Investigating the Global OH Radical Distribution Using Simplified Steady State Approximations

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Introduction and Aims

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- The OH radical is one of the **most important oxidising species** in the atmosphere.
- There are **limited direct measurements** of OH due to its very **short lifetime** (~1 second) and **low abundance**.
- Other methods to calculate global mean OH, such as inferring OH concentration from methyl chloroform and other species, **do not provide spatial information**.
- This study aims to investigate a **new method to approximate the spatial distribution of OH** based on atmospheric observations.

Aims:

- How well can steady state approximations be used to model global OH distributions?
- In which atmospheric regions are different approximations most valid?
- Can satellite data be used in a simplified steady state approximation to model global OH distributions?

Steady State Approximations

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- Due to its short lifetime, OH it is assumed to be in a **steady state**, as it is produced as quickly as it is consumed.
- A steady state approximation can be applied to model OH concentrations.
- OH has many atmospheric **sources and sinks**.
- If **only the main sources and sinks** are considered, can a steady state approximation be used to model global OH distribution?
- Proposed **simplified** steady state approximation:

$$[OH] = \frac{j_1[O_3][H_2O]/(k_1[N_2]+k_2[O_2])}{k_3[CH_4]+k_4[CO]+k_5[O_3]}$$

Inputs:
- Ozone
- Water Vapour
- Methane
- Carbon Monoxide

$\mathbf{j_1} = O_3 + h\nu \rightarrow O(^1D) + O_2$, $\mathbf{k_1} = N_2 + O(^1D)$, $\mathbf{k_2} = O_2 + O(^1D)$, $\mathbf{k_3} = CH_4 + OH$, $\mathbf{k_4} = CO + OH$, $\mathbf{k_5} = O_3 + OH$

Comparison of Steady State Approximations – January 2010

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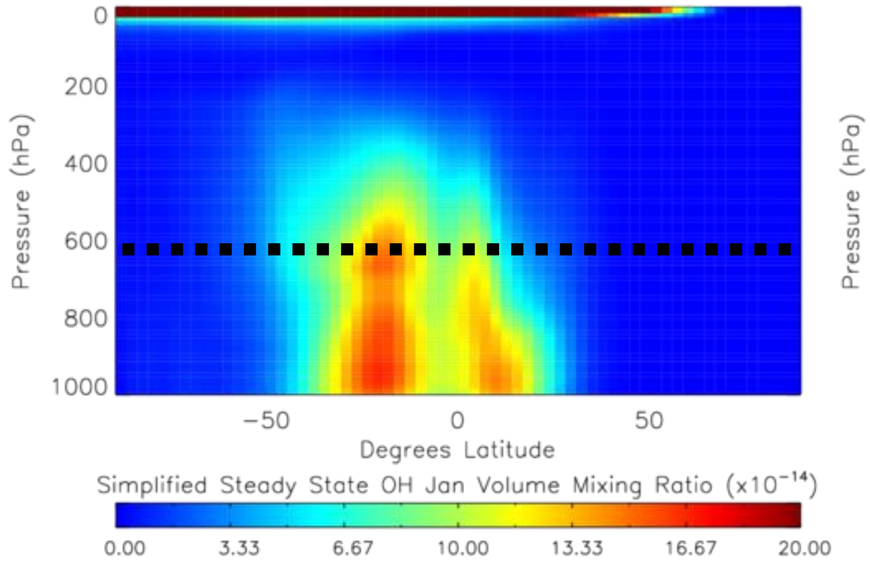
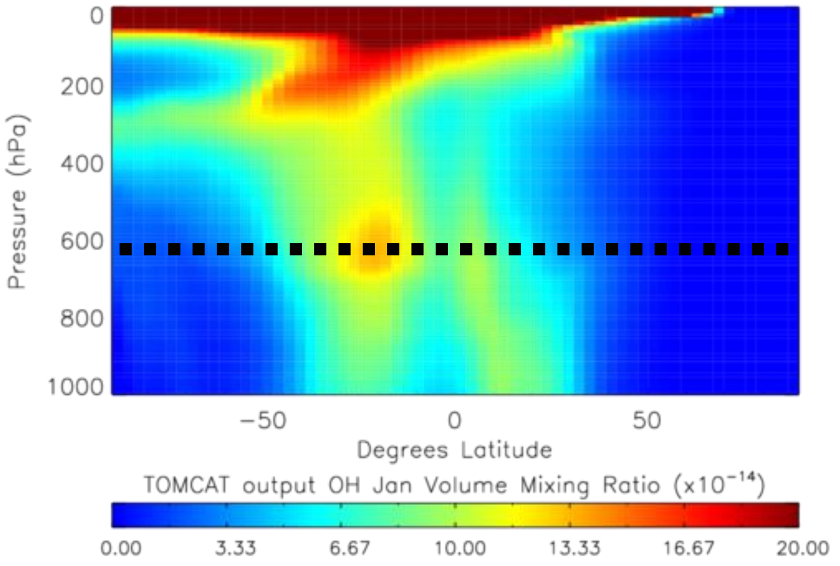
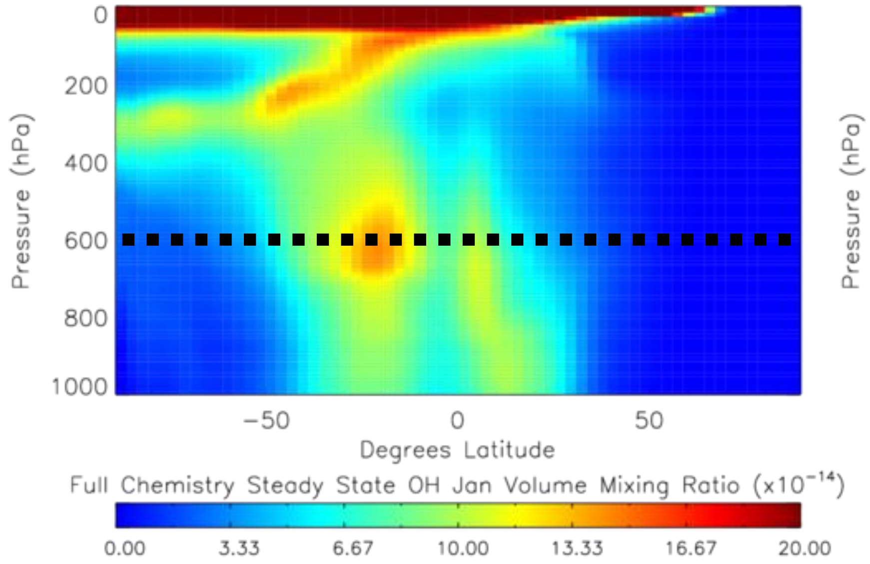
Simplified Steady State Approximation OH

