Evaluation of methane emission status from tropical rice paddies with optical and SAR imagery and validation scheme using GHG observation data

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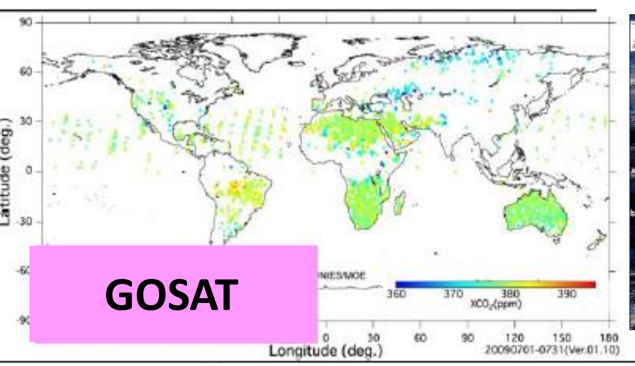
Cycle from Observation to Countermeasure

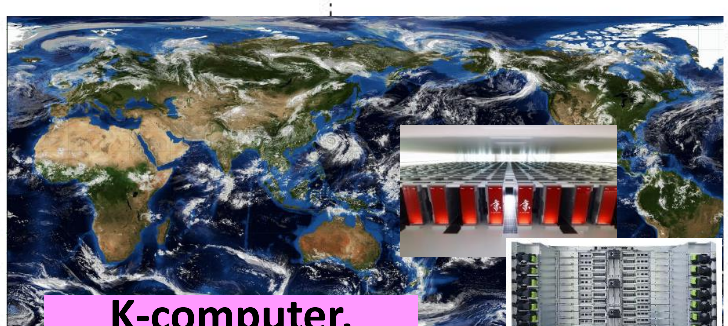
To target | To solution | To target

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

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



GOSAT



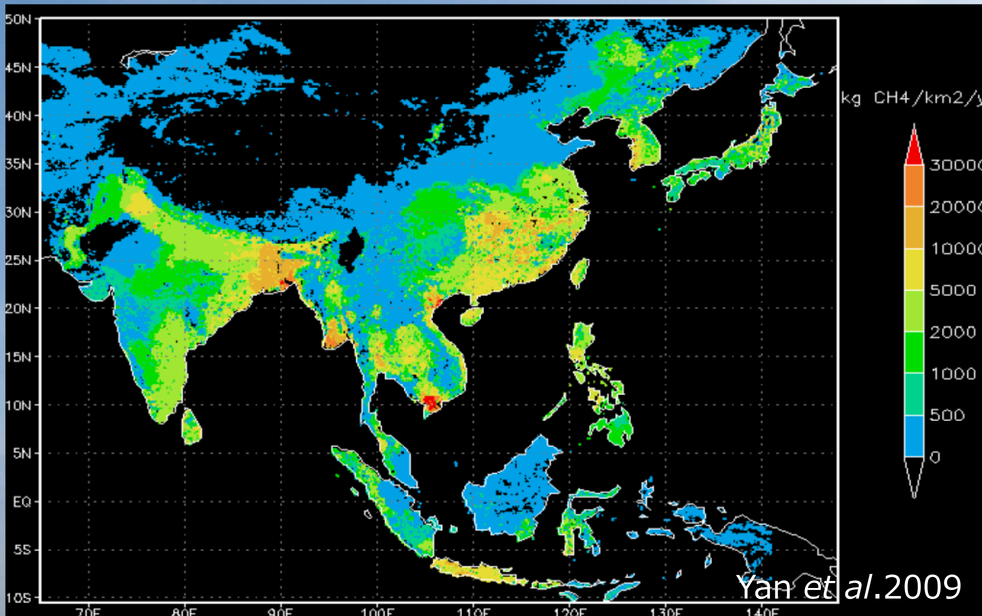
K-computer, Fugaku

Observation of the effect

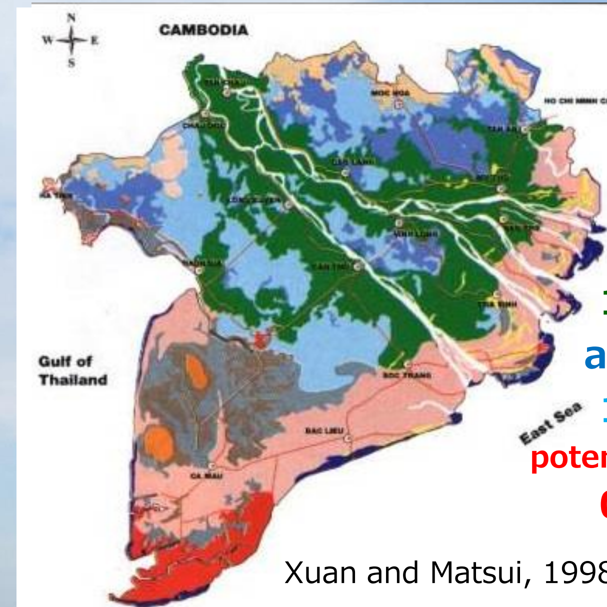
Effect

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

+

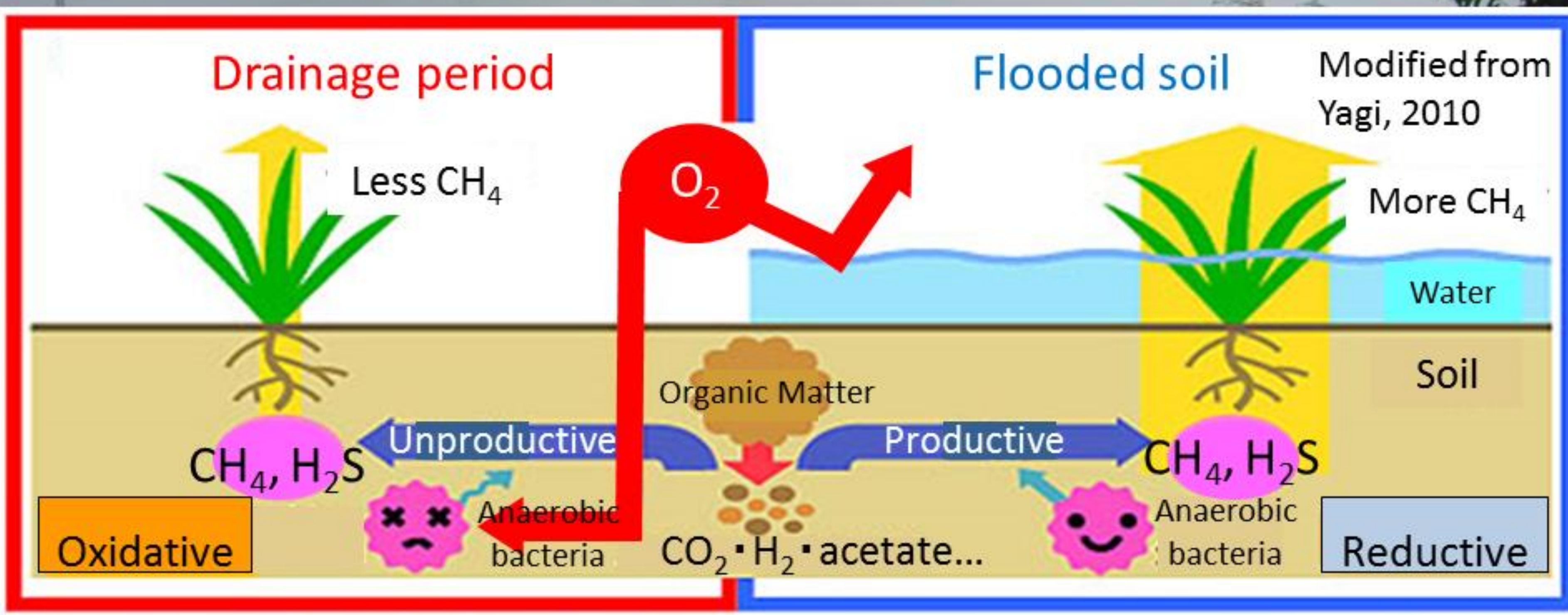
- High straw production

- Anaerobic stress for rice production
- High GHGs emission

AWD

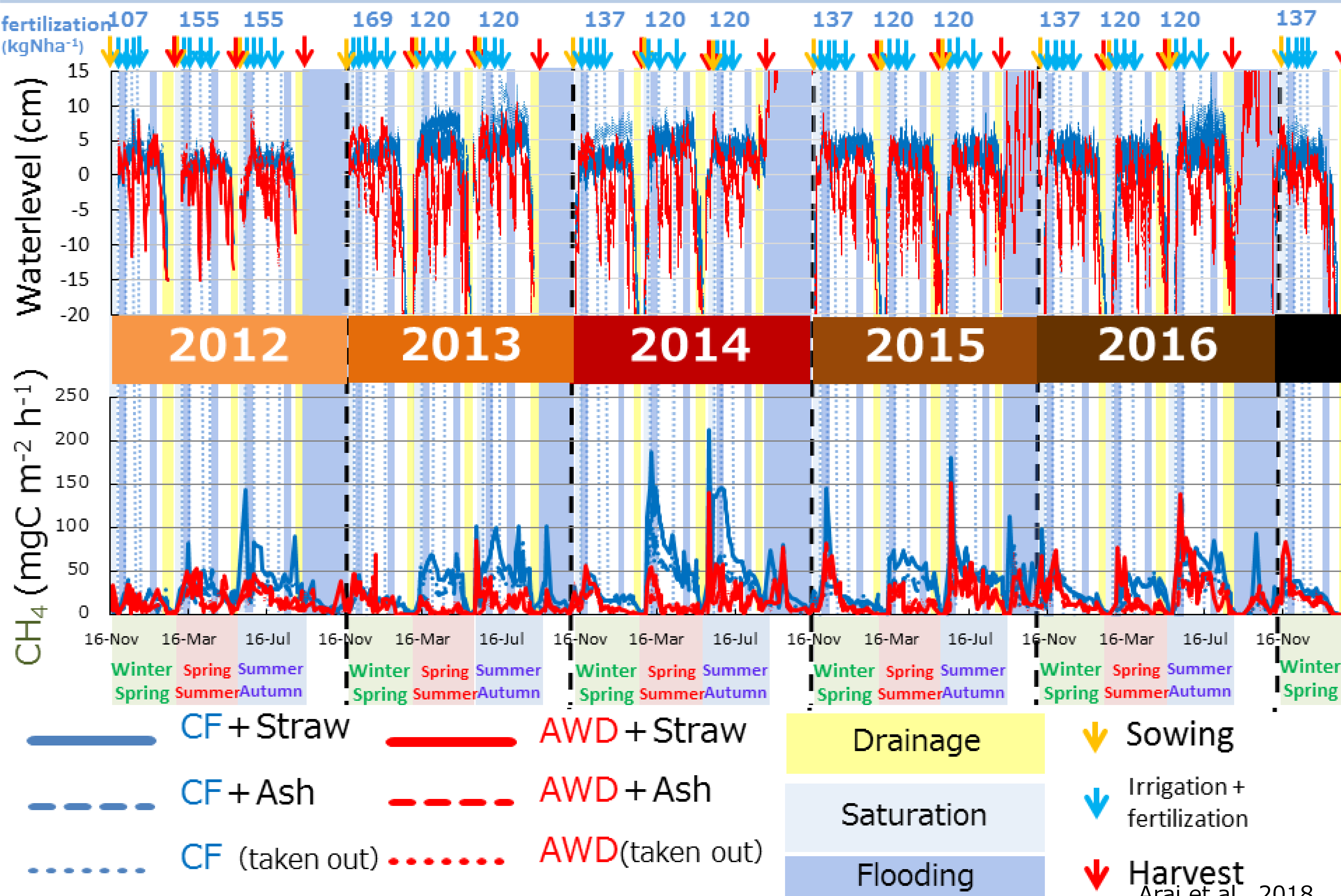
(**A**lternate **W**etting and **D**rying)

