Two-Dimensional performance of MIPAS observation modes in the UTLS

M. Carlotti, E. Papandrea
Dip. Chimica Fisica e Inorganica, University of Bologna

Introductory remarks

- MIPAS can measure the atmosphere with seven observation modes,

- two of them (UTLS-1 and UTLS-2) have been expressly designed for the UTLS region,

- the “nominal” mode (NOM operated for most of the instrument’s measuring time) also sounds the UTLS,

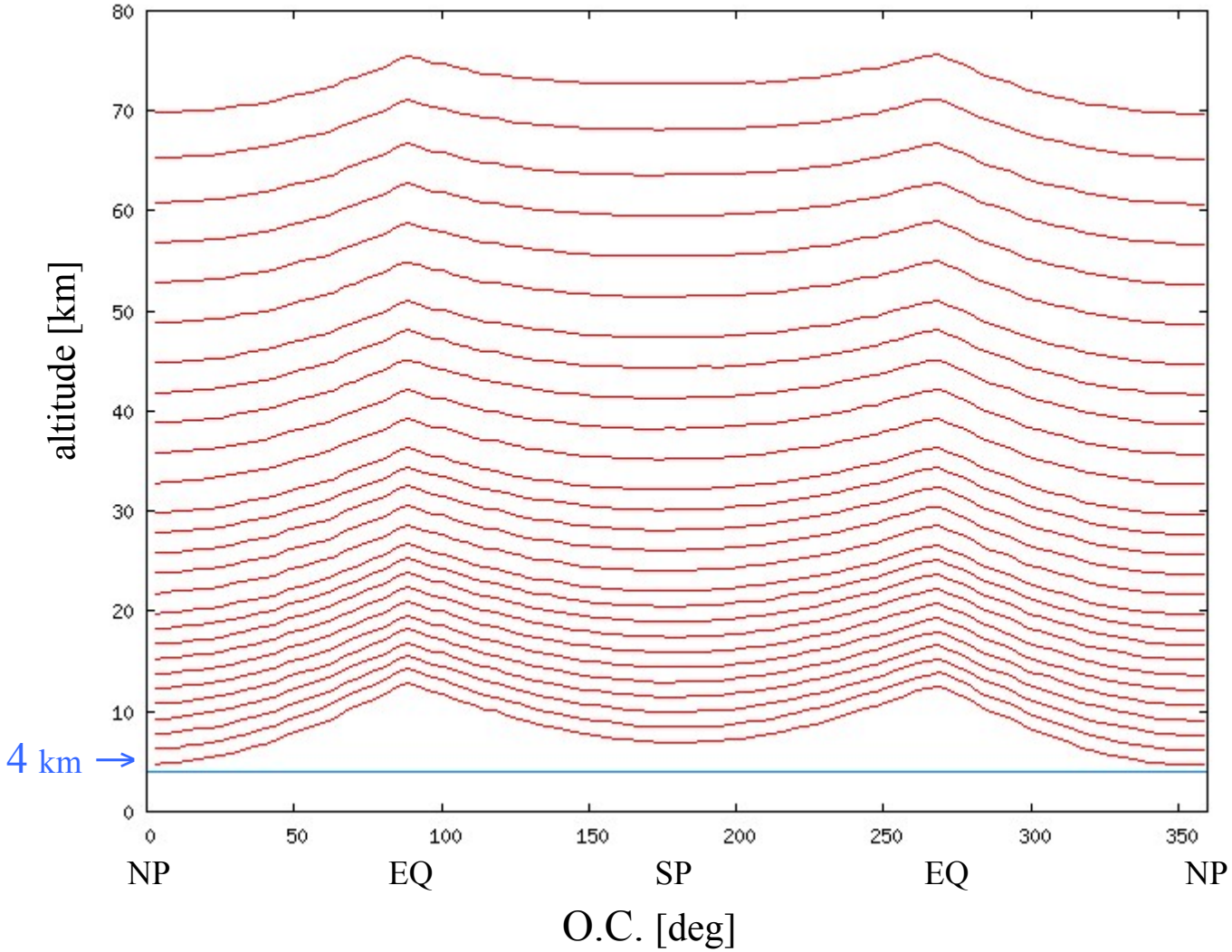
- the three observation modes differ in the limb-scanning pattern at high altitudes therefore, due to the different measuring time required by a single limb scan, they operate different samplings of the atmosphere in the horizontal domain,

- all current MIPAS observation modes that have been designed:
  - on the basis of geometrical considerations only,
  - for 1D analysis.

NOM observation mode 96 scans , 27 sweeps per scan

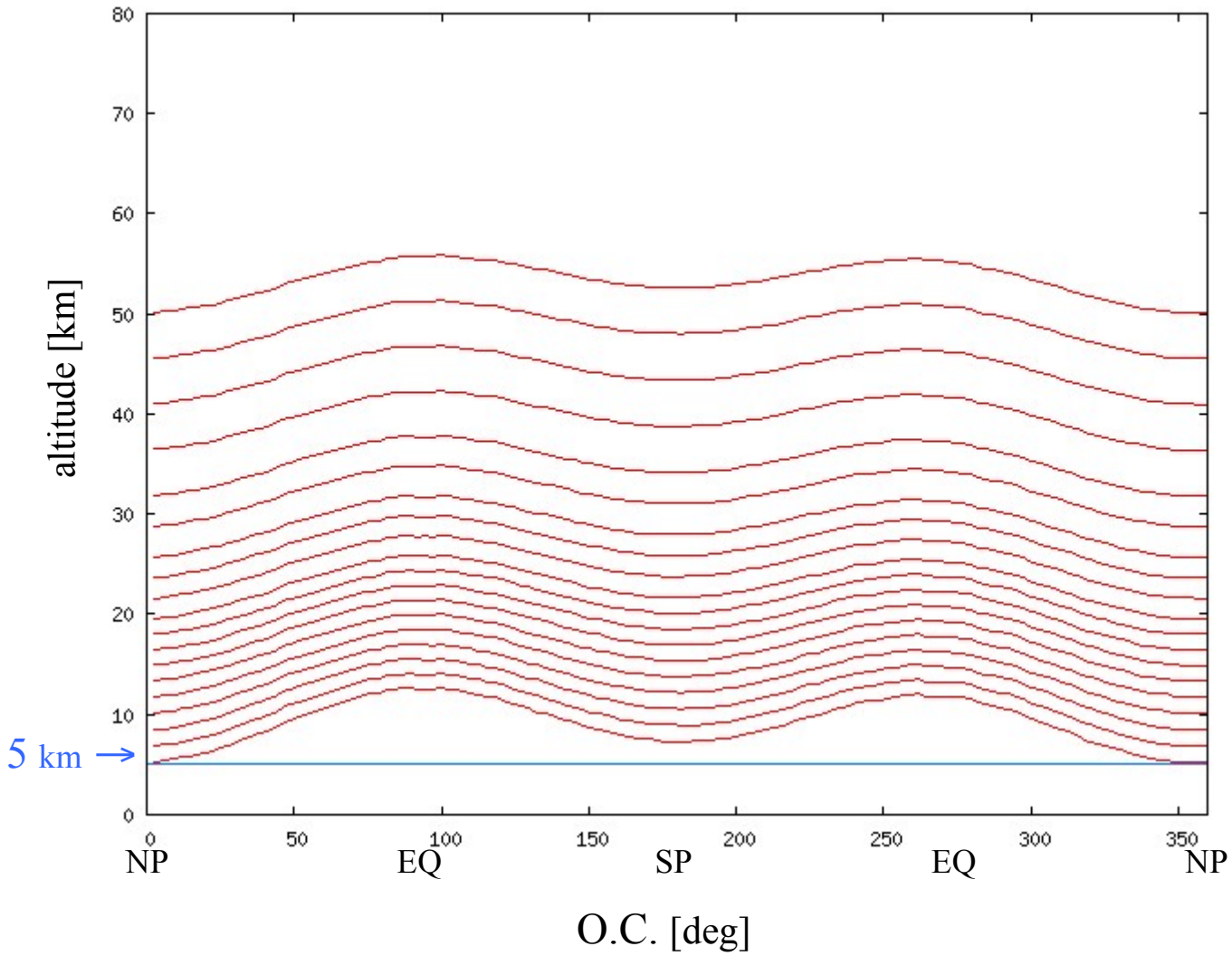
6, 7.5, 9, 10.5, 12, 13.5, 15, 16.5, 18, 19.5, 21, 23, 25, 27, 29, 31, 34, 37, 40, 43, 46, 50, 54, 58, 62, 66, 70 km

