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Quantification of the Near-Infrared Water Vapor Continuum from Atmospheric Measurements at the Zugspitze

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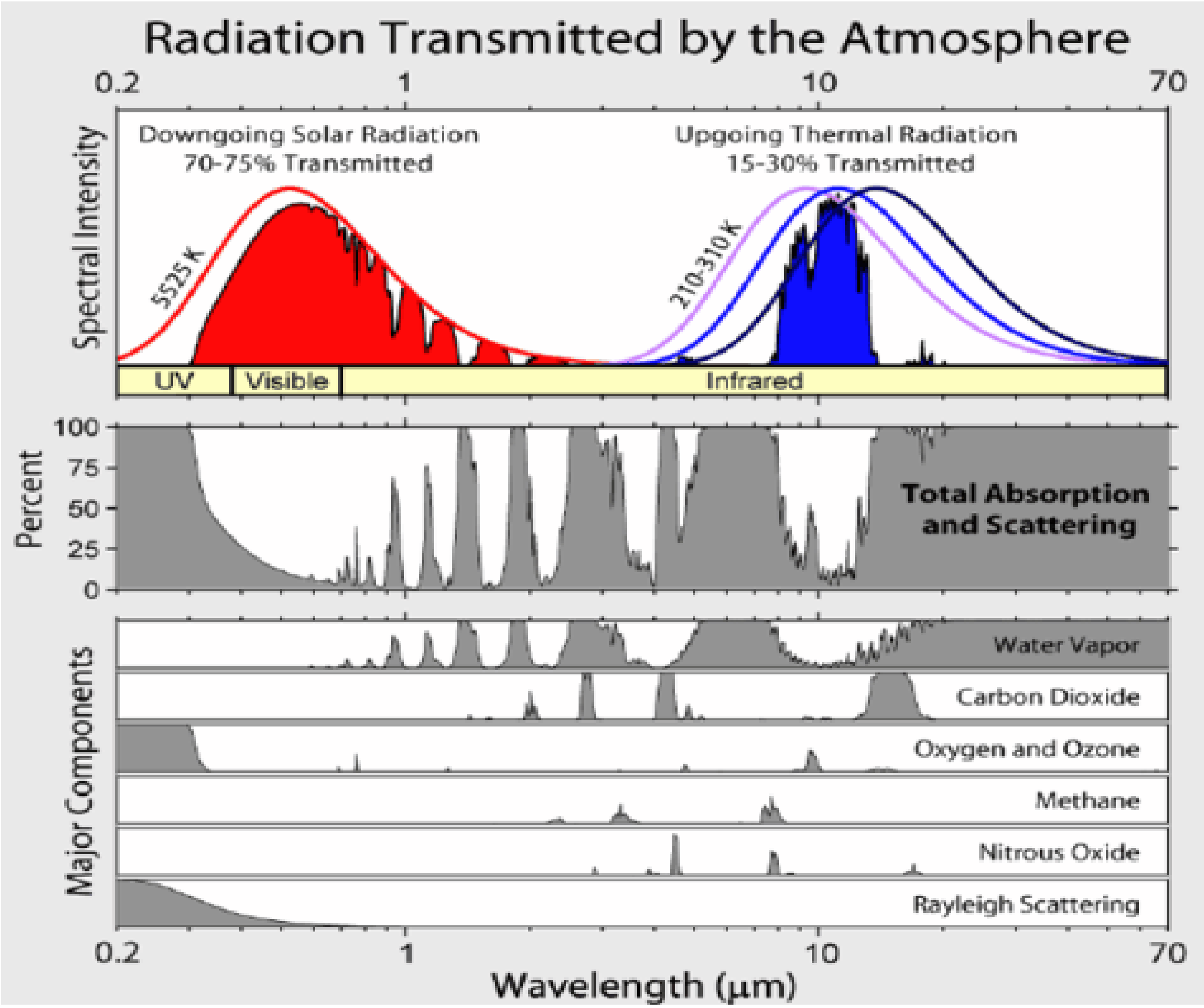
Introduction:

