SCIENTIFIC WORKSHOP | 16 - 17 MAY 2018 | Nicosia, Cyprus

Observed rainfall trends and precipitation uncertainty in the vicinity of the Mediterranean, Middle East and North Africa

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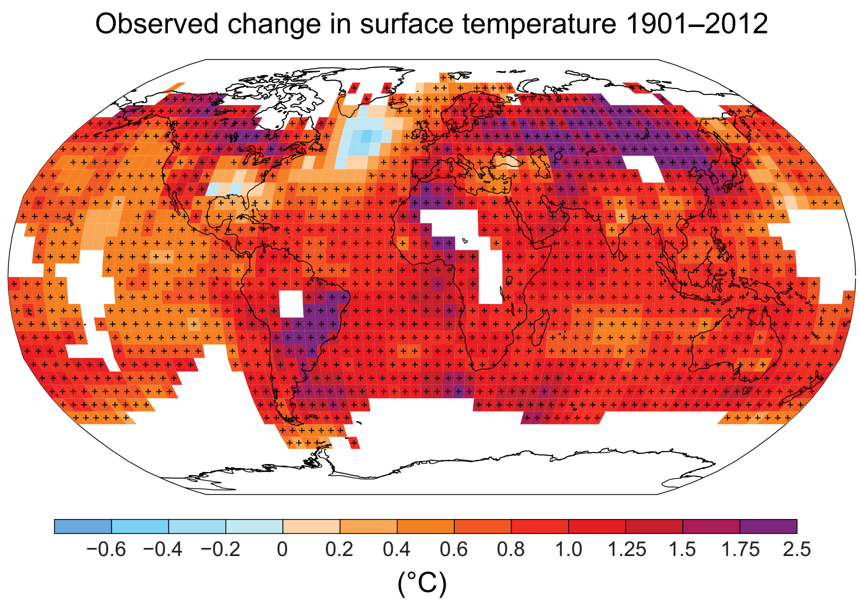
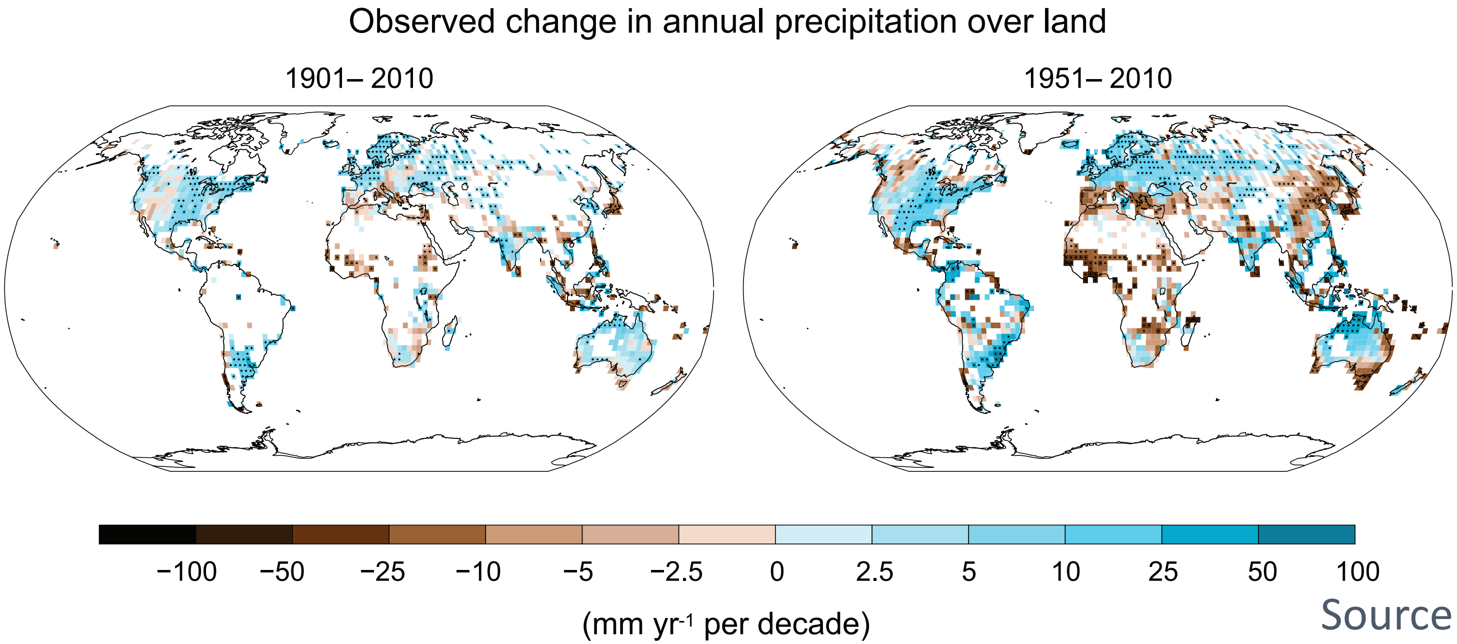
The Cyprus Institute
RESEARCH•TECHNOLOGY•INNOVATION

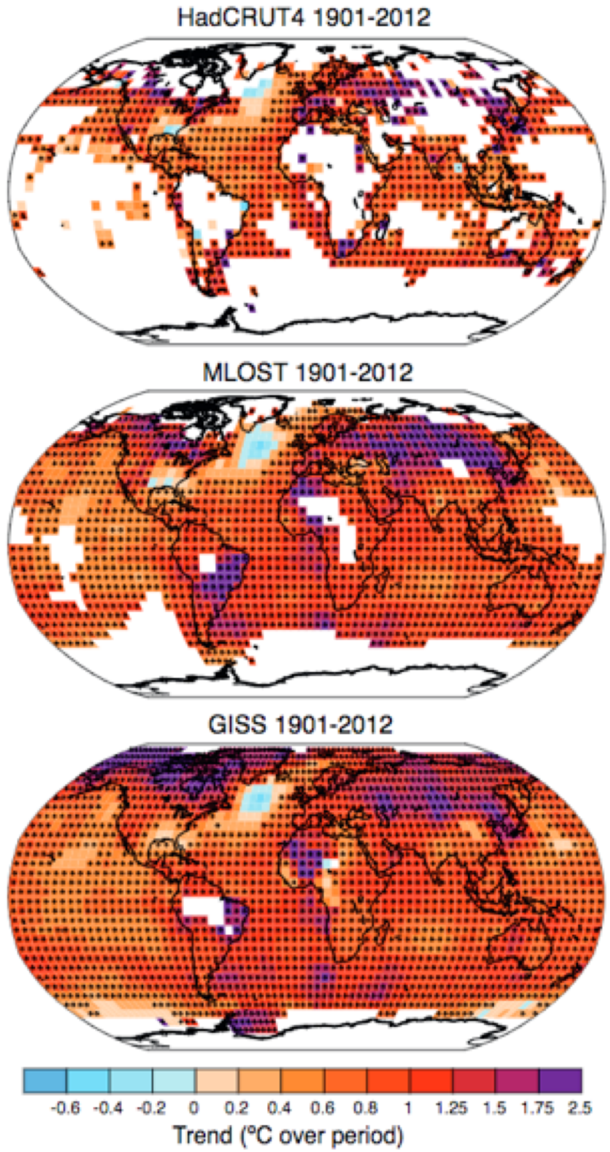
Observed Changes in Global/Mediterranean Climate





