An LETKF-based ocean reanalysis for the Asia-Oceania region using Himawari-8 SSTs and SMOS/SMAP SSS

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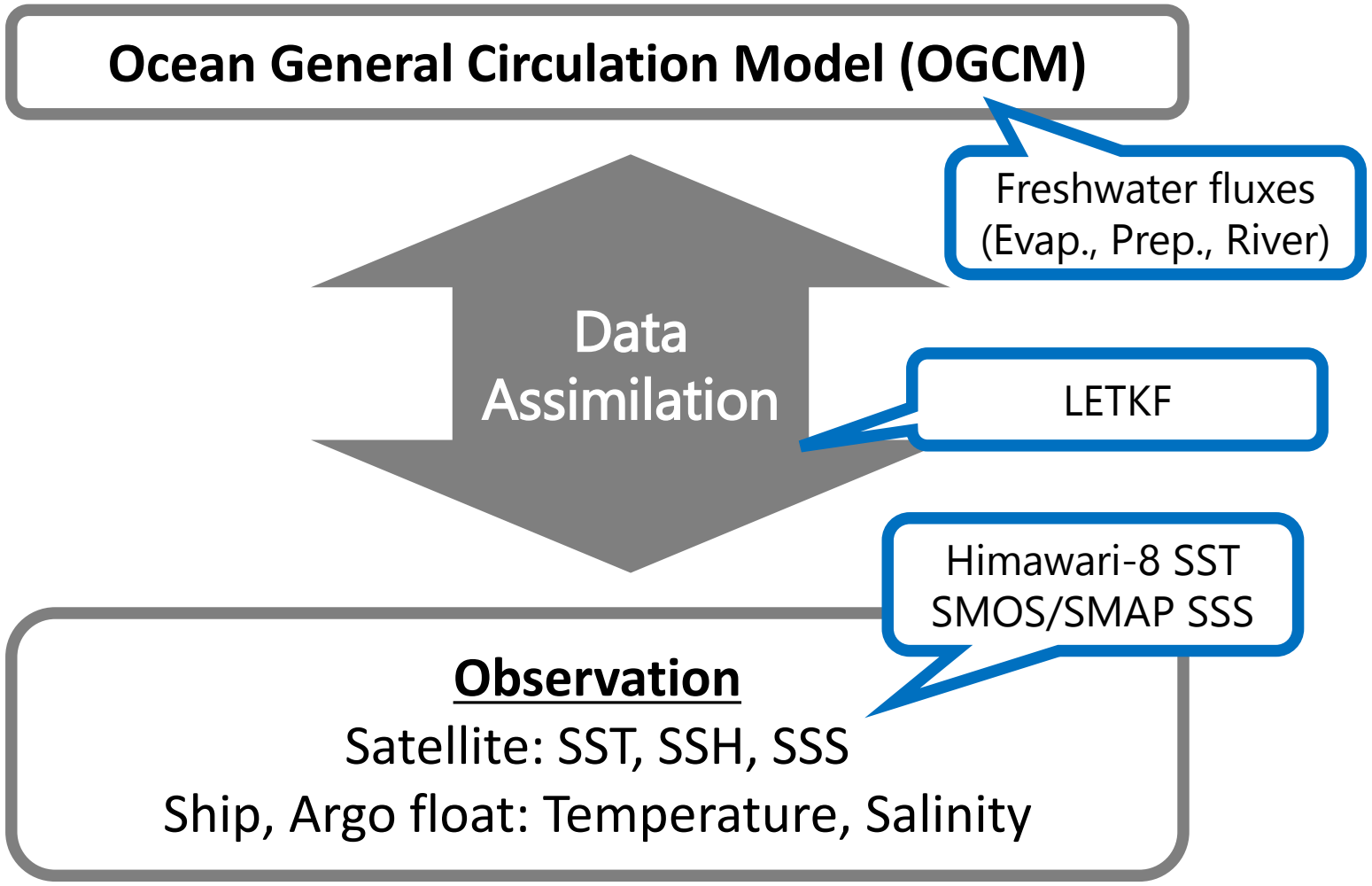
1. Introduction

1. Introduction – Ocean data assimilation system –



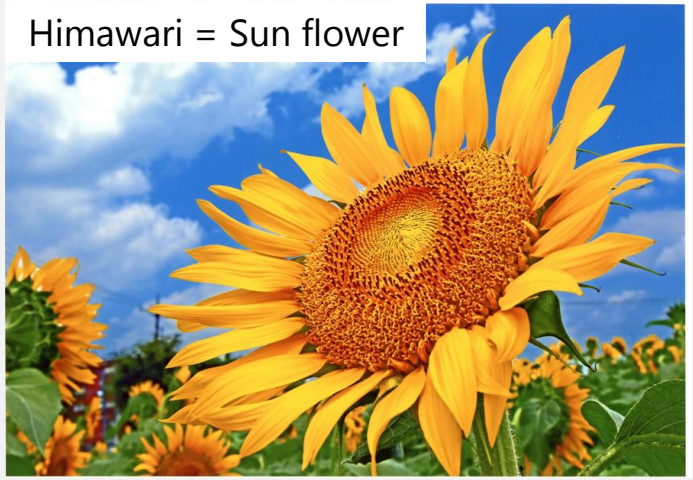
*LETKF: Local Ensemble Transform Kalman Filter
*SMOS: Soil Moisture Ocean Salinity, SMAP: Soil Moisture Active Passive
*SST/SSH/SSS: Sea Surface Temperature/Height/Salinity

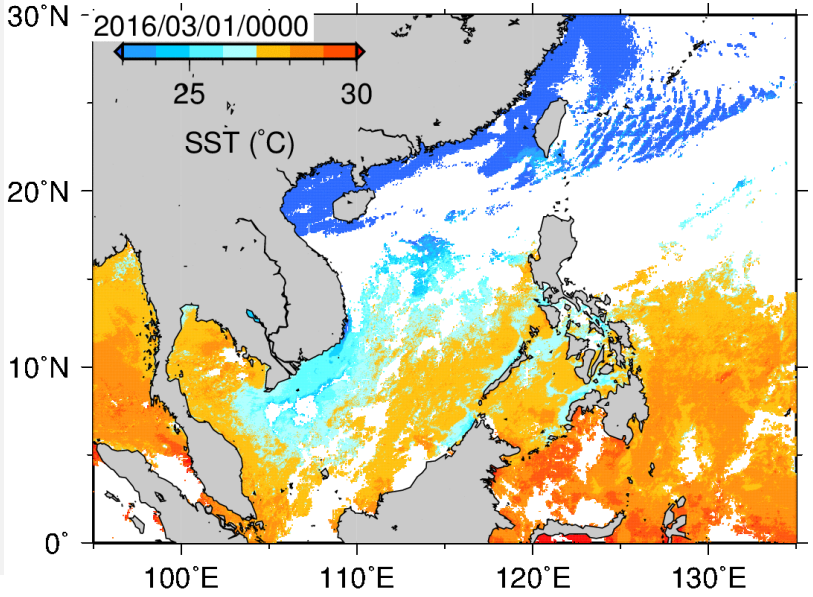
1. Introduction – Himawari-8 satellite –

◆ Himawari-8 satellite

- Geostationary satellite
- Observation from July 2015
  in the western Pacific region
- Infrared sensor “AHI”

→ Unable to observe under cloud areas



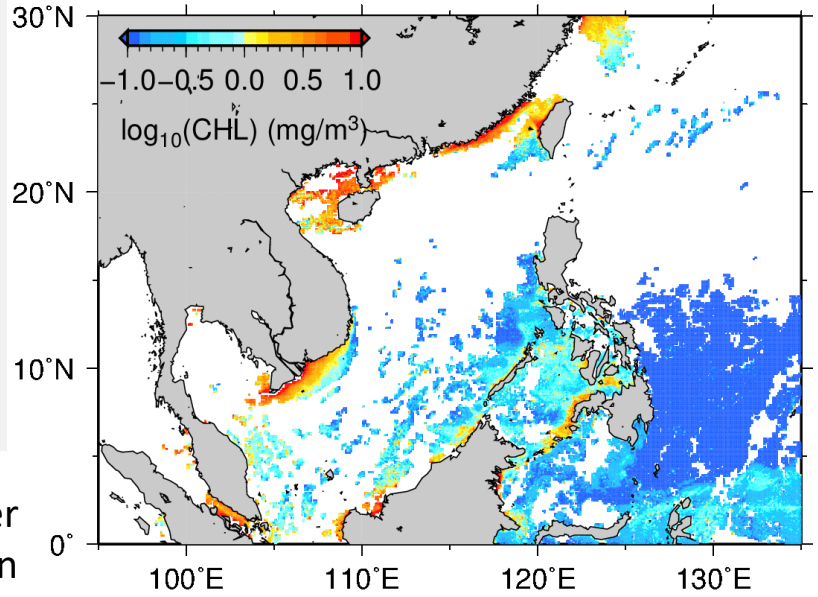


◆ Advantages of Himawari-8

✓ High coverage in 1-day composite maps
by a high spatiotemporal resolution (dx = 2km, dt = 10 min.)

→ Himawari-8/AHI > GCOM-W/AMSR2 (with microwave)

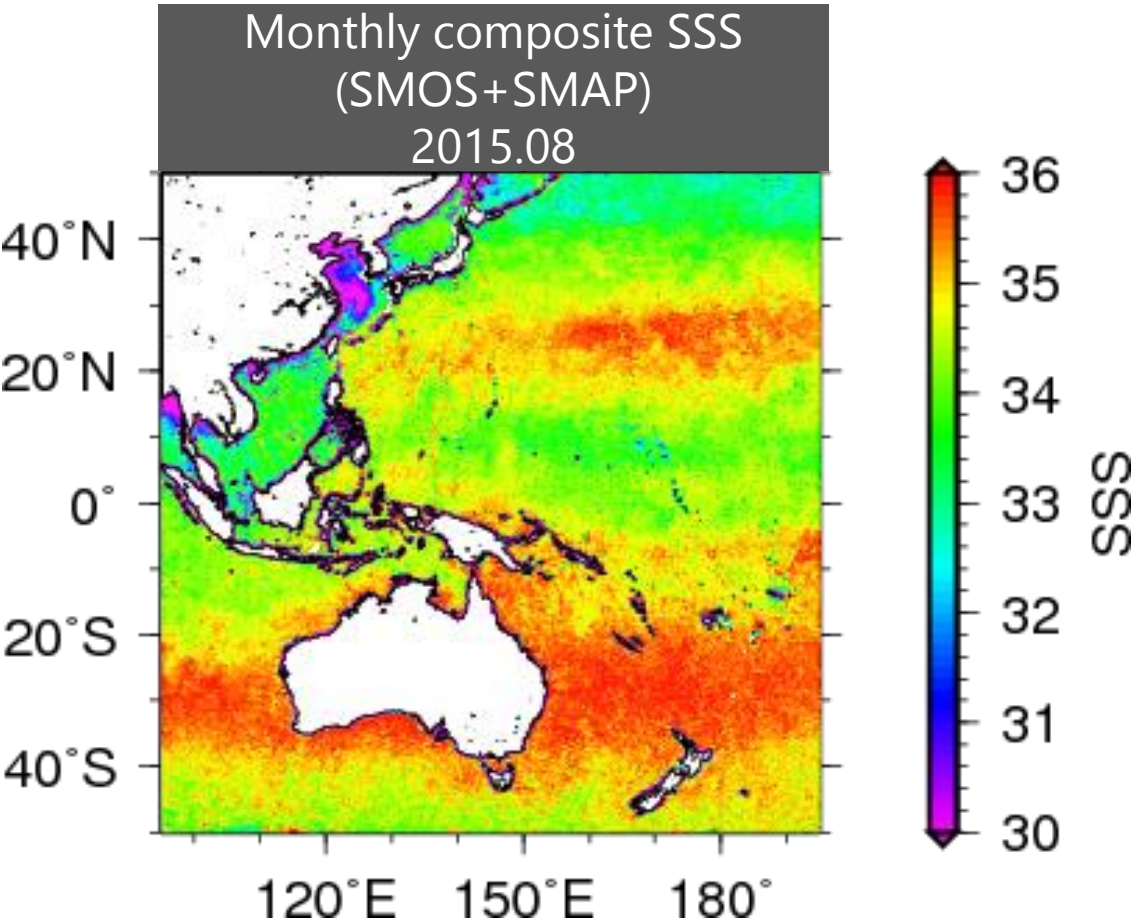
✓ Observation close to coastal regions by the infrared sensor



