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

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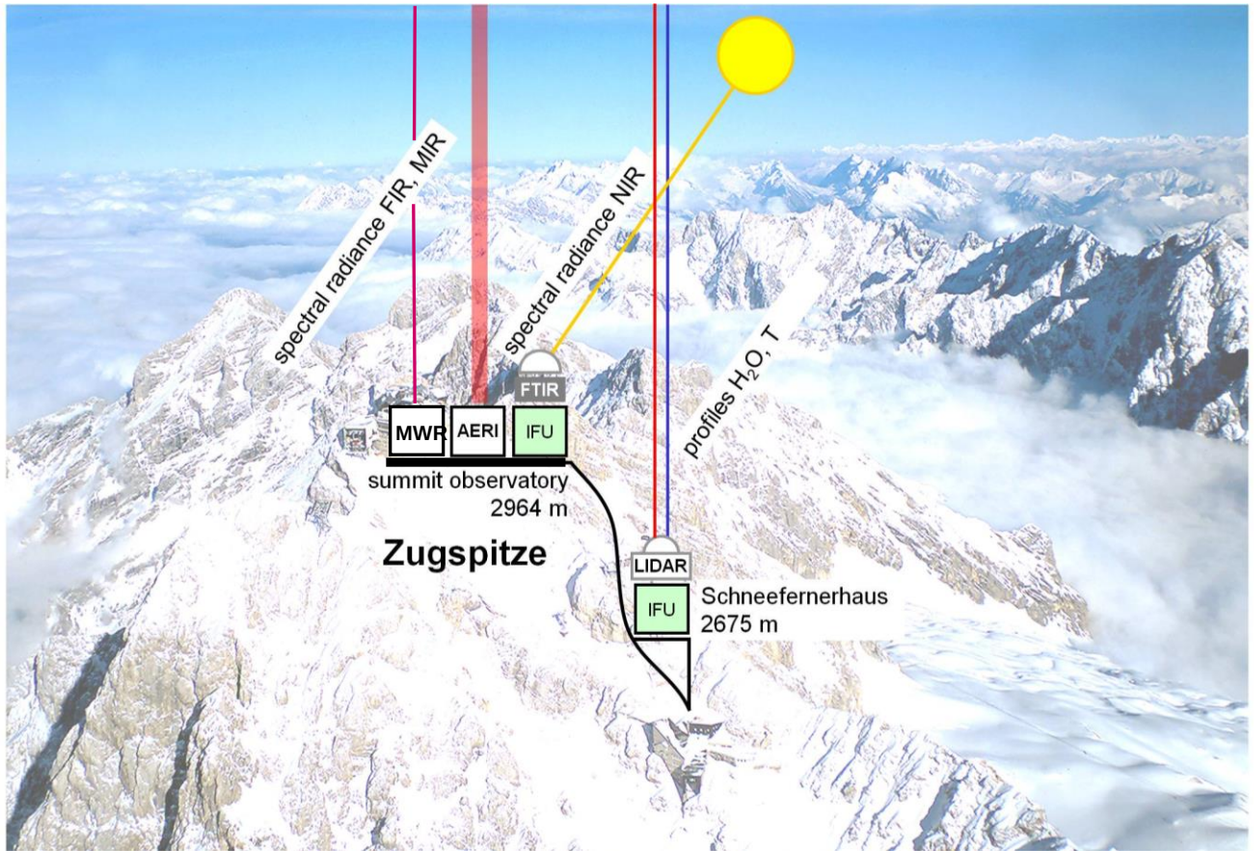
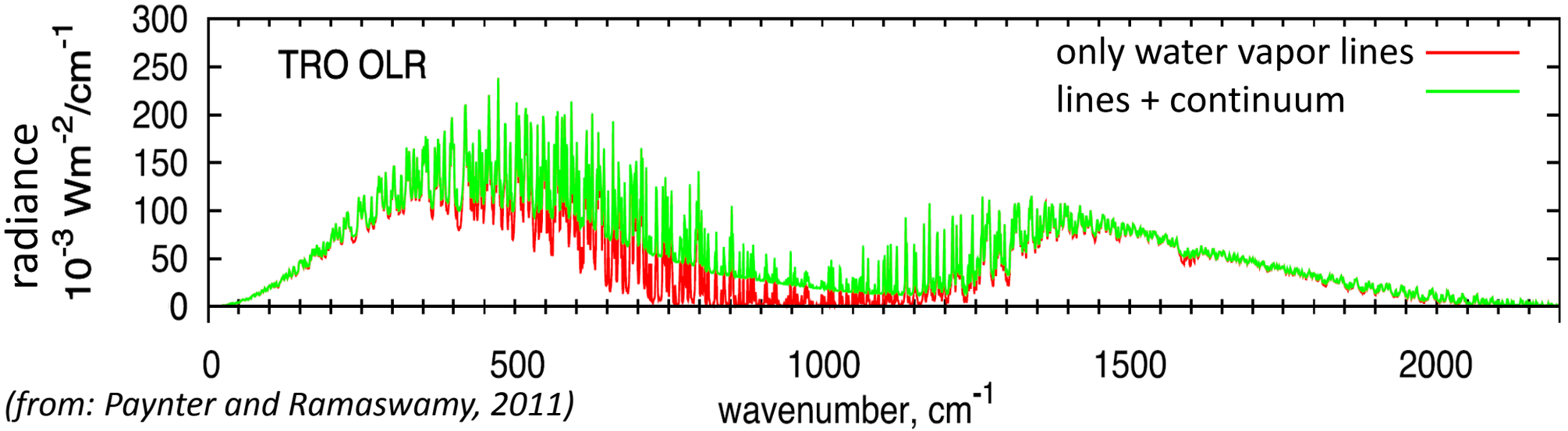


