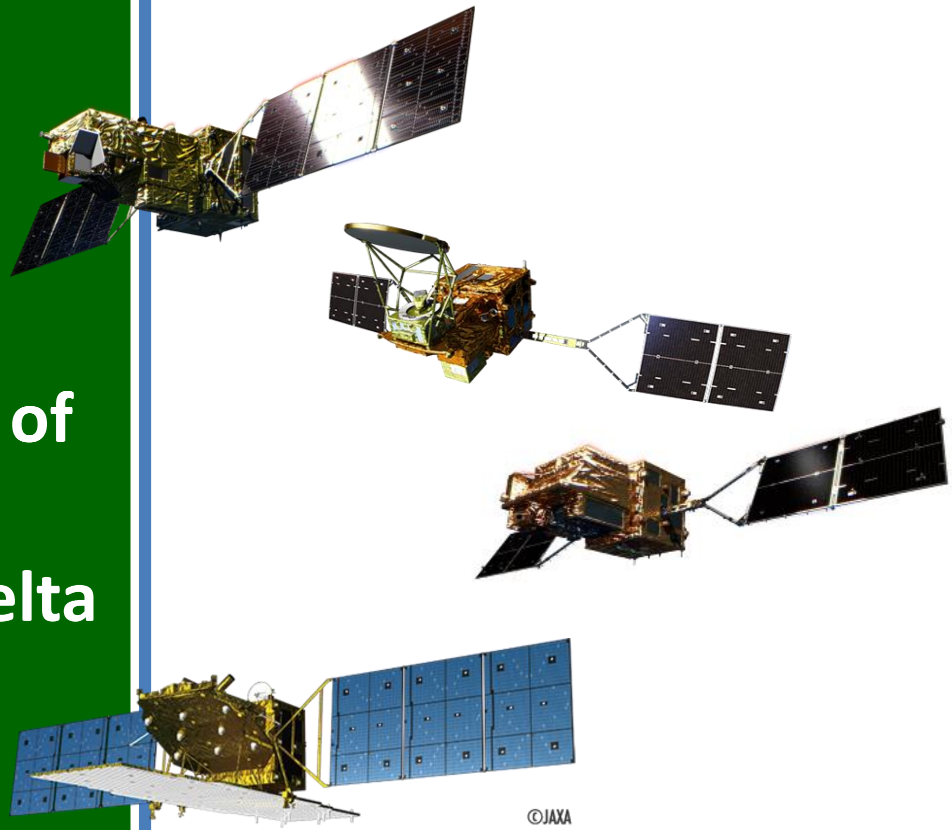
SUSTAINABLE DEVELOPMENT GOALS

# Development of MRV system of Methane emissions from Rice paddies in the Mekong delta




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]

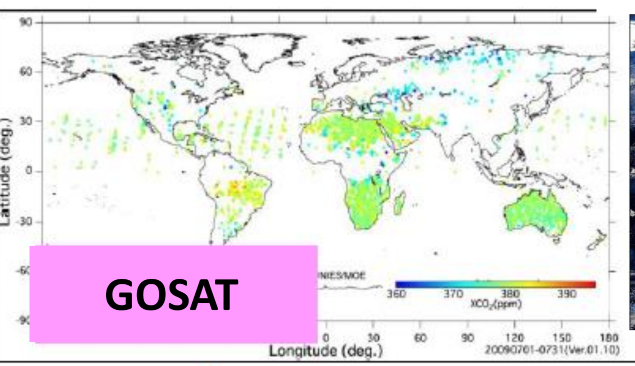
RSED JAXA R-CCS VNSC

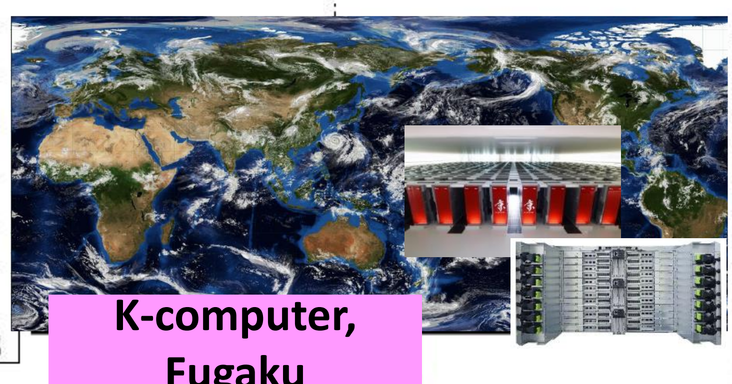
# Cycle from Observation to Countermeasure

To target | To solution | To target

Observ. Survey → Modelling → Simulation Forcast・eval. | Solution design → optimization | management → Evaluation

DATA → information → Estimation | → Strategy → | Policy →



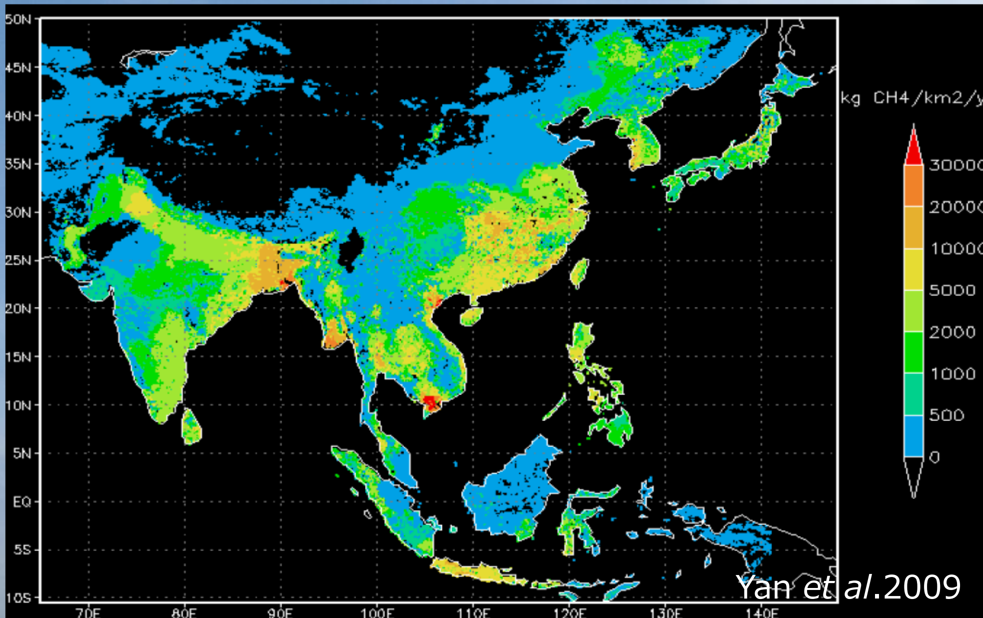




**Observation of the effect**

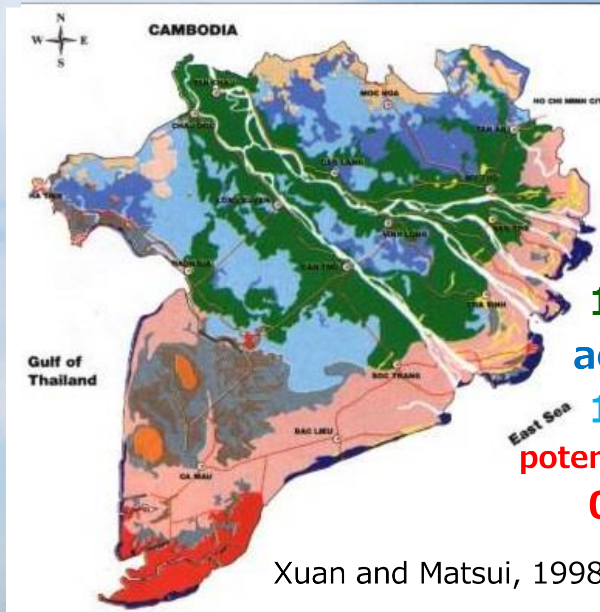
**Effect**

**Each country must submit INDC (Intended Nationally Determined Contributions) to UNFCCC before 2020**

Modified from Yasuoka 2015




Yan *et al*.2009




Xuan and Matsui, 1998

**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

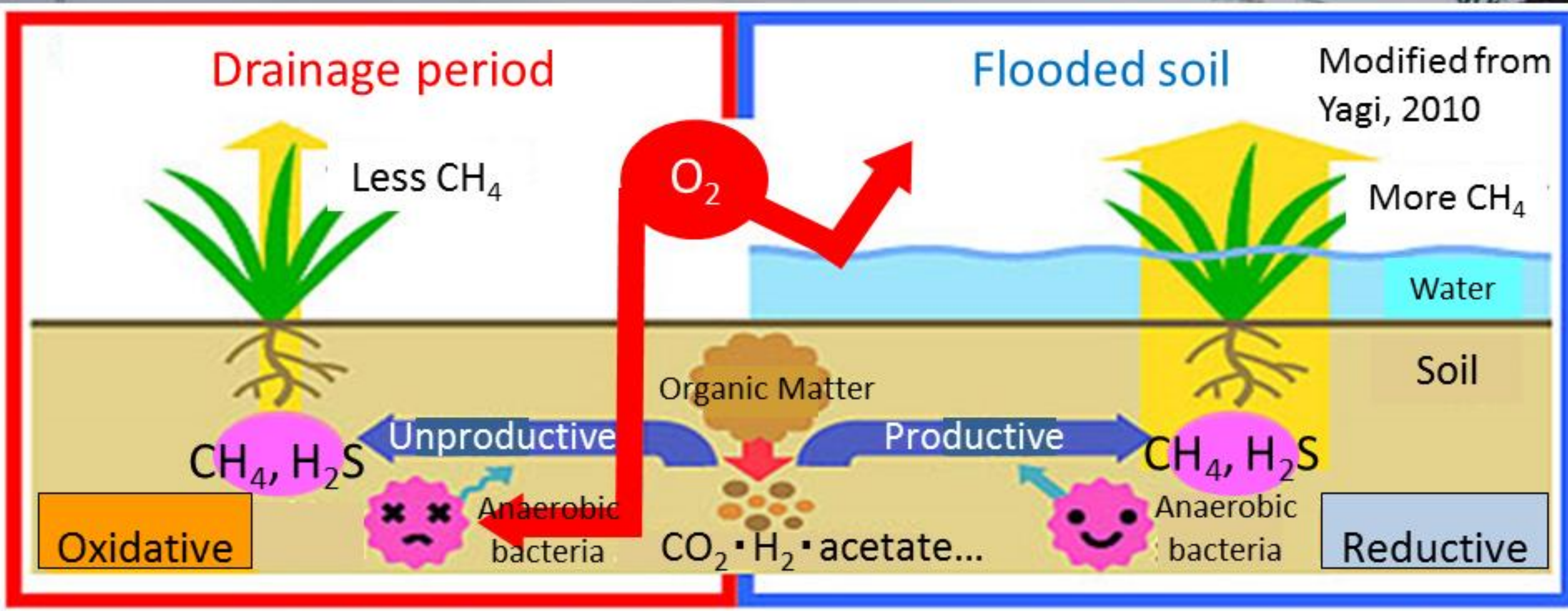
→ ✕

- Anaerobic stress for rice production
- High GHGs emission

**AWD**

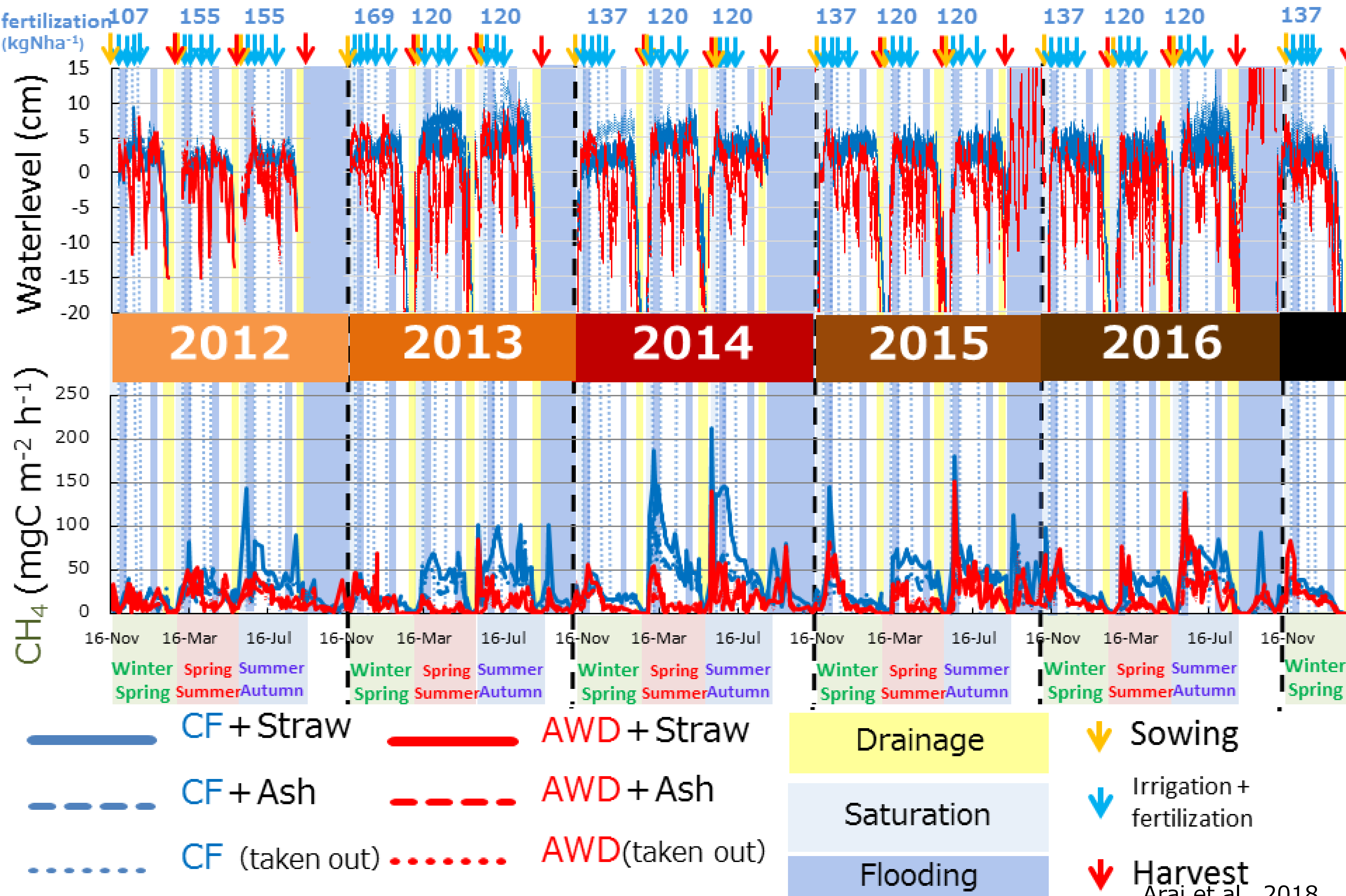
(**A**lternate **W**etting and **D**rying)

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



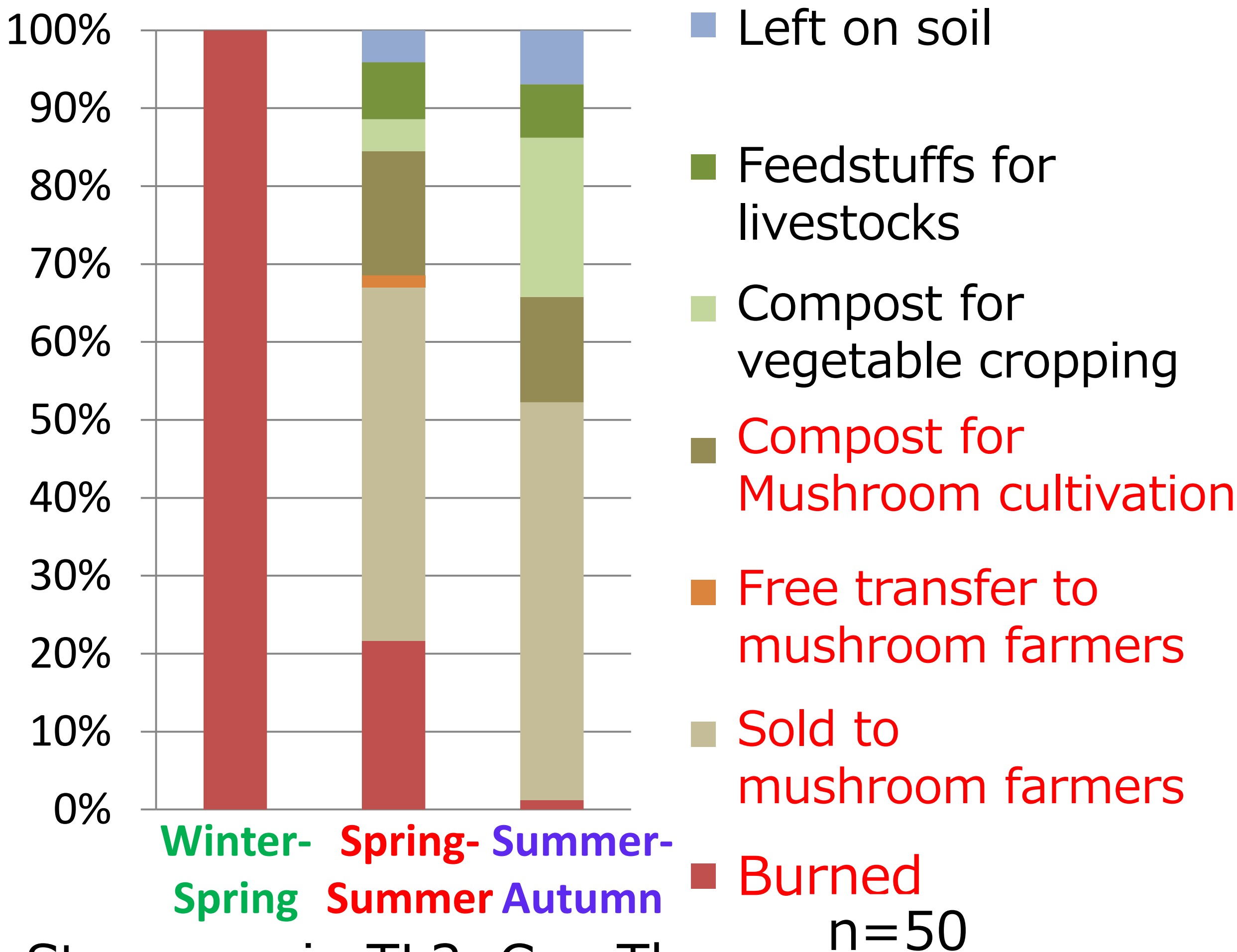

# Rice farmers participatory field observation


# Characteristics of the Mekong delta




Arai et al., 2018

# Greenhouse gas emission derived from rice straw use

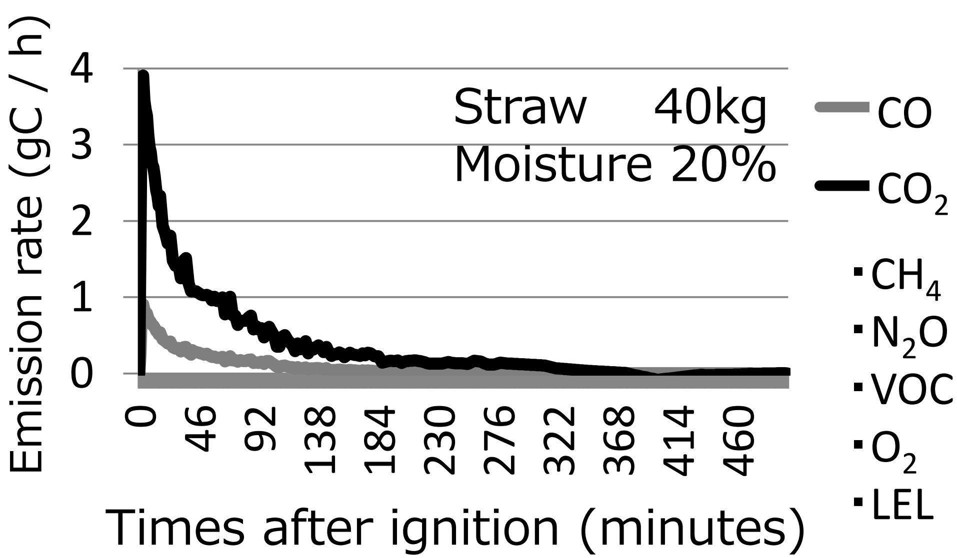



Straw use in TL2, Can Tho (ha $ha^{-1}$)

