National Centre for Atmospheric Science
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University of Reading

Impactful Tibetan Plateau Vortices: structure, lifecycle and environmental conditions

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Tibetan Plateau Vortices (TPVs)

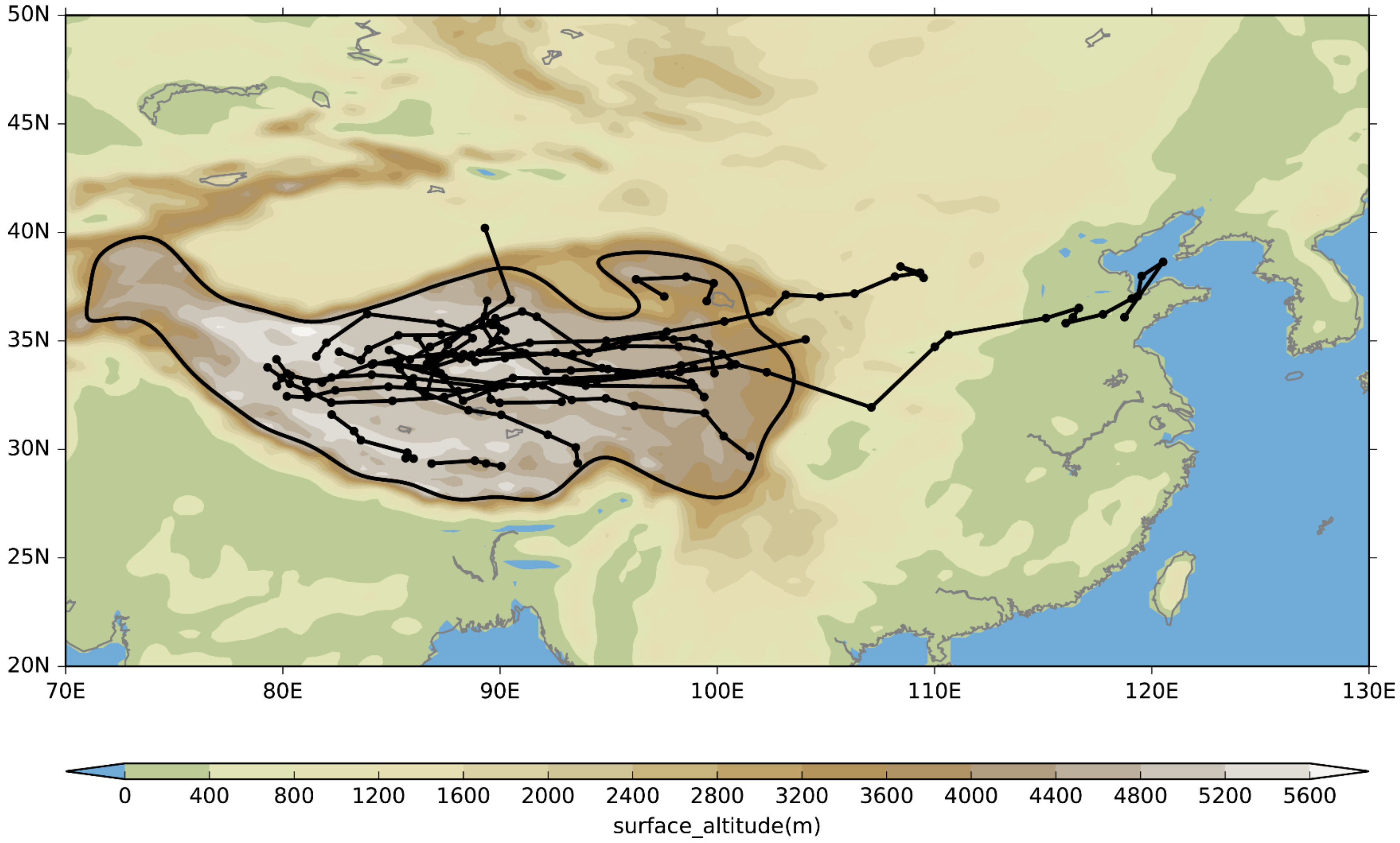
- TPVs one of the major precipitation producing/triggering systems on the Tibetan Plateau
- Mainly present at 500 hPa level
- Spatial scales
  horizontal: Meso-α-scale, 400-800 km
  vertical: 2-3 km
- TPVs can trigger extreme precipitation and severe flooding east of the TP
- July 2008: TPV caused heavy rain over large parts of China

Methodology

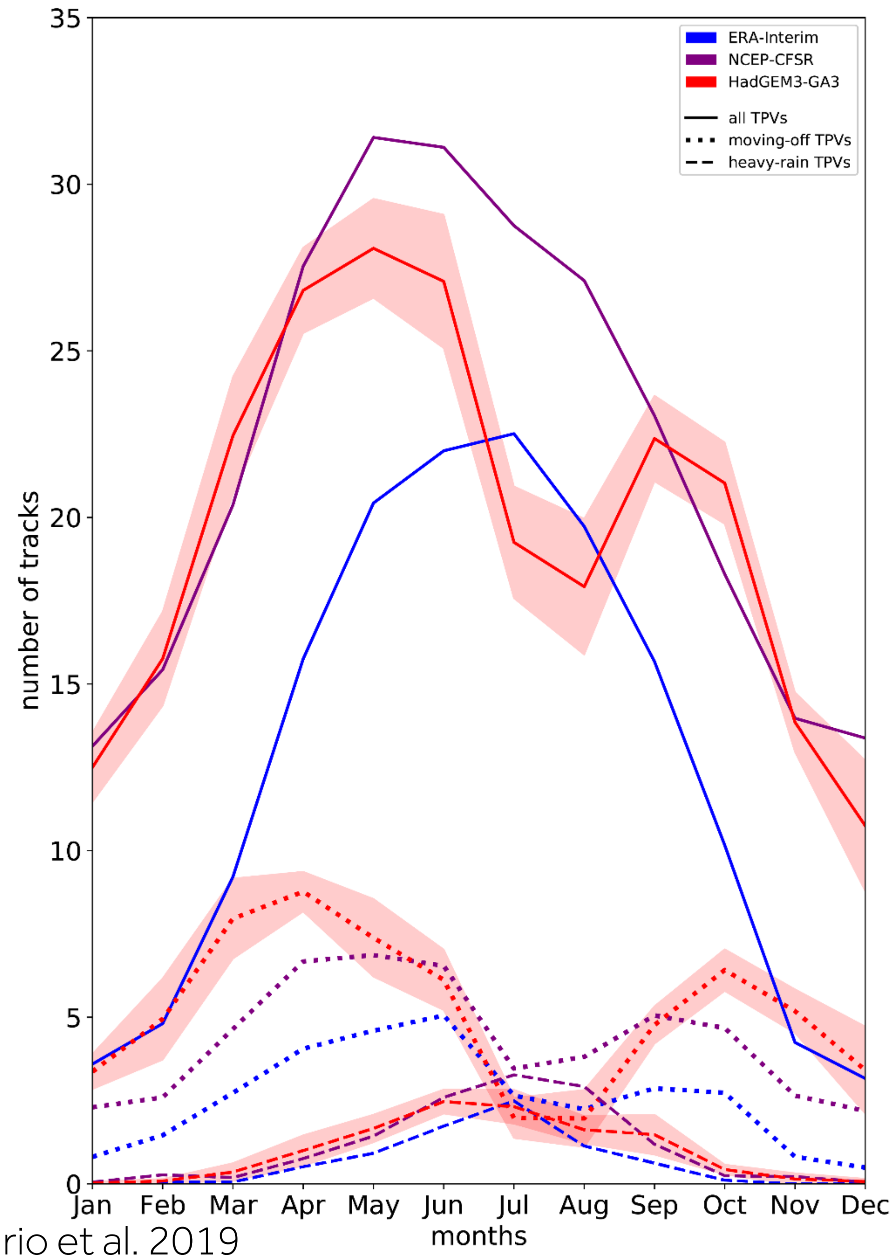
- 500 hPa relative vorticity field (spectrally filtered: T40-100)
- Objective feature-tracking algorithm TRACK (Hodges et al., 1994, 1995, 1999)
- ERA-Interim and NCEP-CFSR
- UK Met Office model (HadGEM3-GA3; 25 km; 5 ensemble member)
- 6-hourly resolution
- Filtering: - originate on Tibetan Plateau (3000 m contour)
  - persistent ≥ 1 day
  - geopotential minimum at one time step (at least)

Curio et al. 2019: Climatology of Tibetan Plateau Vortices in reanalysis data and a high-resolution global climate model. Journal of Climate, **32**, 1933–1950, https://doi.org/10.1175/JCLI-D-18-0021.1.

