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# How synoptic weather activity and interaction with the extratropical wave guide matter for the prediction of blocking and extremes

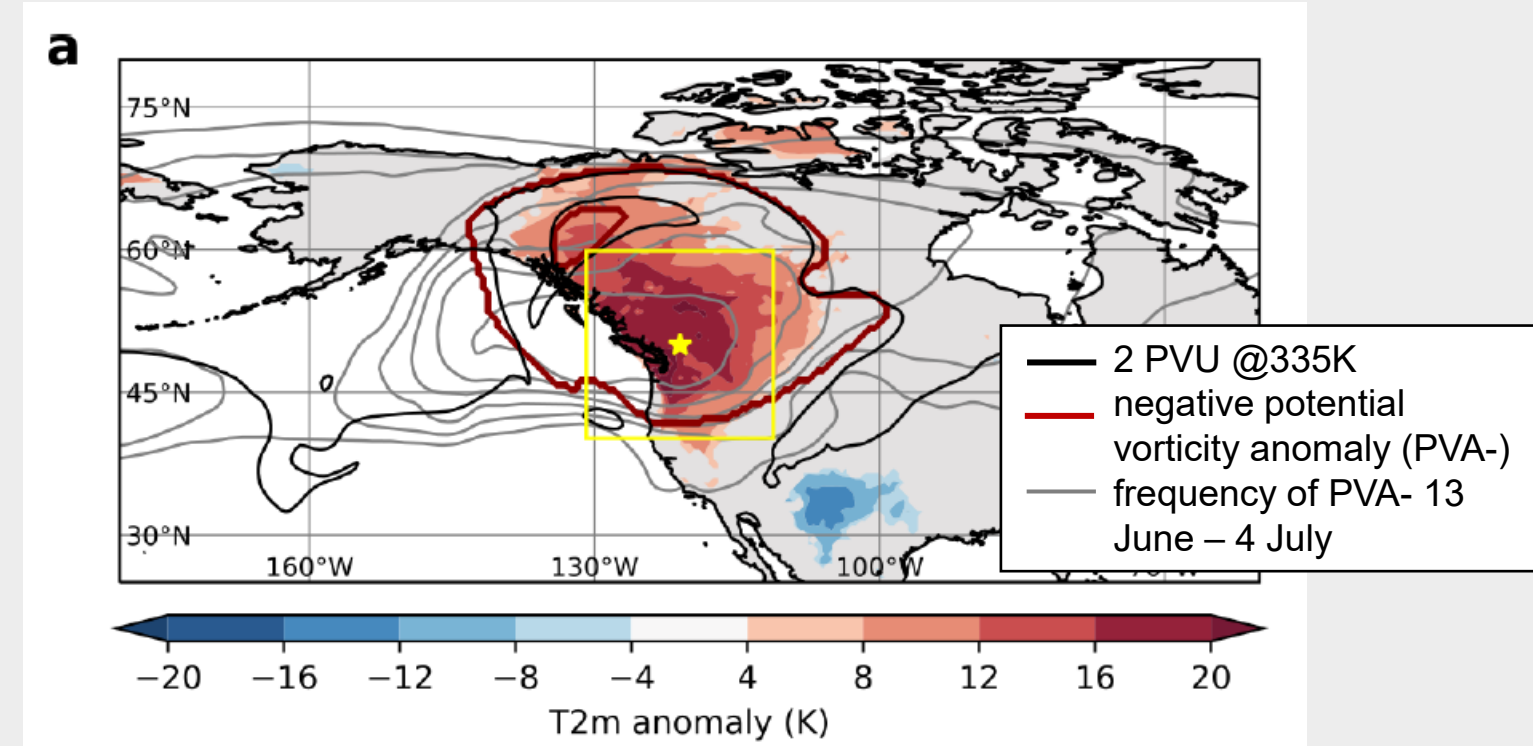
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## Introduction

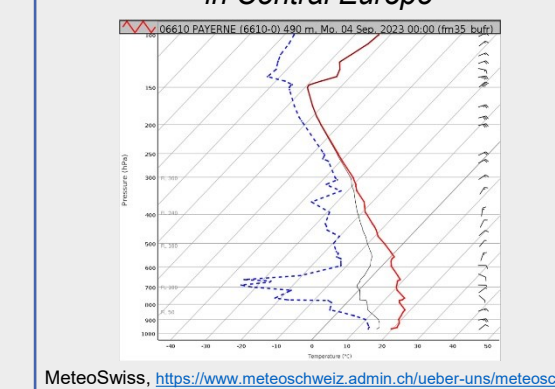
- unprecedented heat wave end of June 2021 in North America
- deadly floods in Iberia, Greece and Libya in September 2023
- both events associated with highly amplified blocks
- dynamical processes and synoptic evolution resulting in blocking and predictability of the events are investigated