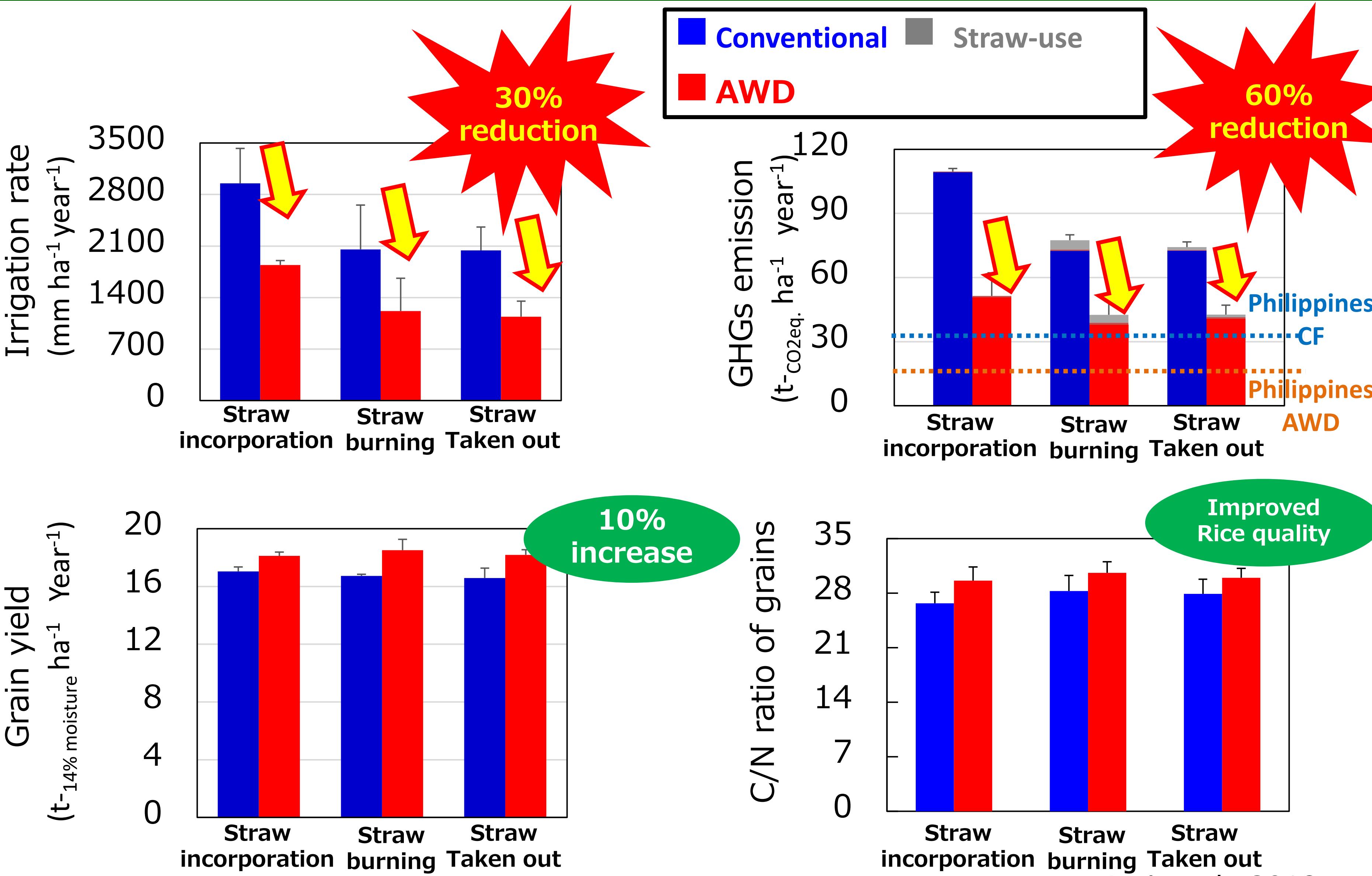
# Greenhouse gas emission derived from straw burning
## - Comparison among different straw size and moisture -





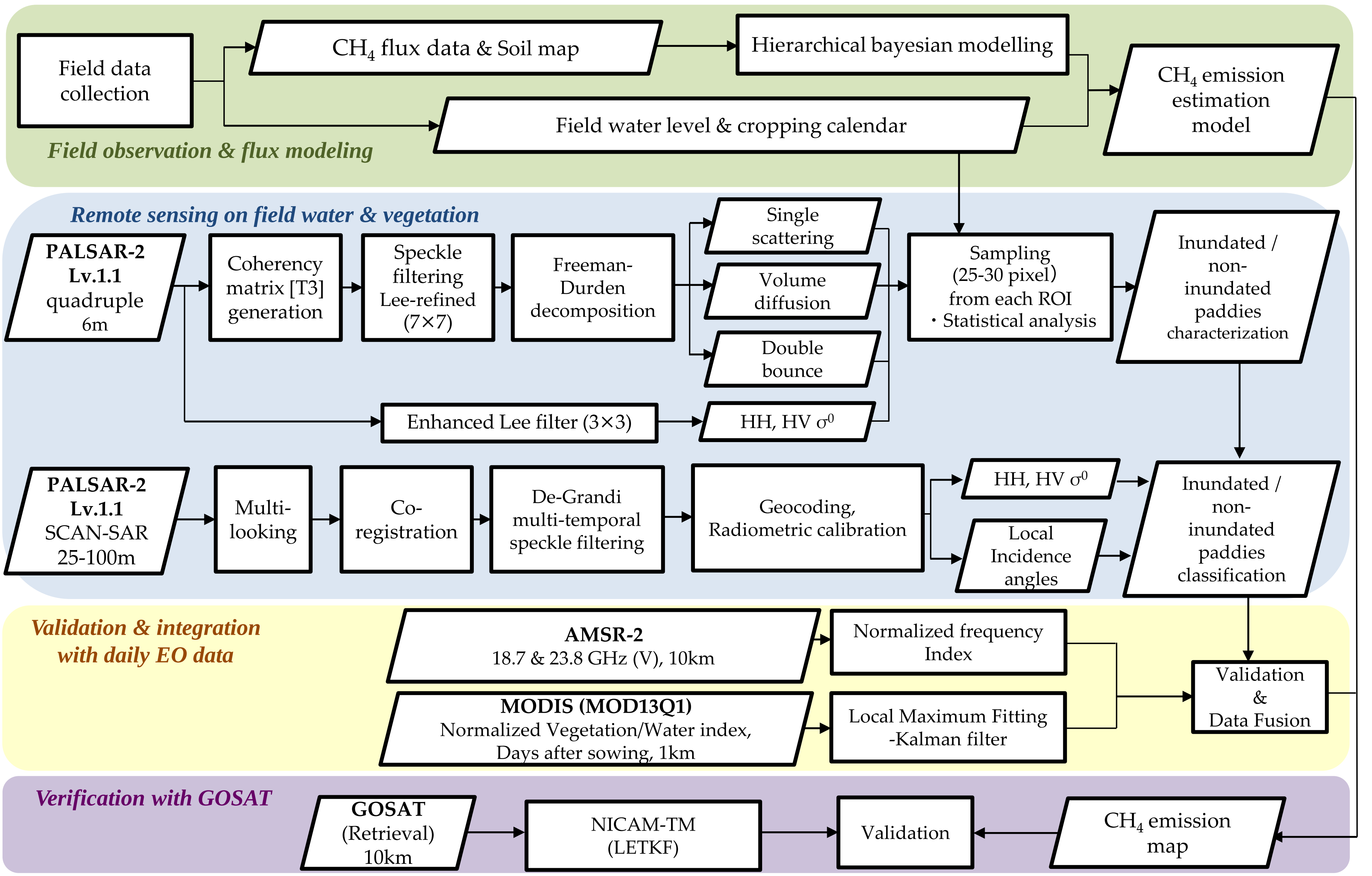



- Reduction of irrigation rate & GHGs (2012-2016)
- Increase of rice grains and its quality



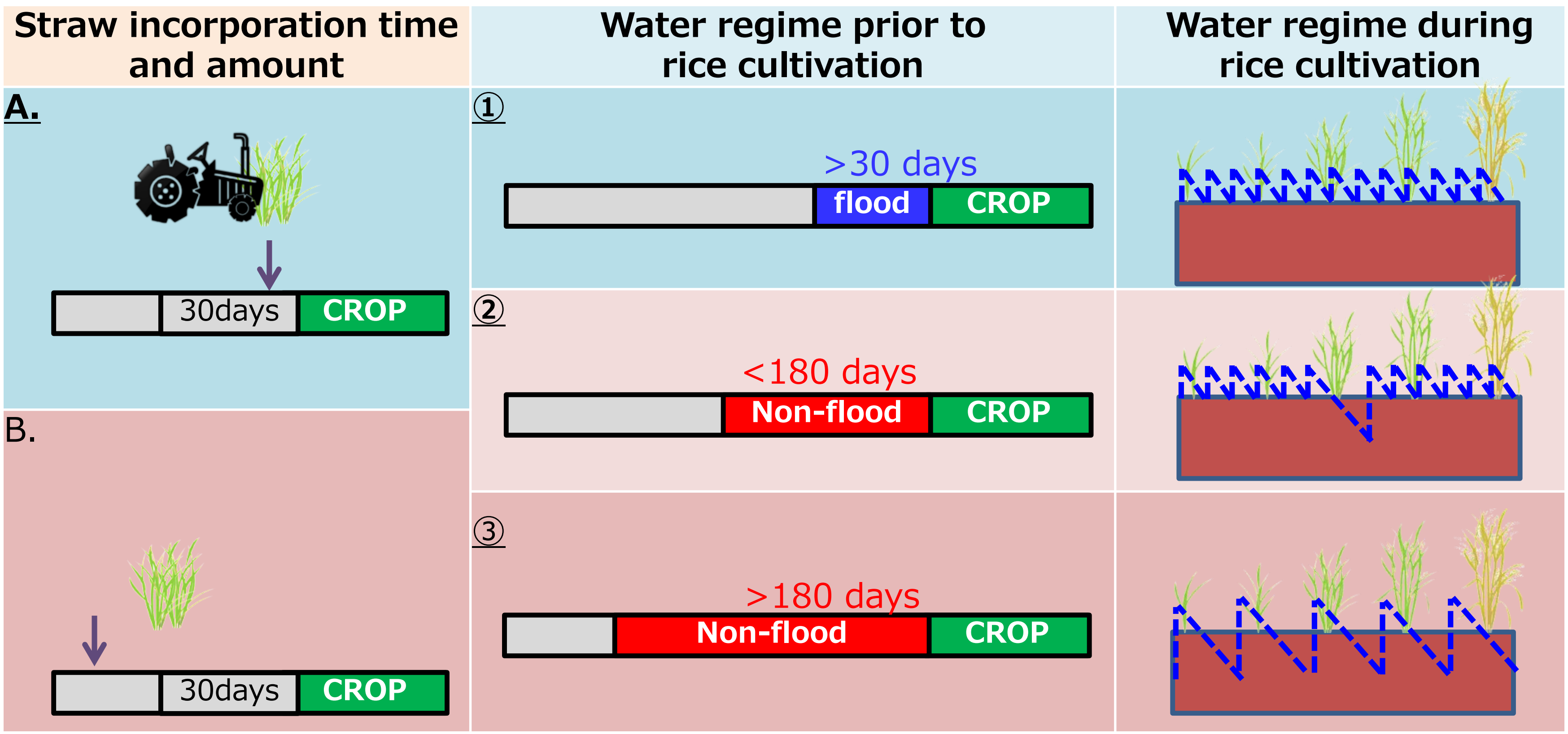

Arai et al., 2018

# Flow chart

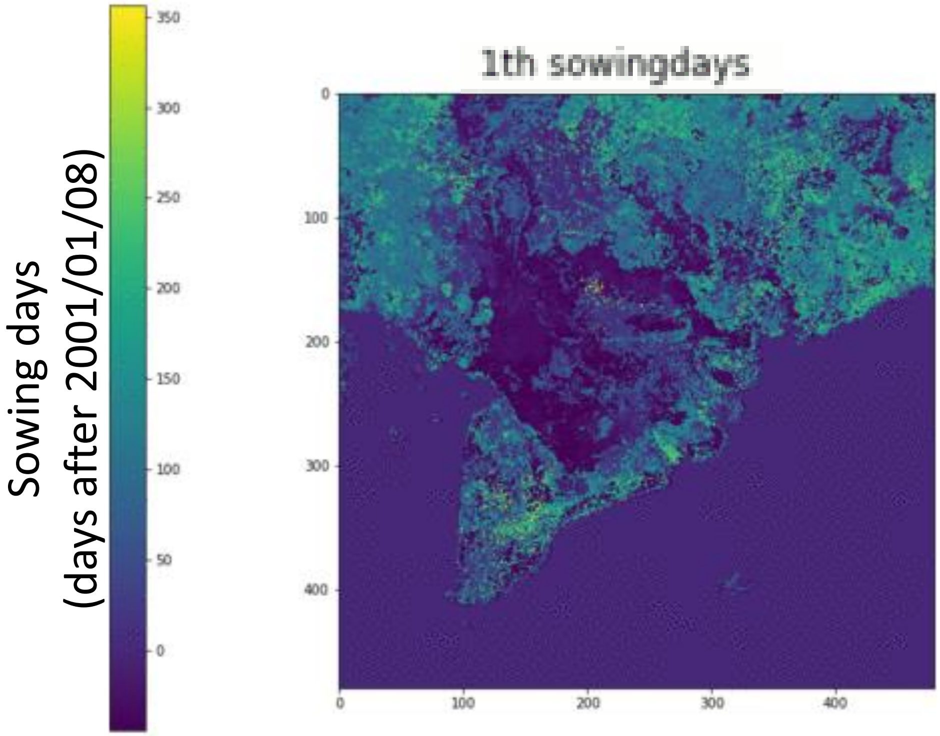


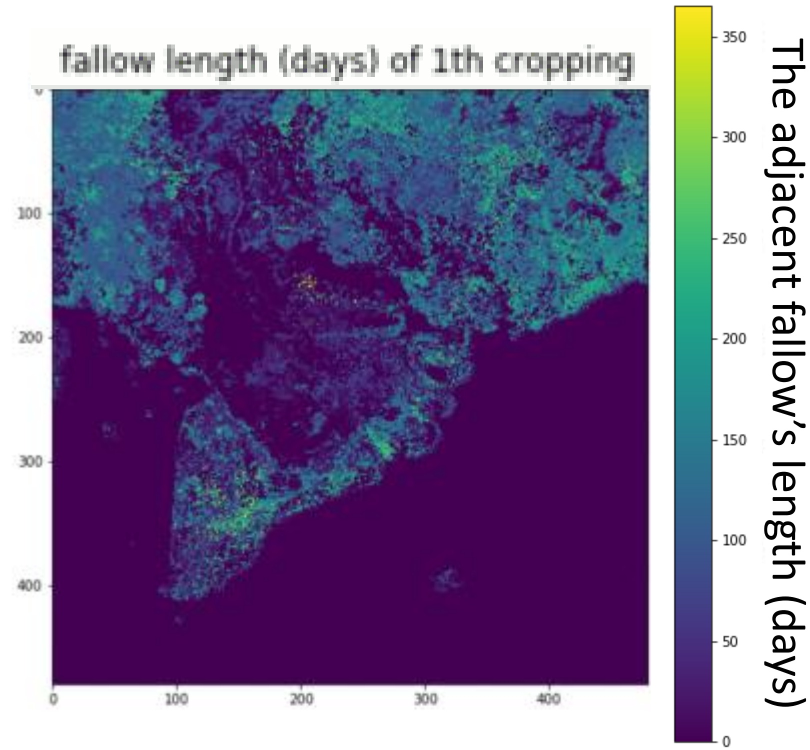
Field data collection
$CH_4$ flux data & Soil map
Hierarchical bayesian modelling
Field water level & cropping calendar
$CH_4$ emission estimation model
Field observation & flux modeling
Remote sensing on field water & vegetation
PALSAR-2 Lv.1.1 quadruple 6m
Coherency matrix [T3] generation
Speckle filtering 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 $\sigma^0$
PALSAR-2 Lv.1.1 SCAN-SAR 25-100m
Multi-looking
Co-registration
De-Grandi multi-temporal speckle filtering
Geocoding, Radiometric calibration
HH, HV $\sigma^0$
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
$CH_4$ emission map

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

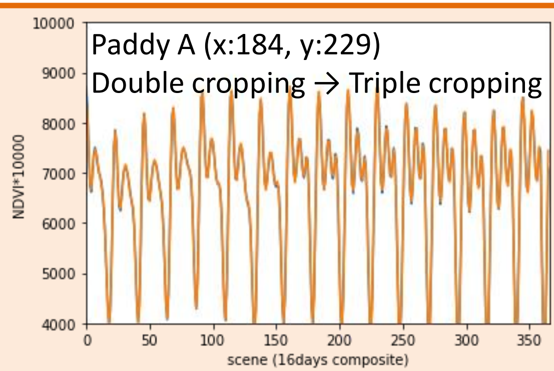


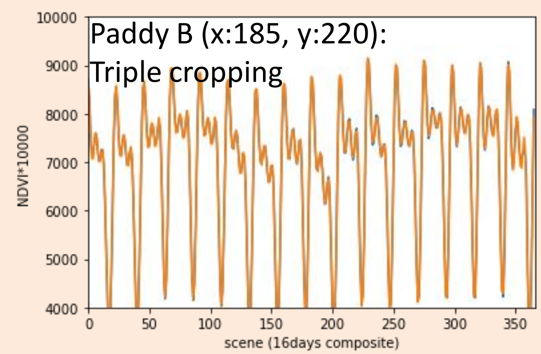
# Cropping calendar evaluation with MODIS-NDVI (LMF-KF) for GCOM-C




Samples of paddies




Arai et al., 2018

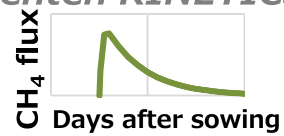
# Semi-empirical **daily** $CH_4$ flux (mg C $m^{-2}$ $hr^{-1}$) Model

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

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

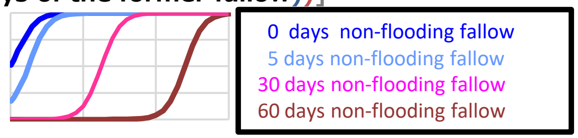
***carbon_management (Michaelis-Menten KINETICS)***

=[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***

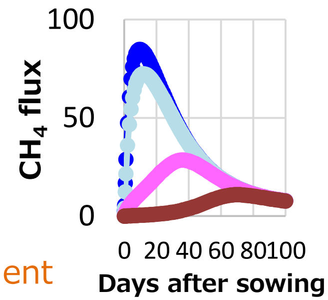
= EXP(η * **inundated days during the last 10days**)

