

A new coupled carbonyl sulfide-CO₂ modeling system for improved photosynthesis estimation and resolving missing COS sources

TM meeting November 2025, Amsterdam

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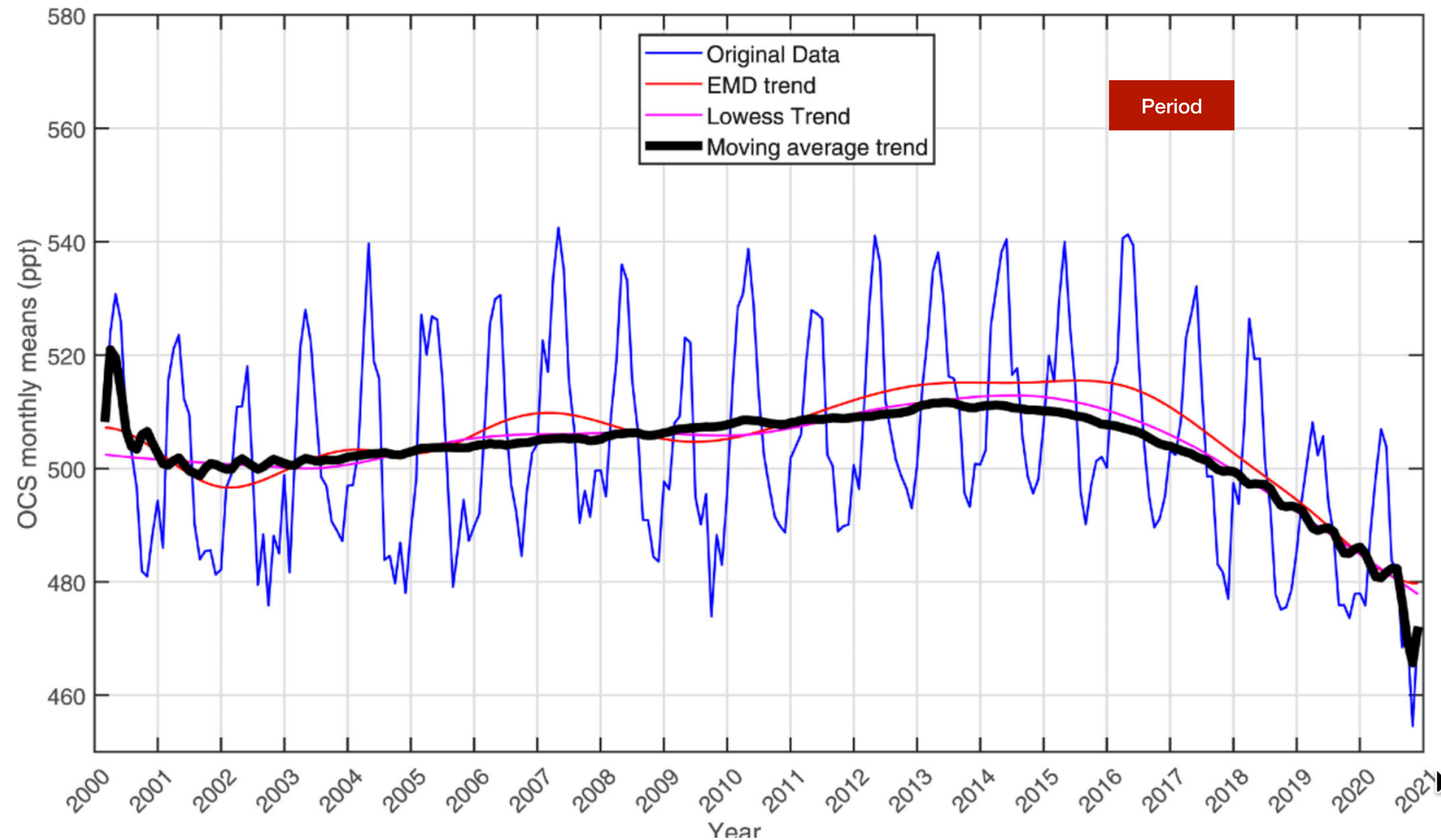


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Global COS: changing!!



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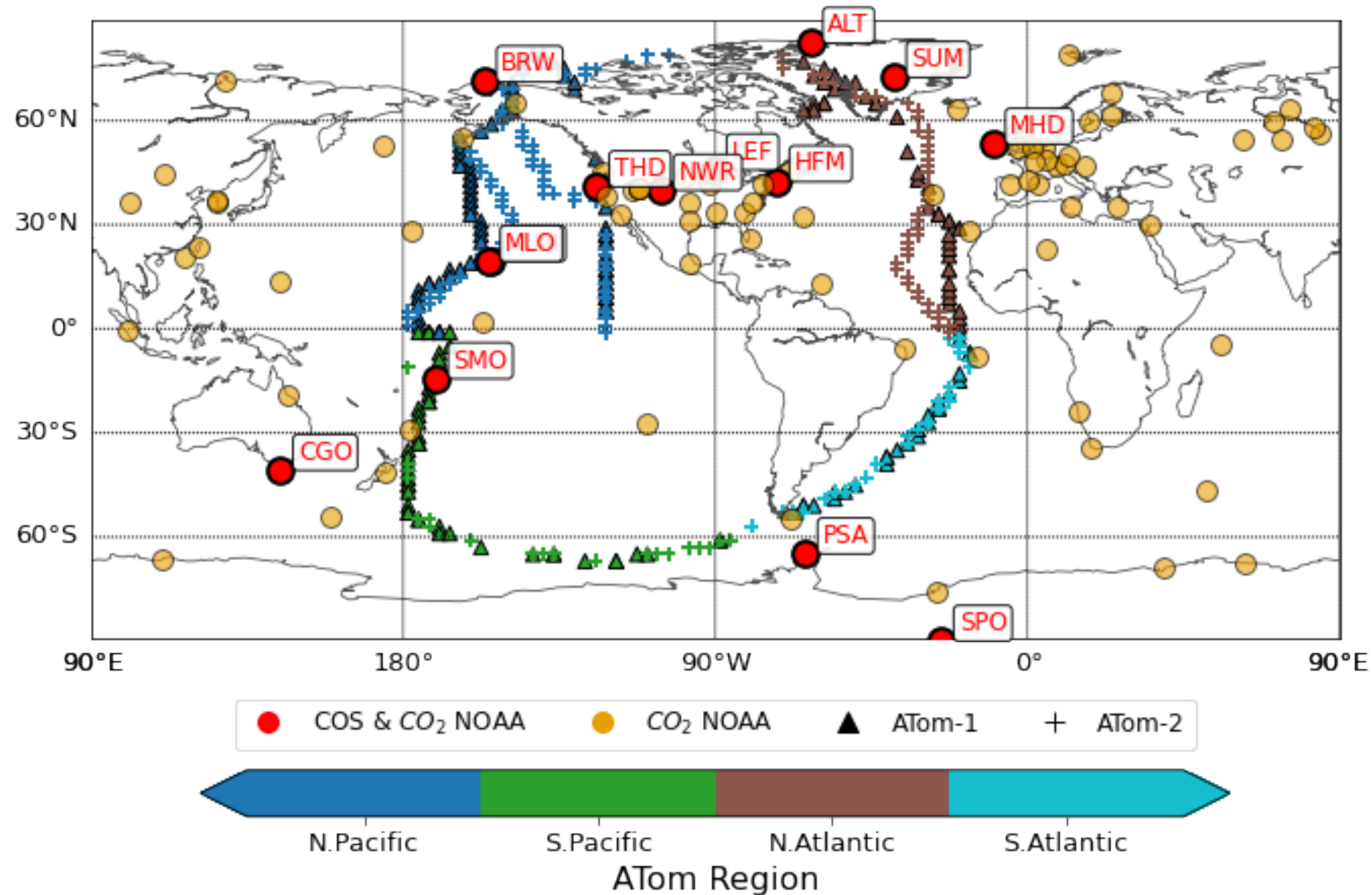
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Cost function based on two tracers!

$$\begin{aligned} J_{\text{Tot}}(\mathbf{x}) &= J_{\text{bg}} + w_{\text{CO}_2} J_{\text{CO}_2} + w_{\text{COS}} J_{\text{COS}} \\ &= (\mathbf{x} - \mathbf{x}_a)^\top \mathbf{B}^{-1} (\mathbf{x} - \mathbf{x}_a) \\ &\quad + w_{\text{CO}_2} (\mathbf{H}(\mathbf{x}) - \mathbf{y}_{\text{CO}_2})^\top \mathbf{R}_{\text{CO}_2}^{-1} (\mathbf{H}(\mathbf{x}) - \mathbf{y}_{\text{CO}_2}) \\ &\quad + w_{\text{COS}} (\mathbf{H}(\mathbf{x}) - \mathbf{y}_{\text{COS}})^\top \mathbf{R}_{\text{COS}}^{-1} (\mathbf{H}(\mathbf{x}) - \mathbf{y}_{\text{COS}}). \end{aligned}$$



Measurement locations/density differ!



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Coupling framework in 4D-VAR

$$F_{\text{CO}_2, \text{NEE}}(i, j, m) = s(i, j, m) GPP_{\text{SiB4}}(i, j, m) + TER(i, j, m),$$

$$F_{\text{COS, veg}}(i, j, m) = s(i, j, m) F_{\text{COS, veg, SiB4}}(i, j, m).$$

$$\frac{\delta J}{\delta s} = \frac{\delta J}{\delta F_{\text{CO}_2, \text{NEE}}} \frac{\delta F_{\text{CO}_2, \text{NEE}}}{\delta s} + \frac{\delta J}{\delta F_{\text{COS, bio}}} \frac{\delta F_{\text{COS, bio}}}{\delta s} = GPP_{\text{SiB4}} \frac{\delta J}{\delta F_{\text{CO}_2, \text{NEE}}} + F_{\text{COS, bio, SiB4}} \frac{\delta J}{\delta F_{\text{COS, bio}}},$$

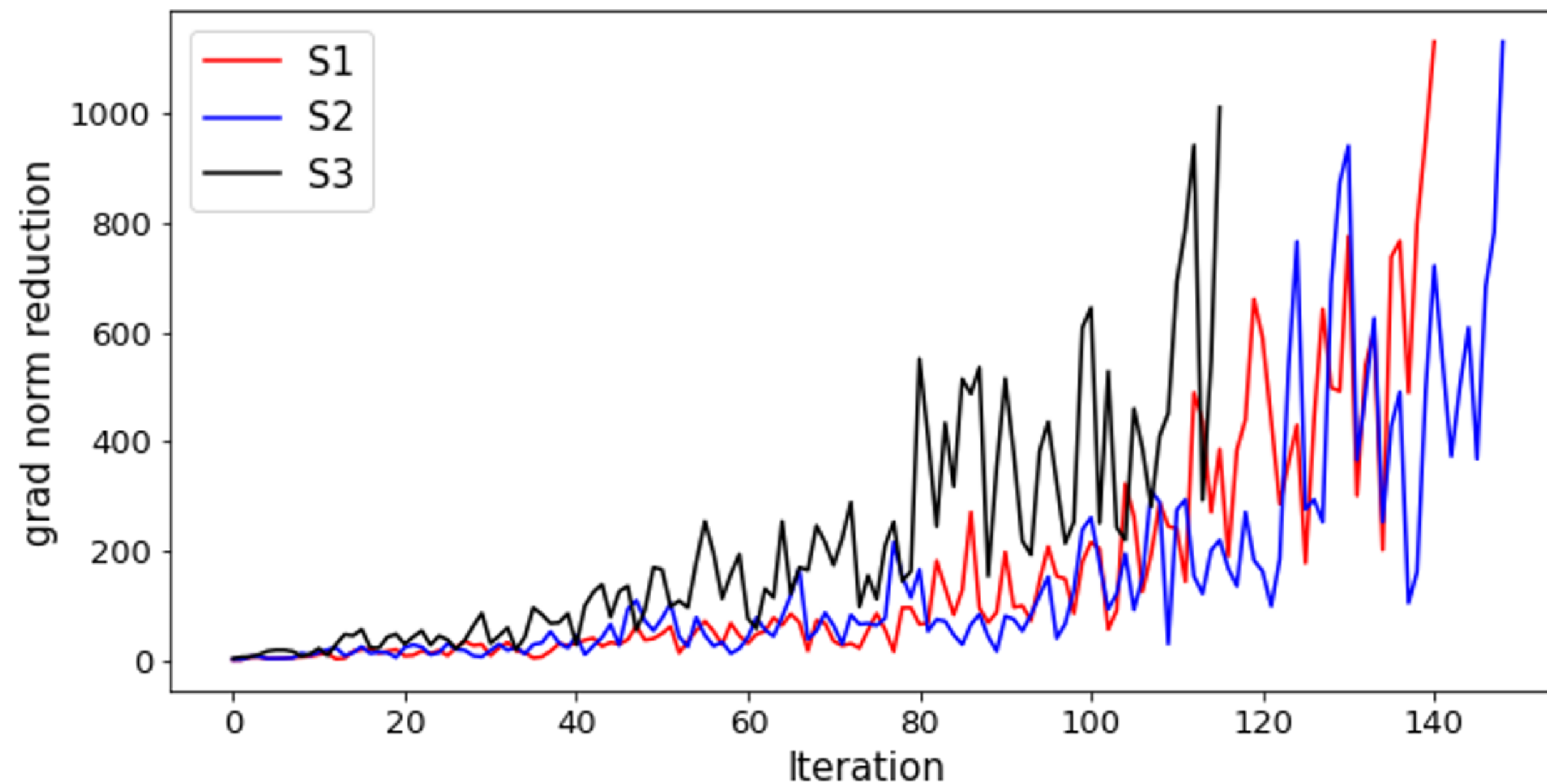
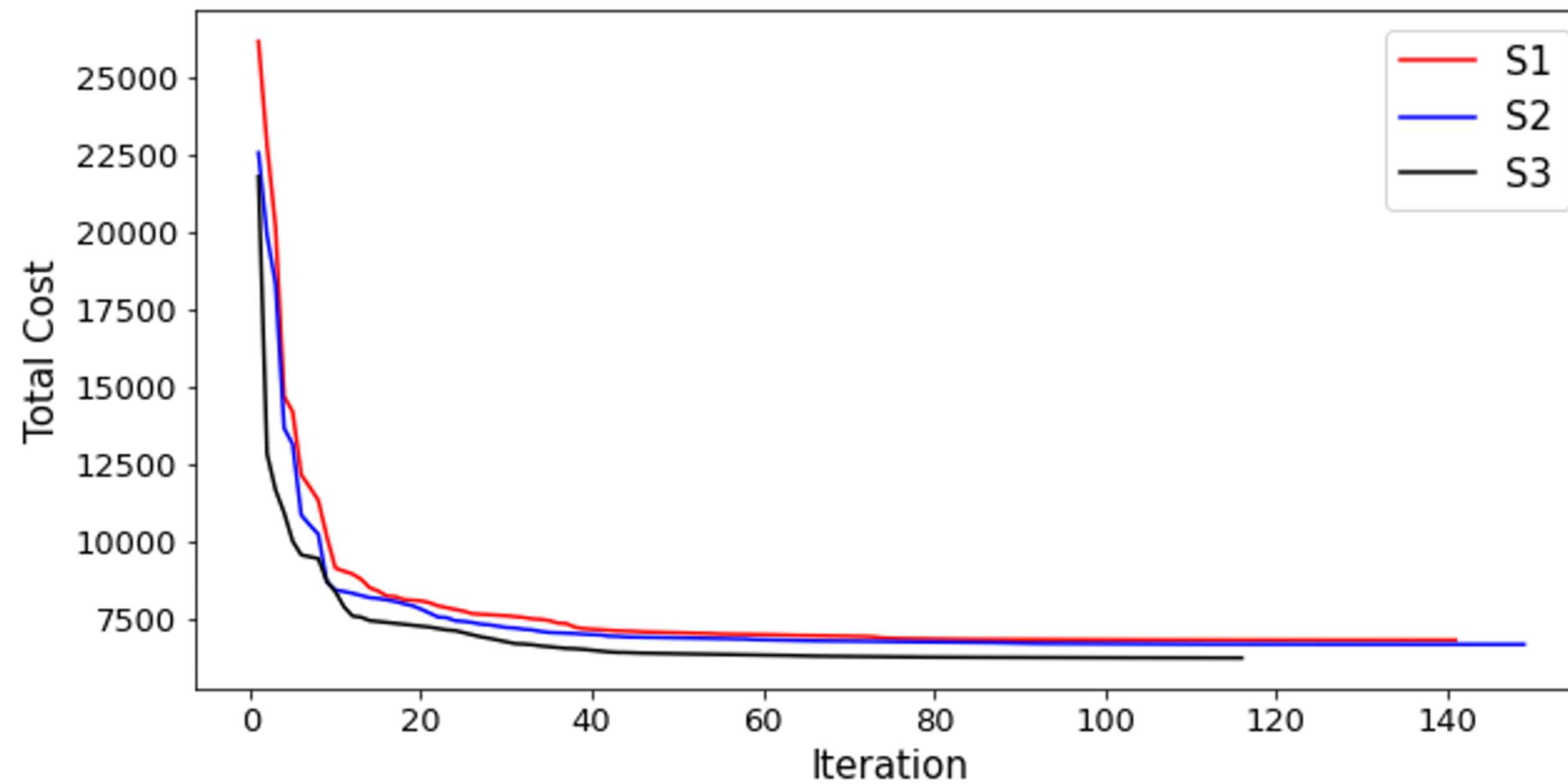
$$\frac{\delta J}{\delta TER} = \frac{\delta J}{\delta F_{\text{CO}_2, \text{NEE}}} \cdot \frac{\delta F_{\text{CO}_2, \text{NEE}}}{\delta TER} = \frac{\delta J}{\delta F_{\text{CO}_2, \text{NEE}}},$$



