The status of the RTTOV forward model and an assessment of its accuracy using high spectral resolution satellite data

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Status of RTTOV-9

- The development of RTTOV-9 is a joint effort of:
  - Met Office (Roger Saunders and Peter Rayer)
  - ECMWF (Marco Matricardi, Deborah Salmond, Niels Bormann, Alan Geer)
  - Météo France (Pascal Brunel and Philippe Marguinaud)

Status of RTTOV-9

- Parameterised aerosol scattering for a range of user aerosol components
- New cloud parameterised scattering for infrared sensors inside RTTOV
- Linear in optical depth approximation for the Planck function to improve the accuracy of the radiance computation
- Include reflected solar radiation for wavelengths below 5 microns.
- Now six variable gas profiles which can be supplied to RTTOV (H2O, O3, CO2, N2O, CO, CH4)
- Further optimisation of optical depth computations for all gases for high resolution IR sensors (RTTOV-9 predictors)
- An altitude dependent variation of local zenith angle and optionally allow for atmospheric refraction
- The input profile levels can be defined by user and the radiances and transmittances output are on the same levels allowing better mapping of computed jacobians on to user levels
- Simplified interface to avoid need to specify polarisation (NB SSM/I chan numbers)
- The 2m surface humidity variable can now be an active variable in the state vector
- The Mie scattering tables used by RTTOV_SCATT updated to increase their dynamic range

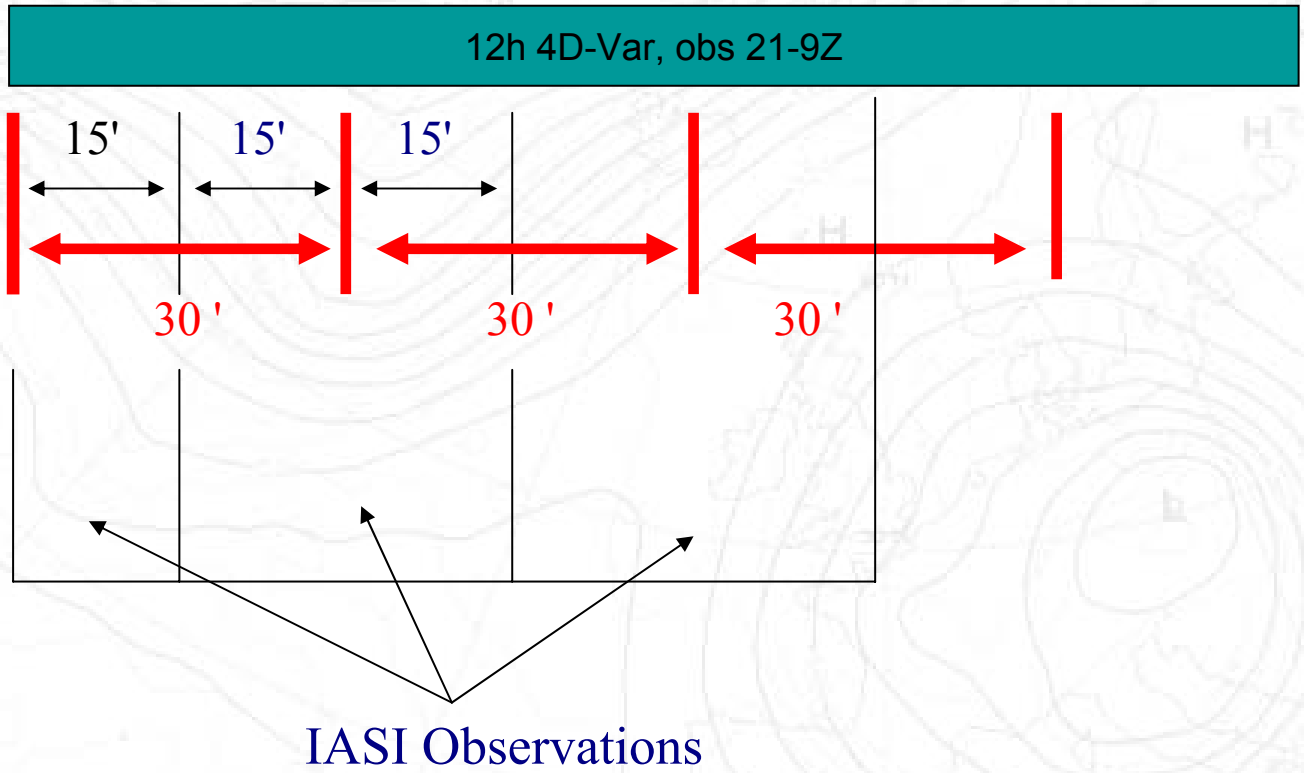
Plans for RTTOV-10

- **Include Zeeman splitting for AMSU-A (14) and SSMIS (Yong Han)**
- **Provide new LBLRTM based coefficients for *CrIS***
- **Add Non-LTE**
- **Rewrite coeff generation software and make available to users**
- **Upgrade FASTEM-3 microwave ocean surface emissivity**
- **Upgrade FASTEM-3 over land for lower frequencies (SMOS**
- **Add new SSU predictors for reanalyses**
- **Design for including principal components capability (PC-RTTOV)**
- ***Simple VIS/NIR optical depth and scattering calculations***

RTTOV-9 monitoring experiments

- Four monitoring experiments have been run using cycle 33R1 of the ECMWF Integrated Forecasting System (IFS) at T799 (25 km) resolution.
- A feature of cycle 33R1 is a vertical discretization of the atmosphere into a grid of 91 pressure levels. The spacing of the grid follows the horography of the terrain while the top level is fixed at 0.01 hPa.
- IASI radiances have been compared to radiances simulated using version 9 of the RTTOV fast forward model over a fifteen day period from the 1st April 2008 to the 15th April 2008.

12h 4D-Var, obs 09-21Z



RTTOV-9 monitoring experiments

Coefficients [1,2]	Continum	CO2 line mixing	Molecular database
kCARTA [1] 52 profile training set *Chevalier (2003)*	MT_CKD_v1.1_UMBC *Mlawer et al. (2004)*	CO_2 P/Q/R branch Line mixing (υ2 and υ3) *Strow et al. (2002)*	HITRAN_2000 *Rothman et al. (2003)*
GENLN2 [2] 43 profile training set *Matricardi and Saunders (2000)*	CKD_2.4 *Clough et al. (1989)*	CO_2 Q branch (υ2 and υ3) *Strow et al. (1994)*	HITRAN_2000 *Rothman et al. (2003)*
LBLRTM [2] 83 profile training set *Matricardi (2008)*	MT_CKD_v1.1 *Mlawer et al. (2004)*	CO_2 P/Q/R branch Line mixing (υ2 and υ3) *Niro et al. (2005)*	HITRAN_2000 HITRAN_2004/06 *Rothman et al. (2005)* GEISA_2003 *Husson et al. (2005)*

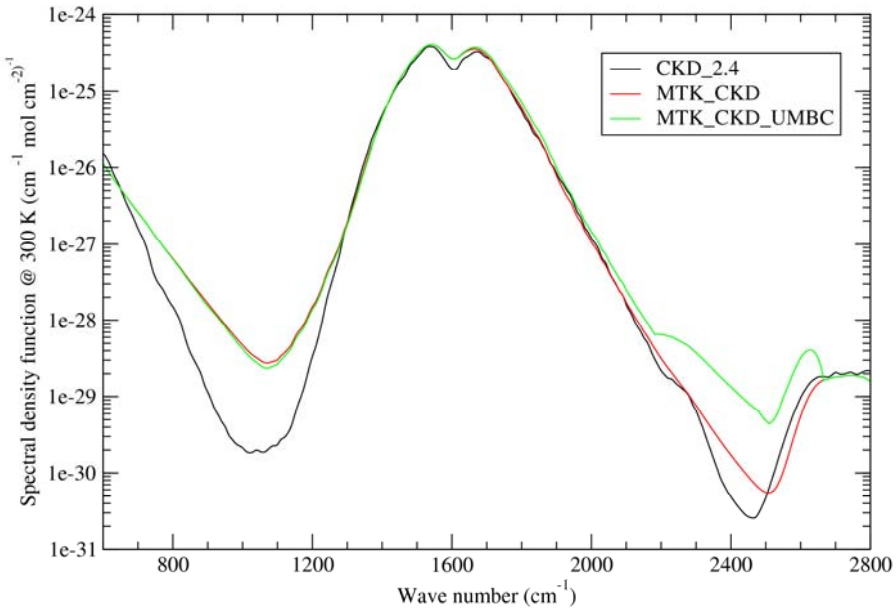
[1] Brunel, Météo France
[2] Matricardi, ECMWF

RTTOV-9 monitoring experiments

- In addition to the three basic experiments where the concentration of CO_2, N_2O, CO and CH_4 is kept fixed, we have run a further experiment (using LBLRTM coefficients) where the concentration of these species is varied.

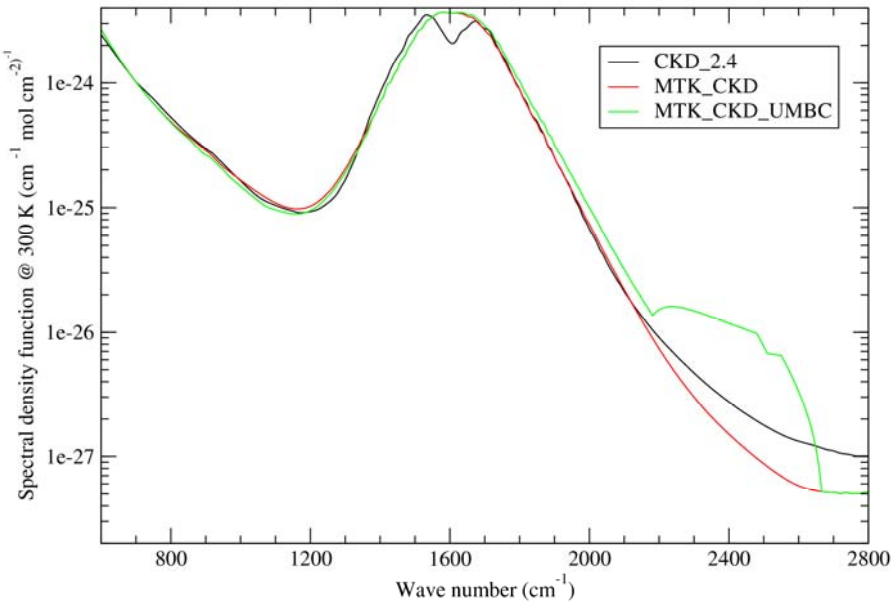
- To vary the concentration of the trace gases we have taken as representative of the in-situ situation the nearest (in geographical terms) profile chosen among those in the 83 profile training set. The concentration has than been scaled according to the monthly average value measured at the nearest CMDL or AGAGE station.

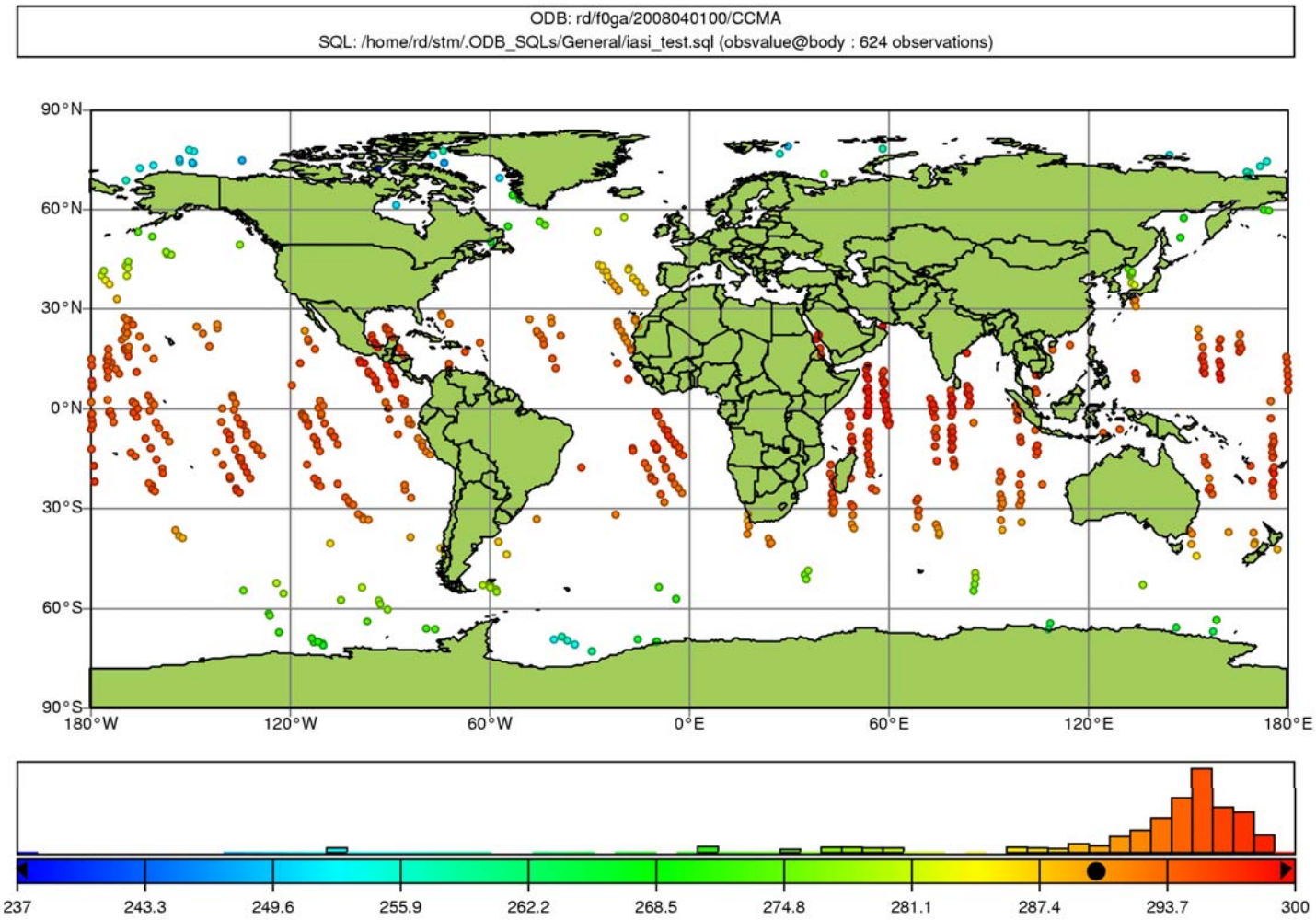
Foreign broadening



UMBC data courtesy S. DeSouza-Machado

Self broadening

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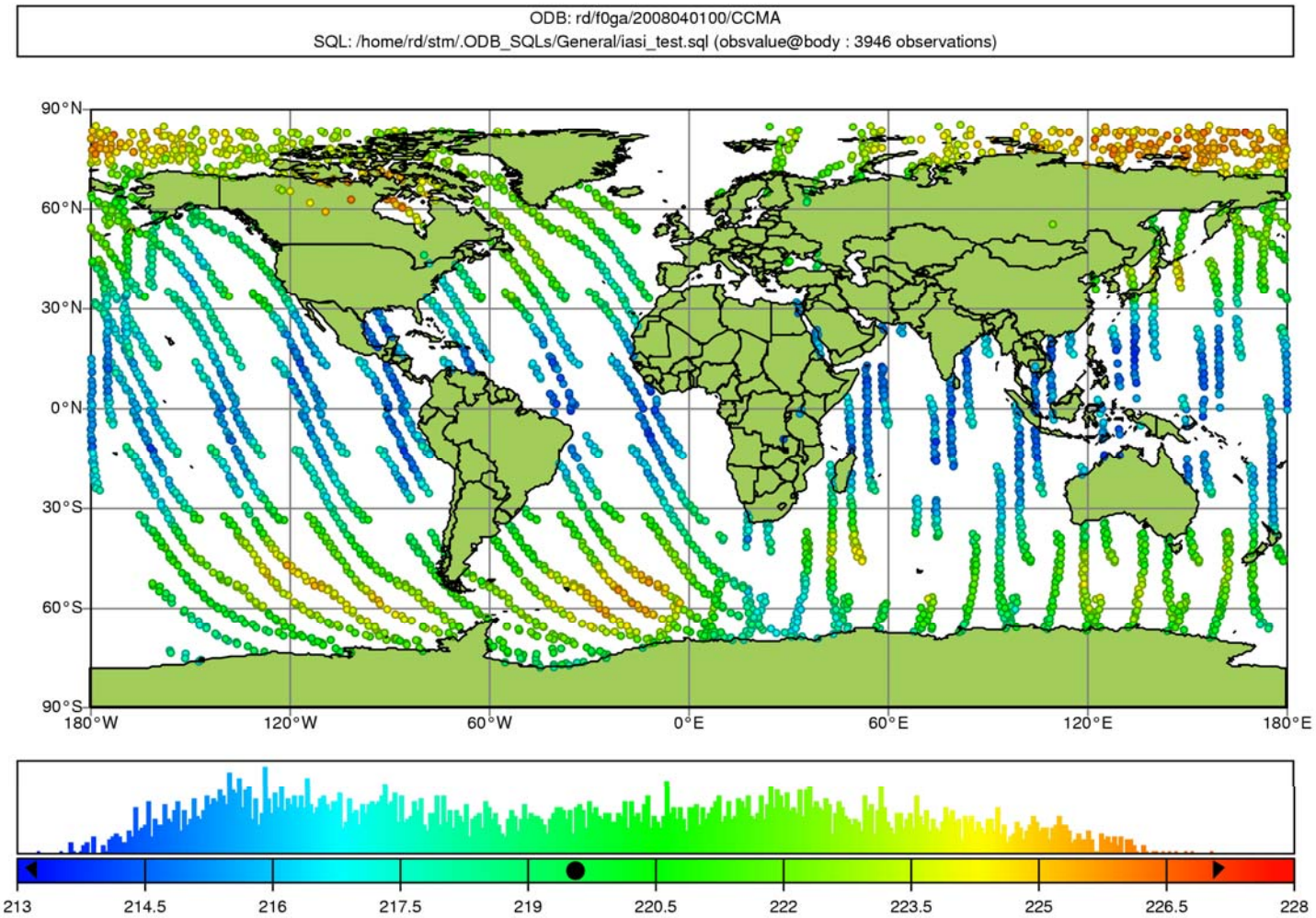
90°N
60°N
30°N
0°N
30°S
60°S
90°S
180°W
120°W
60°W
0°E
60°E
120°E
180°E
237
243.3
249.6
255.9
262.2
268.5
274.8
281.1
287.4
293.7
300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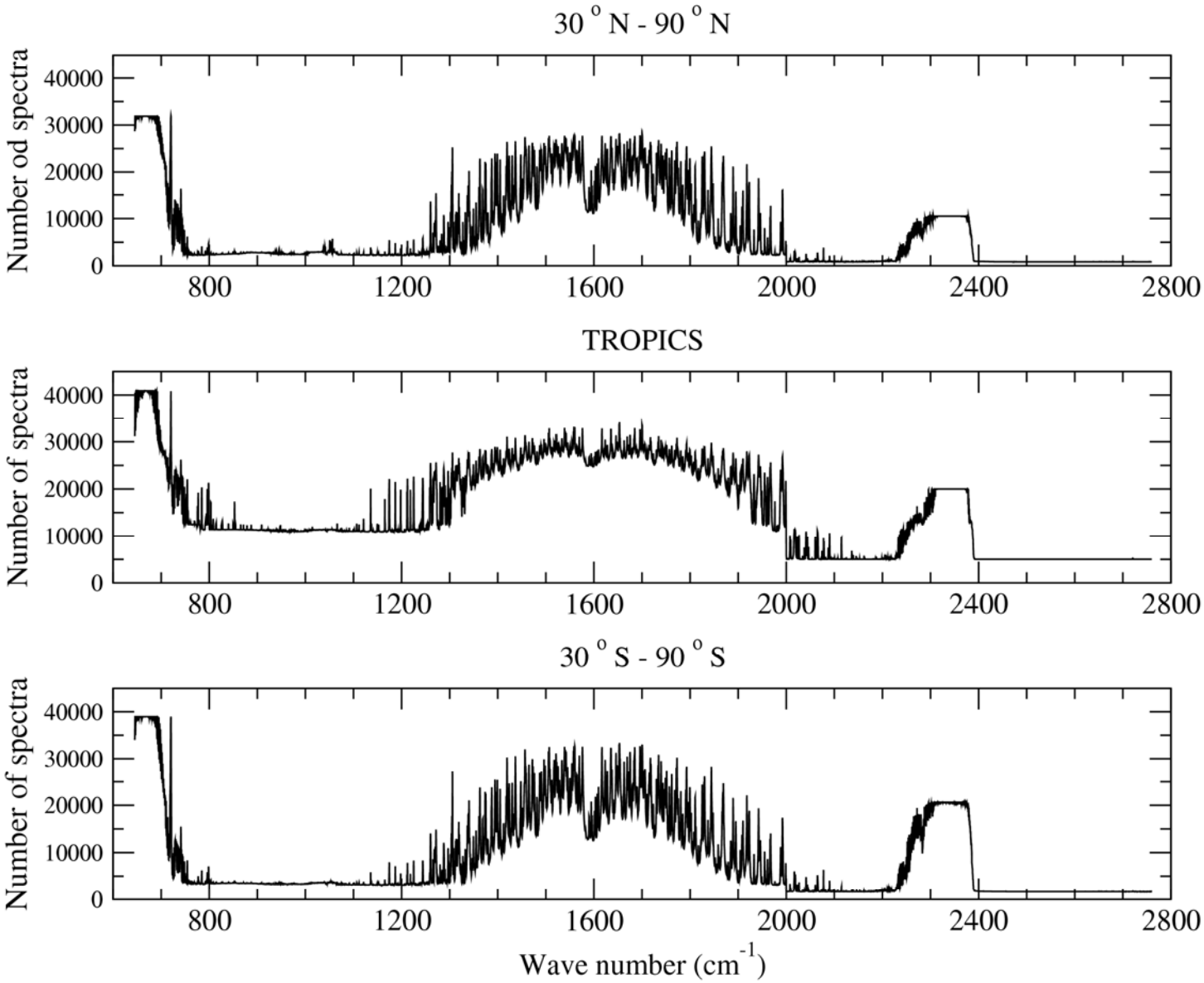
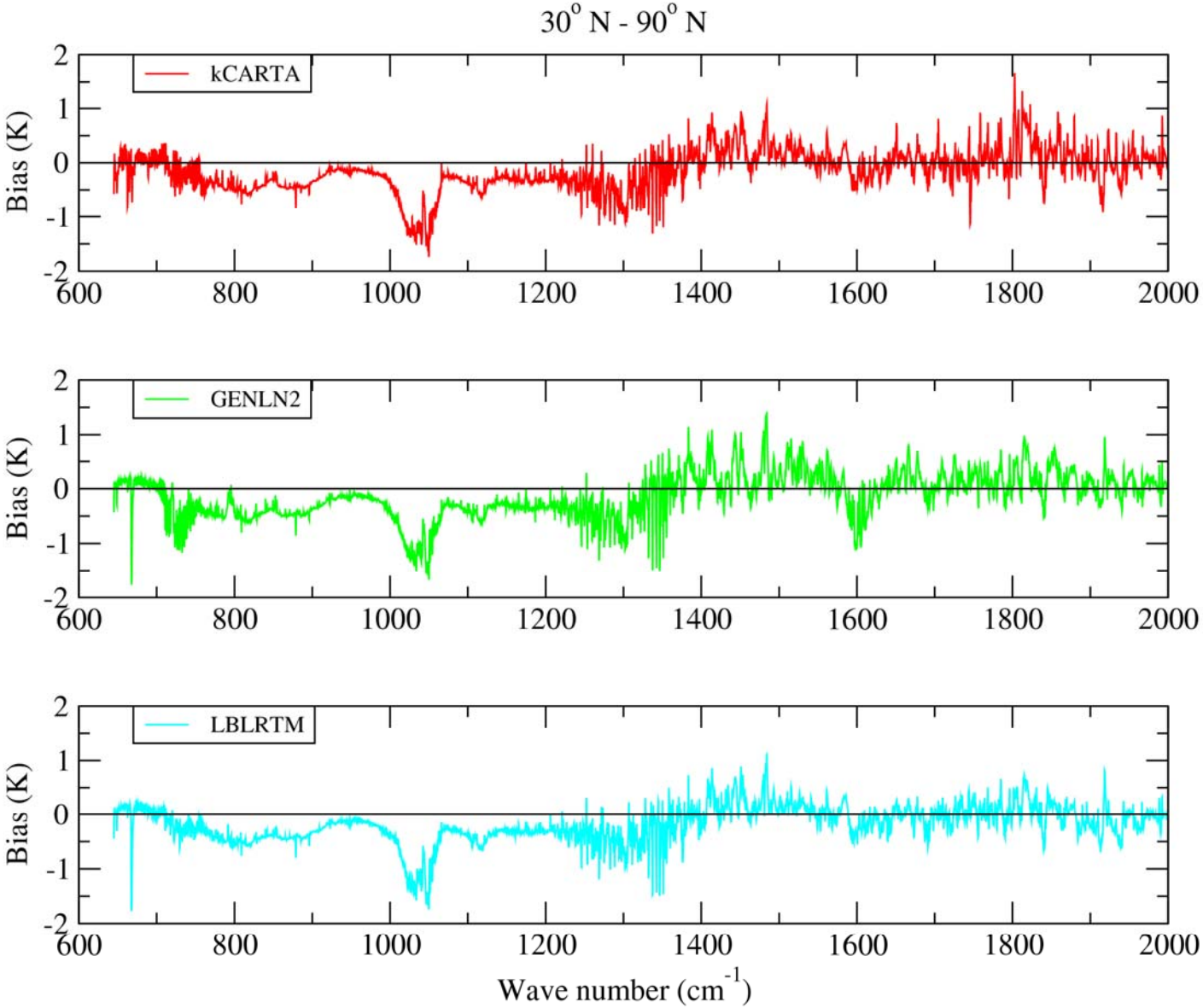
