中国科学院遥感与数字地球研究所
Institute of Remote Sensing and Digital Earth ,CAS

AOGEO Symposium

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Joint session of TG1, 5 and 6 of AOGEO

TG6: Drought Monitoring and Evaluation in Asia-Oceania Region

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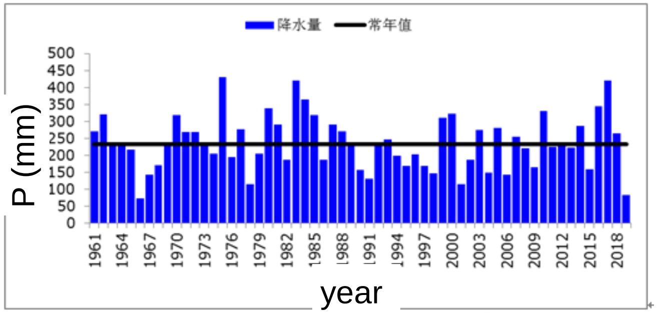
Why Drought Monitoring and Evaluation

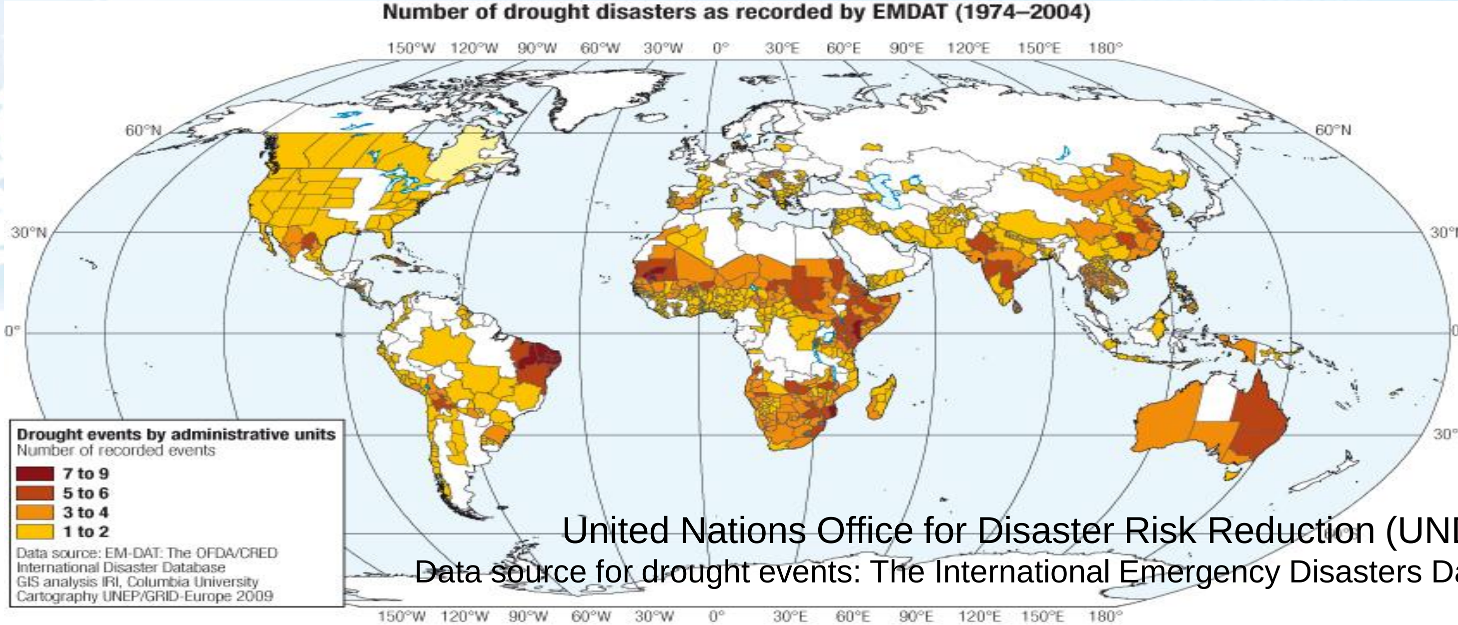
- Drought disasters have often caused great hunger, social instability, large scale migration of the population and extinction of civilizations in the history.
- The conflict between supply and demand of water resources constitutes the biggest problem for food security of a huge population in Asia-Oceania. Major policy responses are needed which relies on effective/efficient information.
- Under climate change, more frequent droughts are anticipated, predication will be necessary for preparedness and adaptation will be essential. e.g. how to adapt to future changes and needs?

Parts of Thailand in their worst drought in 50 years (July 2019)

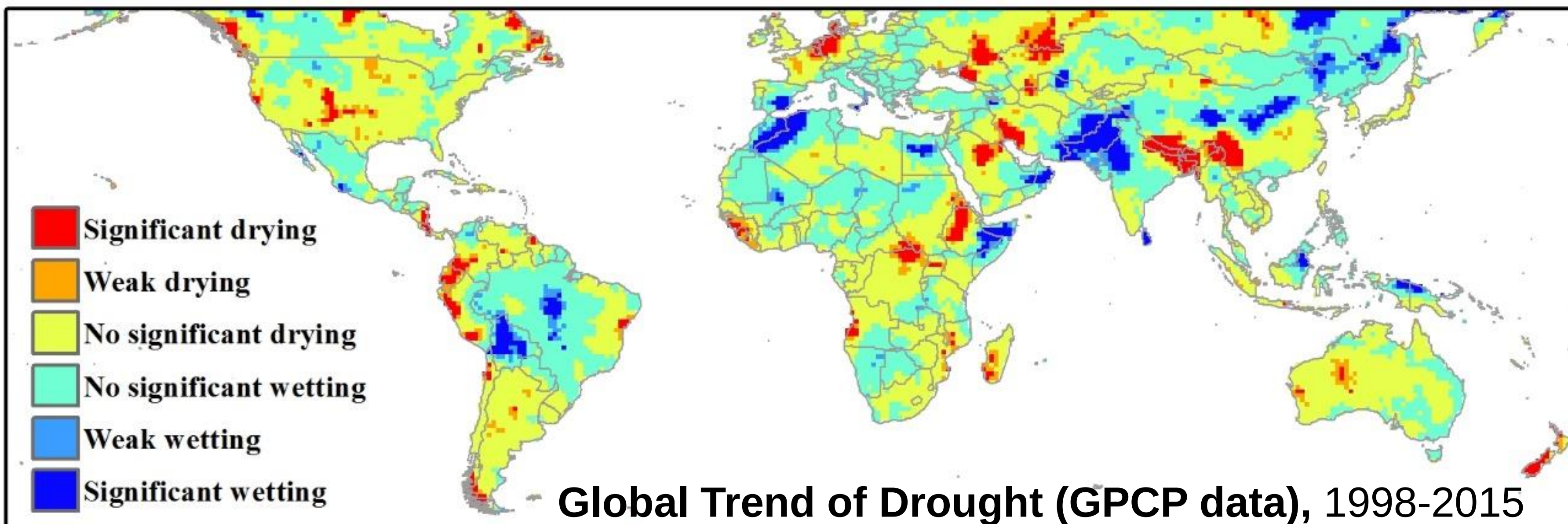
Anhui province of China in its worst drought in 50 years (October, 2019)



Why Drought Monitoring and Evaluation



United Nations Office for Disaster Risk Reduction (UNDRR)
Data source for drought events: The International Emergency Disasters Database (EMDAT)



Global Trend of Drought (GPCP data), 1998-2015

Why Drought Monitoring and Evaluation

The UN 2030 Agenda for SDGs – Drought Related

Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

- 2.4 By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, **drought**, flooding and other disasters and that progressively improve land and soil quality

Goal 13: Take urgent action to combat climate change and its impacts

- 13.18 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

- 15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, **drought** and floods, and strive to achieve a land degradation-neutral world

Goal 6: Clean water and sanitation

AOGEO Task 6

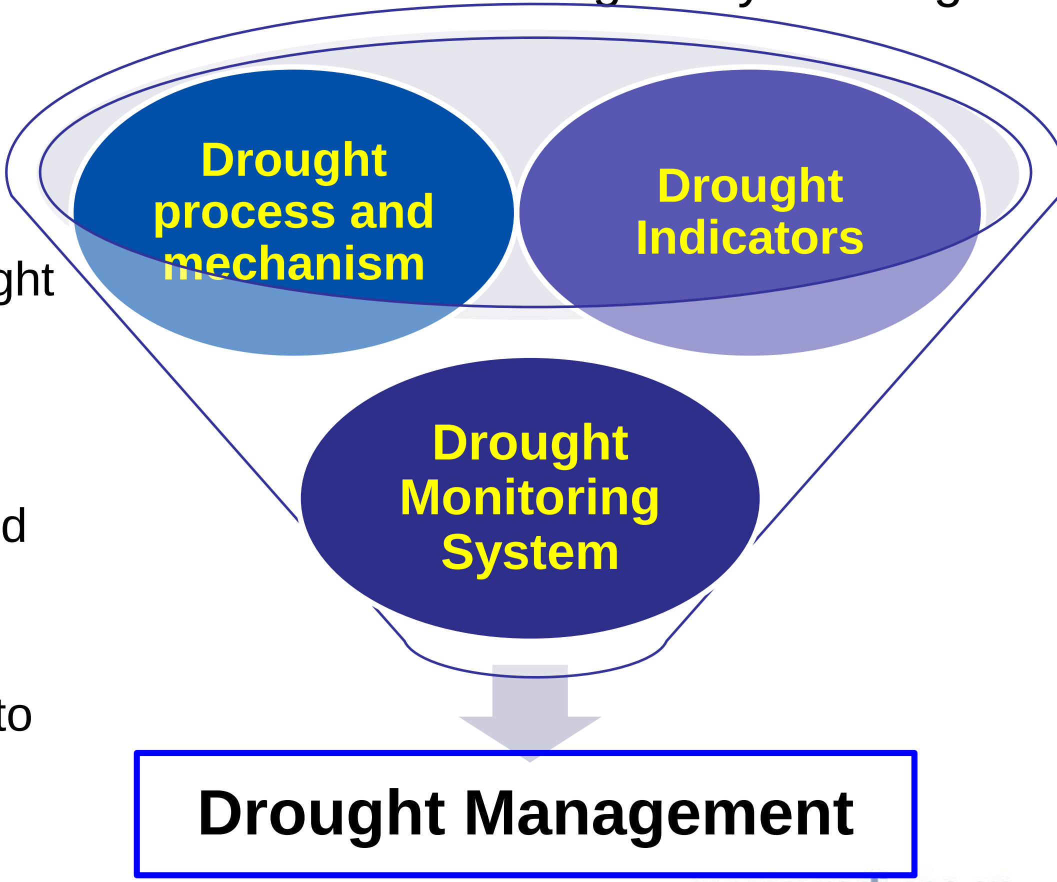
Drought monitoring and evaluation in Asia-Oceania region

Objectives:

Applying Earth Observations and advanced technologies for drought monitoring, evaluation, and management in Asia-Oceania region by building regional cooperative network.

Subjects:

- **TG 6.1** Create and maintain a drought monitoring cooperative network.
- **TG 6.2** Develop a comprehensive, inclusive and robust information system for drought monitoring and evaluation.
- **TG 6.3** Generate policy-relevant advices to support governments to make evidence-based decisions.
- **TG 6.4** Capacity building



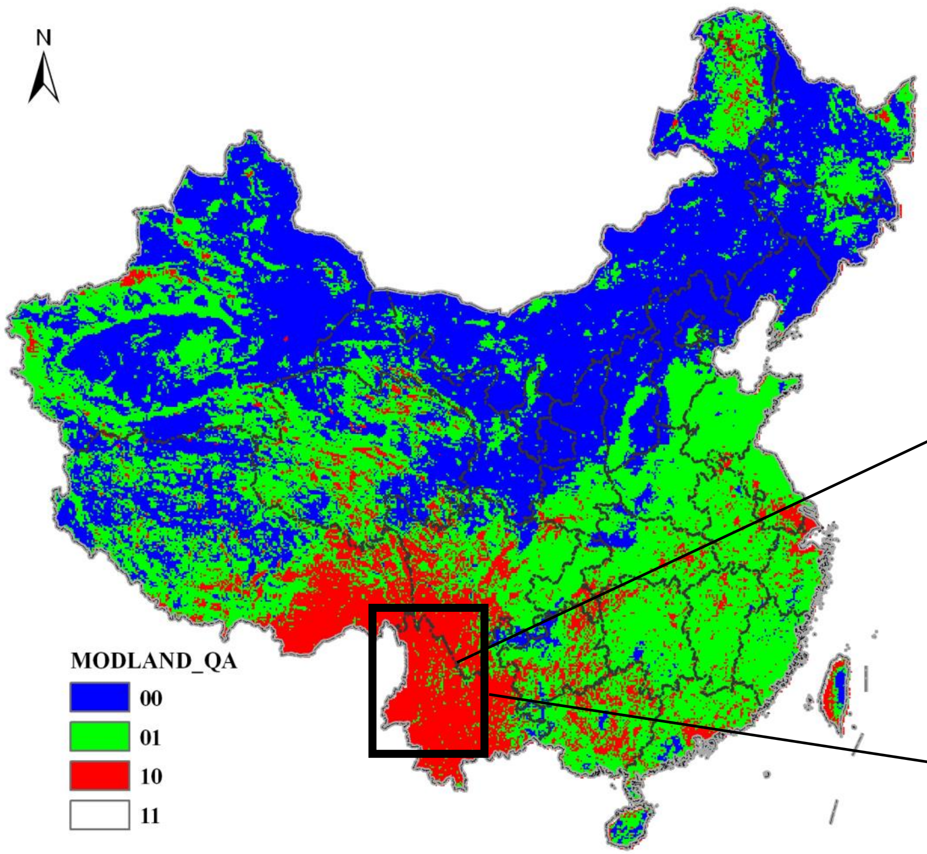
Drought monitoring and evaluation

Issues:

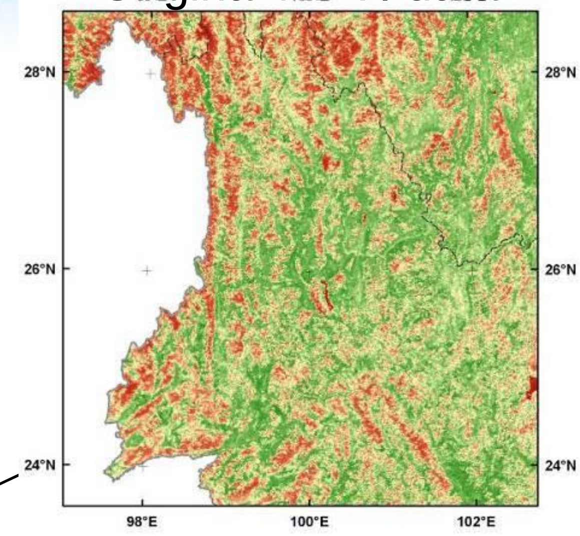
- Data quality
  - Filtering (quality control) is necessary to remove poor quality data
  - Reconstruction of time series (towards gap-free products) to ensure data usability
- Drought indicators
  - Region/process dependence of drought indicators
  - Drought indicator vs. drought severity
  - Drought alert
- Drought impact evaluation
  - Impact on regional water resource
  - Impact on agricultural yield
- Drought monitoring system