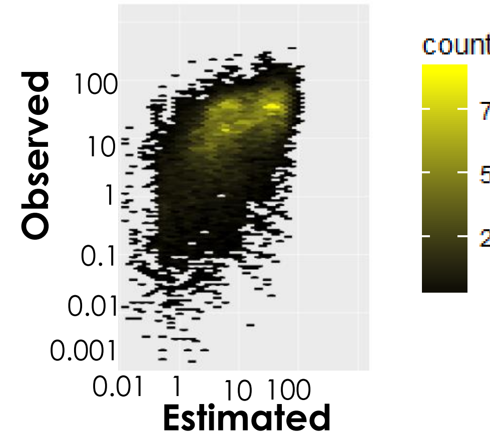
*DAS*←*days after sowing*

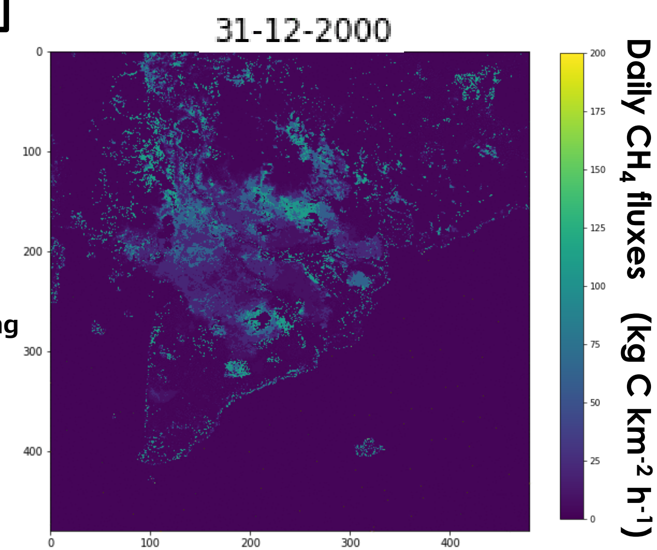
**α** ←straw incorporation coefficient

**β** ←acid sulfate・coastal sandy soil coefficient

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



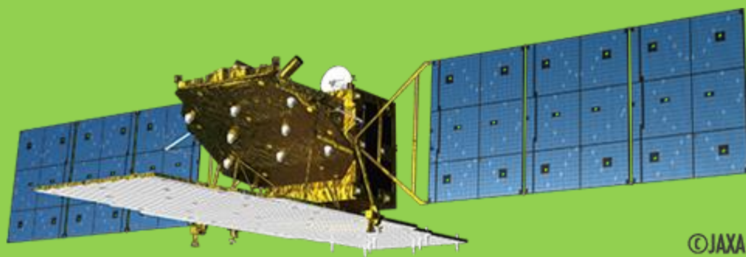



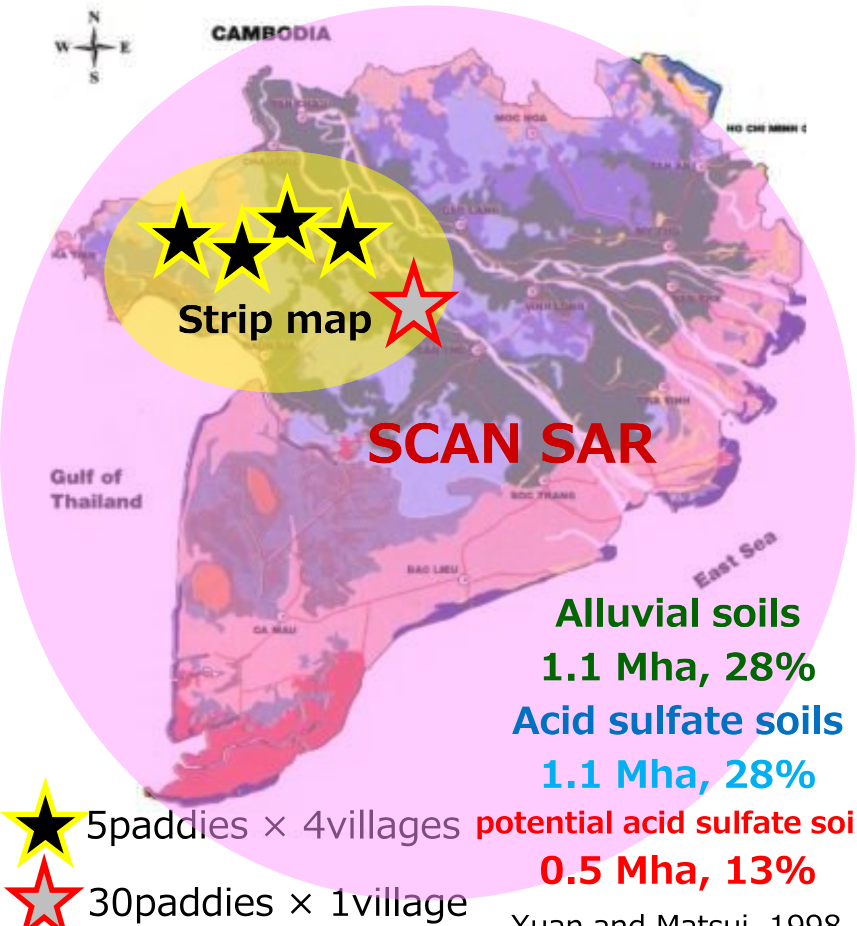




Arai et al., 2018

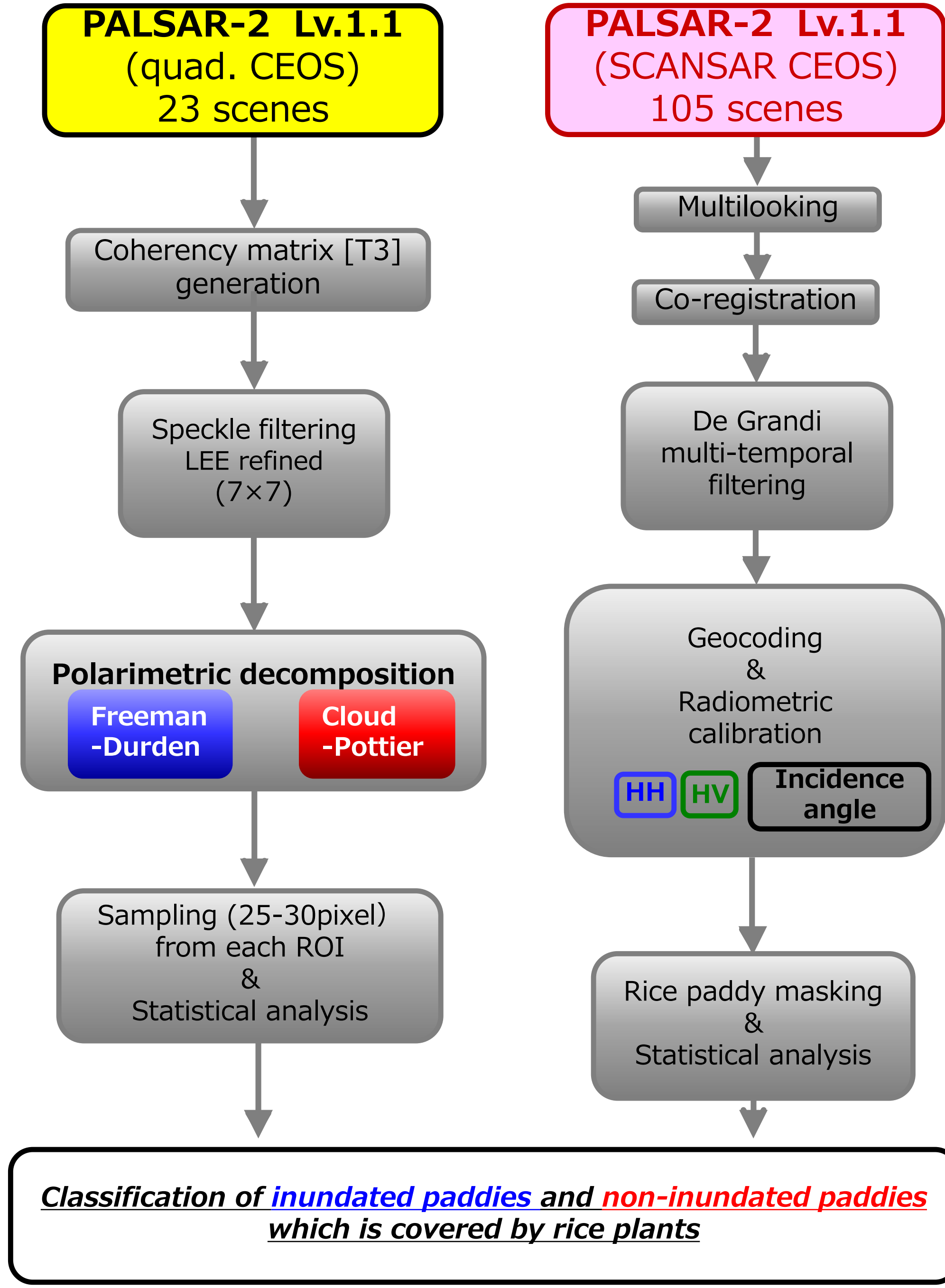
# ALOS-2/PALSAR-2

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



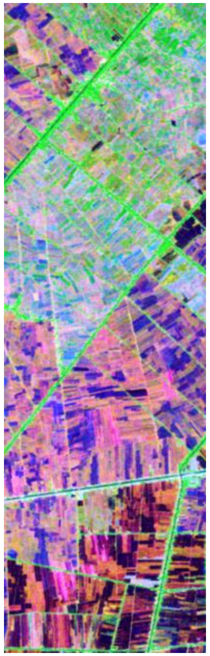



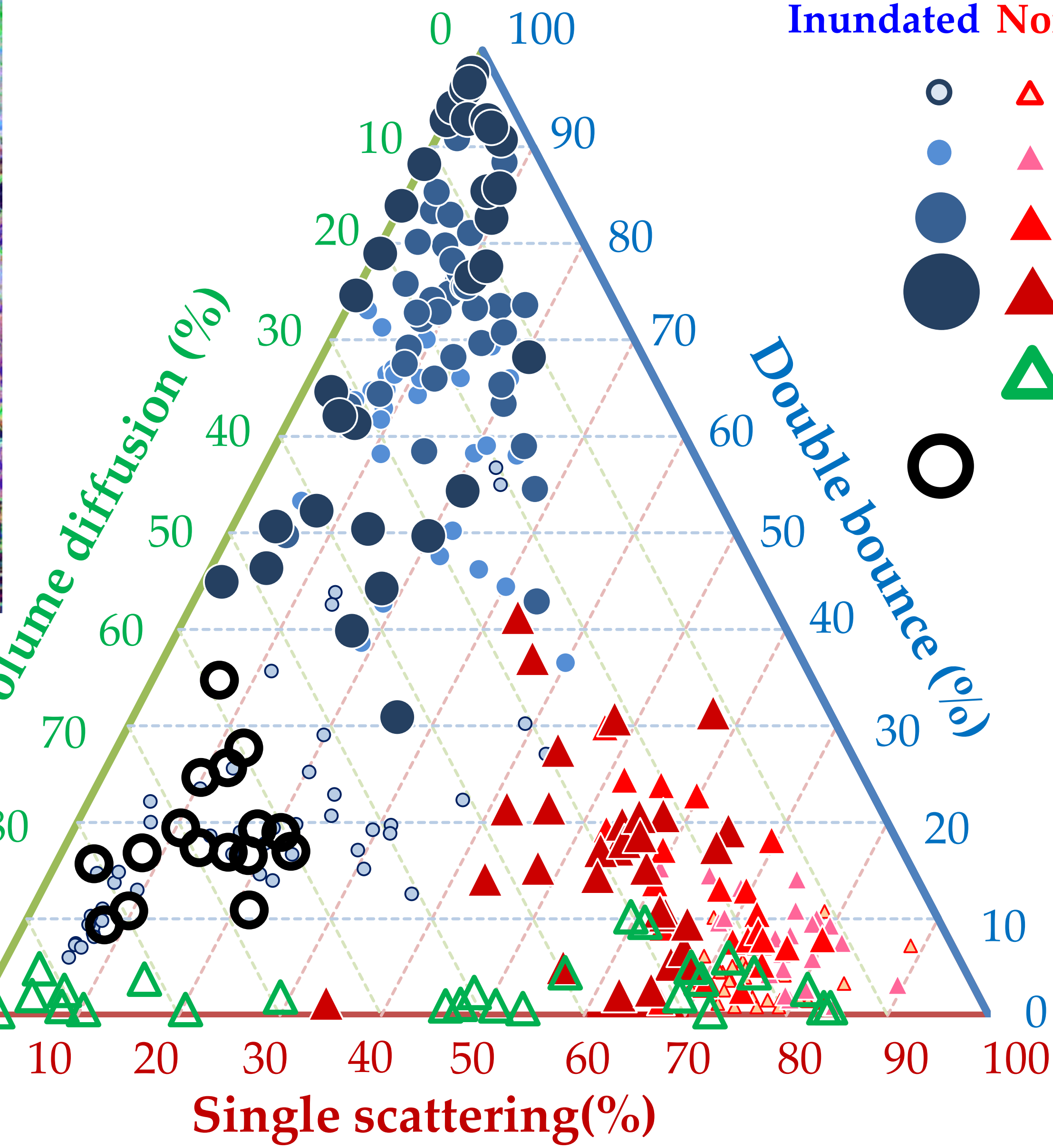

Xuan and Matsui, 1998

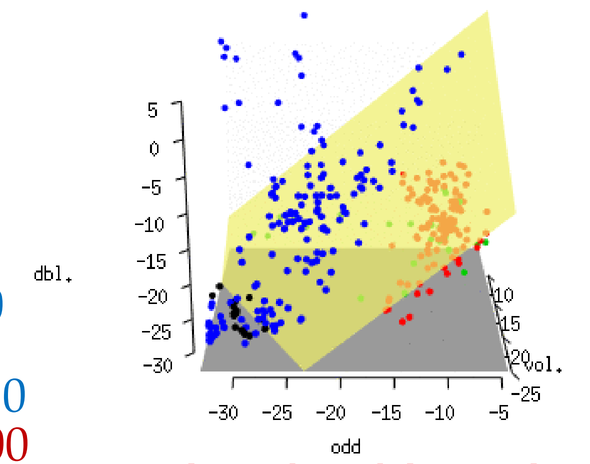



Modified from Avtar *et al*. 2012

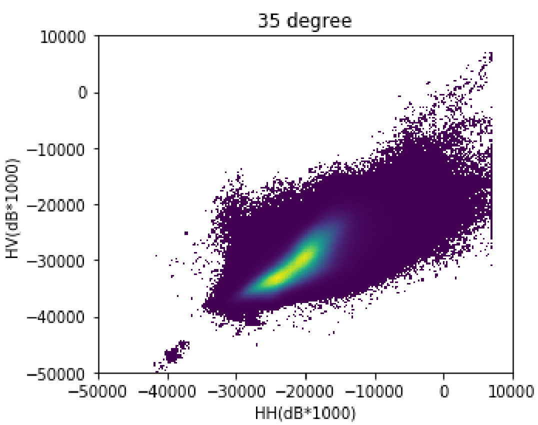
# -Freeman-Durden decomposition-

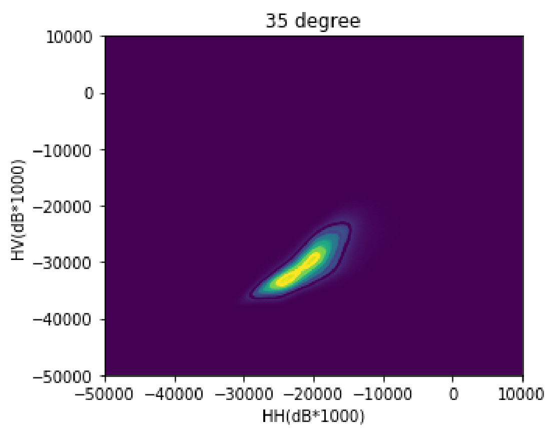




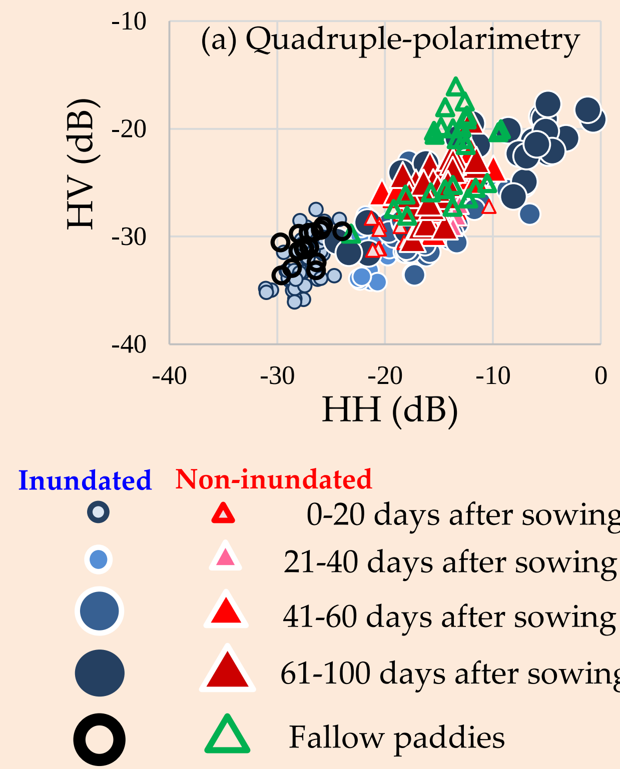



# SCAN-SAR (25m)



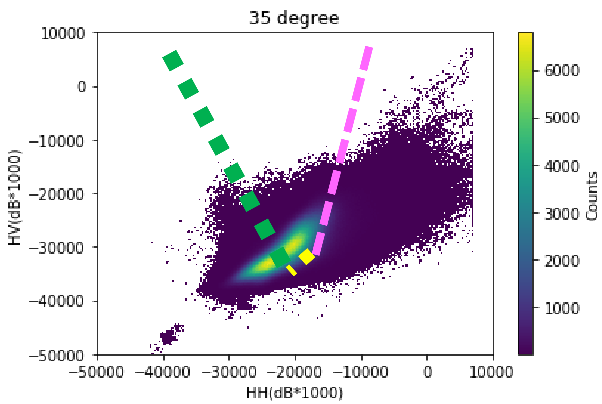



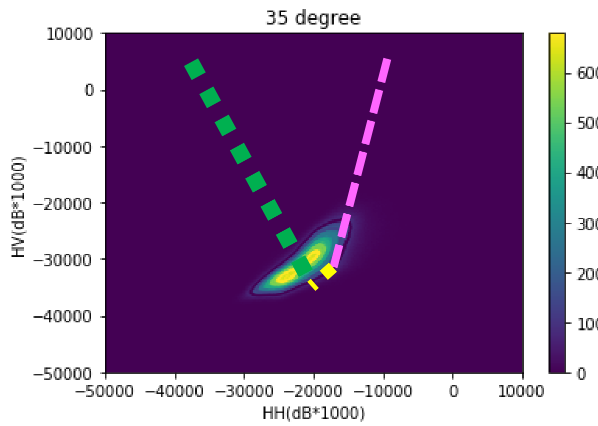

# Full-polarimetry (3m)

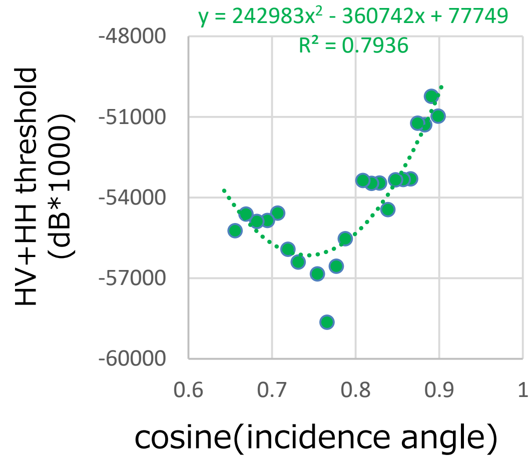


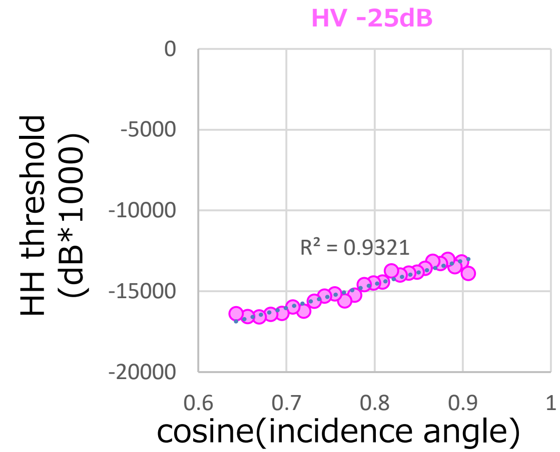

Arai et al., 2018

# SCAN-SAR (25m)



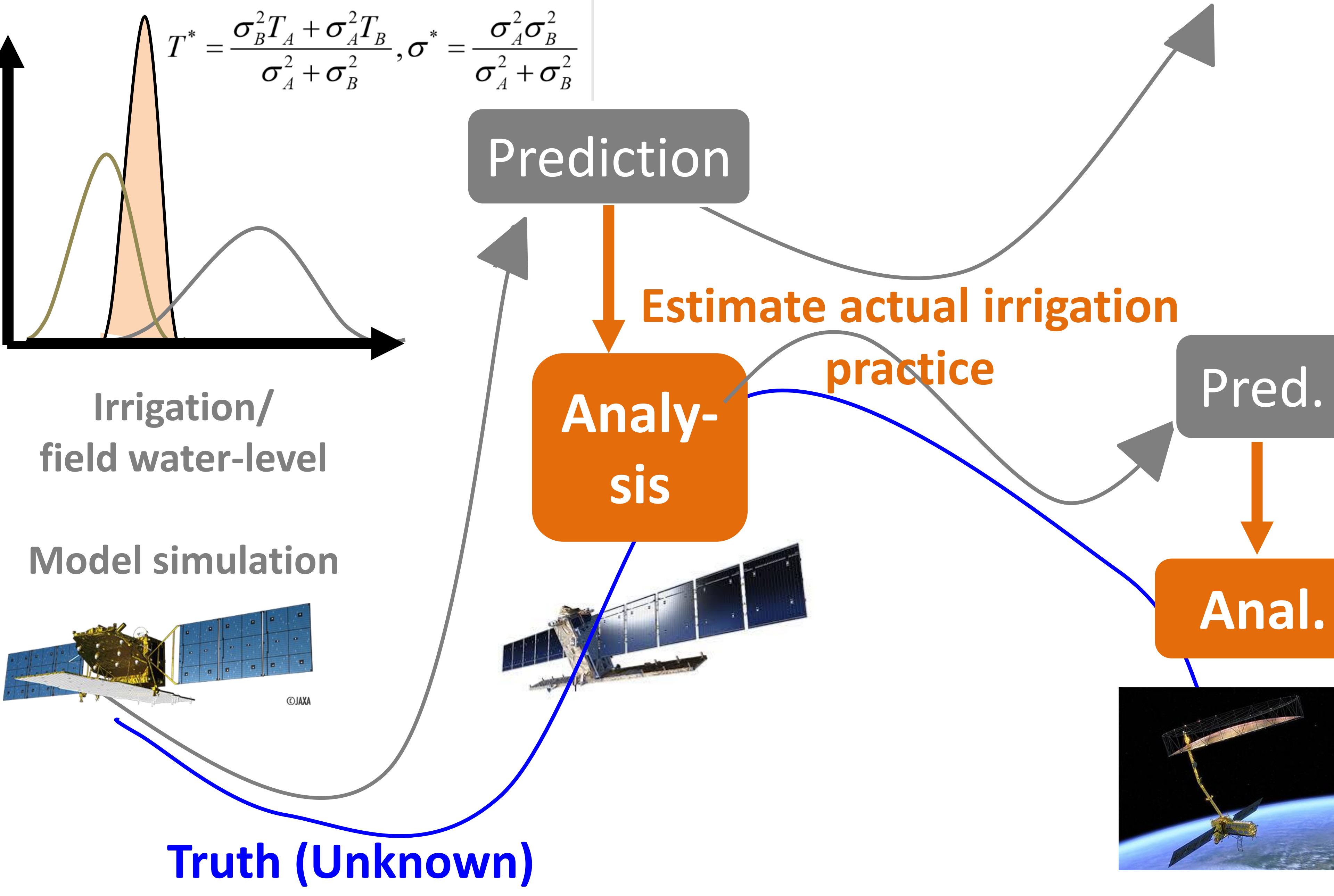



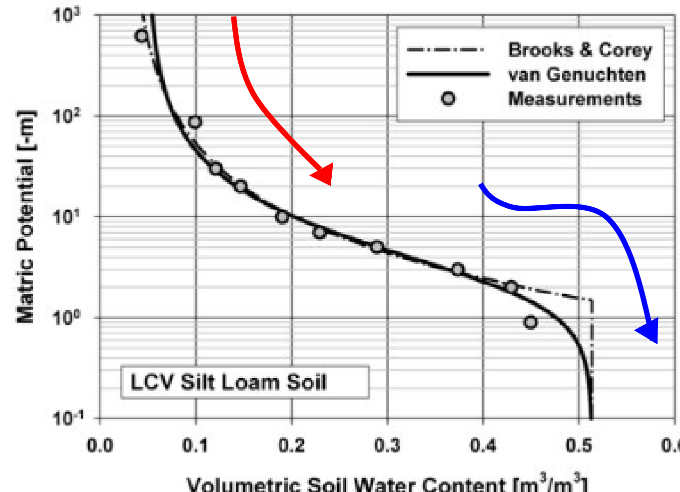

HH threshold (dB) = 0.550*HV
+12.9*cosine(IA)
-11.2

Arai et al., 2018

# Our data integration scheme

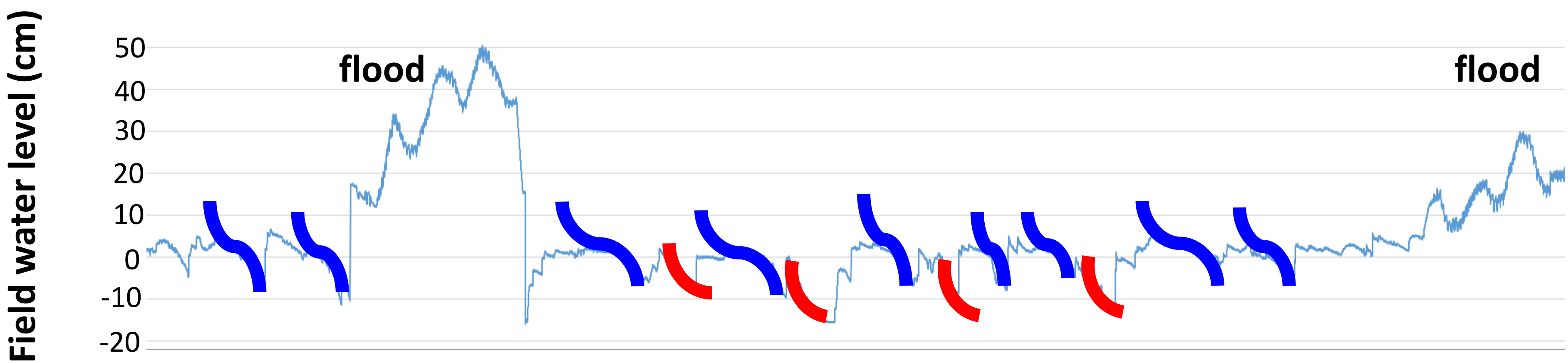


# Simulation scheme with 25m-spatial resolution
# - Hysteresis of soil matric potential energy-




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

***Irrigation, potential energy*** >> Side flow, ground water flow



# 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) · $\alpha_i$

constraint

t = days after irrigation

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

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

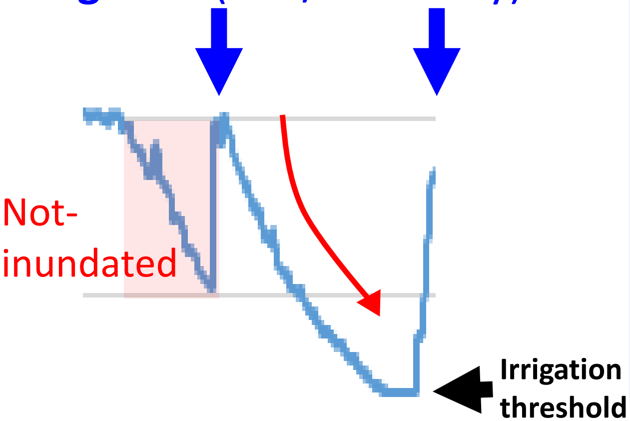
**Irrigation function**

if $WL$ < *threshold* :

