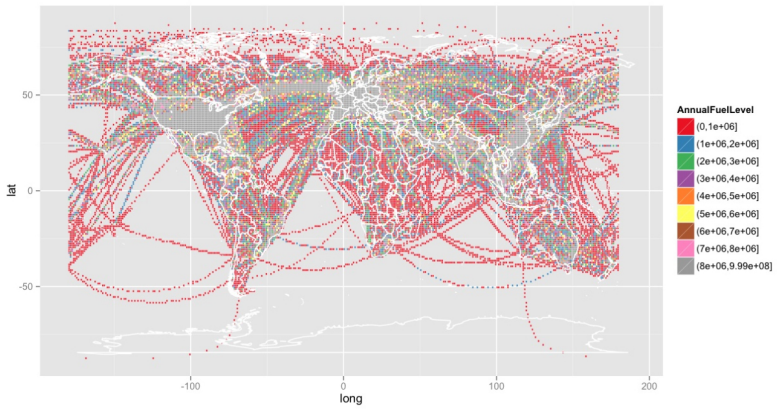

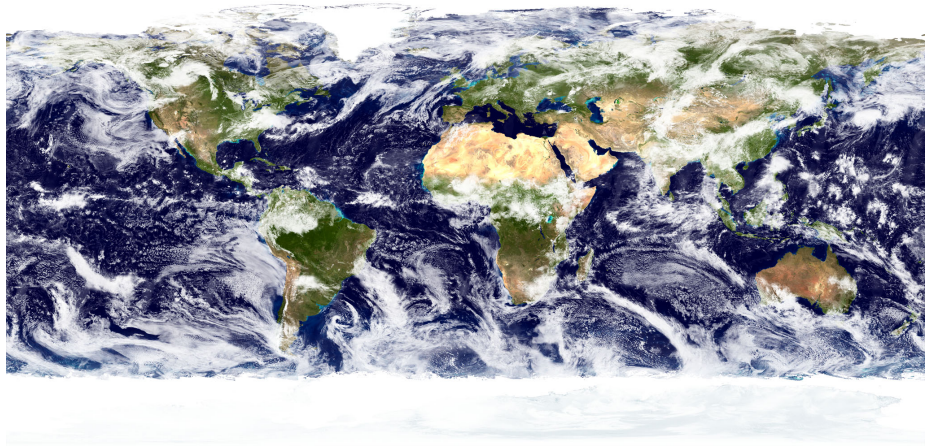

Climate Change Impacts on Air Transport Subsectors

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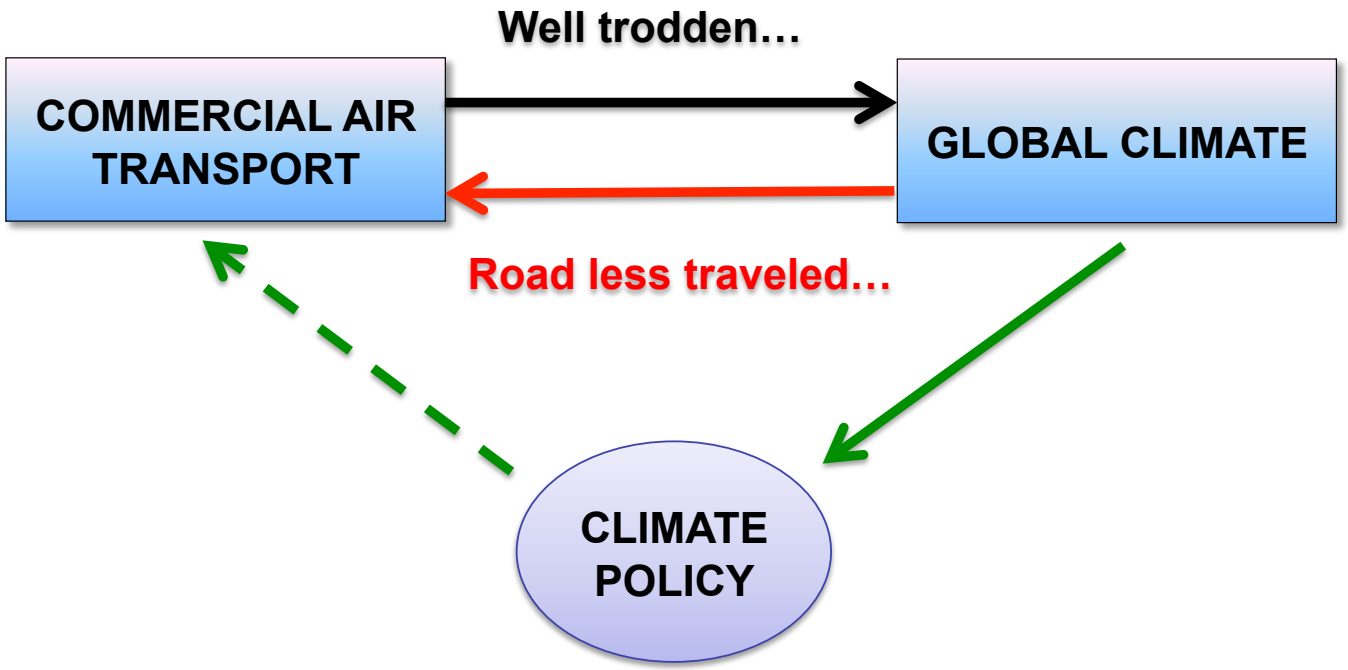
January 2015

