

Remote Oceanic Meteorology Information Operational (ROMIO) Demonstration

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AMS 20TH ARAM Conference, paper 12.1

12-16 January 2020



- **Operational demonstration** to evaluate the *feasibility* to uplink convective weather information to aircraft operating over the ocean and remote regions
 - Cloud Top Height (CTH)
 - Convection Diagnosis Oceanic (CDO)
- **Explore strategies** for using rapidly updated **CTH/CDO** products in the flight deck, by Airline Operations Centers (AOC), and by Oceanic Air Route Traffic Control Centers (ARTCC)
 - Supplemental use only
- **Understand benefits** associated with providing updated convective weather information to flight deck, AOCs, and ARTCC
 - Feedback collected/analyzed

ROMIO Participants & Communications Architecture Overview



Participants:

Sponsor: Weather Technology in the Cockpit (WTIC) Program, FAA ANG-C61

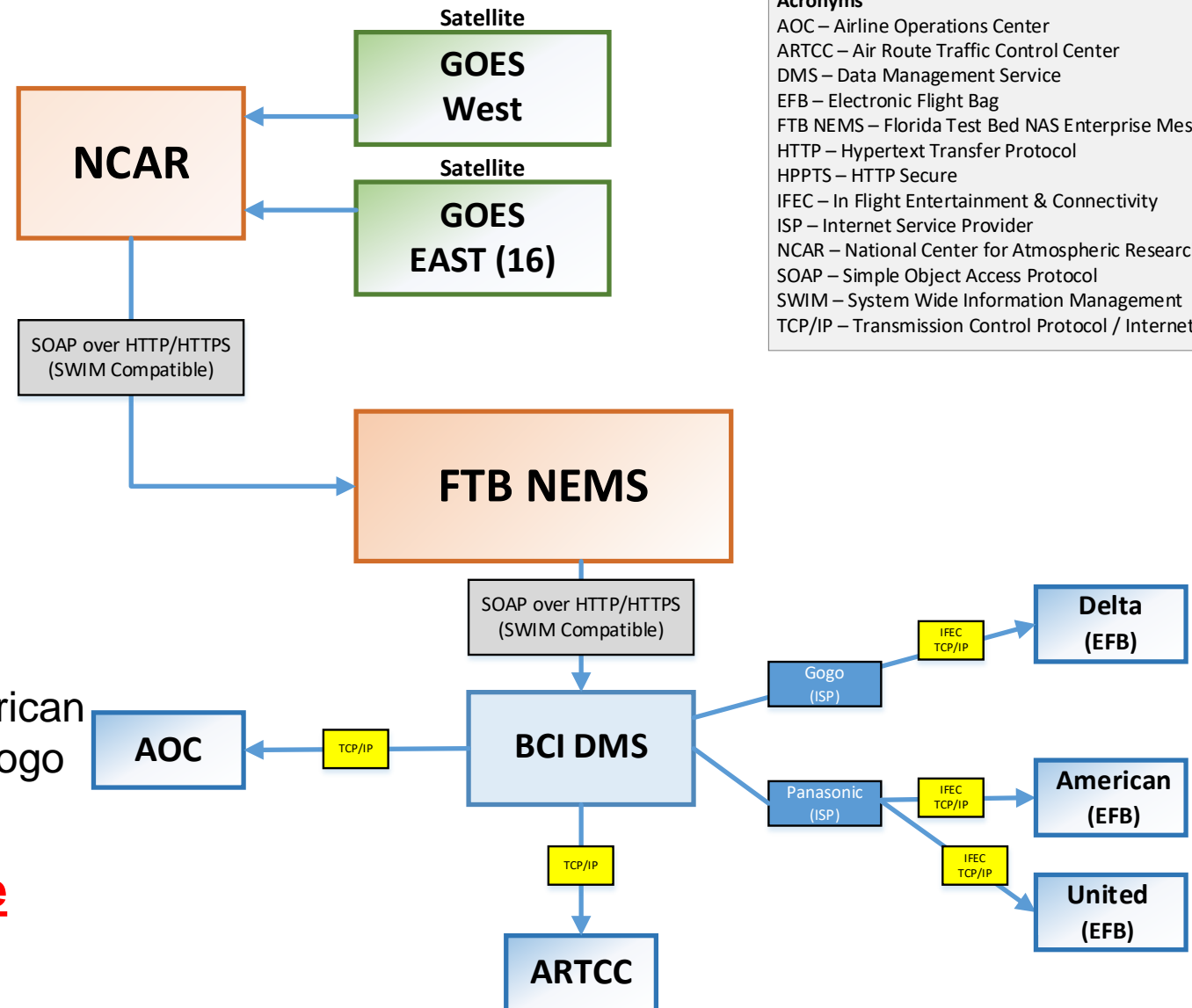
NCAR: Principal Investigator and Overall Project Support

Embry-Riddle Aeronautical University: NextGen Florida Testbed

Basic Commerce and Industries (BCI): Software Applications and Communications Support

Airlines and Providers: Delta Air Lines, American Airlines, United Airlines with Panasonic and Gogo as datalink-to-aircraft providers

