Rapid ascents embedded in a WCB observed and modeled at km-scale resolution

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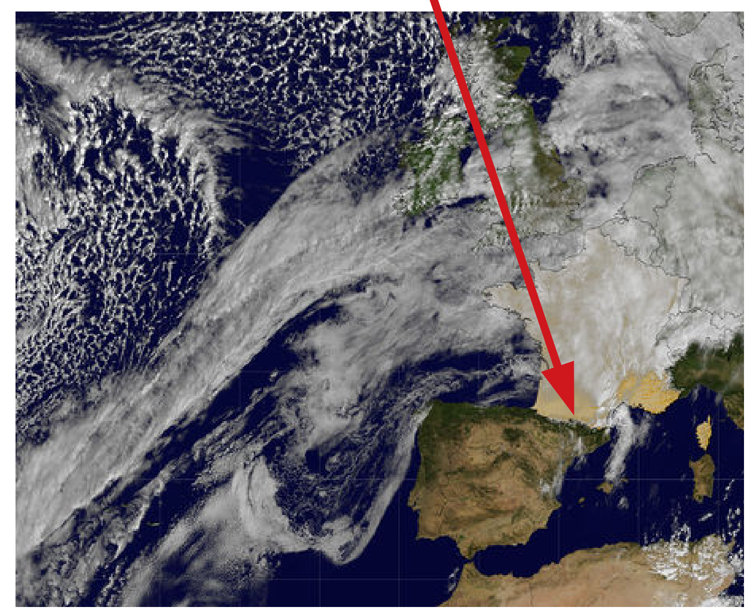
Live from Toulouse!



ECMWF Virtual Workshop
Warm Conveyor Belts – a challenge to forecasting
10-12 March 2020

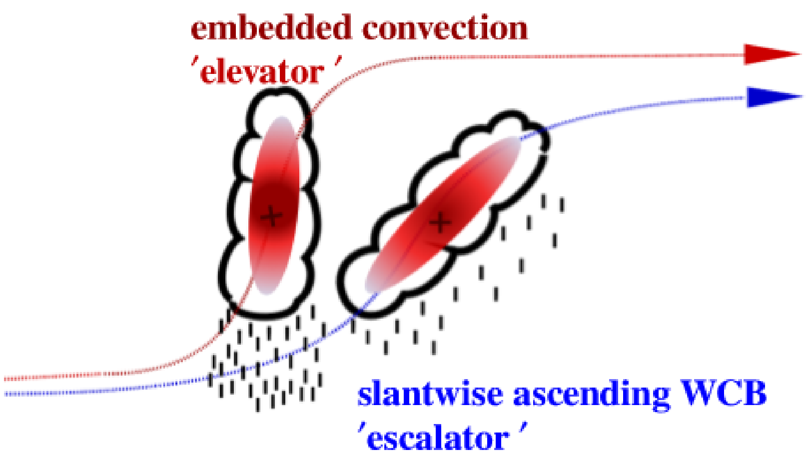
Motivation

WCBs are **continosusly rising** air masses which typically ascend 600 hPa in 48 h

(Browning, 1986; Wernli and Davies, 1997; Madonna et al., 2014)

Recent model studies highlight the occurrence of **rapid ascents** embedded in WCBs

(Rasp et al., 2016; Oertel et al., 2019; 2020)



Schematic by Oertel et al. (2019)

New opportunities at mesoscale

- **Observations** at km-scale resolution from NAWDEX field campaign
- **Simulations** at km-scale resolution over large domains thanks to HPC

Here: "Stalactite" cyclone observed on Oct 2nd 2016 during NAWDEX IOP6

1) What are the WCB characteristics for this case study?

2) What are the processes leading to fast WCB ascents?

Simulation and observations

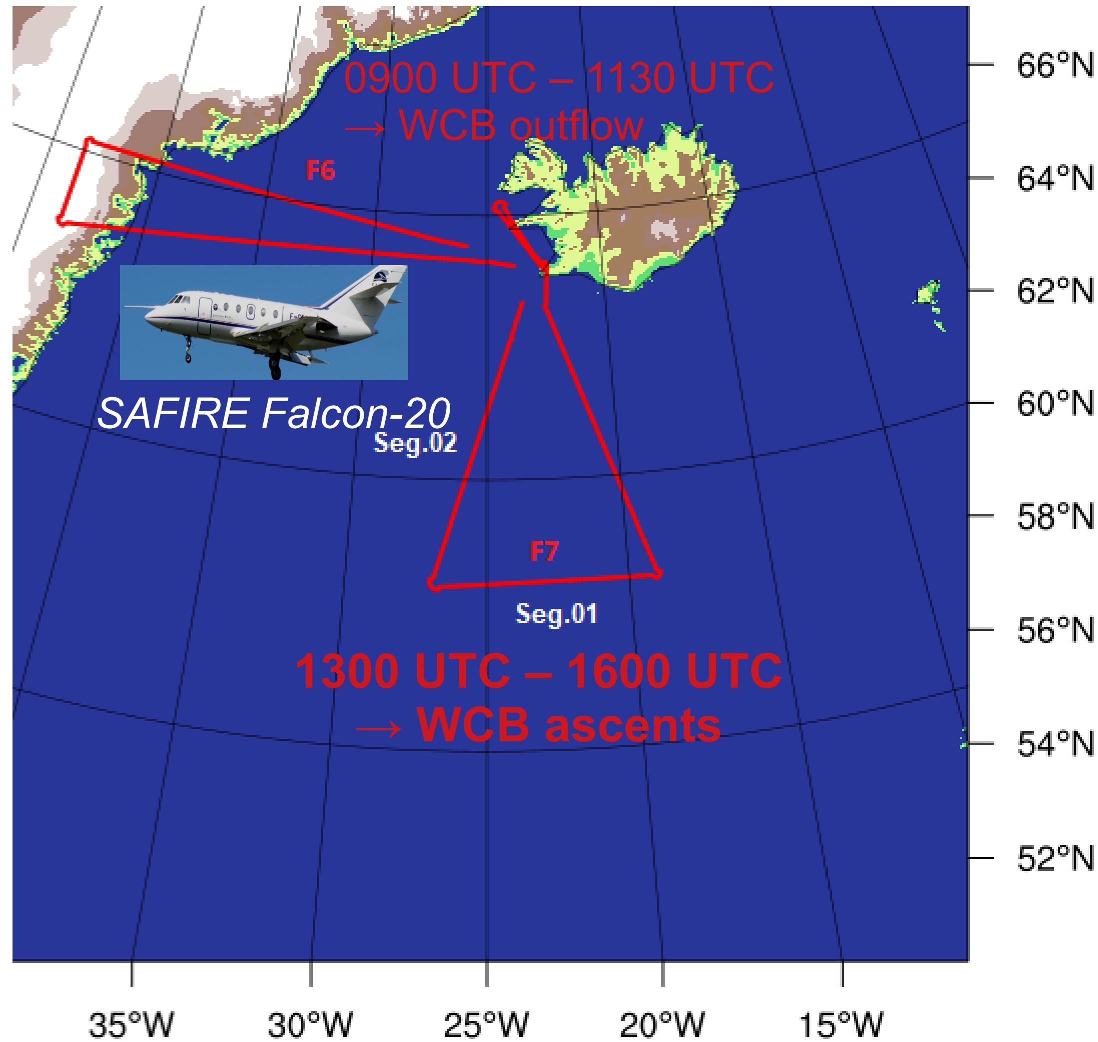
Meso-NH mesoscale non-hydrostatic model **simulation**

- Δx=2.5 km
  → **convection permitting**
- Init 00 UTC, 2 Oct 2016; t=36h
- IC+LBC ECMWF analyses

<u>Identification of rapid ascents</u>

→ **online Lagrangian trajectories**: from passive tracers at all grid point
(Gheusi and Stein 2002)

→ **objects**: connected grid points with vertical velocity above threshold
(Dauhut et al. 2016)



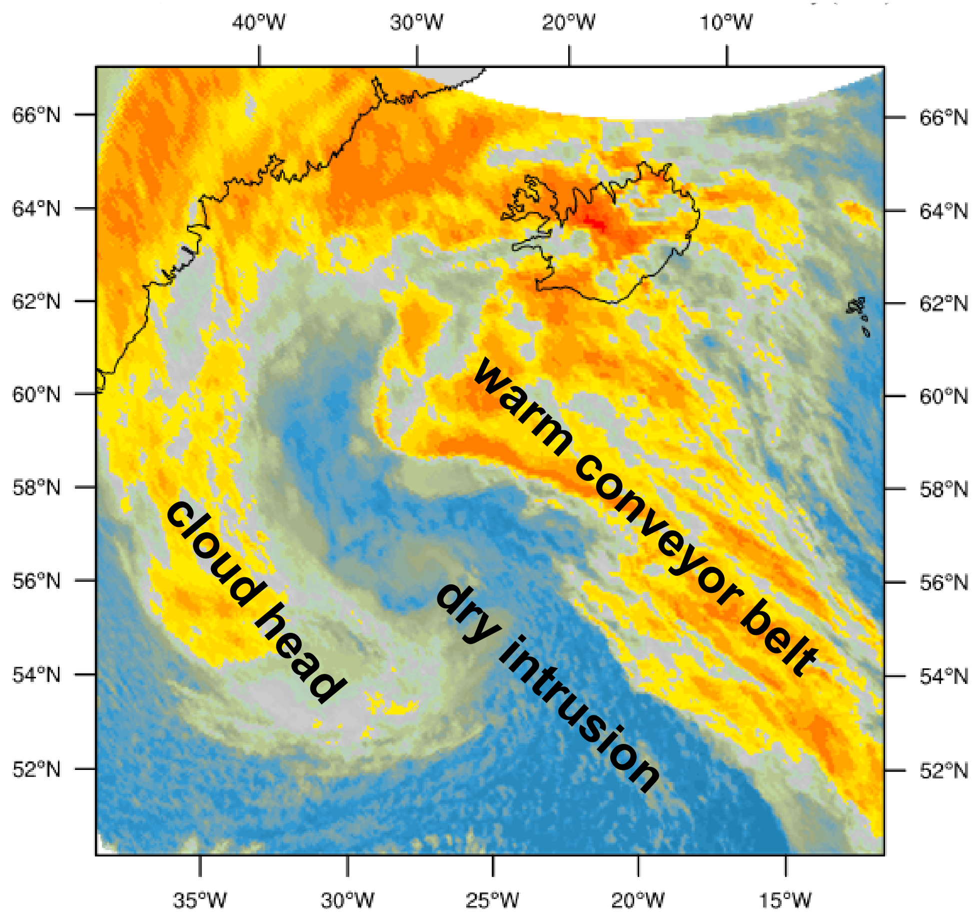
Domain of simulation

Observations (NAWDEX)

