Elevation-dependent warming in the tropical and subtropical Andes

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Elevation-dependent warming

- Trends in air temperature exhibit a dependence on the elevation;
- **EDW** does not necessarily imply that warming is larger at higher elevation, and smaller at lower elevation;
- It means that the warming rate (e.g. in °C per decade) is not the same across all elevation bands;
- Many factors and conditions make it very difficult to document the warming rate in mountainous region;
- The majority of studies on EDW points toward an accelerated warming rates with elevation;

Study Areas

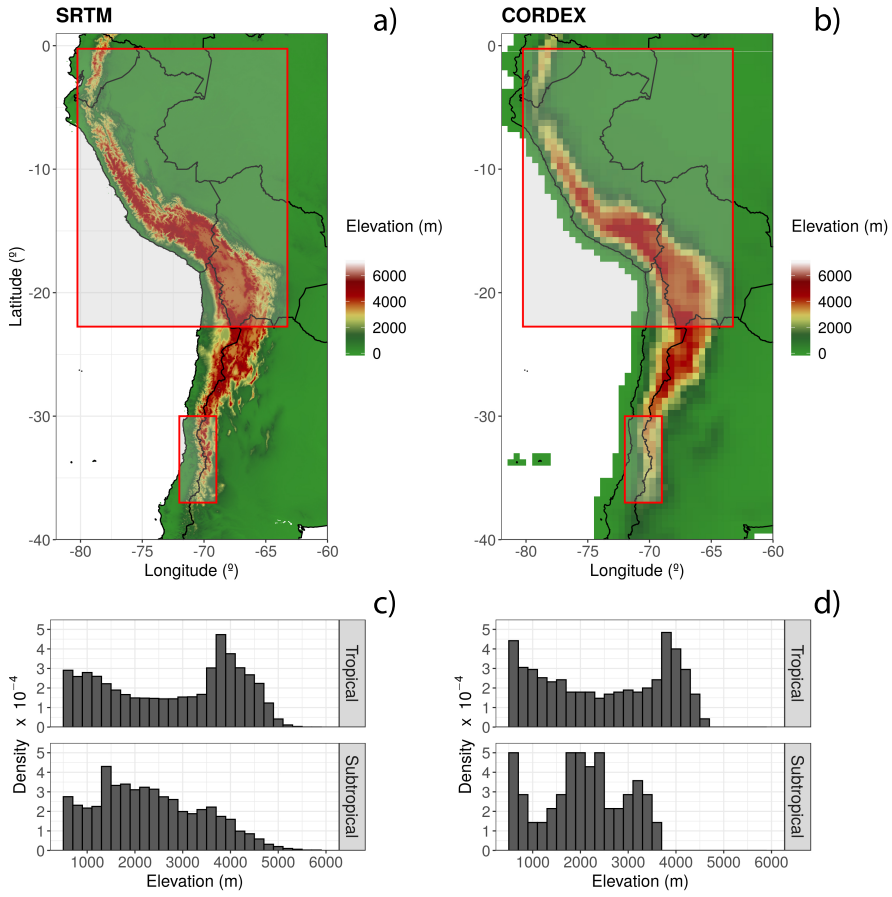

Figure 1: Topographic maps of the two study areas and their location in South America (red box). The left panels refers to NASA Shuttle Radar Topography, while the right panels refers to CORDEX data. Bottom panels (c;d): Fraction of grid cells in each 200m elevational bin across the two study areas.

Methodology

- Data acquisition: Coordinated Regional Climate Downscaling Experiment **(CORDEX)**;
- Domain: South America (SAM);
- Experiment: Historical data **(1976-2005)** and Future projection **(2071-2100)**; **RCP 4.5** and **RCP 8.5** scenarios;
- Time Frequency: **monthly**;
- Variable: Minimum **(tasmin)** and maximum **(tasmax)** surface air temperature;
- Driving model: **Eight different** global climate models;
- RCM Model: Rossby Centre Atmospheric (RCA4);
- Spatial resolution: 0.44 degrees latitude-longitude (approx. 50 km).