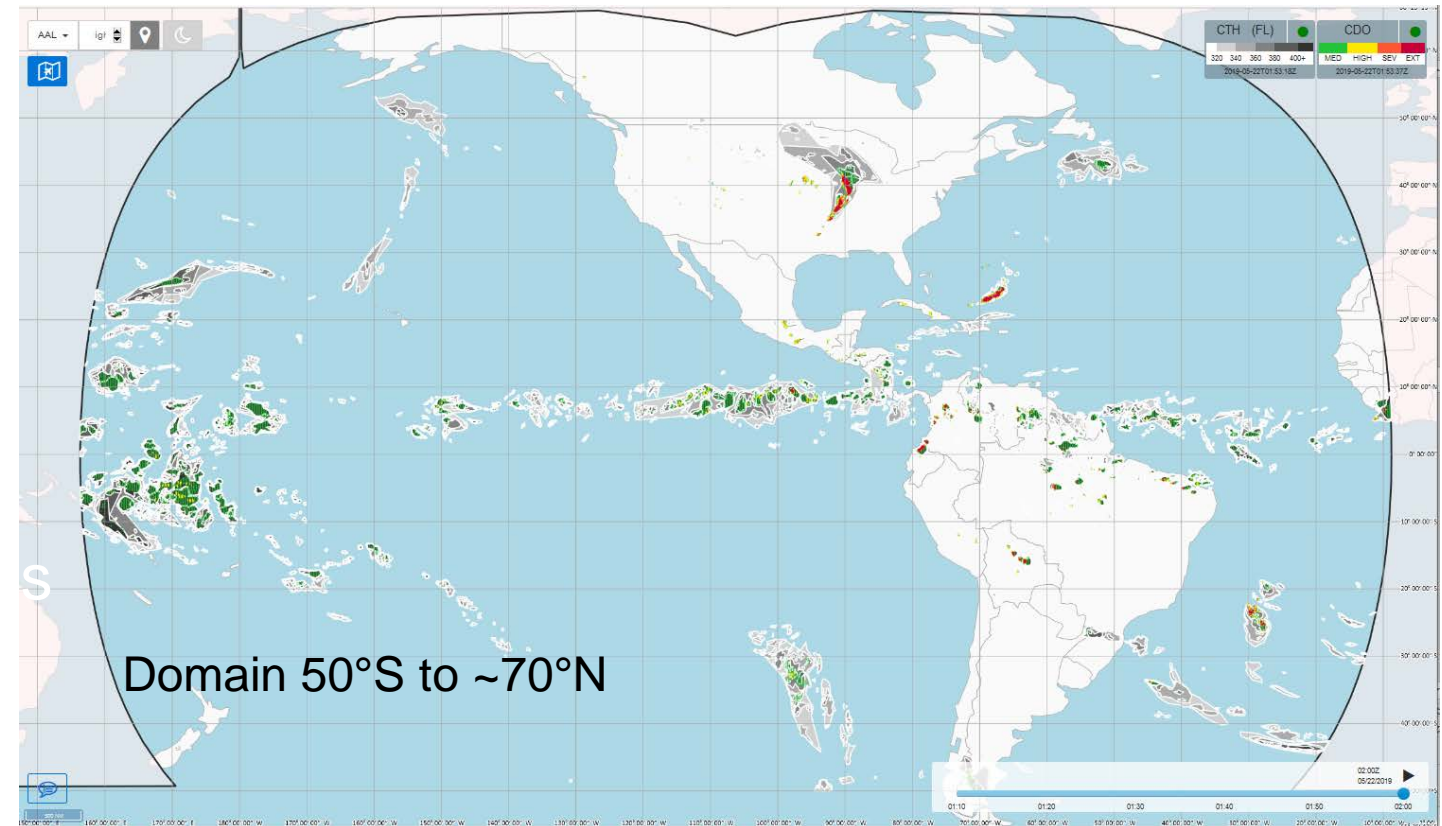
Virginia Polytechnic Institute and State University: Benefit analysis



Acronyms

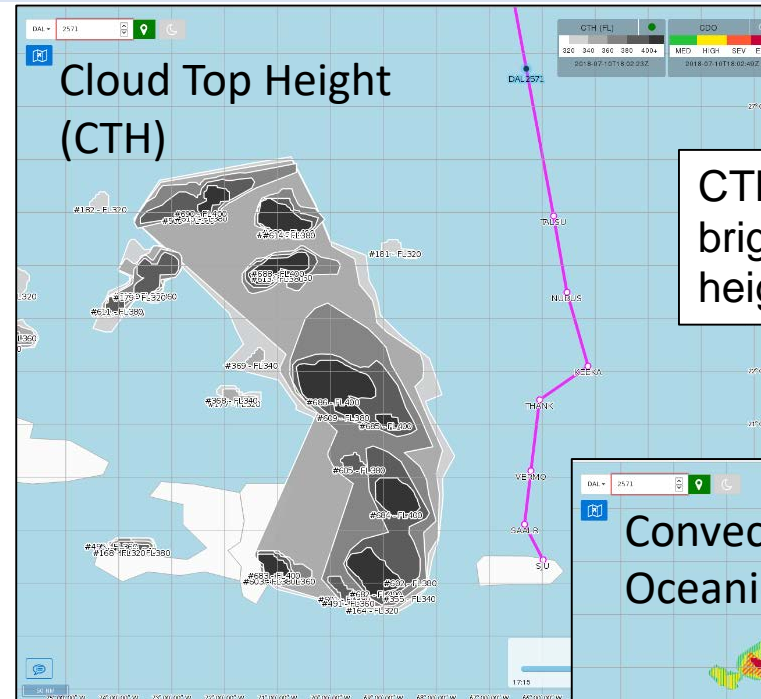
- AOC – Airline Operations Center
- ARTCC – Air Route Traffic Control Center
- DMS – Data Management Service
- EFB – Electronic Flight Bag
- FTB NEMS – Florida Test Bed NAS Enterprise Messaging System
- HTTP – Hypertext Transfer Protocol
- HPPTS – HTTP Secure
- IFEC – In Flight Entertainment & Connectivity
- ISP – Internet Service Provider
- NCAR – National Center for Atmospheric Research
- SOAP – Simple Object Access Protocol
- SWIM – System Wide Information Management
- TCP/IP – Transmission Control Protocol / Internet Protocol

- GOES-East & GOES-West domain
 - 10 min updates, latest data
 - 0.04 deg latitude/longitude grid spacing

