PROYECTO PERÚ GROWS

PEGASUS
PRODUCCIÓN DE ENERGÍA PREVENCIÓN DE PELIGROS

Multi-decadal past and future temperature and precipitation trends in the Peruvian Andes

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Introduction

This work focusses on two river basins in the Peruvian Andes, the upper regions of the Rio Santa in the Cordillera Blanca, about 200 km north of Lima, and the Vilcanota-Urubamba basin which covers the Quelccaya ice cap, near Cusco.

- There is a strong seasonal cycle in precipitation, but not temperature, in both regions (see Fyffe et al., EGU21-7524).
- Both regions have shown warming in the recent past (Vicente-Serrano et al., (2018), Salzmann et al., (2013)).
- Precipitation has been increasing over the Cordillera Blanca, but the trends are less clear over the Vilcanota-Urubamba (Salzmann et al., (2013), Heidinger et al, (2018)).
- Substantial future warming is expected over all of the Peruvian Andes, but varying precipitation trends have been predicted (Neukom et al., (2015), Vuille et al., (2018)).

Vicente-Serrano, S. M., López-Moreno, J. I., Correa, K., Avalos, G., Bazo, J., Azorin-Molina, C., et al. (2018). Recent changes in monthly surface air temperature over Peru, 1964–2014. Int. J. Climatol. 38, 283–306. doi: 10.1002/joc.5176

Salzmann, N., Huggel, C., Rohrer, M., Silverio, W., Mark, B.G., Burns, P. and Portocarrero, C., 2013. Glacier changes and climate trends derived from multiple sources in the data scarce Cordillera Vilcanota region, southern Peruvian Andes. The Cryosphere, 7(1), pp.103-118.

Heidinger, H., Calrvalho, L., Jones, C., Posadas, A., and Quiroz, R. (2018). A new assessment in total and extreme rainfall trends over central and southern Peruvian Andes during 1965–2010. Int. J. Climatol. 38, e998–e1015. doi: 10.1002/joc.5427

Neukom, R., Rohrer, M., Calanca, P., Salzmann, N., Huggel, C., Acuña, D., Christie, D.A. and Morales, M.S., 2015. Facing unprecedented drying of the Central Andes? Precipitation variability over the period AD 1000–2100. Environmental Research Letters, 10(8), p.084017.

Vuille, M., Carey, M., Huggel, C., Buytaert, W., Rabatel, A., Jacobsen, D., Soruco, A., Villacis, M., Yarleque, C., Timm, O.E. and Condom, T., 2018. Rapid decline of snow and ice in the tropical Andes–Impacts, uncertainties and challenges ahead. Earth-Science Reviews, 176, pp.195-213.

Aims

- Characterise the spatial variations in the past trends in temperature and precipitation over the upper Rio Santa and Vicanota-Urubamba river basins, from 1980-2018.
- Determine the average future trends in temperature and precipitation over both regions, for RCP8.5.
- Analyse how extremes in temperature and precipitation are expected to increase in the future.

Methods

- The Weather Research and Forecasting (WRF) model is run over three domains, the outer domain covering all of Peru, with the inner domains (D2 and D3) covering the Upper Rio Santa and the Vilcanota-Urubamba catchments, respectively (Fig. 1).
- The daily precipitation and temperature results are bias-corrected against cleaned observations, from SENAMHI, ANA, MINERA ANTAMINA, MINEAR NEXA and CIAD UNASEM and Prof. Nilton Montoya. In total there are 35 precipitation and 26 temperature stations in D2, and 34 precipitation and 35 temperature stations in D3.
- The bias-corrected gridded precipitation and temperature datasets are then projected into the future, by downscaling 31 CMIP5 models (RCP8.5) to the WRF D2 and D3 grids, using Quantile Delta Mapping (QDM) as described in Cannon et al., (2015).