Methodology

- Grid cells with elevation above **500 meters**;
- **Difference between** the average in the **historical period** (1976–2005) and the **future projection** (2071–2100);
- **For both variables** (tasmin and tasmax); each **RCM of the model ensemble** as well as for the **multi-model mean**;
- Monthly average, using the standard seasons definition for the **Southern Hemisphere**;
- tasmin and tasmax **were separately analyzed** because they may exhibit different EDW;
- tasmin and tasmax were fitted against elevation using a **linear regression model** to identify EDW;

Methodology

- The dependence of the temperature changes with elevation **may not be linear**;
- EDW pattern might be better represented by different more than a unique slope;
- Local Regression **(LOESS)** Method;
- **Piecewise linear regression** - "Estimates the changes in a time series fitting two altitude segments across a breakpoint";
- **Breakpoint** divides the regression line into two segments characterized by a different slope, according to the piecewise regression analysis.

Methodology

To analyze the mechanisms that may contribute to EDW, we considered the role of the four variables possible drivers of EDW:

- $\Delta albedo$
- $\Delta rlds$
- $\Delta rsds$
- $\Delta huss$

  We also took into account their normalized change (calculated relative to the averaged climatology)
- $\Delta rlds/rlds0$
- $\Delta rsds/rsds0$
- $\Delta huss/huss0$

