A portrayal of an orographic Warm Conveyor Belt using observations from aircraft, Lidar and Radar

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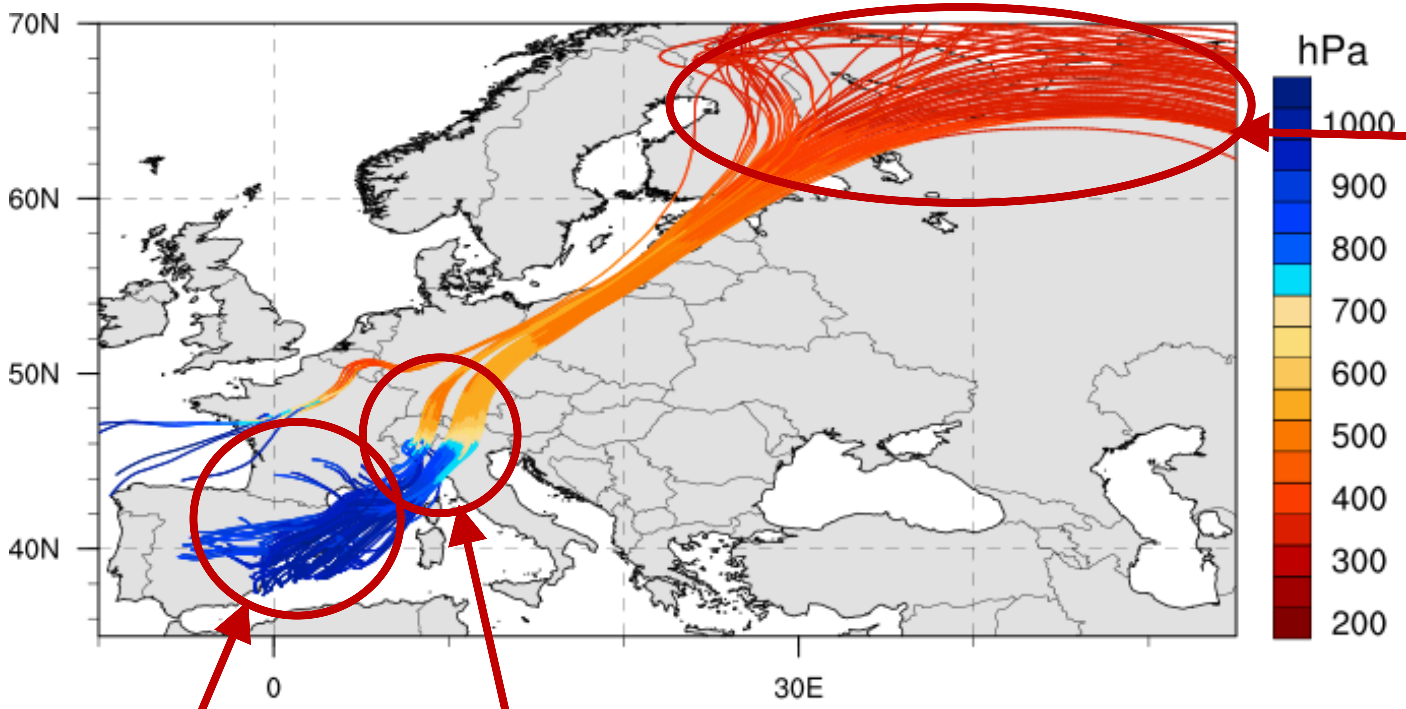
Characteristics and Relevance of WCBs



③ WCB outflow: ascent to upper-tropospheric levels and possible modification of the tropopause-level waves

② WCB ascent: during phase of strongest ascent at mid-levels production of intense precipitation

① WCB inflow: humid inflow from the boundary layer within the warm sector of an extratropical cyclone

- transport of humidity and pollution upward and poleward
- frequently source of forecast uncertainties

Objectives

Starting point

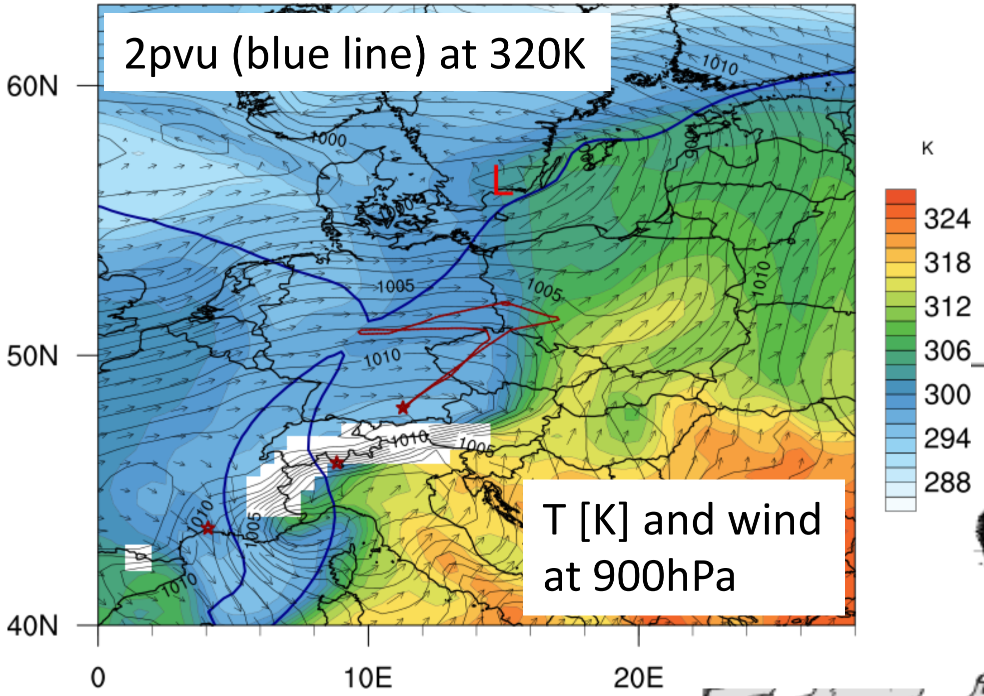
The case study combines model data to calculate WCB trajectories

