OS-43B-2036: Trace Gas Distributions and Correlations Observed In The Southern Ocean Atmosphere During the ORCAS Mission

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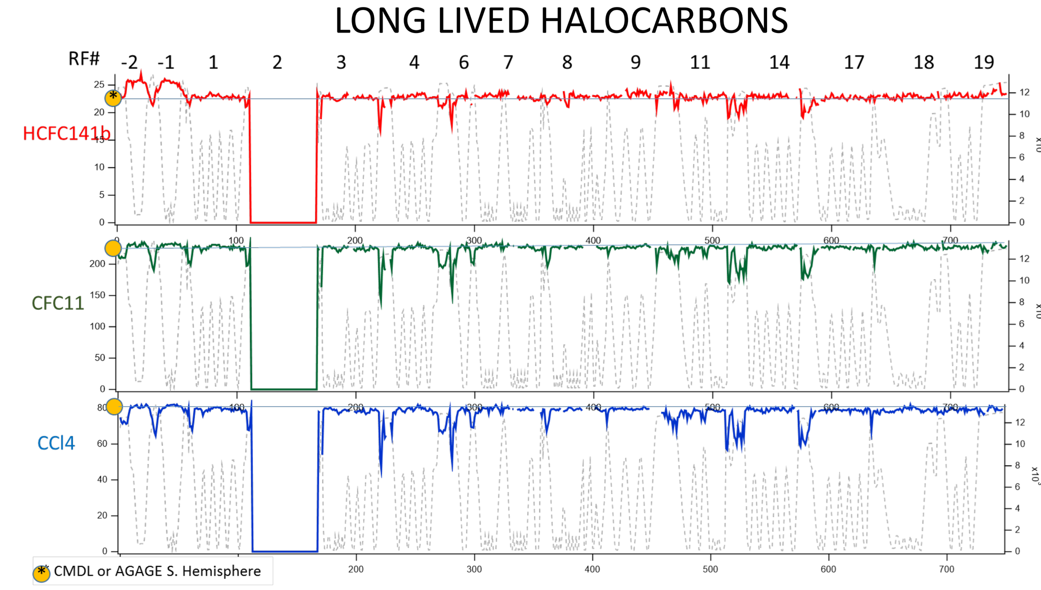
INTRODUCTION

The biologically productive waters of the Southern Ocean are potentially a significant source and sink of trace gases that can impact atmospheric chemistry and climate. However, relatively little is known about the regional variations and, especially, the atmospheric vertical structures of trace gases in this region. During January/February, 2016, the O2/N2 Ratio and CO2 Airborne Southern Ocean (ORCAS) Study, an airborne mission on the NCAR GV aircraft, was conducted to better understand the source/sink relationships of carbon cycle gases, oxygen, and a suite of other trace gases in the austral summer of the Southern Ocean and their relationship to ocean biogeochemistry.

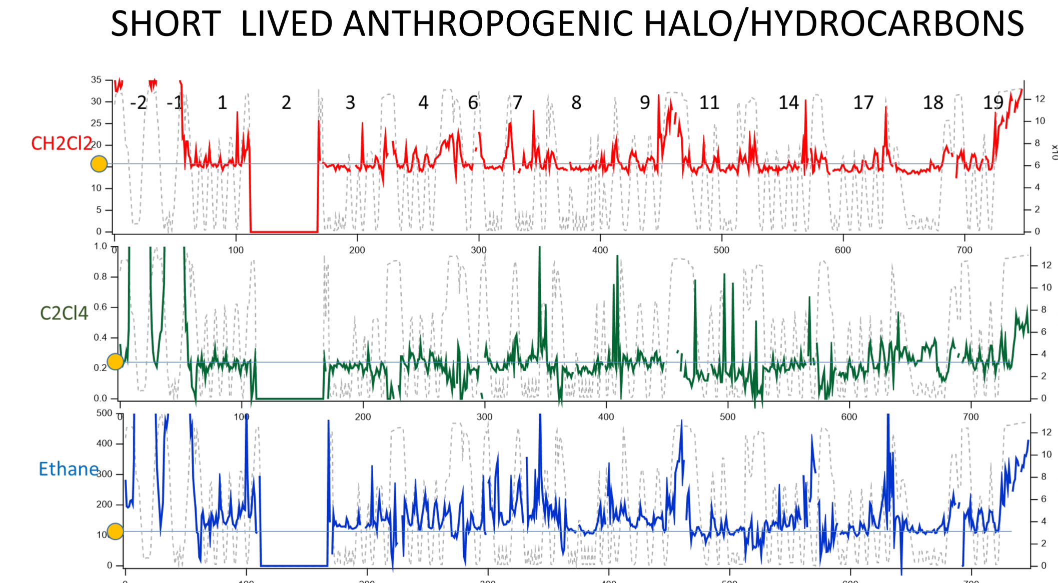
This poster focuses on a selection of gases measured from the Whole Air Sampler and from an in-situ GC/MS system (TOGA). The gases measured by these instruments included a range of reactive halocarbons produced by marine organisms in the surface ocean (e.g., dimethyl sulfide, bromoform, methyl iodide), produced from marine surface photochemistry (e.g., methyl nitrate), and introduced to the region from long-range transport (e.g., chlorinated solvents, CFCs and HCFCs, and non-methane hydrocarbons). Distributions of these gases should reflect the biological productivity of the region, the surface flux rates, the potential source regions of emissions, and the characteristic atmospheric transport pathways.

