Forecast products for flight planning: a researchers' perspective

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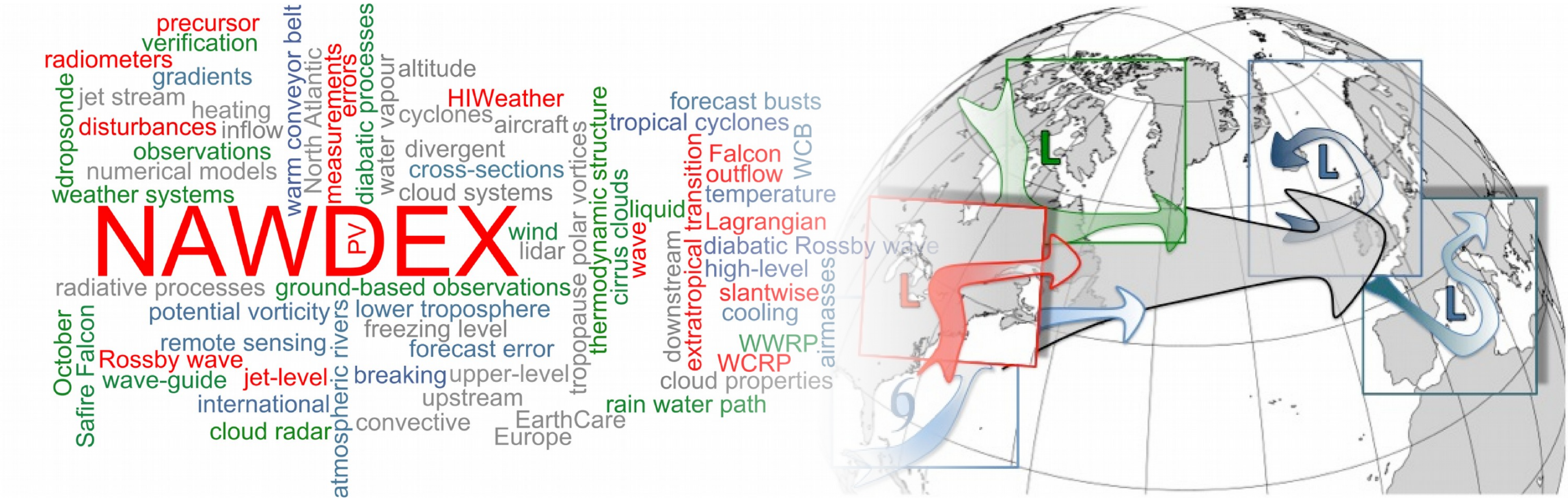

Overarching Hypothesis:

Diabatic processes over North America and the North Atlantic have a major influence on jet stream structure, the downstream development of Rossby waves, and high impact weather phenomena over Europe.

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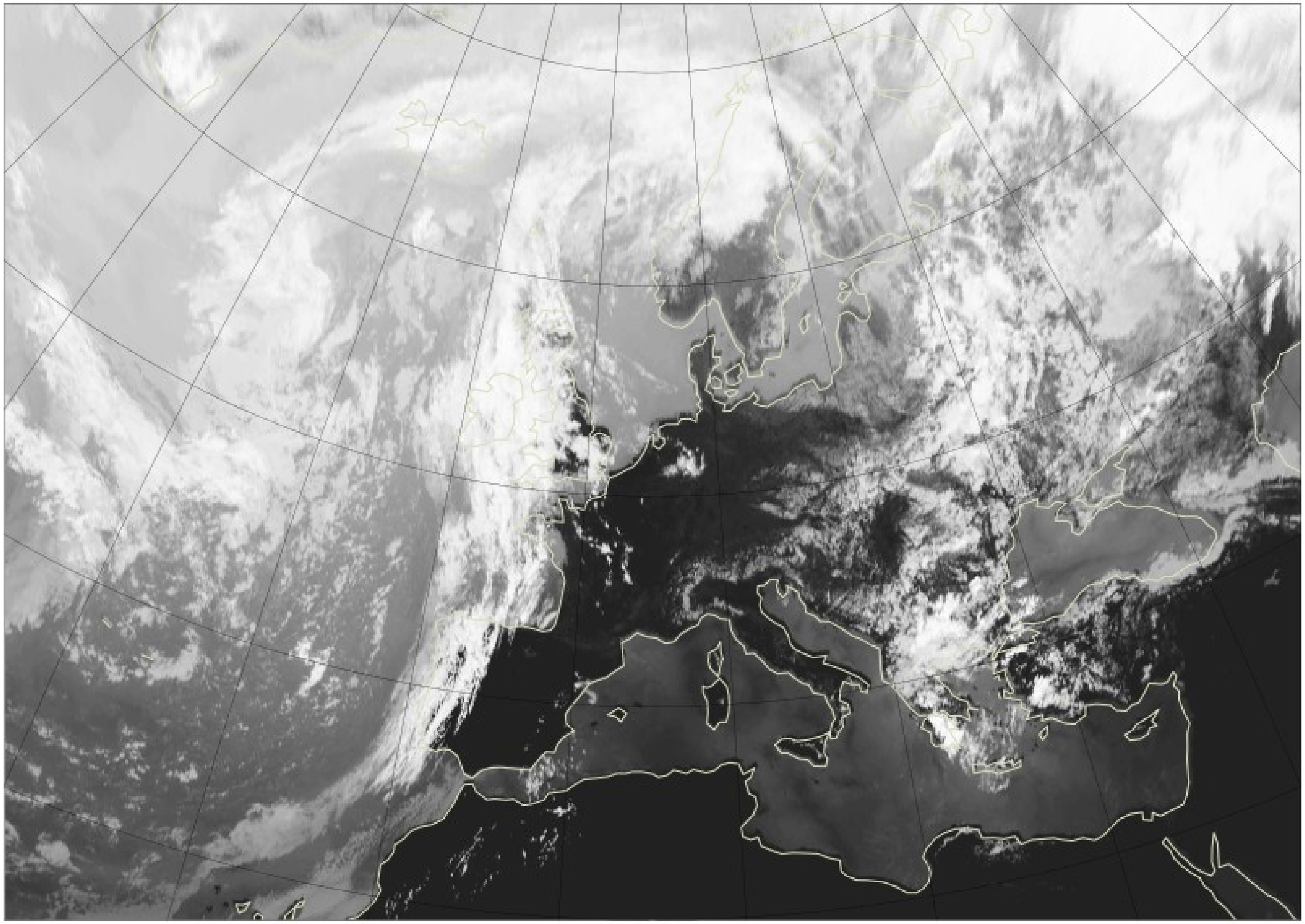

MSG IR satellite 12 UTC 1 July 2015

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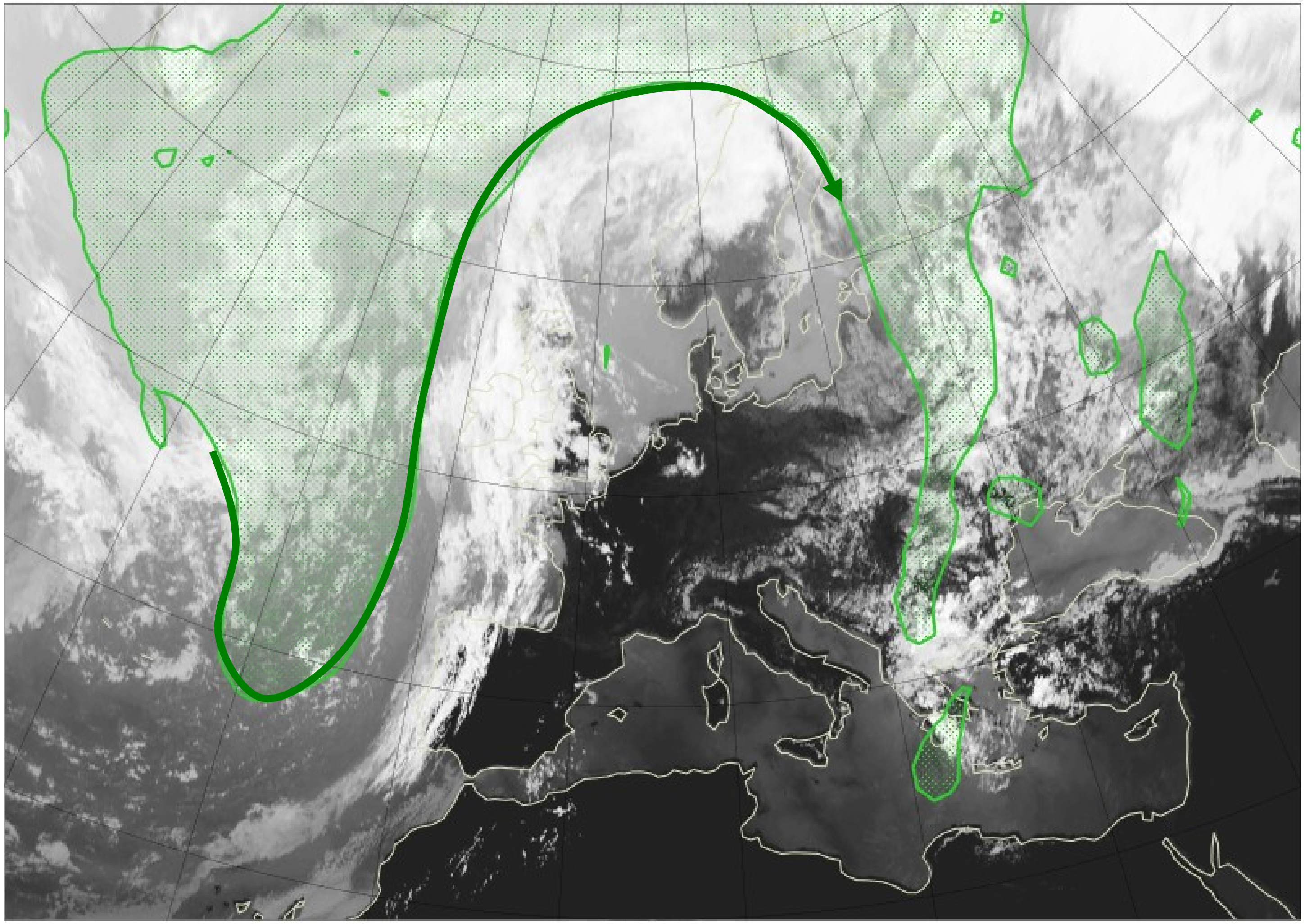

MSG IR satellite 12 UTC 1 July 2015

Jetstream deflected towards Scandinavia (2PVU@325K)

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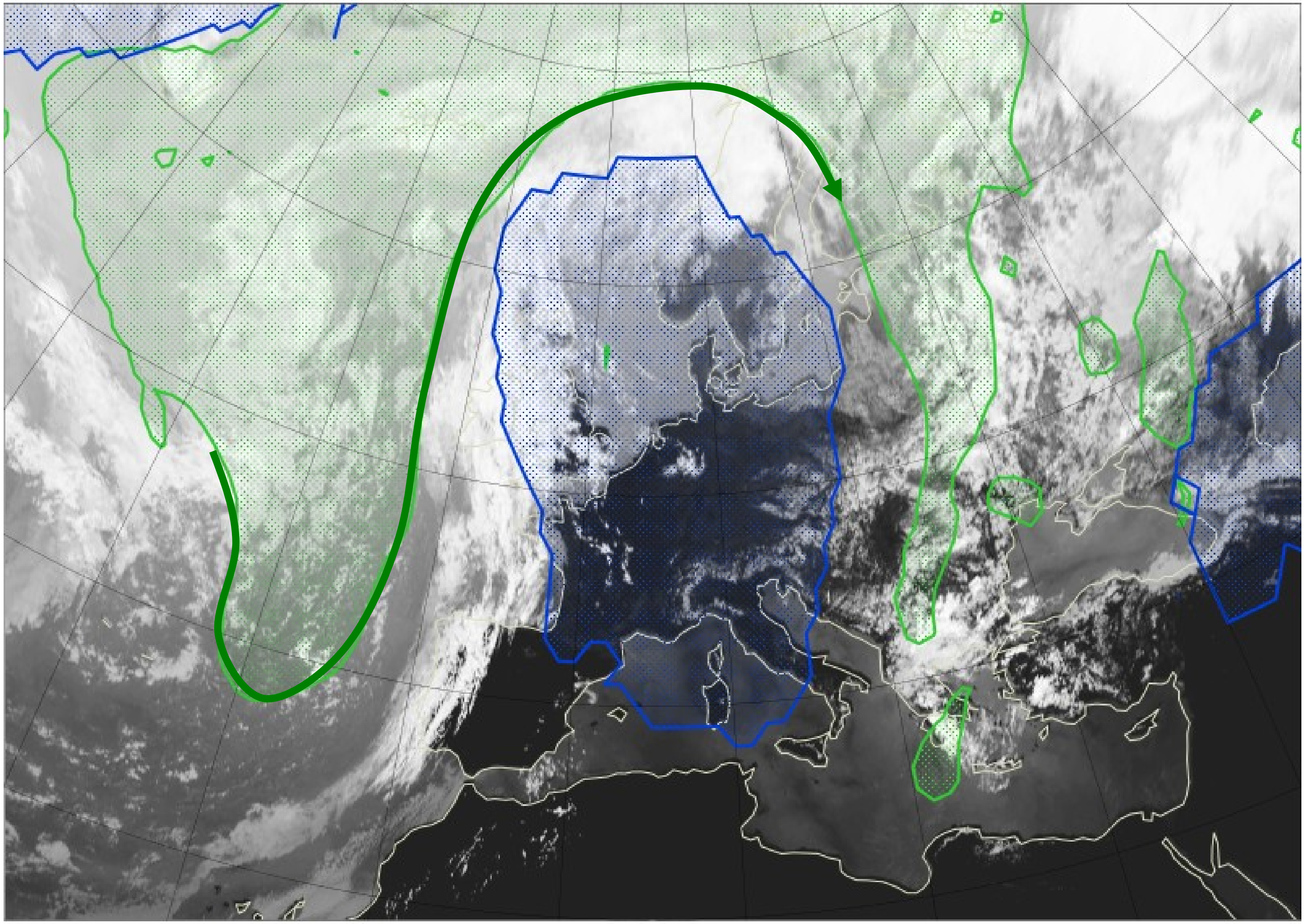

MSG IR satellite 12 UTC 1 July 2015, jetstream (2PVU@325K)

