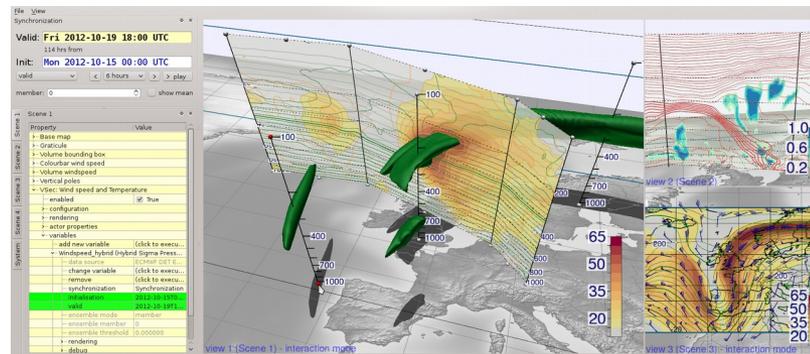


# Interactive 3D visualization of ECMWF ensemble weather forecasts



29 September 2015,  
ECMWF, Reading

**Marc Rautenhaus<sup>(1)</sup>**

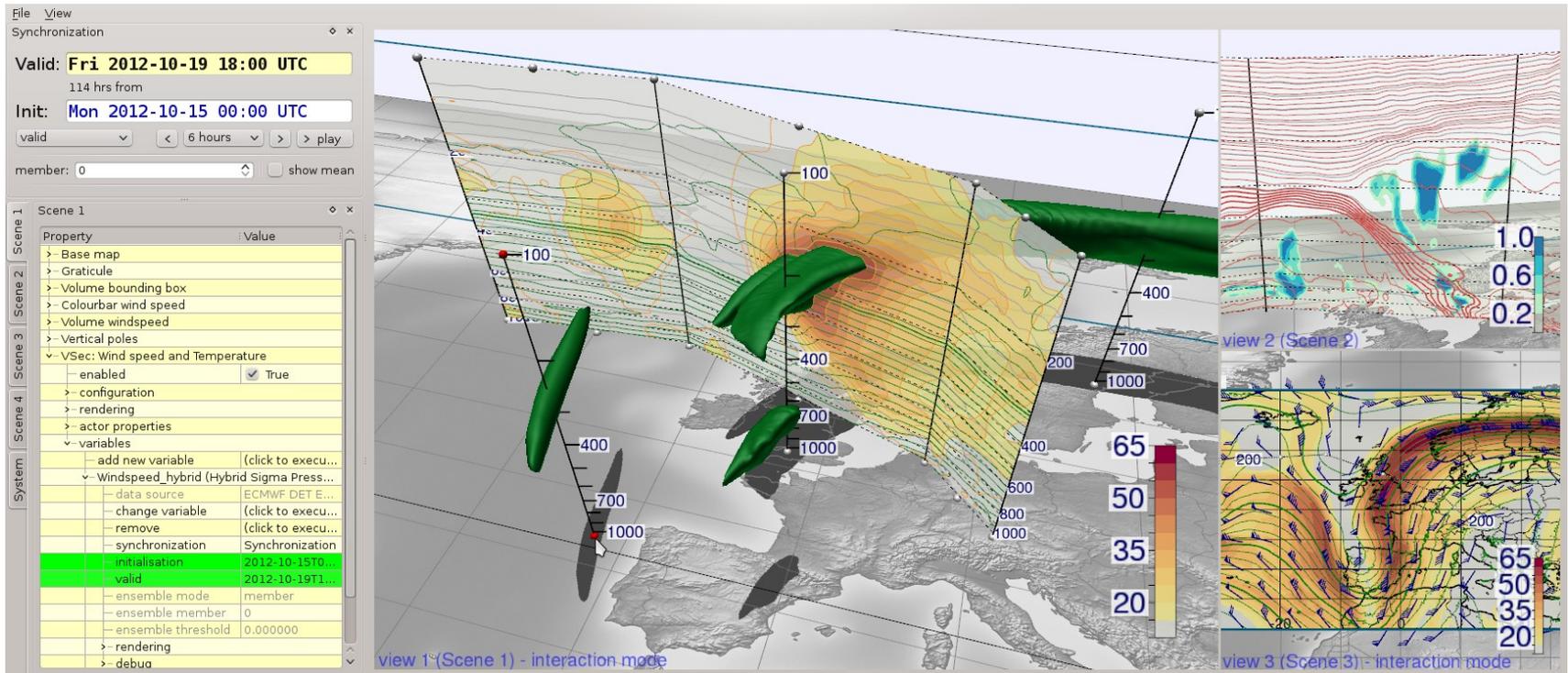
contributions from Florian Ferstl<sup>(1)</sup>, Christian Grams<sup>(2)</sup>, Christoph Heidelmann<sup>(1)</sup>,  
Michael Kern<sup>(1)</sup>, Andreas Schäfler<sup>(3)</sup> and Rüdiger Westermann<sup>(1)</sup>

