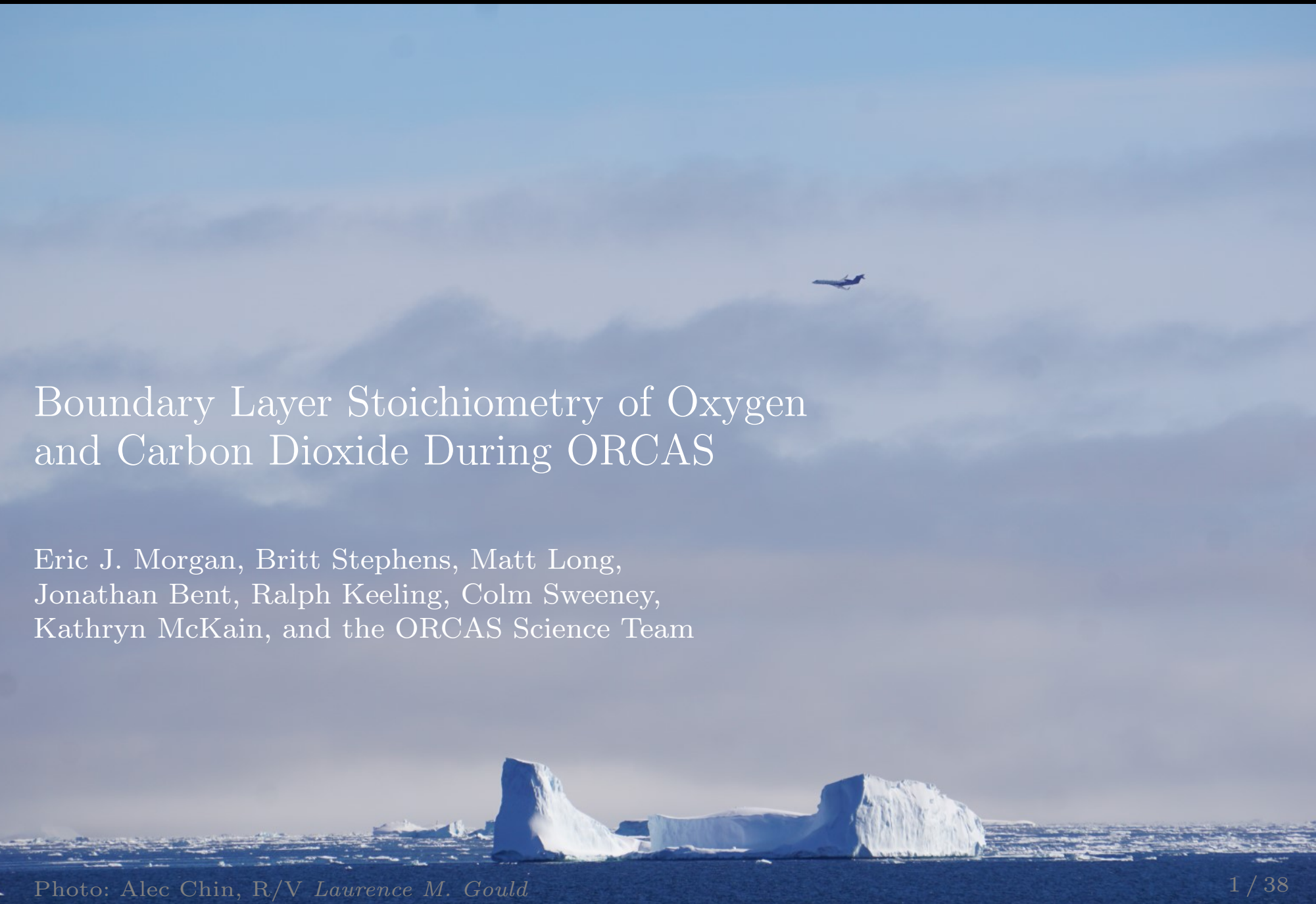


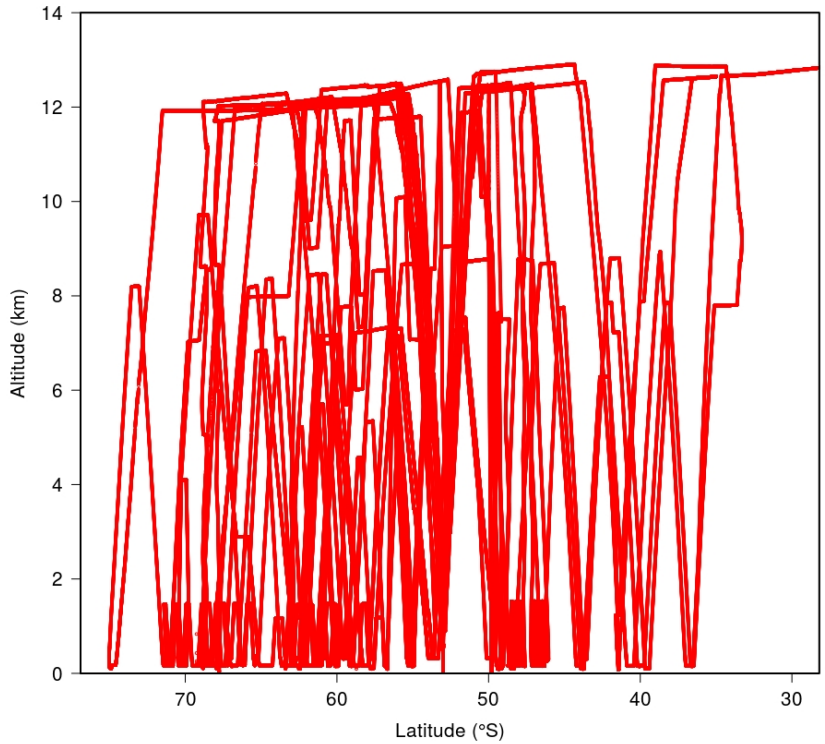
Boundary Layer Stoichiometry of Oxygen and Carbon Dioxide During ORCAS

Eric J. Morgan, Britt Stephens, Matt Long,
Jonathan Bent, Ralph Keeling, Colm Sweeney,
Kathryn McKain, and the ORCAS Science Team

Photo: Alec Chin, R/V *Laurence M. Gould*

Motivation: Why Do We Measure CO_2 & O_2?

- CO_2 is an important greenhouse gas
- O_2 can tell us something about the behavior of CO_2
- O_2 is interesting in its own right
- Vertical profiles of CO_2 and O_2 can be used to test models
- Atmospheric measurements of O_2 and CO_2 can be used to make top-down estimates of surface fluxes, ecosystem stoichiometry

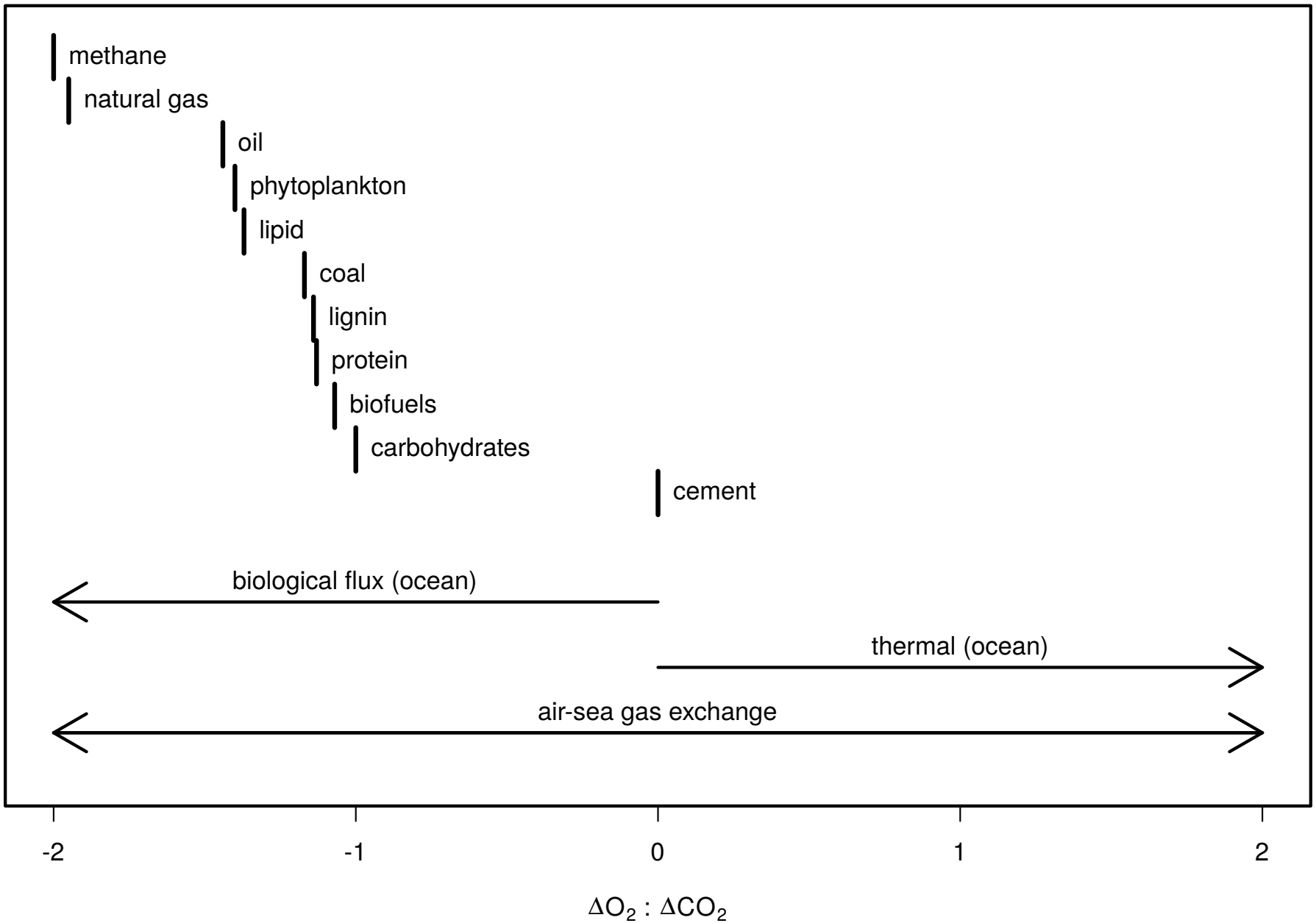


ΔO_2 / ΔCO_2

- Oxidative Ratio (**OR**): moles of O_2 produced or consumed divided by the moles of CO_2 produced or consumed during respiration, photosynthesis, or combustion
- Molar Exchange Ratio (**MER**): ratio of the flux densities of O_2 and CO_2
- Apparent Molar Exchange Ratios (**AMER**) / Concentration Gradient Ratio (**CGR**): ratio of the concentration gradient between a region impacted by flux and background

All expressed on a molar basis (e.g., mol mol^{-1} or ppm eq. ppm^{-1})

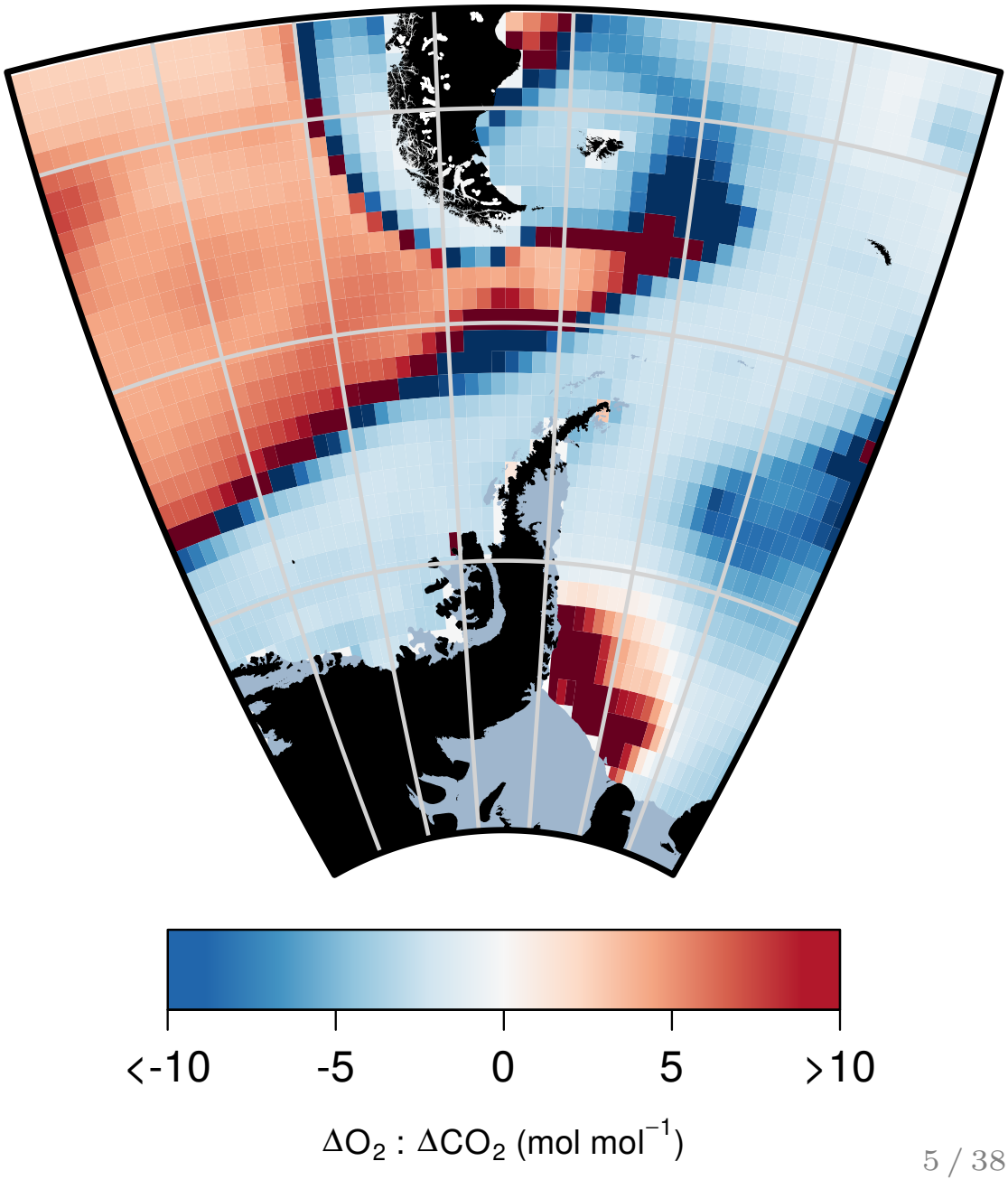
Definitions



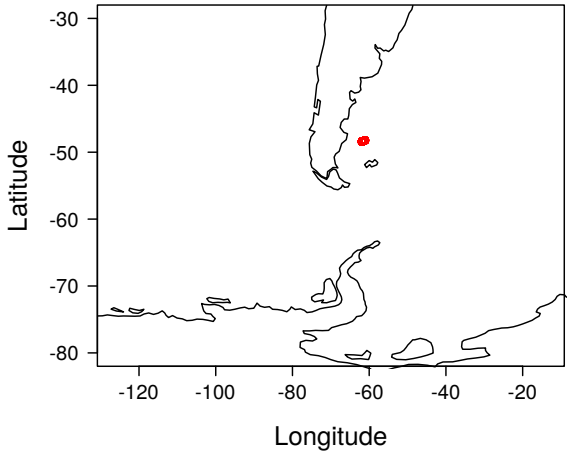
From/after: Keeling, 1988; Masiello, et. al., 2008; Randerson, et al., 2006; Steinbach, et al., 2011

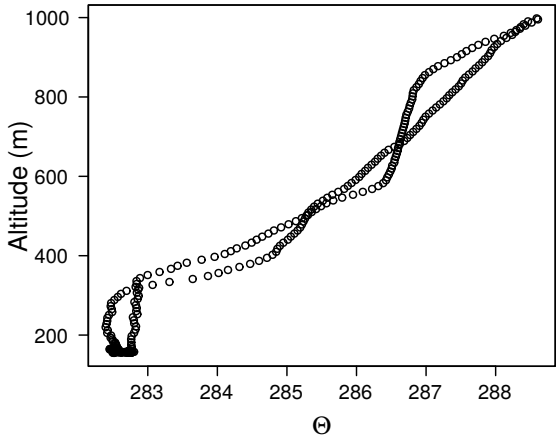
Cumulative Molar Exchange Ratios

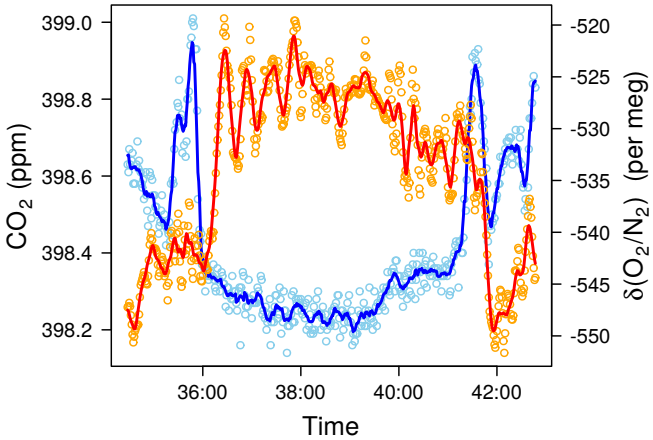
Cumulative CESM
Surface Fluxes
Jan 15–Feb 25 2016