TPV tracks example for July 2008 from ERA-Interim



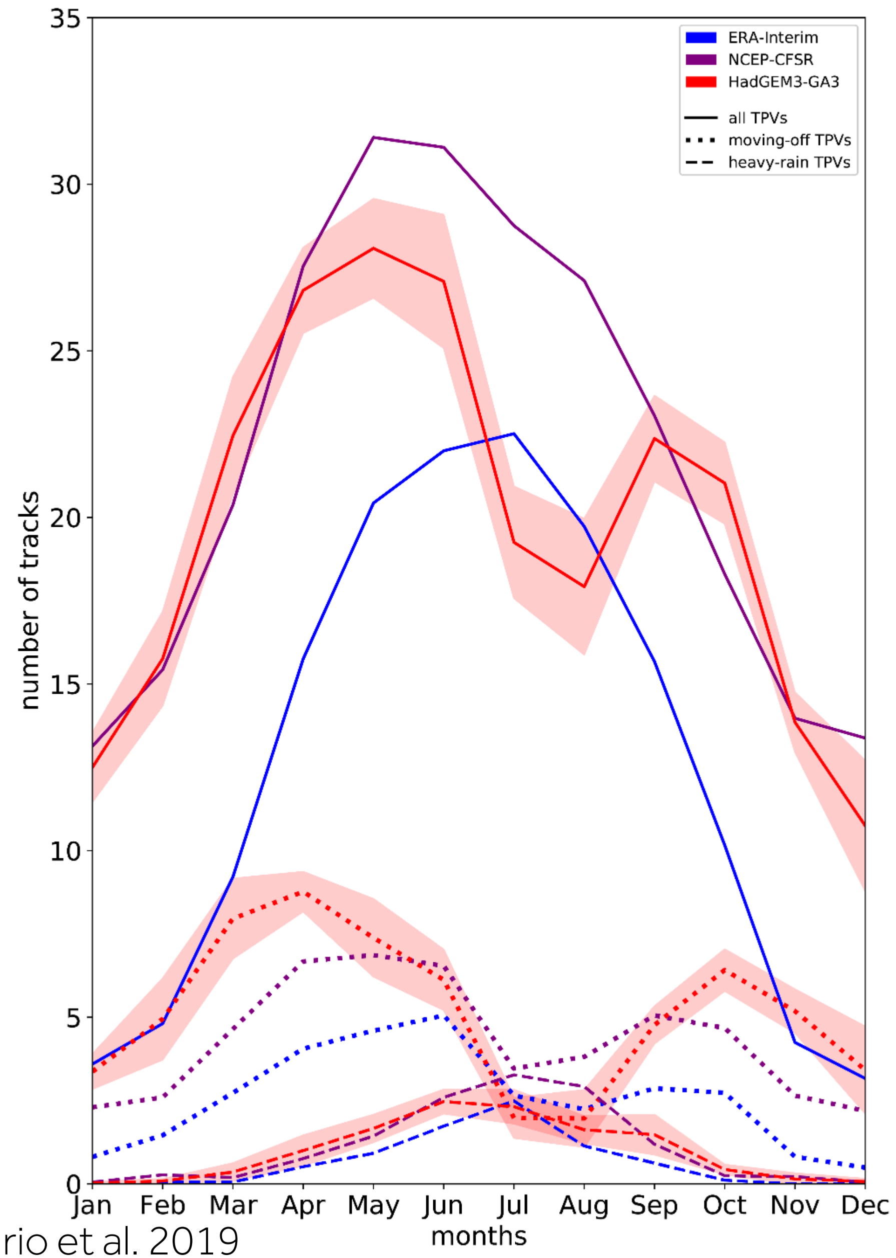
Curio et al. 2019



Curio et al. 2019

Annual cycle

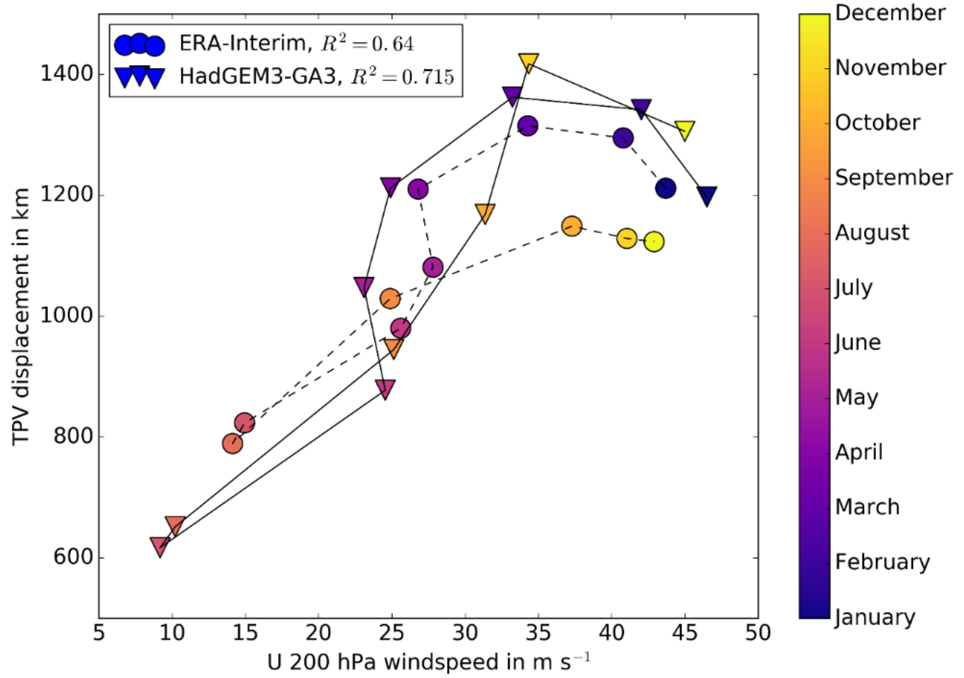
- Frequent phenomena
- Pronounced annual cycle with maximum occurrence frequency in summer and minimum in winter
- Only a minority of TPVs move off the Tibetan Plateau



Curio et al. 2019

Annual cycle

- Frequency of moving-off TPVs is highest in spring and autumn



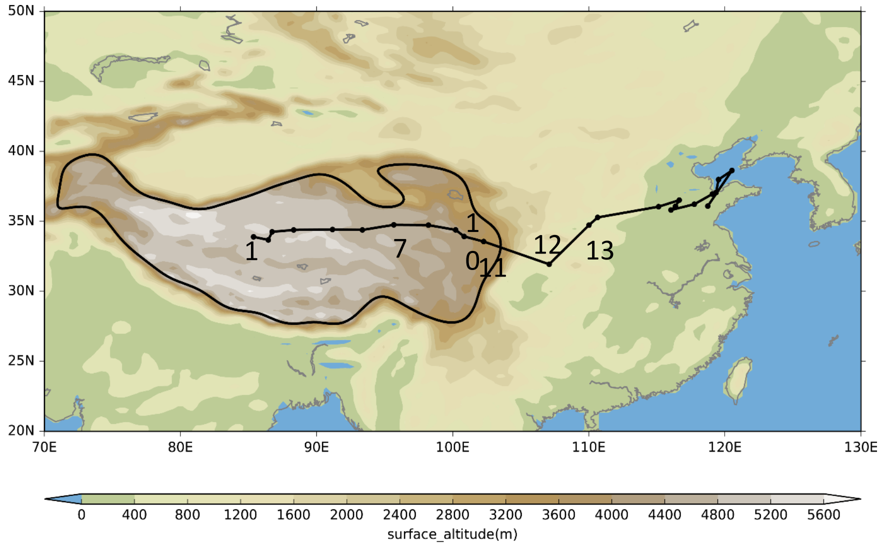
- Close association between jet speed and TPV displacement explains mid summer suppression of moving-off TPVs

Objectives

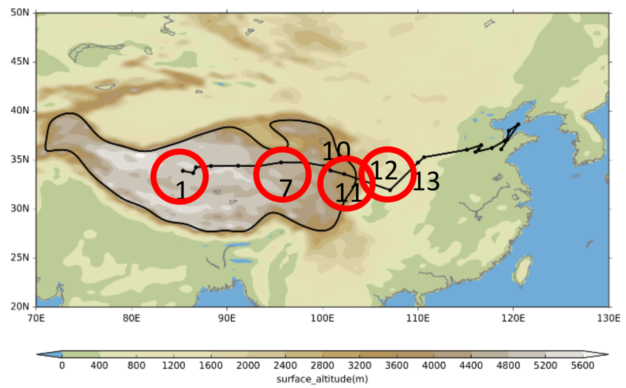
- Under which conditions are TPVs able to move off?
- Connect TPV behaviour and structure with large-scale circulation
- How do TPVs trigger precipitation?