Convergence

**Note: Congrad did not work!
Adjoint/Gradient test OK**

**S1-S3: different COS
biosphere choices**

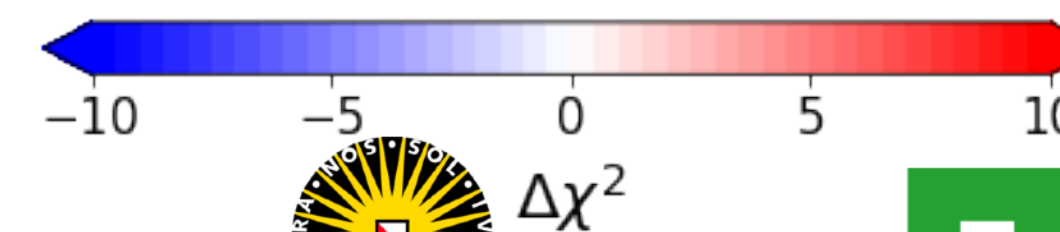
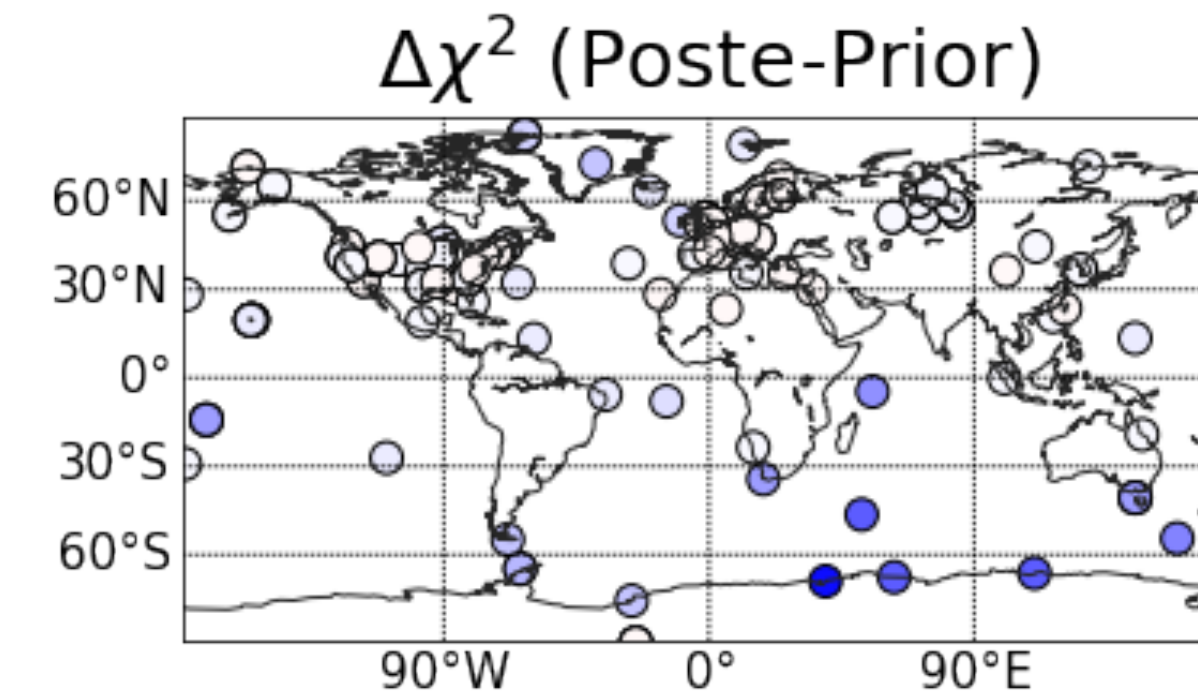
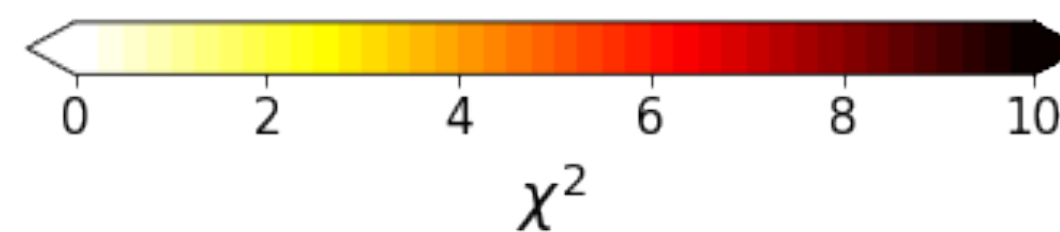
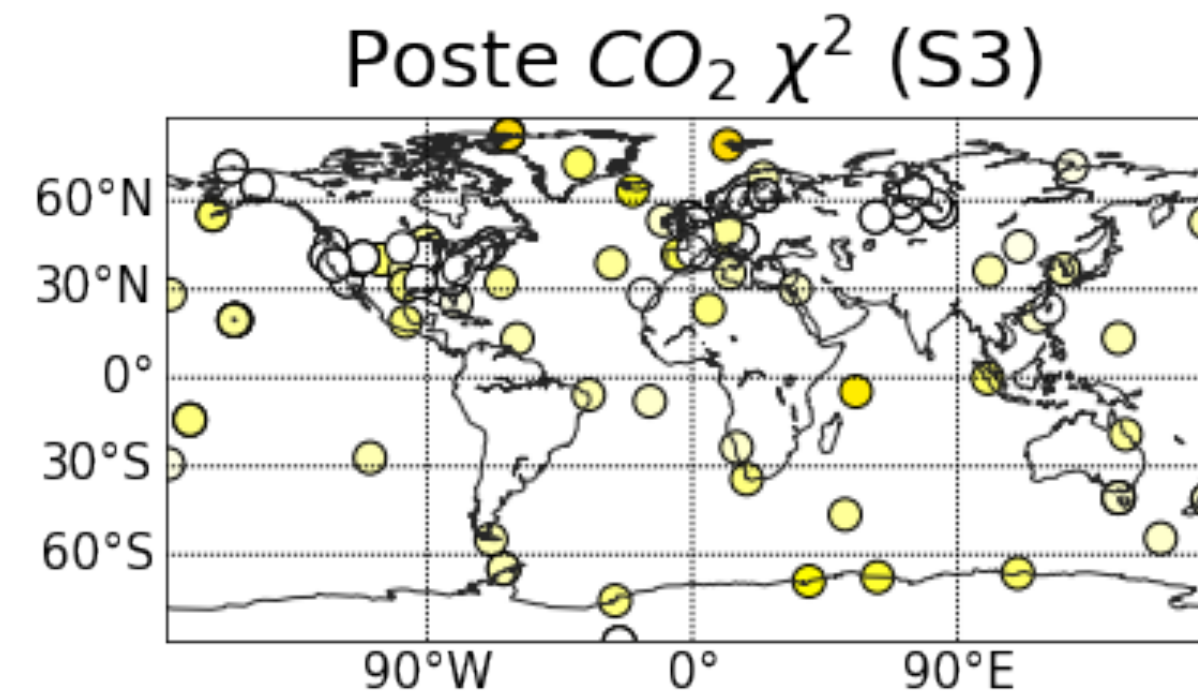
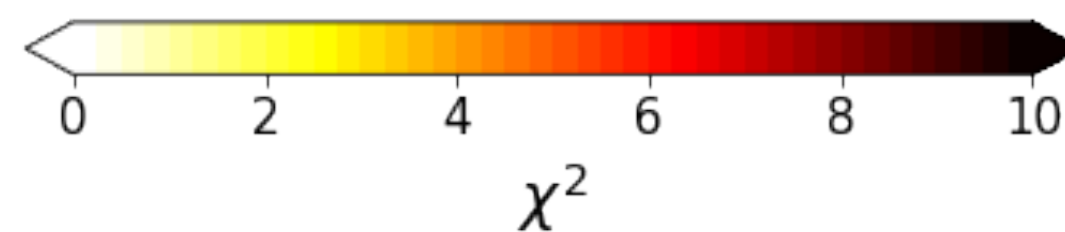
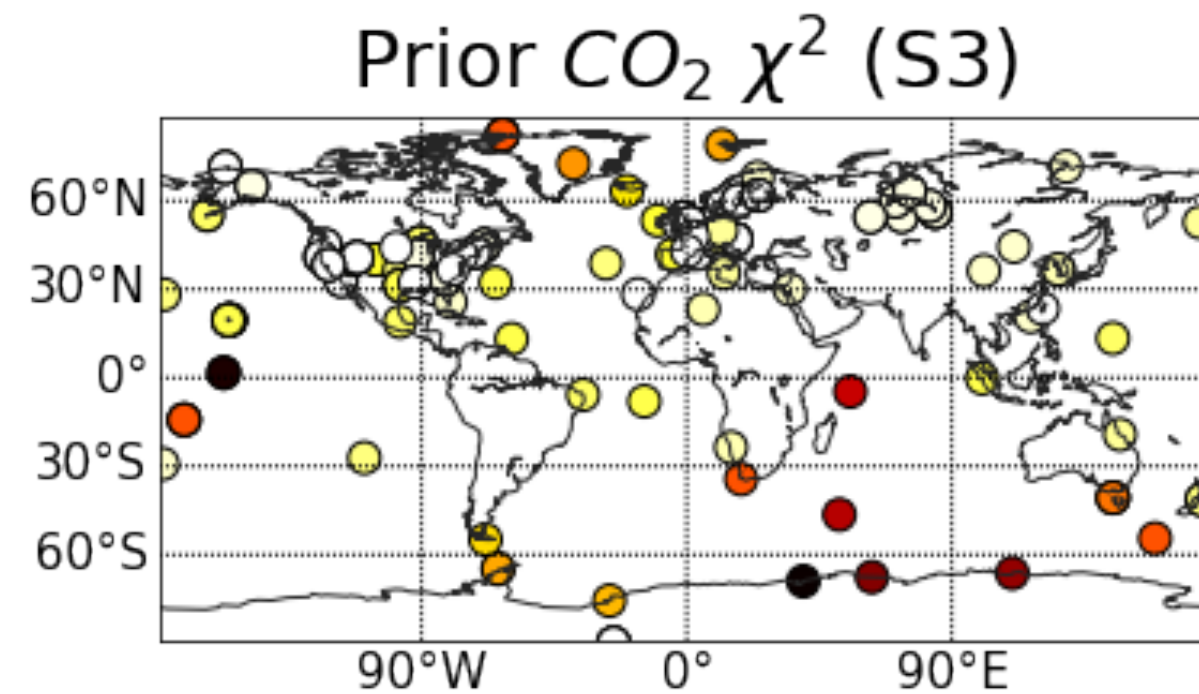
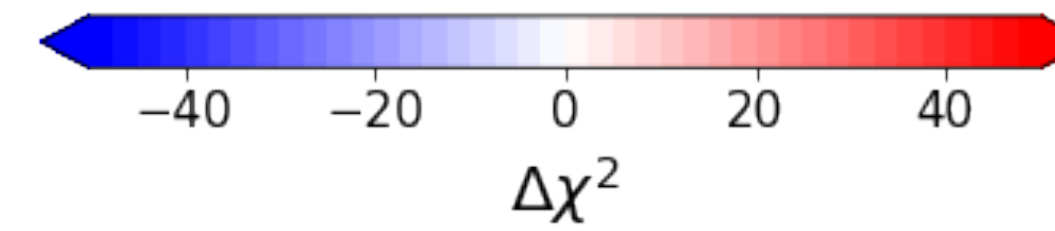
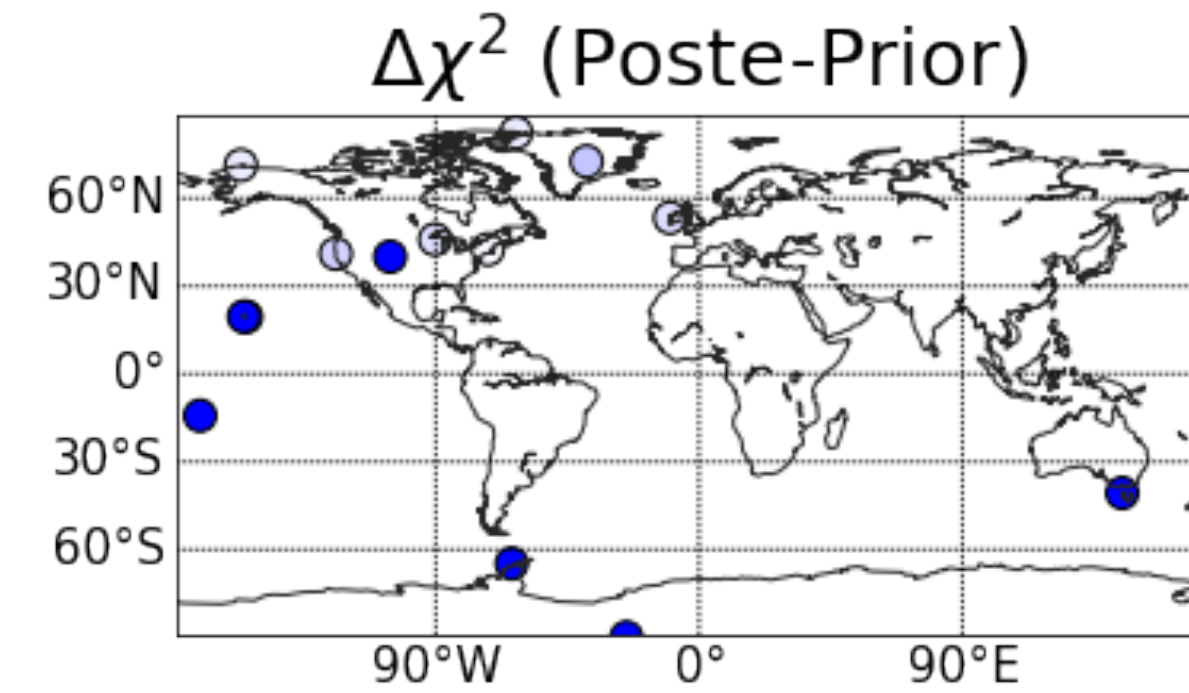
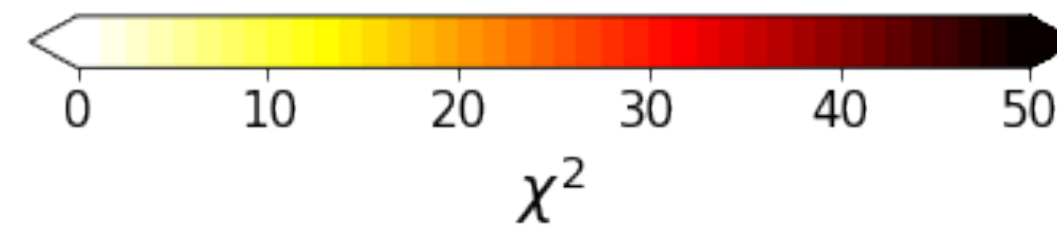
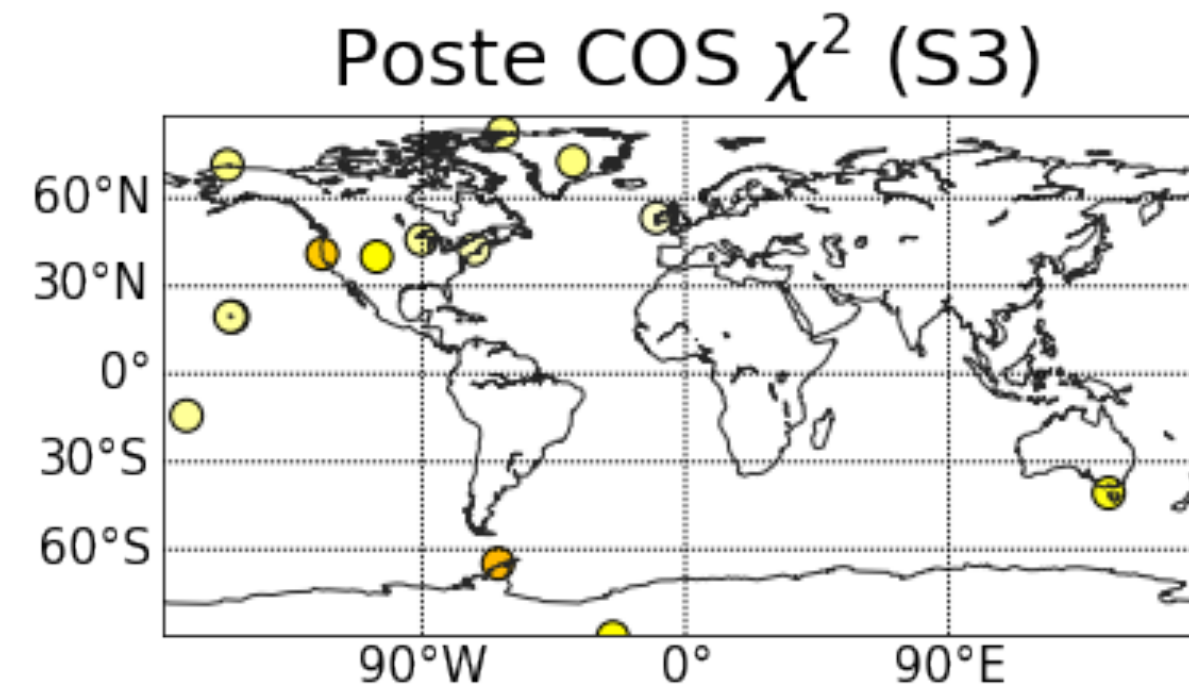
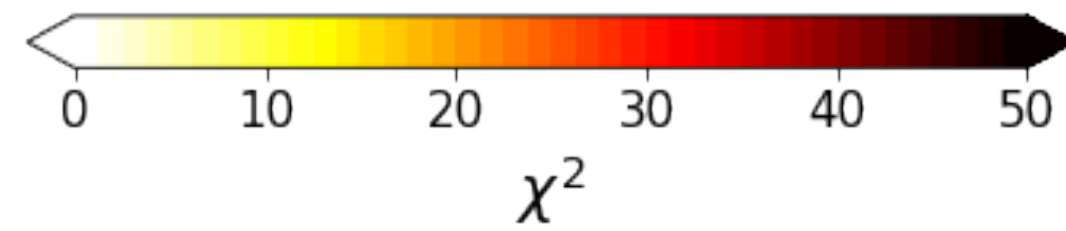
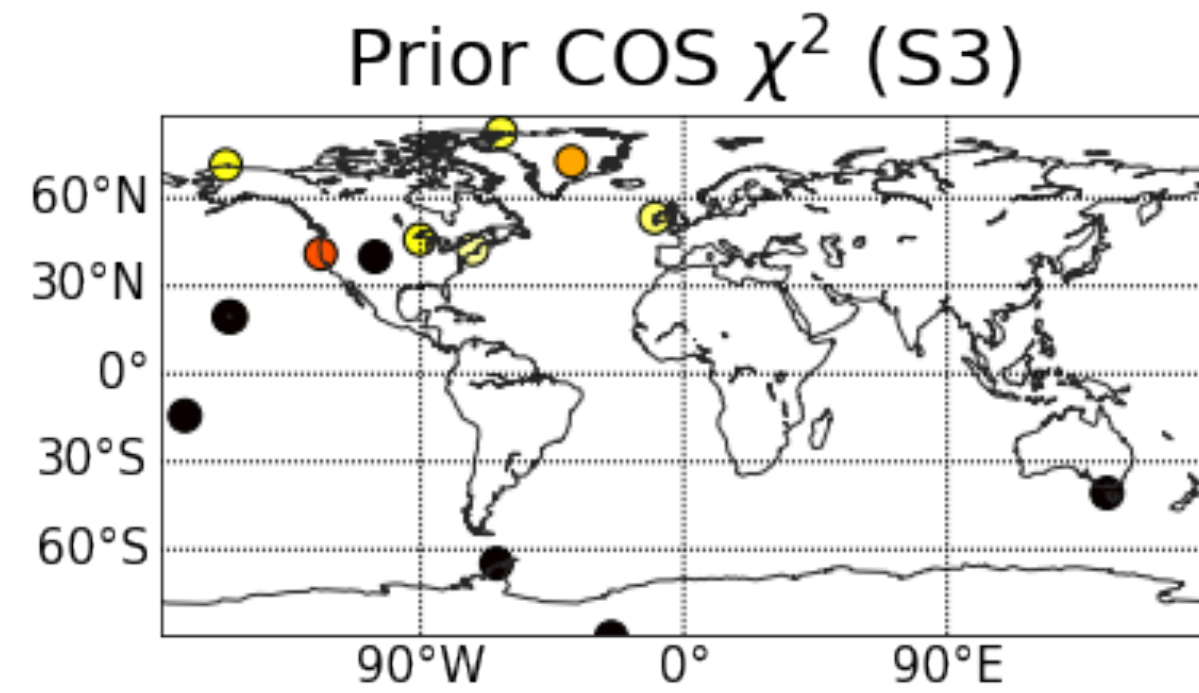


