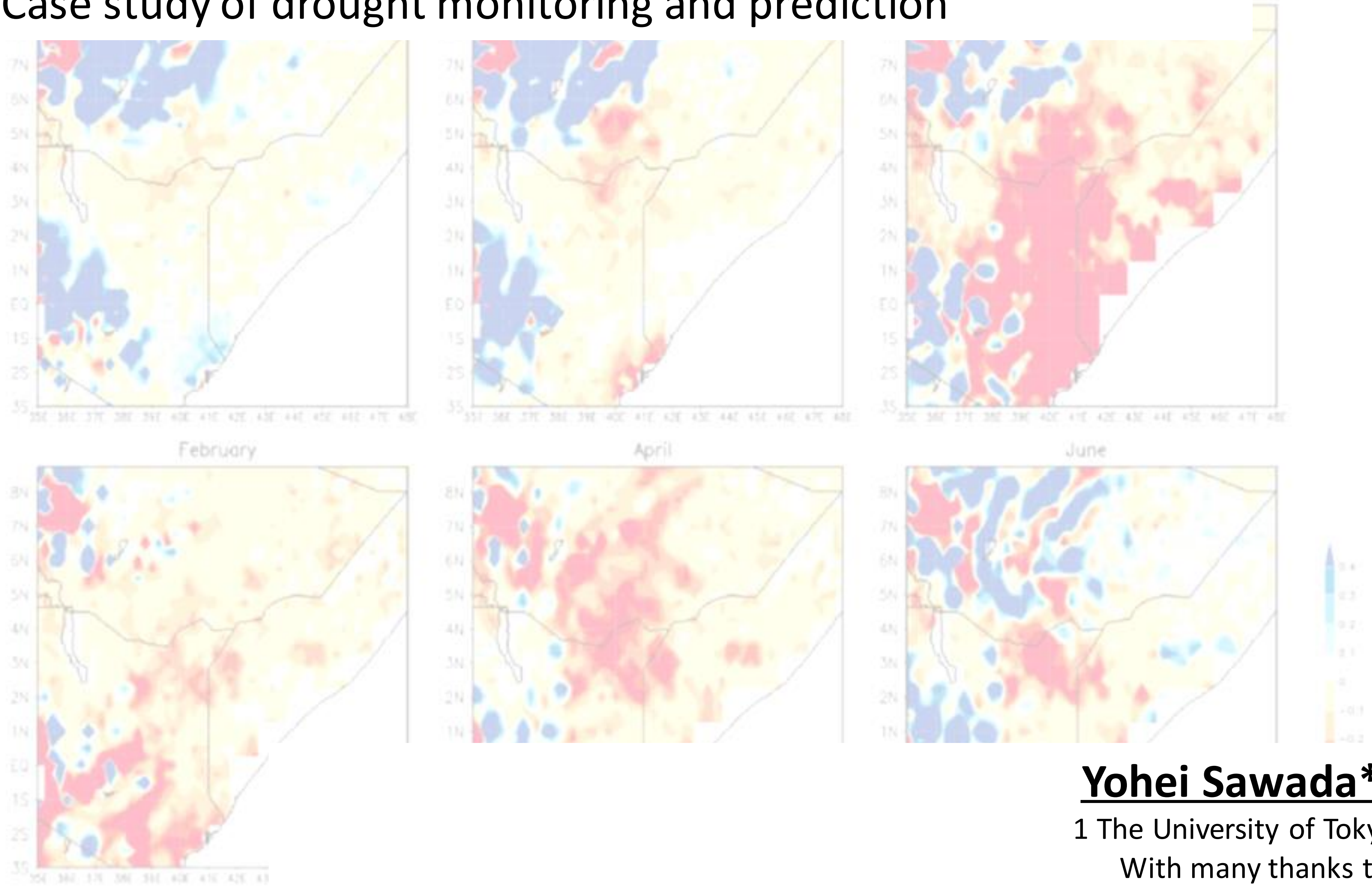
How does space technology save our lives?
Case study of drought monitoring and prediction



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1 The University of Tokyo

With many thanks to:

Toshio Koike, Jeffrey P. Walker, Hiroyuki Tsutsui, Eiji Ikoma, Masaru Kitsuregawa,

2019/12 UNISEC-Global Meeting, the University of Tokyo

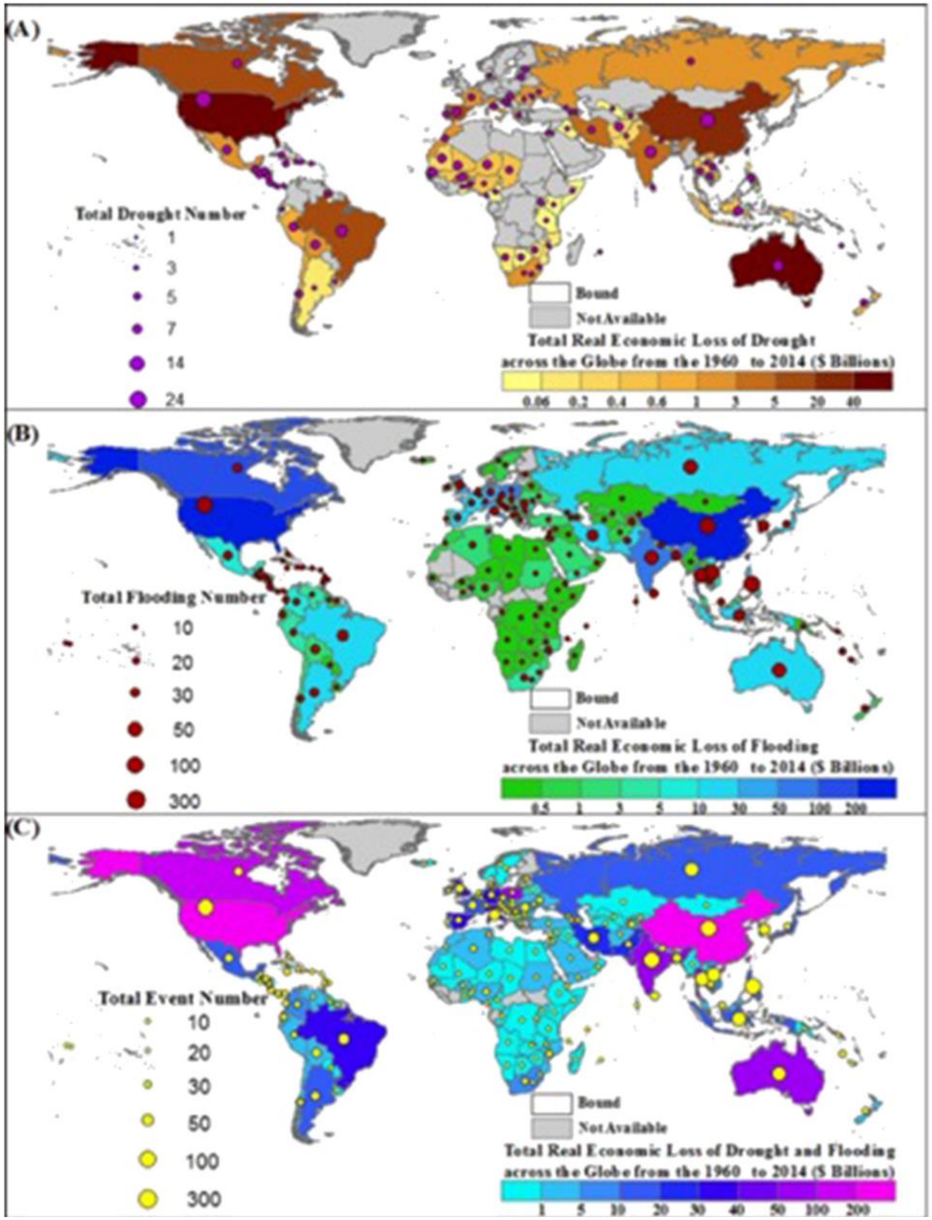
1. Introduction

1.1. Hydrometeorological Disaster Risk Reduction: The Grand Challenge

Drought

Flood

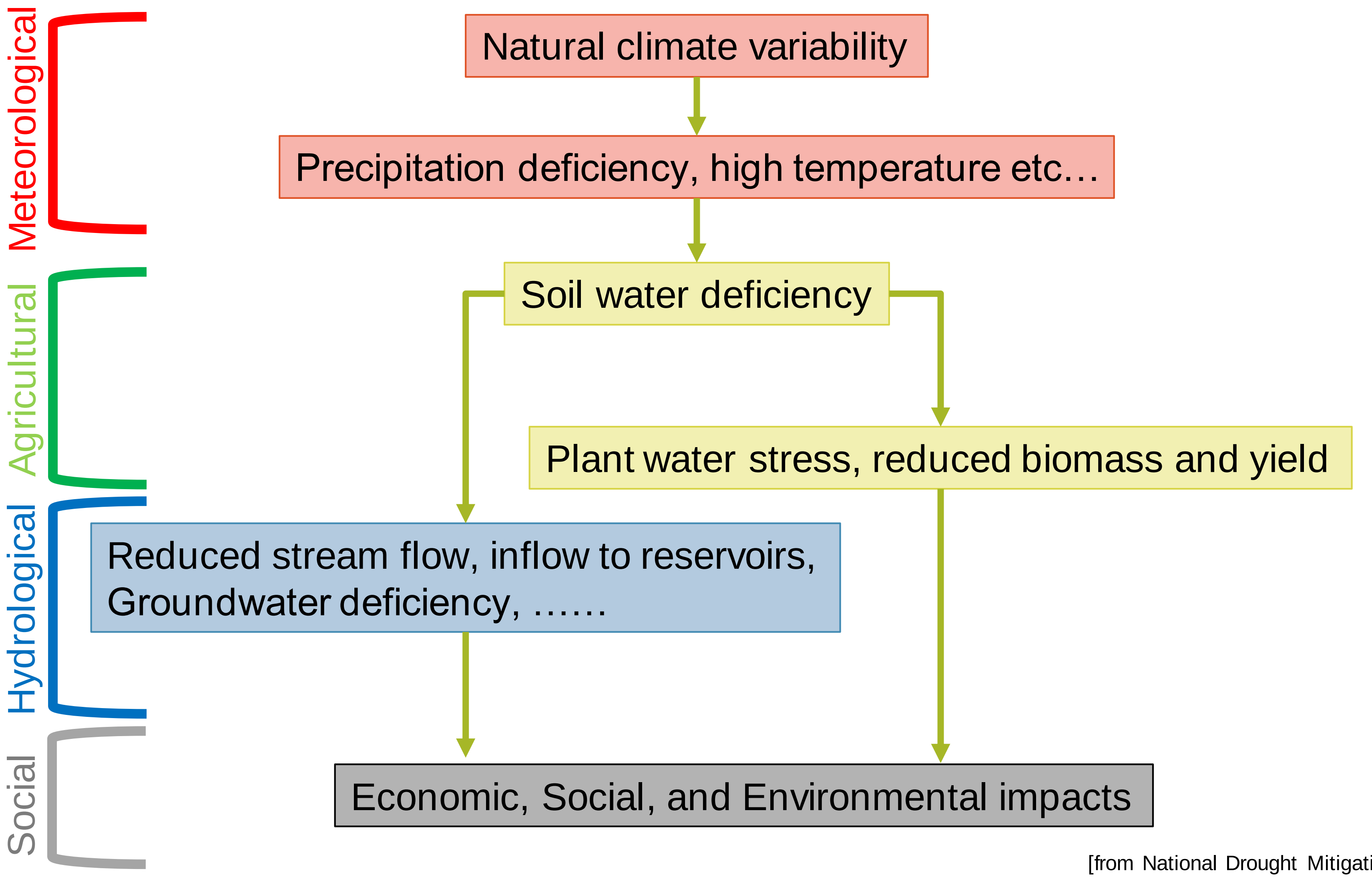
Total



[Gao et al. 2019 WRR]

- Despite a lot of effort to mitigate it, drought and flood still have substantially negative impacts on our society.
- Understanding and reducing hydrogeological disaster risk are the grand challenge toward Sustainable Development Goals.

1.2. What is drought?



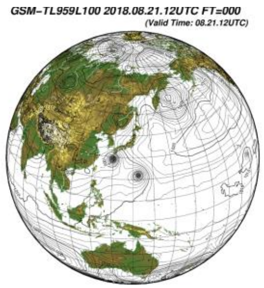
[from National Drought Mitigation Center, University of Nebraska-Lincoln, USA]
See also [Mishra and Singh, 2010]

Drought is a complicated phenomenon and an integrated process of meteorology, agriculture and hydrology.

1.3. How do we predict hydrometeorological disaster?

atmosphere

Numerical Simulation

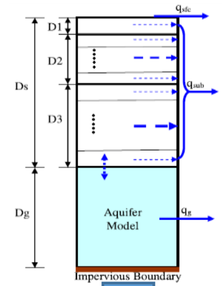


Prediction of weather
(precipitation, wind, temperature,….)

Earth Observation

land

Numerical Simulation

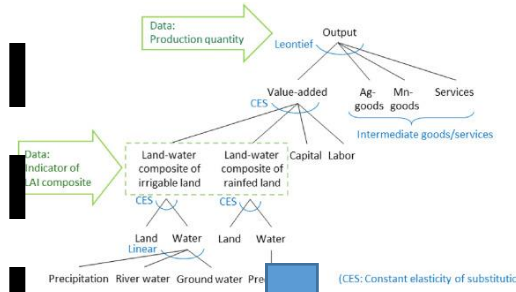


Prediction of natural disaster
(surface water, groundwater, vegetation,…….)

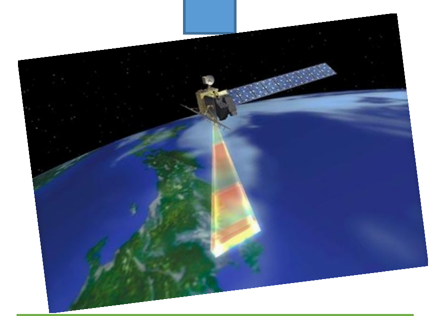
Earth Observation

Social

Numerical Simulation



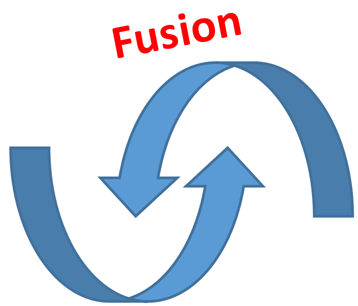
Prediction of the impact on society



Earth Observation

1.4. Key technology – Data Assimilation

Model (numerical simulation)



Data (observation)

Good:
- We can calculate everything
- We can predict the future

Bad:
- (generally) less accurate

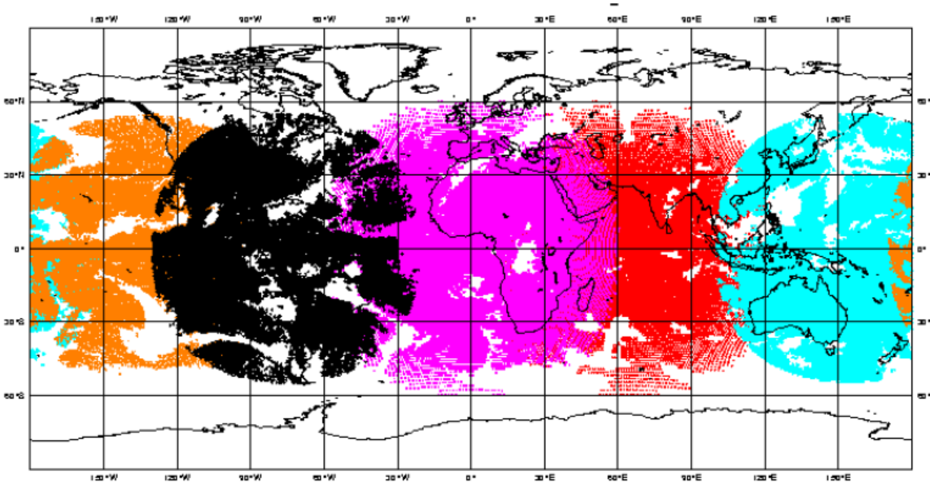
Good:
- (generally) more accurate

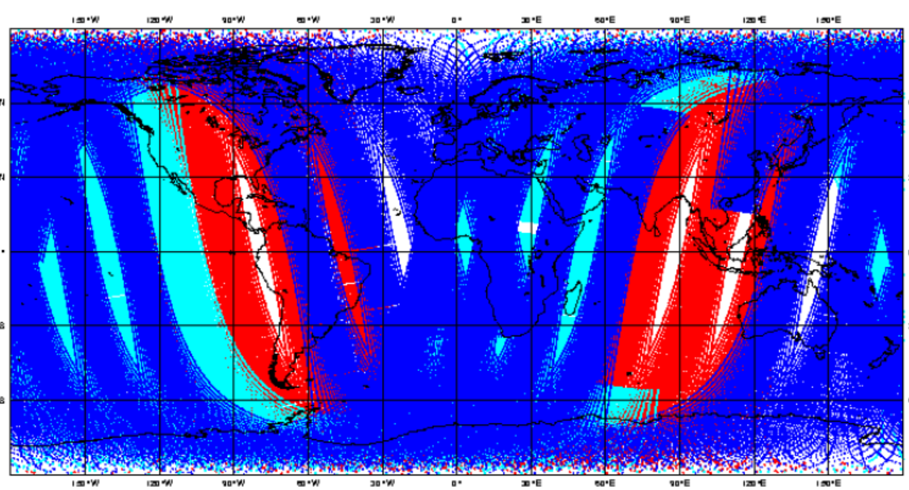
Bad:
- We cannot observe something important for droughts (i.e. root-zone soil moisture)
- We cannot predict the future

→ *Data Assimilation* is strongly recommended to improve our skill of monitoring and predicting natural disasters.

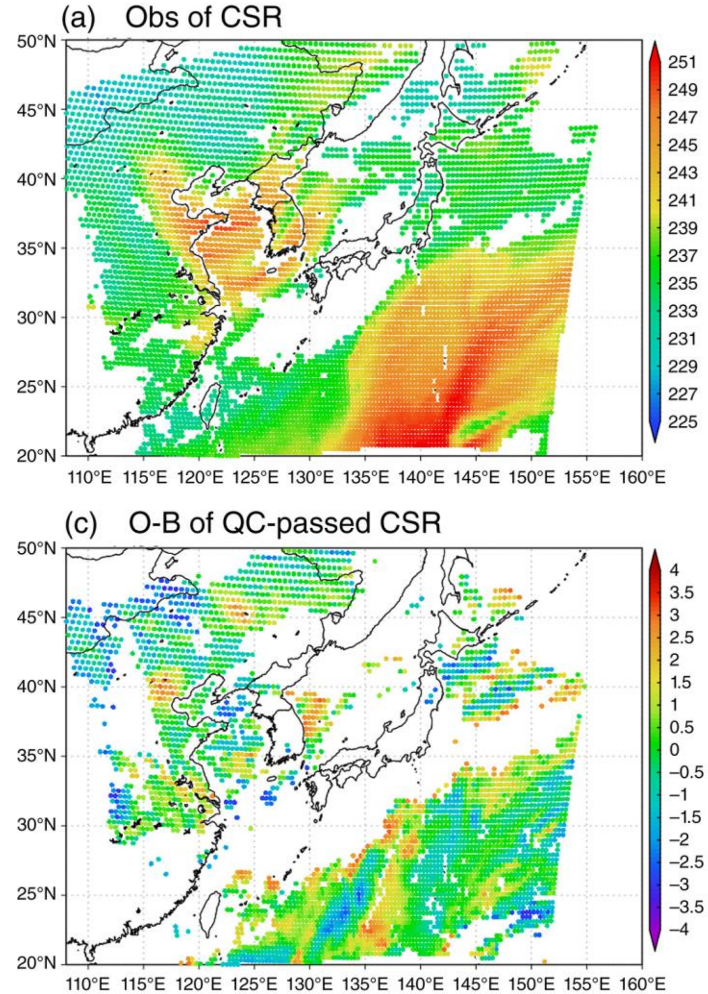
1.5. There have been big data but........

Each dot shows the satellite observation!





Currently, we can use a small subset of “big data”.



[Okamoto et al. 2019 QJ]

It is not straightforward to fully use “big data” from satellite earth observation.

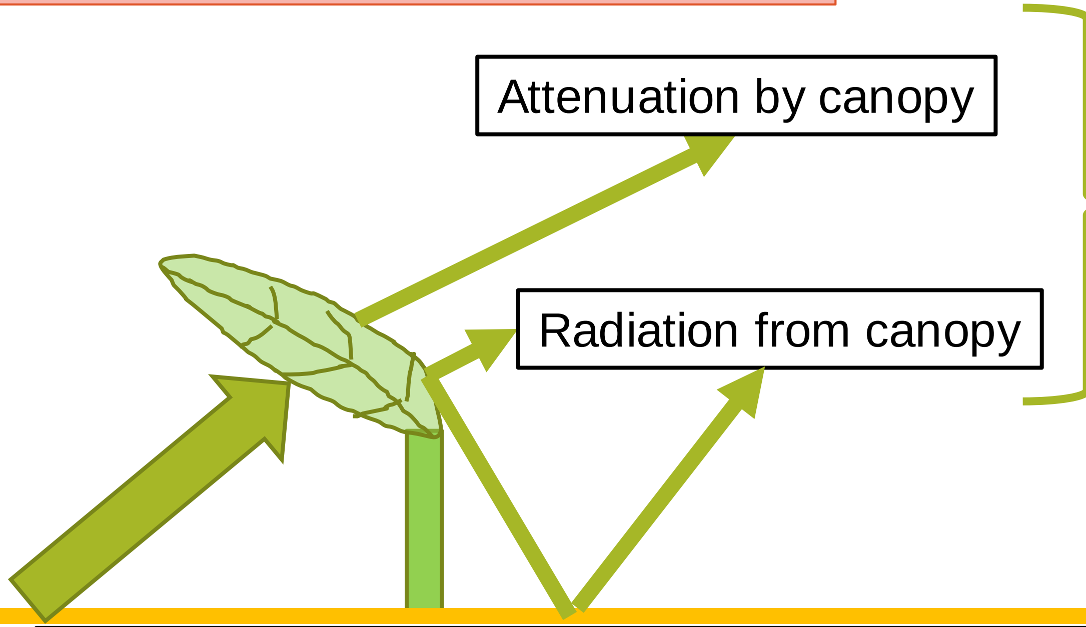
2. Satellite-based drought monitoring and prediction: Methodology

2.1. Satellite passive microwave remote sensing

Radiative Transfer in microwave region

AMSR-E

AMSR2



→ depend on Vegetation water content

Radiation from soil → depends on Surface Soil Moisture

- Microwave brightness temperature is influenced by surface soil moisture, vegetation water content, and temperature [e.g., Paloscia and Pampaloni, 1988]
- It is not strongly influenced by atmospheric condition

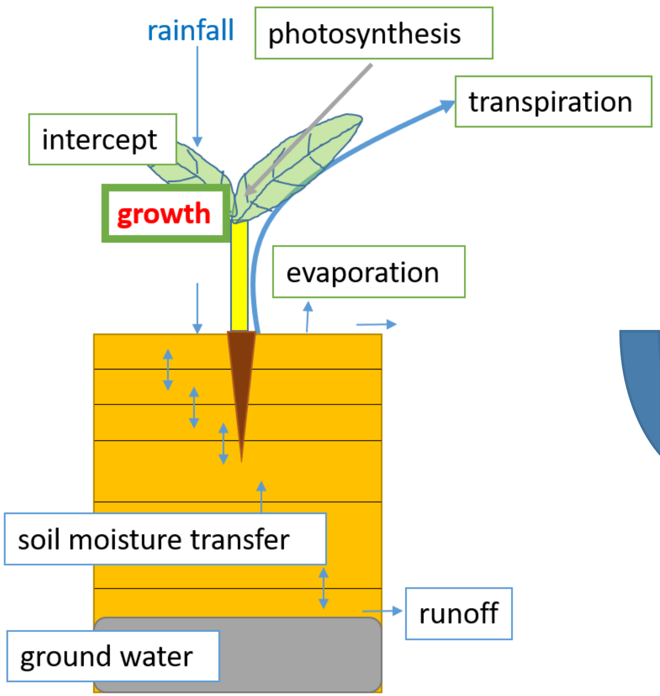
→ By assimilating this data, we can improve the skill of eco-hydrological model to simultaneously calculate soil moisture and vegetation dynamics.

2.2. Simulation-observation integration

Coupled Land and Vegetation Data Assimilation System (CLVDAS)

[Sawada and Koike 2014 JGR-A; Sawada et al. 2015 JGR-A]

Hydrological simulation



EcoHydro-SiB

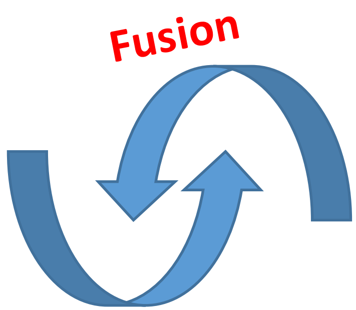
[Sawada et al. 2014 WRR]

Good:

- We can calculate everything
- We can predict the future

Bad:

- (generally) less accurate



Passive microwave observation

Good:

- (generally) more accurate

Bad:

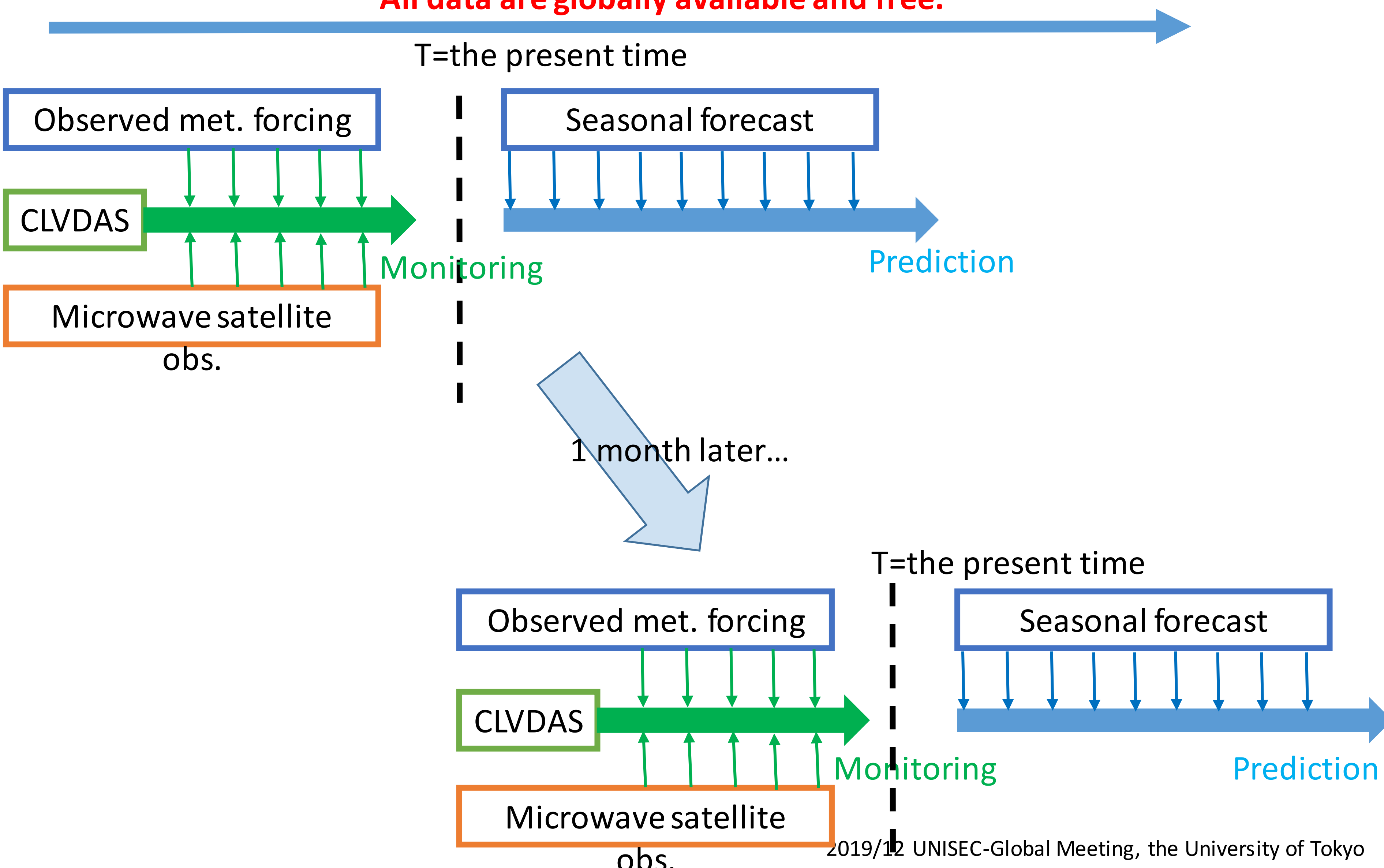
- We cannot observe something important for droughts (i.e. root-zone soil moisture)
- We cannot predict the future