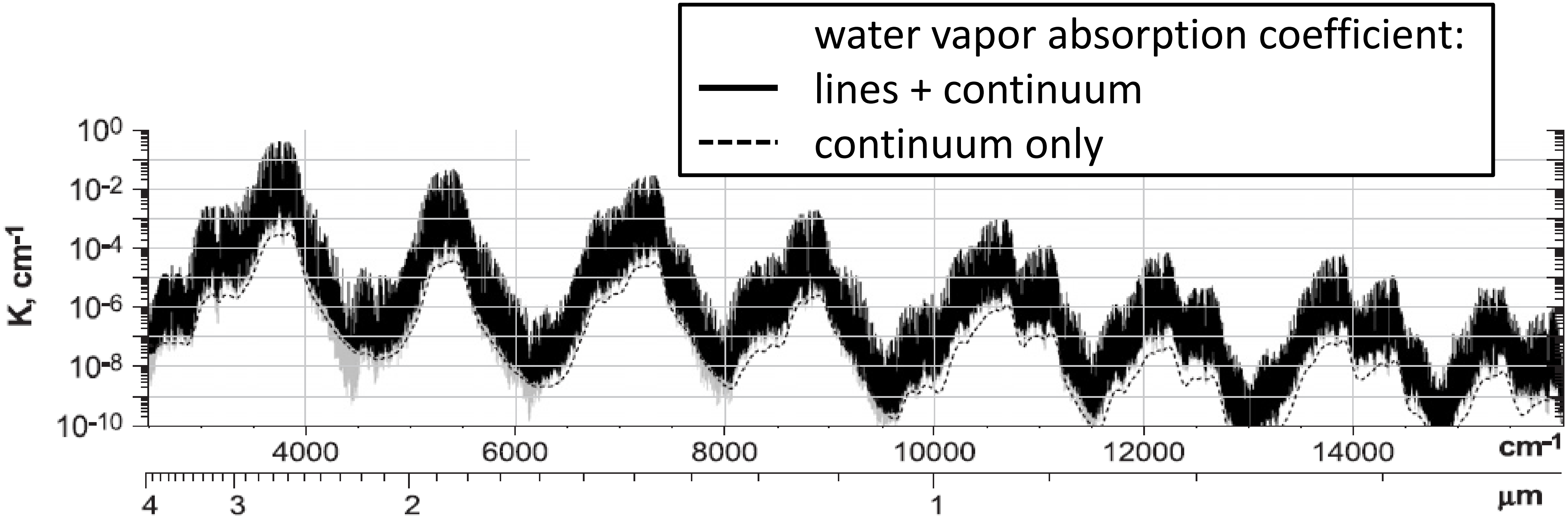
Climate relevance of water vapor



from website of: Oregon Institute Of Science & Medicine

- Largest contribution to IR atmospheric absorption from water vapor
- Precise quantitative knowledge of water vapor radiative processes prerequisite for realistic atmospheric radiative transfer calculations

