SUSTAINABLE DEVELOPMENT GOALS

RESPONSIBLE CONSUMPTION AND PRODUCTION

CLIMATE ACTION

Establishing an integrated MRV system of greenhouse gas emission from wetlands with Japanese earth-observation/modelling technologies and a data assimilation technique

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Koji Terasaki[2], Takemasa Miyoshi[2], Hisashi Yashiro[2]

1) RSED 2) AICS 3) JAXA 4) VNSC 5)

Outline

0．Motivation to DA (Story taking me here today)

1．Background & Objective

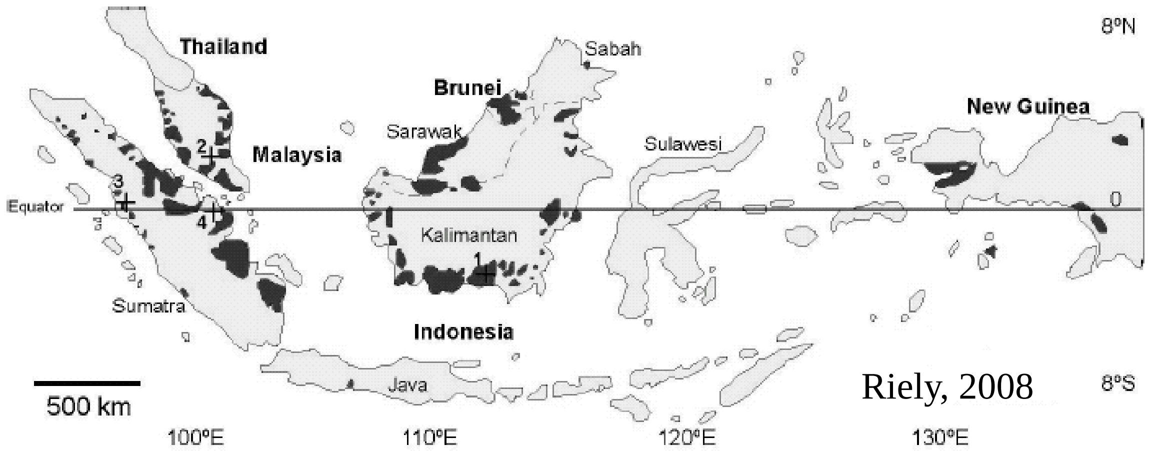
2. Ground observation of greenhouse gas emission and statistical modeling

3. Satellite remote sensing of GHG emitters

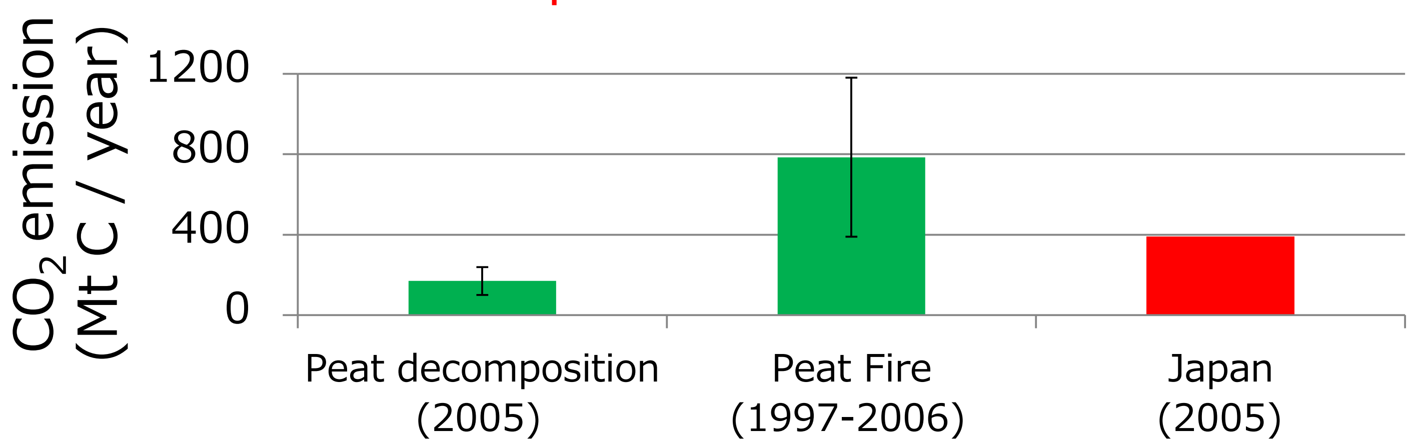
- Cropping calendar & the adjacent fallow length
- Paddy soil/water covered by rice plants
- Top down verification with GOSAT

4. My next work with DA

Drainage on peatlands in SE asia



CO_2 emission (Mt C/year) from peat in south east Asia and Japanese total emission.



Hooijer et al., 2006; Hatano, 2009

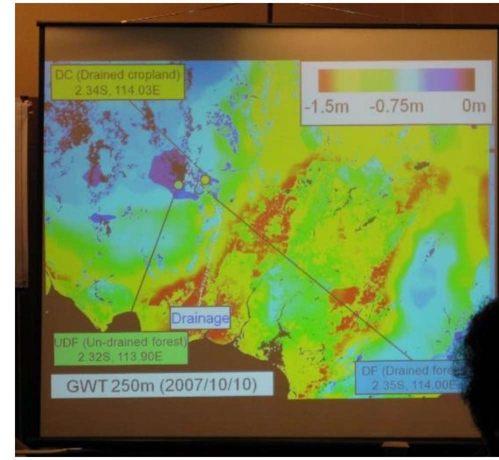
Target fields

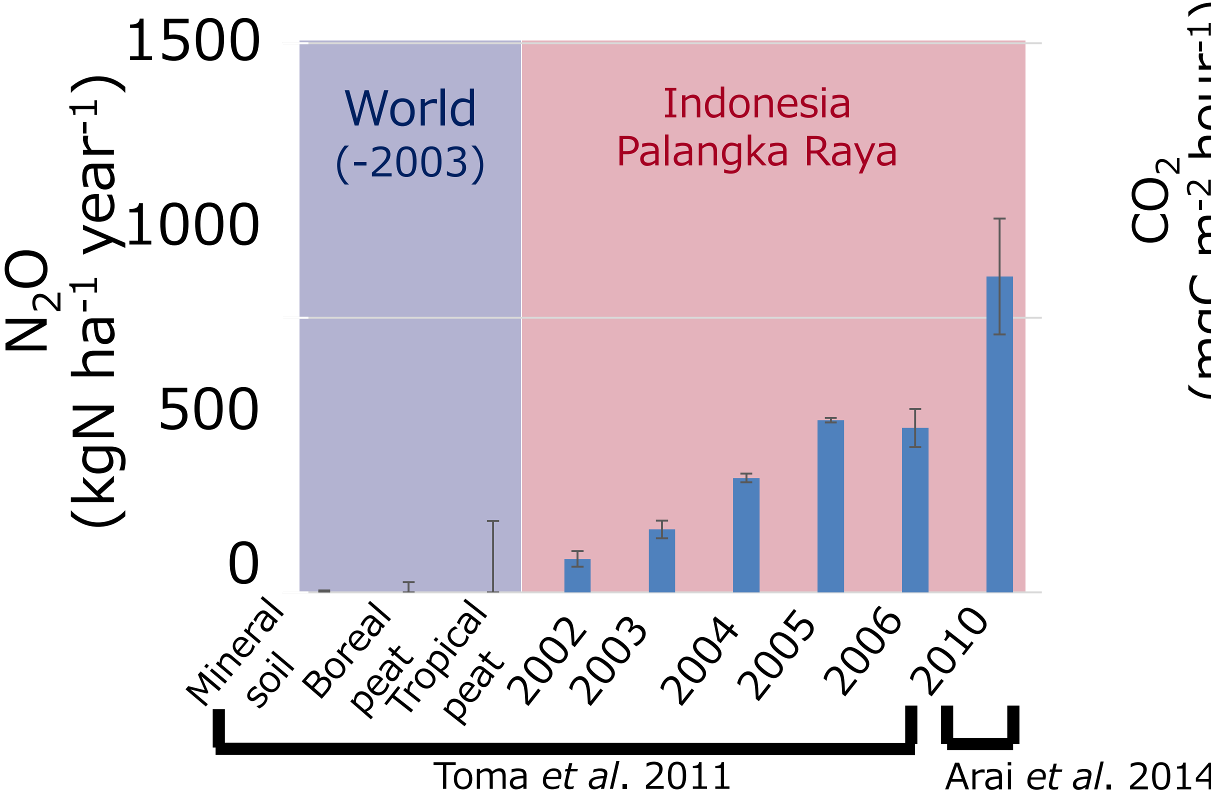
Natural Forest

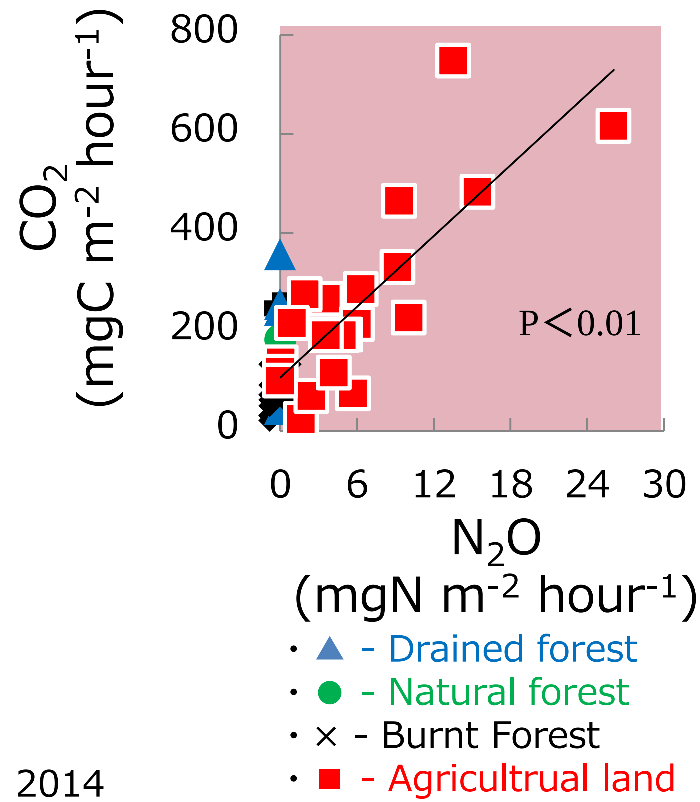
Drained Forest

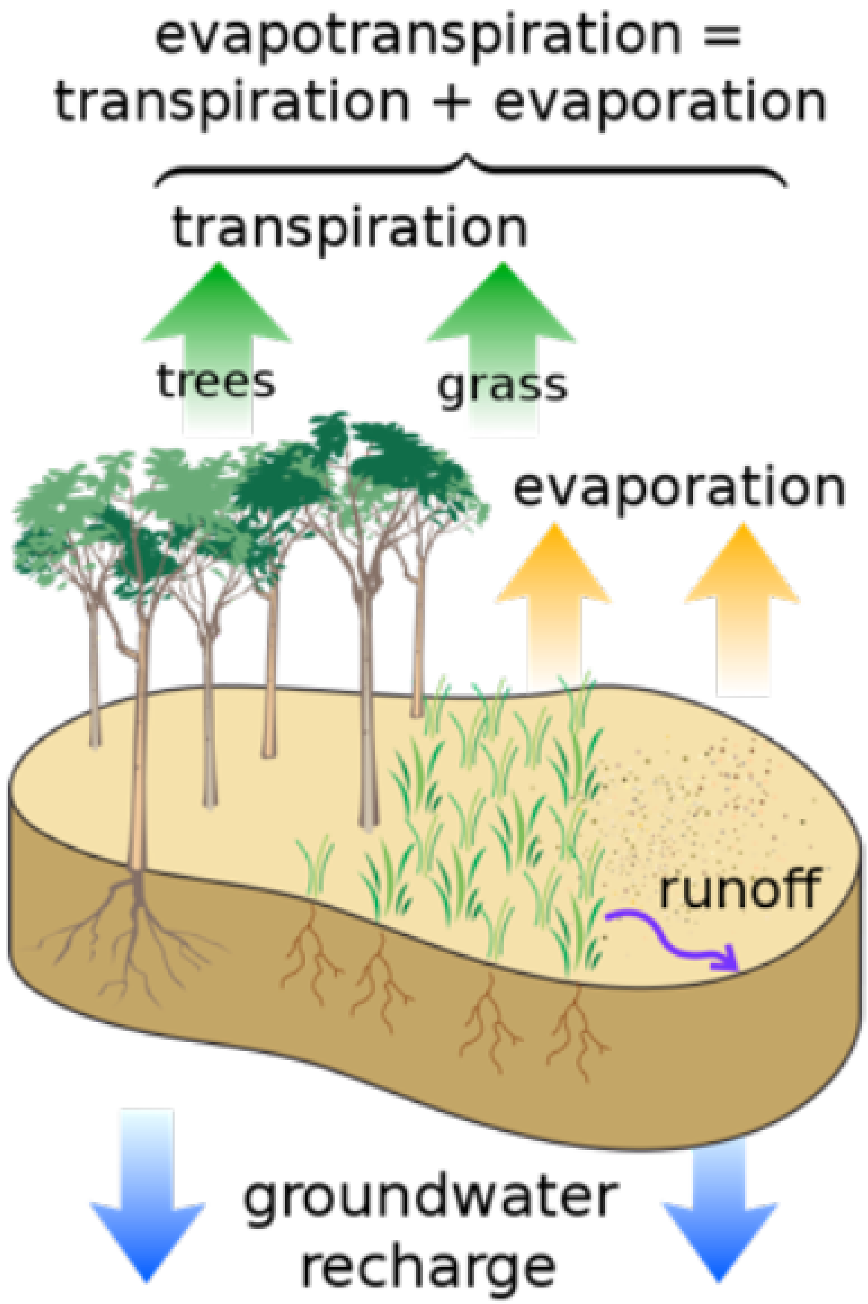
Agricultural land

Burnt Forest


DC (Drained cropland)
2.34S, 114.03E
-1.5m -0.75m 0m
Drainage
UDF (Un-drained forest)
2.32S, 113.90E
GWT 250m (2007/10/10)


N_2O
$(kgN\ ha^{-1}\ year^{-1})$
1500
1000
500
0
World
(-2003)
Indonesia
Palangka Raya
Mineral soil
Boreal peat
Tropical peat
2002
2003
2004
2005
2006
2010
Toma et al. 2011
Arai et al. 2014


CO_2
$(mgC\ m^{-2}\ hour^{-1})$
800
600
400
200
0
0
6
12
18
24
30
N_2O
$(mgN\ m^{-2}\ hour^{-1})$
$P < 0.01$
- Drained forest
- Natural forest
× - Burnt Forest
- Agricultrual land



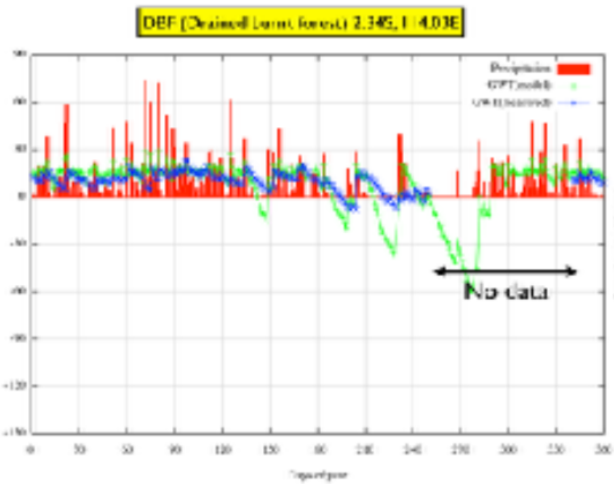
- KBDI index are used to compute the balance between evapotranspiration and precipitation. [Keetch *et. al*, 1965]

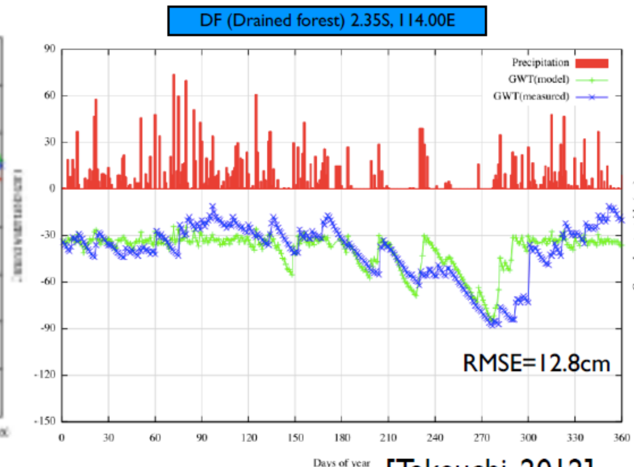
$$dQ = \frac{[800-Q][.968\exp(.0486T) - 8.30]\,d\tau}{1 + 10.88\exp(-.0441R)} \times 10^{-3}$$

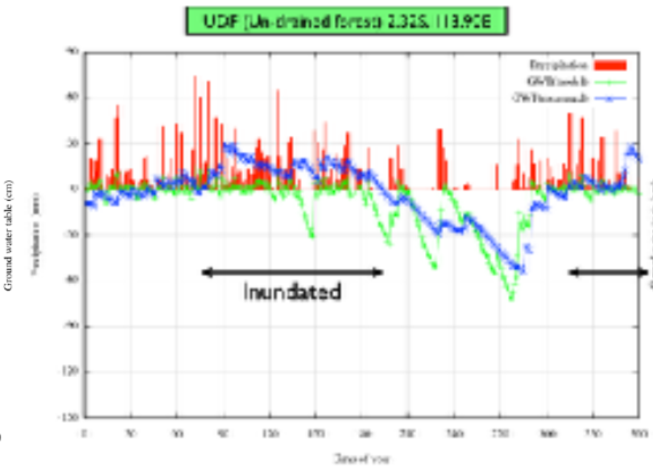
- Presently, this index is derived from satellite observation:
  - land surface temperature (LST) from MTSAT received at IIS/U-Tokyo
  - rainfall from global satellite mapping (GSMaP) provided by JAXA EROC.
- Ground water table (GWT) is modeled as a function of KBDI

