Heavy and extreme precipitation events in the Sichuan Basin during the 2020 summer season in a set of kilometre-scale simulations

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WCRP CORDEX FLAGSHIP PILOT STUDIES

1. Background

- The Sichuan Basin (SB) is a lowland region in southwest China located at the eastern slope of the Tibetan Plateau (TP).
- During the summer of 2020, large parts of East Asia were affected by anomalously high precipitation with record-breaking daily accumulated rainfall at multiple stations in the SB [1].
- Severe consequences like floods and landslides are threatening the lives and livelihoods of the over 100 million people living in the area.
- With global warming, the frequency and intensity of extreme precipitation events is expected to increase [2].
- ***CORDEX Flagship Pilot Study Convection-Permitting Third Pole (CPTP)*** → aims to improve our understanding of the water cycle over the TP with focus on convection and precipitation

2. Model simulations

We use the CPTP simulations for the summer season of 2020, i.e. the months June-August (JJA) that were run with the following models:

- ***WRF 4.2*** (**D2**) by the University of Gothenburg (UGOT) and the National Center for Atmospheric Research (NCAR) with different micro-physics; 4 km grid spacing
- ***COSMO-CLM v.6.0*** (**D3**) by the University of Innsbruck (UIBK), 2.2 km
- ***ICON 2.6.4*** (**D1**) by the Goethe University Frankfurt (GUF), 3.3 km

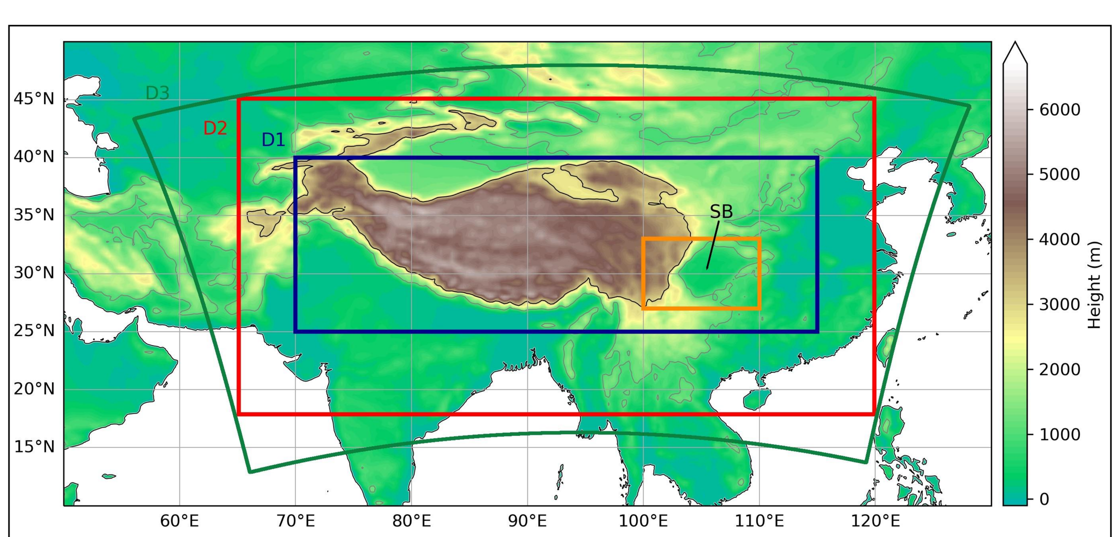

Figure 1. Topography (ERA5) and model domains. The orange box indicates the study area (27-33 °N, 100-110 °E) with the SB.

Research questions:

- How well do the different km-scale simulations capture selected extreme precipitation events that occurred in 2020 in the SB? (June 26-27, July 24-25, August 11-17)
- How do they differ among each other in representing the events and important related physical factors?

3. Observed and simulated precipitation (August)

- Overall, the models underestimate precipitation along the edge of the TP and fail to reproduce the location of the event (Fig. 2).
- ***ICON*** is closest to the observations (***GPM IMERG***).
- ***COSMO*** simulates higher precipitation in different locations than ***IMERG***