average scan-to-scan separation: 3.6° ~ 400 km



UTLS-1 observation mode 125 scans , 19 sweeps per scan

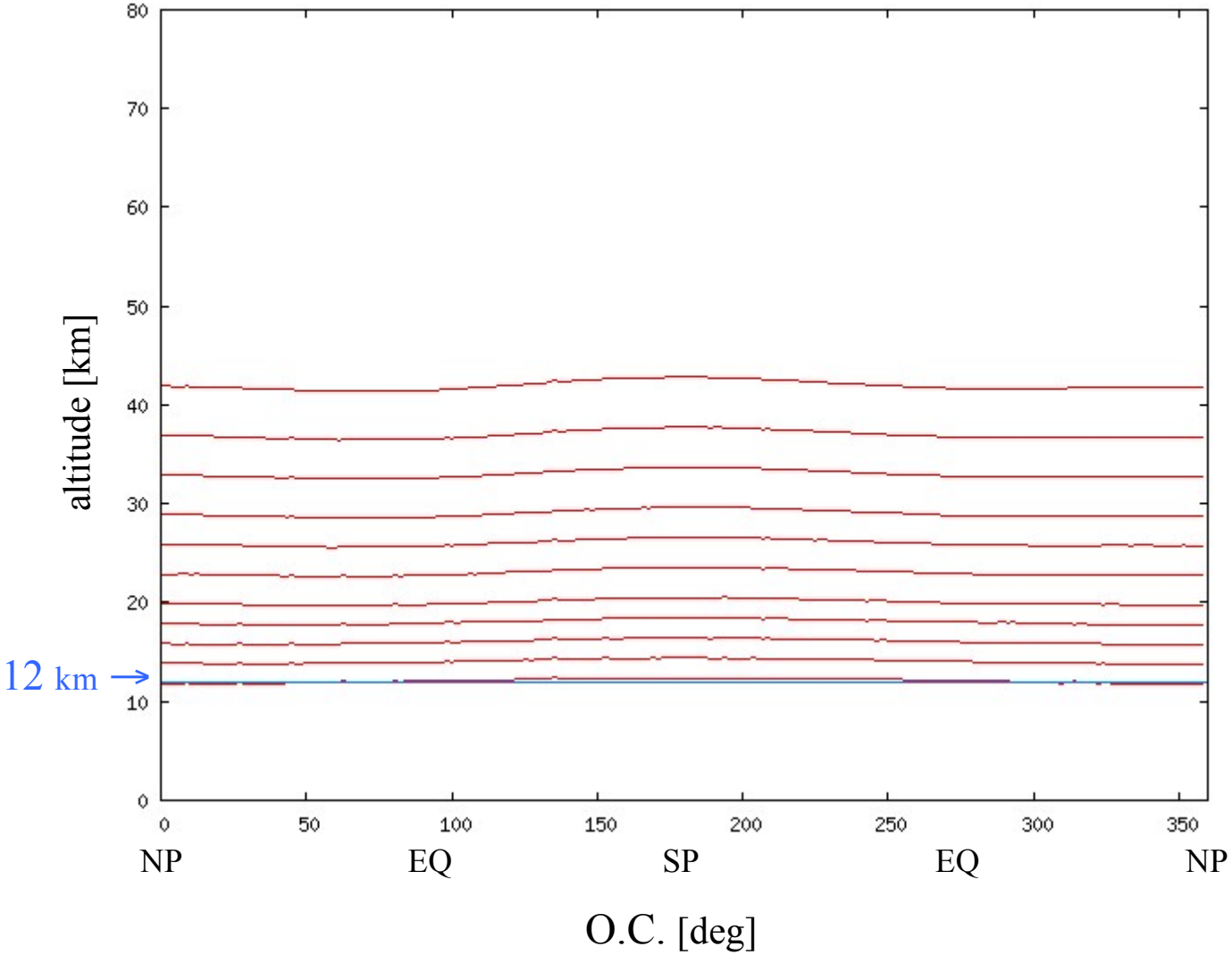
average scan-to-scan separation: 2.6º ~ 290 km



UTLS-2 orbit 213 scans , 11 sweeps per scan

12, 13.5, 15, 16.5, 18, 19.5, 21, 23, 29, 35, 41 km

average scan-to-scan separation: 1.6° ~ 180 km



objective

Compare the performance of the three observation modes in the UTLS when a 2D approach is exploited to derive the atmospheric field of geophysical parameters in the UTLS.

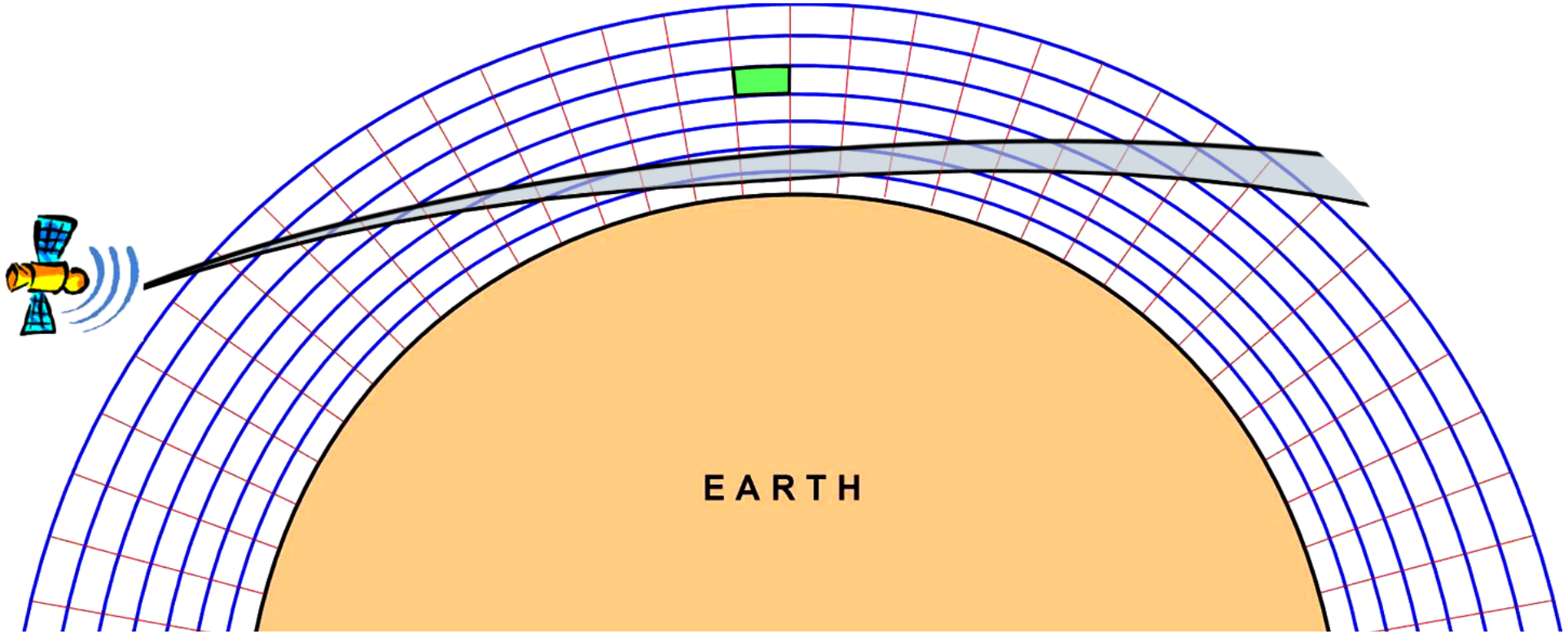
strategy

For the three observation modes evaluate:

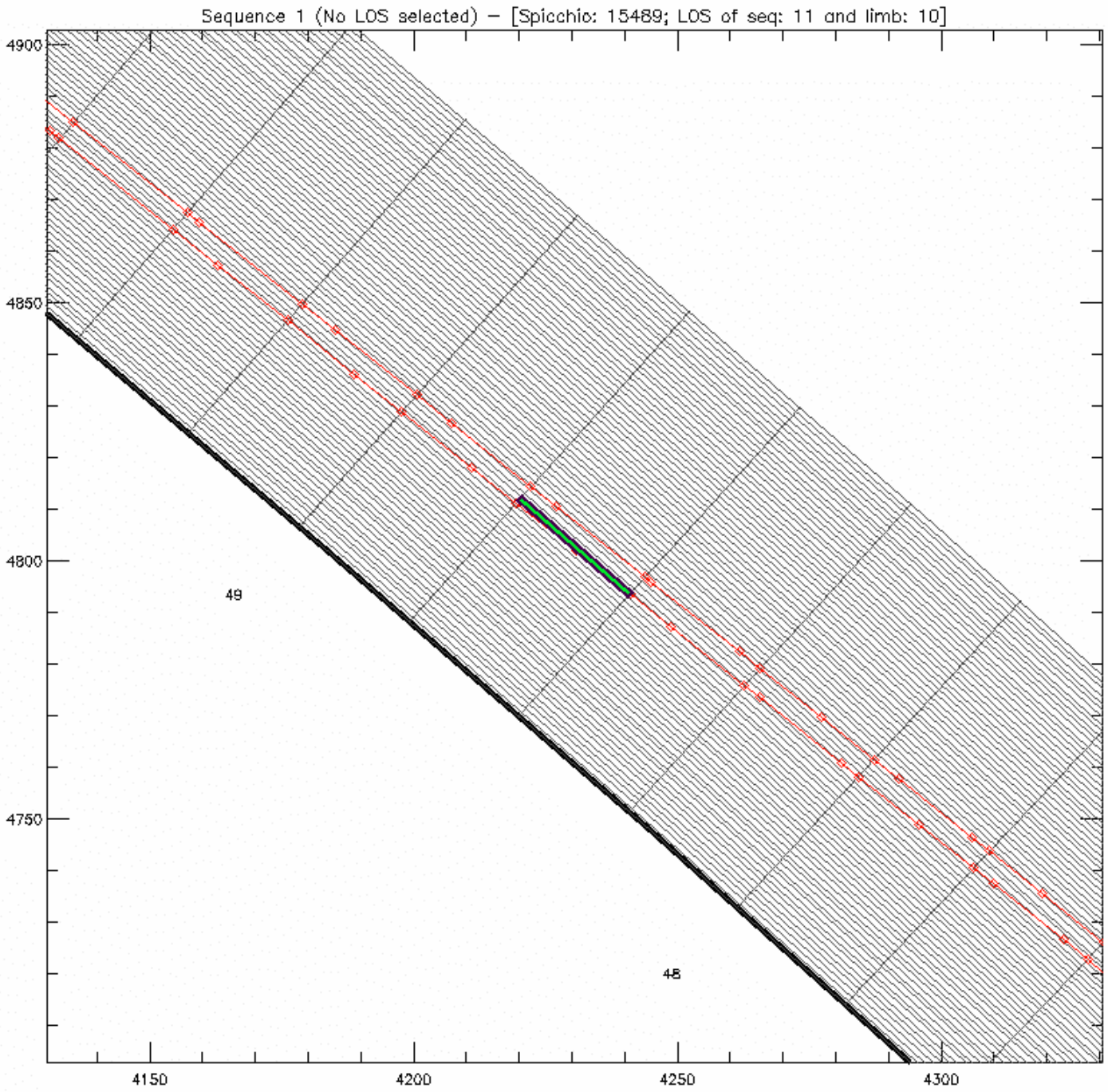
i) Information Load distribution,
ii) precision,
iii) spatial resolution (*horizontal and vertical*)

of the retrieval products.

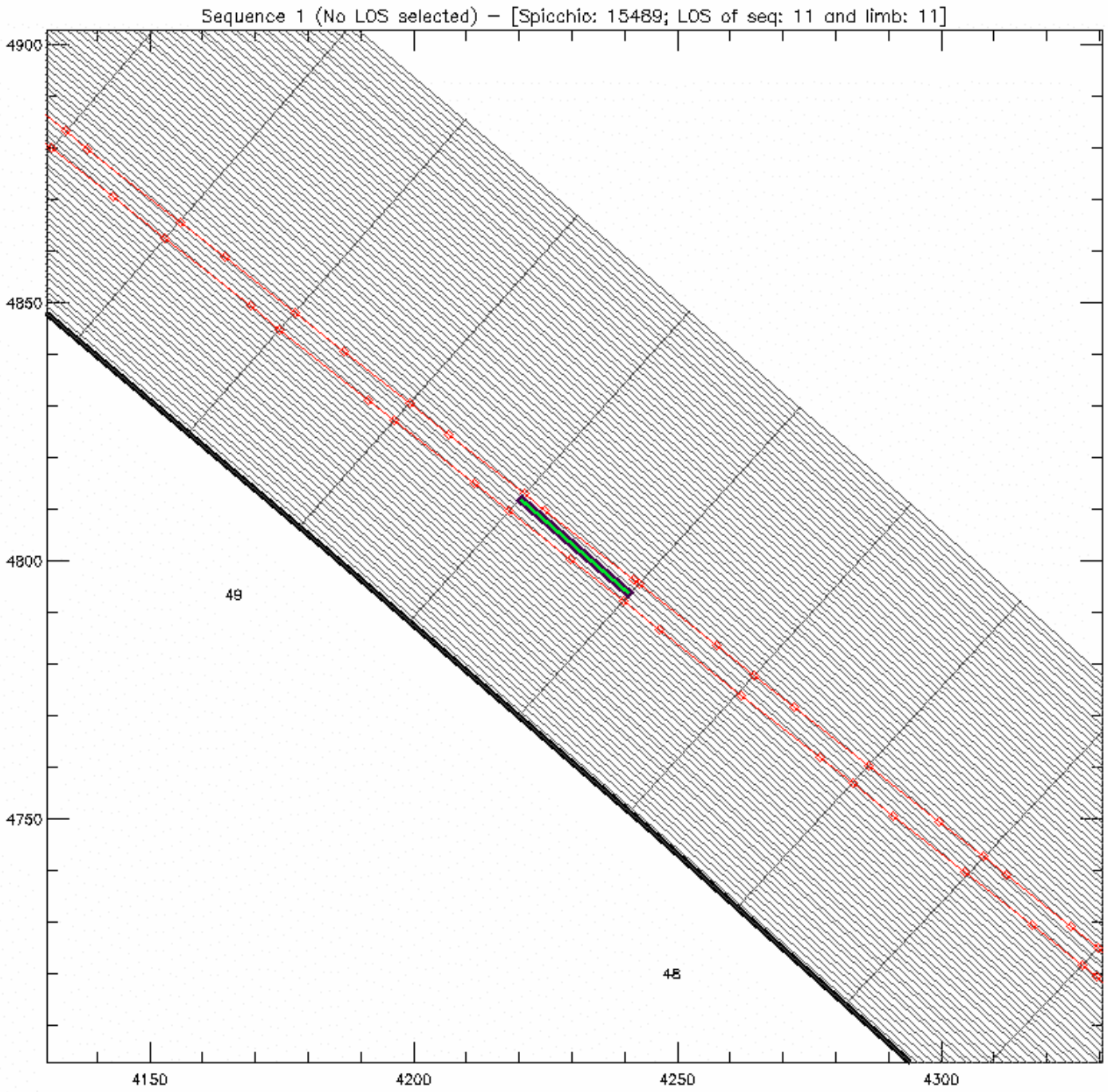
2D discretization of the atmosphere



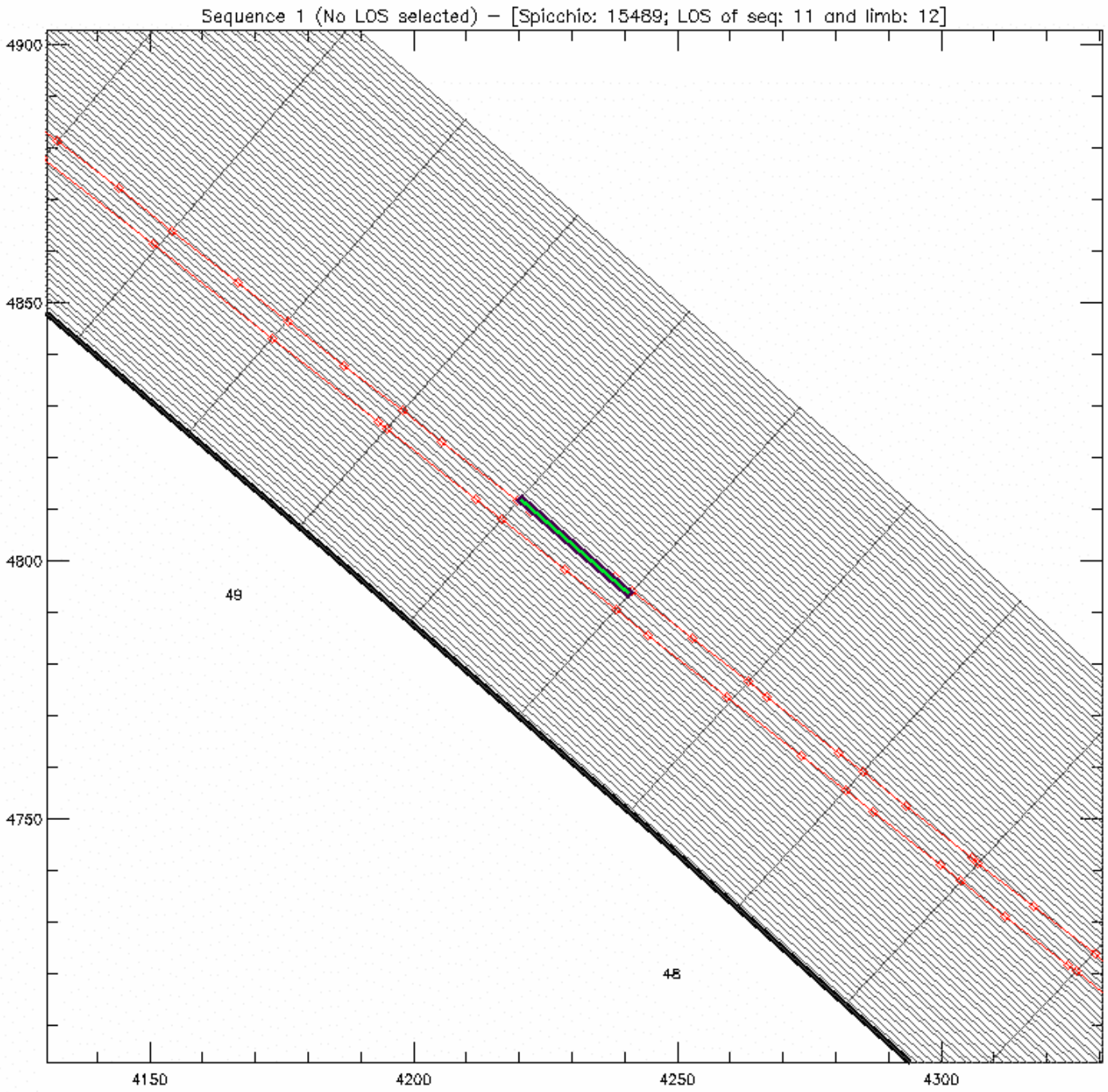
1 km layers
0.25 deg radii



1 km layers
0.25 deg radii



1 km layers
0.25 deg radii



Information Load (Ω)