*AHI: Advanced Himawari Imager
*GCOM-W: Global Change Observation Mission
*AMSR: Advanced Microwave Scanning Radiometer

1. Introduction – Satellite SSS –

	2010	2011	2012	2013	2014	2015	2016~
SMOS	06/01～						
Aquarius		08/25～				～06/07	
SMAP						03/31～	



◆ Use of satellite SSS for data assimilation

- Improvement of reproducibility of
  - Ocean interior structure
    (MLD and Barrier layer)
  - Low salinity water caused by river discharge
- Improvement of ENSO forecast

(e.g. Toyoda et al. 2015, Chakraborty et al. 2015)

*SMOS: Soil Moisture Ocean Salinity
*SMAP: Soil Moisture Active Passive
*MLD: Mixed Layer Depth
*ENSO: El Niño-Southern Oscillation

1. Introduction – Data assimilation –

◆ Data assimilation method

Maximum likelihood method

Low ↓ High

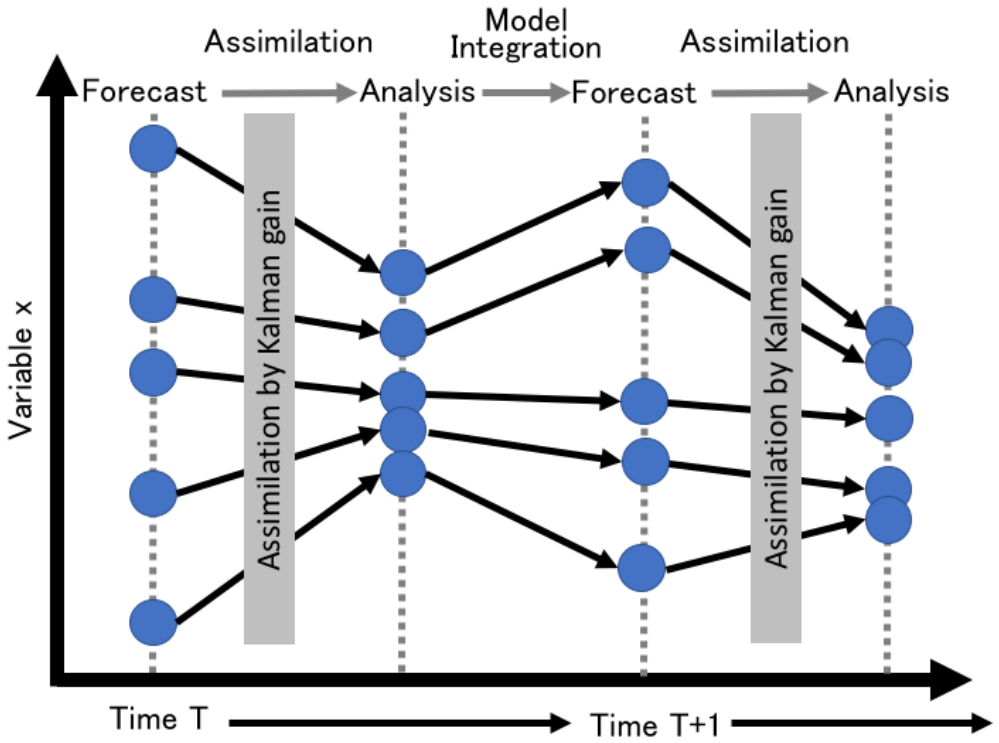
- 3D-VAR
- 4D-VAR

Minimum variance estimate

Low ↓ High

- Optimal Interpolation
- Kalman Filter
- ✓ **LETKF** (Hunt et al. 2007)

Schematic figure – LETKF –



Advantage of LETKF

- Available for non-linear model
- Sequential method
- Efficient for parallel computer

*LETKF: Local Ensemble Transform Kalman Filter

1. Introduction – Ocean reanalysis dataset –

◆Global dataset

Maximum likelihood method		Minimum variance estimate	
3D-VAR	4D-VAR	Kalman Filter	Ensemble Kalman Filter
• CFSR • HYCOM • MOVE • GODAS • ORAS4,S5	• ECCO • GECCO2	• SODA • CMEMS	**None**

◆ High-resolution regional dataset

Maximum likelihood method		Minimum variance estimate	
3D-VAR	4D-VAR	Kalman Filter	Ensemble Kalman Filter
• JCOPE	• FORA-WNP30	• DREAMS	• TOPAZ4 - **North of 65°N**

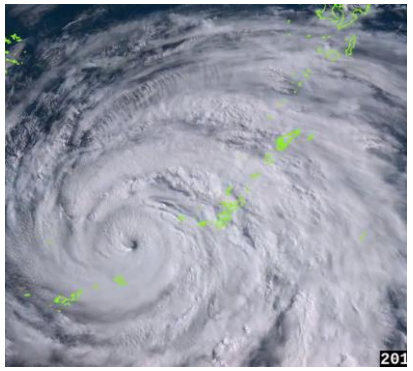
These all regional datasets do not cover south of 10°N.

1. Introduction – Motivation –

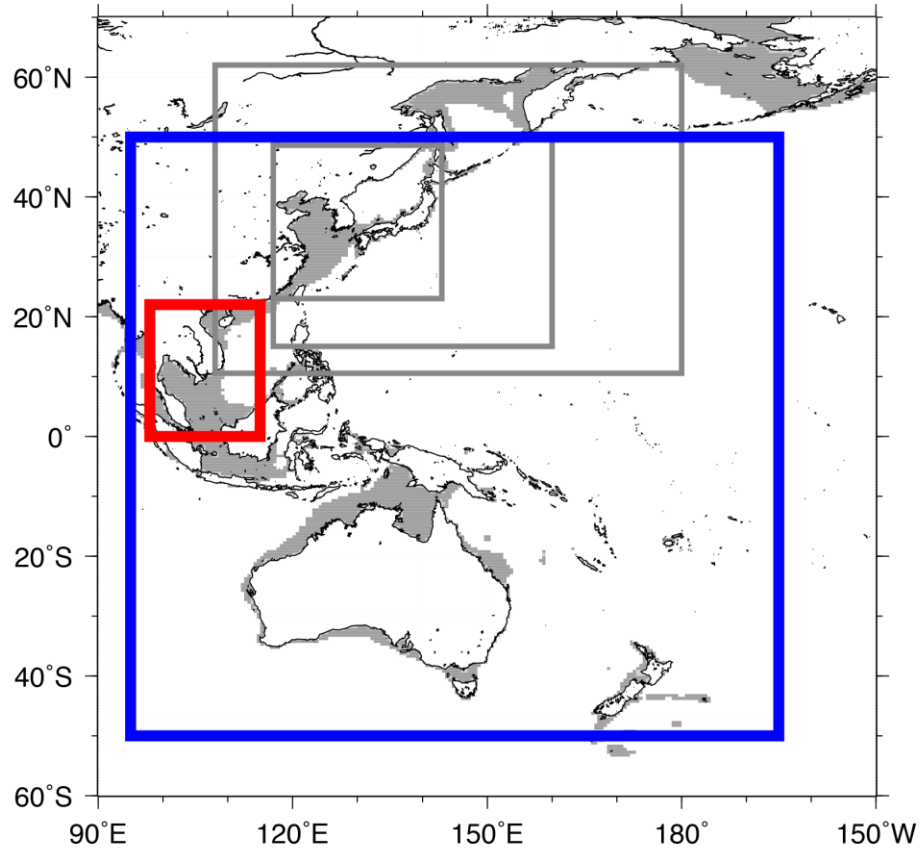
We construct one-way nest ocean data assimilation system

in the Asia-Oceania region using LETKF and the satellite observations.

- Large-scale western Pacific system
  - dx=1/12°
  - For tropical cyclone research



- Southeast Asia coastal system
  - dx=1/36°
  - For fishery research and marine monitoring



*Gray: regional dataset

2. Assimilation system

2. Assimilation system – Ocean model –

Ocean model: sbPOM (Mellor 2004; Jordi and Wang 2012)

Blue: western Pacific
Red: southeast Asia

Region: [95°E–165°W, 50°S–50°N], [98°–115°E, 0°–22°N]

Resolution: 1/12°, 1/36° x 47 layers

Initial condition: WOA13 (Locarnini et al. 2013; Zweng et al. 2013)

Lateral boundary condition: SODA 3.7.2 Monthly clim. (dx=0.5° x 50 layers; Carton et al. 2018)

One-way nest using daily-mean outputs

Atmospheric forcing: JRA55 (dx = 1.25°; Kobayashi et al. 2015)

Precipitation: GSMaP (Kubota et al. 2007), **River discharge: CaMa-Flood/GSMaP** (Hibino et al. 2017)

Topography: ETOPO1 (dx = 1/60°; Amante and Eakins 2009)

Momentum/Heat flux algorithm: COARE version 3.5 (Edson et al. 2013; Brodeau et al. 2017)

Spin-up period: 2011.01.01 – 2015.07.06

2. Assimilation system – Assimilation method –

Assimilation method: **LETKF** (Hunt et al. 2007; Miyoshi and Yamane 2007)

+IAU (Bloom et al. 1996)

Blue: western Pacific
Red: southeast Asia

The number of ensemble: 20

Interval: 1day

Assimilation data:

SST: Himawari-8 (Bessho et al. 2016; Kurihara et al. 2016) + GCOM-W

SSH: MDOT (Maximenko et al. 2009) + SSH anomaly (http://marine.copernicus.eu/)

SSS: SMOS (https://earth.esa.int/web/guest/home) + **SMAP** (http://www.remss.com/missions/smap/)

Temperature/Salinity： GTSPP (Sun et al. 2010)

+ AQC Argo version 1.2a (http://www.jamstec.go.jp/ARGO/argo_web/argo/?page_id=100&lang=en)