Atmospheric blocking extends over heat wave region

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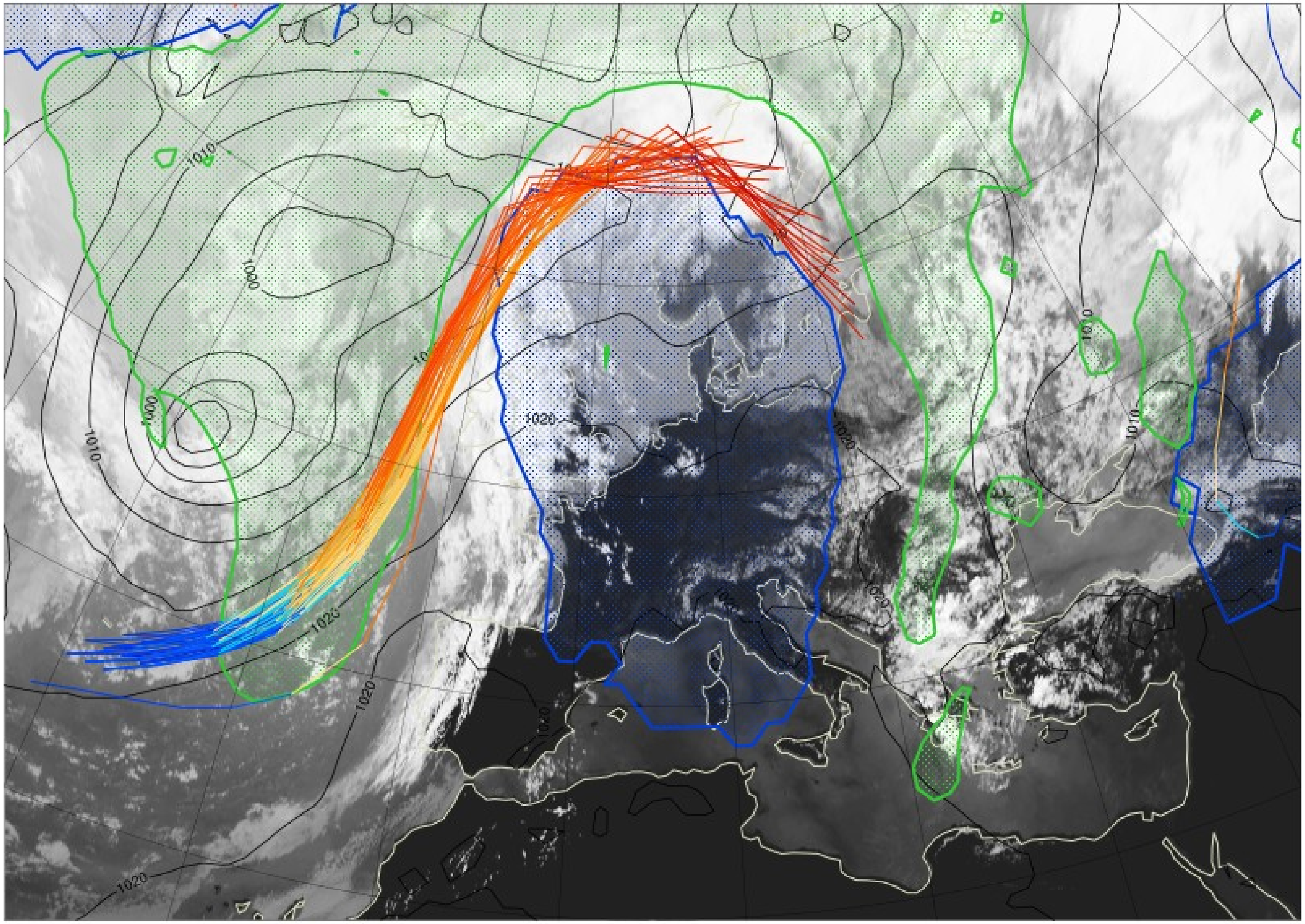
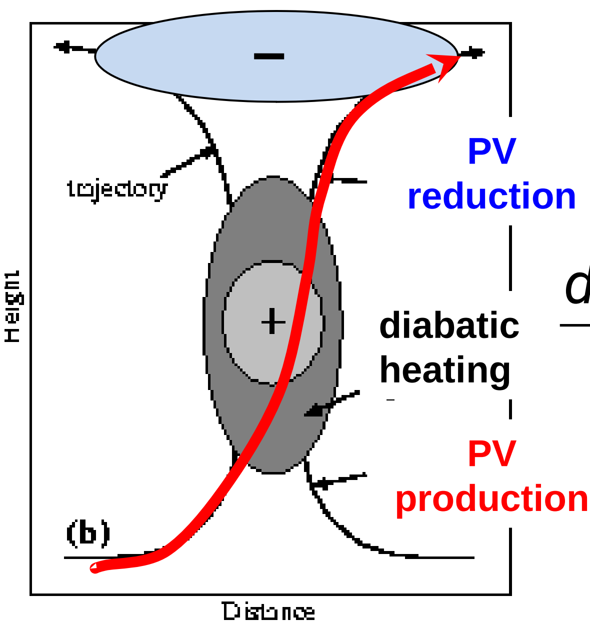


MSG IR satellite 12 UTC 1 July 2015, jetstream (2PVU@325K), blocking
Strongly ascending and precipitating airstream – associated with North Atlantic cyclone - reaches into blocking region (MSLP 12 UTC 29 June 2015)

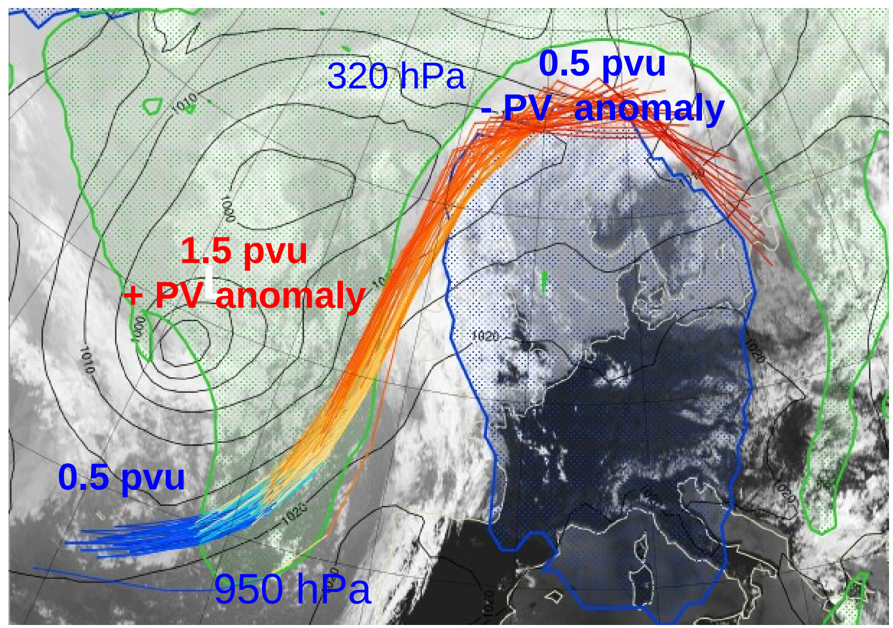
Warm conveyor belts

- rapidly ascending cross isentropic air flows (>600hPa/48h)
- diabatic heating of about 20K / 48h
- diabatic PV production below level of maximum heating
- diabatic PV reduction and low PV values at upper levels

see WCB clim. by Madonna et al. (2014)

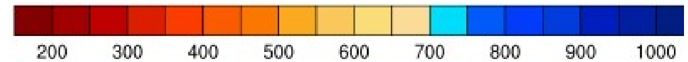


$$\frac{dPV}{dt} \propto \frac{d\dot{\Theta}}{dz}$$



Wernli and Davies (1997), *QJRMS*

p [hPa]



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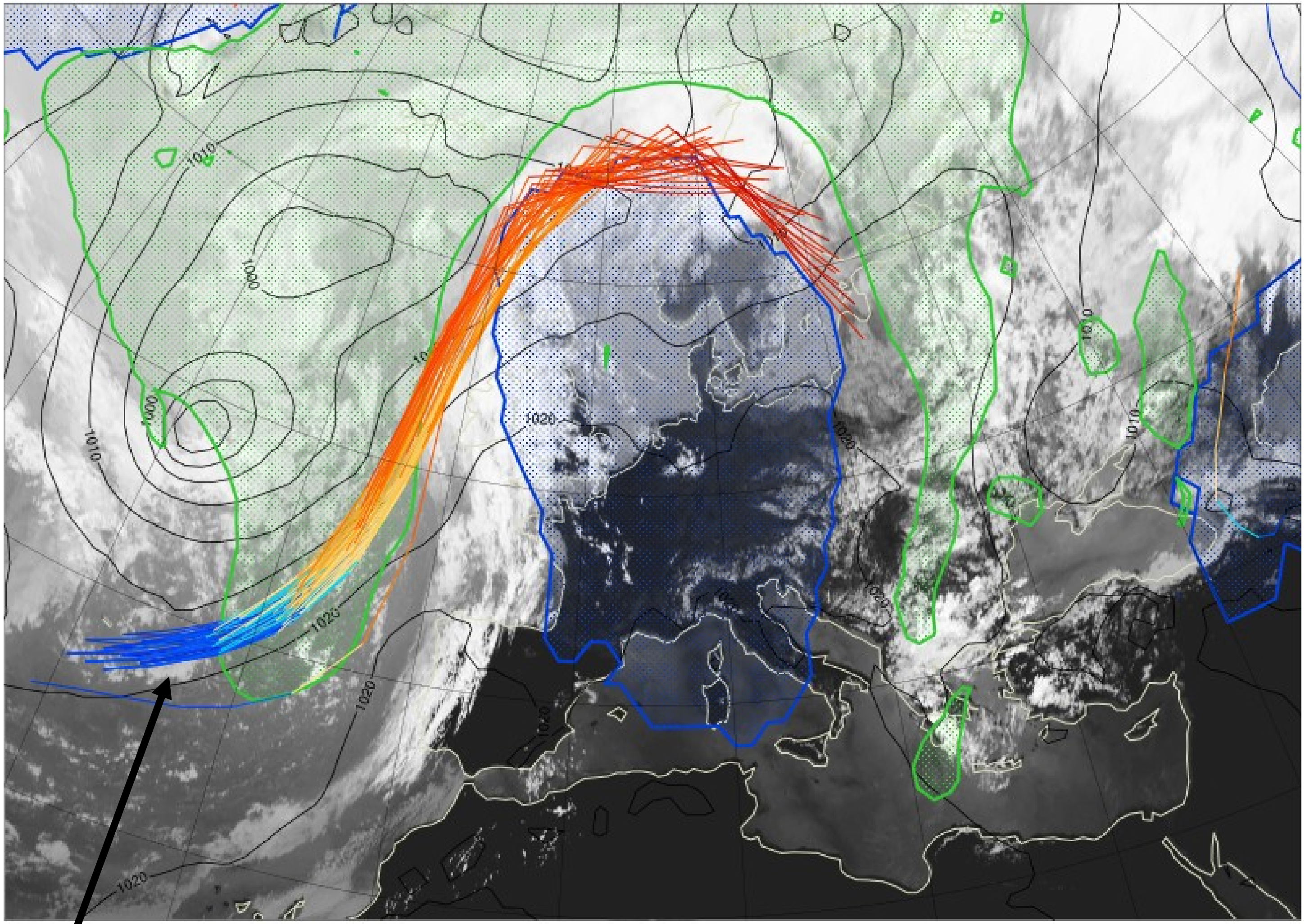

Moisture structure in the boundary layer

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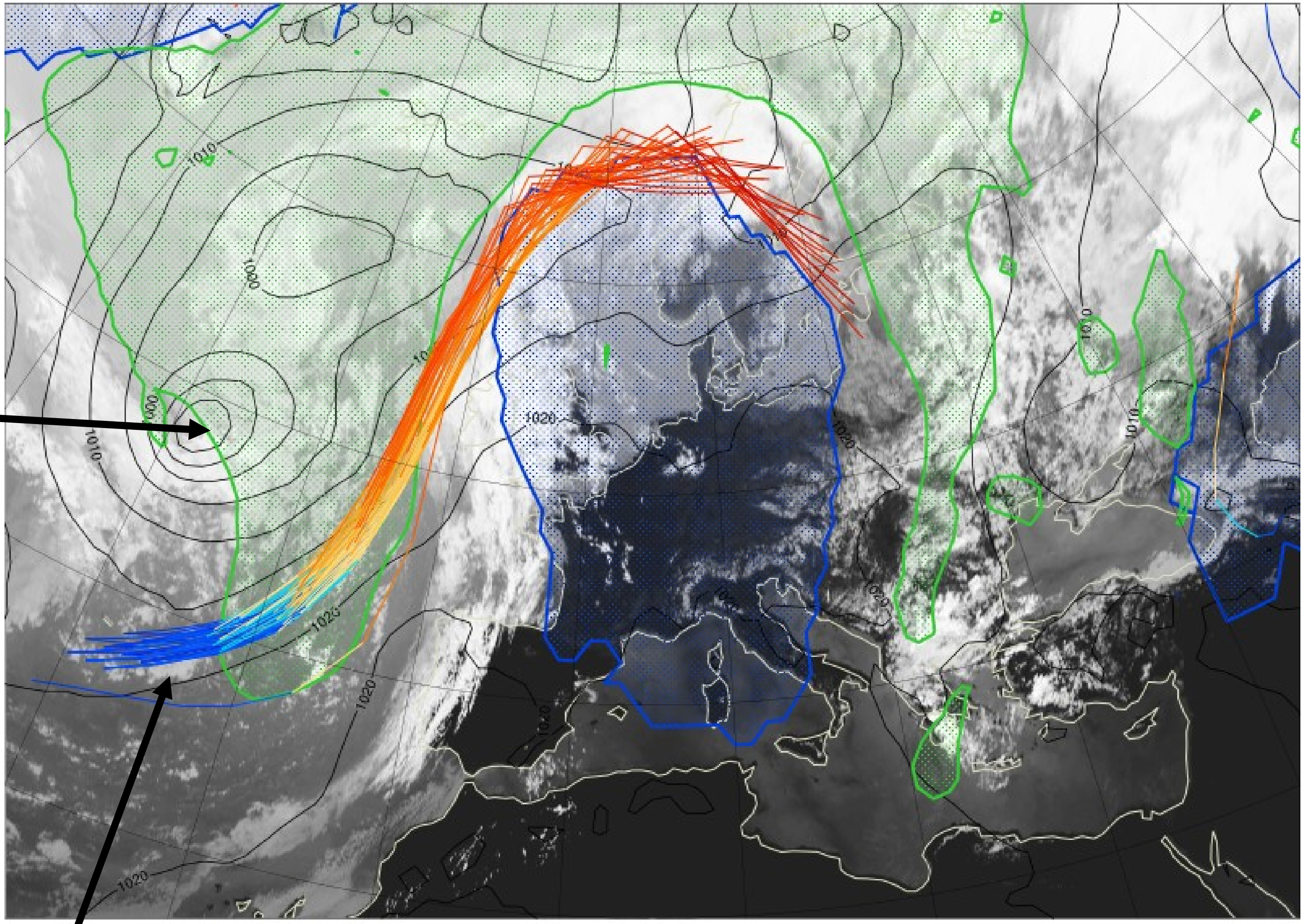

