UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

ISAC Consiglio Nazionale delle Ricerche

Predicting agricultural drought in the Greater Horn of Africa using the new generation of vegetation and precipitation products

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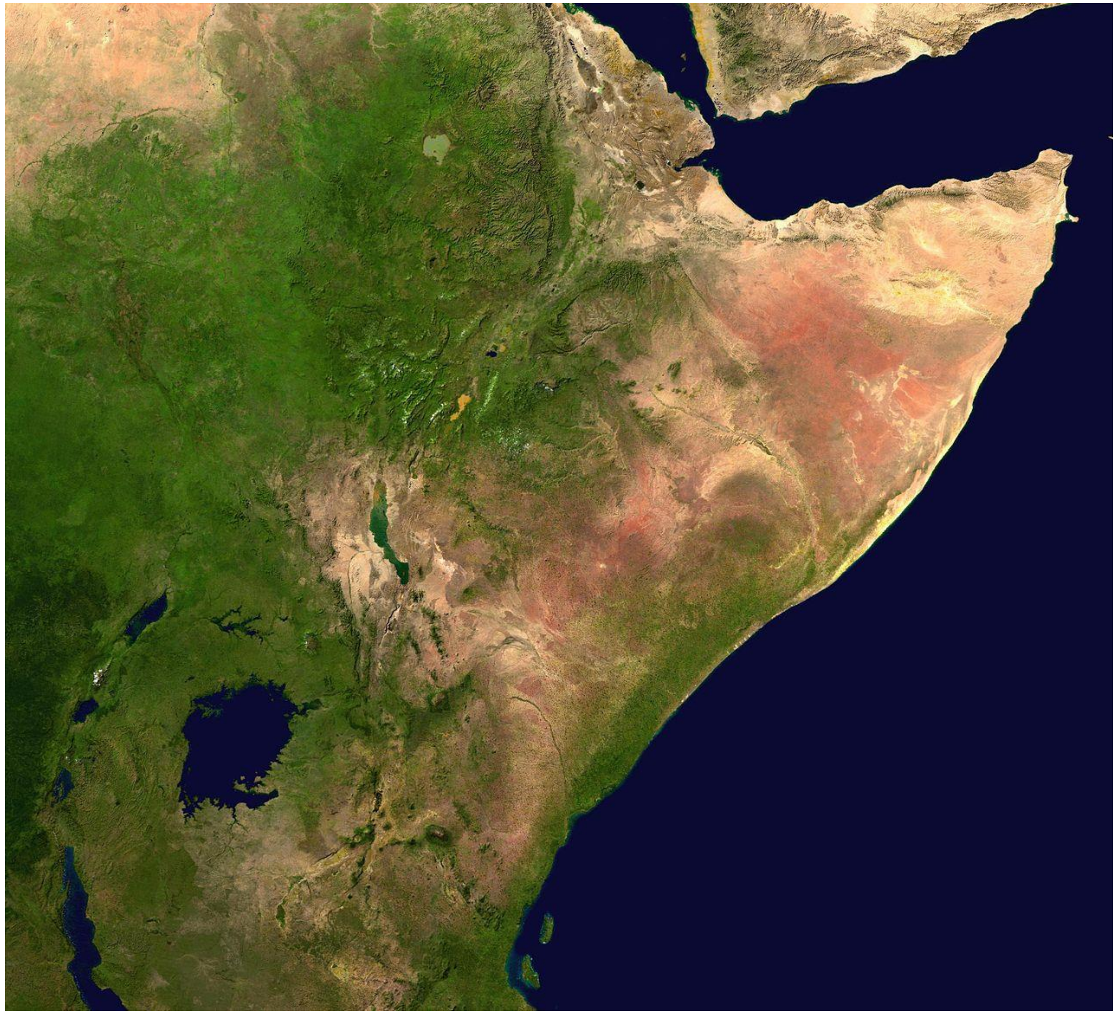


Motivation

- Drought phenomena can have many components (**meteorological, agricultural, hydrological and economic**)
- Droughts are particularly severe in the **Horn of Africa** as they produce damages to **livestock**, **crop losses** and cause **food security emergencies**
- To better understand and anticipate the effects of these events with remote sensing products, better spatial, temporal and spectral resolution are needed (West et al. 2019)
- The fact that drought events are projected to become more **frequent** and **intense** as a result of climate change, motivates the choice of **better temporal resolution**
- For vegetation drought monitoring, current worldwide monitoring systems do not take advantage of **geostationary products** (e.g. FEWSNET) (Fensholt et al. 2011)
- For meteorological drought monitoring, **weather station data is limited** and the station number is decreasing in Africa (Le Coz, 2020)

Geostationary products

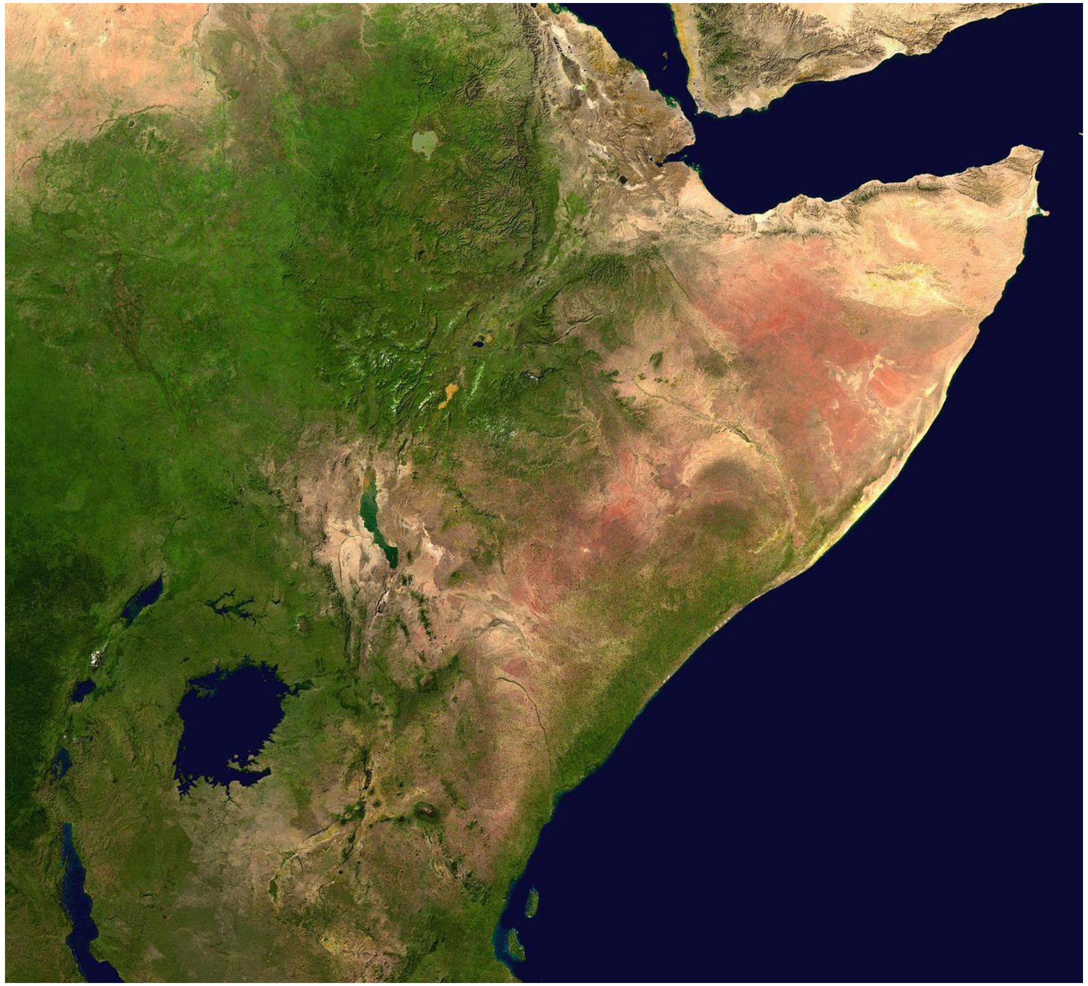
- **Polar Operational Environmental Satellite** data (POES) have better **spatial resolution**
- However, polar-orbiting products are normally able to **generate only 10 or 16 days non-cloud contaminated** vegetation composites (Fensholt et al. 2011)
  - Traditional orbital products are often obscured by clouds which makes it difficult to create consistent time series
  - In equatorial regions droughts occurred in the rainy seasons are associated with persistent cloud cover
  - POES frequently acquire pictures at the moment of maximum cloud built up and coverage (Fensholt et al. 2011)
- MSG **SEVIRI has a 15 minutes temporal resolution**, however it has rarely been used to monitor vegetation
  - East Africa drought case study (Fensholt et al. 2011) in 2008 (March 1-June 30) shows how 5-days NDVI composites for NOAA-17 AVHRR are polluted by clouds 50% of the time; SPOT-VGT 10 days composites are only slightly better; MODIS 16 days composites there was almost 100% of cloud cover in some areas. Same composites with SEVIRI deliver much less cloud covered pixels (1-10% maximum)