Localized scale: 6 grid（1/2°）， 18 grid（1/2°）×2000 m

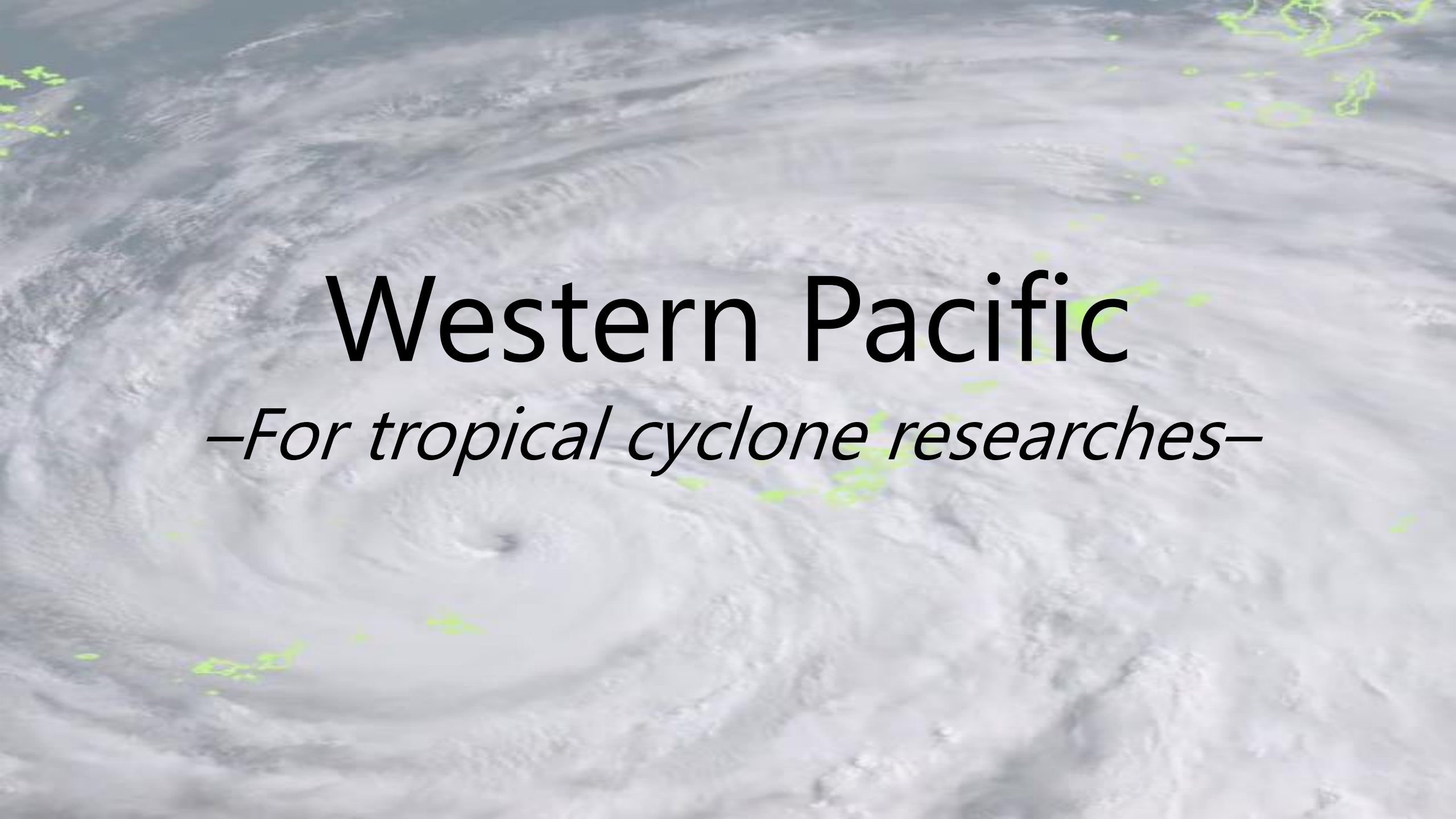
Observational error: T=1 ℃, S=0.4 psu, SSH=0.2 m

Quality check: ΔT=4 ℃, ΔS=2 psu, ΔSSH=1 m

Assimilation period: 2015.07.07 – Currently in progress

*IAU: Incremental Analysis Update
*MDOT: Mean Dynamic Ocean Topography

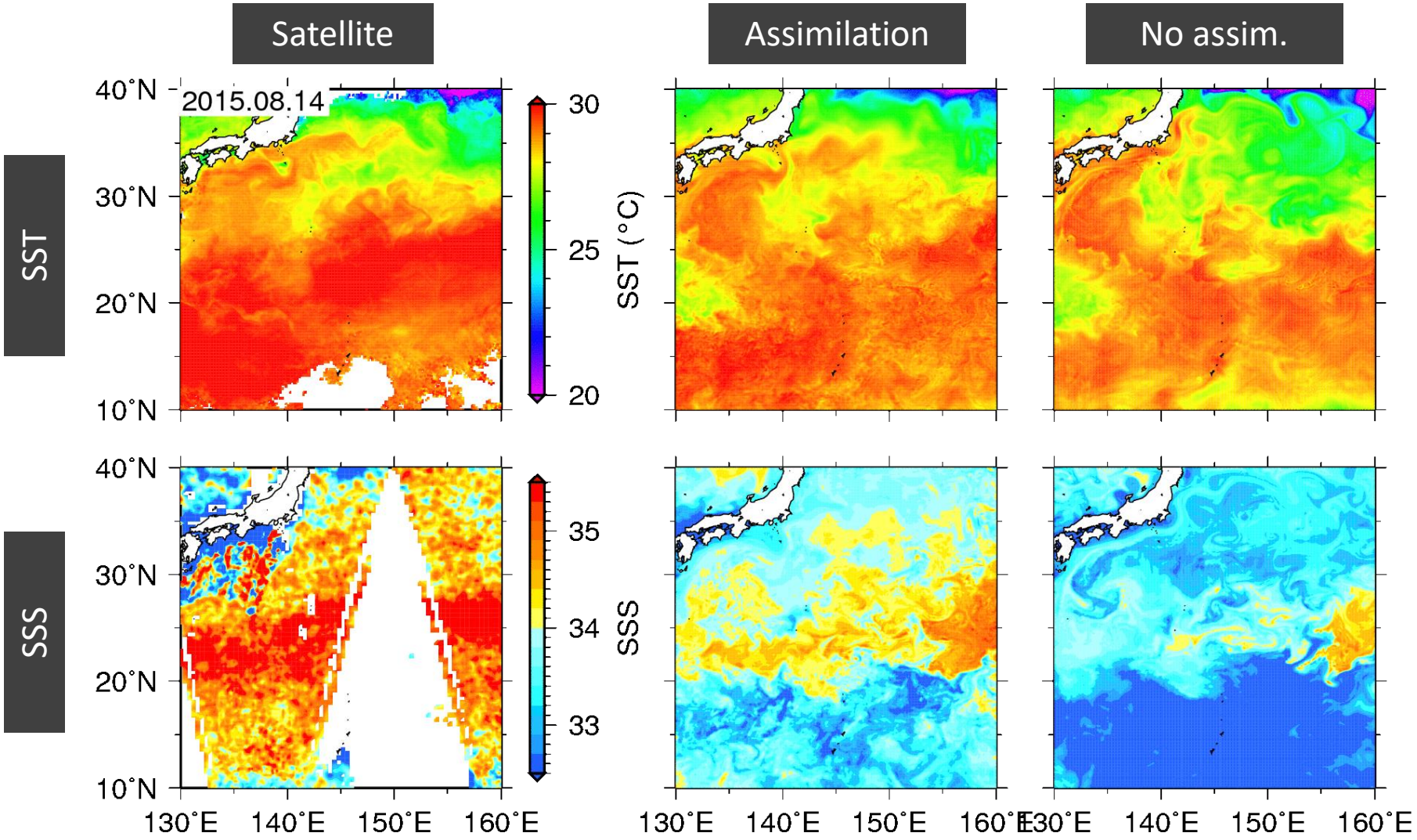
3. Results



Western Pacific

–For tropical cyclone researches–

3-1. Western Pacific system – Typhoon “Atsani” –

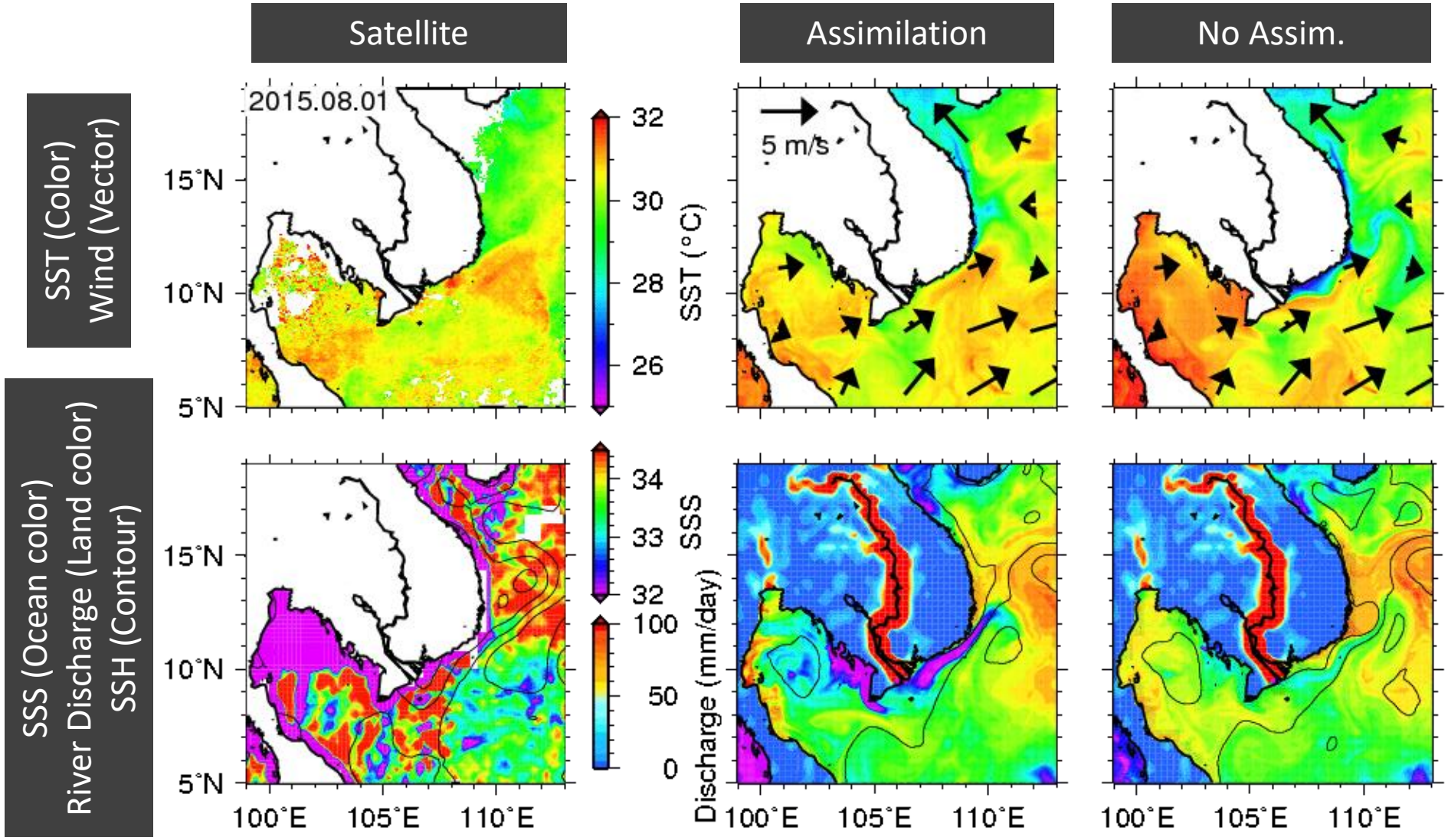


- Decrease of SST and SSS associated with the passage of a typhoon
  - Low SST biases because of model biases
- Improvement of the Kuroshio and Kuroshio Extension path

Southeast Asia

– For ocean monitoring –

3-2. Southeast Asia system – August 2015 –



- SST cooling along the Vietnam coast during southwesterly monsoon
- Low salinity water around the Mekong river

4. Summary

4. Summary

◆ Summary

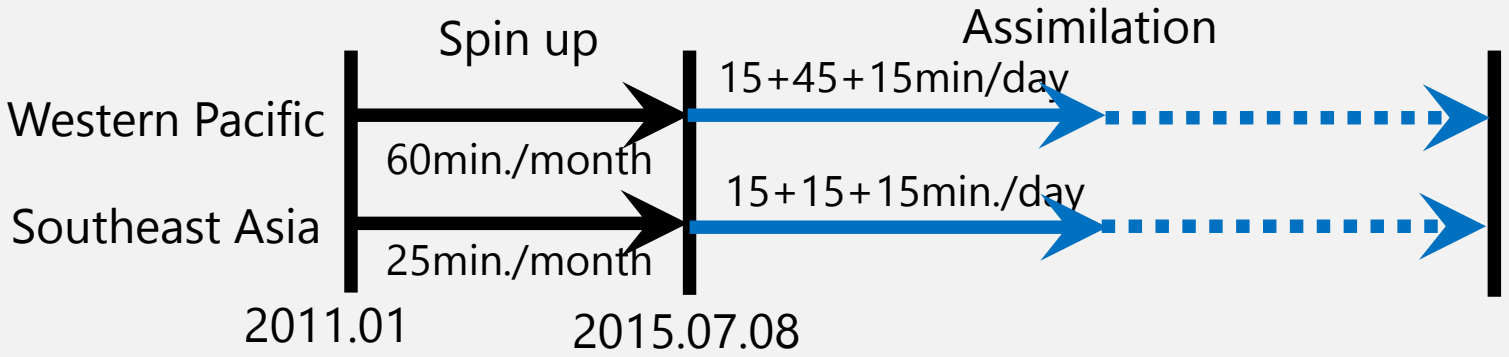
We have established the one-way data assimilation system.

