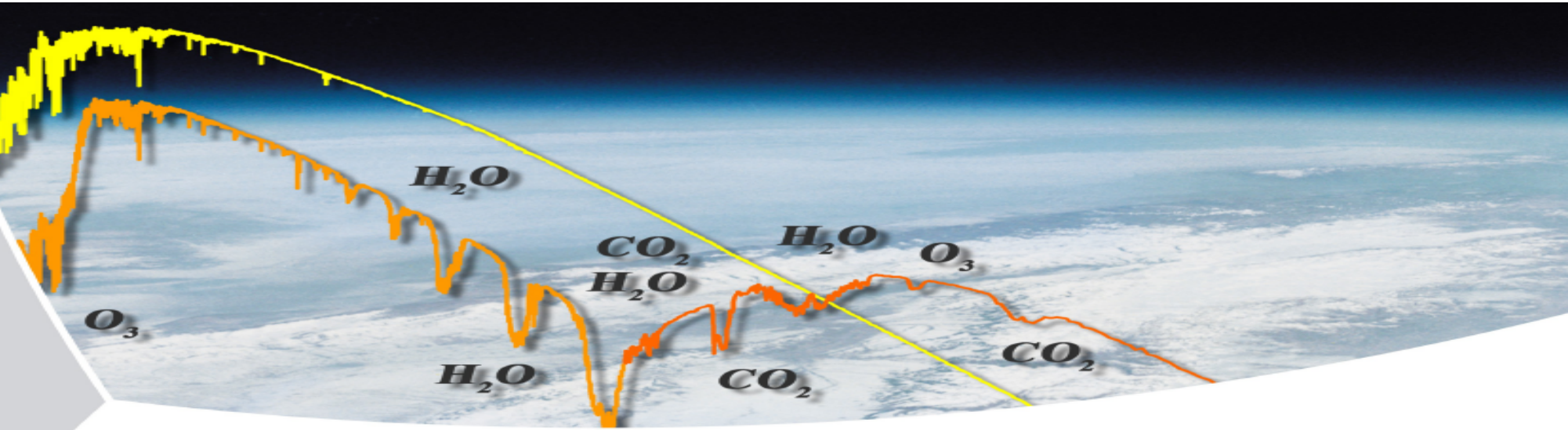

ARTS - GARLIC - KOPRA

A Lbl Model Intercomparison

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ARTS Workshop 2014

Introduction — Motivation

- Verification and validation:
  one of the most important steps of code development
- Quality of radiative transfer models critical for atmospheric remote sensing products
- Dozen(s) of RT model intercomparisons, incl. Lbl models, e.g.
  - AMIL2DA: KOPRA vs. GARLIC and some more
  - IRTMW01: ARTS vs. GARLIC and some others
  - Kristineberg 2009: ARTS vs. KOPRA
  - ARTS – GARLIC – KOPRA ?!?!?

Outline

ARTS — Atmospheric Radiative Transfer Simulator

- Originally developed for microwave applications
  - Nadir: AMSU-B, MHS, HIRS, ...
  - Limb: Odin, SMILES, ...
  - Uplooking: MIAWARA, AMSOS, ...
- Continuum: MT-CKD 2.0

S. Bühler, P. Eriksson et al., JQSRT 91, 65–93, 2005
P. Eriksson, S. Bühler et al., JQSRT 112, 1551-1558, 2011

GARLIC — Generic Atmospheric Radiation Lbl Infrared Code

Line shapes:	Voigt, VanVleck⊗Doppler, Lorentz
Line data:	HITRAN, HITEMP, GEISA, JPL, ...
Continua:	CKD 2.0 (H_2O, CO_2, N_2, O_2), "dry air" (Liebe)
Geometries:	Limb, uplooking, downlooking (refraction optional)
Instruments:	Spectral response: FTS, Heterodyne, Fabry–Perot, ...
	Field-of-view: Box, Gauss, Trapez, ...
Implementation:	FORTRAN 2008, *all data* read from external files
Inversion:	Jacobians by automatic differentation
Extensions:	(multiple) scattering infrared radiative transfer: *J. Mendrok:* SARTRE — approx. spherical geo *(GRL 2007)* *M. Vasquez:* cloudy exo-planet atmospheres *(A&A 2013a,b)*

F. Schreier et al. JQSRT, 137, 29–50, 2014

KOPRA — Karlsruhe Optimized & Precise Radiative transfer Algorithm

- Originally developed for mid infrared
  - Fourier transform spectroscopy
  - Limb: MIPAS-Envisat, MIPAS-balloon
  - Limb+uplooking: MIPAS-STR, GLORIA
  - Uplooking, solar absorption: FTIR Kiruna
  - non-LTE and (single) scattering

- Continuum:
  H_2O: CKD 2.4, CO_2: ??, N_2: Lafferty AO'96, O_2: Tibault 97

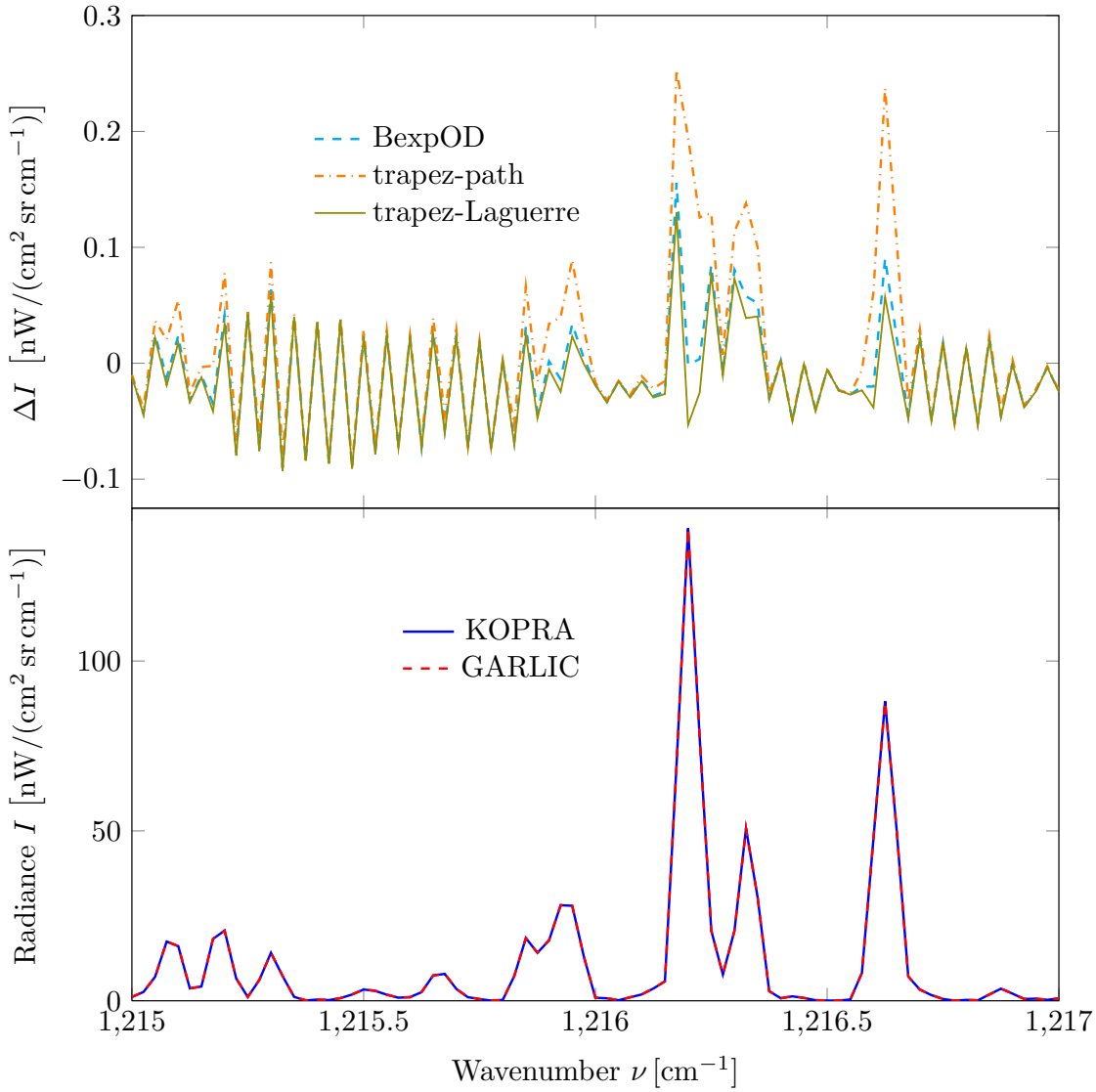
G. Stiller, T. von Clarmann, B. Funke, N. Glatthor, F. Hase, M. Höpfner and A. Linden, JQSRT 72, 249–280, 2002

Outline

AMIL2DA — Advanced MIPAS Level 2 Data Analysis

- Intercomparison of algorithms and data analysis strategies used by five European groups
- Series of exercises: from simple cell transmission to more realistic radiance
- Exercise 20:
  Limb with tangent @ 40 km, apodized FTS line shape, finite field-of-view;
  H_2O, CO_2, O_3, N_2O, CH_4;
  HITRAN 98 and CKD-continuum

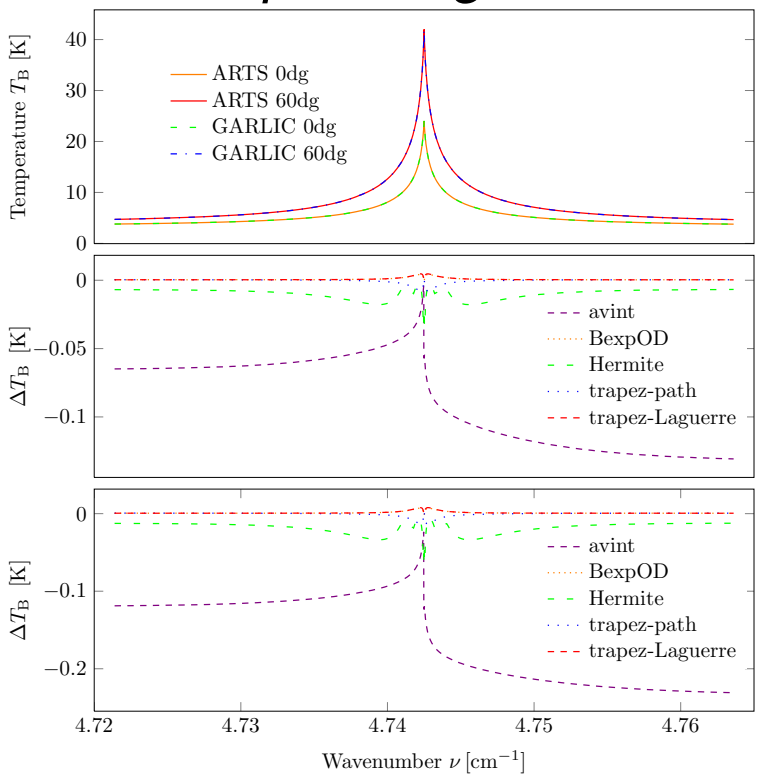
T. von Clarmann et al. JQSRT, 78, 281–407, 2002



