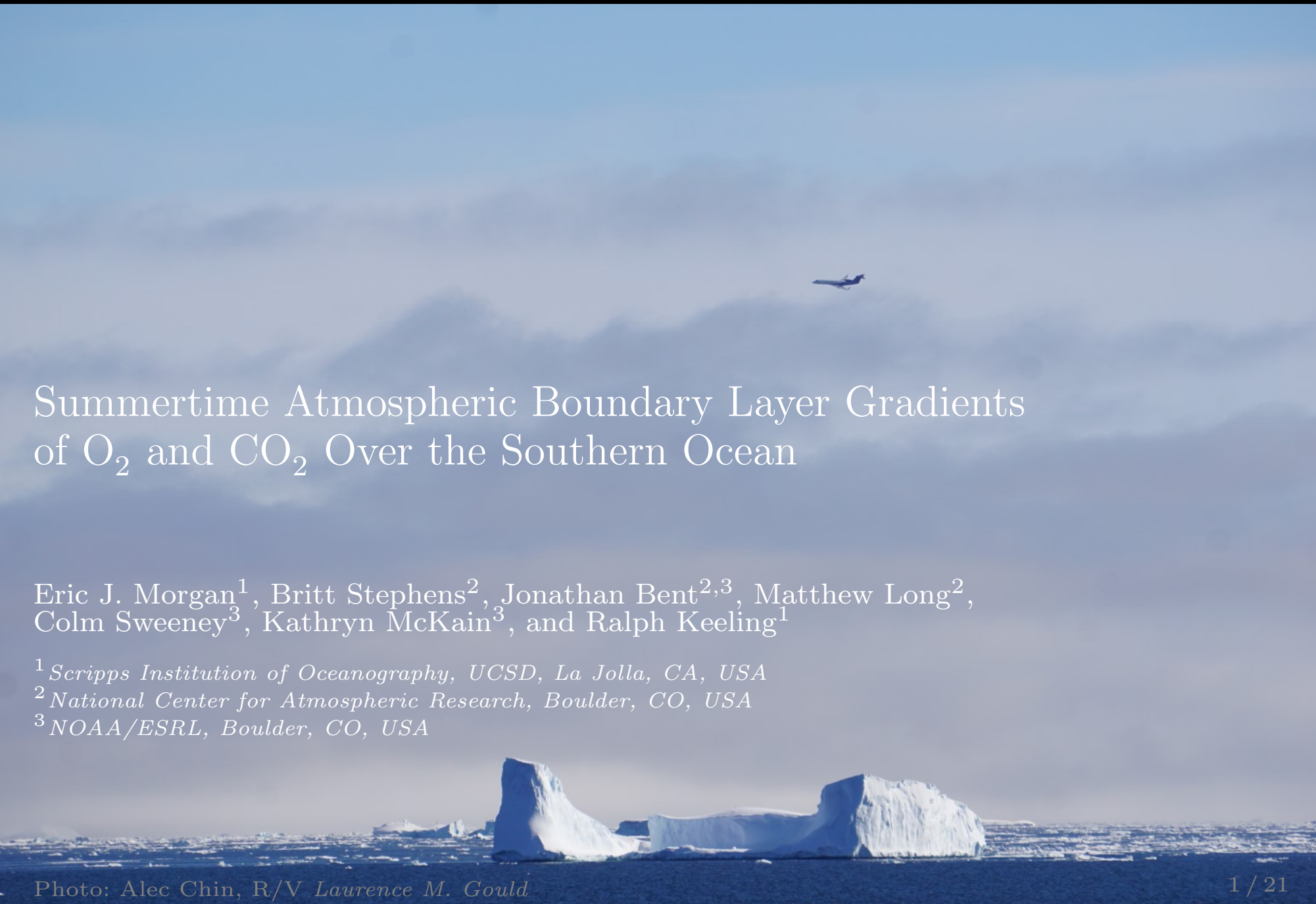

Summertime Atmospheric Boundary Layer Gradients of O_2 and CO_2 Over the Southern Ocean

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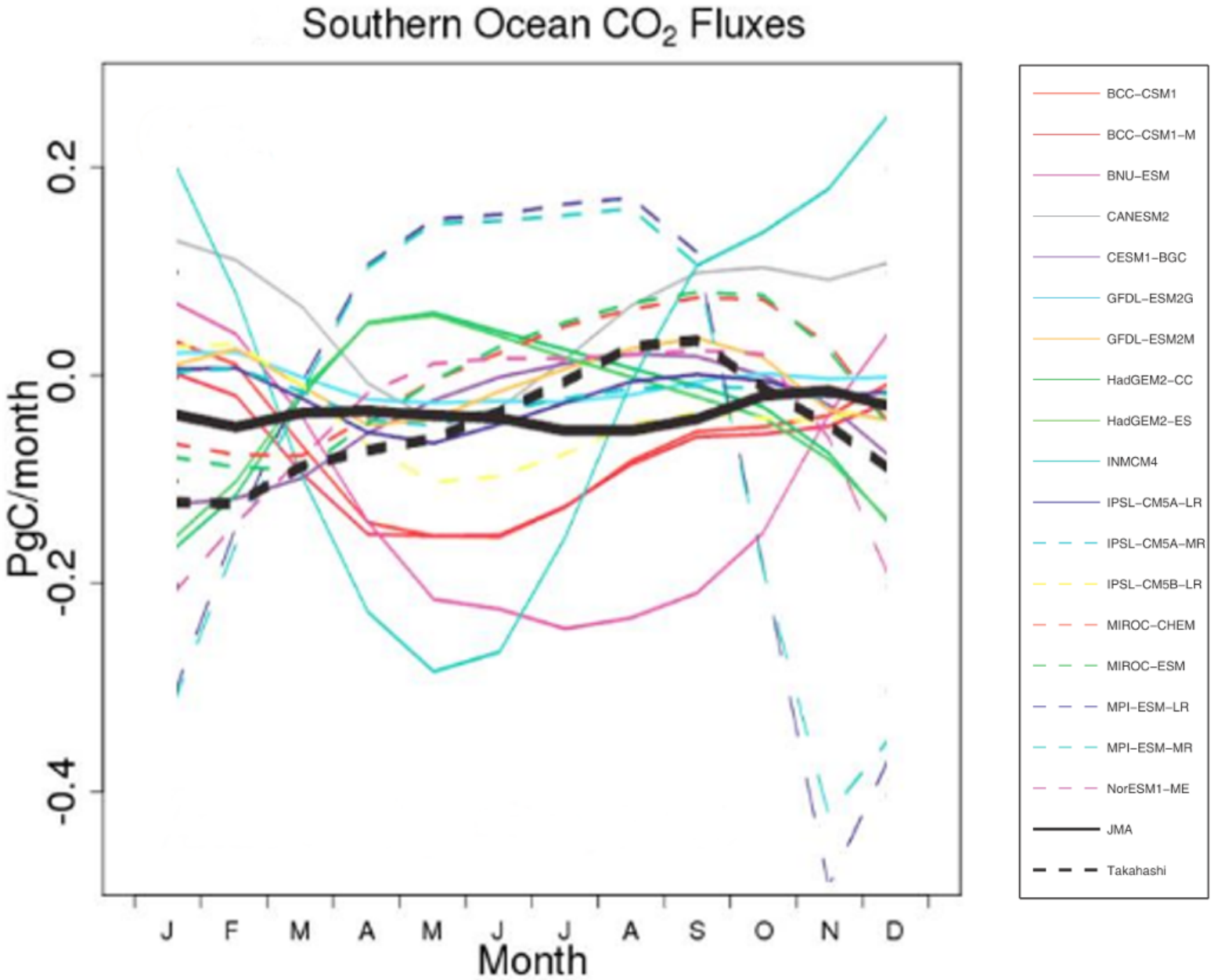
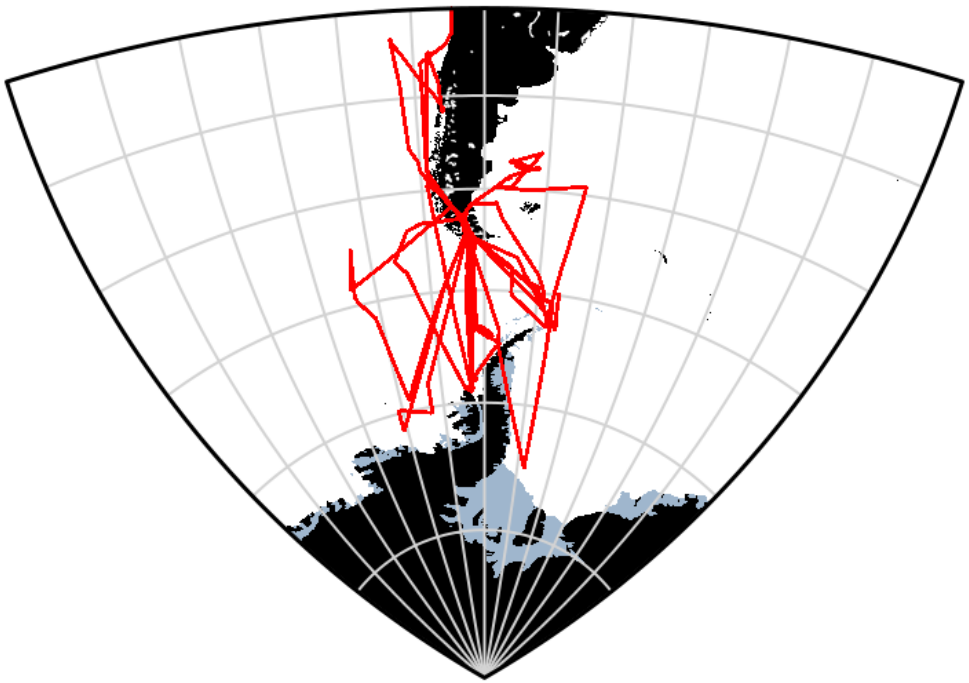
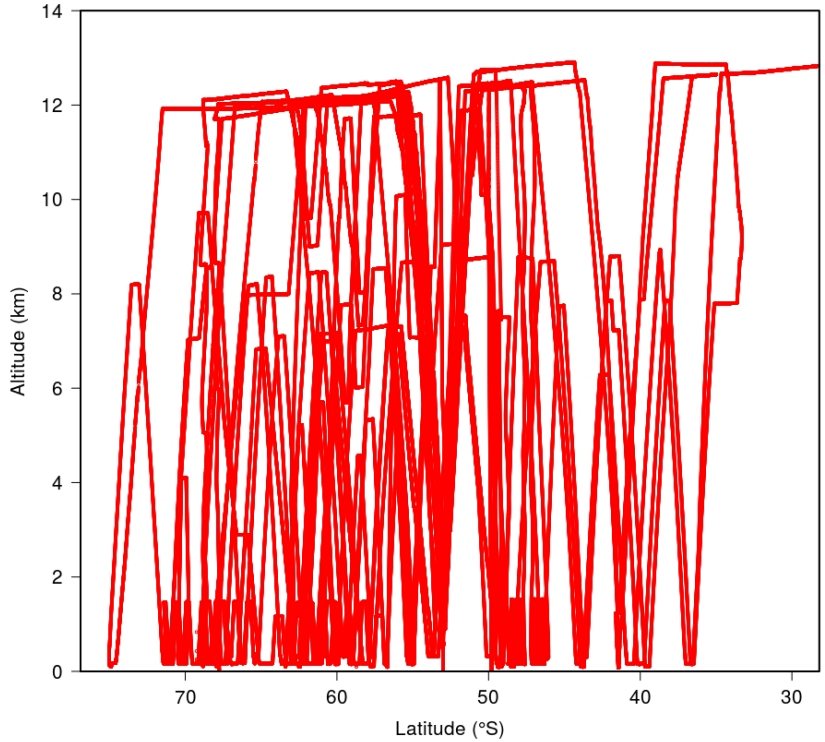
[2] *National Center for Atmospheric Research, Boulder, CO, USA*
[3] *NOAA/ESRL, Boulder, CO, USA*