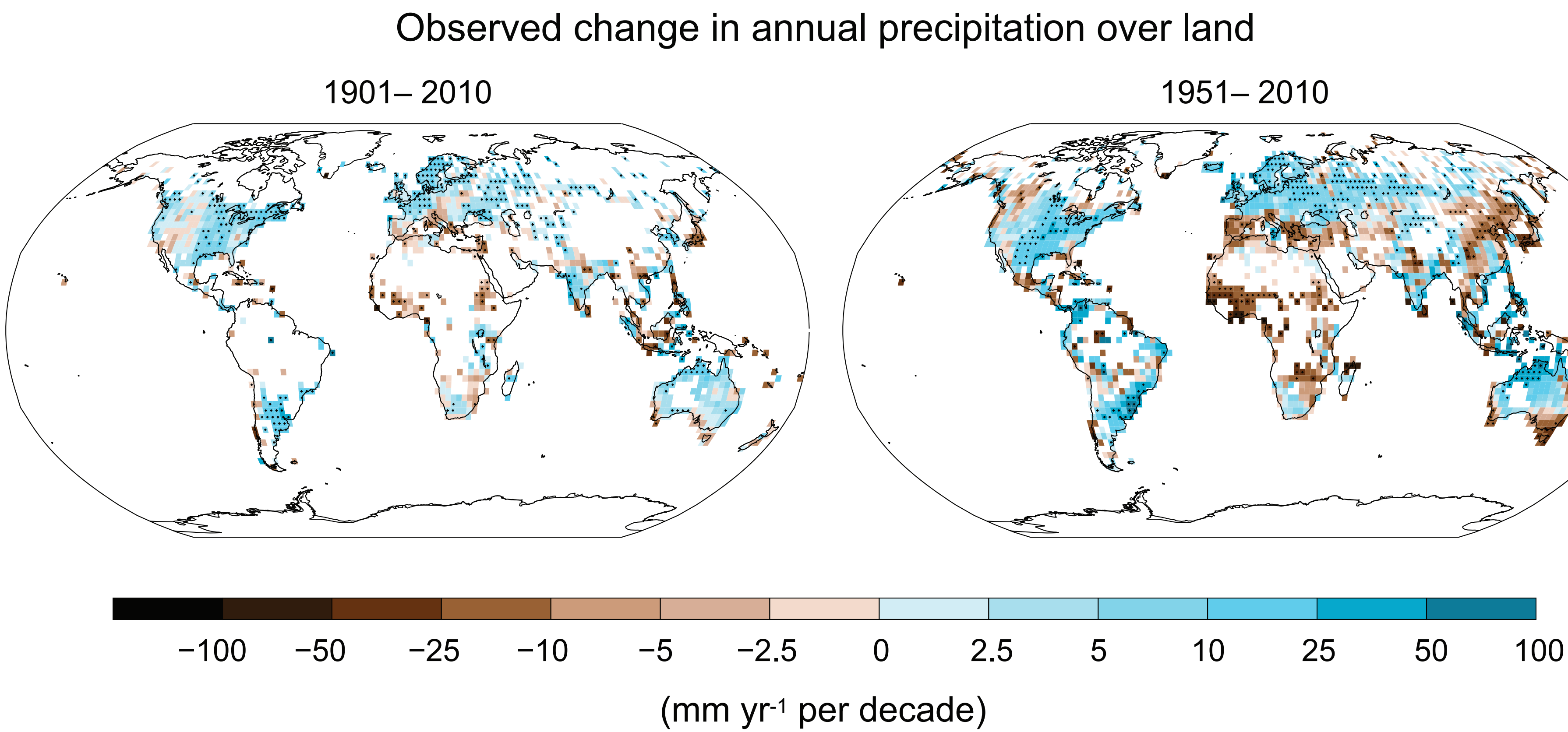
Source: IPCC AR5

Observed Changes in Global/Mediterranean Climate



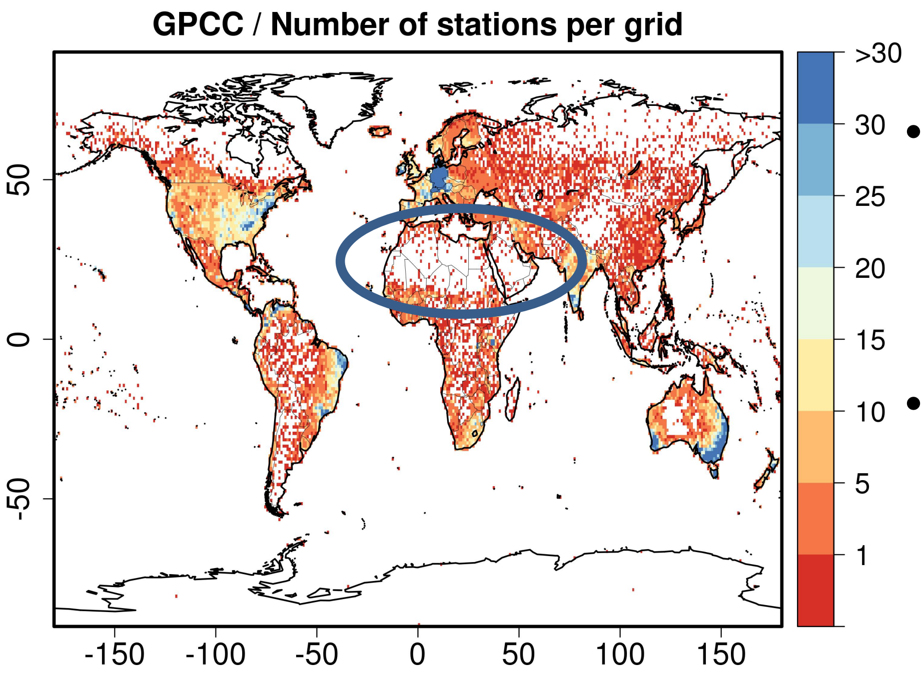
- **HadCRUT4**, Global (Land & Ocean), 5×5°, 1850/01 to 2018/01
- NOAA Merged Land-Ocean Surface Temperature Analysis (**MLOST**), Global (Land & Ocean), 5×5°, 1871/01 to 2016/11
- NASA Goddard's Global Surface Temperature Analysis (**GISTEMP**), Global (Land & Ocean), 2×2°, 1880/01 to 2016/11

Observed Changes in Global/Mediterranean Climate



Global Precipitation Climatology Center (GPCC): Global coverage (land only), 2.5×2.5°, 1901-2010

Objectives:



- **Assess** the **century-long rainfall trends** and better understand precipitation interannual variability throughout the 20th century for the greater **MENA** region.