Research questions

- Can the usage of **better temporal resolution** help improve the prediction of an agricultural drought based on a meteorological drought?
- Given the improved temporal resolution, is the **standard precipitation index (SPI) sufficient** to predict vegetation anomalies (VCI)?
- What is the role of different **SPI daily aggregations** (e.g. scale)?
- Is a considerable difference observed when using **different precipitation products** (e.g. reanalysis, rain gauge, satellite)?

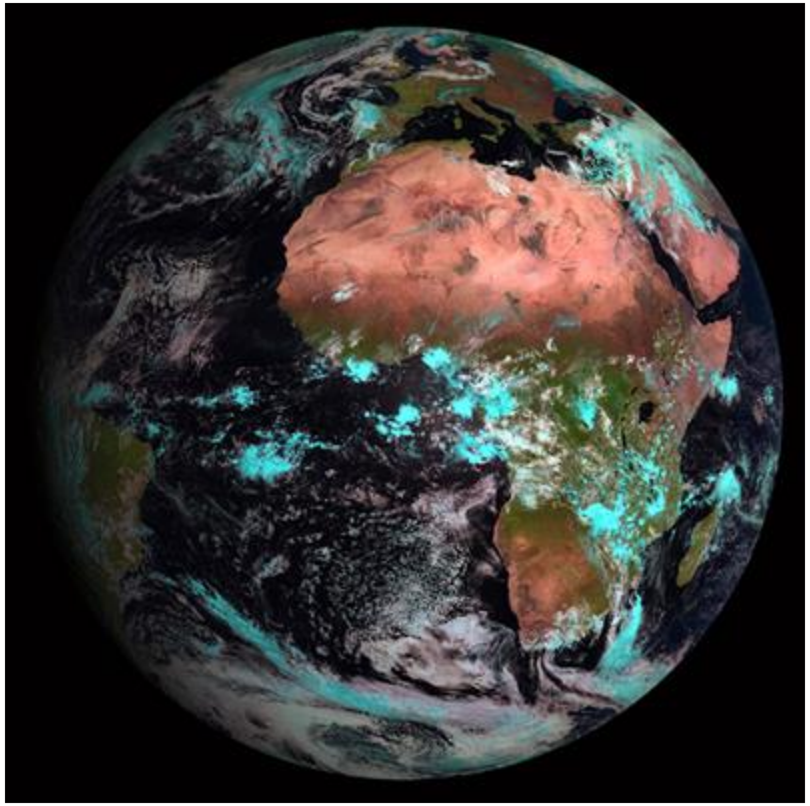
Context

- GHA Intense drought in 2009 followed by another drought period in 2010-2011
- Horn of Africa has a **bimodal pattern** of rainfall, with a short (March-May) and long (October-December) rainy season
- The October to December season **contributes up to 70% of the annual total rainfall** in the equatorial parts
- Ethiopia is covered by **highlands** which can receive about **2000 mm** of rainfall in a year, the lowlands are generally arid
- In **northern Somalia** rainfall in late autumn can generate about **500 mm** of rainfall
- Somalia has little seasonal variation of climate

