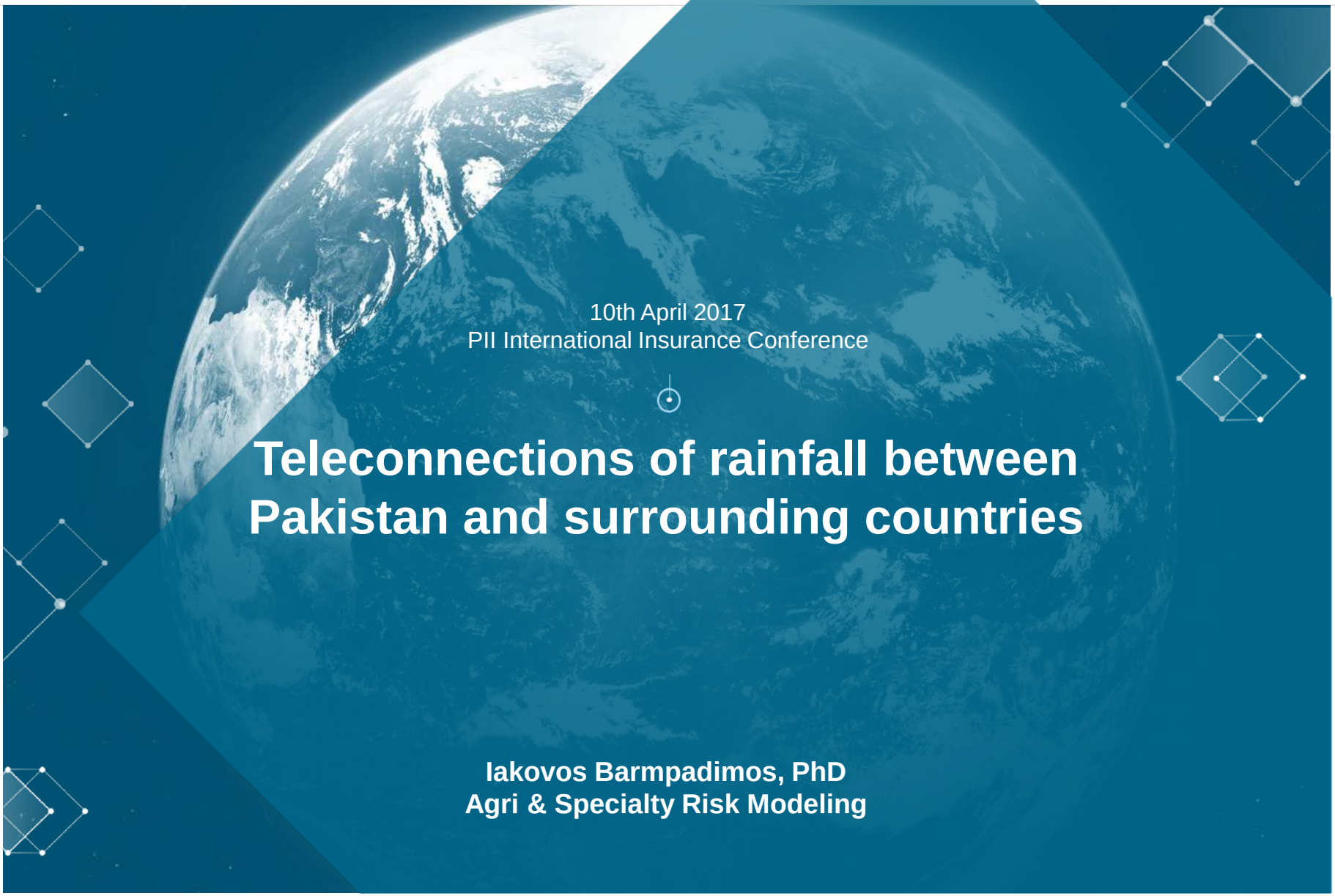

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Teleconnections of rainfall between Pakistan and surrounding countries

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SCOR The Art & Science of Risk | P&C

AGENDA

1 **Introduction and aim**

2 Data and method

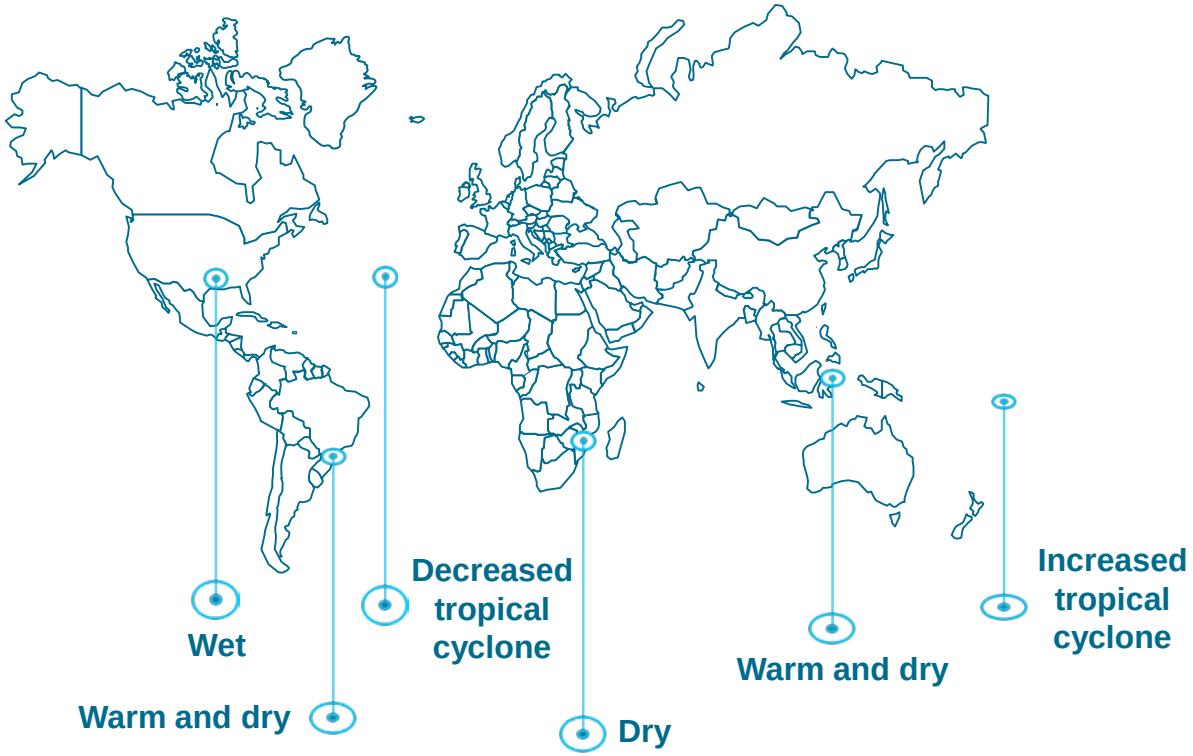
3 Results and discussion

Teleconnections of rainfall between Pakistan and surrounding countries

- Climatic conditions in various peril-regions worldwide exhibit significant dependencies.
- This means that there is a tendency to have certain extreme events in various parts of the world during the same year.

