Elevation-dependent warming in the tropical and subtropical Andes with CORDEX models

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AIMS

Evaluate future projections of Elevation Dependent Warming (EDW) in the tropical and subtropical Andes in the RCP8.5 scenario of CORDEX data:

Assessment of the EDW signal in the Andes, identifying its dependence on latitude (tropics vs subtropics), season, and side (Pacific vs Atlantic) of the Andean Cordillera;

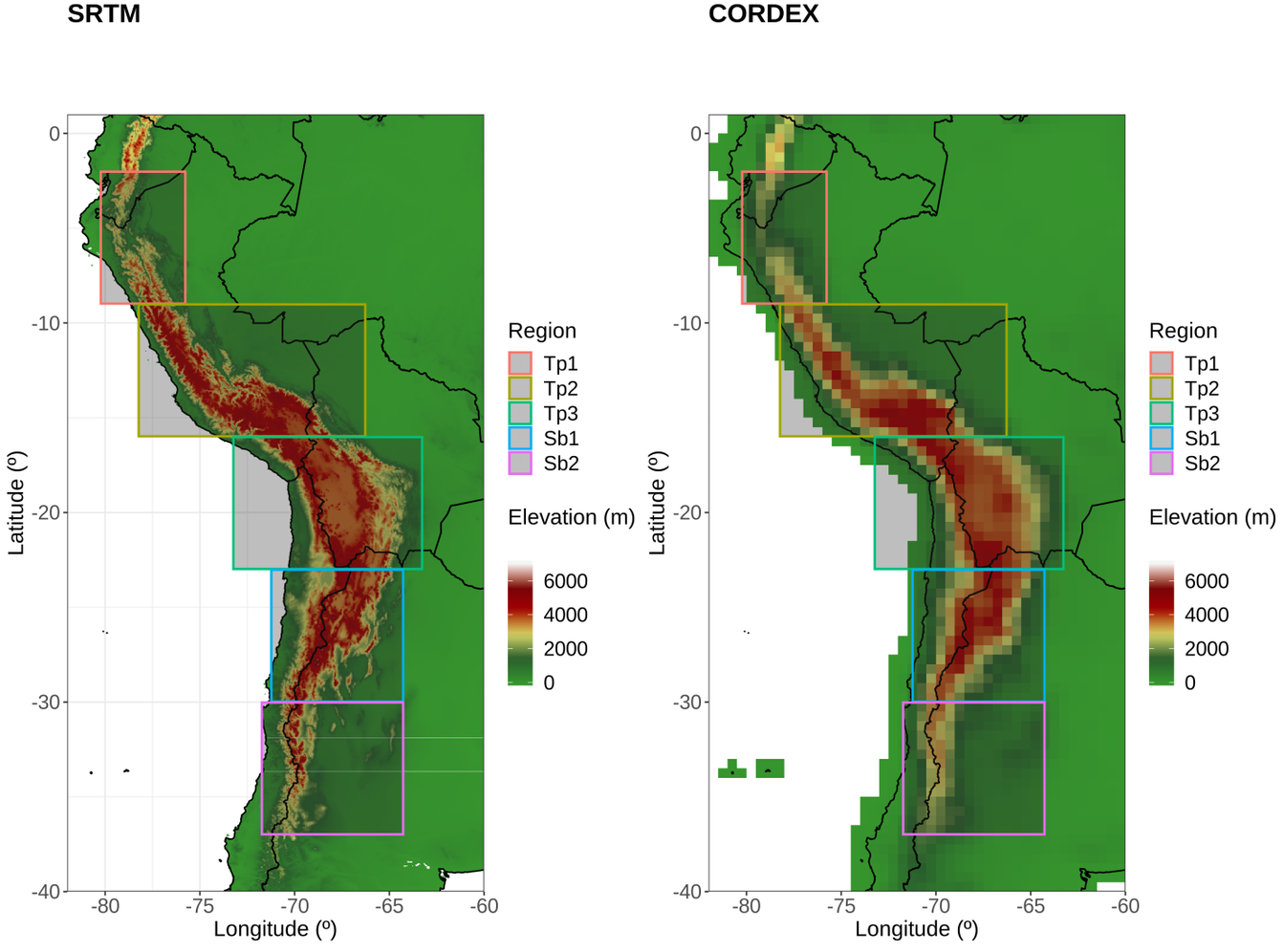
Analyse the role of the possible EDW driving mechanisms (change in albedo, long-wave radiation, shortwave radiation, humidity) and related feedbacks.