M. Carlotti, L. Magnani, Optics Express, 17, 5340-5357, 2009

$$\Omega(q,h) = \left[\sum_{i=1}^{l} \sum_{j=1}^{m} \sum_{k=1}^{n} \left(\frac{\partial S_{ijk}}{\partial q_h} \right)^2 \right]^{1/2}$$

$\Omega(q,h)$ = overall information load of clove h with respect to atmospheric parameter q,

S_{ijk} = spectral signal of observation geometry i at frequency j of the analyzed MW k,

l = number of observation geometries that define the multiplicity of clove h.

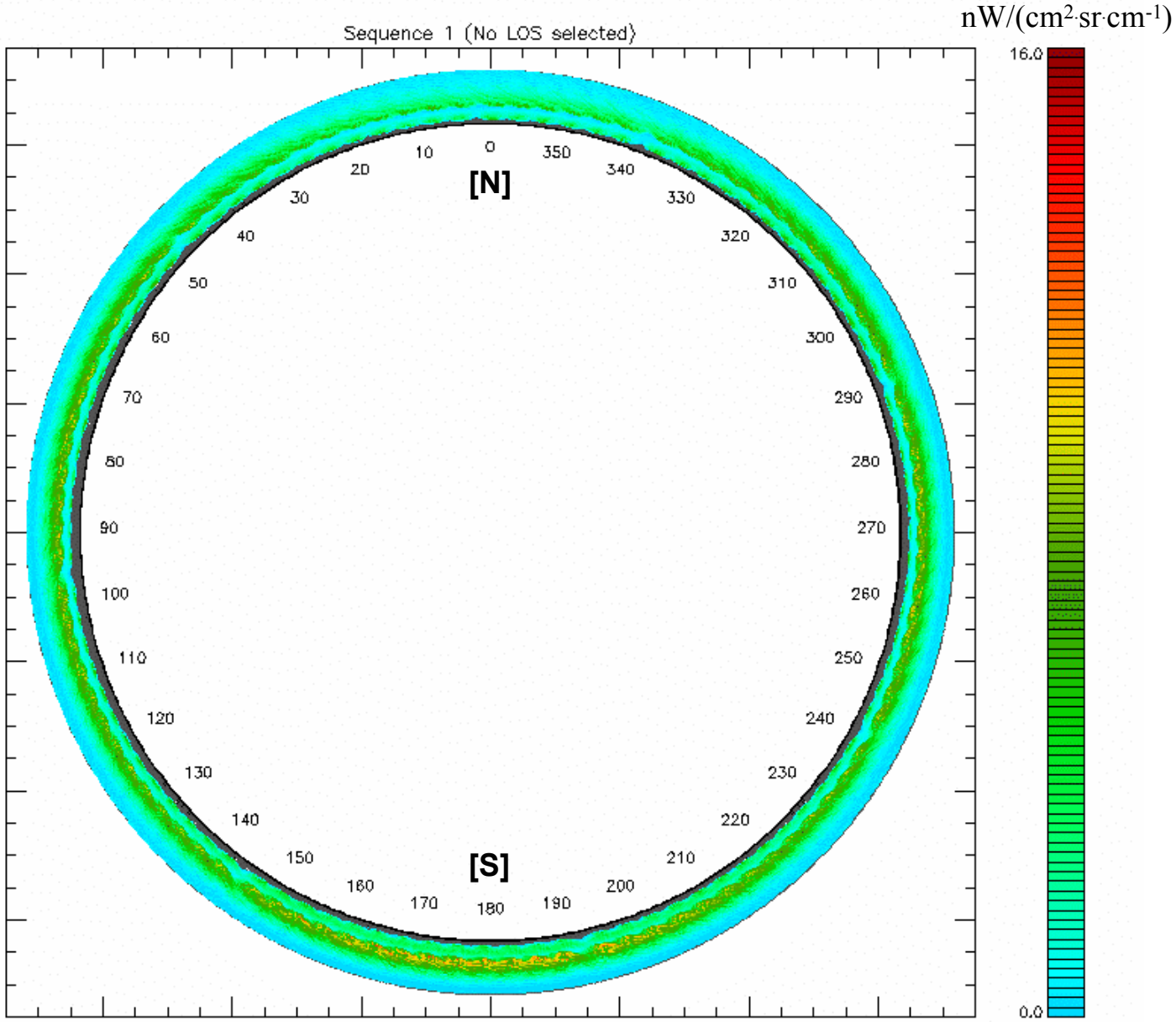
m = number of analyzed MWs in observation geometry i,

n = number of spectral points in MW j,

In a 2D analysis $1/\Omega$ is proportional to the uncertainty on the value of parameter q in clove h (assuming uncorrelated observations all characterized by constant uncertainty).

