Regional Research Network
Central Asian Water

Helmholtz-Zentrum
POTSDAM

Federal Foreign Office

Predictability of cold season precipitation in Central Asia

-

The role of tropical and extratropical drivers

Lars Gerlitz, Eva Steirou, Christoph Schneider, Vincent Moron,
Sergiy Vorogushyn, Bruno Merz

www.cawa-project.net

Outline

1. **CAWa – Project Overview**

2. **Regression based forecast of seasonal precipitation**

   - *Predictor selection, model calibration and evaluation*
   - *Results: Major predictor variables and model skill*

3. **Analysis of weather types**

   - *Classification approach*
   - *Weather types and the large scale circulation*
   - *Interannual variability and forecast potential*

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1. CAWa: Water in Central Asia

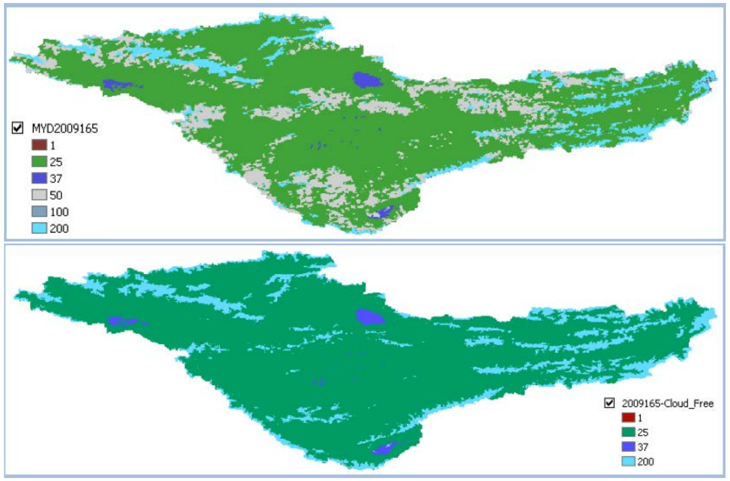
Background

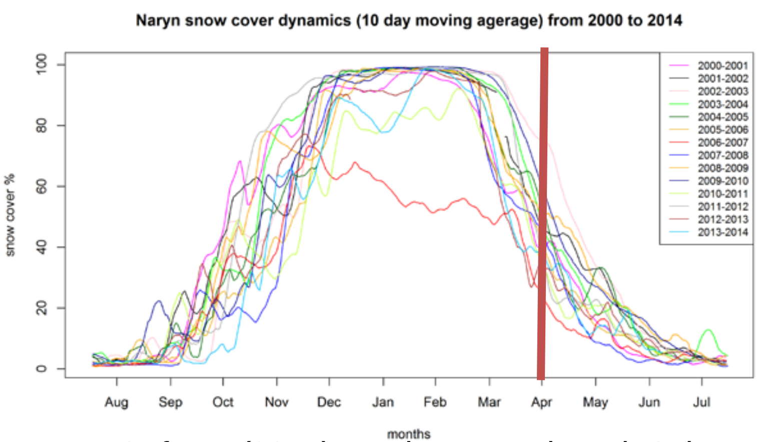
Auswärtiges Amt

- Funded by the German Federal Foreign Office
- Project period 2008-2019
- EU strategy for Central Asia
- Part of the German Water Initiative for Central Asia – the so-called Berlin Process
  - GIZ programme TWMP
  - Research project CAWa
  - German-Kazakh University

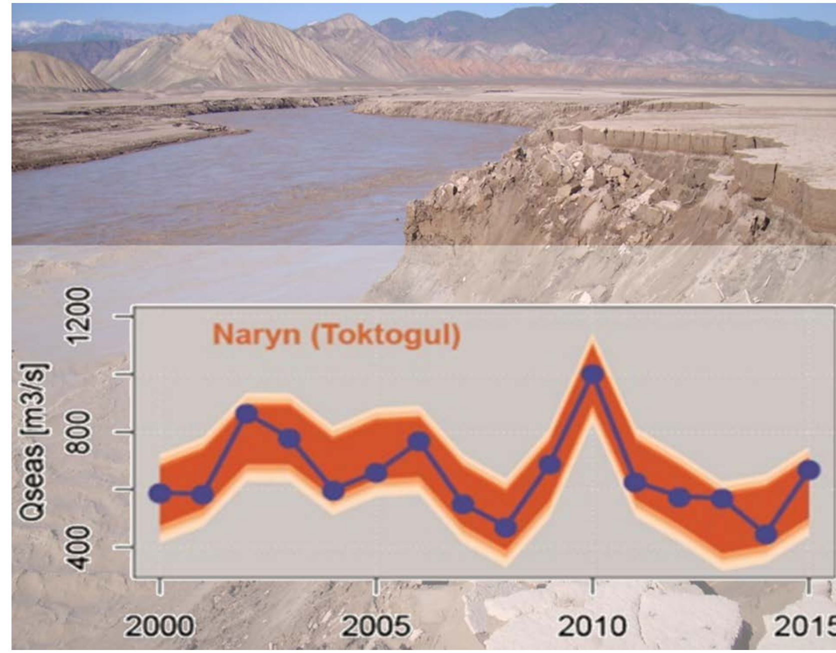
The German Foreign Minister Steinmeier opening the „Water Unites“ Conference in Berlin in April 2008.

Seasonal Runoff Forecast based on Snow Cover Information





Gafurov (2014), Environmental Earth Sciences.



Apel (2017), HESS, under discussion.

- Mean seasonal runoff in Central Asian catchments can be statistically forecasted based on winter precipitation and temperature and spring snow cover extent (r^2 up to 0.7)

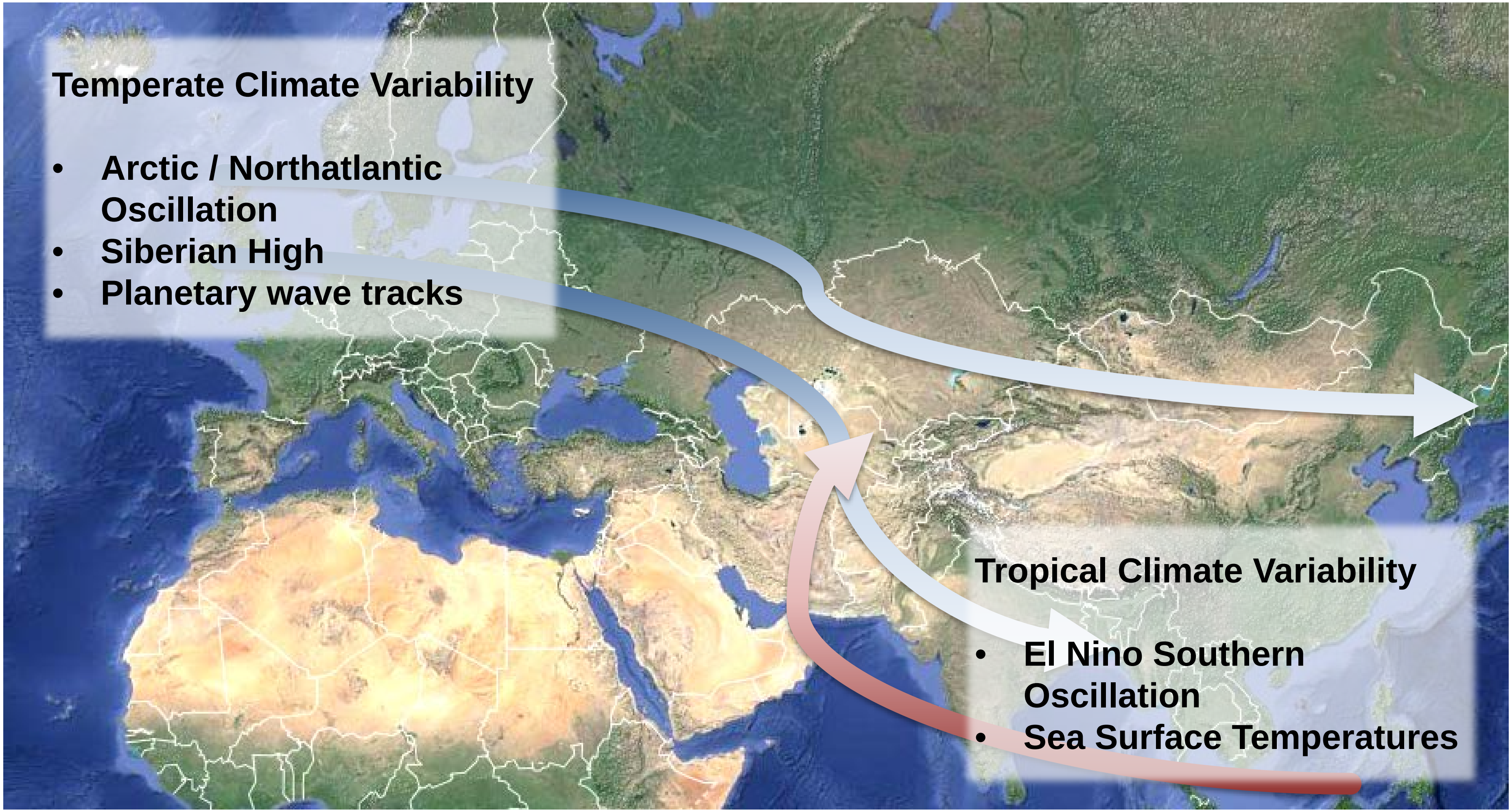
Extension of Leadtime?

- The variability of summer runoff in Central Asian headwater catchments depends on the accumulation of **snow during previous winter and spring season**.
- Seasonal runoff forecast models can be significantly improved by means of remote sensing derived snow cover information
- Suitable snow cover observations are available in late spring

→ **an extension of lead times requires a robust forecast of winter precipitation!**

2. Regression based forecast of seasonal precipitation

Air Masses and Moisture Fluxes



Potential Predictor Variables

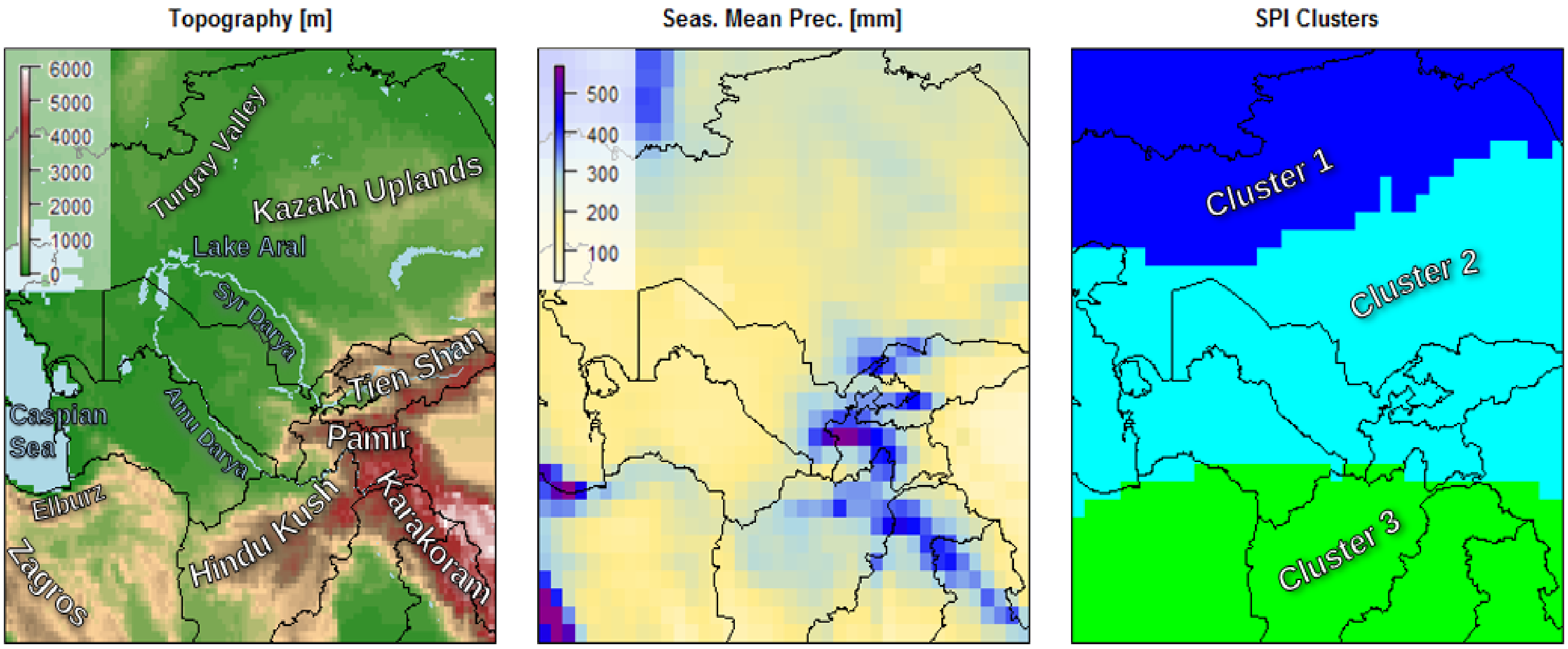
Abbreviation	Definition	Source	Mechanism
AO	Arctic Oscillation	NOAA	W
NAO	North Atlantic Oscillation	NOAA	W
EAWR	East Atlantic / Western Russia Pattern	NOAA	W
EA	East Atlantic Pattern	NOAA	W
SCA	Scandinavian Pattern	NOAA	W
POL/EUR	Polar/Eurasian Pattern	NOAA	W
ATP	Atlantic SST-Tripole	NOAA	W
Eurasia SC	Snow Cover Anomalies over Eurasia	NH-SCE	W
Siberia SC	Snow Cover Anomalies over Siberia (60°W-180°E, 50 N-80 °N)	NH-SCE	W
Europe SC	Snow Cover Anomalies over Europe (20°E-50°E, 30°N-70 °N)	NH-SCE	W
High Asia SC	Snow Cover Anomalies over High Asia (60°W-110°E, 20°N-50°N)	NH-SCE	W
NINO12	Normalized SST in ENSO-12-region (0-10°S, 90-80°W)	NOAA	T
NINO34	Normalized SST in ENSO-12-region (5°N-5°S, 170-120°W)	NOAA	T
NINO4	Normalized SST in ENSO-12-region (5°N-5°S, 160°E-150°W)	NOAA	T
TNI	Trans-Nino-Index, Difference of NINO12 and NINO4	NOAA	T
AMO	American Multidecadal Oscillation	NOAA	W
QBO	Quasi-Biannual-Oscillation	NOAA	W
PDO	Pacific-Decadal-Oscillation	NOAA	T
WP	Normalized SST of Indopacific Warmpool (10°S-10°N, 110-130 °E)	ERSST v03	W/T

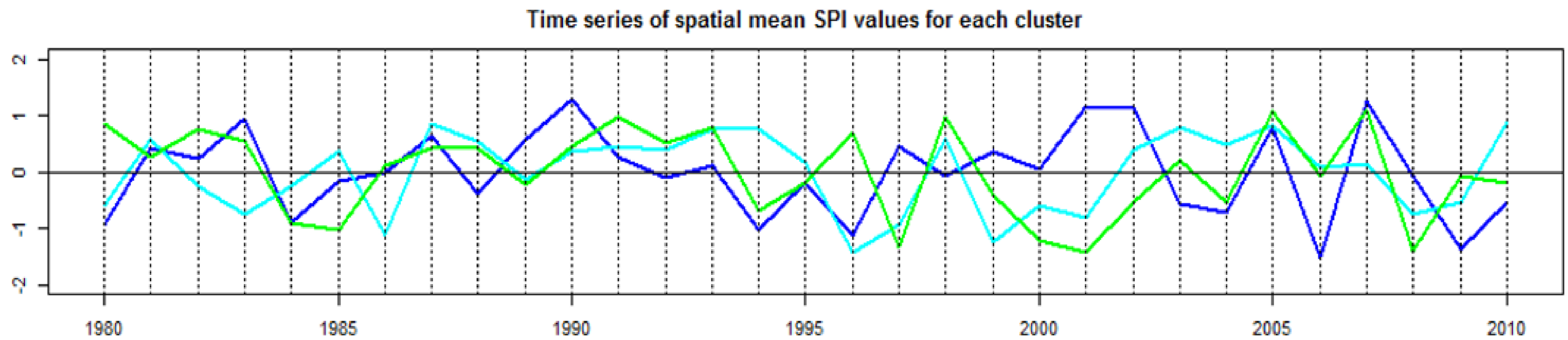
Forecasting Approach

1. Definition of „homogenous regions“ based on gridded precipitation estimates:
   - *Aggregation to seasonal precipitation sums (Nov-Mar)*
   - *Cellwise Normalization (SPI)*
   - *Bootstrap-k-means-clustering of anomalies*

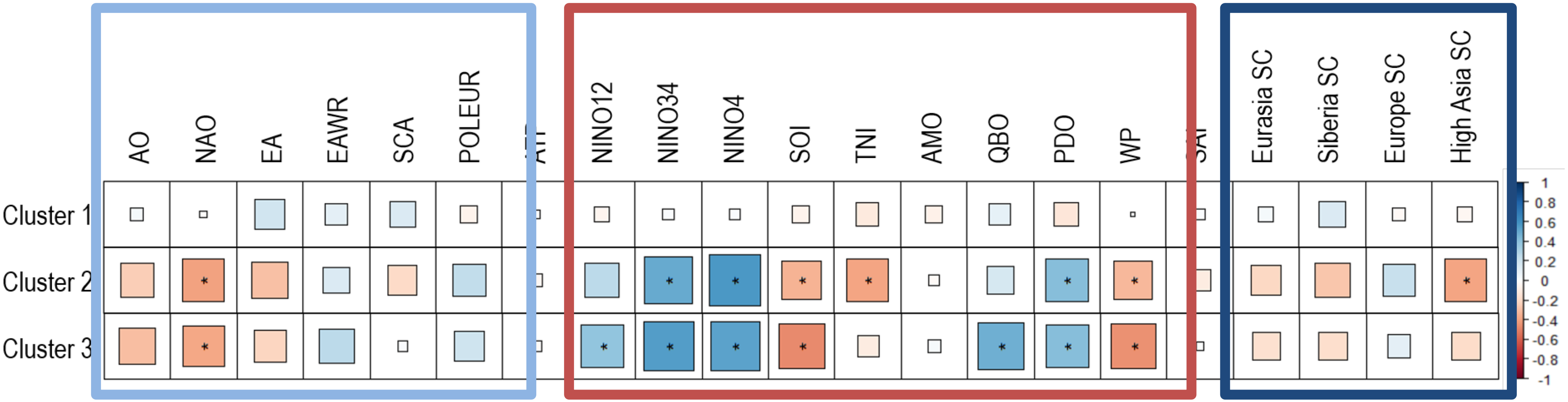
2. Stepwise Linear regression for each cluster region
   - *Predictor selection based on a stepwise approach including foreward selection and backward elimination*
   - *Full cross-validation (including predictor selection and regression calibration)*
   - *Uncertainty estimation based on normal distributed residuals of the cross-validated hindcast*