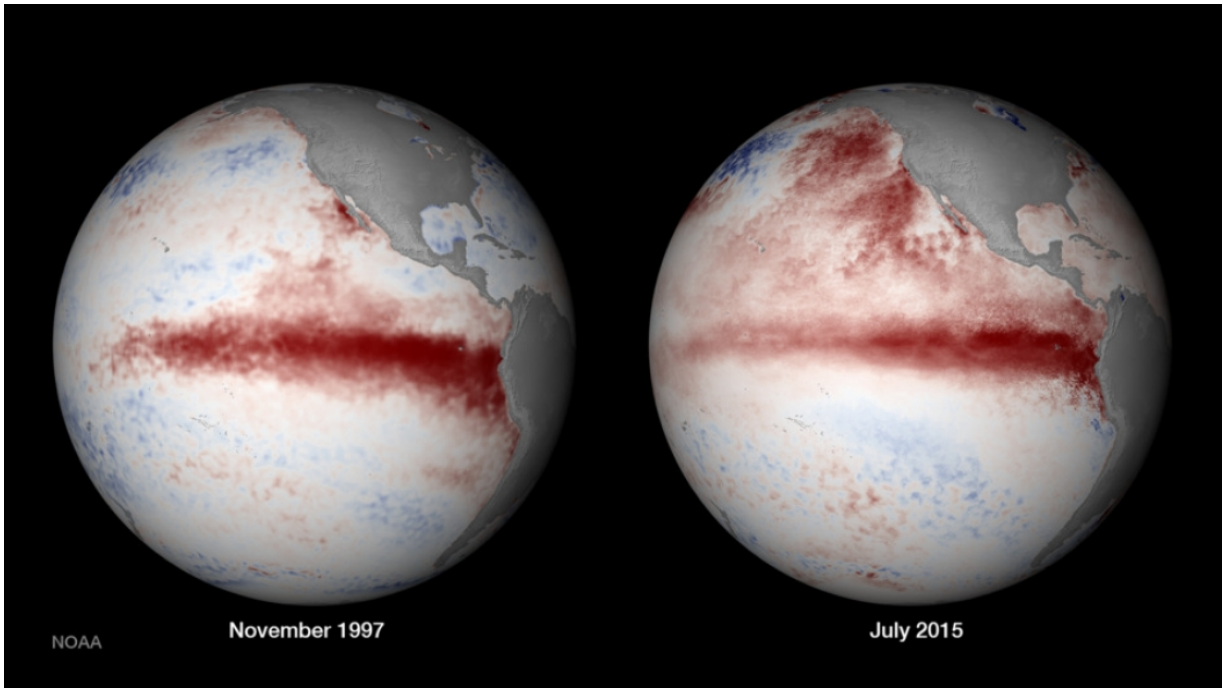
Teleconnections of rainfall between Pakistan and surrounding countries

- Below is a map of weather conditions in various places, which deviated from normal conditions.
- These unusual conditions have occurred at least during two different periods in the last twenty years: 1997-1998 and 2015-2016
- In there a common denominator behind these very different phenomena, which happen so far apart in the world?



Teleconnections of rainfall between Pakistan and surrounding countries

- It has been shown, that weather conditions around the globe in these two periods have been strongly influenced by sea surface temperatures in the equatorial Pacific.
- Every 3-7 years sea surface temperatures in the equatorial Pacific reach unusually high levels.
- This phenomenon is called «El-Nino».
- These high sea surface temperatures trigger a chain of meteorological events that have consequences on weather conditions worldwide.



Sea surface temperatures in November 1997 and July 2015. Credit: NOAA

Teleconnections of rainfall between Pakistan and surrounding countries

- Climate anomalies at large distances, which are related to each other are often referred to as “teleconnections”.
- El-Nino is an example of a teleconnection but not the only one.

- Teleconnections are an interesting phenomenon for an insurance or a reinsurance company with a global portfolio.
- For example, when there is an El Nino, there is an increased probability of flood in western South America and an increased probability of tropical cyclone in Australia.

- Being aware of this teleconnection, helps to decide if we want to write business in these two places simultaneously and how much.
- Ideally, capital allocation for any given contract should depend on how well that contract correlates with the rest of the portfolio. In that sense knowledge of teleconnections helps to improve pricing and capital allocation.

Teleconnections of rainfall between Pakistan and surrounding countries

- In this presentation we will discuss how rainfall in Pakistan is linked to rainfall in other Asian countries and how these links have changed in the last few decades.

Teleconnections of rainfall between Pakistan and surrounding countries

- Rainfall in Pakistan has strong seasonal variation. Here we focus in winter, which is the wheat season.
- Wheat is the most important crop in the country, both from a production and from a consumption point of view.

- Rainfall can affect wheat production both in terms of drought and in terms of excess/unseasonal rainfall, which causes waterlogging.
- An estimated 83% of cultivated land is irrigated[1] and 17% is rainfed. Irrigation limits the consequences of drought to a large extent.

1) *Agricultural Statistics of Pakistan 2011-12, http://www.agripunjab.gov.pk/overview%20new*

