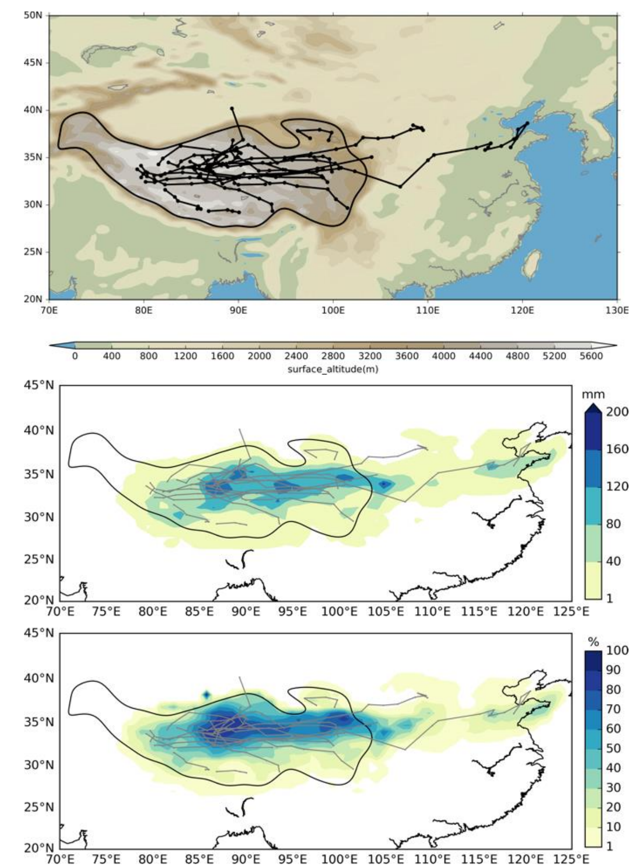
Drivers and variability of Tibetan Plateau Vortices

Lead Supervisor:
Reinhard Schiemann, National Centre for Atmospheric Science (NCAS), University of Reading
Email: r.k.schiemann@reading.ac.uk

Co-supervisors: Julia Curio, Department of Earth Sciences, University of Gothenburg; Kevin Hodges, Andrew Turner, NCAS, Department of Meteorology, University of Reading

Tibetan Plateau Vortices (TPVs) are cyclonic storms, about 500 km in diameter, that form over the Tibetan Plateau (TP) all year round. TPVs are the main precipitation-generating mechanism over the TP and some of these systems move off the plateau to the east where they can trigger heavy precipitation and flooding. Impactful TPVs can affect any part of China but are most frequent over and directly east of the TP in the Sichuan Basin and Yangtze river valley, home to more than 100 million people. For example, in July 2008 a TPV moved off the TP and travelled all the way to the coast of the Yellow Sea (see figure), triggering heavy precipitation in the Sichuan basin, where one station recorded more than 280 mm of precipitation in 24 hours.



TPV tracks during July 2008 (top), associated total precipitation (middle), and fraction of total precipitation associated with TPVs (bottom). Adapted from Curio et al., 2019.

Due to their small size relative to more well-known features such as mid-latitude cyclones, TPVs cannot be represented by classical Global Climate Models (GCMs) that have resolutions (grid spacings) of 100 km or more. The first simulated TPV climatology has recently been derived by researchers at the University of Reading using a high-resolution 25km GCM. By comparing with different observational estimates, including those from Chinese partners at the Institute for Plateau Meteorology in Chengdu, the GCM was shown to credibly represent the climatology of TPVs and their precipitation impacts (Curio et al. 2018, 2019).

This recent success in simulating TPVs in a GCM offers a range of opportunities for model-based investigations of these systems, which will be pursued in this PhD project. Specifically, we will address the following questions:

- What causes TPVs to form? Most TPVs are seen to form in a 'hotspot' located over the western TP (at about 34°N, 83°E) throughout the year. We hypothesise that this hotspot is orographically forced, and we will test if it is due to the large-scale arrangement of the Asian mountains (the TP and surrounding mountain systems such as Himalayas, Hindu Kush, Pamir, Tien Shan) and/or due to smaller (mesoscale) orographic features on the TP near the formation hotspot. To achieve this, we will design sensitivity experiments where parts of the orography are modified in a GCM (the Met Office Hadley Centre HadGEM3 model). We will also contrast the role of mechanical orographic forcing with other factors that have been proposed to be important for TPV formation such as surface heating and convective aggregation over the TP (Zhang et al. 2019).