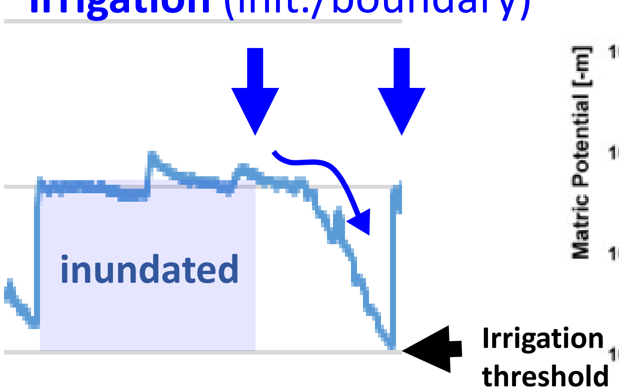
irrigate (i.e., $WL$ += *X*)

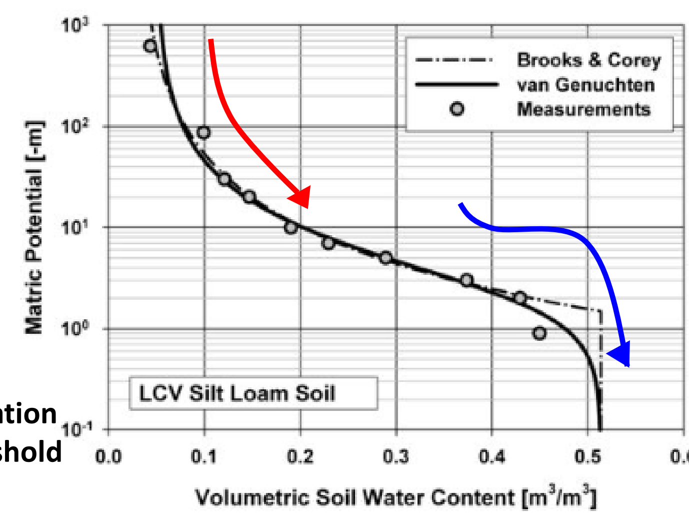
**Parameter update by the analysis with EO data**

**Irrigation** (init./boundary)

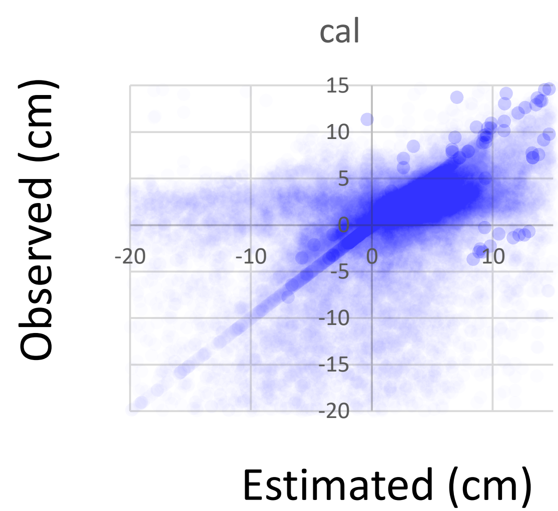



**Irrigation** (init./boundary)



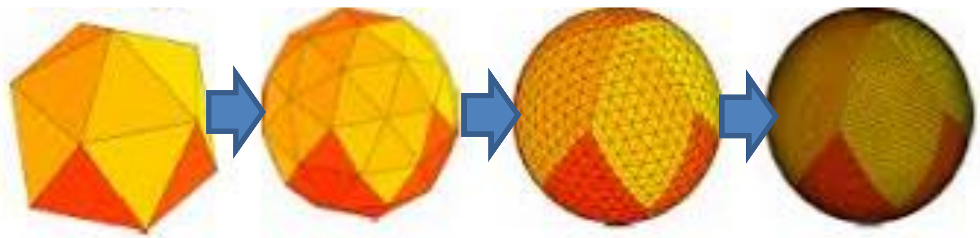



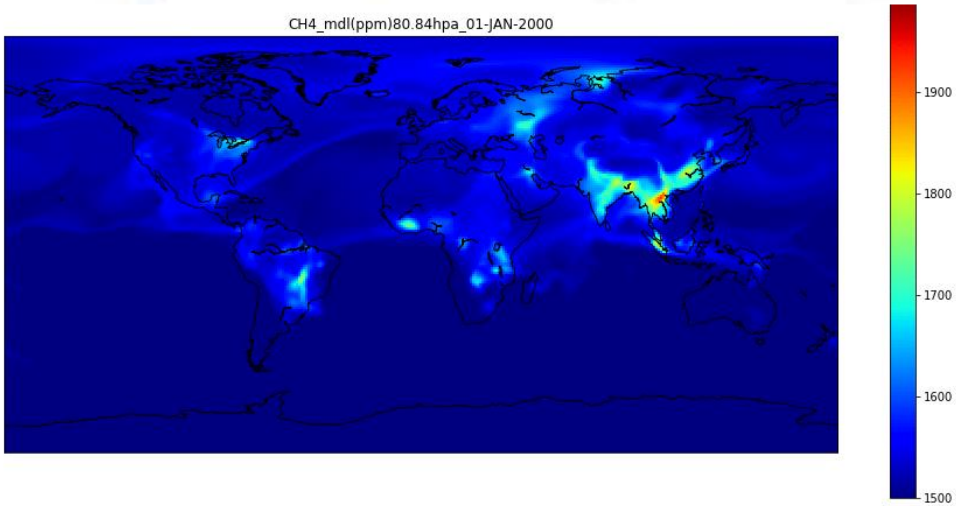

https://slideplayer.com/slide/5038747/



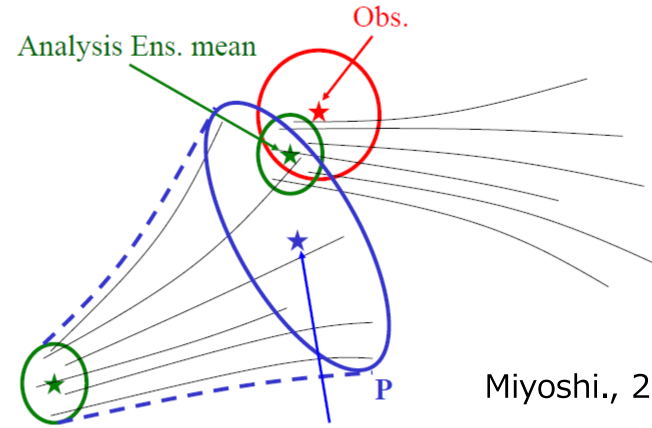
# NICAM-TM(Chem)-LETKF with AMSU, PREPBUFR and **GOSAT/Sentinel-5P**

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

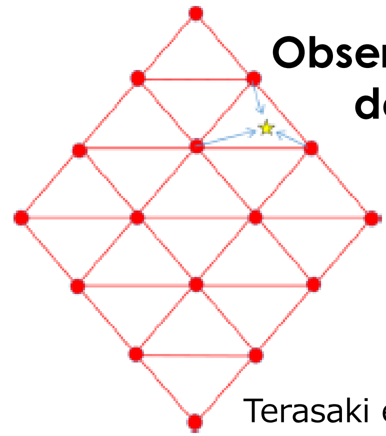





**L**ocal **E**nsemble **T**ransform **K**alman **F**ilter




Miyoshi., 2005



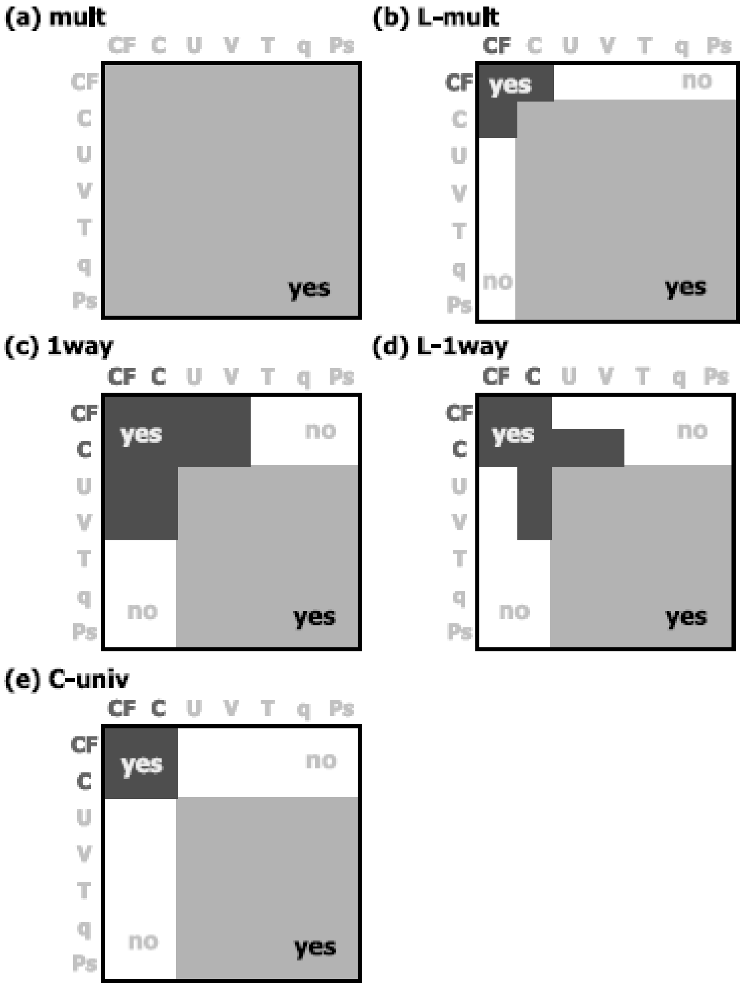
**Observation operator development for GOSAT**

Terasaki et al., 2014

Direct comparison between GOSAT and emission data is meaningless…

→GOSAT data assimilation with NICAM-TM!