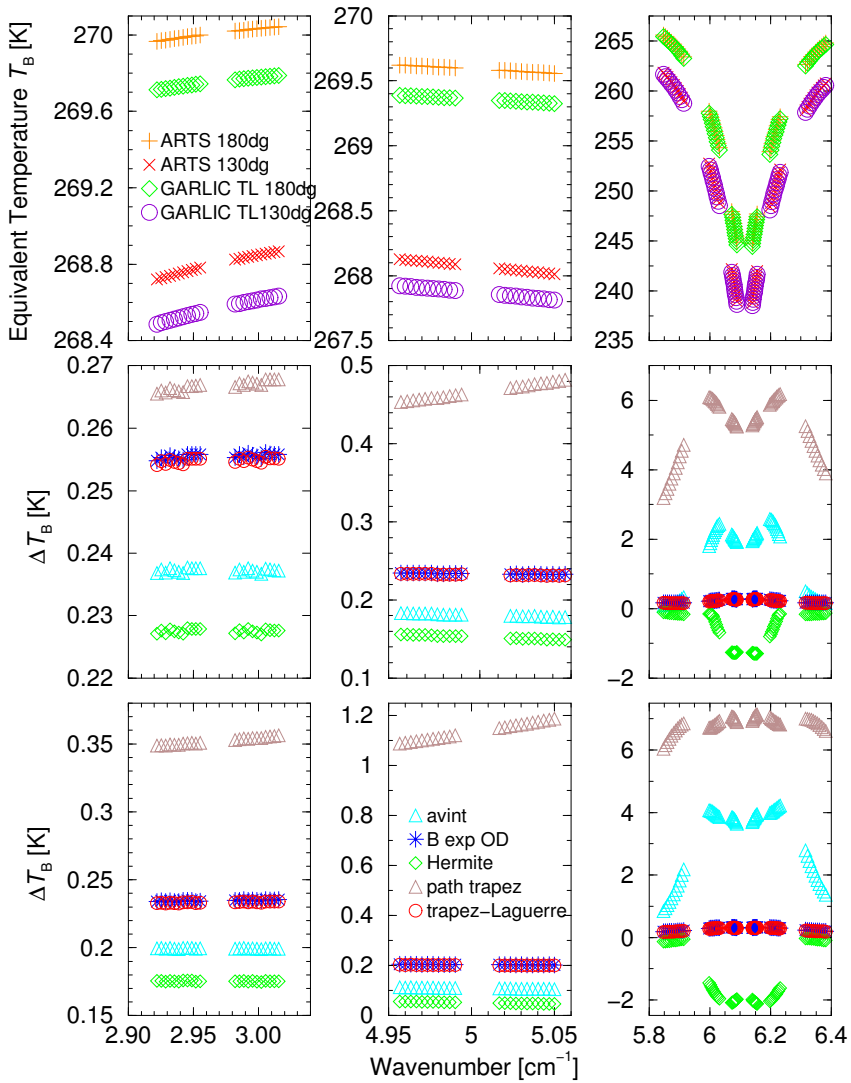
IRTMW01

- Intercomparison of 8 μW codes
- Series of 5 “cases”, starting with line shape and absorption
- Full RT incl. FoV and SRF all geometries

Case 3 Uplooking RAM-like



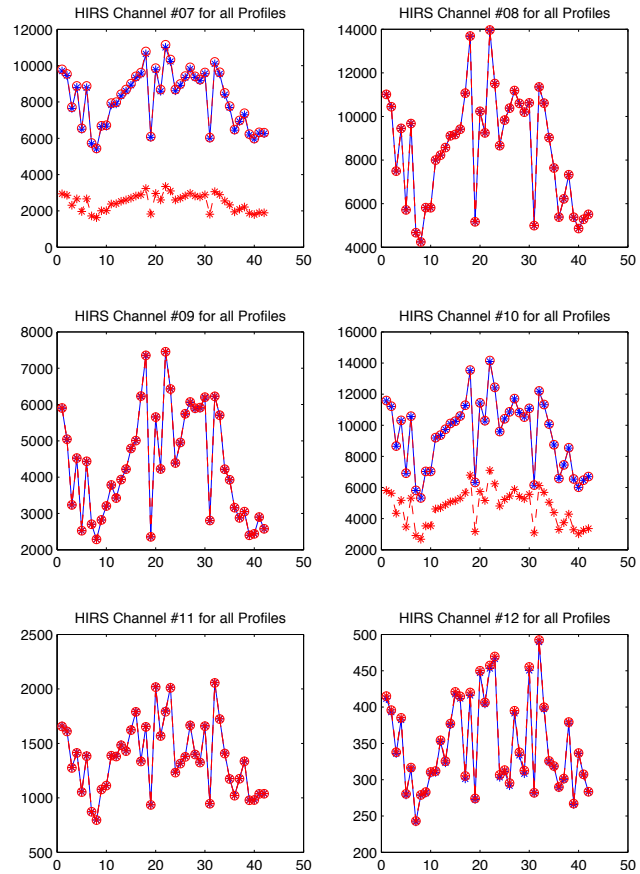
Case 3 Downlooking AMSU-like



C. Melsheimer et al. Radio Science, 40, RS1007, 2005

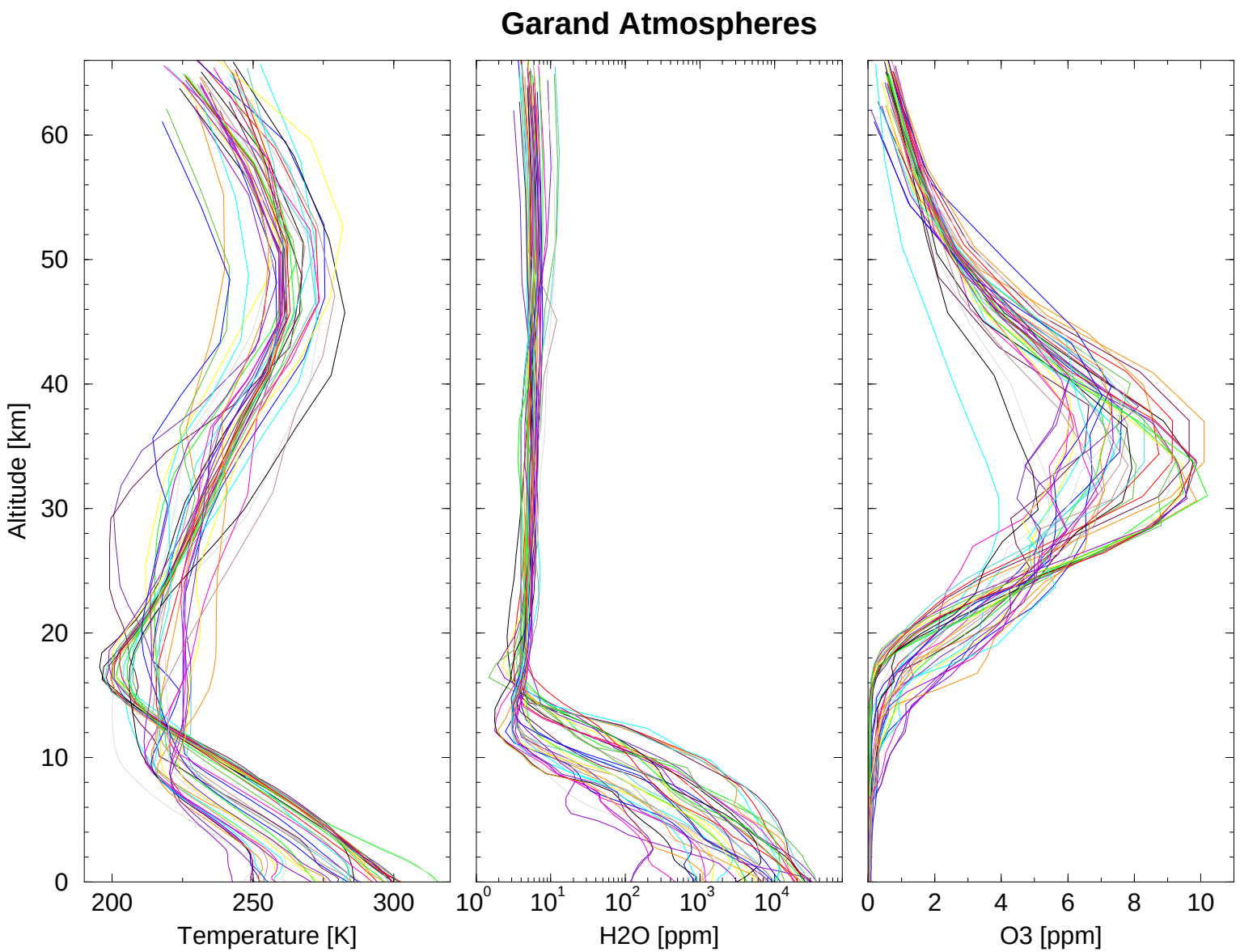
Radiances for one channel

- Motivation:
  Nadir sounding with similar geometry as AMSU-B / MHS since early 80's
- Conclusion:
  Good agreement ARTS–KOPRA (and LblRTM)
- Outlook:
  Update continuum