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



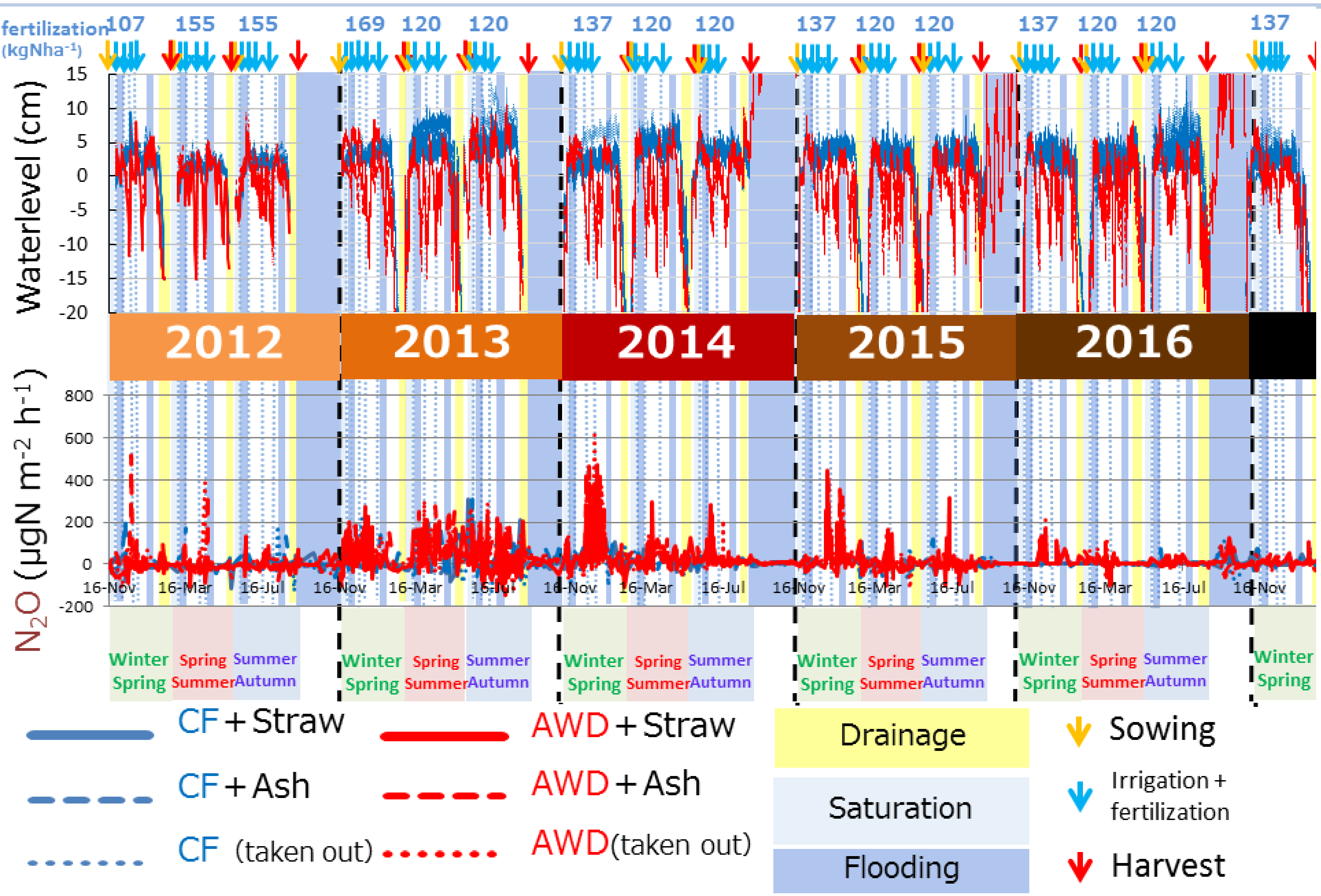

Rice farmers participatory field observation with “fresh” samples and data


Characteristics of the Mekong delta

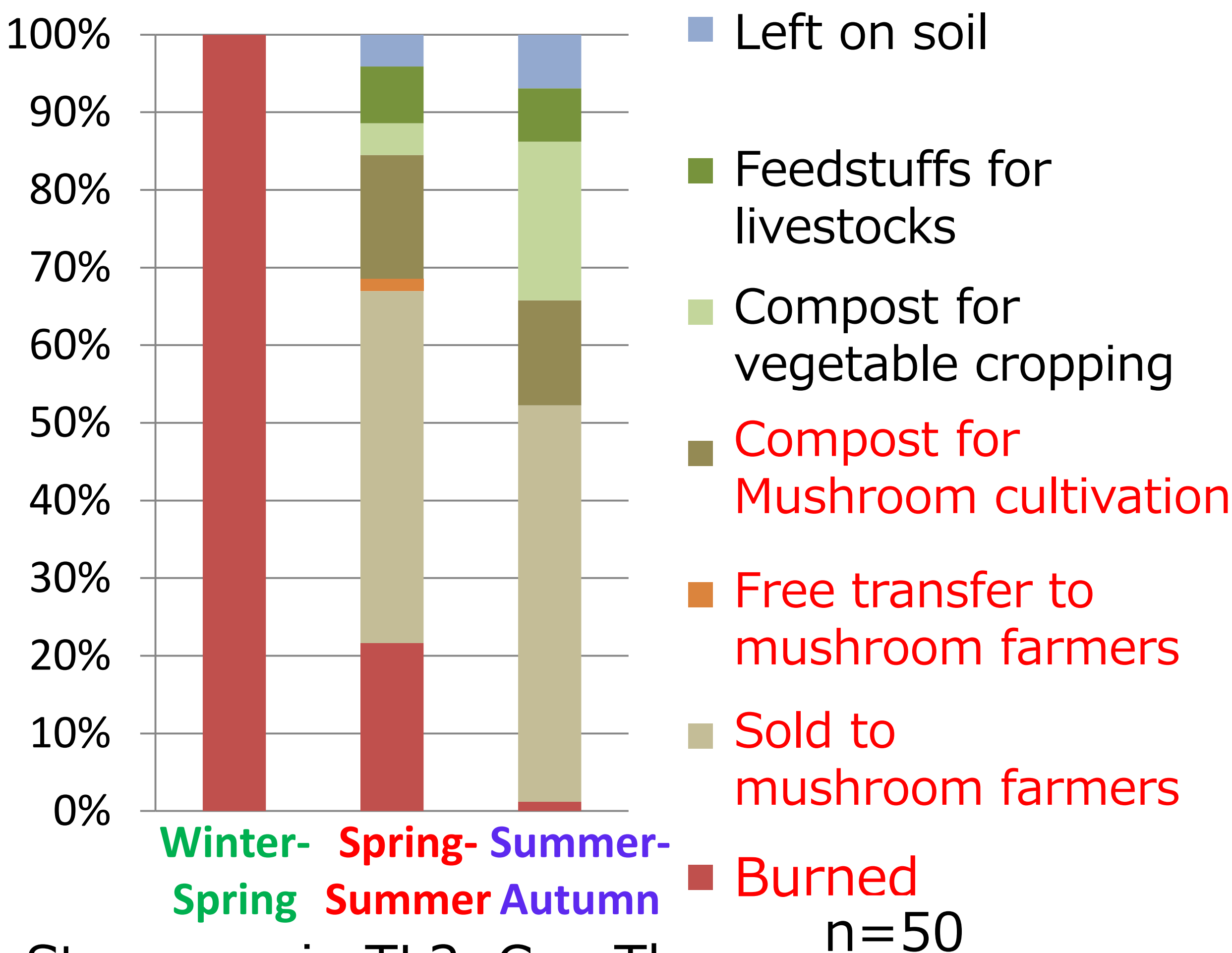


Arai et al., 2018

Characteristics of the Mekong delta

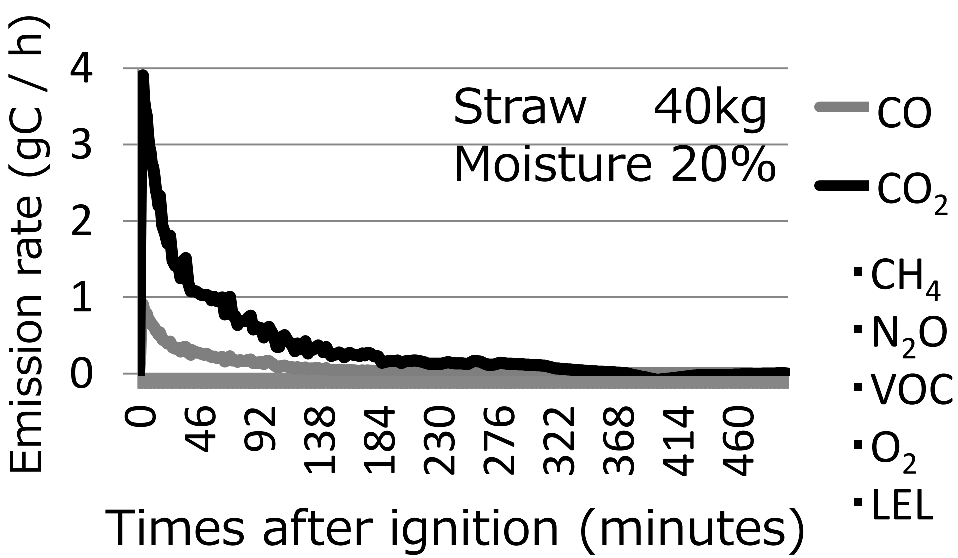


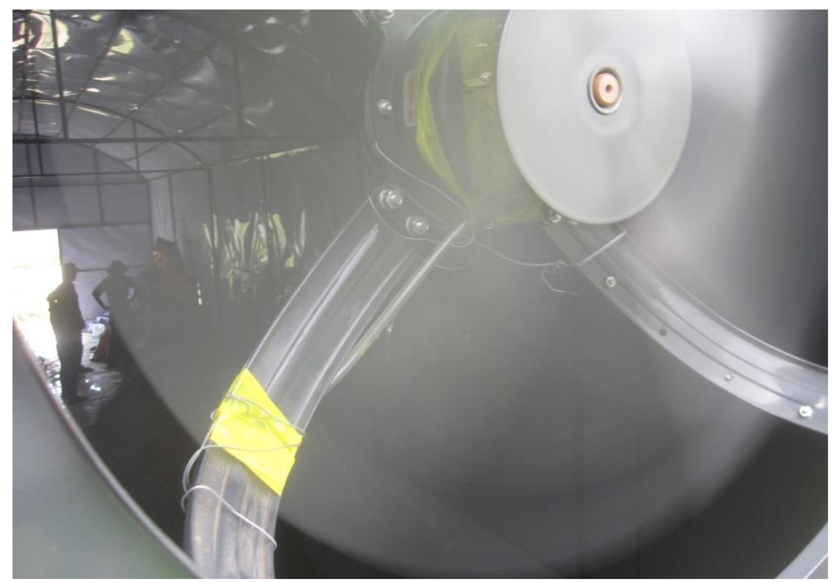
Greenhouse gas emission derived from rice straw use



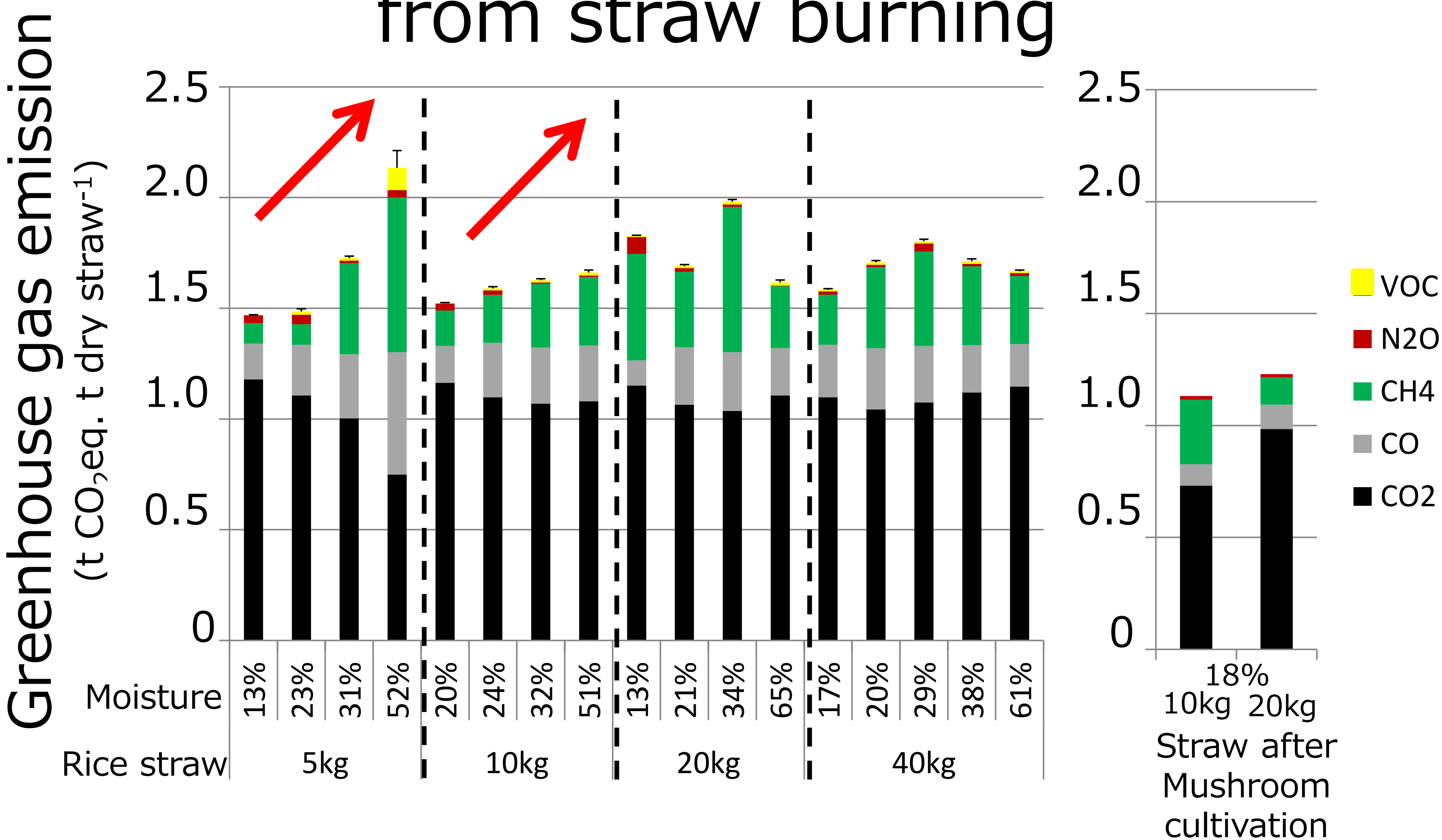
Straw use in TL2, Can Tho
(ha ha^{-1})

