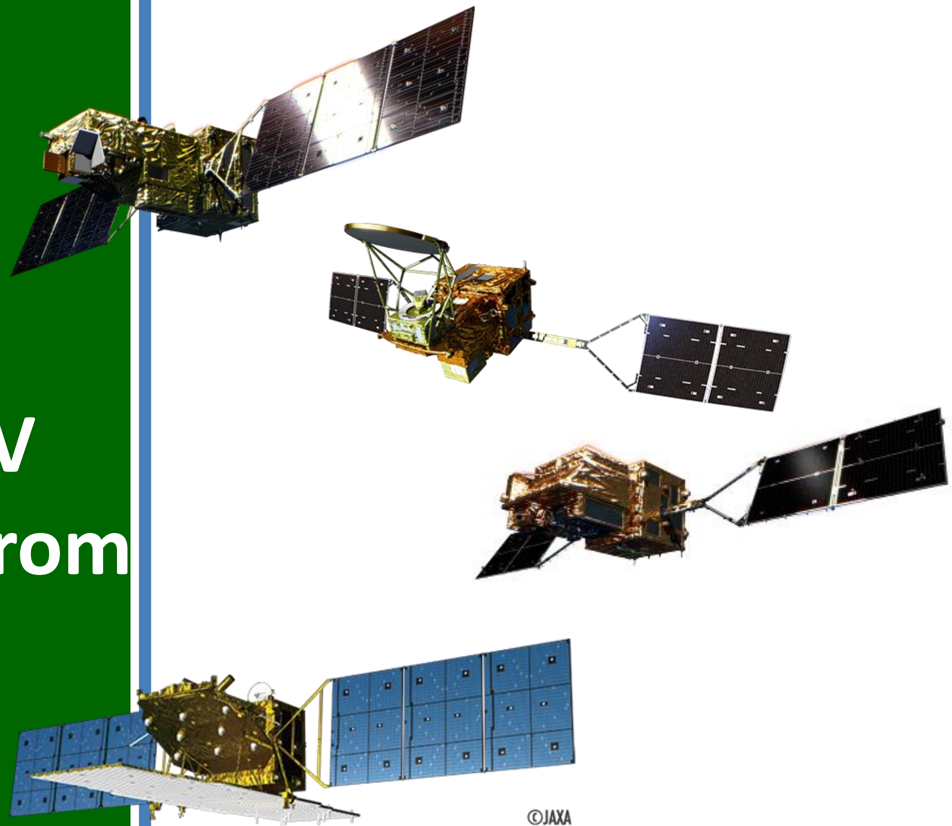
SUSTAINABLE DEVELOPMENT GOALS

RESPONSIBLE CONSUMPTION AND PRODUCTION

CLIMATE ACTION

Satellite data based MRV system of GHGs emission from tropical rice paddies



Hironori Arai[1,3], Wataru Takeuchi[1], Kei Oyoshi[2], Lam Dao Nguyen[4], Towa Tachibana[5], Ryuta Uozumi, Koji Terasaki[3], Takemasa Miyoshi[3], Hisashi Yashiro[3], Kazuyuki Inubushi[5]

RSED JAXA AICS VNSC

Cycle from Observation to Countermeasure

To target

To solution

To target

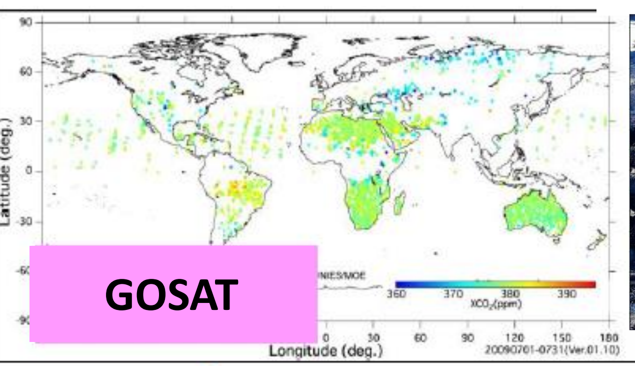
Observ. Survey → Modelling → Simulation Forcast・eval.

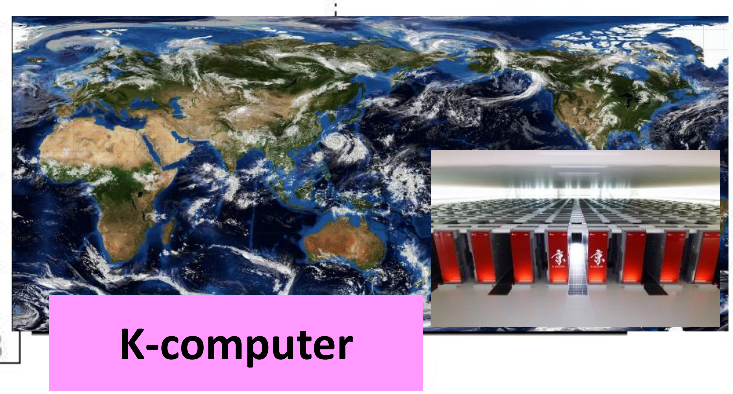
Solution design → optimi zation

manage ment → Evalu ation

DATA → inform ation → Estima tion

→ Strategy → Policy →





Effect

Observation of the effect

Modified from Yasuoka 2015

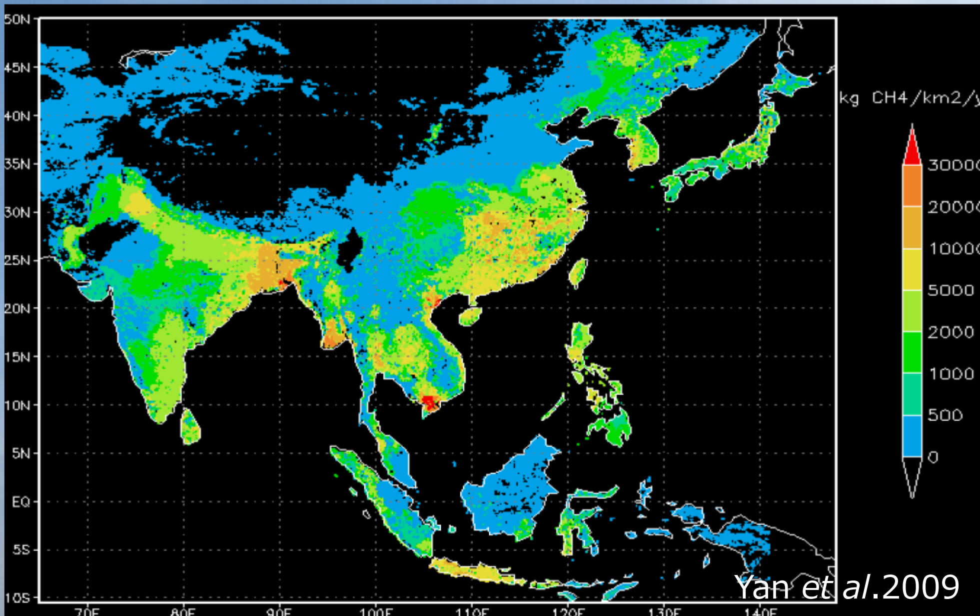
Outline

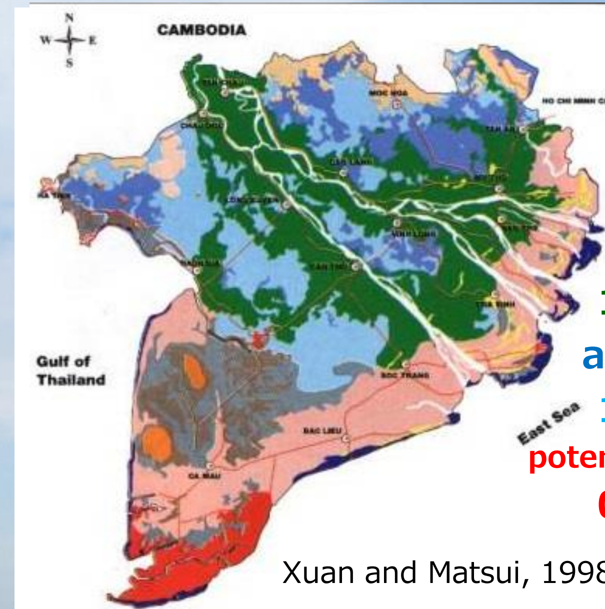
1． Background & Objective

2. Ground observation of greenhouse gas emission and semi-empirical modeling

3. Satellite remote sensing of GHG emitters

- Cropping calendar & the adjacent fallow length
- Paddy soil/water covered by rice plants
- Top down verification with GOSAT





alluvial soil
1.1 Mha, 28%
acid sulfate so
1.1 Mha, 28%
potentially acid sulfate
0.5 Mha, 13%

- Continuously flooded nearly through a year

+

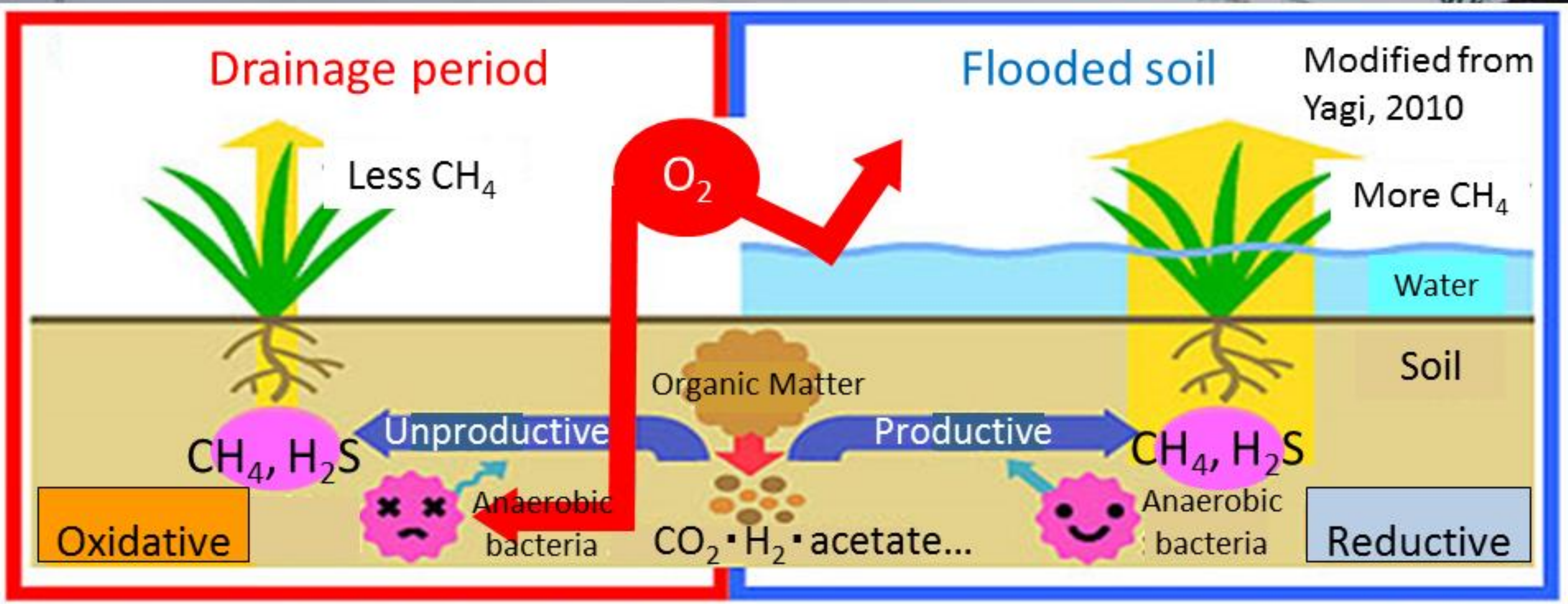
- High straw production

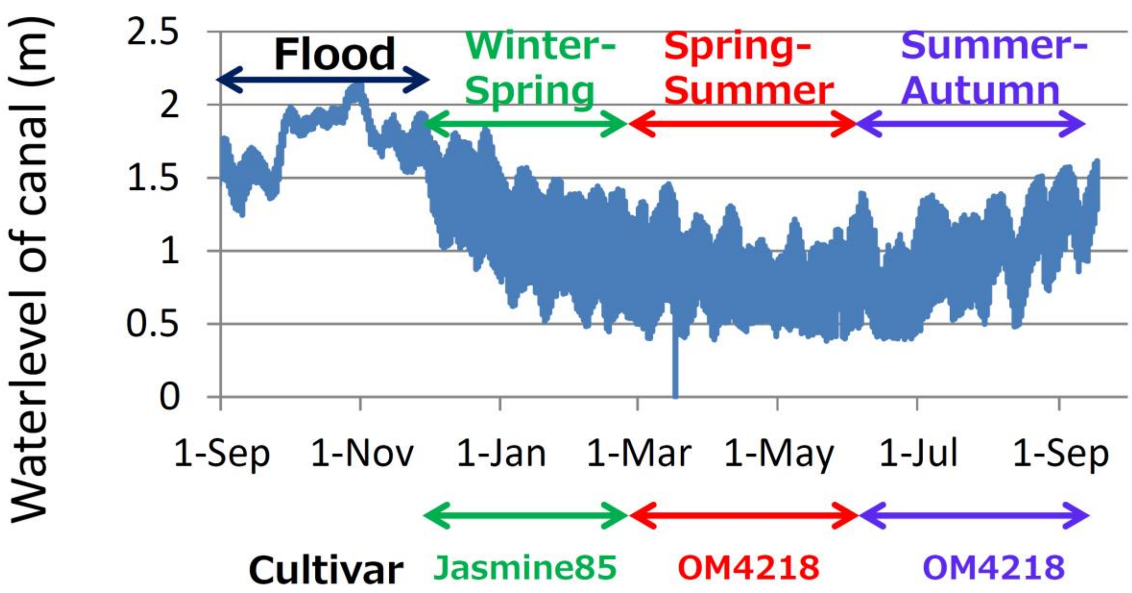
- Anaerobic stress for rice production
- High GHGs emission

