# Airborne active remote-sensing observations of warm conveyor belts

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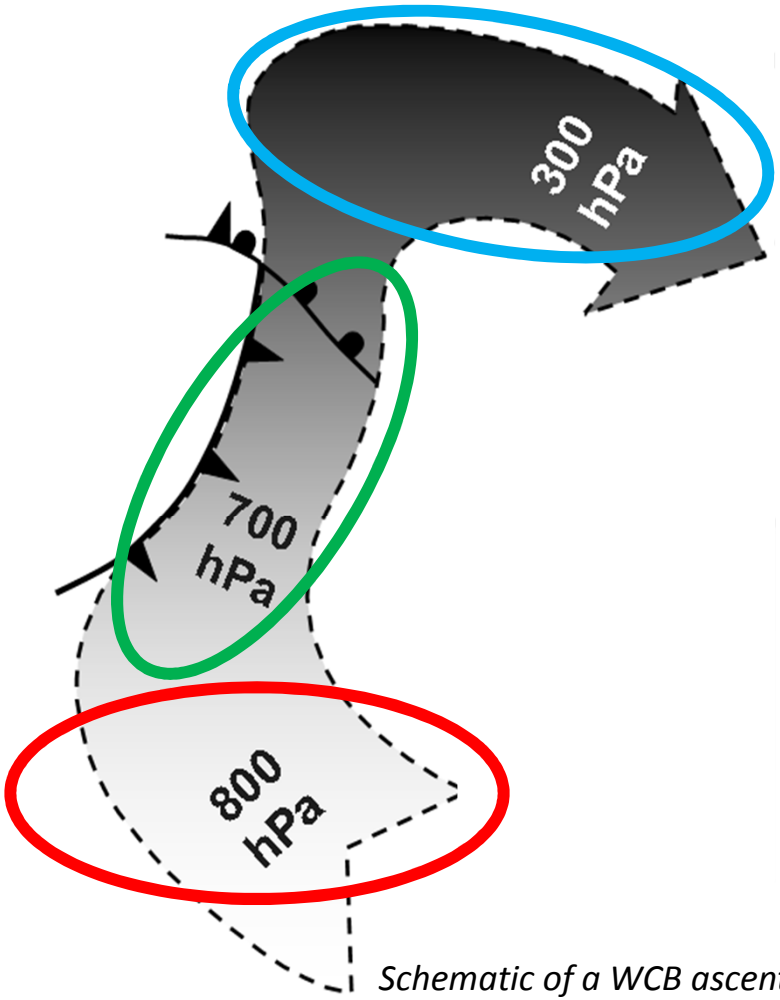
DLR Oberpfaffenhofen

WAVES TO WEATHER

DLR

# Why are we interested in aircraft observations of WCBs?




*Schematic of a WCB ascent*

Diabatic processes in WBCs potentially…

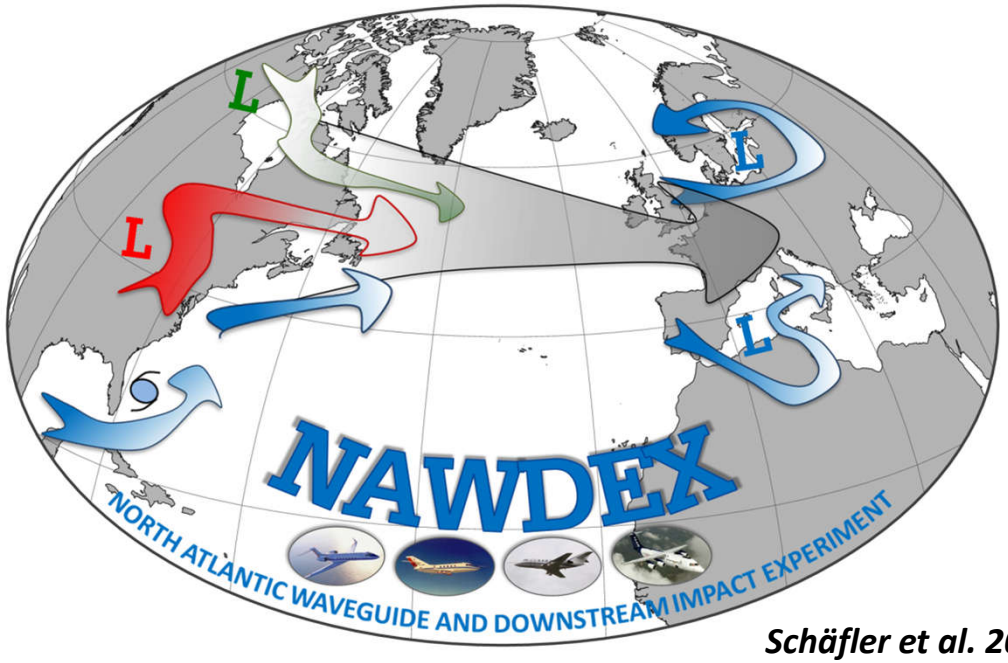
- … depend on the water vapor in the WCB inflow region
- … are insufficiently represented in NWP
- … play a role for forecast errors associated with mid-latitude weather systems

Research questions

- How well is moisture represented in NWP in the WCB inflow region?
- How do uncertainties affect forecast accuracy?
- How are diabatic processes represented by current NWP models?
- How well do NWP models capture upper level dynamics?
- How well is moisture represented near WCB outflow regions?

# Why are we interested in aircraft observations of WCBs?

## NAWDEX observations in 2016




***Schäfler et al. 2018, BAMS***

The overarching scientific hypothesis: **Diabatic processes over the North Atlantic have a major influence on jet stream meanders, the downstream development of Rossby waves on the tropopause and high impact weather over Europe.**