and measurements from aircraft and ground-based instruments in the region of the WCB.

Key questions

- Were the same WCB trajectories measured at different stations and by different instruments?
- How well do water vapour and cloud condensate agree in model data and observations in different stages of the WCB?
- Can the pathway of the WCB trajectories be followed with the release of an inert tracer?

WCB case study of 15 October 2012

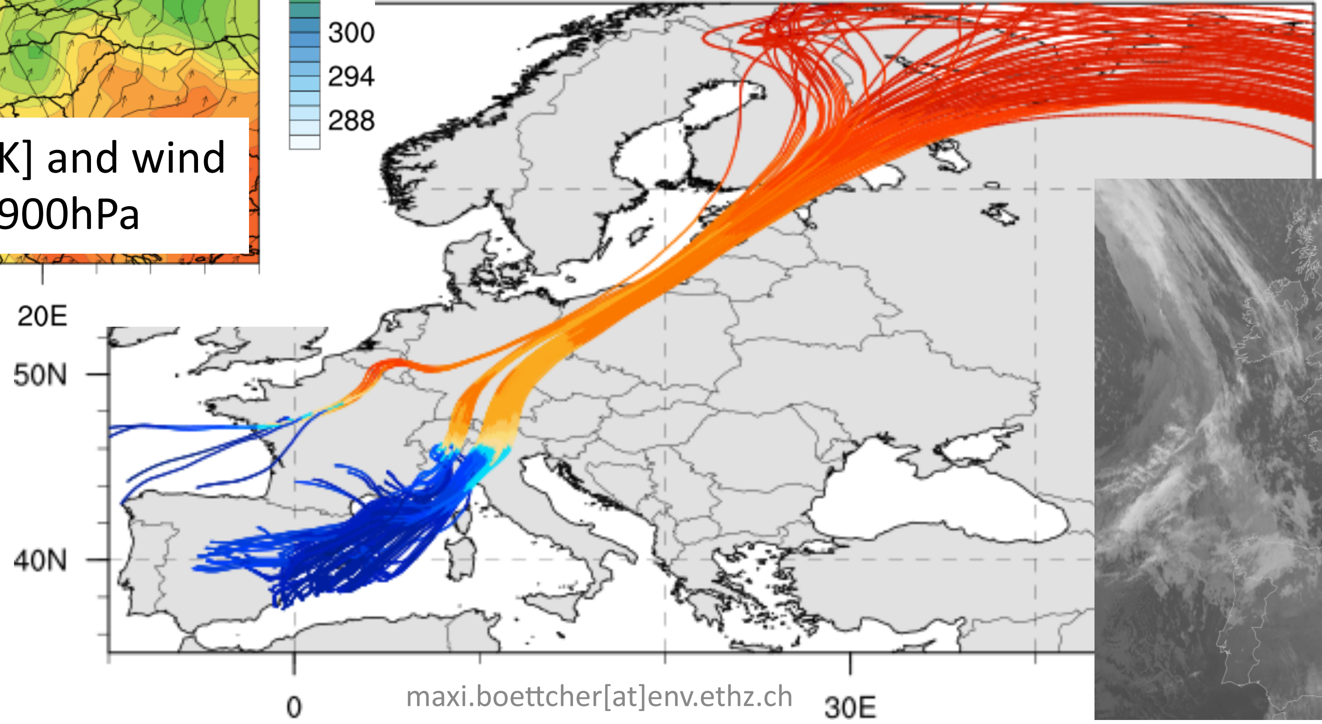


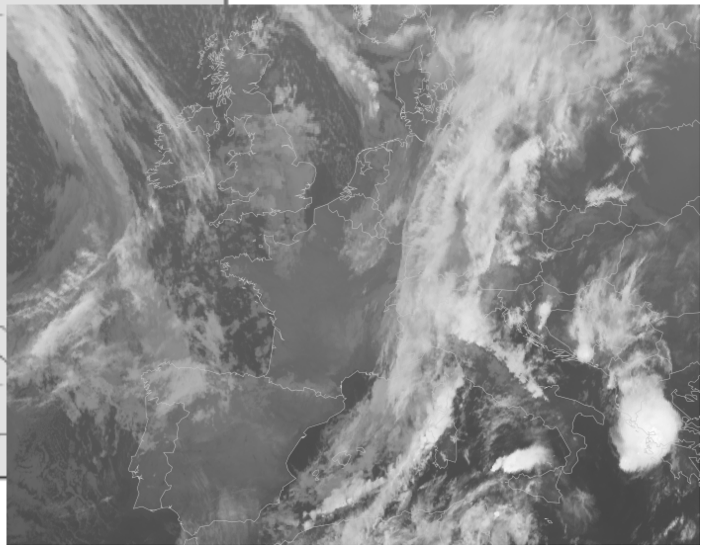
WCB ascends at a surface cold front

Related surface low **L** is over Baltic Sea

WCB outflow follows upper-level PV

WCB appears as cloud band in IR satellite image





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From model data to Lagrangian probability

