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Numerical evaluation of the impacts of emission and meteorological characteristics on air pollution in the Seto Inland Sea region, Japan

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Introduction

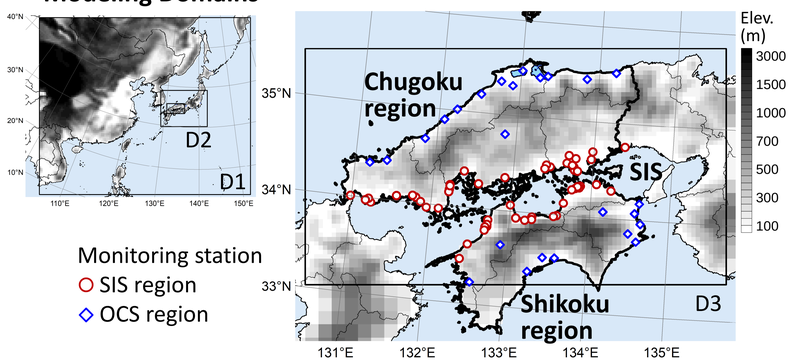
- Seto Inland Sea (SIS) region in Chugoku-Shikoku (CS) region of Japan
  - Higher air pollution level compared to the other regions of Japan
  - Includes SIS with heavy ship traffic volume and its industrialized coastal areas with a number of large point sources (LPSs)
  - Surrounded by mountains, which suppresses atmospheric ventilation
- This study evaluates the impacts of local emission and meteorological characteristics on air pollution in SIS region as well as the surrounding region (other CS (OCS) region).

Method

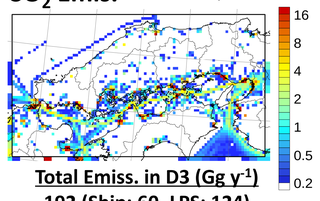
Model Setup

	Baseline Configurations
Model	WRF v3.8, CMAQ v5.2.1
Period	April 2013–March 2014 (JFY 2013)
Domain	East Asia, 45-km grid, 127x107 (D1) Western Japan, 15-km grid, 86x66 (D2) In and around SIS region, 5-km grid, 96x54 (D3) 30 layers (up to 100 hPa, 1st layer height ≈ 50 m)
Topography/Landuse	30-sec USGS/30-sec USGS & 100-m MLIT-GIAJ
Analysis Data	NCEP FNL, JMA MSM-GPV, NCEP/NOAA RTG_SST_HR
WRF Physics	Kain-Fritsch (D1, D2), WSM6, Dudhia/RRTM, YSU PBL, Noah LSM, FDDA: $G_{t,\,q,\,uv}$ = 1.5x10^{-4} s^{-1} (D1, D2), 0.5x10^{-4} s^{-1} (D3)
Boundary Conc.	MOZART-4/GEOS5
Emission Data	Anthropogenic outside Japan: HTAP v2.2 (2010), Japan: EAGrid2010 & JEI-DB (Vehicle) & OPRF (Ship) (2010), Biogenic: MEGANv2.04, Biomass burning: FINN v1.5, Volcano: Aerocom
CMAQ Chemistry	SAPRC07 & AERO6nv with Aqueous chemistry

Modeling Domains

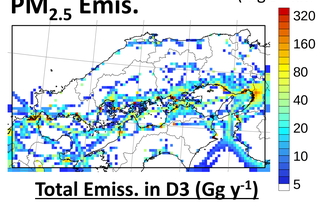


SO_2 Emis. (mmol s^{-1} km^{-2})



Total Emiss. in D3 (Gg y^{-1})
192 (Ship: 60, LPS: 124)

$PM_{2.5}$ Emis. (mg s^{-1} km^{-2})



Total Emiss. in D3 (Gg y^{-1})
38 (Ship: 12, LPS: 11)

Simulation Cases

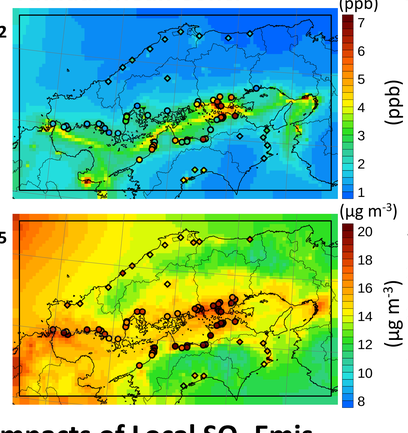
- Baseline simulation case
- Zero-out emission cases for SO_x from ships or from land area (≈ LPSs) in D3
- Passive tracer (non-reactive and no deposition) case with constant and homogeneous emission in 1st layer over D3 area

Results

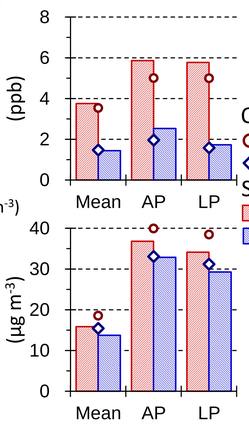
AP: Air pollution days with median value of observed daily $PM_{2.5}$ conc. > 35 μg m^{-3} at SIS stations (23 days)
LP: Local air pollution days with contrib. of SO_x emis. in D3 to SO_2 conc. at SIS stations > 70% in AP (7 days)

Model Performance

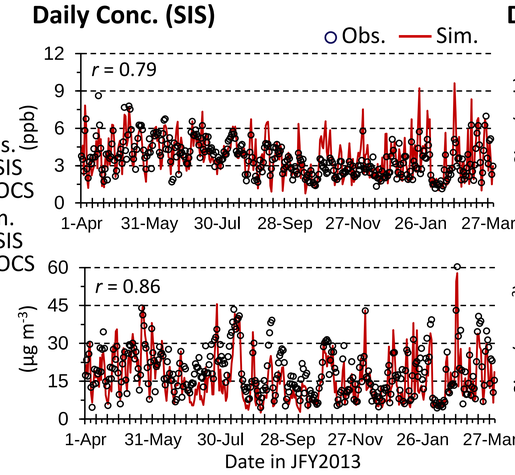
Annual Mean Conc.