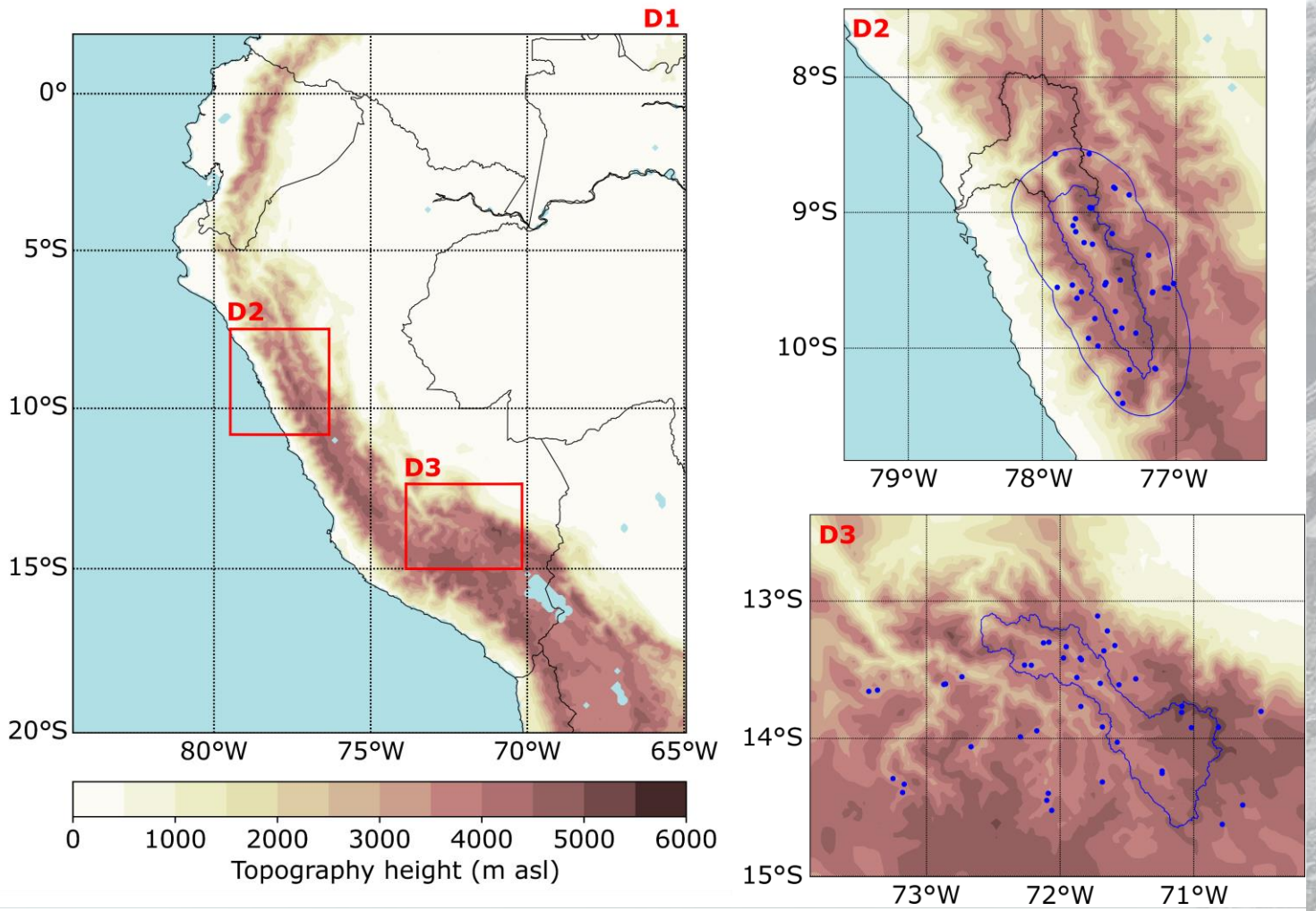

Fig. 1: The three WRF model domains (D1-D3). Elevation is showed as filled contours, and the ocean (and other water bodies) is shown in blue. The left-hand plot shows the outer domains (at 12 km horizontal resolution) covering all of Peru, and the right-hand plots show the two inner domains. D2, at 4 km resolution, covers the full Rio Santa River Basin outlined in black, with the upper Rio Santa outlined in blue, focused on in this research. Station data is taken from a 30 km boundary around the upper Rio Santa, outlined in blue. The Vilcanota-Urubamba basin is shown in blue outline in D3. The locations of all the stations used in the bias-correction are shown as blue dots.