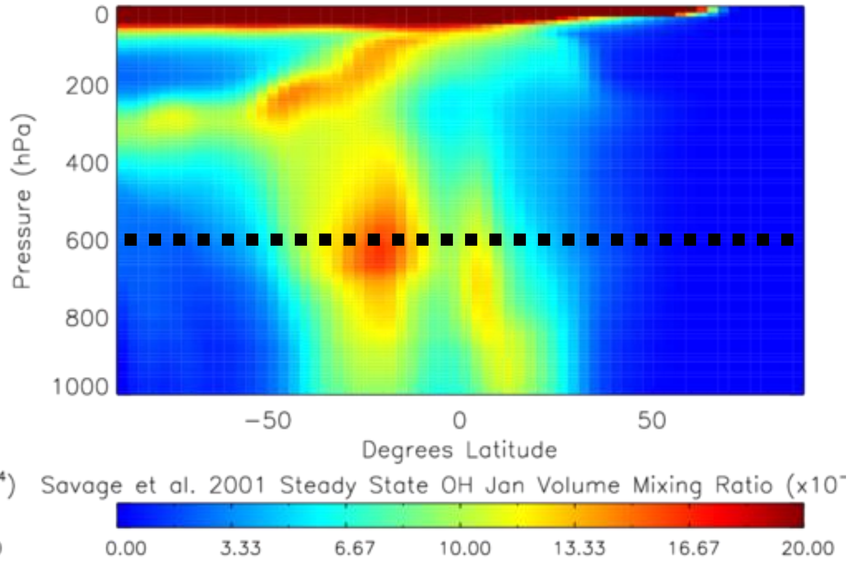




TOMCAT 3-D Model Output OH

Full Chemistry Steady State Approximation OH





Intermediate Steady State Approximation OH (Savage et al. 2001)