Time Series of Trace Gas Measurements

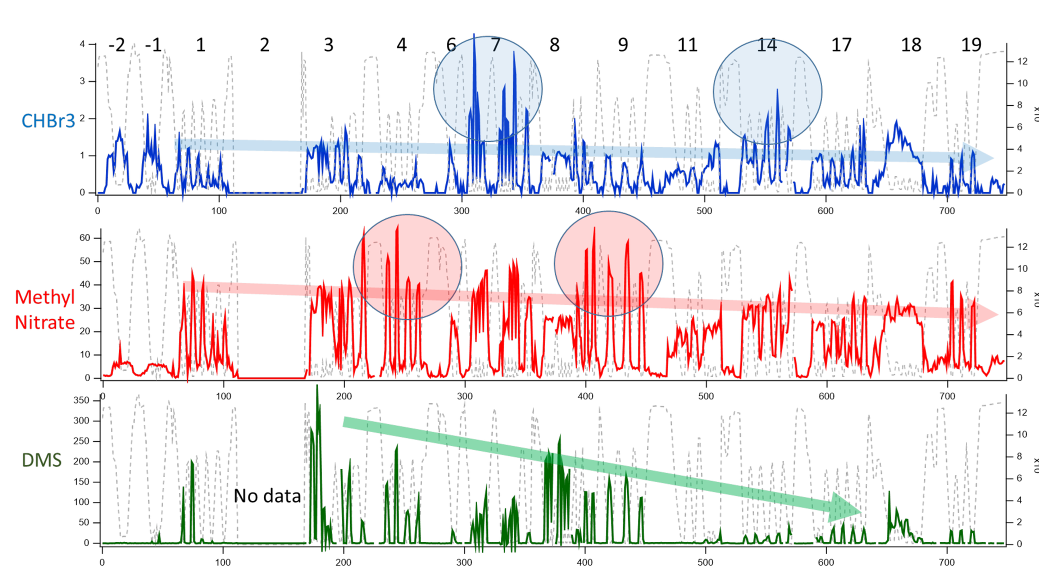
LONG LIVED HALOCARBONS



SHORT LIVED ANTHROPOGENIC HALO/HYDROCARBONS

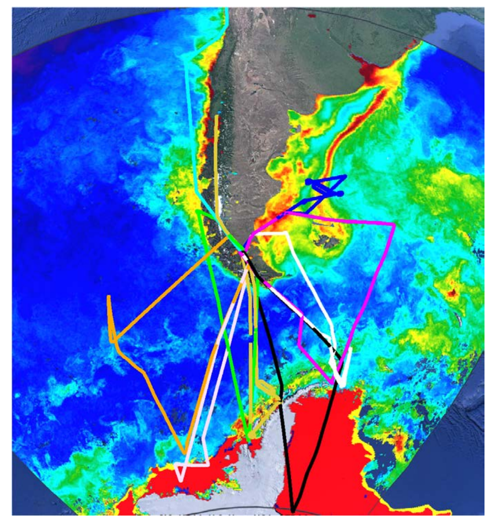


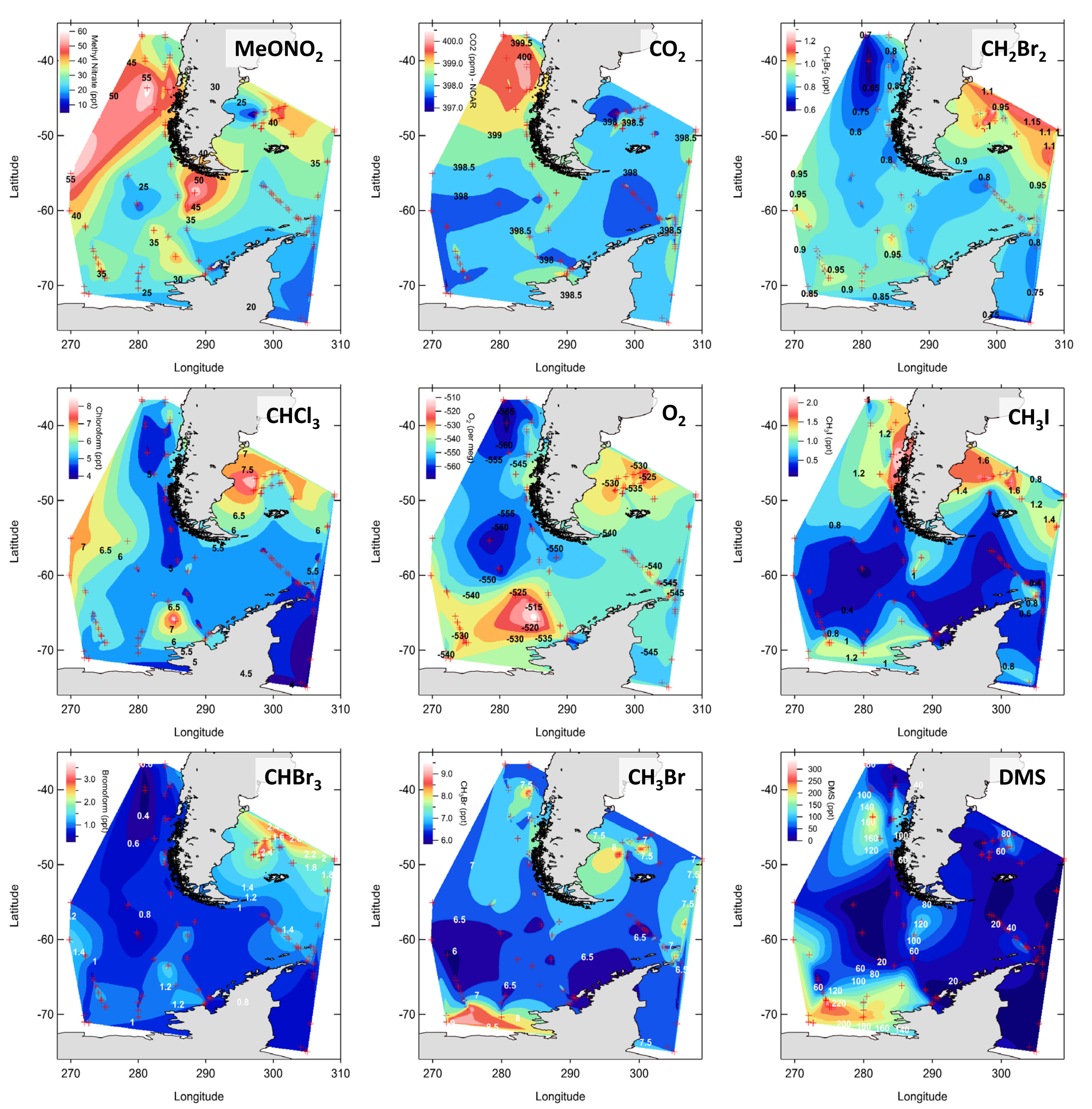
SHORT LIVED MARINE EMISSIONS



The figures in this panel illustrate the sequential measurement of different classes of trace gases during the ORCAS mission. The figures show mixing ratios of trace gases (in pmol/mol) versus sample collection number over the mission. (Negative numbers show test flights in the N. Hemisphere). The gray dotted line (right axis) shows the altitude of the aircraft. Numbers above each graph indicate the Research Flight number. Lines next to the orange dots indicate typical trace gas mixing ratios from AGAGE (Cape Grim) or NOAA ESRL (Palmer Station) sites in the Southern Hemisphere. Each class of gas had common characteristics: 1) (Upper left) Longer lived compounds were very uniform over the course of the mission, with occasional decreased mixing ratio when the aircraft flew in the lower stratosphere. 2) (Upper right). Shorter lived anthropogenic gases (with major sources in the N. Hemisphere) tended also to show lower concentrations in the stratosphere, but enhanced mixing ratios were commonly observed in the mid to upper troposphere (see also panel below). (3) (lower left) Marine emissions of trace gases (typically short lived in the atmosphere) all showed enhanced mixing ratios in the lower atmosphere. A relatively large decline in DMS was noted through the mission, while longer lived gases shown here had only modest declines as the productivity generally declined from the beginning to the end of the mission. "Hot spots" in mixing ratios are highlighted in shaded circles (see also panel below).

Regional Distributions in Marine Boundary Layer





The figures in this panel show the distribution of different trace gases in the marine boundary layer of the ORCAS study region. The upper left figure shows the aircraft flight tracks overlaid on the average chlorophyll a concentrations in the surface waters and the extent of the marginal ice sheet (in red) during the campaign. Major areas of biological productivity are associated with the S. American coast, the Argentine Basin, and areas adjacent to the marginal ice zone. There are varying degrees of correlation between the different gases, which reflects the specific organisms and processes responsible for the surface exchanges. Most gases show enhancements associated with the marginal ice zones and/or Argentine Basin. Methyl nitrate, with a source related to nitrite photolysis, appears different from the gases of direct marine biogenic origin. In general, mixing ratios found during ORCAS are typical of those previously reported from ship cruises in the region, though not as high as has been measured very near sources.

ORCAS

2016 O_2/N_2 Ratio and CO_2 Airborne Southern Ocean Study

https://www.eol.ucar.edu/orcas

SUMMARY:
The trace gas measurements during the ORCAS mission are being used to examine the sources/sink/mixing relationships in the Southern Ocean atmosphere. We showed here only a small sample of the gases that have been measured to illustrate some of the main features observed during the campaign: the seasonality of reactive gas emissions, the significant sources of reactive gases from the Argentine Basin, the west coast of S. America, and the marginal ice zones around Antarctica. However, there are significant variations for different gases and different regions. Other gases (not discussed here) show a significant ocean sink. The importance of N. Hemisphere transport on the upper troposphere of the S. Ocean was clearly identified and is well reproduced for some gases in models. Further analysis is planned to quantify the relationship of the trace gases to remotely sensed information of chlorophyll and potentially other indicators of ocean biology.