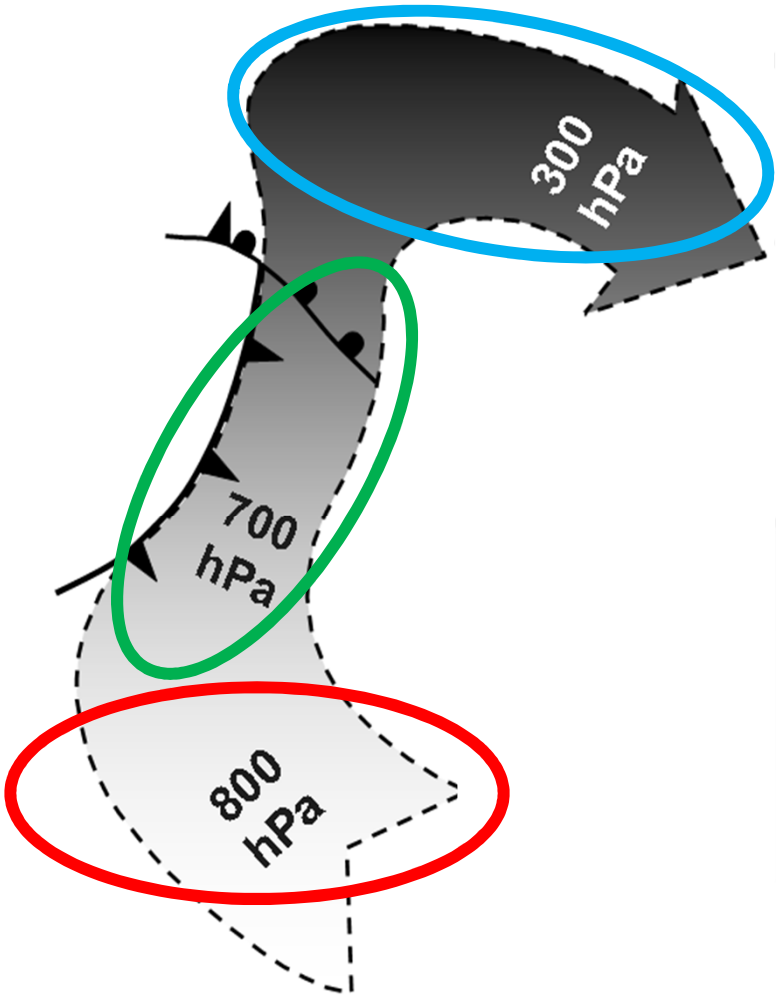
**G: HALO**

**G: DLR Falcon**

**F: SAFIRE Falcon**

**UK: FAAM BAe146**

# Why are we interested in aircraft observations of WCBs?




Tue, 10 March:

10:55 → 11:20 **Embedded convection in the warm conveyor belt of a North Atlantic cyclone and its relevance for large-scale dynamics** (Annika Oertel ETH Zurich)

Wed, 11 March:

11:10 → 11:30 **Revisiting the isentropic view of PV modification in warm conveyor belts** (Ben Harvey, NCAS / University of Reading)

11:35 → 12:00 **Three-dimensional radiative transfer around a tropopause fold** (George Craig, LMU Munich)

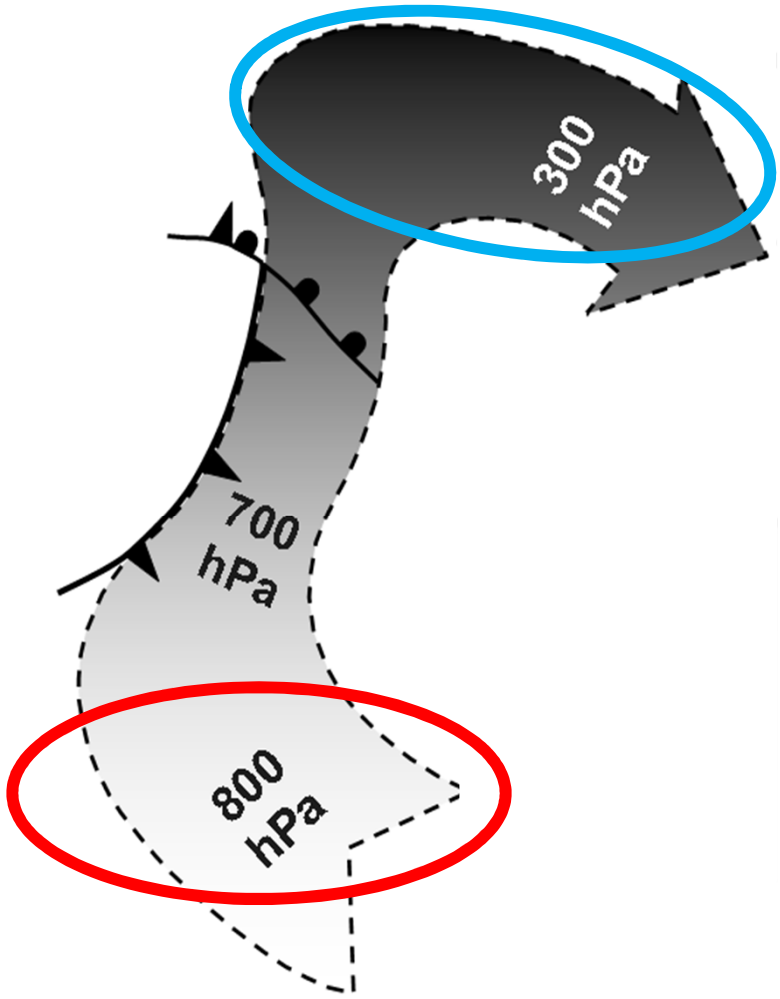
13:30 → 13:50 **Impact of different microphysics on the warm conveyor belt of a deep extratropical cyclone observed during the NAWDEX campaign and on its associated ridge building** (Marie Mazoyer (CNRM, Météo-France/CNRS)

13:55 → 14:15 **Diabatic processes in the Warm Conveyor Belt of the Stalactite Cyclone: sensitivity to two convective parametrization schemes of the global Météo-France model ARPEGE** (Gwendal Riviere, LMD/IPSL, ENS, CNRS)

Tue, 10 March:

15:55 → 16:20 **Influence of Warm Conveyor Belts on the Predictability of Downstream High-Impact Weather** (James Doyle, Naval Research Laboratory)

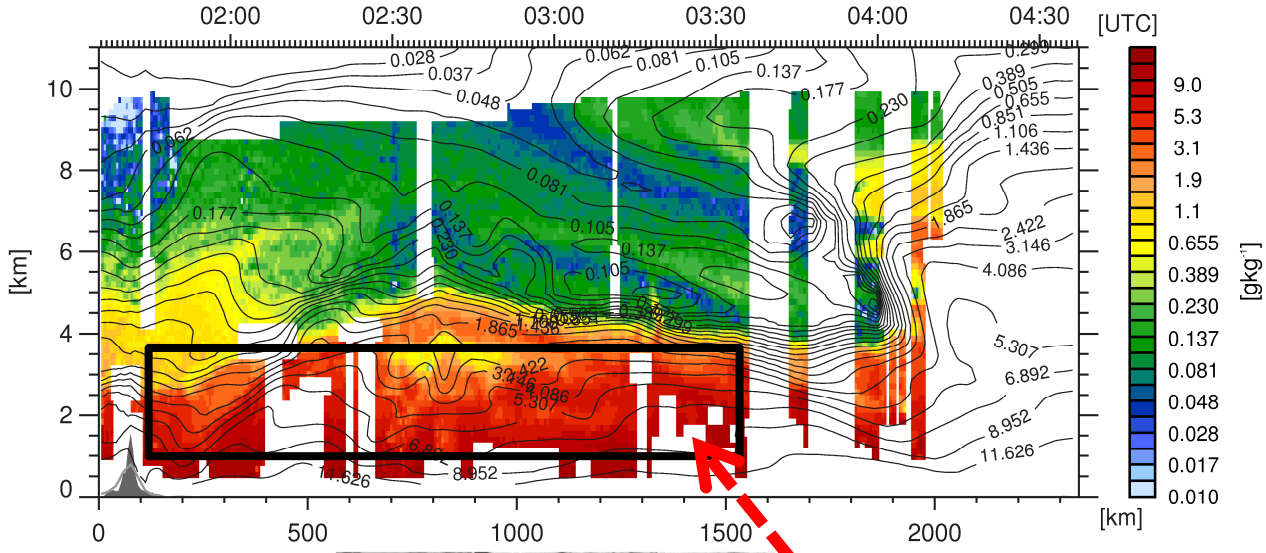
# Why are we interested in aircraft observations of WCBs?