2.3. Data assimilation-based drought monitoring and prediction

INtegrated DRought Analysis system (INDRA)

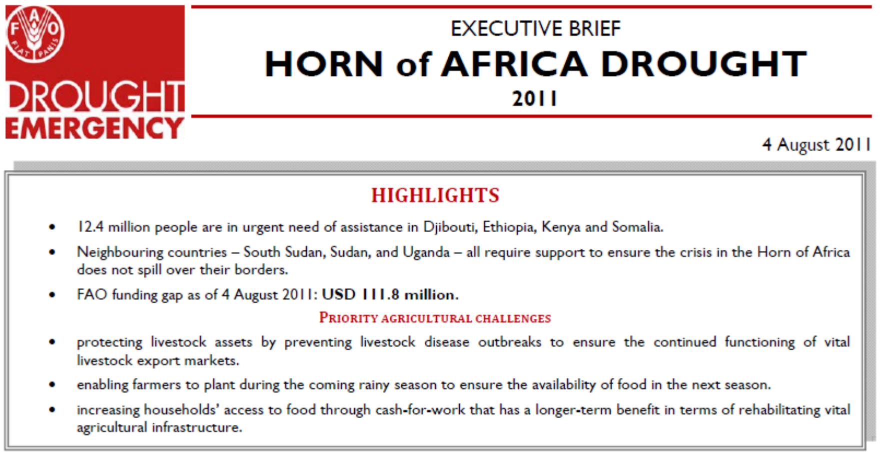
No local data are required.

All data are globally available and free.



3. Satellite-based drought monitoring and prediction: Case studies

3.1. Horn of Africa drought



EXECUTIVE BRIEF

HORN of AFRICA DROUGHT

2011

DROUGHT EMERGENCY

4 August 2011

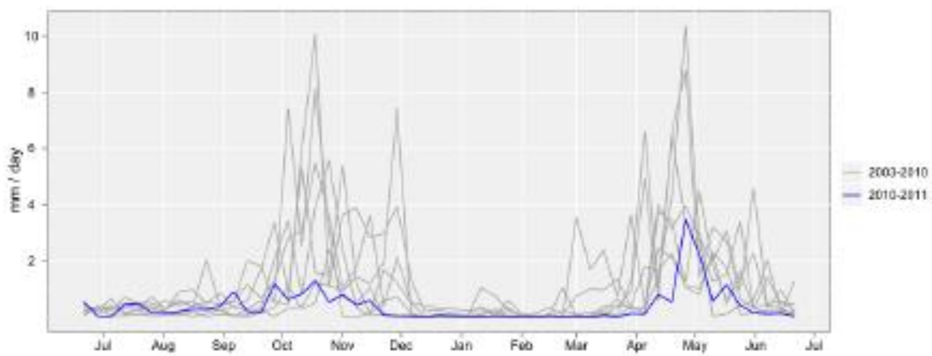
HIGHLIGHTS

- 12.4 million people are in urgent need of assistance in Djibouti, Ethiopia, Kenya and Somalia.
- Neighbouring countries – South Sudan, Sudan, and Uganda – all require support to ensure the crisis in the Horn of Africa does not spill over their borders.
- FAO funding gap as of 4 August 2011: **USD 111.8 million.**

PRIORITY AGRICULTURAL CHALLENGES

- protecting livestock assets by preventing livestock disease outbreaks to ensure the continued functioning of vital livestock export markets.
- enabling farmers to plant during the coming rainy season to ensure the availability of food in the next season.
- increasing households' access to food through cash-for-work that has a longer-term benefit in terms of rehabilitating vital agricultural infrastructure.

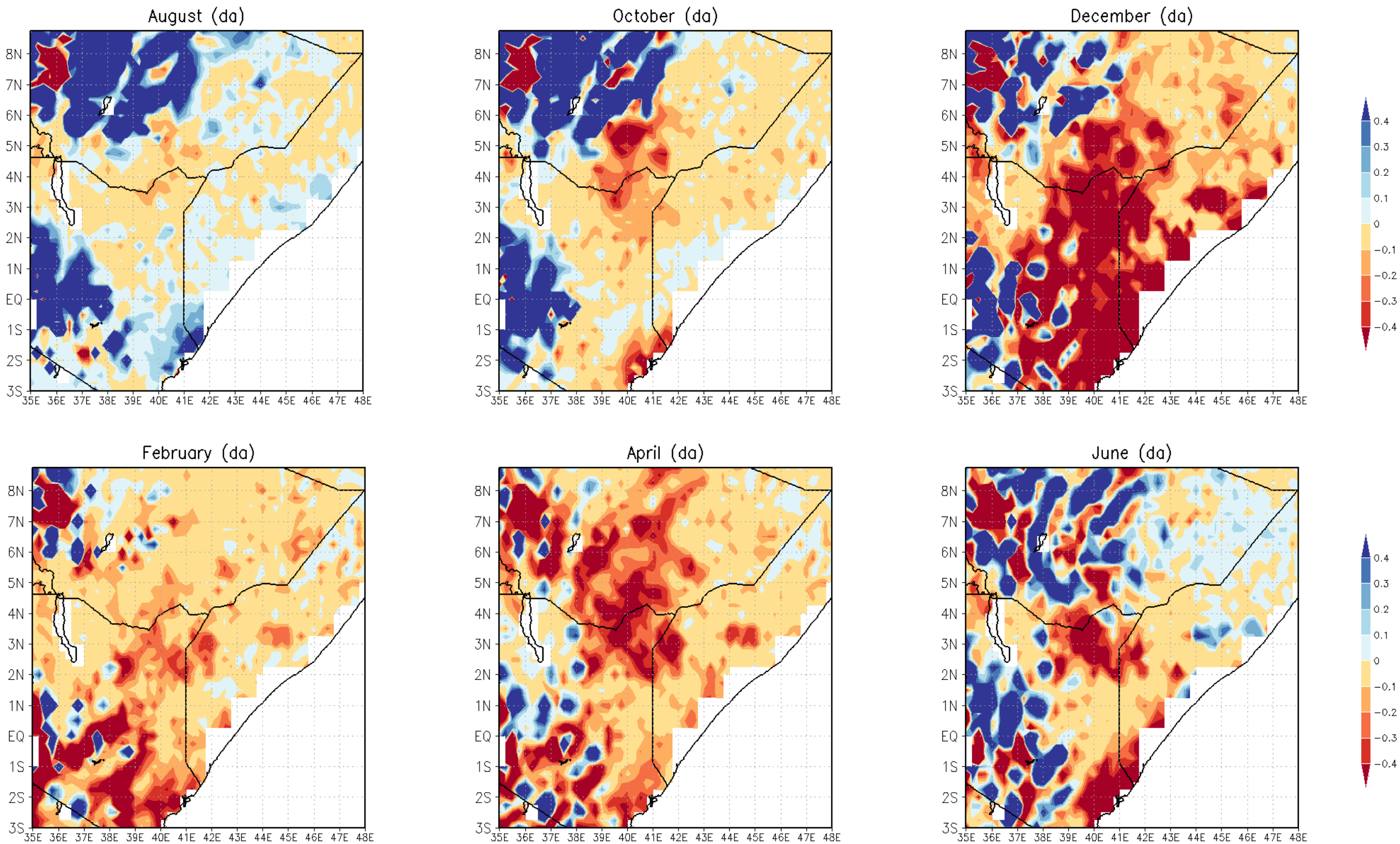
[FAO, 2011]



