Back to the Future

Aviation Weather Opportunities for the Research Community

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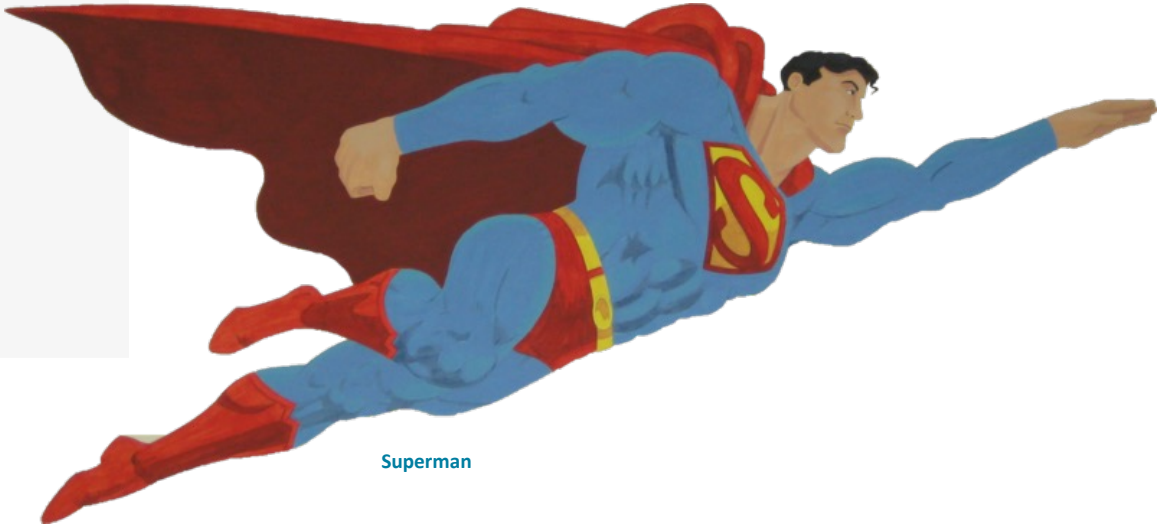
Human Desire to Fly

Mary Poppins

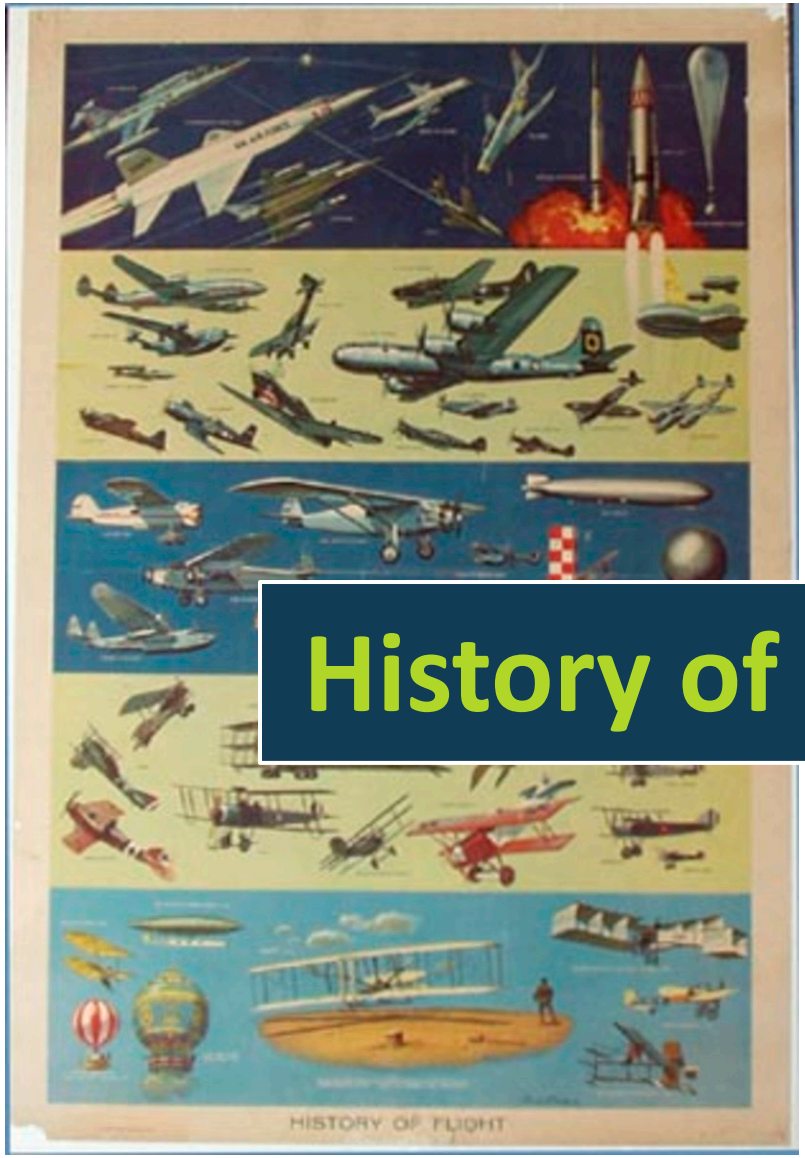
Jetsons



Superman

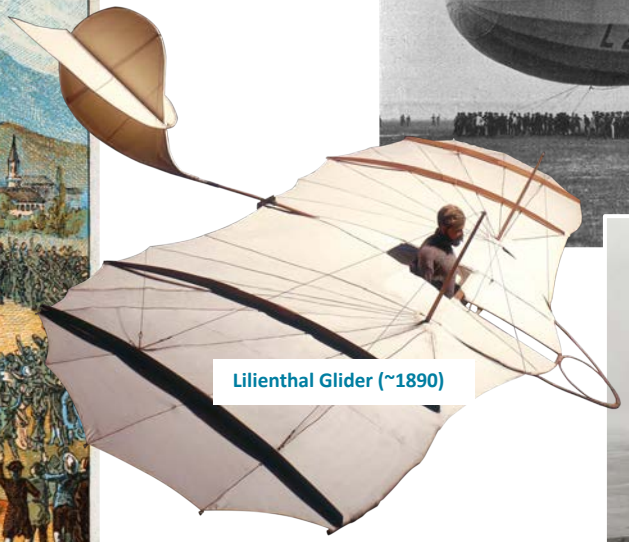
Attraction & Dangers of Flying

Ancient Greek Myth of Daedalus & Icarus



History of Aviation

Montgolfier Hot Air Balloon (1783)