Nov-Mar SPI time series for Central Asian subregions [ERA Interim/Land]





Correlations of seasonal SPI with potential predictor variables in October



- No significantly correlated predictors for sub-region 1 (no forecast skill)
- Strong positive correlations with ENSO related variables for regions 2 and 3
- Negative response to Eurasion / High Asian snow cover
- Some lagged correlations with Northern Hemispheric circulation indices (partially correlated with ENSO…)

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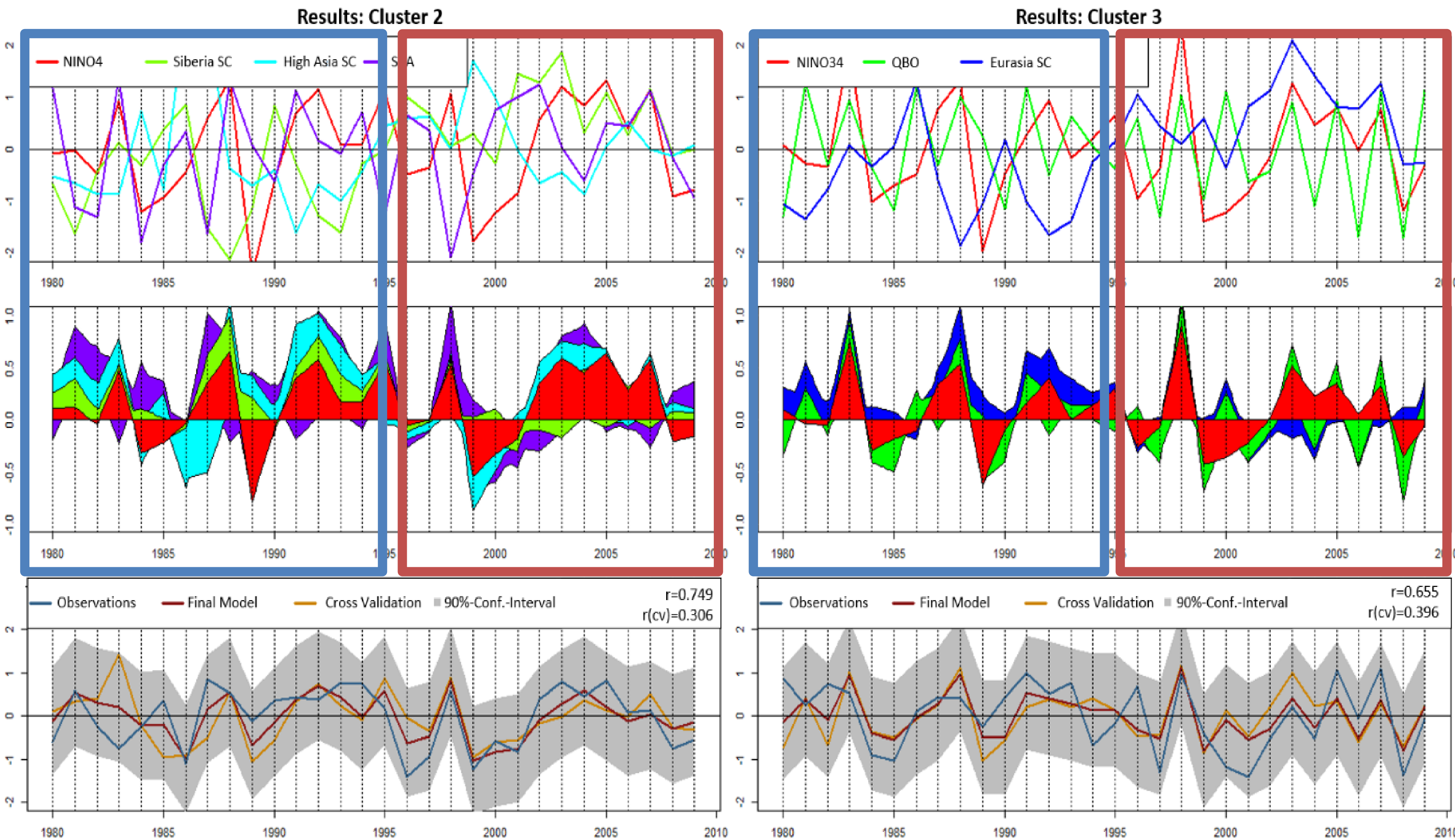
Regression Results (Hindcast)



Conclusions I

- ENSO is selected as the major predictor for both Central Asian regions
- Seasonal precipitation sums react negatively to Eurasian Snow cover extent in October
- Model results indicate a (slight) negative response to increasing snow cover rates after 1995
- For sub-region 3 (Southern CA) a positive response to variations of QBO is detected.
- Forecast results are very moderate, though better than climatology with correlations of observations and cross-validated hindcast results between r=0.3 and r=0.4

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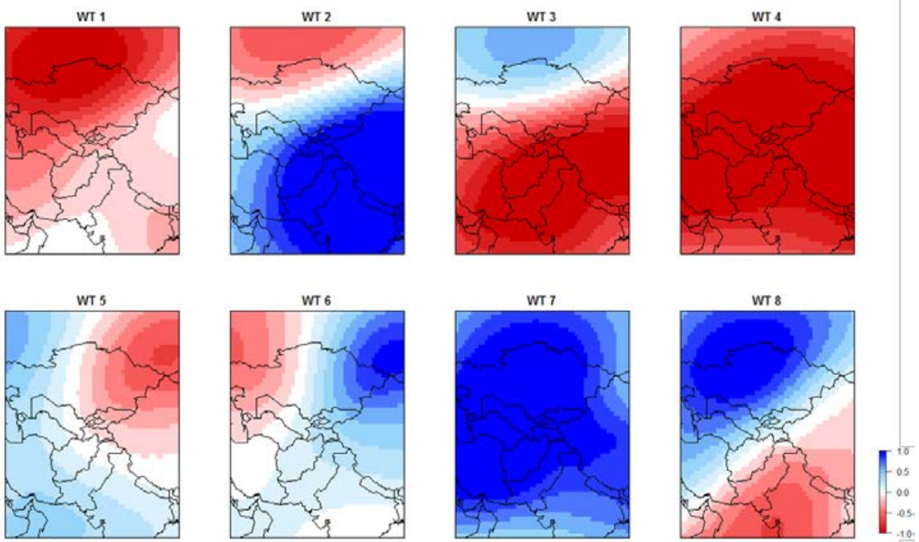
2. Analysis of weather types over Central Asia

Definition of Nov-Mar Weather Types

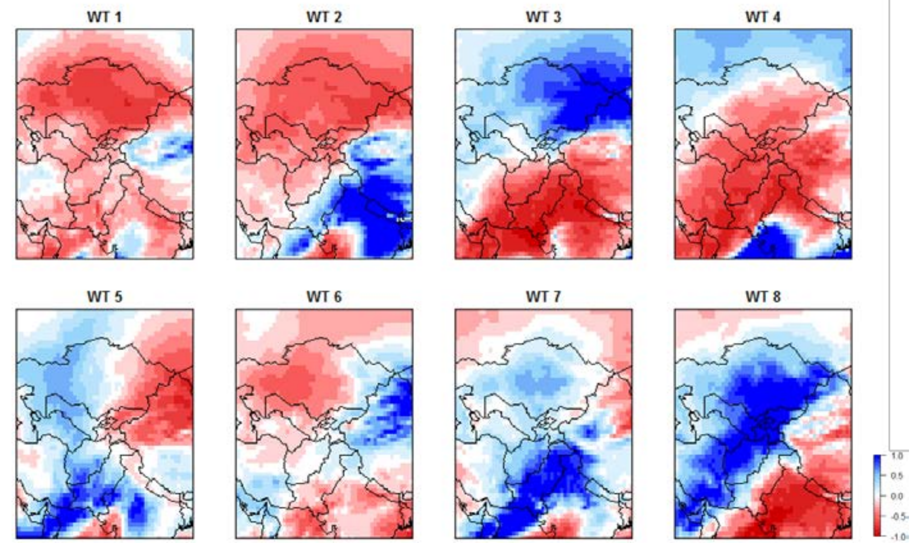
- **Data:**
  - *Normalized 6-hourly 500 hPa Geopotential Height fields for 20°N-60°N/50°E-90°E*
  - *EOF based data transformation (retaining 95% of variance)*

- **Classification:**
  - *1000-fold application of k-means clustering for k=1 to k=20*
  - *The „best“ cluster solution for each k is identified as the one with highest mean anomaly correlation with all other solutions*
  - *A reasonable k is identified by comparing the Classifibility Index of each k with a 95% confidence interval of 1000 artificial ARIMA records*

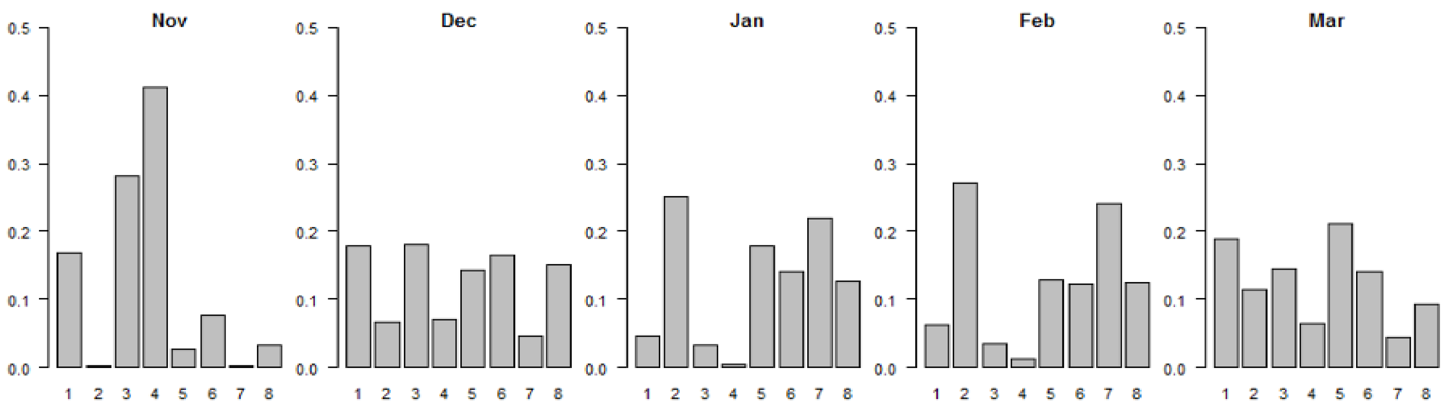
Weather types (8) and precipitation anomalies



Cluster Centroids for 8 WTs (z-normalized GPH 500)

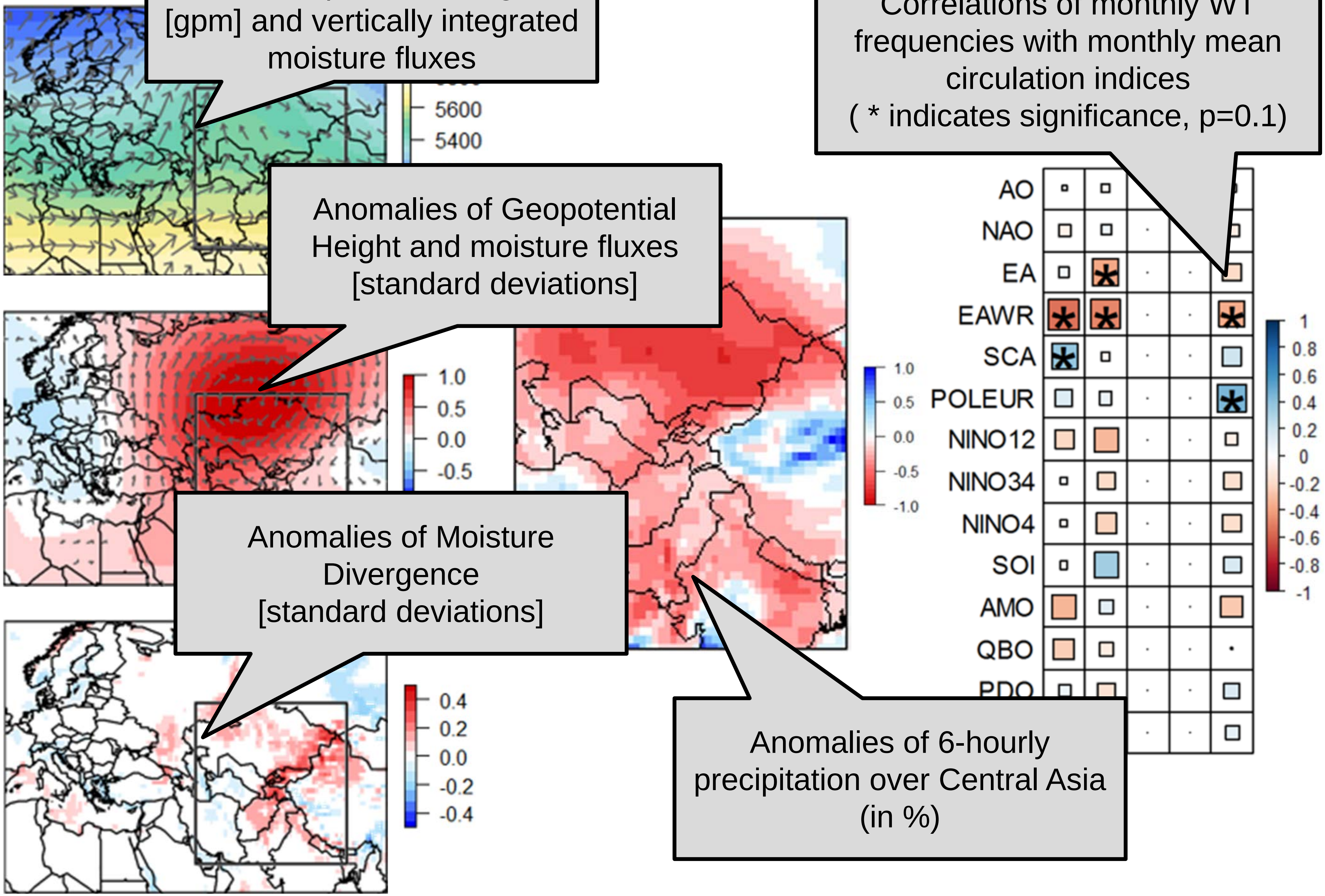


Precipitation composites for each WT (anomaly in percent of the seasonal 6h precipitation mean)

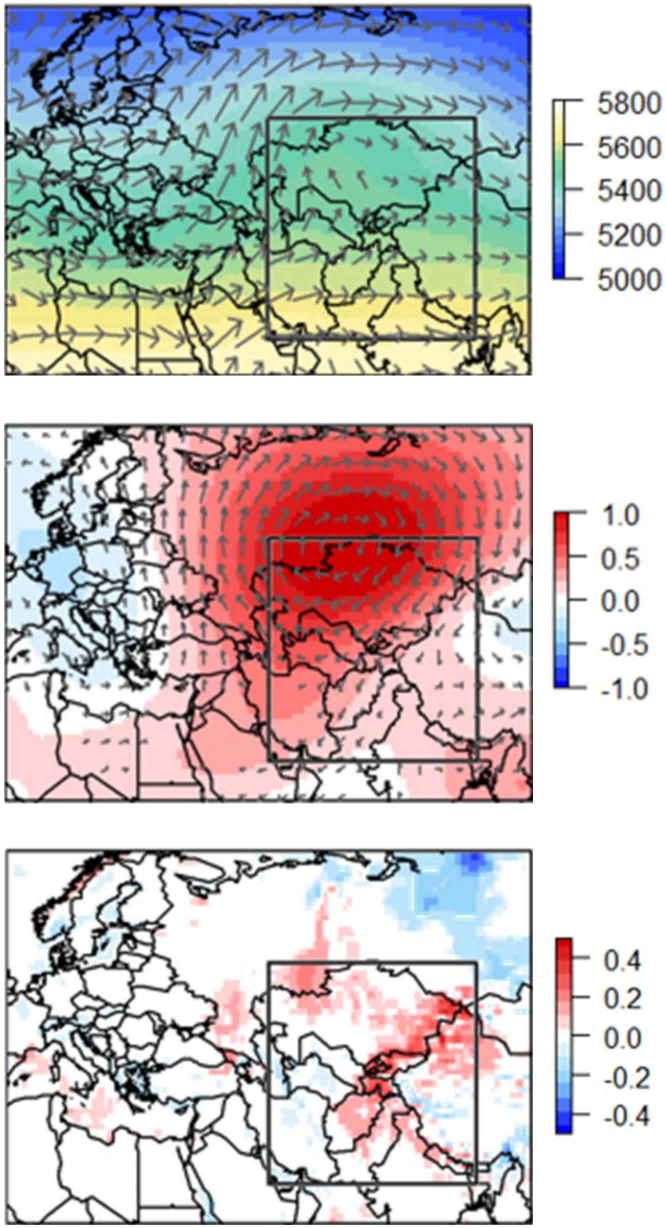


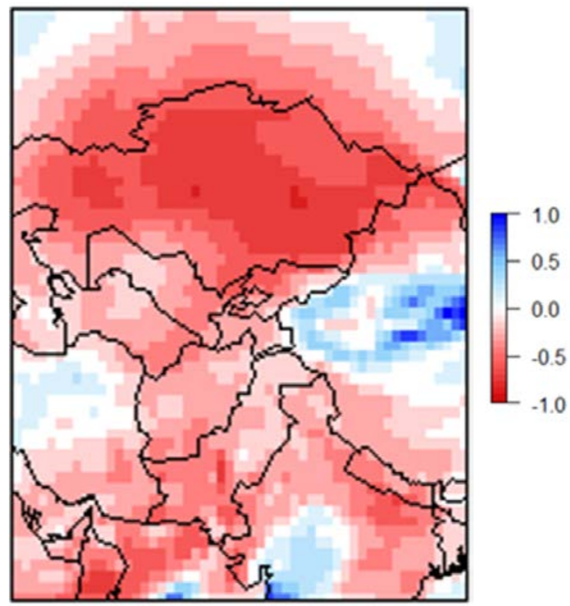
Mean monthly frequency for each WT

WT 1


Large scale composite of 500 hPa Geopotential Height [gpm] and vertically integrated moisture fluxes
5600
5400
Correlations of monthly WT frequencies with monthly mean circulation indices
(* indicates significance, p=0.1)
Anomalies of Geopotential Height and moisture fluxes [standard deviations]
1.0
0.5
0.0
-0.5
Anomalies of Moisture Divergence [standard deviations]
0.4
0.2
0.0
-0.2
-0.4
1.0
0.5
0.0
-0.5
-1.0
Anomalies of 6-hourly precipitation over Central Asia (in %)
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 1