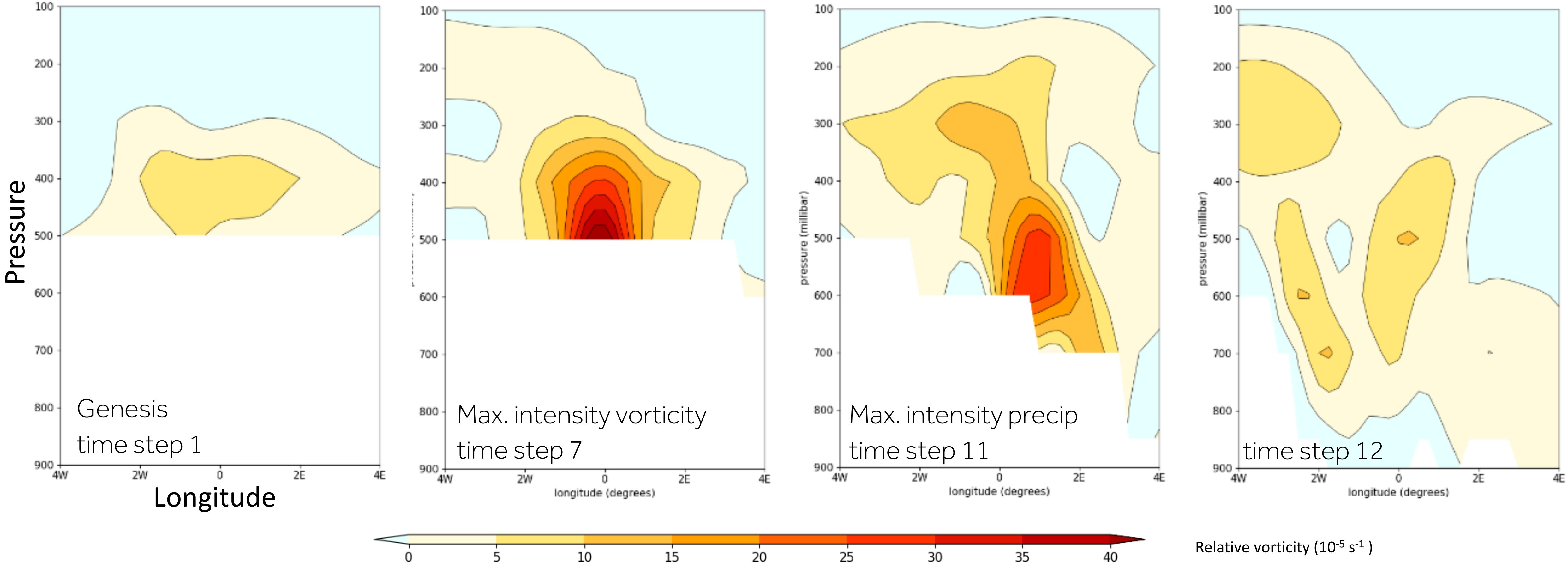
Methodology

- Storm-centred composites of horizontal and vertical structure
- Due to the complex and diverse surface conditions the composites including all TPVs and regions do not provide a complete picture.
- Start with a TPV that caused extreme precipitation in the Sichuan basin in July 2008 as a test case.

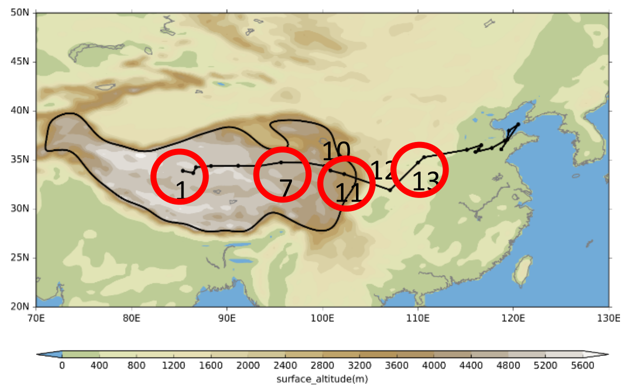


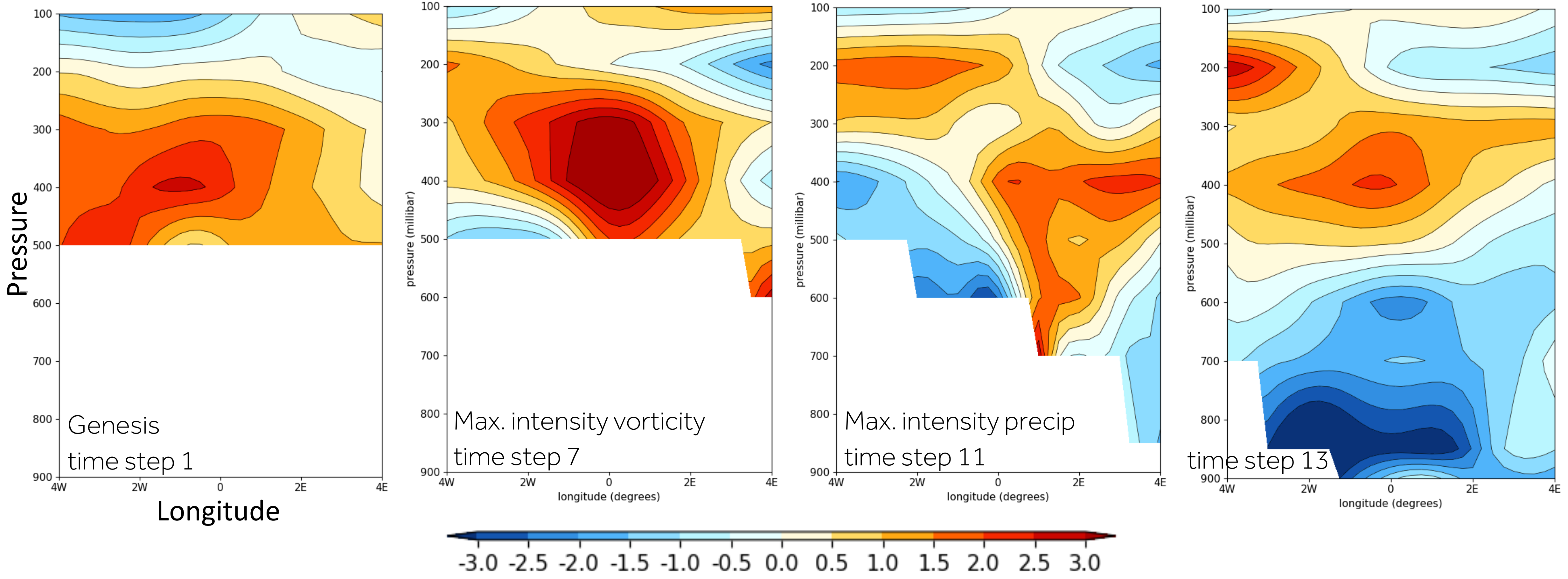
July 2008 TPV vertical structure: relative vorticity