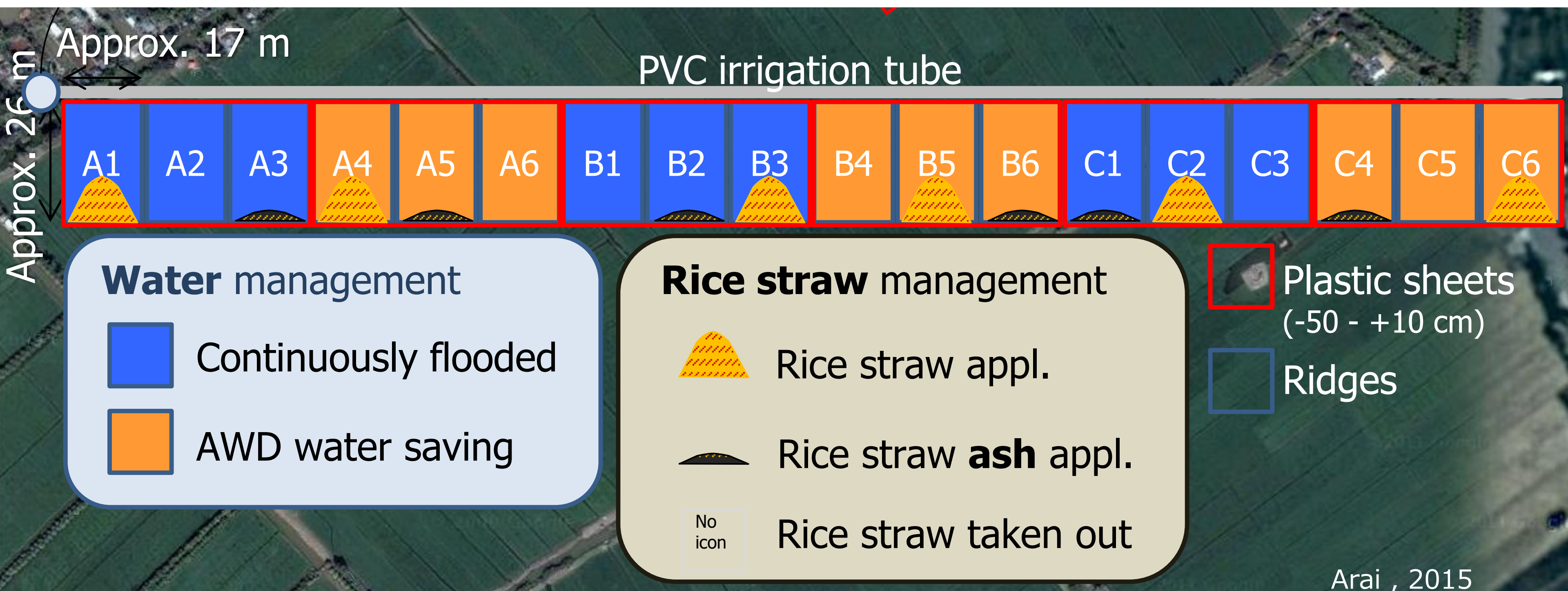
AWD

(**A**lternate **W**etting and **D**rying)

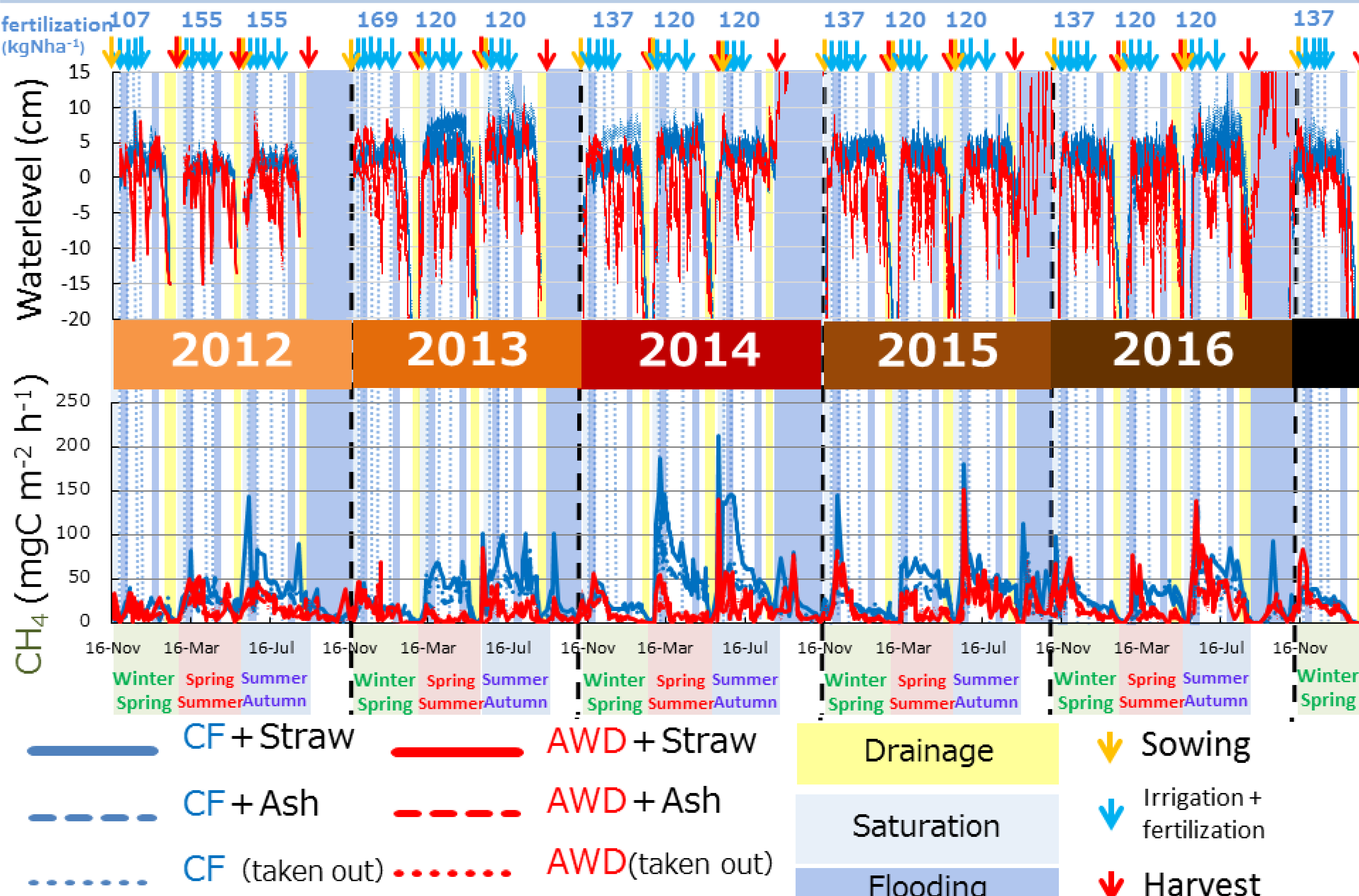
- Irrigation-water saving
- Anaerobic-stress mitigation
- GHGs mitigation




Waterlevel of canal (m)
2.5
2
1.5
1
0.5
0
Flood
Winter-Spring
Spring-Summer
Summer-Autumn
1-Sep
1-Nov
1-Jan
1-Mar
1-May
1-Jul
1-Sep
Cultivar
Jasmine85
OM4218
OM4218

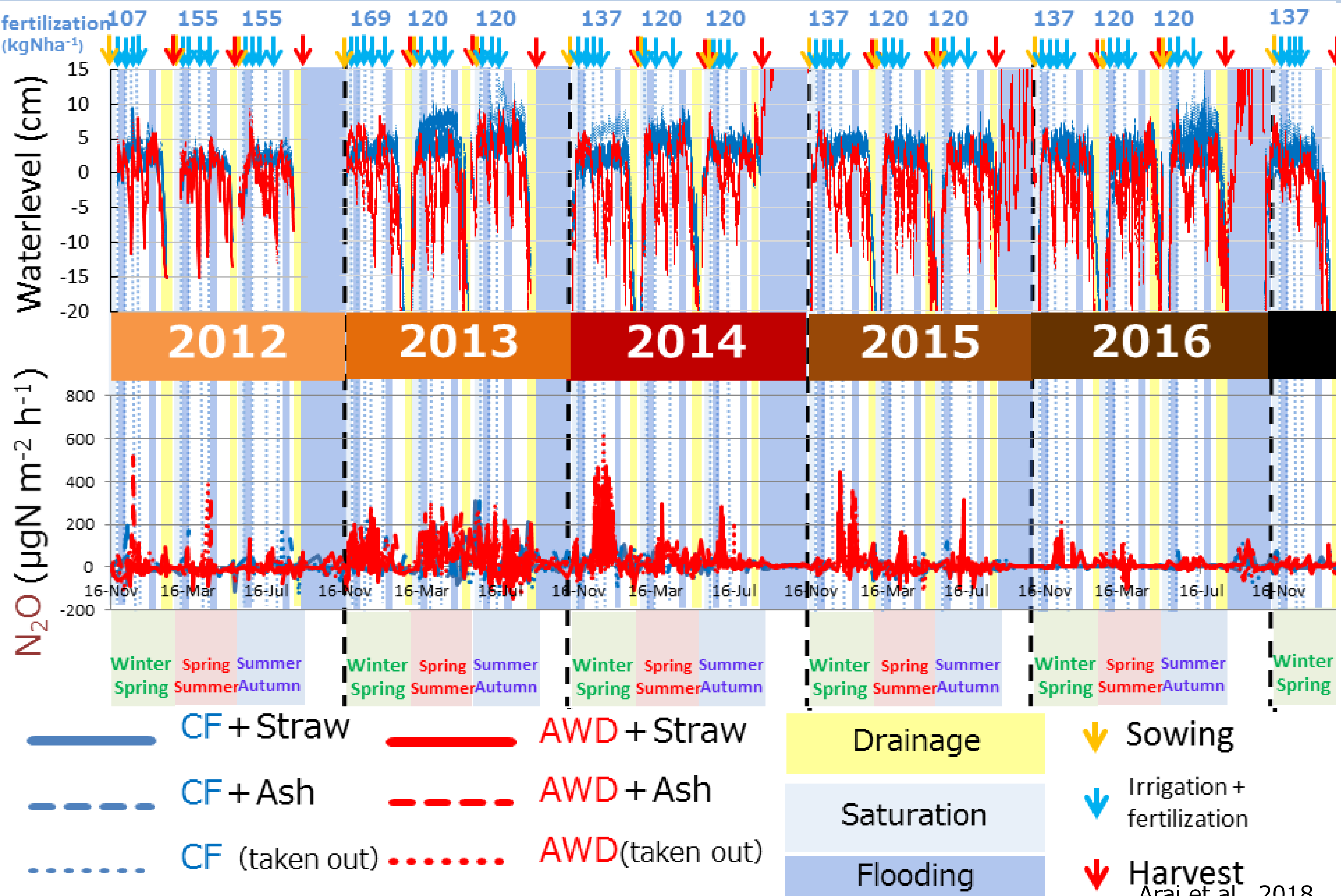

Approx. 17 m
Approx. 26 m
PVC irrigation tube
A1
A2
A3
A4
A5
A6
B1
B2
B3
B4
B5
B6
C1
C2
C3
C4
C5
C6
Water management
Continuously flooded
AWD water saving
Rice straw management
Rice straw appl.
Rice straw ash appl.
No icon
Rice straw taken out
Plastic sheets
(-50 - +10 cm)
Ridges
Arai , 2015