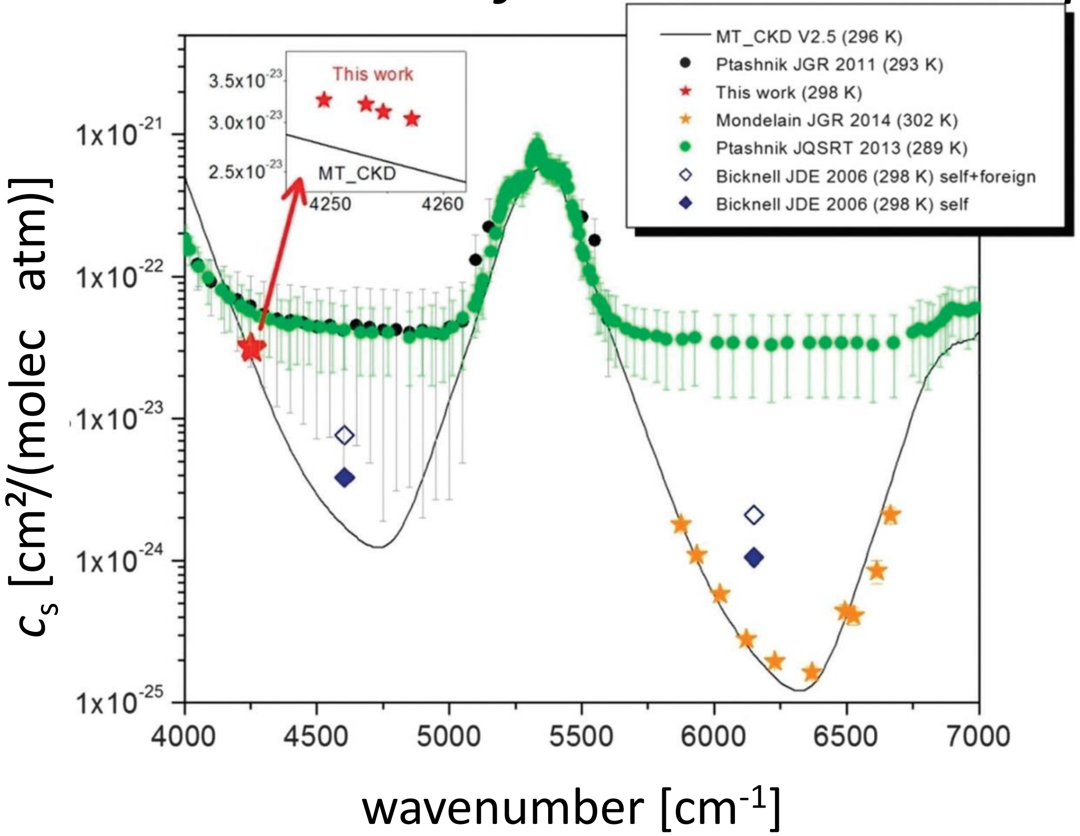
Introduction:
Water vapor continuum

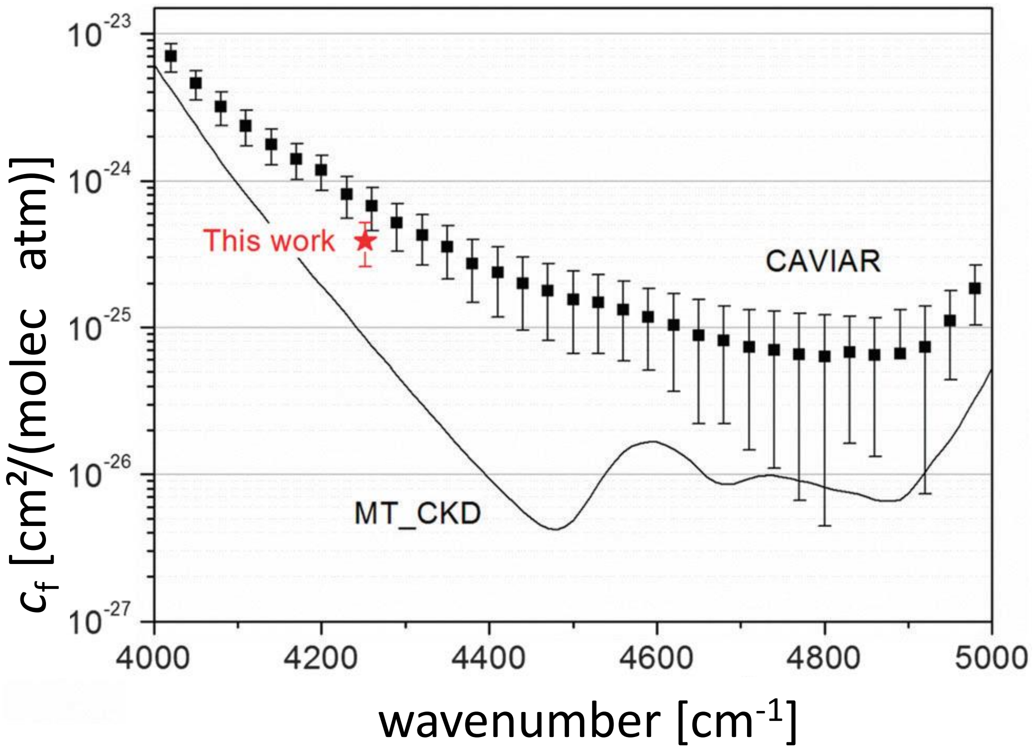


(from: Ptashnik et al., 2007)

- Water vapor absorption processes include: 1) spectral lines + 2) continuum
- Contributions of different causative mechanisms to continuum absorption (line shape, dimers) subject of current research
- MT_CKD continuum model (Mlawer et al., 2012) widely used, ongoing validation and improvement via measurements