July 2008 TPV vertical structure: temperature anomaly

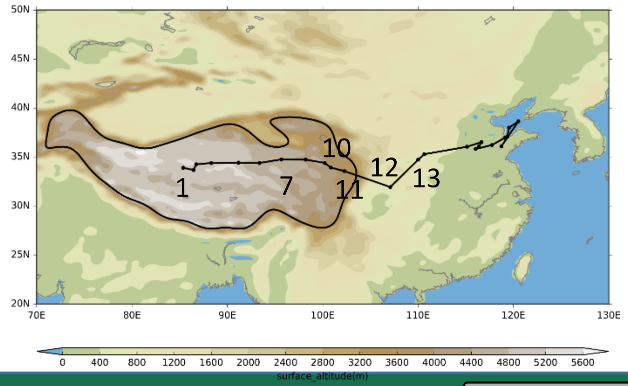


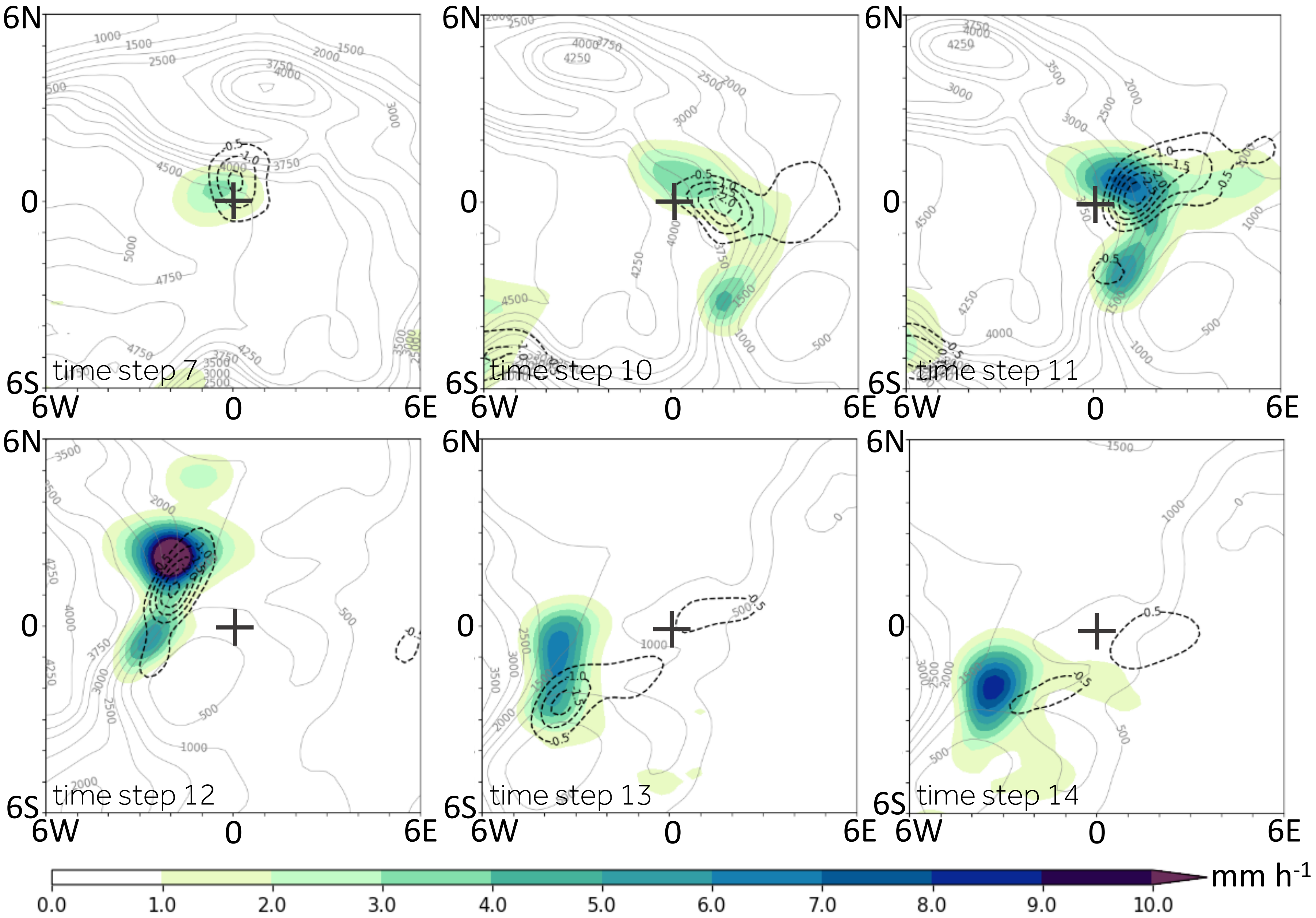


July 2008 TPV precipitation

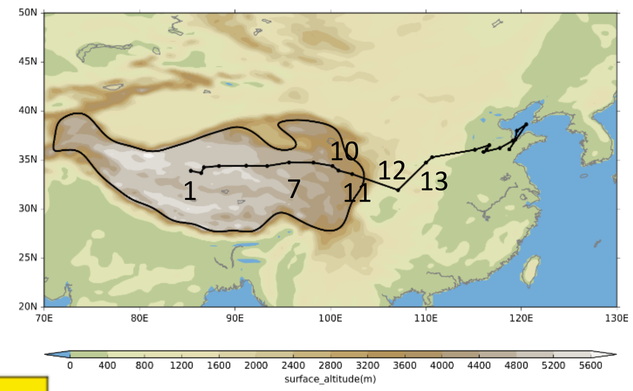
Precipitation starts to form at the edge of the TP and stays terrain locked at the slopes of the TP when the TPV continues to moves further eastwards.

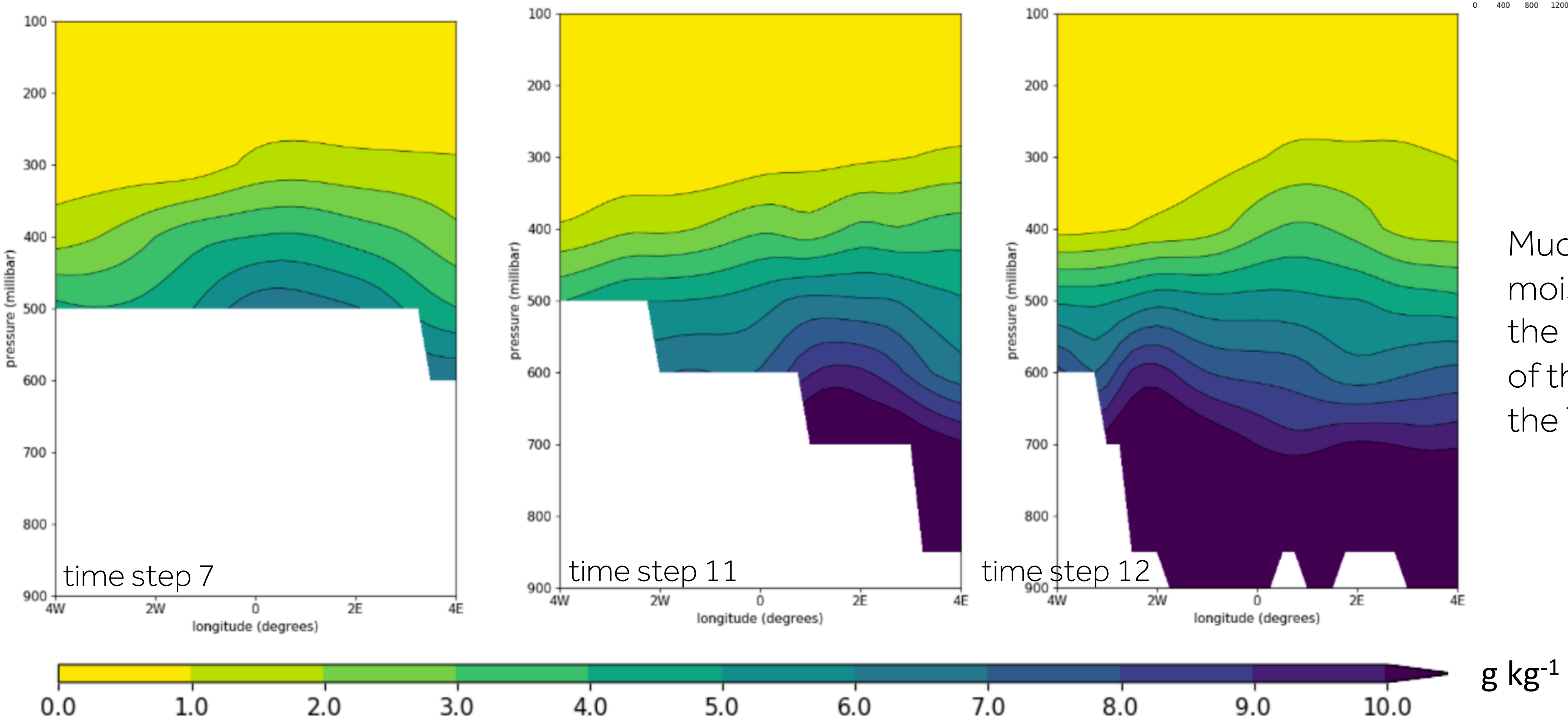
Colour shading: precipitation rate
Grey contours: orography
Dotted contours: updraft





July 2008 TPV vertical structure: moisture



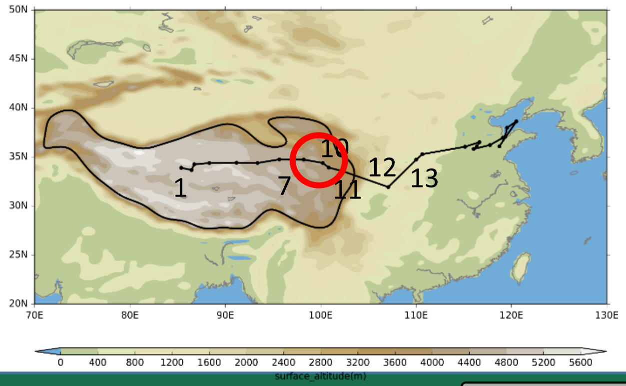


Much more moisture available in the lower levels east of the TP than on the TP.

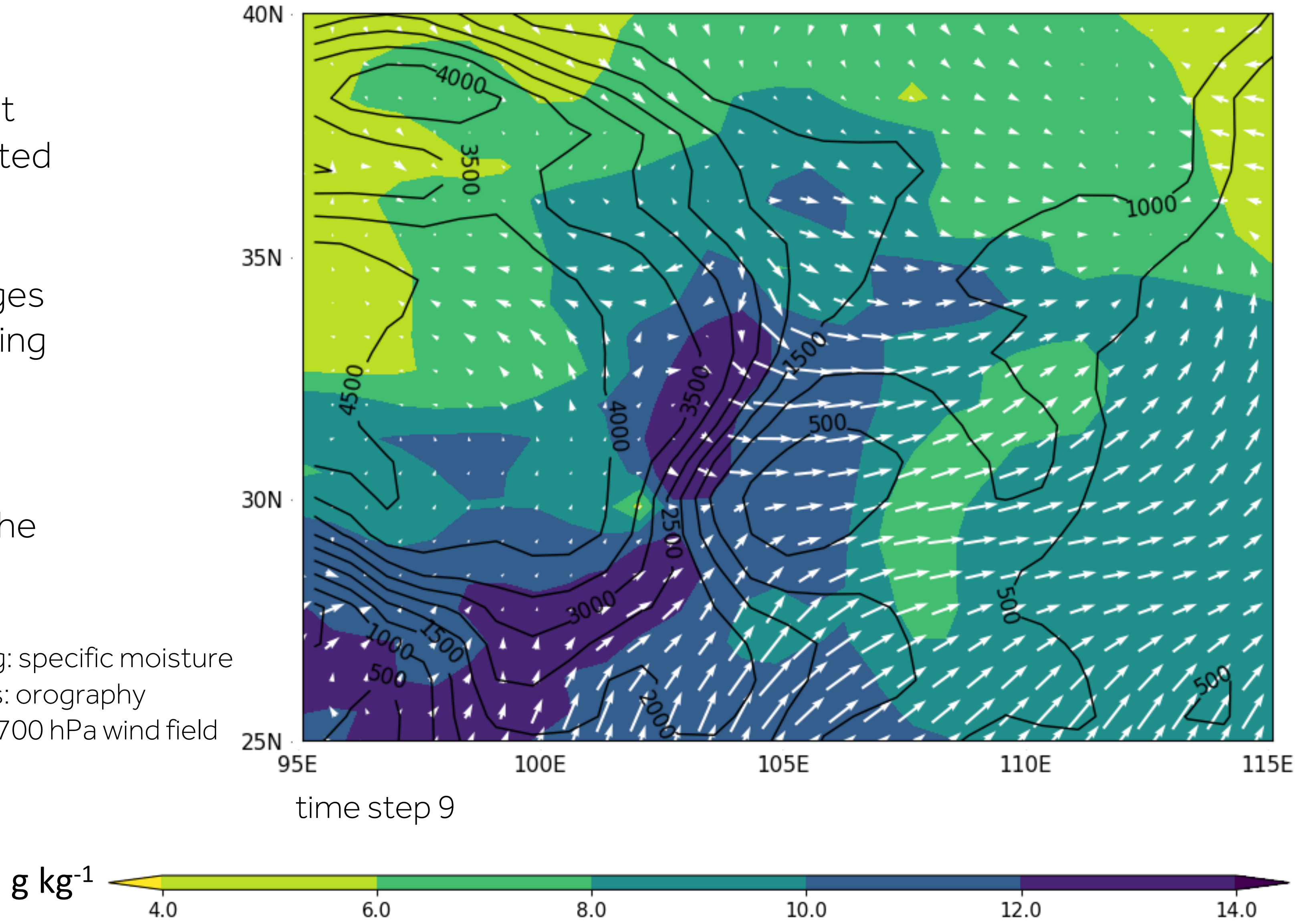
Wind field and moisture at 700 hPa

- Westerly winds in the Sichuan basin at time step 9, when the TPV is still located over the eastern TP.
- The next slides show how the local circulation in the Sichuan basin changes to a easterly winds with the TPV moving off the TP.

→The TPV appears to change the local circulation, thereby directing a flow of moist air towards the eastern slope of the TP.

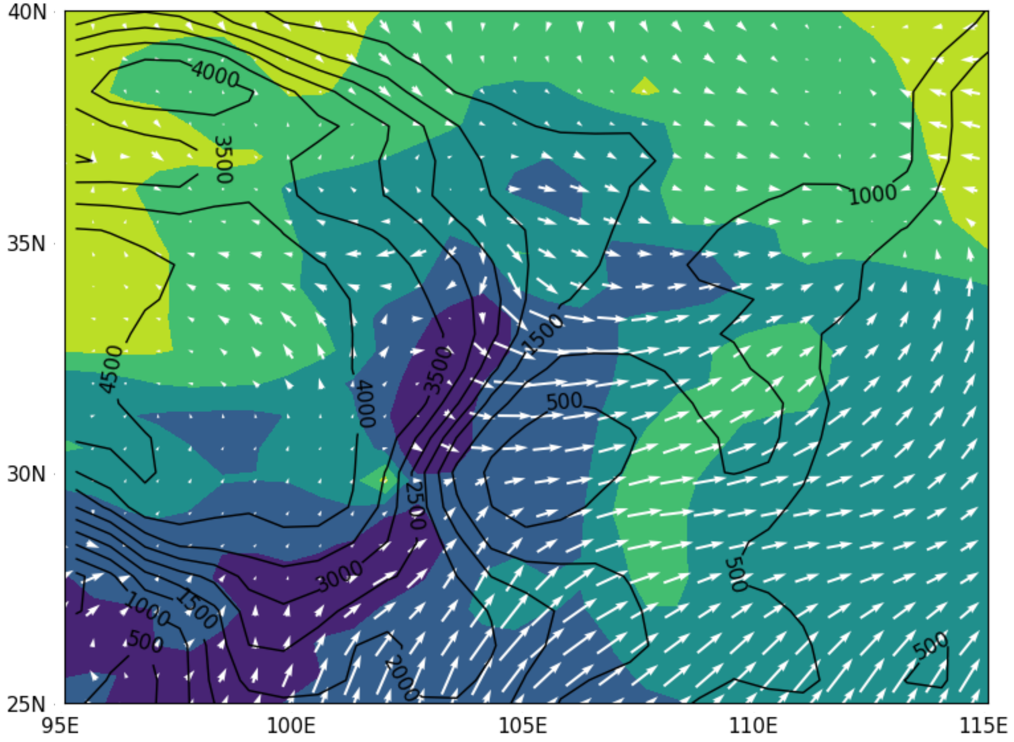


Colour shading: specific moisture
Black contours: orography
White arrows: 700 hPa wind field