Takeuchi, 2013

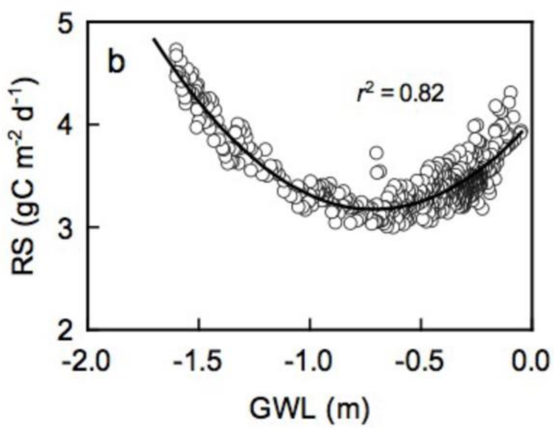
Lower ground water table of peatland in Indonesia are prone to fires and large carbon emission sources







[Takeuchi, 2012]



[Hirano, 2012]

	GWT (m)		SR (gC/m2/yr)	
	Satellite-based model (This study)	In-situ (Hirano, 2012)	Satellite-based model (This study)	In-situ (Hirano, 2012)
2007	-0.07	-0.4	1,386	1,238
2008	-0.26	-0.4	1,331	1,236

Takeuchi, 2013

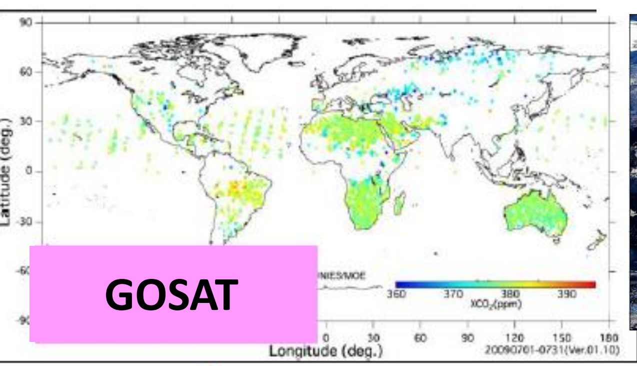

気象衛星ひまわり ~宇宙からの最先端データが
豪雨事例へのひまわり8号同化
色：モデルと実観測それぞれの赤外輝度温度
Simulated/Observed Brightness Temperature B14 (K), at 18:00z08SEP2015
ひま8同化なし
ひま8同化あり
ひま8観測
190 195 200 205 210 215 220 225 230 236 242 248 254 260 266 272 278 284 290 296
低: 高い雲
高: 低い雲/晴天
台風本体や関連する雲域が劇的に改善
三好2017

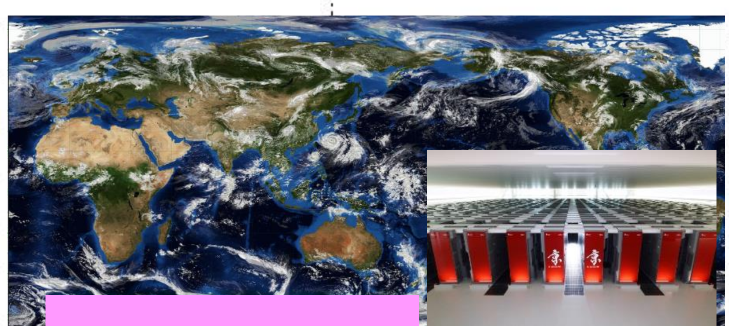
Cycle from Observation to Countermeasure

To target		To solution	To target

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

↓ DATA → information → Estimation → Strategy → Policy → Effect

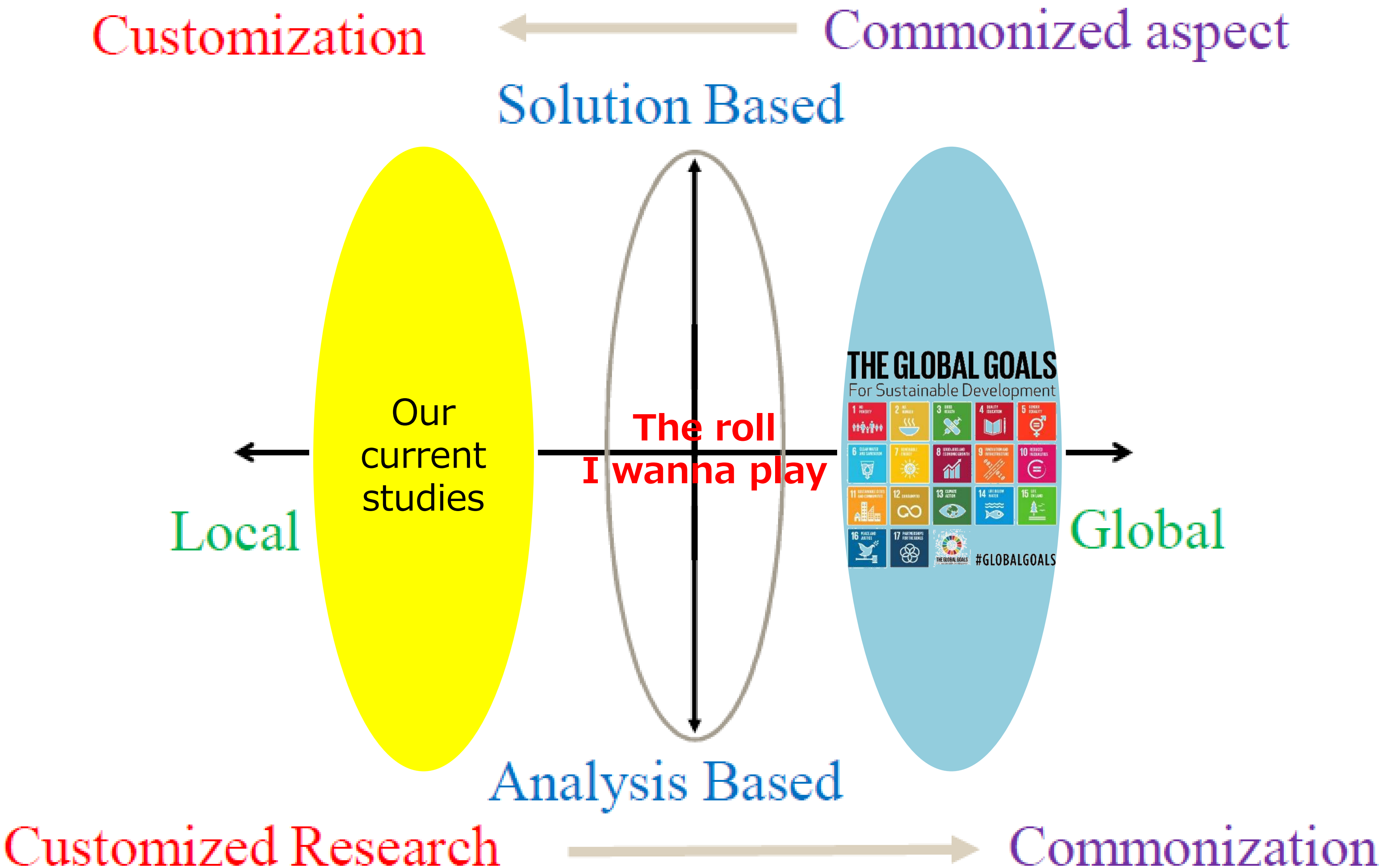




Effect

Observation of the effect

Modified from Yasuoka 2015



Modified from Yasuoka 2017

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0．Motivation to DA (Story taking me here today)

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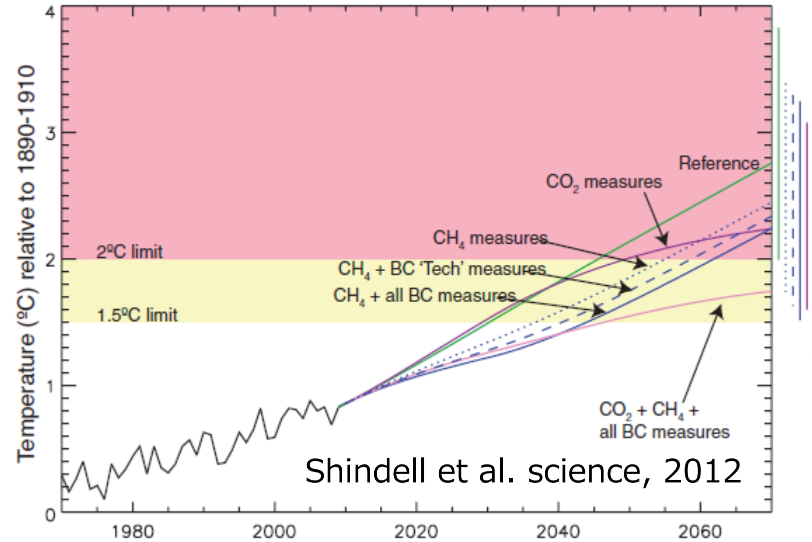
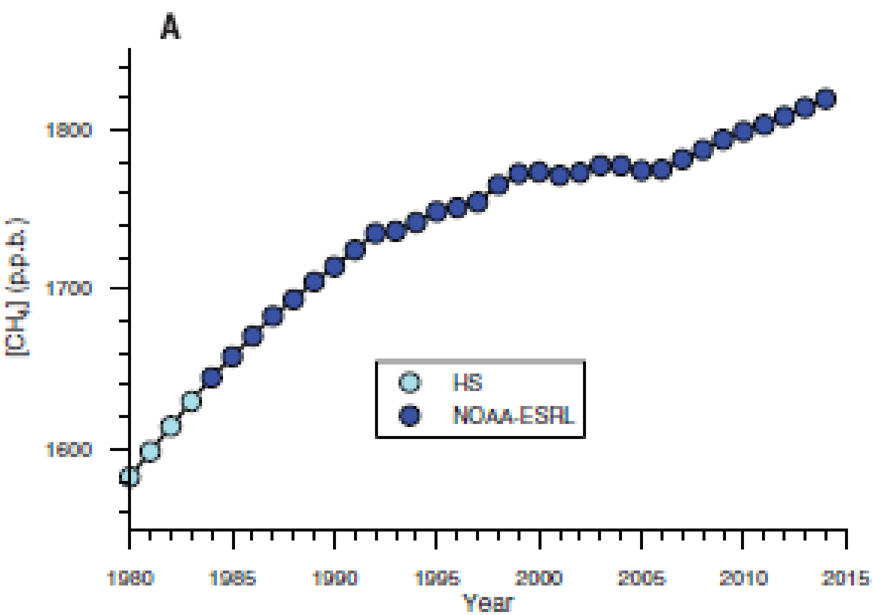
4. My next work with DA

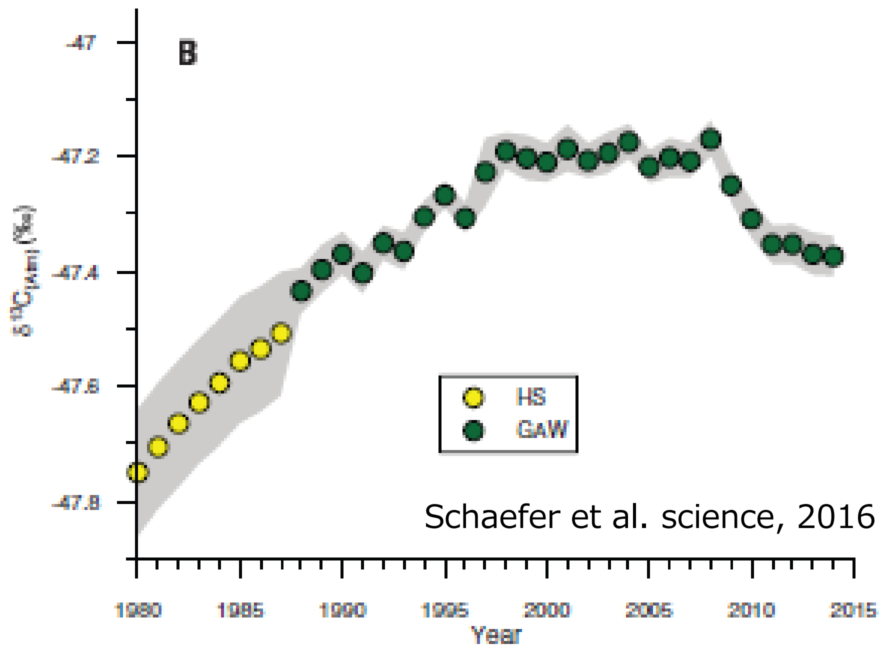
CH_4

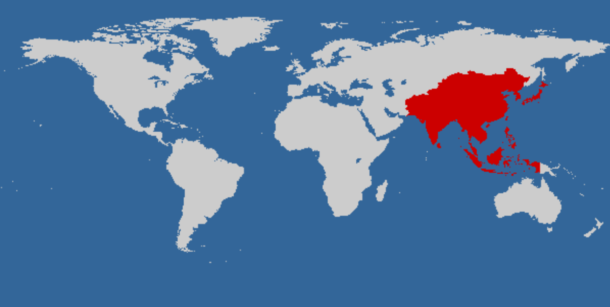
Global Warming Potential of CH_4 (IPCC)
-on a 100-year horizon-

21 →	23 →	25 →	34
AR2 1996	AR3 2001	AR4 2007	AR5 2013

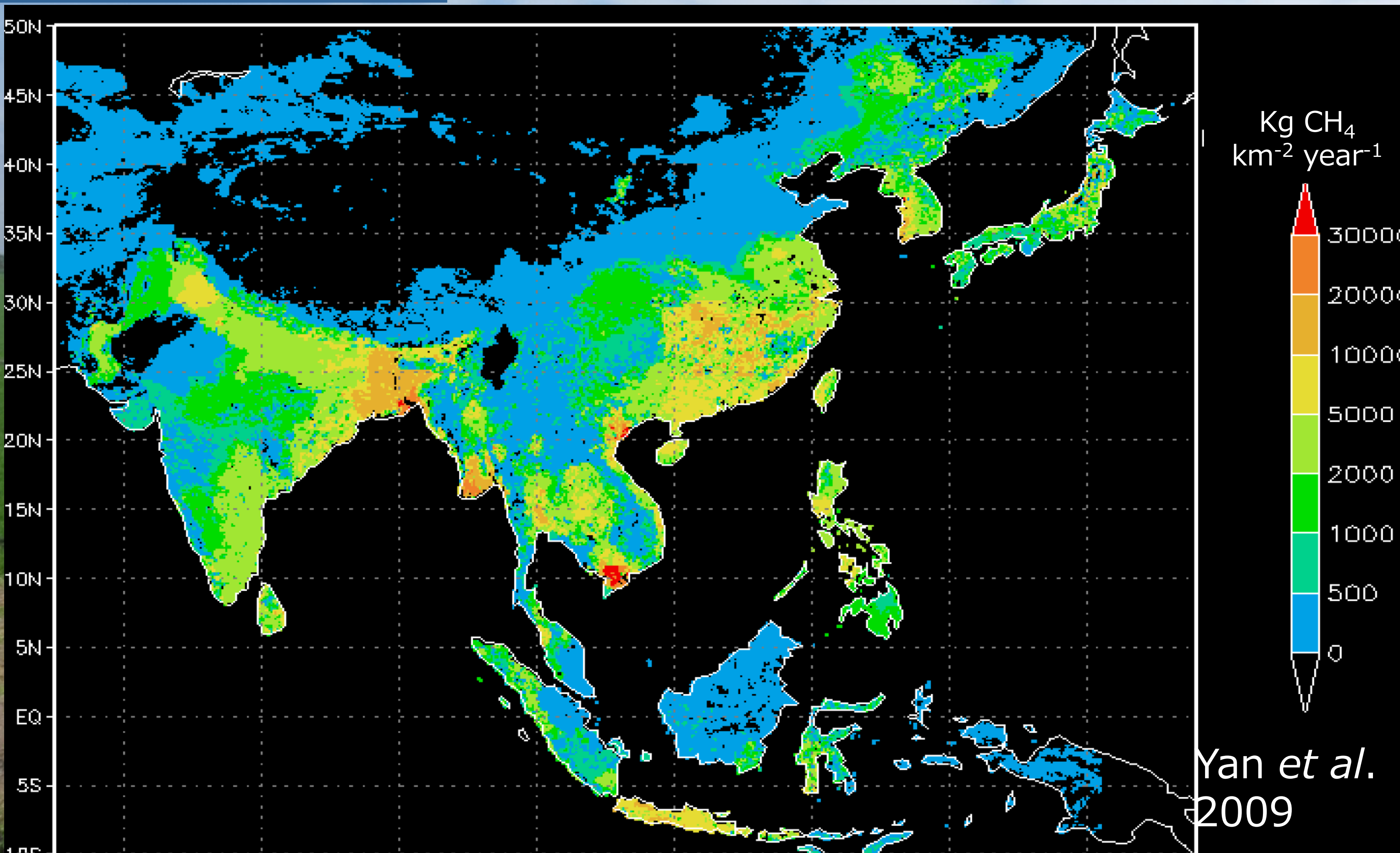




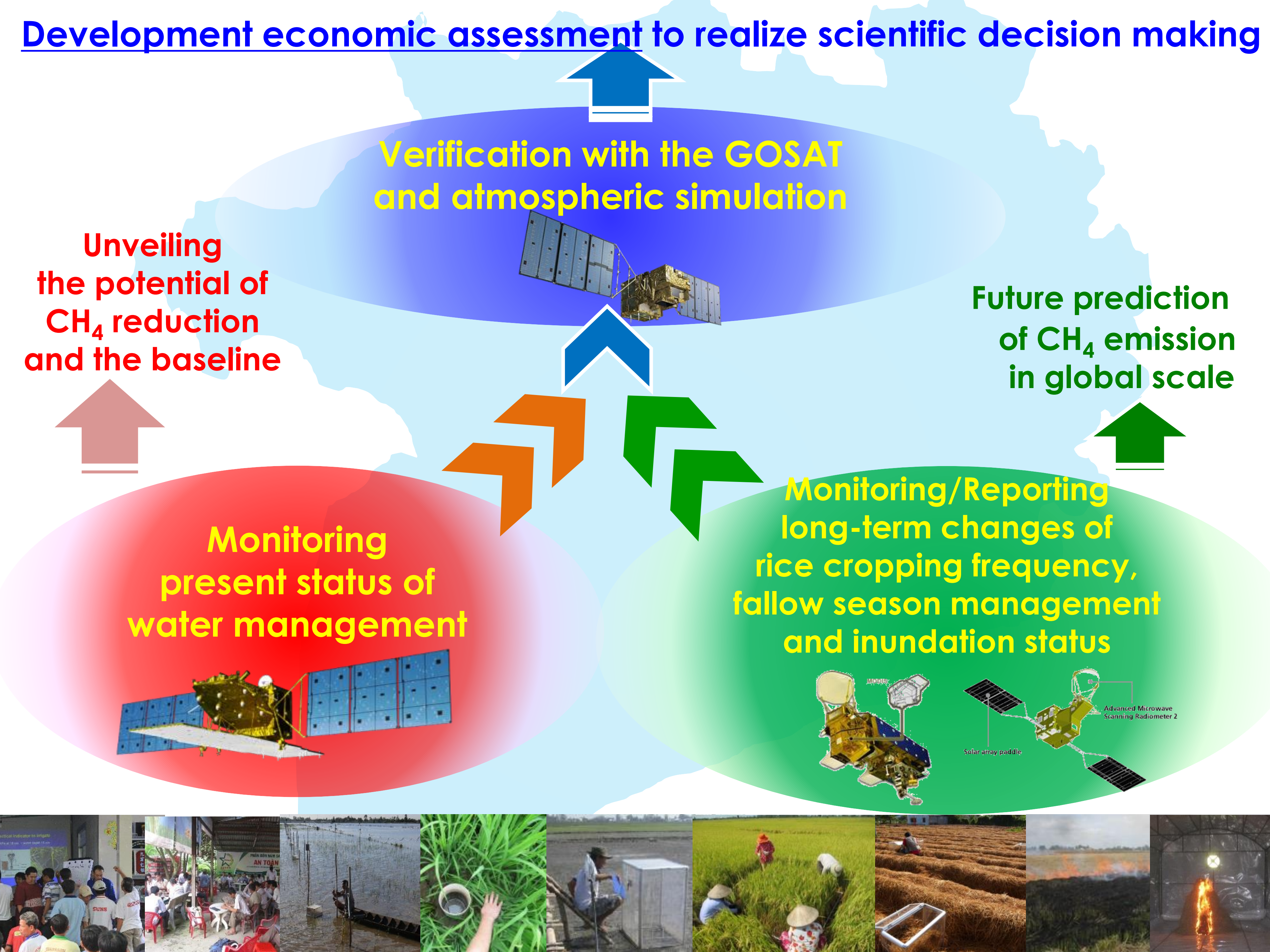




Characteristics of Agriculture in Monsoon Asia



Yan *et al*. 2009


Development economic assessment to realize scientific decision making
Verification with the GOSAT and atmospheric simulation
Unveiling the potential of CH_4 reduction and the baseline
Future prediction of CH_4 emission in global scale
Monitoring present status of water management
Monitoring/Reporting long-term changes of rice cropping frequency, fallow season management and inundation status
Advanced Microwave Scanning Radiometer 2
Solar array paddle

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4. My next work with DA

- Continuously flooded nearly through a year

\+

- High straw production

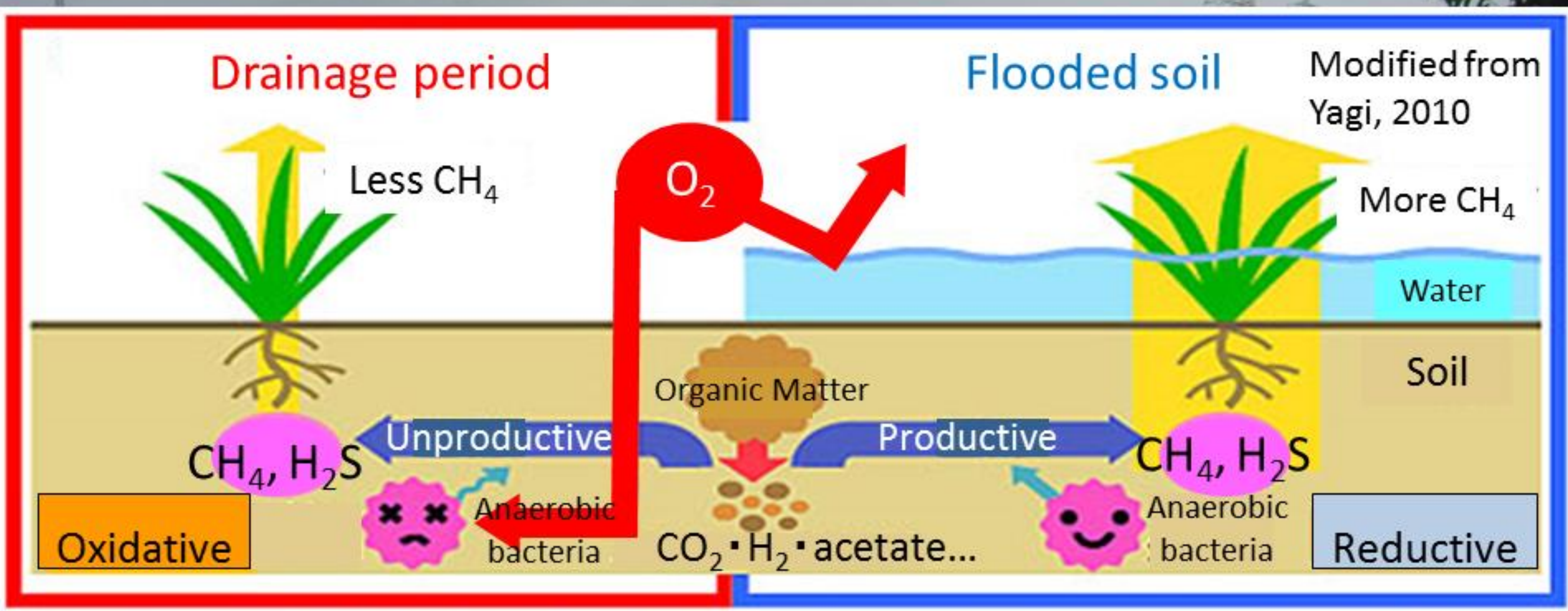
→

- Anaerobic stress for rice production
- High GHGs emission

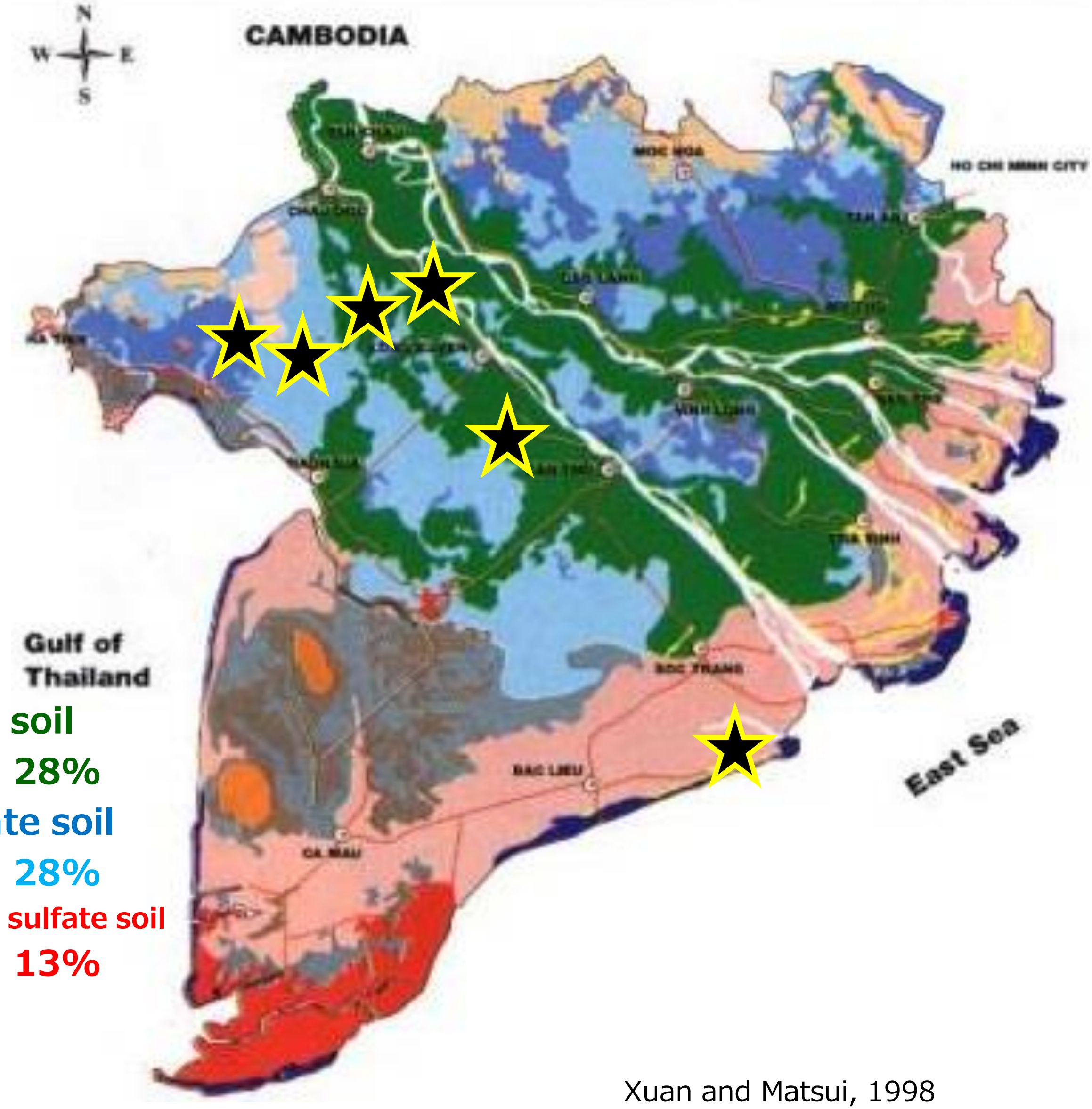
AWD

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

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



Obtained annual CH_4 emission data so far



alluvial soil

1.1 Mha, 28%

acid sulfate soil

1.1 Mha, 28%

potentially acid sulfate soil

0.5 Mha, 13%

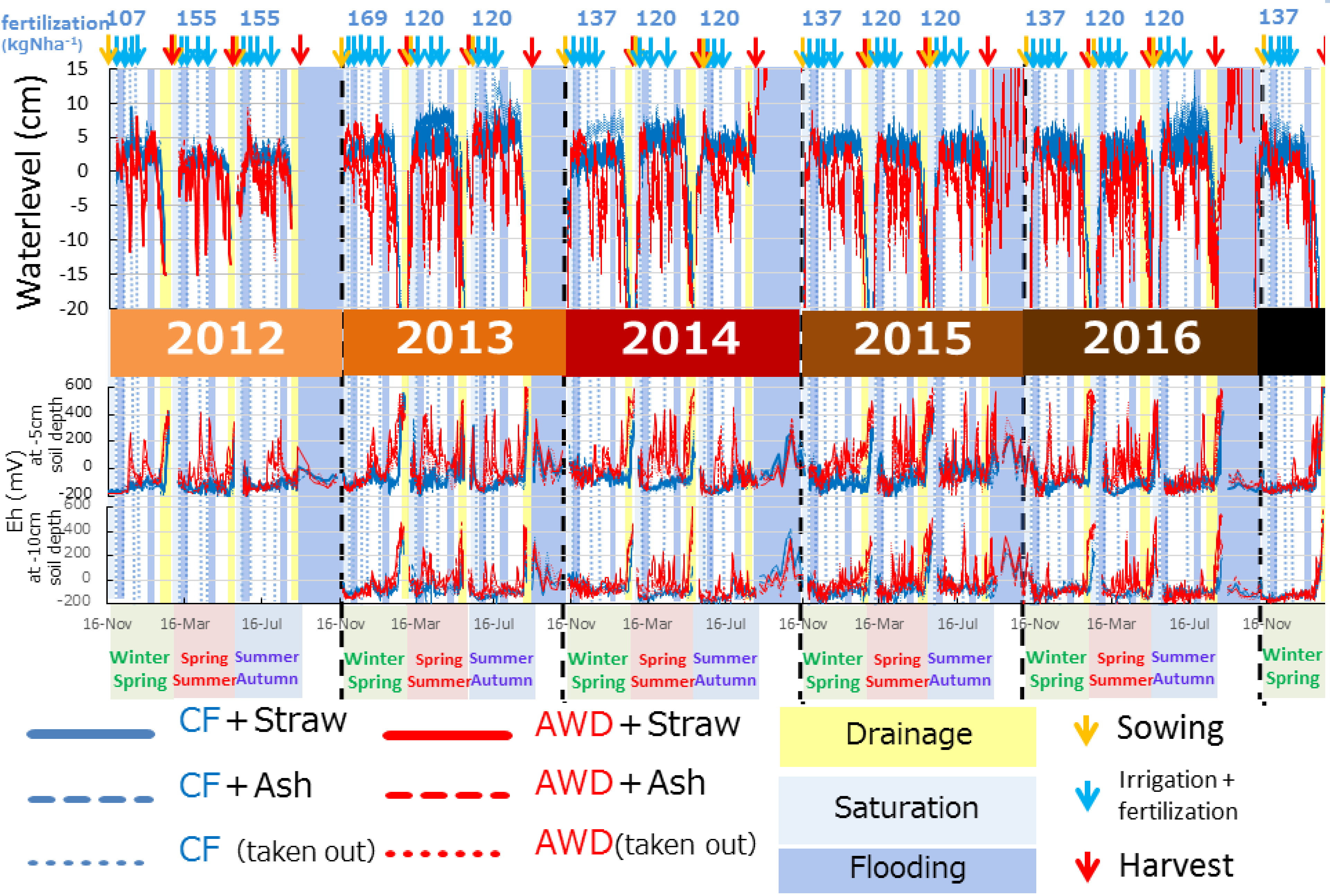
Xuan and Matsui, 1998

EF baselines in philippines
(GoP 2014, Basak 2016)

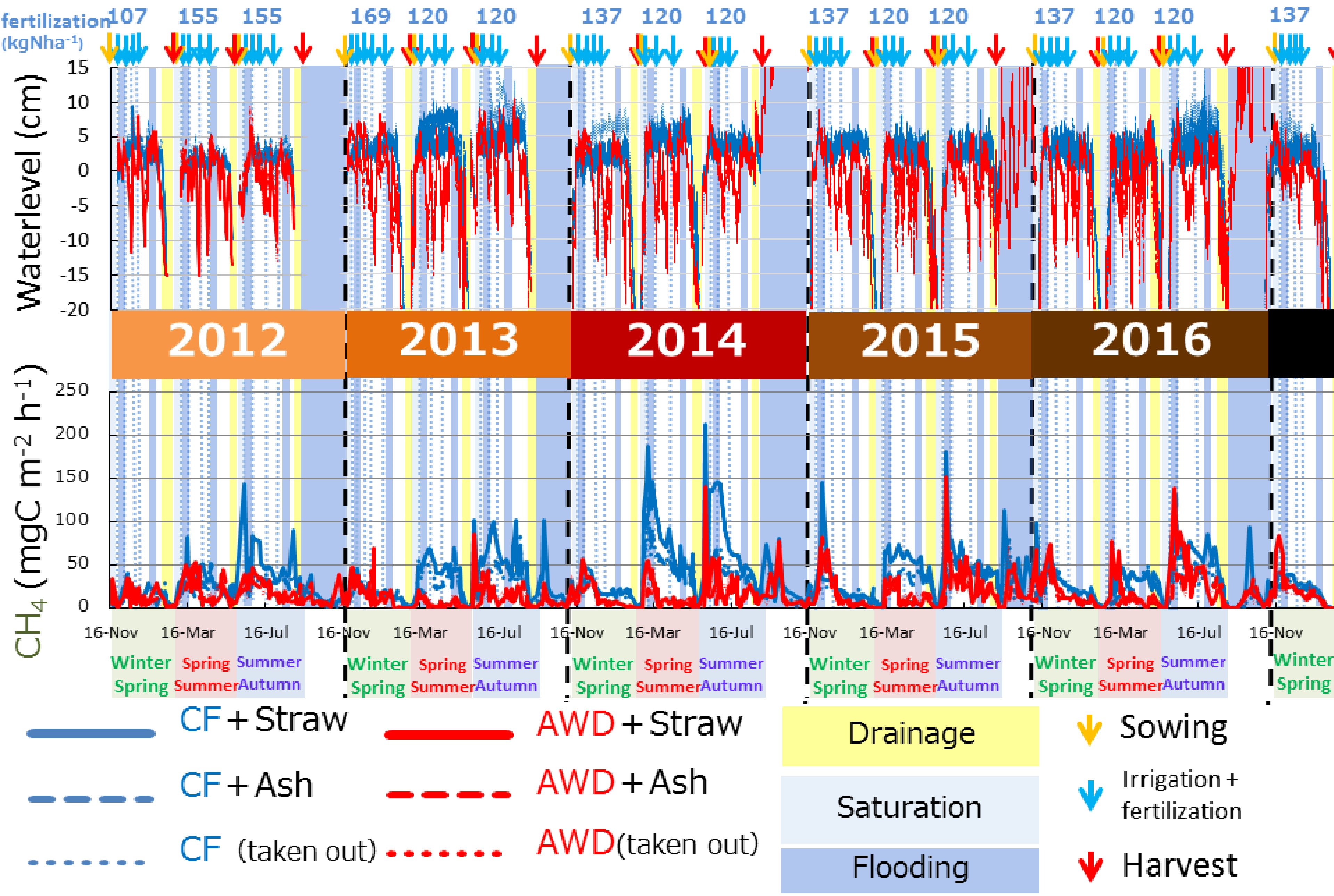
- Single crop (rainy season)
- Single crop (dry season)
- double crop

(n=3)

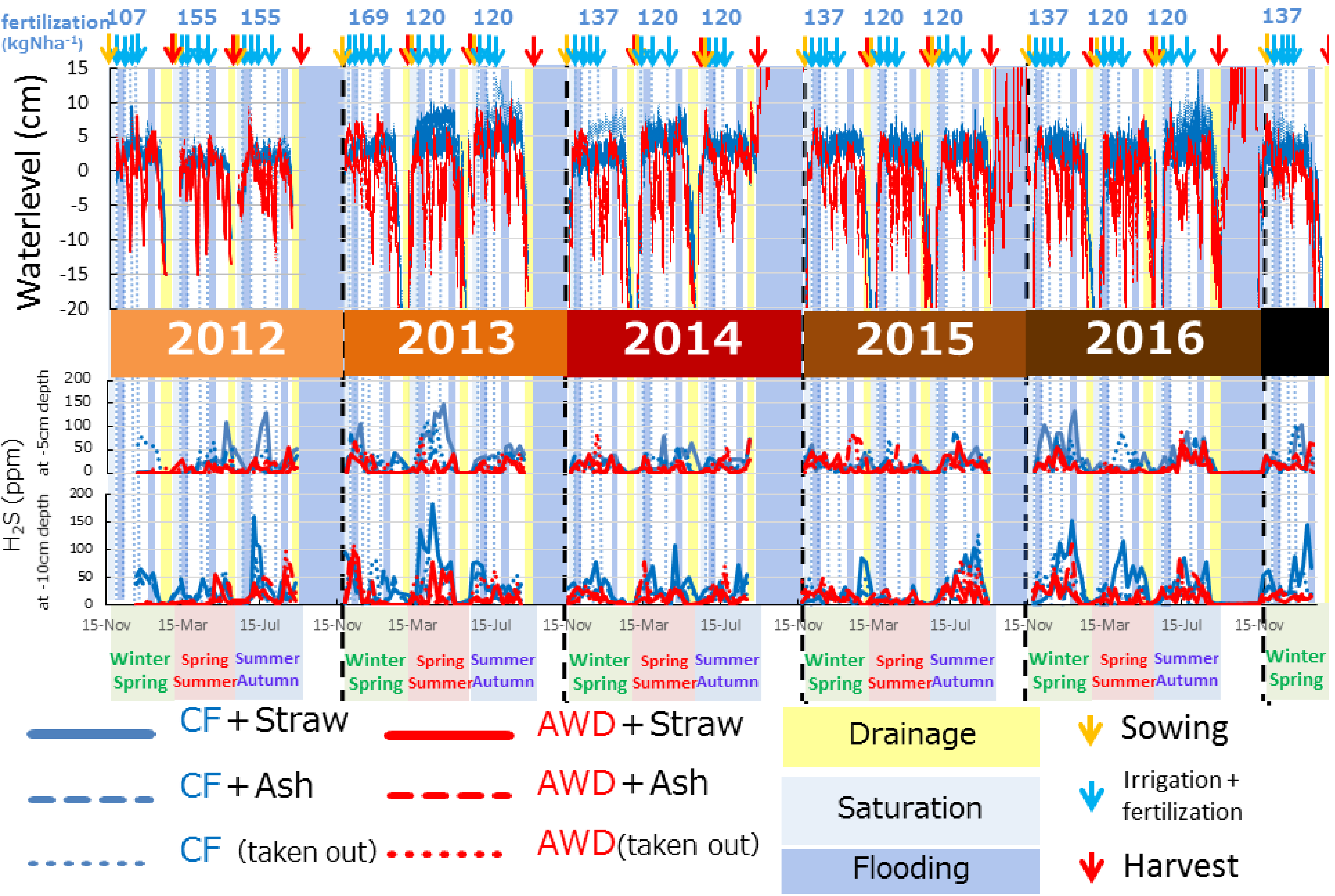
Characteristics of the Mekong delta



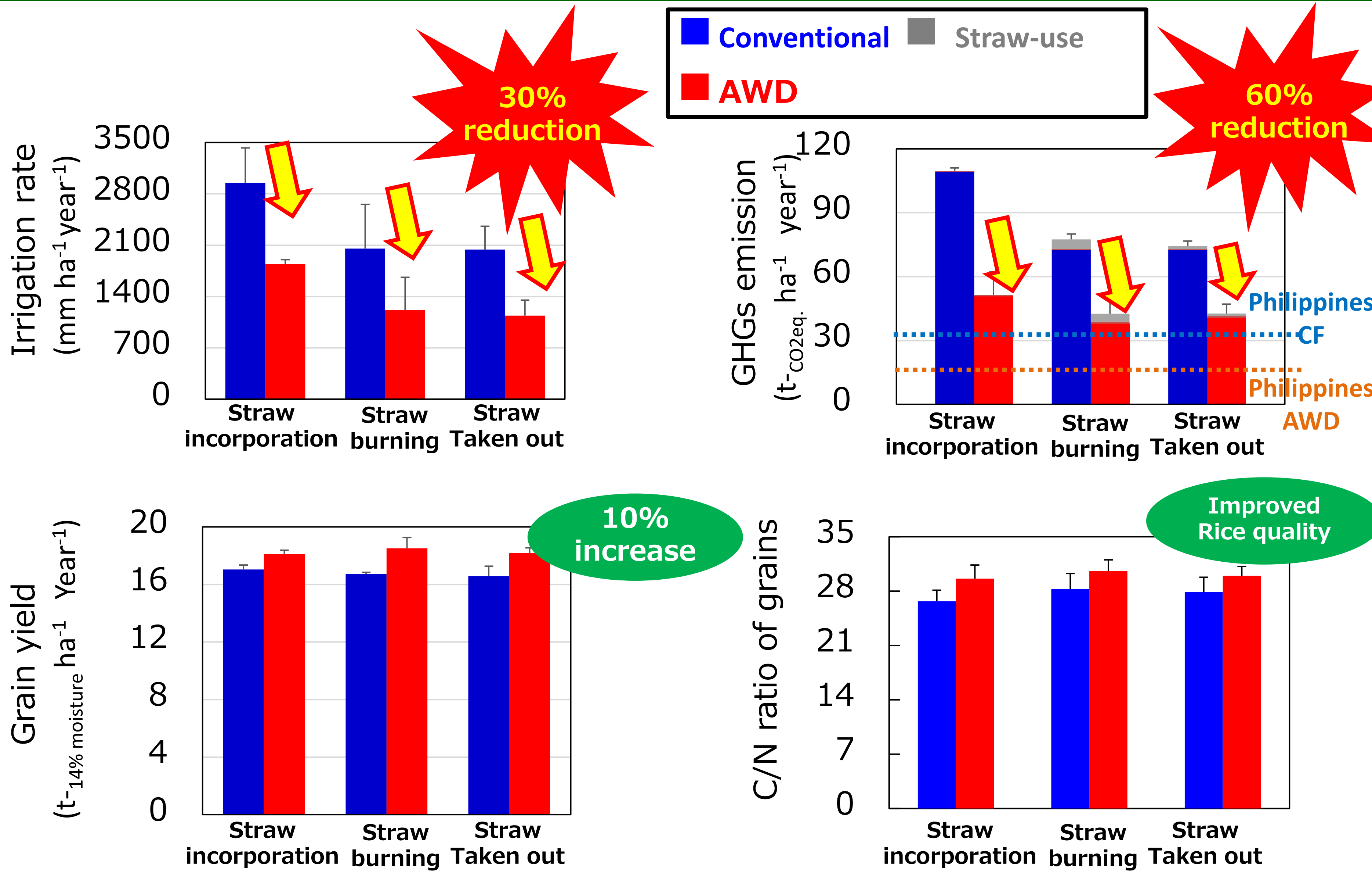
Characteristics of the Mekong delta



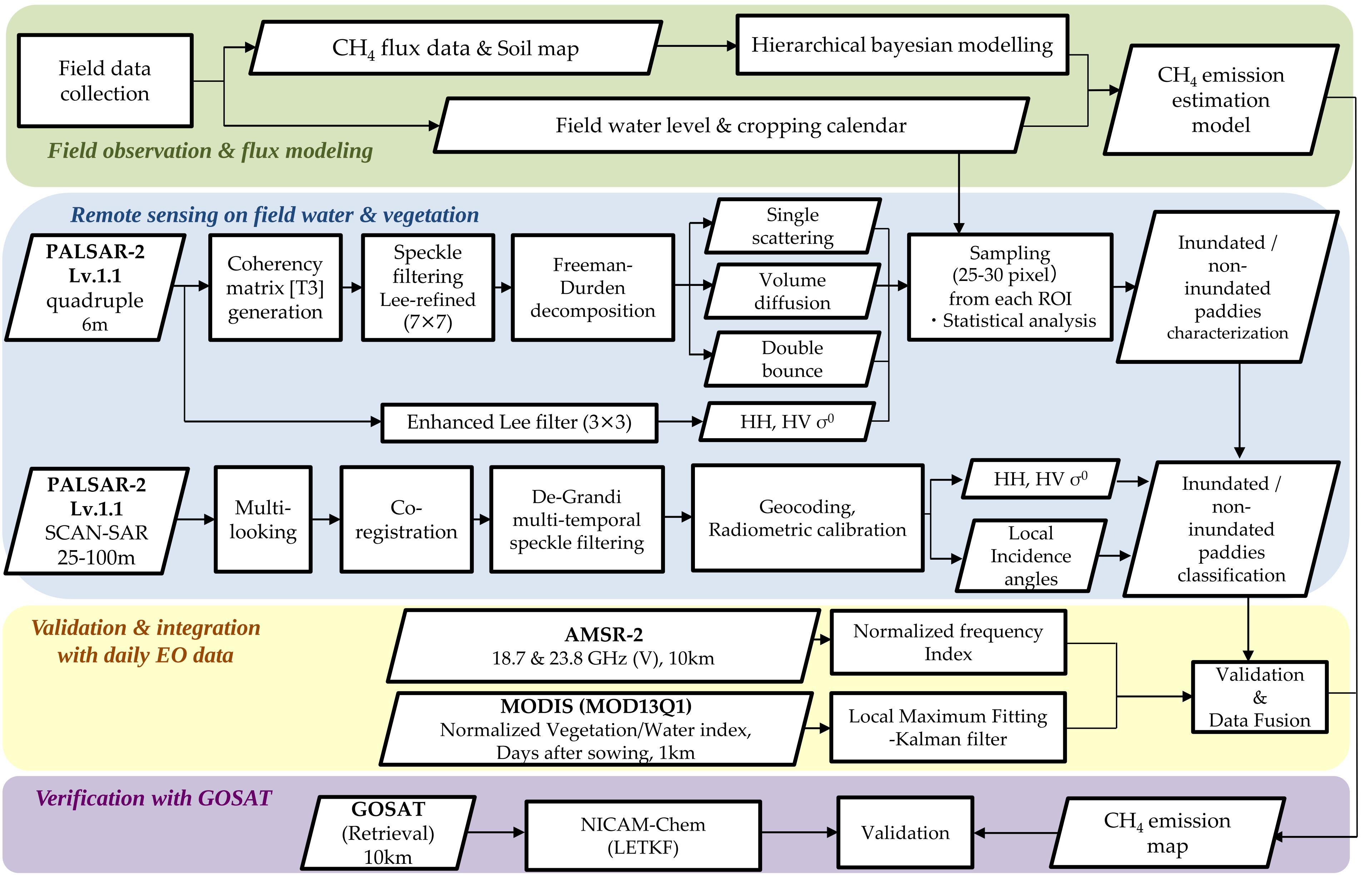
Characteristics of the Mekong delta



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

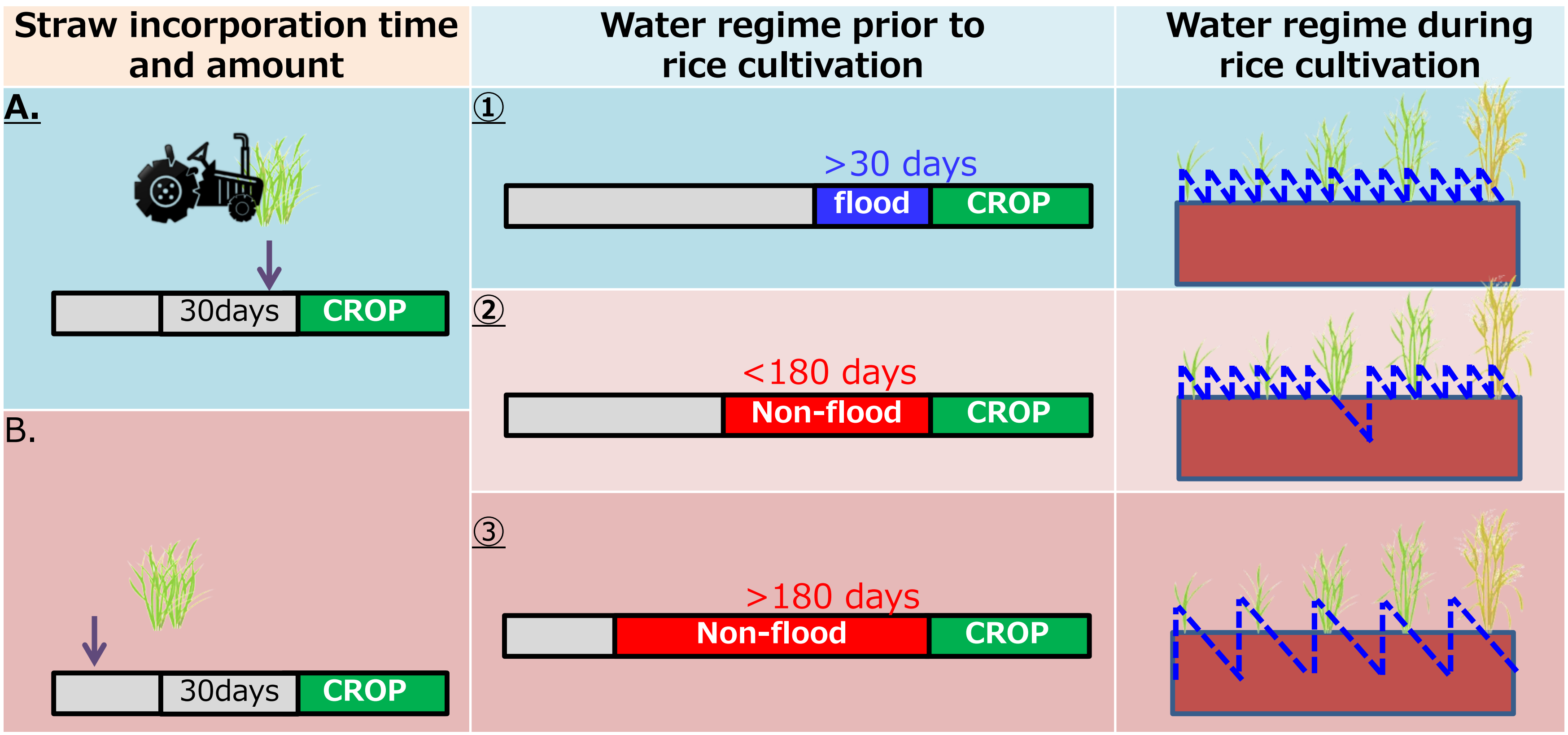


Flow chart

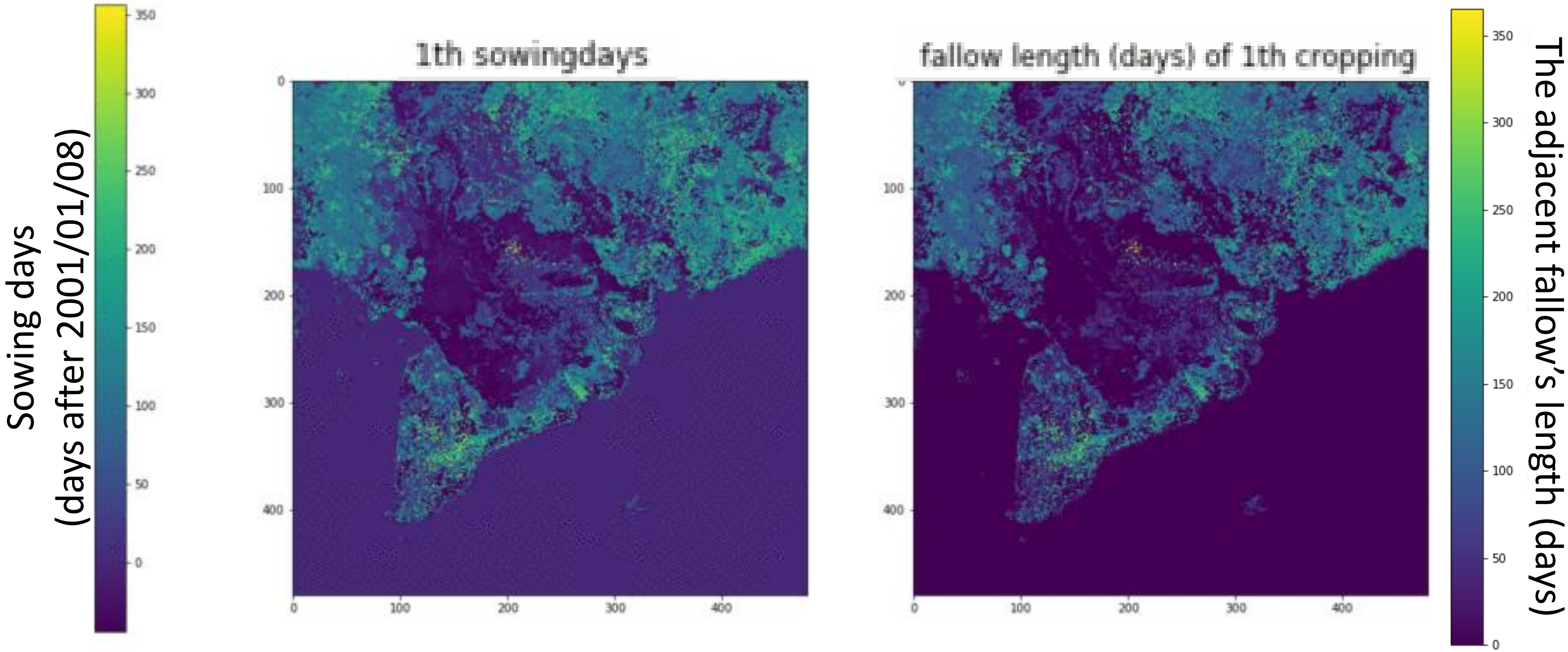


Field data collection
CH4 flux data & Soil map
Hierarchical bayesian modelling
CH4 emission estimation model
Field water level & cropping calendar
Field observation & flux modeling
Remote sensing on field water & vegetation
PALSAR-2 Lv.1.1 quadruple 6m
Coherency matrix [T3] generation
Speckle filtering 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-Chem (LETKF)
Validation
CH4 emission map

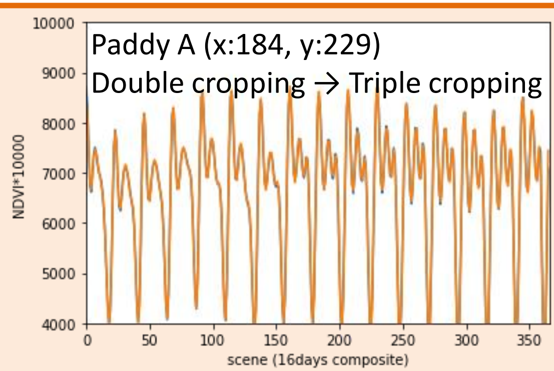
IPCC guideline (Tier1)
[Emission factor × Scaling factor in IPCC guideline]