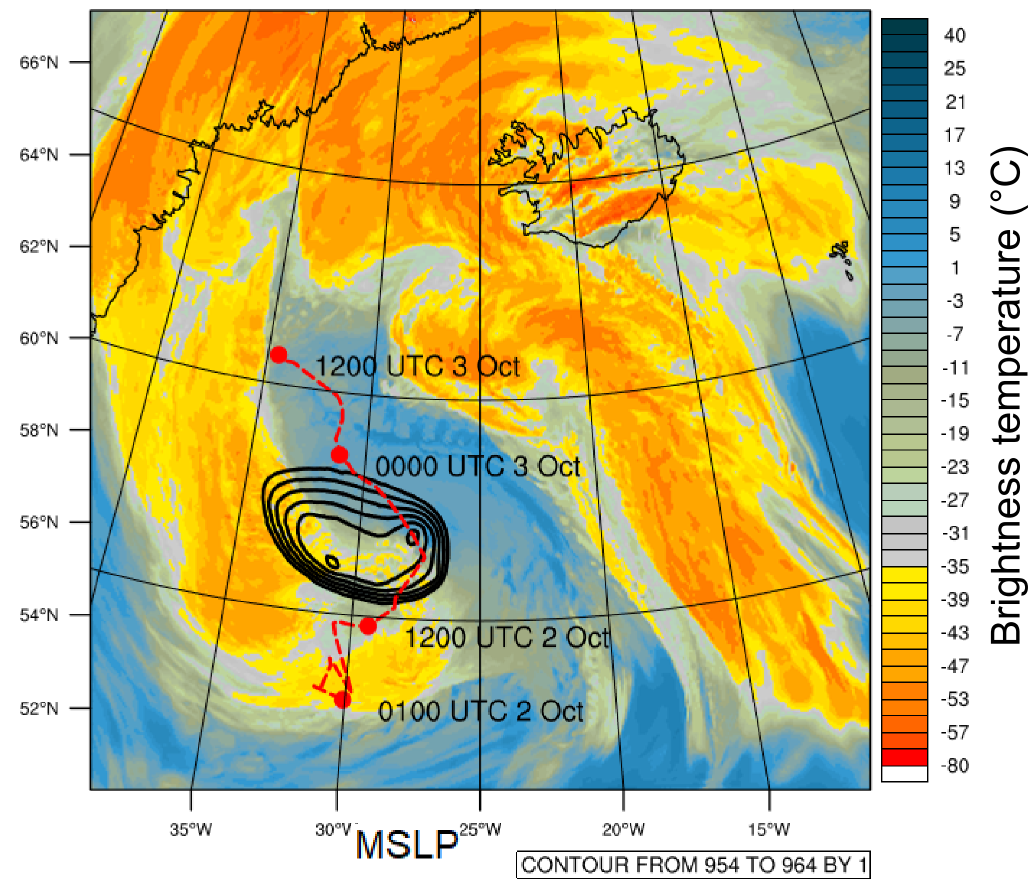
- RASTA cloud Doppler radar (95 GHz)
  Delanoë et al., 2007
- MSG satellite infrared images (10.8 μm)

Structure of the Stalactite cyclone

MSG infrared observation 16 UTC

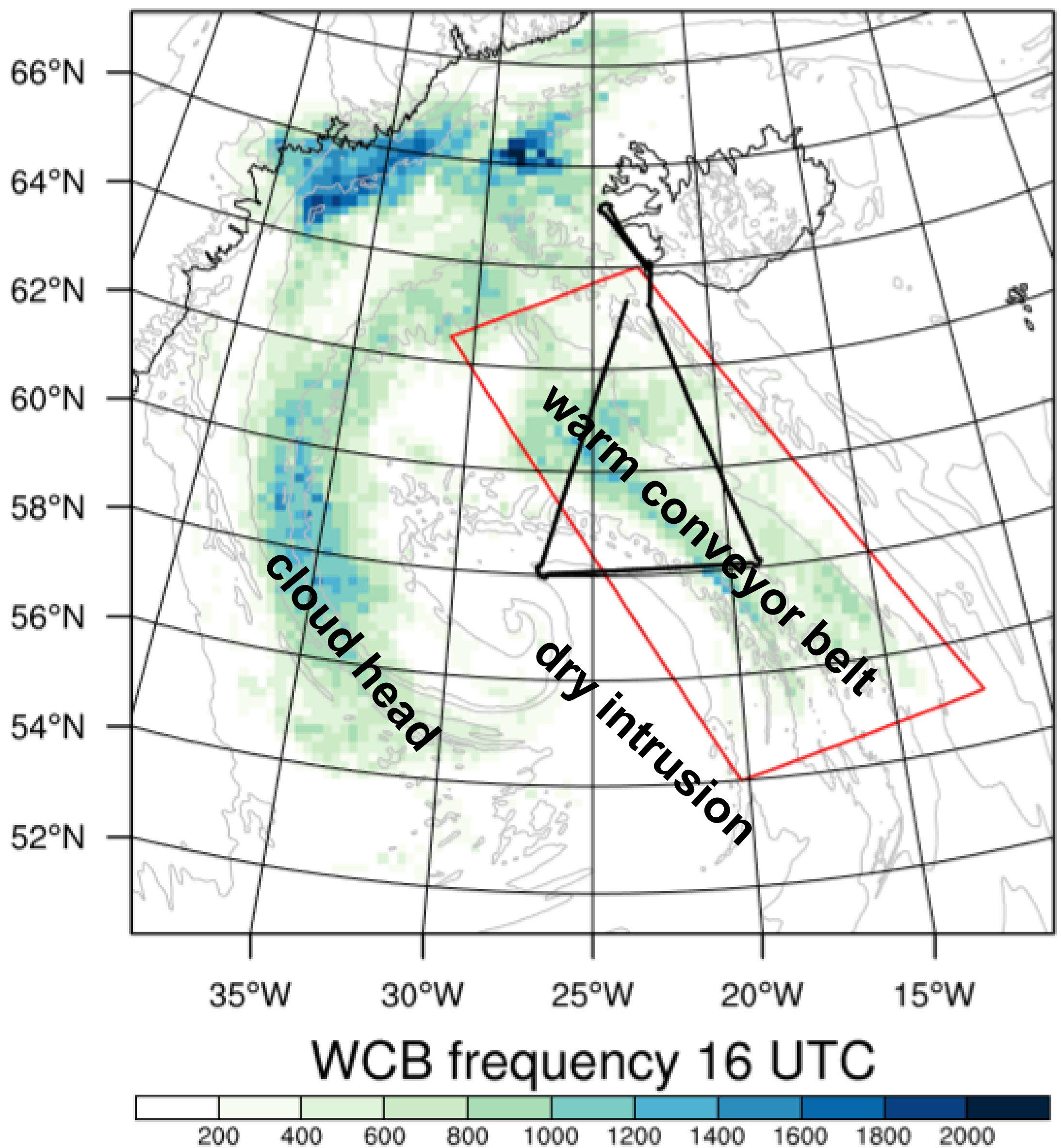


Meso-NH simulation 16 UTC (t+16)



WCB identification at 16 UTC

WCB
if pressure decrease
between 10–22 UTC
$\Delta P_{12h} \leq$ -150hPa
(~600 hPa in 48 h)