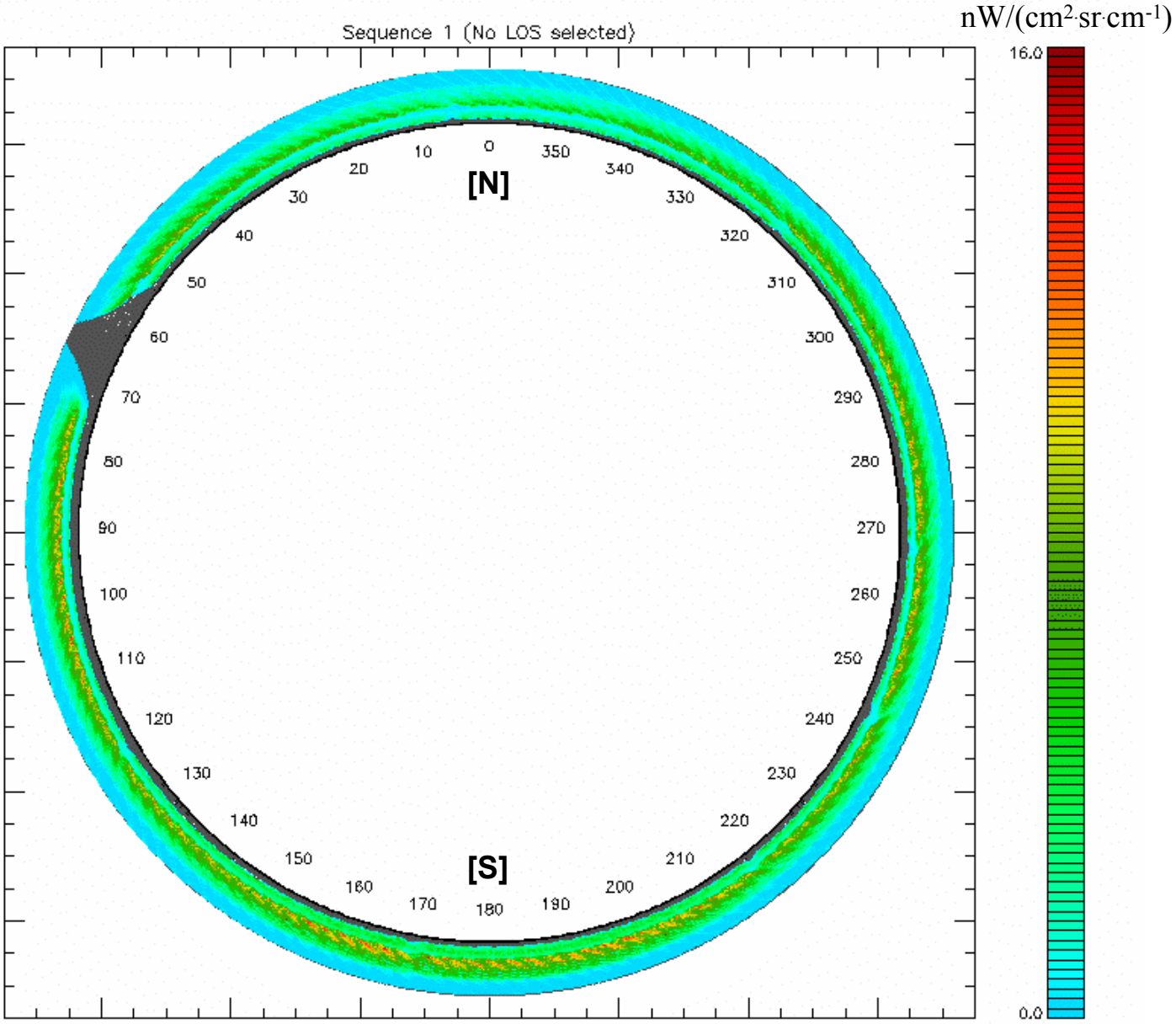
NOM Jan. atmosphere

Ω distribution for T



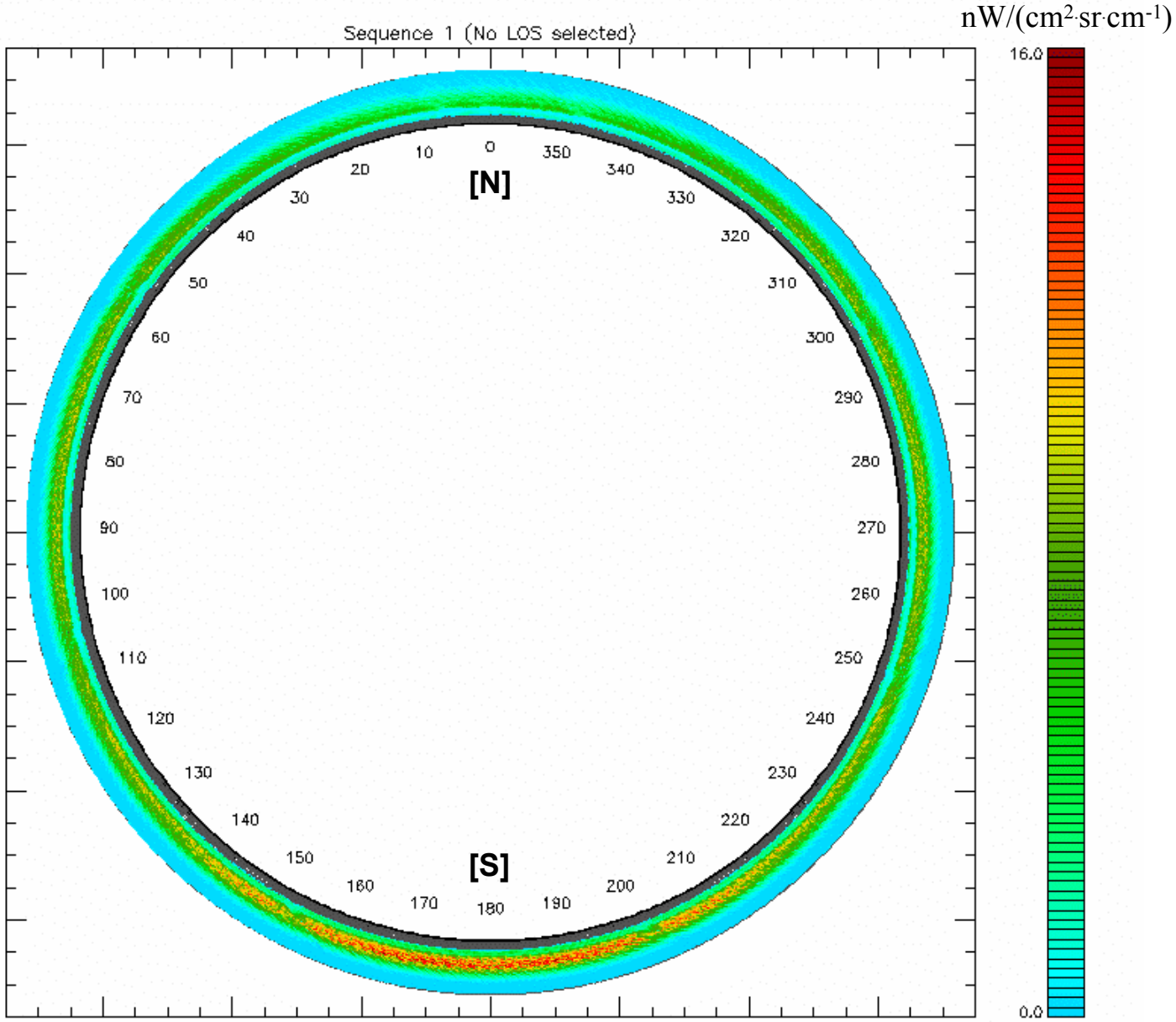
UTLS-1 Jan. atmosphere

Ω distribution for T



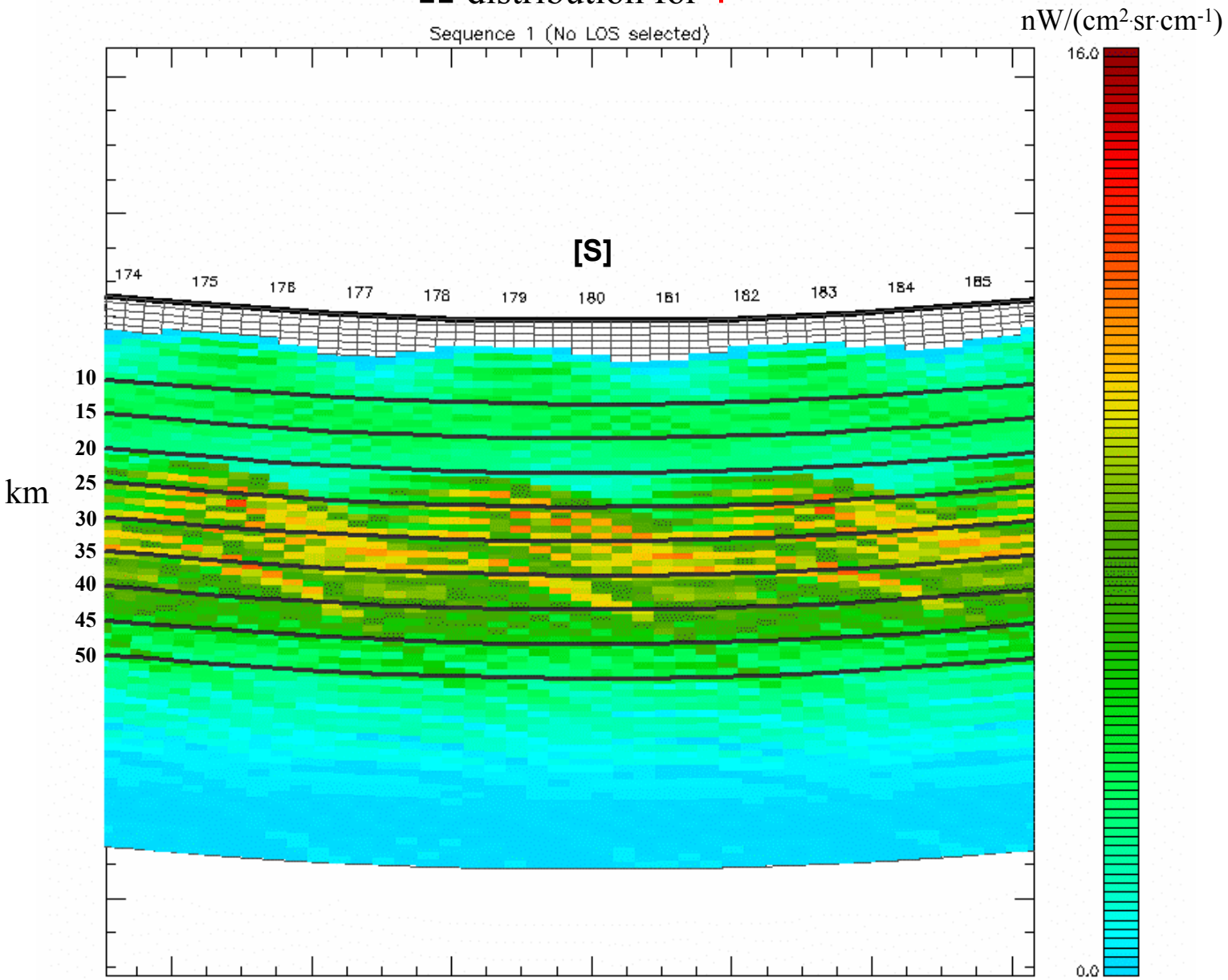