Data quality and Time Series Reconstruction

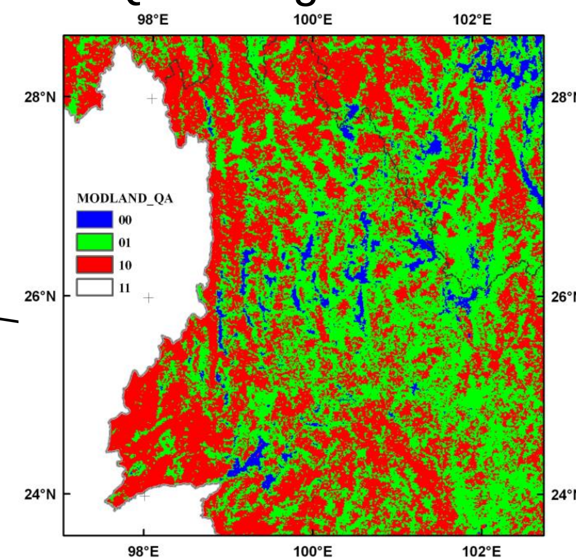
MODIS NDVI data quality layer, 2009



Original NDVI data



QA in original data



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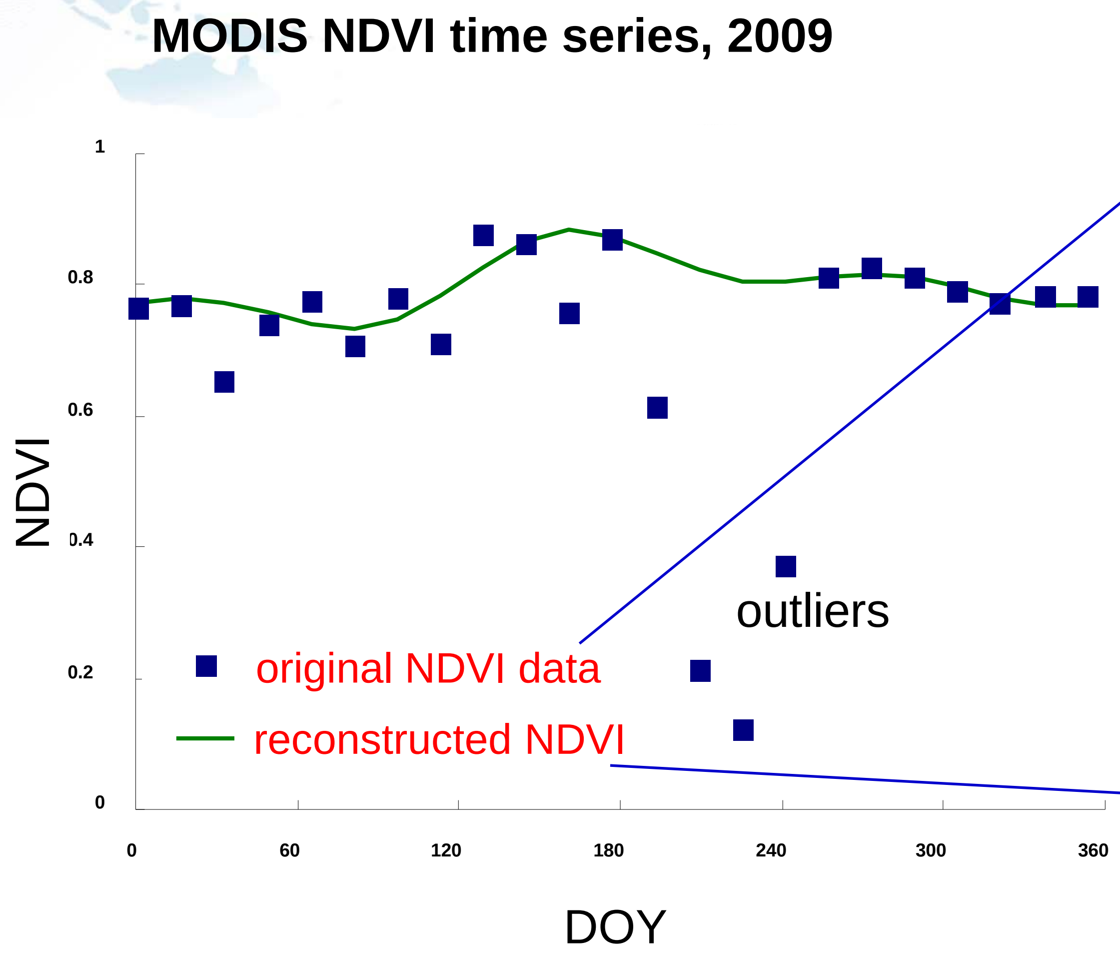
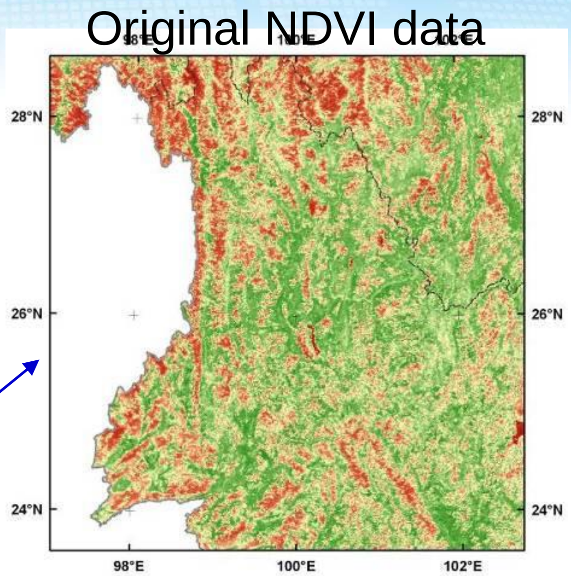
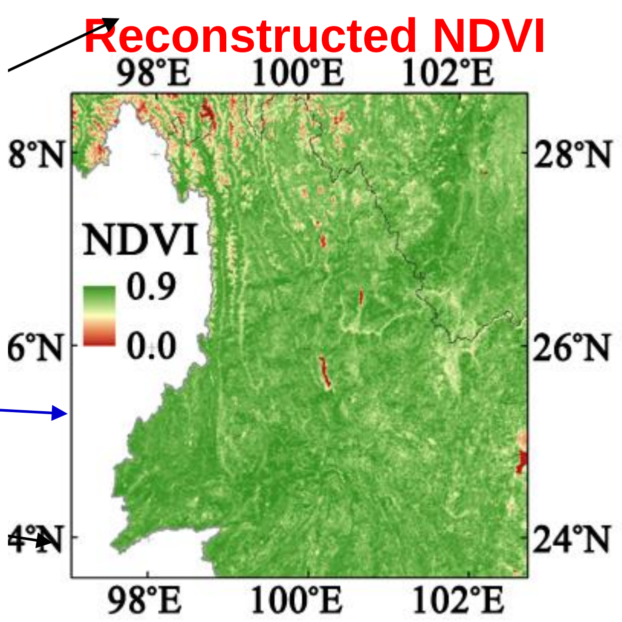
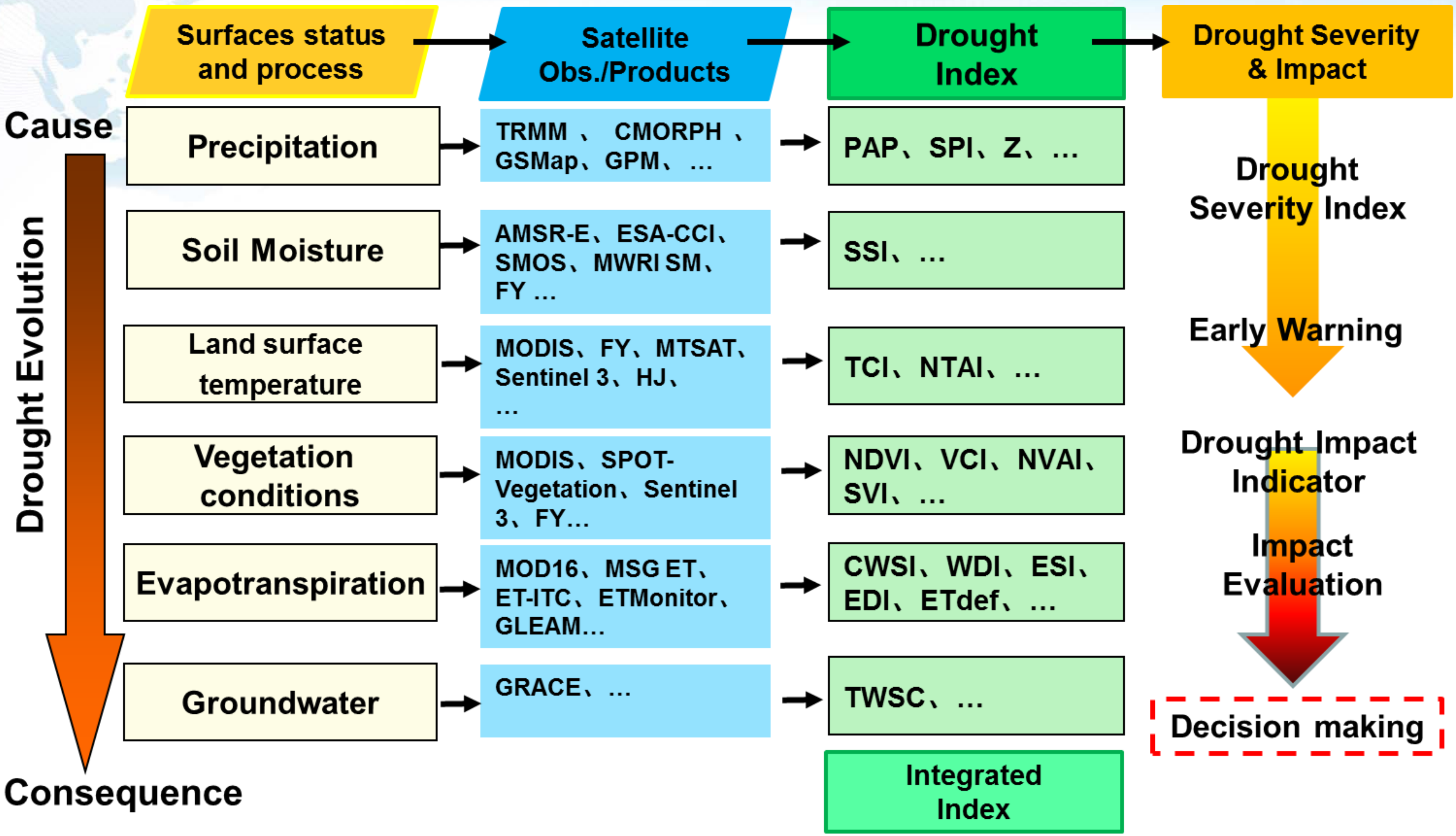
Data quality and Time Series Reconstruction







Drought indicators by EO Data



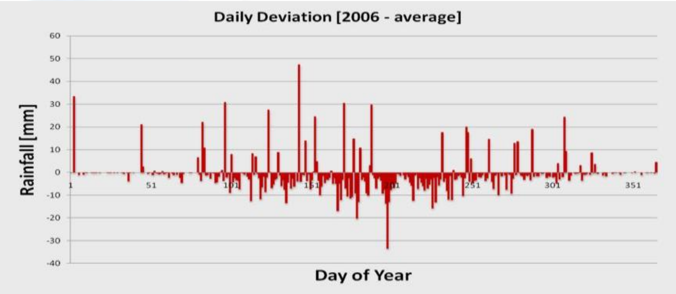
Drought indicators by EO Data

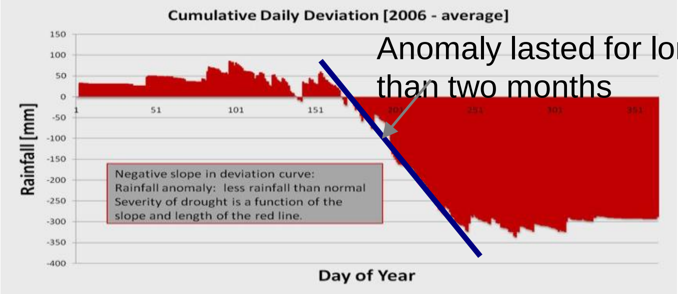
Anomaly in rainfall – driving factor

PAP: Cumulative precipitation anomaly percentage over given time period:

$\Delta P_{acc} = [P_j - P_j\,(\text{mean})] / P_j\,(\text{mean})$ (j: a specific period, week, month, year, etc)

SPI: Standardized Precipitation Index - cumulative probability over a given time scale





Land surface response to drought

- **Normalized Temperature Anomaly Index (NTAI) (Jia et al., 2012):**

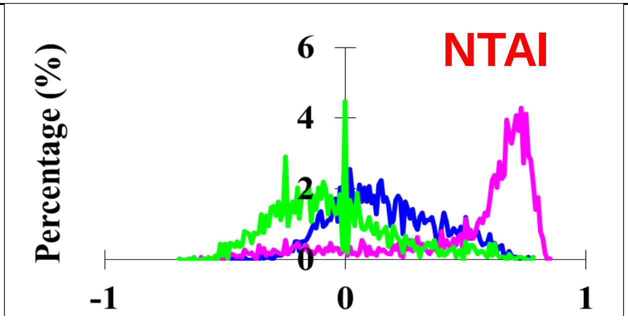
  NTAI $= (LST - LST_{mean}) / (LST_{max} - LST_{min})$

  -1 ~ 0 : cooler than normal condition
  0 ~ 1 : warmer than normal condition

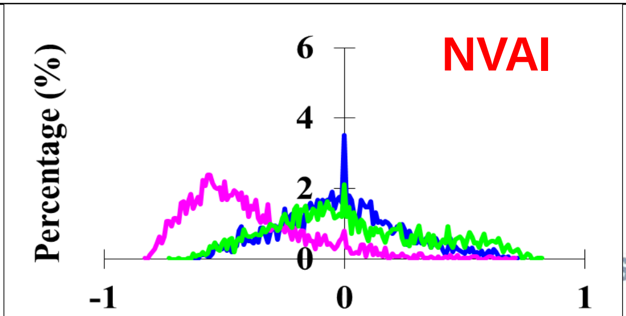
- **Normalized Vegetation Anomaly Index (NVAI) (Jia et al., 2012):**

  NVAI $= (NDVI - NDVI_{mean}) / (NDVI_{max} - NDVI_{min})$

  -1 ~ 0 : decreased vegetation condition
  0 ~ 1 : increased vegetation condition



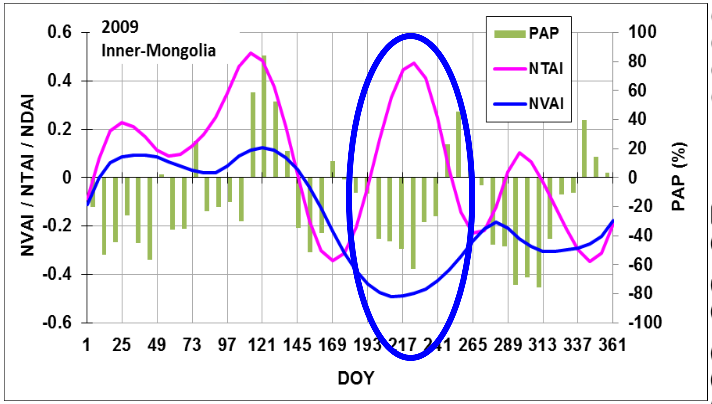
Blue: onset;
Pink: severe stage;
Green: post-drought