5800
5600
5400
5200
5000
1.0
0.5
0.0
-0.5
-1.0
0.4
0.2
0.0
-0.2
-0.4


1.0
0.5
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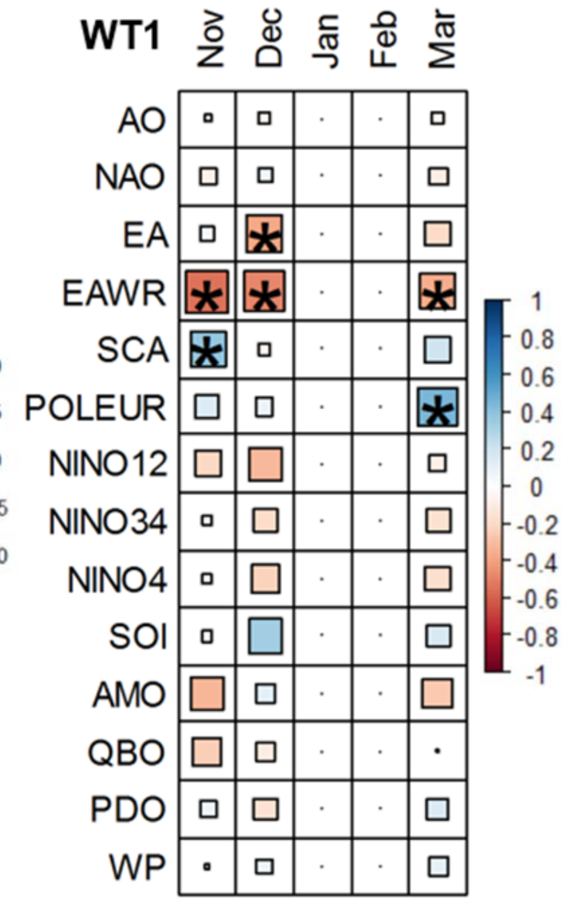
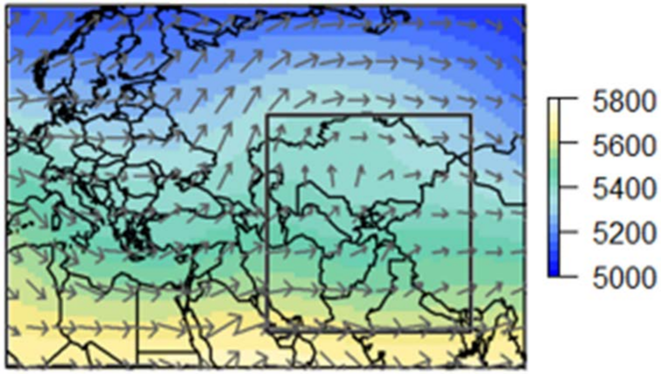
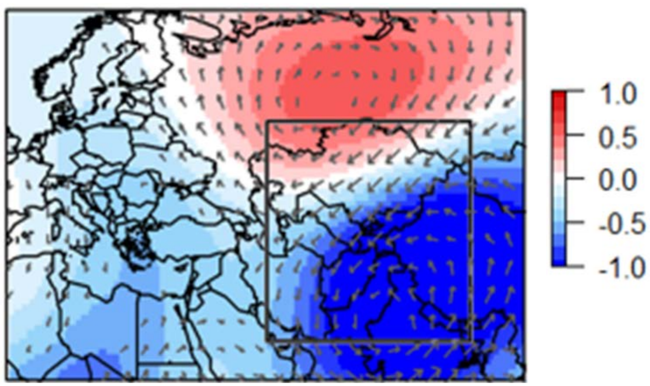
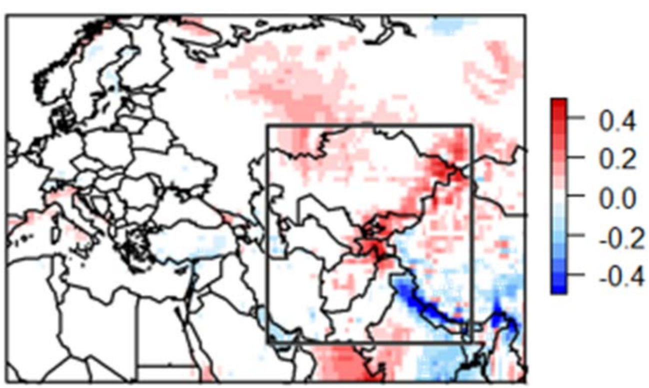
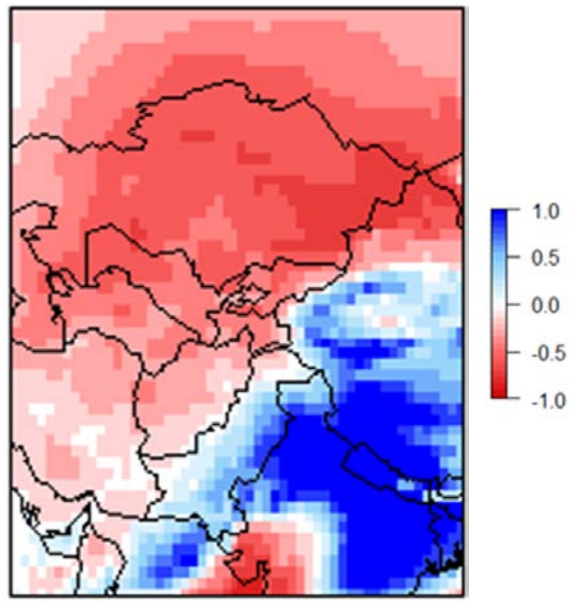

WT1
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 2


5800
5600
5400
5200
5000


1.0
0.5
0.0
-0.5
-1.0


0.4
0.2
0.0
-0.2
-0.4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0.5
0.0
-0.5
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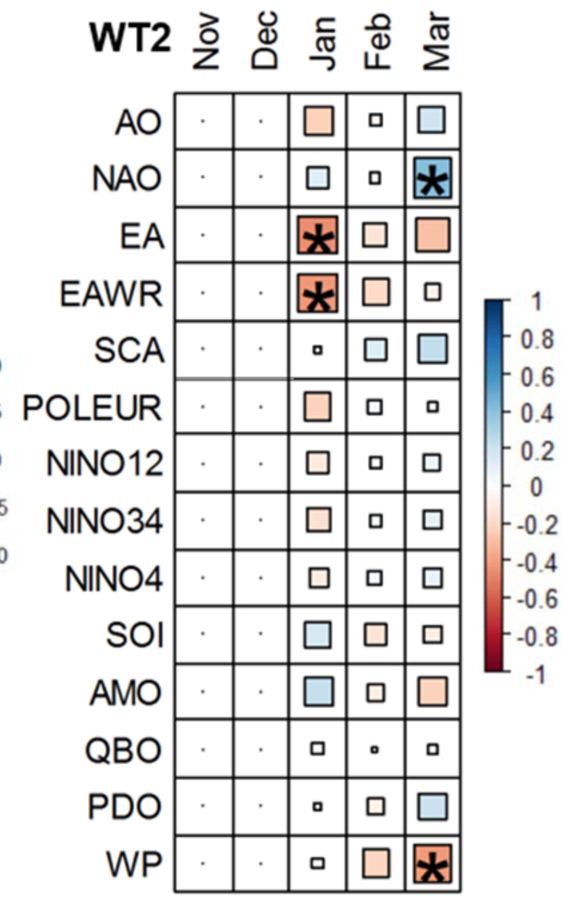
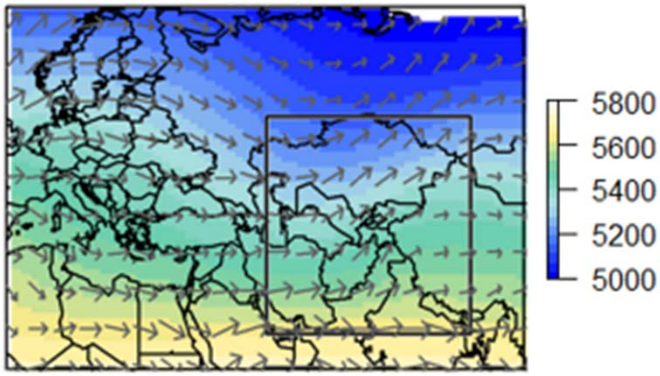

WT2
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 7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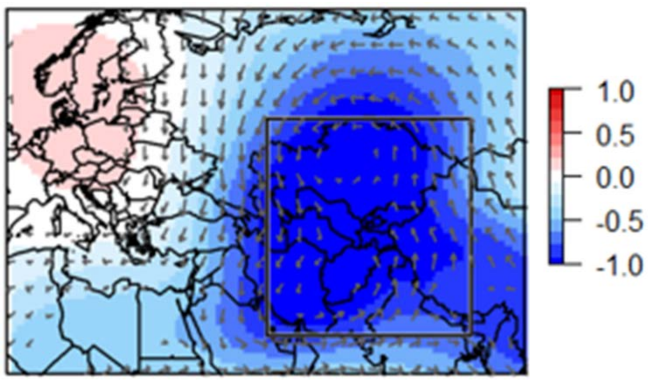
1.0
0.5
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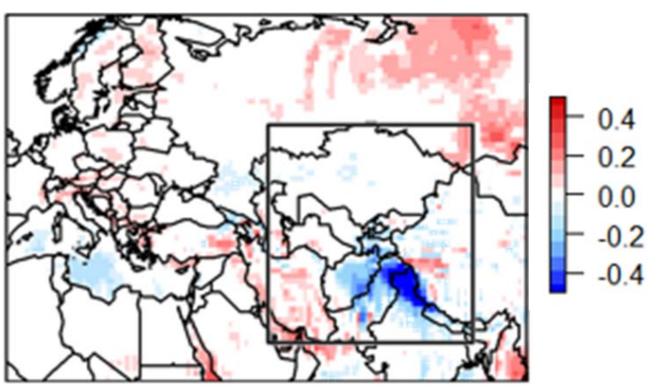
-0.5
-1.0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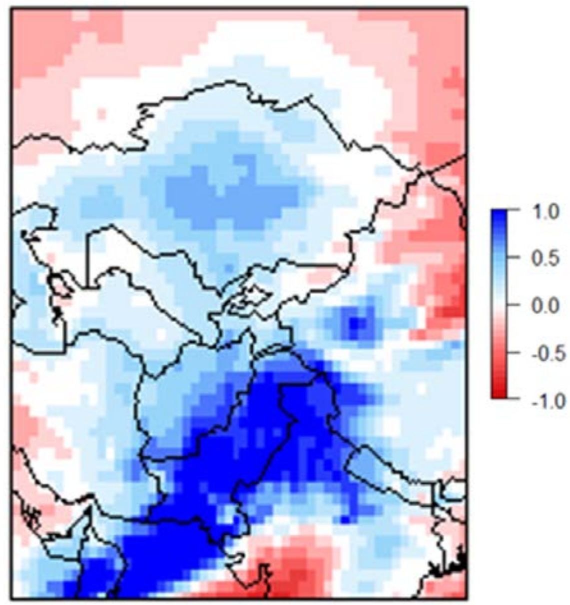
0.2
0.0
-0.2
-0.4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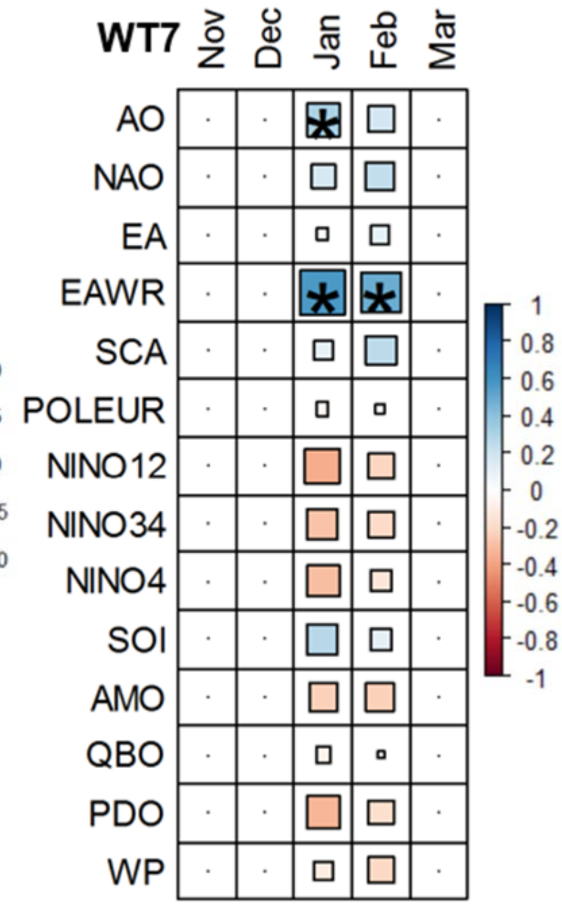
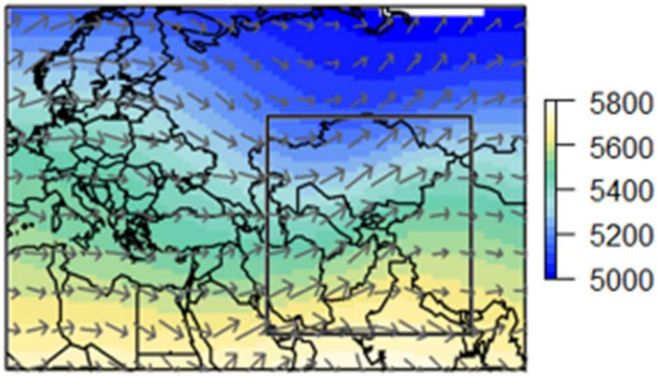
-0.5
-1.0


