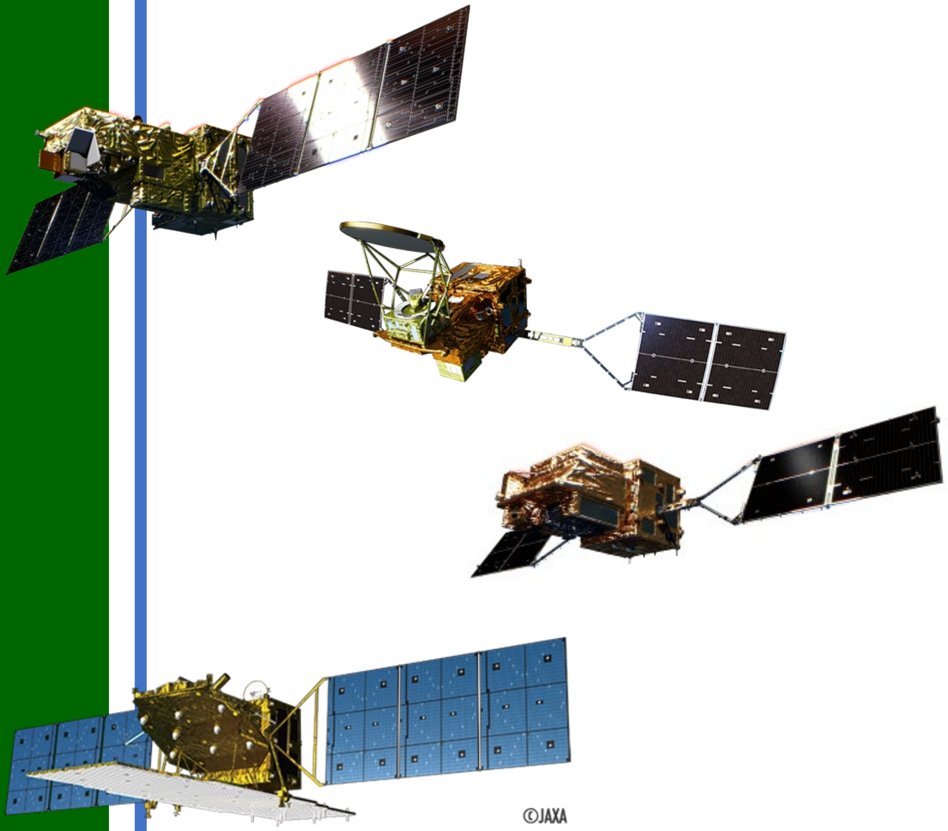
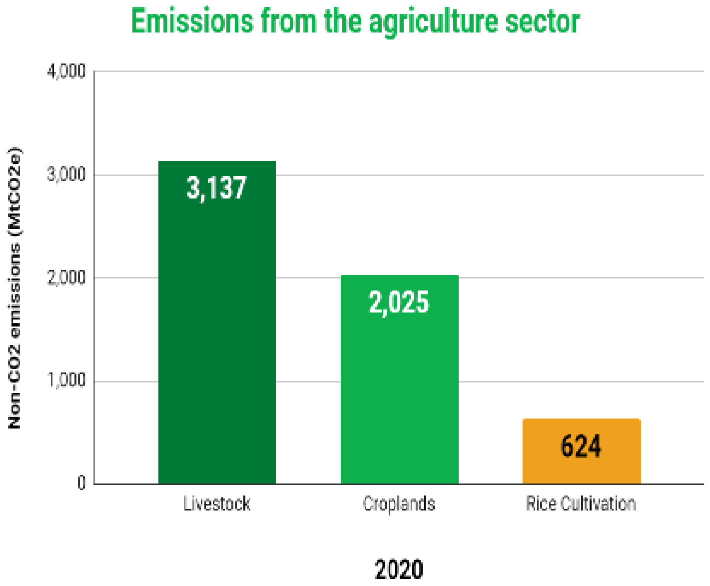
Decision Support System of GHG emissions from rice cultivation systems in the Mekong delta


©JAXA

Hironori Arai[1,2], Thuy Le Toan[3], Kei Oyoshi[4], Mehrez Zribi[3], Yoshinobu Kawahara[2], Wataru Takeuchi[5], Tamon Fumoto[6], Kazuyuki Inubushi[7], Lam Dao Nguyen[8], Shinichi Sobue[4], Bjoern Ole Sander[1]

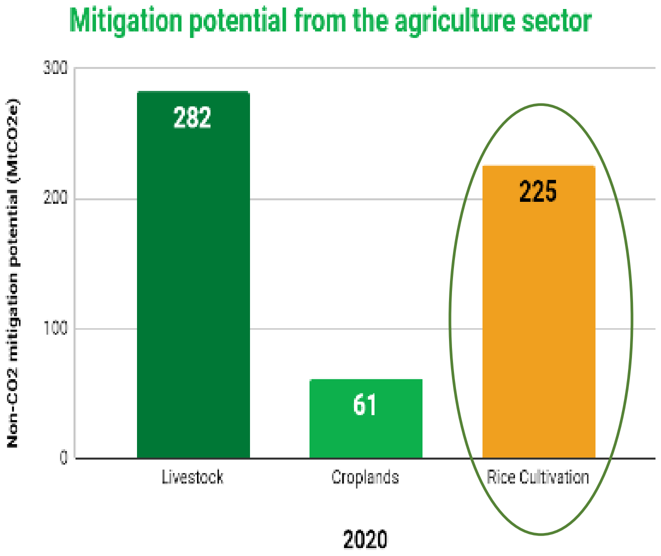
Emission and Mitigation Potential

Net emission is methane plus nitrous oxide minus C sequestration



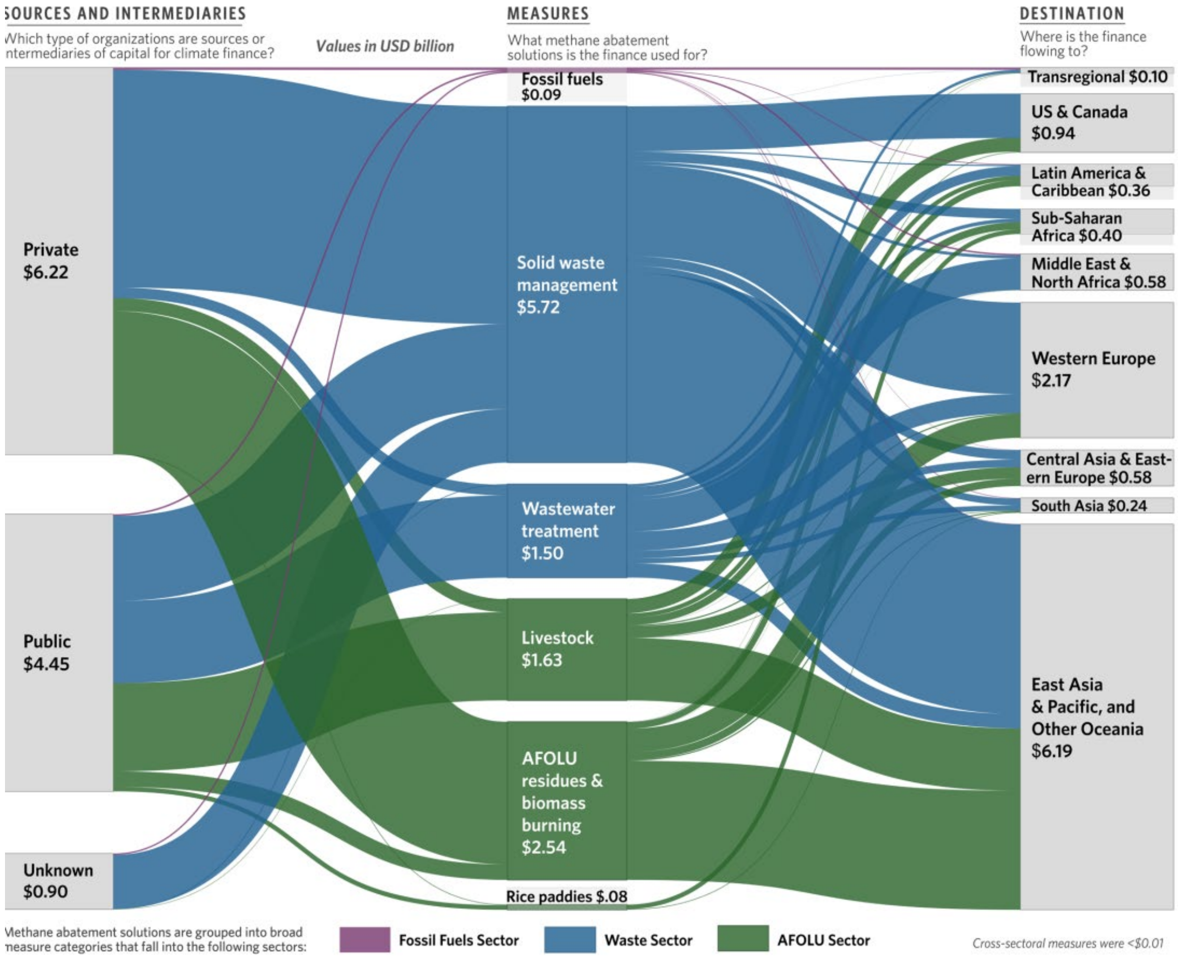
Globally rice cultivation is the **third-largest source of non-CO2 greenhouse gas emissions** in agriculture, next to livestock and all croplands (EPA, 2021)

This is mostly due to the traditional method of paddy farming, where **flooded fields release methane** and other greenhouse gases through anaerobic decomposition



However, the relative **mitigation potential for rice (36%)** is much higher than that of livestock (9%), and croplands (3%) (Roe et al., 2021; EPA, 2021)

Global targeted methane abatement finance flows in 2019/2020



- Investments for methane reduction are geared towards waste management/ wastewater treatment, followed by livestock and residue burning
- Investments in GHG abatement in rice is very low compared to the mitigation potential