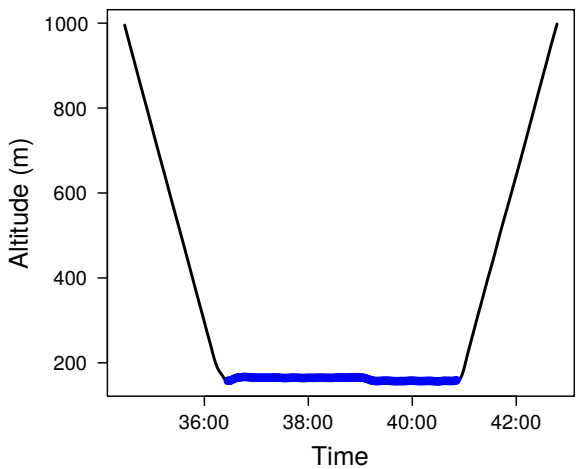


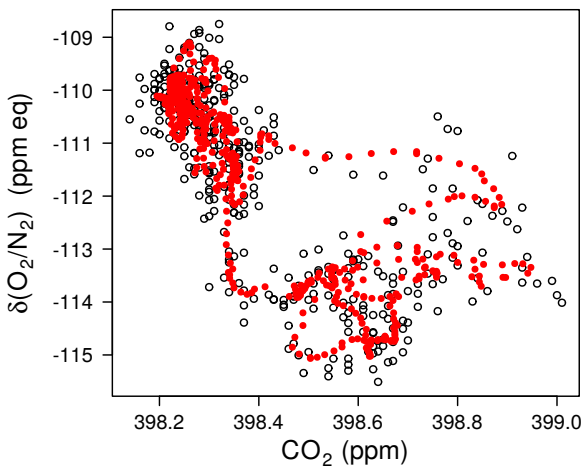
Example Dip (RF07)

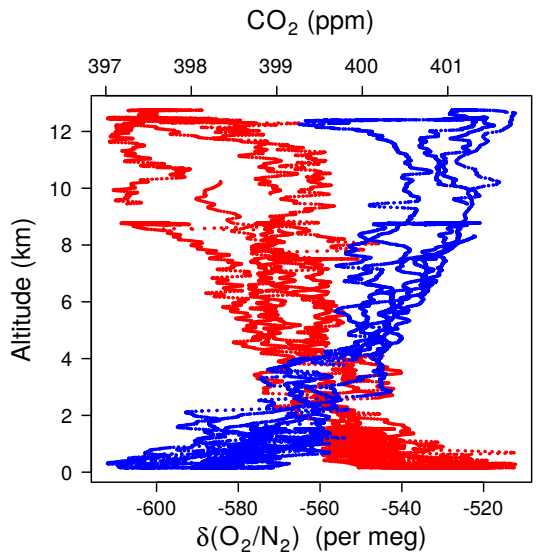






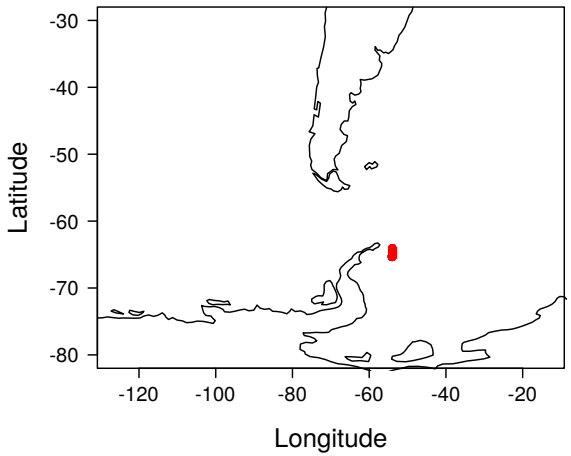


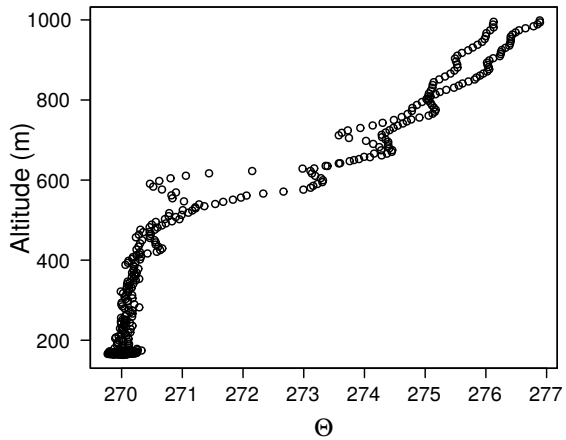


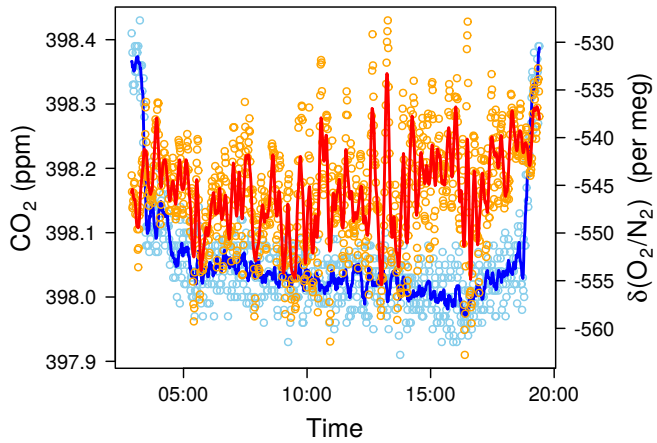


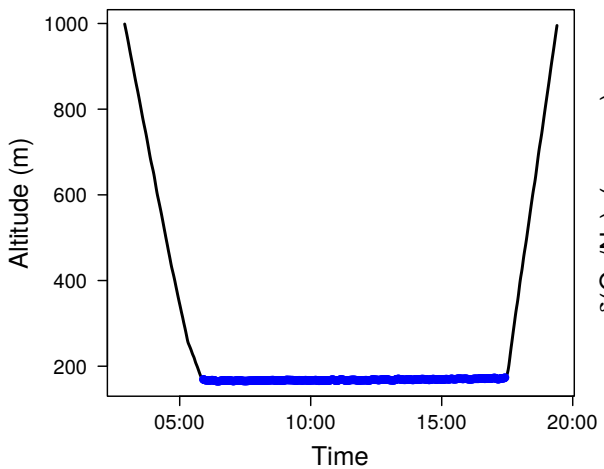
$$\Delta O_2 : \Delta CO_2 = -3.3 \pm 0.1$$

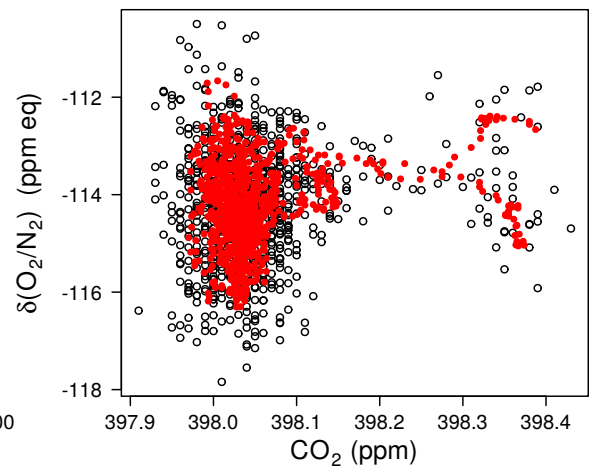
Example Dip (RF11)

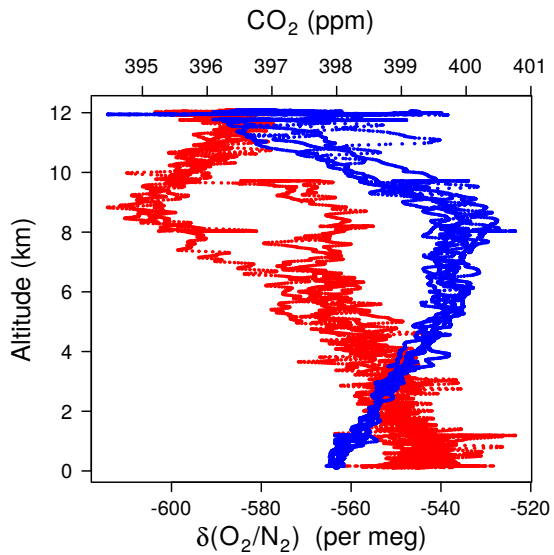






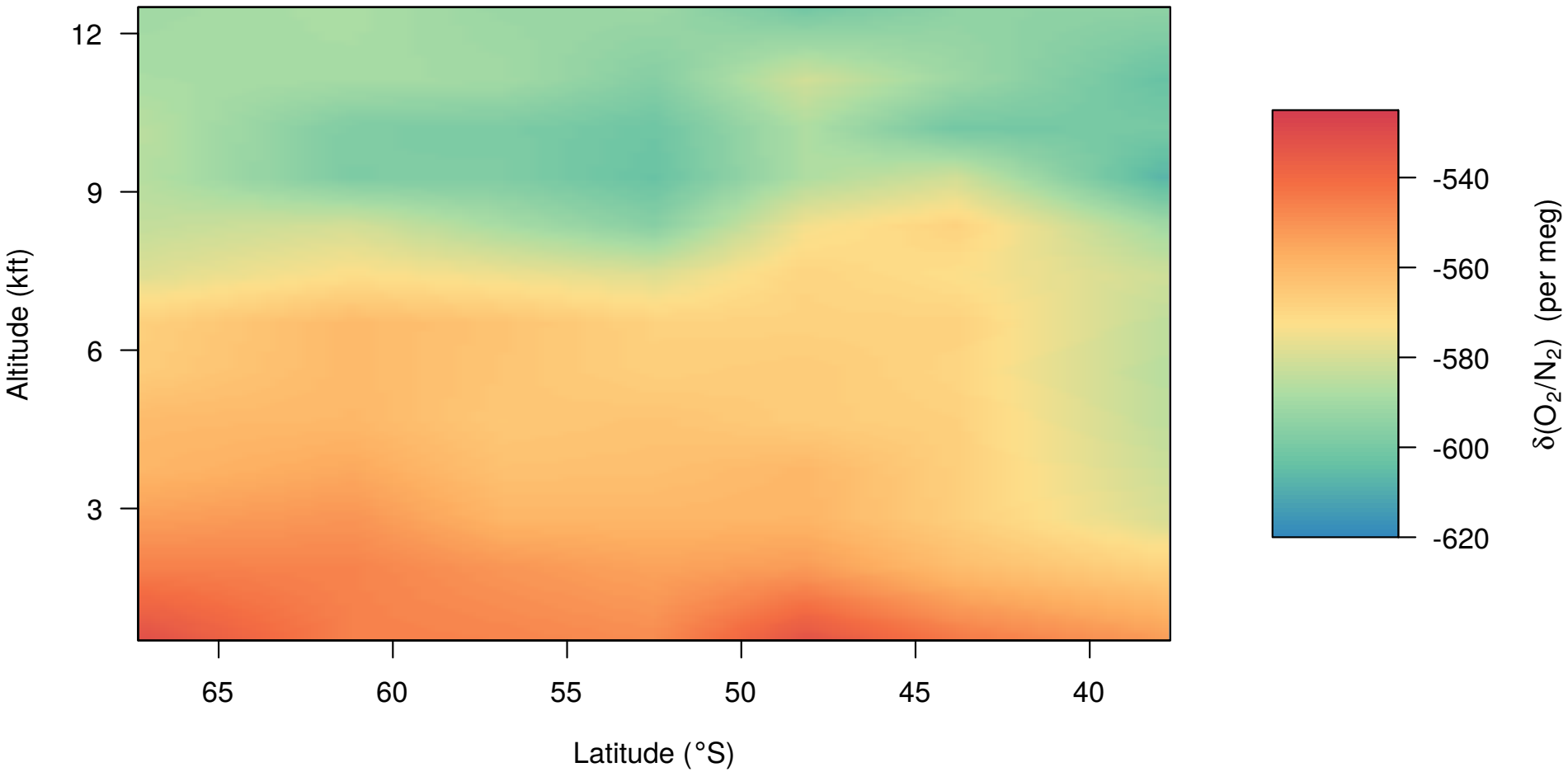






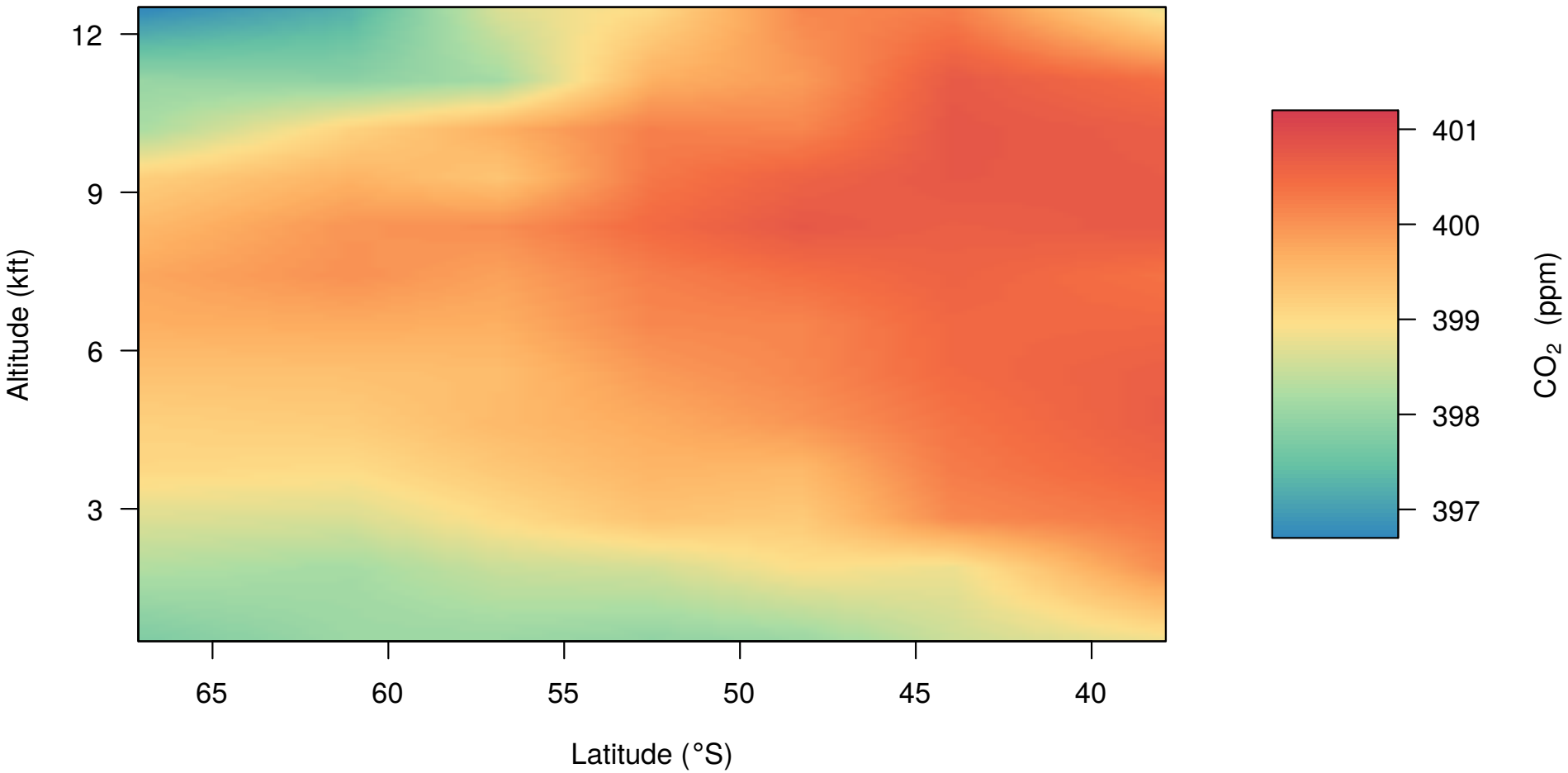
$$\Delta O_2 : \Delta CO_2 = -2.4 \pm 0.3$$

The $\delta(O_2/N_2)$ Curtain Average



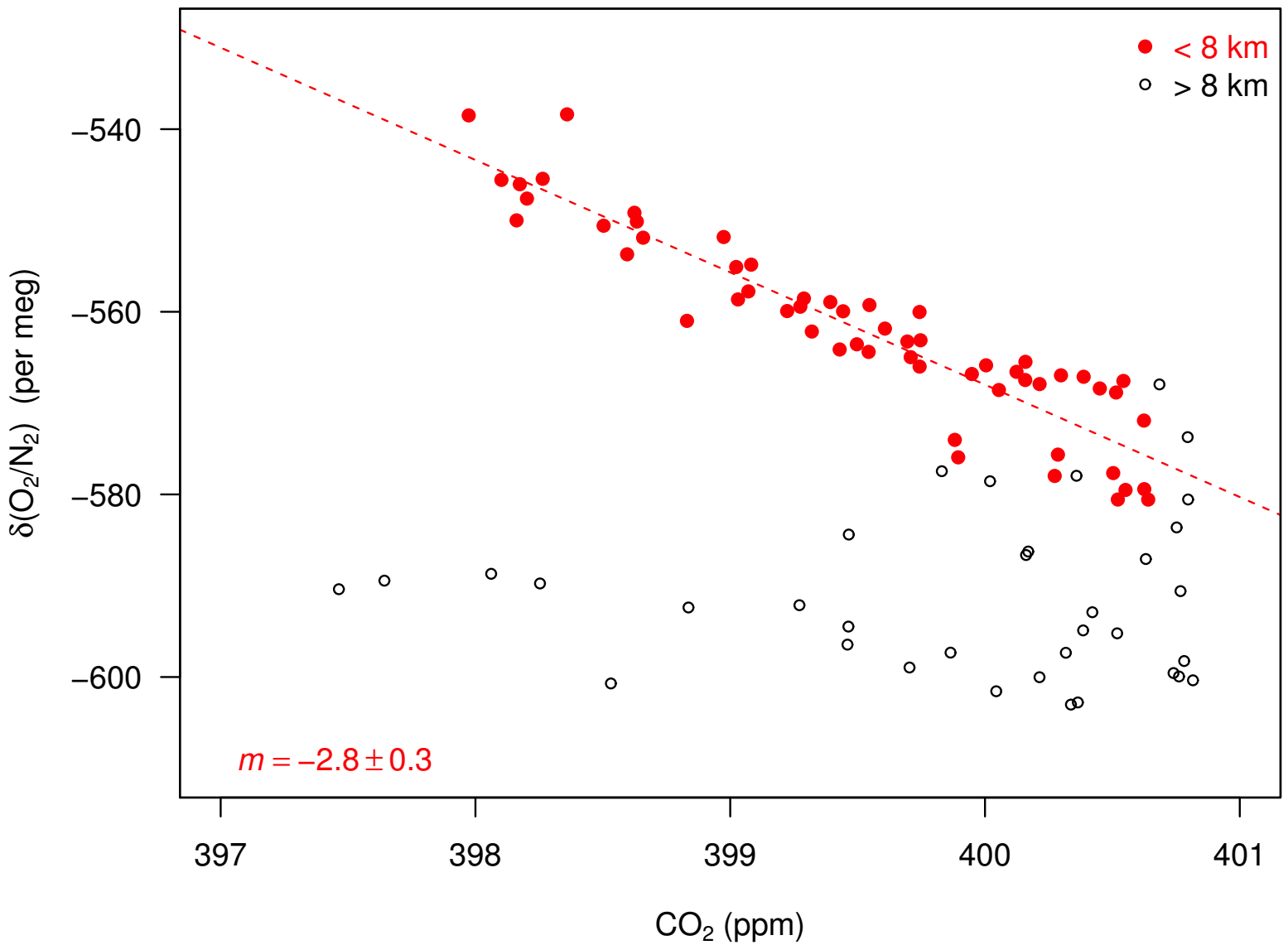
Throughout the campaign, large-scale enhancement of oxygen was seen in the lower troposphere.

