Frontiers of Turbulence Prediction
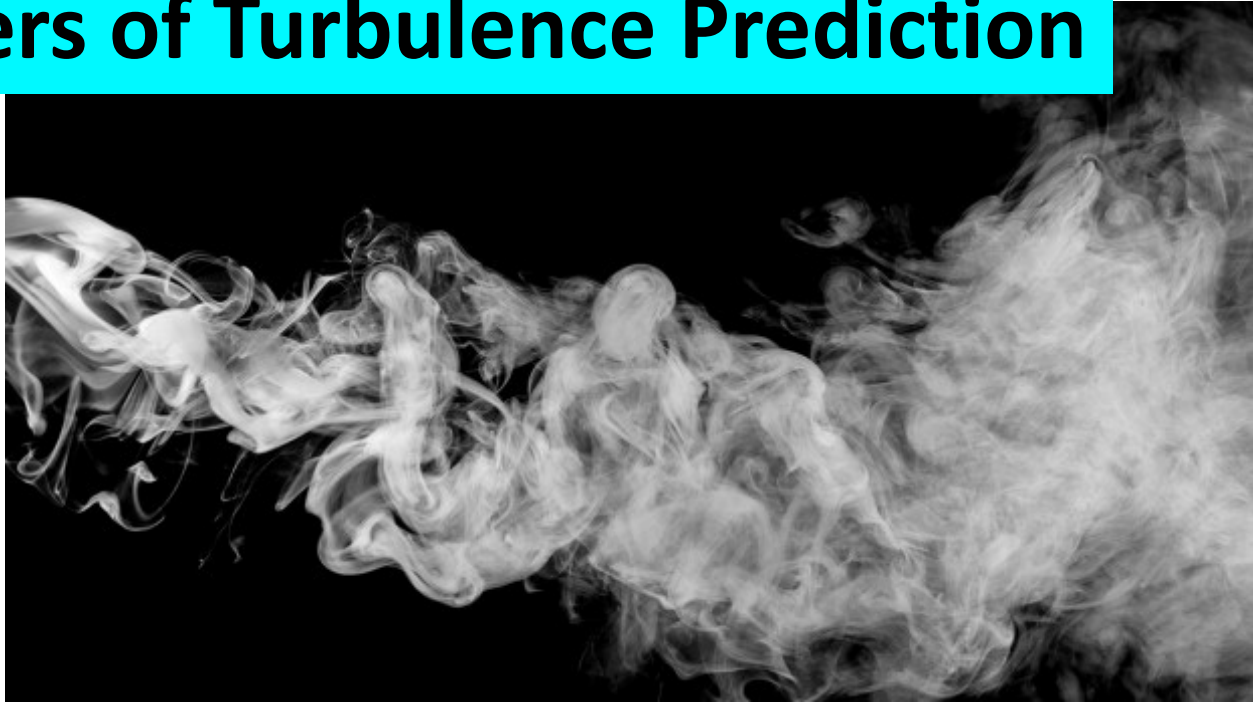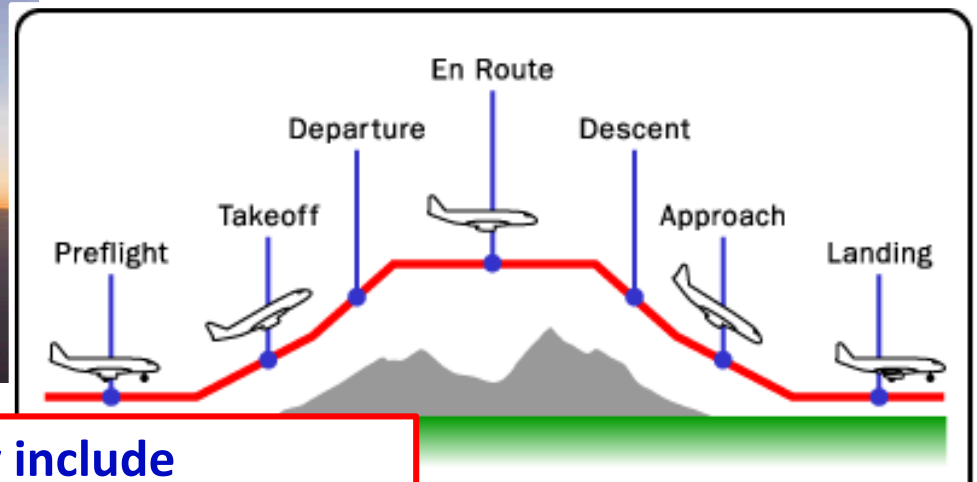
Matthias Steiner
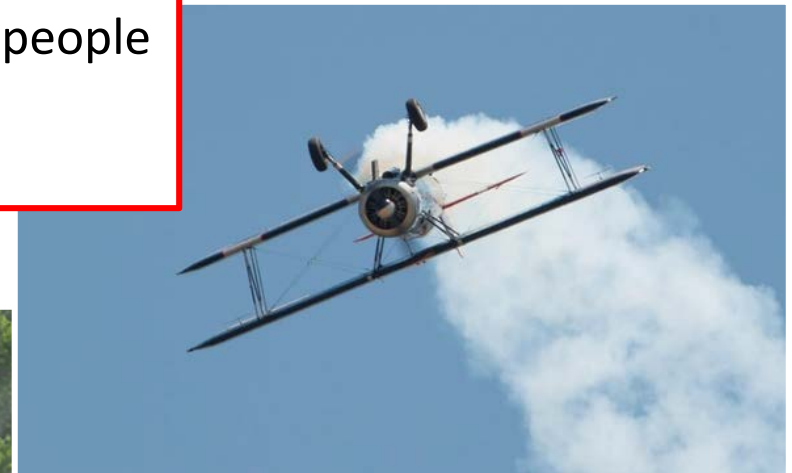
National Center for Atmospheric Research
msteiner@ucar.edu