UTLS-2 Jan. atmosphere

Ω distribution for T



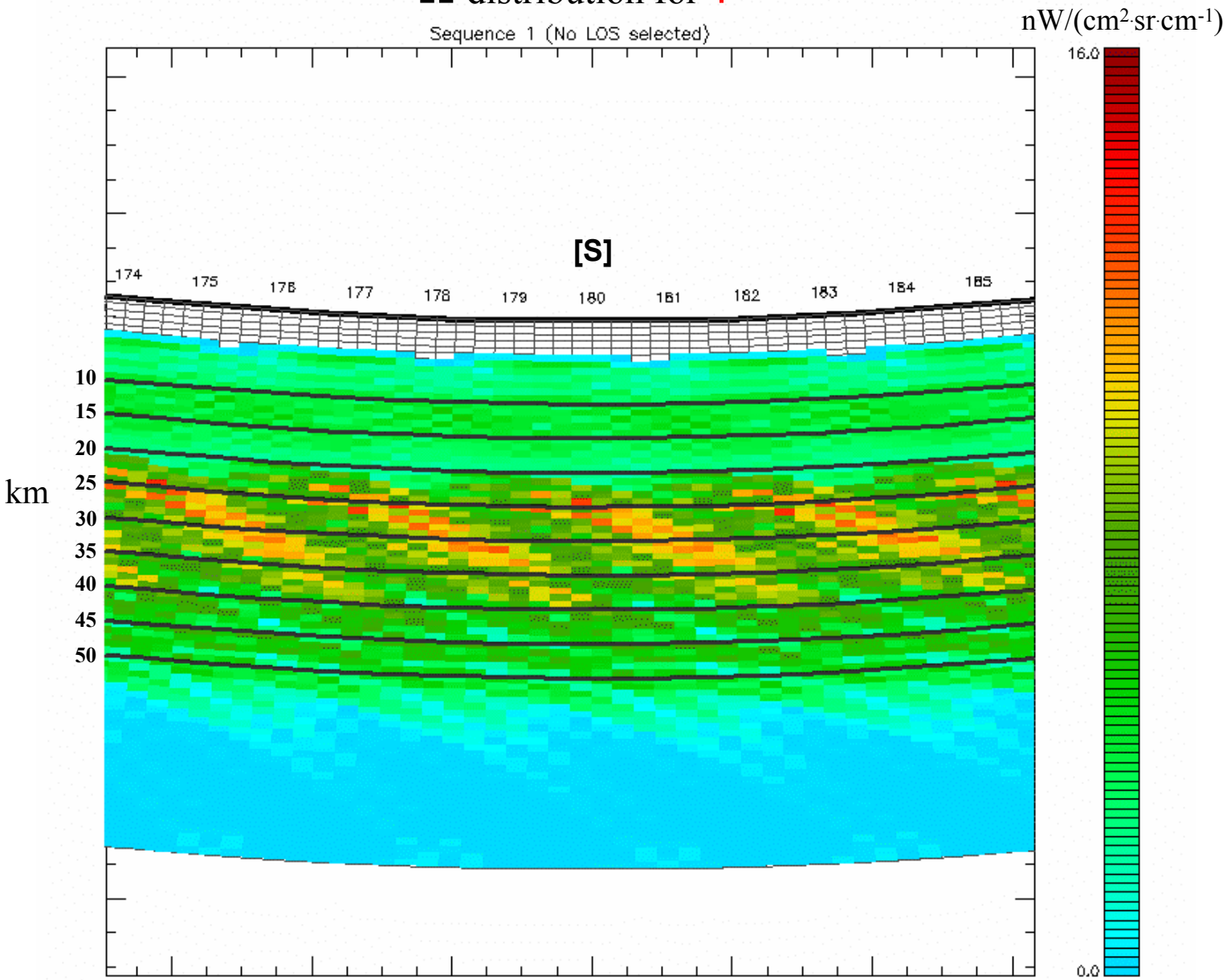
NOM

Ω distribution for T



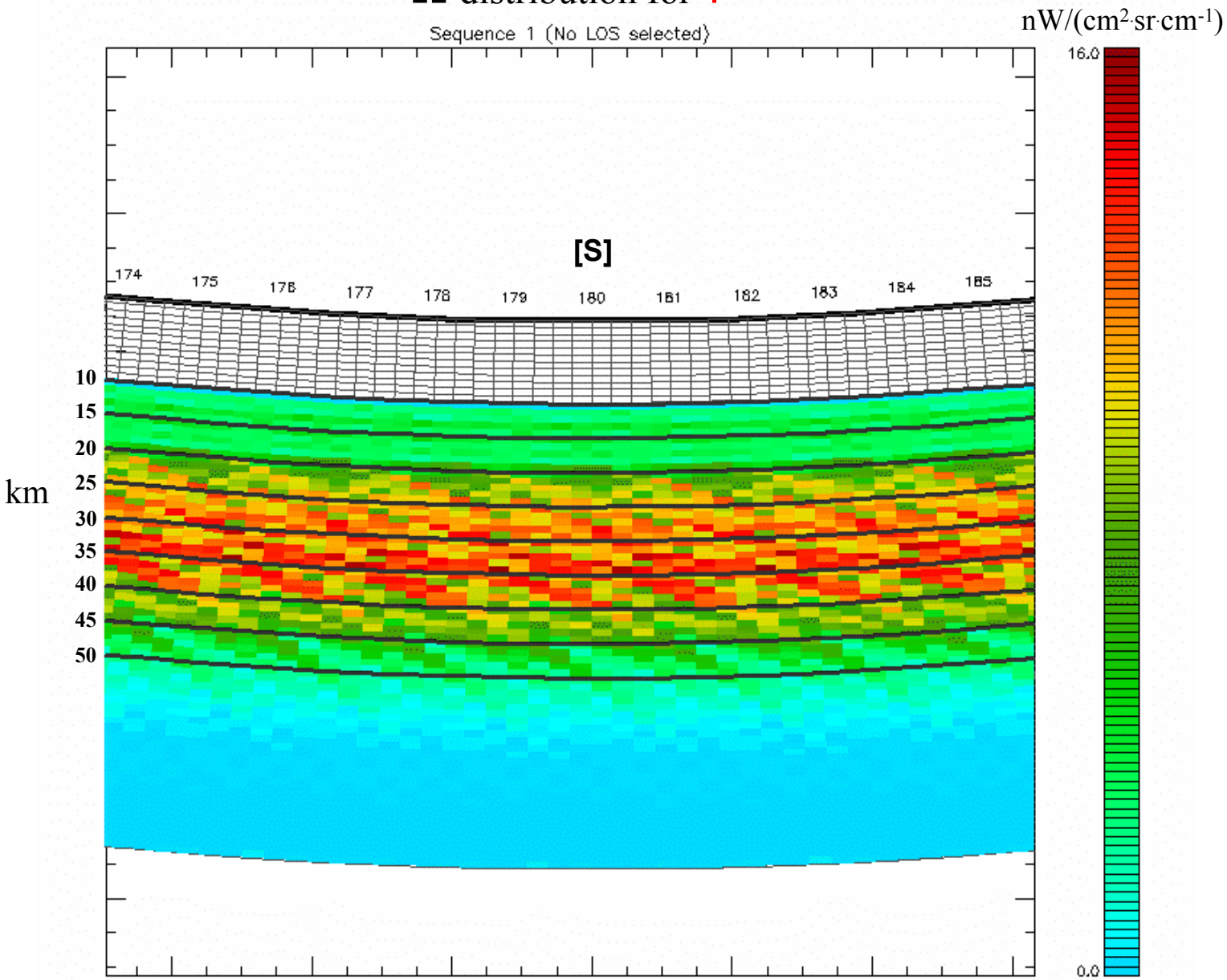
UTLS-1

Ω distribution for T