ACKNOWLEDGEMENTS:
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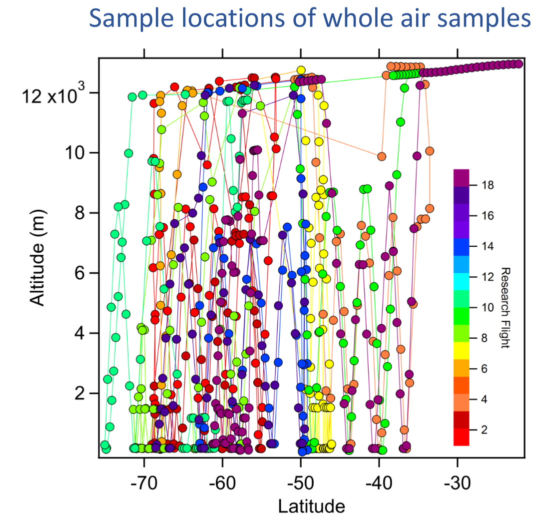
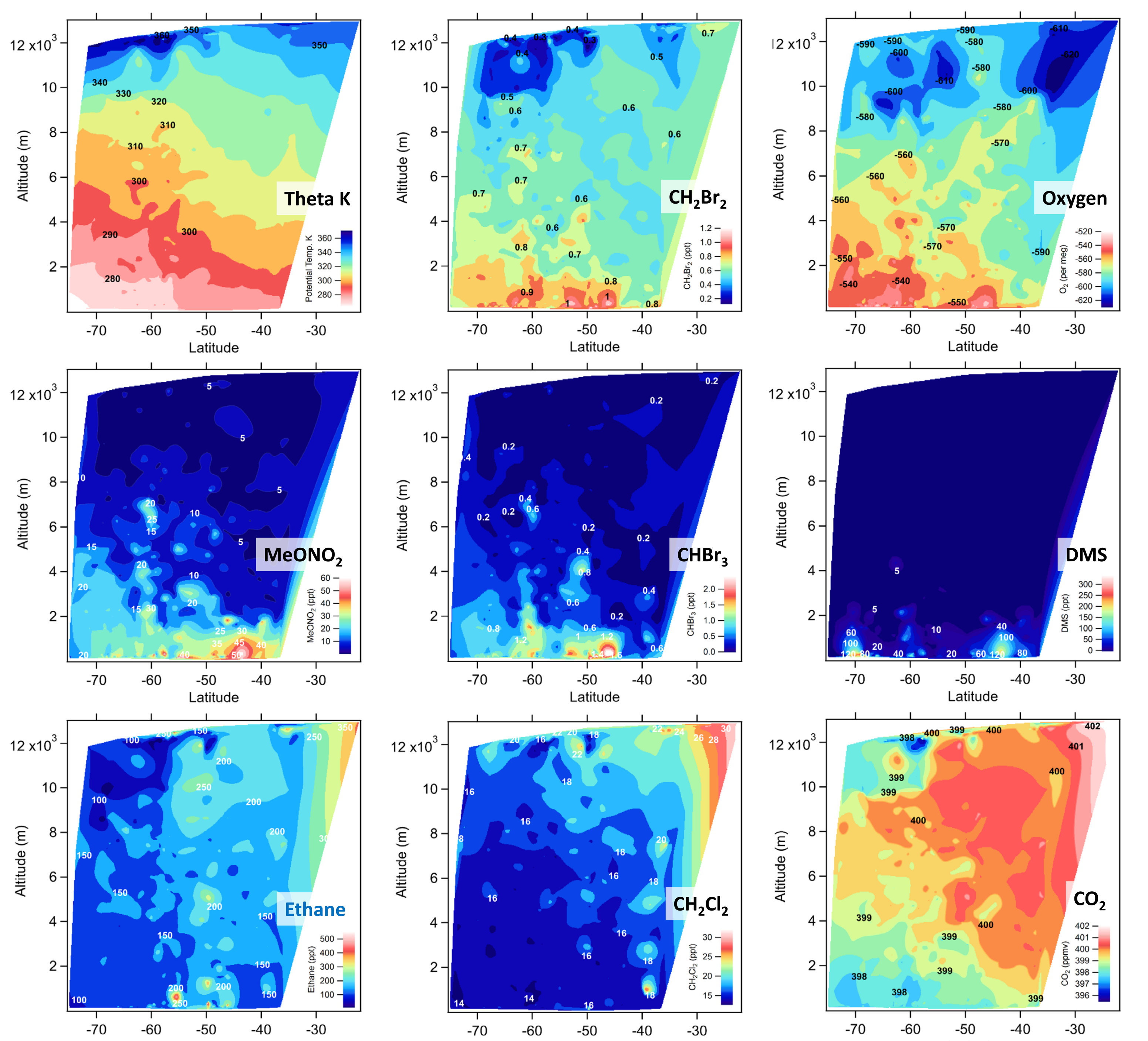
Interhemispheric Transport and Vertical Structures

