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Sustainable Skies Conference: Contrails in Focus

Forecast of Potential Persistent Contrails

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EUROCONTROL's Brussels HQ

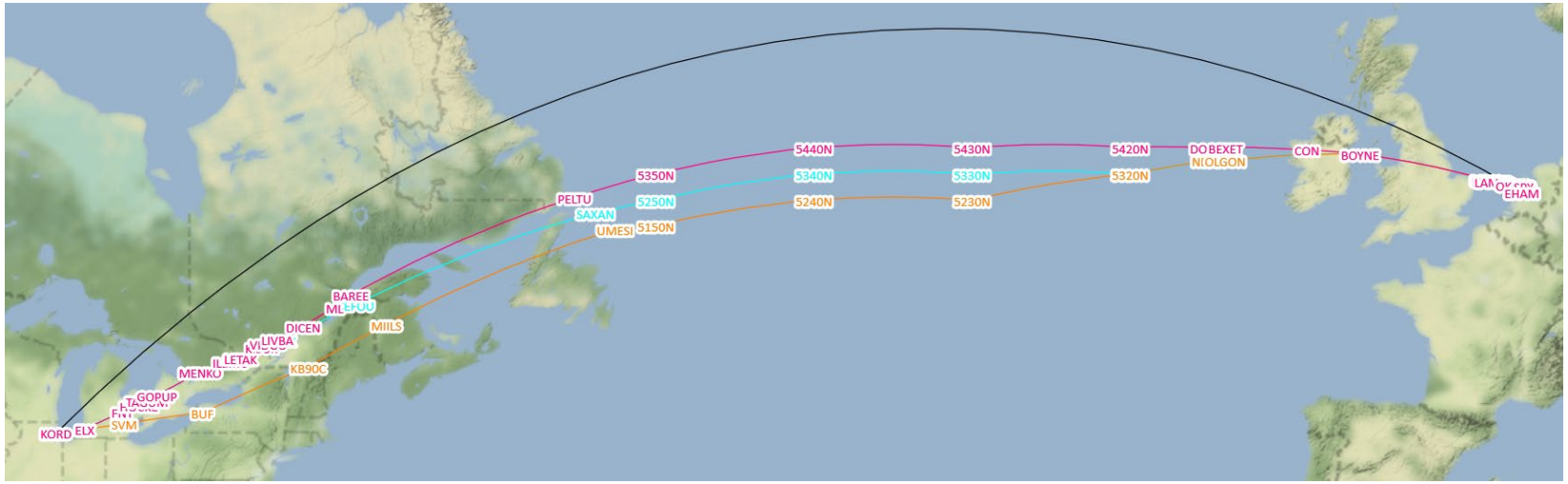
Deutscher Wetterdienst
Wetter und Klima aus einer Hand