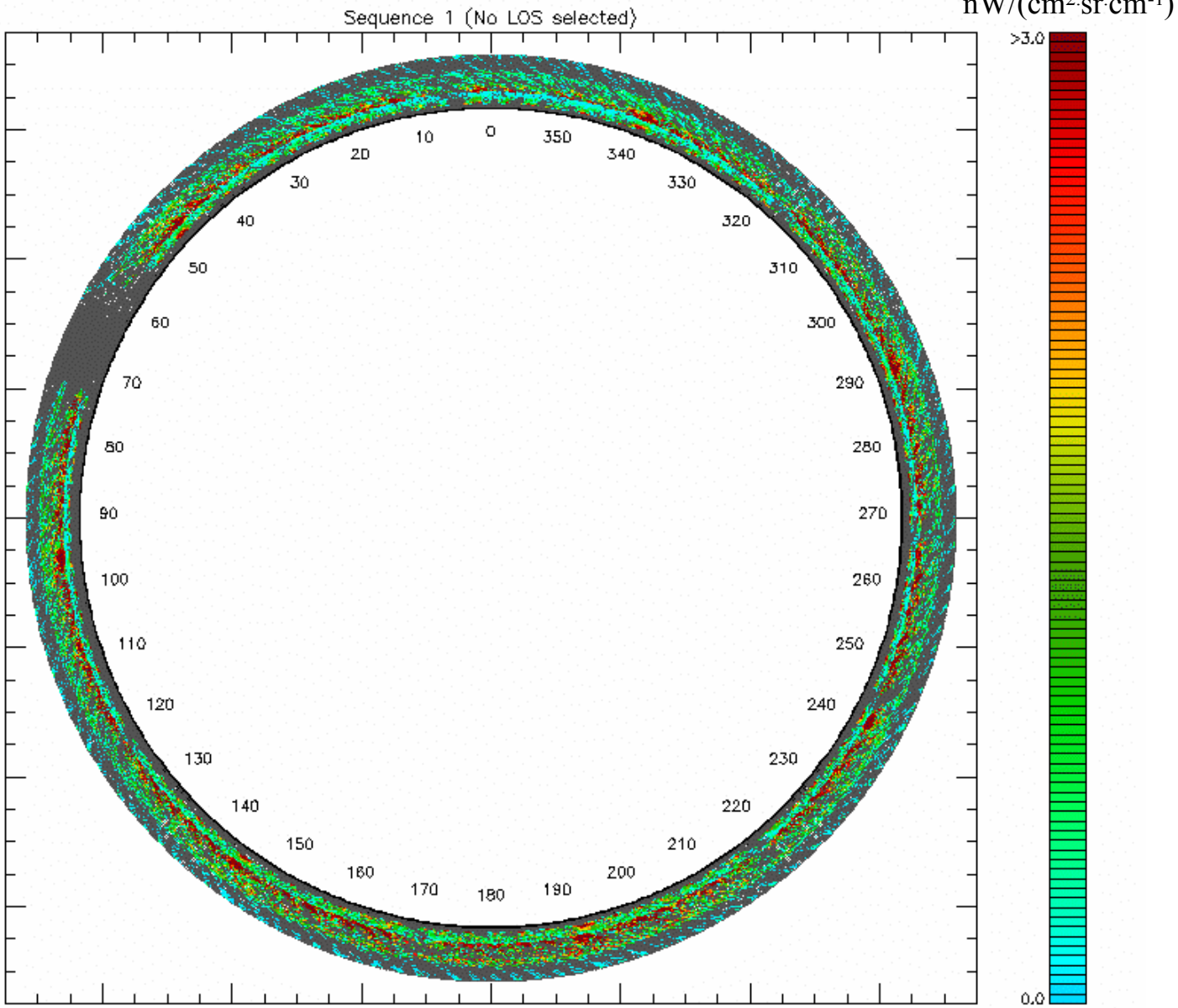
UTLS-2

Ω distribution for T



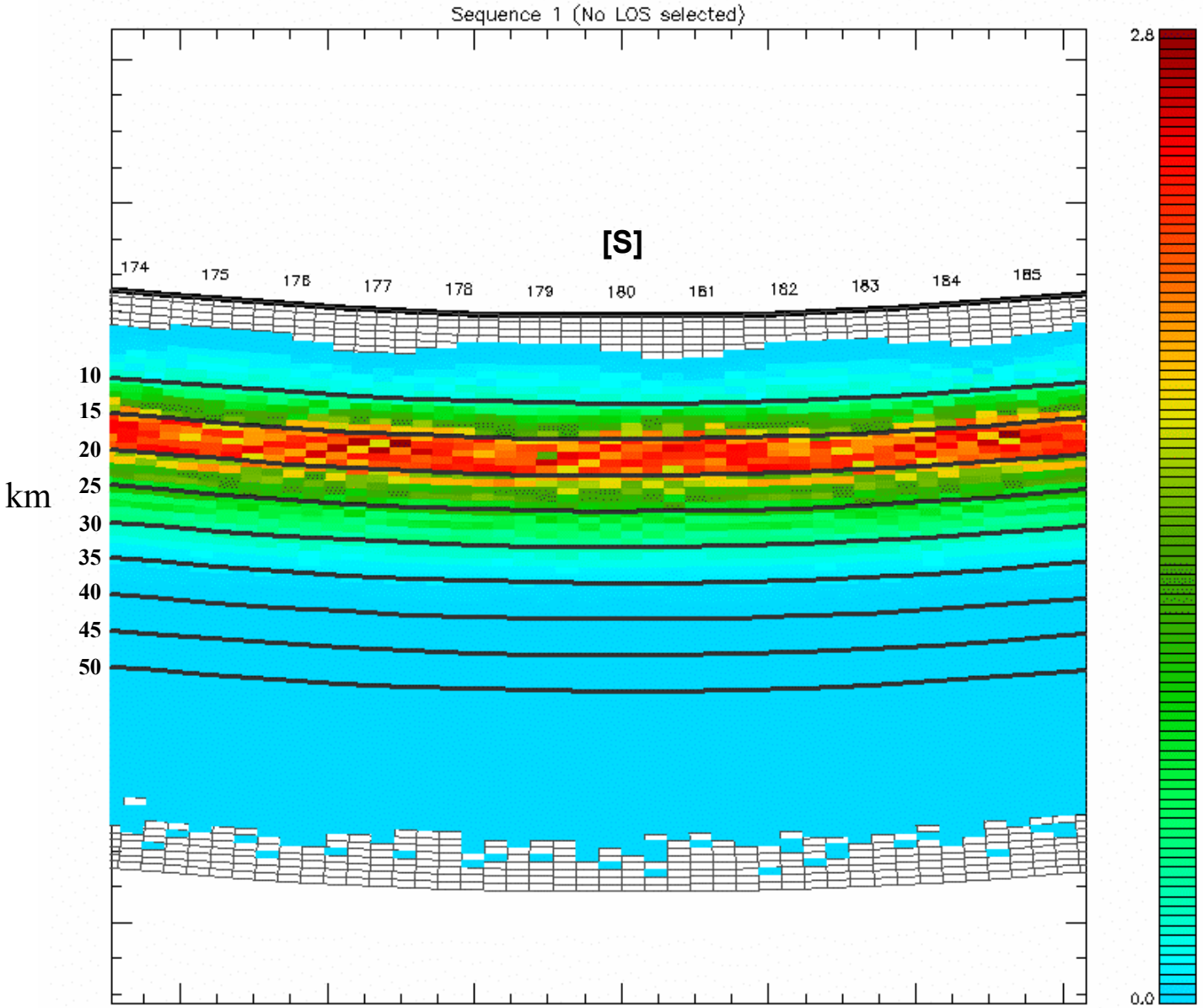
T

Ω (UTLS-1) - Ω (NOM) *positive values*



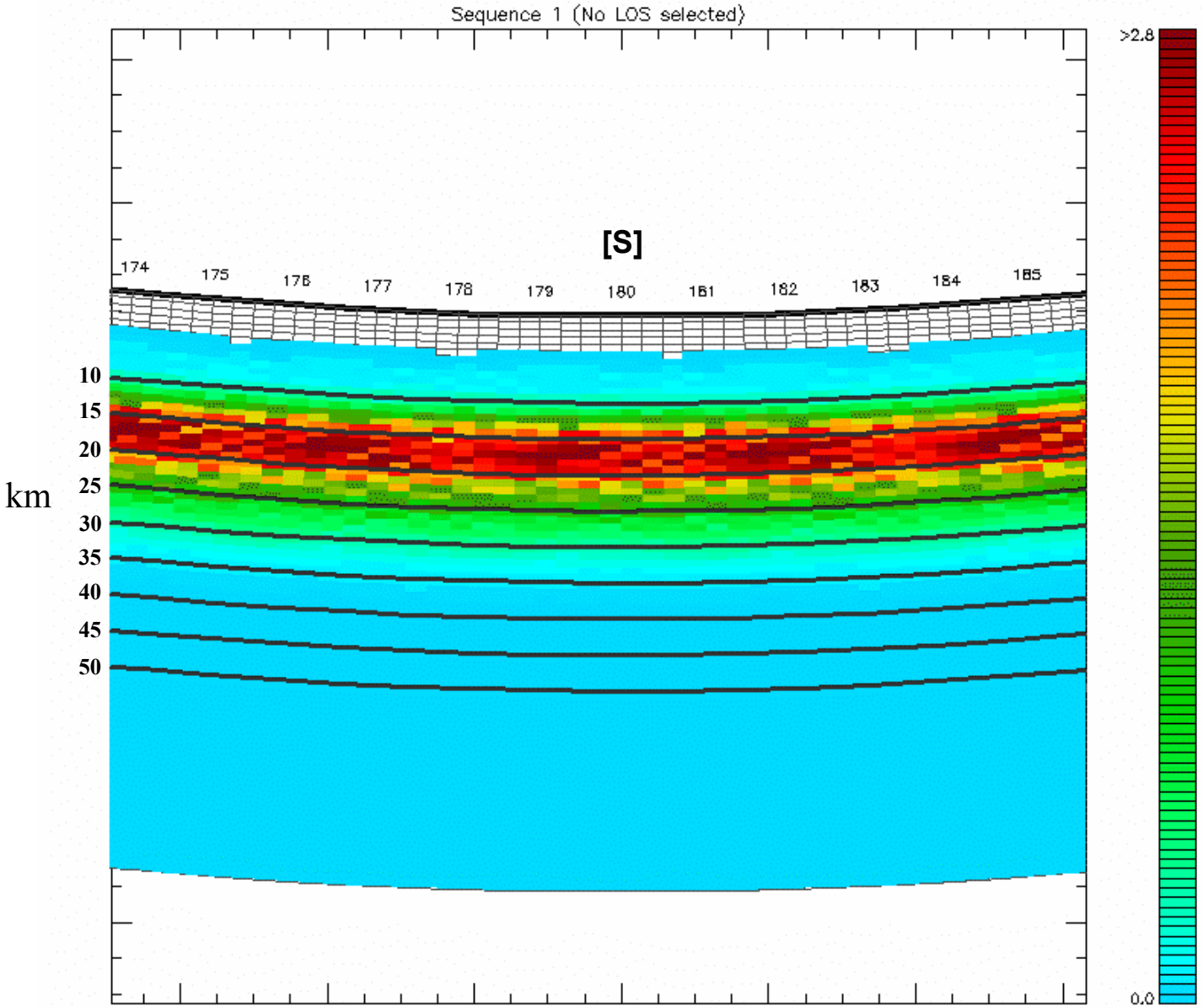