LMI

Air Transport and Climate - Context



What Are the Major Subsectors in Commercial Air Transport?

- *Airports* – Provide fixed infrastructure for passenger/cargo handling, aircraft departure/arrival operations, and serve as interfaces to road and rail surface transport.
- *Airlines* – Operate aircraft at airports and in en route airspace; determine four-dimensional trajectories (within constraints from ANSPs below) and associated operational characteristics; plan frequency and type of service between airports.
- *Air-navigation Service Providers (ANSPs)* – Provide traffic-control services that maintain safe separation of aircraft and manage access to constrained resources (e.g., arrival/departure slots at airports, airspace throughput) within the air-transport network.
- *Aircraft Industry* – Develops, constructs, and maintains airframes, engines, avionics, and other equipment associated with the aircraft.

Climate Impacts on Commercial Air Transport

- Airports
- Aircraft and engines
- Airspace
- Passenger safety and comfort
- Atmospheric effects (CO_2, water/ice, NOx, SOx, PM)
- Shifts in passenger travel preferences
- Future air-transport concepts
- Public perception

Physical Effects Linked to Different Aspects of Business Performance

Climate Effect	Infrastructure	Aircraft Performance	Passenger and Cargo Demand	Flight Safety	Passenger Comfort	Environmental Impact
Temperature increase	Heat damage to runway/taxiway surfaces	Decreased climb performance	Shifts in geographic region and season	-	-	Changes in noise impact
Change in precipitation	Loss of efficiency, increased delays	-	Shifts in geographic region and season	-	-	Changes in air-quality impact
Frequency and intensity of convective weather	Loss of efficiency, increased delays	-	-	Increased turbulence, etc.	Increased turbulence	-
Changes in wind patterns	Loss of efficiency, increased delays	-	-	Increased crosswinds	-	Changes in air-quality impact
Sea-level rise, increased storm surge	Intermittent or permanent airport closures, loss of efficiency, increased delays	-	Shifts in geographic region and season	-	-	-

Level of Concern Regarding Impact Differs Across Subsectors

- Different business objectives focus concern on particular impacts:

Sector Component	Infrastructure	Aircraft Performance	Passenger and Cargo Demand	Flight Safety	Passenger Comfort	Environmental Impact
Airports	High	Low	High	Moderate	Low	High
Airlines	Moderate	High	High	High	High	Moderate
ANSPs	High	Moderate	Low	High	Low	Low
Aircraft Industry	Moderate	High	High	High	Moderate	Moderate

FAA Responsibilities and Activities

- Under Executive Order 13514*, FAA is to identify vulnerabilities to climate change and to develop programs to mitigate climate impacts and adapt to climate change. Recent activities include**:
  - *Airport sustainability planning* – Providing funding for airports to develop sustainability plans;
  - *Navigation infrastructure assessment* – Compare NOAA SLOSH data with FAA assets in coastal areas; and
  - *Advanced weather-information assessment* – Complete investment decision regarding NextGen Network-Enabled Weather that is to provide unified weather information to FAA and system users.