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



Redrawn by Britt Stephens from Anav et al., 2013, J. Climate





- The O_2/N_2 Ratio and CO_2 Airborne Southern Ocean Study
- 19 research flights, 98 flight hours, Jan 15–Feb 25 2016

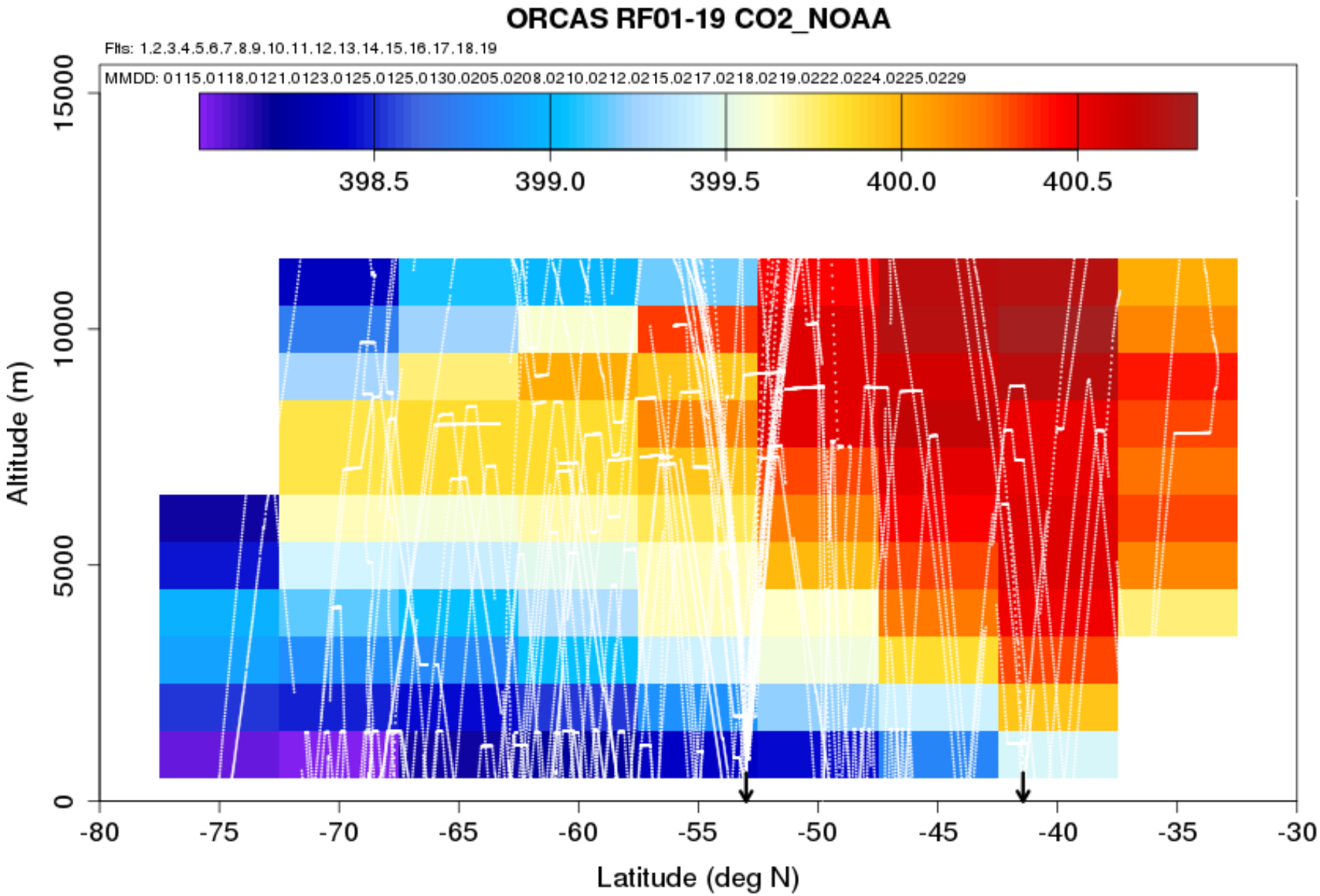


Figure courtesy of Britt Stephens

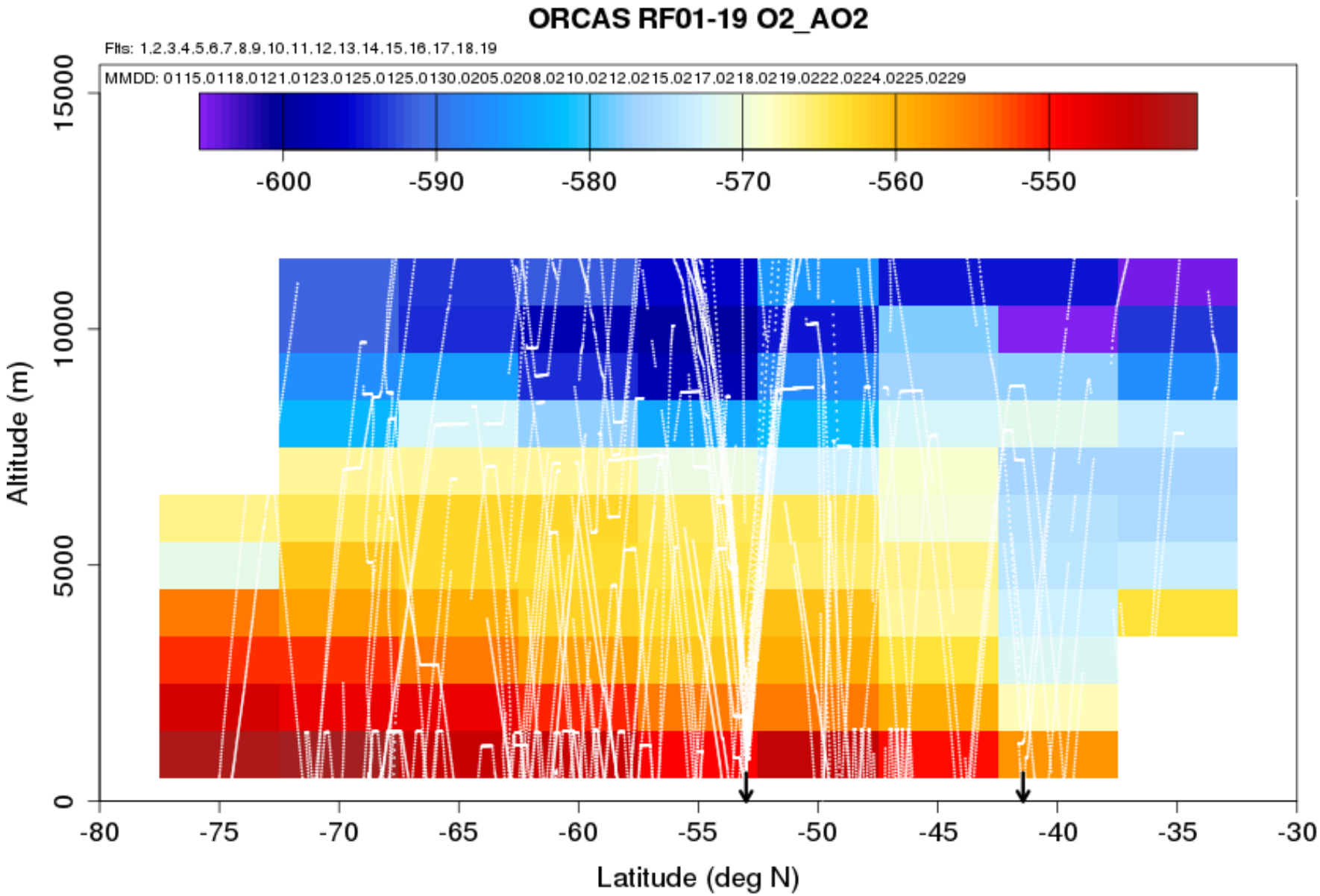


Figure courtesy of Britt Stephens

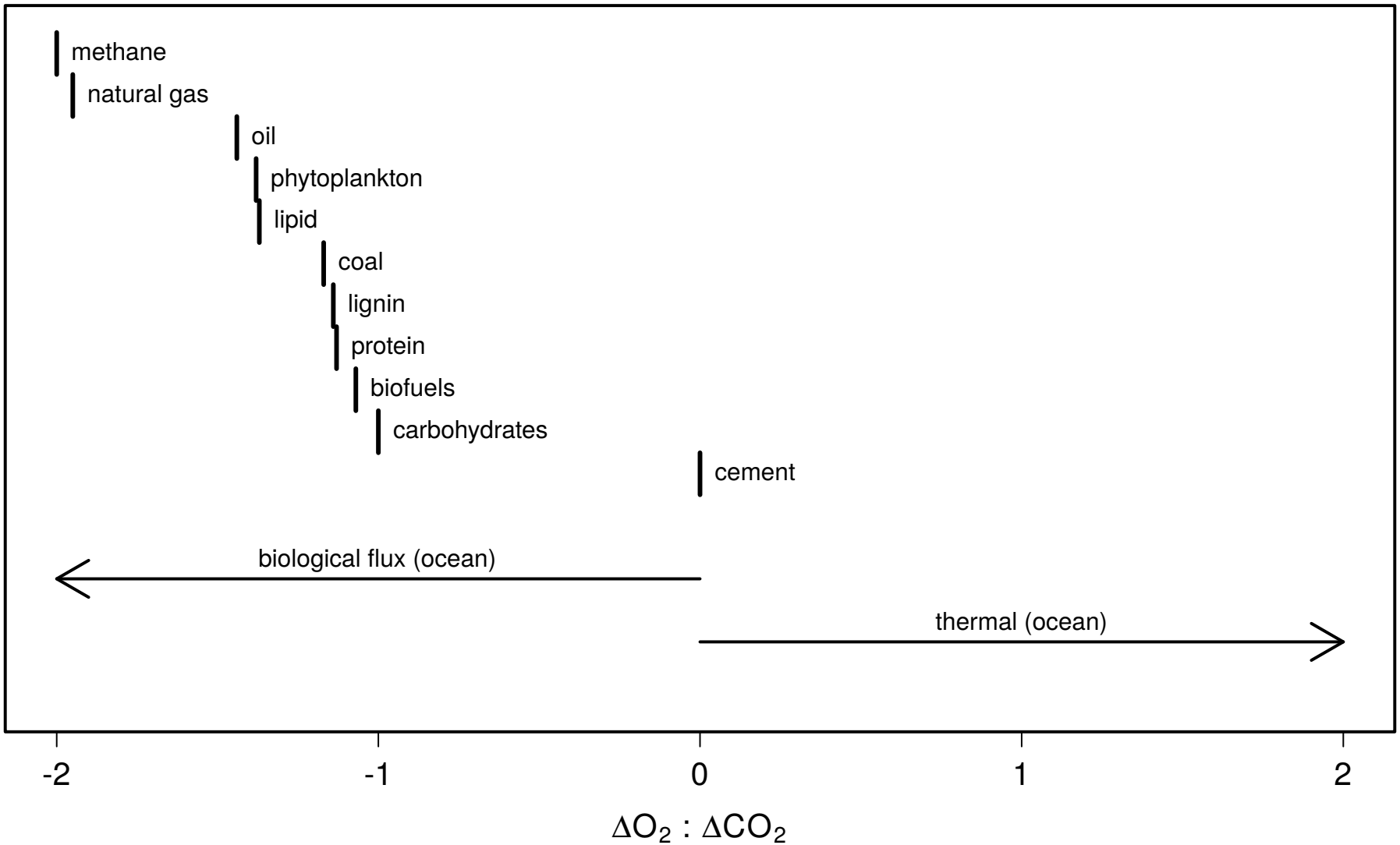
ΔO_2 / ΔCO_2

- 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

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

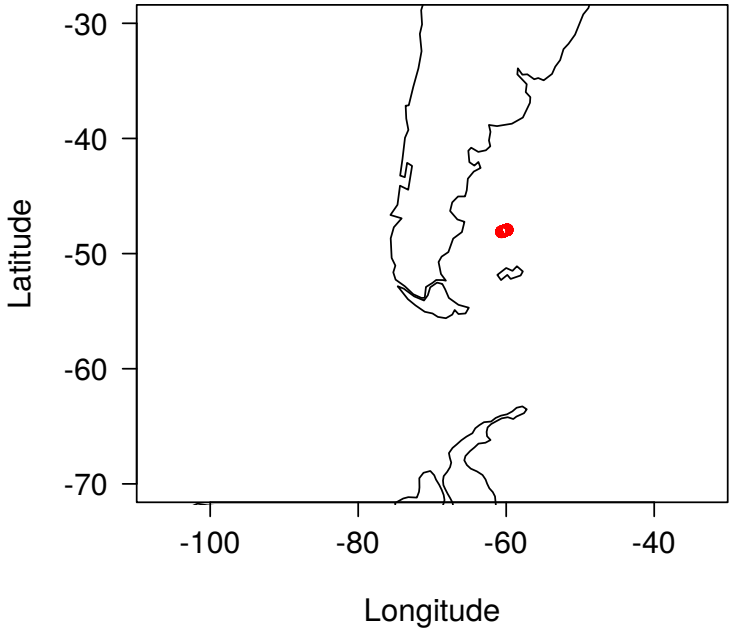
δAPO

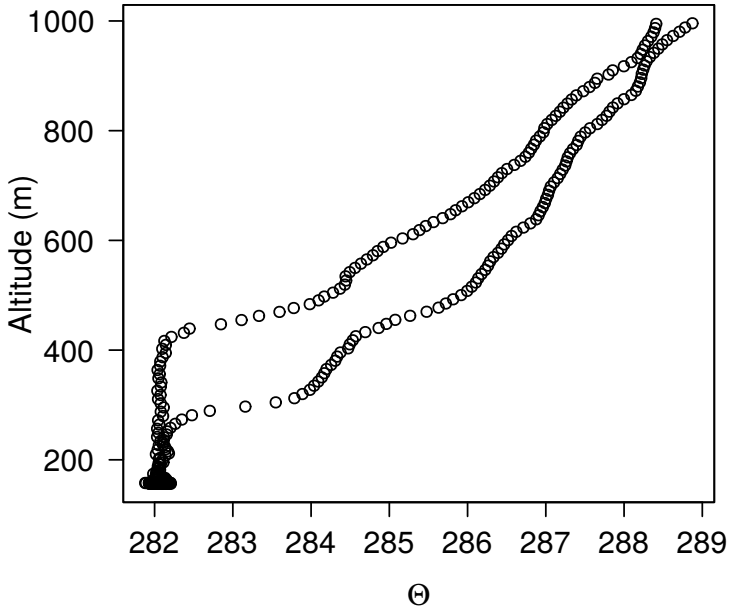
- Atmospheric Potential Oxygen
- $\delta\text{APO} = \delta(O_2/N_2) + \frac{1.1}{X_{O_2}}(CO_2 - 350)$
- *i.e.*, atmospheric oxygen with the influence of the terrestrial biosphere removed, in units of per meg (*Stephens et al., 1998*)

