Climatology of dry air intrusions and their relation to strong surface winds in extratropical cyclones

....and intro to synoptic and meso-scale cyclone dynamics

Shira Raveh-Rubin and Heini Wernli

Institute for Atmospheric and Climate Science (IACETH), ETH Zurich

FNSNF
Swiss National Science Foundation

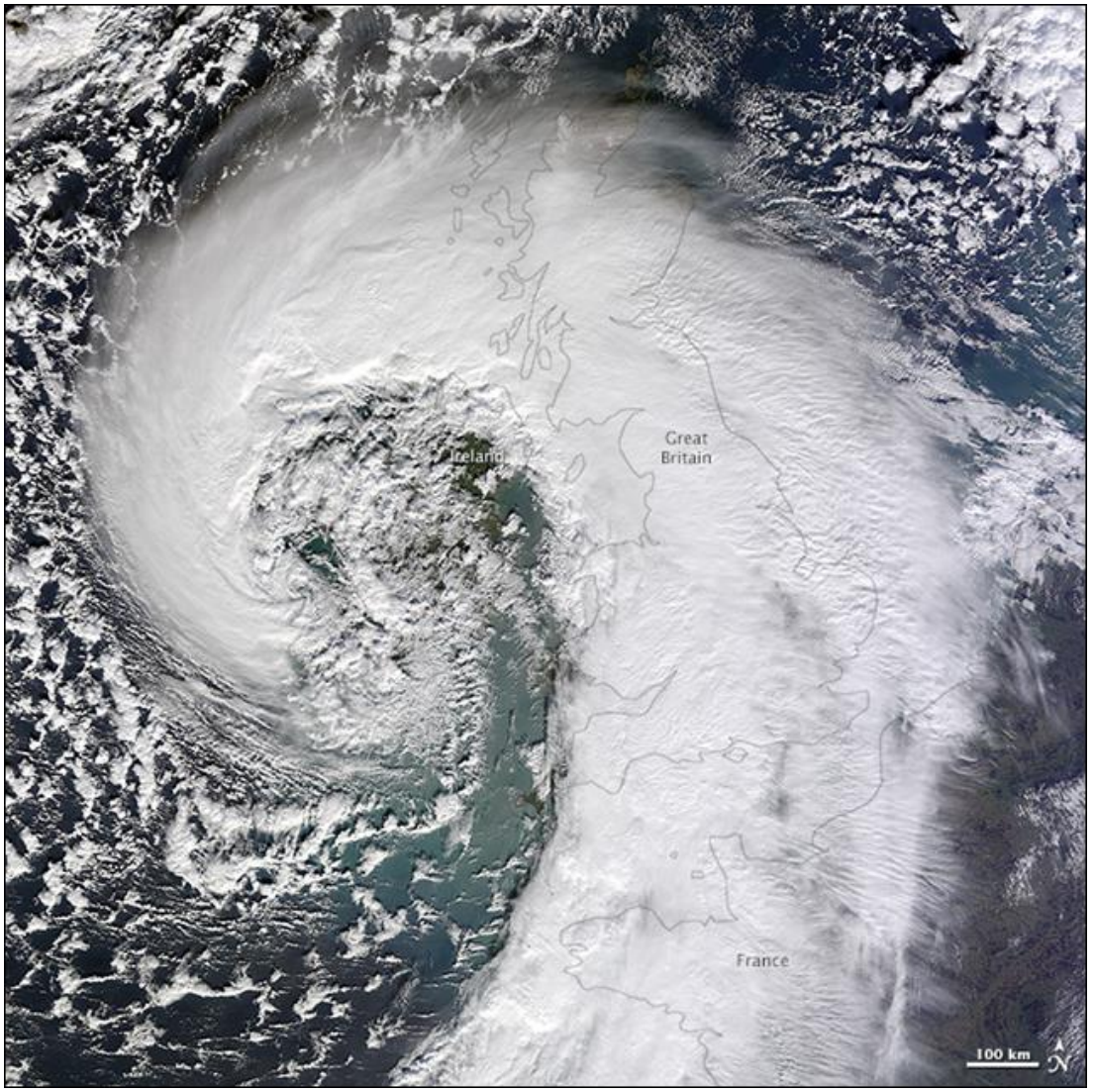
5th European Windstorm Workshop StormEx, Bern, 31 August 2015

Impact of cyclones – what?

- **strong damaging surface winds**
- **extended heavy precipitation**
- hail, thunderstorm...

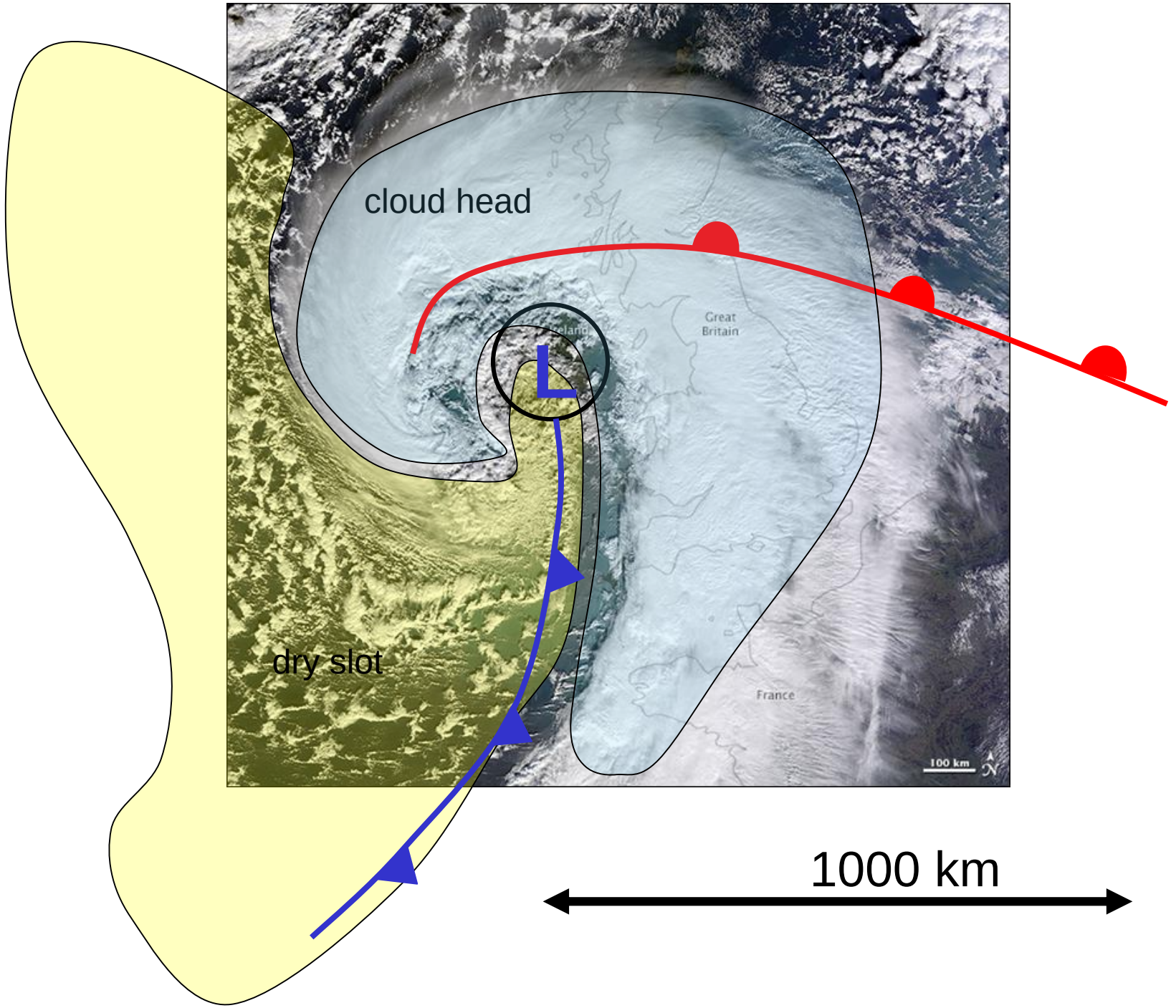
→ damage, fatalities, floods, landslides, storm surge, economic losses

Impact of cyclones – where and when?

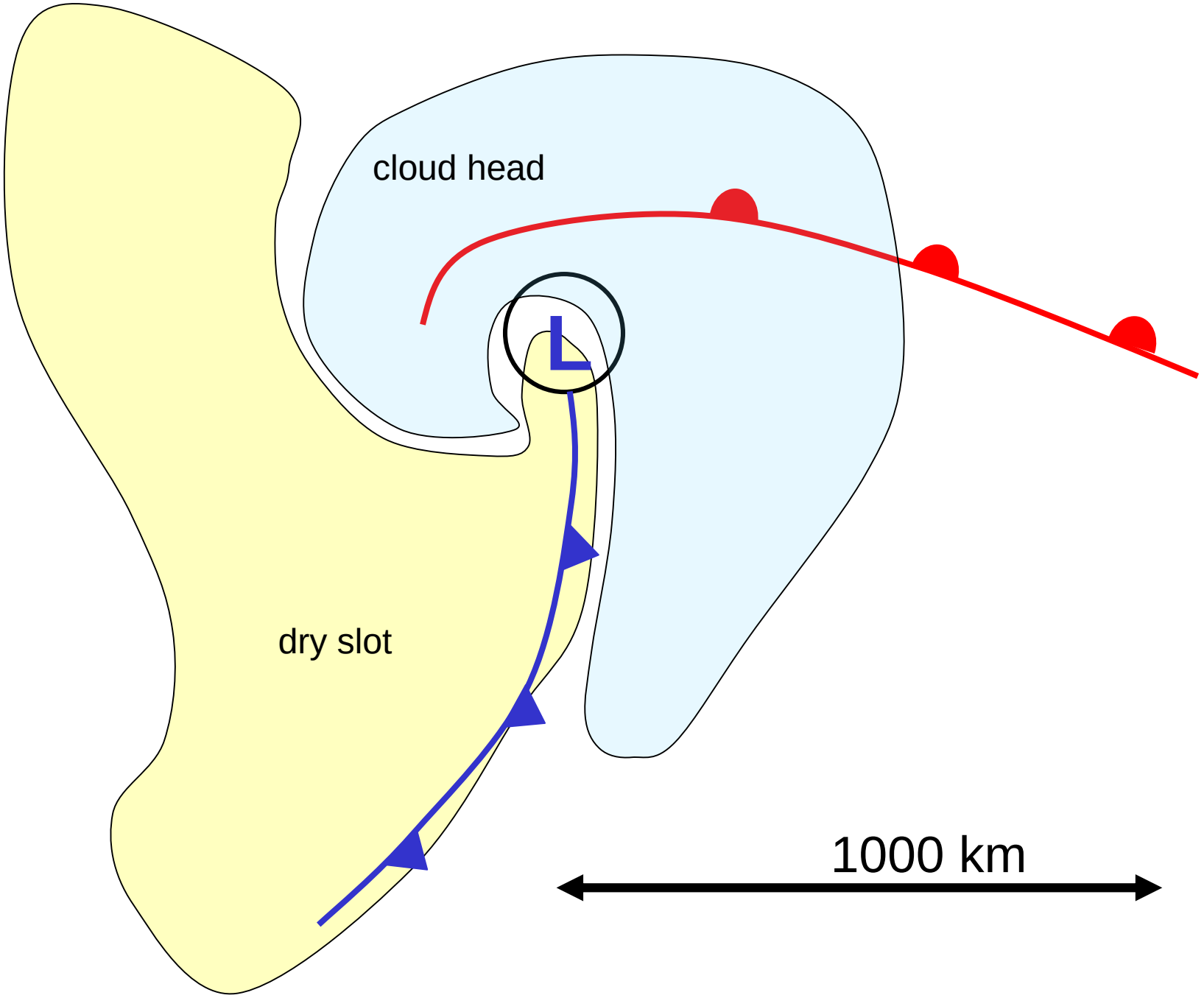


MODIS on Terra satellite, NASA,12 February 2014

Impact of cyclones – where and when?



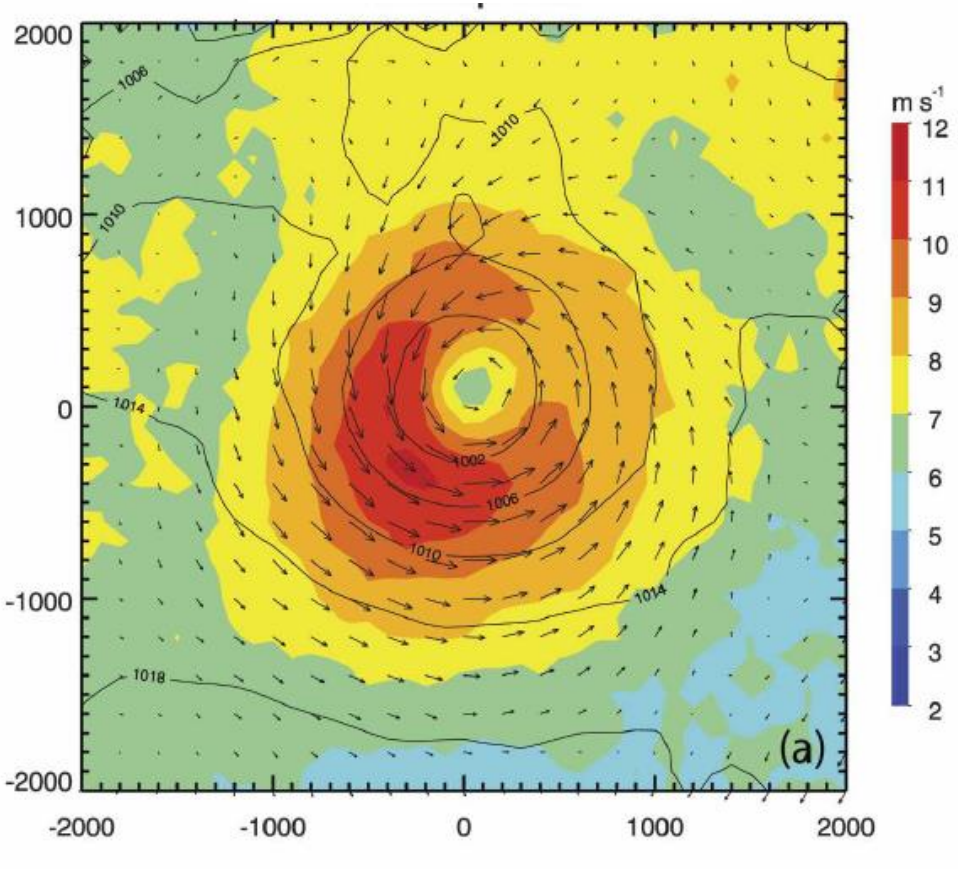
Impact of cyclones – where and when?



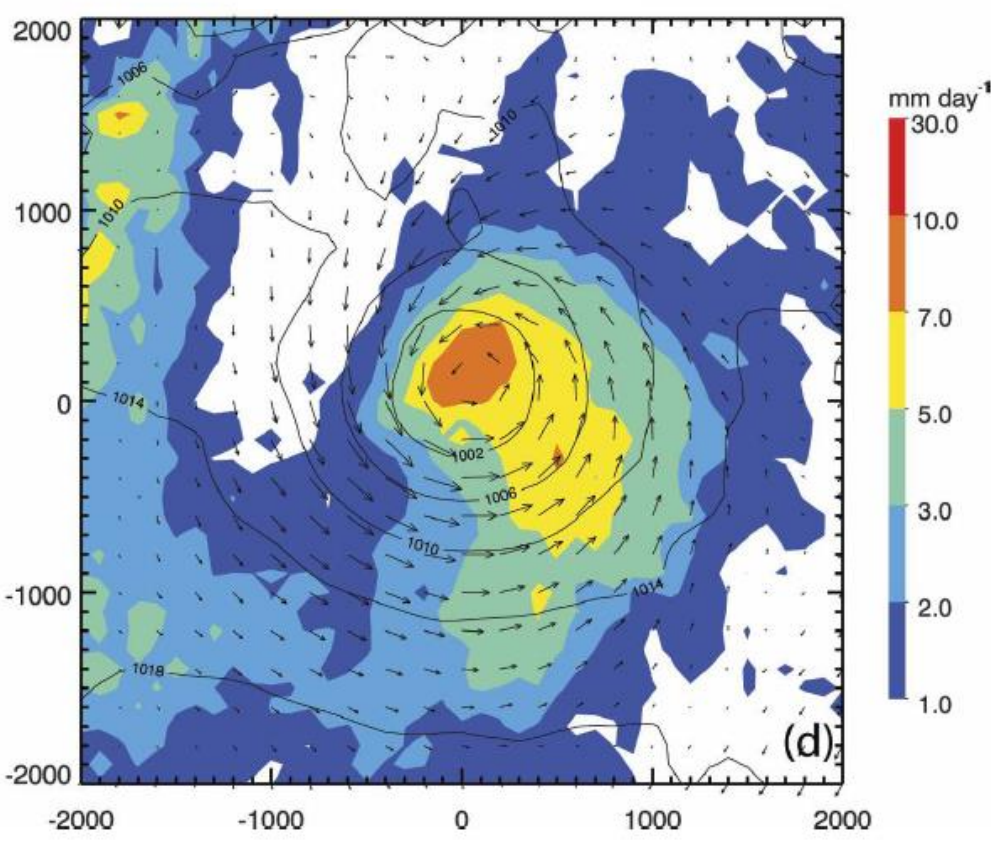
Impact of cyclones – where and when?