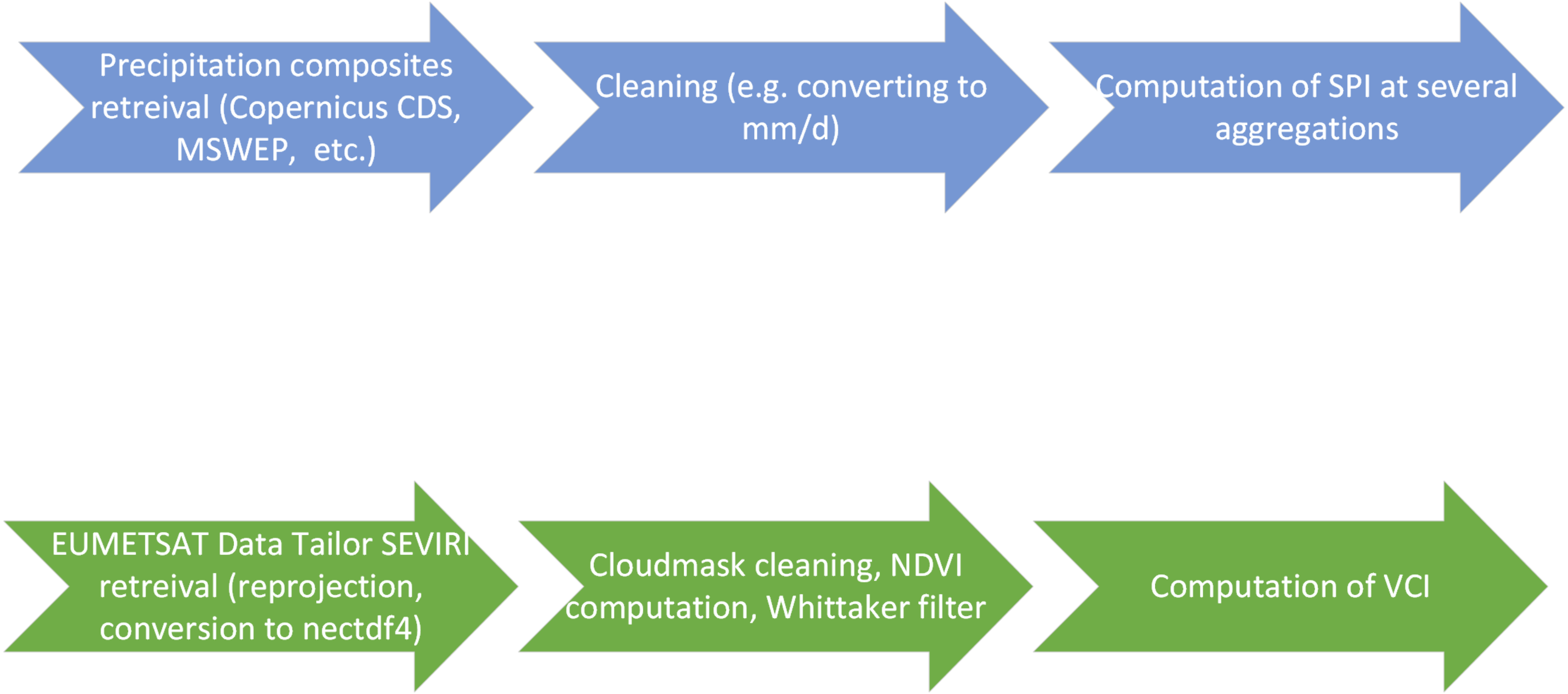


Data

- Precipitation
  - Rain Gauge
    - GPCC daily 1° x 1°
  - Reanalysis
    - ERA5 daily aggregates global 0.25° x 0.25°
  - Satellite
    - CHIRPS daily 0.25° x 0.25°
    - IMERG-GPM L3 Half Hourly 0.1° x 0.1°
  - Mix (satellite, rain gauge and reanalysis)
    - MSWEP daily 0.1° x 0.1°
- Vegetation
  - High Rate MSG SEVIRI 1.5 Image data



Pre-processing



Indices

PRECIPITATION

- Standard Precipitation Index (SPI)
  - 30, 60, 90, 180 days time scale

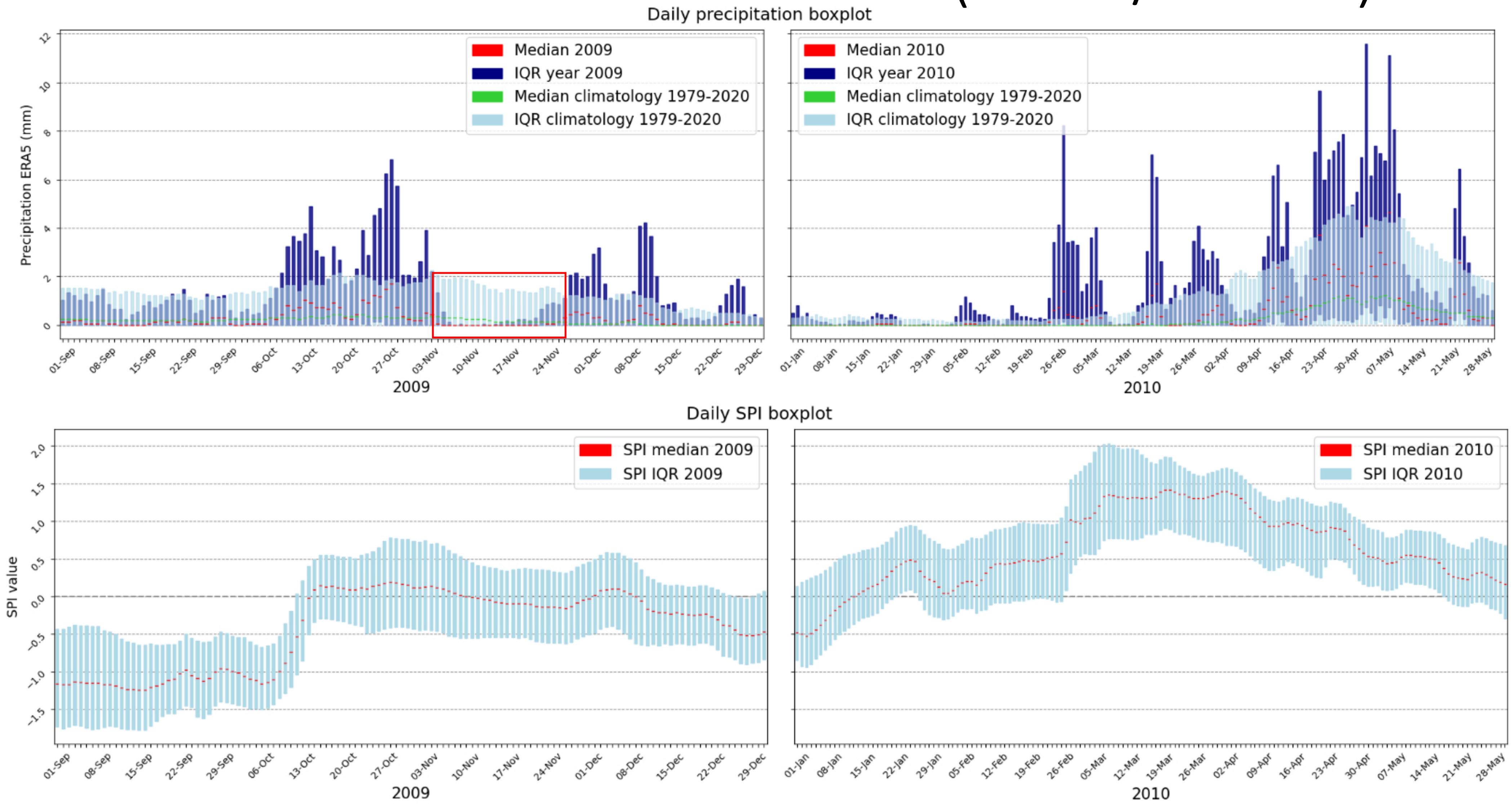
VEGETATION

- Normalized Difference Vegetation Index (NDVI)
- Vegetation Condition Index (VCI)

Classification (Winkler et al. 2017; Klisch and Atzberger, 2016; WMO, 2012):