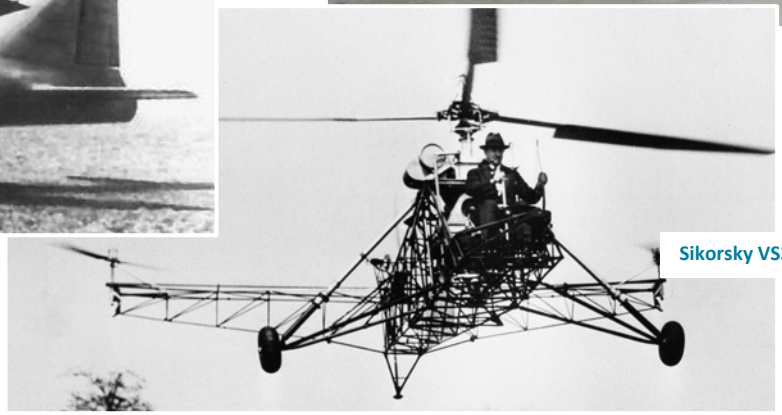


Lilienthal Glider (~1890)

Zeppelin Airship (~1900)

Wright Flyer (1903)

Heinkel He-178 (1939)



Sikorsky VS300 (1939)

Weather & Aviation

Weather Proof – Think Again . . .

NSF T-28 Research Aircraft (retired)

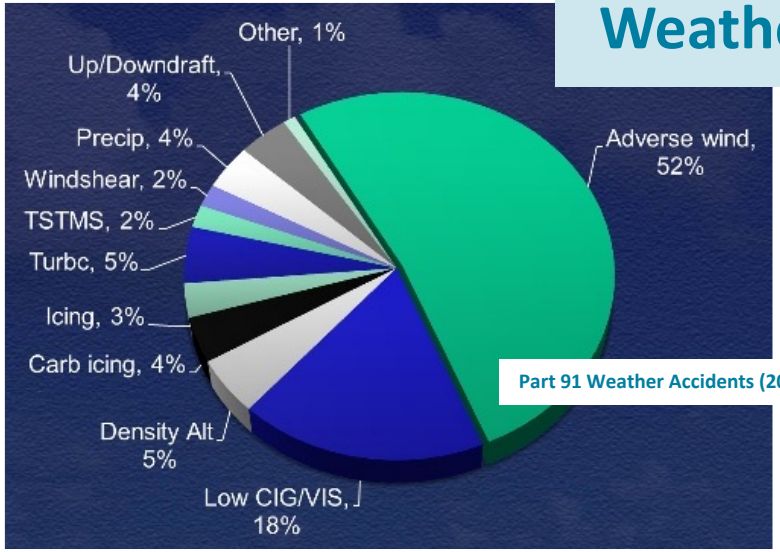
- Armor plated to fly into hailstorms

Weather affects Safety, Efficiency & Reliability

NRC Convair Research Aircraft

- Used to study aircraft icing conditions

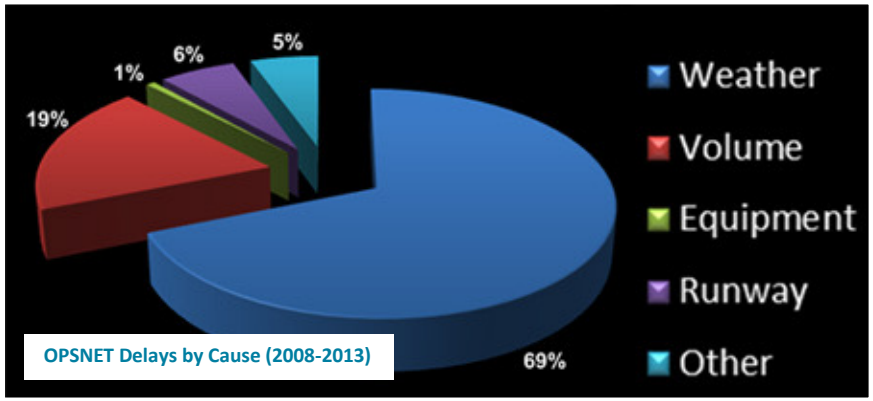
Weather Sensitivities of Operations



Part 91 Weather Accidents (2007-2009)

Safety

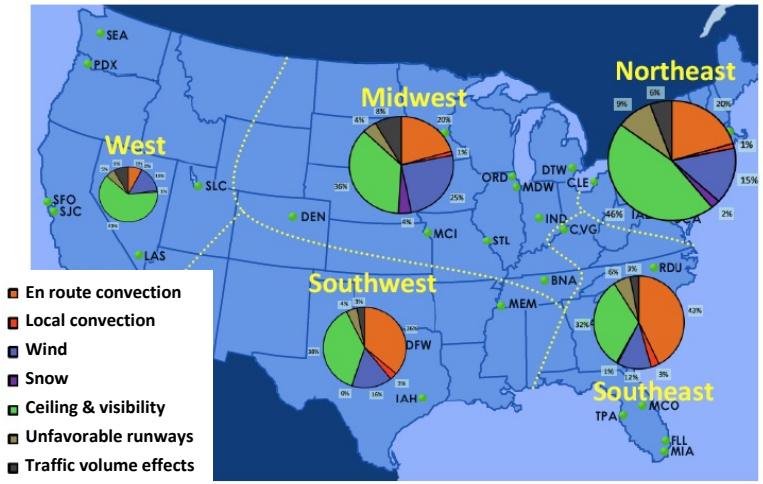
- Weather can be a safety hazard
  - icing, turbulence, wind shear, etc.
  - volcanic ash, space weather



OPSNET Delays by Cause (2008-2013)