N. Atlantic composite (~400 cyclones)

Surface wind velocity



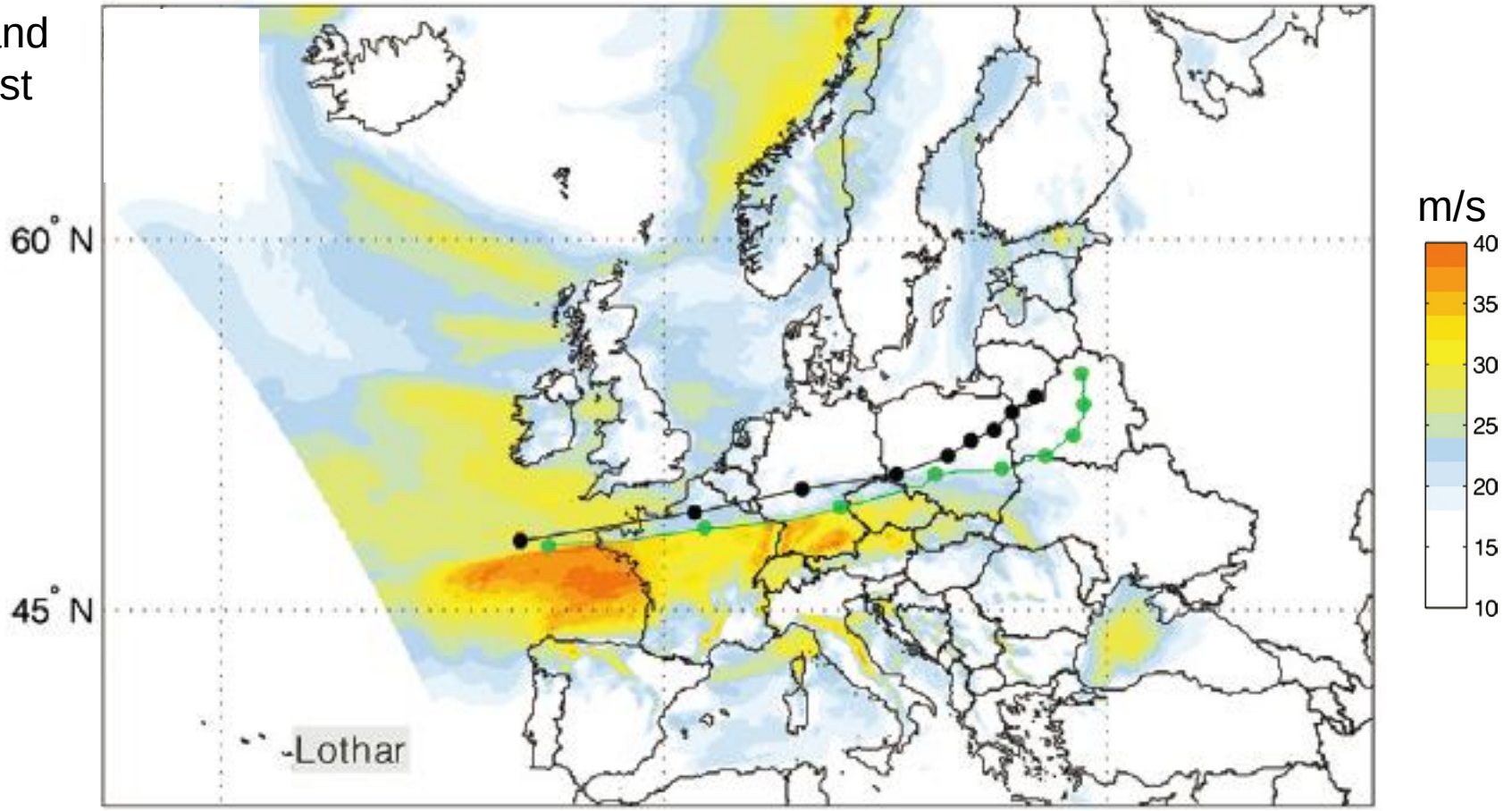
Precipitation rate



Field and Wood 2007 (*J Climate*)

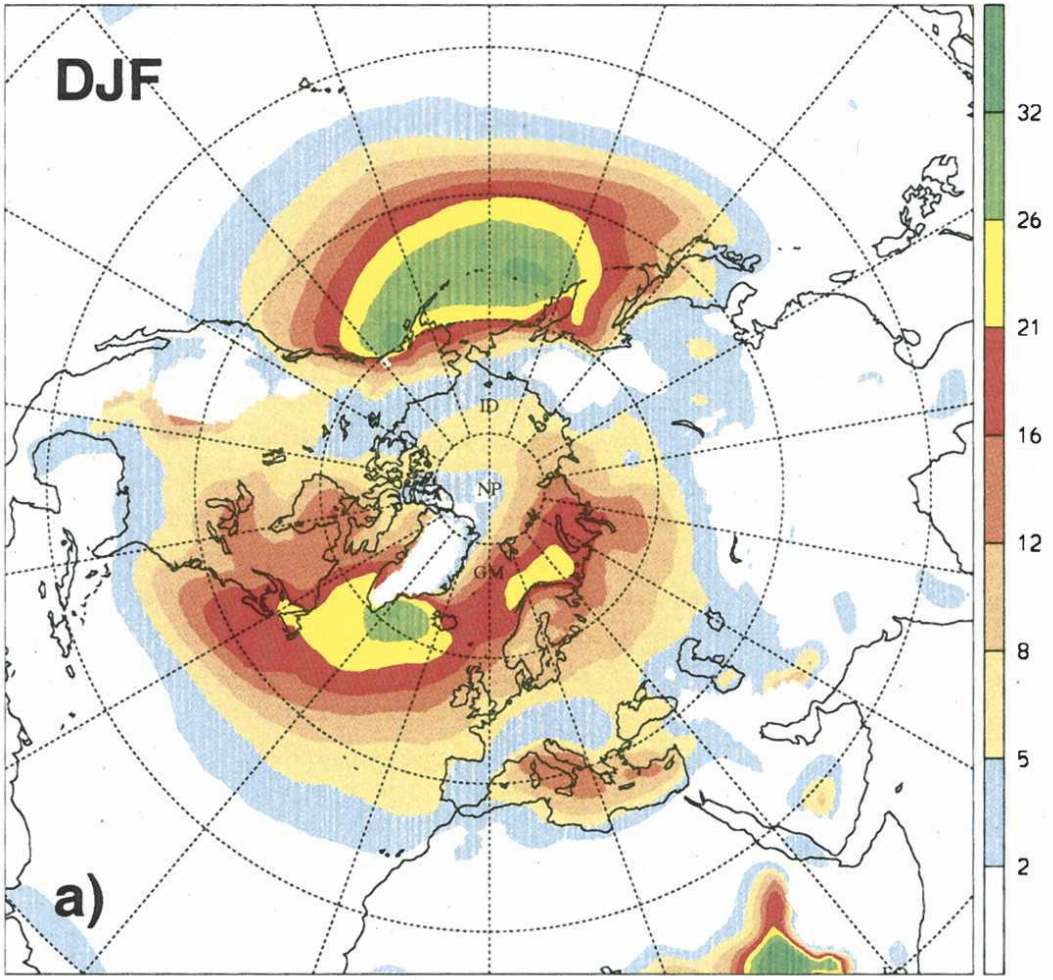
Impact of cyclones – wind footprint

Storm track and max. wind gust speed



Born et al., 2012 (*Tellus*)

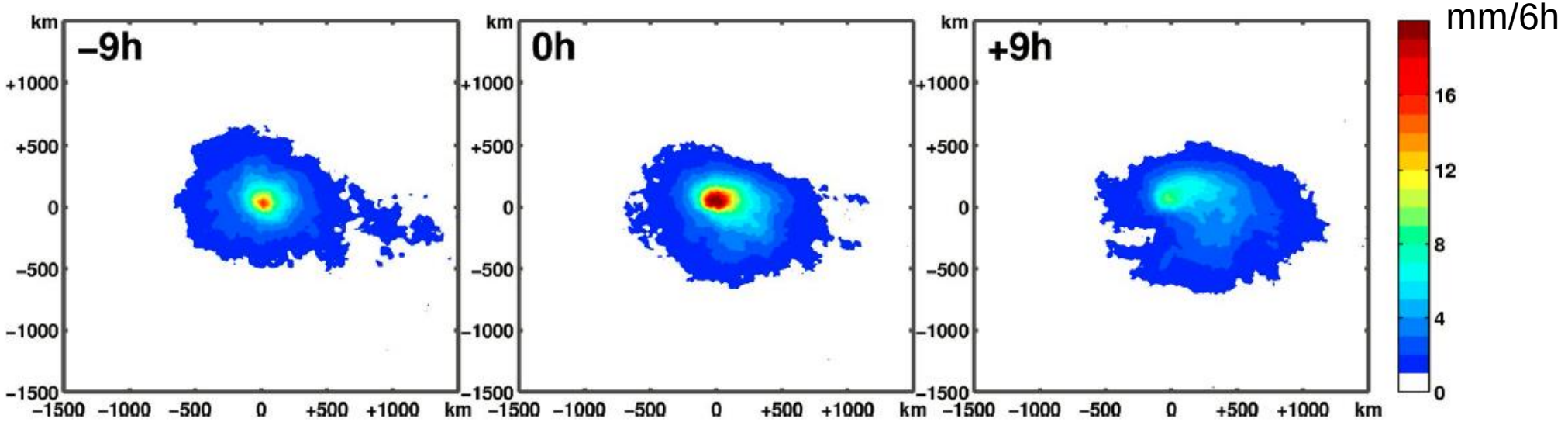
Storm tracks



Cyclone frequency [%]

Wernli and Schwierz 2006 (*JAS*)

Precipitation in intense Mediterranean cyclones

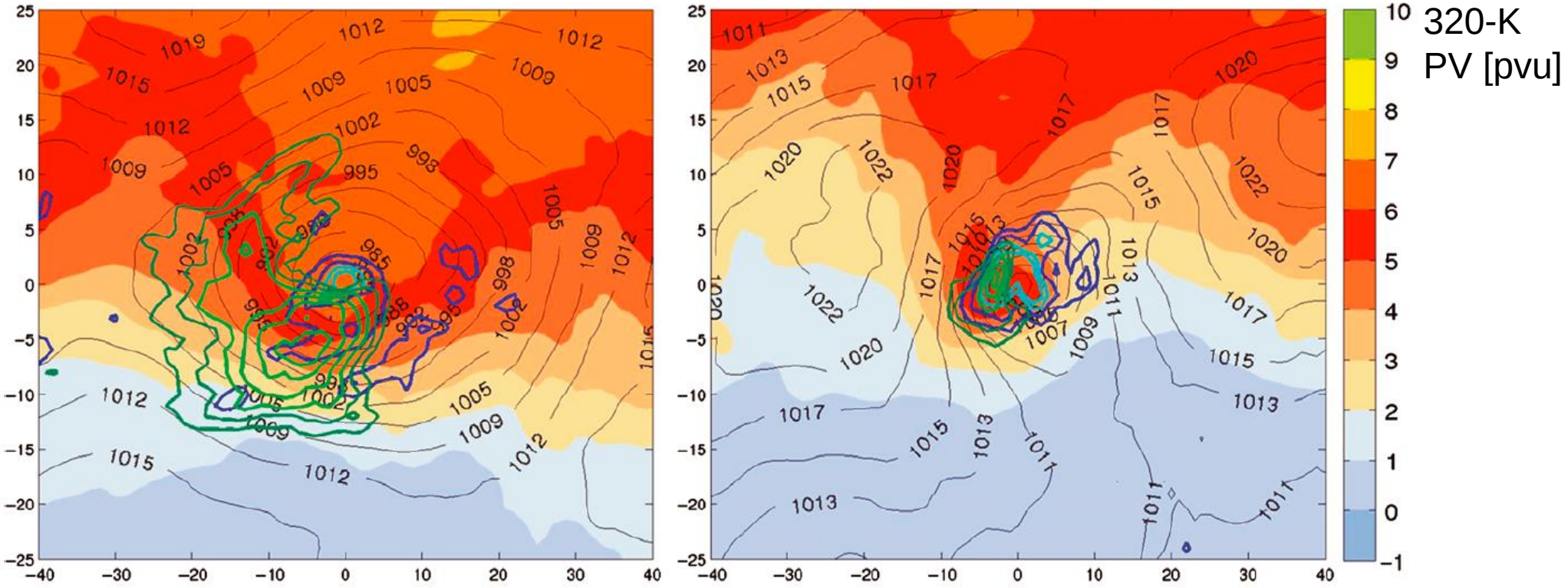


Flaounas et al., 2015 (*Clim Dyn*)

Co-occurrence of precipitation and gust extremes in Mediterranean

Atlantic cyclones

Mediterranean cyclones



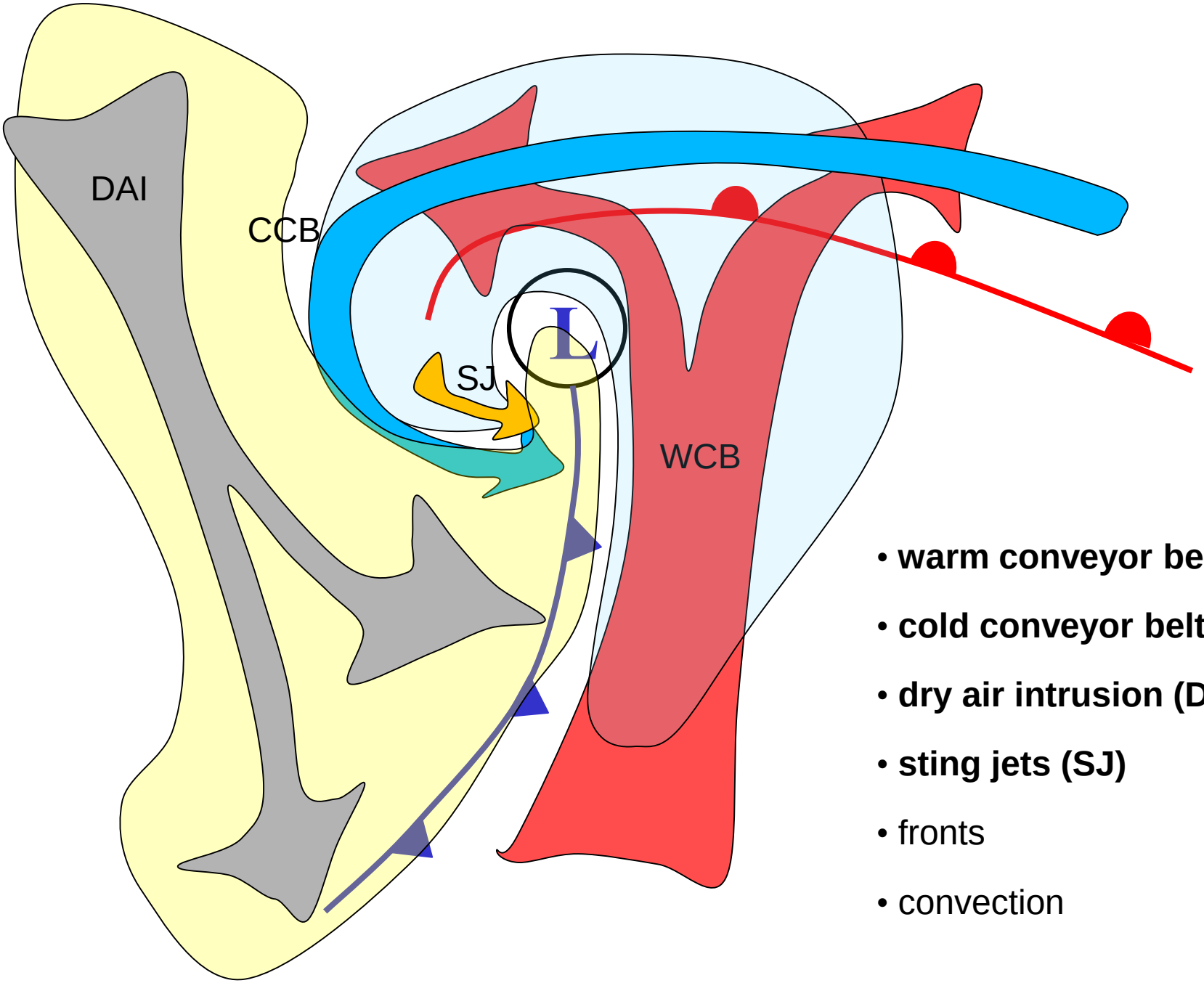
6-h 10-m gust > 15 m/s

6-h precipitation > 2 mm/(6h)