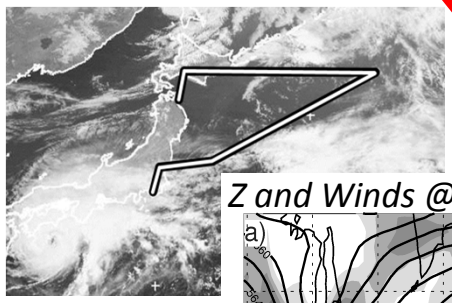

- **Observation of moisture in the inflow region of warm conveyor belts**
  - A T-PARC Case Study
  - Outlook: NAWDEX case study on cyclone Walpurga
- **Observation of near-tropopause gradients**
  - Jet stream winds during NAWDEX
  - Outlook: PhD work on tropopause-based uncertainties

# 1) Moisture in the inflow of WCBs

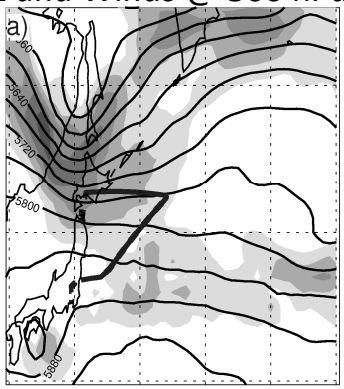
## T-PARC case study

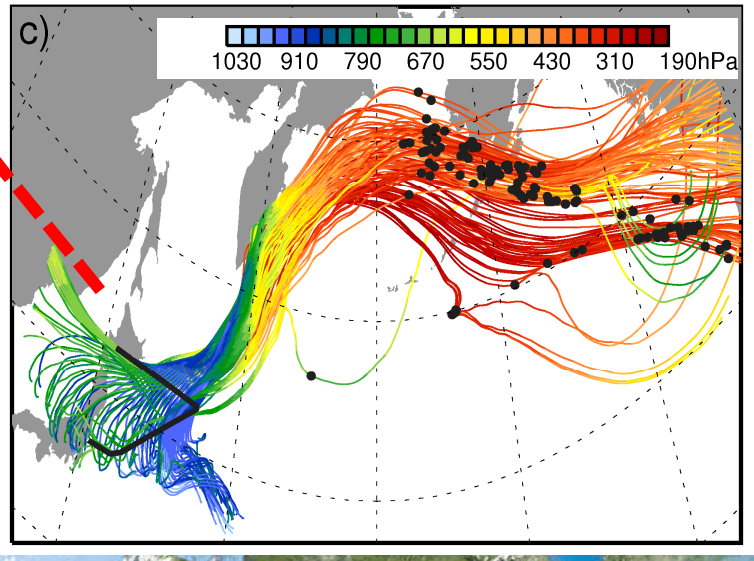



***Water Vapor observations in a WCB inflow east of Japan in 2008***



*Z and Winds @ 300 hPa*



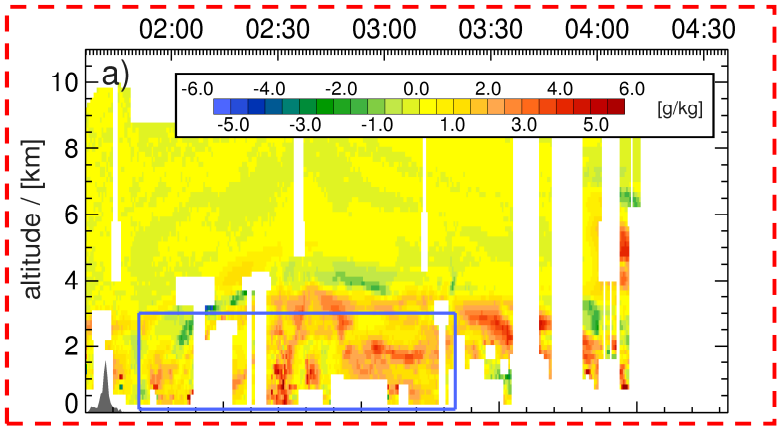




***Schäfler and Harnisch 2015, QJ***
***Harnisch et al. 2011, QJ***

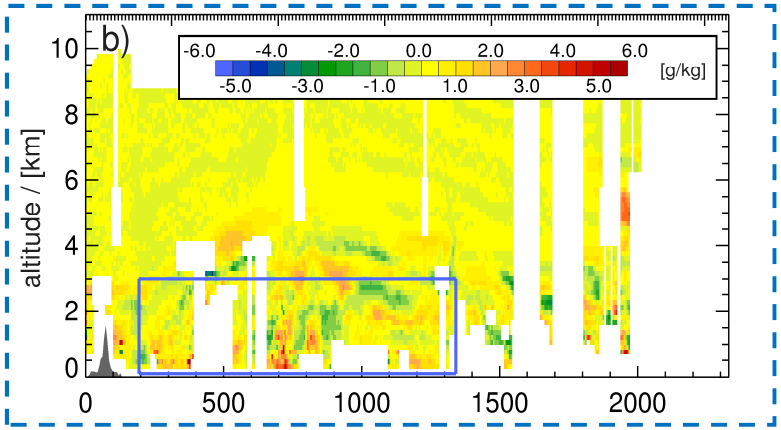
# 1) Moisture in the inflow of WCBs

## T-PARC case study

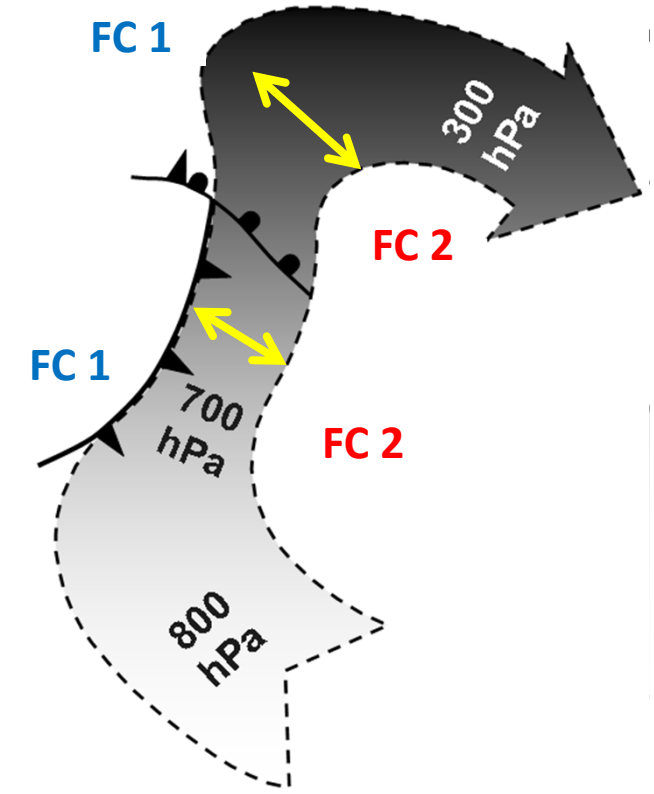
**OPERATIONAL ANALYSIS 1:**




**ANALYSIS 2: + LIDAR WV**




***Water Vapor Differences between ECMWF and Observations ($\Delta q = q_{ECMWF} - q_{LIDAR}$)***



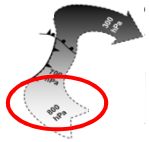

