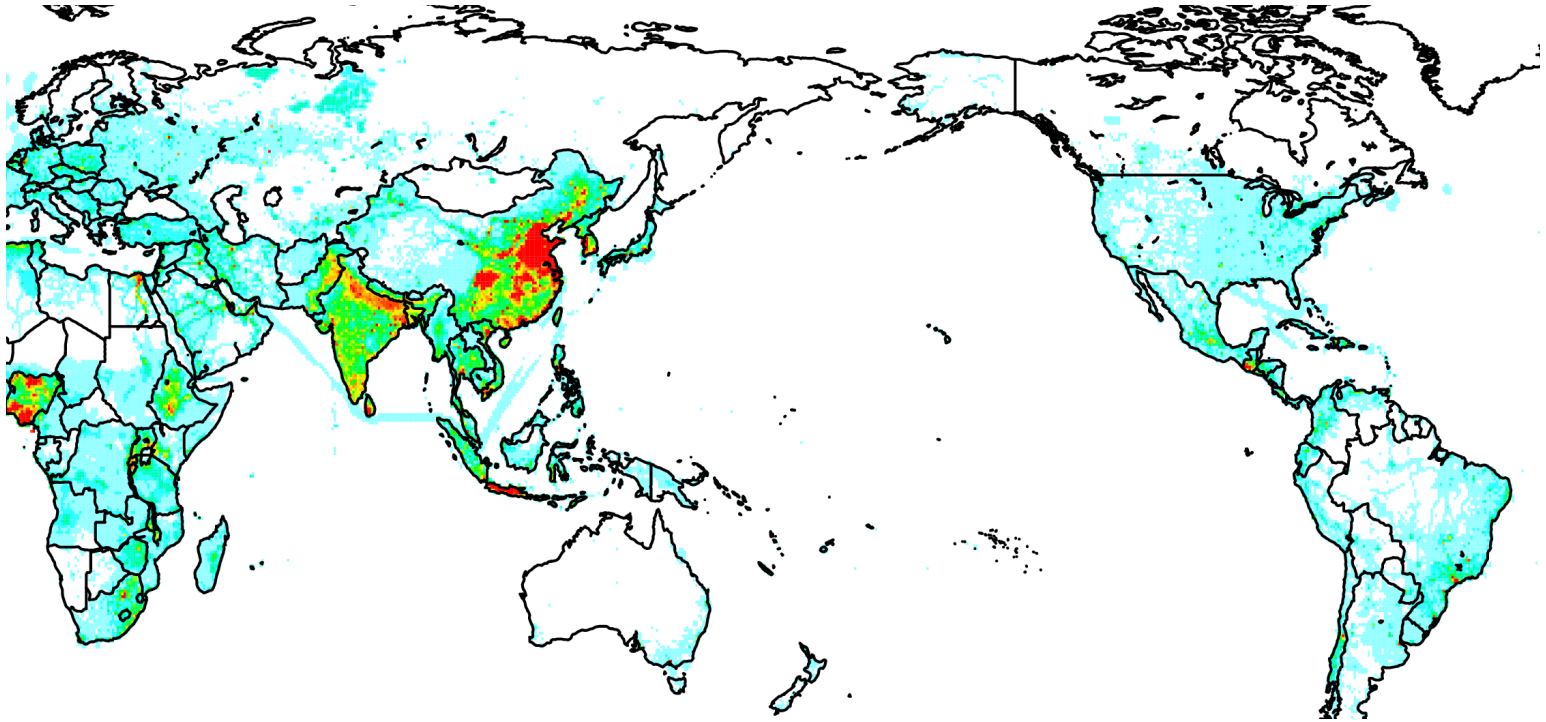
Observation-based evaluation of East Asian black carbon emission inventories and its implications for the CMIP6 climate model simulations



Kohei Ikeda[1], Hiroshi Tanimoto[1], Yugo Kanaya[2], Fumikazu Taketani[2] and Atsushi Matsuki[3]

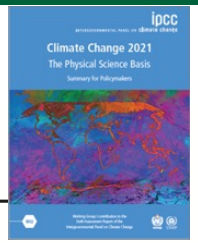
[1] National Institute for Environmental Studies (NIES), Japan

[2] Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Japan

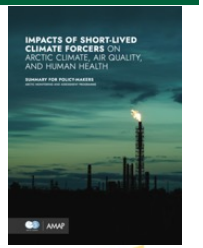
[3] Kanazawa University, Japan

Climate impacts of black carbon on global and Arctic climate

IPCC AR6 (2021)



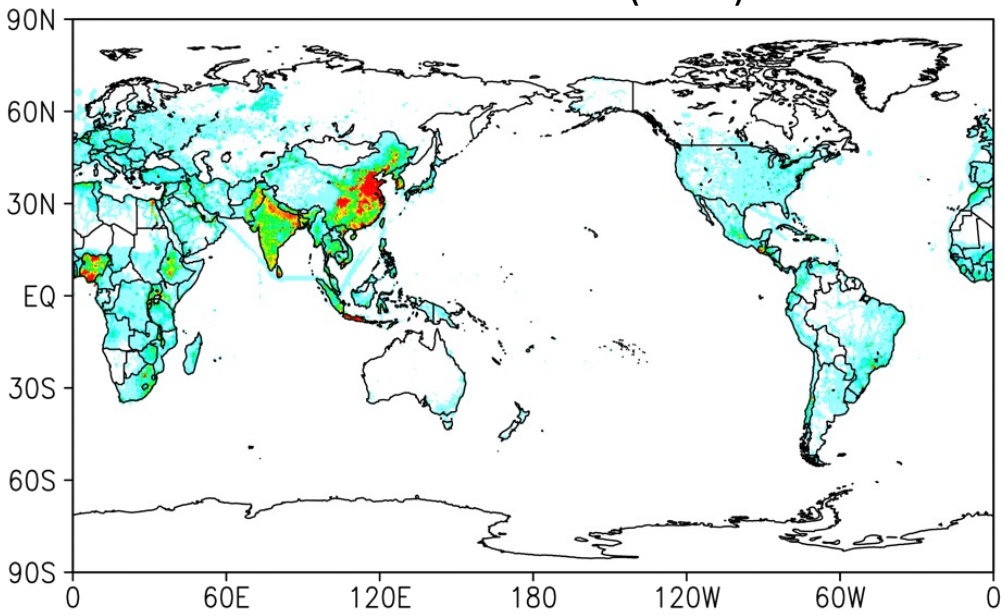
AMAP SLCF Assessment (2021)



- Black carbon -- emitted from fossil/biofuel combustions and wildfires
- BC absorbs solar radiation and contributes to global warming (**Short Lived Climate Forcers; SLCF**)
- Climate impacts are rigorously assessed in **IPCC AR6** and **AMAP Assessment**

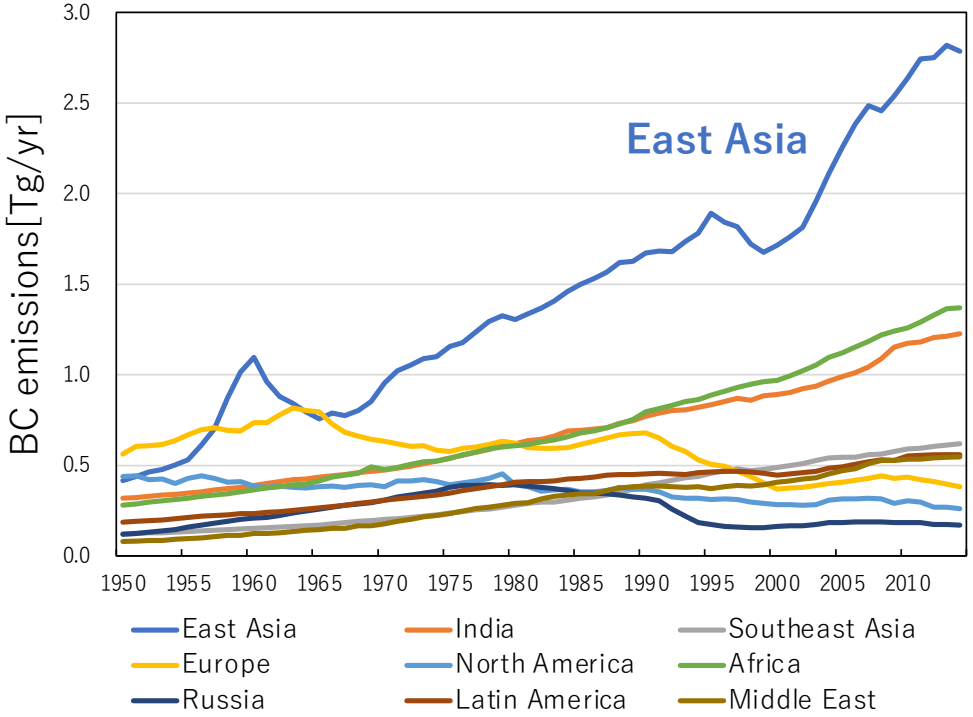
BC emissions from Asia

CEDS BC emissions (2014)



Hoesly et al., 2018

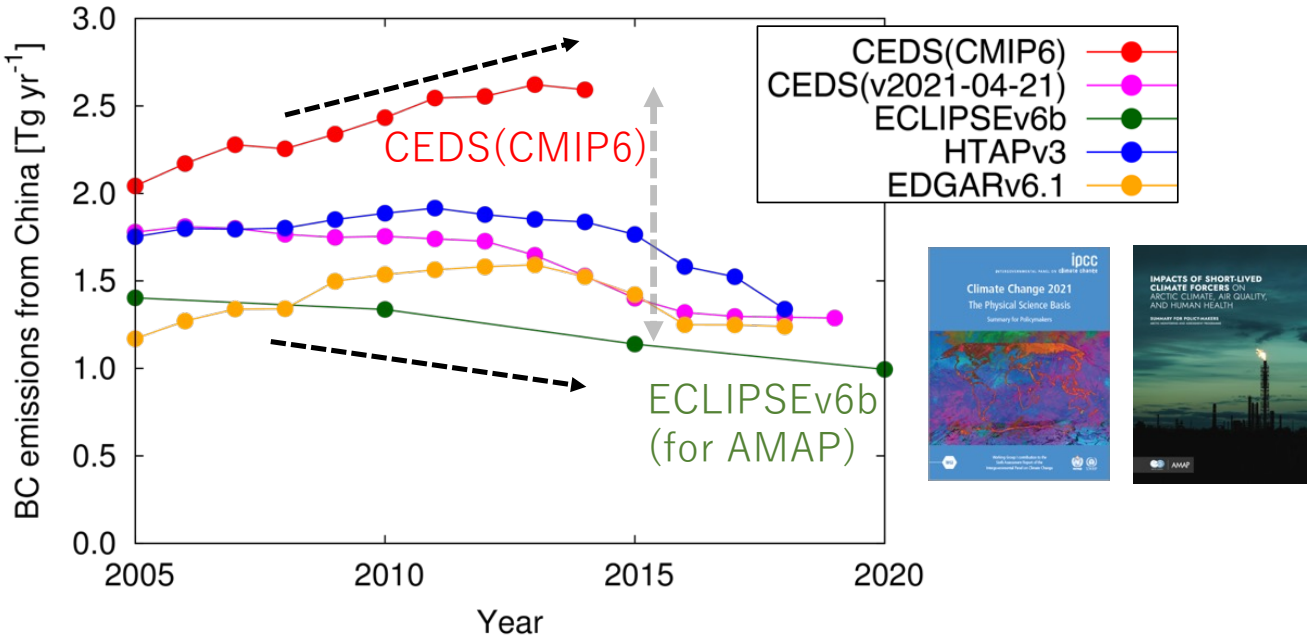
Anthropogenic BC emissions (CEDS for CMIP6)



