Regional Training Workshop
"Advances in Remote Sensing Application in Water Resources Management"

Flood and Drought Monitoring and Prediction by Satellite-based Microwave Remote Sensing

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Chair, River Council of Japan

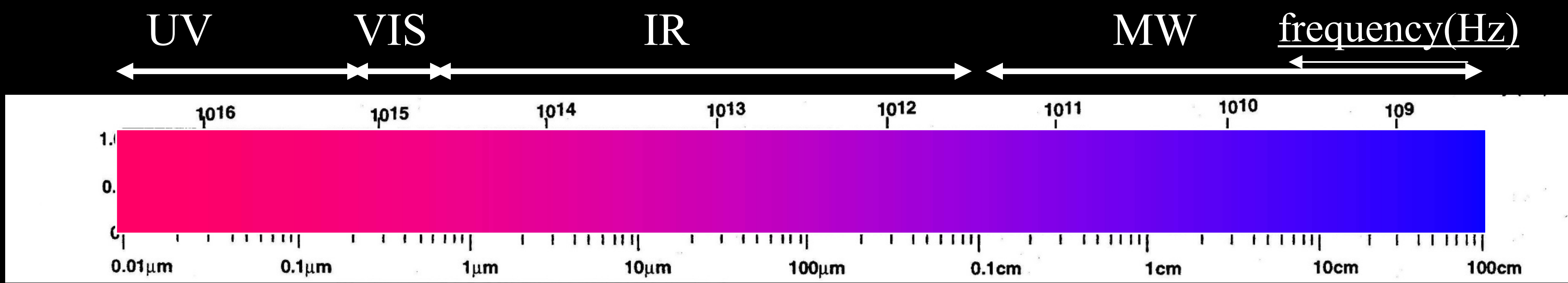
United Nations Educational, Scientific and Cultural Organization

International Centre for Water Hazard and Risk Management under the auspices of UNESCO

Public Works Research Institute, National Research and Development Agency, Japan

Definition of Remote Sensing

Remote Sensing is a technology for
identifying a target and
estimating its physical, chemical and biological conditions
without touching
by using its inherent characteristics of
emission, reflection, absorption and transmission of
electromagnetic wave and its radiation transfer.



0.4-0.7um

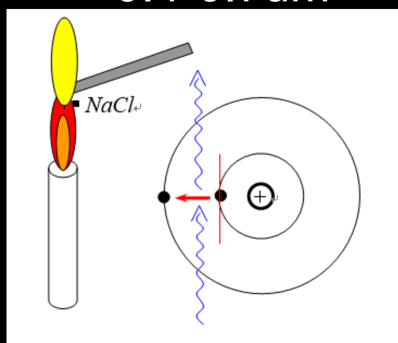
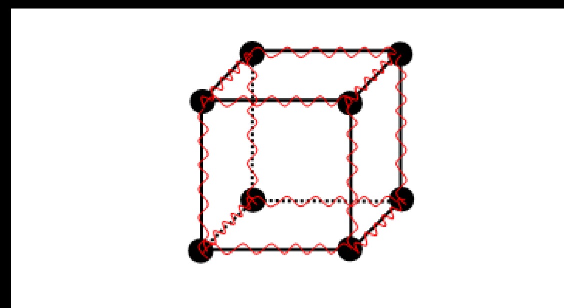


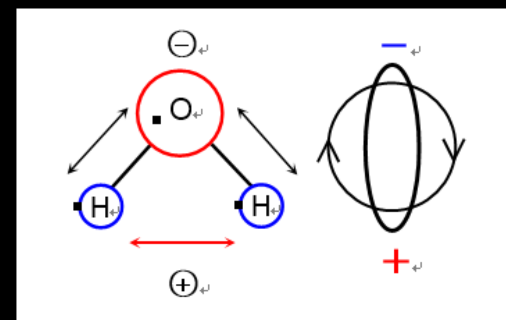
Fig. 4. Optical Emission Spectrometry

0.7um-1mm



- *Fig.5. Thermal Vibration of Lattice*

1mm-1m

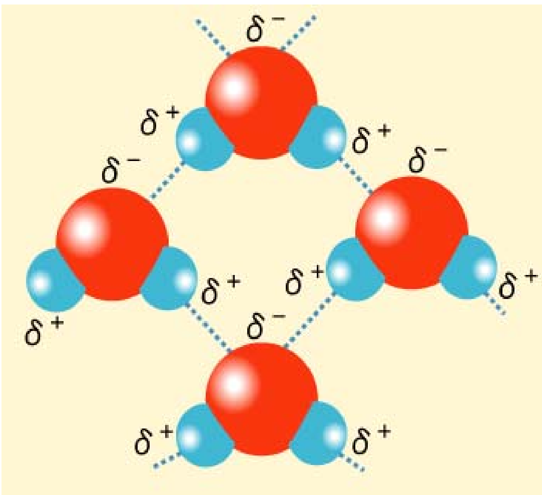


- *Fig.6. Rotation of Dipole Molecule*

Electromagnetic Waves		Wavelength	generated by
γ-RAY		- 0.1 nm	atomic nucleas interaction
X-RAY		0.1 - 10 nm	core electron ionization
UV		10 nm - 0.4 µm	hull electron ionization
VISIBLE		0.4 - 0.7 µm	hull electron excitation
INFRARED	NEAR	0.7 - 1.3 µm	thermal vibration of molecule and lattice of the substance
	SHORT WAVE	1.3 - 3 µm	
	MEDIUM	3 - 8 µm	
	THERMAL	8 - 14 µm	
	FAR	14 µm - 1 mm	
MICROWAVE		1mm - 1m	rotation/reversal mode

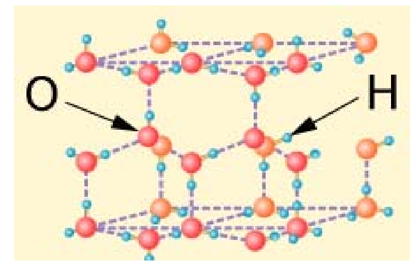
WATER Microwave Remote Sensing

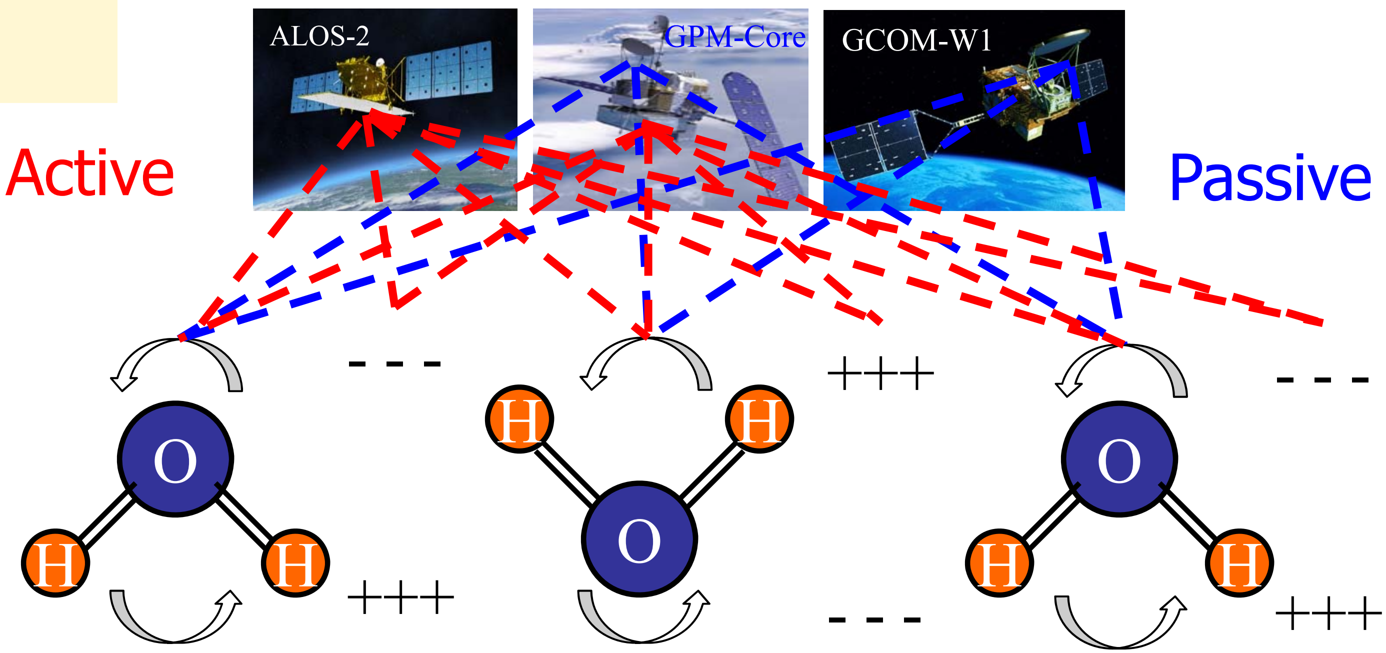
Strong Dipole Molecule



Unique Roles in the Earth Environment

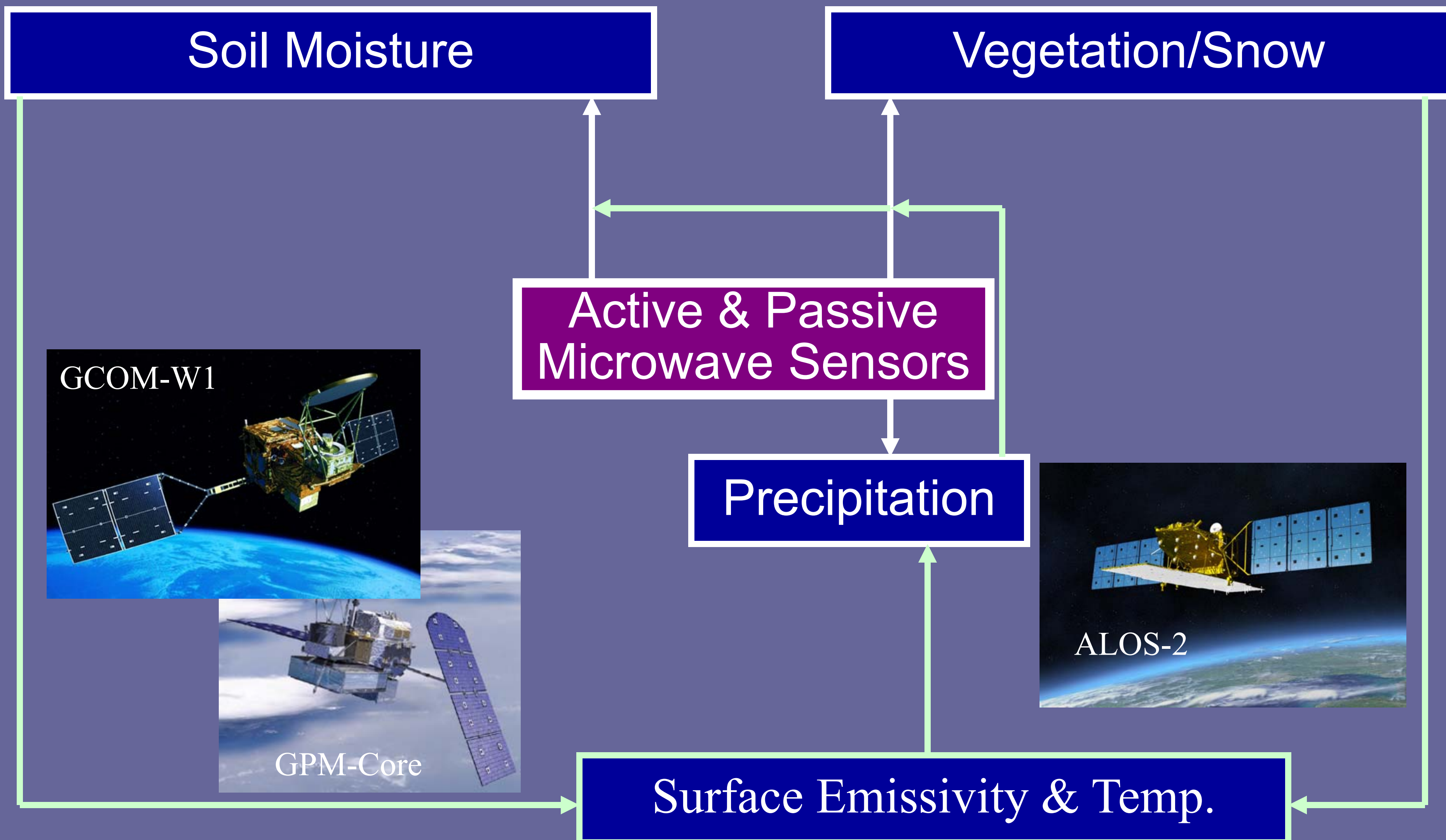
- Large Specific Heat of Liquid Water:
  → *Ocean as a heat transporter*
- Large Heat Exchange through Liquid – Gas Phase Transition → *Water vapor as a heat transporter*
- Solid ICE Crystal Lattice:
  → *Ice floats in water & bine drives the great ocean conveyor belt.*