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





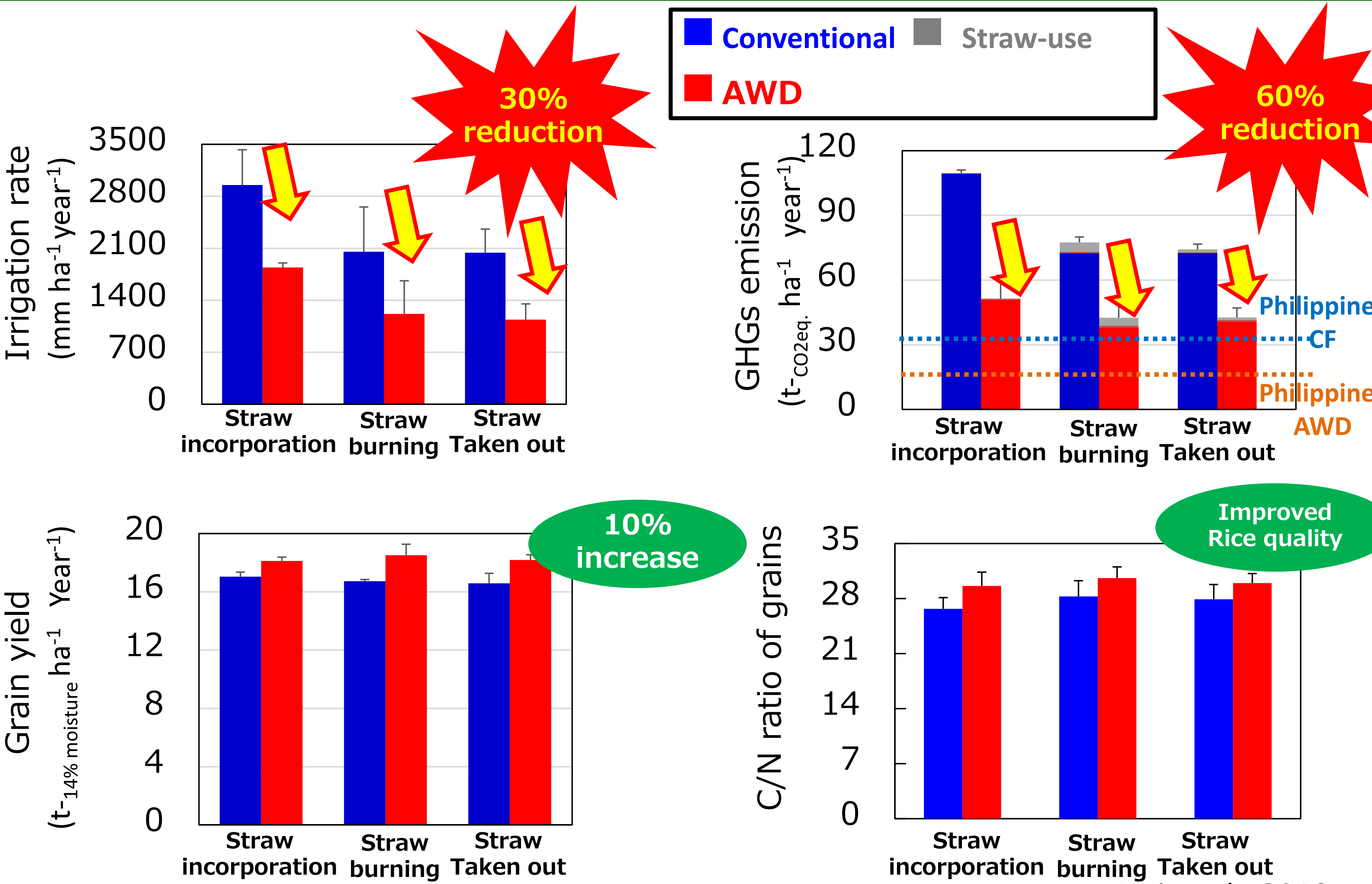
Greenhouse gas emission derived from straw burning



Global warming potential CO_2=1, CO=1.9, CH_4=25, N_2O=298, VOC=2.4~20.7

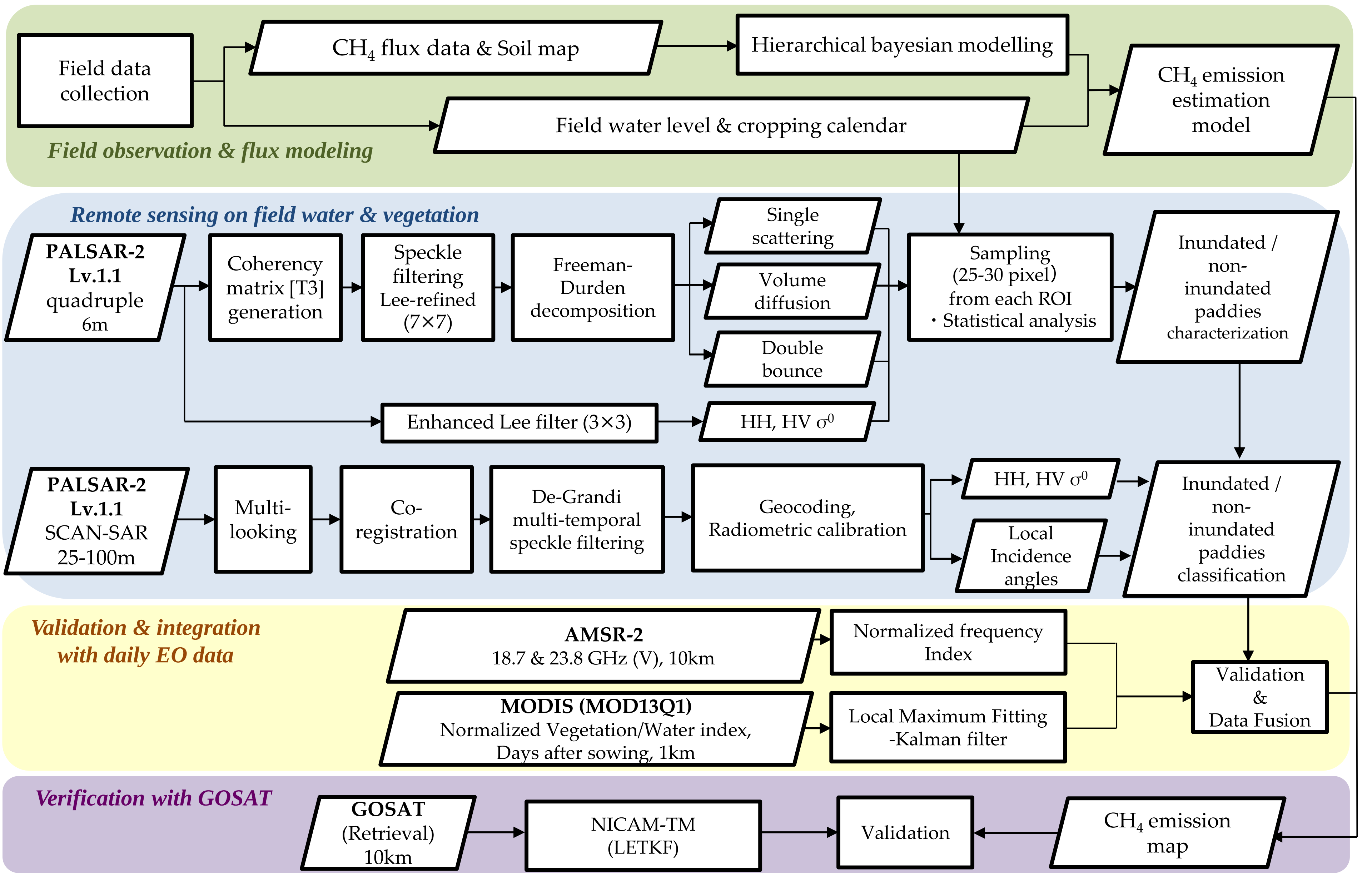
*Error bars show ranges of VOC's global warming potential

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



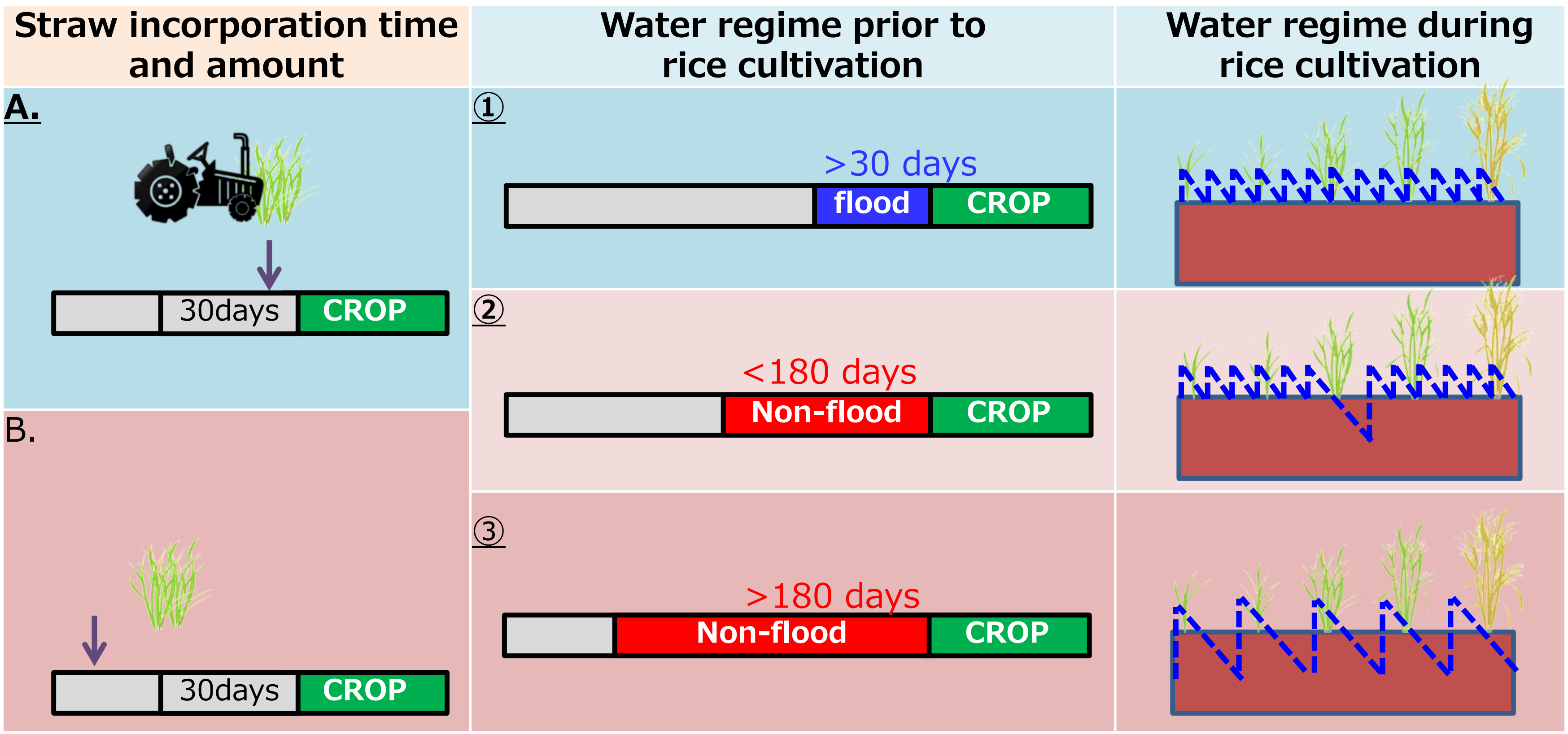
Arai et al., 2018

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

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



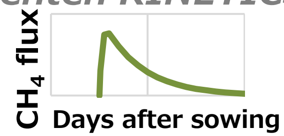
Semi-empirical **daily** CH_4 flux (mg C m^{-2} hr^{-1}) Model

