Wave-resonance fingerprint in the 2010 summer: a modelling experiment

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Session AS1.15 – Atmospheric Rossby waves and Jet Dynamics, and their Impacts on Weather and Climate events

Drivers and Impacts of the 2010 Russian Heatwave and Pakistan Flooding

- Summer 2010 was characterized by **La Niña** conditions in the tropical Pacific. Between and of July and beginning of August, a powerful **heatwave** hit European **Russia**, causing thousand of deaths and severe wildfires. Meanwhile, **Pakistan** was affected by a devastating **flood**, which caused massive damages to economy, infrastructures and society (Barriopedro 2011, Trenberth & Fasullo 2011).

- Analyzing the circulation pattern that led to these coinciding extremes shows that the two events where part of the same **wavy jetstream** configuration over Eurasia, bringing warm air from the subtropics into Russia and cold mid-latitude air towards the western Himalayan foothills, thus enhancing rainfall in the Pakistan Indus basin (Lau & Kim 2011).

- Next to La Niña conditions, 2010 summer was identified as a **Quasi-Resonance Amplification** (QRA) event (Kornhuber et al. 2017). QRA events are characterized by a double jet in the mid-latitudes, which acts as a waveguide, a pre-condition for amplification of slow moving Rossby waves, often linked to heat extremes in the mid-latitude regions (Petoukhov et al 2013). It has been shown that QRA events also bear a characteristic "**fingerprint**" in the zonal temperature profile in the Northern Hemisphere (Mann et al. 2018).

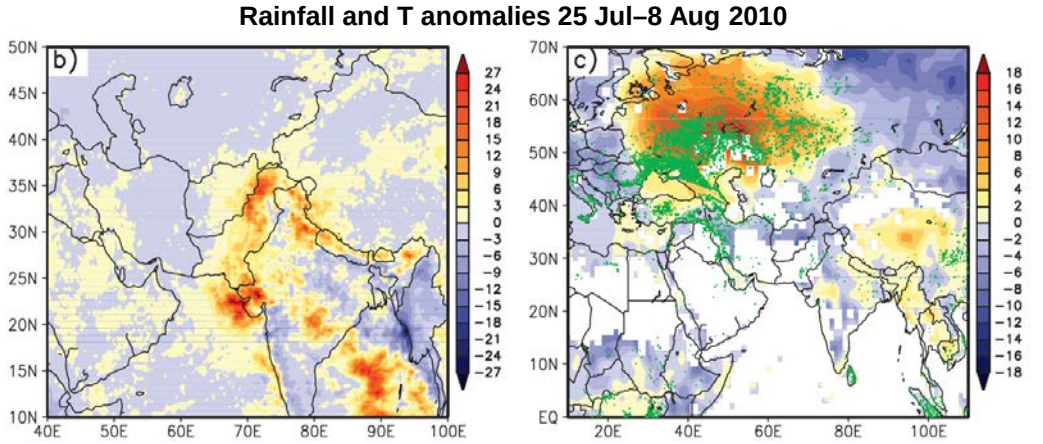


Fig. 1: (b) TRMM rainfall anomaly over Pakistan and (c) AIRS surface temperature anomaly, and MODIS daily fire pixel (green dots) for the period 25 Jul–8 Aug 2010 (Figure 1 from Lau and Kim 2011).

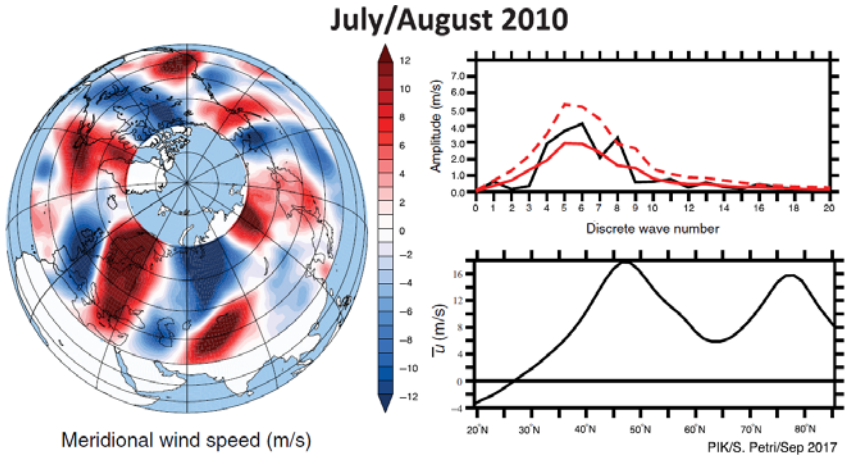


Fig. 2: Upper-troposphere (300 hPa) meridional wind, zonal wave number spectra, climatological mean spectra (red solid) and associated 1.5s upper limit (red dashed curve), and zonal mean zonal wind profiles associated with 2010 QRA event (Figure 1 from Mann et al. 2018).