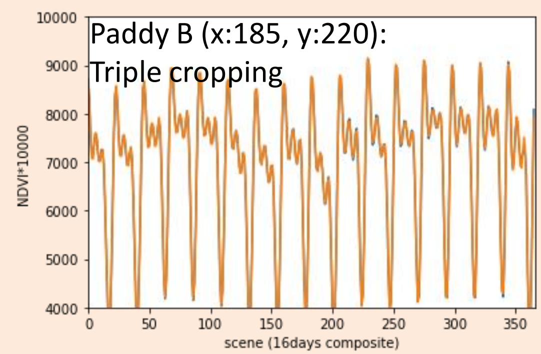


Cropping calendar evaluation with MODIS—NDVI (LMF-KF)



Samples of paddies





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

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

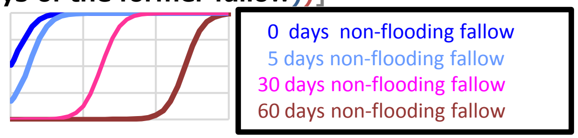
= γ * *carbon_management* / *non-inundated_fallow* / *inundated_fallow* * *water_management* *α*β

carbon_management

=[exp(-*DAS**δ)-exp(-*DAS**(δ+ω))+κ]

non-inundated_fallow

= [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

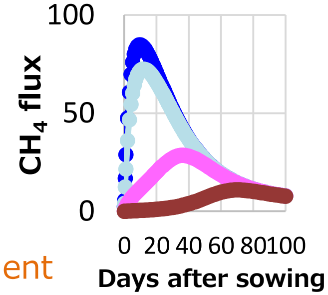
= EXP(η * **inundated days during the last 10days**)

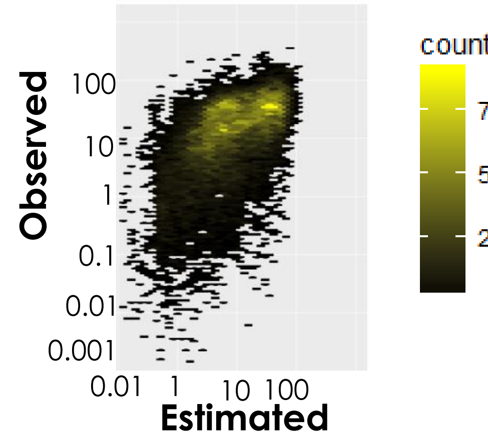
DAS←*days after sowing*

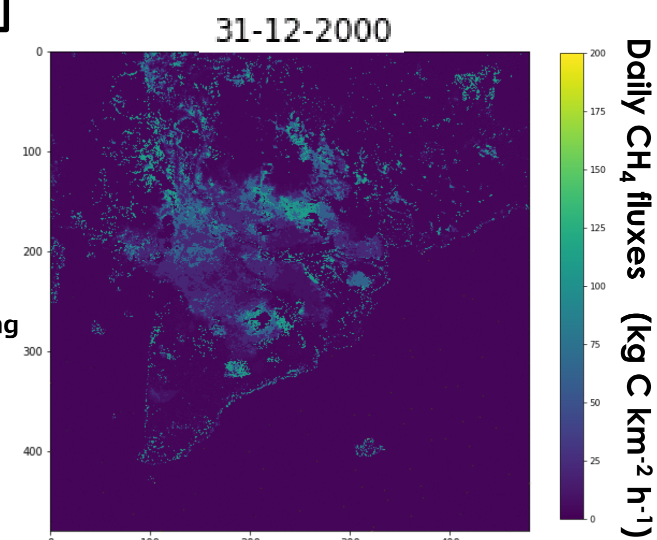
α ←straw incorporation coefficient

β ←acid sulfate・coastal sandy soil coefficient

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







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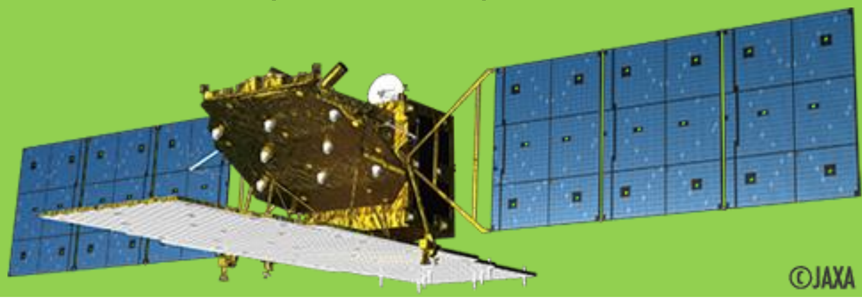
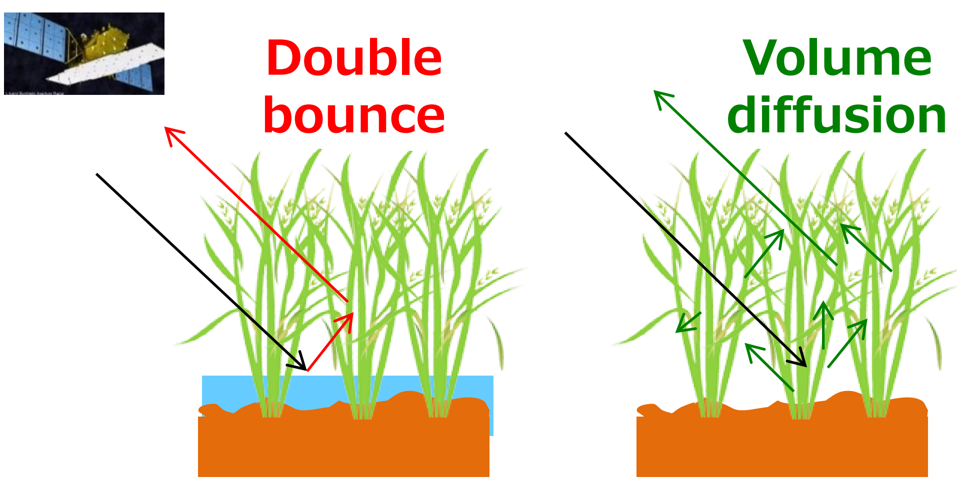
Satellite remote sensing of soils

ALOS-2/PALSAR-2

– Lband-Synthetic Aperture Radar –

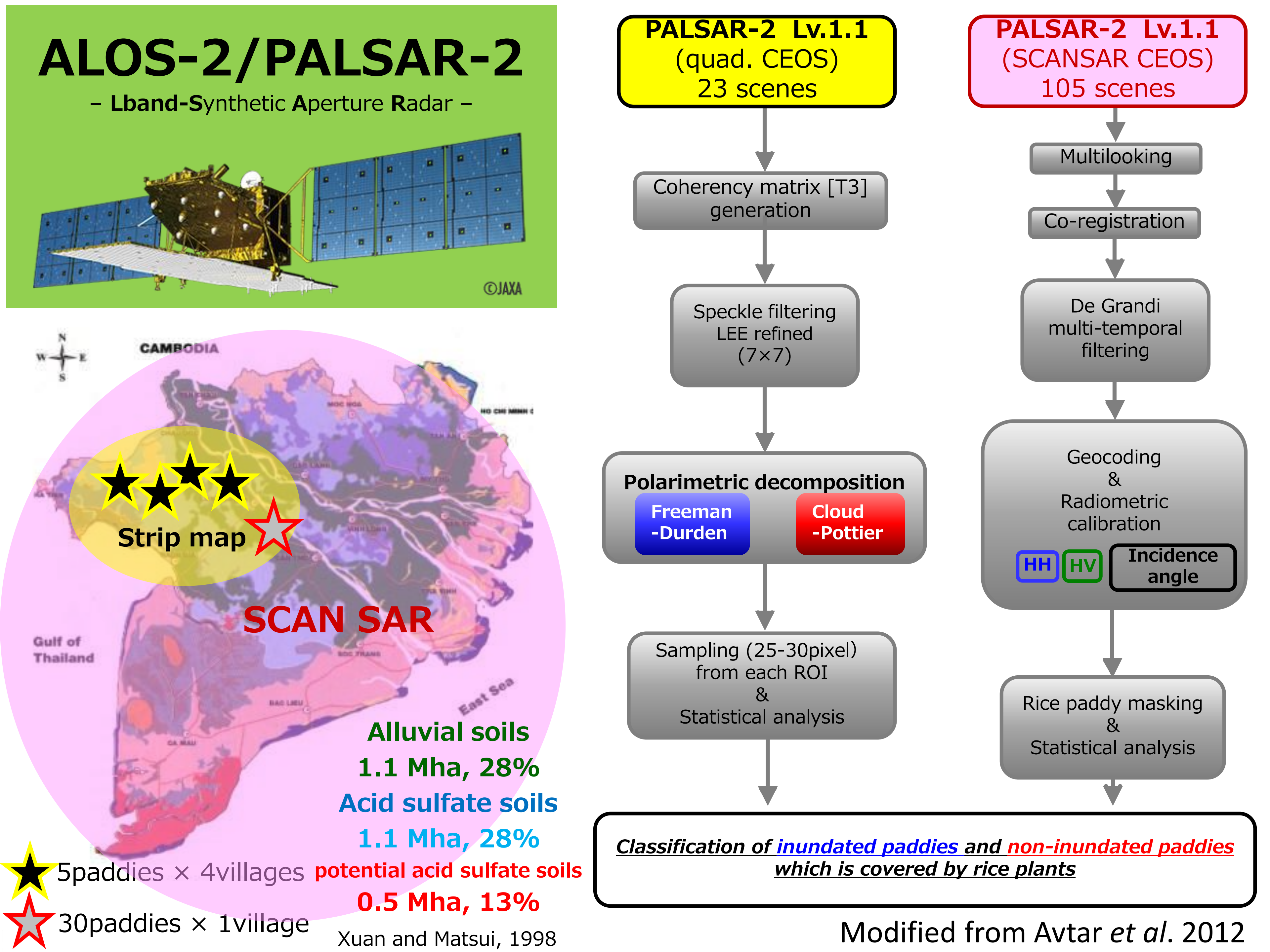


Scattering model decomposition

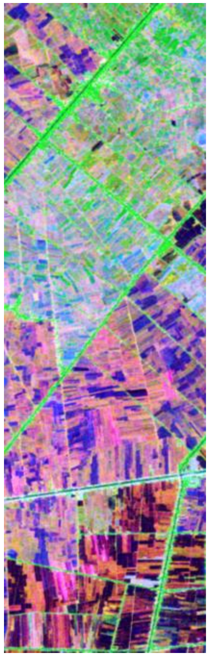


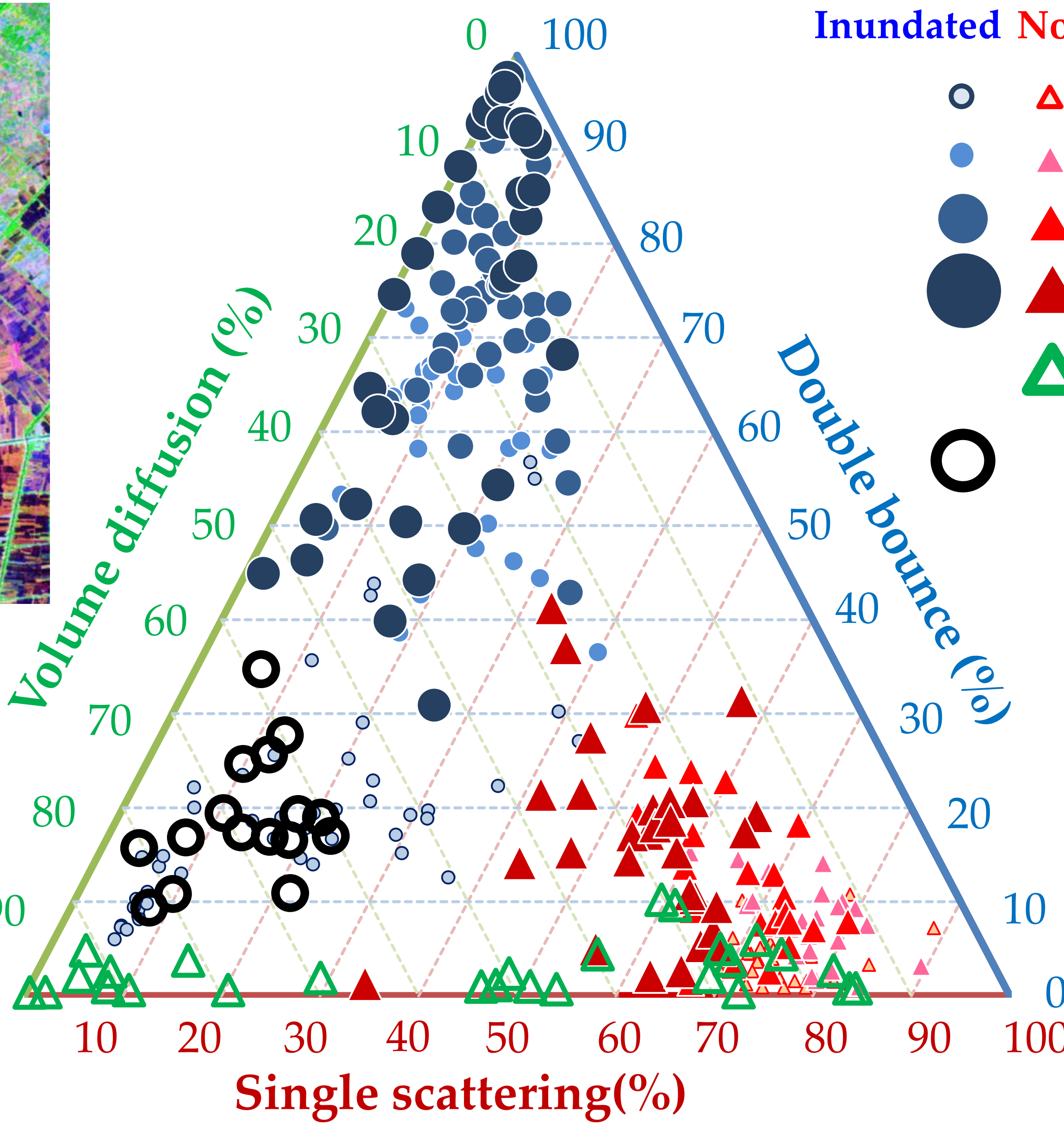
High transparency

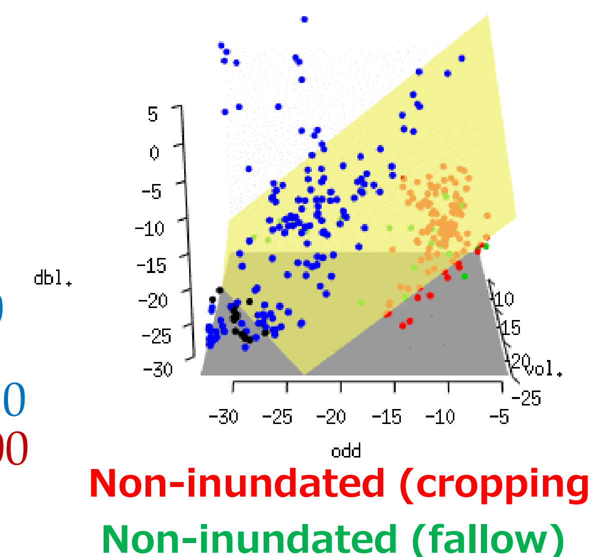
MITSUBISHI CO, LTD.


ALOS-2/PALSAR-2
– Lband-Synthetic Aperture Radar –
©JAXA
CAMBODIA
Strip map
SCAN SAR
Gulf of Thailand
East Sea
Alluvial soils
1.1 Mha, 28%
Acid sulfate soils
1.1 Mha, 28%
potential acid sulfate soils
0.5 Mha, 13%
Xuan and Matsui, 1998
5paddies × 4villages
30paddies × 1village
PALSAR-2 Lv.1.1 (quad. CEOS) 23 scenes
Coherency matrix [T3] generation
Speckle filtering LEE refined (7×7)
Polarimetric decomposition
Freeman -Durden
Cloud -Pottier
Sampling (25-30pixel) from each ROI & Statistical analysis
PALSAR-2 Lv.1.1 (SCANSAR CEOS) 105 scenes
Multilooking
Co-registration
De Grandi multi-temporal filtering
Geocoding & Radiometric calibration
HH
HV
Incidence angle
Rice paddy masking & Statistical analysis
Classification of inundated paddies and non-inundated paddies which is covered by rice plants
Modified from Avtar et al. 2012