- Horizontal resolution: western Pacific 1/12°, southeast Asia 1/36°
- Freshwater flux: Evap. + Precip. + River discharge
- Assimilation method: LETKF+IAU
- Assimilation SST: Himawari-8+GCOM-W, SSS: SMOS+SMAP

◆ Future work

- ✓ Conservation of each term of heat/salinity budget equations
- Release of datasets after validation

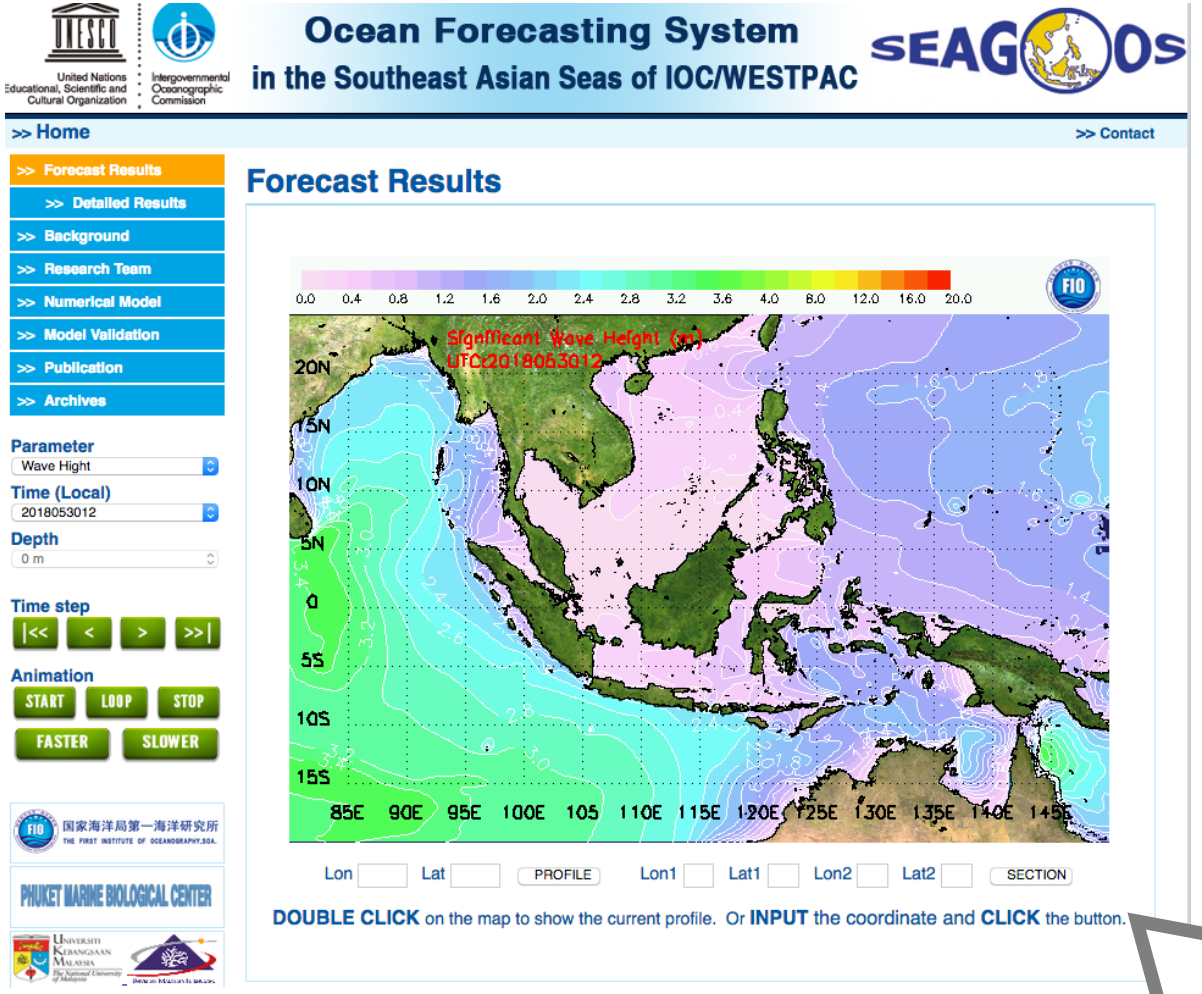
◆Computational cost



Thank you

Appendix

4. Summary



- Ocean-wave-tide model without assimilation
- Constructed by Malaysia, China, and Thailand group
- Less validation

4. Summary

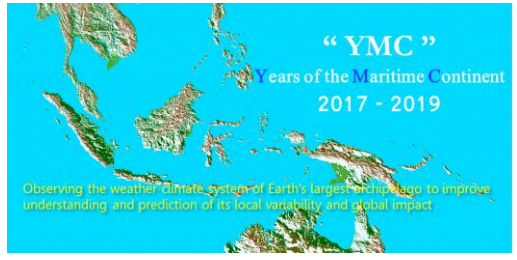
- Search observational data in the southeast Asia
- Link with southeast Asian countries

◆ Recent information:

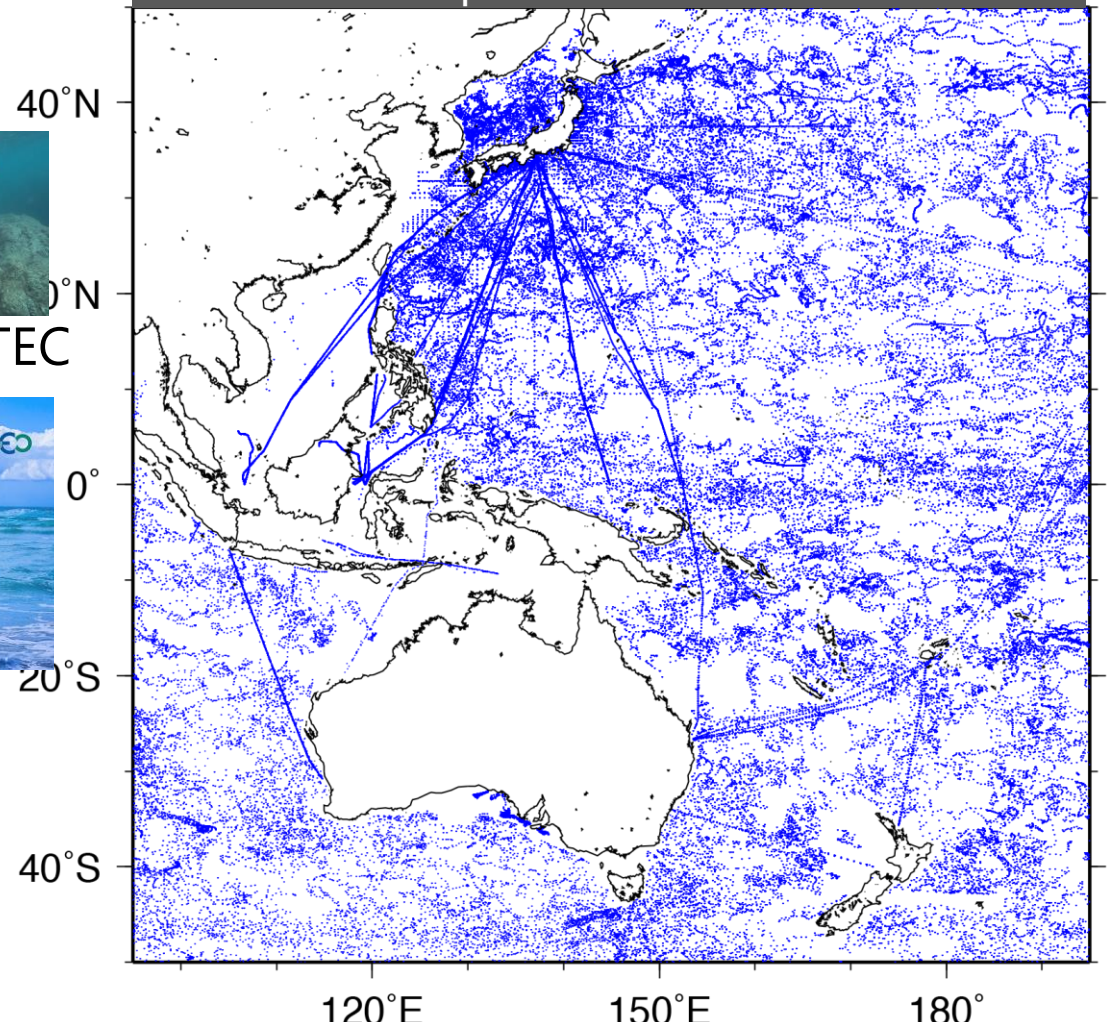
- Turtle biologging

- GEOSS promoted by JAMSTEC

- YMC project



Observation points in the ocean interior



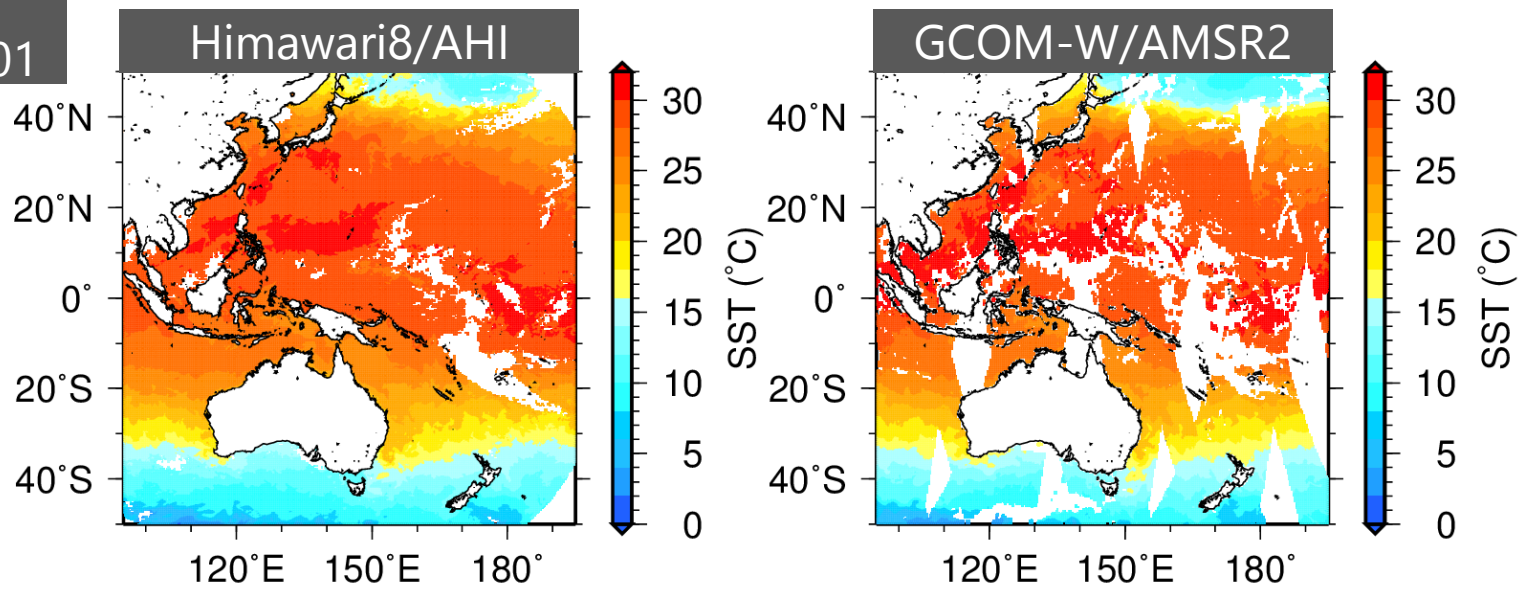
1. Introduction
– Himawari-8 satellite –