Results

Identification of Elevation-dependent warming

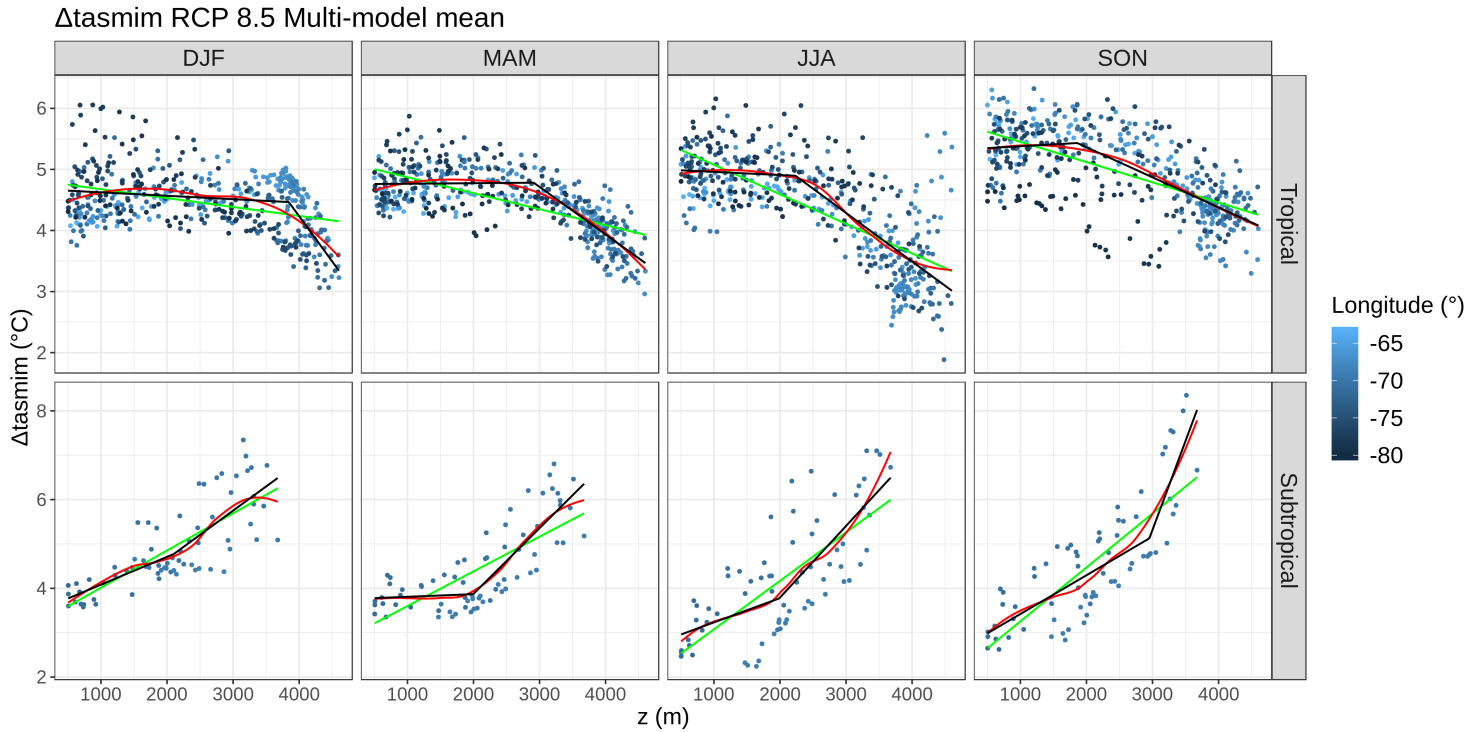

Figure 2: Scatterplots of the seasonal minimum temperature changes versus altitude for the multi model mean in the two study areas for RCP 8.5. The green line represents the simple regression model, the read line represents the LOESS fit and the piecewise regression is shown in black. The minimum temperature changes points are colored according to their longitude.

Results

Identification of Elevation-dependent warming

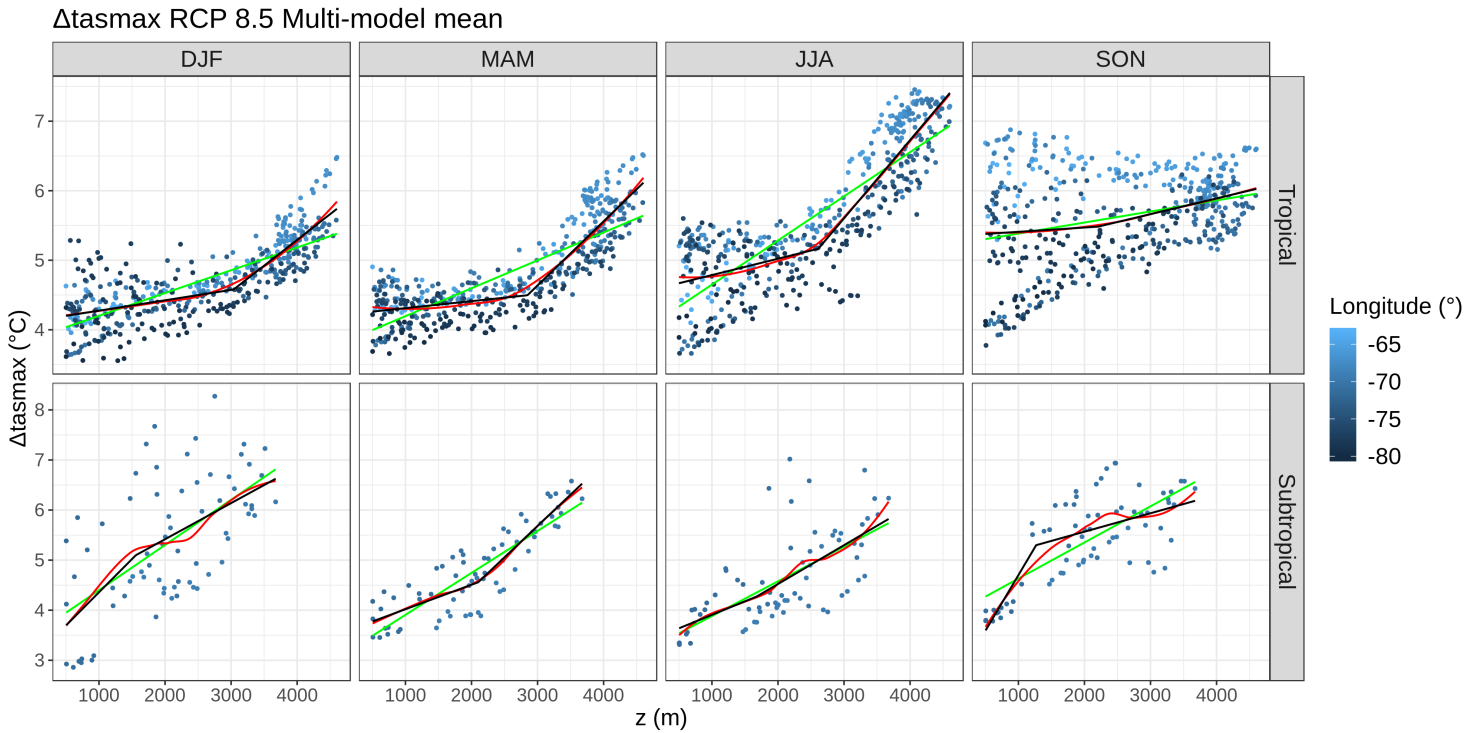

Figure 3: Scatterplots of the seasonal maximum temperature changes versus altitude for the multi model mean in the two study areas for RCP 8.5. The green line represents the simple regression model, the read line represents the LOESS fit and the piecewise regression is shown in black. The maximum temperature changes points are colored according to their longitude