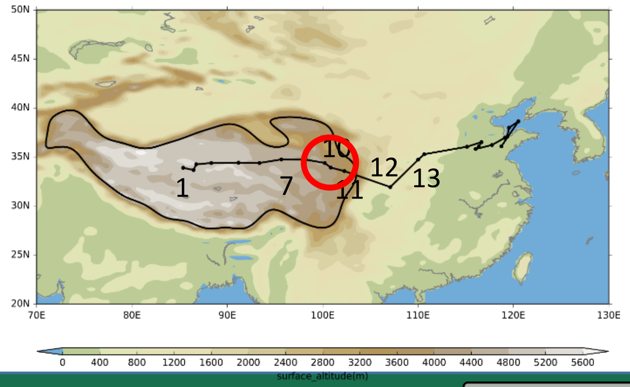


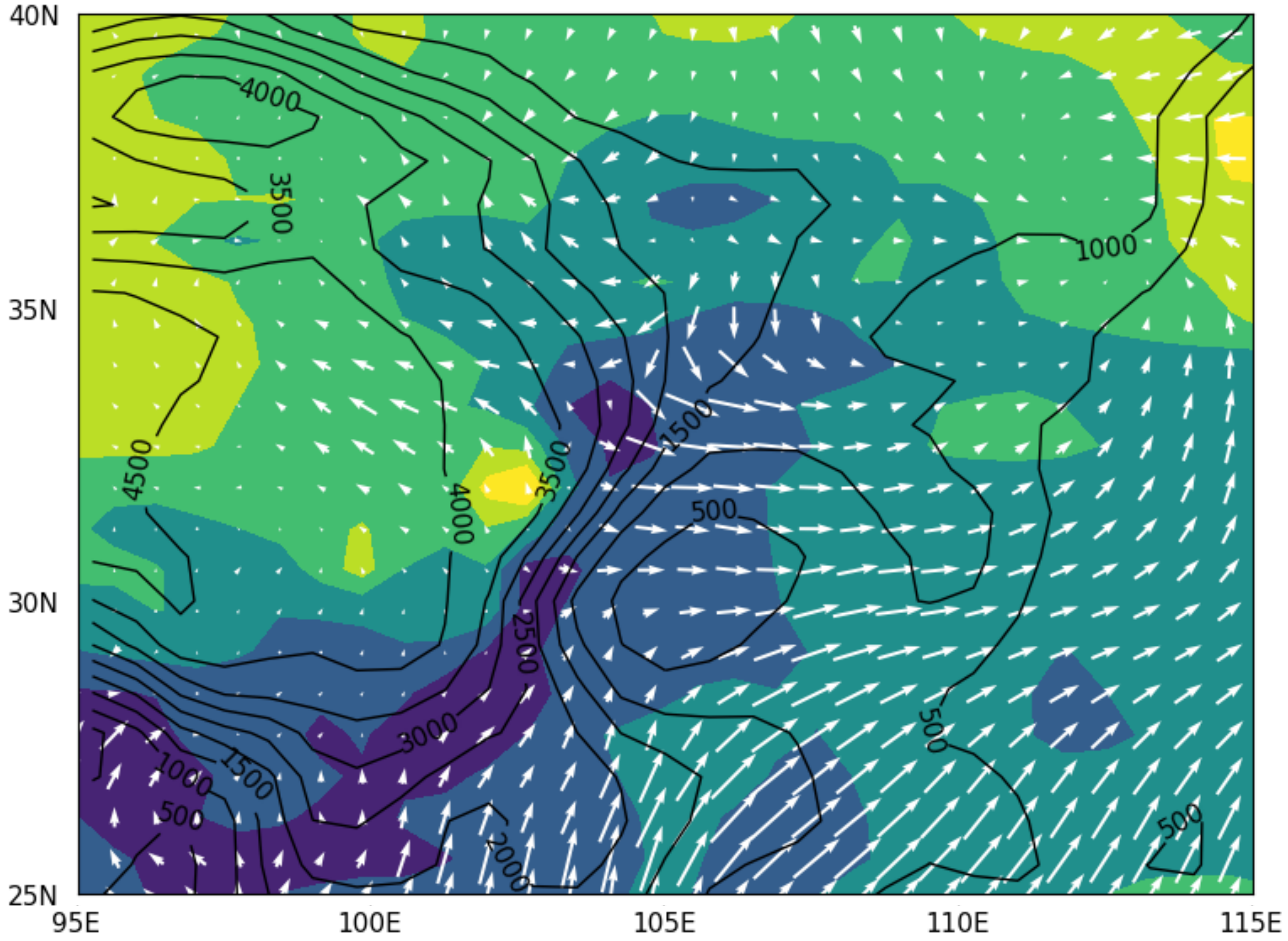
time step 9

Wind field and moisture at 700 hPa



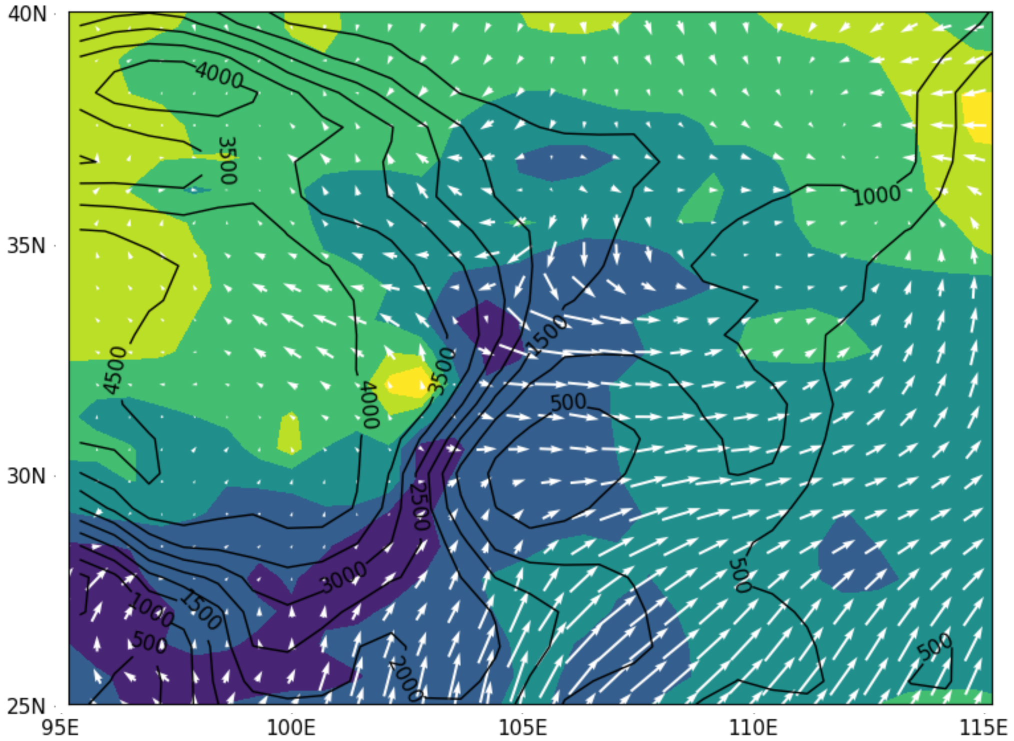
time step 9



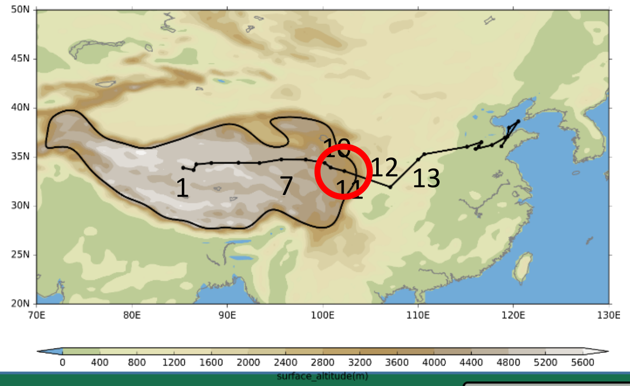


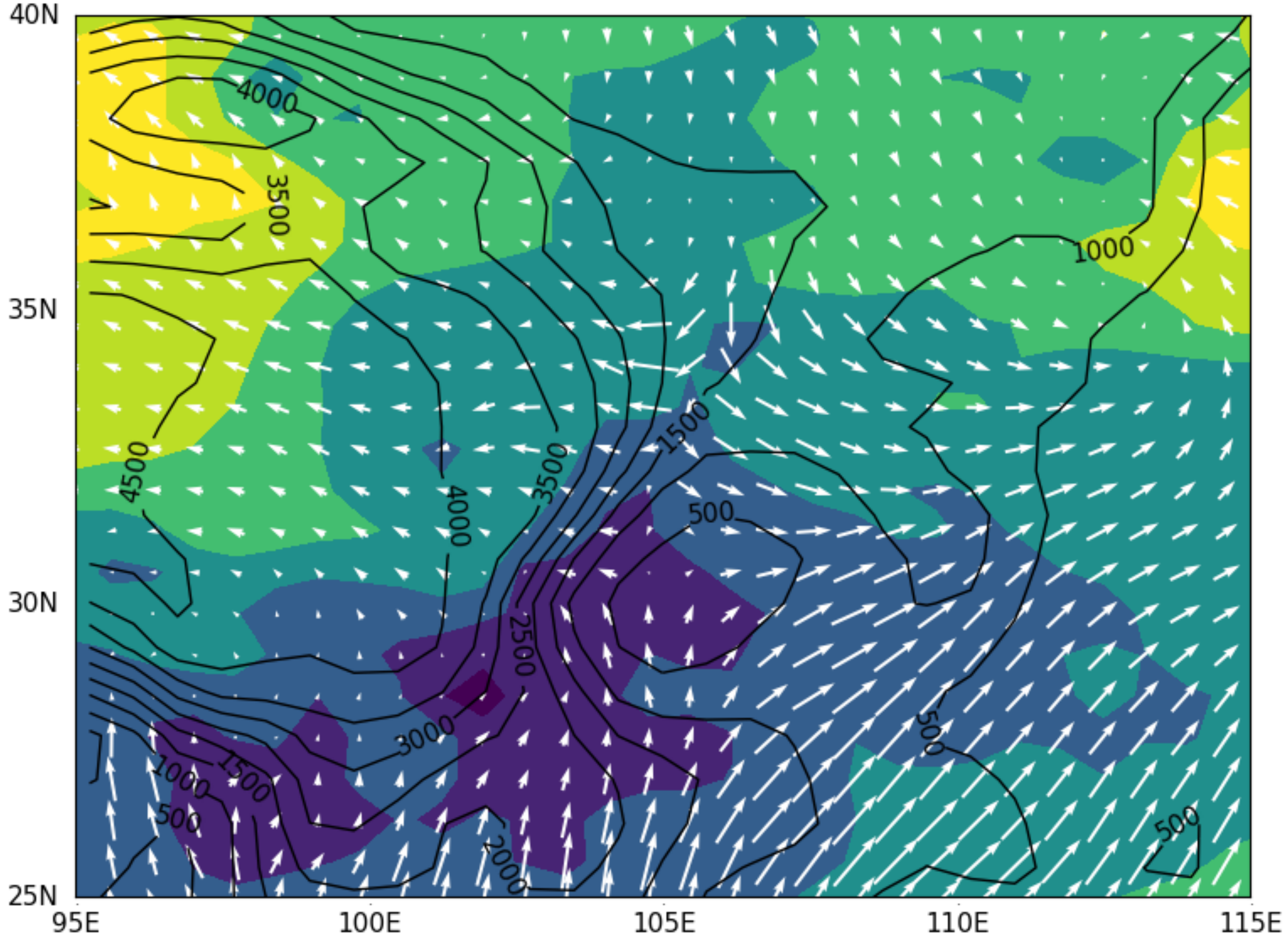
time step 10

Wind field and moisture at 700 hPa



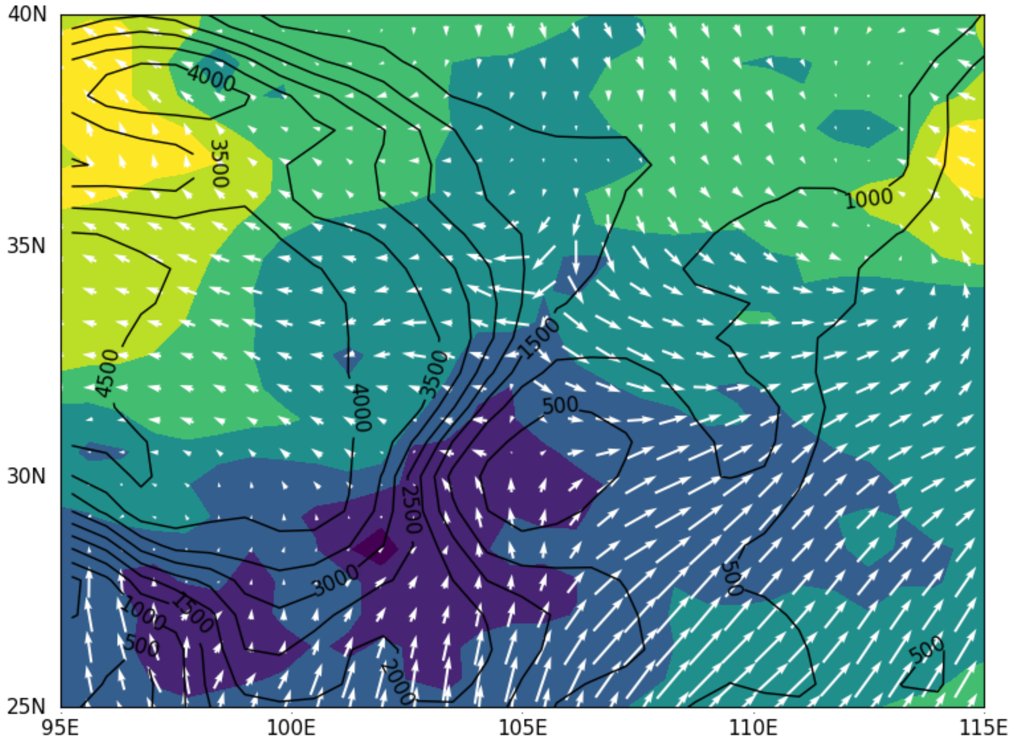
time step 10



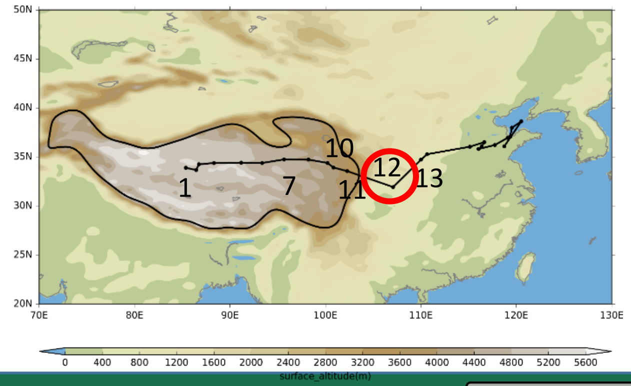


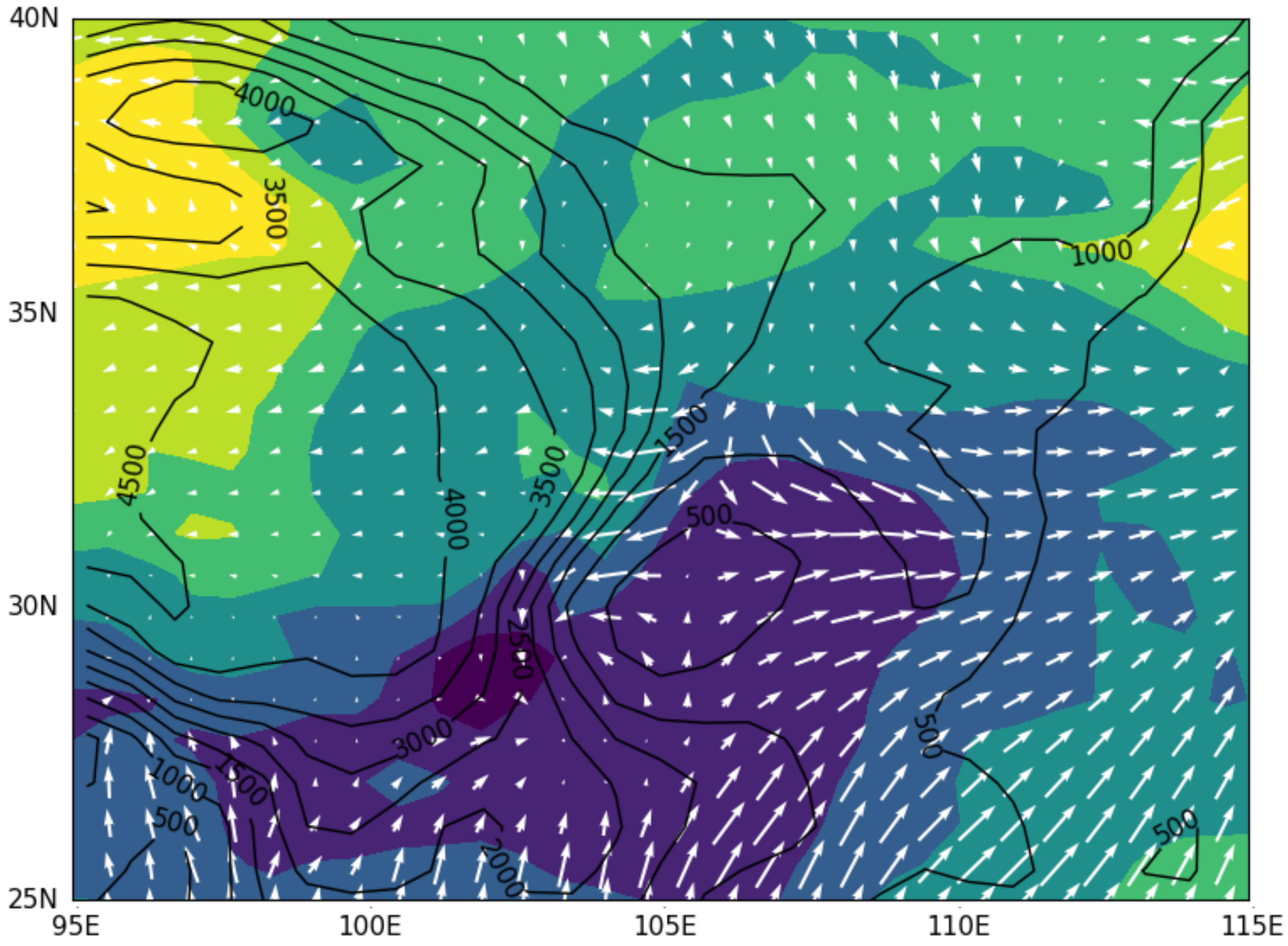
time step 11

Wind field and moisture at 700 hPa



time step 11

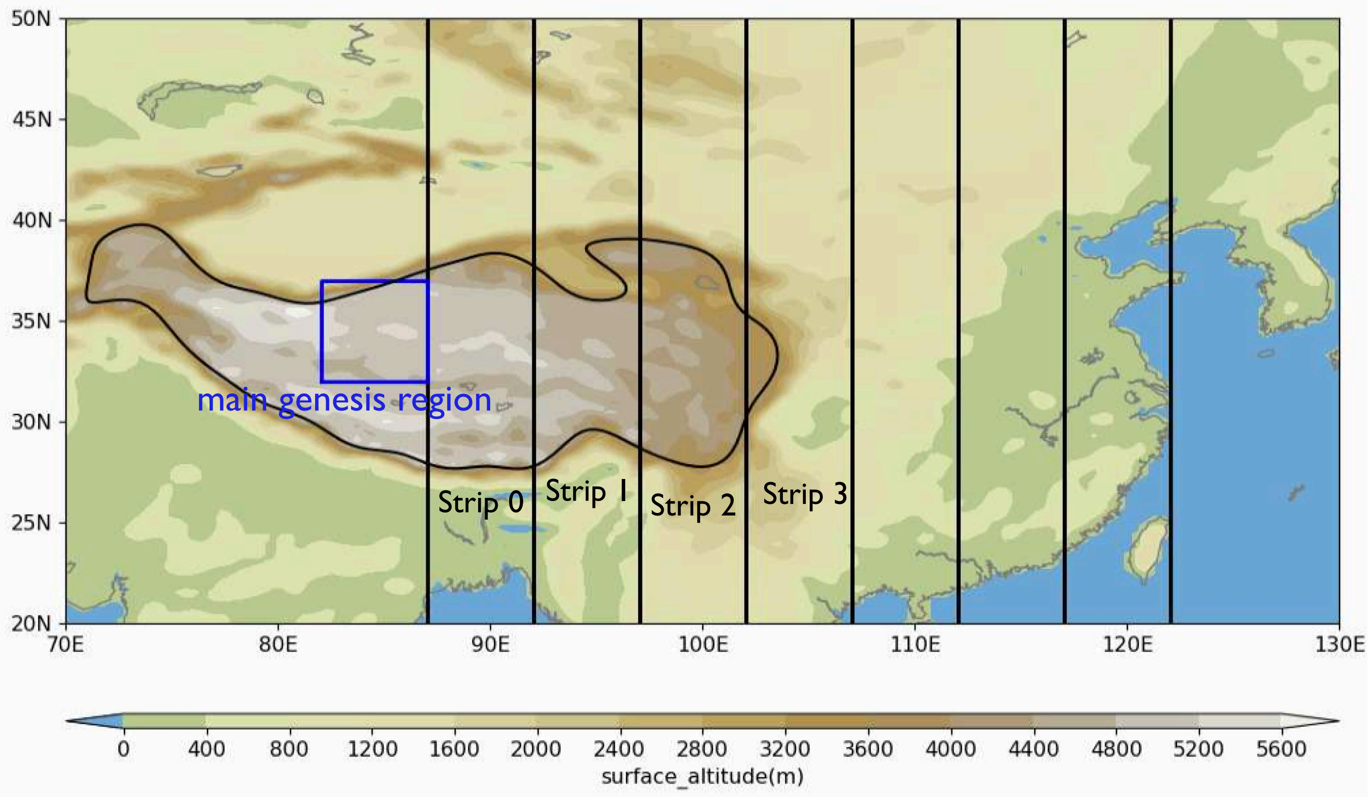




time step 12

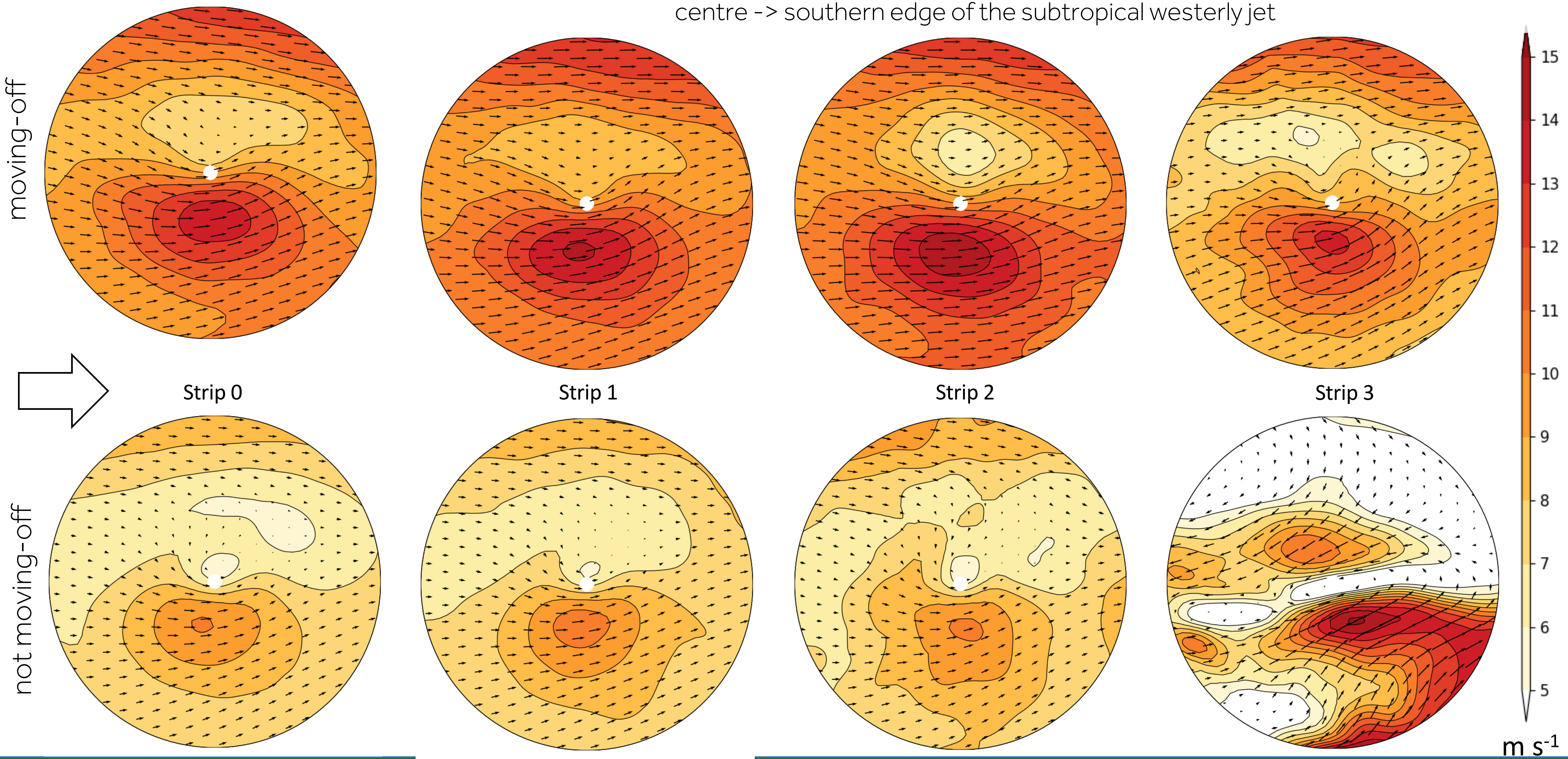
Composites for different regions

- subsample all moving-off and not moving-off TPVs generated in the main genesis region (all months)
- generating relatively homogeneous groups of TPVs
- composites over 5° wide longitudinal strips



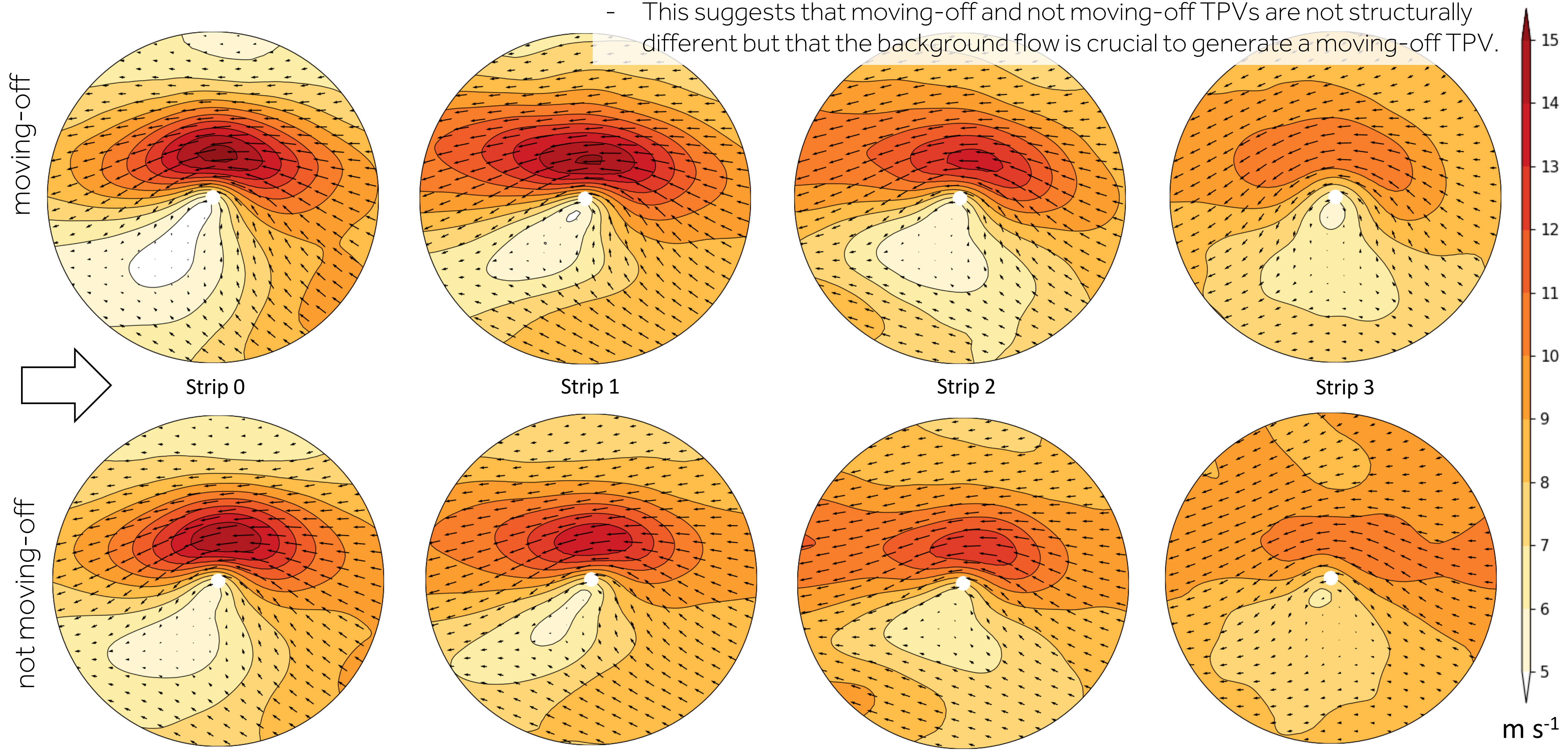
Earth relative winds 500 hPa