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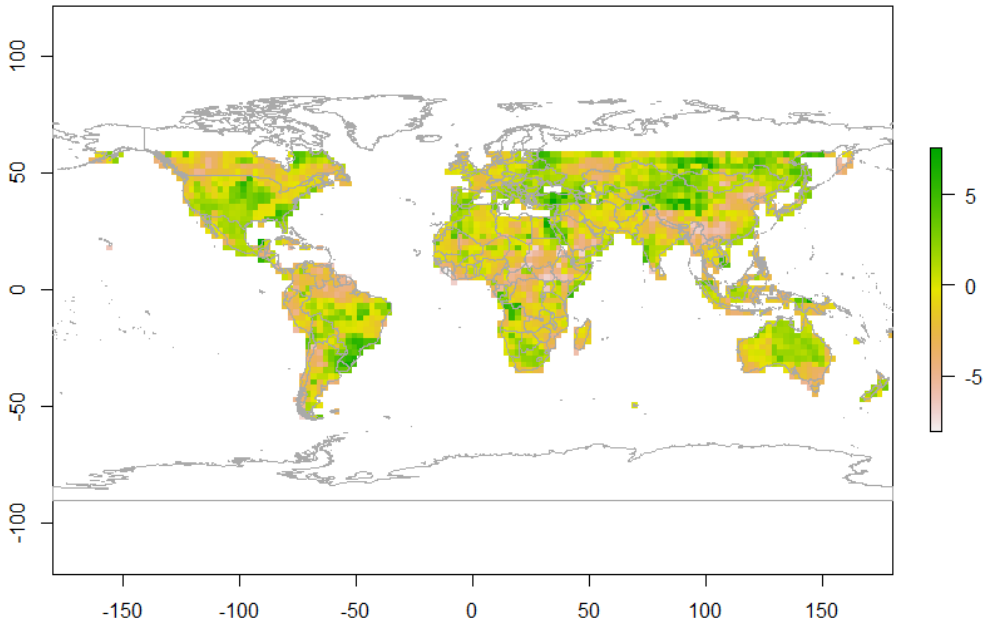
Teleconnections of rainfall between Pakistan and surrounding countries

- We have used the Palmer Drought Severity Index (PDSI) as an indicator of meteorological drought.
- PDSI values depend on antecedent conditions, on moisture supply and on moisture demand.
- Positive PDSI values mean excess rainfall while negative values mean drought.

- A global dataset put forward by Dai et al. (National Centre for Atmospheric Research) was used.
  - Spatial resolution is 2.5° x 2.5°. For Pakistan this is a box about 225 km wide and 275 km long.
  - Monthly time resolution.
  - Records begin in 1850 but data since 1950 are used here for better quality and quantity of underlying observations.



Global PDSI values in January 2010

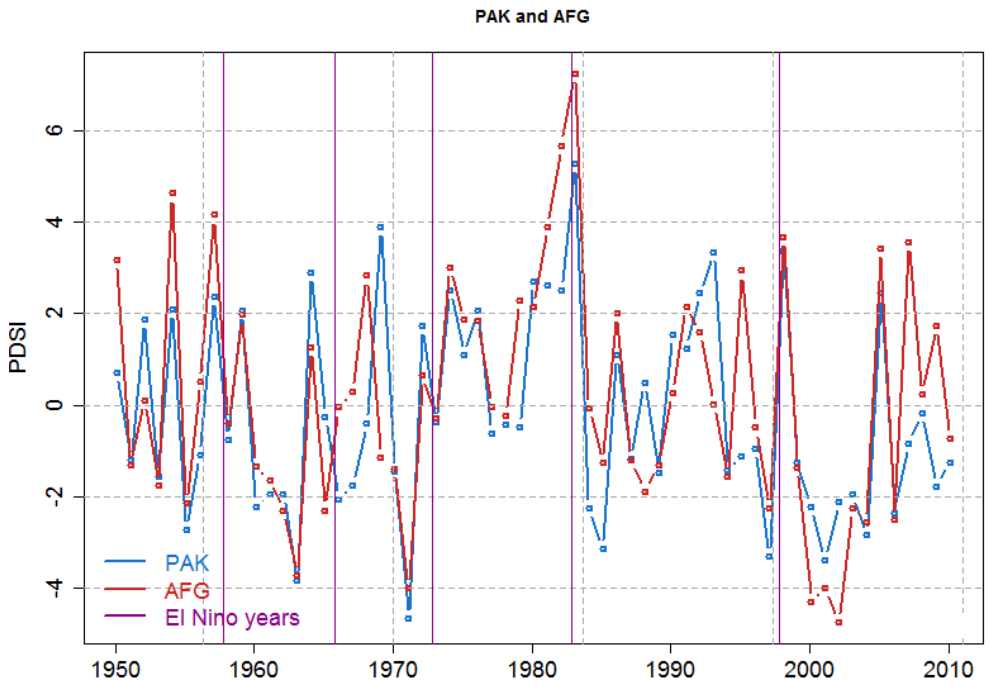
Teleconnections of rainfall between Pakistan and surrounding countries

- To quantify dependencies of PDSI between different regions, we use the correlation coefficient.
- The correlation coefficient is a quantity that tells us how much two variables depend on each other.

- For example, the plot on the right shows PDSI for Pakistan and Afghanistan.
- We can see it happens often that when one of the two countries has drought or excess rainfall, the other one has too.
- These two countries will have a high correlation coefficient.

- Correlation coefficient in general ranges from -1 to +1.
- If it is +1, the two countries would have perfect correlation.
- If the correlation coefficient is zero, the two countries would have no correlation at all.
- If it is -1, the two countries would have perfect anti-correlation, i.e. increased rainfall in one country would always mean decreased rainfall in the other.

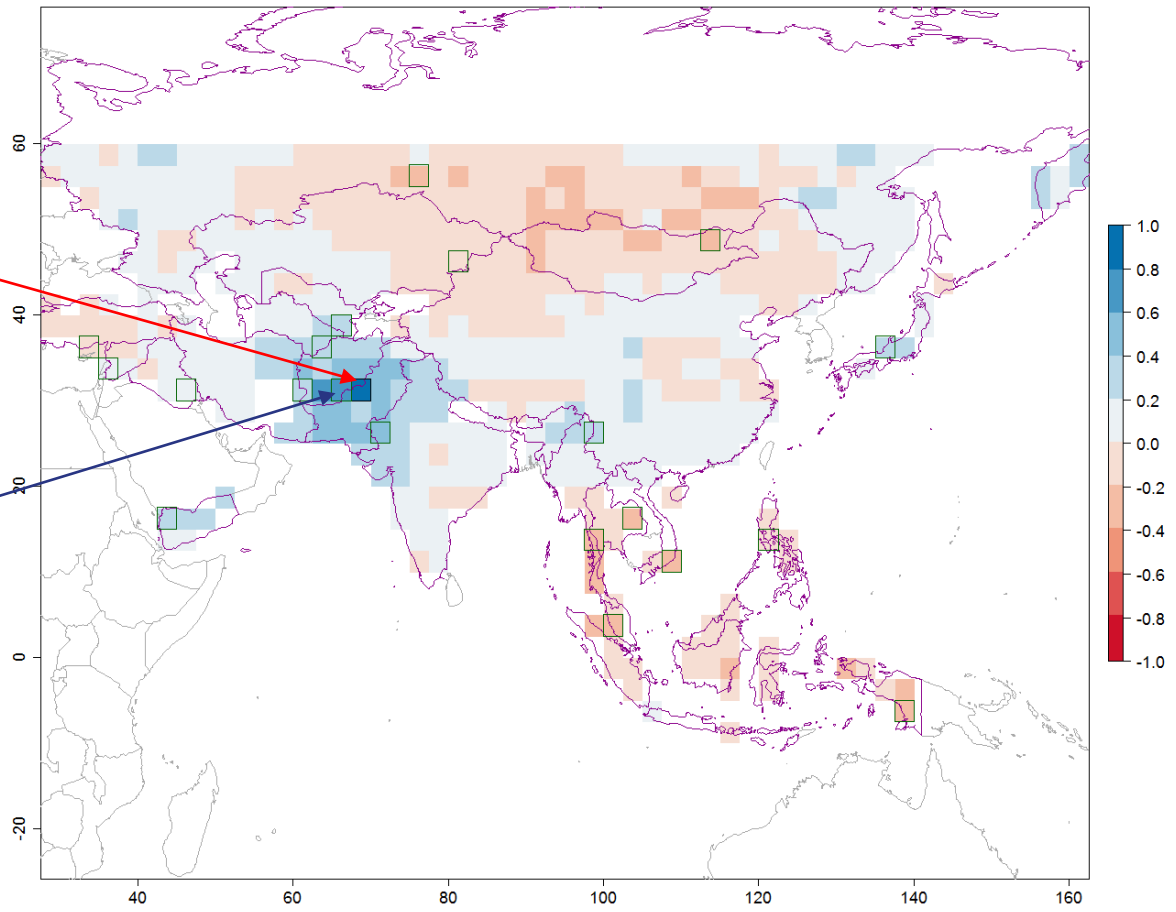
- In the example of Afghanistan and Pakistan, the correlation coefficient is 0.8.