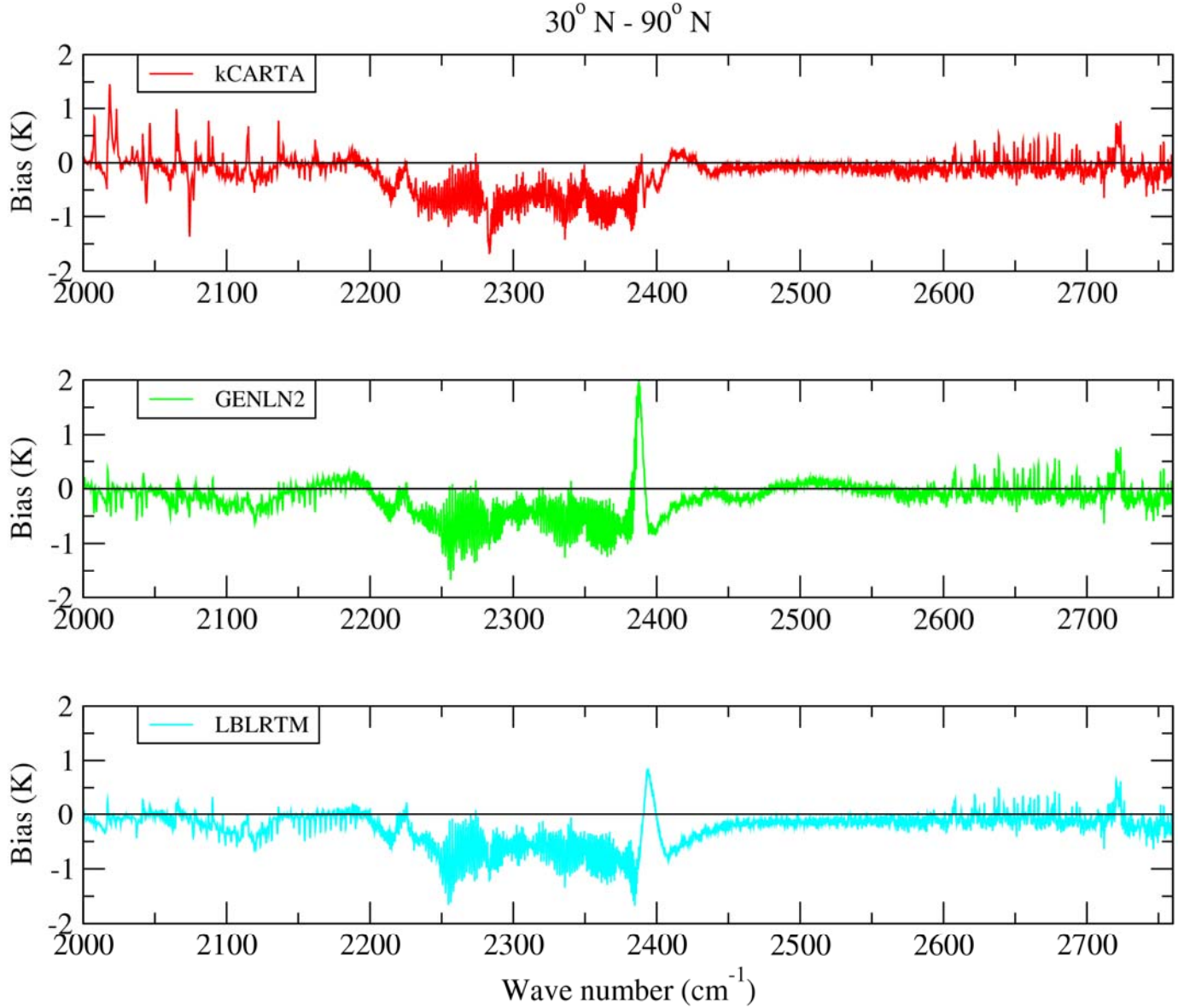
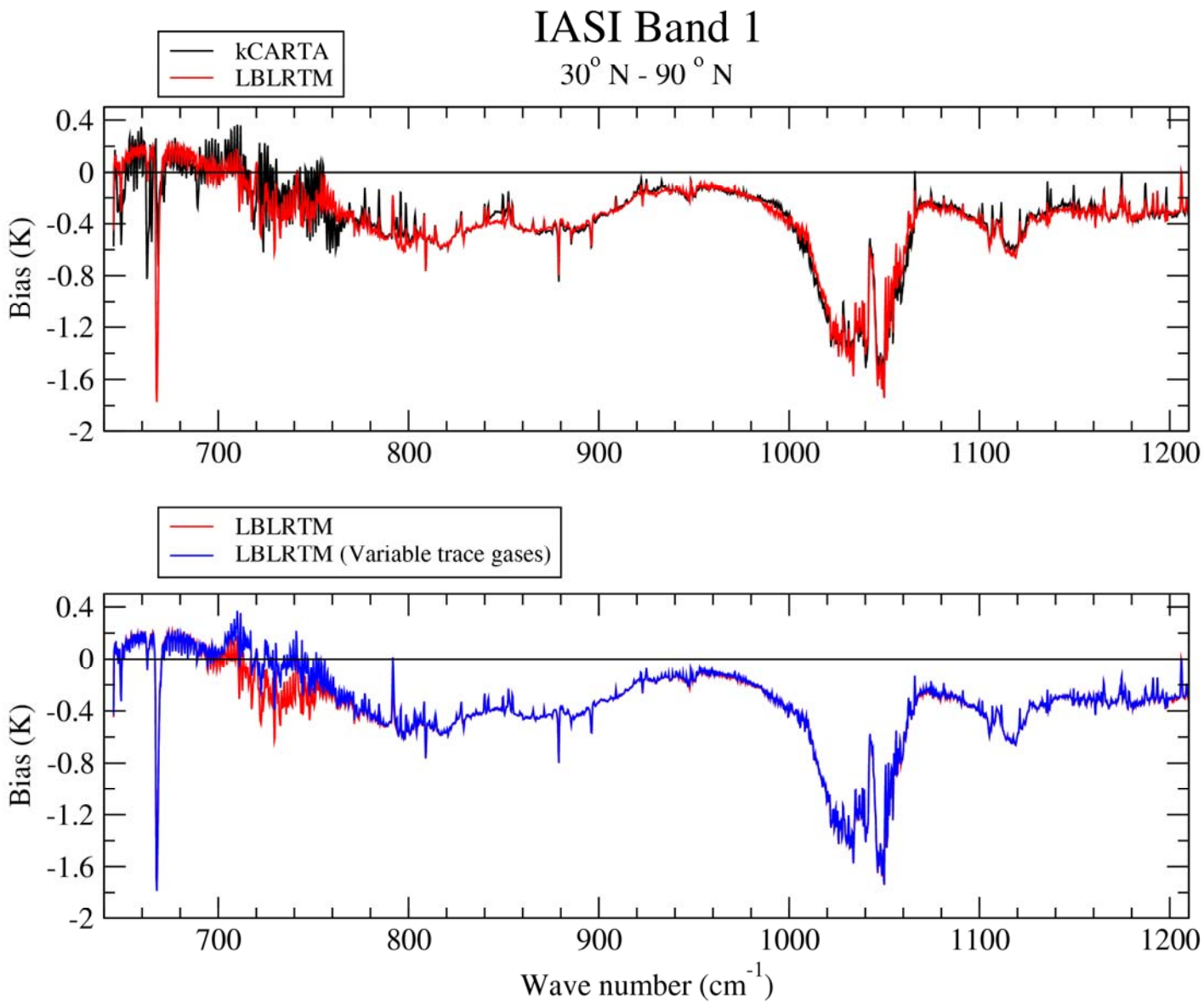
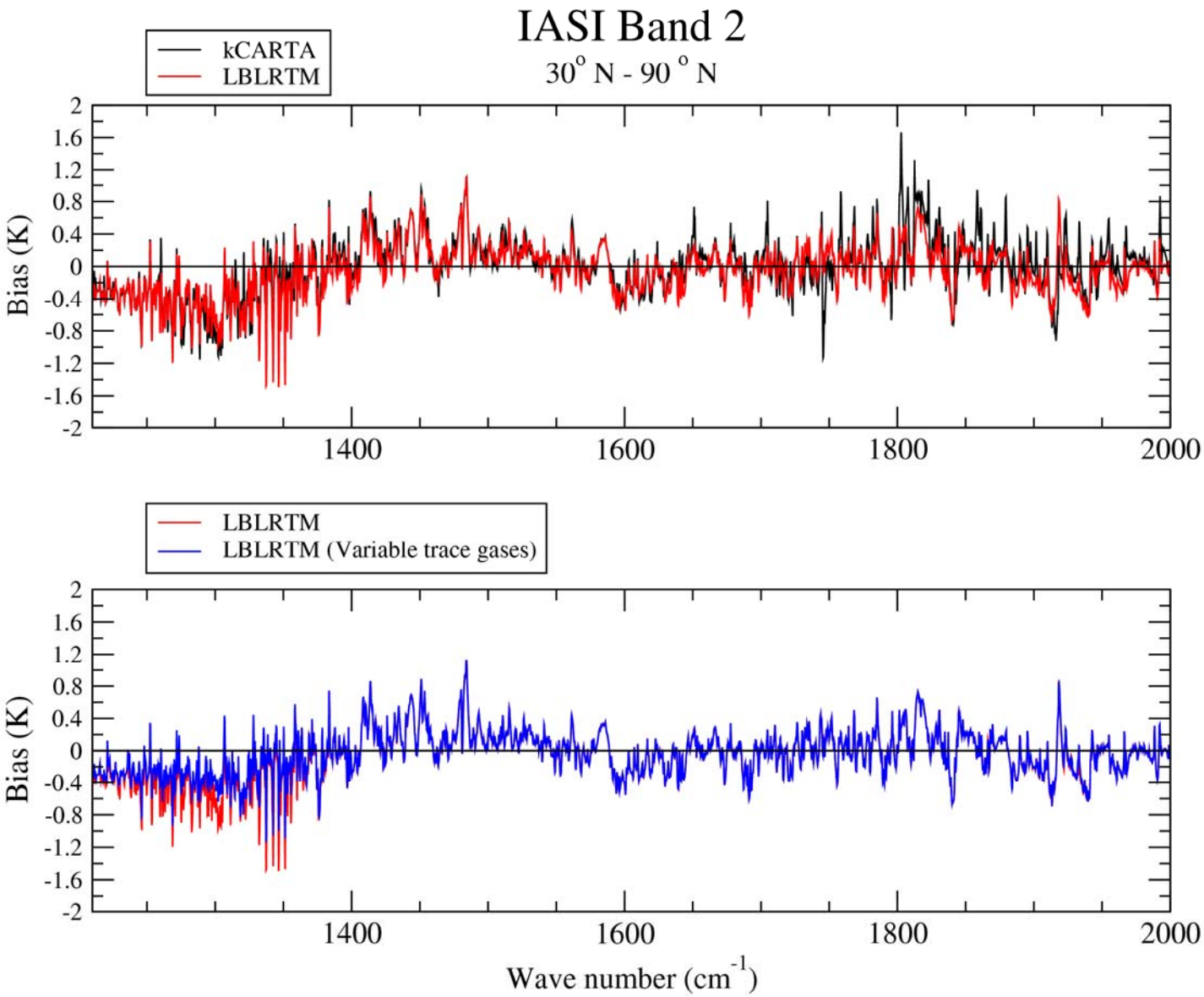
90°N
60°N
30°N
0°N
30°S
60°S
90°S
180°W
120°W
60°W
0°E
60°E
120°E
180°E
213
214.5
216
217.5
219
220.5
222
223.5
225
226.5
228

