Convective rain over the Ethiopian highlands: orographic driving factors in a convection-permitting simulation

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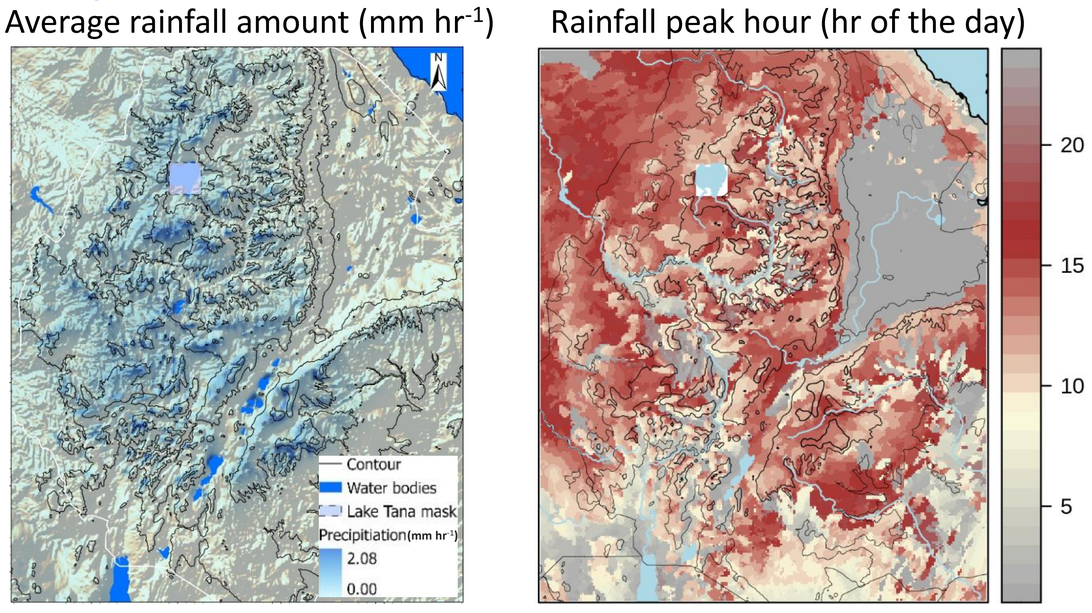
Motivation

- The Ethiopian highlands are home to more than 90% of the Ethiopian population and the total area suitable for agriculture.
- The livelihood of 66% of Ethiopia's population rely on subsistence rainfed agriculture, which is highly susceptible to climate variability.
- Rainfall variability can cause massive economic loss for farmers reliant on rain-fed agriculture.

This work therefore aims at understanding sub daily distribution of summer rain, including the role of orography in driving the diurnal distribution of rainfall over the Ethiopian highlands using ALARO-0 regional climate model at convection-permitting resolution of 4 km.

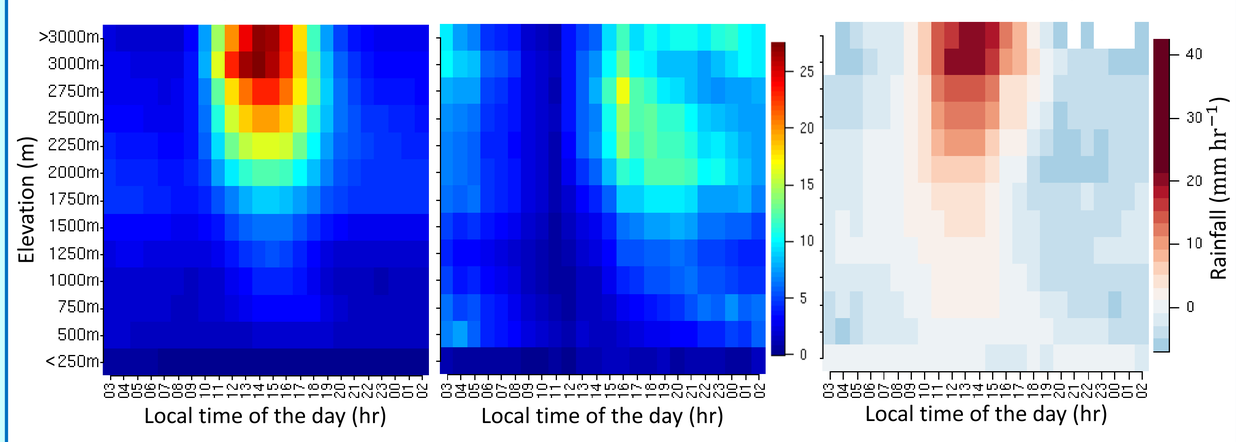
1. Study area and model simulations

Average rainfall amount (mm hr^{-1}) | Rainfall peak hour (hr of the day)