Cannon, Alex J., Stephen R. Sobie, and Trevor Q. Murdock. "Bias correction of GCM precipitation by quantile mapping: How well do methods preserve changes in quantiles and extremes?." Journal of Climate 28.17 (2015): 6938-6959.

Spatial variations in the past trends: near-surface air temperature

- Both regions show increases in temperature over the most areas (calculated on the hourly average from 1980-2018), between 0.0064 and 0.023 ˚C/year over the Rio Santa, and between 0.011 and 0.027 ˚C/year over the Vilcanota-Urubamba-Vilcabamba.
- Over the higher-elevation, glacierised regions of the Rio Santa, the positive trend in temperature is smaller than elsewhere, and not statistically significance.
- In the Vilcanota-Urubamba-Vilcabamba, there is a significant positive trend in all areas of the region. There is a slightly larger warming at high elevations in the southern regions of the eastern end, but a slightly smaller warming at the high elevations in the northern regions of the eastern end (covering the Quelccaya ice cap).

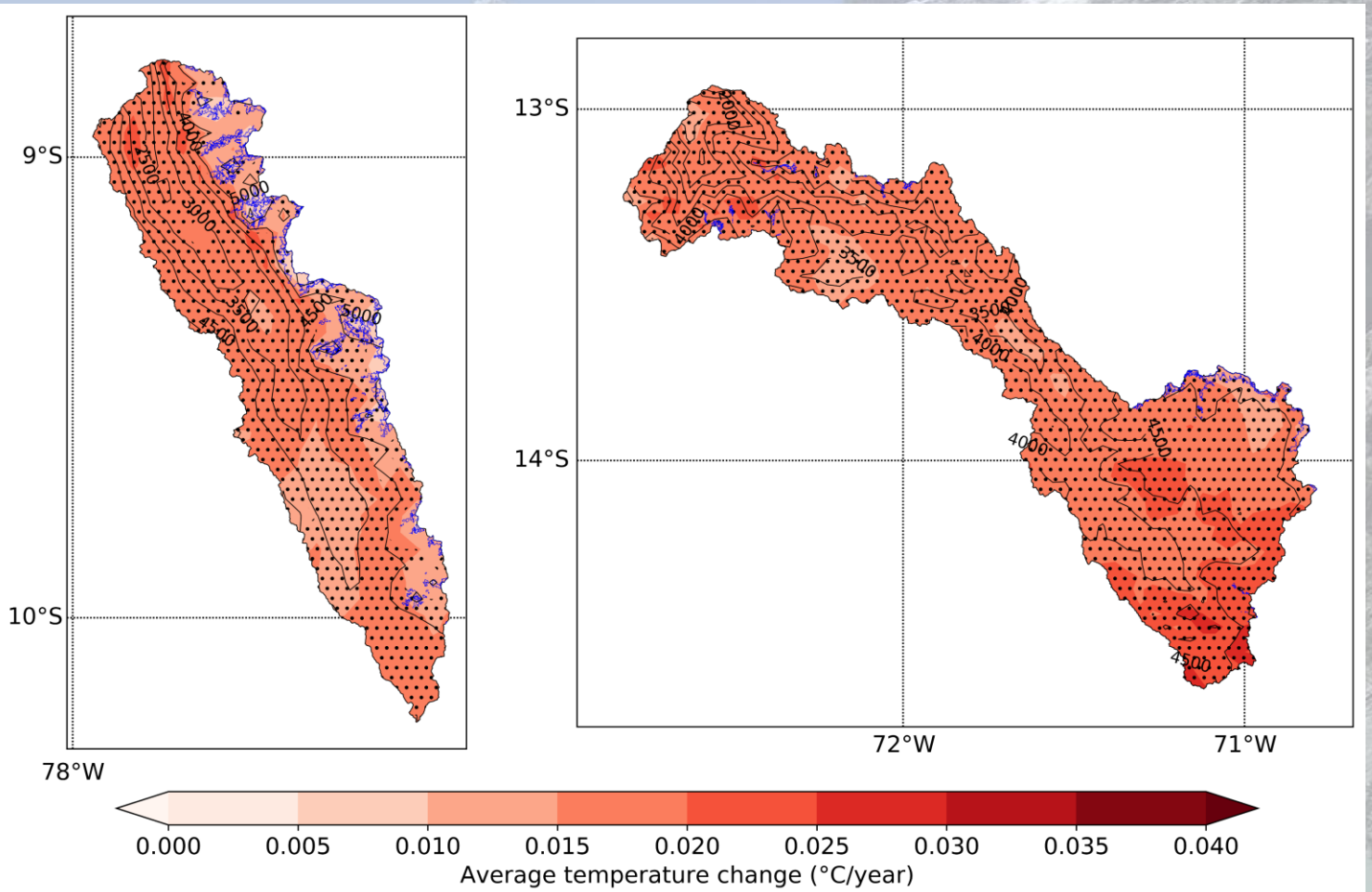

Fig 2: Average yearly trends in temperature in the Rio Santa (left) and Vilcanota-Urubamba-Vilcabamba (right). The average yearly trends (mean annual temperature), are the Theil-Sen slopes. Background contours show the trends, solid black contours show the elevation, blue contours show locations of the glaciers in the two regions, and stippling shows whether the trend is significantly statistically significant ($p<0.05$), according to the Mann-Kendall test for monotonic trends.

Spatial variations in the past trends: precipitation

- Over the Rio Santa, there is an increase in precipitation over some of the region, with a statistically significant increase (of 5-7 mm/year) over the western side of the southern regions. There is also a statistically significant (but smaller) monotonic increase over some of the lower-elevation regions in the North. Over the glacierised regions, there is no statistically significant monotonic increase.
- Over the Vilcanota-Urubamba-Vilcabamba, there is no statistically significant monotonic increase or decrease over the entire regions, with some regions showing a slight decrease and some a slight increase in precipitation.

