A brief overview of climate change impacts on aviation, industry needs, and the resulting “home work” for scientists.

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Part a) Brief overview of climate change impacts on aviation:

The general outline of the expected impacts of climate change on aviation (as part of a global, intermodal transport and logistic system) have been given in several publications both in the science domain and in WMO and ICAO reports and White Papers. There is general agreement that

- While climate change is a global issue, the most important impacts on air transport are likely to be highly regionalized, scenario dependent and subject to strong temporal variations on a variety of time scales, but typically in the decadal to multi-decadal scale
- Despite all efforts of limiting climate change to an agreed temperature change limit, strong impacts are likely to occur well before such a limit is reached on a regional and temporal scale

Part b) Industry concerns with special emphasis on Original Equipment Manufacturers:

From the perspective of an Original Equipment Manufacturer, climate change may have multifactorial impacts:

- How will this change affect the design and required performance and resilience of aircraft, and how will it affect maintenance cycles and requirements?
- What will be the risk for production and maintenance sites including the full supply chain and logistics?
- What will be the consequences of climate change on demand for air travel, and how will customer support have to evolve to cope with climate change impacts on aviation operations?

Concerning scientific questions and issues, the aircraft designers require quite detailed and quantified information for specific regions and locations, with a focus on the following phenomena:

- Universal max/min temperatures
- In-flight icing conditions
- Turbulence and surface winds
- Humidity conditions
- Frequency and extreme intensity of lighting strikes

There is a need of convergence between the current scientific knowledge and the type of information required by aircraft designers, in order to anticipate climate evolution while avoiding costly “over-designing”.

Part c) What will be required from the scientific community to address the above-mentioned user concerns?

- Mitigation will rely on a multi-disciplinary effort taking into account many fields of research, ranging from Geology, Hydrology, Biology (vegetation studies) and Medical research into pandemics and airborne diseases apart from the need for innovative technology to address individual issues
- There is a strong need to consider not only long-term, model-based climate projections, but a continuous validation of these projections against emerging evidence of high impact scenarios occurring and documented already now,
- The study of such impact-scenarios already becoming evident needs to be linked to a down-scaling of long-term projections of future climates to identify priorities in mitigation measures.

Among the scientific subjects to be explored with a degree of urgency, we draw attention to a list of issues without claiming completeness and/or defining relative priorities as of now.

- Issues of temperature and humidity limiting take-off and landing performance:
  - Extremes of temperature at and near the surface of the earth occurring during extended periods of heat waves or cold outbreaks in mid-latitudes
  - Role of regional and local wind systems (sea breeze effects, valley winds, low-level jets), how issues such as soil moisture, vegetation and land use will influence extremes
  - Increase of moisture on density altitude, diurnal cycle of temperatures, changes in vegetation pattern around major hub airports
- Issues of surface winds:
  - Focus on severe storms, tropical cyclones (their frequency, location/paths, and intensity) and local wind systems as they are affected by flow pattern and regimes
  - Questions of storm surge affecting coastal aerodromes
  - Occurrence of extreme cross-winds with severe storms, prevalence of high amplitude-low wave-number regimes etc, and their impact on runway availability
- High-Level Icing as a result of stronger convection producing high values of icicle mass per volume
- Changing propagation and movement of convective systems under low shear-high CAPE regimes, their predictability and their effects on airport throughput/shut-down
- Issues of moderate and severe/extreme turbulence:
  - Location and frequency of moderate turbulence as a result of changing flow patterns (jet positions, stronger anti-cyclonic curvature in extreme ridges, troughs)
Fundamental question of extreme turbulence in high shear with high stability situations (not detected by typical Richardson -number based algorithms), possibly enhanced by convective cells pushing into Tropopause

- Aviation becoming an even more important factor in disaster relief where surface-based transport is more vulnerable to weather extremes
- Issues of strong/extreme precipitation leading to drainage problems on runways, runway excursions and infrastructure issues
- Issues of air quality and environmental concerns:
  - Stagnant situations in mid-latitude and lower latitudes with absence of precipitation and prevalence of bush fires/smoke
  - Issues of NOx/PM becoming highly political around large population centers

- General considerations:
  - Consider the need to re-evaluate pragmatic modes of operation (e.g. Pareto-Rule) in the light of extended periods of high-impact weather
  - Consider alternative methods of mitigation where rare events could become more frequent, or last for longer time scales (e.g. snow clearing process, flood mitigation, sand-and dust storms)