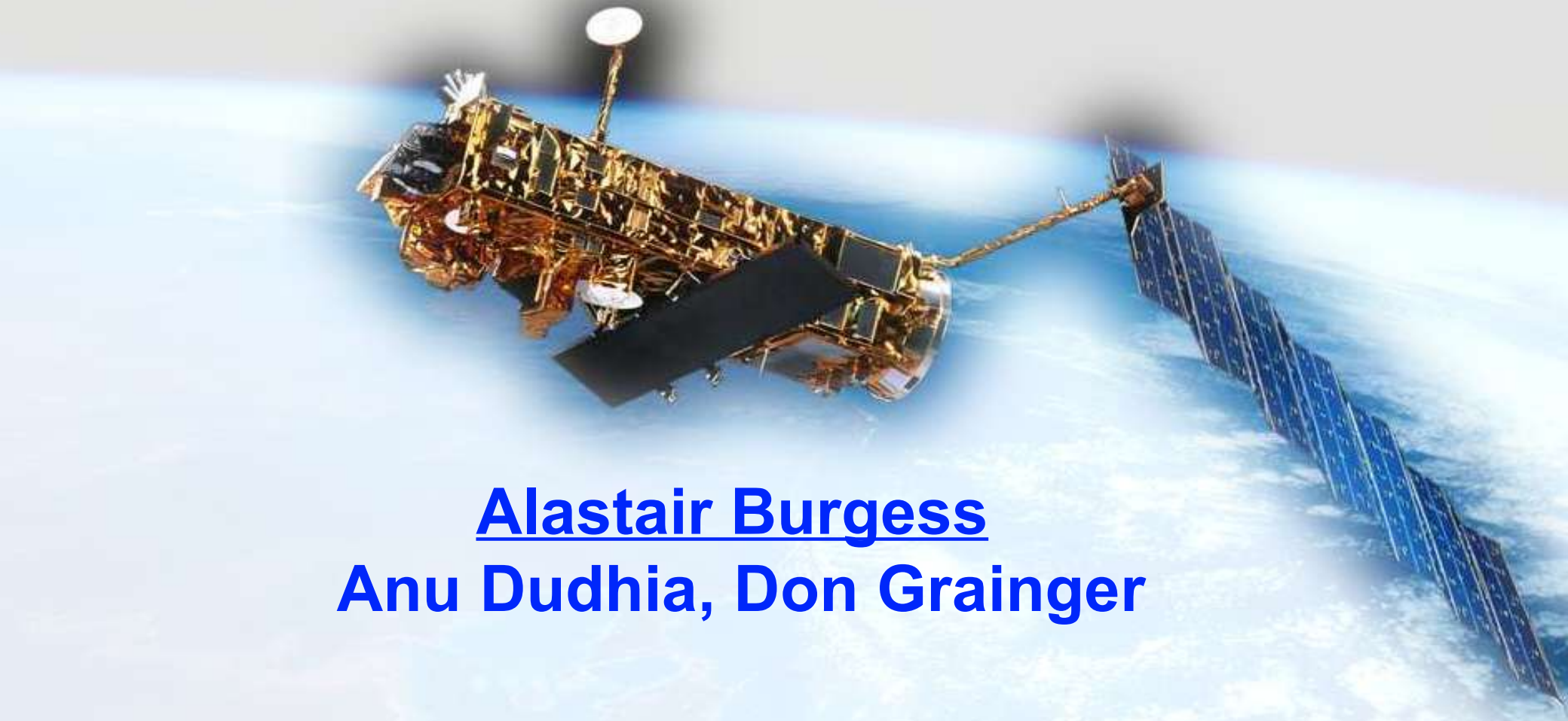
Sulphur From Space

Retrievals from the MIPAS Satellite Instrument



Alastair Burgess

Anu Dudhia, Don Grainger

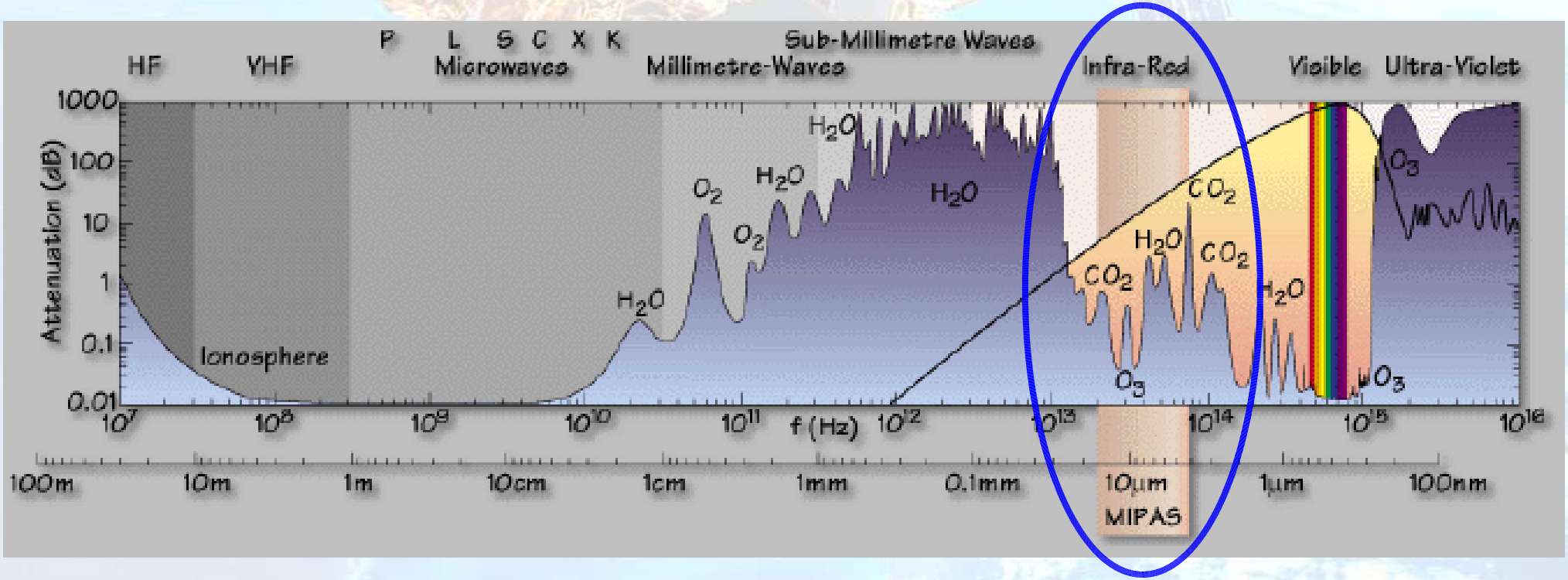
AOPP, University of Oxford

aburgess@atm.ox.ac.uk

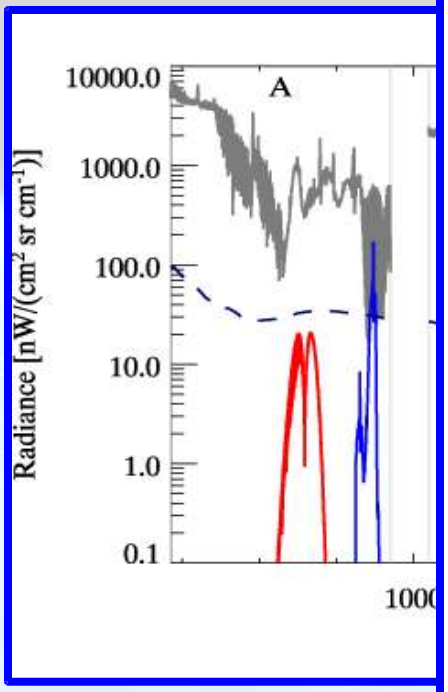
NATURAL ENVIRONMENT RESEARCH COUNCIL

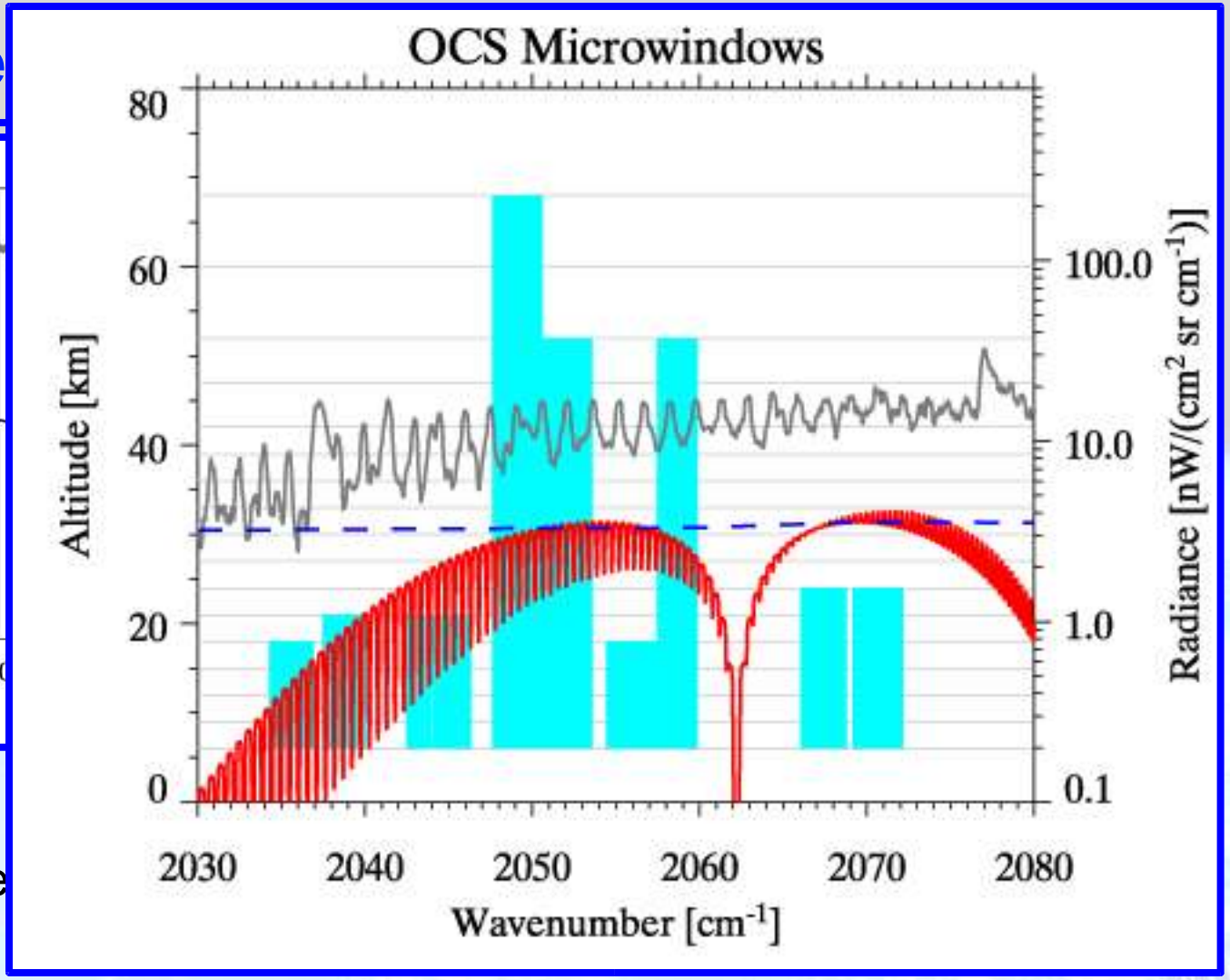
What is MIPAS?

- **M**ichelson **I**nterferometer for **P**assive **A**tmospheric **S**ounding
  - 685 - 2410 wavenumber (4 -16 micron) range at 0.025 cm^{-1} resolution.
  - Fourier Transform Limb Thermal Emission Infrared Spectrometer
- Launched 1st March 2002 as a part of Envisat
  - Polar orbit of 100 minutes at 800 km



