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**The Extratropical Transition  
of  
Hurricane Debby (1982)  
and  
its re-development into an  
Intense Windstorm Mauri  
over Finland**

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# Why Debby / Mauri?

- One of the **most intense windstorms** in Finland  
→ 2 fatalities and 3 milj. m<sup>3</sup> of forest damage
- Probably the **only Finnish storm to originate from a hurricane**  
→ Speculated at the time but never investigated before

Fallen trees in Lapland in Sep 1982.  
*Picture: YLE*





# Hurricane Debby (1982)

- **15 Sep:** category 1
- **18 Sep:** category 4  
→ max. winds 58 m/s  
→ min. pressure 950 hPa
- **19-20 Sep:** extratropical transition (ET)
- NHC tracks only the tropical part



# Outline

## Synoptic overview

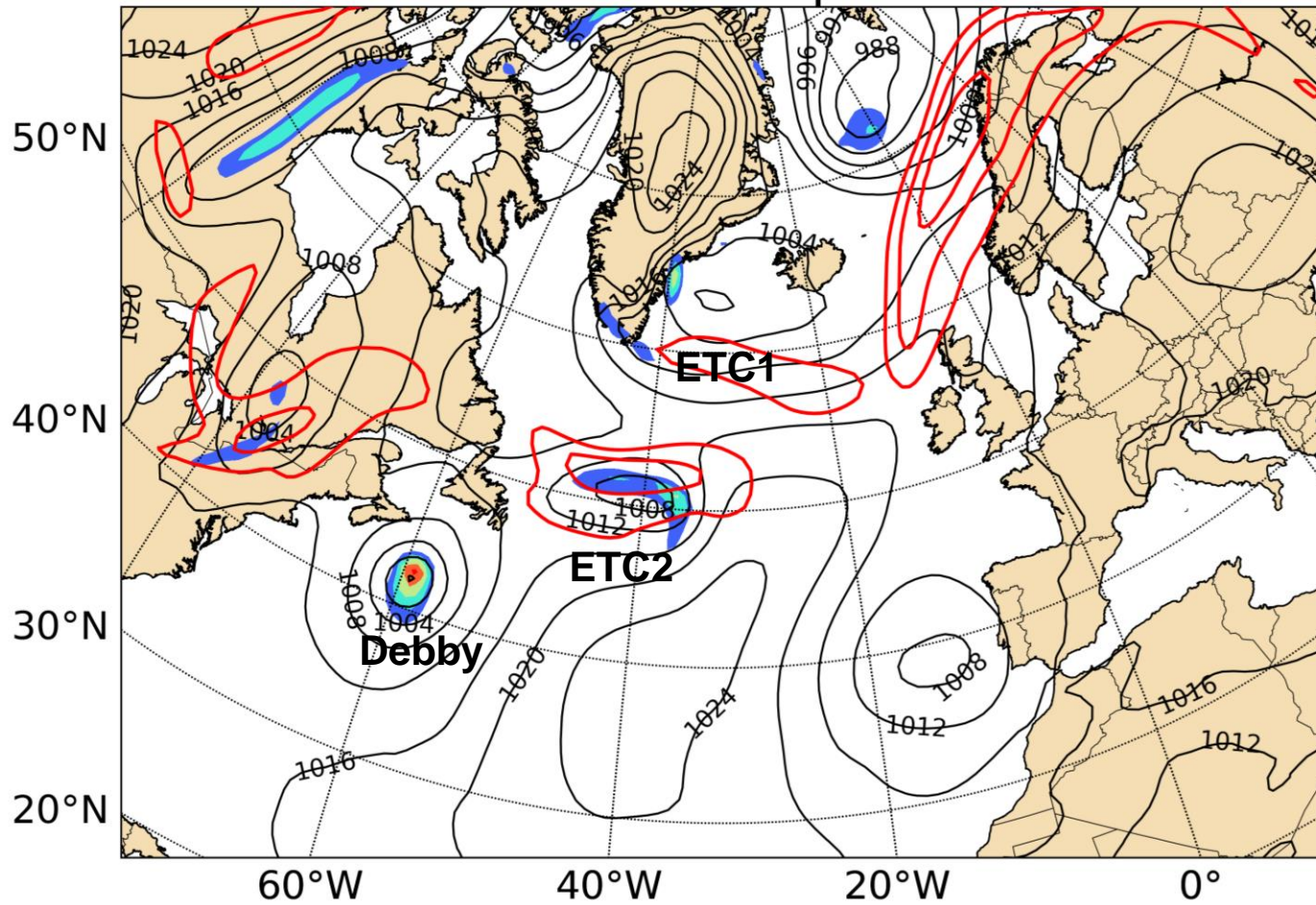
→ **ERA-Interim reanalysis** (*T255: ~ 80 km, 60 levels*)

## Meso- and synoptic-scale dynamic evolution

→ **OpenIFS simulations** (*T1279: ~ 16 km, 137 levels*)

1. Why did ex-Debby travel across the Atlantic?
2. Why did ex-Debby re-intensify over the UK?
3. What were the reasons for strong winds over Finland?

12 UTC 18 Sep 1982



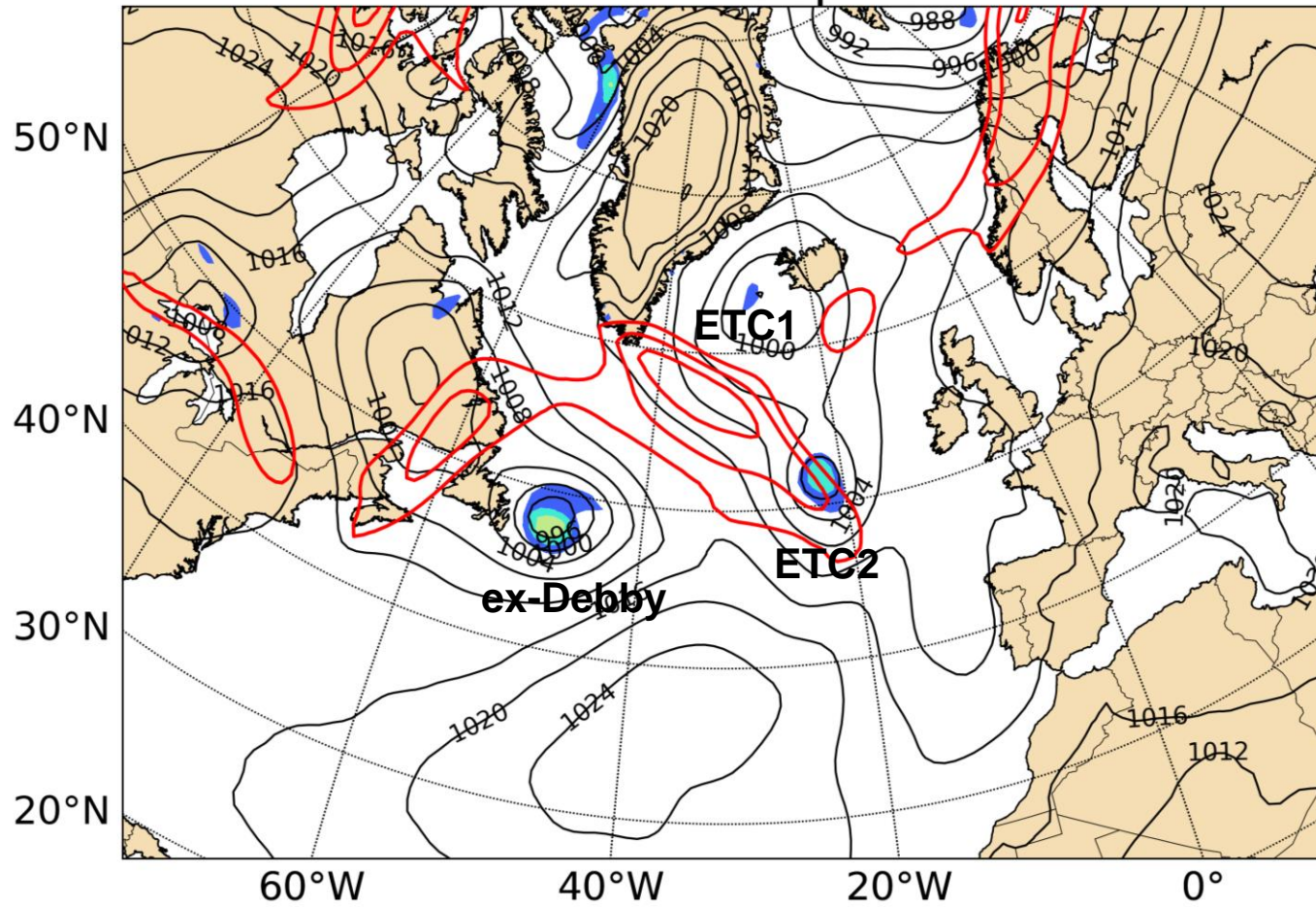
- Debby still a hurricane
- Two extratropical cyclones (ETC1 and ETC2) present
- Jet streaks over northern Europe and north-eastern Atlantic



