Deutsches Zentrum für Luft- und Raumfahrt

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Climate-induced Meandering Jet Stream and its Influence on Air Distance

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Research Workshop:
Climate change and the role of air traffic control

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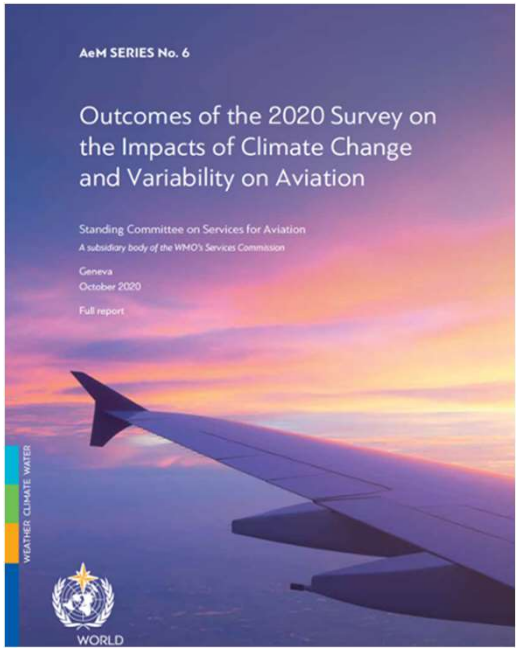
Overview activities - climate change impact and aviation

- **Collaboration with national aviation stakeholder:** MET requirements and impacts on aviation under climate change conditions are composed and prioritised in workshop meetings

WMO – Standing Committee on Services for Aviation

Expert Team on Climate Change and Variability on Aviation

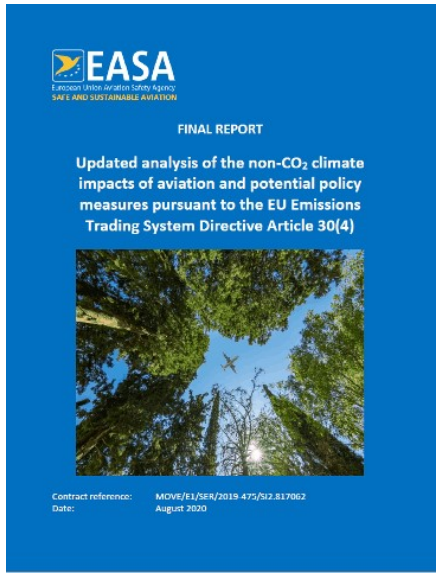
- Survey on the impacts of climate change on aviation
- Contact with EASA – Advisory in climate change impacts and risks on aviation questions



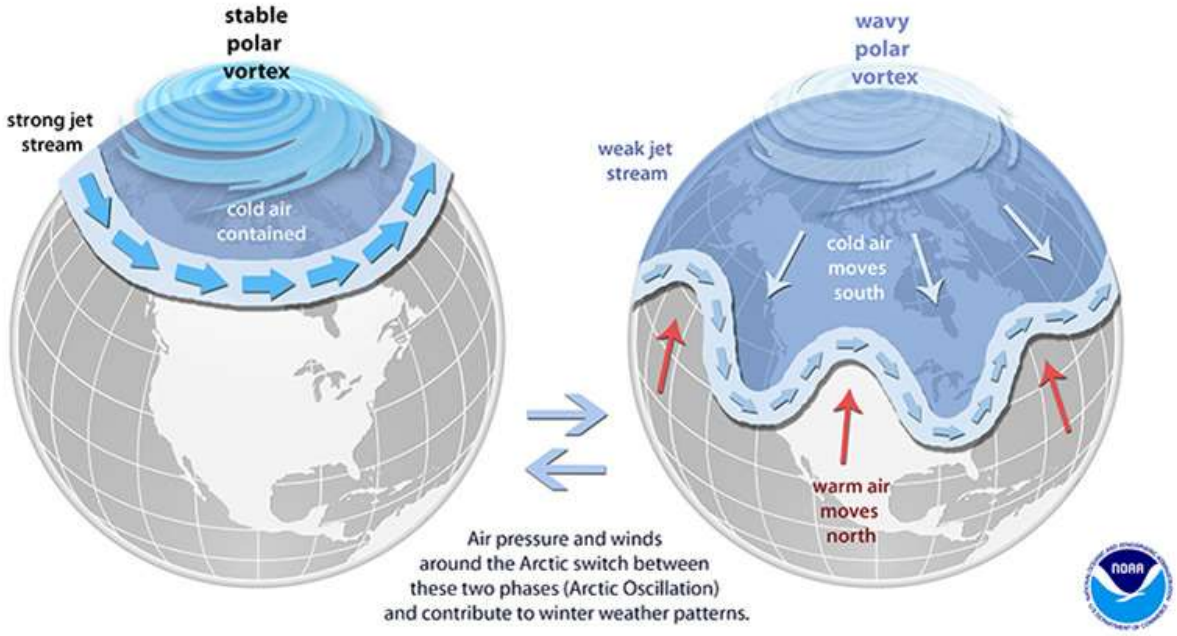
Overview activities - climate change impact and aviation