Efficiency

- Weather is a significant factor constraining efficiency

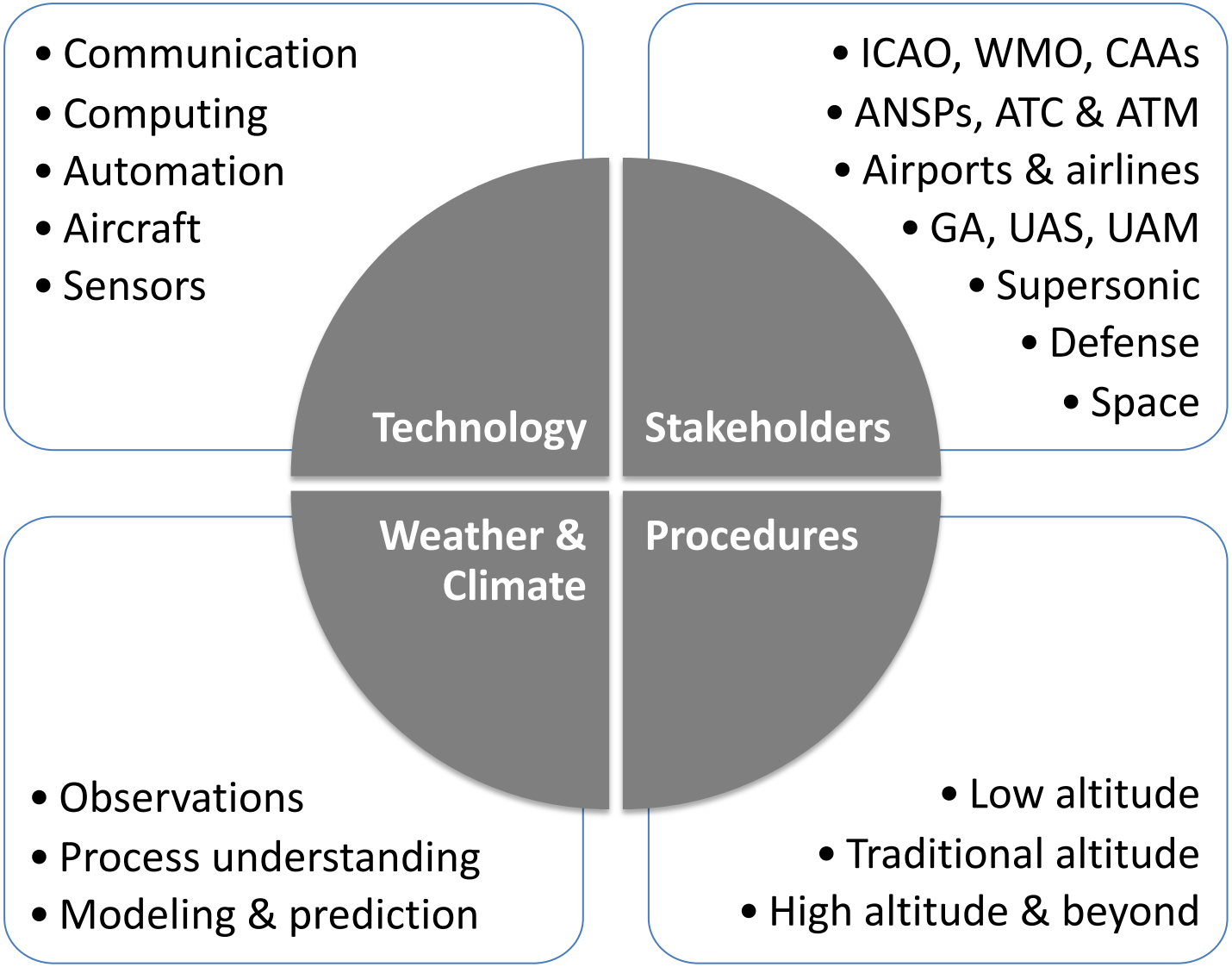


Weather Impacts

- Depend on type of aircraft & phase of flight
- Impacts vary geographically & by season, airport, traffic density, & other factors

Beyond the Horizon

Evolving Aviation/Aerospace Industry



Stakeholders

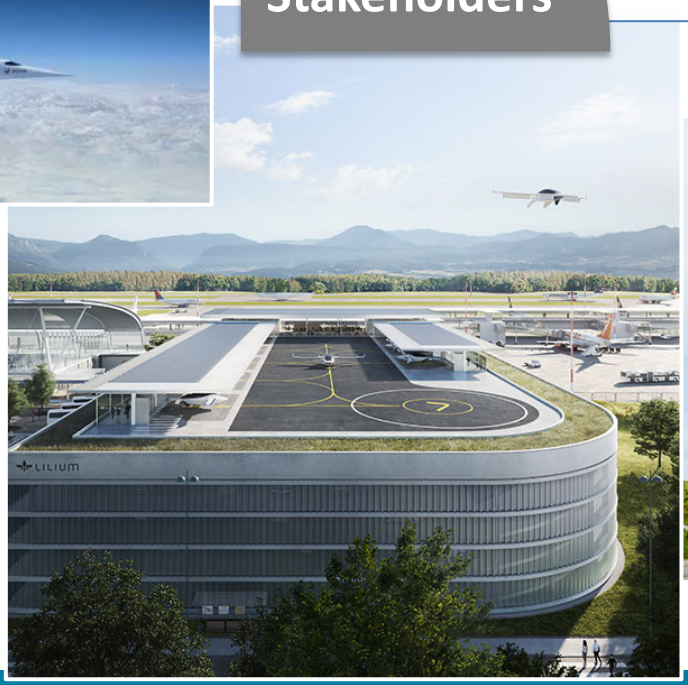
- ICAO, WMO, CAAs
- ANSPs, ATC & ATM
- Airports & airlines
- GA, UAS, UAM
- Supersonic
- Defense
- Space

Resurging Demands

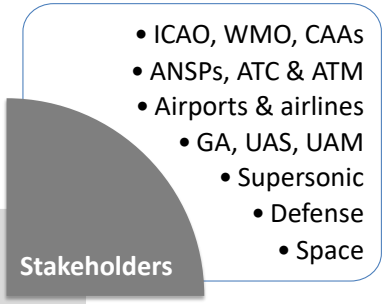
- Super/hypersonic flight
- Space launch & travel

Novel Entrants

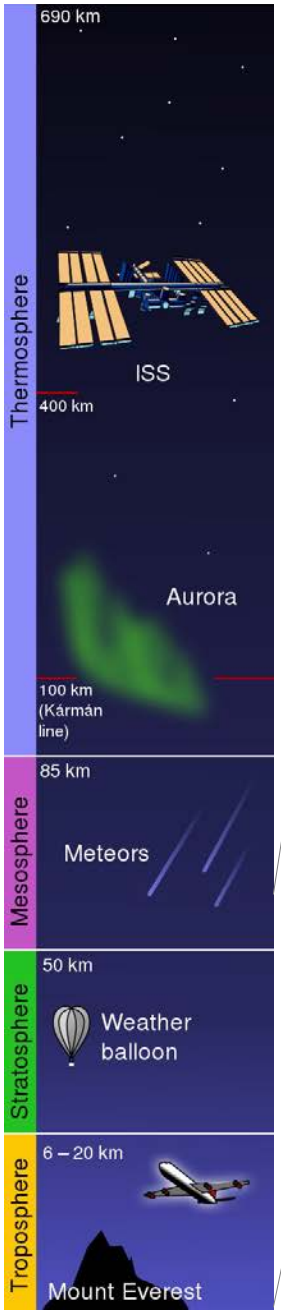
- Uncrewed aerial systems
- Regional/urban air mobility