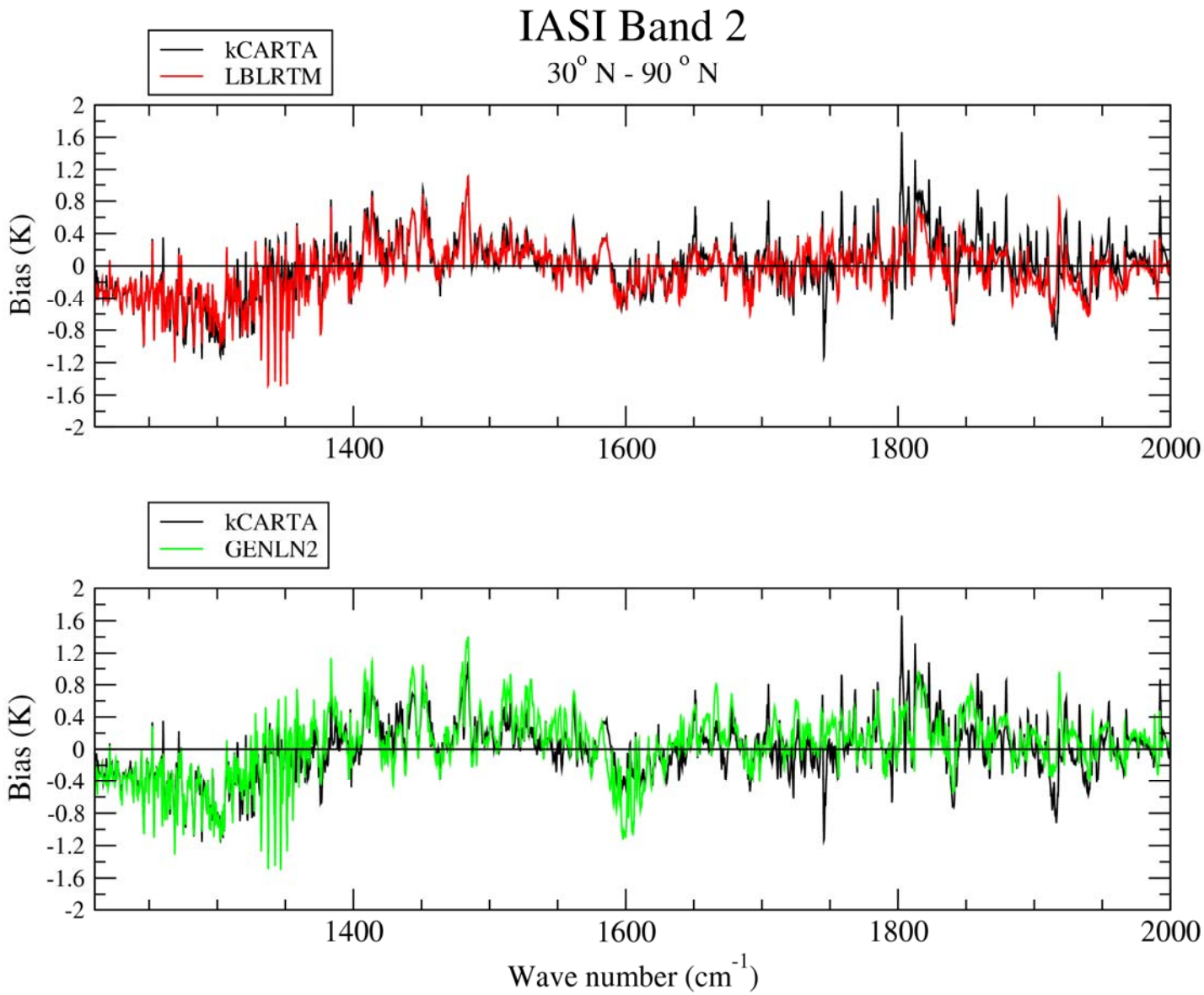

30 ° N - 90 ° N
Number od spectra
40000
30000
20000
10000
0
800
1200
1600
2000
2400
2800
TROPICS
Number of spectra
40000
30000
20000
10000
0
800
1200
1600
2000
2400
2800
30 ° S - 90 ° S
Number of spectra
40000
30000
20000
10000
0
800
1200
1600
2000
2400
2800
Wave number (cm -1)

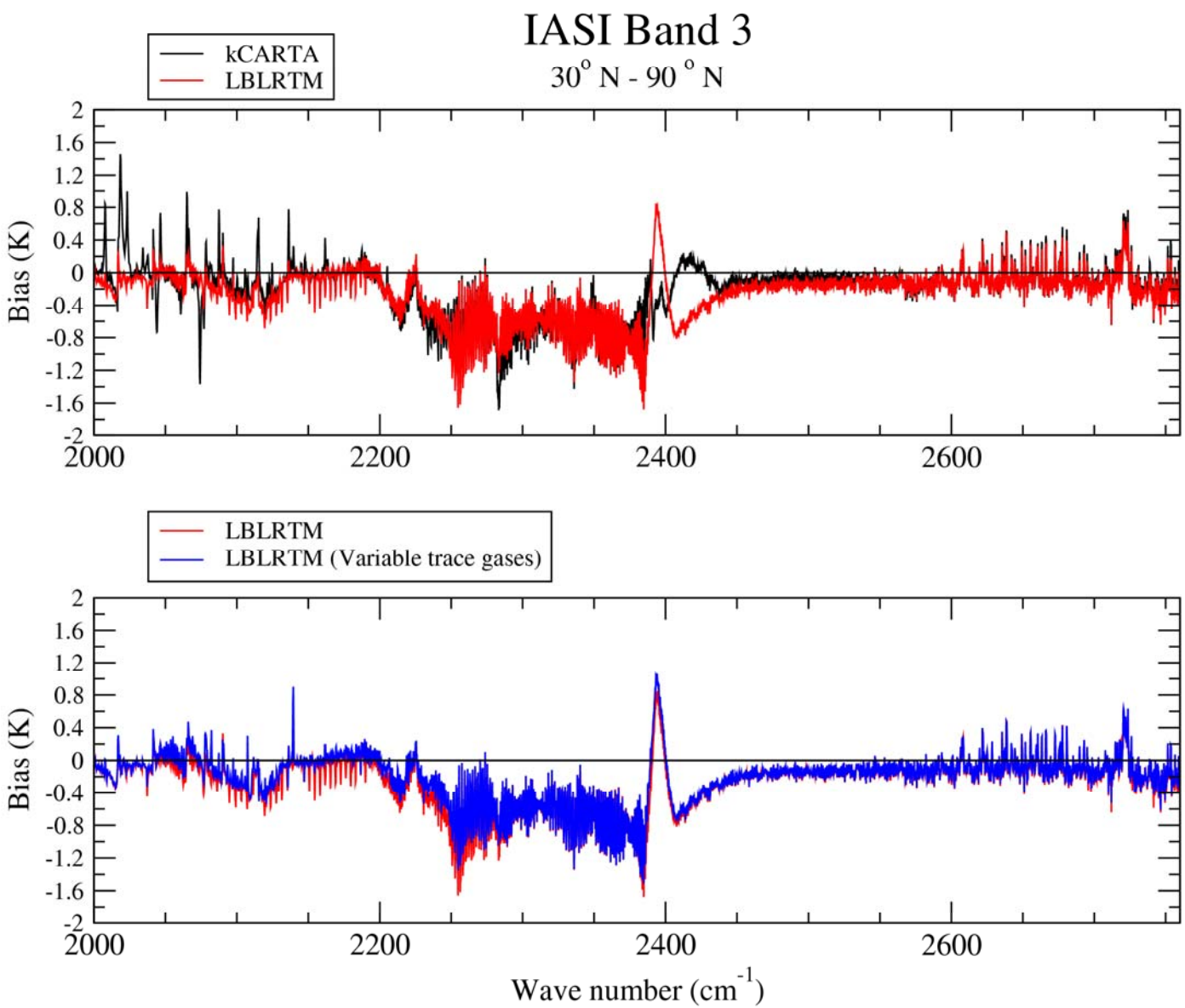

30° N - 90° N
kCARTA
GENLN2
LBLRTM
Bias (K)
2
1
0
-1
-2
600
800
1000
1200
1400
1600
1800
2000
Wave number (cm-1)

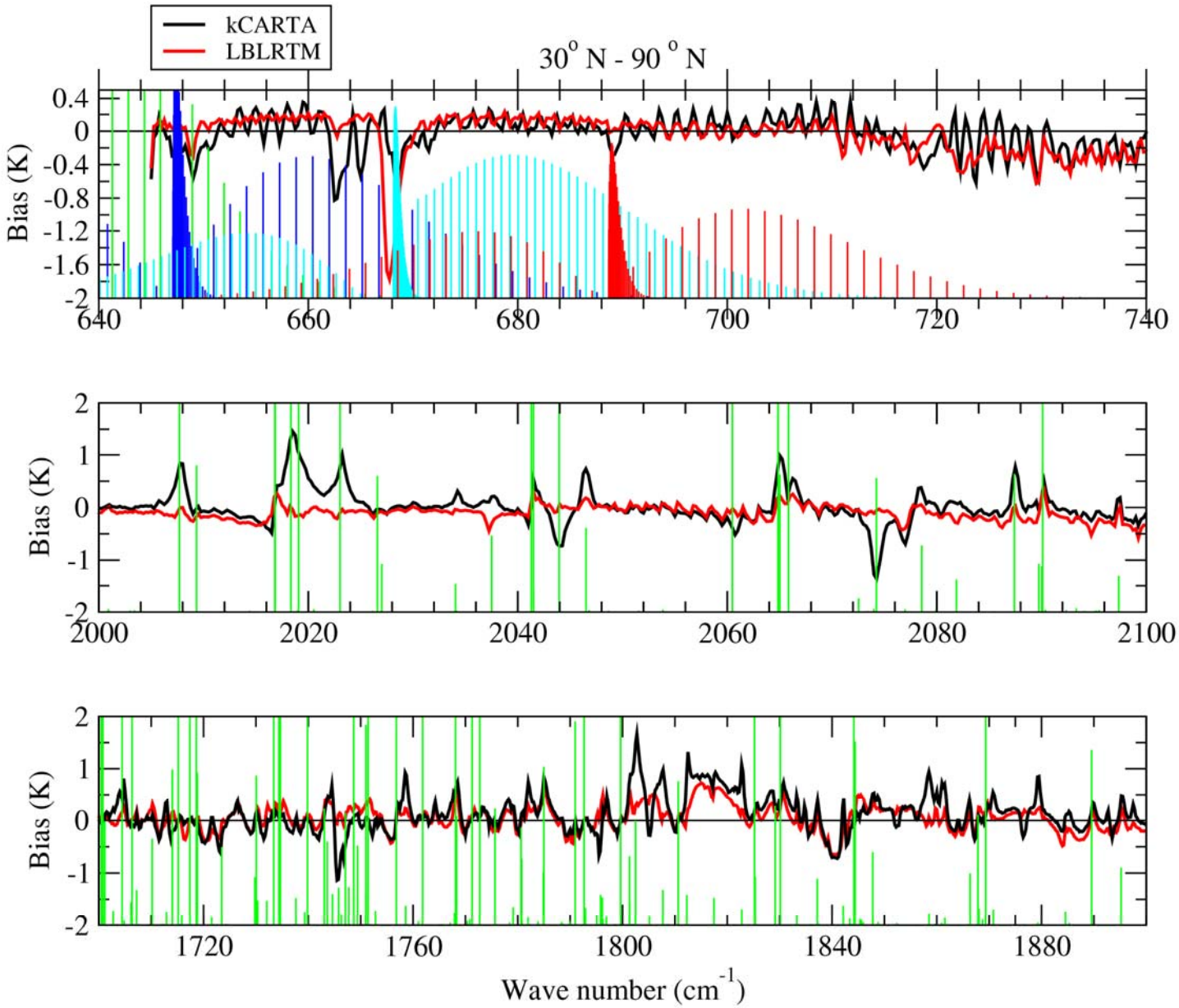

30° N - 90° N
kCARTA
GENLN2
LBLRTM
Bias (K)
2
1
0
-1
-2
2000
2100
2200
2300
2400
2500
2600
2700
Wave number (cm-1)