Introduction:
Previous near-infrared continuum quantification studies



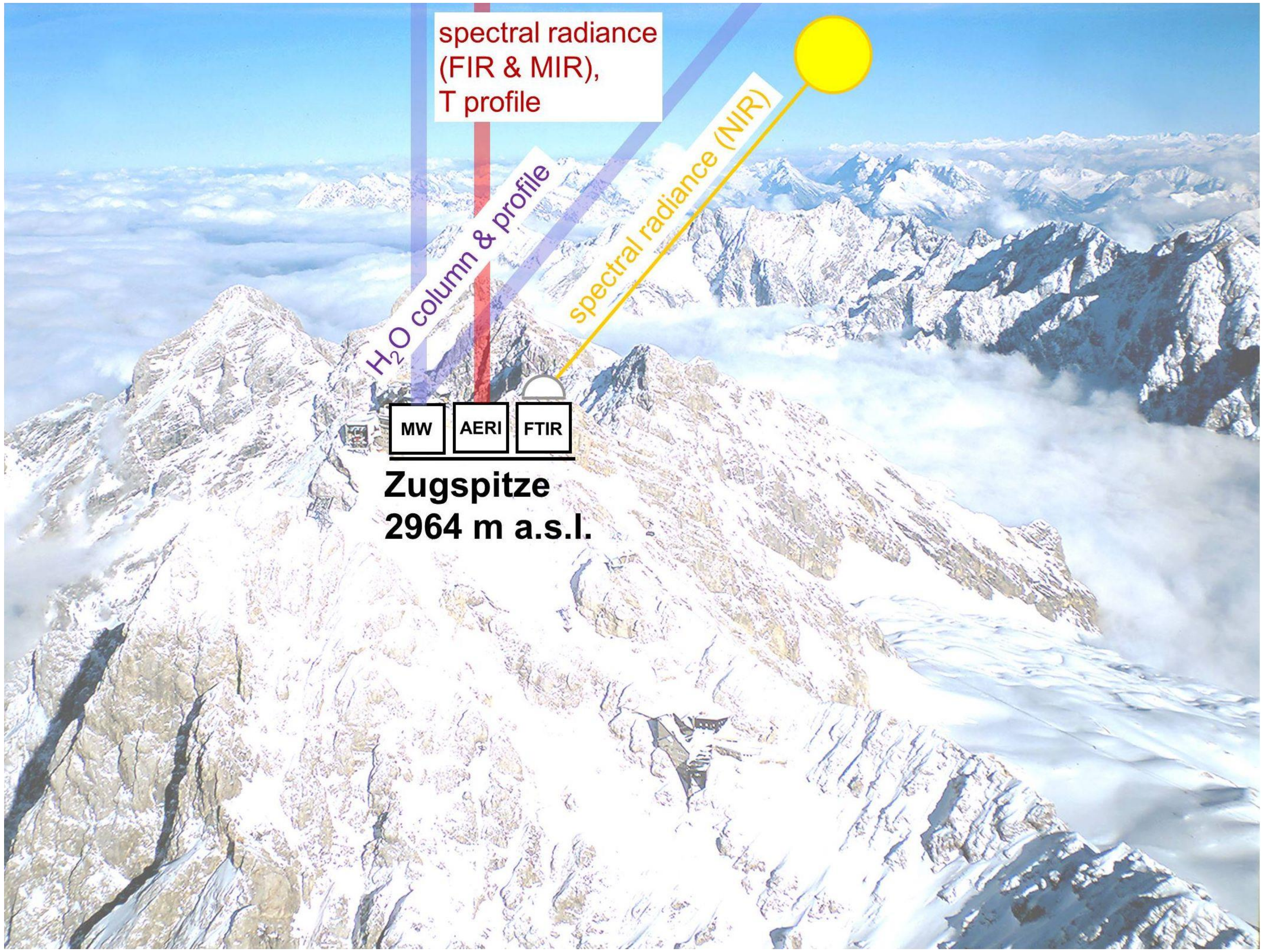


(from: Mondelain et al., 2015)

- Ongoing efforts to validate MT_CKD model in the NIR with laboratory measurements
- Different experimental methods (FTIR, CDRS, …) yield contradictory results
- Lack of constraints on temperature dependence

→ **Need for atmospheric measurements**

Continuum quantification method:
The Zugspitze site



- High-altitude site (2960 m a.s.l)
- Extensive permanent instrumentation (spectral radiance + atmospheric state measurements)
- Easily accesible
- Low IWV (this study: 1.4-3 mm)
- Very low AOD (this study: < 0.004 at 7800 cm^{-1})

Continuum quantification method:

Schematic setup

Spectral radiance measurements	
	NIR spectral radiance measurements: **Solar FTIR** 2500-7800 cm^{-1}

Atmospheric state measurements		
H_2O column  Solar FTIR	**CO_2, CH_4 and N_2O column**  Solar FTIR (NIR)	**H_2O profile, *pT* profile** NCEP data **AOD** sun photometer **O_3 column** Dobson/Brewer

Measured spectral radiance → **Spectral residuals** ← **Modeled spectral radiance** ← **Radiative transfer model (LBLRTM)**

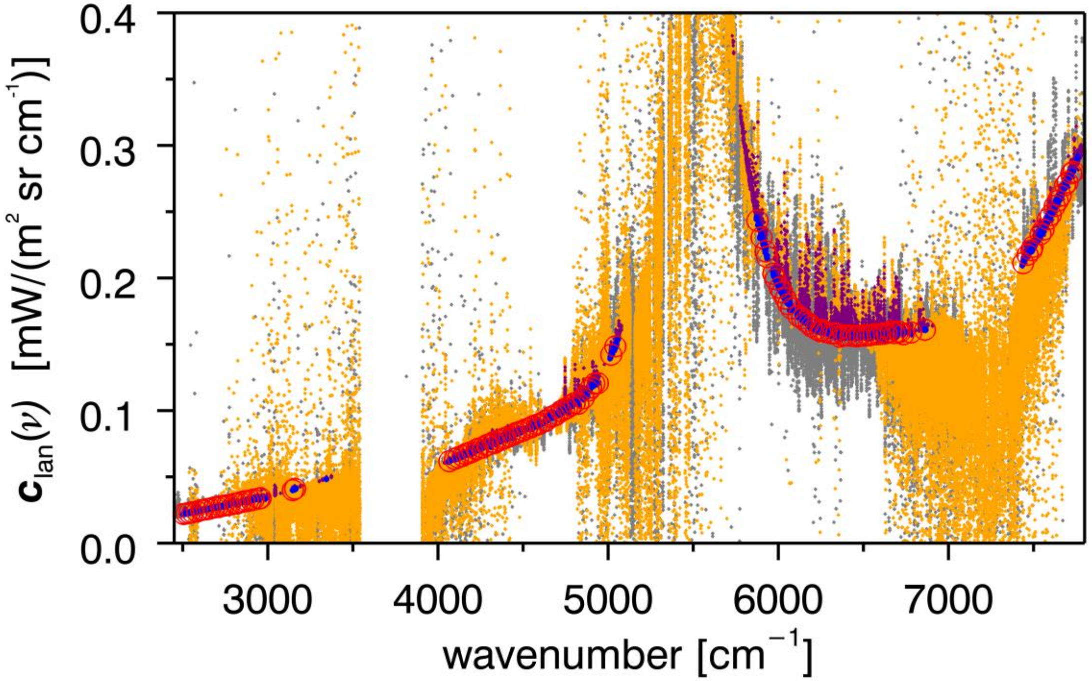
minimization of spectral residuals via adjustment of absorption parameters