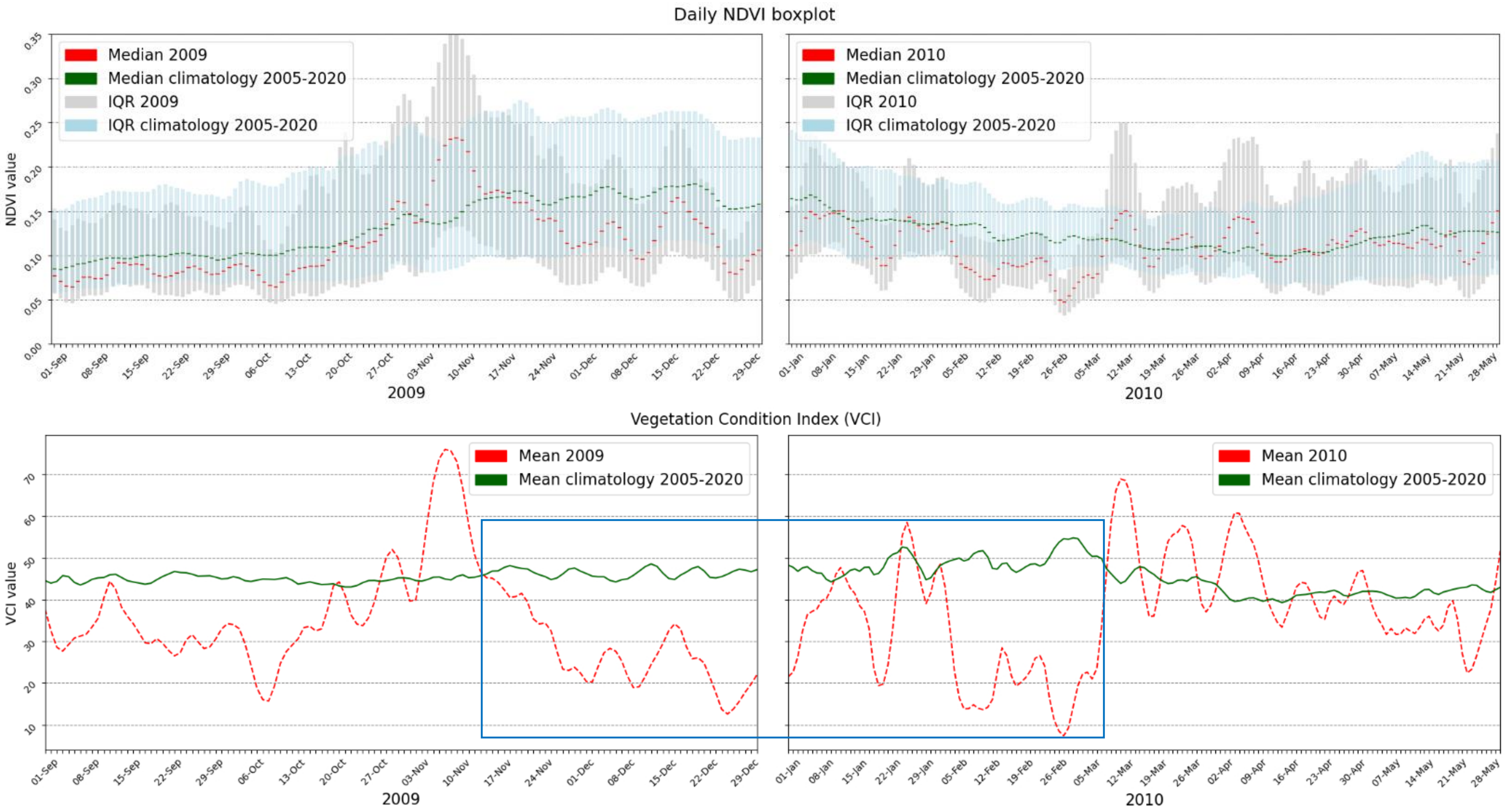
Drought Category	SPI Range	VCI Range (%)
Extreme drought	$SPI \leq -2$	$VCI < 10$
Severe drought	$-2 < SPI \leq -1.5$	$10 \leq VCI \leq 20$
Moderate drought	$-1.5 < SPI \leq -1$	$20 < VCI < 35$
No drought	$SPI > -1$	$VCI \geq 35$

Results – rainfall 2009-2010 (ERA5/SPI-60)



Daily precipitation shows a **20 days rainfall deficit** which **the SPI fails to signal** due to previous **intense precipitation**

Results – vegetation 2009-2010



The NDVI and VCI identifies **a strong agricultural drought** which is not signaled by the SPI

Results – drought spatial extent

Results

- The daily rainfall boxplot for 2009 compared to the climatology detects a **precipitation deficit between the 3rd and 24th of Nov 2009**
- However, the **SPI** estimates **becomes weaker** due to **intense short-term precipitation events followed by a drought period**
  - The index does not signal a meteorological drought at the end of 2009, and therefore does not efficiently predict the event of an intense vegetation drought in 2010
- The **spatial extent of the meteorological drought** is quite different from the **agricultural drought**
  - Maximum 2.5% of the pixels per day are identified to be on a severe meteorological drought from Nov 2009 to Jun 2010
  - At the beginning of March 2010 80% of the pixels are on severe vegetation drought

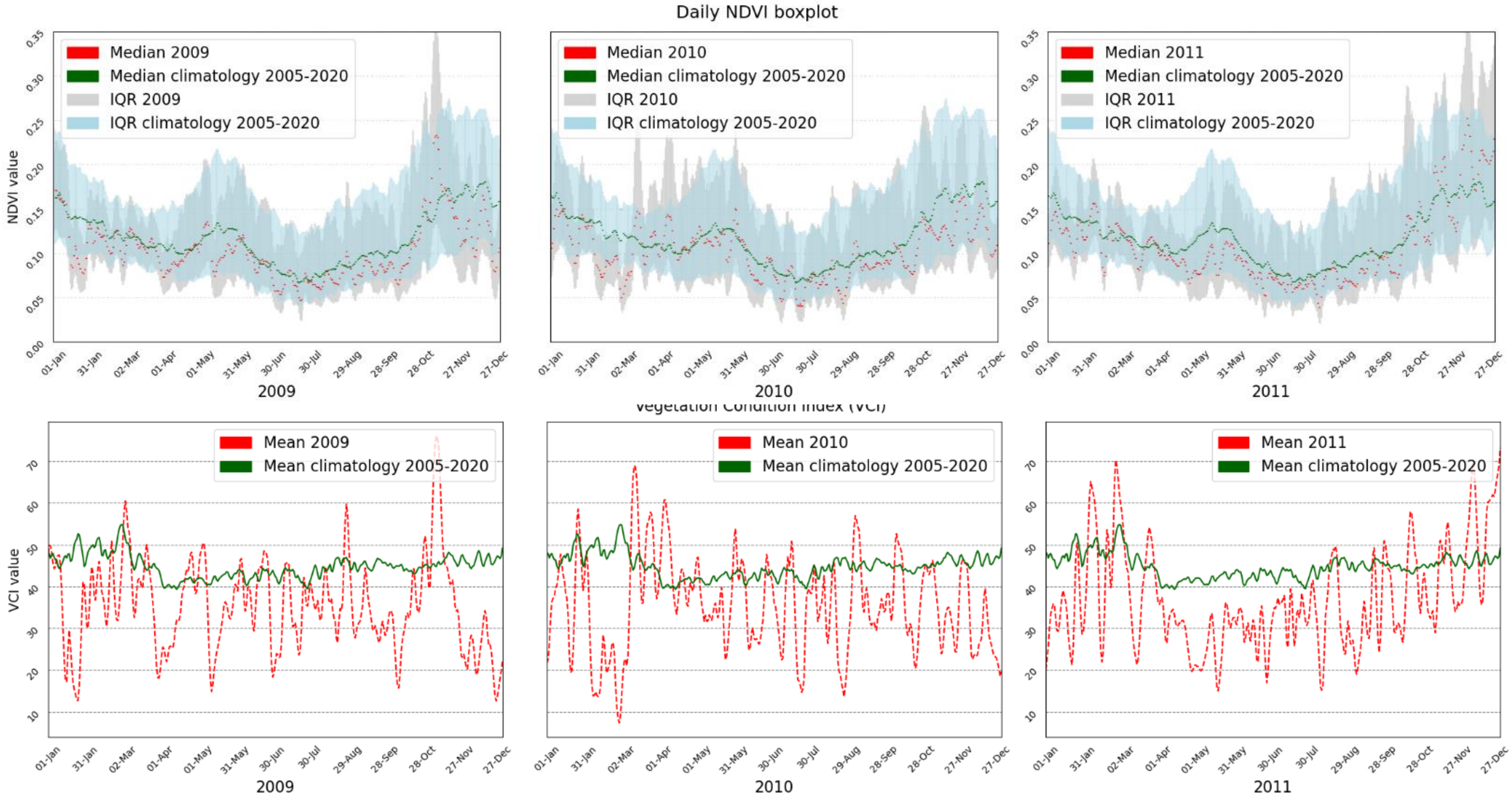
➔ Difficult to use the sole SPI in every case to capture future vegetation anomalies

➔ The result does not sensibly change when using other precipitation products or other SPI accumulations (e.g. 30, 60, 90, 180 days)

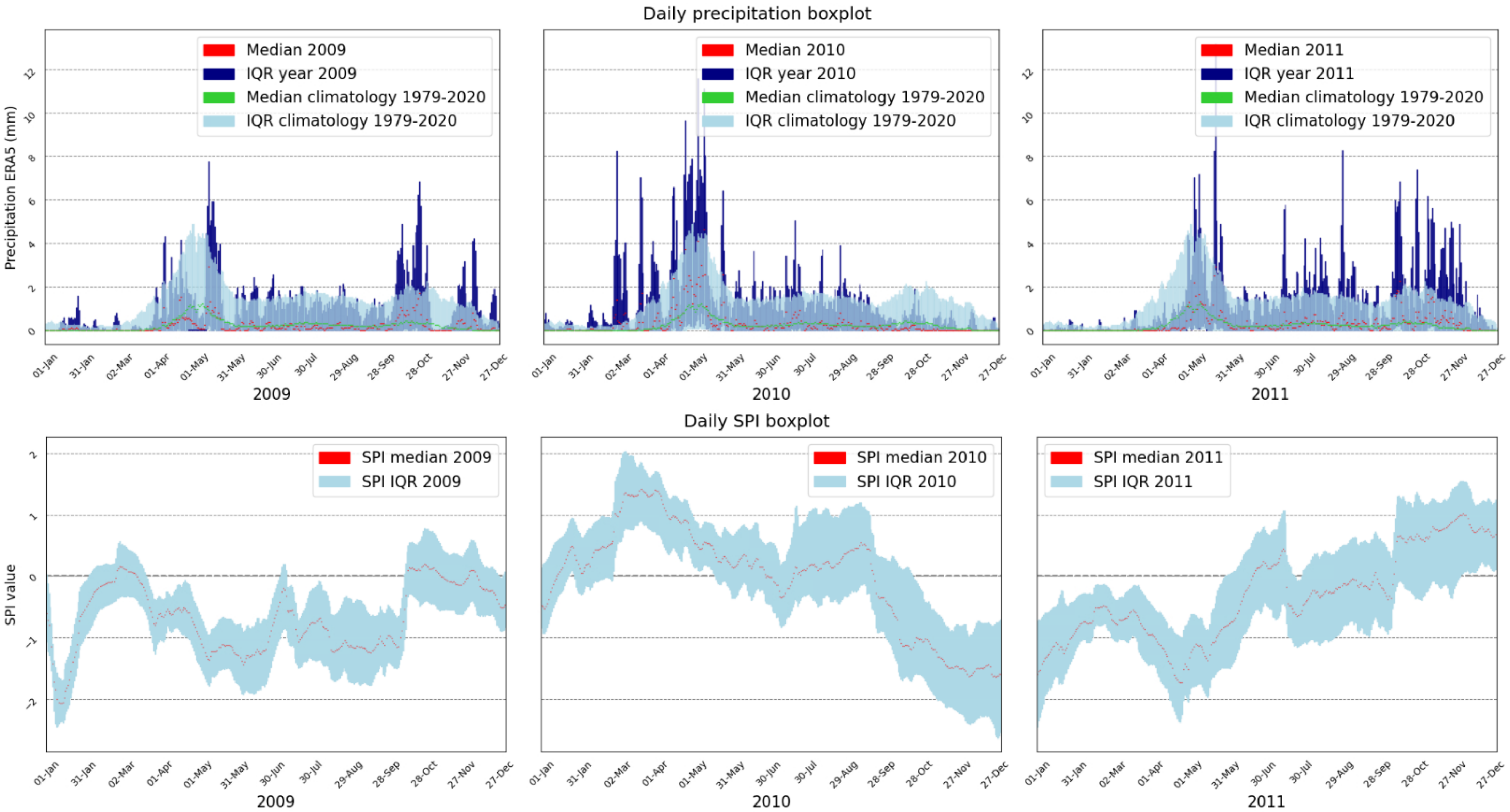
Future work

- The difficulty to use a standard precipitation index at daily scale to predict vegetation anomalies motivates **alternative approaches** that can better **understand the relationship between meteorological and vegetation drought** (e.g. Machine Learning systems)
- Modeling the effect of drought events on food security at improved temporal resolution using data from LMS (Living Measurement Survey)

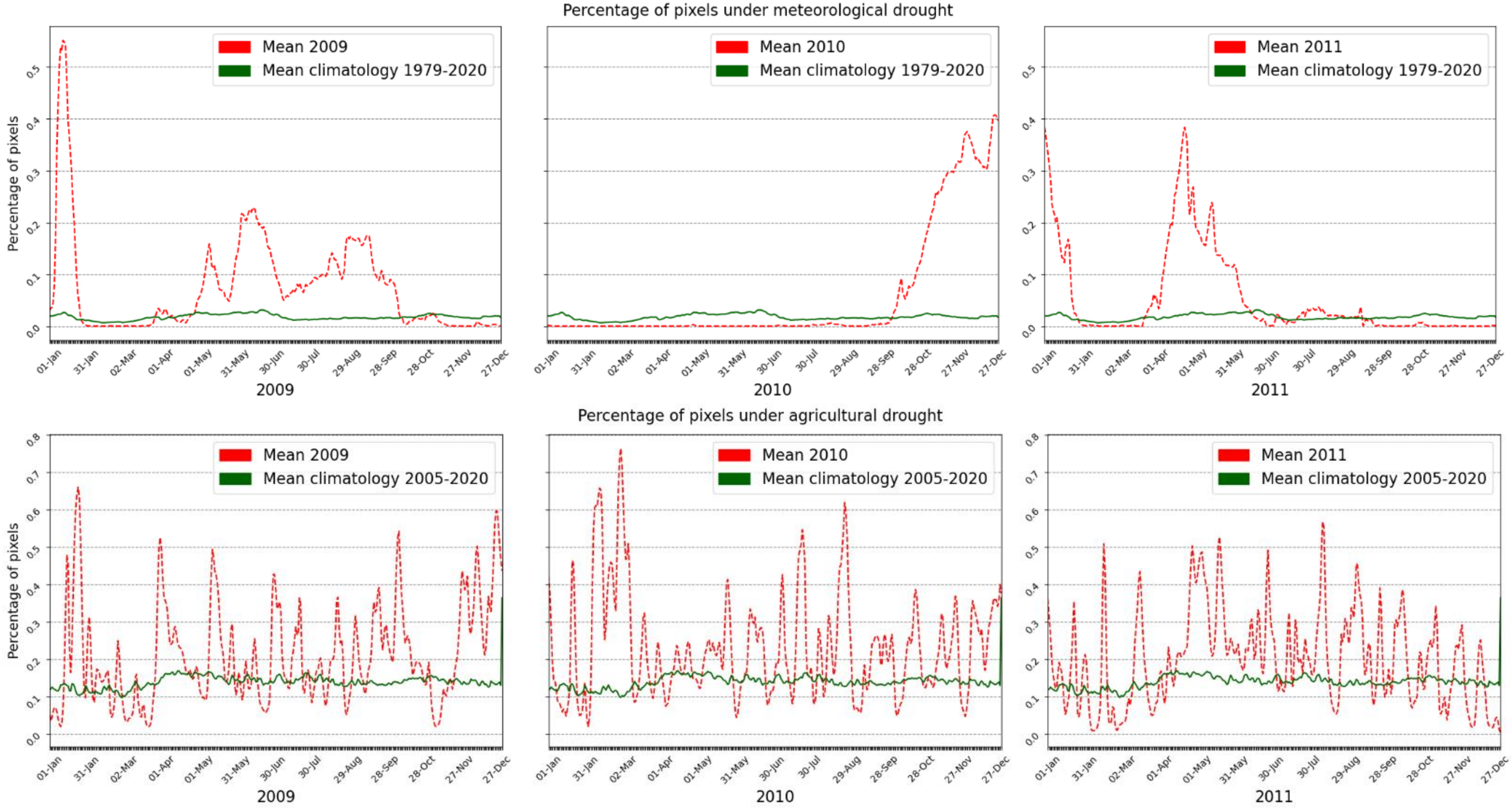
Appendix – Vegetation whole drought period