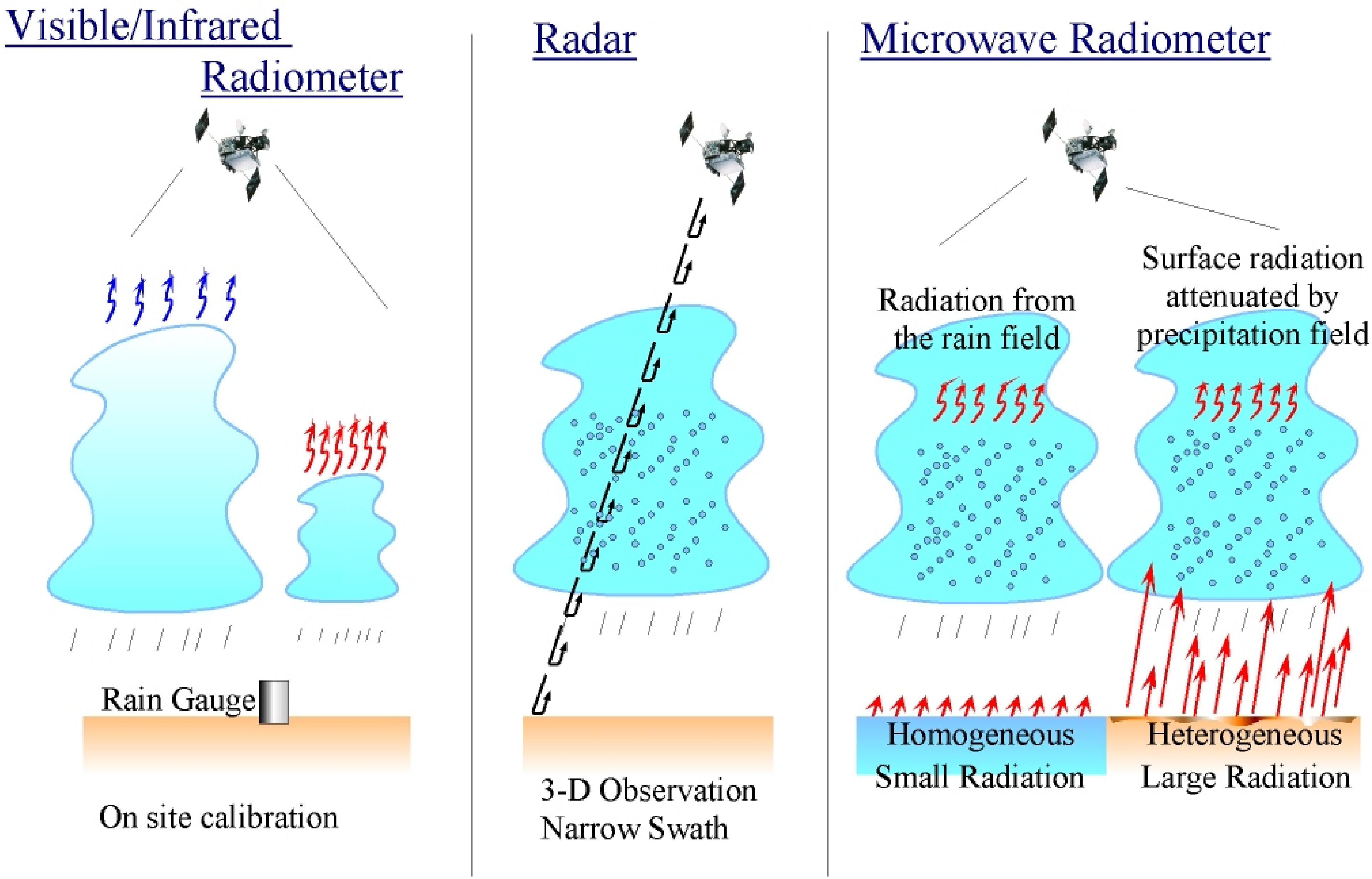


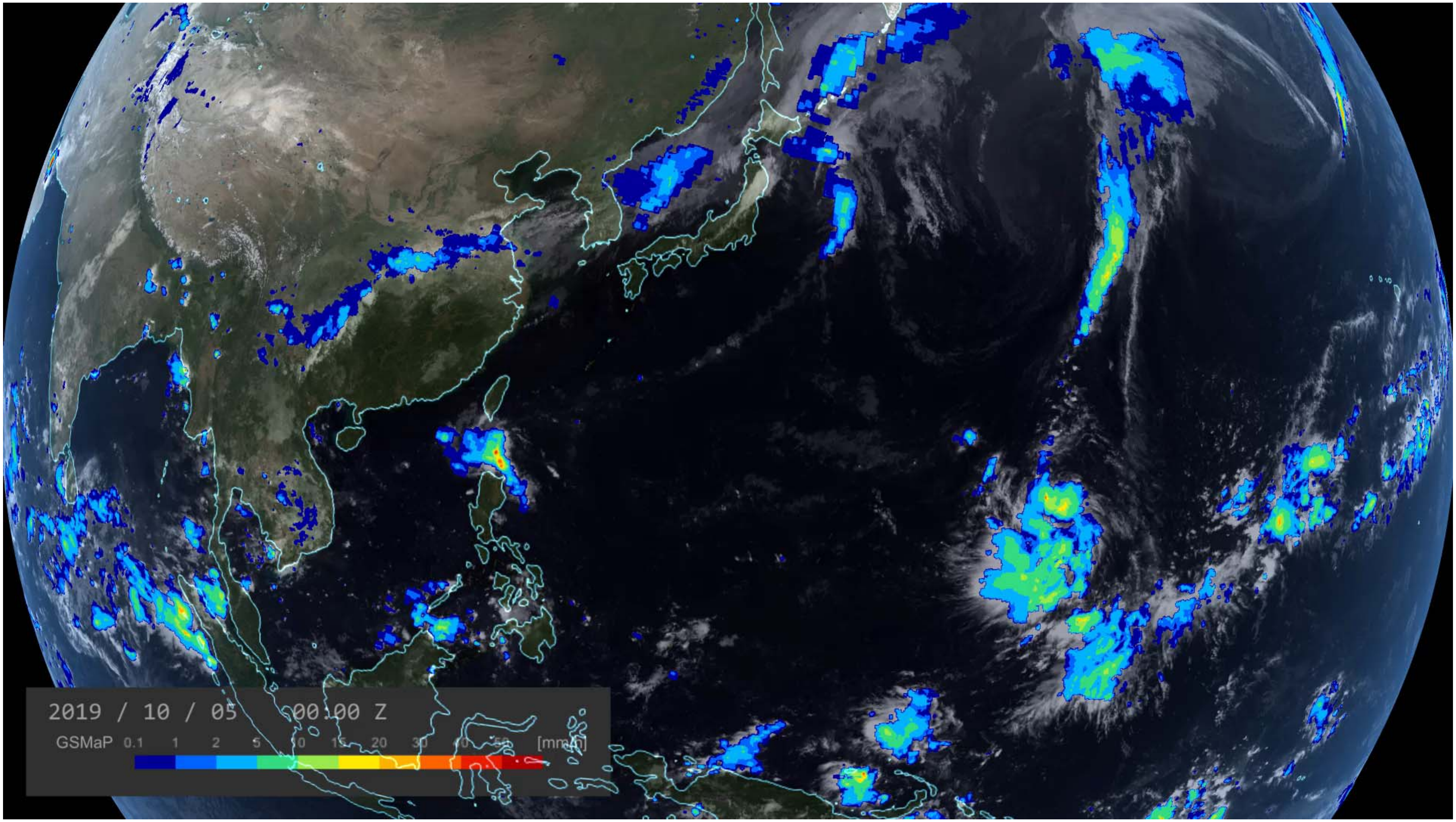
Strong Dielectric Material

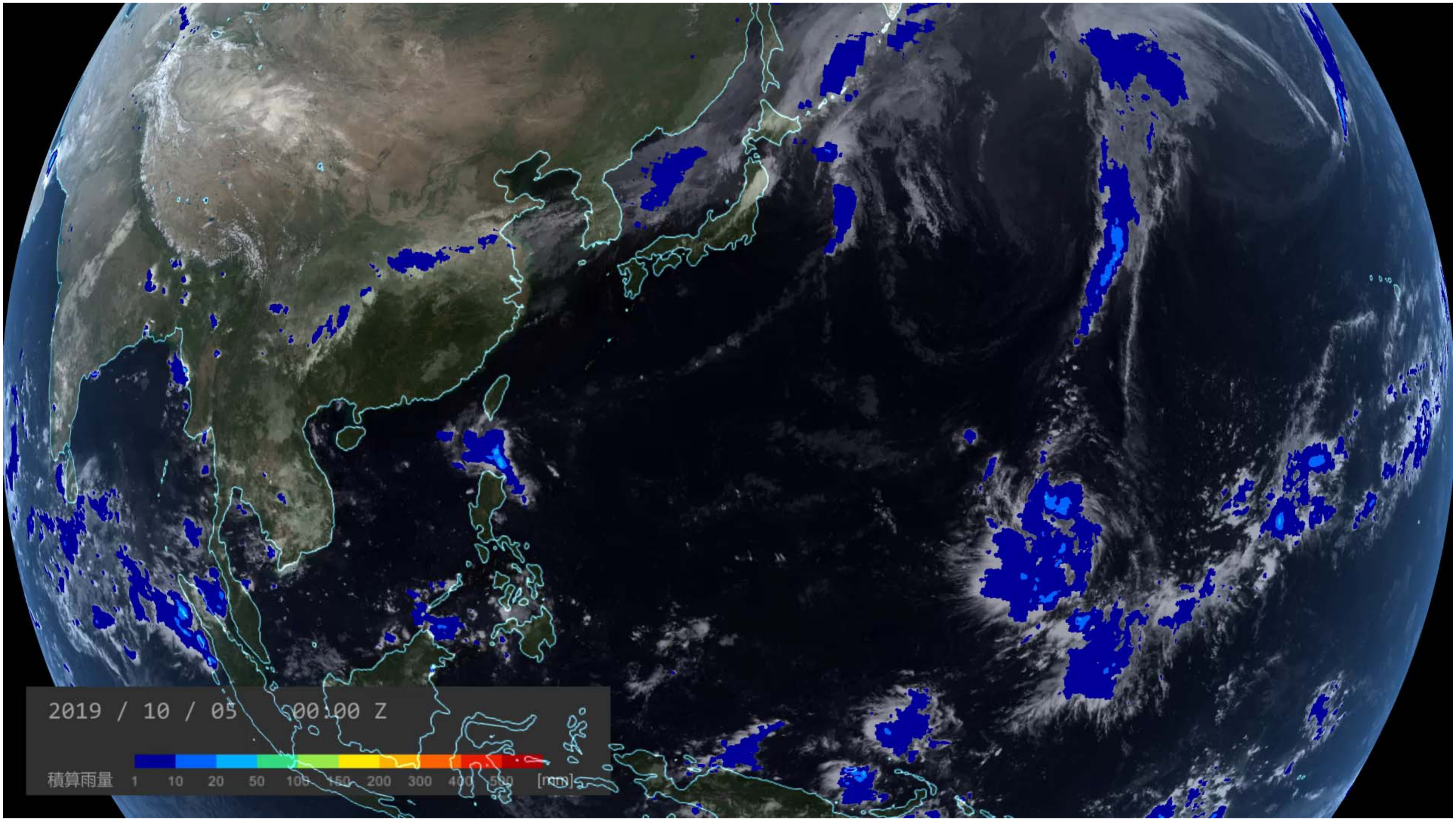
Microwave Remote Sensing of Land Hydrology



Satellite Precipitation Sensors

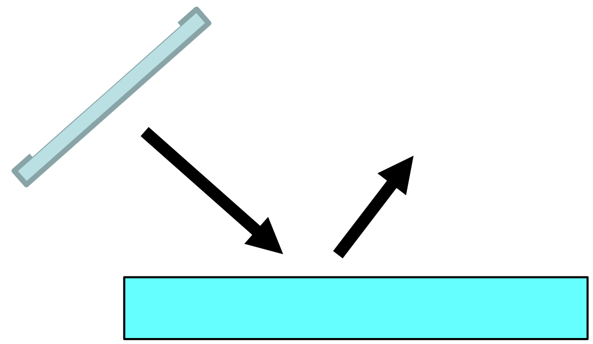



2019 / 10 / 05 00:00 Z
GSMaP 0.1 1 2 5 10 15 20 30 40 50 [mm/h]


2019 / 10 / 05 00:00 Z
積算雨量
1 10 20 50 100 150 200 300 400 500 [mm]

Land Surface Monitoring by SAR

SAR measures a intensity of microwaves reflected from the earth's surface



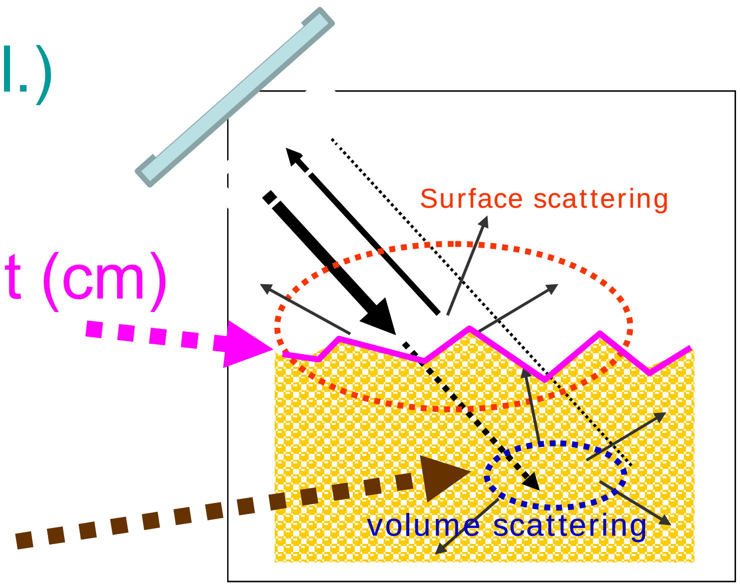
The intensity is called "backscattering coefficient

σ^0 = f(Mv, Sd, Cl, Sv, D)

Soil moisture:
Mv : Volume fraction of soil moisture (vol.)

Surface roughness:
Sd : Standard deviation of surface height (cm)
Cl : Surface correlation length (cm)

Soil parameter:
Sv : Volume fraction of soil grains (vol.)
D : mean diameter of soil grains (cm)



Scattering image

Nigeria Flood in September 2018

World Africa Americas Asia Australia China Europe India Middle East United Kingdom Edition

Nigeria declares 'national disaster' after severe floods kill 100

By Damilola Odufuwa and Bukola Adebayo, for CNN

Updated 1029 GMT (1829 HKT) September 18, 2018

A man gestures next to his flooded house following heavy rain near the Nigerian town of Lokoja, in Kogi State, on September 14, 2018.

Residents steer a dugout canoe past flooded houses in Lokoja capital of Kogi State on September 14,

NEWS / NIGERIA

Nigeria floods kill 100 people across 10 states

A national disaster has been declared in four states after devastating floods hit different parts of Nigeria.

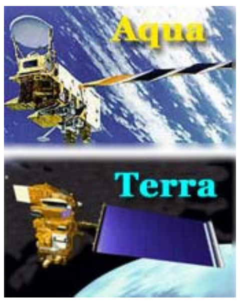
Nigeria's rainy season brings with it inevitable flooding [Afolabi Sotunde/Reuters]

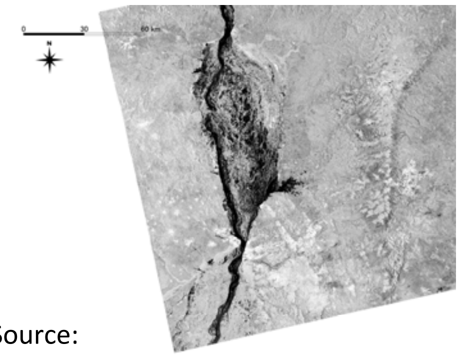
https://www.aljazeera.com/news/2018/09/nigeria-floods-kill-100-people-10-states-180917193612830.html

https://edition.cnn.com/2018/09/18/africa/nigeria-flood-national-disaster/index.html

Identify inundation area on Sep-22, 2018

MODIS (optical)



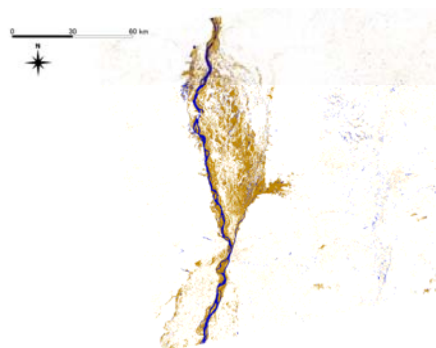


Source:
Copernicus Sentinel Data

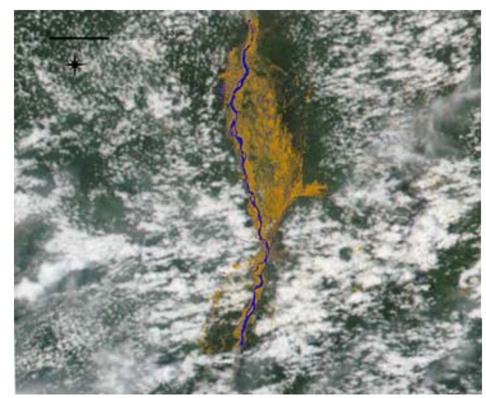
Sentinel1 (SAR)

Easily identification & high frequency
but covered with cloud

All weather & high spatial resolution
but low frequency



Flood Area by SAR



Flood Area map

Source of back image: "NASA Worldview"

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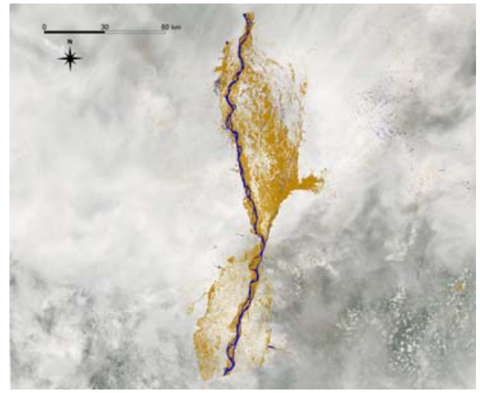
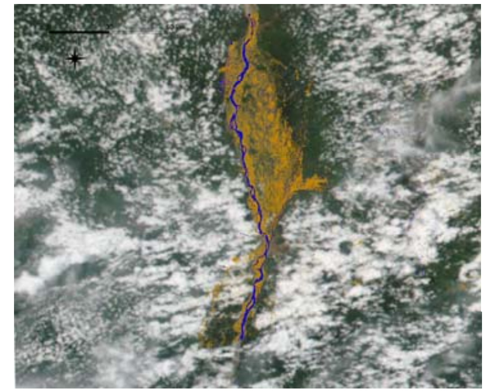
Niger River Flood Area Map

1) Sep-04, 2018

2) Sep-16, 2018

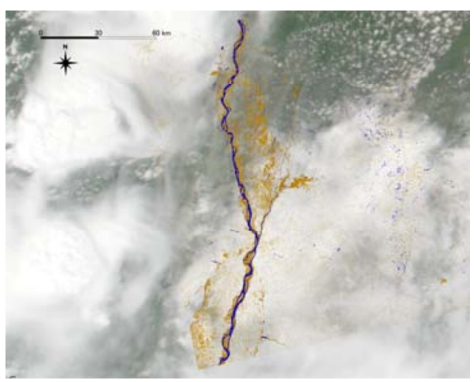


3) Sep-22, 2018

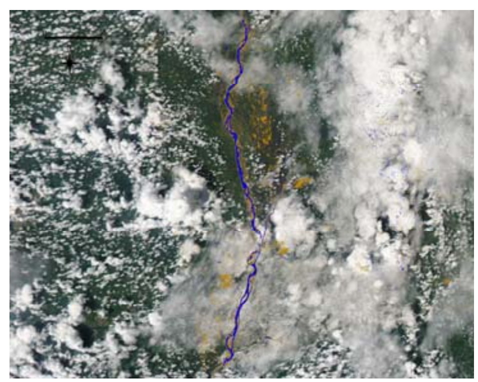


4) Sep-28, 2018

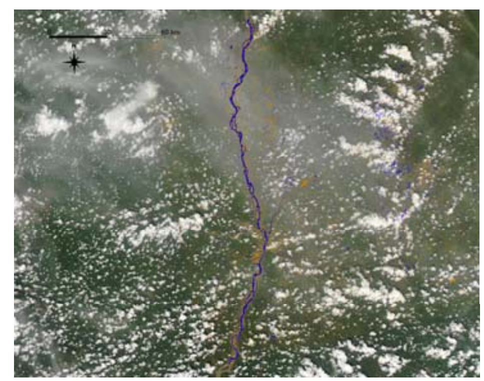
5) Oct-10, 2018



6) Oct-22, 2018



7) Nov-03, 2018



8) Nov-15, 2018

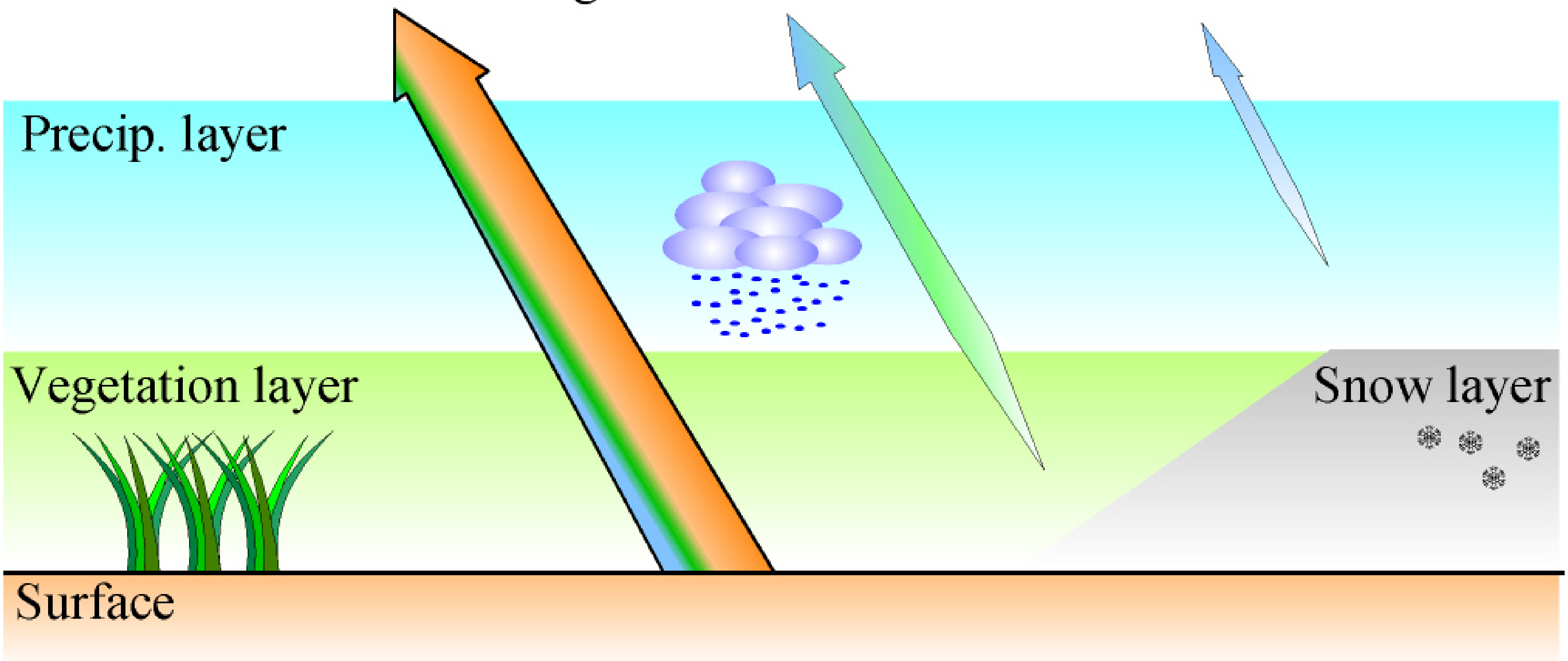
Source of back image: "NASA Worldview"