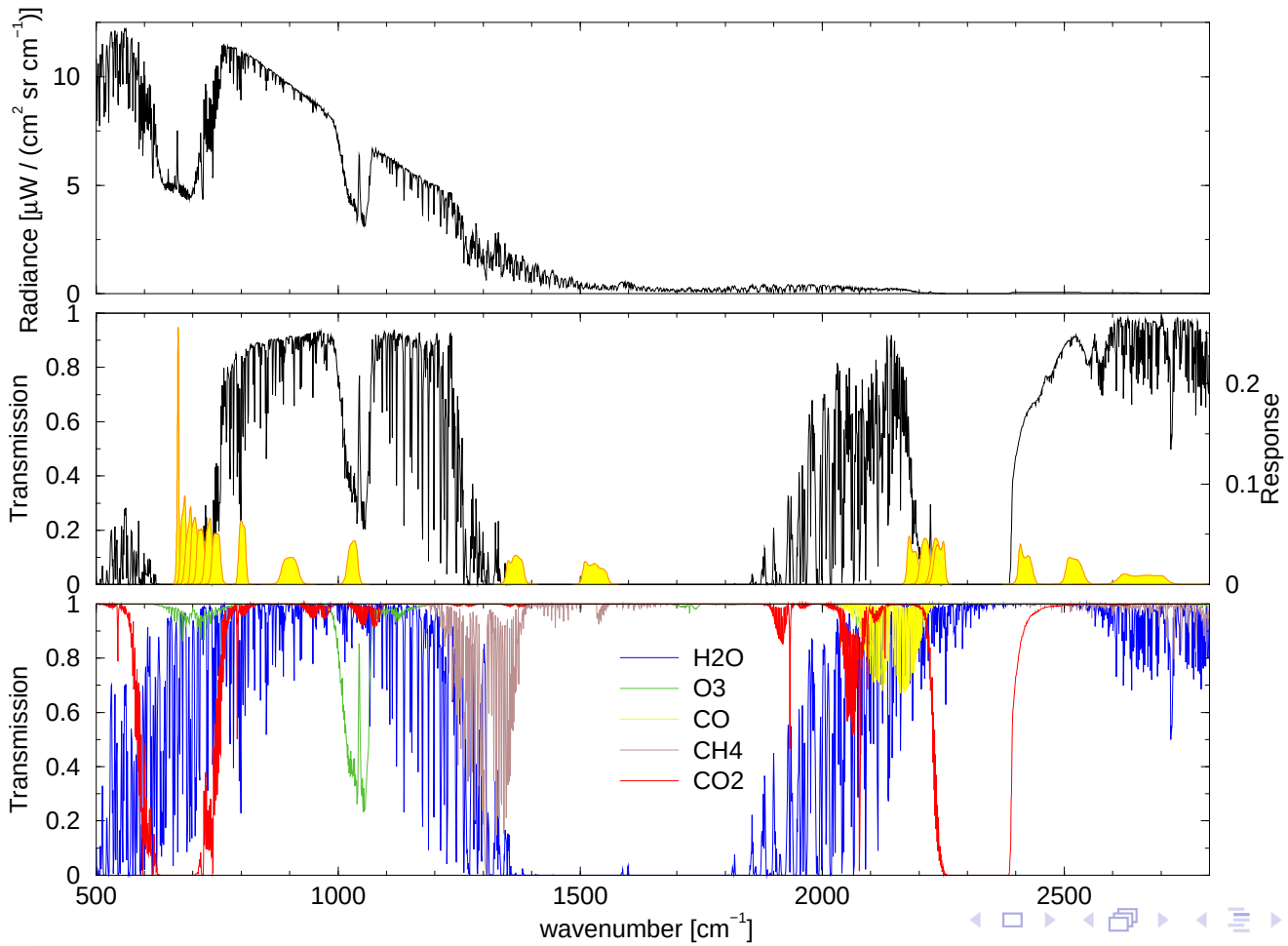
Outline

GARAND atmospheres



HIRS — High Resolution Infrared Sounder

- 19 infrared channel scanning radiometer used for operational atmospheric sounding by NASA/NOAA and EUMETSAT.
- CO_2 absorption bands for temperature sounding. Also measures water vapour, ozone, N_2O and cloud and surface temperatures.



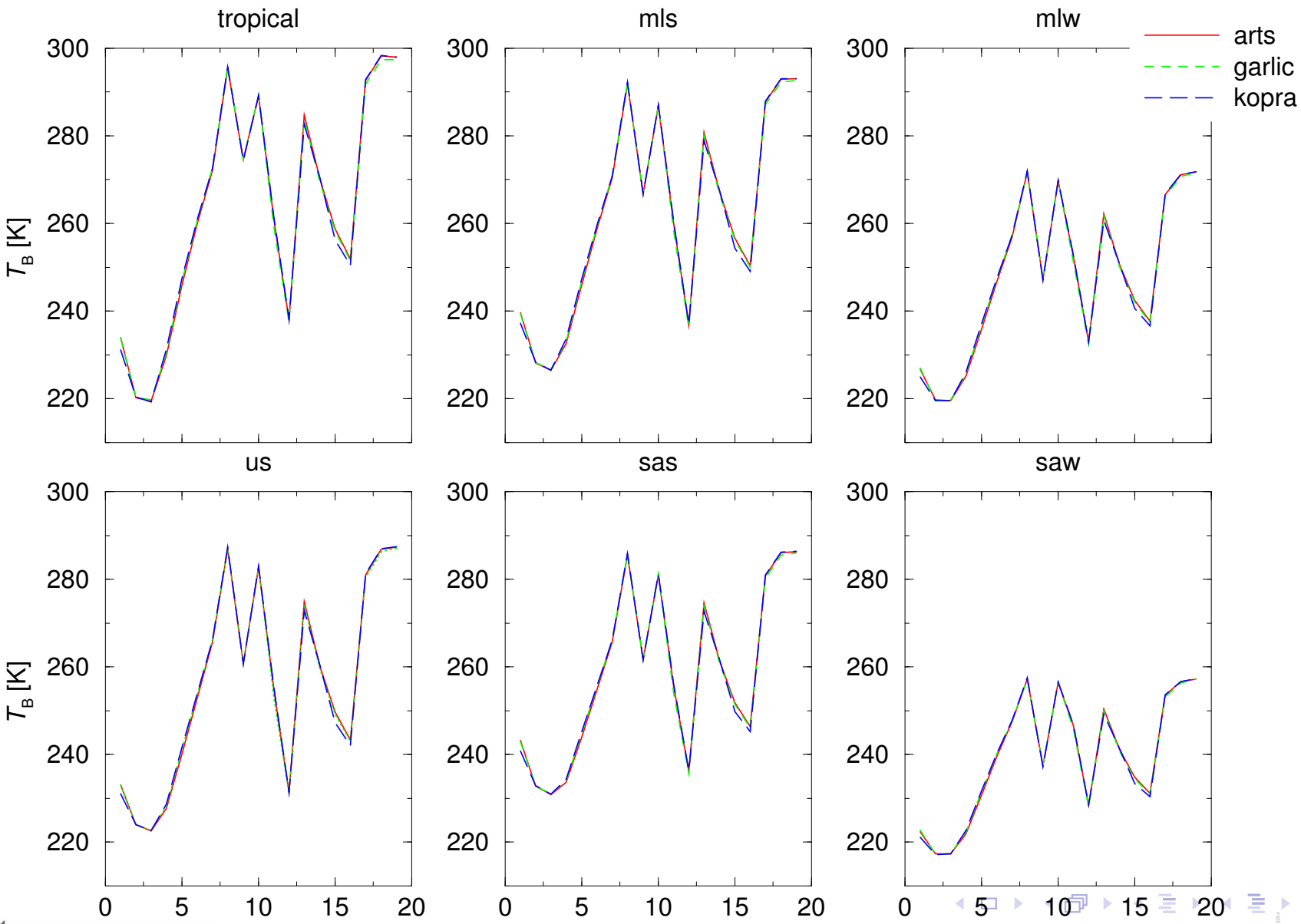
NOAA17!

Further Assumptions

- HITRAN 2004, “main” molecules only
- Continuum: CKD or MT-CKD
- Voigt line shape (no prefactor)
- Geometry: nadir (downlooking 180°), no FoV
- Surface temperature $T_{\text{surf}} = T_{\text{atm}}(0\,\text{km})$

Outline

Brightness Temperatures



Perfect!