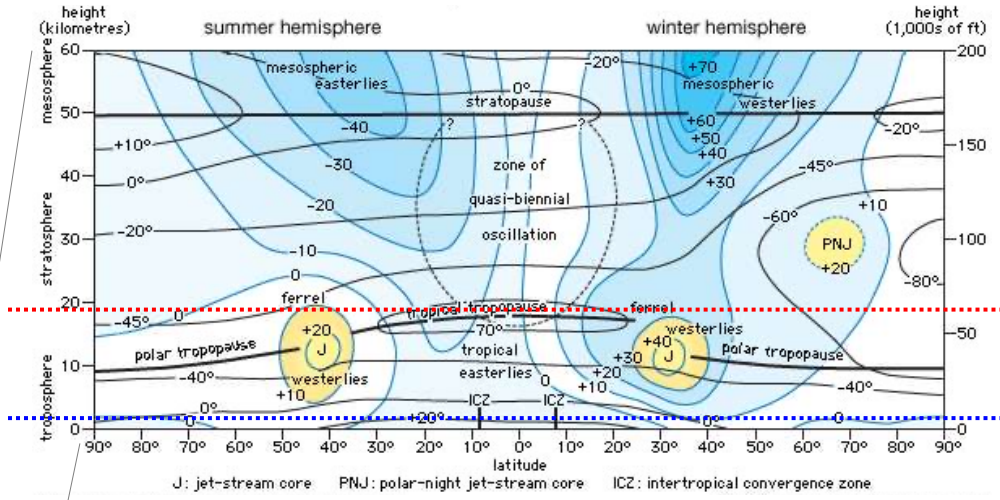
Lots of questions . . .



What are the weather sensitivities of resurgent & novel entrants?	Wide variety of operations with different needs, handling of off-nominal & emergency situations, etc.
What weather guidance do they need to safely, efficiently & reliably operate?	Requirements for spatial & temporal resolution, refresh rate, look ahead times, weather parameters, etc.
Is that weather guidance available & who will provide it?	FAA is Met Authority, providers may be NOAA/NWS or commercial sector?
Do we understand operational environments enough to provide relevant weather guidance?	Dynamic boundary layer, complex terrain & urban environments, stratosphere & beyond?
How does weather factor into safety standards?	Controllability of aircraft under windy & turbulent conditions, fuel/energy management, etc.
What weather standards may need updating?	International standards to enable interoperability, standards for new data
Who will approve/certify novel weather information?	Sensors, data, algorithms, products
To what extent is weather part of pilot/operator training?	Shouldn't fail weather questions in test & still get licensed/rated



Meridional cross section



- ICAO, WMO, CAAs
- ANSPs, ATC & ATM
- Airports & airlines
- GA, UAS, UAM
- Supersonic
- Defense
- Space

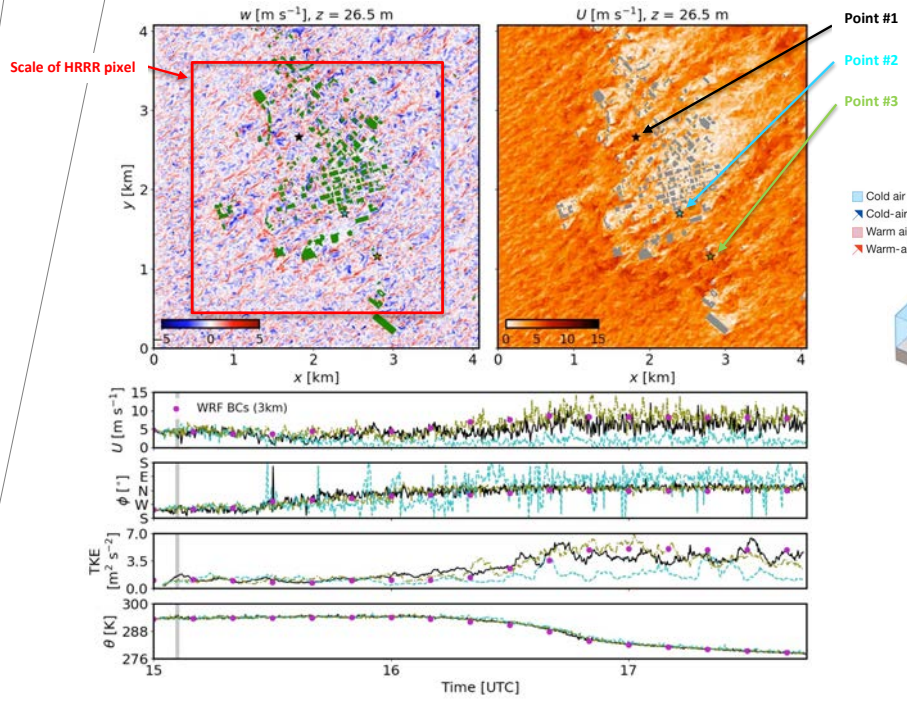
Stakeholders

Upper Class E Airspace

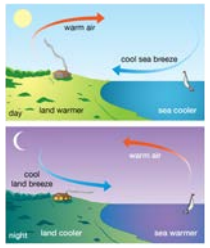
Traditional Airspace

UAS, UAM, etc.

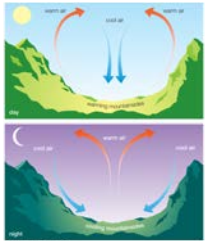
Urban dynamics based on NCAR's FastEddy model