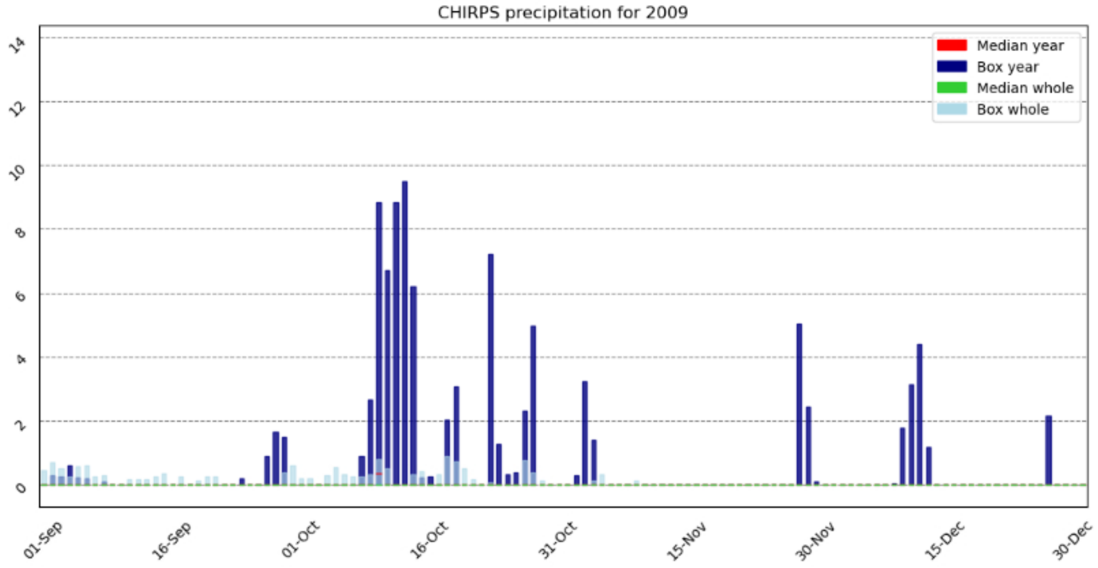
Appendix – Precipitation whole drought period

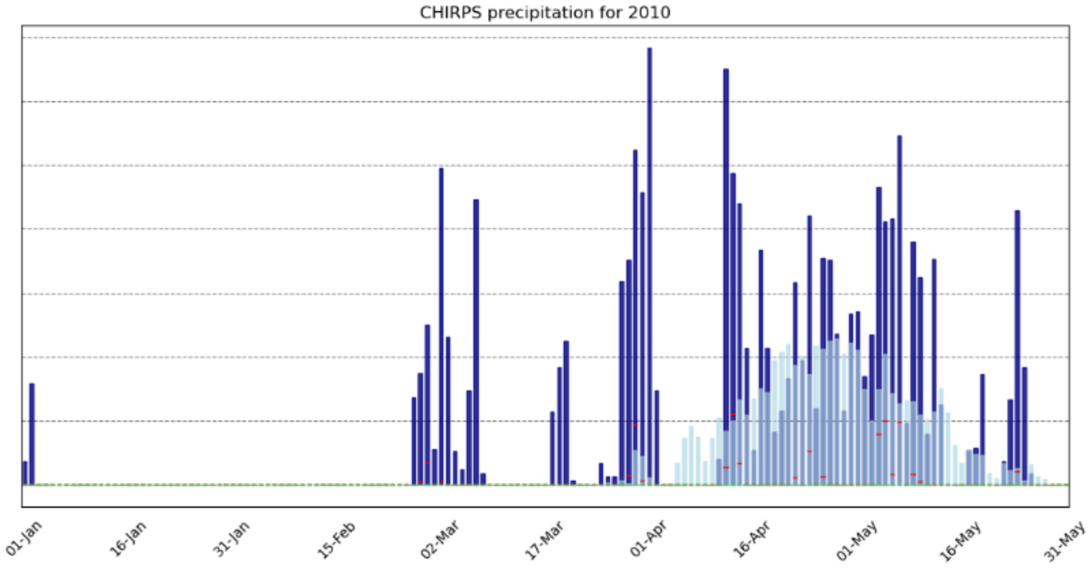


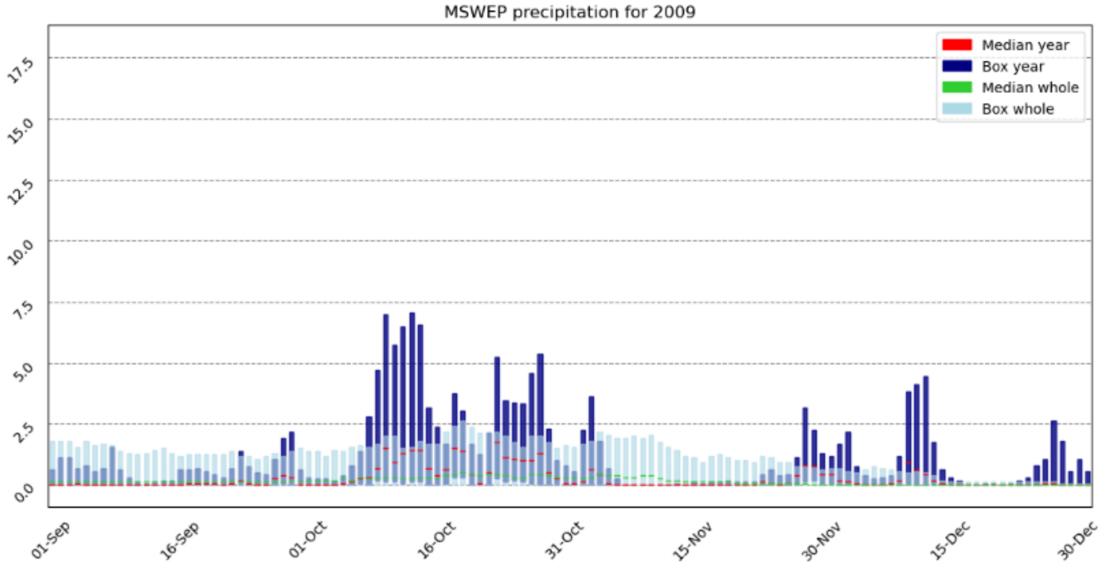
Appendix – Drought spatial extent whole period