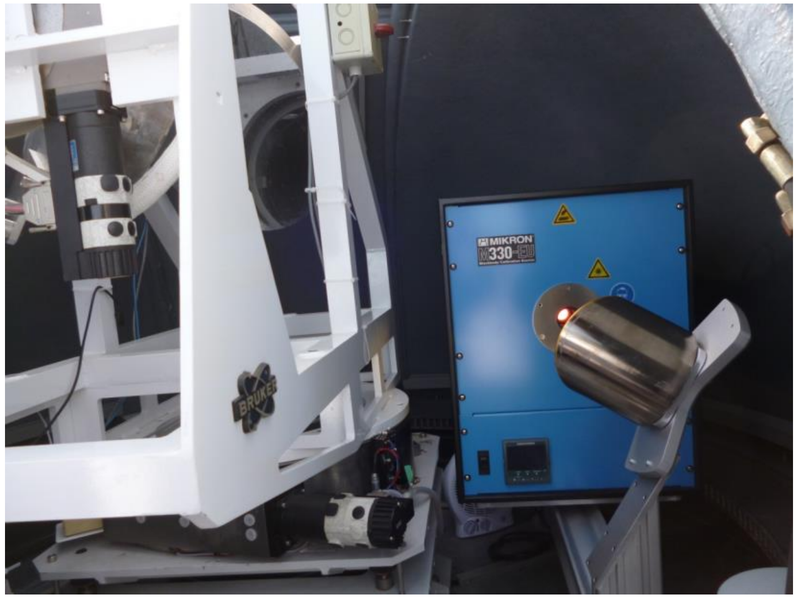
Continuum quantification method:
Atmospheric state measurements

Precise atmospheric state constraints from extensive permanent instrumentation:

- **Solar FTIR:** key parameter water vapor column, CO_2, CH_4, N_2O
- **E-AERI:** near surface temperature profile (< 3500 m a.s.l.)
- **Brewer/Dobson** (DWD Hohenpeissenberg): O_3 column
- **SSARA-Z sun photometer** (MIM/LMU): aerosol optical depth
- **NCEP data:** water vapor profile shape, *T*-profile (> 3500 m a.s.l.)

Continuum quantification method:
Solar FTIR radiometric calibration





Beer-Lambert law: $F_\nu = F_{\nu 0}\, exp(-\tau_\nu m)$

Langley plot: $ln(F_\nu) = ln(F_{\nu 0}) - \tau_\nu m$

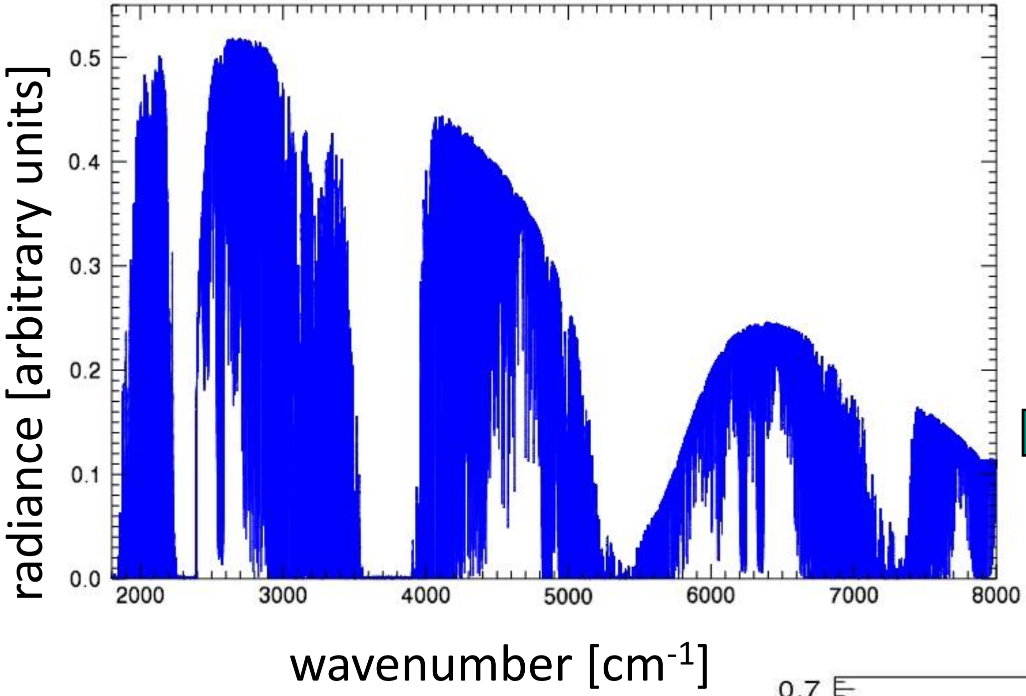
- Langley method: precise absolute calibration at spectral regions with little molecular absorption

