Improved limb measurements: what can they be used for?

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ESA Expert Meeting on Limb Sounding
Bologna, March 7-8 2016
Outline of talk

A. SPARC implementation plan

B. Scientific Uses
   • Trends
   • Process understanding
   • Use with models

C. Relevance at this workshop

Thanks to:
Quentin Errera, Greg Bodeker
A: SPARC Implementation Plan
2016-2020

Stratosphere-troposphere Processes And their Role in Climate

SPARC Implementation Plan 2016-2020

Atmospheric Dynamics & Predictability
Chemistry & Climate
Long-term Records for Climate Understanding
A: SPARC Implementation Plan
2016-2020

On-going activities

- Dynamical Variability
- Quasi-biennial Oscillation
- Gravity Waves & Momentum Budget
- Assessing Predictability
- Reanalyses Intercomparison
- Data Assimilation
- Atmospheric Dynamics & Predictability
- Chemistry & Climate
- Long-term Records for Climate Understanding

- Coupled Chemistry Modeling
- Chemistry in Asian Monsoon Region
- Solar & High-Energy Particle Influences
- Stratospheric Sulfur
- Carbon Tetrachloride
- Polar Stratospheric Clouds
Developing interests

Long-term Records for Climate Understanding

Combining records and understanding uncertainties
B: Scientific Uses

Trends

What to measure?
O₃, H₂O, Brewer-Dobson Circulation, tracers (chemical & dynamical)

What to ensure?
Stability, reduced uncertainties, clear error analysis, better resolution near tropopause,

What to aim for?
Production of merged data sets – or at least seamlessly usable with other data sets

Questions:
Simultaneous fields (e.g. T)
**B: Scientific Uses**

Trends - age of air critical for understanding circulation changes

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**Important for age of air**

- Increased precision
- Improved vertical resolution
- Similar CO₂ product? / extend?

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**Figure 6.** Top: Altitude–latitude cross-section of the model-error corrected linear increase of MIPAS AoA over the years 2002 to 2012, i.e. after including the model error and autocorrelations between the data points in the fit. Hatched areas indicate where the trend is not significant, i.e. it is smaller (in absolute terms) than its 2σ uncertainty. Bottom: 1σ uncertainty of the trend in terms of years/decade.

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*Haenel et al., ACP, 2015.*
B: Scientific Uses

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*Haenel et al., ACP, 2015.*
*Stiller et al., ACP, 2012.*
B: Scientific Uses

Trends – ozone: clarity on uncertainties

1979-97

Northern hemisphere
Various data sets
Some merged

All sorts of important merging issues not addressed here!!
B: Scientific Uses
Trends – ozone: clarity on uncertainties

1979-97

1998-2012

O3 trend [%/dec], 35N–60N, 1979–1997

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B: Scientific Uses
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1979-97

O3 trend [%/dec], 35N–60N, 1979–1997

Pressure [hPa]
Altitude [km]

1998-2012

O3 trend [%/dec], 35N–60N, 1998–2012

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Altitude [km]

Northern hemisphere
Various data sets
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Can the trend uncertainties propagated rigorously?

Not at the moment.
B: Scientific Uses
Trends – ozone: clarity on uncertainties

O3 trend [%/dec], 35N–60N

NH ML 1979-97

NH ML 1997-12

Dependent + drift
Dependent
Independent
How do we know which is best estimate of uncertainty?
How can the estimate be improved?

- better data selection
- improved error propagation all the way from the measurements right through the analysis
Trends

**What to measure?**
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**Questions:**
Simultaneous fields (e.g. T)
B: Scientific Uses
Process understanding

- water entry to stratosphere and the stratospheric tape recorder
- polar ozone variability
- monsoons
- trop O₃ budget
- particle properties?
- downward propagation?
- special products, e.g. during aircraft campaigns?

ozone, H₂O, CO, other tracers with different sources lifetimes
B: Scientific Uses
Process understanding

- water entry to stratosphere and the stratospheric tape recorder
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ozone, H$_2$O, CO, other tracers with different sources lifetimes

leaving the mesosphere to experts......
Time series of stratospheric $H_2O$ [ppmv] between 10°S-10°N from two limb sounders without bias correction: UARS HALOE and Aura MLS.

Courtesy Karen Rosenlof
B: Scientific Uses
Process understanding: polar ozone

Are the cold winters getting colder?
What drives interannual variability in polar vortex?

Important for:
Understanding polar ozone loss
Stratospheric role in weather

Courtesy WMO(2014), Markus Rex and Peter von der Gathen
B: Scientific Uses
Process understanding: monsoon

Tracers suitable for monsoon studies
Improve existing ones and develop new ones
CO, particles, CH$_4$, H$_2$O isotopes

Uncertainties.....

Fadnavis et al., ACP, 2014
B: Scientific Uses
Process understanding: tropospheric \( O_3 \) budget

- Need to quantify transport of \( O_3 \) from stratosphere into troposphere
  - \( \sim \sim 50\% \) of tropospheric \( O_3 \) is from stratosphere
- Aim to understand interannual variability as well as provide mean for benchmark period
- Obviously \( O_3 \), but also other tracers at high resolution (CO, \( H_2O \,... \)) where there is a strat:trop contrast
B: Scientific Uses
Process understanding

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ozone, H$_2$O, CO, other tracers with different sources lifetimes
C: Use with models

- model validation
- data assimilation
- combined model / measurement studies
Standard deviation of the multi-instrument mean (MIM) multi-annual mean datasets for $O_3$, $H_2O$, $CH_4$, $N_2O$, CFC-11, CFC-12, CO, HF, and $SF_6$ (color contours). The black contour lines in each panel represent the MIM trace gas distribution for each species. The number of instruments included is given by the right-hand grey bar.
Real value in making 2000-2020 an observational benchmark in order to improve CCMs (whether nudged or not)

but....... need to define what is meant
Can meteorological data (+ models) enhance the composition measurements?
Can composition measurements enhance meteorological reanalyses?

- Benchmark period, not whole of past record
- Tracers can improve stratospheric circulation
- Assimilated MIPAS N$_2$O, CH$_4$ data gives better comparison with ACE-FTS
- Stratospheric ozone radiative coupling important (including surface T)

*Radiances?*
Define a benchmark?

Timeline of high vertical resolution satellite Upper Troposphere / Stratosphere observations. Vertical black lines indicate design lifetime / end of prime mission; hatching indicates potential extended mission operations.

Courtesy Nathaniel Livesey (NASA-JPL)
So what?

Twin approach

1. Core measurements (ECVs)
   - Improve quality and resolution
   - Ensure rigorous uncertainty analysis and clarity for user
   - Stability critical
   - Complementary to other measurements
   - MLS AURA probably best current satellite instrument
     - how to extend/improve/add information
   - Ground measurements
     - best calibrated in principle

2. Trace species for scientific studies
   - Improve existing ones
   - Develop new ones