Effects of Extreme Heat on Aviation

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Regional Aircraft
- Maximum operating temperature of Canadair Regional Jet: 118°F
- 25 Cancellations due to “Weather” or “NAS”
- Cost of cancellations: ~ $26,250
- ~ 1,000 passengers needed to be rebooked
- Similar experiences at McCarran International Airport in Las Vegas
- Why Use Regional Jets?
  - Higher flight frequency: ~ 3.7 flights/day
  - Hub-and-Spoke system
  - Service smaller markets
  - Cheaper crew salaries
- Regional Jet Routes: 6 in 1990 vs. 1,091 in 2005
- Number of regional jets expected to increase ~ 12% by 2037

Amplified Effects in the Future?
- Will temperatures continue to increase? “Global mean surface temperatures have increased ~ 1°C above pre-industrial levels, with most of that change after 1980.”
- Enplanements expected to increase ~ 40% from 2017 to 2037

Larger Aircraft
- Weight restrictions very common
- Maximum takeoff weight of aircraft reduced
- Factors include: runway length, airport elevation, and temperature
- Can result in less passengers and/or cargo on-board → less revenue, rebooking and “buying off” passengers, delayed departures
- Effective altitude of PHX increased by ~ 4,233 feet on June 20: hotter air → less density → less lift
- 122 Boeing 737 (most produced commercial plane)⁴ flights subjected to weight restrictions – not all implemented: low load factor, shorter route, etc.
- 52 of these were > 15 minutes late in departure
- 2,008 total minutes delayed at a cost of ~ $125,600
- Number of days of some form of weight restriction for B737s expected to increase 100-300% in future⁶

<table>
<thead>
<tr>
<th>Number of Affected Flights at PHX Airport on 6/20/2017</th>
<th>CRI Aircraft</th>
<th>Boeing 737 Aircraft</th>
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<tbody>
<tr>
<td>Time</td>
<td>Temperature</td>
<td>Cancellations</td>
</tr>
<tr>
<td>09:51</td>
<td>104.0°F</td>
<td>2</td>
</tr>
<tr>
<td>10:51</td>
<td>108.0°F</td>
<td>10</td>
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<tr>
<td>11:51</td>
<td>108.0°F</td>
<td>9</td>
</tr>
<tr>
<td>12:51</td>
<td>111.9°F</td>
<td>12</td>
</tr>
<tr>
<td>13:51</td>
<td>116.1°F</td>
<td>4</td>
</tr>
<tr>
<td>14:51</td>
<td>118.0°F</td>
<td>11</td>
</tr>
<tr>
<td>15:51</td>
<td>118.9°F</td>
<td>7</td>
</tr>
<tr>
<td>16:51</td>
<td>118.0°F</td>
<td>4</td>
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<tr>
<td>17:51</td>
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<td>8</td>
</tr>
<tr>
<td>18:51</td>
<td>117.0°F</td>
<td>19</td>
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</tbody>
</table>

** No Temperature Data for 19:51 **

Additional Effects of Heat:
Increased turbulence (can tally up to ~ $200 million/year), change in jet stream winds leading to longer flight times (putting planes airborne for another 2,000 hours, burning 7.2 million more gallons of fuel, costing $22 million and emitting 70 million more kg of carbon dioxide); rising sea level threatening coastal airports

June, July & August 2017 # of Days of B737 Weight Restriction

<table>
<thead>
<tr>
<th></th>
<th>PHX</th>
<th>DEN</th>
<th>LGA</th>
<th>DCA</th>
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<tbody>
<tr>
<td>10,000 lb</td>
<td></td>
<td>4</td>
<td>59</td>
<td>22</td>
</tr>
<tr>
<td>15,000 lb</td>
<td>0</td>
<td>4</td>
<td>7</td>
<td>19</td>
</tr>
</tbody>
</table>

Potential Solutions

Adjust Aircraft Routing
- Big cities with multiple airports
- Challenges: well-developed structures at current airport; differences in size and runway lengths; most already at/near max capacity
- Examples: None...Not viable

Aircraft Design Improvements
- Improve performance of aircraft
- Challenges: planes in service for decades; cost; R&D; limitations such as tire speed & engine size
- Examples: B737 winglets; more effective engines; composite B787; B777X folding wingtip

Increase Runway Lengths
- B737 needs 18% more runway with 25°C increase at sea-level
- Challenges: limited/no room; cost; regulations; RSA
- Examples: BNE (accounted for higher temps); TYS (1,000 feet); DCA (~270 feet, $9.66 million)

Adjust Departure Times
- Depart at cooler parts of the day
- Challenges: decreased consumer choice; need flexibility at hubs; most near capacity; restricting flight time → less revenue
- Examples: LAS: Hainan 2:10pm to 1:10am & Norwegian seasonal

Swap Aircraft on Routes
- Some planes can generate more lift/hour. Common solution
- Challenges: availability; different characteristics; need advanced planning; like a “puzzle”
- Examples: Swapping B757 for B737, A319 for E175

Decrease On-Board Weight
- Less effects of weight restriction
- Challenges: Designs already try to minimize weight
- Examples: Many phasing out IFE systems & emphasizing Wi-Fi (WS ↓ 1,200 lb/plane & LH ↓ 103 lb of fuel/year per A340)¹¹

Bibliography: