Comparison of isotopic signatures in speleothem records and model simulations for the past millennium

Janica Bühler[1], Kira Rehfeld[1], and Carla Roesch[1]

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Abstract

Global changes in climate not only affect its mean, but also its variability, which mainly impacts society. For better projections of future climate changes it is crucial to improve the understanding of changes in both the mean, the variability and their relationship. Model-Data comparison between climate simulations and speleothem paleoclimate archives can test and validate the capability of different general circulation models (GCMs) to simulate changes in variability. However, the d18O values measured in climate archives don't directly represent temperature or precipitation but result from multivariate, non-linear processes on top of the dominant atmospheric controls on precipitation d18O. We aim to assess a model's capability to simulate climate variability on timescales longer than those observable. Our strategy combines a Proxy System Model (PSM) for the relevant processes with isotope-enabled GCMs. We focus on speleothems, as they are precisely date-able and provide well preserved (semi-)continuous climate signals in the lower and mid-latitudes. We evaluate trends, correlations between different records and power spectral densities across a speleothem database, focusing on the past millennium. We compare proxy results to those obtained by forward models based on isotope-enabled HadCM3 simulations and PSM approaches of increasing complexity. We evaluate the sensitivity of results to parameter choices, and test options to constrain them. We find that some parameters, e.g. transit times of water from the surface to the speleothem's cave, strongly influences the slope of the spectra in the PSM. Based on the ample proxy and model evidence for the past 1000ys, we test for realistic parameter ranges and the sufficient complexity of speleothem PSM for global application. Given a successful application on this more recent period we envisage application on longer, millennial to orbital timescales, to provide estimates of low-latitude changes in climate variability.

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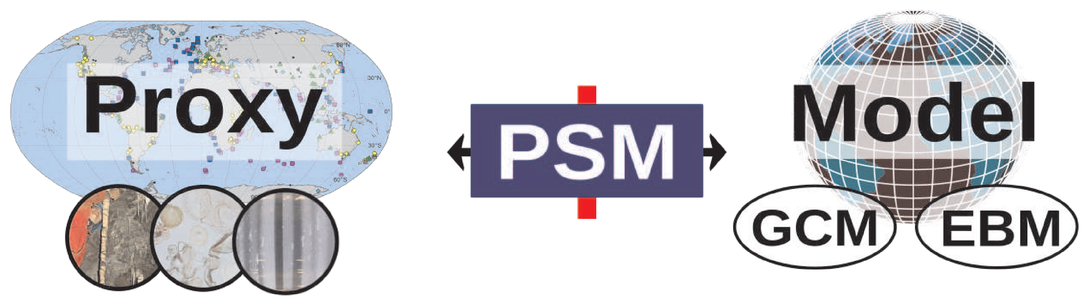
1 Motivation

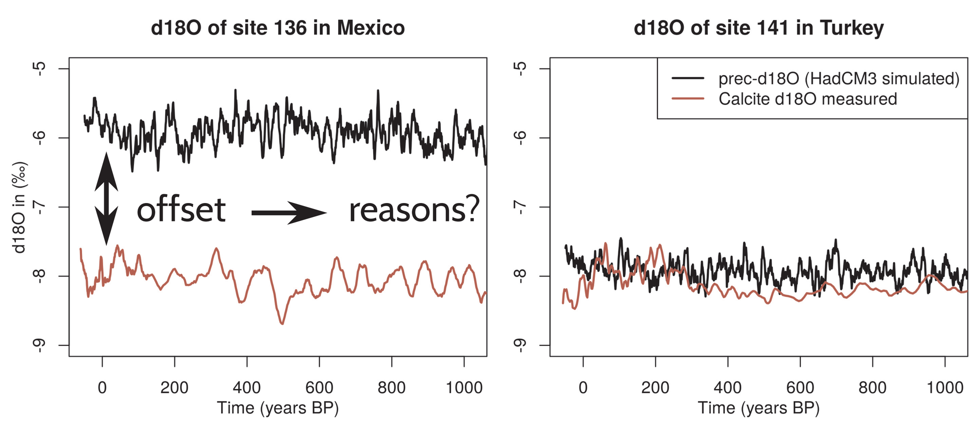
Global changes in climate not only affect its mean, but also its variability[1], and thus living conditions on Earth. Model-data comparison between climate simulations and paleoclimate archives can test and validate the capability of general circulation models (GCMs) to simulate changes in variability.

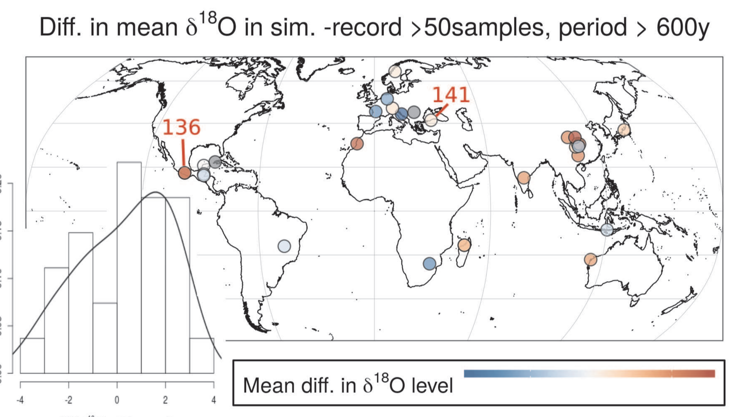
However, the precisely dateable and well preserved (semi-)continuous $\delta^{18}O$ signal in speleothem calcite[2] doesn't directly represent the local $\delta^{18}O$ composition of precipitation. We compare modeled changes in $\delta^{18}O$ over the last millennium in mean (2) and correlations (3, 5) with the aim to assess the isotope-enabled model's[3,4] capability to simulate climate variability beyond the instrumental period.



(A) Schematic of a PSM interacting between different types of both models and proxies

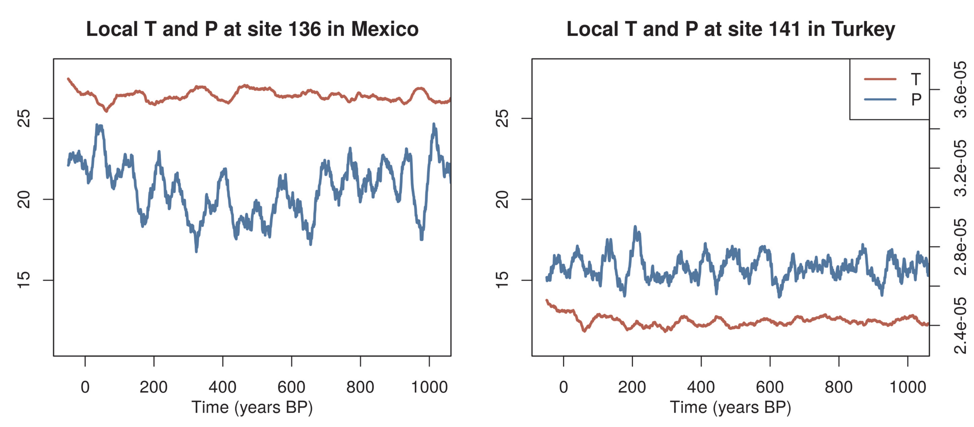
2 Example: Two Caves



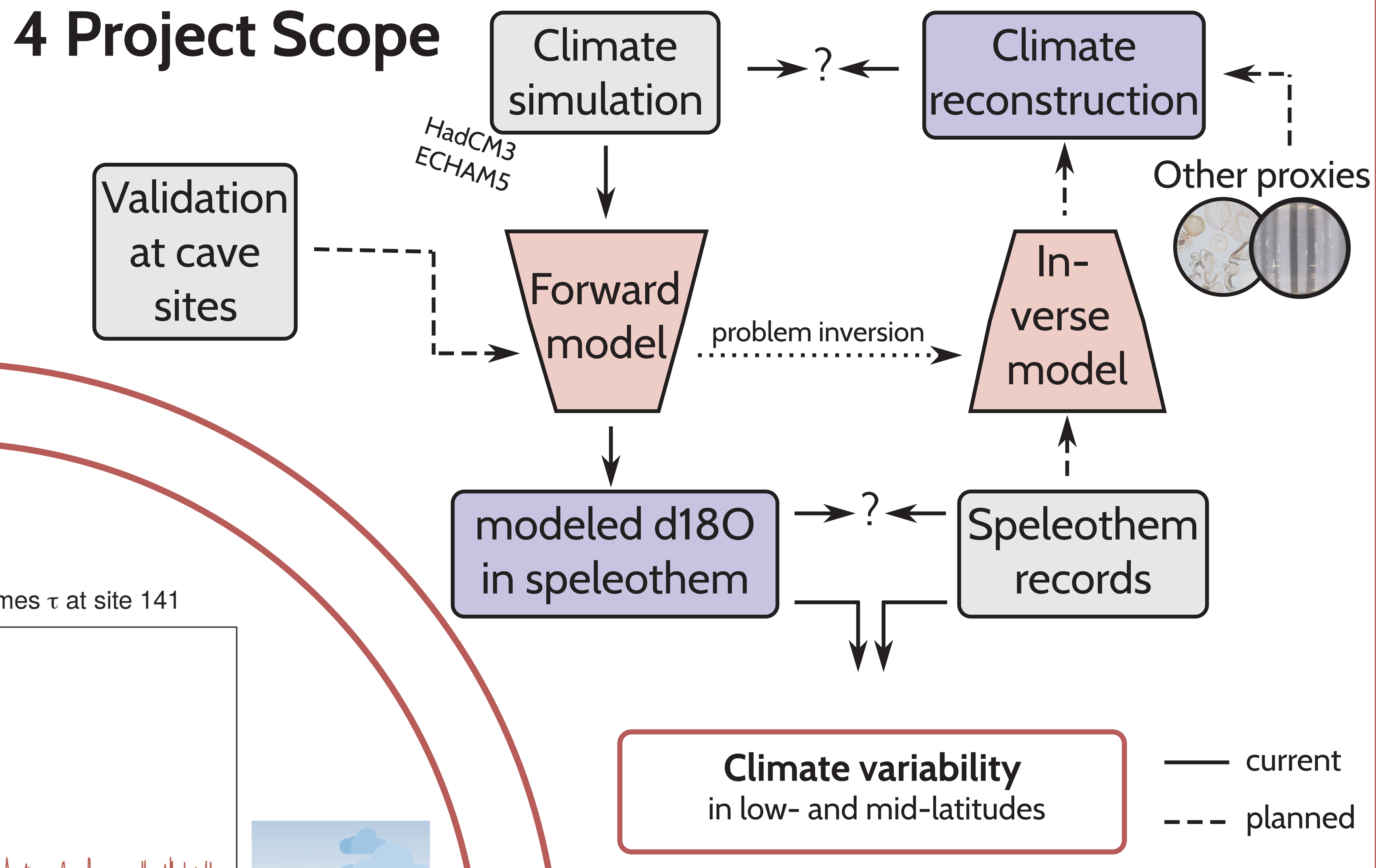


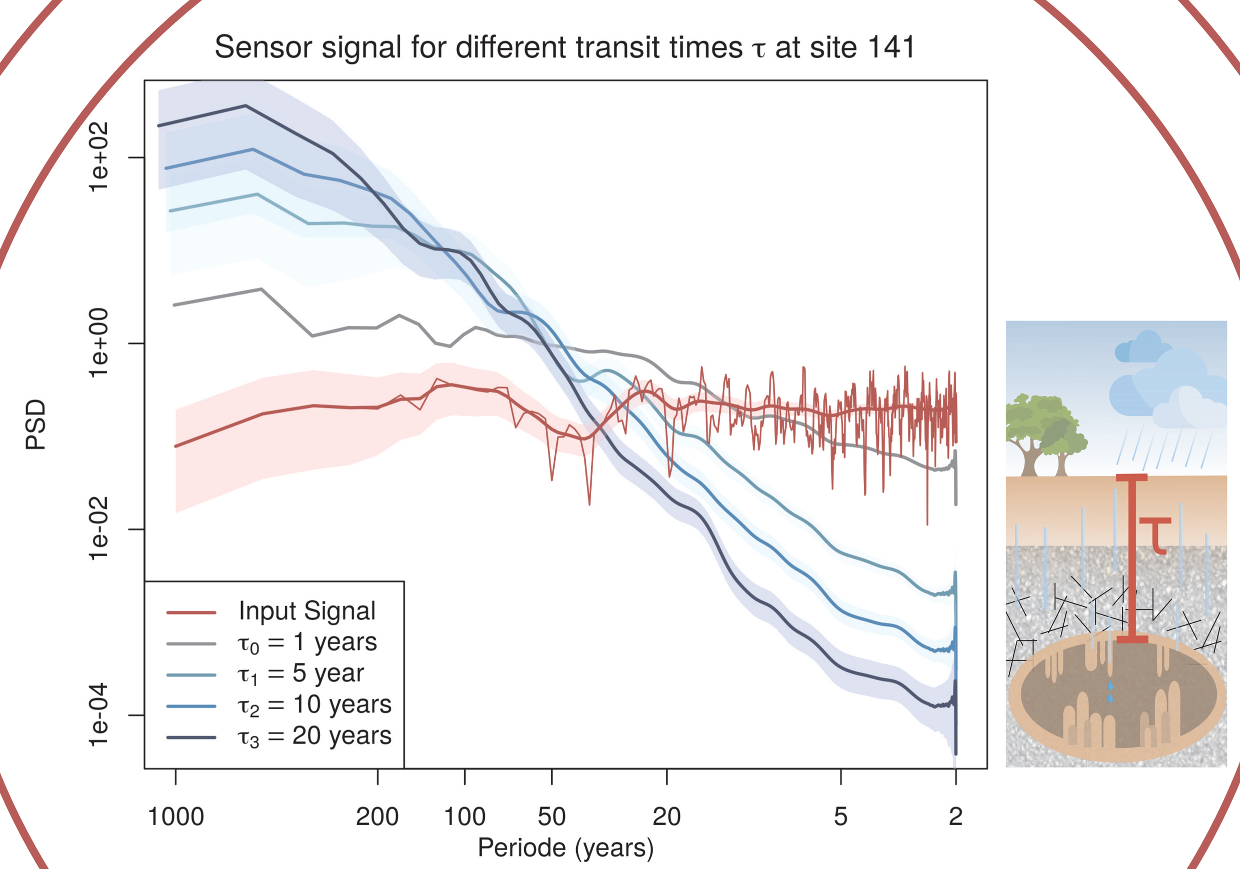
(B) Site locations[5,6] w/ mean diff. of $\delta^{18}O$ over last 1ky

Calcite $\delta^{18}O$ can be influenced by both local precipitation (P) and temperature (T) but also other factors (e.g. evapo-transpiration, parent rock, vegetation) play a role.



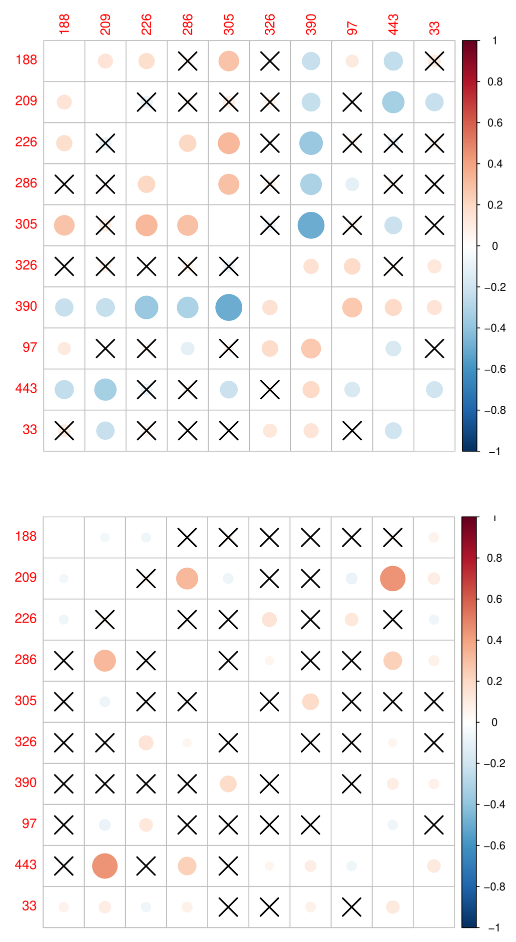
4 Project Scope





(E) PSM filter characteristics: transit time τ strongly influences the variability of the signal on different time scales[7,8].