Teleconnections of rainfall between Pakistan and surrounding countries

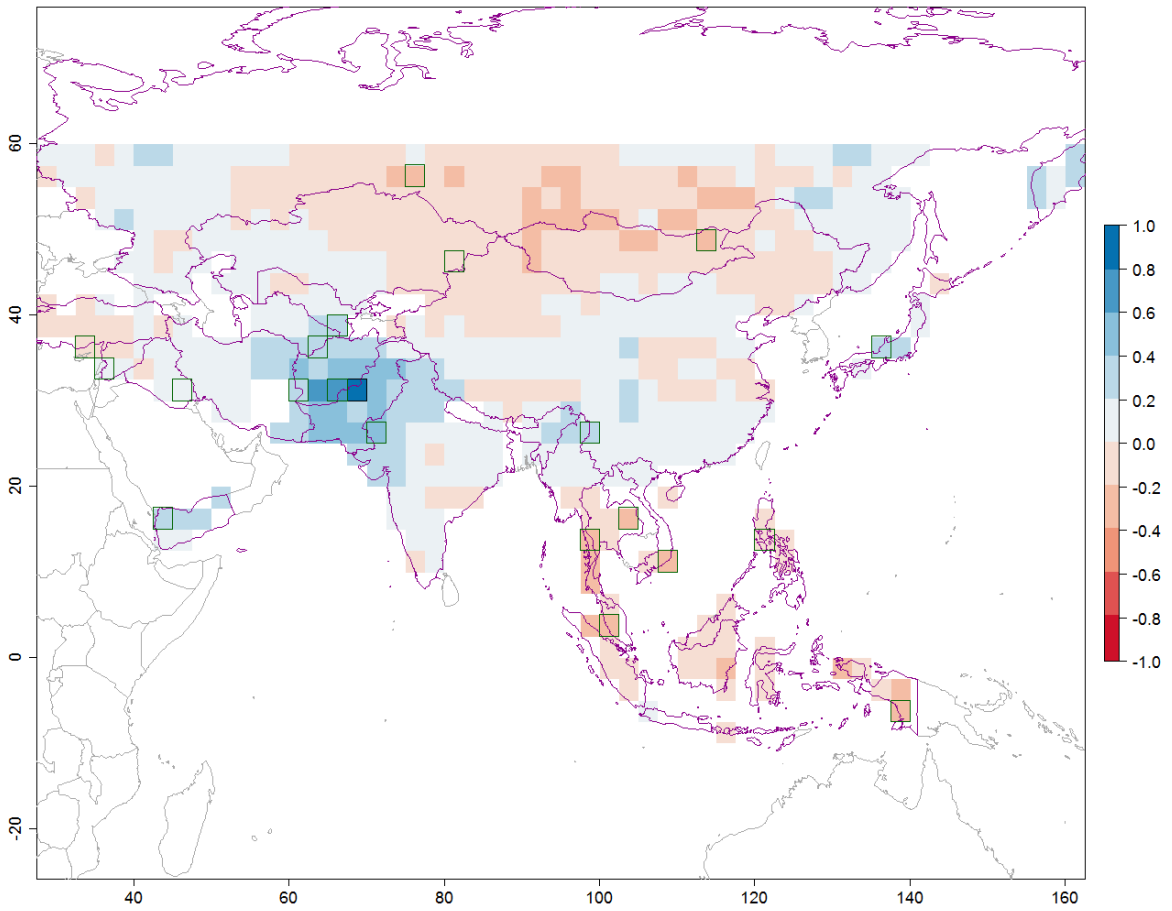
- Another way to look at correlations is to put them on a map.
- For each grid cell we have a monthly time series of PDSI from 1950 to 2010.
- We take a grid cell in Pakistan as a reference cell.
- We then calculate the correlation coefficient between the reference cell and every other grid cell on the map.

- The PDSI time series shown in the previous slide is from a grid cell in Afghanistan, right next to the reference cell.



Teleconnections of rainfall between Pakistan and surrounding countries

- Although PDSI is a reasonably good indicator of drought and excess rainfall, one should keep in mind that it is not always well-correlated to agri insurance losses.
- Agri insurance losses do not depend only on rainfall but also on other weather variables (temperature, radiation), on farming practices (e.g. irrigation), on good selection of sowing date etc.
- Here we talk about Pakistan in general. However, there are local variations in the climate of the country, which also have to be considered in a detailed analysis.



