An interactive method to predict warm conveyor belt occurrence for aircraft-based field campaigns

Marc Rautenhaus\textsuperscript{(1)}, Christian Grams\textsuperscript{(2)}, Michael Kern\textsuperscript{(1)}, Andreas Schäfler\textsuperscript{(3)} and Rüdiger Westermann\textsuperscript{(1)}

\textsuperscript{(1)} Computer Graphics and Visualization Group, TU München
\textsuperscript{(2)} Institute for Atmospheric and Climate Science, ETH Zürich
\textsuperscript{(3)} Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen

17 August 2014, WWOSC 2014, Montréal
Context: 3D ensemble visualization for forecasting

Flights are **expensive** and need to be **planned multiple days in advance:** Improve planning by use of **ensemble uncertainty information** and advanced **3D exploration techniques.**

**Met.3D** – 3D forecast tool developed due to lack of a suitable tool to interactively explore forecast data for research flight planning.

→ Met.3D can be used for all kinds of campaigns. Example here: T-NAWDEX.
Application: Predict Warm Conveyor Belts

Use ECMWF ensemble forecast to predict WCBs.

→ Where will, in 3-7 days and within aircraft range, be the highest probability that a WCB will occur?

→ Where is the WCB located in relation to cyclone, fronts, ... ?

→ Demonstrated here with T-NAWDEX-Falcon case, intended for T-NAWDEX 2016 (and further campaigns)
Application: Predict Warm Conveyor Belts

Use ECMWF ensemble forecast to predict WCBs.

→ Where will, in 3-7 days and within aircraft range, be the highest probability that a WCB will occur?

→ Where is the WCB located in relation to cyclone, fronts, ... ?

→ Demonstrated here with T-NAWDEX-Falcon case, intended for T-NAWDEX 2016 (and further campaigns)

Required steps:

→ Detect WCB in each ensemble member.

→ Create gridded field of WCB occurrence for each member.

→ Compute probability of WCB occurrence, $p(\text{WCB})$. 
Application: Predict Warm Conveyor Belts

Required steps:

→ Detect WCB in each ensemble member.

→ Create gridded field of WCB occurrence for each member.

→ Compute probability of WCB occurrence, $p(\text{WCB})$.

Lagrangian particle Trajectories
- Wernli und Davies (1997)
- Stohl (2001)
- Eckhard et al. (2004)
- Madonna et al. (2014)
Domain-filling trajectories

For each ensemble member:
Domain-filling trajectories with LAGRANTO (Wernli und Davies, 1997)
Domain-filling trajectories

Select according to ascent:
e.g. 500-600 hPa in 48 hours
Trajectories with strong ascent (500hPa/48h)

Mark the corresponding grid points.
Grid points in regions of strong ascent

For each ensemble-member:
Binary volume that stores WCB events.
Domain-filling trajectories for a single member
Trajectories with strong ascent (500hPa/48h)
Particle positions at forecast valid time
Particle positions at forecast valid time
Regions that experience strong ascent
Probability of WCB occurrence

19 October 2012 18 UTC
Challenges

→ Flexible ascent criterion \((dp/dt)\) → interactive specification in Met.3D.

→ Suitable 3D visualization.

→ Interpretation of results.
Why are the probabilities so low?

30% probability
10% probability
19 October 2012: 85% of members „contribute“
Demonstration

Video:


→ Explore p(WCB) product.
Summary

Met.3D
Interactive 3D visualization of ensemble forecasts to improve flight planning.

p(WCB)
Gridded trajectories allow computation of 3D p(WCB).

Interactive visual analysis of p(WCB)
Interactive 3D exploration quickly shows structure.

Region contribution important for interpretation.
Summary

**Met.3D**
Interactive 3D visualization of ensemble forecasts to improve flight planning.

**p(WCB)**
Gridded trajectories allow computation of 3D p(WCB).

**Interactive visual analysis of p(WCB)**
Interactive 3D exploration quickly shows structure.

**Continuing work:**
Other selection criteria.
Improvements of 3D exploration.
Improvements of flight planning functionality.

Region contribution important for interpretation.
Summary

Met.3D
Interactive 3D visualization of ensemble forecasts to improve flight planning.

p(WCB)
Gridded trajectories allow computation of 3D p(WCB).

Interactive visual analysis of p(WCB)
Interactive 3D exploration quickly shows structure.

Continuing work:
Other selection criteria.
Improvements of 3D exploration.
Improvements of flight planning functionality.

Thank you!
Additional slides
T-NAWDEX-Falcon case: ET, through and WCB

19 October 2012 12 UTC
WCB trajectories started in lower atmosphere

800 hPa

48 h forward
Comparison of setups

DF-T 0.25°

DF-T 1.0°

ABL-T 10hPa 1.0°
Ensemble with 10 members and 9 features

max. probability: 30% 
caused by features in 8 members
Visual sampling along normal curves
Find the highest probability in 3D
Find the highest probability in 3D