850-hPa relative vorticity (colors),  
mean sea level pressure (black contours),  
300-hPa wind speed (red contours at 40,50,60 m/s)



12 UTC 19 Sep 1982

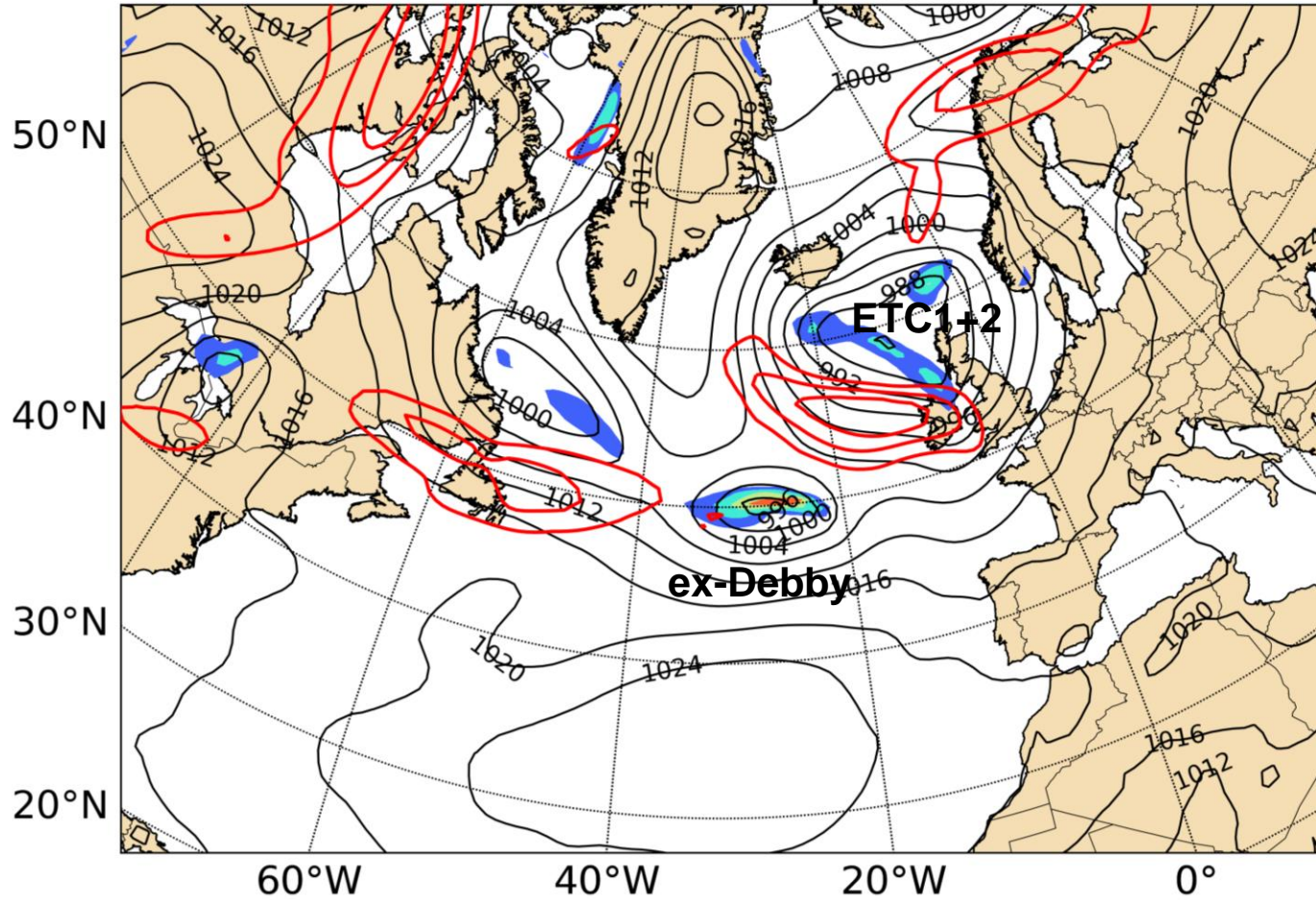


- Debby undergoes ET → ex-Debby
- ETC1 intensifies
- ETC2 reaches the left exit of the jet



850-hPa relative vorticity (colors),  
mean sea level pressure (black contours),  
300-hPa wind speed (red contours at 40,50,60 m/s)