Characteristics of the Mekong delta



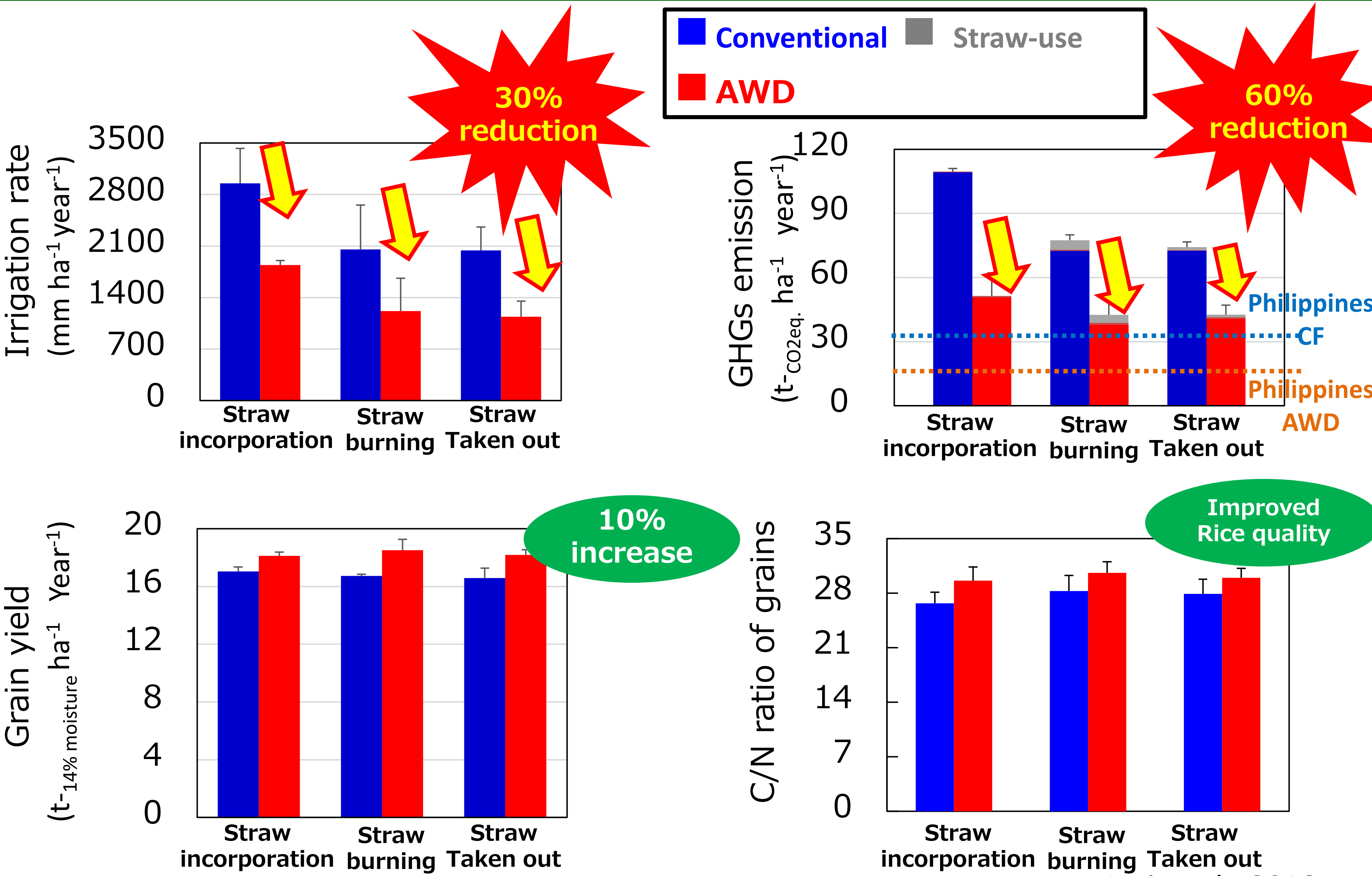
Arai et al., 2018

Characteristics of the Mekong delta



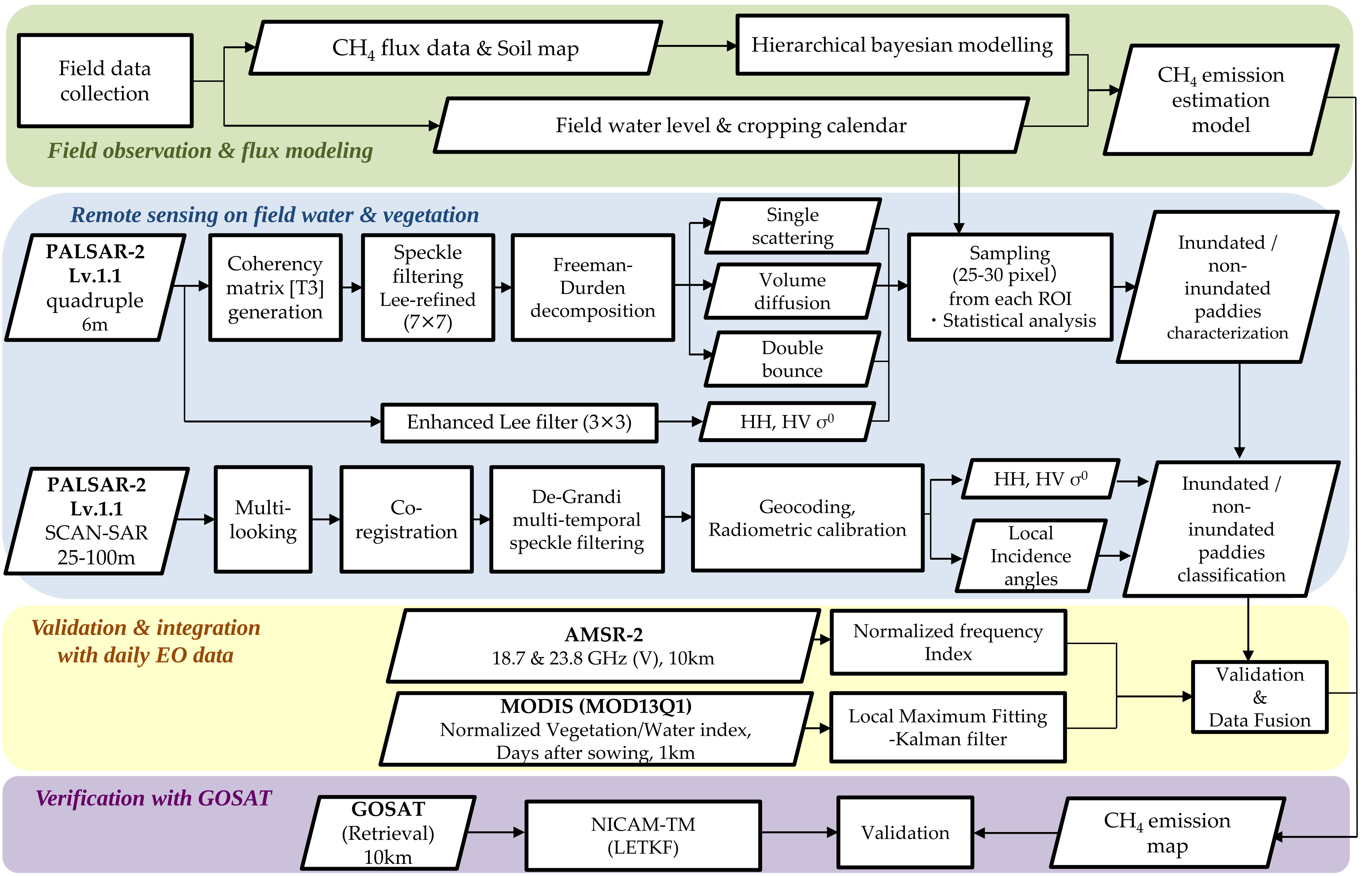
Arai et al., 2018

- Reduction of irrigation rate & GHGs (2012-2016)
- Increase of rice grains and its quality



Arai et al., 2018

Flow chart



Field data collection
CH4 flux data & Soil map
Hierarchical bayesian modelling
CH4 emission estimation model
Field water level & cropping calendar
Field observation & flux modeling
Remote sensing on field water & vegetation
PALSAR-2 Lv.1.1 quadruple 6m
Coherency matrix [T3] generation
Speckle filtering Lee-refined (7×7)
Freeman-Durden decomposition
Single scattering
Volume diffusion
Double bounce
Sampling (25-30 pixel) from each ROI
・Statistical analysis
Inundated / non-inundated paddies characterization
Enhanced Lee filter (3×3)
HH, HV σ0
PALSAR-2 Lv.1.1 SCAN-SAR 25-100m
Multi-looking
Co-registration
De-Grandi multi-temporal speckle filtering
Geocoding, Radiometric calibration
HH, HV σ0
Local Incidence angles
Inundated / non-inundated paddies classification
Validation & integration with daily EO data
AMSR-2
18.7 & 23.8 GHz (V), 10km
Normalized frequency Index
MODIS (MOD13Q1)
Normalized Vegetation/Water index, Days after sowing, 1km
Local Maximum Fitting -Kalman filter
Validation & Data Fusion
Verification with GOSAT
GOSAT (Retrieval) 10km
NICAM-TM (LETKF)
Validation
CH4 emission map

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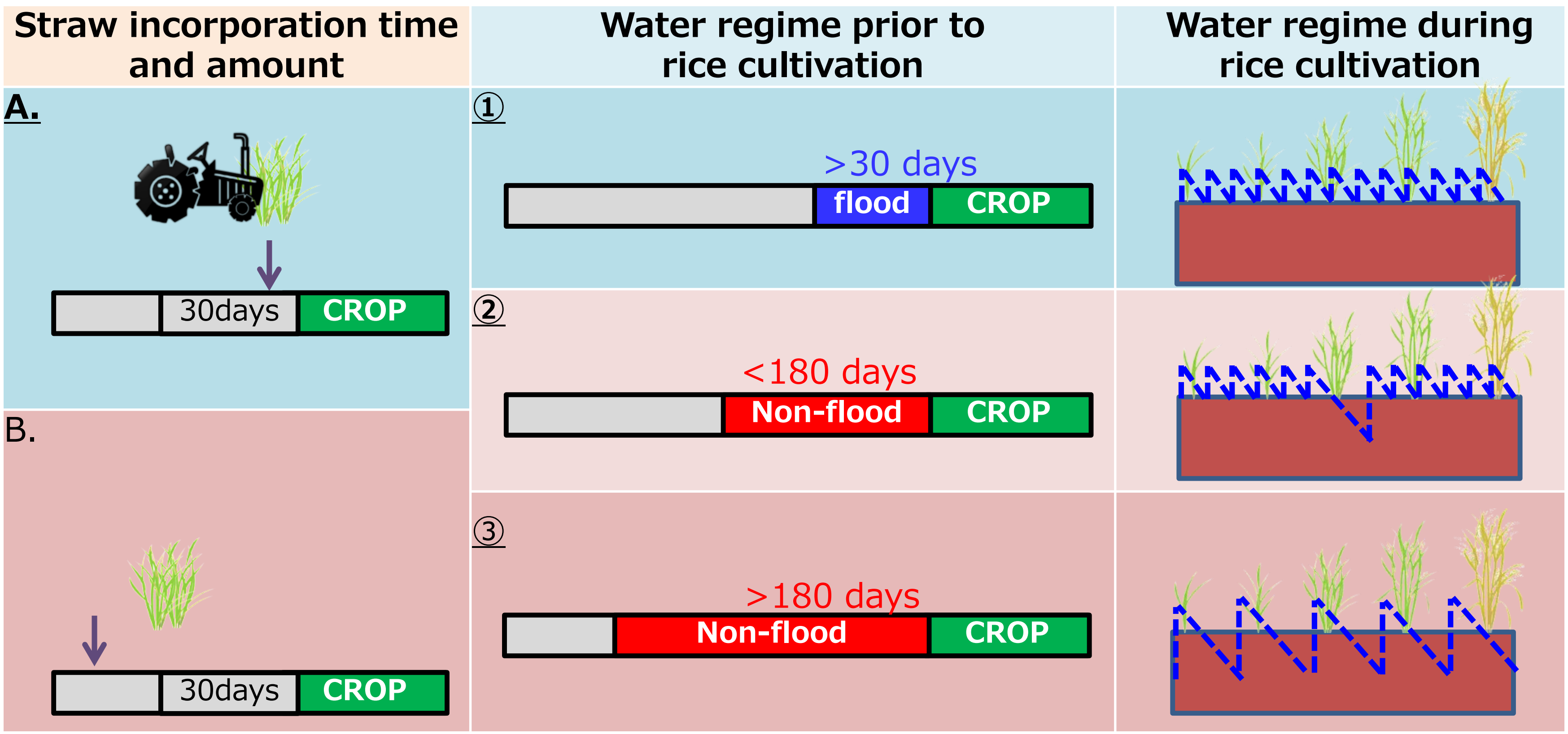
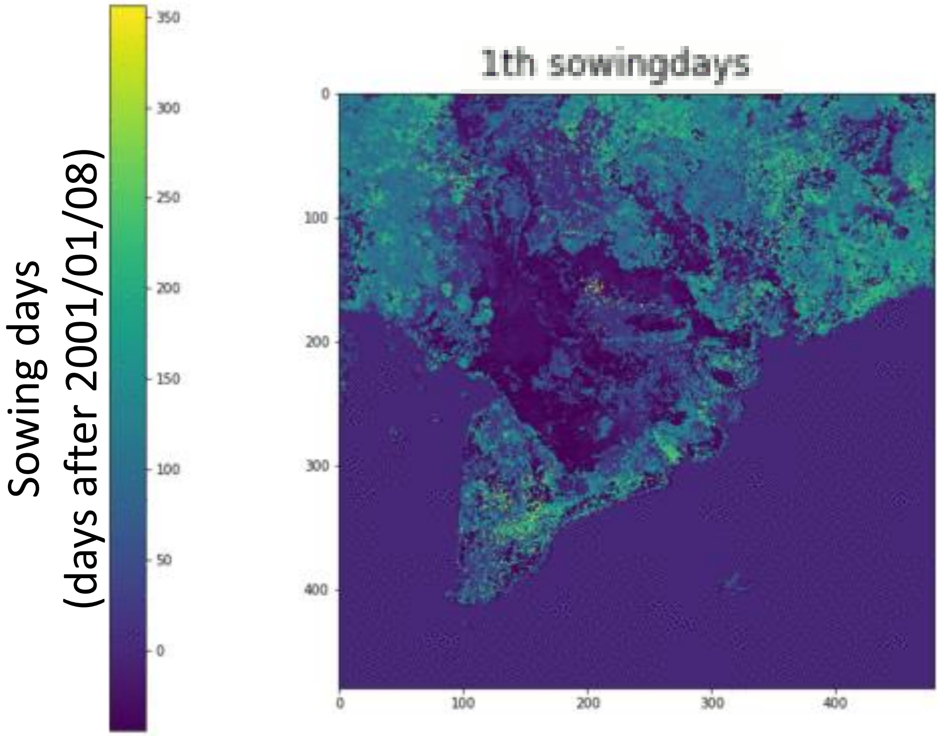
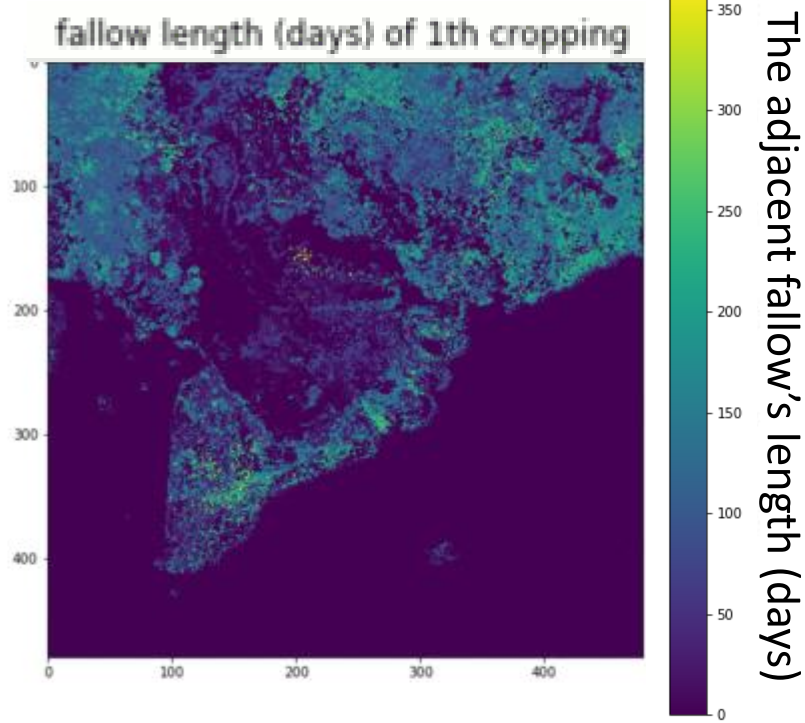
IPCC guideline (Tier1)
[Emission factor × Scaling factor in IPCC guideline]

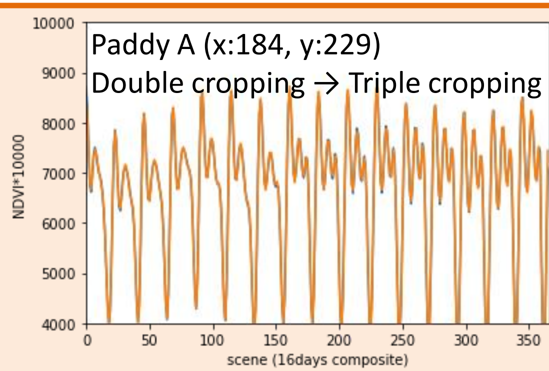


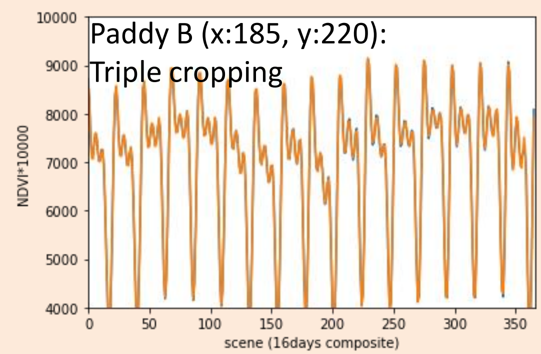
Cropping calendar evaluation with MODIS-NDVI (LMF-KF) for GCOM-C





Samples of paddies





Arai et al., 2018

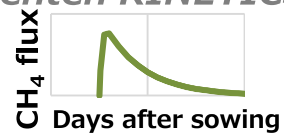
Semi-empirical **daily** CH_4 flux (mg C m^{-2} hr^{-1}) Model

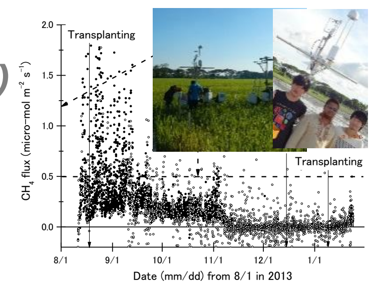
CH_4 emission <u>on a specific date</u>

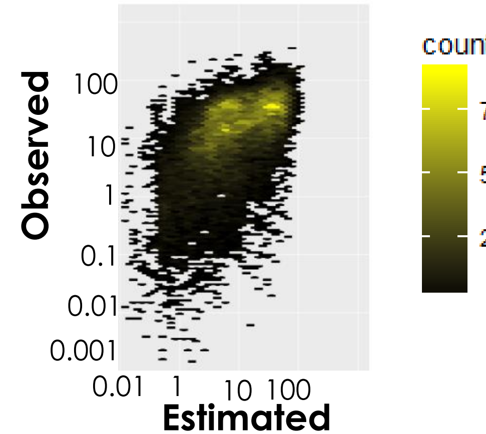
= γ * *carbon_management* / *non-inundated_fallow* / *inundated_fallow* * *water_management* *α*β

***carbon_management* (Michaelis-Menten KINETICS)**

=[exp(-***DAS****δ)-exp(-***DAS****(δ+ω))+κ]

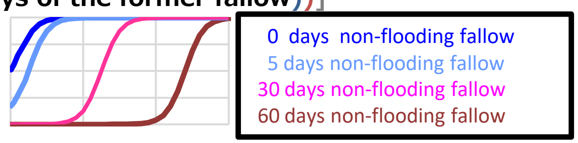






***non-inundated_fallow* (OXYDATION CAPACITY)**

= [1+EXP(-1* ζ *(***DAS*** – ι* **days of nonflooding days of the former fallow**))]