- **Update** these trends for the very recent decades by utilizing supplementary **gauge** and **satellite-based** datasets.

- Investigate if there is a climate change signal in several aspects of **extreme precipitation** (incl. duration and intensity).

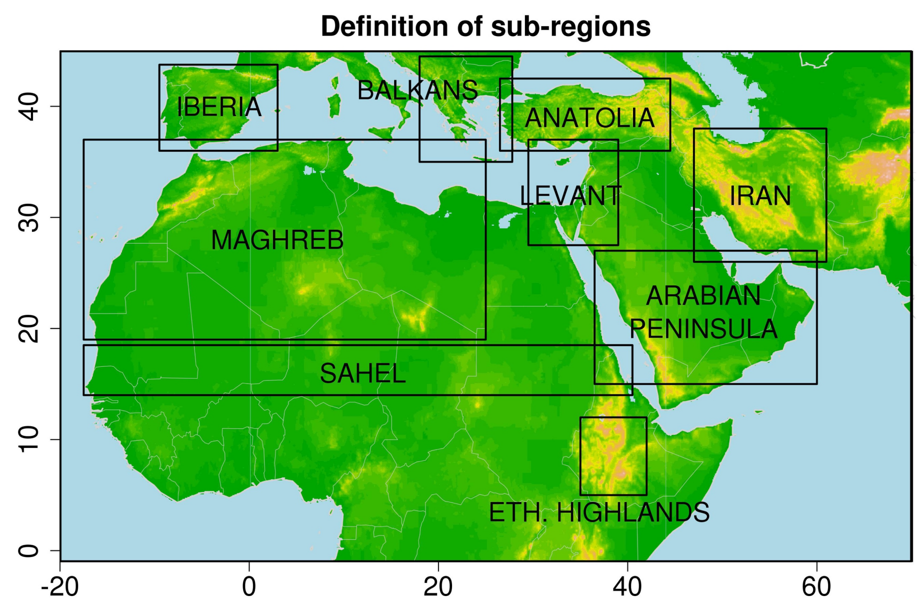
- Explore up to what level the tested datasets agree/disagree over the region of interest. **Quantify the observational uncertainty** of rainfall.

Study region and Datasets

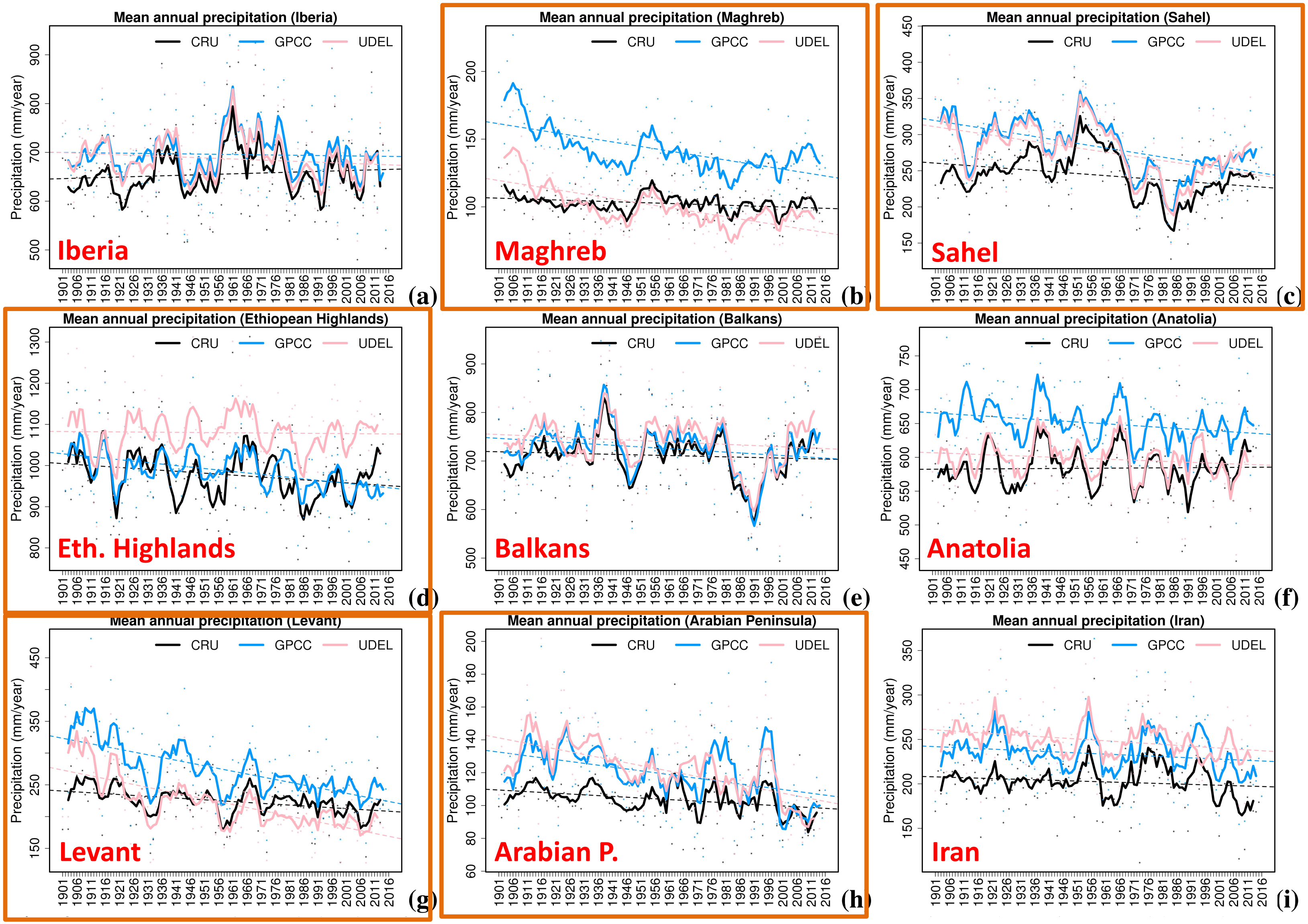
5 state-of-the-art monthly/daily precipitation datasets:

Dataset	Version	Grid Spacing	Temporal Resolution	Institution	Reference
CRU	v3.24.01	0.5°	Monthly (1901-2015)	Climate Research Unit, University of East Anglia	Harris et al., 2014
UDEL	v4.01	0.5°	Monthly (1901-2014)	Center for Climatic Research, University of Delaware	Willmott and Matsuura, 2001
GPCC	v6.0	1°	Monthly (1901-Now) / Daily (1988-Now)	Global Precipitation Climatology Center, Deutscher Wetterdienst	Schneider et al., 2011
CPC	v1.0GLB	0.5°	Daily (1979-Now)	Climate Prediction Center, National Oceanic and Atmospheric Administration	Chen et al., 2008
CHIRPS	v2.0	0.25°	Daily (1981-Now)	Climate Hazards Group	Funk et al., 2015