Comparison of Steady State Approximations – June 2010

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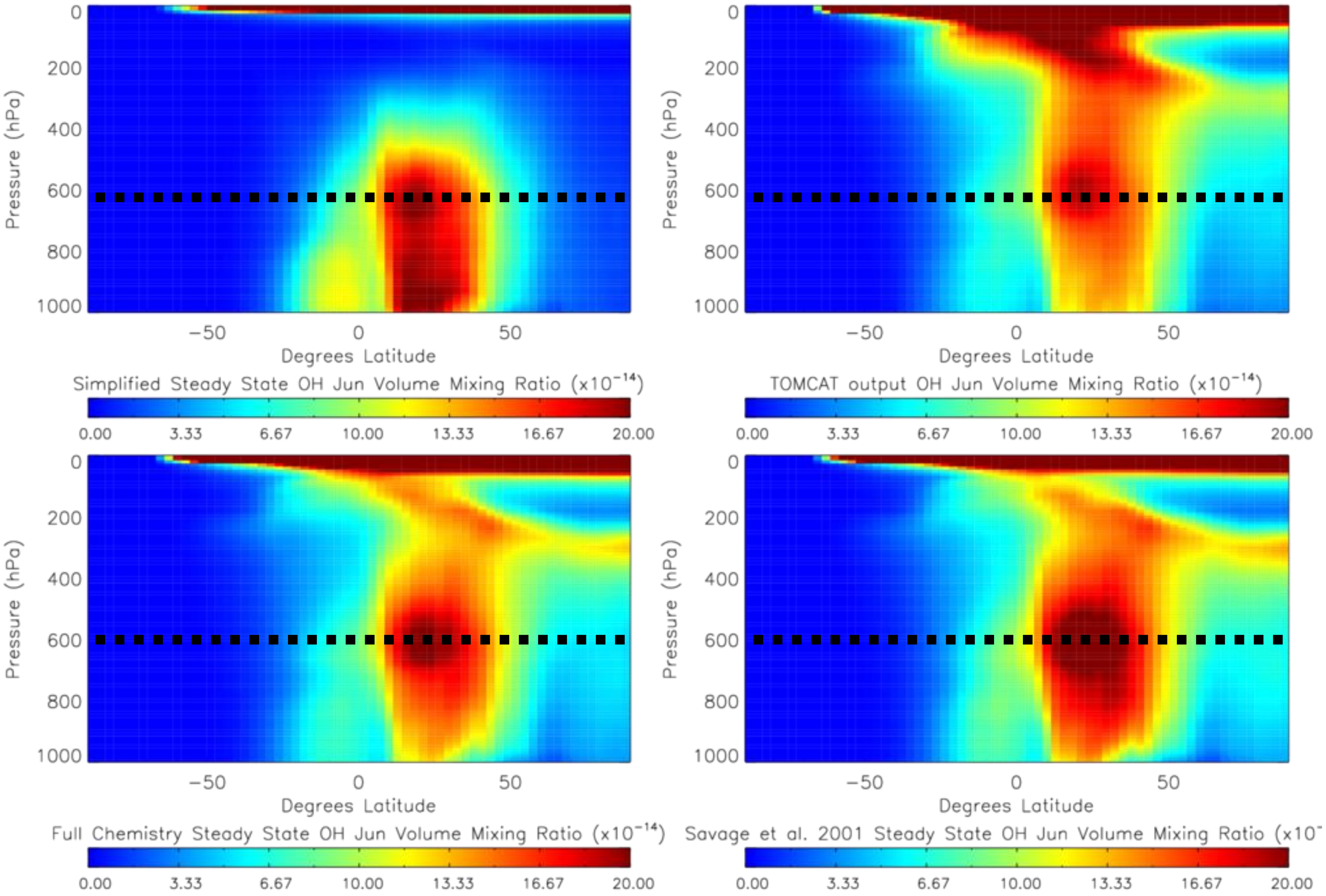
Simplified Steady State Approximation OH