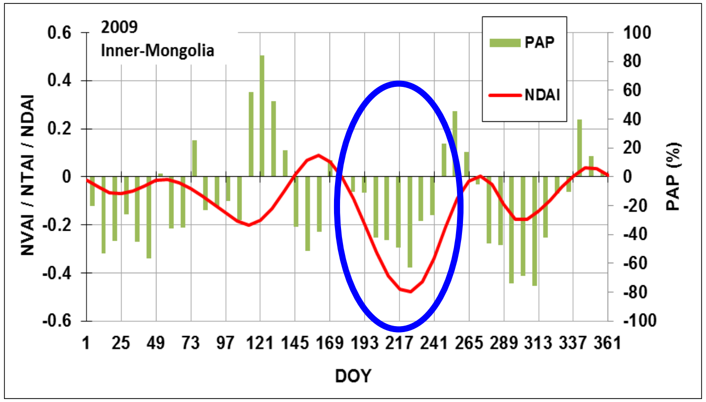


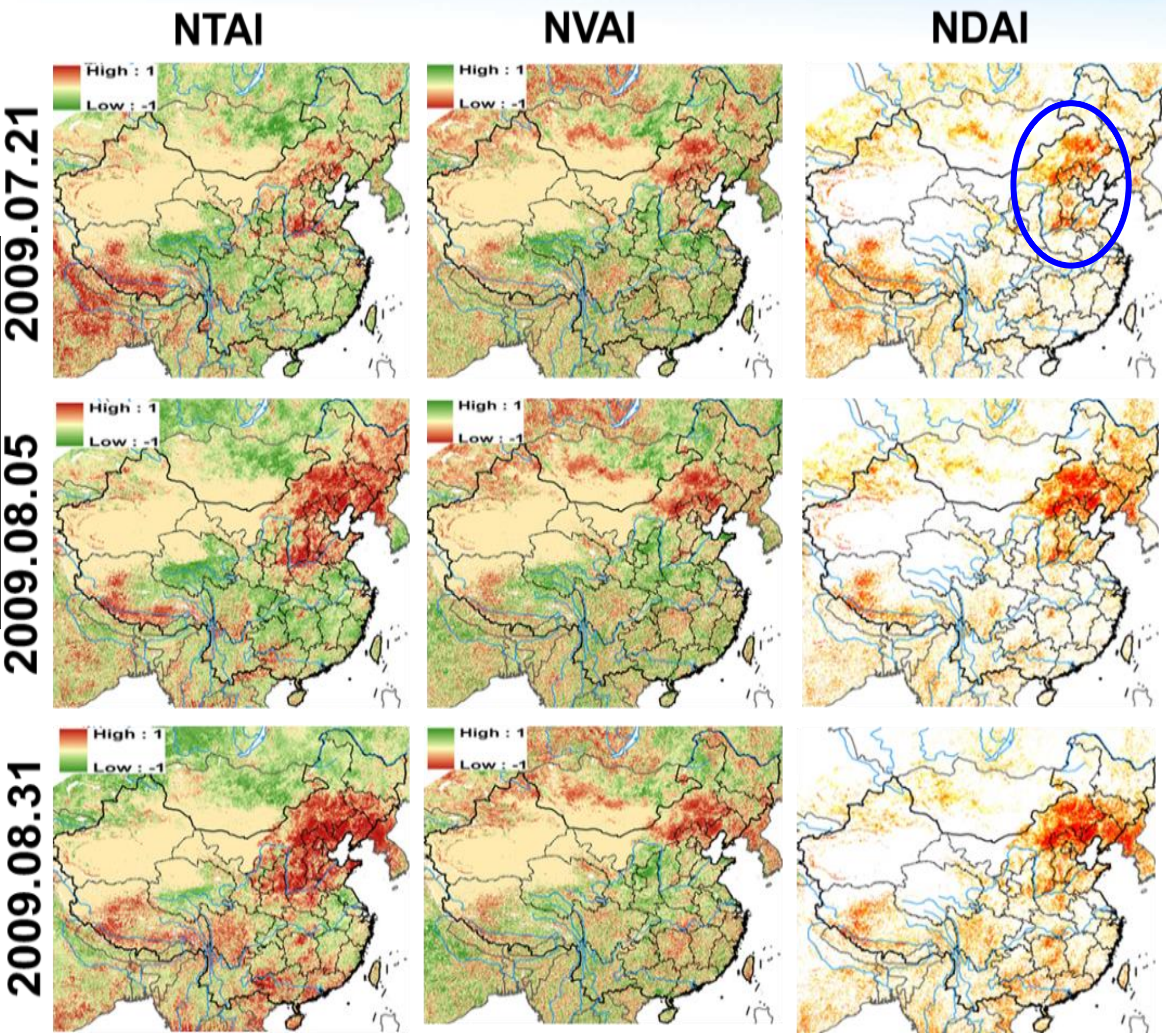
Drought indicators by EO Data

Land surface response to drought – case studies

China Inner-Mongolia 2009 Summer Drought



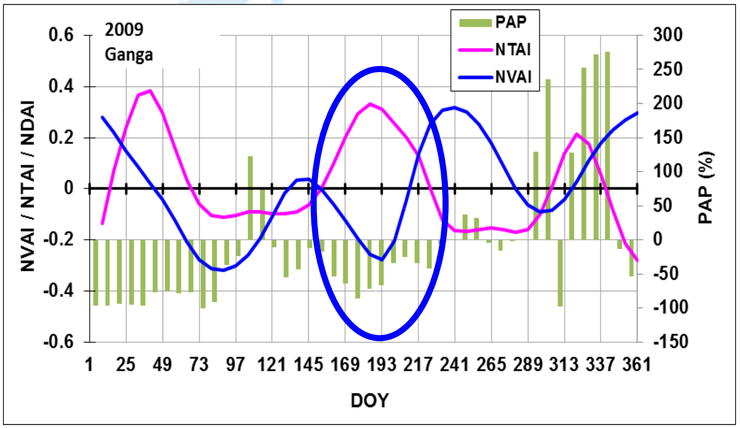


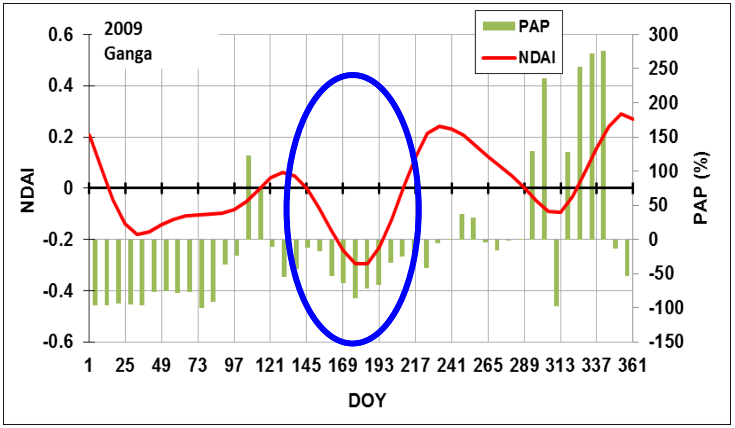


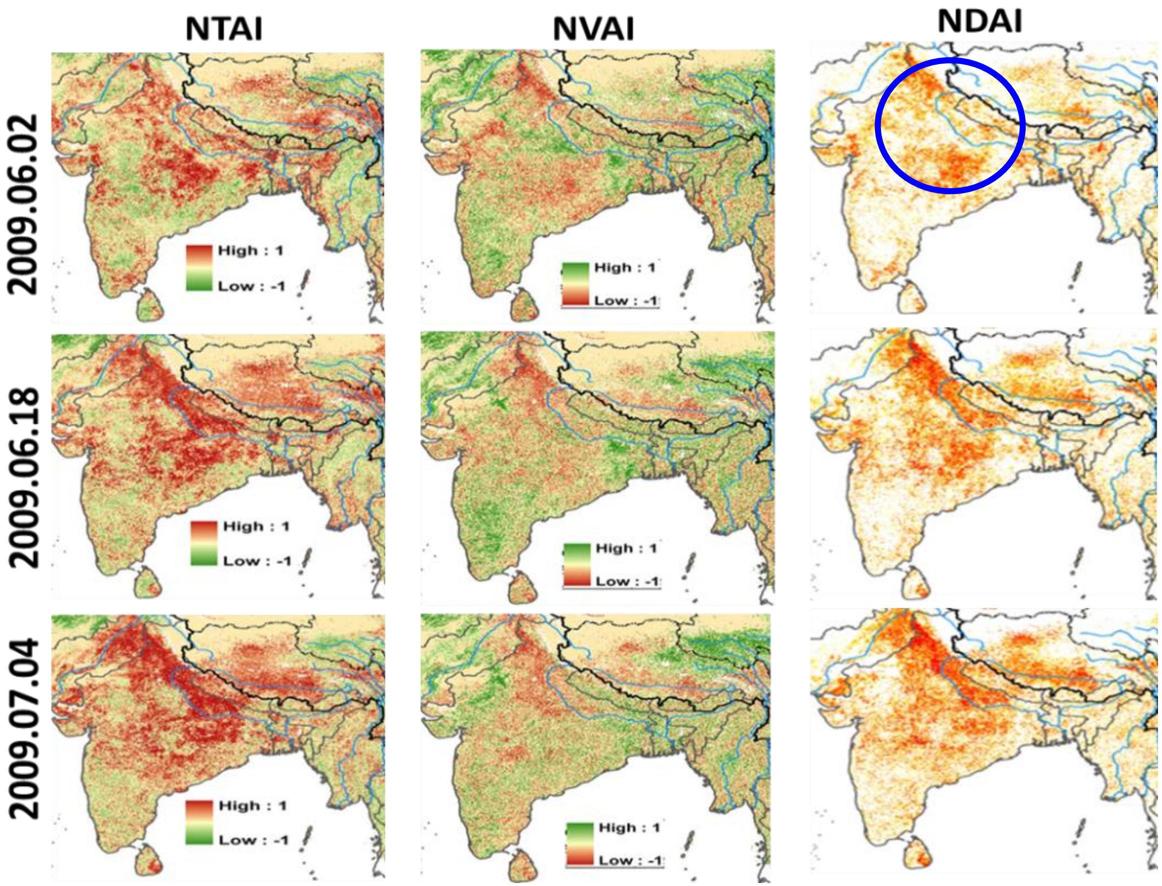
Drought indicators by EO Data

Land surface response to drought – case studies

India Ganga Basin 2009
Summer Drought



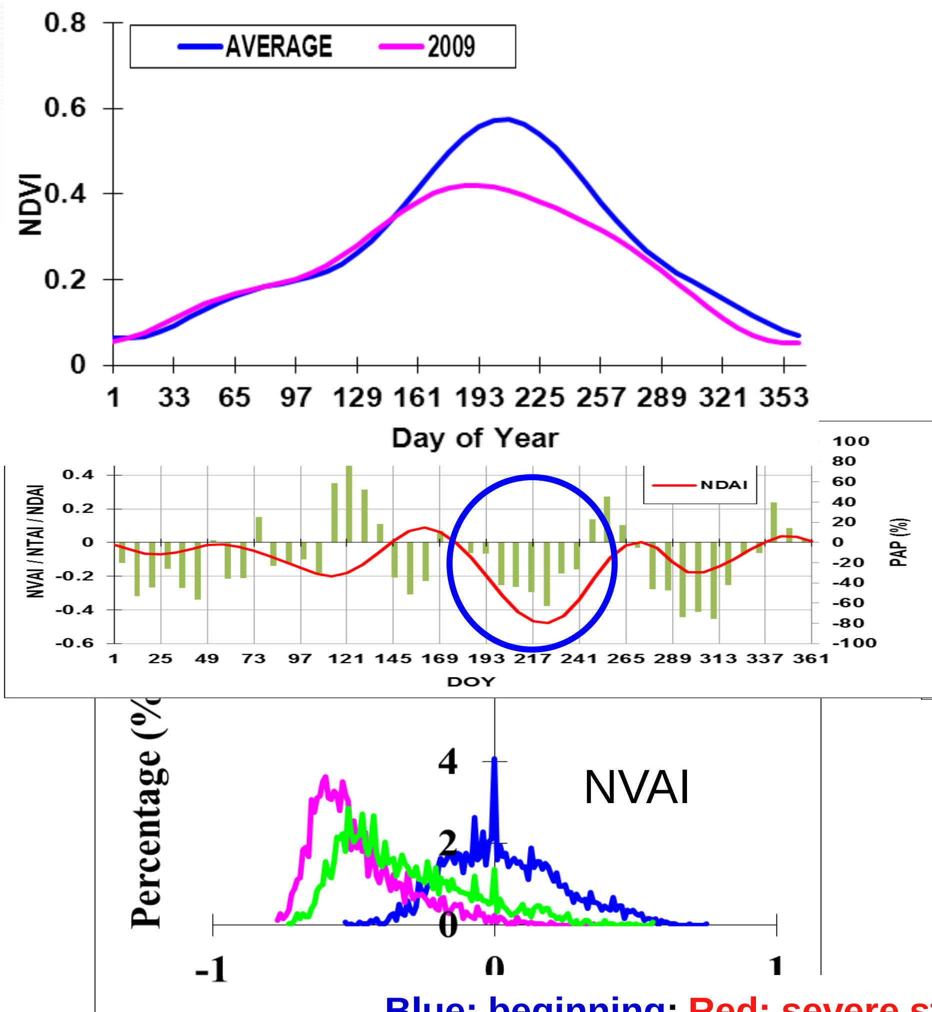




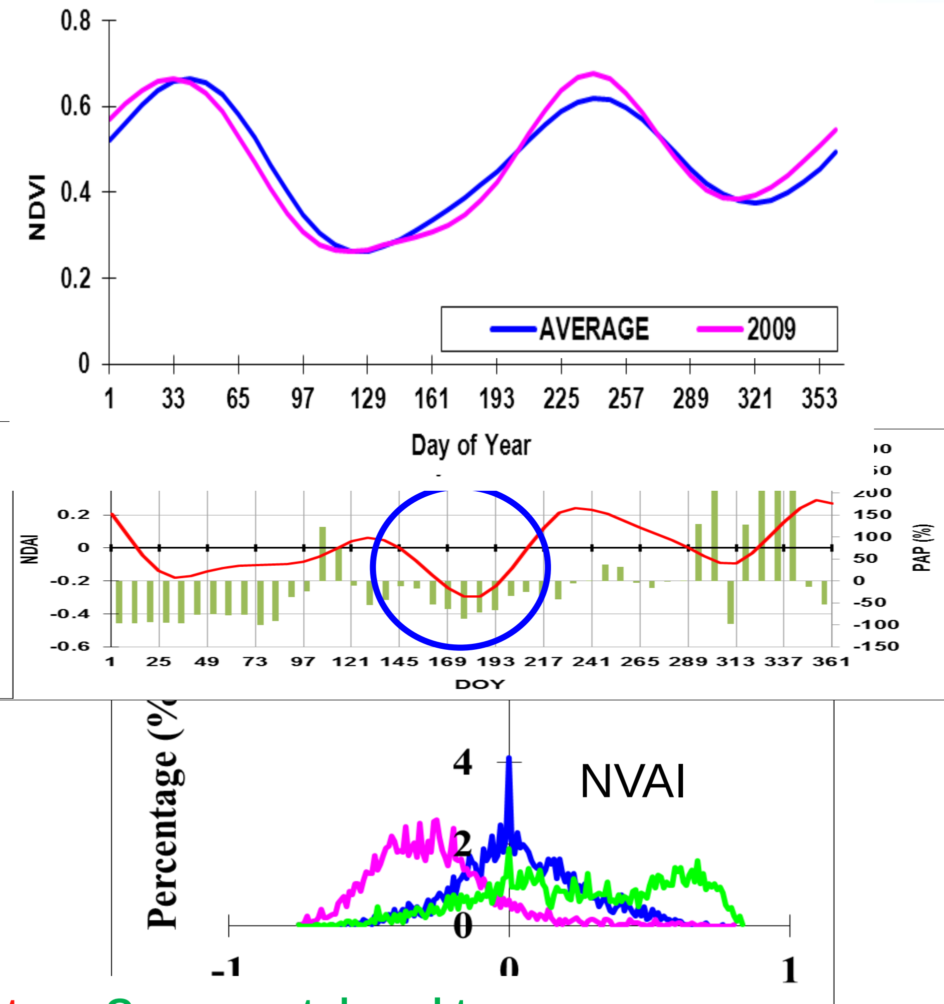
Drought indicators by EO Data

Land surface response to drought – case studies

China Inner-Mongolia



India Ganga Basin

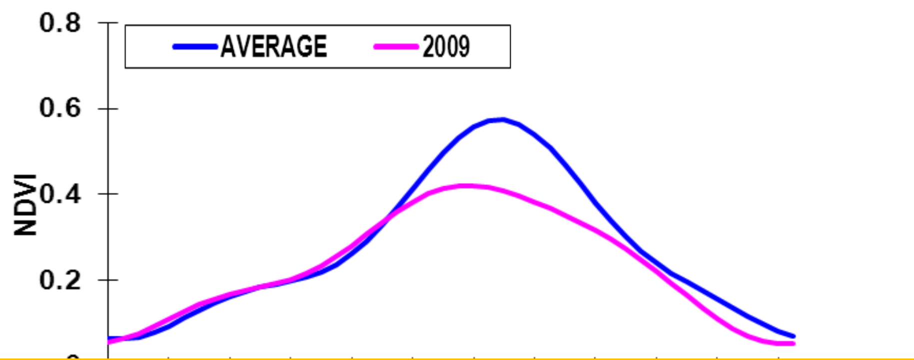


Blue: beginning; Red: severe stage; Green: post-drought

Drought indicators by EO Data

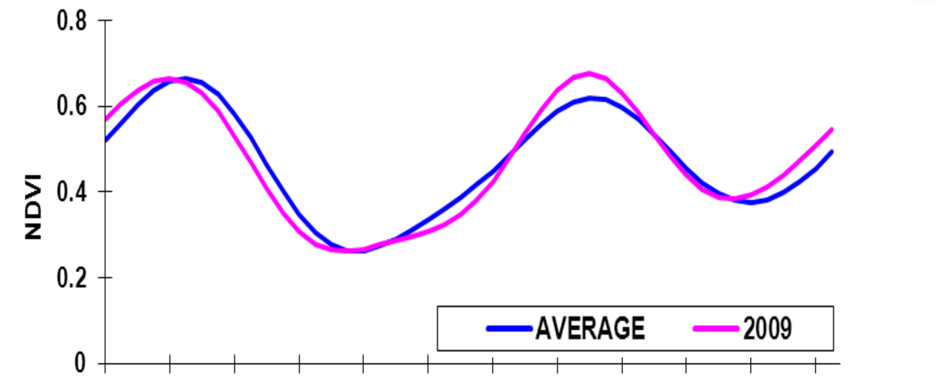
Land surface response to drought – case studies

China Inner-Mongolia

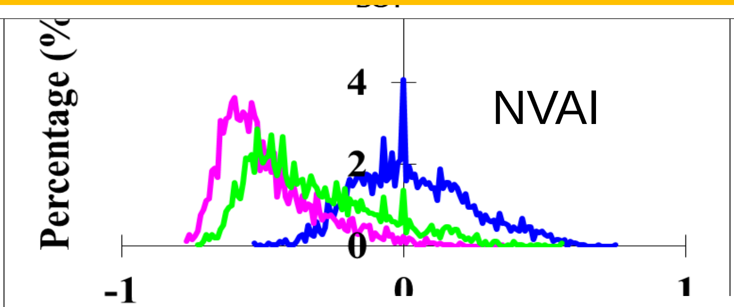


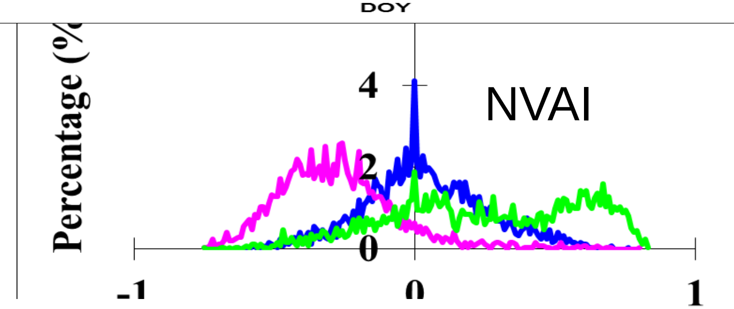
- Natural grassland (or single crop)
- Vegetation damage cannot recover

India Ganga Basin



- Double cropping
- Vegetation was recovered and even better conditions than multiple year average in the 2nd growing cycle





Blue: beginning; Red: severe stage; Green: post-drought

Drought indicators by EO Data

Flash drought

- caused by precipitation deficit
- accompanied by an abnormal high air temperature, solar radiation and wind speed that will intensify the rate of soil water loss.

Evapotranspiration (ET) -- determined by **available soil water, available energy and atmospheric water demand** -- has been considered as a good candidate to build drought indicators of rapid response to soil water stress.

"**ET-based indicators**, quantifying anomalous rates of water use or loss, may be uniquely sensitive to rapidly changing conditions relating to flash drought. " (Anderson, 2013)

Better indicators for flash drought

The Actual Evapotranspiration Anomaly Index (AEAI)

$$AEAI = (ETa - ETa_{mean}) / (ETa_{max} - ETa_{min}) \quad [-1 \sim 1]$$

high evaporation rate with possibly abnormal high air temperature and available energy to accelerate soil moisture depletion.

The Potential Evapotranspiration Anomaly Index (PEAI)

$$PEAI = (ETp - ETp_{mean}) / (ETp_{max} - ETp_{min}) \quad [-1 \sim 1]$$

more influenced by available energy and humidity of the atmosphere during the drought evolution.

The Evaporative Stress Anomaly Index (ESAI)

$$rET = ETa / ETp$$

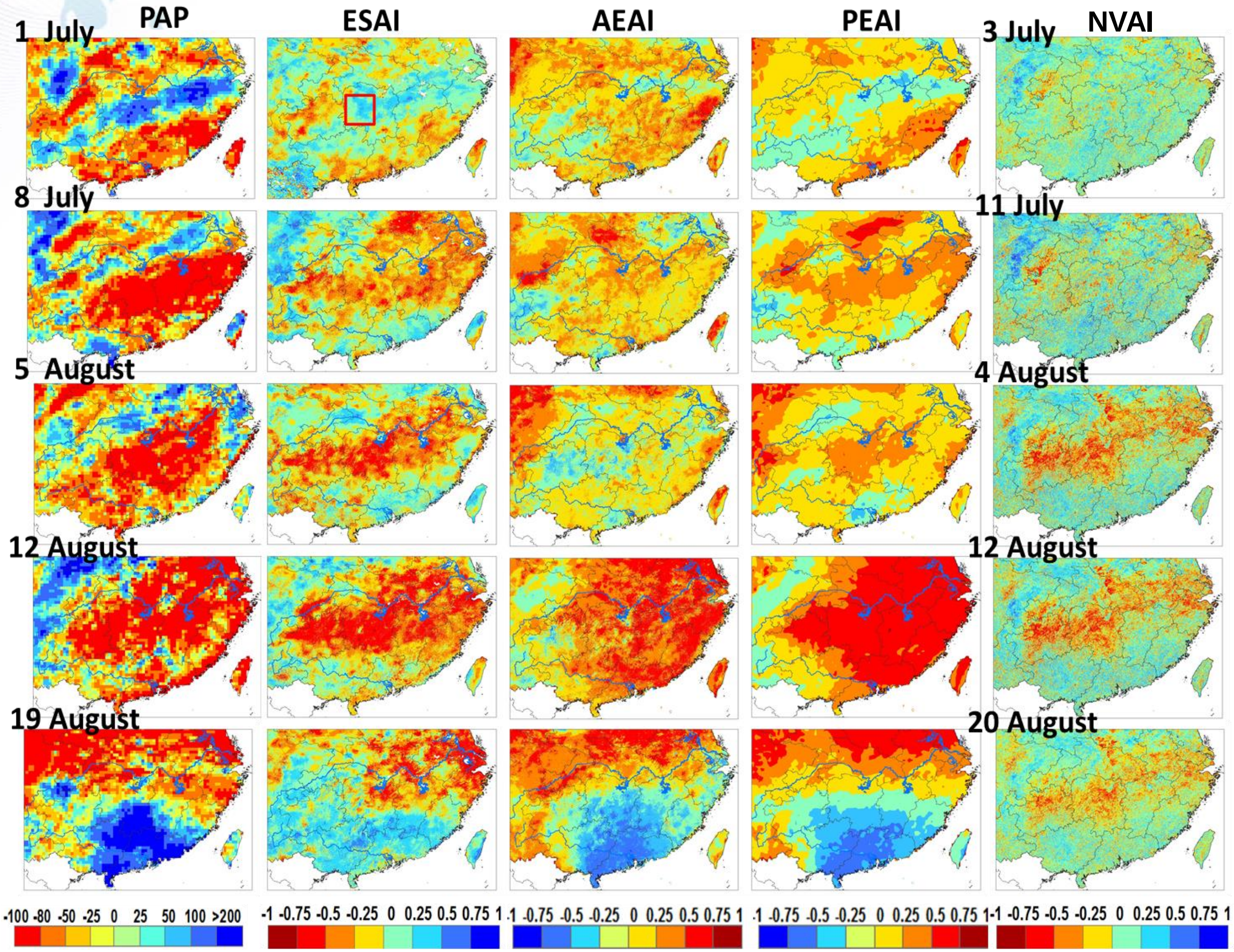
$$ESAI = (rET - rET_{mean}) / (rET_{max} - rET_{min})$$

-1 ~ 0 : vegetation is stressed 0 ~ 1: no stress

Drought indicators by EO Data

Flash drought

Flash drought lasted from 1 July to 12 August in 2013, in southern China



1/7 – 12/8, AEAI showed more positive anomalies, indicating that evaporation rate was higher than normal conditions

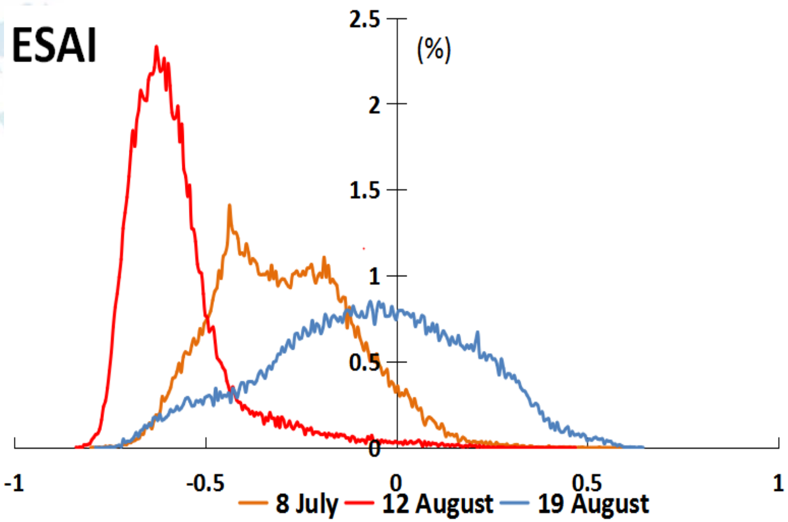
ESAI followed very well the rainfall anomaly

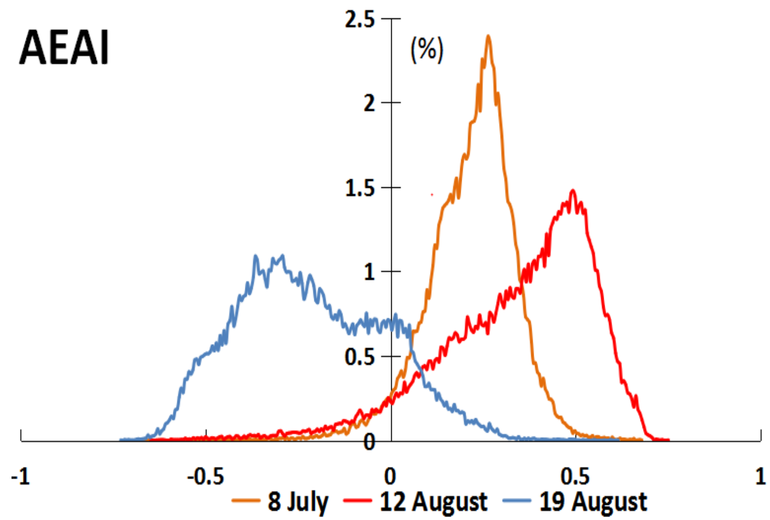
The vegetation-index based indicator, i.e. NVAI, showed a slower response to precipitation anomaly with about 1-2 weeks time-lag compared with ESAI and AEAI.