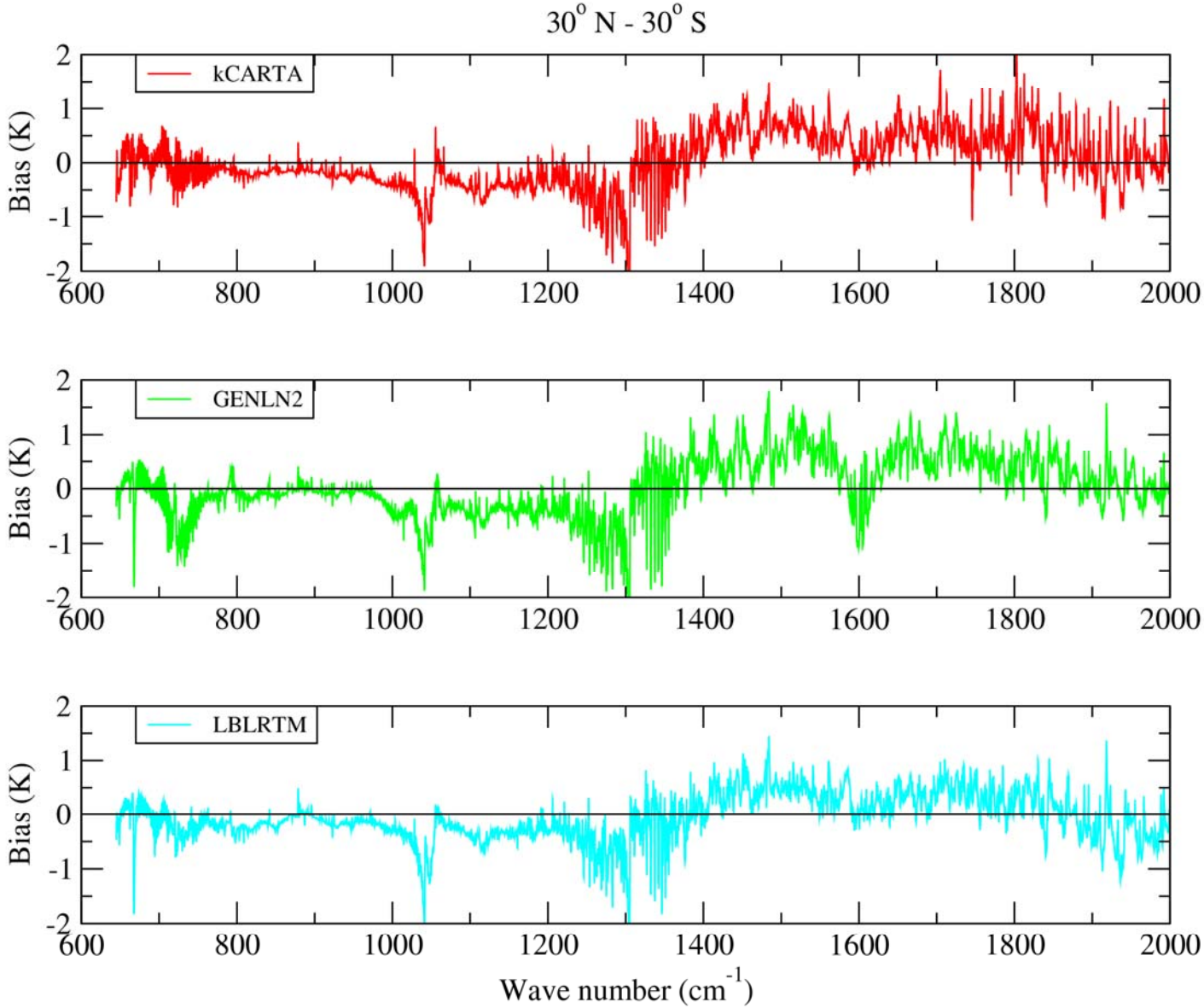

IASI Band 1
30° N - 90 ° N
kCARTA
LBLRTM
Bias (K)
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
700
800
900
1000
1100
1200
LBLRTM
LBLRTM (Variable trace gases)
Bias (K)
Wave number (cm-1)

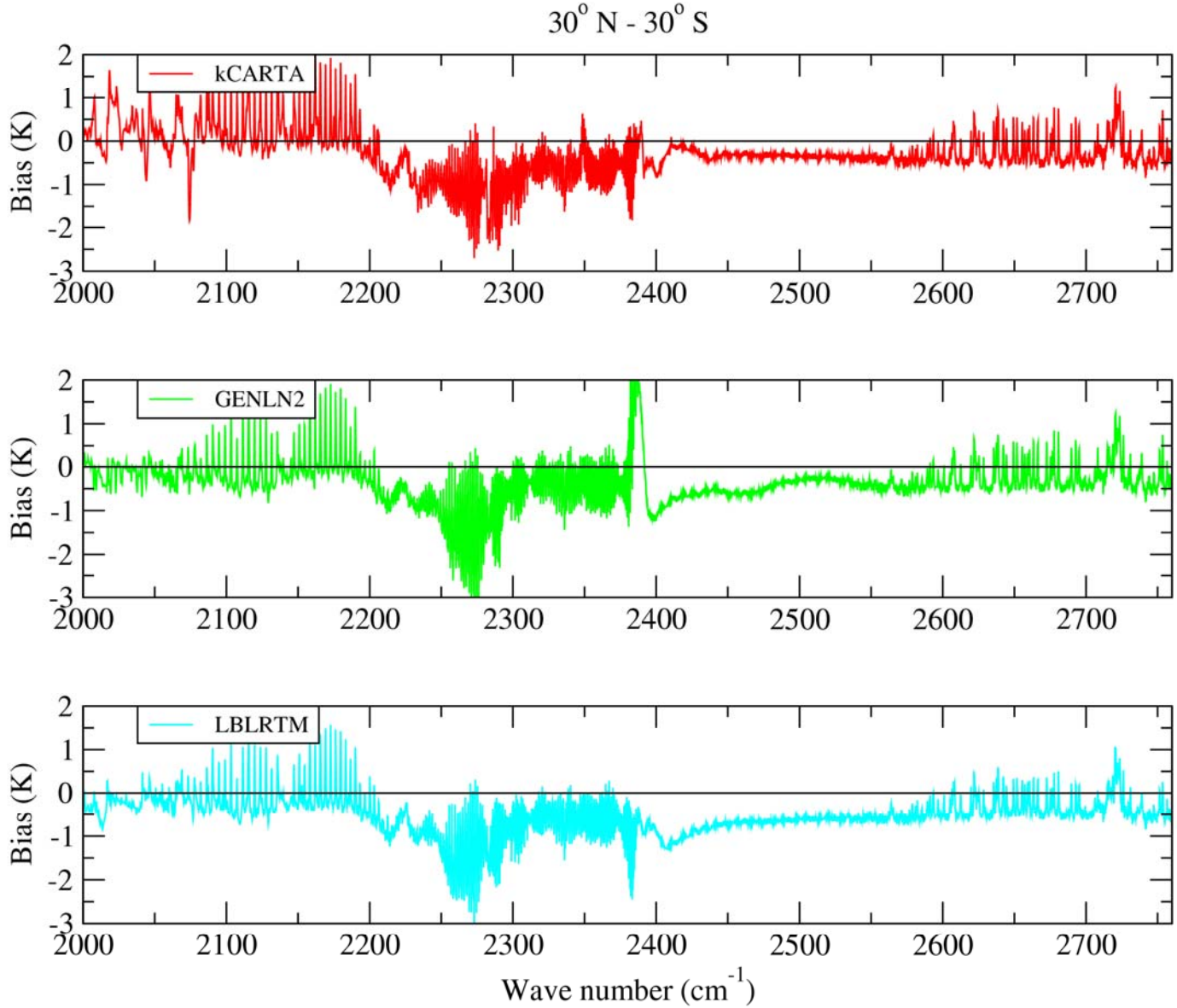

IASI Band 2
30° N - 90 ° N
kCARTA
LBLRTM
Bias (K)
2
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
1400
1600
1800
2000
LBLRTM
LBLRTM (Variable trace gases)
Bias (K)
Wave number (cm-1)