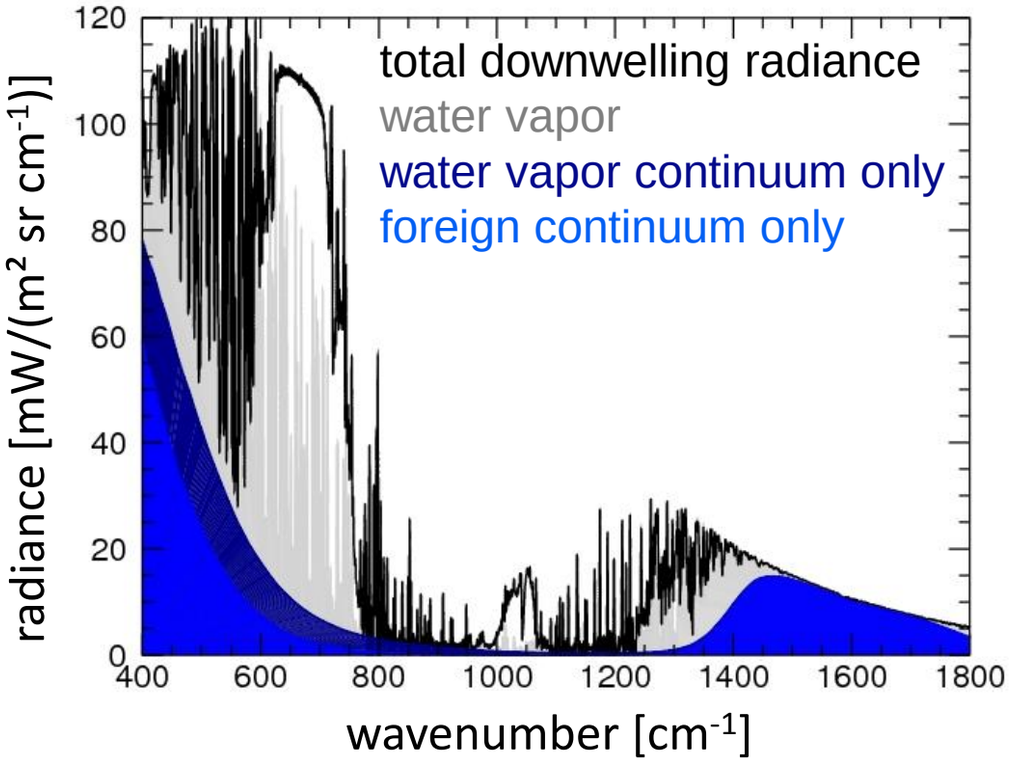
FIR water vapor continuum:
atmospheric relevance



(from: Paynter and Ramaswamy, 2011)

- 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 atmosperic radiative transfer, e.g. in climate models
- Quantification of water vapor radiative processes is a major contribution to uncertainty of current climate models