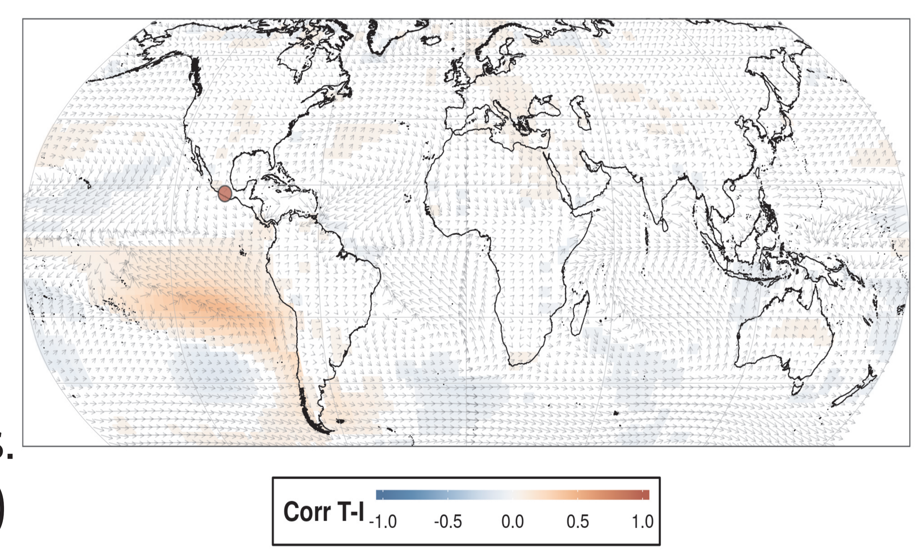
3 Correlation Analysis



Correlation patterns of records from SISAL database[5,6] (top) differ from those of simulated P-$\delta^{18}O$ from HadCM3[3,4] (bottom).

(C) Cross-correlation table of selected entities. 'X' = insignificant (p>0.1)

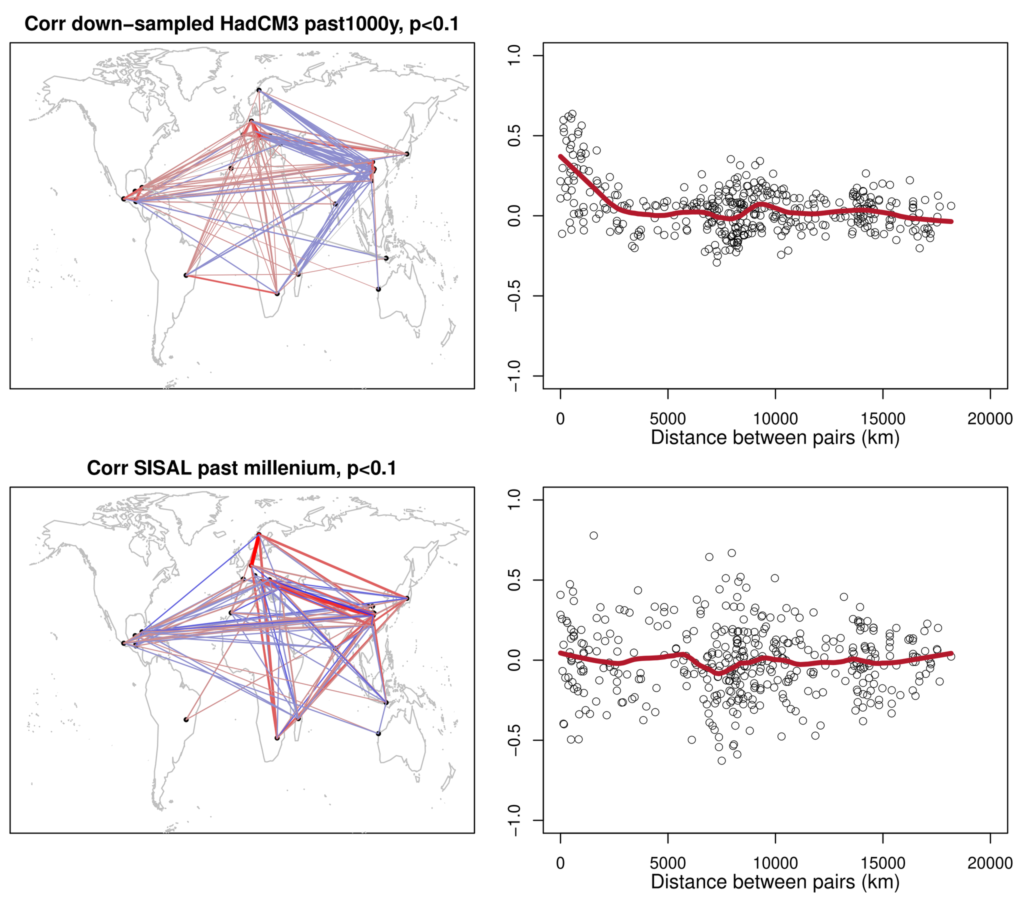
(D) Point corr.-map for example cave site 136 (2) T w/ local isot.-comp. including wind, p<0.1



More Plots!

5 Network Analysis

(F) Cross-corr. btw caves for last 1000y. Sim. down-sampled to res. of records.



Network (left) and correlation decay over distance (right) for HadCM3 (top) and SISAL cores (bottom).

6 Outlook

- Compare $\delta^{18}O$ gained from forward model to $\delta^{18}O$ from record by correlation, trend, spectral analysis
- Include other past millenium simulations for model-data comparison
- Cave site validation and forward model optimization

7 Acknowledgements

PAGES PAST GLOBAL CHANGES
JGU JOHANNES GUTENBERG UNIVERSITÄT MAINZ
HGSFP
SISAL
Emmy Noether-Programm
DFG Deutsche Forschungsgemeinschaft

Collaborations welcome!

8 References

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[5] Atsawawaranunt, K. et al, ESSD 10, 1687-1713, (2018)
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[7] Dee, S. et al., J Adv Model Earth Sy 7, 1220-1247 (2015)
[8] Wackerbarth, A. et al., Earth Planet Sc Lett 299. 387-397 (2010)

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STACY

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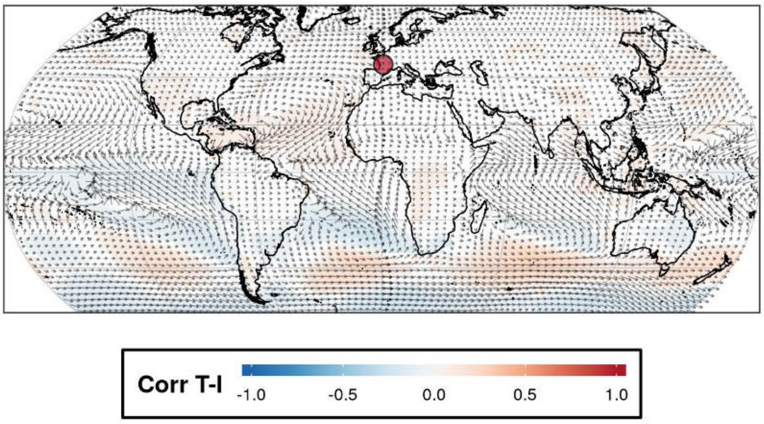

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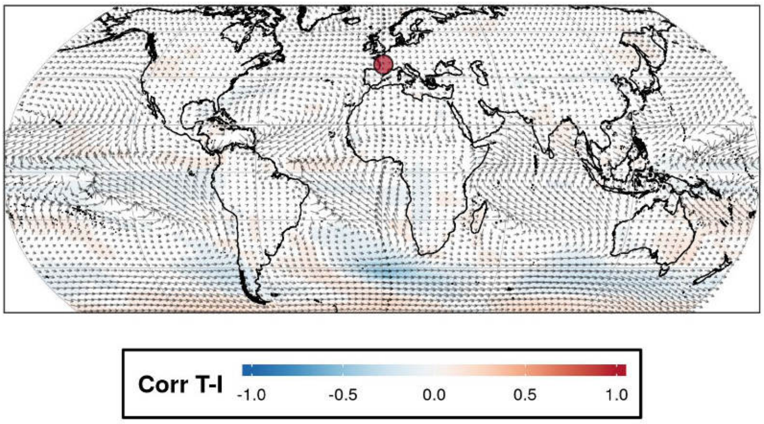

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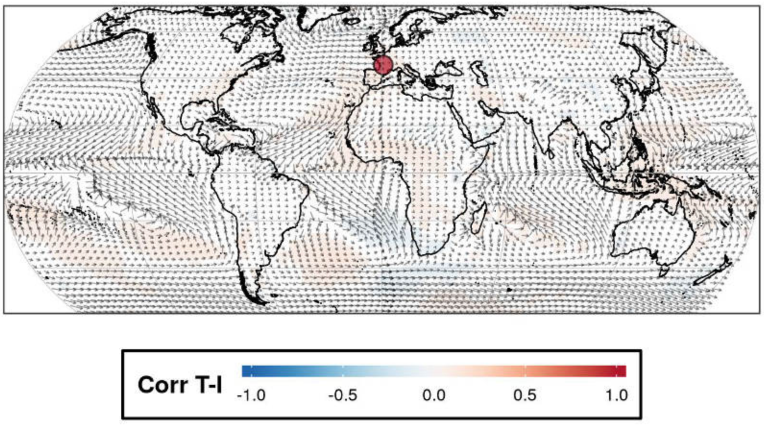

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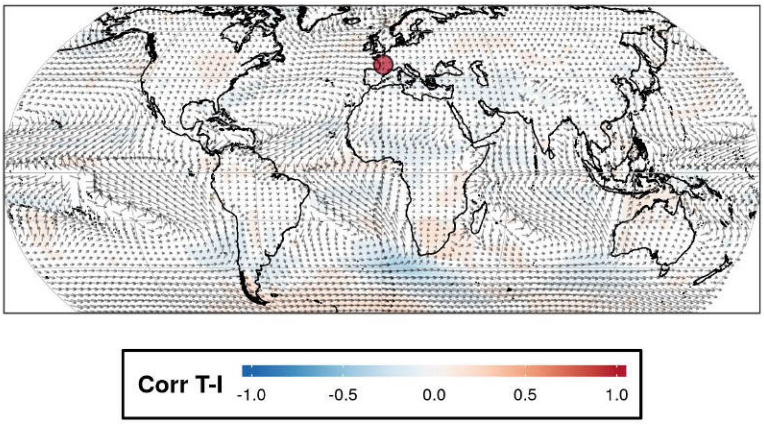

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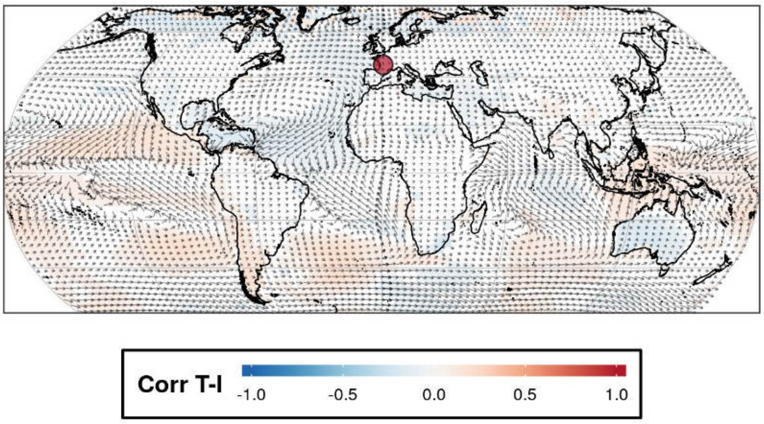

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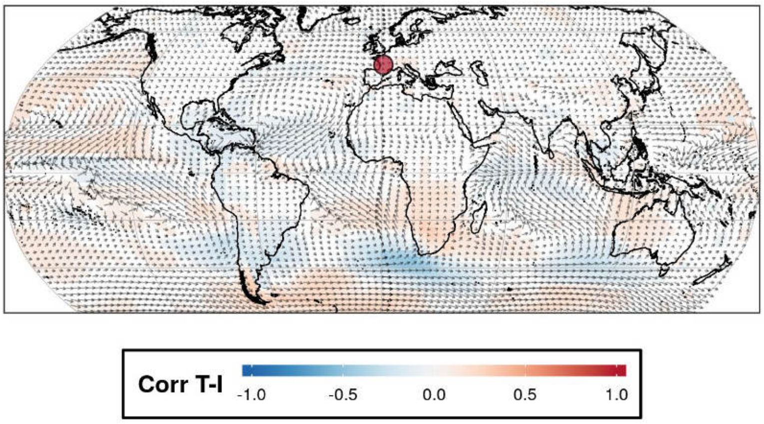

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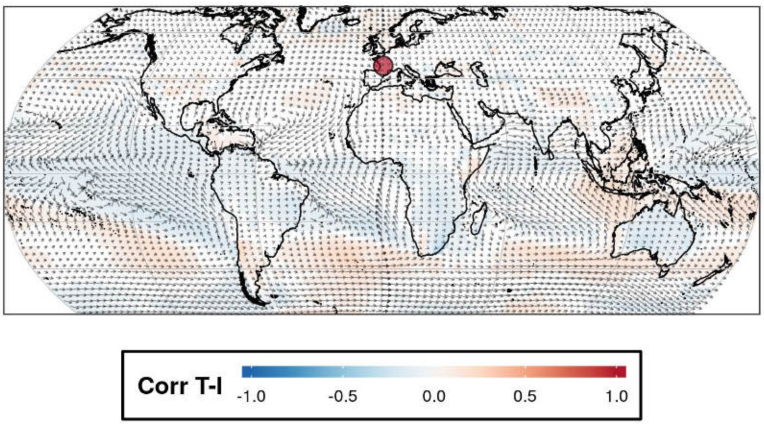

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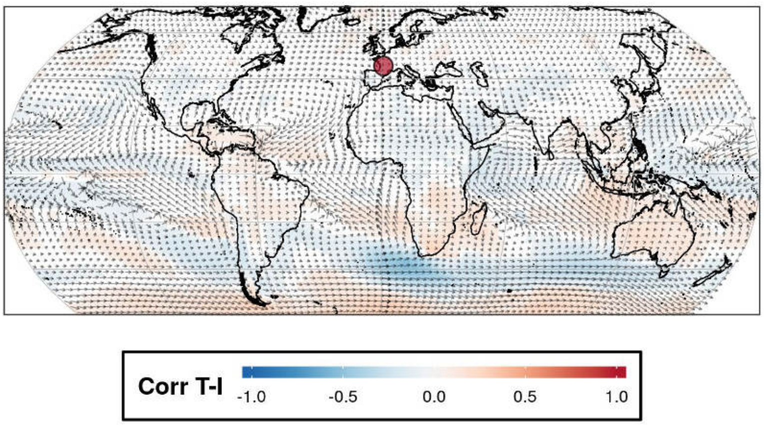