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Improvement

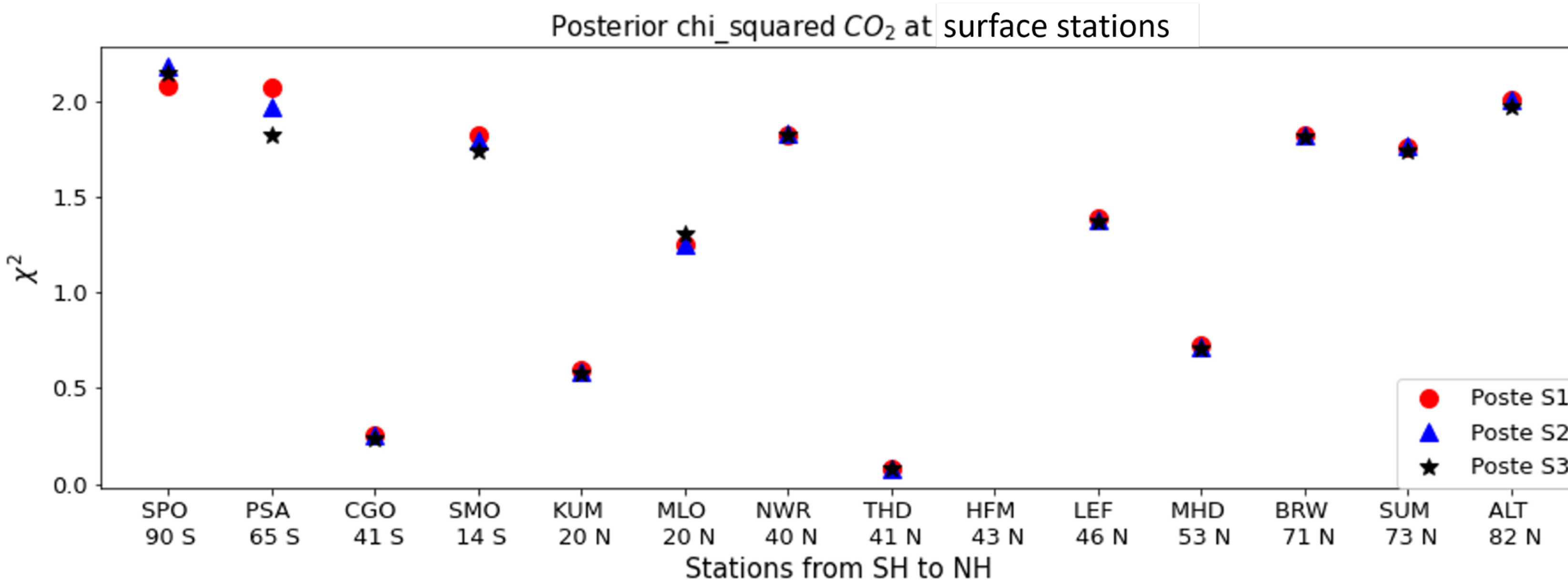
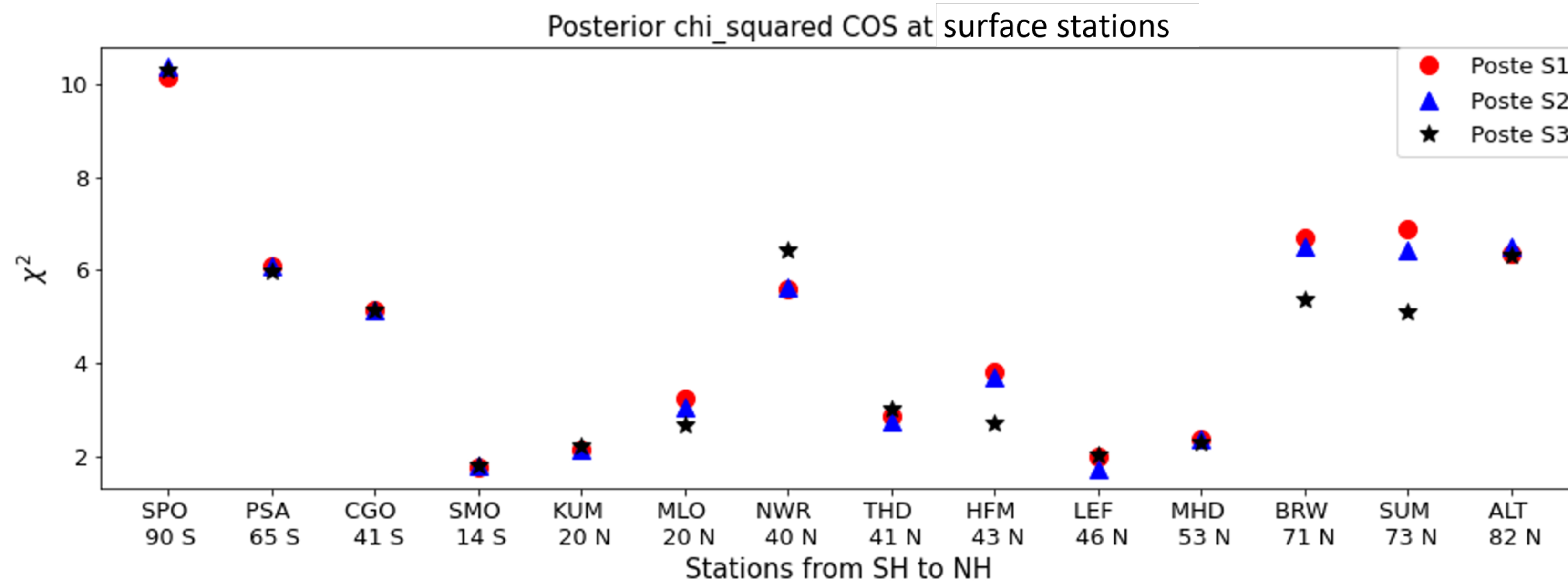