WT7
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 8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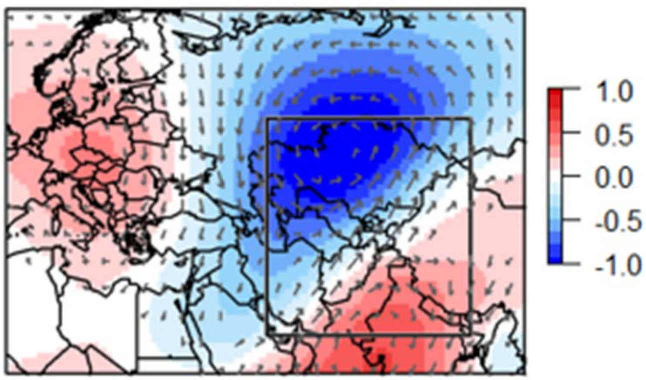
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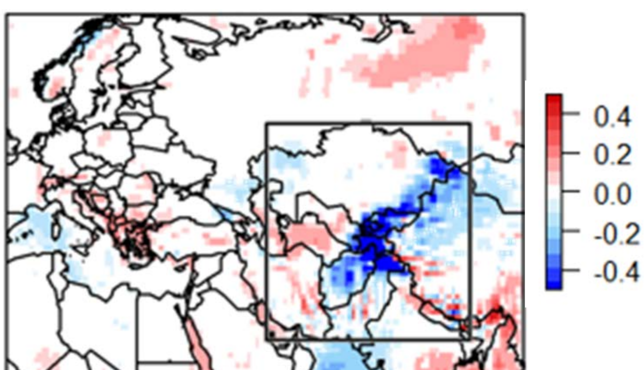
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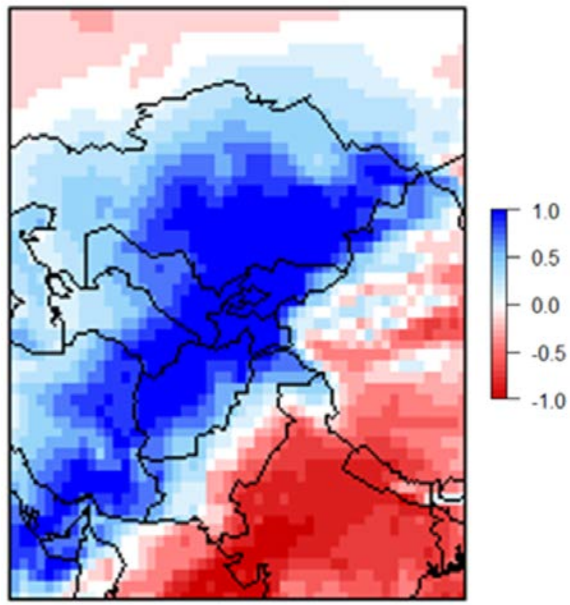
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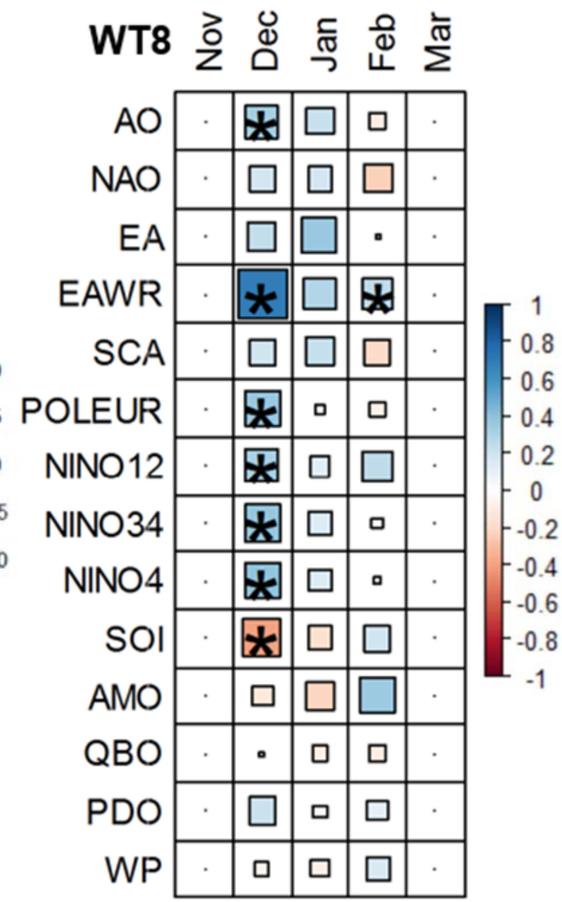
WT8
Nov
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QBO
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WP
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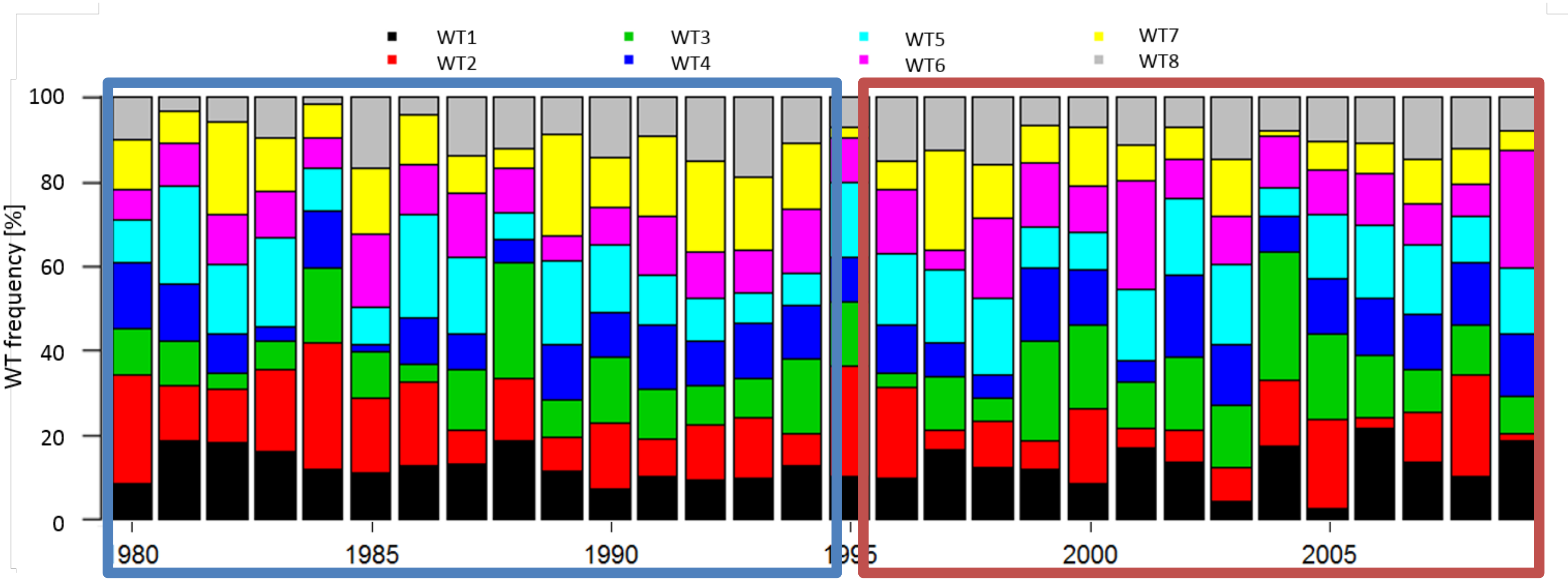
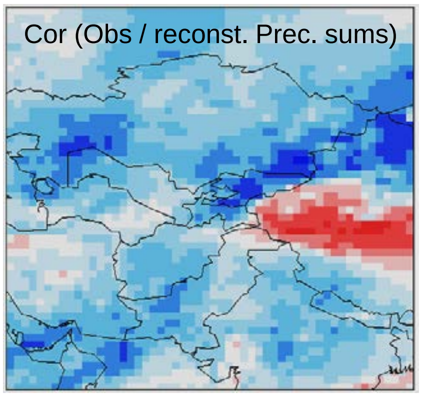
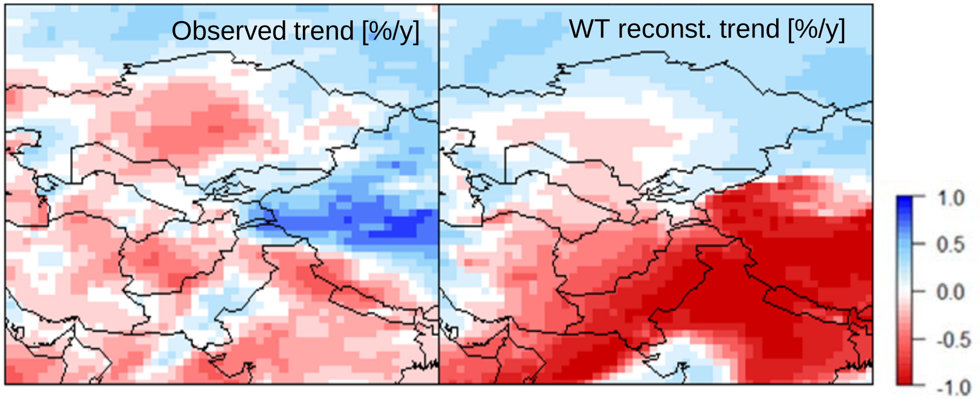
-0.8
-1

Inter-annual variability of WT frequency







Correlation between observed and WT based hypothetical precipitation (left) and trends of observed and hypothetical precipitation sums (right)

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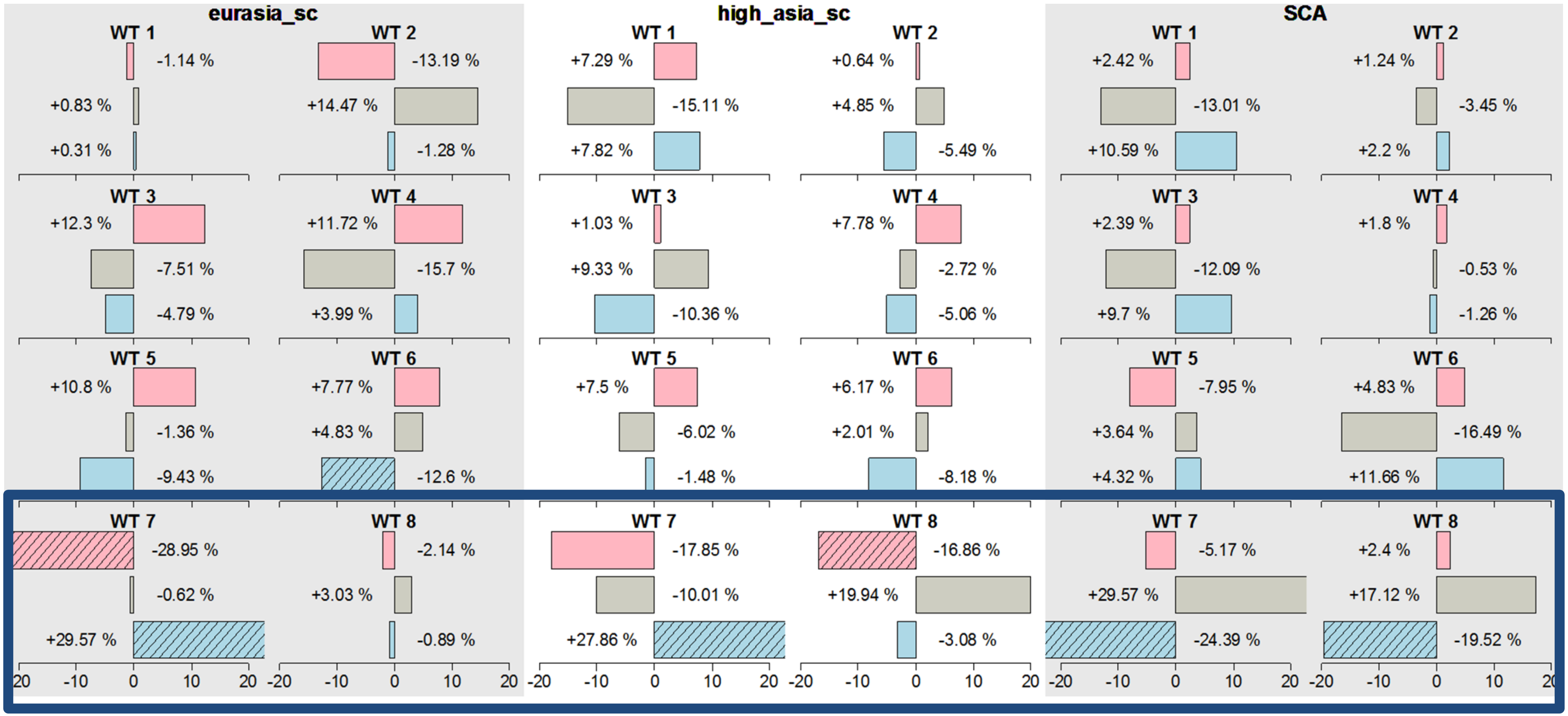
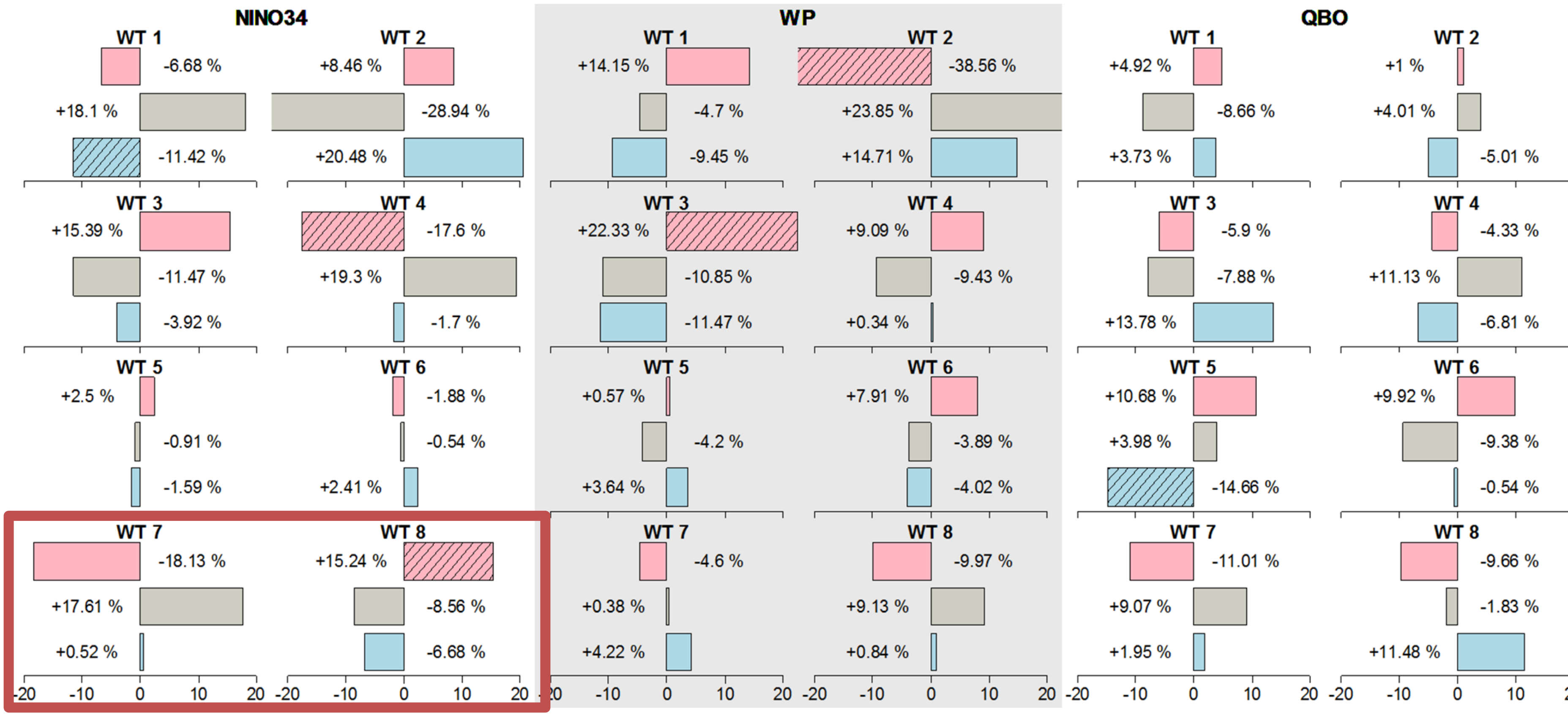
Influence of predictor variables on WT frequencies (1)



Percentage anomalies of seasonal WT frequencies preceded by anomalous conditions of selected predictors. Blue bars include seasons preceded by values below the 33%-quantile of the considered index, red bars indicate values above the 66%-quantile. Significant (p=0.1) anomalies are striped.

Influence of predictor variables on WT frequencies (2)



Percentage anomalies of seasonal WT frequencies preceded by anomalous conditions of selected predictors. Blue bars include seasons preceded by values below the 33%-quantile of the considered index, red bars indicate values above the 66%-quantile. Significant (p=0.1) anomalies are striped.

Conclusions II

- Weather patterns over Central Asia represent both, Northern Hemispheric Rossby tracks and tropical circulation modes
- Winter El Nino is associated with anti-cyclonic circulation anomalies over South Asia, enhancing moisture fluxes into Central Asia
- Moist conditions in Central Asia are triggered by a superposition of positive states of the Arctic Oscillation and the East Atlantic/Western Russia pattern.
- The frequencies of associated WTs are significantly reduced, if autumn snow cover is high, most likely due to a negative response of AO.
- Recent negative precipitation trends over Central Asia might be triggered by recovery of Eurasian snow cover after 1995

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Thanks a lot for your Attention ☺

contact: lars.gerlitz@gfz-potsdam.de

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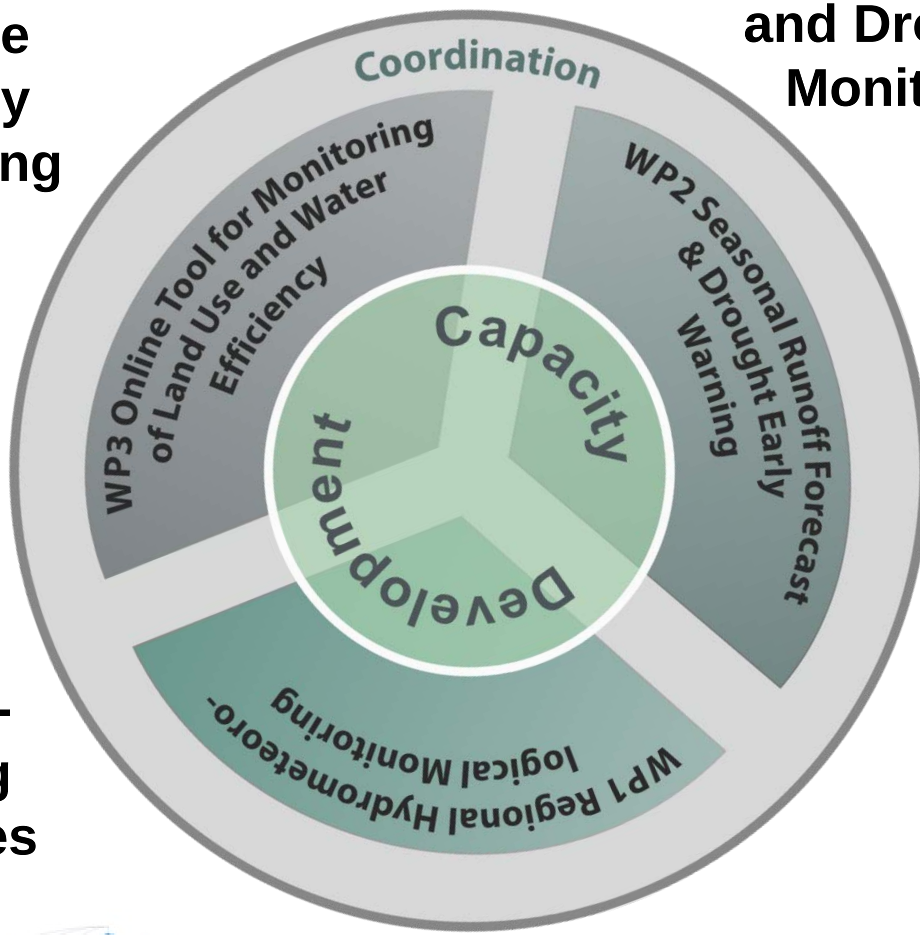
Topics and Partners

