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# Evaluation of HAM-M7 within the ECMWF IFS and OpenIFS frameworks

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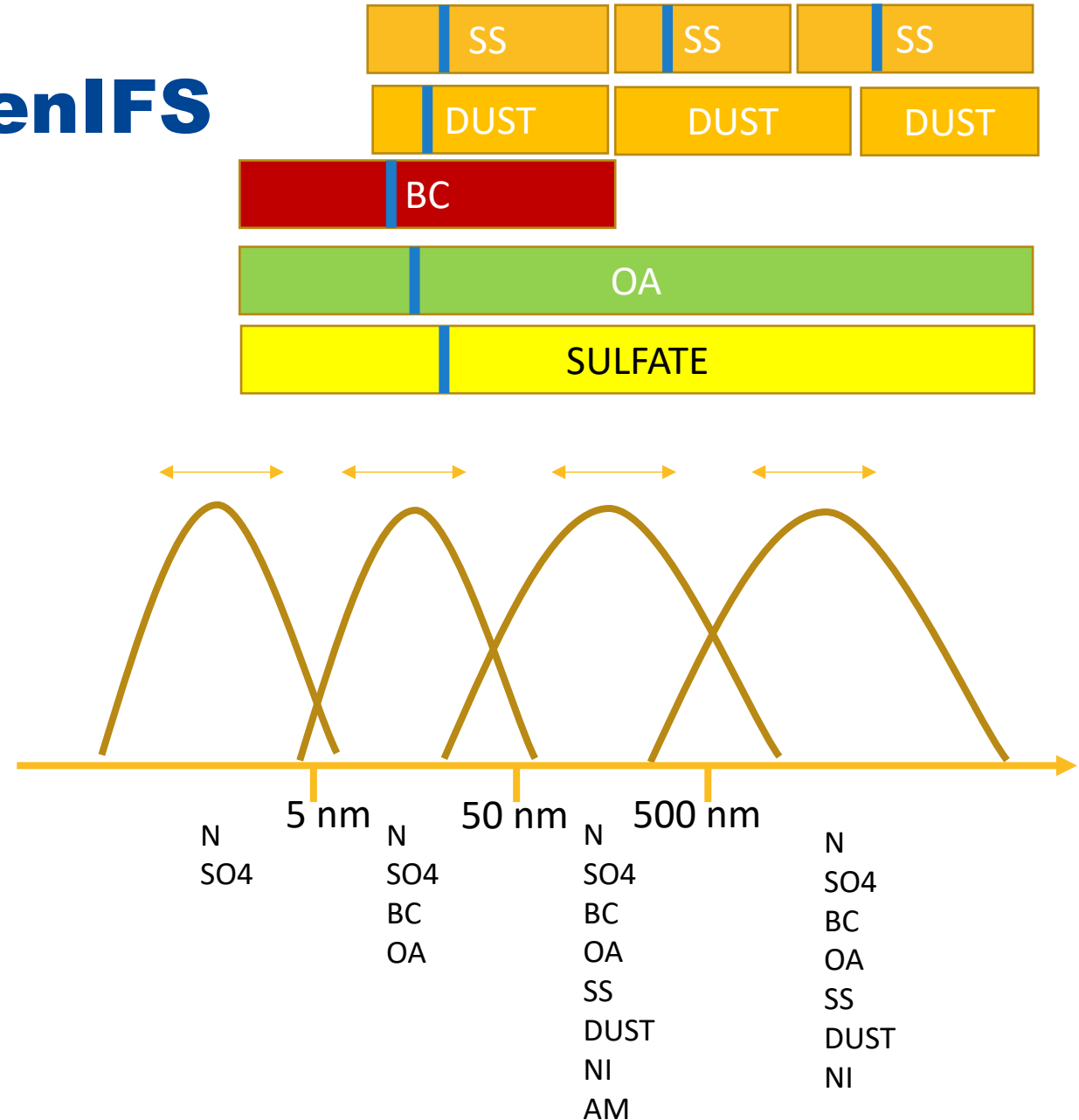
**ECMWF:** Adrian Hill, Marcus Köhler,

**HYGEOS:** Samuel Rémy

**RC.io:** Swen Metzger

# HAMM7 in IFS and OpenIFS

- OpenIFS includes AER
  - Remy et al (2019)
  - Fixed size distributions
  - Only mass simulated
  - No interaction
- HAM-M7
  - 7 Lognormal modes
  - Number and mass simulated
  - ~30 tracers

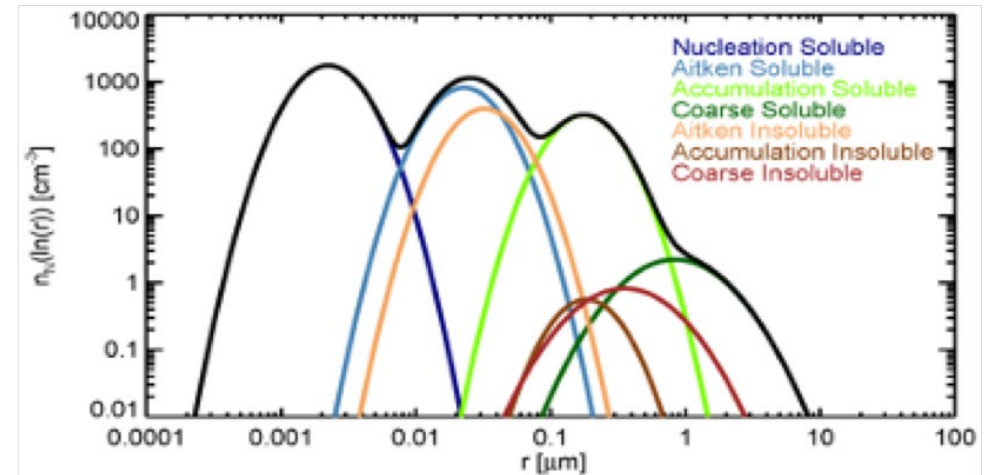




# HAM-M7

- HAM-M7
  - M7: 7 log-normal modes for aerosol microphysics
  - HAM: cloud activation, wet deposition, dry deposition, sedimentation, radiative properties
- aerosol, cloud droplet, and ice crystal size dependent in-cloud & below-cloud wet deposition rates (Croft et al.)
- Hydration: Kappa Köhler (Petters & Kreidenweis)
- Optical properties: aerosol-radiation interactions for SW and LW
- Cloud activation:
  - Abdul-Razzak & Ghan (2000)
  - Morales & Nenes (2014)

| MODES                                                               | Hydrophilic                             | Hydrophobic |
|---------------------------------------------------------------------|-----------------------------------------|-------------|
| <b>NUCLEATION</b><br>( $r < 0.005 \mu\text{m}$ )                    | SO <sub>4</sub>                         |             |
| <b>AITKEN</b><br>( $0.005 \mu\text{m} < r < 0.05 \mu\text{m}$ )     | SO <sub>4</sub> , BC, OC                | BC, OC      |
| <b>ACCUMULATION</b><br>( $0.05 \mu\text{m} < r < 0.5 \mu\text{m}$ ) | SO <sub>4</sub> , BC, OC, SS, DU NI, AM | DU          |
| <b>COARSE</b><br>( $0.5 \mu\text{m} < r$ )                          | SO <sub>4</sub> , BC, OC, SS, DU, NI    | DU          |





# Model and observation details

|                            | OpenIFS-HAMM7        | IFS-HAMM7            | IFS-AER               | ECHAM6-HAMM7 |
|----------------------------|----------------------|----------------------|-----------------------|--------------|
| Anthropogenic emissions    | CMIP7/CEDS           | CAMS-GLOB-ANT        | CAMS-GLOB-ANT         | CMIP6/CEDS   |
| Sea salt emission          | Gong et al. + Salter | Gong et al. + Salter |                       | Long et al.  |
| Dust emissions             | IFS                  | IFS                  | IFS                   | Tegen et al. |
| Year                       | 2010                 | 2019                 | 2019                  | 2010         |
| EQsam4Clim                 | No                   | Yes                  | yes                   | No           |
| Clouda activation          | Yes                  | No                   | No                    | Yes          |
| Aerosol-radiation coupling | Yes                  | No                   | No                    | Yes          |
| Resolution                 | T255                 | T255                 | T255(as pp'd by MARS) | T63          |

## Observations:

- PM2.5:
  - EBAS
  - AIRSHOW
  - CHINA AQ

## Observations:

- Number size distributions:
  - EBAS



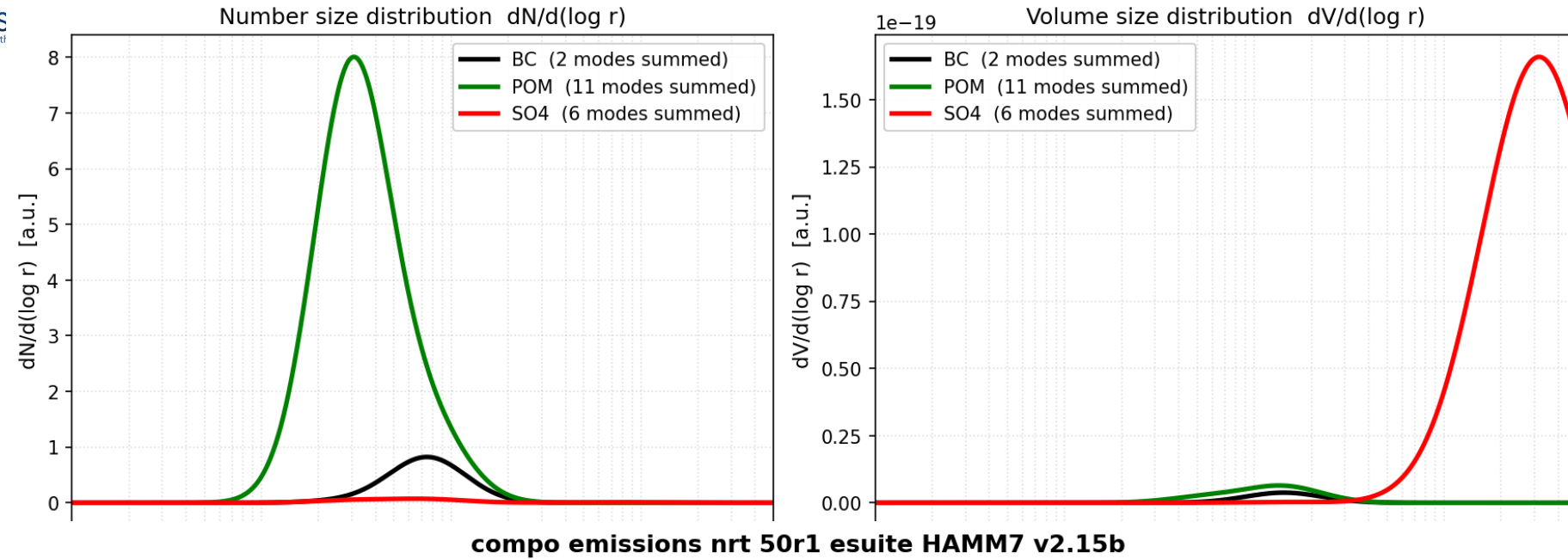
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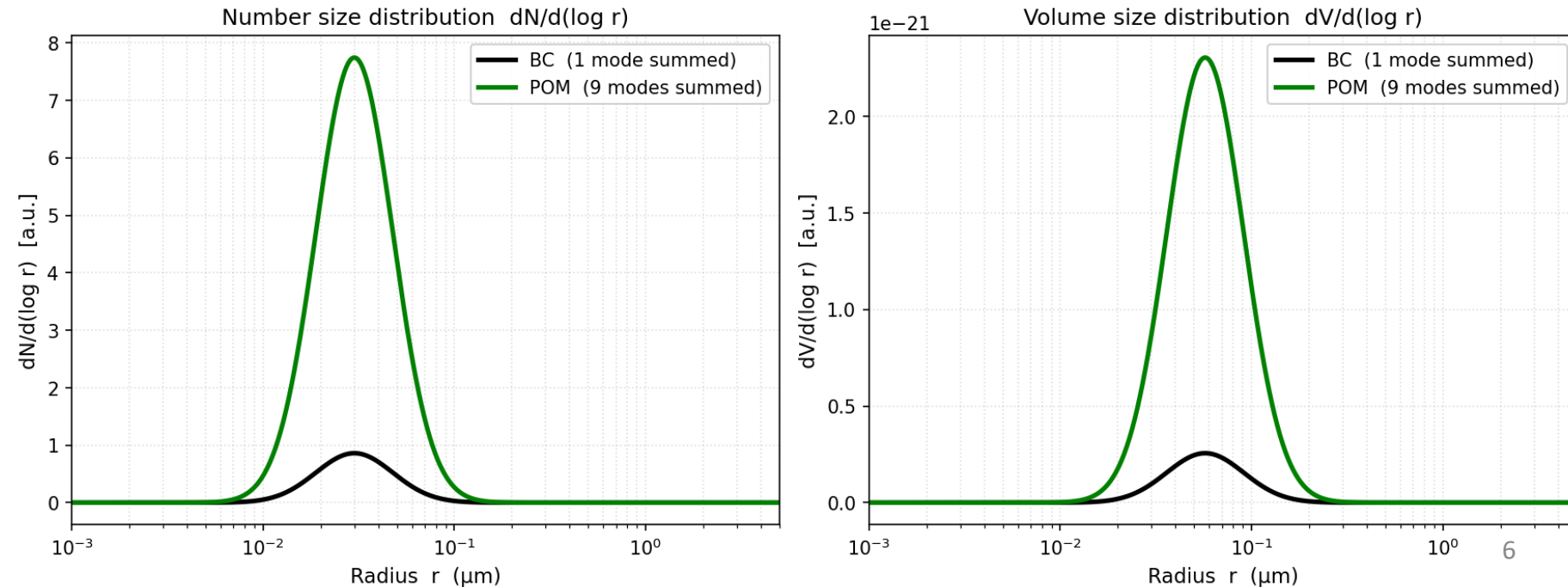
# Emission distributions