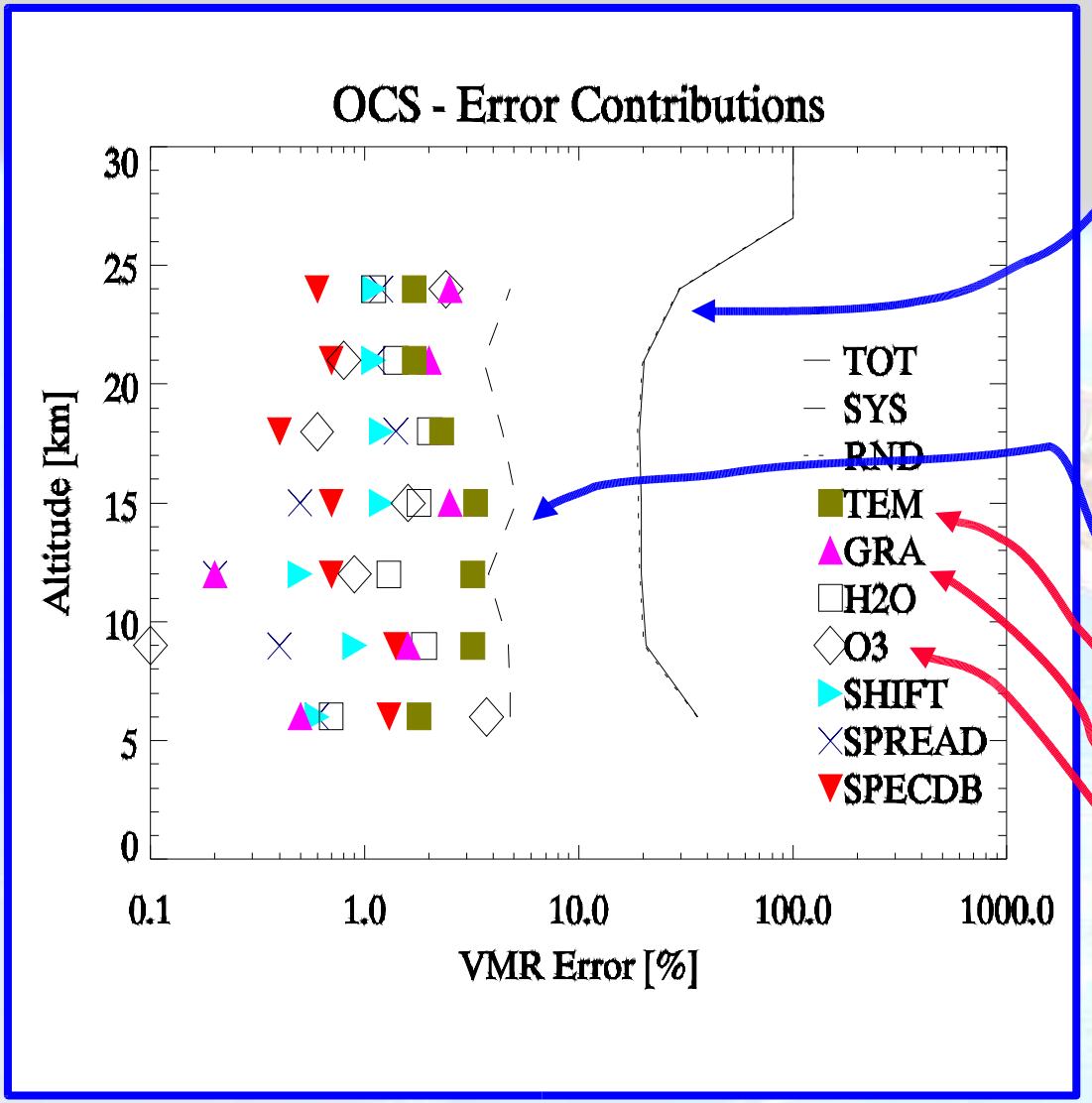
Asse





- Simulate expected
  - Model target specie
  - Check noise level
- Feasibility assessment based on ‘microwindow’ selection approach
  - Allows tracking and minimization of both systematic and random error sources
- Do we gain on the climatological uncertainty?

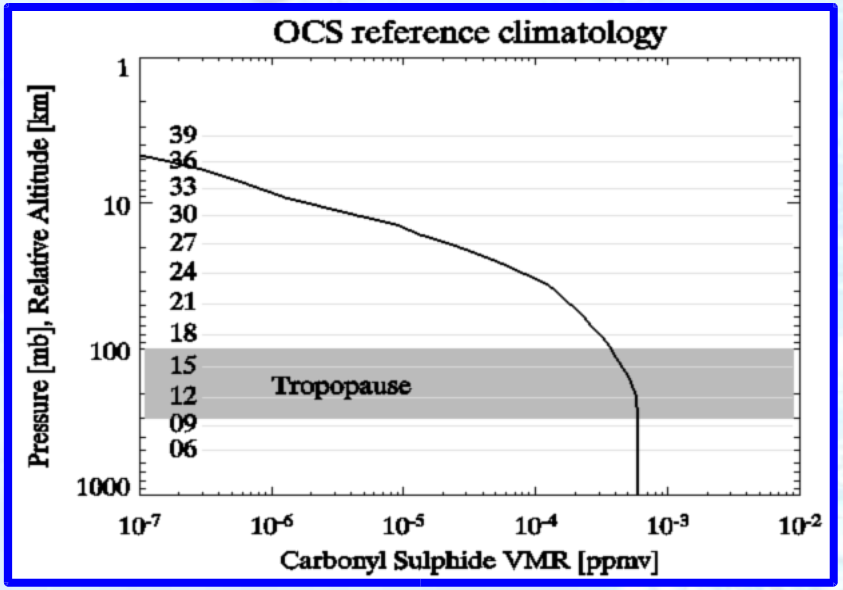
Microwindow Error Analysis (e.g. OCS)



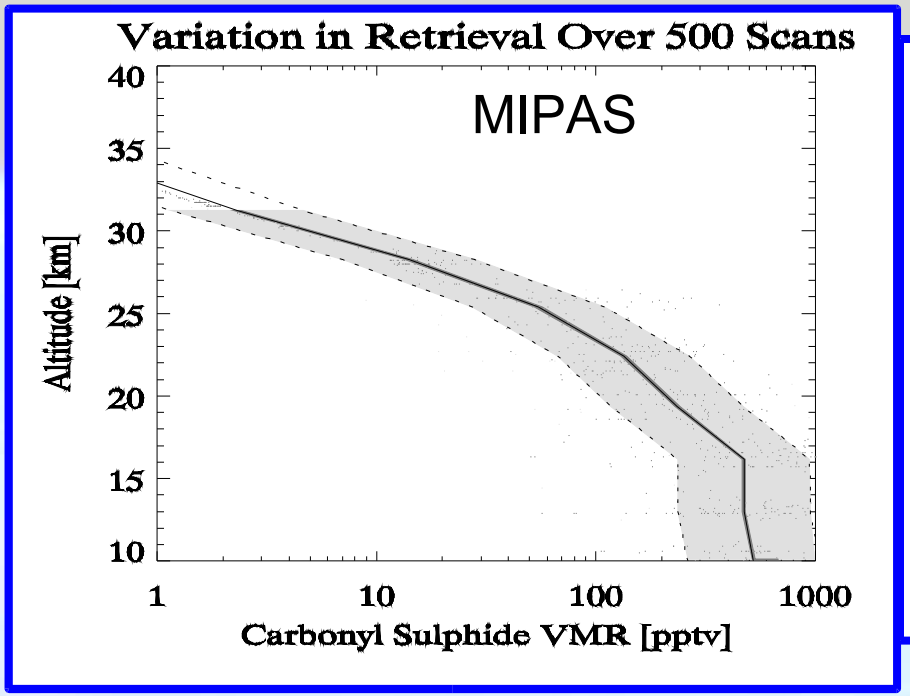
- Random error dominated
  - Coaddition
    - Radiance - non-linear
    - Retrieval - apriori bias
    - Residual - compromise?
- Systematics contribute <5%
- Most sensitive to
  - Temperature retrieval
  - Strong radiance gradient
  - Ozone (lowermost level)

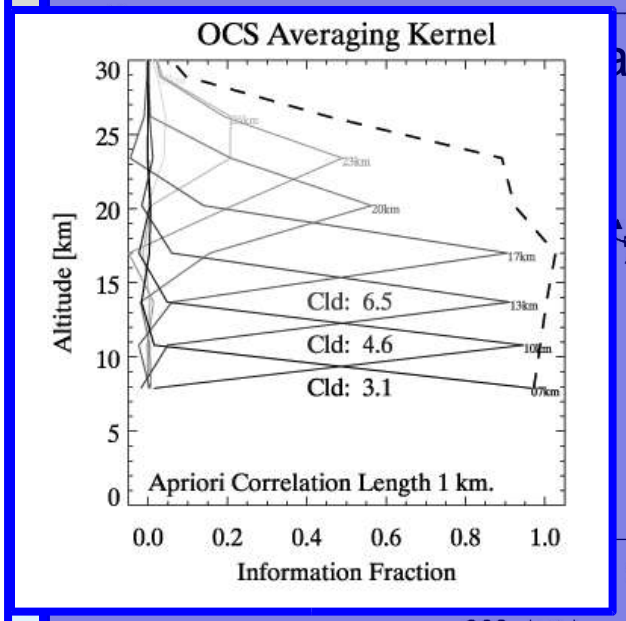
Carbonyl Sulphide

- Sources
  - Biomass burning, Industry, Forests, Oceans, Soils….
- Sinks
  - Oceans, Forests, Soils… Depending on season. OH and O radicals.
- Trends and Distribution
  - Long lifetime (few years) in troposphere… well mixed around 500 pptv
    - ranges 450 - 550 pptv, possible inter-hemispheric ratio and long-term trend.
  - Susceptible to UV photolysis… falls to 10 pptv by 30 km.