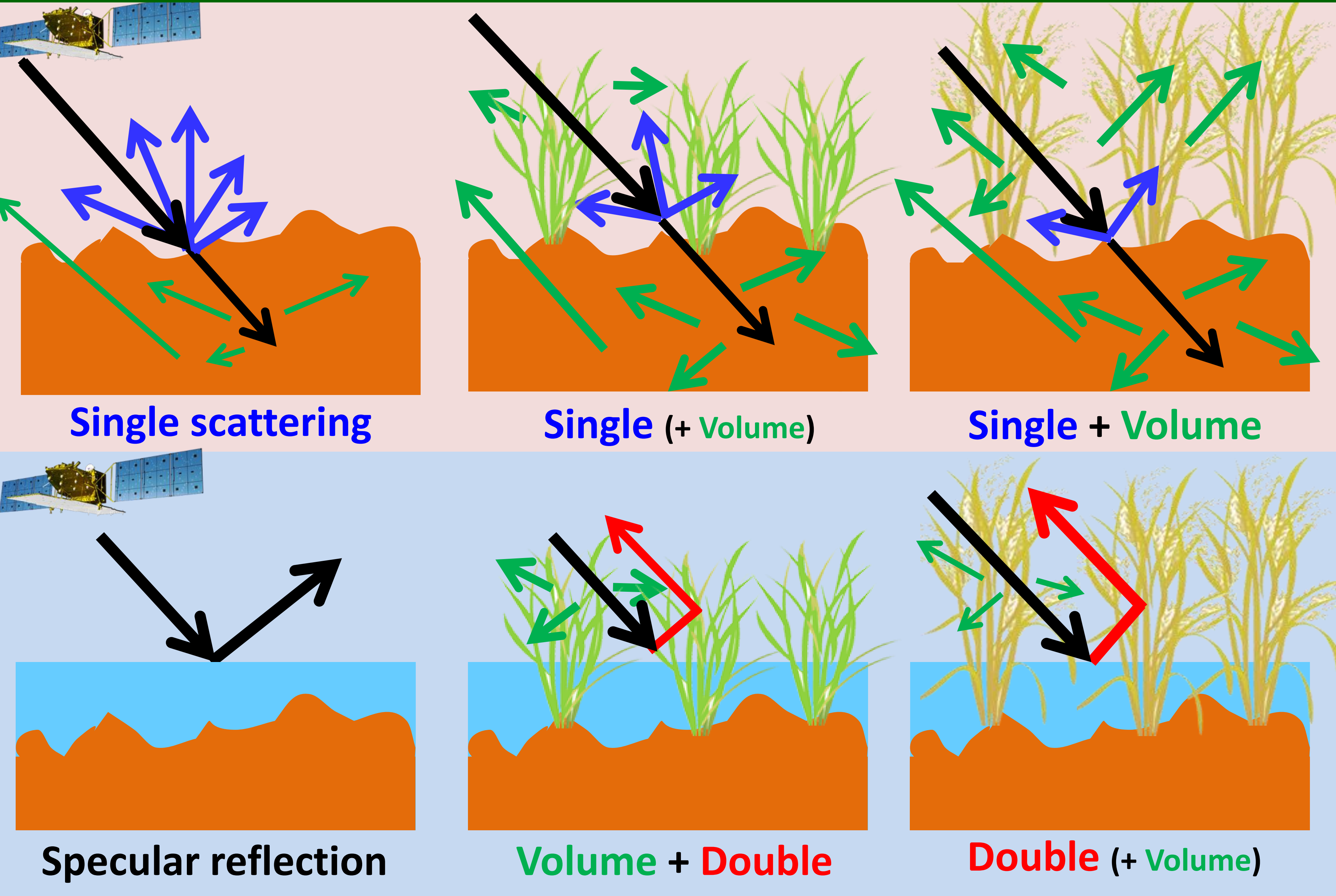
-Freeman-Durden decomposition-





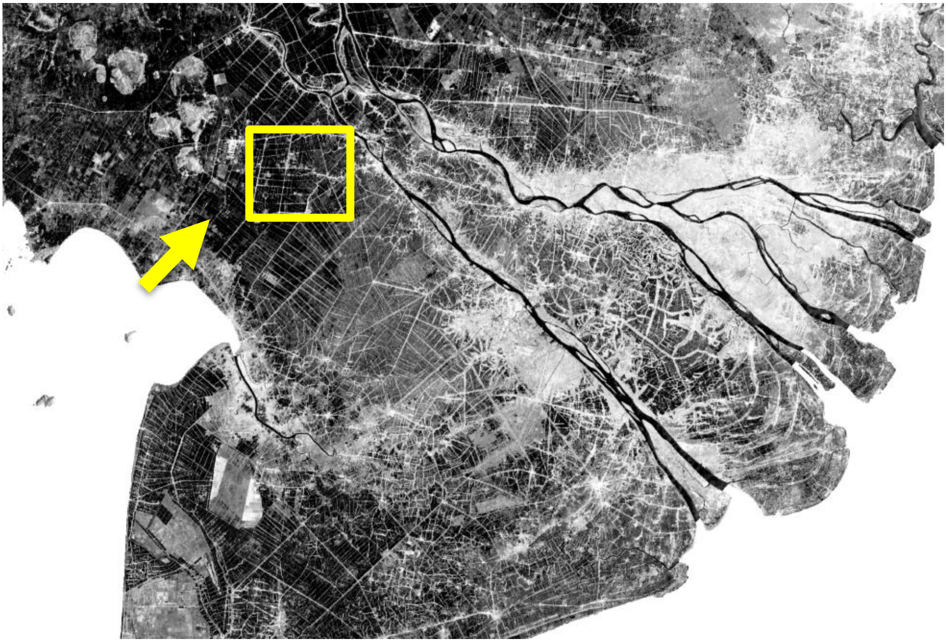


Dominant scattering type

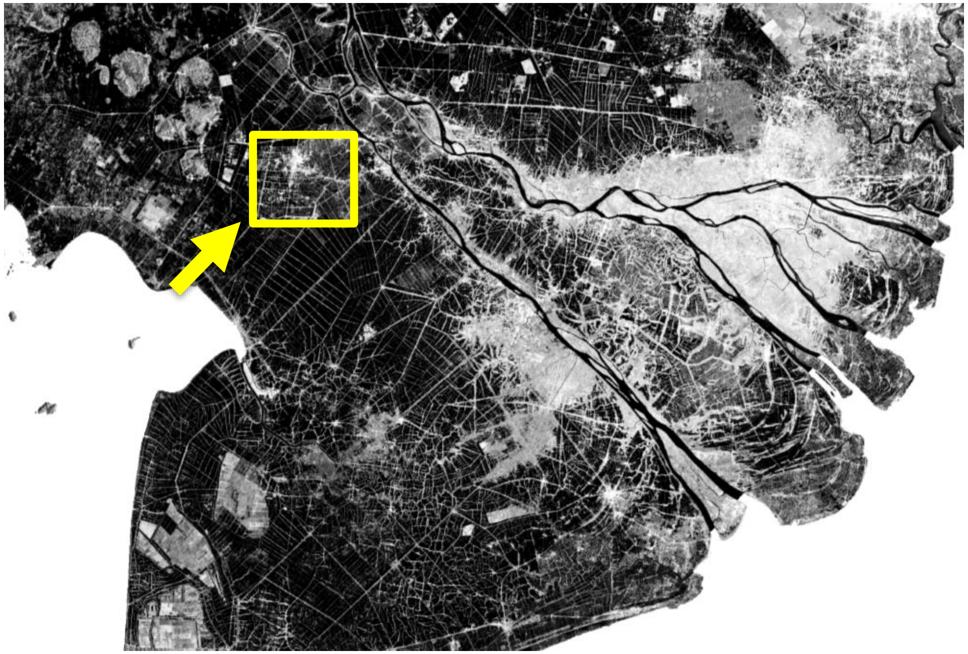


SCANSAR (intensity - $HH\sigma^0$)

Dry season (2015 Apr. 10)

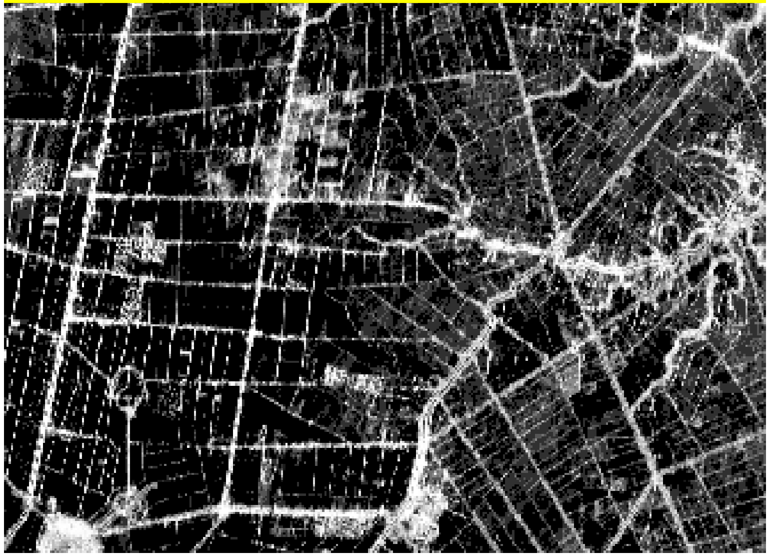


Flooding season (2015 Oct. 23)

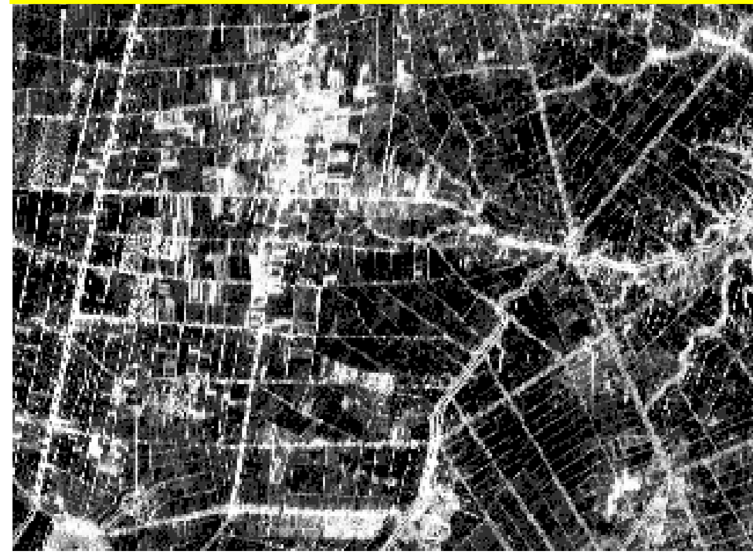


Double bounce detection by SCANSAR (intensity - $HH\sigma^0$)

Dry season (2015 Apr. 10)



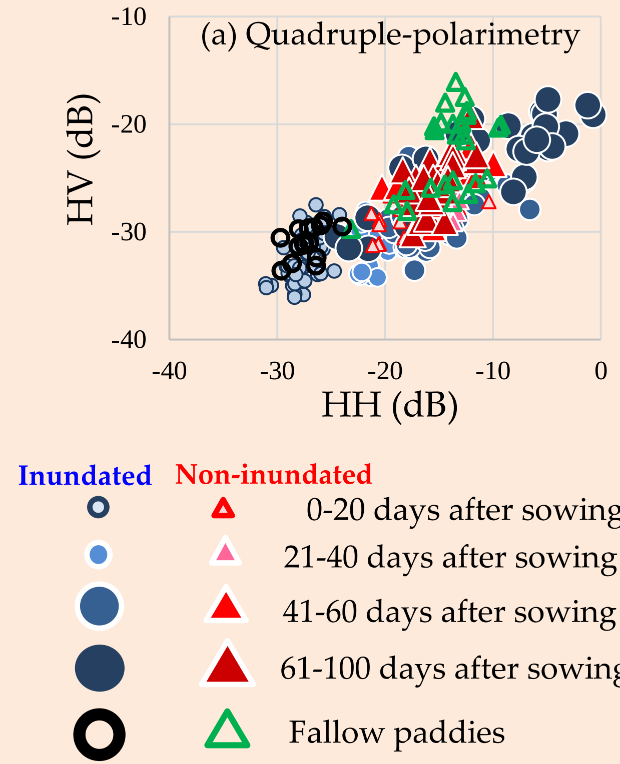
Rainy season (2015 Jul. 03)

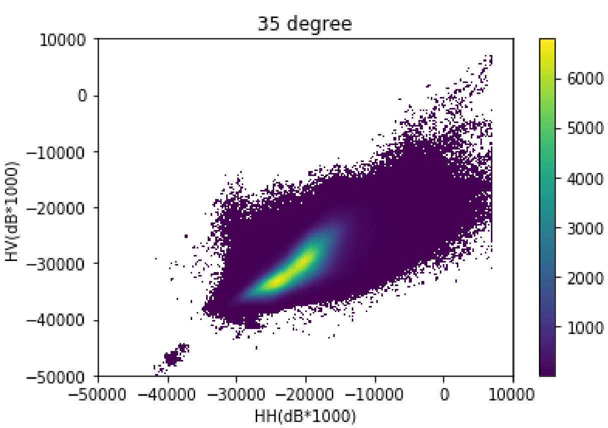


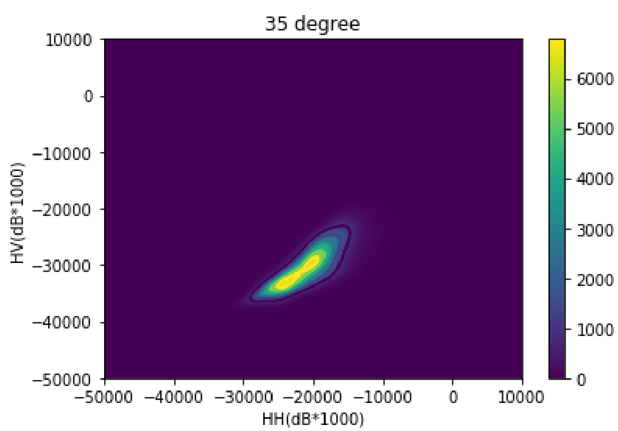
Flooding season (2015 Oct. 30) **-LANDSAT-8-**

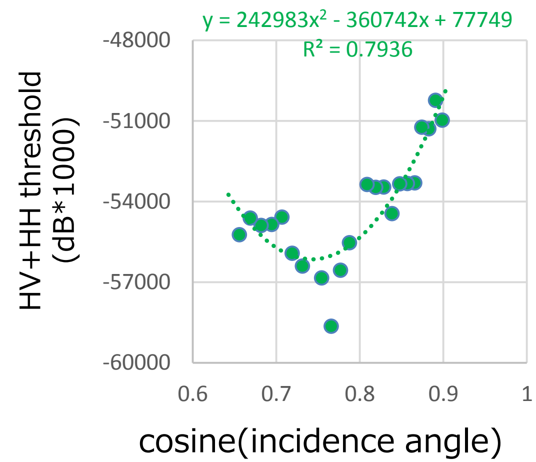
Flooding season (2015 Oct. 23)

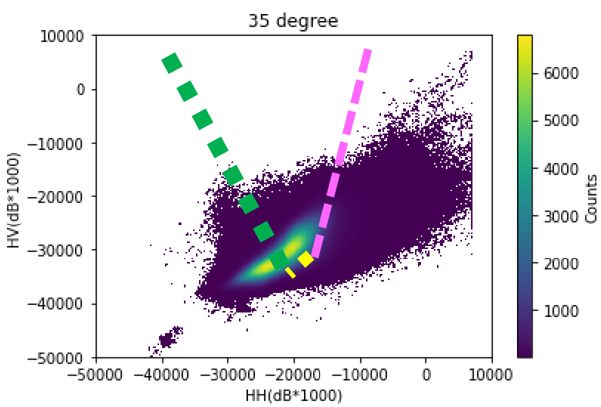
Full-polarimetry (3m)