**ANALYSIS 1:**
Operational Observations

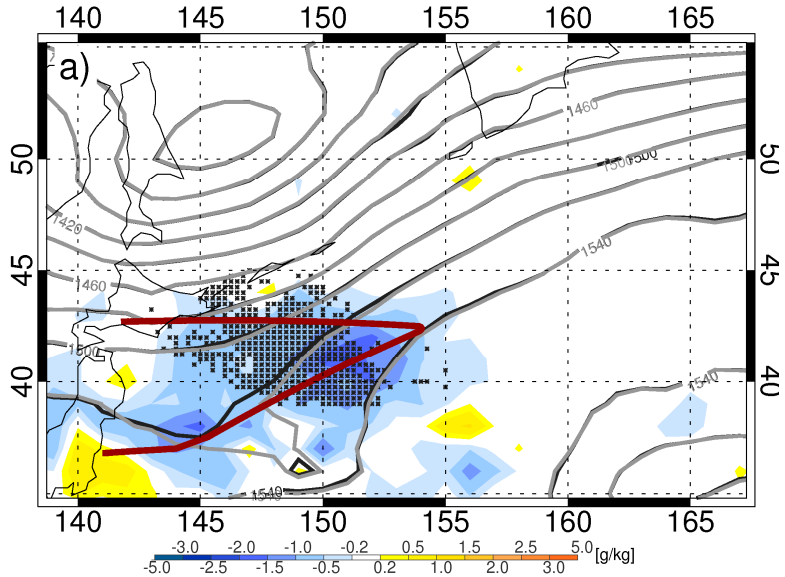
**ANALYSIS 2**
+ LIDAR WV
Reduction of inflow moisture

***Data Assimilation Experiment***

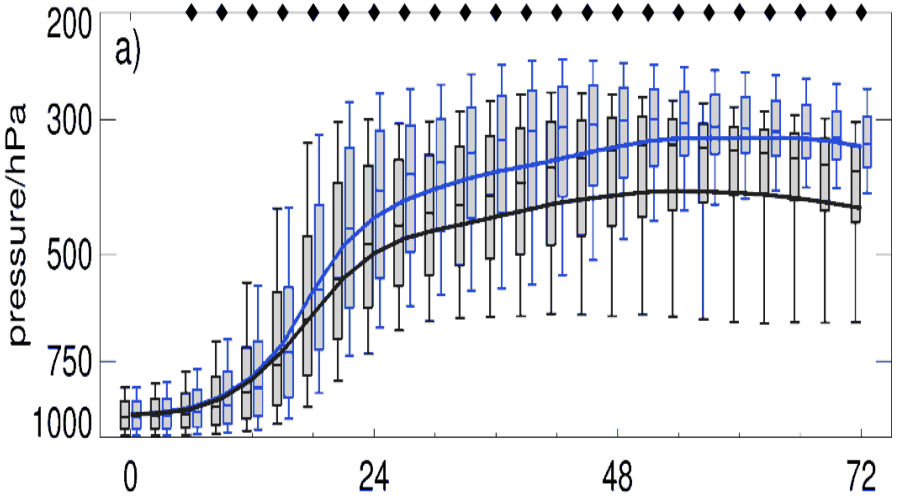
# 1) Moisture in the inflow of WCBs

## T-PARC case study






***Data assimilation of Lidar data reduced moisture on average by 2 g/kg***



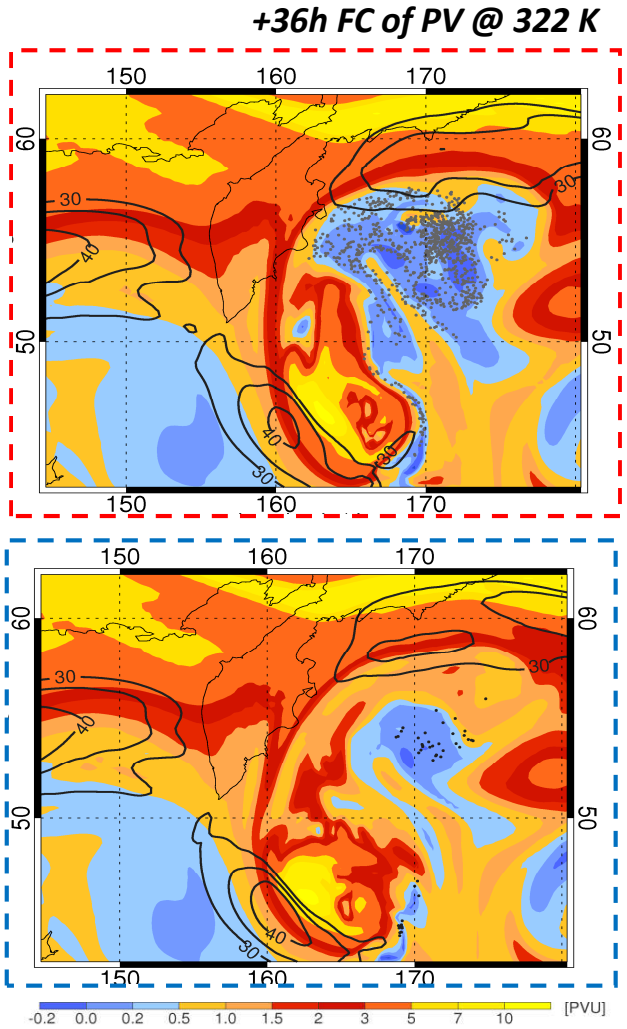

***Reduction of moisture showed significant impact on WCB outflow height***

# 1) Moisture in the inflow of WCBs

## T-PARC case study

Impact of realistic analysis perturbations of WV in the WCB inflow on the large scale flow

- positive impact on the dynamic structure of the cyclone
- improvement of the PV structure at low and mid-levels
- lower outflow height & reduced tropopause height caused a change in the jet-stream wind speeds