◆ Advantage of Himawari-8 satellite

High spatiotemporal resolution (dt=10 min., dx=2km)

→ Large coverage area in the open ocean

Daily SST
in 2015.08.01



- Cloud area ×
- High temporal resolution

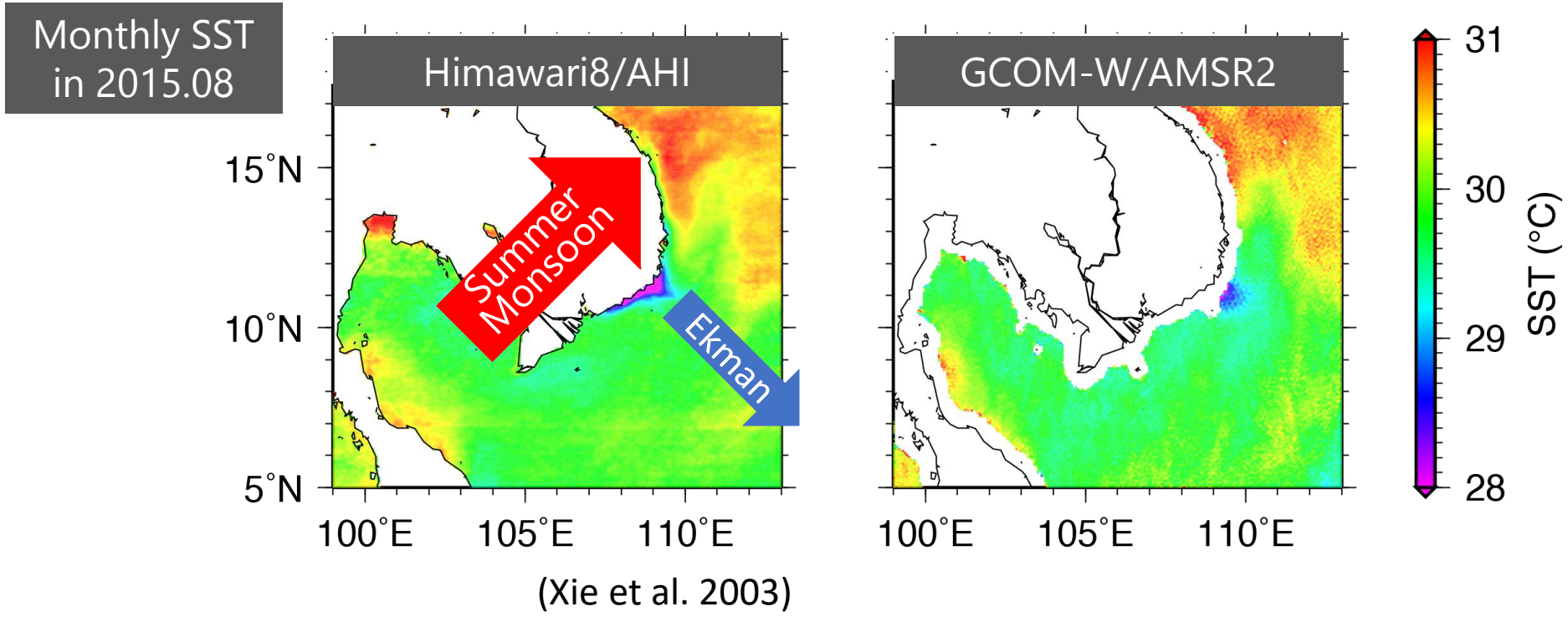
- Cloud area ○
- Rain area ×
- Observation gap

1. Introduction
– Himawari-8 satellite –

◆ Advantage of Himawari-8 satellite

High spatiotemporal resolution **+ Infrared sensor**

→ Observation close to coastal regions



(Xie et al. 2003)

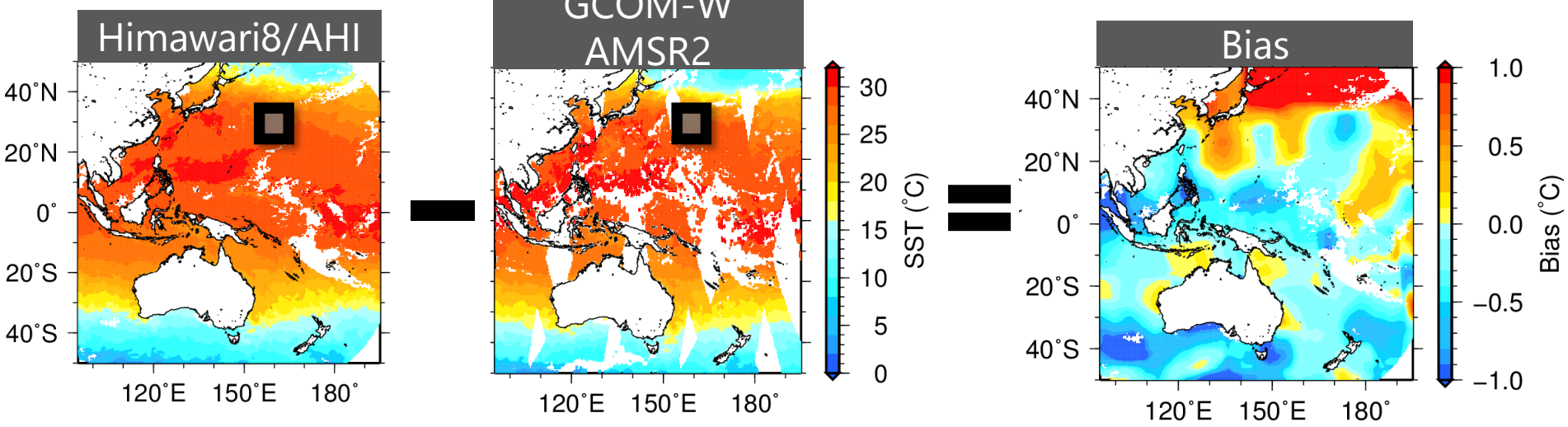
1. Introduction
– Himawari-8 satellite –

◆ Kurihara et al (2016): Cold SST biases in Himawari-8 satellite

◆ Our calculation method of SST biases:
Calculating difference between Himawari-8 and GCOM-W SSTs in 10°×10° box at each grid

Daily SST
in 2015.08.01

Smallest biases among satellites



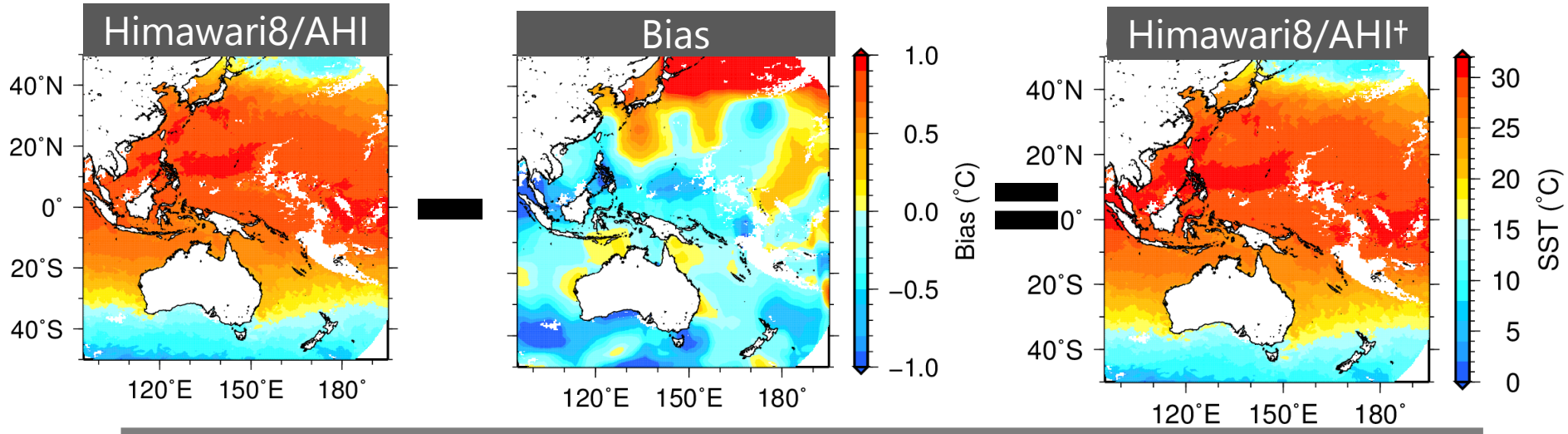
Himawari-8 has both positive & negative biases

1. Introduction
– Himawari-8 satellite –

◆ Kurihara et al (2016): Cold SST biases in Himawari-8 satellite

◆ Our calculation method of SST biases:
Calculating difference between Himawari-8 and GCOM-W SSTs in 10°×10° box at each grid

Daily SST
in 2015.08.01



Our modified Himawari-8 SSTs are used for assimilation

1. Introduction
– Ocean reanalysis dataset –

◆ Atmosphere vs. Ocean reanalysis dataset

Atmosphere reanalysis: 1990s (e.g. NCEP-NCAR reanalysis; Kalnay et al. 1997)

⬇

Ocean reanalysis: 2010s (e.g. ORA-S4; Balmaseda et al. 2015)

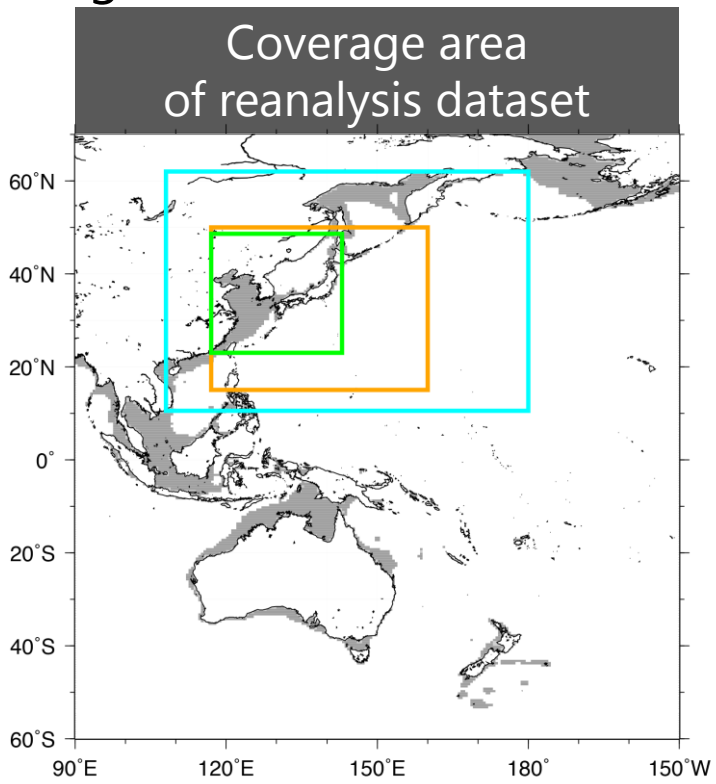
◆ High-resolution ocean reanalysis in the Pacific region