DWD

WORLD METEOROLOGICAL ORGANIZATION

MET forecast data for flight planning and air space monitoring

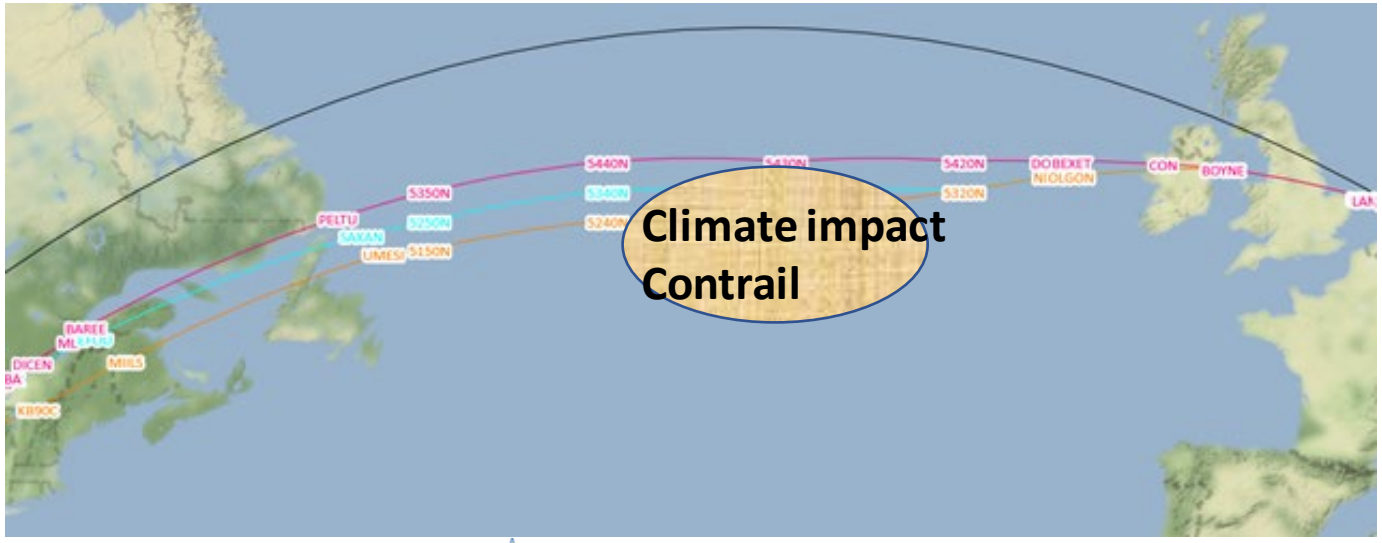
- Provision of MET forecast parameters from Numerical Weather Prediction (NWP) models, like wind, air temperature, air pressure
  - ICAO World Area Forecast System (WAFS) dataset:
  - World Aviation Weather Forecast (WAWFOR) dataset:



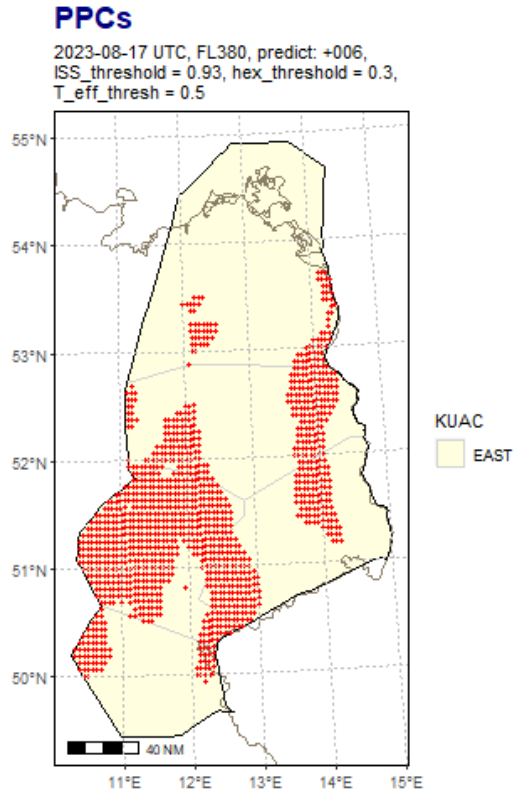
Flight trajectory planning
Source: LH Systems

Additional MET data set for climate optimised flying

- At DWD a data set with climate relevant parameters is under development in addition to WAWFOR, it contains (in collaboration with project LuFo D-KULT / DLR):
- Potential Persistent Contrail (PPC): *Schmidt-Appleman criterion and saturation of humidity*
- Transmission degree due to cloud cover above PPC
- Output postprocessing climate change impact due to contrails
- Output climate change impact due to further non-CO_2 effects



Considering climate impact due to contrails in flight trajectory planning
Source: LH Systems