- ECMWF Ensemble Data Analyses (EDAs):

  = set of 11 slightly different analyses that

  represent the uncertainty of the data assimilation and

  serve operationally as initial conditions of the ensemble forecast

- Identification of WCBs:

  Calculation of forward trajectories in each of the 11 EDA members

  WCB criterion: keep only trajectories with ascent of **Δ**p >= 600hPa in 48hrs

  WCB trajectories are also calculated starting from the flight route

- Lagrangian probability measure:

  percentage of EDA members that have a (WCB) trajectory position in a certain grid box at a given time

T-NAWDEX-Falcon aircraft campaign

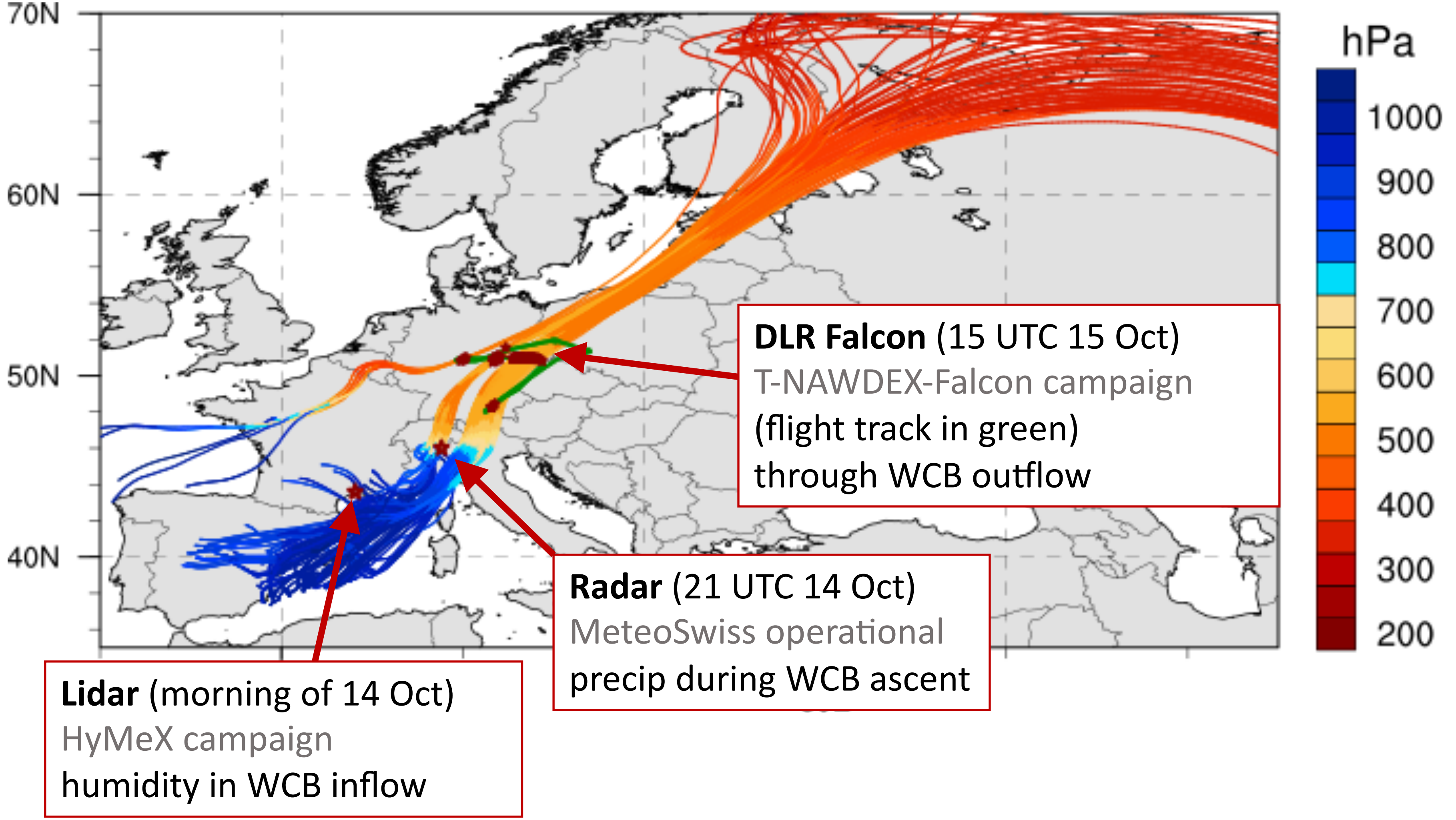
3-week aircraft campaign in October 2012 with the DLR Falcon