The CO_2 Curtain Average

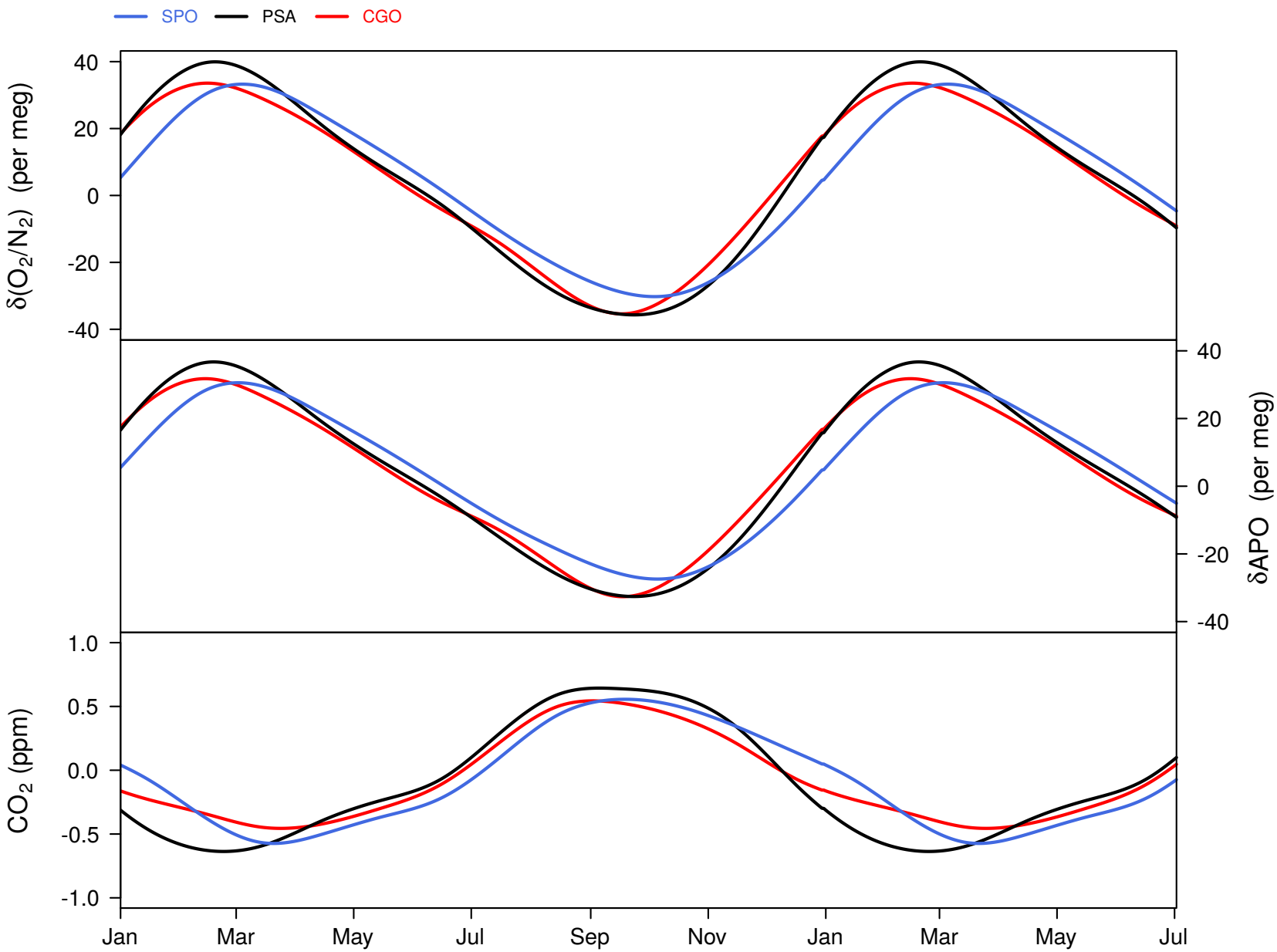


Conversely, large-scale drawdown of CO_2 is seen in the lower troposphere.

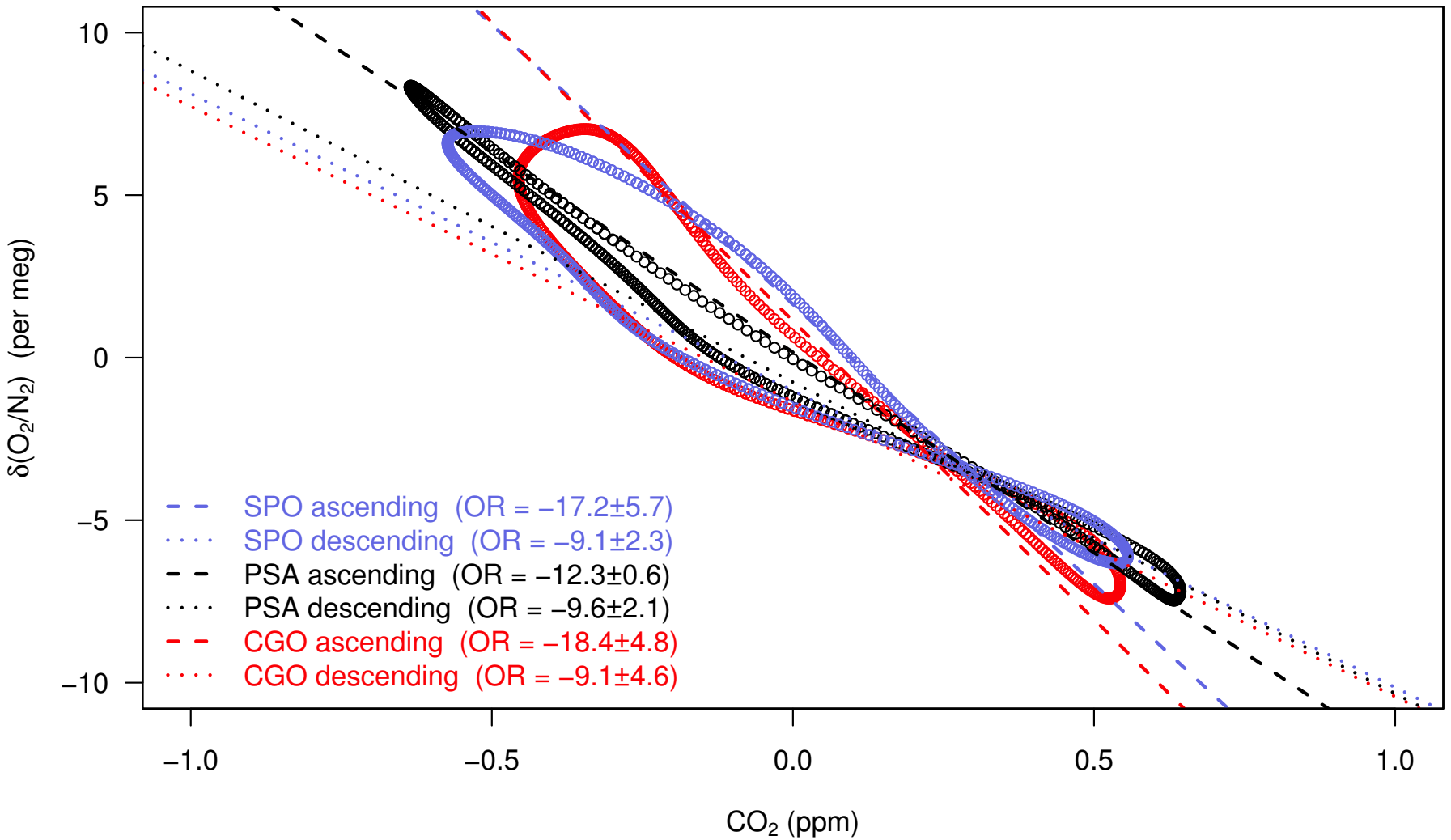
Mid-Troposphere–Surface Gradients



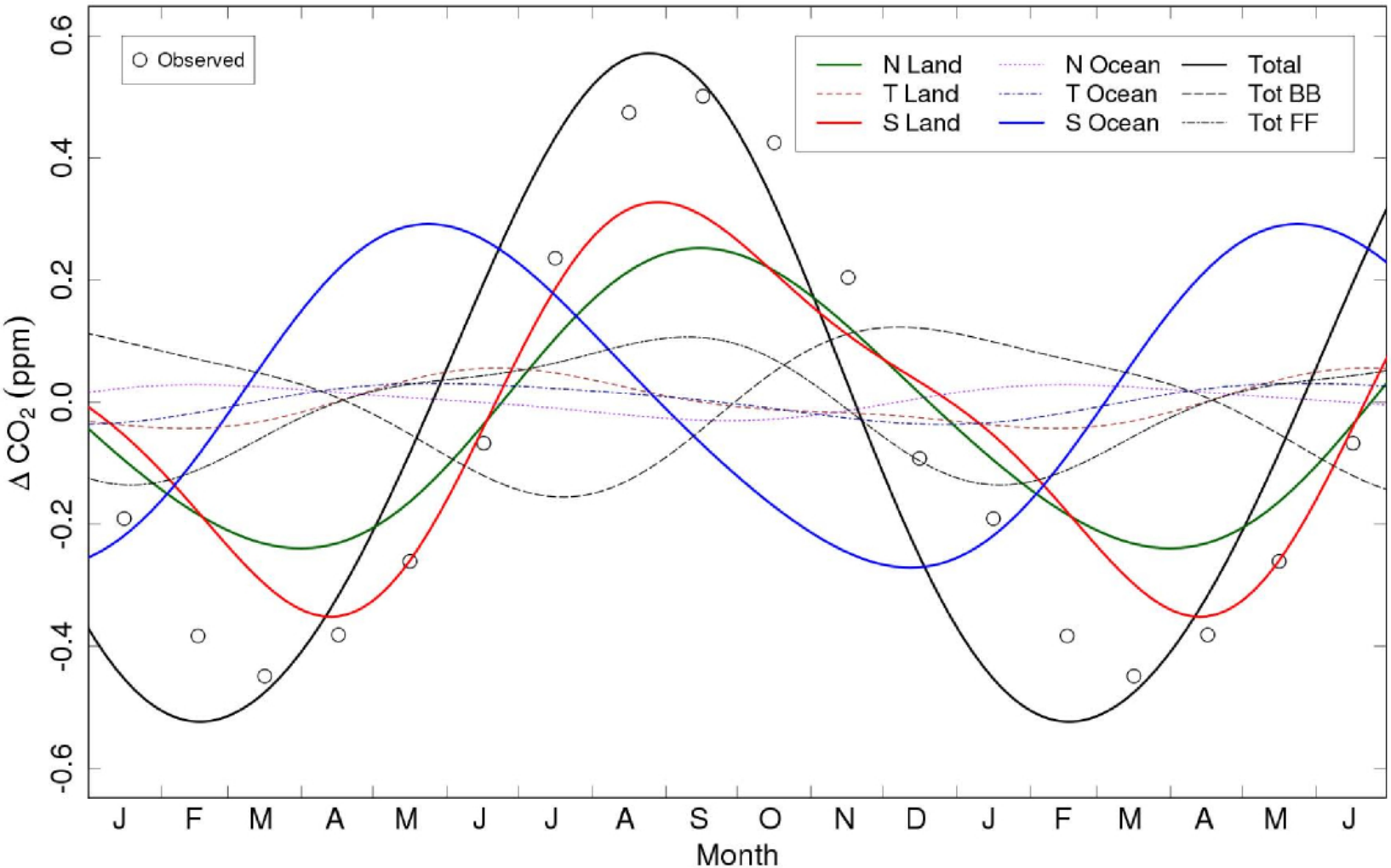
Seasonal Cycle Molar Ratios of Southern Hemisphere Stations