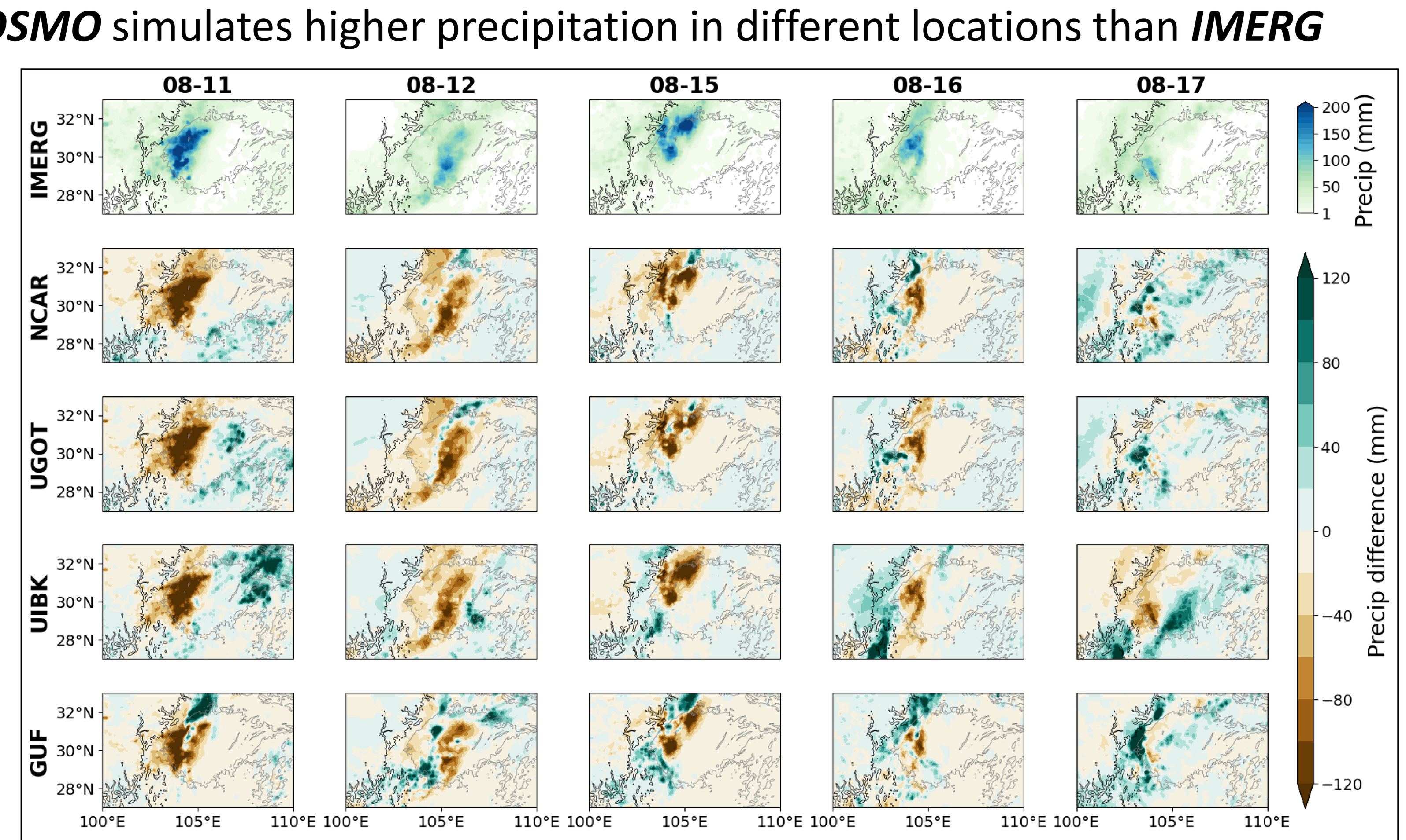

Figure 2. Daily accumulated precipitation of GPM IMERG *(first row)* and difference in daily accumulated precipitation of CPTP simulations and GPM IMERG *(rows 2-5)* for August 11-12 and 15-17, 2020. The black and grey lines mark the 3000 m and 700 m contour of the TP, respectively.

4. Model performance

- ***Fractions skill score (FSS)*** is a verification metric used to evaluate the skill of a model in simulating an observed preci-pitation field at different thresholds and spatial scales [3].
- ***ICON*** performs best
- ***WRF*** and ***COSMO*** are very similar and have low skill for higher thresholds and lower spatial scales
- lower performance for all models during other events *(not shown)*