On average: gust maximum **~12h after** precipitation maximum

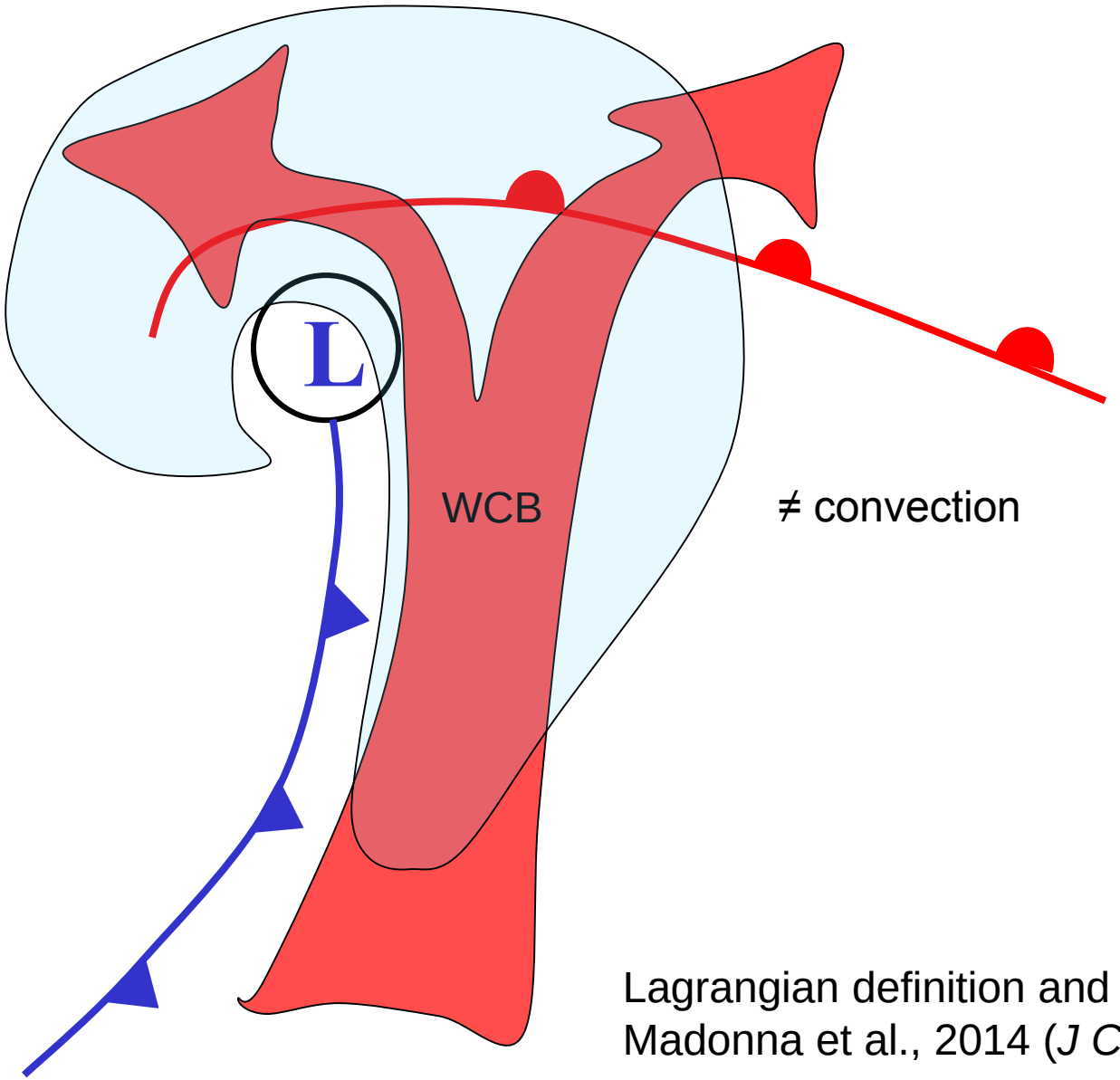
Raveh-Rubin and Wernli 2015 (*QJ*)

Impact of cyclones – associated features



- **warm conveyor belt (WCB)**
- **cold conveyor belt (CCB)**
- **dry air intrusion (DAI)**
- **sting jets (SJ)**
- fronts
- convection

Warm conveyor belts (WCBs)



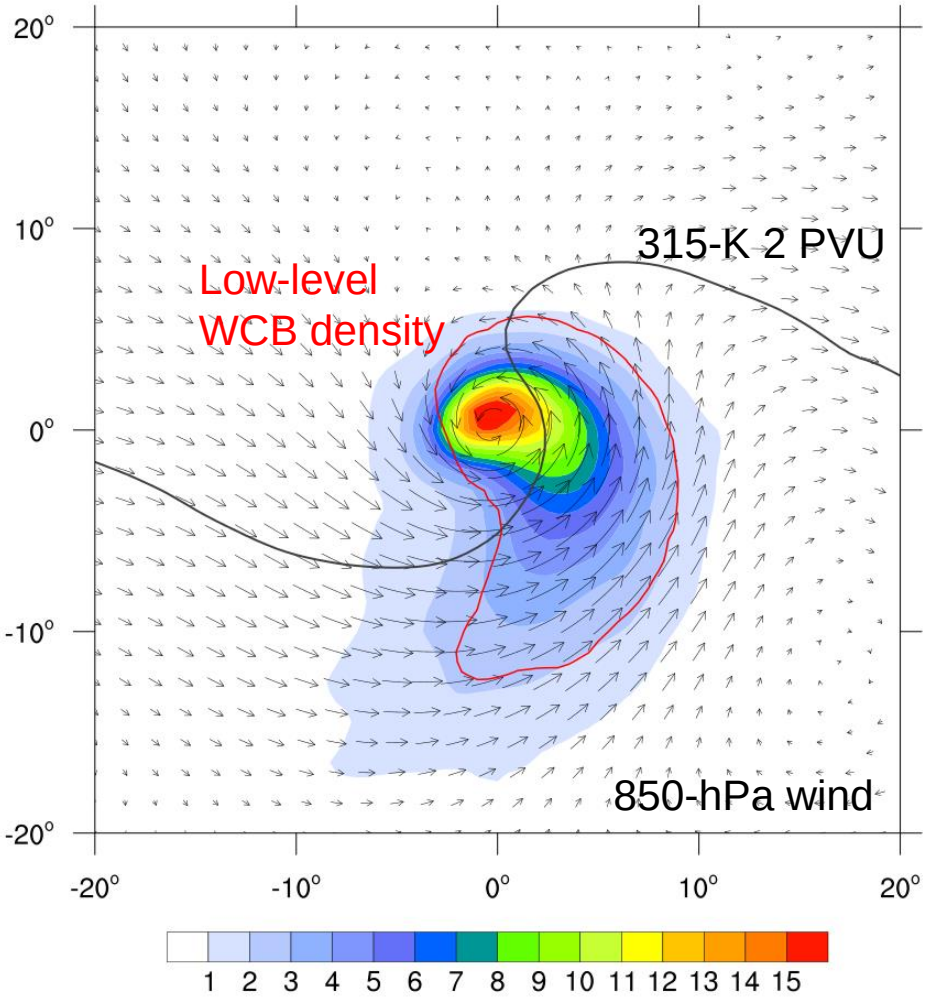
≠ convection

Lagrangian definition and climatology:
Madonna et al., 2014 (*J Climate*)

WCBs and precipitation

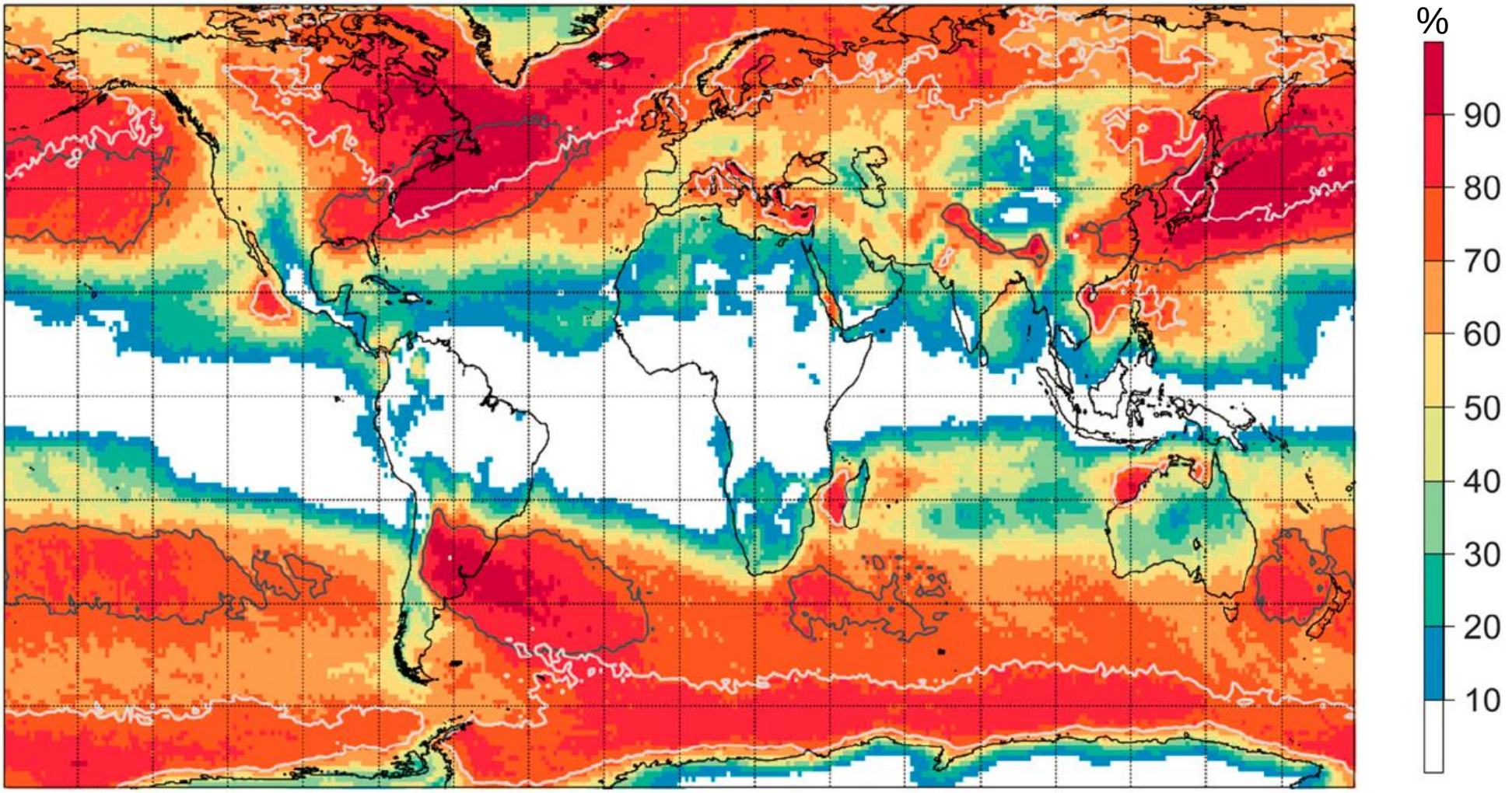
composite of 500 explosively intensifying cyclones associated with a strong WCB

> 600 hPa ascent in 48 h



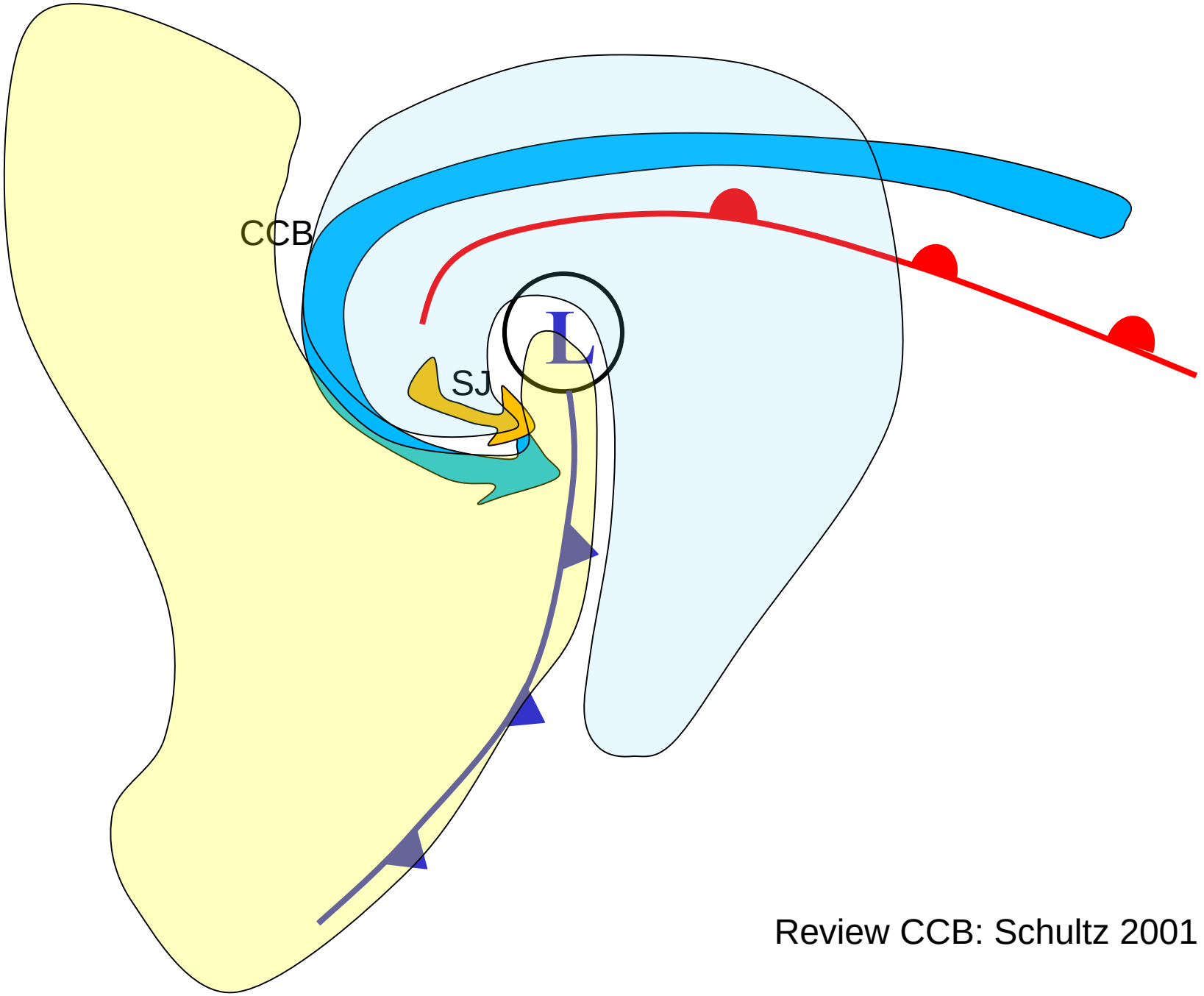
Hanin Binder

WCBs and extreme precipitation



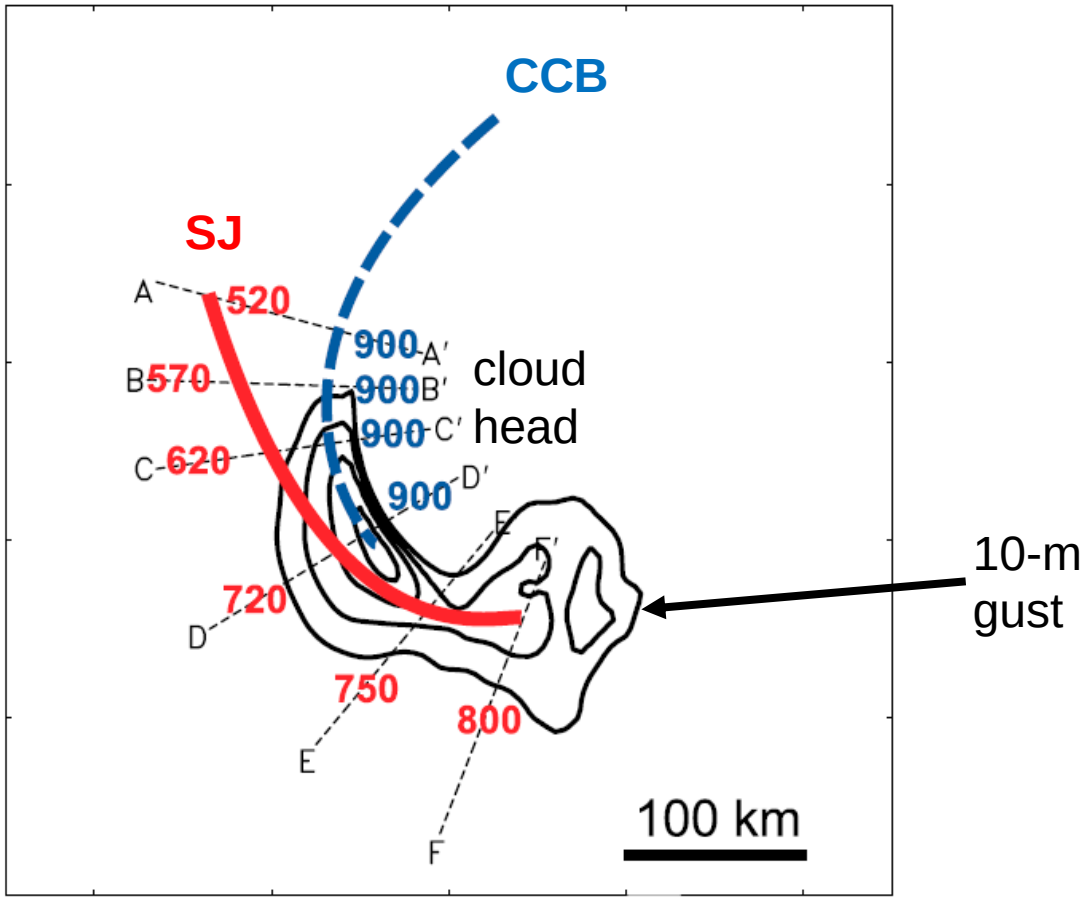
Pfahl et al., 2014 (*J Climate*)

Cold conveyor belt (CCB) and sting jet (SJ)