OpenIFS

cmip7 hamm7 tm5 ecfs



IFS







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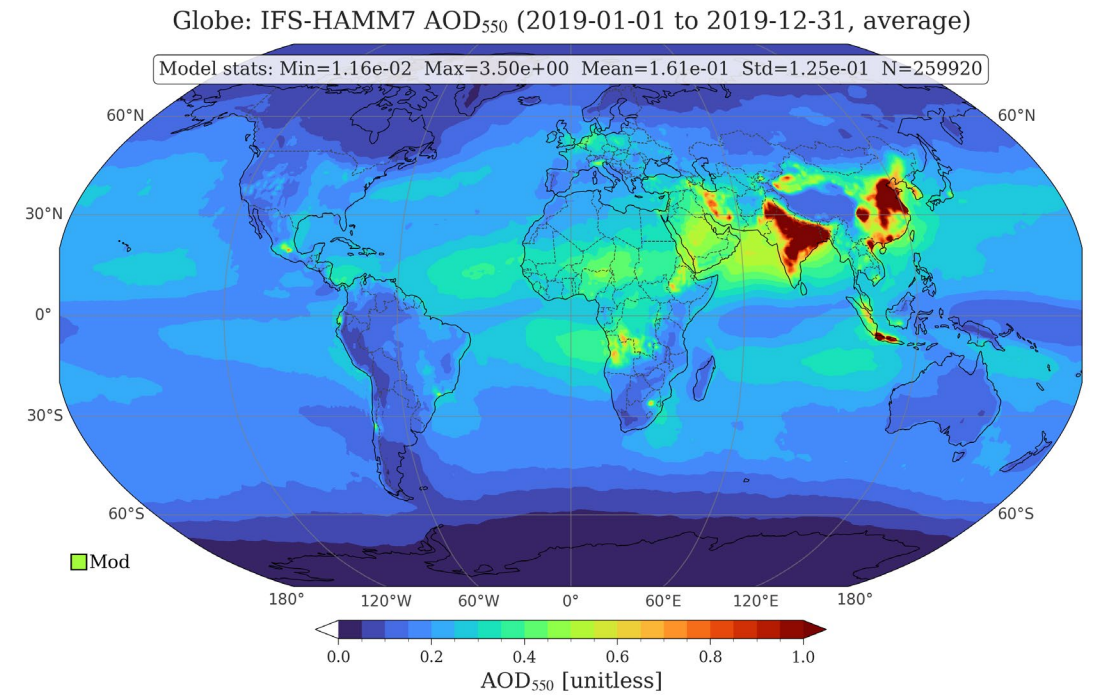
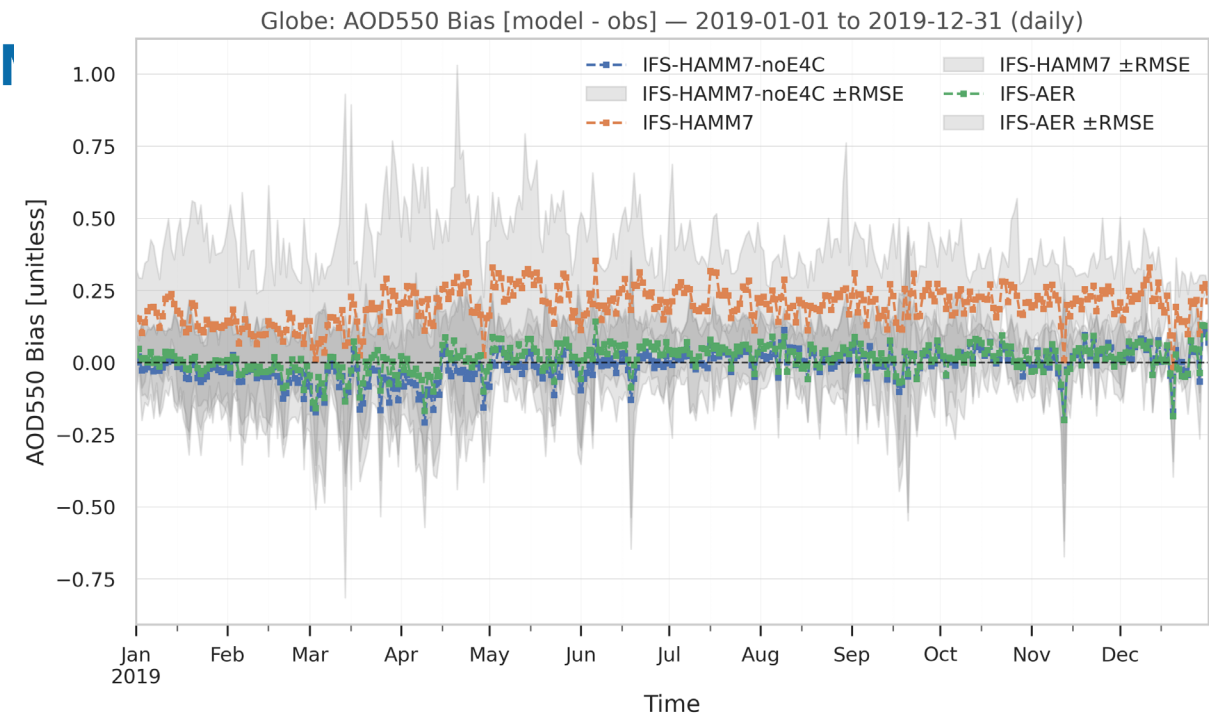
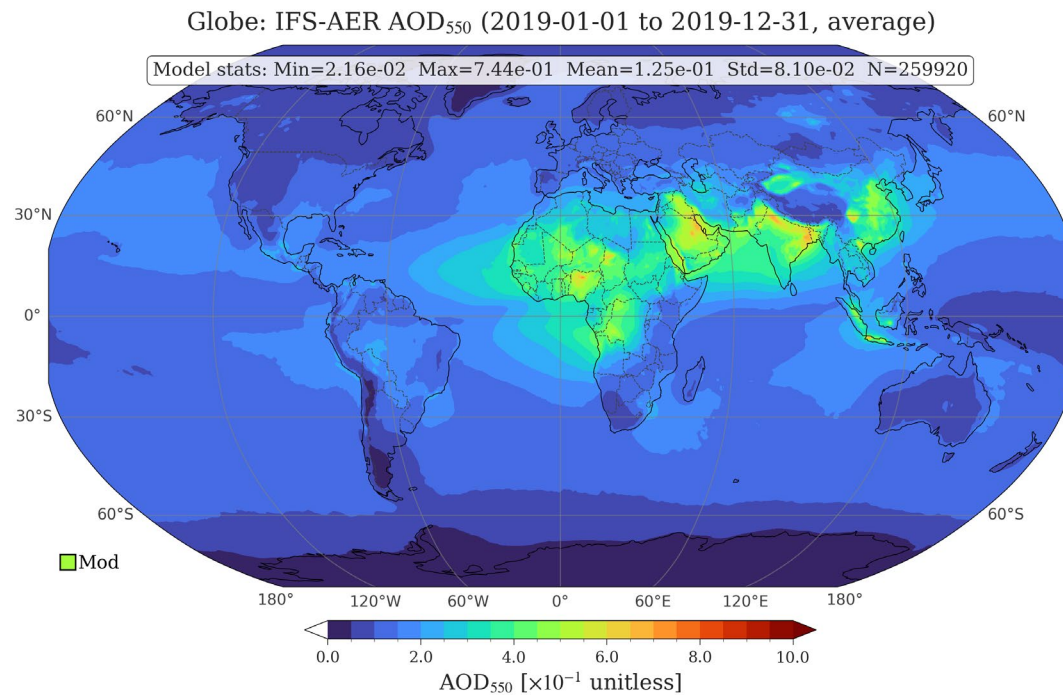
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# Results

# Aerosol optical depth

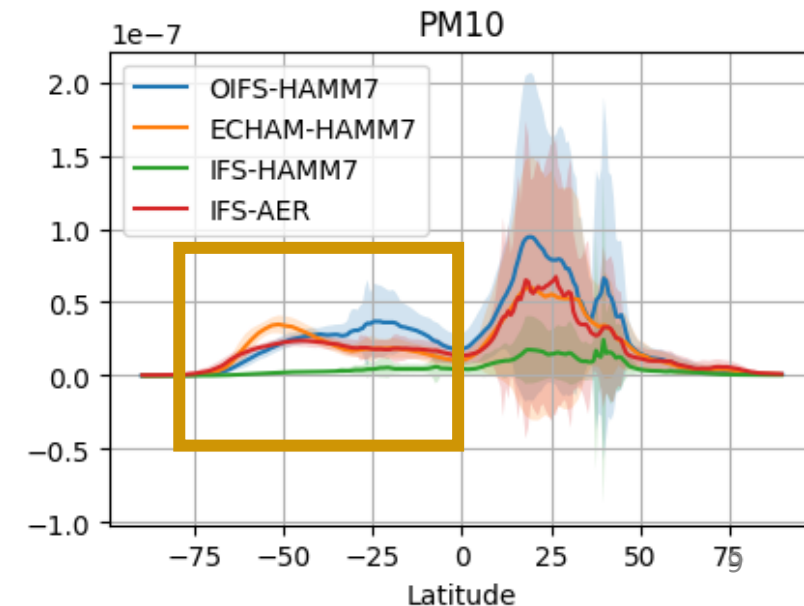
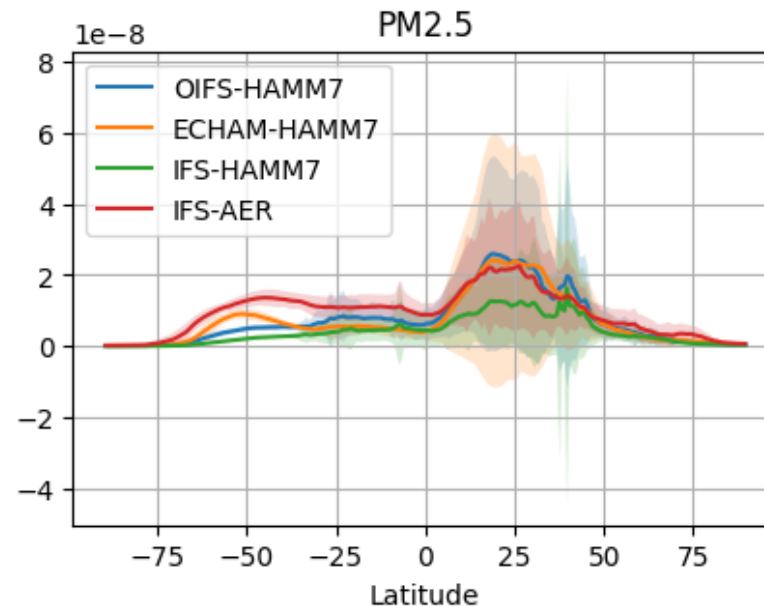
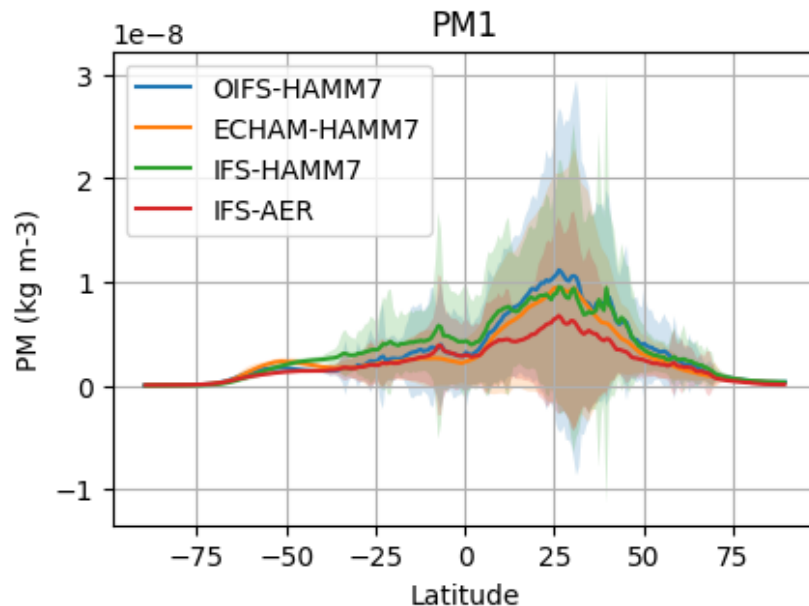
- Overestimation of AOD
  - China
  - India