Research question: Can we find evidence of a connection between the Russian heatwave, Pakistan flooding and the QRA fingerprint in models?

Large Ensemble Modelling to investigate the Dynamics of Summer 2010

- To assess whether the coinciding weather extremes in Russia and Pakistan can be generated when imposing QRA conditions, we run a large ensemble of simulations from a global general circulation model from the **Weather@home/Climateprediction.net** project (https://www.climateprediction.net/weatherathome/) for summer 2010 using prescribed sea surface conditions (Massey et al. 2015, Guillod et al. 2017).

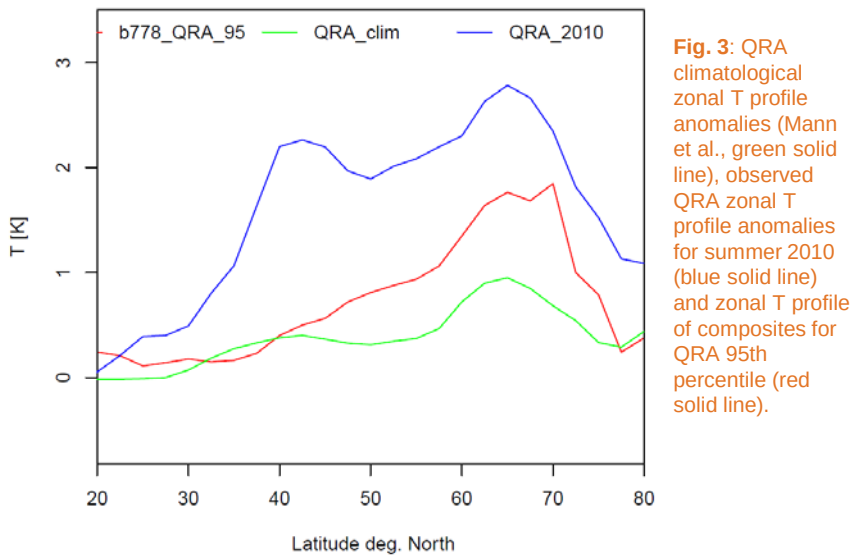


Fig. 3: QRA climatological zonal T profile anomalies (Mann et al., green solid line), observed QRA zonal T profile anomalies for summer 2010 (blue solid line) and zonal T profile of composites for QRA 95th percentile (red solid line).

- Out of 667 ensemble members, for each month (July and August), we select those days for which the **correlation** between the zonal T profile anomalies and the **QRA climatological T profile** is higher than the 95th percentile. For comparison, we also select those days that show an amount of **precipitation over the Pakistan/western Himalayan foothills** region higher than the **95th quantile.**