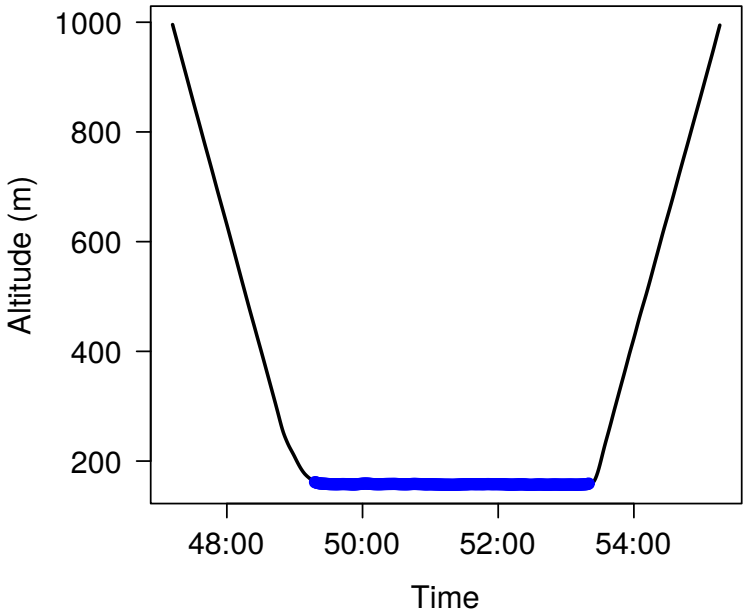


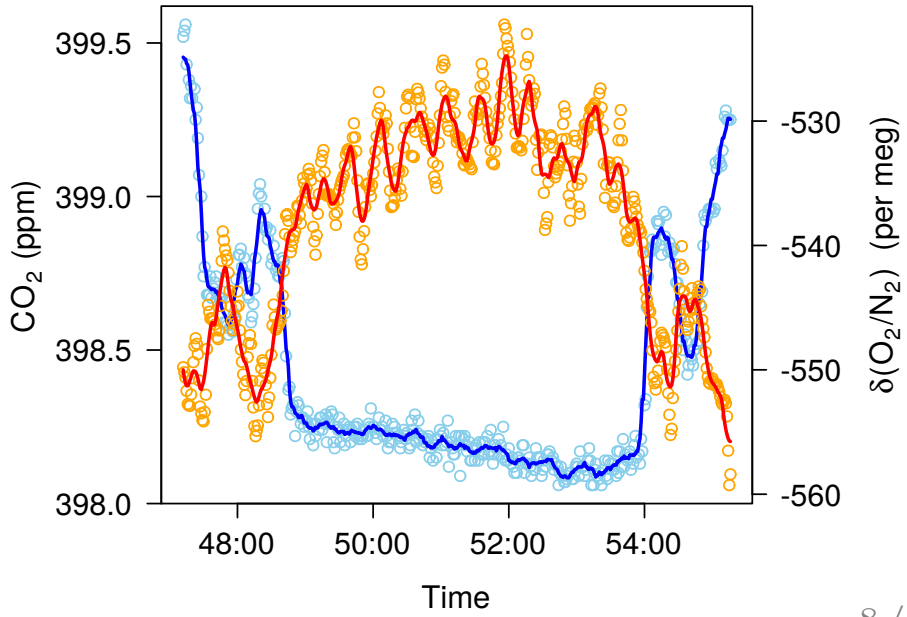
From/after: Keeling, 1988; Masiello, et. al., 2008; Randerson, et al., 2006; Steinbach, et al., 2011

Results | Example Dip (RF07)