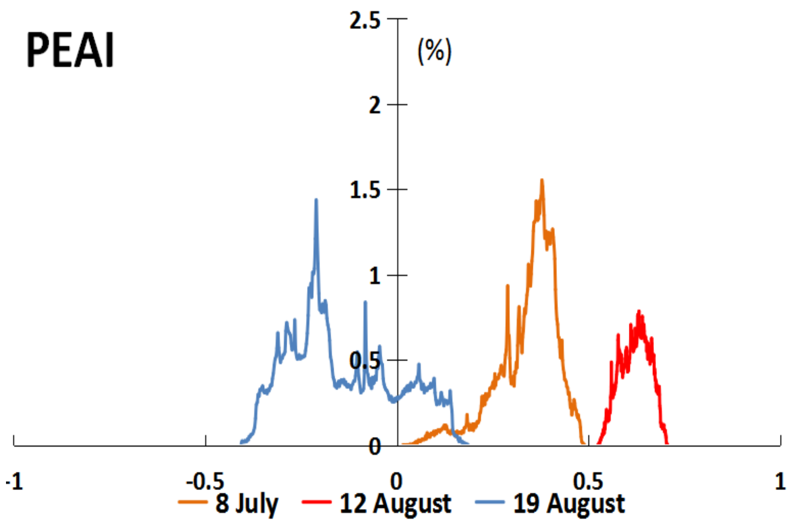
Drought indicators by EO Data

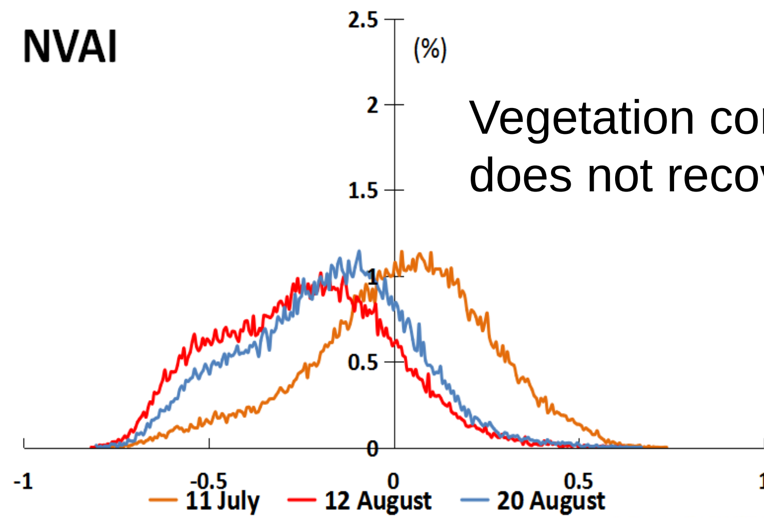
Flash drought

Flash drought lasted from 1 July to 12 August in 2013, in southern China







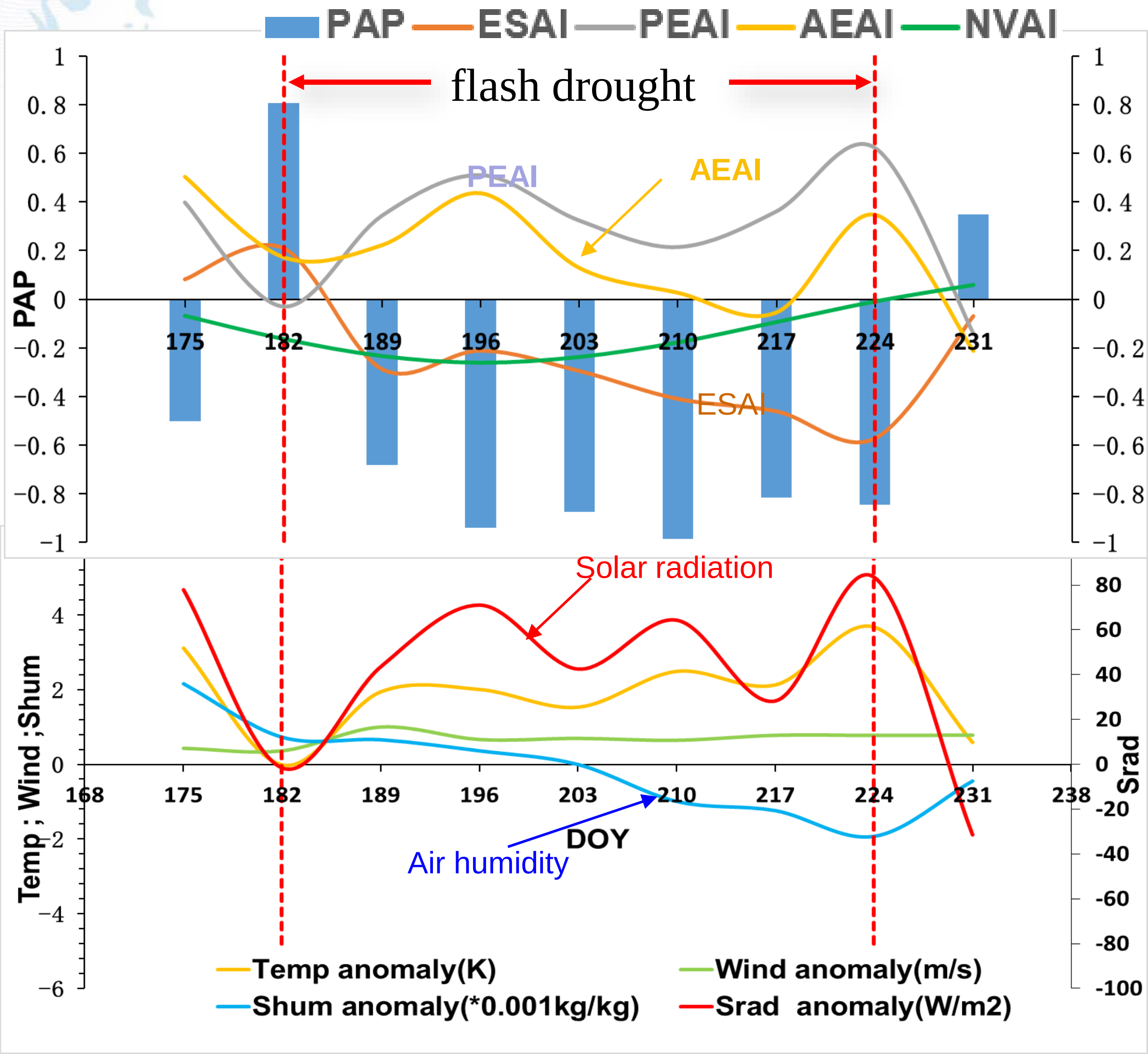


Vegetation condition does not recover

Drought indicators by EO Data

Flash drought

Flash drought lasted from 1 July to 12 August in 2013, in southern China

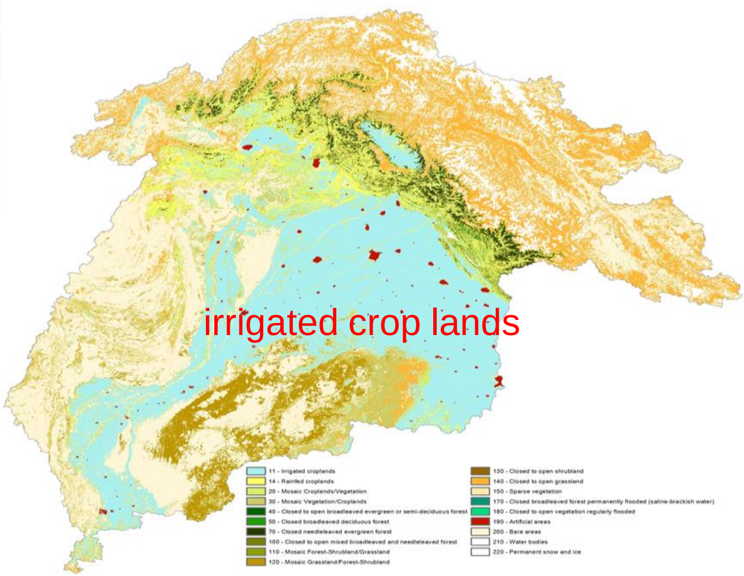


- **AEAI**: fast increase in the period of drought, indicating higher evaporative rate when abnormal high air temperature, wind and available energy and decreasing atmospheric humidity accelerate the rate.
- **PEAI** increased quickly, with the rapid increase of solar radiation and decreased with the decrease of solar radiation.
- At the end of drought on 18 August, **ESAI** responded rapidly to the resume of rainfall (positive PAP) with an immediate increase. ESAI did provide a significantly better temporal detail.

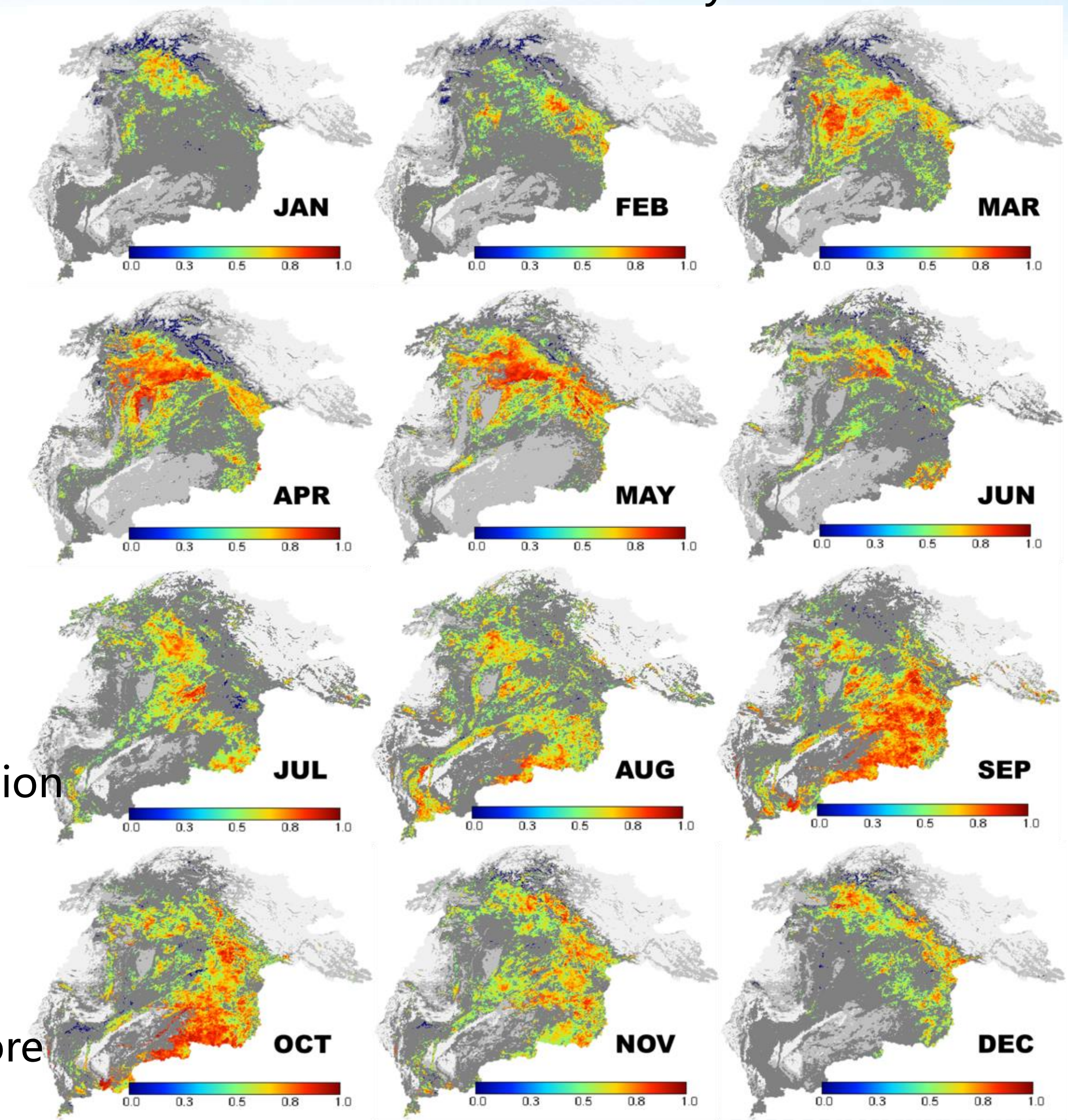
Drought indicators by EO Data

Drought in irrigated crop lands

Case in Indus river basin



Correlation between monthly SPI and SVI

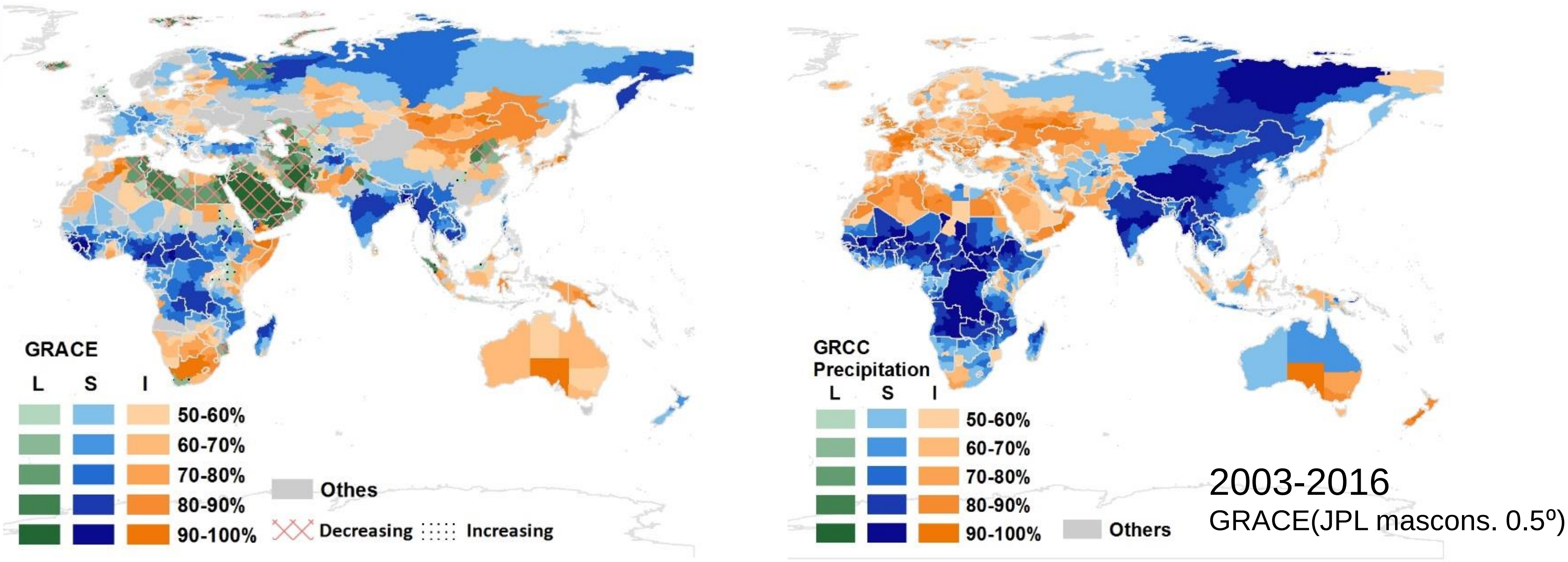


- Large spatial variability in correlation between SPI and SVI
- Spring: downstream area: no correlation between SPI and SVI which might be attributed to irrigation。
- Autumn (July – October), obvious correlation between SPI and SVI, indicating that crop growth relies more on precipitation.

Drought impact evaluation

- **Drought impact on terrestrial water storage change**

De-compose of time series of terrestrial water storage (TWS) change observed by GRACE

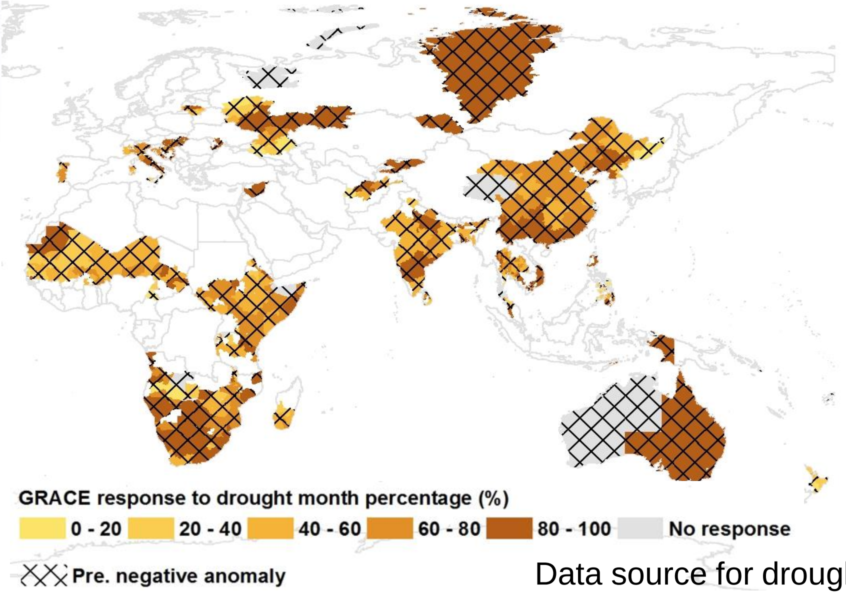


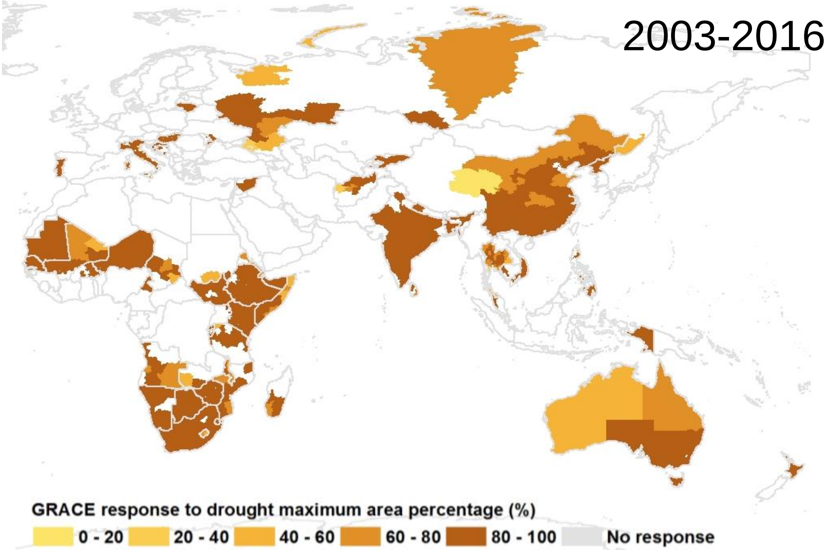
- ✓ **Linear trend**: middle-east, northeast Africa, northwest and North Plain of China, northeast of India. Decreased linear trends indicate groundwater depletion, mining for oil and coal etc..
- ✓ **Seasonality**: monsoon influenced area in southern Asia, mid of Africa, Russia, following the seasonality of precipitation.
- ✓ **Irregular signal**: northeastern Asia, southern Africa, Australia, most likely influenced by drought events.