TOMCAT 3-D Model Output OH



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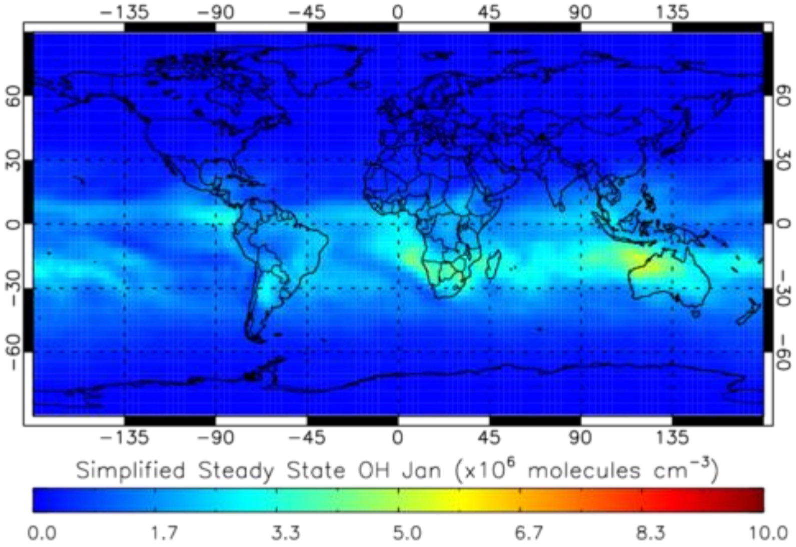
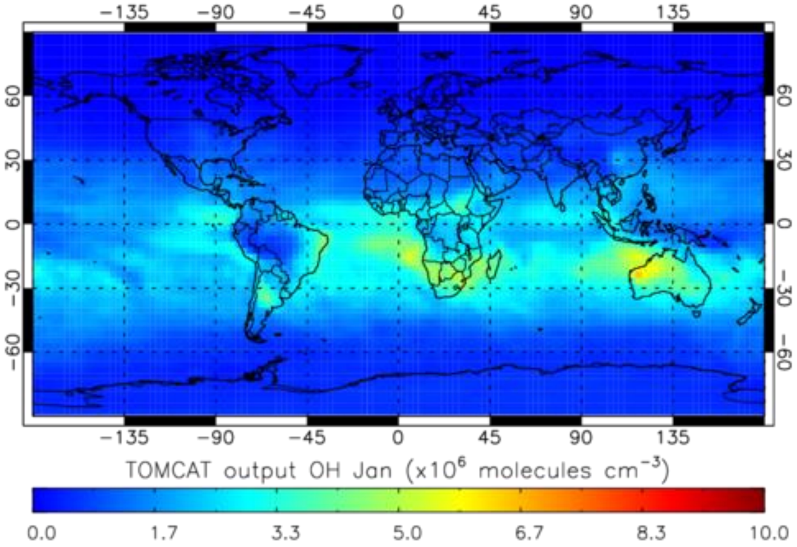
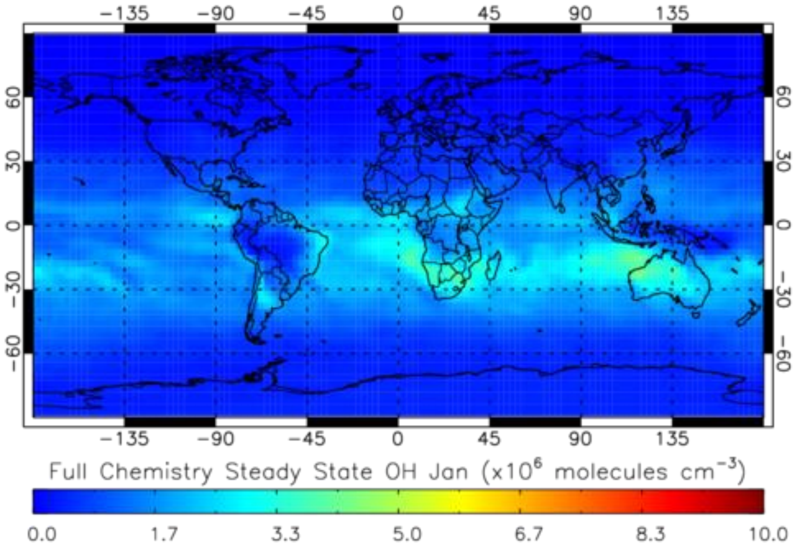
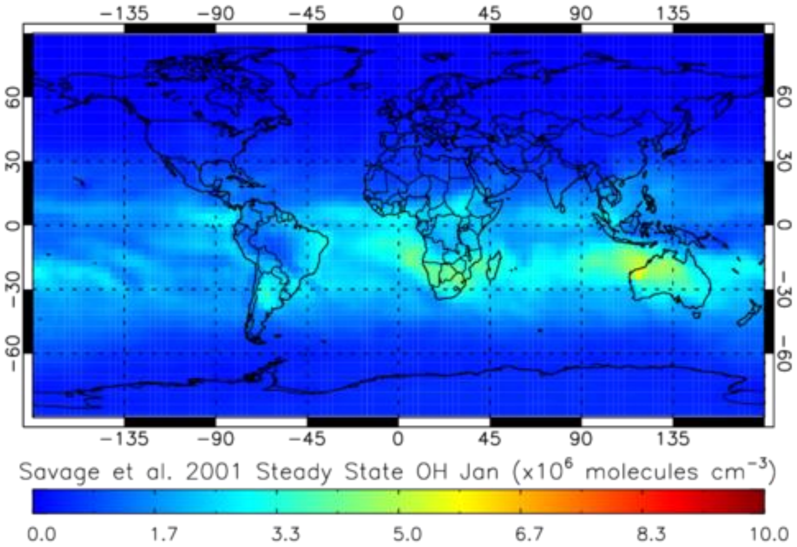