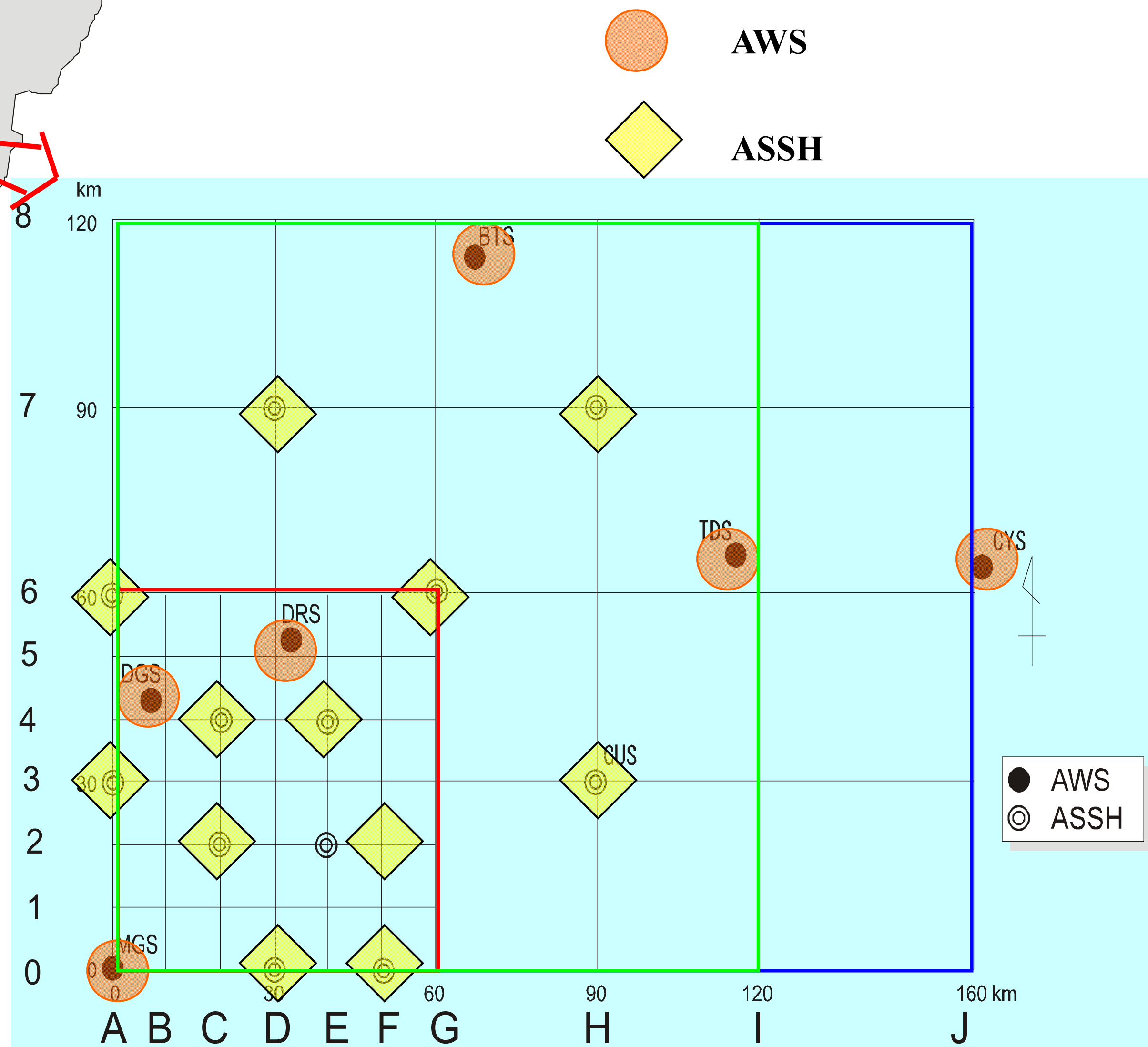
Physical Measurement Approach

The Radiative Transfer Equation

$$T_b = T_{bs}\, e^{-\tau_c}\, e^{-\tau_r} + \left(1-\omega_c\right)\left(1-e^{-\tau_c}\right) T_c\, e^{-\tau_r} + \sum \left(1-\omega_{r_i}\right)\left(1-e^{-\tau_{r_i}}\right) T_{r_i}$$

surface radiation vegetation emission rainfall emission

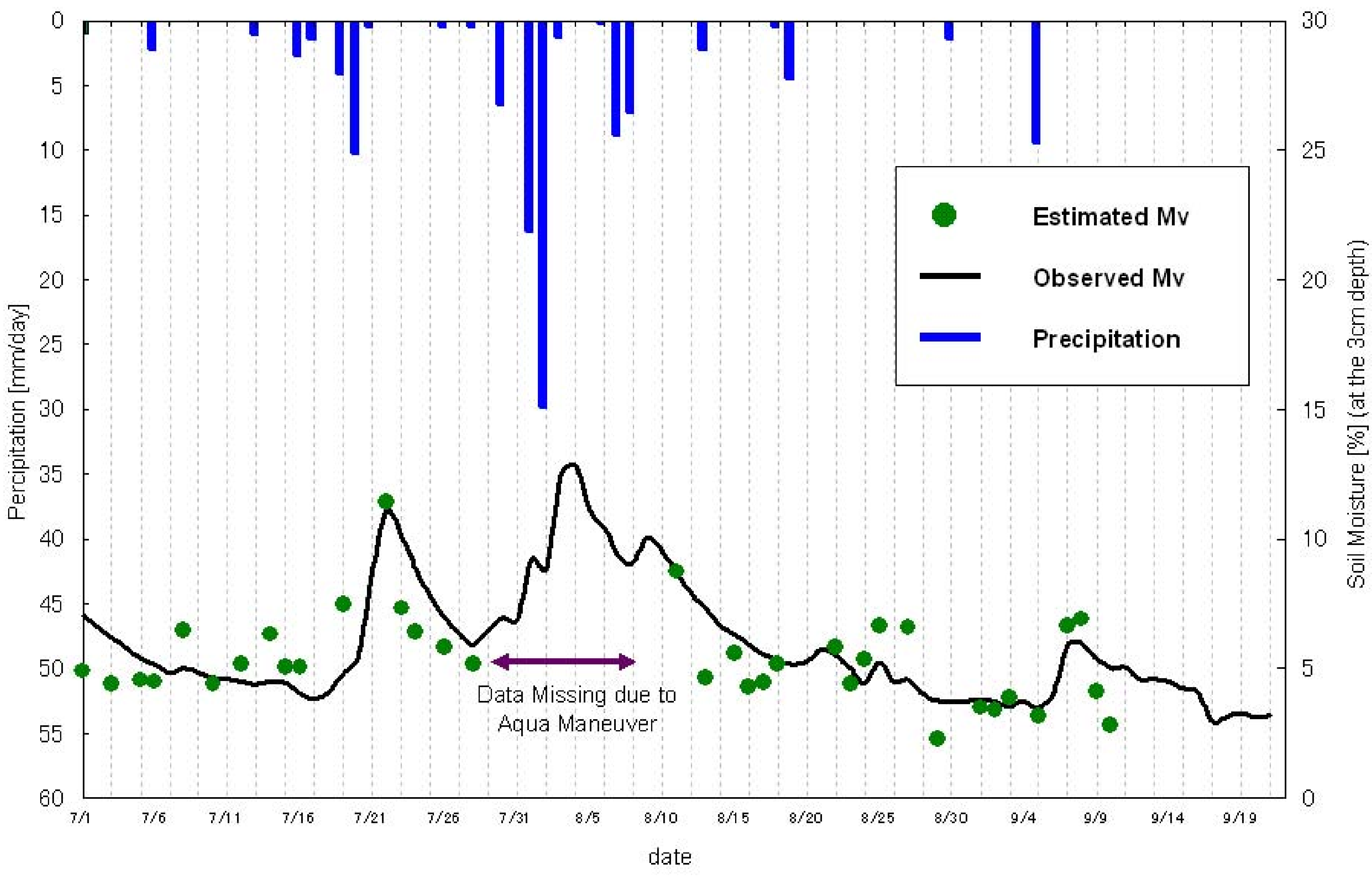




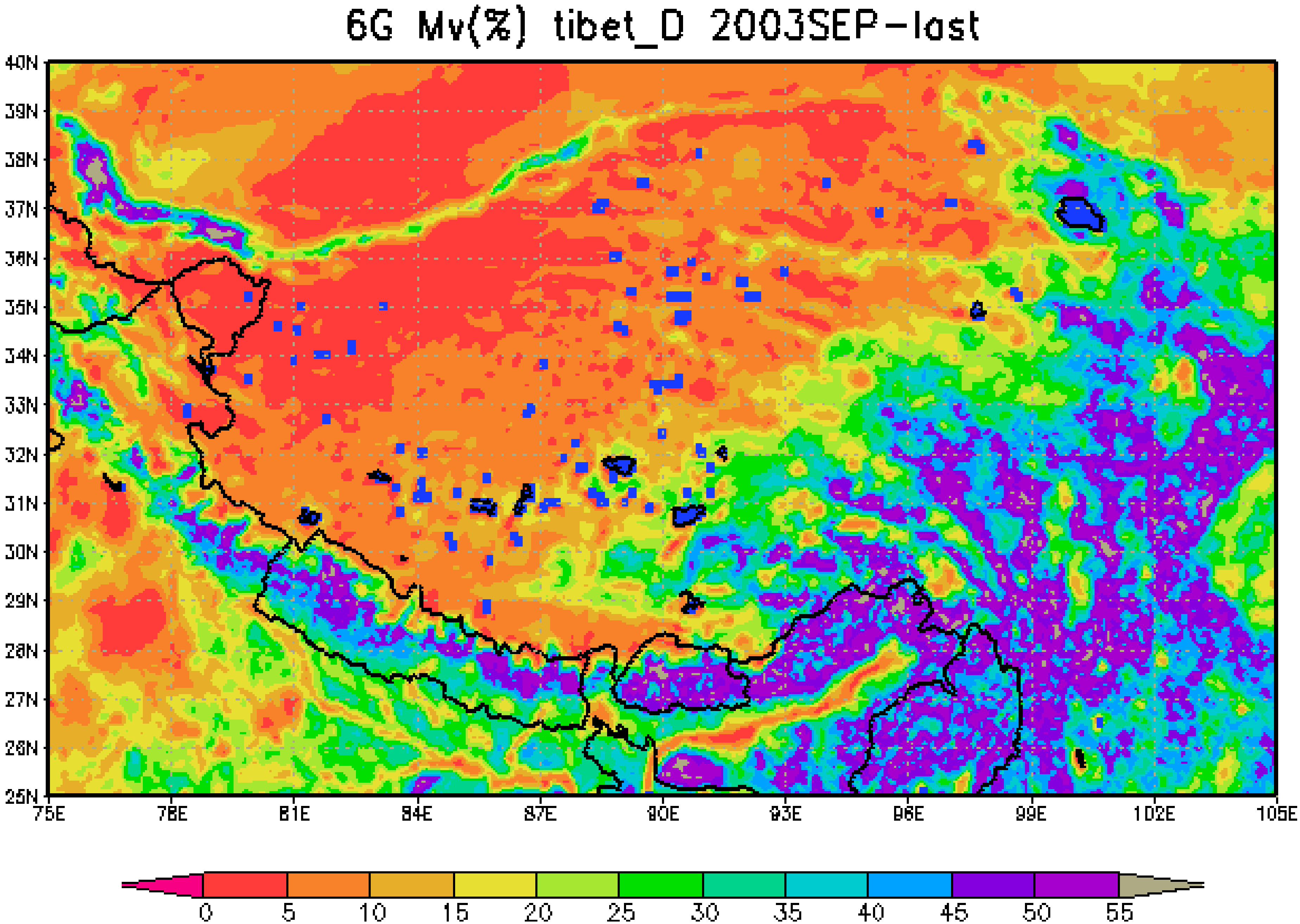
Location of AWS and ASSH in AMSR experimental fields of the study area

(UB:Ulaanbaatar, CY:Choir, MG:Mandalgobi, SA:Study area)

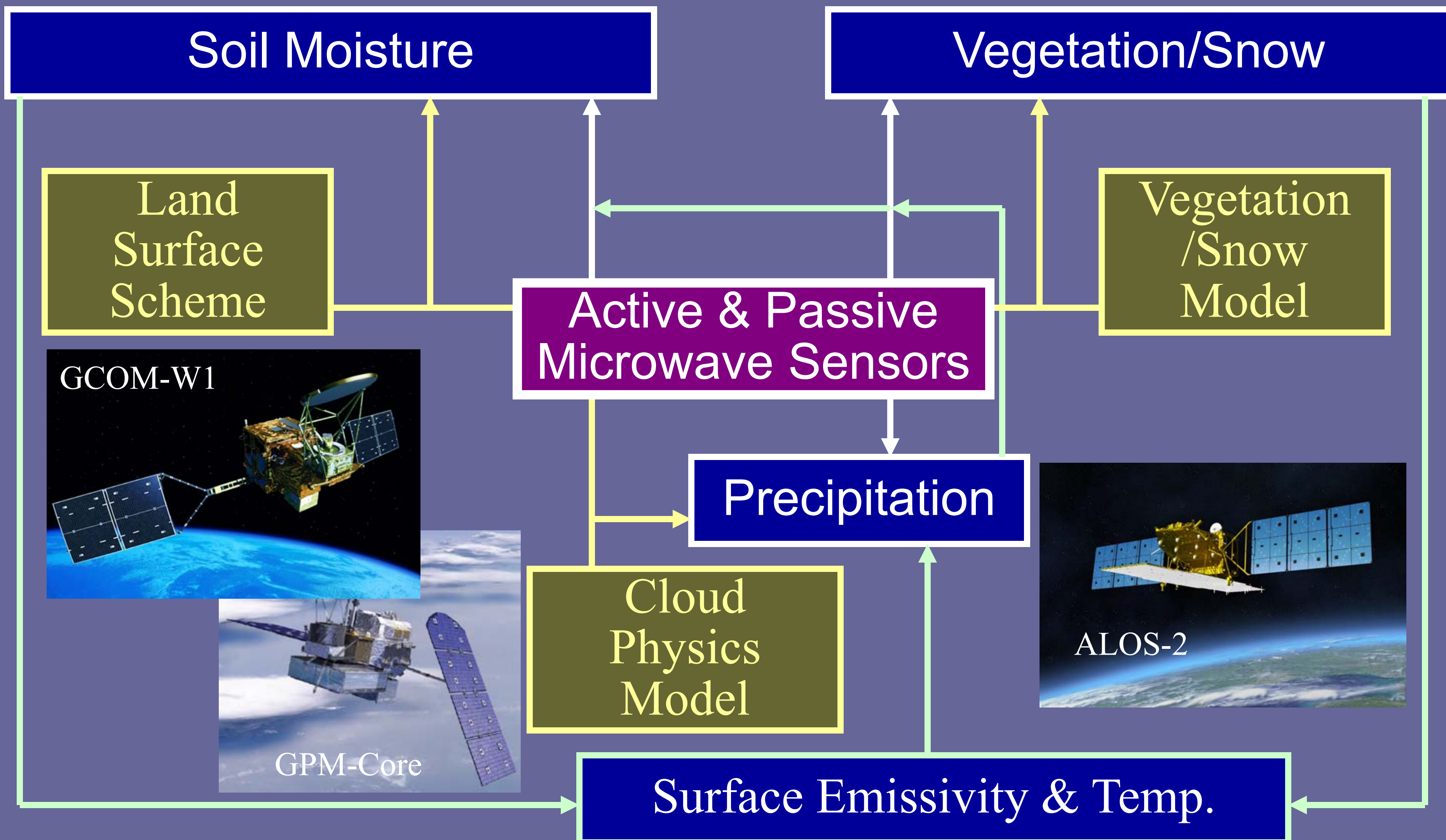
Temporal Variation of Spatially Averaged Validation



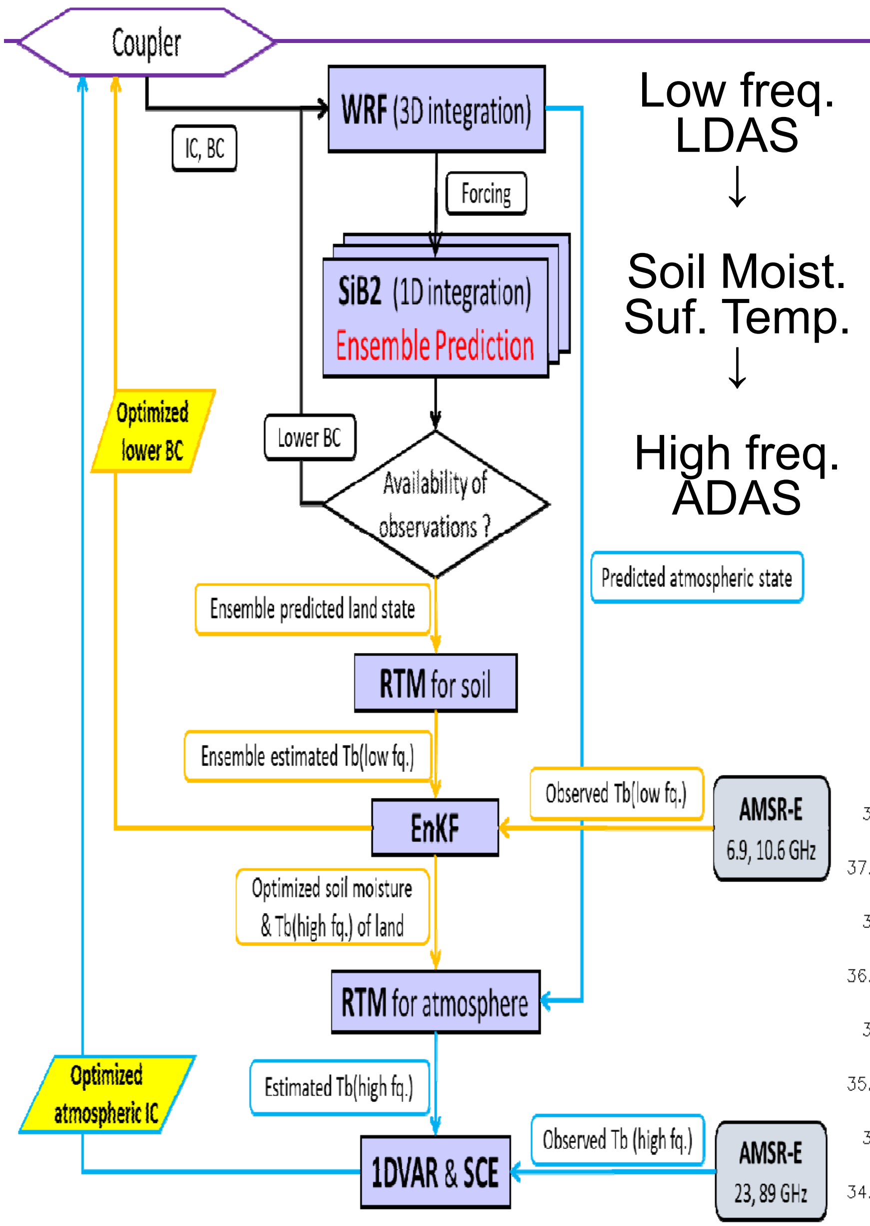
Seasonal Variation of the Soil Moisture in the Tibetan Plateu

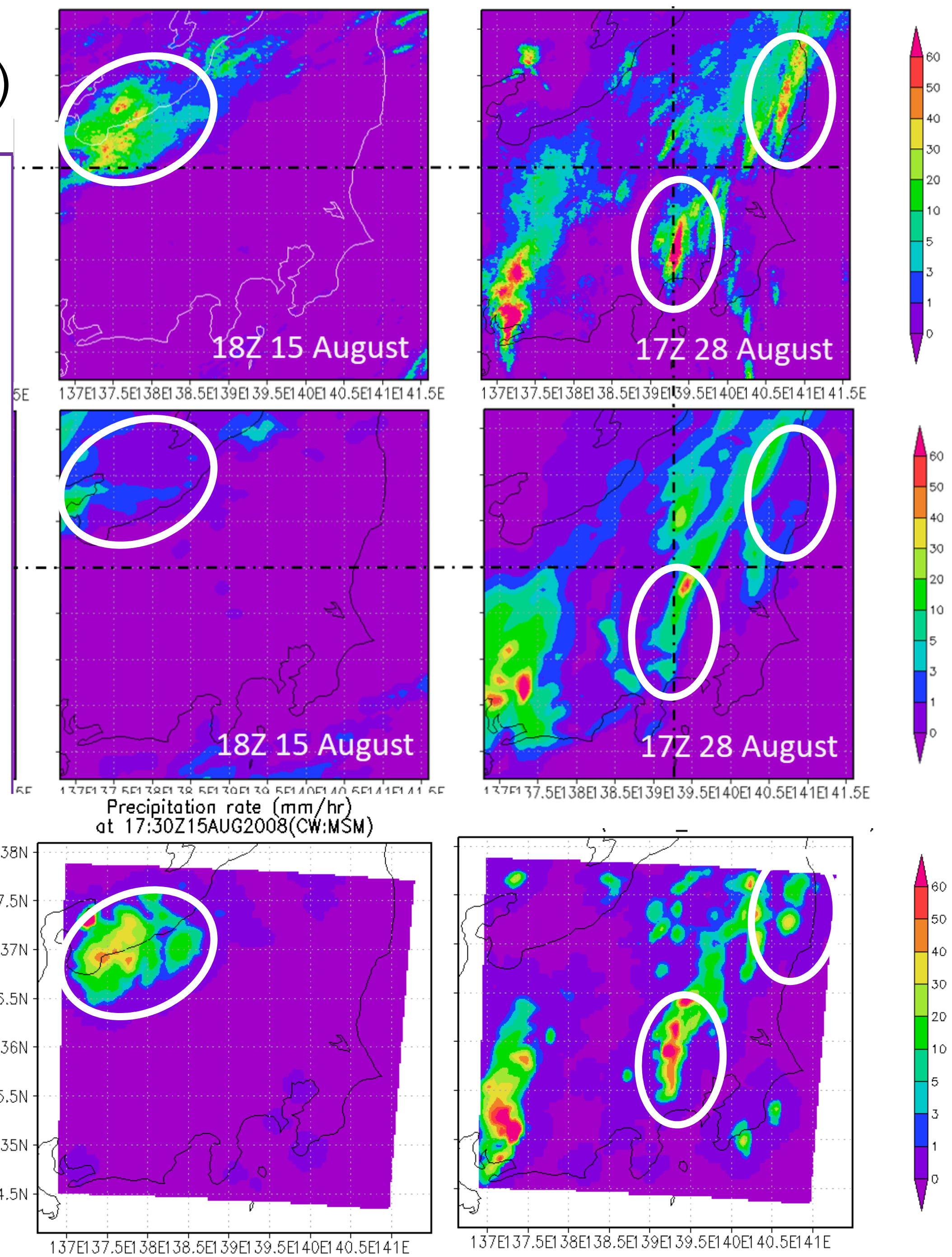


Microwave Remote Sensing of Land Hydrology



Coupled Atmosphere-Land Data Assimilation System (CALDAS)