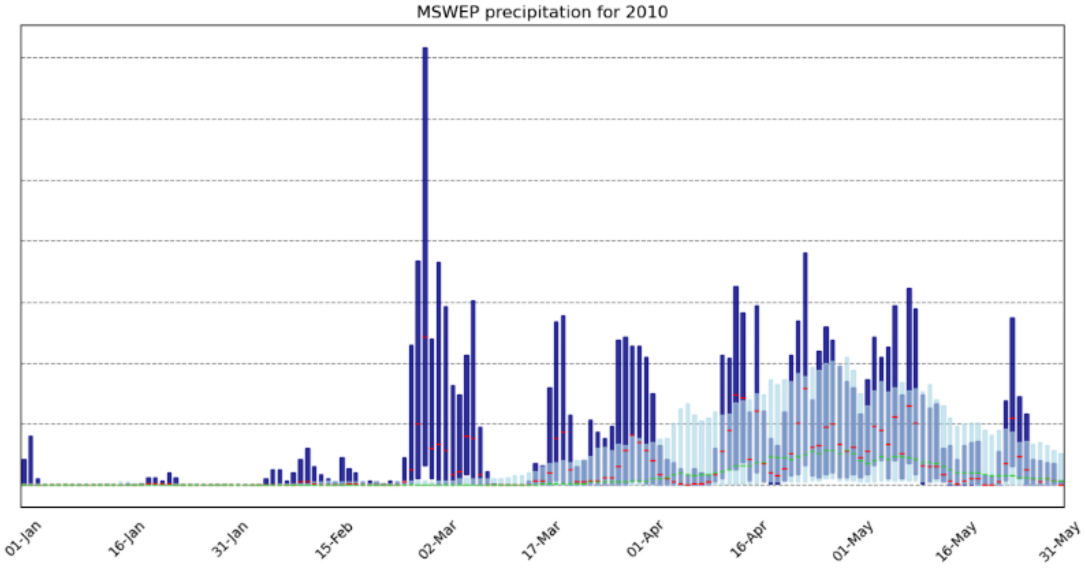


Appendix - Total precipitation – other products

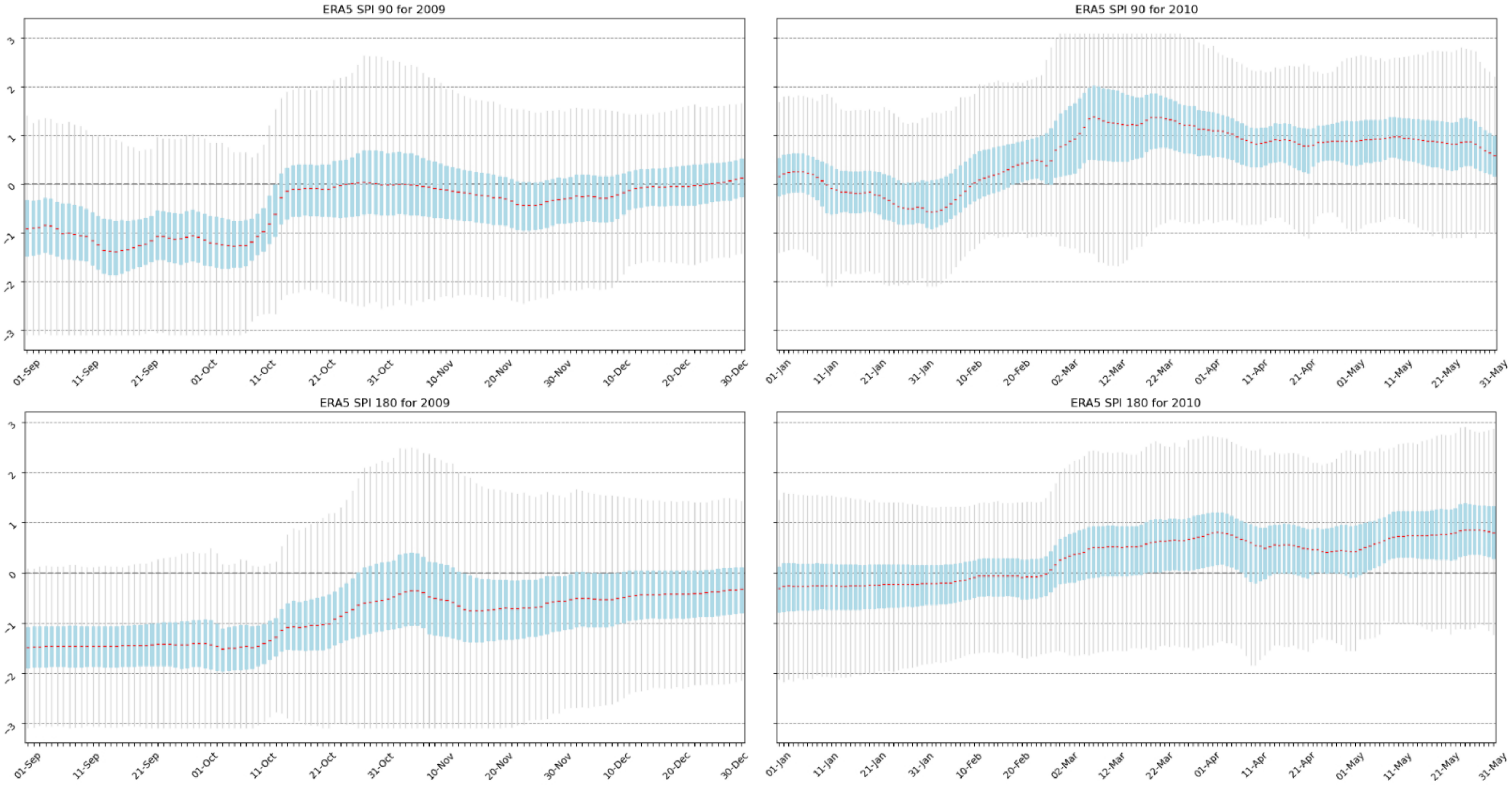




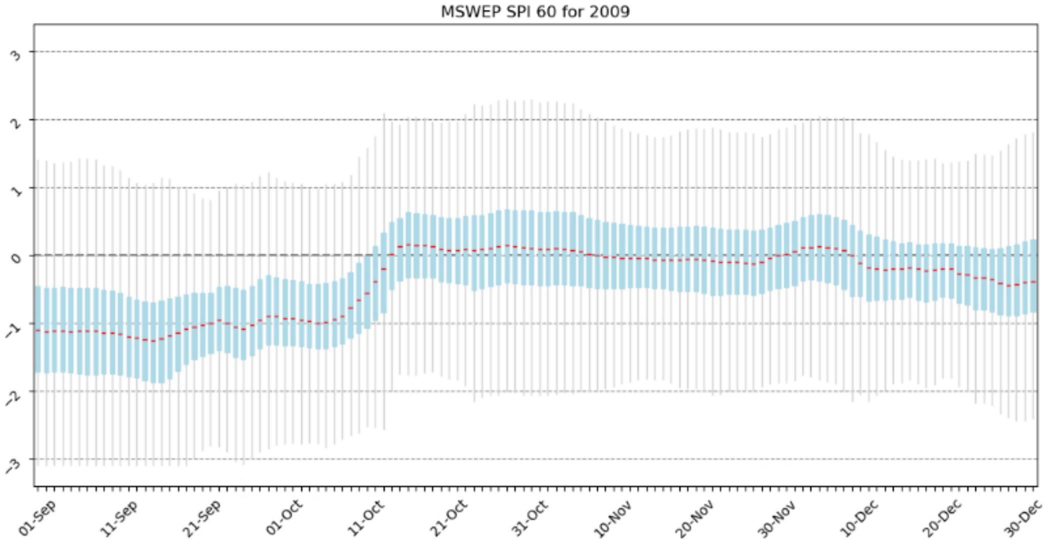


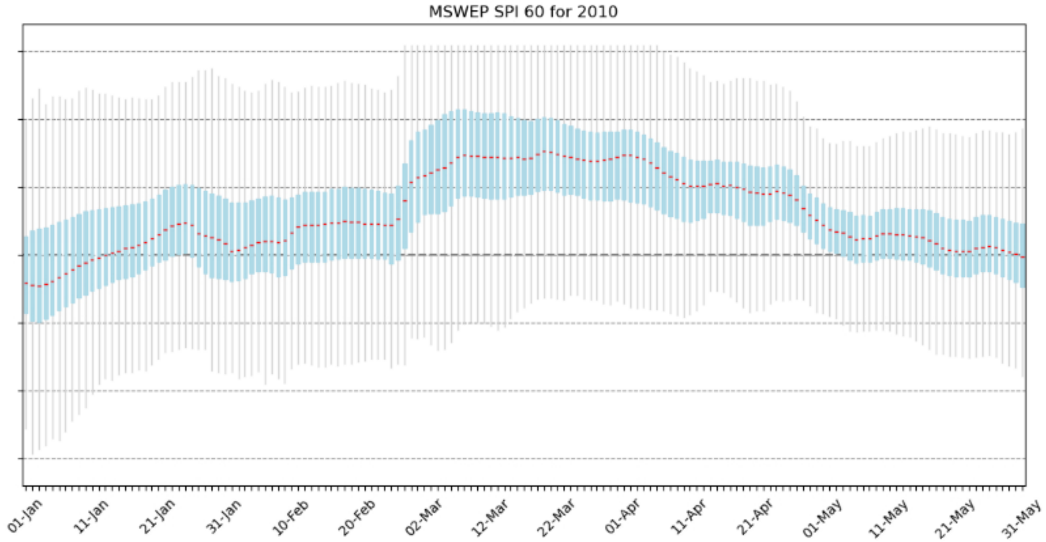