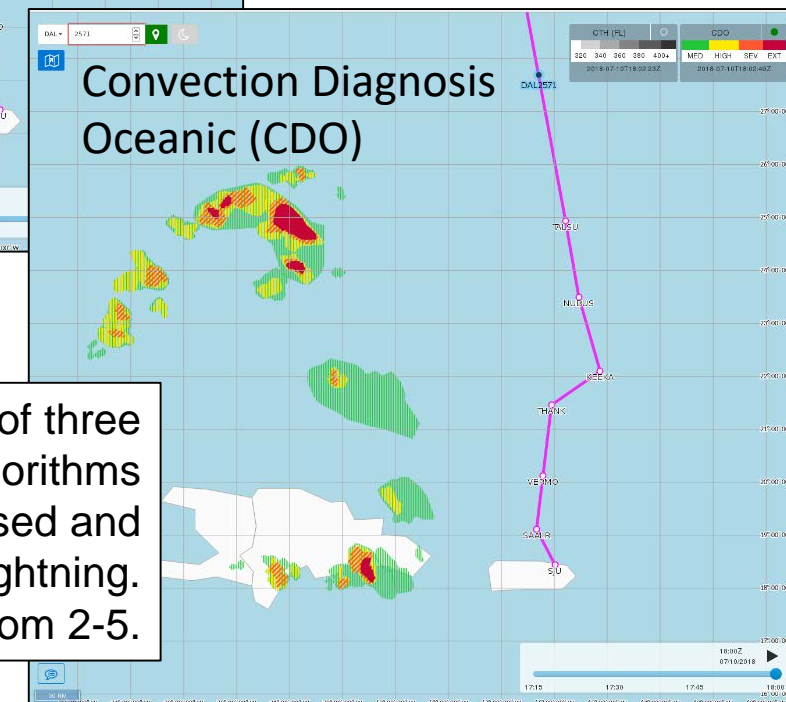


ROMIO Viewer showing
GOES-East and GOES-West domain

- **GOES-East & GOES-West domain**
 - 10 min updates, latest data
 - 0.04 deg latitude/longitude grid spacing
- **CTH product**
 - Top contours between FL320-FL400
- **CDO product**
 - Locates hazardous updraft regions
 - Medium, High, Severe, Extreme
- **Gridded products turned into polygons**
 - Reduces bandwidth
 - Polygons “represent” gridded products
- **Response bytes per 10 min update**
 - CTH used 475 – 650 Kbytes
 - CDO used 200 – 450 Kbytes
 - Seven aircraft used ROMIO that day



CTH maps 11 micron IR brightness temperature to height using GFS sounding.



CDO is a data fusion of three satellite-based algorithms plus ground-based and geostationary lightning. Interest field, values from 2-5.

Demonstration Details and Schedule

- Number of pilots trained:
 - Delta: 367
 - 767-300, 767-400, 777, A330, A350 (167 total)
 - United: ~10 Line Check Airmen
 - 777 and 787
 - American: ~40 Line Check Airmen
 - 777-200
- Flight Routes:
 - CONUS to/from international destinations
 - Inter-Tropical Convergence Zone
 - Route seen beyond range of onboard radar
 - **Improved situational awareness**



