A portrayal of an orographic Warm Conveyor Belt using observations from aircraft, lidar and radar

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Introduction

WCBs are usually identified and often investigated using model data. There, one relies on the model's correct representation. Here, in contrast, an observational WCB study is performed. The case study follows a complex WCB over Central Europe where the WCB was observed in different phases using in-situ aircraft and ground-based water vapour lidar and radar measurements. A tracer release experiment in the real atmosphere complements the analyis.

Summary

1. During the T-NAWDEX-Falcon aircraft campaign in 2012 a WCB was measured north of the Alps during the ascent in the mid-troposphere.
2. Ensemble analysis data enable a probabilistic analysis of trajectories and the WCB.
3. Lagrangian linkages are found between the aircraft measurements and
   (i) a lidar in southern France that measured moisture in the WCB inflow, and
   (ii) a radar of the MeteoSwiss operational network during WCB ascent south of the Alps.
4. The lidar measured higher humidity values in the WCB inflow compared to analysis.
5. The radar observed WCB trajectories above the melting layer leading to strong precipitation.
6. The airborne measurements show less cloud water and less water vapour compared to the IFS analyses.
7. A tracer experiment confirms the long-range transport of WCB air from the Mediterranean to Central Europe.

T-NAWDEX-Falcon aircraft campaign[1)]

- 3-week aircraft campaign in October 2012 with the DLR Falcon
- Aim: measurements of moist processes in different phases of WCBs over Central Europe

Case study IOP2

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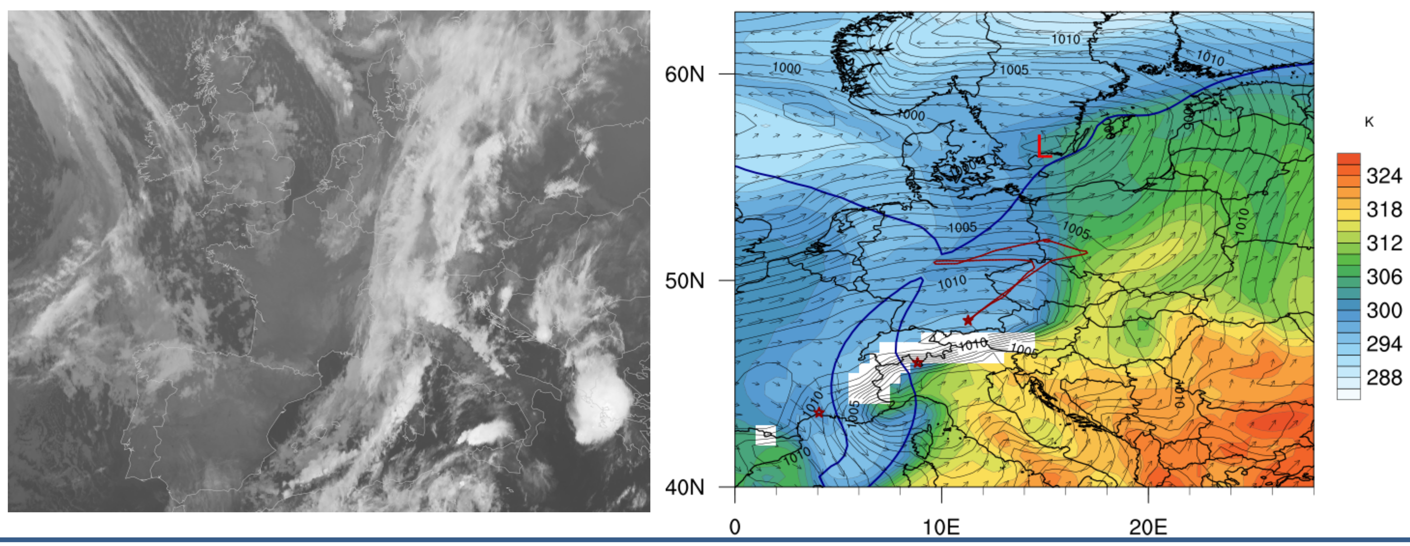
- DLR Falcon flight in the afternoon of 15 Oct 2012 (red line in Fig below)
- Flight crosses a surface cold front
- In situ airborne measurements in WCB ascent and outflow



Model data

- ECMWF ensemble data analyses (EDA)
- Set of 11 slightly different analyses with 3-hourly resolution
- EDAs express uncertainty of the analysis field
- here: they are used to quantify uncertainties in the trajectory calculations!