2021: T2m anomaly and blocking



Oertel et al., 2023, *Geophys. Res. Lett.* doi:10.1029/2022GL100958

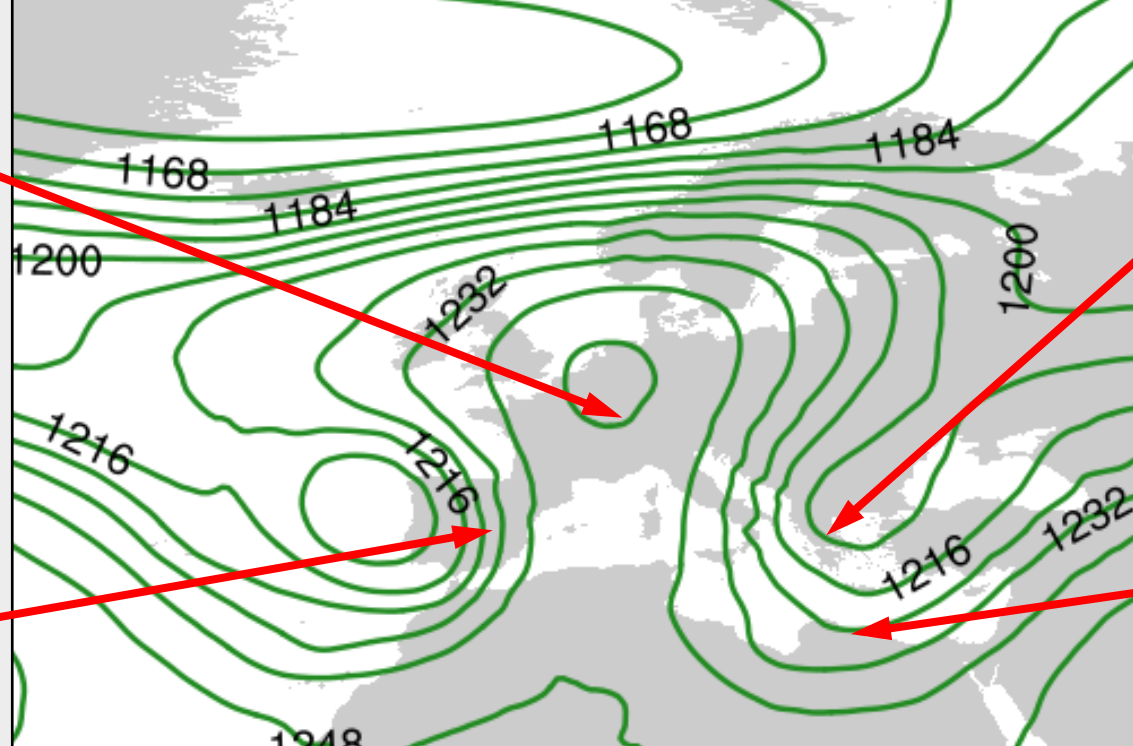
Heat wave and record high 0°-line in Central Europe



