Benefit Analysis of Remote Oceanic Meteorology Information Operational (ROMIO) Demonstration

A. Izadi, J. Seo, N. Hinze, and A. Trani
Air Transportation Systems Laboratory

Aviation Weather Industry Technology Meeting
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Outline

- ROMIO Benefit Analysis: a Multi-step Approach

1. Survey Analysis
2. Convective Weather Avoidance Analysis
   - Quantifies the operational benefits of strategic deviation maneuvers
   - Compares the deviation maneuvers to avoid convective weather in the Pre-ROMIO and Post-ROMIO periods
3. Simulation-Based Analysis
   - Evaluated potential fuel and travel time savings benefits using the FAA/Virginia Tech Global Oceanic Model
4. Potential Injury and Airframe Benefits
   - Evaluated potential passenger injury and airframe cost savings

Acknowledgements

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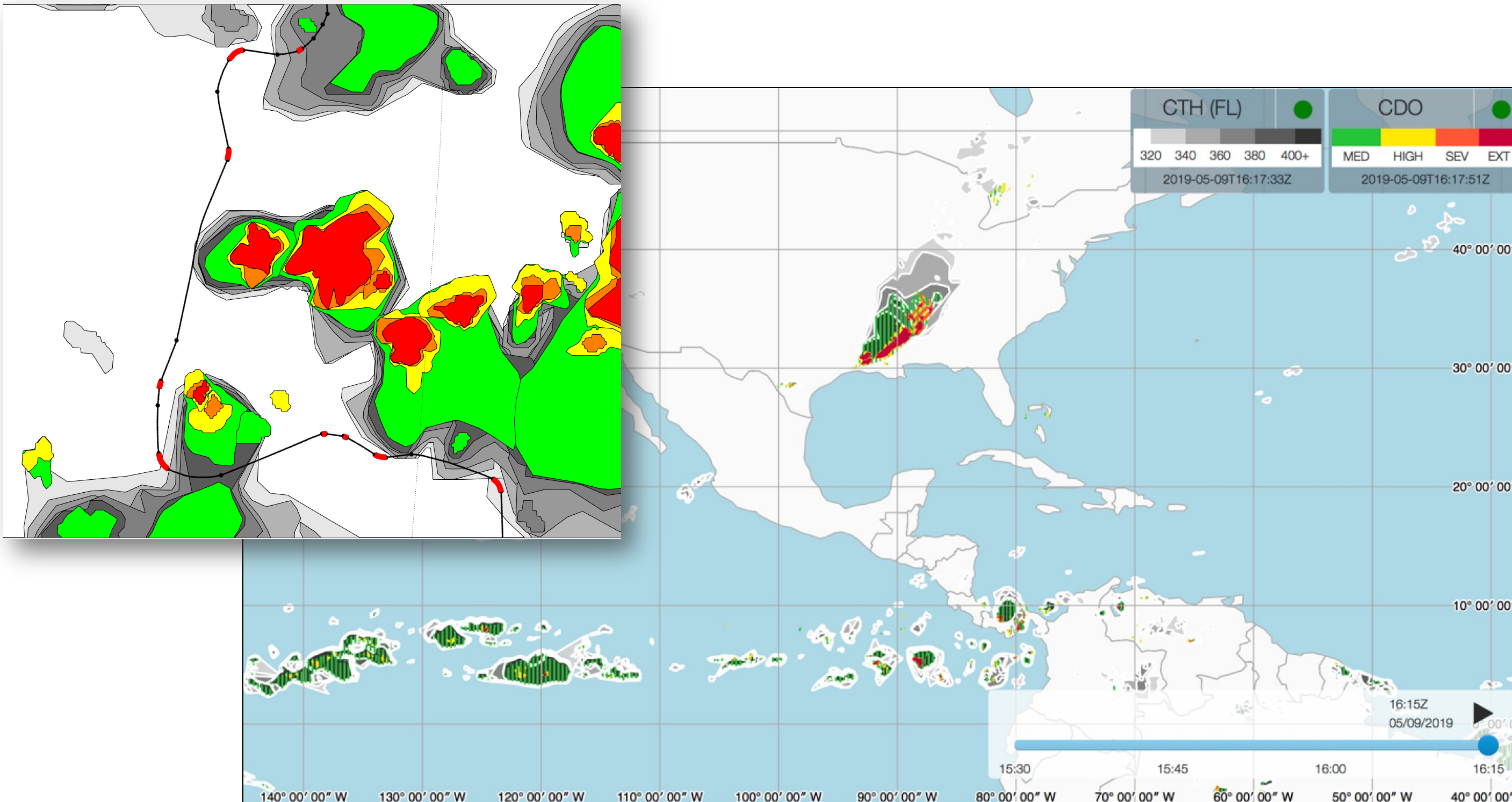
- Arman Izadi supported by the Najeeb E. Halaby Graduate Student Fellowship (summer)
- The authors would like to thank the US airline pilots who provided survey feedback in the project
- We also acknowledge the collaboration of US airlines, BCI, Gogo, and Panasonic Avionics
- Any opinions, findings, and conclusions presented herein are those of the authors and do not necessarily reflect the views of the FAA.

ROMIO – An Onboard Weather Situational Display System

- Provides 15-minute convective weather update
- iPad or Surface Tablet hardware/software



Report Deliverables

Benefit Analysis of Remote Oceanic Meteorology Information Operational Demonstration (ROMIO): Volume 1

Jungmin Seo
Armand Izadi
Nicolas Hinze
Antonio A. Trani

- Review of previous benefit studies
- Pilot, dispatcher and AOC surveys
- Statistical analysis of ROMIO Pilot survey
- August 2019

Benefit Analysis of Remote Oceanic Meteorology Information Operational (ROMIO) Demonstration: Volume 2

Arman Izadi, Nicolas Hinze, Howard Swingle, and Antonio A. Trani

Air Transportation Systems Laboratory

Virginia Tech

- Statistical analysis of flights
- Weather deviation analysis
- September 2019

Benefit Analysis of Remote Oceanic Meteorology Information Operational (ROMIO) Demonstration: Volume III

Arman Izadi, Nicolas Hinze, Navid Mirmohammadsadeghi, and Antonio A. Trani

Air Transportation Systems Laboratory

Virginia Tech

- Simulation-based analysis
- Injury analysis
- June 2020

Produced 3 technical papers

Summary of Findings (1)

- **Survey**
  - More than 110 surveys with ROMIO questions answered
  - 54% of the flights involved in the survey performed a weather deviation
  - Generally, pilots offer positive feedback about ROMIO
  - Pilots comment that ROMIO provides ***10-minute additional time*** to plan weather deviations compared to on-board weather radar
- **Convective Weather Deviation Analysis**
  - Analysis of 18,326 commercial flights shows that strategic weather deviations using ROMIO could save 1.6 minutes per flight (355 lbs. savings per flight)
  - Annual fuel consumption savings of **6.8** million pounds of fuel

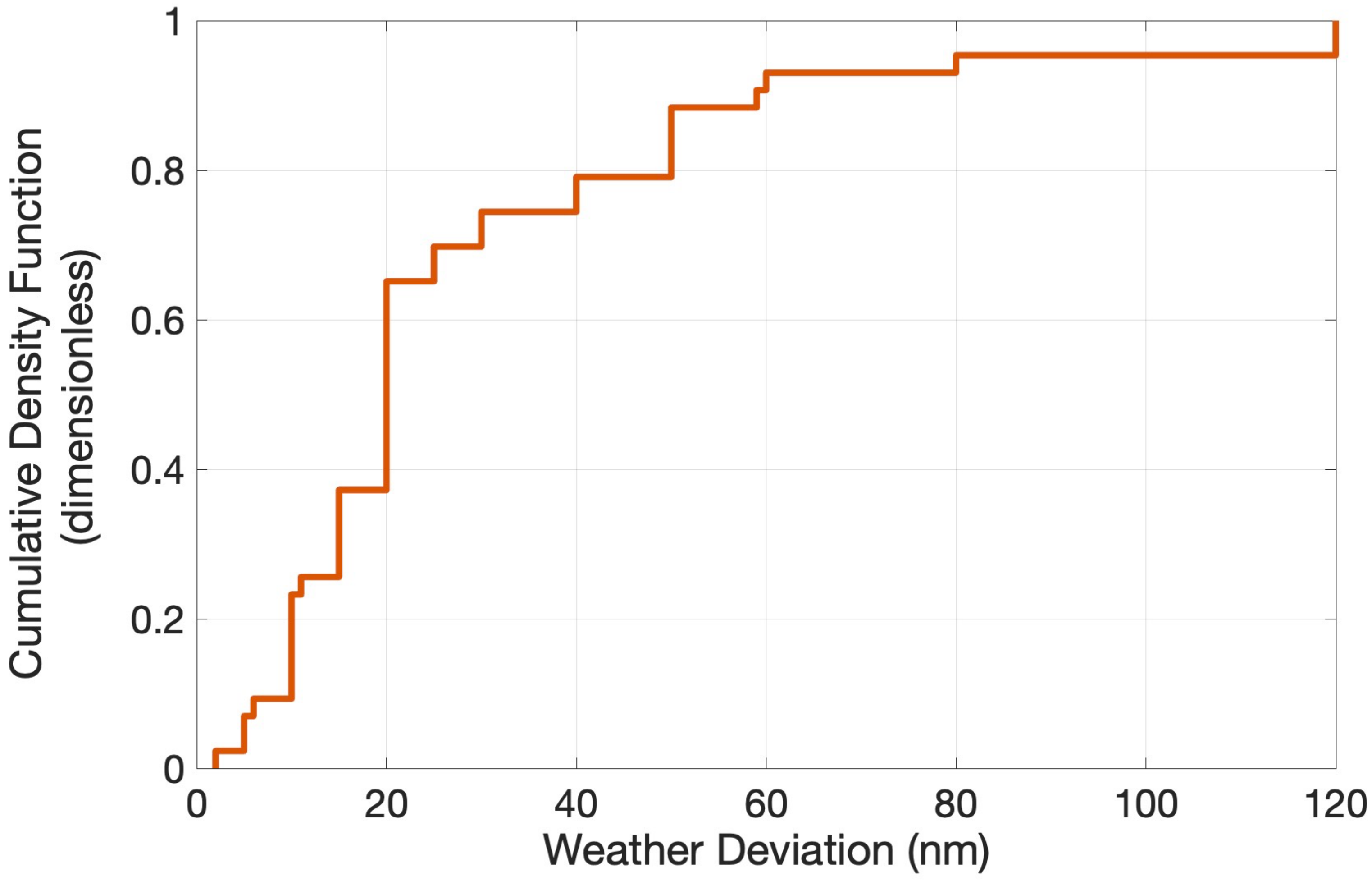
Summary of Findings (2)

- **Simulated-Based Benefits Analysis**
  - Considered South America and North Atlantic traffic
  - 115 kilograms (253 lbs.) saved per flight
  - 1.8-minute travel time savings
  - Annual fuel savings: $15.3 million
- **Injury and Airframe Mitigation Cost**
  - 20% reduction in potential exposure to severe convective weather events
  - Annual savings derived from ROMIO demonstration
  - $5.54 million in the Atlantic Ocean
  - $1.35 million in the South Pacific Ocean