➢ FRA-JCOPE2 (Miyazawa et al. 2009)
- dx=1/12°
- 3D-VAR

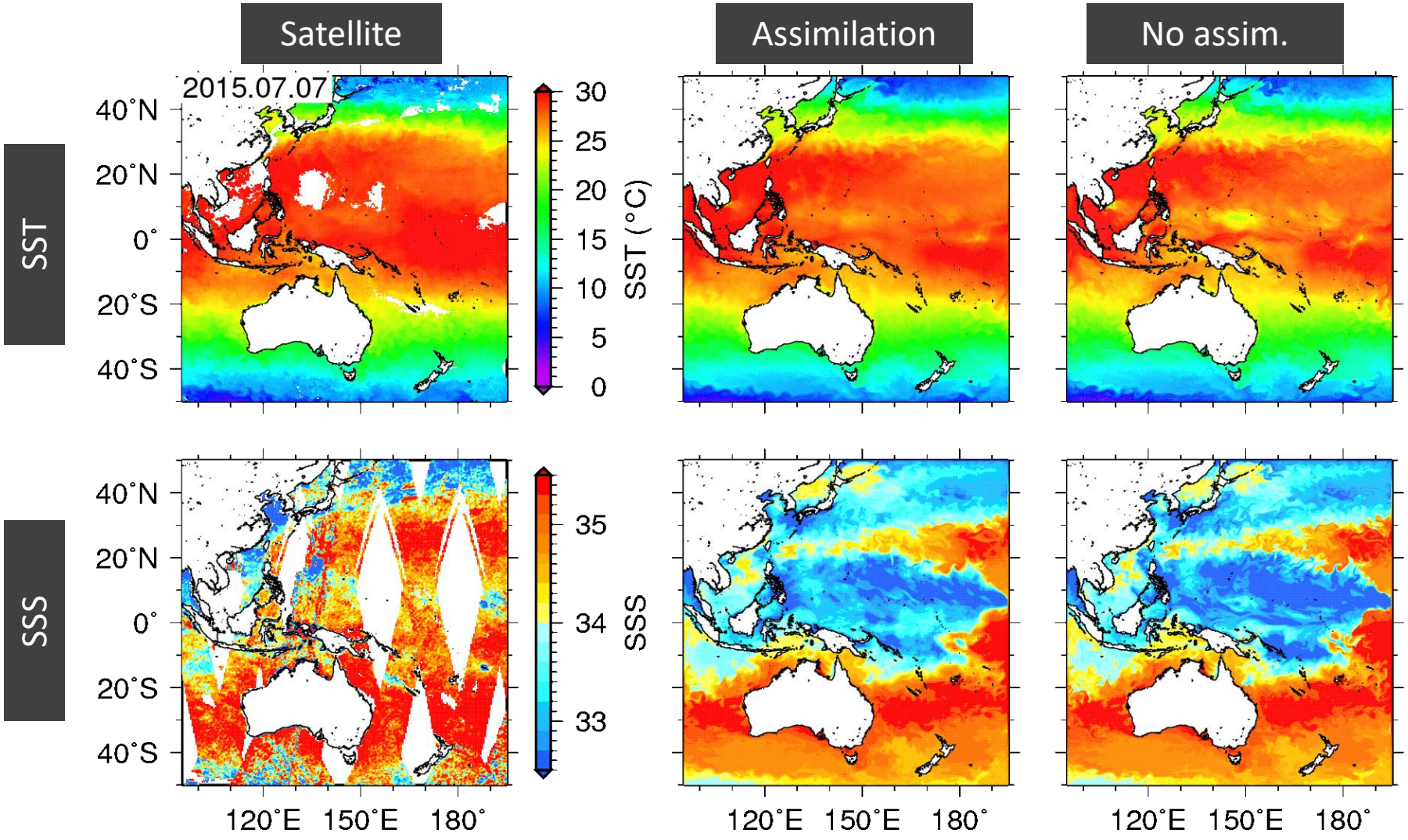
➢ FORA-WNP30 (Usui et al. 2017)
- dx=1/10°
- 4D-VAR

➢ DREAMS (Hirose et al. 2013)
- dx=1/12°×1/15°
- Kalman Filter

These datasets do not cover south of 10°N

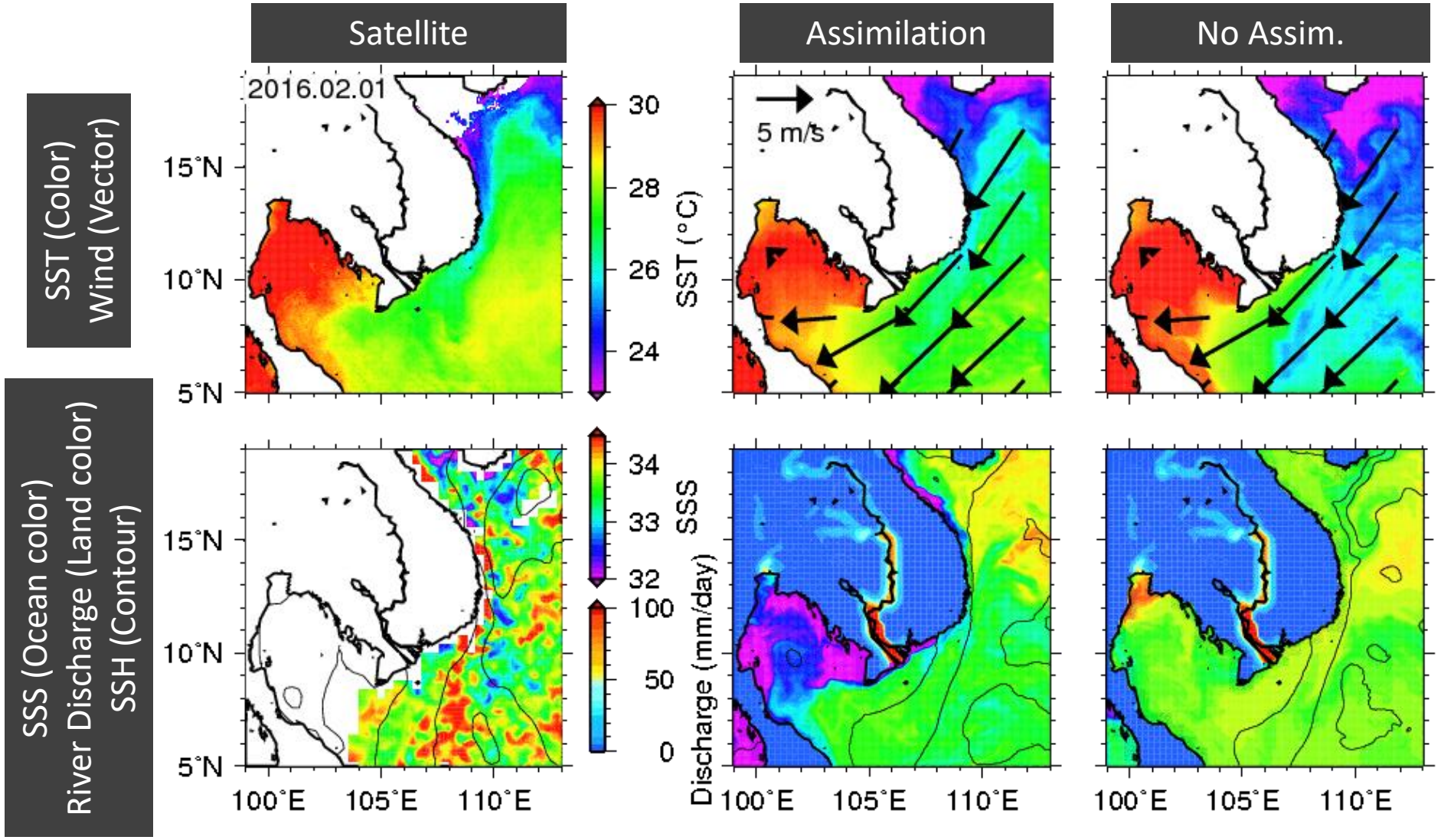


3-1. Western Pacific system – Jul.~Dec. 2015 –



Improvement of reproducibility of SST and SSS field

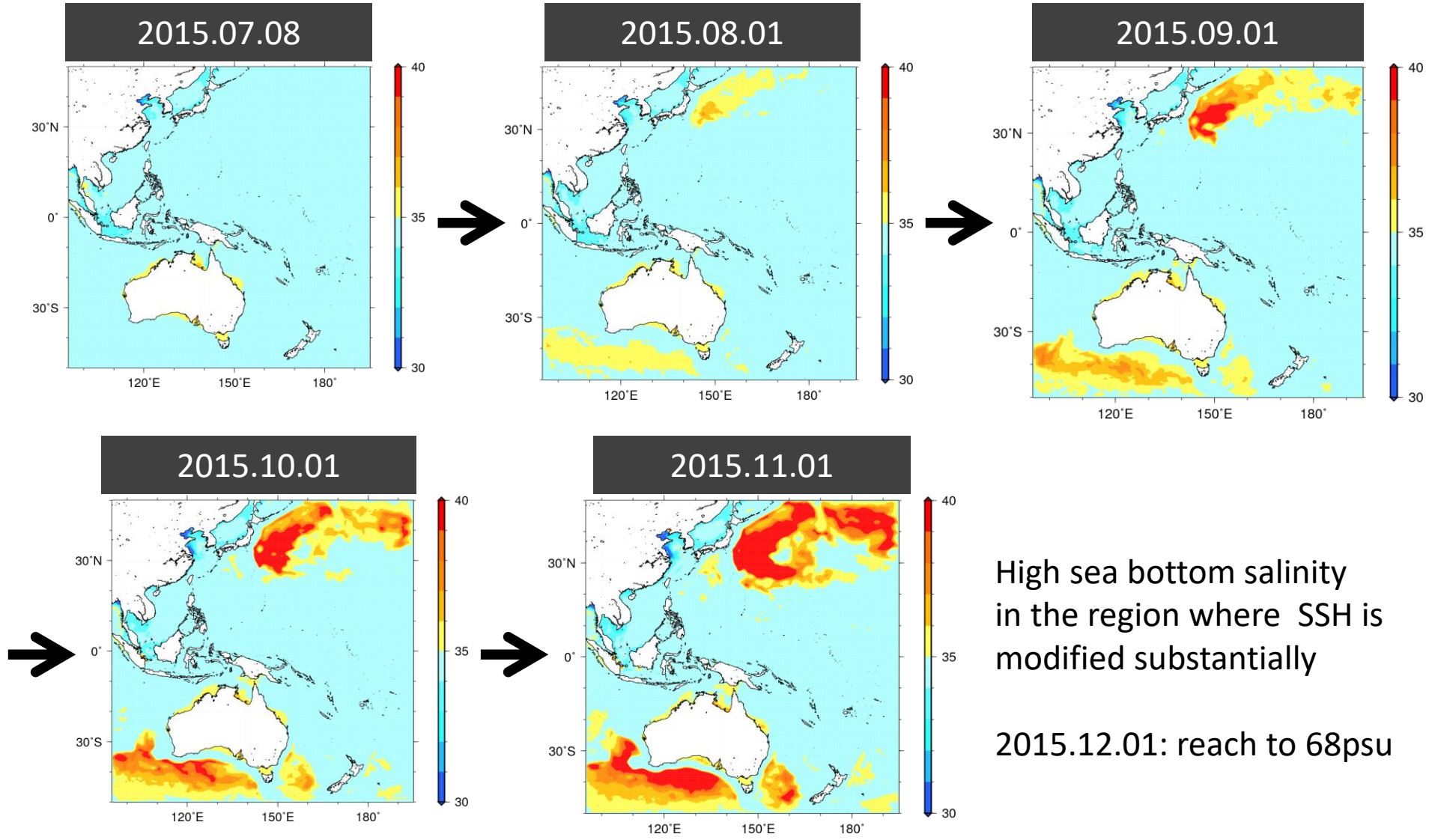
3.2 Southeast Asia system – February 2016 –