Flash-floods in Iberia 3 September

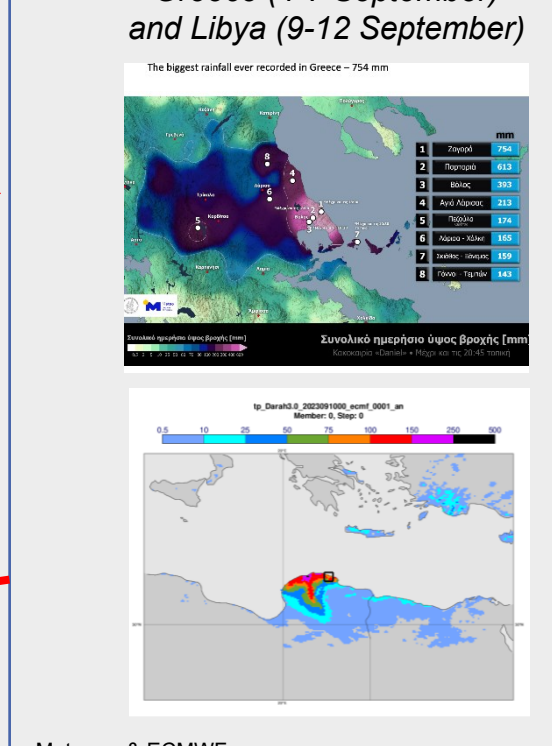


2023: Geopotential height at 200hPa



(in gpm), ERA5 12 UTC, 4 September 2023

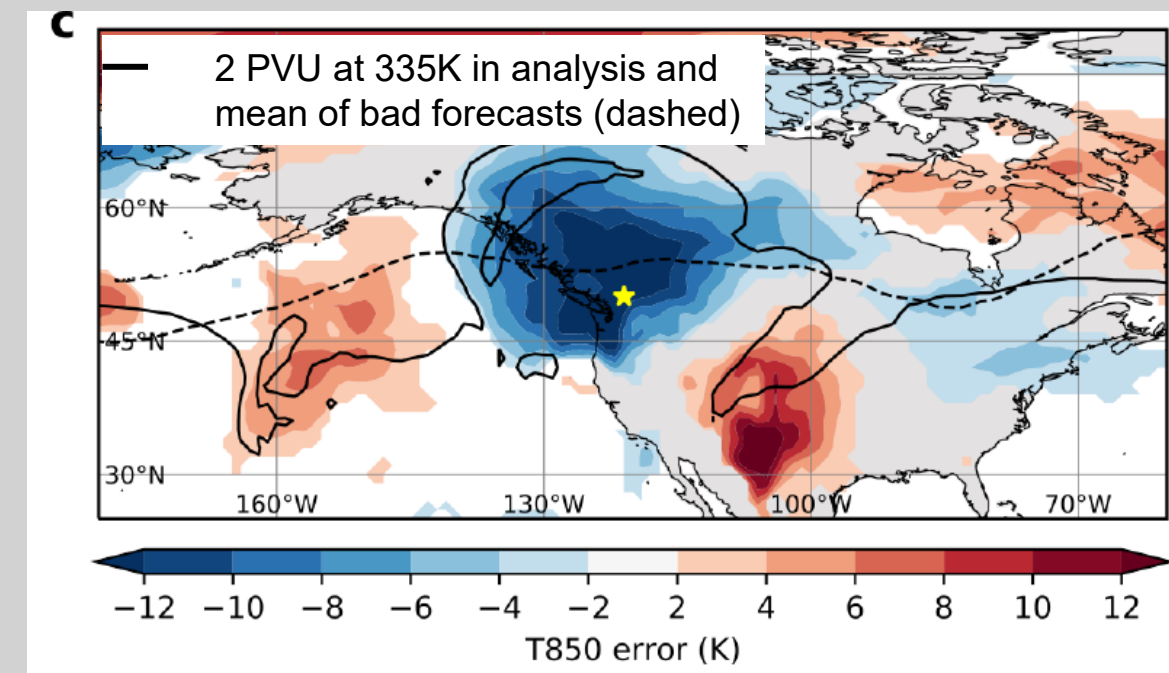
Severe Flooding in Greece (4-7 September) and Libya (9-12 September)



Meteo gr & ECMWF: <https://confluence.ecmwf.int/pages/viewpage.action?pageId=348806265>

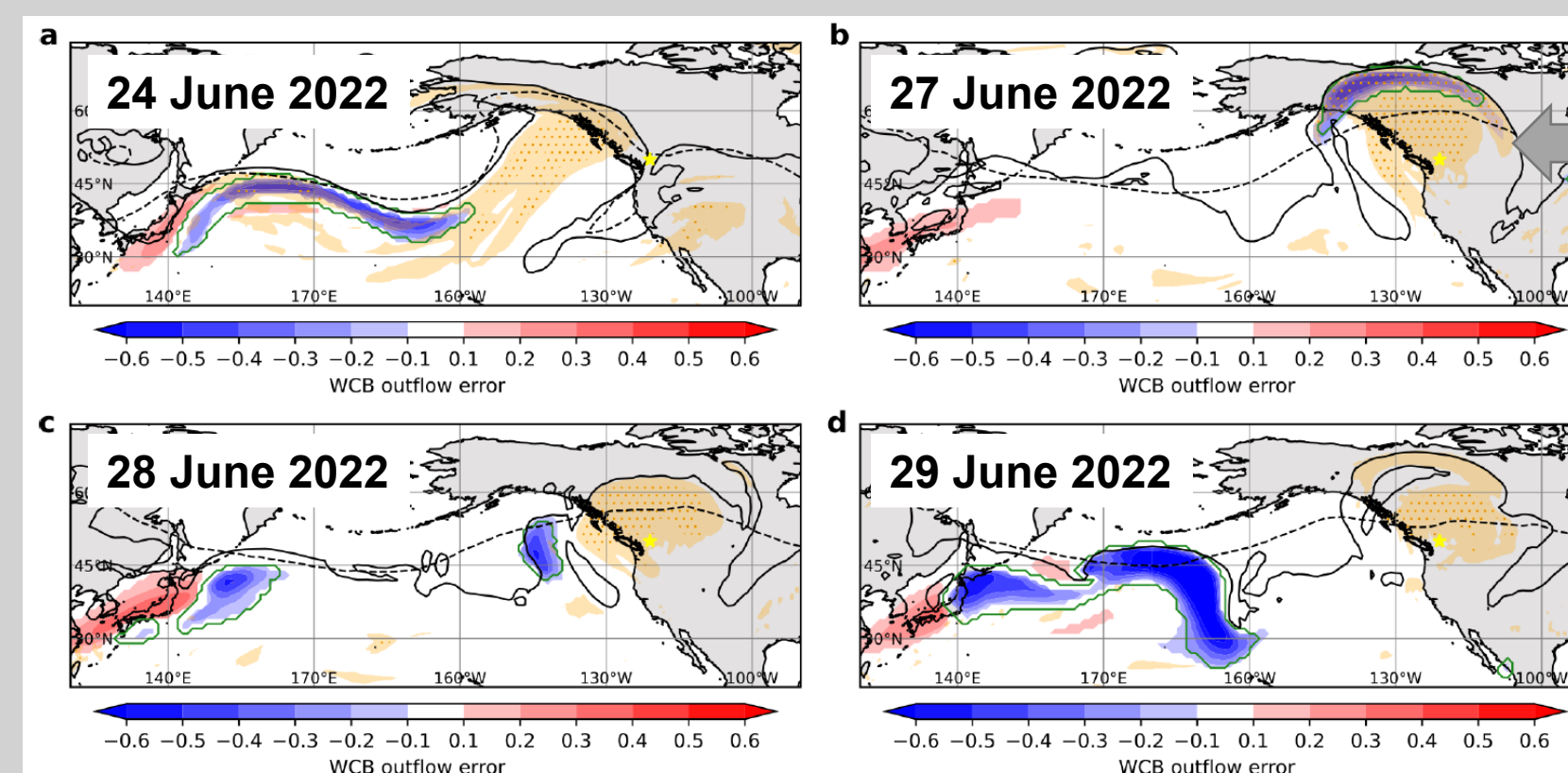
## The 2021 North American heat wave

Oertel et al., 2023, *Geophys. Res. Lett.* doi:10.1029/2022GL100958



10d backward trajectories from upper-tropospheric block (originating from >800hPa)