Aim: measurements of moisture processes in different phases of WCBs over Central Europe

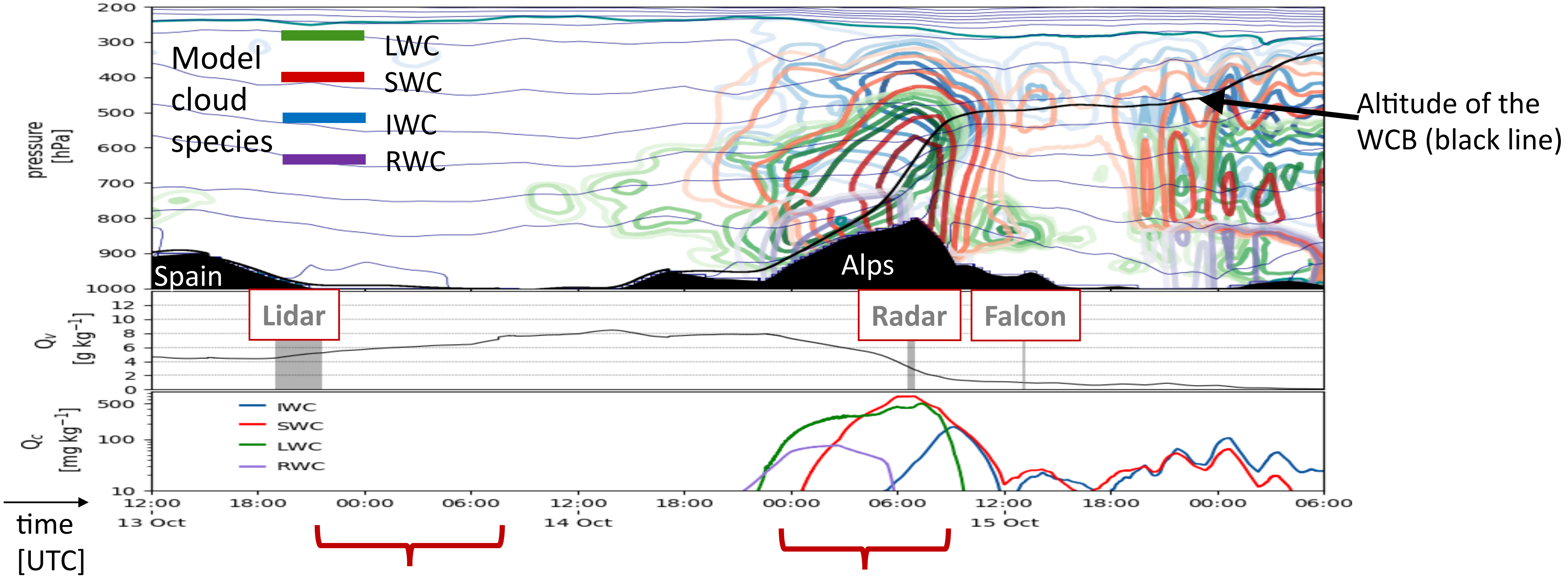
Measurements used in this study:

- Water vapour
- Total water

Measurement overview



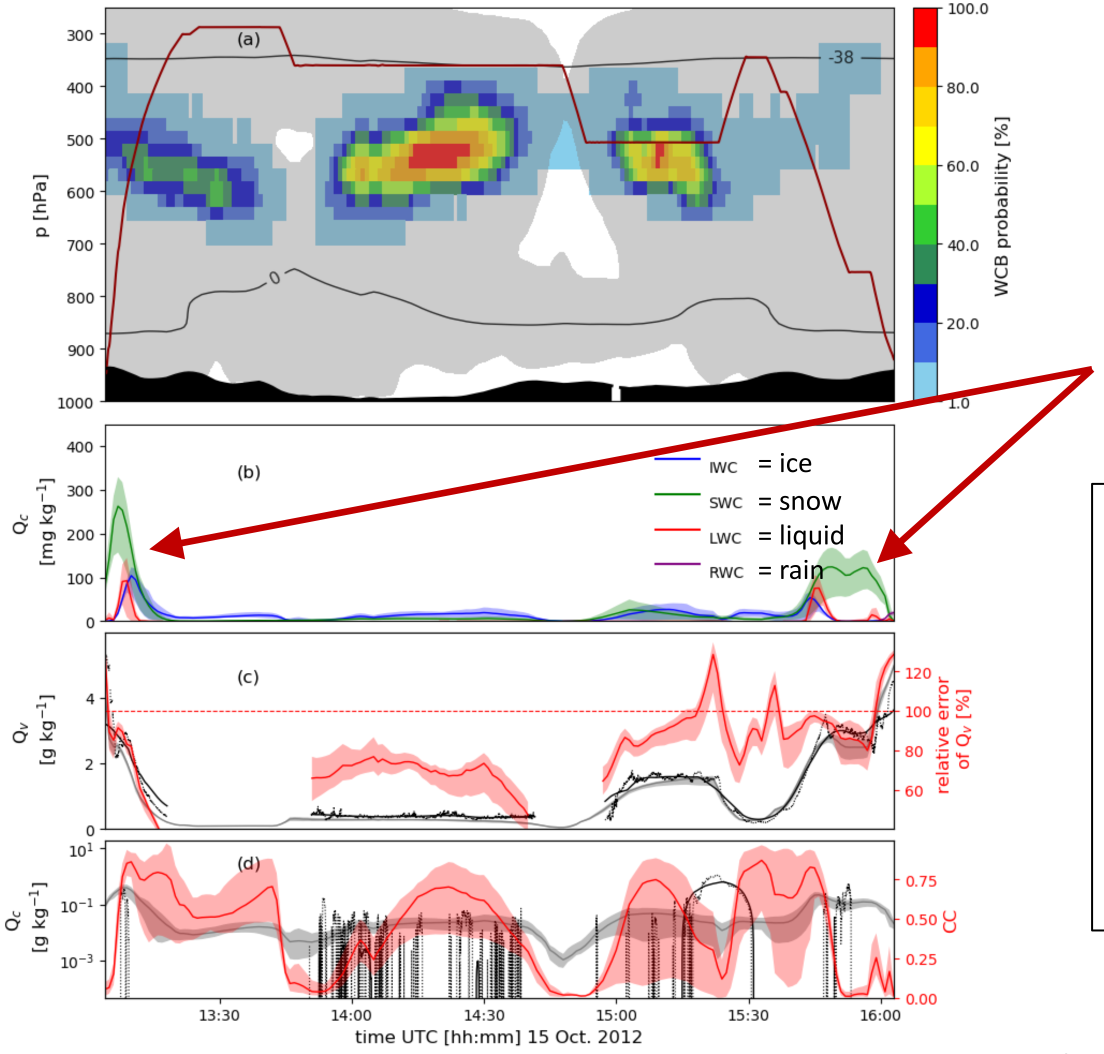
WCB evolution in a vertical cross section



WCB takes up moisture while crossing the Mediterranean (specific humidity increases)

WCB is part of a massive deep (orographic) cloud when ascending at the Alps

DLR Falcon flight and measurements in WCB outflow



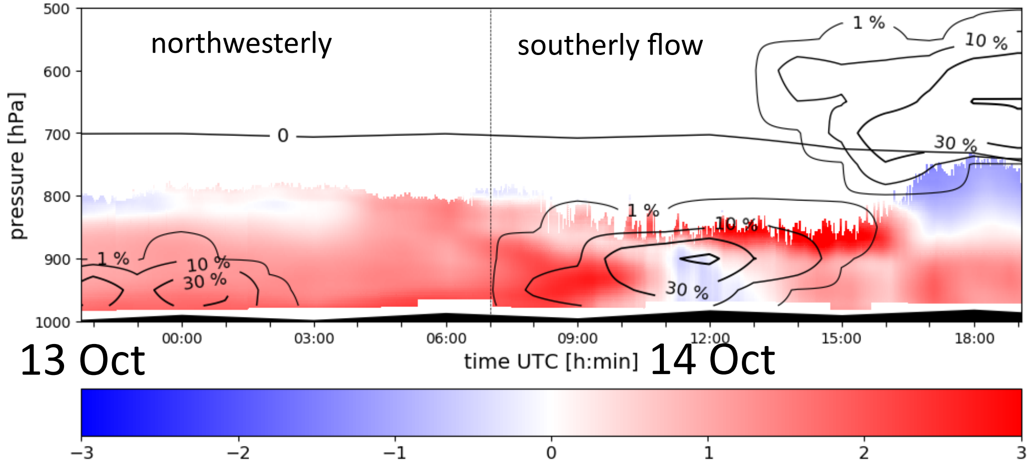
Aircraft (red line) intersects high WCB probability (colours) at 500hPa twice, at 13:45 and 15:15 UTC

Cloud species, in particular snow, are high in the model where aircraft intersects WCB

Comparison with measurements (lower panels)