Toledo, O., Palazzi, E., Cely Toro, I.M., Mortarini L. Comparison of elevation-dependent warming and its drivers in the tropical and subtropical Andes. Clim Dyn (2021). https://doi.org/10.1007/s00382-021-06081-4

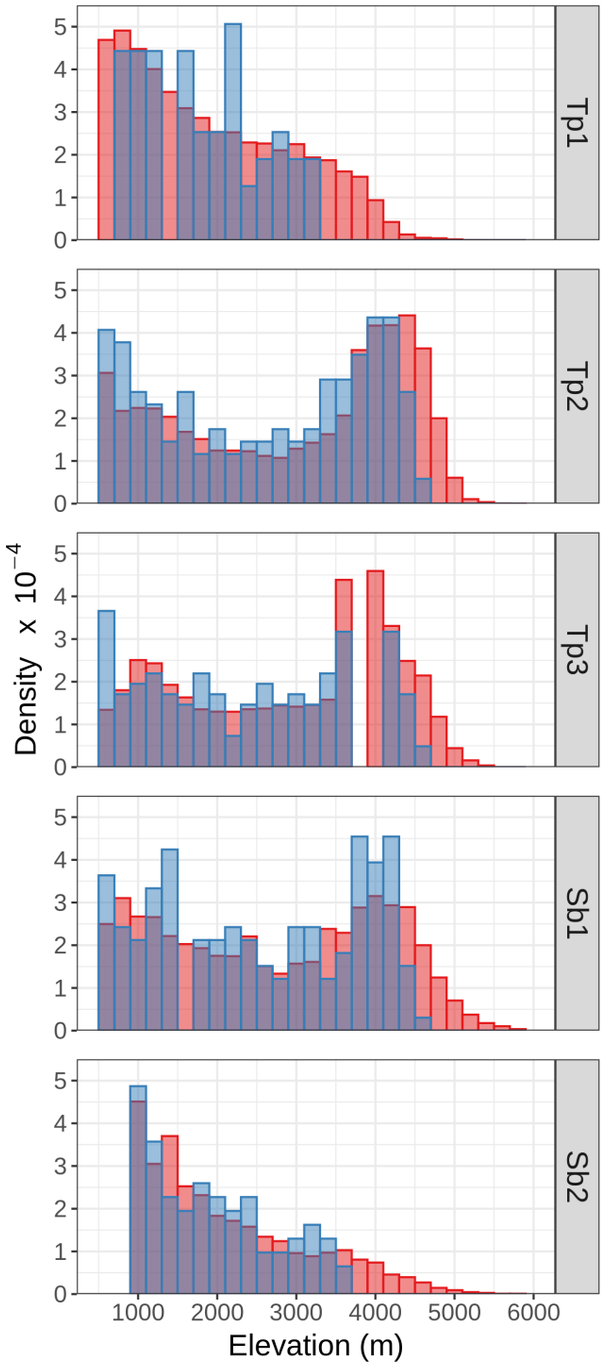
CORDEX Dataset and study areas

GCMs driving RCA4 RCM

GCM name	Institution	Resolution lon x lat°Lev	Key reference
CanESM2	CCCMA	2.8125 × 2.8125L35	Arora et al. (2011)
CSIRO-Mk3-6-0	CSIRO-QCCCE	1.875 × 1.875L18 (T63)	Rotstayn et al. (2012)
EC-Earth	EC-EARTH	1.125 × 1.125L62 (T159)	Hazeleger et al. (2012)
CM5A-MR	IPSL	1.25 × 2.5L39	Dufresne et al. (2013)
MIROC5	MIROC	1.40625 × 1.40625L40 (T85)	Watanabe et al. (2010)
HadGEM2-ES	MOHC	1.25 × 1.875L38 (N96)	Bellouin et al. (2011)
MPI-ESM-LR	MPI-M	1.875 × 1.875L47 (T63)	Giorgetta et al. (2013)
GFDL-ESM2M	GFDL	2.5 × 2L24(M45)	Delworth et al. (2006)



