Limb Sounding workshop: Summary

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Long-term changes

1. $\text{H}_2\text{O}$: Variability v. large - how long to detect trend? – aim for “ESA” data to beat MLS uncertainties, (changing biases?) – especially p>100 hPa – offsets!! – higher resolution around tropical tropopause (0.5 km) – use other data, e.g. Costa Rica (2004 on), as reference for limb sounders

**aim for “ESA” data to beat MLS uncertainties, (changing biases?)**

2. Ozone: common set of uncertainty parameters – focus below 20 km and above 40 km (the regions of ozone loss!!) – reach into troposphere

**agree simple, user-friendly estimates of stability (%/dec), accuracy and precision**

3. Radiances – what can be done with Level 1b? Individual instruments then as a group?

**Hmm**

*My estimate of stability target for $\text{O}_3$ and $\text{H}_2\text{O}$ @~20km is ~2-5 % / decade, so improved accuracy of measurement suite in last 15-20 years is important.*

*(For $\text{H}_2\text{O}$, it depends on when we want to know it is changing!)*

**Aim: 1-2 km vertical resolution**
Long-term changes II

4. Age – Make MIPAS as ACE consistent – range of tracers to look low down and high up – SF6, CH4 (also gives water), N2O, CO2,

**Make MIPAS as ACE consistent as possible to extend data (for long series)**

Improve data during MIPAS operational period

5. Remember CFCs

**Maintain quality, again MIPAS/ACE**

*Potentially important for use in reanalyses*
Long-term changes III

6. Aerosols – best at moment is optical depth from combined limb data set from SAGE II (GOMOS, OSIRIS, Calypso...) through to OMPS – SO2

**Important in themselves and for other retrievals**

**What other properties could be derived?**

7. CO – raise importance especially in UTLS (convection, e.g. monsoon) and in free troposphere

**Should become one of the fundamental data products**

8. Other questions on approaches and ancillary information: merging, anomalies, available reanalyses

**Tbd**
New species and products

Three main groups:

• Tropospheric ozone budget:
  - O3, CO, CH4, PAN, NO2 (existing but improve) (HCHO – SCIA nadir)
  - VOC, acetone, HCO2H, hydrocarbons (MIPAS)
  - STE tracers

• Particles – what more information is possible
  - Ice, black carbon, dust, organics.....

• Particle precursor gases
  - SO2, OCS, NH3

• CO2 as a new species (retrieval for ACE and poss. SCIA and MIPAS)
Issues for discussion

Model validation
i) Contribute to on-going CCMi activities for next IPCC report
   • Major opportunity for wide impact of ESA measurements

Identify which products would have the biggest impact
i) Develop new CCMi diagnostics using new species (two-way street!!)
   • HCN, PAN, HDO, other isotopologues

What else is in the pipeline?
i) UTLS important here, too

Data assimilation
i) Initiatives in Europe and US
ii) Improved trace gas measurements and increasing range of species
iii) Not obvious if radiances will be used in time
   • Stay in touch with ECMWF etc for next set of reanalyses

Communication
Issues for discussion: Mesosphere

Understanding key processes in the mesosphere

i) understand solar forcing on the upper atmosphere

ii) the propagation of solar effects to the stratosphere and troposphere,

iii) the impact of climate change on the mesosphere and its circulation.

Identify which products would have the biggest impact

i) Improvements in knowledge of water vapour, CO/CO2 in the mesosphere; non-LTE water vapour understanding could liberate long-term series of data from SABER.

ii) Synthesis of NOy measurements from different instruments in the upper stratosphere and mesosphere

iii) Check on temperature quality in mesosphere

iv) Further work on noctilucent clouds including particle size estimates (on NLCs: GOMOS, SCIAMACHY, MIPAS, ACE, OSIRIS)

v) Interests in metal atom concentrations; comparison of SCIAMACHY, GOMOS, OSIRIS?

vi) OH airglow estimates should be incorporated into the product line and made more available.

Needs further work on level 1 calibration for mesosphere products, e.g., band C, band D calibration.