Summary of Pilot Surveys

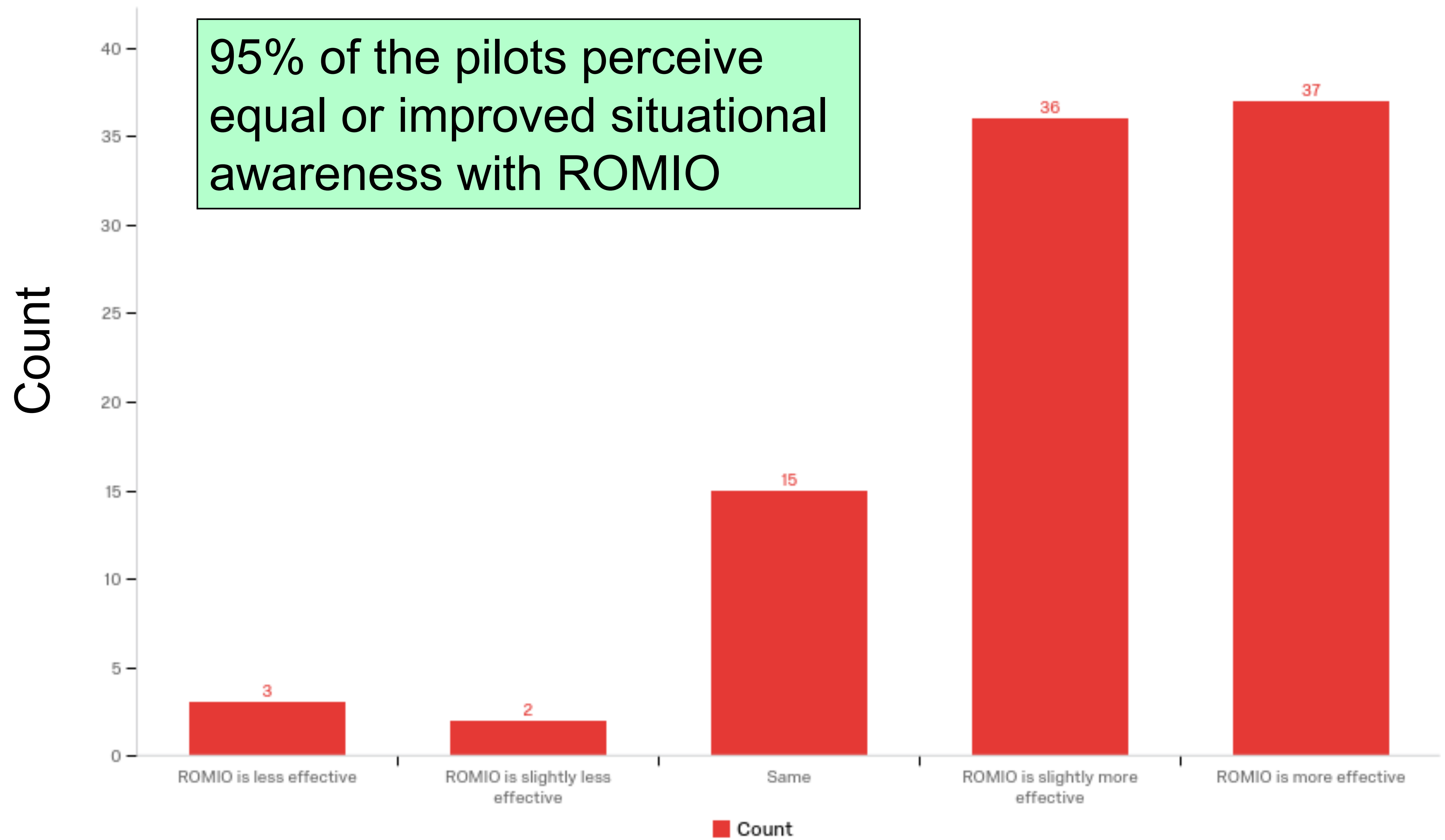
- More than 110 surveys with ROMIO questions answered
- 54% of the flights involved in the survey performed a weather deviation
- Generally, pilots offer positive feedback about ROMIO
- Pilots comment that ROMIO provides ***10-minute additional time*** to plan weather deviations compared to on-board weather radar

- ROMIO provides excellent capability for cabin crew coordination
- Average weather deviation for flights in survey is 29 nautical miles

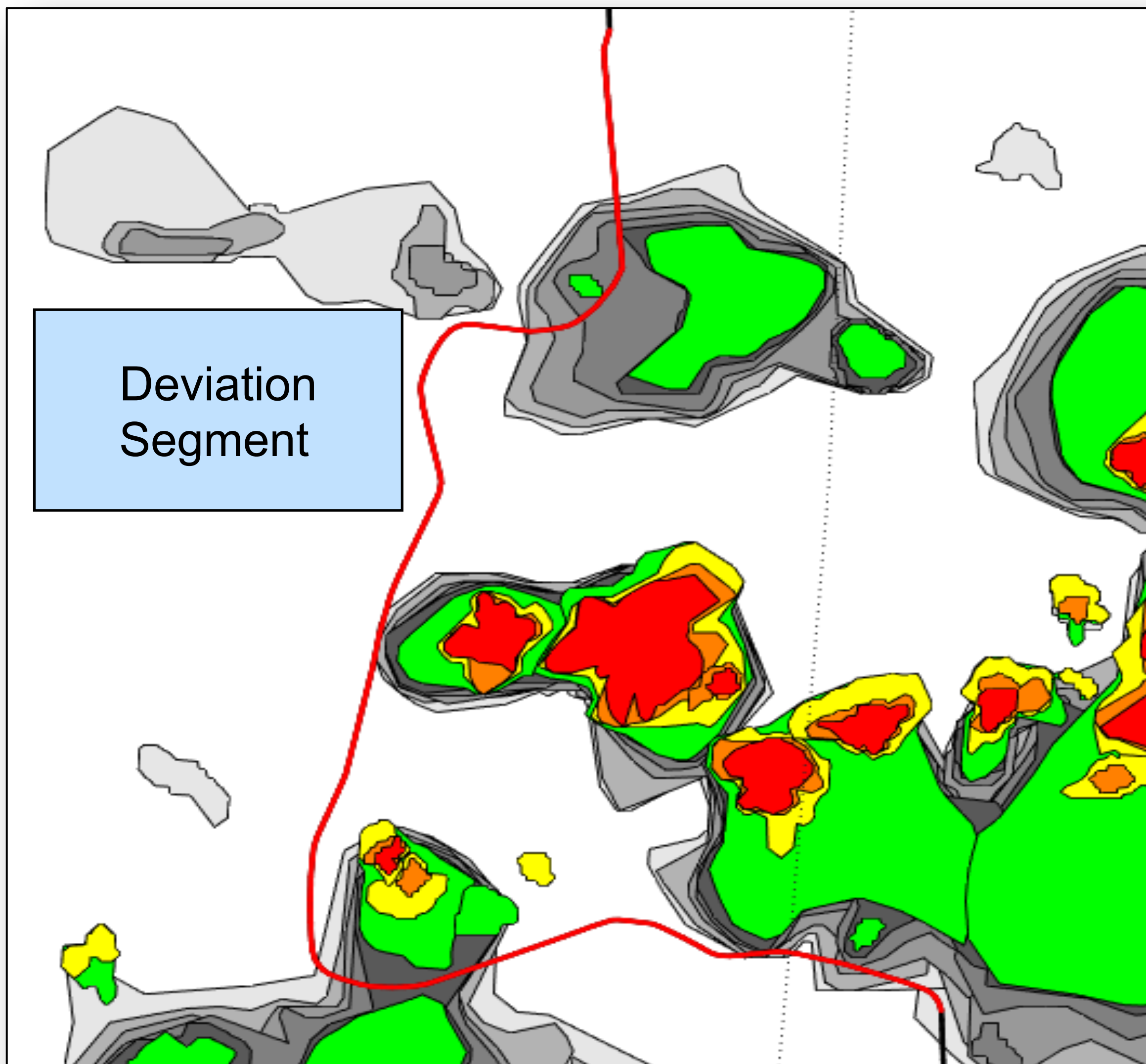


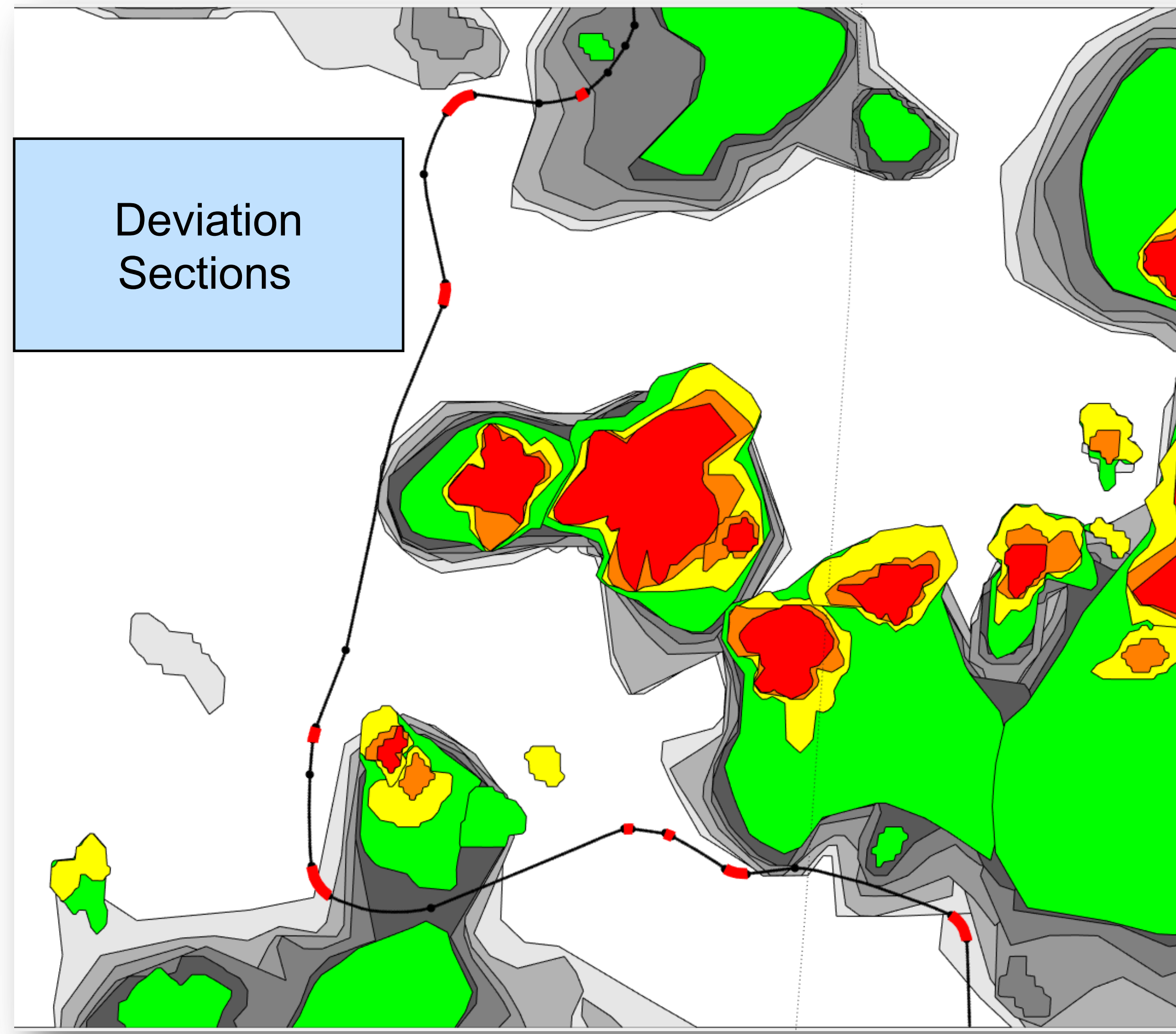
Situational Awareness: How well does ROMIO enable situational awareness in terms of monitoring weather along your route of flight in comparison to the current system of hardware and procedures?