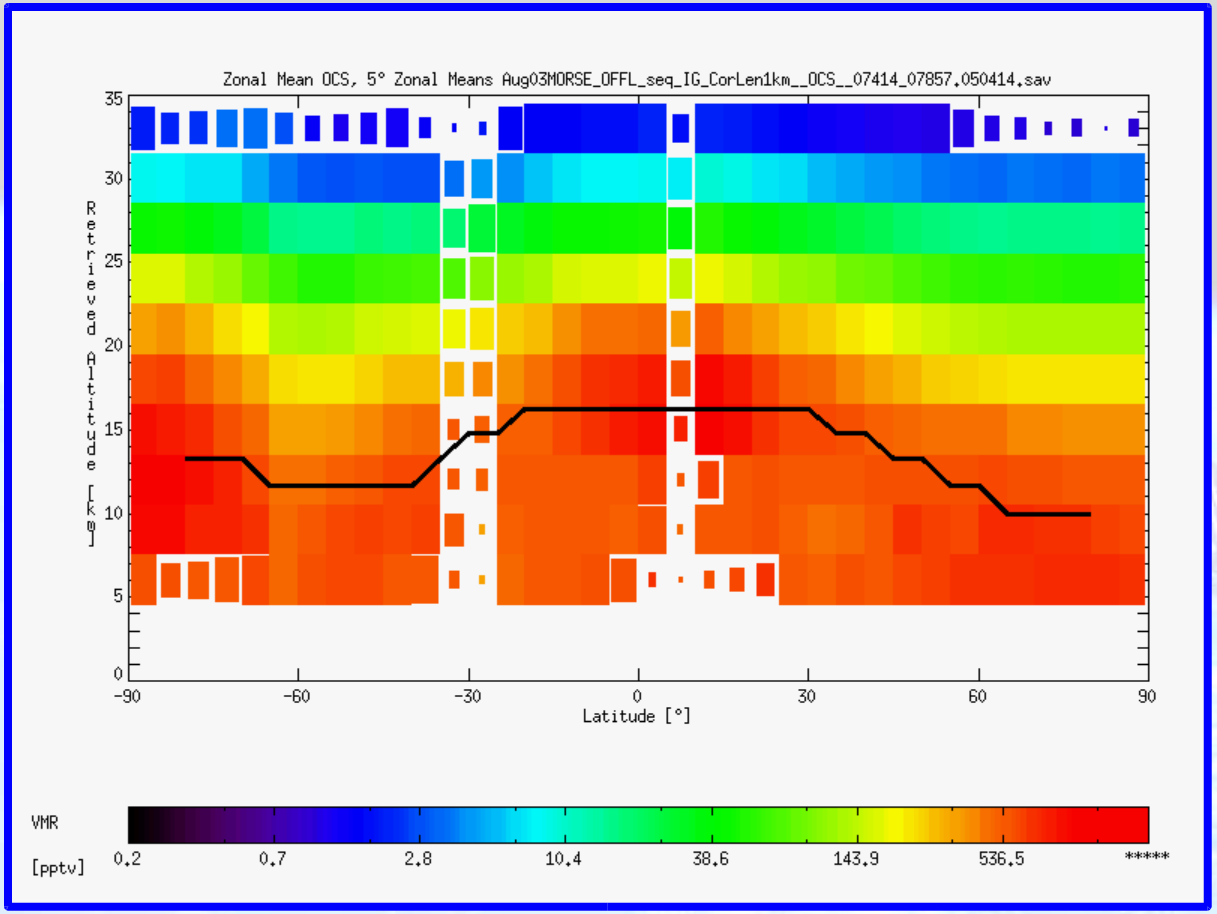
OCS Retrieval





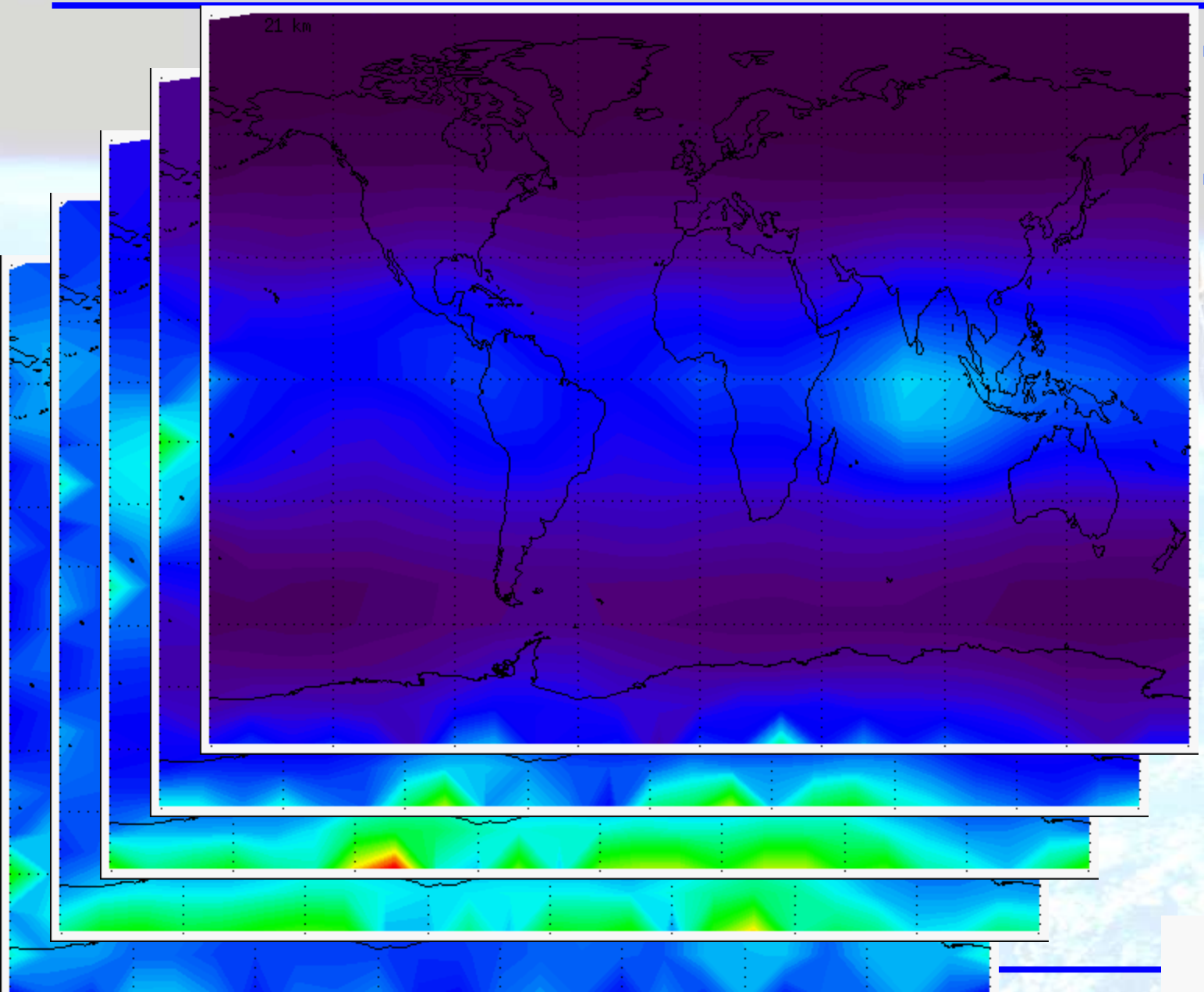
- Stratospheric values shown
  - Same scales… good agreement with literature profile.
  - Many *many* more measurements above 22 km
  - Shaded region is standard deviation
    - Combination of retrieval error and global variability
    - Individual profiles show 15-45% random error below 20 km.