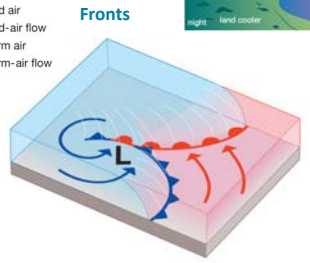
Land/sea breezes



Mountain/valley breezes

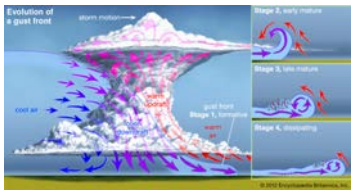


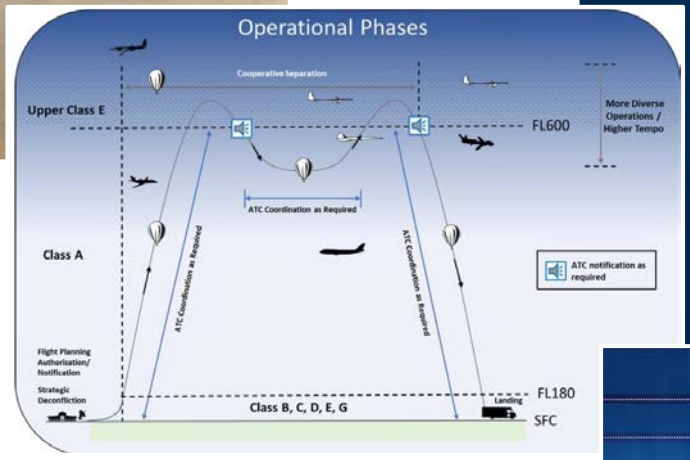
Fronts



Downslope windstorms

Thunderstorm dynamic





High altitude

- Transition to high altitude
- Lesser known environment

Low altitude

- Non-traditional airports, if any
- Dynamic boundary layer

Procedures

- Low altitude
- Traditional altitude
- High altitude & beyond

How will airspace be managed?	Different approaches throughout depth, traditional ATC versus UTM or self-separation, performance & risk-based management, etc.
What weather guidance will be utilized?	Could vary between airspaces, & among NOAA/NWS, Supplemental Data Providers, commercial vendors
Challenges associated with transitioning from/to high-altitude operations or in/out of managed airspace for low-altitude operations	Includes delicate vehicles with limited maneuverability that may be highly sensitive to weather
How does weather factor into regulations & procedures for resurgent & novel entrants?	Regulations may push responsibility to operators but no sanctioned weather guidance available
How to better integrate weather within decision making process?	Translation of weather into operational impacts & support tools to guide operations

Procedures

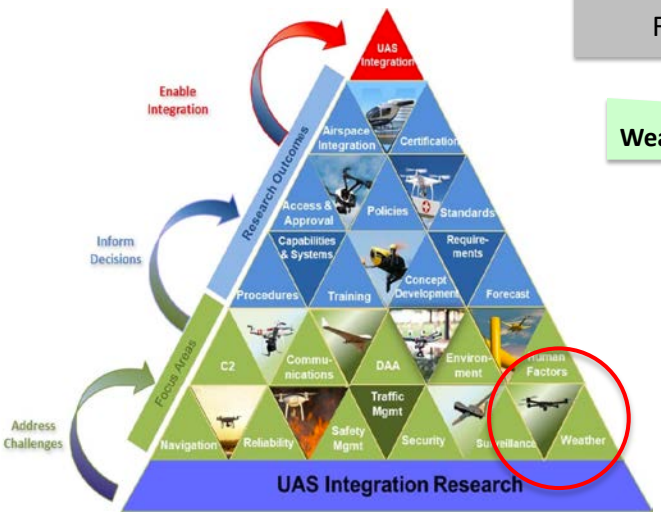
- Low altitude
- Traditional altitude
- High altitude & beyond

Weather translation & integration in decisions

Weather Forecast ↔ Impacting Weather Aspects ↔ Operational Context ↔ Mitigation Strategies

Weather Information User

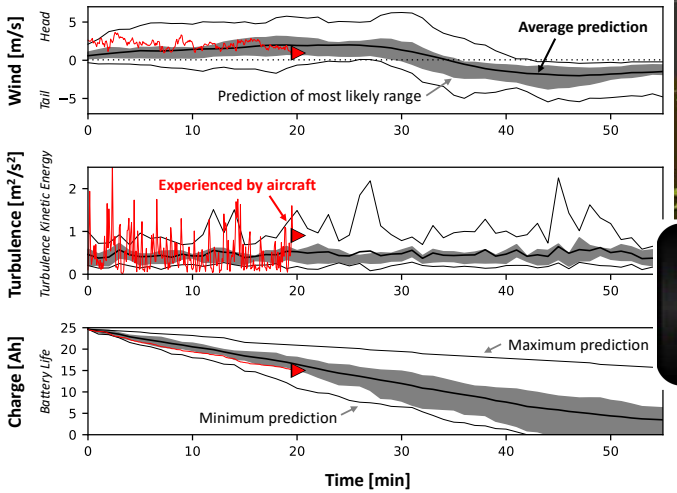
Weather Information Provider



FAA's integration approach

UAS in urban wind field based on ICT's RIDE* & NCAR's FastEddy

Translation of weather into remaining battery charge



High-glance decision guidance

Procedures

- Low altitude
- Traditional altitude
- High altitude & beyond

*https://ict.usc.edu/prototypes/ride/

- Communication
- Computing
- Automation
- Aircraft
- Sensors

Technology

Novel Aircraft

- Faster development cycles
- Electric, hydrogen, & hybrid propulsion

Computing & Automation

- Increasing data & connectivity
- From automation to autonomy
- Many tradeoffs to consider

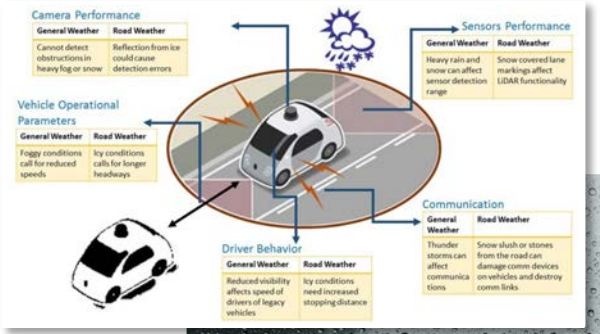
- Communication
- Computing
- Automation
- Aircraft
- Sensors