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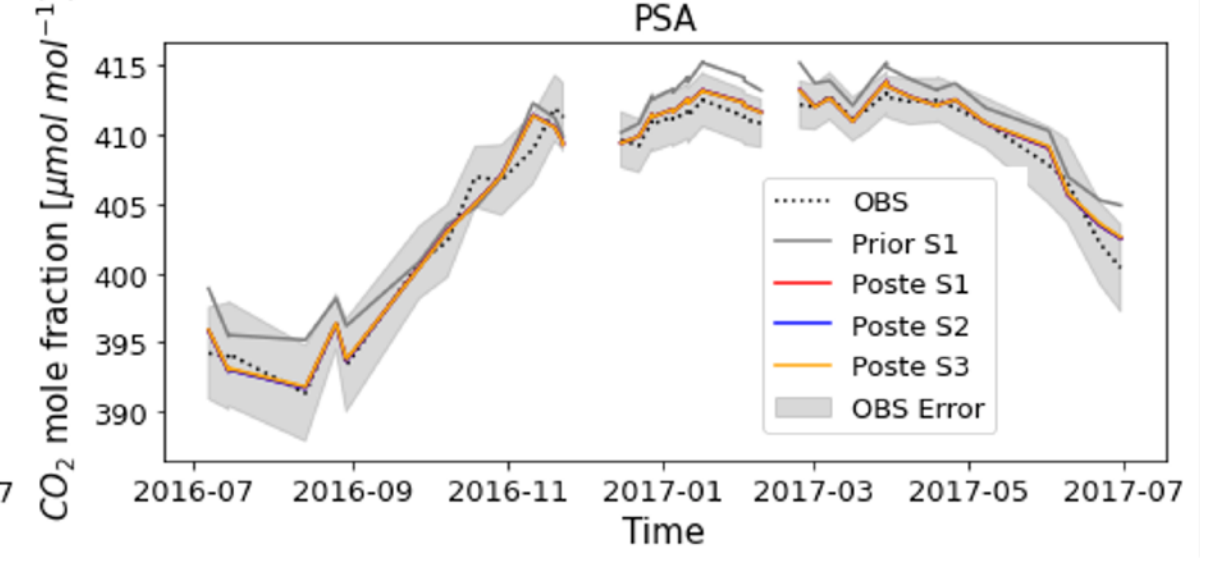
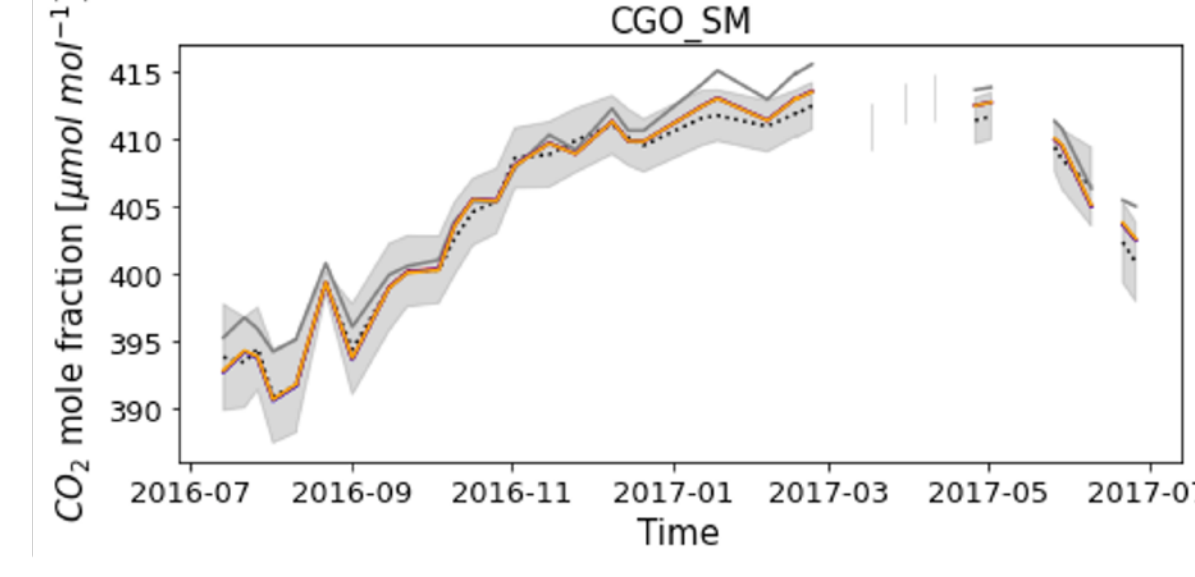
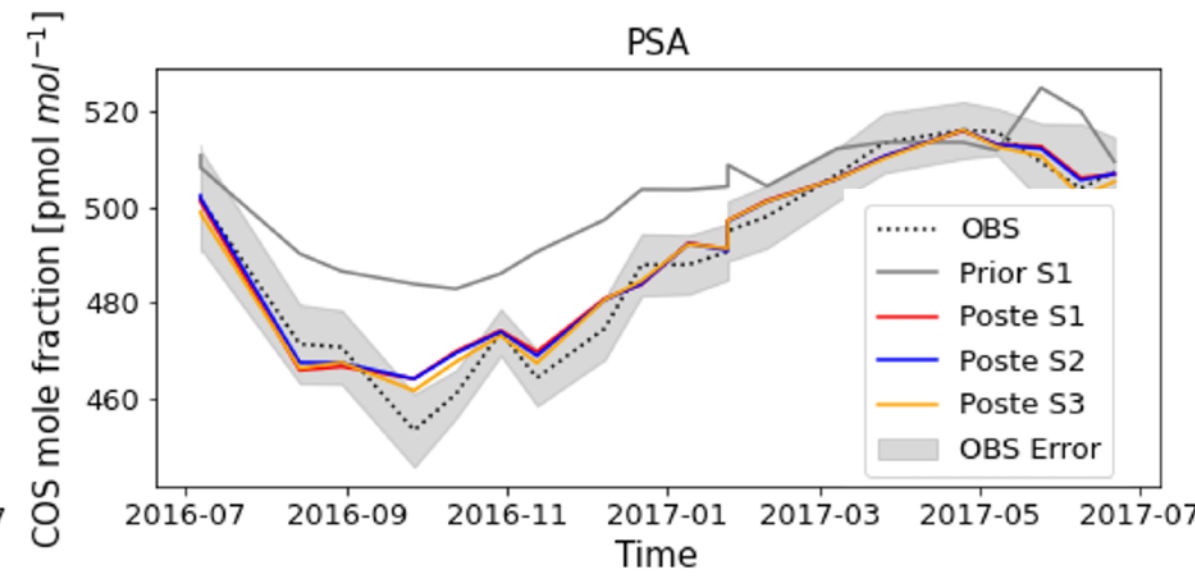
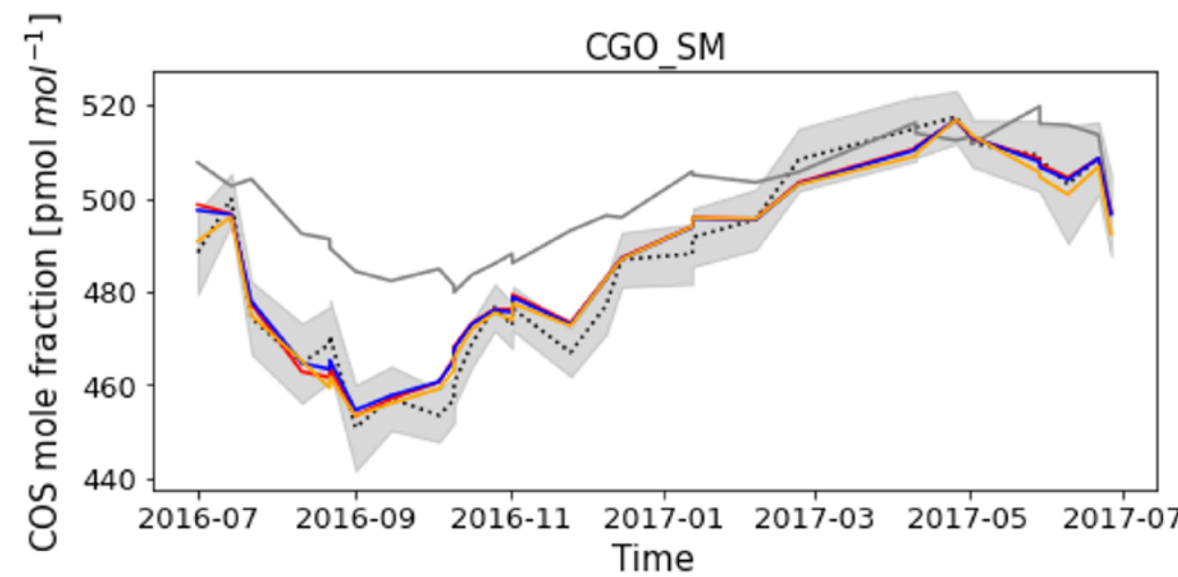
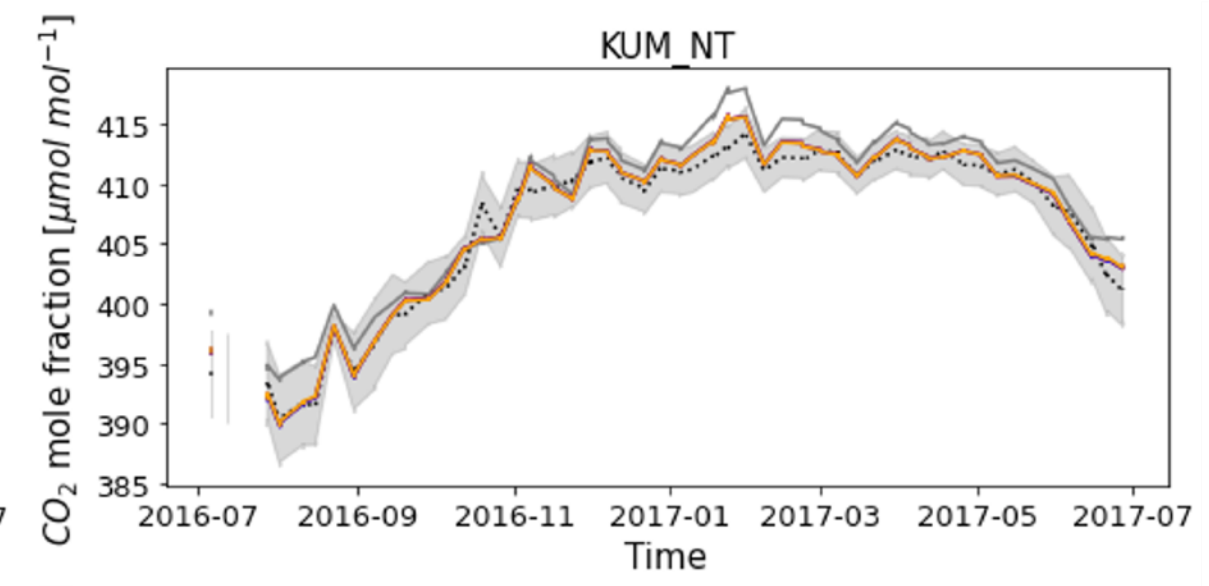
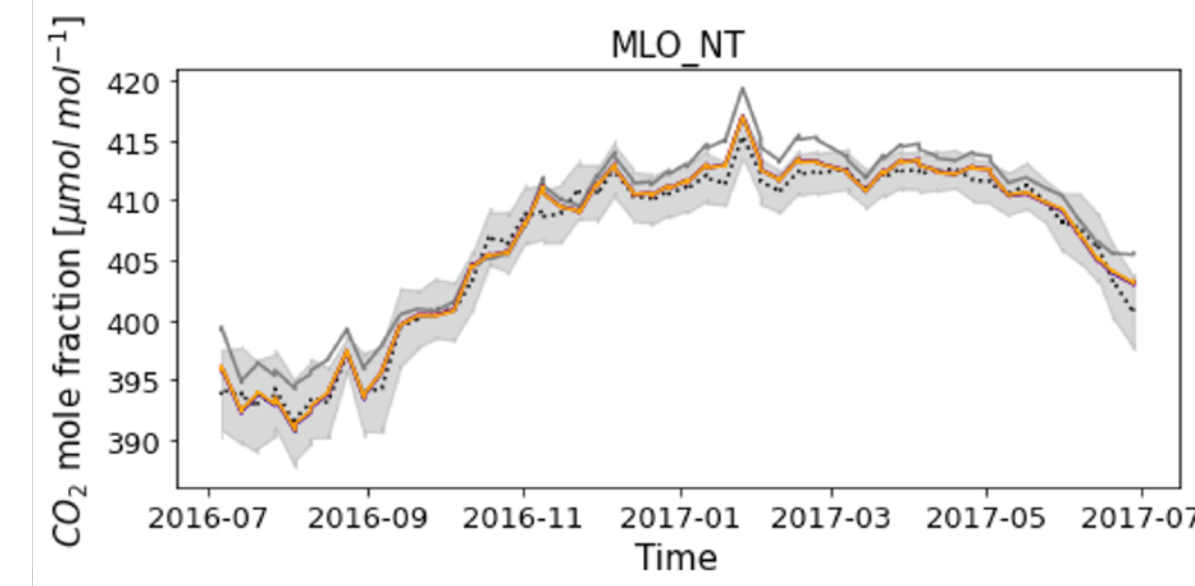
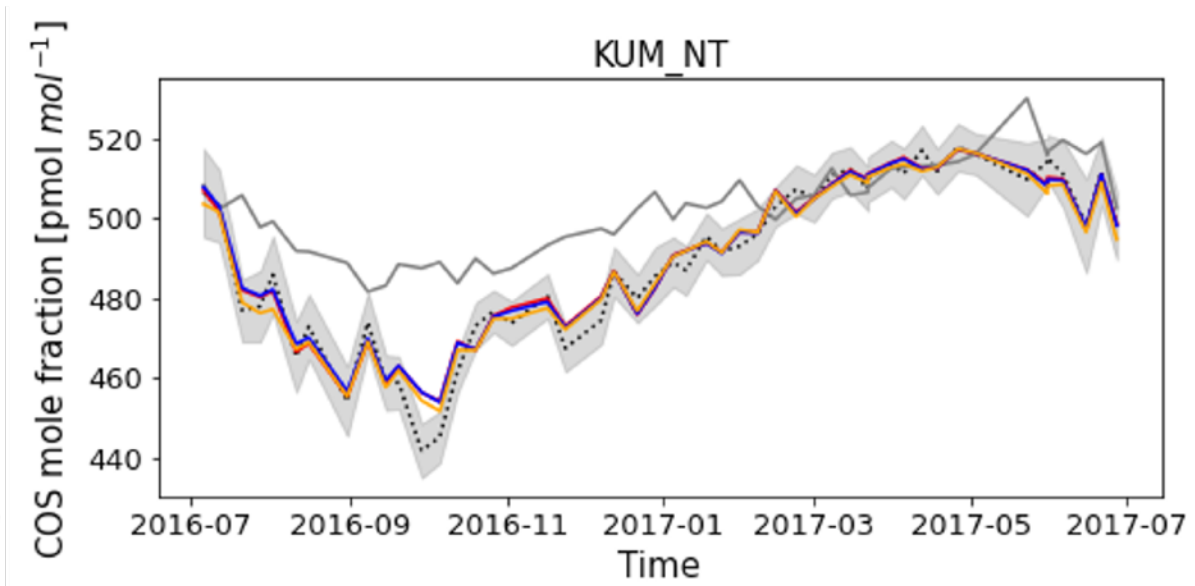
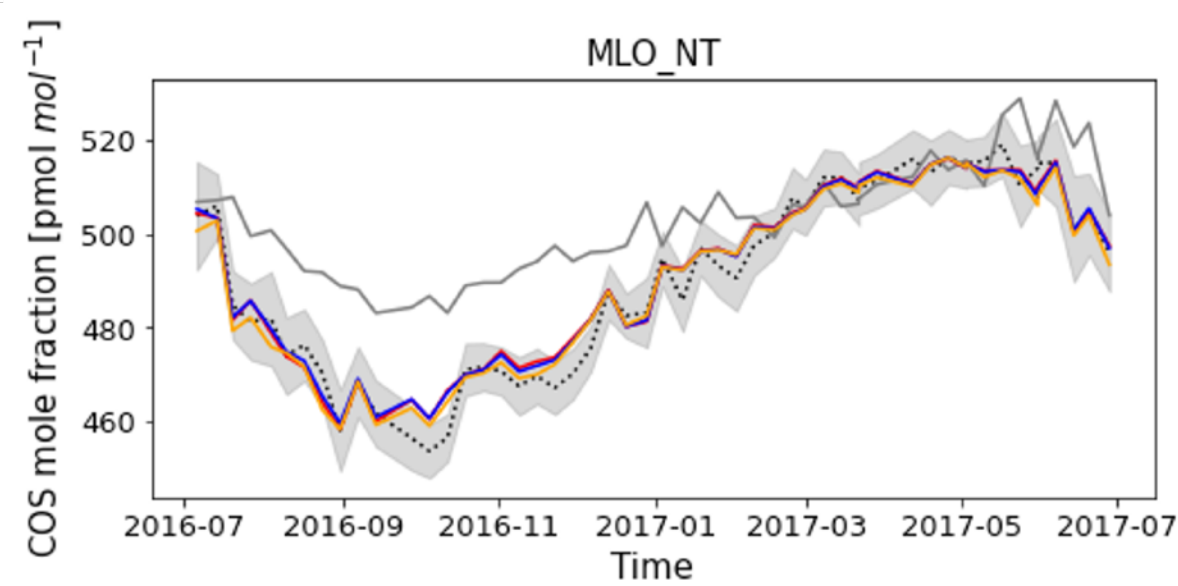