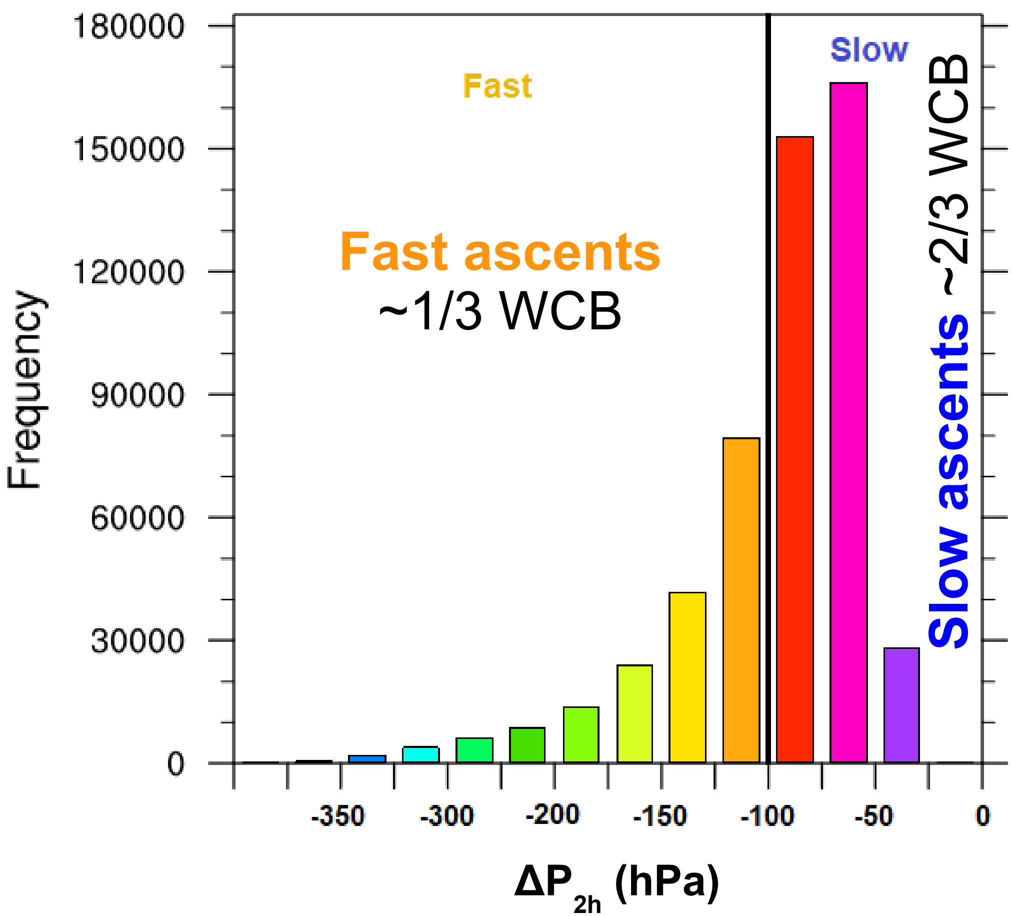
Contours: equivalent potential temperature at z~1 km (K)

Selection (box)
> 500 000 trajs

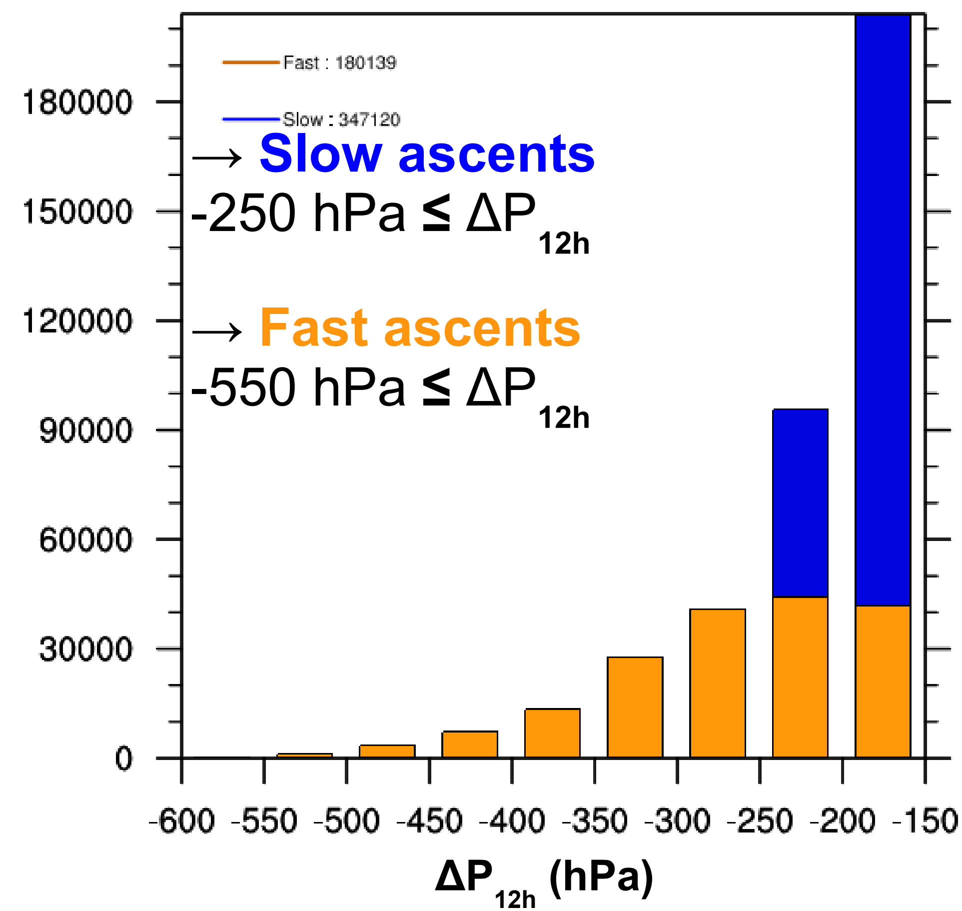
Two categories of WCB ascents

Fast ascents if **maximum** pressure decrease during 2-h segment $\mathbf{\Delta P_{2h} \leq -100hPa}$ (Oertel et al. 2019)