# Particulate matter at the surface: Annual and zonal mean

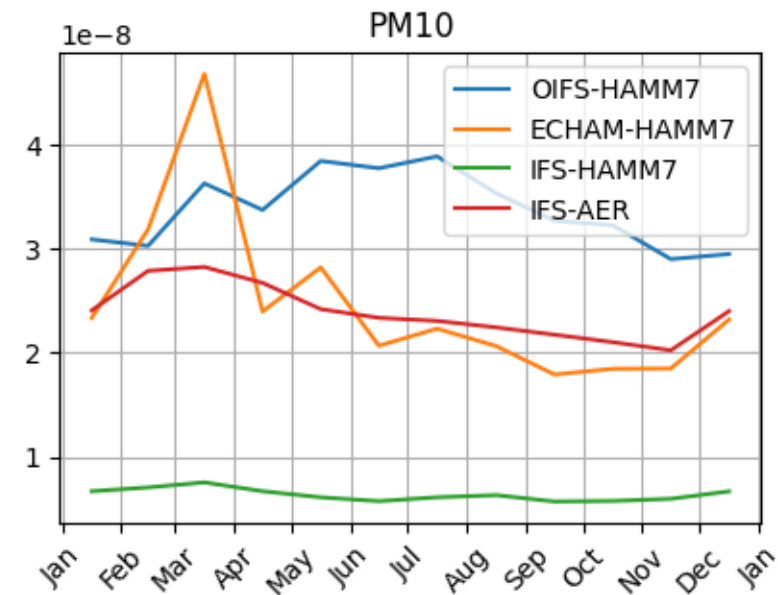
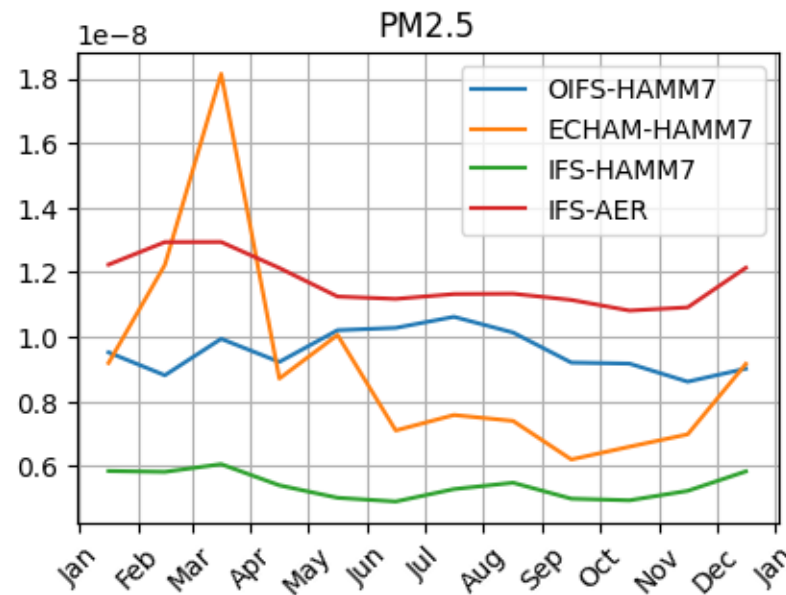
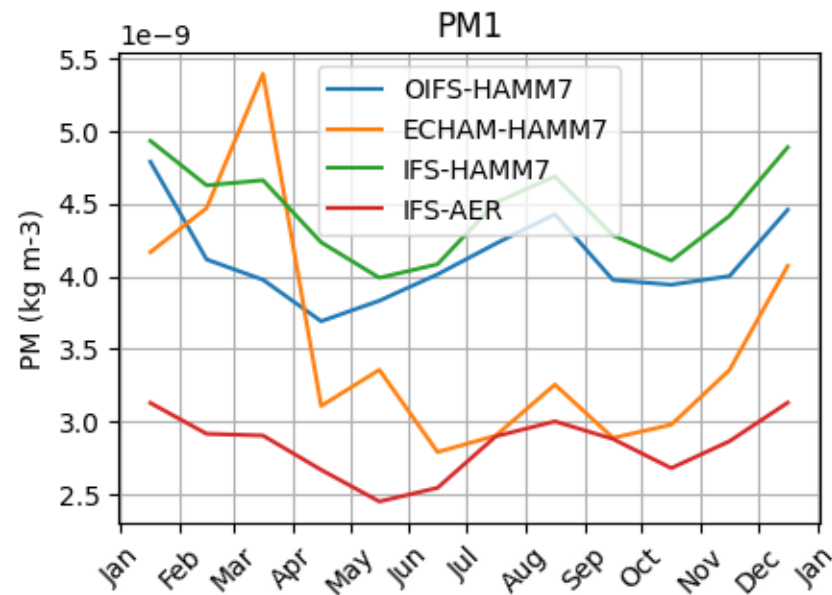
- PM1 similar for all models
  - AER lower in mid northern latitudes
- PM2.5 lower with IFS-HAMM7 than others
  - ECHAM and OIFS similar
  - Southern ocean AER highest
- PM10 shows error in the diagnostic in IFS-HAMM7
  - Especially southern ocean with mainly Sea salt





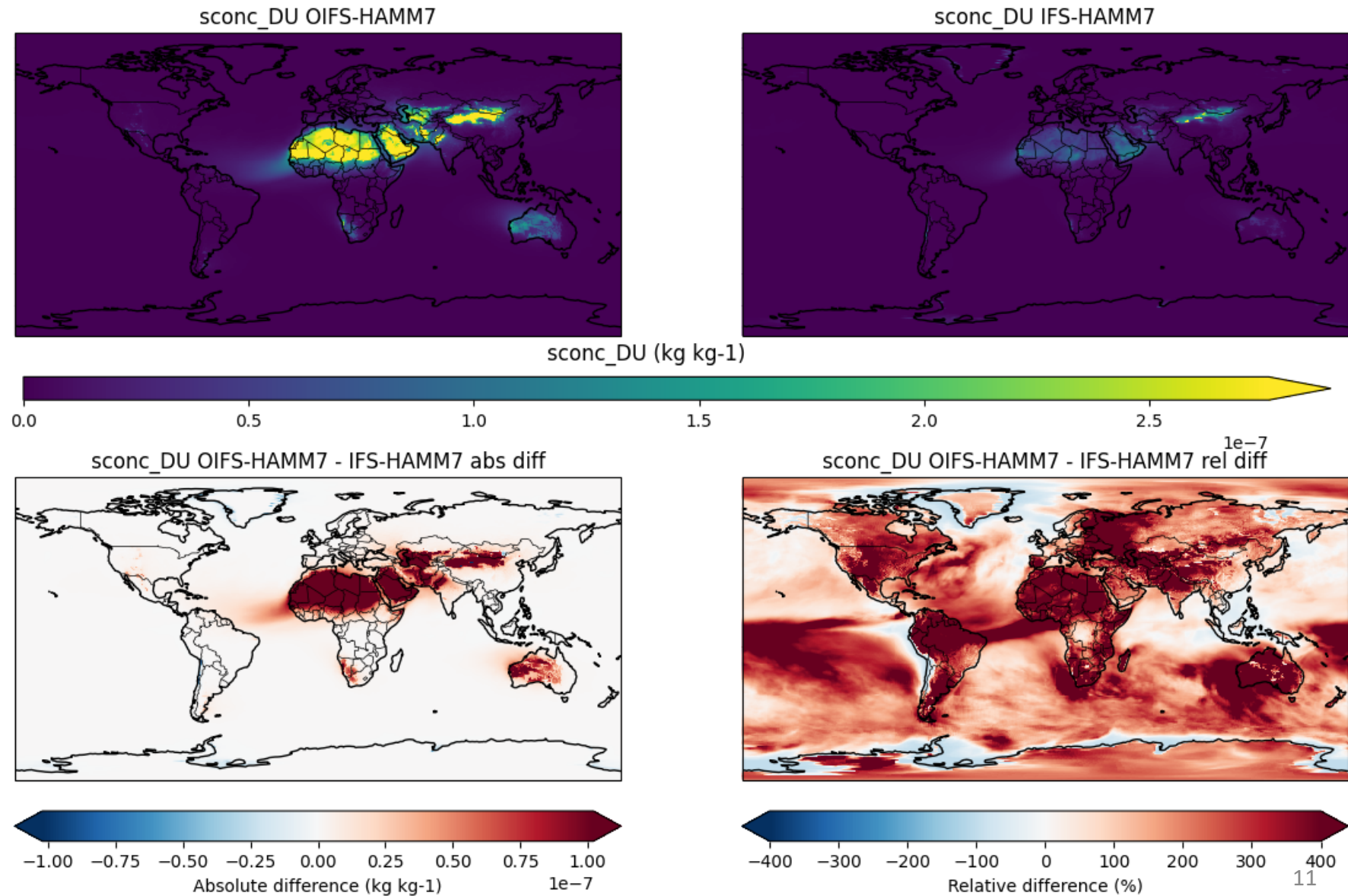
# Particulate matter annual cycle

- PM1 similar for both models
  - Higher with IFS-HAMM7
- PM2.5 lower with IFS-HAMM7
  - Even cycle different
- PM10 shows missing mass in IFS-HAMM7
  - IFS-AER and ECHAM-HAMM7 similar