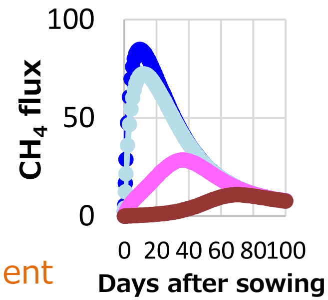


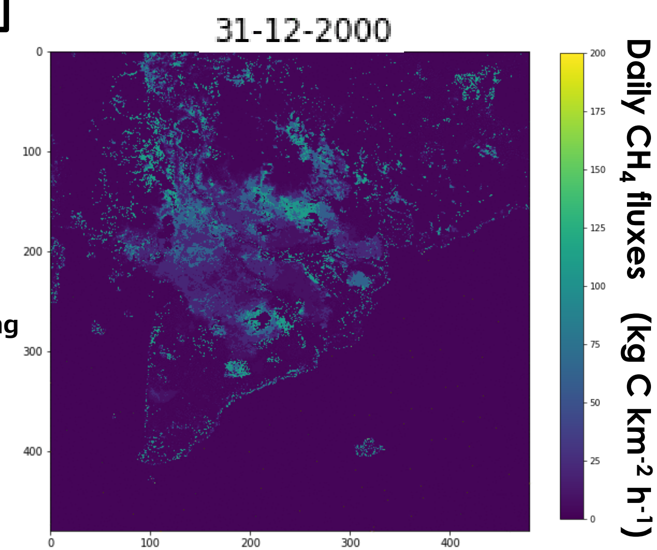
inundated_fallow

= EXP(ε * **days of flooding days of the former fallow**)

water_management

= EXP(η * **inundated days during the last 10days**)





DAS←*days after sowing*

α ←straw incorporation coefficient

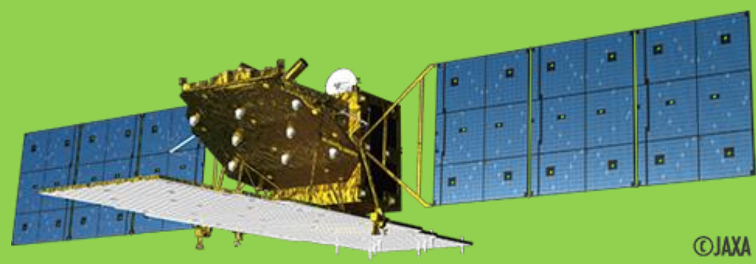
β ←acid sulfate・coastal sandy soil coefficient

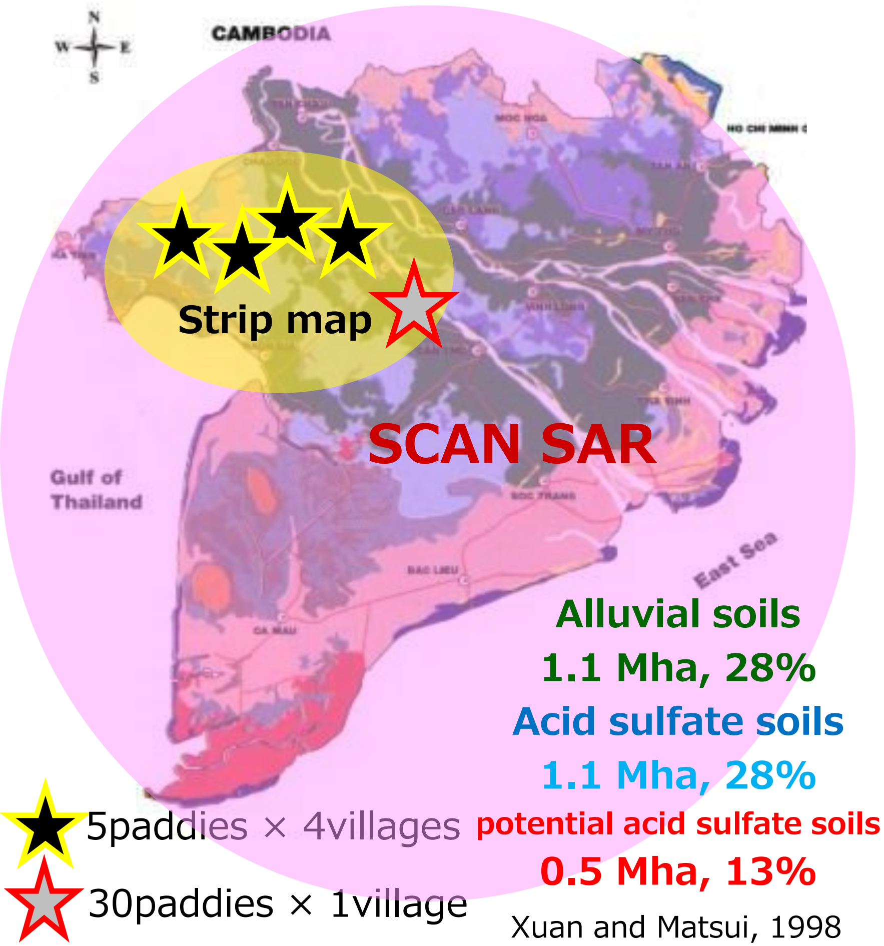
γ, η, δ, ε , ω , ζ , ι, κ←constant (>0)