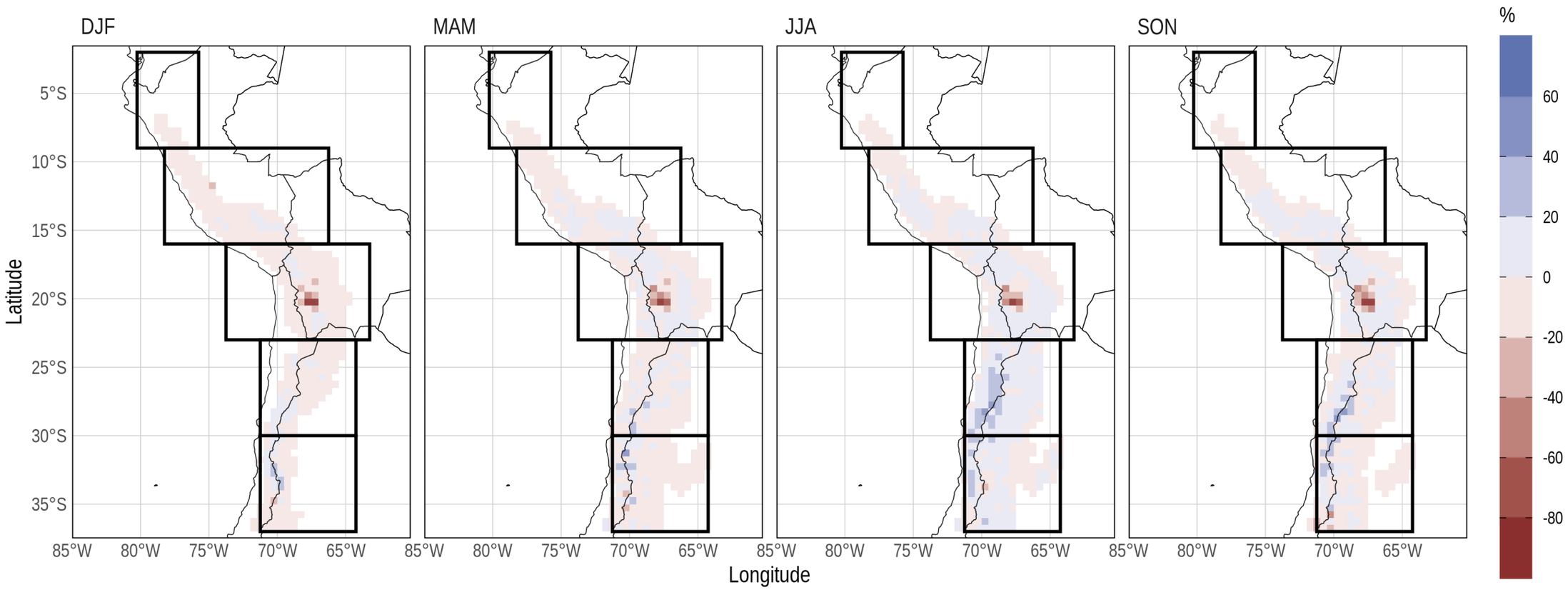
(a) (b)



(c)

orography comparison

CORDEX - MODIS snow cover comparison



anomaly CORDEX MMM - MODIS, 2000 - 2020

In the subtropical areas, along the Chile-Argentina border, the largest differences between the model mean and the satellite data are observed (JJA and SON) → CORDEX > MODIS

In the tropical areas data show a particularly good agreement. Except in a very defined area where CORDEX clearly underestimates the satellite data.

EDW IDENTIFICATION

Both Δtasmin and Δtasmax were fitted against elevation using a linear regression model:

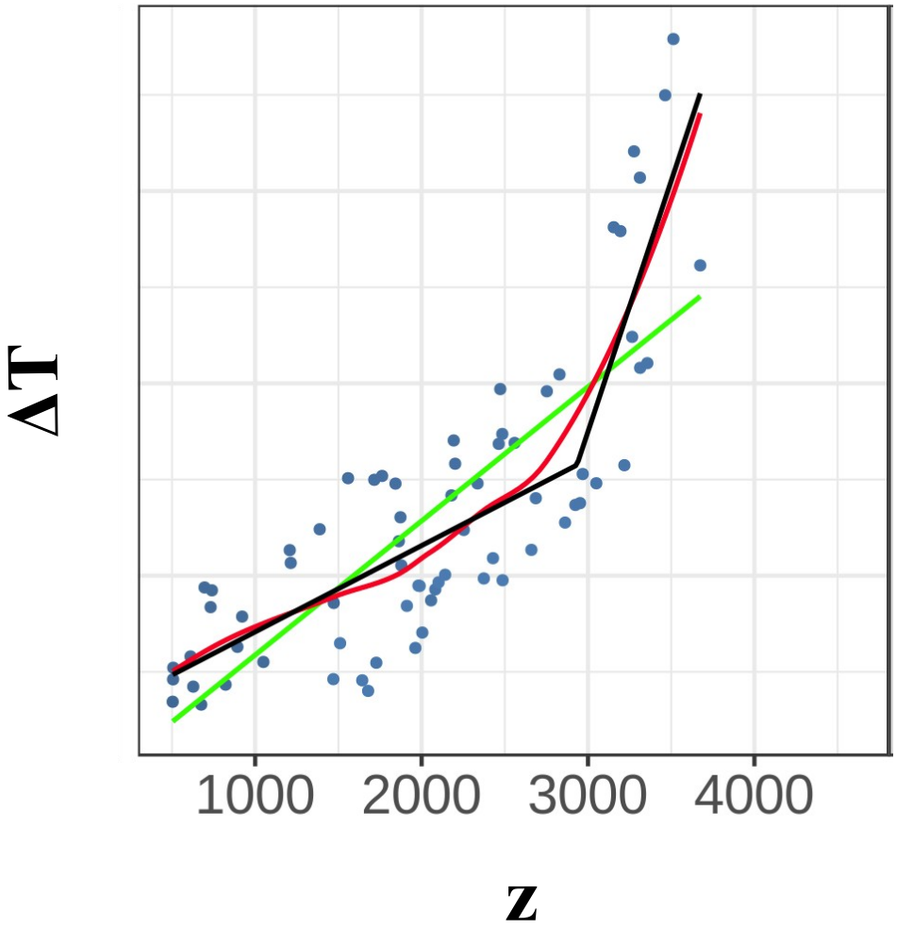
– Positive slope $\left(\frac{d\Delta T}{dz} > 0\right)$ identifies a positive EDW