12 UTC 20 Sep 1982



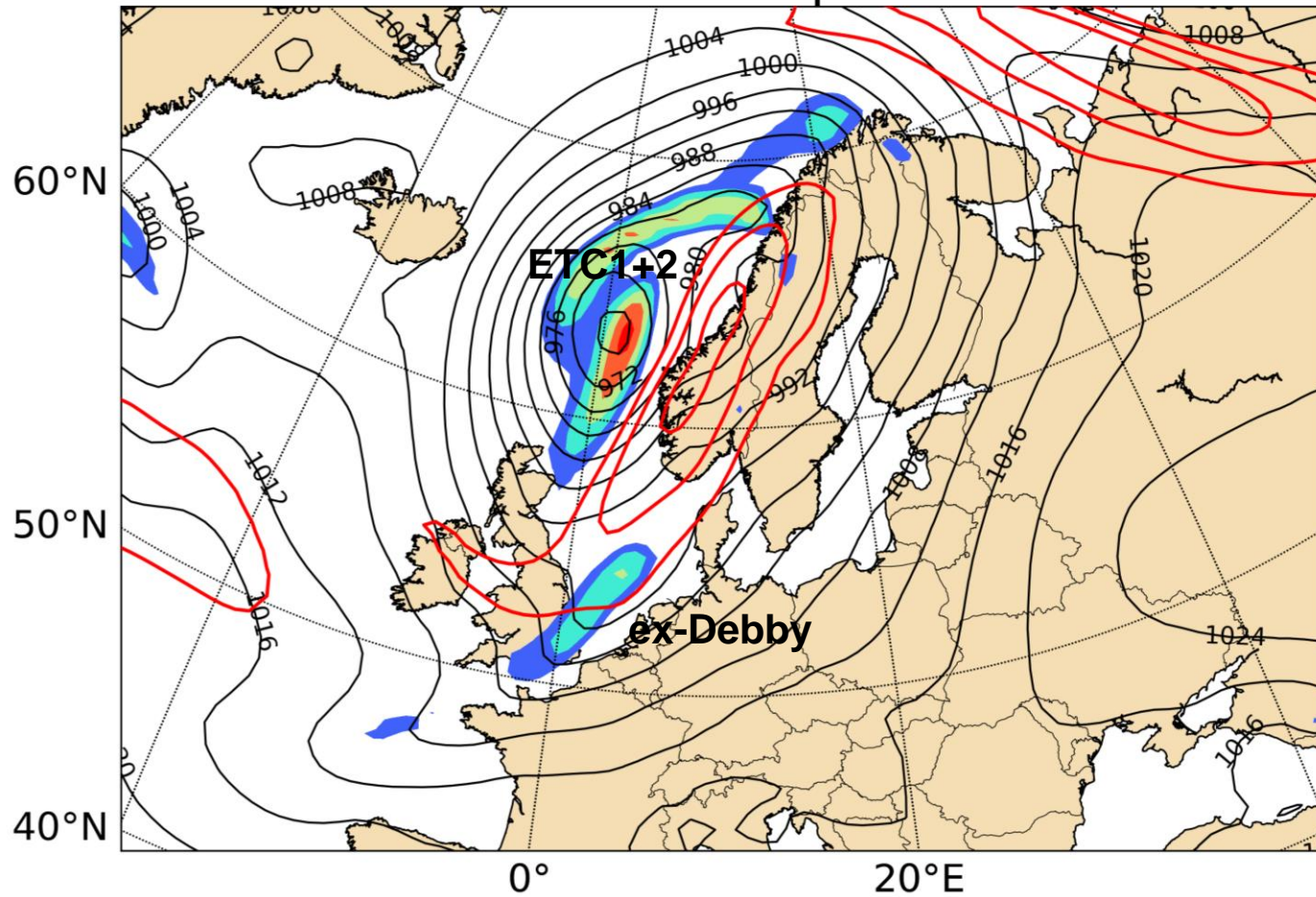
- Ex-Debby travels rapidly across the Atlantic
- ETC2 merged with ETC1 → large and intense low pressure system
- ETC1+2 stays in the left exit of the jet



850-hPa relative vorticity (colors),  
mean sea level pressure (black contours),  
300-hPa wind speed (red contours at 40,50,60 m/s)



12 UTC 21 Sep 1982

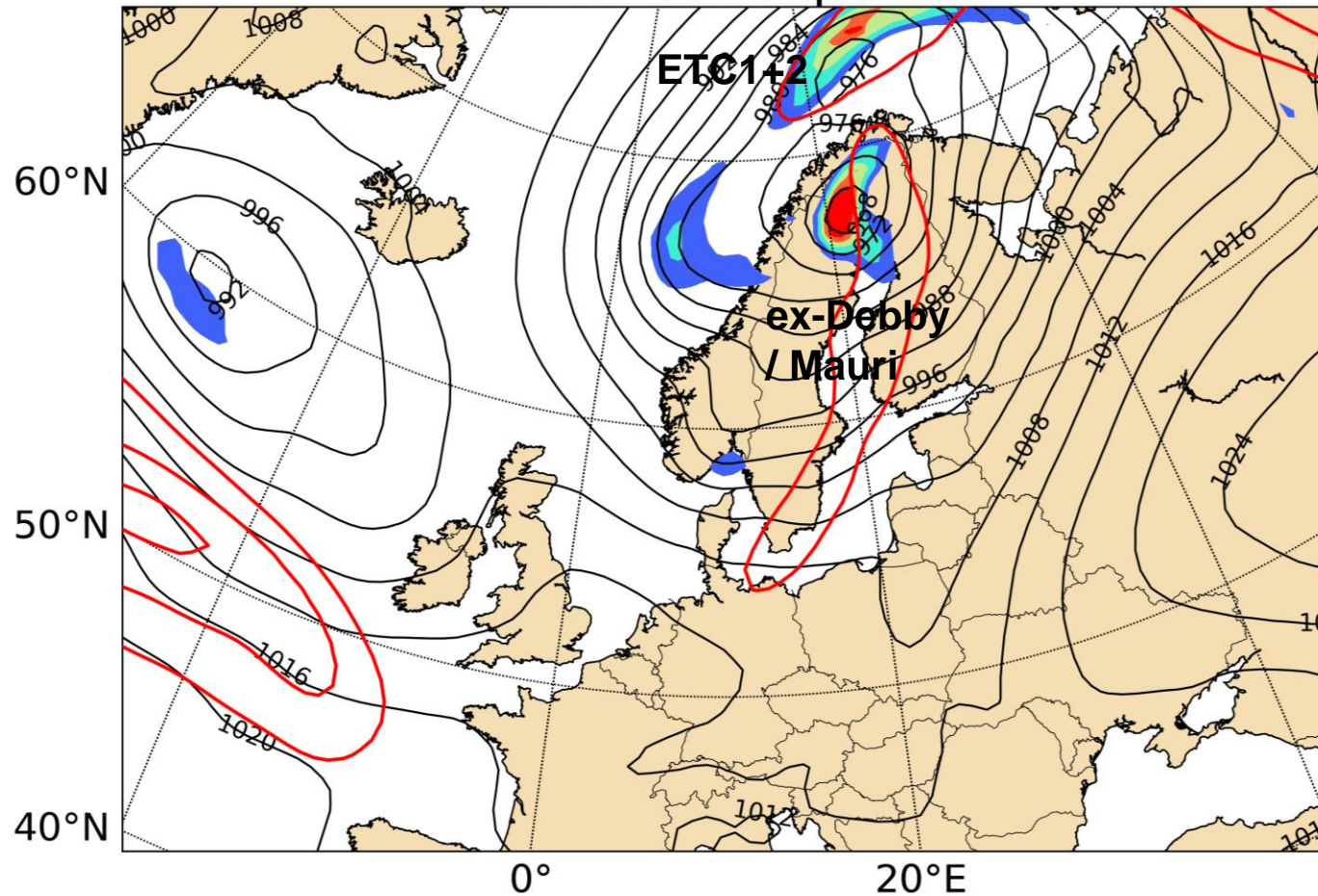


- Ex-Debby resembles a frontal trough rather than a closed low
- Ex-Debby reaches right entrance of the jet
- ETC1+2 intensifies
- T-bone structure: bent-back warm front and cold front