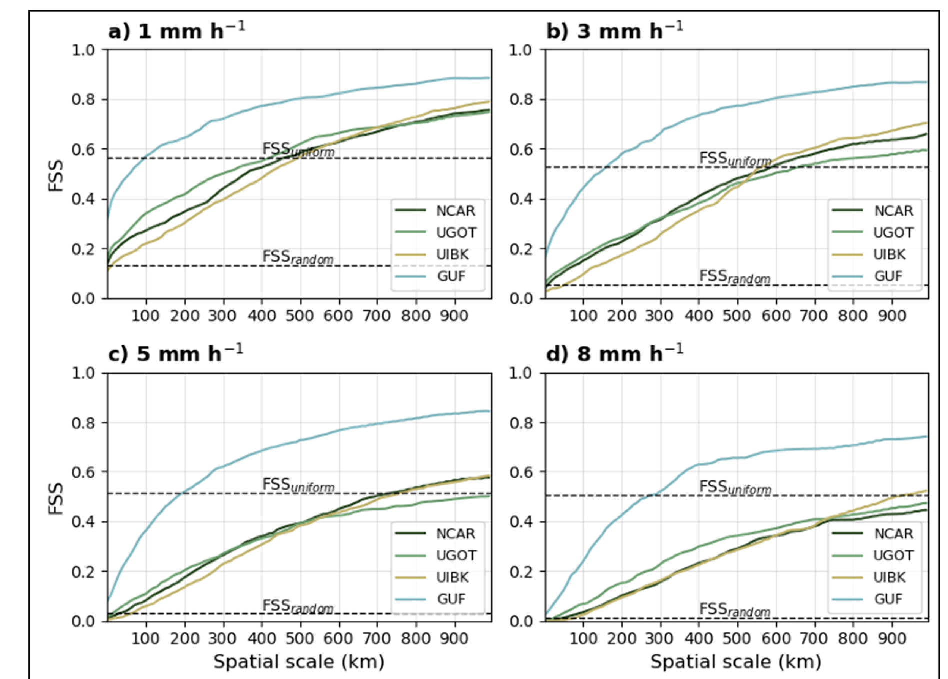

Figure 3. Median FSSs of hourly precipitation fields during August 11-17, 2020, with GPM IMERG as reference field compared to the CPTP simulations at different thresholds.

5. Related physical factors

Subtropical westerly jet

- A recent study using a set of CPTP simulations for one extreme precipitation case suggest that an accurate representation of the large-scale forcing is crucial to correctly simulate the event [4].
- All models produce a pattern similar to ERA5 for the August event (Fig. 4), but not for other events *(not shown)*.

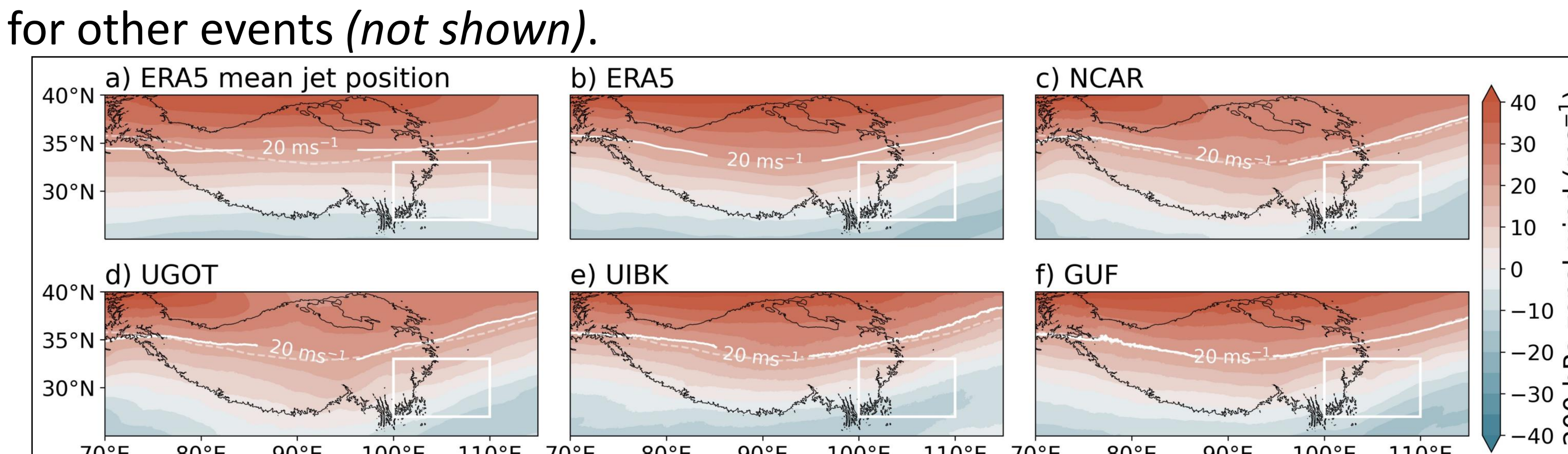

Figure 4. Mean zonal wind at 200 hPa during August 11-17, 2020, for (b) ERA5 and (c)-(f) the CPTP simulations. The white contour shows the 20 ms^{-1} zonal wind and the ERA5 mean jet stream position during July-August 2020 is shown in (a). The black line marks the 3000 m contour of the TP, and the white box indicates the study area. The dashed white line in (a), (c)-(f) indicates the jet position during the event as in (b) for comparison.