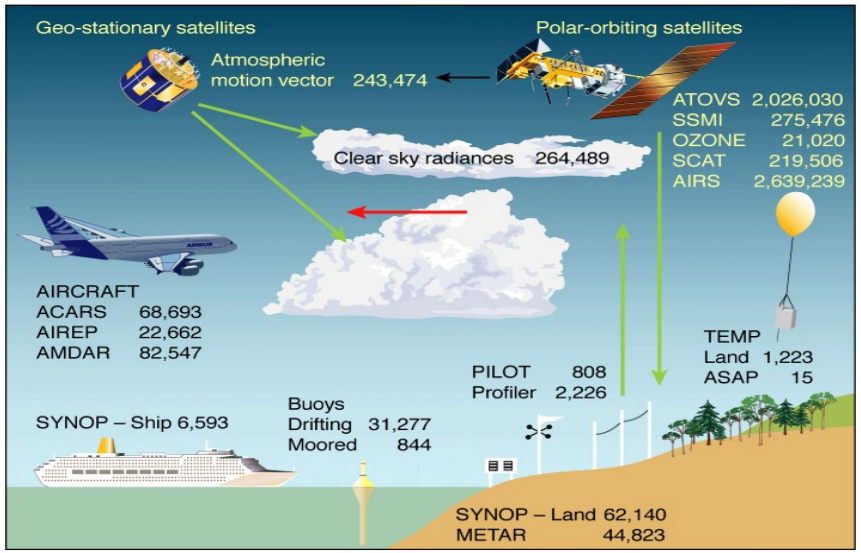


Considering PPC fiels for upper air space control – example DFS Upper Air Space Karlsruhe East in FL 380
Source DFS/A. Liedtke

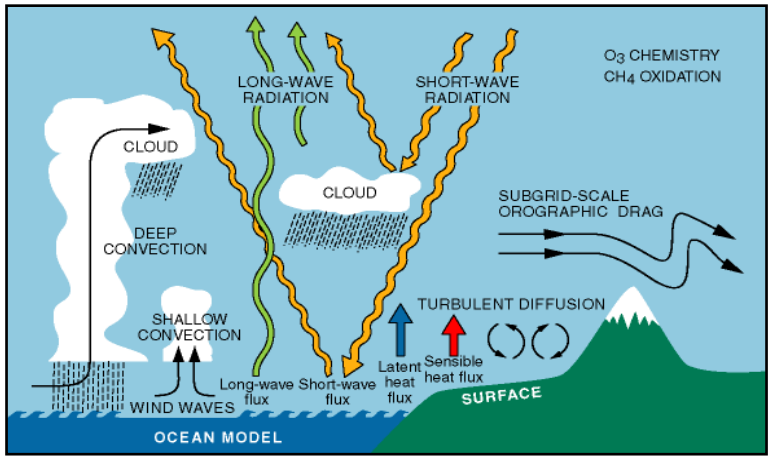
Creation of Numerical Weather Prediction (NWP)

Observations

Integration of observational and measured data into data assimilation scheme - Description of initial state of atmosphere