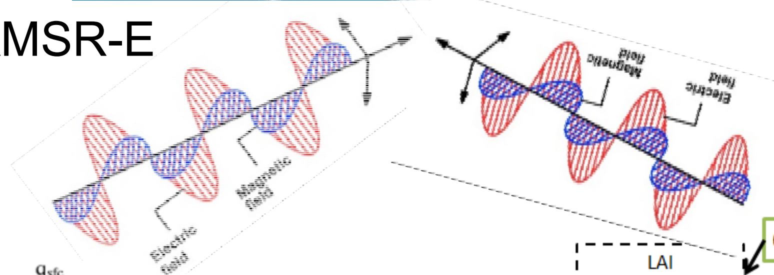
Seto, Koike, et al.JGR(2013)

Background: Scientific Contribution

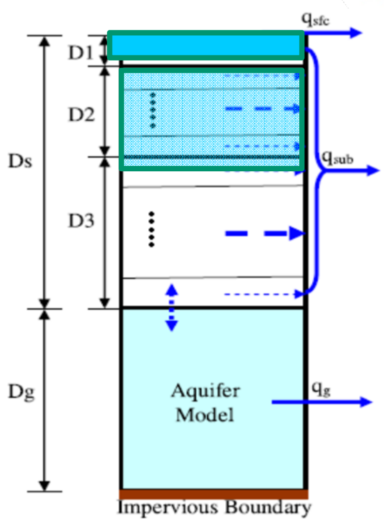
Coupled Data Assimilation

AMSR-E

AMSR2

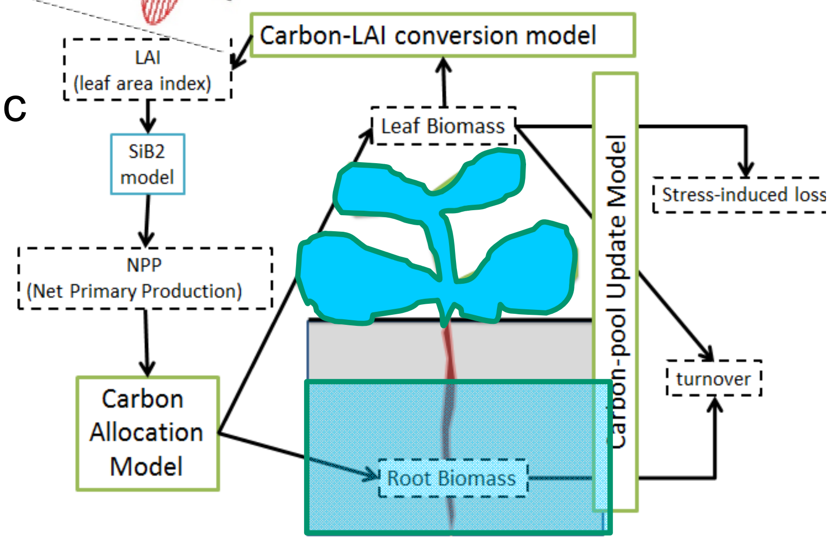


Electronic-Magnetic Wave



Yang, Koike, et al. JMSJ (2007)

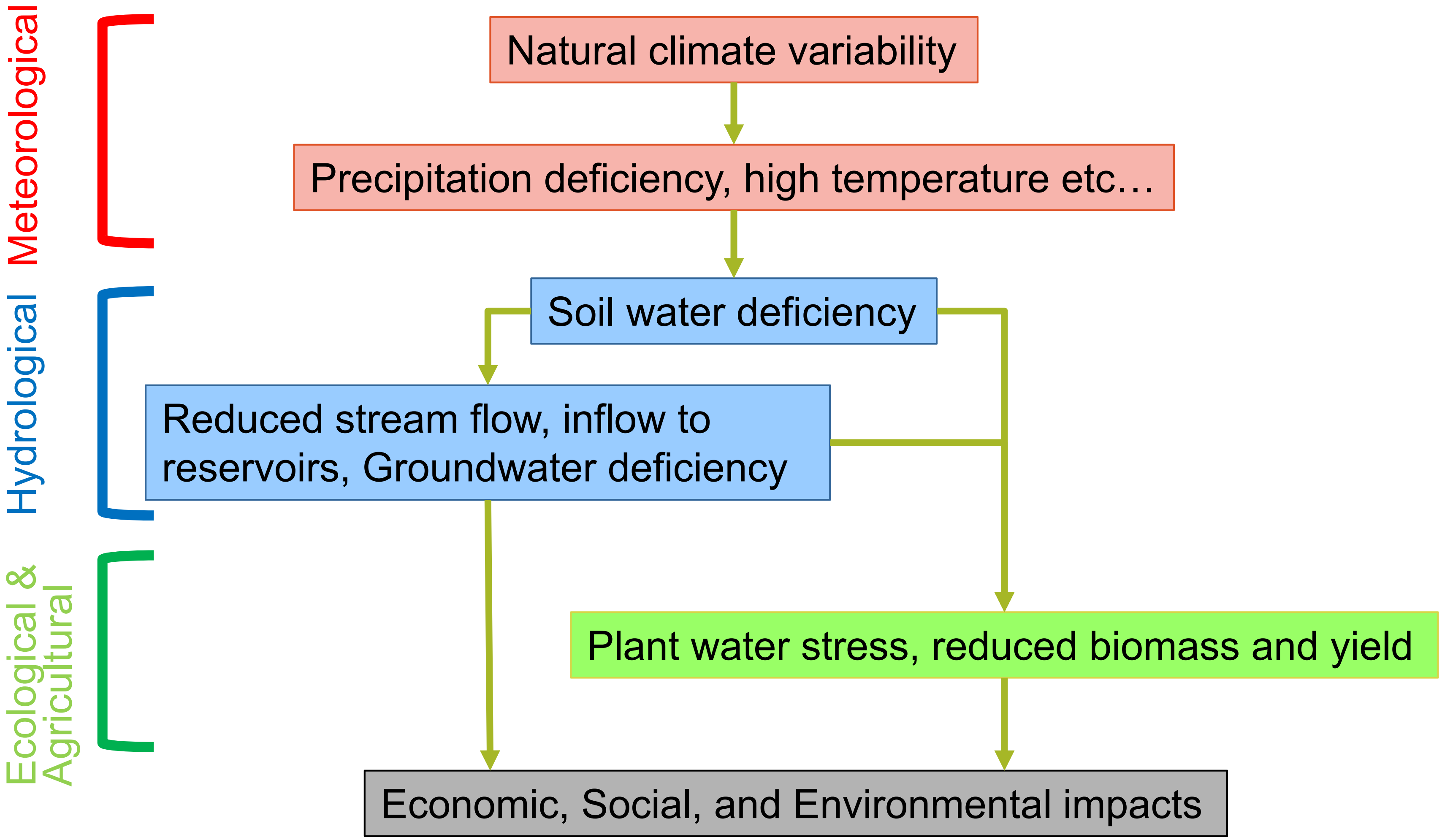
+



Dynamic Vegetation Model

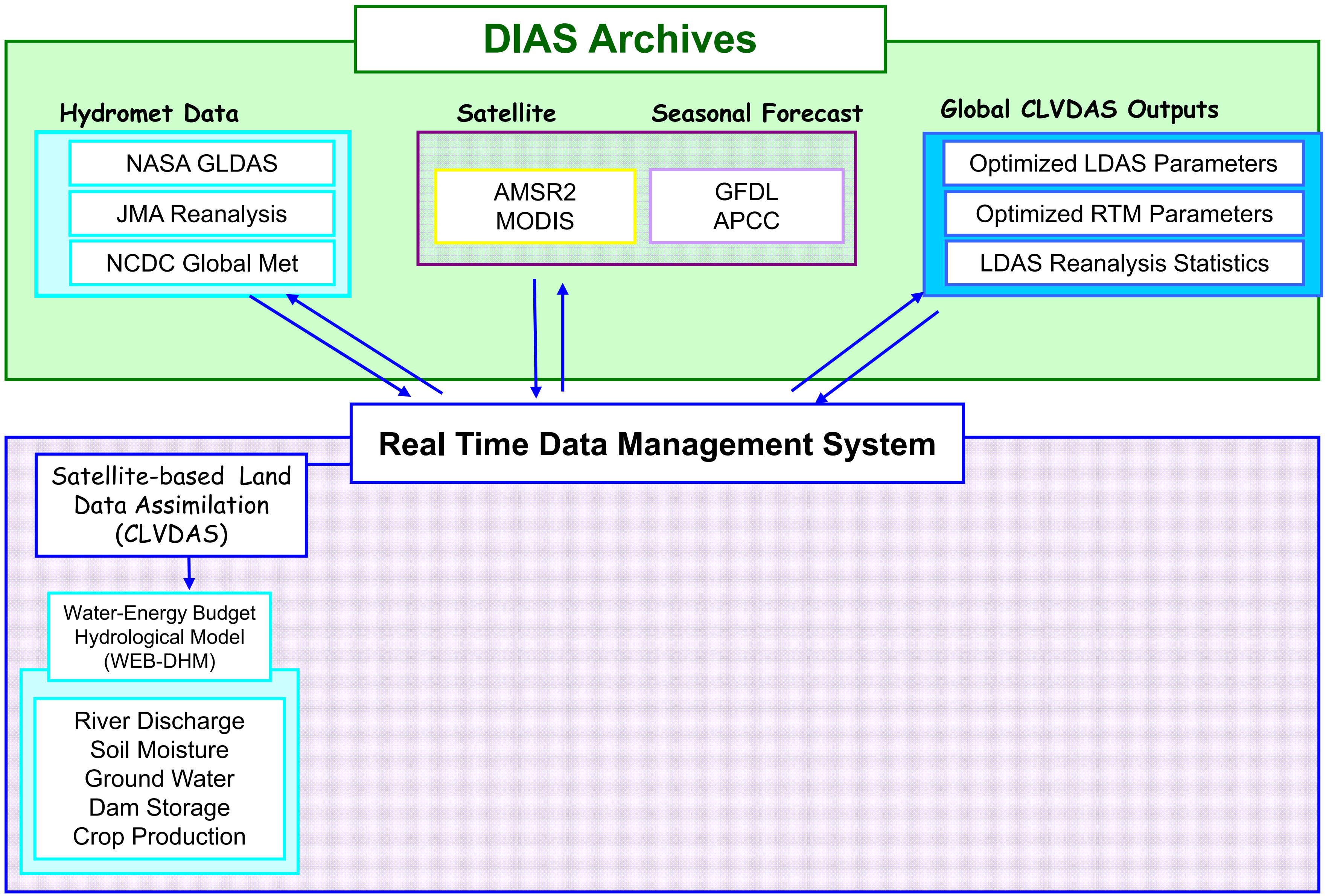
Sawada & Koike, JGR (2014)

The grant which financed this Pilot for Agriculture Drought Monitoring and Prediction in Brazil was received under the Japan-Bank Program for Main-streaming DRM in Developing Countries which is financed by the Government of Japan



→ Relationship between ecological and hydrological processes is important for analyzing drought process.

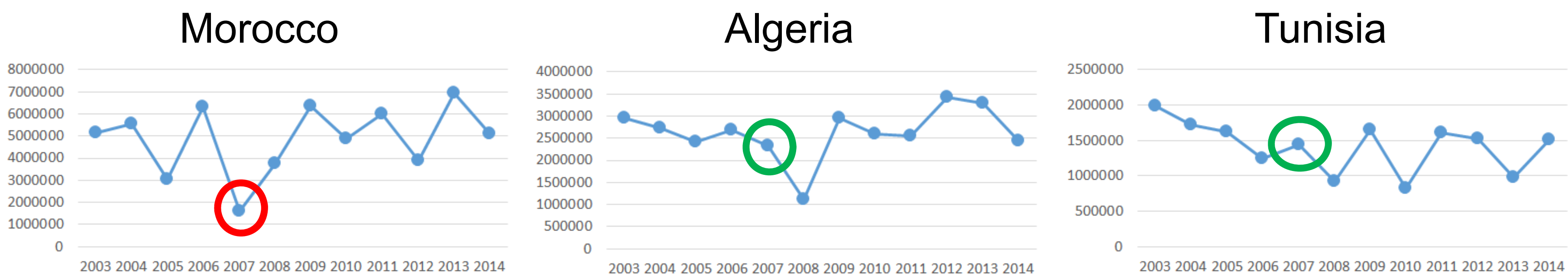
Hydrometeorology-Agriculture Droughts Prediction System