OCS - Zonal Mean - August 2003



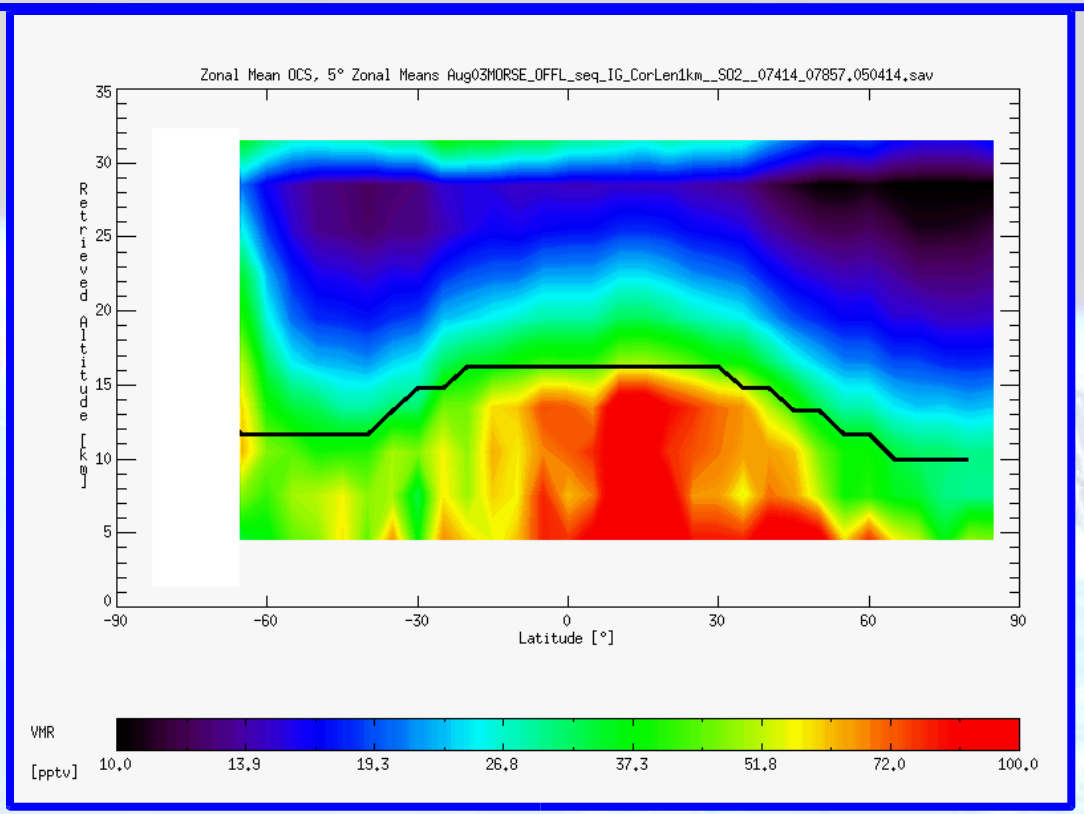
- Cloud
  - Data gaps at low levels
- Highs in south polar night
  - Low Temperature coupled with D-band?

OCS - Global Maps - August 2003



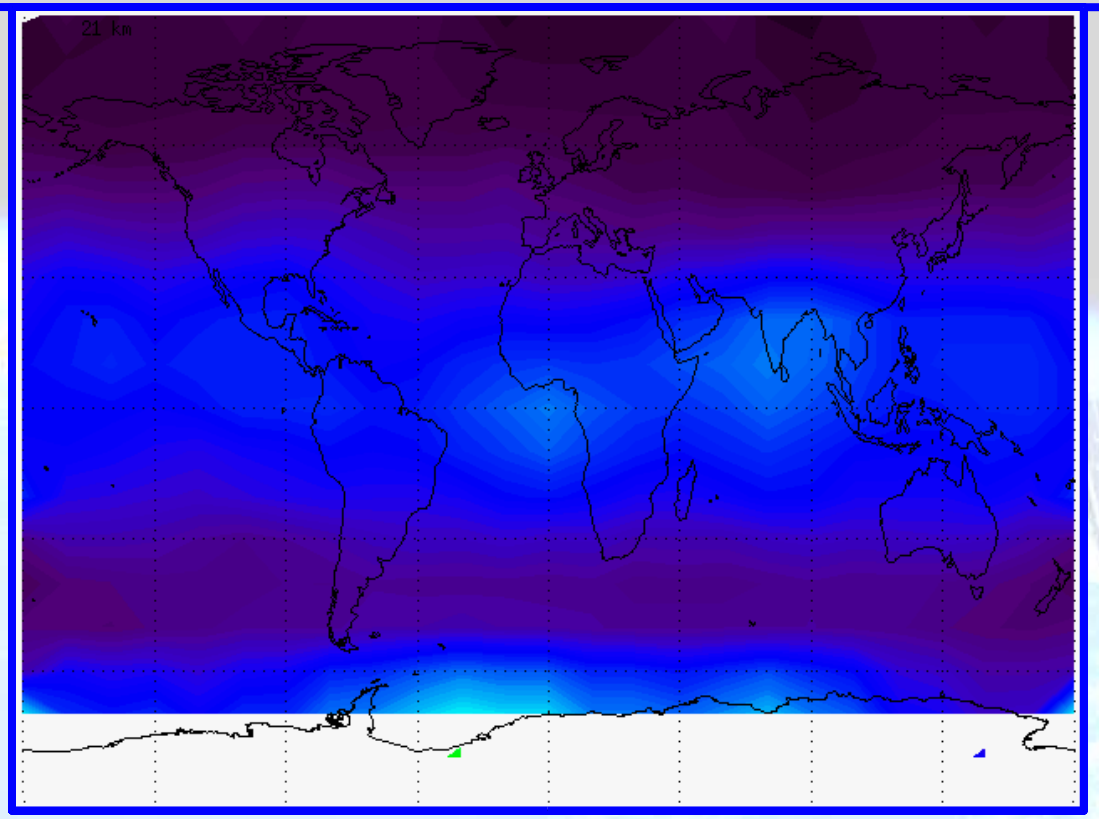
- 6 & 9km levels well mixed.
- High values over Indonesia
  - Intertropical convergence zone?
  - Biomass burning?
  - Cloud bias :(?
  - Some ‘highs’ have a low measurement density (tens) so biased by an outlier?