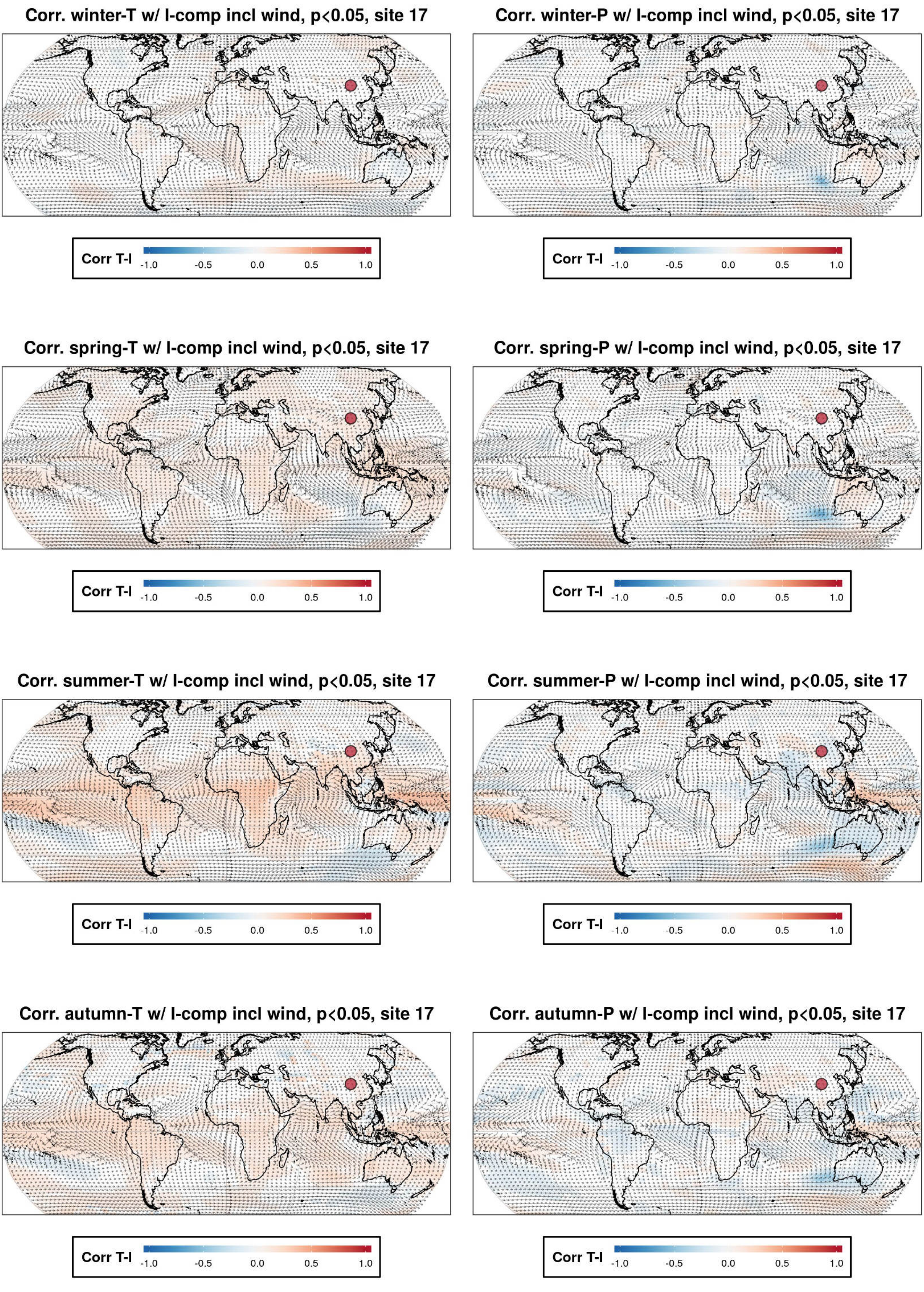
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Corr. winter-P w/ I-comp incl wind, p<0.05, site 17
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Corr. spring-T w/ I-comp incl wind, p<0.05, site 17
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Corr. summer-P w/ I-comp incl wind, p<0.05, site 17
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Corr. autumn-P w/ I-comp incl wind, p<0.05, site 17
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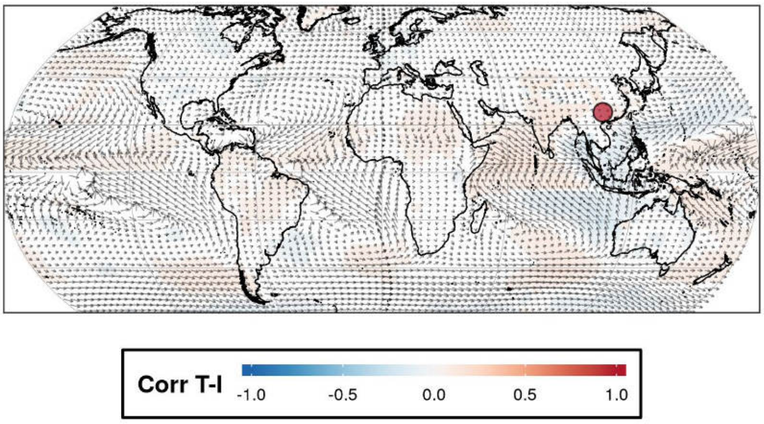

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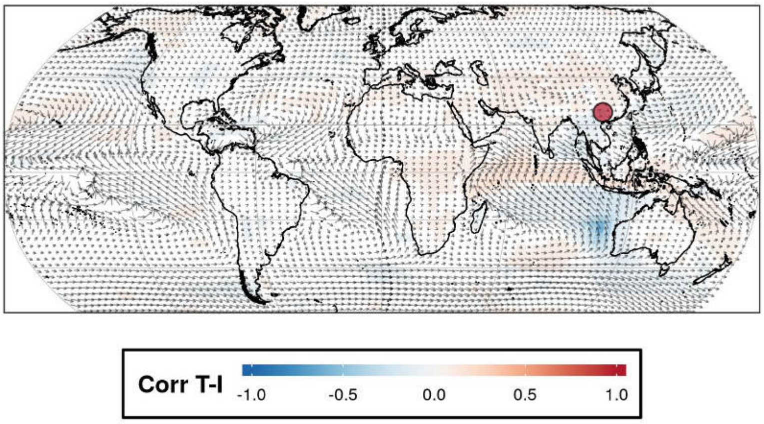

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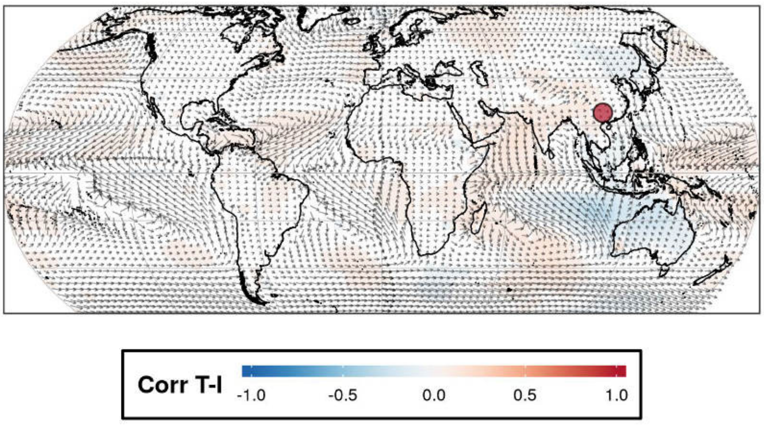

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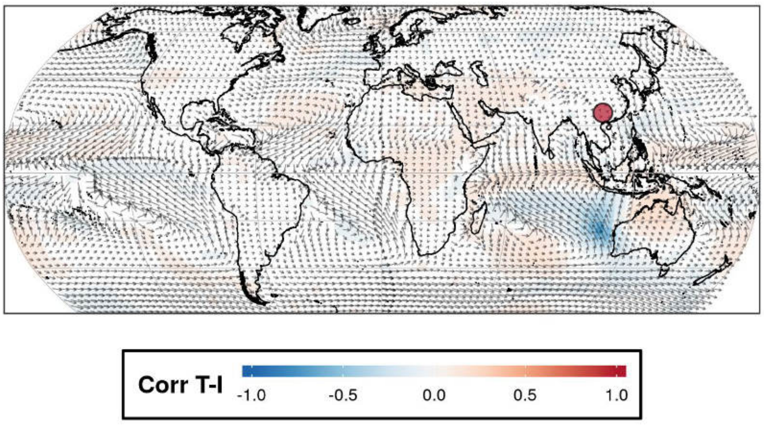

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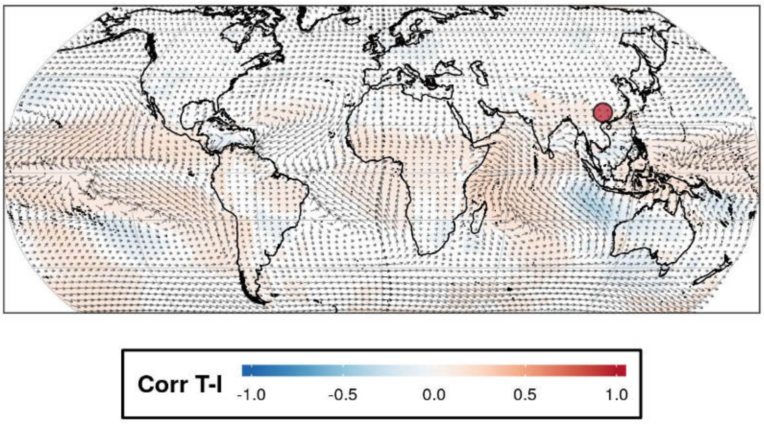

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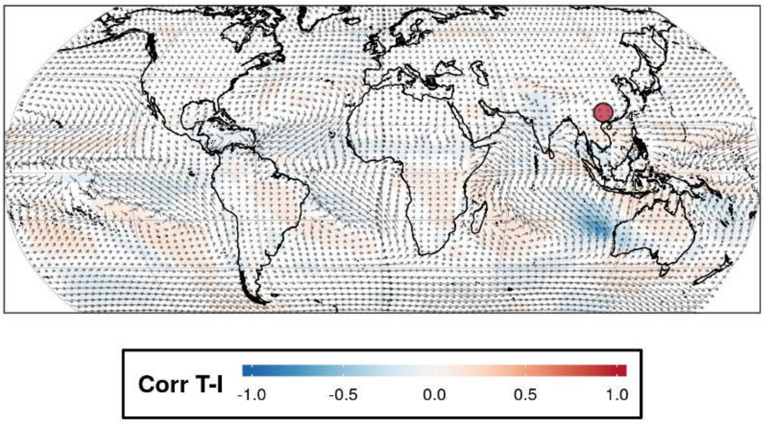

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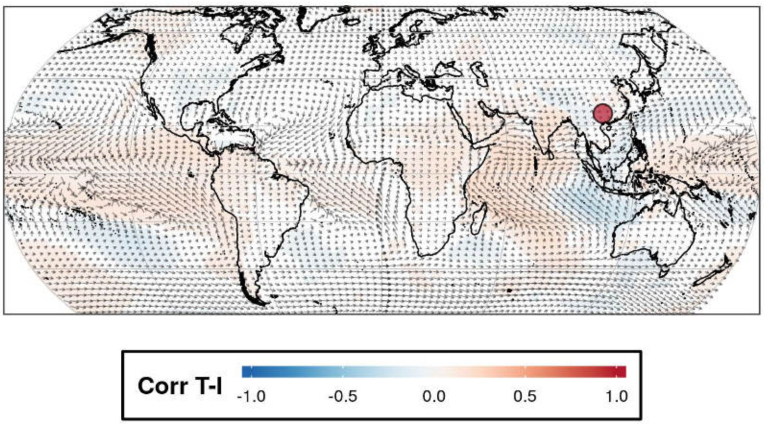

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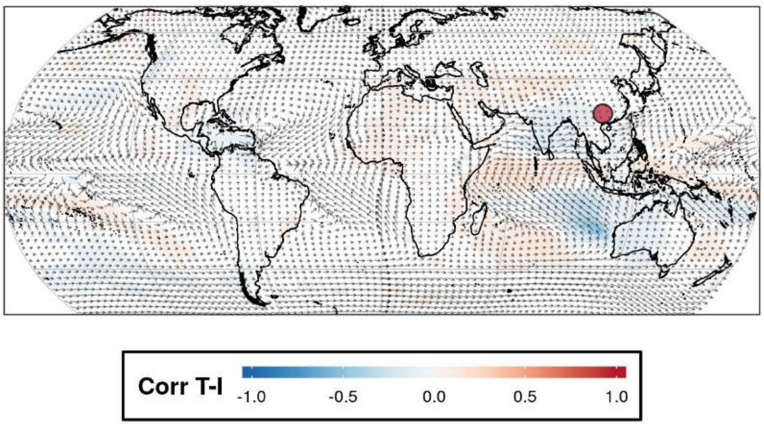

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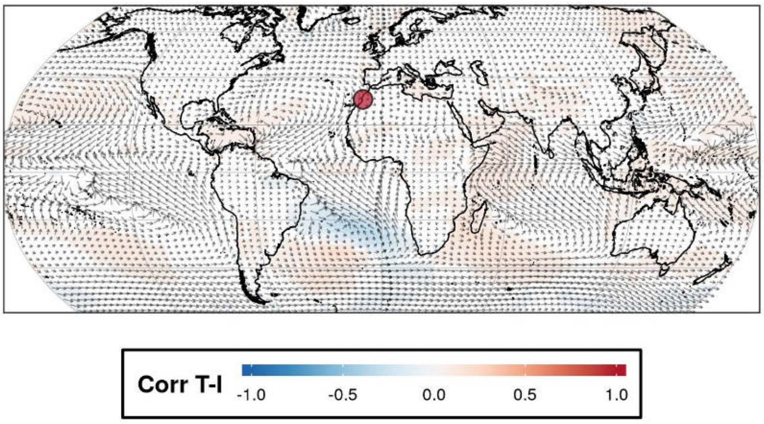

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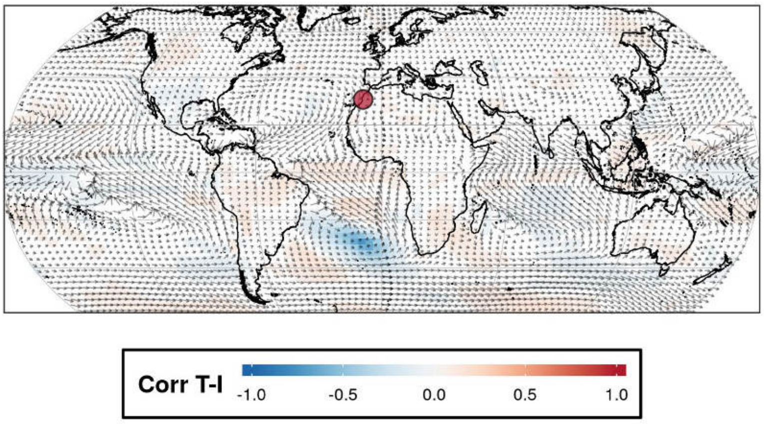

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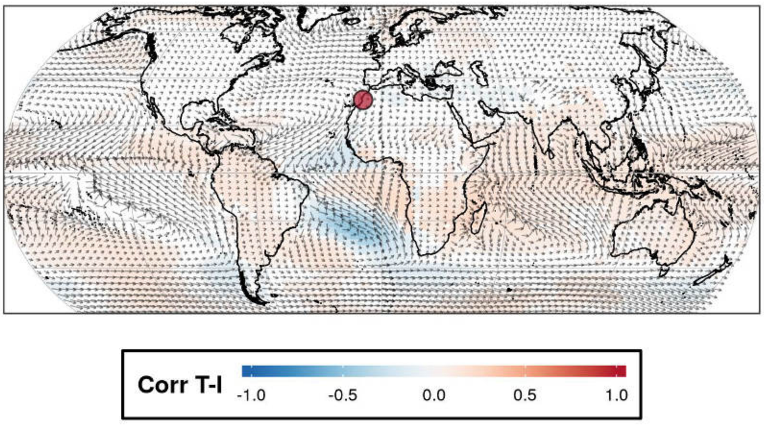

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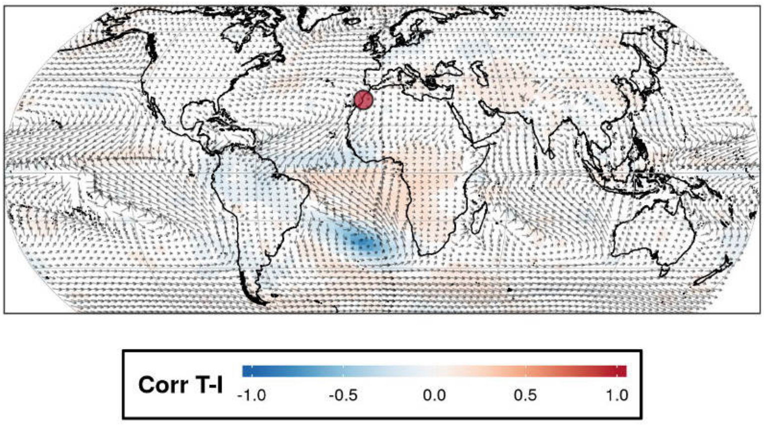