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Turbulence Impact Mitigation Workshop #3
5 – 6 September 2018, McLean, VA

Typical Flight Patterns

Purpose of a flight may include
- ➤ Delivery or retrieval of goods & people
- ➤ Collection of information
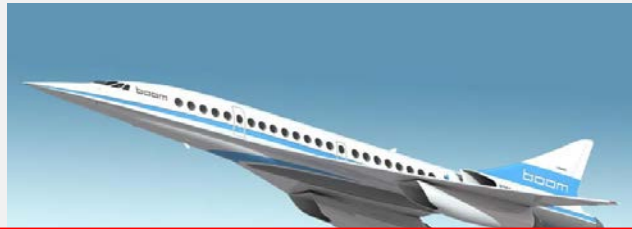- ➤ Recreation

Today's Air Transportation

	Scheduled	On Demand
Manned		
Unmanned		

Future Air Transportation

	Scheduled	On Demand
Manned		
Unmanned		

Emerging modes of transportation => new requirements
- ➢ Space travel => takeoff, reentry & landing
- ➢ Supersonic flight => cover higher altitudes
- ➢ Shared & personal aerial rides => lower altitudes & urban environments
- ➢ Unmanned aerial transport => micro weather for small drones
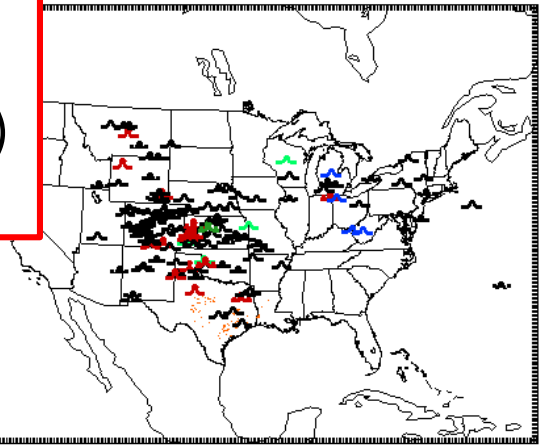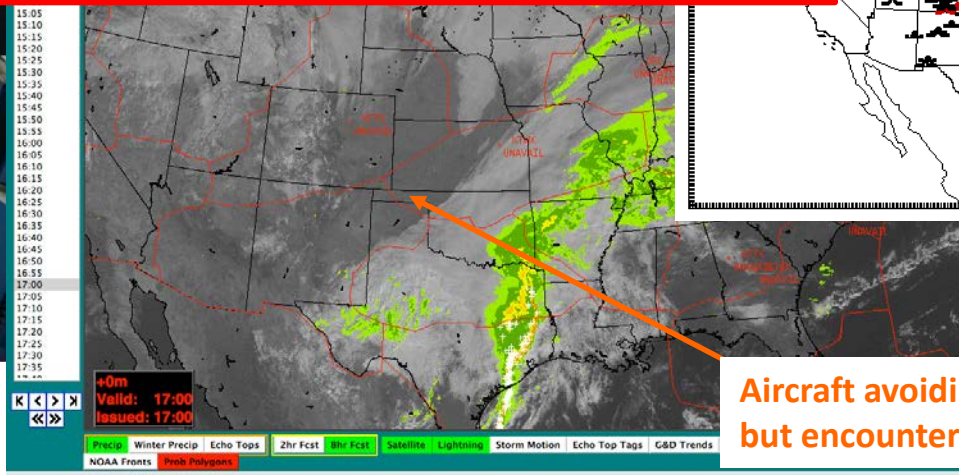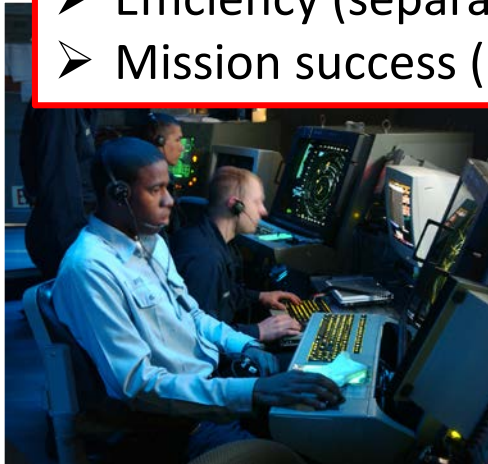- ➢ Pseudo satellite drones => cover higher altitudes, takeoff & landing

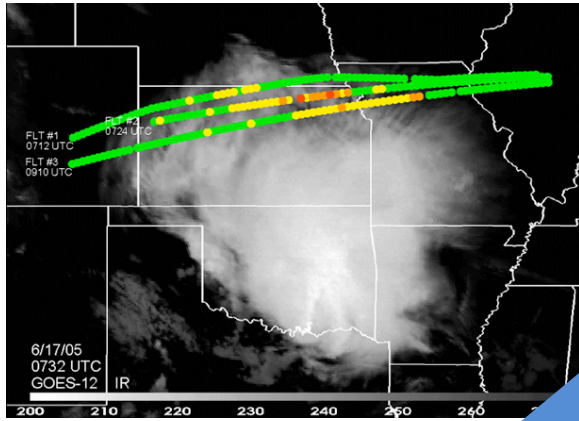# Turbulence Impacts on Operations

Turbulence affects
- ➢ Safety (aircraft, people, goods)
- ➢ Efficiency (separation, avoidance, workload, fuel burn)
- ➢ Mission success (platform stability)

25 January 2012
16 – 20 UTC

Aircraft avoiding deep convection but encountering CIT

In situ, radar, lidar & satellite

Turbulence Prediction

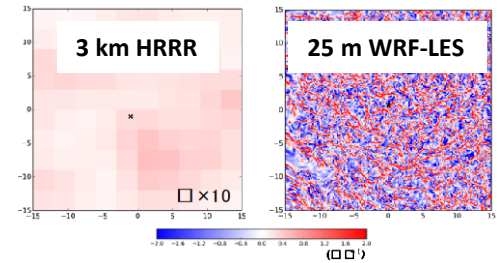**Higher resolution, ensembles & probabilistic prediction**