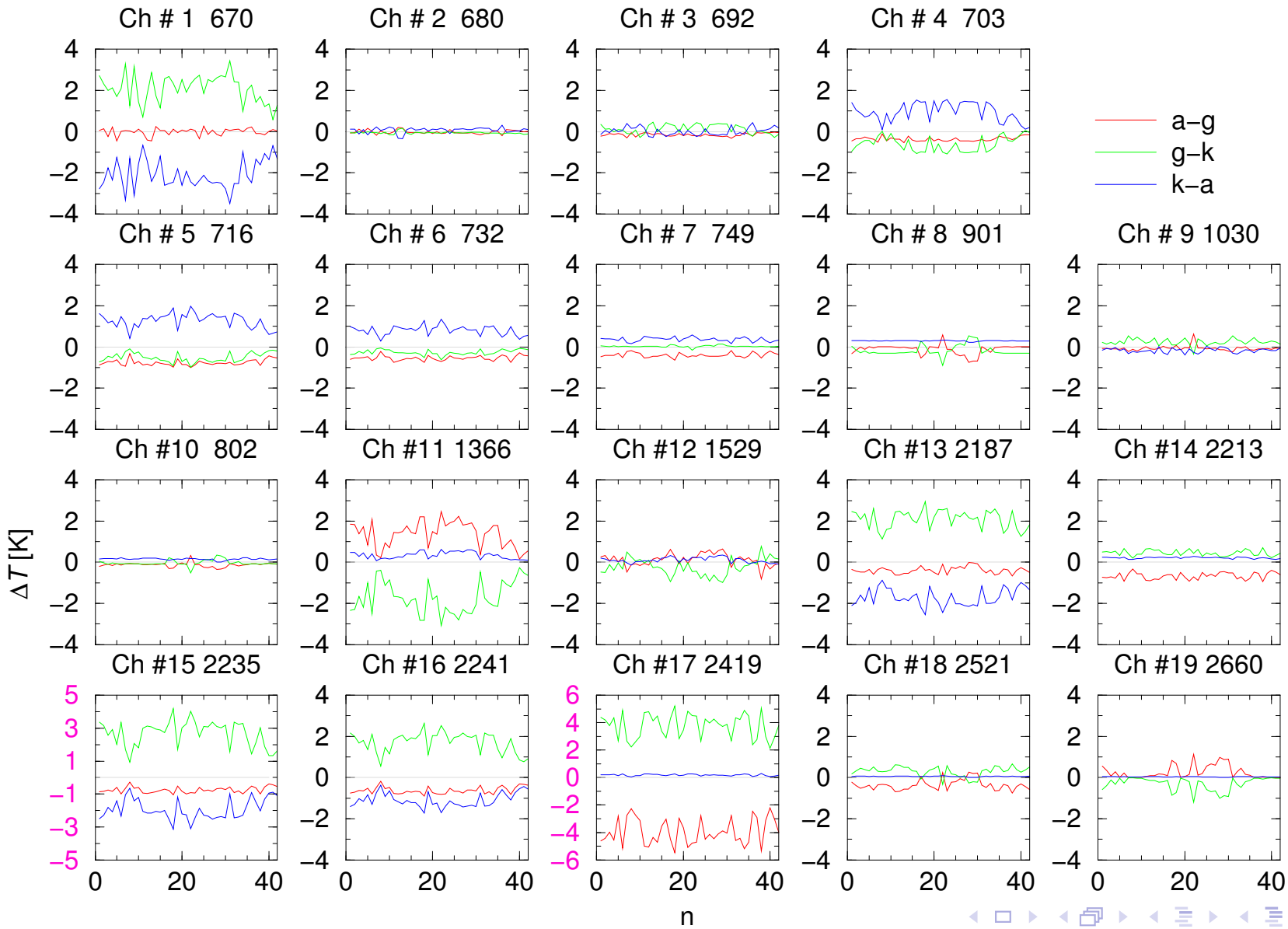
Thanks for your attention

Perfect! ..... wait a moment

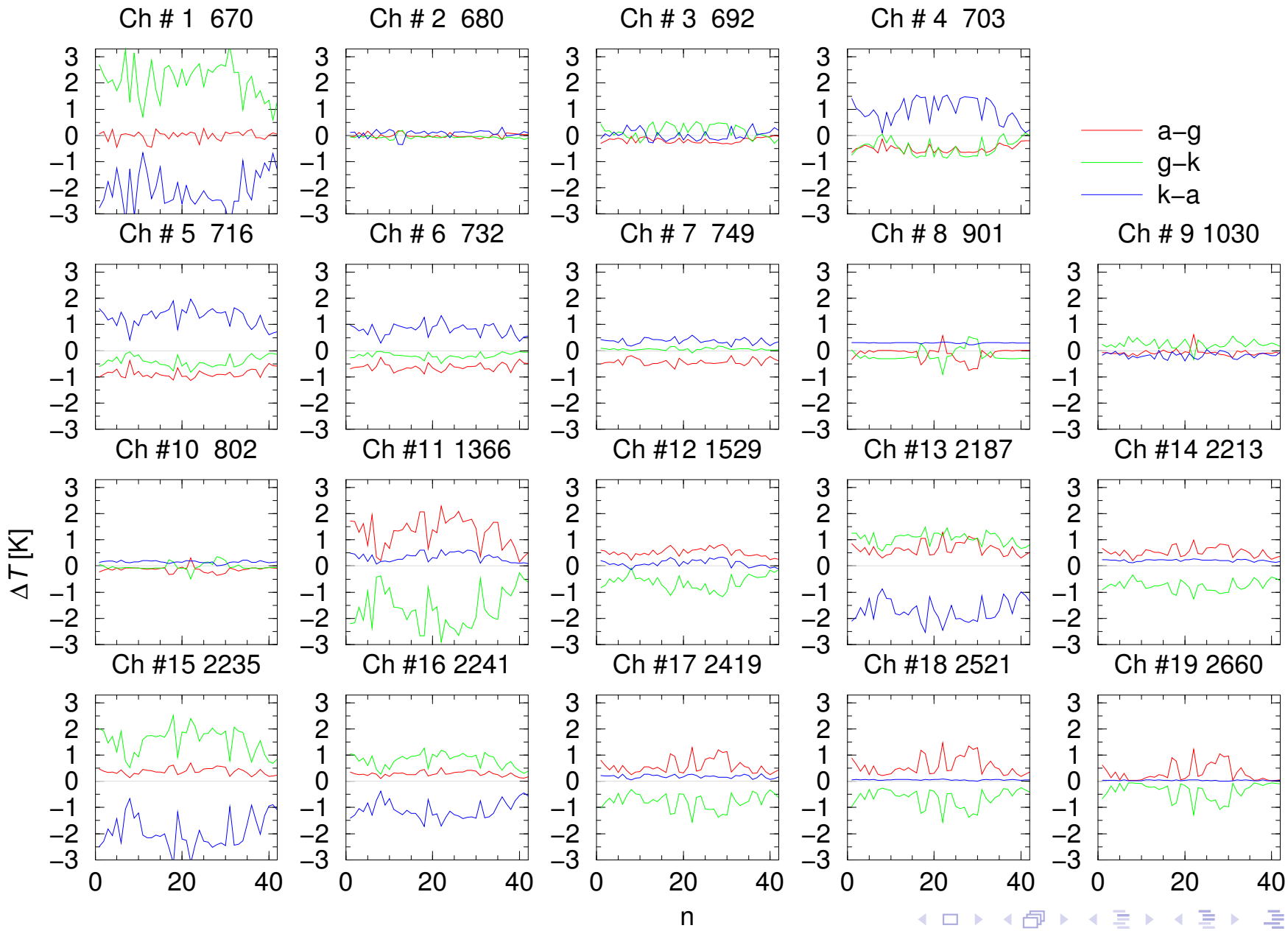
- whats about the other atmospheres?
- . . . and differences etc. ???

- Remember: IASI etc. have sub-Kelvin sensitivity!

First results IRS 2012

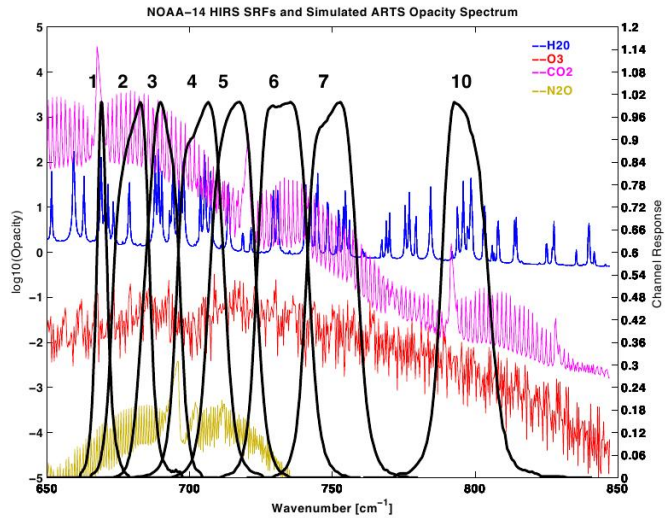


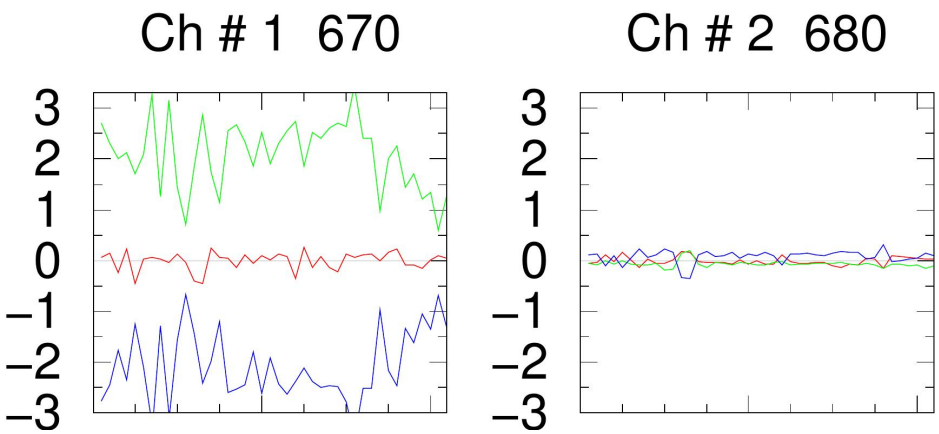
2013: $N_2 + O_2$ lines & continuum added in GARLIC



Channel 1: ARTS ≈ GARLIC

- Channel 1 $\subset$ Channel 2
  Similar absorption:
  $CO_2 > H_2O > O_3 > N_2O$
- Mostly stratospheric emission
  - Continuum & H_2O irrelevant
- Q-branch, convolution, . . . ??





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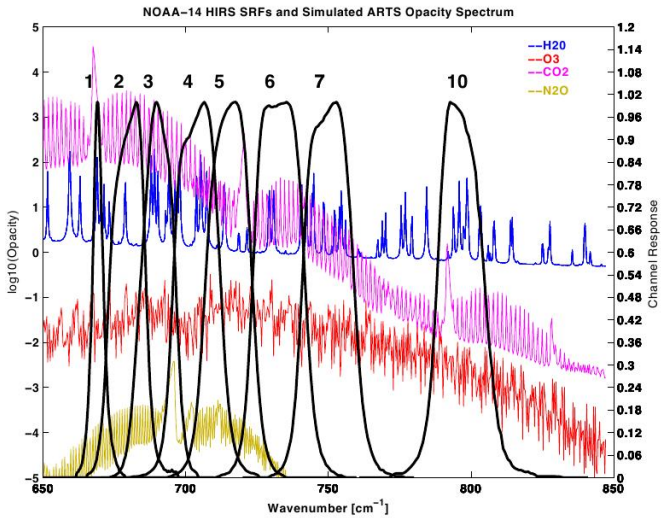
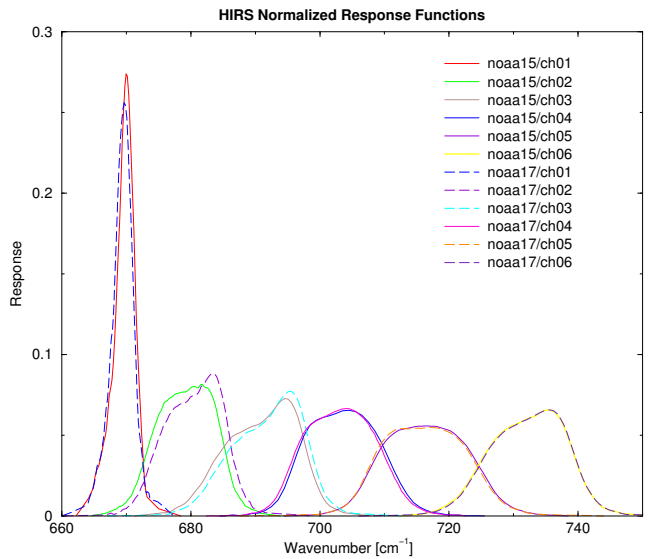
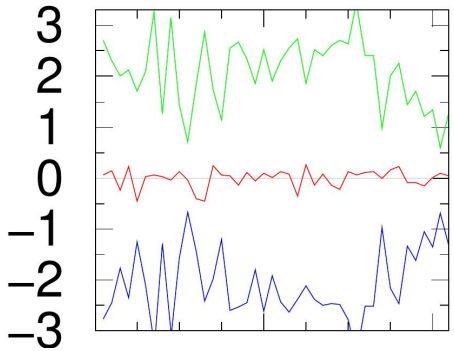
- Mostly stratospheric emission
  - Continuum & H_2O irrelevant
- Q-branch, convolution, . . . ??
- NOAA15-HIRS for KOPRA !!!