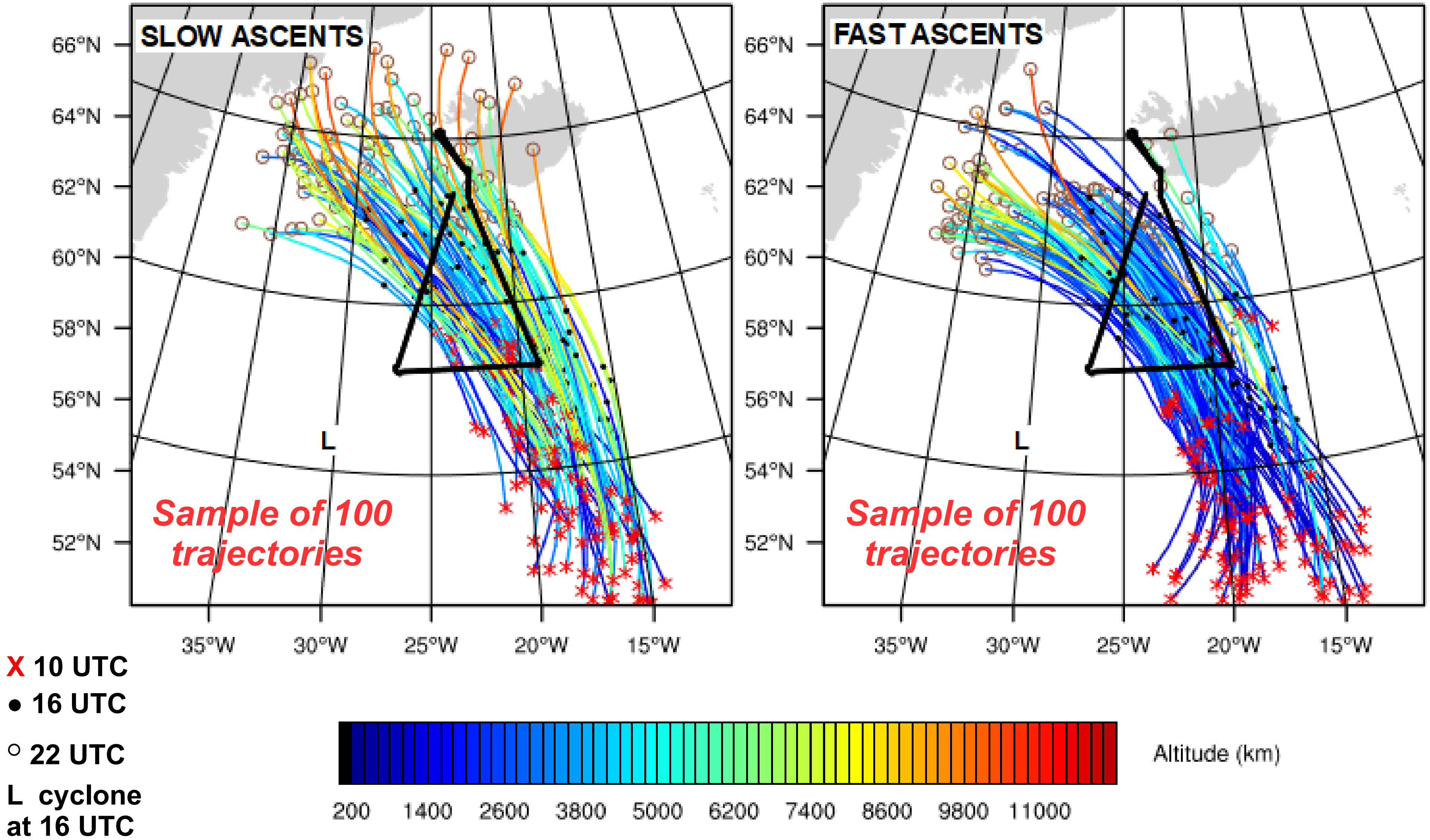
Maximum 2-h ascent



Total 12-h ascent

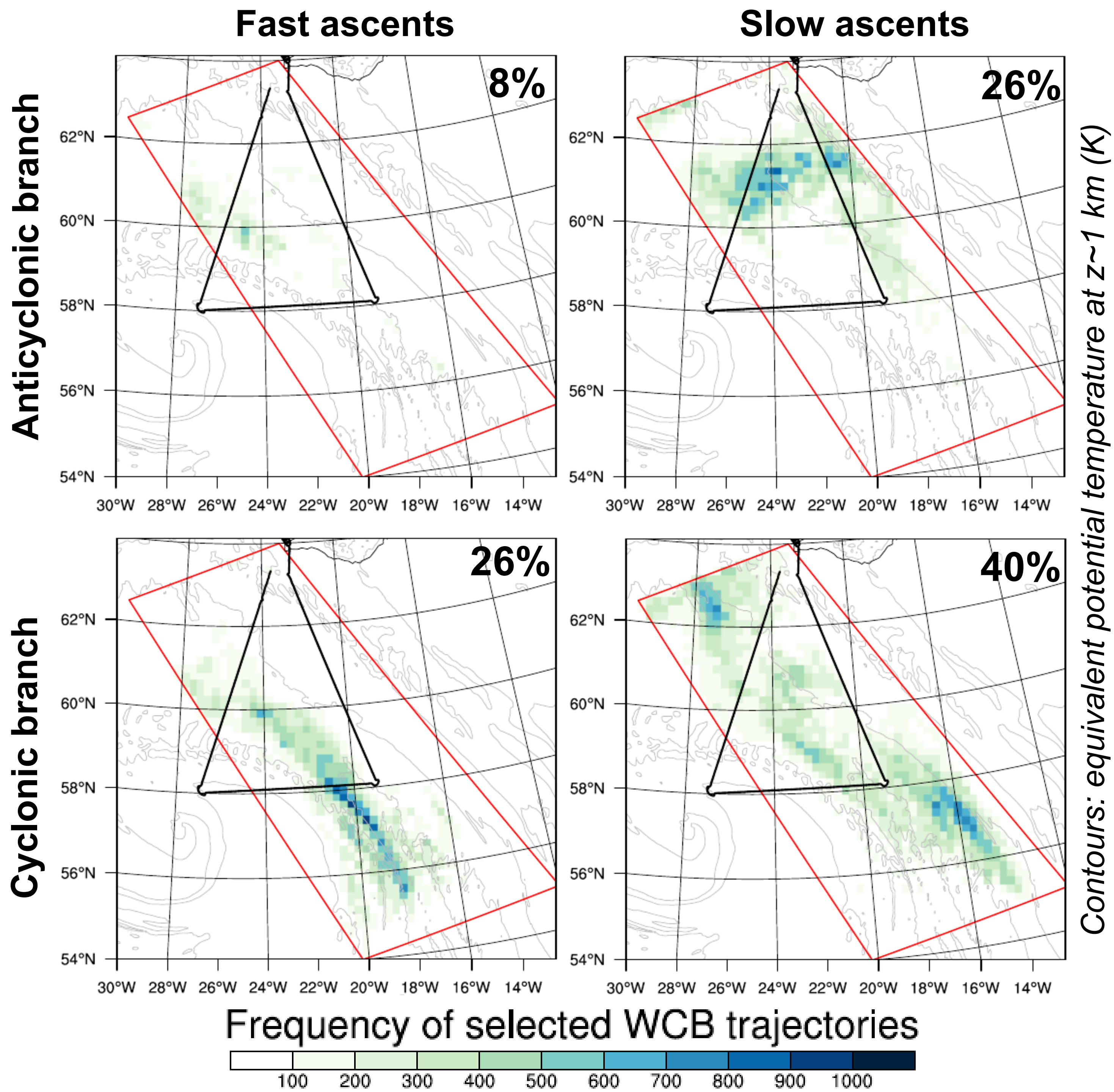


Trajectories between 10–22 UTC

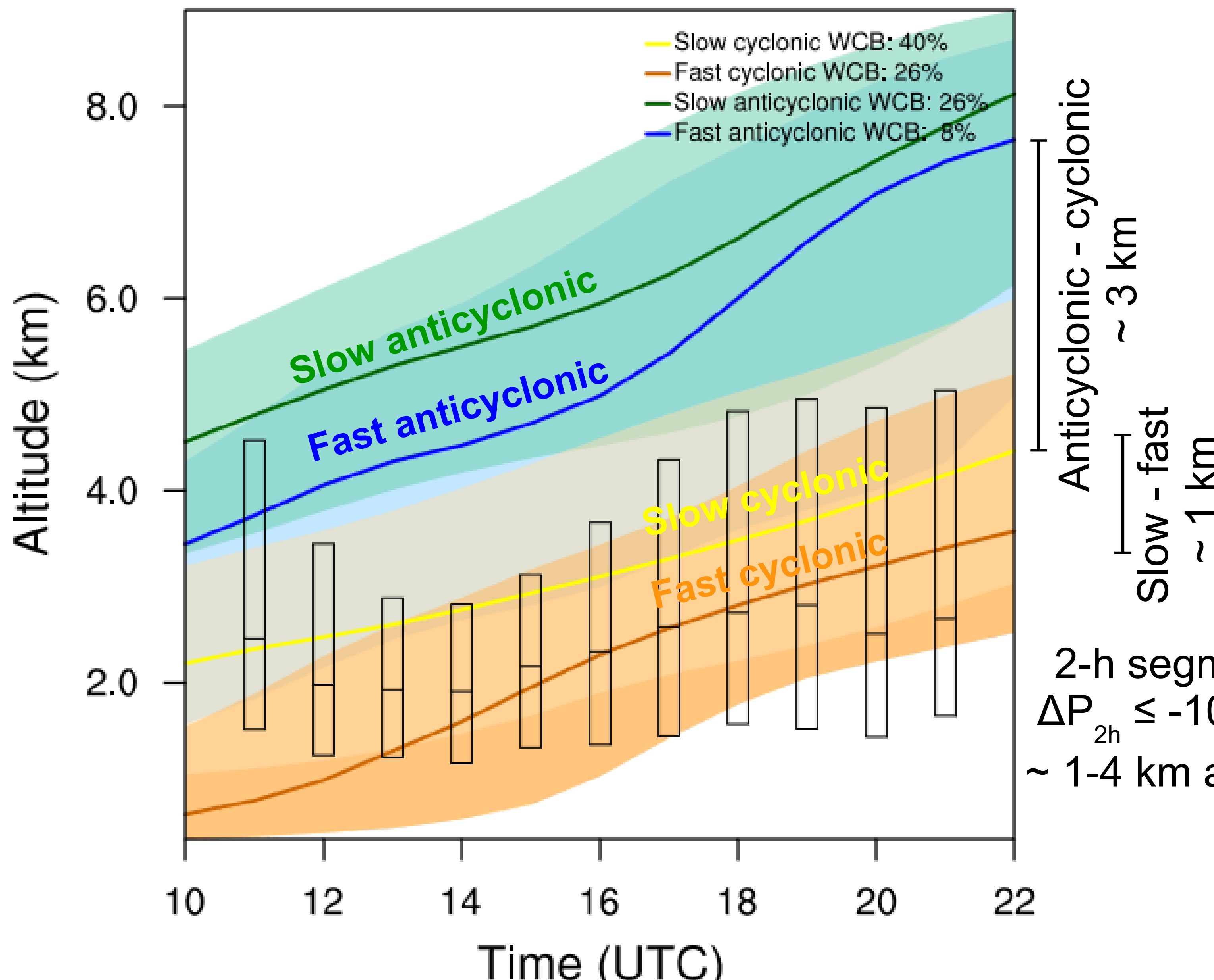


- ***Location of slow vs. fast ascents?***
- ***Altitude of slow vs. fast ascents?***
- ***Proportion of cyclonic vs. anticyclonic branch?***