PV

Moisture structure in the boundary layer

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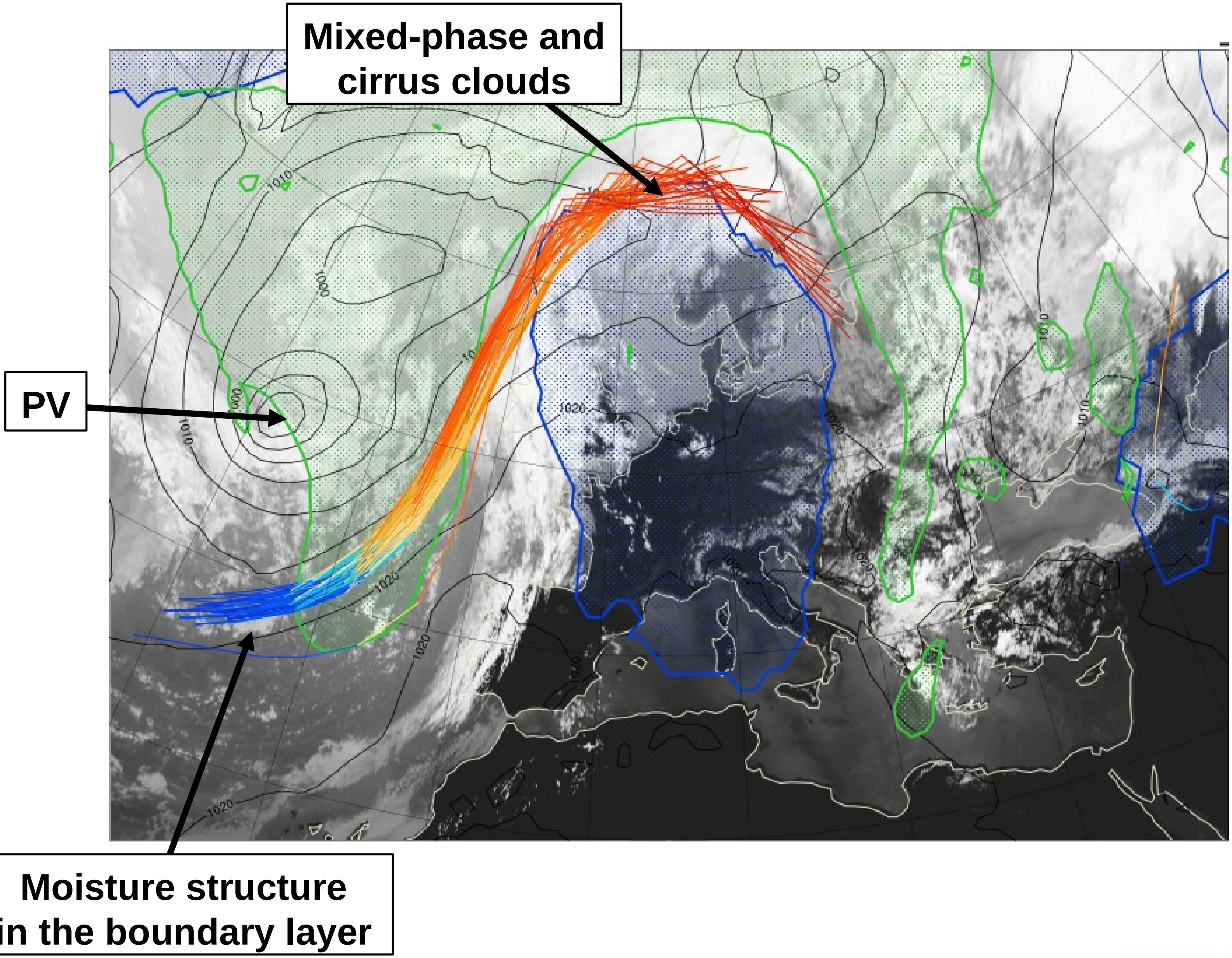

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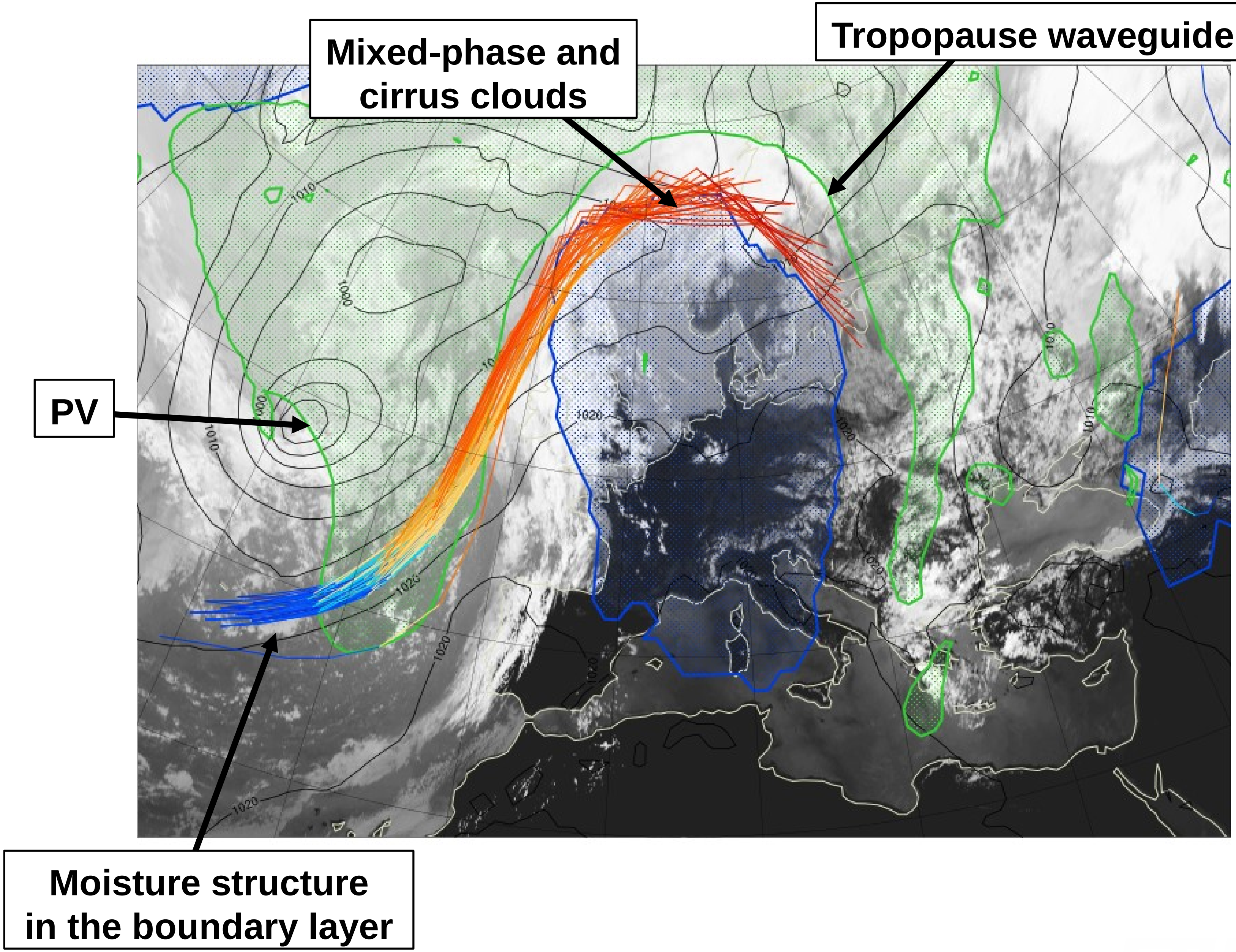

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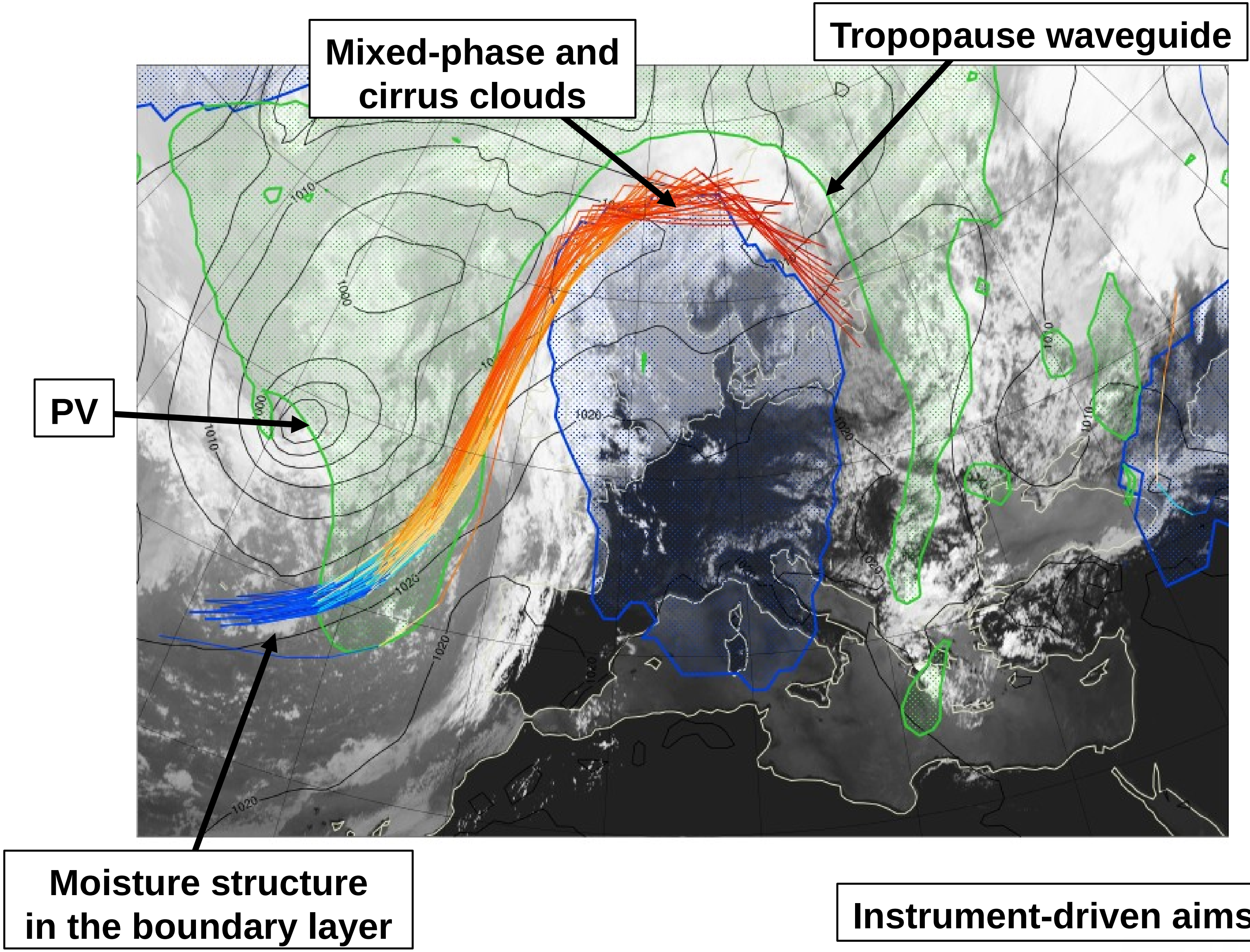

Instrument-driven aims

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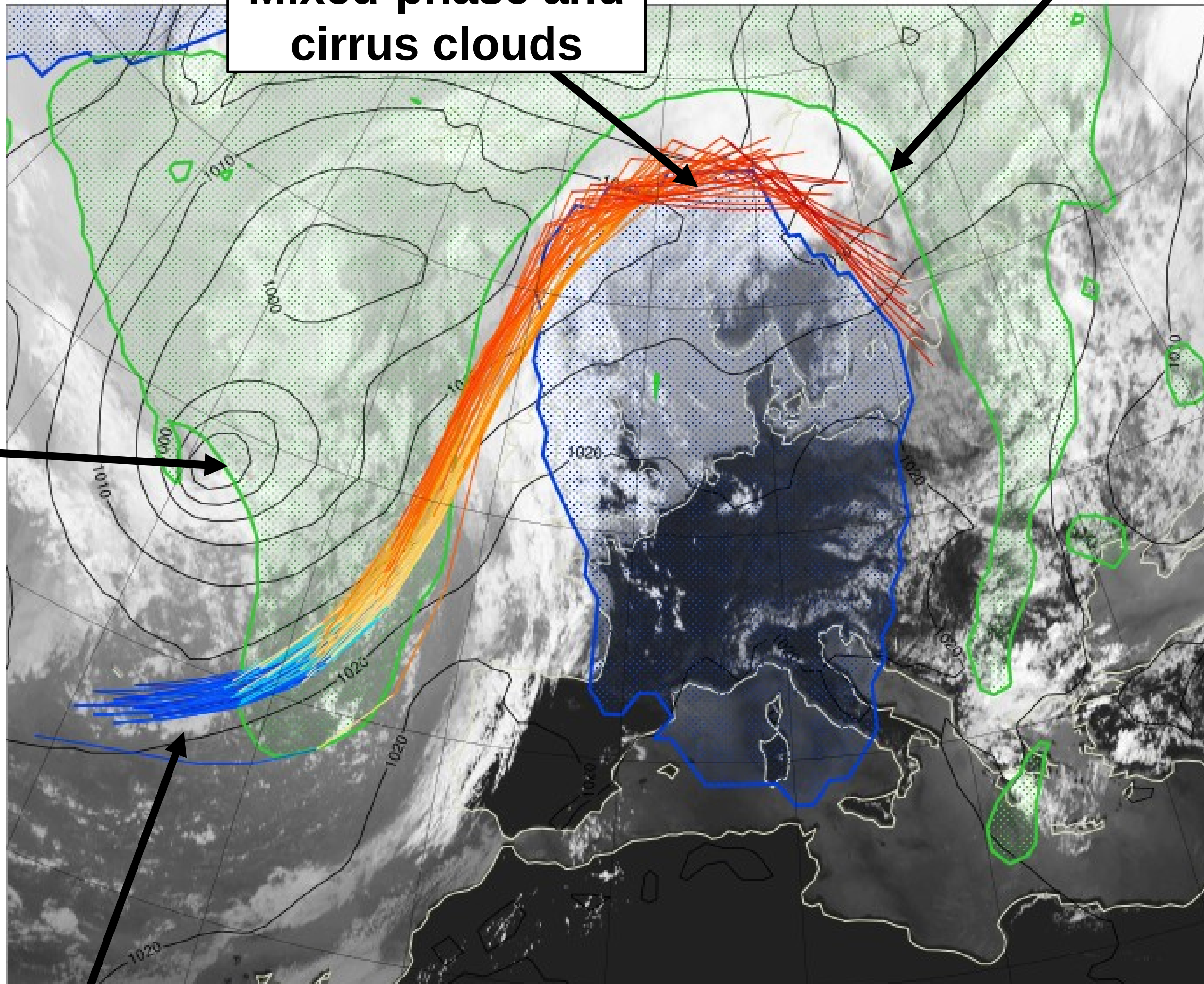
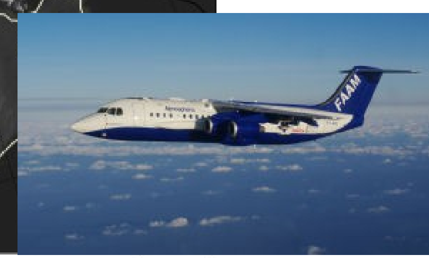
Mixed-phase and cirrus clouds