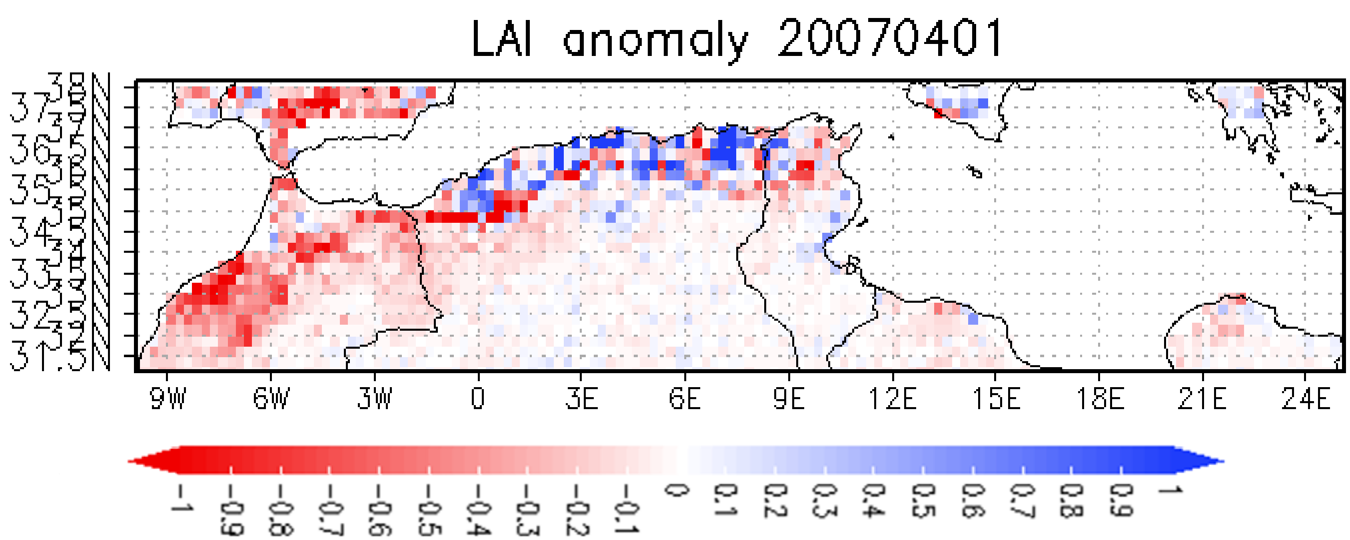
Drought analysis

Wheat production

2007 Morocco Drought

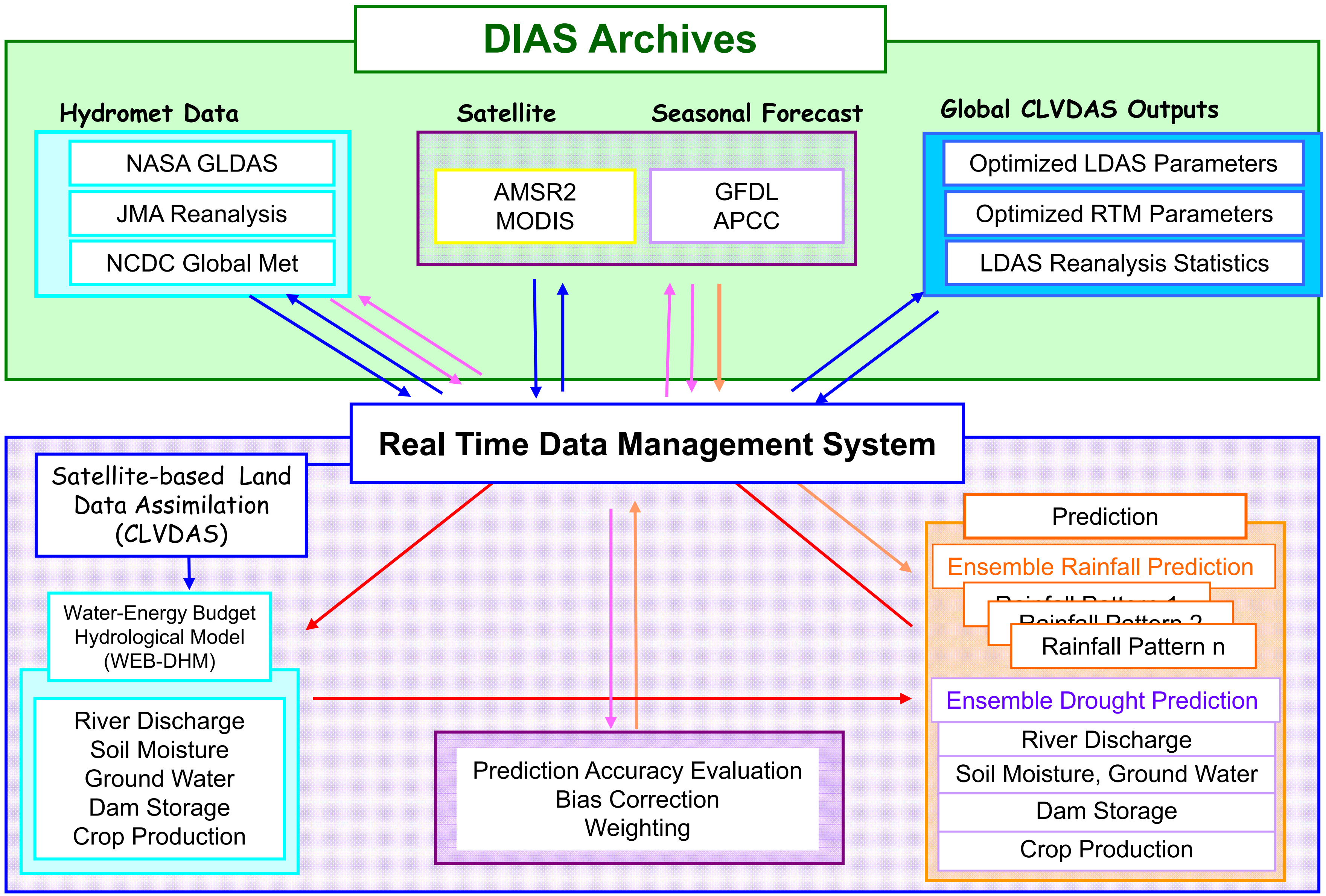


LAI anomaly from CLVDAS



from Sawada & Ikoma

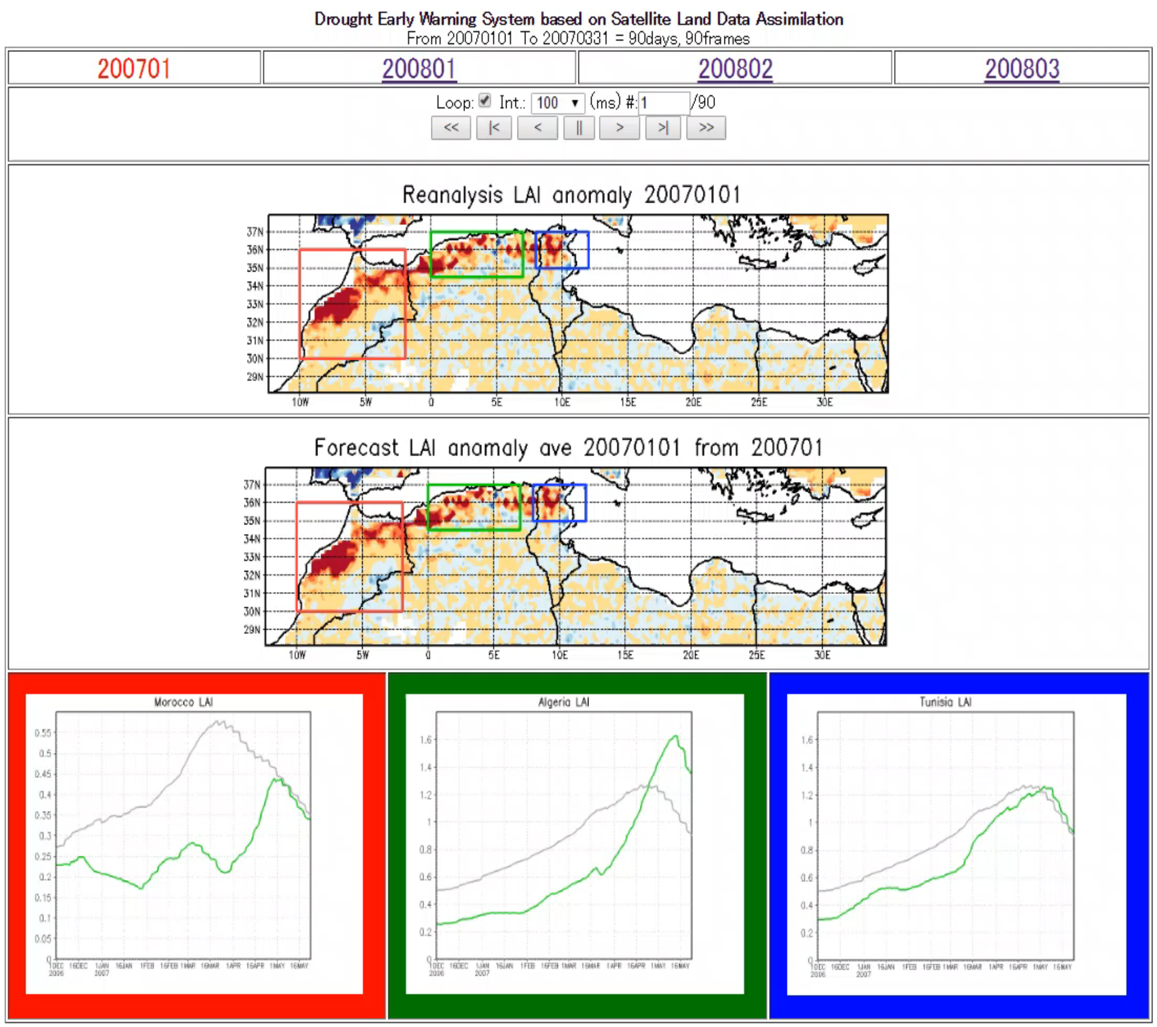
Hydrometeorology-Agriculture Droughts Prediction System



Agricultural Drought Monitoring-Prediction

Aqua AMSR-E

North Africa



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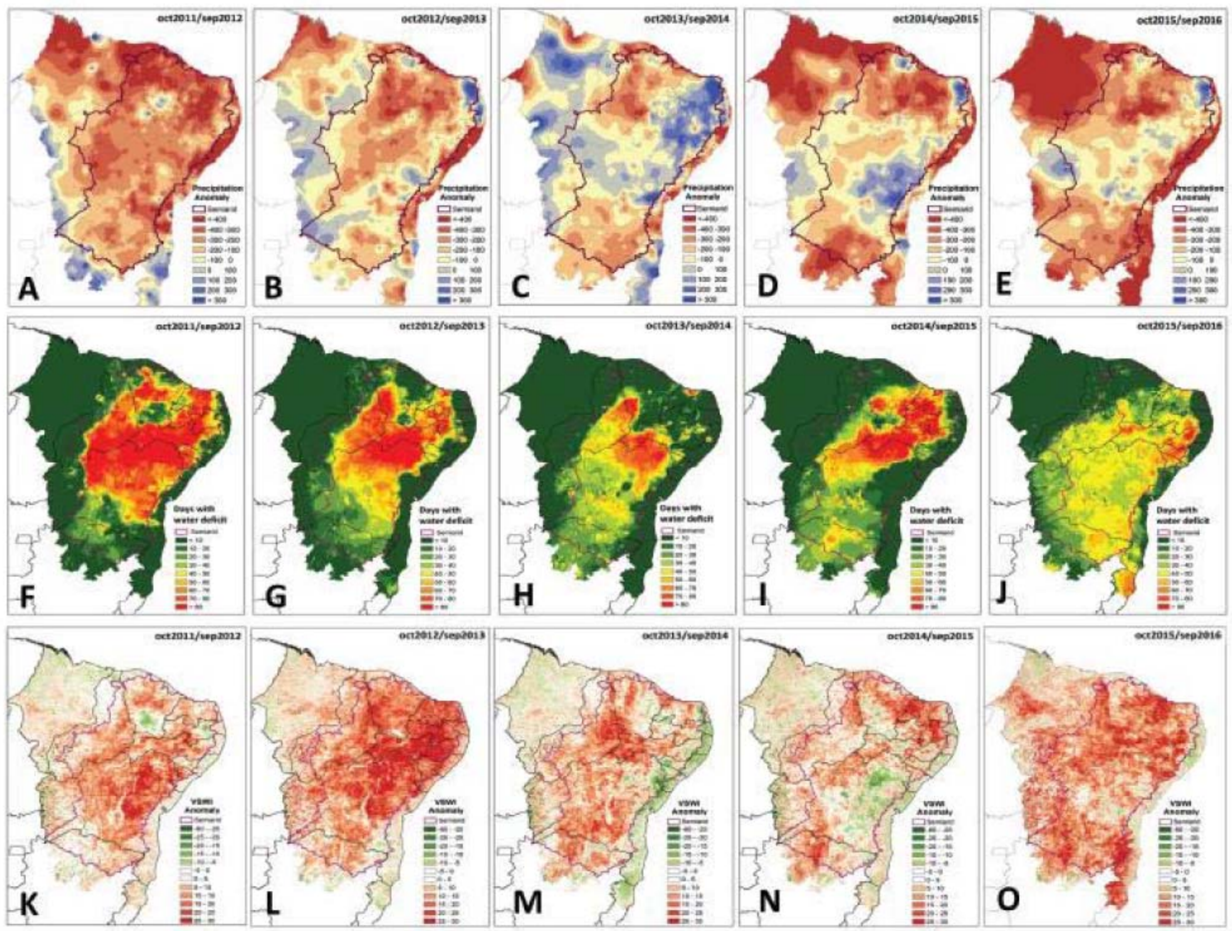
Background: Long-term Serious Droughts

2012 2013 2014 2015 2016

Rainfall Anomaly

Number of Dry Days

Vegetation Water Supply Index (VWSI) Anomaly



Marengo et al., 2017

The grant which financed this Pilot for Agriculture Drought Monitoring and Prediction in Brazil was received under the Japan-Bank Program for Main-streaming DRM in Developing Countries which is financed by the Government of Japan

#	Deliverable	Expected Date
0	On signing of the Contract and commencement of the Services	On or around May 31, 2018
Component 1: Northeast Agriculture Drought Overview		
1	Action Plan for Components 1 and 2	On or around June 18, 2018
2	First Face to Face exchange in Fortaleza, Brazil	Week of 18-22 June, 2018
3	Agricultural drought monitoring: system parameter confirmation	On or around August 31, 2018
4	Agricultural drought monitoring and seasonal prediction system for the Northeast of Brazil	On or around December 31, 2018
Component 2: Agricultural Drought Monitoring and Forecasting Pilot for the Ceará State		
5	Second Face to Face exchange, training activities in Tokyo, Japan	October (4 weeks), 2018
6	Pilot agriculture-drought monitoring and prediction system for the Ceará State	On or around March 31, 2019
Component 3: Assess the pilot's results and establish a strategy to scale up the system		
7	Action Plan to scale up the system in other States of Brazil and in LAC (roadmap and guidelines) and Final Report	On or around April 30, 2019
8	Third Face to Face exchange to present preliminary results of Components 1 and 2 and discuss scaling up strategy	On or around March 31, 2019

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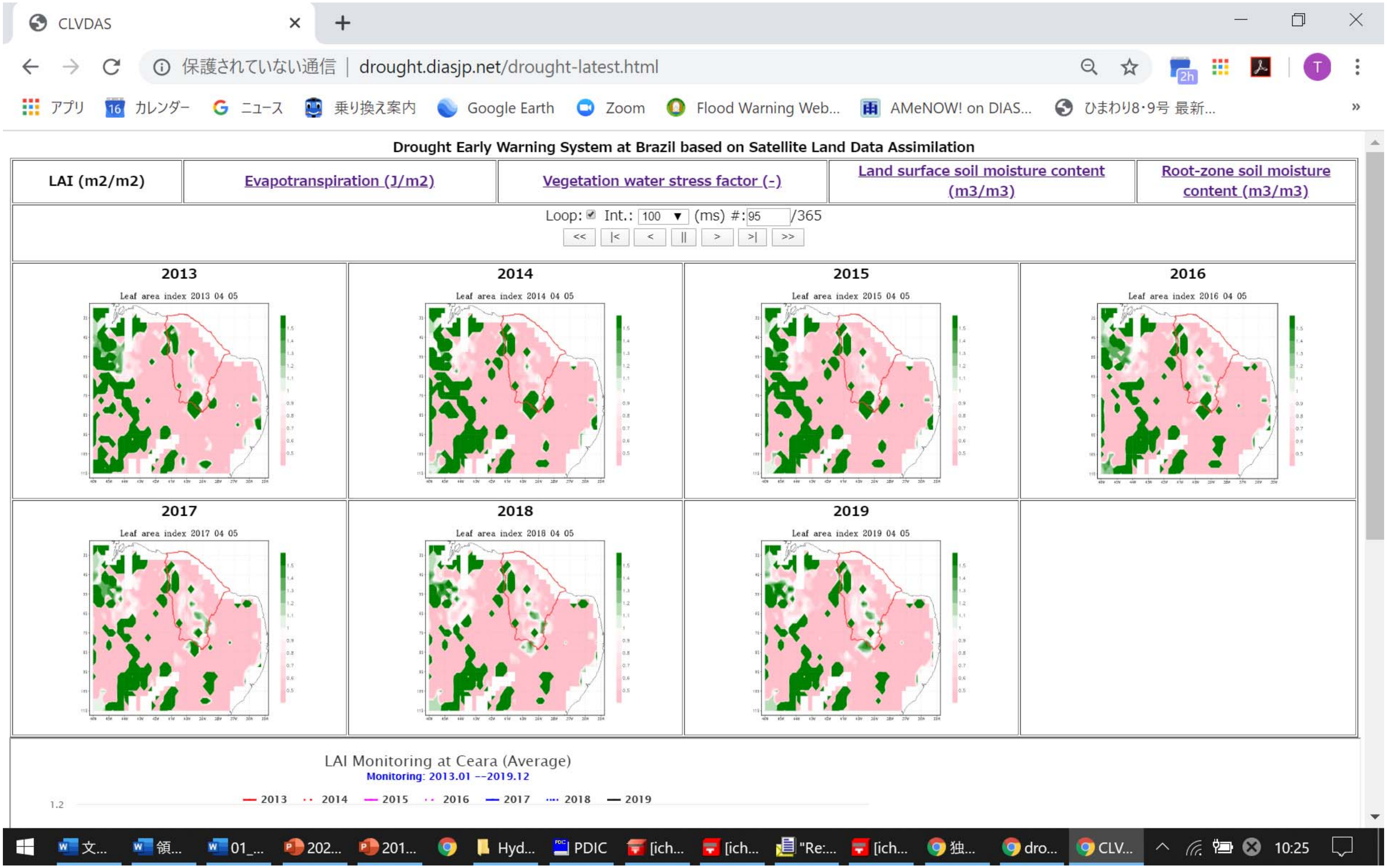

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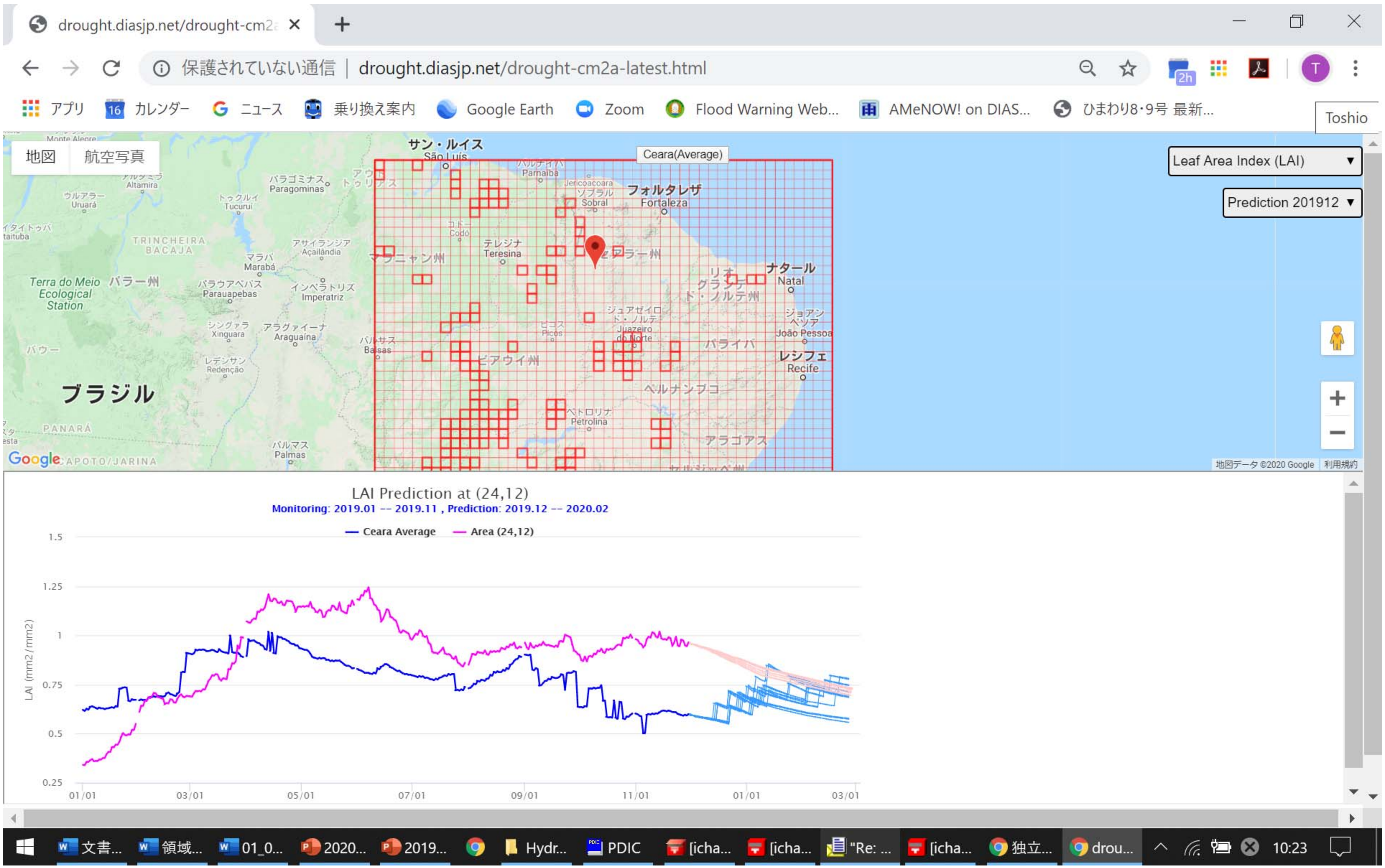
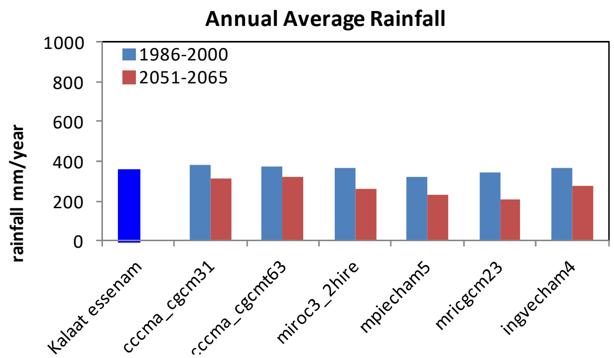
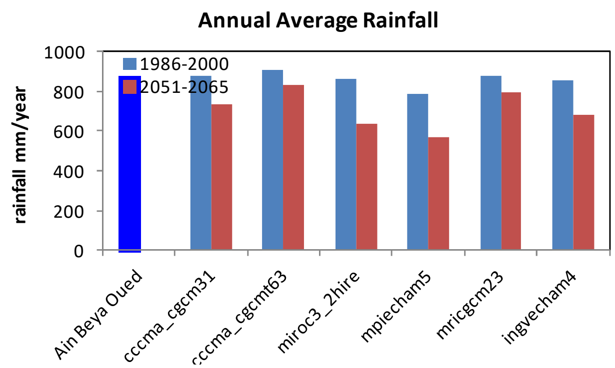


Mejerda River

It is virtually certain that drought will become more severe.