[Anderson et al., 2012]

3.1.1. Drought monitoring

Leaf area index (i.e. vegetation health) anomaly of 2010-2011 droughts in “reanalysis”.



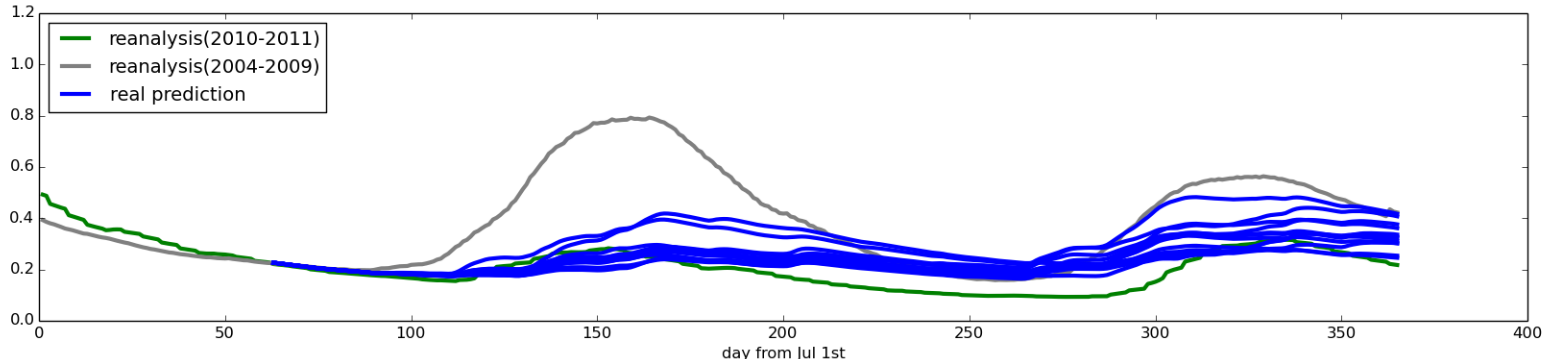
[Sawada and Koike, 2016 JGR-A]

3.1.2. Drought prediction

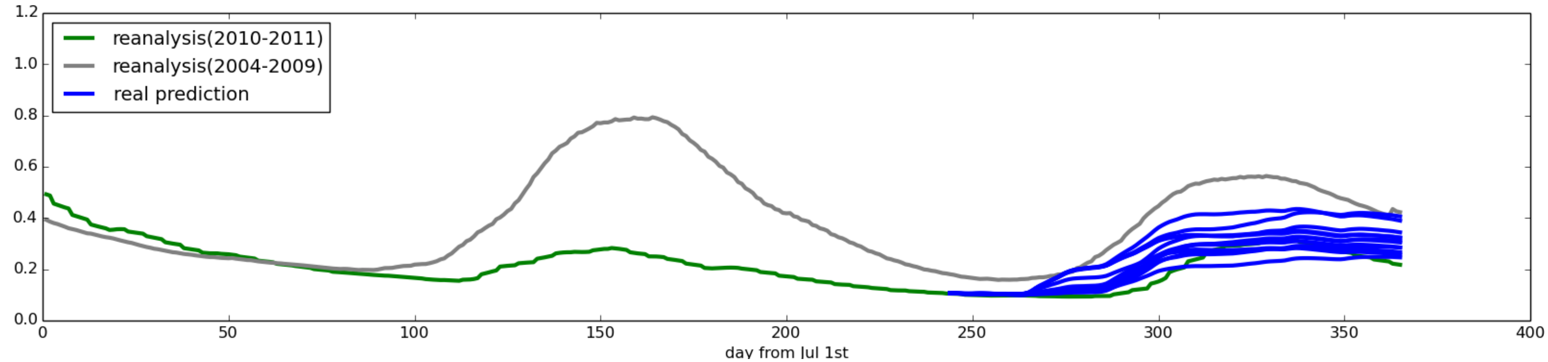
Leaf Area Index timeseries

Gray: Climatology (i.e. normal year)
Green: time series in Horn of Africa drought