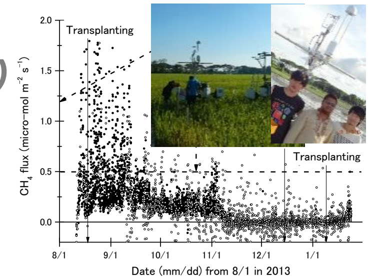
CH_4 emission on a specific date

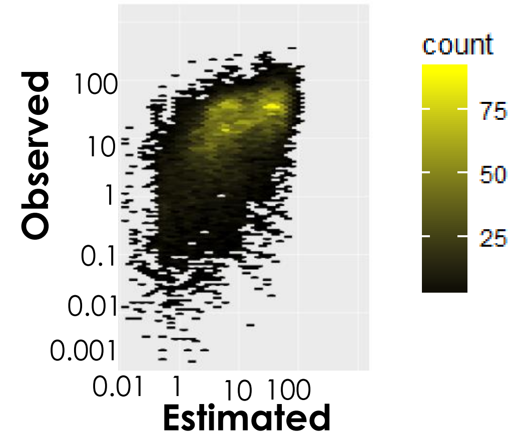
= γ * *carbon_management* / *non-inundated_fallow* / *inundated_fallow* * *water_management* *α*β

carbon_management (Michaelis-Menten KINETICS)

=[exp(-*DAS**δ)-exp(-*DAS**(δ+ω))+κ]

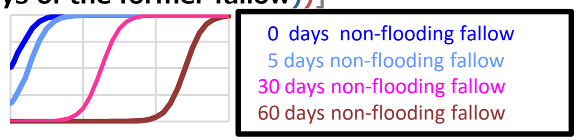






non-inundated_fallow (OXYDATION CAPACITY)

= [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

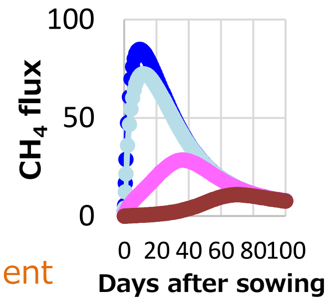
= EXP(η * **inundated days during the last 10days**)

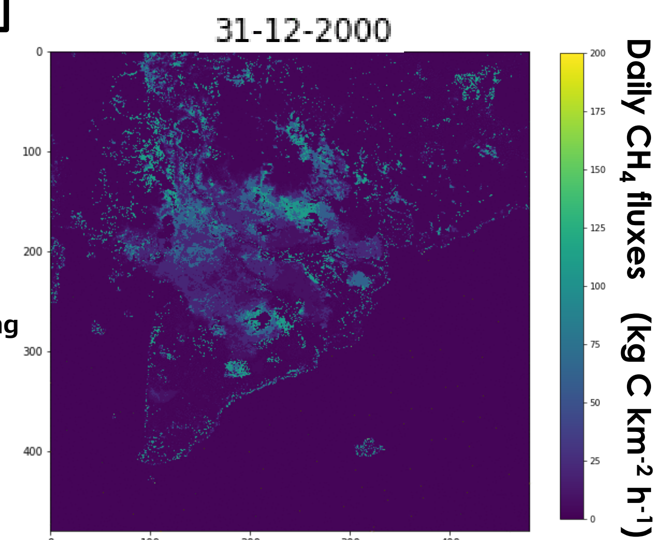
DAS←*days after sowing*

α ←straw incorporation coefficient

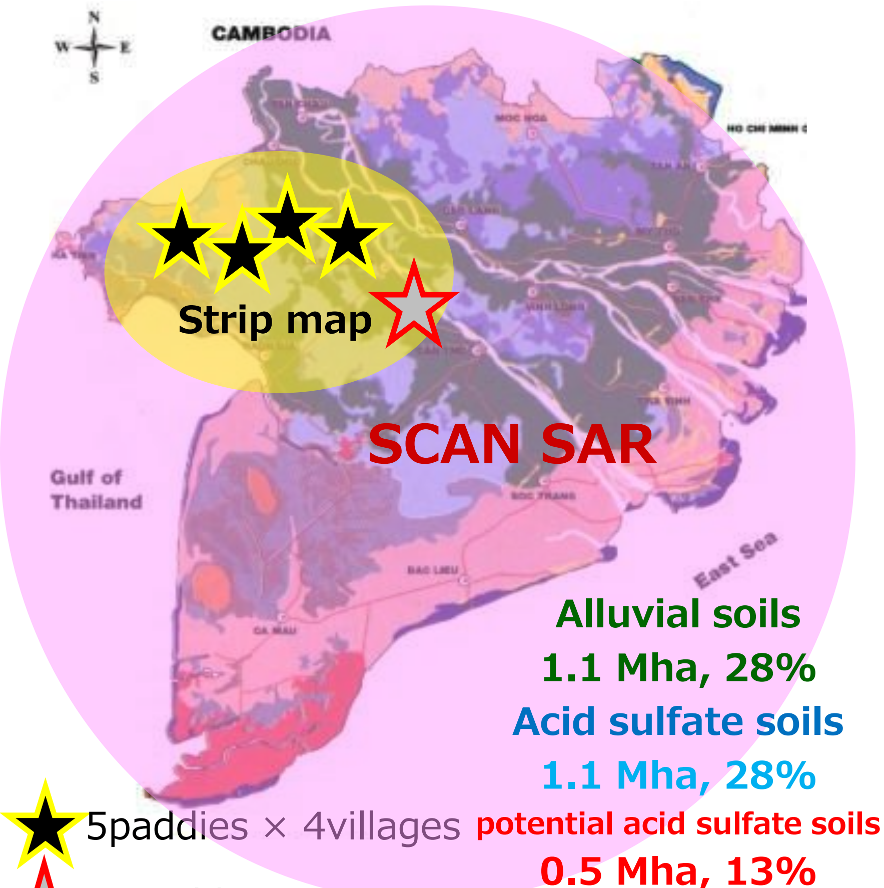
β ←acid sulfate・coastal sandy soil coefficient

