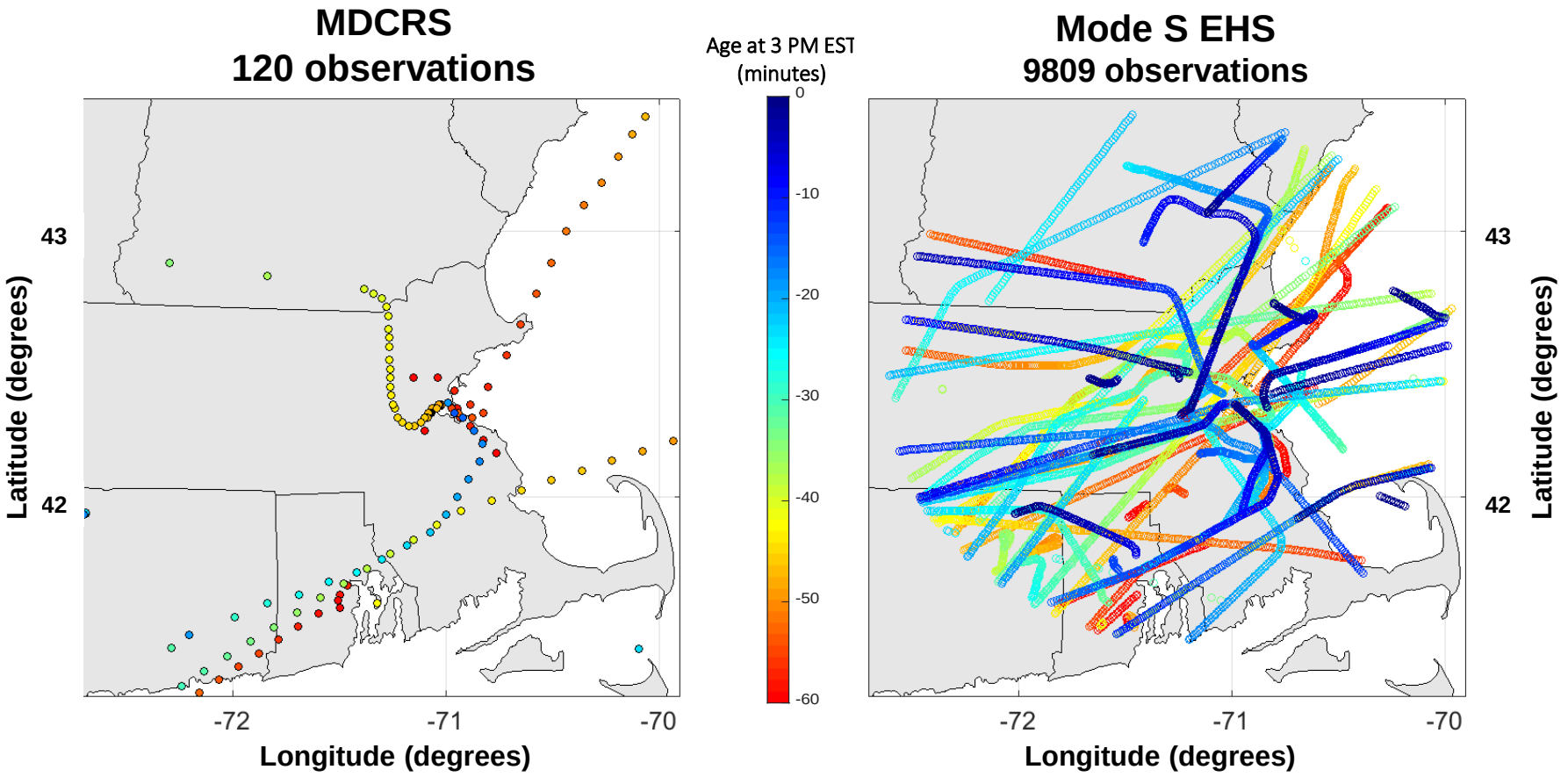
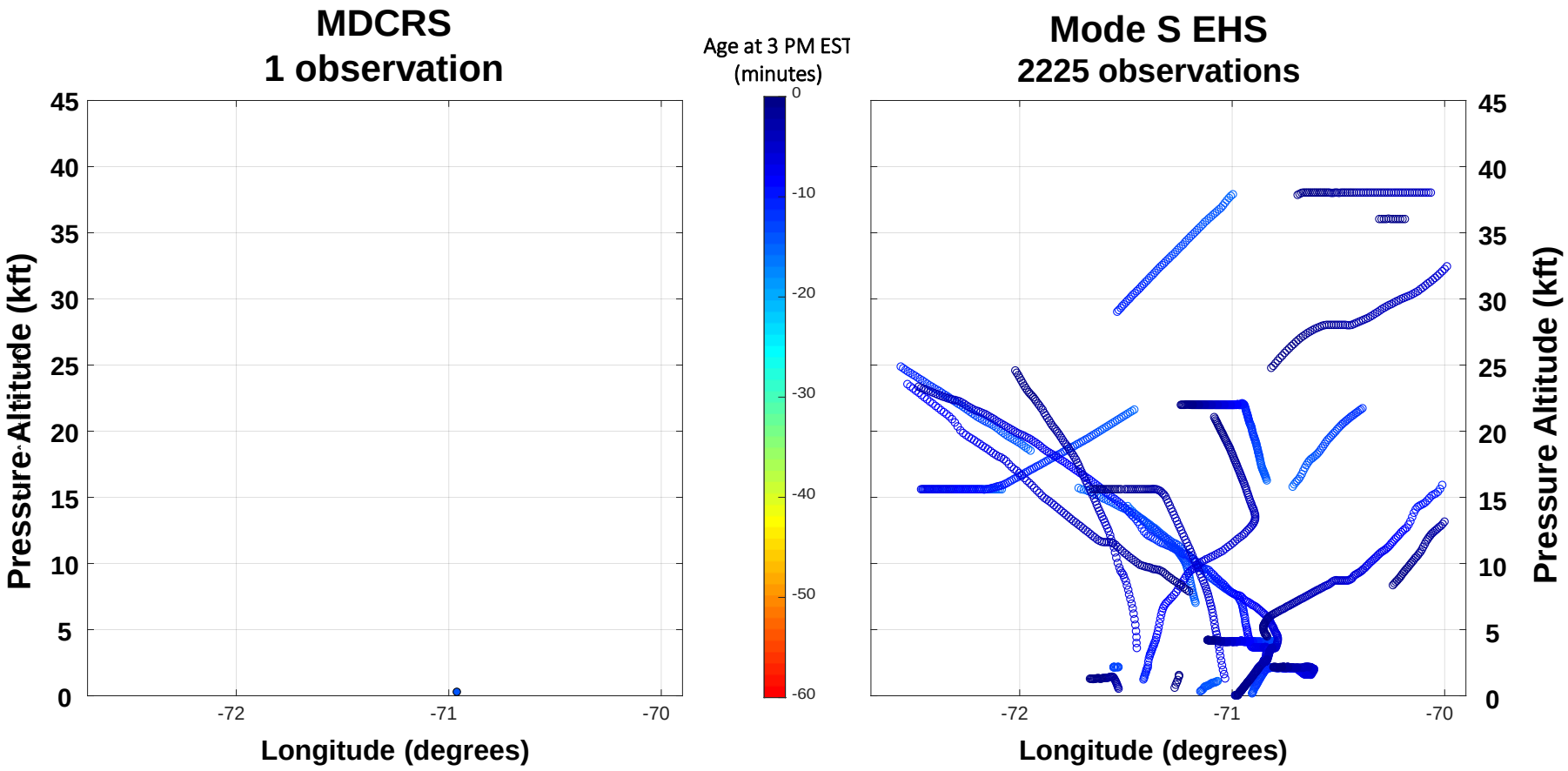


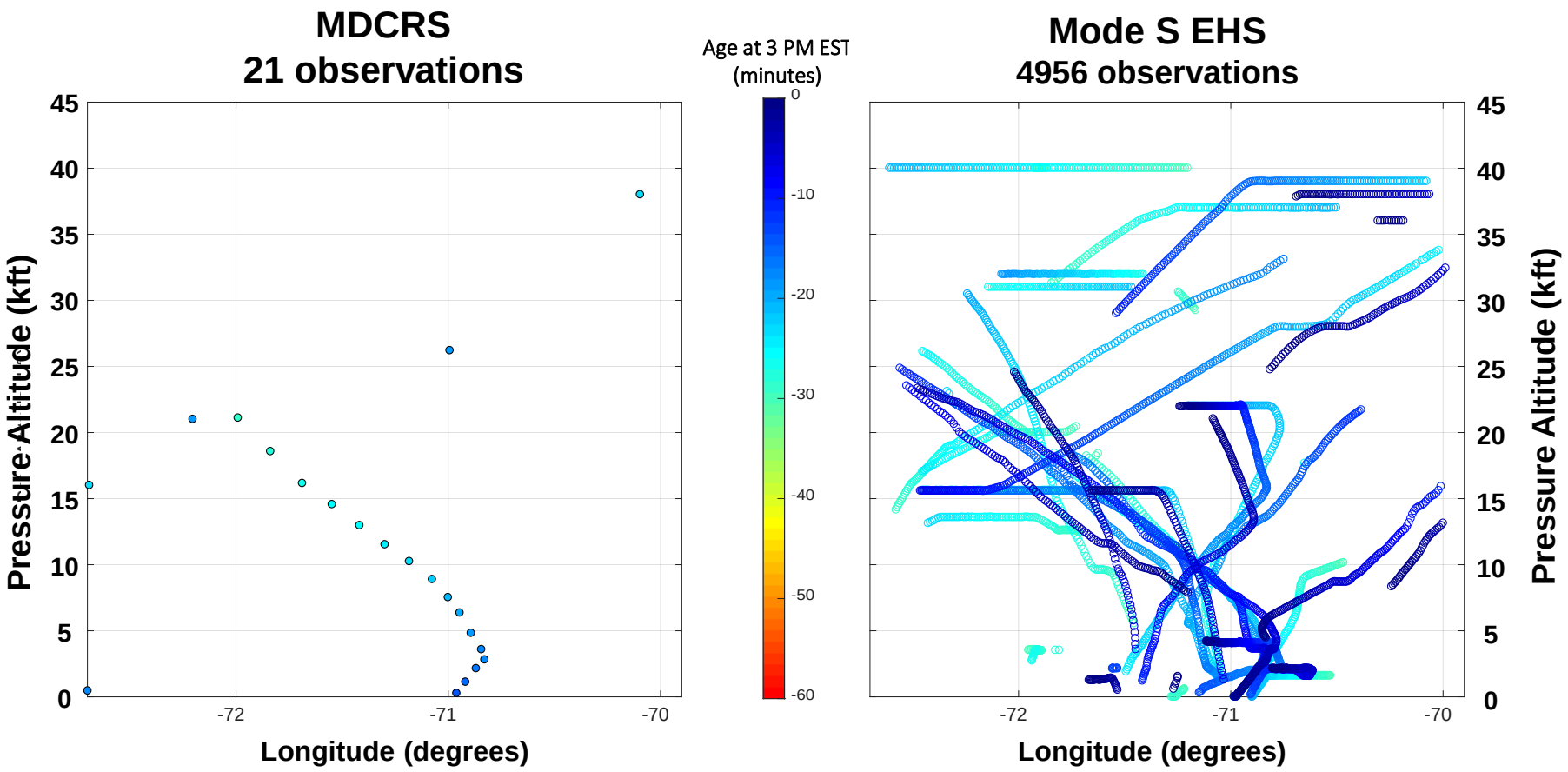