Atlanta to Bogota Route

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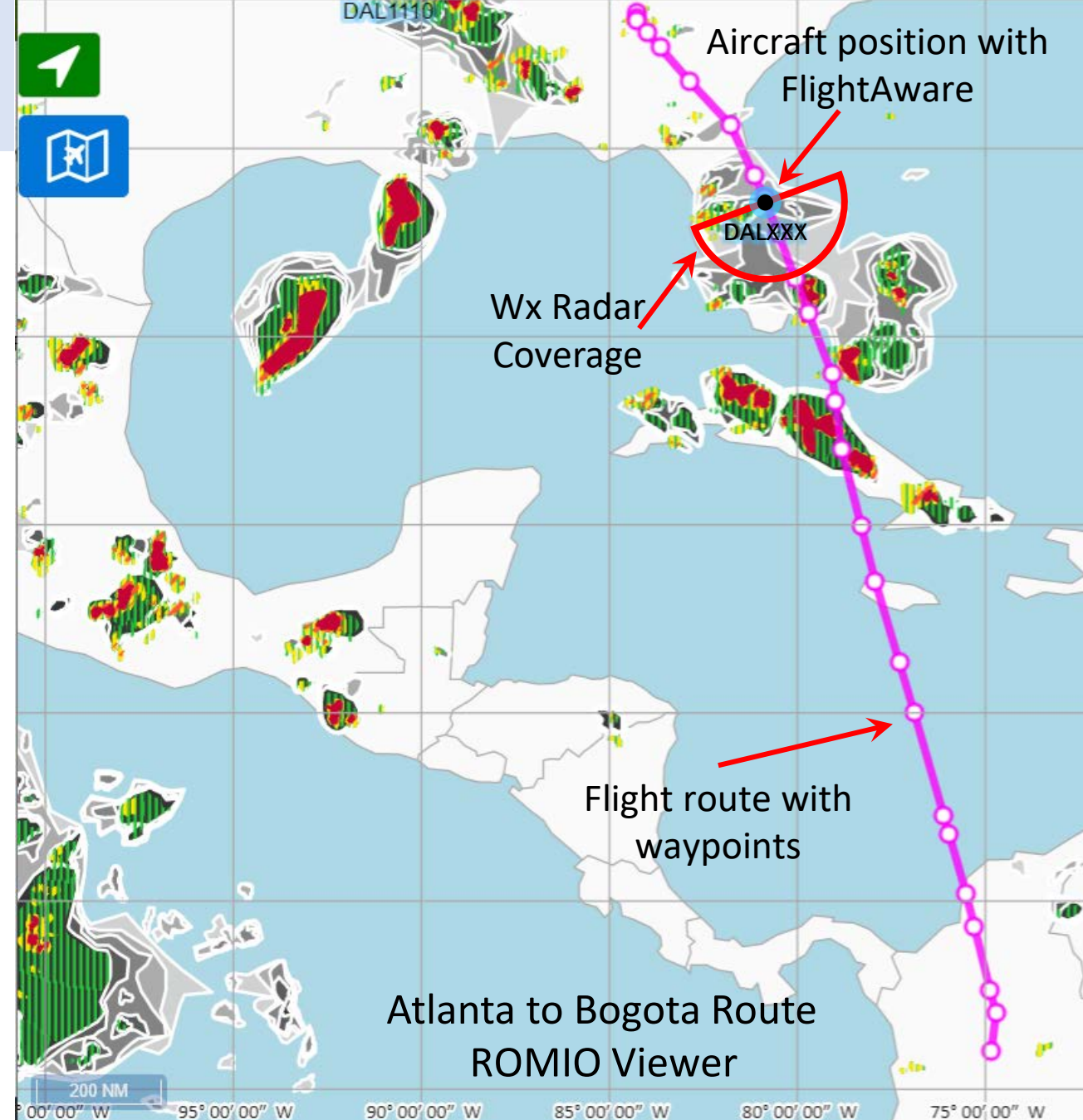
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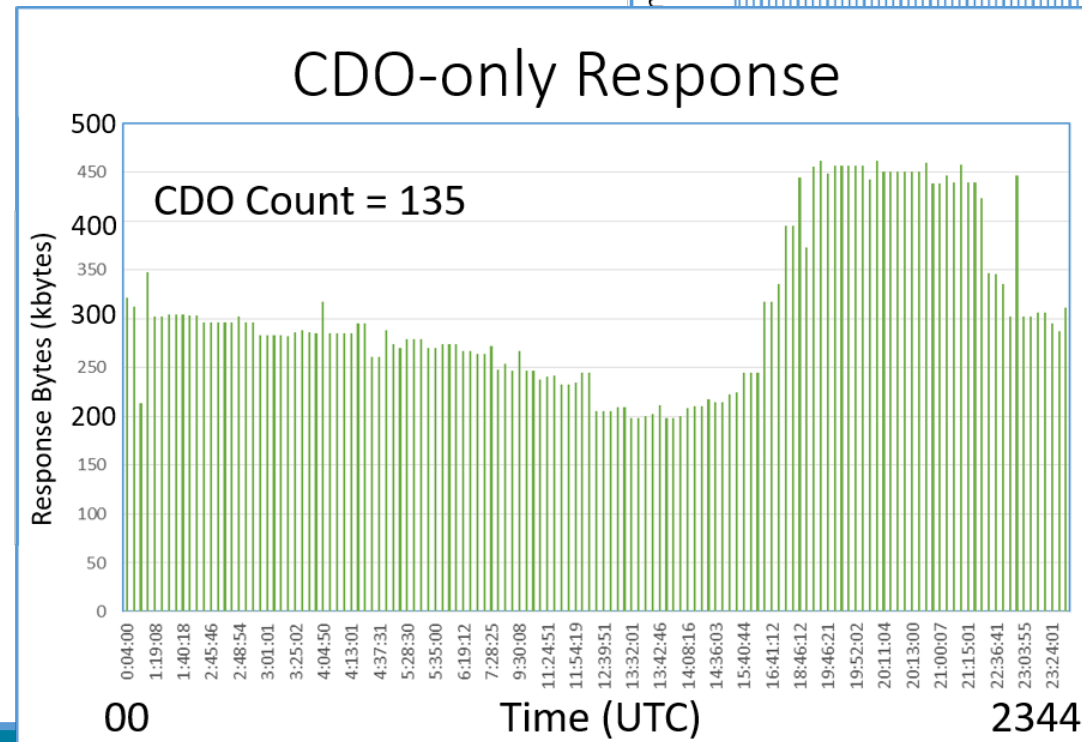
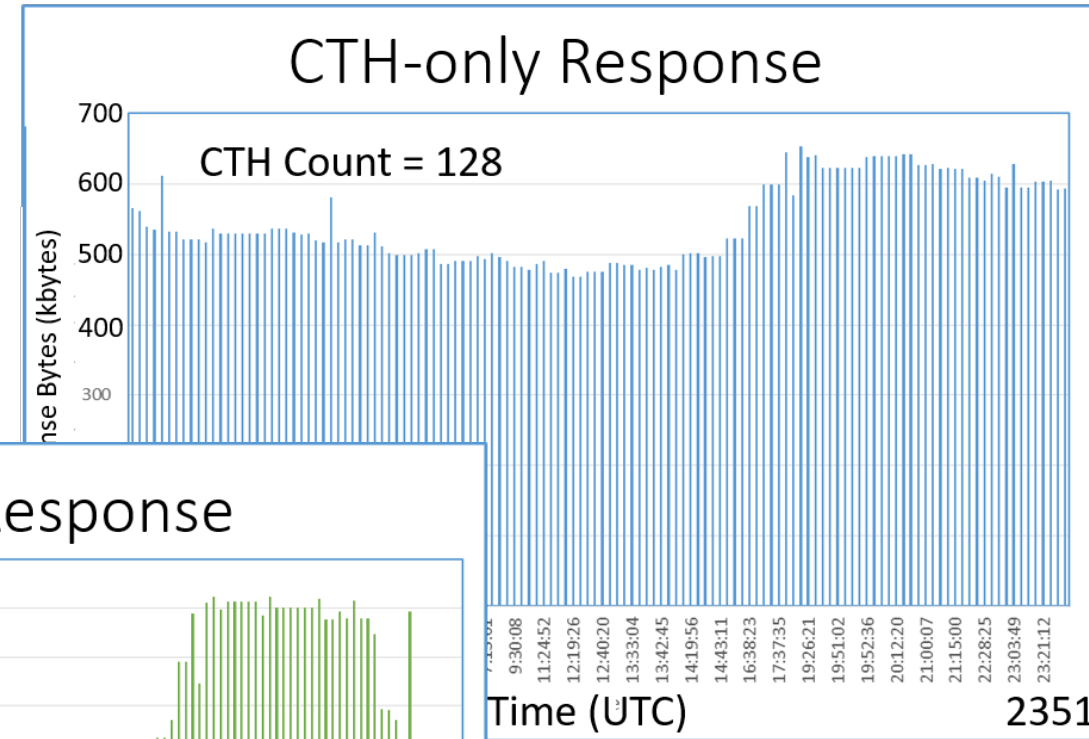
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 - **Improved situational awareness**
- Demonstration schedule:
 - Began July 2018 with Delta
 - United and American began spring 2019
 - Gov't shutdown slowed start
 - Ended 25 December 2019
 - 3 weeks in Aug-Sept, average 26 flights/day