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

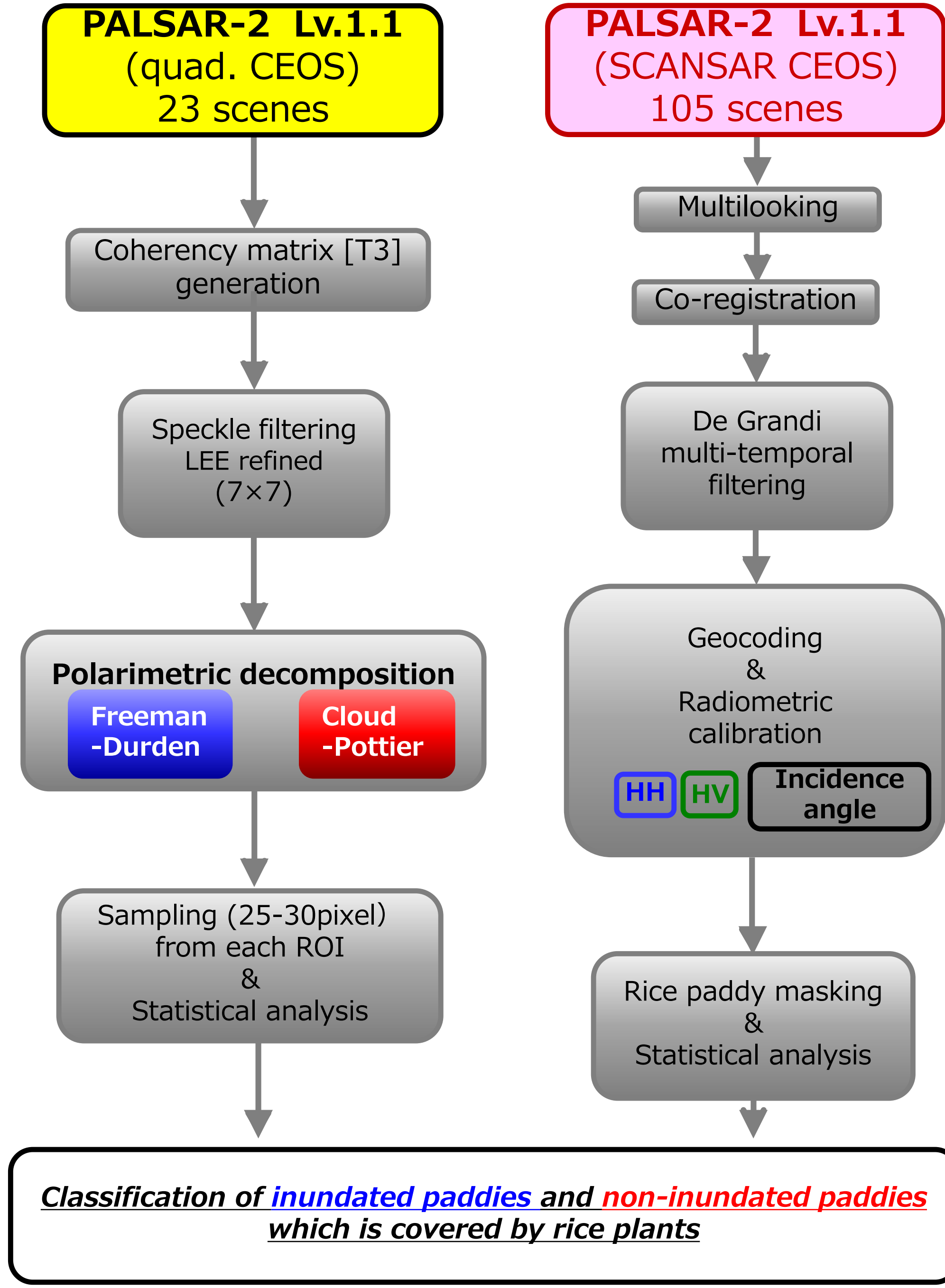




Arai et al., 2018

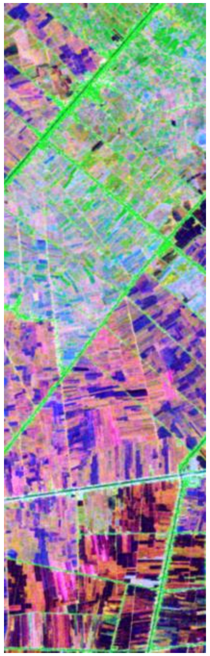


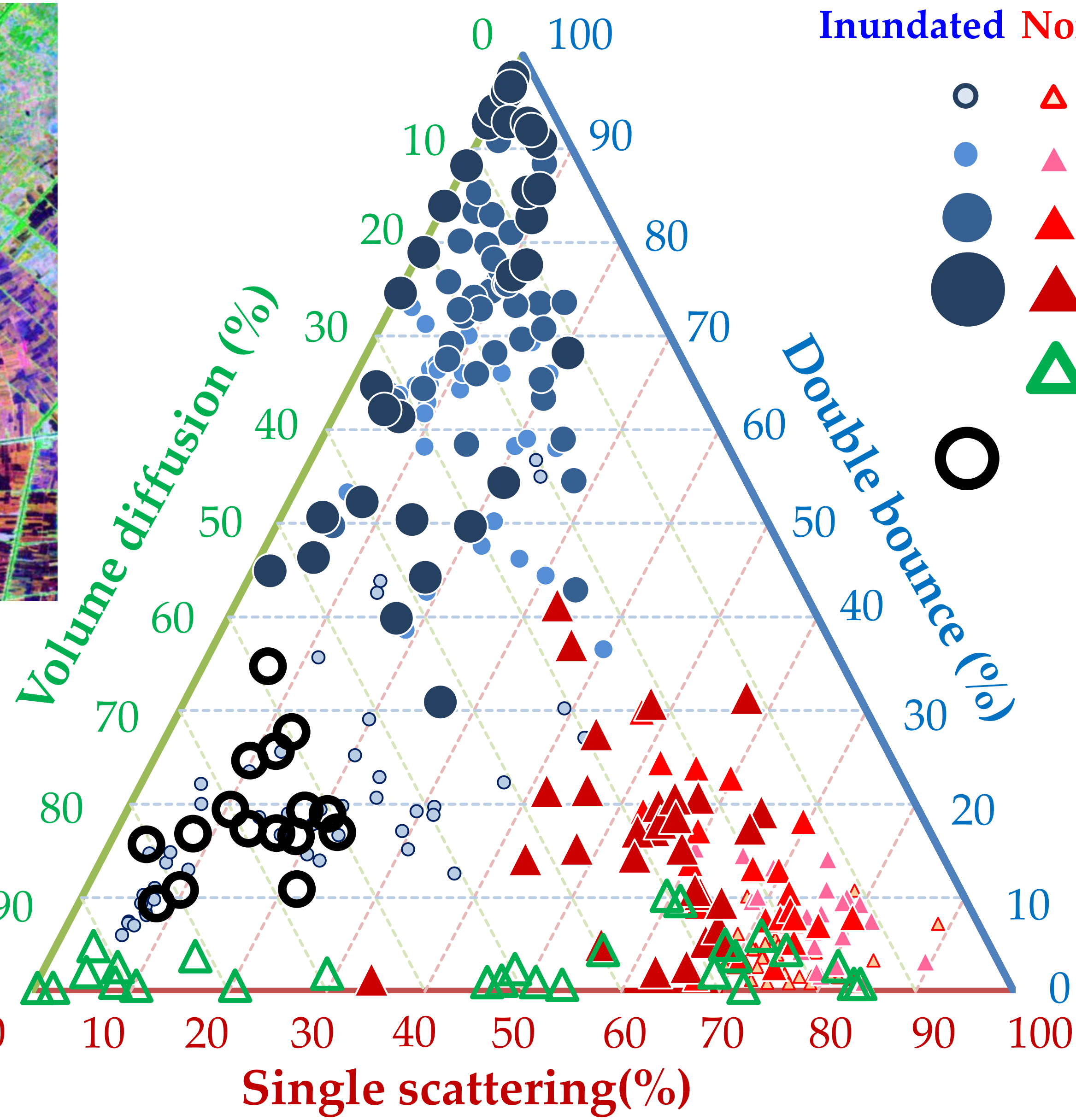
Xuan and Matsui, 1998

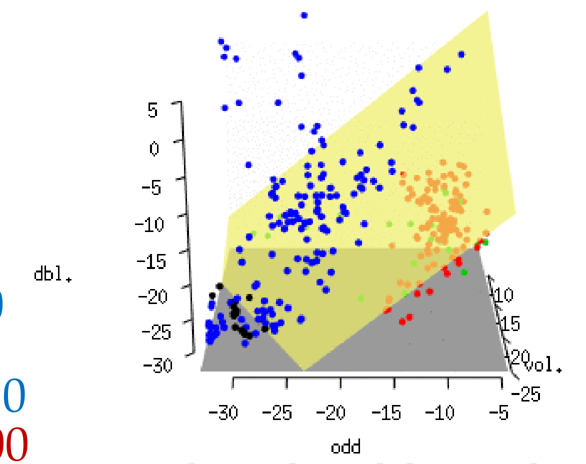


Modified from Avtar *et al*. 2012

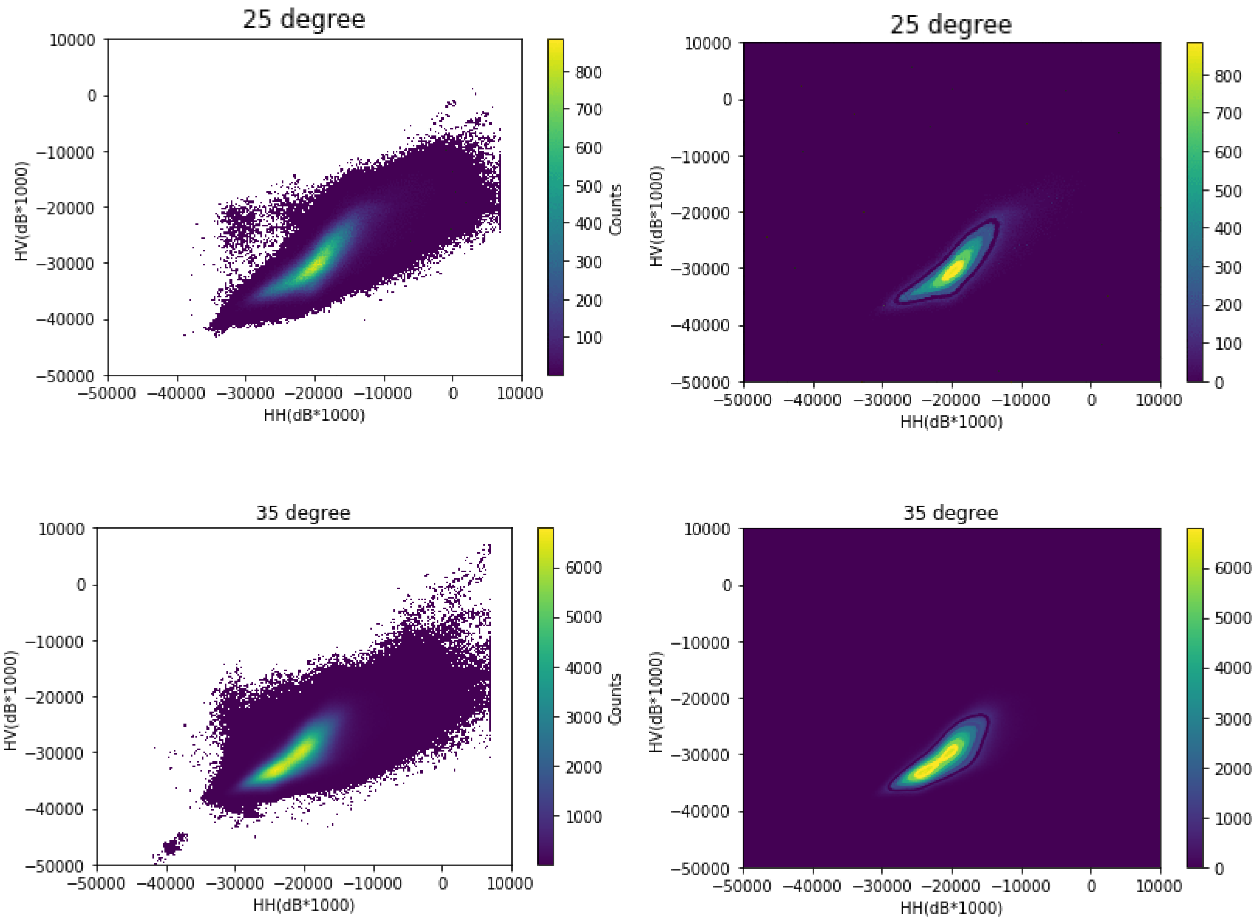
-Freeman-Durden decomposition-



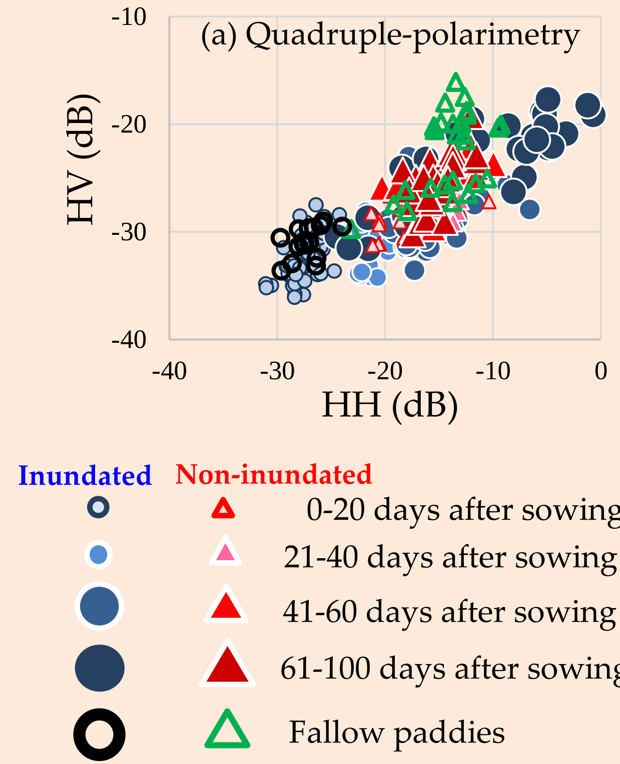




SCAN-SAR (25m)

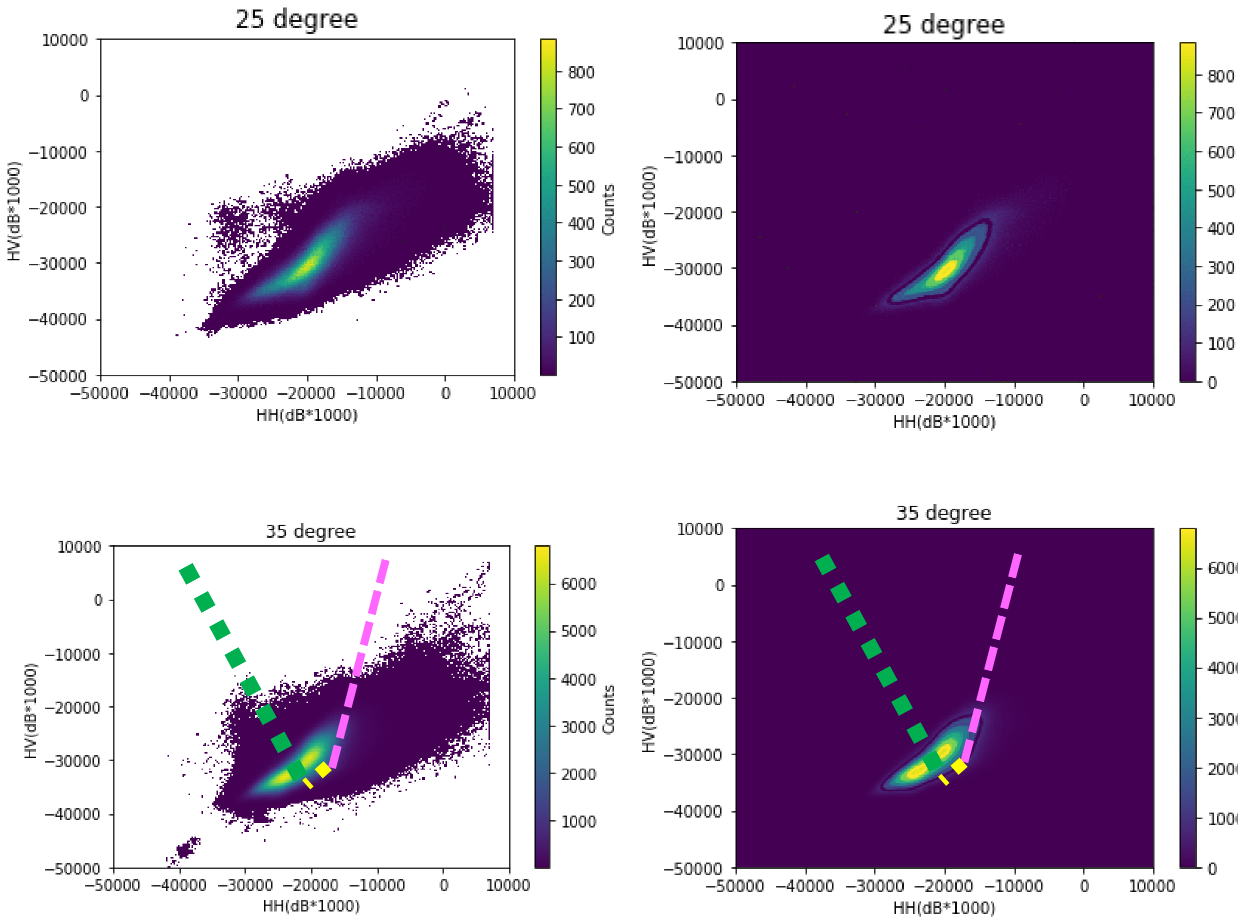


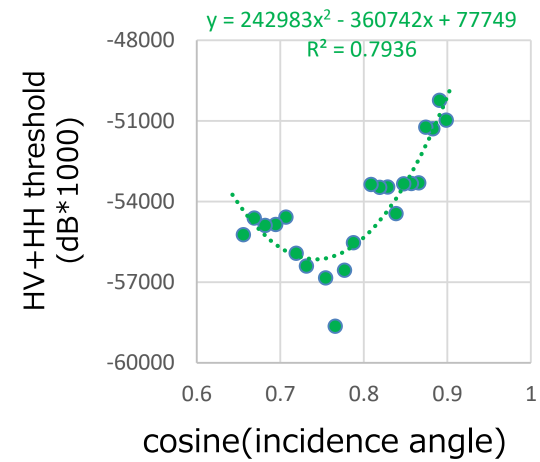
Full-polarimetry (3m)

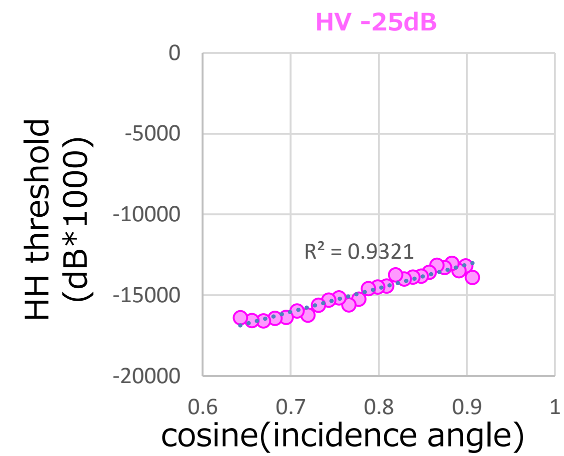


Arai et al., 2018

SCAN-SAR (25m)