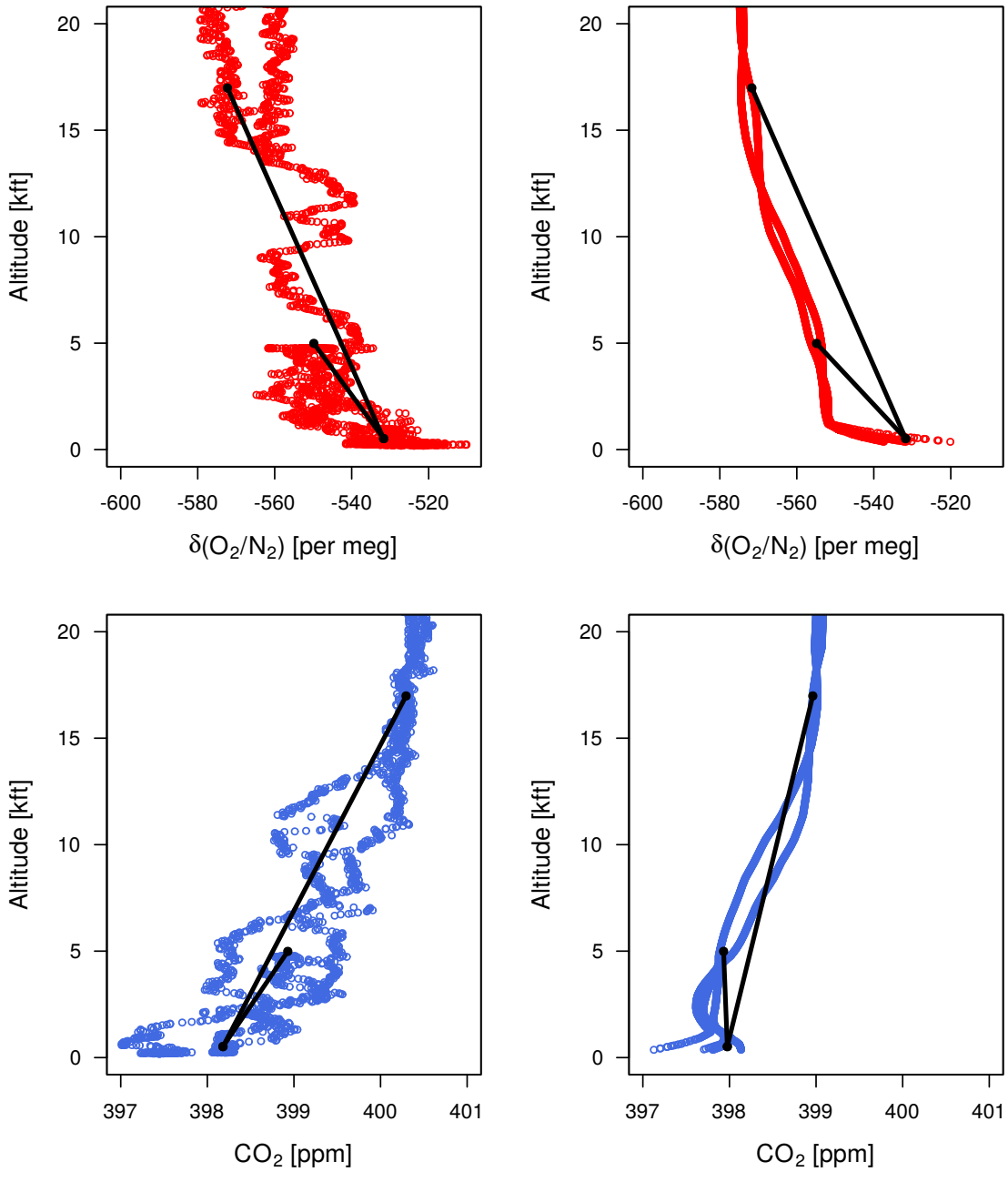




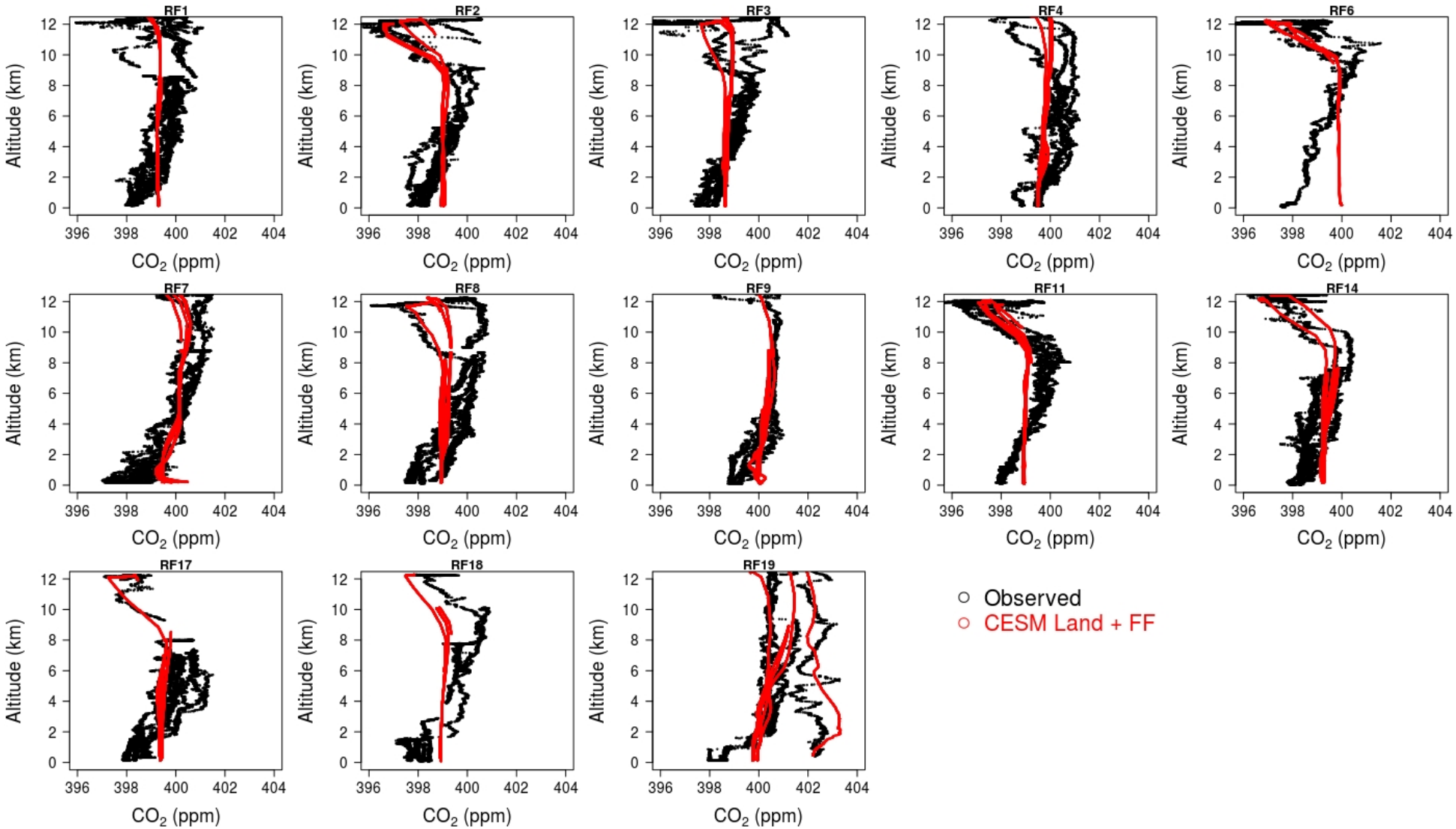


Results | Example Dip (RF07)

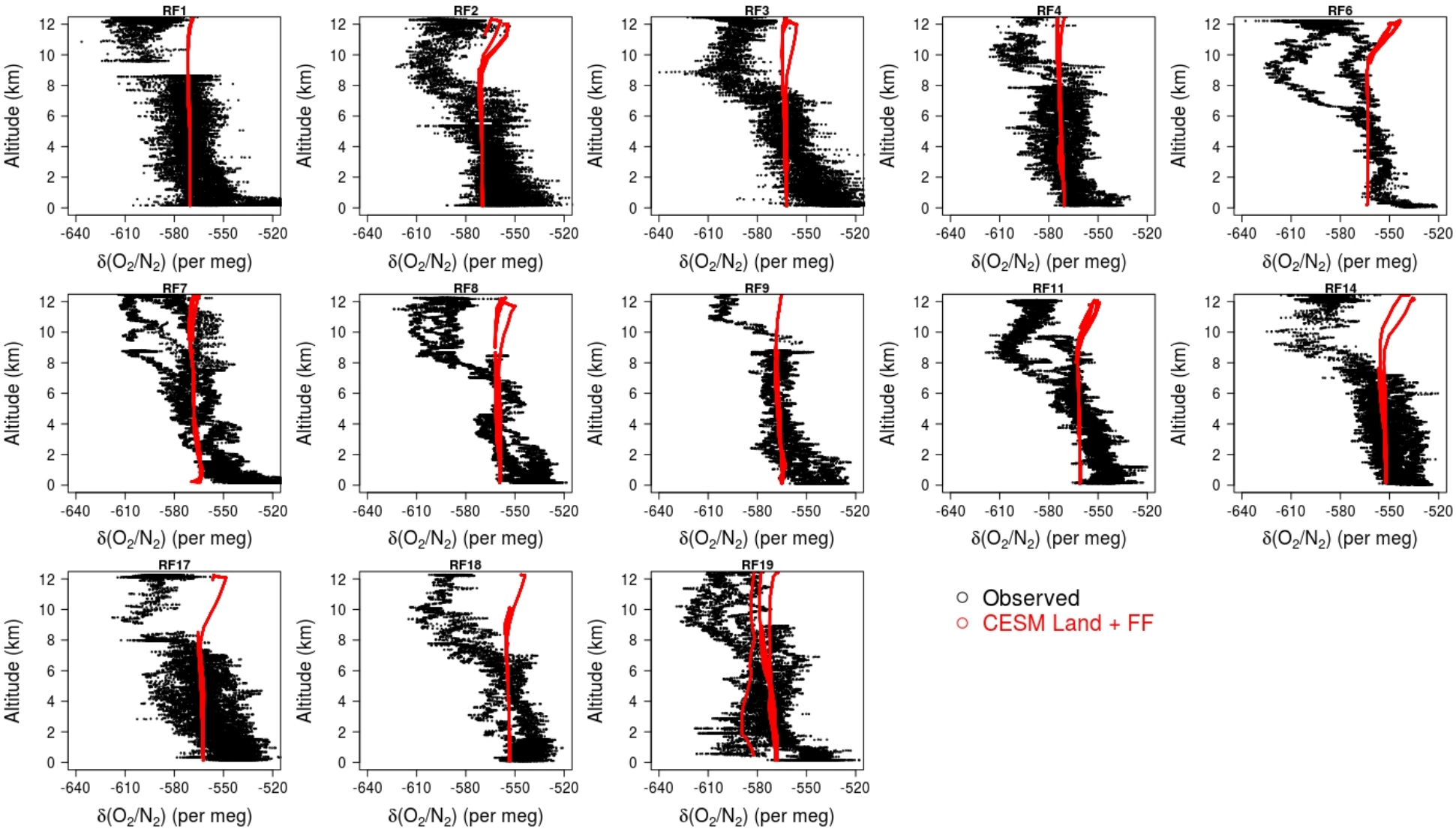
Observed $\mathrm{CGR}_{5\mathrm{kft}} = -5.1$