- What are the drivers of TPV variability? This part of the project will advance understanding of how TPV occurrence is embedded in and interacts with the atmospheric circulation over Eurasia. We will investigate, for example, if and how TPV activity is related to indicators of the Asian monsoon circulation such as the Tibetan (Monsoon) High and the East Asian Monsoon Front. We will also determine how TPVs are driven by the westerly circulation upstream of the TP, for example, by the Subtropical Westerly Jet and the North Atlantic Oscillation.
- What is the role of TPVs in transporting atmospheric moisture to the TP? The TP is key to the Asian water cycle and origin of many major Asian rivers. We hypothesise that atmospheric moisture transport onto the TP is strongly episodic and occurs through narrow valleys in the Himalayas, for example. We will determine to what extent TPVs cause moisture transport onto the TP, and if the simulation of this transport in a GCM is sensitive to resolution, particularly that of the orography around the TP.

The student will work closely with our high-resolution global climate modelling group, thus gaining access to a state-of-the-art model and simulations. An extra dimension of this project is the link with the Regional Climate Group at the University of Gothenburg, one of the leading groups worldwide for research on the weather and climate of the Tibetan Plateau. This group has strong links to the Third Pole Environment programme and is collaborating with Chinese partners on multiple projects. The group is also leading a WCRP-CORDEX flagship pilot study on "High resolution climate modelling with a focus on mesoscale convective systems and associated precipitation over the Third Pole region".

Training opportunities:

The student will be able to visit the University of Gothenburg for one month allowing for interactions with researchers in the Regional Climate Group and partners in the Third Pole Environment programme.

The student will learn to conduct sensitivity experiments with HadGEM3, a state-of-the-art GCM developed by the Met Office and partners, and used widely for weather and climate research in the UK and internationally. The student will also learn how to use advanced analysis techniques to identify and track TPVs and their properties.

The student will be in a good position to apply for attending the NCAS Climate Modelling Summer School, organized biennially by NCAS at the University of Cambridge (entry competitive).

Through this project the student will develop strong programming skills and the ability to manage large datasets, including receiving training for this in NCAS courses for cf-python/cf-plot. NCAS also conducts other short courses that may be beneficial (https://preview.tinyurl.com/NCAS-training).

Student profile:

We are looking for an enthusiastic student with a natural science background from subjects like meteorology, physics, environmental/Earth science, or mathematics, with demonstrated strong analytical skills and a keen interest to study the physics of Tibetan Plateau Vortices and their drivers.

The student will also need to have or acquire the necessary programming and data analysis skills required for the quantitative analysis of big climate data sets and for learning to set up and run a GCM on a supercomputer.

References:

Curio, J., Chen, Y., Schiemann, R., Turner, A. G., Wong, K. C., Hodges, K., et al. (2018). Comparison of a Manual and an Automated Tracking Method for Tibetan Plateau Vortices. *Advances in Atmospheric Sciences*, *35*(AUGUST), 965–980. https://doi.org/10.1007/s00376-018-7278-4

Curio, J., Schiemann, R., Hodges, K. I., & Turner, A. G. (2019). Climatology of Tibetan Plateau Vortices in Reanalysis Data and a High-Resolution Global Climate Model. *Journal of Climate*, *32*(6), 1933–1950. https://doi.org/10.1175/JCLI-D-18-0021.1

Zhang, F., Wang, C., & Pu, Z. (2019). Genesis of tibetan plateau vortex: Roles of surface diabatic and atmospheric condensational latent heating. *Journal of Applied Meteorology and Climatology*, *58*(12), 2633–2651. https://doi.org/10.1175/JAMC-D-19-0103.1

https://research.reading.ac.uk/scenario/