Draft EoC from Switzerland to COST Action-723

Name of proposer: Prof. .Kämpfer
Institute of Applied Physics, University of Bern
Sidlerstr. 5
CH-3012 Bern
Switzerland
Tel.: +41 31 631 89 08
Fax: +41 31 631 37 65
Email: kaempfer@mw.iap.unibe.ch

Title of contribution: **Water vapor profiles from the ground to the mesosphere**

Summary of the planned research:

Water vapour is an atmospheric constituent of fundamental importance for climate in the troposphere as the most important greenhouse gas. It also plays many roles in stratospheric chemistry and dynamics. However, very little is known about its actual distribution above the lower and mid troposphere where it is observed by meteorological balloon sondes on a regular basis. Especially in the climate-relevant upper troposphere/lower stratosphere (UT/LS) region that is targeted by COST action 723, measurements of the water vapour distribution are very sparse. Long term observations hardly exist at all, even though a trend in stratospheric water vapour has been established over the last few years that might be related to global change.

The main idea of this project is to establish a ground based station that can provide altitude profiles of atmospheric water vapour from the ground to the mesosphere on a routine basis. Since no single measurement technique can cover this large altitude range, several techniques have to be employed at the same location to provide a complete profile. It is also necessary to develop methods for joining profiles that were retrieved with different measurement principles. A complete water vapour profile could answer a lot of open questions such as the actual amount of tropospheric water vapour entering the stratosphere through the UT/LS region. Such a station would also be very useful for the validation of satellite instruments and atmospheric models. It could also serve as the core of a future network of similiar stations that would provide these measurements on a more global level.

The most promising techniques that can be used to provide parts of a joined water vapour altitude profile are

- Meteorological balloon sondes for the lower troposphere (0-6 km)
- Raman Lidar measurements for the lower to upper troposphere (0-10 km)
- Cryogenic balloon sondes for the upper troposphere and lower stratosphere (8-30 km) and other dew/frost point sondes for the whole troposphere (0-11 km)
- Microwave radiometers for the lower stratosphere to mesosphere (20-70 km)

Most of these techniques are available in Switzerland today but have not been used together yet, neither here nor anywhere in the world. In a first step, these measurement techniques have to be set up at the same location. Raman Lidar instruments for water vapour retrieval have been built and operated by the EPFL Lausanne and the University of Bern has a long tradition in microwave radiometry. Besides the expertise that is needed to operate these instruments tools and methods have to be developed to merge profiles derived from different measurement techniques. That requires atmospheric scientists with a background in data assimilation and modelling. It is also necessary to include institutions that have experience with balloon sonde launches like Meteo Swiss. The cryogenic balloon sondes are only available from NOAA in Boulder, USA, and have not been used in Europe before.

The project organisation would follow five distinct phases that overlap partly. During the preparation phase, the microwave and Lidar instruments would be set up at the same location, for example at the Jungfraujoch Scientific Station. The next phase would be the measurement phase, during which the instruments would collect data continuously and regular sonde launches take place. During this time, methods for merging the retrieved profiles would be developed. These methods would be employed to provide joined profiles during the assimilation phase. These profiles would then be validated against satellite or other measurements in the vaildation phase. In the final distribution phase, the results would be submitted to the COST 723 climatology data base, introduced at the COST 723 workshops, and published in reports and journal articles. The expected total project lifetime is four years.

The project has the following main objectives:

- Set up one or more ground based stations that will provide continuous measurements of the water vapour altitude distribution from the troposphere to the mesosphere. Raman Lidar systems will provide the tropospheric profiles while microwave radiometers will measure the stratospheric and mesospheric distribution. Special radiosondes will be used to provide data from the lower stratosphere which is not covered by the remote sensing techniques or regular radiosondes. In addition, special radiosonde measurements using the "SnowWhite" hygrometer of Meteolabor AG (Switzerland) will be performed by MeteoSwiss for validation purposes in the upper troposphere.
- Build up a water vapour dataset and provide data to the other members of COST-723 in order to generate an assimilated dataset.
- Improve the interpretation of these measurements and our understanding of the role of atmospheric water.

Demonstrate the feasibility of this approach and provide the basis for a future network of such water vapour stations on a European or global level.
The project links with several existing and proposed atmospheric research projects as water vapour and the UT/LS region are primary targets of the upcoming 6th Framework Research Programme of the European Commission. There are also a number of new satellite instruments like Odin or SCIAMACHY on Envisat that will provide atmospheric water vapour measurements in the future.

Expertise in the field

As it was mentioned above, several measurement techniques need to be combined to provide a complete vertical profile of atmospheric water vapour from the ground to the top of the atmosphere. Each technique can only cover a specific altitude region by itself. The established measurement techniques for the different regions are:

- Meteorological balloon sondes for the lower troposphere (0-6 km)
- Raman Lidar measurements for the lower to upper troposphere (0-10 km)
- Cryogenic balloon sondes for the upper troposphere and lower stratosphere (8-30 km) complemented by dew/frost point sondes for the troposphere (0-11 km)
- Microwave radiometers for the lower stratosphere to mesosphere (20-70 km)

Meteorological balloon sondes with standard hygrometers are launched by Meteo Swiss on a daily basis for weather forecasting purposes. The standard hygrometers provide a very high altitude resolution in the lower troposphere but fail at the low water vapour abundance at the upper troposphere and above the tropopause. Meteo Swiss has a deep experience with launching Snowhite sondes that provide high quality water vapour profiles. These sondes are defined as a new reference for WMO intercomparisons of humidity sondes.