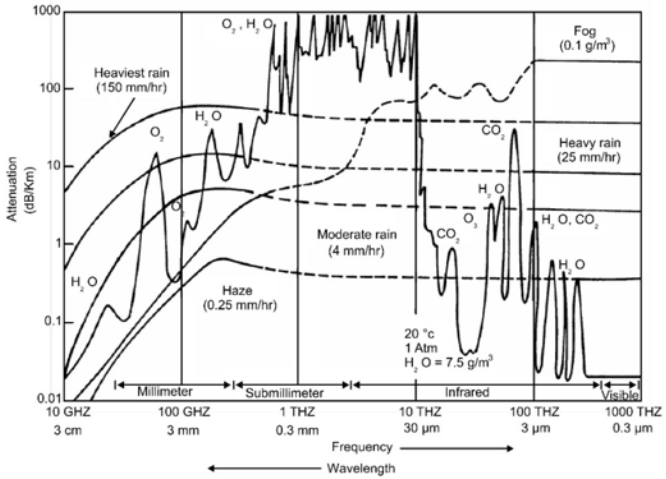
Technology

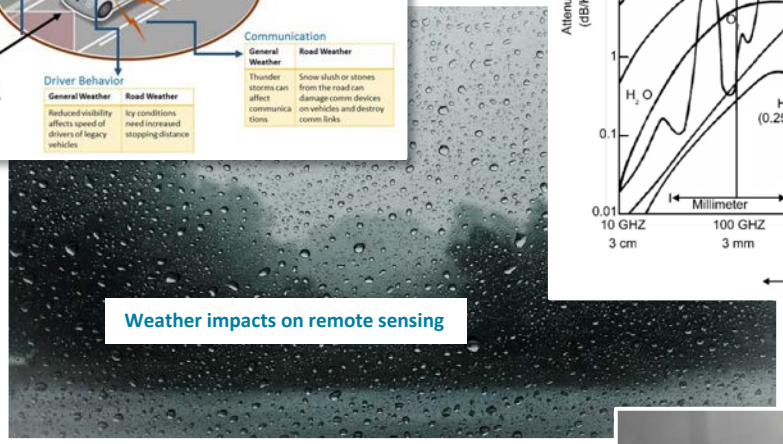
How does weather impact communication, navigation & surveillance?	Impacts of selling parts of frequency spectrum, interference concerns, coverage in urban areas
What aspects of weather & climate matter for aircraft design & certification?	Temperature sensitivity of new fuel/energy sources, wind & turbulence effects on delicate designs, needs to build upon solid understanding of operational environment, etc.
How should computing algorithms & ultimately autonomy get certified?	Modern aircraft increasingly rely on automation, autonomy builds on lots of data & algorithms
How does weather impact sensors used for flight safety, detect & avoid, etc.?	Data quality control is essential for algorithms to yield meaningful guidance
Should there be a weather sensing requirement for novel entrants?	Weather sensing is key for flight safety of large aircraft, would be beneficial for small aircraft as well, data sharing provides great benefits

- Communication
- Computing
- Automation
- Aircraft
- Sensors

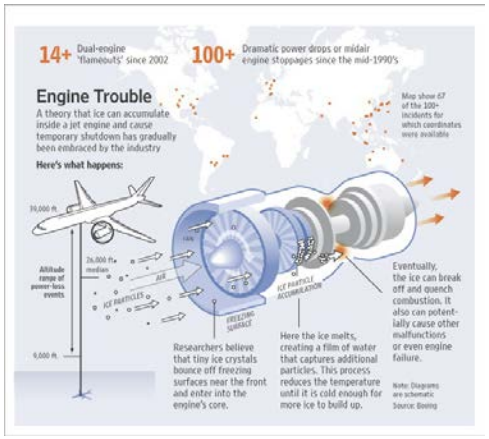
Technology



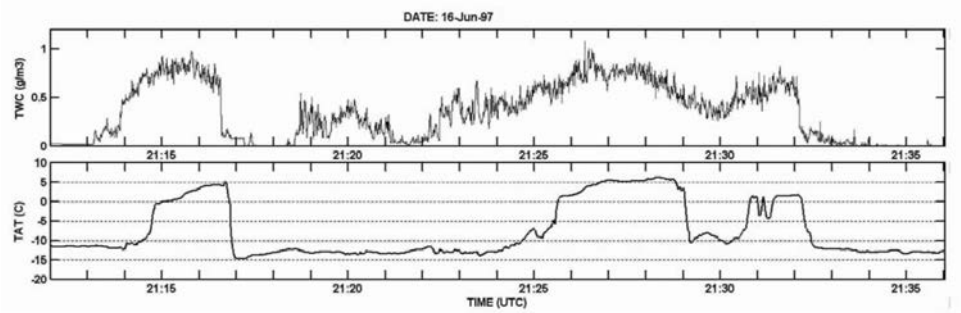


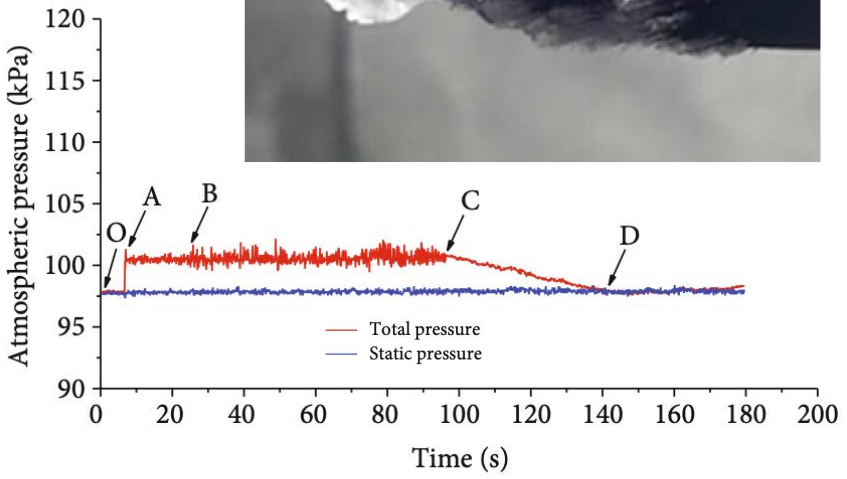


Weather impacts on remote sensing



Temperature anomalies related to high ice crystal ingest





New Capabilities

- Novel observations
- Improved process understanding
- Faster & smarter processing
- Uncertainty characterization

Climate Impacts

- Aviation impacts on Earth's climate system
- Climate change impacts on aviation

Weather & Climate

- Observations
- Process understanding
- Modeling & prediction

Climate risk	Impact	Actors
Precipitation change	■ disruption to operations e.g. airfield flooding, ground subsidence ■ reduction in airport throughput ■ inadequate drainage system capacity ■ inundation of underground infrastructure (e.g. electrical) ■ inundation of ground transport access (passengers and staff) ■ loss of local utilities provision (e.g. power).	
Temperature change	■ changes in aircraft performance ■ changes in noise impact due to changes in aircraft performance ■ heat damage to airport surface (runway, taxiway) ■ increased heating and cooling requirements ■ Increased pressure on local utilities e.g. water and power (for cooling).	
Sea-level rise	■ loss of airport capacity ■ impacts on en-route capacity due to lack of ground capacity ■ loss of airport infrastructure ■ loss of ground transport access	
Wind changes	■ convective weather: disruption to operations ■ convective weather: route extensions ■ jet stream: increase in en-route turbulence ■ local wind patterns: disruption to operations and changes to distribution of noise impact	
Extreme events[1]	■ disruption to operations, route extensions ■ disruption to ground transport access ■ disruption to supply of utilities	

[1] *sudden intense and short-lived precipitation and wind events e.g. storm surges, hurricanes, hail storms, lightning as opposed to seasonal or annual changes*