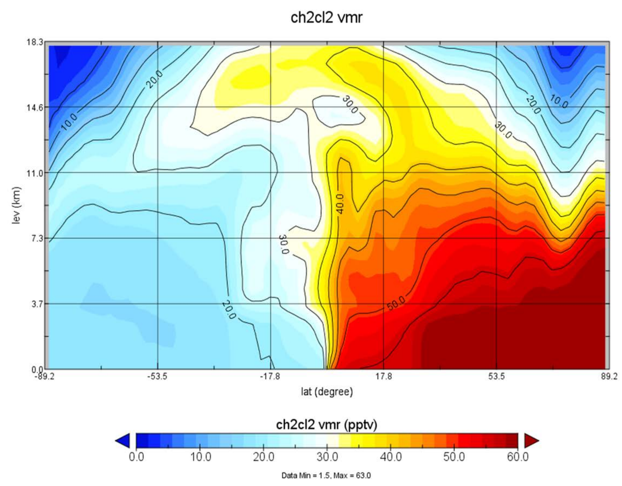
Sample locations of whole air samples



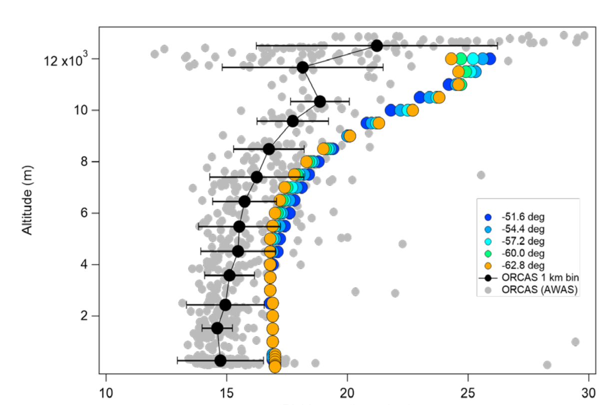


The figures in this panel illustrate the mission averaged concentrations or values over the latitude and altitude coverage of the whole air samples (See above). The latitude/altitude curtains reflect the source/sink/mixing characteristics of the various gases. The left upper panel shows the sloping surfaces of potential temperature that influence the mixing pathways for trace gases. This is apparent in most of the gases illustrated. The marine emissions tend to correlate with oxygen (upper right), with generally higher concentrations and deeper mixing towards the southern end of the sample domain. As expected, CO2 (lower right) anticorrelates with oxygen, but also shows positive correlations with gases transported from the N. Hemisphere (Ethane and CH2Cl2 shown here).

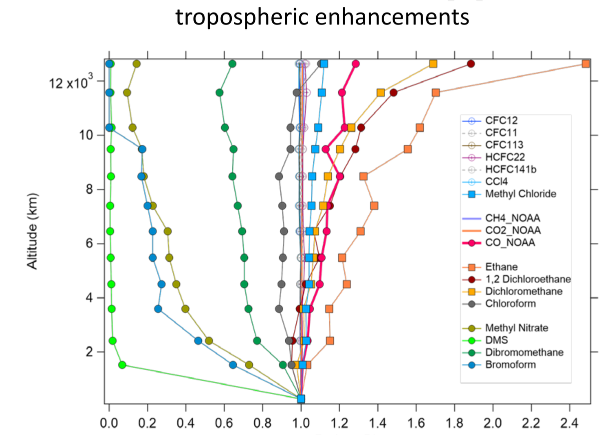
The interhemispheric transport pathway is clearly seen in a variety of model simulations (see panel to the right). We show here an example for CH2Cl2 from the TOMCAT model. The impact of cross hemispheric transport is reflected in the increasing concentrations of species with altitude (and decreasing latitude). Comparison of average tropospheric mixing ratios vs altitude (relative to average boundary layer concentrations) (lowest graph) shows the impact of northern hemispheric sources into the Southern Ocean region, as well as illustrating the sources and mixing of marine emissions into the Southern Hemisphere atmosphere.