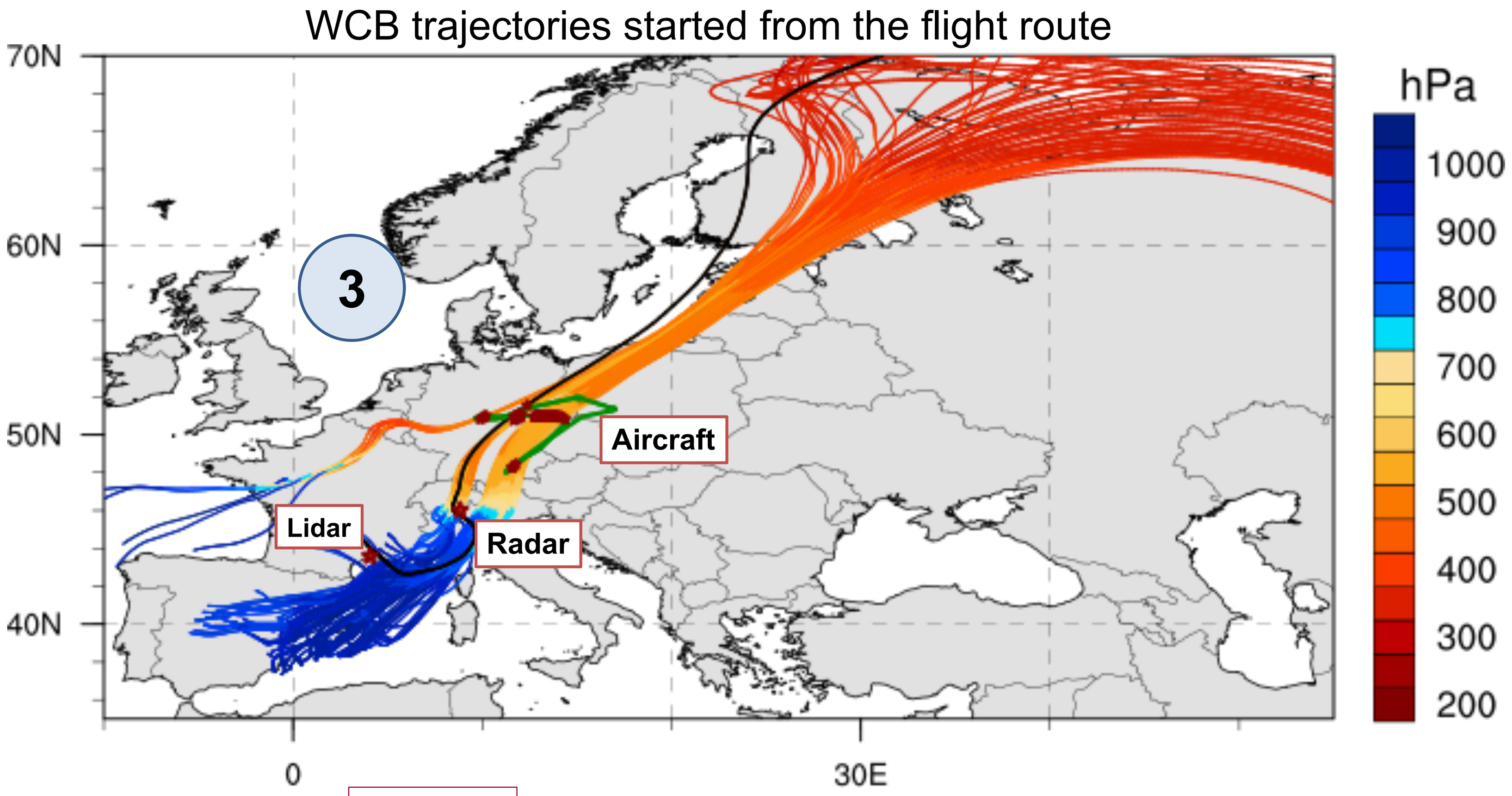
2

→ **Lagrangian probabilities[1)]**

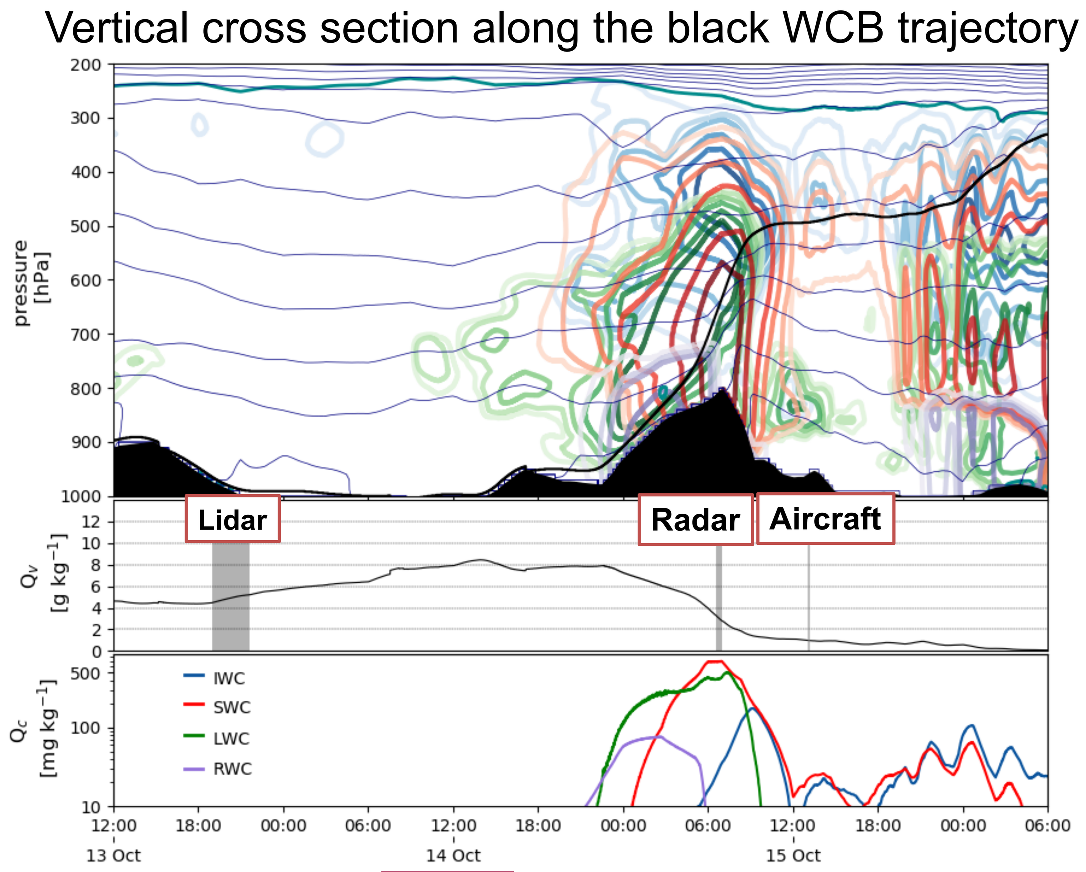
- Calculation of trajectories[2)] in each EDA member
- Use criterion Δp ≥ 600 hPa in 48 h to identify WCBs
- Lagrangian probability measure: percentage of EDA members that have a (WCB) trajectory in a respective grid box