Seasonal Cycle Molar Ratios of Southern Hemisphere Stations

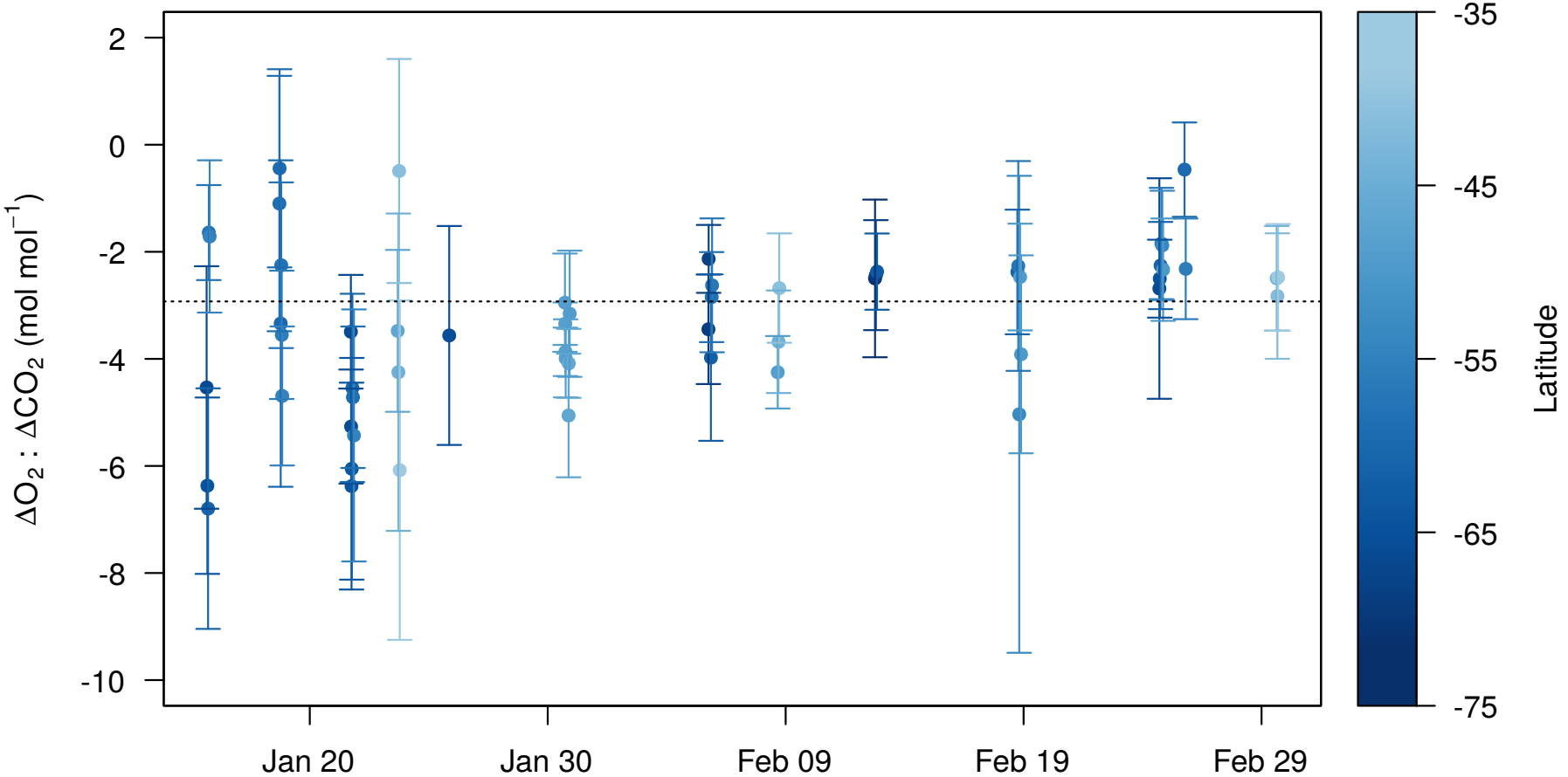


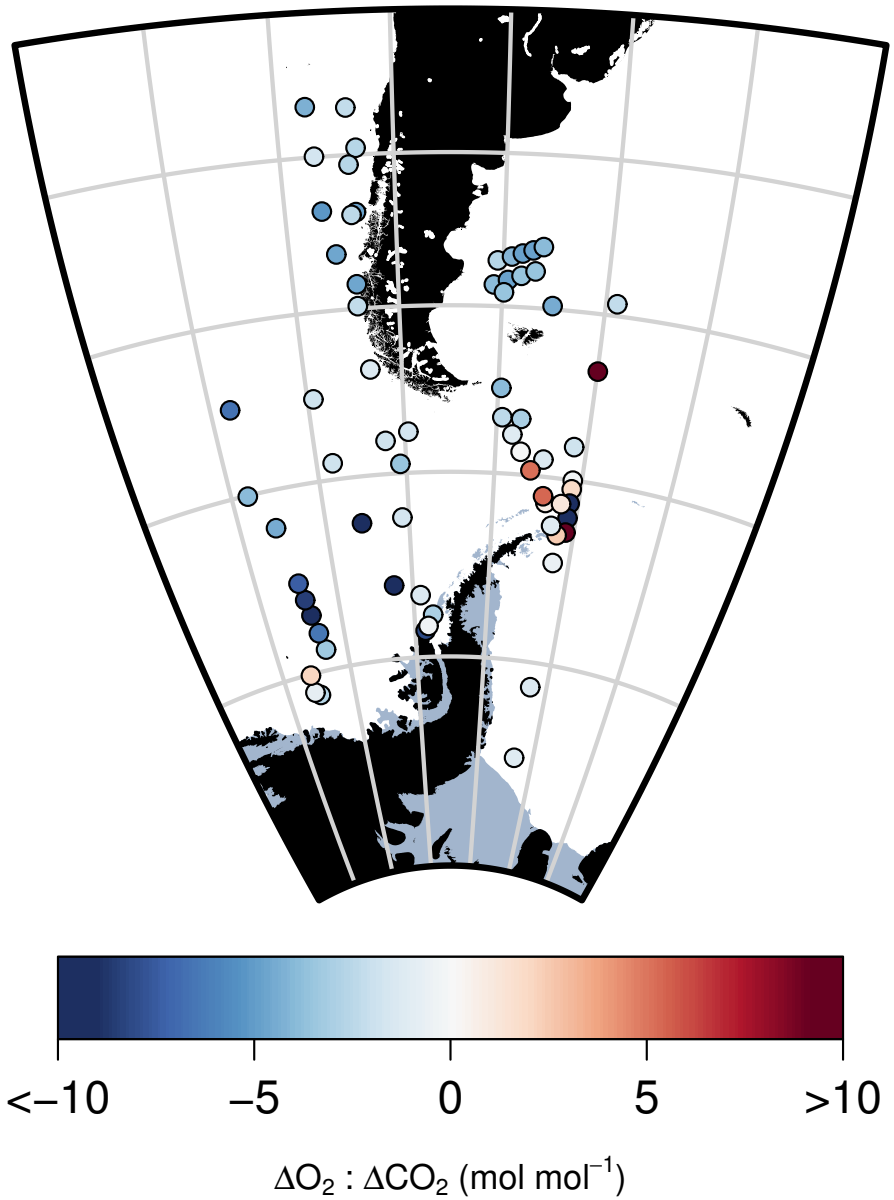
Seasonal Cycle Molar Ratios of Southern Hemisphere Stations



Decomposition of the seasonal cycle at Baring Head, NZ
Stephens *et al.*, *Biogeosciences*, 10, 2013

Mid-Troposphere–Surface Gradients | Observations

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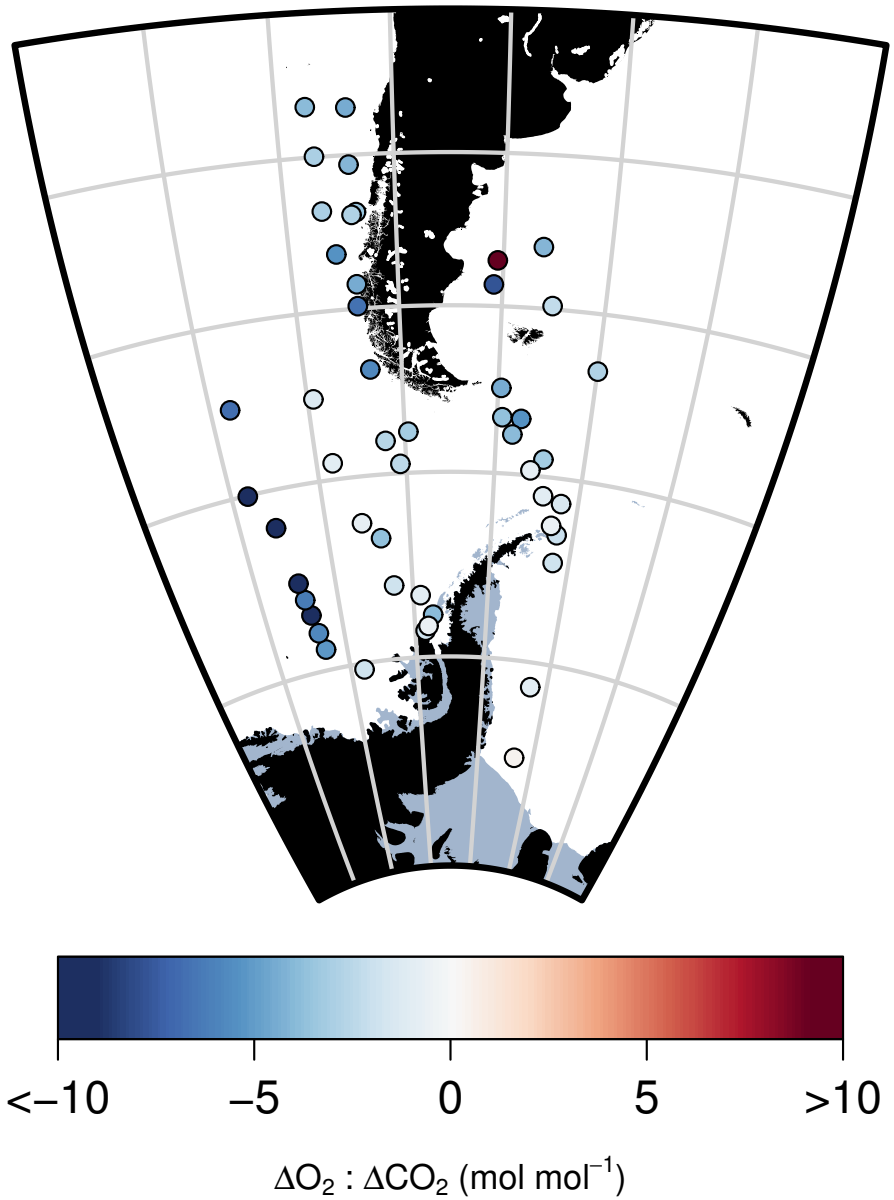
ΔO2 : ΔCO2 (mol mol−1)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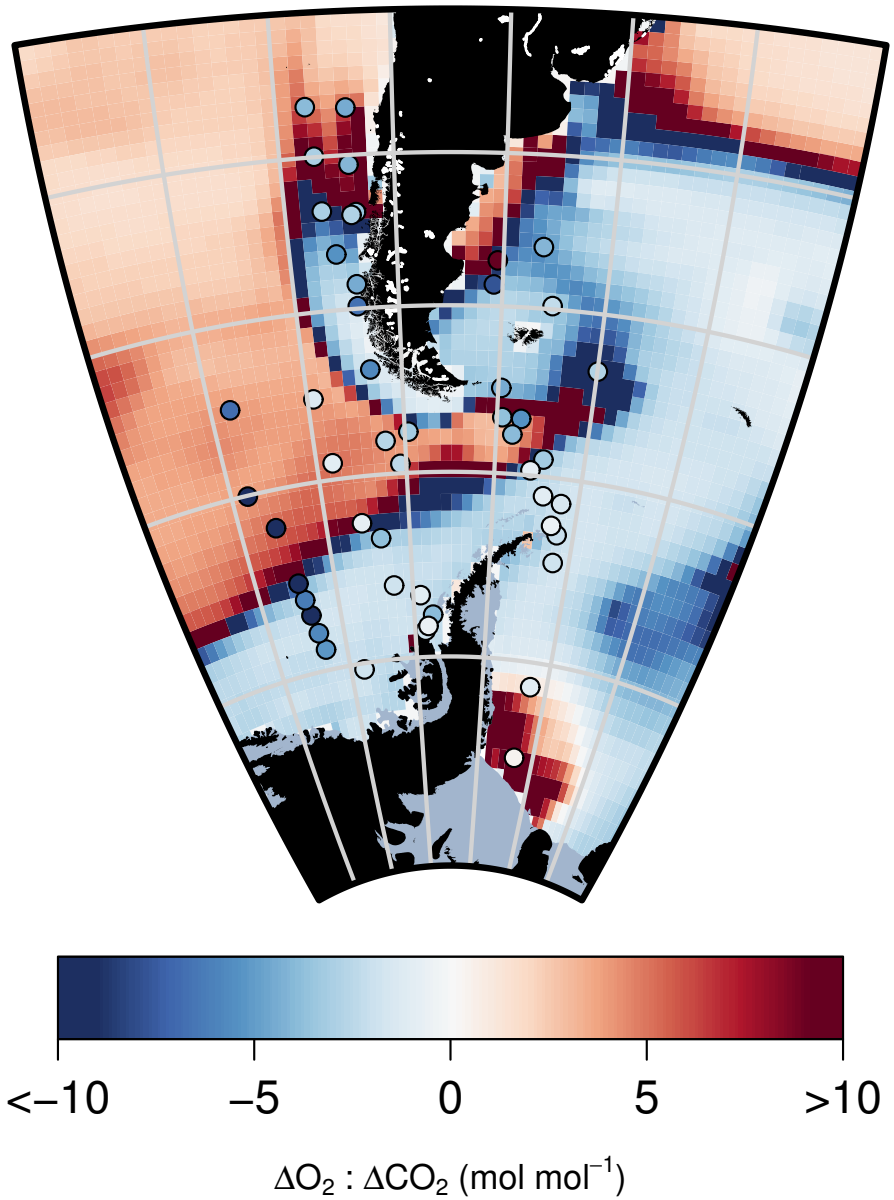
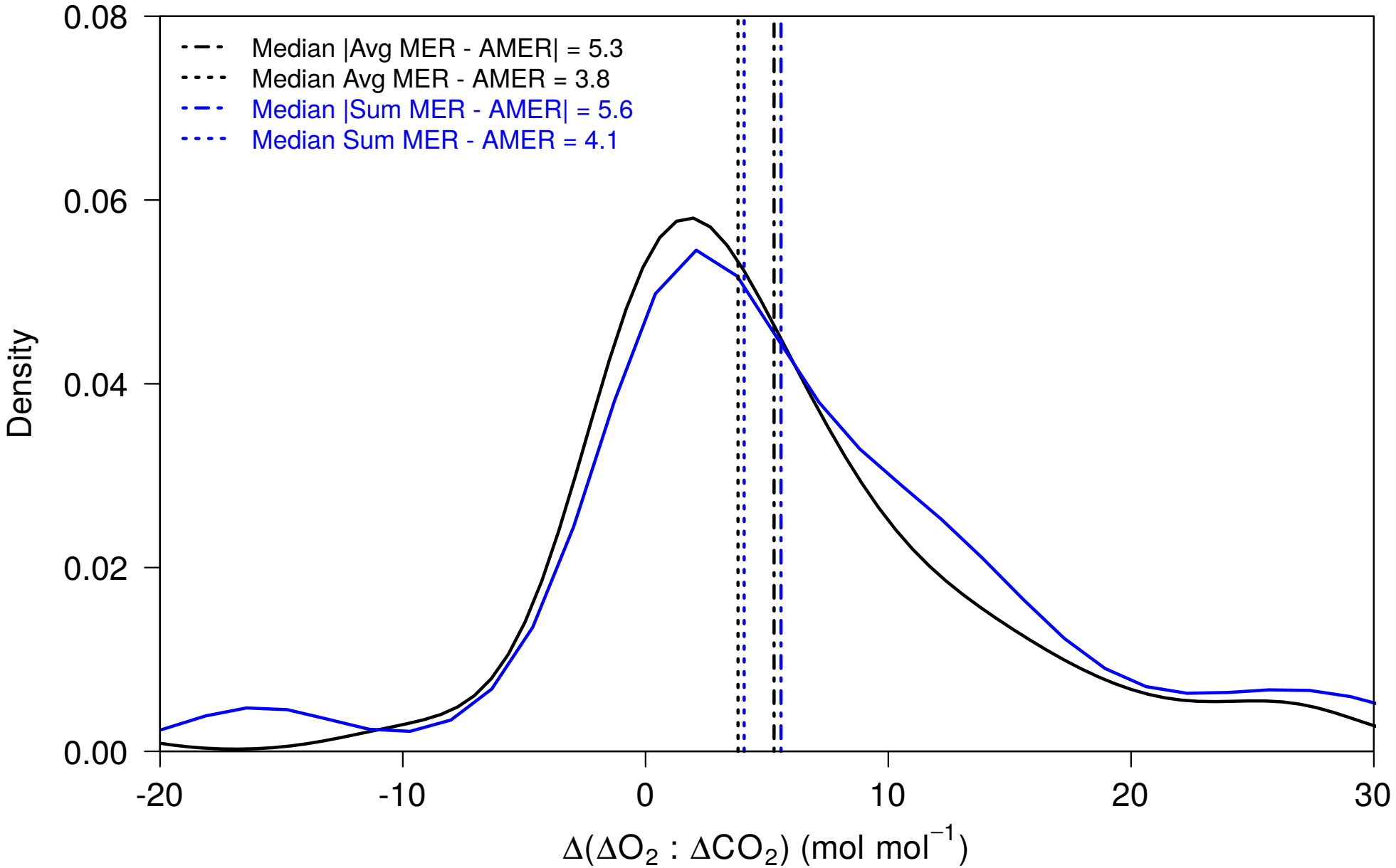
ΔO2 : ΔCO2 (mol mol−1)

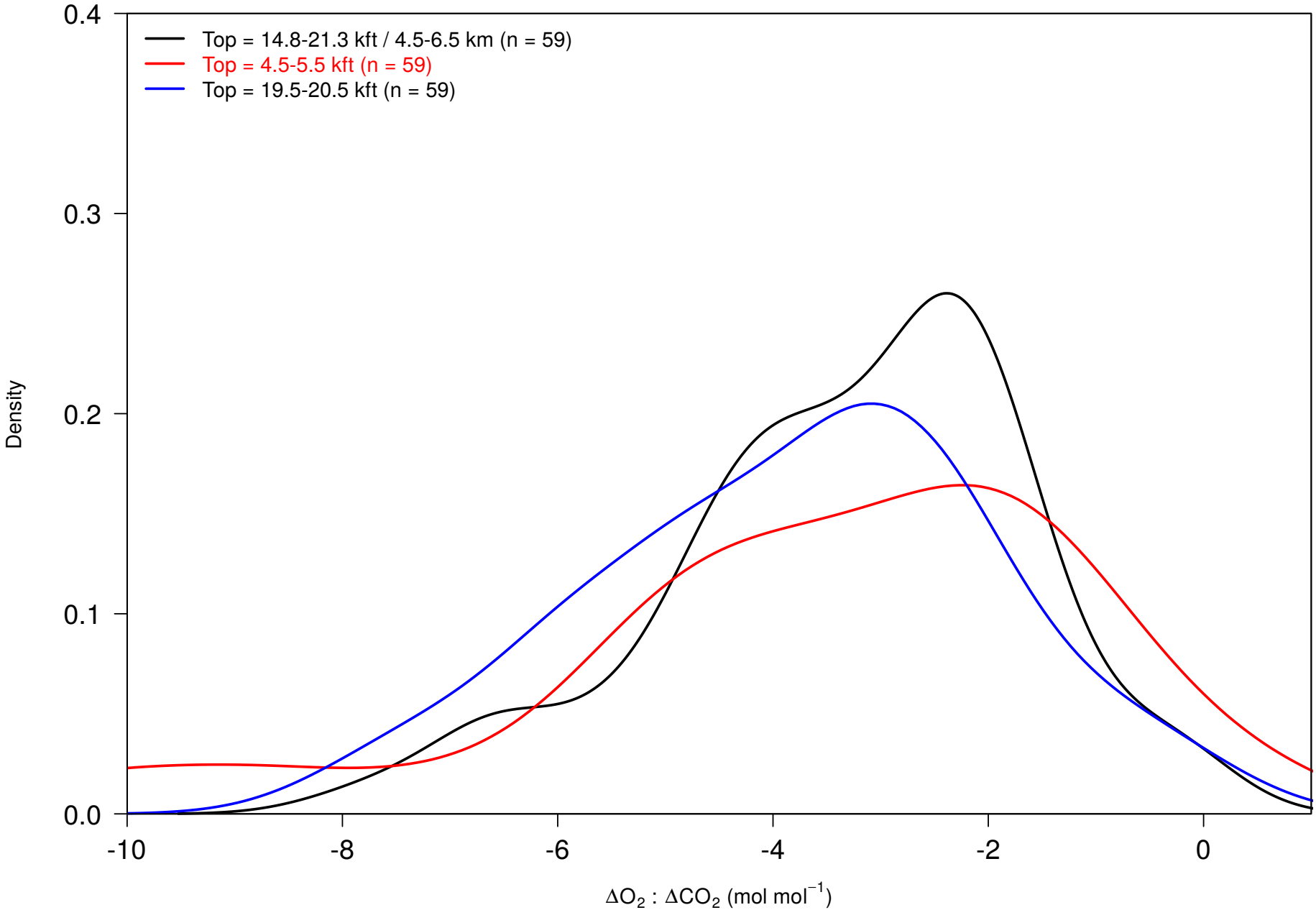
Mid-Troposphere–Surface Gradients | CESM with MER



