Microwave Radiometry of Water Vapor


Institute of Applied Physics
University of Bern
Switzerland

WG1 workshop of COST-WAVACS
Outline

Principles of microwave radiometry

Examples of what can be achieved

Conclusions
Microwave radiometry of stratospheric H$_2$O

Atmospheric transmission at microwave frequencies
Microwave radiometry of stratospheric H$_2$O

Microwave radiometer

![Diagram of microwave radiometer components](image)

- **Atmosphere**: H$_2$O
- **RF**: 22.2 GHz $\pm$ 0.5 GHz
- **Local Oscillator (LO)**: 22 GHz
- **IF**: 0 to 0.5 GHz
- **Power**: LSB, USB
- **Frequency**: DC to LO

**Principles**

- **Science**
- **Conclusions**
Microwave radiometry of stratospheric H$_2$O
Measurement of pressure broadened emission lines

MIAWARA: Middle atmospheric water vapor radiometer

Measured spectrum of H$_2$O at 22 GHz
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MIAWARA: Middle atmospheric water vapor radiometer

Measured spectrum of H$_2$O at 22 GHz

Question: What is the distribution of water vapor in the atmosphere that leads to such a spectrum?

\[
I(\nu) = I_0 e^{-\tau(z_0)} + \int_{0}^{z_0} T(z)e^{-\tau(z)} k_a(p, T, n(z)) \, dz
\]
Optimal estimation technique

The radiative transfer problem is an ill posed problem
→ solution is not unique
Optimal estimation technique

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... but by combining a priori knowledge, \( x_a \), with measurement, \( y \), in an optimal way allows to retrieve an altitude profile, \( \hat{x} \), from the measurements by considering uncertainties in the measurement, \( S_y \) and in the a priori knowledge, \( S_a \)

\[
\hat{x} = x_a + S_a K^T (K S_a K^T + S_y)^{-1} (y - K x_a)
\]

\( K \) is the so called kernel function or weighting function
Water vapor: a key research topic at IAP

Different techniques used to measure H₂O from the ground to the mesopause
Distribution of H$_2$O from 20 to 70 km over Bern measured by microwave radiometry in the frame of NDACC

Ph.D. thesis Haefele
Distribution of tropospheric H$_2$O

Combining information of channels
→ tropospheric water vapour and
→ temperature profiles

Ph.D. thesis Schneebeli
Water vapor column density climatology

Model of TROWARA time series from Jan94 to Oct07

0.08 mmyr$^{-1}$ [−0.02, 0.18]

Morland et al. tbs 2008
Examples of present research topics
Sudden stratospheric warming

Reaction of $O_3$ and $H_2O$ to a sudden stratospheric warming

Flury, Haefele, Hocke and Kämpfer in preparation for JGR
Examples of present research topics

Tides in the atmosphere

Tidal structures of temperature (from SABER satellite) and H$_2$O (from MIAWARA Zimmerwald) in the mesosphere

Ph.D. thesis A.Haefele
Conclusions

Microwave radiometry operated from the ground is well suited to retrieve:

- water vapour profiles
- integrated water vapour
- integrated liquid water
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Continuous measurements possible during most of time

- middle atmospheric profiles from 20 - 70 km
  - time resolution approx. 1 hour
  - averaging kernels approx. 10 - 15 km
  - validation with satellites within 10%
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  - time resolution few minutes
  - validation with close-by radio sondes
  - potential for nowcasting of thunderstorms
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THANK YOU
Microwave radiometry of $\text{H}_2\text{O}$ from aircraft
SCOUT-O$_3$ campaign Nov. 2005

Ph.D. thesis Th.Flury