- **DLR and DWD are involved with ANSP and aviation stakeholder in a governmental funded project proposal D-KULT**
  - Feasibility study of climate optimised flight trajectory planning due to avoidance of contrails and ice-supersaturated areas . – Mitigation of climate change
  - Reducing Non-CO2 effects based on EASA recommendation – *Arrowsmith et.al, 2020*

- **Starting with impact studies regarding climate induced meandering jet streams**



Strong and Meandering Jet Stream



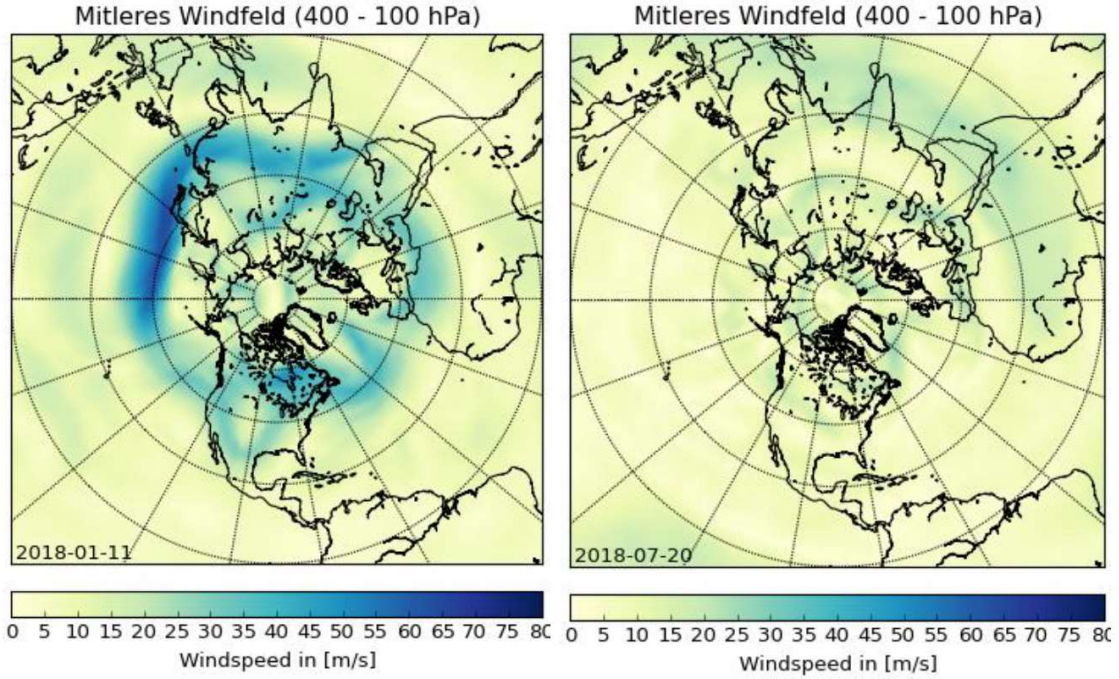
- **Jet Stream:** Strong westerly wind patterns in about 10 km altitude with 500 km/h wind speeds
- In the last years it could be observed that the jet stream meandered increasingly.
- Instead of fast and almost westerly winds, wind speeds decrease and wind direction show more variation.

