Climate Services Needs in the Air Transport Sector

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Air Transport and Climate - Context

Well trodden…

Road less traveled…

COMMERCIAL AIR TRANSPORT

GLOBAL CLIMATE

CLIMATE POLICY
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

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

<table>
<thead>
<tr>
<th>Sector Component</th>
<th>Infrastructure</th>
<th>Aircraft Performance</th>
<th>Passenger and Cargo Demand</th>
<th>Flight Safety</th>
<th>Passenger Comfort</th>
<th>Environmental Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airports</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Airlines</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>ANSPs</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Aircraft Industry</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
</tbody>
</table>
Impacts on Airports Similar to Other Coastal Infrastructure

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

Impacts on Airports Similar to Other Coastal Infrastructure (Cont’d)

- Example: Greater detail for airports via NOAA SLOSH model.

Must Understand Cost/Benefit Landscape in order to Define Needed Climate Services

- Example: planning of route adjustments to reduce climate impact

<table>
<thead>
<tr>
<th>Adjustment Type</th>
<th>Estimated Benefit</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systematic lowering of flight altitudes by 2000,</td>
<td>(1) Contrail RF in 2100 reduced by ~13%, 30%, and 48% compared with 2100 base case. Same for global mean surface temperature increase related to contrails. (2) Total aviation RF in 2100 (incl. CO₂, H₂O, O₃, CH₄) reduced by ~10%, 18%, and 26% compared with 2100 base case. Essentially the same for global mean surface temperature increase for the combined effects.</td>
<td>Fuel increases by ~2.6%, 5.2%, and 5.9% globally.</td>
</tr>
<tr>
<td>4000, and 6000 feet globally⁶</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systematic lowering of altitudes with appropriate</td>
<td>(1) Contrail benefits should be the same as the first item above since speed does not affect contrail formation or persistence. (2) Combined total benefits would be higher due to fuel-saving speed adjustments.</td>
<td></td>
</tr>
<tr>
<td>speed adjustments</td>
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</tr>
</tbody>
</table>

- Route adjustments based on historical conditions shown.
- Different costs and benefits for adjustments based on current/predicted conditions.
How Climate Data Enters the Picture

- Need: historical patterns of region-specific weather conditions.

Five winter weather types for aviation over the North Atlantic* (3 summer types):

- Based on 1989-2010 ERA-Interim data and NAO/EA teleconnections
- Black contours - geopotential height anomalies at 250 hPa
- Red contours - 250 hPa wind speed above 40m/sec
- Heavy black line - Great-circle route
- Blue - actual trajectories

How Business Objectives Enter the Picture

- Minimal “cost” can be economic, climate*, or a combination of these.

**Economic cost:**  \( E_{ij} = \text{fuel}_{ij} \) (fuel cost) + \( \text{time}_{ij} \) (time cost)

**Climate cost:**  \( C_{ij} = \sum_m \{ \text{fuel}_{ijm} (M_{\text{CO2ijm}} + M_{\text{H2Oijm}}) + \text{NOx}_{ijm} (M_{\text{O3ijm}} + M_{\text{CH4ijm}} + M_{\text{PMOijm}}) + \text{dist}_{ijm} (M_{\text{AICijm}}) \} \)

**Total cost** = \( A \times \text{EconomicCost} + B \times \text{ClimateCost} \)

\( i \) and \( j \) refer to a particular pair of airports and \( m \) refers to a sequence of segments along each route.

\( M \) refers to climate costs for CO2, water vapor, ozone, methane, and aviation-induced cloudiness.

London Heathrow Airport risk-management process:

1. Identify risks and potential consequences from climate change;
2. Estimate likelihood of the consequence on a five-level scale for the short, medium, and long term;
3. Estimate severity of the consequence on a five-level scale for the short, medium, and long term;
4. Establish risk priorities on a three-level scale based on likelihood and severity the short, medium, and long term;
5. Evaluate adequacy of any risk-control measures already in place;
6. Evaluate uncertainty/confidence associated with climate projections on a three-level scale;
7. Define required adaptation responses (taking action, making plans, monitoring) based on the above.

Complexities in Application of Climate Services to Commercial Aviation

• Data availability (and complexity) exploding.
• Different levels of understanding and uncertainty for various climate effects, particularly at high spatial resolution.
• “Commercial air transport” is not a single user community.
• Business focus is near-term.
• Risk-management needs are specific to each sub-sector and depend on complicated and differing business contexts.
• Need better decision-making under uncertainty on timescale of years to decades.
Key Challenges

- Identifying what types of climate data are most relevant to the different decisions facing the several segments of this industry.

- Determining decision-appropriate time horizons and spatial resolutions for forecasts of this data.

- Coupling the uncertainties inherent in these forecasts to the decision process.
Questions?

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