TOMCAT Output OH

Full Chemistry Steady State Approximation OH





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Comparison of Steady State Approximations – June 2010

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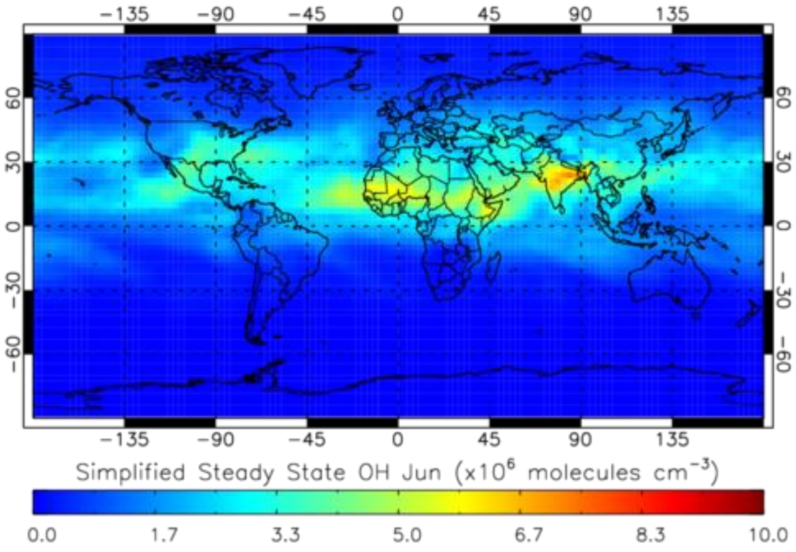
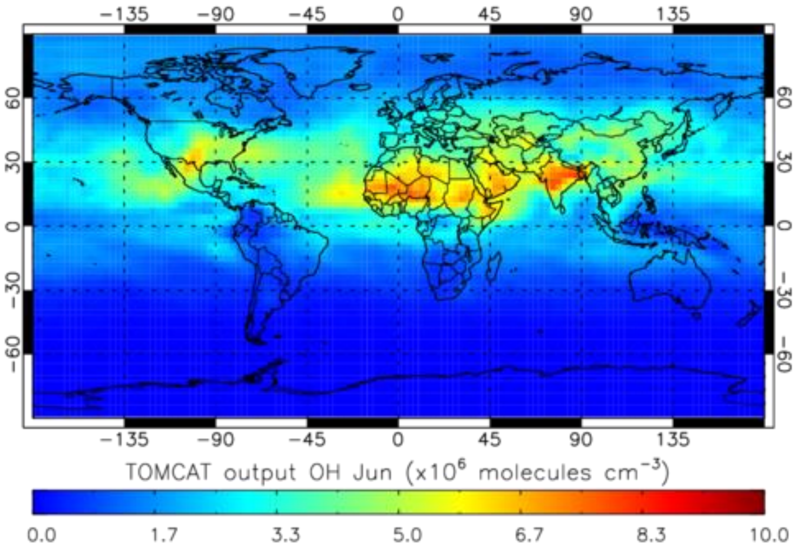
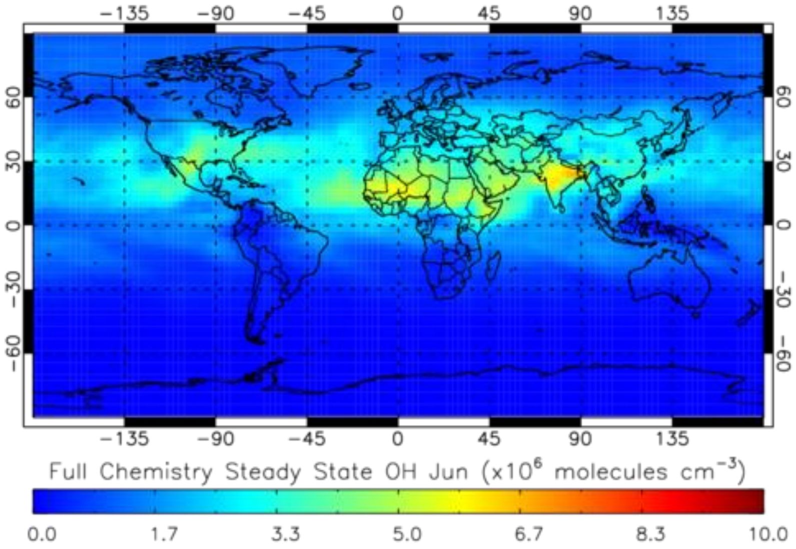
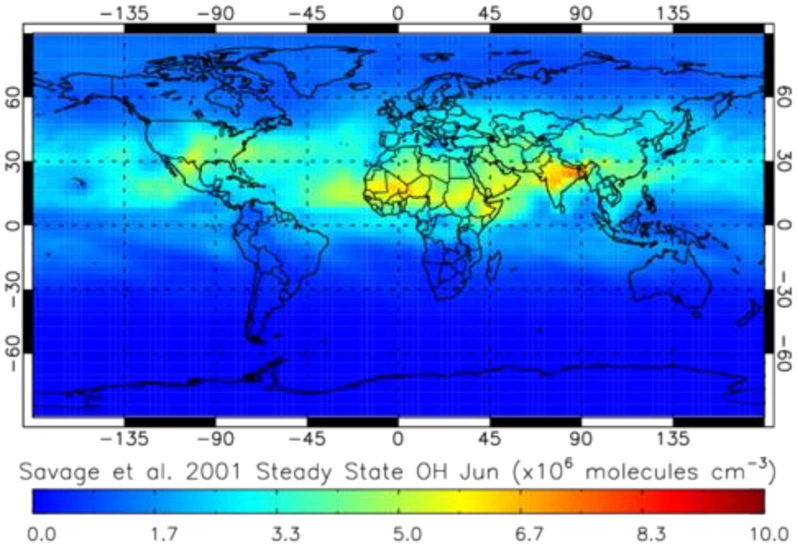