(1) Computer Graphics and Visualization Group, TU München

(2) Institute for Atmospheric and Climate Science, ETH Zürich

(3) Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen

# 3D ensemble visualization for forecasting

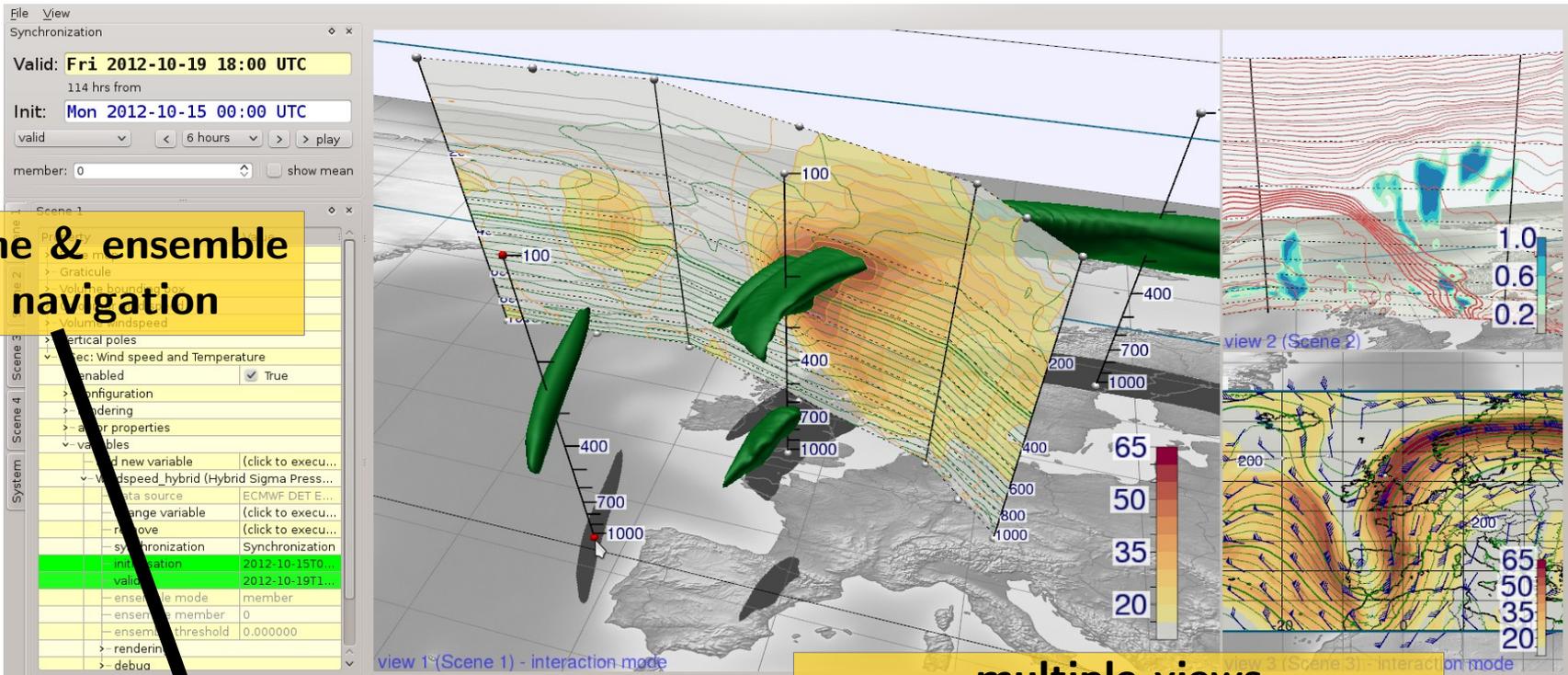


Met.3D – improve forecasting for flight planning by use of **ensemble uncertainty information** and combined **2D/3D exploration techniques**.



(c) DLR

# Met.3D – an interactive 3D forecasting tool

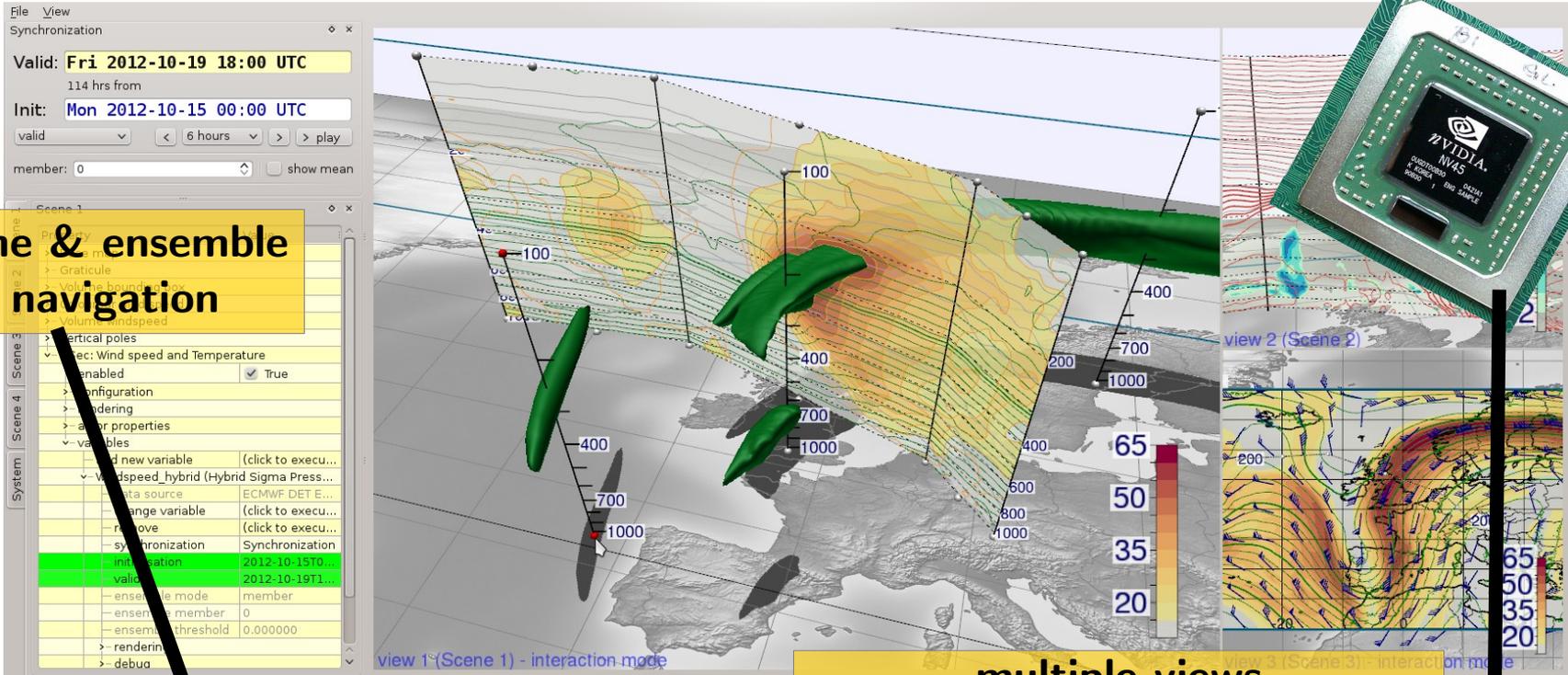


time & ensemble navigation

multiple views with 2D & 3D visualization

User interface elements required for forecast exploration.

# Met.3D – an interactive 3D forecasting tool



time & ensemble navigation

multiple views with 2D & 3D visualization

User interface elements required for forecast exploration.

GPU based.