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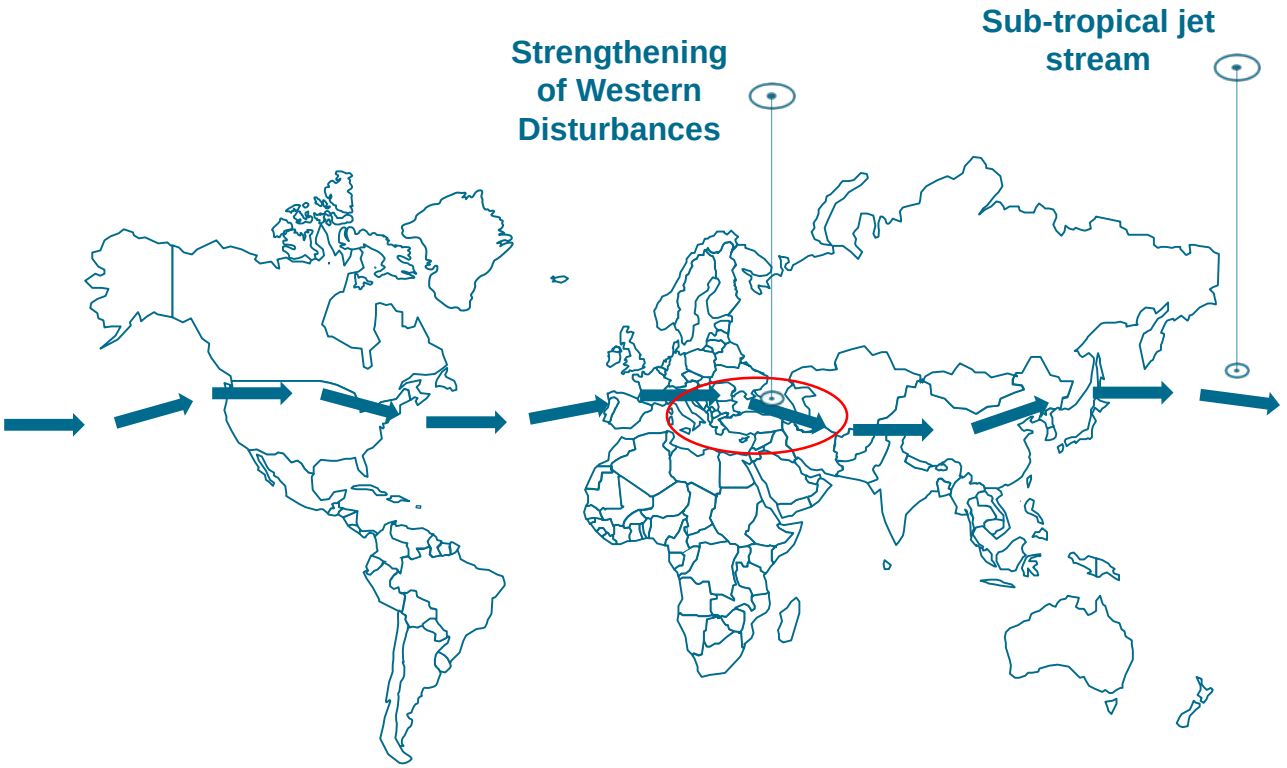
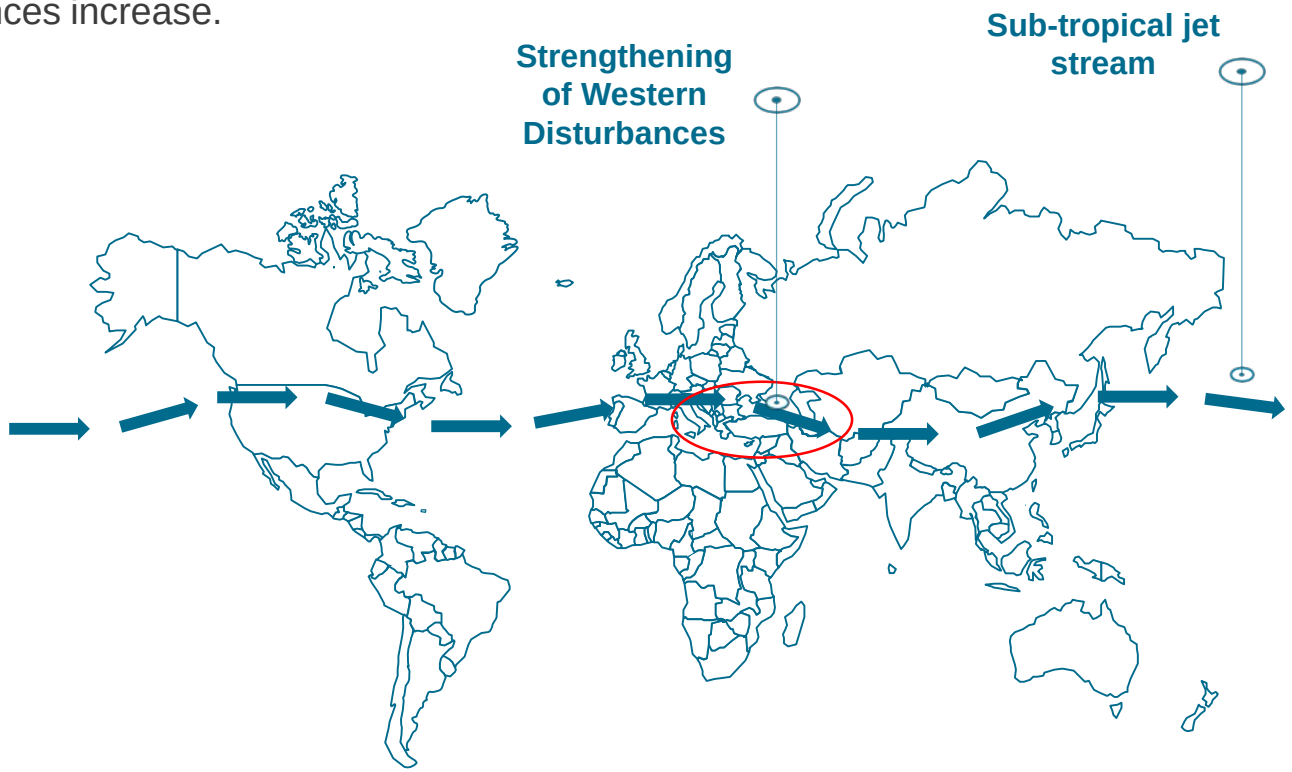
Teleconnections of rainfall between Pakistan and surrounding countries

- Winter climate in Pakistan is shaped by the Western Disturbances
- Western Disturbances are weather systems originating from the Mediterranean and the Caspian sea, which bring rainfall in Pakistan and surrounding areas.
- The path of Western Disturbances is influenced by the sub-tropical jet stream: a global westerly wave-like flow.