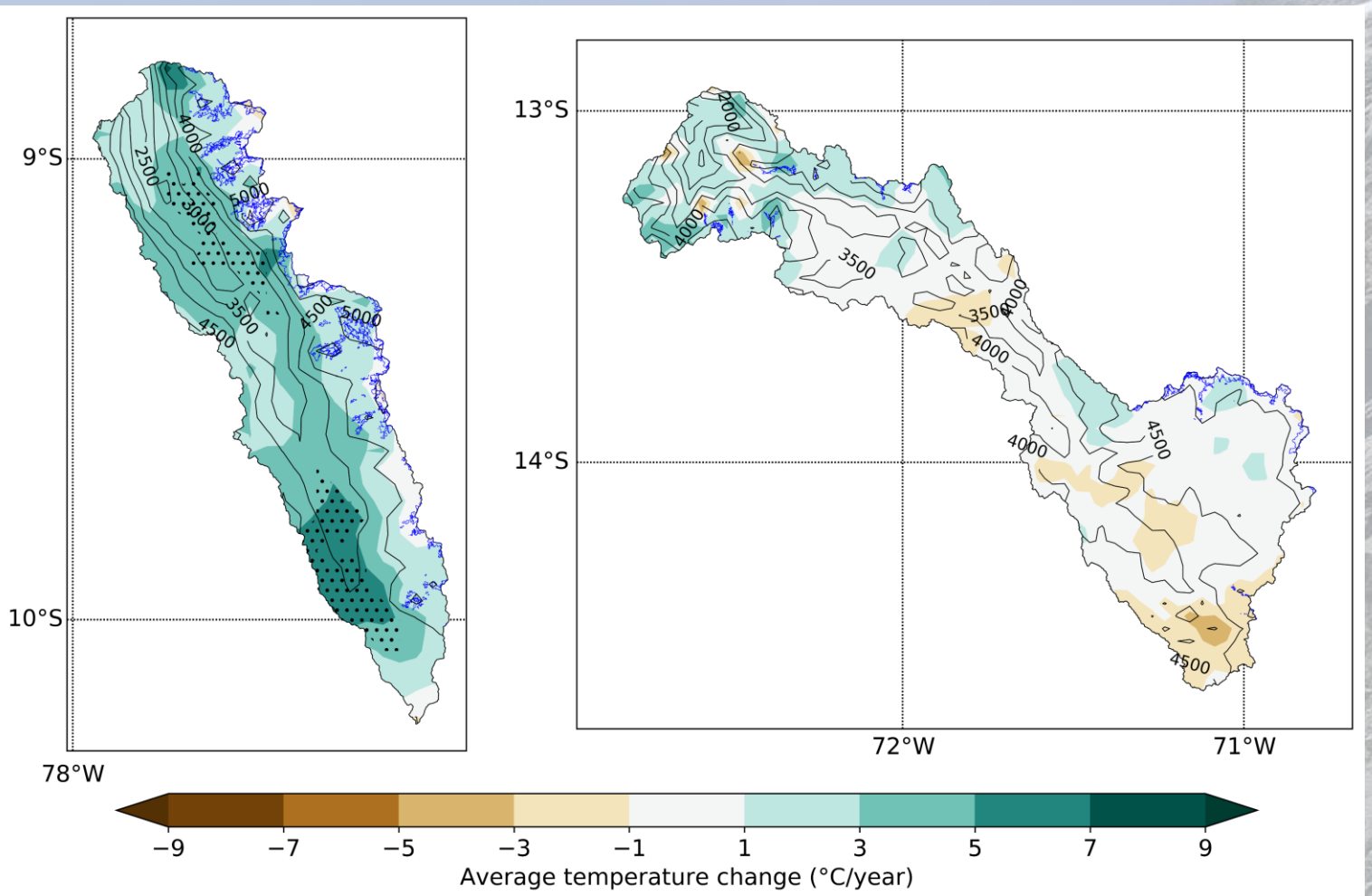

Fig 3: Average yearly trends in precipitation in the Rio Santa (left) and Vilcanota-Urubamba-Vilcabamba (right). The average yearly trends (total yearly preciptiation), are the Theil-Sen slopes. Background contours show the trends, solid black contours show the elevation, blue contours show locations of the glaciers in the two regions, and stippling shows whether the trend is significantly statistically significant ($p<0.05$), according to the Mann-Kendall test for monotonic trends.

Average future trends in temperature

- Both regions show a substantial increase in minimum and maximum daily temperature, under an RCP 8.5 scenario.
- There is a substantial difference between the different CMIP5 models, but all models show a stark increasing temperature trend.