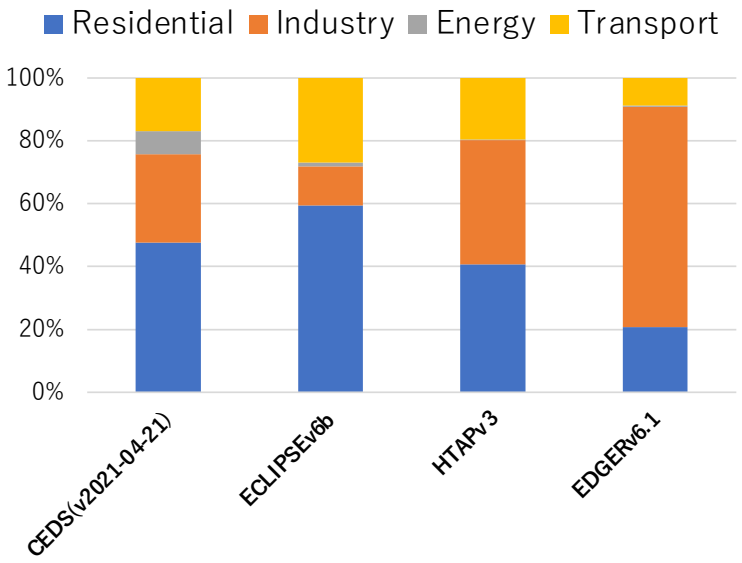
- East Asia contributes to ~30% of global anthropogenic emissions
- Regional emissions in Asia rapidly changed in recent decades
- Accurate estimates of BC emissions from East Asia are essential to assess its impacts on climate

Uncertainties in BC emissions in bottom-up inventories

BC emissions from China



Sector breakdown in China (2015)



- Large uncertainties in bottom-up inventories
  - Amount: 1–2 Tg/yr
  - Trend: Increase or decrease?

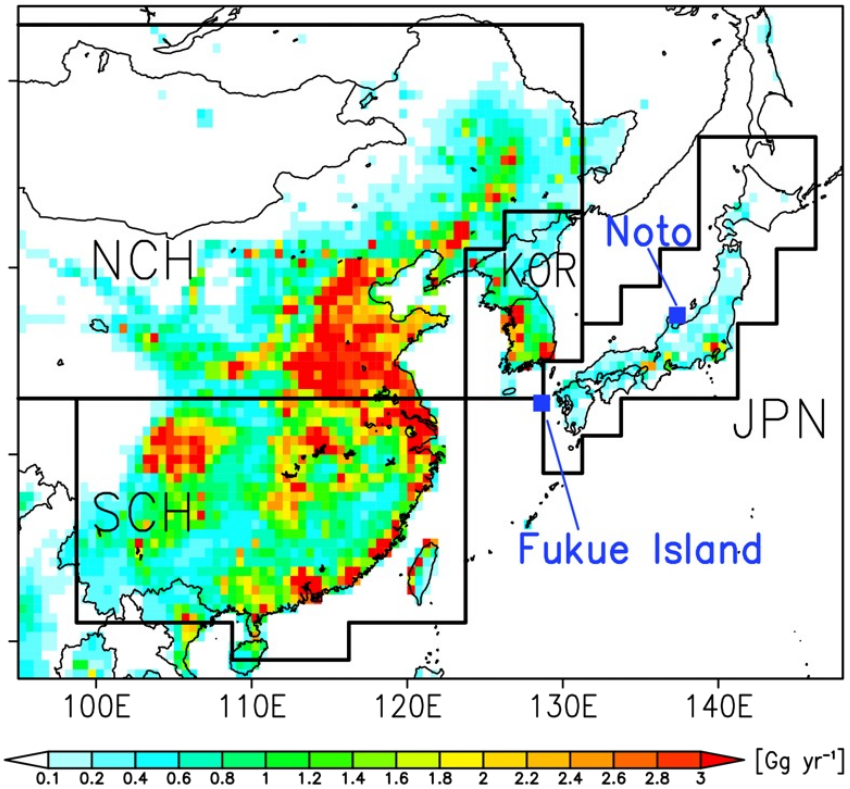
- Major sectors: Residential or industry

Evaluations using atmospheric observations and models!

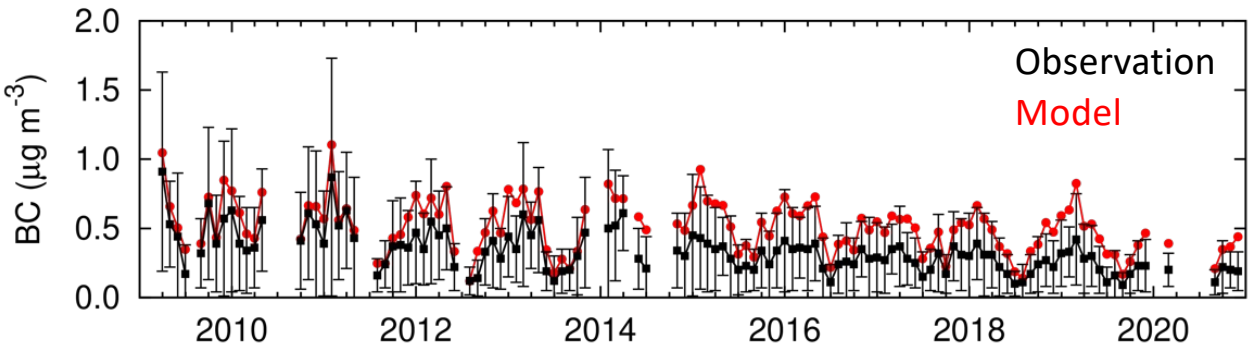
Estimation of BC emissions from China

BC observations (MAAP)

- Fukue Island (Kanaya et al., 2016, 2020, 2021)
- Noto (Taketani et al., 2016; Choi et al., 2020)