FIR water vapor continuum:
definition



Continuum coefficient:

$$k = k_{local} + c_f(\rho_f/\rho_0) + c_s(\rho_s/\rho_0)$$

Coefficient excluding radiation field term:

$$c_f = \nu \tanh(hc\,\nu/2kT)\tilde{c}_f$$

- **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

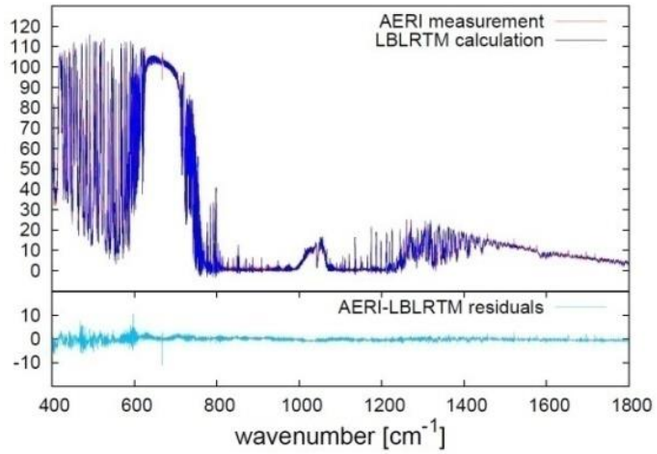
- H_2O column, profile
- pT profile
- further trace gas columns (CO_2,CH_4,O_3)

Spectral radiance measurements

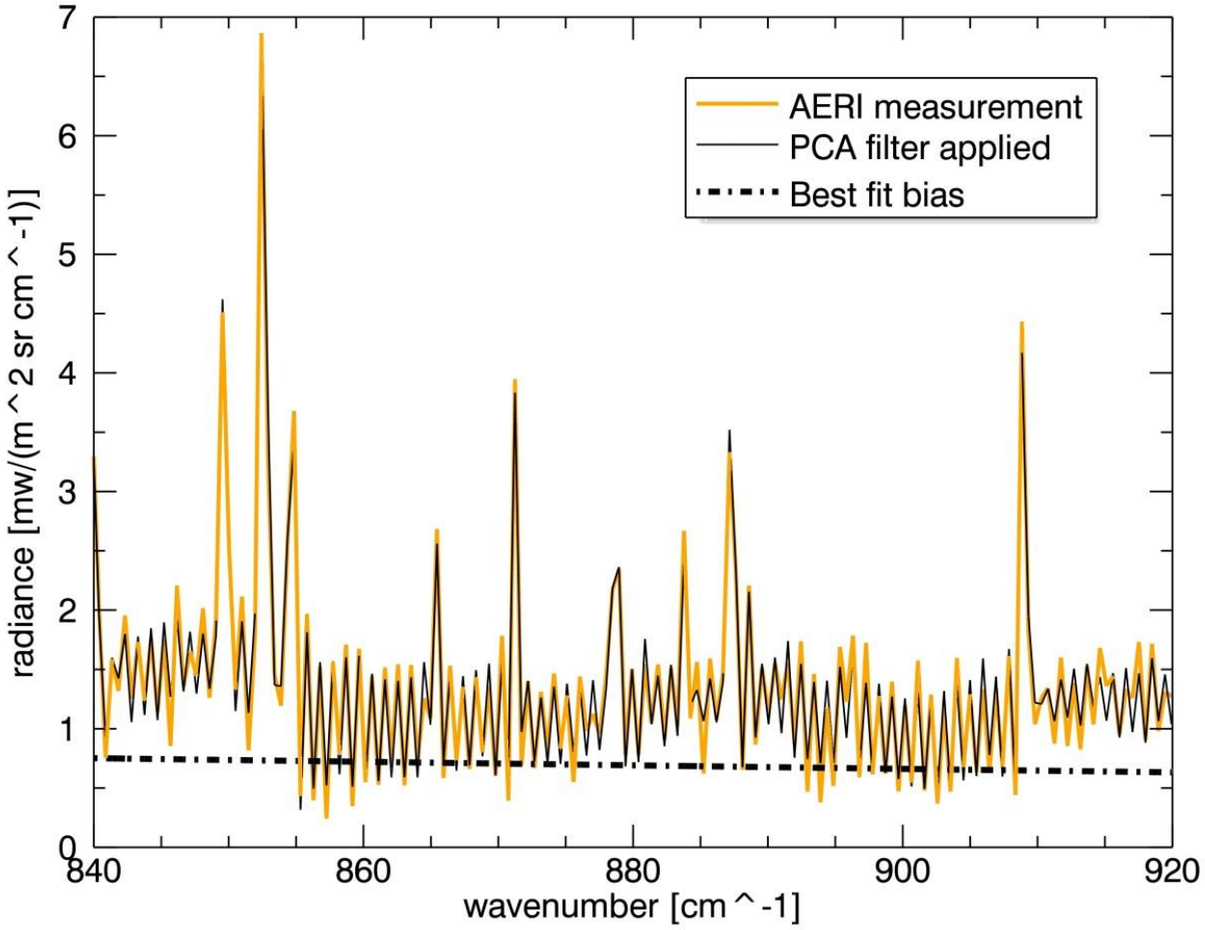
- AERI far-/mid-infrared thermal emission spectra