* U.S. Executive Order (EO) 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," 2009. See https://www.fedcenter.gov/programs/eo13514/ .
** U.S. Department of Transportation. “Climate Adaptation Plan – 2014”, 2014, pp. 16-18, available at http://www.dot.gov/sites/dot.gov/files/docs/2014-%20DOT-Climate-Adaptation-Plan.pdf .

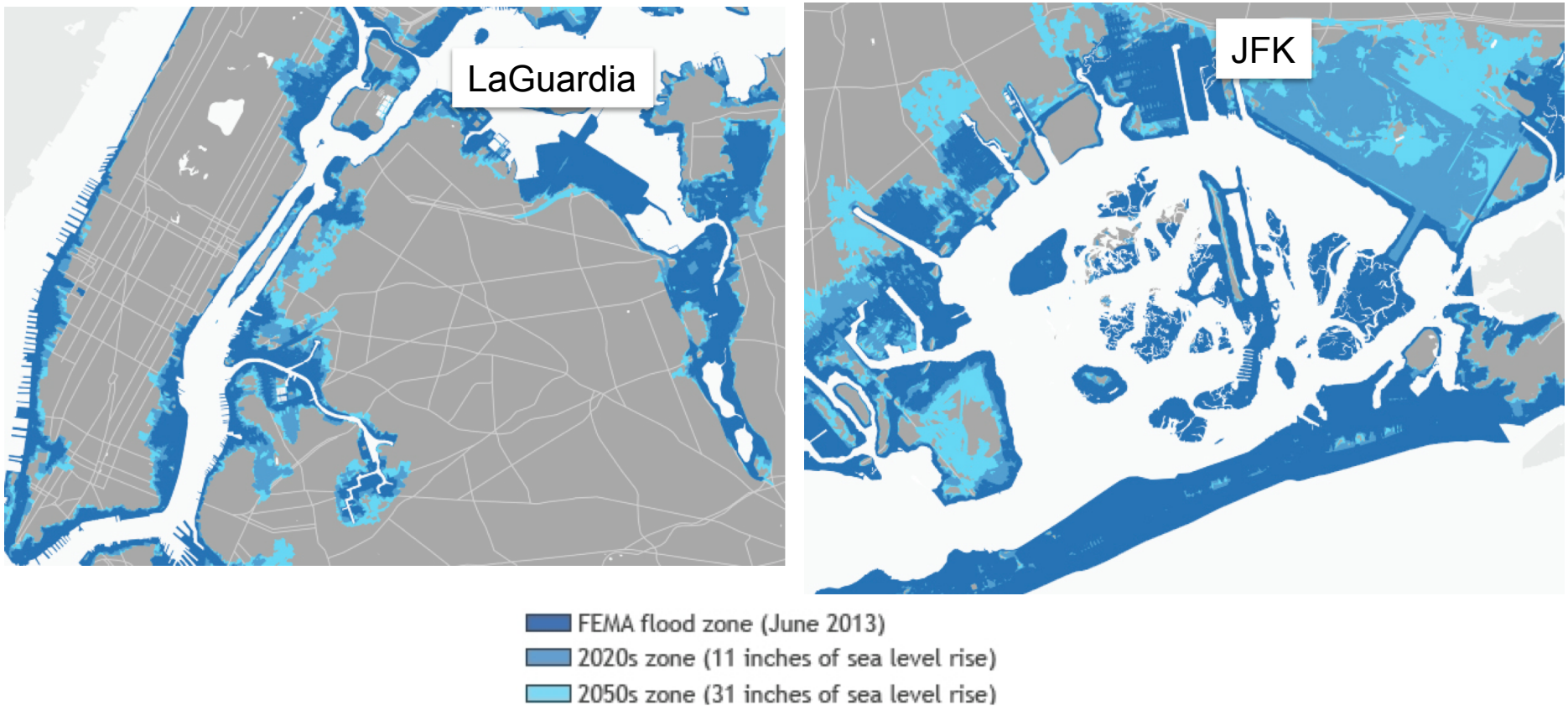
Airport Sustainability Planning Includes Climate-related Components

- Major airports with such plans include Newark, Atlanta, and London Heathrow.
- Newark's plan includes*:
  - *Climate-change risk assessment for capital projects* – Increased risk of flooding requires, for example, that such projects be designed for flood-avoidance and resiliency
  - *Tracking of past weather-related costs* - Analysis of such costs over the last ten years is being used to quantify future costs associated with shifts in weather associated with climate change.
  - These initiatives are aimed at developing a risk assessment and climate-change adaptation plan by the end of 2015.