– Negative Slope $\left(\frac{d\Delta T}{dz} < 0\right)$ identifies a negative EDW

The dependence of the temperature changes with elevation may not be linear and EDW pattern might be better represented by more than a unique slope:

Local Regression (LOESS) Method

Piecewise linear regression

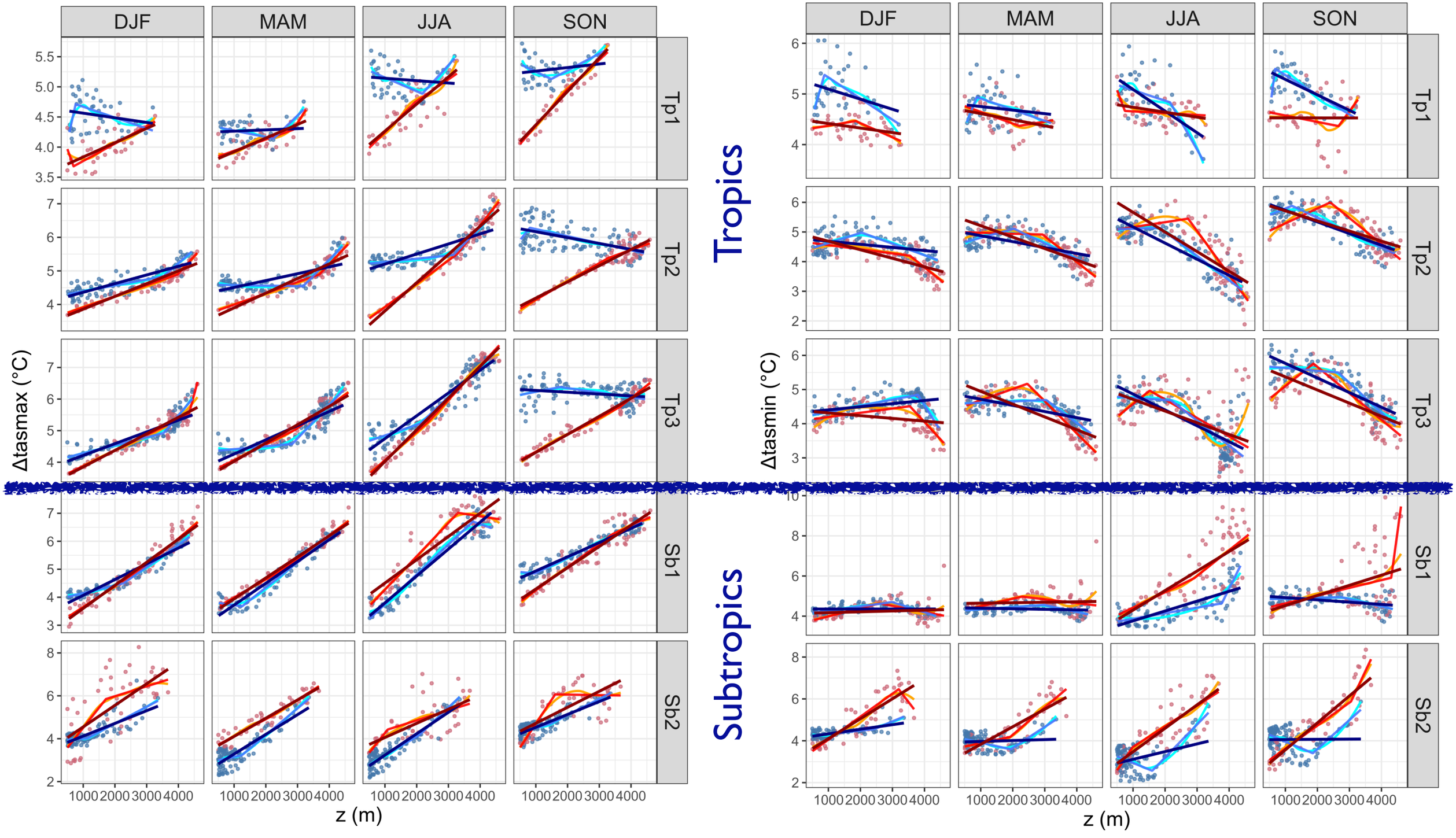


EDW IDENTIFICATION

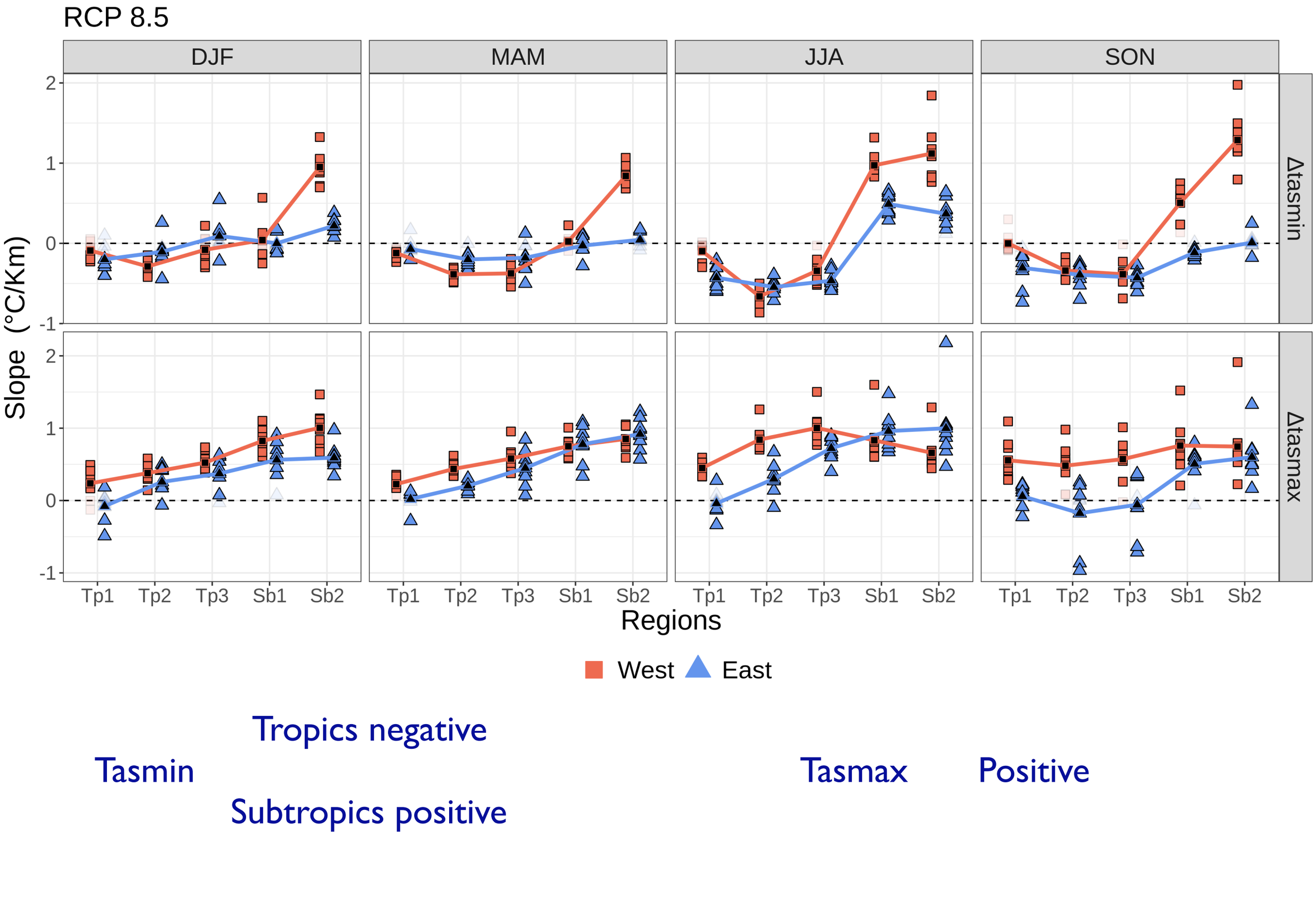
East
West

Δtasmax RCP 8.5 Multi-model mean

Δtasmin RCP 8.5 Multi-model mean