# Outline

---

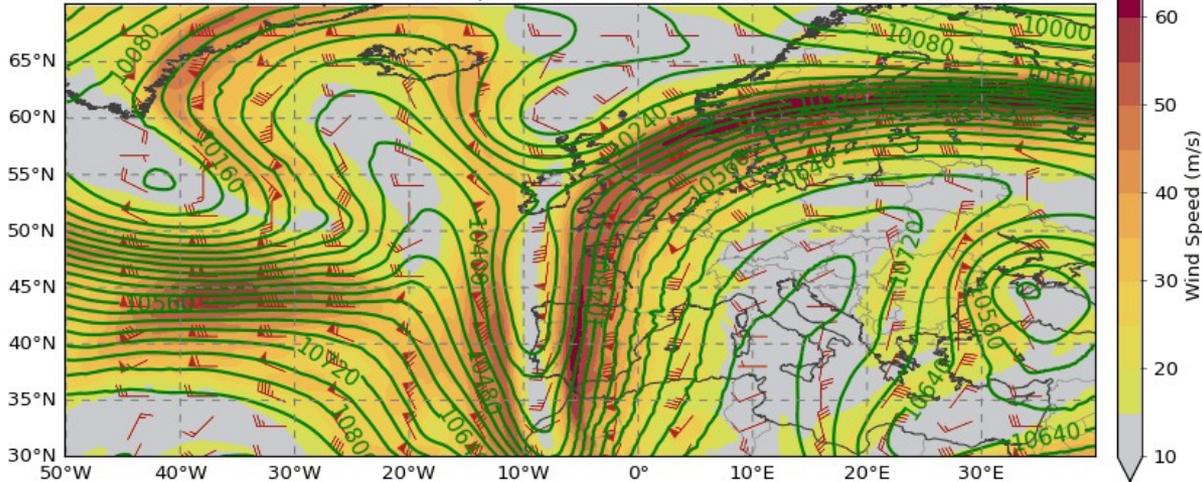
- (1) A „bridge“ from 2D to 3D,
- (2) support for (ECMWF) ensemble forecasts,
- (3) interactive ensemble forecast products,
- (4) future work in „Waves to weather“ – feature based ensemble visualization.

## Technical specs:

- **desktop application (C++/OpenGL/Linux);**
- **support for ECMWF ENS NetCDF/Grib;**
- **support for hybrid sigma-pressure levels.**

# Bridge from 2D to 3D – horizontal sections

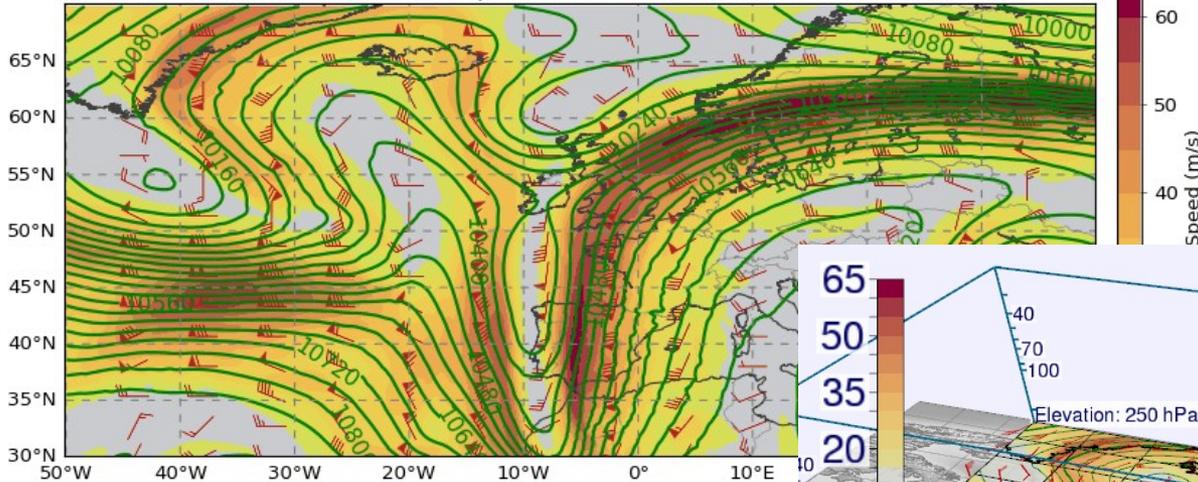
Geopotential Height (m) and Horizontal Wind (m/s) at 250 hPa  
Valid: Fri 2012-10-19 18:00 UTC (step 66 hrs from Wed 2012-10-17 00:00 UTC)



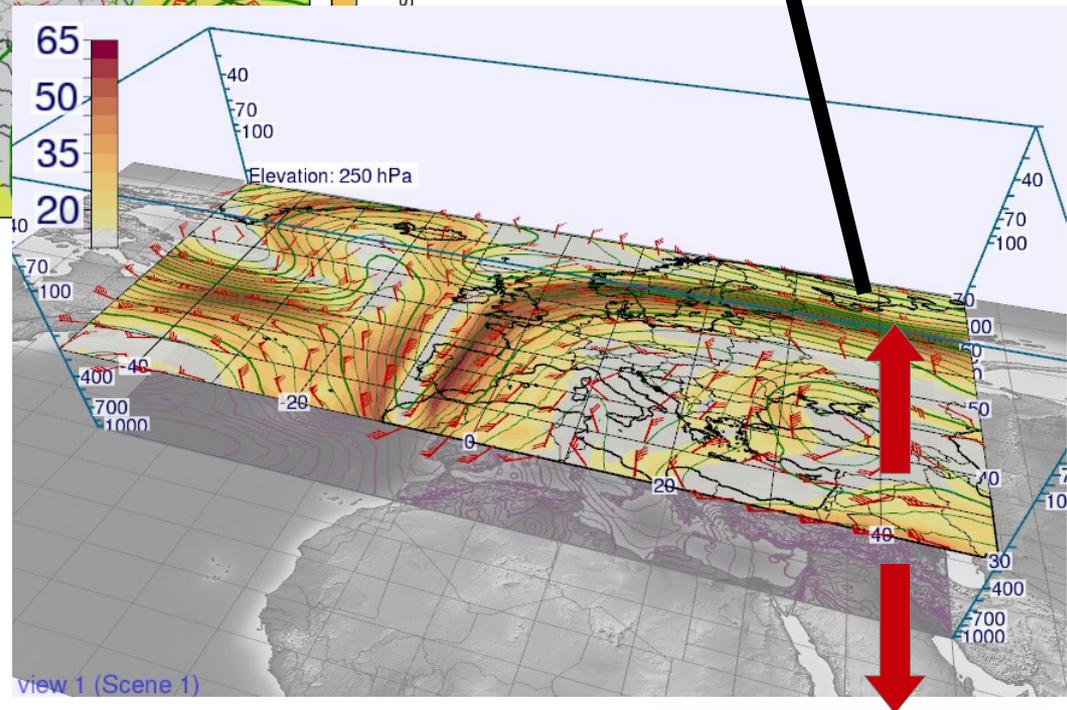
Do not replace proven 2D techniques but put them into a 3D context and use 3D elements to add value.