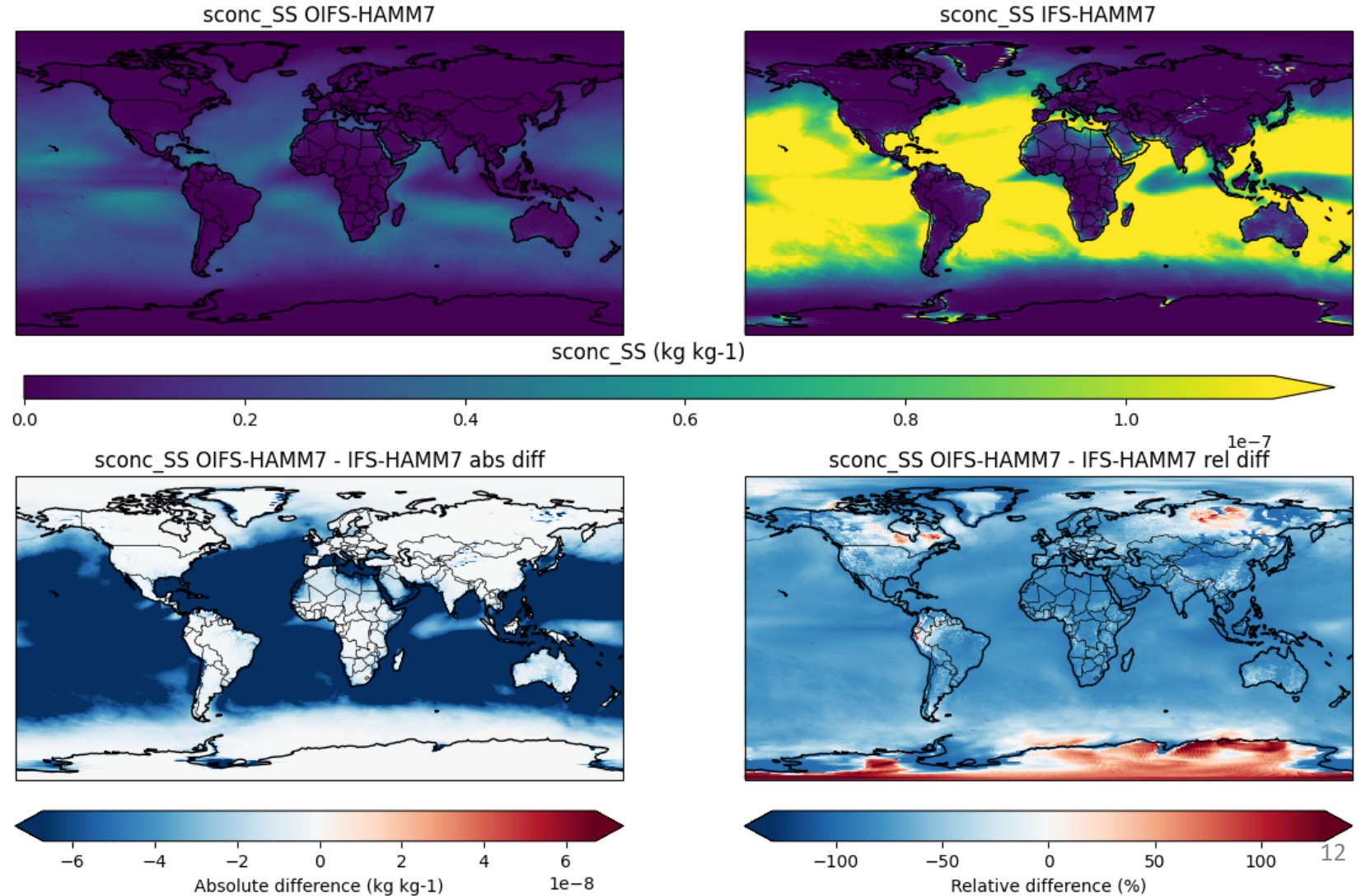
# Dust

- IFS shows much lower concentration



# Sea salt

- IFS shows much higher sea salt than OpenIFS







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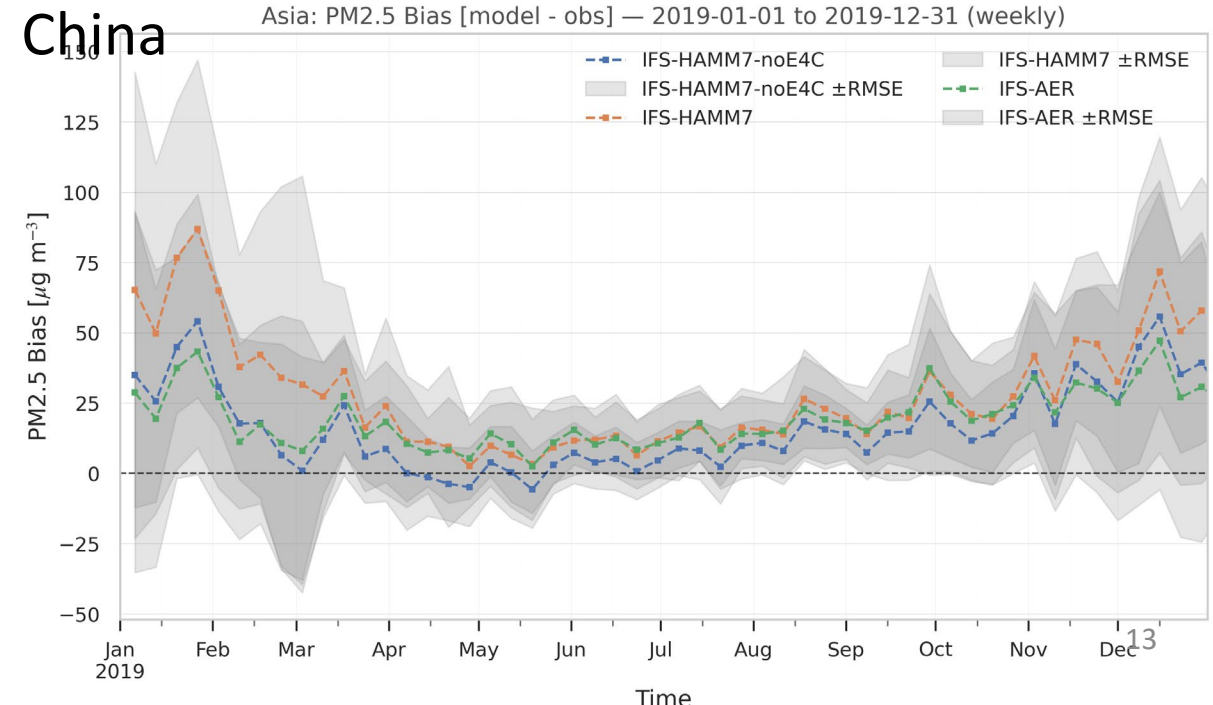
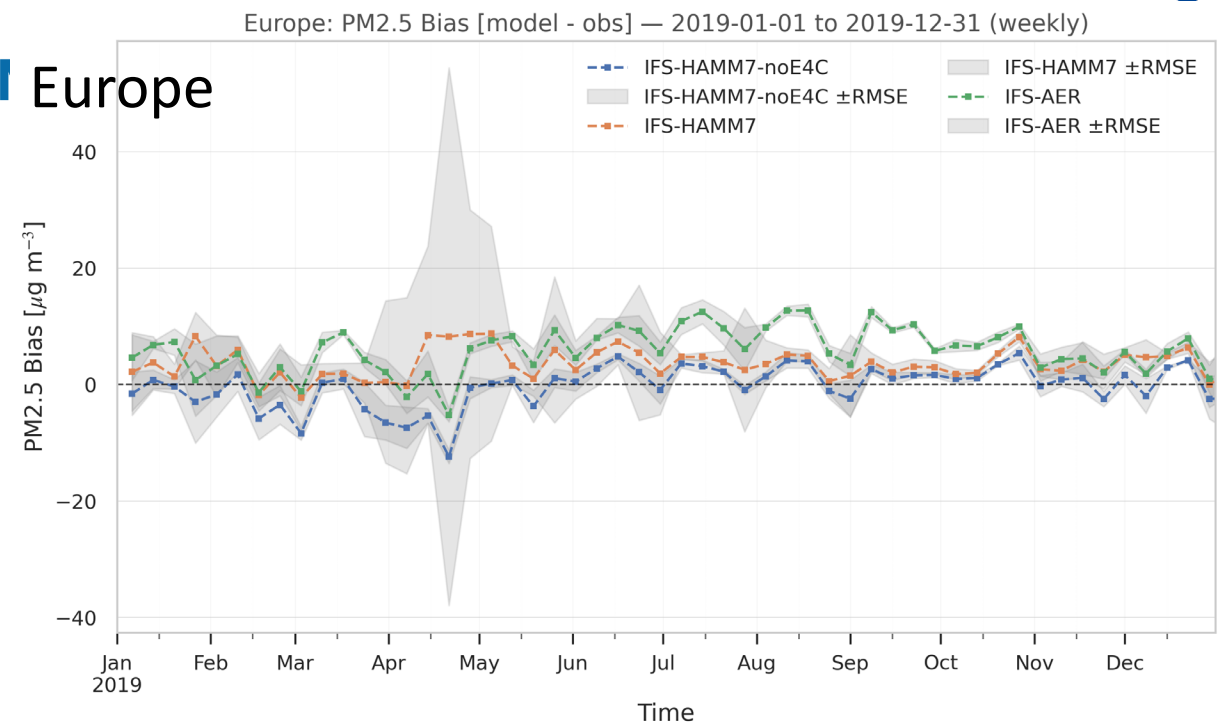
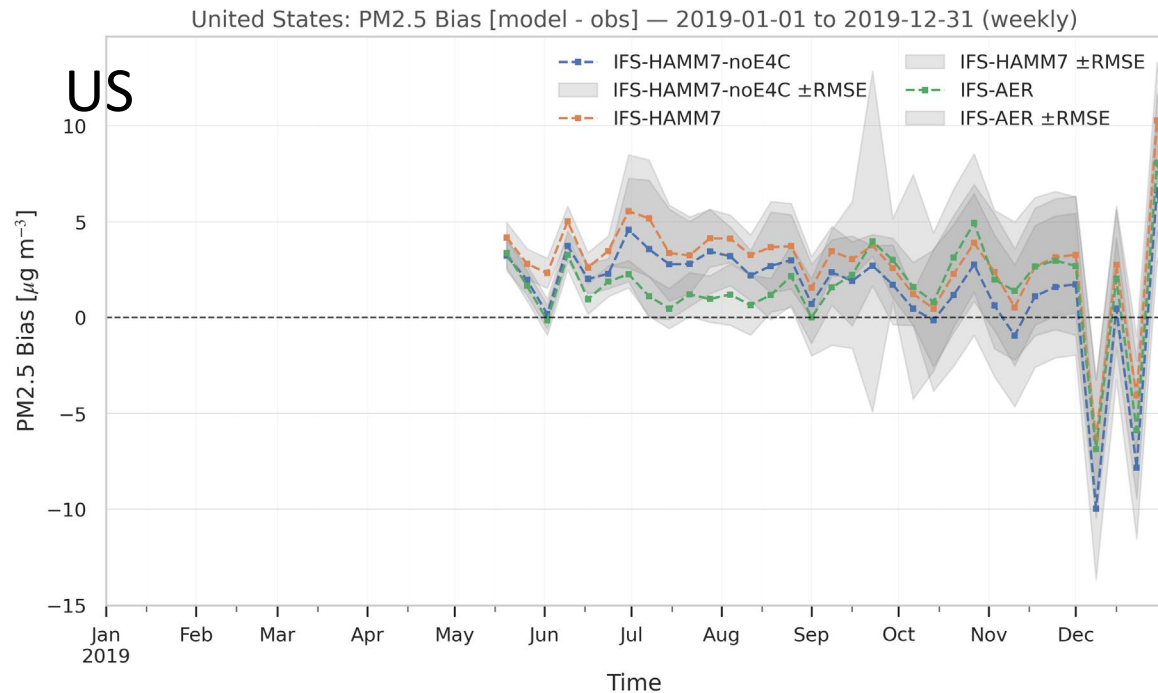


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# IFS-HAMM7 PM2.5 at EBAS stations

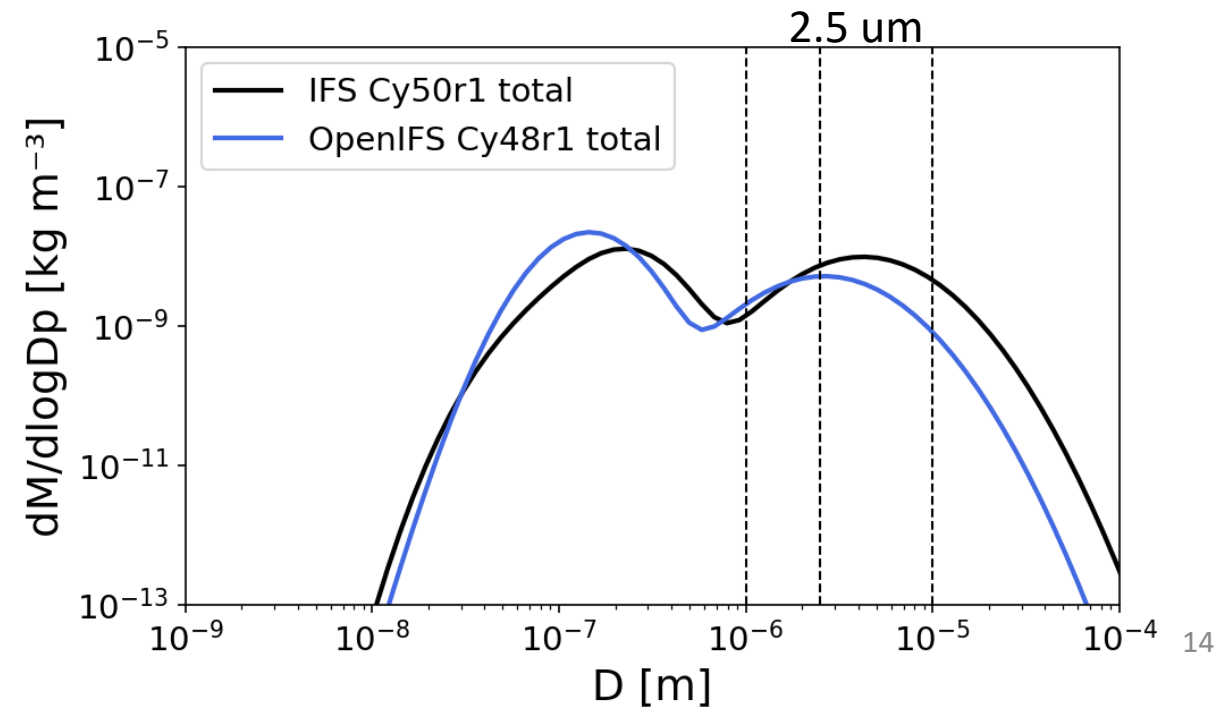
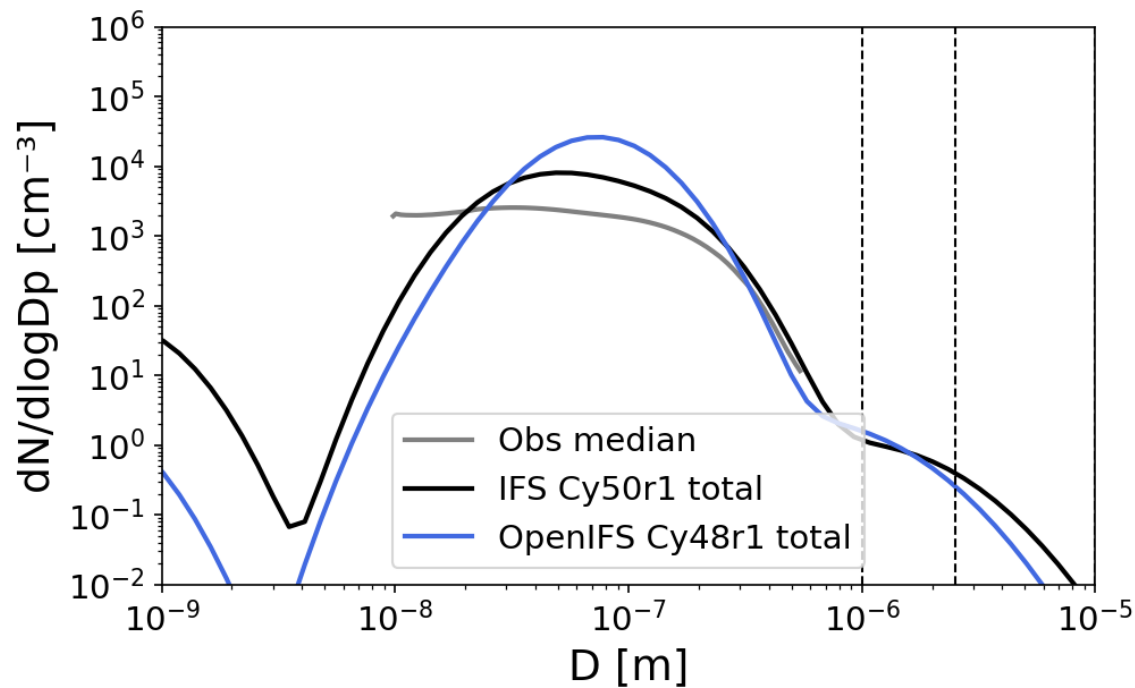
- IFS-HAMM7 PM2.5 performs well in Europe
  - Overestimation reduced compared to IFS-AER
- Chinese stations show high bias
  - Bias increased over winter months
- US high bias
  - Limited data