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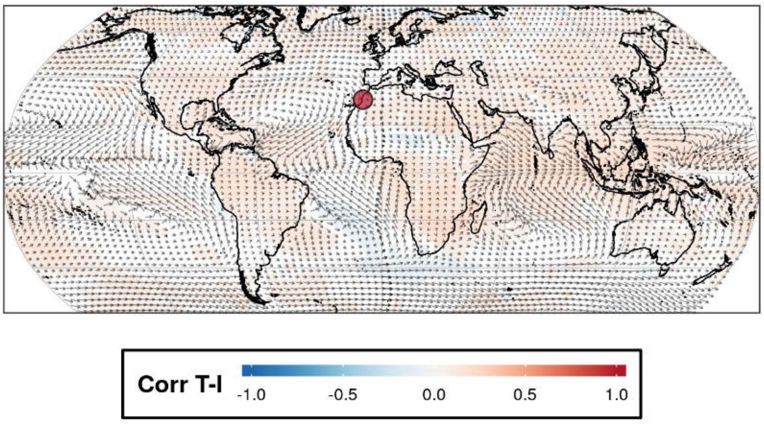

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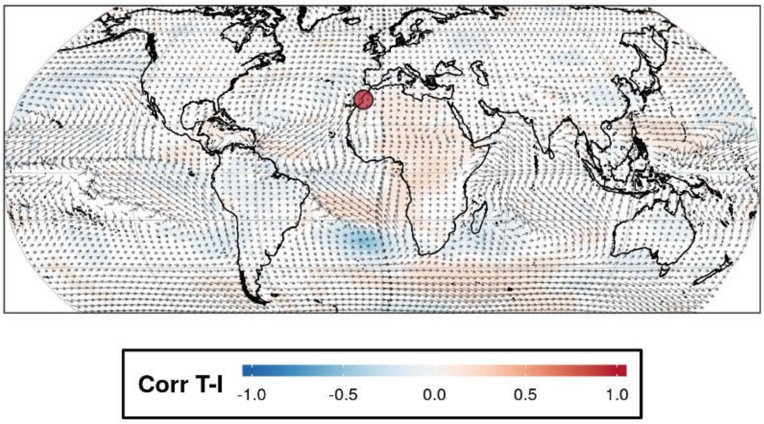

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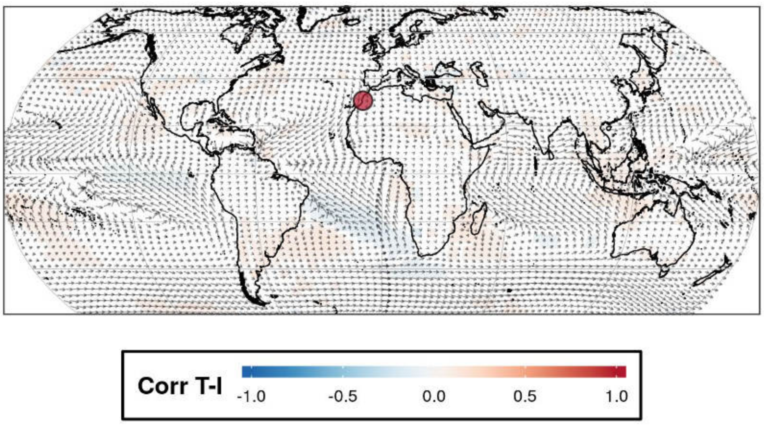

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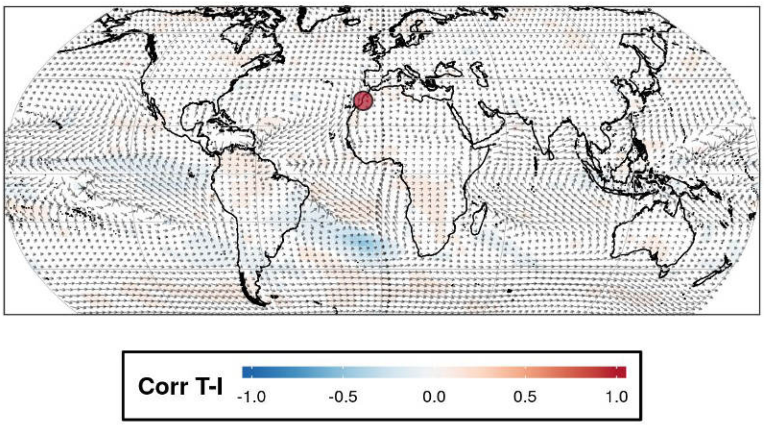

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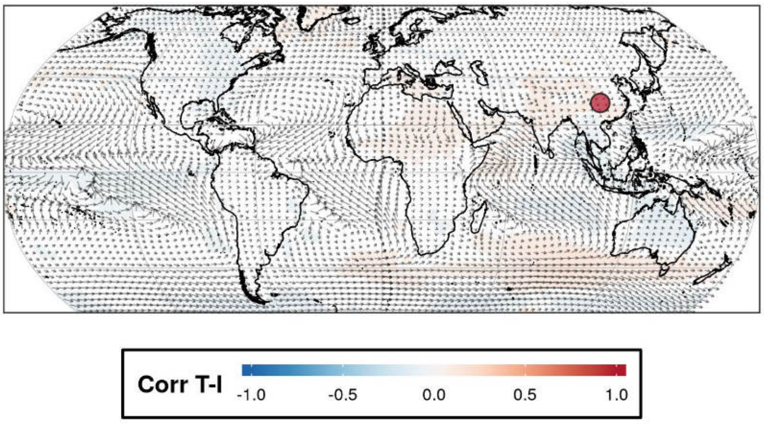

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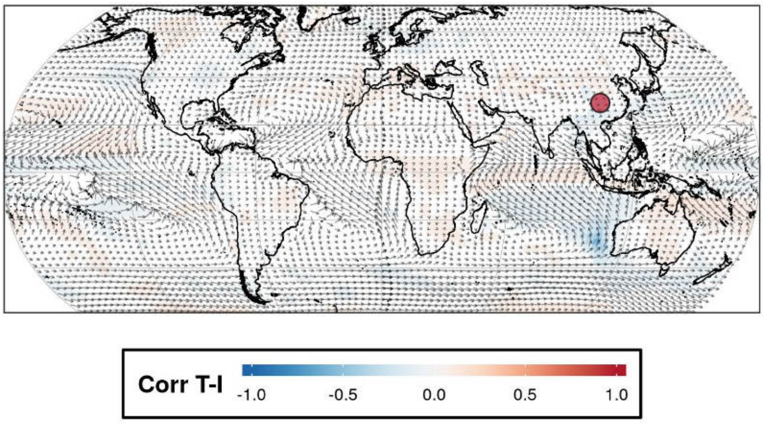

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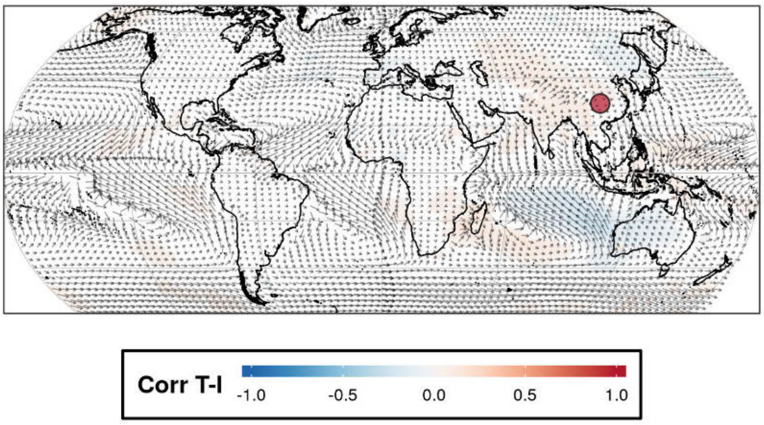

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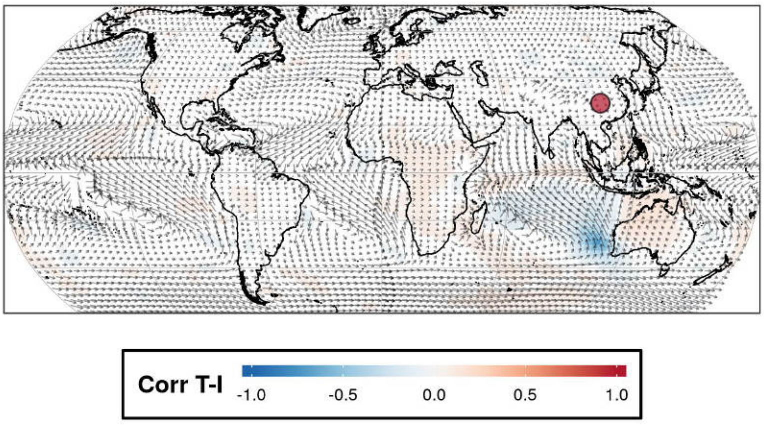

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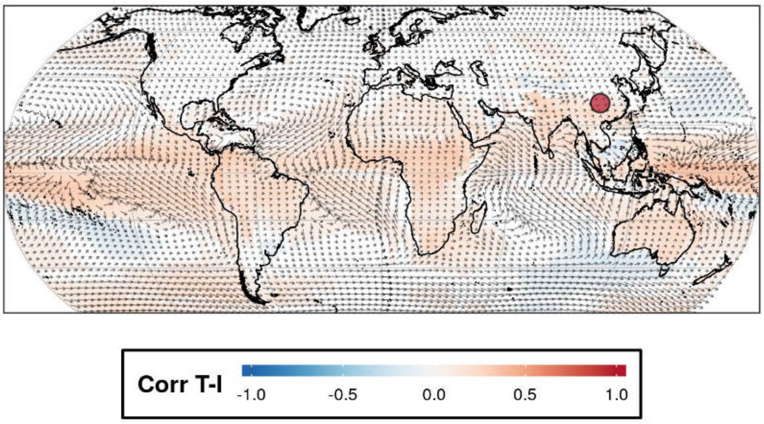

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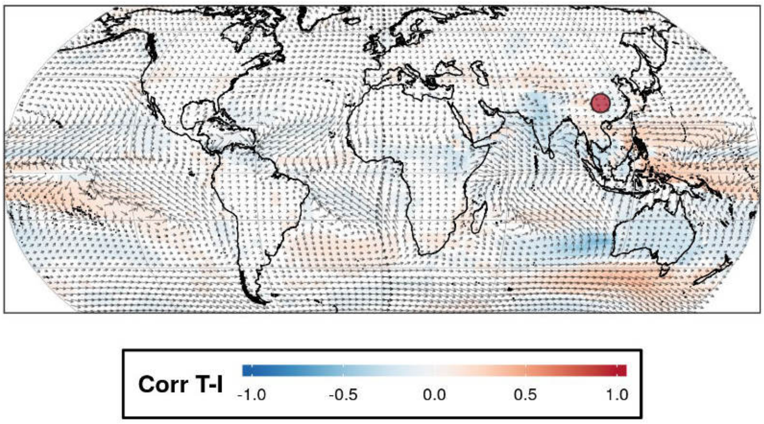

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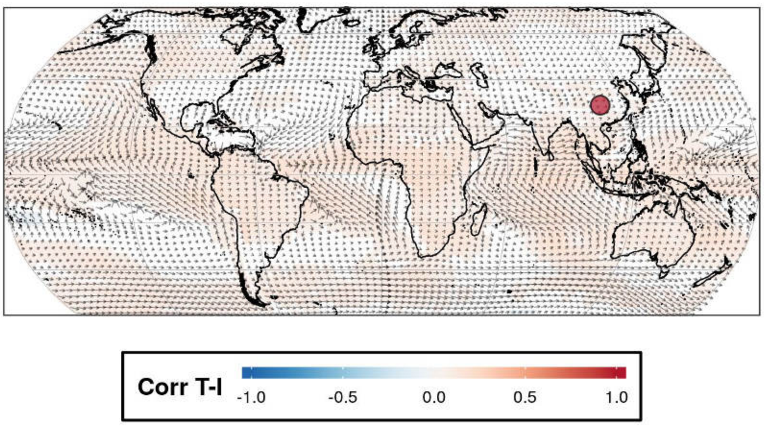

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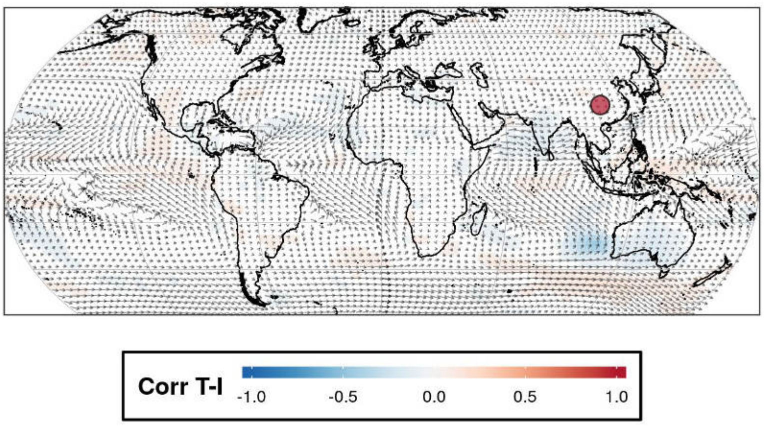