- Strongest winds south of the TPV centre for both groups
- Winds stronger for moving-off TPVs, a second maximum north of the TPV centre -> southern edge of the subtropical westerly jet



System relative winds 500 hPa

- When looking at the system relative winds, propagation speed removed, the wind fields of both groups look very similar.
- This suggests that moving-off and not moving-off TPVs are not structurally different but that the background flow is crucial to generate a moving-off TPV.



Summary

- Only a small fraction of TPVs can move off the TP to the east.
- Impact of subtropical westerly jet on moving-off TPVs visible.
- Background flow appears to be crucial for moving-off
- TPV triggers precipitation on the eastern slopes of the TP when moving off: change in circulation and higher moisture availability in region with conditions already favourable for convection.

Next steps

- Where do impactful TPVs form?
- Which ingredients necessary to produce an impactful TPV?
- Where is the moisture for TPV-associated precipitation coming from?
- Understanding how a combination of the (right) large-scale atmospheric conditions and a TPV-induced change in the local circulation downstream of the TP can create an impactful TPV may enable improved forecasts of TPVs and their impacts.

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Please let me know if you have any questions

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Curio, J., R. Schiemann, K. I. Hodges, and A. G. Turner, 2019: Climatology of Tibetan Plateau Vortices in reanalysis data and a high-resolution global climate model. J. Climate, **32**, 1933–1950, https://doi.org/10.1175/JCLI-D-18-0021.1.

Curio, J., Y. Chen, R. Schiemann, A. G. Turner, K. C. Wong, K. I. Hodges, and Y. Li, 2018: Comparison of a manual and an automated tracking method for Tibetan Plateau vortices. Advances in Atmospheric Sciences, 35 (8), 965-980, https://doi.org/10.1007/s00376-018-7278-4.