WP 3: Space-based land and water use efficiency monitoring

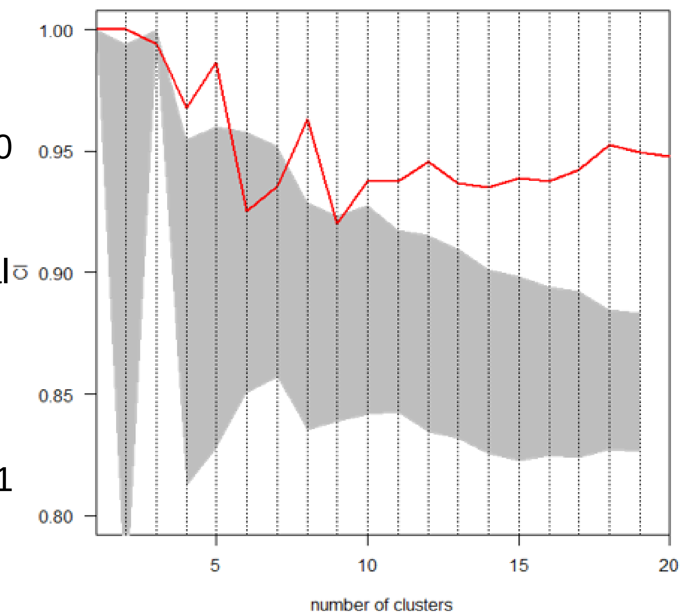
WP 2: Seasonal Runoff Forecast and Drought Monitoring

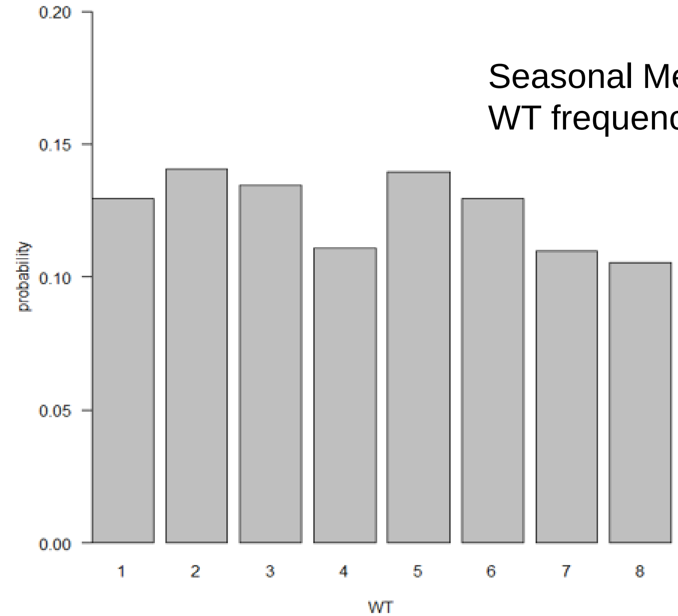


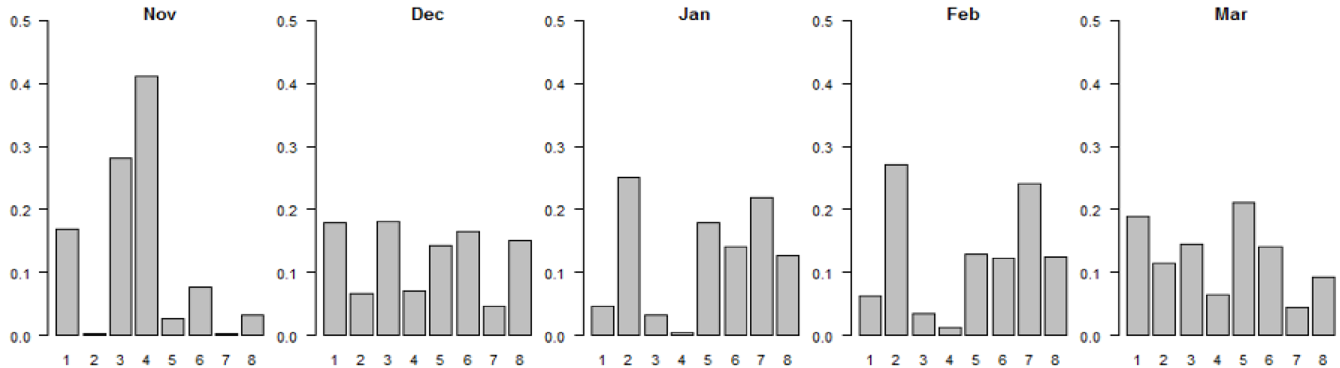
WP 1: Ground-based and space-based monitoring of water resources

Weather types (8) and precipitation anomalies

Classifiability Index for original GPH data with k=1 to 20 clusters (red line) and the CI confidence interval derived from 1000 artificial ARIMA records, retaining mean, standard deviation and lag-1 autocorrelation

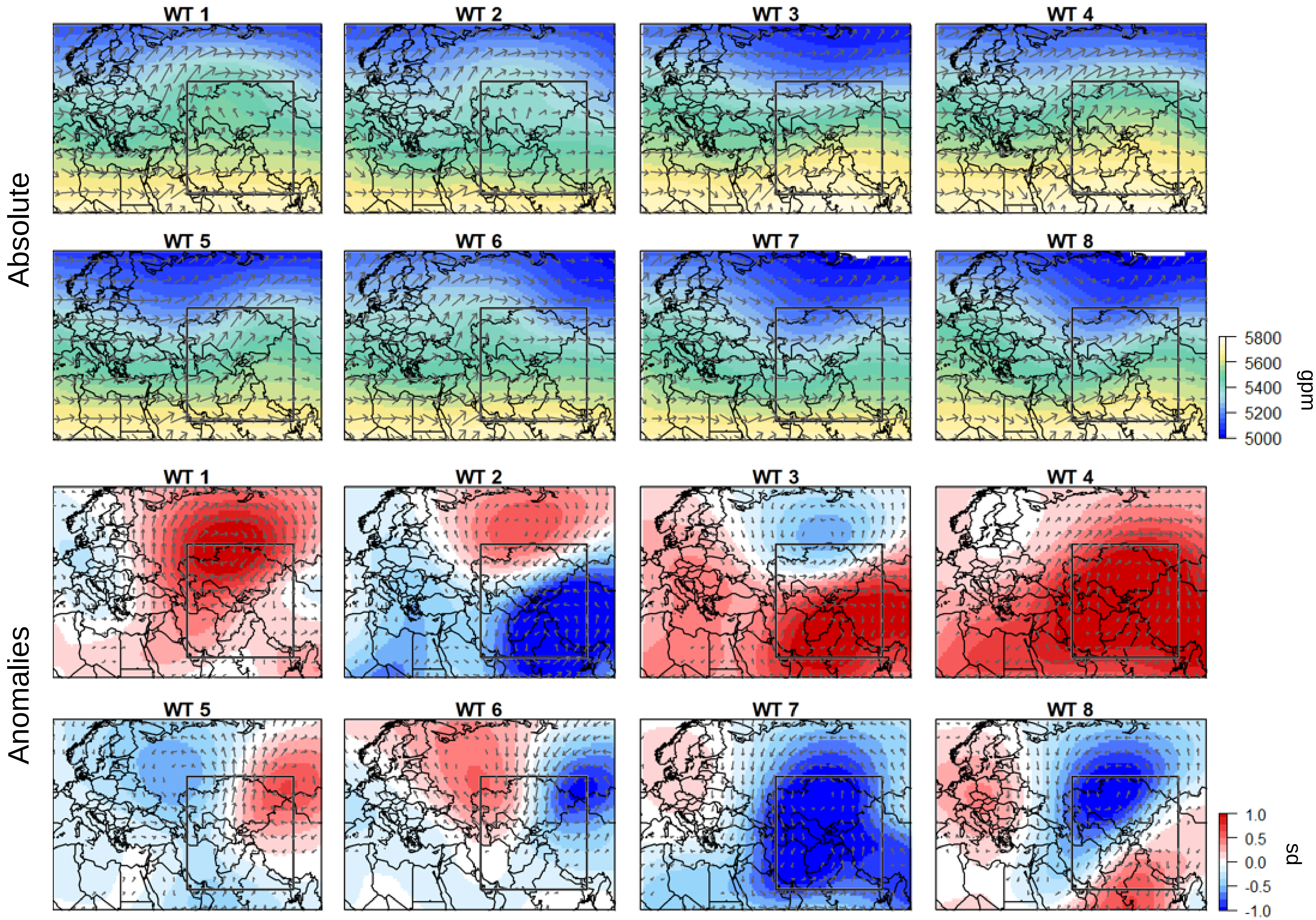




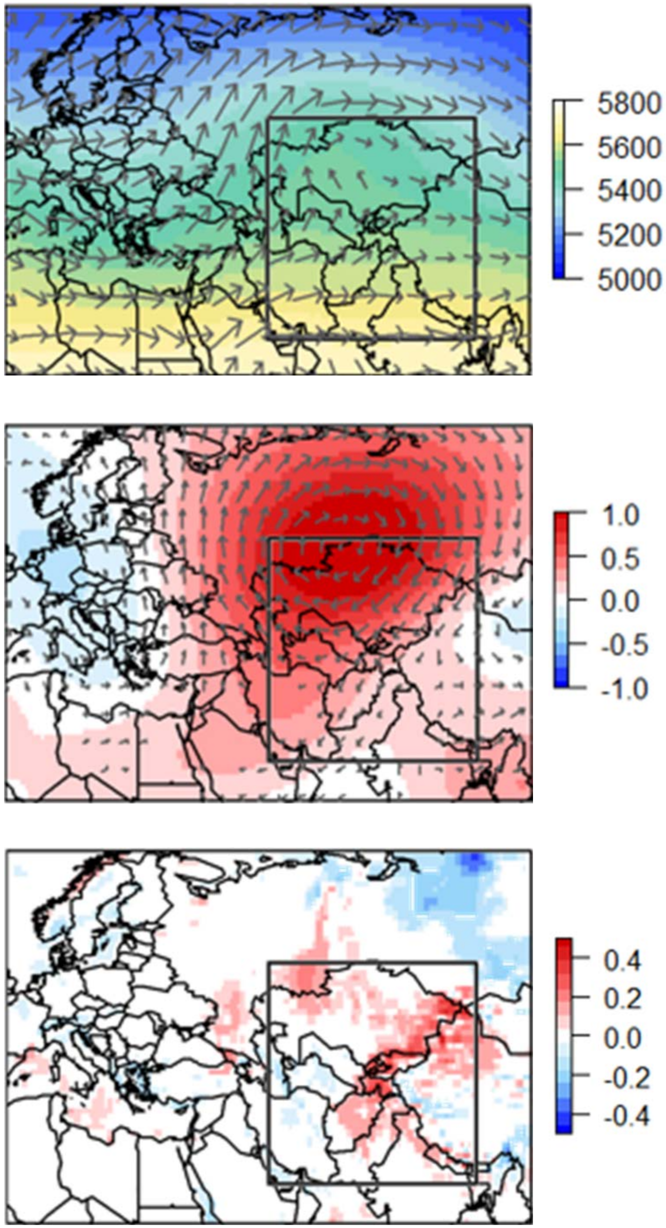


Mean monthly frequency for each WT

Large scale composites of GPH and Moisture Fluxes



WT 1



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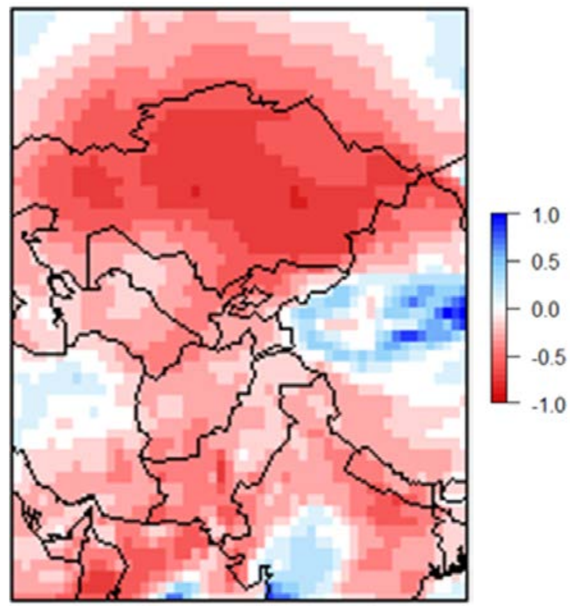

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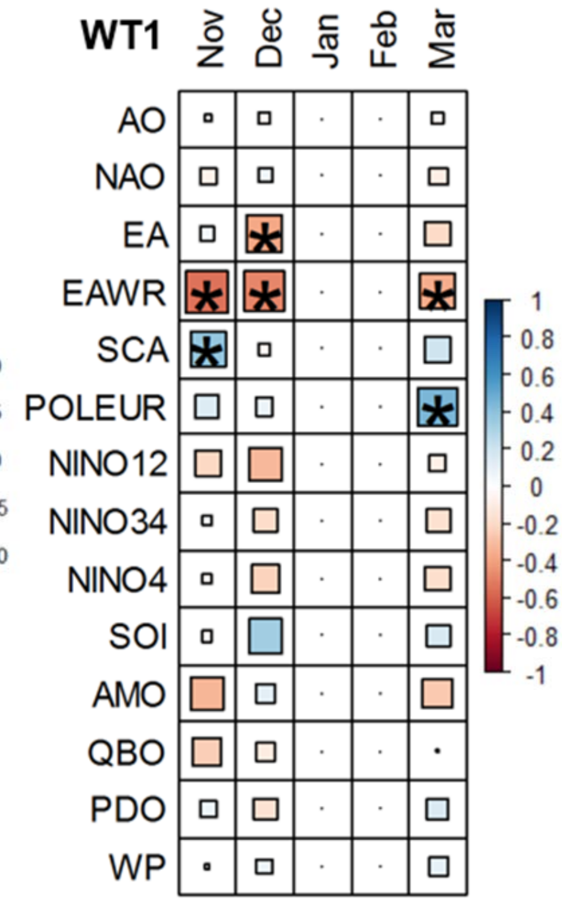
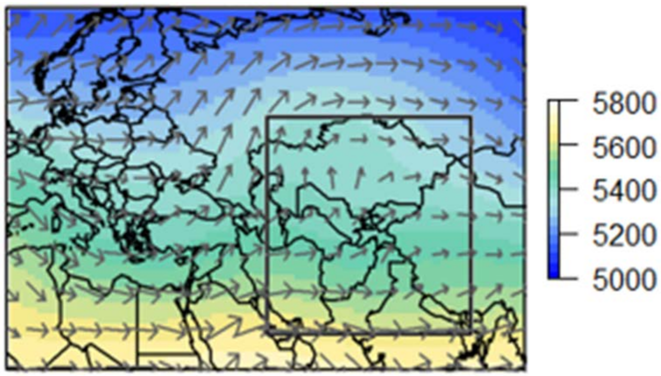