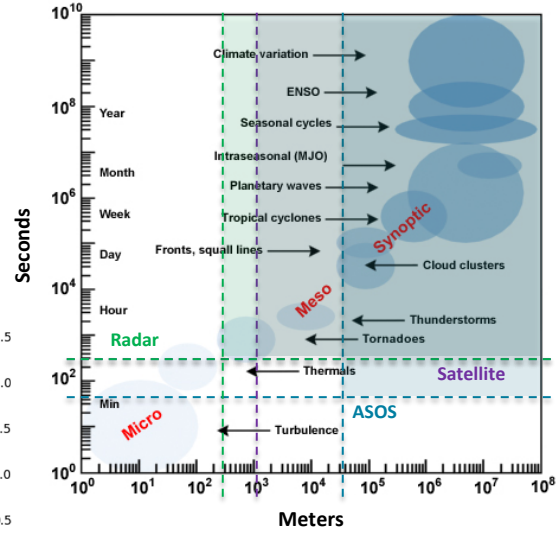
Aircraft operators | Airport operators | ANSP | External

How will novel observations benefit scientific understanding & weather prediction?	Cubesat, MeteoDrones, small radars, mobile sensors, crowdsourced data, etc.
How to fill data voids at low & high levels, & in complex environments?	Limited observations above ground & especially in urban environments, very limited observations at high altitudes as well
How will new technologies benefit weather prediction?	GPU accelerated model runs, artificial intelligence & machine learning, probabilistic prediction, etc.
How will aviation reduce emissions to become greener?	Noise, contrails, soot & CO2, alternate fuels, etc.
How will climate change affect aviation operations & infrastructure?	Sea level rise, changes to jet stream, changes to storms, increased wildfires & dust storms, etc.
What steps are taken to mitigate impacts towards climate resilience?	Changes may require substantial lead times

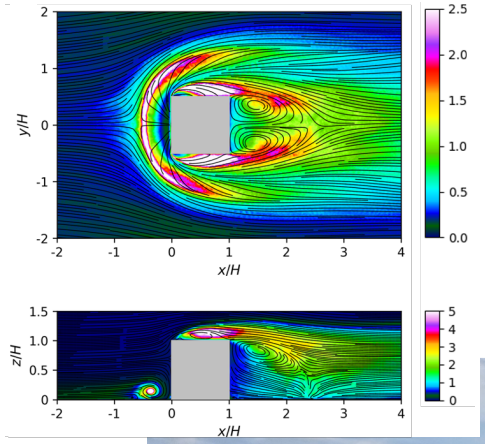
Weather & Climate

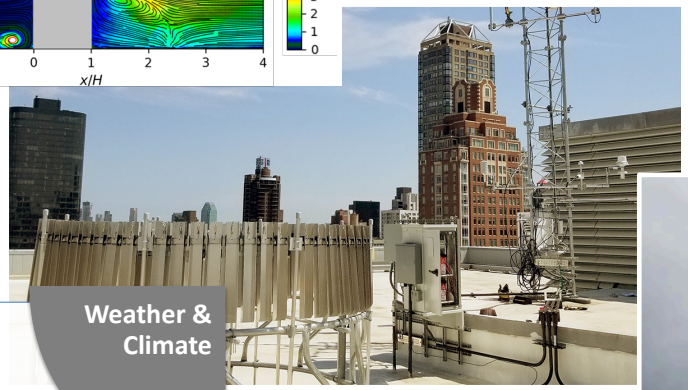
- Observations
- Process understanding
- Modeling & prediction

Observing gaps at micro scales



Sensor placement in cities





Fine-scale weather guidance gap

Need for better fine-scale low-level weather guidance

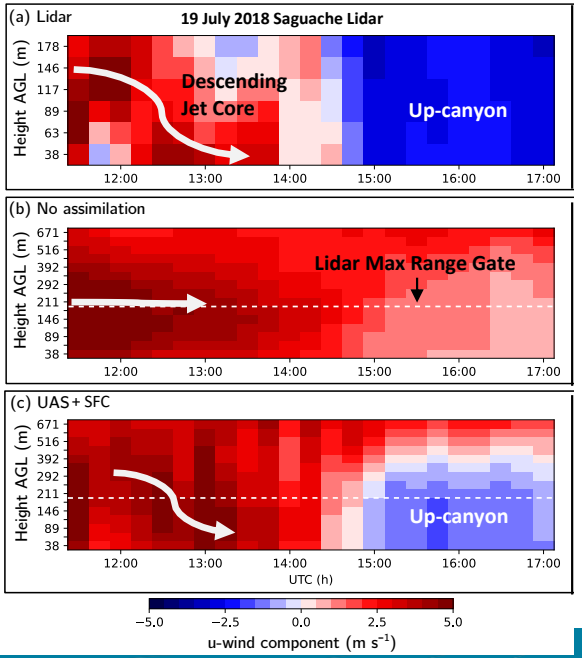
Product	Type	Space	Time	Aviation	Synop	Meso	Storm	Urban
RAP	A & F	13 km	15-60 min	😊	😊	😊	😐	☹
HRRR	A & F	3 km	15-60 min	😊	😊	😊	😊	😐
RTMA-RU	A	2.5 km	15 min	😊	😊	😊	😐	😐
NWS Warnings	N & F	County/Polygon	Variable	😐	😐	😊	😊	😐
NCVA	A	5 km	5 min	😊	😊	😊	😐	😐
CIP & FIP	A & F	13 km	60 min	😊	😊	😊	😐	☹
GTG-N & GTG	A & F	13 km	15-60 min	😊	😊	😊	😐	☹
CIWS & CoSPA	A & N	1 km	1-5 min	😊	😊	😊	😊	😐
MRMS	A & N	1 km	1-5 min	😊	😊	😊	😊	😐
TAF	F	Airport	6 hour	😊	😊	😊	😐	☹
AIRMET & SIGMET	N & F	Coarse	Variable	😊	😊	😐	😐	☹
LAMP	A & F	2.5 km	15-60 min	😊	😊	😊	😐	😐
GFA (Display Tool)	A & F	Variable	Variable	😊	😊	😊	😊	😐
HEMS (Display Tool)	A	Variable	Variable	😊	😊	😊	😊	😐