Arai et al., 2018

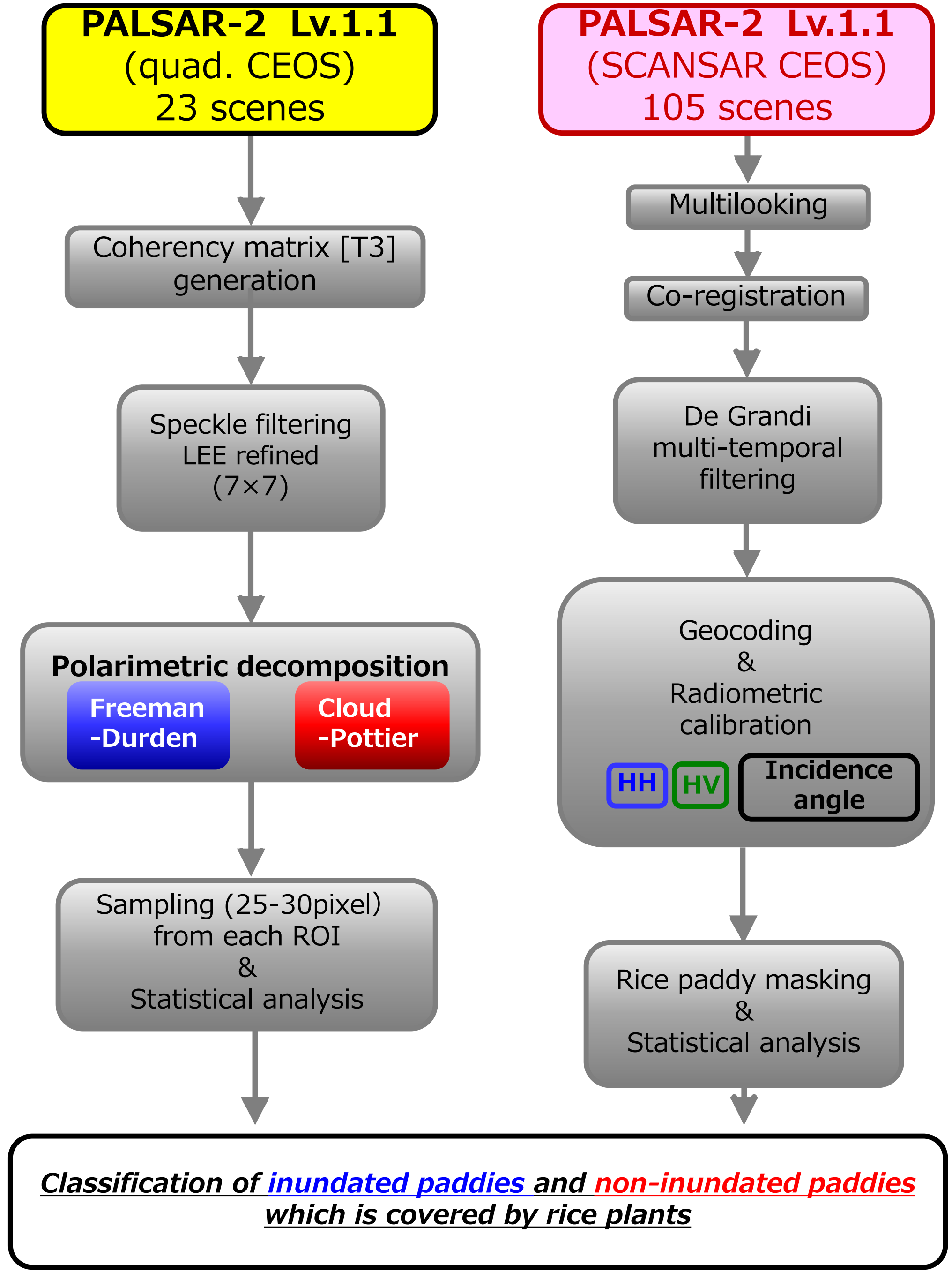
ALOS-2/PALSAR-2

– **L**band-**S**ynthetic **A**perture **R**adar –



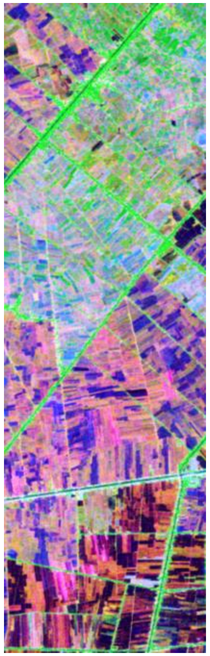


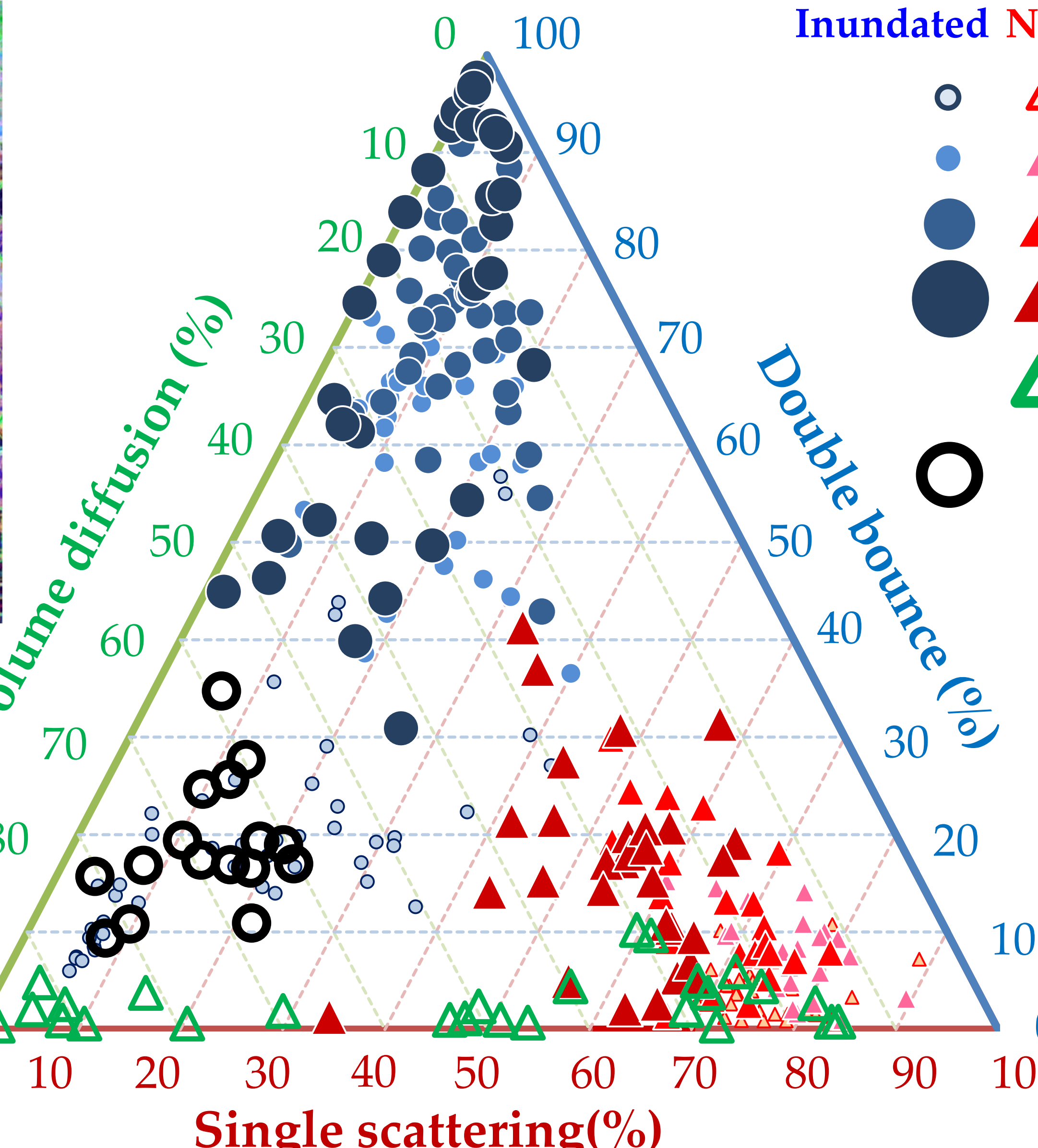
Xuan and Matsui, 1998

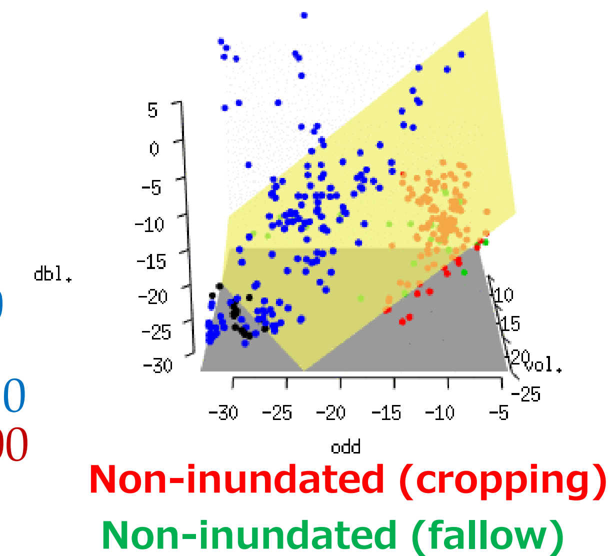


Modified from Avtar *et al*. 2012

-Freeman-Durden decomposition-

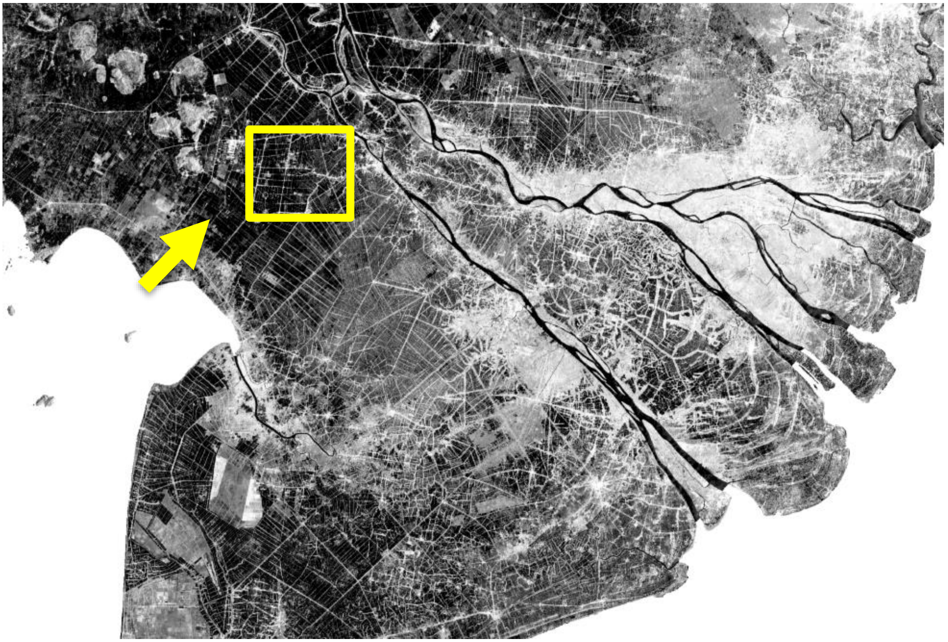




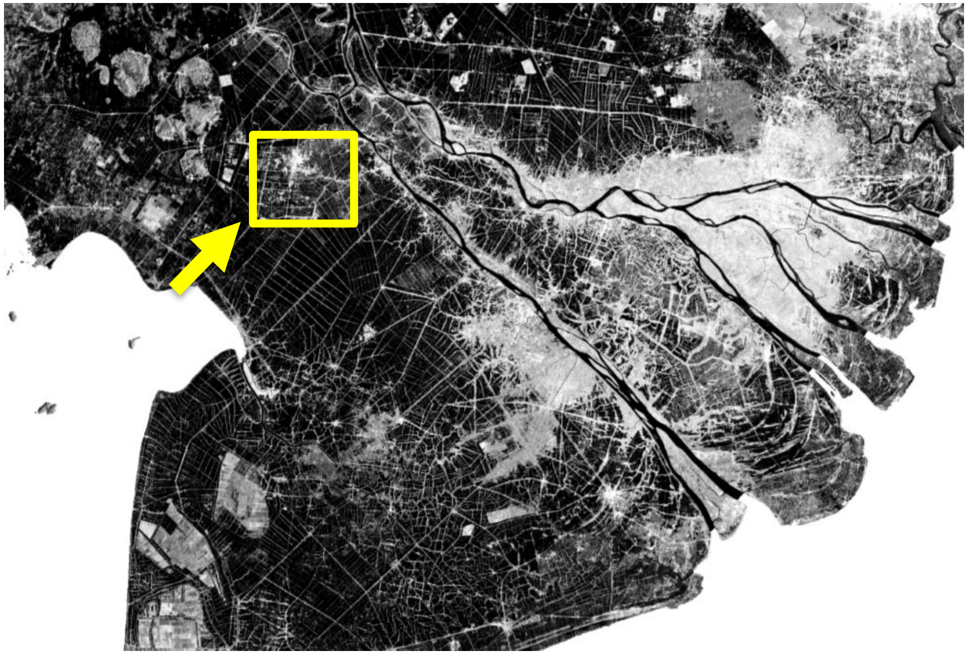


SCANSAR (intensity - HHσ^0)

Dry season **(2015 Apr. 10)**



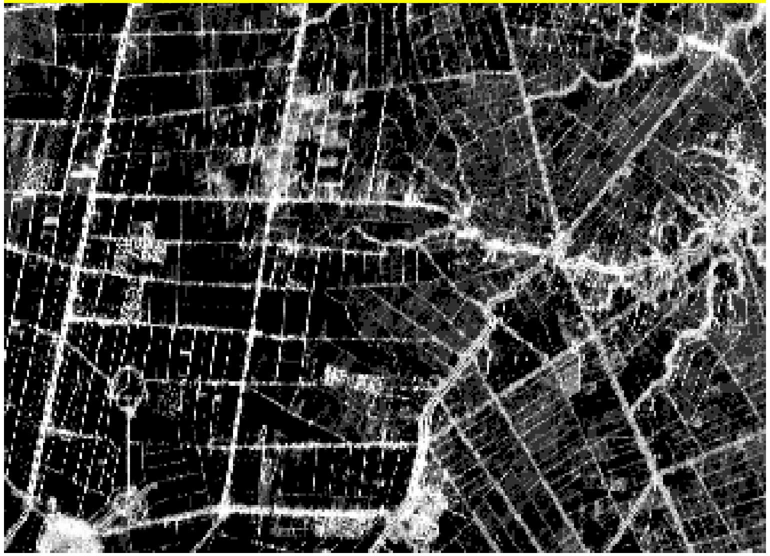
Flooding season **(2015 Oct. 23)**



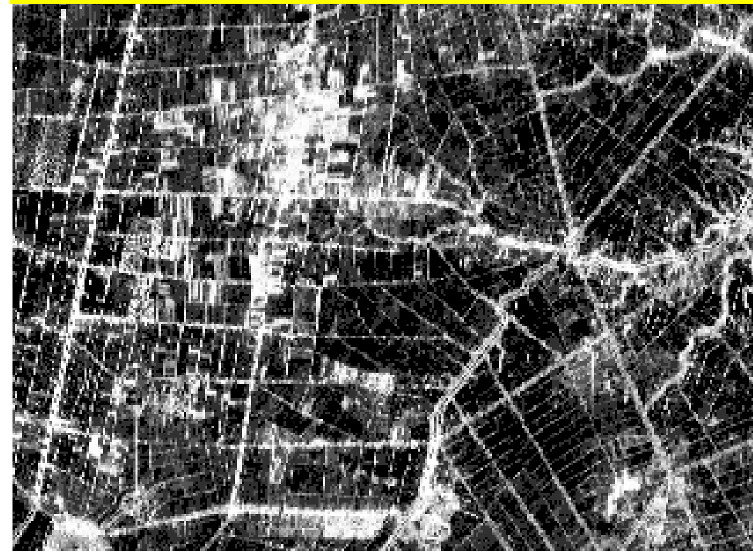
Arai et al., 2018

Double bounce detection by SCANSAR (intensity - $HH\sigma^0$)

Dry season (2015 Apr. 10)



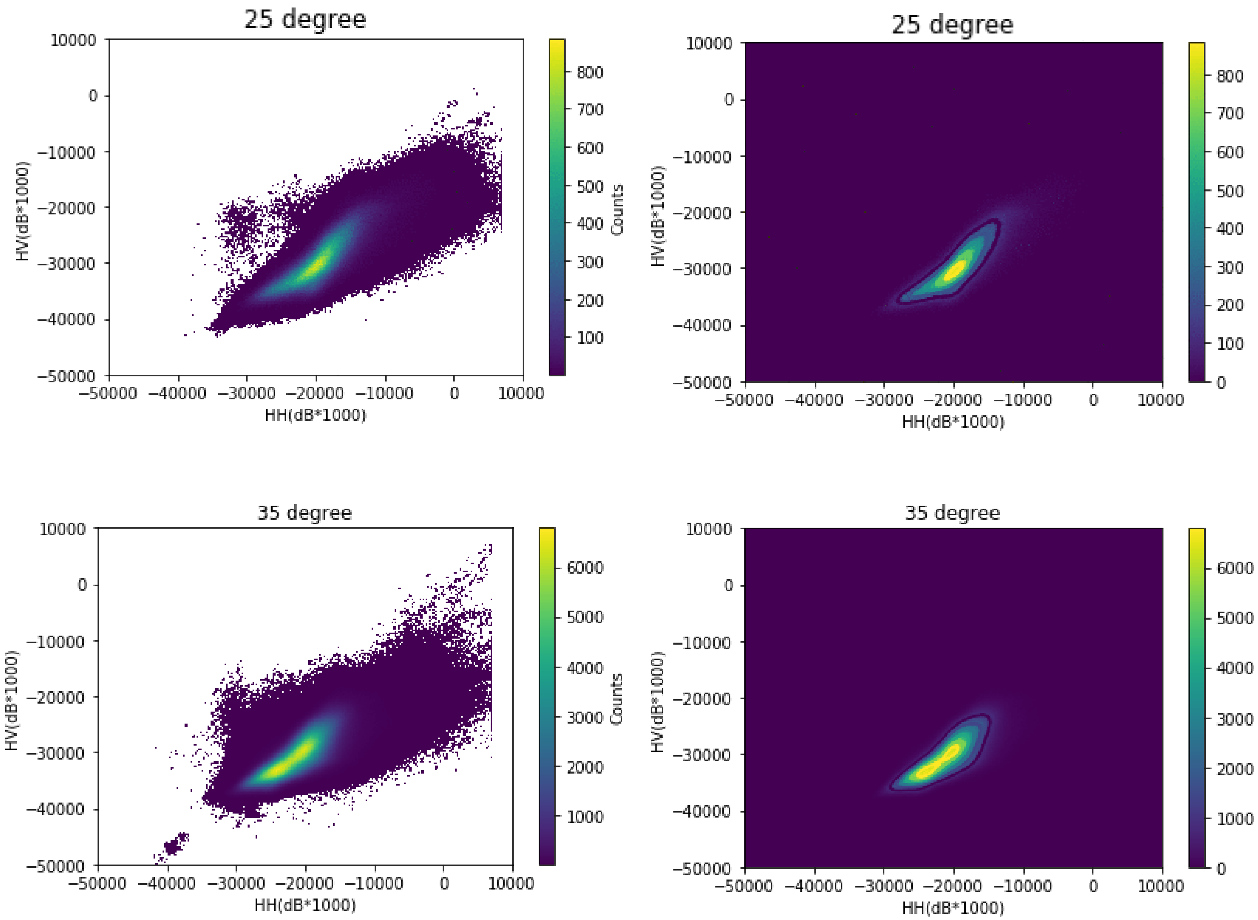
Rainy season (2015 Jul. 03)



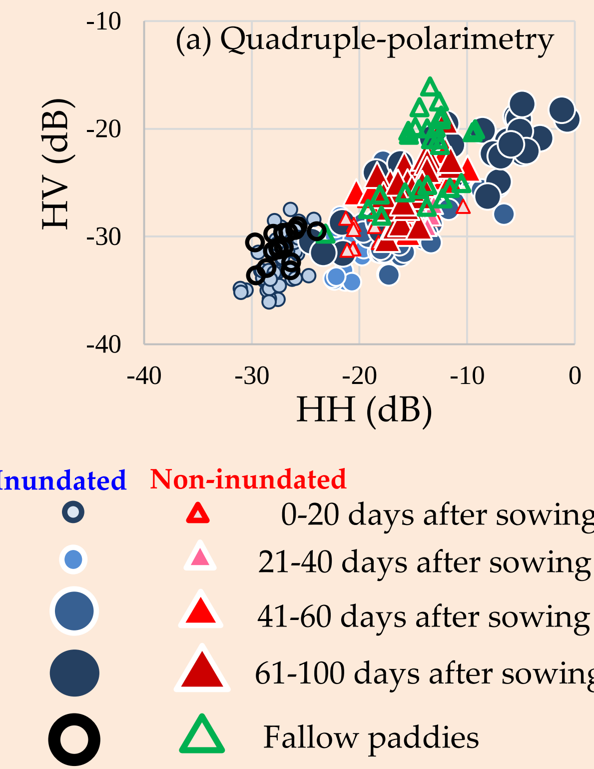
Flooding season (2015 Oct. 30) **-LANDSAT-8-**

Flooding season (2015 Oct. 23)

SCAN-SAR (25m)



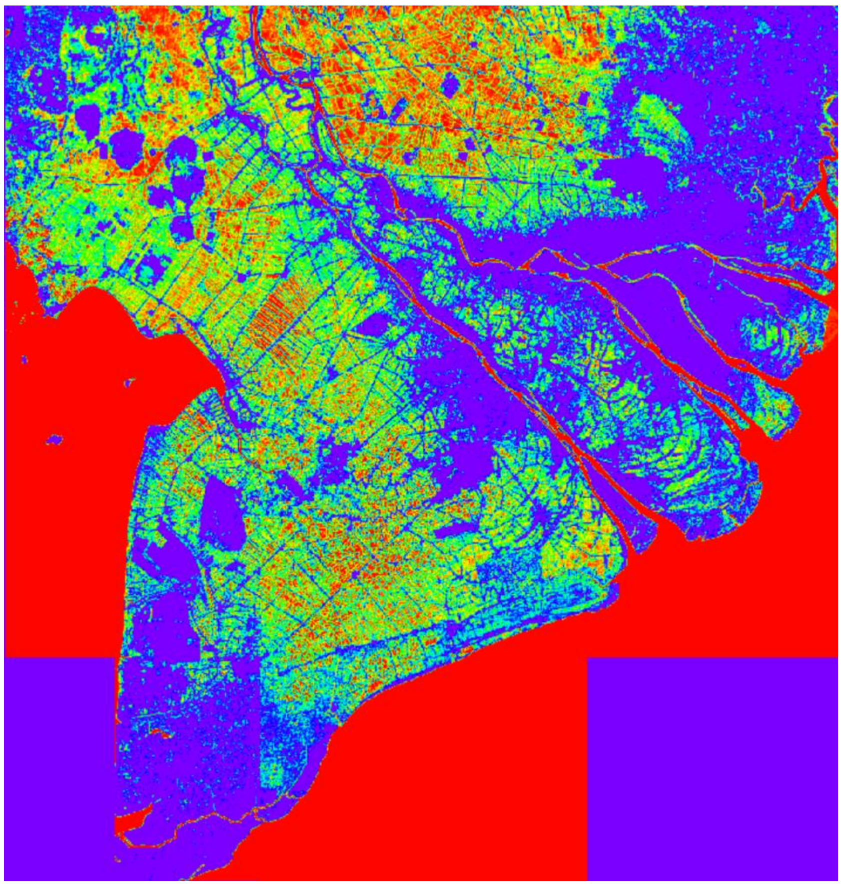
Full-polarimetry (3m)