Meandering Jet Stream

- Investigation show that effects of climate change strengthen the condition of meandering jet stream (*see e.g. AWI Report https://doi.org/10.1038/s41598-019-43823-1*)
- Main forcing of jet stream are temperature gradients between arctic and tropic latitudes
- Due to increasing average temperatures at higher latitudes, temperature gradient decrease.
- Meandering jet streams causes blocking weather systems with cold air breaks in winter, extreme long hot temperature periods or also heavy precipitation events in summer.

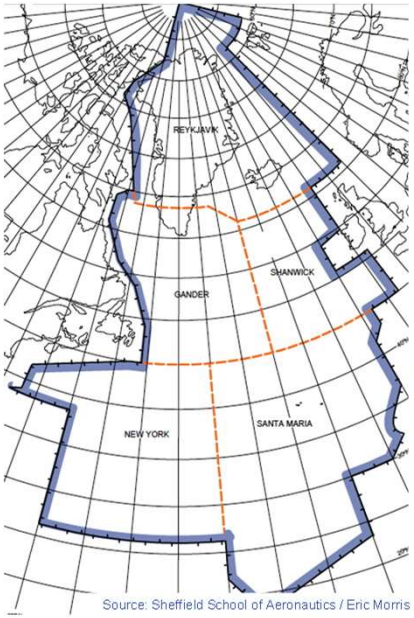
Selected weather situations for impact study

- Data Base: Global atmospheric reanalysis ECMWF (*Berrisford, 2011*)
- Selected days with meandering jet stream conditions (*Renk, 2020*): 20 Jul 2018, 01 Nov 2018
- Selected days with conventional jet stream conditions: 16 Jan 2018, 31 Jan 2018, 06 Jun 2018, 23 Sep 2018, 24 Oct 2018

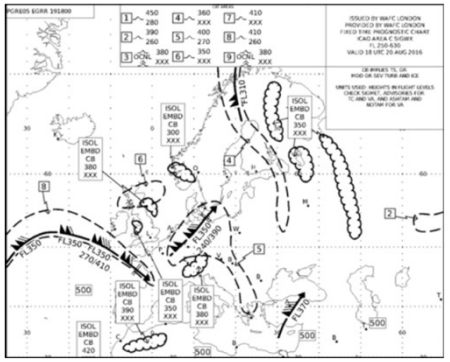


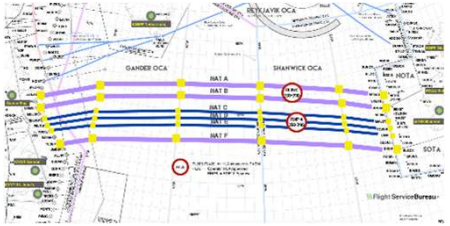
North Atlantic Airspace

- North Atlantic Airspace and Track System (NATS) spatially affected by jet streams
- The operation in eastbound direction is usually economically favorable due to utilization of tailwind effects
- When operating in westbound direction, the jet stream often causes detours due to headwind avoidance, resulting in higher flight times and values of ground distance
- Objective of flight planning to operate economically in both directions: minimize air distance



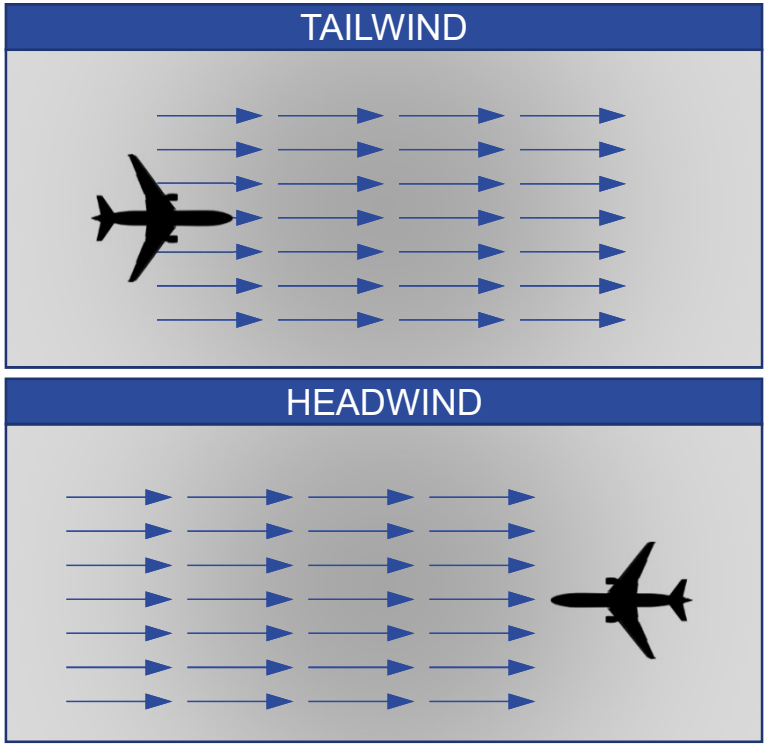
Source: Sheffield School of Aeronautics / Eric Morris