Observed $\mathrm{CGR}_{15\mathrm{kft}} = -4.0$
CESM $\mathrm{CGR}_{5\mathrm{kft}} = 113.2$
CESM $\mathrm{CGR}_{15\mathrm{kft}} = -8.4$



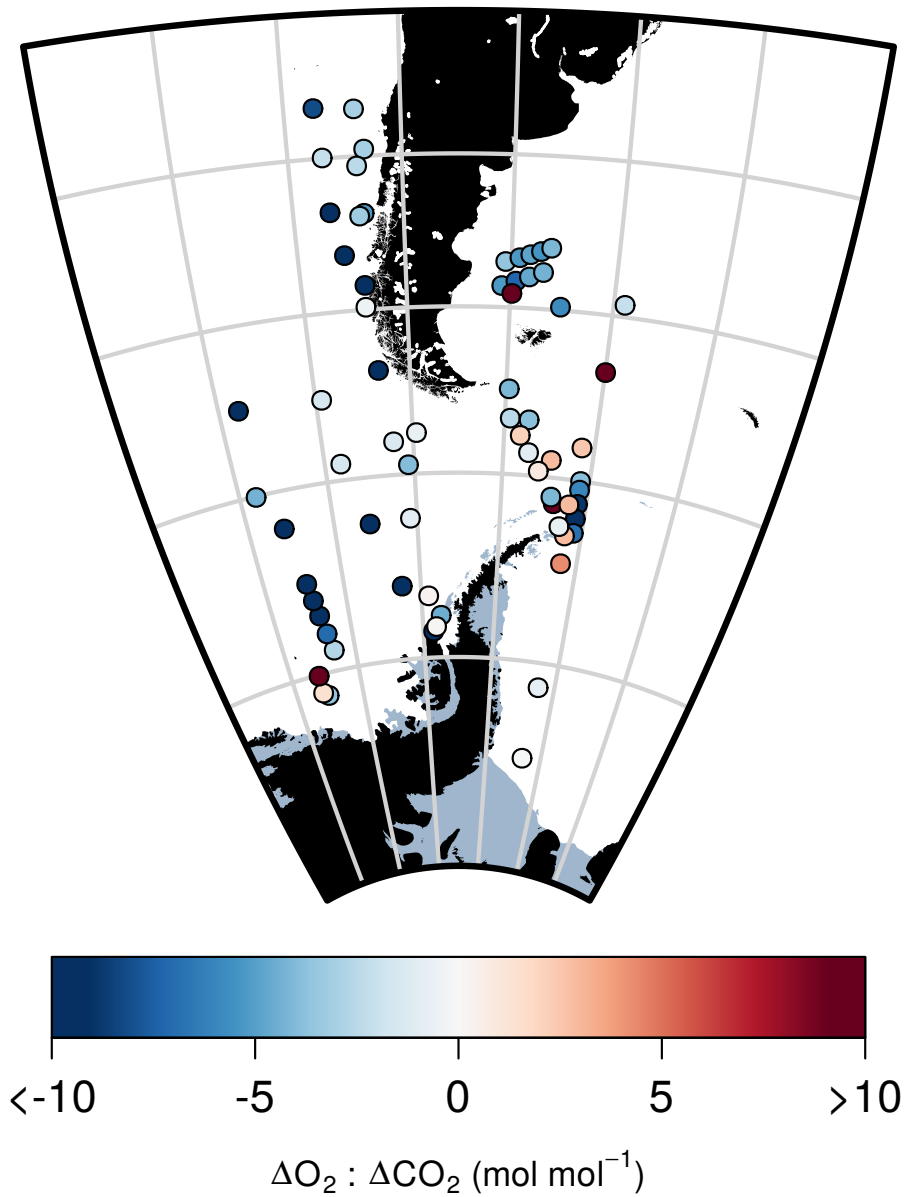
Results | Terrestrial and Fossil Fuel Vertical Gradients