# Bridge from 2D to 3D – horizontal sections

Geopotential Height (m) and Horizontal Wind (m/s) at 250 hPa  
Valid: Fri 2012-10-19 18:00 UTC (step 66 hrs from Wed 2012-10-17 00:00 UTC)

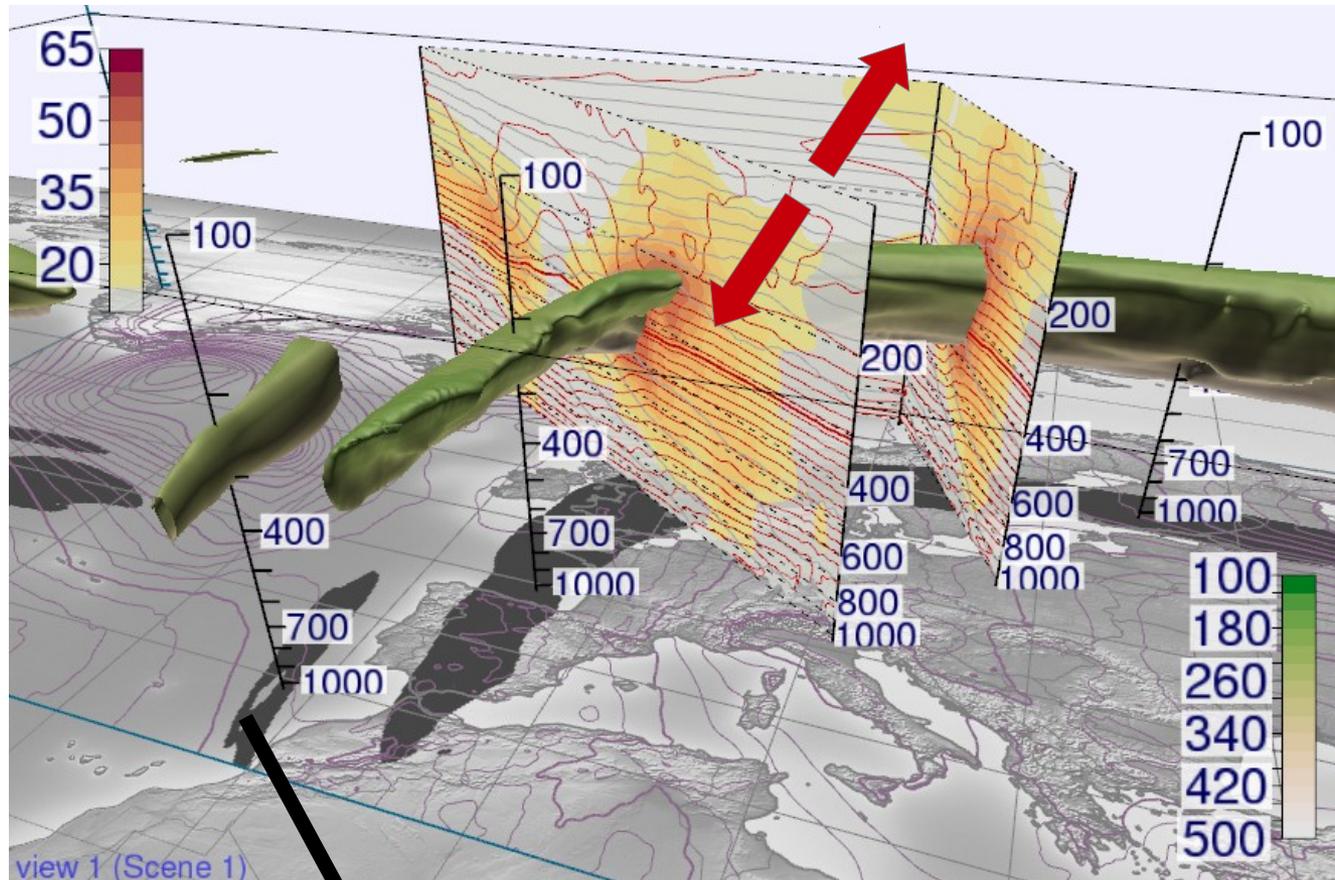


Interactively move section:  
fast means to explore  
vertical structure.



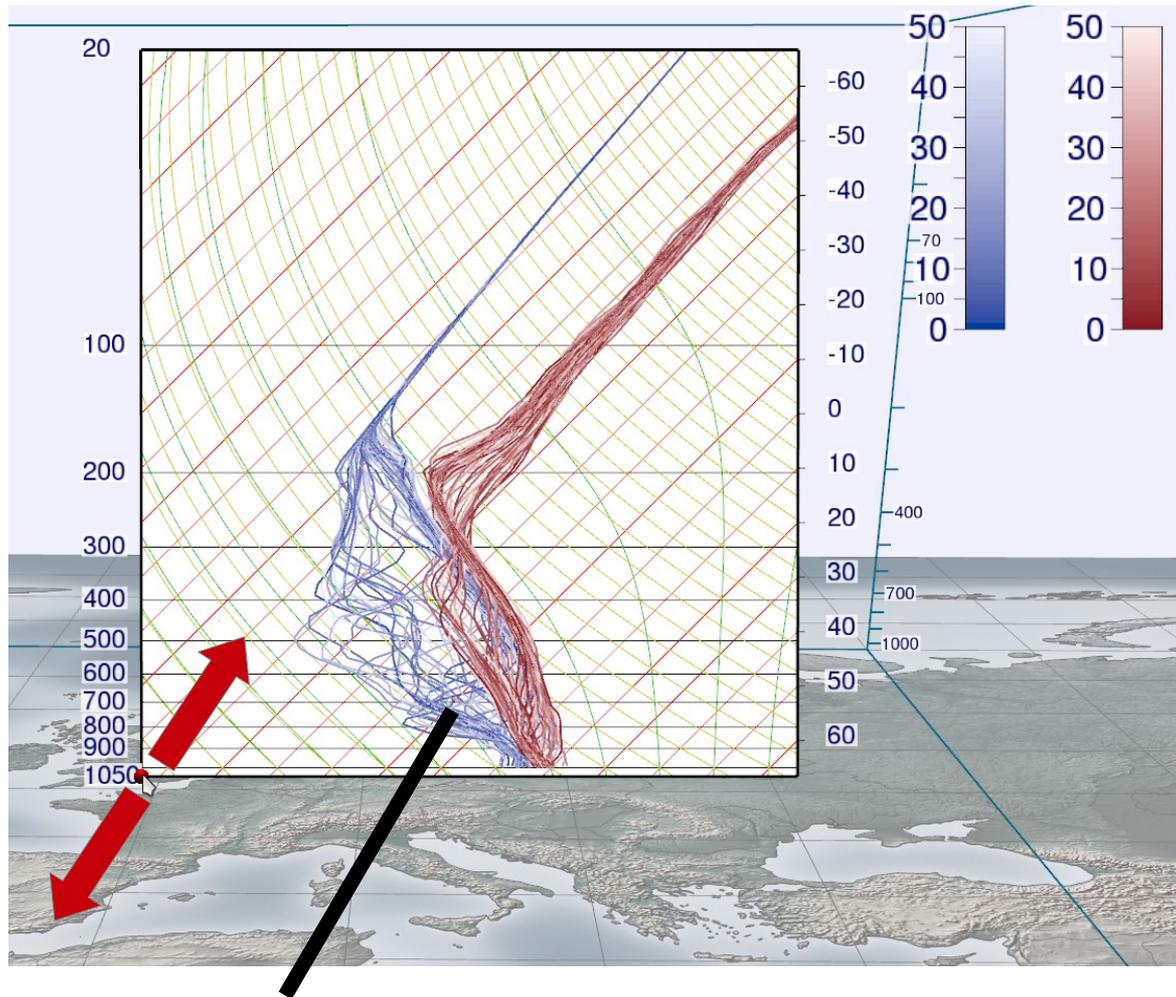
Do not replace proven 2D techniques but put them into a 3D context and use 3D elements to add value.