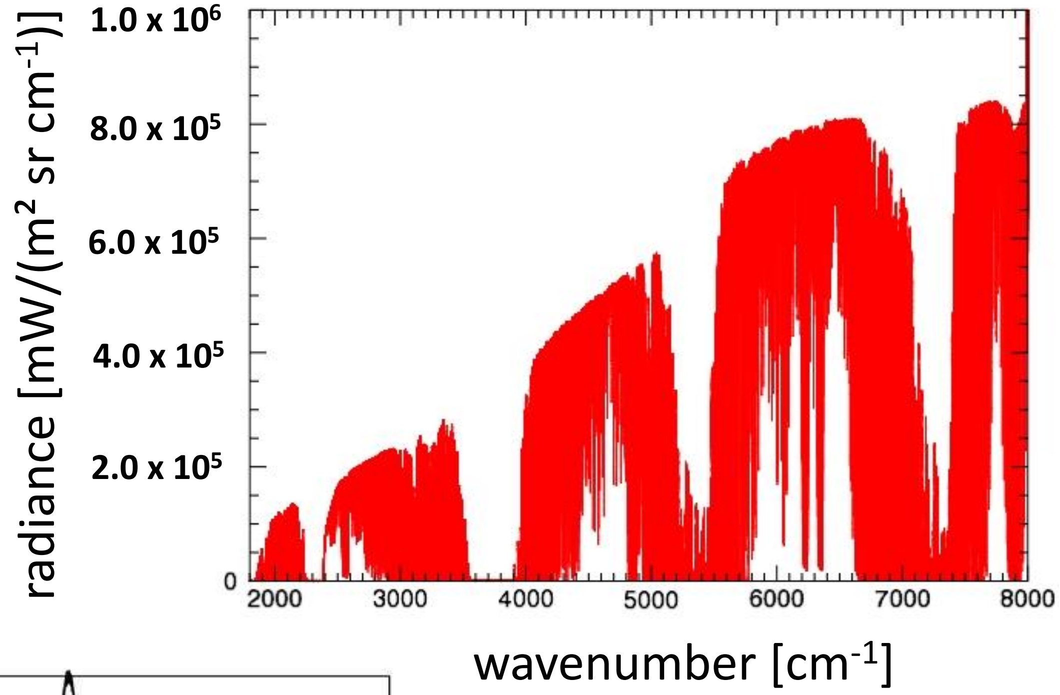
- Shape of the calibration curve between Langley calibration points determined with high-temperature (1970 K) blackbody source

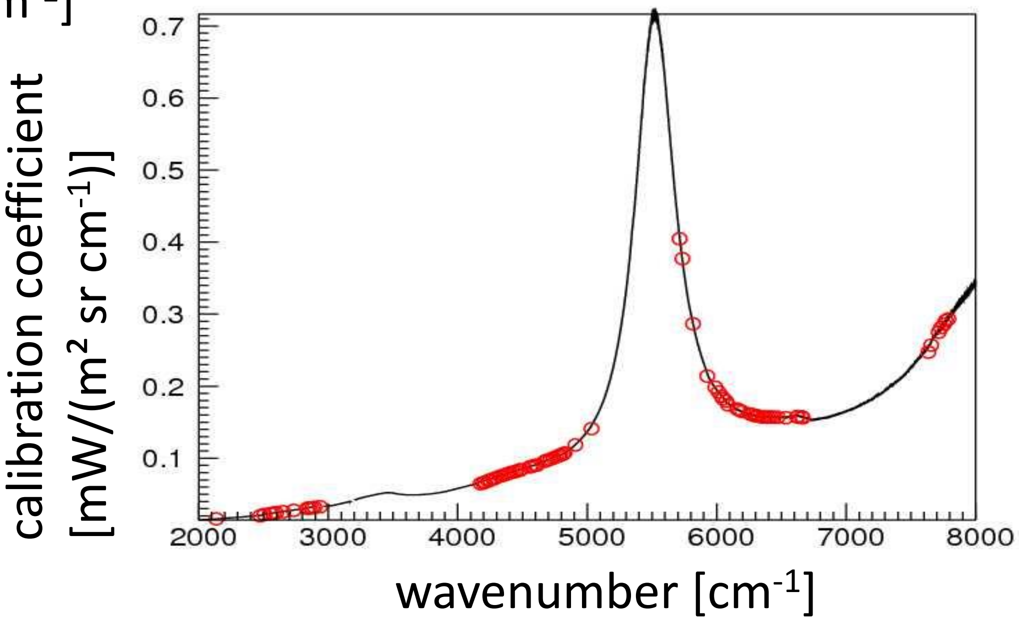
→ Combined calibration uncertainty: 1 - 1.7 % in 2500 - 7800 cm^{-1}-range