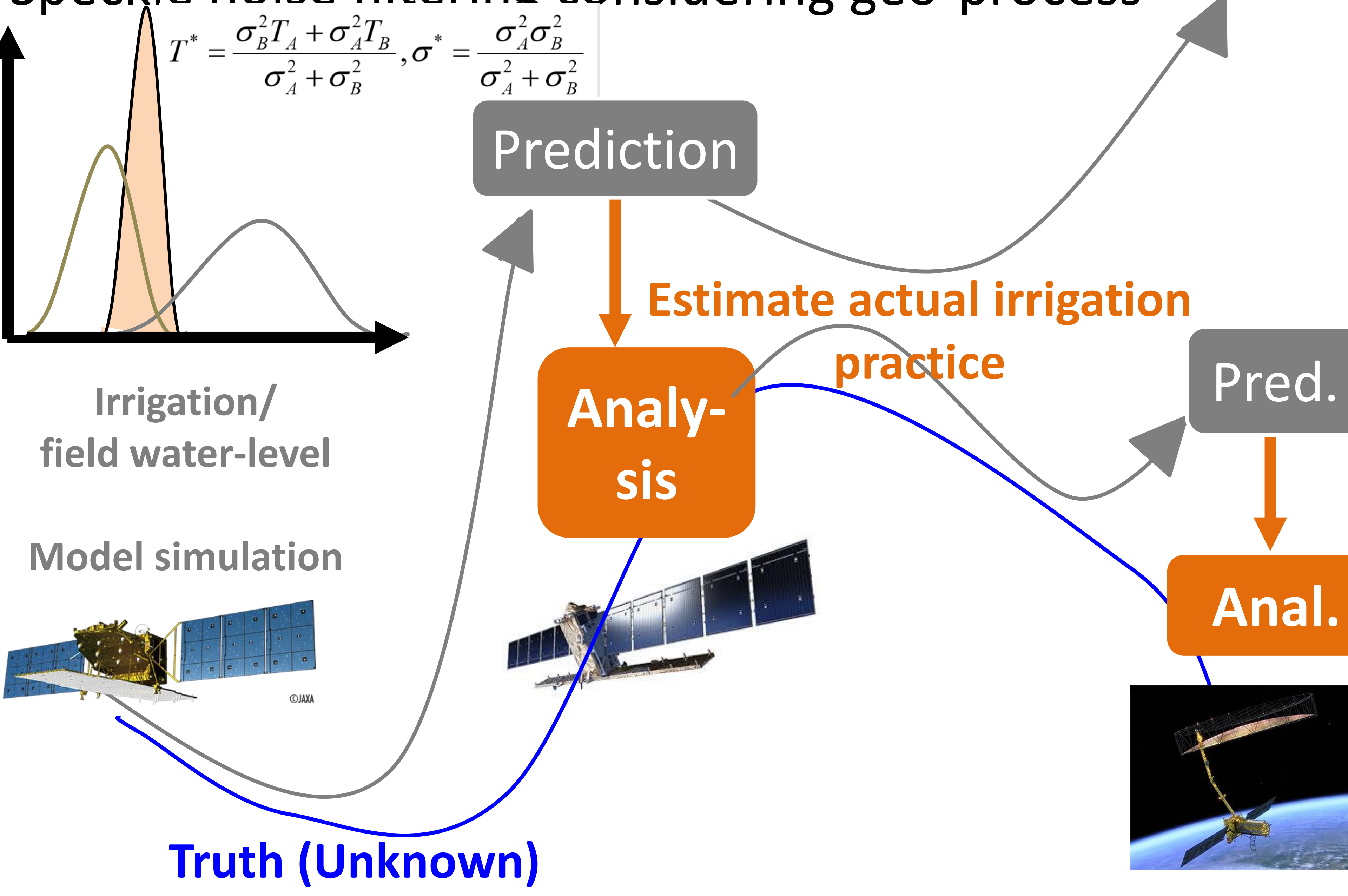




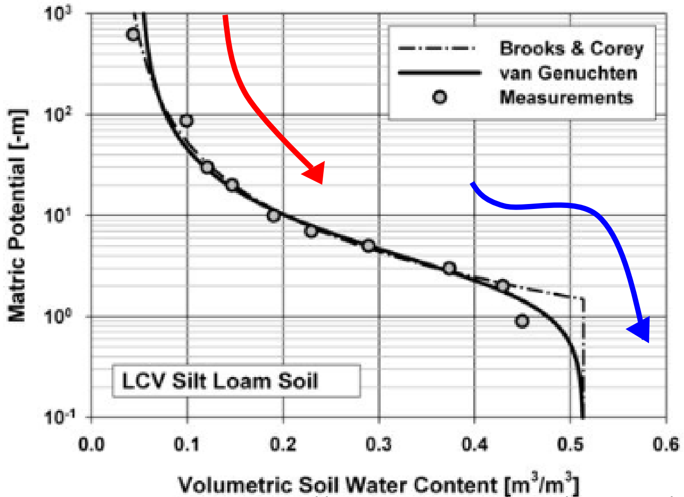
HH threshold (dB) = 0.550*HV +12.9*cosine(IA) -11.2

Arai et al., 2018

Our data integration scheme &
Speckle noise filtering considering geo-process

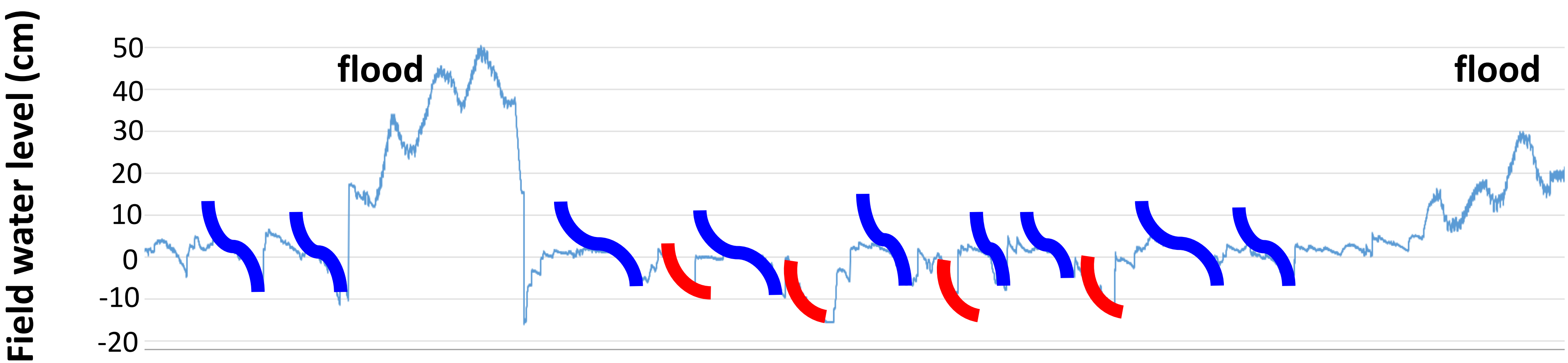


Simulation scheme with 25m-spatial resolution
- Hysteresis of soil matric potential energy-



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)・α_i

constraint

t = days after irrigation

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

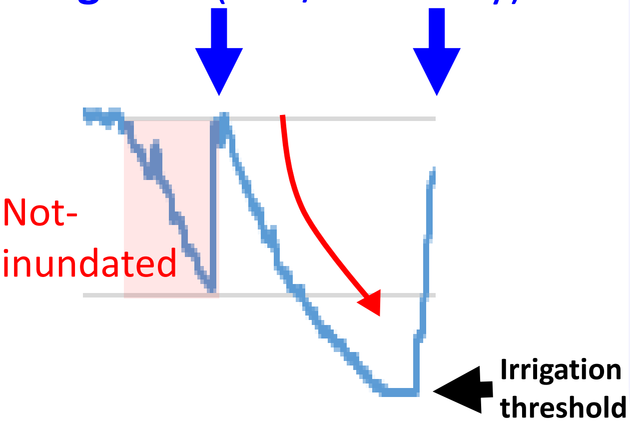
$$\frac{dWL}{dt} = \gamma * \exp\Big(\delta * \{1 - \log[\exp(Di*(t-G)) + 2 + \exp(-Di*(t-G))]\} * Di*(t-G)\Big) - \frac{\delta * [\exp(Di*(t-G)) - \exp(-Di*(t-G))] * Di*(t-G)}{\exp(Di*(t-G)) + 2 + \exp(-Di*(t-G))} + Di*\{1 - \log[\exp(Di*(t-G)) + 2 + \exp(-Di*(t-G))]\} + \text{rain-fall}$$

Irrigation function

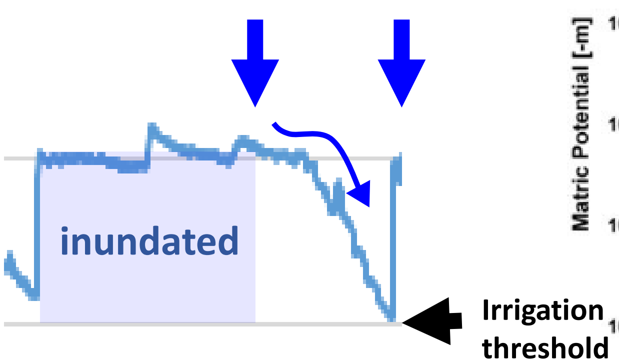
if WL < *threshold* :
irrigate (i.e., WL += *X*)

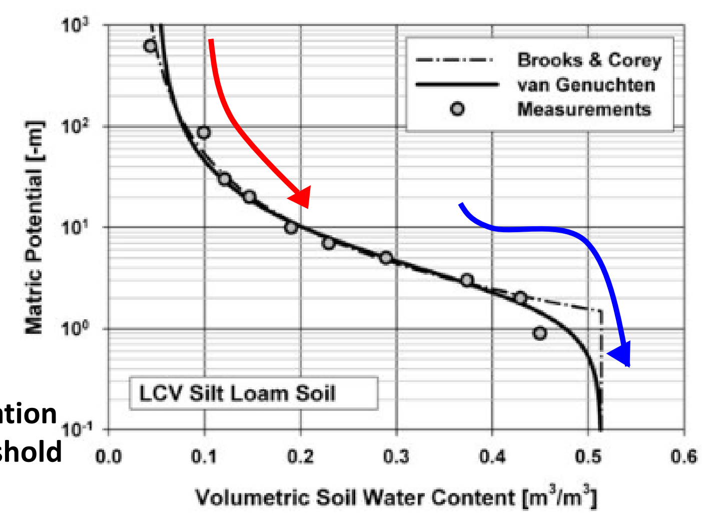
Parameter update by the analysis with EO data

Irrigation (init./boundary)



Irrigation (init./boundary)





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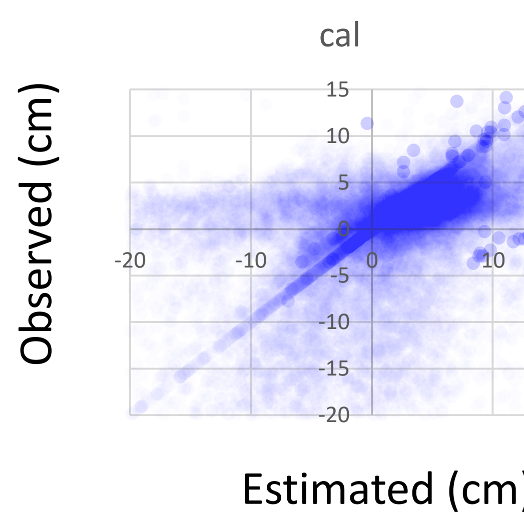
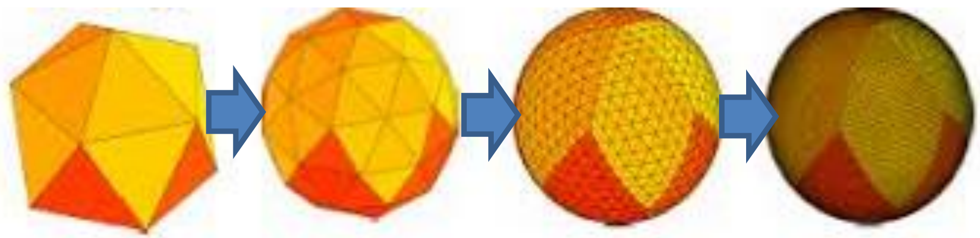
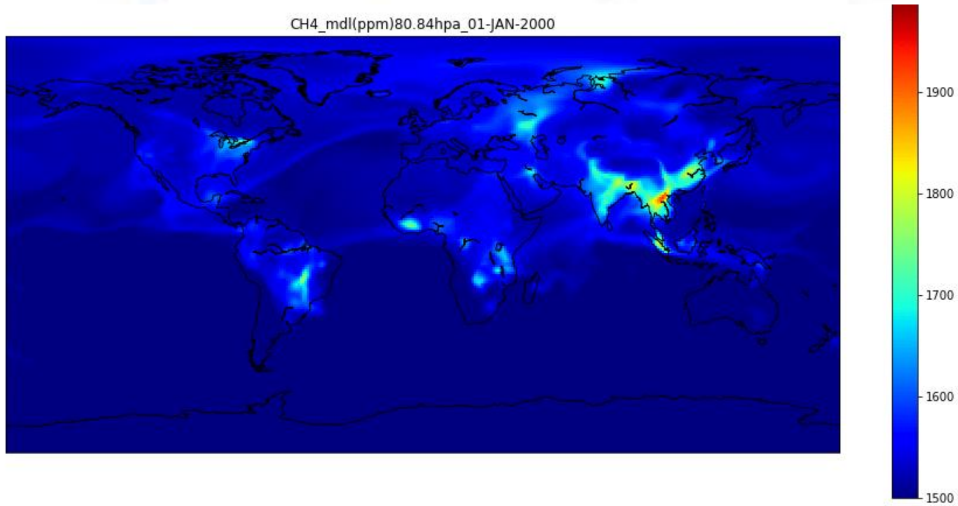