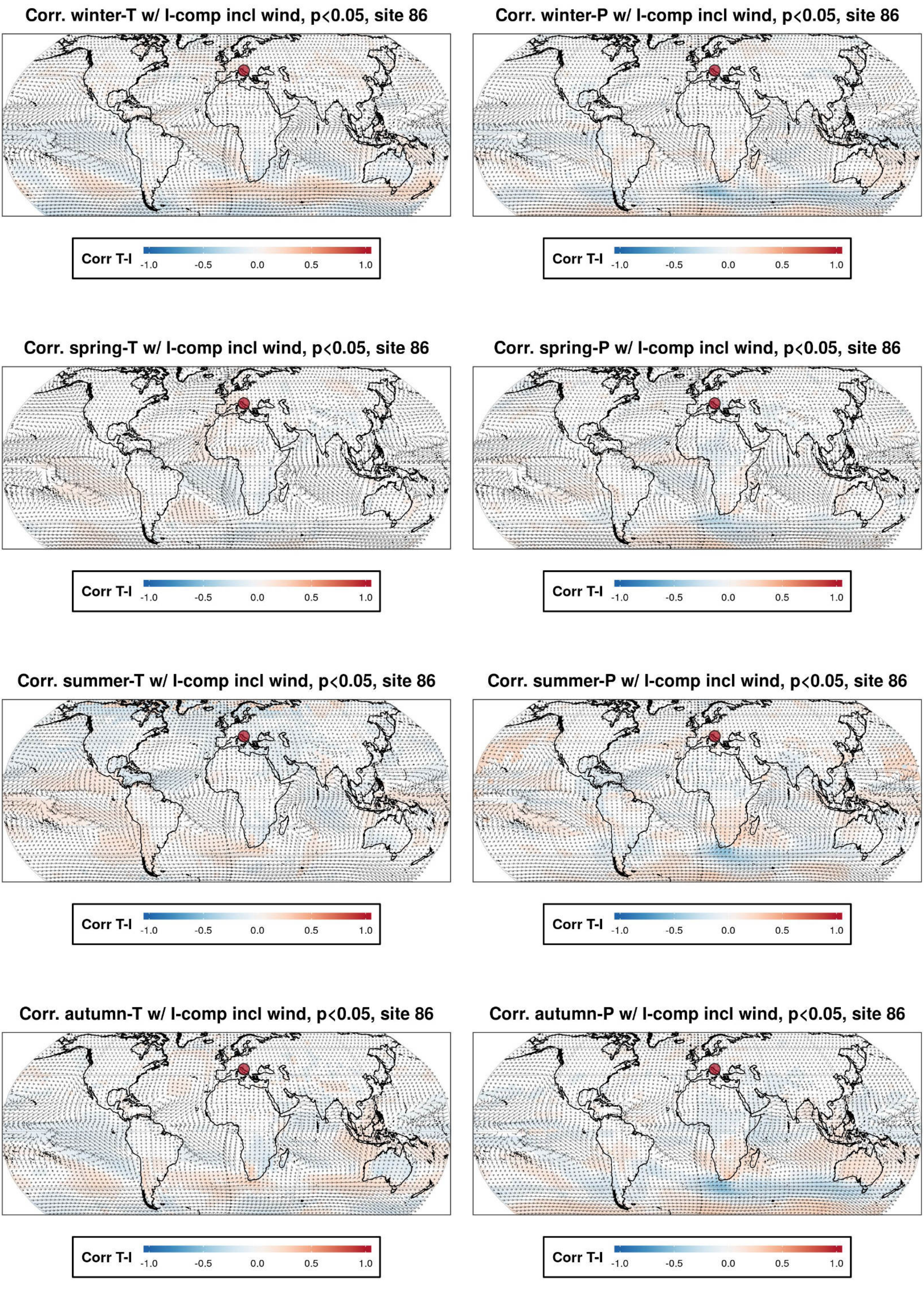
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Corr T-I
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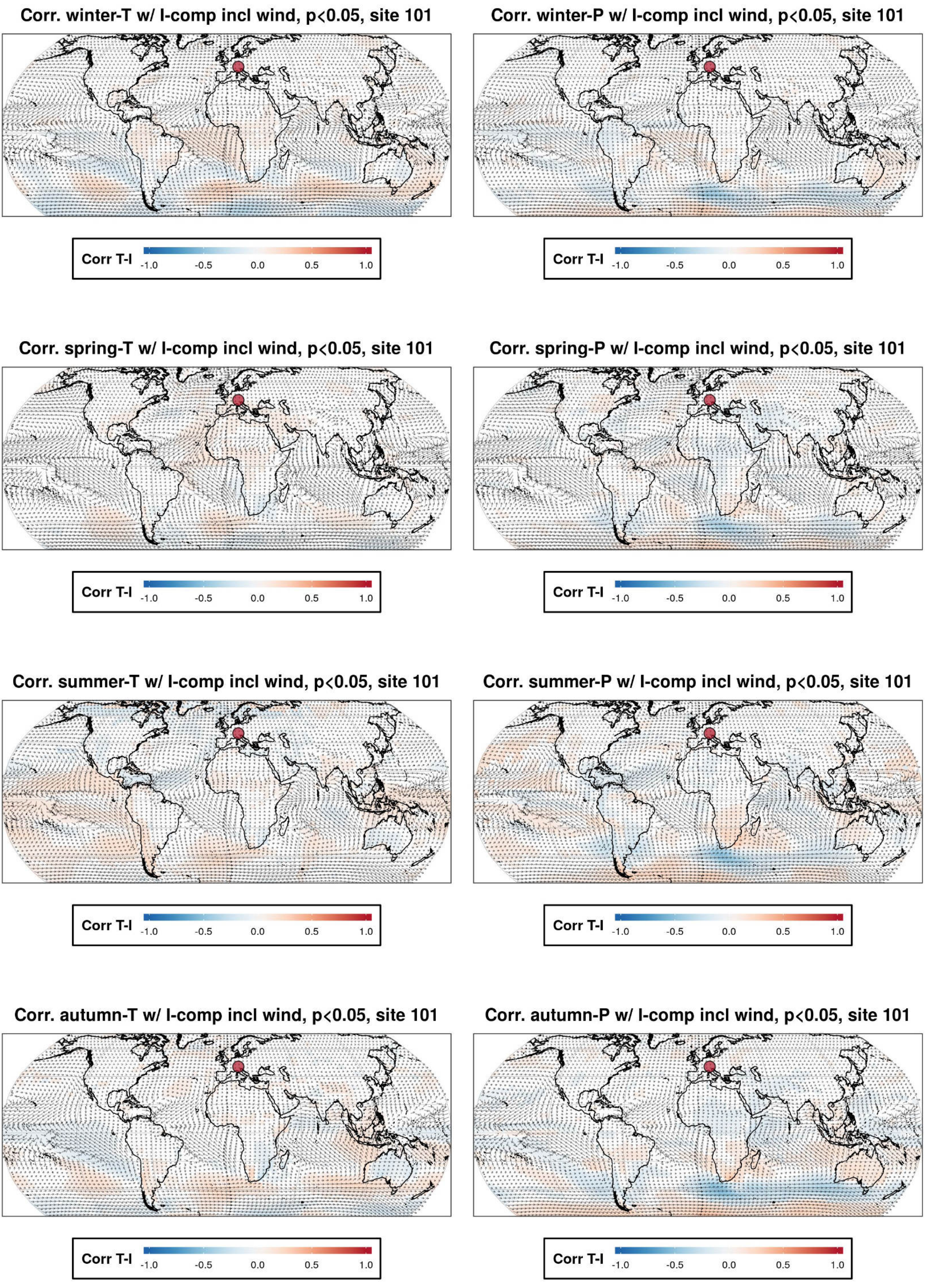
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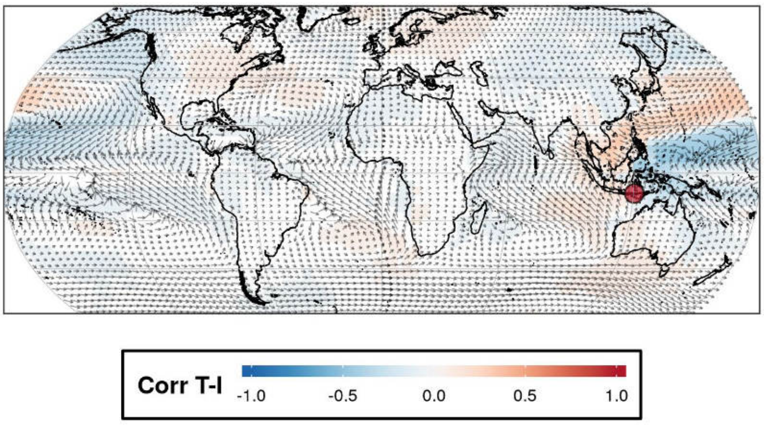
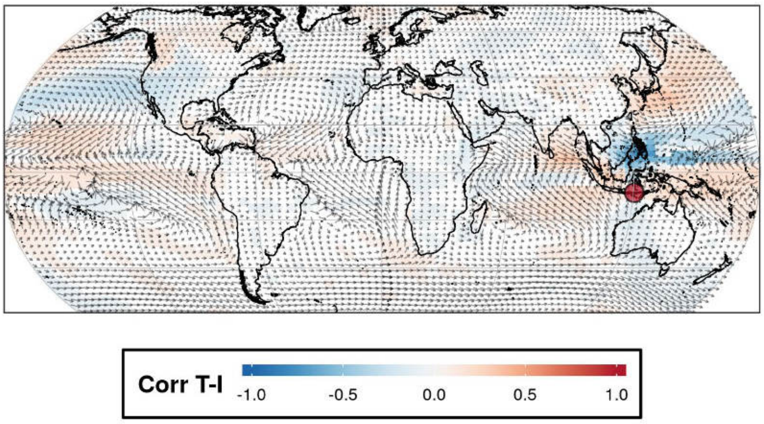
1.0

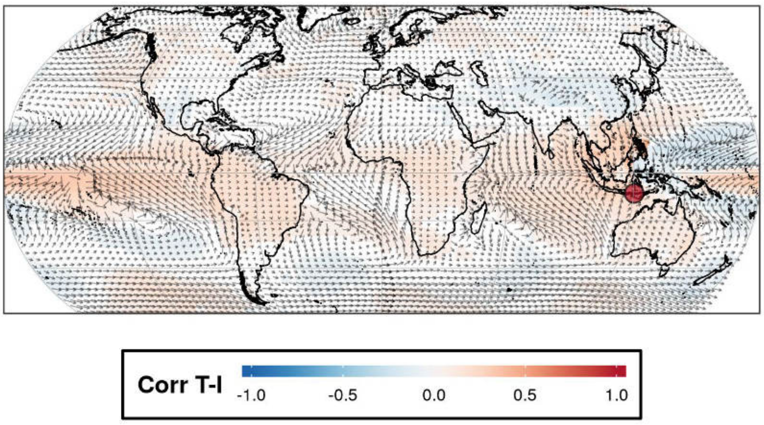
Corr. winter-T w/ I-comp incl wind, p<0.05, site 104



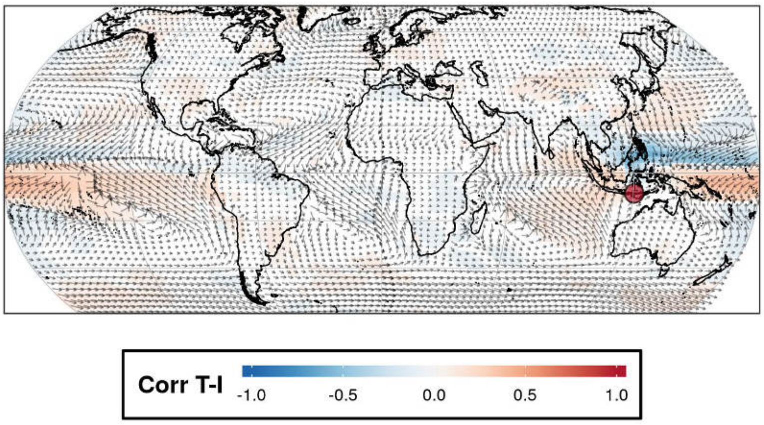
Corr. winter-P w/ I-comp incl wind, p<0.05, site 104



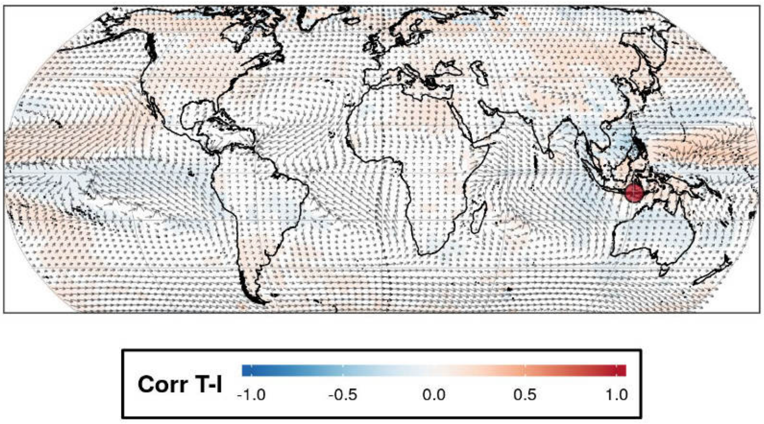
Corr. spring-T w/ I-comp incl wind, p<0.05, site 104



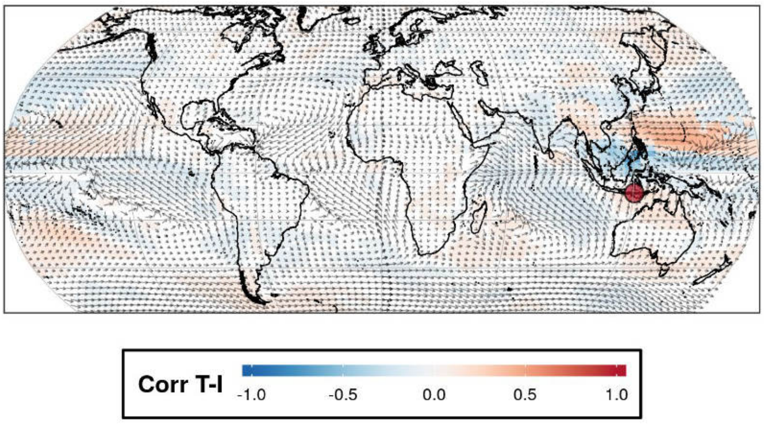
Corr. spring-P w/ I-comp incl wind, p<0.05, site 104



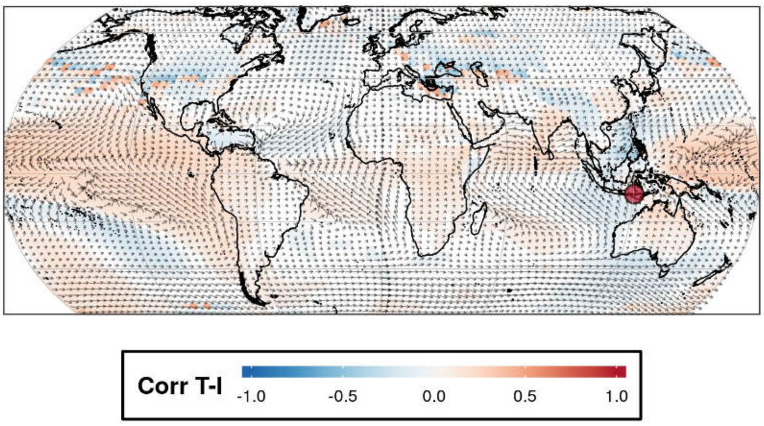
Corr. summer-T w/ I-comp incl wind, p<0.05, site 104



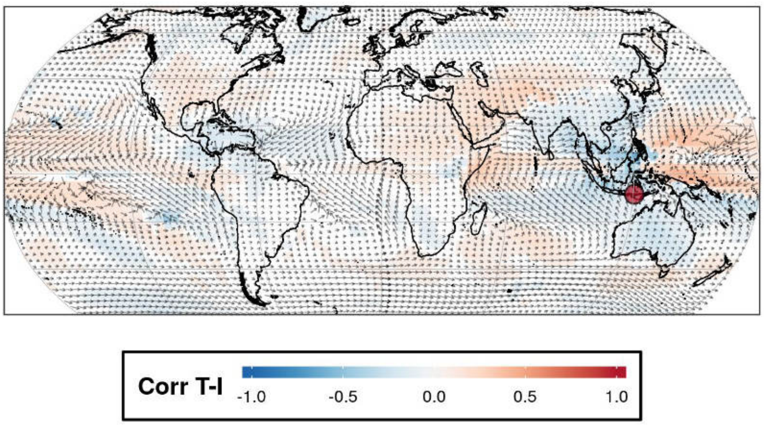
Corr. summer-P w/ I-comp incl wind, p<0.05, site 104