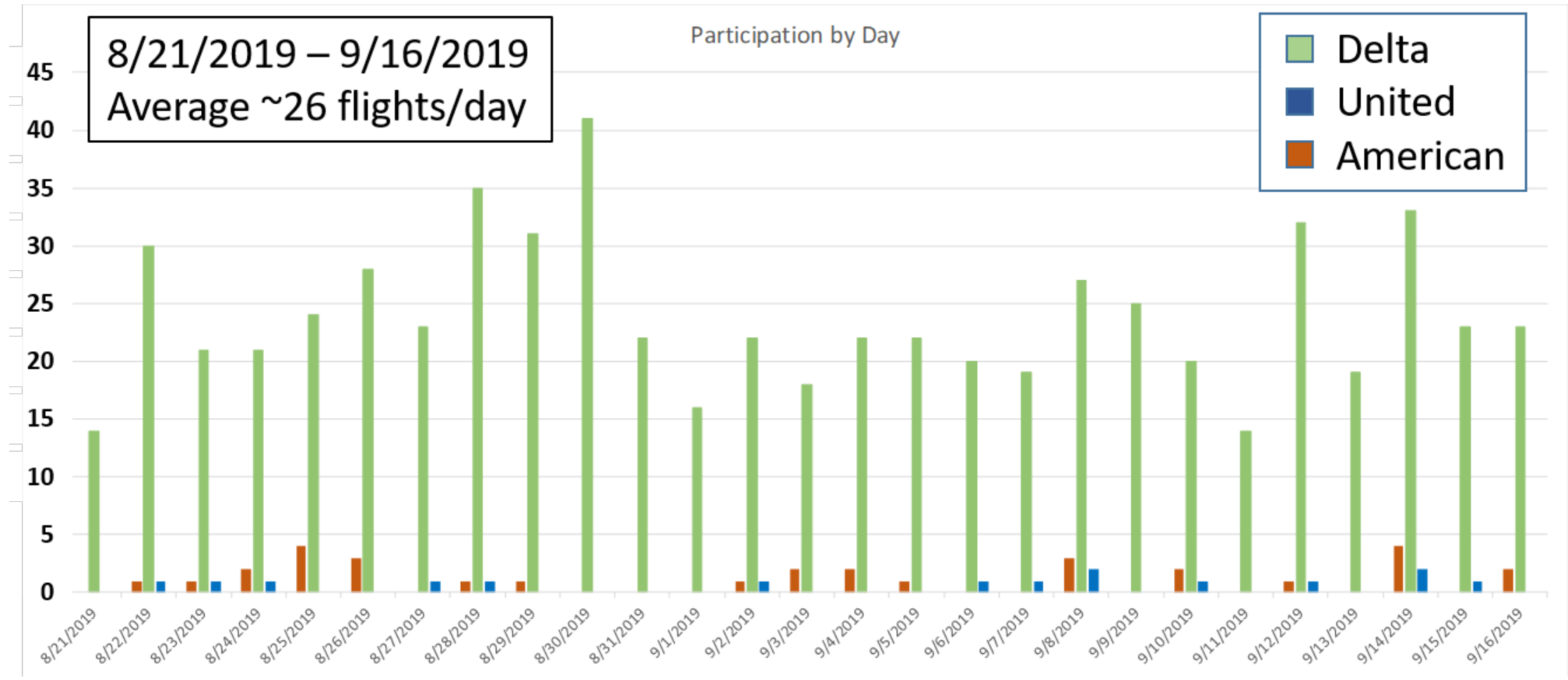
ROMIO Product Bandwidth Use

- Timely uplinks require small product size
 - Use the entertainment wifi for uplinking
- Response bytes for day shown
 - CTH use 475 – 650 kbytes
 - CDO use 200 – 450 kbytes
 - Sizes for all flights at any given time
 - Up to 7 aircraft that day
- Diurnal cycle of storm development seen in response bytes



Source: J. Bracken

Demonstration Details and Schedule





ROMIO Benefit Analysis: a Multi-step Approach

- **Survey Analysis**
 - 90 usable surveys of pilot feedback, as of September 2019
 - 54% performed weather deviation
 - Average weather deviation 29 nautical miles (range of 2-120 nm)
- **Statistical Data Analysis**
 - Types of events
 - Quantifying operational benefits of strategic deviation maneuvers
- **Simulation Based Analysis (Global Oceanic Model)**
 - To be completed March 2020



90 Survey Responses

- **General Workload:** How much effort was required to process information provided by ROMIO compared to current system?
 - 94% of pilots said using ROMIO required the same or less effort
- **Situational Awareness:** How well does ROMIO enable situational awareness in monitoring weather along your flight route in comparison to current system of hardware and procedures?
 - 95% of the pilots perceive equal or improved situational awareness with ROMIO
- **Timeliness:** How well does ROMIO enable obtaining relevant, timely weather information in comparison to current system and hardware?
 - 92% of pilots perceive ROMIO as equal or more effective compared to existing tools
- **Accuracy of CTH and CDO:** How well did ROMIO information correspond to your observation outside the cockpit window? (only for cases where there was an observation)
 - 94.7% of pilots rate ROMIO accuracy between Somewhat to Very Accurate to depict CTH
 - 94.8% of pilots rate ROMIO accuracy between Somewhat to Very Accurate to depict CDO



Cabin Crew Coordination

- **Efficiency and safety:** ROMIO in the context of cabin crew coordination with weather events
- Most common pilot response: **I was able to seat the flight attendants early**
 - Enhanced safety of passengers and crew

I had the flight attendants **take their seats well in advance** of the weather event and maneuvered between multiple cells. ROMIO gave me precise information during this period and enhanced my deviation decision.
ROMIO provided a clearer picture when used in conjunction with the aircraft weather radar.