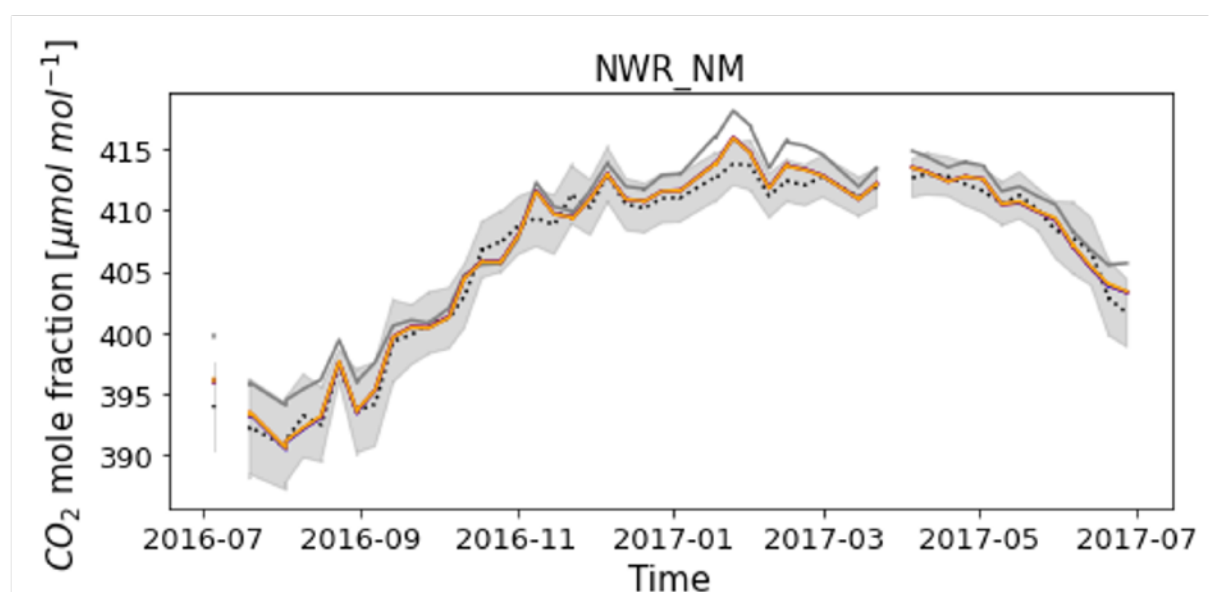
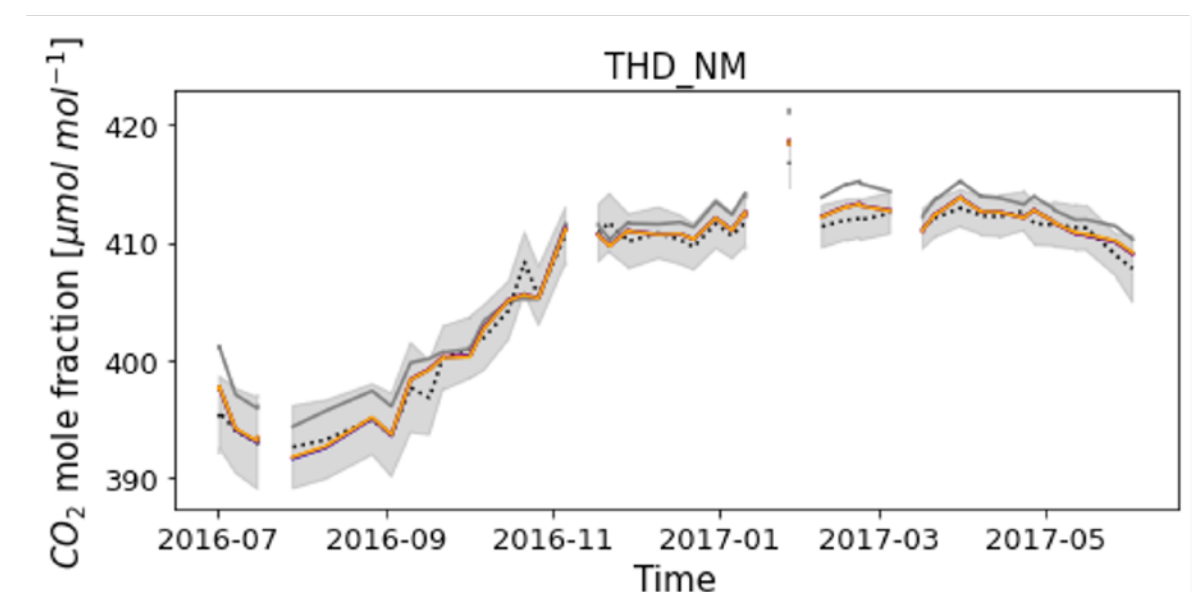
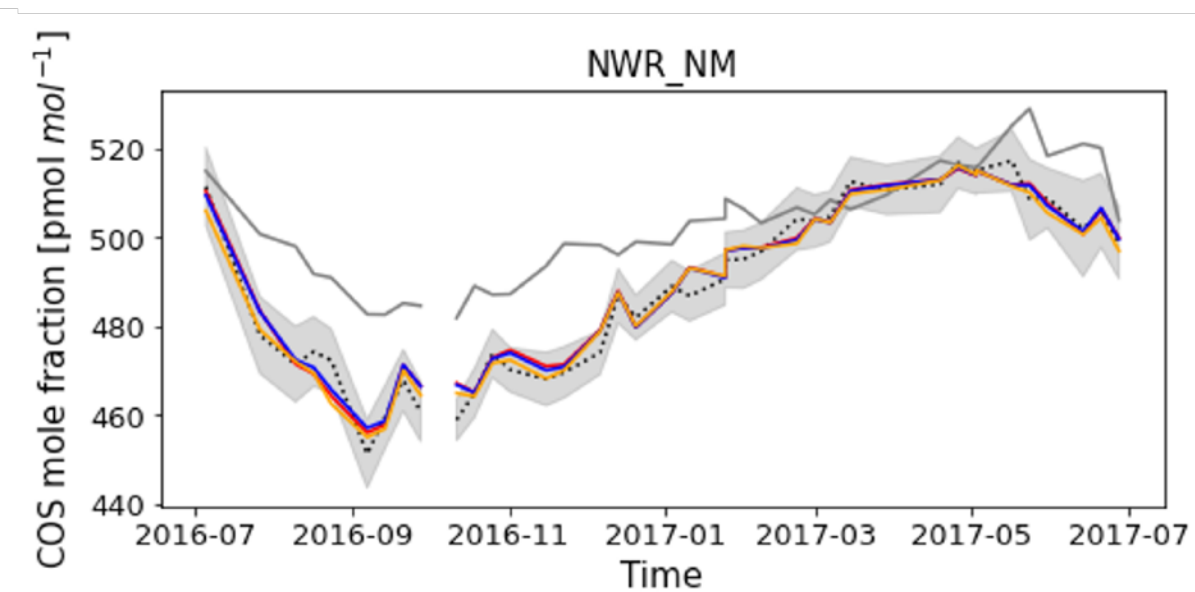
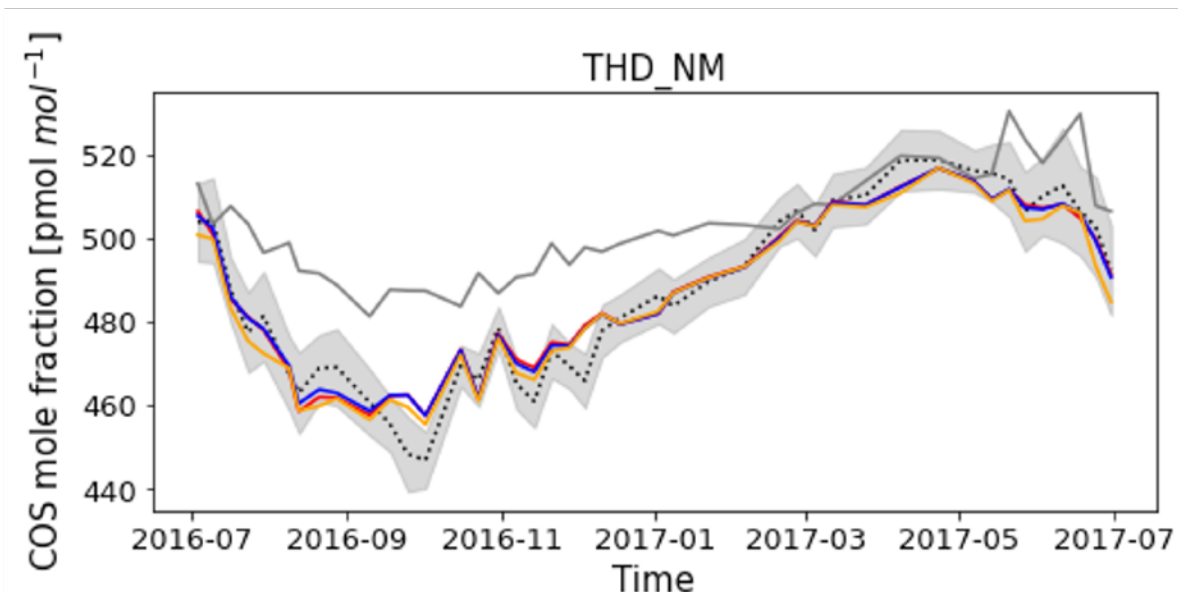
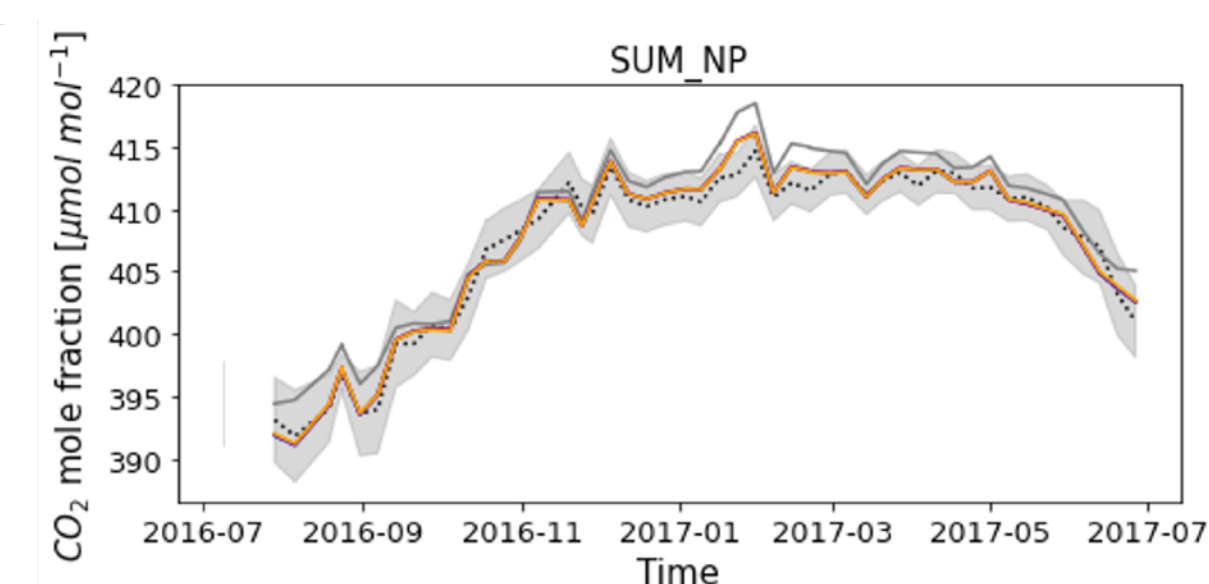
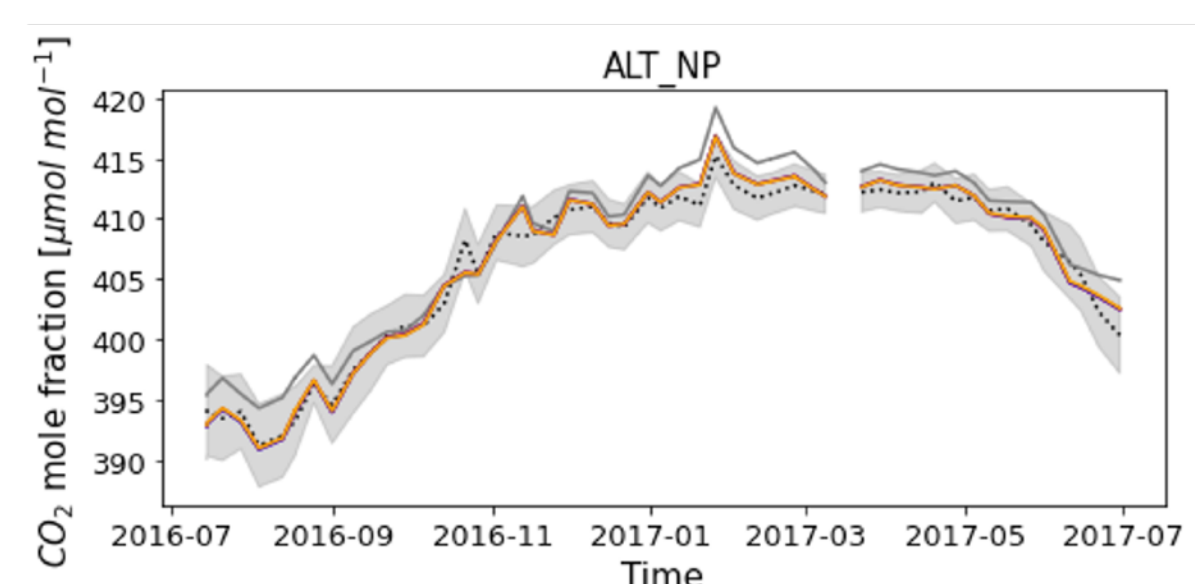
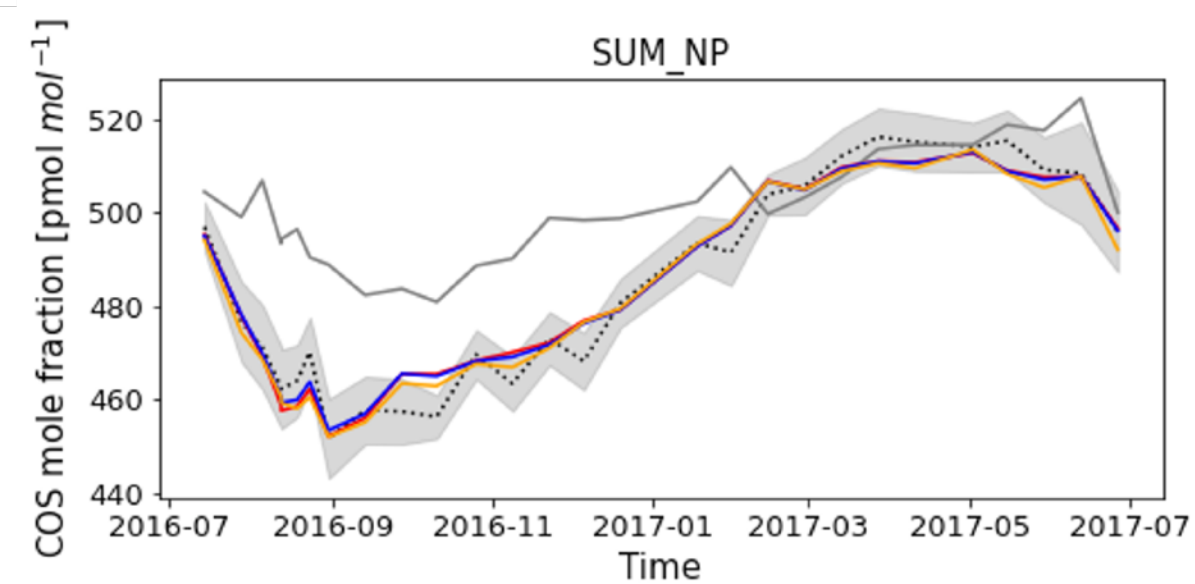
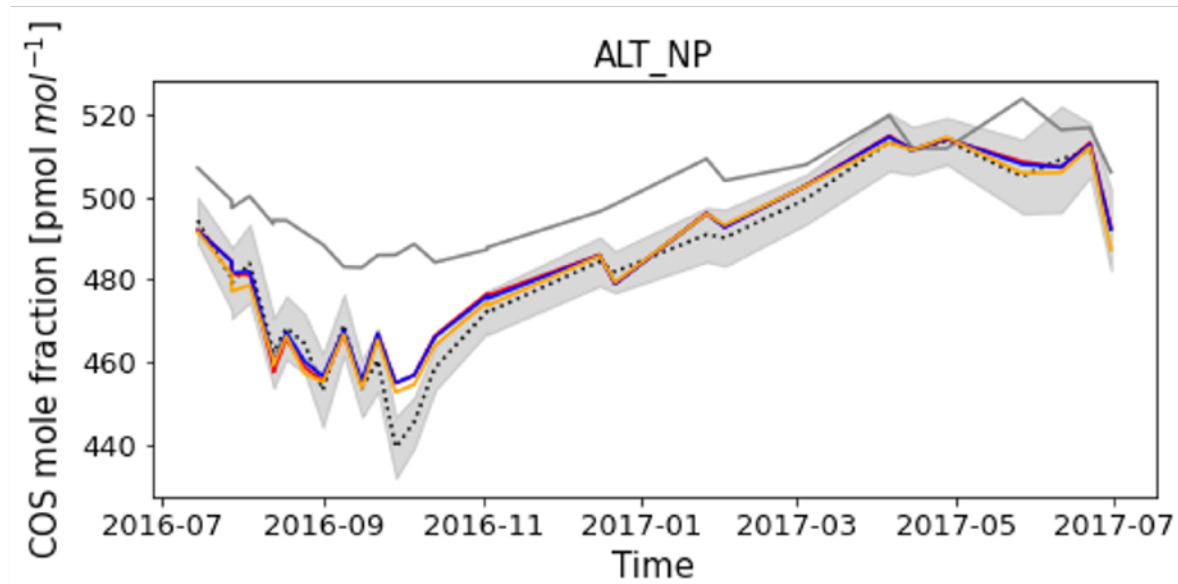
Improvement