*850-hPa relative vorticity (colors),  
mean sea level pressure (black contours),  
300-hPa wind speed (red contours at 40,50,60 m/s)*



12 UTC 22 Sep 1982

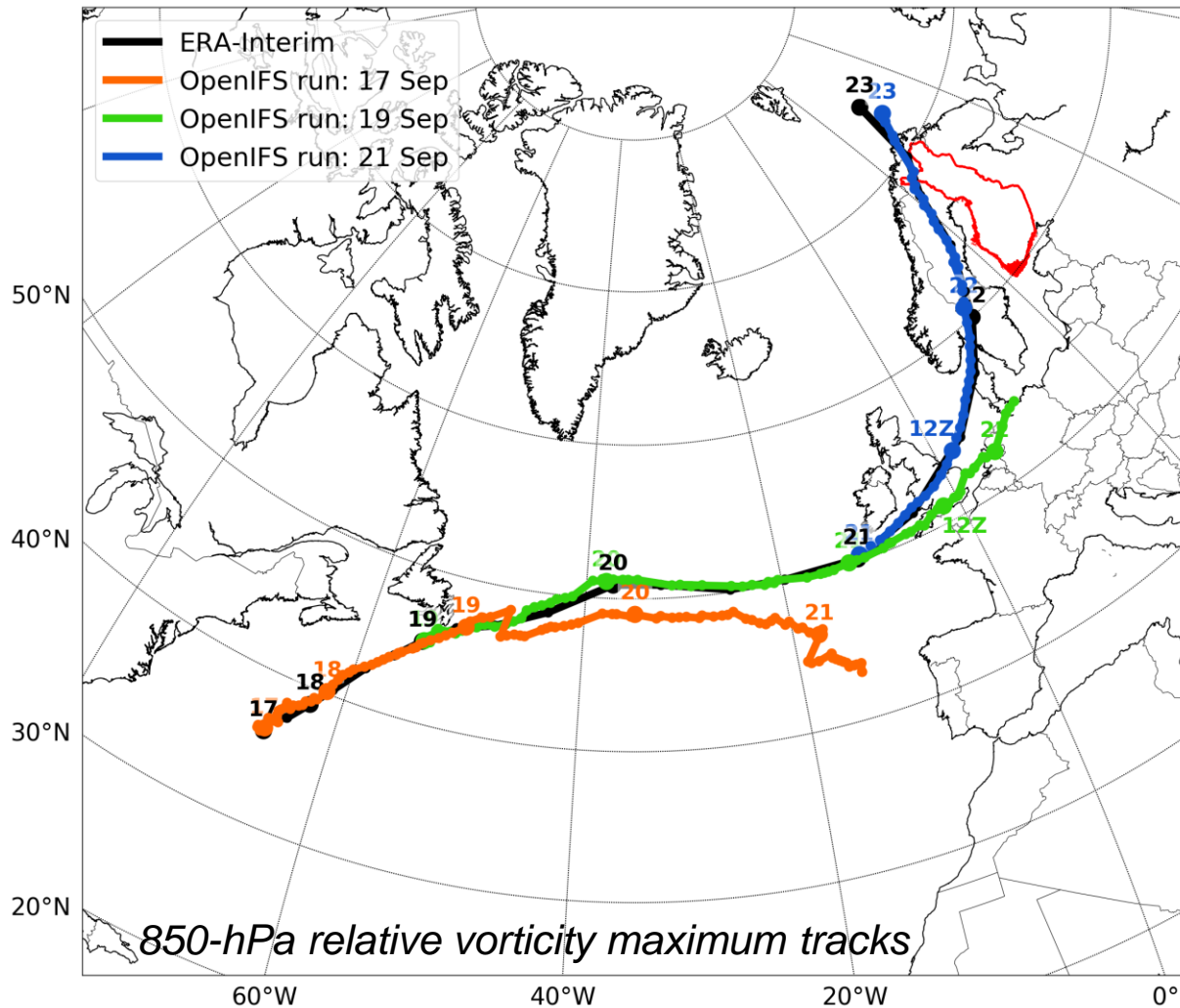


- Ex-Debby over Finland → Mauri
- Other low centre near the warm front
- Ex-Debby more intense of the two

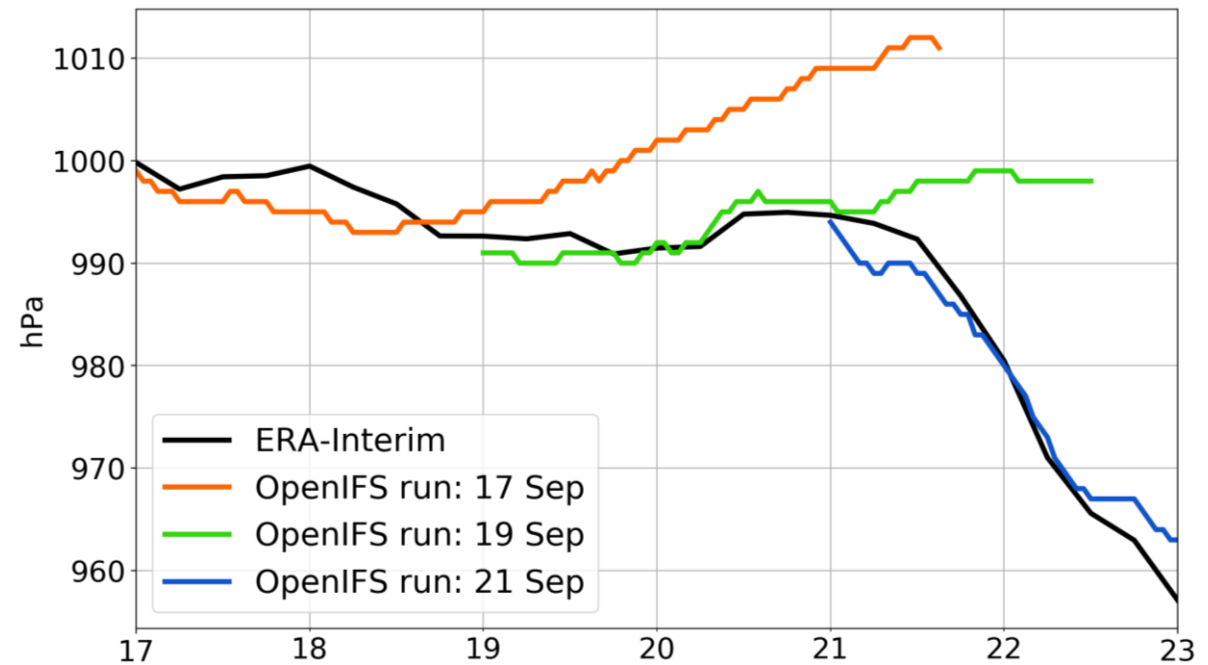


850-hPa relative vorticity (colors),  
mean sea level pressure (black contours),  
300-hPa wind speed (red contours at 40,50,60 m/s)