CLVDAS
With weather prediction



CLVDAS
With weather prediction

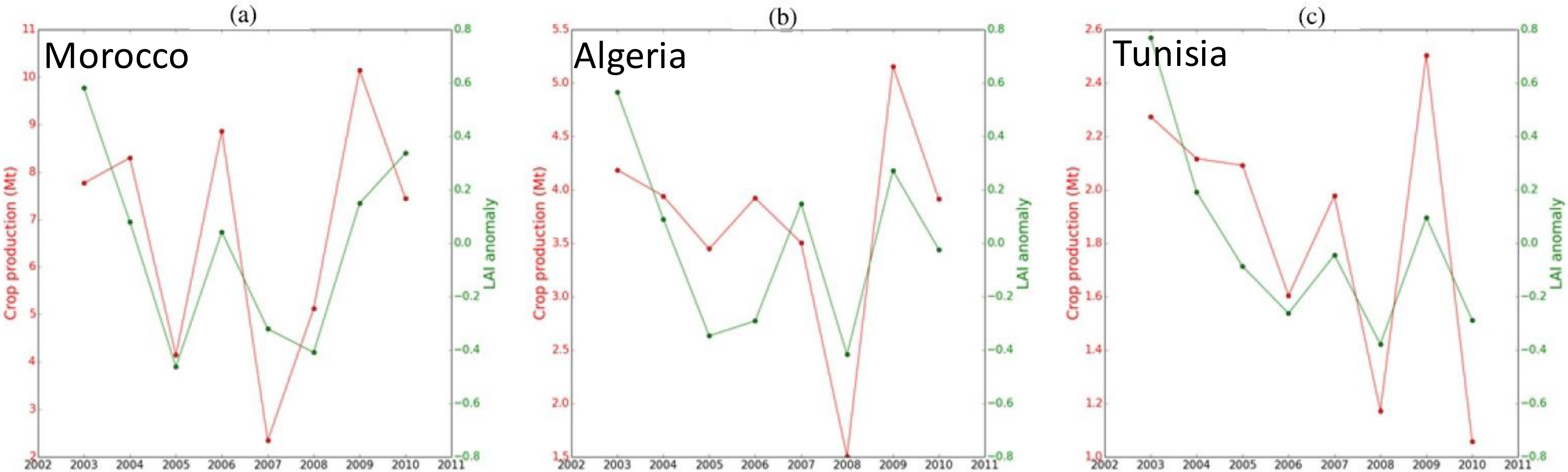


[Sawada and Koike, JGR-A 2016]

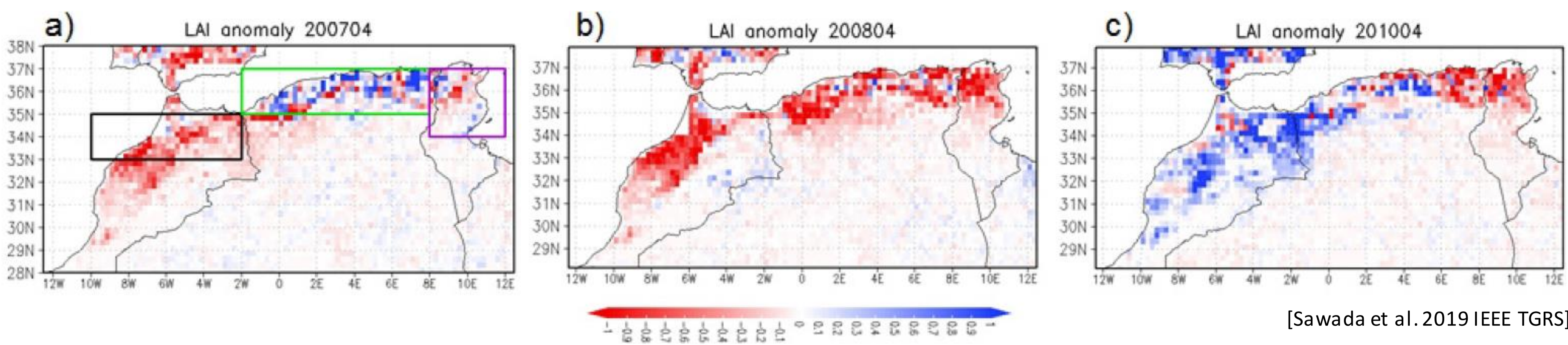
Combining the weather prediction, we can predict the degradation of vegetation in 10-month lead time.

3.2.1. Drought monitoring in North Africa

Simulated and observed crop production



Spatial distribution of leaf area index in drought years



[Sawada et al. 2019 IEEE TGRS]

→ Our drought monitoring system somehow simulates the nationwide crop production as well as water shortages (i.e. root-zone soil moisture).