Results

Identification of Elevation-dependent warming

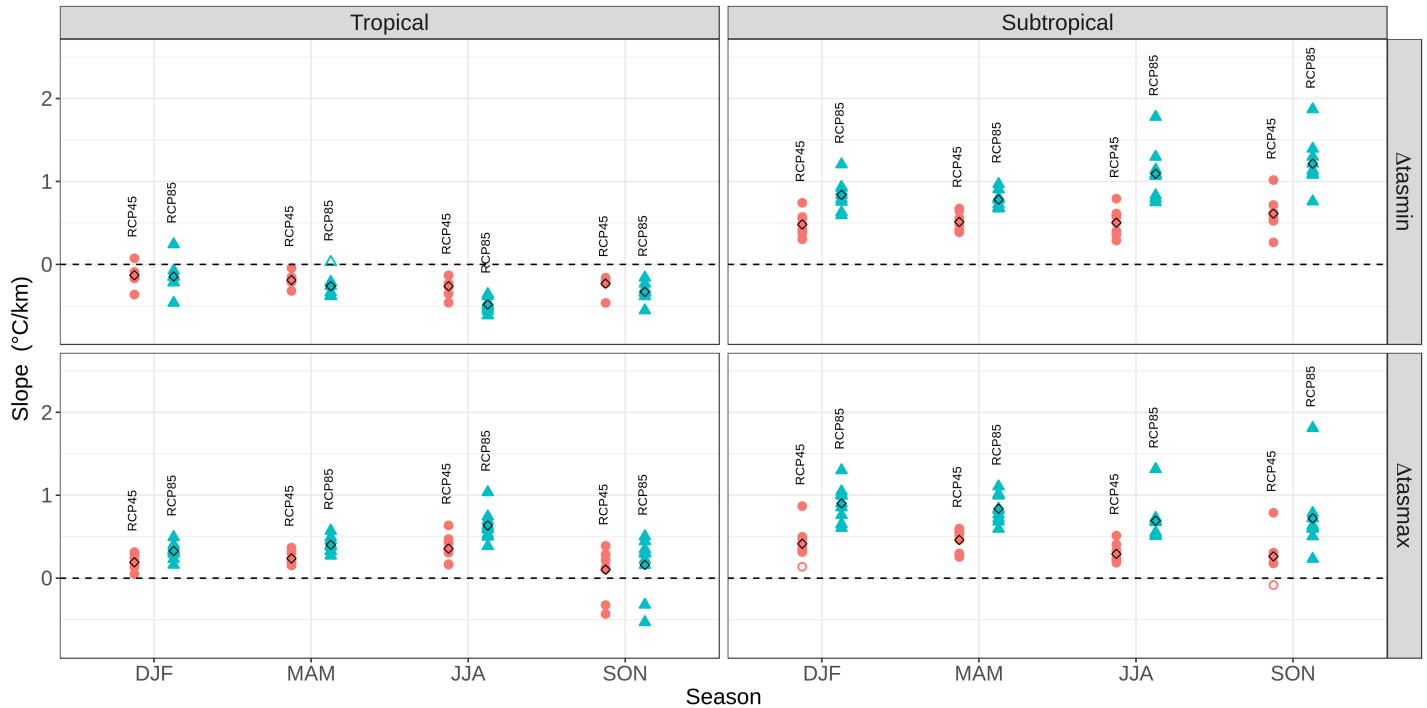

Figure 4: Elevational gradients of the seasonal temperature change in the tropical (left) and subtropical (right) Andes, for each member of the RCM ensemble (colored symbols) and for the multi-model mean (black diamonds). The filled colored symbols represent statistically significant slopes while the open ones are not significant.