95% of the pilots perceive equal or improved situational awareness with ROMIO



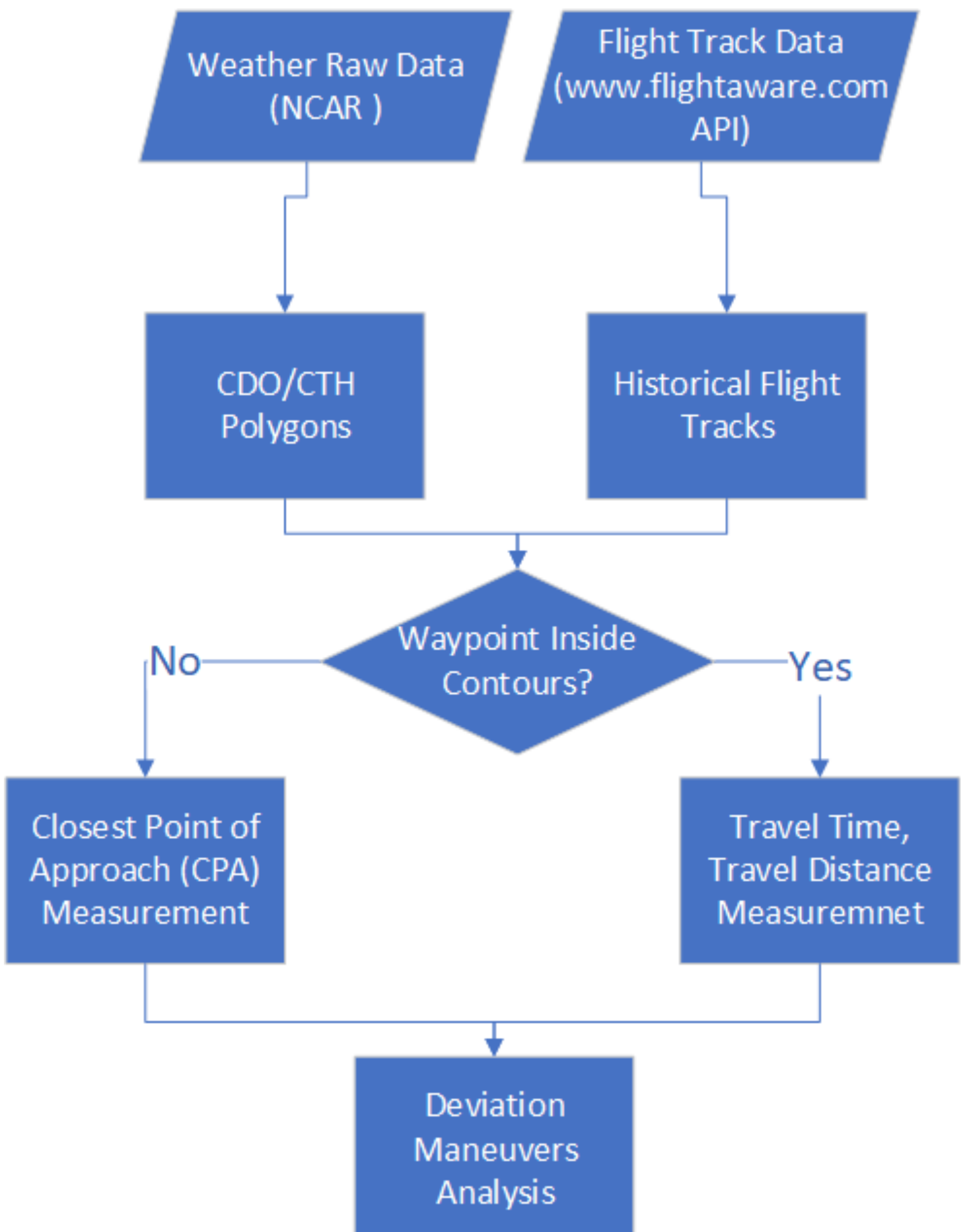
Convective Weather Deviation Avoidance Analysis using Historical Flight Data

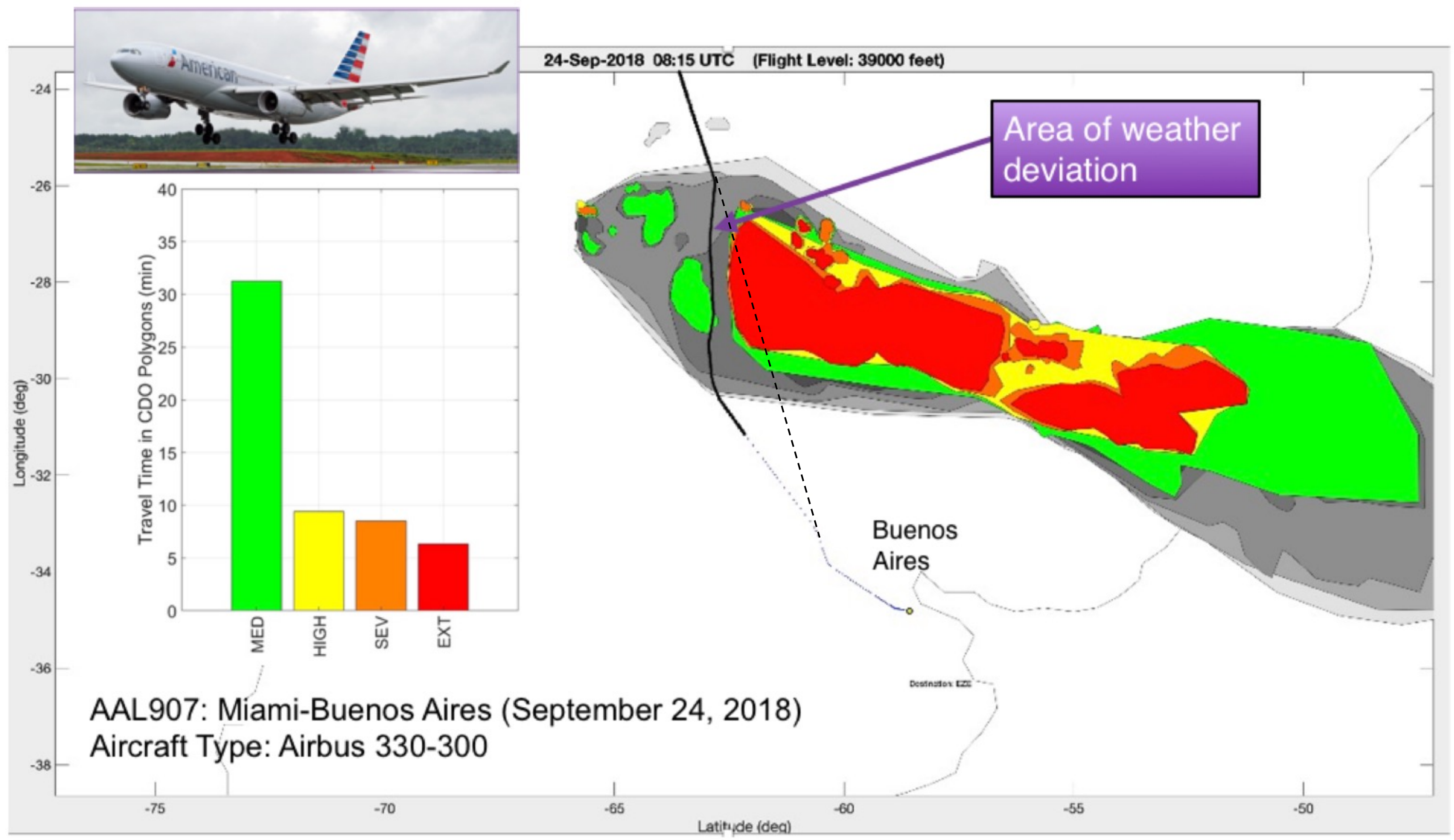




Historical Flight Analysis to Identify Convective Weather Avoidance Rules

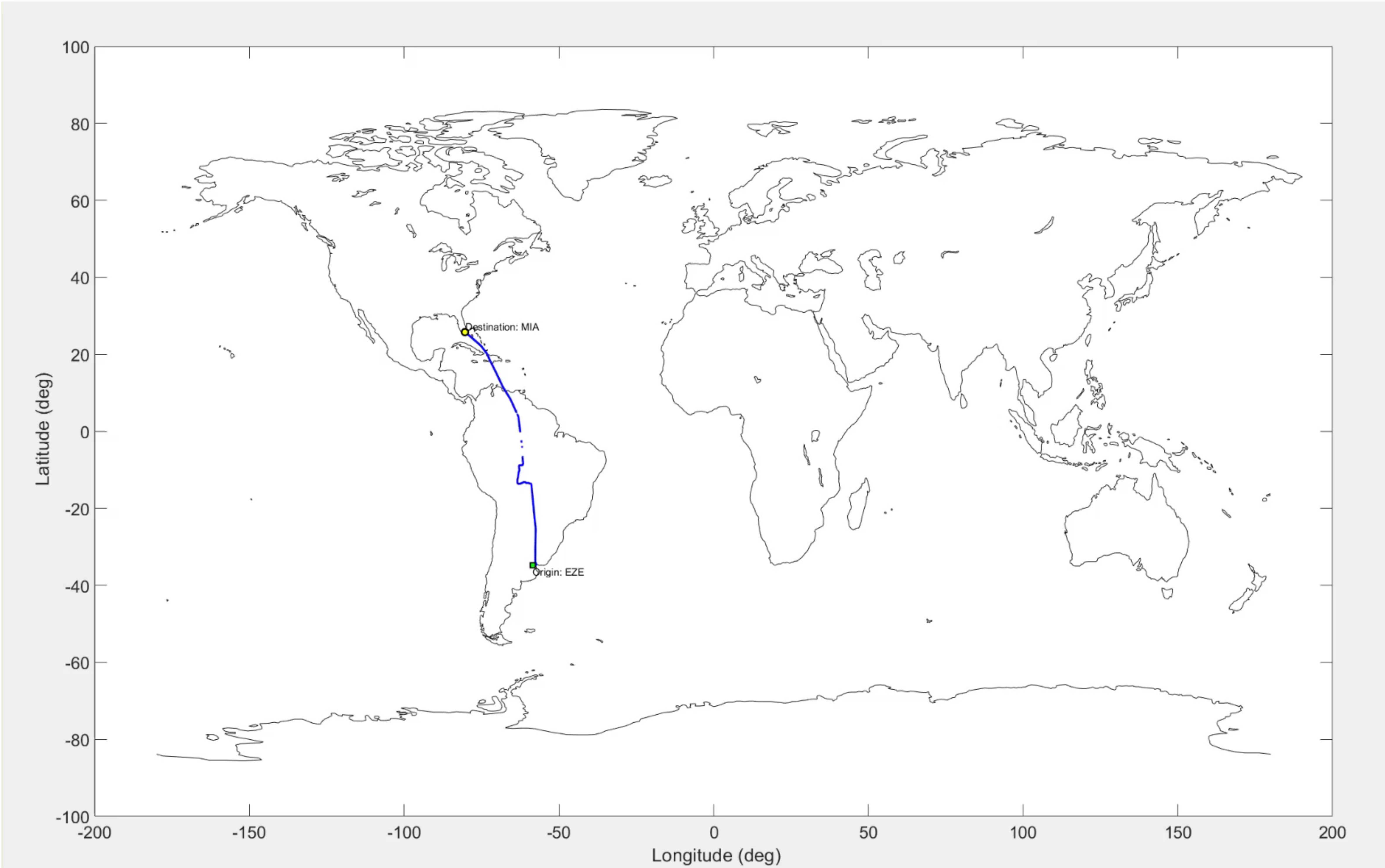
- 18,632 flights among 30 bi-directional origin-destination pairs
- Pre-ROMIO Period : March, April, May, June , July– 2018 (5 months)
- Post-ROMIO Period : August 2018 to May 2019 (10 months)