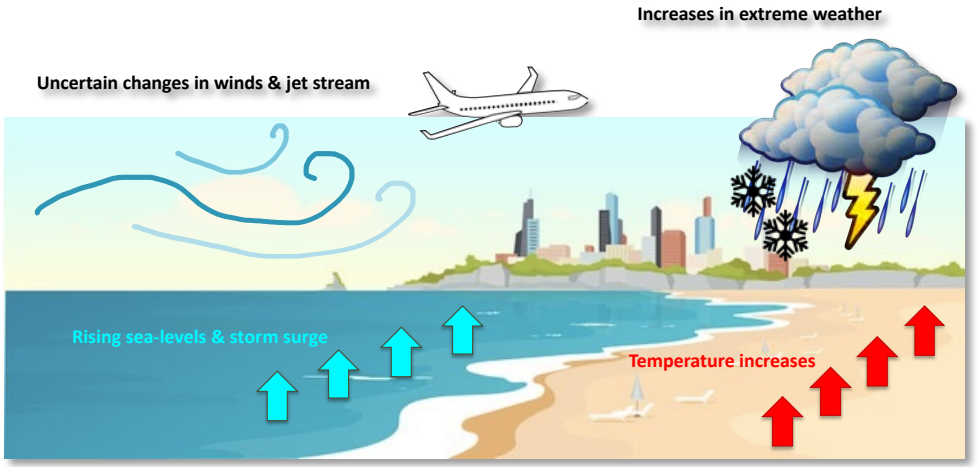
A = Analysis ; N = Nowcast ; F = Forecast

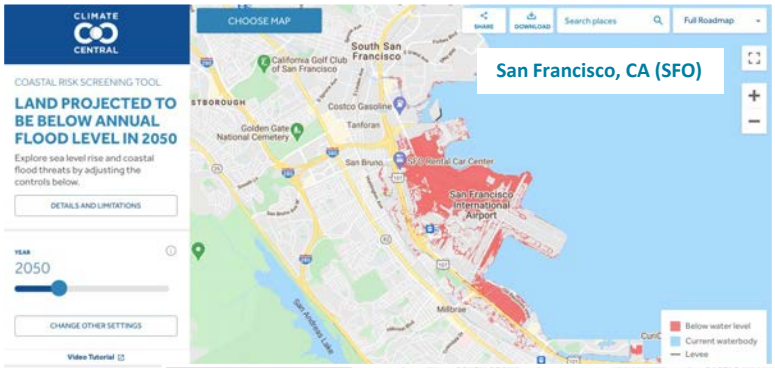
Weather & Climate

- Observations
- Process understanding
- Modeling & prediction

Assimilation of UAS weather data for improved prediction



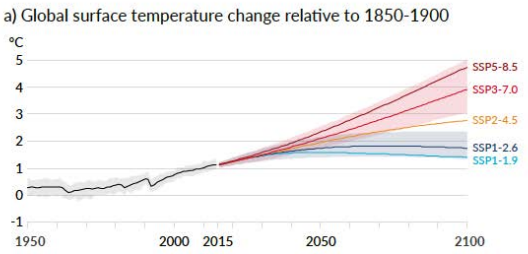


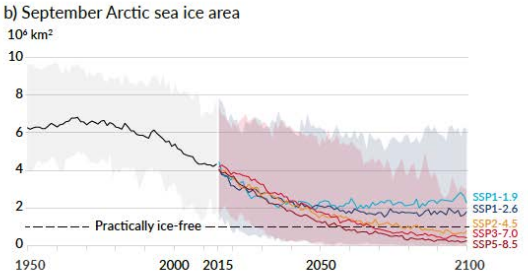


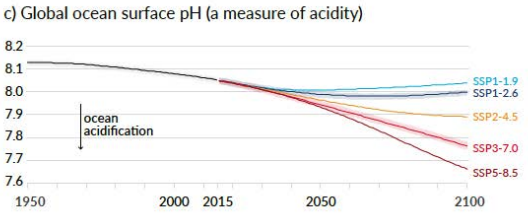
Weather & Climate

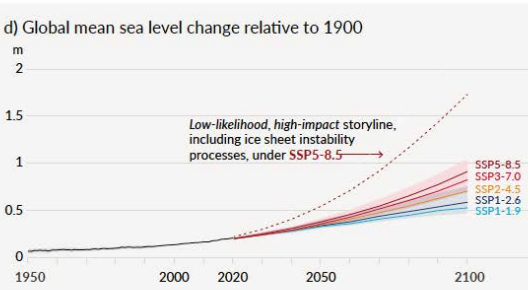
- Observations
- Process understanding
- Modeling & prediction

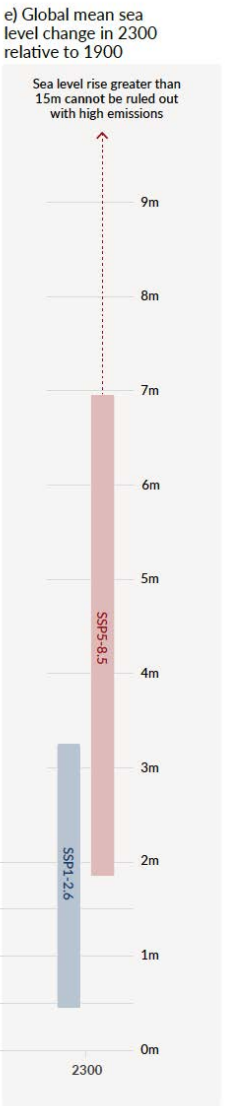
https://www.climatecentral.org







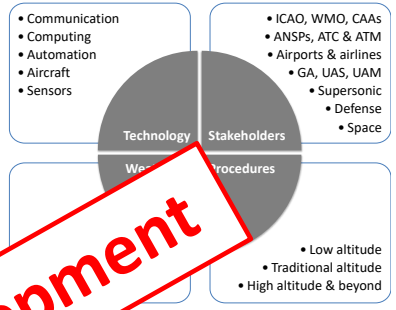




$8B LGA airport redevelopment (is it climate resilient?)

Summary & Outlook

Summary



Key Points

- Aviation/aerospace industry is evolving rapidly
- Novel & resurgent operations exhibit unique weather sensitivi
- Improved weather guidance needed to support these e erations
- Scientific understanding of low & high altitude ope vironments necessary to develop actionable weather guid
- Environmental challenges must inform ai gn & certification, operational procedures & regulatio , etc.
- Evolving climate will likely am g & bring new weather challenges for operations & infrastr

Resilient Operatio

- Need to fo anced predictability, efficiency, reliability & sust of aviation operations
- W eeds to be an integral part of infrastructure & rations planning, & decision making
- Collaboration across disciplinary boundaries is essential for developing effective solutions
- Agile prototyping & testing beneficial to accommodate evolving industry needs

Ample Opportunities for Wx Research & Development

The views and opinions expressed in this presentation are those of the author and do not necessarily reflect the official policy or position of the sponsoring agencies.