Process Understanding

Case studies

Observations

Validation & verification

Enhancement

Diagnosis & Prediction
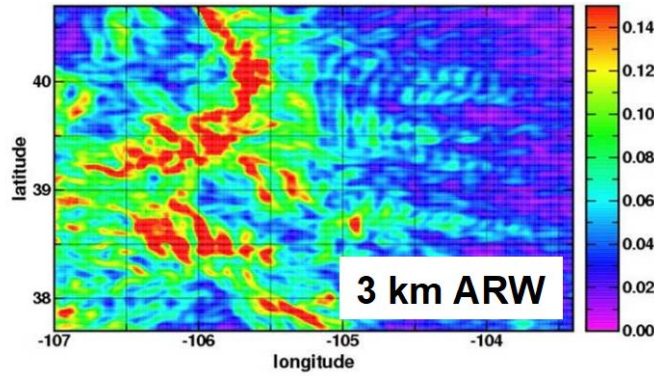
Higher resolution to better resolve atmospheric processes

GTG = Weighted ensemble of turbulence diagnostics

0 h forecast valid at 22 Sep 2006 15Z

Diagnostic ensemble & probabilistic hazard guidance

In situ, radar, lidar & satellite

Case studies

Turbulence Prediction

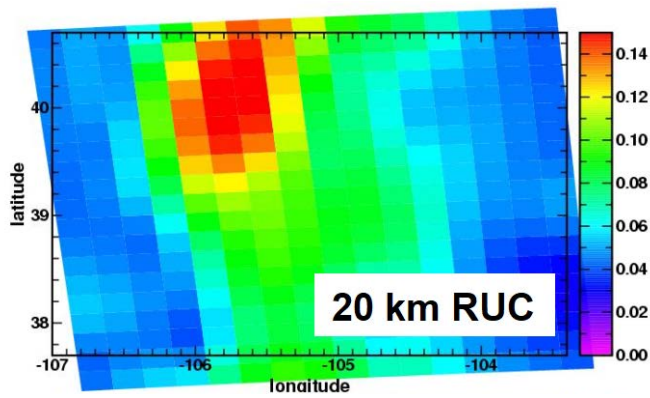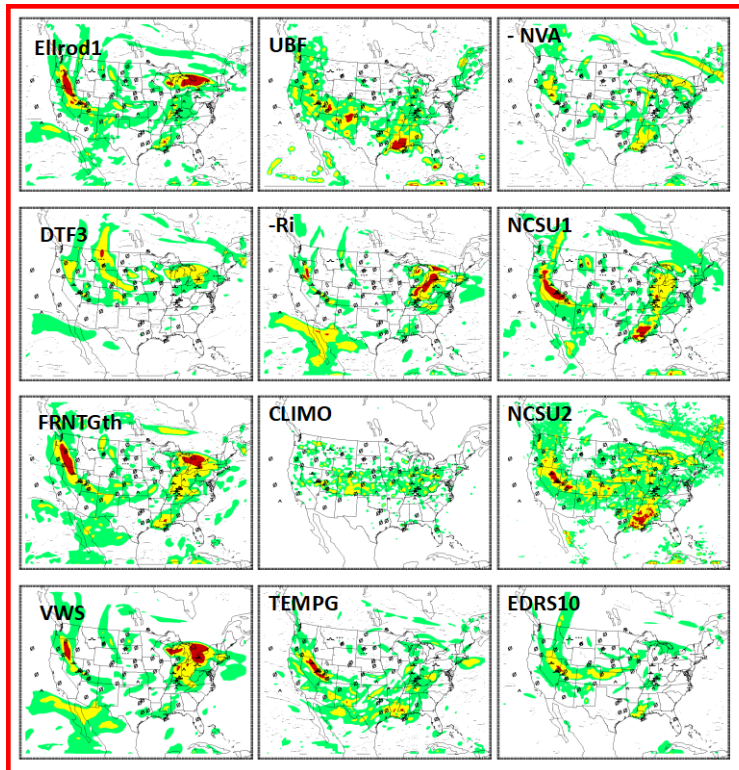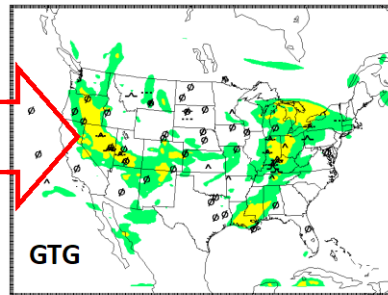**Higher resolution, ensembles & probabilistic prediction**