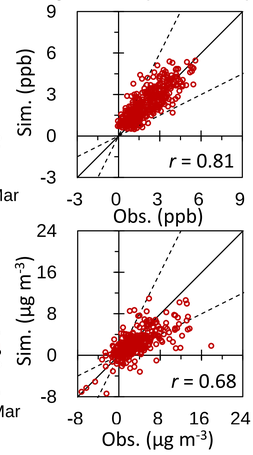
Mean Conc.



Daily Conc. (SIS)

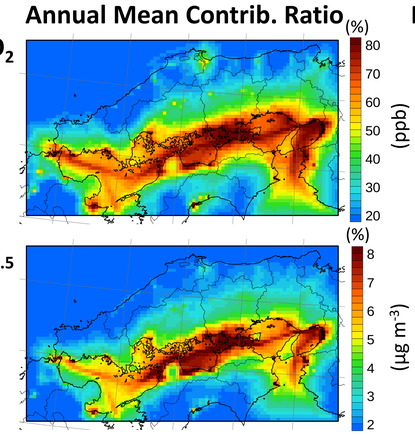


Daily Conc. (SIS–OCS)

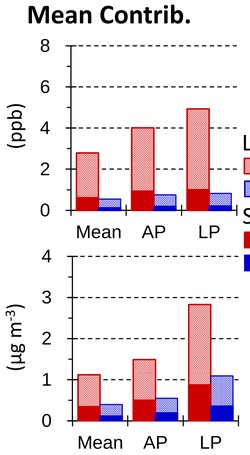


Impacts of Local SO_x Emis.

Annual Mean Contrib. Ratio

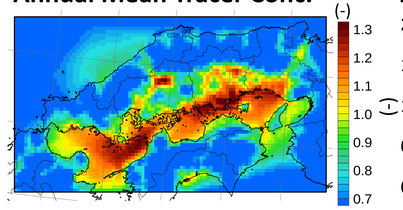


Mean Contrib.

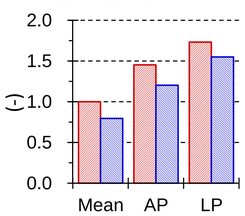


Impacts of Local Meteorol.

Annual Mean Tracer Conc.

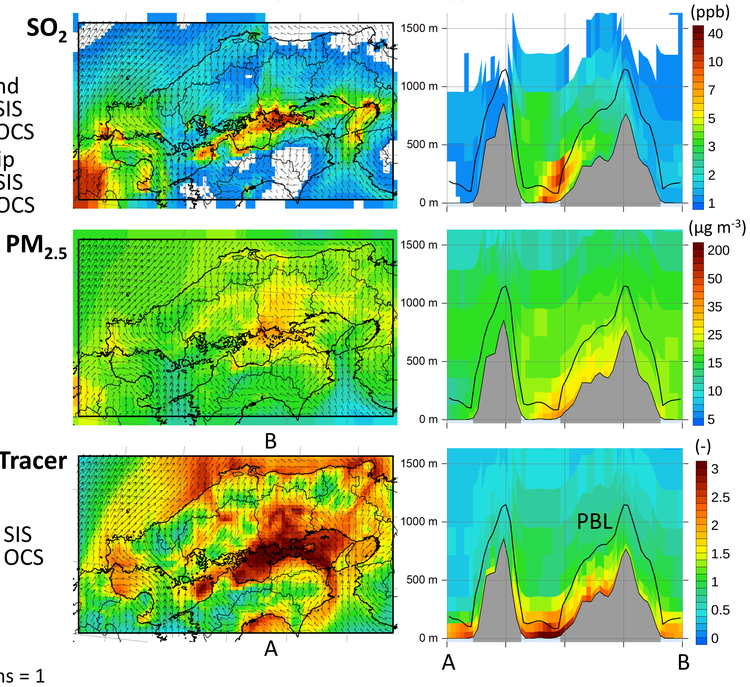


Mean Conc.



Annual mean conc. at SIS stations = 1

Conc. Fields on Sep. 13, 2013 (Typical LP)



Summary

- WRF-CMAQ successfully simulated SO_2 and $PM_{2.5}$ pollution levels in both SIS and OCS (SIS > OCS).
- Contributions of local SO_x emissions to SO_2 and $PM_{2.5}$ concentration were about 5 and 3 times higher in SIS than in OCS, respectively.
- Passive tracer concentration was about 1.3 times higher in SIS than in OCS, indicating lower ventilation efficiency in SIS.
- Local SO_x contribution and tracer concentration become larger during LP.
- Local emission and meteorological characteristics mainly and partly contribute to higher air pollution level in SIS, respectively.

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