KALAAT ESSENAM



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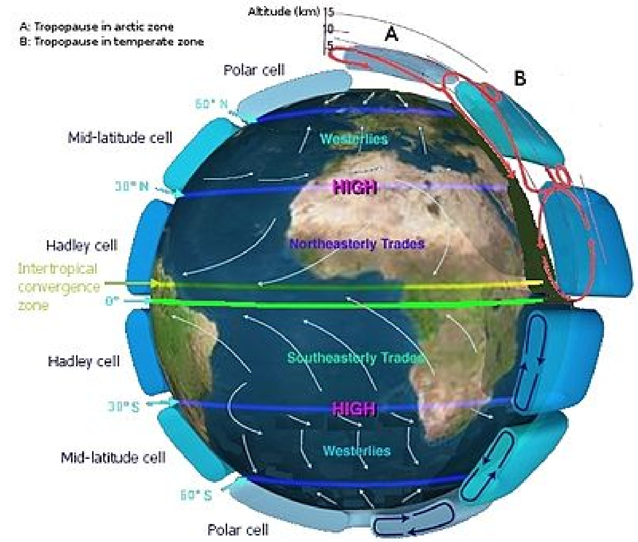
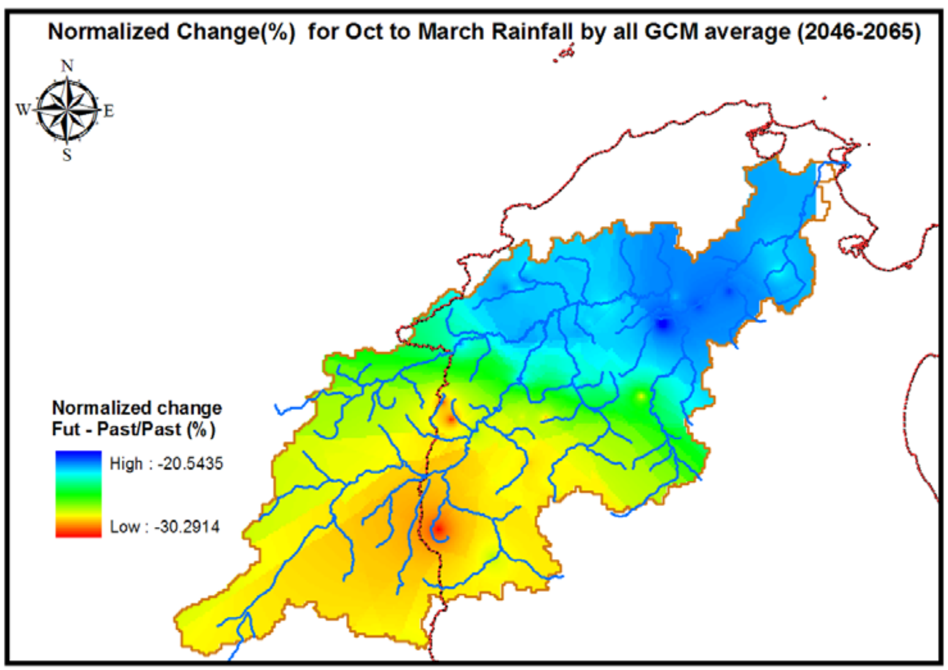
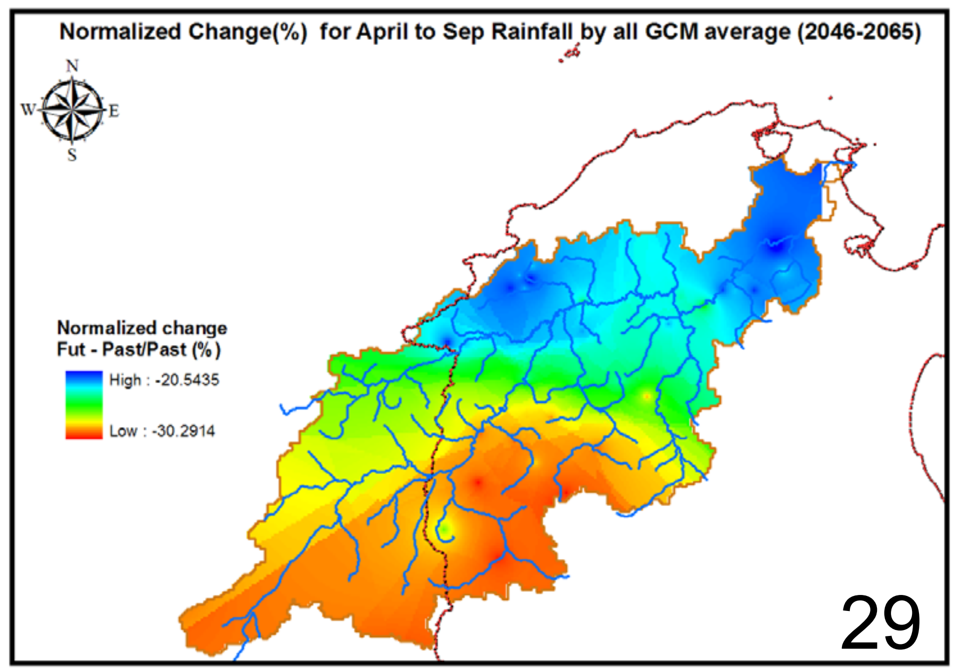
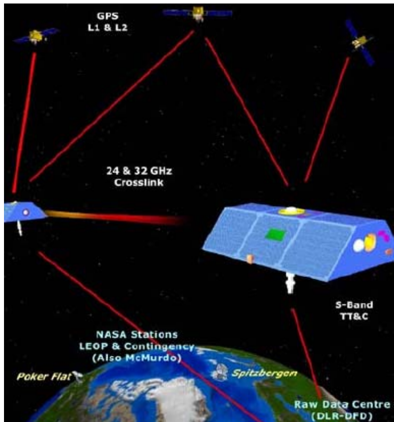
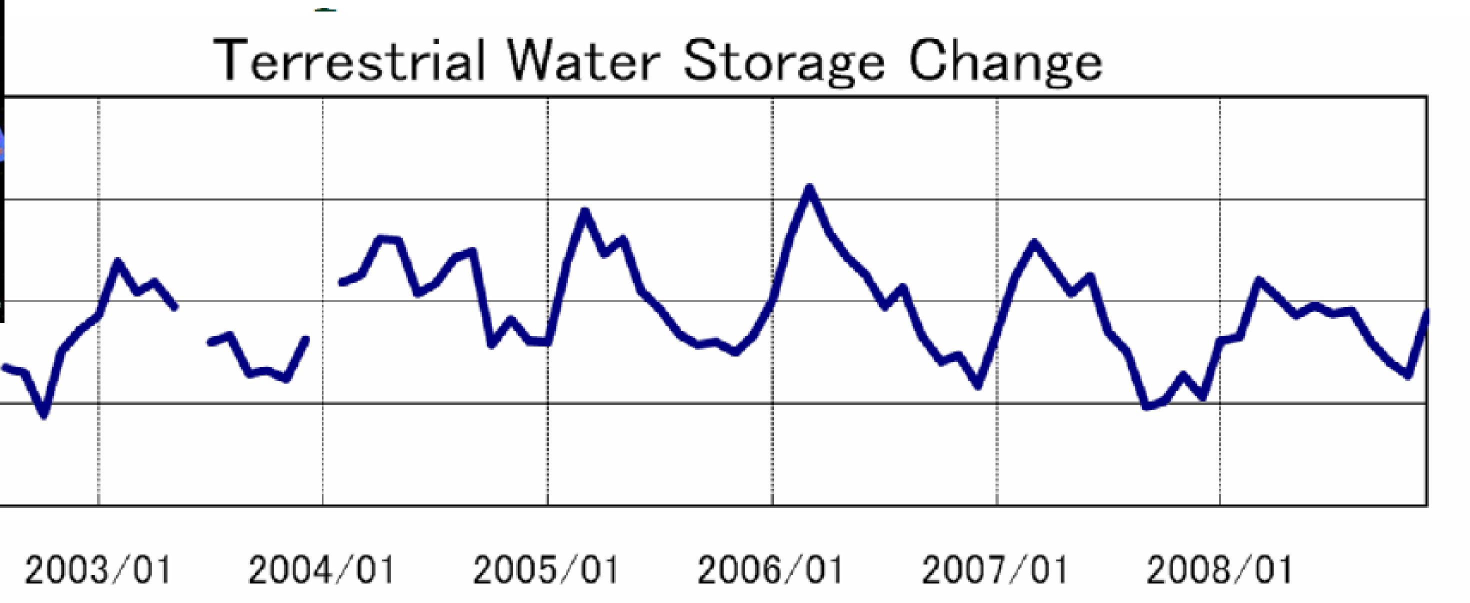
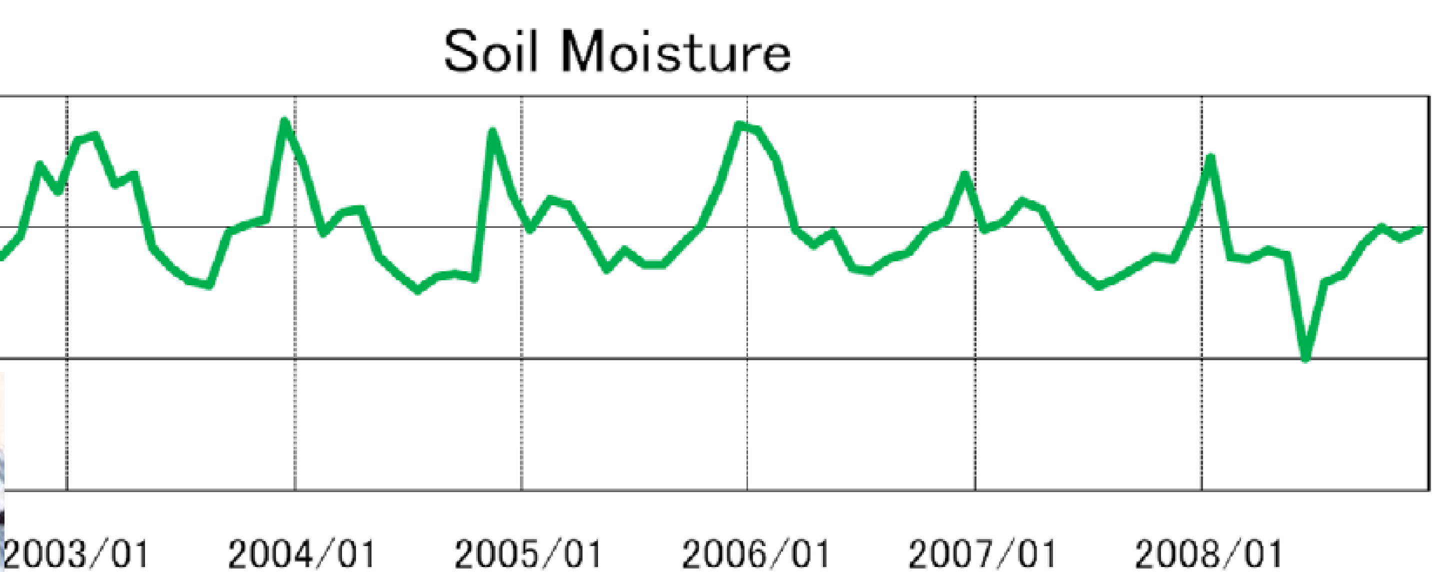


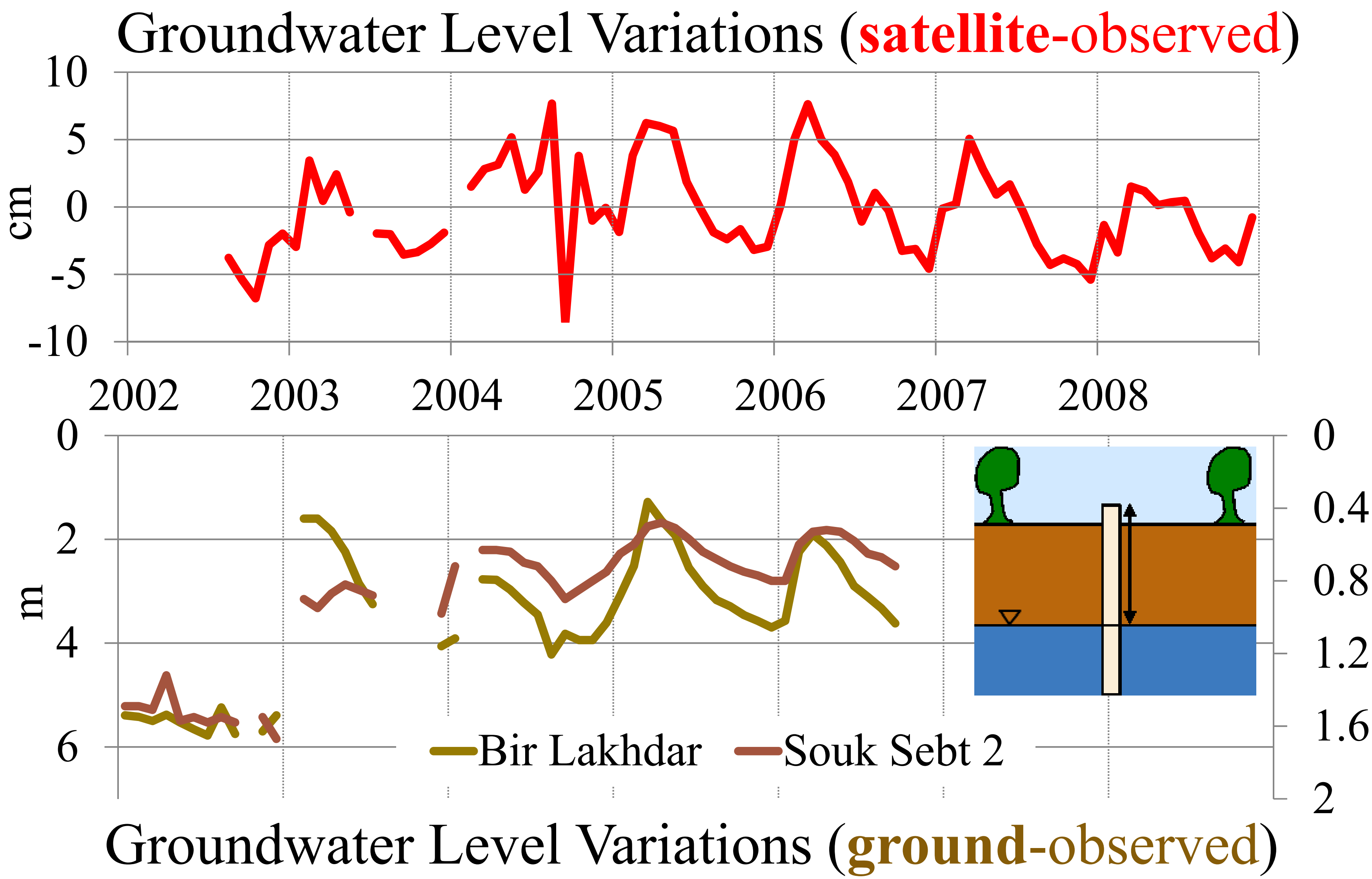




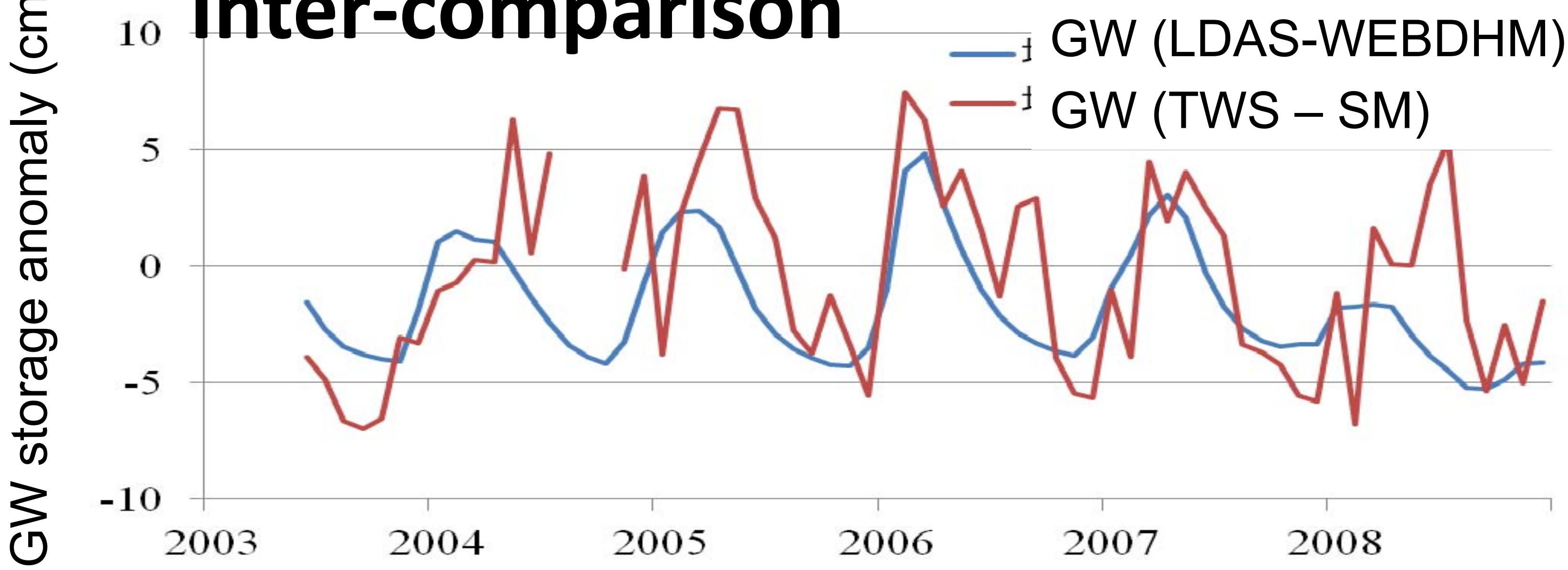

GPS
L1 & L2
24 & 32 GHz
Crosslink
S-Band
TT&C
NASA Stations
LEOP & Contingency
(Also McMurdo)
Poker Flat
Spitzbergen
Raw Data Centre
(DLR-DFD)


Terrestrial Water Storage Change
TWS (c
−5
−10
2002/01
2003/01
2004/01
2005/01
2006/01
2007/01
2008/01

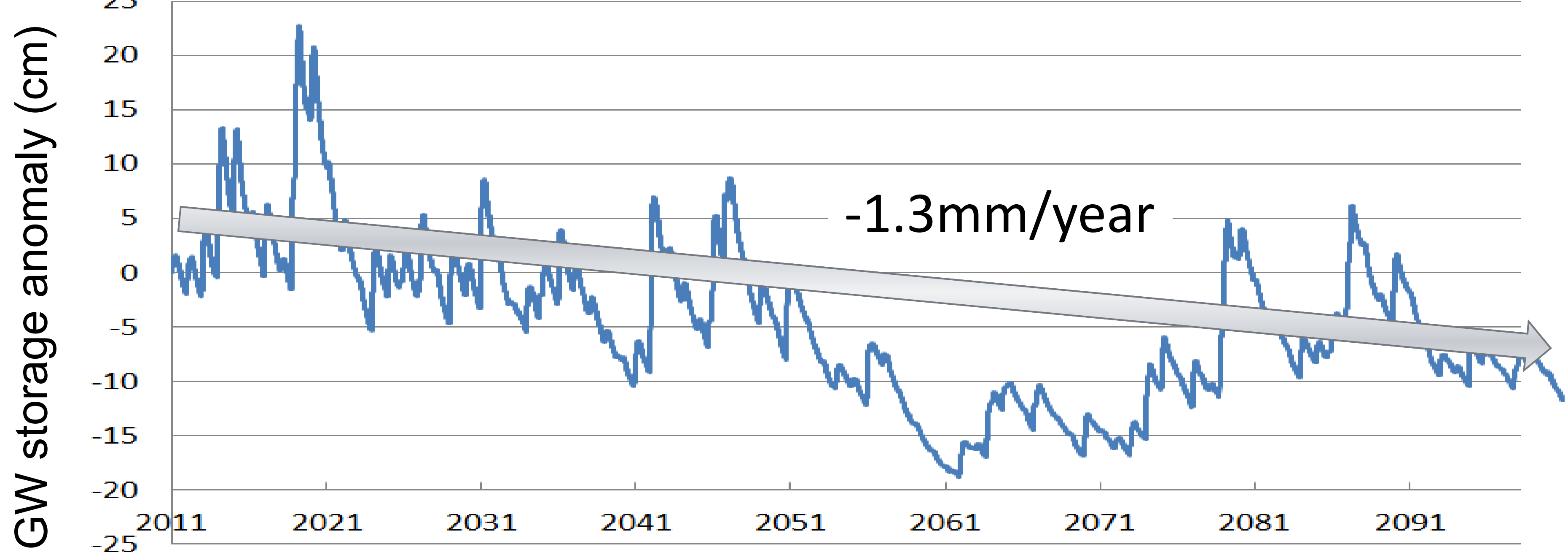

Soil Moisture
isture (g/cm3)
0.15
0.1
0.05
2003/01
2004/01
2005/01
2006/01
2007/01
2008/01