# OpenIFS simulations

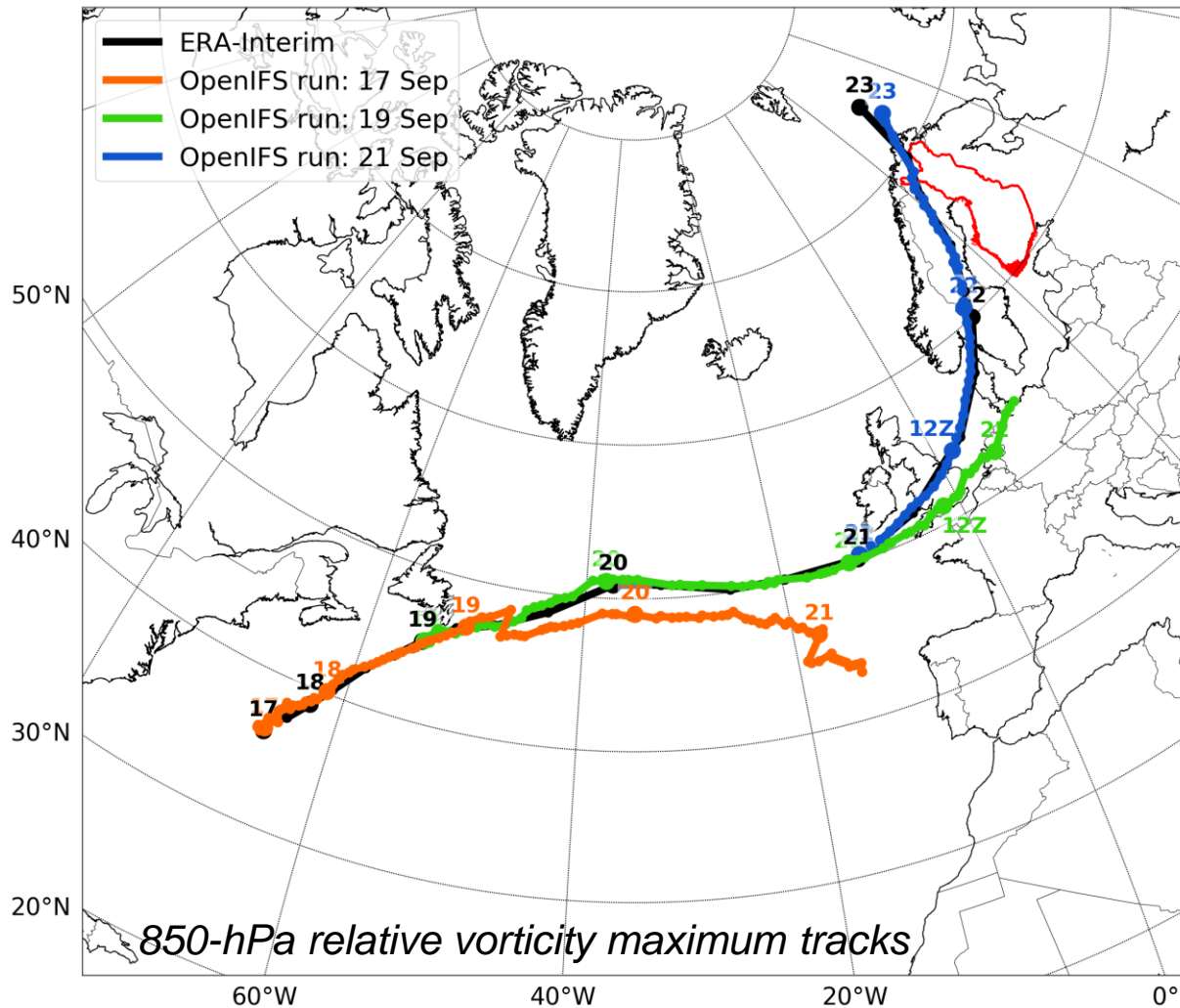


- **High resolution** (T1279) simulations  
→ coarser resolutions did not capture
- **Three runs** with different initialization dates  
→ forecast skill ~2 days