What else is in the pipeline?

i) HEPPA activities under SPARC

ii) New possible drivers from UV spectrum changes.

iii) FMI is leading a project “Exploiting Mesosphere”:
Breakout session 2: products

Overall comments

• Validation results are encouraging, particularly with respect to ACE. Feeling that lots of progress has been made in main products.
• Level 1 has some fundamental issues to be characterised: radiance calibration and drift (all); stray light and polarisation (uv-visible; i/r?).
• Some species etc are intrinsic to success as important for science and underpinning retrievals.
• Understanding the broad spectrum and being able to model it would it be really useful (particularly MIPAS; the tie for MIPAS and ACE is important).

Intrinsic products (science + retrieval quality)

• Temperatures are very good, better than re-analyses but we need to understand the real agreement.
• Aerosols and clouds
  – Total Extinctions; particle type
  – Aerosol parameters/Particle size distribution
  – Clouds e.g. NLCs
  – Little combined work across sensors in ESA
• Water vapour, particularly UTLS. Requires lots of work and is fundamental.
Individual products I

Individual products and issues:
• UTLS and mesospheric ozone
• Mesospheric NO$_y$: be sure of quality; inter-sensor information tests; involve modellers (e.g. through HEPPA).
• N$_2$O$_5$ needs further checking (assimilation problem).
• CFC-11 retrievals including Phosgene (reference for lifetimes); spectroscopy for weak CFCs, HCFCs.
• Improved BrO (retrieval) and BrONO$_2$ (spectroscopy); need to establish need. How does BrO relate to total Bry? Do BroNO2 and BRO tell us about Bry partitioning. How well do we know injection of source gases into tropical lower stratosphere?
• MIPAS CH4, N2O issues. A known challenge but important. Test/combine with ACE CH4 /N2O and SMR CH4.
Individual products II

Discussion on individual products and processes was joint with Applications group who were advised that:

- Many scientific products with increased translation into ESA products.
- New ESA MIPAS V7 products include HCN, CCl₄, COF₂, HCFC-22, CFC-14.
- New SCIAMACHY offline products include NO₂, H₂O, O₃, BrO, potentially CH₄.
- MIPAS science products which could be operational in V8 include C₂H₂, CH₃Cl but suggestions were also made around C₂H₆, formic acid, NH₃, SO₂. Acetone is likely to be scientific only.
Underpinning issues:

- Spectroscopy important for minor species but note previous comment on broad spectra.
- Need a focus on the interfering species, not just the target species.
- Traceability of Errors. Clear we need to do this; clear that there is not yet a community consensus. Needs to be required in next phase; errors need to be consistent across at least instrument families.
- Vertical representation – consistent messaging to users. Provide AK or weighting functions in files. Ensure they get used.
- Common approach for clouds, e.g., w.r.t. water vapor retrieval.
- Usage or characterisation of horizontal gradients of temperature (and vmrs).
- Assimilation is a good tool for testing progress (stratosphere).
LEVEL 1

- **POINTING**: Schiamachi ~20-30 m (lower limit, to be consolidated), MIPAS +/-120m, GOMOS: Stars, ACE: Pb with sun

- Access to Calibration/characterization data and documentation crucial.

- **KEEP LEVELS 0 and 1 DATA AND THE PROCESSOR**

- Envisage strongly the capability of reprocessing levels 1 and 2 whenever required

- Involve simultaneously current level 1 and Level 2 experts for future projects.

- Future: To assimilate radiances better calibration from 1st principles than comparisons between instruments. **Uncertainties essential!**

- How to merge the radiances of different instruments?
What are the spectroscopic needs?

- Still missing quantified uncertainties (Especially for air broadening and air pressure shifts and T dependences).
- Line narrowing almost entirely missing
- H2O, O3, CO2, CH4, SF6 (in progress), CFC11 (in progress), PAN,....
- O3: Consistency between different wavelength ranges: MW-11μm-4.8 μm- VIS-UV
- H2O, CO2, CH4, (O3): line shapes, widths, continuum and T dependence
- CH4: Completeness?
- Cross-sections: P (~Factor of 2) and T (~20K) dependences. **Right spectral resolution.** T inhomogeneity (~1K). **FOR IR and UV.**
- **Recom:** Review of existing spectroscopic studies before starting a project.
LEVEL 2

• Only a small amount of the MIPAS or ACE data is used in the level 2 analysis (Microwindows).
• Different/better in Schiamachy. SWIR underused in Schiamachy (Bad pixels)??