TOMCAT Output OH

Full Chemistry Steady State Approximation OH





Intermediate Steady State Approximation OH (Savage et al. 2001)

Detailed Steady State Approximations

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- Steady state approximations with more terms show better agreement with the full model.
- Compared to the simplified steady state approximation (shown in red) the Savage et al. (2001) has extra source and sink terms.

$$[OH] = \frac{((2j_1k_2[O_3][H_2O])/(k_3[N_2]+k_4[O_2])) + k_{17}[NO][HO_2] + k_{18}[HO_2][O_3] + 2j_{23}[H_2O_2] + j_{25}[CH_3O_2H]}{k_5[CH_4]+k_6[CO]+k_7[O_3]+k_8[HCHO]+k_9[SO_2]+k_{10}[NO_2]+k_{20}[NO]+k_{21}[DMS]+k_{22}[H_2O_2]+k_{24}[CH_3O_2H]+k_{26}[H_2]+\Sigma_i(k_i[RH_i])}$$

- The additional sources are important in the upper troposphere and stratosphere.
- The additional sinks are important at the surface.

Savage, N.H., Harrison, R.M., Monks, P.S., Salisbury, G., 2001. Steady-state modelling of hydroxyl radical concentrations at Mace Head during the EASE '97 campaign, May 1997. Atmos. Environ. https://doi.org/10.1016/S1352-2310(00)00315-0

Application of Satellite Data

- Satellite data for ozone (OMI), water vapour (IASI), carbon monoxide (MOPITT) and methane (IASI) has been applied to the simplified steady state approximation.

- The approximation has been calculated at the 650 hPa level.

Current limitation:

The satellite data for the input species are not from all the same satellite instrument so there will be errors associated with different vertical resolutions, retrieval schemes, overpass times etc.