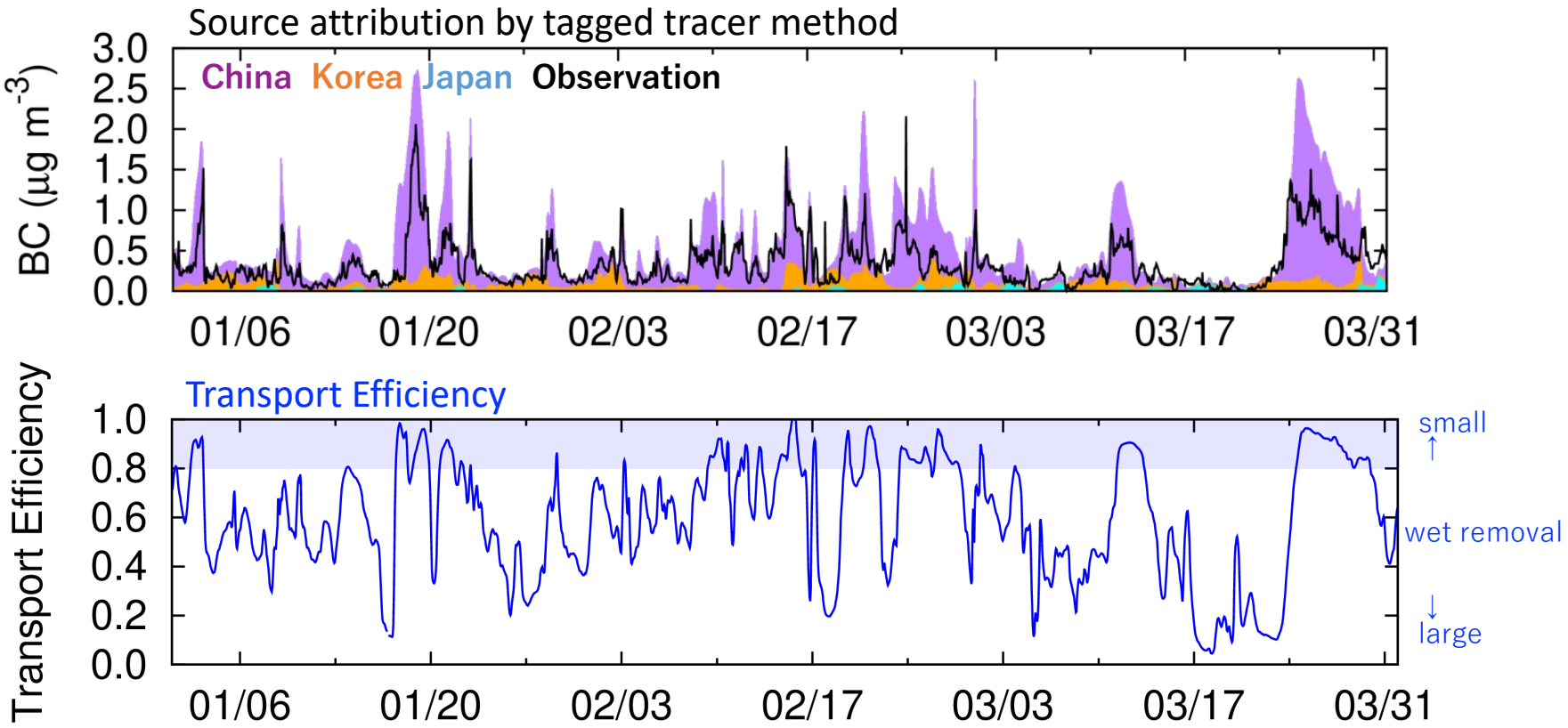


Fukue Island



- **Decreasing trend** over the last decade
- Long-term records are used to analyze **emission trends** from China