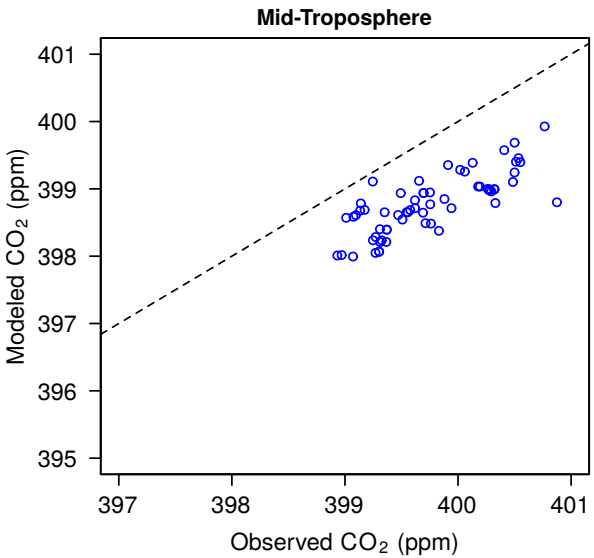
CESM MERs and AMERs

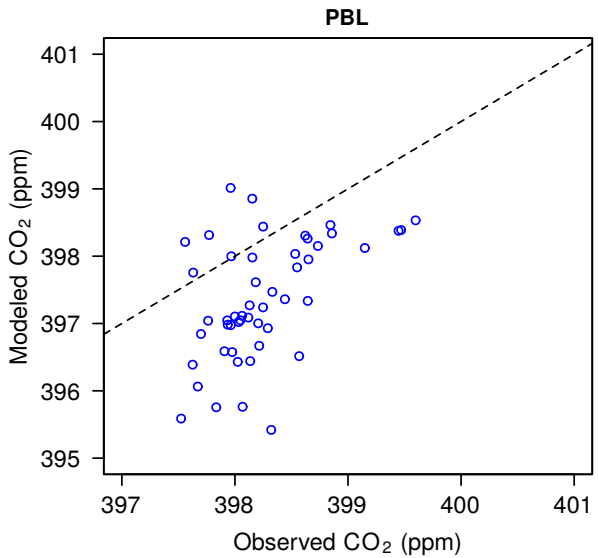


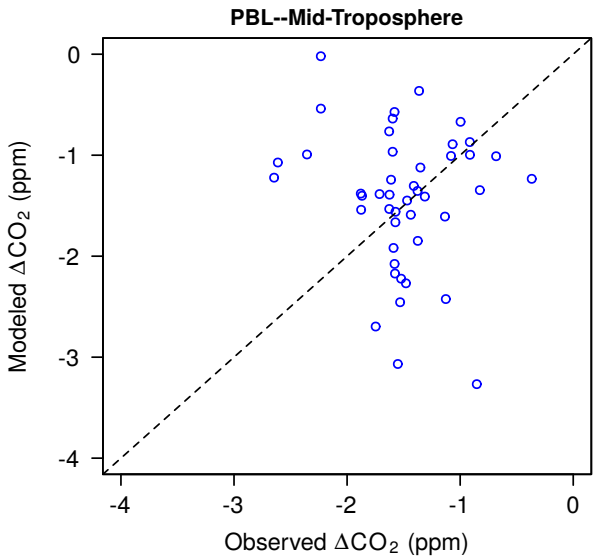
Background Selection



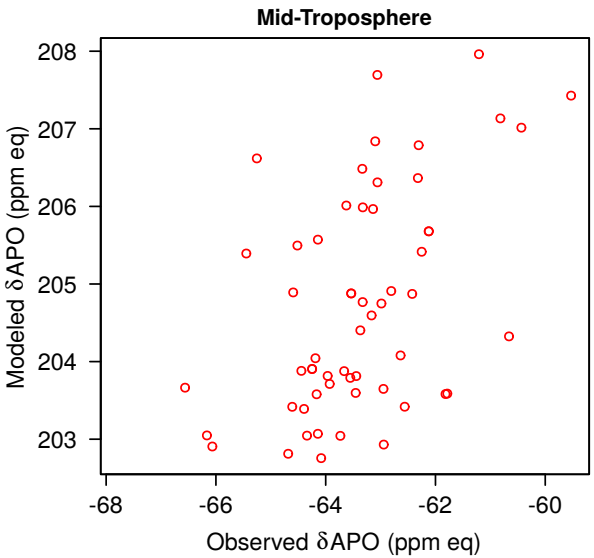
Mid-Troposphere–Surface Gradients (CO_2)

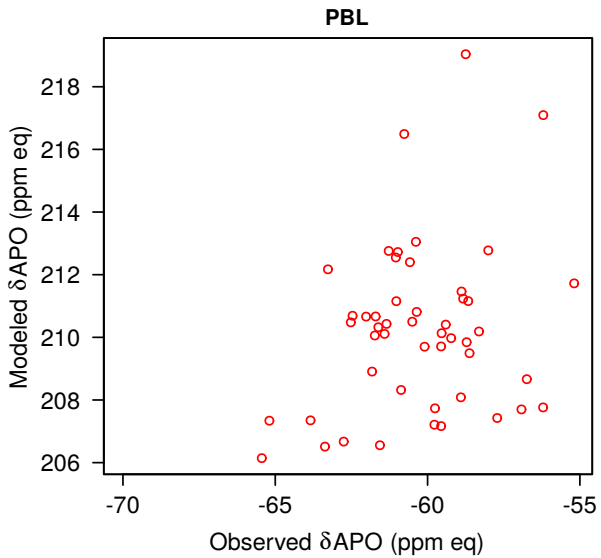


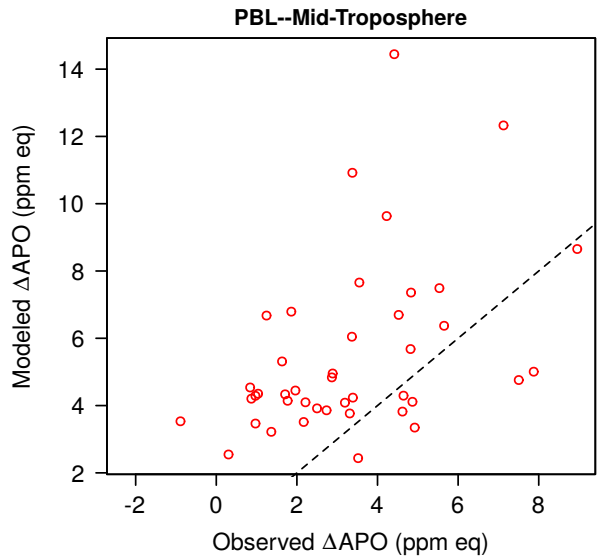




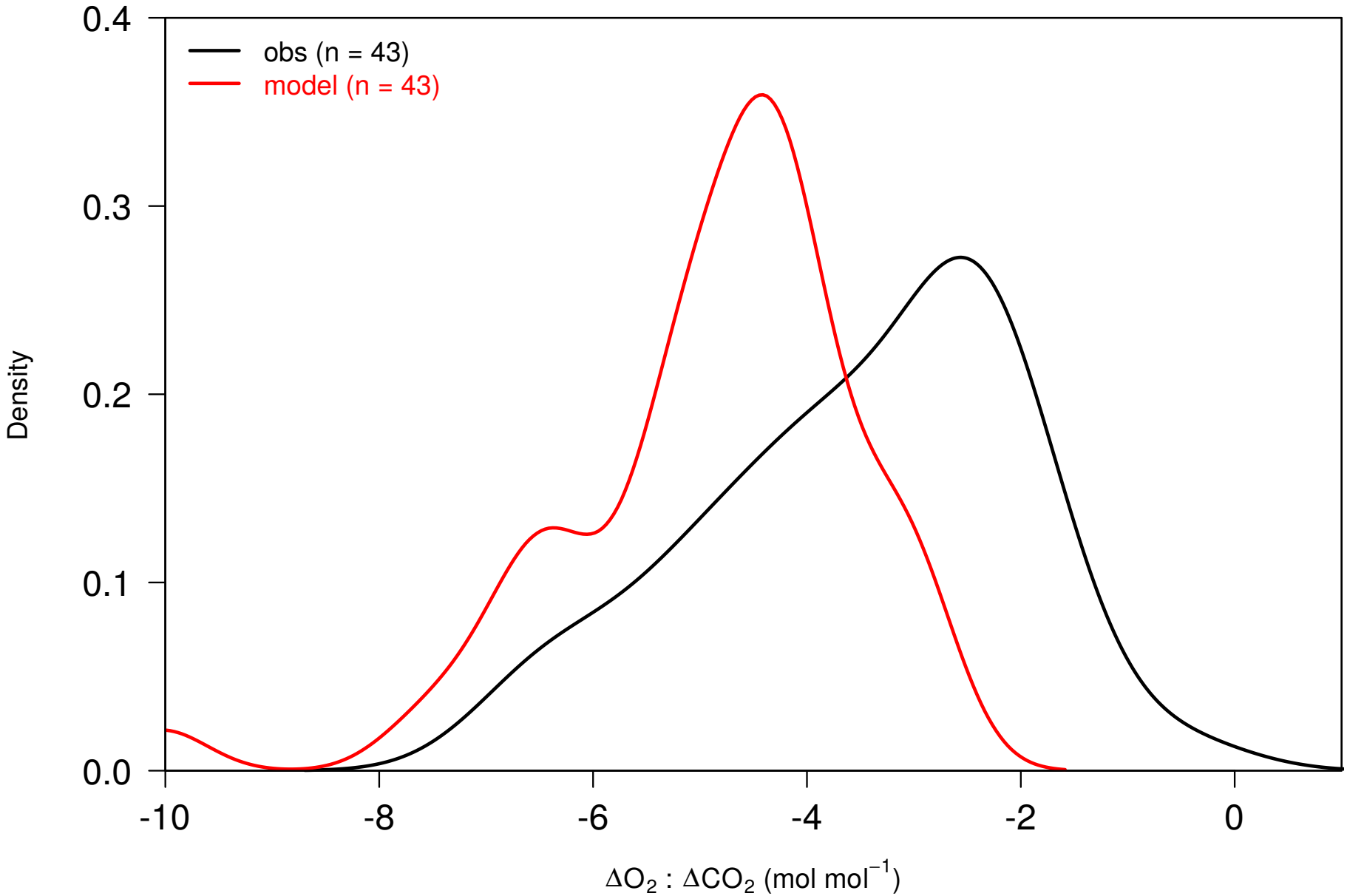
Mid-Troposphere–Surface Gradients (APO)



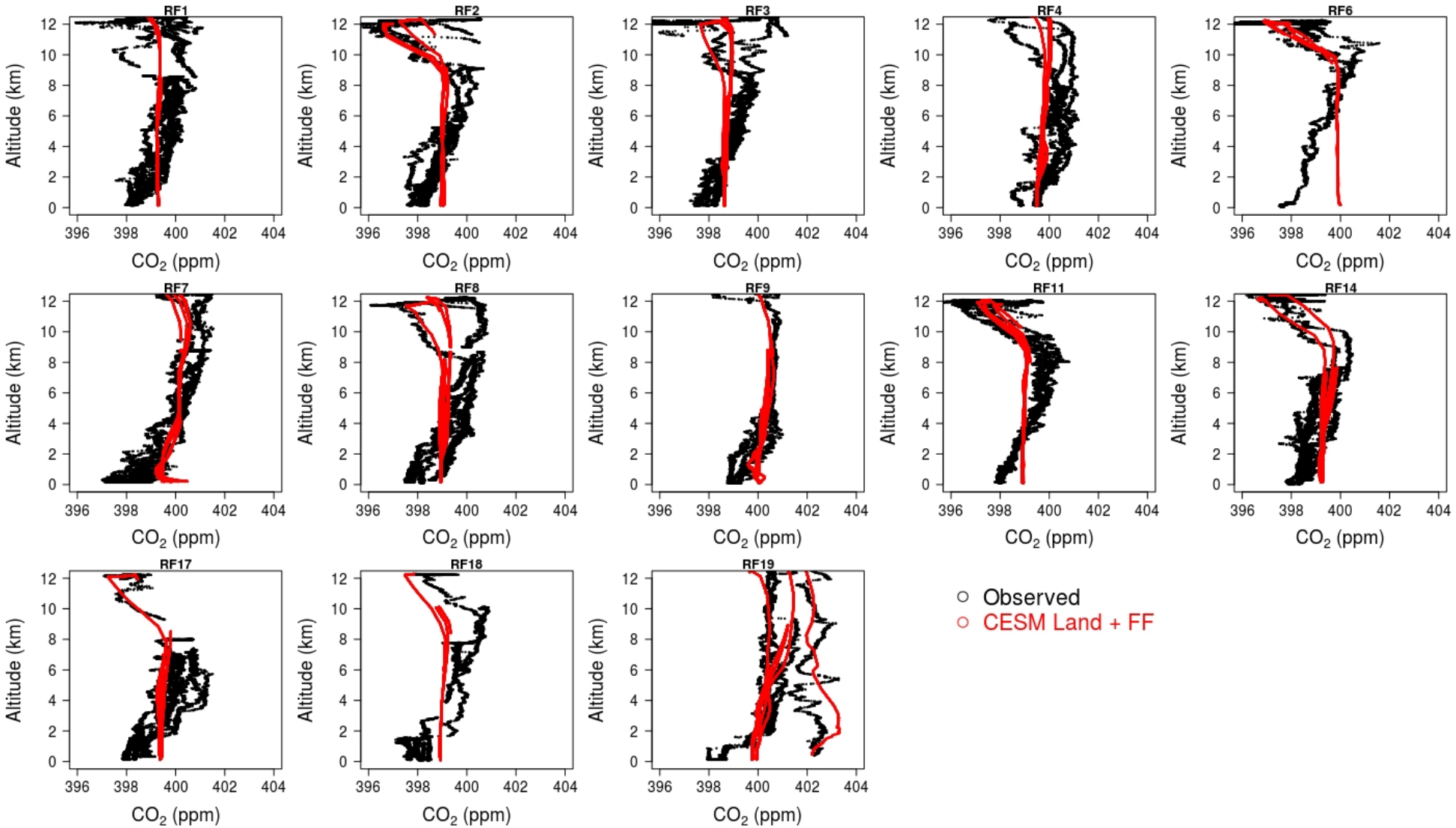




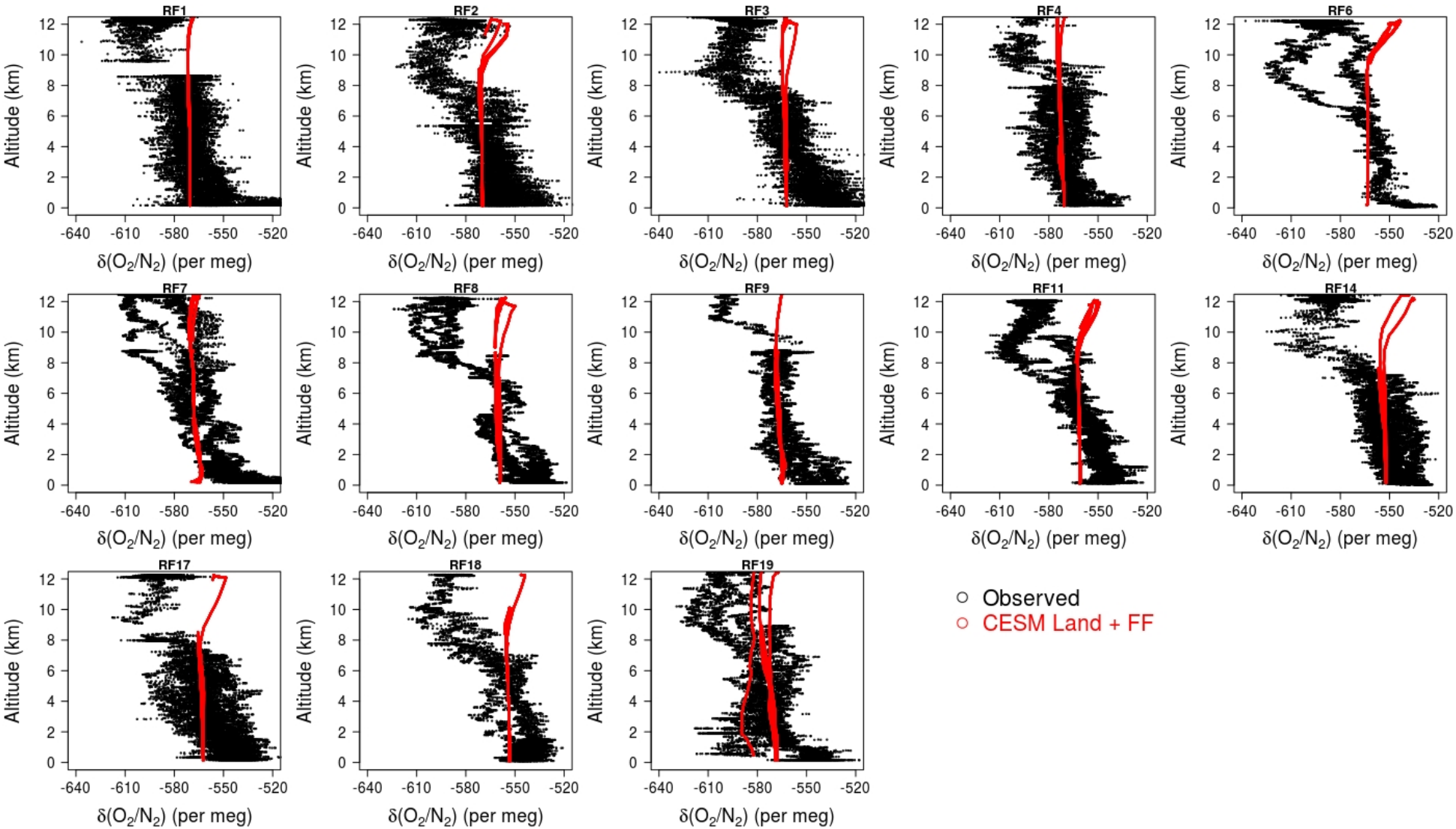
Mid-Troposphere–Surface Gradients (Ratios)