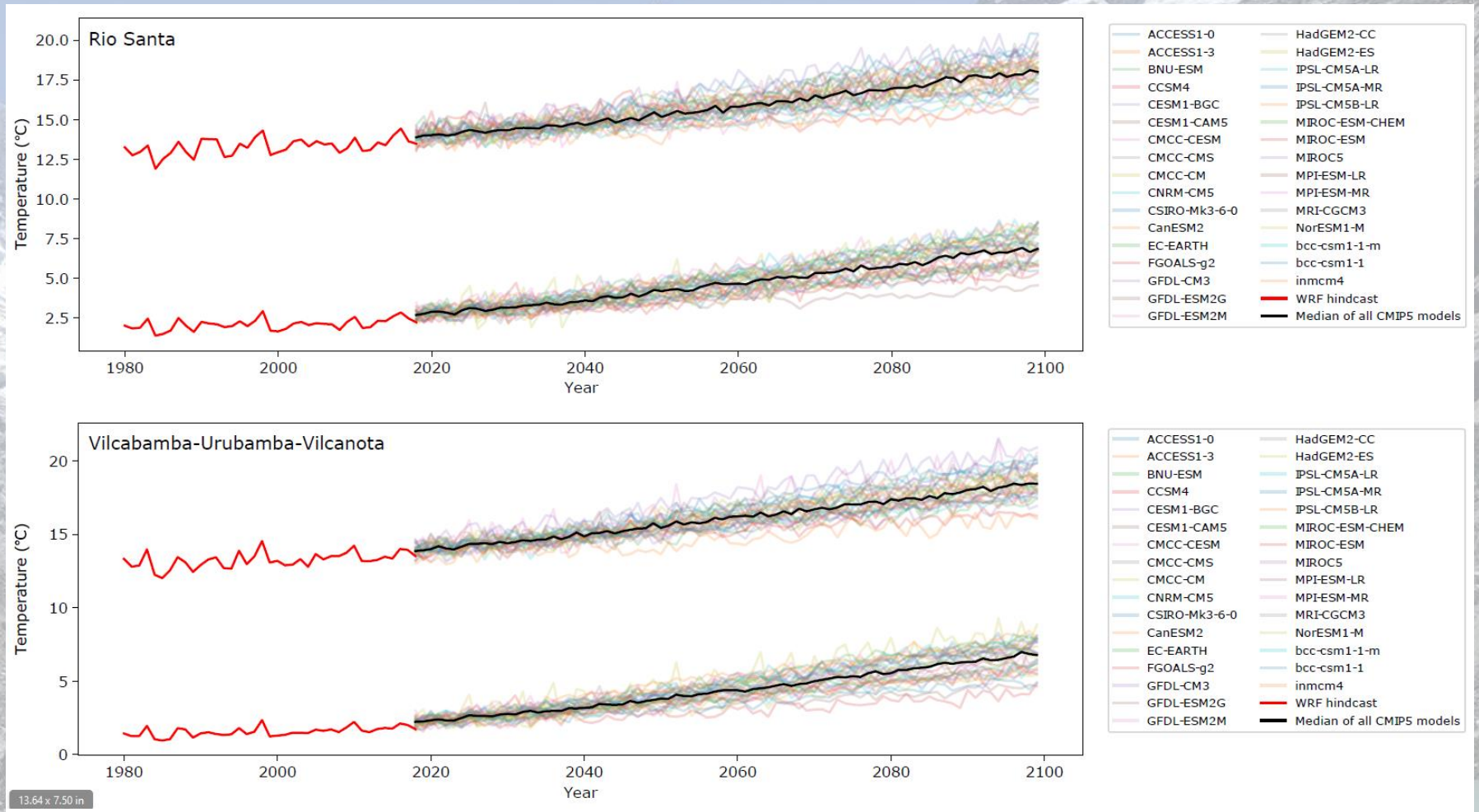

Fig 4: The valley-averaged trends in annual minimum and maximum daily temperature (yearly averaged), over the Rio Santa (top panel) and Vilcabamba-Urubamba-Vilcanota (bottom panel) regions. The red line shows the results from the bias-corrected WRF data, and the thin coloured lines show the projected downscaled CMIP5 models. The black line shows the median of all CMIP5 models.

Average future trends in precipitation

- Overall, the downscaled CMIP5 models suggest an increase in precipitation in both regions.
- There is considerable variation between the CMIP5 models, with only some models showing a statistically significant trend into the future.