9 sub-regions of special interest:



Precipitation trends since 1901



Annual Precipitation and trends for the period 1901-Today. 3 datasets: CRU, GPCC, UDEL

Precipitation trends: sub-period analysis

Annual Precipitation (mm/yr)

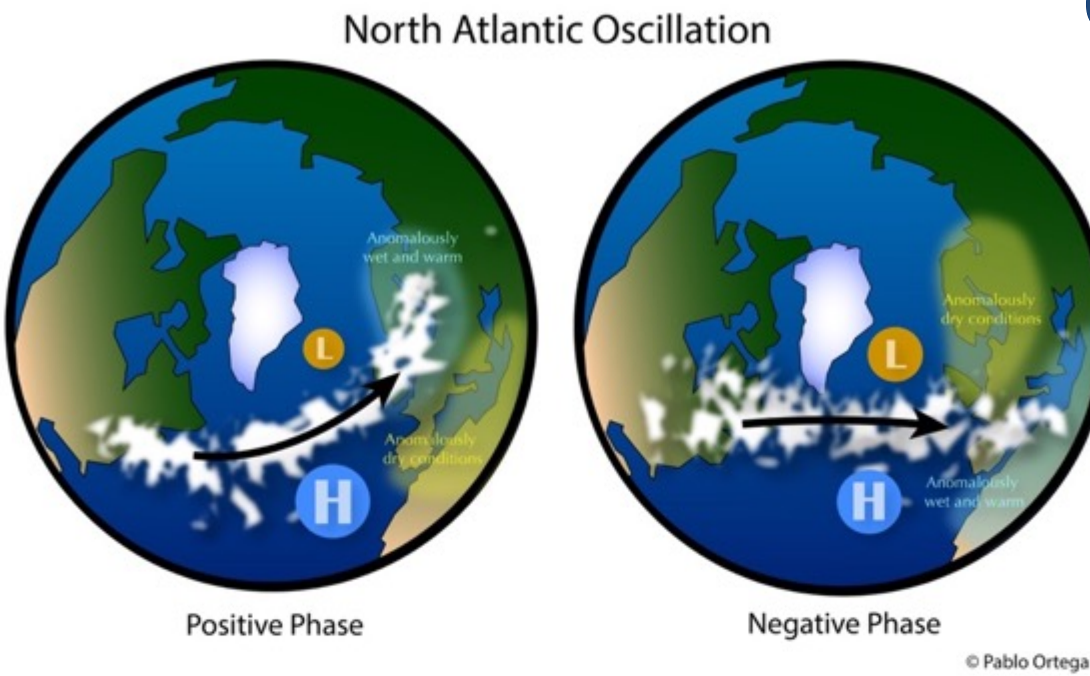
	1901-1930			1931-1960			1961-1990			1991-Today		
	CRU RAIN (mm/year)	GPCC RAIN (mm/year)	UDEL RAIN (mm/year)	CRU RAIN (mm/year)	GPCC RAIN (mm/year)	UDEL RAIN (mm/year)	CRU RAIN (mm/year)	GPCC RAIN (mm/year)	UDEL RAIN (mm/year)	CRU RAIN (mm/year)	GPCC RAIN (mm/year)	UDEL RAIN (mm/year)
IBERIA	634.3	688.6	687.8	665.1	699.7	692.6	672.9	715.2	697.2	648.8	677.3	667.5
MAGHREB	105.5	163.6	120.2	103.4	138.5	97.7	101.8	130.6	89.8	99.7	134.7	93.1
SAHEL	244.1	304.7	296.4	274.5	310.2	305.5	222.9	249.8	243.3	233.2	265.5	263.2
ETHIOPEAN H.	1007.6	1010.2	1077.9	955.6	995.3	1080.9	981.6	994.5	1083.1	965.9	943.9	1076.8
BALKANS	712.5	733.9	746.6	725	744.7	753	701.2	716.5	730.1	706.9	707.8	729.3
ANATOLIA	577.4	662.6	599.8	588.3	652	603.5	584.9	644.3	595.3	585.2	642	592.4
LEVANT	239.7	320.4	271.4	218.2	268.6	215.4	225.6	257.9	200.9	212.5	243.3	195
ARABIAN P.	106.7	128.5	134.9	104.8	121.7	126.3	104.3	118.6	117.8	99	107.3	106.6
IRAN	203.2	240.5	258.8	205.7	234.1	250.6	205.8	232.3	247.9	193.9	227.6	237

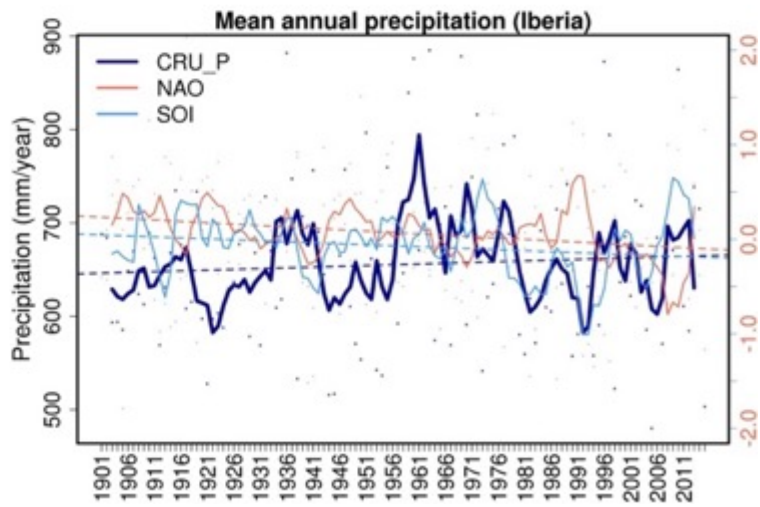
Precipitation trend (mm/decade)