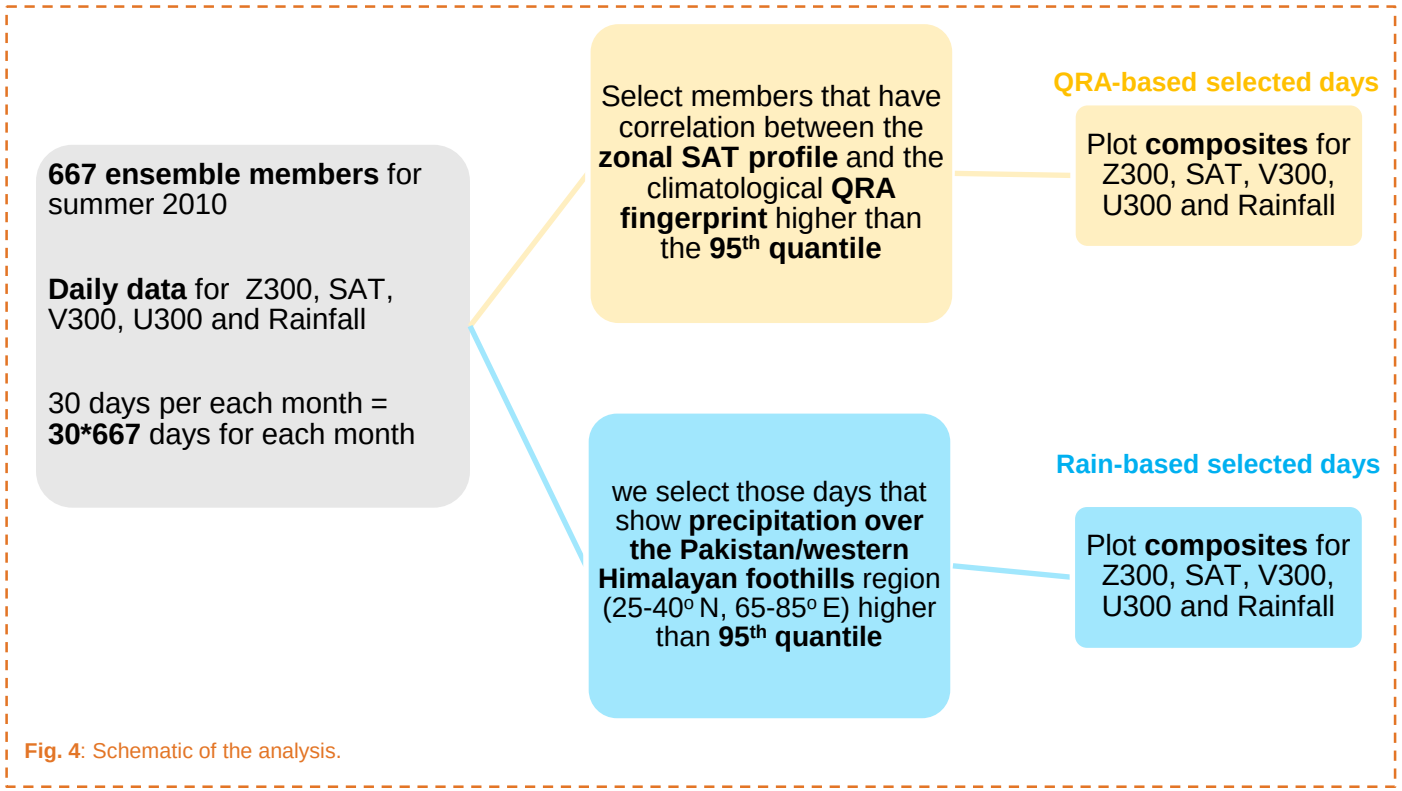


Fig. 4: Schematic of the analysis.

Sampling for QRA-fingerprint and Extreme Pakistan rainfall

- Members depicting the QRA fingerprint, are characterized by **warm temperature anomalies** over European Russia and eastern US/Canada (Fig. 5c).
- Further, QRA-Fingerprint members exhibit **higher than normal precipitation** over Pakistan and the north-eastern Arabian Sea (Fig. 5a; similarly to observations, see Fig. 1b).
- When selecting for members with enhanced rainfall over Pakistan (Fig. 5b), similar temperatures anomalies (though with smaller magnitude) over both Russia and eastern Canada are seen (Fig. 5d).
- As for SAT and rainfall, also patterns of meridional wind (V300) and geopotential height at 300hPa (Z300) show a striking similarity when QRA-fingerprint and Pakistan rainfall based composites are compared (Figs. 5g and 5i compared with Figs. 5h and 5l).
- Zonal wind (U300) anomalies show a strong jet in higher latitudes ~60° N (Fig. 5i) for QRA-fingerprint based composites but not for Pakistan rainfall based anomalies (Fig. 5l).