TOMCAT model (Jan mean) of CH_2Cl_2 illustrates upper tropospheric transport pathway

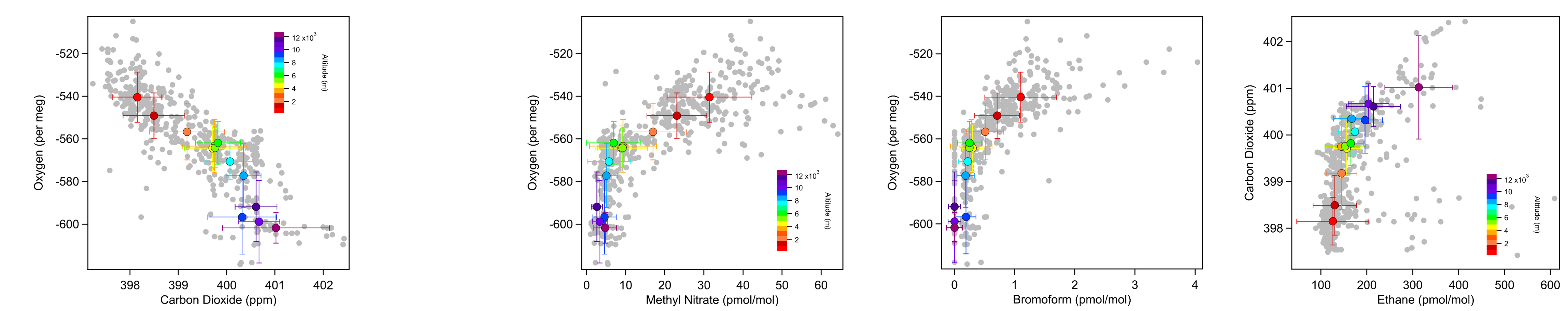


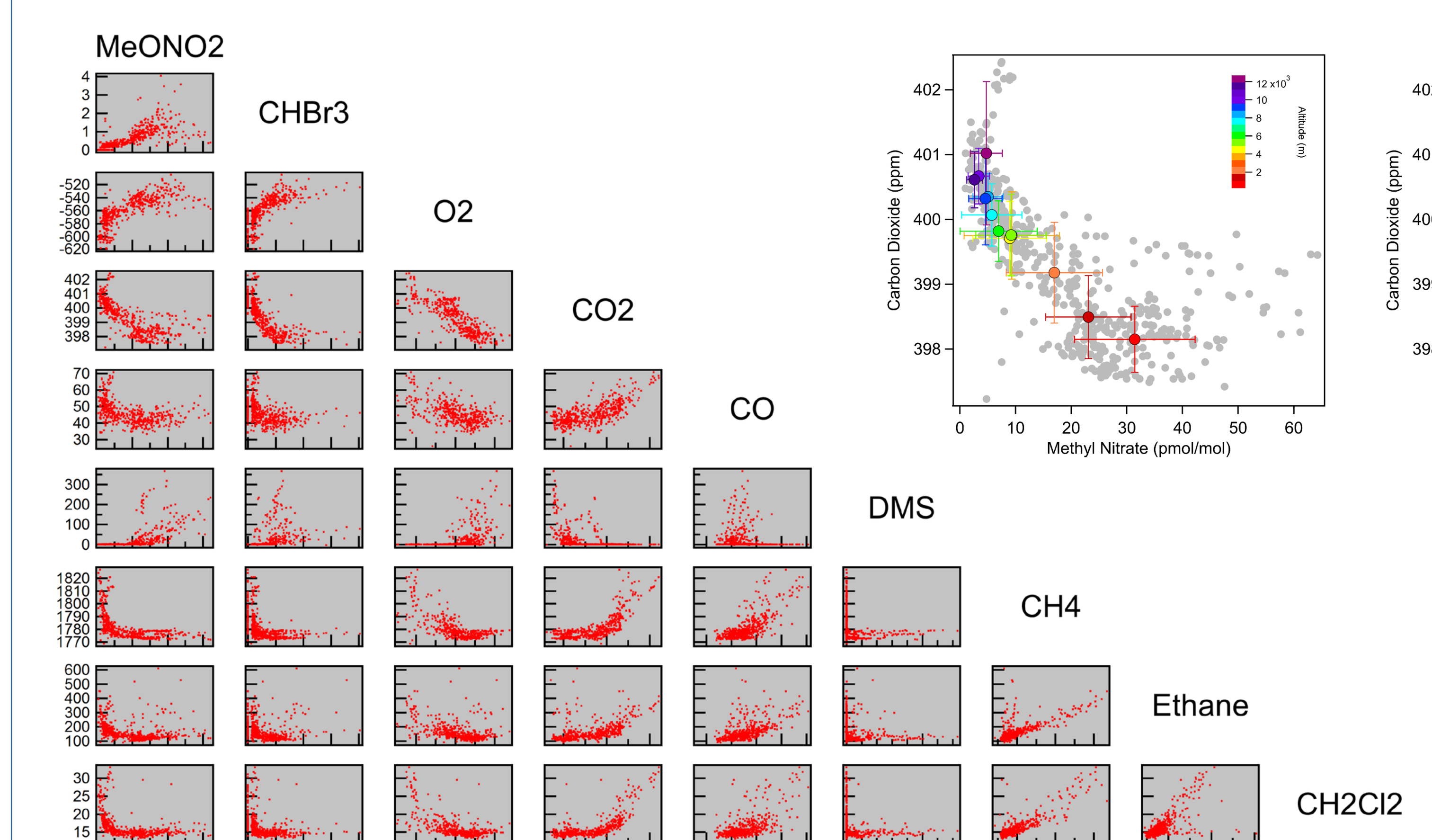
Model-Measurement comparison for CH_2Cl_2 shows upper tropospheric enhancements