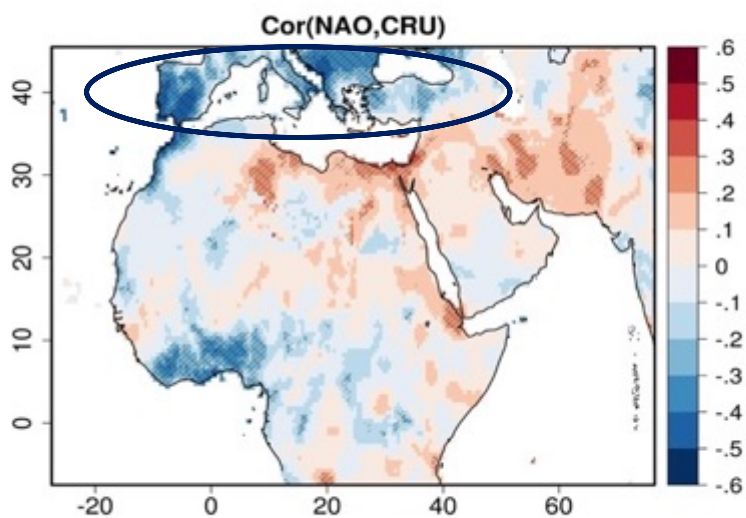
	1901-1930			1931-1960			1961-1990			1991-Today		
	TREND CRU (mm/decade)	TREND GPCC (mm/decade)	TREND UDEL (mm/decade)	TREND CRU (mm/decade)	TREND GPCC (mm/decade)	TREND UDEL (mm/decade)	TREND CRU (mm/decade)	TREND GPCC (mm/decade)	TREND UDEL (mm/decade)	TREND CRU (mm/decade)	TREND GPCC (mm/decade)	TREND UDEL (mm/decade)
IBERIA	-7.0	-4.9	-14.1	10.1	13.1	7.1	-28.3	-26.4	**-38.0**	10.2	-6.1	14.3
MAGHREB	**-5.2**	**-14.7**	**-14.5**	4.8	6.5	5.1	-2.6	-6.0	-6.0	0.6	3.0	-1.5
SAHEL	8.5	-3.1	-3.4	11.4	6.8	8.1	**-35.8**	**-34.4**	**-34.4**	13.4	6.7	20.2
ETHIOPEAN H.	-2.6	-17.7	1.9	-32.5	-2.5	6.3	**-68.2**	-33.2	**-48.3**	40.1	-9.8	18.3
BALKANS	14.8	14.1	-4.6	-6.7	-14.4	4.6	**-39.7**	-44.2	**-46.9**	**57.7**	**51.6**	**81.4**
ANATOLIA	-0.8	4.4	1.3	-11.7	-10.8	-7.4	-19.6	-20.3	-16.5	14.4	3.0	-21.1
LEVANT	-3.7	-18.7	**-29.4**	-7.1	-8.3	-3.3	-8.1	-14.7	-13.5	-6.7	-9.4	-8.9
ARABIAN P.	-0.1	7.2	4.7	**-4.7**	-7.0	**-9.4**	-4.8	-0.8	-6.5	-7.6	-15.3	**-21.2**
IRAN	0.8	7.8	6.6	2.2	2.9	1.4	3.8	0.7	1.3	**-27.0**	-28.2	-5.5