Process Understanding

Predictability & climate change

Validation & verification

Observations

Diagnosis & Prediction

Enhancement

Dissemination for Operational Use

Wake turbulence
➤ Prediction of wake vortex hazards near ground & aloft

Use of Turbulence Information

Dissemination for Operational Use

Impact Translation

Operational Context

Mitigation Strategy

Response to turbulence

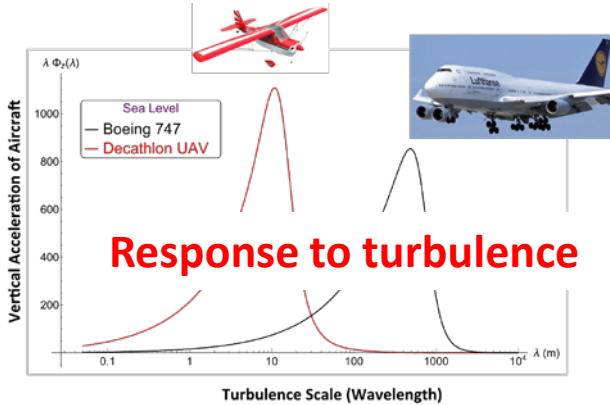Flight planning or execution

Runway, terminal or en route

Urban environment

Go/no-go decision

Aircraft separation

Cabin management

Weather avoidance

All Classes of aircraft must avoid the hard constraints

Weather Event Type

Class of Aircraft	1	2	3	4
1		x		x
2	x	x		x
3	x		x	x

Weather Impact Interaction Grid

As specified in the interaction grid, Class 2 aircraft can freely penetrate type 3 weather events
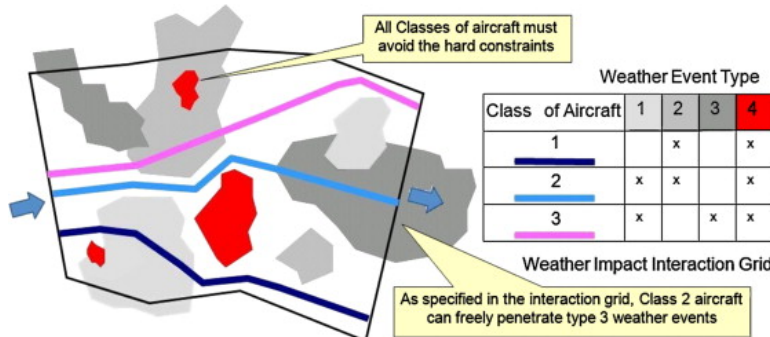
Hard & soft constraints

Smart decision support based on big data & data analytics

➢ What-if scenarios for traffic management
  - record of past weather, air traffic, & other data
  - ability to search for "similar events" in past
  - ability to replay situation using different TMIs
  - ability to simulate conditions into future
➢ Useful for training & real-time decision making