CGIAR

IRRI

Existing mitigation options across the rice production cycle

can reduce as much as 65% - mostly methane

UP TO 10%

Timing of residue incorporation in field

UP TO 7%

Planting short-duration rice varieties

Average 33%

Alternate Wetting & Drying, Efficient use of fertilizer

UP TO 15%

Amount of residue left after harvest, no straw burning

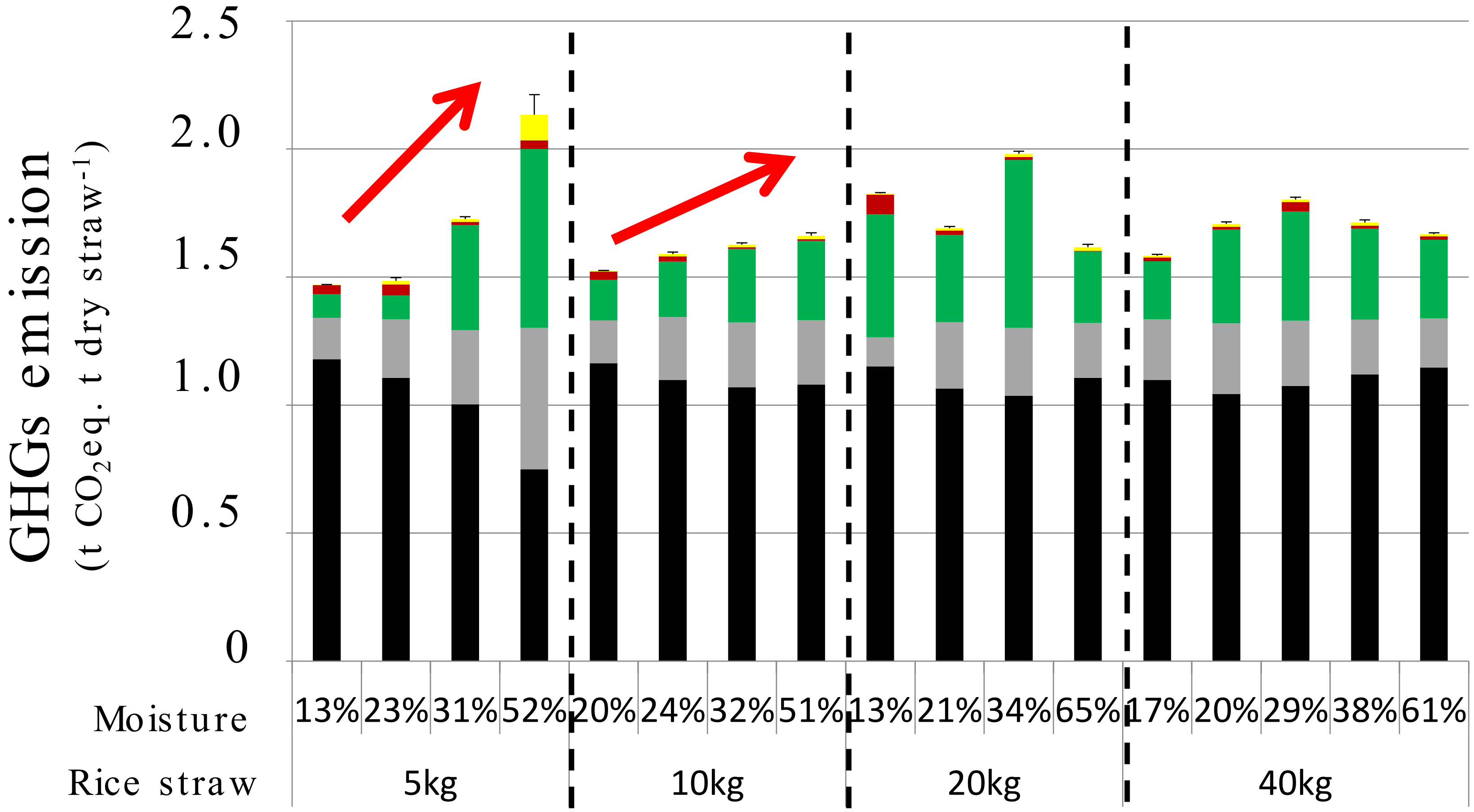
Different **rice cultivars** have different CH$_4$ emission potentials

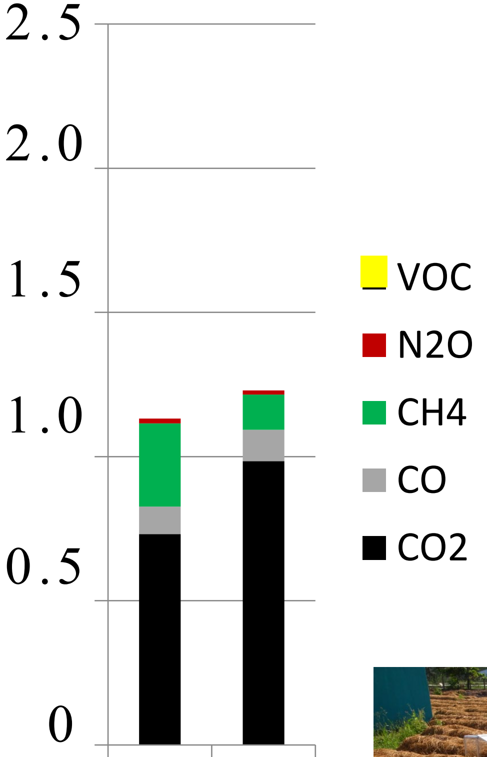
Water-saving technologies adapting rice production to climate change while reducing emissions

a) Mushroom production for a nutritious, profitable product

b) Mechanized composting to produce organic fertilizer

Greenhouse gas emission derived from straw burning



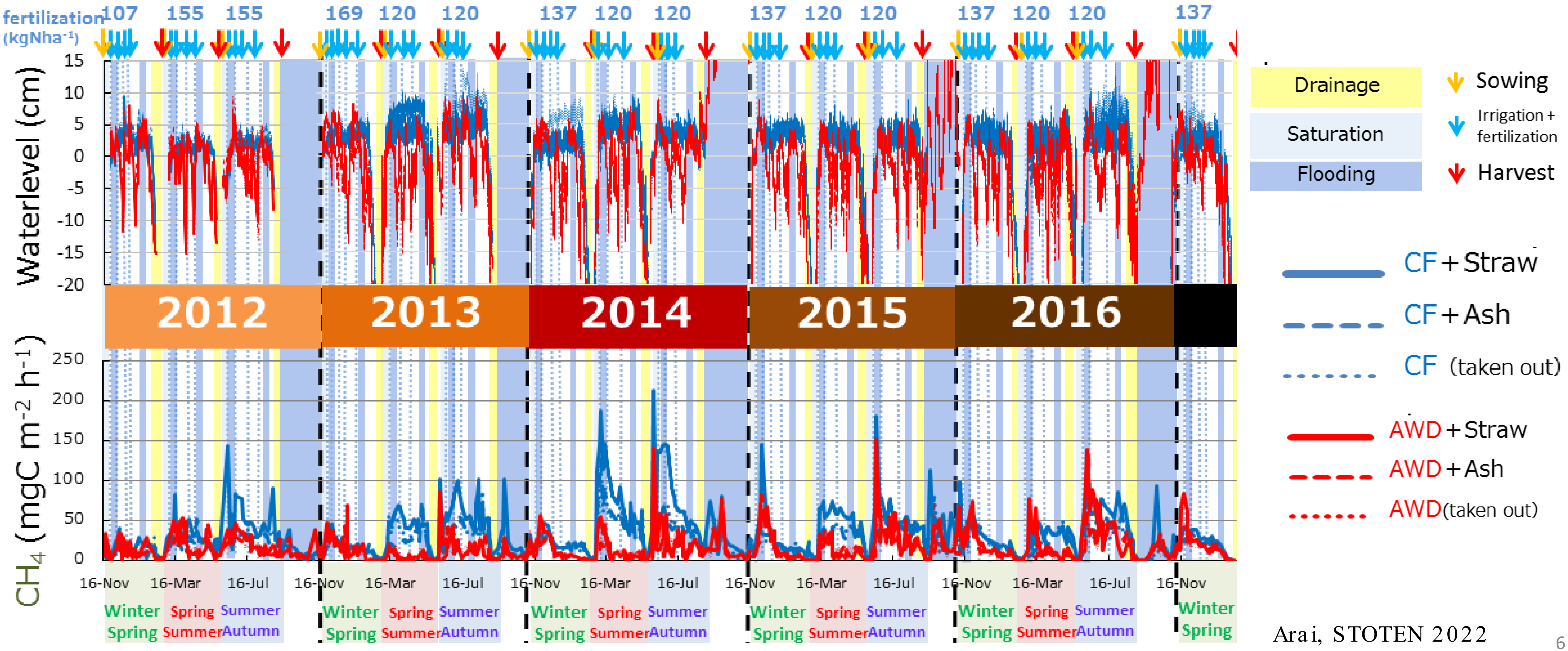


Straw after Mushroom cultivation

Arai et al., 2015

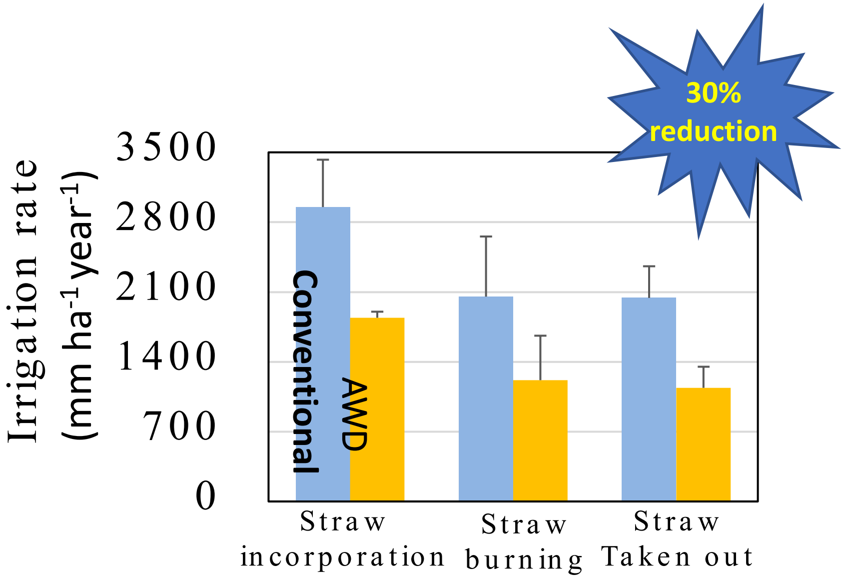
AWD has been carried out based on research works in last decades

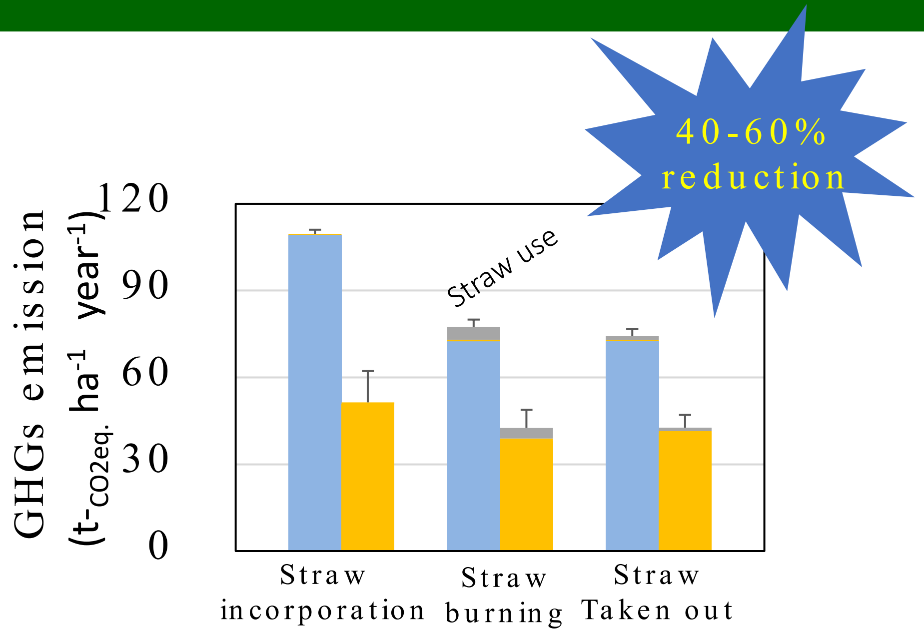
Multi-year study conducted on a farmer's fields in the Mekong Delta

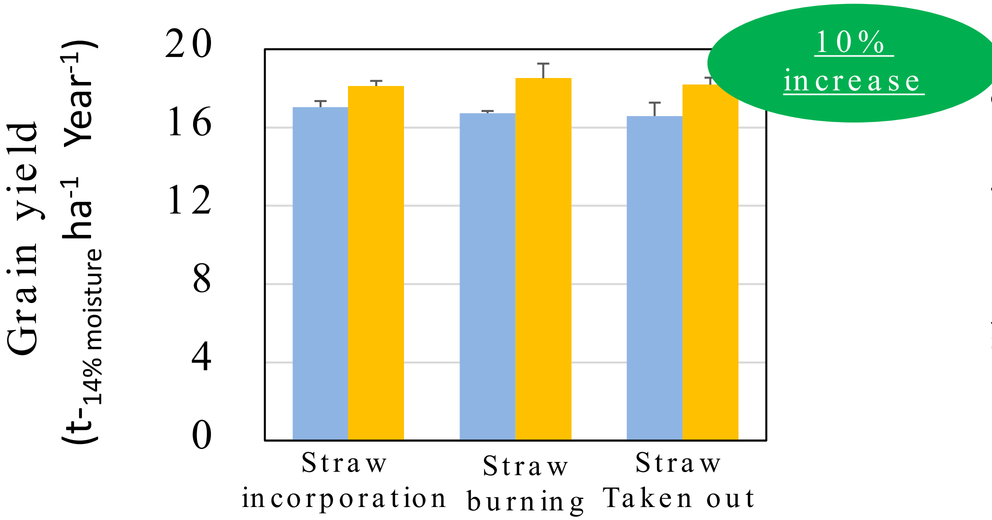


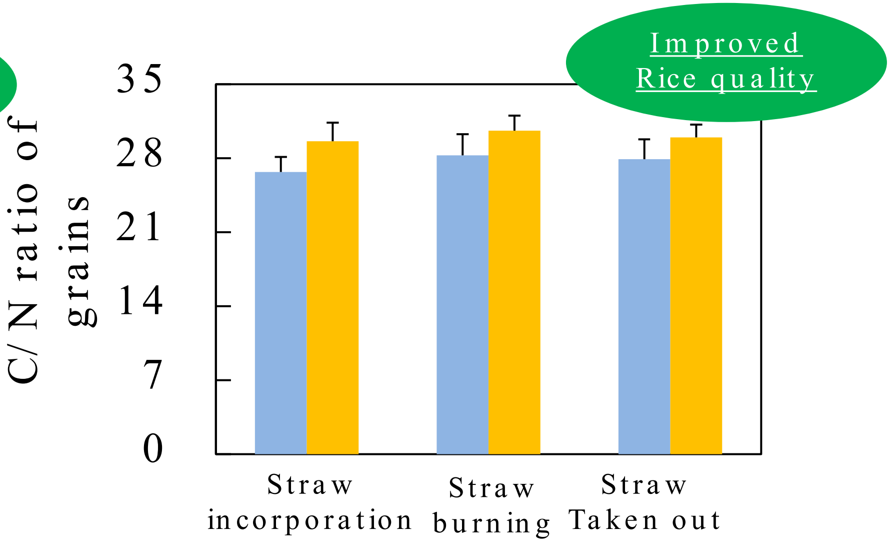
Arai, STOTEN 2022

AWD reduces methane emission, water demand, with slightly improved grain yield and quality (2012-2016 experiment)









Arai et al., Springer SARI-book chapter 2022

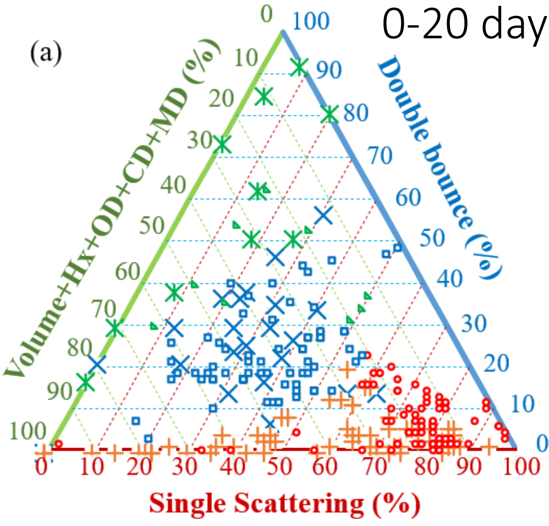
σ^0 based inundation detection with ALOS2-HR data

white pixels
Not-inundated

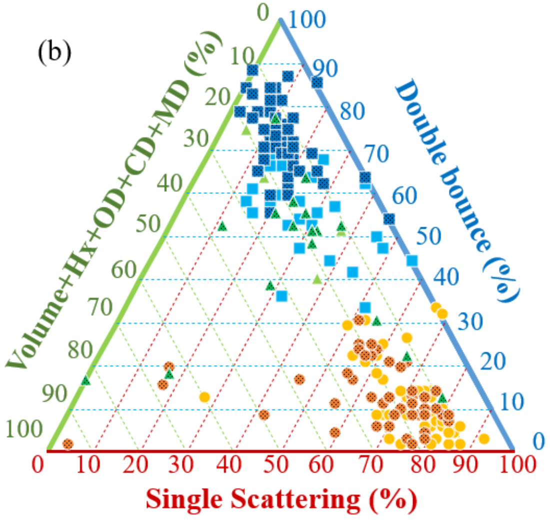
69 days after sowing, 6th May 2016

L-band PALSAR-2 rice monitoring

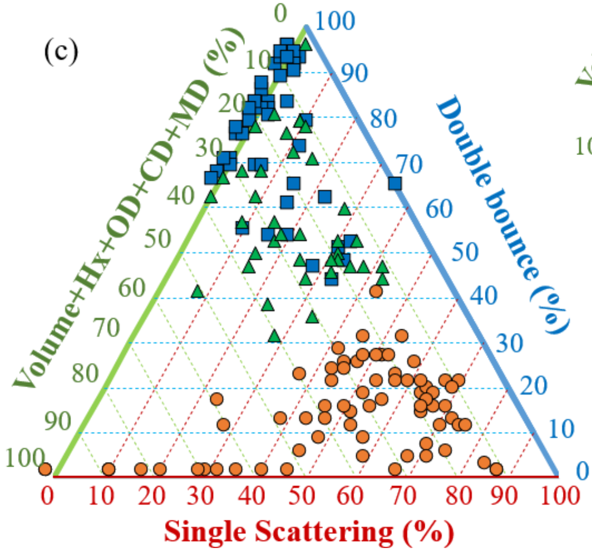
-inundation detectable in the whole stages-



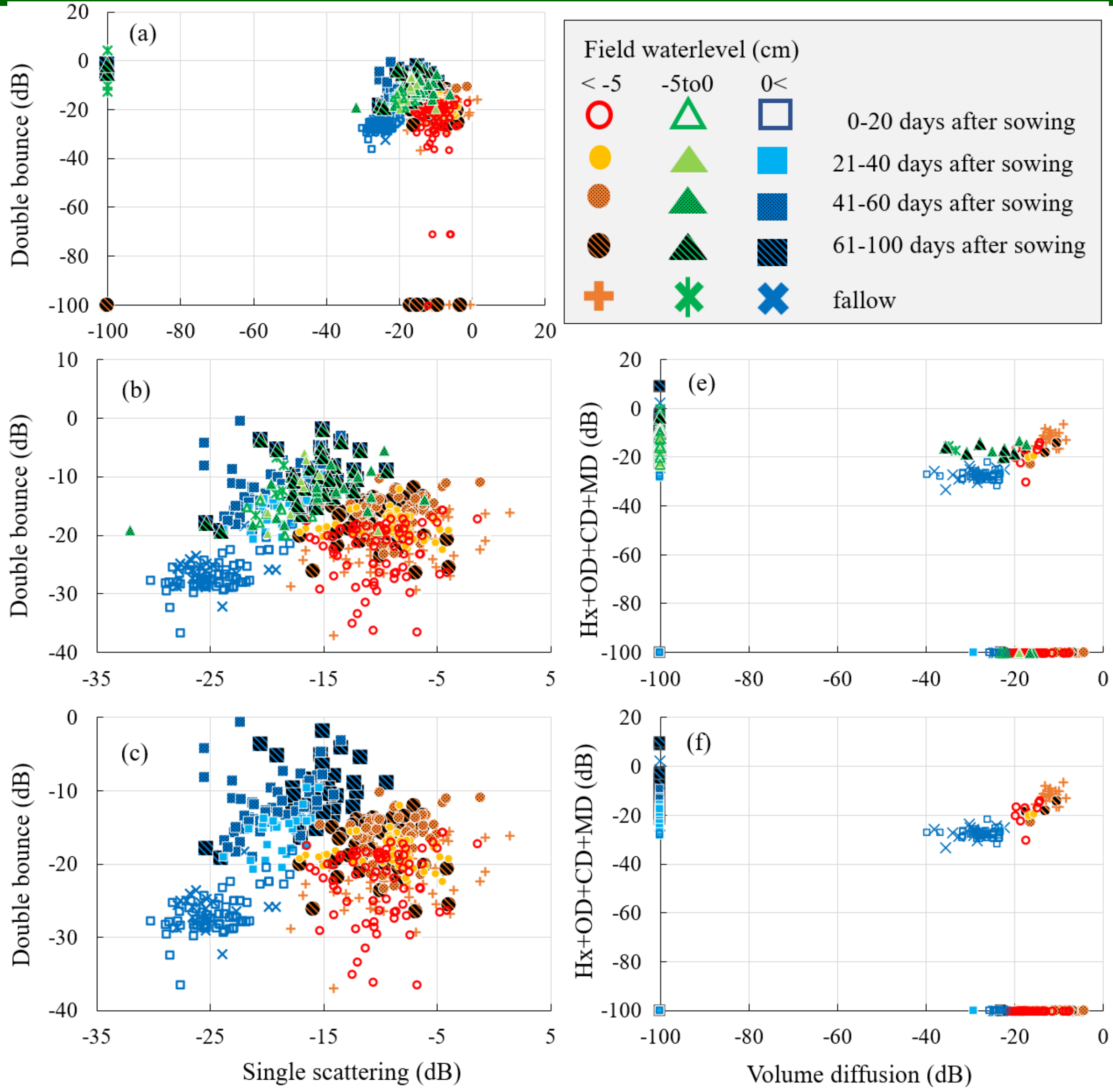
0-20 days after sowing + fallow



21-60 days after sowing

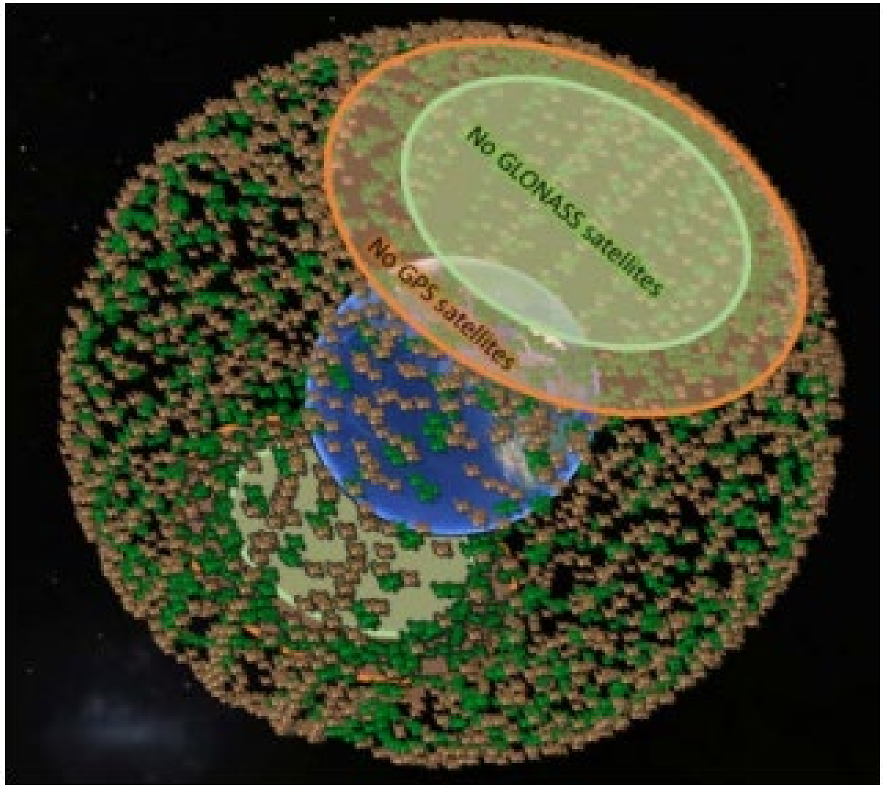


61-105 days after sowing

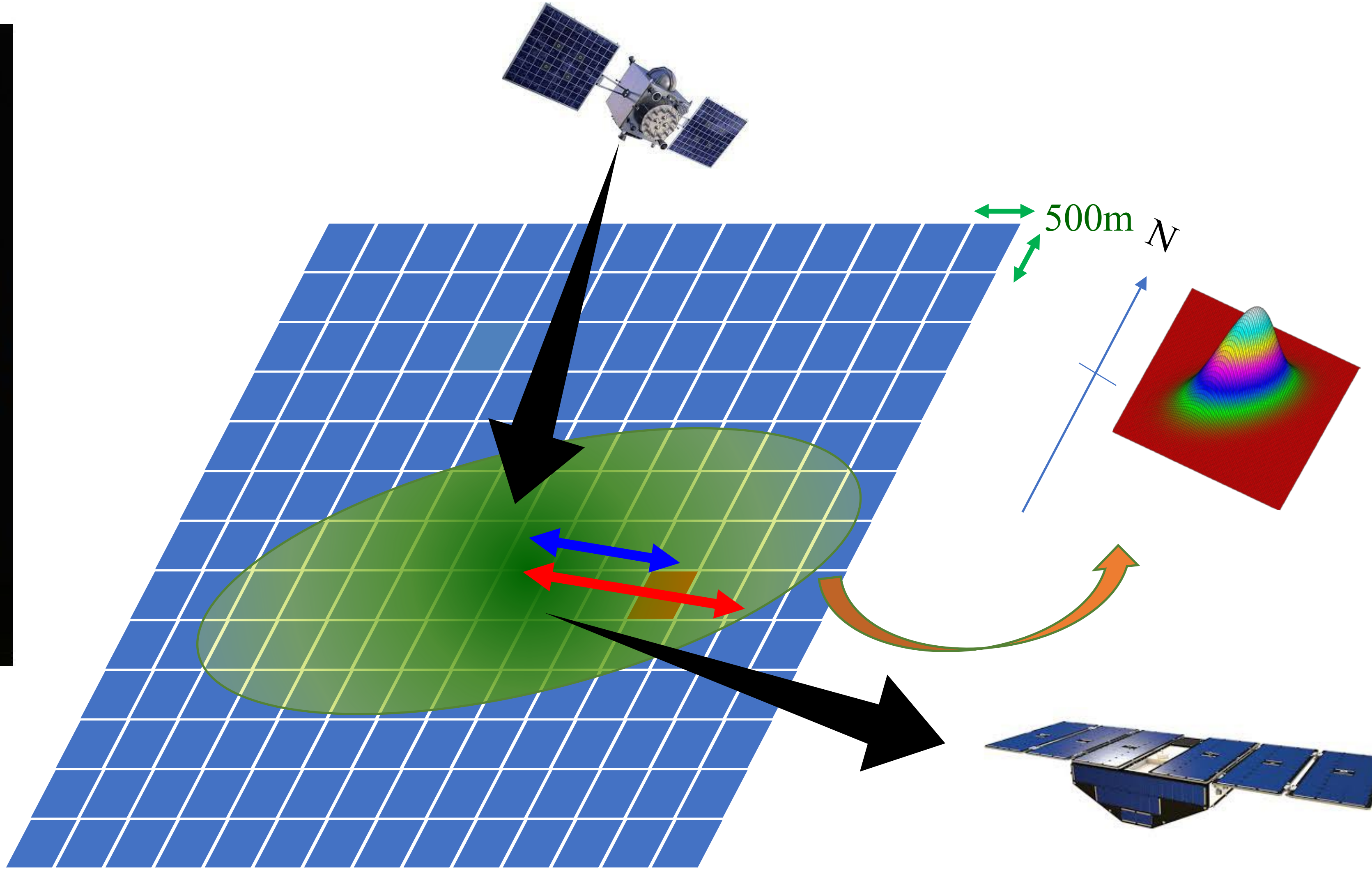


Arai et al., RSE 2022

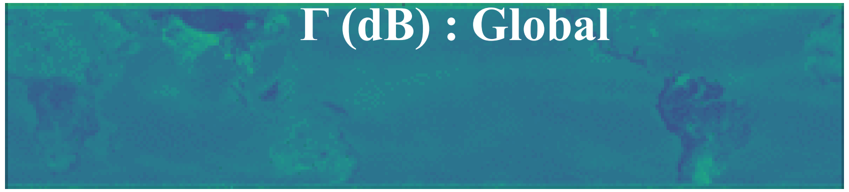
GNSS signals available for inundation detection



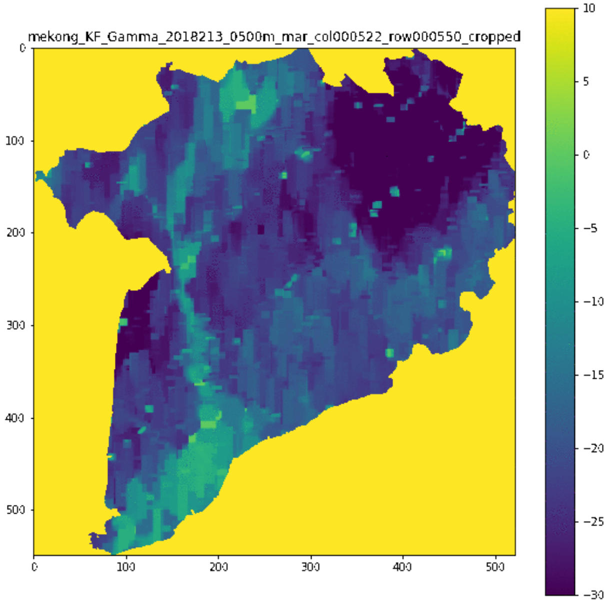
Here we can see the dense coverage of the two oldest GNSS constellations: the American GPS (orange) and the Soviet system GLONASS (green).



Kalman filter product (500m_res, 15-days resolution)

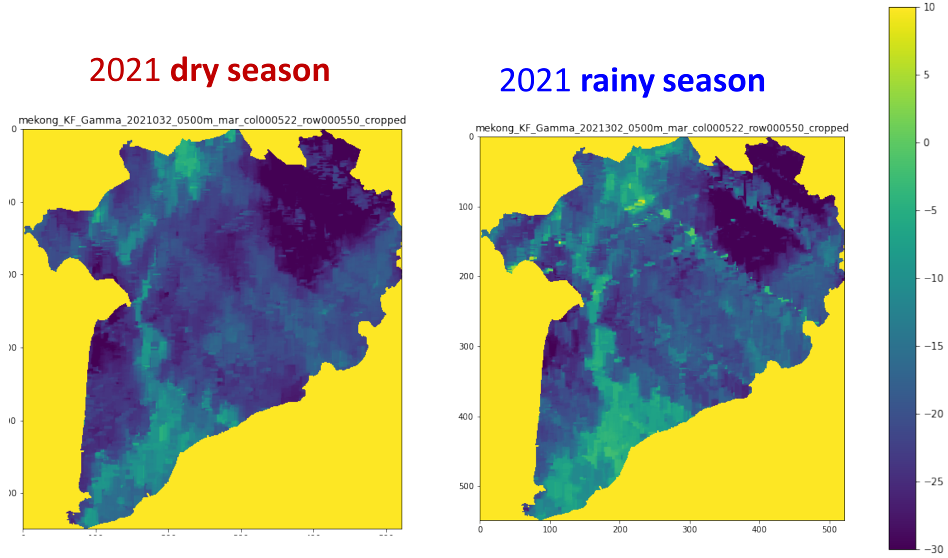


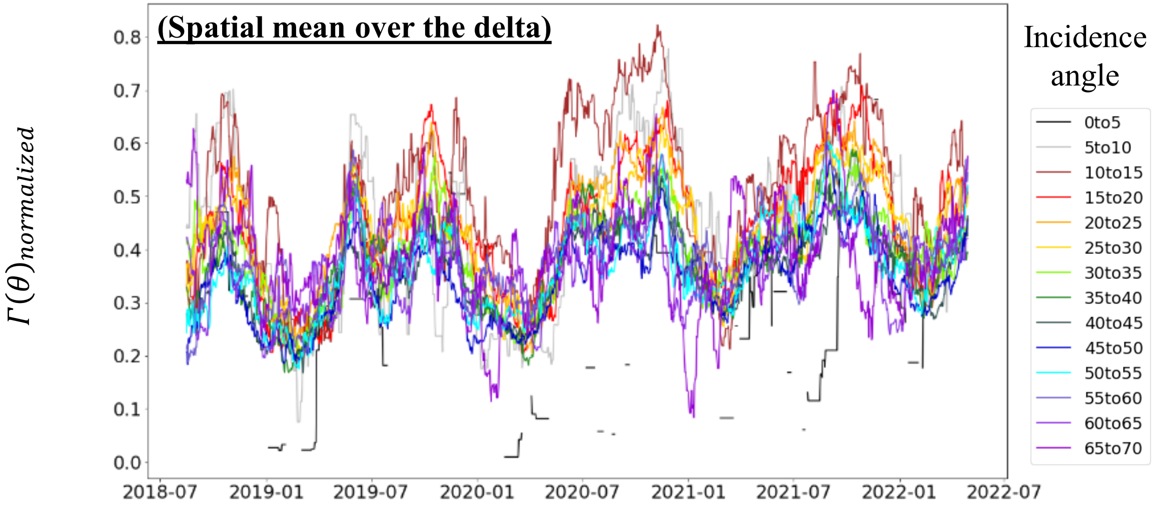
Γ (dB)



2021 **dry season**

2021 **rainy season**





No more ad hoc parameter setting! Everything adaptive!!

We can use all specular signals！

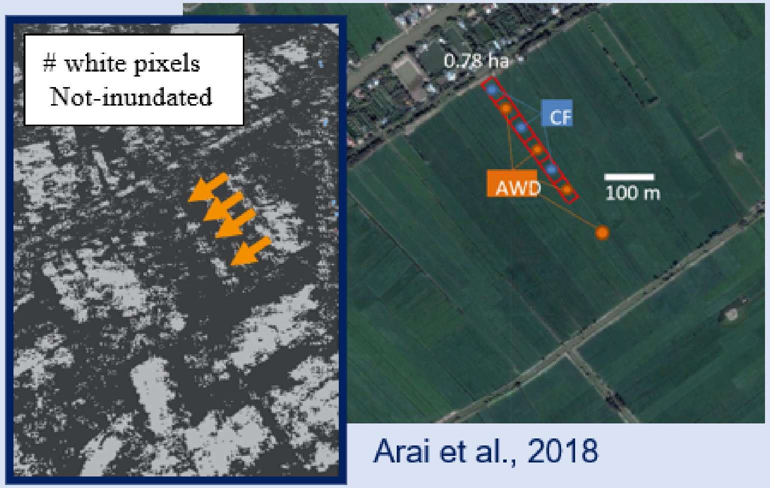
Spatio-temporal pattern clearly appears!

Arai et al., Remote sensing, 2022

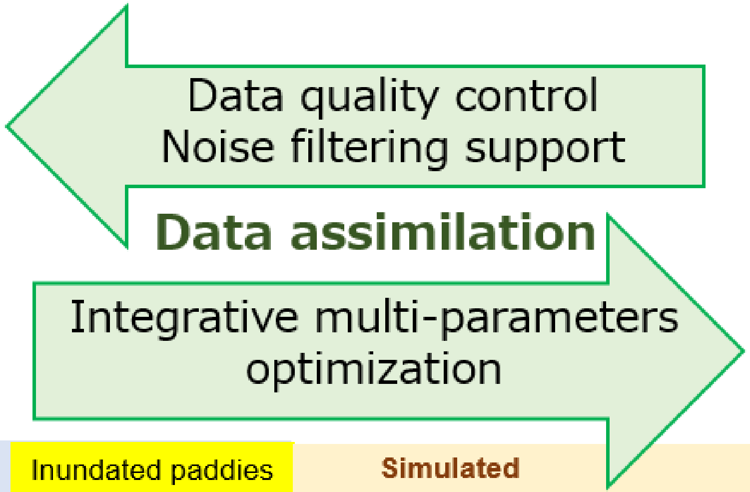
Pixel-based (50m-res.) Inversion of Daily waterlevel/GHGfluxes, rice growth/yield and Nitrogen-usage

L-SAR observation on inundation

ALOS-2/4, NISAR, ROSE-L



Arai et al., 2018



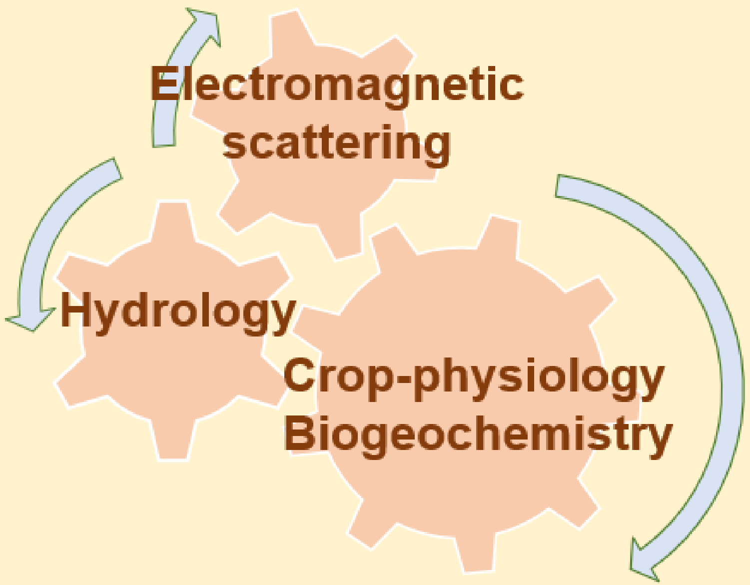
Data quality control
Noise filtering support

Data assimilation

Integrative multi-parameters optimization

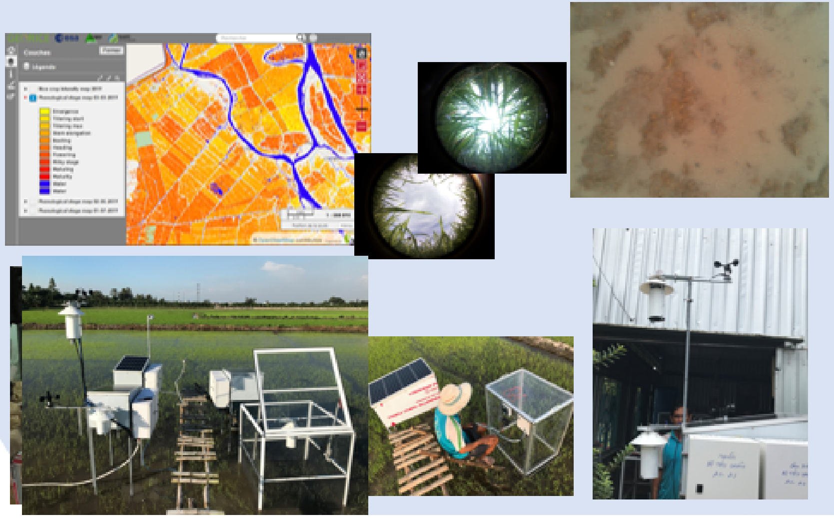
Cyber-LCA coupling system

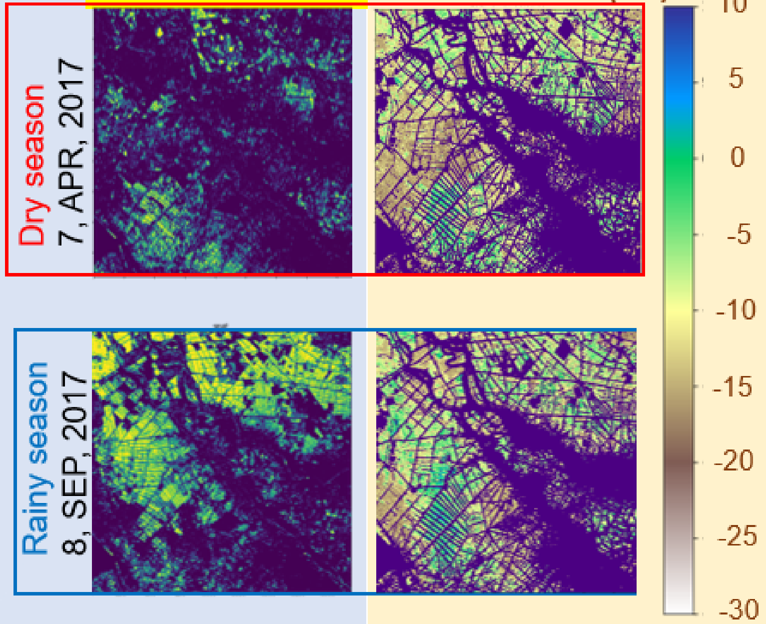
w/ high spatio-temporal resolution models

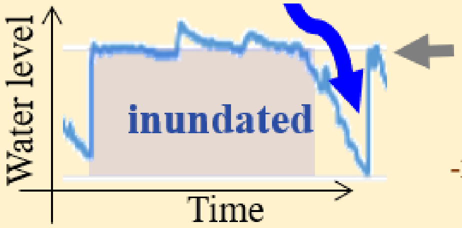


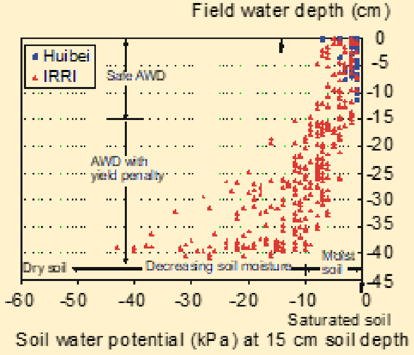
GeoRice & IoT tech.

Regional Rice monitoring in S E Asia with Sentinel-1
http://www.georice.net/lm/index.php/

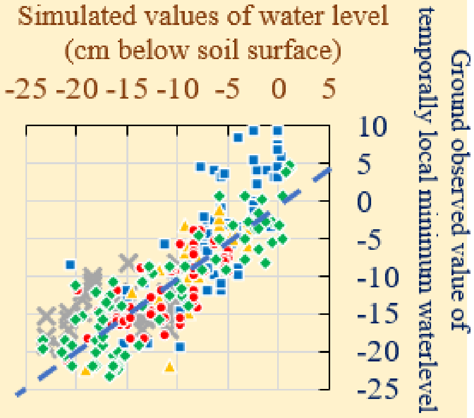








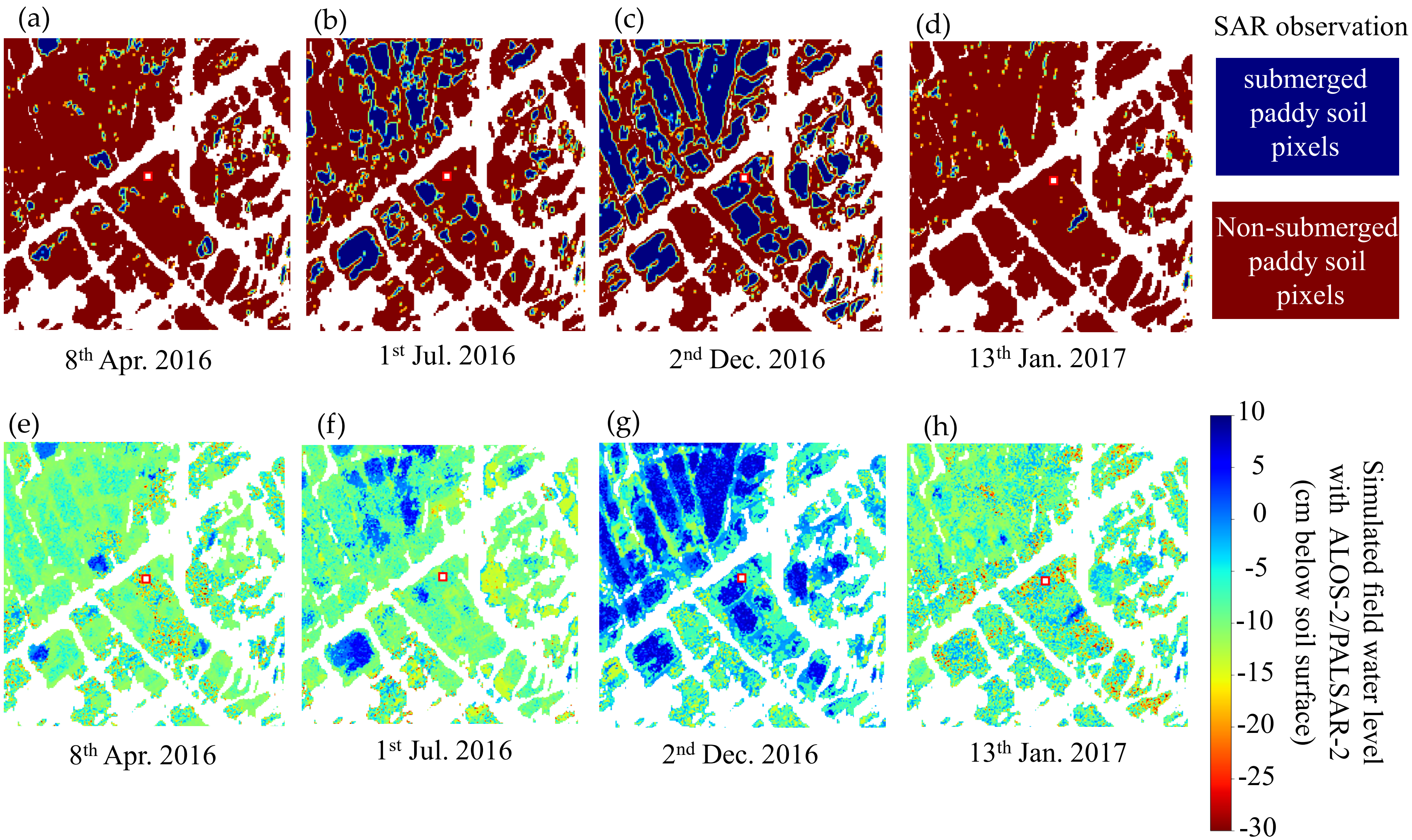
Lampayan et al., 2015



Data from 5 sites x 5 plots x 10 seasons

Arai et al., 2021 RSE submitted

SAR data assimilation of field water level simulation
-binding cyber space and real space-



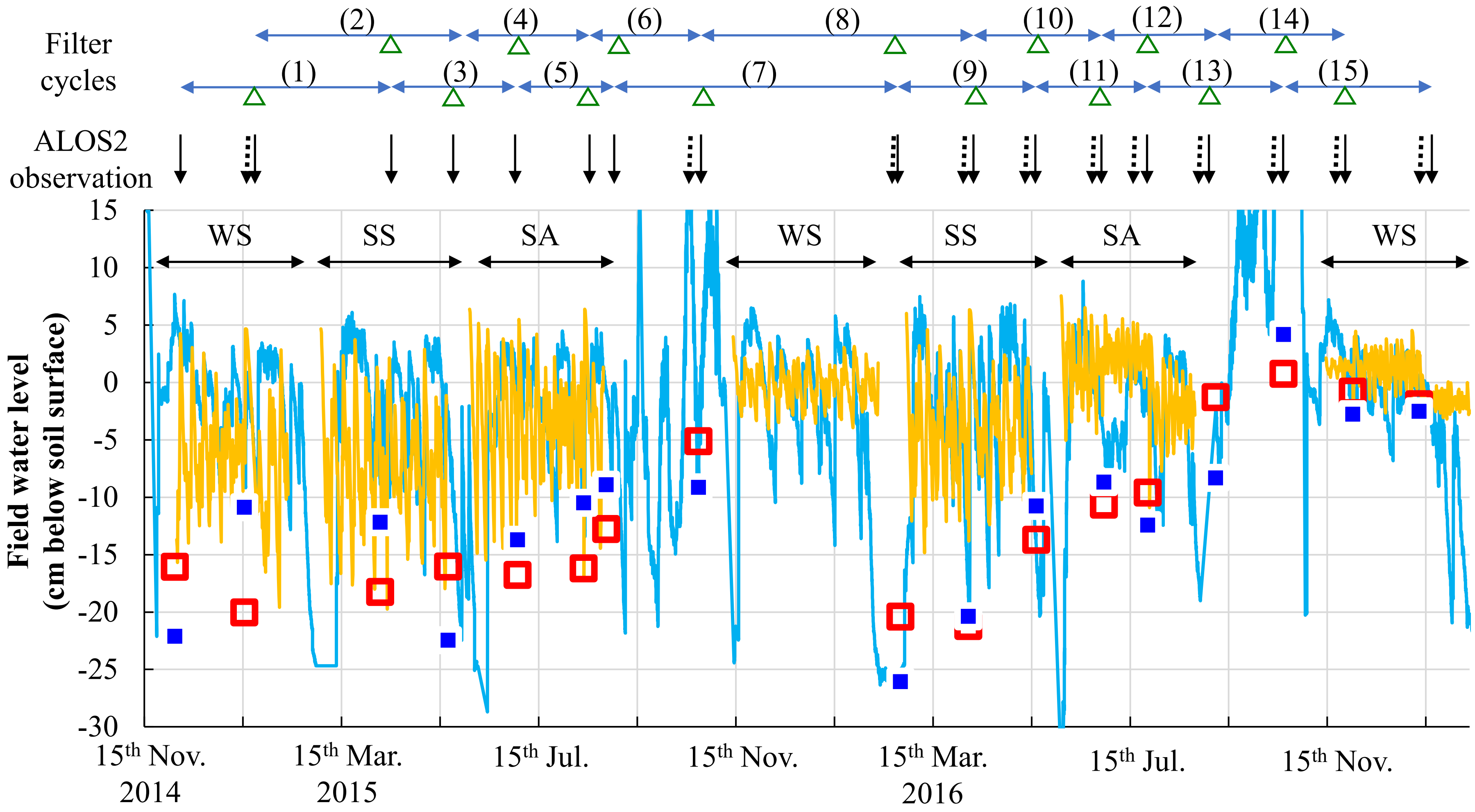
8th Apr. 2016 | 1st Jul. 2016 | 2nd Dec. 2016 | 13th Jan. 2017