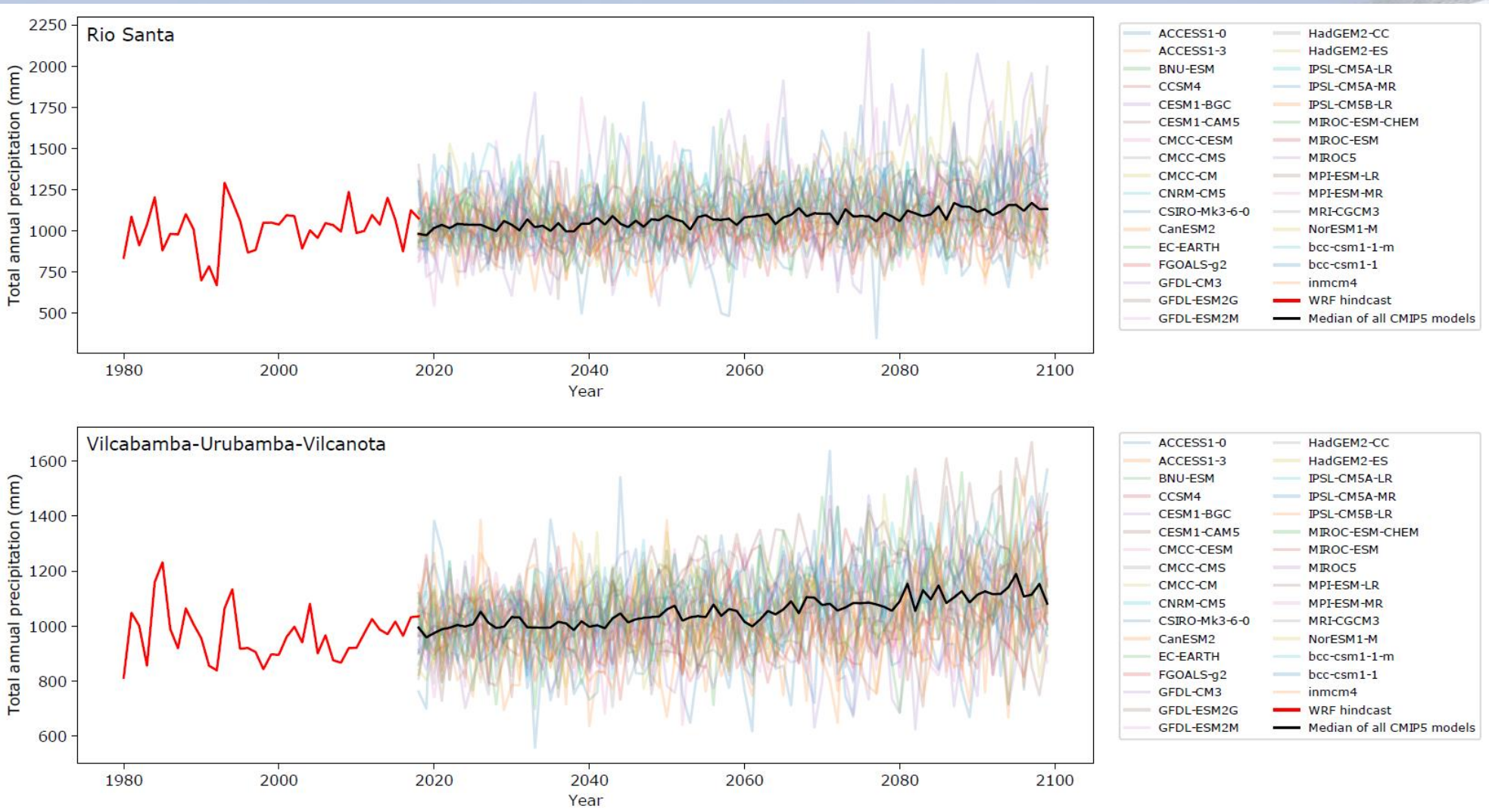

Fig 5: The valley-averaged trends in annual precipitation, over the Rio Santa (top panel) and Vilcabamba-Urubamba-Vilcanota (bottom panel) regions. The red line shows the results from the bias-corrected WRF data, and the thin coloured lines show the projected downscaled CMIP5 models. The black line shows the median of all CMIP5 models.

Changes to future extremes in precipitation

- In both regions, total precipitation falling in the 95th quantile is expected to increase (where the quantiles are taken from the control period, 1980-2018).
- However, there is also an expected increase in the number of continuous dry days (i.e. potential drought periods) in the future.