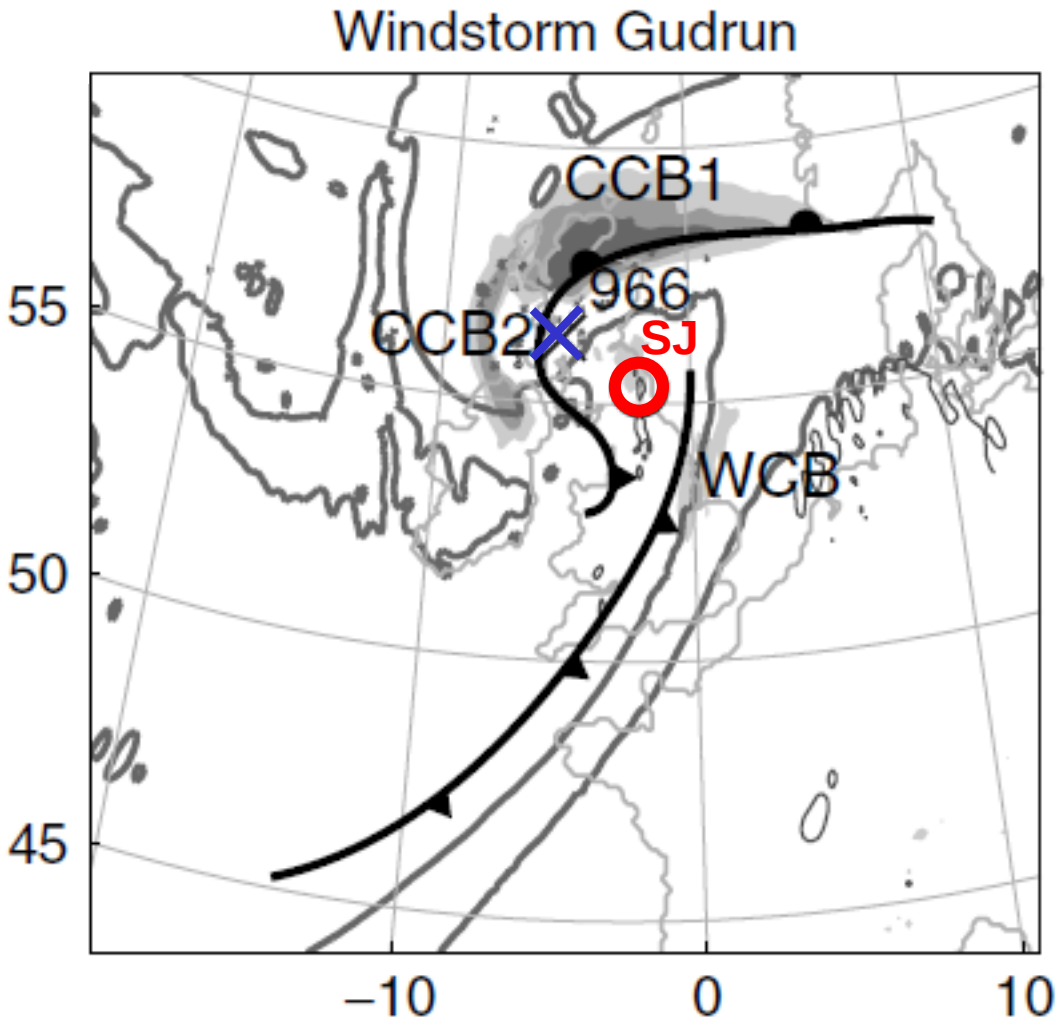
Review CCB: Schultz 2001 (*MWR*)

Cold conveyor belt (CCB) and sting jet (SJ)



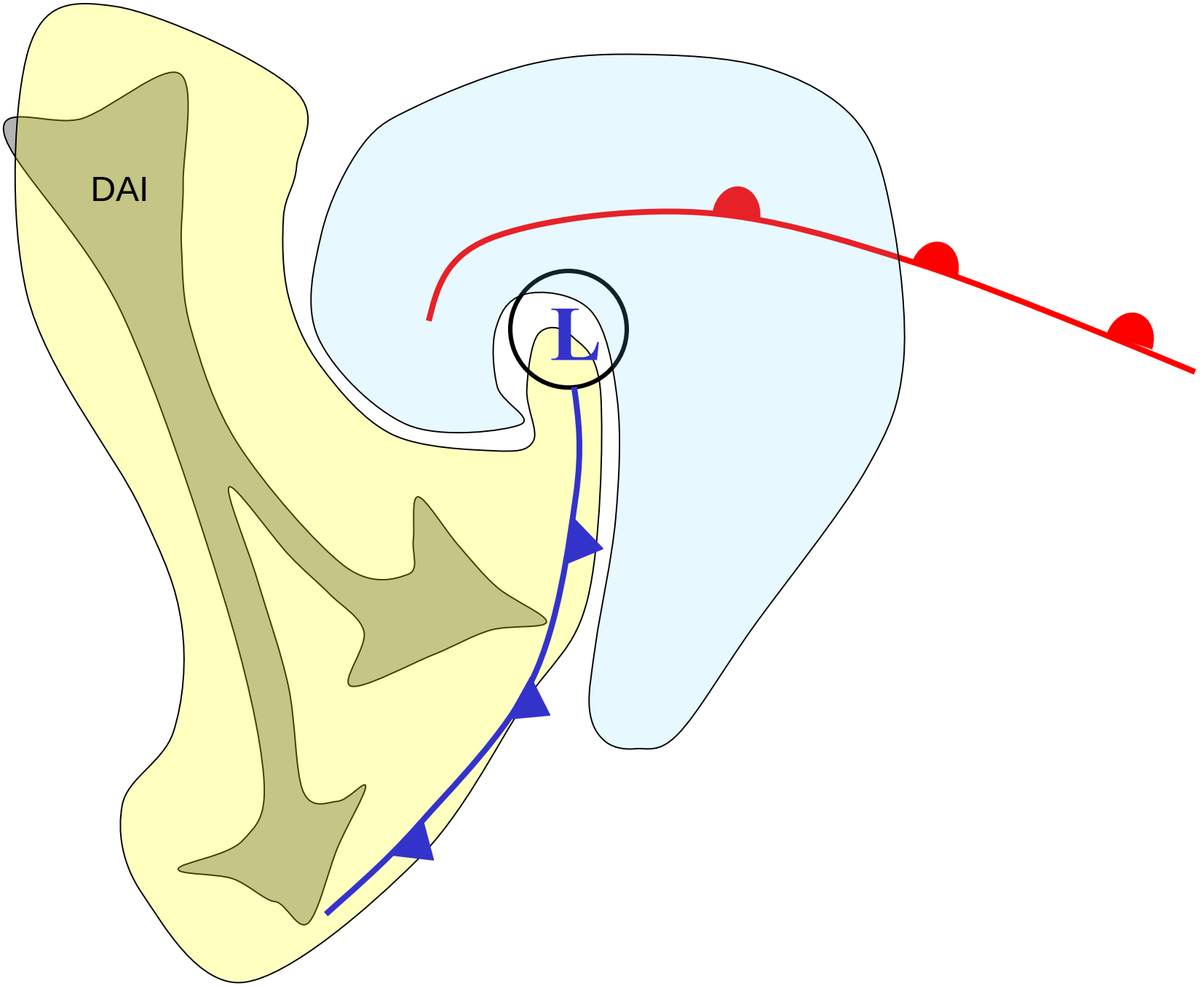
Smart and Browning 2014 (*QJ*)

Cold conveyor belt (CCB) and sting jet (SJ)

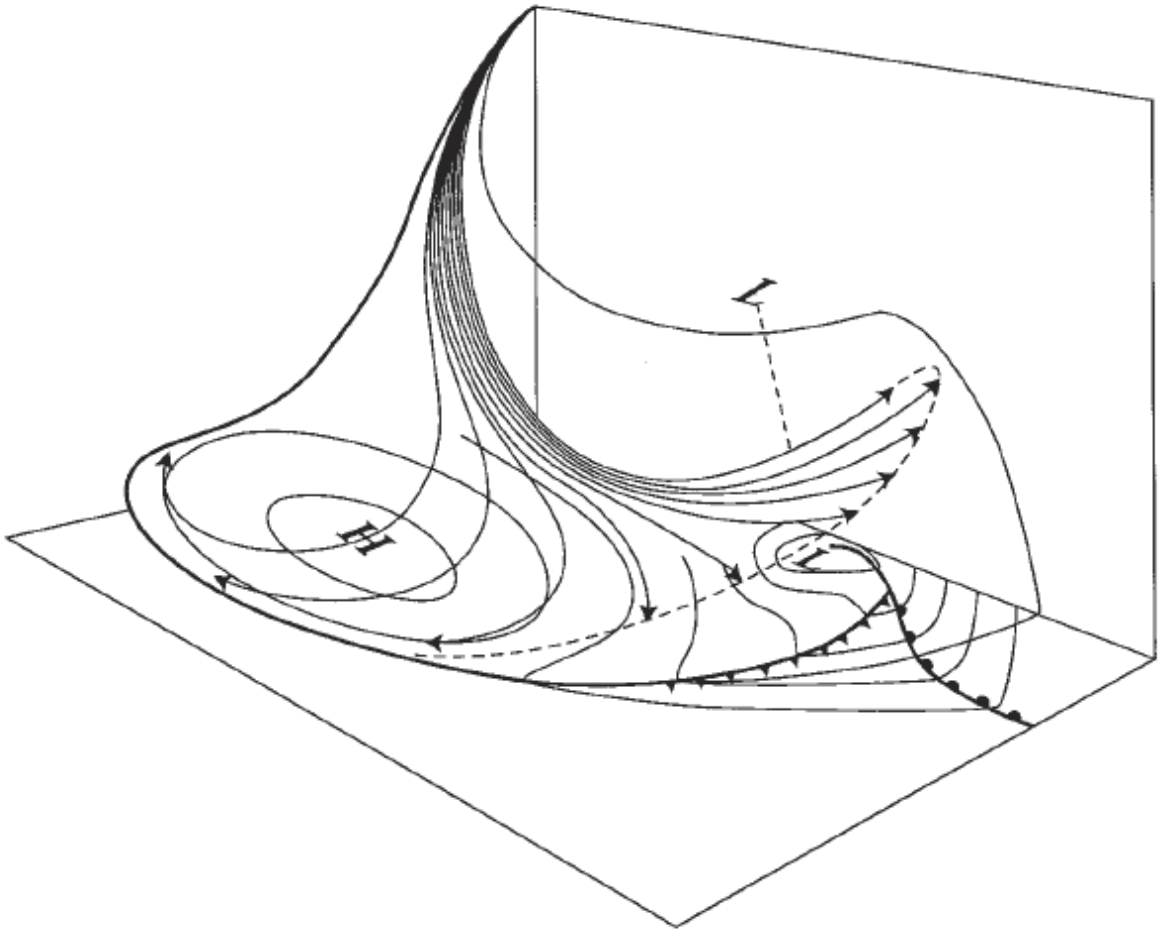


Gray et al., 2011 (*QJ*)

Dry air intrusions (DAIs)

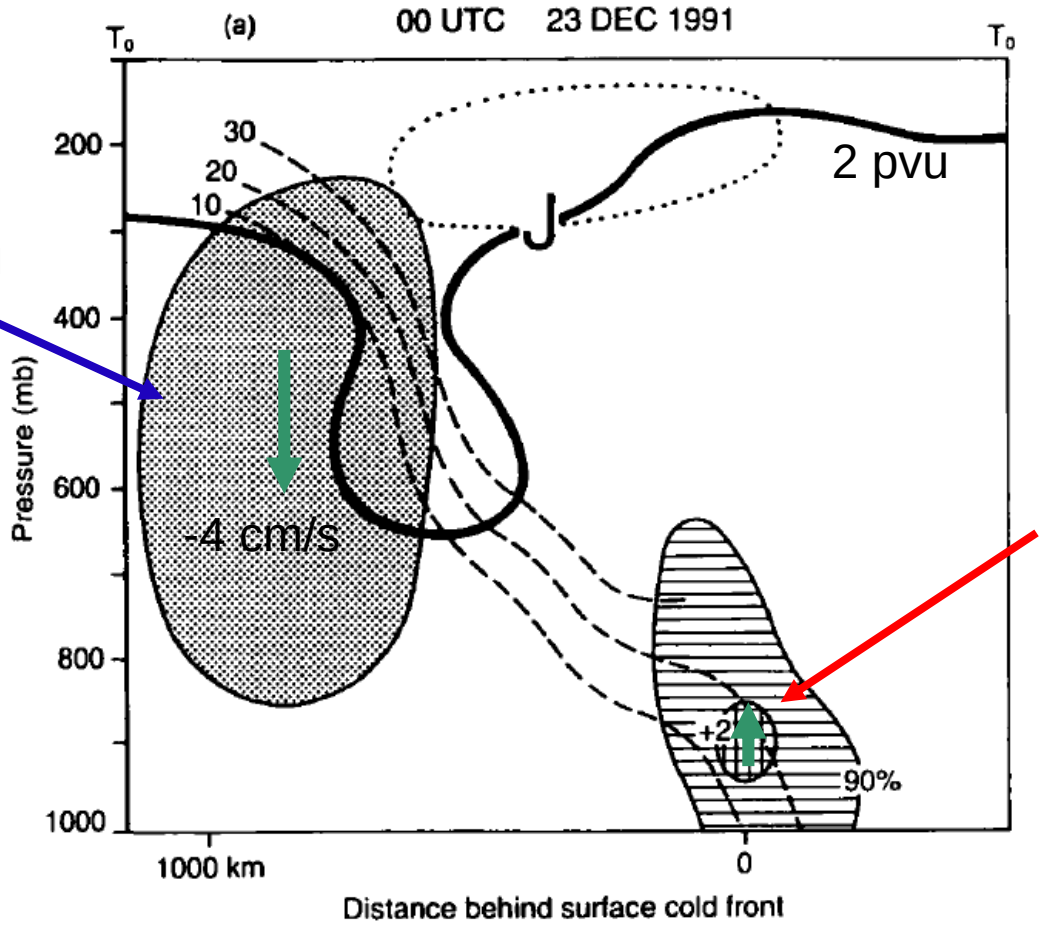


Dry air intrusions (DAIs)



Browning 1997 (*Meteorol. Appl.*)

DAI and extreme surface wind



Dry descending air

Moist ascending air

Browning and Reynolds 1994 (*QJ*)

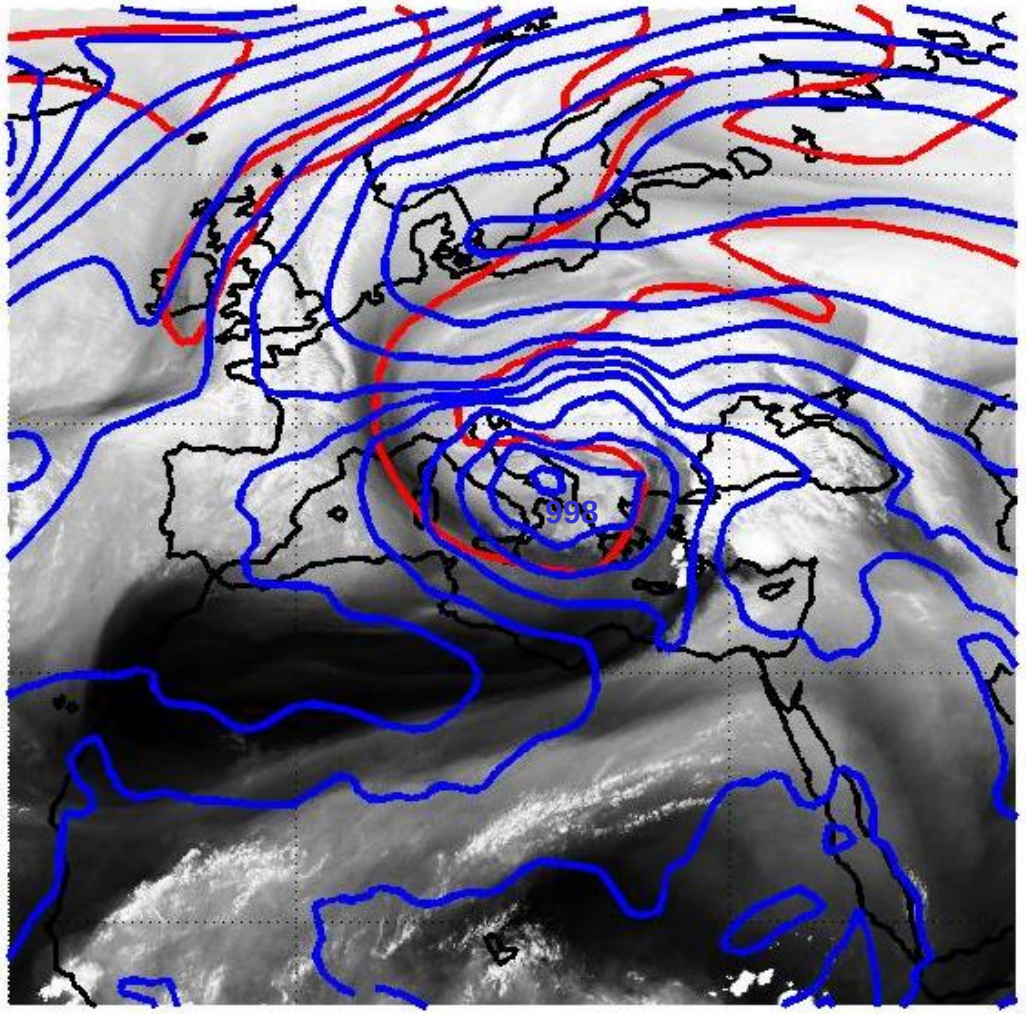
Extreme large-scale wind and precipitation

Case study: 21-23 October 2007 Mediterranean cyclone

2 PVU on 330 K

SLP

WV (Dundee satellite receiving station)