EDW ASSESMENT



Tropics negative

Tasmin

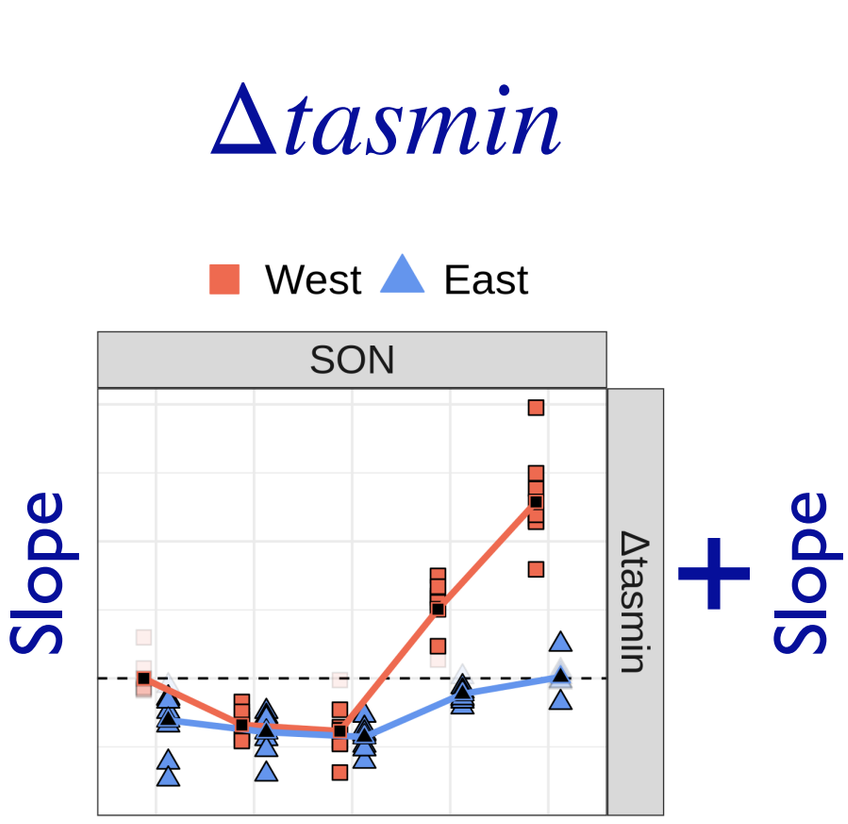
Subtropics positive

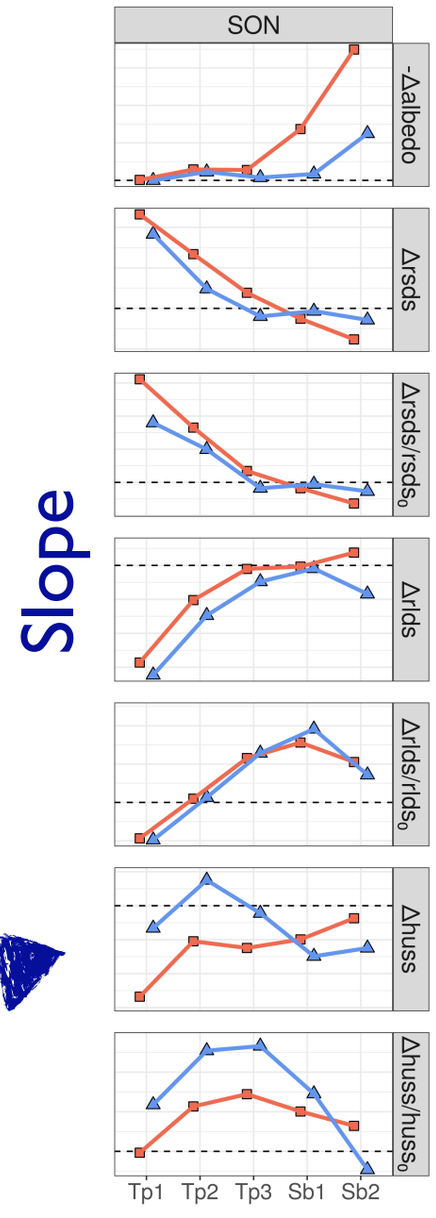
Tasmax Positive

Drivers

– $\Delta albedo$, $\Delta rlds$, $\Delta rsds$, $\Delta huss$ are identified as possible EDW drivers if:

i) They exhibit a dependence on elevation that is physically consistent with EDW
ii) They are positively spatially correlated with the temperature changes when their dependence on the elevation is removed.