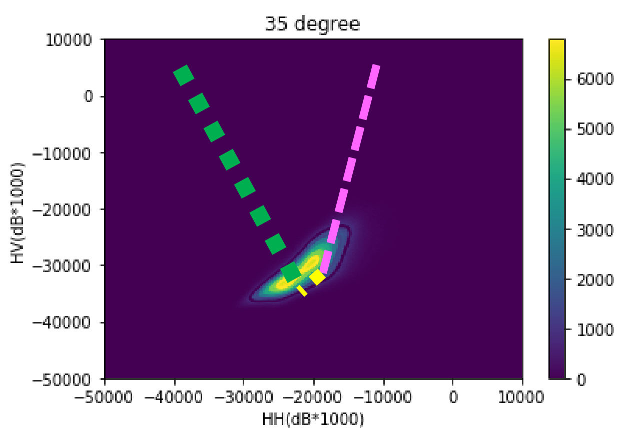


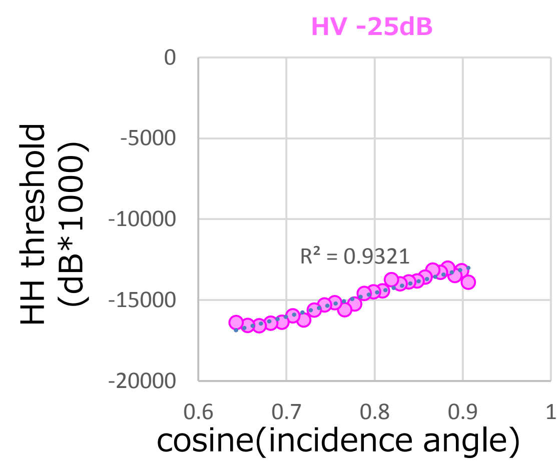








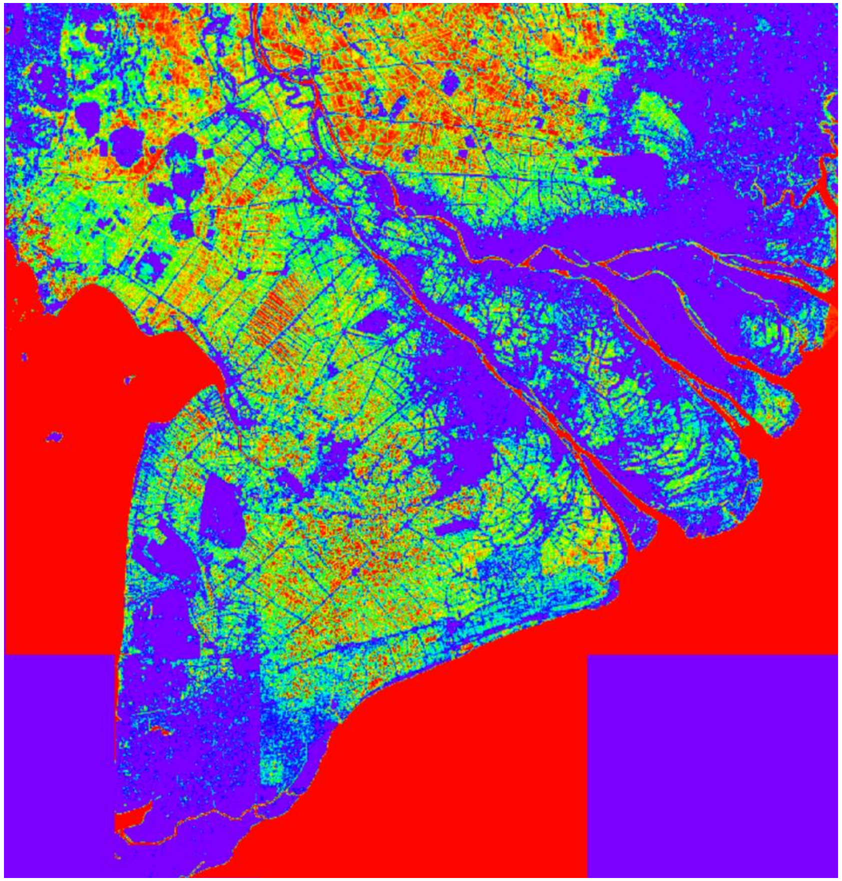


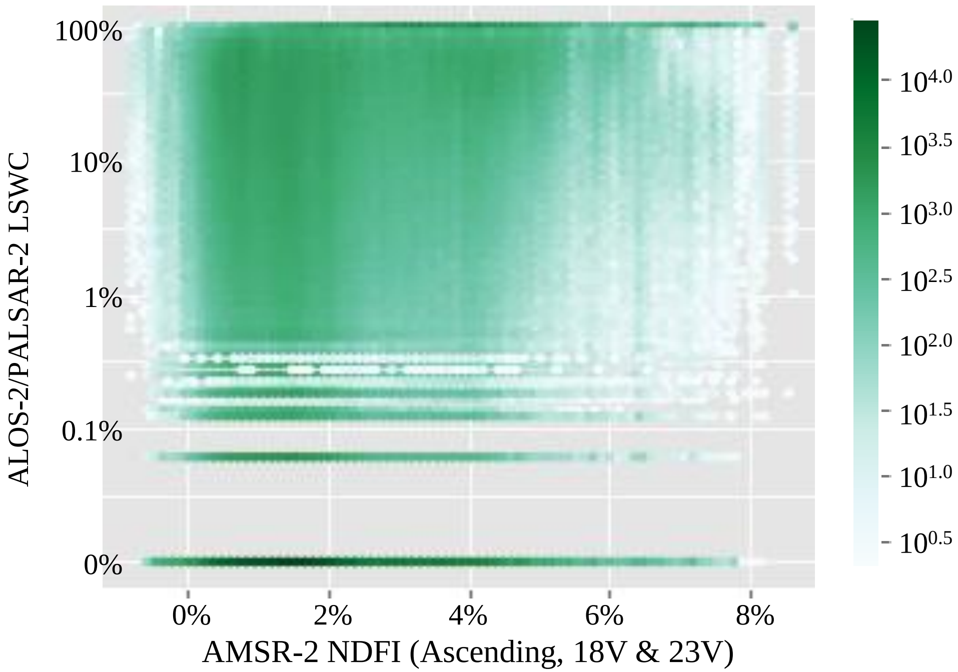


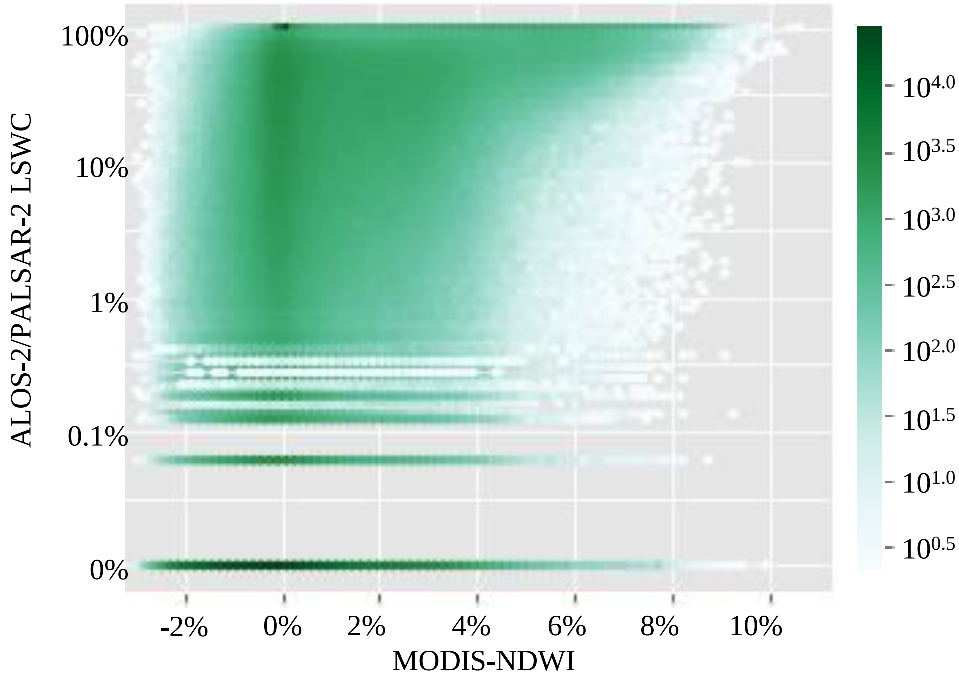
HH threshold (dB) = 0.550*HV
+12.9*cosine(IA)
-11.2

Floodability analysis

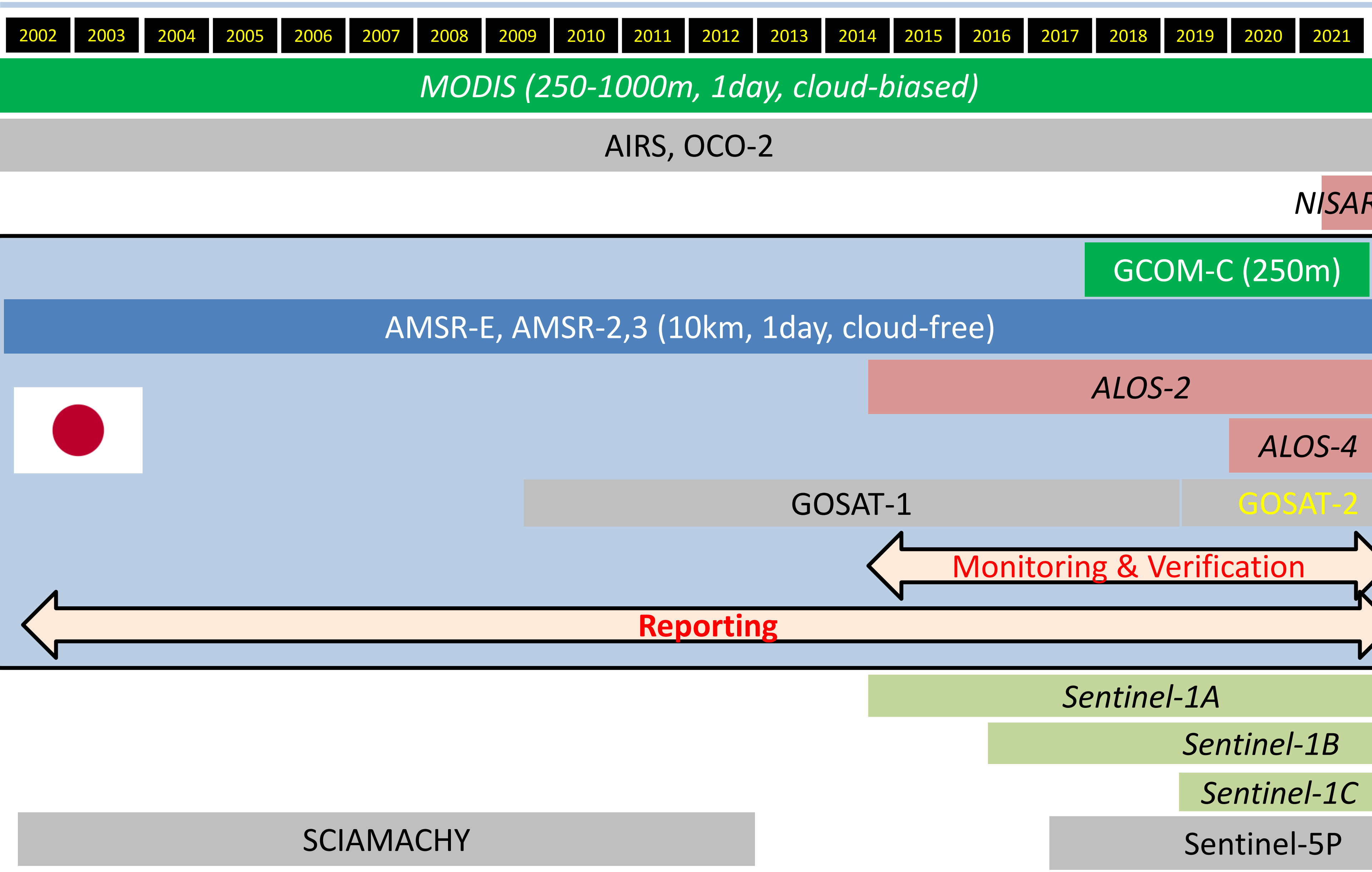
(Cumulative LSWC/
observation scenes)





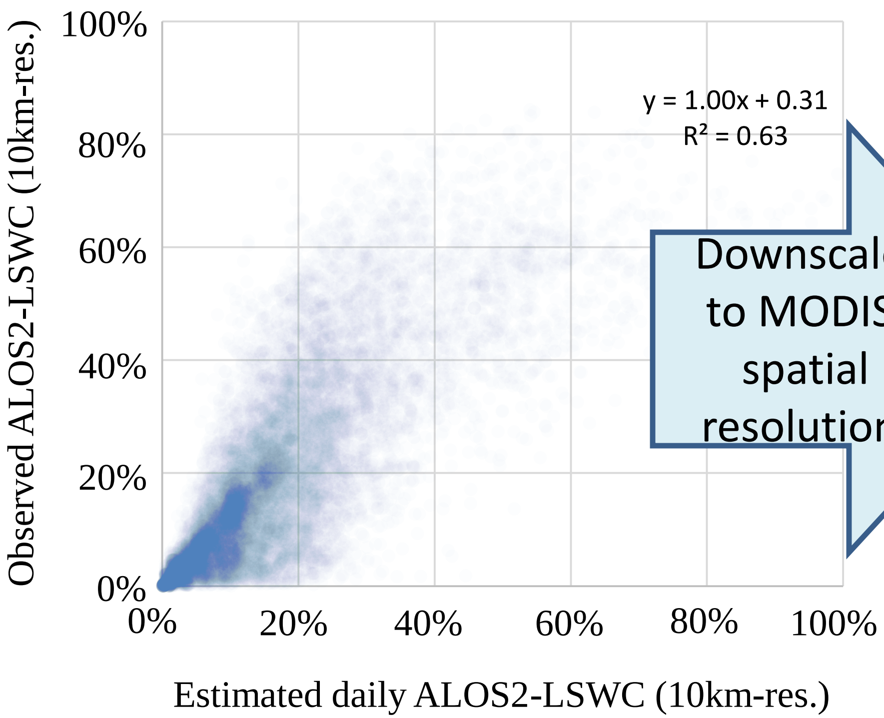


MRV and available data

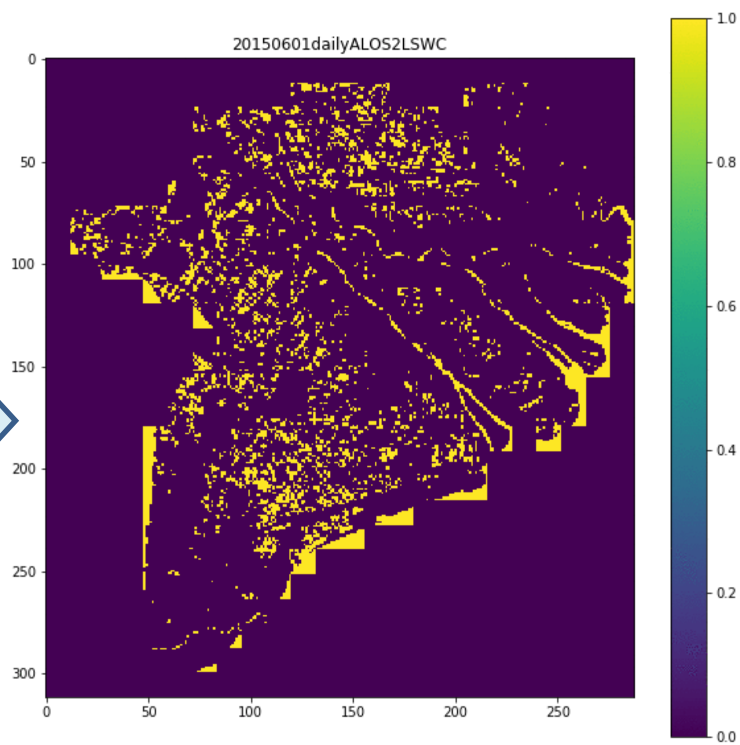


Daily ALOS2-LandSurfaceWaterCoverage estimation

$$= (\textit{ALOS2}\text{floodability}*\omega+\zeta)*\exp(\textit{AMSR}\text{NDFI}*\delta-\textit{MODIS}\text{LSVC}*\delta)$$



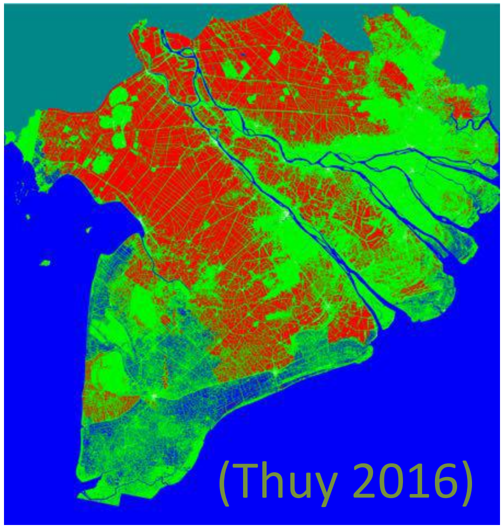
Downscale to MODIS spatial resolution



MONITORING with ALOS2 (since 2014)

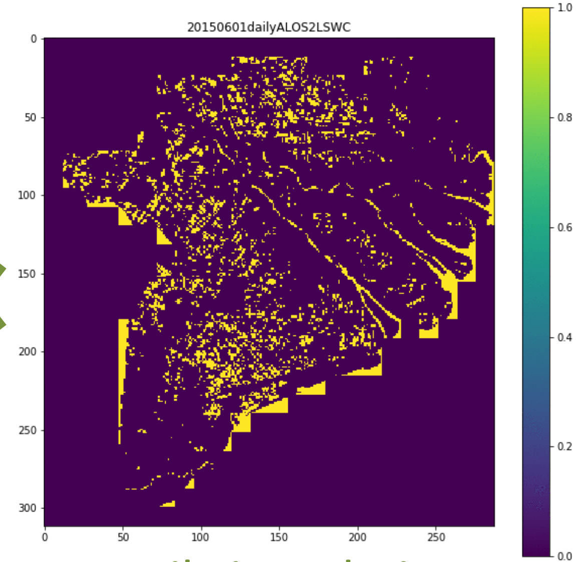
↓

REPORTING with AMSR, MODIS, GCOM-C/W (since 2002,daily)



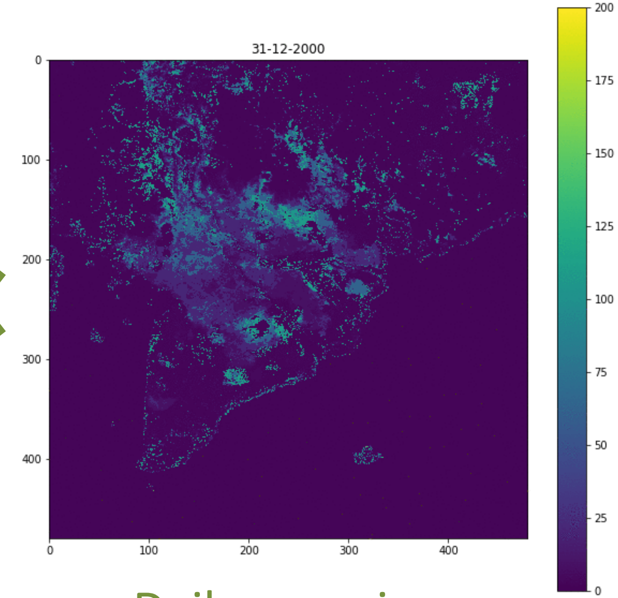
Paddy distribution

×



Daily inundation status

×

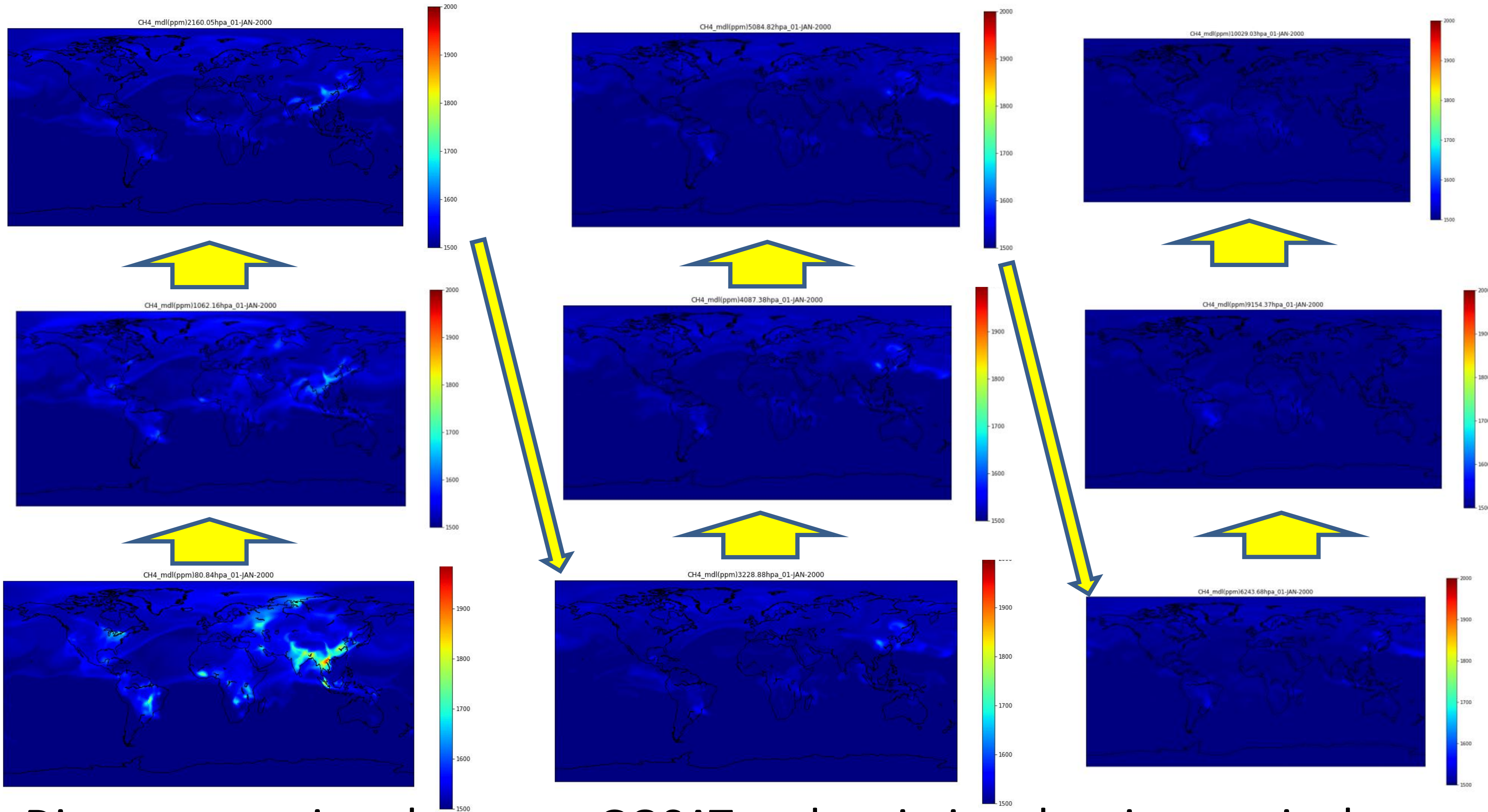


Daily cropping calendar

Estimate daily CH_4 emission REPORT (250m res., 2002-)