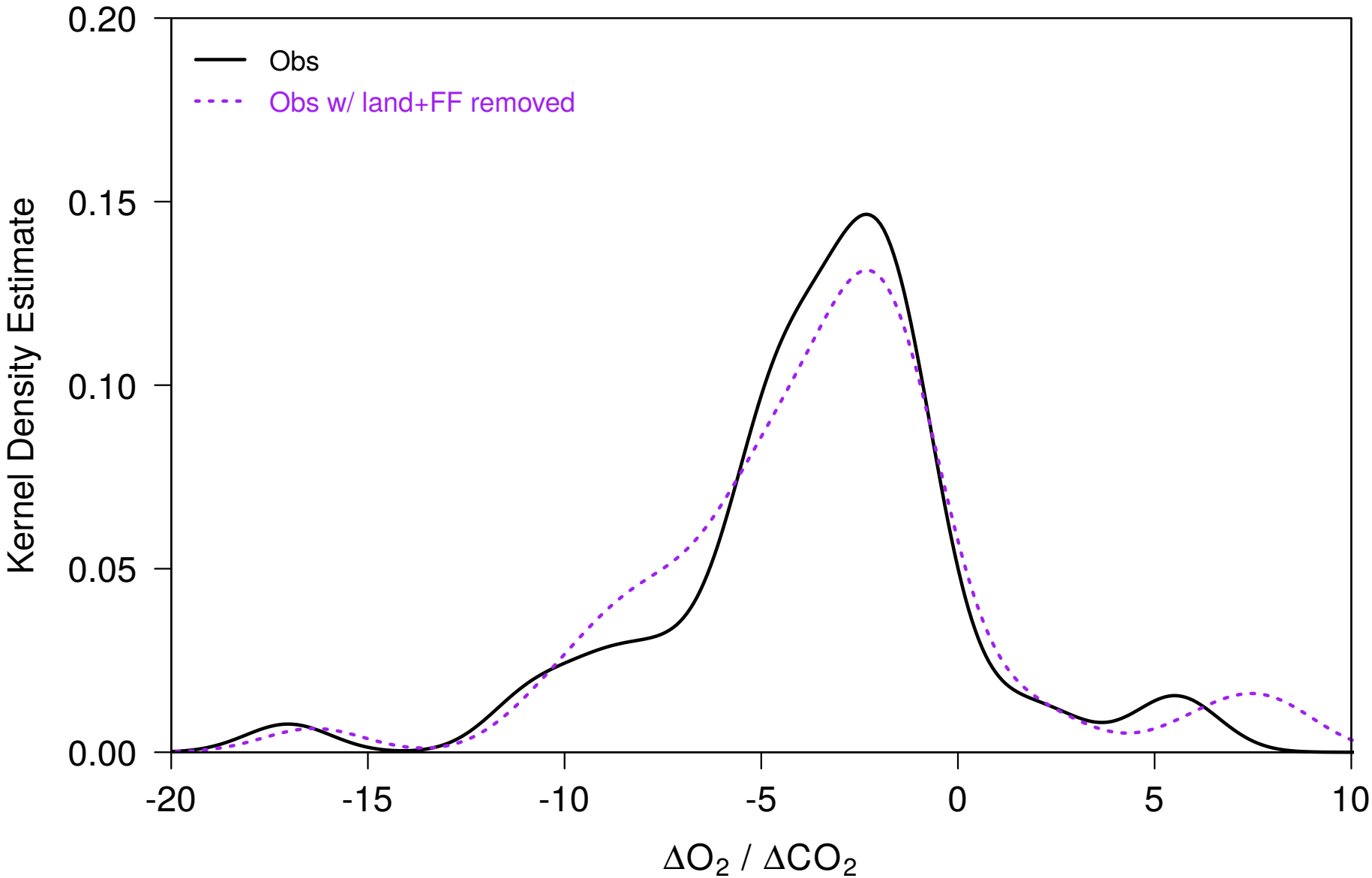
Terrestrial and Fossil Fuel Vertical Gradients



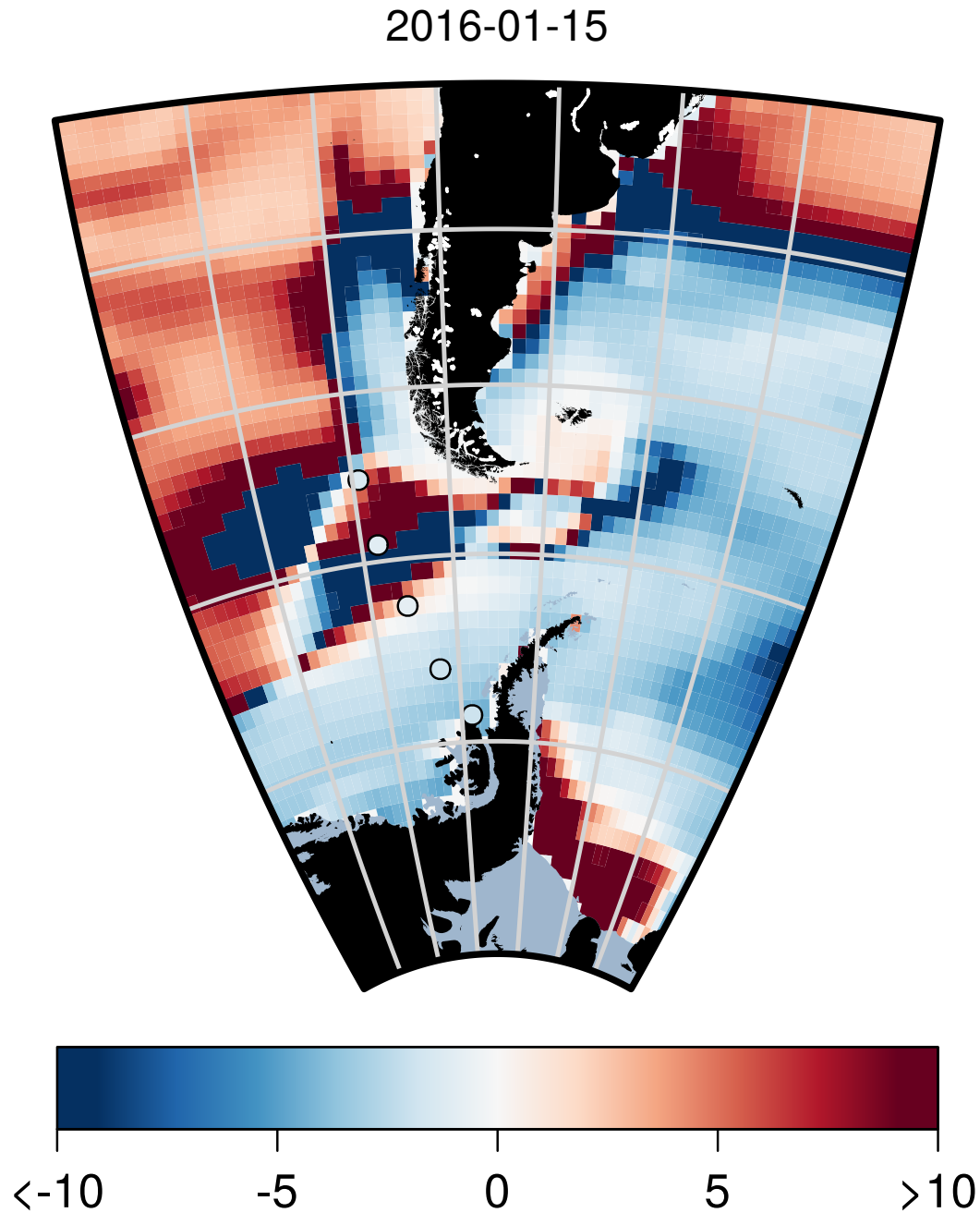
Terrestrial and Fossil Fuel Vertical Gradients