# European size distributions: OPE, near Nancy, France

- Number size distribution follows observed but biased high
- Mass concentrations are similar though IFS particles higher and larger fraction not accounted in PM<sub>10</sub>

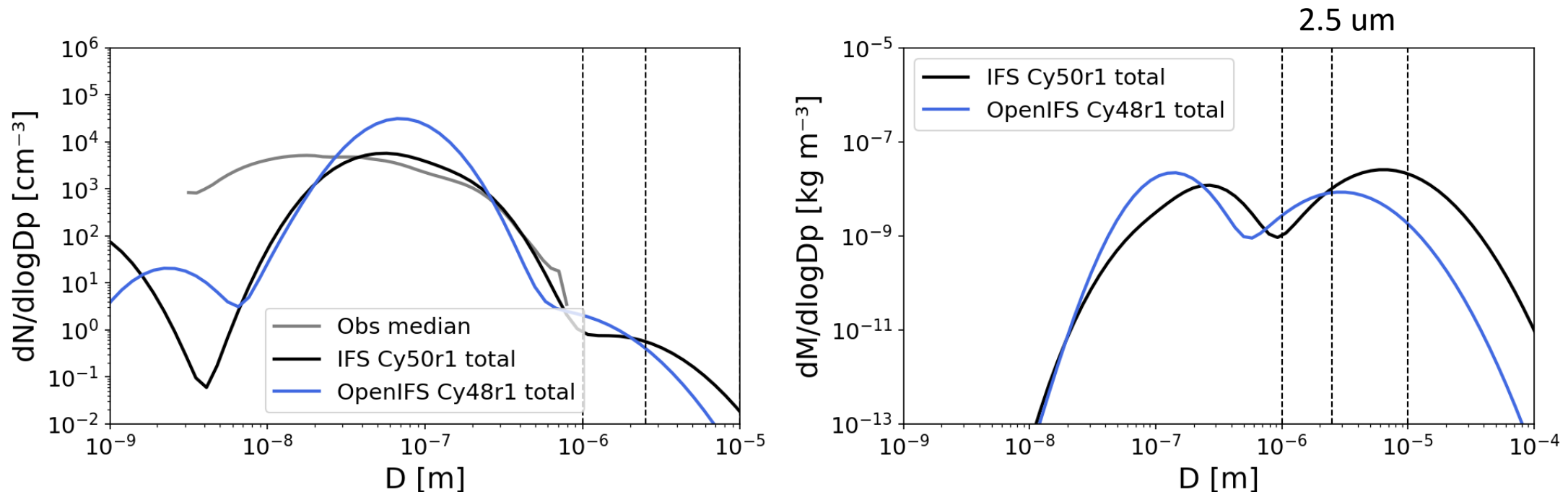
FR0022R



# Annual mean size distribution at Helsinki (urban)

- IFS size distribution follows closely from 20 nm to 1  $\mu\text{m}$ .
- OpenIFS run less well
- IFS has larger particles due to higher emissions sizes
- Mass in PM<sub>2.5</sub> similar for both models

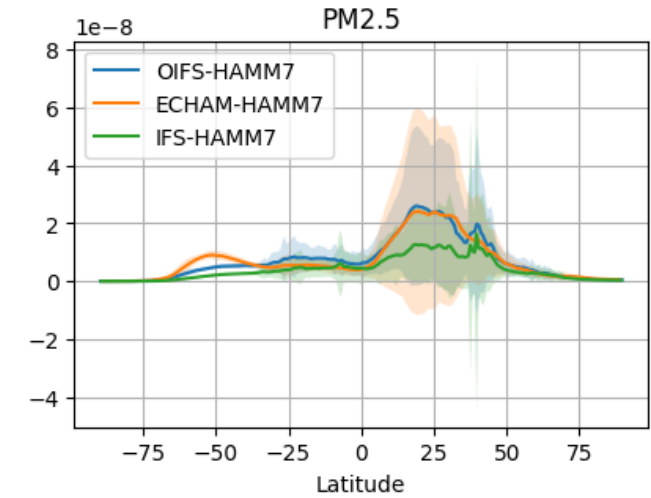
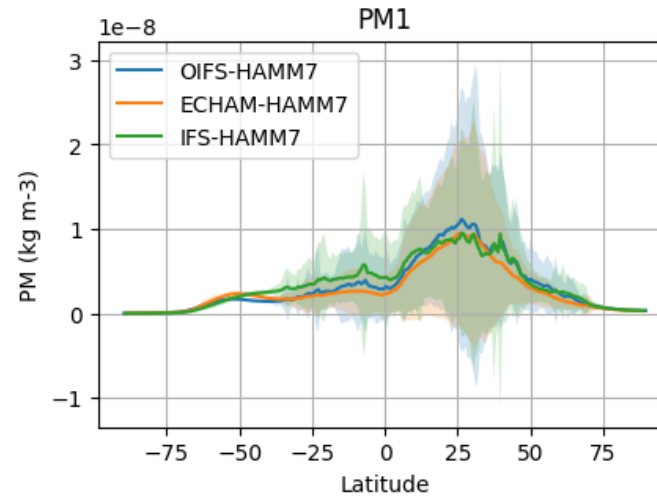
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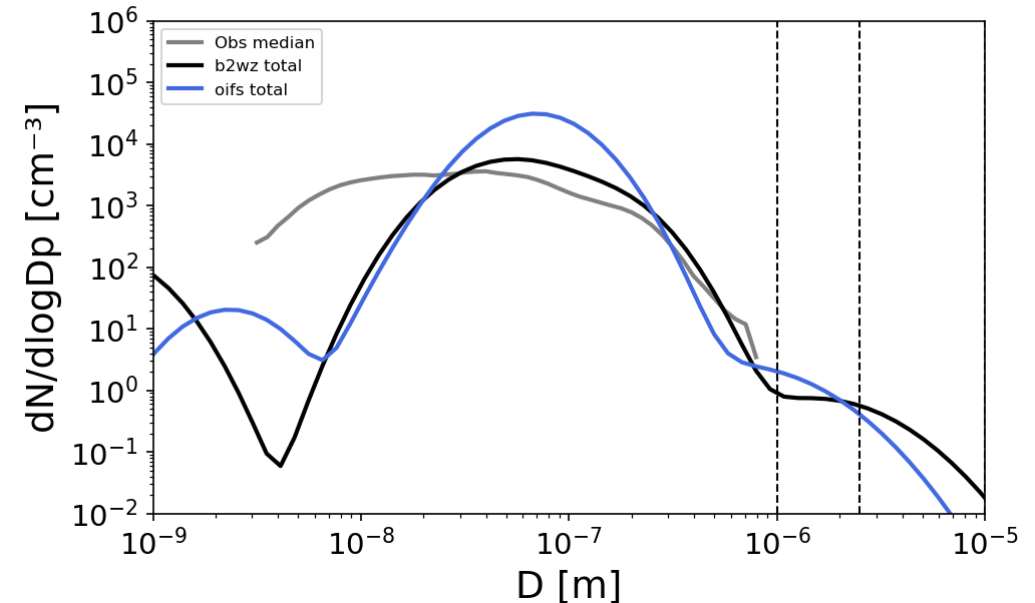


# Summary

- Globally PM1 similar in all three models
  - Globally PM2.5 lower with IFS than with OpenIFS
    - model code harmonisation needed still
  - Global PM10 needs checking for coarse mode particles
- 
- **PM2.5 at European stations follow observed nicely**
  - PM2.5 at US and China over estimated and need investigation for the reasons
- 
- **Number size distributions follow observations well**
  - Mass size distributions need to be compared with observations



FIG





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# Thank you



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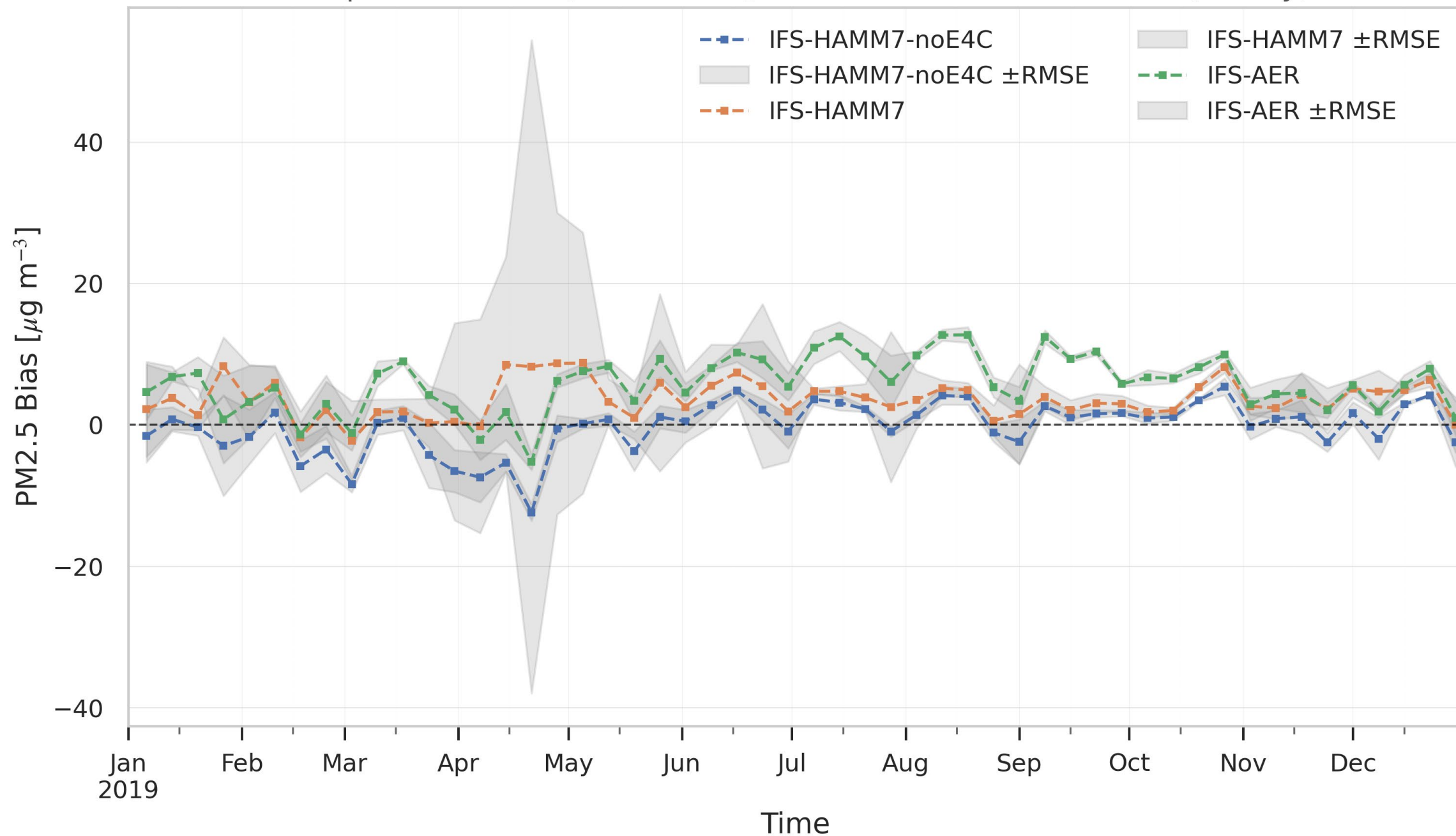
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# Backups