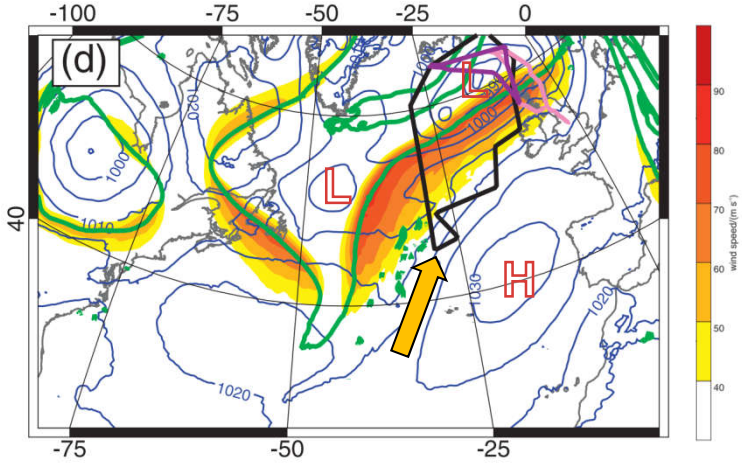


# 1) Moisture in the inflow of WCBs

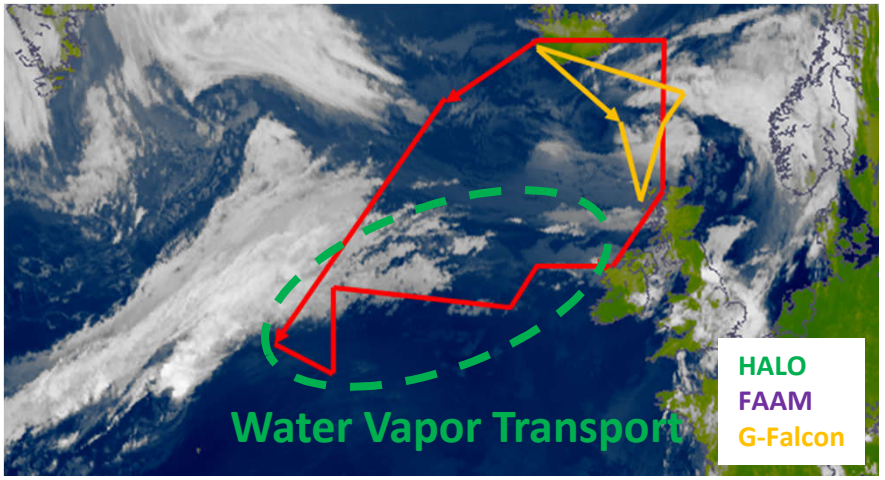
## Outlook: NAWDEX case study on cyclone Walpurga

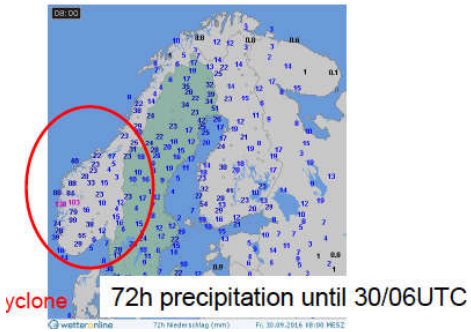
Observations of large-scale strong moisture transport in an atmospheric river–type flow upstream of Cyclone Walpurga causing HIW over UK/ Scandinavia