* Port Authority of New York and New Jersey, "Newark Liberty International Airport: Sustainable Management Plan", 2012.

Impacts on Airports Similar to Other Coastal Infrastructure

- Need: merge climate and infrastructure information on fine scale.



See http://www.climate.gov/sites/default/files/NPCC100year_floodProj_large.jpg , based on New York City Panel on Climate Change, "Climate Risk Information 2013", June 2013.

Some Airports Substantially Advanced in Climate Risk Analysis

- London Heathrow assessment* identified and evaluated 34 risks.

Risks and Control Measures

Heathrow
Making every journey better

R	Significant
A	Moderate
G	Low

Risk ID	Risk	Climate Variable	Threshold	Confidence (climate projections and or consequences)	Risk Grading (no adaptation)	
					Short Term (to 2020)	Medium / Long (2020 to 2050s)
					AIRSIDE	
1	**Flashpoint of aviation fuel exceeded on hot days** - potential fire hazard.	Temp	Aviation fuel flash point is 38°C. Temperatures during the summer of 2003 peaked at 37.5C	H	A	R
2	**Increased incidence of fuel venting** from aircraft in warm weather.	Temp	Aviation fuel flash point is 38°C.	H	A	A
3	**Increased fire risk** due to hotter temperatures combined with increased lightning and drought potential.	Temp	Requires research	M	G	A
4	**Change in distribution of pests and wildlife species.** Potential changes to bird migration patterns and bird strike risk.	Temp	Requires research	L	G	G
5	**Reduced lift** for departing aircraft due to 'thin air' and reduced engine efficiency in very hot weather.	Temp	Aircraft operate in multiple temp zones, unlikely to be breached	H	G	G
6	**Torrential rain creates hazardous conditions for vehicles and planes** i.e. airside and landside road vehicles, and taxiing and landing aircraft.	Precip.	Defined in Strategic Flood Risk Assessment (SFRA)	H	G	A
7	**Seasonal changes to fog related disruption** (increase in winter months, decrease for remainder of year).	Fog	Low Visibility Procedures when the Runway Visual Range (RVR) is < 600m and/or cloud ceiling is < 200 ft. Projections do not suggest any critical thresholds would be crossed	L	G	G
8	**Increased risk of schedule interruption** from stormy conditions.	Storms	High wind procedures and cross wind procedures enacted at defined criteria (dependent on aircraft type).	L	G	A
9	**Increased longevity of wing tip vortex effect** due to general becalming of surface wind speeds.	Wind	Wing tip vortex is particularly problematic for small planes taking off in quick succession after large aircraft.	L	G	G
10	**Change to prevailing wind direction affects runway utilisation** and schedules.	Wind speed/ direction	All commercial aircraft are tested to a "demonstrated" maximum crosswind as part of their certification. Large aircraft are better able to handle cross winds than light aircraft. Technology is improving all of the time.	L		
11	**Disruption to airfield operations from lightning** i.e. refuelling suspension, changes to flight routing.	Lighting	All commercial aircraft are tested for resilience to lightning strike as part of their certification. Planes can withstand lightning strike in the air but during take off and landing instrument loss would be critical hence the diversion of routes and stacks.	L	G	A

* Heathrow Airport, "Climate Change Adaptation Reporting Power Report", May 2011.

<u>Most serious:</u>

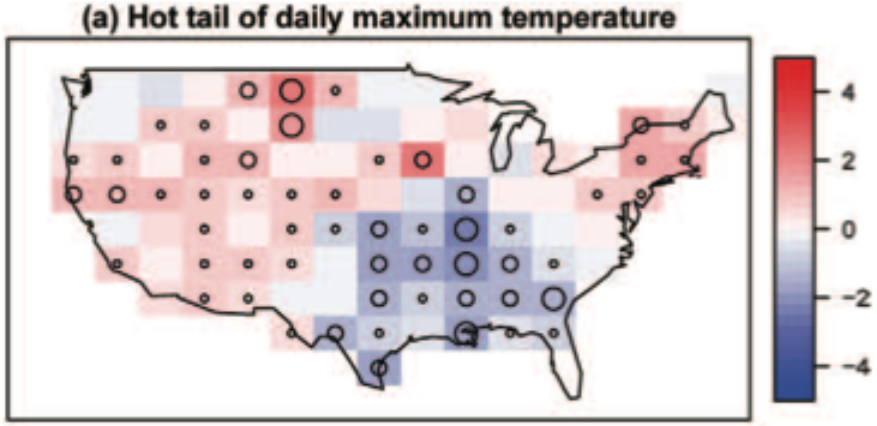
Projected longer term changes to temperature and precipitation extremes. (Summer temperatures in 2003 approached the flashpoint of jet fuel.)

