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. m³ 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 \((T255: \sim 80 \text{ km}, 60 \text{ levels})\)

Meso- and synoptic-scale dynamic evolution

→ OpenIFS simulations \((T1279: \sim 16 \text{ km}, 137 \text{ levels})\)

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?
- 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)
- 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)
- 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)
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)
- 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?
   → 19th forecast

2. Why did ex-Debby re-intensify over the UK?
   → 21st forecast (compared to 19th forecast)

3. What are the reasons for strong winds over Finland?
   → 21st forecast

Time series of minimum pressure

850-hPa relative vorticity maximum tracks

ERA-Interim
OpenIFS run: 17 Sep
OpenIFS run: 19 Sep
OpenIFS run: 21 Sep
Why did ex-Debby travel across the Atlantic?

- **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

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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** (> 5PVU)
  3. Substantial low-level baroclinicity → **yes** (15.5K > 5K)
  4. Fast propagation → **yes** (510km / 6h > 250km / 6h)
  5. Sufficient moisture → **yes** (850-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)
Why did ex-Debby re-intensify over the UK?

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

Valid at 03 UTC 21 Sep 1982

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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 21st Sep (colors)
Reasons for strong winds over Finland?

Wind gust in OpenIFS:

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

- 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 (colors) at 12 UTC 22 Sep, mean sea level pressure (contours)

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

\[ \text{gust} = 10\text{-m wind} + \text{turbulent mixing} + \text{convective downdrafts} \]
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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