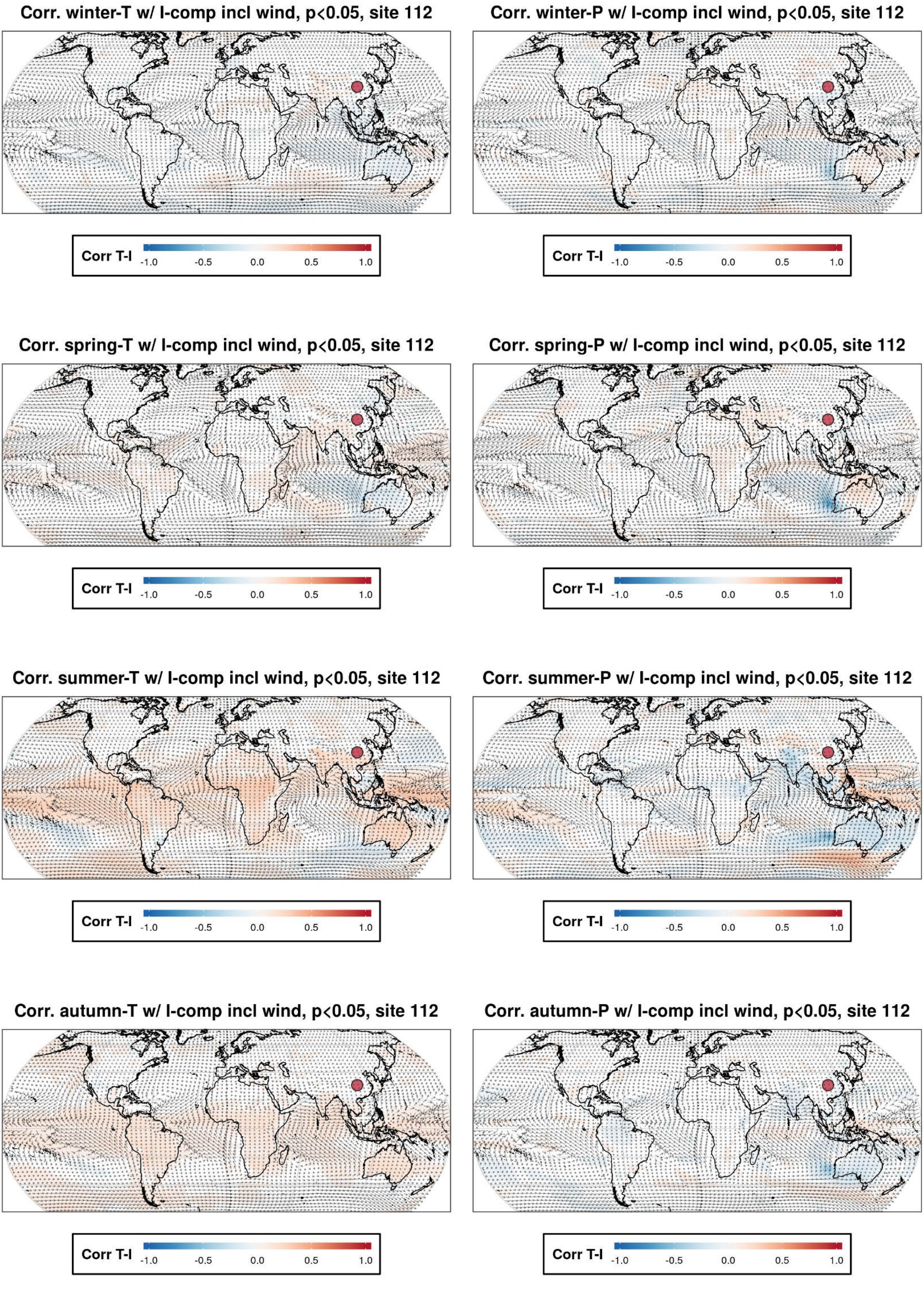


Corr. autumn-T w/ I-comp incl wind, p<0.05, site 104

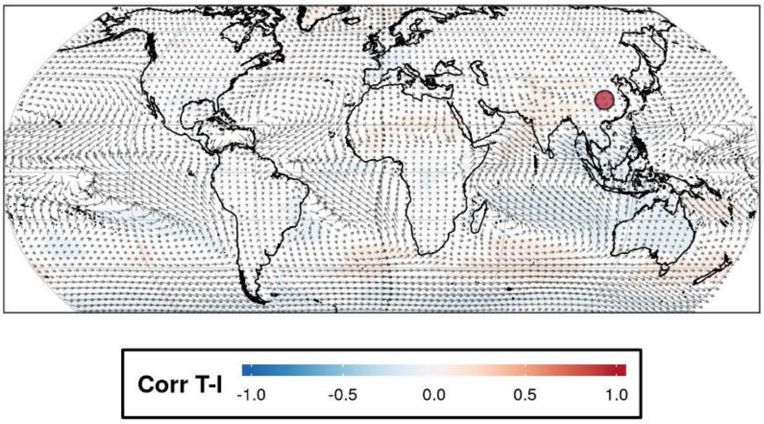


Corr. autumn-P w/ I-comp incl wind, p<0.05, site 104

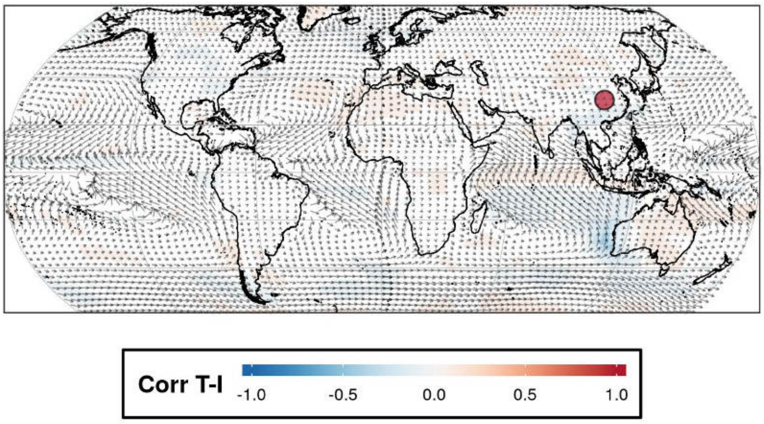



Corr. winter-T w/ I-comp incl wind, p<0.05, site 112
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. winter-P w/ I-comp incl wind, p<0.05, site 112
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. spring-T w/ I-comp incl wind, p<0.05, site 112
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. spring-P w/ I-comp incl wind, p<0.05, site 112
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. summer-T w/ I-comp incl wind, p<0.05, site 112
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. summer-P w/ I-comp incl wind, p<0.05, site 112
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. autumn-T w/ I-comp incl wind, p<0.05, site 112
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. autumn-P w/ I-comp incl wind, p<0.05, site 112
Corr T-I
-1.0
-0.5
0.0
0.5
1.0

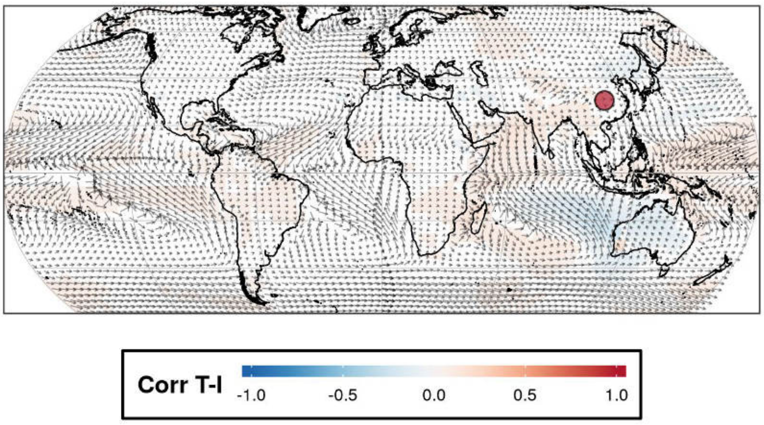
Corr. winter-T w/ I-comp incl wind, p<0.05, site 122



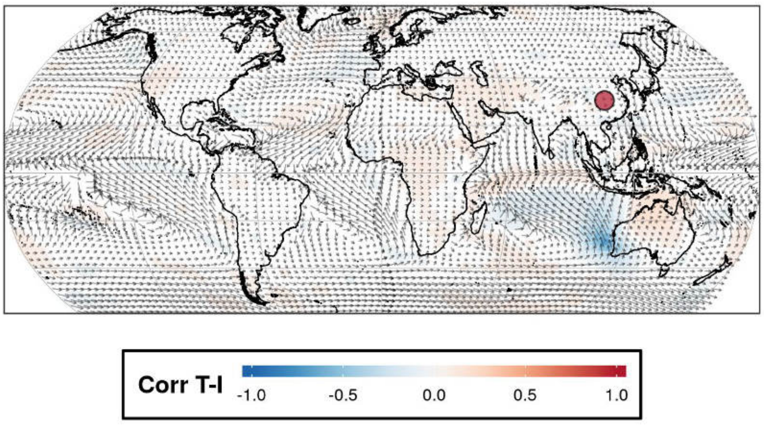
Corr. winter-P w/ I-comp incl wind, p<0.05, site 122



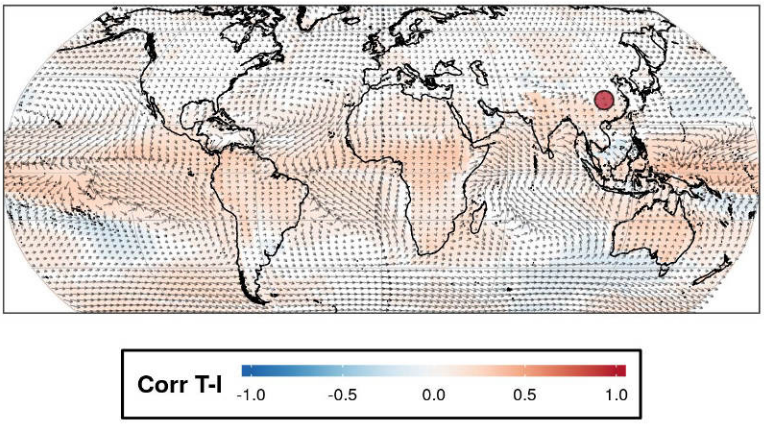
Corr. spring-T w/ I-comp incl wind, p<0.05, site 122



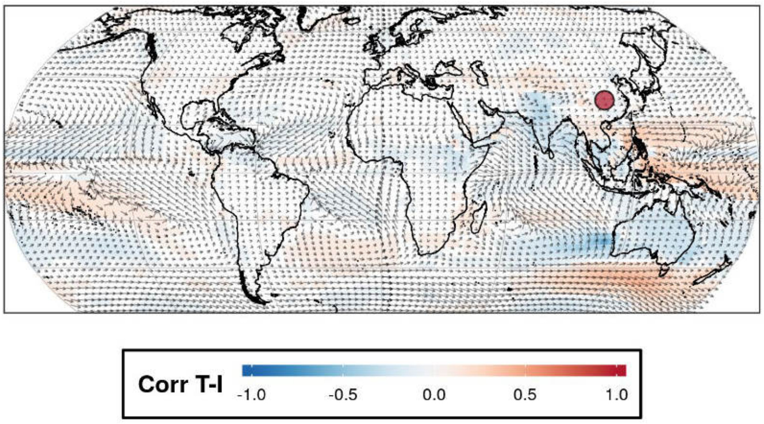
Corr. spring-P w/ I-comp incl wind, p<0.05, site 122



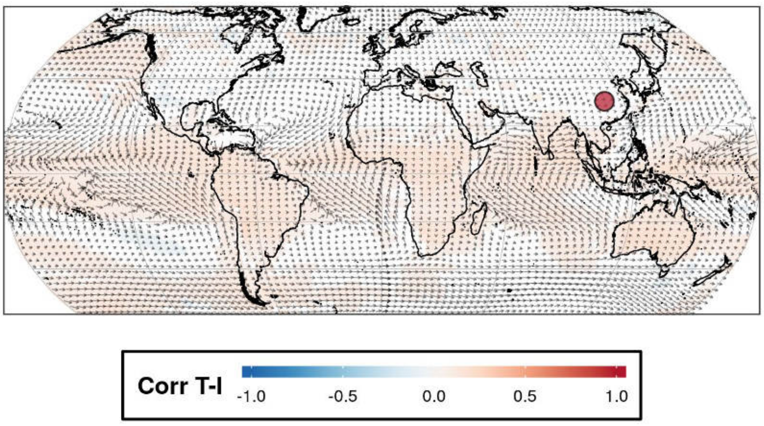
Corr. summer-T w/ I-comp incl wind, p<0.05, site 122



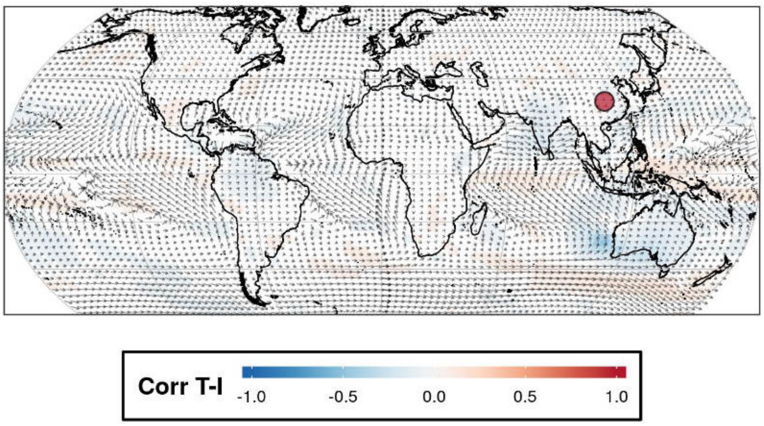
Corr. summer-P w/ I-comp incl wind, p<0.05, site 122



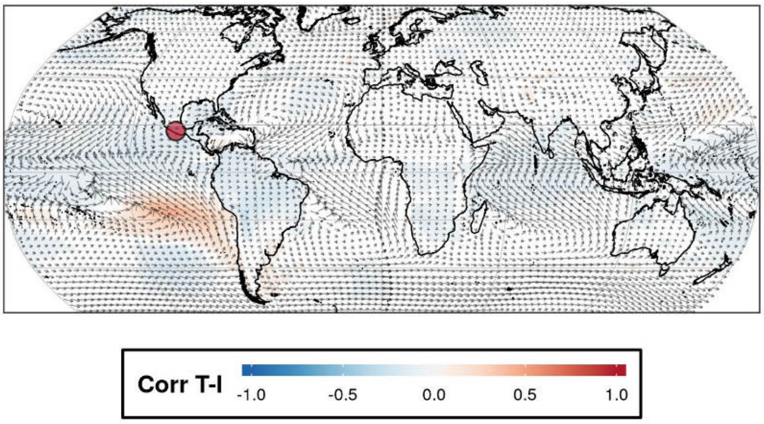
Corr. autumn-T w/ I-comp incl wind, p<0.05, site 122



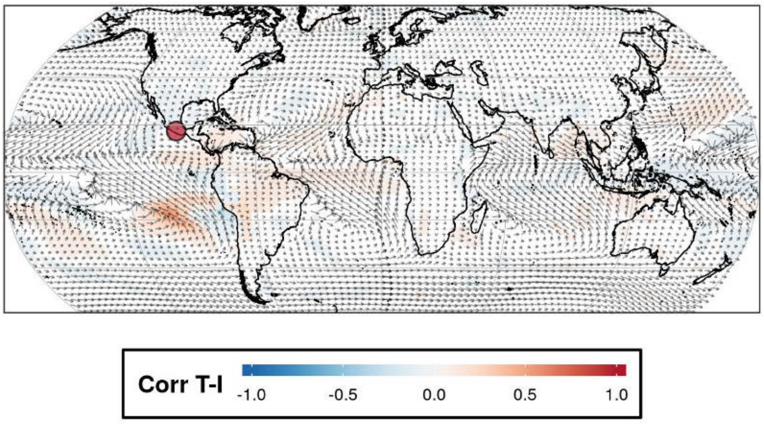
Corr. autumn-P w/ I-comp incl wind, p<0.05, site 122



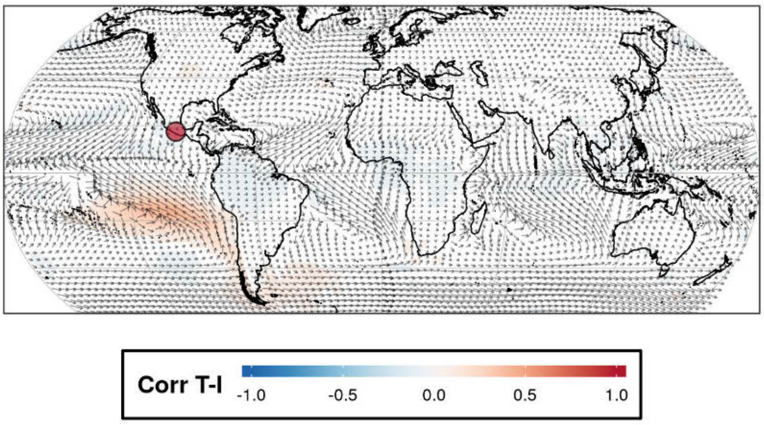
Corr. winter-T w/ I-comp incl wind, p<0.05, site 136



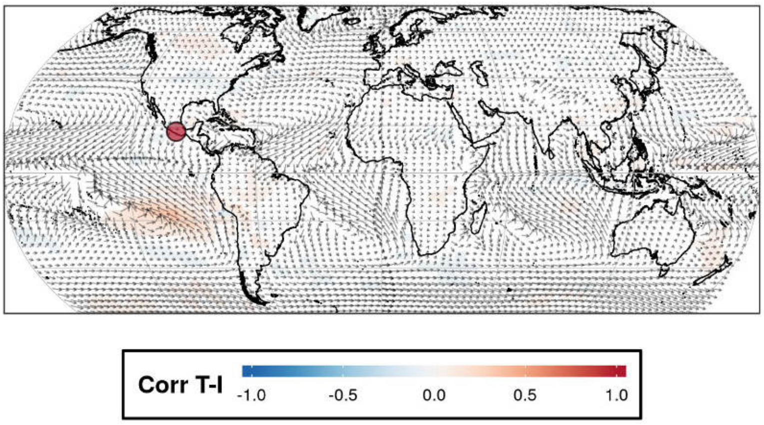
Corr. winter-P w/ I-comp incl wind, p<0.05, site 136