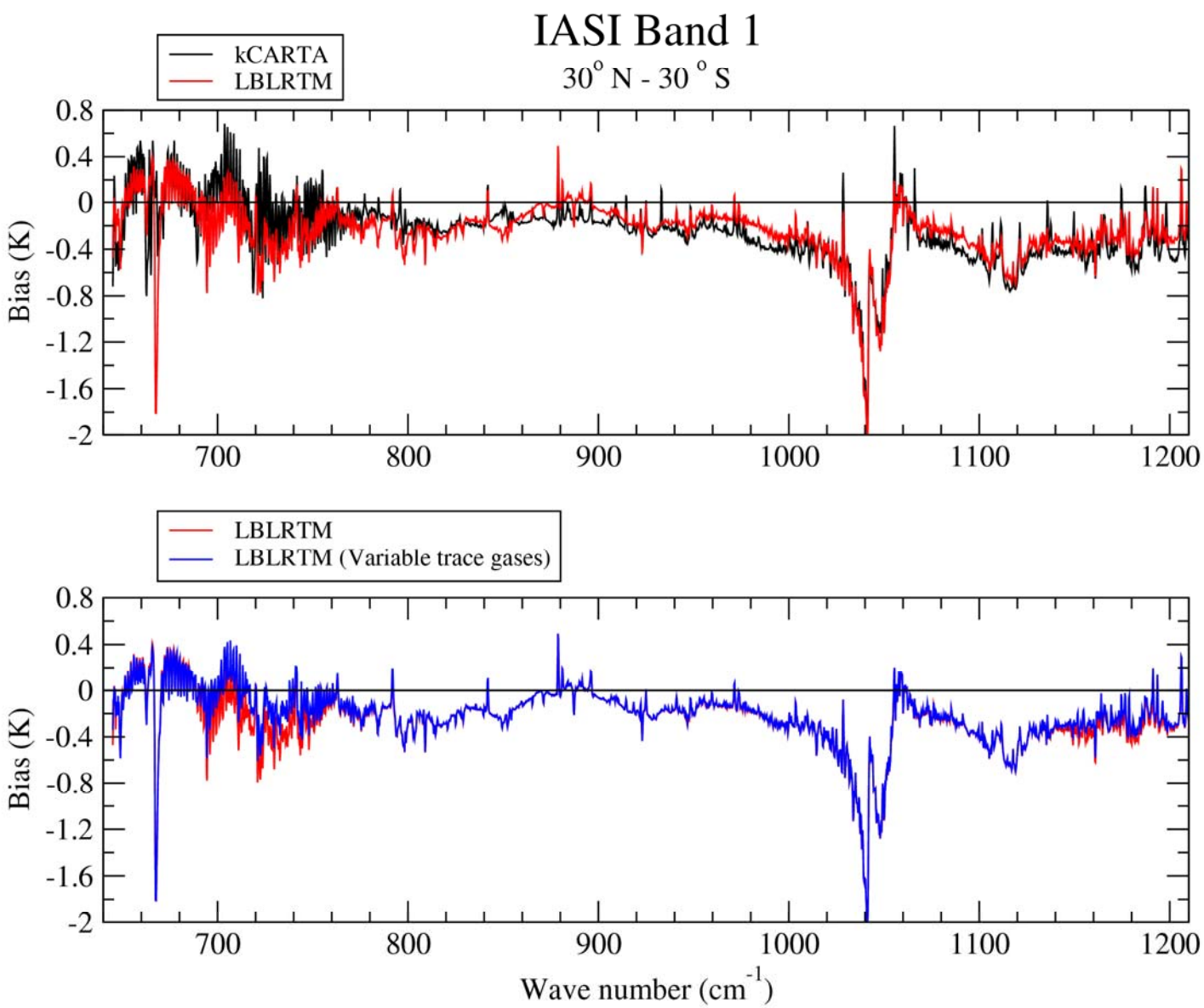

IASI Band 2
30° N - 90 ° N
kCARTA
LBLRTM
Bias (K)
2
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
1400
1600
1800
2000
kCARTA
GENLN2
Bias (K)
Wave number (cm-1)

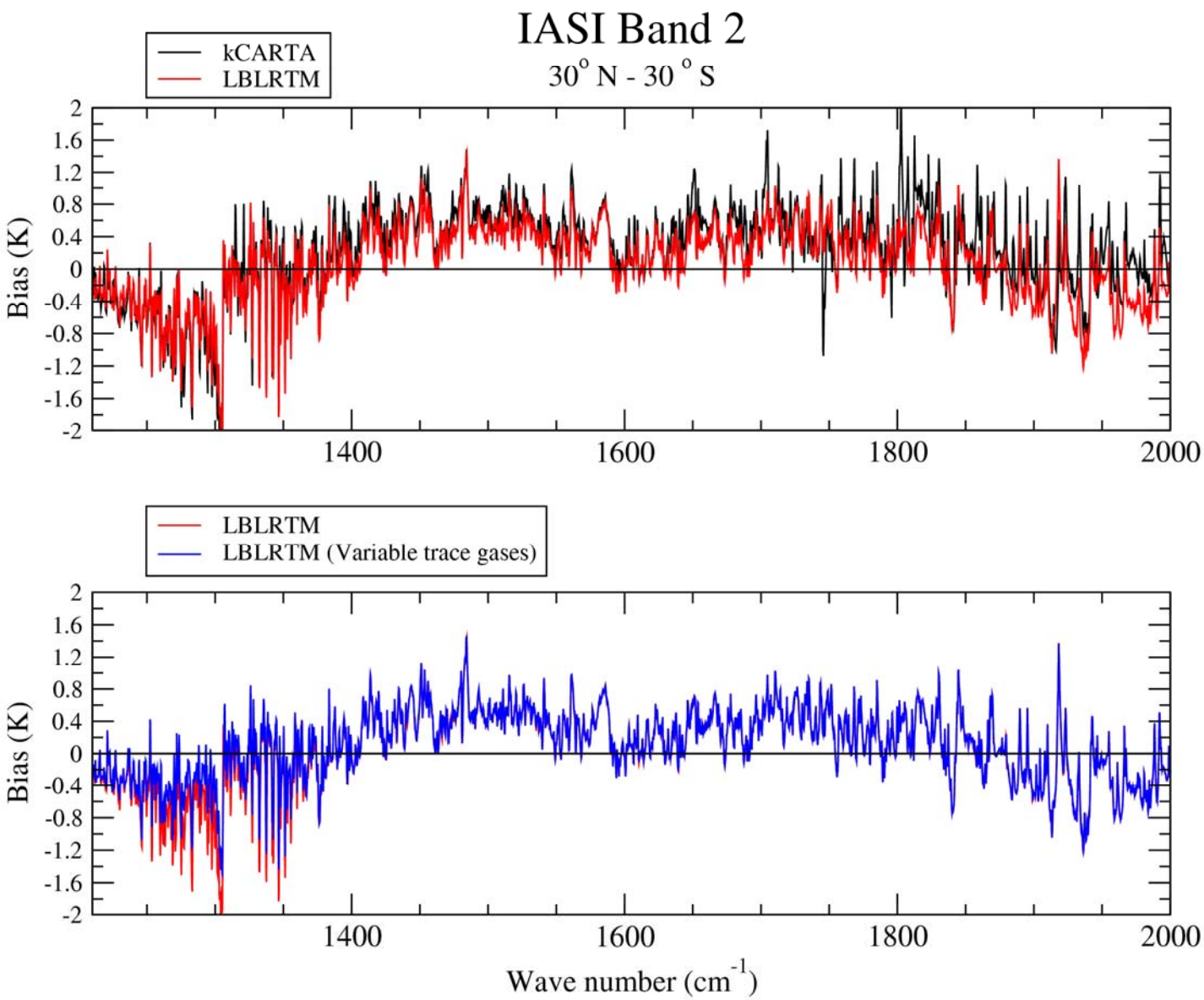

IASI Band 3
30° N - 90 ° N
kCARTA
LBLRTM
Bias (K)
2
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
2000
2200
2400
2600
LBLRTM
LBLRTM (Variable trace gases)
Bias (K)
Wave number (cm-1)

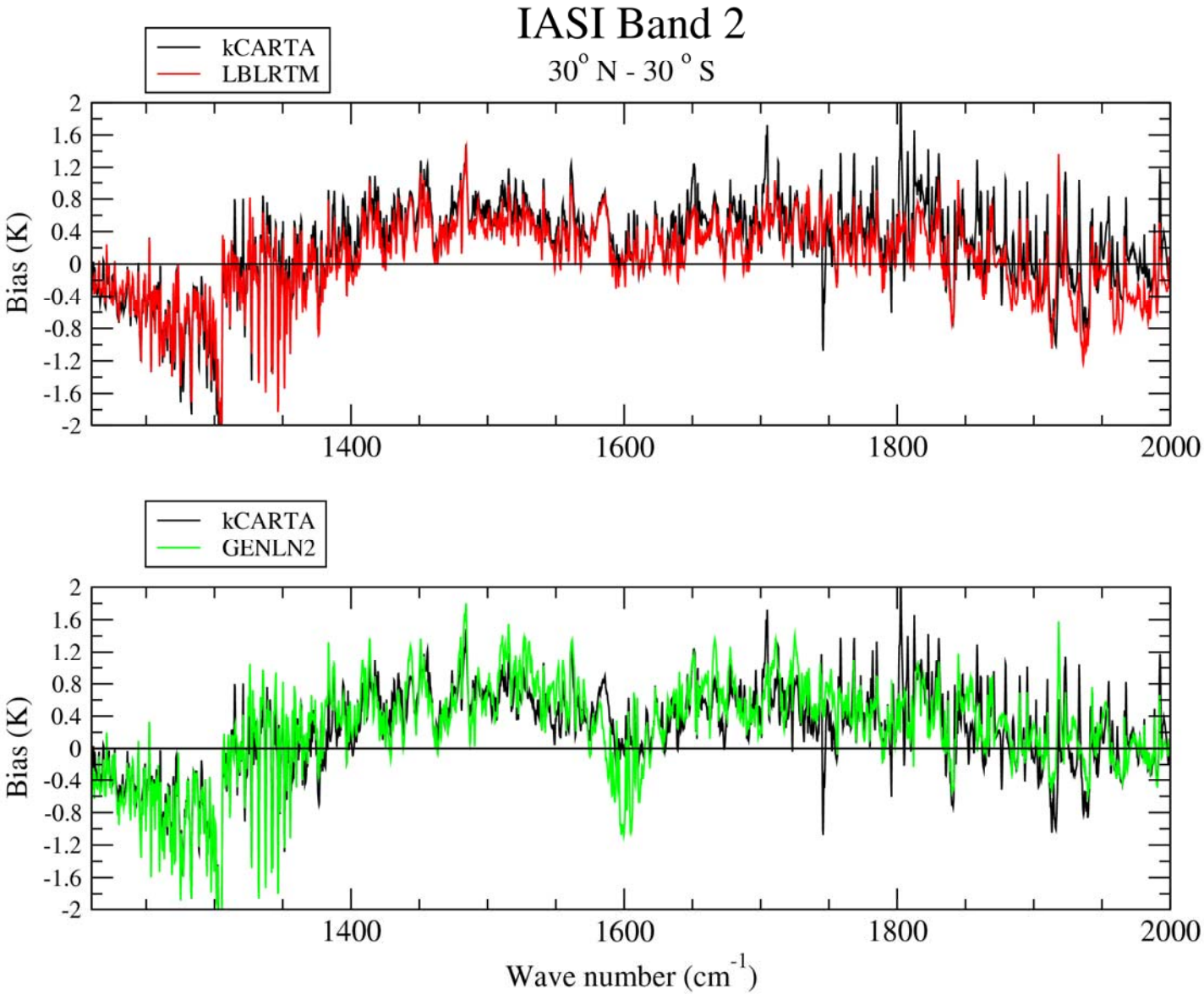

kCARTA
LBLRTM
30° N - 90 ° N
Bias (K)
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
640
660
680
700
720
740
Bias (K)
2
1
0
-1
-2
2000
2020
2040
2060
2080
2100
Bias (K)
2
1
0
-1
-2
1720
1760
1800
1840
1880
Wave number (cm-1)

