Airborne active remote-sensing observations of warm conveyor belts

Andreas Schäfler
DLR Oberpfaffenhofen
Why are we interested in aircraft observations of WCBs?

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?
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.*

*Why are we interested in aircraft observations of WCBs?*

NAWDEX observations in 2016

*Schäfler et al. 2018, BAMS*
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

Schäfler and Harnisch 2015, QJ
Harnisch et al. 2011, QJ
1) Moisture in the inflow of WCBs

T-PARC case study

OPERATIONAL ANALYSIS 1:

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

ANALYSIS 2: + LIDAR WV

Data Assimilation Experiment

ANALYSIS 1: Operational Observations

ANALYSIS 2: + LIDAR WV Reduction of inflow moisture
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

9 h / 6500 km

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 Conveyer 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