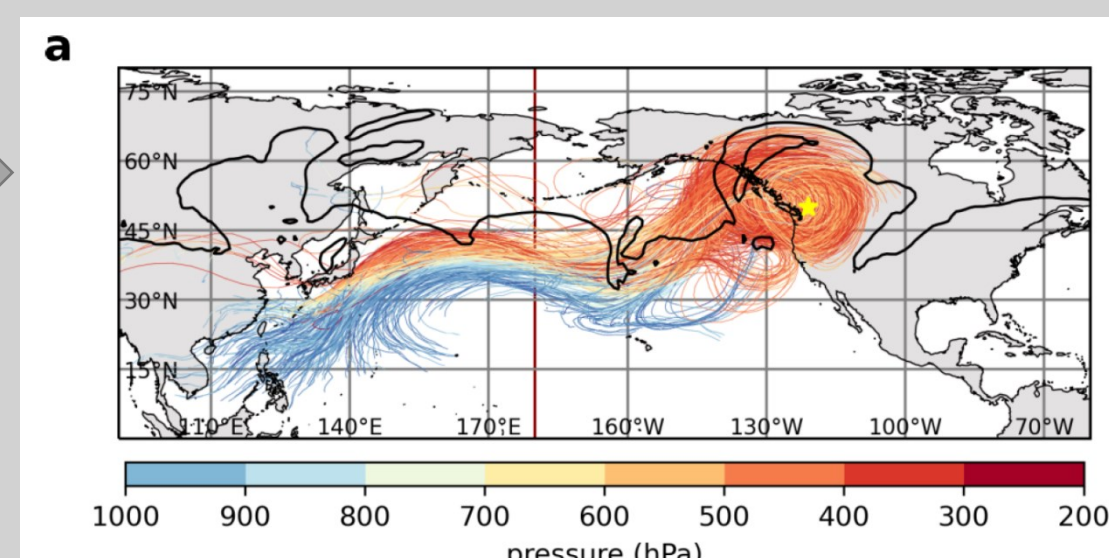
- partly originating from subtropical western North Pacific
- teleconnection and downstream Rossby wave dispersion



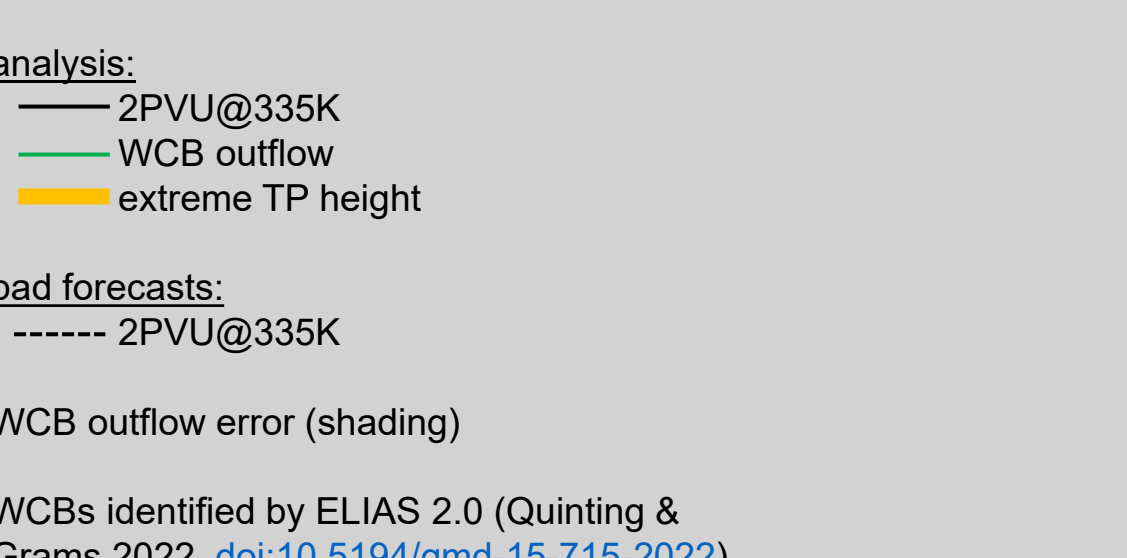
- optimal phasing of warm conveyor belt (WCB) outflow and jet needed in order to enable downstream development and ridge amplification