Drought impact evaluation

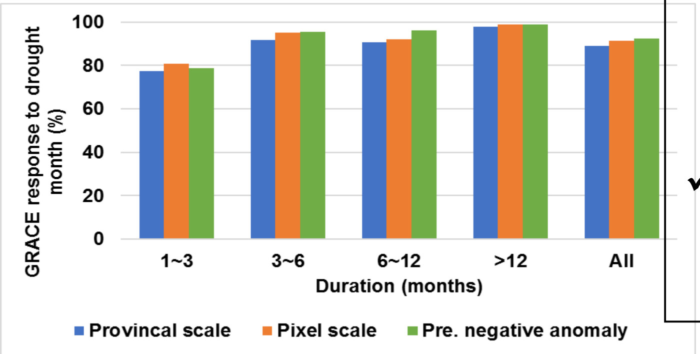
- **Drought impact on terrestrial water storage (TWS) change**

Drought impact analysis after de-trending and de-seasonality





Data source for drought events: The International Emergency Disasters Database (EMDAT)



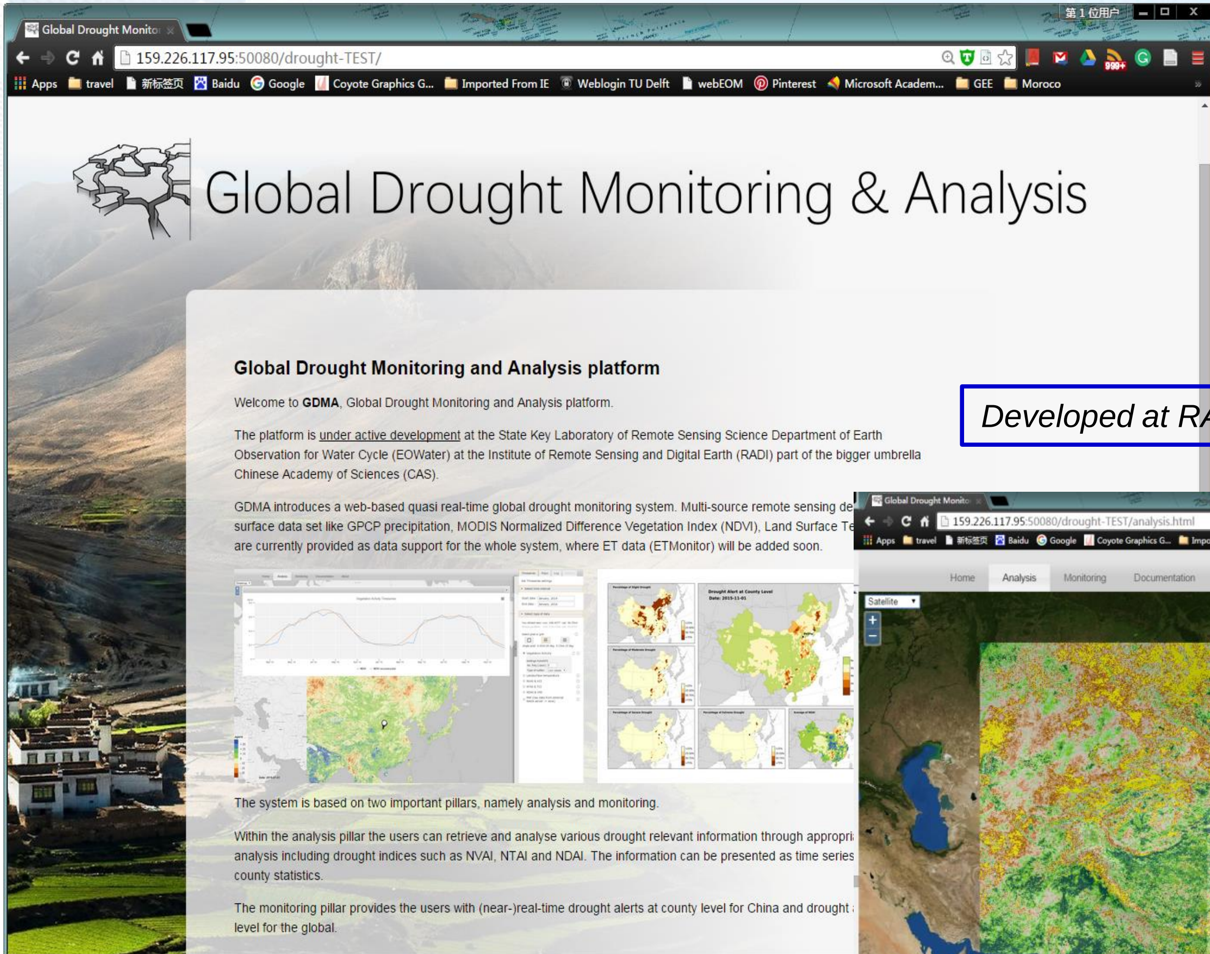
- ✓ Negative anomalies in TWS change were observed with consistence of 96% of drought occurrence area and of 89% drought events, which followed negative anomalies in precipitation.
- ✓ Frequency in TWS change showed increased trends with the duration of drought, i.e. long-term droughts have led to high possibility of impact on TWS change.

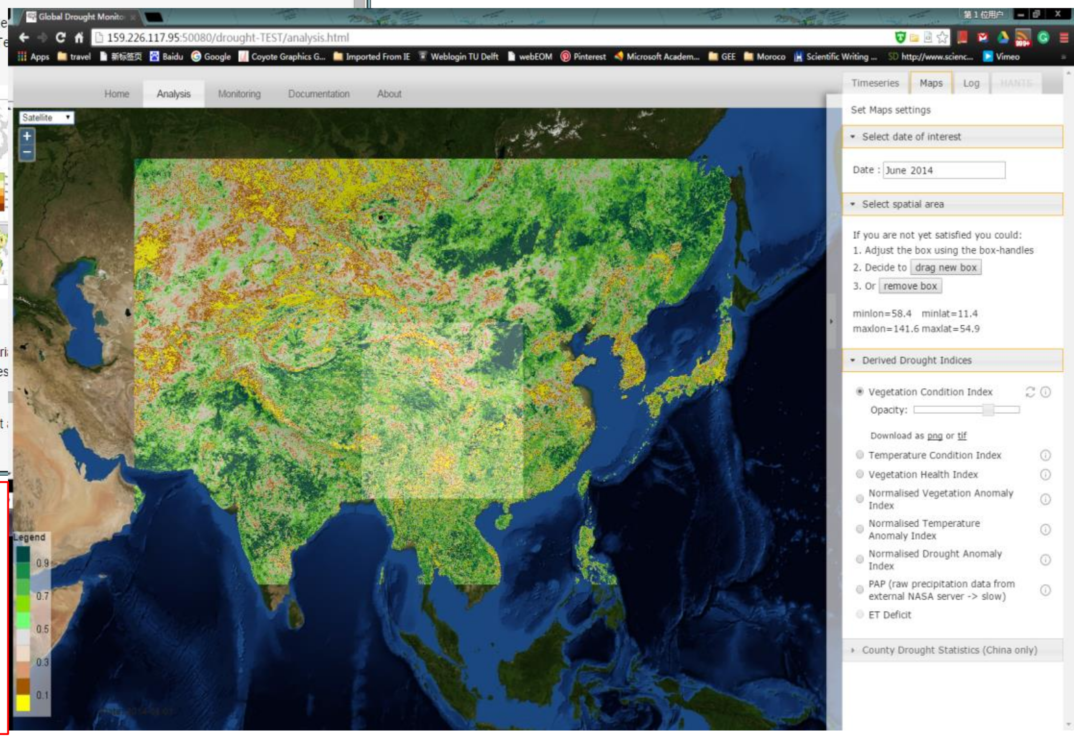
Web based Global Drought Monitoring & Analysis Platform (Web-GDMAP)

Characteristics:

- Ad-hoc drought analysis
- Web-based information system
- Cloud/Big data management and Analysis
- Open source architecture
- Distributed data storage

Developed at RADI (Hoek, Jia, et al., 2016, RS; 2019, IJDE)





Proposal (to be funded by the MOST of China) under preparation (transplant the system to pilot application countries).

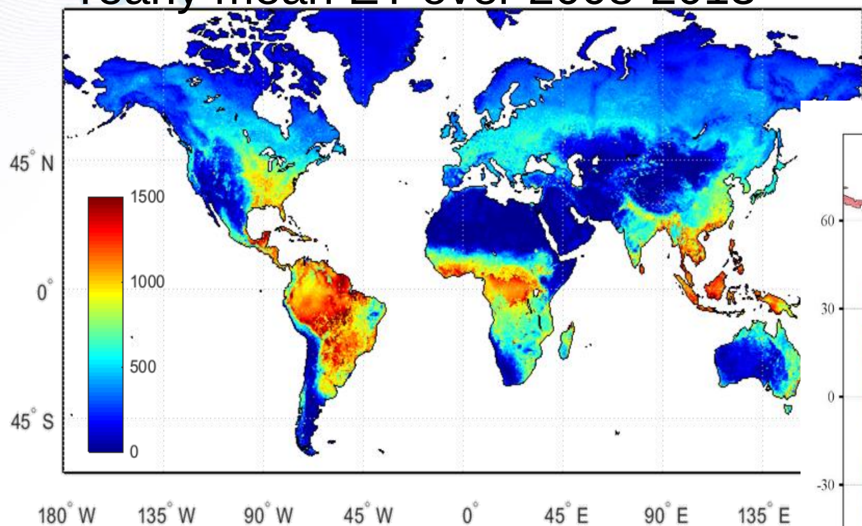
Summary

- Data quality and reliable gap-free time series are vital.
- Better understanding and quantification of terrestrial water cycle processes, e.g. relations between forcing and response.
- Effective use of multi-source data.
- Linkage between satellite derived variables/indicators/indices and land surface processes.
- Time lag between anomaly in precipitation and response of vegetation needs to be understood in a quantitative way.
- Linkage/distinguish between physical and societal processes and impact is important and a challenging subject.

Beyond Drought: Highlights of Water Research

- Global Evapotranspiration data product from **ETMonitor**

Yearly mean ET over 2008-2013

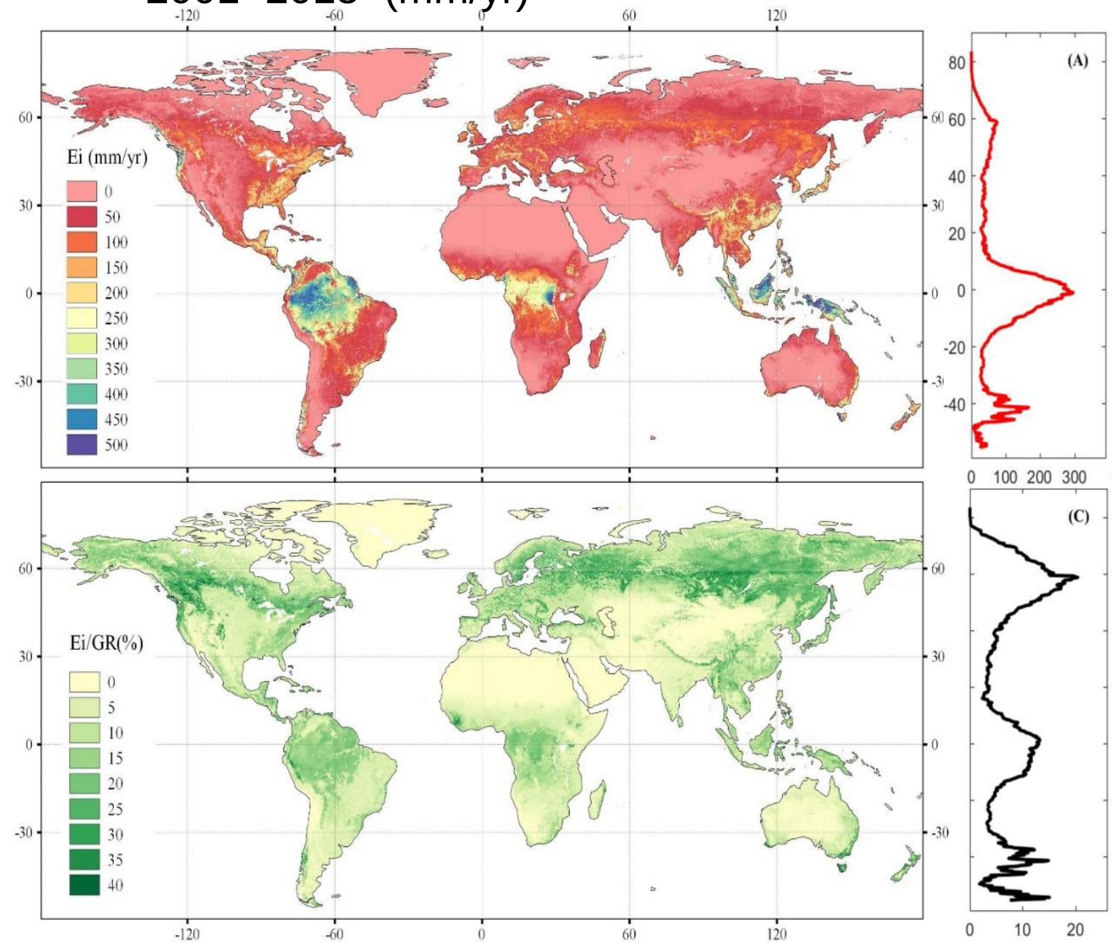


Global total ET product @1km spatial resolution, daily

Aiming at period of 2001 – 2019 (updating with time)

Interception rate: annual averaged interception loss / annual averaged gross rainfall, 2001~2015 (%)

Global annual averaged interception loss 2001~2015 (mm/yr)