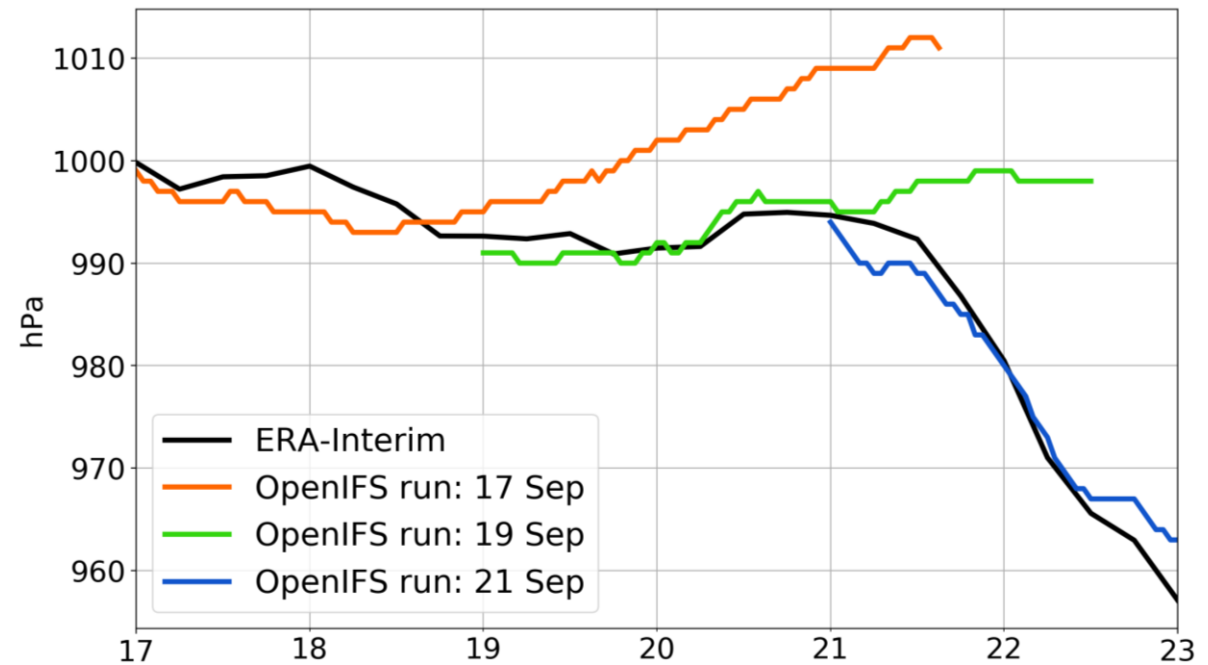




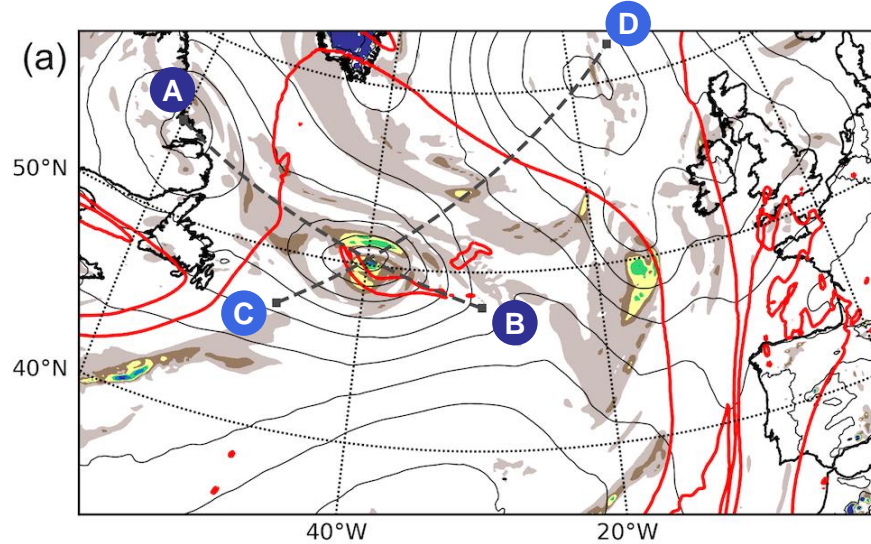
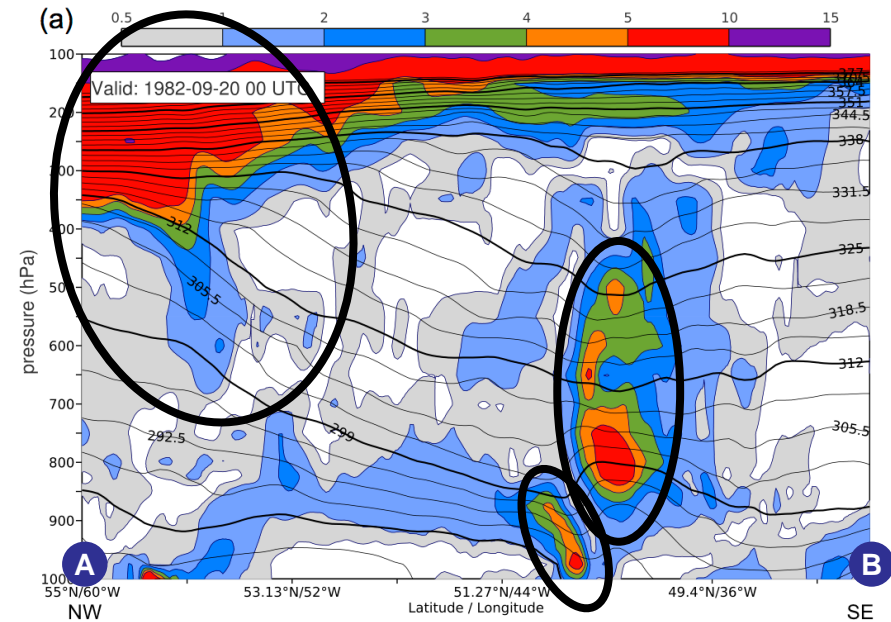
# OpenIFS simulations



1. Why did ex-Debby travel across the Atlantic?  
→ 19<sup>th</sup> forecast
2. Why did ex-Debby re-intensify over the UK?  
→ 21<sup>st</sup> forecast (compared to 19<sup>th</sup> forecast)
3. What are the reasons for strong winds over Finland?  
→ 21<sup>st</sup> forecast

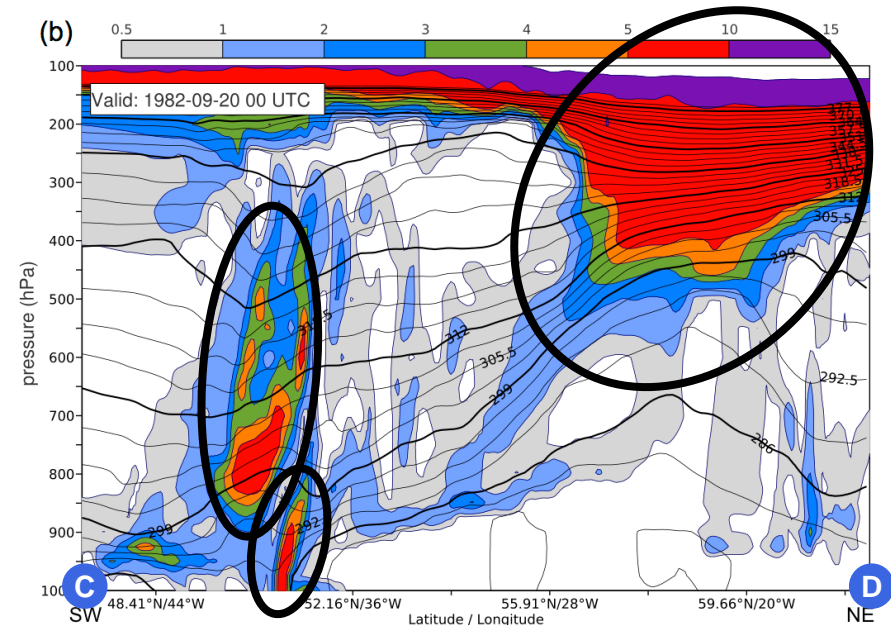


# Why did ex-Debby travel across the Atlantic?



Map: 850-hPa potential vorticity (colors), 250-hPa potential vorticity at 2 PVU (red contour), mean sea level pressure (black contours)

Cross sections: potential vorticity (colors), potential temperature (contours)



- **PV tower** remaining from ET process
  - **Surface PV** anomaly from the bent-back warm front
  - **Upper-level PV** anomaly from the trough
- Upper levels not interacting with low-level PV  
 → No upper-level forcing  
 → Ex-Debby did not intensify