Radiative transfer model (LBLRTM)

Difference spectrum ("residuals")



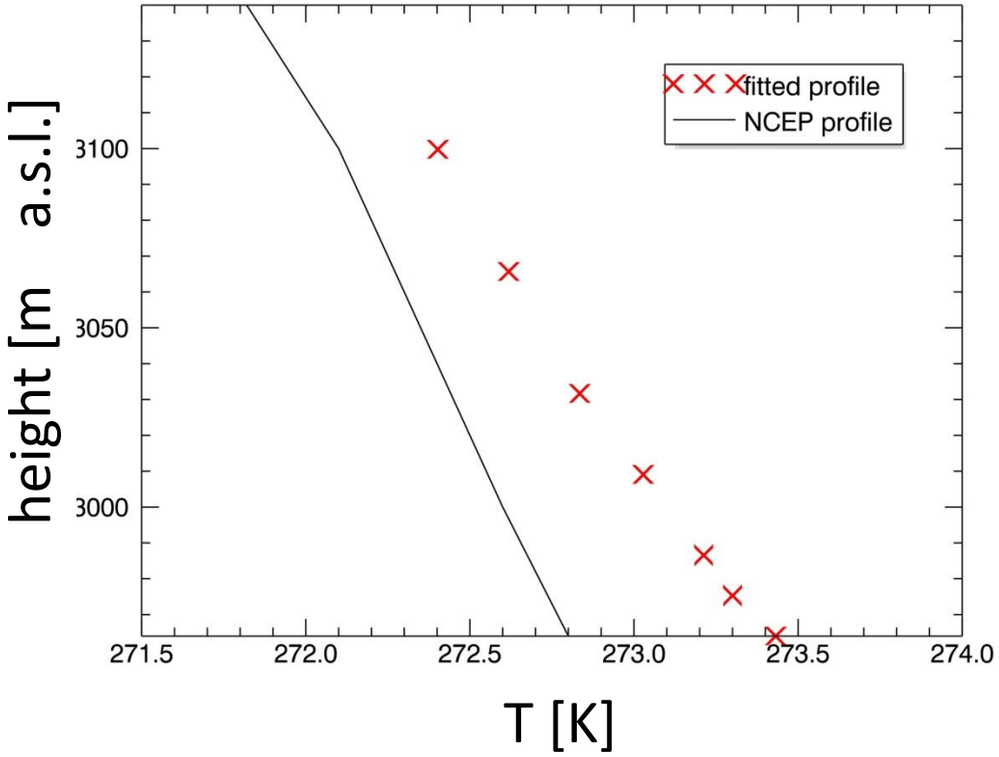
The Zugspite closure experiment:
analysis steps for measured spectra