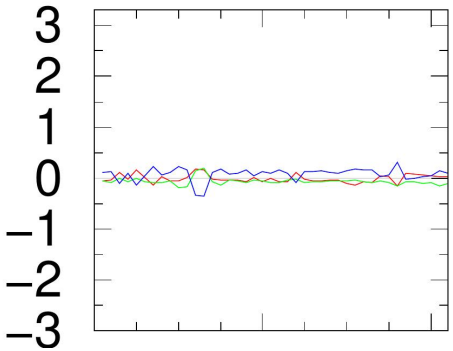




Ch # 1 670

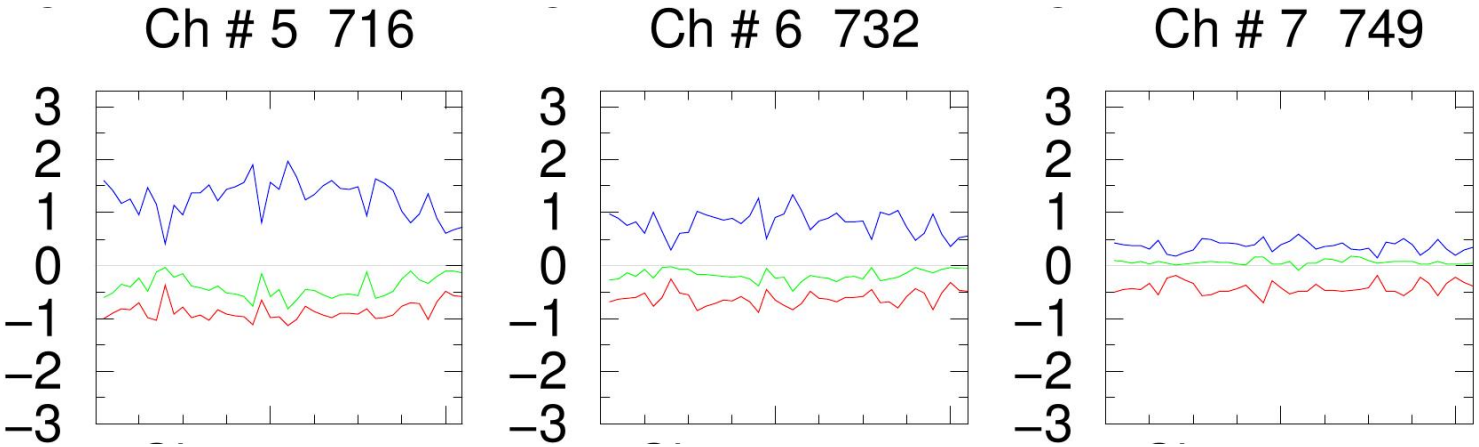


Ch # 2 680



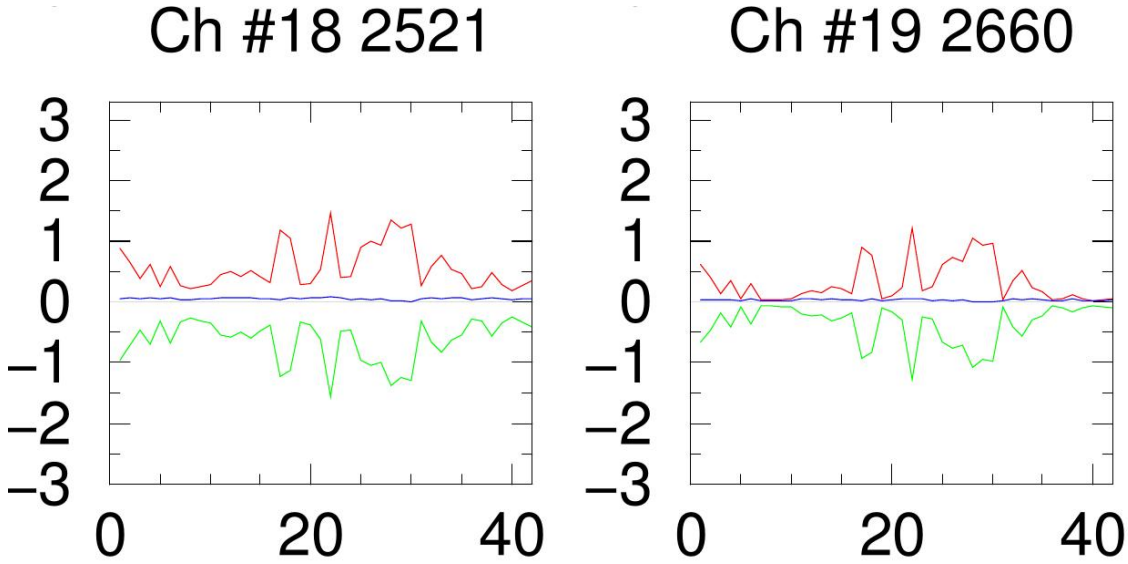
Channel 5, 6, and 7: GARLIC $\approx$ KOPRA

- $CO_2 \approx H_2O > O_3 > N_2O$
- Mostly free troposphere emission
  (Weighting functions peak at 8 and 4 km for 708 and 745 cm^{-1})



Channel 18 and 19: ARTS ≈ KOPRA

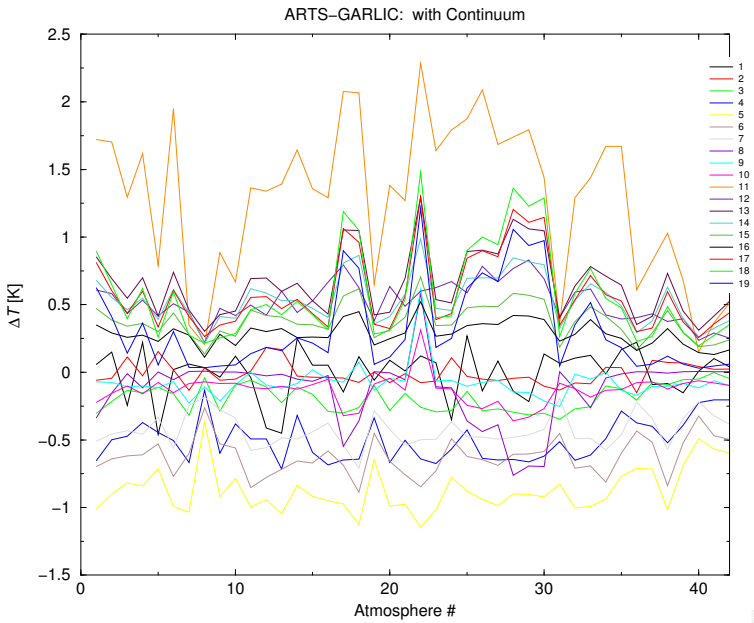
- Weak absorption transparent down to troposphere
- Continua and/or H_2O **?¿?**

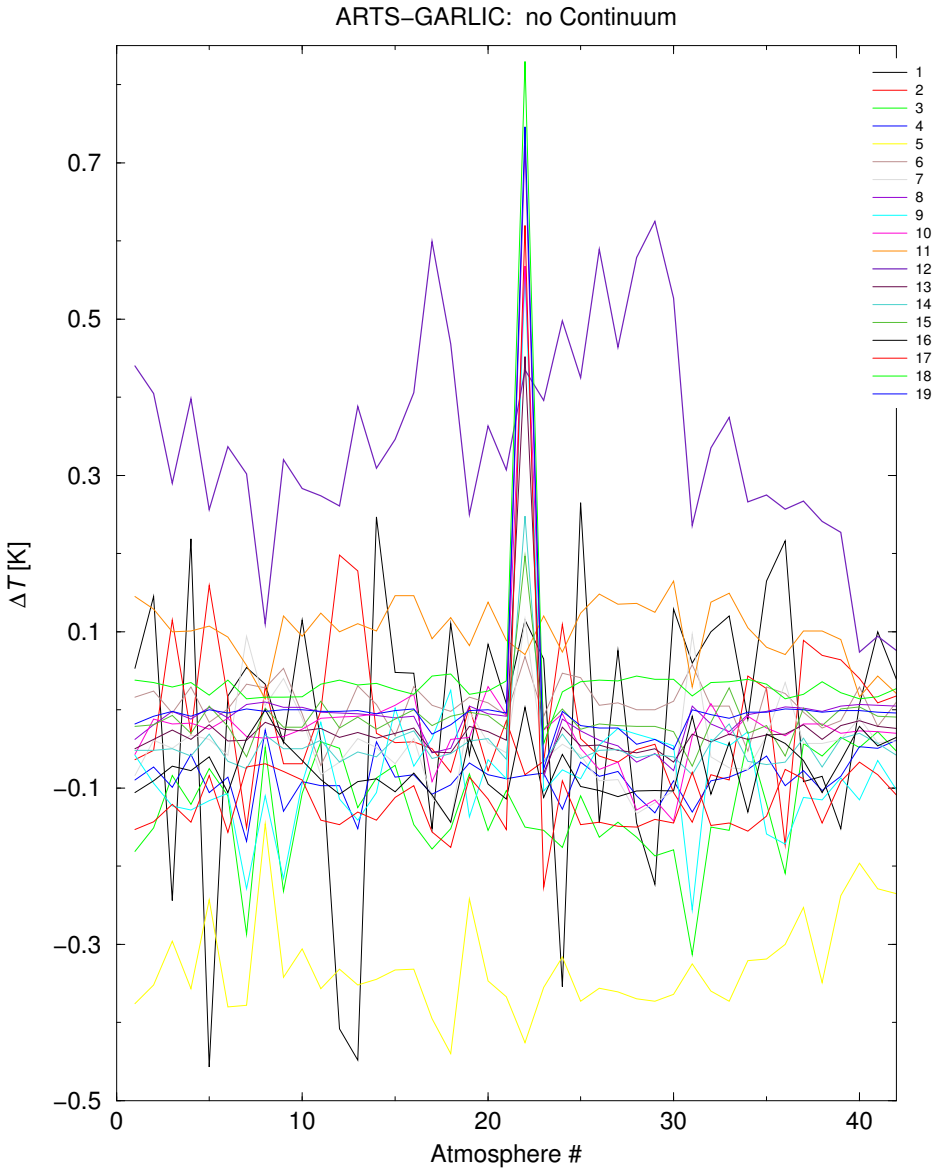


Without continuum?

ARTS vs. GARLIC

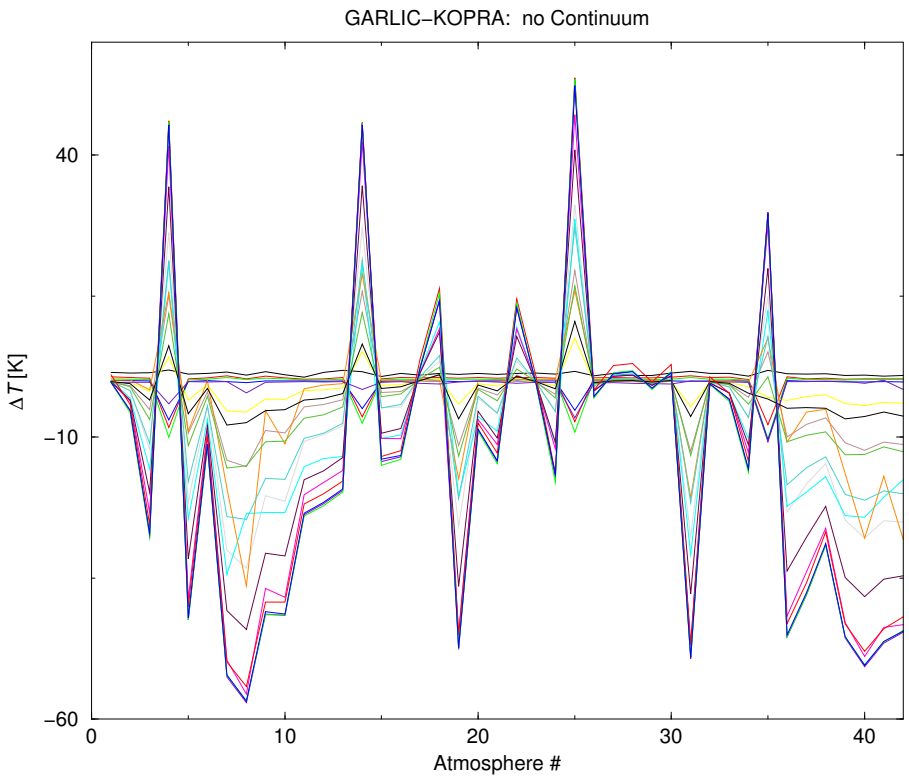
- Differences mostly $< 0.25\,\mathrm{K}$
- What is special with atm # 22
  Channels: 8, 9, 10, 17, 18, 19
  (901, 1030, 802, 2419, 2521, 2660 cm^{-1})
- What is special with
  channel # 12 @ 1529 cm^{-1} ?