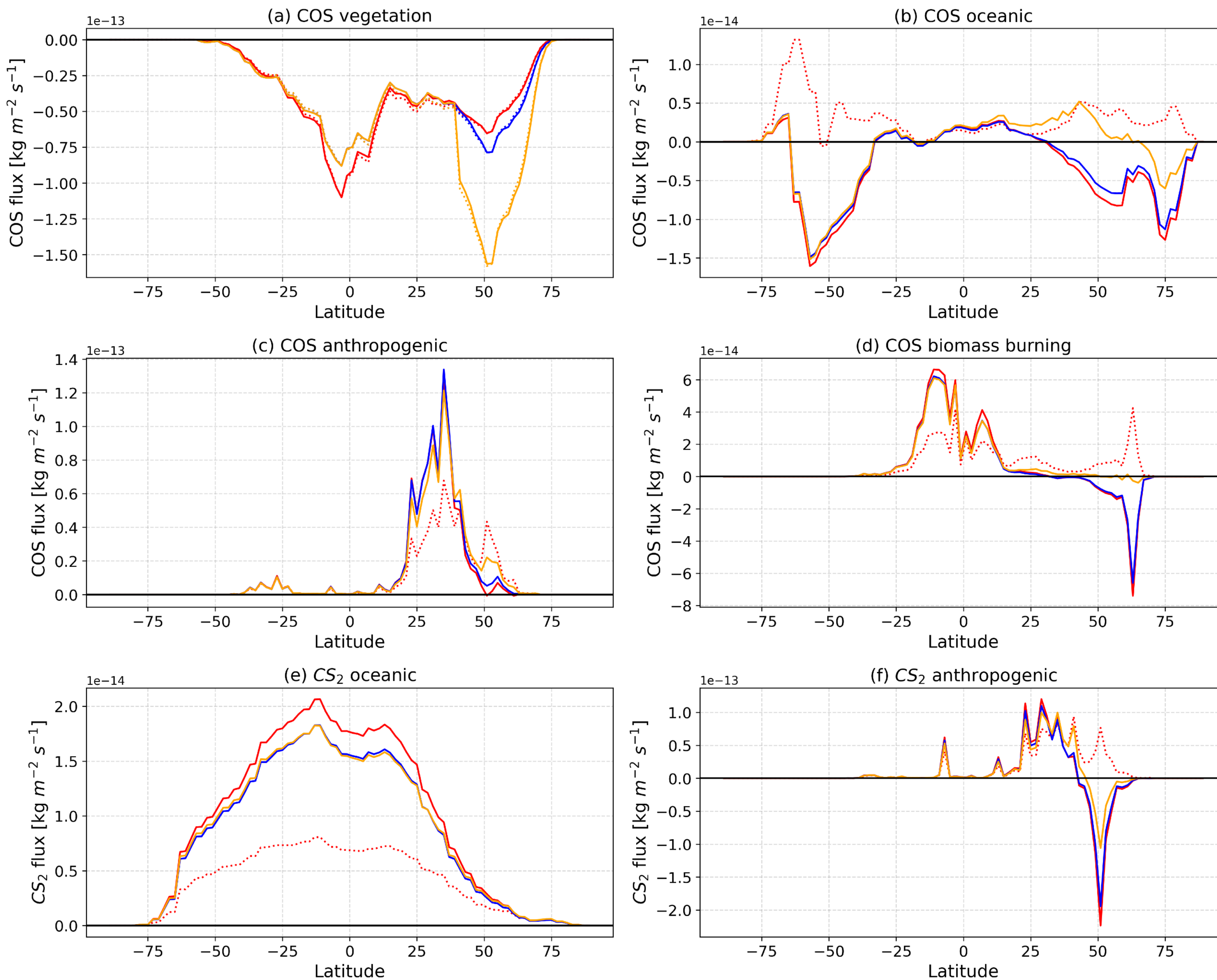
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Fluxes COS