Teleconnections of rainfall between Pakistan and surrounding countries

- Western disturbances in turn are influenced by climatic phenomena as far away as the North Atlantic and the Eastern Pacific.
- Namely, two major climatic phenomena have been shown to influence Western Disturbances[1]:
  - The North Atlantic Oscillation
  - The El-Nino
- Both these phenomena intensify and shift the sub-tropical jet stream in such a way, that Western Disturbances increase.



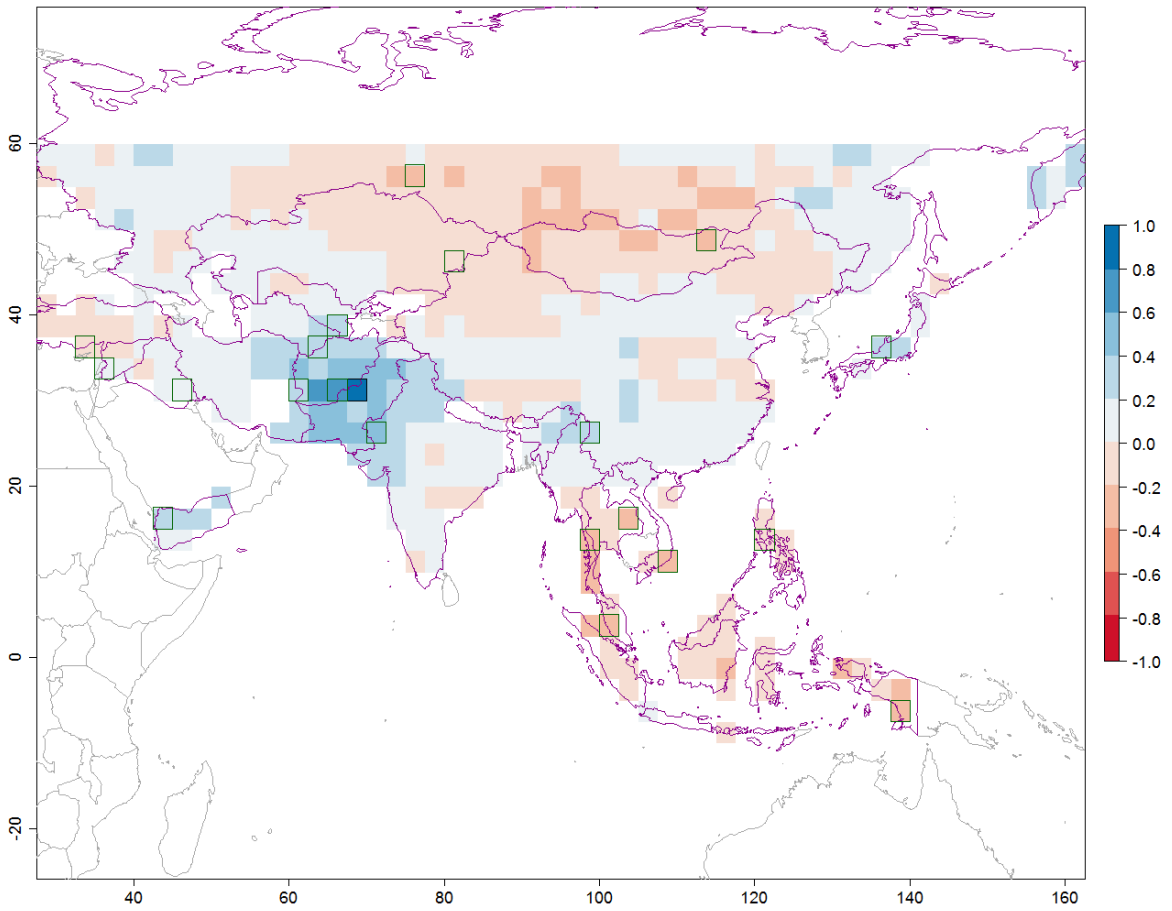
1) Yadav, et al., 2009

Teleconnections of rainfall between Pakistan and surrounding countries

- In general, winter rainfall in Pakistan is un-correlated or anti-correlated with the rest of Asia.

- Correlation exists mainly with neighboring areas in Afghanistan and NW parts of India.
- Pakistan, Afghanistan and NW India are all influenced by the Western Disturbances.

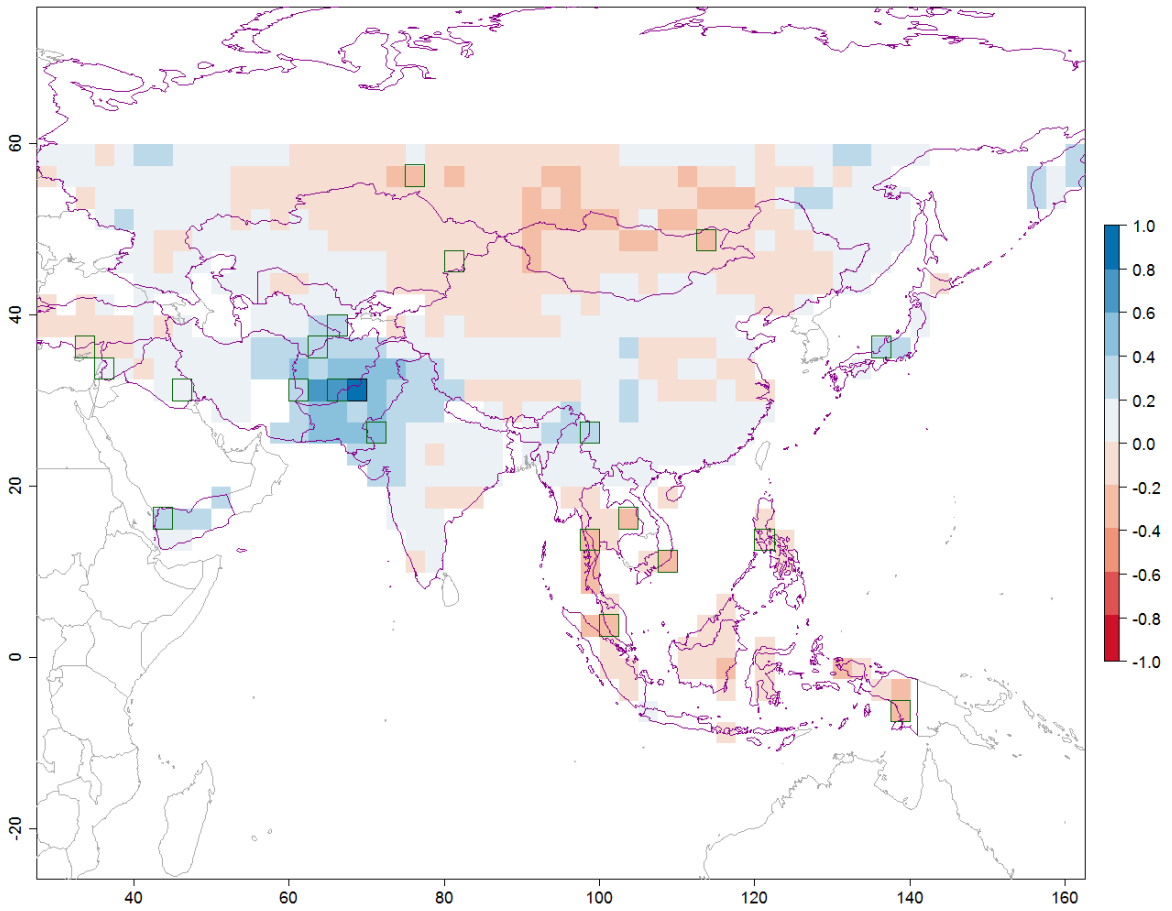
- Anti-correlated areas around Mongolia during winter are under the influence of the Siberian High: a semi-permanent weather system that creates stable dry conditions.
- It has been shown[1] that the Siberian High does not have much relation to any other major climate patterns.
- The Himalaya range acts as a barrier to Western Disturbances, which can explain to some extent the anti-correlation between Pakistan and Mongolia.