Correlation between detrended temperature change and detrended driver

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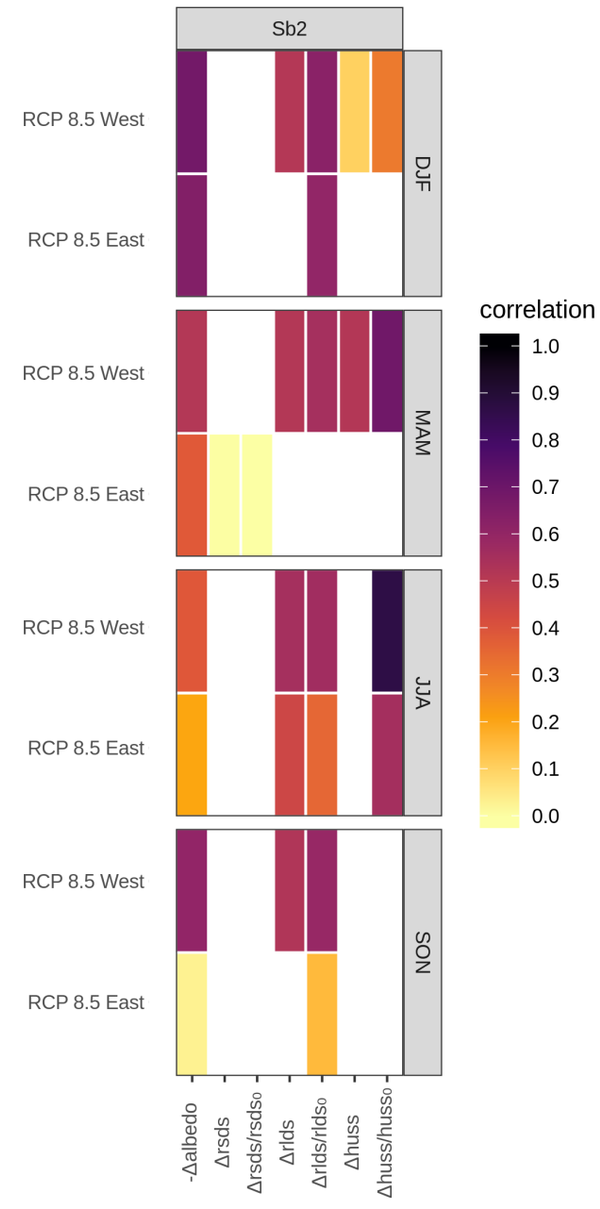
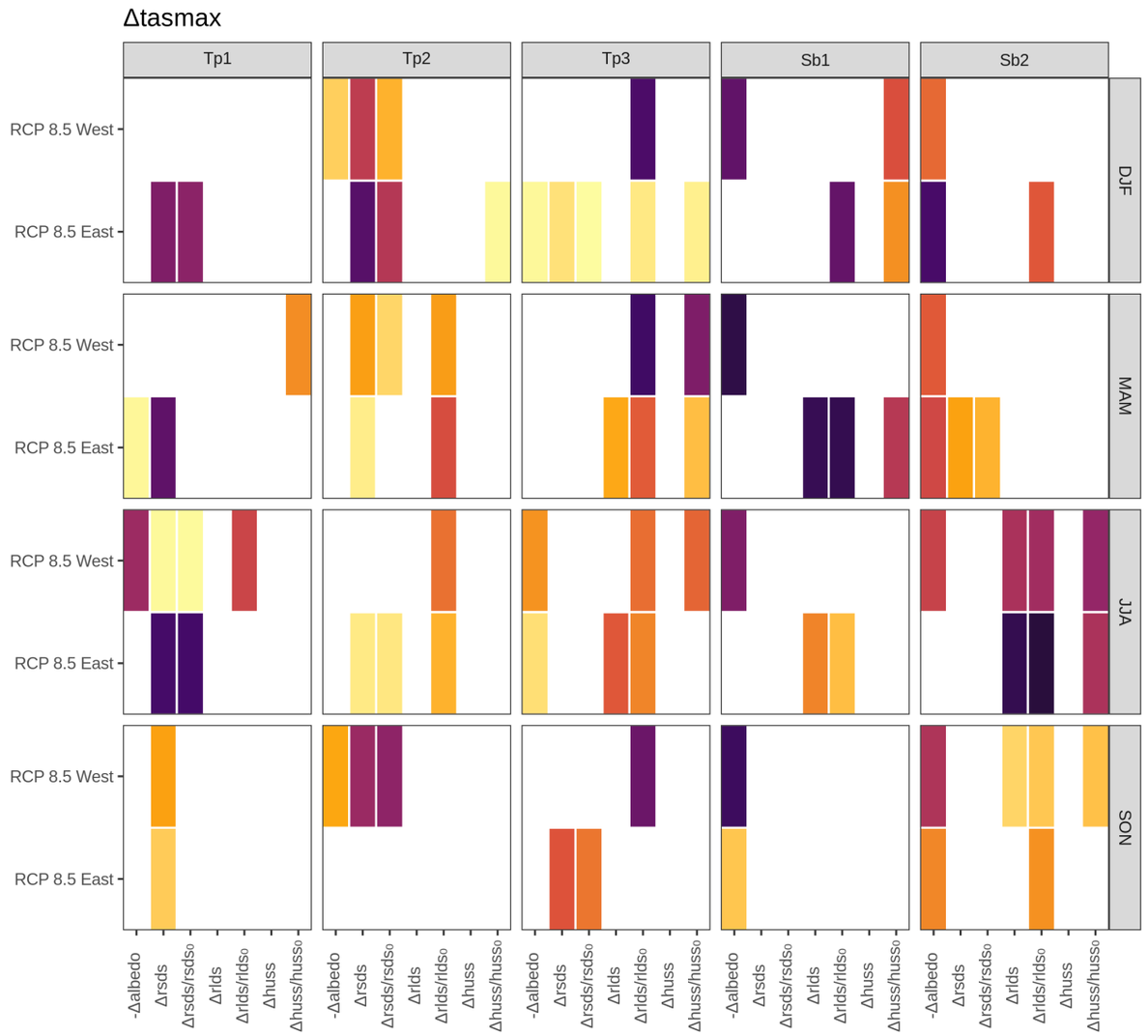
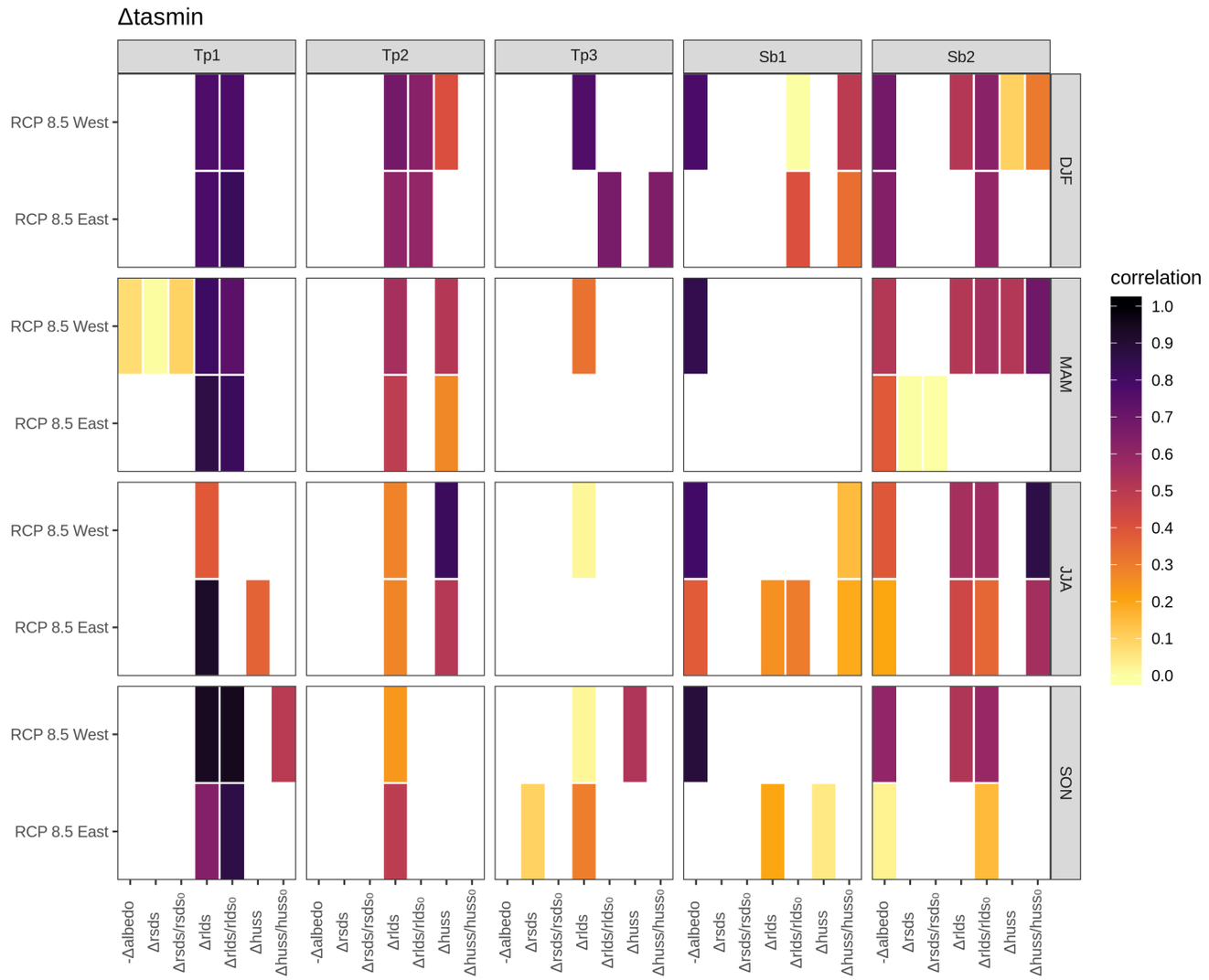