850 hPa T error and block in bad forecasts at 00 UTC 29 June 2021

- heat dome occurs under extreme upper-level ridge
- bad forecasts miss upper-level ridge resulting in strong T850 hPa error
- chain of synoptic events prior to heat wave involves WCB activity



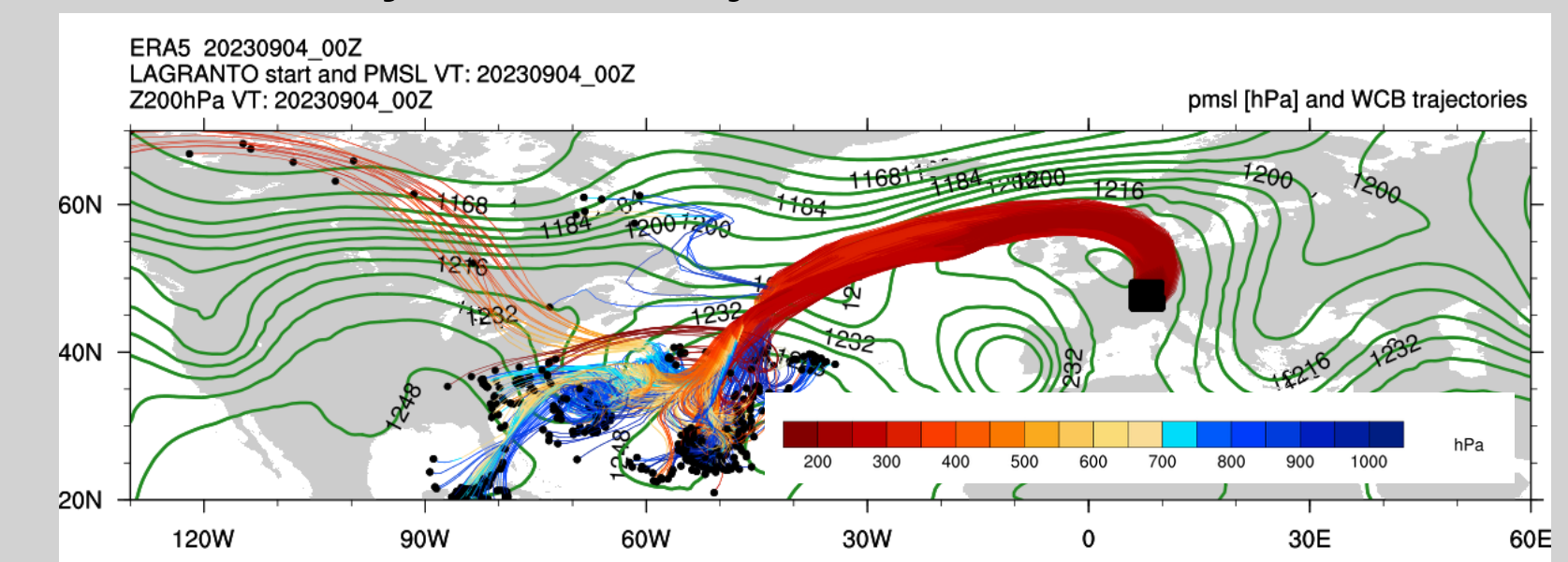
Synoptic Evolution in June 2021: 2PVU at 335K (contours), WCB activity, and extreme tropopause height



- WCBs identified by ELIAS 2.0 (Quinting & Grams 2022, doi:10.5194/gmd-15-715-2022)

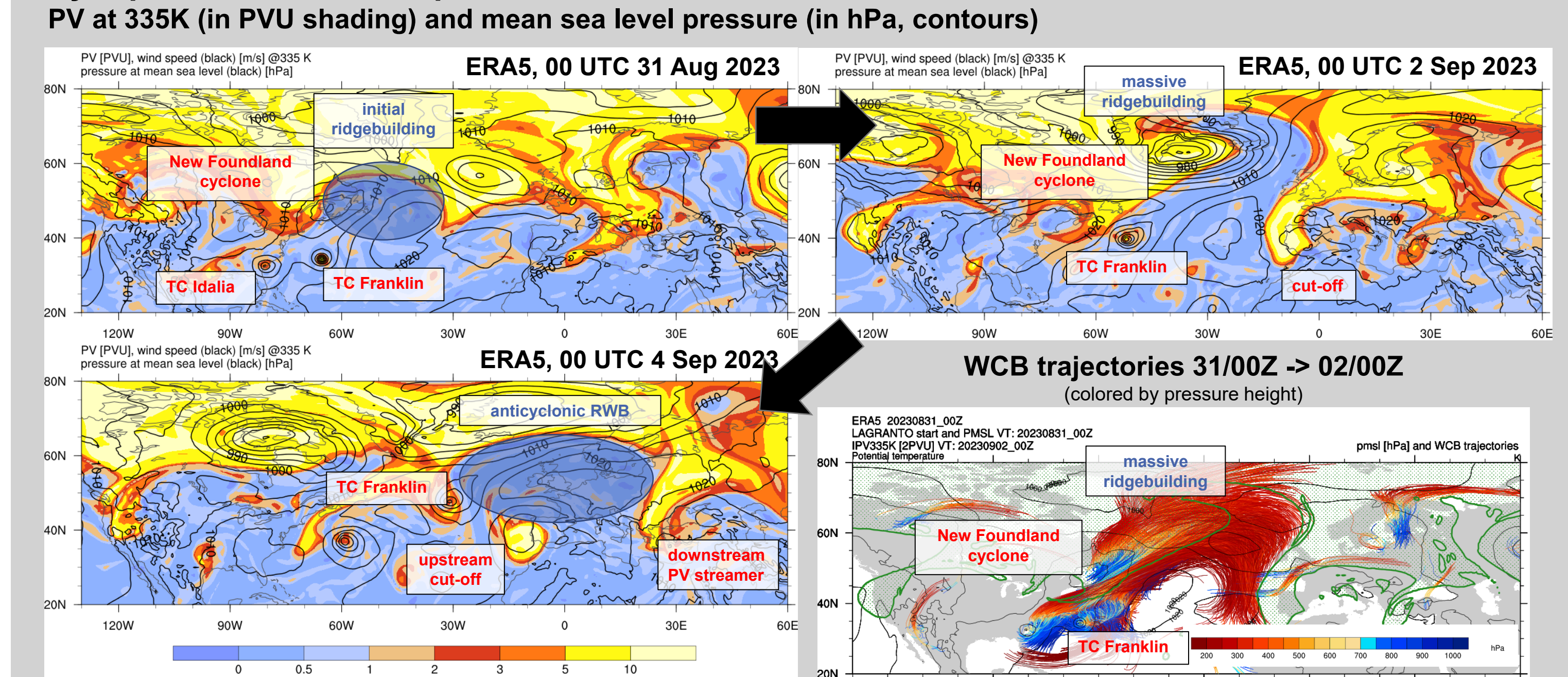
## The 2023 block and Mediterranean floods