1) Panagiotopoulos et al., 2005

Teleconnections of rainfall between Pakistan and surrounding countries

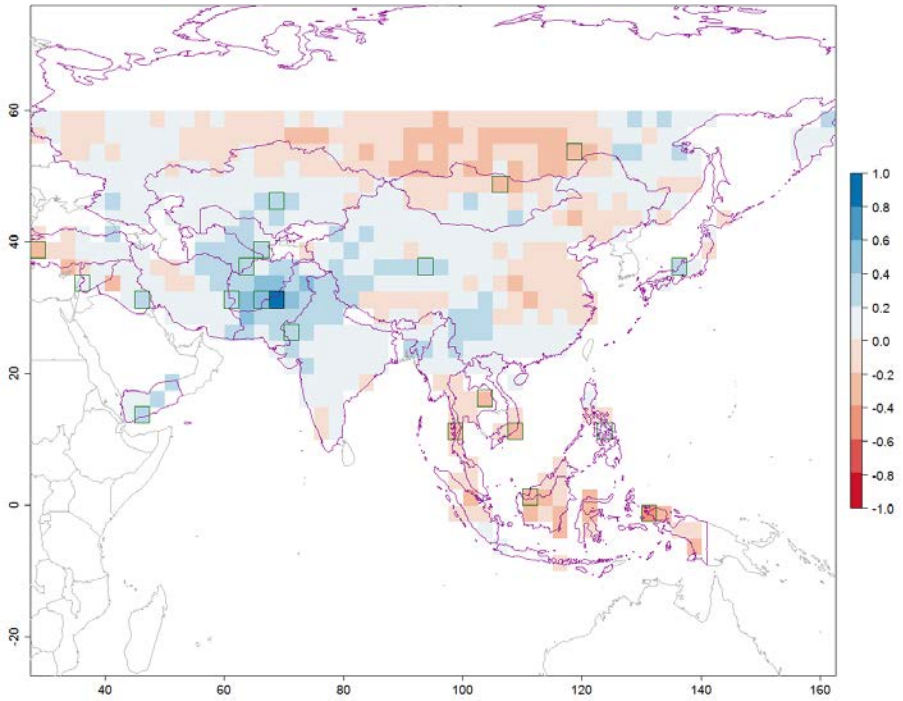
- Another anti-correlation is observed with SE Asia.
- This can be attributed to El-Nino: El Nino years have been associated with below average rainfall in SE Asia and above-average rainfall in Pakistan.



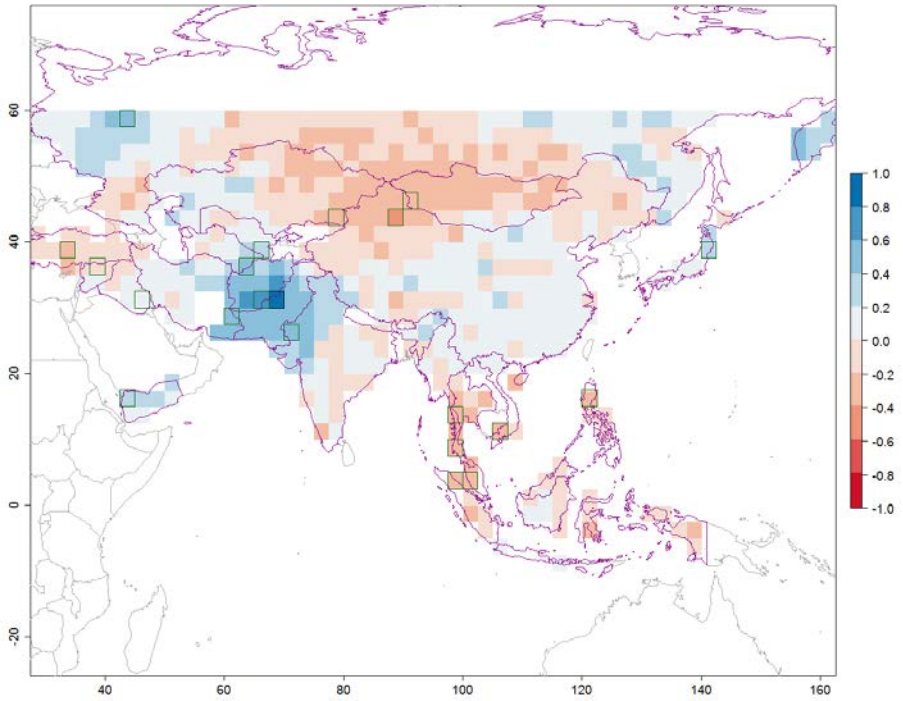
Teleconnections of rainfall between Pakistan and surrounding countries

- In the following we calculate correlations is the same way, but for two different 30-year periods: 1950-1979 and 1980-2010.
- In general, many (anti-)correlations have intensified in the recent decades.