Results

Identification of Elevation-dependent warming

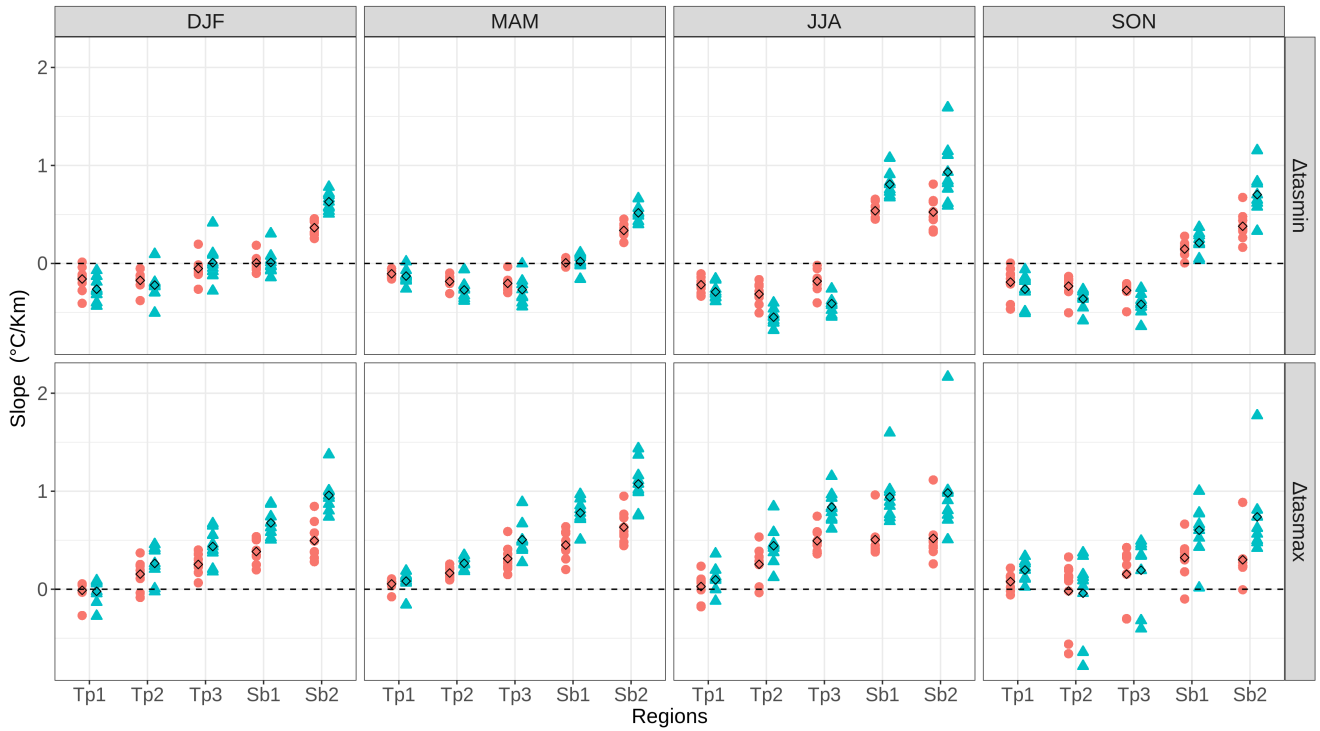

Figure 5: Elevational gradients of the seasonal temperature change in five regions along the Andean cordillera, for each member of the RCM ensemble and the multi-model mean (black open diamond). All open diamonds denote statistically-significant values. Tp1,Tp2,Tp3 represents the tropical and Sb1,Sb2 subtropical Andes.