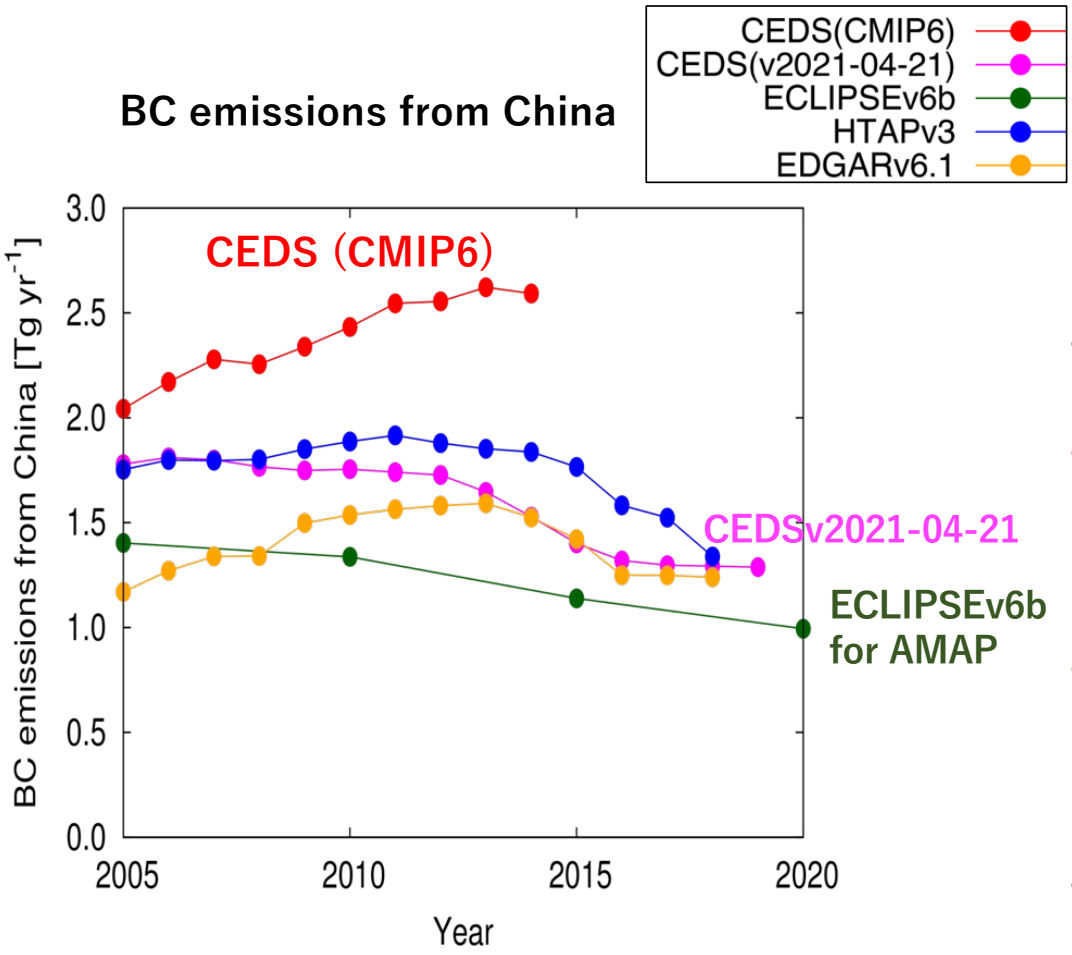
Estimation of BC emissions from China

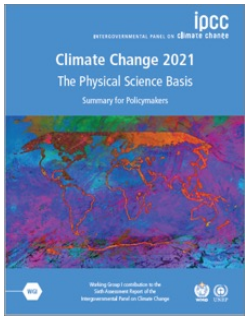


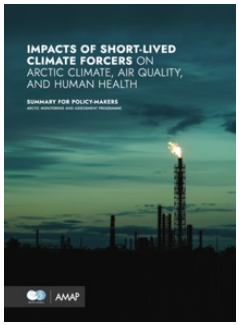
■ Estimation of BC emissions from Model/Obs. ratio (GEOS-Chem)

- Extract data with dominant contribution from China
- Exclude data with influence of wet deposition

Reduction in BC emissions from China

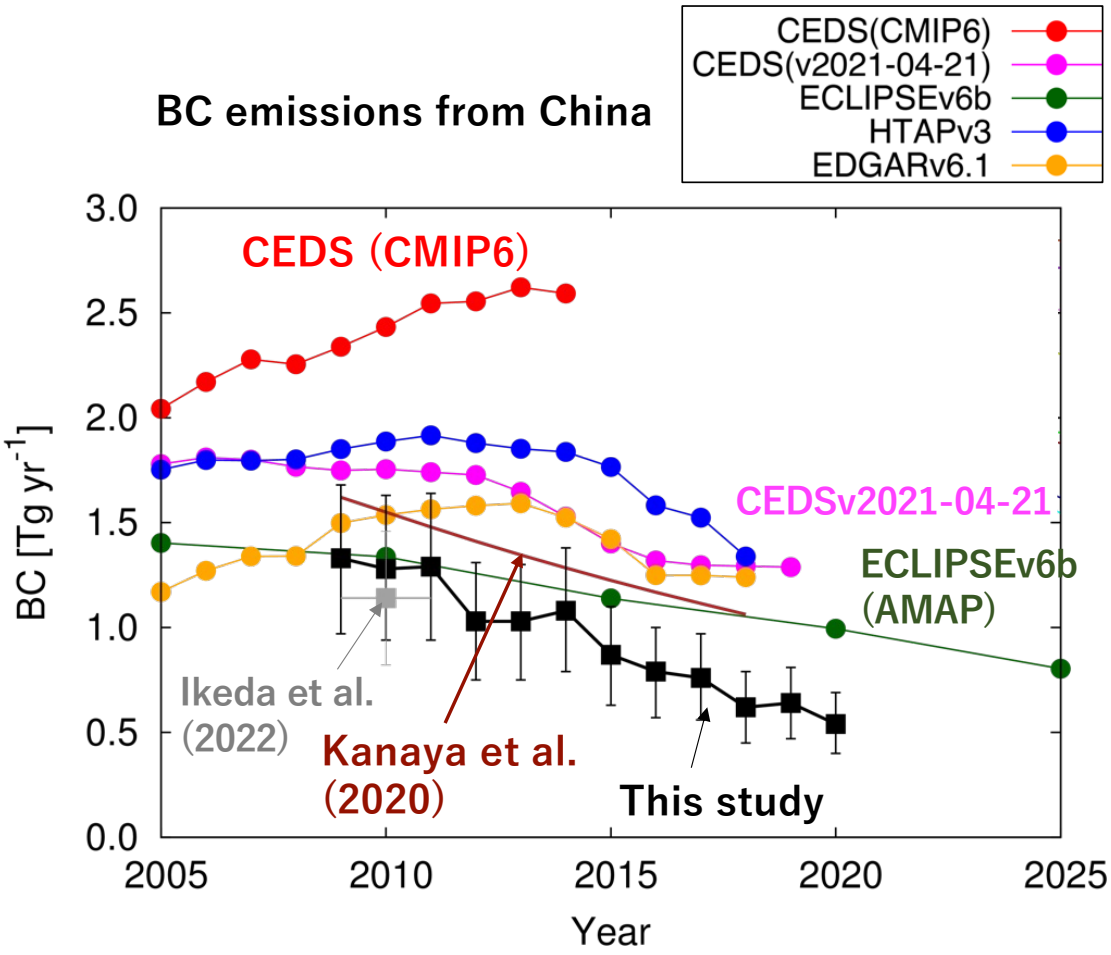


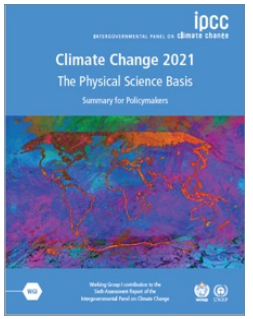


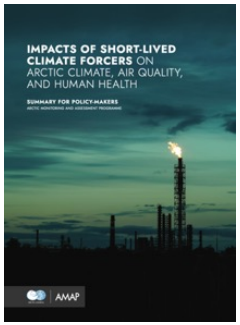


- **Rapid reduction** in BC emissions from China
- **CEDS for CMIP6** was found to overestimate and was revised to **v2021-04-21** with lower values and decreasing trend
- **ECLIPSEv6b** for AMAP Assessment is close to our model/observation-based estimation among recent bottom-up inventories
- GEOS-Chem based estimation is consistent with **Kanaya et al. (2020)** (WRF/CMAQ based)

Reduction in BC emissions from China







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Evaluation of BC simulations in CMIP6

■ BC Observations (MAAP)