Measurements and their Lagrangian connections

WCB trajectories started from the flight route



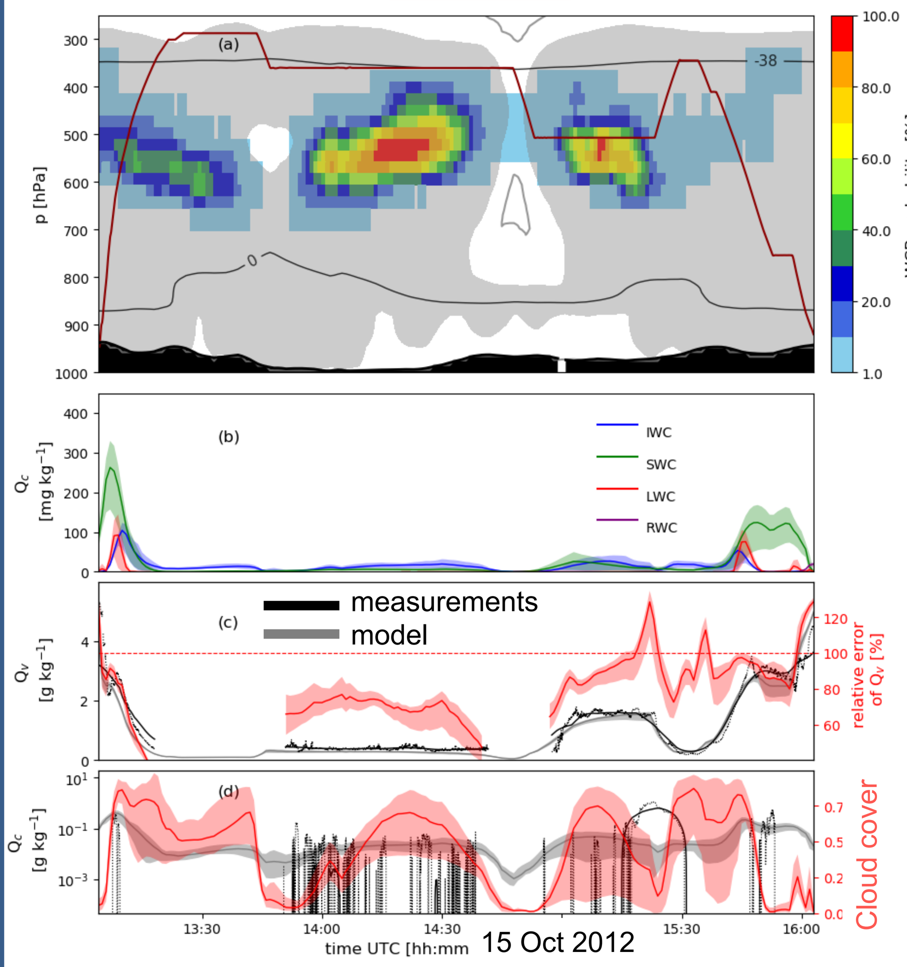
Vertical cross section along the black WCB trajectory



Cloud species: LWC, SWC, IWC, RWC

- WCB is lifted first at the Alps (radar), accompanied by deep clouds
- A 2nd lifting above 500 hPa occurs at the warm front
- After moving over the Massif Central (lidar) the trajectory takes up water over the Mediterranean
- Trajectories constantly loose moisture once starting to ascent
- Cloud liquid, snow and rain forms abruptly upstream of the Alps
- Ice and snow increase during 2nd ascent

Aircraft



- Aircraft (red line) intersects high WCB probability twice
- WCB is embedded in a deep cloud (gray)