WT1
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 2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5400
5200
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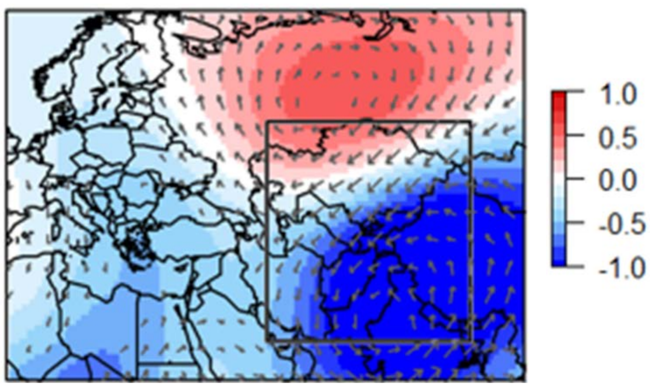
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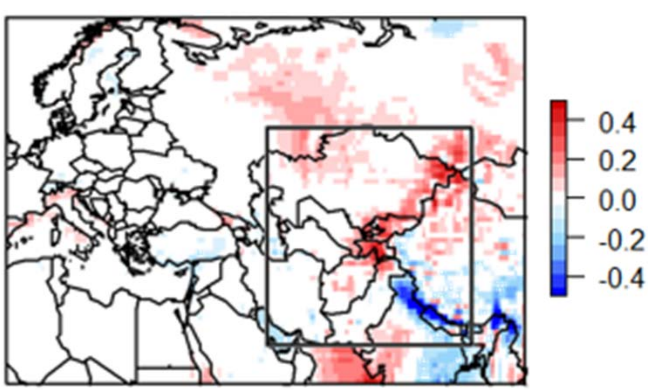
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0.2
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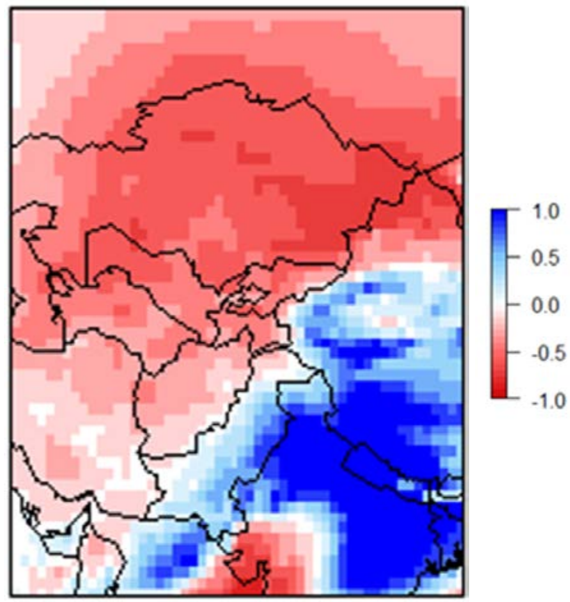
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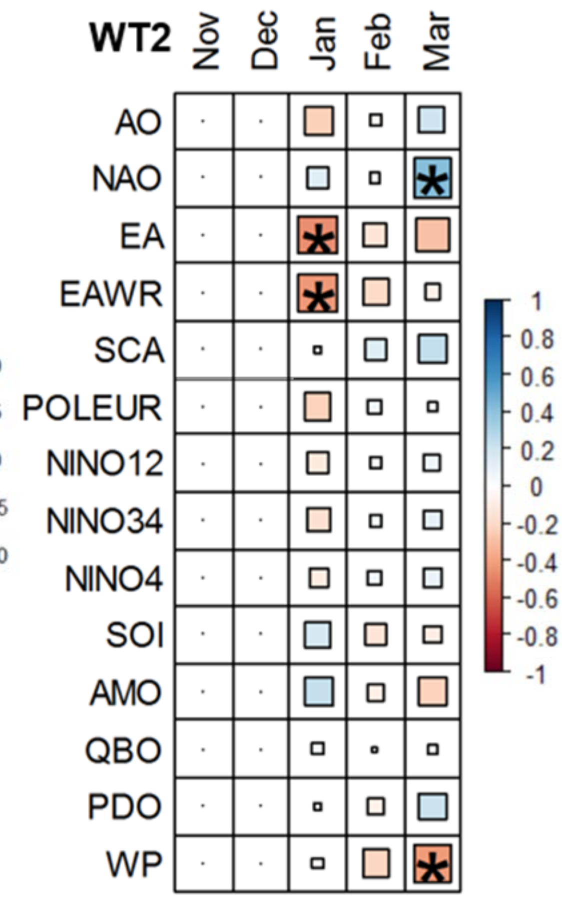
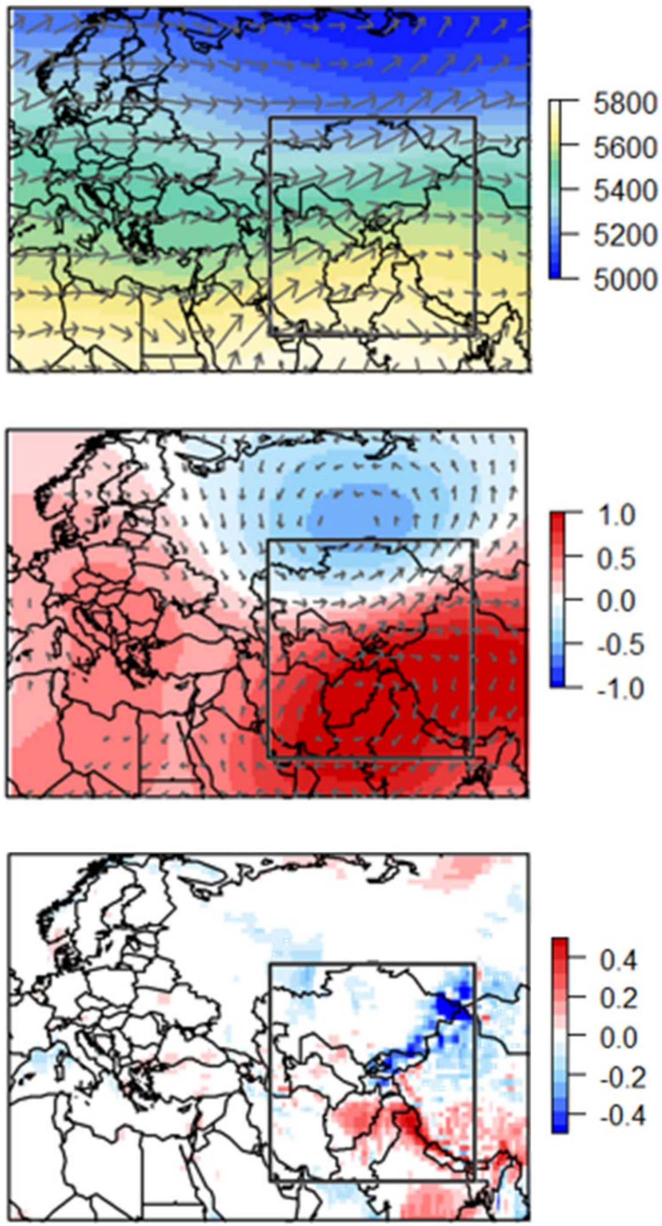
-1.0


WT2
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 3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5600
5400
5200
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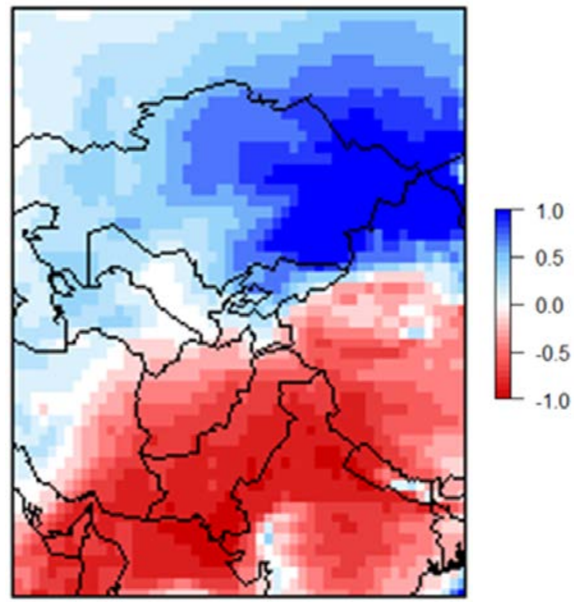
0.5
0.0
-0.5
-1.0
0.4
0.2
0.0
-0.2
-0.4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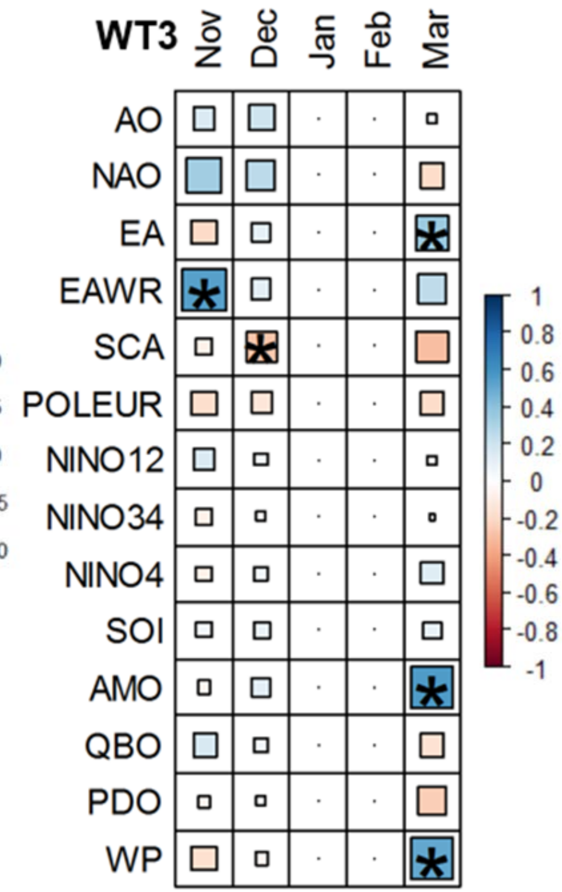
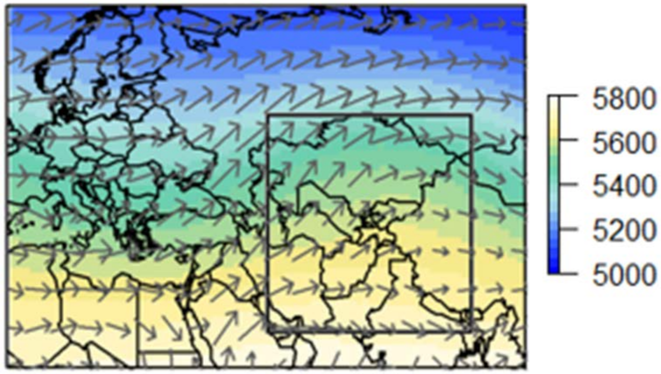

WT3
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 4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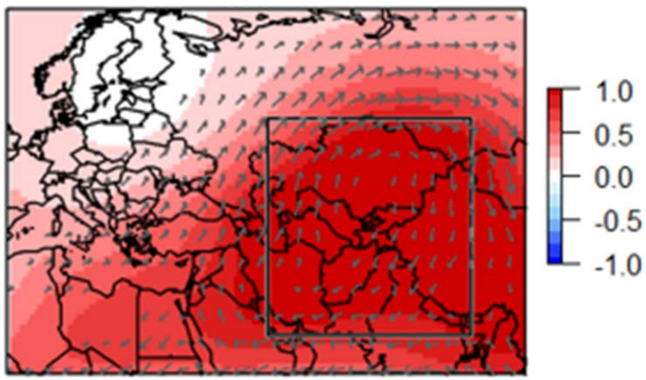
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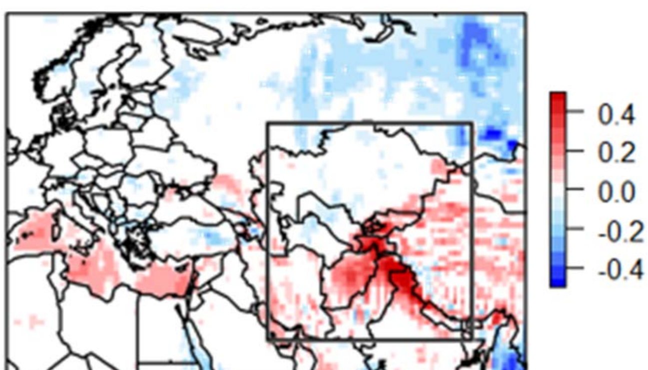
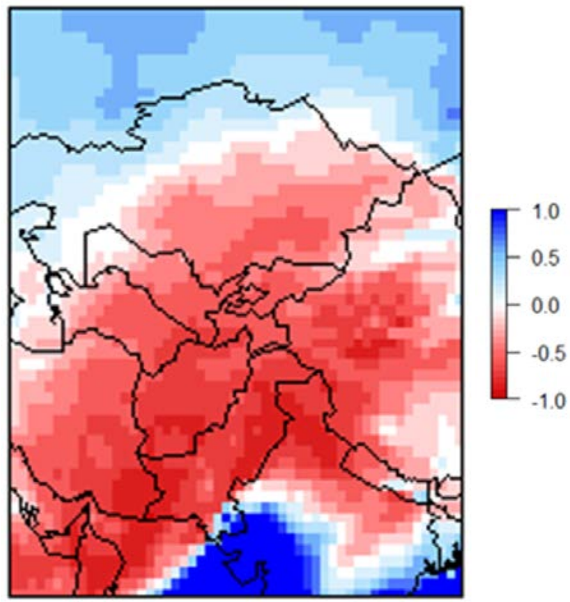

0.4
0.2
0.0
-0.2
-0.4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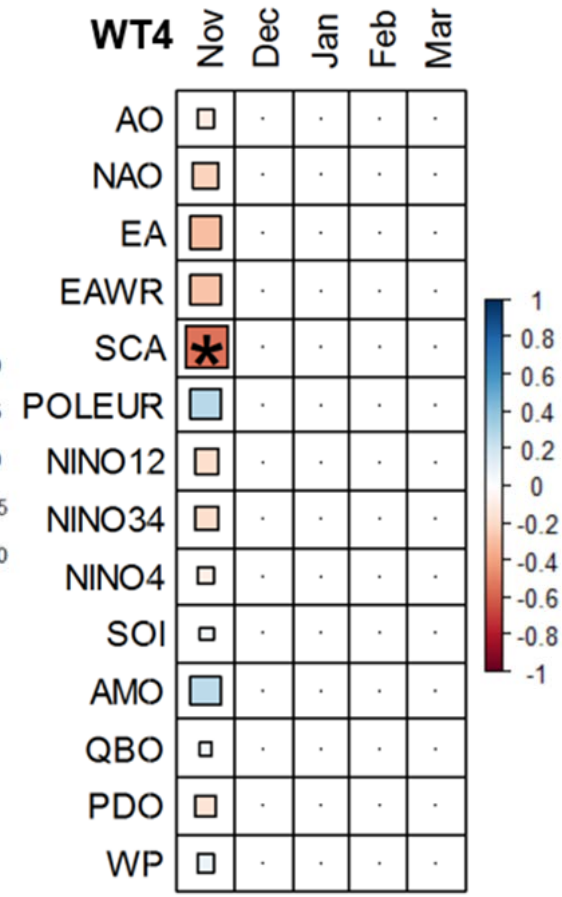
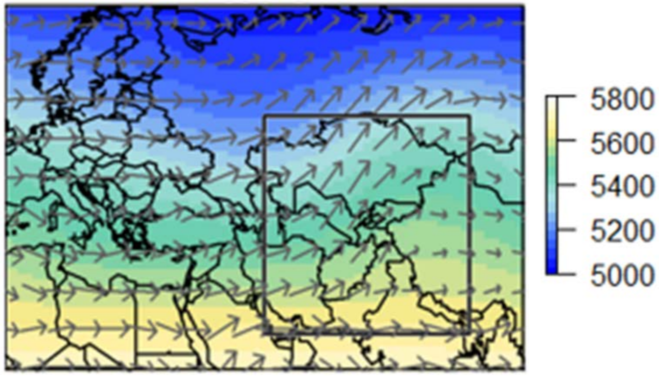
-1.0


WT4
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
*
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 5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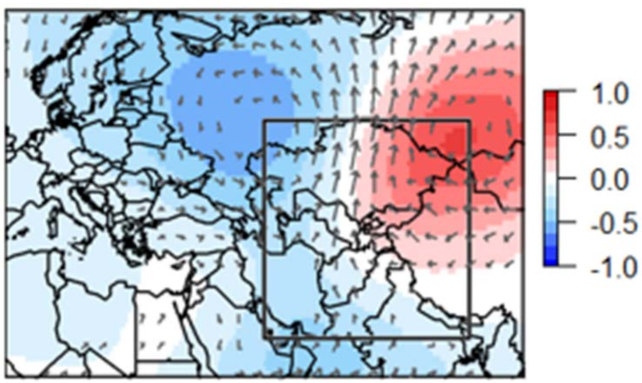
5600
5400
5200
5000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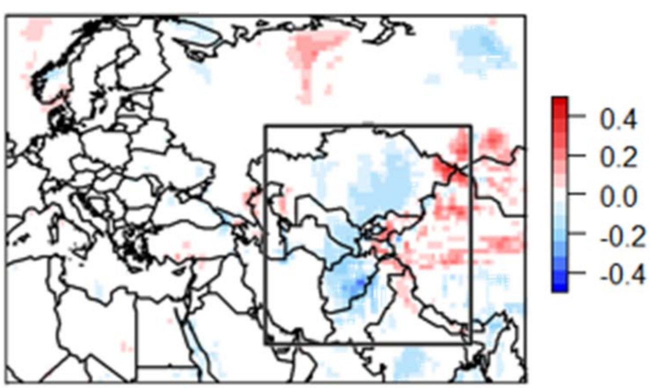
0.4
0.2
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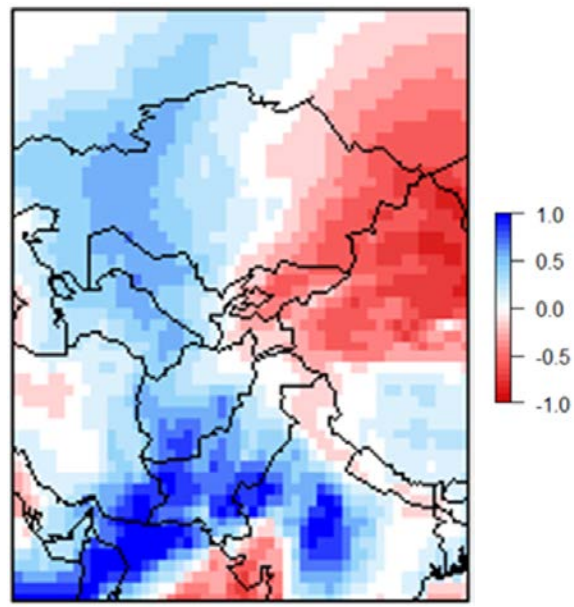
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0.5
0.0
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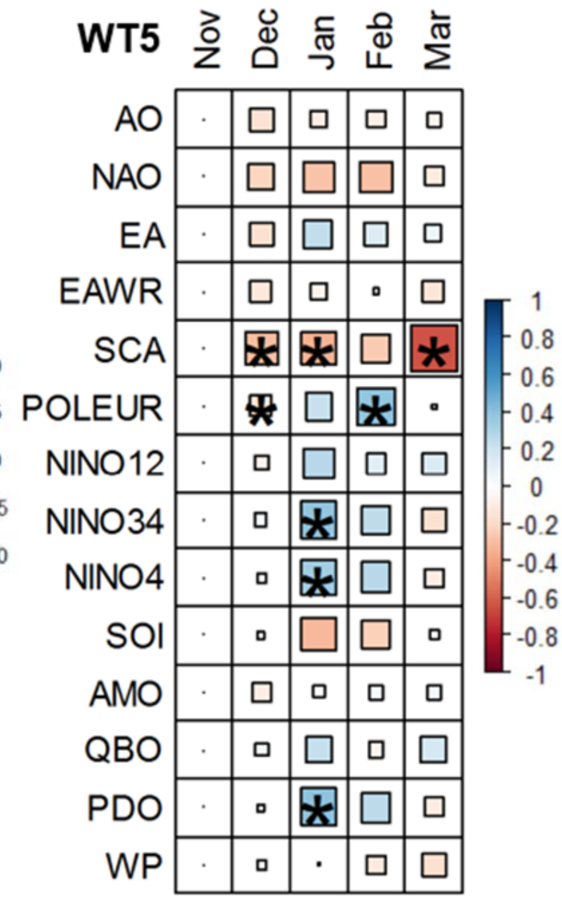
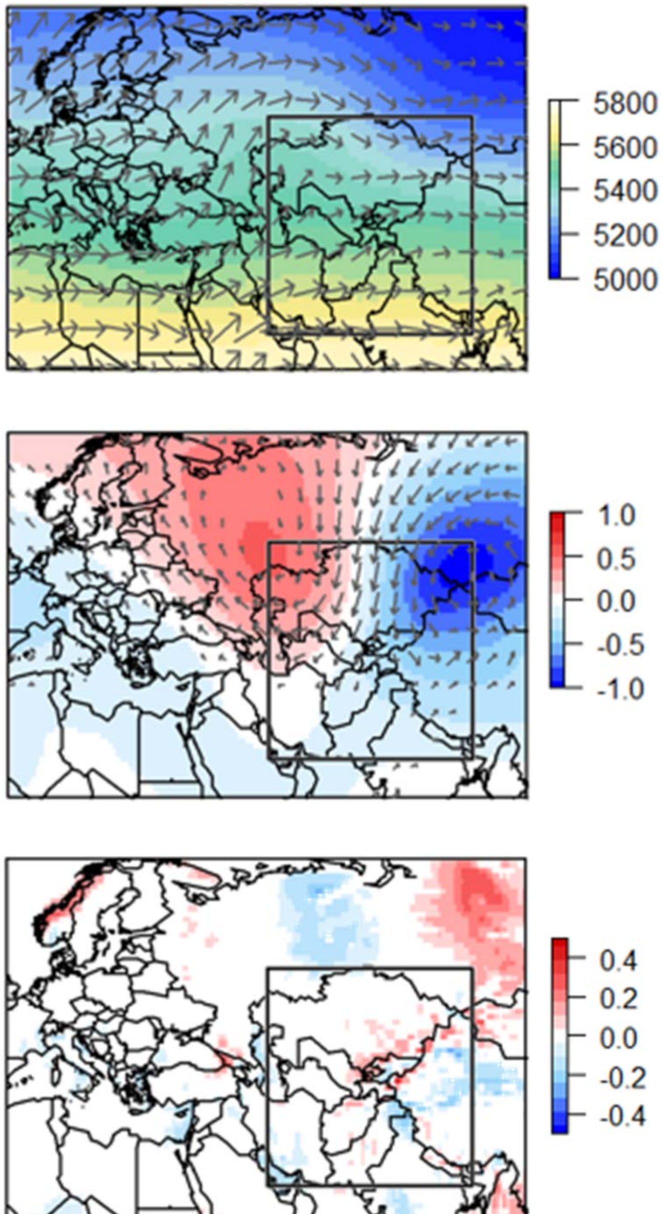
-1.0