Example of Weather Deviation in the Amazon Region

Aircraft Type: B777-300ER

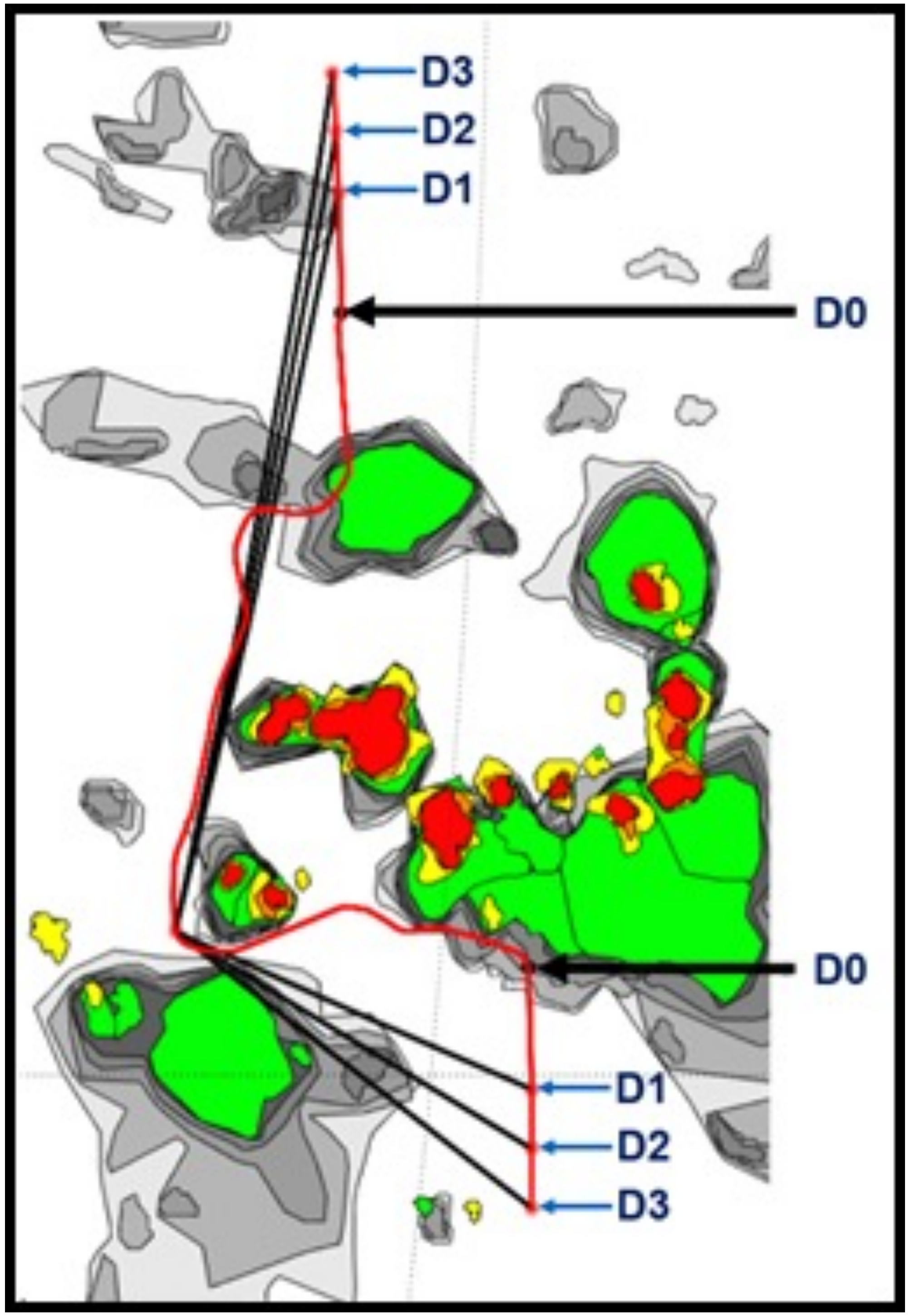


Quantifying ROMIO-Aided Strategic Weather Deviations

Aircraft Type: B777-300ER
Average Aircraft Speed : Mach 0.84
Weight ~ 685,000 lb (319 lb/minute cruise fuel flow)

Deviation Alternatives	Early Strategic Deviation	Travel Distance Savings (nm)	Travel Time Savings (min)	Potential Fuel Saved (lb)	Greenhouse Gas 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**.*



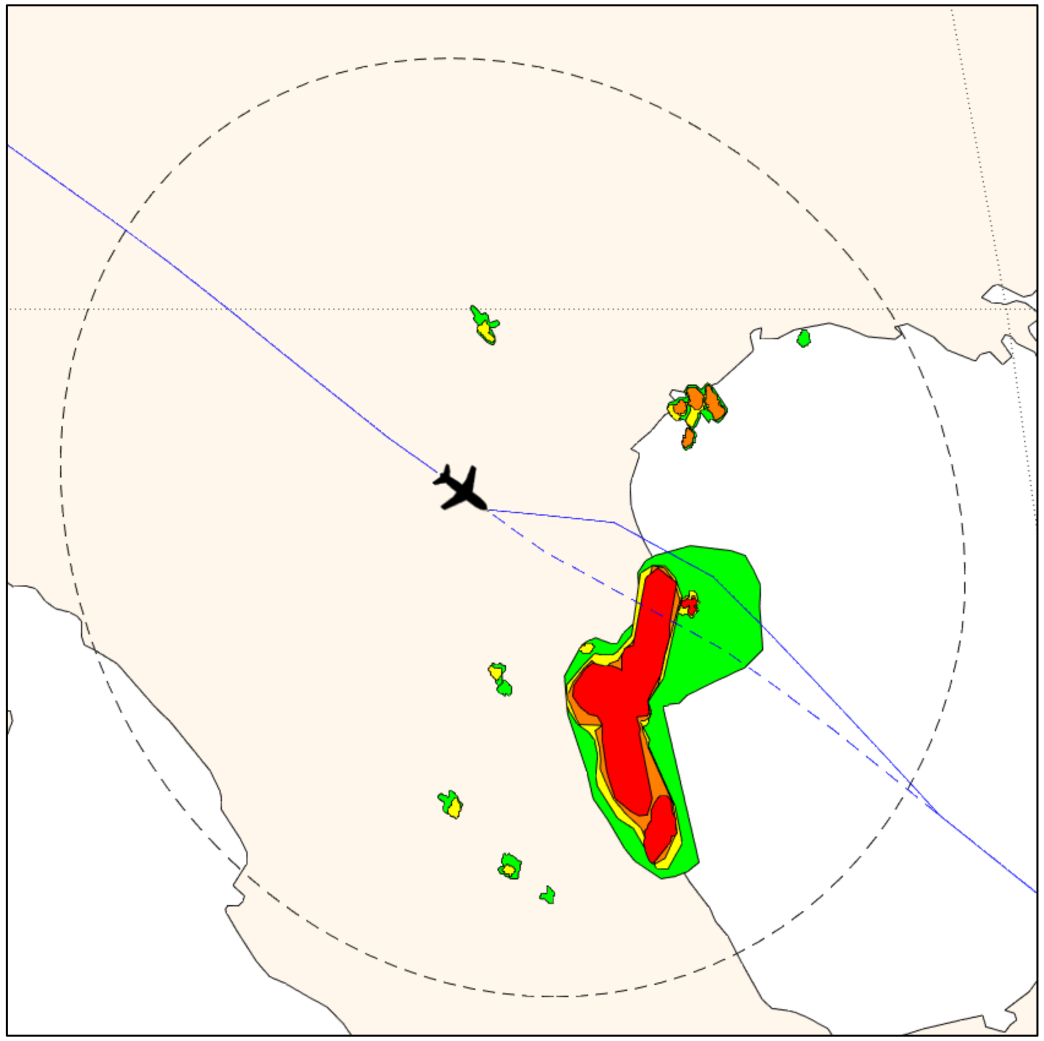
Max Lateral Deviation: 240 nm

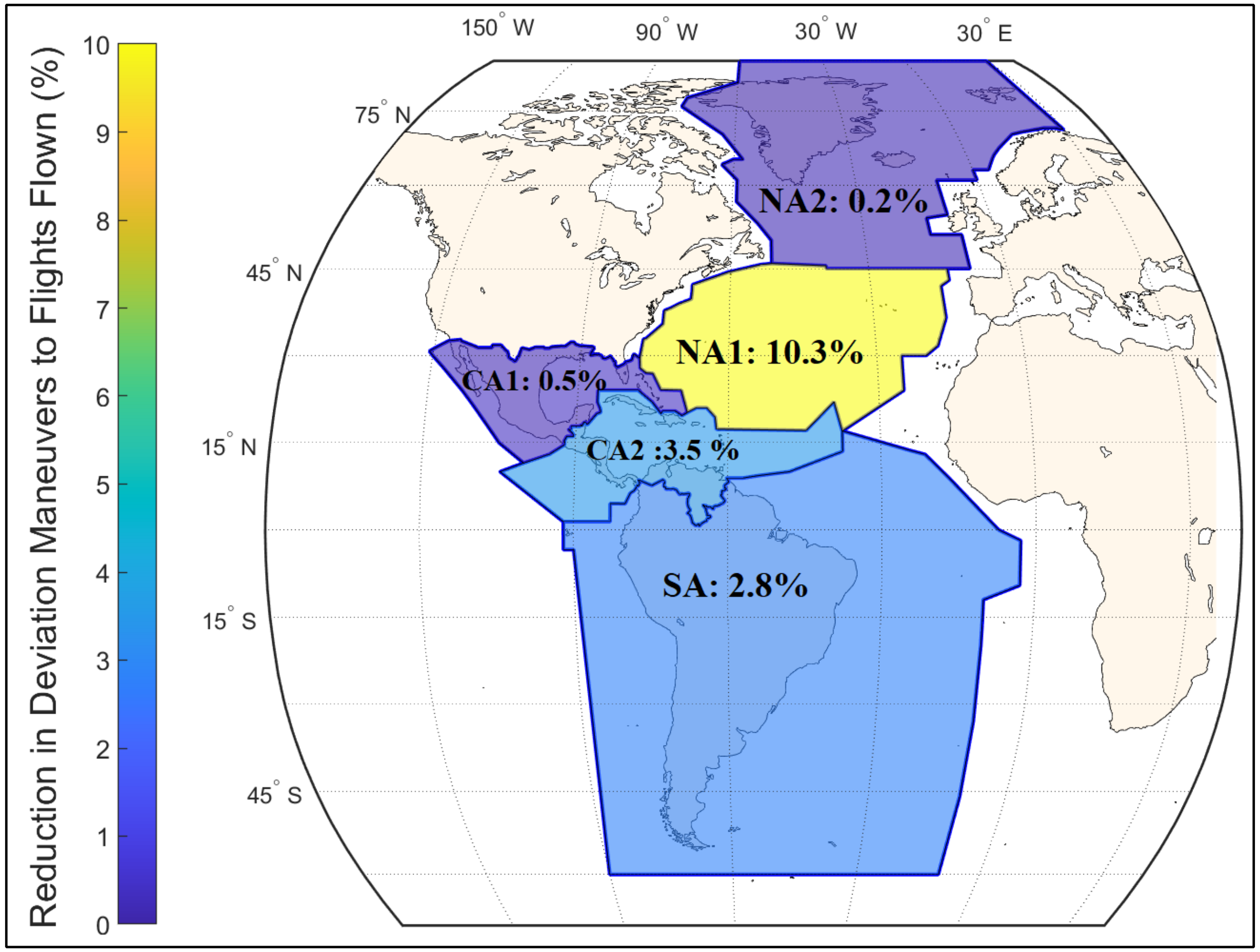
Operational Benefits of 10-Minute Earlier Deviation Maneuvers