SO_2 - Zonal Mean - August 2003



- North : South Tropospheric asymmetry
  - Anthropogenic emissions
- Problem with the South Polar region – unfeasible highs.
- Only 2-3 (of 9 levels) degrees of freedom per profile
  - Uppermost levels have much reduced confidence

SO_2 - Global Map - August 2003



- Few Profiles low down
  - (due to high numbers cloud invalidated)
- Some similarities to OCS.
  - Biomass burning?
- Anthropogenic sources visible?

Sulphur Hexafluoride

- Sources
  - Electric & Aluminium industry
- Sinks
  - Photololysis and high energy electron capture in the Mesosphere
- Trends and Distribution
  - Very Long lifetime in troposphere and stratosphere (1000s years)
    - <5 pptv. Tropospheric variability purely from dynamics w.r.t source locations.
    - Inter-hemispheric ratio observed (Only N.H. sources). Annual trend ~7%

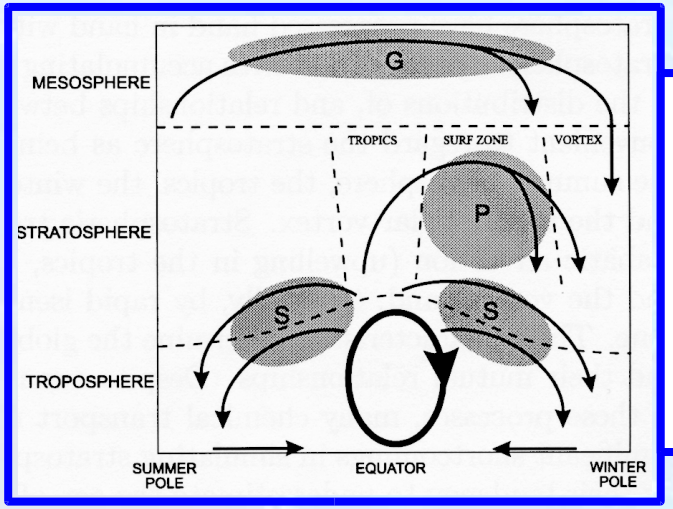


Figure from *A. Plumb, J Met Soc Jap 2002*

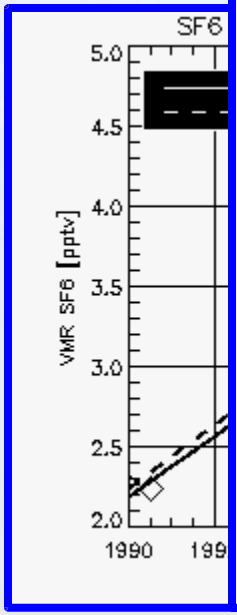
Inert tracer

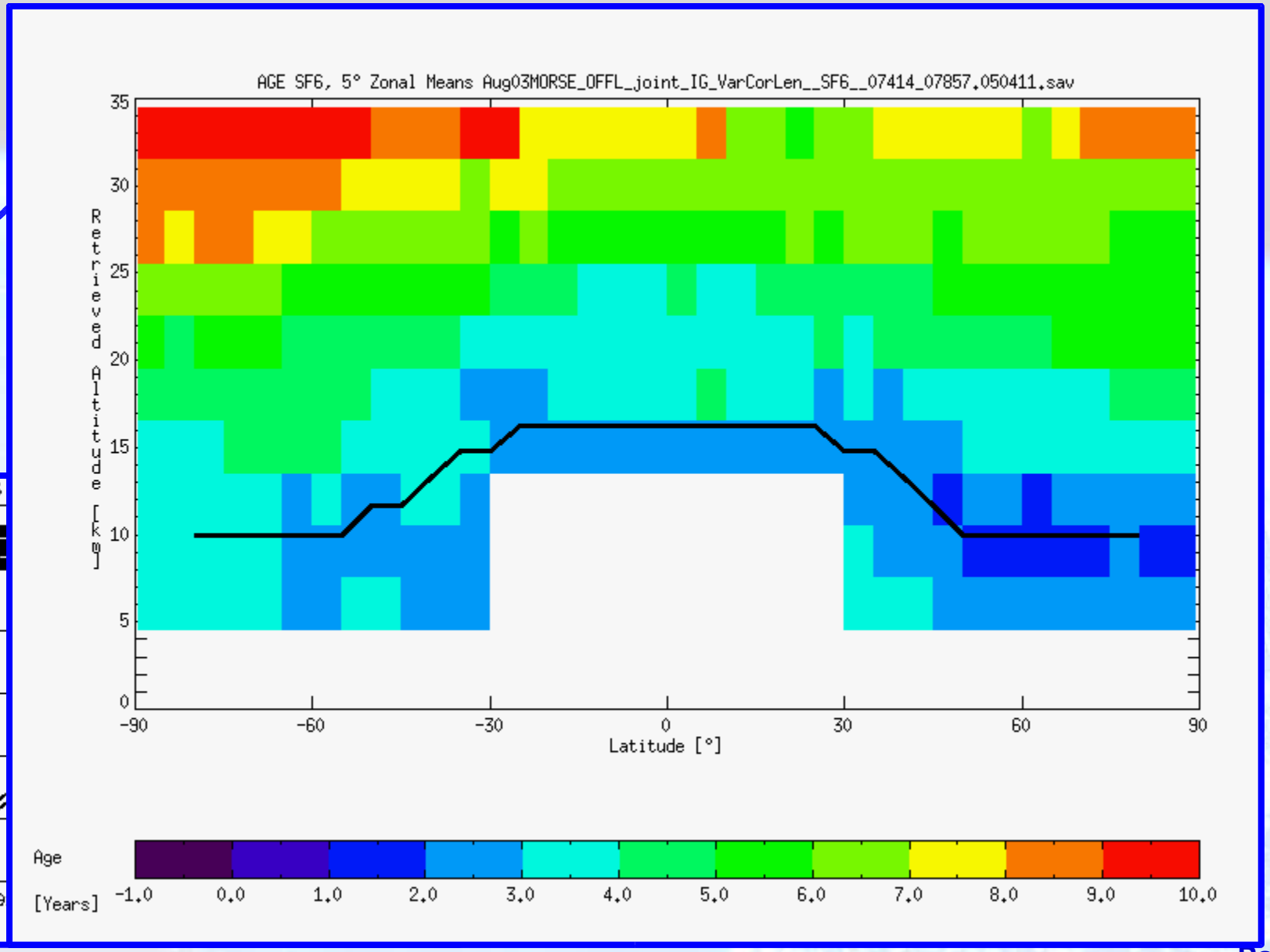
Allows study of dynamics

Especially, age of air

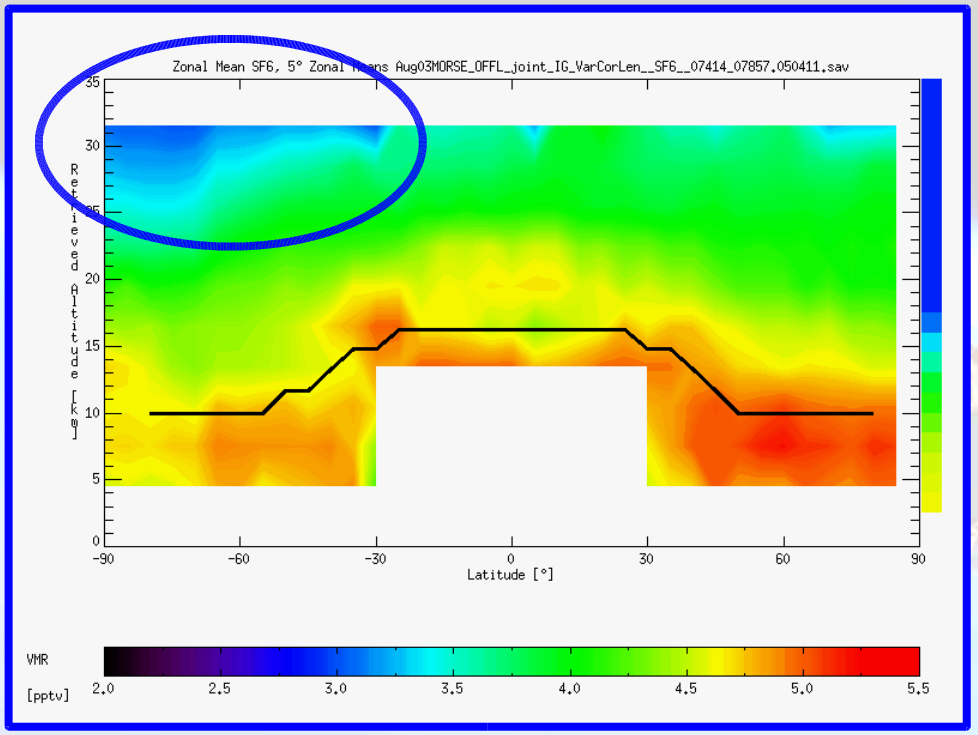