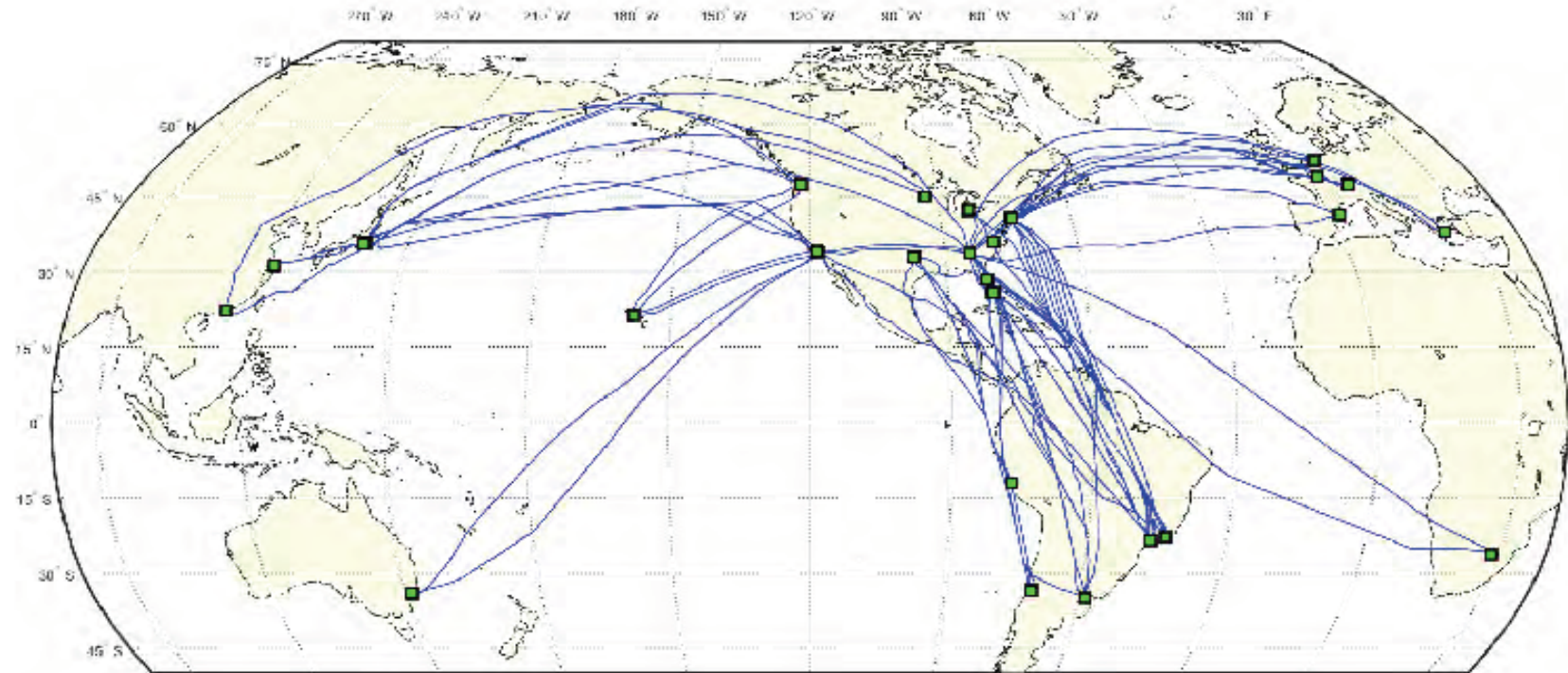


Statistical Data Analysis

Motivation: Show ROMIO provided quantifiable benefits

- 18,326 flights among 45 bi-directional origin-destination pairs
 - Using FlightAware database

Airline	Percent
AAL	40%
DAL	35%
UAL	25%



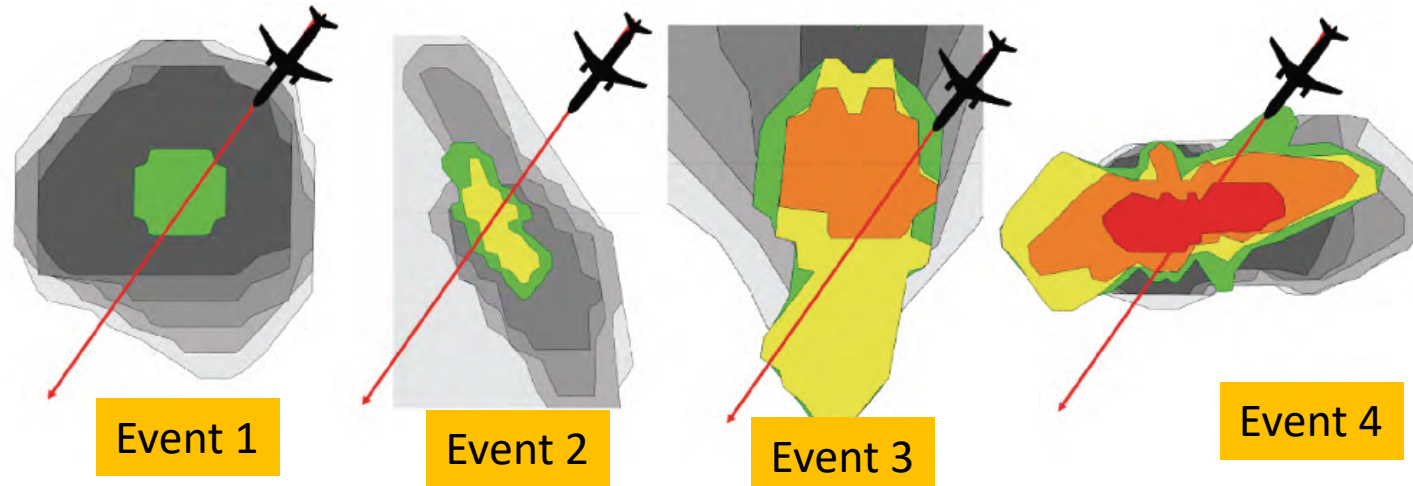


Event-Based Analysis

- Measured distance traveled inside each CDO contour
- CDO intensities:
 - Medium (green)
 - High (yellow)
 - Severe (orange)
 - Extreme (red)
- CDO contours “generous” due to grid spacing, causes dilation
- CDO shows 3D structures as 2D product