No	Aircraft Type	Average Travel Distance Savings (nm)	Average Travel Time Savings (min)	Average Fuel Consumption Savings (lbs)	Average Greenhouse Emissions Savings (lbs)
1	'A332'	13.2	1.6	320	1001
2	'A333'	12.5	1.6	315	983
3	'B763'	9.4	1.2	211	660
4	'B764'	10.7	1.3	248	774
5	'B772'	12.3	1.5	355	1111
6	'B77L'	13.0	1.8	525	1640
7	'B77W'	14.6	1.8	543	1697
8	'B788'	13.0	1.6	282	882
9	'B789'	16.5	2.1	397	1241
Average		**12.8**	**1.6**	**355**	**1110**

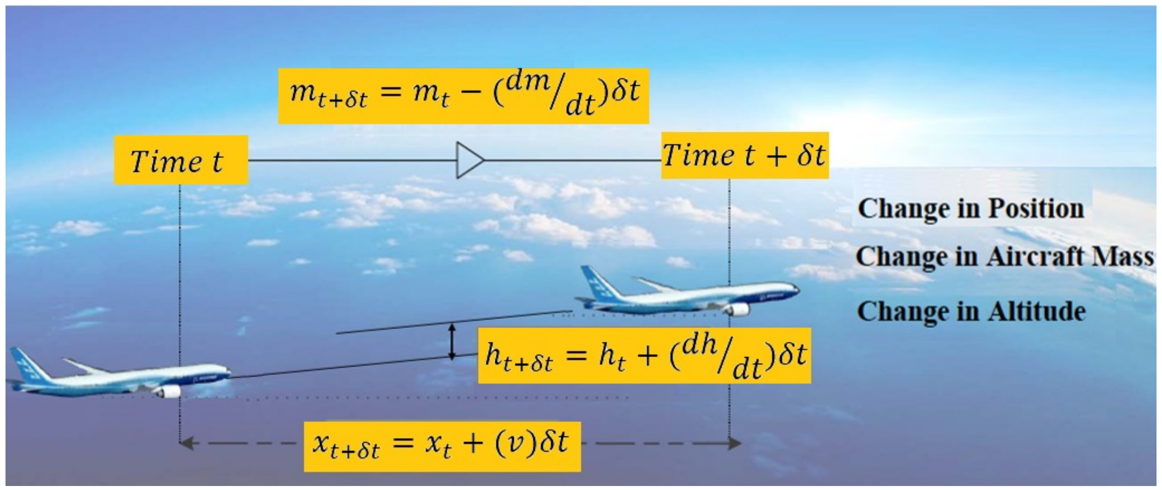
Assuming **60** flights crossing ITCZ per day, **320** operational days per year, the annual fuel consumption savings is estimated to be **6.8** million pounds. This is the lower bound for the benefits.

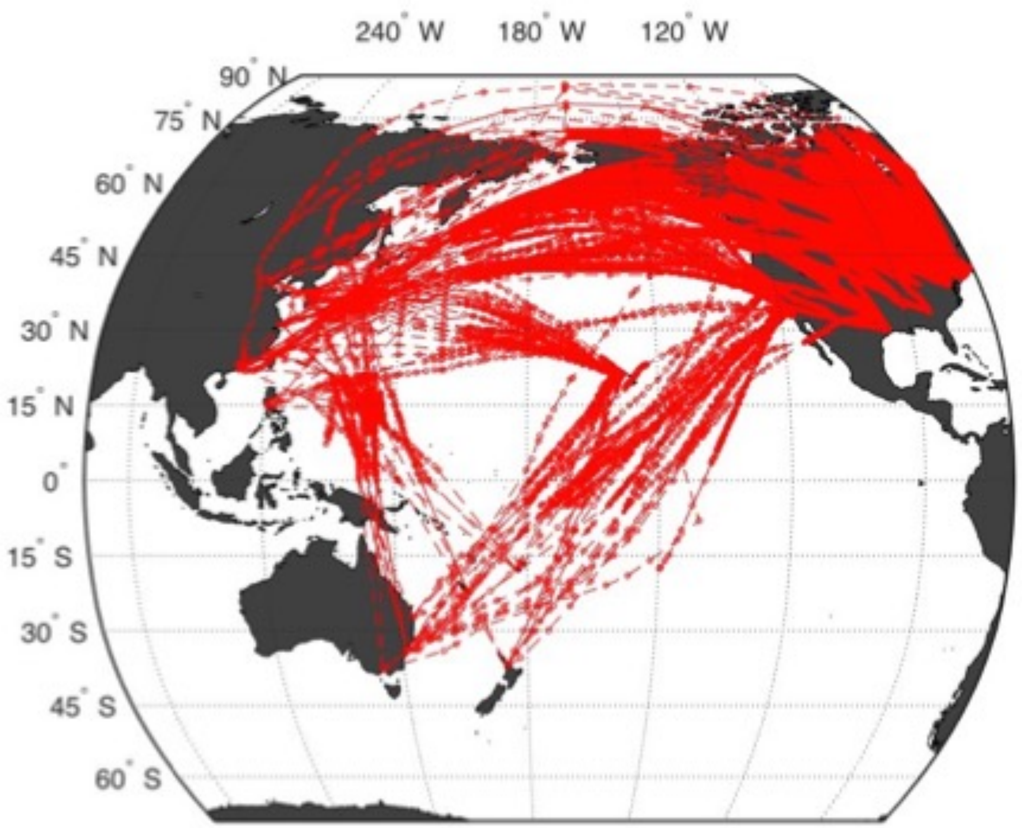
Simulation-Based Analysis using the FAA/Virginia Tech Global Oceanic Model