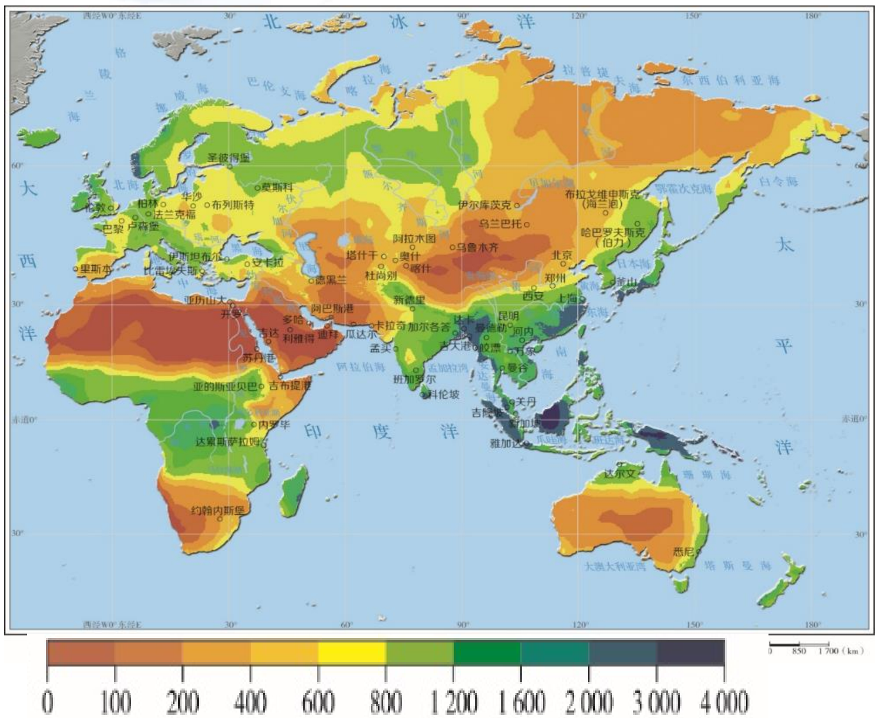
Zheng and Jia, 2019, Journal of Hydrology, under review

Beyond Drought: Highlights of Water Research

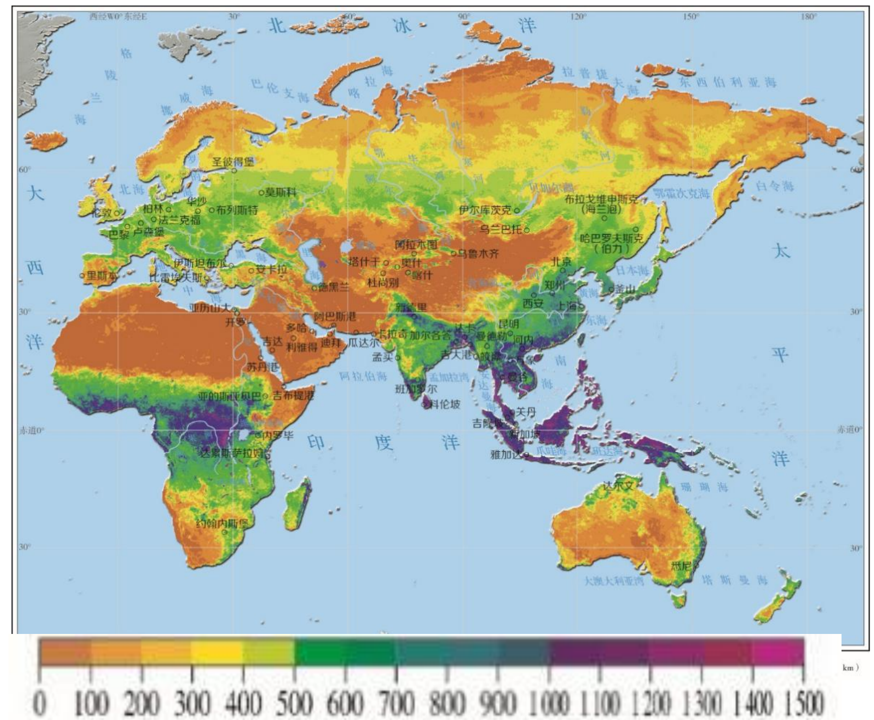
- Water Resource/Use Evaluation

Satellite-observation-based-information of **precipitation** and **evapotranspiration** serve as surrogates of available water and water use.

Precipitation



Evapotranspiration

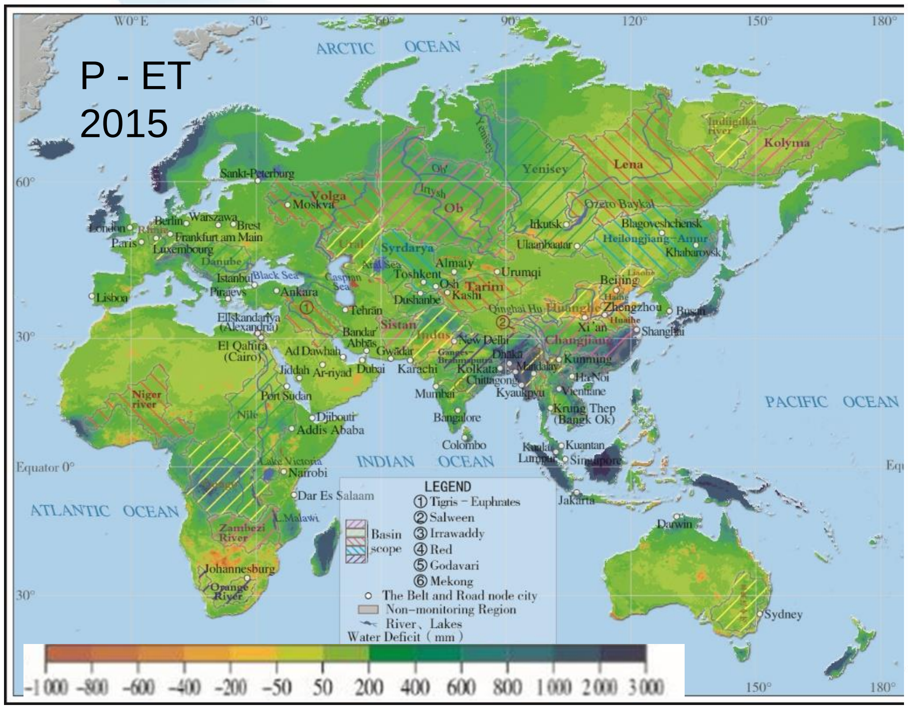


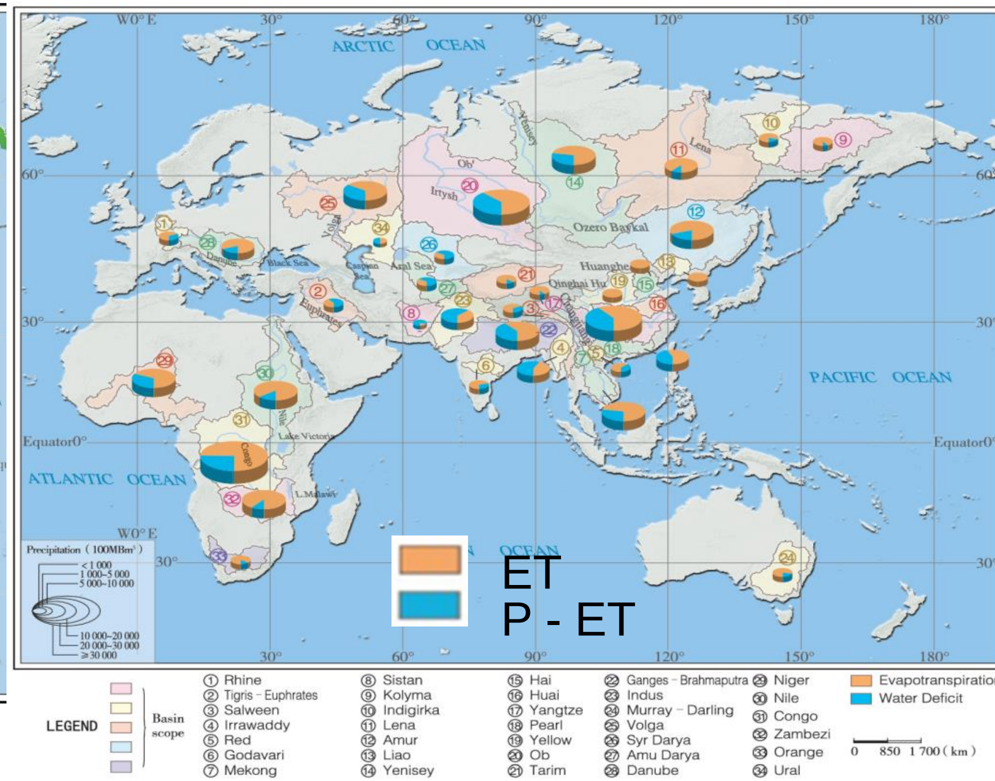
Beyond Drought: Highlights of Water Research

- Water Resource/Use Evaluation

Water budget P-ET

> 0 ➔ more runoff
< 0 ➔ more precipitation deficit



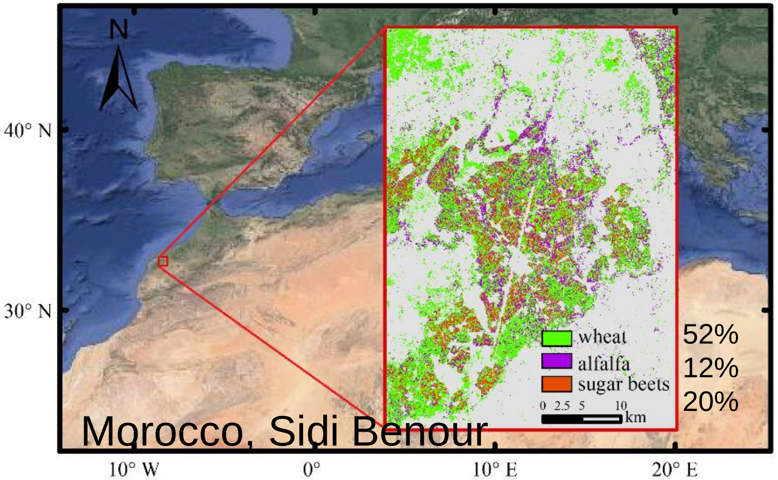


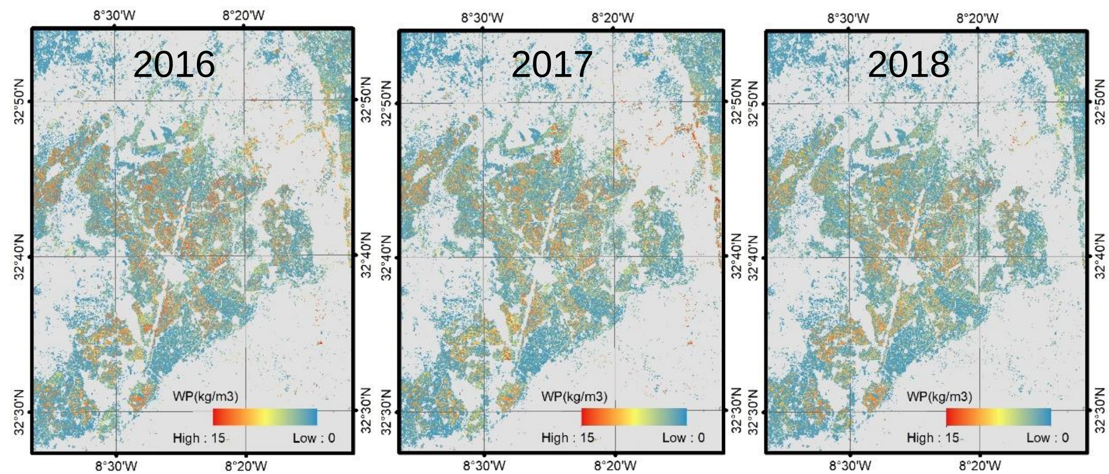
Beyond Drought: Highlights of Water Research

- Crop Water Productivity

$$WP = \frac{crop\ yield}{ET} \quad (kg / m^3)$$

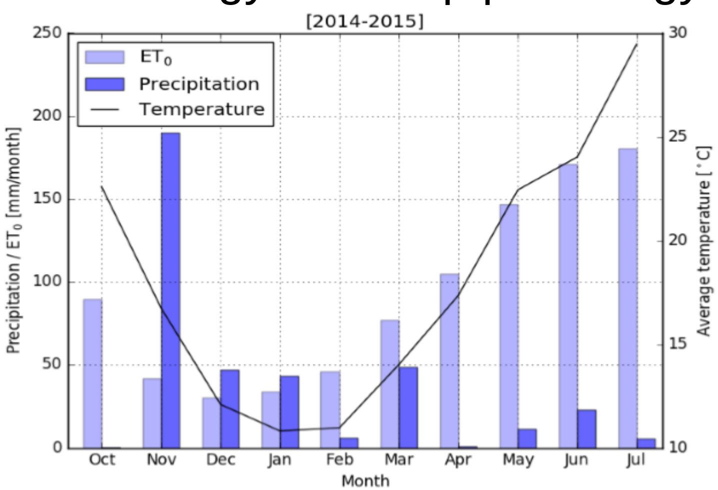
Method for SDG6.4.1: Change in water use efficiency over time.

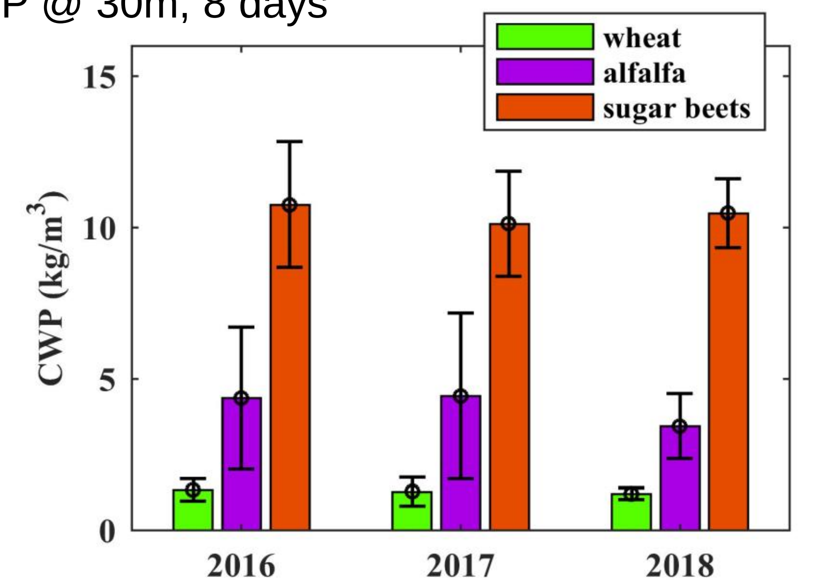




ET and CWP @ 30m, 8 days

Climatology and crop phenology





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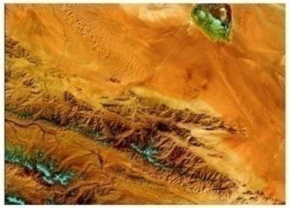
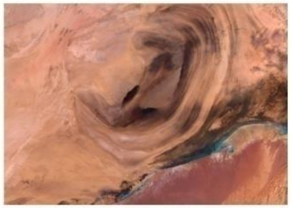
谢 谢 ！