- Fukue (2009- : Kanaya et al., 2016, 2020, 2021)
- Noto (2011- : Taketani et al., 2016; Choi et al., 2020)

■ **CMIP6 simulations (Ocean-Atmosphere coupled) : 12 models**

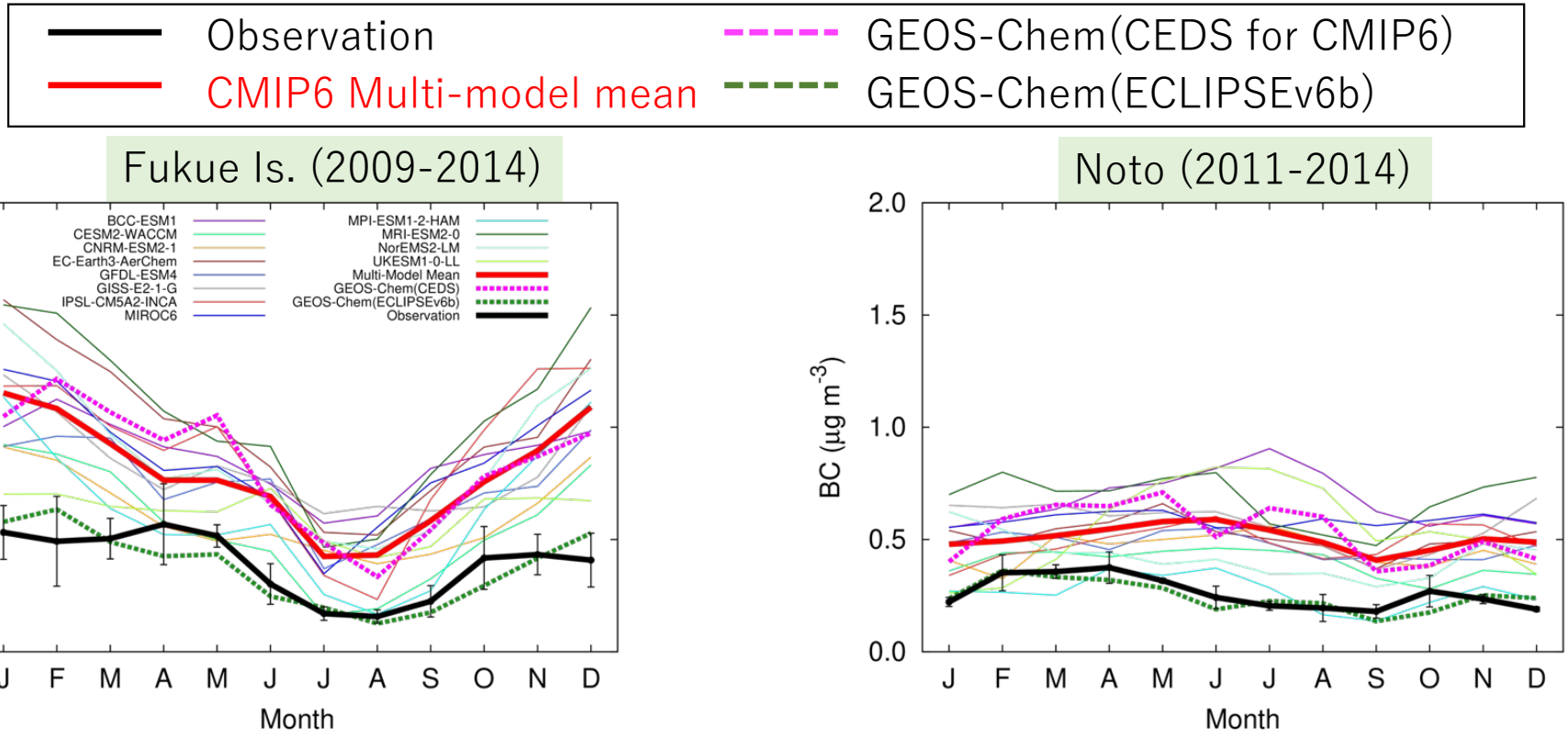
- **Historical simulations : CEDS (anthropogenic emissions)**
- **Scenario simulations : SSP126, SSP370**

■ GEOS-Chem v13.1.2 (Chemistry-transport model)

- Reanalysis meteorological data : MERRA-2
- CEDS(CMIP6), SSP126, SSP370, ECLISPEv6b (AMAP)