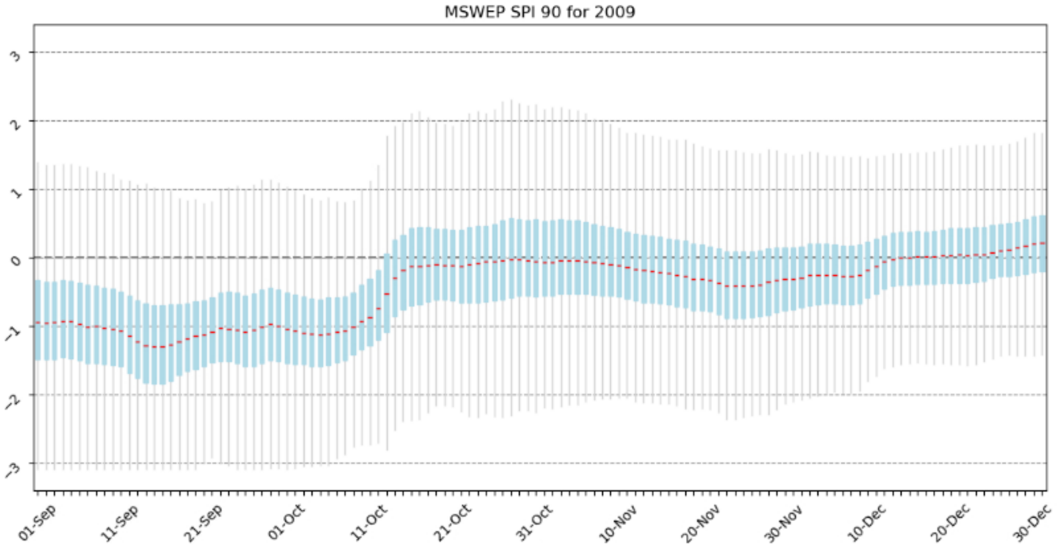
Appendix – Meteorological drought ERA5

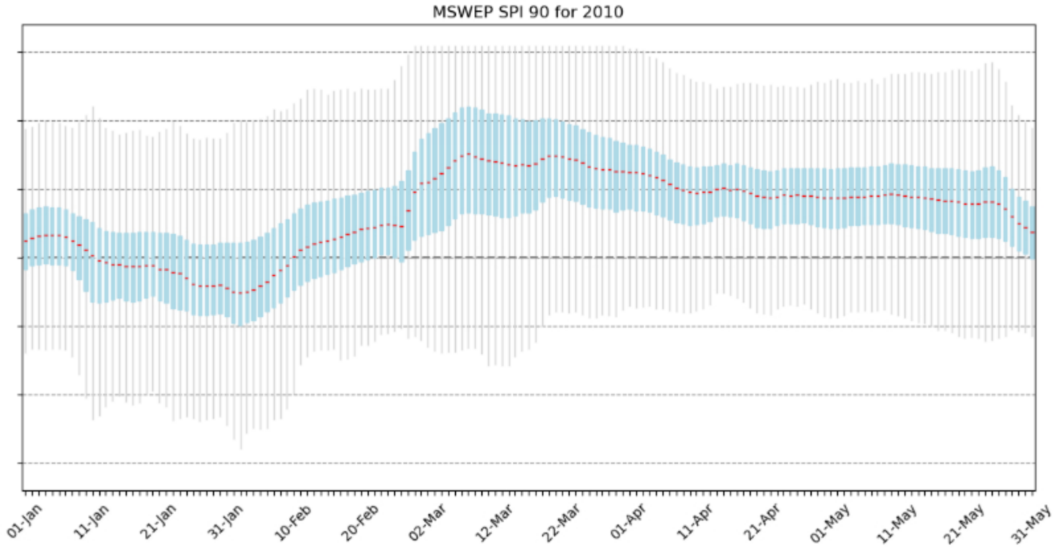


Appendix – Meteorological drought MSWEP









Appendix – Meteorological drought CHIRPS