# Why did ex-Debby travel across the Atlantic?

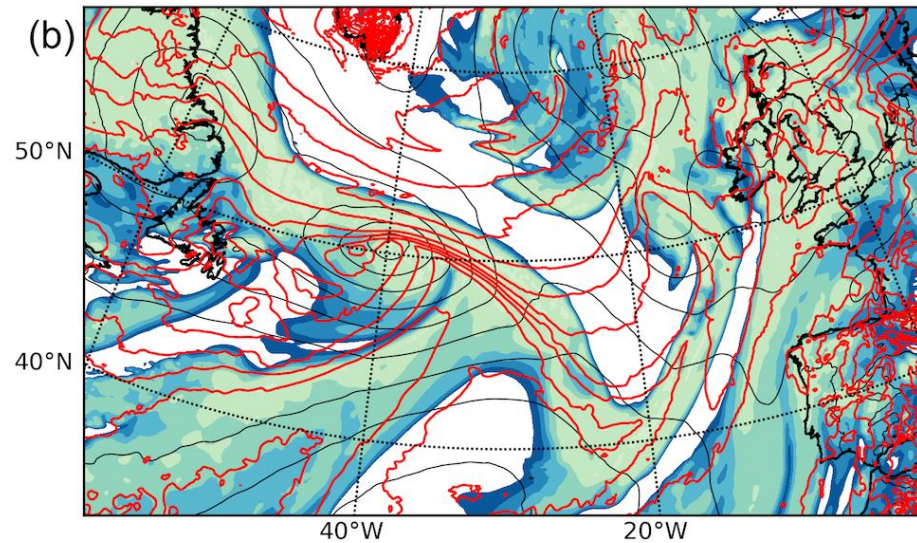
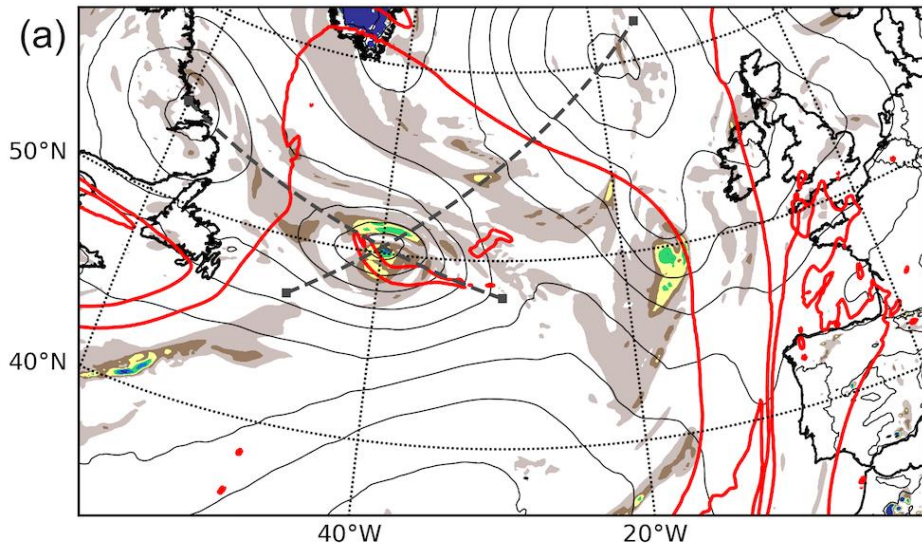
- **Diabatic Rossby wave** can maintain itself by constant diabatic PV generation

- Criteria by Boettcher and Wernli (2013):

1. Closed surface pressure contour → **yes**
2. Positive low-level PV anomaly → **yes** ( $> 5\text{PVU}$ )
3. Substantial low-level baroclinicity → **yes** ( $15.5\text{K} > 5\text{K}$ )
4. Fast propagation → **yes** ( $510\text{km} / 6\text{h} > 250\text{km} / 6\text{h}$ )
5. Sufficient moisture → **yes** ( $850\text{-hPa RH} > 90\%$ )
6. Very weak upper-level forcing → **yes**

→ Ex-Debby travelled rapidly across the Atlantic as a diabatic Rossby wave

00 UTC 20 Sep 1982

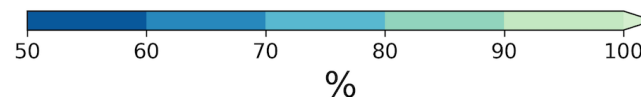
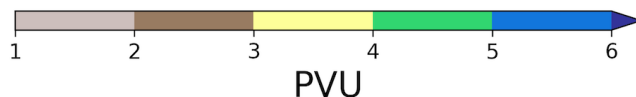


(a) 850-hPa potential vorticity (colors), 250-hPa potential vorticity at 2 PVU (red contour), mean sea level pressure (black contours)

(b) 850-hPa relative humidity (colors), 950-hPa potential temperature (red contours), mean sea level pressure (black contours)