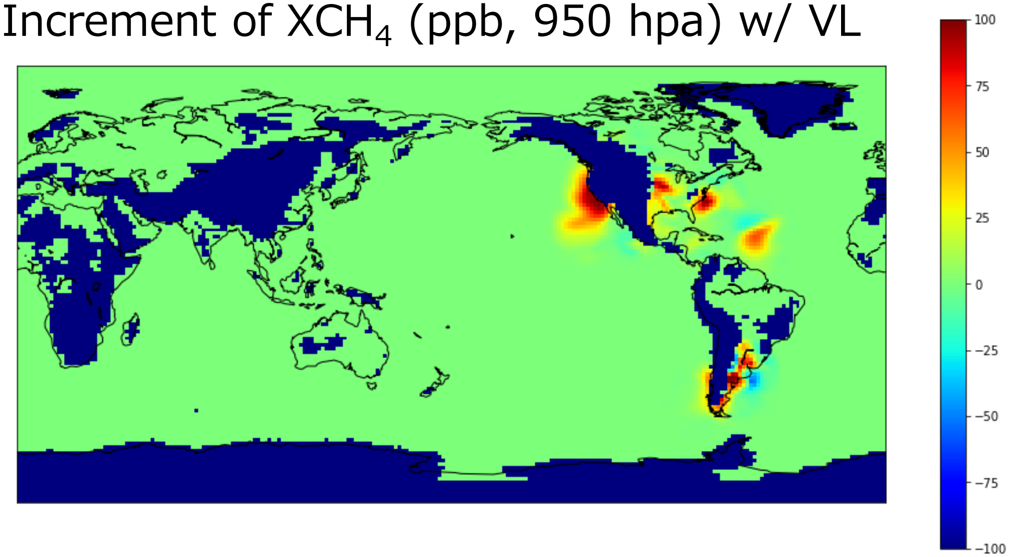
# Implementation of variable localization scheme in NICAM-TM-LETKF (PREPBUFR&GOSAT)



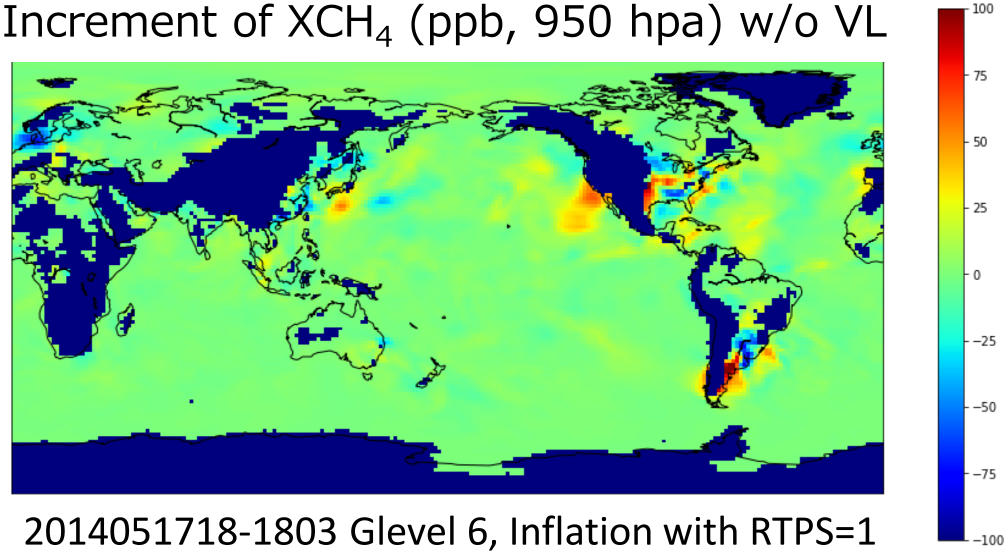

Back ground covariance matrices

Kang et al., 2012

Increment of $XCH_4$ (ppb, 950 hpa) w/ VL



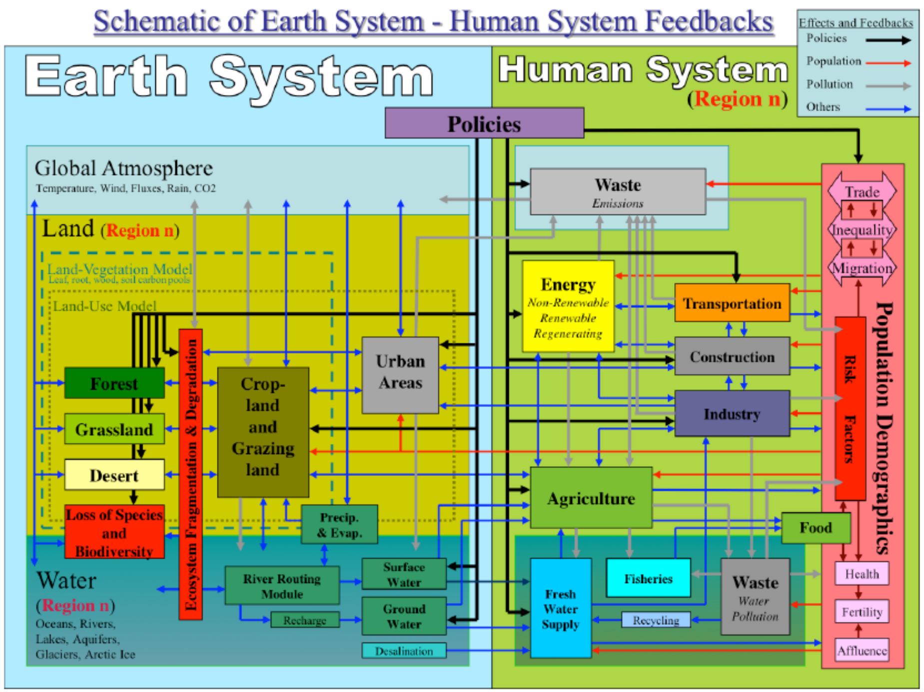

Increment of $XCH_4$ (ppb, 950 hpa) w/o VL




2014051718-1803 Glevel 6, Inflation with RTPS=1

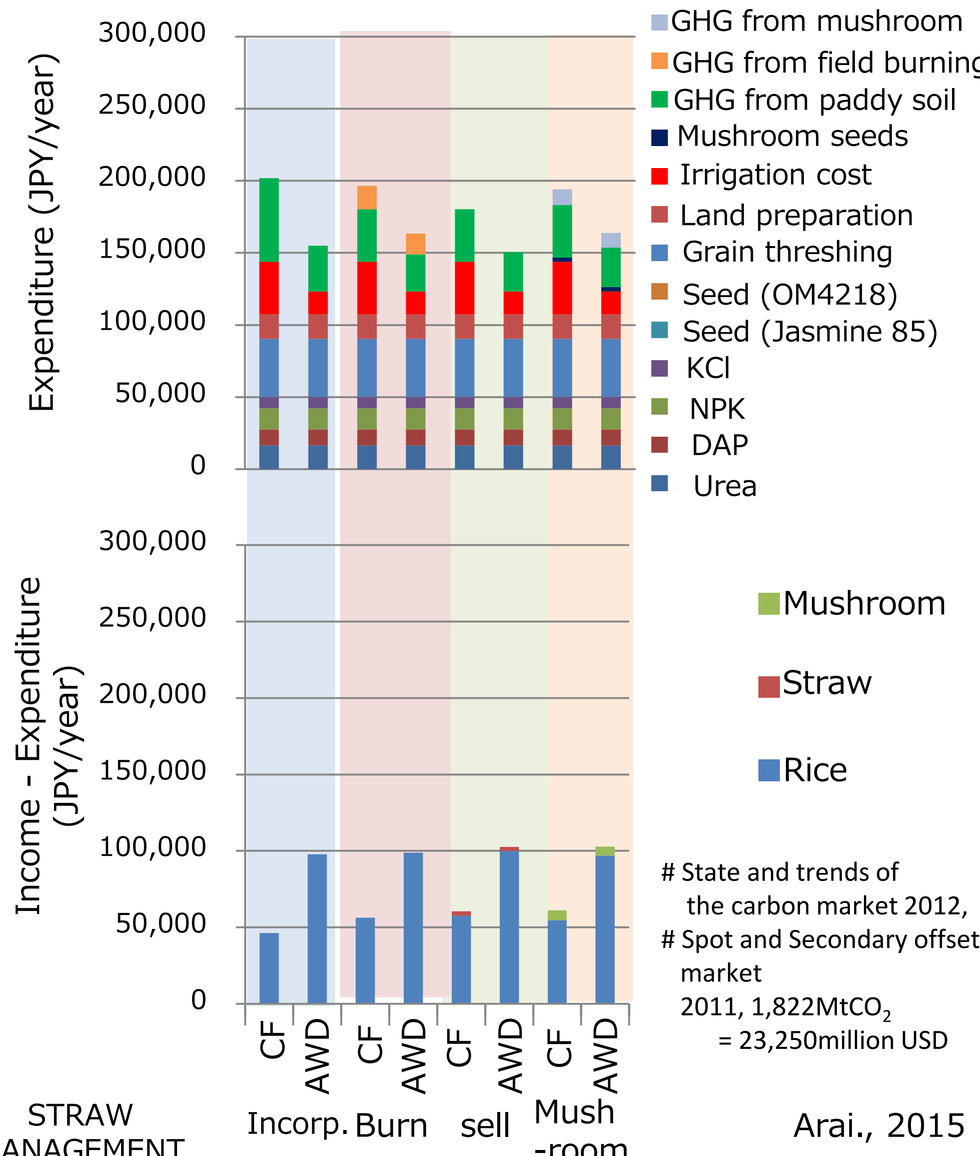
→ **Flux parameter estimation!**

# Economic assessment of GHG mitigation under various uncertainties




Kalnay *et al*. 2017

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




Arai., 2015