Groundwater Level Variations (satellite-observed)
cm
10
5
0
-5
-10
2002
2003
2004
2005
2006
2007
2008
m
0
2
4
6
0
0.4
0.8
1.2
1.6
2
Bir Lakhdar
Souk Sebt 2
Groundwater Level Variations (ground-observed)

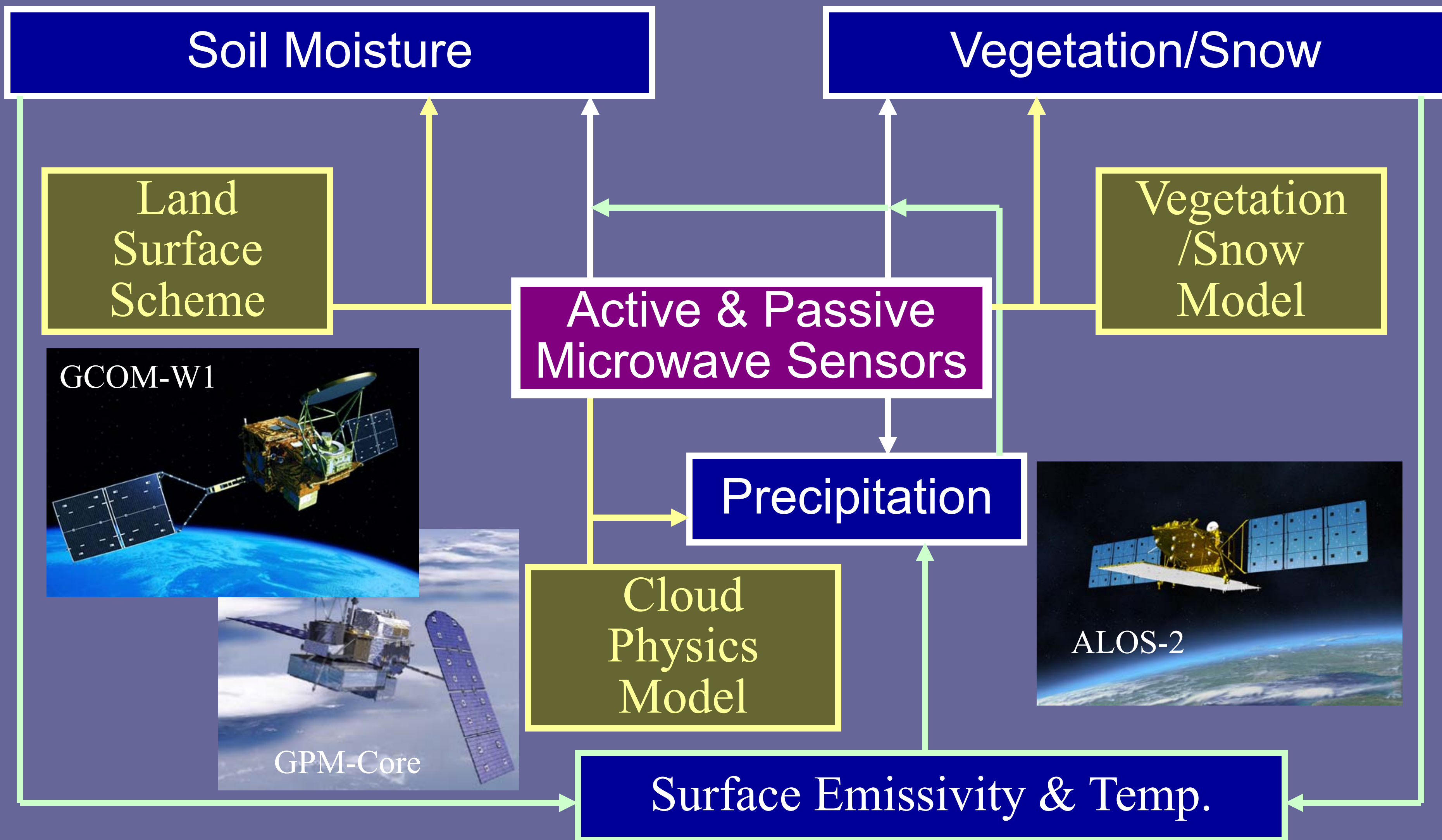
Inter-comparison



Future GW Variations

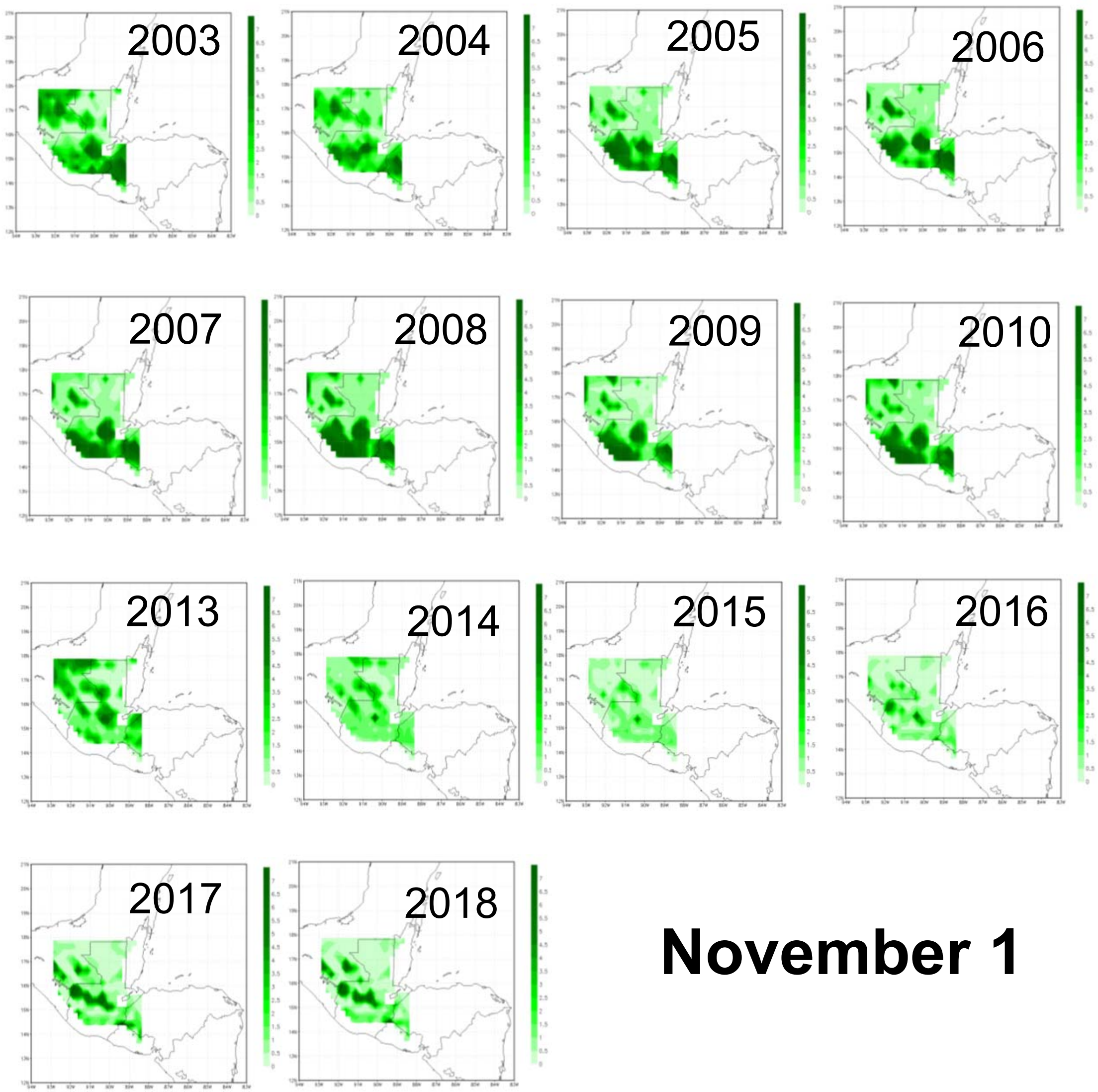


Microwave Remote Sensing of Land Hydrology

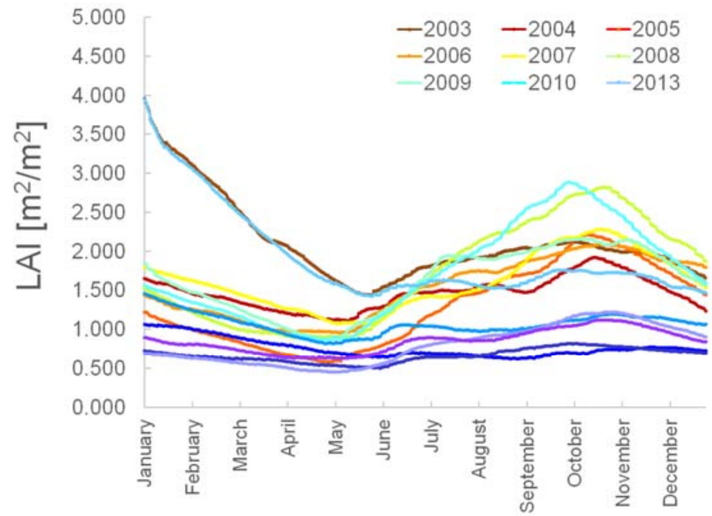


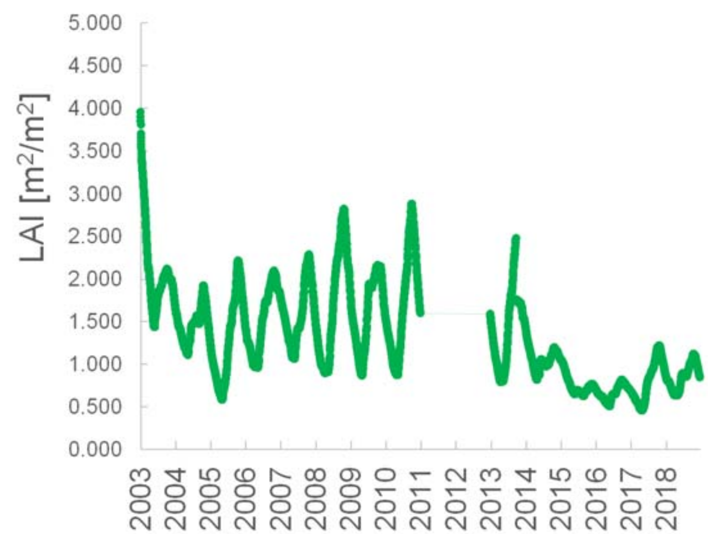
Preliminary outputs Gautemala

LAI output from CLVDAS



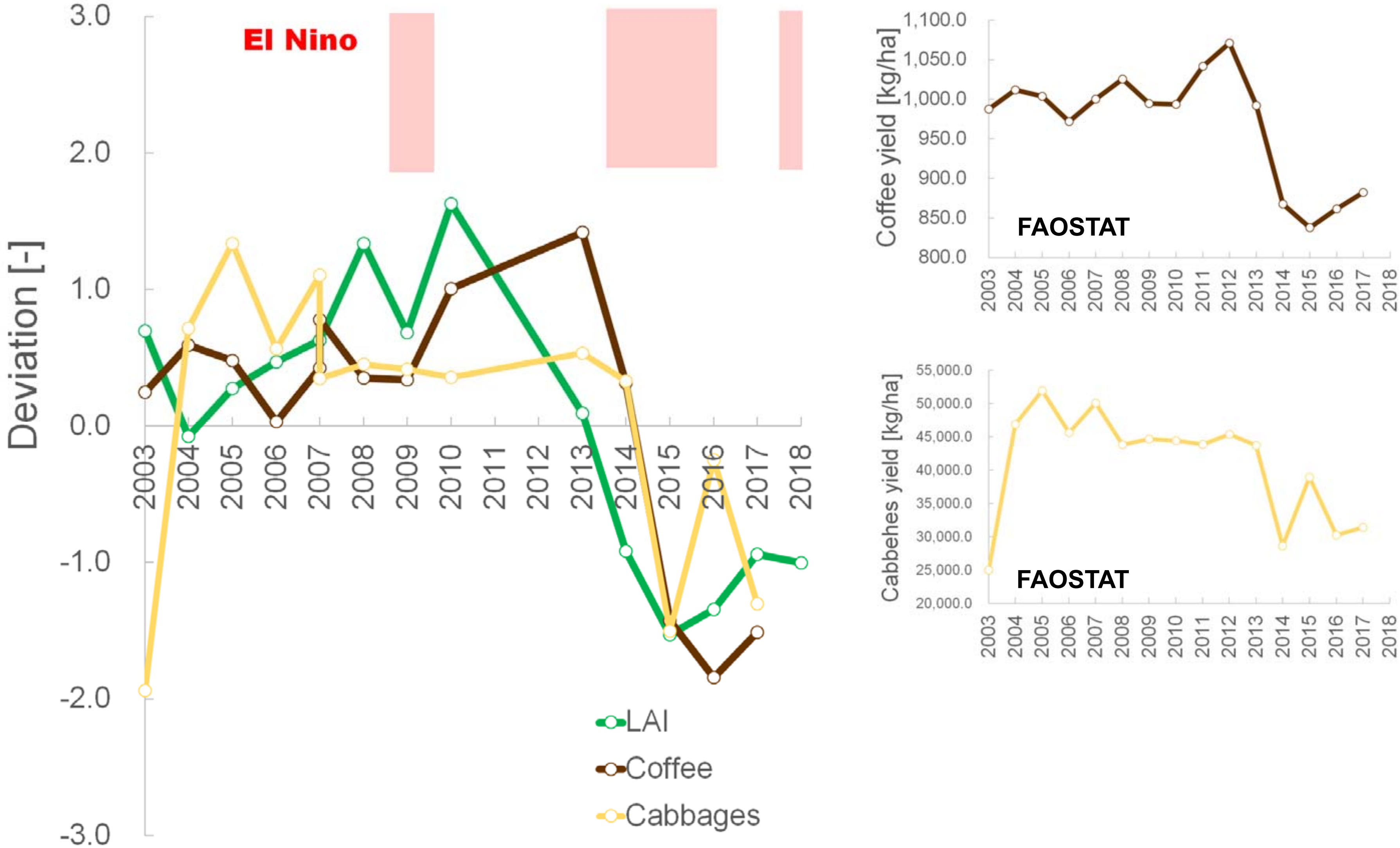
November 1



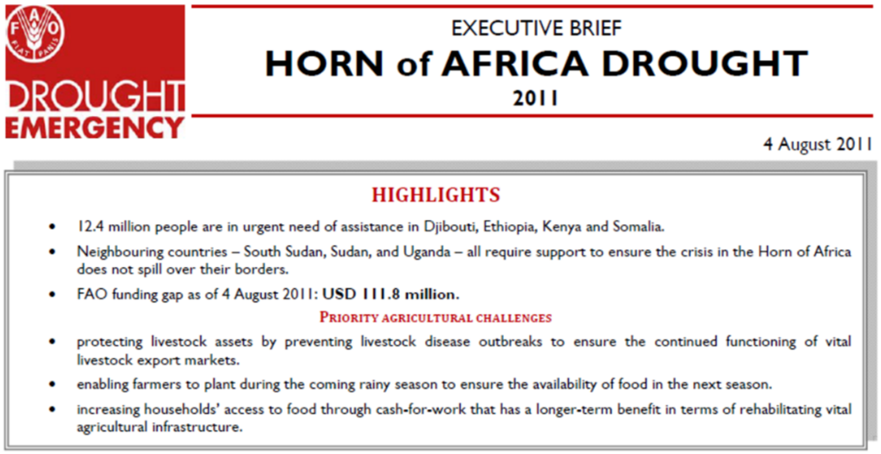


Gautemala spatial average

CLVDAS LAI and major products



3.3. Application: Horn of Africa drought



DROUGHT EMERGENCY

EXECUTIVE BRIEF

HORN of AFRICA DROUGHT

2011

4 August 2011

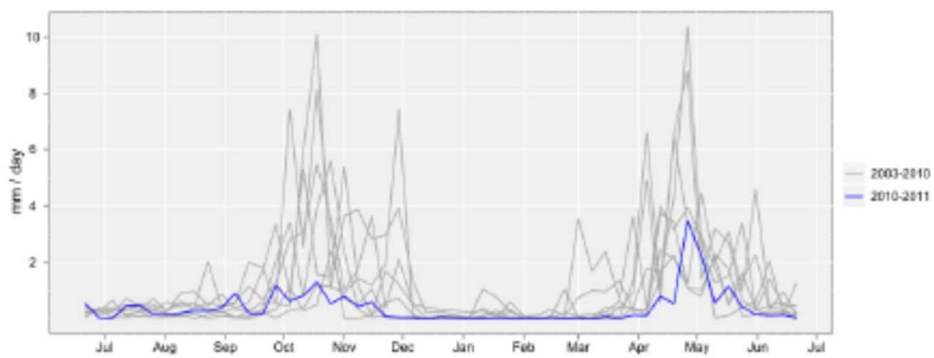
HIGHLIGHTS

- 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]



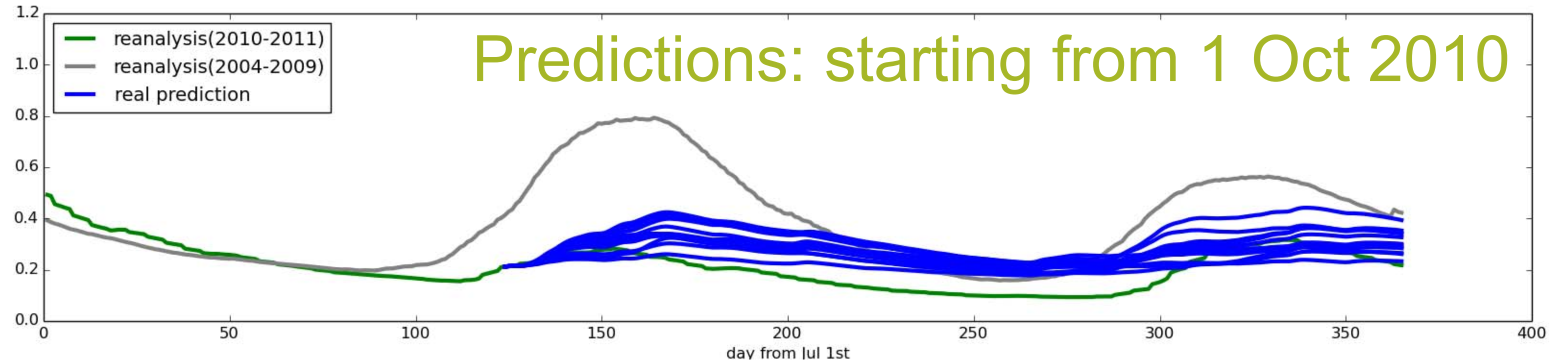
[Anderson et al., 2012]

→ We cannot have the access to many ground observations to develop the drought prediction system.