# Bridge from 2D to 3D – vertical sections



Shadows and vertical axes for spatial perception.

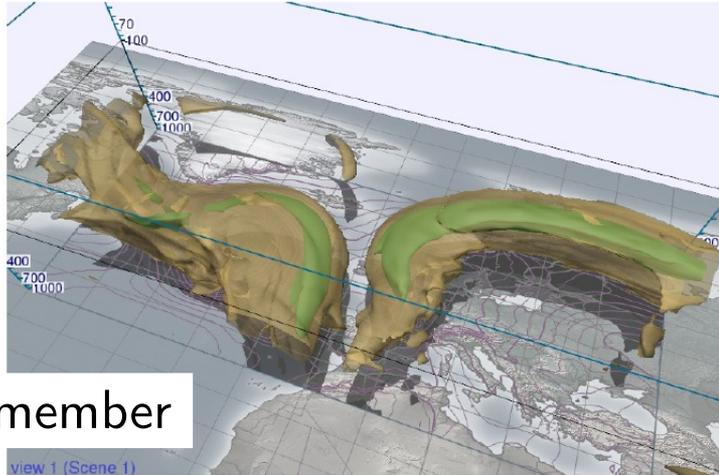
# Bridge from 2D to 3D – Skew-T-diagrams



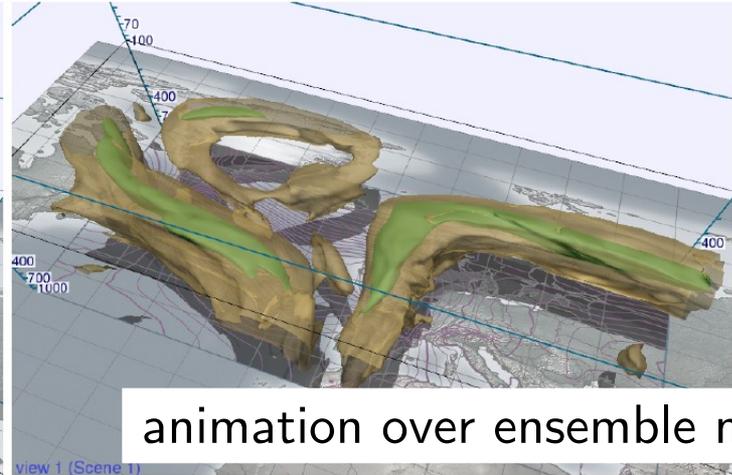
Spaghetti plots for temperature and dew point

# Support for ensemble forecasts

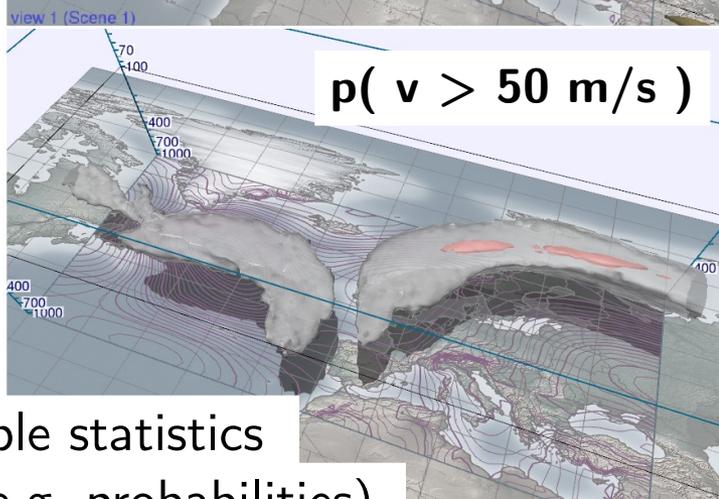
jetstream – 3D isosurfaces 50 m/s and 30 m/s



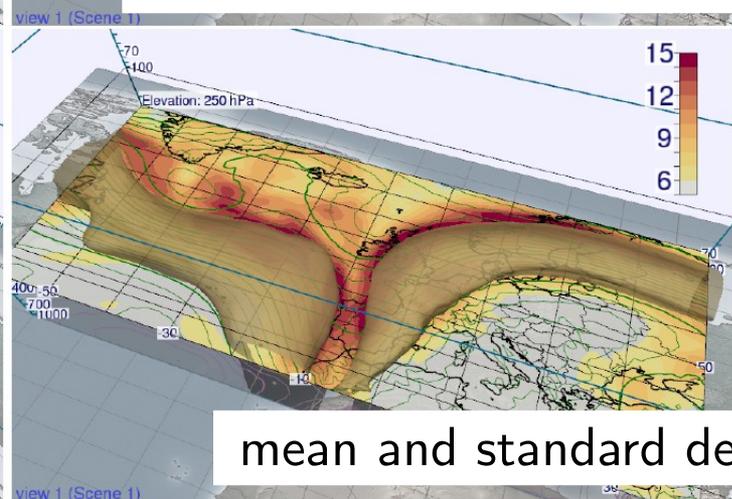
single member



animation over ensemble members



ensemble statistics  
(e.g. probabilities)