Location of WCB ascents at 16 UTC

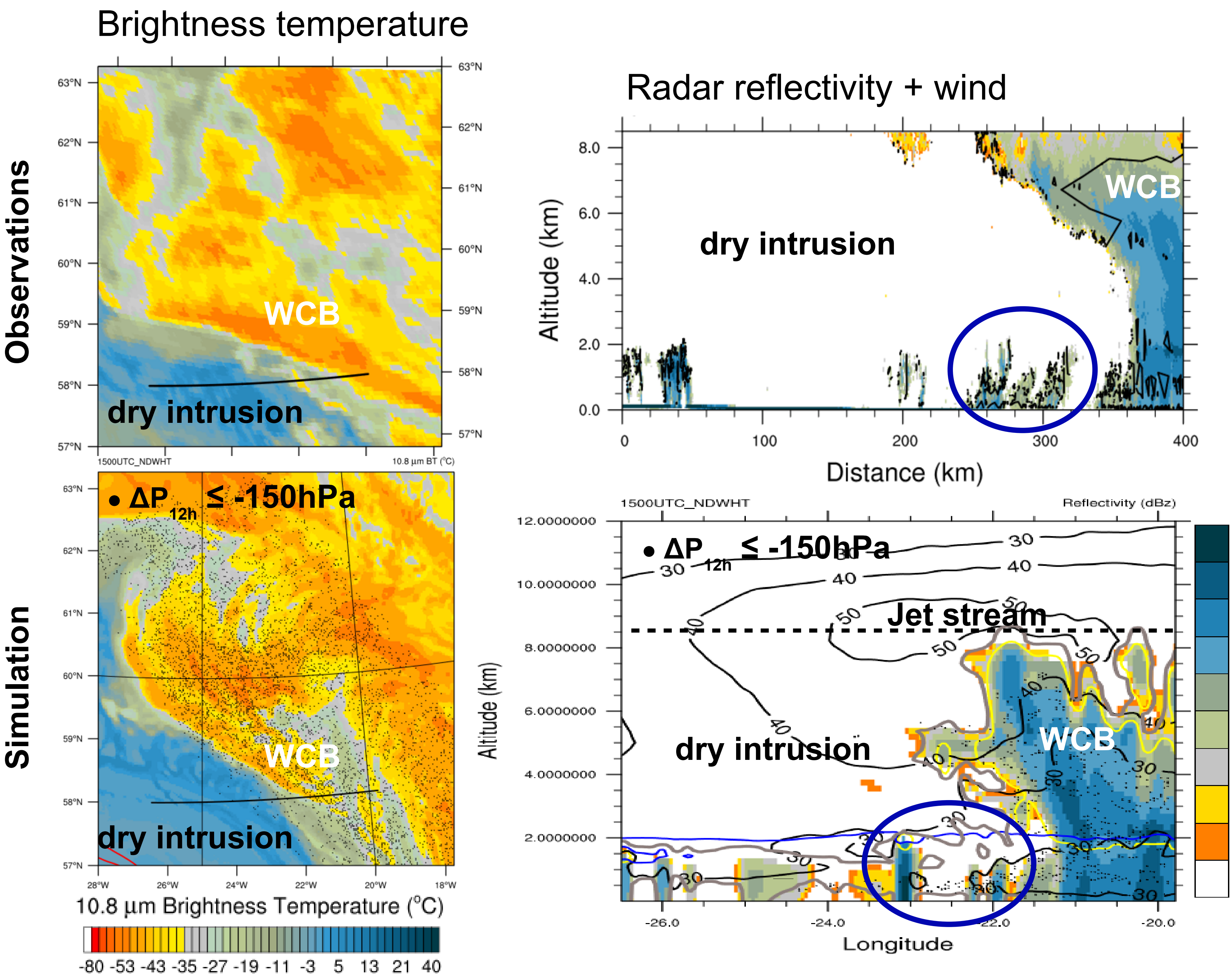


Temporal evolution of WCB ascents

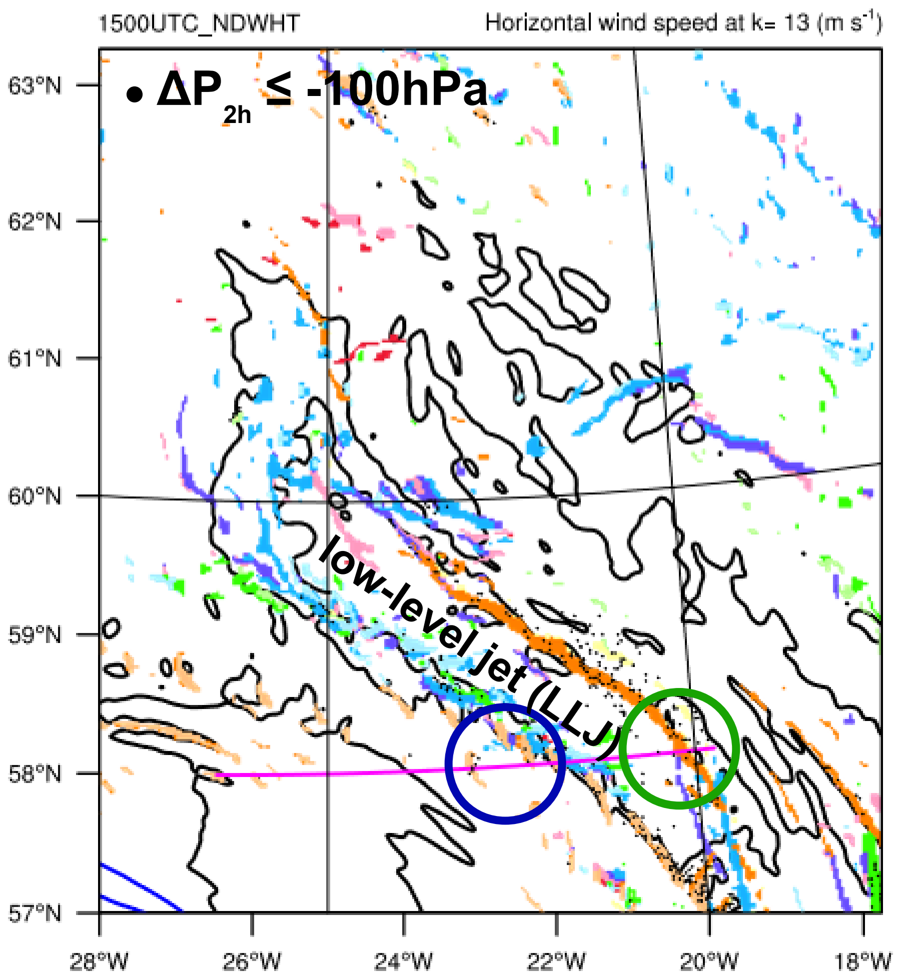


2-h segments
$\Delta P_{2h} \leq$ -100hPa
~ 1-4 km altitude

Zoom on flight leg at 15 UTC

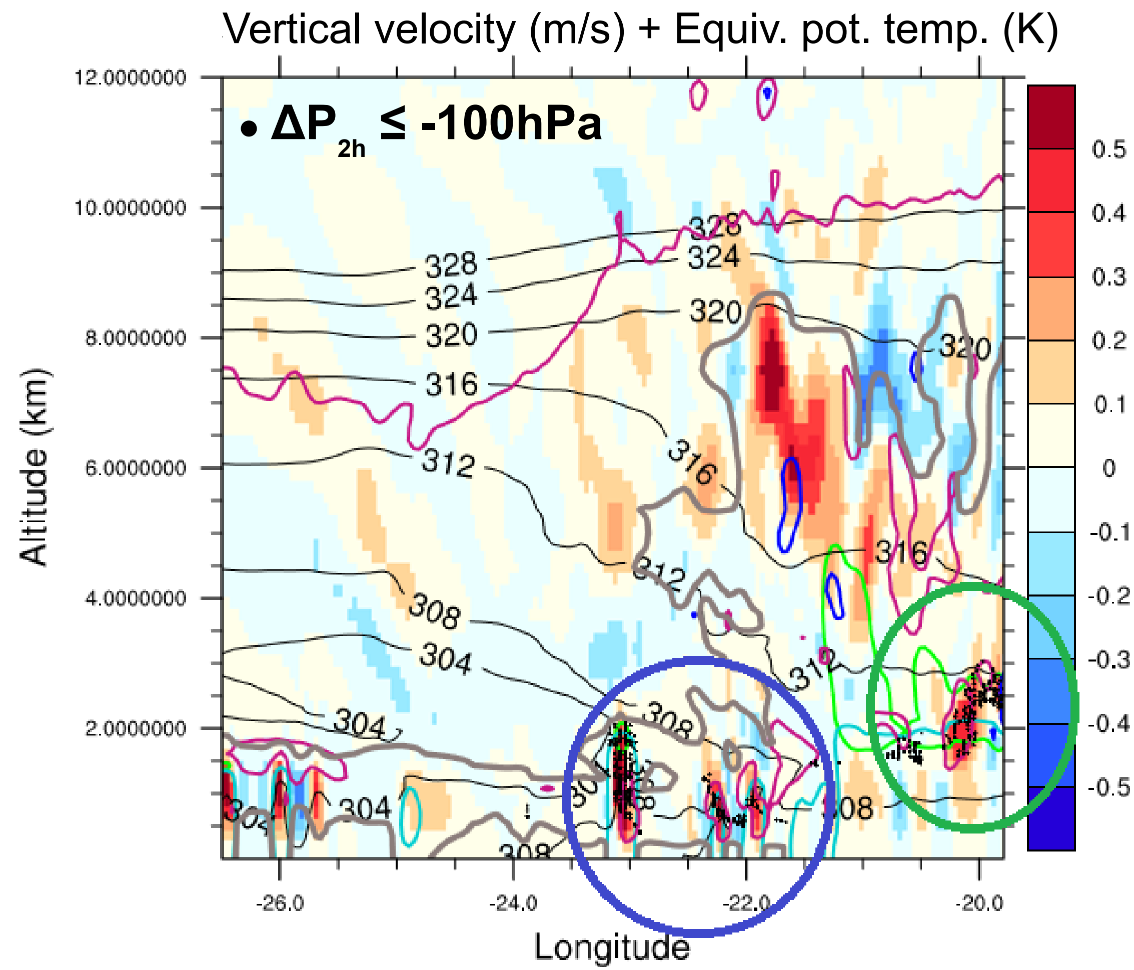


Fast ascents at 15 UTC



Base of connected grid points with w > 0.3 m/s

Contours: wind > 30/35 m/s

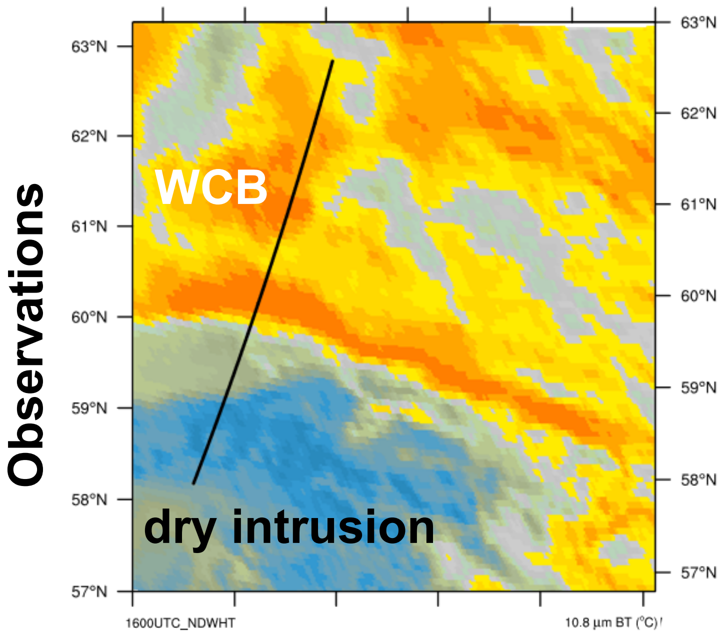


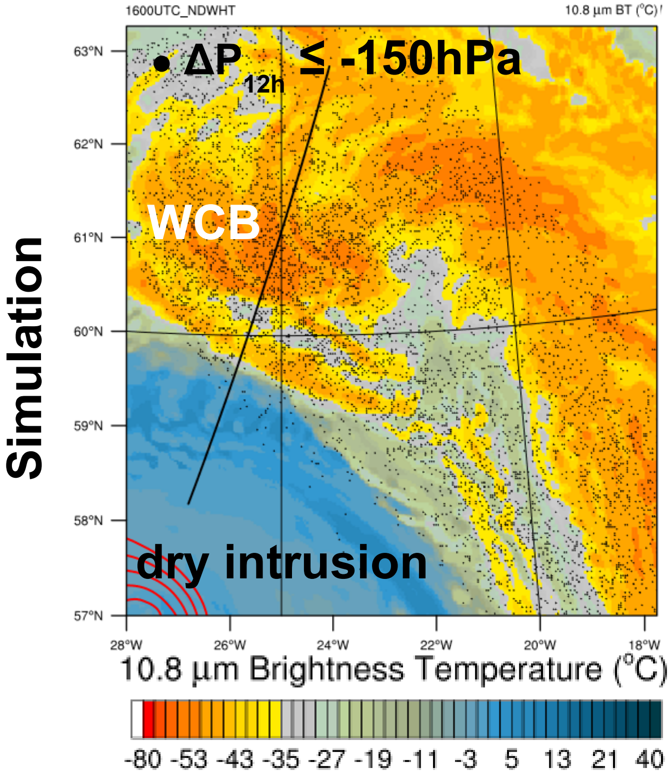
→ **Isolated shallow convection**
located at **western edge of WCB and LLJ**