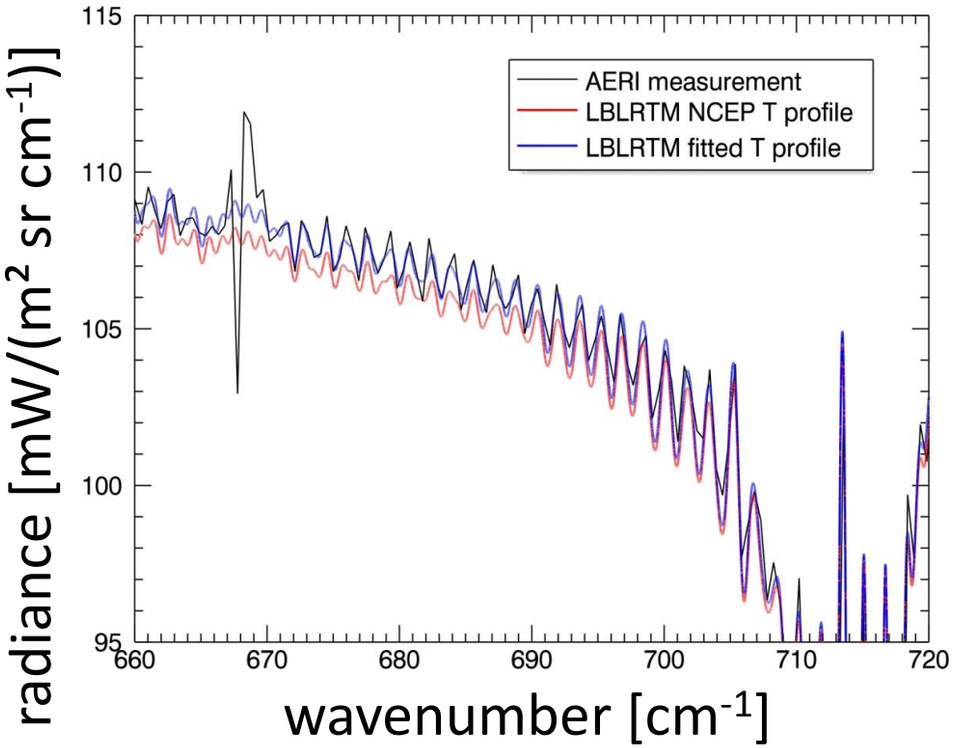


- Analysis steps for measured AERI spectra include:
  bias correction and noise reduction with PCA filter

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)

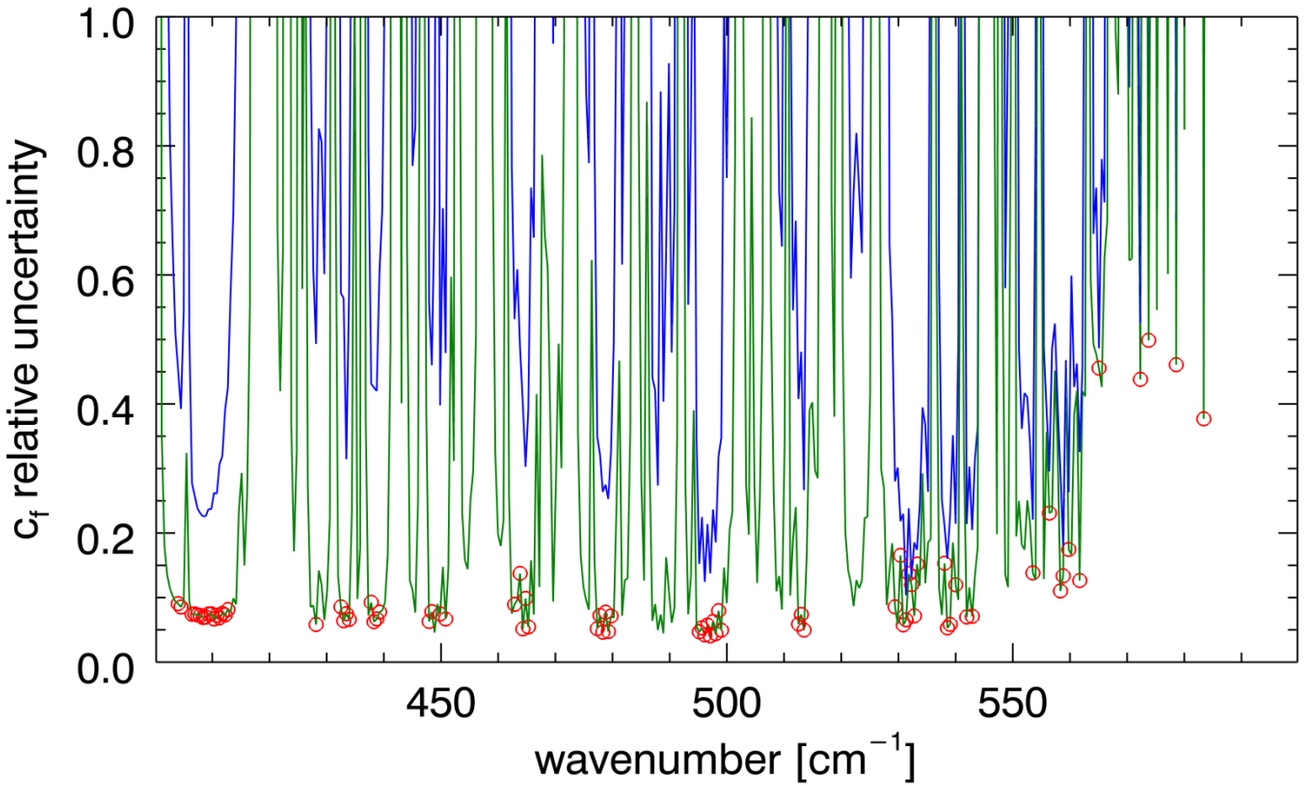




The Zugspite closure experiment:

selection of microwindows for continuum retrieval

total uncertainty
no line parameter contribution
selected windows



- 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:

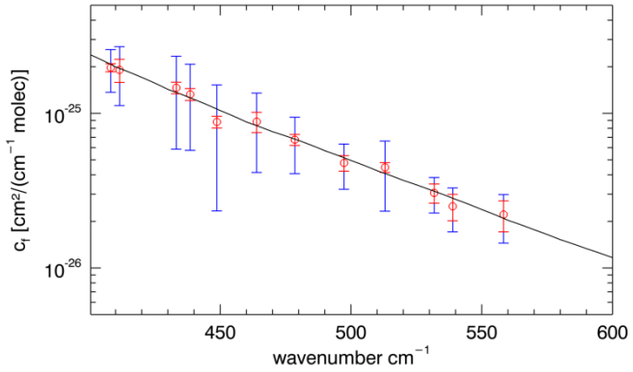
continuum quantification from spectral residuals

spectral residuals in selected microwindows

→

adjustment of continuum coefficients according to continuum jacobian

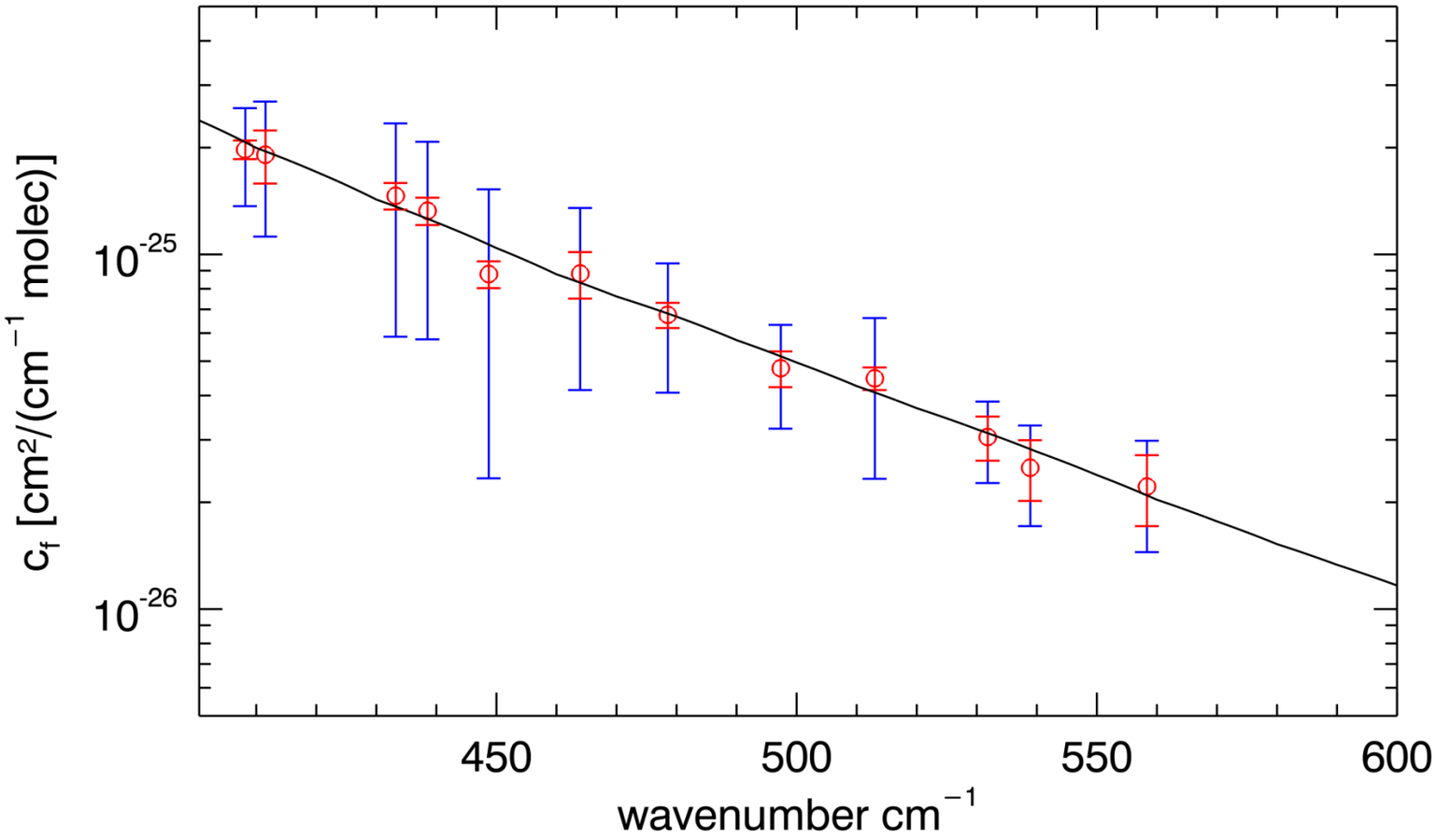
recalculation of synthetic radiance



iteration is stopped if residuals in selected microwindows below AERI uncertainties
→ set of adjusted continuum coefficients