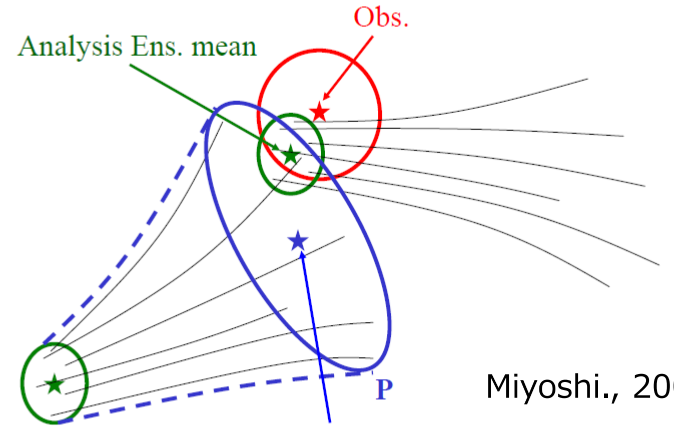
NICAM-TM(Chem)-LETKF with AMSU, PREPBUFR and GOSAT/Sentinel-5P

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

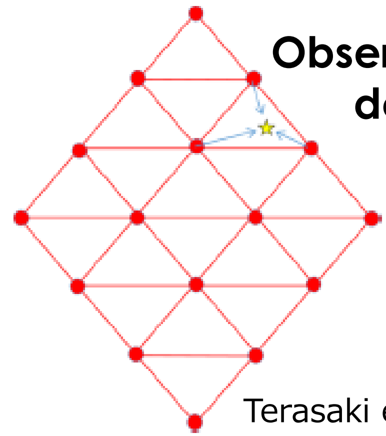




Local **E**nsemble **T**ransform **K**alman **F**ilter



Miyoshi., 2005



Observation operator development for GOSAT

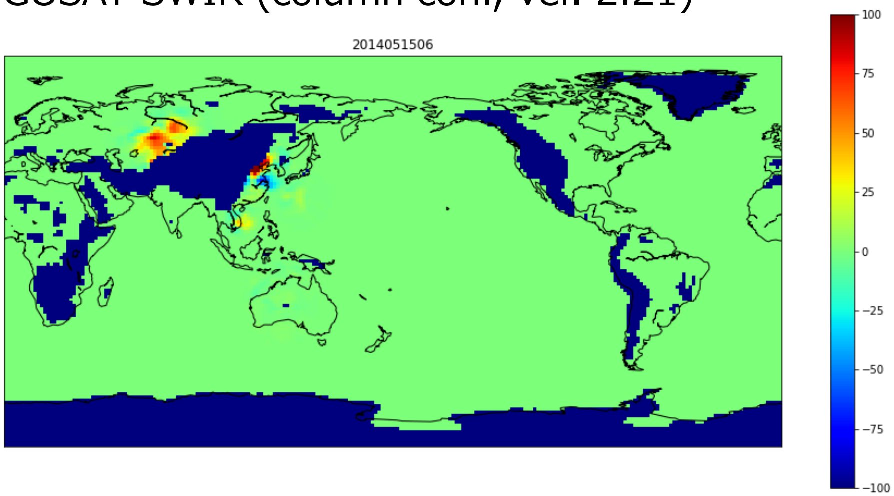
Terasaki et al., 2014

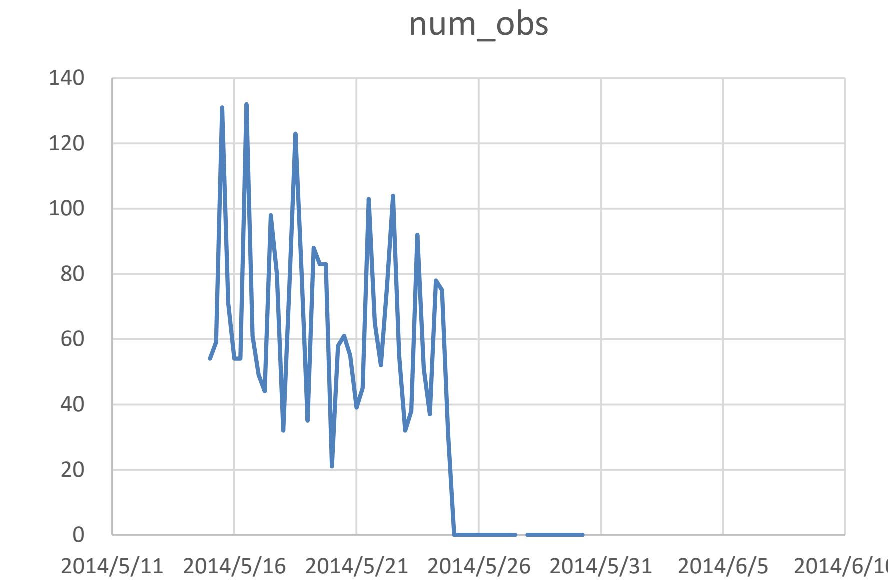
Direct comparison between GOSAT and emission data is meaningless…

→GOSAT data assimilation with NICAM-TM!

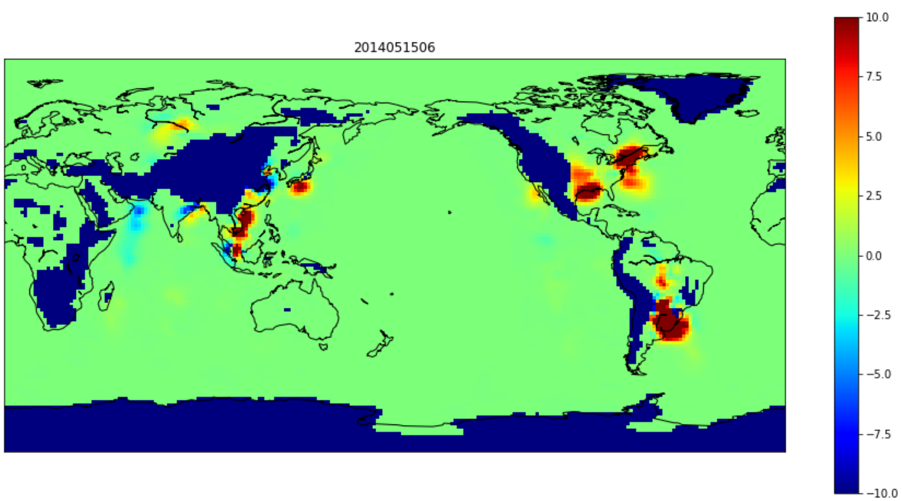
Implementation of GOSAT data (column/profile) DA system in **NICAM-TM-LETKF** (PREPBUFR&GOSAT)

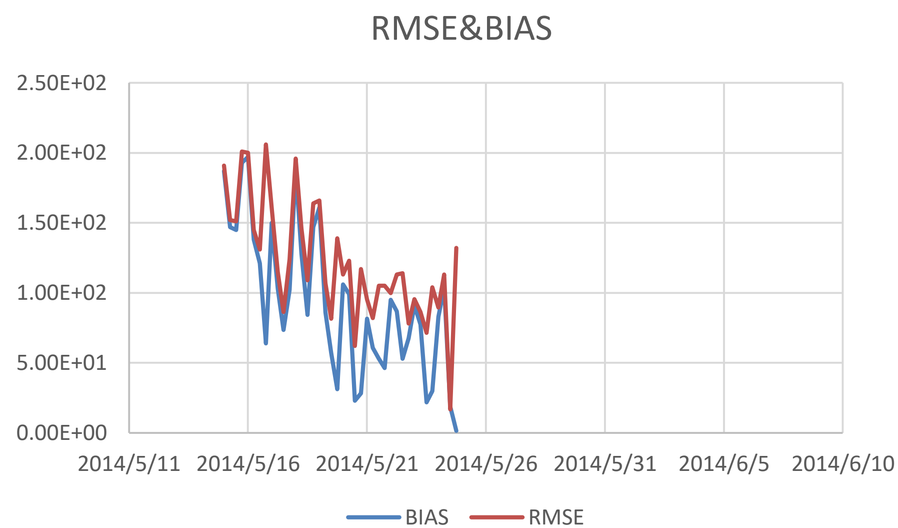
Increment of XCH_4 (ppb, 900 hpa) w/ DA GOSAT SWIR (column con., ver. 2.21)



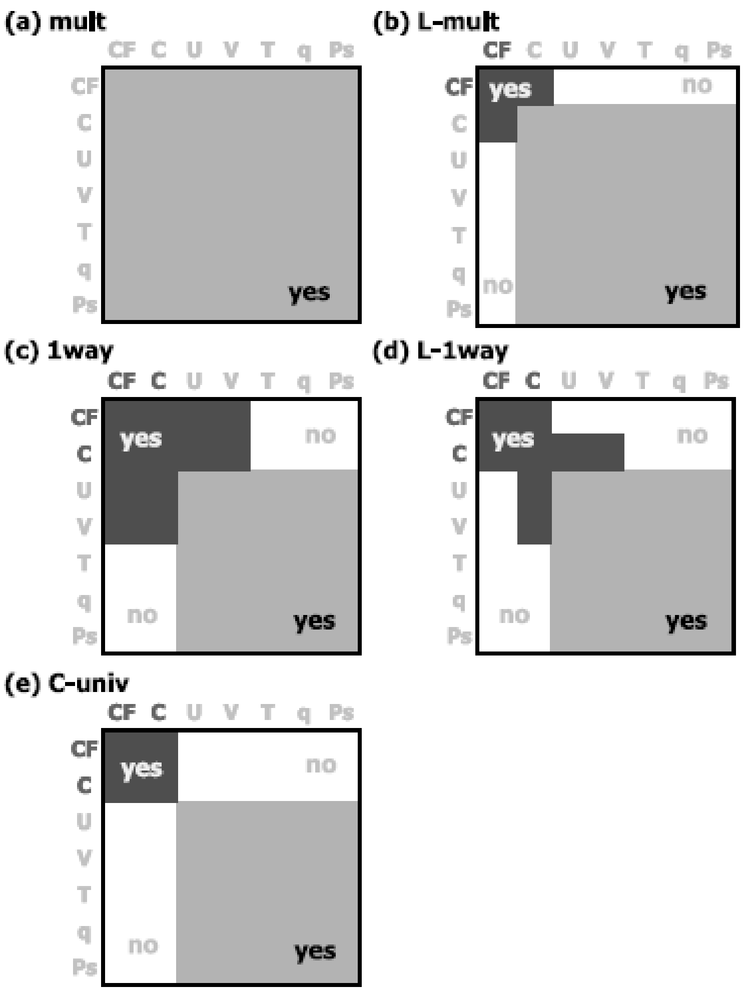


Increment of XCH_4 (ppb, 900 hpa) w/ DA GOSAT TIR (CH_4 profile., ver. 1.2)





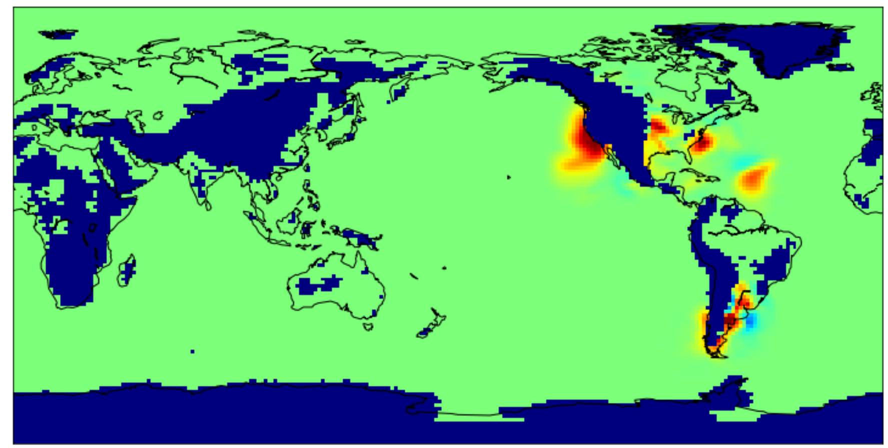
Implementation of variable localization scheme in NICAM-TM-LETKF (PREPBUFR&GOSAT)