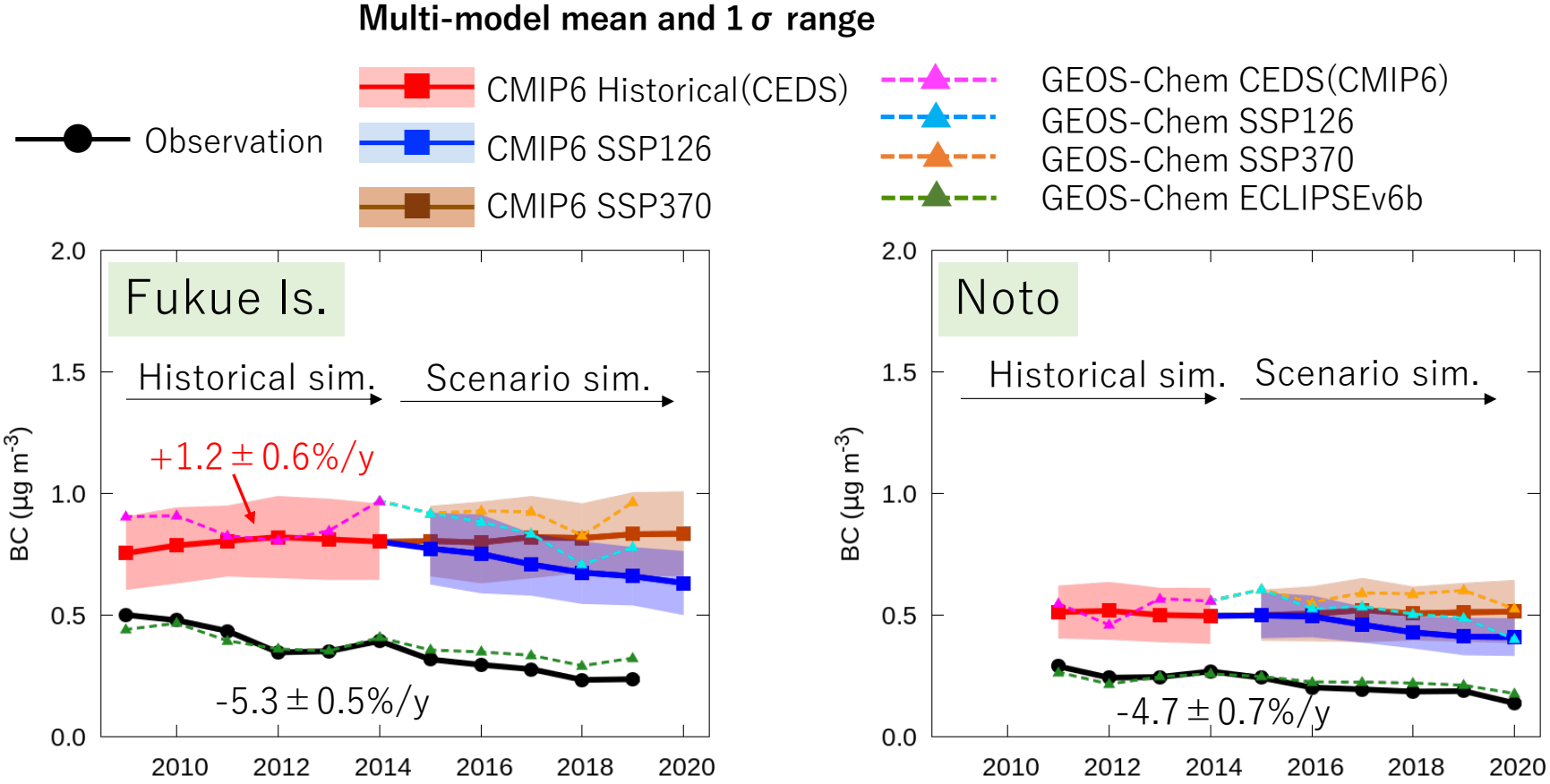
Analyze **levels and trends** with observations for 2009–2020

Historical Simulations vs Observations



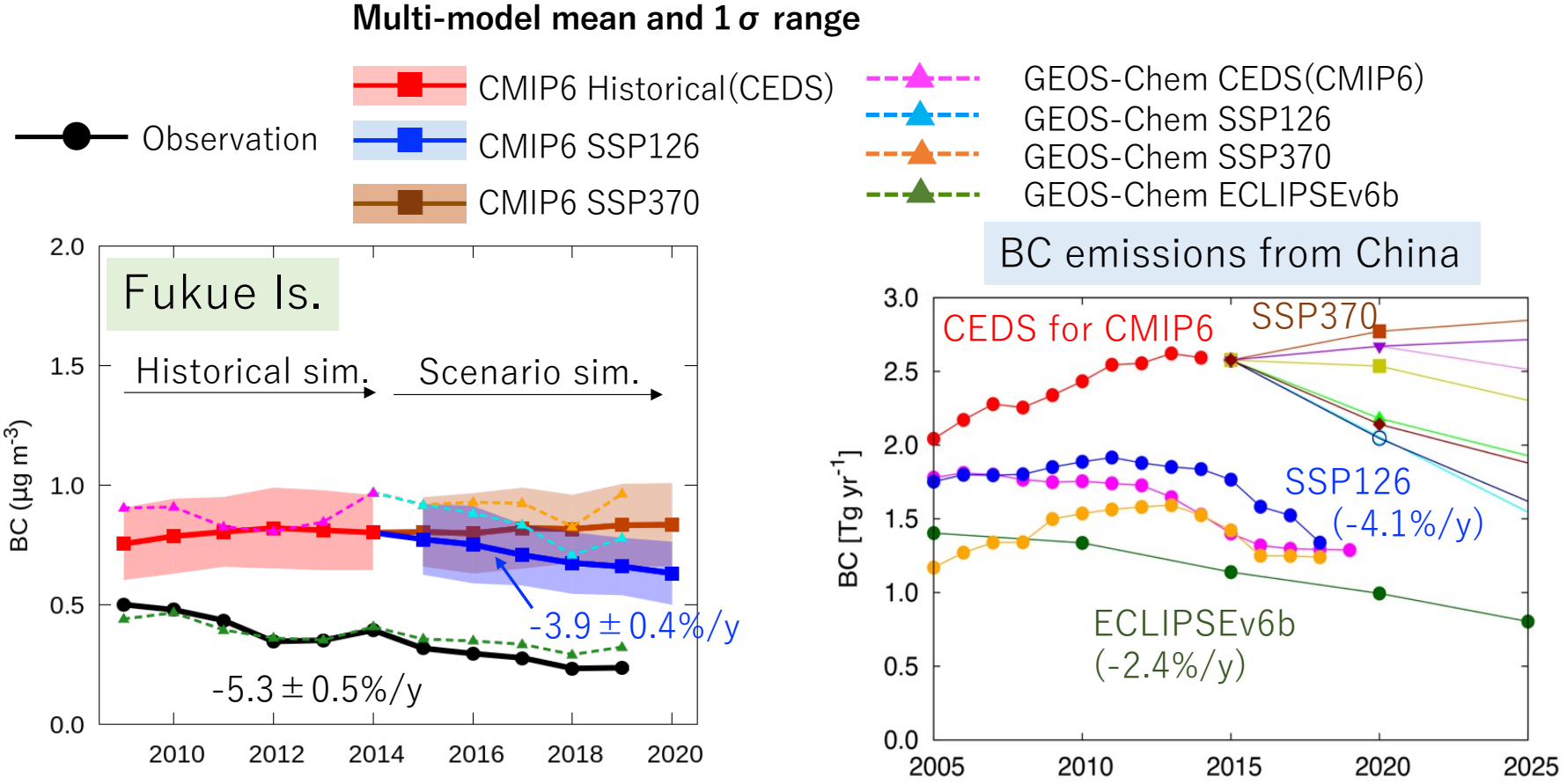
- CMIP6 multi-model mean overestimates observations
- GEOS-Chem with ECLIPSEv6b reproduces observations
- China's BC emissions (2014)：CEDS=2.6 Tg/yr, ECLIPSEv6b=1.2 Tg/yr