Need to be **VERIFIED !**

NICAM-TM
with different altitudes（2000/Jan.）



Direct comparison between GOSAT and emission data is meaningless…

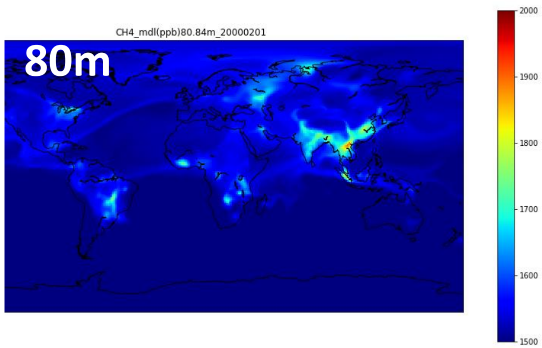
→Need transport model! But,,,,

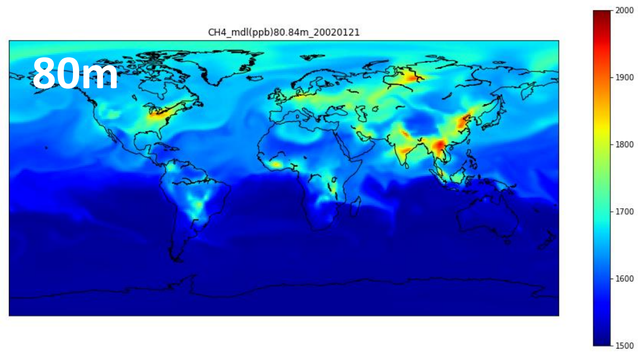
Check spin-up status

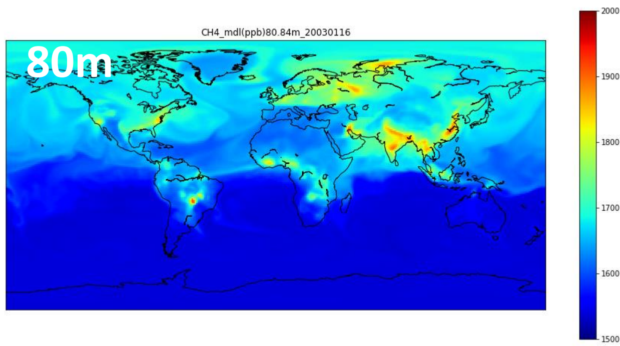
2000/2/1 (1 month after)

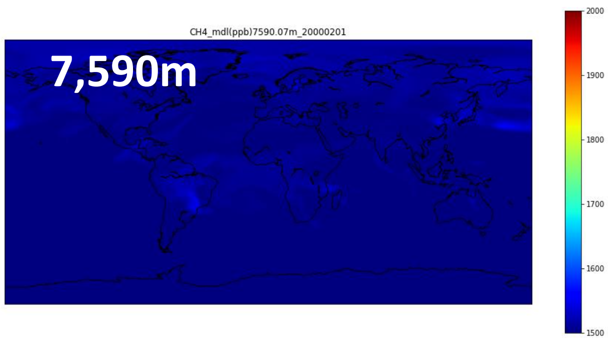
2002/1/21 (2 years after)

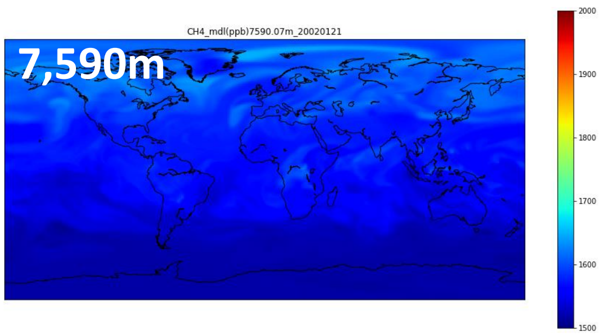
2003/1/16 (3 years after)

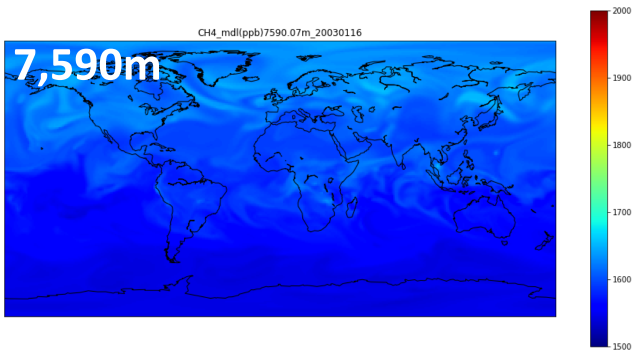












Long years are needed for spin up

+ strong dependency on initial condition,,,

→DA is essential!

Geoscientific Model Development
An interactive open-access journal of the European Geosciences Union

GOSAT-4DVAR ?

Geosci. Model Dev., 10, 2201-2219, 2017
https://doi.org/10.5194/gmd-10-2201-2017

Volume 10, issue 6

Development and technical paper

15 Jun 2017

A 4D-Var inversion system based on the icosahedral grid model (NICAM-TM 4D-Var v1.0) – Part 2: Optimization scheme and identical twin experiment of atmospheric CO_2 inversion

Yosuke Niwa et al.

Model code and software

NICAM-TM 4D-Var
1. H. Tomita and M. Satoh; 2. M. Sato, T. Matsuno, H. Tomita, H. Miura, T. Nasuno and S. Iga; 3. M. Satoh, H. Tomita, H. Yashiro, H. Miura, C. Kodama, T. Seiki, A. T. Noda, Y. Yamada, D. Goto, M. Sawada, T. Miyoshi, Y. Niwa, M. Hara, T. Ohno, S. Iga, T. Arakawa, T. Inoue, and H. Kubokawa
http://nicam.jp/hiki/?Research+Collaborations

GOSAT + NICAM-TM

GOSAT-2 + NICAM-TM-4DVAR

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

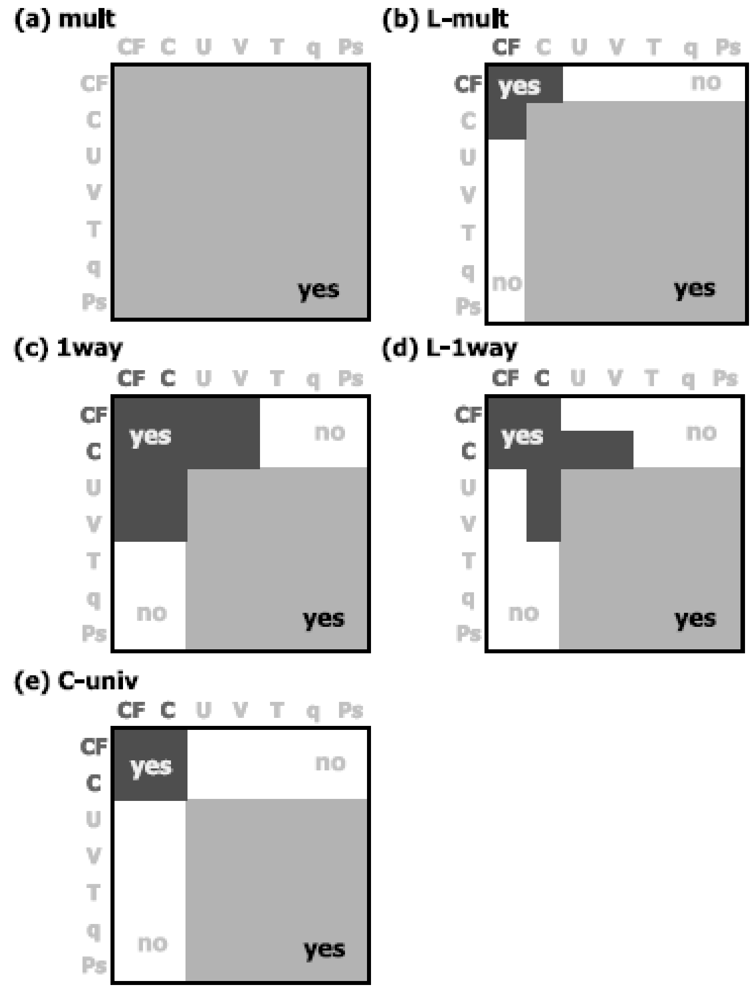
"Variable localization" in an ensemble Kalman filter: Application to the carbon cycle data assimilation

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 MRV with NICAM-LETKF!



Back ground covariance matrices

Outline

0．Motivation to DA (Story taking me here today)

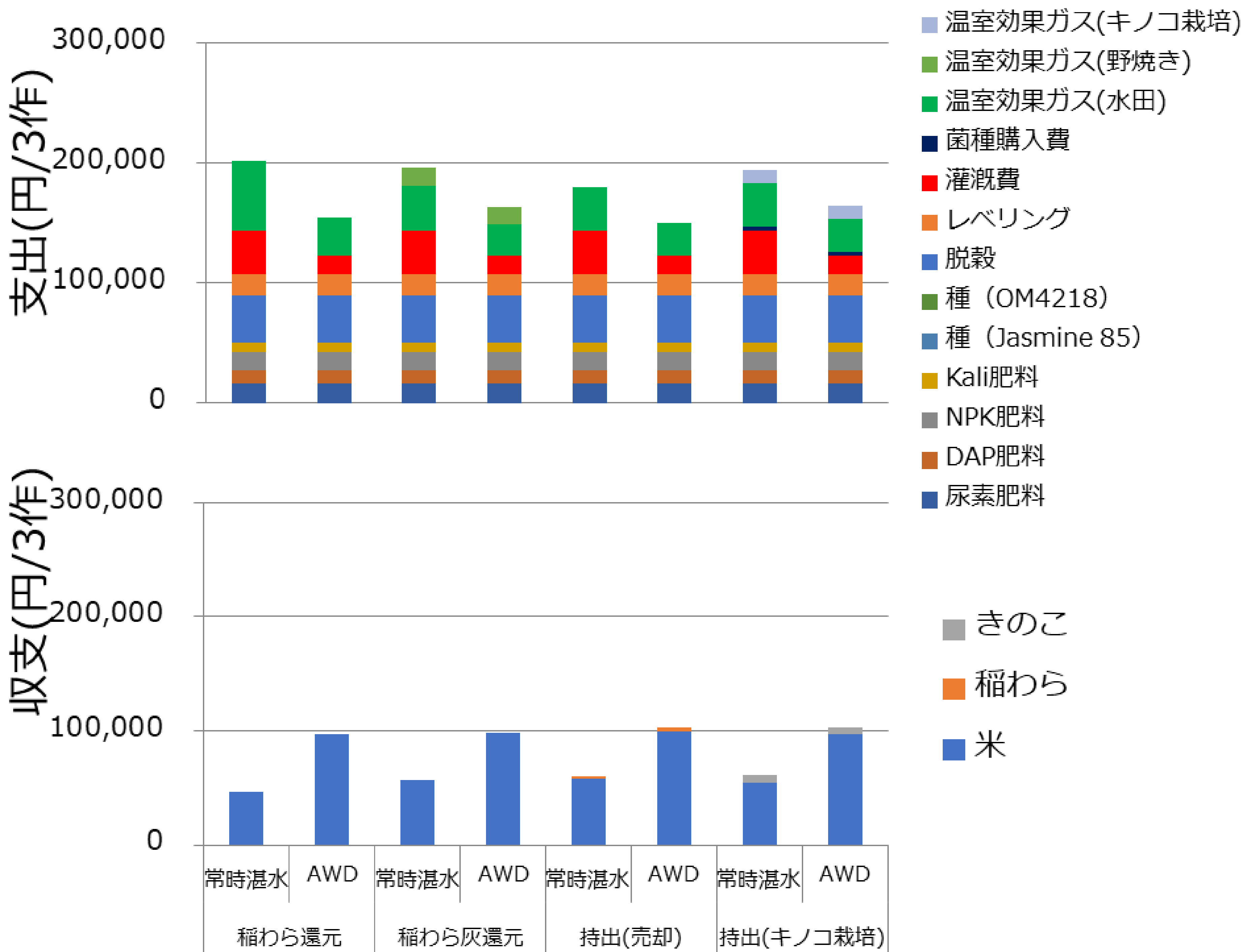
1．Background & Objective

2. Ground observation of greenhouse gas emission and statistical 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**

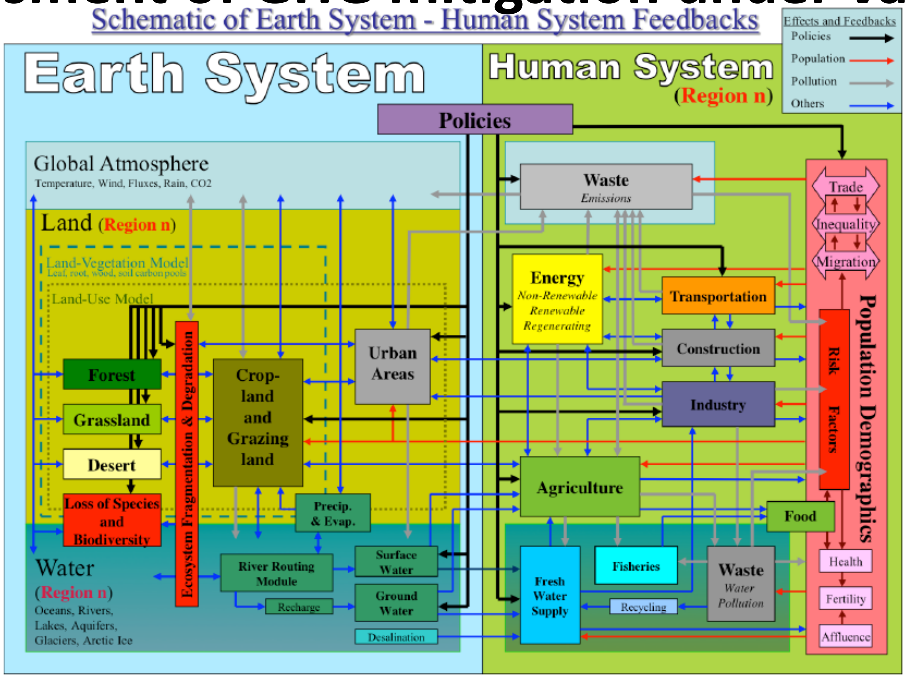
4. My next work with DA



支出(円/3作)
300,000
200,000
100,000
0
温室効果ガス(キノコ栽培)
温室効果ガス(野焼き)
温室効果ガス(水田)
菌種購入費
灌漑費
レベリング
脱穀
種（OM4218）
種（Jasmine 85）
Kali肥料
NPK肥料
DAP肥料
尿素肥料
収支(円/3作)
300,000
200,000
100,000
0
きのこ
稲わら
米
常時湛水
AWD
常時湛水
AWD
常時湛水
AWD
常時湛水
AWD
稲わら還元
稲わら灰還元
持出(売却)
持出(キノコ栽培)

My next work with DA

Economic assessment of GHG mitigation under various uncertainties

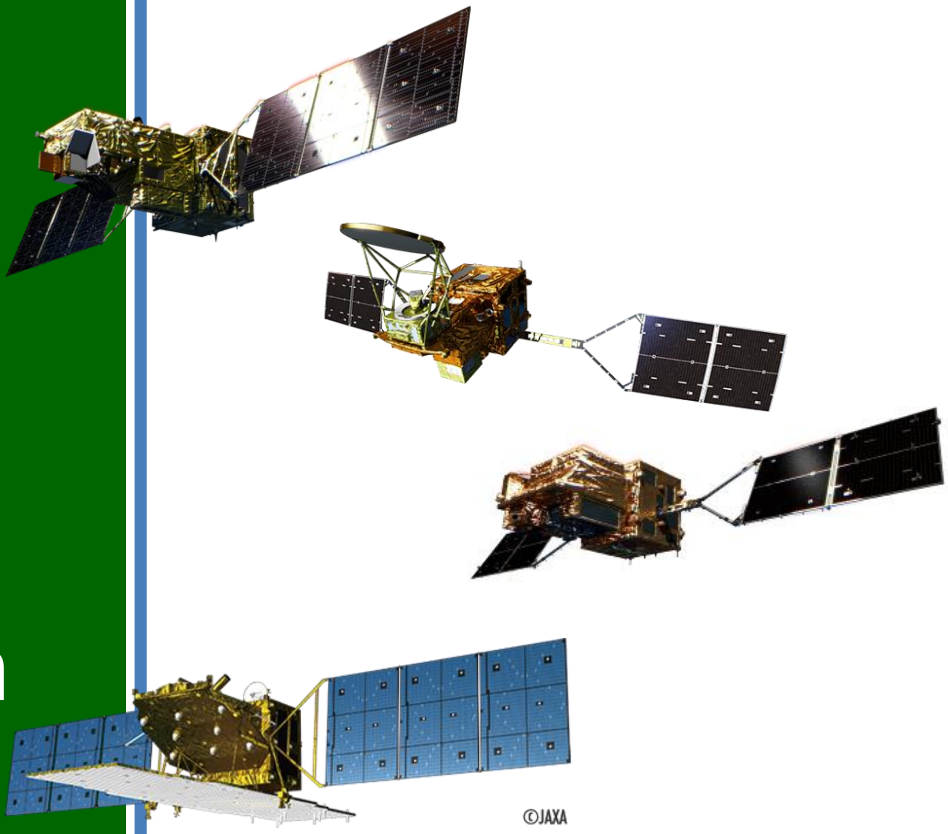


Kalnay *et al*. 2017

And if possible…

Soil moisture/Drought assessment/GHG emission estimation with AHI-LST and its DA with atmospheric observation data

PM2.5 emission status estimation with AHI & NICAM-LETKF



Thank you for your attention