Thank you for your attention

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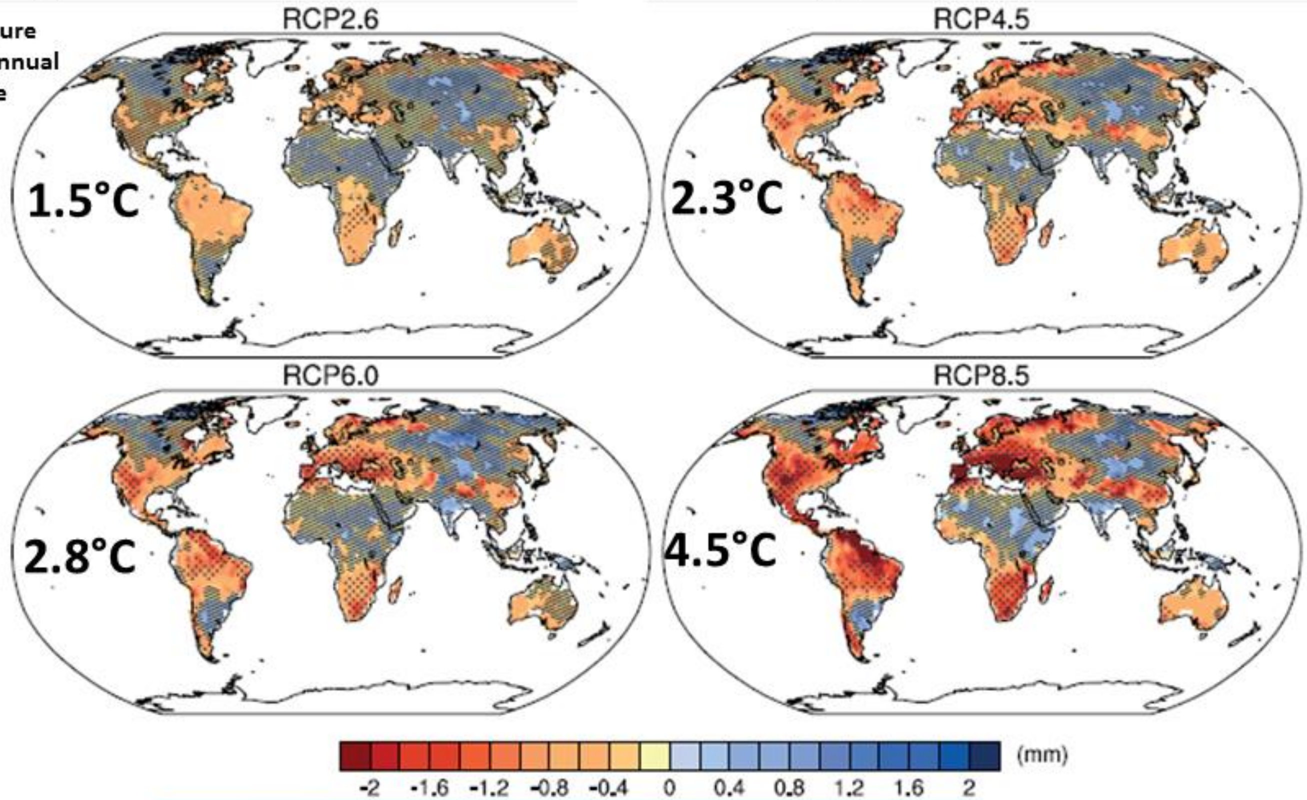
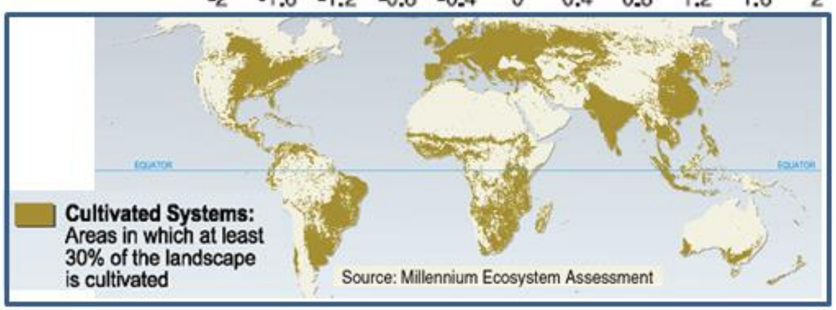
Change in soil moisture (drought) IPCC AR5

IPCC AR5 WG1. Figure 12.23: Change in annual mean soil moisture projected for 2081–2100 .





Projected increase in drought frequency

Global warming
from 1850

at a global warming of 2.25°C

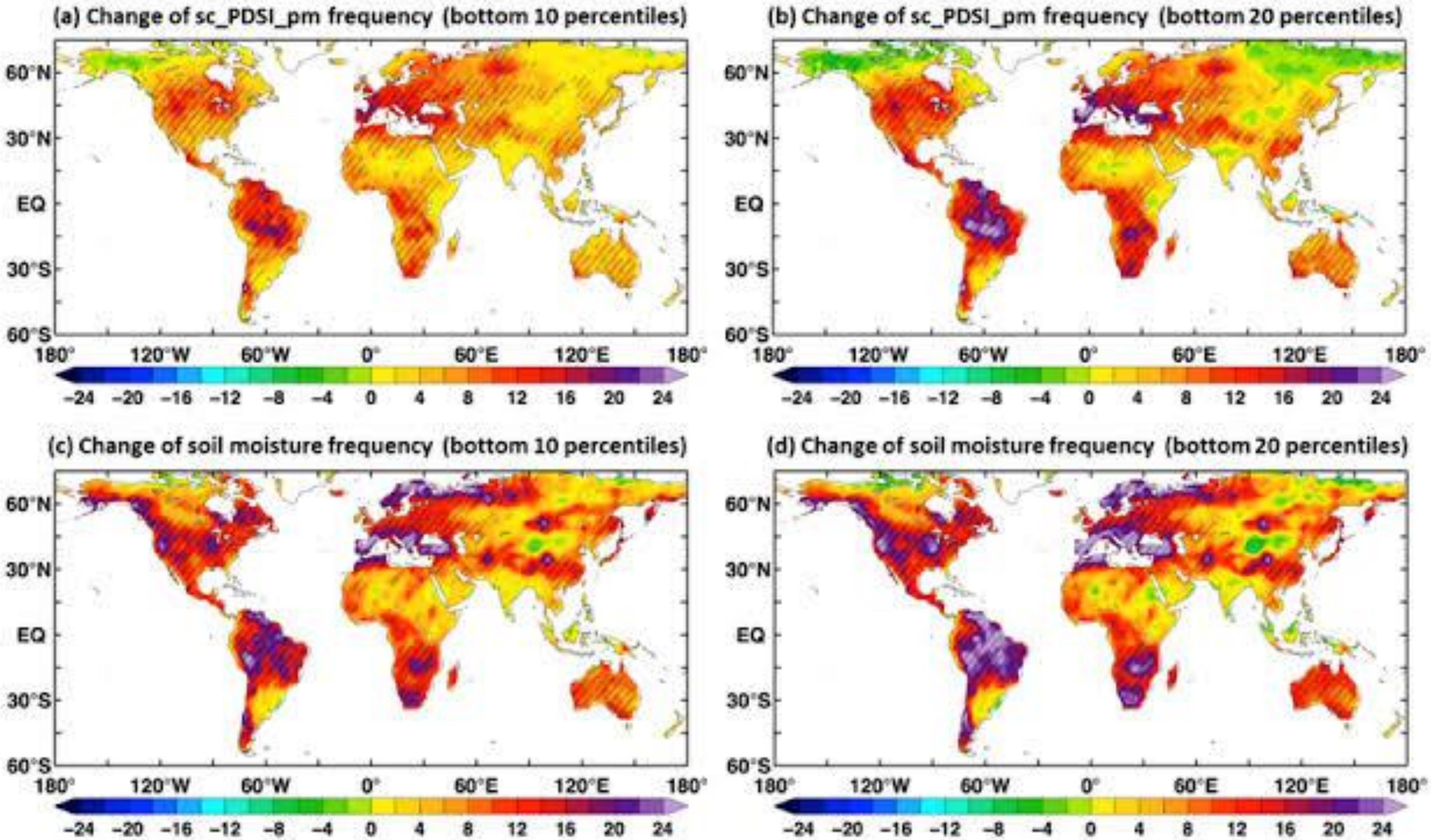
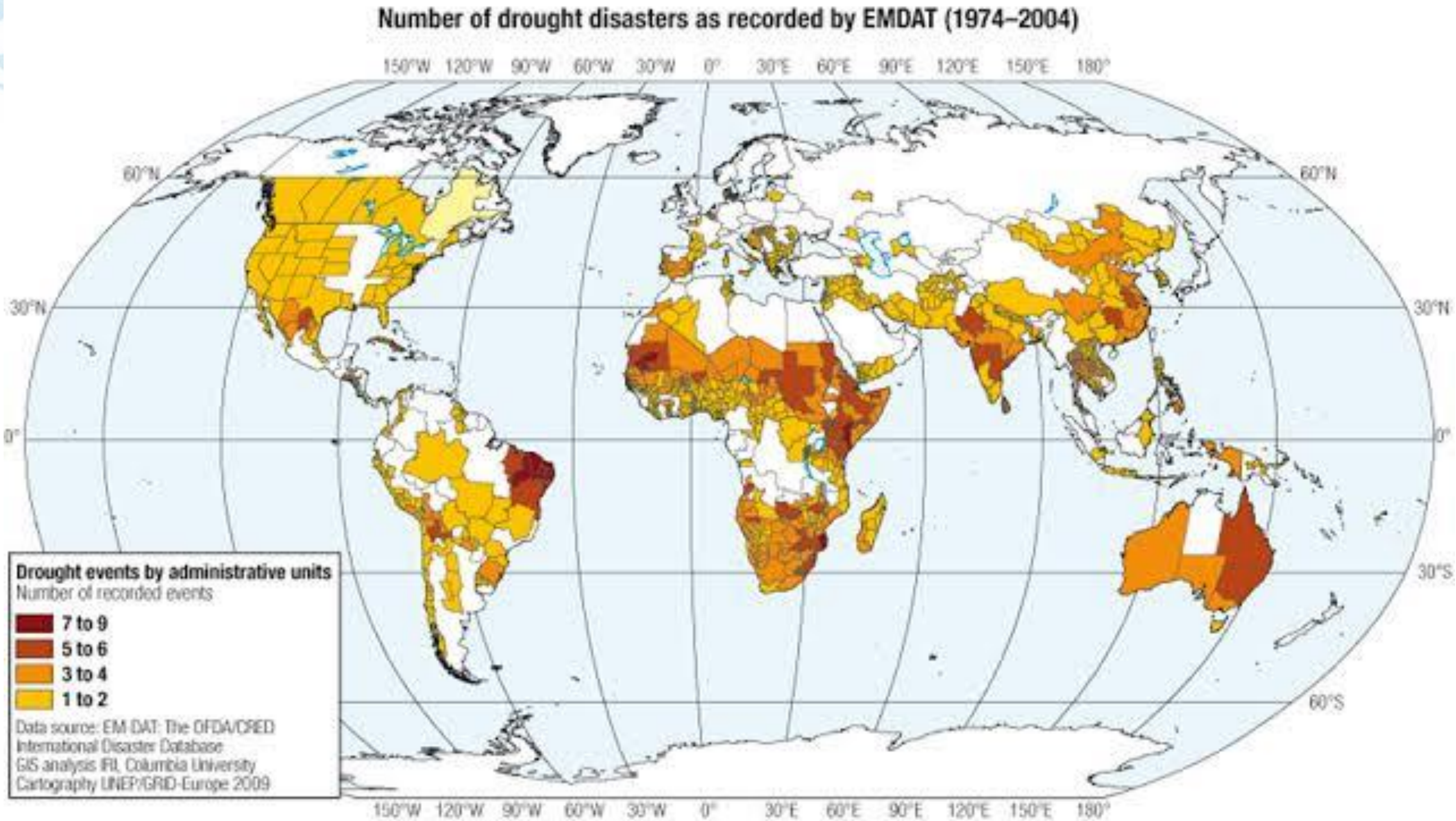


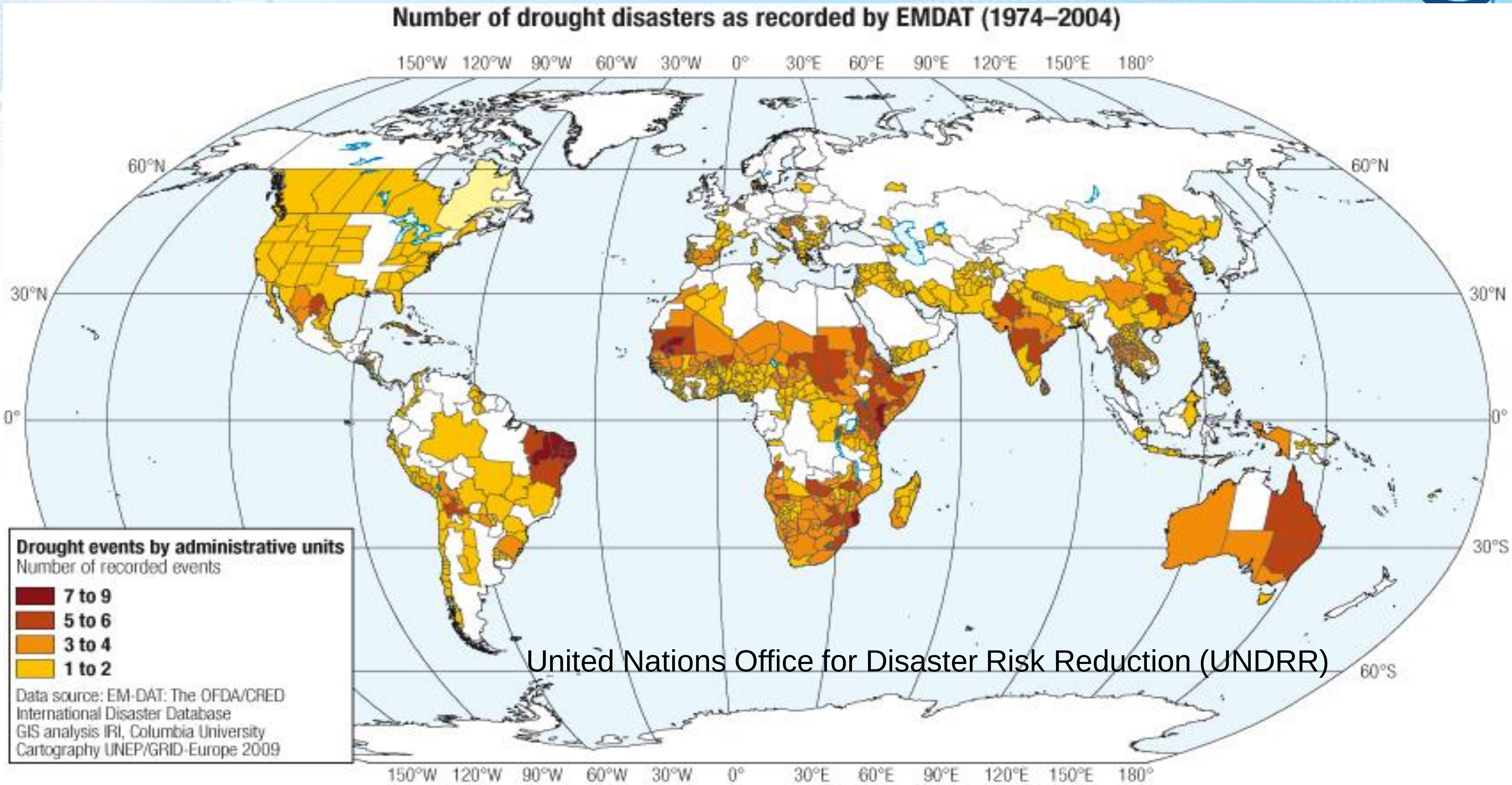
FIG. 8: Multi-model ensemble averaged changes of drought frequency (defined as the percentage of the time in drought conditions, not percentage changes) from 1970–1999 to 2070–2099 under the RCP 4.5 scenario,. The stippling indicates at least 80% of the models agreeing on the sign of change. (From Zhao and Dai 2014)

Number of drought disasters

as recorded by EMDAT (1974–2004)



United Nations Office for Disaster Risk Reduction (UNDRR)



[United Nations Office for Disaster Risk Reduction (UNDRR)]