**1200 UTC 27 Sep 2016**



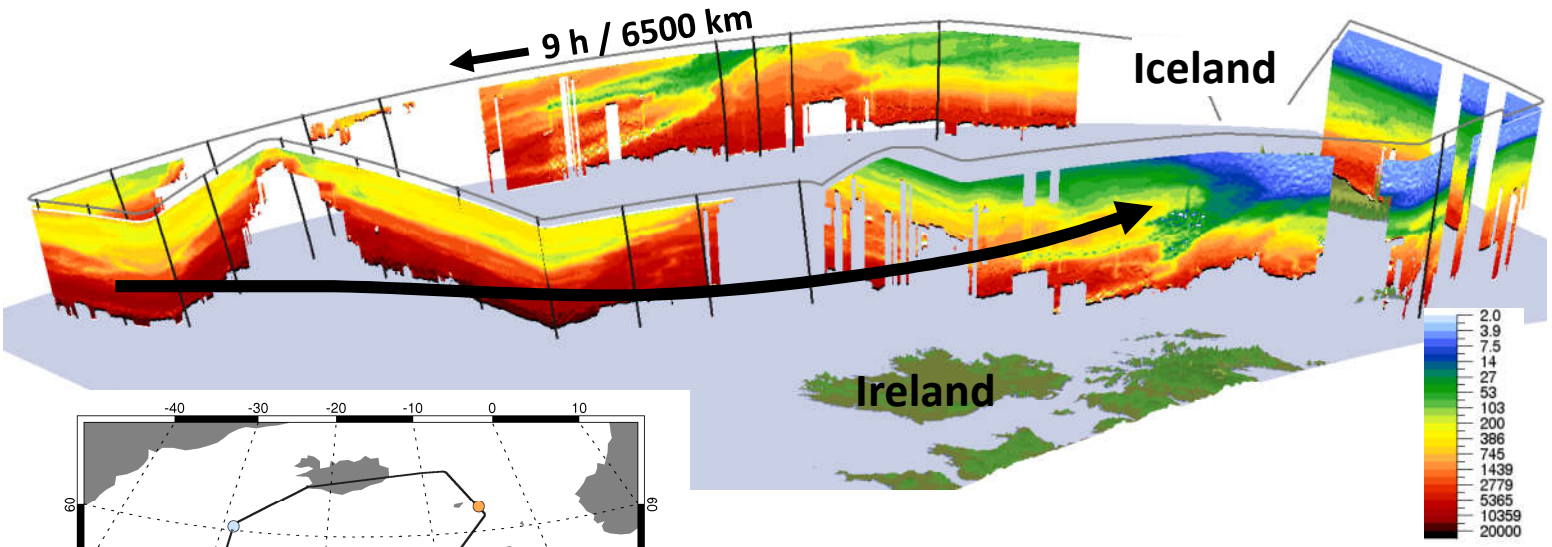

**HALO:** 11:30 – 20:30 UTC

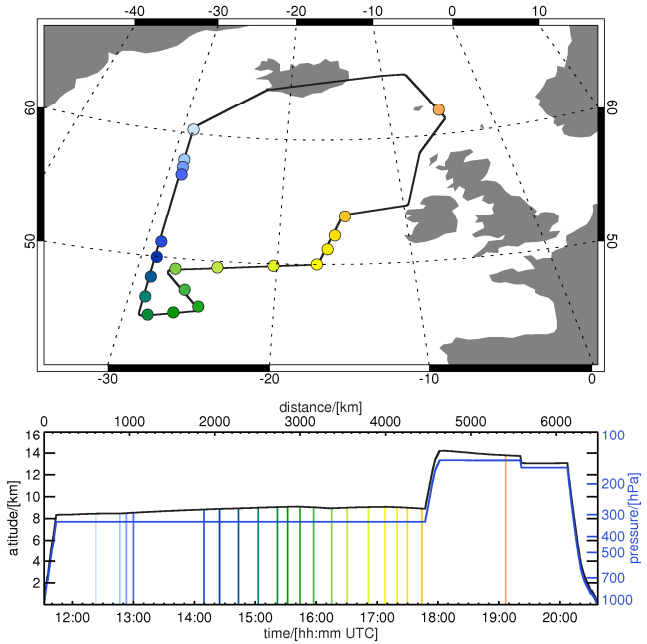


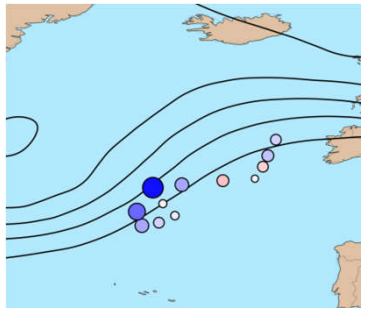
# 1) Moisture in the inflow of WCBs

## Outlook: NAWDEX case study on cyclone Walpurga




**28 Sep, 00 UTC**



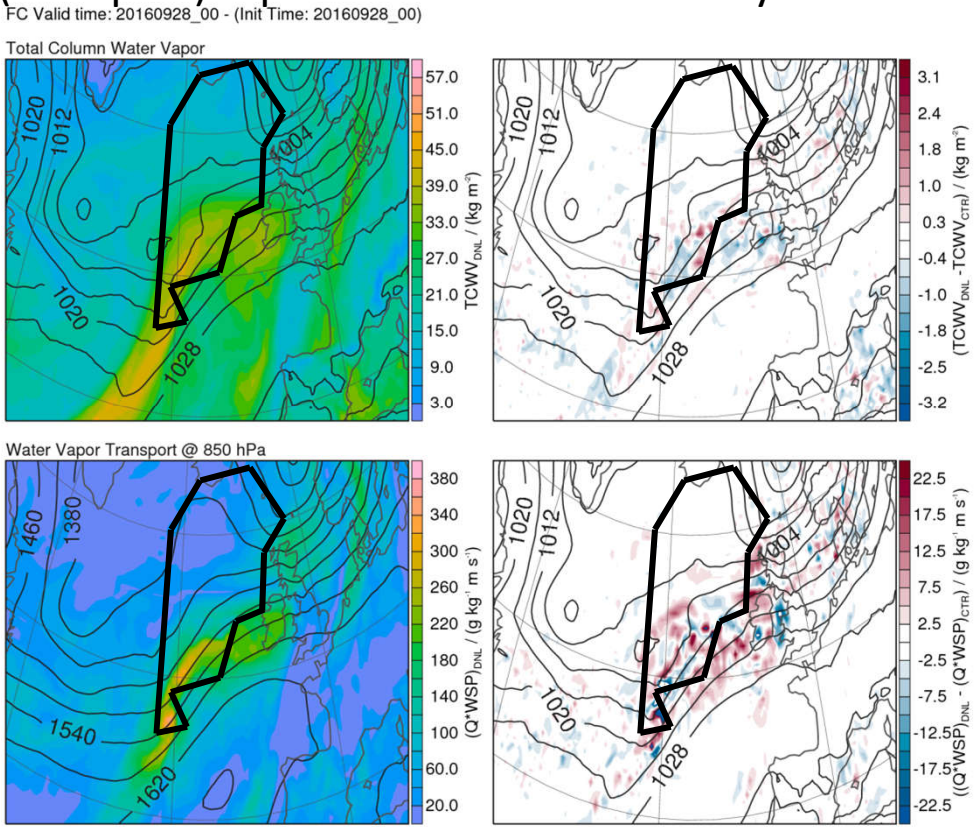
Data denial experiment to compare AN and FC with and without dropsondes

# 1) Moisture in the inflow of WCBs

## Outlook: NAWDEX case study on cyclone Walpurga

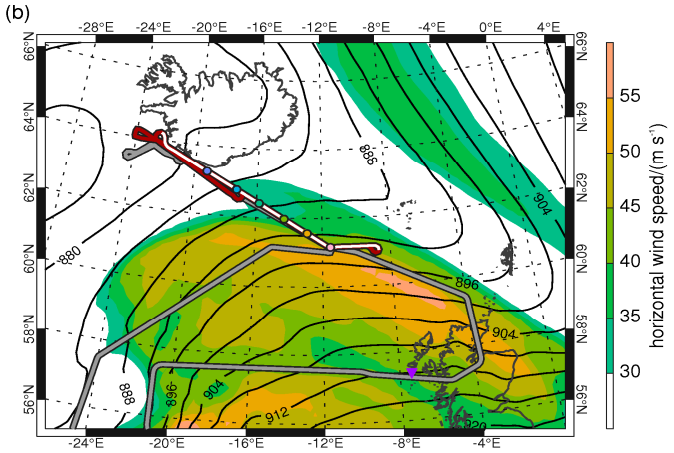
- **Representation of Walpurga in NWP:**
  - What was the impact of DSO observations on the moisture and wind field in the initial conditions?
  - How well is the observed moisture (transport) reproduced in ECMWF analysis? What errors do occur?

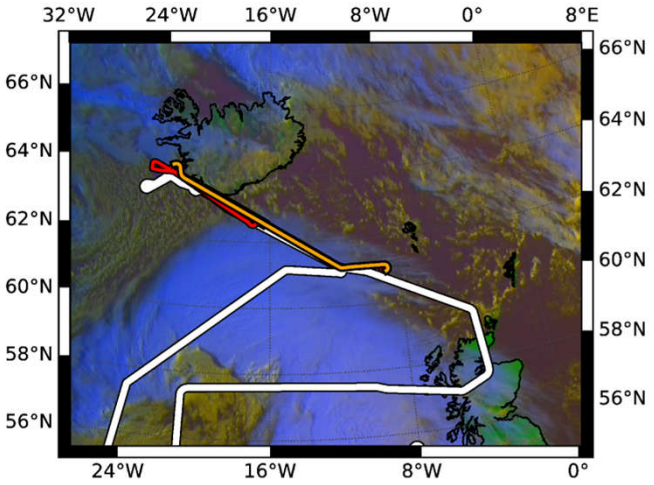
- **Impact of analysis uncertainties of moisture (transport):**
  - Did the moisture directly or indirectly affect the HIW rain event over UK/Norway?
  - How much does the uncertainty in moisture impact the cyclone evolution, WCB, the upper-level flow and eventually the downstream HIW?