MDCRS & MODSEF
Observations Around KBED/KBOS across Altitudes

Nov 1, 2017, 3:00 PM EST forecast assimilation = 15 Minutes



MDCRS & MODSEF
Observations Around KBED/KBOS across Altitudes

Nov 1, 2017, 3:00 PM EST forecast assimilation = 30 Minutes



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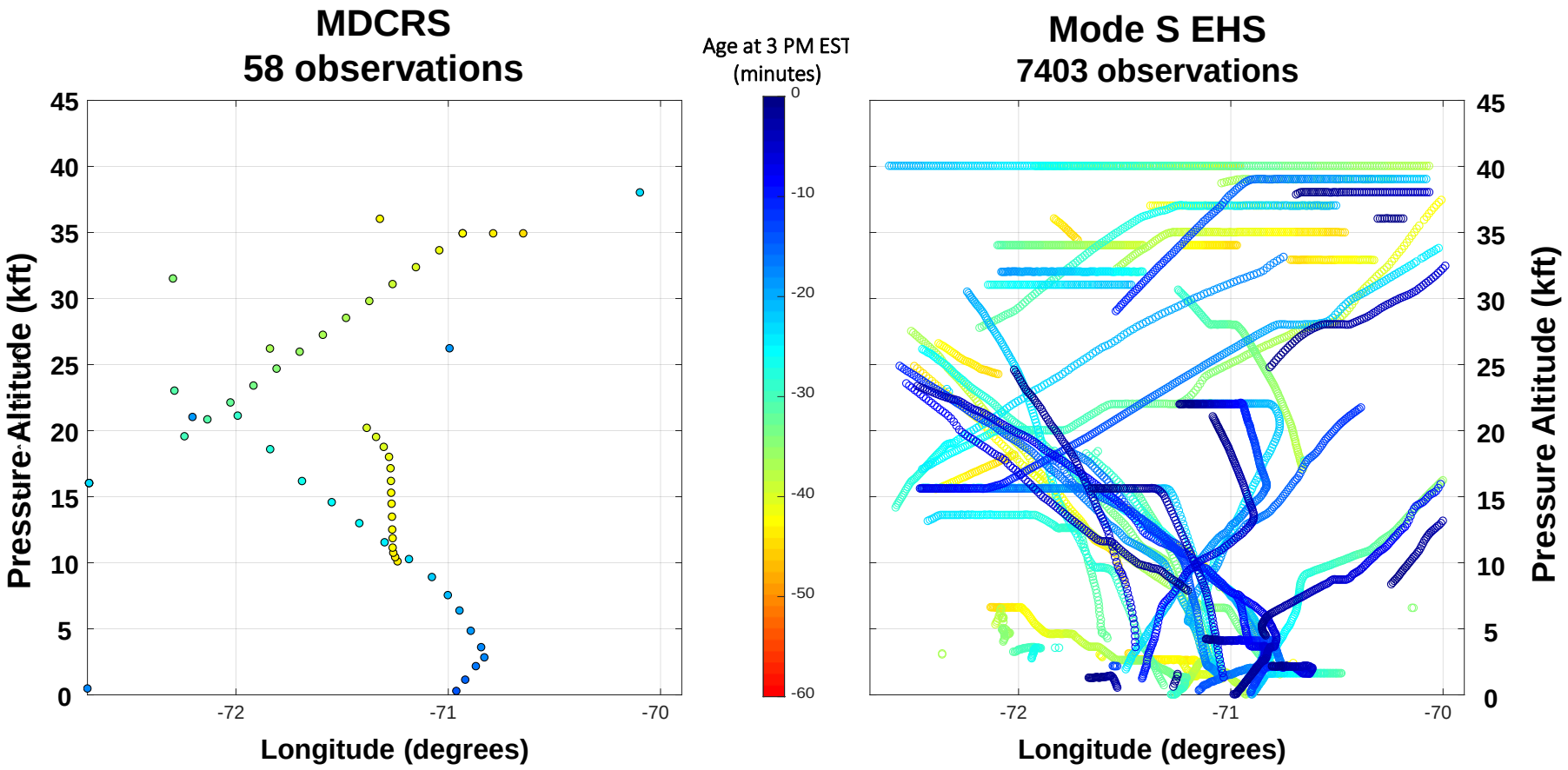

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