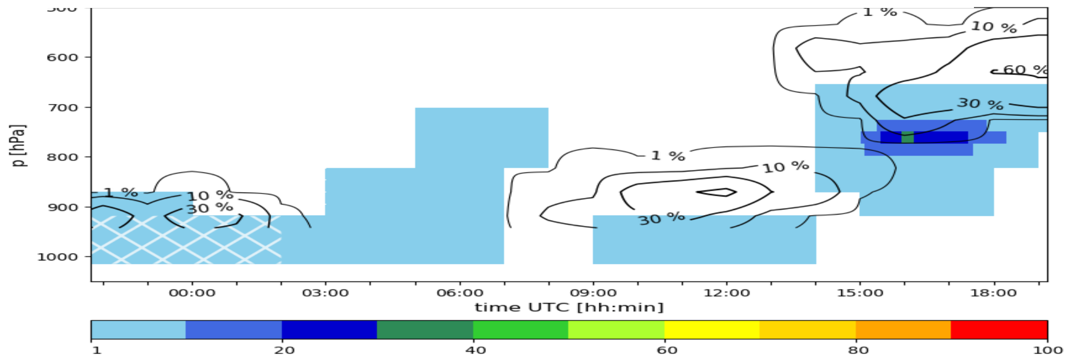
- Water vapour Q_v is mostly lower in the model (grey) compared to measurements (black), see also relative error (red)
- Measured cloud water Q_c (black solid line) is also often lower than in the model (grey)

Lidar: humidity in WCB inflow



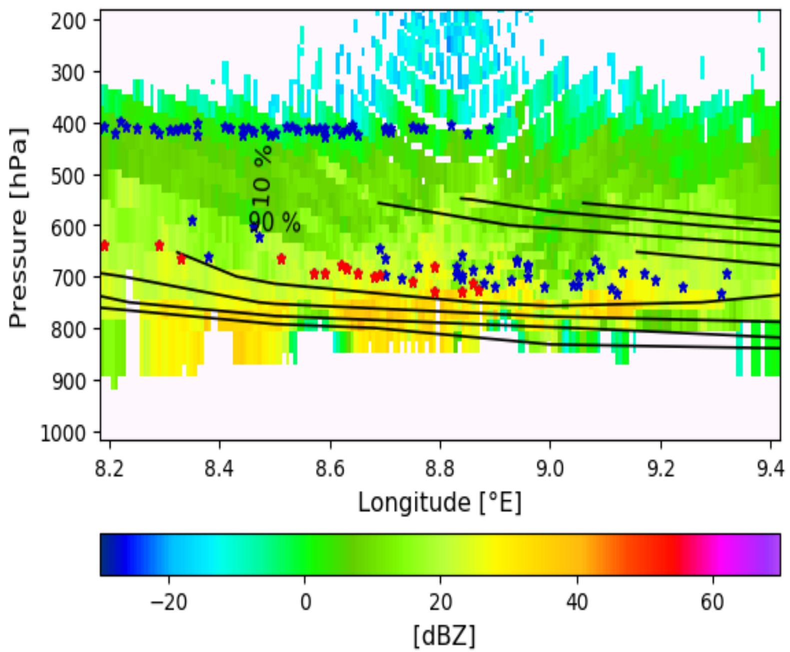
Specific humidity difference (model - obs) [g kg^{-1}]

→ model boundary layer is too moist



From the model's perspective: probability of WCB passing the Lidar and later measured by DLR Falcon

Radar: reflectivity in WCB ascent



Radar reflectivity 21 UTC 14 Oct

WCB air mass (**Δ**p >= 600hPa) from Falcon flight (red star) and other air mass from Falcon flight (**Δ**p < 600hPa) (blue star) is in region of strong precipitation just above the melting layer

— in all Figs.: total WCB probability (1, 10, 30, 90%)

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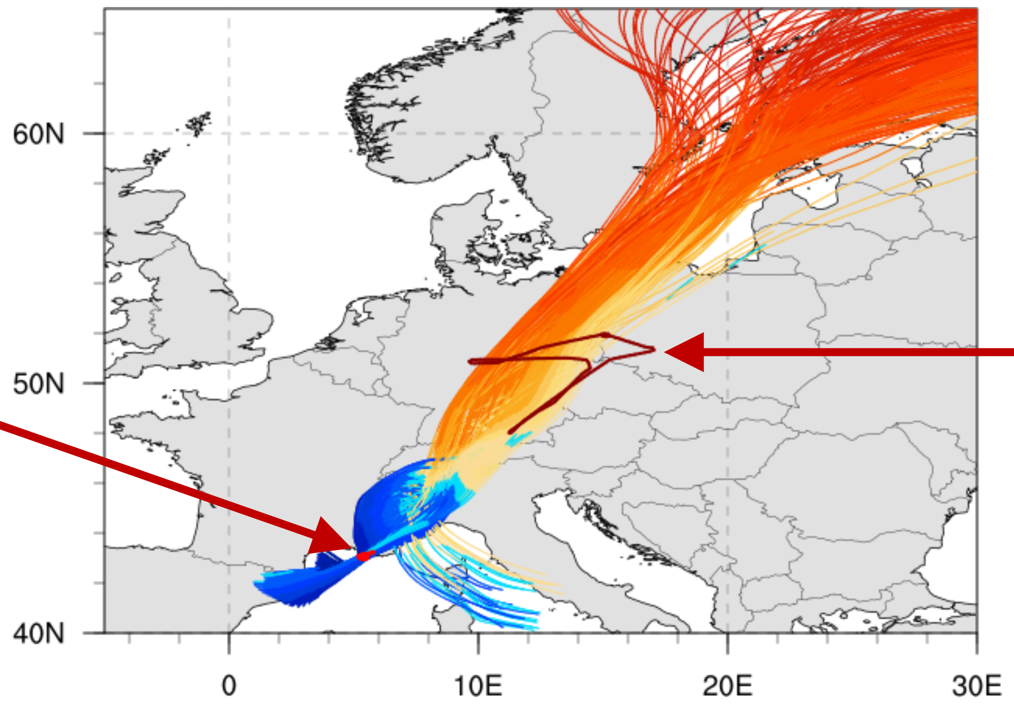
Tracer experiment