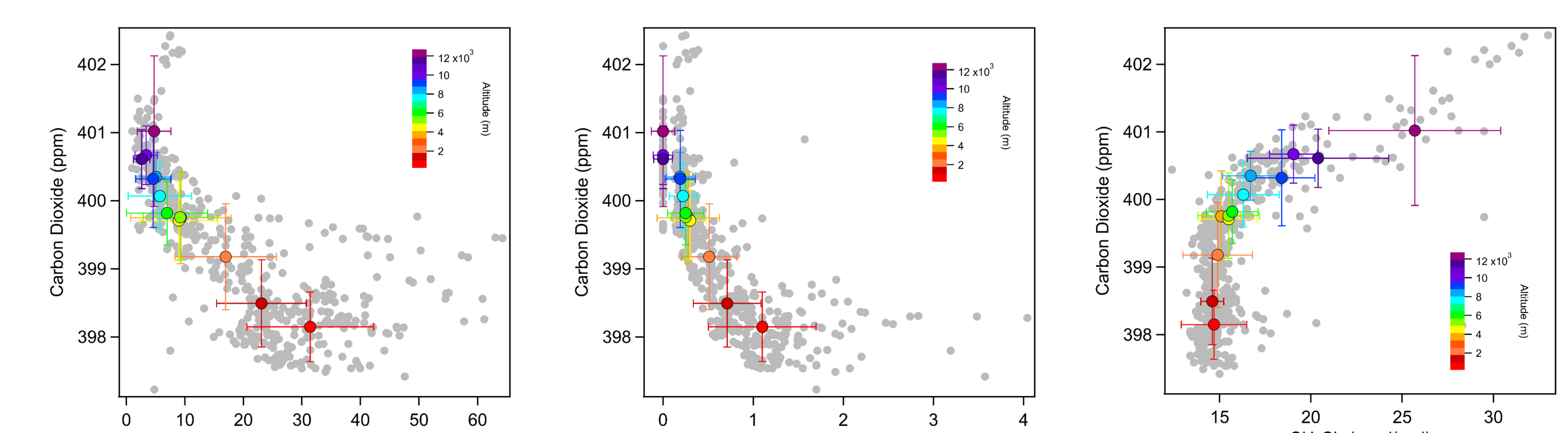


Ratio of gas mixing ratio to average boundary layer concentration illustrates effect of lifetime and source region

Correlations and Relationships







A selection of correlations between trace gases is shown in these graphs. The degree of correlation reflects common regions of sink or source combined with mixing of air in the region. The use of multiple tracers with different source regions or transport pathways will be used in subsequent analyses to help discriminate sources of carbon dioxide in the area. The multi-variable correlation plot (left) shows all data from the Whole Air Sampler and averages of other gases (O_2, CO_2, CH_4) measured with fast time response instruments. The individual plots above show the correlation of several marine or anthropogenic gases versus oxygen or carbon dioxide. Gray points are all tropospheric data. The colored points + error bars are average data in 1 km altitude bins. The marine source gases are well correlated to CO_2 or O_2 in the lower atmosphere, while anthropogenic gases correlate well with CO_2 in the upper troposphere.