Uncertainties in prevailing wind conditions in the future (of concern because the airport's two runways are parallel and there is no crosswind runway)

Impacts on Aircraft and Engines

- Aircraft take-off performance is degraded at high surface temperatures.
- Engine wear increases under dusty conditions.
- Data examples:
  - Magnitude of extreme event for fixed return period
  - Return period of extreme event of given magnitude
  - Measures of statistical significance

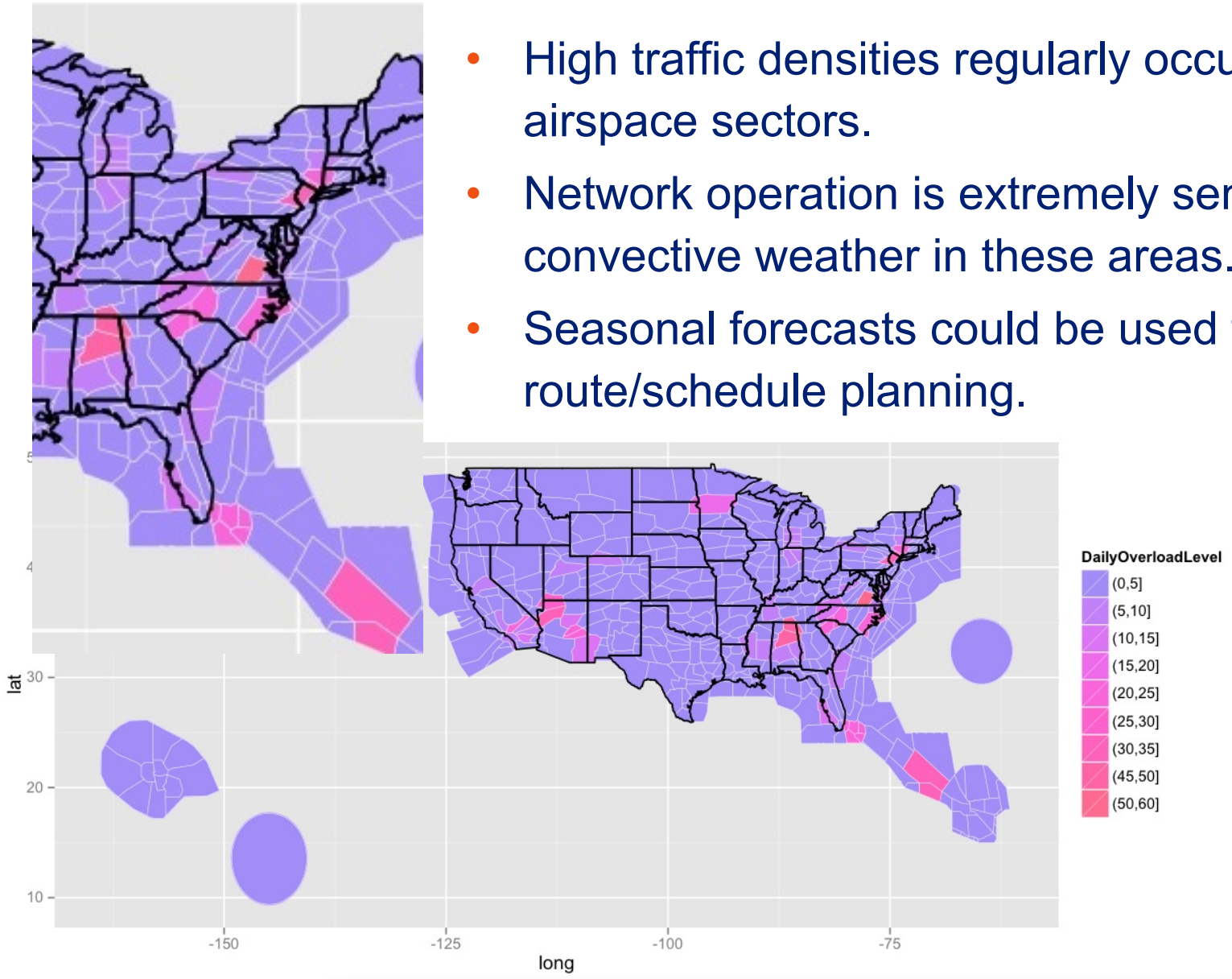
1950-2007 change in estimated 20-year return value