… which allows air flux calculation

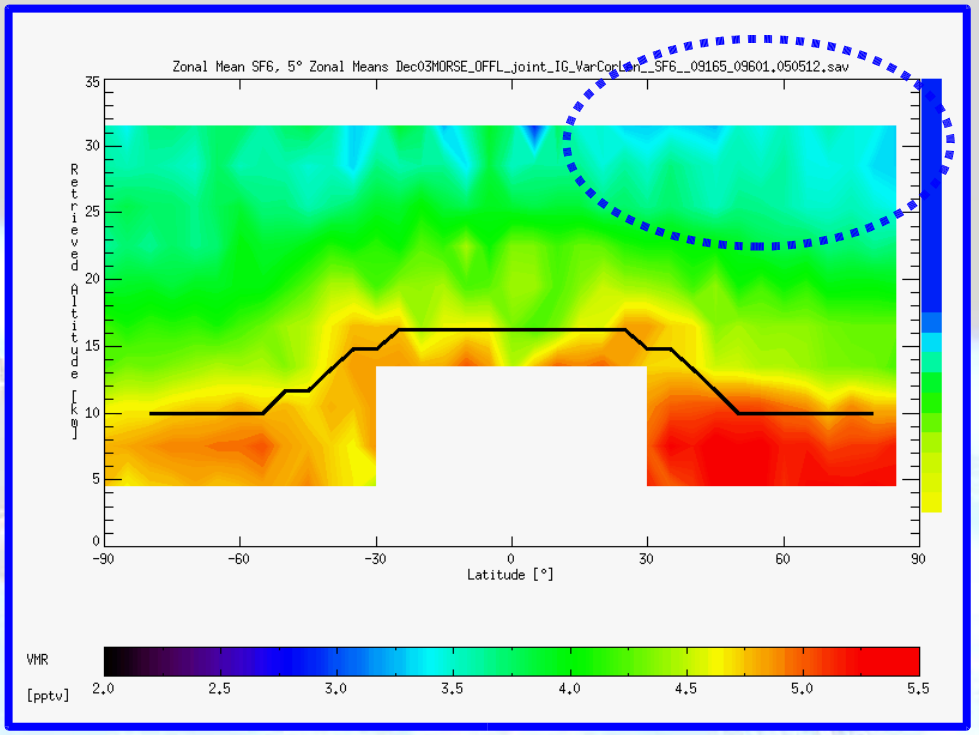
SF_6 - Zonal Mean - August 2003



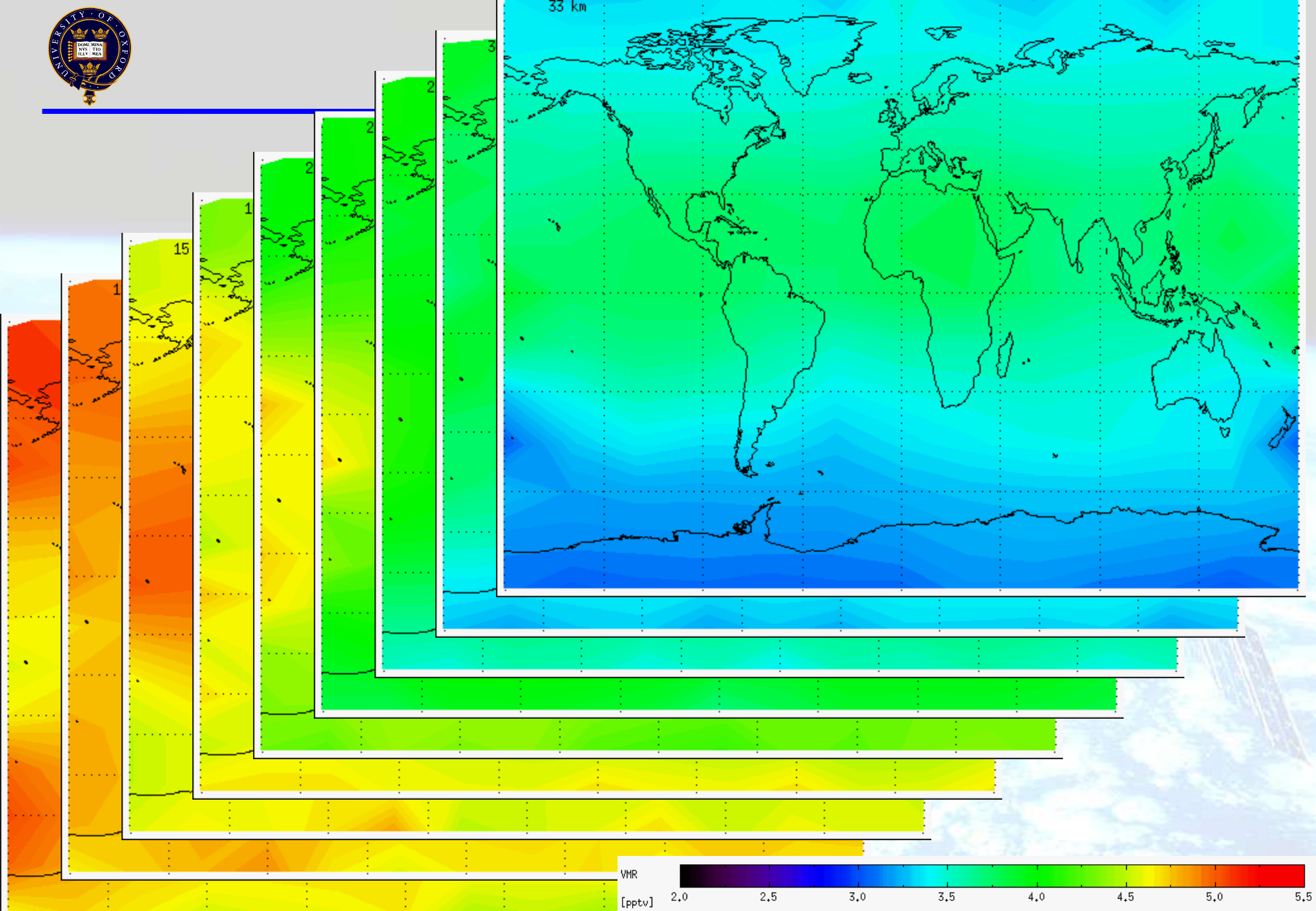


SF_6 - Monthly Variation



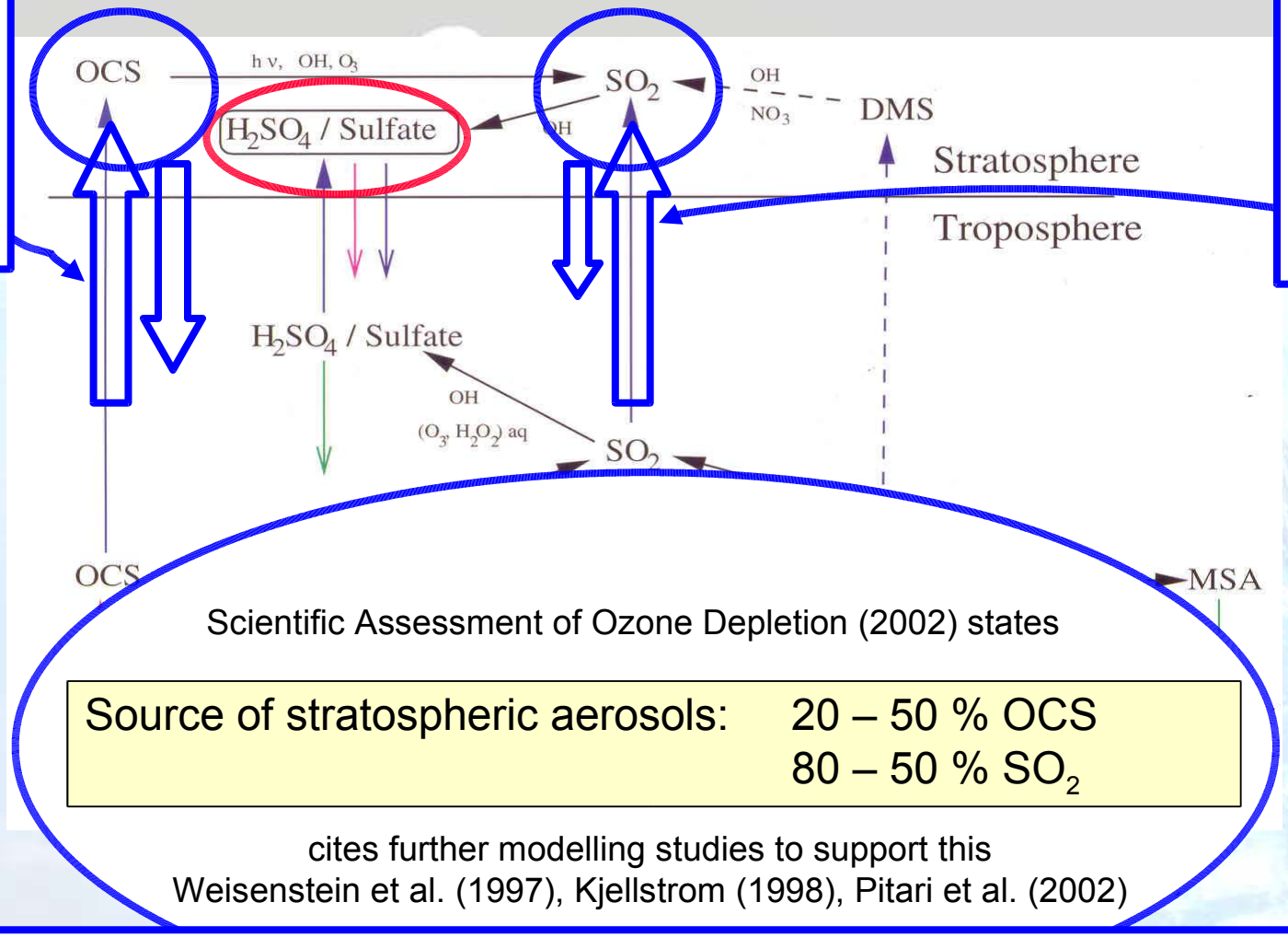


- Monthly variation
  - Mesospheric Descent? (Or temperature bias!?)
  - Random error rises above 50% at 25km…
- Magnitude of interhemispheric variation
  - Literature: ~1.5 years = 7-10% in SF6 VMR.


33 km
VMR
[pptv]
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5

Stratospheric Aerosol Layer – Putting it all together

Net flux
0.03 Tg/yr
based on
VMR
550pptv at TP



Net flux
0.03 Tg/yr
based on
VMR
40pptv at TP

Scientific Assessment of Ozone Depletion (2002) states

Source of stratospheric aerosols:	20 – 50 % OCS
	80 – 50 % SO_2

cites further modelling studies to support this
Weisenstein et al. (1997), Kjellstrom (1998), Pitari et al. (2002)

Combining MIPAS OCS and SO_2 measurements with aerosol data limits SSA sources: 30% - 50% SO_2

Conclusions

- OCS, SO_2 and SF_6 have been successfully retrieved
  - Global, height resolved fields.
  - Trade-off time / space resolution to improve random errors
    - These species are all a ‘bonus’ to the baseline mission expectations
  - Far from perfect, however.
    - Tropics short of low altitude measurements - cloud.
    - Large differences between some adjacent points - real?
    - Higher than expected values consistently retrieved in some areas - biases?
- Further work
  - In progress
    - Equinox and Solstice months where MIPAS available
    - Compare the annual cycle with model fields & other external validation
    - Climatologies - based on global measurement by the same instrument
  - Sulphur budgets and aerosol pathways
    - Have already calculated reservoir masses and approximate fluxes
- The latest developments: ***http://www.atm.ox.ac.uk/groups/mipas/***

Sulphur Dioxide

- Sources
  - Industry, Power generation, Aircraft..., Volcanoes, Atmospheric oxidation
- Sinks
  - Oceans, Forests, aerosol formation (SO_4^{2-}) in stratosphere…
- Trends and Distribution
  - Short lifetime in troposphere… not well mixed. ~50 pptv >6km.
    - ranges 10 (clean) - 1000s (city) pptv. Complex distribution.
    - Enters st nd 25 km.