5-day backward trajectories, 04/00Z -> 30/00Z



- upper-tropospheric air in block over Europe originates from Subtropics, lifted during extratropical transition of TC Franklin and TC Idalia

Synoptic Evolution in September 2023: PV at 335K (in PVU shading) and mean sea level pressure (in hPa, contours)



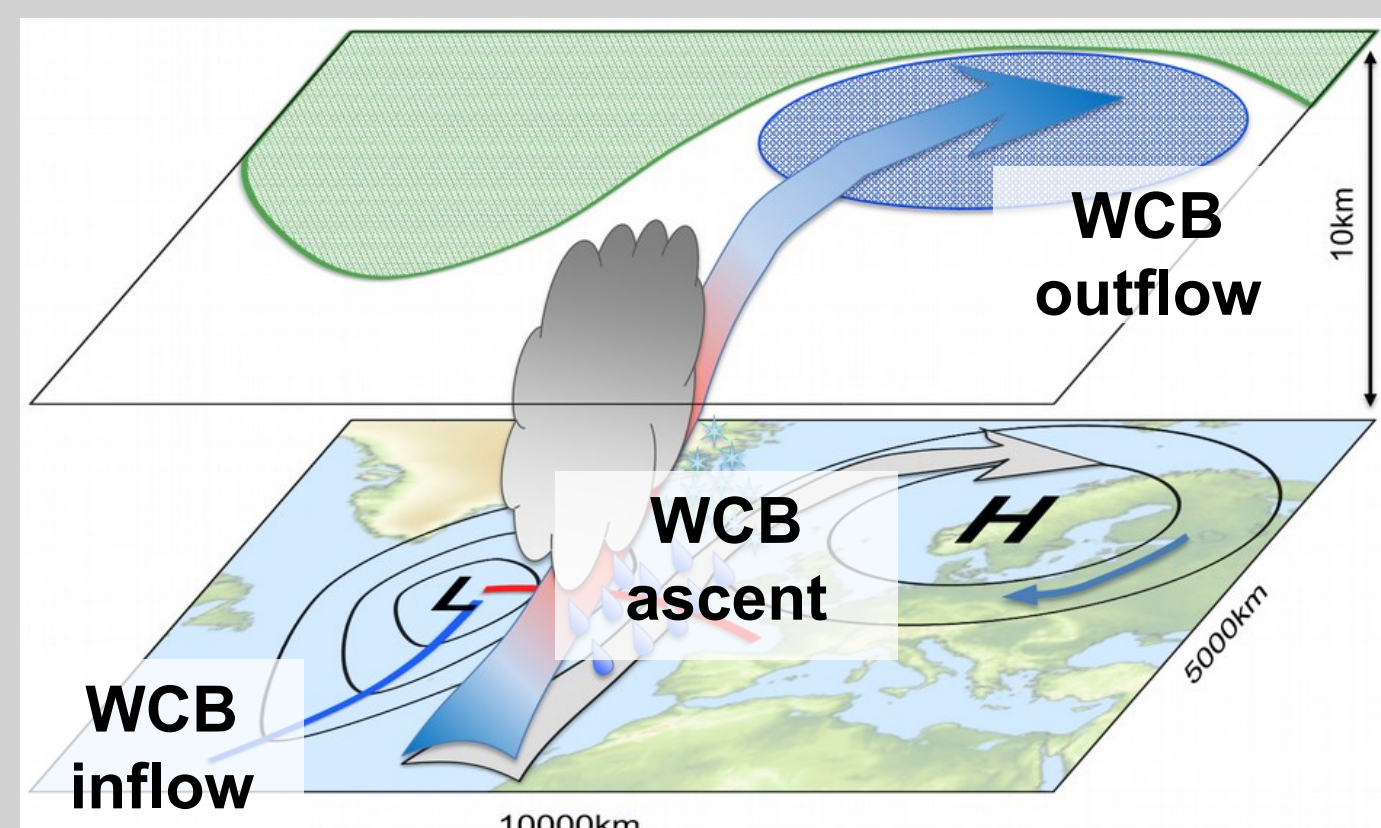
- downstream development during extratropical transition amplifies Rossby wave guide
- initial ridge and later block massively amplified by warm conveyor belt (WCB) diabatic outflow from Ex-TC Franklin and new Newfoundland cyclone