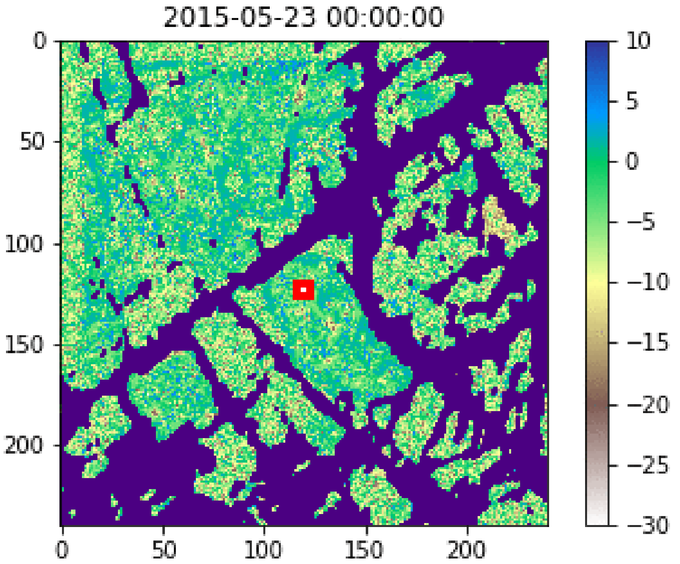
8th Apr. 2016 | 1st Jul. 2016 | 2nd Dec. 2016 | 13th Jan. 2017

Note Lite blue: Not submerged (i.e., water level is lower than 0) Blue: submerged (i.e., water level is taller than 0)

Arai et al., RSE 2022

A sample of validation result with ground observation data –semi dyke system-



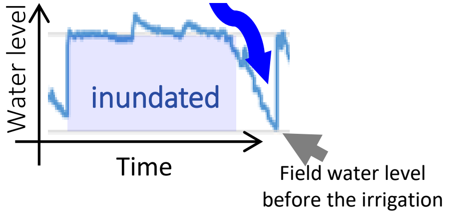


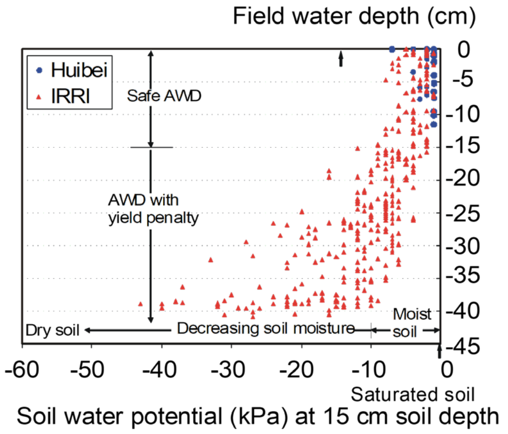
Field waterlevel (cm)

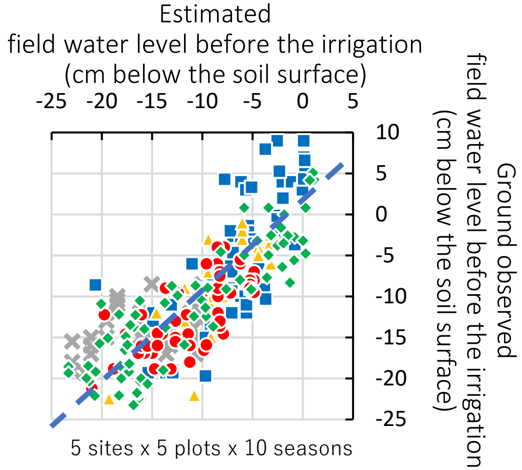
- Ground-observed field waterlevel
- Mean values of simulated field waterlevel (4 × 4 pixel windows around the ground observation point)
- 🟦 The temporally local minimum water level around the data-assimilation date ± 10days
- 🟥 Mean values of estimated irrigation threshold model parameter (4 × 4 pixel windows around the ground observation point)

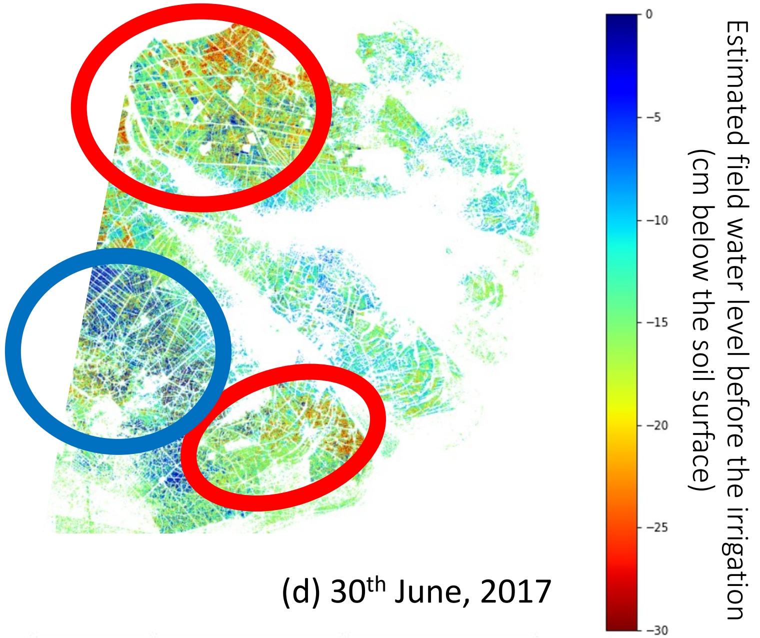
Arai et al., RSE 2022

How deep the field water was dropped by next irrigation?
– Estimation by DA model parameter estimation -