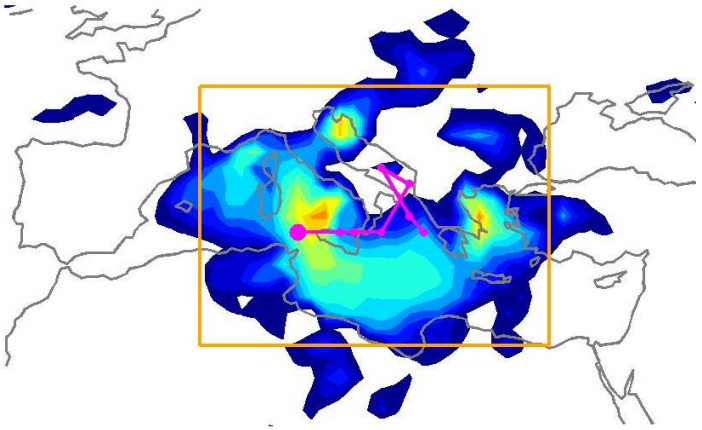


12 UTC 22/10/2007

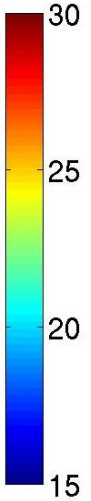
Total wind and precipitation

ERA Interim

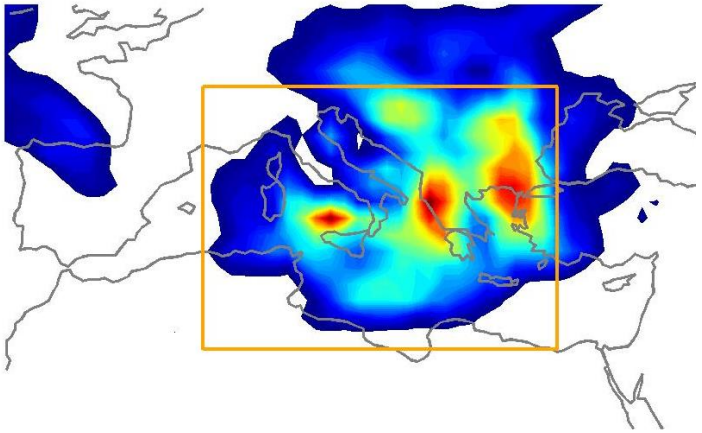
Maximum 10-m gust



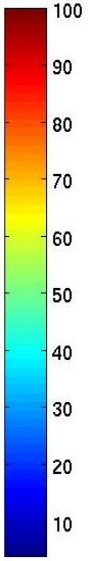
[m/s]



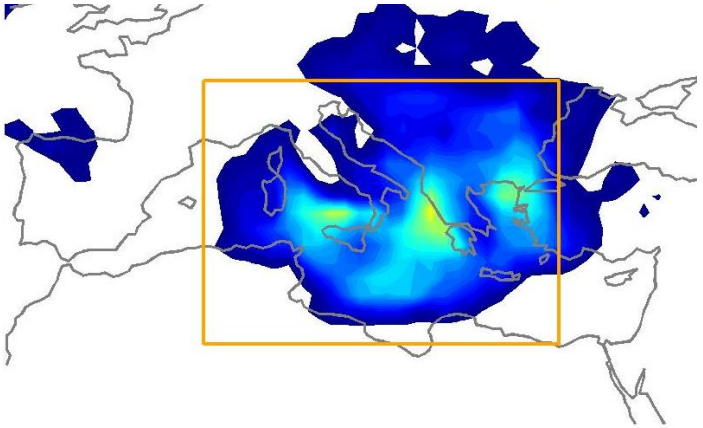
Total precipitation



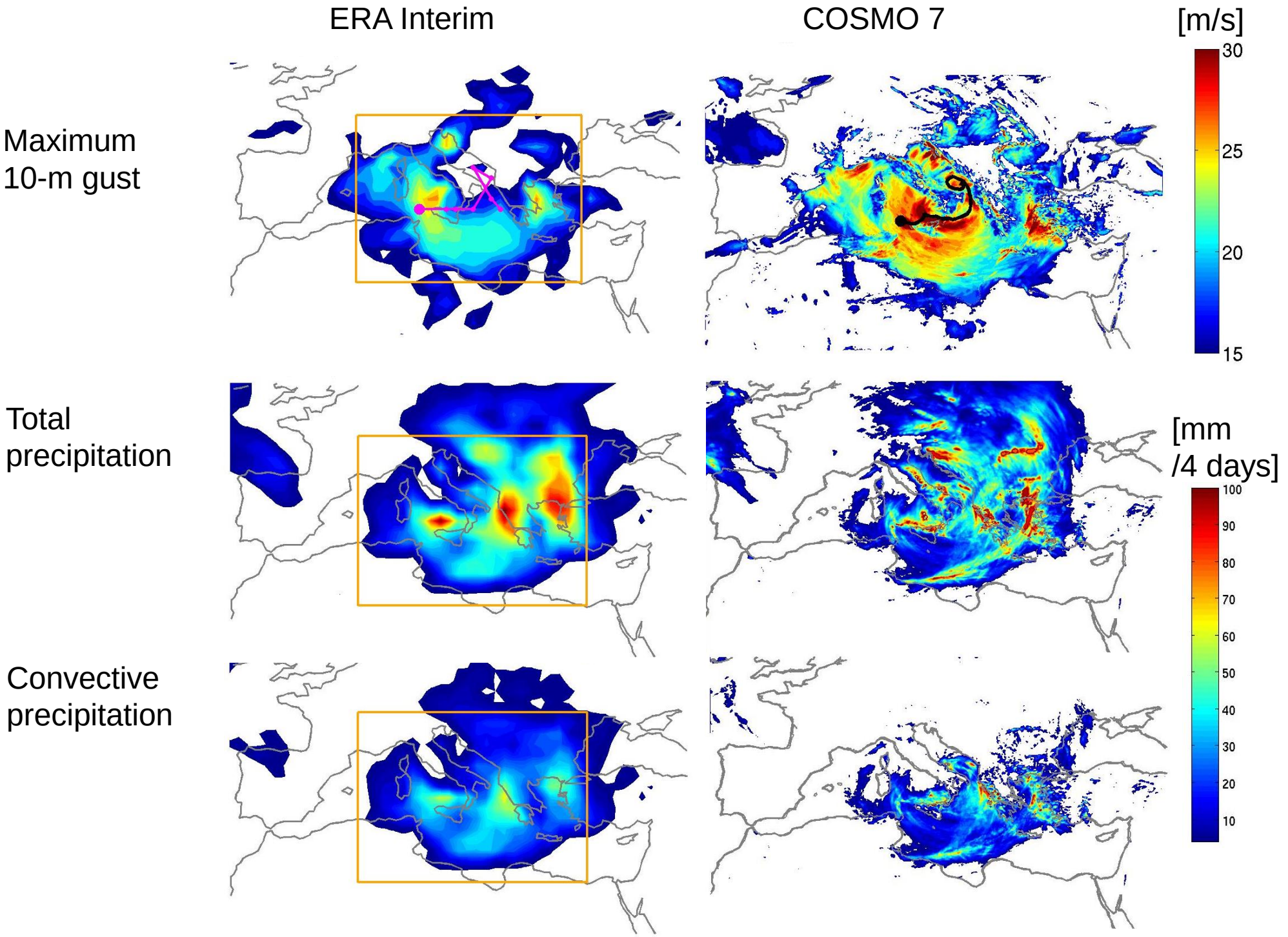
[mm /4 days]



Convective precipitation

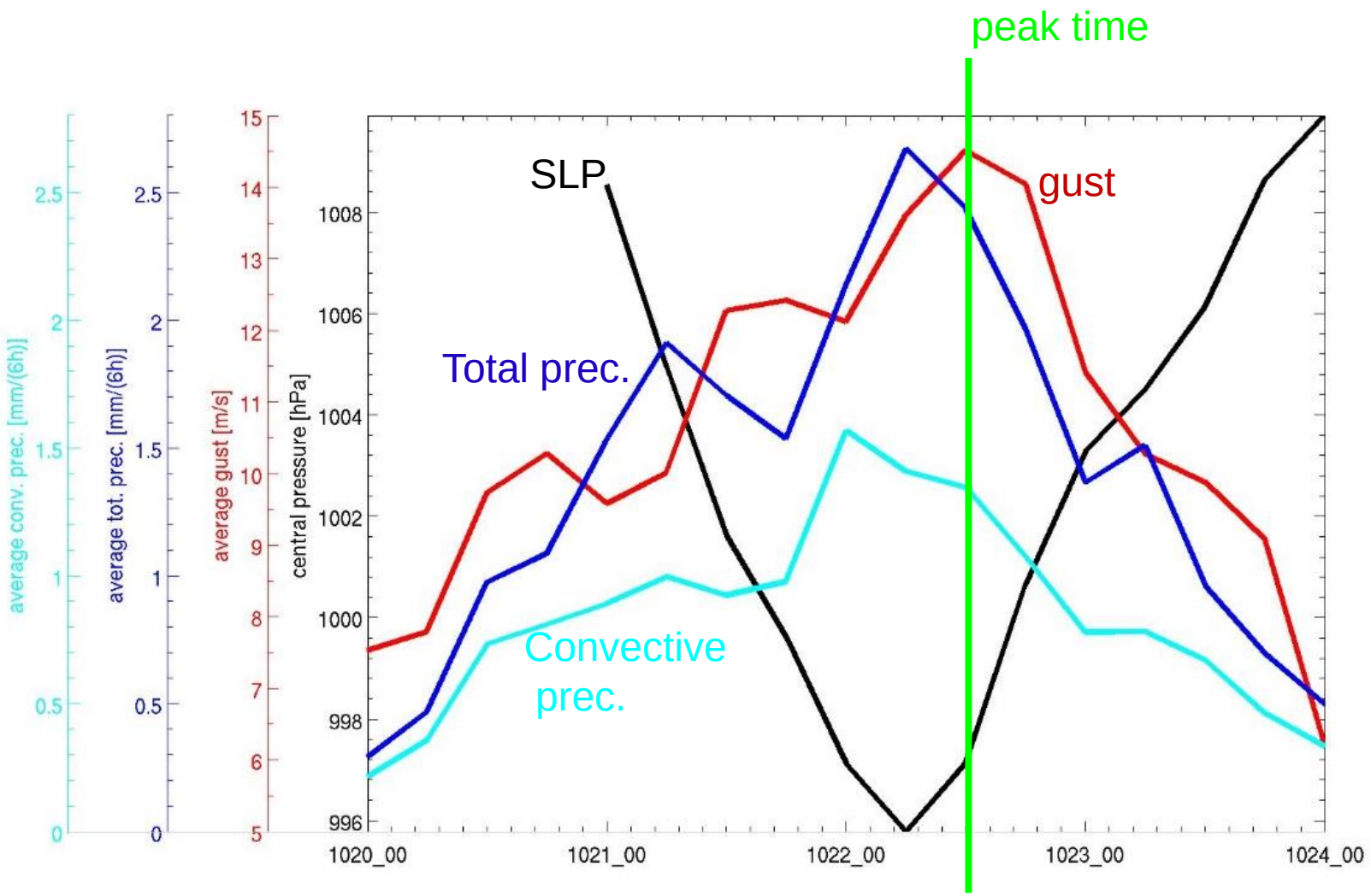


Total wind and precipitation



Temporal evolution

ERA Interim



Peak wind / precipitation and Lagrangian airstreams

Ascending trajectories

500-hPa ascent in 48 h

Total 6-h precipitation

Descending trajectories

400-hPa descent in 96 h

Maximum 6-h gust (at 10 m)

Trajectories reaching max. gust

Gust > 22 m/s
P>900 hPa

Peak wind / precipitation and Lagrangian airstreams

Ascending trajectories

500-hPa ascent in 48 h

Total 6-h precipitation

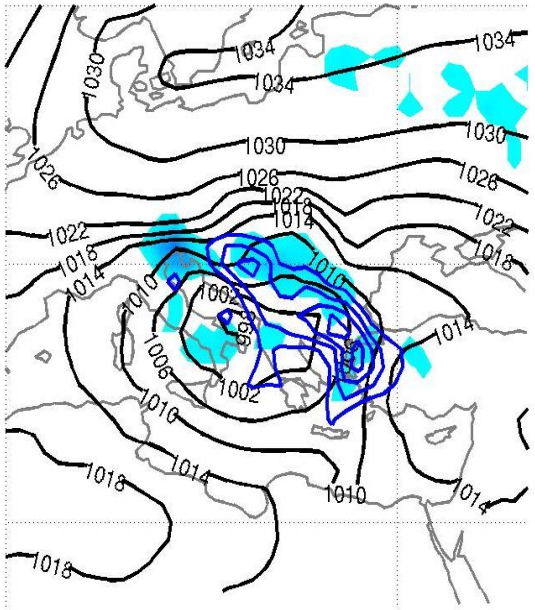
Descending trajectories

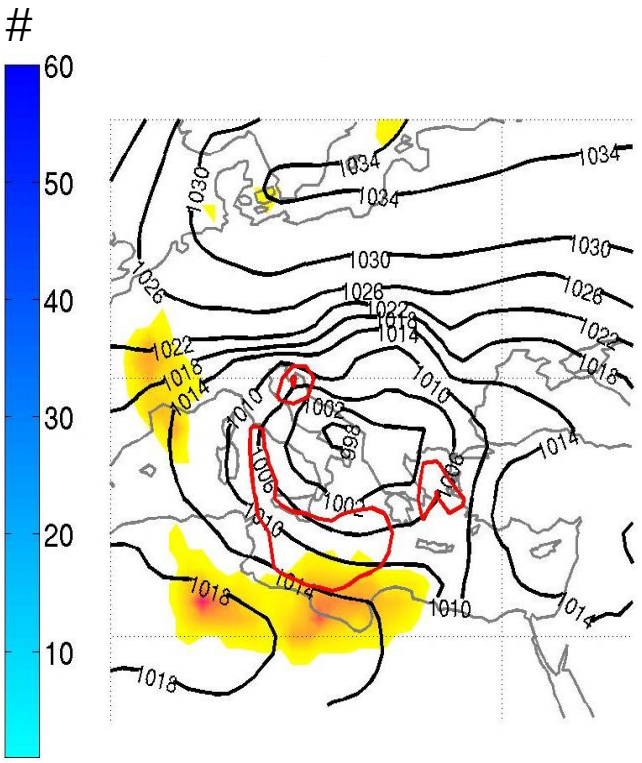
400-hPa descent in 96 h

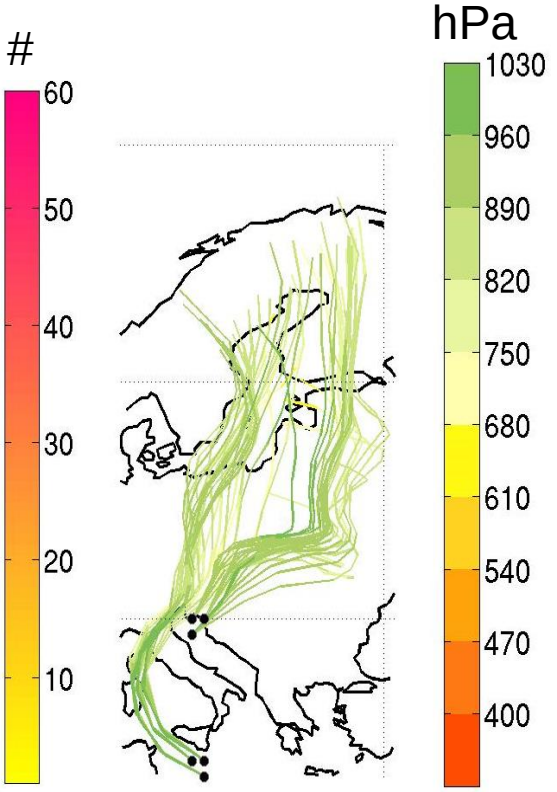
Maximum 6-h gust (at 10 m)