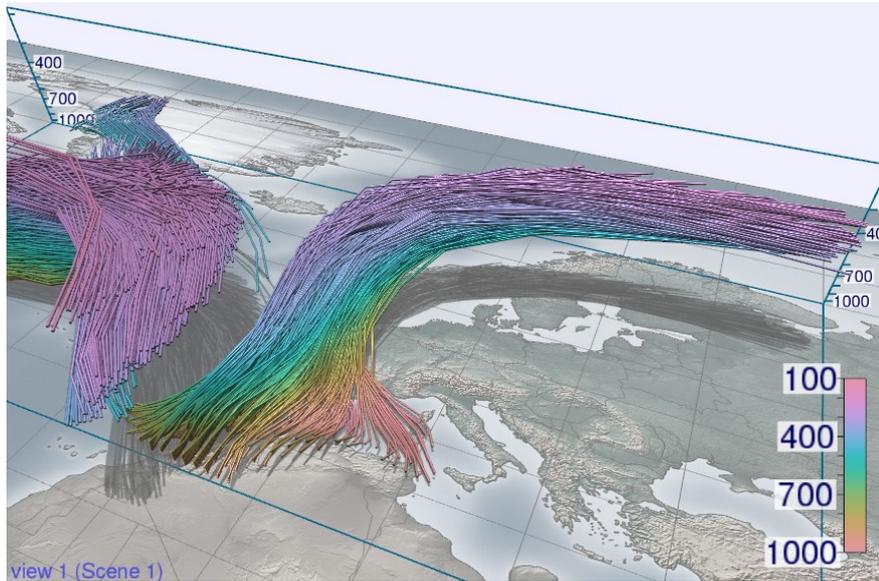


mean and standard deviation

---

- video -

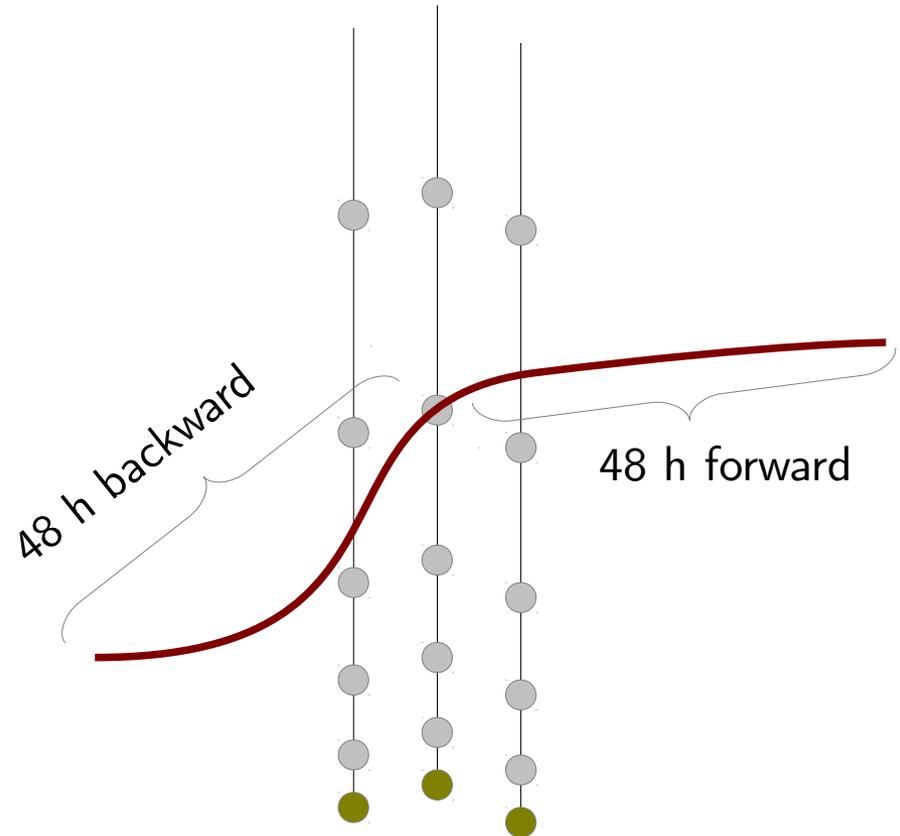
# Ensemble forecast product: warm conveyor belts



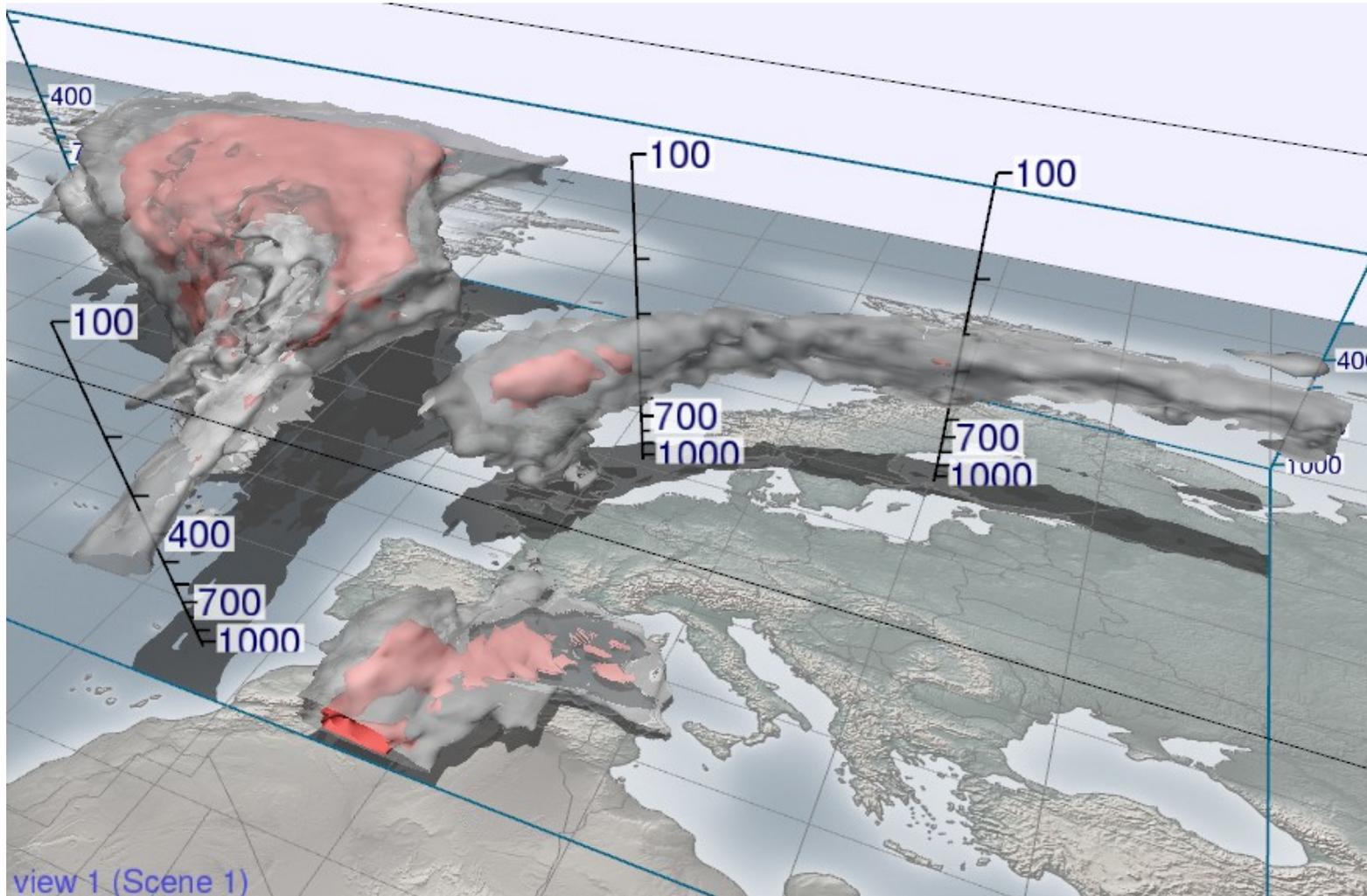
select trajectories according to ascent:

e.g. **500 hPa in 48 hours**  
(interactively in Met.3D)

(Wernli and Davis, 1997)



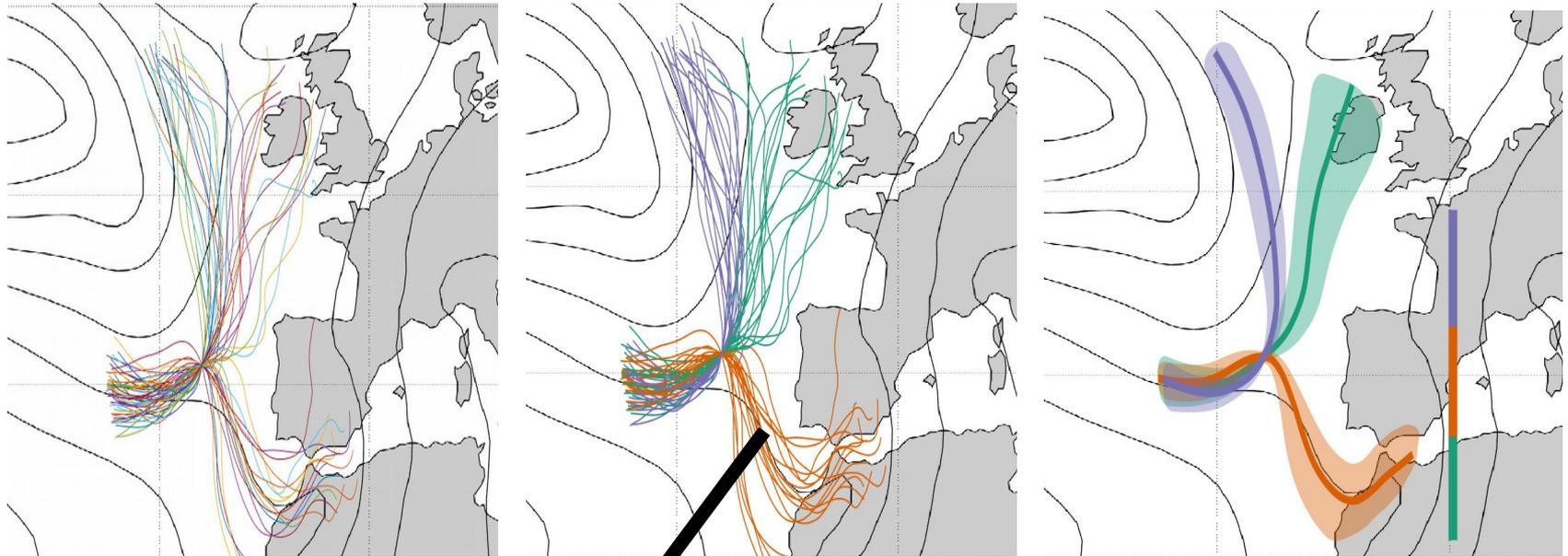
# Probability of WCB occurrence



---

- video -

# Current work: Spaghetti plots and clustering

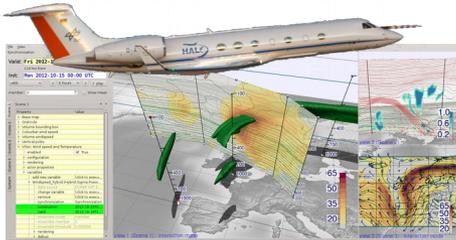


Ferstl et al. (TVCG, 2015)

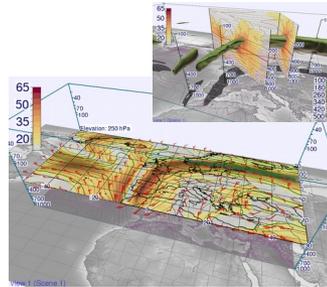
Interactive clustering of an ensemble of streamlines/trajectories

Future work: feature based ensemble visualization in „Waves to weather“ (2015-19)  
**[PhD position available!]**