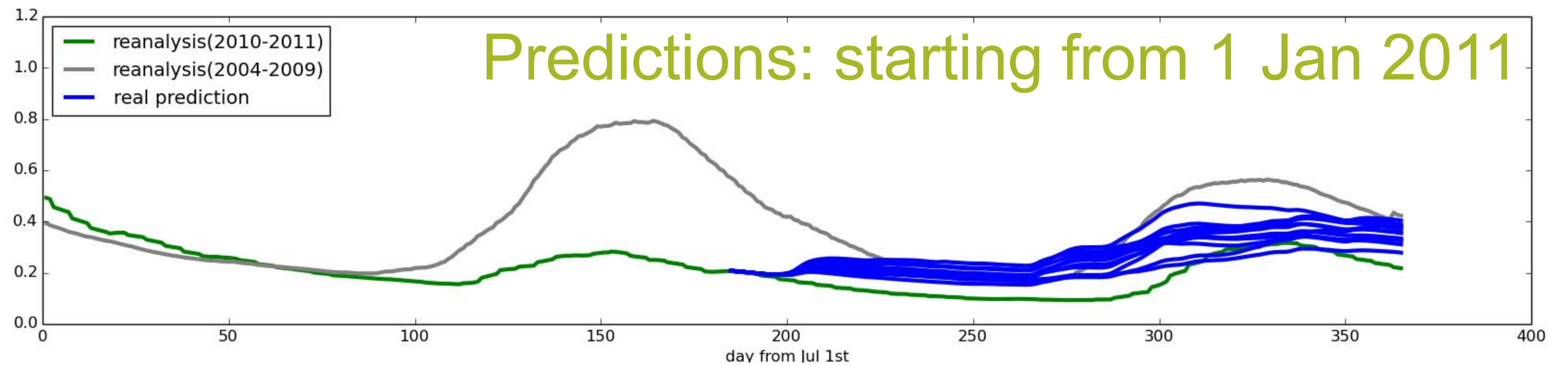
Leaf Area Index timeseries

Blue: Prediction
Green: Horn of Africa drought (reanalysis)

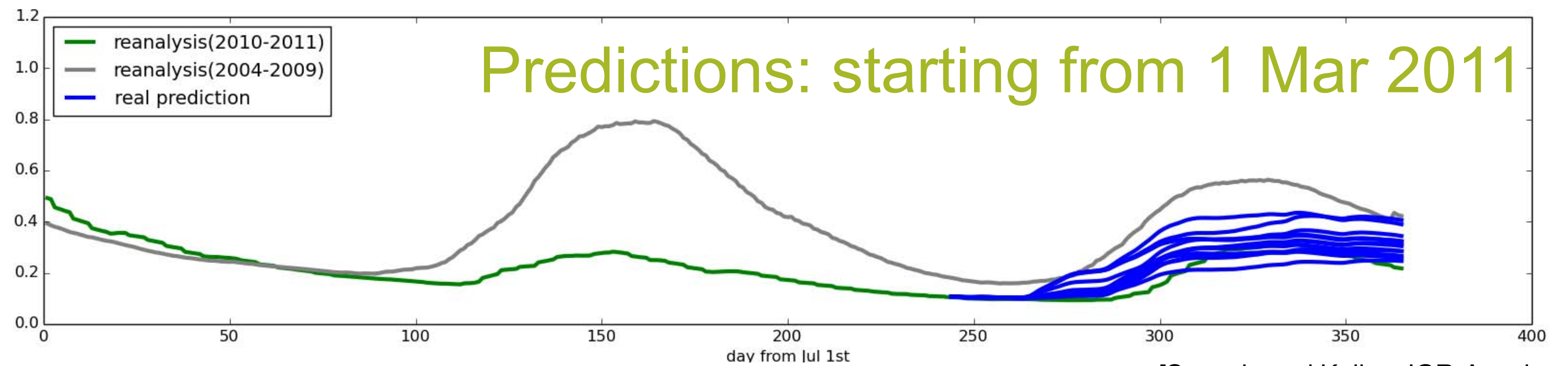
CLVDAS
(Real Predicion)



CLVDAS
(Real Predicion)



CLVDAS
(Real Predicion)



[Sawada and Koike, JGR-A, submitted]

United Nations Educational, Scientific and Cultural Organization

International Centre for Water Hazard and Risk Management under the auspices of UNESCO

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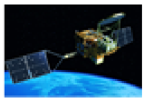
DIAS
Data Integration & Analysis System

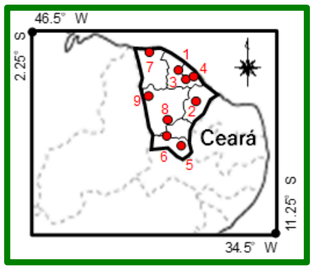
THE UNIVERSITY OF TOKYO

Monitoring | Prediction

AMSR2
Satellite microwave brightness temperature



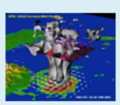
Bias Corrected Rainfall & Hydro-met Forcing



GLDAS 2.1 meteorological forcing

Previous Year Hydro-met Forcing with Modified Rainfall by Seasonal Prediction

GFDL CM2p5 Seasonal prediction precipitation



Forcing	Date	Monitoring	Prediction
	Dec.1		
	Dec.15	Nov.	Dec. Jan. Feb.
Dec.1-31 / Jan.-Mar.	Jan.1		
Dec.1-31	Jan.15	Dec.	Jan. Feb. Mar.
Jan.1-31 / Feb.-Apr.	Feb.1		
Jan.1-31	Feb.15	Jan.	Feb. Mar. Apr.
Feb.1-31 / Mar.-May	Mar.1		
Feb.1-31	Mar.15	Feb.	Mar. Apr. M

The grant which financed this Pilot for Agriculture Drought Monitoring and Prediction in Brazil was received under the Japan-Bank Program for Main-streaming DRM in Developing Countries which is financed by the Government of Japan

United Nations Educational, Scientific and Cultural Organization

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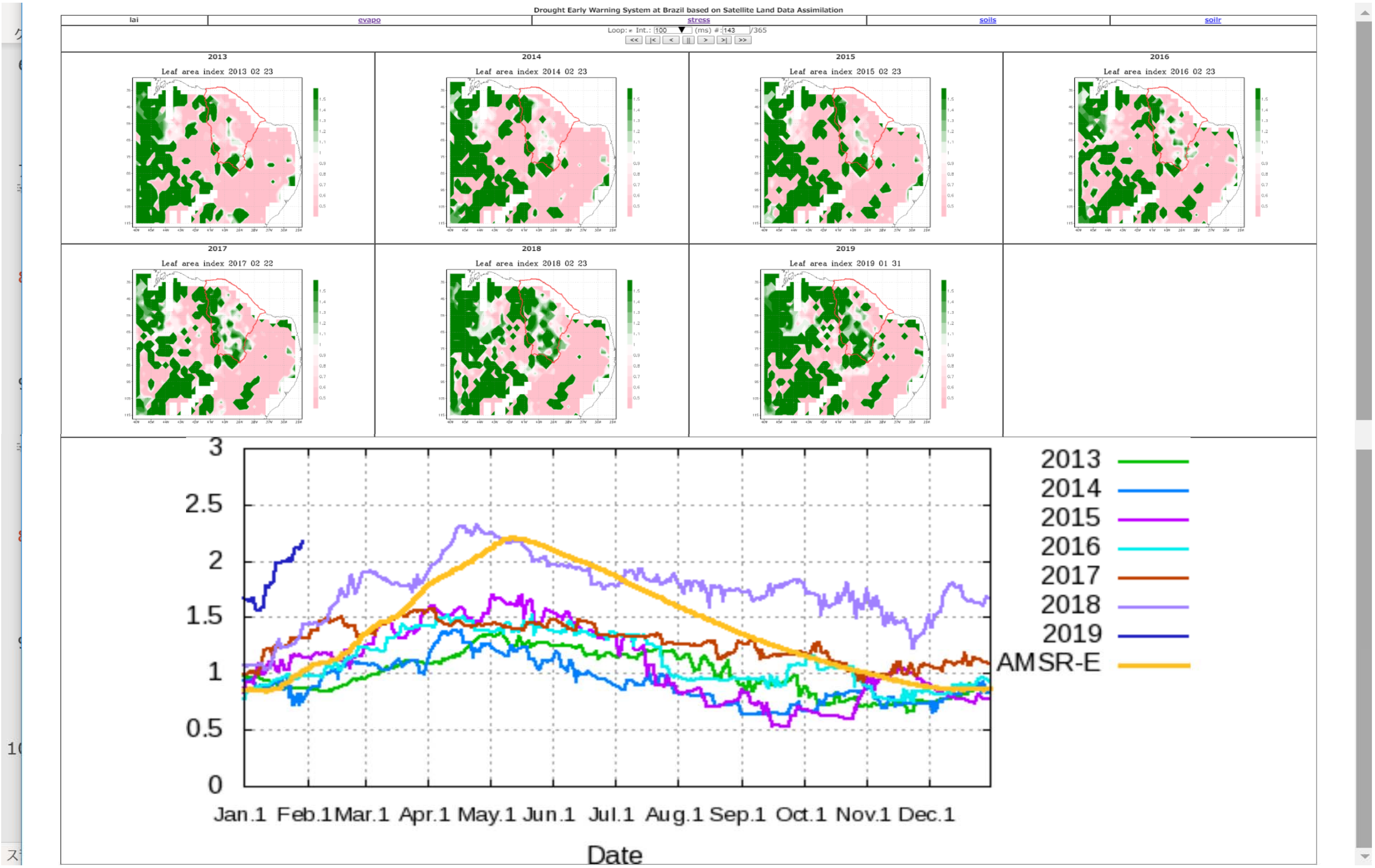
DIAS Data Integration & Analysis System

THE UNIVERSITY OF TOKYO



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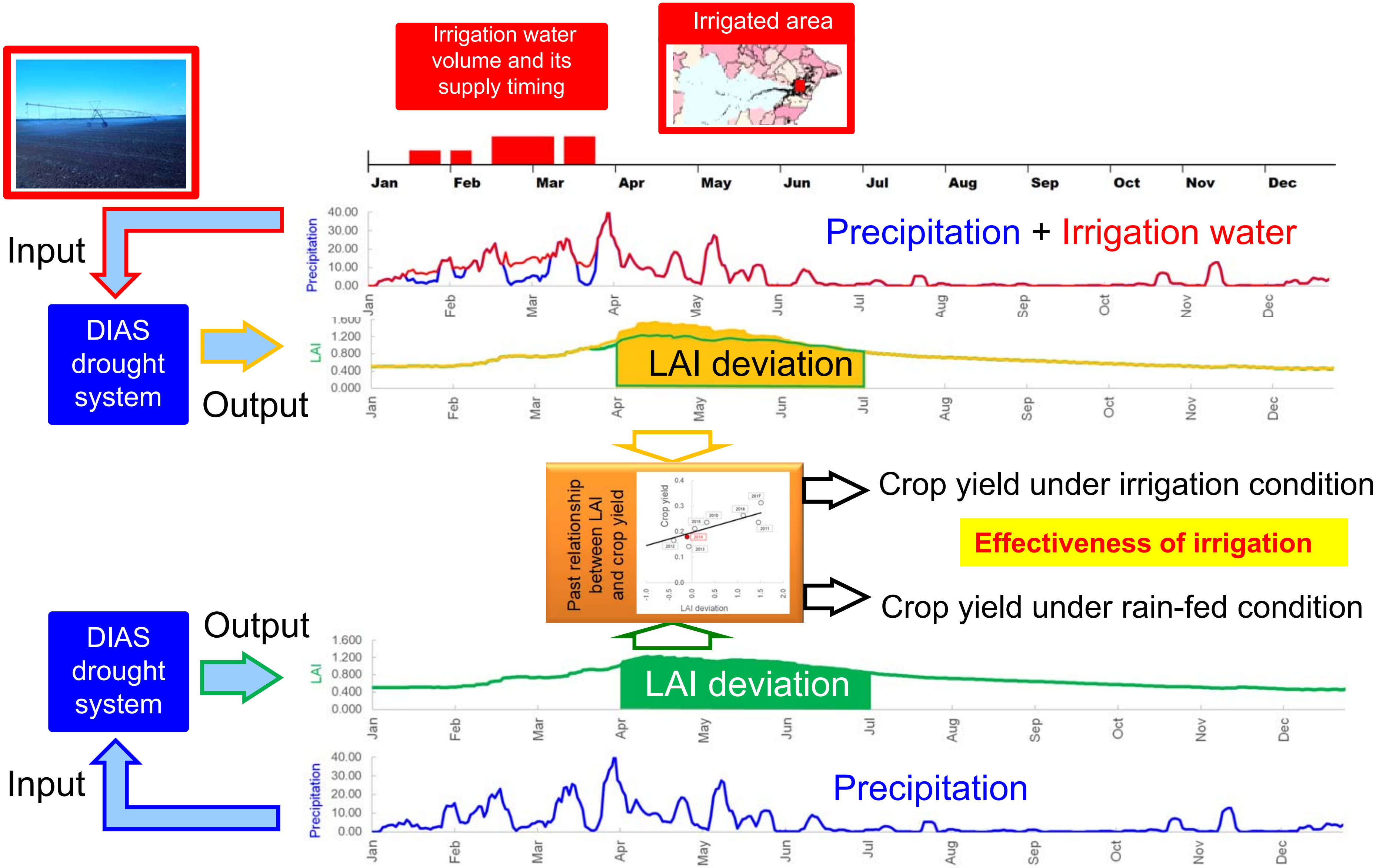
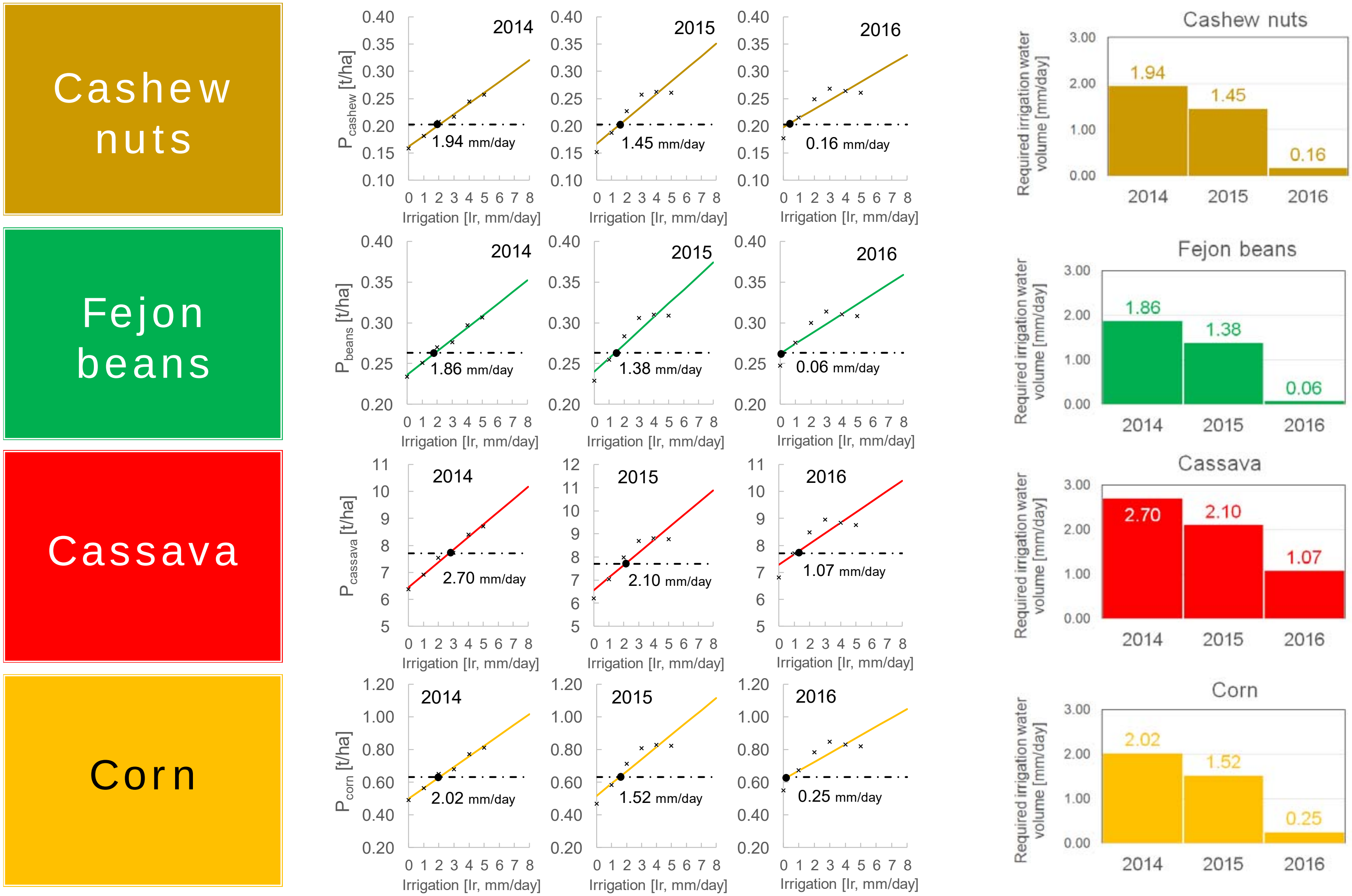
Application to estimate required irrigation water volume without the irrigated water volume and its supply timing



Irrigated area, water volume and its supply timing: Li#zh#rewdlq#wkh#luuljdwhg#duhd/#zdwhu#yroxph#dqg#lwv#vxsso|#wlplqj/#zh#fdq#fdofxodwh#ODL#dqg#furs#|lhog# xqghu#wkh#luuljdwlrq#frqglwlrq#e|#lqsxwwlqj#suhflslwdwlrq#dqg#luuljdwlrq#zdwhu#lqwr#wkh#GLDV#gurxjkw#v|vwhp#dqg#fdq#frpsduh#lw#zlwk#wkh#furs#|lhog#xqghu#udlq0ihg#frqglwlrq1# Lq#frqvhtxhqfh/#zh#fdq#hydoxdwh#wkh#hiihfwlyhqhvv#ri#luuljdwlrq1



Estimation of the required irrigation water volume: Zh#dvvxphg#wkh#dyhudjh#furs#|lhog#lq#wkh#shulrg#ehwzhhq#5336#dqg#534:#dv#wkh#wdujhw#furs#|lhog#ri#hdfk#idup1#Wkh#uhtxluhg#luuljdwlrq#zdwhu#yroxph#zdv#hvwlpdwhg#e|#frpsdulqj#wkh#wdujhw#furs#|lhog#dqg#wkh#uhodwlrqvkls#ehwzhhq#dvvxphg#luuljdwlrq#zdwhu#dqg#hvwlpdwhg#furs#|lhog1#Lq#frqvhtxhqfh/#rxu#vlpxodwlrqv#fohduo|#vkrz#frqvlvwhqw#ghfuhdvhv#lq#uhtxluhg#luuljdwlrq#zdwhu#yroxph#dv#wkh#gurxjkw#frqglwlrq#lpsuryhg#judgxdoo|#lq#5348#dqg#5349#diwhu#d#vhyhuh#gurxjkw#lq#53471