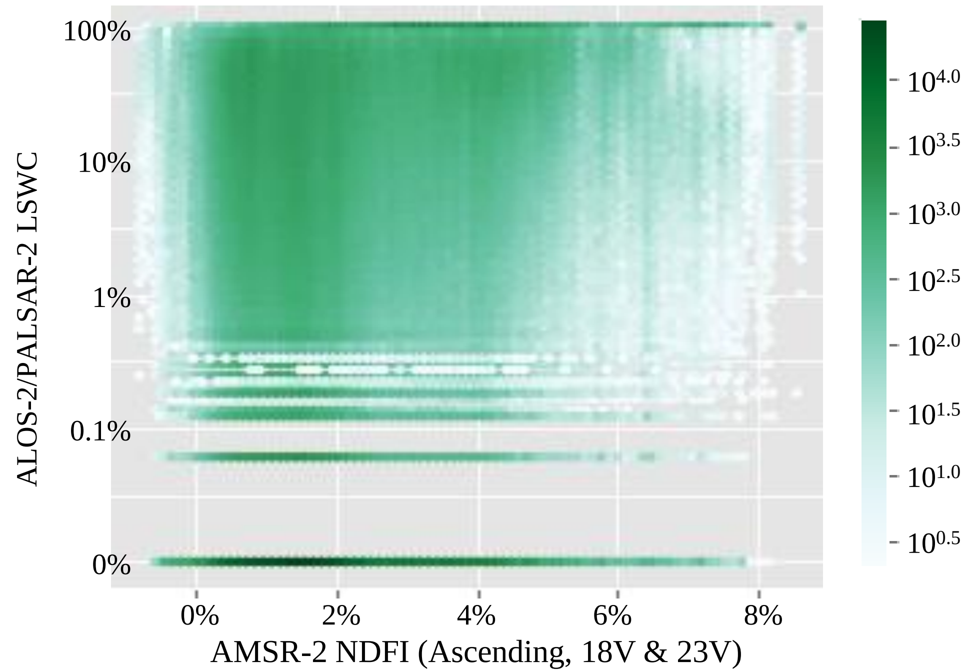


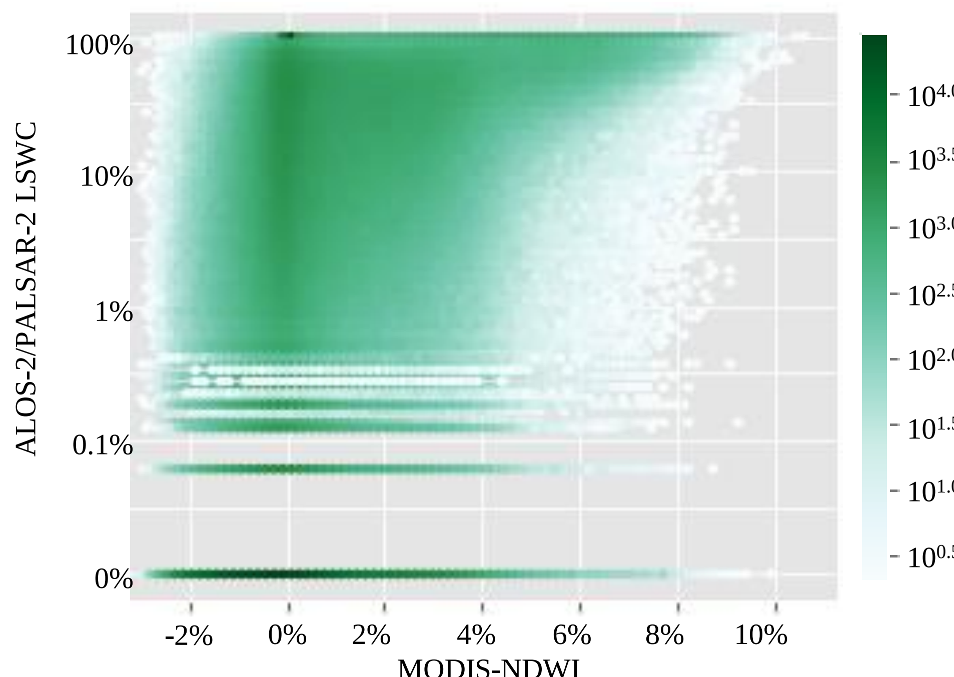
Arai et al., 2018

Floodability analysis

(Cumulative LSWC/
observation scenes)

