A comparison between observations and modeled carbon tetrachloride (CCl_4)

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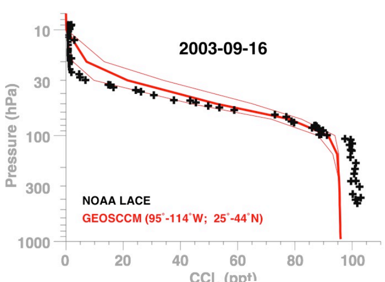
Abstract: Carbon tetrachloride (CCl_4 or CTC) is a major ozone depleting substance and greenhouse gas: with an ozone depletion potential (with respect to CFC-11) of 0.72 [WMO, 2015], and a 100-year global warming potential of 1730 [WMO, 2014]. Unfortunately, estimated CCl_4 sources and sinks remain inconsistent with abundance observations. Liang et al. [2014] used surface observations of trends and the inter-hemispheric gradient to estimate a 35 (32–37) year global lifetime and 39 (34–45) Gg yr^{-1} for CCl_4. The near zero UNEP report emissions and this 39 Gg yr^{-1} top-down emissions suggest that there is a large unknown source of CCl_4.

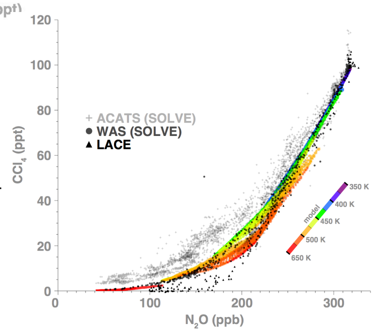
Model: Simulations are conducted with the NASA 3-D GEOS Chemistry Climate Model (GEOSCCM) Version 2, which couples the GEOS-5 GCM with a detailed stratospheric chemistry module. A CCM comprehensive evaluation shows that GEOSCCM agrees well with meteorological, transport-related, and chemical diagnostic observations. Of particular importance, GEOSCCM represents the mean atmospheric circulation as demonstrated by its realistic age-of-air, and further, realistic loss and ODS lifetimes.

Stratospheric simulation



NOAA LACE profiles show excellent agreement with model simulation, with a tropospheric offset

SOLVE (2000) WAS observations (black circles) are also in excellent agreement with model output (colors). The NOAA ACATS-IV data show similar slopes but are offset from both the WAS data and model output.



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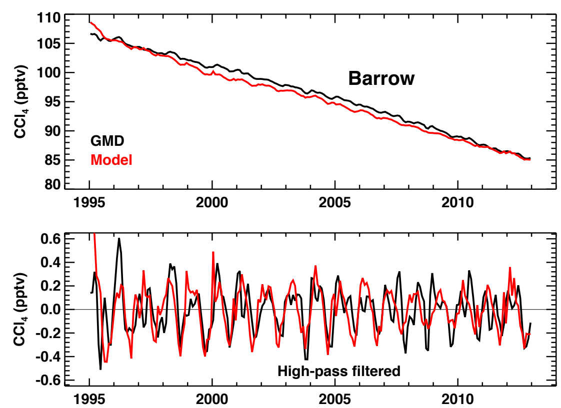
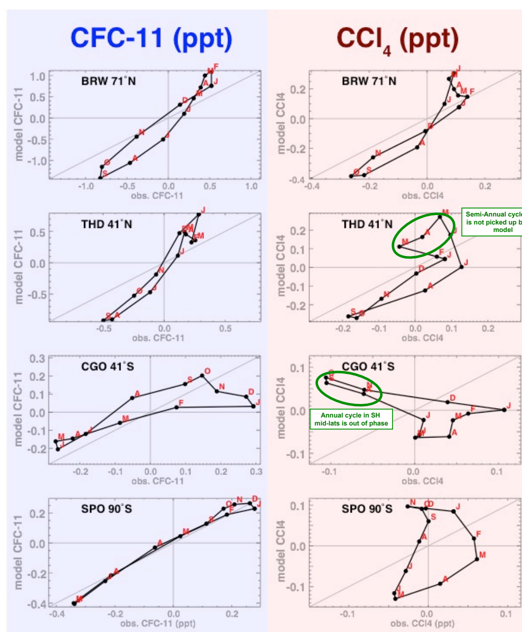
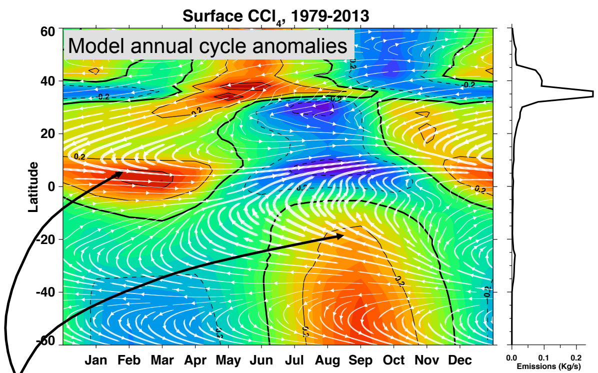
Tropospheric simulation



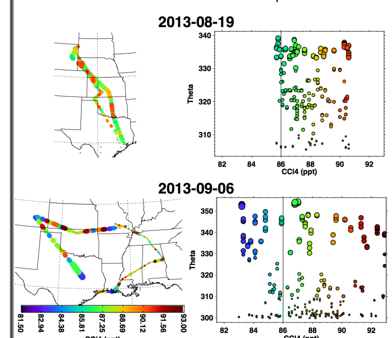
Trend and annual cycle are very close to the obs at Barrow.



The model captures the CFC-11 (left) trend and annual cycle. Aside from Barrow, the CCl4 annual cycle is poorly captured.



1. Trade-winds drive transport of CCl_4 from emission region (40˚N) to tropics.
2. ITCZ lofting of high CCl_4 values is mixed into SH upper troposphere during Jun.–Sep. period, driving an increase of CCl_4 in the SH surface region.



SEAC4RS

- ❖Two SEAC4RS flights show anomalously high CCl_4 values
  - ❖ 19 Aug. (top panels)
  - ❖ 6 Sep. (bottom panels)
- ❖CCl_4 SEAC4RS ave. = 86 ppt
- ❖Aug. 2013 Niwot Ridge = 85 ppt
- ❖Note that all of 19 Aug. are above about 86 ppt. In contrast, flight of 26 August (not shown) has all observations below 86 ppt. Calibration issue?

Summary

- Stratospheric CCl_4 simulations are in good agreement with observations, indicating that atmospheric lifetime estimates from the model are quite reasonable.
- Tropospheric CCl_4 simulations are fair-to-poor, while CFC-11 and -12 simulations are very good. This implies two possible problems.
  - CCl_4 emission patterns are poor
  - Ocean and soil sinks/sources are poorly known.
- SEAC4RS data are suggestive of possible CCl_4 emissions in North America.