Tropopause waveguide

PV



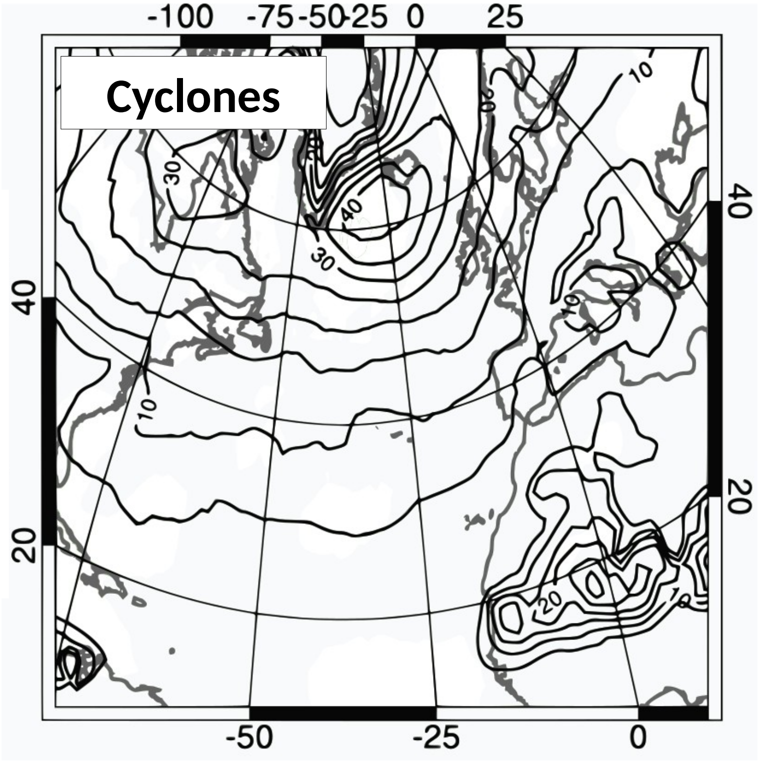


Moisture structure in the boundary layer

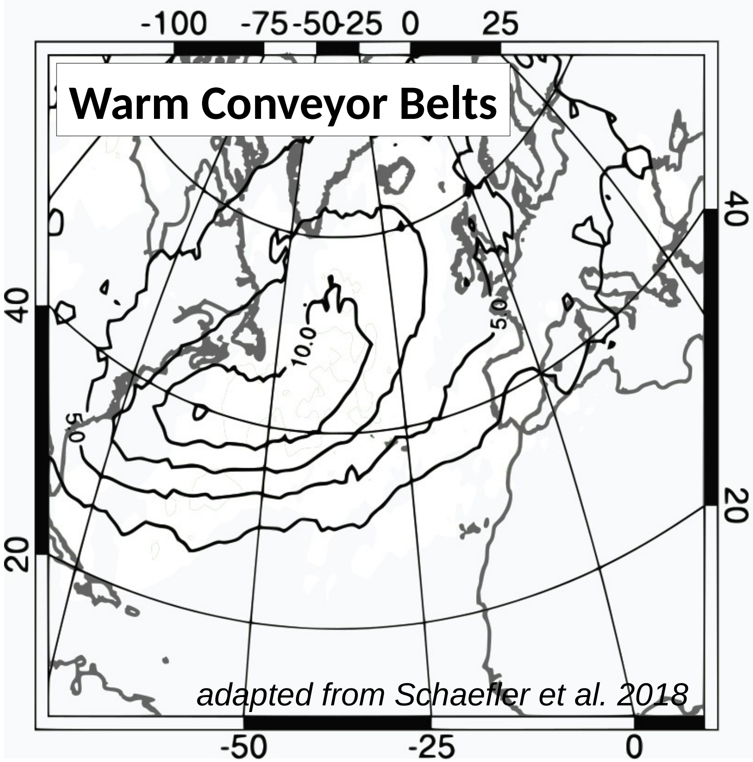
Instrument-driven aims

Challenge: be in the right spot at the right time

Use reanalyses to decide on time of year and operation base



____ ERAI cyclone frequency in September/October



____ ERAI WCB frequency in September/October

Challenge: be in the right spot at the right time

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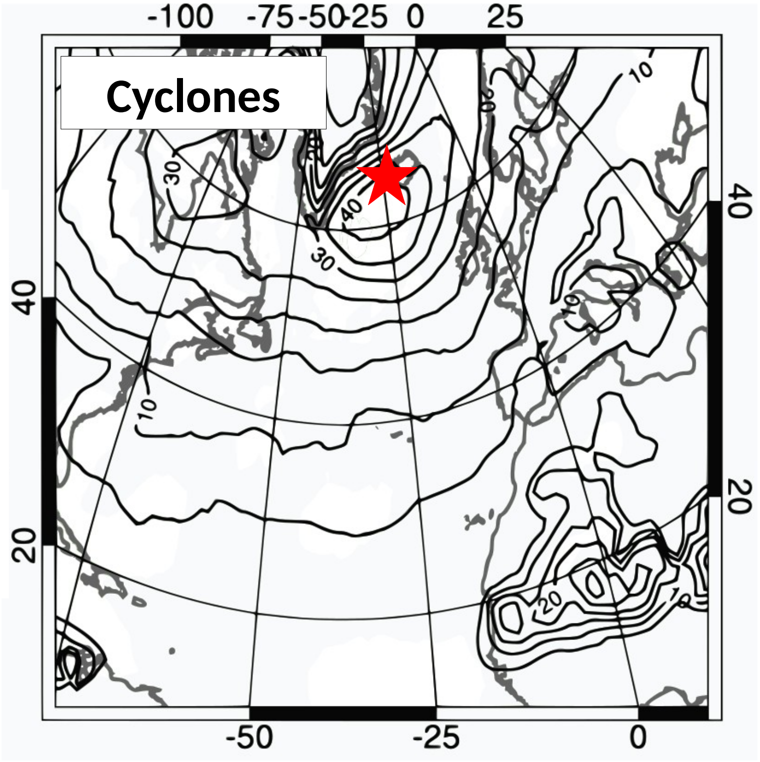

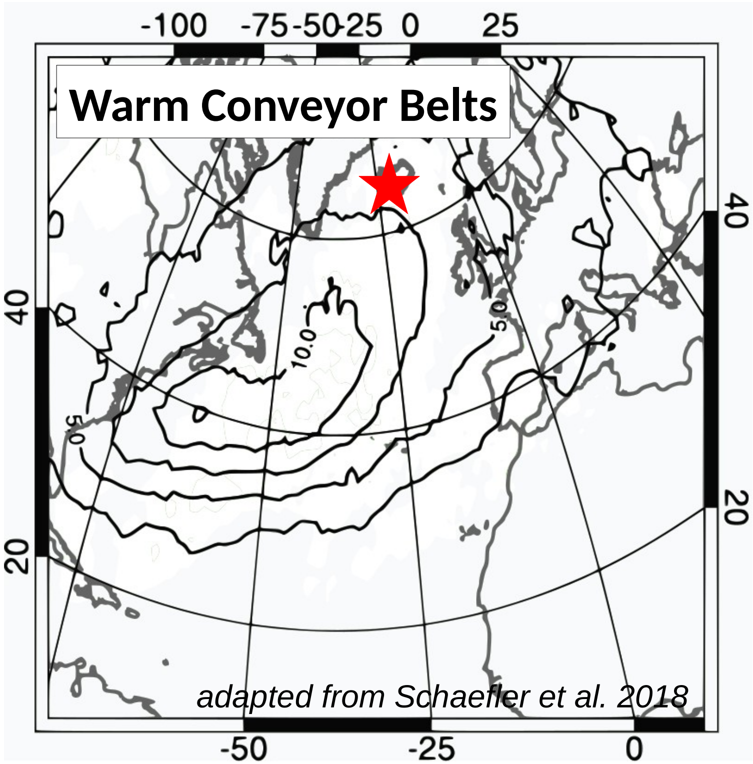

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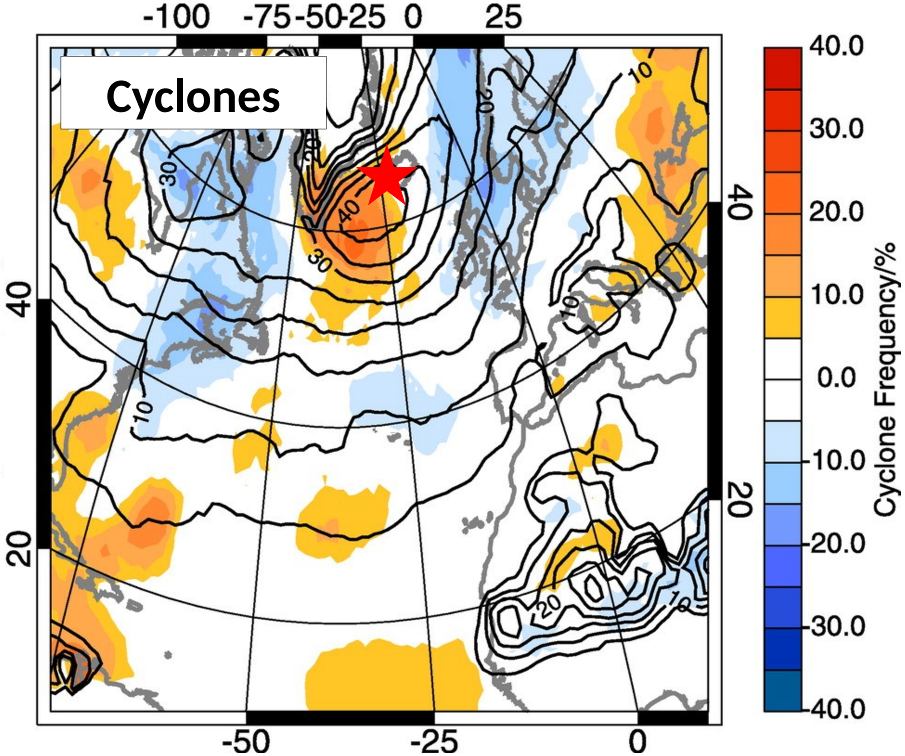

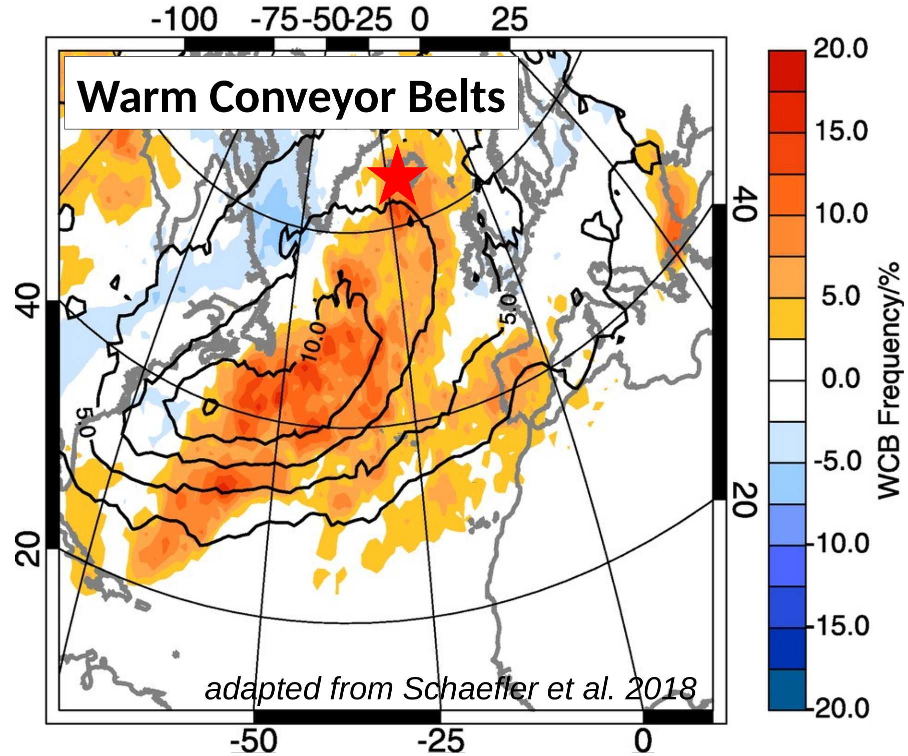

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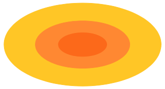
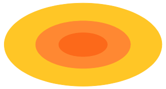

cyclone frequency anomaly during NAWDEX

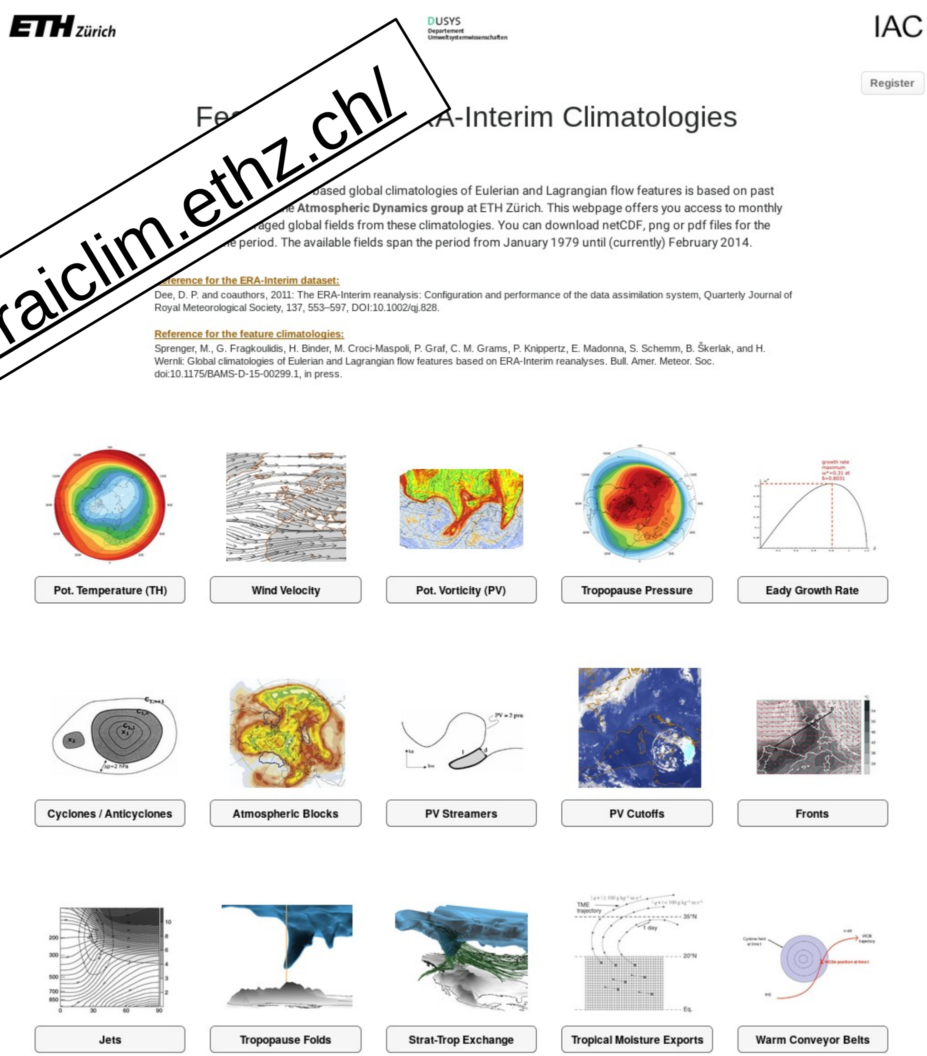
____ ERAI WCB frequency in September/October


WCB frequency anomaly during NAWDEX

Challenge: be in the right spot at the right time

Publicly available data set of objectively identified weather systems (Sprenger et al. 2017, BAMS)

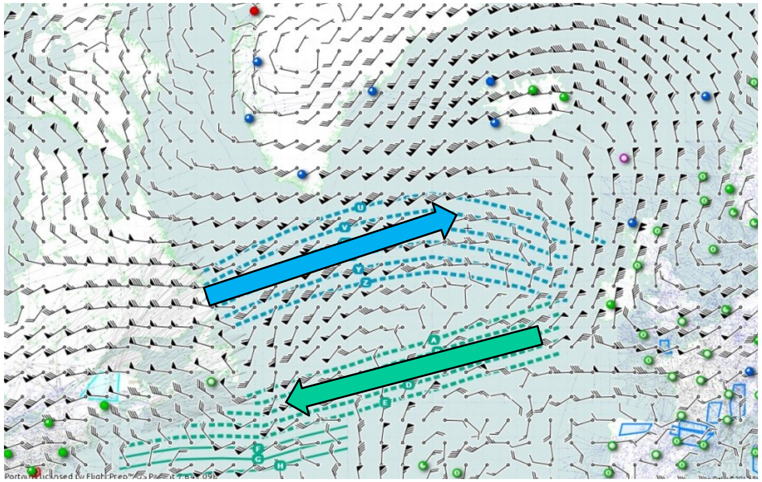
http://eraiclim.ethz.ch/



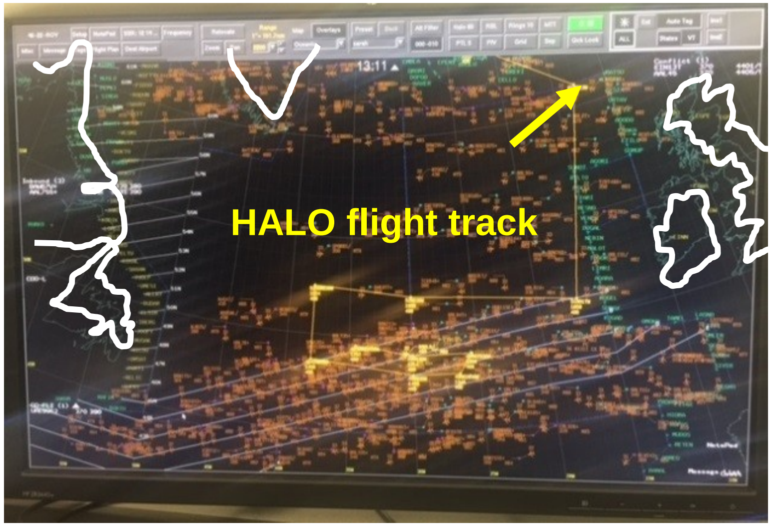
Challenge: be in the right spot at the right time