Raman Lidar measurements are provided by the EPFL Lausanne from the International Scientific Station Jungfraujoch. These measurements are only possible during the night and under clear weather conditions. They provide high resolution water vapour profiles from the ground at 3600 m almost up to the tropopause. Cryogenic balloon sondes have not been used in Europe on a regular basis yet. They are only available from the Climate Monitoring and Diagnostics Laboratory (CMDL) of the National Oceanic and Atmospheric Administration (NOAA) in Boulder, USA. This institution has a long term record in launching these sondes since 1980 and has managed to establish them as a widely recognised climatological standard. The sondes are unique for the fact that they are the only balloon sondes that can provide reliable water vapour measurements across the tropopause region. They can be launched at typical sonde-launching facilities and need only little additional equipment. Microwave radiometers for the observation of a number of atmospheric trace gases have been built and operated by the Institute of Applied Physics (IAP) at the University of Bern for a number of years already. These instruments can operate under most weather conditions during day and night. They provide altitude profiles of trace gases at a rather coarse altitude resolution but cover almost the whole stratosphere and mesosphere up to an altitude of 60-70 km. The IAP has just built a new water vapour radiometer at 22 GHz that currently operates from Bern. Another water vapour radiometer at 183 GHz has successfully been used to retrieve stratospheric water vapour profiles from the International Scientific Station Jungfraujoch.
With the exception of cryogenic balloon sondes, all the above mentioned measurement techniques are available in Switzerland today. Their altitude ranges overlap but they are not yet used in combination to provide a complete picture of the atmospheric water vapour distribution. To achieve this, two problems have to be solved first:

- The measurements have to be taken from the same location or close one on a regular basis.
- Methods for merging profiles from different measurement techniques have to be developed.

The first problem is more of a logistical nature while the second requires additional expertise from atmospheric scientists that have experience with data assimilation techniques. Both problems can be solved through close cooperation between different research groups and institutions. A COST project seems to be well-suited to start such a cooperation.

Recent publications

Peter, R., Stratospheric and measospheric latitudinal water vapor distributions obtained by an airborne millimeter-wave spectrometer, *J. Geophys. Res*., 103(D13), 16,275-16,290, 1998.

Kämpfer, N.; Microwave remote sensing of the atmosphere in Switzerland, *Optical Engineering*, 34 (8), 2413-2424, 1995.

Siegenthaler, A., O. Lezeaux, D. G. Feist, and N. Kämpfer; First water vapor measurements at 183 GHz from the high alpine station Jungfraujoch, IEEE Trans. Geosci. Remote Sens., 39, No. 9, pp. 2084-2086, 2001.

Vömel, H., S. J. Oltmans, F. Hasebe, M. Shiotani, M. Fujiwara, N. Nishi, M. Agama, J. Cornejo, F. Paredes, and H. Enriquez, Balloon-borne observations of water vapor and ozone in the tropical upper troposphere and lower stratosphere, J. Geophys. Res., submitted, 2001

B. Lazzarotto, M. Frioud, G. Larchevêque, V. Mitev, P. Quaglia, V. Simeonov, A. Thompson, H. van den Bergh, and B. Calpini. Raman-DIAL O3 and H2O measurements in the planetary boundary layer; Applied Optics, 40, No. 18, pp. 2985-2997, 2001.

Time schedule

The project consists of several workpackages that start out individually and are later joined as soon as data is available from all instruments:

1. Preparation phase (month 0-11)

   Improve existing Raman Lidar system to extend vertical range up to tropopause. Improve capabilities for automated routine measurements. (EPFL)

   Set up and install microwave radiometer(s) at or near existing Raman Lidar station(s) in Switzerland (currently on Jungfraujoch). Improve altitude range towards tropopause. Develop retrieval algorithm for low altitude retrievals. (IAP)

   Coordinate launch facilities for cryogenic, dew/frost-point (SnowWhite type) and regular sondes with simultaneous operation. Develop algorithm for direct intercomparison purposes, quality assessment and quality control of the data. (MeteoSwiss)

2. Measurement phase (month 12-47)

   Operate Raman Lidar system and microwave radiometer(s) from the same location over an extended period of time. (IAP, EPFL)

   Launch cryogenic and dew/frost-point balloon sondes simultaneously on a regular basis under favorable observation conditions. (MeteoSwiss)

3. Assimilation phase (month 6-17)

   Develop algorithms and techniques for joining water vapour profiles derived from Raman Lidar measurements, microwave radiometry, cryogenic, dew/frost-point and as regular balloon sondes. (all)

   Assimilate data from Raman Lidar instruments, microwave instruments, cryogenic, dew/frost-point and regular balloon sondes to provide water vapour profiles from the ground to the mesosphere.(all)

4. Validation phase (month 24-41)

   Produce detailed error analysis of the combined profiles, taking into account the measurement overlap over different altitude ranges. (all)

   Compare joined profiles to satellite and model results. (all)

   Compare joined profiles to other in-situ sources like MOZAIC or SPURT campaign measurements. (all)

5. Distribution phase (month 36-47)

   Provide joined profiles to COST 723 climatology data base.(all)

   Advertise joined-profile data set at COST 723 workshops.(all)

   Write scientific reports. (all)

   Publish in scientific journals.(all)