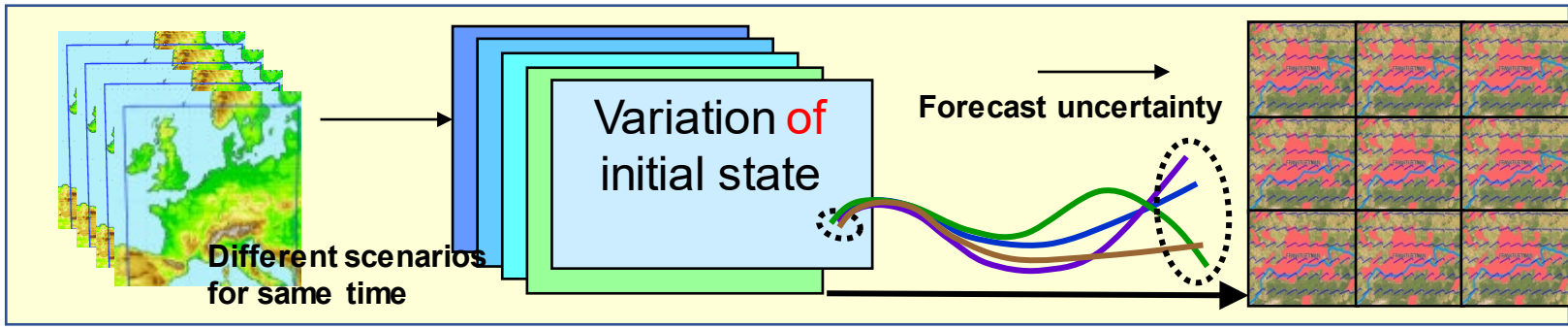


Model

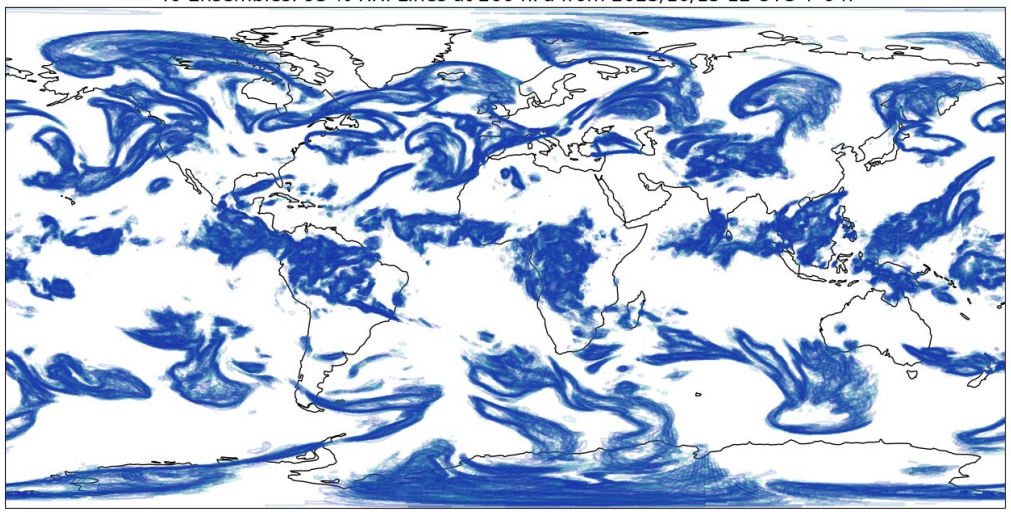


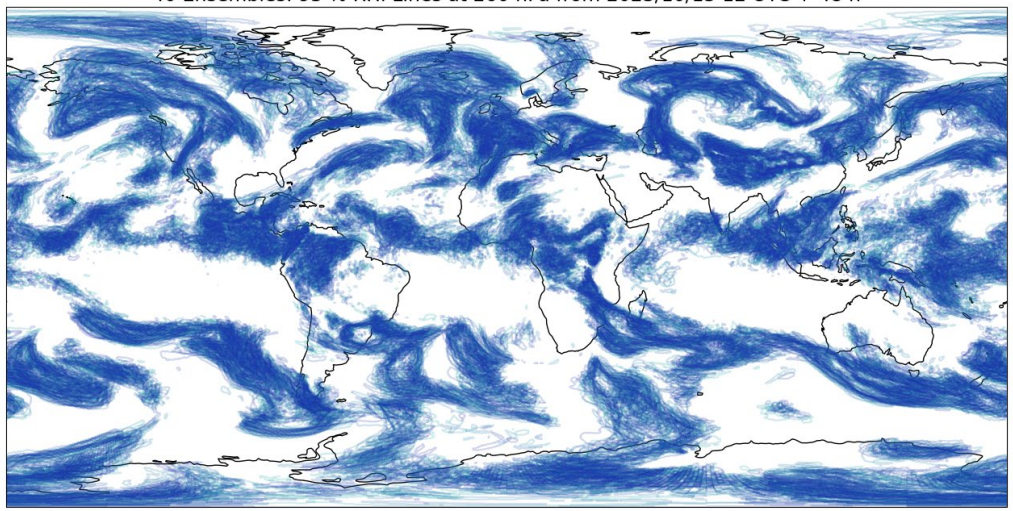
HPC

Considering forecast uncertainty by ensemble forecasts: different forecast „member“ by variation the initial state