KIT-Campus Alpin
IMK-IFU: Atmospheric Environmental Research

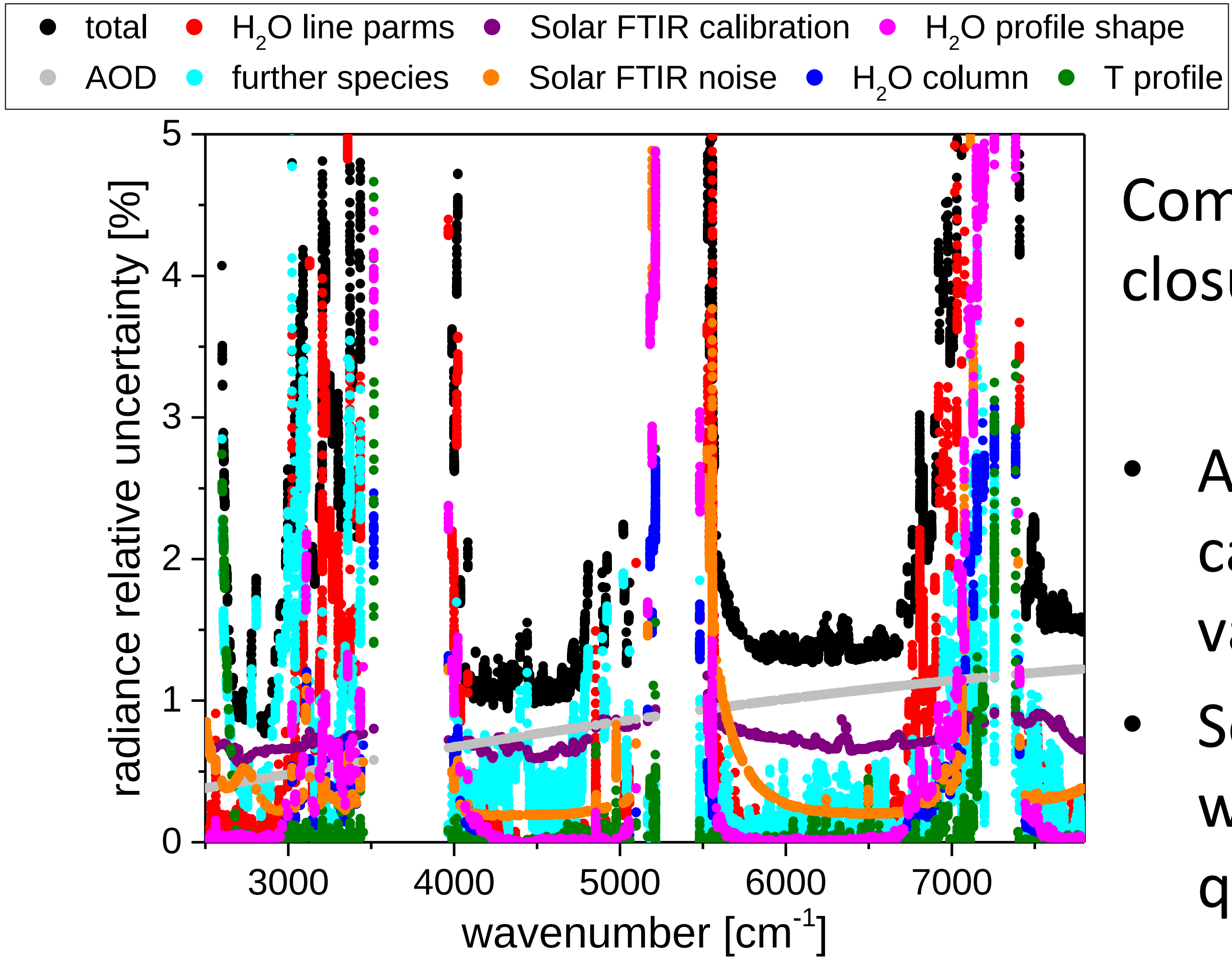
Continuum quantification method:
Calibrated solar absorption spectra