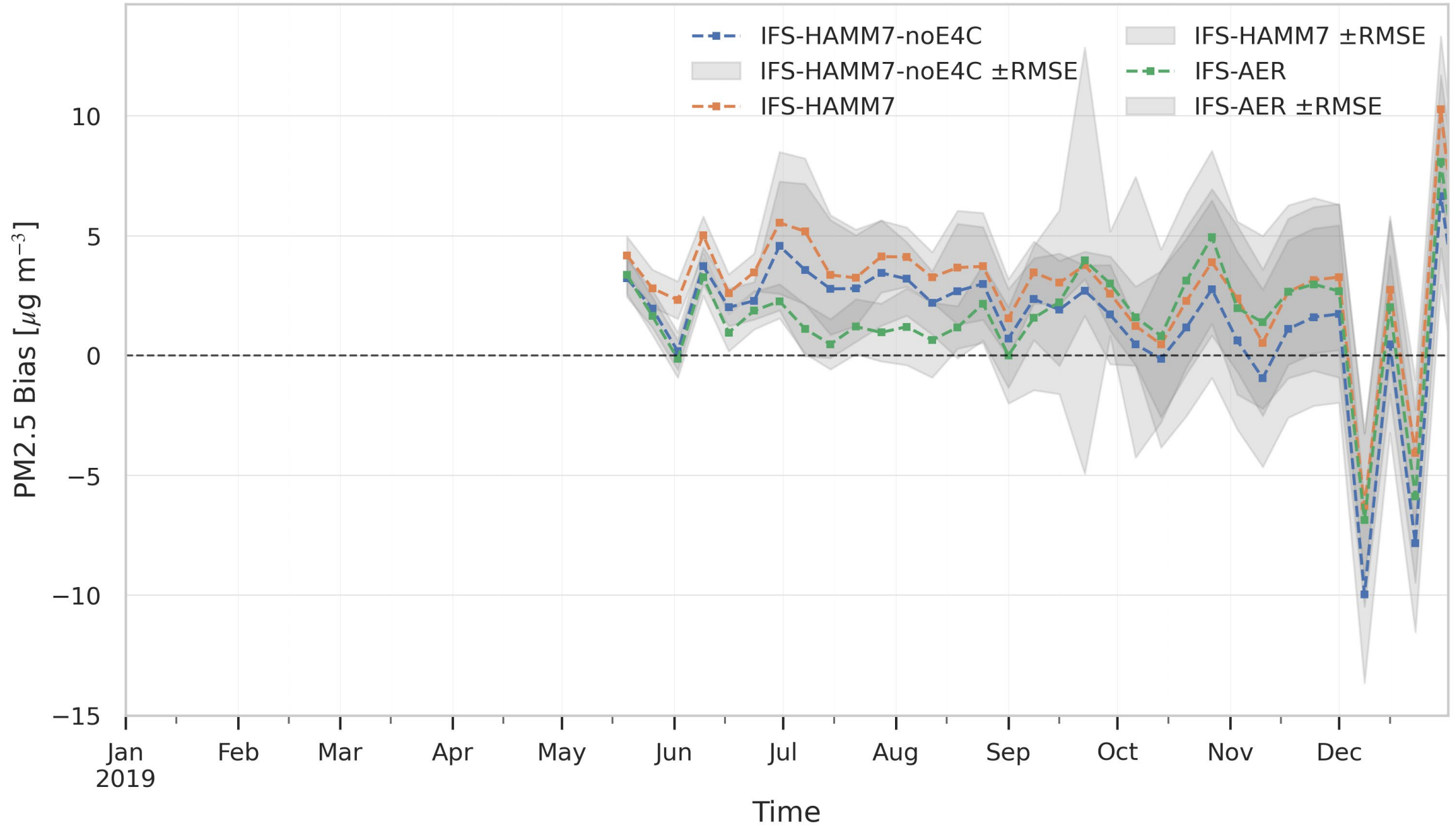


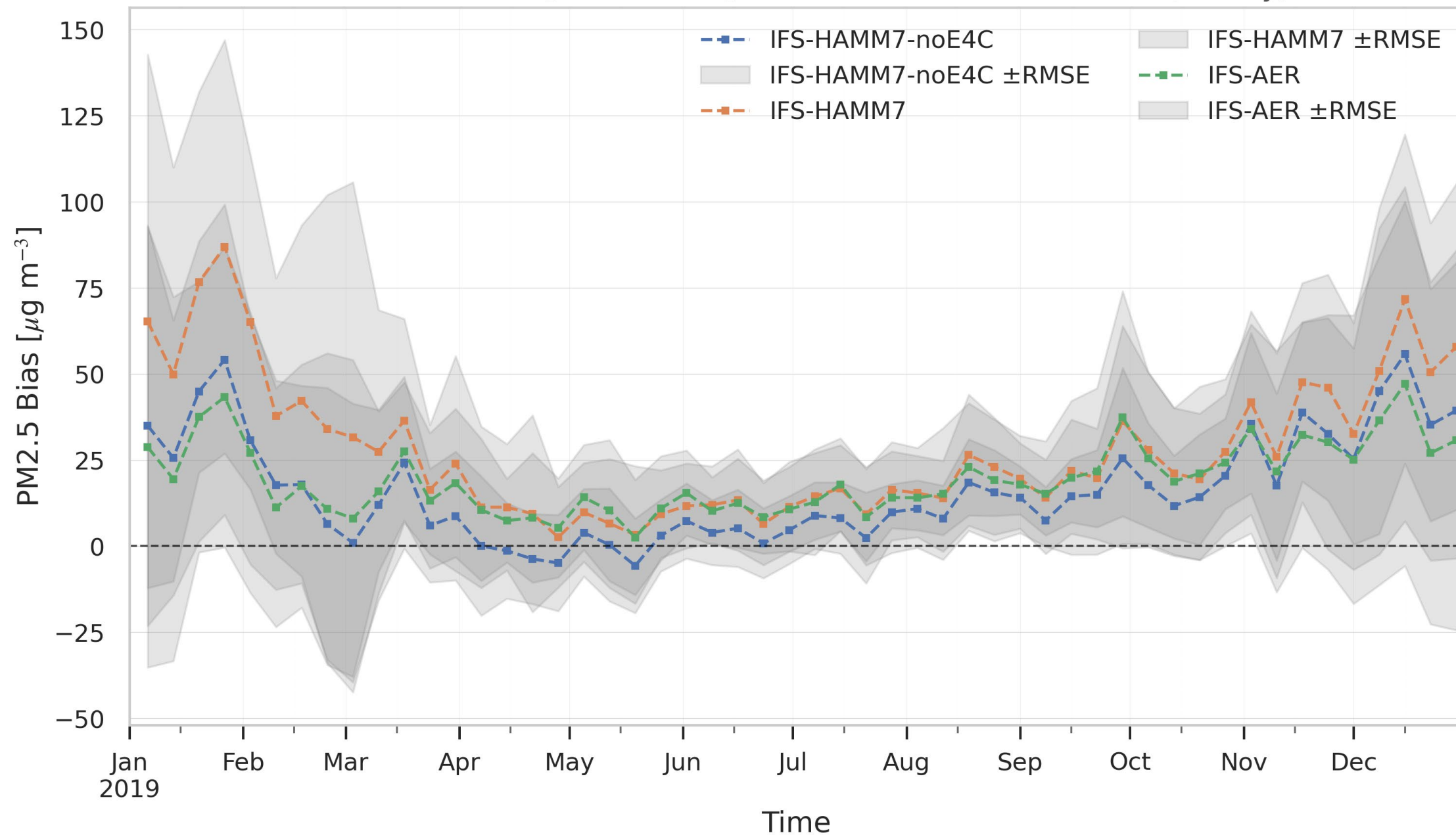
Europe: PM2.5 Bias [model - obs] — 2019-01-01 to 2019-12-31 (weekly)





## United States: PM2.5 Bias [model - obs] — 2019-01-01 to 2019-12-31 (weekly)



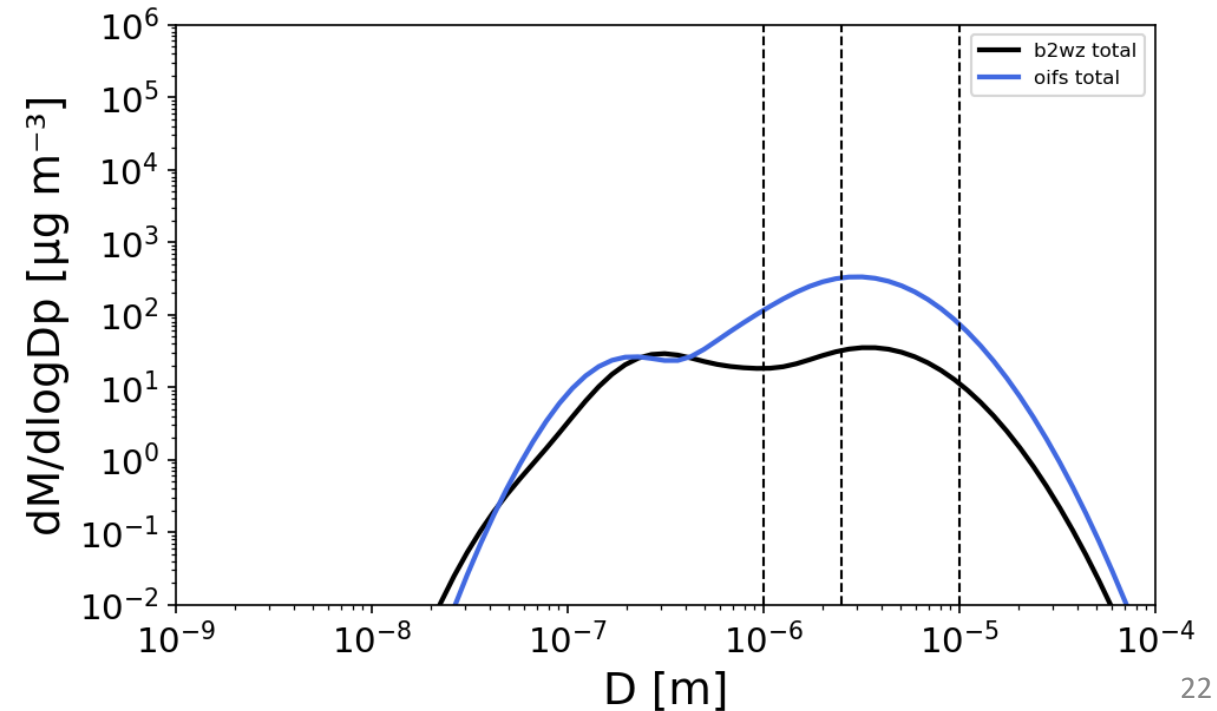
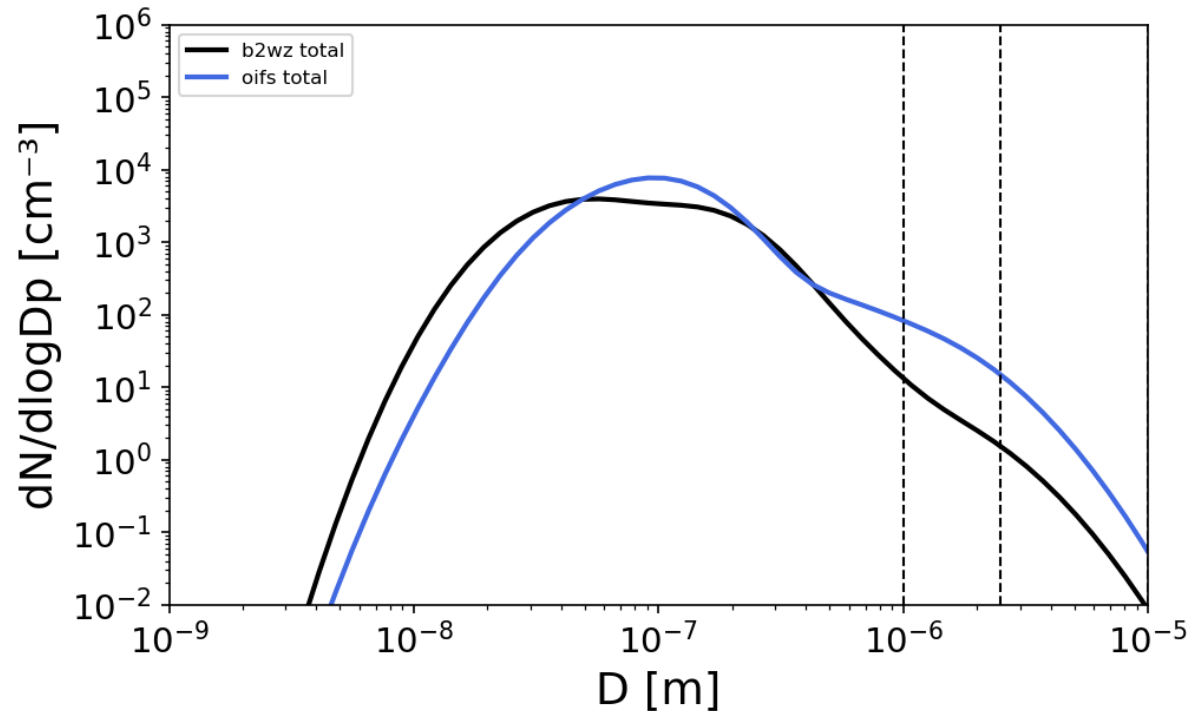
Asia: PM<sub>2.5</sub> Bias [model - obs] — 2019-01-01 to 2019-12-31 (weekly)