MITRE

Use of Turbulence Information

Dissemination for Operational Use

Impact Translation → **Operational Context** → **Mitigation Strategy**

Response to turbulence

Flight planning or execution
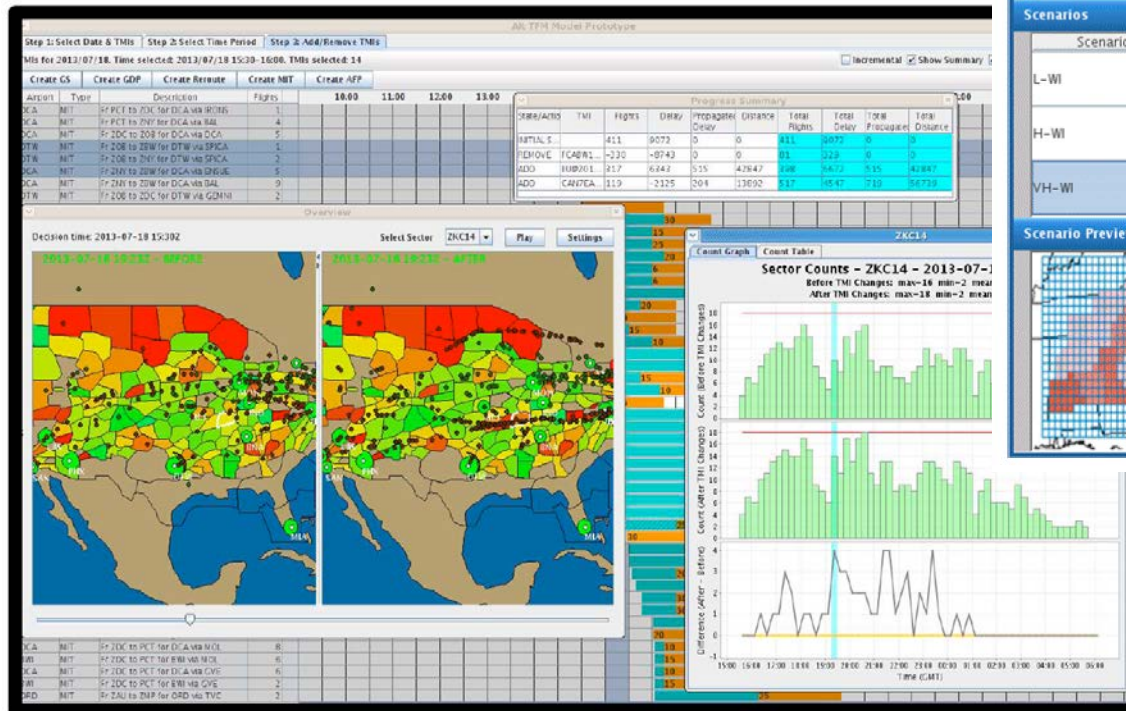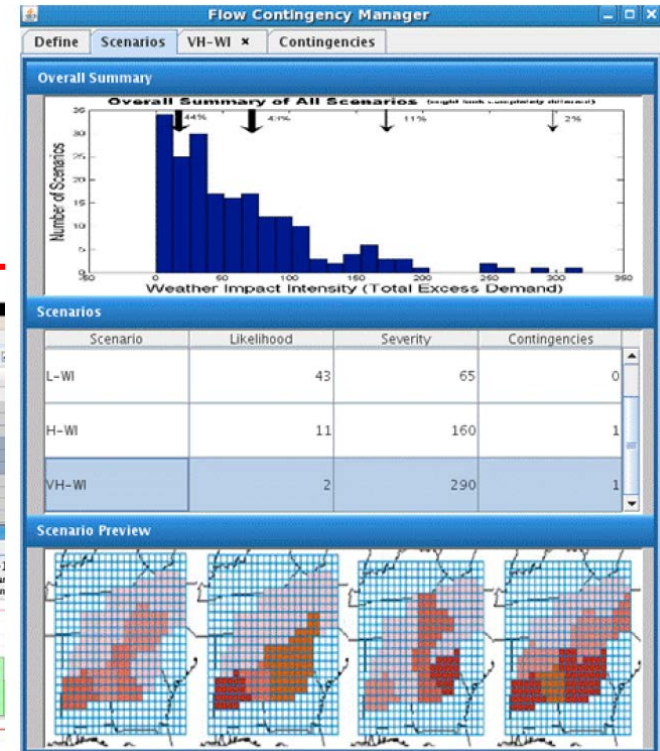
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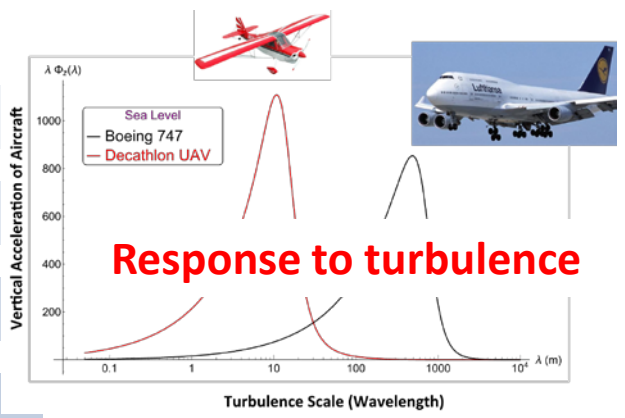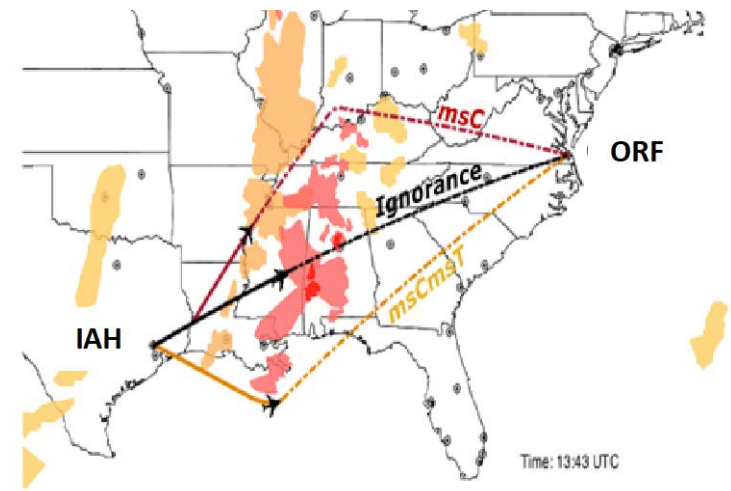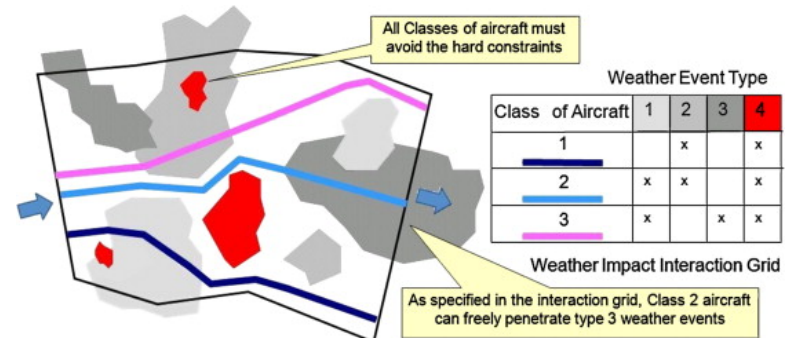
Key Points

New Requirements

➤ emerging modes of transportation will need turbulence information
  - at higher & lower altitudes, including urban environments

Turbulence Observation & Prediction

➤ opportunities for enhancing automated collection & sharing of turbulence data
  - improve coverage of oceanic airspace
  - beneficial sharing across aviation industry
➤ increasing computational capabilities enable
  - higher resolution to better resolve atmospheric processes
  - use of ensembles to capture forecast uncertainty & probabilistic predictions

Weather Integration

➤ characterization of weather impacts (translation) along flight paths
  - understanding response of aerial vehicle to turbulence & critical thresholds
➤ enabling consistent flight/flow planning & execution through increased predictability
➤ examination of what-if scenarios in real time yielding smarter decisions
  - supported by large amounts of data & data analytics

Story Telling

➤ enhance quantification of turbulence impacts & benefits from
  better turbulence forecasts & use thereof