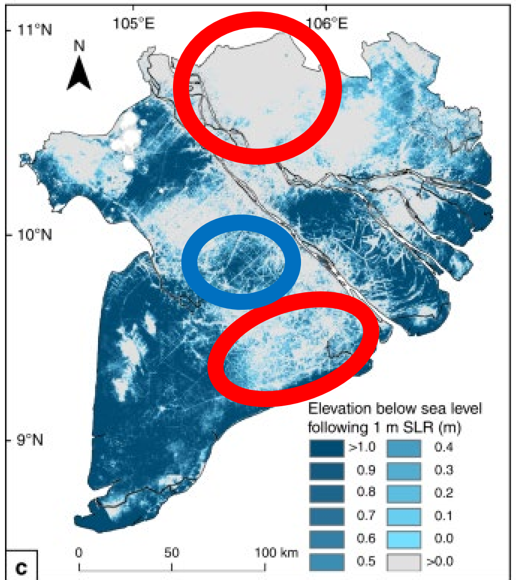


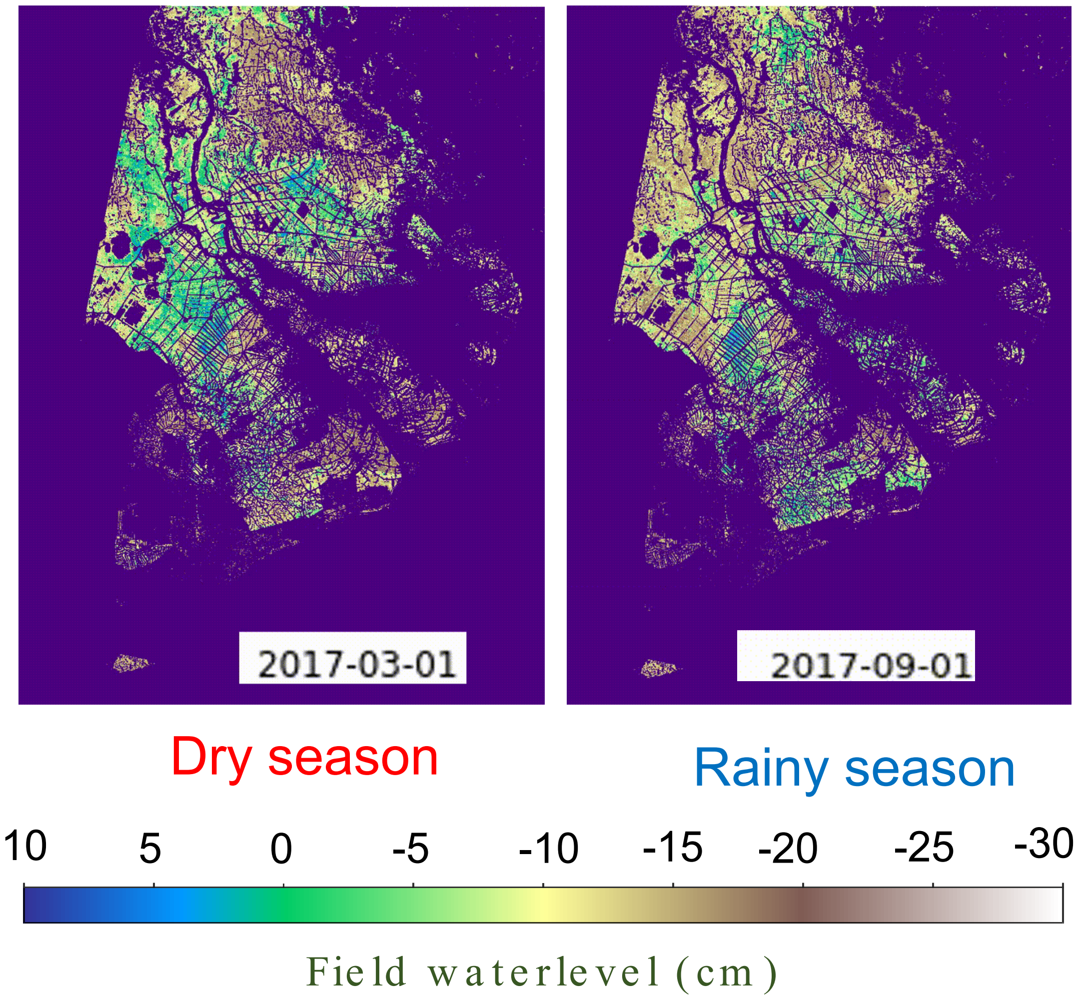






(d) 30th June, 2017



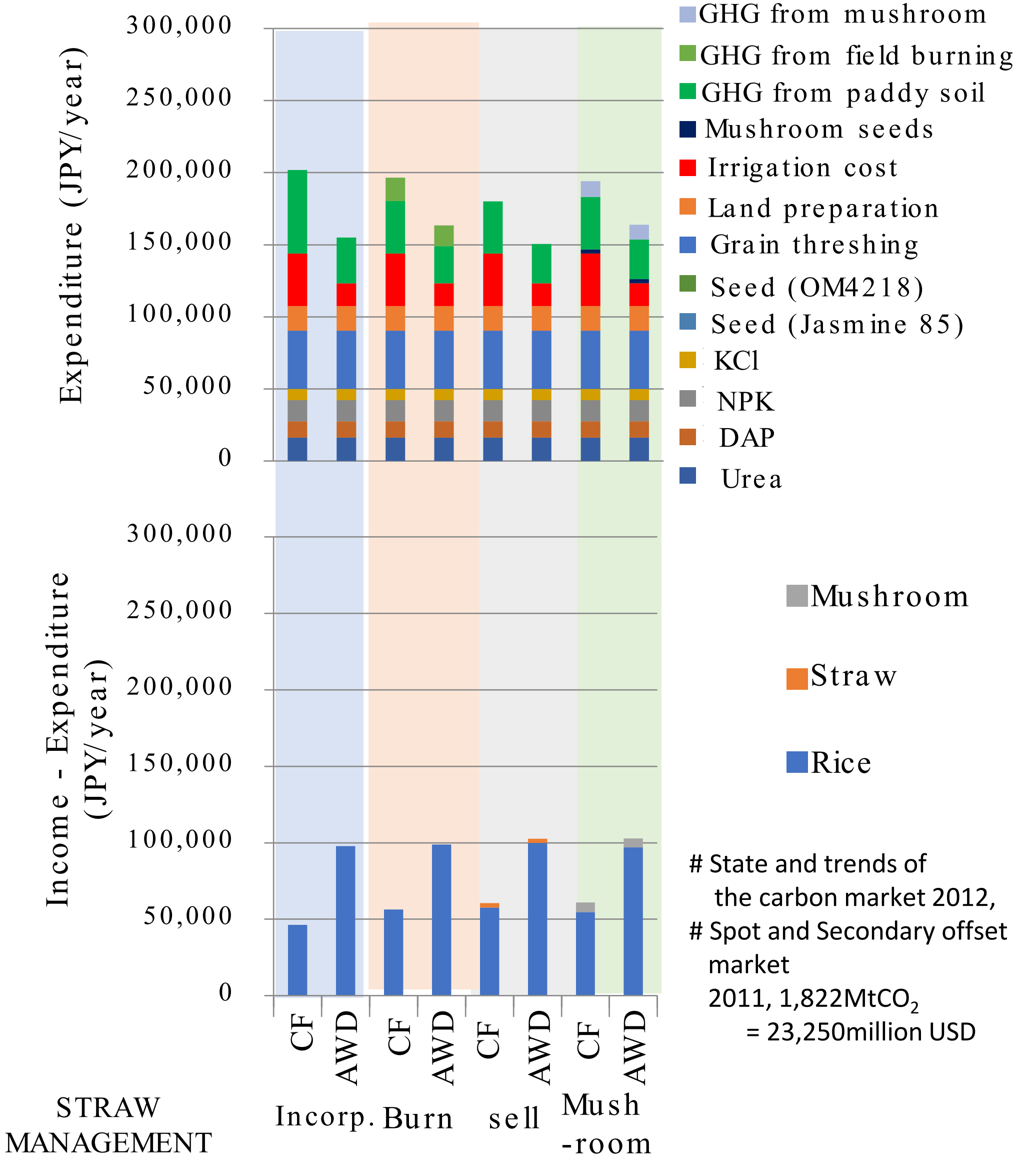


Arai et al., RSE 2022

Economic assessment of GHG mitigation measures under large uncertainties

Clear cost/benefits and actual farmers' participation are the keys to the adoption of new technologies by farmers.

Transparent MRV system on baselines/mitigation-effects with EO data should be enhanced.



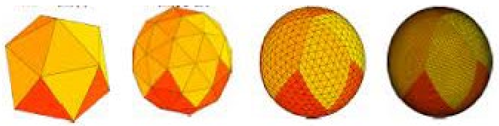
State and trends of the carbon market 2012,
Spot and Secondary offset market
2011, 1,822MtCO$_2$ = 23,250million USD

Arai et al., Springer SARI-book chapter 2022

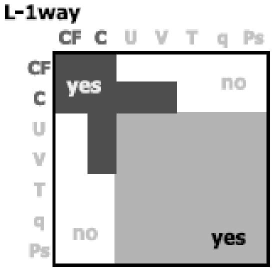
Lack of atmospheric EO observation data in the Mekong delta -Importance of land surface observation-

Estimate methane emission with LETKF-variable localization

Nonhydrostatic **IC**osahedral
Atmospheric **M**odel-**TM**

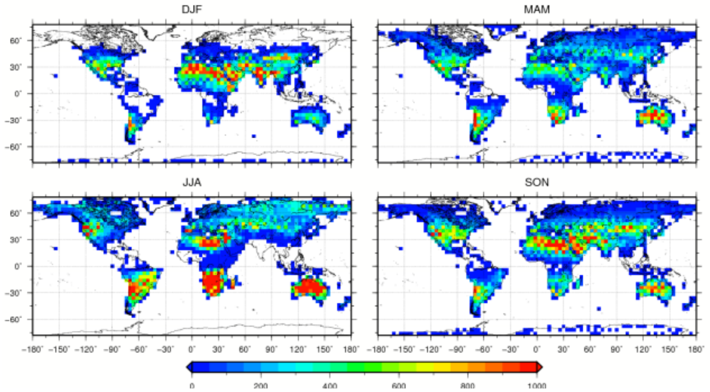


Decorrelation on models' covariance matrix



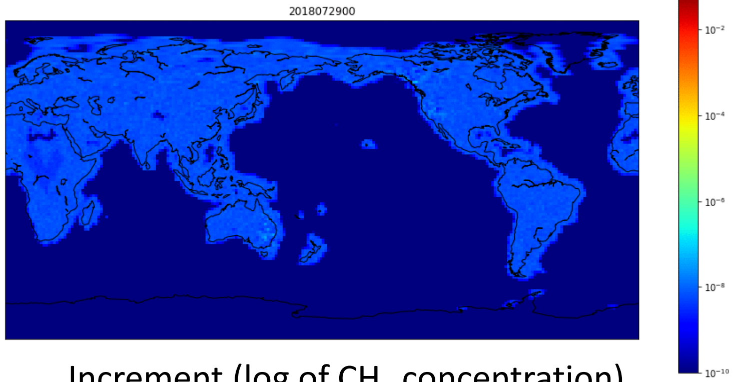
Zeroing out non-correlated non-diagonal elements in B matrix
→inverse estimation of emission without prior information

Sparce modeling Technique for multico.

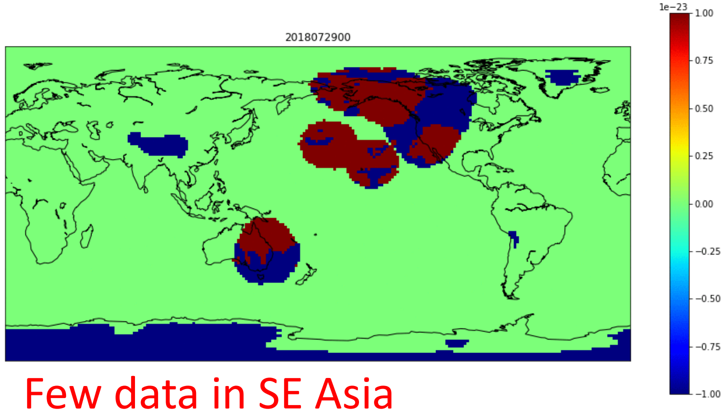


Number of GOSAT SCAN (Someya et al., 2020)

mean (log of CH_4 emission)



Increment (log of CH_4 concentration)
1000hpa p-surface



Few data in SE Asia
(inter-tropical convergence zone)

-> underestimate the emission in tropical region!

Arai et al., 2020