During the T-NAWDEX-Falcon campaign, the perfluorocarbon tracer system (PERTRAS, Ren et al. 2015) was installed in the DLR Falcon aircraft

The inert tracer gas was released in the WCB inflow near the French Mediterranean coast by an independent aircraft in the morning of 14 October

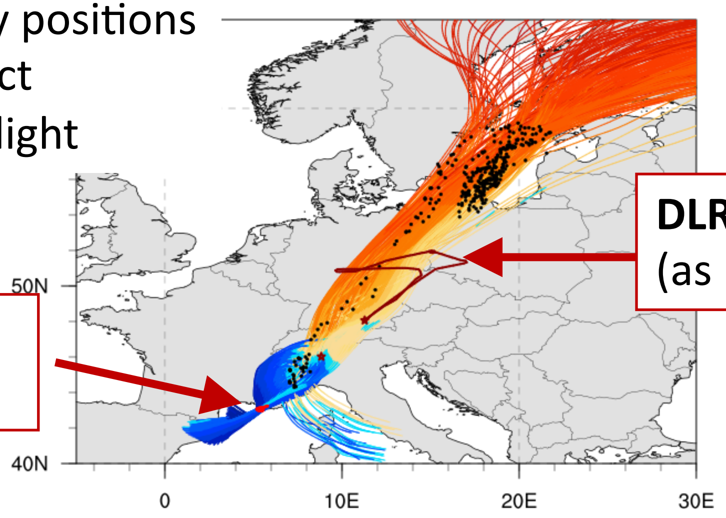


The figure shows trajectories that were started from the flight leg of the release

During the flight on 15 October the sampler device of PERTRAS onboard of Falcon collected air samples to identify the tracer gas

Tracer experiment

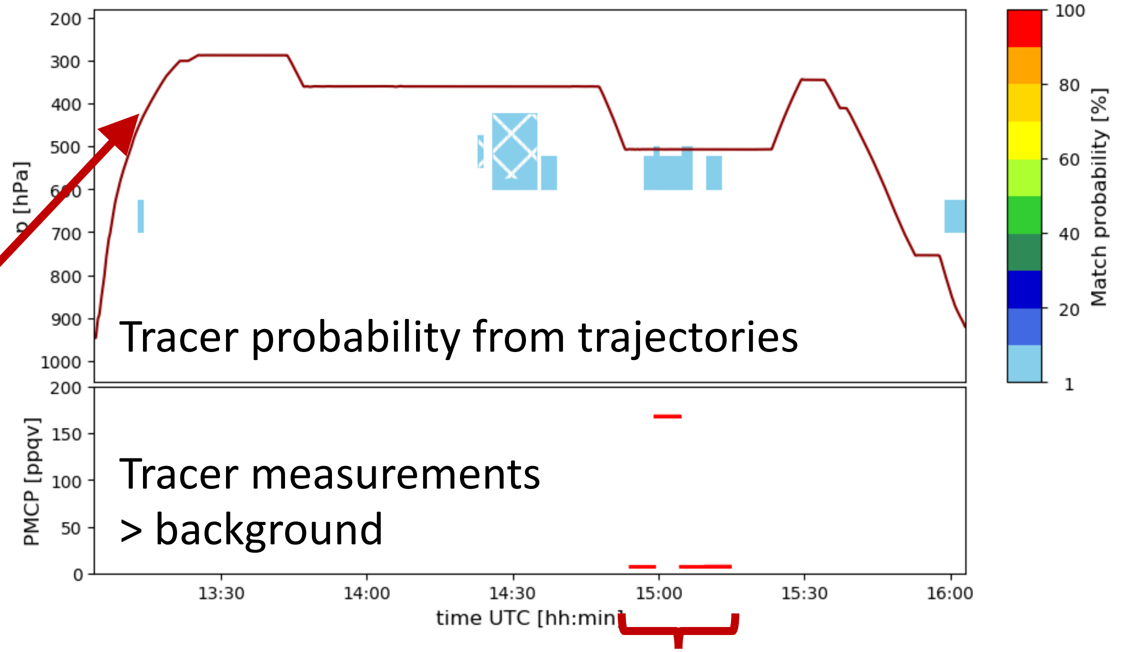
Dots: trajectory positions at 15 UTC 15 Oct during Falcon flight



Tracer release
09 UTC 14 Oct

DLR Falcon flight
(as before)