WT5
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 6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5600
5400
5200
5000
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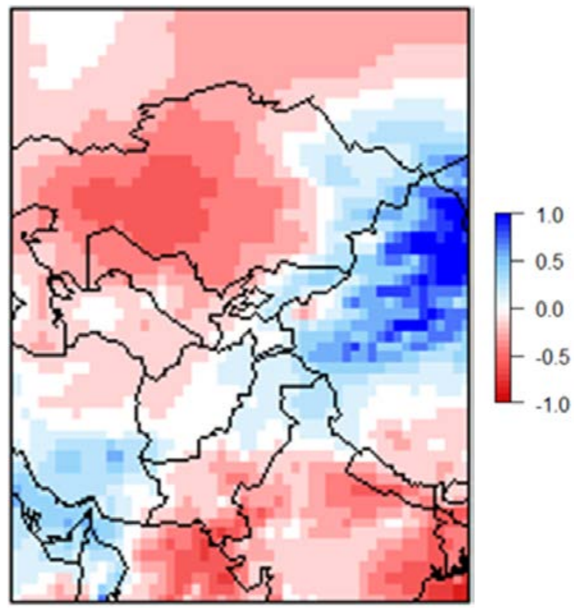
0.5
0.0
-0.5
-1.0
0.4
0.2
0.0
-0.2
-0.4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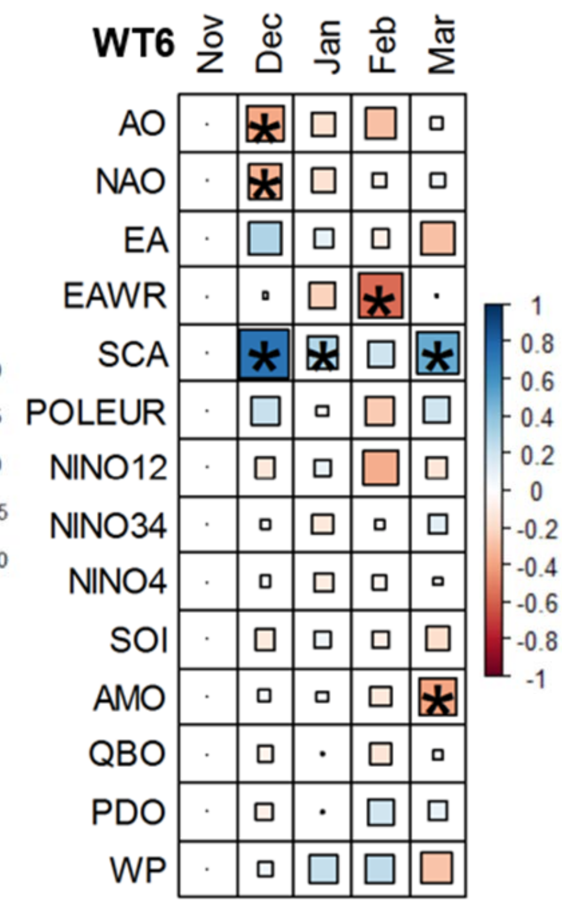
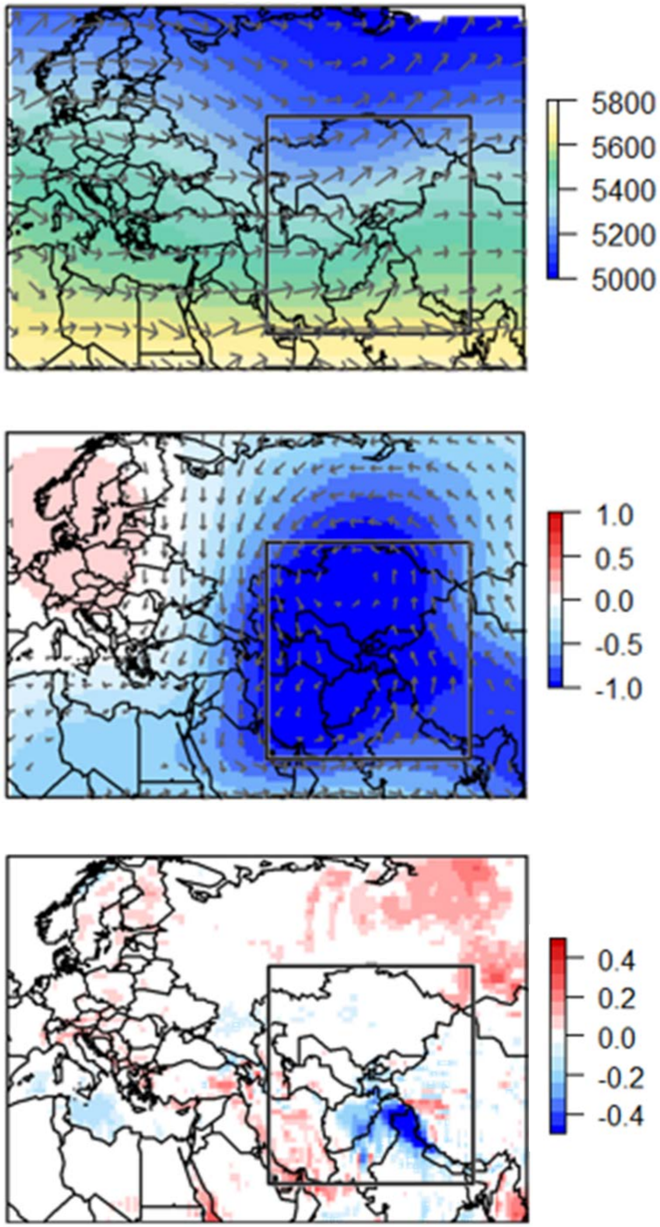
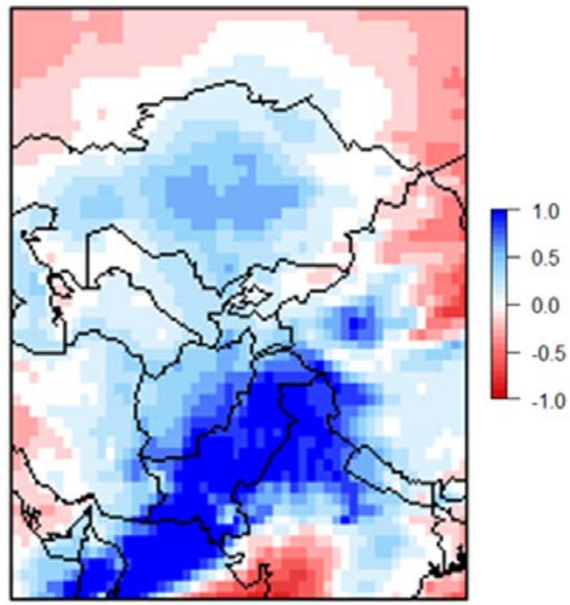
0.5
0.0
-0.5
-1.0


WT6
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

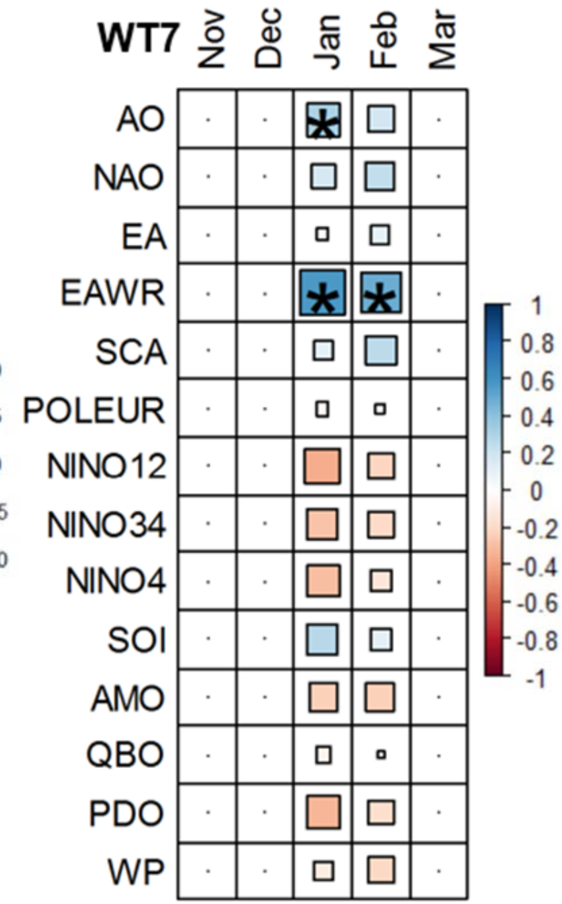
WT 7



5800
5600
5400
5200
5000
1.0
0.5
0.0
-0.5
-1.0
0.4
0.2
0.0
-0.2
-0.4

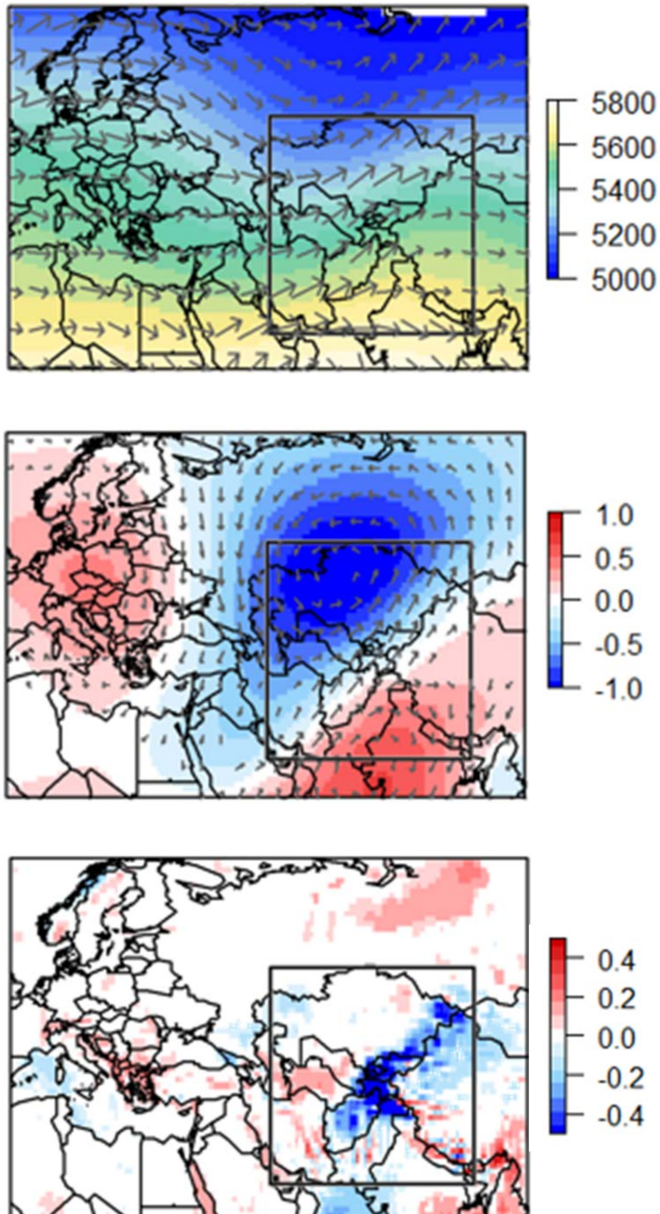


1.0
0.5
0.0
-0.5
-1.0



WT7
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT 8


5800
5600
5400
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0.0
-0.5
-1.0
0.4
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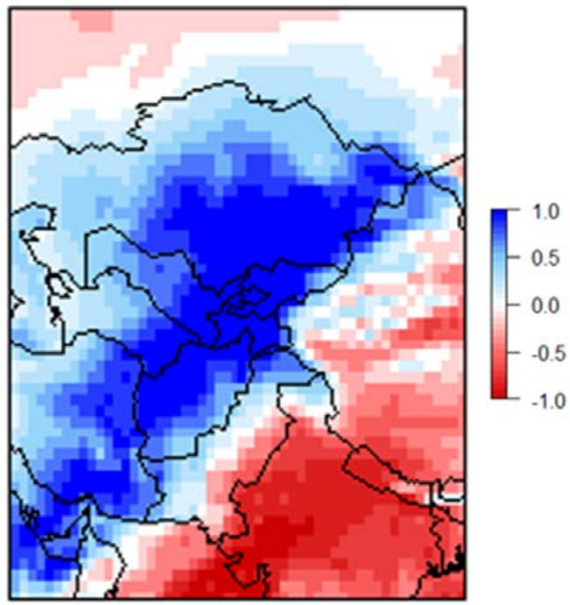
-0.2
-0.4