Terrestrial and Fossil Fuel Vertical Gradients



- Boundary layer $\Delta O_2 : \Delta CO_2$ show local variability but converge to the campaign average of -2.8
- But this simple approach to estimating AMERs/CGRs should be seen as distinct from measurements or estimates of MERs
- Vertical gradients of CO_2 and O_2 were dominated by a persistent marine productivity signal with minimal contributions from recent terrestrial biosphere activity or fossil fuel burning
- Airborne CO_2 and $\delta(O_2/N_2)$ measurements provide a useful diagnostic for CESM simulations
- The CESM output analyzed here appears to overestimate the summertime Southern Ocean CO_2 sink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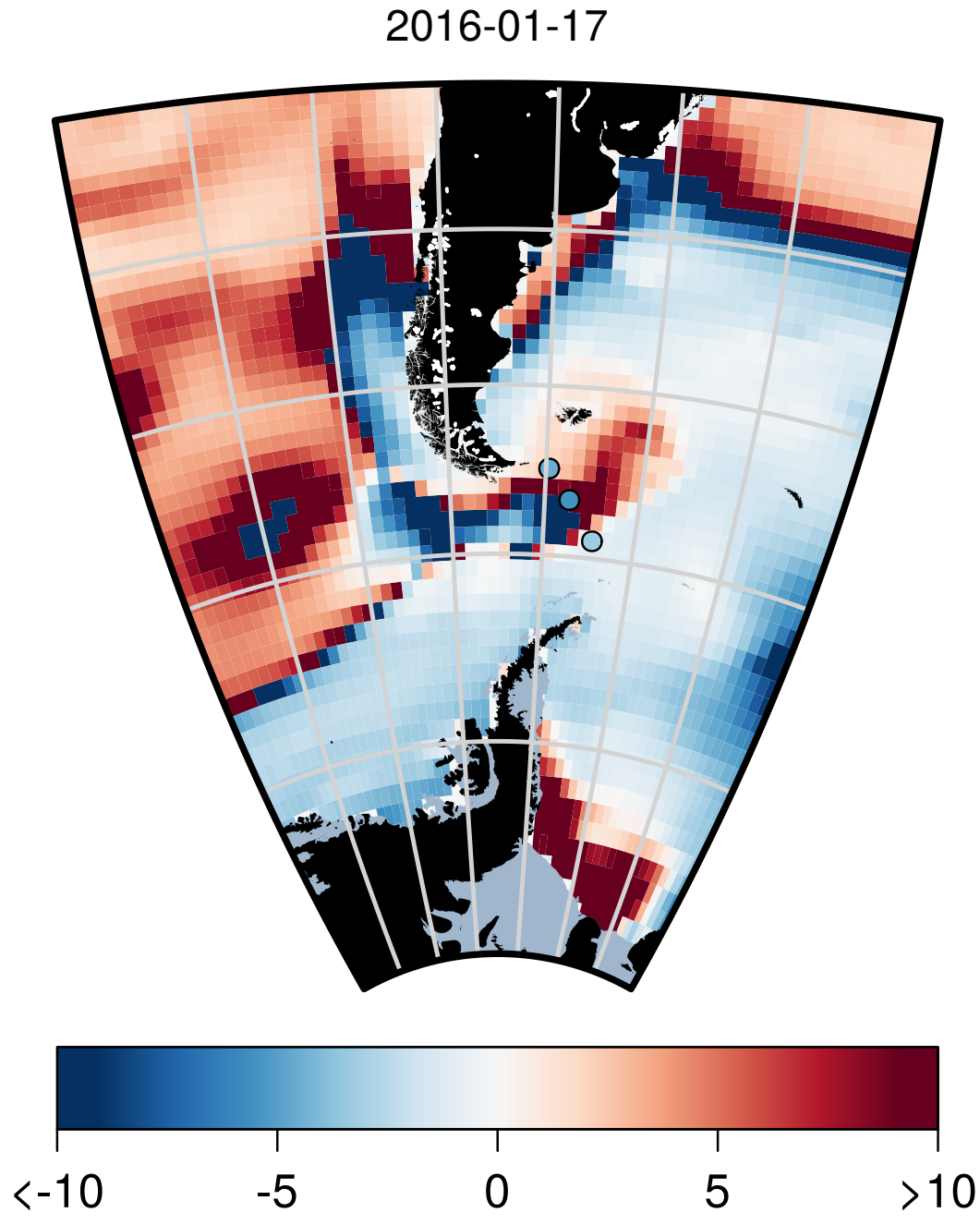
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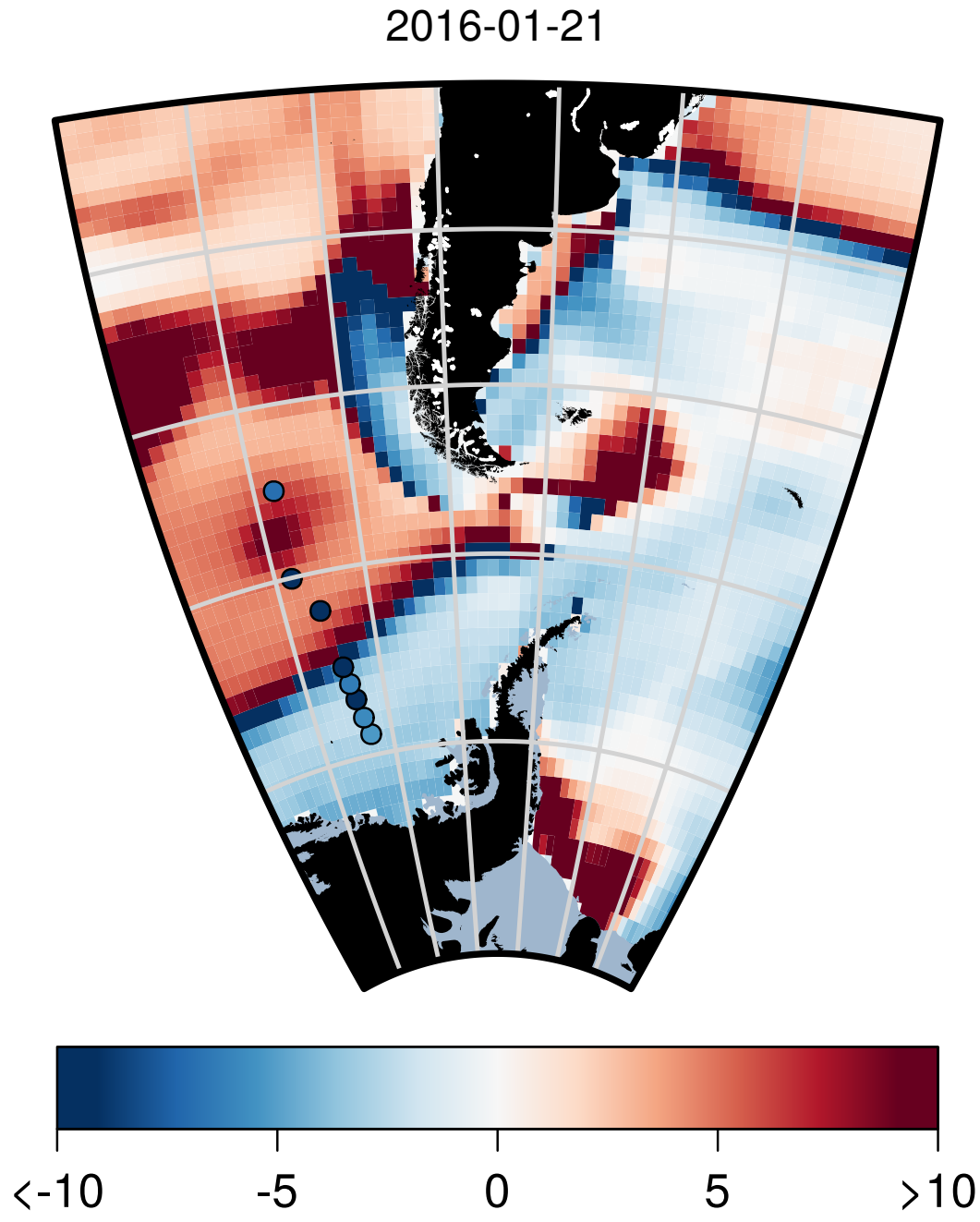
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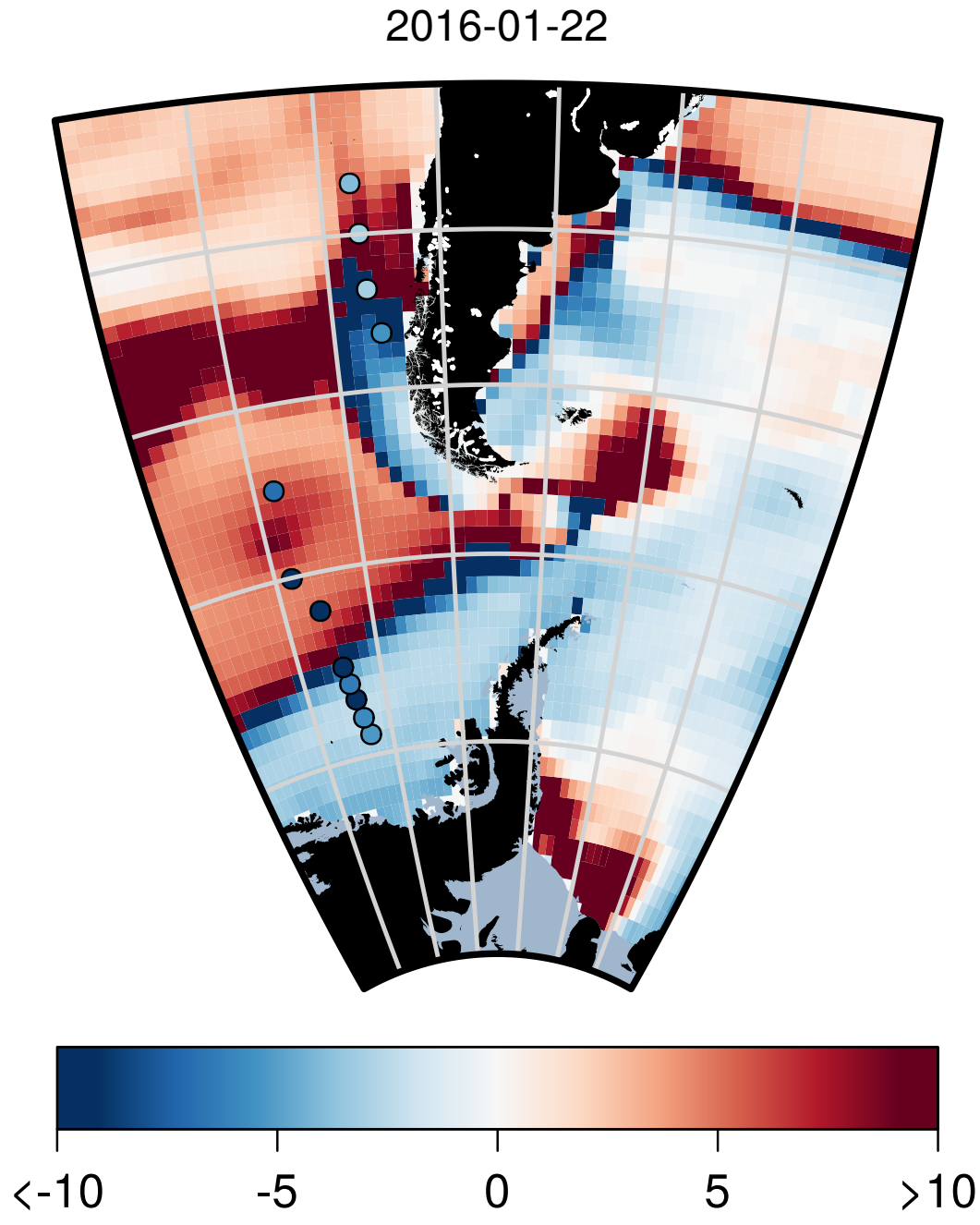