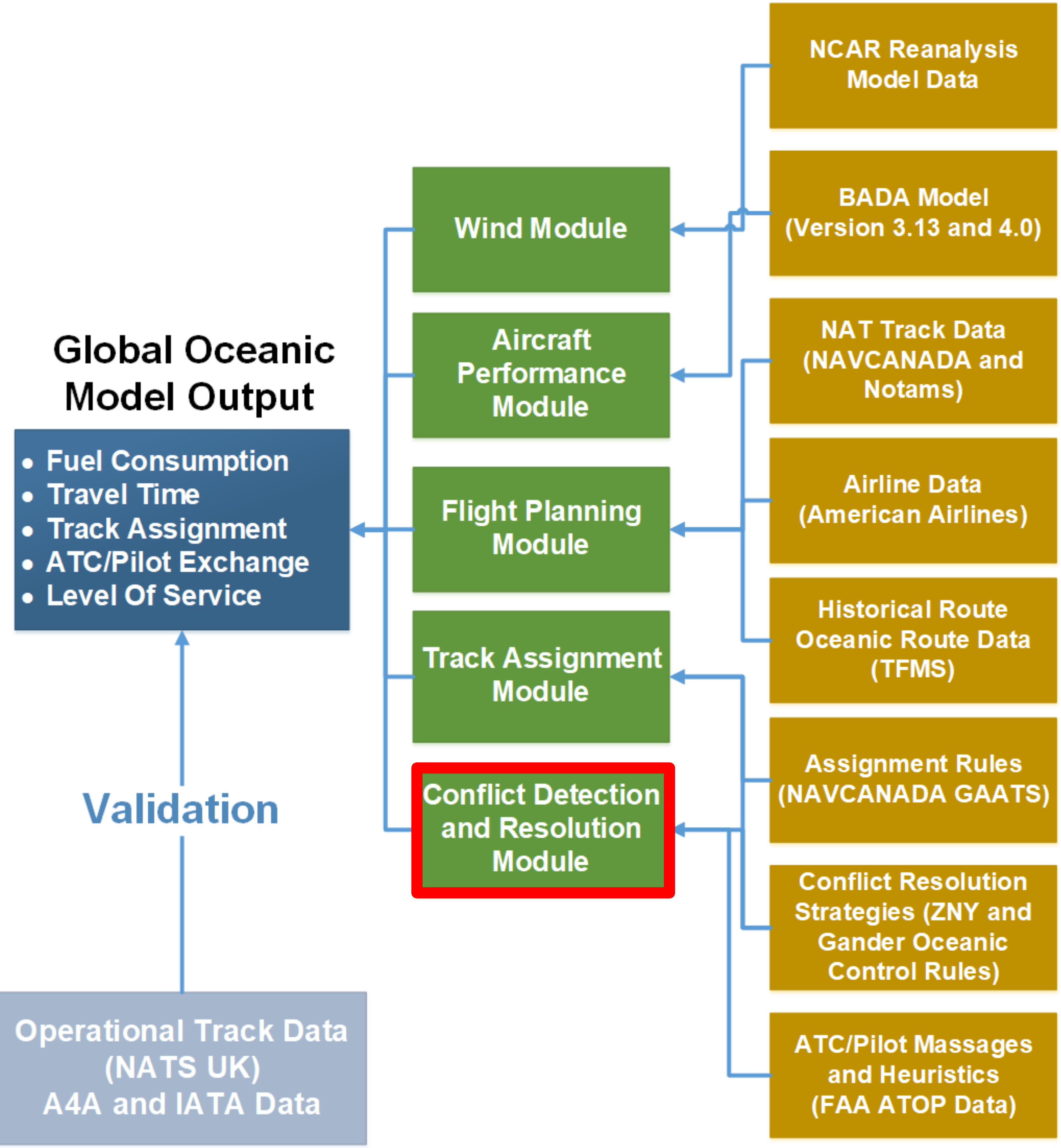


Global Oceanic Model





TFMS Flight Plan Data

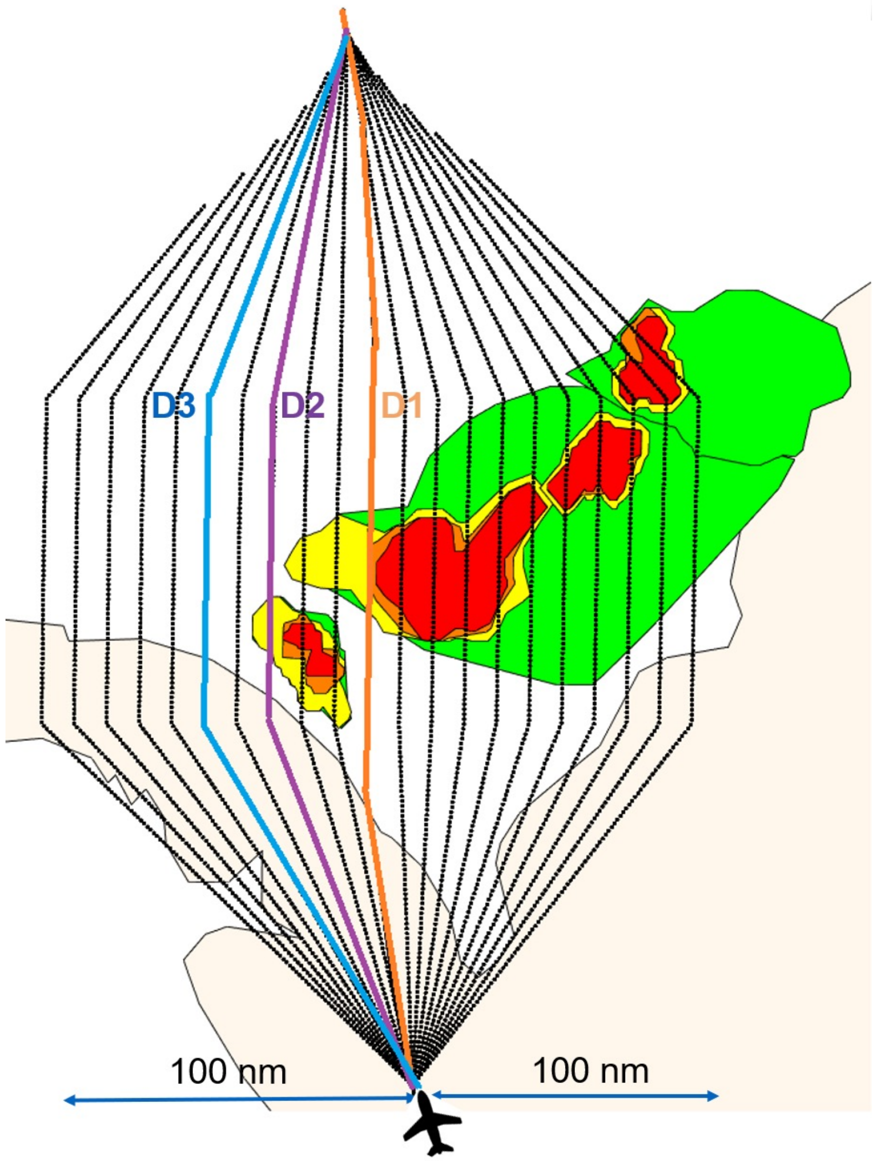


Weather Conflict Detection and Resolution

The weather conflict detection and resolution is programmed using the rule and strategies derived from:

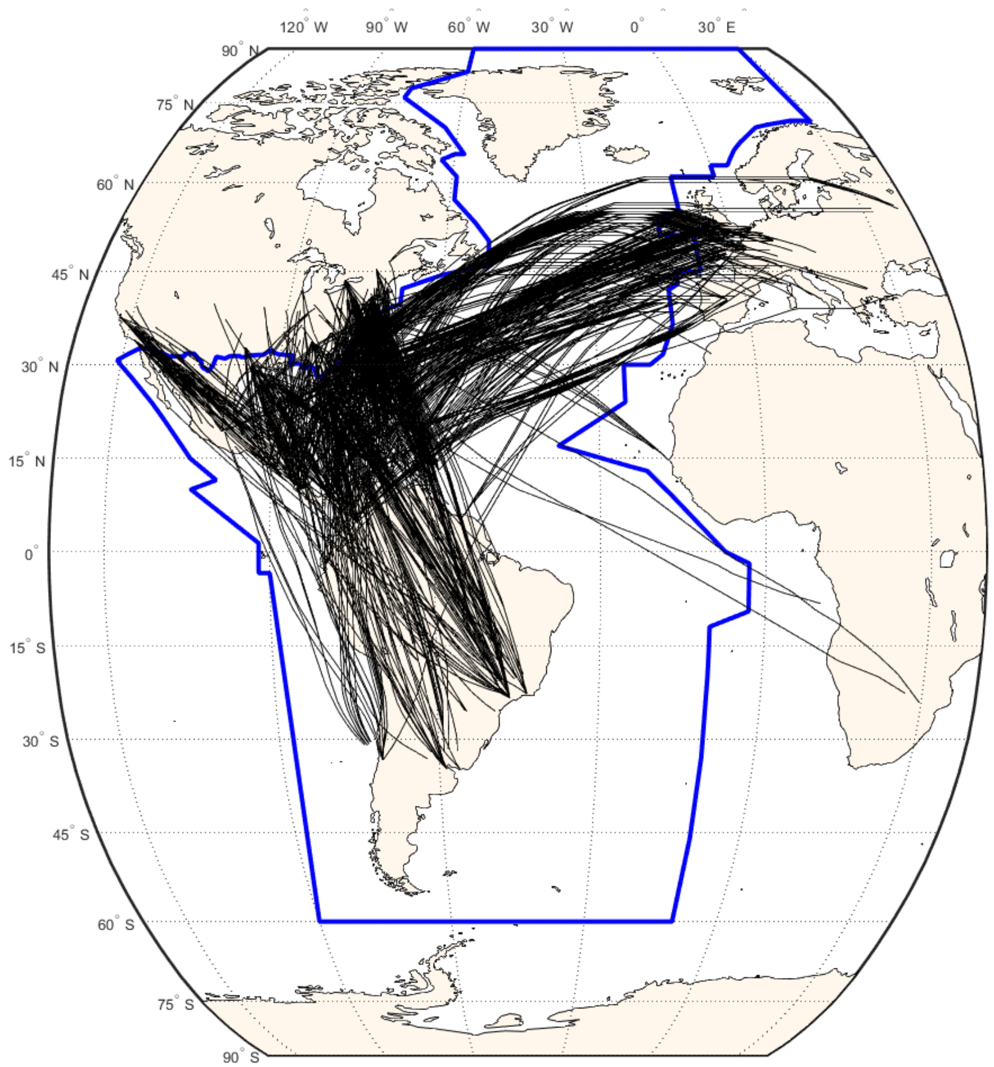
1) Historical flight analysis
2) FAA advisory circular for thunderstorms (AC-0024C)

Deviation Alternative	Lateral Deviation	Travel Distance in CDO Contours	Min Distance to Severe and Extreme CDO Contours
D1	0 (Flight Plan)	Medium: 28 nm High: 26 nm Severe: 4 nm	0 nm
D2	30 nm to the Right	Medium: 22 nm High: 22 nm	4 nm
D3	50 nm to the Right		24 nm

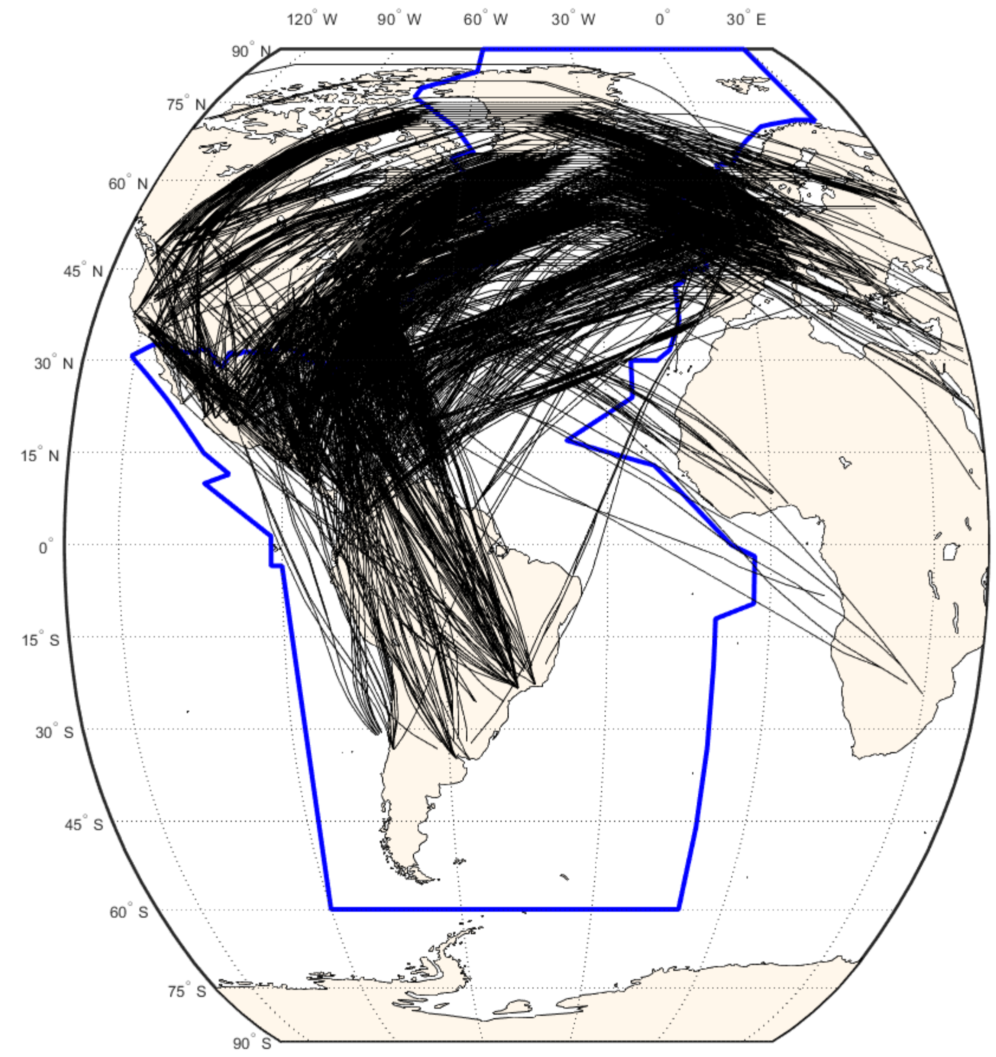


Simulated Traffic in the Global Oceanic Model

The traffic is derived from the Traffic Flow Management System (TFMS) for June 24,25,26, 2016 with forecast to 2019.