Trajectories reaching max. gust

Gust > 22 m/s
P>900 hPa



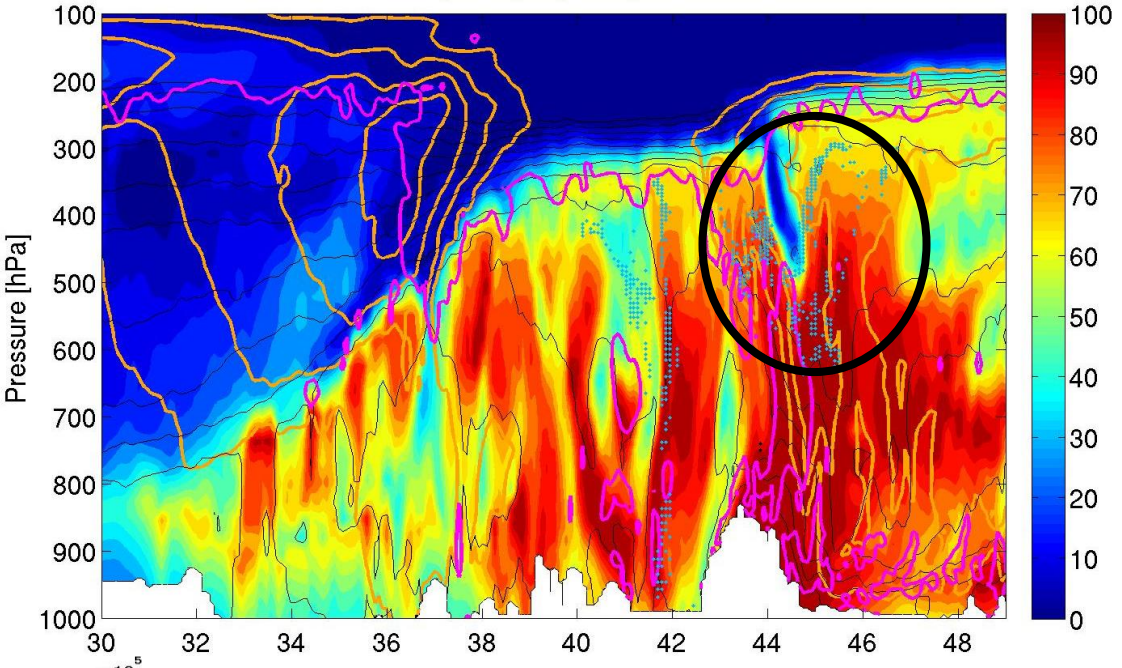


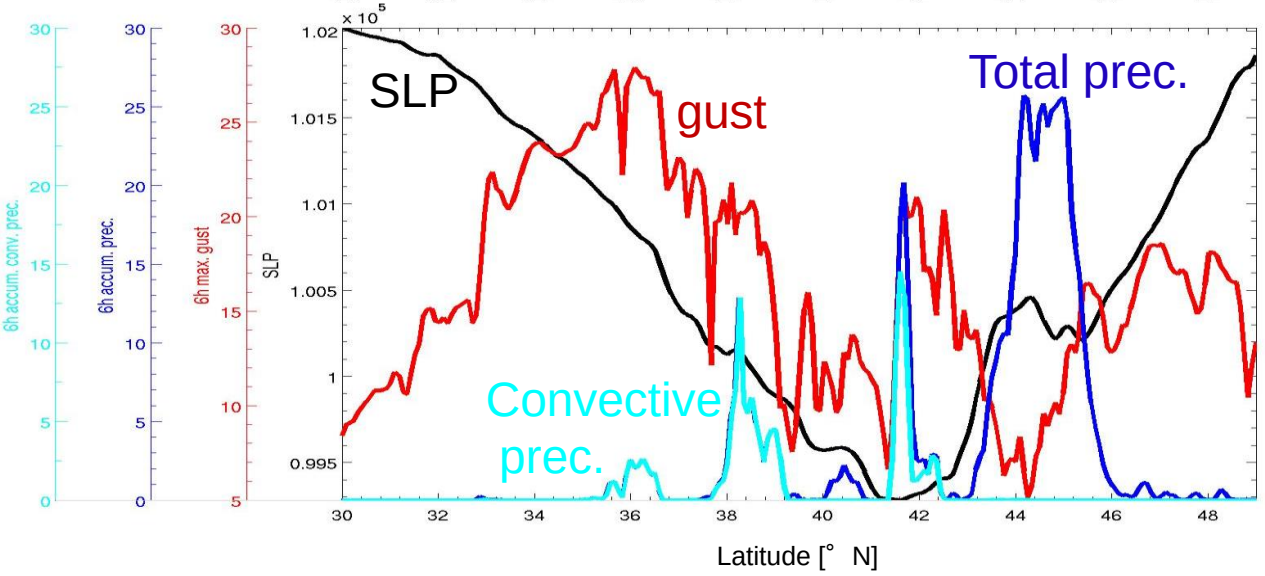


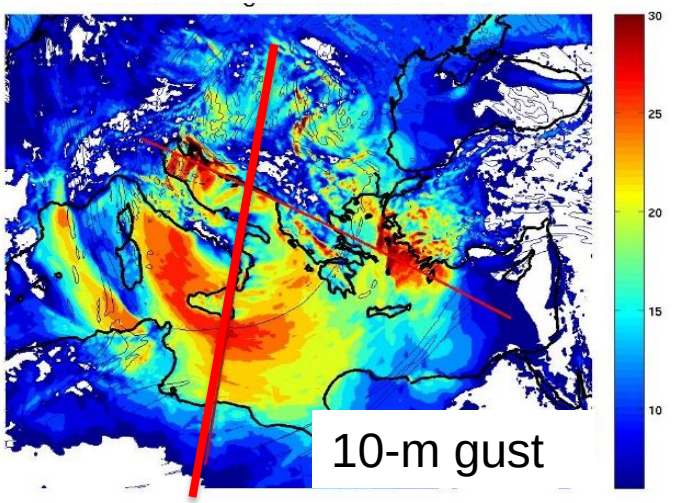
12 UTC, 22 October 2007

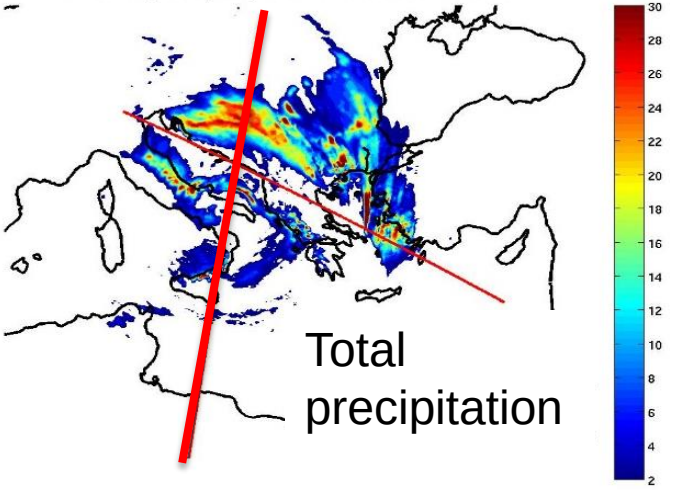
COSMO 7
12 UTC, 22 October 2007

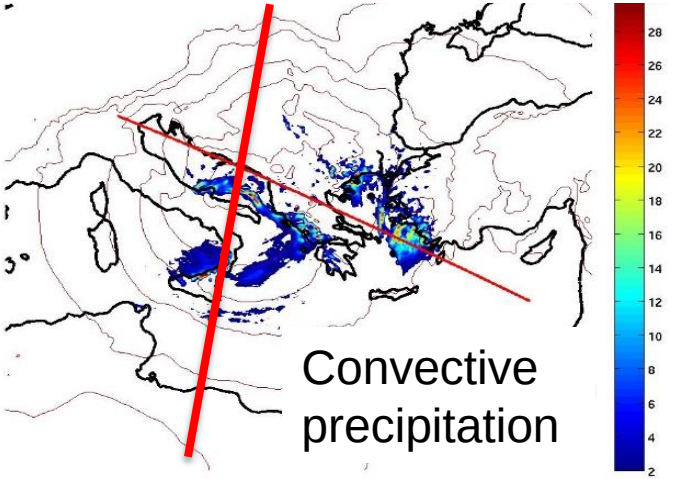
PV>2 pvu
Wind vel.
> 20 m/s
θe



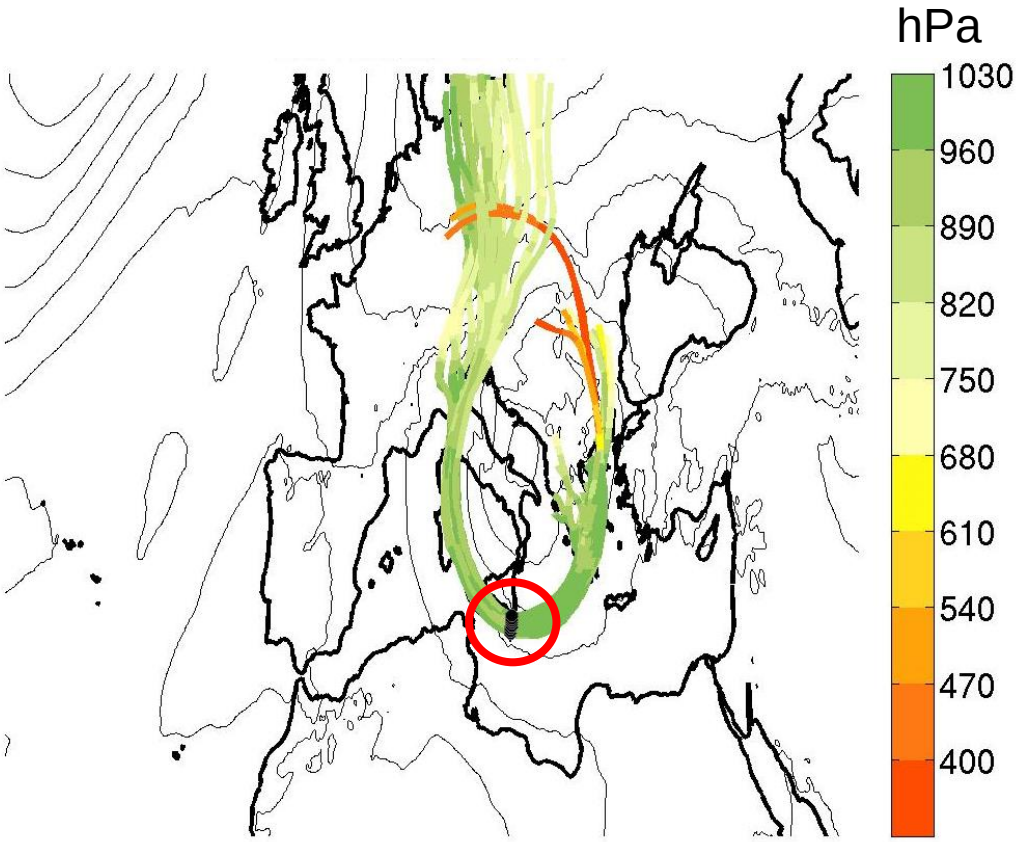


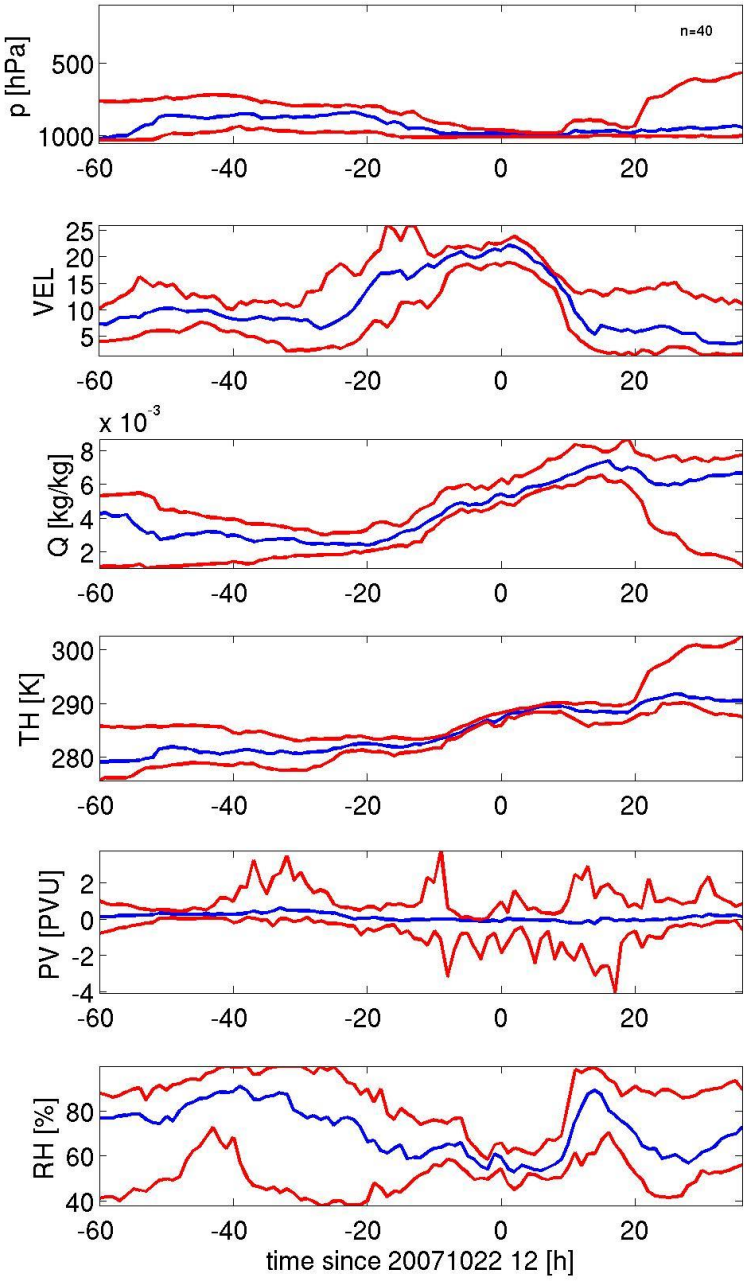






COSMO trajectories reaching high gust

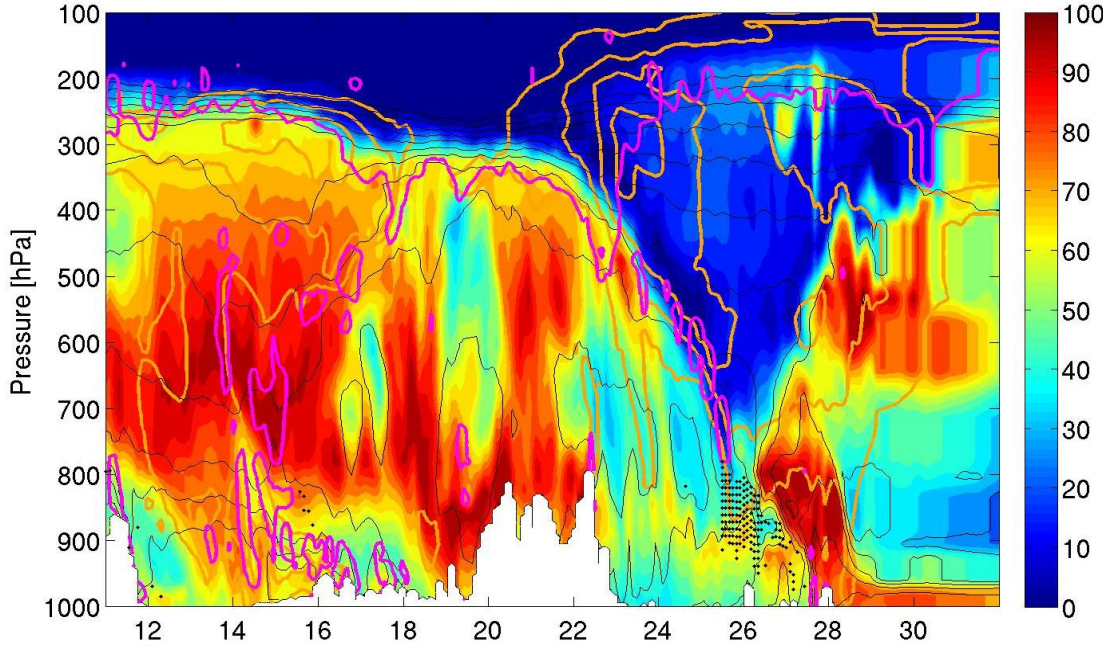


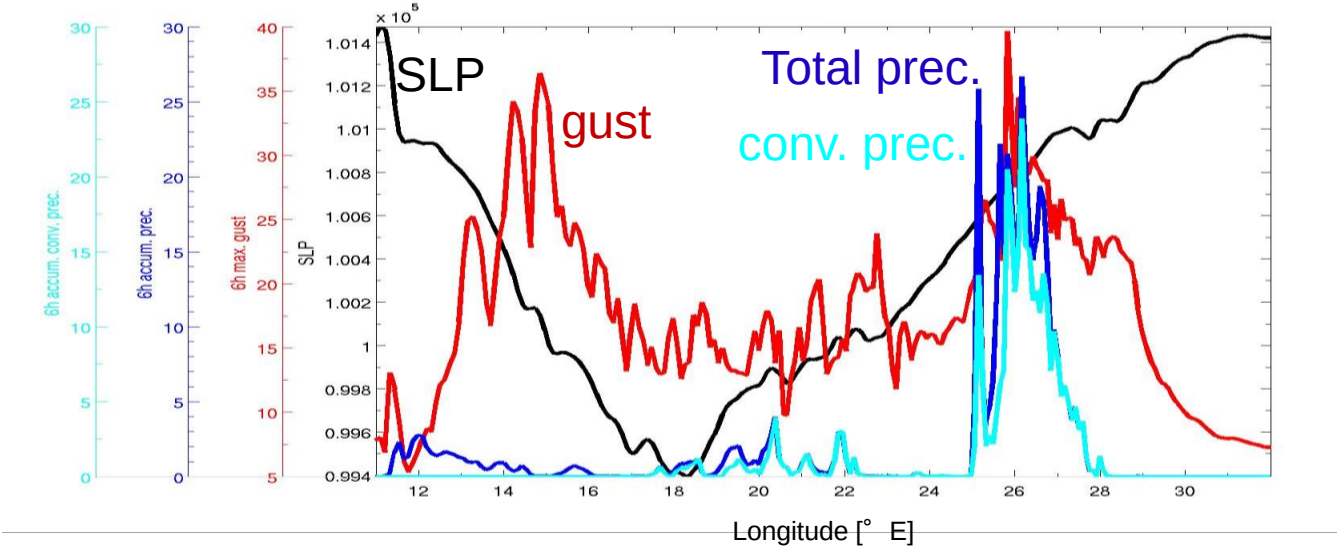


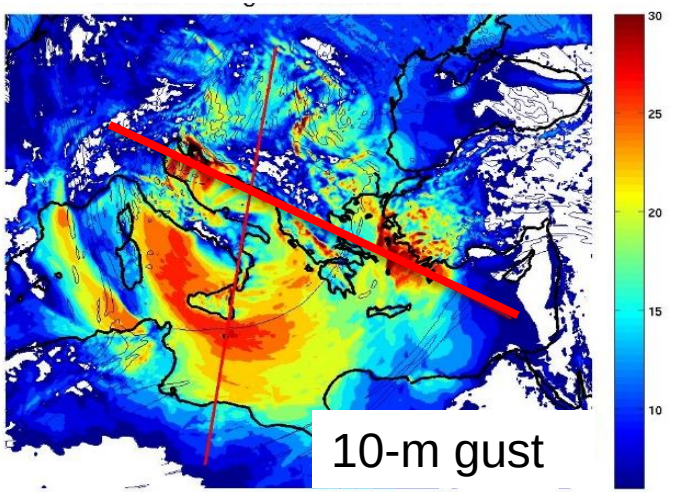
COSMO 7
12 UTC, 22 October 2007

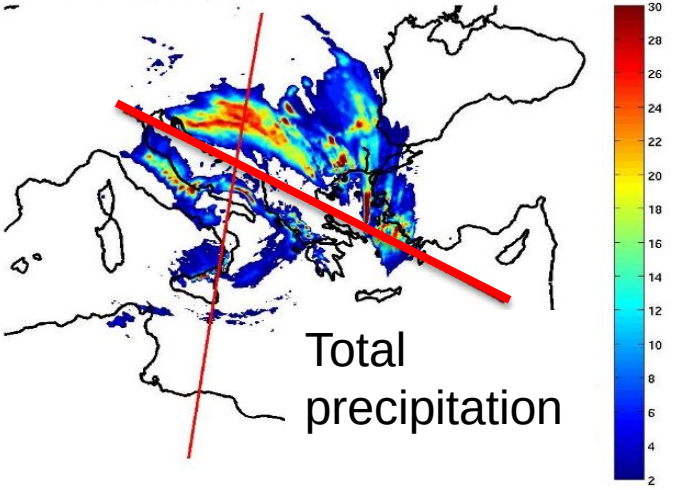
PV>2 pvu
Wind vel.
> 20 m/s
θe

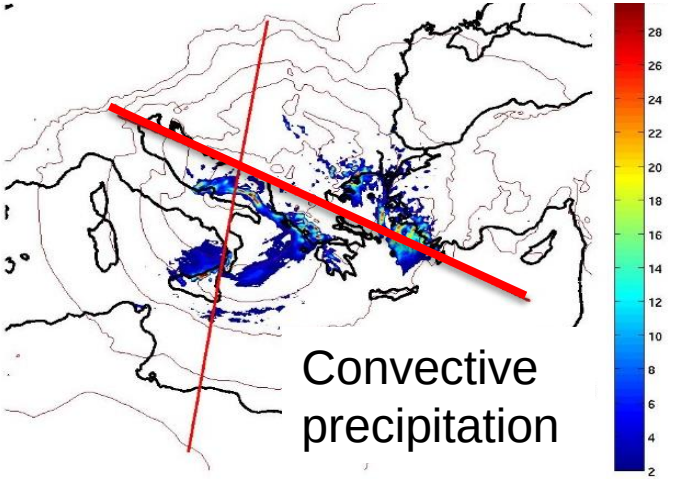
RH [%]