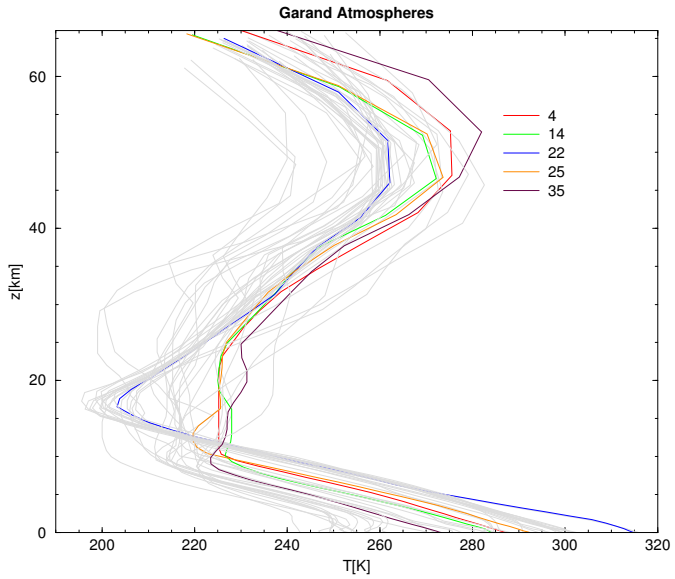


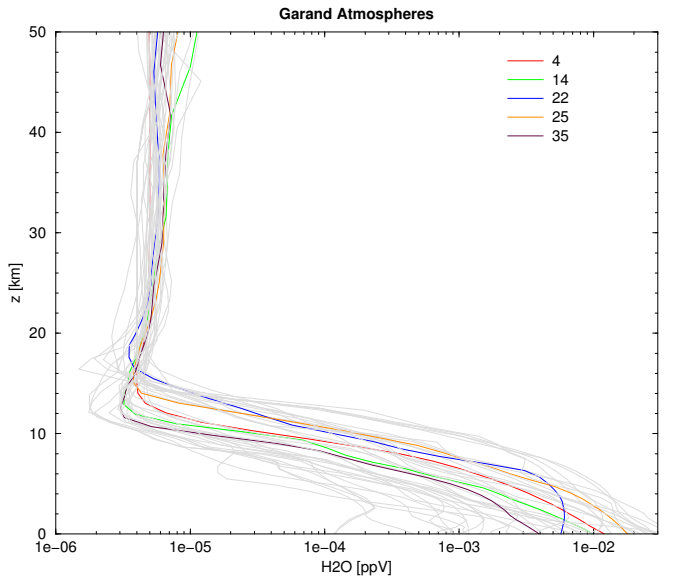


Without continuum? GARLIC vs. KOPRA

- “Good” agreement (1.9 K) in channel 1
- KOPRA failed for atm # 4, 14, 25, 25







What's common . . . . . and what's different?

	ARTS	GARLIC	KOPRA
$S(T)$ conversion	"semi-TIPS"	Atmos	TIPS
Weak lines	?	all	rejection?
Line wings	$25\,\mathrm{cm}^{-1}$???	$10\,\mathrm{cm}^{-1}$, $\mathrm{H_2O}$: $25\,\mathrm{cm}^{-1}$	
Continuum	MT-CKD 1.0	CKD 2.0	CKD 2.4, . . .
Inhomogeneous Path ?	?	quadrature B linear τ	layers ?

Conclusions and Outlook

- *No* code is “the best” for all channels and/or atmospheres
  - max $\Delta T_{ag} = +2.3\,\mathrm{K}$ in channel 11 @ $1366\,\mathrm{cm}^{-1}$
  - max $\Delta T_{gk} = +2.5\,\mathrm{K}$ in channel 15 @ $2235\,\mathrm{cm}^{-1}$
  - max $\Delta T_{ka} = -3.1\,\mathrm{K}$ in channel 15 @ $2235\,\mathrm{cm}^{-1}$

(channel 1 ignored)

Conclusions and Outlook

- *No* code is "the best" for all channels and/or atmospheres
  - max $\Delta T_{ag} = +2.3\,\mathrm{K}$ in channel 11 @ $1366\,\mathrm{cm}^{-1}$
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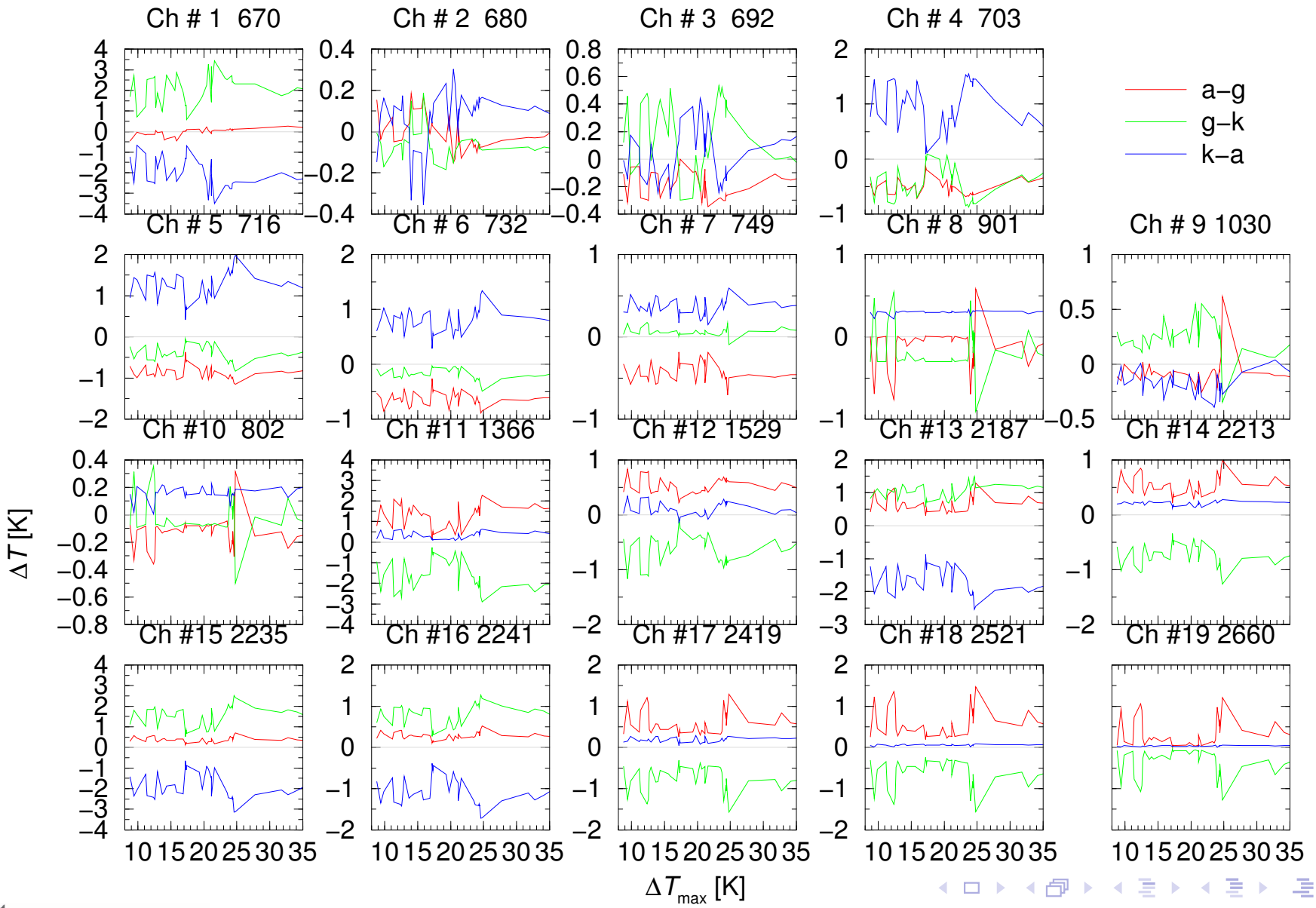
  - max $\Delta T_{ka} = -3.1\,\mathrm{K}$ in channel 15 @ $2235\,\mathrm{cm}^{-1}$

  (channel 1 ignored)
- Use another code (e.g. LblRTM) as reference? *NO!*
- Include more codes? *hmmmm?*
- Use common absorption coefficients
- Plot differences vs. (min, max, delta, ...) temperature, $\mathrm{H_2O}$, ...
- Compare monochromatic spectra and/or transmission
- Open questions
  - Continuum
  - Lines strength T conversion
  - Line wing cut-off ($\mathrm{CO_2}$ at $2400\,\mathrm{cm}^{-1}$)
  - Weak line suppression