Recom: Simulate the whole MIPAS spectrum to check spectroscopic errors and/or missing species

• Is redundant and new information properly used: How the spectroscopic errors are propagated in the selection of microwindows? How to define better the microwindows?
LEVEL 2

Propagation of spectroscopic errors

• Global scalar error for trace gas profiles (scalar line intensity errors): this error is not fully critical since, in principle, it can be removed by validation. However accuracies of 1-10% are extremely difficult to reach.

• Spectroscopic errors with contributions varying with pressure and temperature and thus height, geolocation, time of year, day – night require sensitivity calculations.

• Recom: Use laboratory (Absolute intensities) and/or atmospheric spectra (Consistency between different spectral regions)
LEVEL 2

• Identify species **where specific scientific issues** require an improved data quality and consistency (T issue?)

• Test the impact of spectroscopic errors by doing retrievals with different microwindows.

• **Recom:** Keep precise track of the changes in the database (extensive documentation essential)
Recommendations to ESA

• There are some key areas where coupled improvements to level 1 and level 2 (and spectroscopy) will make a big difference:
  – Improve water vapour and ozone in key regions (UTLS and above 40 km) with good stability 2-5%/decade, with focus on adding value to MLS (lower uncertainties)
  – Make the most of info’ on tracers in the MIPAS record compared to ACE and SMR. Ensure the ties to ACE are strong.
  – Focus on key species in the upper troposphere and UTLS: organics and NOy, aerosols and precursors (chlorine and bromine source gases?)
  – New activity on CO2 retrieval (stratosphere and troposphere) would be excellent.
  – For mesosphere, ensure all instruments but particularly MIPAS (bands C/D) are well calibrated.
  – Examine carefully new products in mesosphere that could make a difference, e.g. metals, OH airglow estimates.
  – Encourage a synthesis on NLCs: GOMOS, SCIAMACHY, MIPAS, ACE, OSIRIS
Intrinsic products

Some products are intrinsic because of their effects on both subsequent retrievals and their own value for science.

The weighting of each of these varies with instrument but broadly temperature and water vapour are more important for i/r and aerosols for uv-visible.

• Temperatures are very good, better than re-analyses but we need to understand the real agreement. Strong efforts to validate and intercompare data; identify reanalysis efforts.

• Aerosols and clouds
  – Total Extinctions; particle type identification; separation between aerosols and clouds
  – Aerosol parameters/Particle size distribution
  – Clouds e.g. NLCs
  – Little combined work across sensors in ESA

• Water vapour, particularly UTLS. Requires lots of work and is fundamental
Level 1 and Spectroscopy

- Critical to keep level 1 traceable. KEEP LEVELS 0 and 1 DATA AND THE PROCESSOR (including software code). Curation should include on-ground calibration documentation.
- Pay particular attention to radiance calibration (all), and straylight/polarisation (visible)
- Review of existing spectroscopic studies before starting a project.
- Simulate the whole MIPAS spectrum to check spectroscopic errors and/or missing species. Create a unified test set of MIPAS and ACE spectra.
- Use laboratory (Absolute intensities) and/or atmospheric spectra (Consistency between different spectral regions)
- Keep precise track of the changes in a spectroscopic database (extensive documentation essential)
• For users:
  – Look at traceable uncertainties (possible SPARC activity). For users: simple, user-friendly estimates of stability (%/dec), accuracy and precision
  – Make data easily accessible, e.g. web portal
  – Consistent messaging in obvious places as to which data product to use.

• For the future: ESA to encourage studies of new instruments and group to strongly promote next step instruments (low-cost?). Should be in context of international activities e.g. SPARC, NASA.
• Maintain QWGs as much as possible in the framework of the new ESA activity.