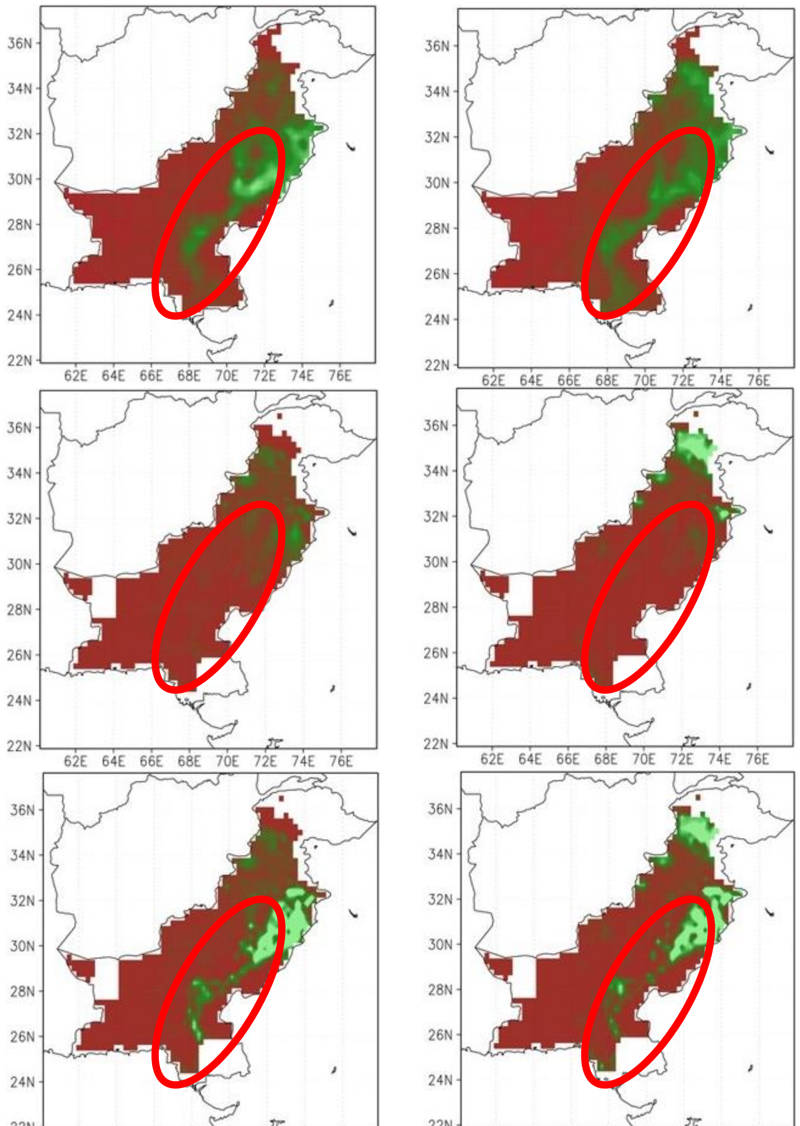
3.3.1. Drought analysis in Pakistan

2007 winter **2007 summer**

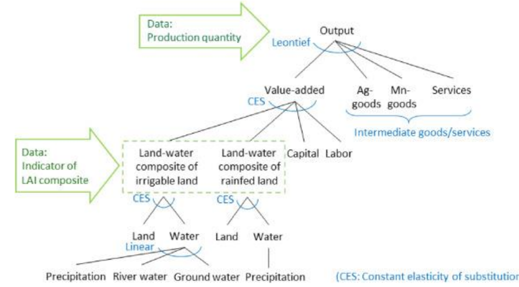
Satellite

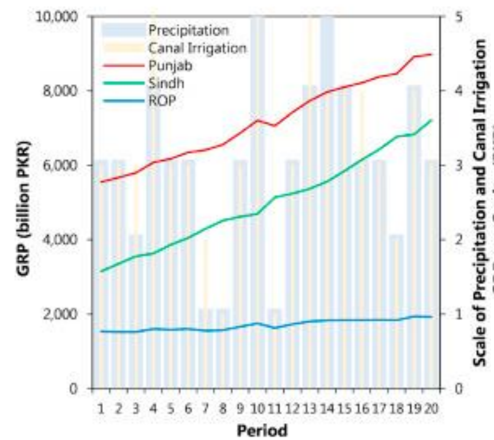
w/o irrigation

w/ irrigation

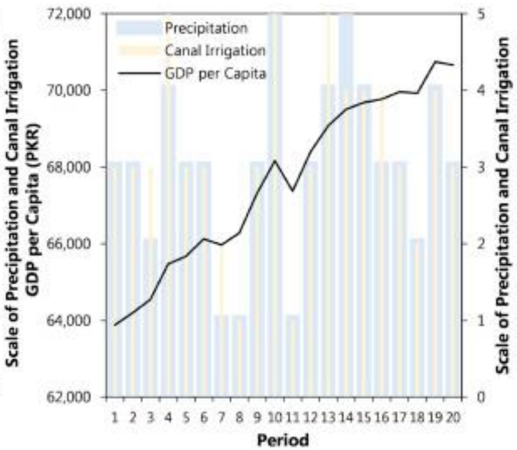


Economic model





(i) Regional GDP (GRP)



(k) GDP per capita

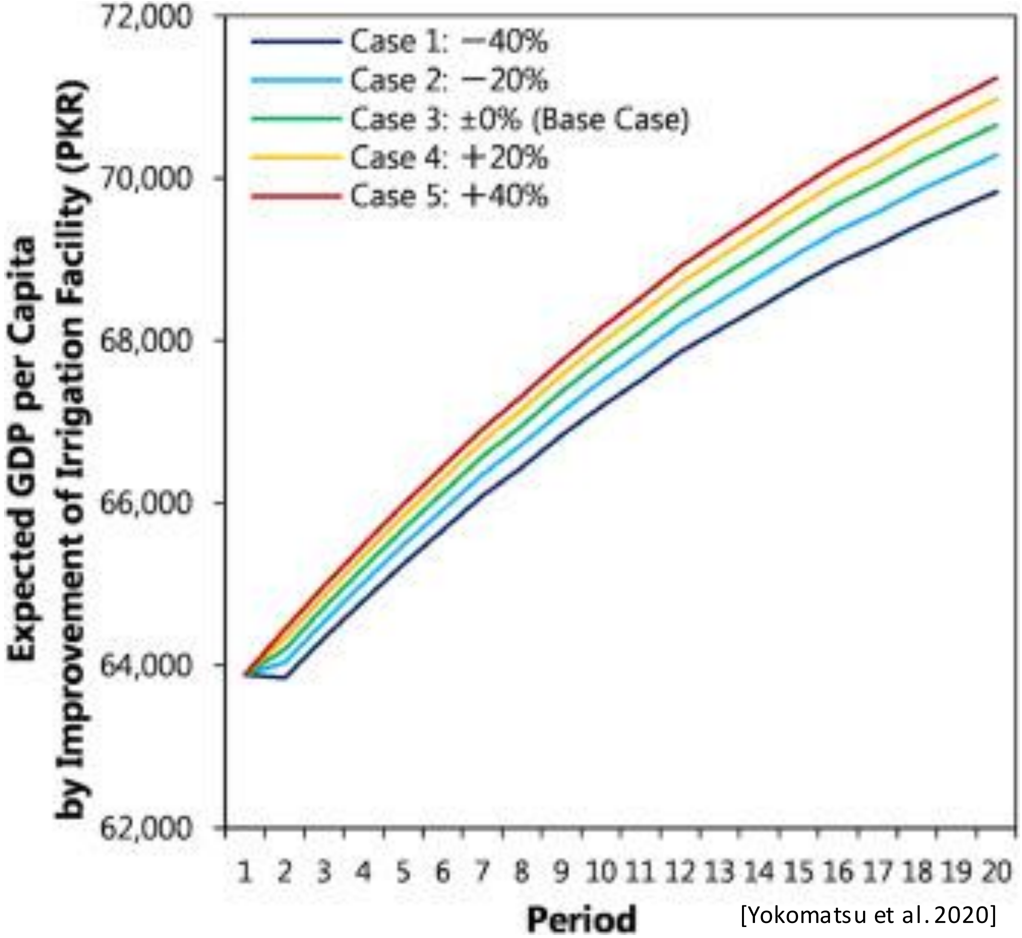
[Yokomatsu et al. 2020]

→ Linkage between agricultural degradation and economic growth was investigated.

3.3.2. Drought analysis contributing to decision making

Impact of improved efficiency of the irrigation system on GDP

Good decision making



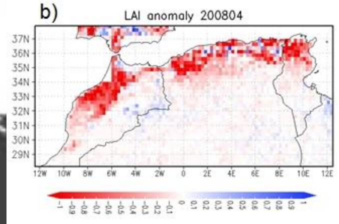
[Yokomatsu et al. 2020]

3.4. Let's tackle with the grand challenge for mankind together

North Africa

Drought monitoring & prediction

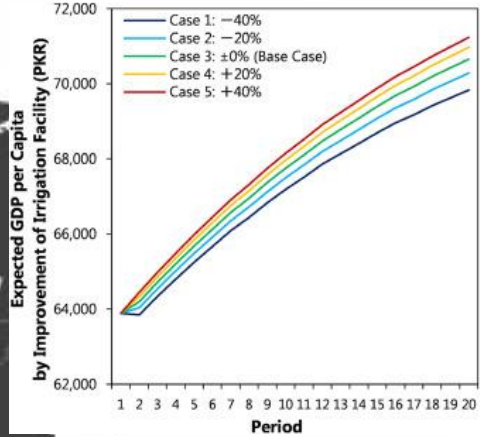
[Sawada et al., 2019 IEEE TGRS]



Pakistan

Cost/Benefit evaluation for irrigation infrastructure against drought

[Yokomatsu et al., 2020 IJDRR]



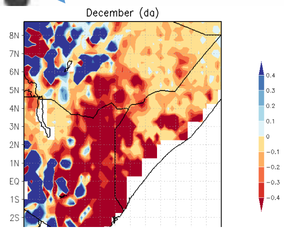
Northeastern Brazil

Drought monitoring & prediction

[Tsutsui et al., 2019 JSCE]

Angola

Ongoing…?



East Africa

Drought monitoring & prediction

[Sawada and Koike, 2016 JGR-A]

Co-design by local-stakeholders, civil engineers and space engineers might be a key to success!

4. Conclusion and discussion

- Space technology secures our safety and justice.
- Earth observation is key technology to save our lives from natural disasters.
- You can maximize the potential of space technology by integrating it with other technology.
- Many different physical & social variables should be observed to get holistic view of droughts. A single observation system cannot solve this problem

→ Co-design of observation system by local stakeholders, space engineer & civil engineer is important!!