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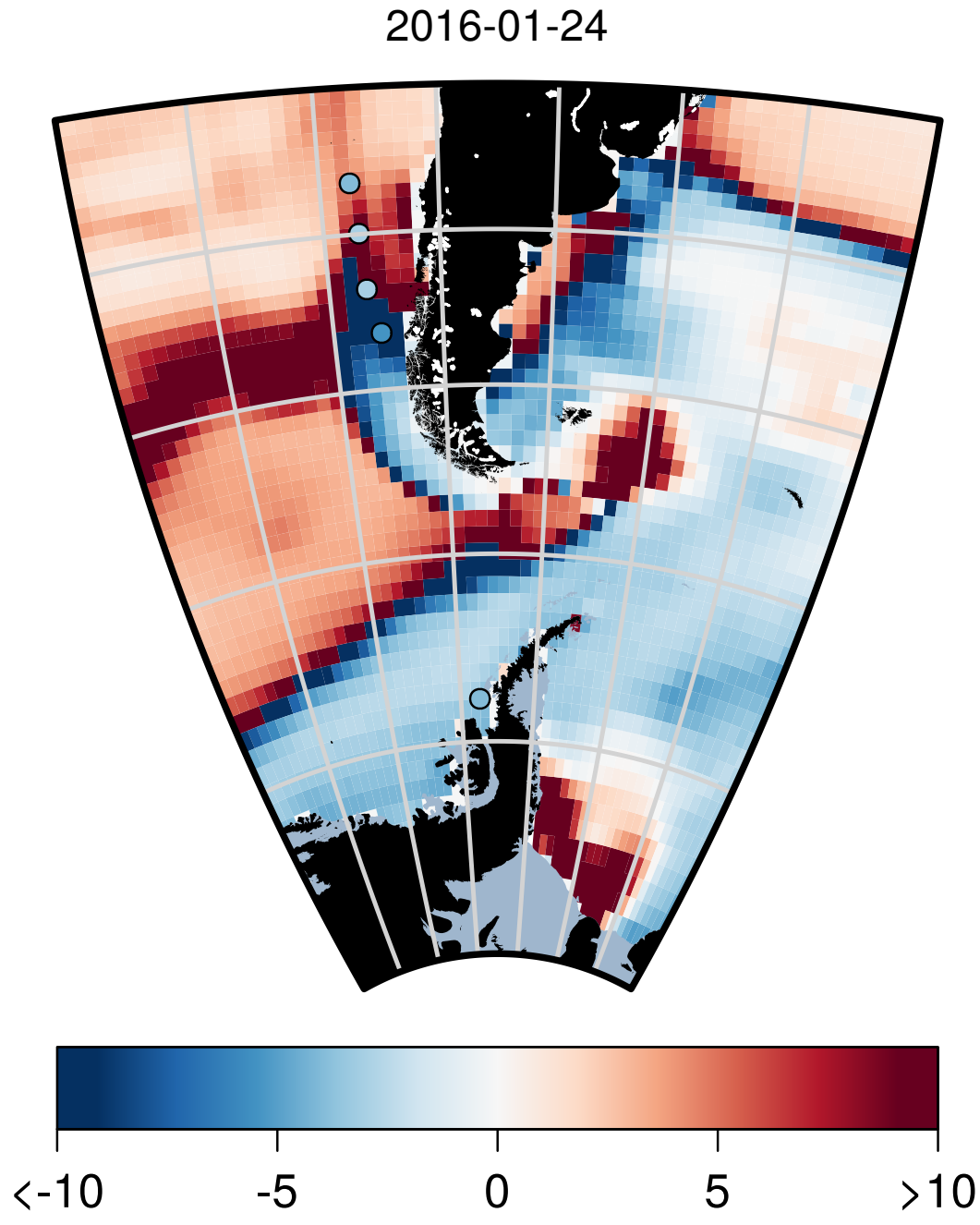
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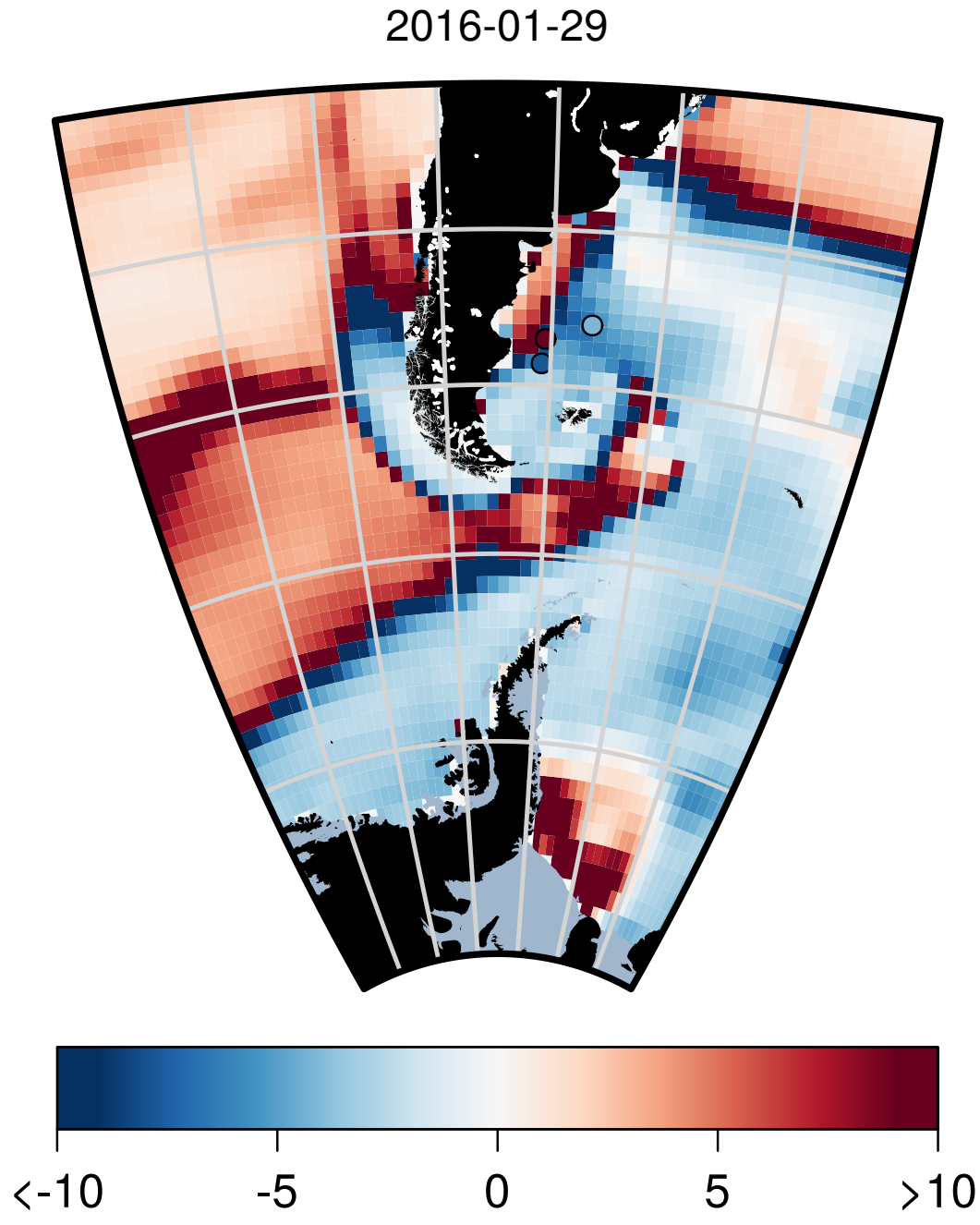
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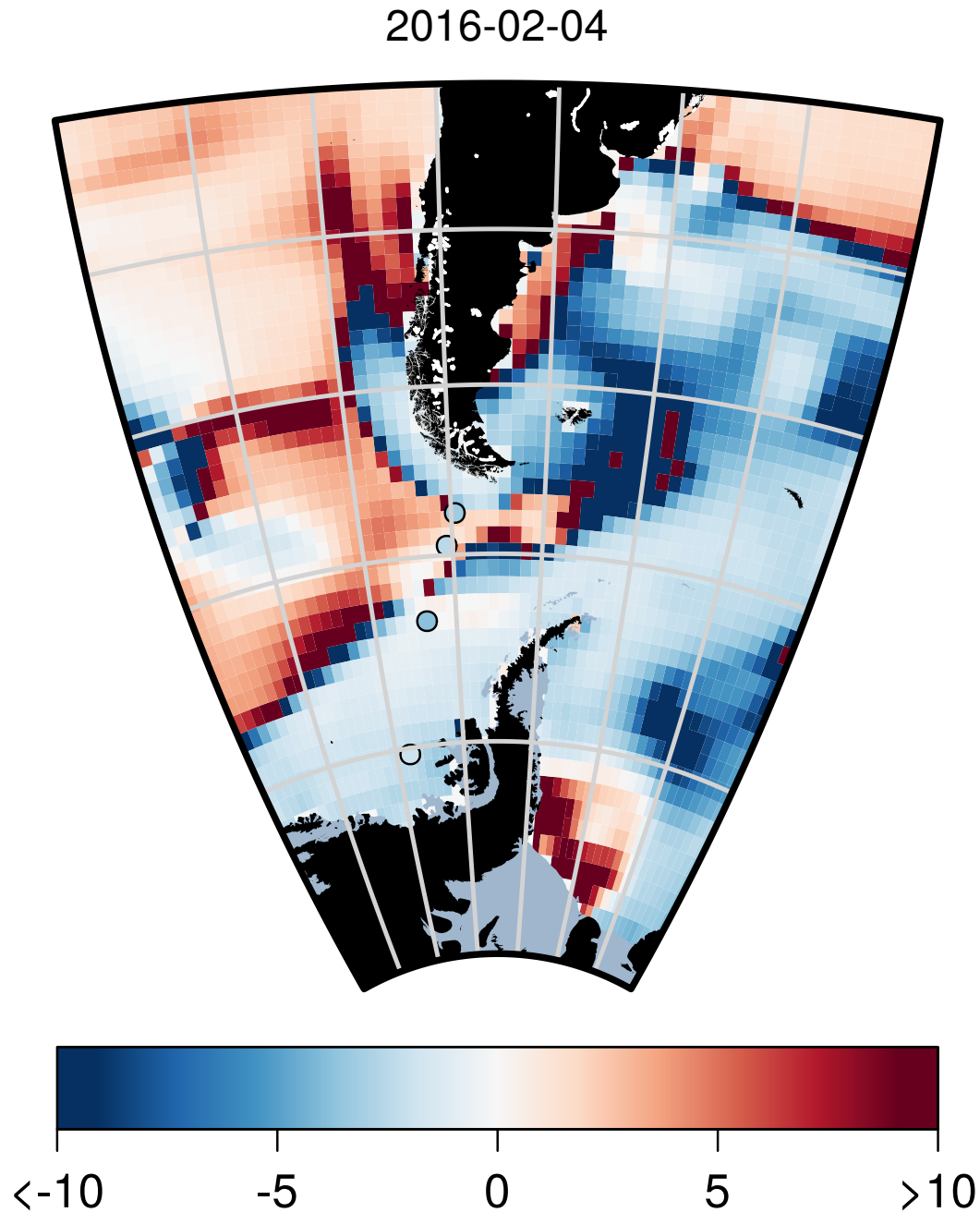
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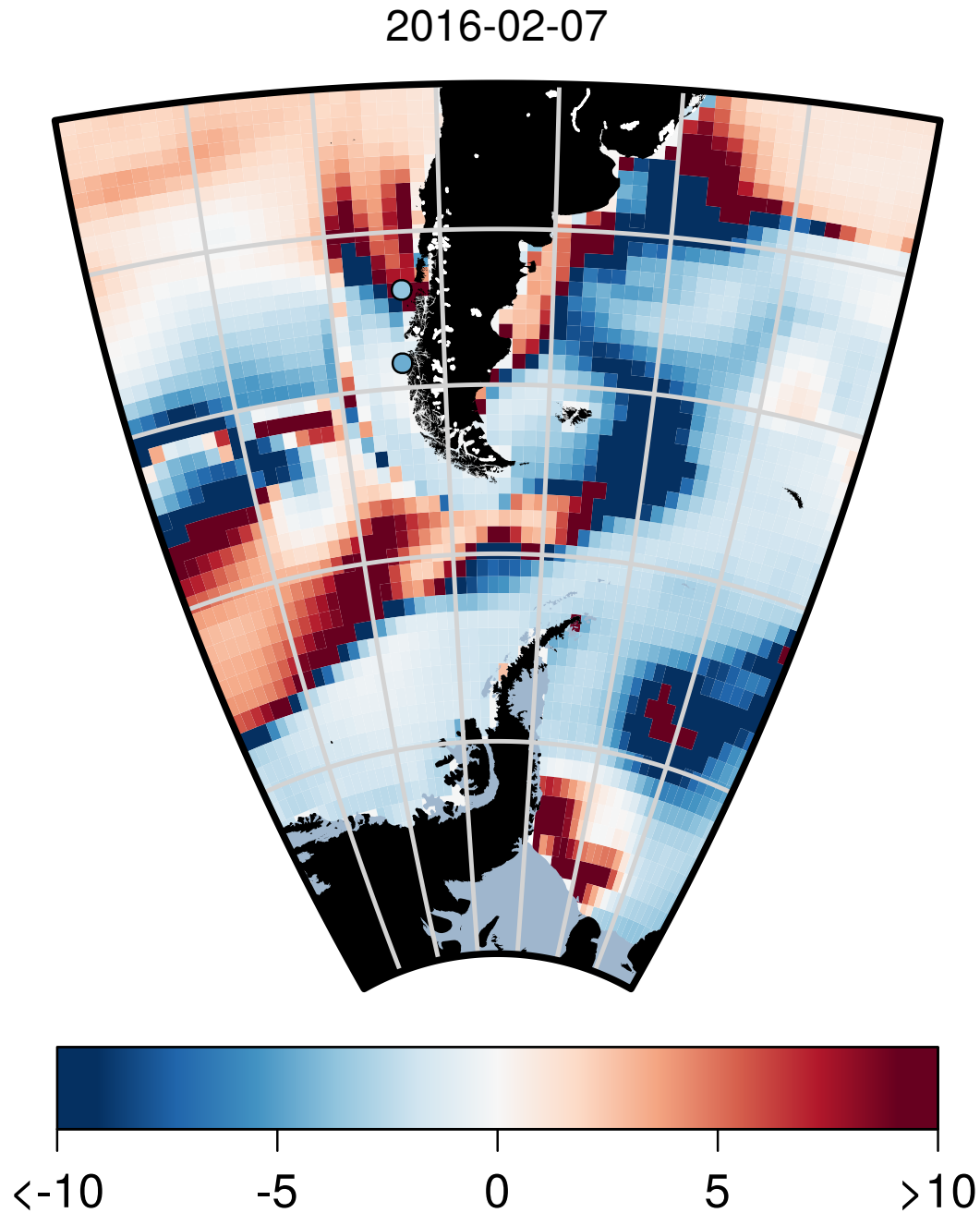
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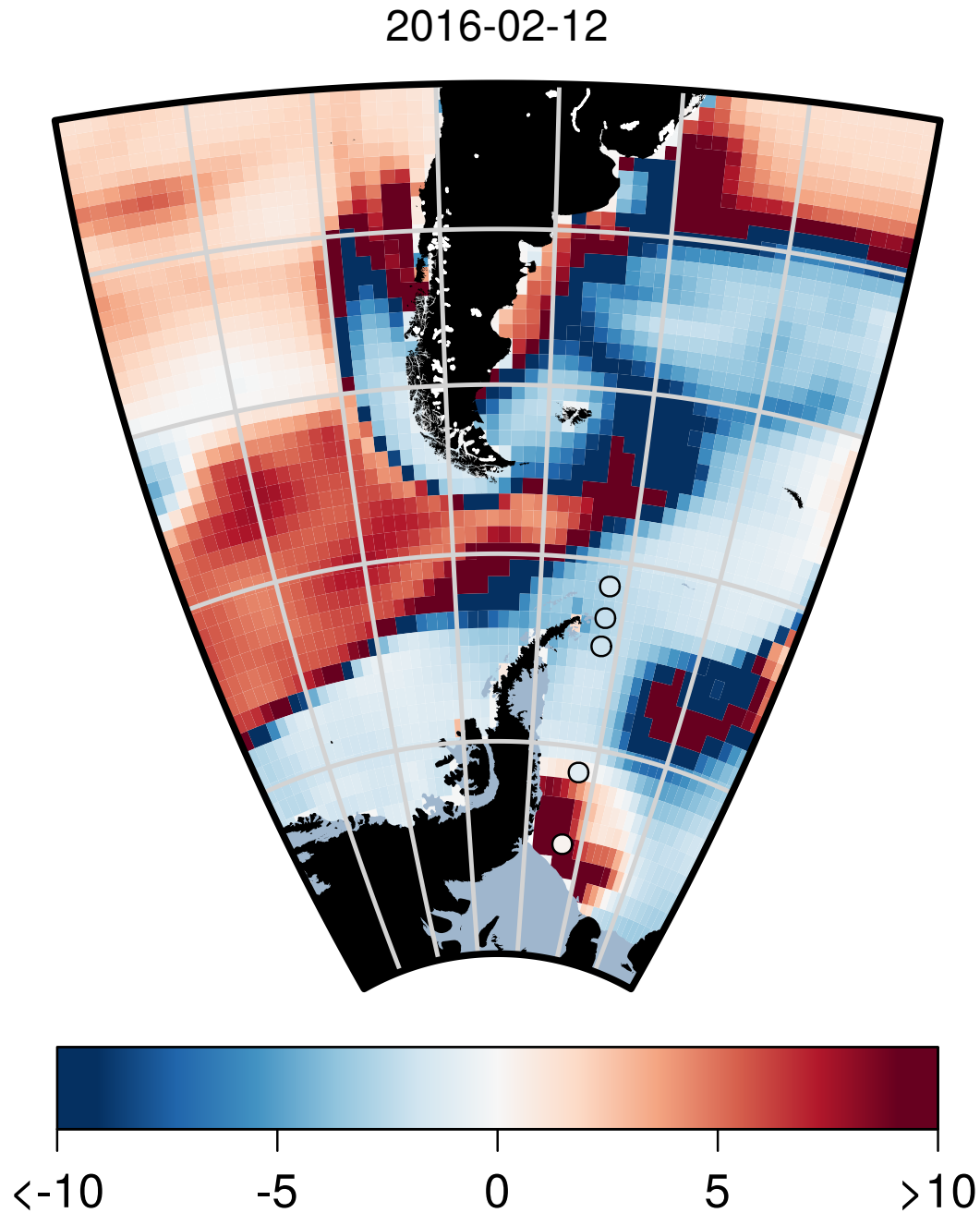
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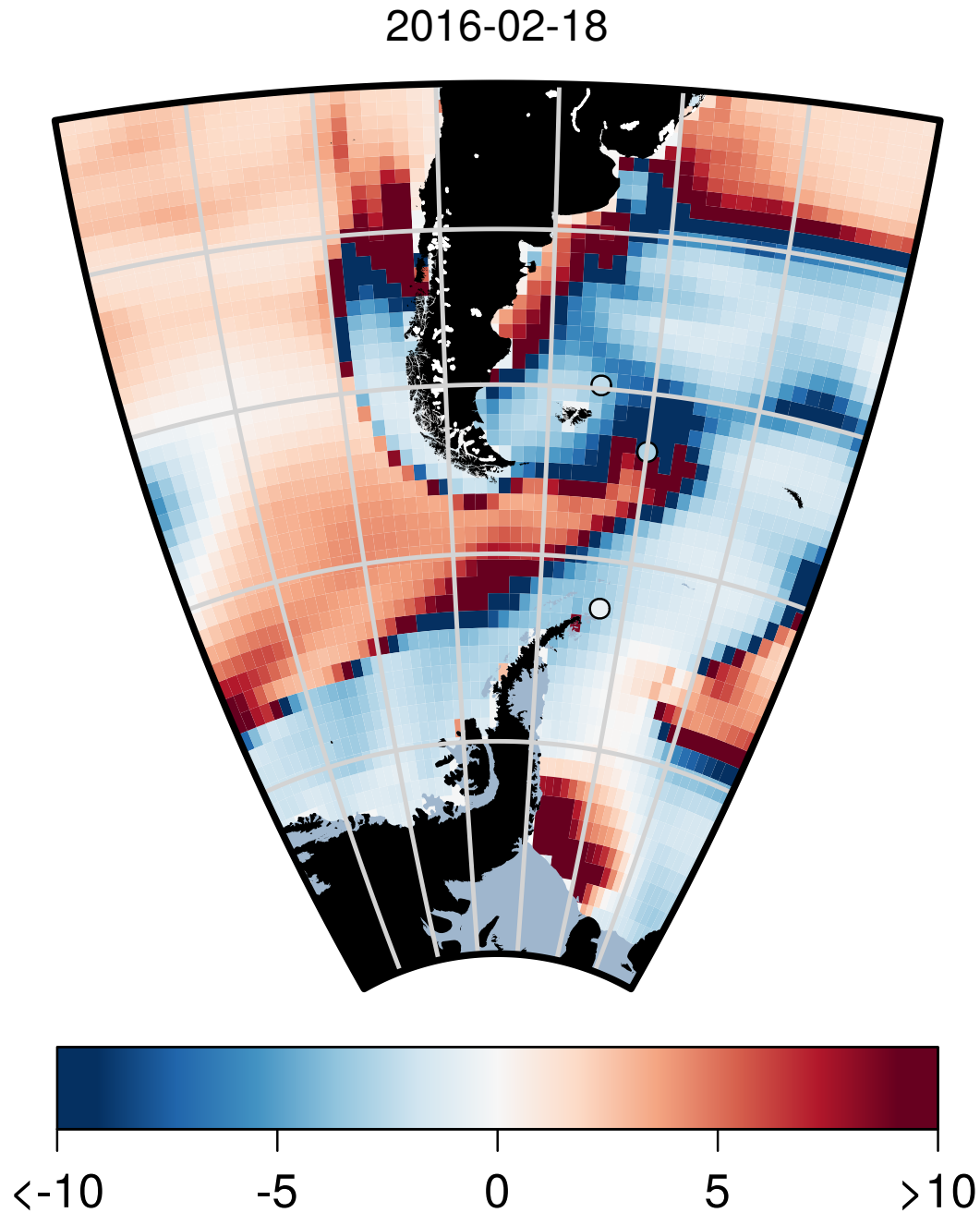
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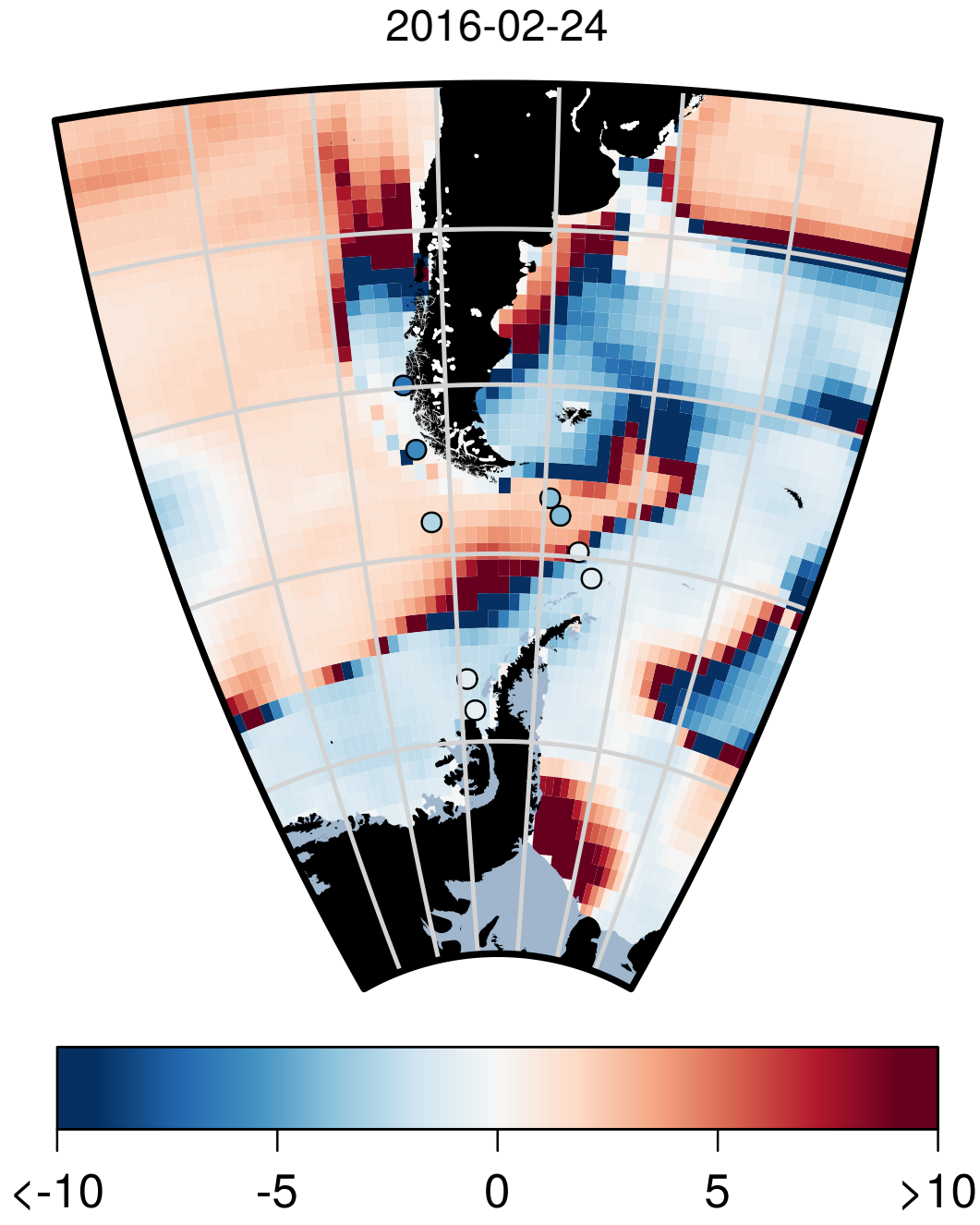
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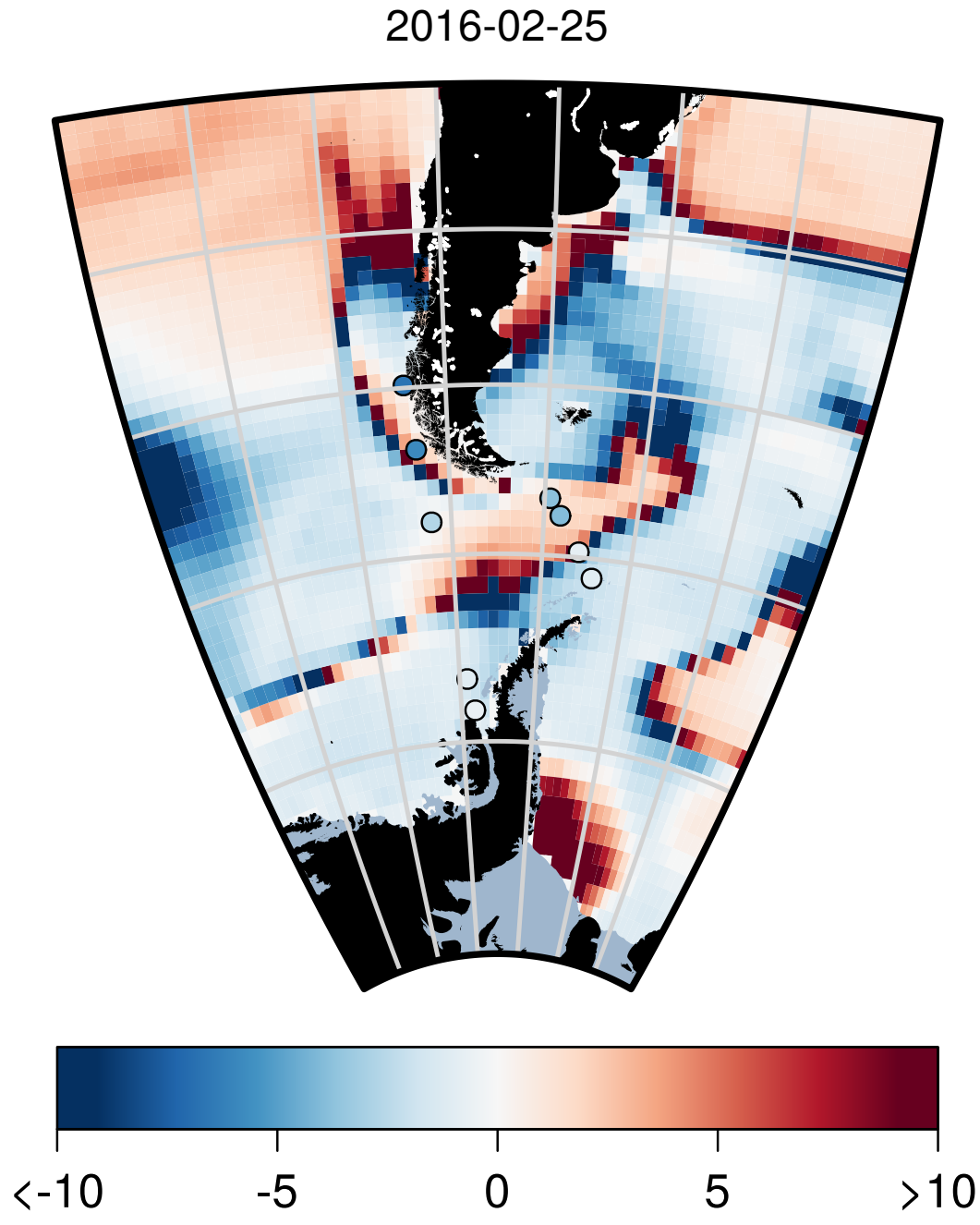
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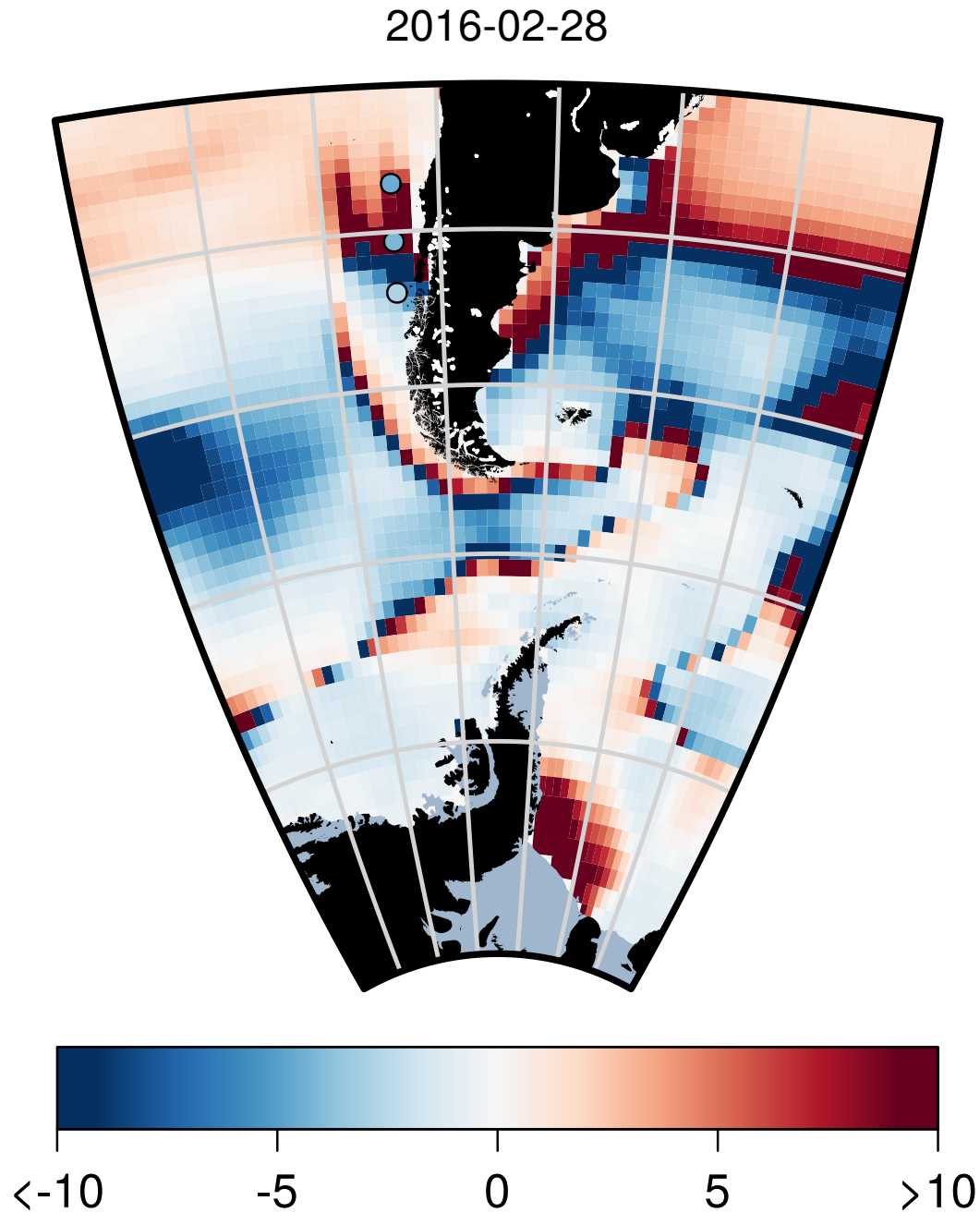
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