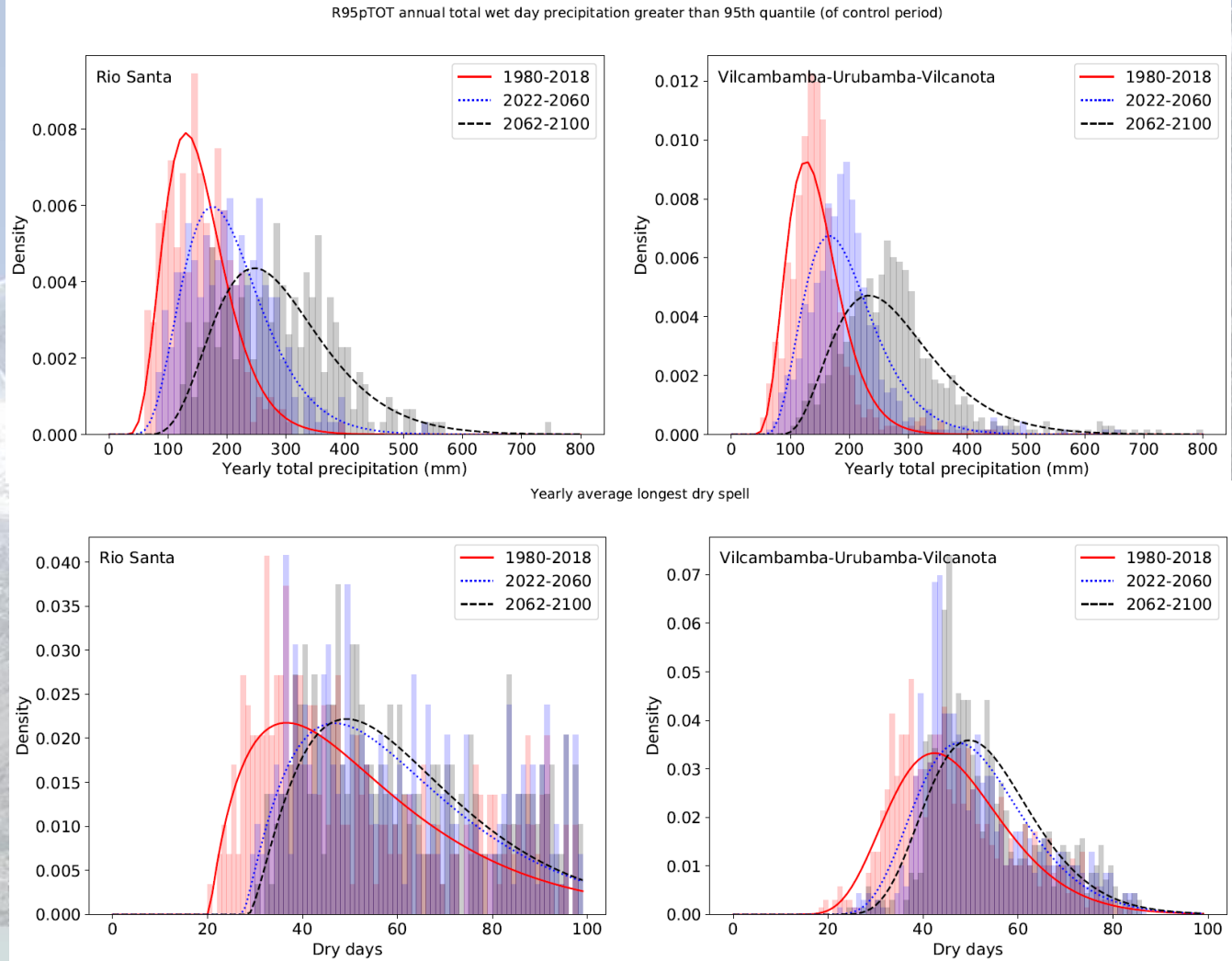

Fig 6: The change in yearly total precipitation falling above the 95th quantile of the control period (1980-2018) (top), and the maximum number of continuous dry days (precipitation under 1 mm/day) (bottom). The control period from the WRF model is shown in red, the near future (2022-2060 average) in blue, and the latter period of the 21st century (2066-2100) shown in black. A gamma distribution has been fitted to each histogram. Note that the CMIP5 data has been averaged between models and over time, and the histogram bars represent spatial variation.

Conclusions

- There has been an increase in temperature in both the upper Rio Santa (inside the Cordillera Blanca), and the Cordillera Vilcanota-Urubamba since 1980.
- The patterns in precipitation are spatially variable, but with some increase in precipitation in the upper Rio Santa over this period.
- In the future, temperature is projected to increase substantially by 2100.
- Precipitation is overall expected to increase a small amount in both regions by 2100.
- Both extreme wet and extreme dry events are projected to increase in the future.

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