The Zugspitze water vapor radiative closure experiment. Part 2: validation of continuum coefficients in the far-IR

A. Reichert, R. Sussmann, and M. Rettinger
**FIR water vapor continuum:**
*atmospheric relevance*

- Water vapor continuum is a major contribution to atmospheric absorption (e.g. 4% OLR reduction, 14% SDR increase for TRO atmosphere, 100% of absorption in certain spectral regions)
- Accurate description of continuum crucial for realistic modelling of atmospheric radiative transfer, e.g. in climate models
- Quantification of water vapor radiative processes is a major contribution to uncertainty of current climate models

(from: Paynter and Ramaswamy, 2011)
**FIR water vapor continuum: definition**

- **Definition of continuum absorption**: sum of absorption contributions not included in Voight line shape within 25 cm\(^{-1}\) of center
- **Further decomposition in self- and foreign continuum**
FIR water vapor continuum: current situation and previous studies

• MT_CKD continuum model widely used in radiative transfer calculations, e.g. also climate models

• Model parameters constrained/validated by comparison to atmospheric and laboratory measurements, e.g.:
  Burch et al., 1974 -> laboratory measurements, used in original CKD model
  Tobin et al., 1999 -> CKD 2.3,
  Serio et al., 2008
  Delamere et al., 2010 -> MT_CKD 2.4,
  Liuzzi et al., 2014

• Ongoing debate about validity of MT_CKD approach (e.g. dimer contribution)
The Zugspite closure experiment:
setup for FIR continuum retrieval

Atmospheric state measurements
- H₂O column, profile
- pT profile
- further trace gas columns (CO₂, CH₄, O₃)

Radiative transfer model (LBLRTM)

Difference spectrum ("residuals")

Spectral radiance measurements
- AERI far-/mid-infrared thermal emission spectra
The Zugspite closure experiment: analysis steps for measured spectra

- Analysis steps for measured AERI spectra include: bias correction and noise reduction with PCA filter
The Zugspite closure experiment: constraining the atmospheric state

• Measurements: MWR (iwv, water vapor profile), solar FTIR (further trace gas columns), BREWER/Dobson (ozone column)

• Additional information from AERI spectra: fit of near-surface T profile, Esposito et al. (2007)
The Zugspite closure experiment: selection of microwindows for continuum retrieval

Microwindow selection based on continuum uncertainty estimate: iwv and further trace gas column errors, T profile errors, AERI measurement noise, calibration uncertainty, water vapor line parameter uncertainties

- Line parameter uncertainties are dominant contribution, but poorly quantified
The Zugspite closure experiment: continuum quantification from spectral residuals

- Spectral residuals in selected microwindows
- Adjustment of continuum coefficients according to continuum jacobian
- Recalculation of synthetic radiance
- Iteration is stopped if residuals in selected microwindows below AERI uncertainties
  → Set of adjusted continuum coefficients
**Results:**

*foreign continuum coefficients*

- Mean foreign continuum coefficients from the Dec 13 - Feb 14 Zugspitze dataset compared to MT_CKD 2.5.2

**uncertainty:**
- no line parameter contribution
- line parameter uncertainty included

**graph:**

- Black line: MT_CKD 2.5.2
- Red circles with error bars: Data points from the Zugspitze dataset
Results:
comparison to previous studies

red: Zugspitze measurements
black: Delamere et al., 2010/MT_CKD 2.5.2
green: Serio et al., 2008
Results:

self/foreign continuum ratio and temperature dependence

- Long-term dataset \( \rightarrow \) T dependence and self/foreign contributions
- Results consistent with MT_CKD, broader range of iwv/T\(_{eff}\) will be investigated
Summary and Conclusions

• Accurate quantification of water vapor continuum crucial for realistic atmospheric radiative transfer calculations, contributes significantly to uncertainties of current climate models.

• Zugspitze site ideally suited to improve continuum quantification in closure experiments due to elevation and available instrumentation.

• Extensive long-term dataset → more accurate continuum constraints and investigation of self/foreign contributions and T dependence.
Summary and Conclusions

• Good agreement of measured FIR continuum with MT_CKD model
• For better constraints on decomposition in self/foreign-continuum contributions + investigation of T dependence data with broader range of atmospheric conditions (iwv, T) will be analyzed
Acknowledgements

Funding by the Helmholtz Association, the Bavarian State Ministry of the Environment and Consumer Protection as well as by the Deutsche Bundesstiftung Umwelt (DBU) is gratefully acknowledged.