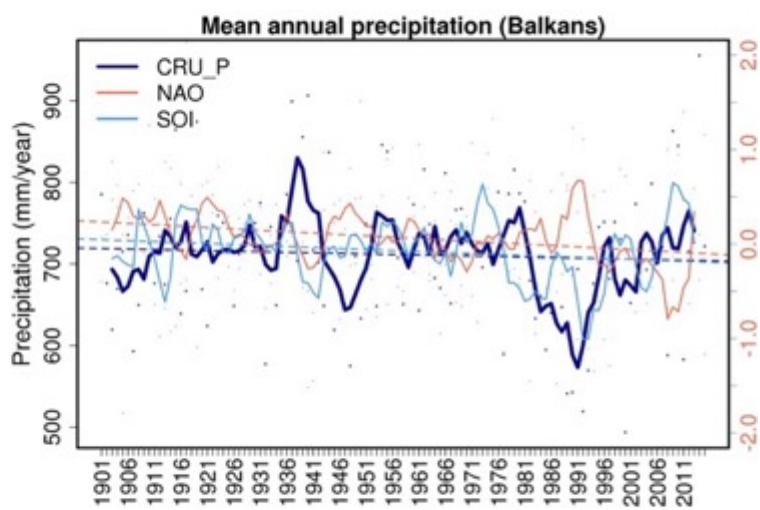
3 datasets: CRU, GPCC, UDEL

Connection with NAO



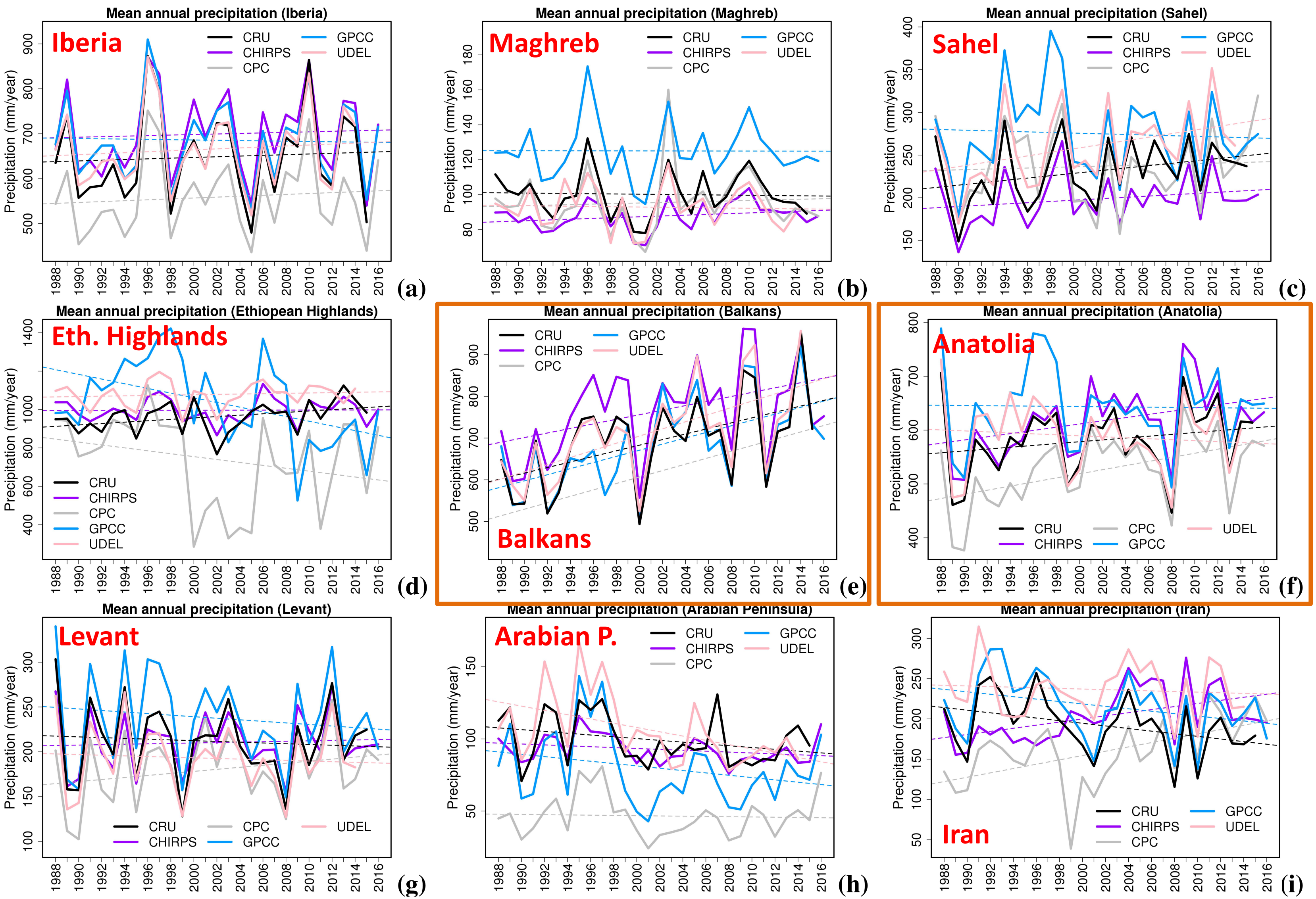






Correlation coefficient between North Atlantic Oscillation index and annual rainfall. Statistically significant correlations are hatched.

Precipitation trends since 1988



Annual Precipitation and trends for the period 1988-Today.
5 datasets: CRU, CHIRPS, CPC, GPCC, UDEL

Assessment of Extremes (1988-2014)

Six indices, amongst the ones suggested by **WMO**, were calculated*.

*for the three datasets that provided daily precipitation values (**GPCC, CHIRPS, CPC**)

1. Consecutive dry days (CDD)
2. Consecutive wet days (CWD)
3. Annual count of rainy days (RR1)
4. Annual count of days with precipitation larger than 20 mm (R20).
5. Highest 5-day precipitation amount for each year (R5D).
6. Simple precipitation intensity index (SDII)

- Strong uncertainty in results between the 3 datasets
- Increase of CDD: Sahel, Ethiopian Highlands, Levant
- **Increase of CWD: Balkans, Anatolia, Iran**
- **Increase of RR1 & R20: Balkans**
- No significant trends for the other indices or disagreement between the datasets

Drought in Syria

Low-level water in dams (Cyprus)

Flood in Jeddah

Observational Uncertainty: Deviation from ensemble mean

Annual Precipitation Sum (1988-2014)