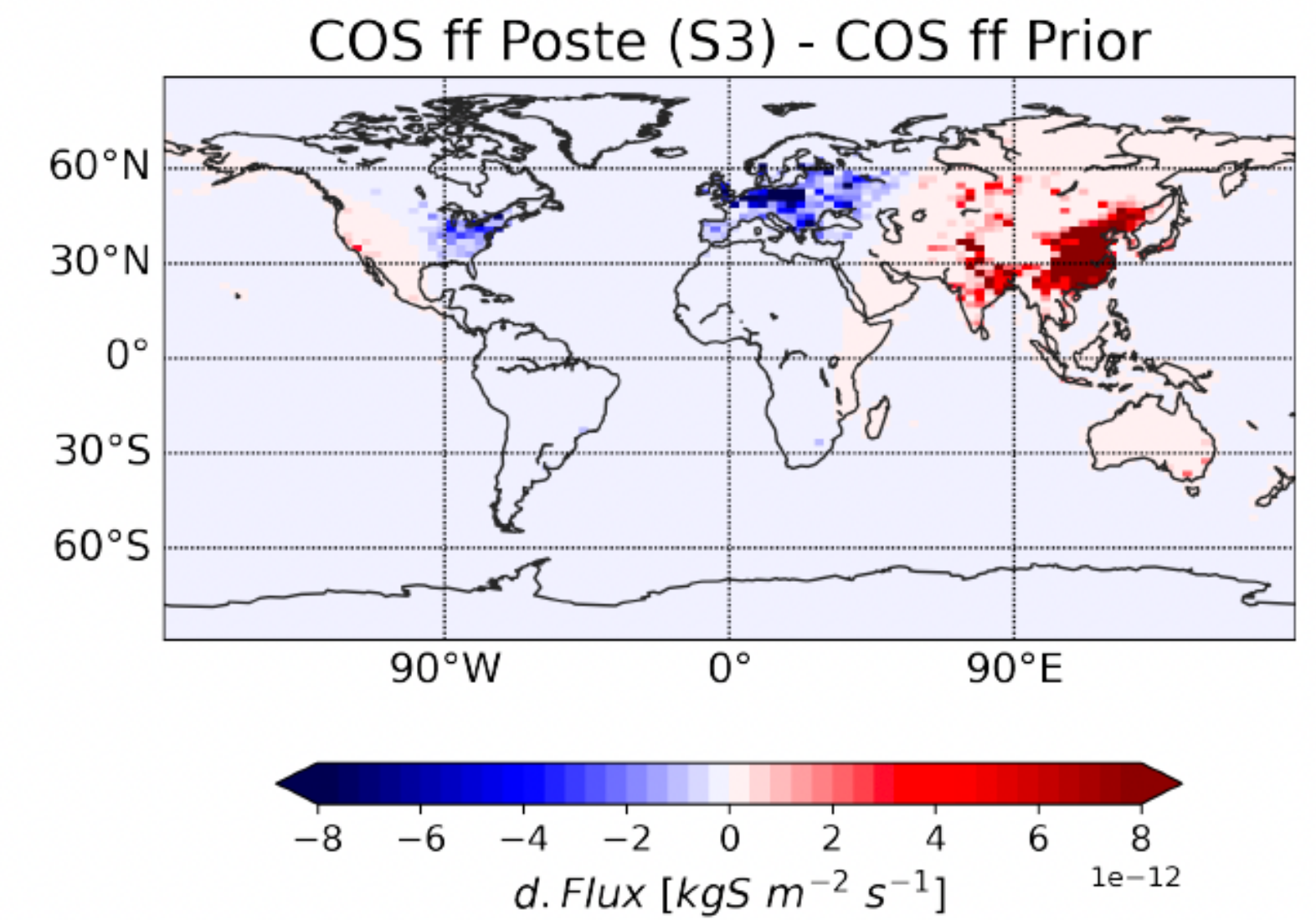
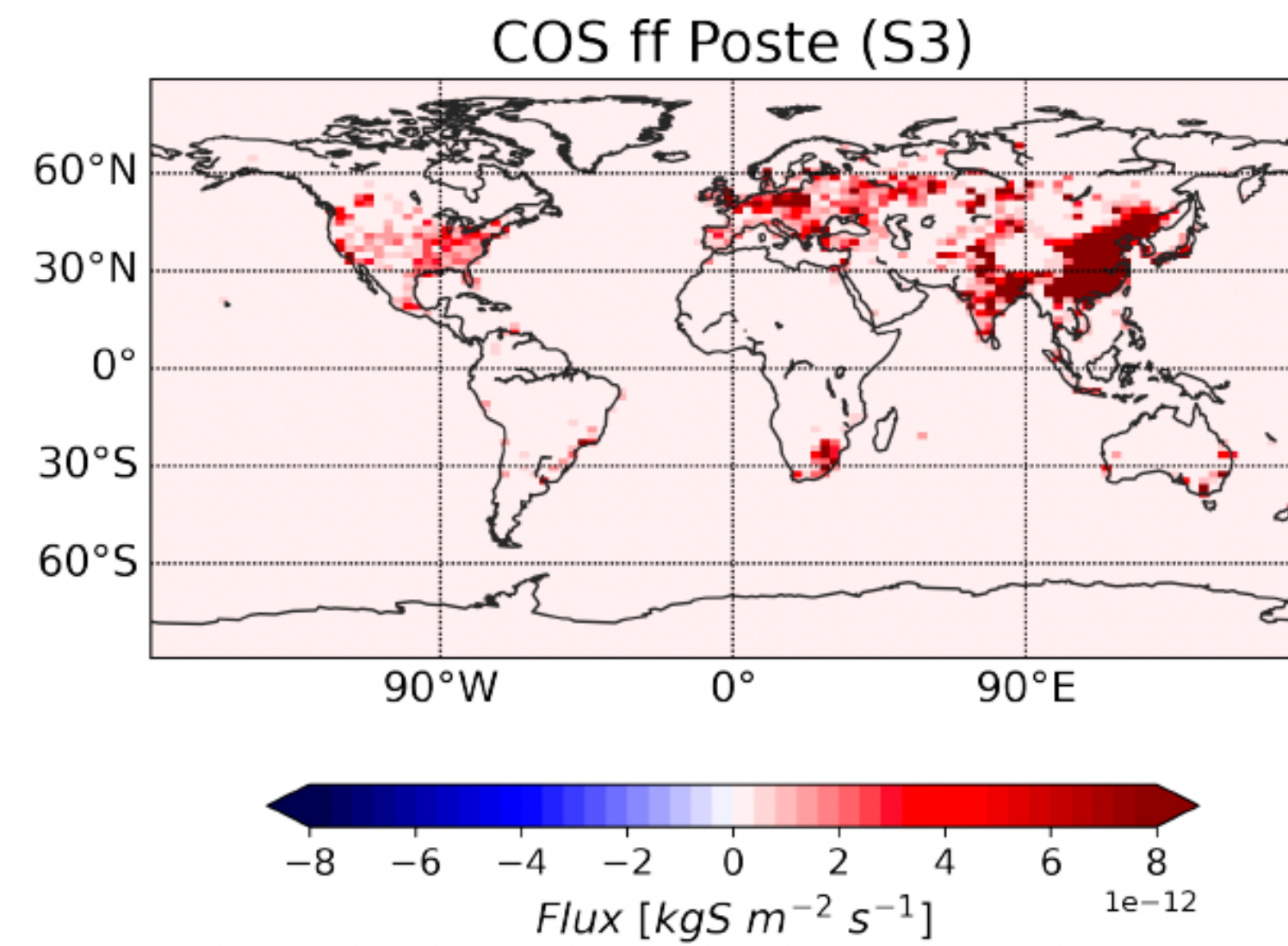
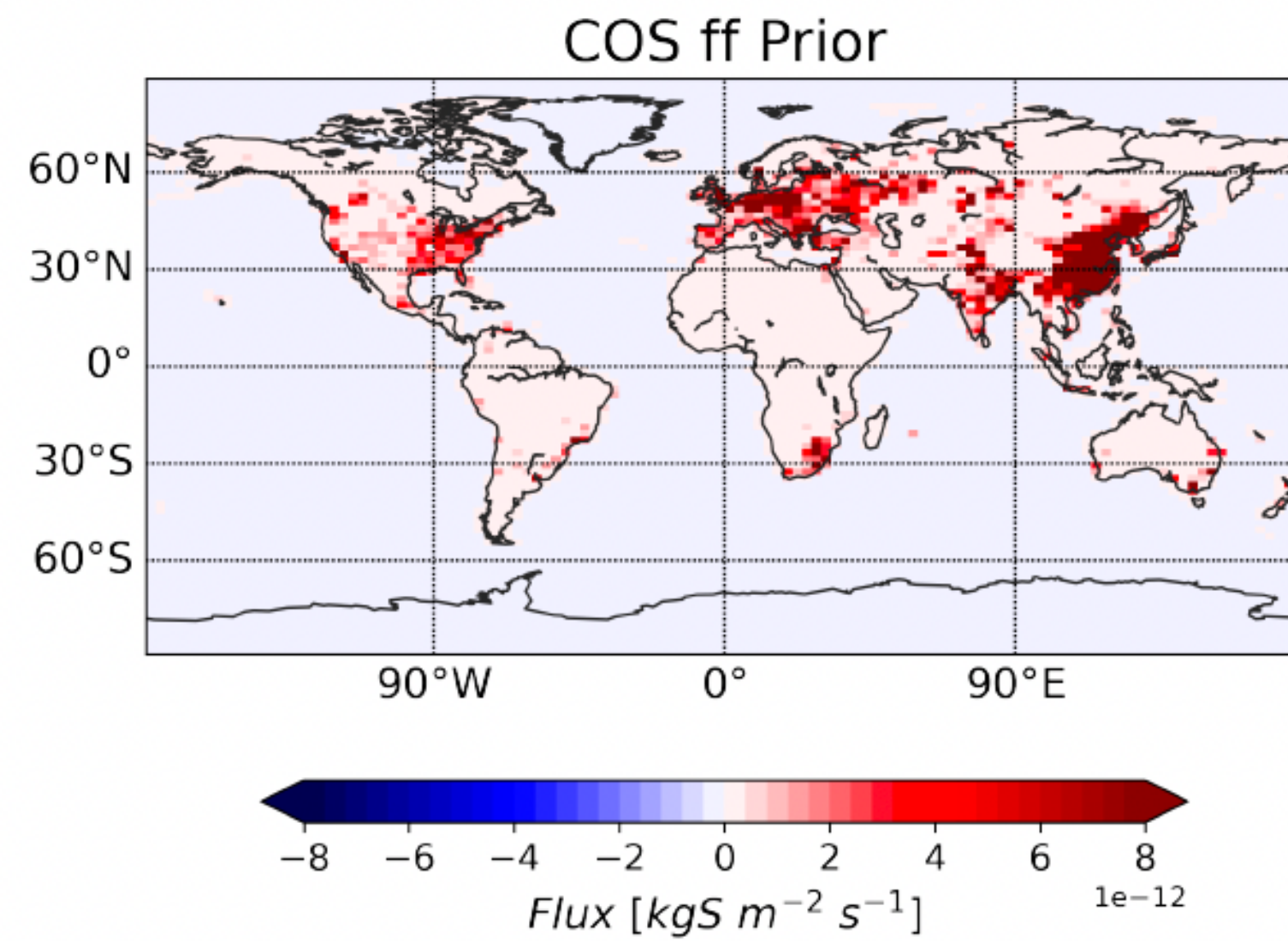
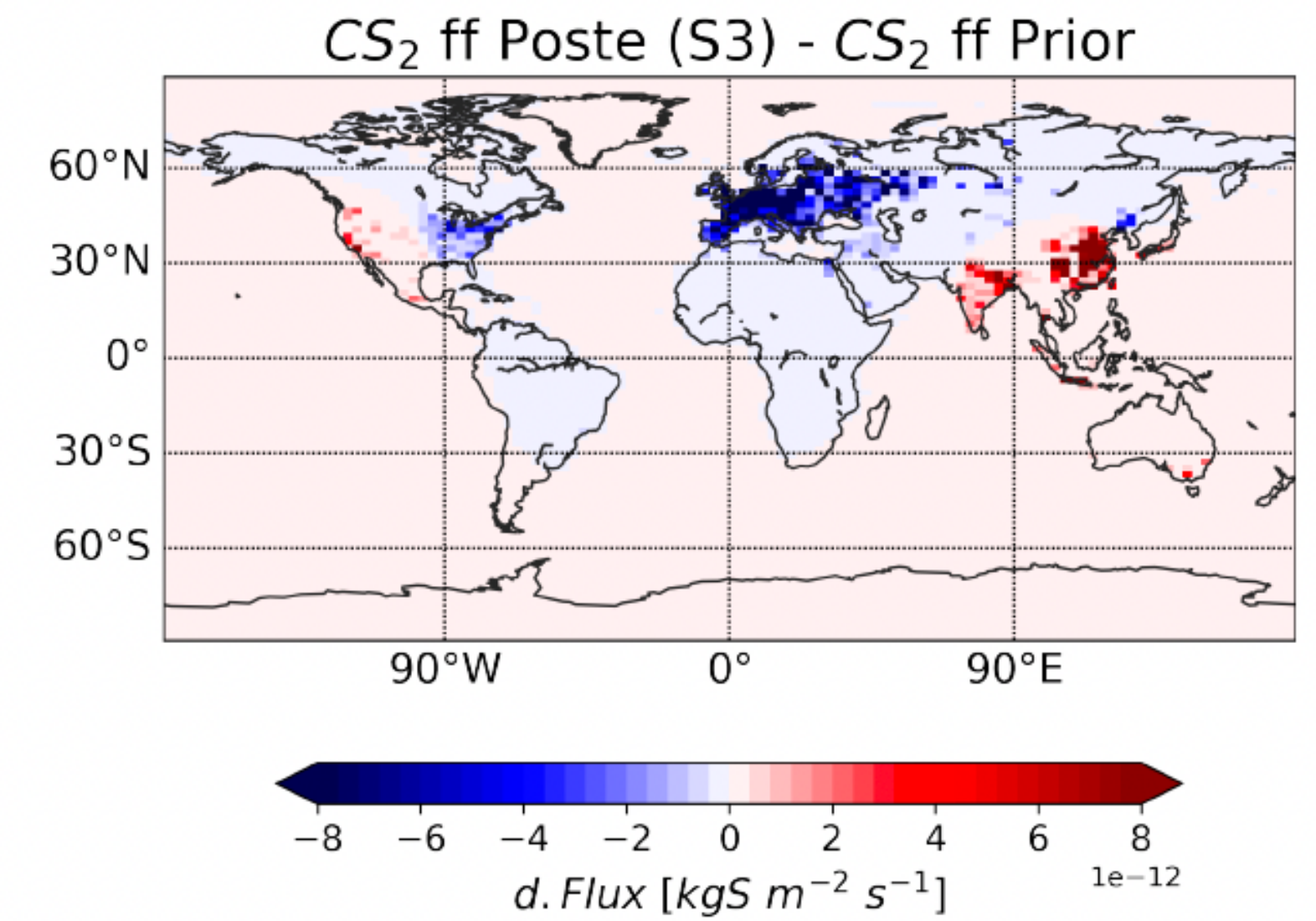
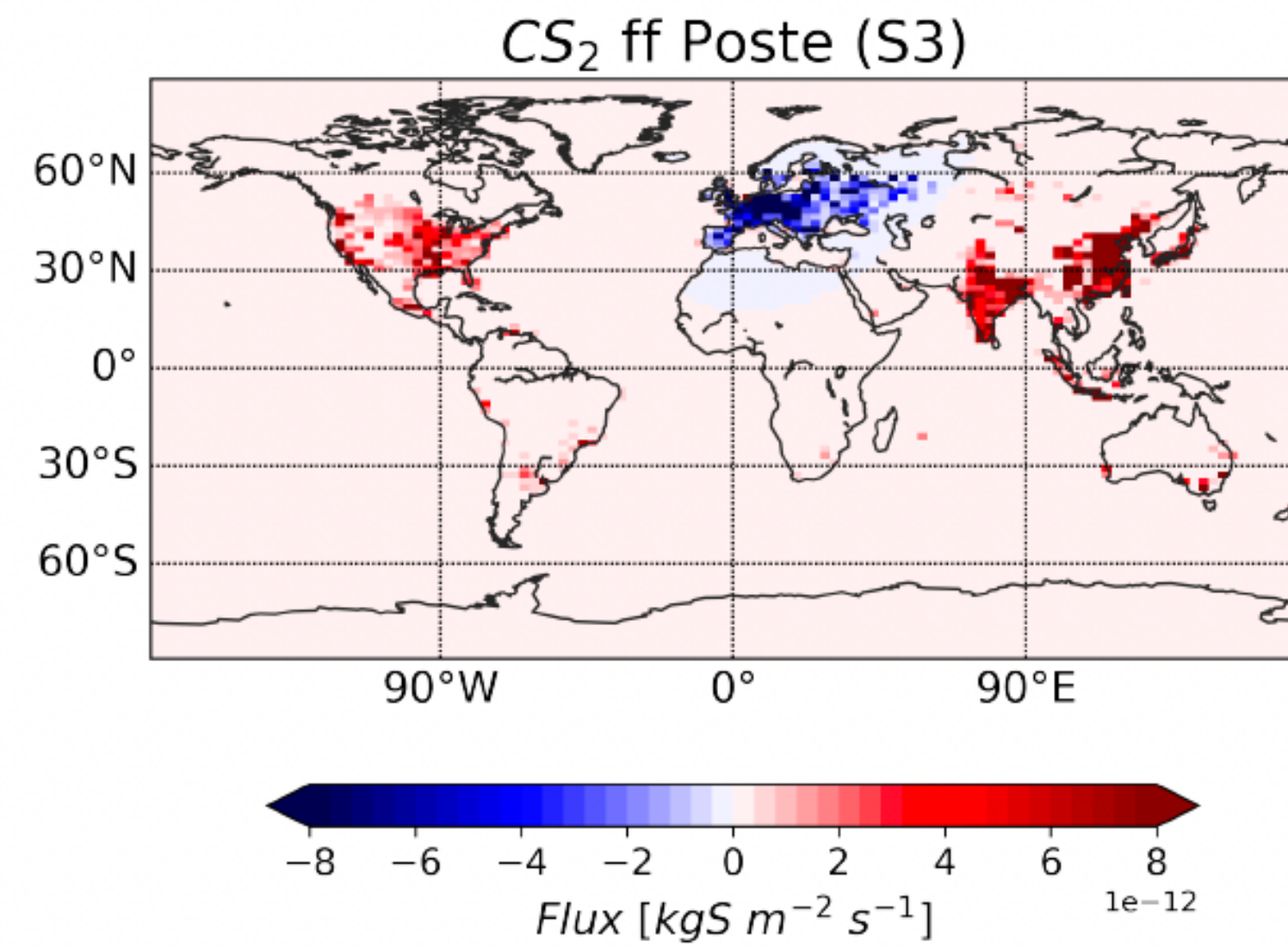
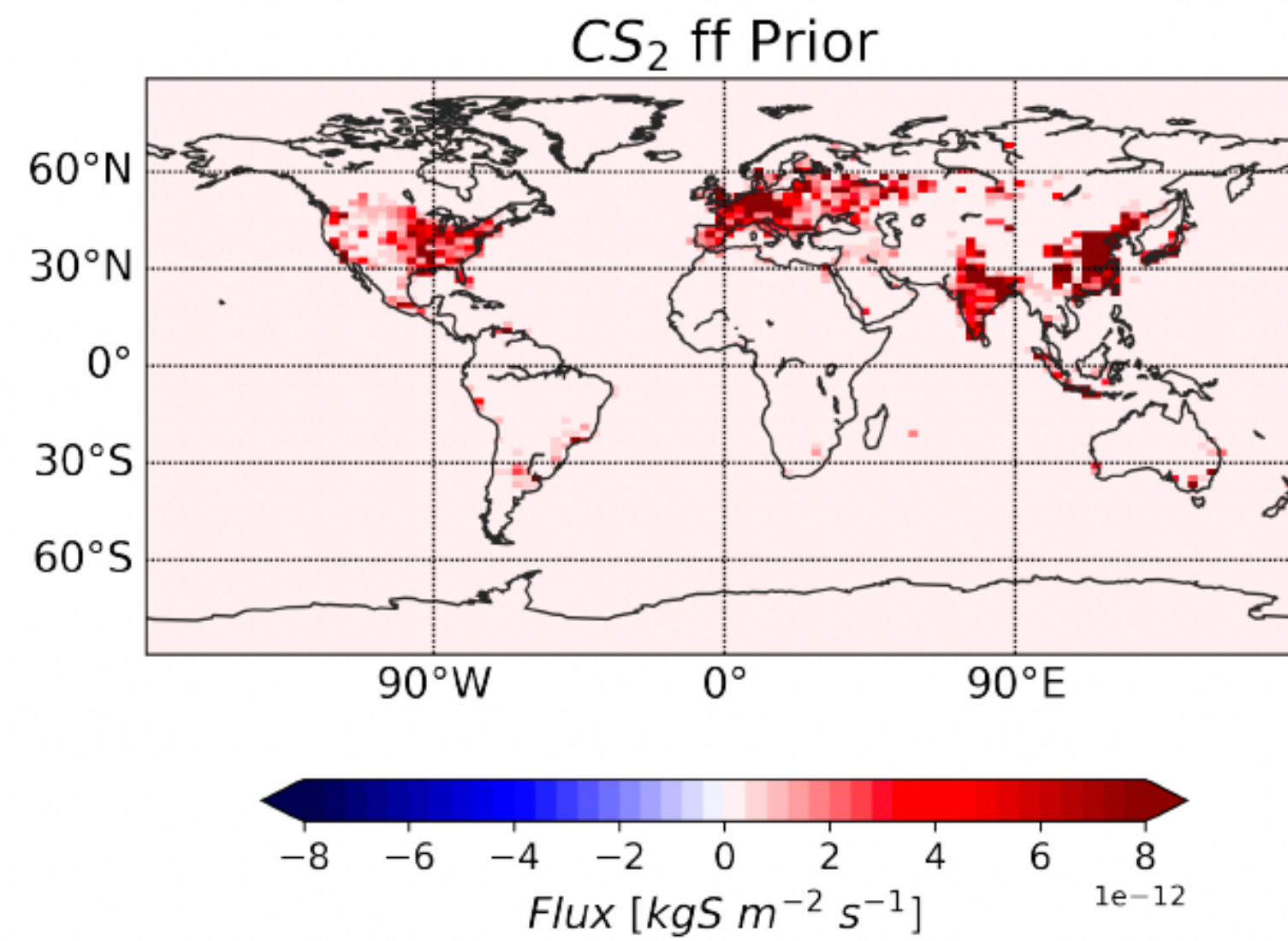
..... prior S1
 prior S2
 prior S3
 ——— poste S1
 ——— poste S2
 ——— poste S3