- Cloud water is high where aircraft intersects WCB

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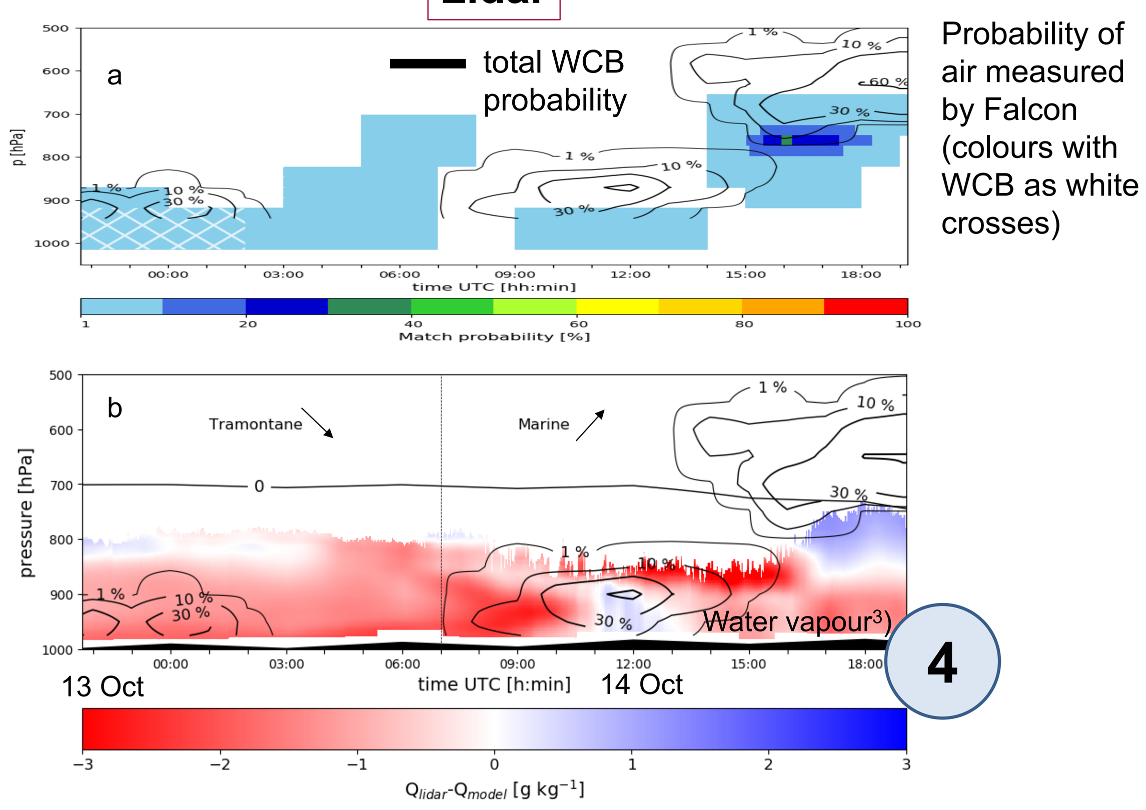
Comparison with measurements:

- Water vapour is mostly lower in the model (see relative error, red)
- Measured cloud water (black) is often lower than in the analysis (gray)
- Increased cloud water and WCB are displaced at 15 UTC

Lidar



Probability of air measured by Falcon (colours with WCB as white crosses)

- WCB air from Falcon flight passes the lidar (a, colours with white crosses)
- Analysis water vapour is higher as observed, also in WCB inflow (b, black)

Radar

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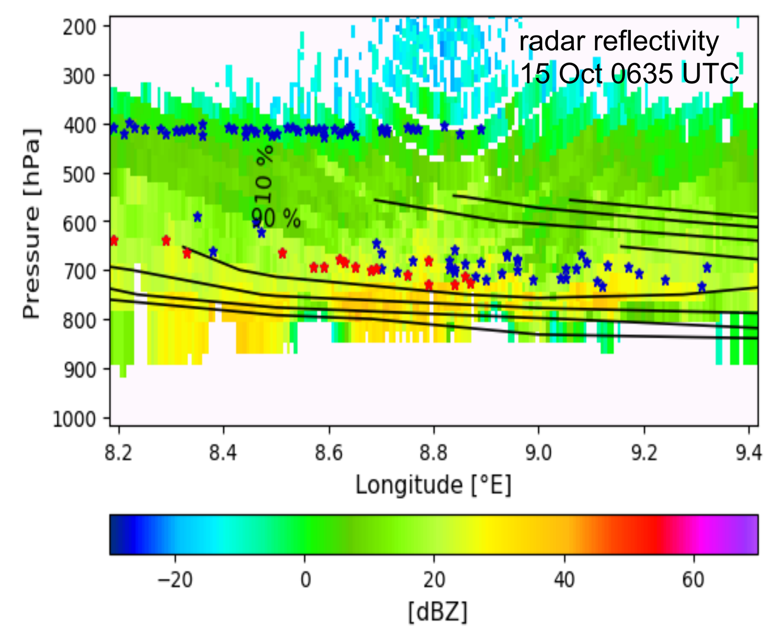