→ **Organized low-level convection**
located in **WCB core** and **east of LLJ**

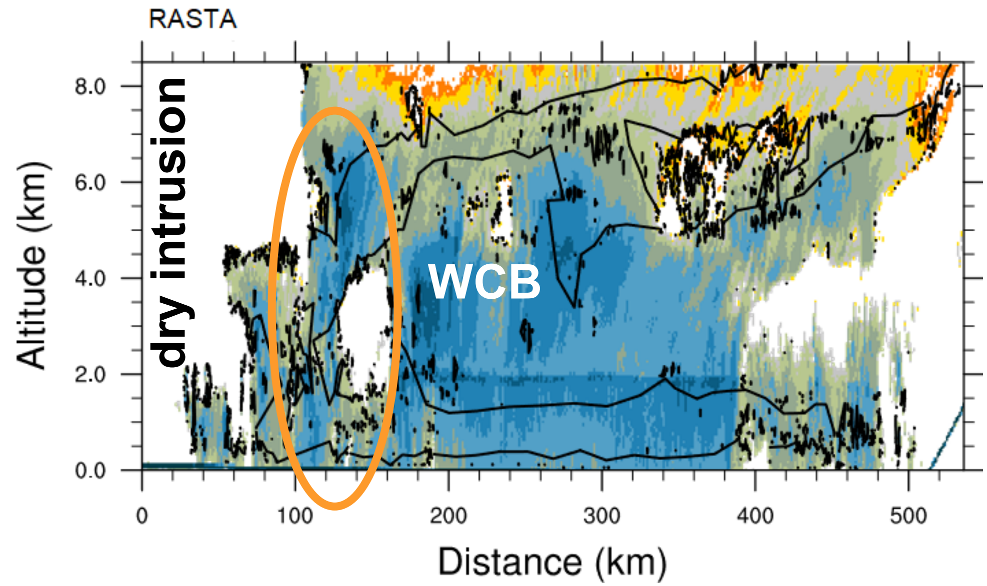
Zoom on flight leg at 16 UTC

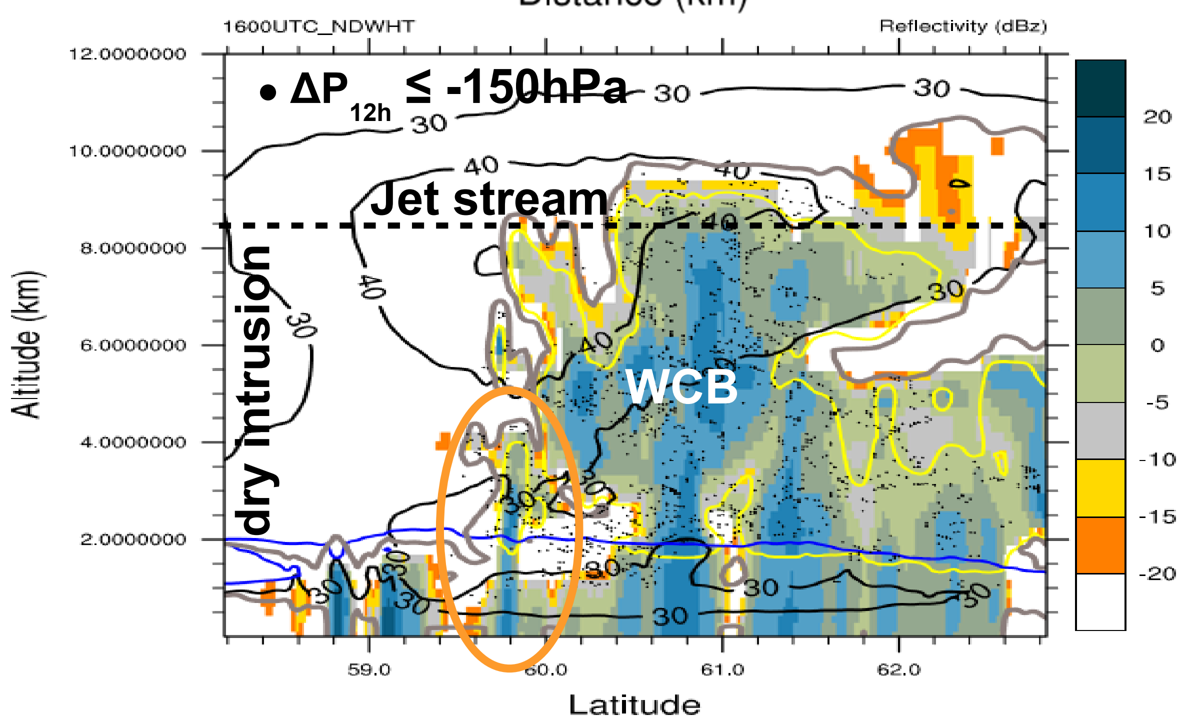
Brightness temperature



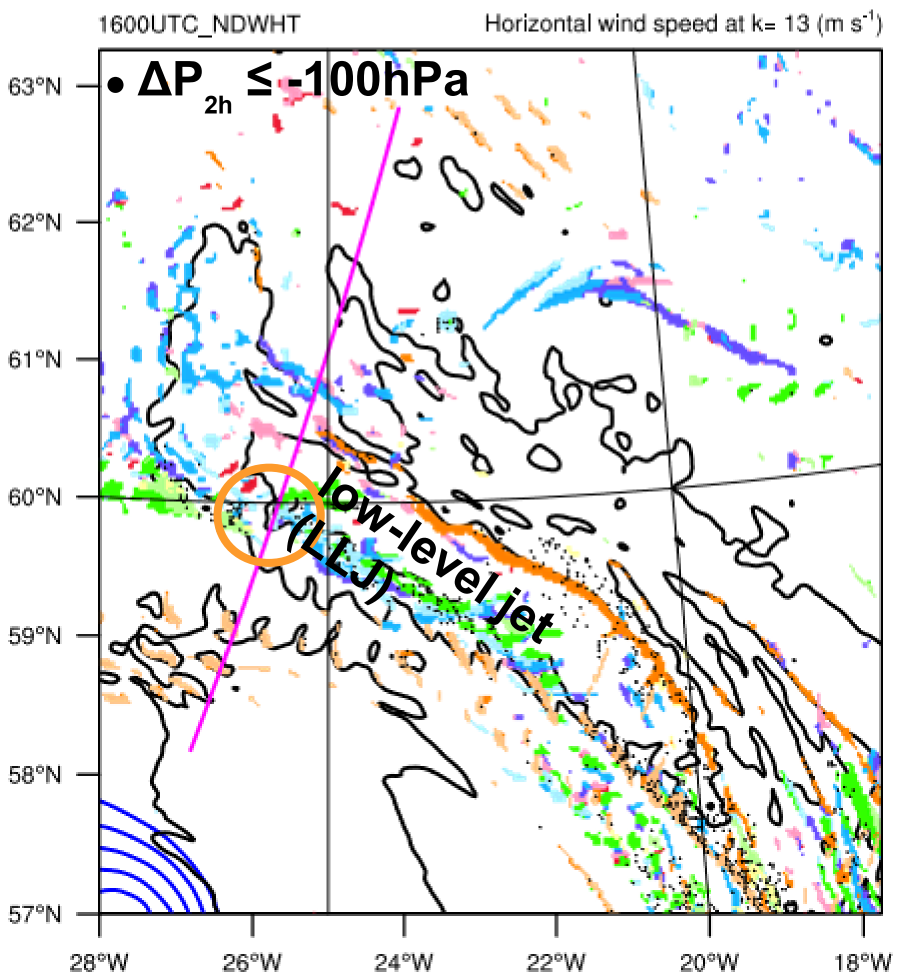


Radar reflectivity + wind

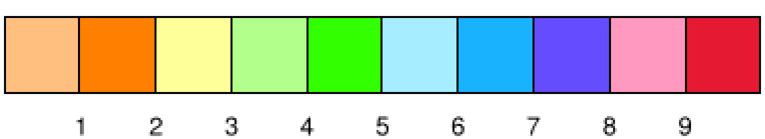




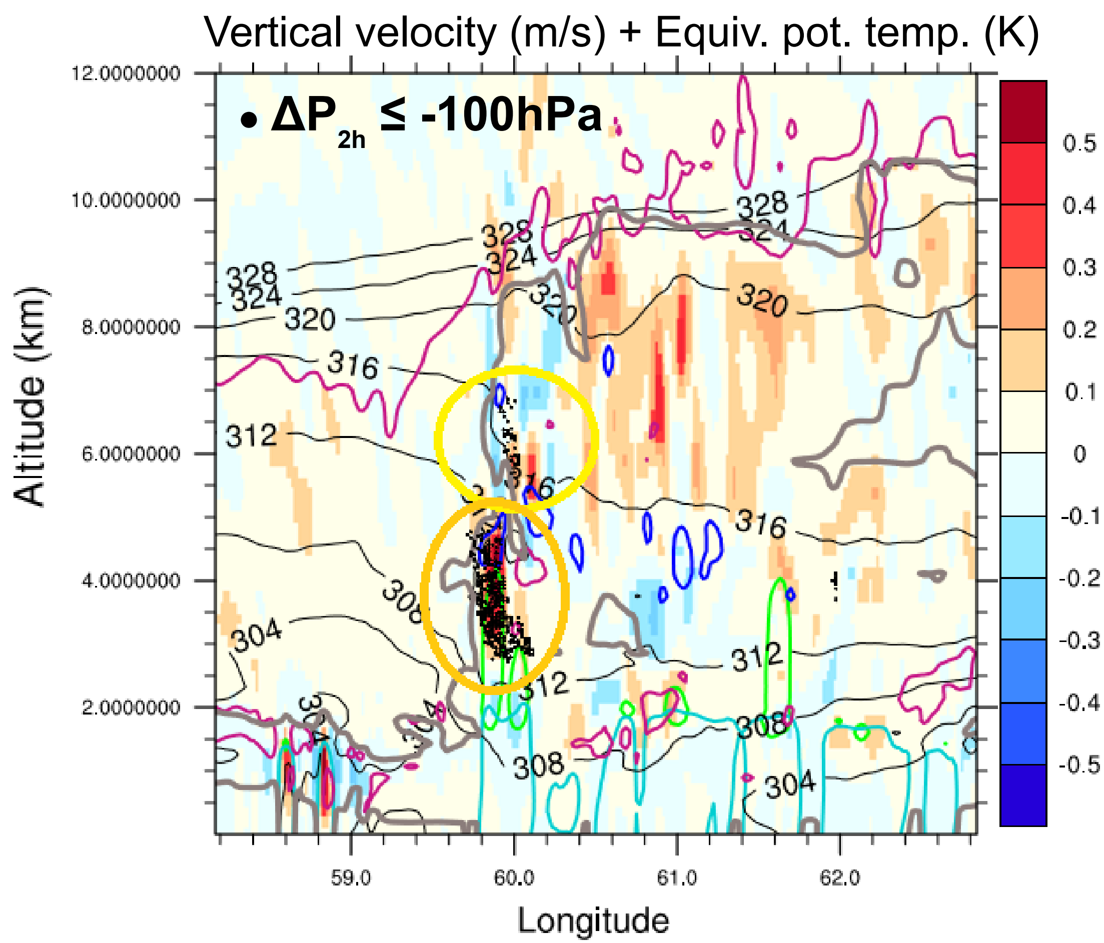
Fast ascents at 16 UTC



Base of connected grid points with w > 0.3 m/s

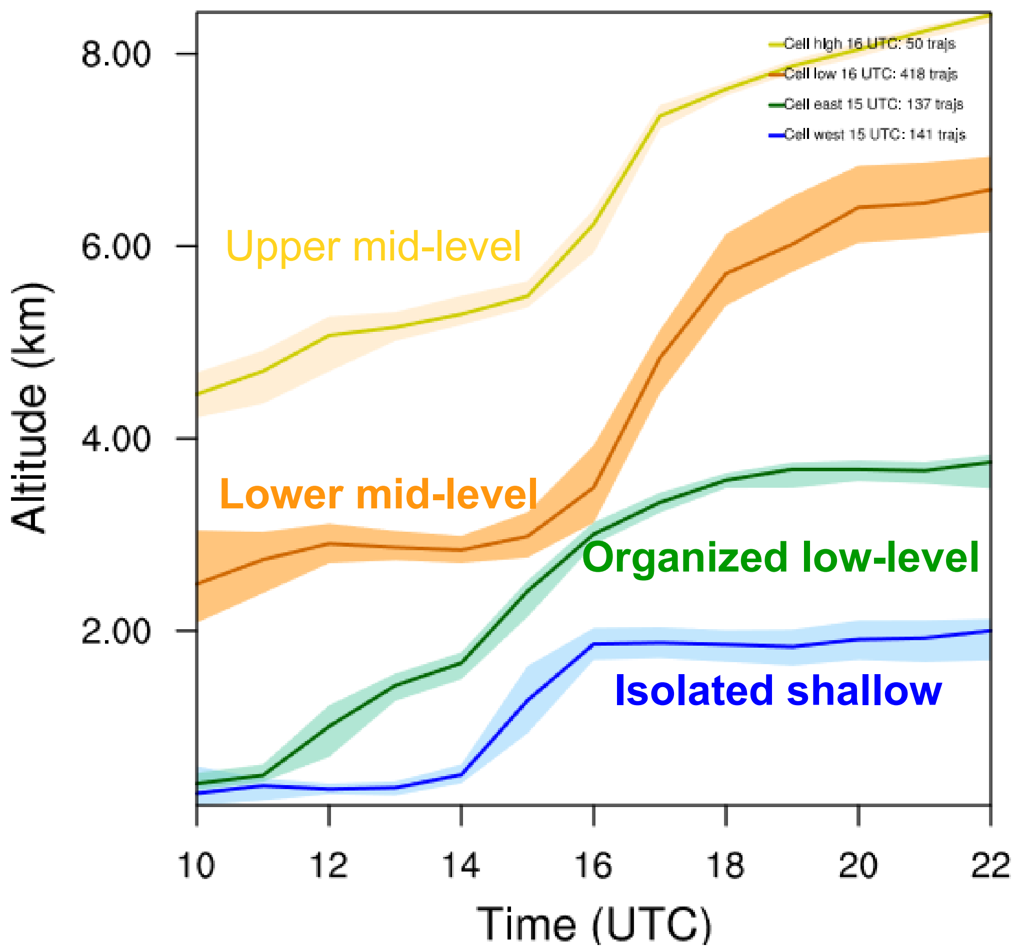


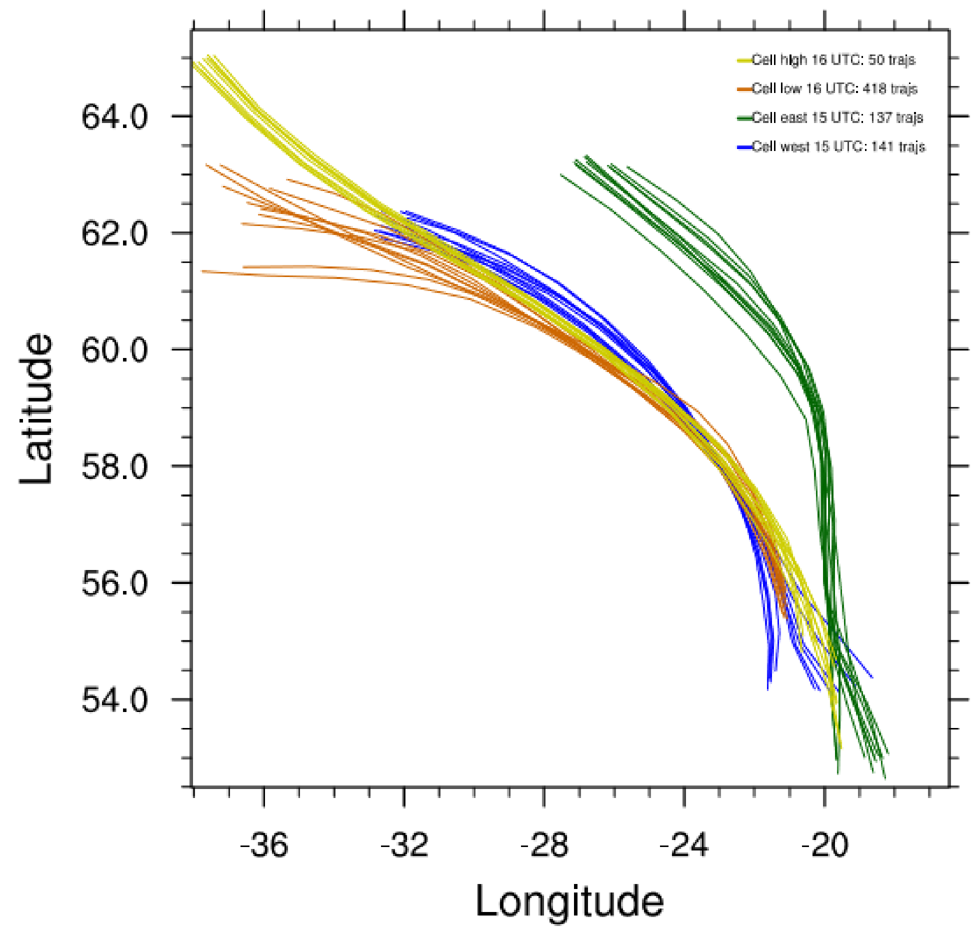
Contours: wind > 30/35 m/s



→ **Mid-level (upper/lower) convection** located at **western edge of WCB**

Temporal evolution of the identified convective cells





- **Organized low-level convection**: stays in WCB core, cyclonic branch
- **Isolated shallow convection**: stays at western edge of WCB, cyclonic branch