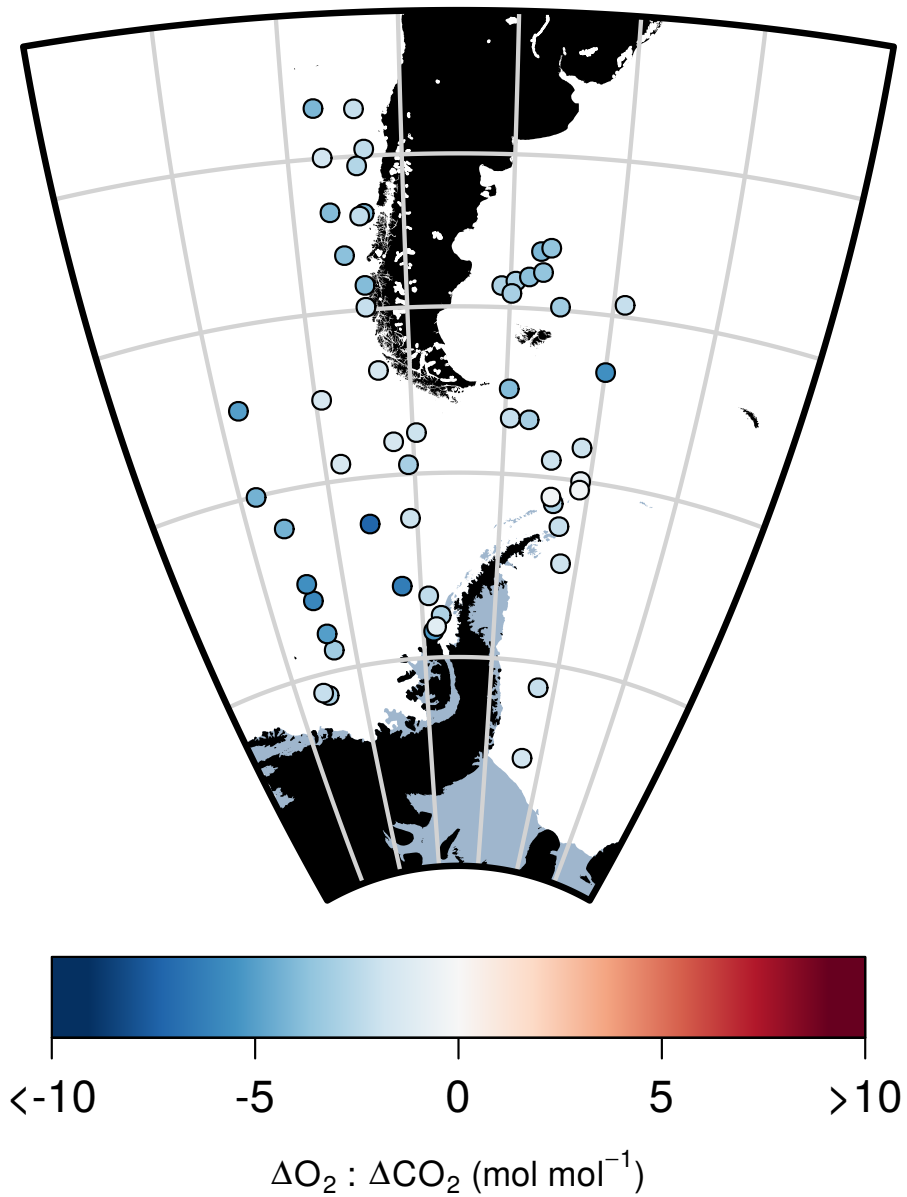


Results | Terrestrial and Fossil Fuel Vertical Gradients

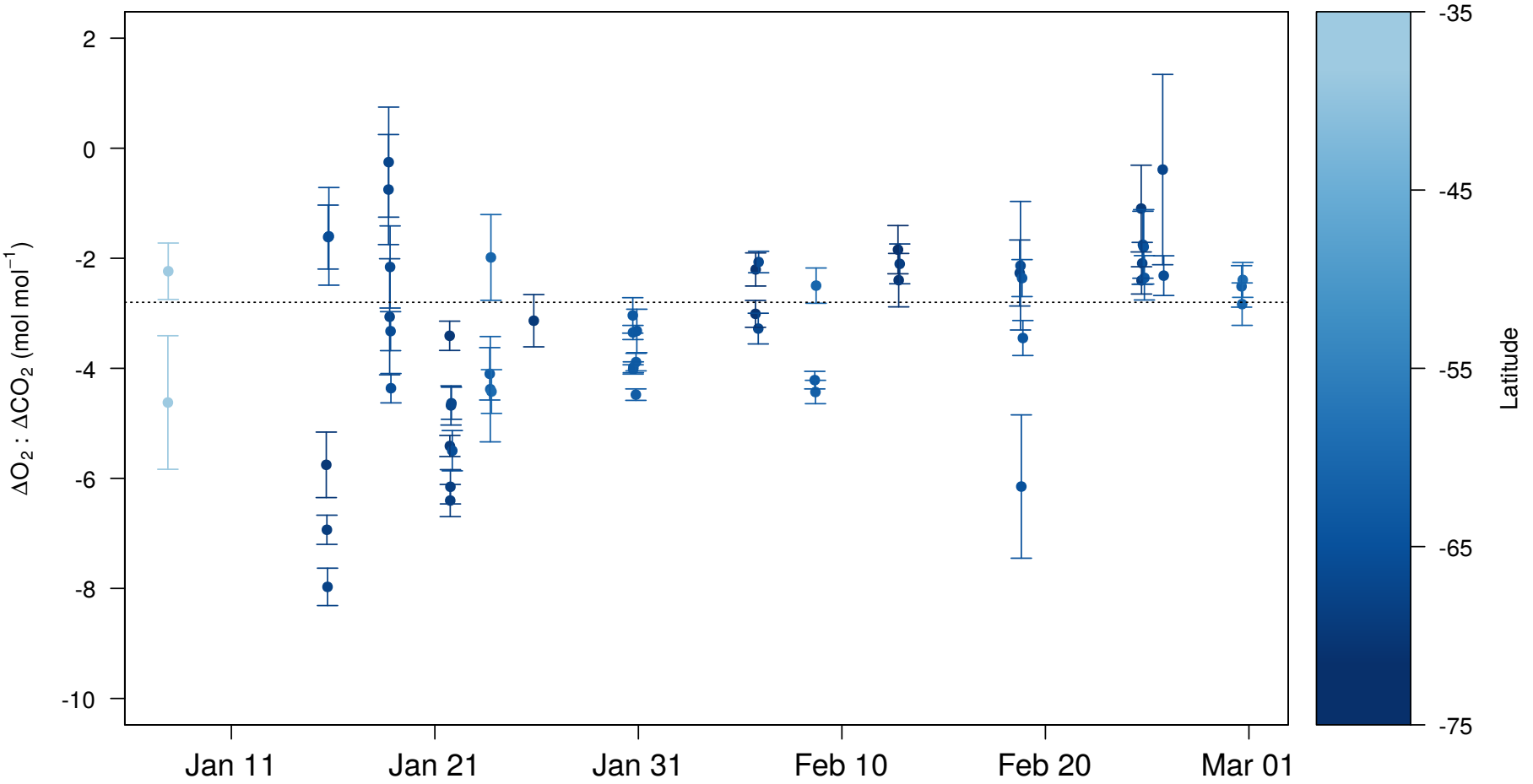


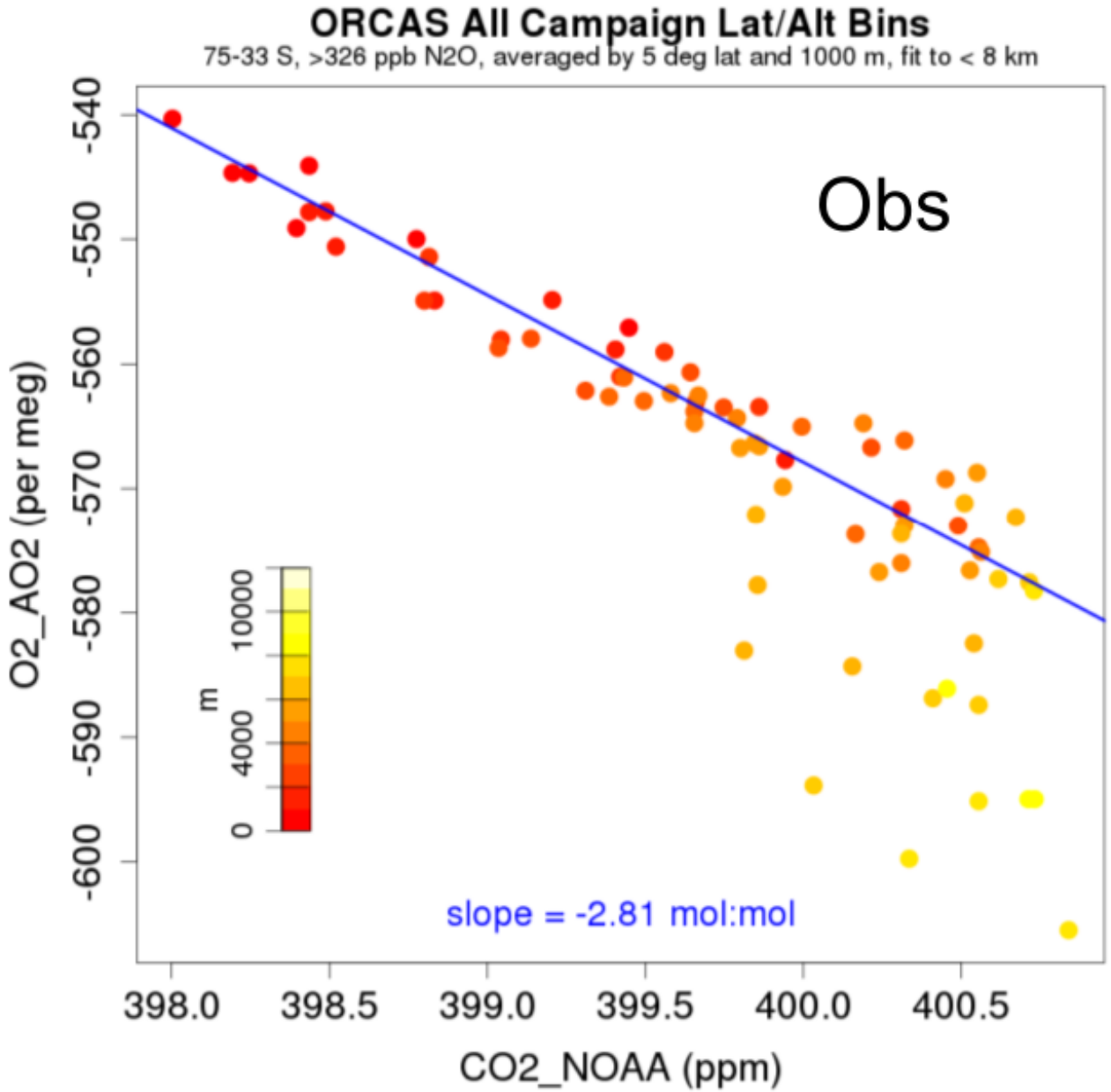
Reference Height	Description	Mean $\pm 1\sigma$
5 kft	ΔCO_2 (ppm)	-0.32 ± 0.5
	ΔO_2 (ppm eq)	1.6 ± 2.5
	ΔAPO (ppm eq)	1.2 ± 2.1
	$\Delta O_2/\Delta CO_2$	-2.6 ± 16.4