Modeling Air Distance

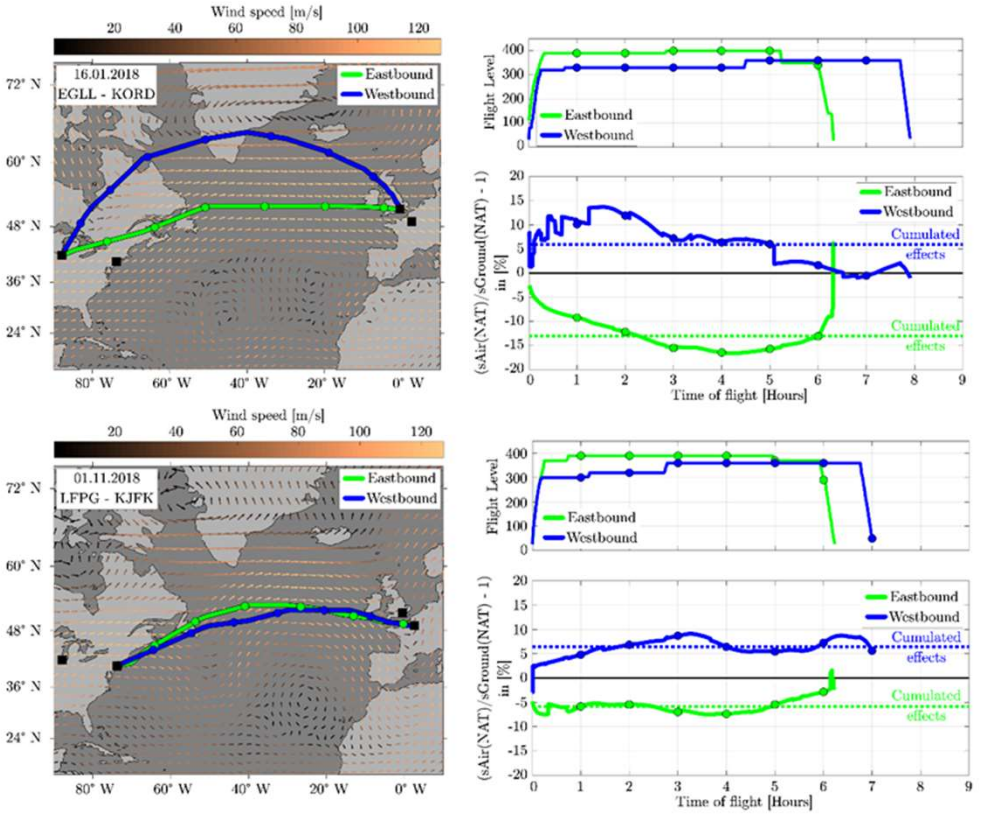
- Kinematic approach according to the model of *Swaid et al. (2016)*
- Aircraft considered as massless point moving along 3-dimensional flight plan trajectories (ECTRL DDR2) with constant Mach number
- Real atmospheric wind data based on ECMWF ERA-interim
- Ground speed is determined by super-imposing local wind vector with TAS for each discrete interval of 1000m ground distance
- Wind corrected air distance resulting from numerical integration of the discrete intervals between the trajectory points