Comparison of Global OH Distributions (650 hPa) - January

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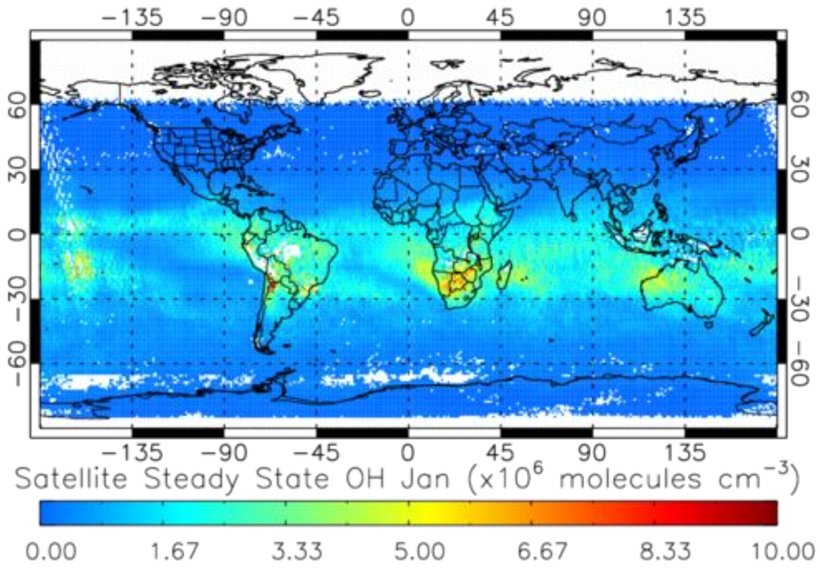
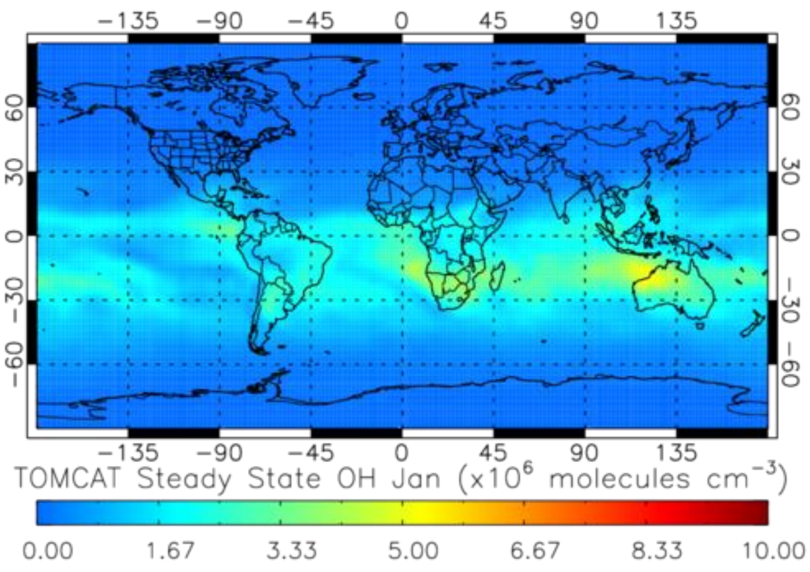
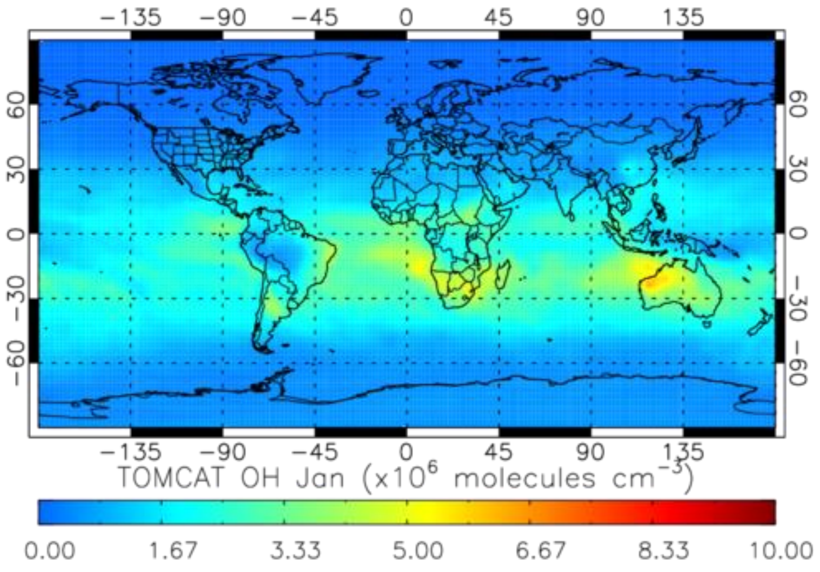