	$\Delta APO/\Delta CO_2$	-1.5 ± 16.8
15 kft	ΔCO_2 (ppm)	-1.36 ± 0.8
	ΔO_2 (ppm eq)	4.4 ± 3.0
	ΔAPO (ppm eq)	3.0 ± 2.4
	$\Delta O_2/\Delta CO_2$	-3.3 ± 1.6
	$\Delta APO/\Delta CO_2$	-2.3 ± 1.6


<-10
-5
0
5
>10
ΔO2 : ΔCO2 (mol mol−1)

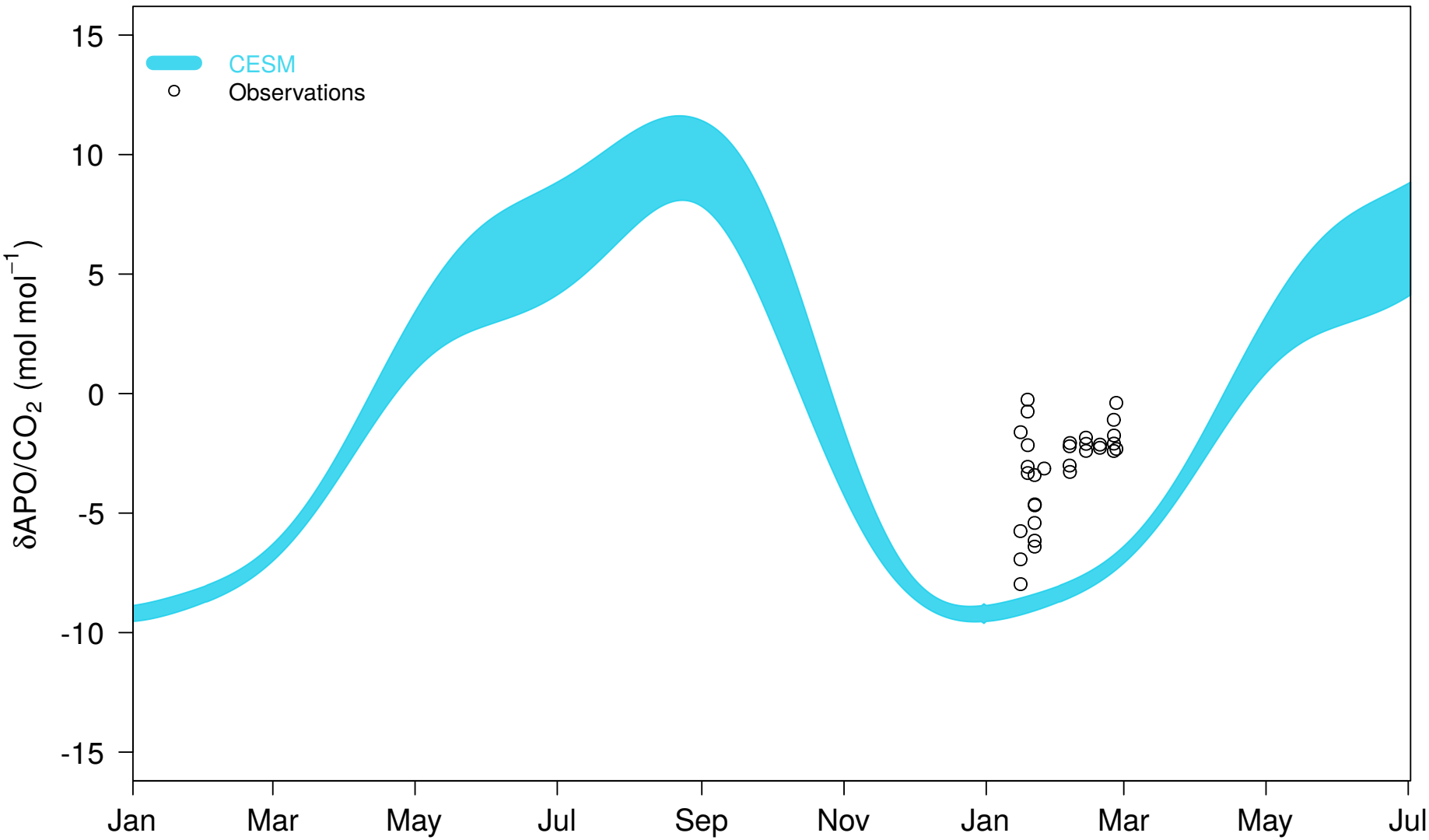

<-10
-5
0
5
>10
ΔO2 : ΔCO2 (mol mol−1)

Results | Timeseries of ORCAS CGRs (15kft)