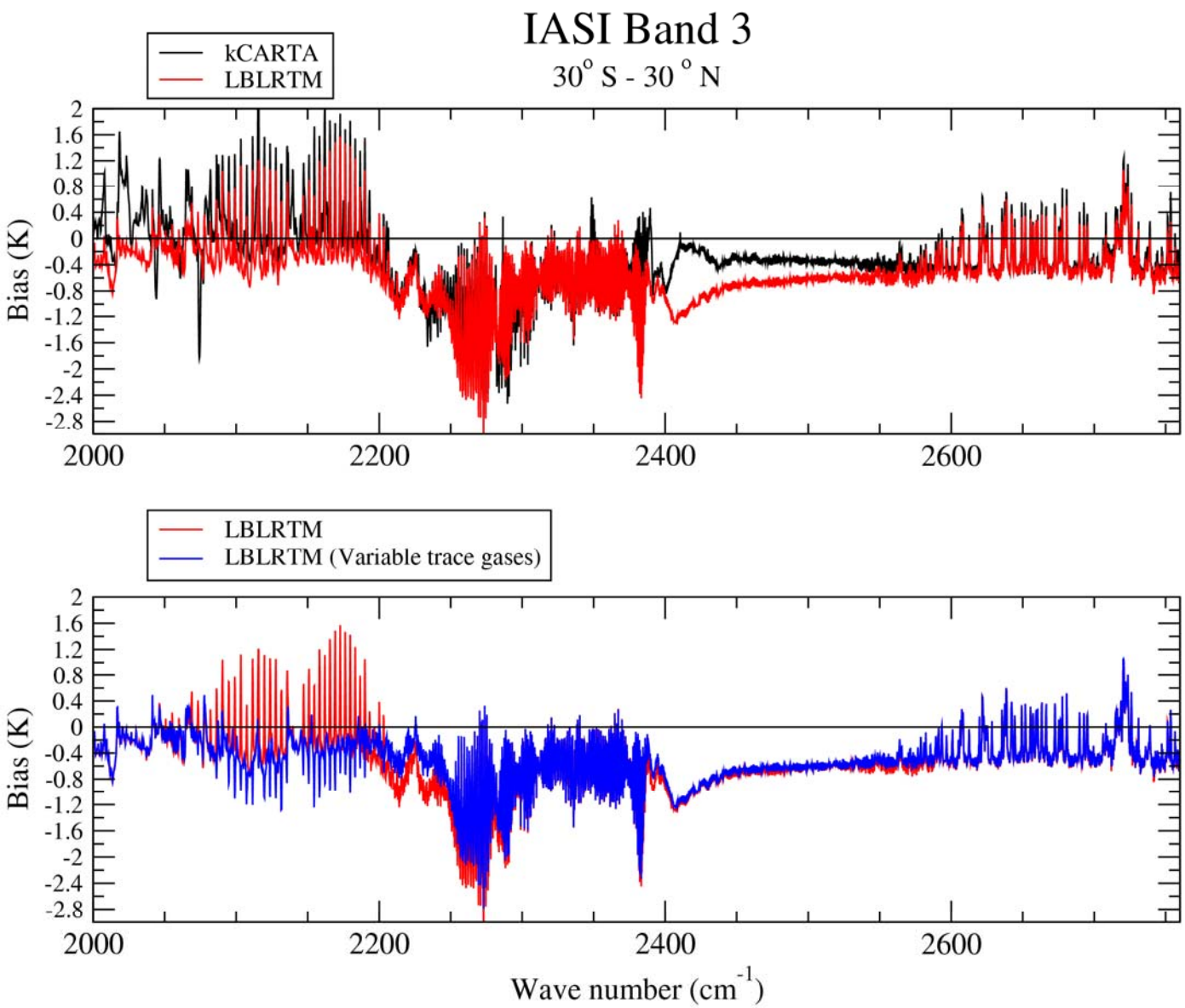

30° N - 30° S
kCARTA
GENLN2
LBLRTM
Bias (K)
Wave number (cm-1)
2
1
0
-1
-2
600
800
1000
1200
1400
1600
1800
2000

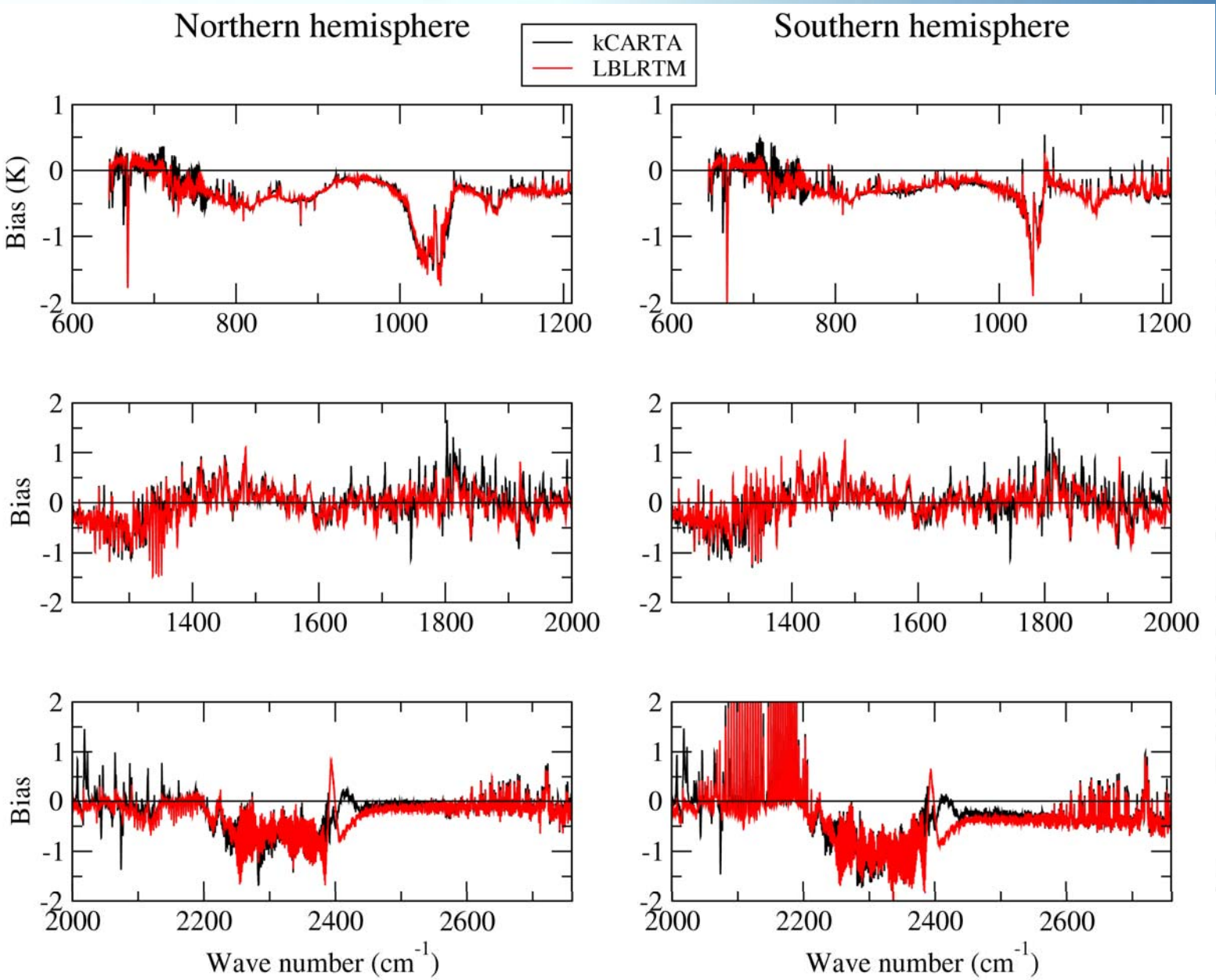

30° N - 30° S
kCARTA
GENLN2
LBLRTM
Bias (K)
Wave number (cm-1)
2
1
0
-1
-2
-3
2000
2100
2200
2300
2400
2500
2600
2700


IASI Band 1
30° N - 30 ° S
kCARTA
LBLRTM
Bias (K)
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
700
800
900
1000
1100
1200
LBLRTM
LBLRTM (Variable trace gases)
Bias (K)
Wave number (cm-1)


IASI Band 2
30° N - 30 ° S
kCARTA
LBLRTM
Bias (K)
2
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
1400
1600
1800
2000
LBLRTM
LBLRTM (Variable trace gases)
Bias (K)
Wave number (cm-1)


IASI Band 2
30° N - 30 ° S
kCARTA
LBLRTM
Bias (K)
2
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
1400
1600
1800
2000
kCARTA
GENLN2
Bias (K)
Wave number (cm-1)


IASI Band 3
30° S - 30 ° N
kCARTA
LBLRTM
Bias (K)
2
1.6
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
-1.6
-2
-2.4
-2.8
2000
2200
2400
2600
LBLRTM
LBLRTM (Variable trace gases)
Bias (K)
Wave number (cm-1)


Northern hemisphere
Southern hemisphere
kCARTA
LBLRTM
Bias (K)
Bias
Wave number (cm-1)