(magnitude color-coded in degC; size of circles indicates statistical significance)

T. Peterson, *et al,* "Monitoring and Understanding Changes in Heat Waves, Cold Waves, Floods and Droughts in the United States". Bull. Am. Met. Soc., 2013, Figure 2(a).

Impacts on Airspace Operations

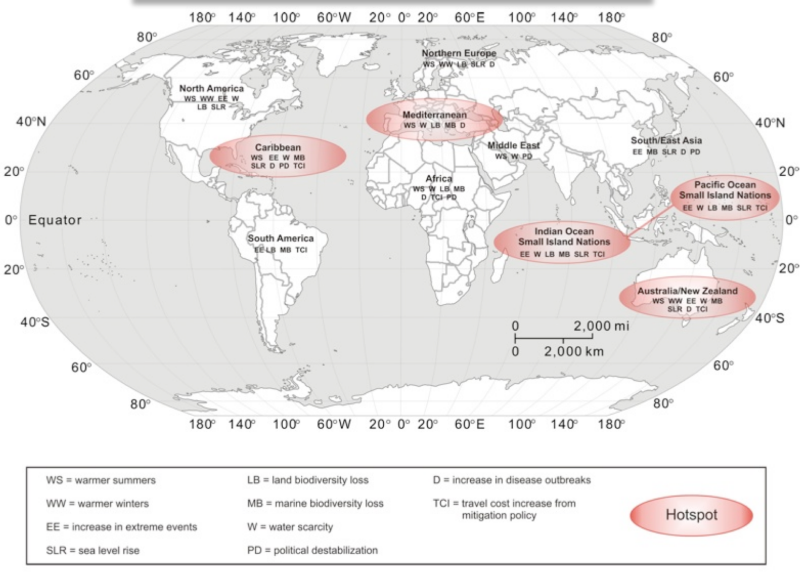


- High traffic densities regularly occur in certain airspace sectors.
- Network operation is extremely sensitive to convective weather in these areas.
- Seasonal forecasts could be used for strategic route/schedule planning.

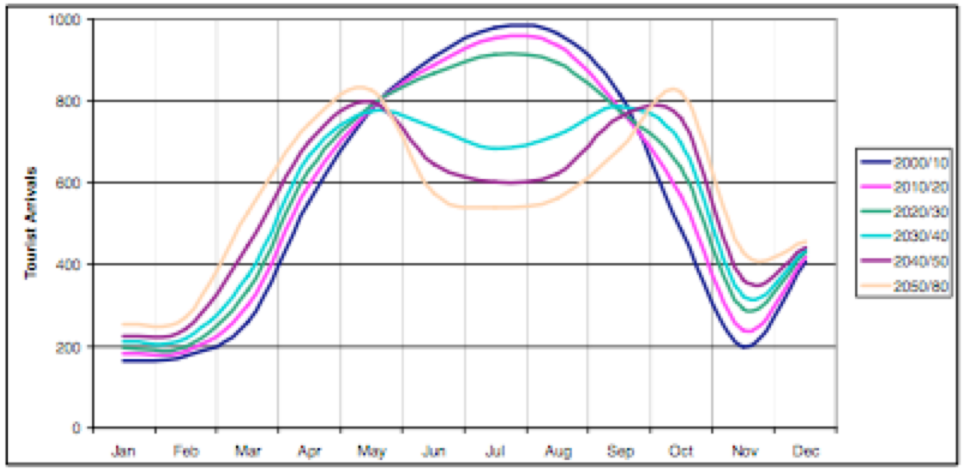
Impacts on Passenger/Cargo Demand

- Changing travel destinations mean shifts in airline and airport market shares. Changing travel seasons mean shifts in aircraft utilization, maintenance schedules, etc.