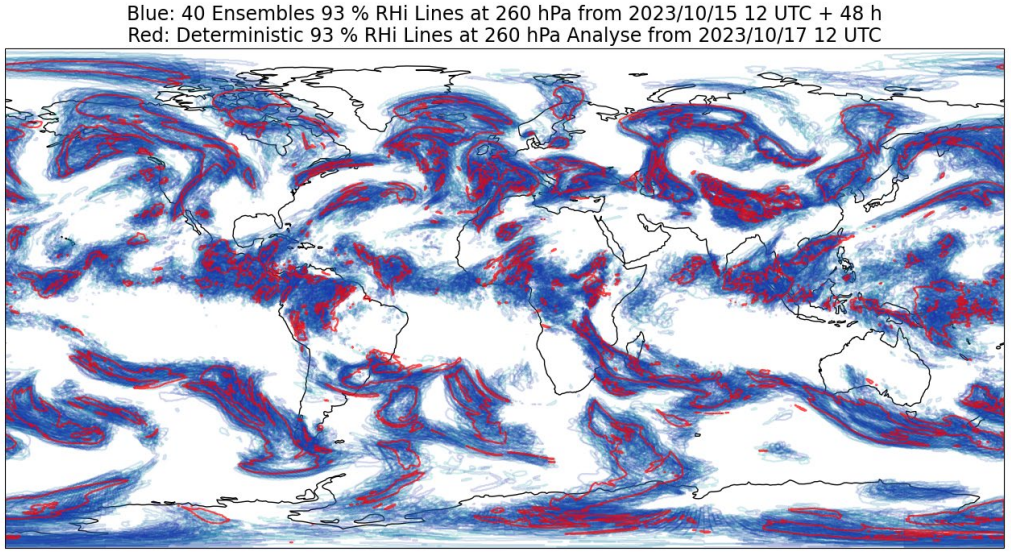
Quality of humidity forecast at cruise level





DWD ICON NWP model investigations:

- **Left:** forecast of relative humidity > 93% - suitable model threshold – based on 40 ensemble members in 260 hPa
  - **Above Figure:** +00 h forecast time
  - **Below Figure:** +48 h forecast time *(increasing uncertainty)*
- **Right Figure:** Relative humidity > 93%: model analysis in red and 40 ensemble-member forecast +48 h in blue
  - *Humidity forecast uncertainty could be shown*



Source: DWD/R. Engelhardt

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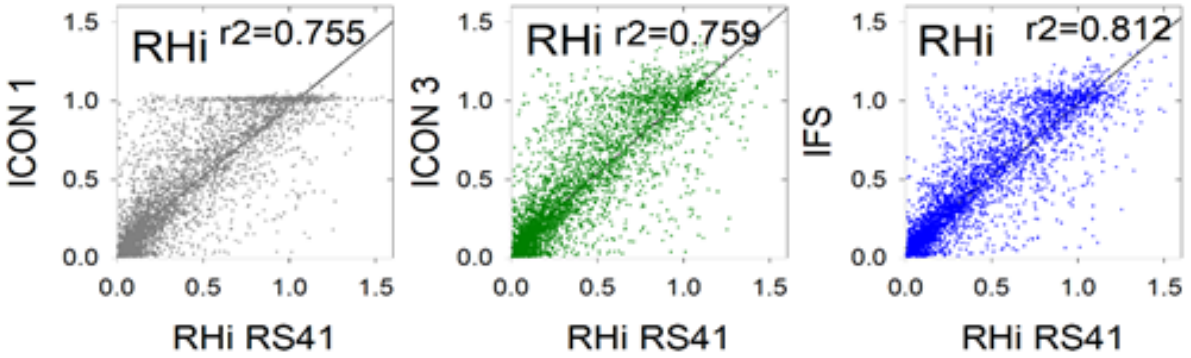
Improving humidity forecast

NWP model parametrisation:

- Improved cloud ice micro physics: Two moment scheme

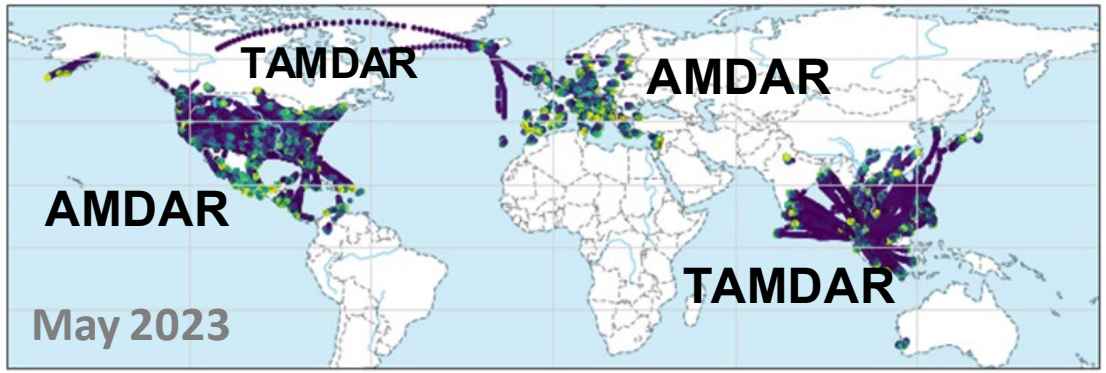


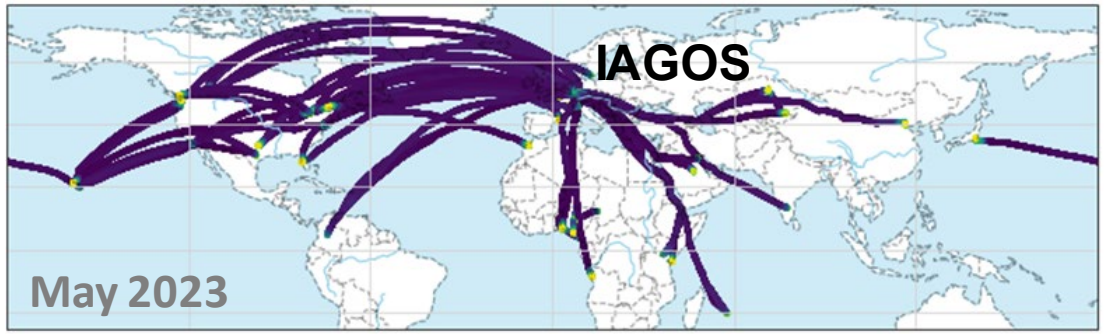
Source: DLR/U. Schumann, DWD/A. Seifert

- **ICON 1:** DWD model – no humidity supersaturation
- **ICON 3:** DWD model with improved cloud ice micro physics – allowed humidity supersaturation over ice
- **IFS:** ECMWF model shows also humidity supersaturation

Assimilation of additional observational and measured data into NWP, e. g.:

- **Especially airborne water vapor in-situ observations**
- Satellite based measurements





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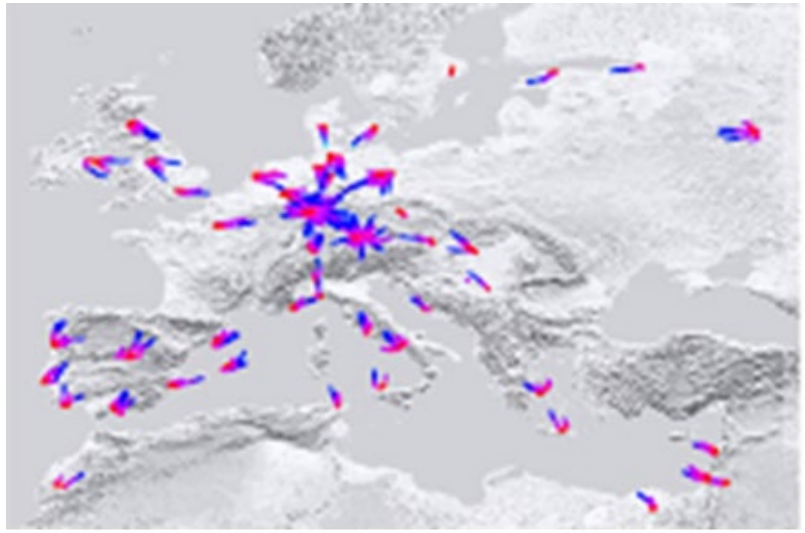
Using operational airborne water vapor observations