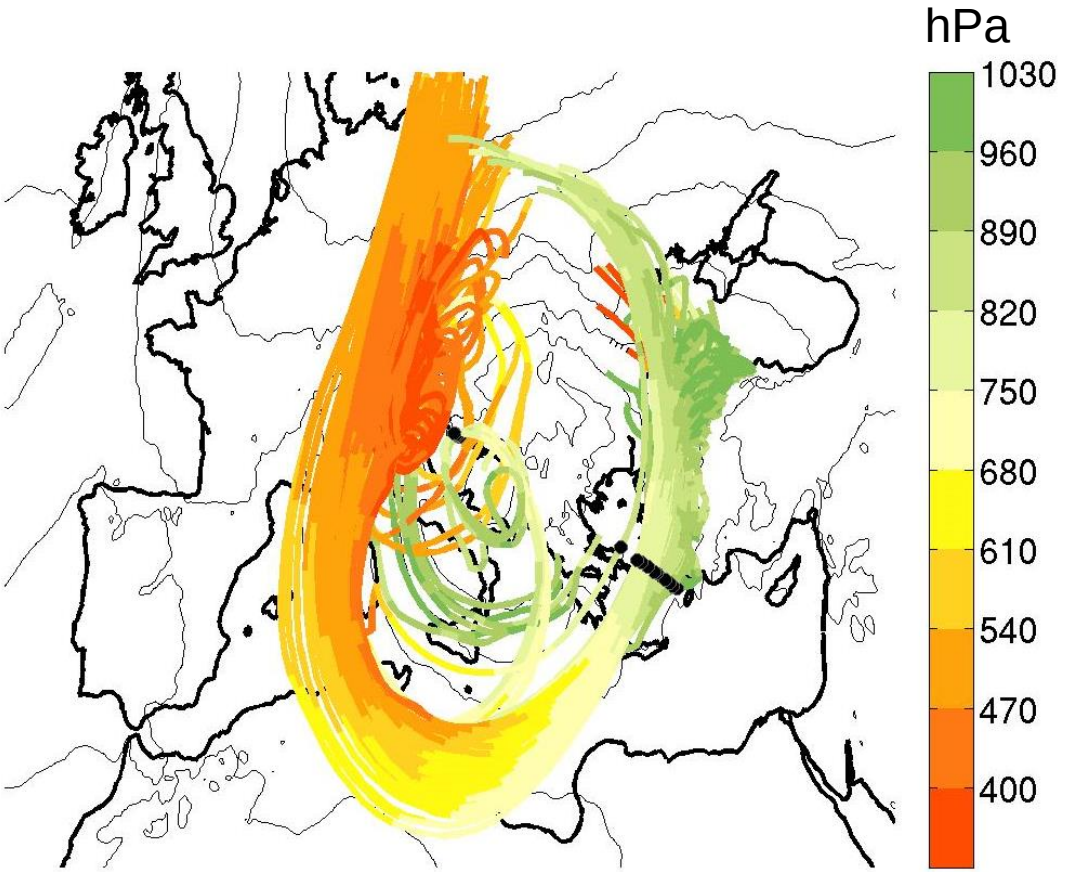


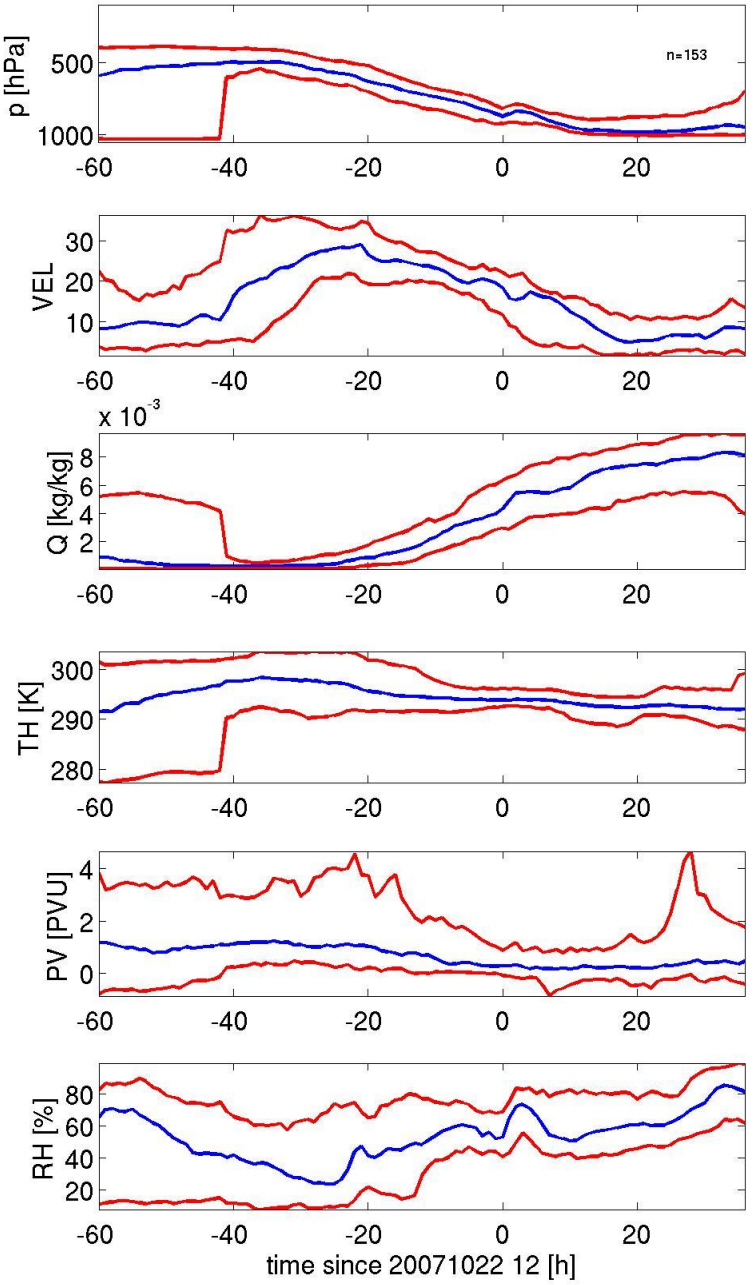




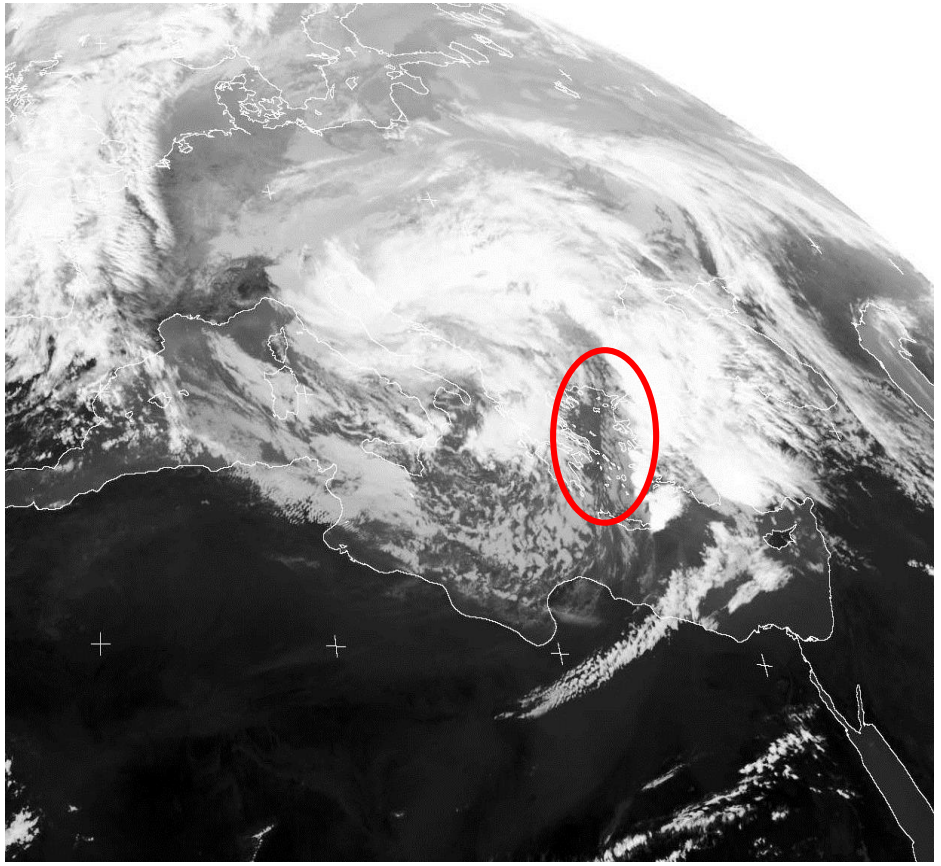


COSMO trajectories which descend strongly 400 hPa in 24 h

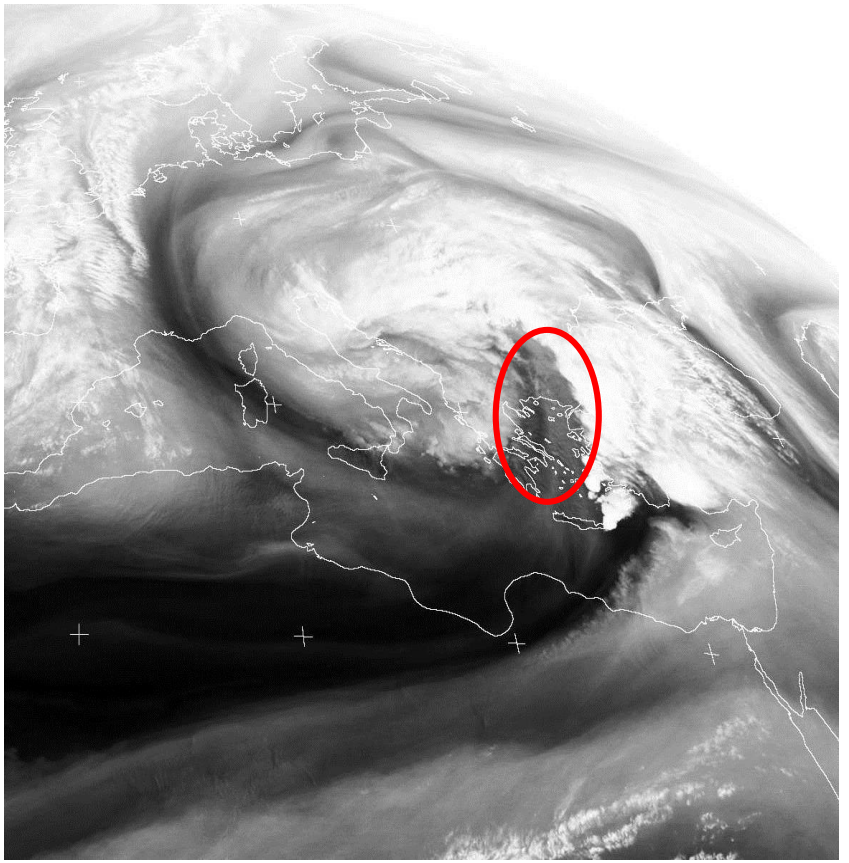




Observation of shallow convection



Channel 10 - IR
11.00-13.00 µm



Channel 5 - WV
5.35-7.15 µm

Case study - summary

- Large-scale and persistent non-convective precipitation associated with WCB trajectories
- Large-scale high gust associated with CCB and instability
- At the cold front environment – shallow convection and destabilization by a DAI – important for co-location of strong wind and precipitation
- Strong wind and precipitation are otherwise separated

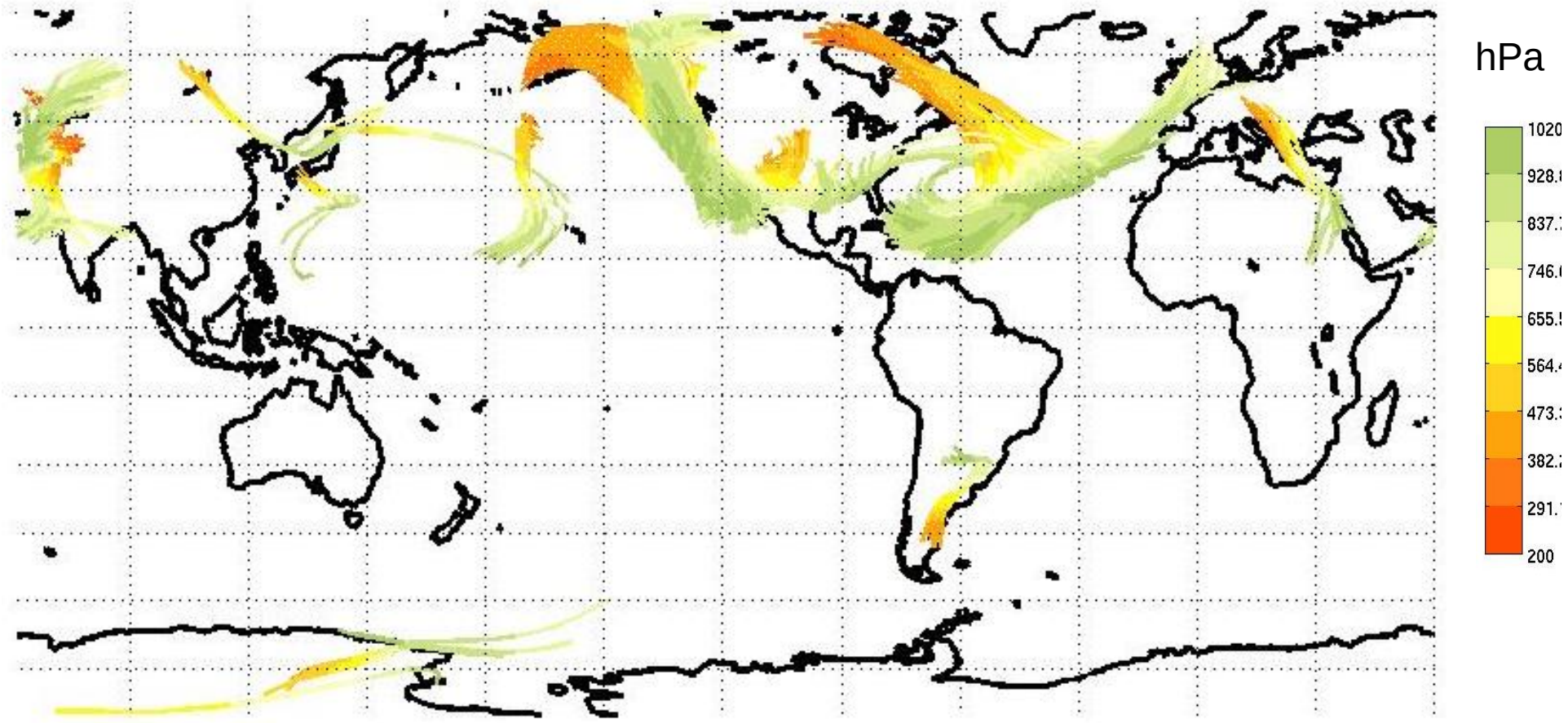
Dry air intrusions – Lagrangian definition