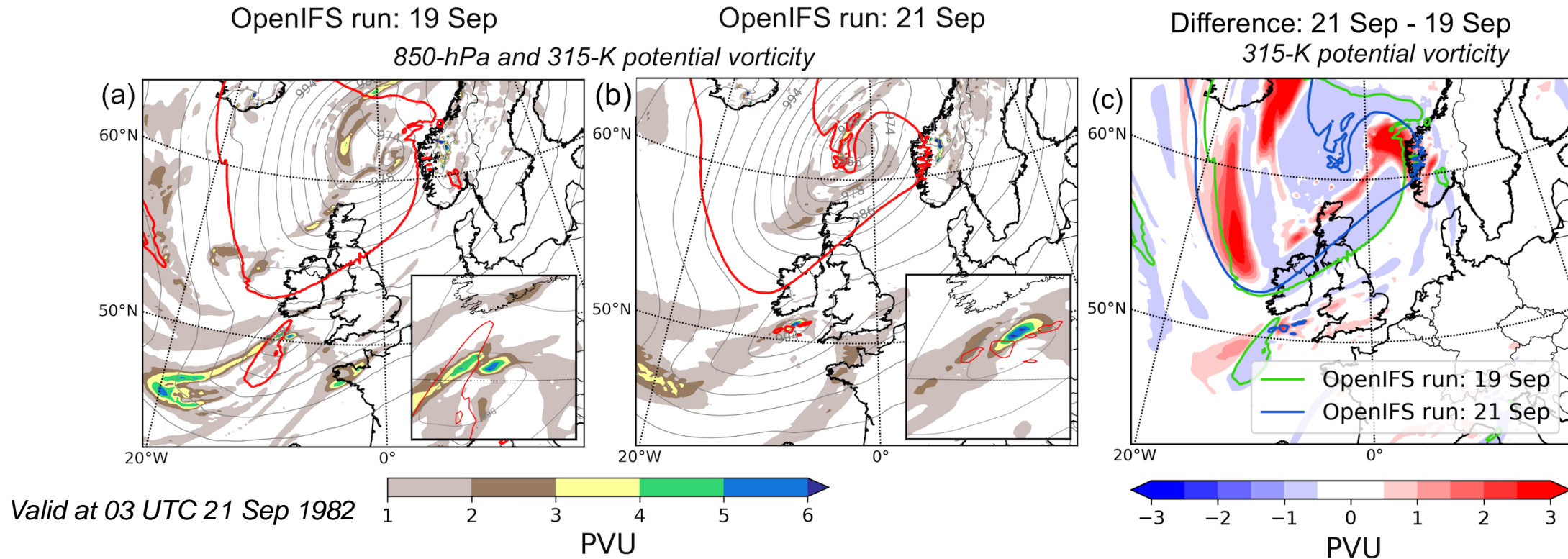


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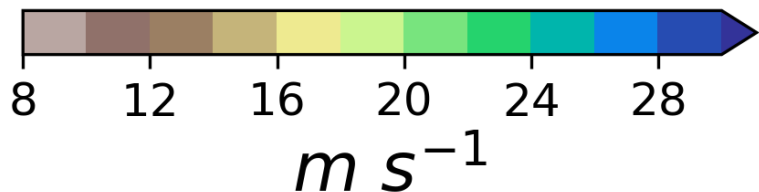
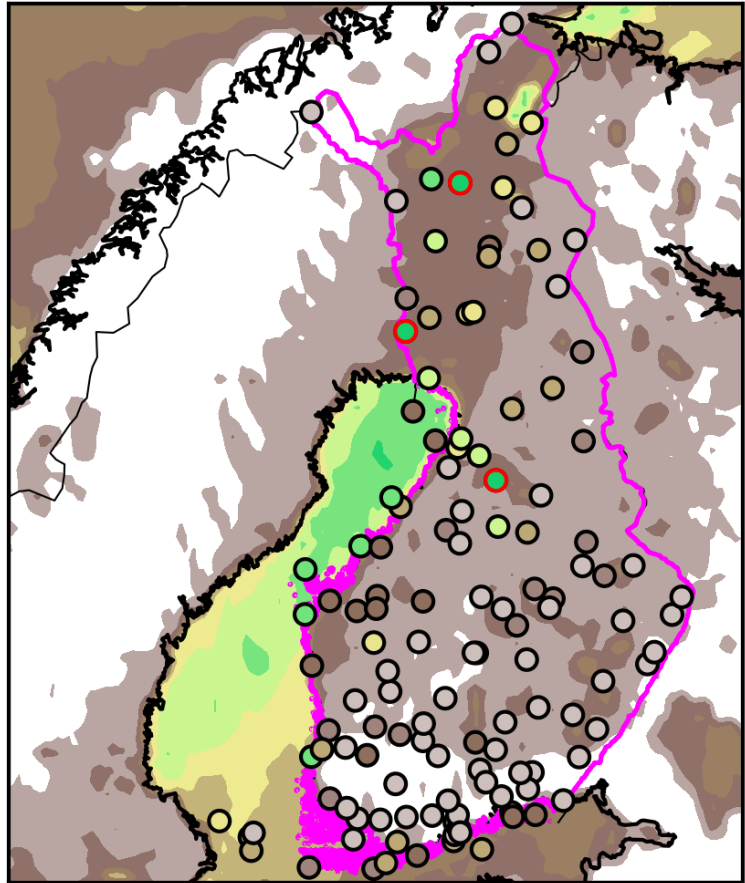
# Why did ex-Debby re-intensify over the UK?

- **21<sup>st</sup> forecast:** sharp upper-level trough just west of the low-level PV anomaly of ex-Debby
- **Differences in low-level PV:** in 19<sup>th</sup> ex-Debby weaker, less coherent and farther south and west
- **Differences in phasing:** in 19<sup>th</sup> upper and low-level PV anomalies vertically stacked  
→ Upper-level trough intensified ex-Debby in 21<sup>st</sup> but not in the 19<sup>th</sup> forecast





# Reasons for strong winds over Finland?



## Verification of winds:

- Strongest observed winds **23 m/s** (red circles)
- Strongest simulated winds over sea **22 m/s** and over land **14 m/s**
- OpenIFS underestimates the wind speeds (mainly over land) but correctly locates the strongest winds

*Max. 10-m wind speed during 22 Sep 1982 from FMI observations (circles) and OpenIFS run of 21<sup>st</sup> Sep (colors)*

# Reasons for strong winds over Finland?

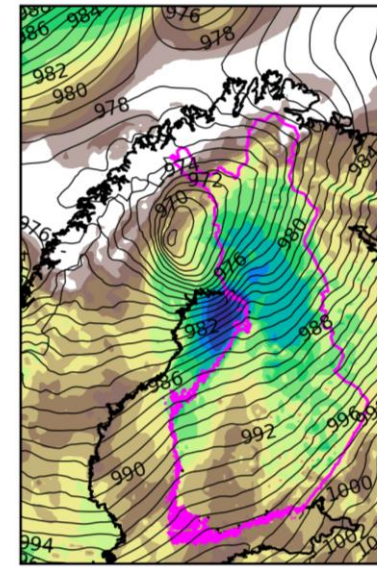
## Wind gust in OpenIFS:

$$F_{gust} = F_{10} + C_{ugn}u_* + C_{conv}\max(0, U_{850} - U_{950})$$

*gust = 10-m wind + turbulent mixing + convective downdrafts*

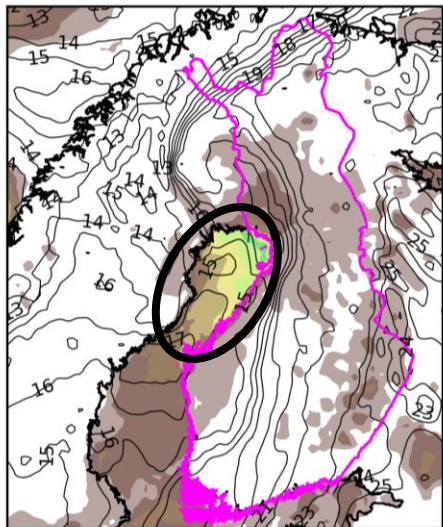
↓  
surface friction,  
boundary layer stability

↓  
vertical wind shear,  
convection

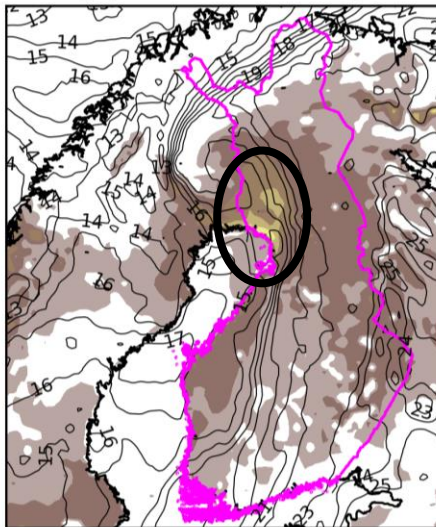


*Wind gust (colors) at 12 UTC 22 Sep, mean sea level pressure (contours)*

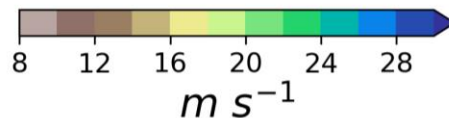
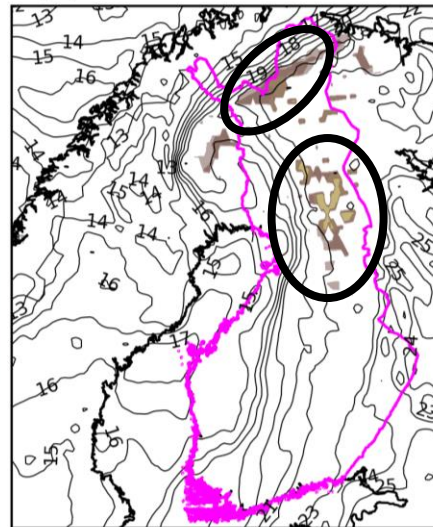
(c) 10-m wind speed



(d) Turbulent mixing



(e) Convective downdrafts



- Strong winds due to strong pressure gradient and low surface roughness
- Turbulent driven gusts behind the cold front
- Gusts due to convective downdrafts in the warm sector

*Wind gust components (colors) at 12 UTC 22 Sep, 850-hPa potential temperature (contours)*



# Conclusions

- **Why did ex-Debby travel across the Atlantic?**  
→ Maintained itself as a diabatic Rossby wave.
- **Why did ex-Debby re-intensify over the UK?**  
→ Phasing with other extratropical cyclone was crucial.
- **What are the reasons for strong winds over Finland?**  
→ Strong pressure gradient and low surface roughness caused strongest winds but turbulent mixing and convective downdrafts enhanced the gusts.
- Complex case, three high resolution simulations needed to cover whole evolution.
- OpenIFS correctly located but underestimated the 10-m wind speeds.

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