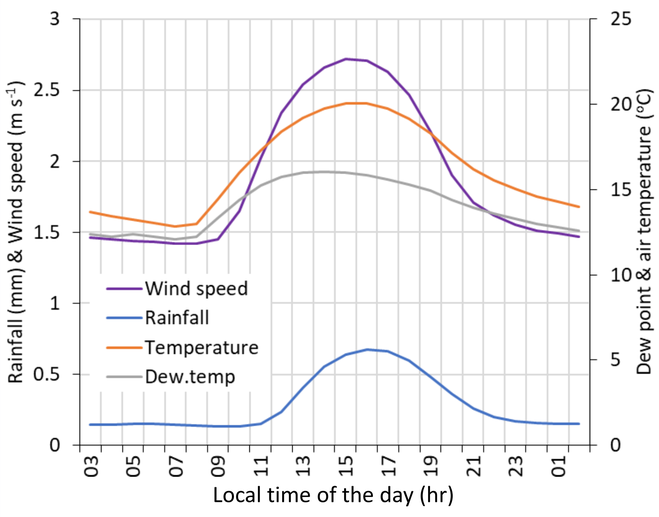
- Elevation is the most important determinant factor for rainfall.
- Peaks occur earlier in the day at higher elevations, and at night in the lowlands.

2. Model evaluation against IMERG



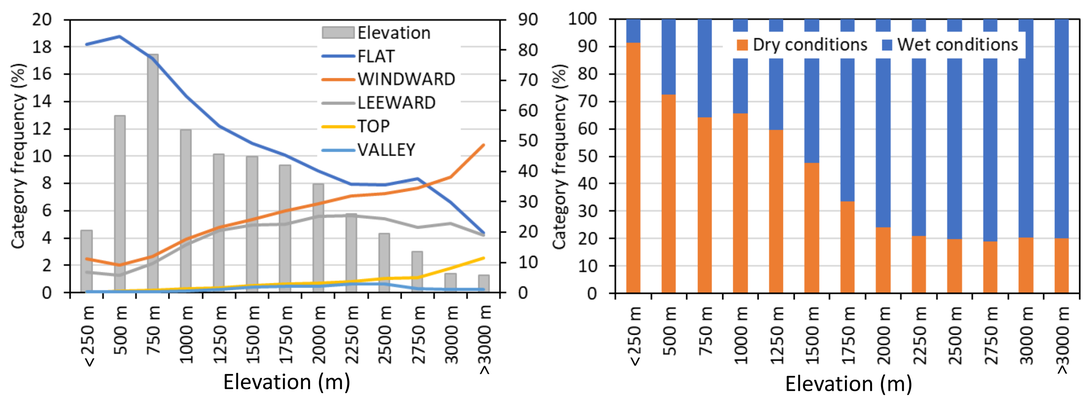
- Early onset of the modelled day-time convective cycle resulting in an overestimation at noon while stark underestimation in the evening.
- Both agree in the fact that most rain falls during the daytime and increases with altitude.