Drivers


Δtasmax
Tp1
Tp2
Tp3
Sb1
Sb2
DJF
MAM
JJA
SON
RCP 8.5 West
RCP 8.5 East
-Δalbedo
Δrsds
Δrsds/rsds0
Δrlds
Δrlds/rlds0
Δhuss
Δhuss/huss0


Δtasmin
Tp1
Tp2
Tp3
Sb1
Sb2
DJF
MAM
JJA
SON
RCP 8.5 West
RCP 8.5 East
-Δalbedo
Δrsds
Δrsds/rsds0
Δrlds
Δrlds/rlds0
Δhuss
Δhuss/huss0
correlation
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

Conclusions

EDW assessment

- **Tropics**: Opposite EDW signal in tasmax (positive) and in tasmin (negative) was identified in the tropics;
- **Subtropics**: Positive EDW signal in both tasmax and tasmin, which presents with larger values in the western side of the Cordillera

EDW drivers

- **Tropics**: $d\Delta tasmax/dz$ driven by changes in downward shortwave radiation, $d\Delta tasmin/dz$ driven by changes in downward longwave radiation and in specific humidity
- **Subtropics**: change in albedo is an ubiquitous driver for both tasmin and tasmax. Longwave radiation and humidity are also significantly correlated to EDW, but with different relevance throughout the seasons and the sides of the Andes