- **WMO AMDAR** – Aircraft Meteorological Data Relay
- Data transmission of water vapor observations only during descent and ascent phase of flights due to costs
- Project LuFo MEFKON: Extension of AMDAR data collection on cruise level of 9 Lufthansa aircrafts over Europe
  - Assimilation of data into NWP: Benefit on humidity forecast

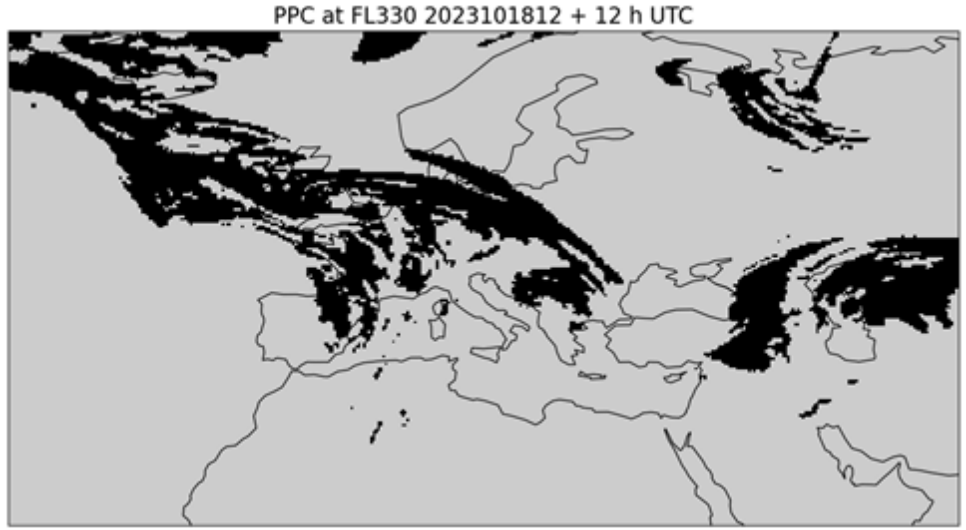


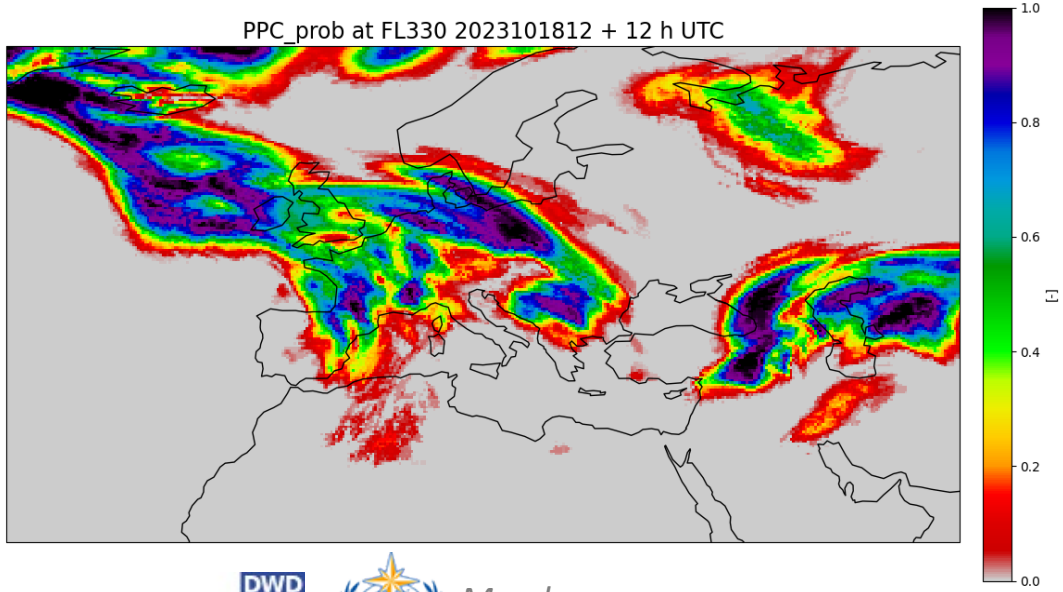
AMDAR water vapor observations 30 Sep – 06 Oct 2019