Medium Traffic
2050 flights in three-day simulation
1051 flights in middle day of simulation



High Traffic
4437 flights in three-day simulation
2258 flights in middle day of simulation

Scenarios Modeled using the GO Model

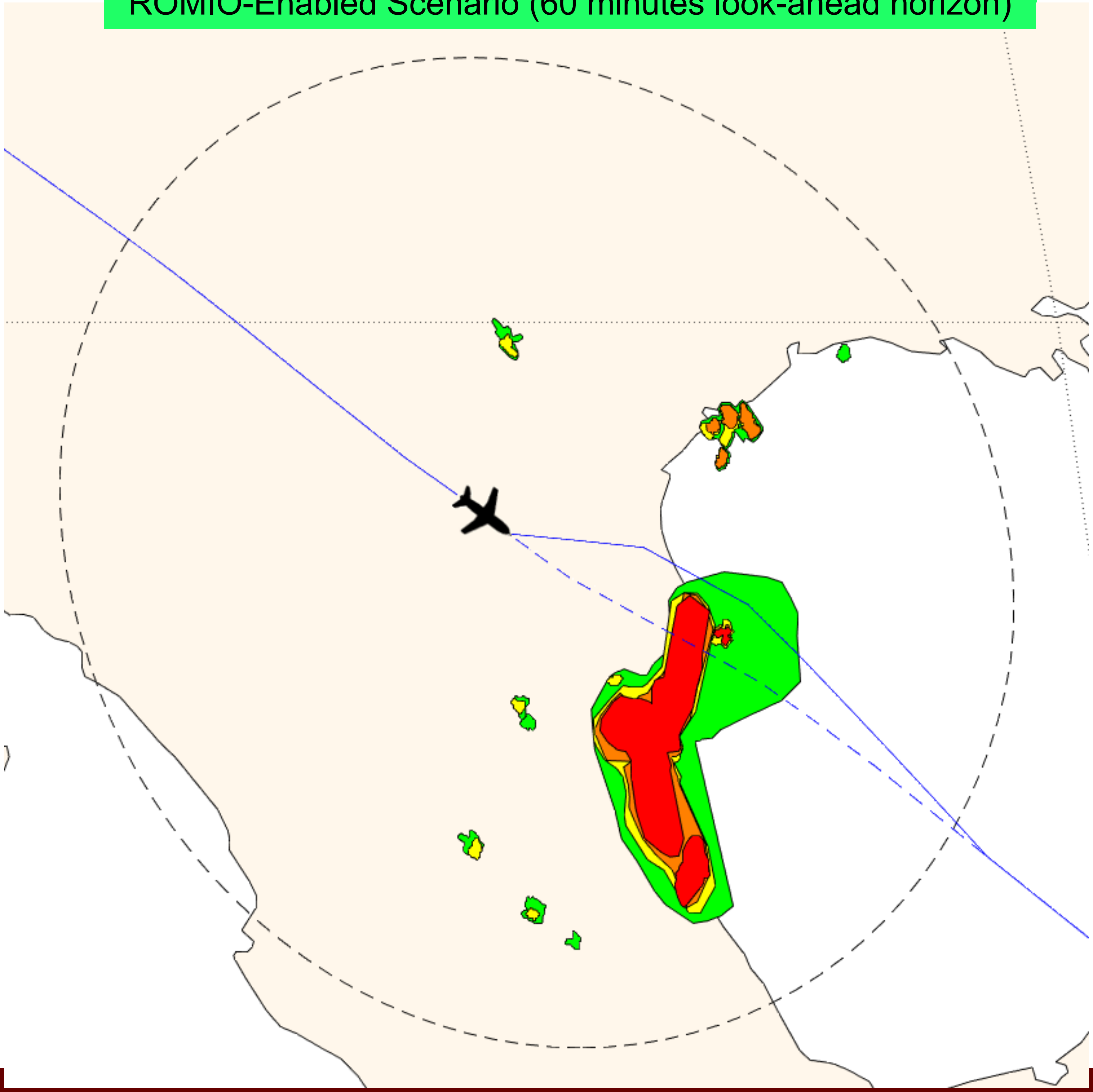
Scenario Sets		Traffic: Medium	Traffic: High
Weather	Moderately-Dynamic	Medium Traffic, Moderately-Dynamic Weather	Medium Traffic, Highly-Dynamic Weather
	Highly-Dynamic	High Traffic, Moderately-Dynamic Weather	High Traffic, Highly-Dynamic Weather

No.	Scenarios	Weather Conflict Detection Look-Ahead Horizon	Maximum Deviation Angle
1	Onboard Radar	20 minutes (∼160 nm)	75
2	ROMIO-Enabled	25 minutes (∼200 nm)	65
3	ROMIO-Enabled	30 minutes (∼240 nm)	65
4	ROMIO-Enabled	40 minutes (∼320 nm)	65
5	ROMIO-Enabled	60 minutes (∼480 nm)	55

Note: the maximum deviation angle is reduced with more look-ahead horizon.

Example : Strategic Decision-Making for Avoiding Convective Weather Beyond Onboard Radar

ROMIO-Enabled Scenario (60 minutes look-ahead horizon)



ROMIO-Enabled Scenario Statistics : Flights that Deviate from Weather and Affected Flights

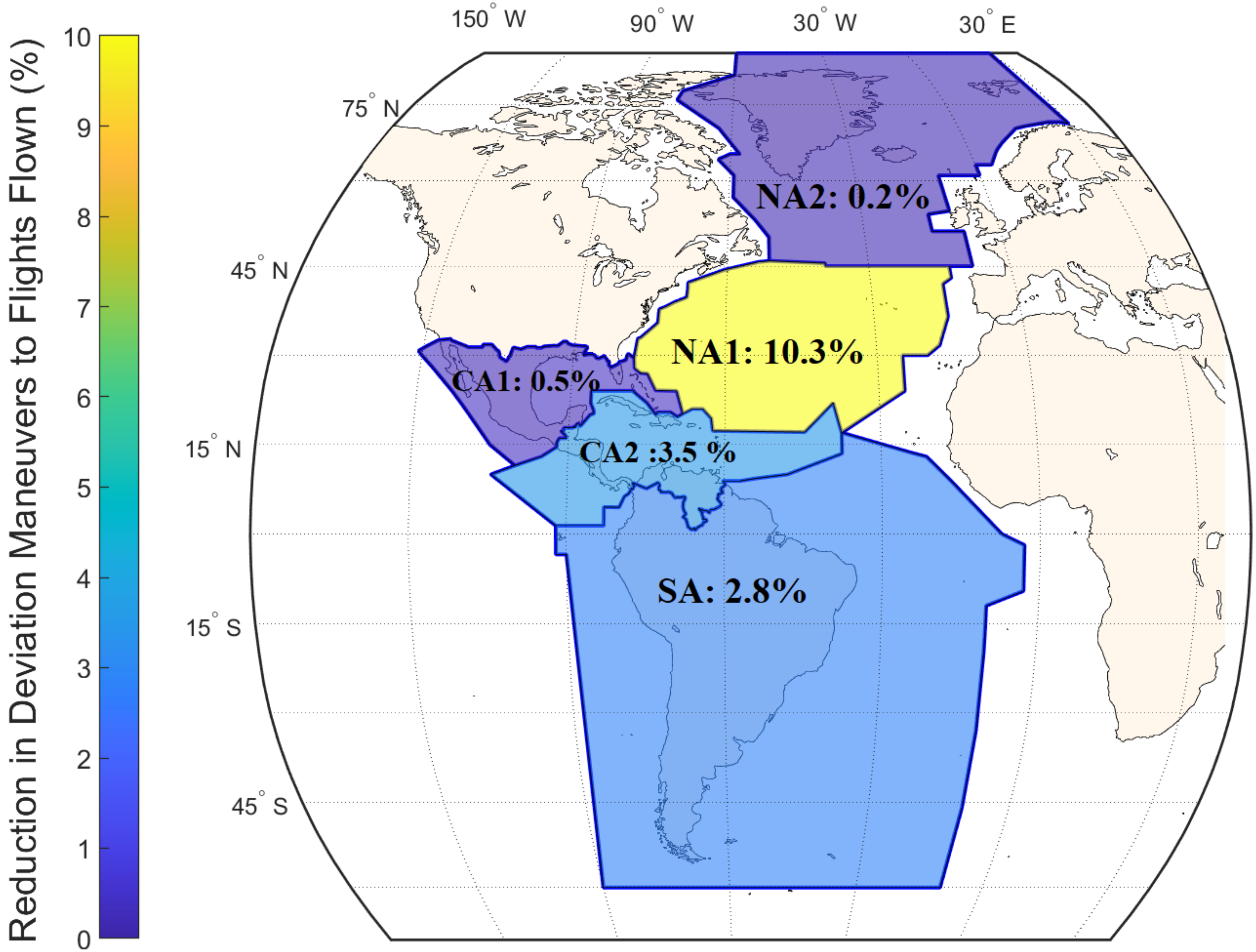
Flights affected by traffic deviation and Flights that deviated from their original track due to weather

Scenario Set	Average Fuel Consumption Saving (kg)	Average Travel Distance Saving (nm)	Average Travel Time Savings (min)	Average Greenhouse Gas Emission Saving (kg)
Medium Traffic, Moderately-Dynamic Weather	86	9.1	1.5	271
Medium Traffic, Highly-Dynamic Weather	84	7.6	1.0	264
High Traffic, Moderately-Dynamic Weather	88	8.3	1.4	277
High Traffic, Highly-Dynamic Weather	91	6.9	1.0	289
Average	**87**	**8.0**	**1.2**	**275**

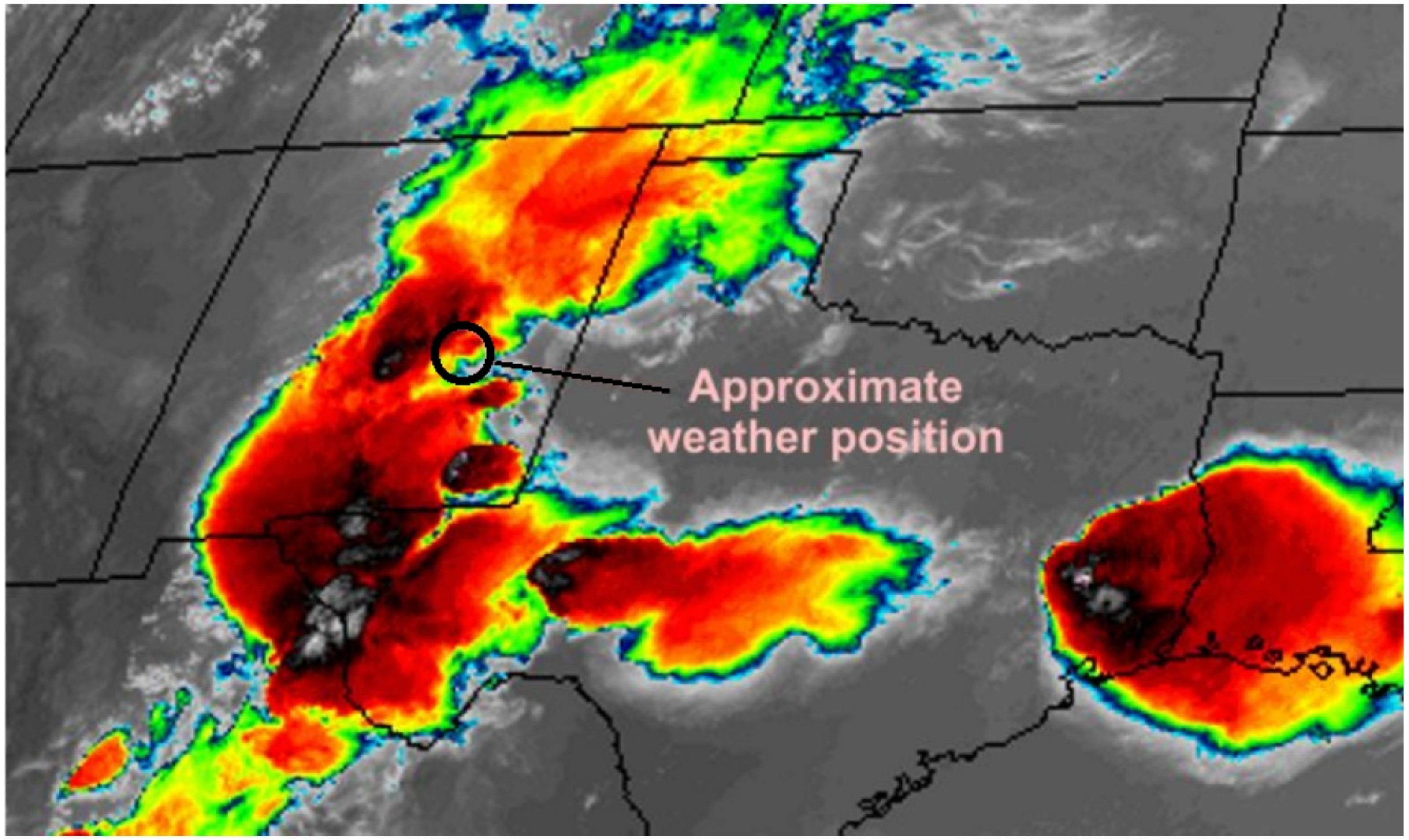
Flights that deviated from their original track due to weather