Event Type	Percent of Events	CDO Layers			
		MED	HIGH	SEV	EXT
1	50 %	*			
2	32 %	*	*		
3	10 %	*	*	*	
4	8 %	*	*	*	*

Often possible to transit areas with “medium” or “high” convection, with heightened vigilance
 Areas of “severe” and “extreme” usually not passable



Typically occur in Terminal Area

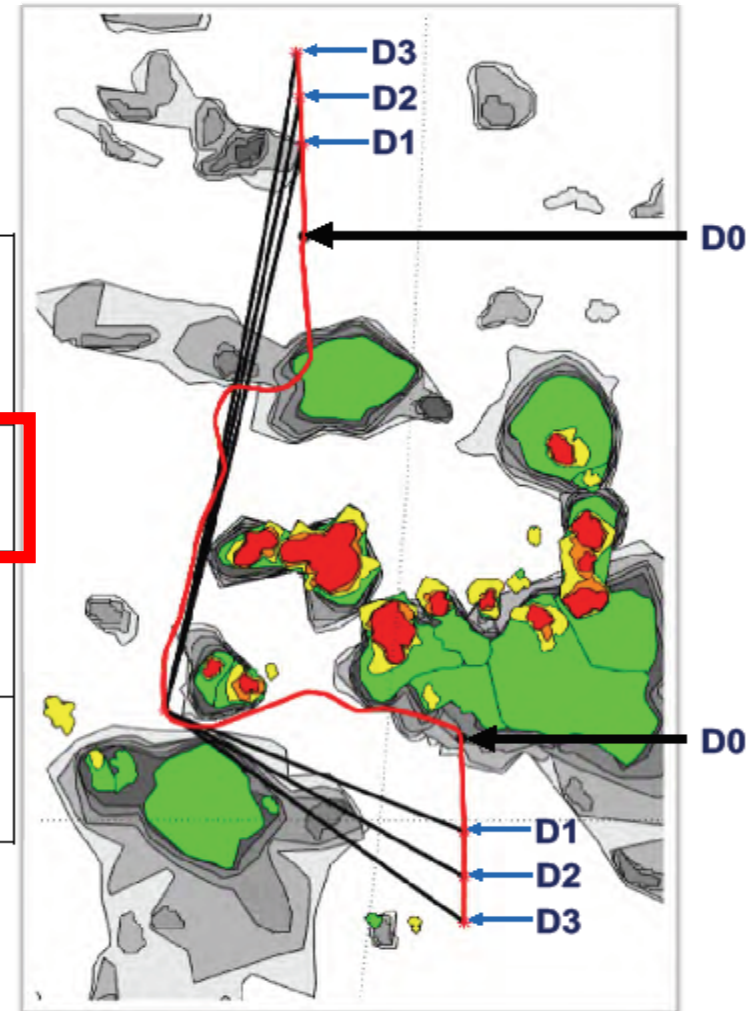


Quantifying ROMIO-Aided Strategic Deviations due to Convective Weather

Aircraft Type: B77W
 Average Aircraft Speed : Mach 0.84
 Weight ~ 685,000 lb (319 lb/minute cruise fuel flow)

Deviation Alternative	Early Strategic Deviation	Travel Distance Savings (nm)	Travel Time Savings (min)	Potential Fuel Saved (lb)	Greenhouse Emissions (lb)
D1	10 min (80 nm)	133	16.1	5,136	16,050
D2	15 min (120 nm)	154	18.6	5,934	18,543
D3	20 min (160 nm)	171	20.6	6,571	20,534

“Worked as advertised. The threat of adverse weather was first identified with ROMIO and then within approximately 10 minutes was validated by on board radar and visual sighting.



Max Lateral Deviation: 240 nm



Operational Benefits of 10-Minute Earlier Deviation Maneuvers

Assume:

- 60 flights crossing ITCZ per day
- 320 operational days per year,
- \$1.82/gallon ajet fuel price
 - Annual fuel consumption savings **~6.8 million pounds or \$1.8 million**
- This is lower bound for benefits

NO	Aircraft Types	Average Travel Distance Savings (nm)	Average Travel Time Savings (min)	Average Fuel Consumption Savings (lb)	Average Greenhouse Emissions Savings (lb)
1	Airbus A330-300	12.9	1.60	318	992
2	Boeing 767-400	10.1	1.25	230	717
3	Boeing 777-200	12.3	1.50	355	1111
4	Boeing 777-300	13.8	1.80	534	1669
5	Boeing 787-9	14.8	1.85	339	1062
Average		12.8	1.6	355	1110