# Ocean PM issues: size distributions

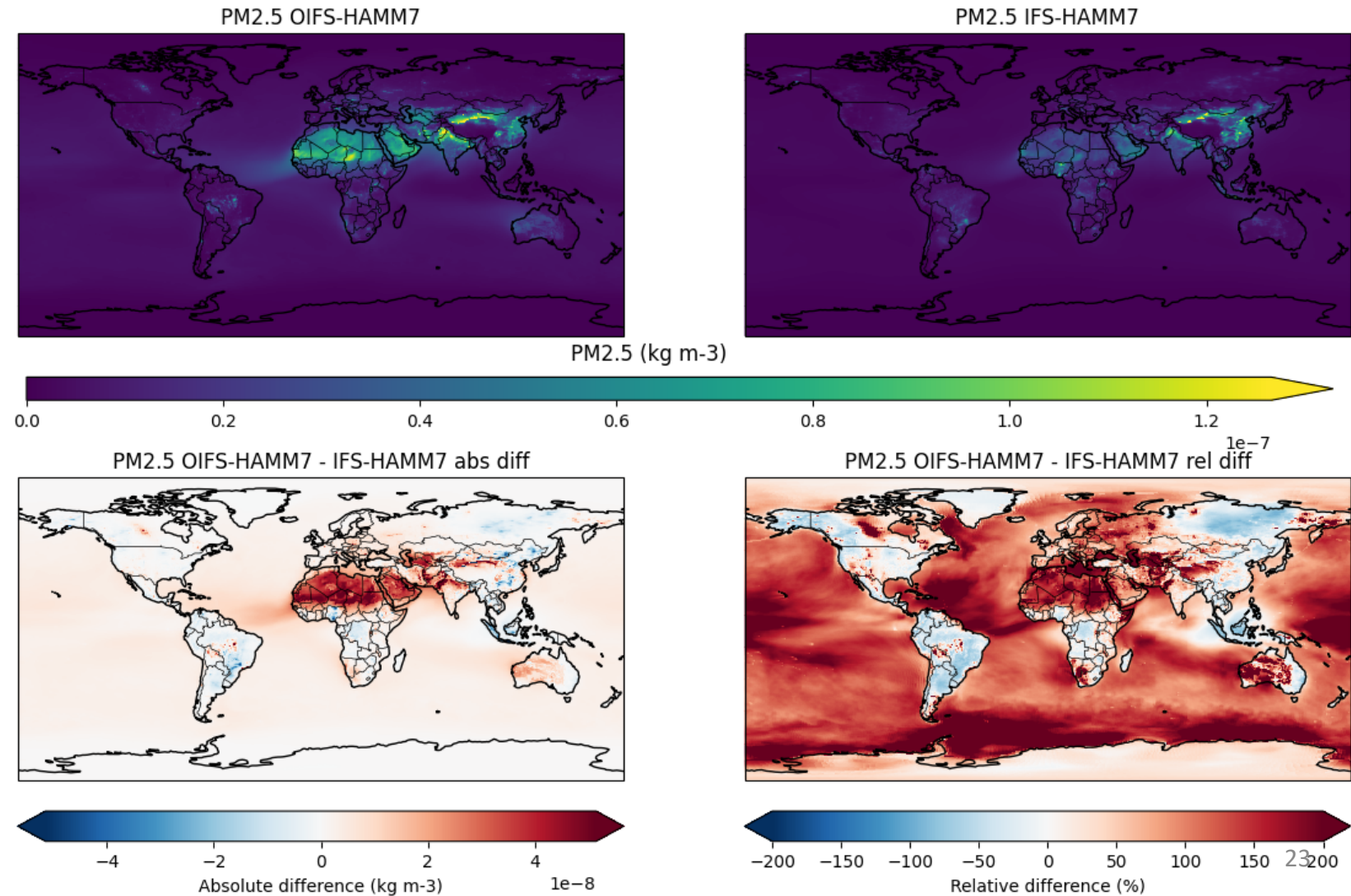
- IFS broad mode of particles below 1  $\mu\text{m}$
- OpenIFS higher mass in coarse mode particles than IFS

Pacific



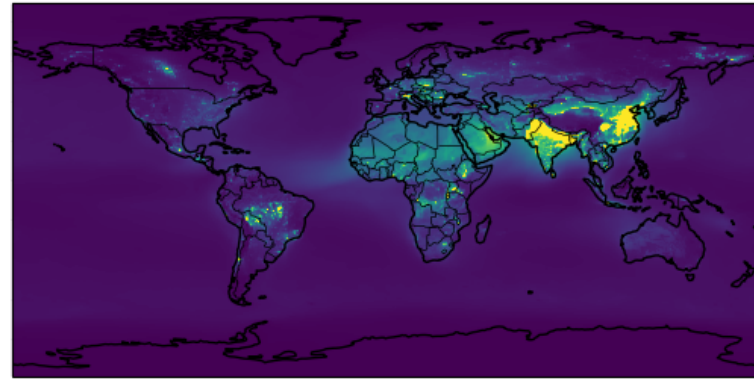


# Global PM<sub>2.5</sub> in OIFS-HAMM7 and IFS-HAMM7

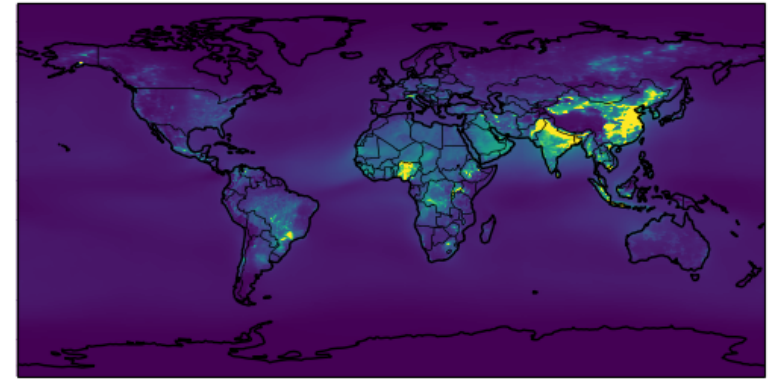




PM1 OIFS-HAMM7



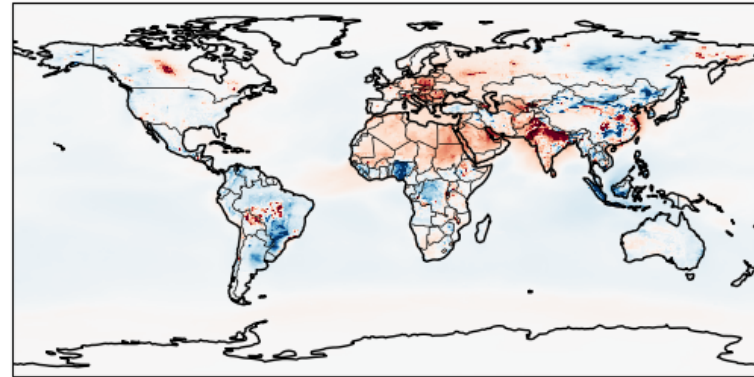
PM1 IFS-HAMM7



PM1 (kg m<sup>-3</sup>)



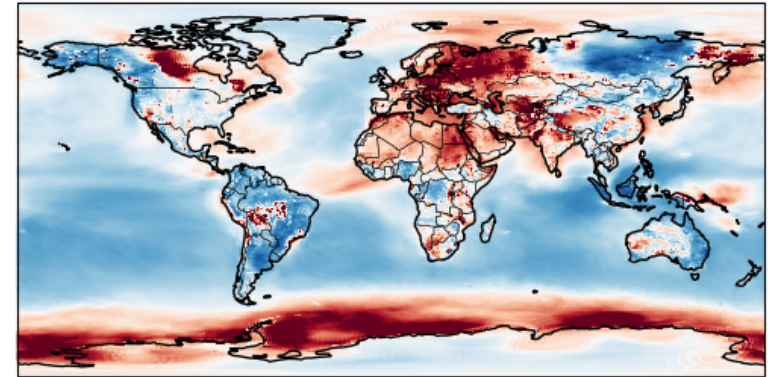
PM1 OIFS-HAMM7 - IFS-HAMM7 abs diff



Absolute difference (kg m<sup>-3</sup>)  
1e-8



PM1 OIFS-HAMM7 - IFS-HAMM7 rel diff  
1e-8

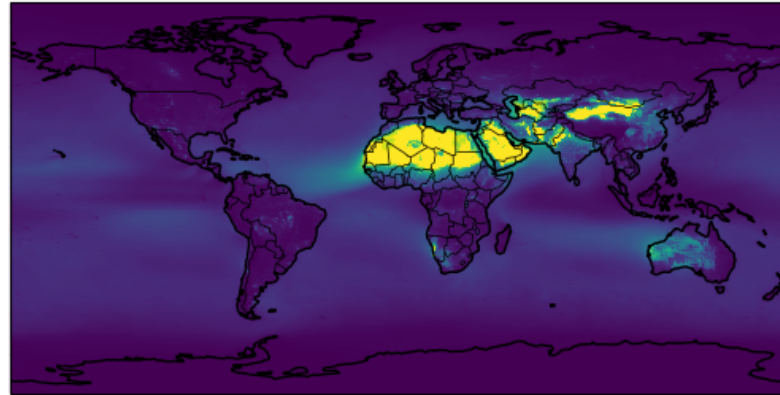


Relative difference (%)

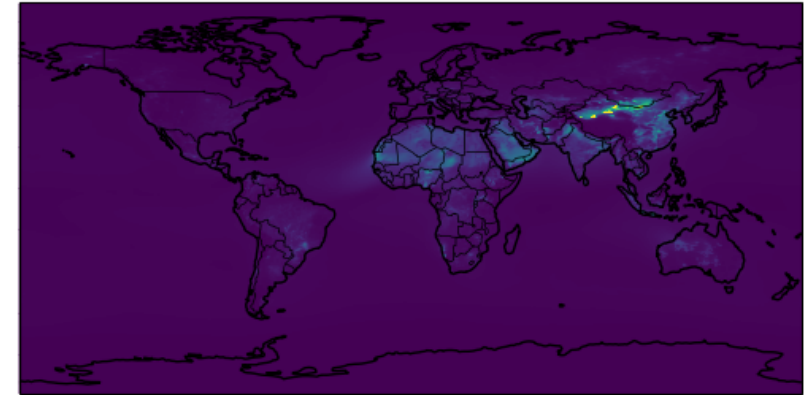




PM10 OIFS-HAMM7



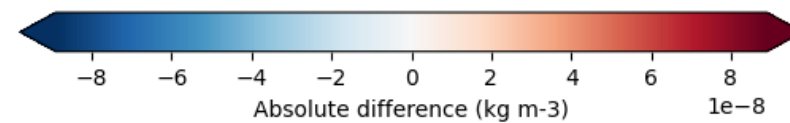
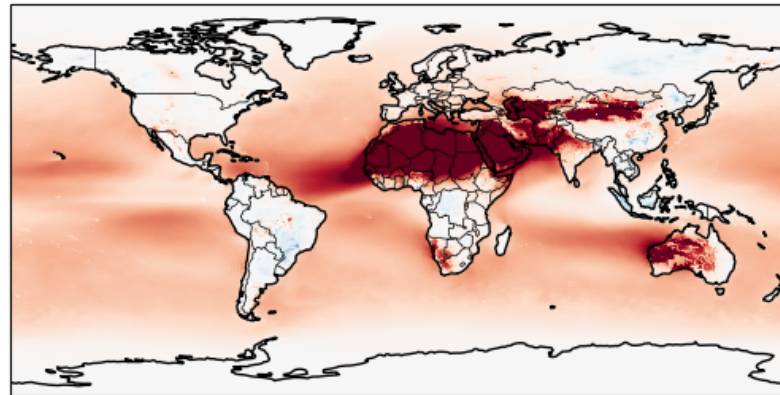
PM10 IFS-HAMM7



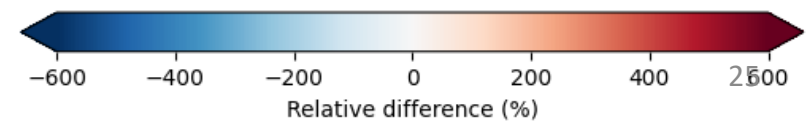
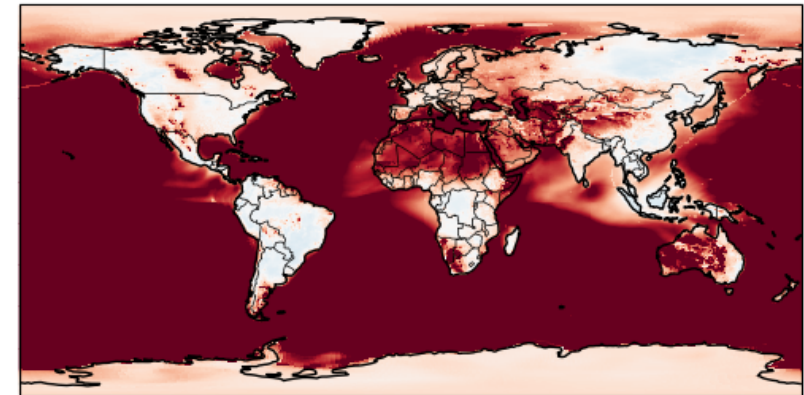
PM10 ( $\text{kg m}^{-3}$ )