Results:

foreign continuum coefficients



black: MT_CKD 2.5.2

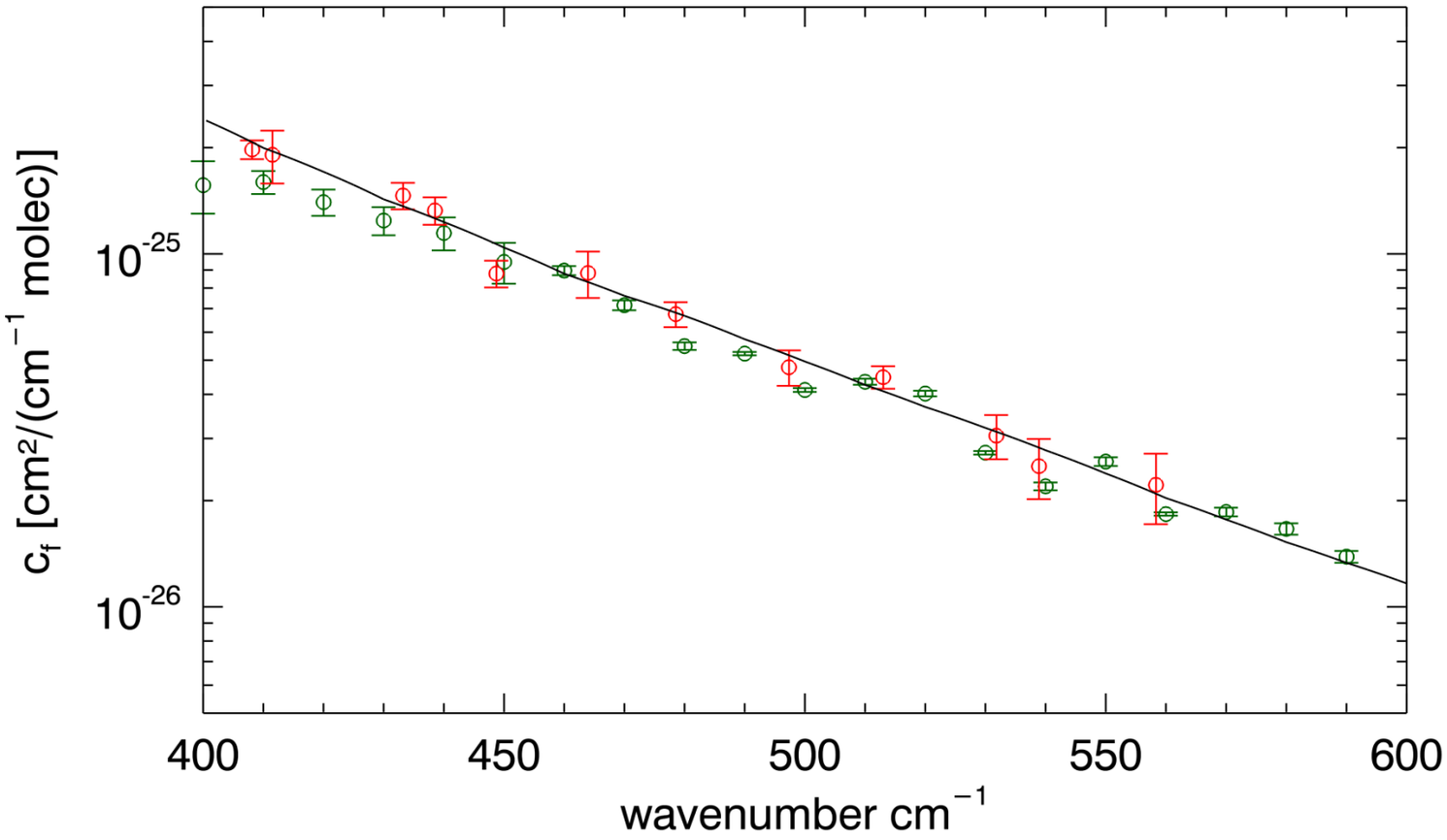
uncertainty:

- no line parameter contribution
- line parameter uncertainty included

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

Results:

comparison to previous studies



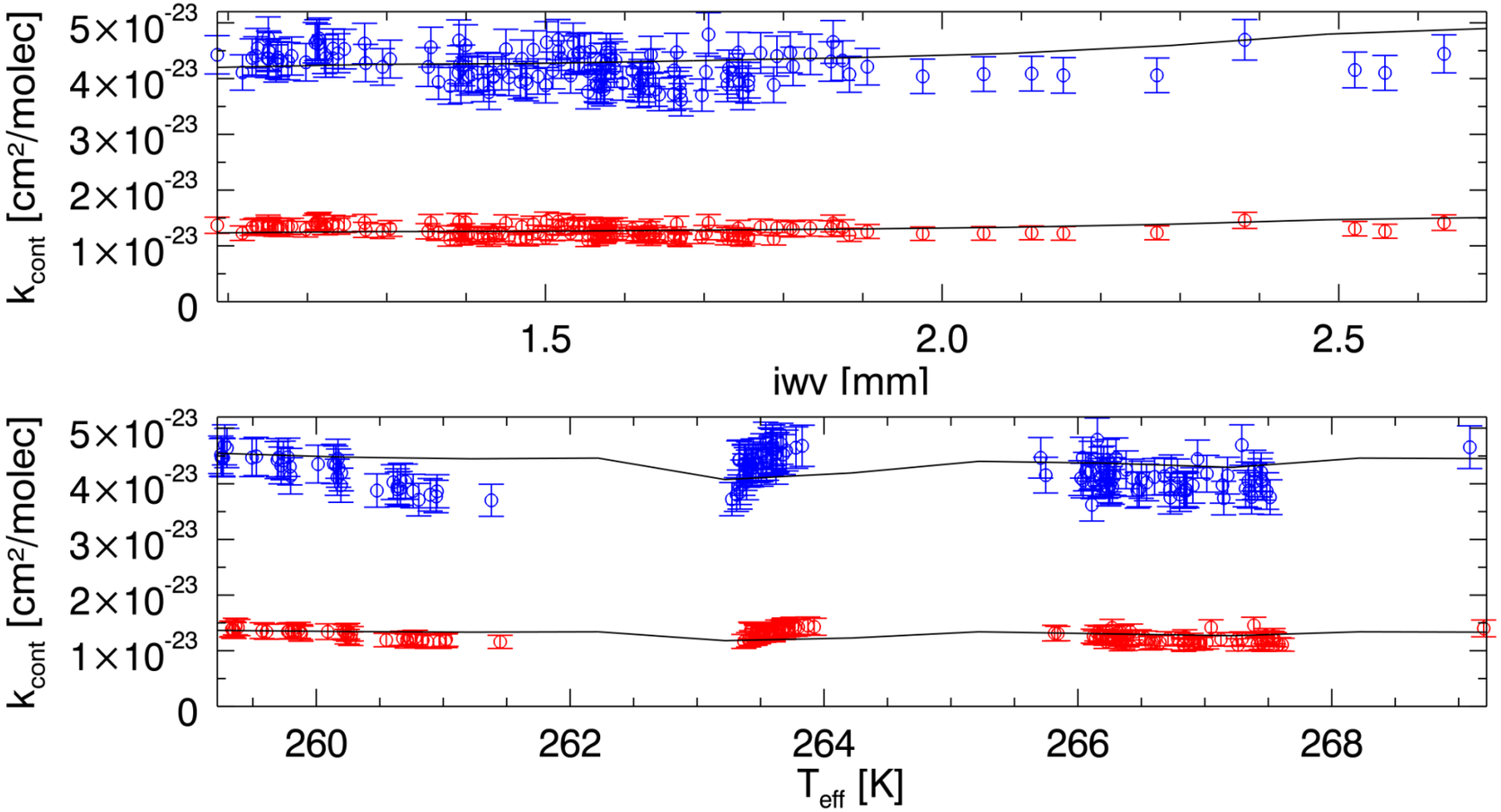
red:
Zugspitze measurements

black:
Delamere et al., 2010/
MT_CKD 2.5.2

green:
Serio et al., 2008

Results:

self/foreign continuum ratio and temperature dependence



blue:
mean k_{cont}
400 - 450 cm^{-1}

red:
mean k_{cont}
500 - 550 cm^{-1}

- Long-term dataset → 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

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