1950-1979

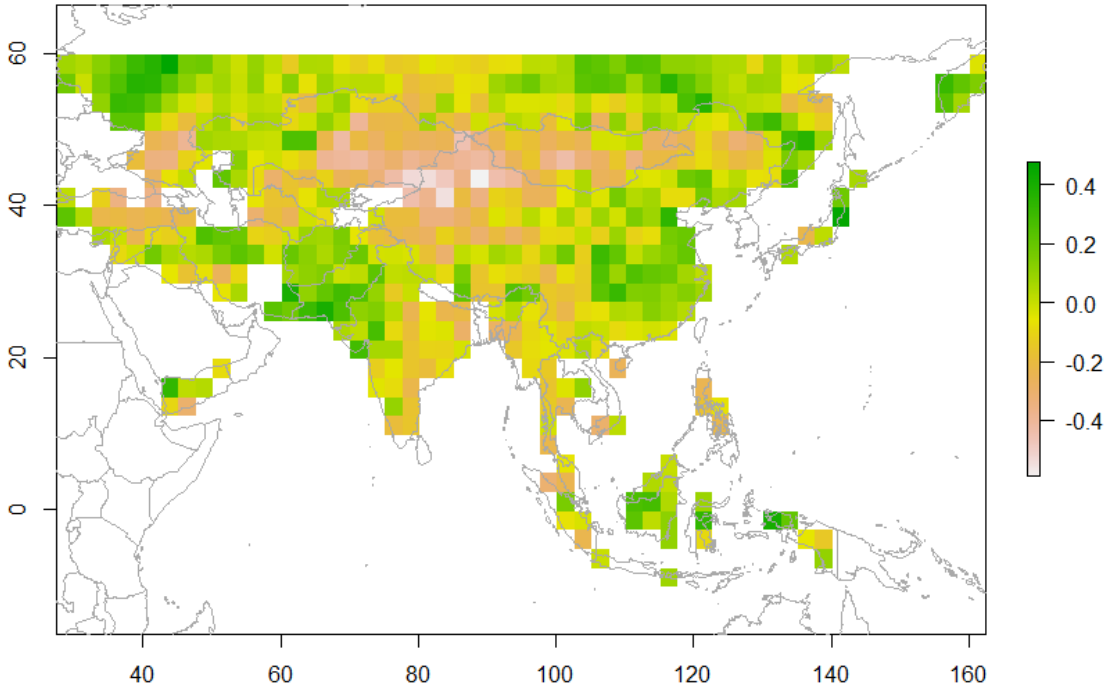


1980-2010



Teleconnections of rainfall between Pakistan and surrounding countries

- To identify changes in correlations more easily, we make a map of the difference in correlations 1980-2010 – 1950-1979.
- We observe:
  - A stronger correlation with NW India
  - An emerging anti-correlation with SE India
  - An emerging correlation with Eastern China
- The observed intensification of these patterns can be attributed to the an increasing influence of El Nino: For example, an increasing influence of El Nino has been identified for NW India[1].
- These changes have been observed in the recent decades, however it is uncertain if they will persist in the future and for how long.
- We also observe a strengthening anti-correlation with NW China, Mongolia and Kazakhstan. The causes behind this are less well understood.

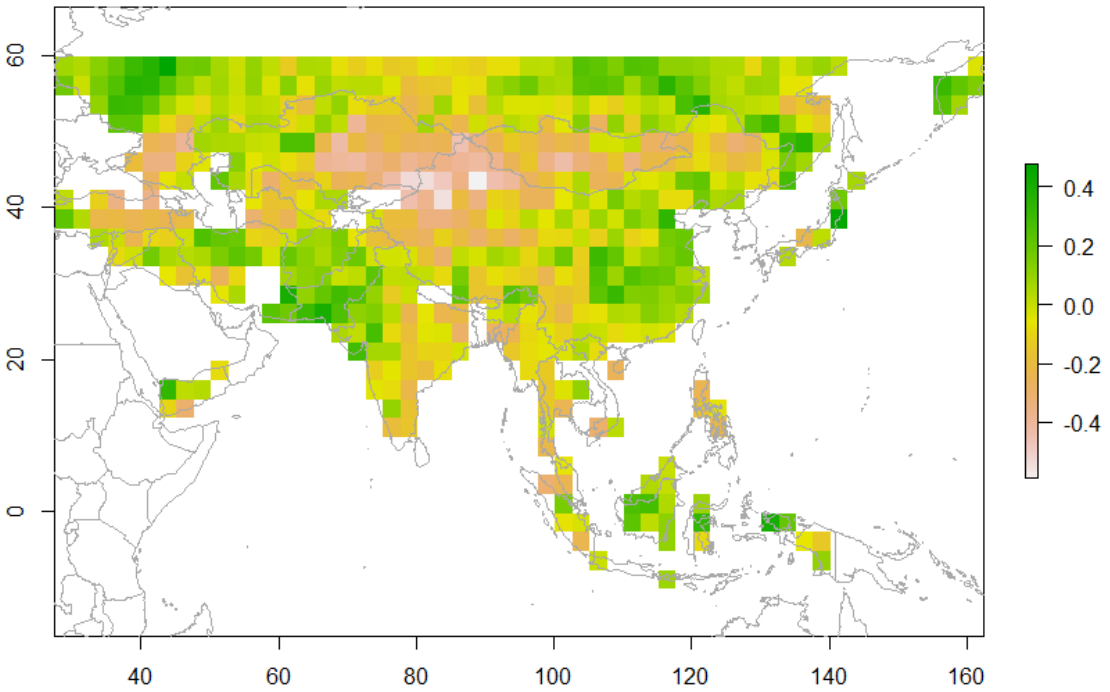


Difference in PDSI correlations with Pakistan in the periods 1980-2010 – 1950-1979.

1) Yadav, et al., 2009, Yadav, at al., 2010, Chun, et al.,2012

Teleconnections of rainfall between Pakistan and surrounding countries

- These observations can have practical implications for portfolio steering of an international agri insurance portfolio.
- For example, if correlations between Pakistan and NW India increase, writing agri business in both countries creates a risk accumulation, namely an accumulation of unseasonal rainfall risk for wheat crops.
- Similar considerations apply to Pakistan and East China.
- At the same time, correlation analysis can reveal opportunities to diversify risk:
  - For example, correlations between Pakistan and SE Asia are rather weak and they do not seem to increase consistently.



Difference in PDSI correlations with Pakistan in the periods 1980-2010 – 1950-1979.

Conclusion

- Winter rainfall in Pakistan is shaped by Western Disturbances, which in turn are influenced by two remote climate patterns: El-Nino and the North Atlantic Oscillation
- Winter rainfall in Pakistan is correlated with neighboring areas and it is anti-correlated with SE Asia
- We observe an emerging correlation with E China and an emerging anti-correlation with SE India
- In the absence of reliable/enough insurance data, correlation analysis of weather data can reveal potential risk accumulations as well as potential opportunities for risk diversification
- SCOR has developed the required sophisticated weather analysis tools to run this type of analysis