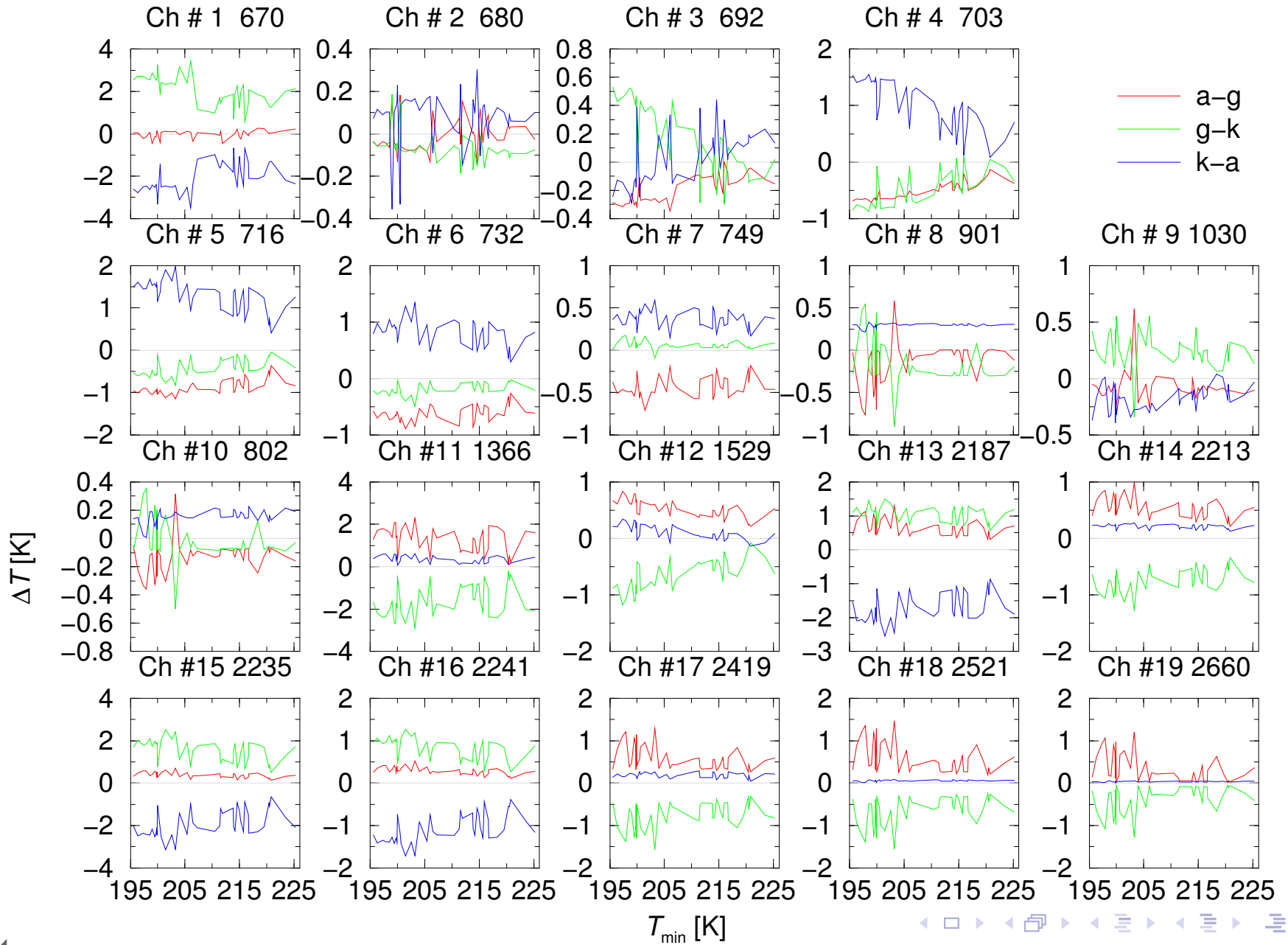
Outline

5 Appendix
- More T Difference Plots
- Weighting and Response Functions
- Continua

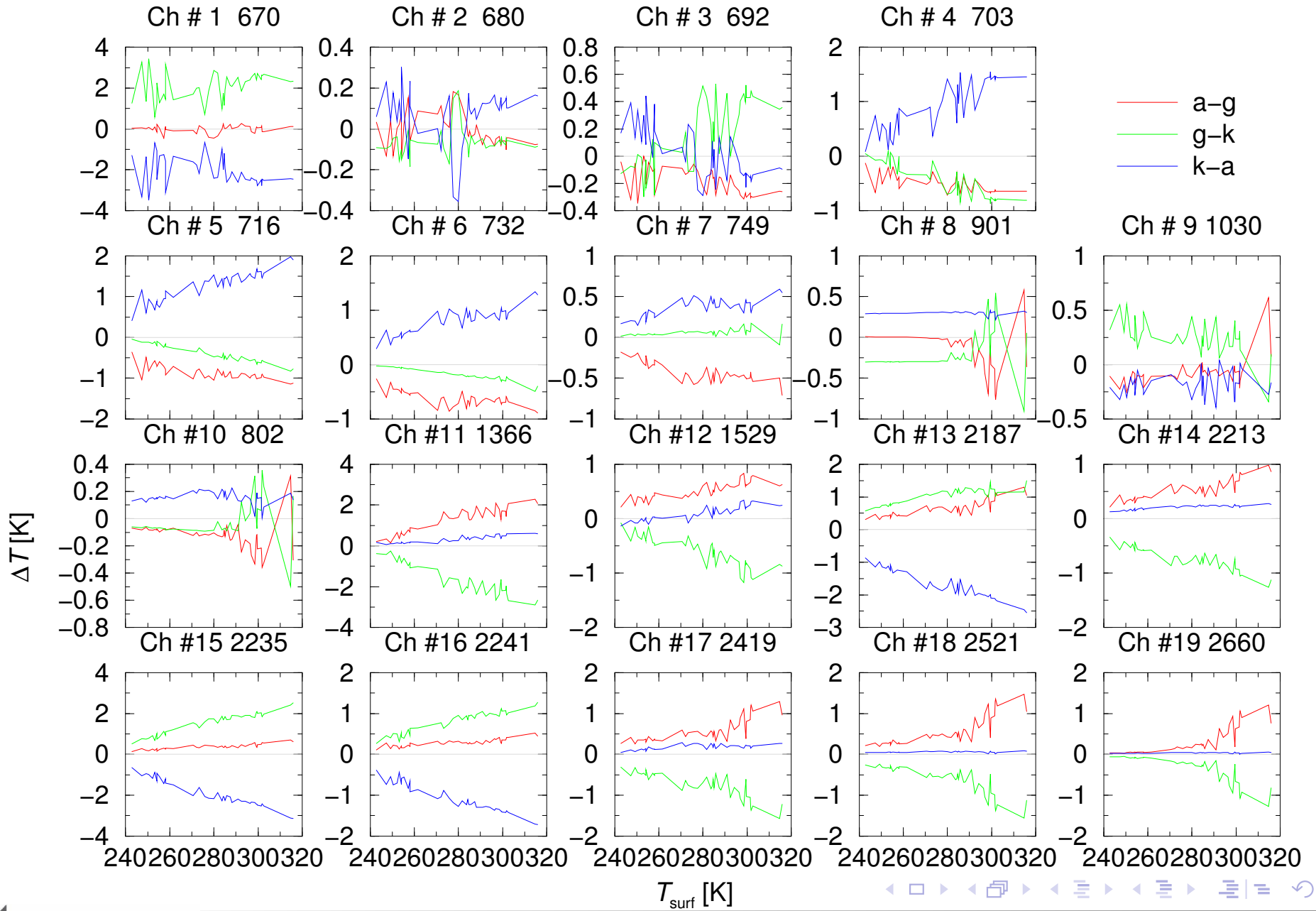
Max. Temperature Delta in Layer



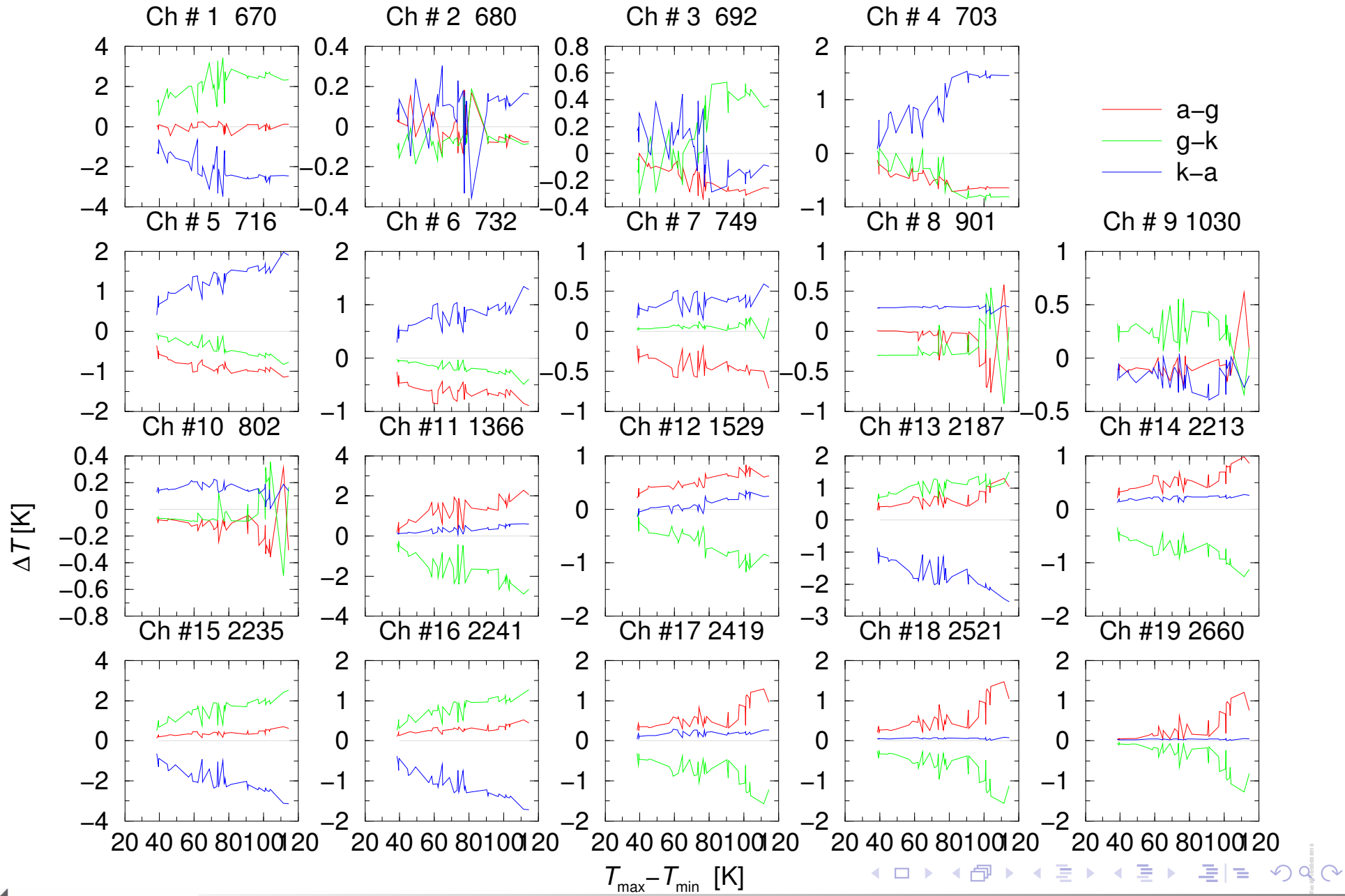
Brightness Temperature Difference vs Minimum Temperature