- Huge **operation area**: the entire North Atlantic (north of 35°N) and Northern and Central Europe
  - multiple ATC authorities require flight plans announced 2-3 days in advance
  - peaks of east- and westbound trans-Atlantic traffic alternate: North Atlantic Tracks (NATs), between altitudes of 9 and 12 km
  - Little/no radar coverage

- NAWDEX research flights:
  - in regions of high winds and clouds
  - release dropsondes
  - height changes
  - coordination of up to three aircraft
  - coordination with satellite overpasses
  - observe situations with high forecast uncertainty

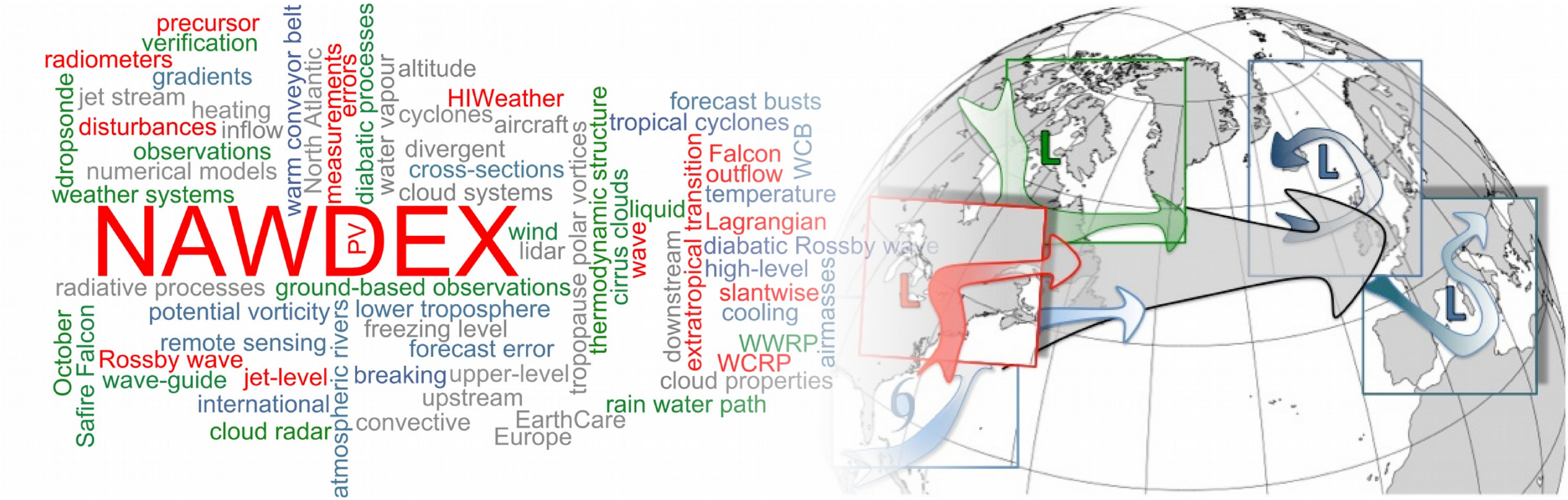


Example of NAT tracks on 8 July 2015. East- and westbound traffic, wind barbs at 300 hPa, skyvector.com



ATC view on a HALO flight track on top of North Atlantic air traffic routes.

Challenge: be in the right spot at the right time

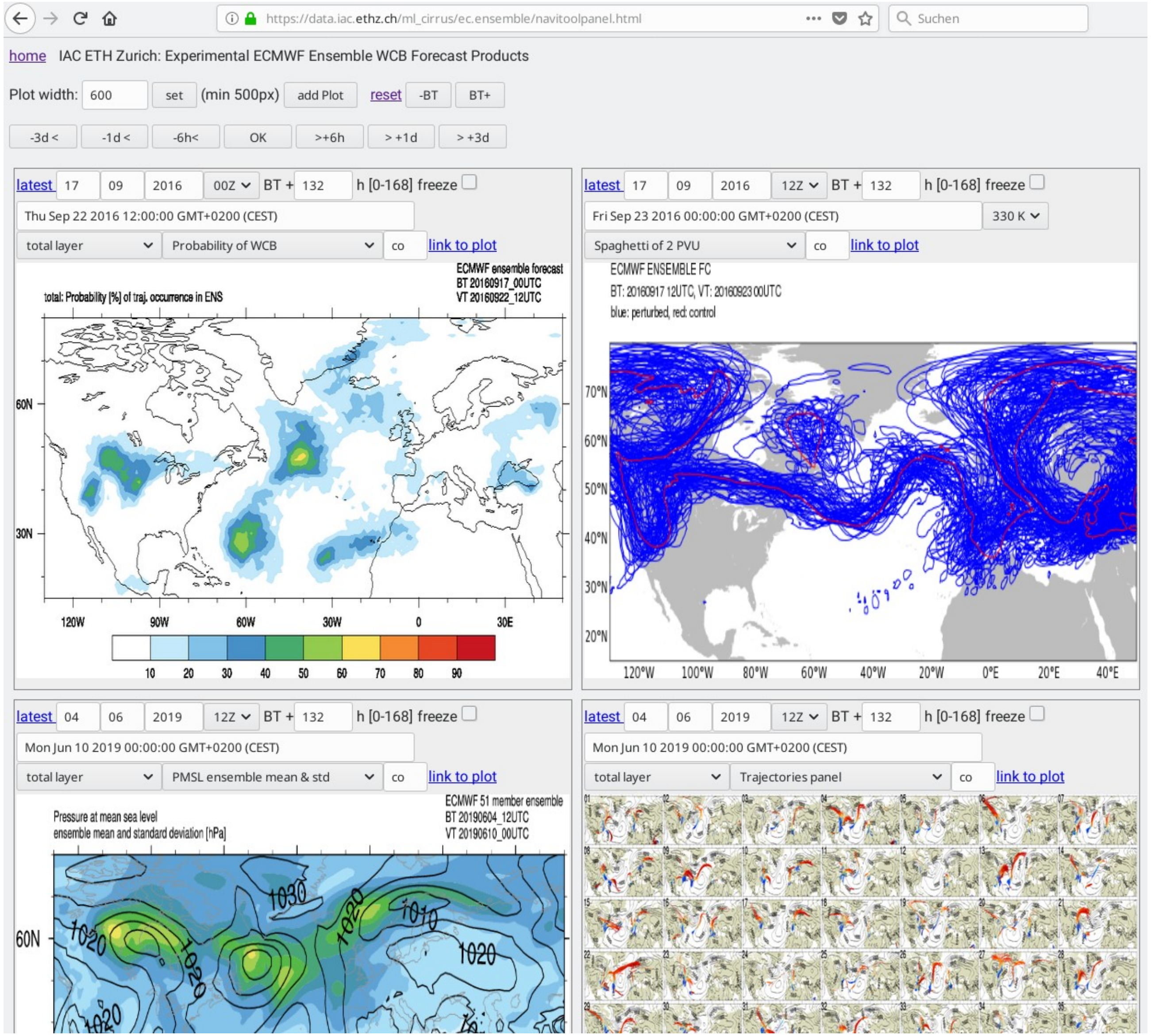


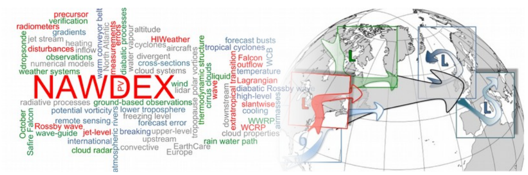
Demonstration of flight planning for IOP2 21 Sep 2016

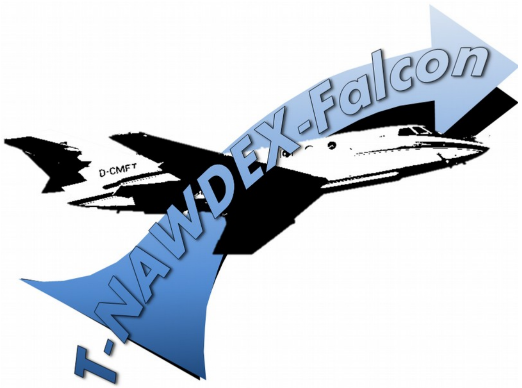
http://nawdex.ethz.ch/

https://data.iac.ethz.ch/nawdex/index.php
(restricted access)

Challenge: be in the right spot at the right time

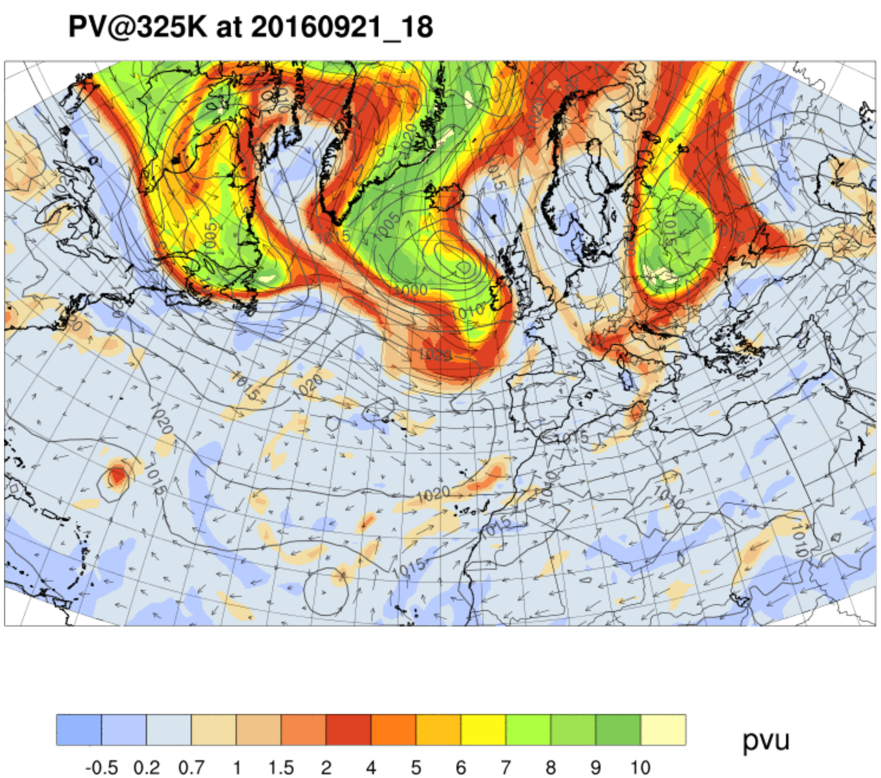


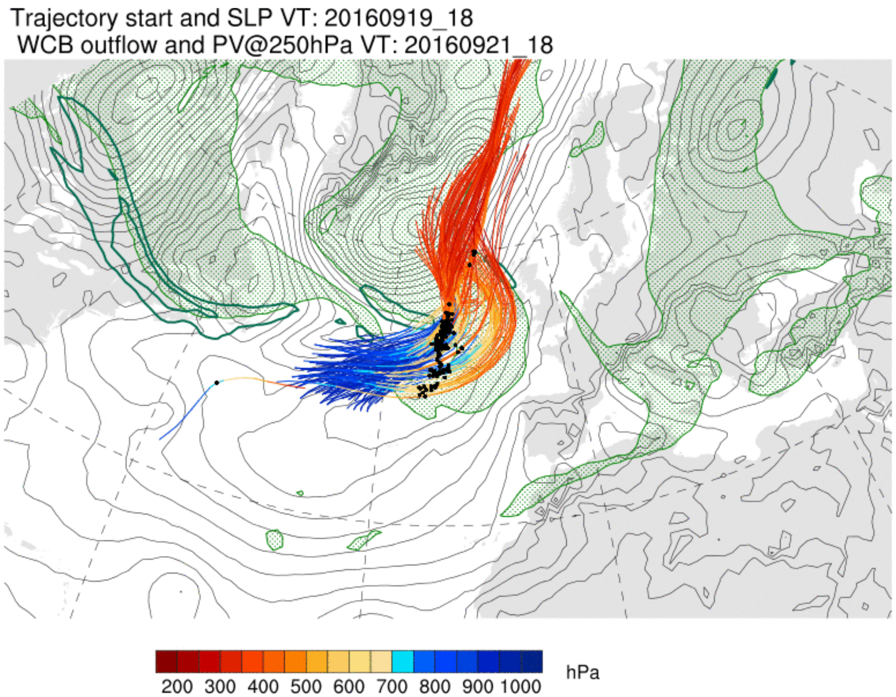




Challenge: be in the right spot at the right time

3-5 days before mission:
- Monitoring of evolution in **hres** and confirmation with **ensemble**