Travel Change Locations



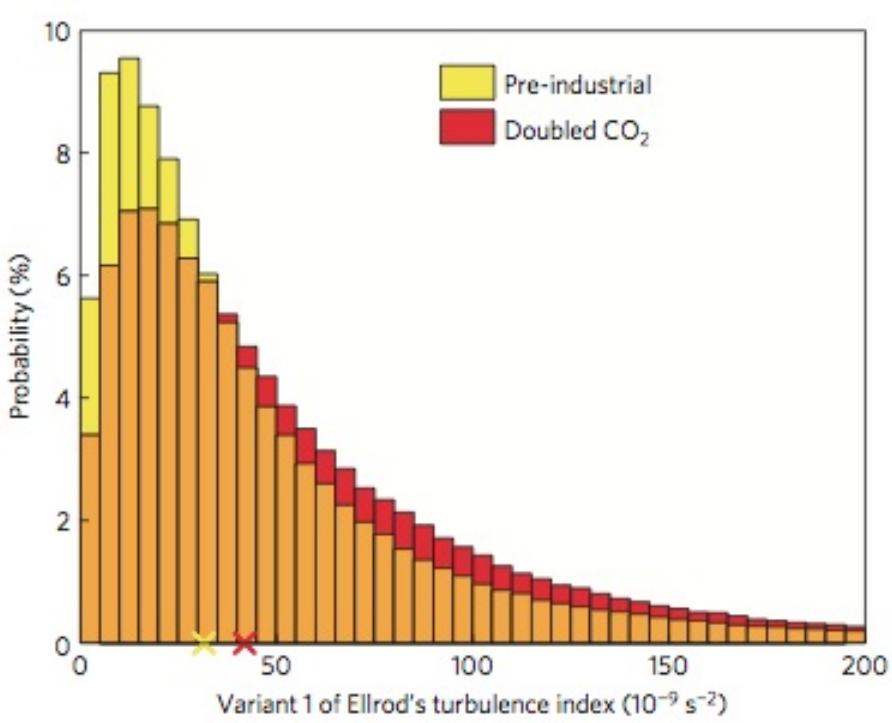
Potential Seasonal Travel Shifts in Greece



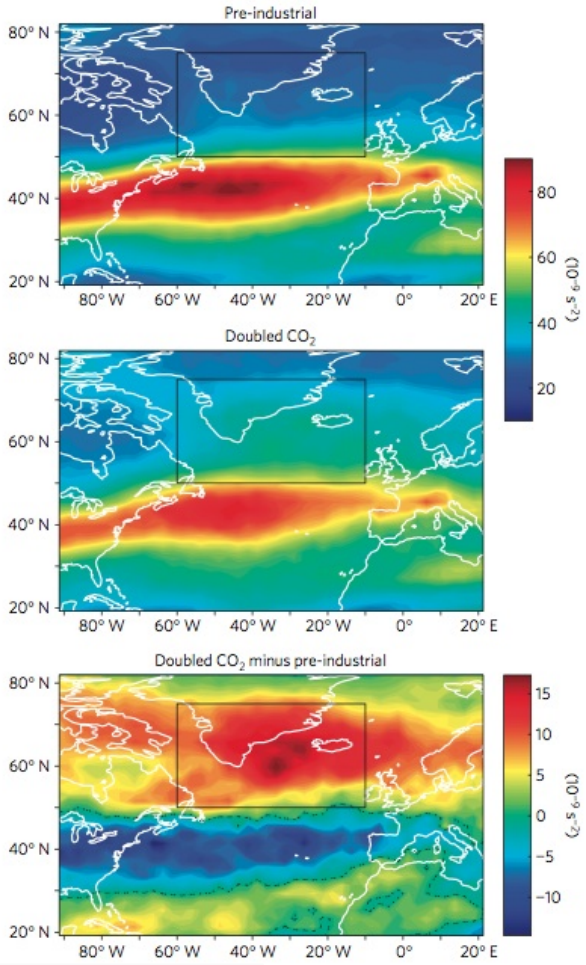
Left: "Climate Change and Tourism: Responding to Global Challenges", 2007. Available at http://www.wmo.int/pages/themes/climate/applications_tourism.php .
Right: Burbridge, R., Melrose, A., and Watt, A., "Potential Adaptation to Impacts of Climate Change on Air Traffic Management", Ninth USA/Europe Air Traffic Management Research and Development Seminar, 2011. Available at http://www.atmseminar.org/papers.cfm?seminar_ID=9 . The figure shown is Figure 3 from this study.