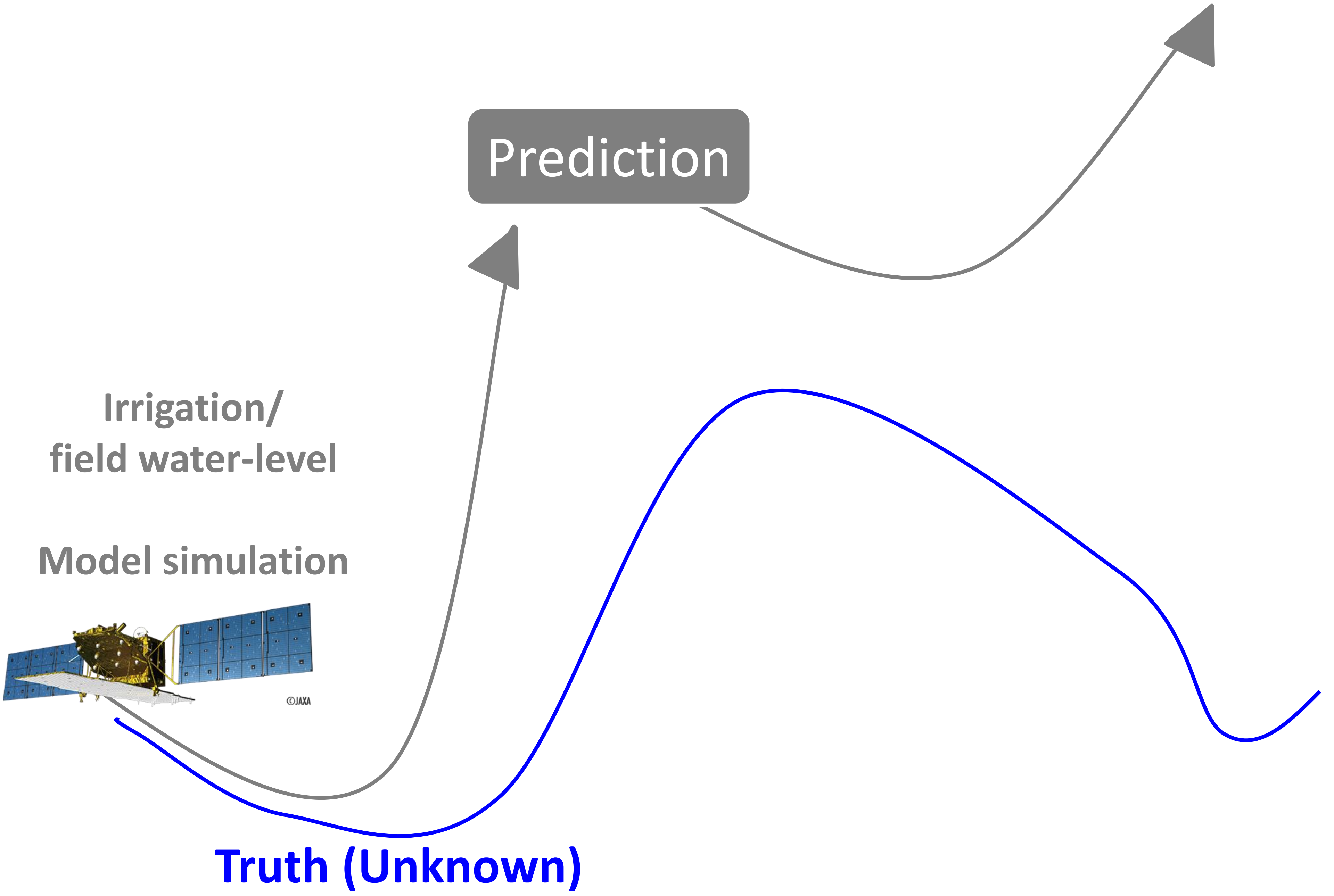




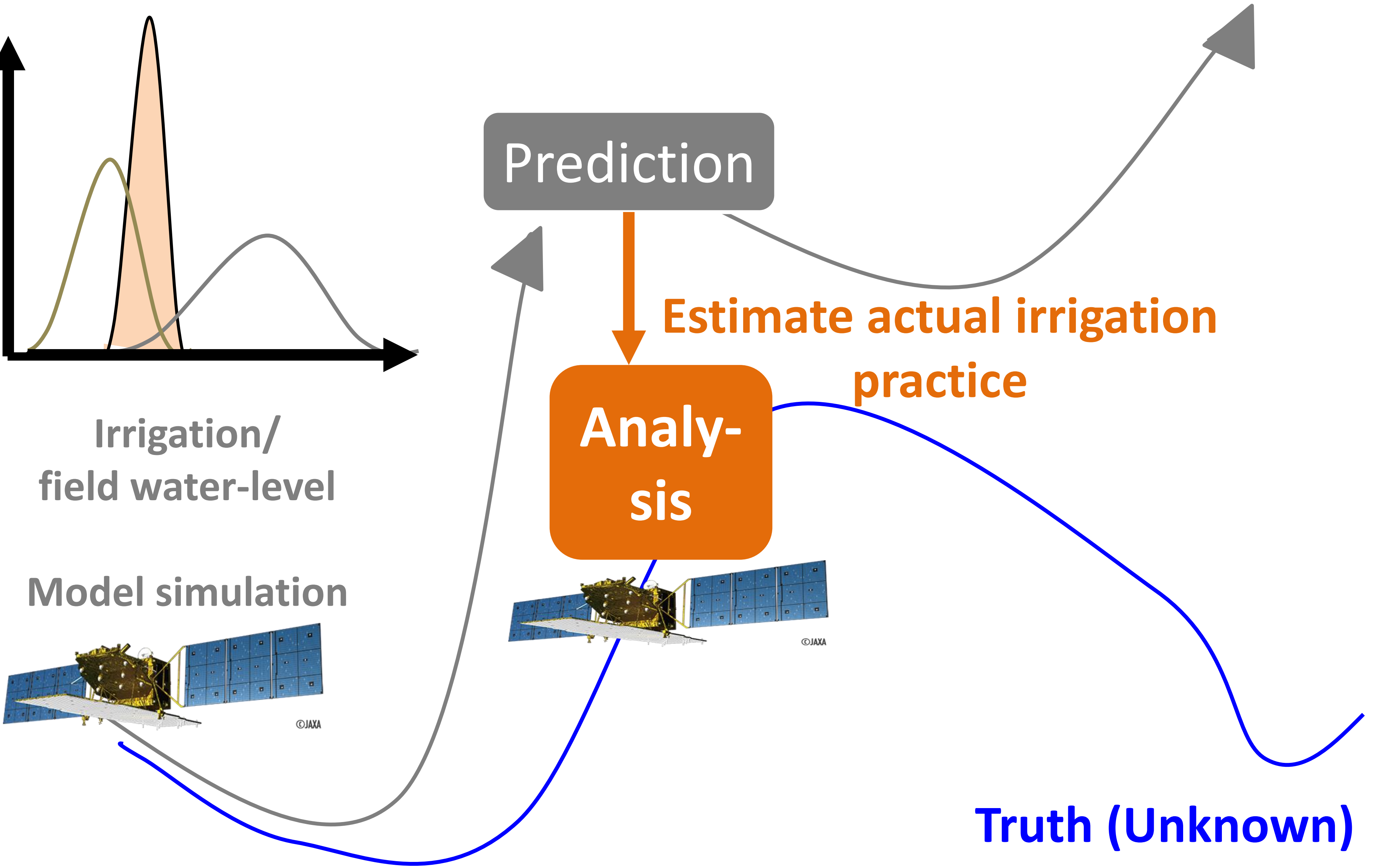


Arai et al., 2018

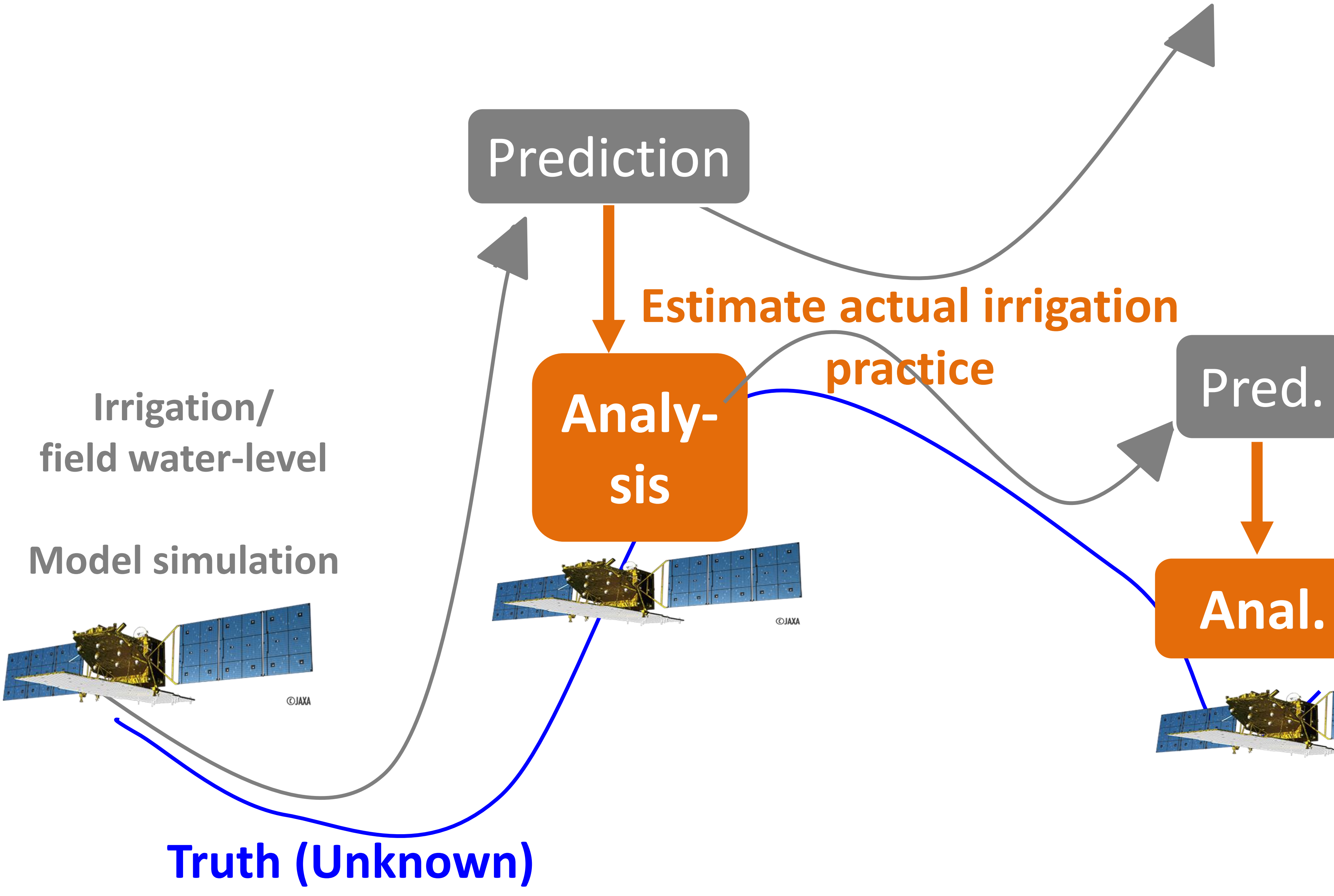
Our data integration scheme



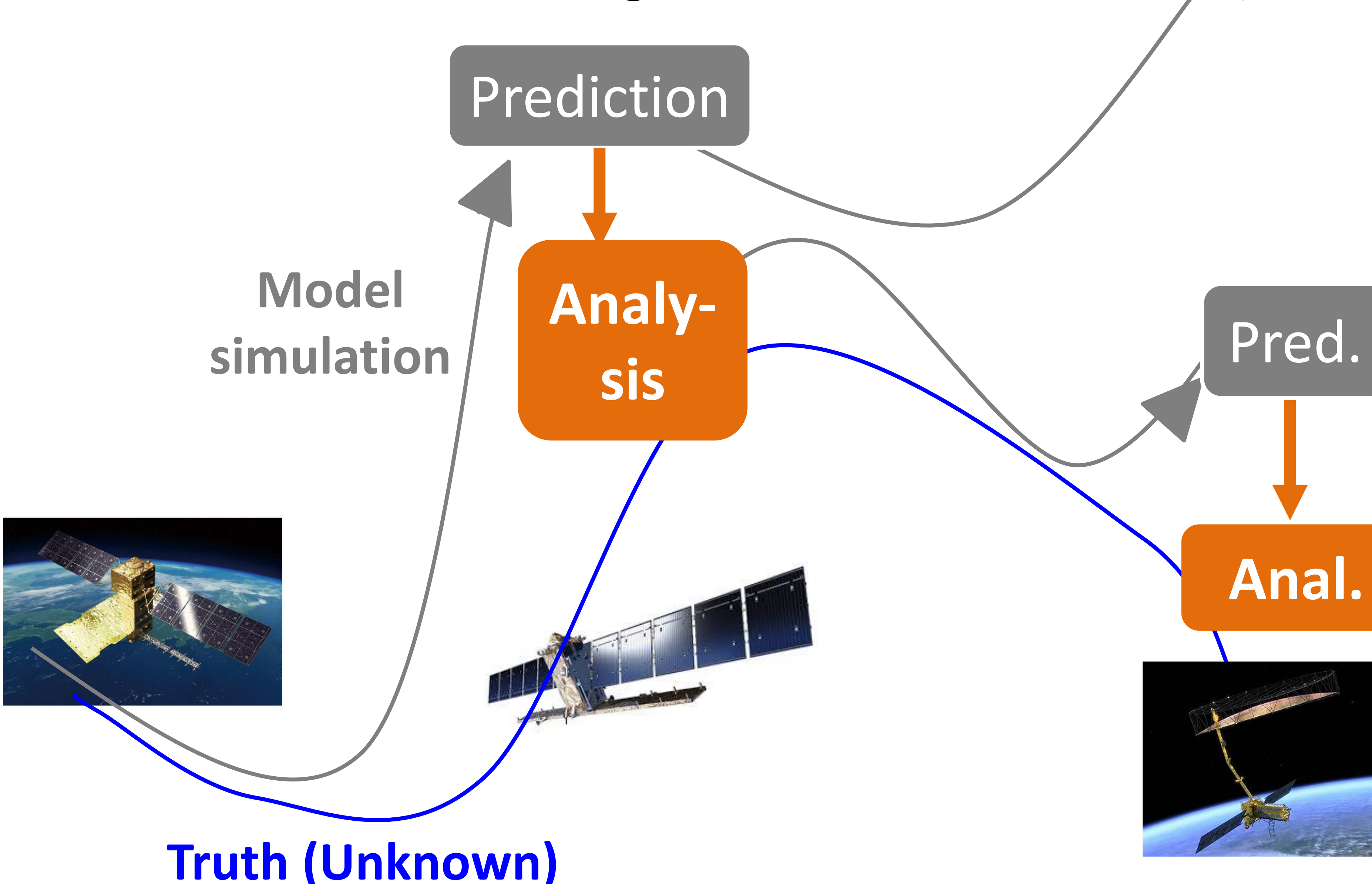
Our data integration scheme



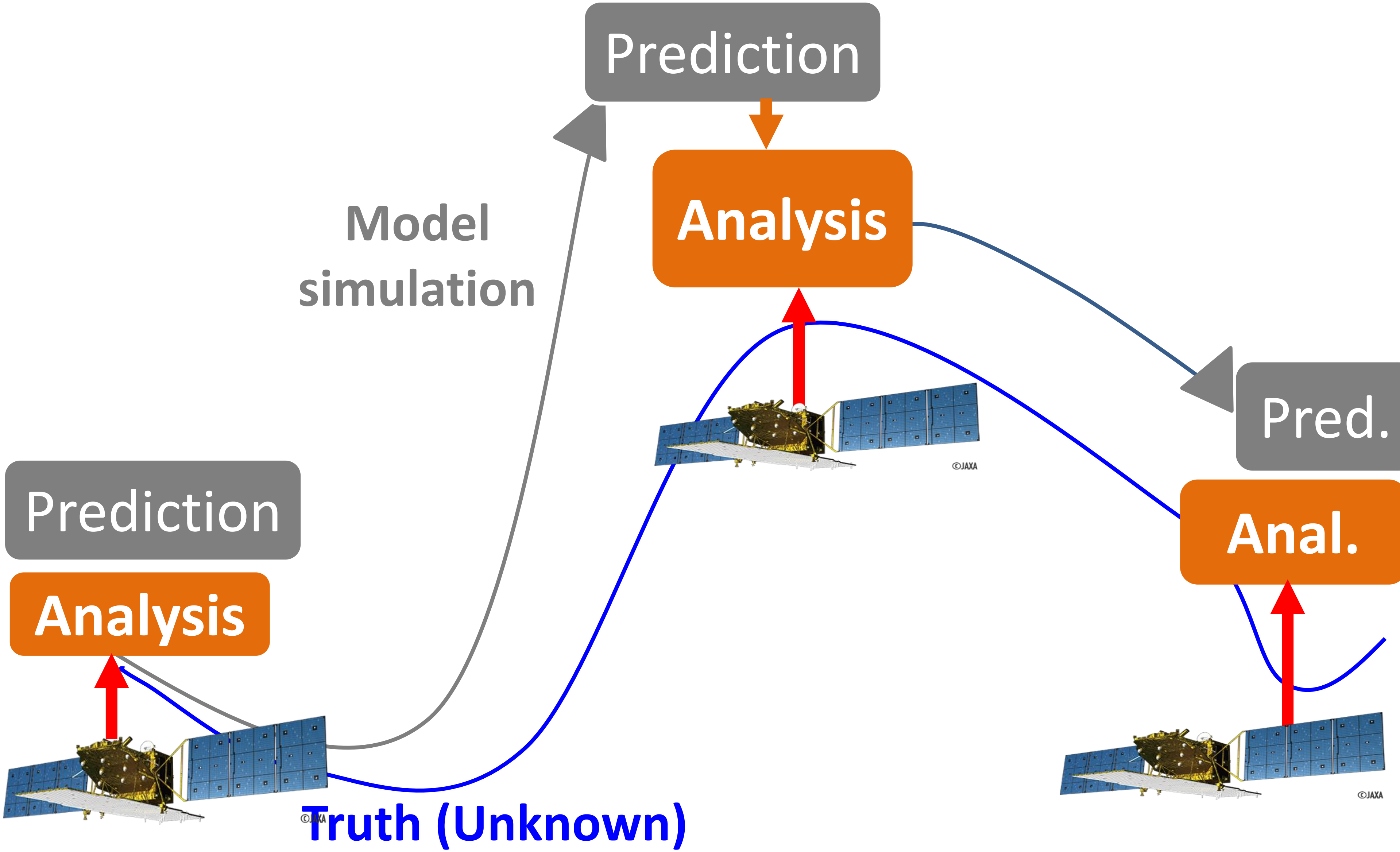
Our data integration scheme



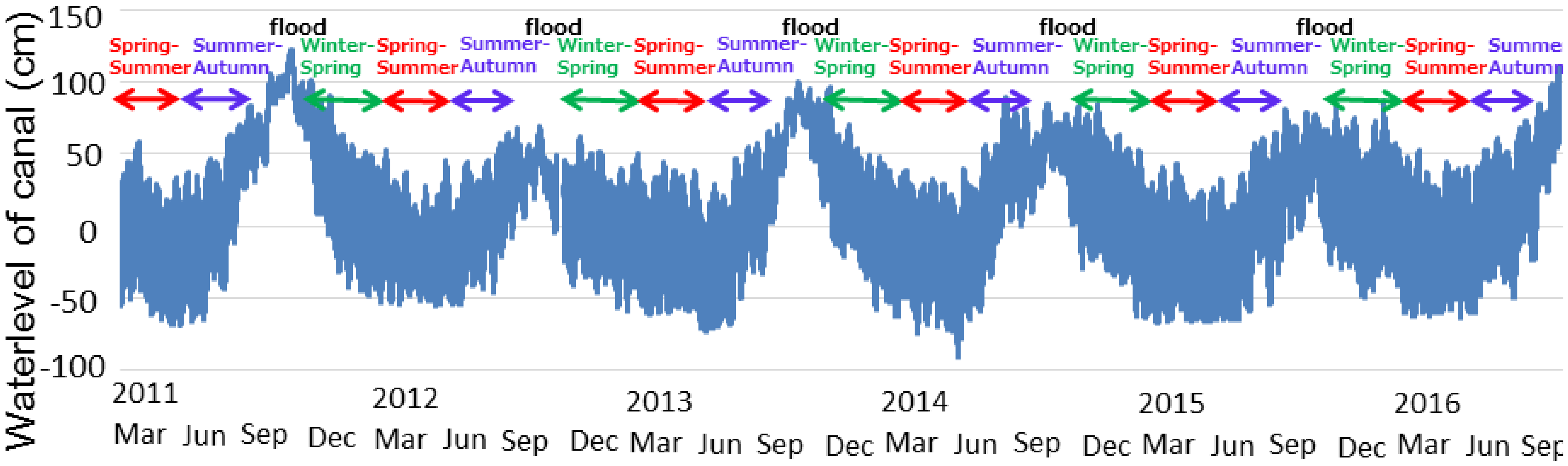
Different frequency SARs / optical sensors integration

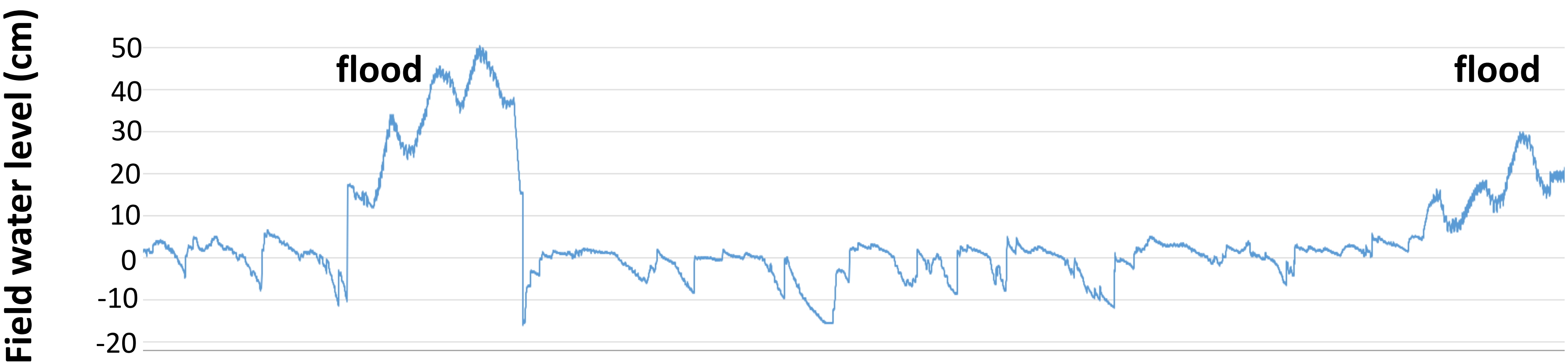


Speckle noise filtering considering geo-process

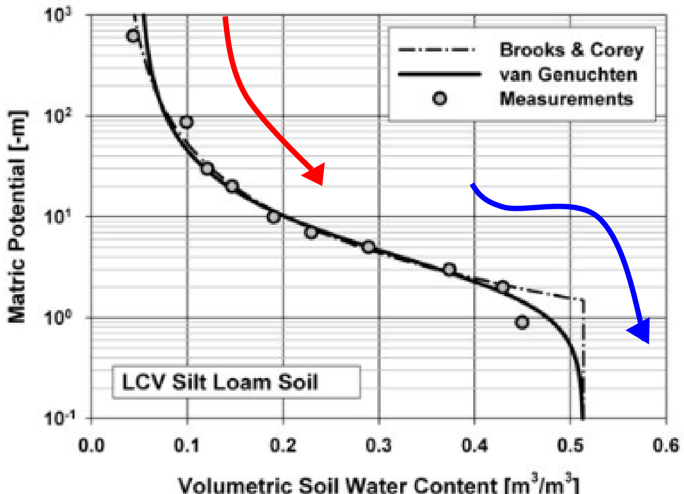


Simulation scheme considering actual states of the delta

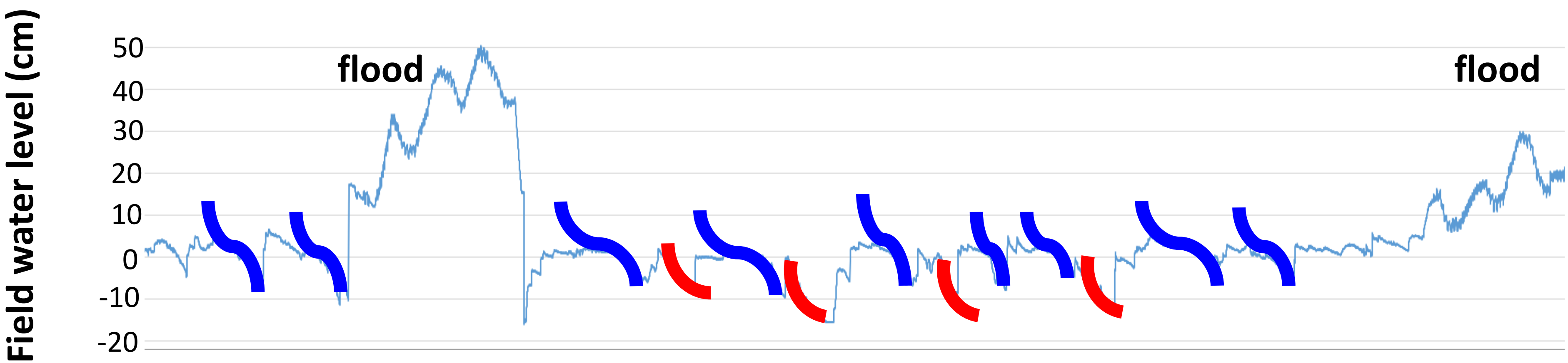




Simulation scheme
Hysteresis of soil matric potential



https://slideplayer.com/slide/5038747/



Model structure

Implicit RK4 integration model

WL = field water level

Matric-potential at irrigation index (Di) = Σ(soil inundation rate before the irrigation, days after sowing, clay content)·α_i

constraint

t = days after irrigation

Gravitational-potential at irrigation index (G) = field water level after irrigation *β

$$\frac{dWL}{dt} = \gamma * \exp\left(\delta * \left\{1 - \log\left[\exp\left(Di * (t - G)\right) + 2 + \exp\left(-Di * (t - G)\right)\right]\right\} * Di * (t - G)\right)$$

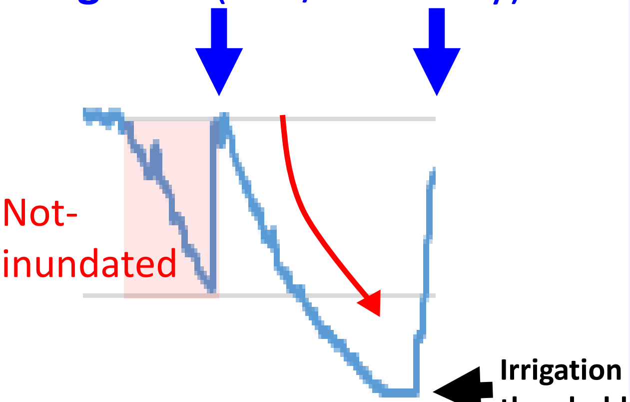
$$- \frac{\delta * \left[\exp\left(Di * (t - G)\right) - \exp\left(-Di * (t - G)\right)\right] * Di * (t - G)}{\exp\left(Di * (t - G)\right) + 2 + \exp\left(-Di * (t - G)\right)}$$

$$+ Di * \left\{1 - \log\left[\exp\left(Di * (t - G)\right) + 2 + \exp\left(-Di * (t - G)\right)\right]\right\} + \text{rain-fall}$$