Source: Linke 2016

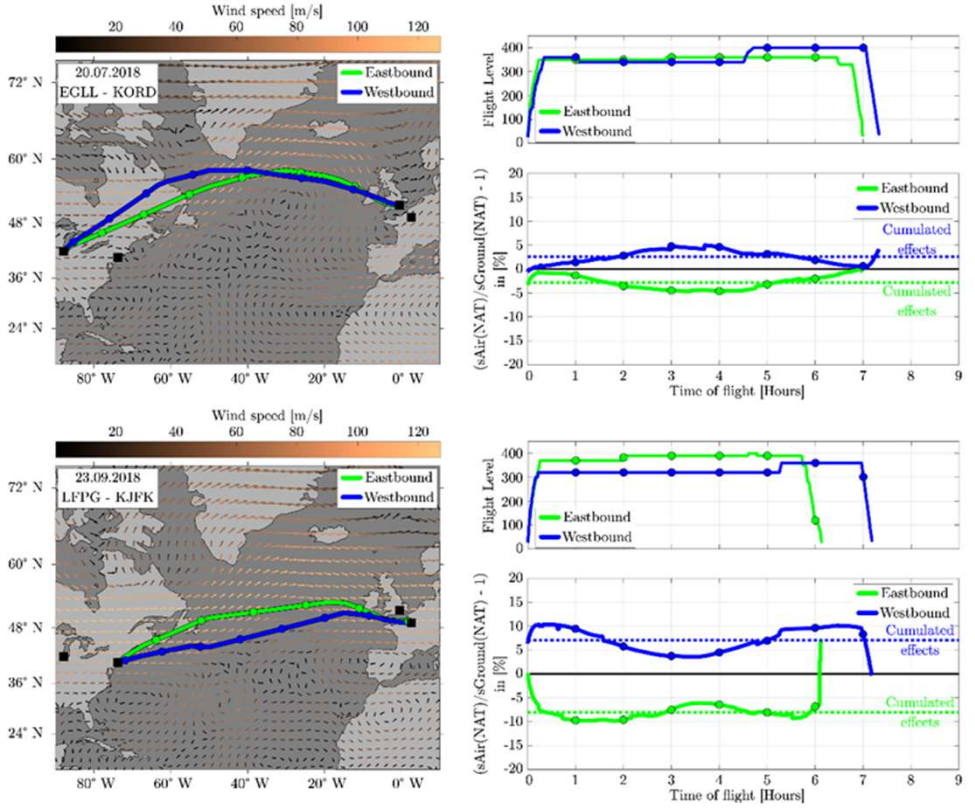
Impact Scenarios

- Two days: 16 Jan 2018 (conventional, upper figures) and 01 Nov 2018 (meandering, lower figures) with bi-directional representative tracks between EGLL-KORD and LFPG-KJFK
- Wind situation at FL390 showing the difference between conventional and meandering jet stream wind fields
- Flight profile is divided into hourly segments showing percentage air distance impacts on each of these segments
- Blue: westbound track with mostly air distance increases, green: eastbound track with mostly air distance decreases
- Conventional jet: better usage of tailwind effects of up to 18% per segments due to stronger continuous wind field
- Meandering jet: Decreased headwind effects westbound (only about 10% air distance decrease), but also lower tailwind effects of only max. 6% eastbound



Impact Scenarios

- Another two days (rather summer days): 20 Jul 2018 (meandering, upper figures) and 29 Sep 2018 (conventional, lower figures) with bi-directional representative tracks between EGLL-KORD and LFPG-KJFK
- **Meandering jet stream:**
  - Clearly wind fields with higher wind velocities at higher latitudes
  - Less effects on air distances east- and westbound due to lower meandering wind velocities and stronger northward orientation of the wind fields
- **Conventional jet stream:**
  - Stronger tailwind effects on air distance due to stronger wind velocities
  - Possiblity of southern bypass



Conclusion

- The frequency of meandering jet streams is increased in last years also strengten due to climate change conditions.
- The meandering jet stream effects air distance increases and therby impacts the flight trajectory planning.
- The impact due to meandering jet stream wind conditions should be more considered in the long-term strategic flight route planning.
- In further investigations the impact studies will be extended on a larger data base and will be described more detailed.

Thank you for your attention!

Fall Back:

Air Distance Variations

- Upper figure: evaluation of percentage ground distance increases between NATS tracks and orthodrome of all flights on the selected O-Ds as an implicit measure of wind effects
- Lower figure: relation between air distance and ground distance along the operated tracks
- 01 Nov 2018 (meandering) indicates slightly higher inefficiencies regarding air distance compared to the other winter days
- 20 Jul 2018 (meandering) indicates less inefficiencies compared to days with conventional jet stream
- Recommendation to focus on winter season for further research regarding meandering jet stream behavior and its impact on air distance