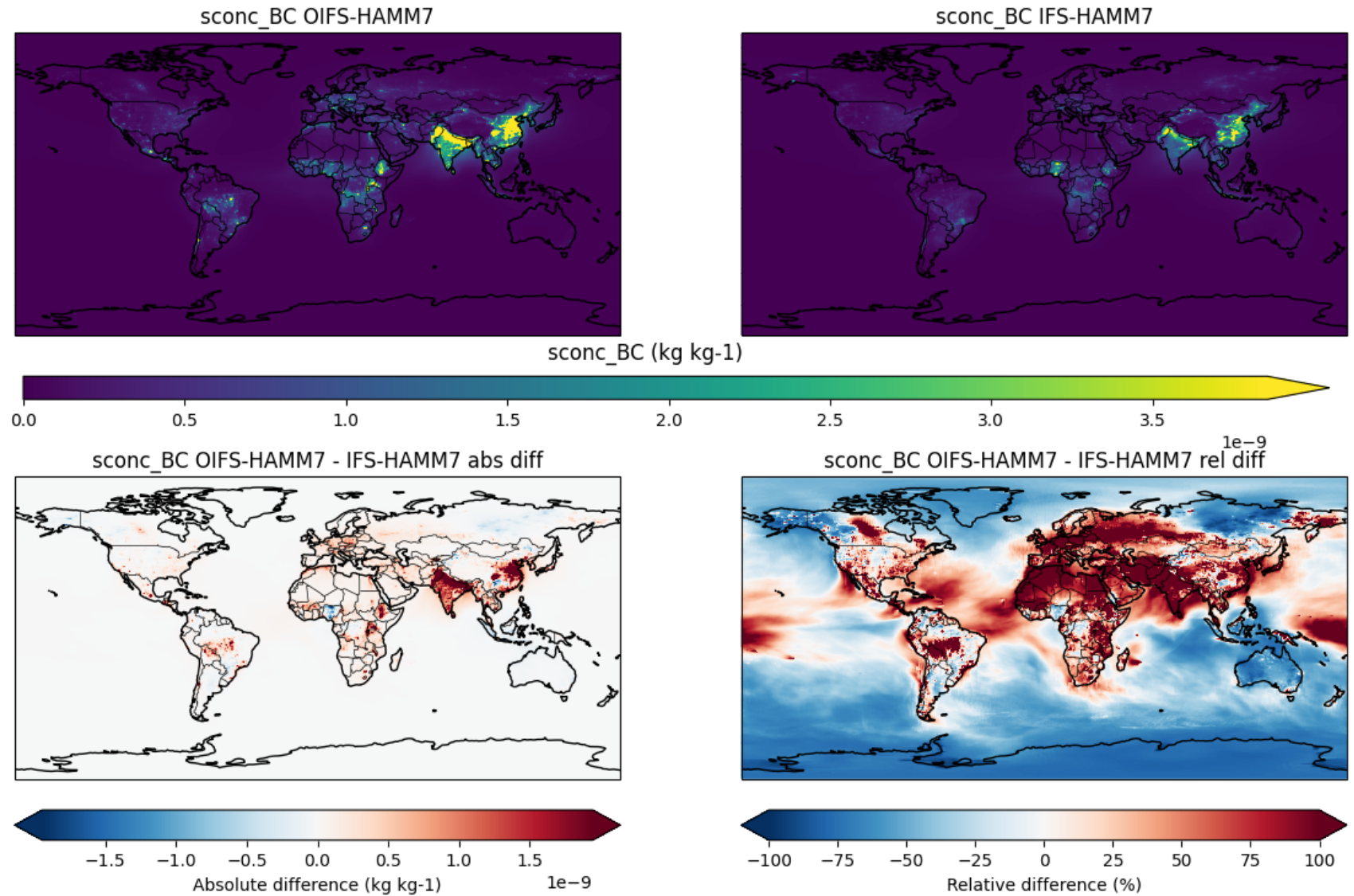


PM10 OIFS-HAMM7 - IFS-HAMM7 abs diff



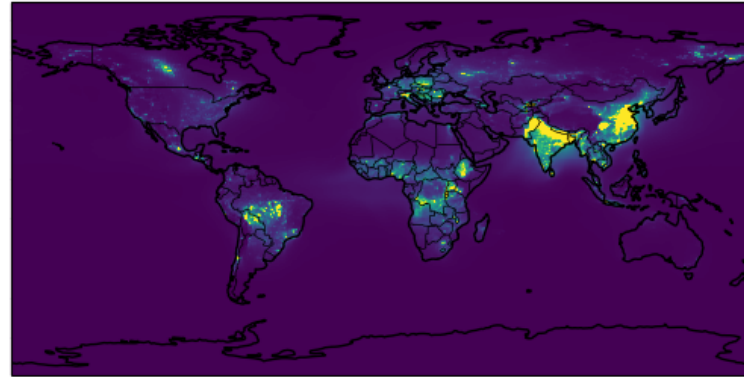
PM10 OIFS-HAMM7 - IFS-HAMM7 rel diff  $10^{-7}$



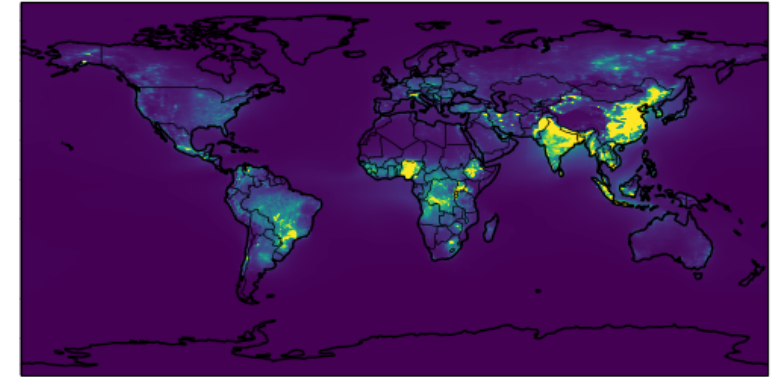




sconc\_OC OIFS-HAMM7



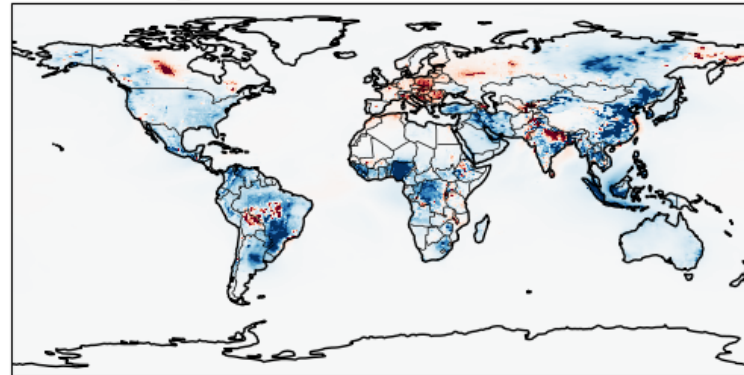
sconc\_OC IFS-HAMM7



sconc\_OC (kg kg-1)

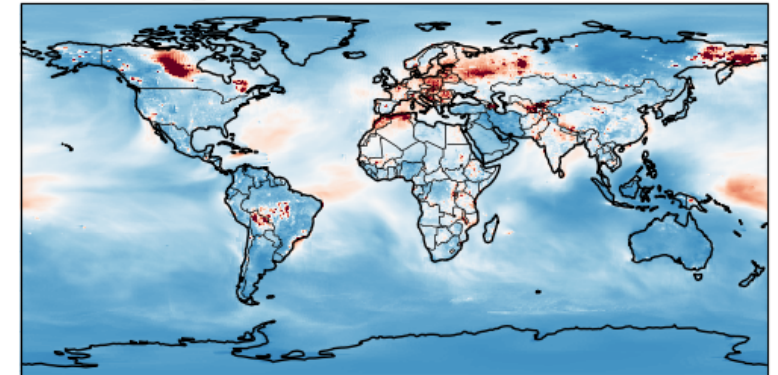


sconc\_OC OIFS-HAMM7 - IFS-HAMM7 abs diff



Absolute difference (kg kg-1) 1e-9

sconc\_OC OIFS-HAMM7 - IFS-HAMM7 rel diff



Relative difference (%) 1e-8





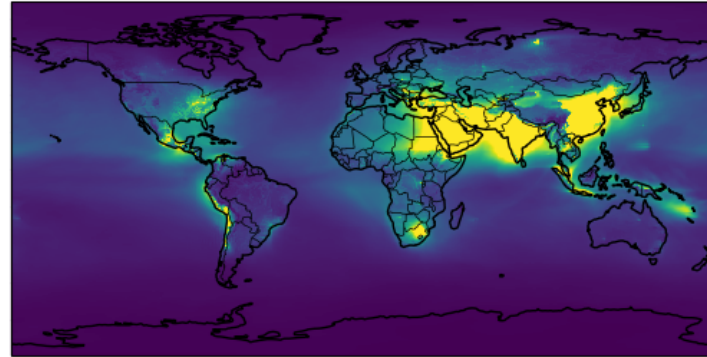
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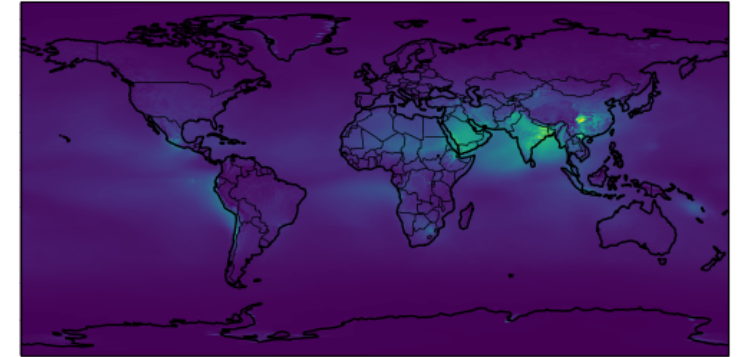
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sconc\_SO4 OIFS-HAMM7



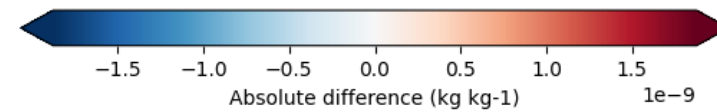
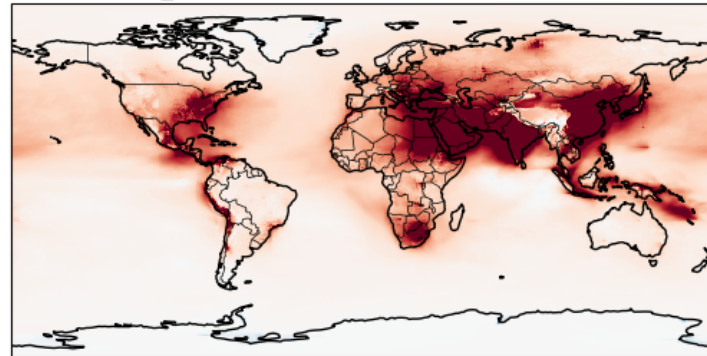
sconc\_SO4 IFS-HAMM7



sconc\_SO4 (kg kg<sup>-1</sup>)

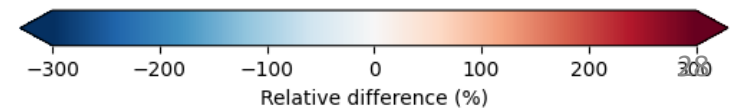
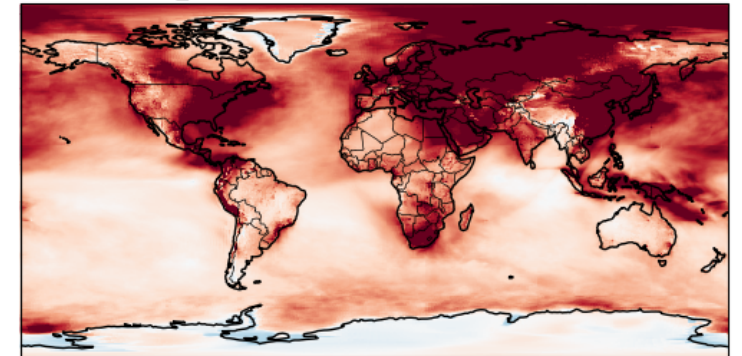


sconc\_SO4 OIFS-HAMM7 - IFS-HAMM7 abs diff



Absolute difference (kg kg<sup>-1</sup>)

sconc\_SO4 OIFS-HAMM7 - IFS-HAMM7 rel diff



Relative difference (%)