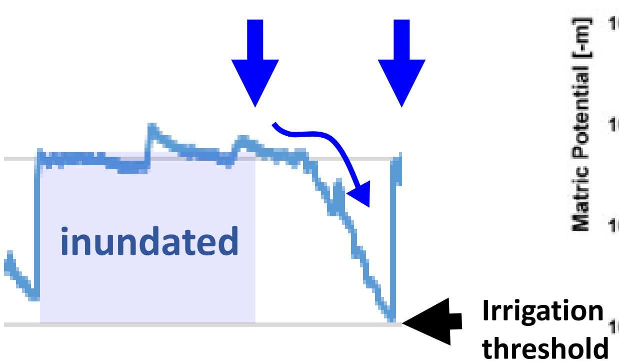
Irrigation function
if WL < *threshold*
WL = *x-cm above the soil*

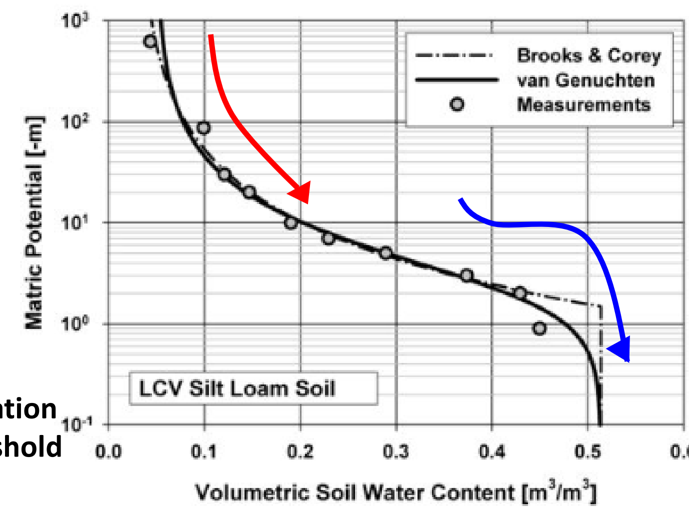
Parameter update by the analysis with EO data

Irrigation (init./boundary)



Irrigation (init./boundary)





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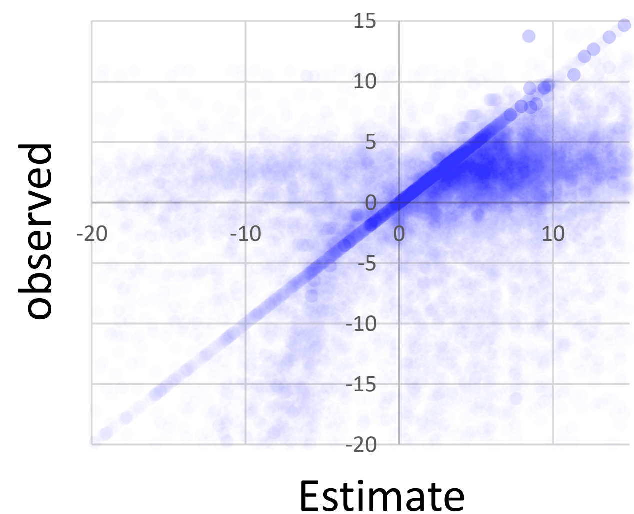
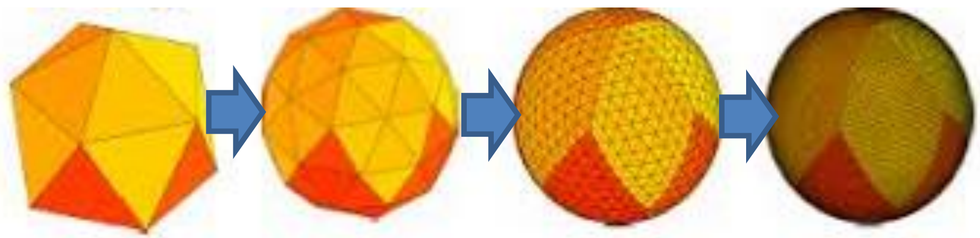
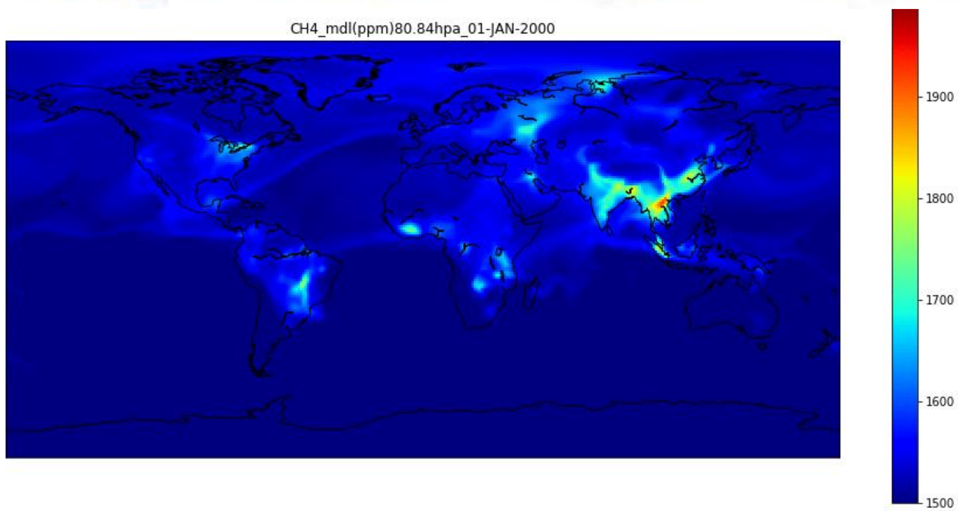


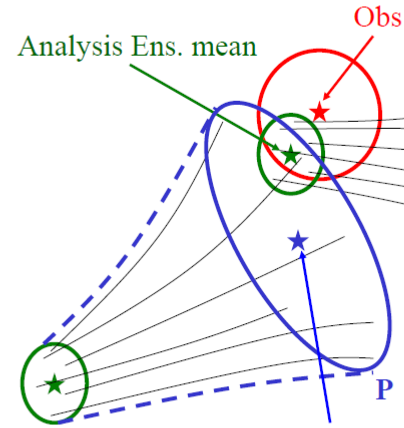
NICAM-TM(Chem)-LETKF with AMSU, PREPBUFR and GOSAT

Local **E**nsemble **T**ransform **K**alman **F**ilter

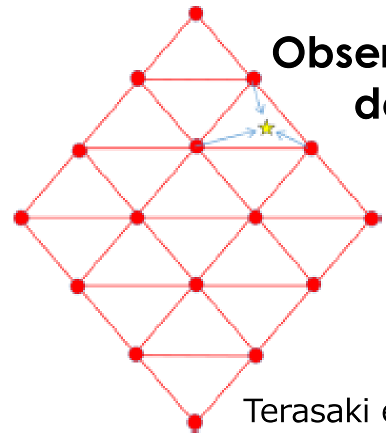
Nonhydrostatic **IC**osahedral **A**tmospheric **M**odel**-TM(Chem)**







Miyoshi., 2005



Observation operator development for GOSAT

Terasaki et al., 2014

Direct comparison between GOSAT and emission data is meaningless…

→GOSAT data assimilation with NICAM-TM!

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D09110, doi:10.1029/2010JD014673, 2011

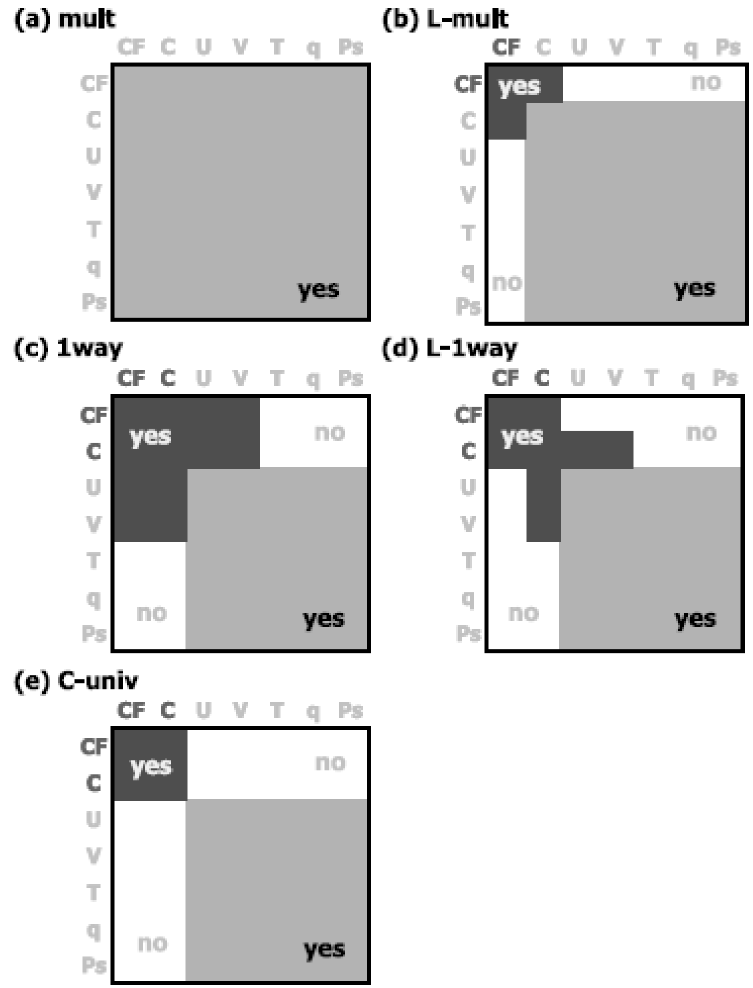
"Variable localization" in an ensemble Kalman filter: Application to the carbon cycle data assimilation

Ji-Sun Kang,[1] Eugenia Kalnay,[1] Junjie Liu,[2] Inez Fung,[2] Takemasa Miyoshi,[1] and Kayo Ide[1]

Flux estimation from atmospheric concentration by omitting multi-collinearity

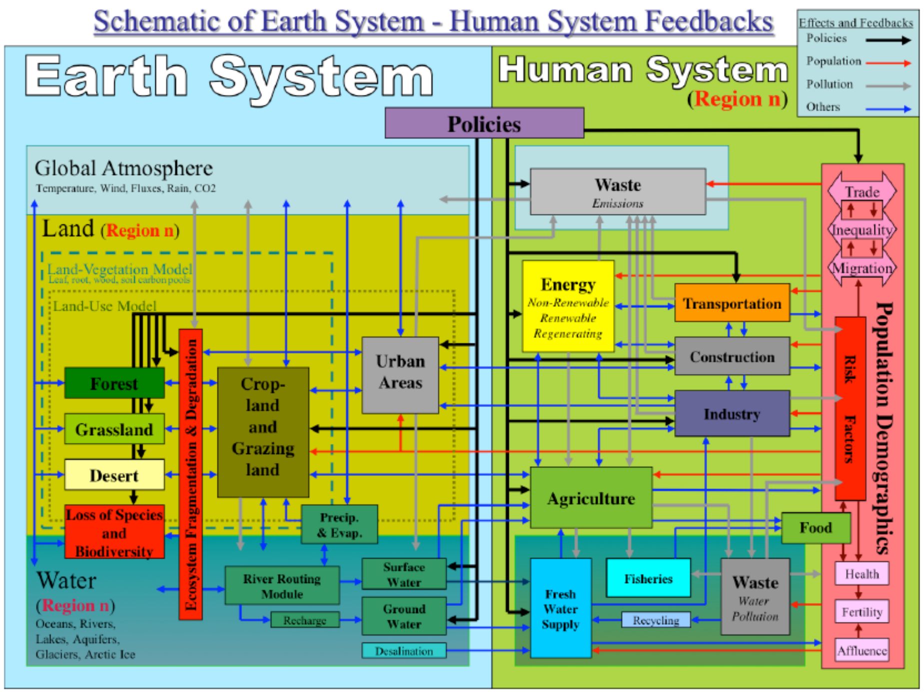
- **No direct emission or apriori info. is required!**

Transparent MR**V**!!

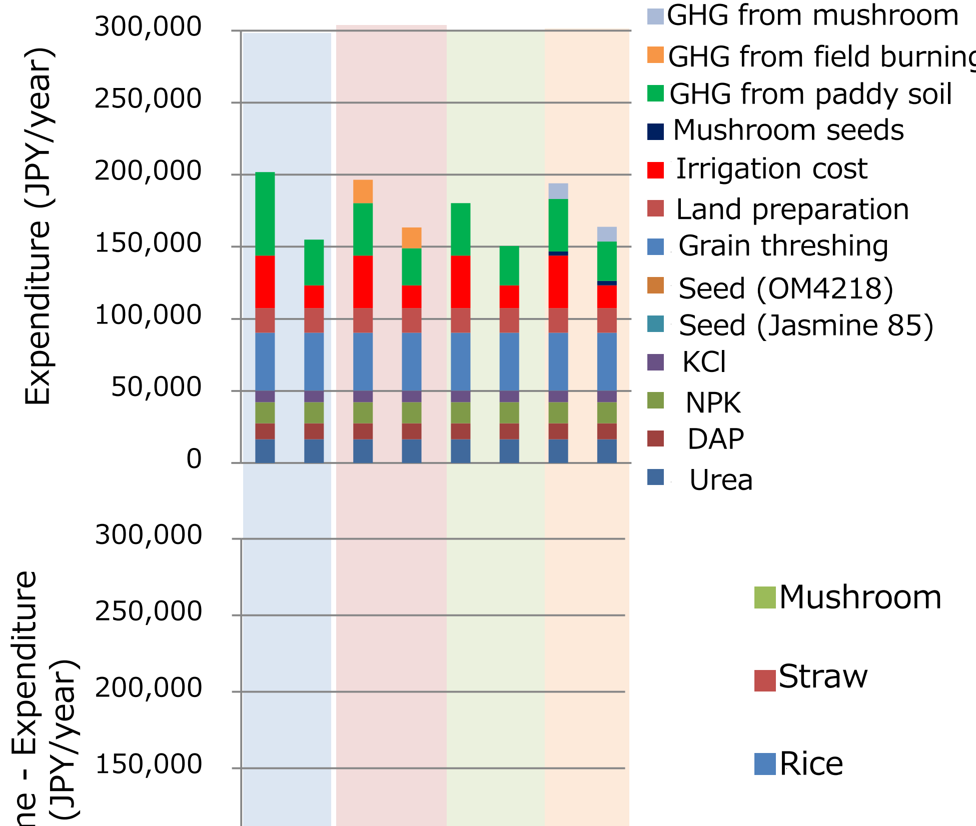


Back ground covariance matrices

Economic assessment of GHG mitigation under various uncertainties



Kalnay *et al.* 2017



State and trends of the carbon market 2012,
Spot and Secondary offset market
2011, 1,822MtCO_2
= 23,250million USD

Arai., 2015

Transparent MRV system on baselines/mitigation-effects with satellite data is the key !

Thank you
for your attention