Results

Analysis of the possible EDW drivers

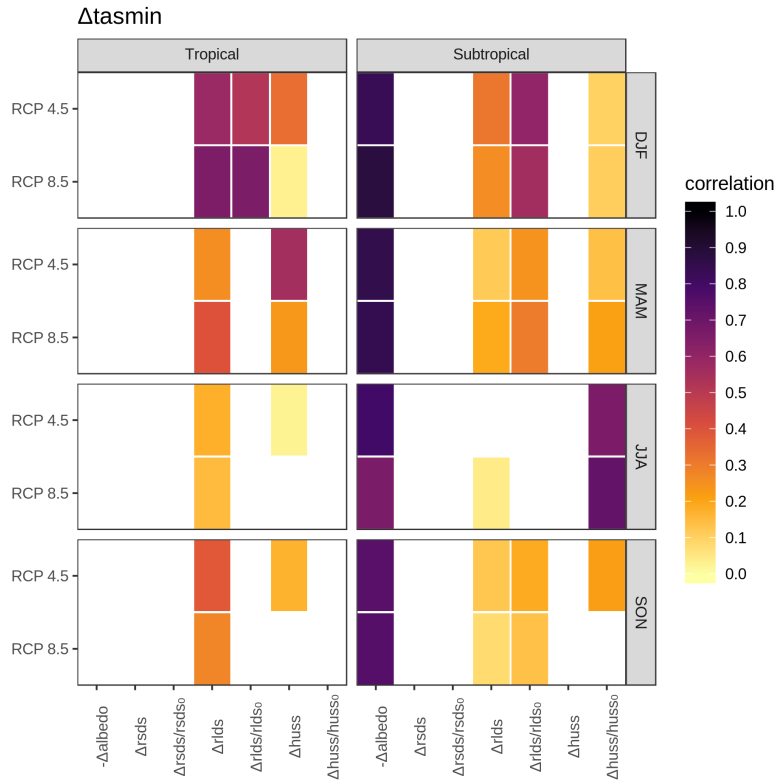

Figure 6: Correlation coefficient between each of the seven possible EDW drivers and the minimum temperature change, for the two RCP scenarios, in the two regions (columns) and four seasons (rows). The drivers are displayed along the x-axis. White boxes identify the cases in which the correlation is negative and/or the elevational dependence of a given driver has not the same sign as EDW

Results

Analysis of the possible EDW drivers

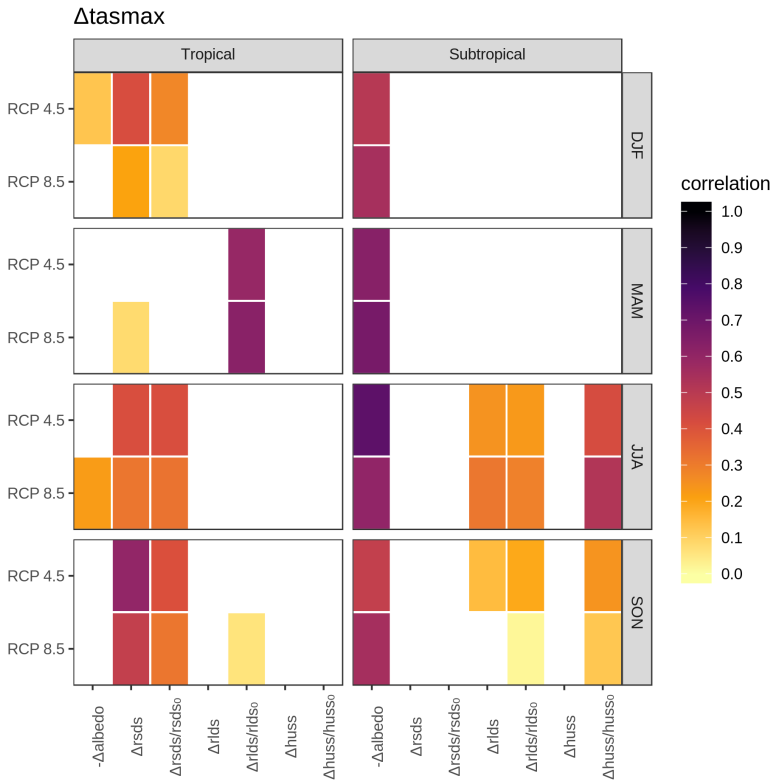

Figure 7: Correlation coefficient between each of the seven possible EDW drivers and the maximum temperature change, for the two RCP scenarios, in the two regions (columns) and four seasons (rows). The drivers are displayed along the x-axis. White boxes identify the cases in which the correlation is negative and/or the elevational dependence of a given driver has not the same sign as EDW.

Conclusions

- An opposite EDW signal in the tasmax and in the tasmin was identified in the tropical Andes;
- In the Tropics, no common driver was found for EDW in the tasmin and in the tasmax;
- For the tasmax, the changes in shortwave radiation are the main EDW driver while those in longwave radiation and specific humidity are found to trigger the tasmin changes;
- Changes in albedo are the main driving mechanism for EDW in the Subtropical Andes, for both variables

THANK YOU

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