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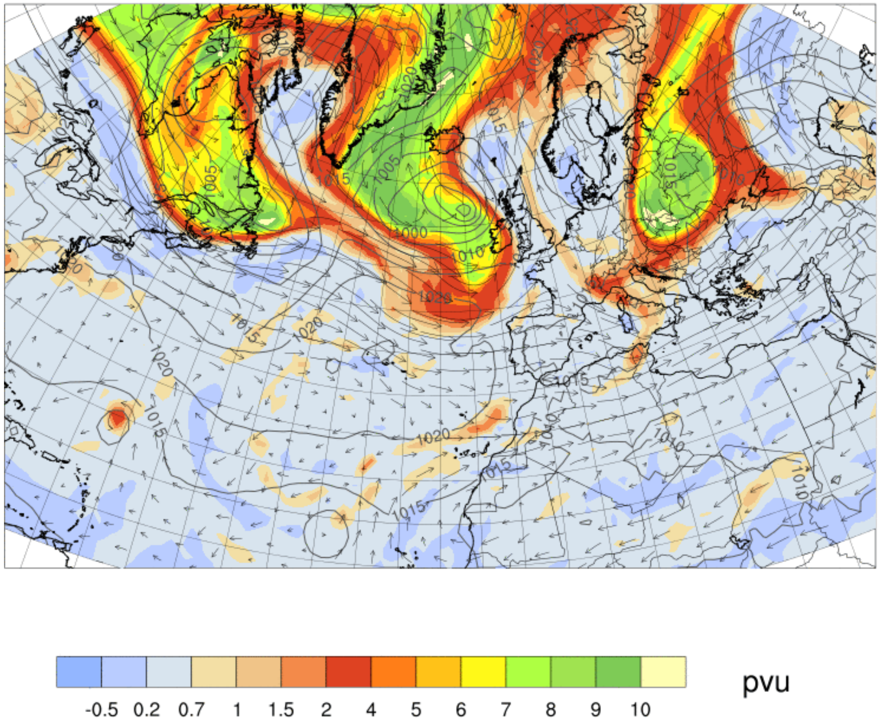
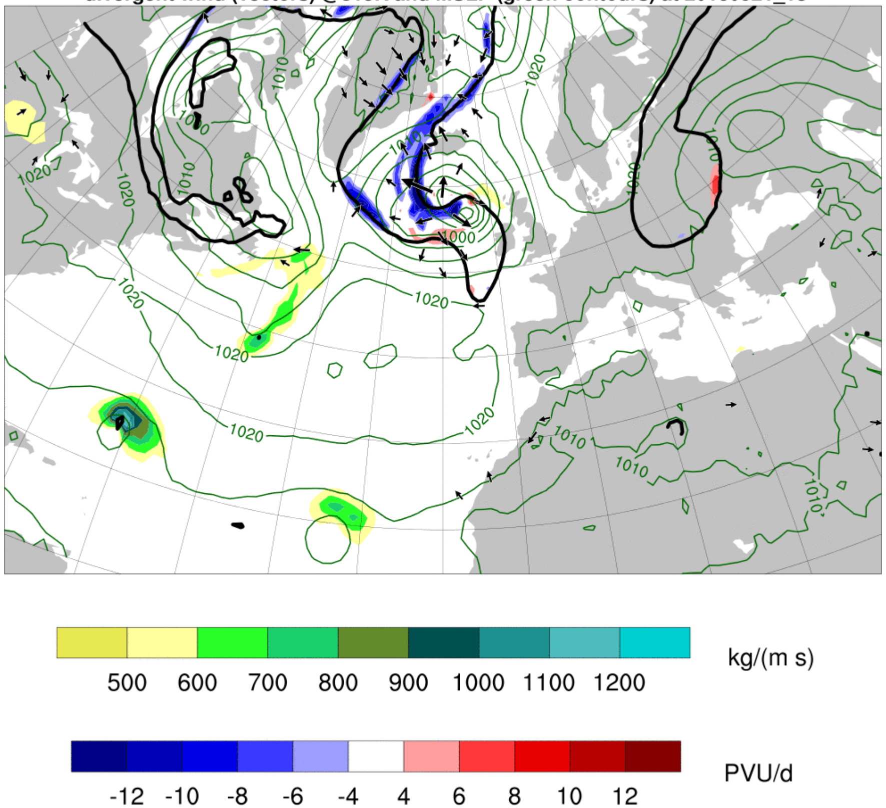
PV@325K at 20160921_18



2 PVU (black contour), PV advection through divergent wind (shading), divergent wind (vectors) @315K and MSLP (green contours) at 20160921_18



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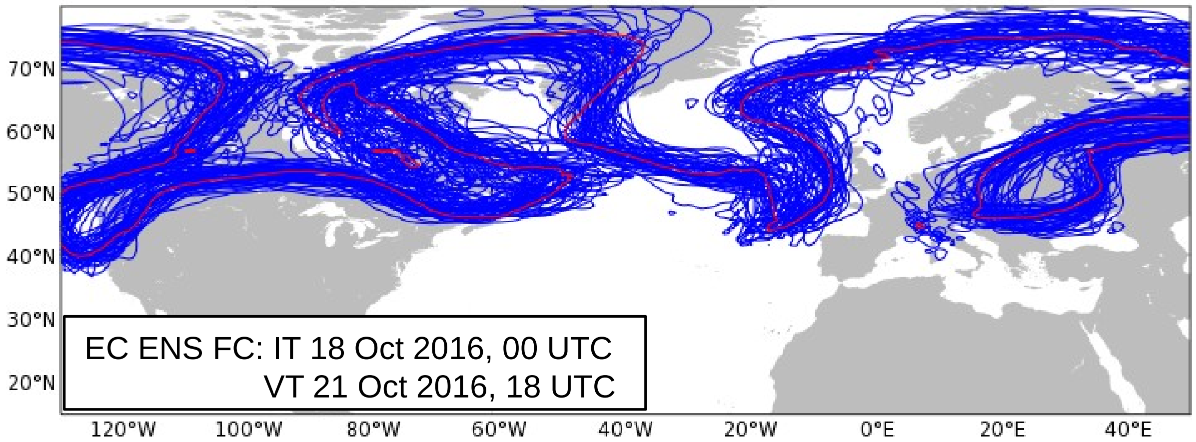
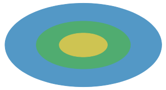
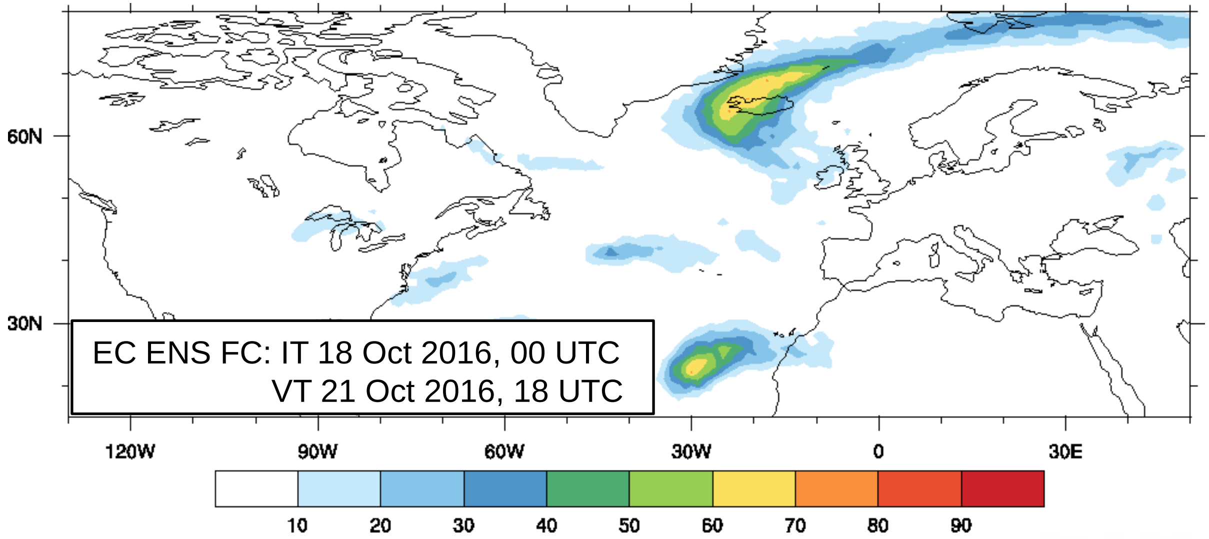
PF

CF





Ensemble
WCB probability

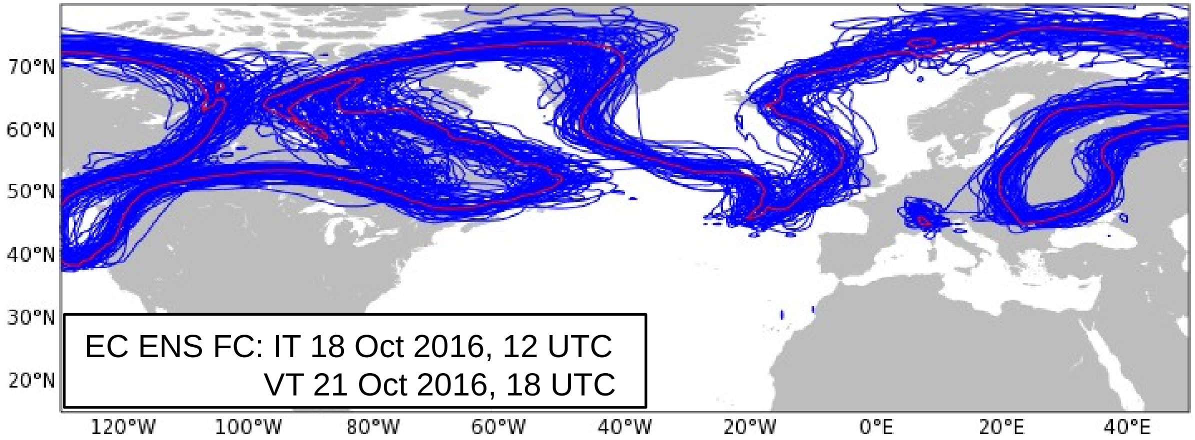


Challenge: be in the right spot at the right time

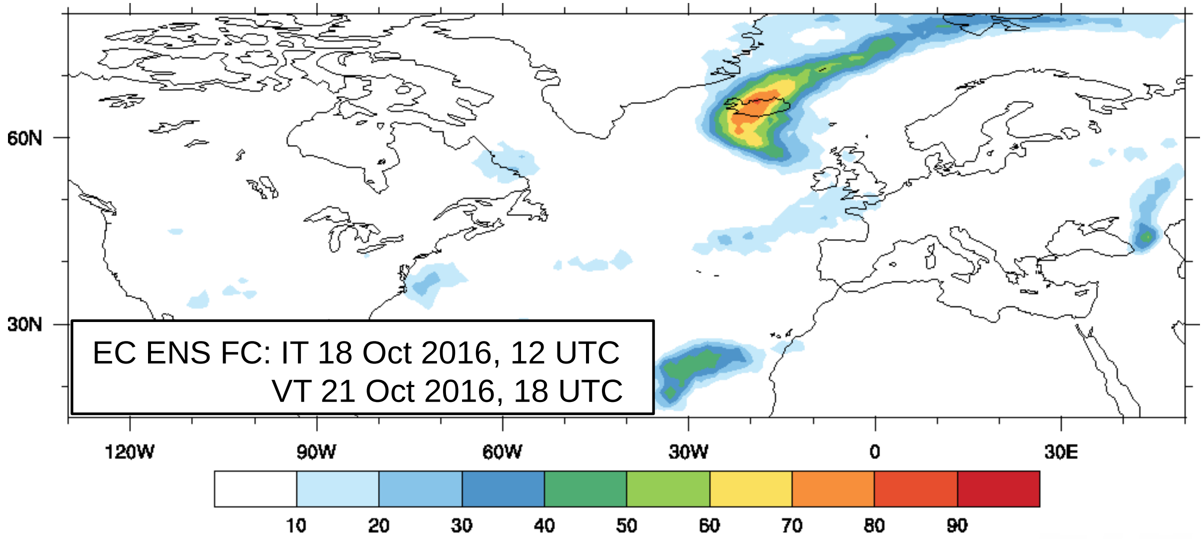
2 days before mission:
- Monitoring of model consistency
- Definite decision about mission, planning of tentative **flight track** and t**imes**

PF

CF



Ensemble WCB probability



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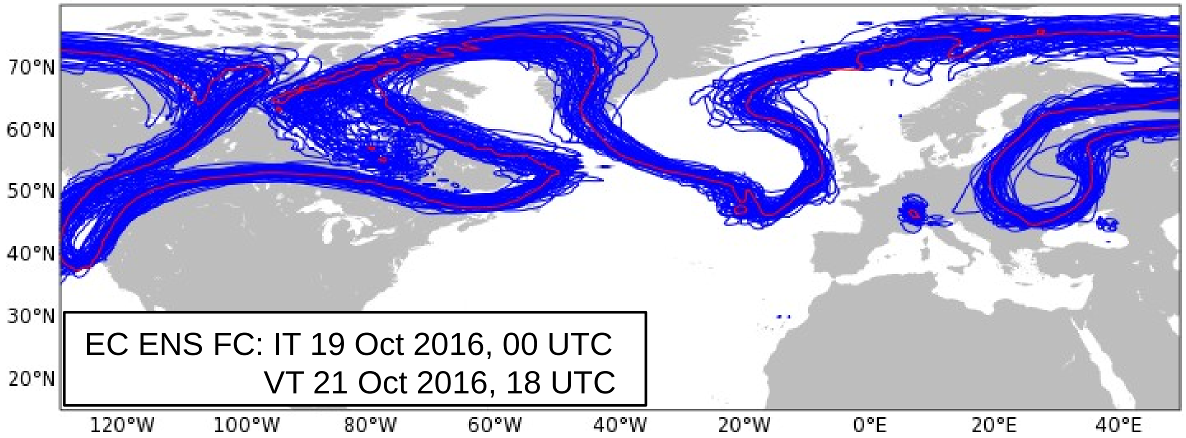

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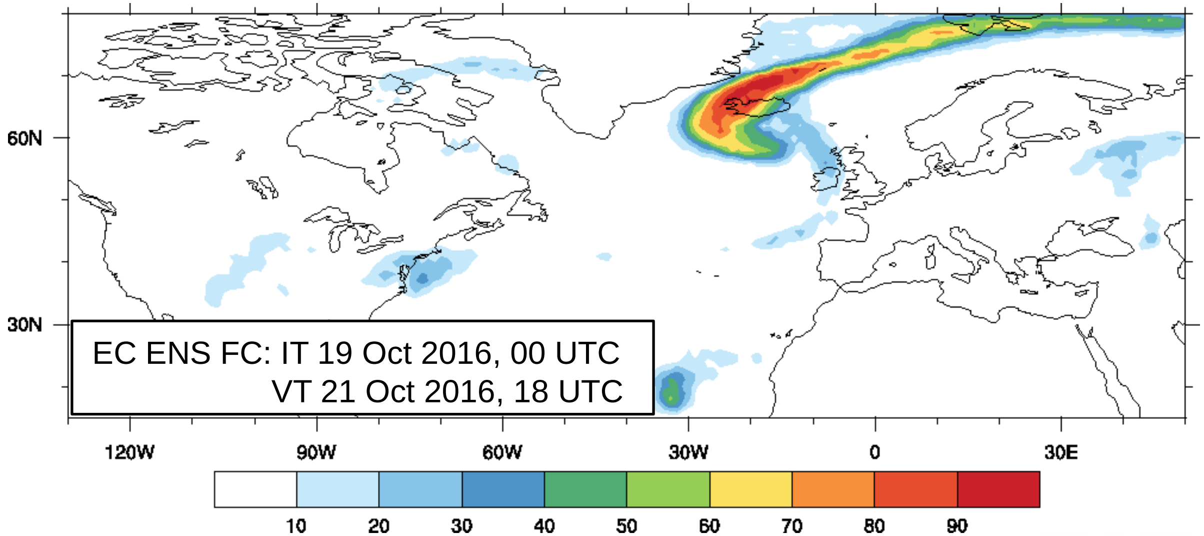