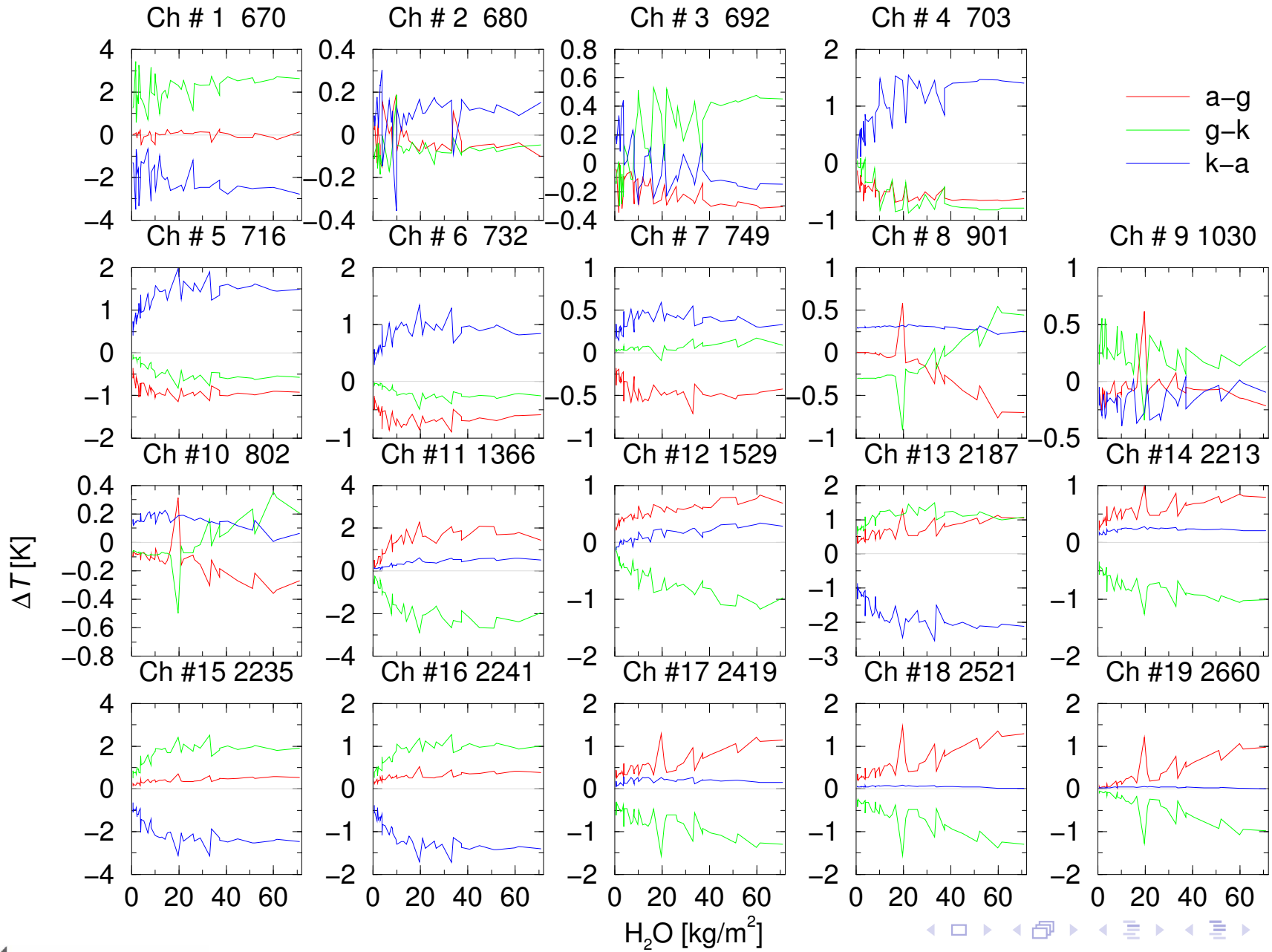
Brightness Temperature Differences vs. Surface Temperature



Brightness Temperature Differences vs Temperature Range

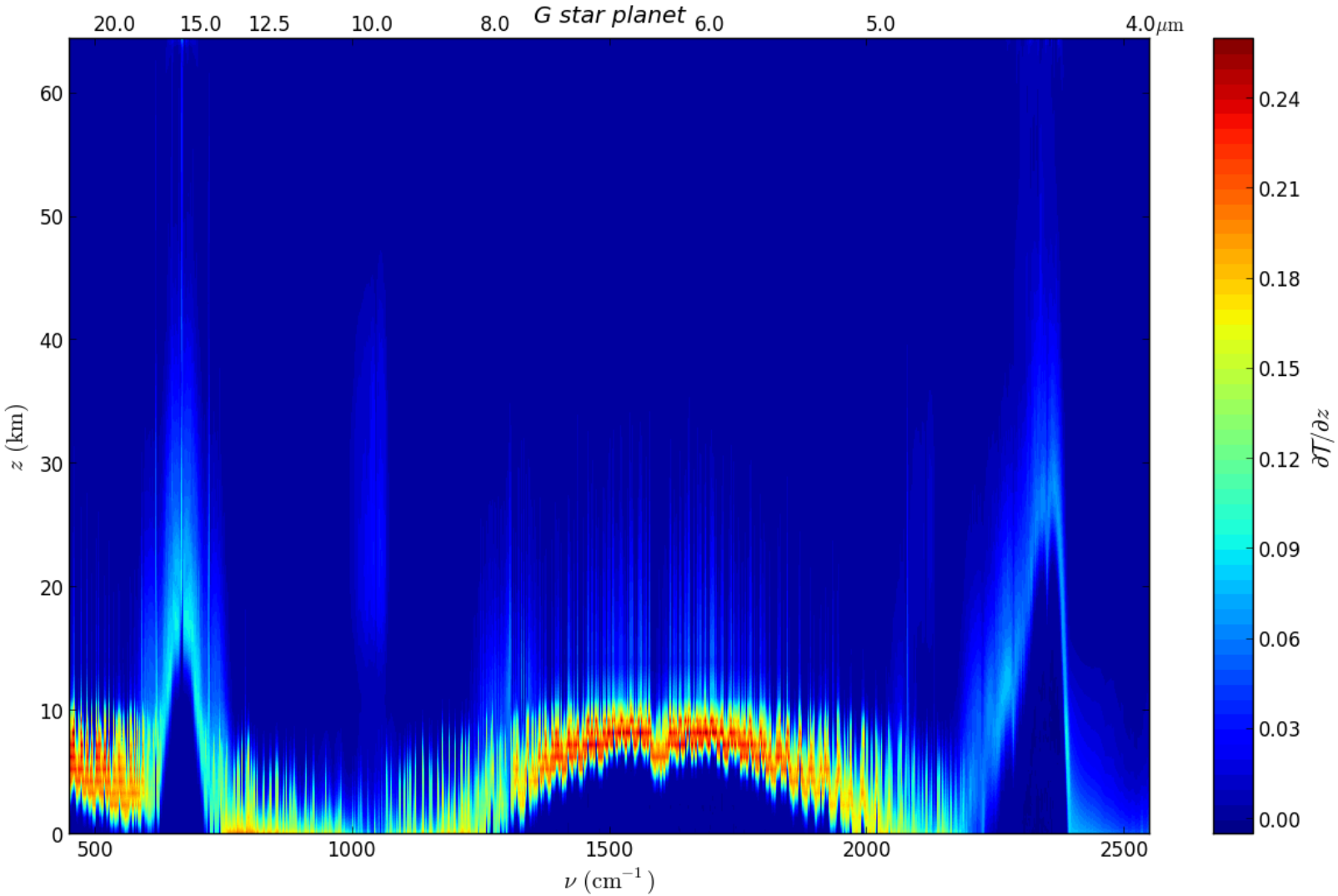


Brightness Temperature Difference vs Water Column

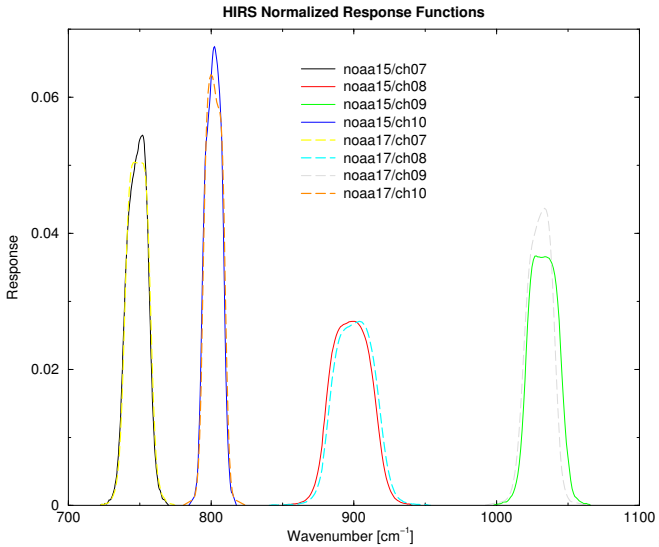


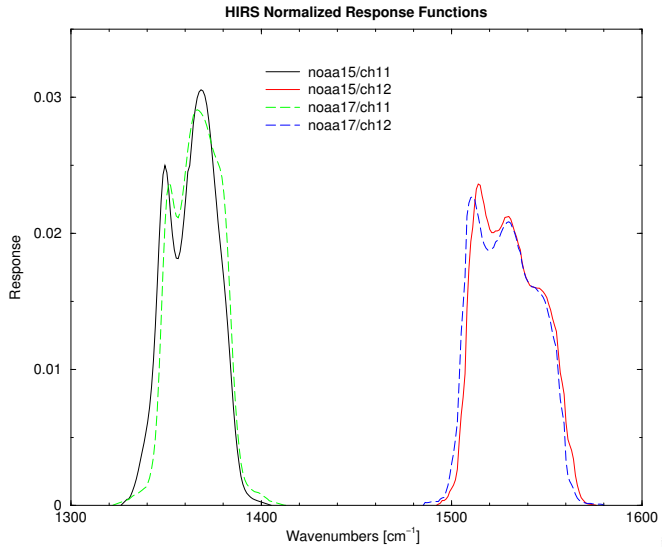
Weighting Functions

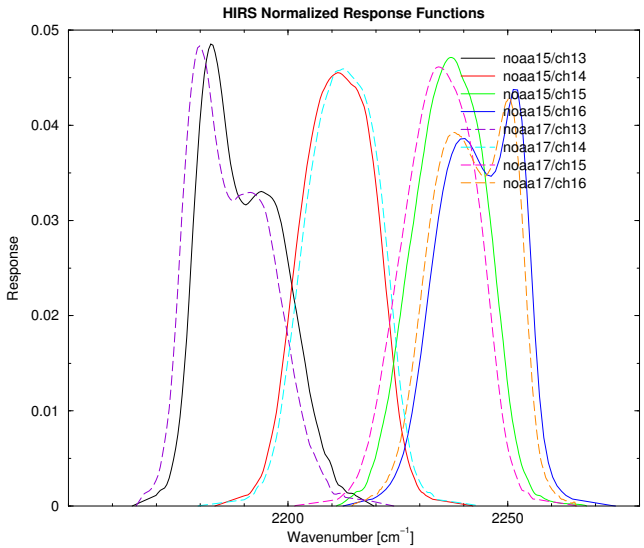
$$I(\nu, s) = \int_0^s B(\nu, T) \frac{\partial \mathcal{T}(\nu, s')}{\partial s'} \, \mathrm{d}s'$$

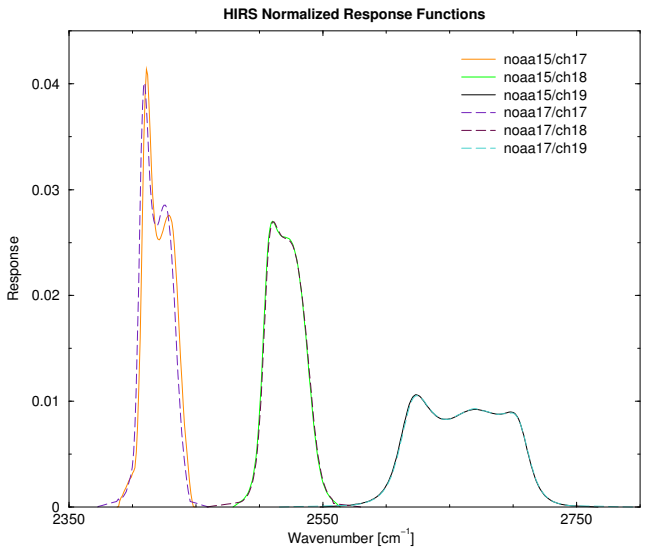


Response Functions









CO_2 Continua