- Cold tongue along the Vietnam coast

3. Identified problems

◆Sea bottom salinity

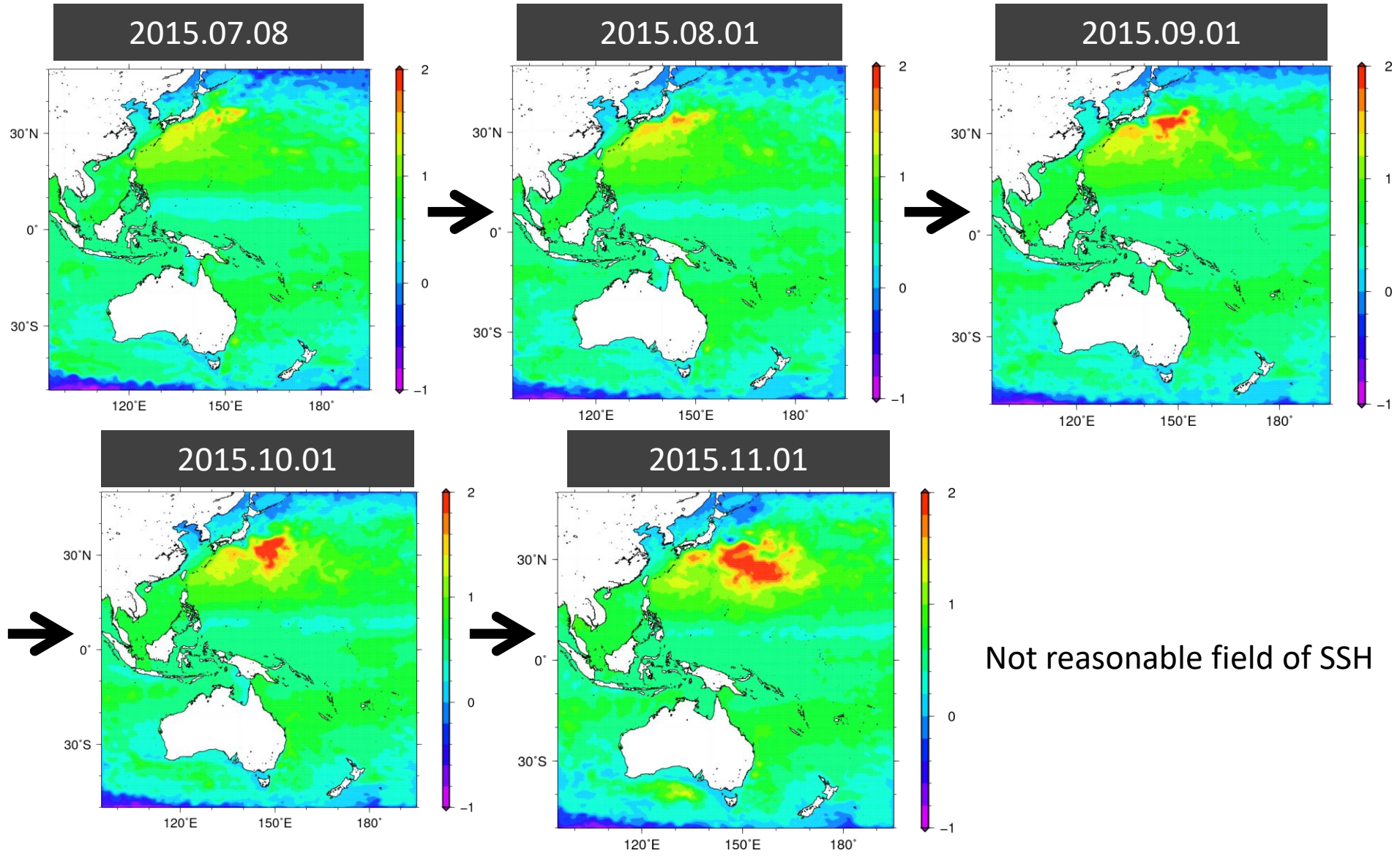


High sea bottom salinity
in the region where SSH is
modified substantially

2015.12.01: reach to 68psu

3. Identified problems

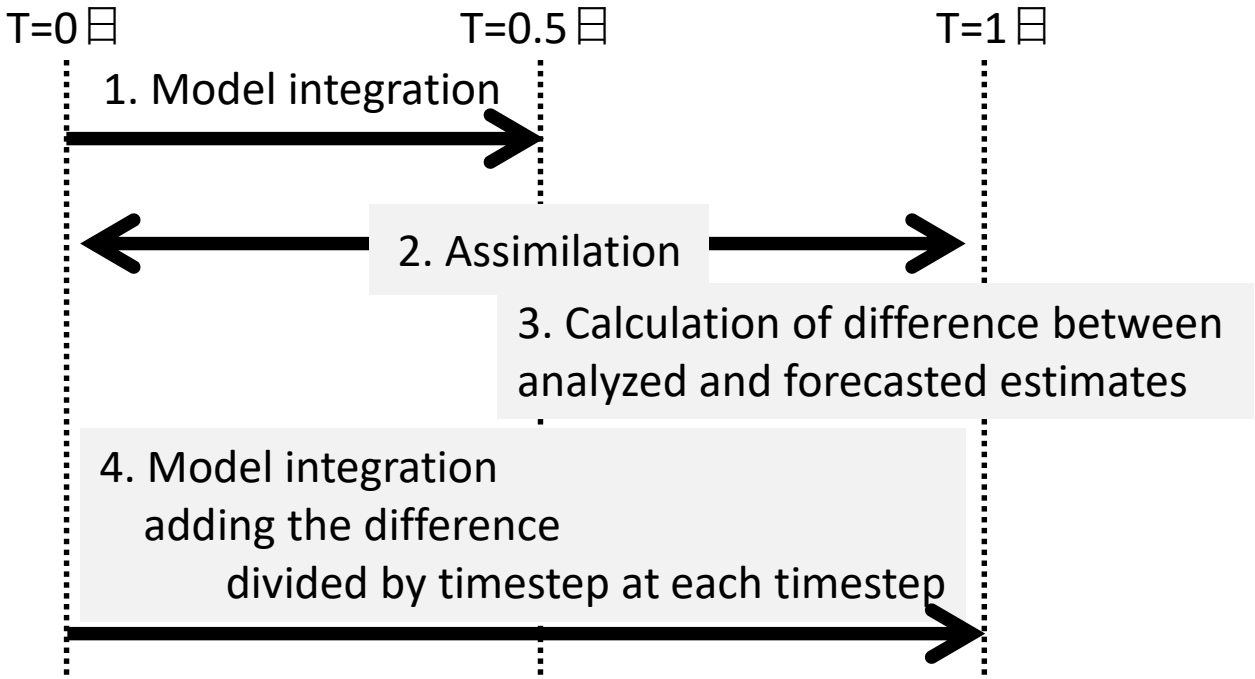
◆SSH



Not reasonable field of SSH

3. IAU method

◆Incremental Analysis Updates method （IAU method； Bloom et al. 1996）



- Advantage
  Reduction of noise by high-frequency gravity waves
- Disadvantage
  50% increase of computational costs

2. Western Pacific system + IAU

◆Mean Dynamic Ocean Topography (MDOT)