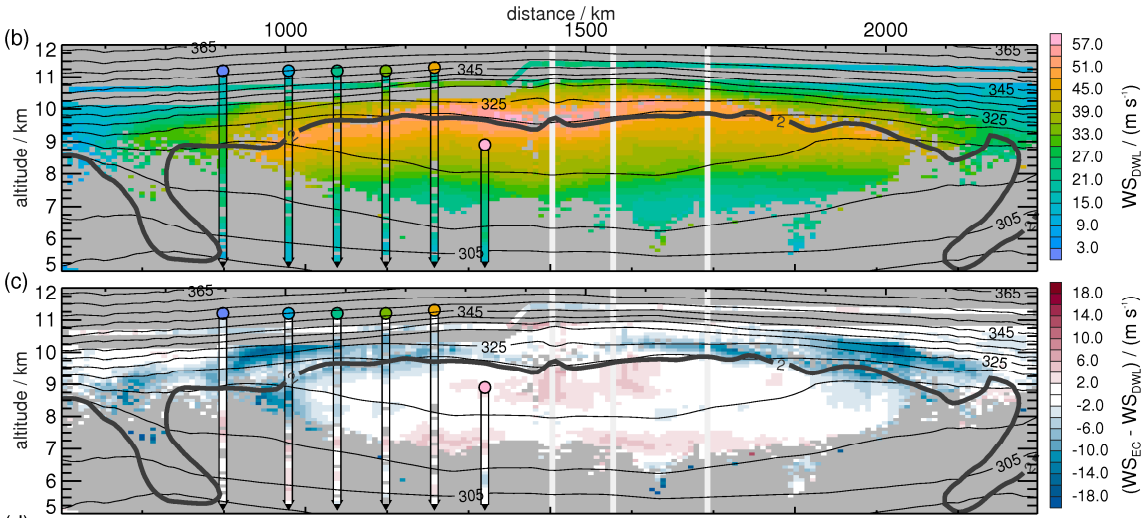


# 2) Tropopause-based gradients

## Jet stream winds during NAWDEX



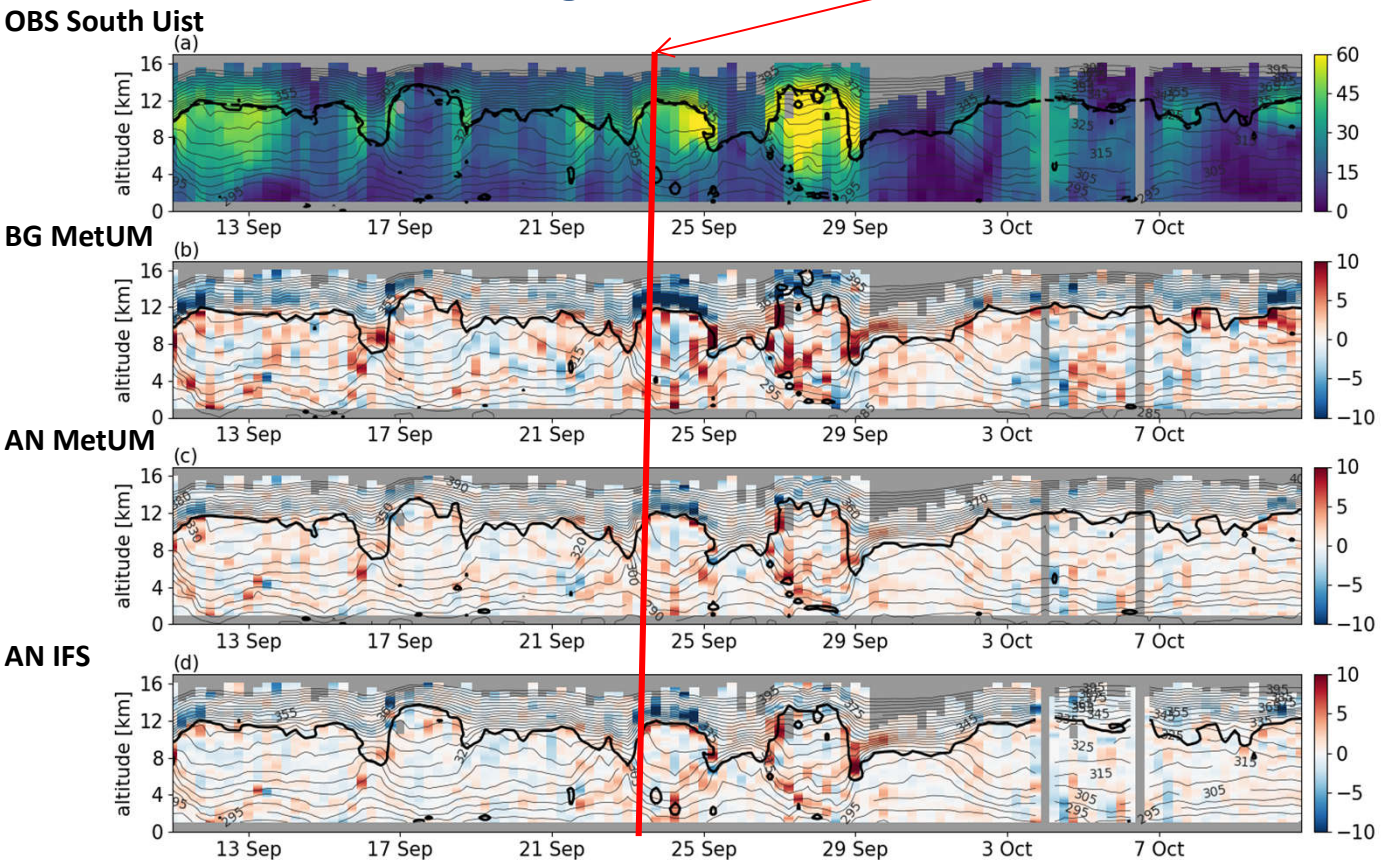



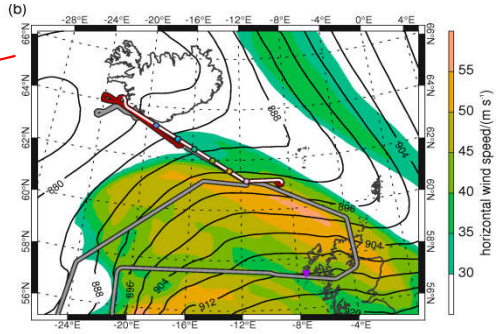




- Remarkably good representation: median biases of -0.41 m $s^{-1}$ (IFS) and -0.15 m $s^{-1}$ (MetUM)
- **increased uncertainty** in analyses and short-forecasts was found **directly above the tropopause**

# Tropopause-based gradients

## Jet stream winds during NAWDEX



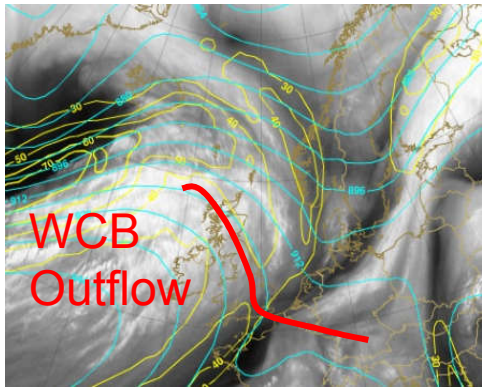




Comparison with South Uist wind profiler →**analysis errors are increased in situations of elevated tropopauses** related to ridges downstream of cyclones providing particularly strong wind gradients