## Role of diabatic processes

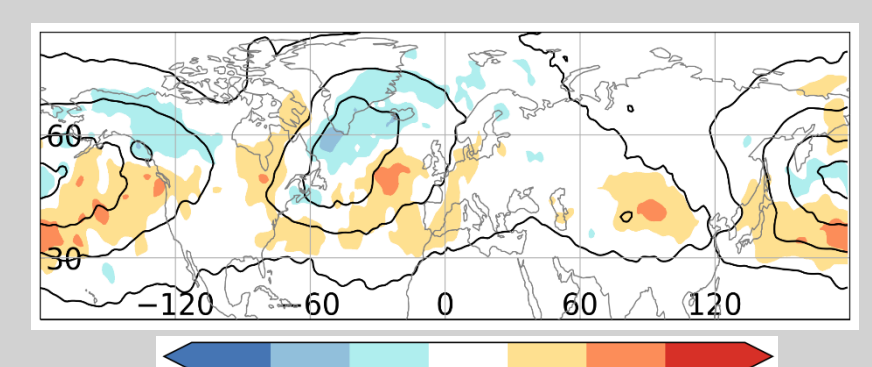
- air mass injection in upper-troposphere due to latent heat release is a **1st order process for onset and maintenance** of blocking (Pfahl et al. 2015, doi:10.1038/ngeo2487)
- confirmed in independent PV framework and **linked to WCB activity** (Hauser et al. 2023, doi:10.5194/wcd-4-399-2023, Hauser 2023 doi:10.5445/IR/1000162808)
- forecasts of blocking depend upon correct representation of WCBs** (Grams et al. 2018, doi:10.1002/qj.3353)

→ see also key note **Tue 1:30pm** and onsite poster **Mon 11:30am** by **S. Hauser!**

- CNN-based WCB Metric allows **easy identification of WCBs** in (climate) models (Quinting and Grams 2022 doi:10.5194/gmd-15-715-2022)
- Systematic biases in WCB outflow** in IFS extended-range reforecasts. (Wandel et al. 2021, doi:10.1175/JAS-D-20-0385.1, Wandel 2022 doi:10.5445/KSP/1000151831)
- Misrepresentation of WCB outflow hinder S2S prediction of **European blocking** (Wandel et al. 2024, doi:10.22541/essoar.169264761.11688311/v1)
- Sensitivity of WCB activity on model error representation** (Pickl et al. 2022 doi:10.1002/qj.4257, Deinhard & Grams 2023 doi:10.5194/egusphere-2023-1938)



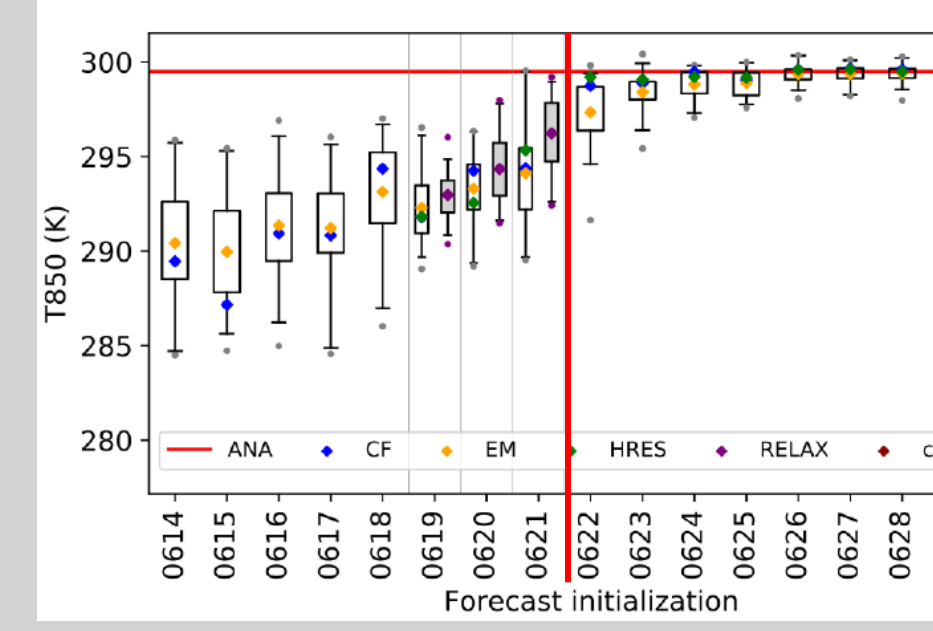
example: DJF WCB outflow bias in IFS S2S reforecasts week 2