Trends of BC in East Asia



- CMIP6 historical and scenario simulations show higher concentrations than observations
- Decreasing trend in observations
- CMIP6 historical simulations show no decrease

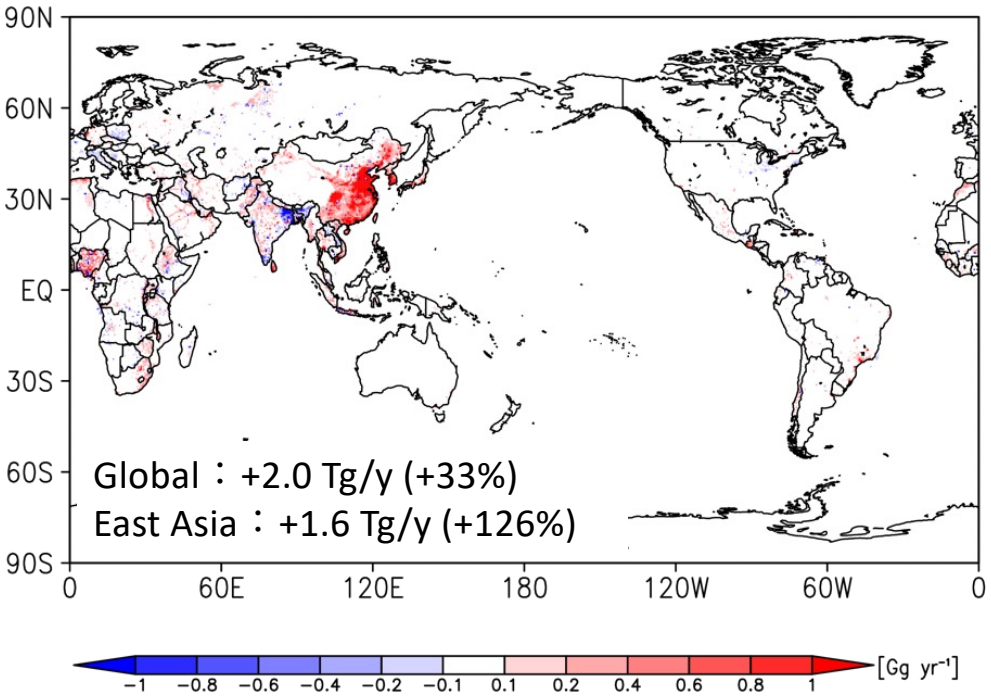
Trends of BC in East Asia



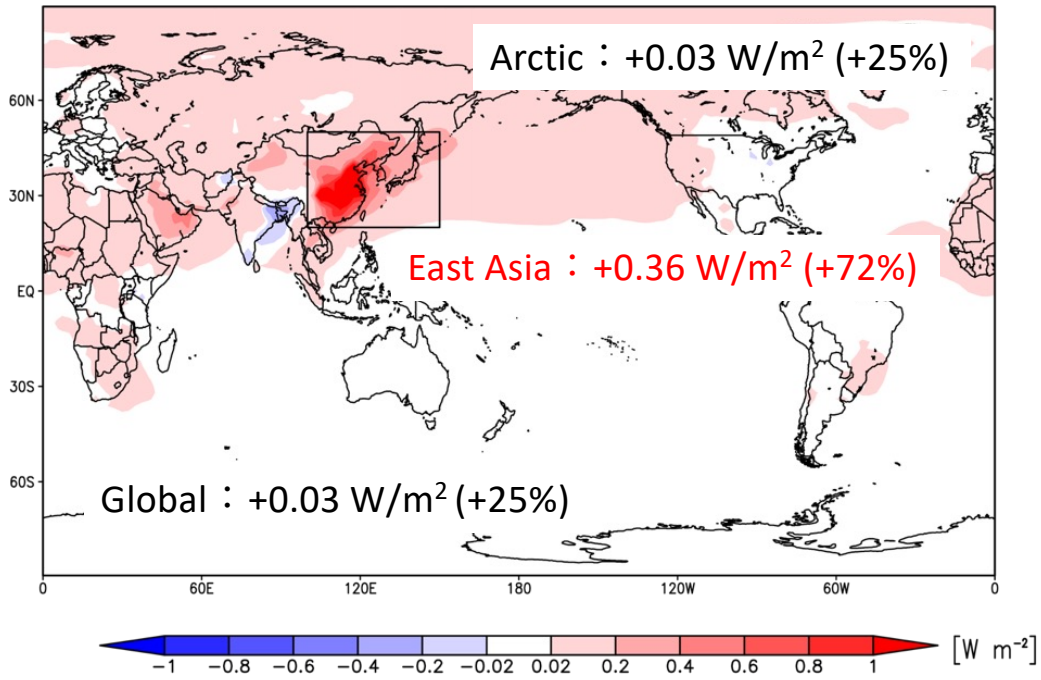
- SSP126 simulations show decreasing trend close to observations (but higher concentration level)
- GEOS-Chem with ECLIPSEv6b shows decreasing trend at concentration level close to observations

Implications: BC Direct Radiative Effects, 2014

ΔEmissions: CEDS−ECLIPSEv6b



ΔDRF@TOA：CEDS-ECLIPSEv6b



Ikeda et al., submitted, 2023

Summary

- We analyzed **BC emission trends** in East Asia using **atmospheric observations and model**
- **Rapid reduction in China's BC emissions** was identified
- We evaluated **BC simulations in CMIP6** with long-term observations in East Asia during 2009–2020
- **CMIP6 model simulations** are not able to capture **observed concentration levels** and **recent decreasing trends of BC** in East Asia
- Evaluation of inventories using **atmospheric observations and models** is important not only for **historical simulations** but also for **future projections**