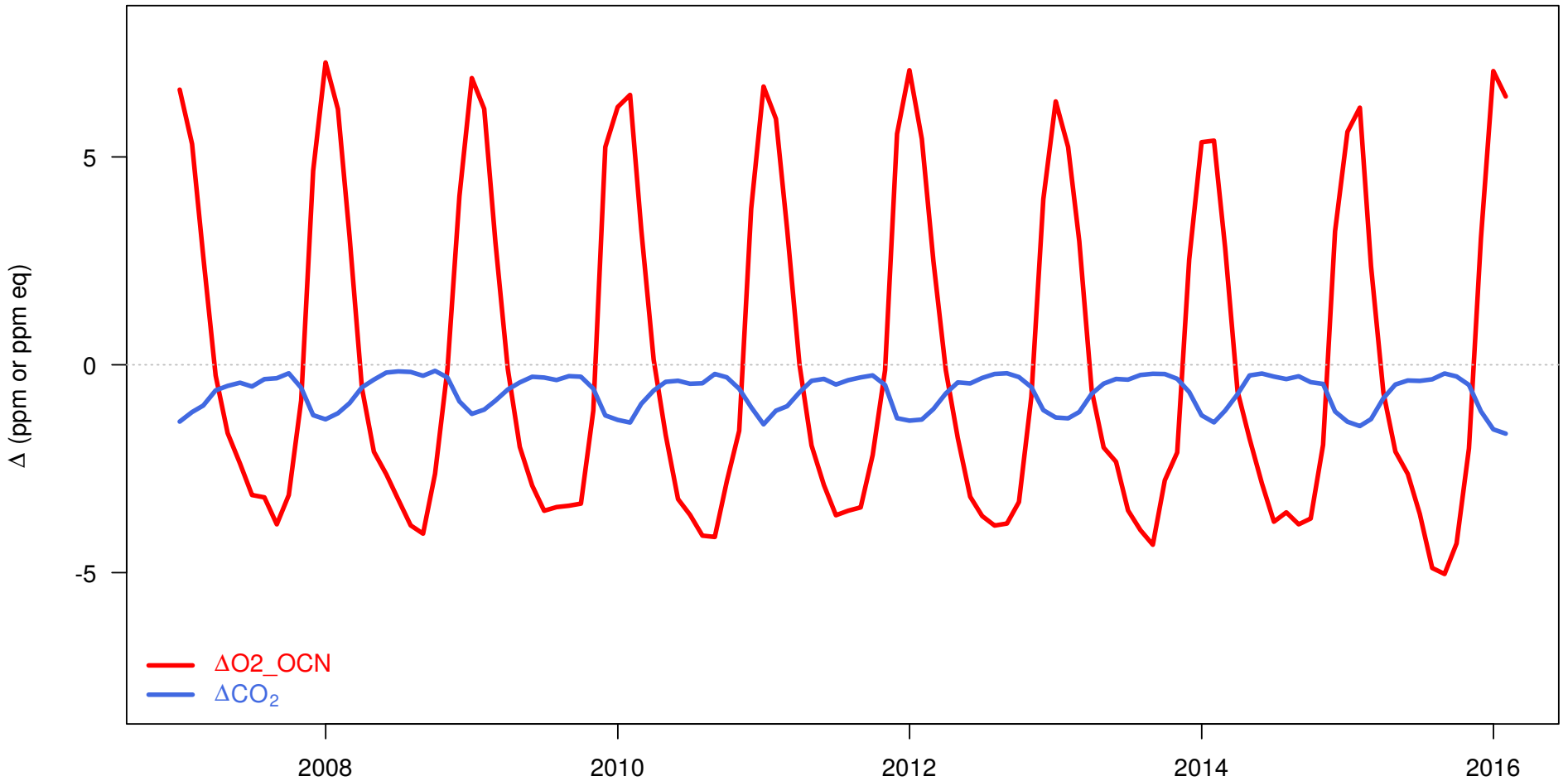

ORCAS All Campaign Lat/Alt Bins
75-33 S, >326 ppb N2O, averaged by 5 deg lat and 1000 m, fit to < 8 km
Obs
slope = -2.81 mol:mol
O2_AO2 (per meg)
-540
-550
-560
-570
-580
-590
-600
m
0
4000
10000
398.0
398.5
399.0
399.5
400.0
400.5
CO2_NOAA (ppm)

Seasonality of δAPO/CO_2 and $O_2{}^{ocn}/CO_2$

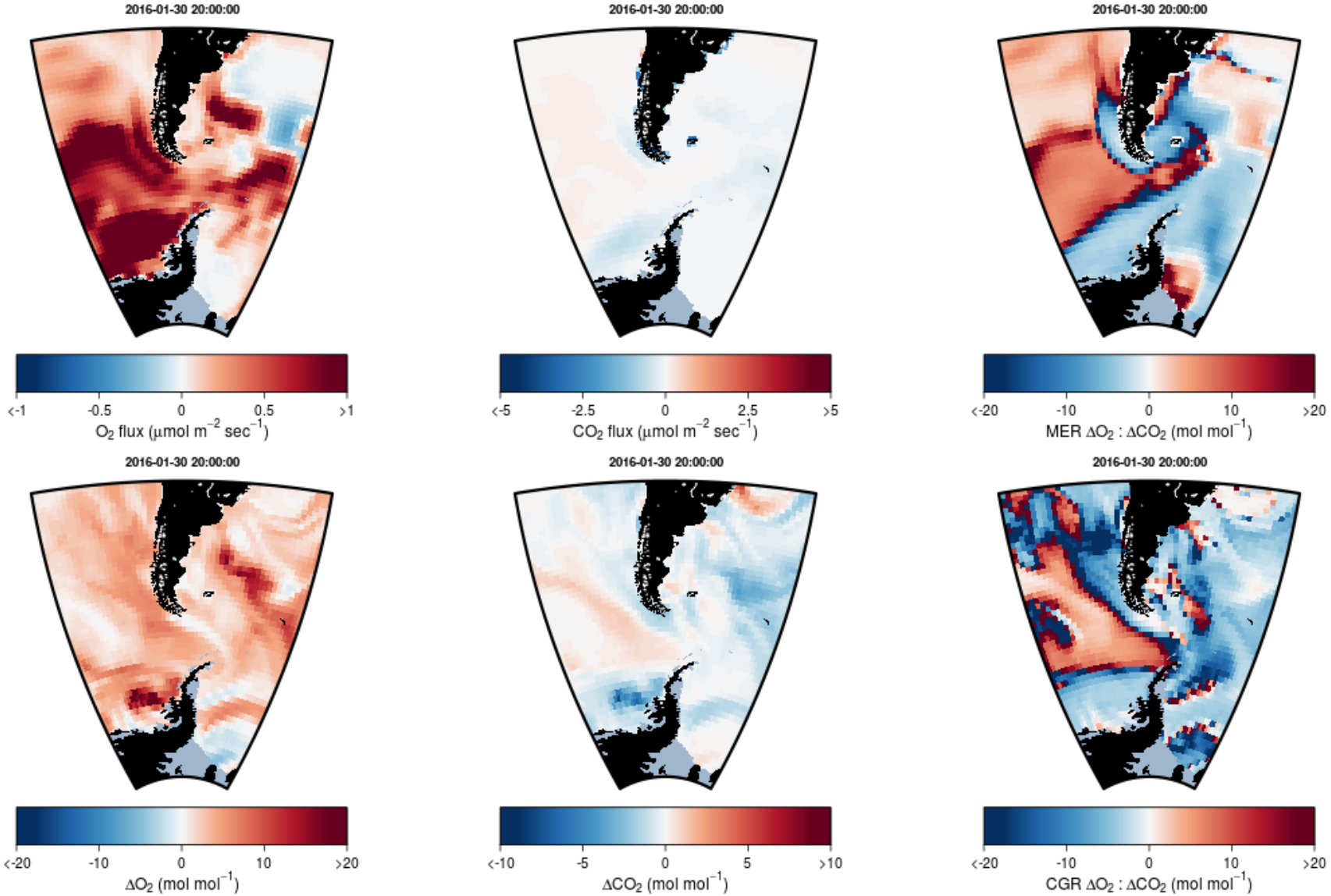


- Vertical gradients of CO_2 and O_2 were dominated by a persistent marine productivity signal with minimal contributions from recent terrestrial biosphere activity or fossil fuel burning
- O_2:CO_2 are sensitive to reference height, the selection of which influences the representivity of a given gradient ratio
- While there is considerable variability in these ratios, they converge to a campaign average of -2.8
- Based on model simulations, this large-scale representative $\Delta O_2 : \Delta CO_2$ should display a prominent seasonal cycle
- This seasonal cycle is an interesting test for model simulations, as it combines thermal, biological, and transport processes into a single metric

Supplemental | CESM $\Delta O_2{}^{ocn}$, ΔCO_2



Supplemental | CESM Example Dip (RF07)



Supplemental | 15 kft CESM vs Observations