WCB air mass from Falcon flight (red) and other air mass from Falcon flight (blue) is within strong precipitation and partly (particularly Falcon-WCB) just above the melting layer

Tracer experiment

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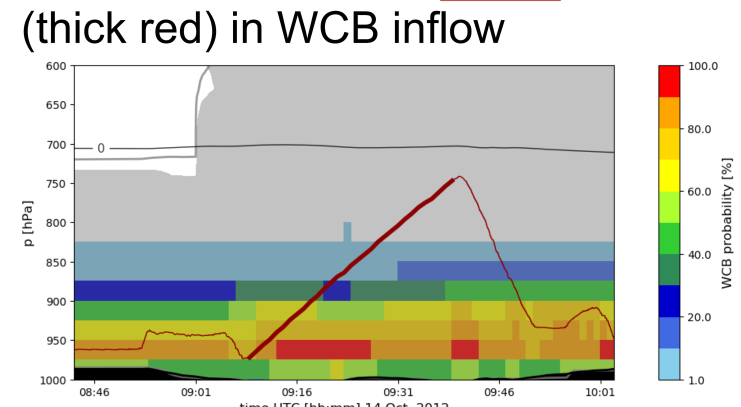
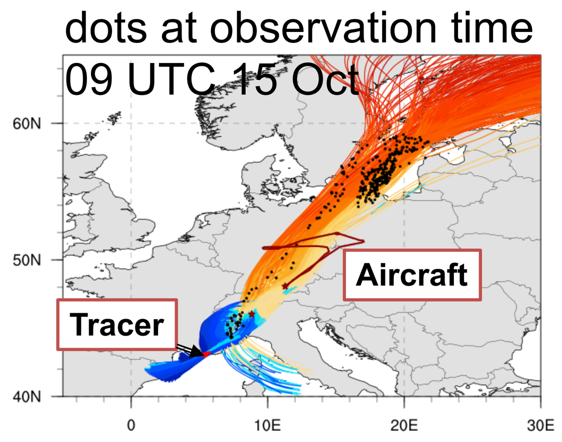
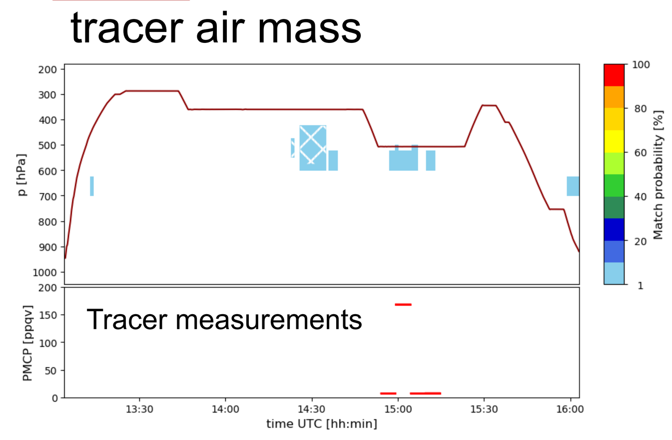
Flight route along the Tracer release (thick red) in WCB inflow



Tracer trajectories, dots at observation time



Aircraft flight through the tracer air mass



- An inert tracer[4] gas was released by an independent aircraft in southern France in the morning of 14 Oct
- The tracer was carried by the WCB over the Alps
- The tracer could be collected by the research flight over Germany
- Increased probability of air from tracer trajectories coincides with the location where tracer was measured

References

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4) Schlager et al. (2015) An airborne perfluorocarbon tracer system and its first application for a Lagrangian experiment. Atmos. Meas. Tech., 8, 69–80.