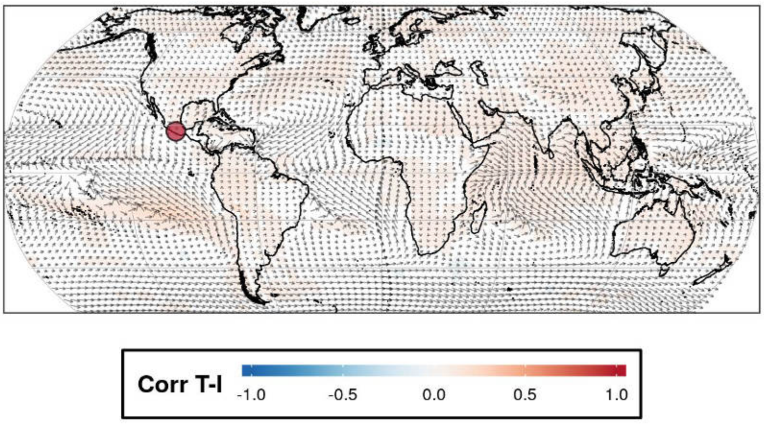
Corr. spring-T w/ I-comp incl wind, p<0.05, site 136



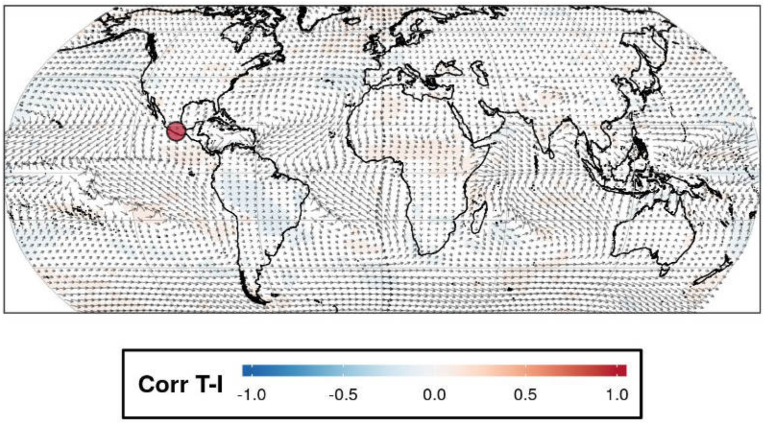
Corr. spring-P w/ I-comp incl wind, p<0.05, site 136



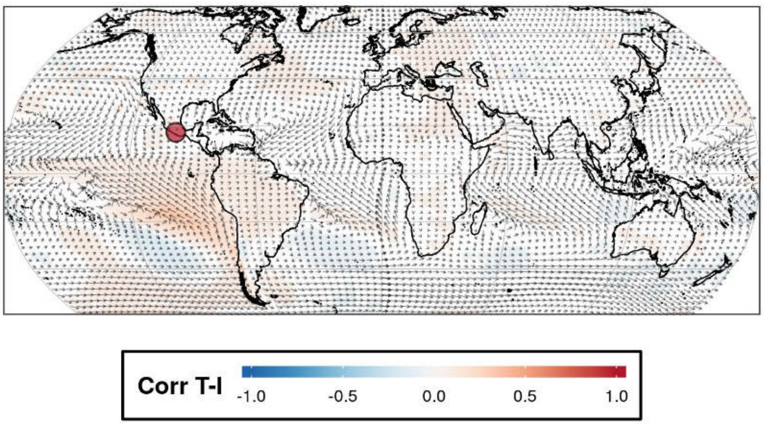
Corr. summer-T w/ I-comp incl wind, p<0.05, site 136



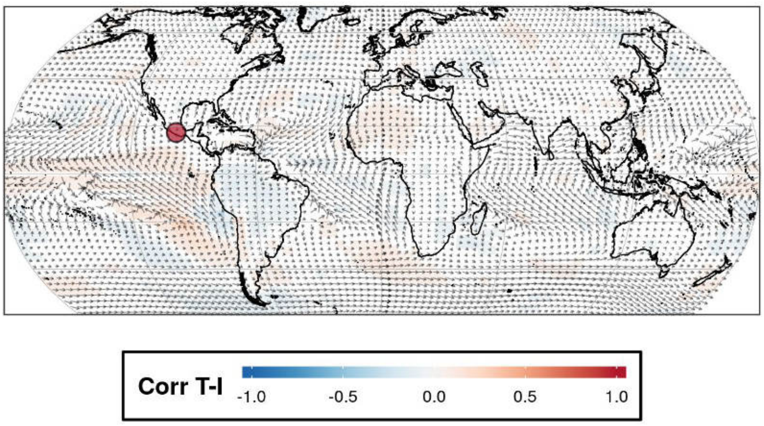
Corr. summer-P w/ I-comp incl wind, p<0.05, site 136



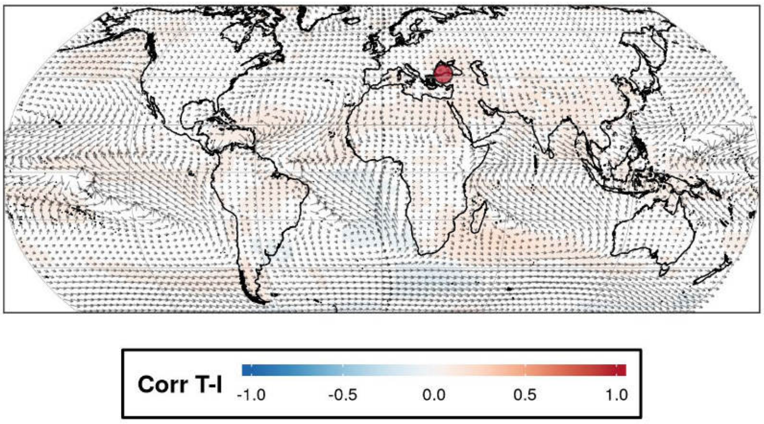
Corr. autumn-T w/ I-comp incl wind, p<0.05, site 136



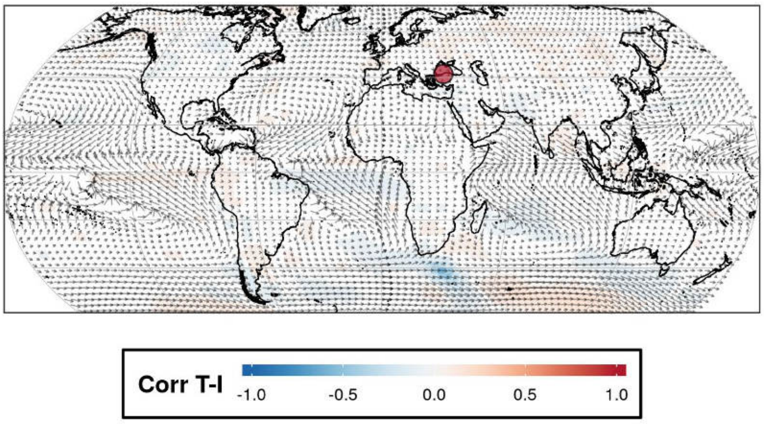
Corr. autumn-P w/ I-comp incl wind, p<0.05, site 136



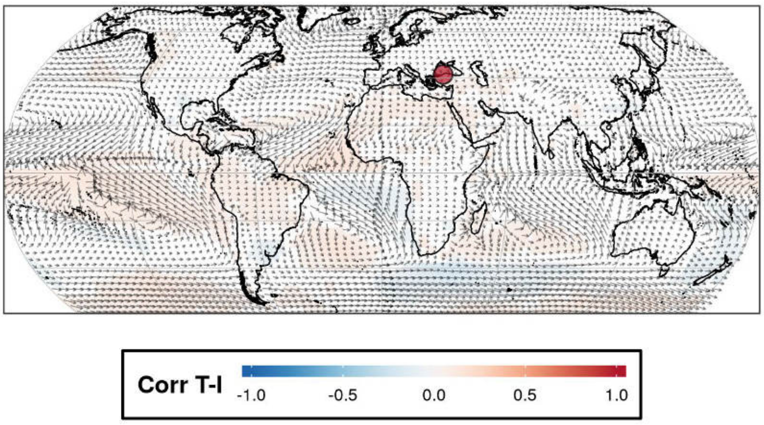
Corr. winter-T w/ I-comp incl wind, p<0.05, site 141



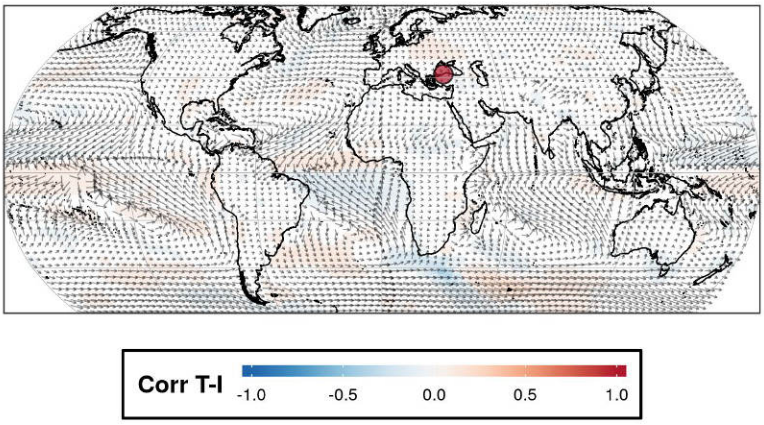
Corr. winter-P w/ I-comp incl wind, p<0.05, site 141



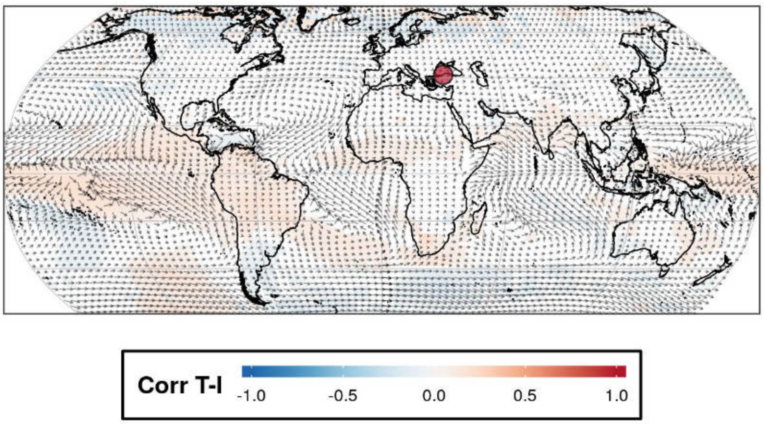
Corr. spring-T w/ I-comp incl wind, p<0.05, site 141



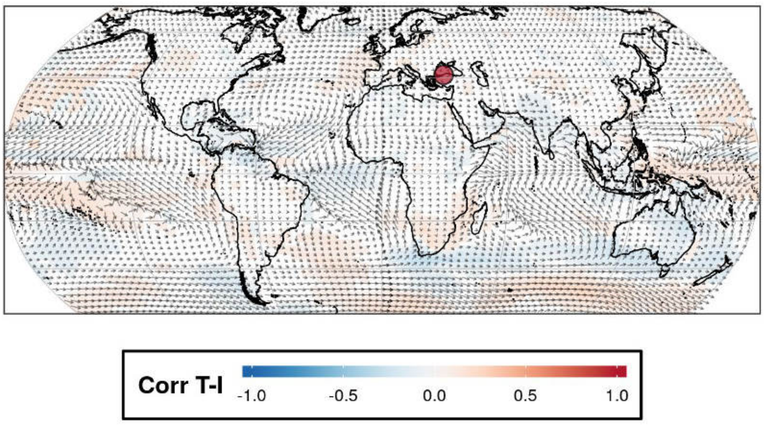
Corr. spring-P w/ I-comp incl wind, p<0.05, site 141



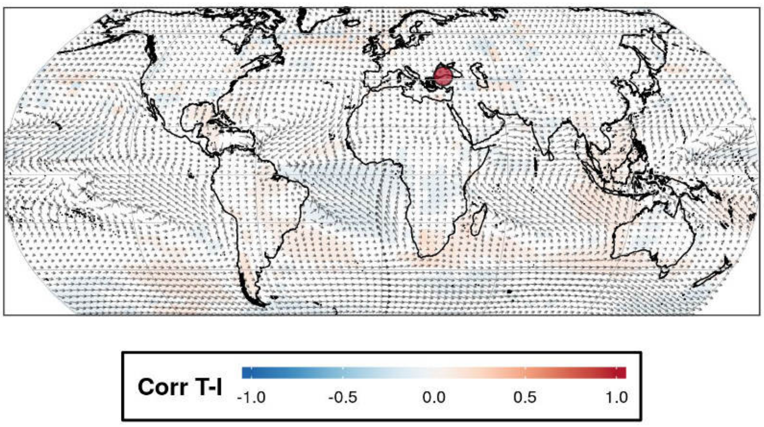
Corr. summer-T w/ I-comp incl wind, p<0.05, site 141



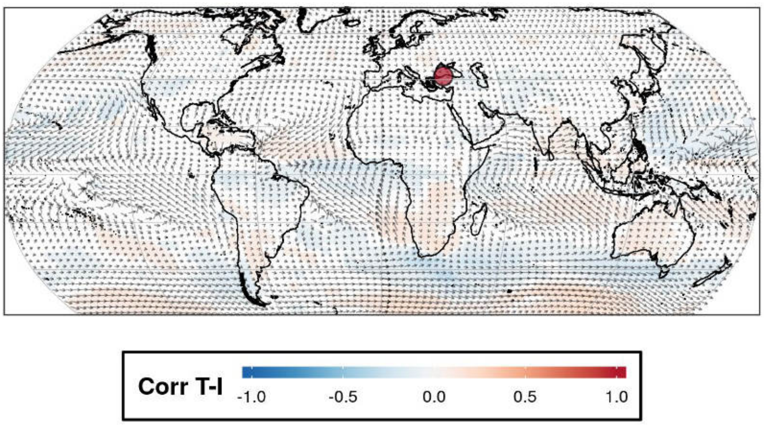
Corr. summer-P w/ I-comp incl wind, p<0.05, site 141



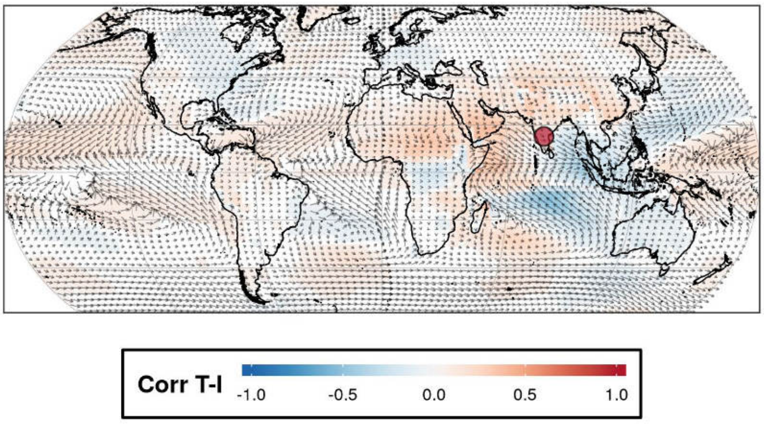
Corr. autumn-T w/ I-comp incl wind, p<0.05, site 141



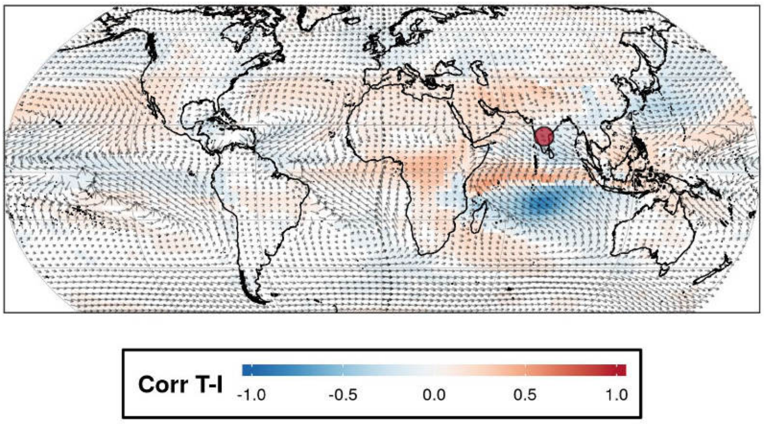
Corr. autumn-P w/ I-comp incl wind, p<0.05, site 141