Impacts on Passenger Safety/Comfort

- "Clear-air" turbulence may be increasing (particularly dangerous due to lack of forewarning)



North Atlantic flight-level winter clear-air turbulence in a changing climate.

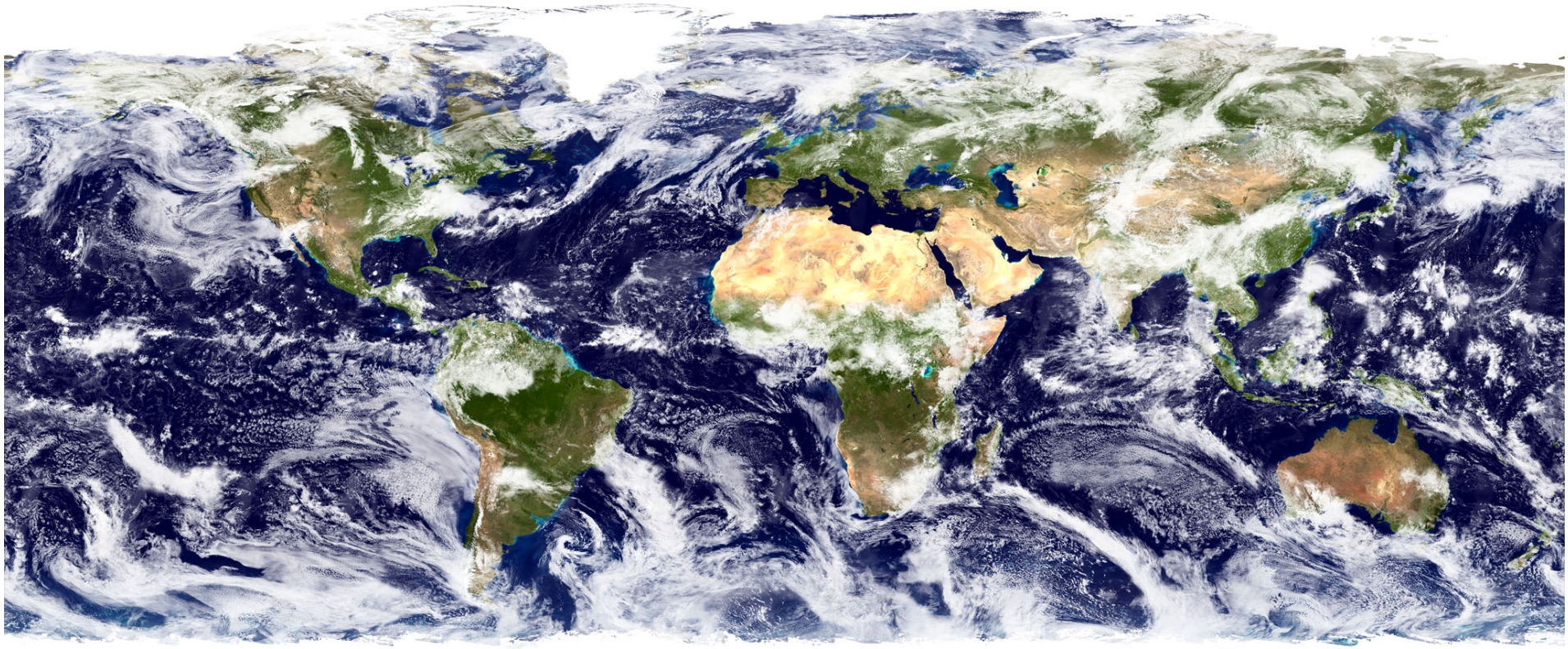


The quantity shown is the median of variant 1 of Ellrod's turbulence index, computed from 20 years of daily-mean data in December, January and February at 200 hPa.

Paul D. Williams and Manoj M. Joshi, "Intensification of winter transatlantic aviation turbulence in response to climate change", Nat. Clim.Change, 2013.

Next Steps (All Challenging)

- Specifying what types of climate data are most relevant the different decisions facing the several segments of this industry;
- Determining decision-appropriate time horizons and spatial resolutions for forecasts of this data;
- Performing syntheses across data sets, addressing gaps, inconsistencies, etc.
- Coupling the uncertainties inherent in these forecasts to the various decision processes.



Questions?

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