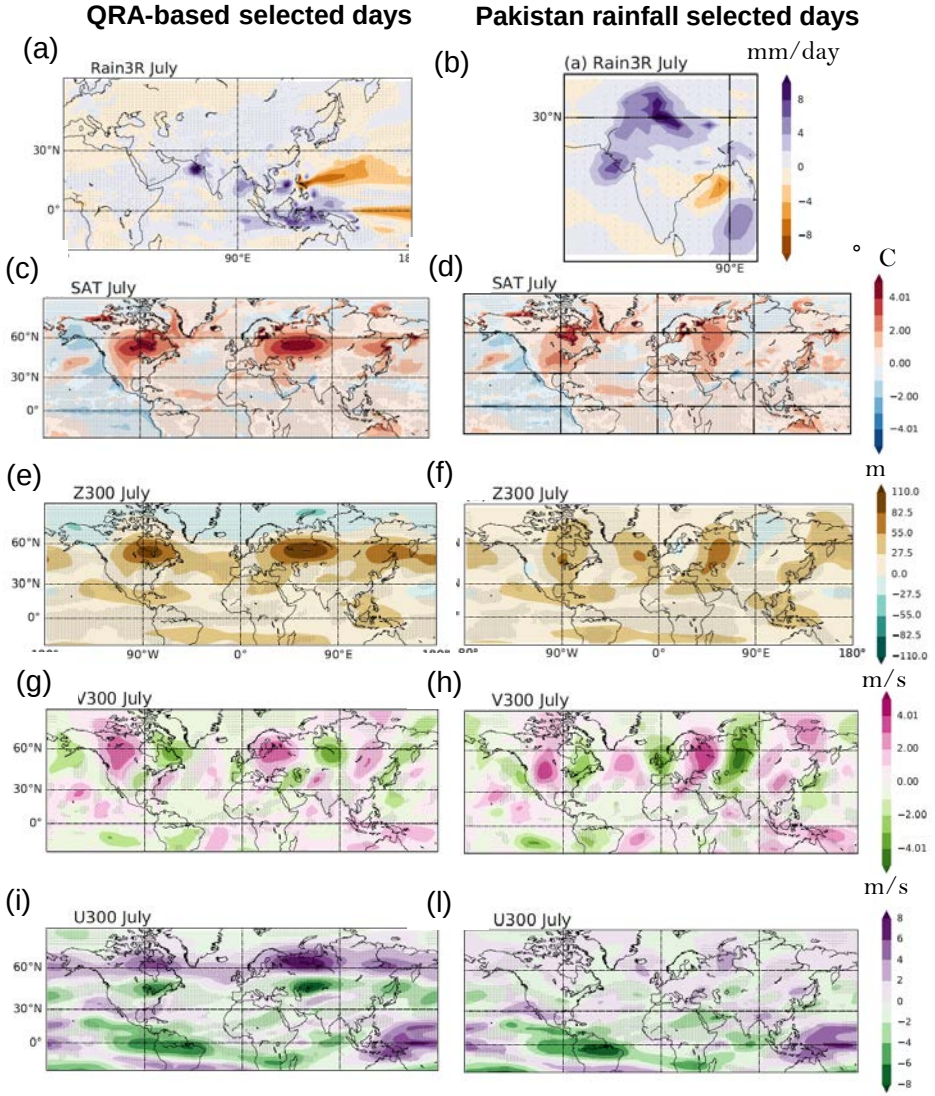
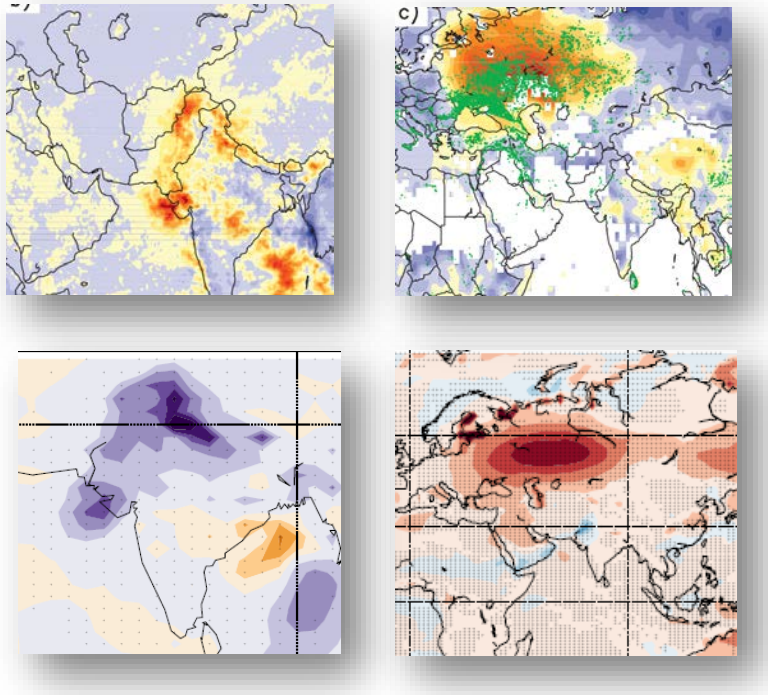


Fig. 5: Left panels: Composites of daily SAT, Z300, V300, U300 and 3-day running mean rainfall (Rain3R) anomalies for days with correlation between zonal T profile and QRA climatological T fingerprint higher than 95th percentile for July. Right panels: Same as for the left column but for days with rainfall over the Pakistan regions (25-40° N, 65-85° E) higher than 95th percentile for July.

Summary & Outlook

- Past episodes of **amplified planetary waves** were characterized by specific zonal T mean profiles and surface conditions.
- Here, we produce a **large ensemble of simulations for summer 2010** and analyze how the surface conditions are represented in a model availing ourselves of a large statistics.
- When **selecting for the zonal mean QRA fingerprint**, temperature anomalies over European Russia and Canada and precipitation anomalies over the north-eastern Arabian Sea and Pakistan **resemble the patterns observed** in summer 2010.
- Further, meridional wind anomalies highlight a **wave-6 pattern**, similar to summer 2010.
- When we **select for enhanced rainfall anomalies over the Pakistan/western Himalayan foothills region**, **similar temperature and meridional wind patterns** are seen in the mid-latitudes as for QRA-fingerprint events.
- Similar results for August are found (Figs. not shown)



Next steps:

- Can sea surface temperatures alone, related to ENSO events, explain the modelled relationship between warm temperature anomalies over Russia and rainfall over Pakistan?
- Can causal discovery tools help to better understand the causal chain of events?

Thank you for participating to this year online EGU session and for reading about our work!!

Any question can be e-mailed to G. Di Capua (dicapua@pik-potsdam.de) or asked directly during the live online session (06.05.2020, 08:30-10:15 CEST)

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