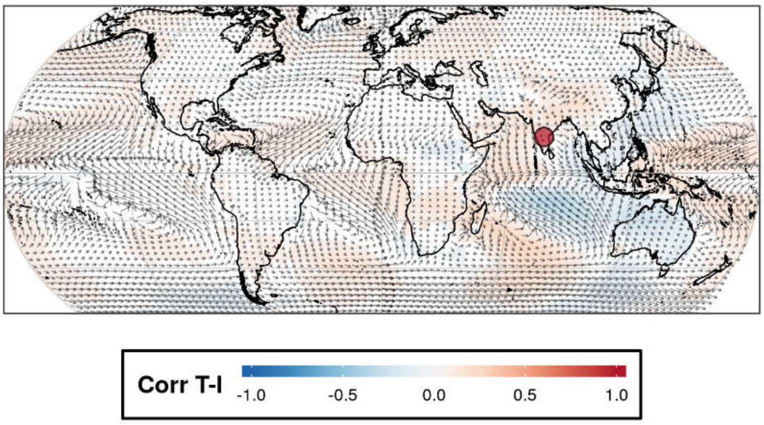
Corr. winter-T w/ I-comp incl wind, p<0.05, site 157



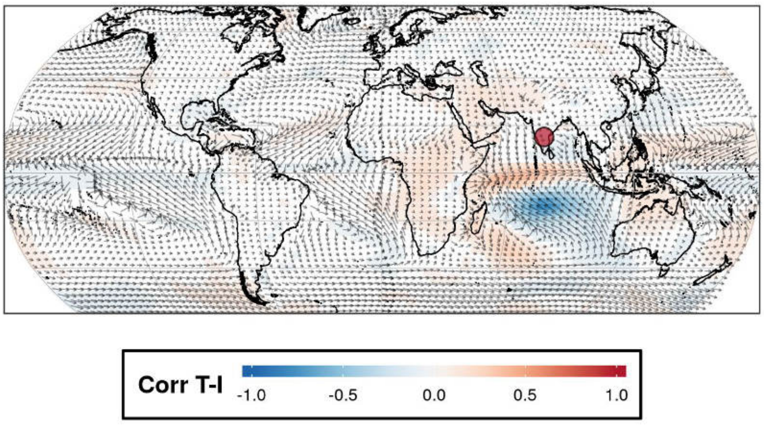
Corr. winter-P w/ I-comp incl wind, p<0.05, site 157



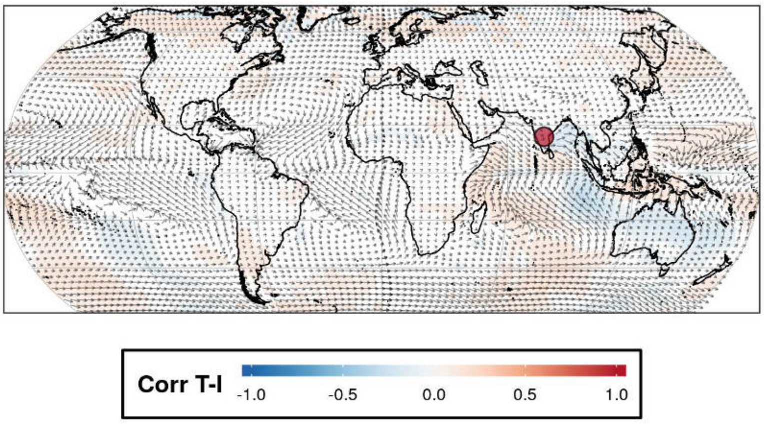
Corr. spring-T w/ I-comp incl wind, p<0.05, site 157



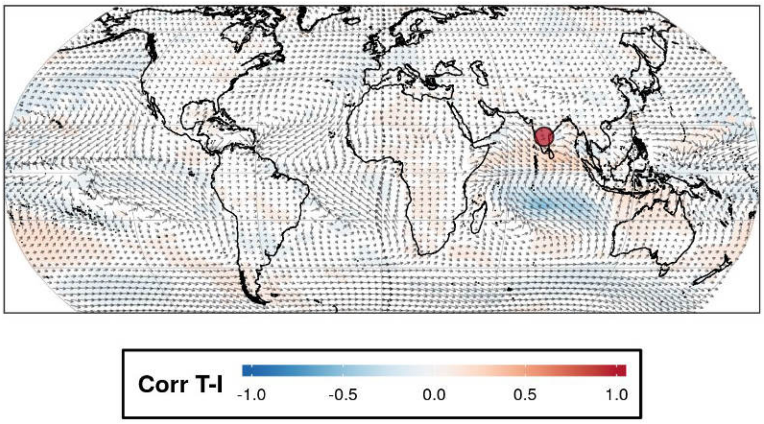
Corr. spring-P w/ I-comp incl wind, p<0.05, site 157



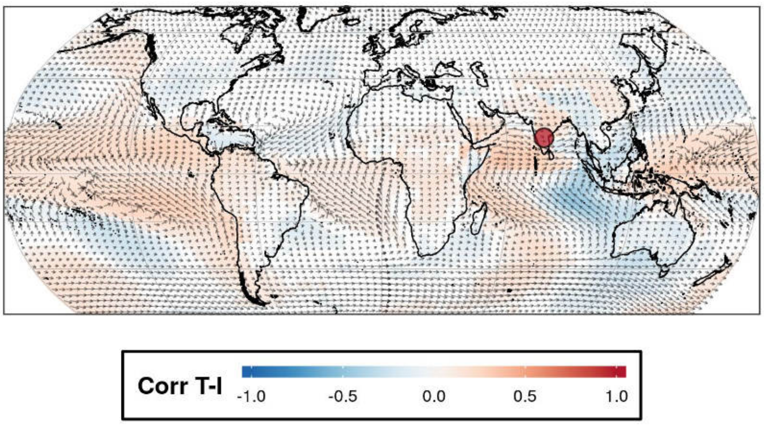
Corr. summer-T w/ I-comp incl wind, p<0.05, site 157



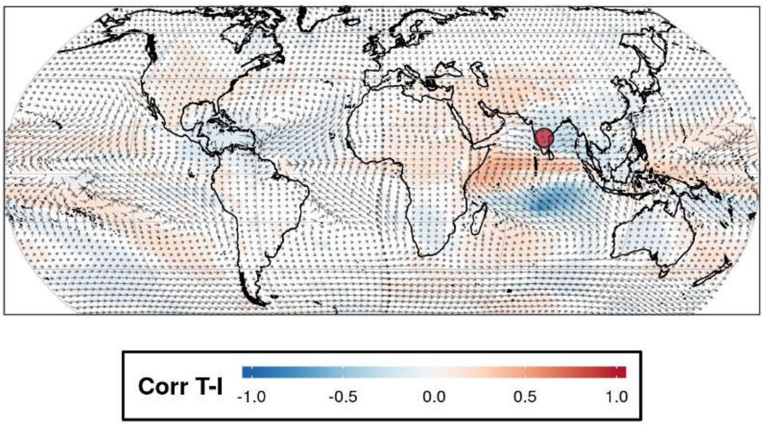
Corr. summer-P w/ I-comp incl wind, p<0.05, site 157

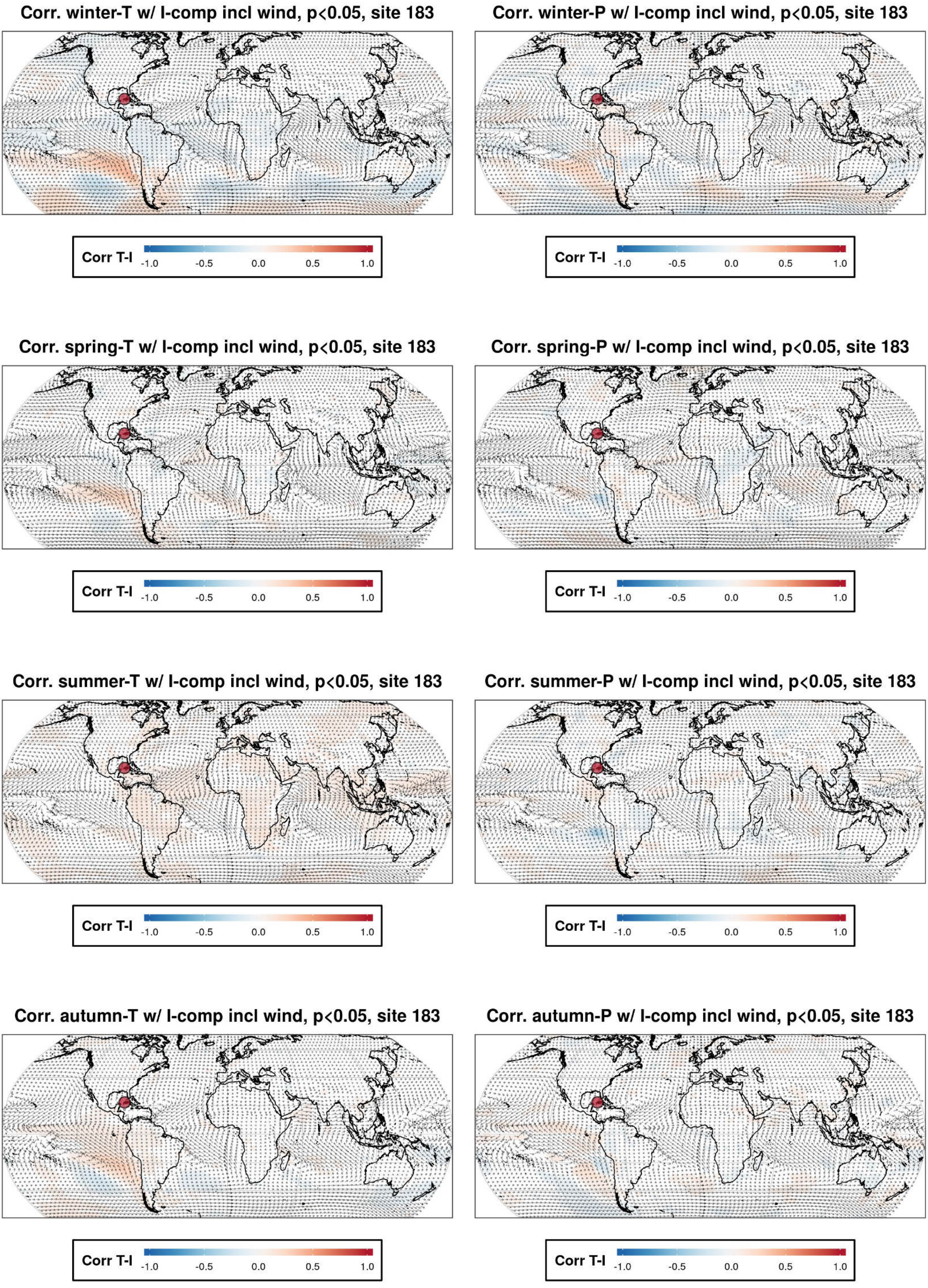


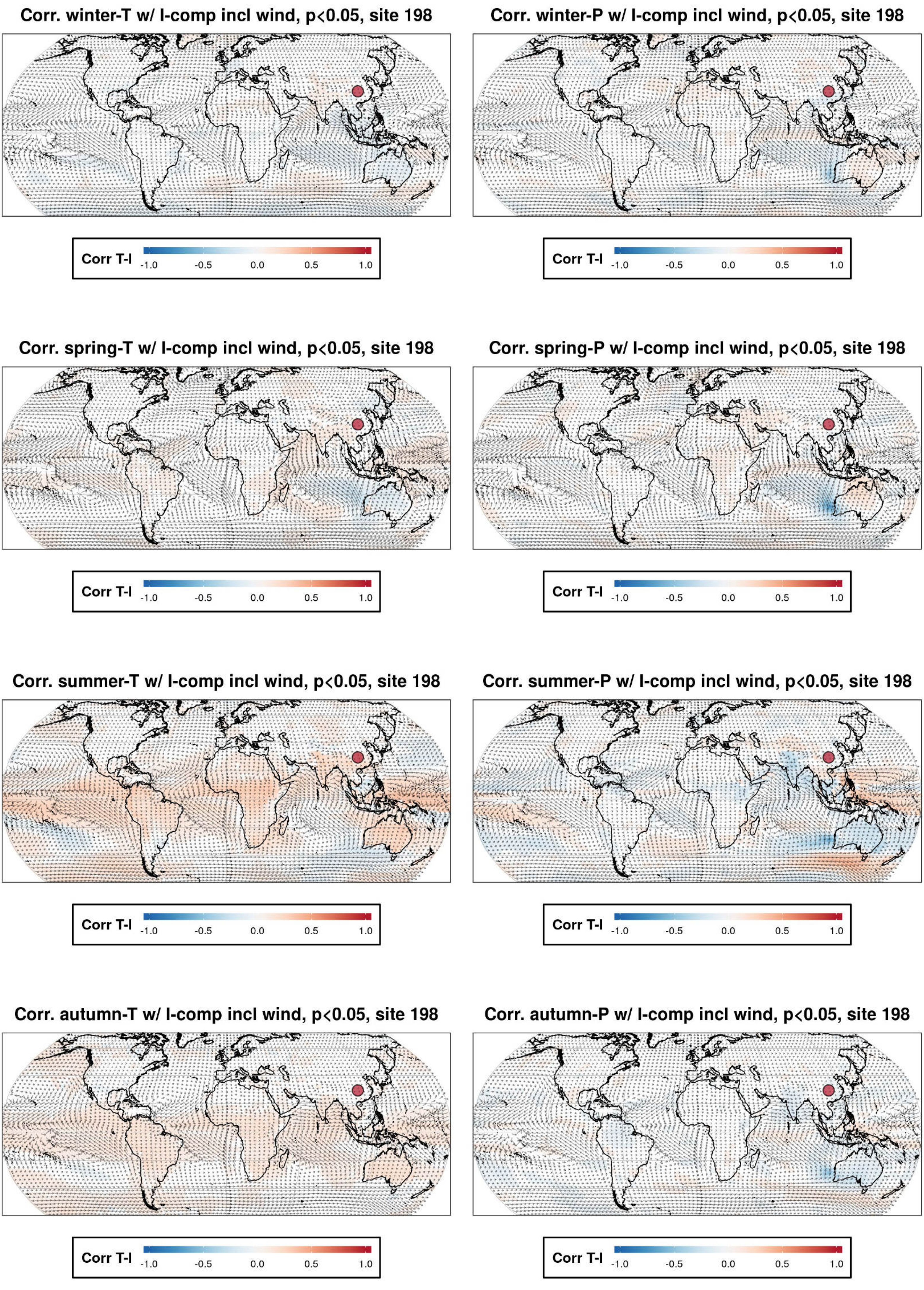
Corr. autumn-T w/ I-comp incl wind, p<0.05, site 157



Corr. autumn-P w/ I-comp incl wind, p<0.05, site 157




Corr. winter-T w/ I-comp incl wind, p<0.05, site 183
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. winter-P w/ I-comp incl wind, p<0.05, site 183
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. spring-T w/ I-comp incl wind, p<0.05, site 183
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. spring-P w/ I-comp incl wind, p<0.05, site 183
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. summer-T w/ I-comp incl wind, p<0.05, site 183
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. summer-P w/ I-comp incl wind, p<0.05, site 183
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. autumn-T w/ I-comp incl wind, p<0.05, site 183
Corr T-I
-1.0
-0.5
0.0
0.5
1.0
Corr. autumn-P w/ I-comp incl wind, p<0.05, site 183
Corr T-I
-1.0
-0.5
0.0
0.5
1.0


Corr. winter-T w/ I-comp incl wind, p<0.05, site 198
Corr T-I
-1.0 -0.5 0.0 0.5 1.0
Corr. winter-P w/ I-comp incl wind, p<0.05, site 198
Corr T-I
-1.0 -0.5 0.0 0.5 1.0
Corr. spring-T w/ I-comp incl wind, p<0.05, site 198
Corr T-I
-1.0 -0.5 0.0 0.5 1.0
Corr. spring-P w/ I-comp incl wind, p<0.05, site 198
Corr T-I
-1.0 -0.5 0.0 0.5 1.0
Corr. summer-T w/ I-comp incl wind, p<0.05, site 198
Corr T-I
-1.0 -0.5 0.0 0.5 1.0
Corr. summer-P w/ I-comp incl wind, p<0.05, site 198
Corr T-I
-1.0 -0.5 0.0 0.5 1.0
Corr. autumn-T w/ I-comp incl wind, p<0.05, site 198
Corr T-I
-1.0 -0.5 0.0 0.5 1.0
Corr. autumn-P w/ I-comp incl wind, p<0.05, site 198
Corr T-I
-1.0 -0.5 0.0 0.5 1.0