Ensemble Mean of the 5 datasets

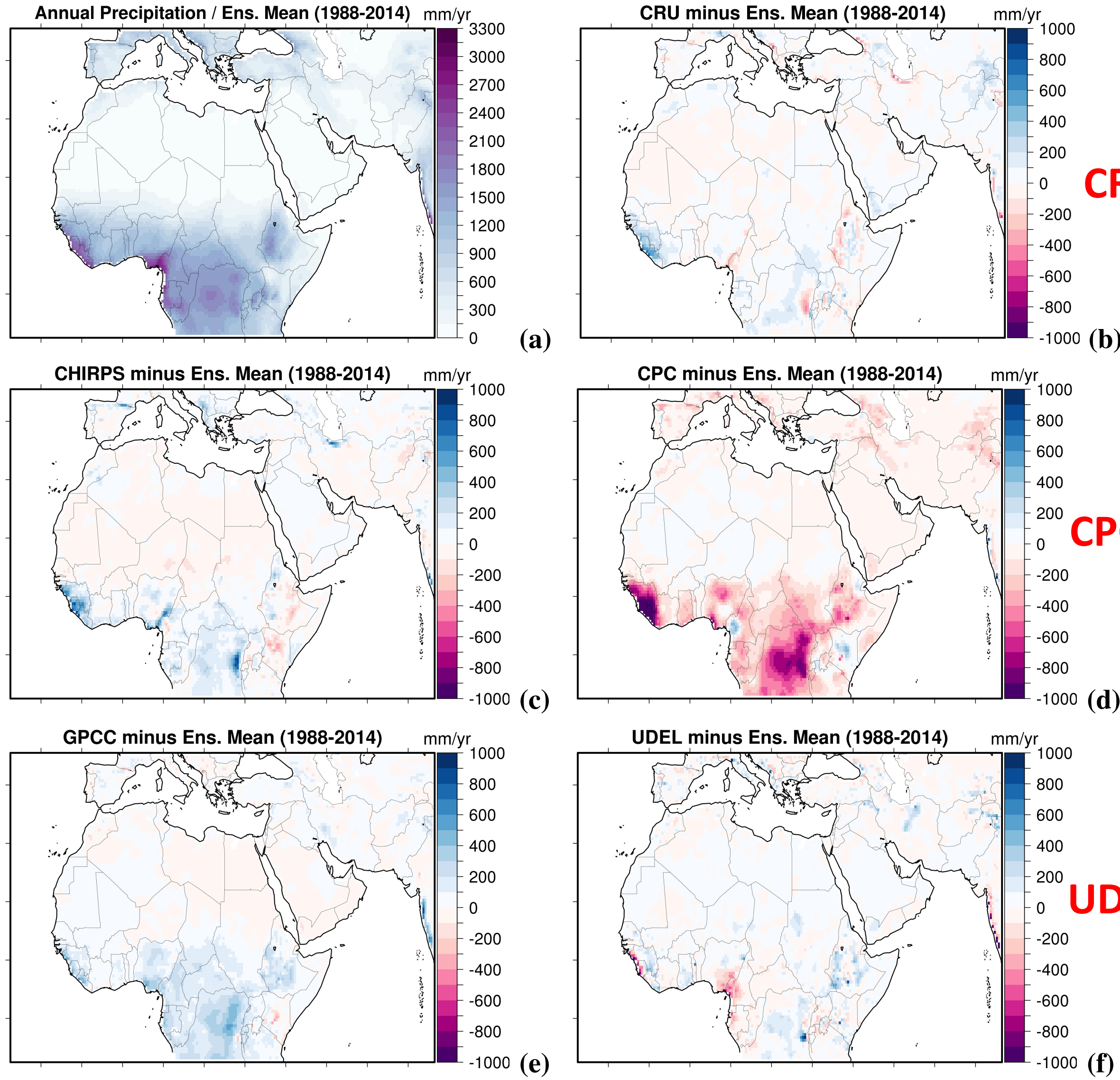
CRU – Ens. Mean

CHIRPS – Ens. Mean

CPC – Ens. Mean

GPCC – Ens. Mean

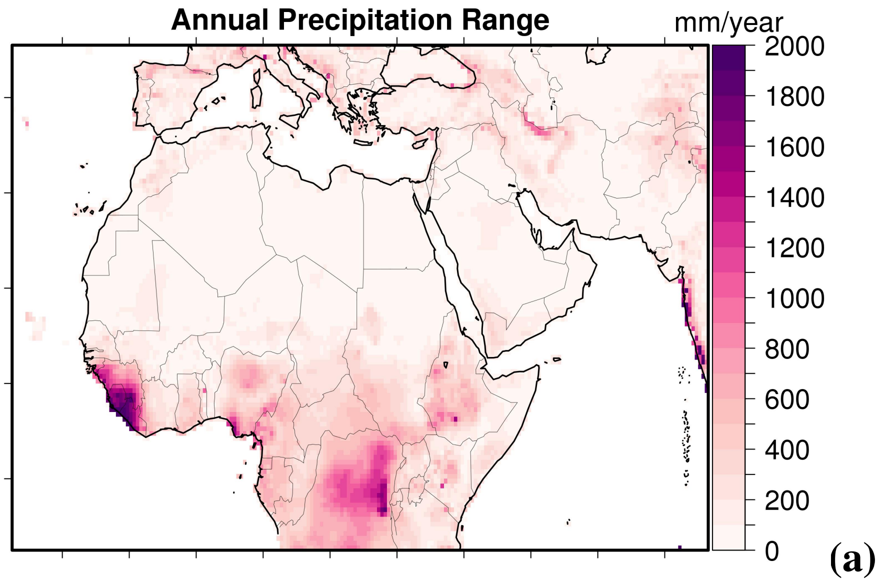
UDEL – Ens. Mean

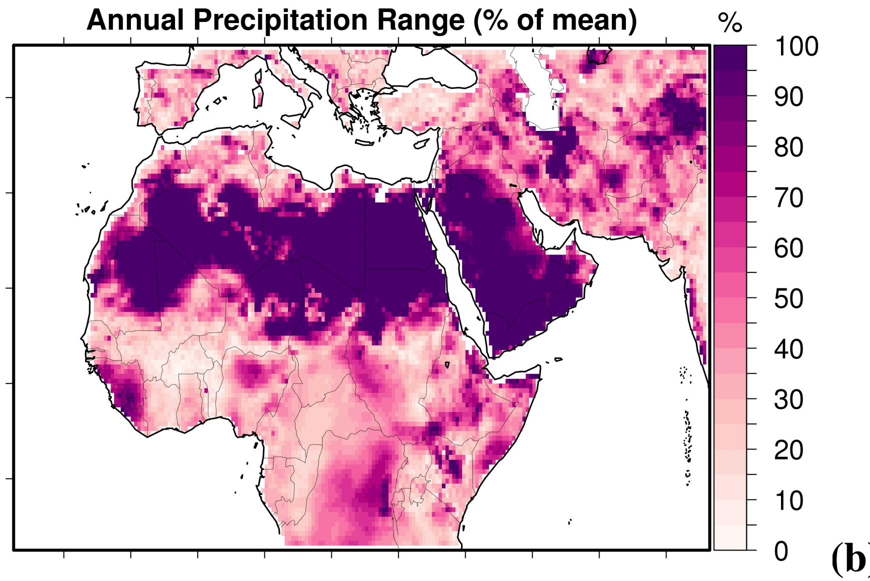


Observational Uncertainty:

Range between datasets

Range of annual precipitation climatology (1988-2014) between the 5 datasets



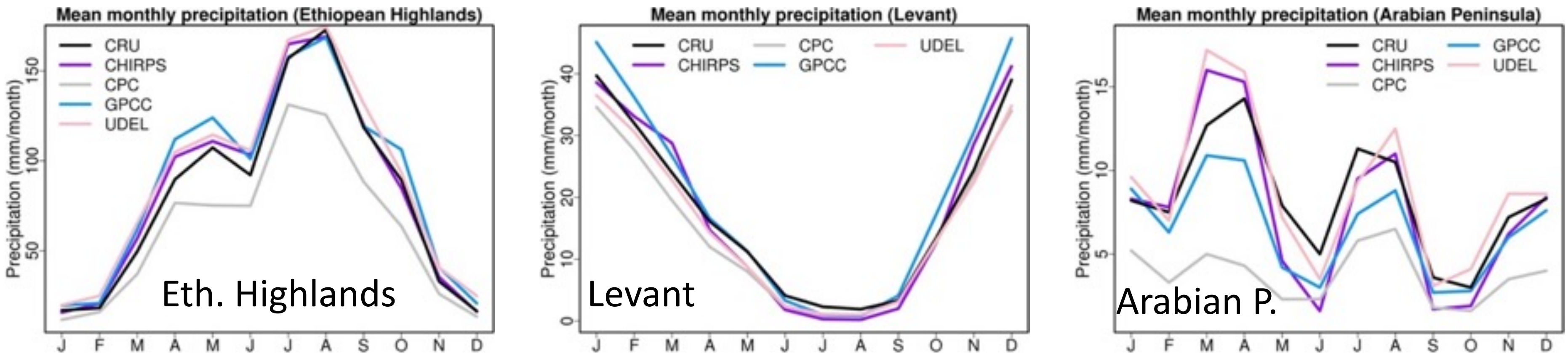


Absolute values (mm/year) **Percentage (%) of mean**

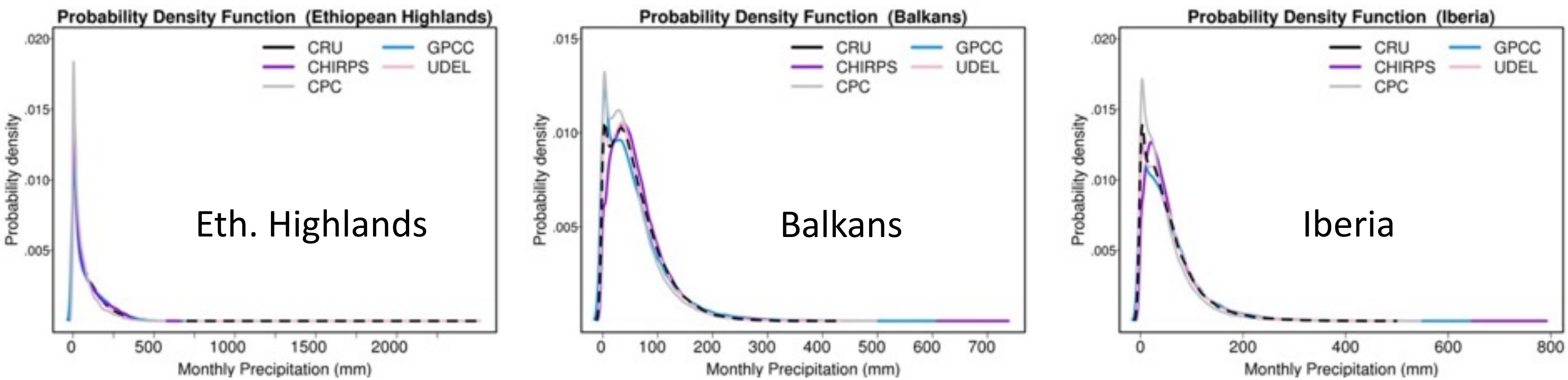
Observational Uncertainty:

Monthly distribution and Extremes (1988-2014)

Monthly Distribution



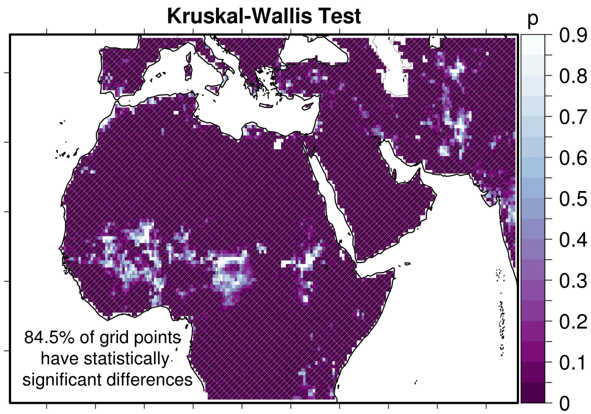
Probability Density Functions (PDFs)



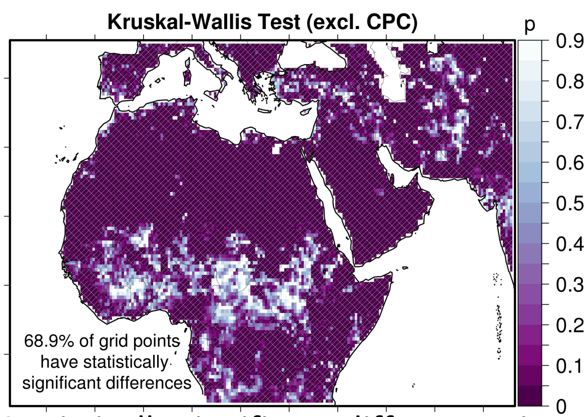
Observational Uncertainty:

Application of non-parametric statistical tests

The Kruskal-Wallis H-test (Kruskal and Wallis 1952)



Statistically significant differences in **84.5%** of grid points



Statistically significant differences in **68.9%** of grid points (excl. CPC)

- ✓ Appropriate for multivariate analysis since more than two samples (i.e. datasets) are compared.
- ✓ A nonparametric method it does not assume a normal distribution of the tested samples.
- ✓ The parametric equivalent to this test is the one-way analysis of variance (ANOVA).
- ✓ Our null hypothesis is that the distributions of the monthly values of all observational datasets are equal.
- ✓ When the Kruskal-Wallis H-test leads to statistically significant results, then at least one of the datasets is different from the rest.
- ✓ The level of statistical significance is set to 95%.

Conclusions (1/2)

- The long-range trends indicate an overall **drying of the MENA region**, since the beginning of the 20th century (significant trends: **Maghreb, Sahel, Levant and Arabian Peninsula**).

- Particularly important is the **strong** and **significant drying** over the period **1961-1990** that most of the region has experienced.

- The impact of global warming in precipitation is apparently not as straightforward as it is for temperature. Modes of internal climate variability, such as **NAO**, are likely still the dominant drivers.

- Recent precipitation trends are **less pronounced** and **robust** (with the exception of significant increases in **Balkans** and **Anatolia**).

- The trends of **extremes** are **not profound**. Exception are again the positive trends of **heavy precipitation** indices for the **Balkans** and **Anatolia**.

Conclusions (2/2)

- At each stage of the analysis, **differences** between the tested datasets were observed.

- These are evident not only for mean climate conditions but also for the **indices of extremes** and also for the sub-regions with a sufficient coverage of meteorological stations (e.g. **Iberia, Anatolia, Balkans**).

- This could be related to the different **grid spacing**, the various **interpolation methods** used or different treatment of periods of **missing information** in the raw meteorological records.

- The significance of differences between datasets is highlighted using advanced **non-parametric** methods (Kruskal-Wallis, Dunn's test).

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ORIGINAL PAPER

CrossMark

Observed rainfall trends and precipitation uncertainty in the vicinity of the Mediterranean, Middle East and North Africa

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Abstract
The present study investigates the century-long and more recent rainfall trends over the greater region of Middle East and North Africa (MENA). Five up-to-date gridded observational datasets are employed. Besides mean annual values, trends of six indices of drought and extreme precipitation are also considered in the analysis. Most important findings include the significant negative trends over the Maghreb, Levant, Arabian Peninsula, and Sahel regions that are evident since the beginning of the twentieth century and are more or less extended to today. On the other hand, for some Mediterranean regions such as the Balkans and the Anatolian Plateau, precipitation records during the most recent decades indicate a significant increasing trend and a recovering from the dry conditions that occurred during the mid-1970s and mid-1980s. The fact that over parts of the study region the selected datasets were found to have substantial differences in terms of mean climate, trends, and interannual variability, motivated the more thorough investigation of the precipitation observational uncertainty. Several aspects, such as annual and monthly mean climatologies and also discrepancies in the monthly time-series distribution, are discussed using common methods in the field of climatology but also more sophisticated, nonparametric approaches such as the Kruskal–Wallis and Dunn's tests. Results indicate that in the best case, the data sources are found to have statistically significant differences in the distribution of monthly precipitation for about 50% of the study region extent. This percentage is increased up to 70% when particular datasets are compared. Indicatively, the range between the tested rainfall datasets is found to be more than 20% of their mean annual values for most of the extent of MENA, while locally, for the hyper-arid regions, this percentage is increased up to 100%. Precipitation observational uncertainty is also profound for parts of southern Europe. Outlier datasets over individual regions are identified in order to be more cautiously used in future regional climate studies.

1 Introduction

Both observed trends and future climate projections suggest that the broader region of the Middle East and North Africa (MENA) is expected to be greatly affected by global warming (Lelieveld et al. 2016). In this already environmentally stressed part of the world, anthropogenic climate change is likely to induce a further warming, combined with prominent changes in the hydrological cycle. Further challenges such as the rapid population increase and strong urbanization trends, political and religious conflicts, economic instability, will likely enhance the climate change-related impacts and reduce the resilience and adaptive capacity for both human communities and natural ecosystems.

Particularly for precipitation in the region of interest, most of the studies on observed climatic changes focus over the Mediterranean countries. Xoplaki et al. (2000) and Maheras et al. (2004) identified significant negative trends in winter and autumn precipitation amounts over parts of Greece. Zhang et al. (2005) analyzed a large number of Middle East meteorological stations for a long period covering mainly the second half of the twentieth century. They identified strong interannual variability of precipitation but an absence of significant trends. Partal and Kahya (2006) used data from 96 weather stations in Turkey for the period 1929–1993. They suggest a downward precipitation trend, predominantly in the western and southern part of the country. Similarly, for the period 1967–2006, Shaban (2009) identified a declining trend of precipitation and snow cover in Lebanon. Philandras et al. (2011), based on station observations and gridded datasets, suggest that annual rainfall was subject to statistically

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Thank you for your attention!!

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