400-hPa descent in 48 h

- ERA Interim
- LAGRANTO (Sprenger and Wernli 2015, *Geosci. Model Dev.*)
- Start forward trajectories every 6 h, 80 km, above 600-hPa level

Dry air intrusions – Lagrangian definition

400-hPa descent in 48 h



Start at 19921121_06

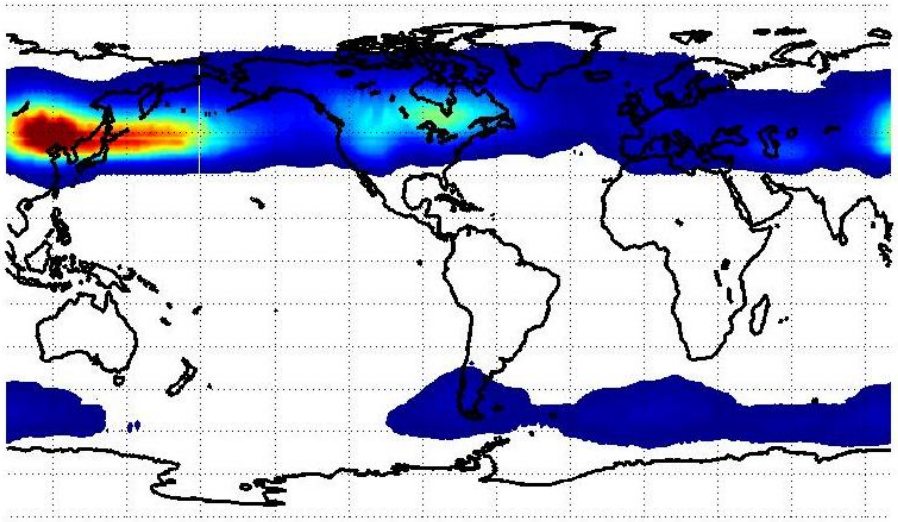
Dry air intrusions climatology

DJF

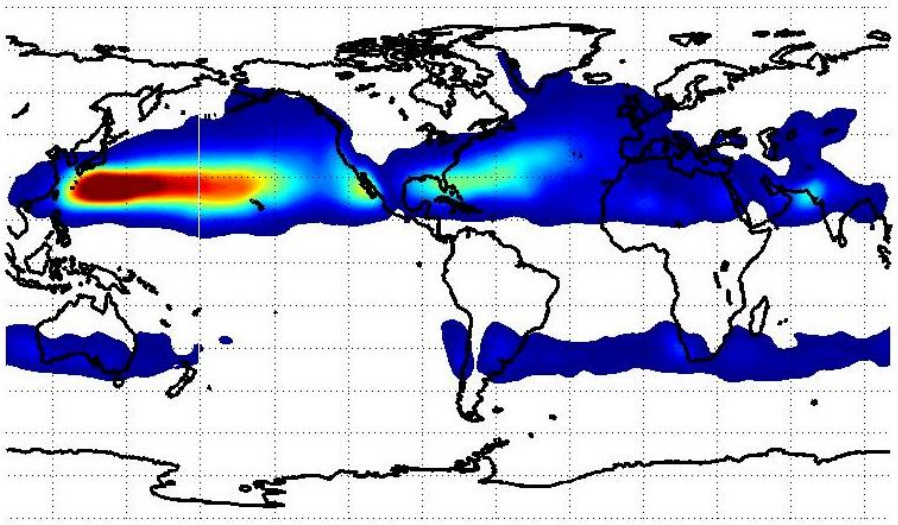
/ (6h deg^2)

0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05

0 h



+48 h



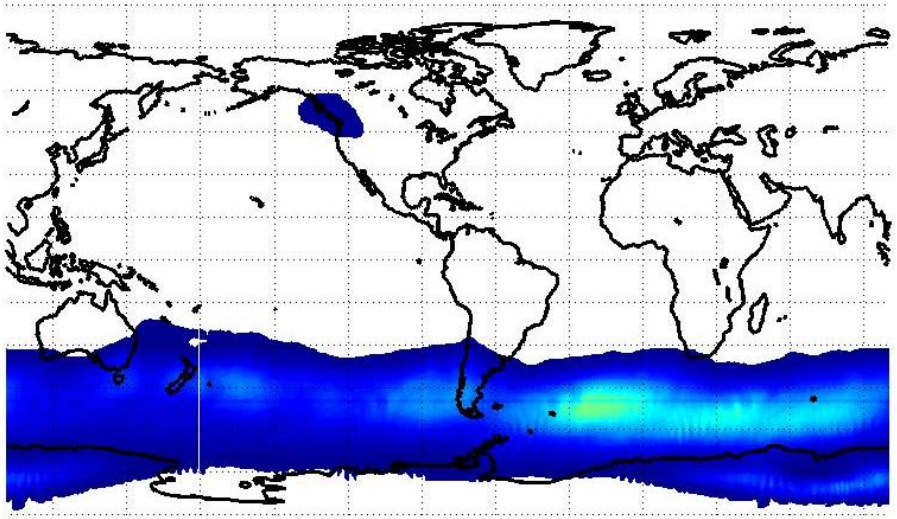
Dry air intrusions climatology

JJA

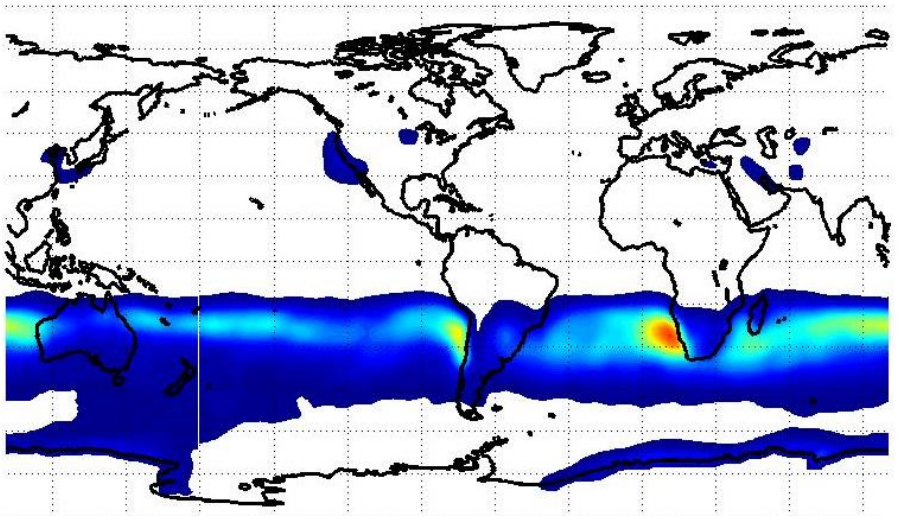
/ (6h deg^2)

0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05

0 h

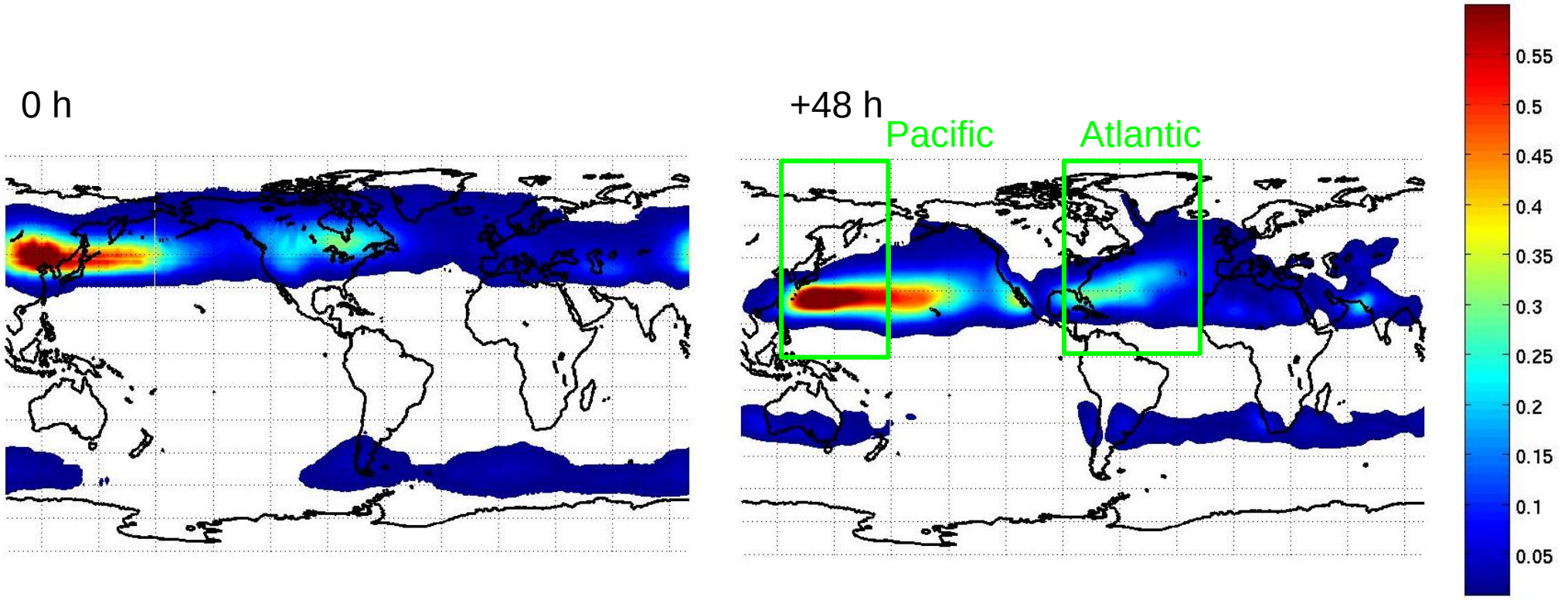


+48 h



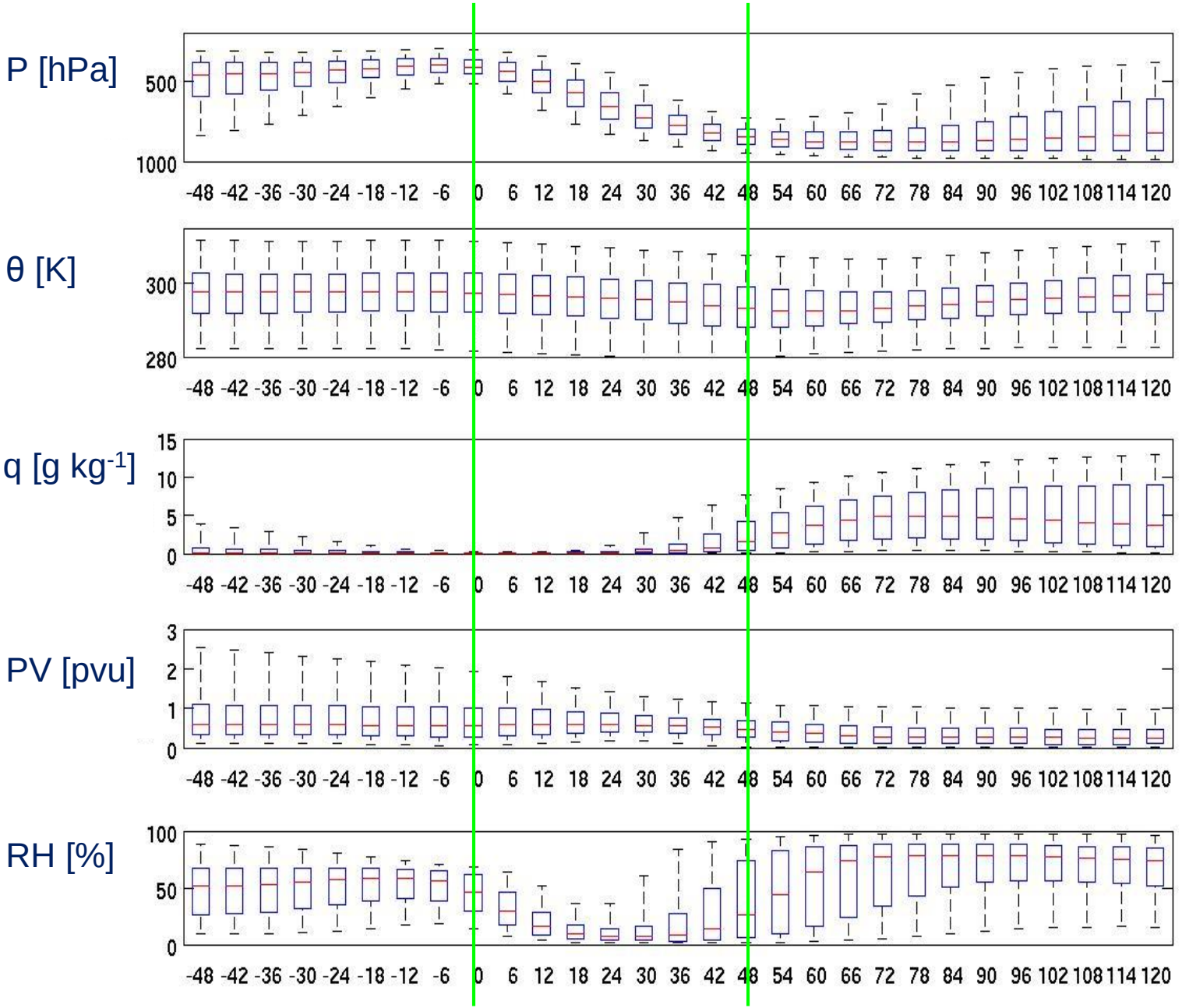
Dry air intrusions climatology

DJF



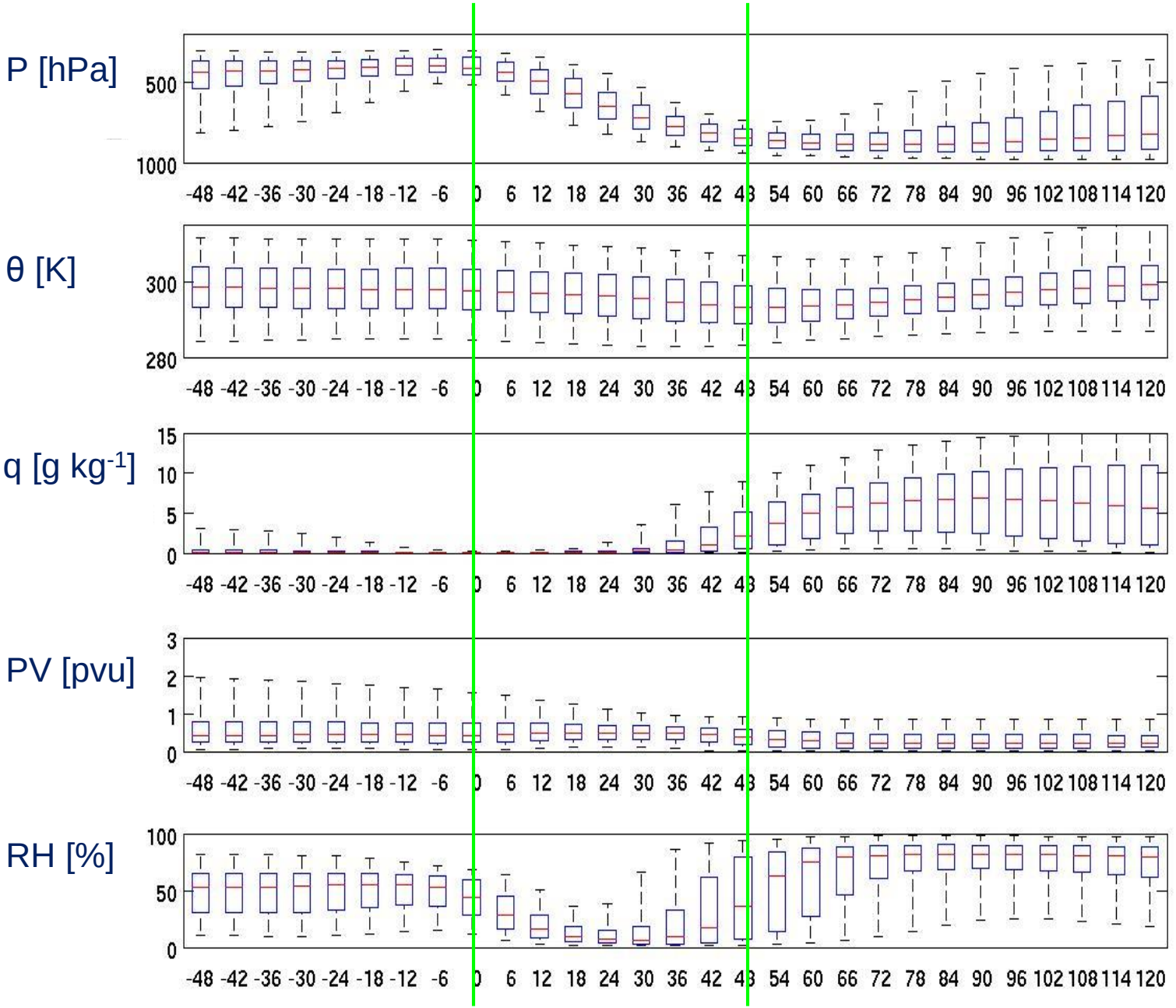
Temporal evolution

Atlantic / DJF



Temporal evolution

Pacific / DJF



Dry air intrusions – outlook

- How do DAIs interact with cyclones?
- What is the origin of DAIs?
- What initiates DAIs?
- What is the impact of DAIs on extreme weather at the surface?

Thank you!