1. Model mean (2012.01 – 2014.12)
2. **Observation (Maximenko et al. 2009)**

2. Western Pacific system – 2. Model mean MDOT –

Black: Analysis
Gray: Forecast

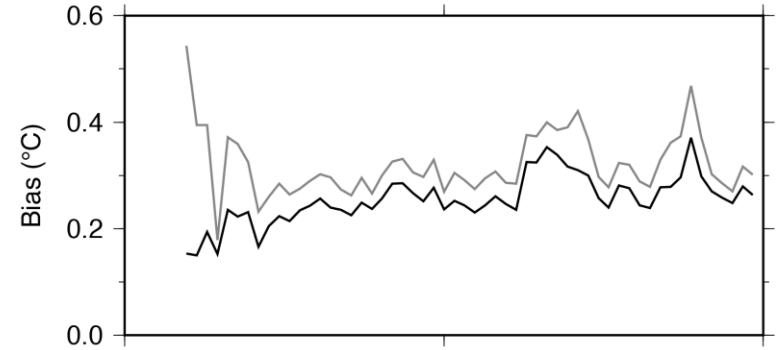
Bias

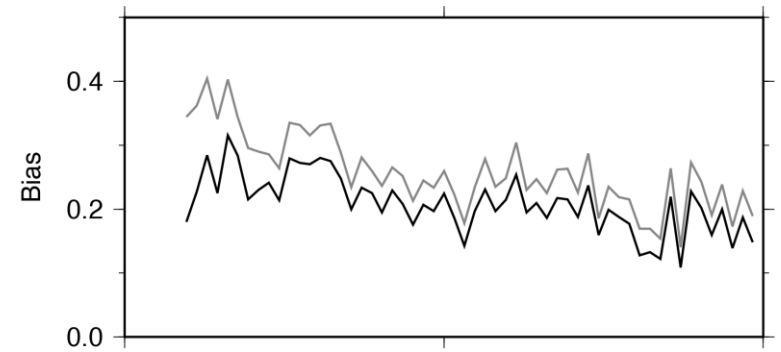
RMSE

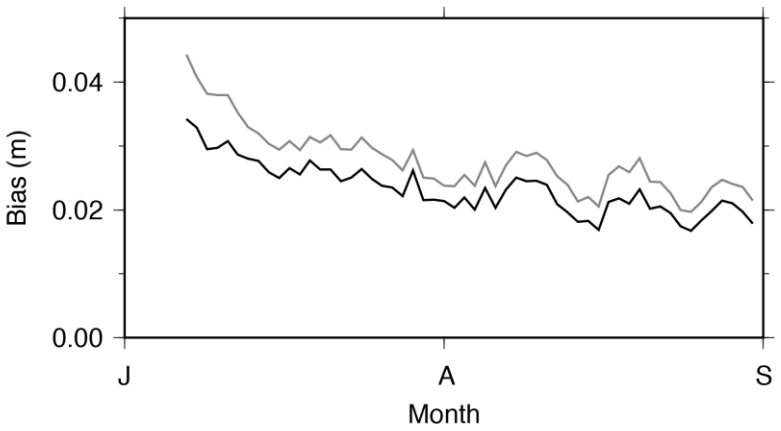
SST

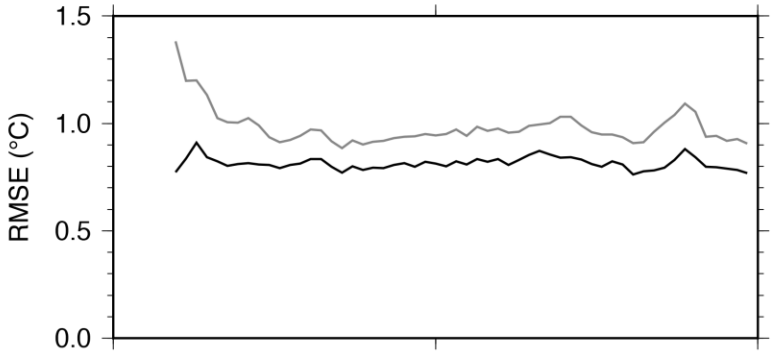
SSS

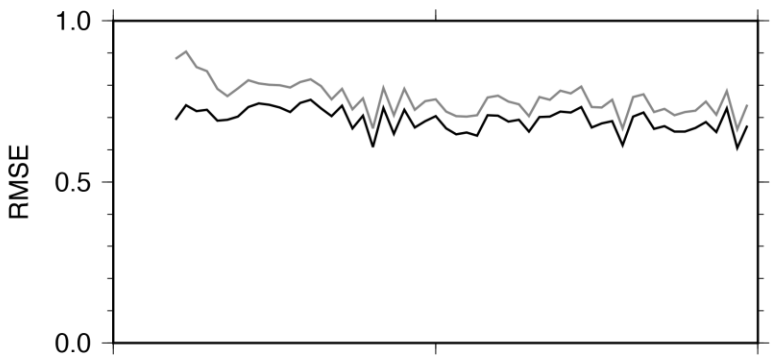
SSH

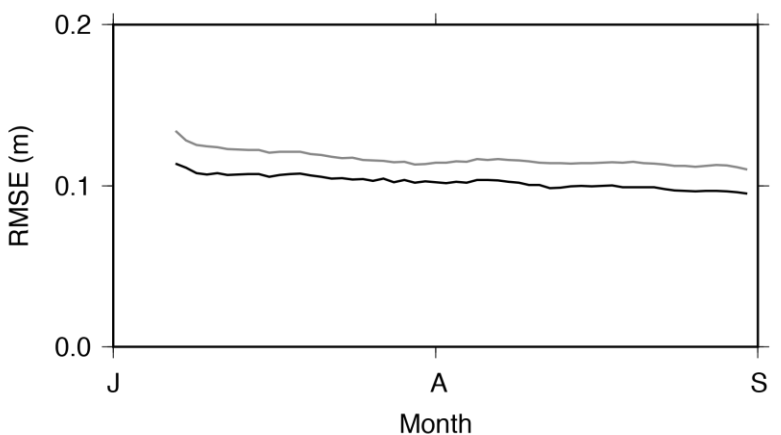






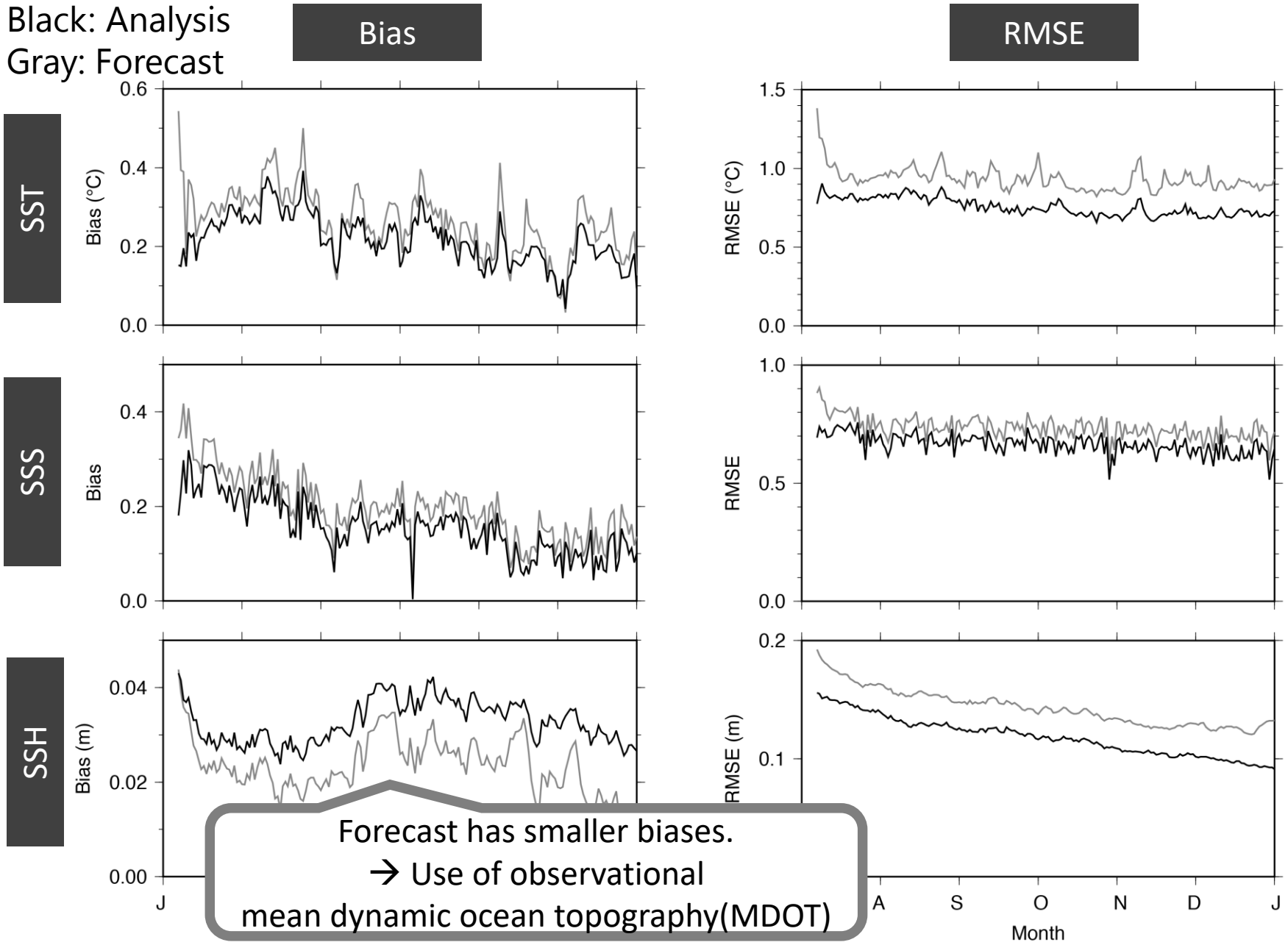






2. Western Pacific system – 1. Observational MDOT –

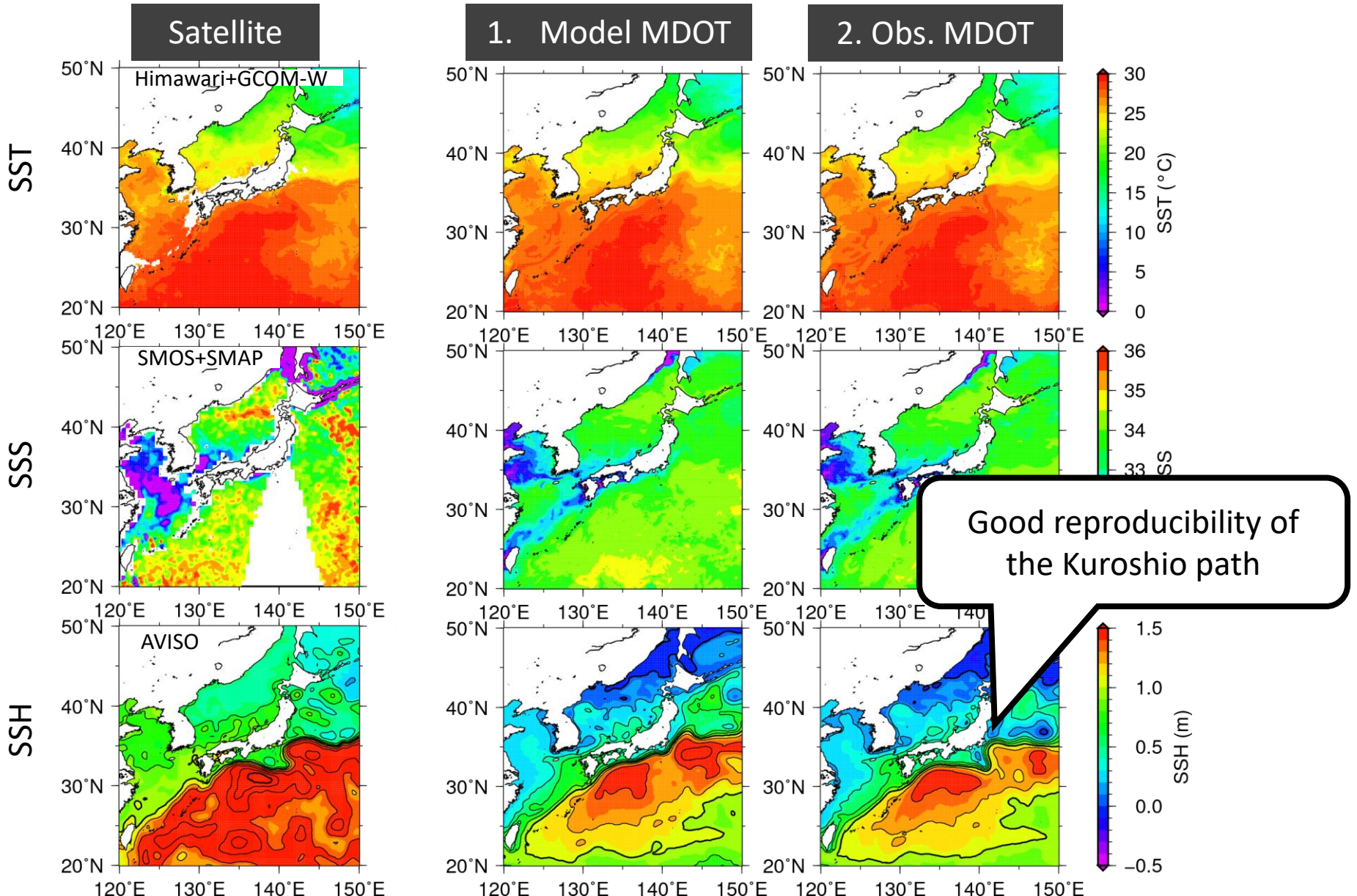
Black: Analysis
Gray: Forecast



Forecast has smaller biases.
→ Use of observational mean dynamic ocean topography(MDOT)

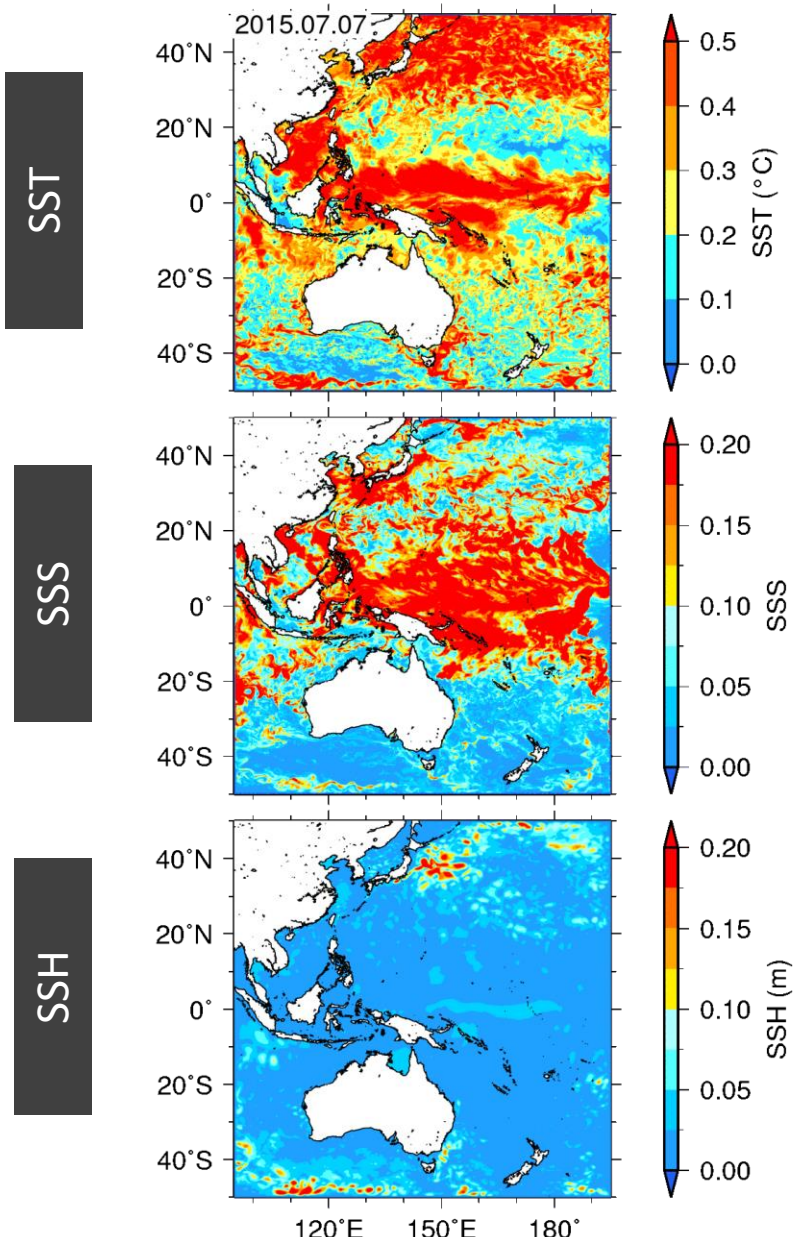
1. Model vs. Observational MDOT

2015.08.31



2. Western Pacific system – Spread –

◆ Spread



◆SST & SSH
Western boundary region

◆SSS
Western boundary
& interior regions