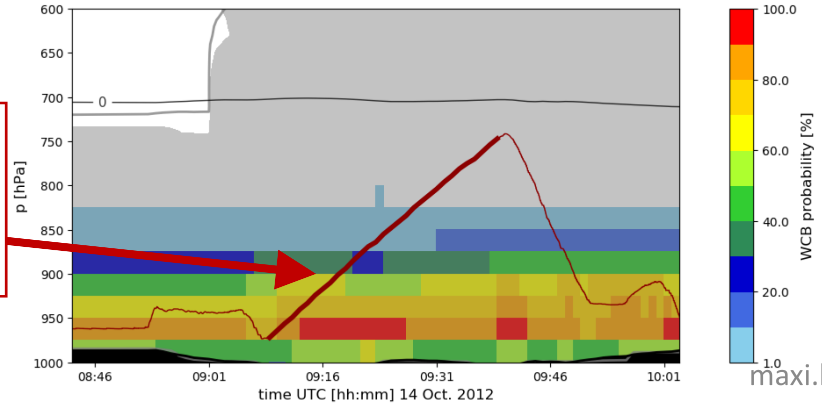
Collection of tracer air mass during Falcon flight



Tracer probability from trajectories

Tracer measurements
> background

Vertical cross section of the tracer flight (red line) “through” WCB probability



Tracer release during thick red line

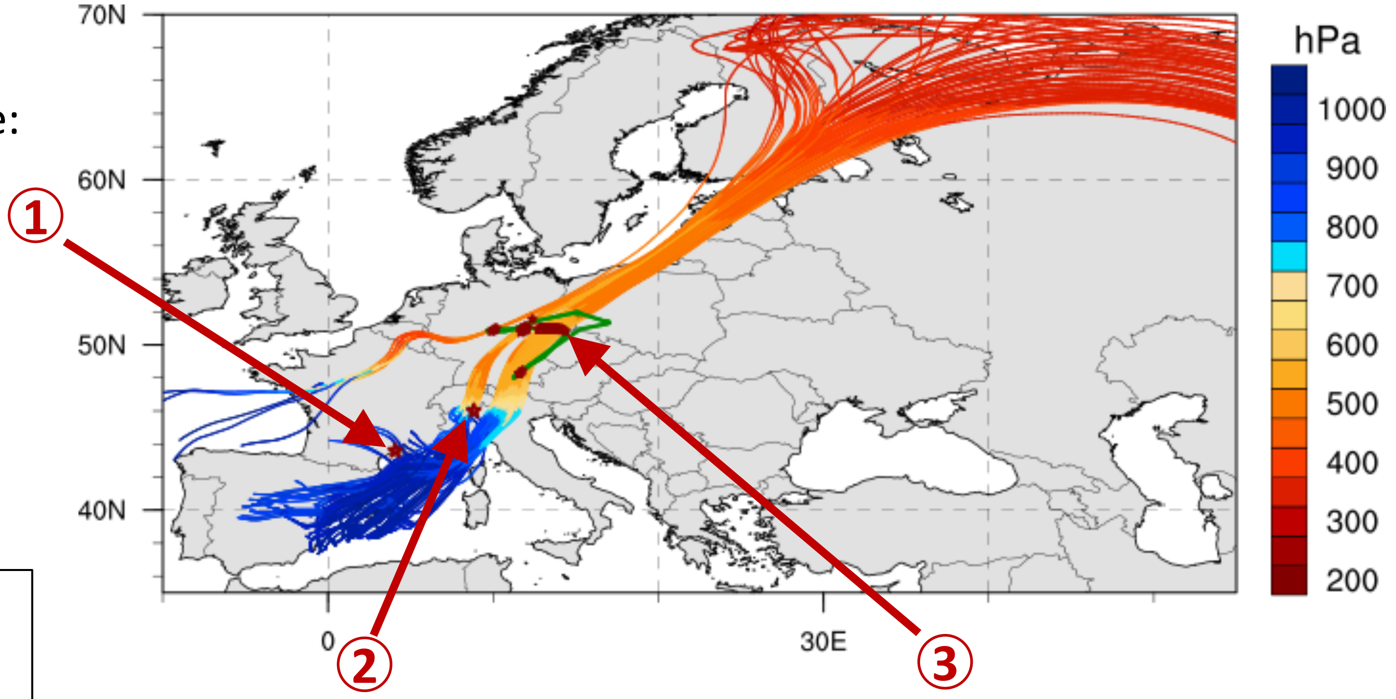
Increased probability of air from tracer trajectories overlapping with the flight coincides with the location where tracer was actually measured

→ Tracer was carried with the WCB from the Mediterranean over the Alps to Germany

Summary

A **W**arm **C**onveyor **B**elt over Europe in October 2012 was measured multpile times at different places by water vapour lidear, precipitation radar and aircraft:

WCB inflow over southern France:
Boundary layer in the model was clearly moister than measured



A tracer experiment confirms the long-range transport and ascent of the WCB

WCB ascent at the Alps:
WCB is part of a massive cloud with strong precipitation

WCB outflow over Germany:
compared to the measurements, the model contains too little water vapour and too much cloud condensate