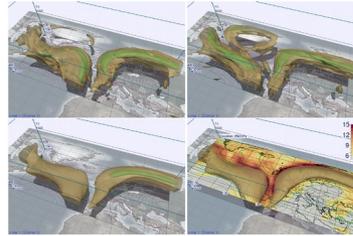
# Summary



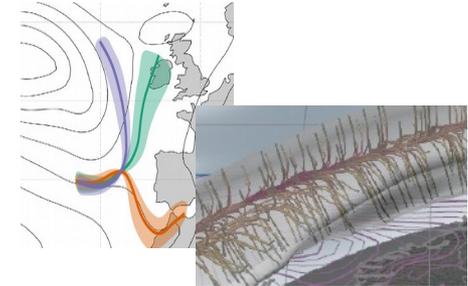
**Met.3D**



**Bridge from  
2D to 3D**

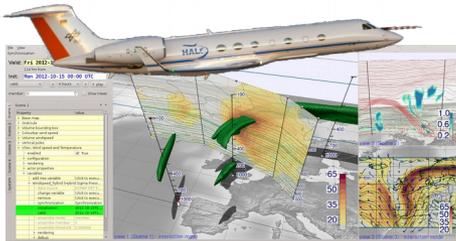


**Ensemble  
support**

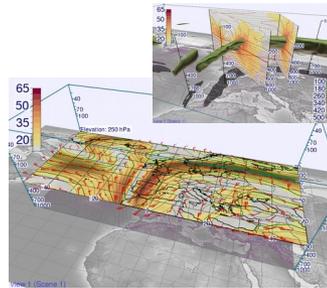


**Ongoing research in  
visualization techniques**

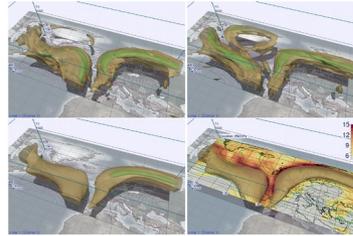
# Summary



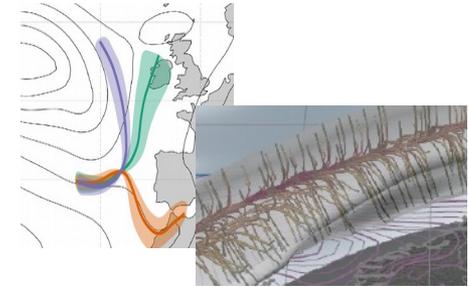
**Met.3D**



**Bridge from  
2D to 3D**



**Ensemble  
support**



**Ongoing research in  
visualization techniques**

Publication:  
**Rautenhaus et al. (2015a,b)**  
**Geosci. Model Dev. (8)**

Met.3D open-source repository:  
**<https://bitbucket.org/wxmetvis/met.3d>**

**Users wanted!**  
Contact me at **[marc.rautenhaus@tum.de](mailto:marc.rautenhaus@tum.de)**

Geosci. Model Dev., 8, 2329–2353, 2015  
[www.geosci-model-dev.net/8/2329/2015/](http://www.geosci-model-dev.net/8/2329/2015/)  
doi:10.5194/gmd-8-2329-2015  
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Model Development  
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## **Three-dimensional visualization of ensemble weather forecasts – Part I: The visualization tool Met.3D (version 1.0)**

M. Rautenhaus<sup>1</sup>, M. Kern<sup>1</sup>, A. Schäfer<sup>2</sup>, and R. Westermann<sup>1</sup>

<sup>1</sup>Computer Graphics & Visualization Group, Technische Universität München, Garching, Germany

<sup>2</sup>Deutsches Zentrum für Luft- und Raumfahrt, Institut für Physik der Atmosphäre, Oberpfaffenhofen, Germany

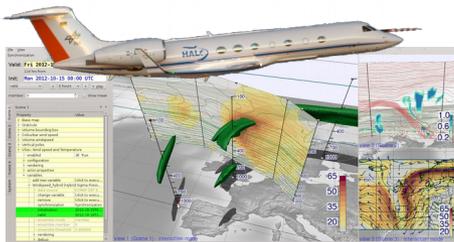
Correspondence to: M. Rautenhaus ([marc.rautenhaus@tum.de](mailto:marc.rautenhaus@tum.de))

Received: 4 February 2015 – Published in Geosci. Model Dev. Discuss.: 27 February 2015

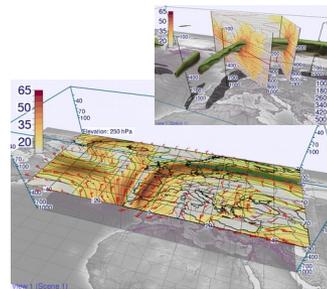
Revised: 23 June 2015 – Accepted: 25 June 2015 – Published: 31 July 2015

# Summary

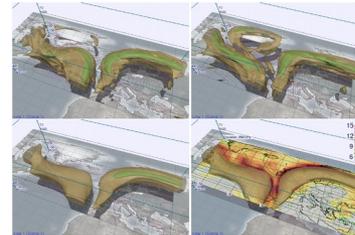
See Met.3D live at the exhibition!



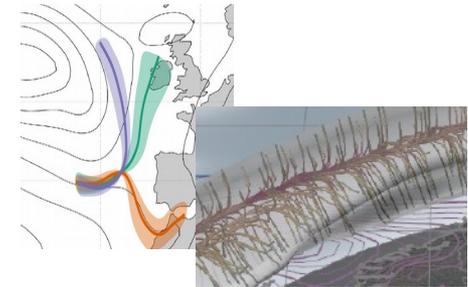
Met.3D



Bridge from  
2D to 3D



Ensemble  
support



Ongoing research in  
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[www.geosci-model-dev.net/8/2329/2015/](http://www.geosci-model-dev.net/8/2329/2015/)  
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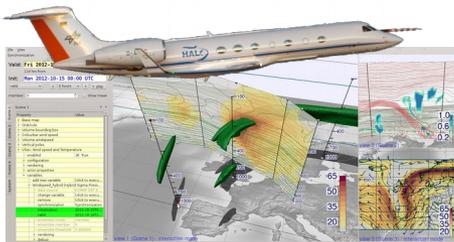
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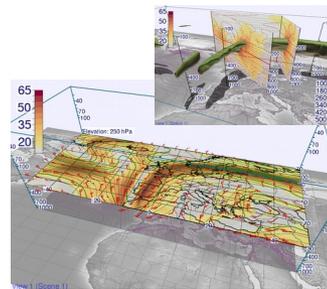
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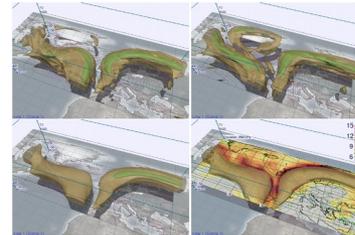
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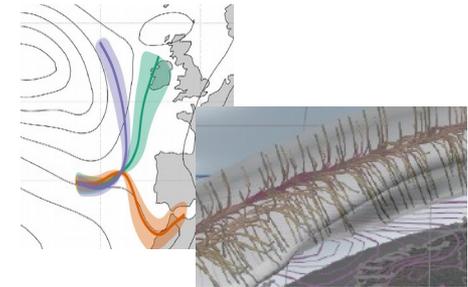
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Ensemble  
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Ongoing research in  
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