Continuum quantification method:
Residual uncertainty estimate

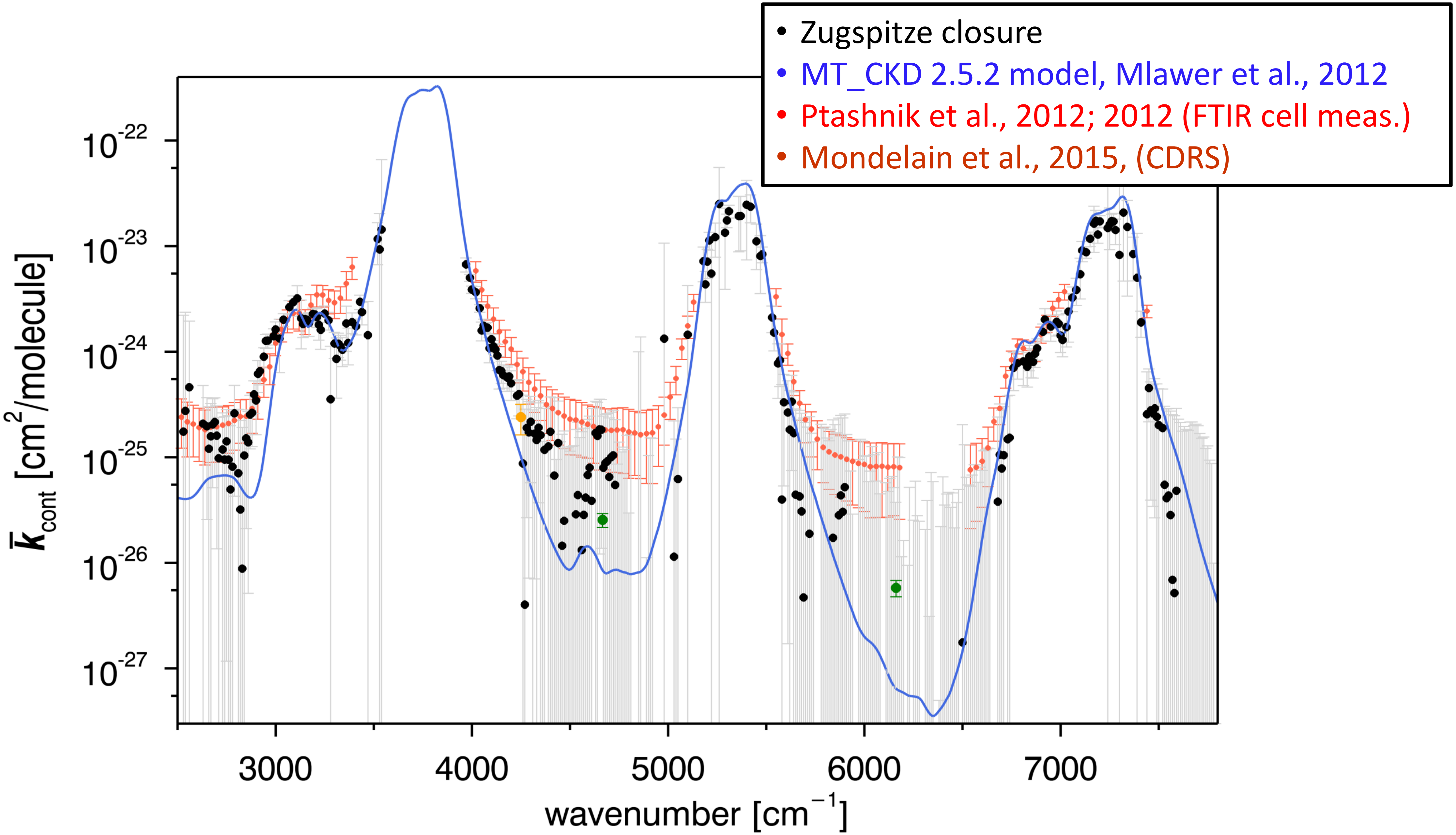


Comprehensive uncertainty budget of closure experiment required for:

- Assignment of spectral residual to causative processes, e.g. water vapor continuum
- Selection of suitable spectral windows for continuum quantification

Results:

Atmospheric quantification of NIR continuum



Summary and conclusions

- Accurate quantification of water vapor continuum crucial for realistic atmospheric radiative transfer calculations
- Closure experiment at Zugspitze: Quantification of the near-infrared continuum under atmospheric conditions
- Enables validation of MT_CKD continuum model and laboratory studies

Acknowledgements

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