- **UK Met Office:** Implementation of FLYHT WVSS-II water vapor sensors on aircrafts – Embraer 145 – of Loganair Airline
- Observations and data collection are also planned at cruise level

Source: Met. Technology Int. 09/2023

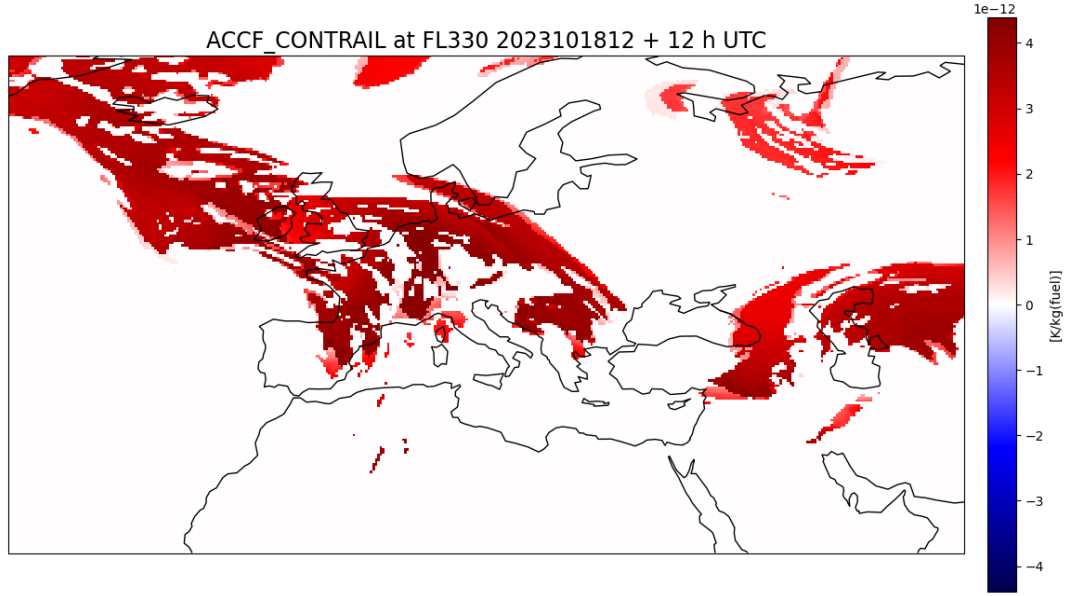
Example for forecasted climate parameters





Figures based on experimental climate data set according to WAWFOR:

- **Left above:** PPC at FL 330 and at night, +12h forecast time
- **Left below:** PPC probability shows areas of greater predictive uncertainty in some cases. *NWP improvements should reduce the uncertainty.*
- **Right:** Output of algorithmic climate change function aCCF contrail in Kelvin/kg(fuel) – red colour: warming effect



Source: DWD/R. Engelhardt

Conclusion

- In regions with high PPC probability, DWD will provide climate-relevant parameters in addition to WAWFOR for climate optimized flight trials for project partners.
- In order to minimize further capacity reductions due to PPC fields in airspaces that are already heavily congested, PPC predictions in space and time must be as precise as possible.
- Further improvements in humidity and climate-related prediction parameters are needed.
- Integration of additional cruise-level airborne water vapor observations into NWP data assimilation can make an important contribution.
- To this end, the further equipment of aircraft with water vapor sensor technology and the question of costs must be clarified.
- Regulations to establish the Monitoring, Reporting and Verification (MRV) system may form one approach.

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