1.0
0.5
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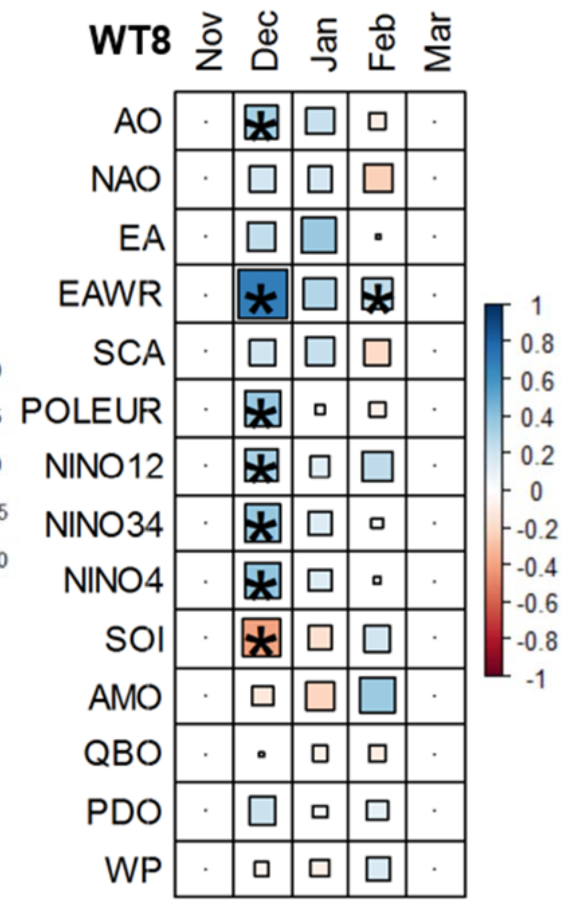
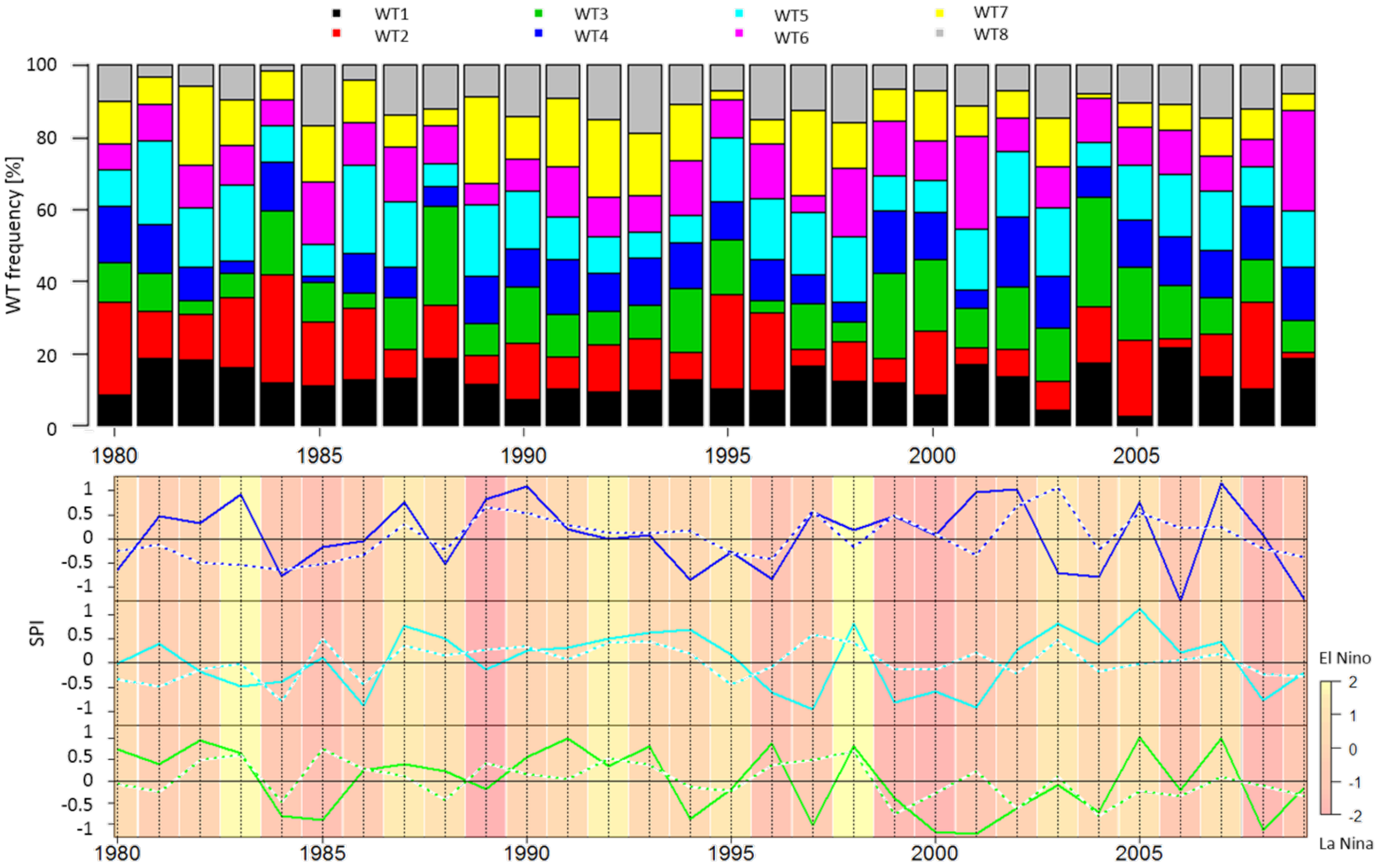
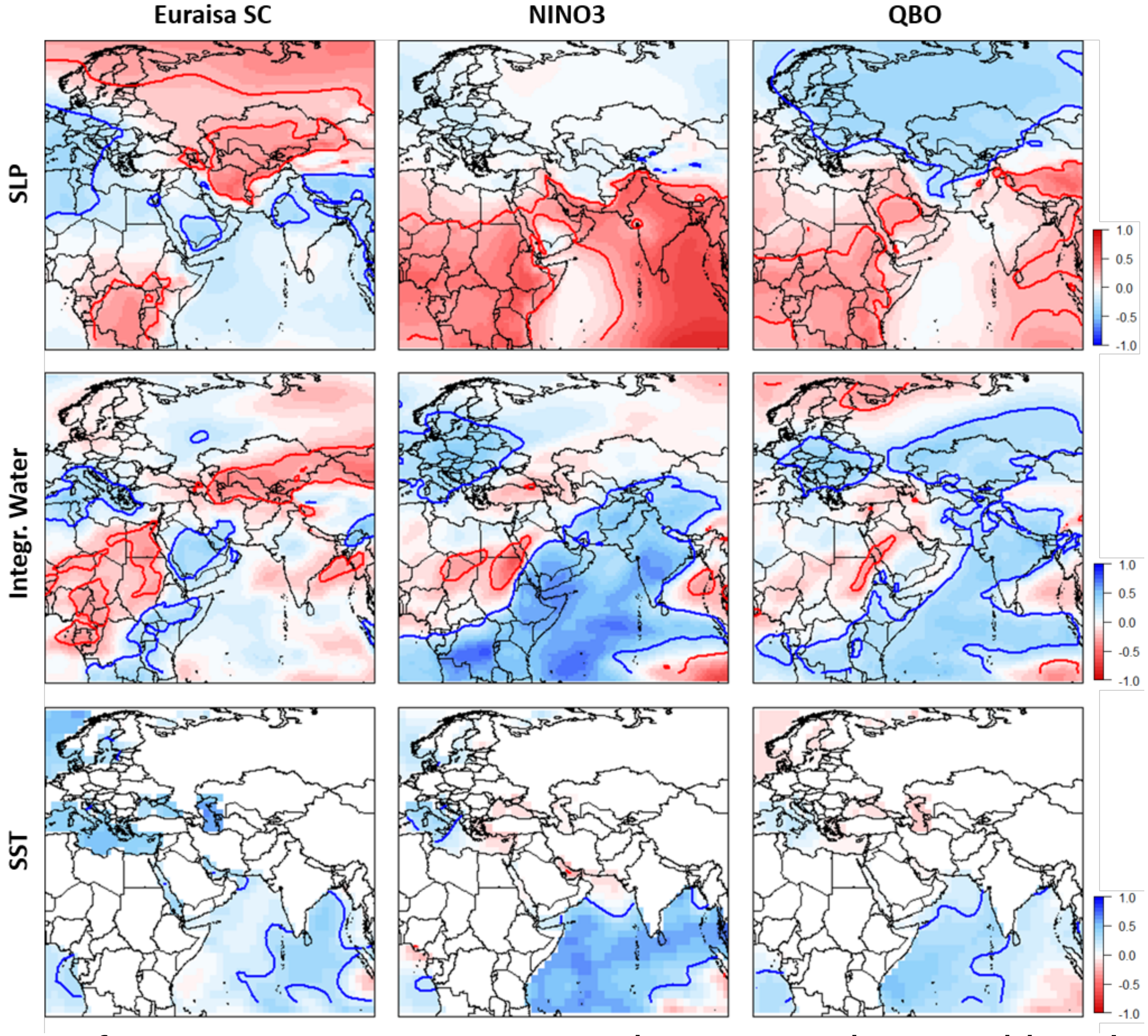
-1.0


WT8
Nov
Dec
Jan
Feb
Mar
AO
NAO
EA
EAWR
SCA
POLEUR
NINO12
NINO34
NINO4
SOI
AMO
QBO
PDO
WP
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1

WT frequency and

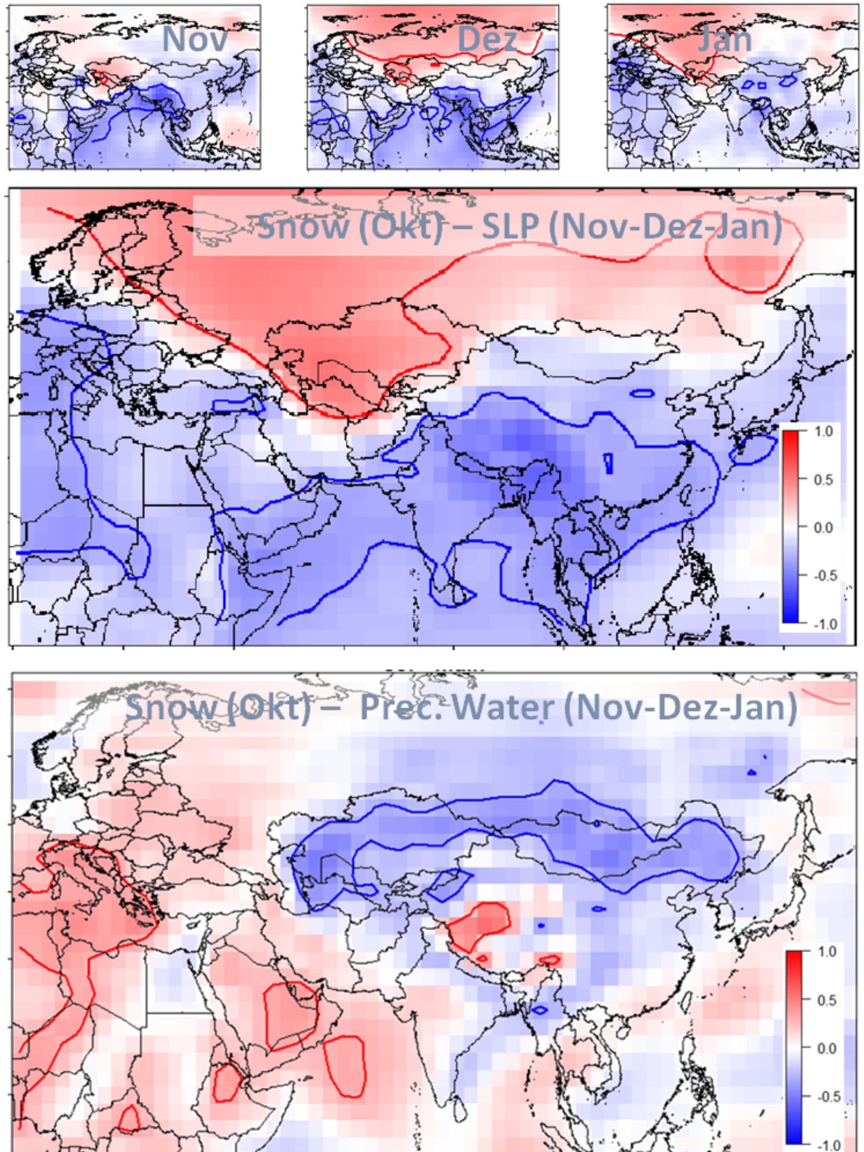


Physical Mechanisms?



Correlations of mean DJF SLP, Integrated Water and SST with selected predictors in October. Significant correlations (p=0.1) are marked.

Snow Cover Influence on winter circulation



Correlations of winter-time Sea Level Pressure and Atmospheric Water Content with Eurasian snow cover extent in October.

→ Snow Cover cools the continents

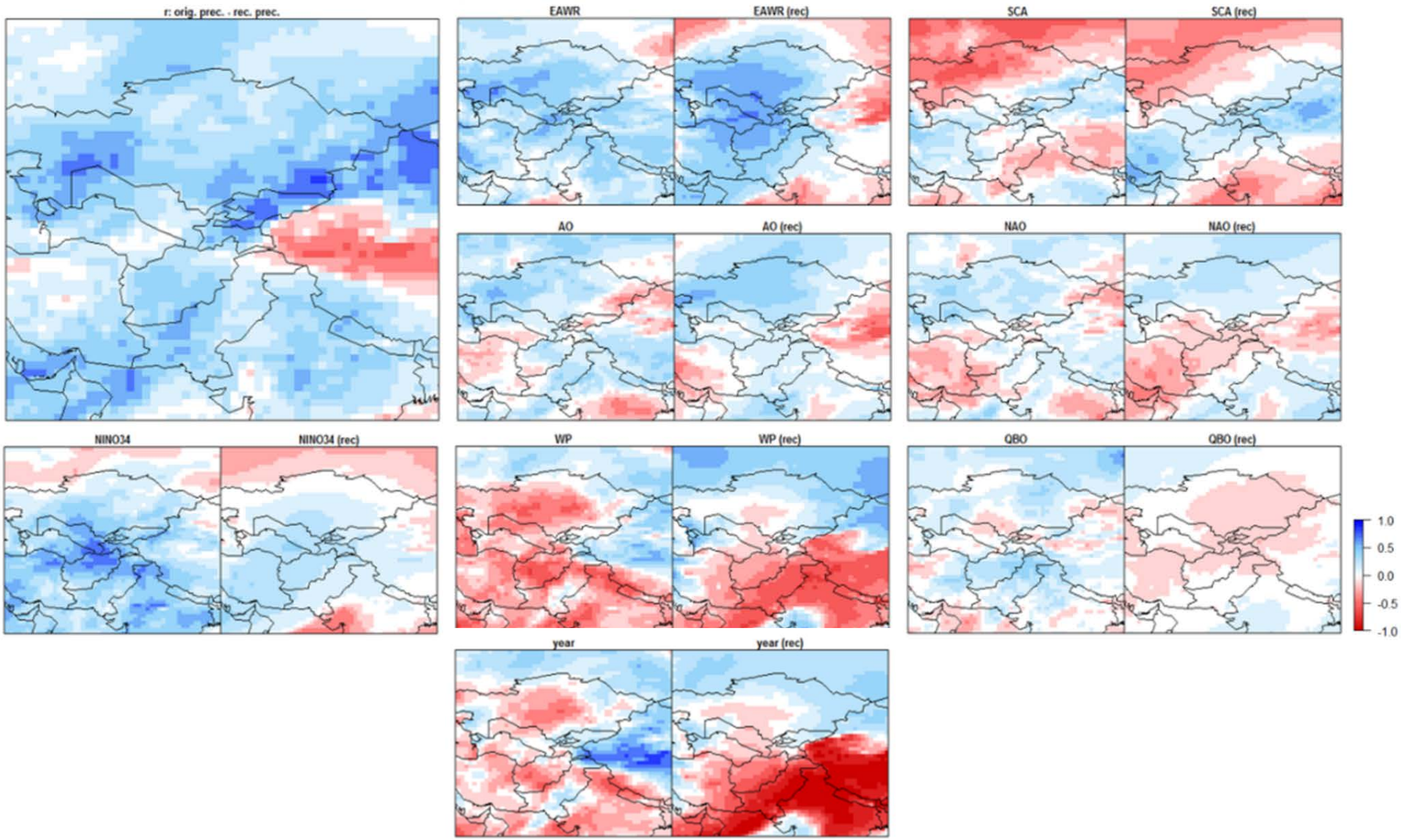
→ High pressure is developing over Eurasia

→ Blocking of westerly air masses!

→ Decrease of precipitation sums in Northern Central Asia!

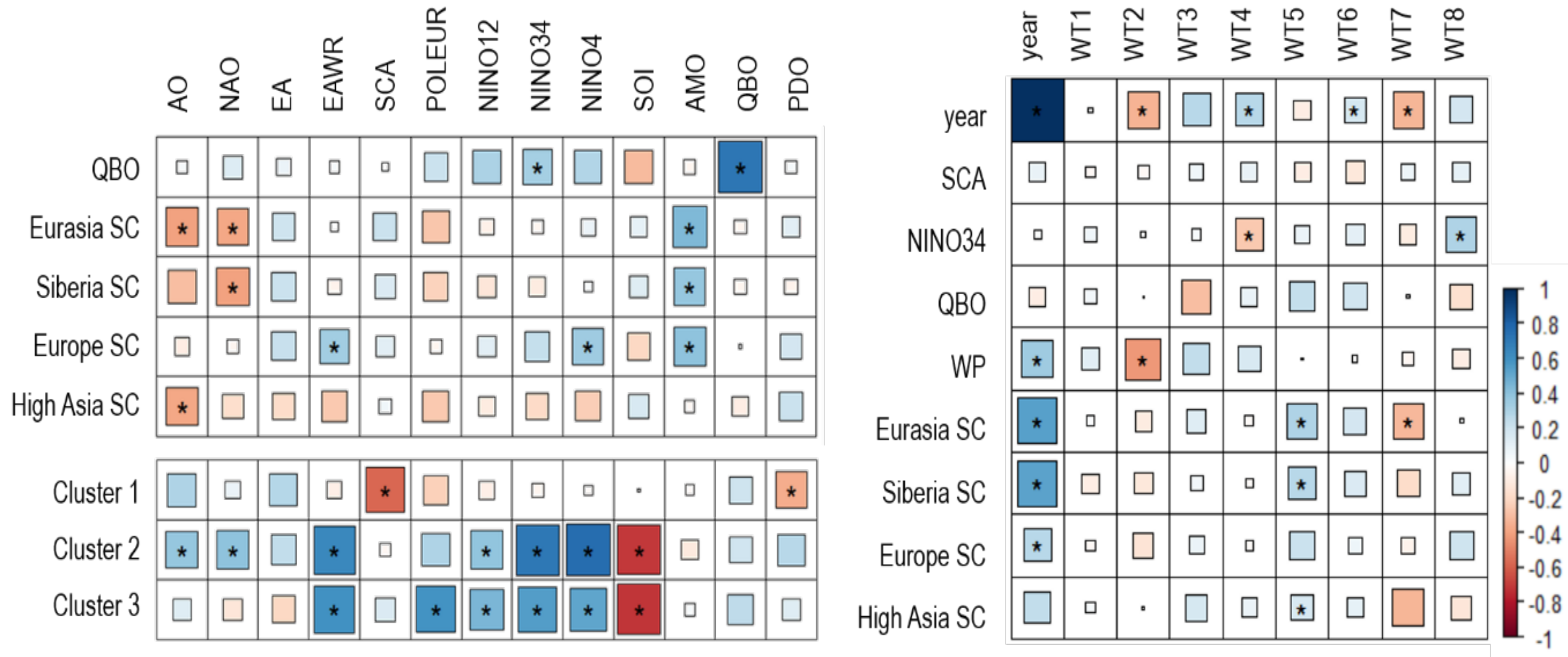
Lars Gerlitz et al., Predictability of cold season precipitation in Central Asia, EMS 2017, Dublin

Correlations of observed and reconstructed precipitation with large scale climate indices



Lars Gerlitz et al., Predictability of cold season precipitation in Central Asia, EMS 2017, Dublin

Physical Mechanisms? (2)



Pearson Correlation matrix of mean teleconnection indices during cold season (Nov-Mar) and selected predictor variables in preceding October (upper left panel) and with simultaneous precipitation anomalies in Central Asian sub-regions (Cluster 1, 2, 3) (lower left panel). Spearman Correlations of selected predictor variables in October the frequency of WTs in subsequent cold season (right).