Scenario Set	Average Fuel Consumption Saving (kg)	Average Travel Distance Saving (nm)	Average Travel Time Savings (min)	Average Greenhouse Gas Emission Saving (kg)
Medium Traffic, Moderately-Dynamic Weather	120	13.6	1.7	379
Medium Traffic, Highly-Dynamic Weather	119	12.7	1.7	377
High Traffic, Moderately-Dynamic Weather	97	14.1	1.6	306
High Traffic, Highly-Dynamic Weather	122	15.7	2.0	386
Average	**115**	**14.0**	**1.8**	**363**

Using ROMIO May Reduce in the Number of Lateral Deviation Maneuvers in all Regions Simulated

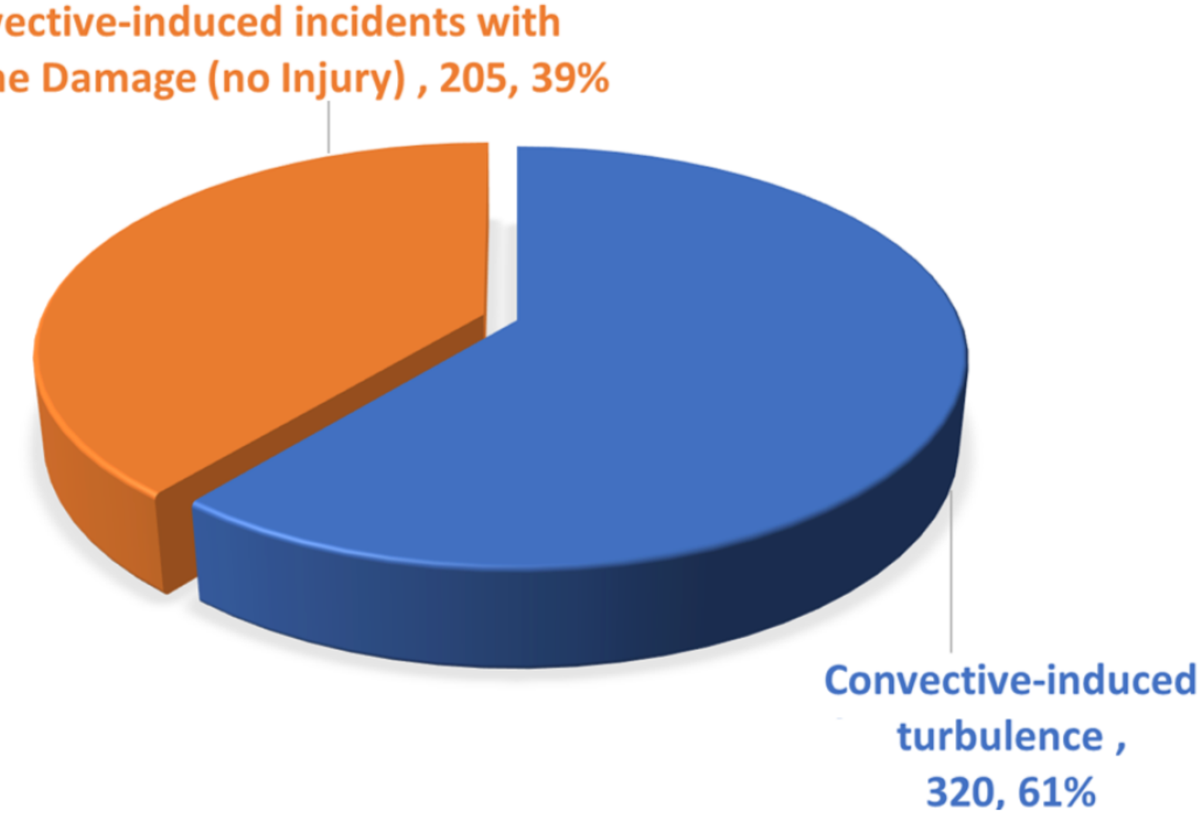


Another Potential Benefit: Injury and Airframe Cost Mitigation

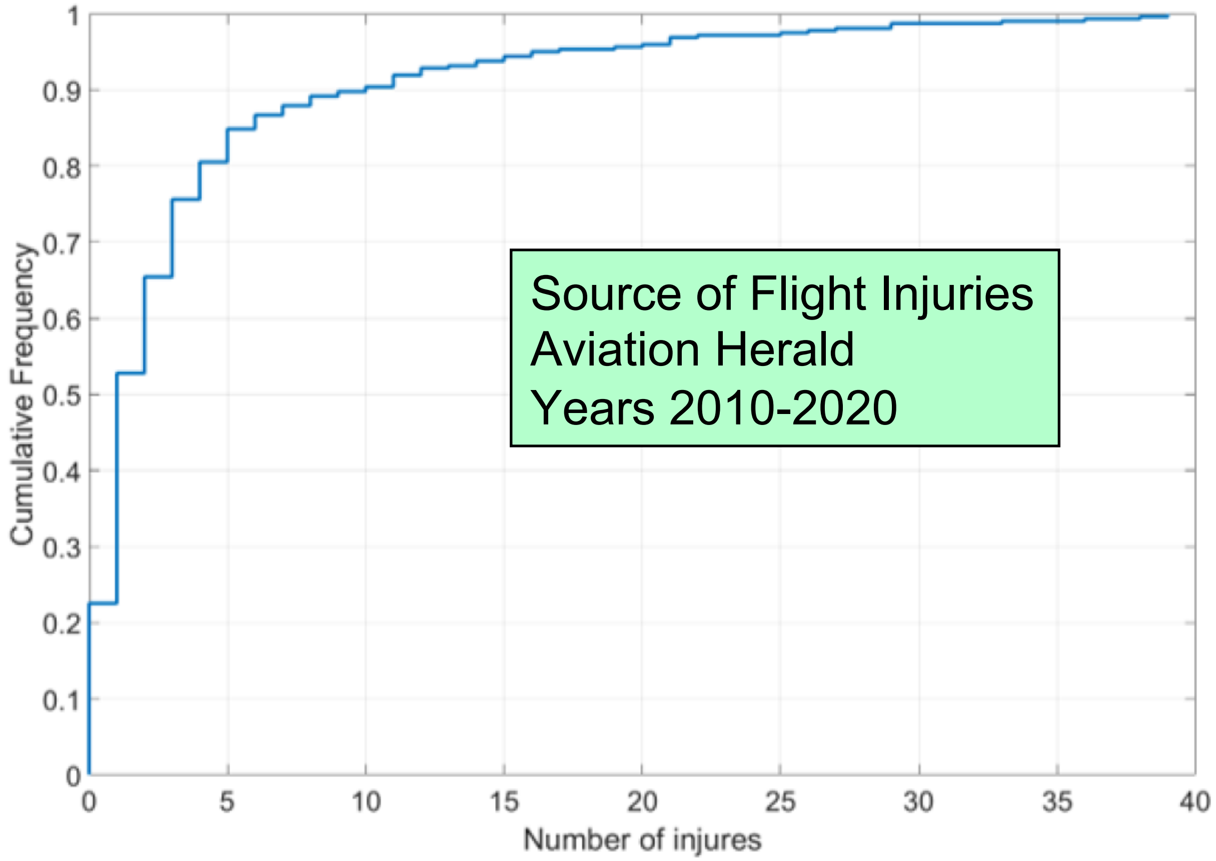


Source: Aviation Herald (http://avherald.com/h?article=4b97224e)

Historical Flights with Injuries and Cost of Injuries



(a) Types of convective-induced incidents.



(b) Distribution of number of injuries.

Table 9: Annual convective-induced turbulence statistics.

Injury Category	Number of Injuries (2009-2014)	Percentage of Injuries	FAA Injury Value
Serious	26	57%	1,084,469
Minor	20	43%	30,947

Source: Campbell et al. (2015) – MIT Lincoln Laboratory Study

Potential ROMIO Benefits to Avoid Injuries and Aircraft Damage

$P(C) = P(I \cap E) = P(E) \times (I|E)$ where:

P(C) is the probability of convective-induced incidents,

P(I) is the probability incidents,

P(E) is the probability of high exposure events in event type 4, P(E)=(0.017,0.027)

$P(I|E)$ is the conditional probability of incidents in high exposure events occur in event type 4,

$N(C) = E(Op) \times P(C)$ where:

N(C): is number of convective-induced incidents,

E(Op): is the expected number of annual flight operations crossing the ROMIO-covered airspace,

P(C): is the probability of convective-induced incidents,

$P(C) = (0.00008, 0.00012)$

$E(Op_{NorthAmerica-SouthAmerica}) = 112,284$ flights per year

$E(Op_{NorthAmerica-SouthwestPacific}) = 26,929$ flights per year

$N(C_{NorthAmerica-SouthAmerica}) = 112,284 \times (0.00008, 0.00012) \simeq [9 - 15]$

$N(C_{NorthAmerica-SouthwestPacific}) = 26,929 \times (0.00008, 0.00012) \simeq [2 - 4]$

Table 10: Total benefits of the ROMIO application in saving convective-induced incidents.

Region	**Damage Type**	**Injury Category**	**Expected Number of Occurrence**	**Expected Cost per Unit ($)**	**Total Cost ($)**
North America - South America	Injury	Serious	4.1	1,084,469	4,446,323
		Minor	3.1	30,947	95,936
	Aircraft damage		1	1,000,000	1,000,000
Total					**5,542,259**
North America-Southwest Pacific	Injury	Serious	1	1,084,469	1,084,469
		Minor	0.75	30,947	23,210
	Aircraft damage		0.25	1,000,000	250,000
Total					**1,357,679**

Summary of Findings (1)

- **Survey**
  - More than 110 surveys with ROMIO questions answered
  - 54% of the flights involved in the survey performed a weather deviation
  - Generally, pilots offer positive feedback about ROMIO
  - Pilots comment that ROMIO provides 10-minute additional situation awareness to plan weather deviations vs on-board radar
- **Convective Weather Deviation Analysis**
  - Analysis of 18,326 commercial flights shows that strategic weather deviations using ROMIO could save 1.6 minutes per flight (355 lbs savings per flight)
  - Annual fuel consumption savings of **6.8** million pounds of fuel savings

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- **Simulated-Based Benefits Analysis**
  - Considered South America and North Atlantic traffic
  - 115 kilograms (253 lbs.) saved per flight
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- **Injury and Airframe Mitigation Cost**
  - 20% reduction in potential exposure to severe convective weather events
  - Annual savings derived from ROMIO demonstration
  - $5.54 million in the Atlantic Ocean
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