Satellite-derived OH using a simplified steady state approximation



TOMCAT-derived OH using a simplified steady state approximation



TOMCAT OH output

Comparison of Global OH Distributions (650 hPa) - June

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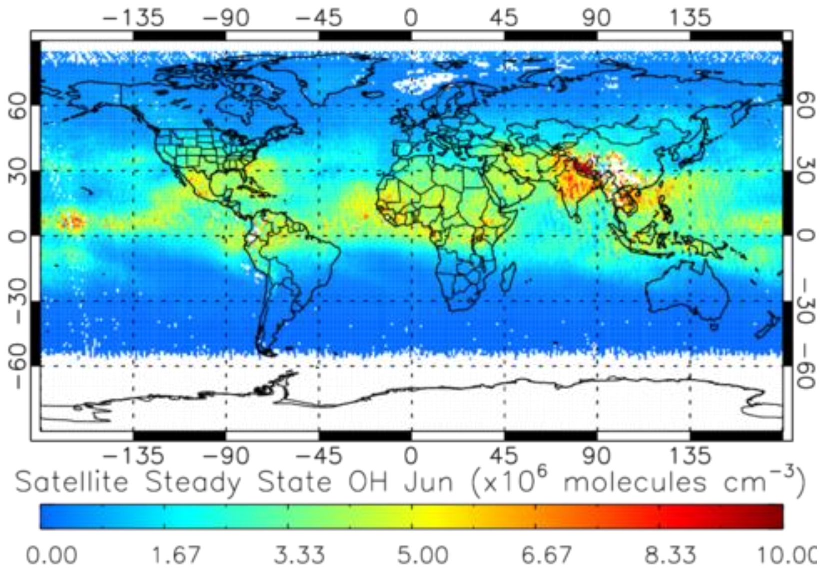
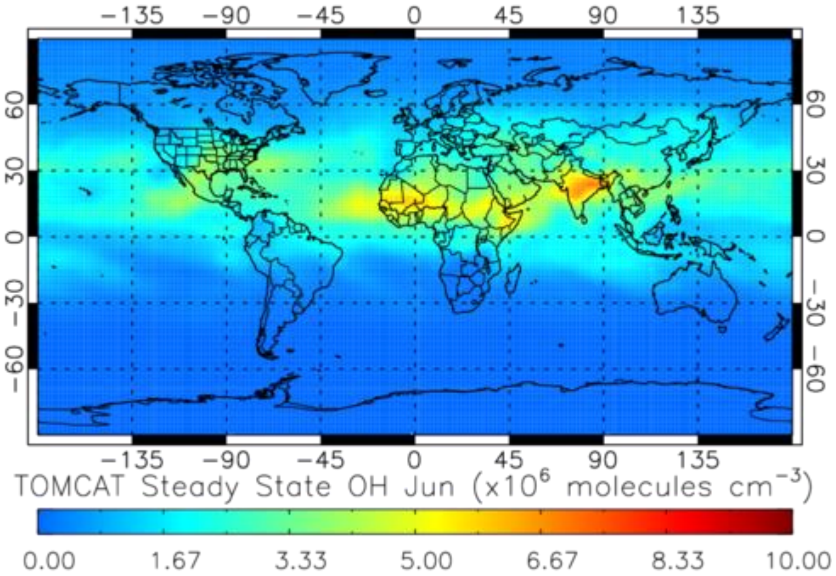
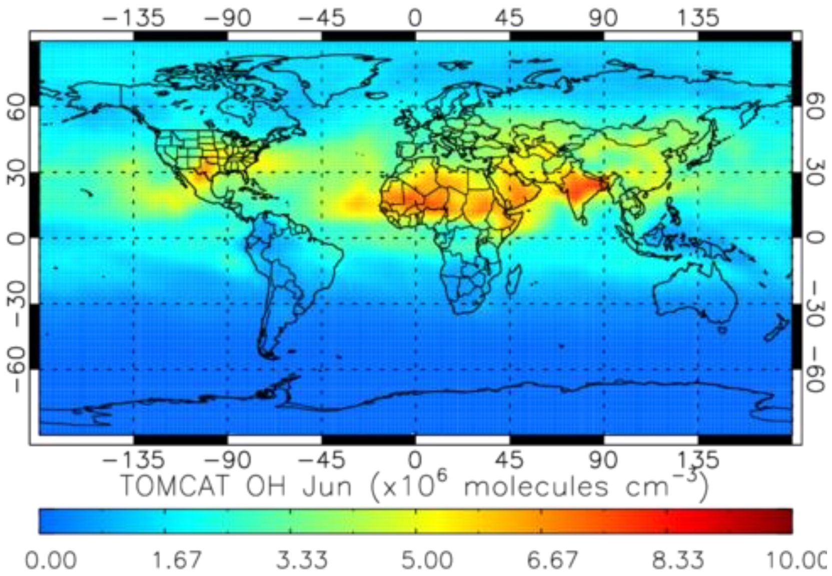


Satellite-derived OH using a simplified steady state approximation



TOMCAT-derived OH using a simplified steady state approximation



TOMCAT OH output

Summary

- A simplified steady state approximation shows good spatial agreement to modelled OH in the region around 600 hPa.
- Steady state approximations with more terms show better agreement with modelled OH but cannot be applied to satellite data.
- At 600 hPa, satellite-derived OH shows promising agreement with modelled OH in terms of absolute abundance and spatial variability.

Next steps:

- In the process of using satellite data from the same instrument, IASI, to decrease errors associated with using different instruments.
- Investigate the inter-annual variability of global OH distribution.