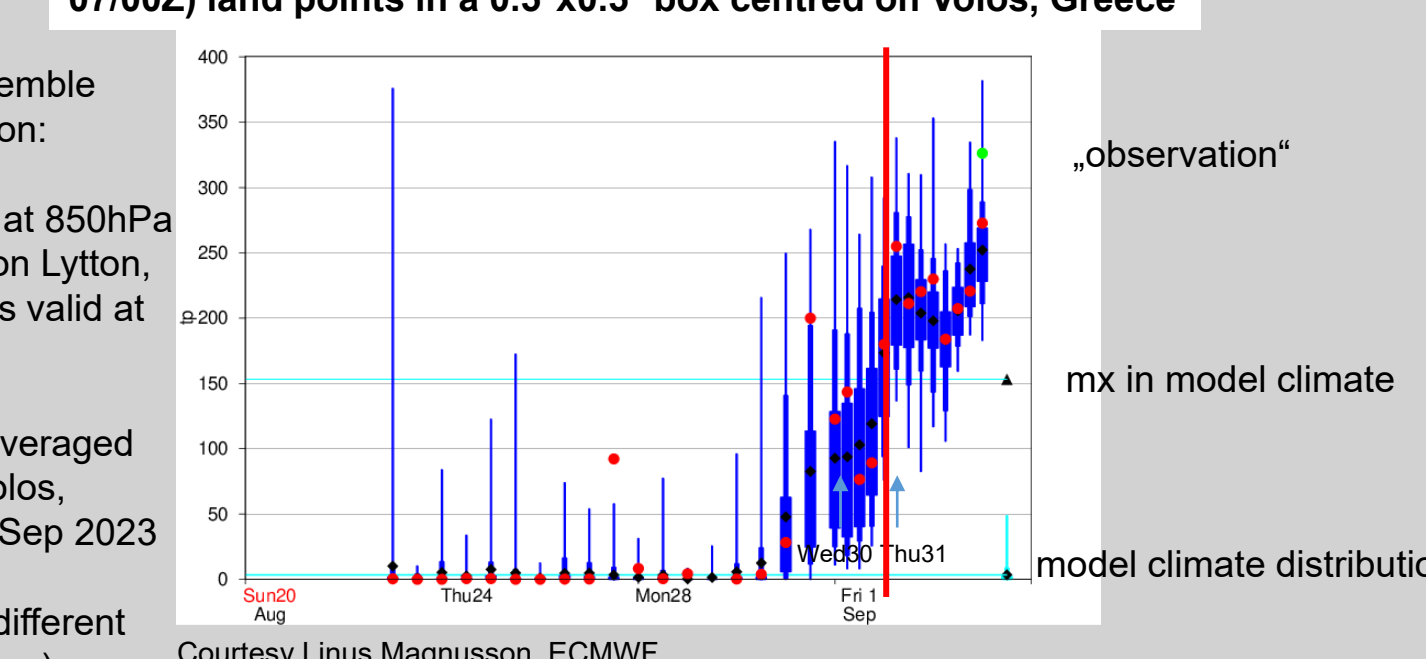
## Predictability barrier at medium-range lead times

- sudden "jump" in ensemble forecasts for magnitude of the extreme weather
- certainty only after outflow-jet interaction occurred → **predictability barrier**

IFS ENS for T850 on 29 June



forecast evolution 72h precipitation (in mm, Sep 2023, 04/00Z - 07/00Z) land points in a 0.5°x0.5° box centred on Volos, Greece



## Conclusions

- highly-amplified blocks** caused devastating North American heat wave in 2021 and deadly floods in eastern Mediterranean in 2023
- blocks embedded in **Rossby wave pattern** and resulted from **downstream development** along upper-tropospheric jet
- diabatic outflow due to latent heat release** in ascending air streams strongly **amplified blocks** during extreme events in 2021 and 2023
- interaction of weather systems and jet constitutes a **predictability barrier for the amplitude of blocks** and magnitude of associated extremes

## Selected references

- Deinhard & Grams, 2024: Process-oriented understanding of stochastic perturbations on model climate. *WCD*, doi:10.5194/egusphere-2023-1938
- Grams et al., 2018: An atmospheric dynamics perspective on the amplification and propagation of forecast error. *QJRM*, doi:10.1002/qj.3353
- Hauser et al., 2024: Life cycle dynamics of Greenland blocking from a potential vorticity perspective. *WCD*, doi:10.5194/egusphere-2023-2945
- Oertel et al., 2023: How remote rainfall matters for the prediction of the 2021 North American heat wave. *GRL*, doi:10.1029/2022GL100958
- Quinting and Grams, 2022: Eulerian Identification of ascending AirStreams (ELIAS 2.0) - Part 1: *GMD*, doi:10.5194/gmd-15-715-2022
- Quinting et al., 2024: WCB activity over the Pacific: modulation by the MJO and impact on teleconnections. *WCD*, doi:10.5194/wcd-5-65-2024