3. What variables explain the simulated diurnal cycle



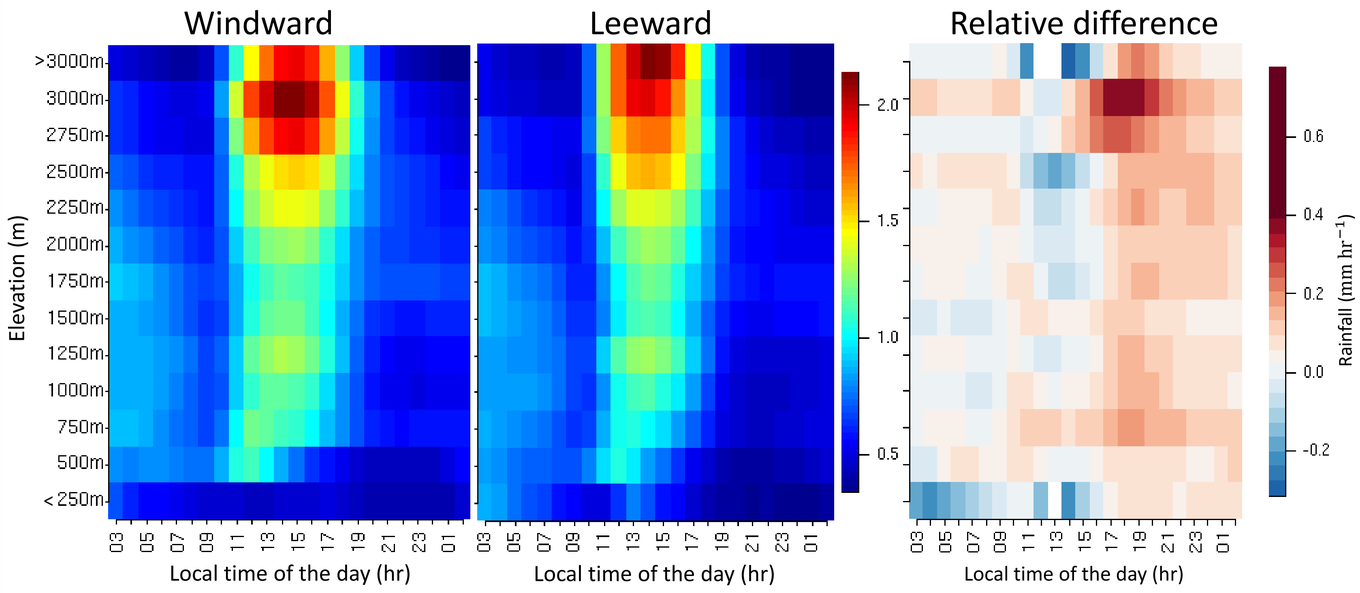
- Cycles of temperature and humidity precede windspeed and rainfall.
- Temperature drops in the afternoon due to reduced insolation and increased clouds.
- Surface humidity increases in the morning due to latent heating but decreases due to vertical mixing.

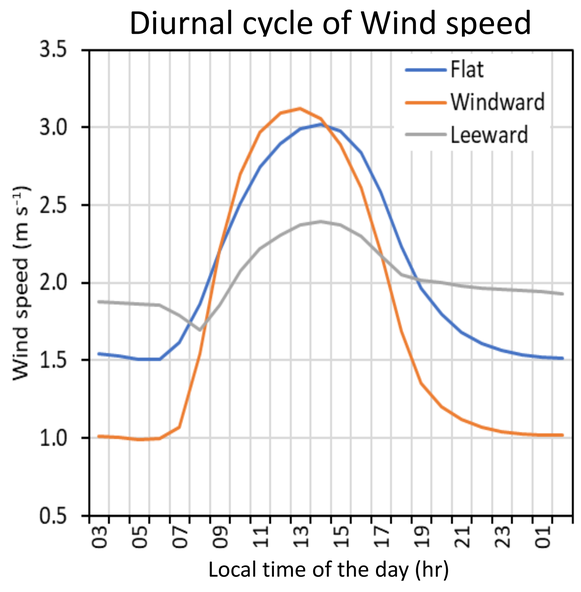
4. Terrain effects on precipitation diurnal cycle



- Proportional area of elevation categories continuously decline with altitude.
- Lowland areas are mainly attributed to flat and dry conditions; while wet windward and leeward events prevail towards higher elevation.

5. Slope orientation effects on precipitation diurnal cycle





- Hours of the day, 12:00-16:00, experience peak rain per rainfall event, unlike night and morning.
- Rainfall is generally higher at higher elevation and on windward sides, except during the peak hours.
- Clear wind cycle for windward, but weak cycle for leeward.
- Although there are almost no winds at night, slight rain persists on windwards.

Summary

- There is generally more rainfall mainly during the day, especially at higher elevation and windward events.
- The predominant afternoon maximum rainfall as well as prevalence of windward over leeward events and high orographic rain suggest terrain-induced ascent owing to thermal rather than wind-induced forcing.
- These differences are very likely to determine hydrology and vegetation distribution, as well as farmers economy at large.

Future Research and Impact

- More research is needed to understand differences between windward and leeward sides of a mountain.
- Further investigation is needed towards precipitation-temperature dependence at different heights in light of climate change.
- Relating precipitation with vegetation and other topographic variables using Machine Learning tools will be done to understand the local rainfall climate.
- These outcomes could reorient the existing "one-size-fits-all" agro-ecosystem management approach with a site-specific one considering climatic differences.

References

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- Van den Hende, C., Van Schaeybroeck, B., Nyssen, J., Van Vooren, S., Van Ginderachter, M., Termonia, P., 2021. Analysis of rain-shadows in the Ethiopian Mountains using climatological model data. *Climate Dynamics*.

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