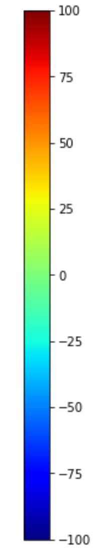


Back ground covariance matrices

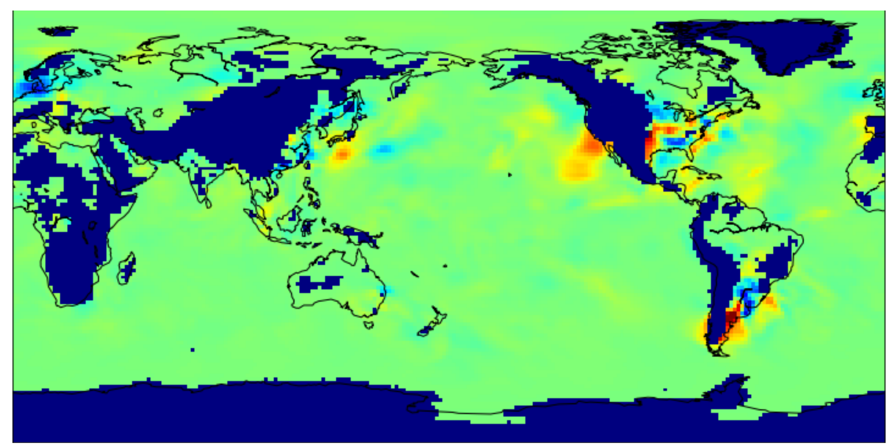
Kang et al., 2012

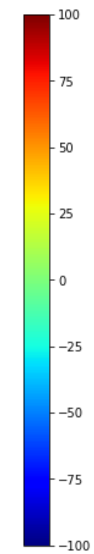
Increment of XCH_4 (ppb, 950 hpa) w/ VL





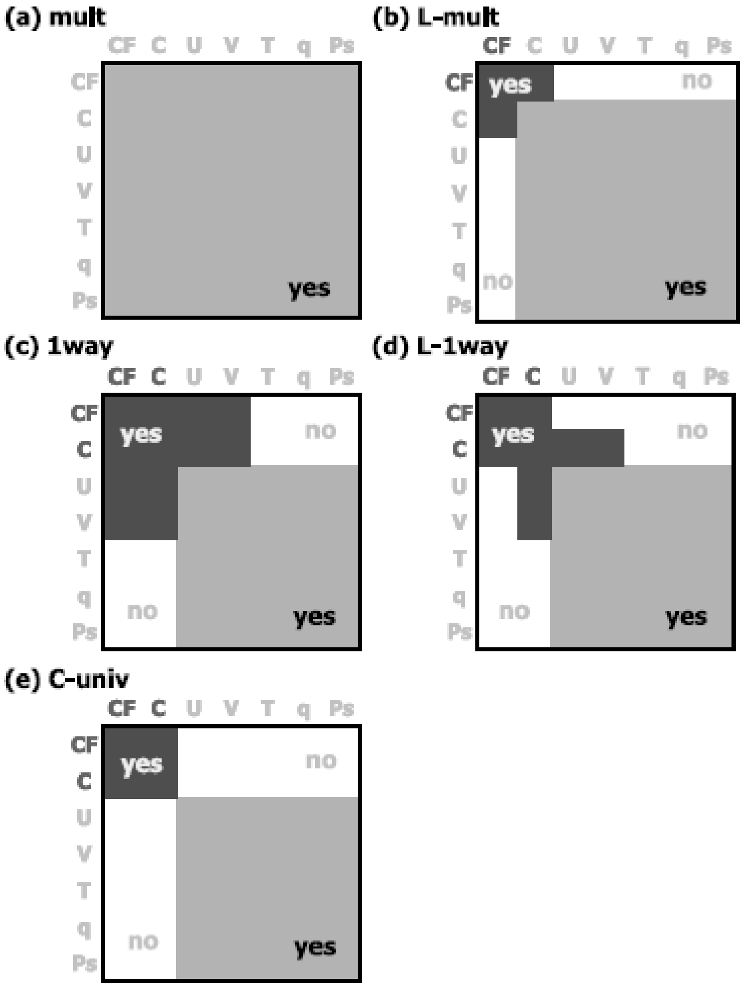
Increment of XCH_4 (ppb, 950 hpa) w/o VL





2014051718-1803 Glevel 6, Inflation with RTPS=1

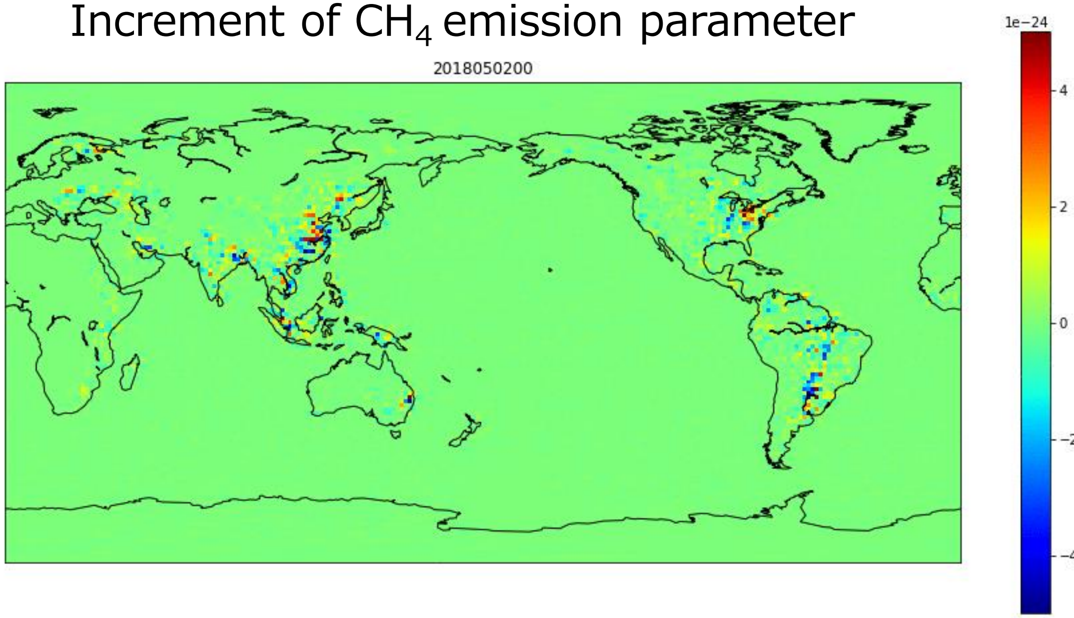
Implementation of variable localization scheme in NICAM-TM-LETKF (PREPBUFR&GOSAT)



Back ground covariance matrices
Kang et al., 2012

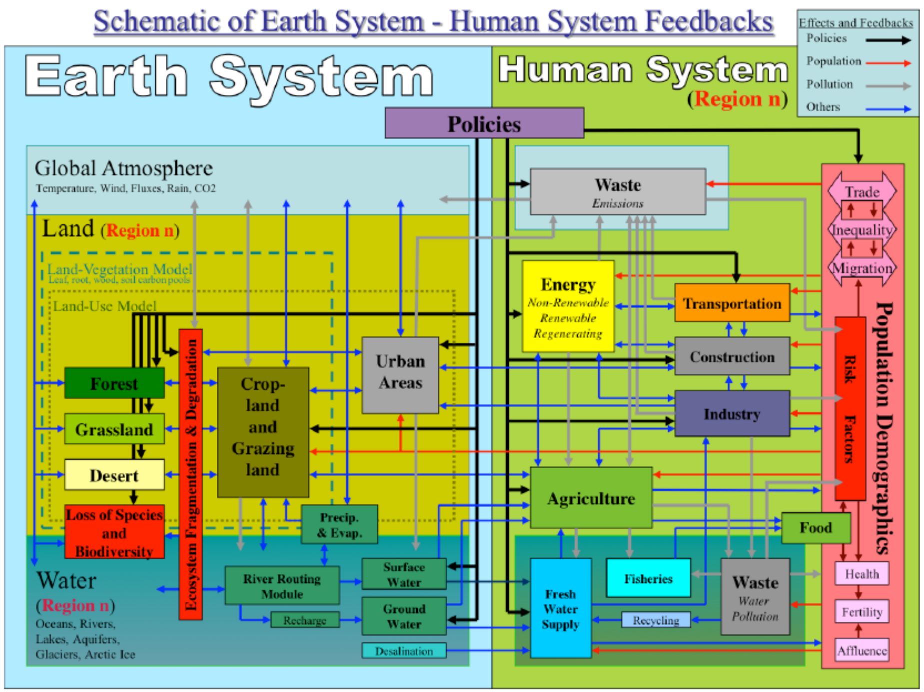
A Result of test-run

Increment of CH_4 emission parameter



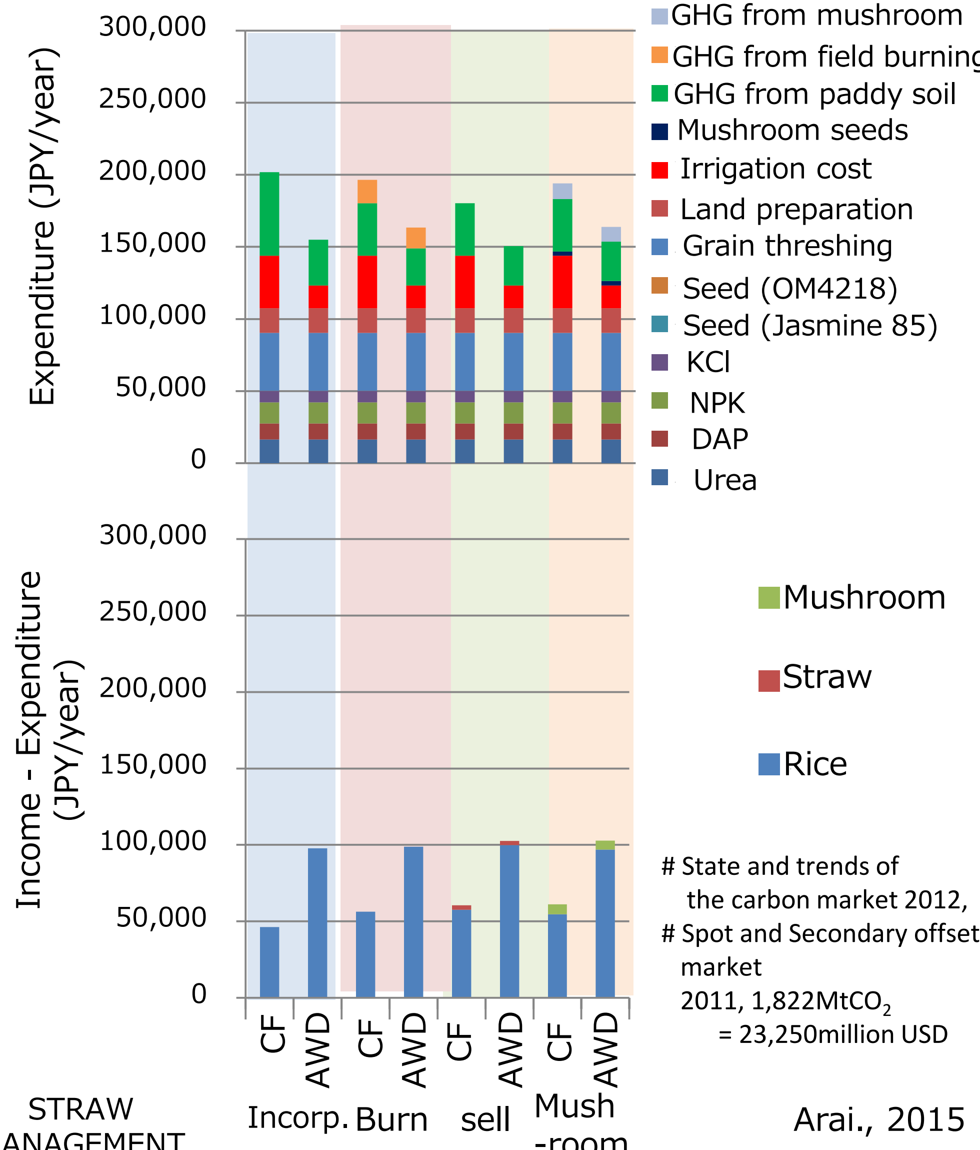
→ Flux parameter estimation w/o apriori information!

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 !



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

Arai., 2015

We won JSPS fellowship!

L/S/C band SAR data fusion
& ensemble Bayesian simulation
(Probabilistic-approach, 20m-res.)

CH_4 emission estimation
w/ GOSAT-2&Sentinel-5P
Implementation of CH_4 emission estimation scheme in new-NICAM-LETKF
(+ATMS,MHS,GSMAP,IASI,CRIS,AIRS)

Comparison with DNDC model
(Deterministic-approach, ?km-res.)

DA with MERLIN in regional Atm.-model
(e.g., SCALE-TM-LETKF, 250m-res.)
For bias correction &
CH4 emission estimation from
another emission source
(e.g., live stock)

Thank you very much!!!

WTLAB @ U-Tokyo

Oyoshi-san @JAXA

VNSC-HCM

Field work collaborators

Dr. Thuy @CESBIO

Dr. Sobue @JAXA

RIKEN-DA team

Soil Sci. Lab @ Chiba Univ.