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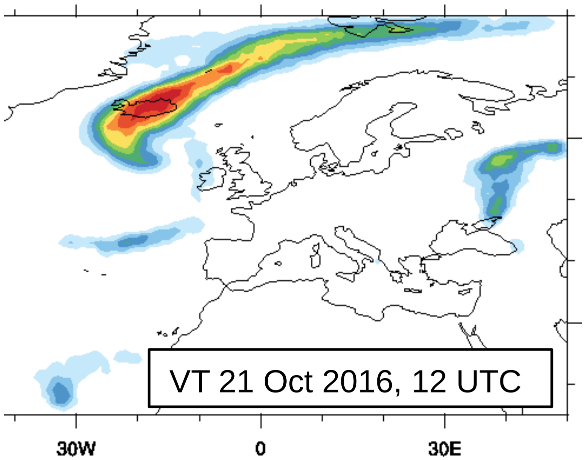
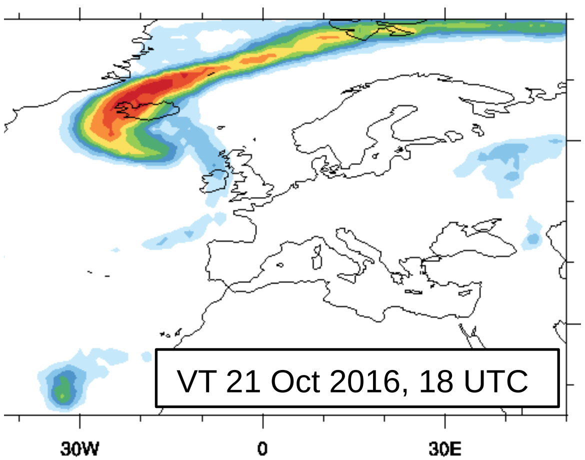
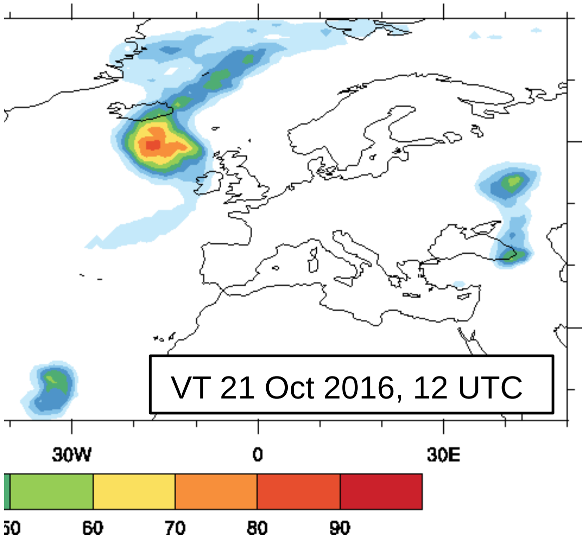
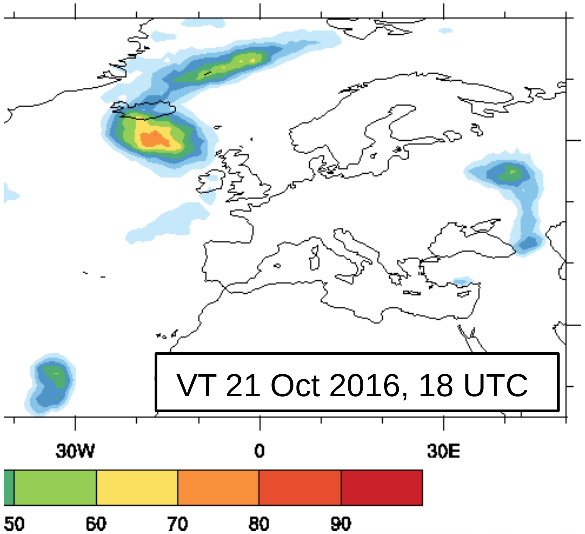


WCB outflow





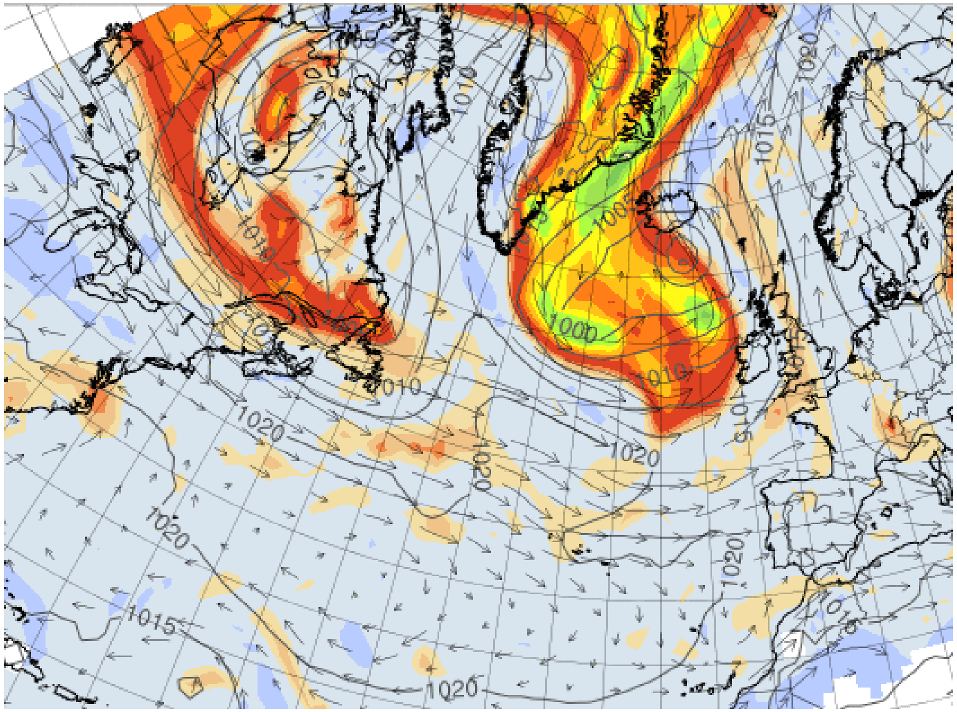
WCB ascent

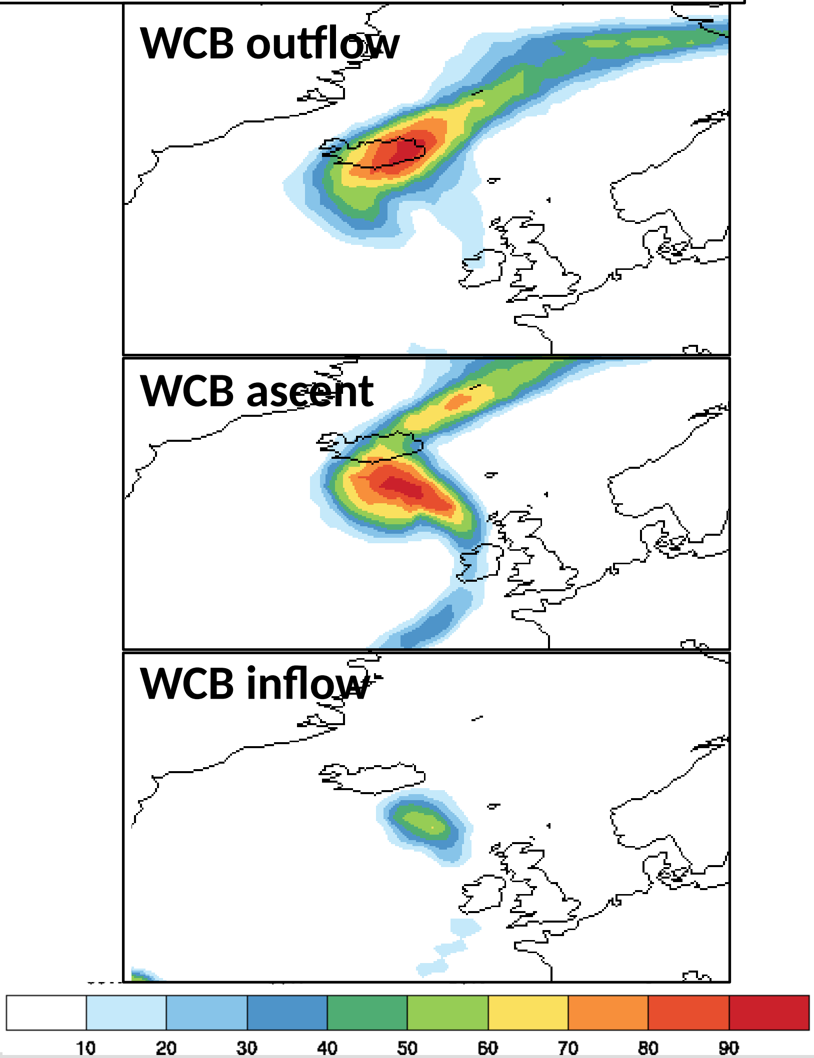


Challenge: be in the right spot at the right time

1 days before mission:
- Monitoring of model consistentcy
- Finalisation of flight track: **Location, times & levels**

PV@315K at 20160921_15





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1 days before mission:
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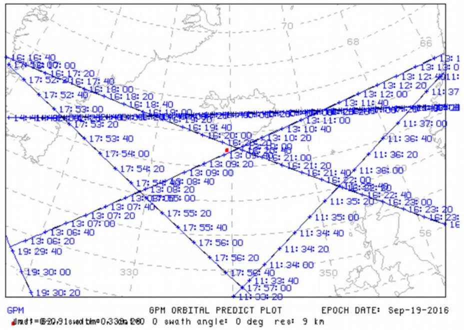
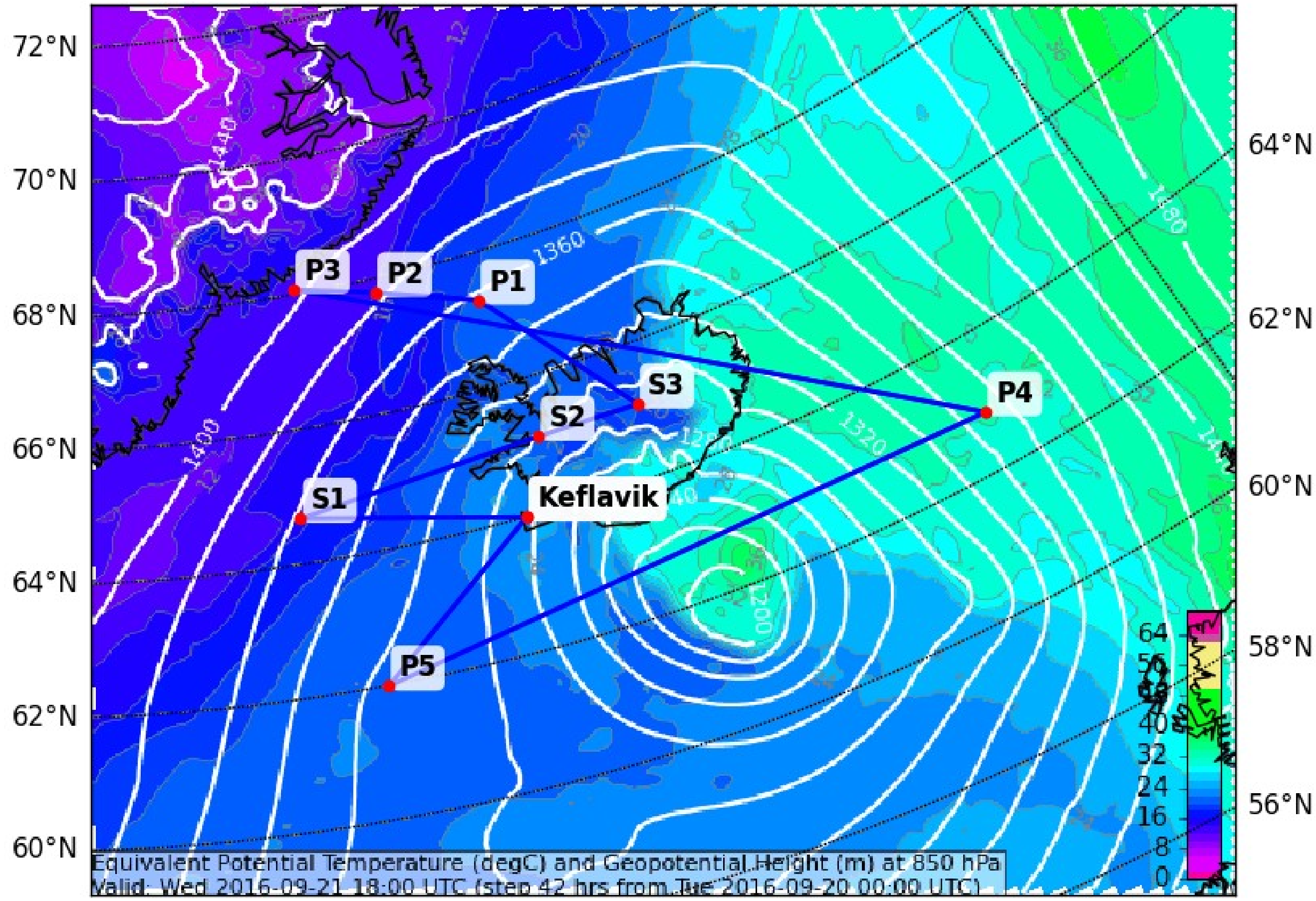
HALO
- Coordinated leg with Falcon, 5 dropsondes, sampling TP structure
- Triangle south of Iceland to sample WCB ascent region / warm sector 8 sondes
- GPM satellite overpass over Iceland





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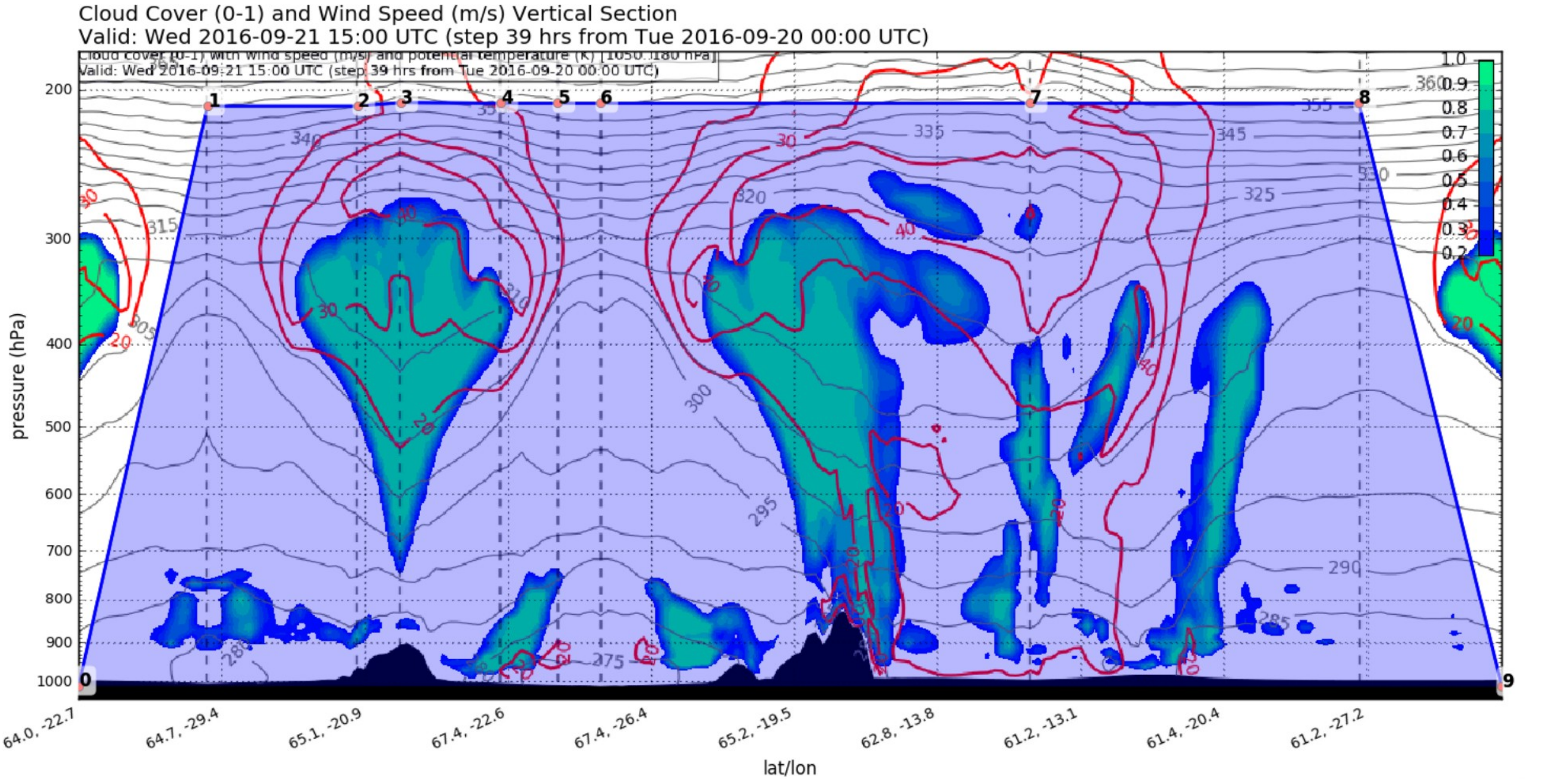