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Fossil Fluxes CS₂/COS

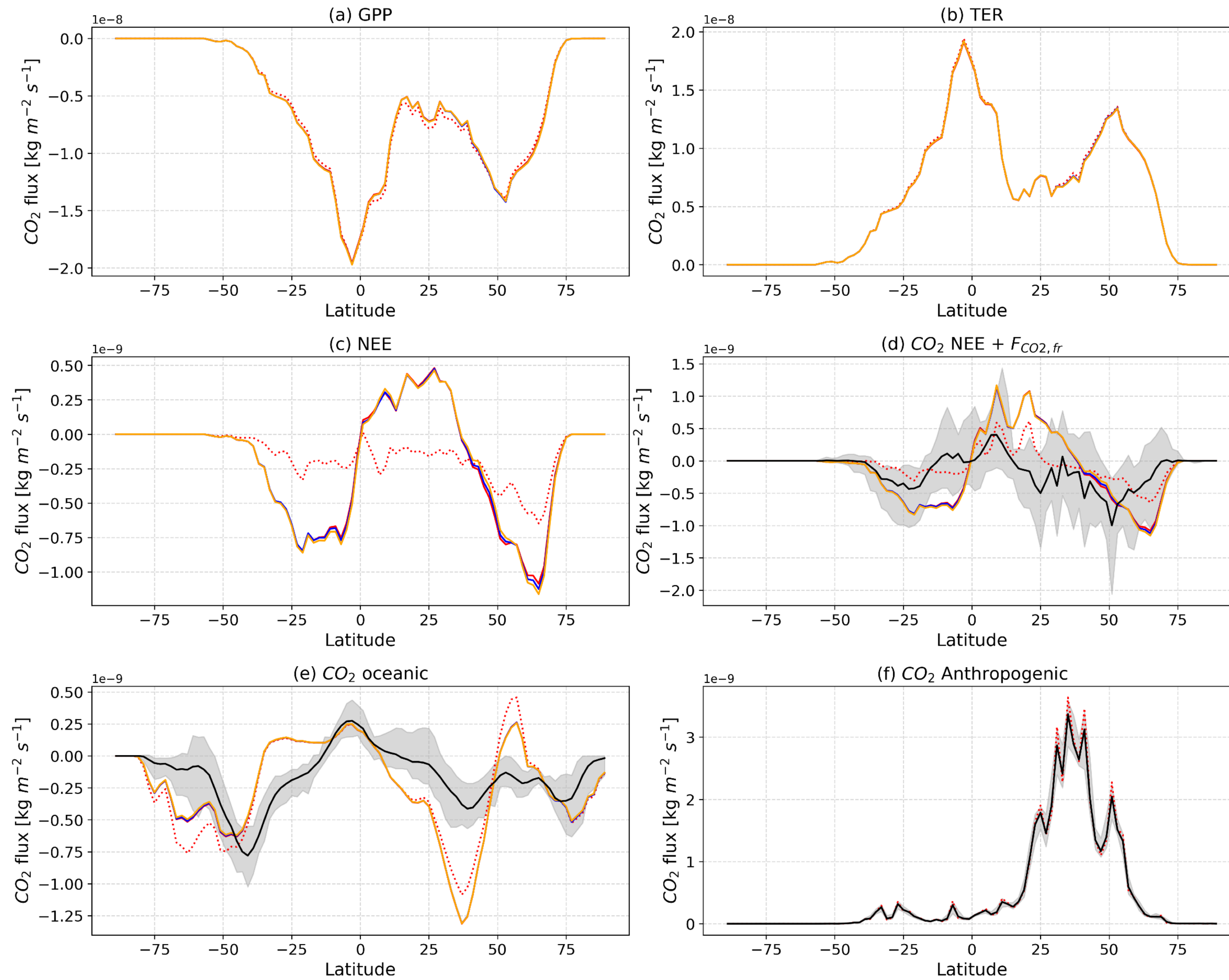


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Fluxes CO₂

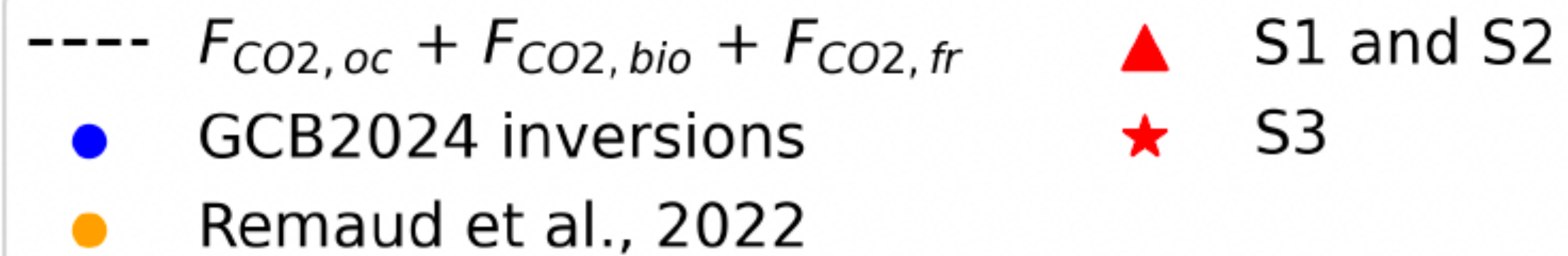
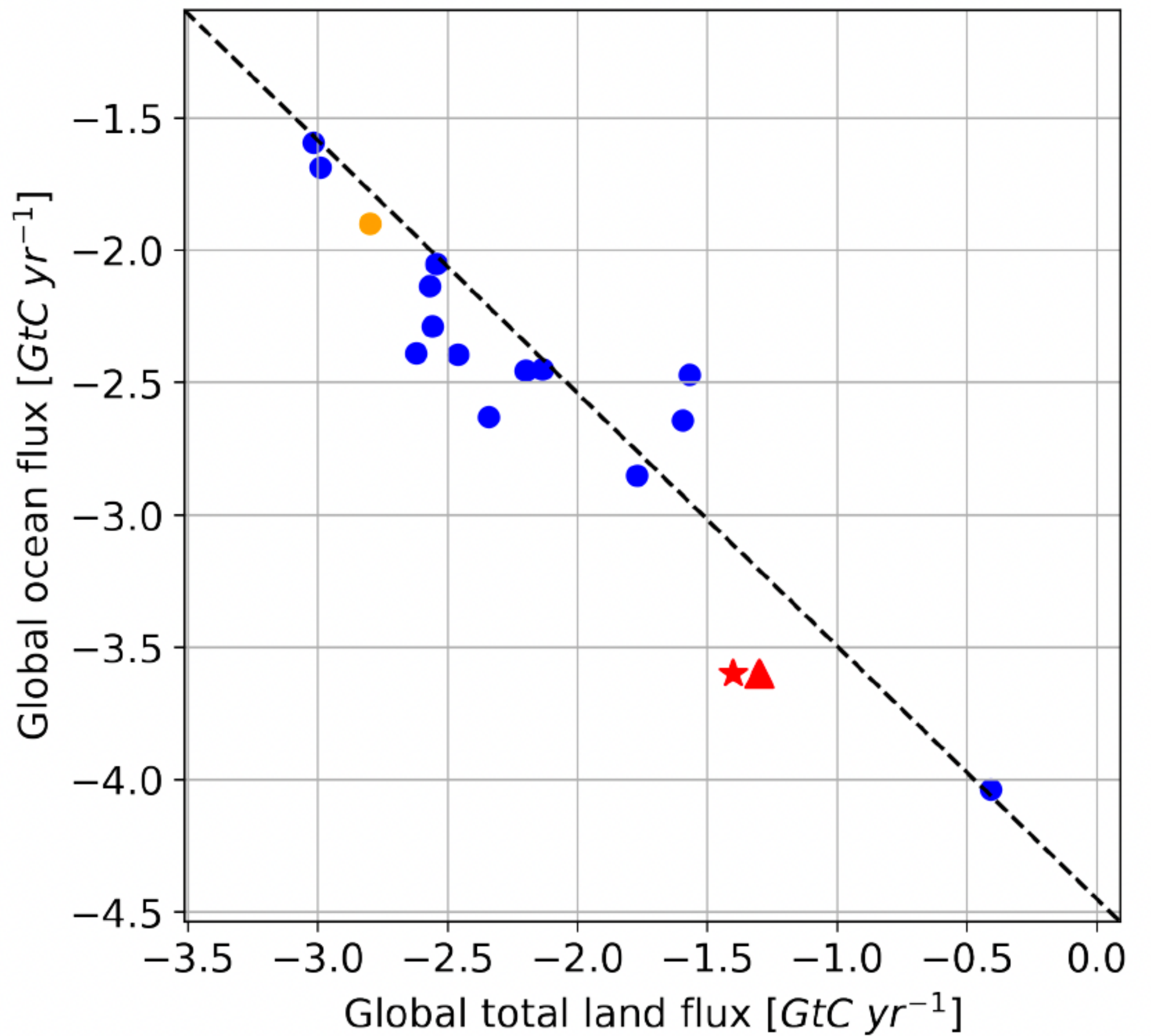


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Compared to GCP



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Remarks and Conclusion

- Technically the system works
- Diurnal cycle in adding fluxes was removed, but might be important!
- “settings” tricky and arbitrary...Error on TER?
- COS budget updates unrealistic: missing terms in budget?
- CO₂ updates outside GCP envelope: diurnal cycle?



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