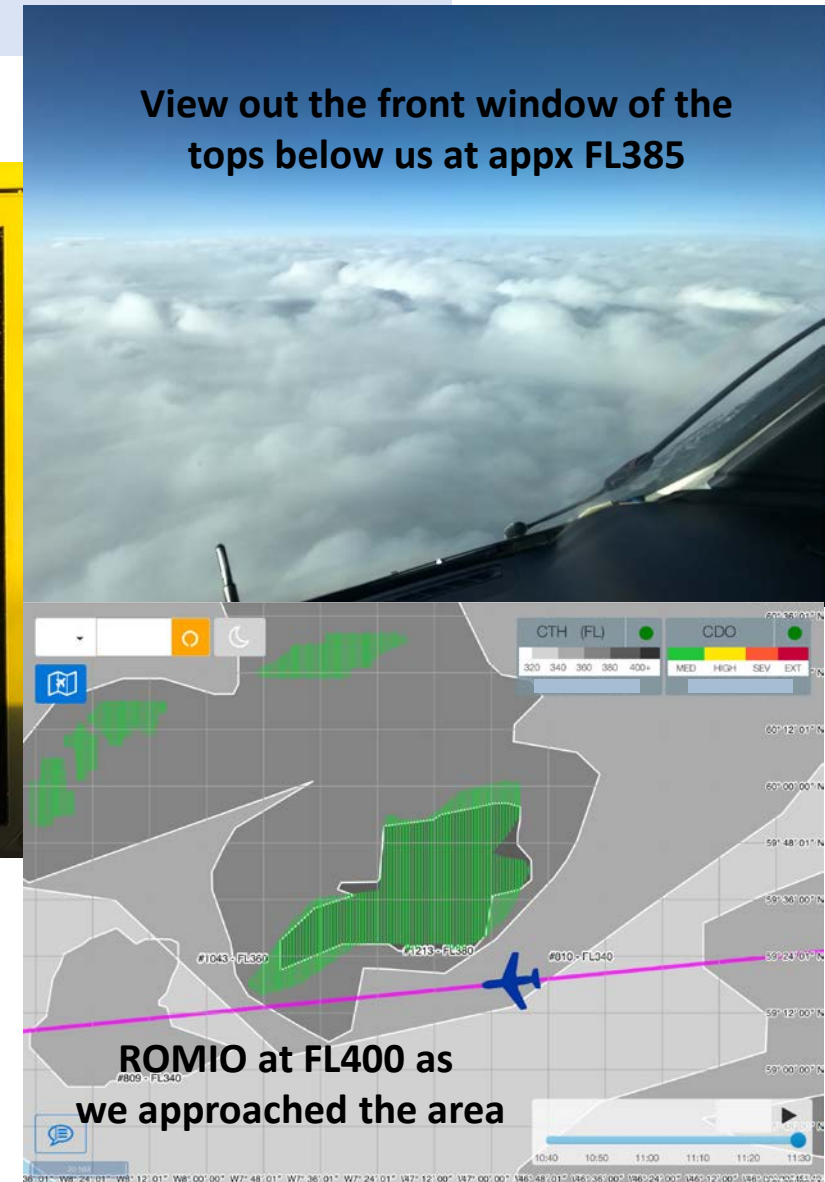
Derived from 18,326 flights

ROMIO Flight From AMS-DTW

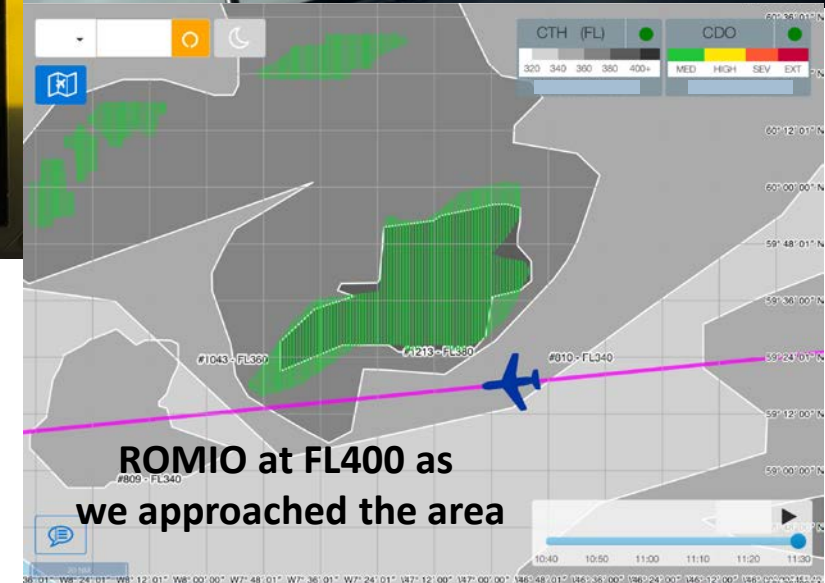
- We were very pleased with the accuracy of the depiction we had on ROMIO and, using that in combination with our onboard radar, we were able to successfully find a smooth ride and validate the information provided by the program.
- Had this been a night flight this would have been even more helpful as we would not have been able to see the clouds and the radar was only indicating the precipitation below us but not the turbulence at our initial altitude.



ND and WX RADAR at FL400 showing precipitation below our altitude. The hashed area indicates weather below FL250 along our route and the vertical display indicated the same.



View out the front window of the tops below us at appx FL385



ROMIO at FL400 as we approached the area

Summary

- ROMIO shown to provide quantifiable benefits to aviation
 - Fuel savings
 - Efficiency enhanced of strategic flight routing
 - Cabin management enhanced
 - Improved safety of passengers and crew

Next Steps

- WTIC Program plans to transition CDO/CTH from research to operations
 - Will write a Transition Plan to document requirements process, once funded
 - NCAR continues to run the satellite system, producing gridded data and polygons
 - CDO/CTH products will be available for free through a license agreement with UCAR
 - Contact Cathy Kessinger (kessinge@ucar.edu; 303-497-8481) if interested
- WTIC Program considering a ROMIO-Alaska demonstration with CDO/CTH for GA
 - If approved and funded, will first write a Demonstration Plan

Thank you!

*And “Thank you!” to all the ROMIO participants
who made this demonstration a success!*

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*This research is in response to requirements and funding by
the Federal Aviation Administration (FAA). The views
expressed are those of the authors and do not necessarily
represent the official policy or position of the FAA.*