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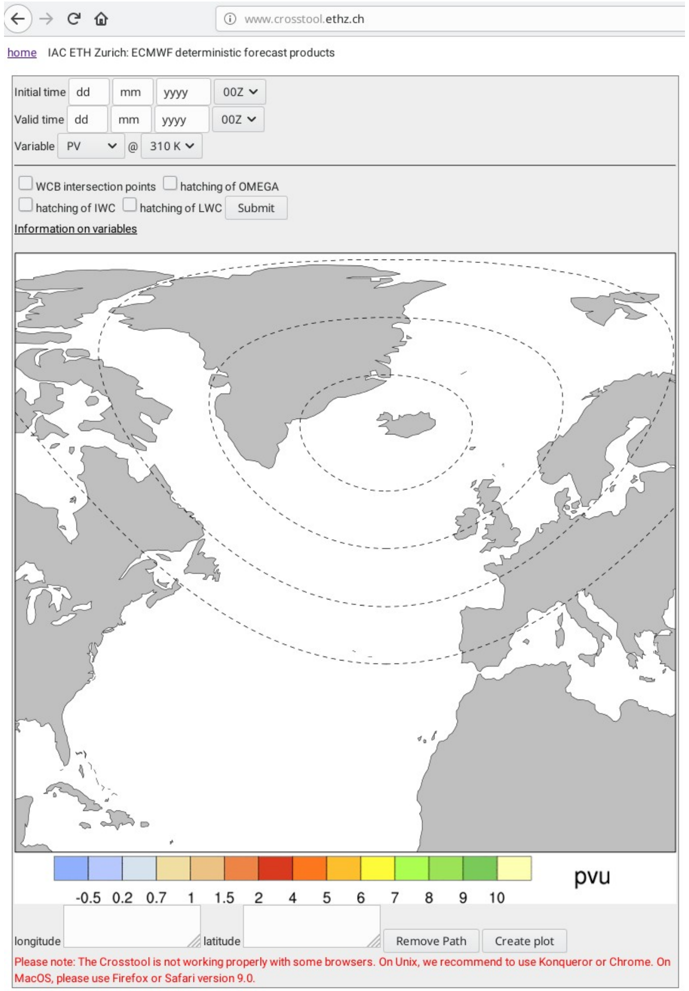
Web-based interactive cross-section tool



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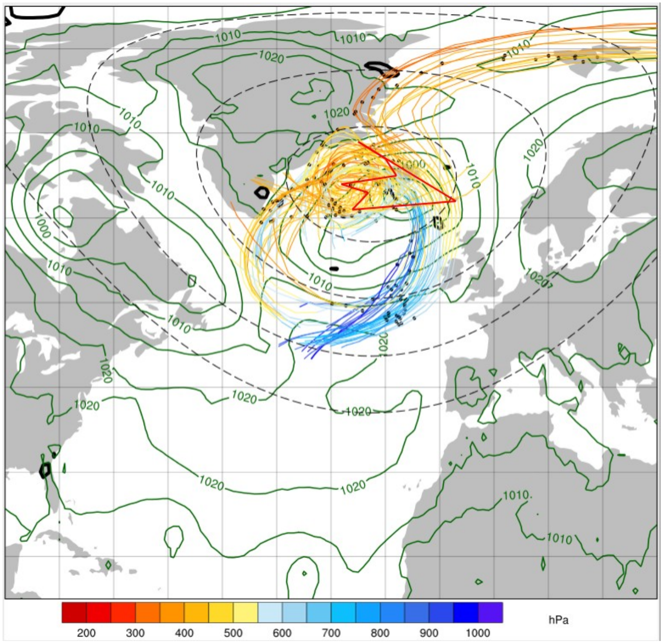
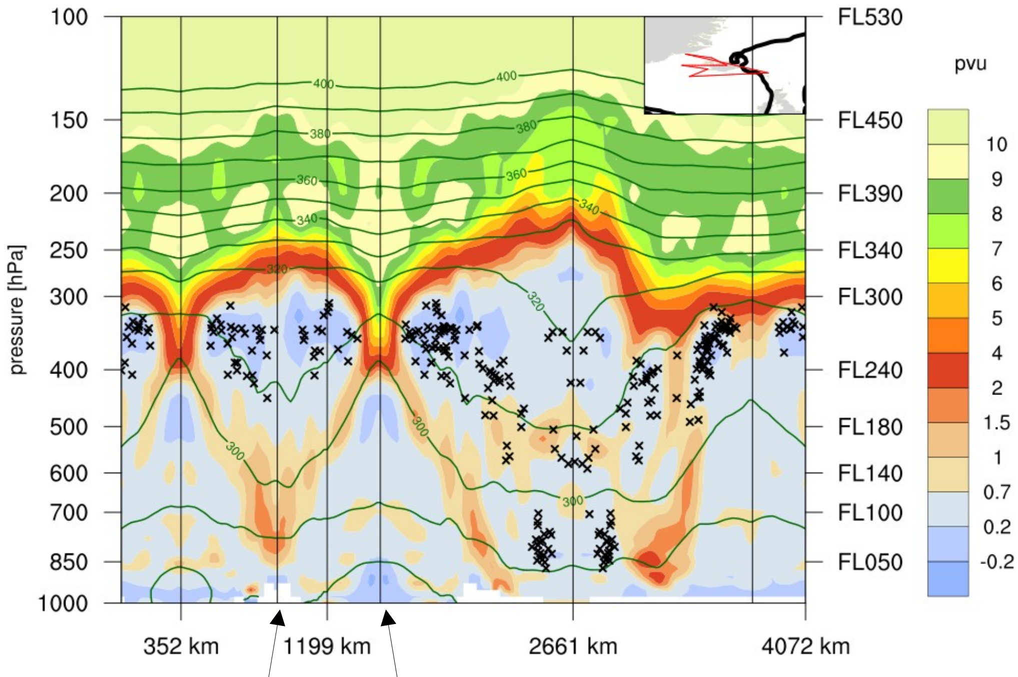
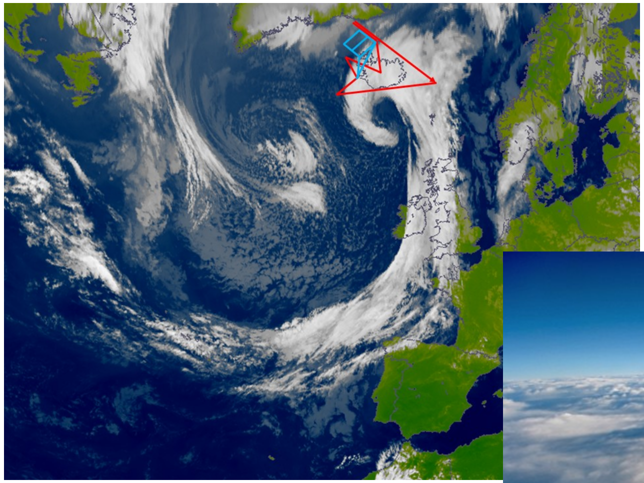
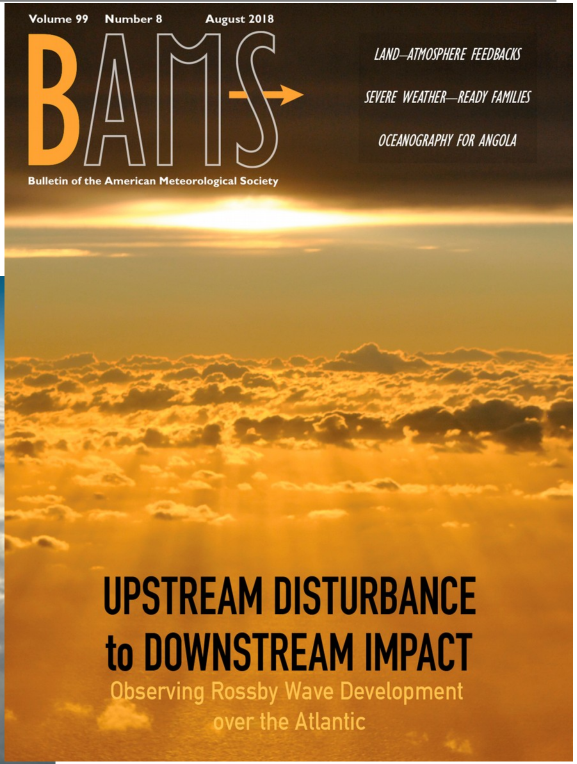




Coordinated with DLR Falcon

Successful mission

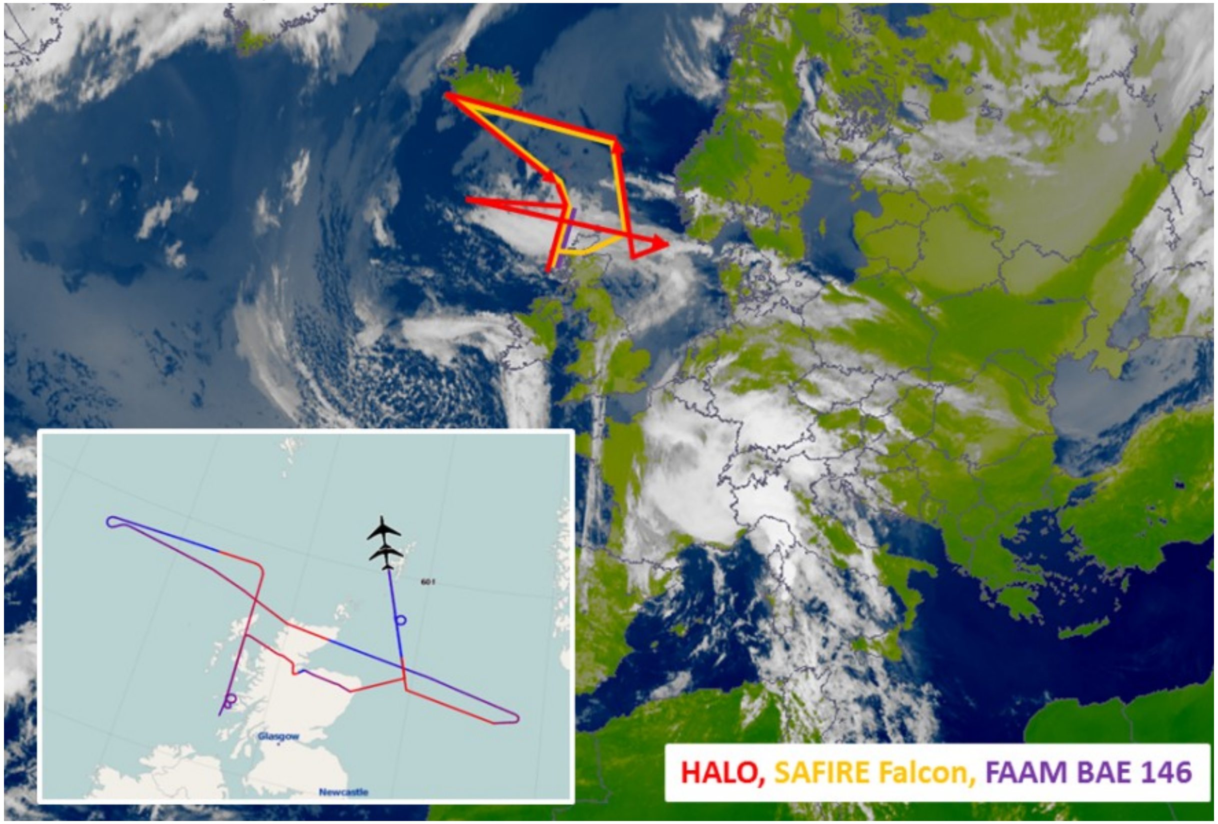




More succesful missions

Aircraft Coordination:

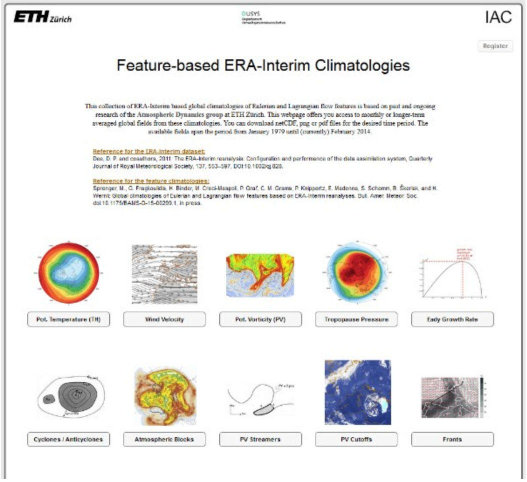
Overview of a coordinated flight of HALO, SAFIRE Falcon and FAAM BAE 146 on 14 Oct 2016



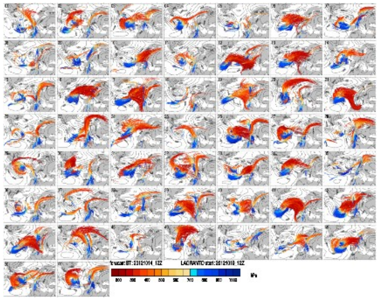
- multiple coordinated flights: two or more aircraft flying the same flight leg
- 16 coordinated flight legs with an accumulated flight time of 14.5 h (10,000 km)
- On two occasions: coordination of three aircraft (FAAM BAe, HALO and SAFIRE)

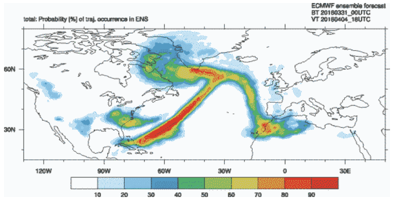
Summary

- Comprehensive catalogue of feature-based ERA-I climatologies to plan timing of field campaigns from a climatological perspective http://eraiclim.ethz.ch/



- LAGRANTO trajectory model applied to ECMWF ensemble forecast provides invaluable information when planning days ahead http://lagranto.ethz.ch/





- Specific forecast products enable flight planning for atmospheric measurement campaigns http://nawdex.ethz.ch/

A. Potential Vorticity

Potential vorticity

$$PV = \frac{1}{\rho}\vec{\eta}\cdot\nabla\Theta$$

$$\boxed{PV = \frac{1}{\rho}\eta\frac{\partial\Theta}{\partial z}}$$

unit: 1PVU = 10^{-6} K m^2 kg^{-1} s^{-1}

$$\eta = f + k \cdot \nabla \times v_h$$

Absolute vorticity / horizontal flow

Vertical stratification of the atmosphere/stability

$$\frac{dPV}{dt} = \frac{1}{\rho}\vec{\eta}\cdot\nabla\dot{\Theta} + \frac{1}{\rho}(\nabla\times\vec{F})\cdot\nabla\Theta$$

Total change in PV — diabatic PV modification — frictional processes

- PV is conserved under adiabatic frictionless flow (**conservation principle**)

→ use PV as air mass tracer on isentropic surfaces to identify PV signatures of weather systems

- PV can be inverted given a balance condition and boundary conditions (**inversion principle**)

→ derive wind, T, p field from a given PV distribution