Water vapour transport

- Moisture is transported into the SB from the south during the August event (Fig. 5), and from the southwest during other events *(not shown).*
- ***NCAR*** overestimates the moisture transport during the event, while ***UGOT*** slightly underestimates.
- ***ICON*** is closest to ERA5.

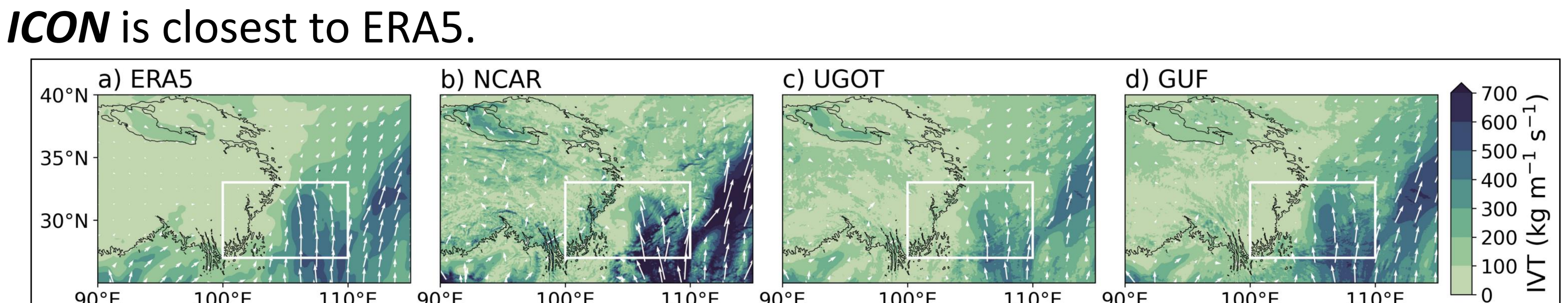

Figure 5. Total mean vertically integrated water vapour transport (IVT) for August 11-17, 2020 (kg $m^{-1}s^{-1}$) for (a) ERA5 and (b)-(d) CPTP simulations. The black line marks the 3000 m contour of the TP, and the white box indicates the study area.

6. Conclusions

- All models fail to reproduce the exact intensity and location of the observed extreme events.
- The simulations differ in their representation of the jet stream and the transport of water vapour for different events.
- ***ICON*** performs best throughout the whole analysis.
- Simulation of precipitation in the SB, especially at high rain rates and low spatial scales (Fig. 3), needs further improvement.

Take home messages:

- Model systems differ from each other in their representation of the observed precipitation events, depending on how accurately they simulate large-scale circulation and moisture transport
- Need for improvement of model performance over TP and its surrounding regions

References. [1] Qian, C., Ye, Y., Zhang, W., & Zhou, T. (2022). Heavy Rainfall Event in Mid-August 2020 in Southwestern China: Contribution of Anthropogenic Forcings and Atmospheric Circulation. *Bulletin of the American Meteorological Society*, 103(3), 111–117. doi: 10.1175/BAMS-D-21-0233.1. **[2] IPCC (2023).** Weather and climate extreme events in a changing climate. Climate Change 2021 – The Physical Science Basis: Working Group Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Chapter 11, 1513–1766. *Cambridge University Press*. doi: 10.1017/9781009157896.013. **[3] Roberts, N. M. & Lean, H. W. (2008).** Scale-Selective Verification of Rainfall Accumulations from High-Resolution Forecasts of Convective Events. *Monthly Weather Review*, 136(1), 78–97. doi: 10.1175/2007MWR2123.1. **[4] Kukulies, J., Prein, A.F., Curio, J., Yu, H., & Chen, D. (2023).** Kilometer-Scale Multimodel and Multiphysics Ensemble Simulations of a Mesoscale Convective System in the Lee of the Tibetan Plateau: Implications for Climate Simulations. *Journal of Climate*, 36(17), 5963–5987. doi: 10.1175/JCLI-D-22-0240.1.