- **Mid-level (upper/lower) convection**: stays at western edge of WCB, then **anticyclonic** or **cyclonic** branch = **bifurcation** depending on altitude

Perspectives: negative PV bands

Origin?

Evolution?

~Fast ascents?

1600 UTC

PV at θ=320 K

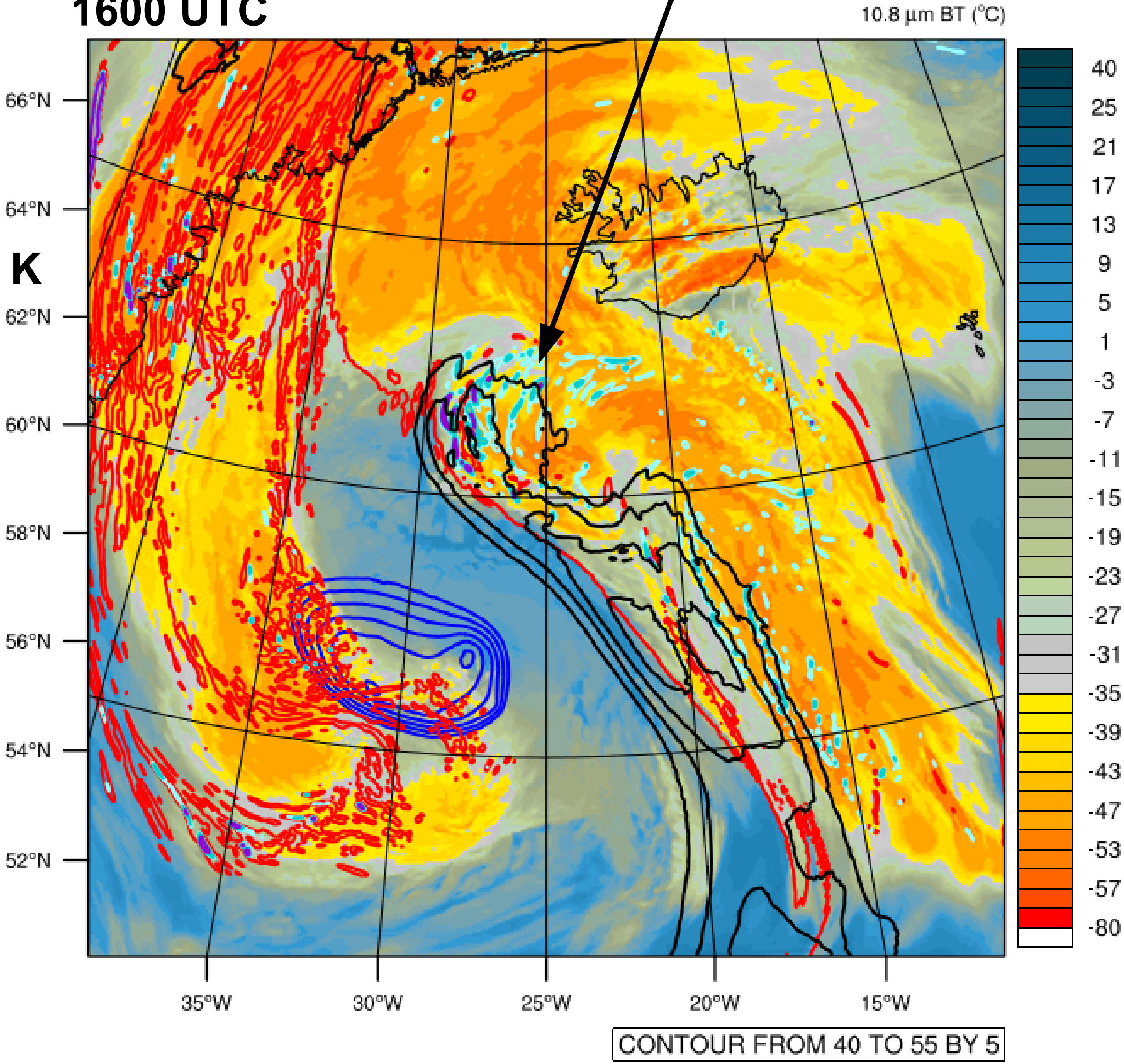
+2 PVU

-0.5 PVU

-1 PVU

-2 PVU

MSLP



Work in progress: predictability of NAWDEX cyclones

WCBs can impact cyclone dynamics

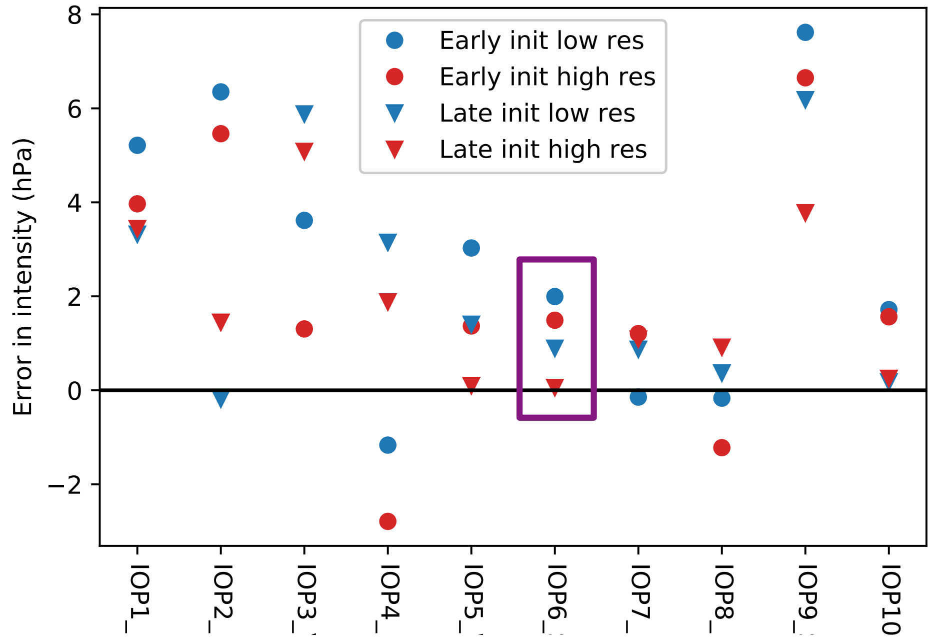
→ contribution of WCB representation to **cyclone predictability**?

→ **systematic study** during NAWDEX!

Meso-NH runs of intensification phase

- Large domain 3000 x 3000 km
- Initialization 48h (**early**) / 36h (**late**) before time of maximum intensity
- dx=10km (low res) / 2.5km (high res)
- *To do: sensitivity to representation of microphysics, surface fluxes, etc.*

Error in MSLP minimum for **all IOPs**



*Example **Stalactite cyclone**: low error and sensitivity → why?*

Conclusions

“Stalactite” cyclone on 2nd Oct 2016 observed and modeled at km-scale resolution

1. **What are the WCB characteristics for this case study?**

- **1/3 of fast ascents** ($\Delta P_{2h} \leq$ -100hPa)
  → located **to the west** and **~1-km lower** than slow ascents

- **2/3 of cyclonic trajectories**, 4/5 for fast ascents and 3/5 for slow ascents
  → located **behind** and **~3-km lower** than anticyclonic ascents

2. **What are the processes leading to fast WCB ascents?**

- **Organized low-level** convection: WCB core, east of LLJ, cyclonic branch

- **Isolated shallow** convection: western edge WCB and LLJ, cyclonic branch

- **Isolated mid-level** convection : western edge WCB, branch depends on altitude