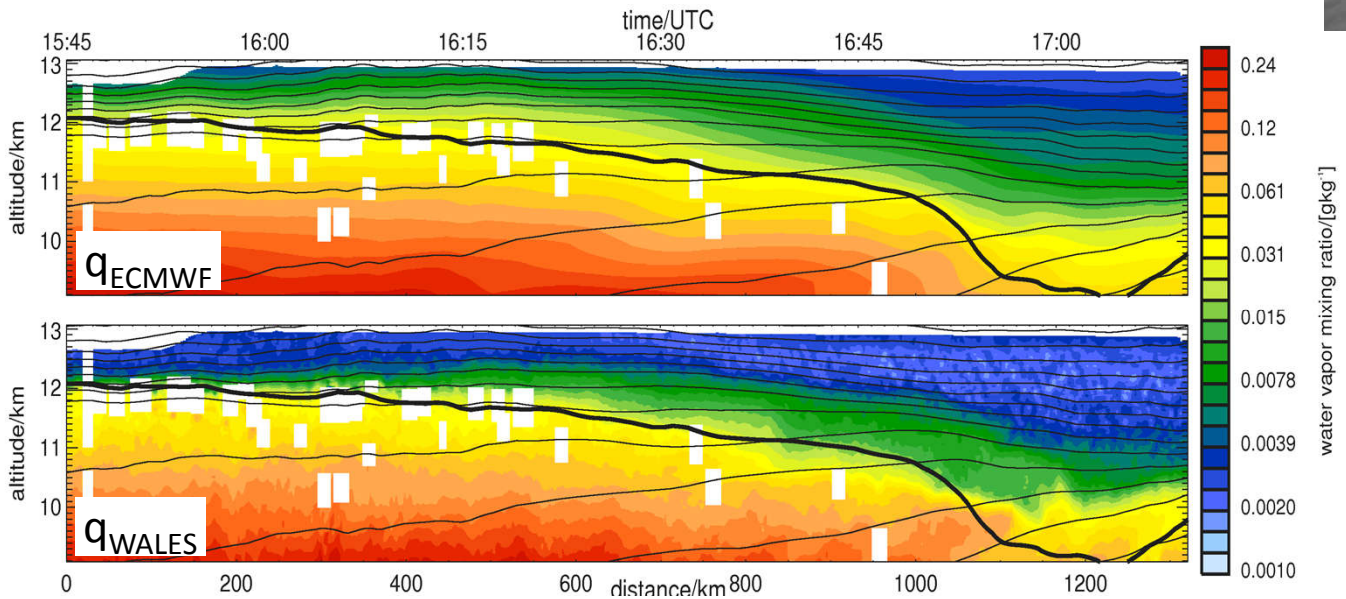
***Schäfler et al. 2020, MWR, in review***

# Tropopause-based gradients

## Outlook: PhD thesis on tropopause-based uncertainties




**Use the unique NAWDEX data set to investigate vertical gradients of humidity (and temperature) across tropopause**




***Humidity from ECMWF and WALES Lidar-Observations in the outflow of a Warm Conveyor Belt on 1. April 2015 during ML-CIRRUS***

# Tropopause-based gradients

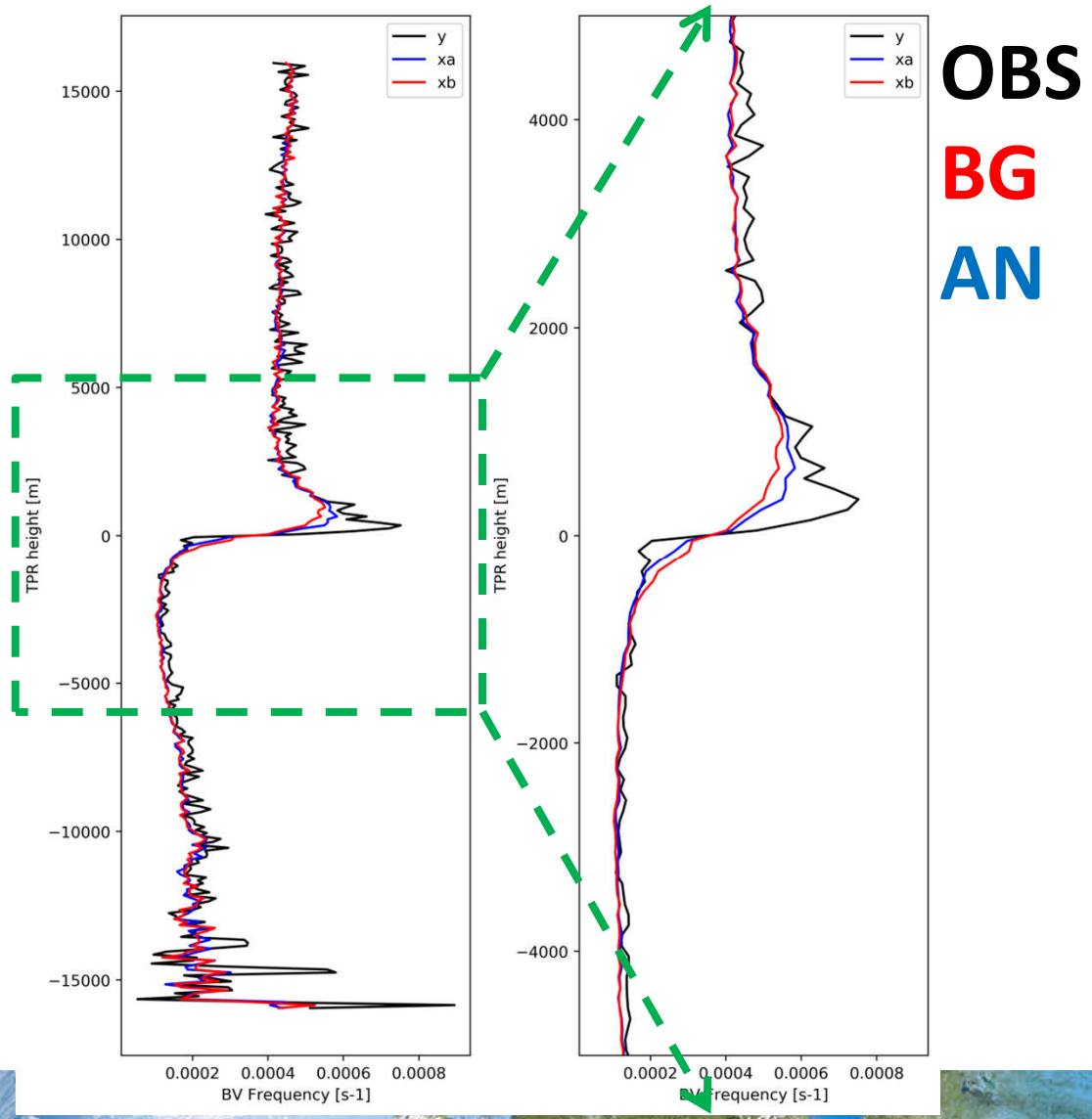
## Outlook: PhD thesis on tropopause-based uncertainties

**Investigate how data assimilation (DA) affects gradients at the tropopause**

Average over 471 NAWDEX radiosondes for Brunt Vaisala frequency in tropopause-relative coordinates

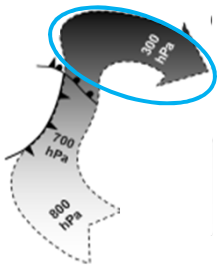
DA strengthens vertical temperature gradients above and weakens them below the tropopause

***Ongoing work by M. Schindler (LMU)***



# Summary


- Moisture in ECMWF boundary layer is uncertain
- Analysis errors in low-level humidity can substantially deteriorate medium-range forecast quality
- Future work on NAWDEX cases study Walpurga




- Largest jet stream wind errors in situations of high tropopauses (WCB outflows)
- Sharpness of the moisture gradients at the tropopause was underestimated
- PhD position will look at campaign data to more systematically analyze TP based errors and uncertainties plus their potential implications