NOM

Ω distribution for HNO_3



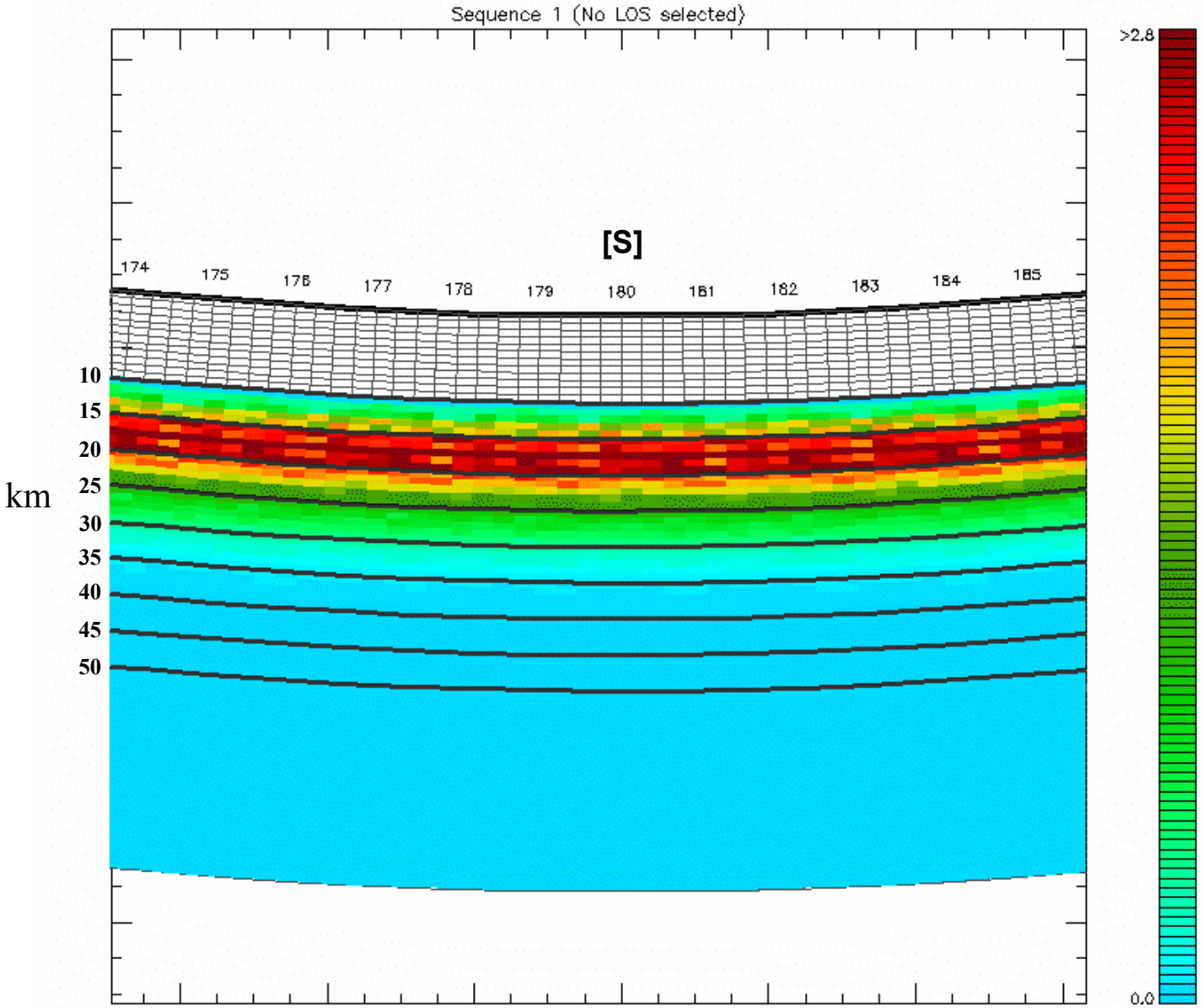
UTLS-1

Ω distribution for HNO_3



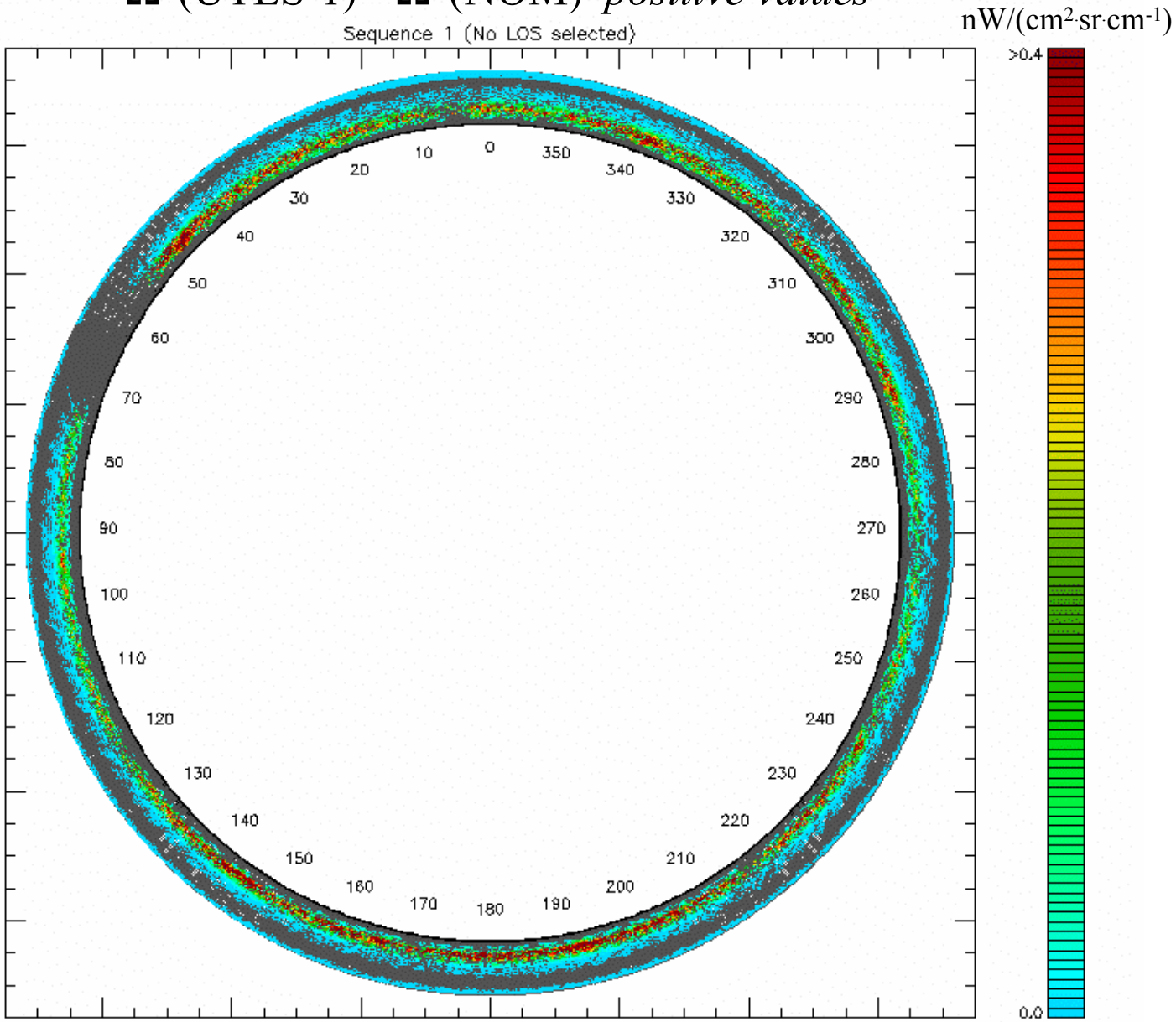
UTLS-2

Ω distribution for HNO_3



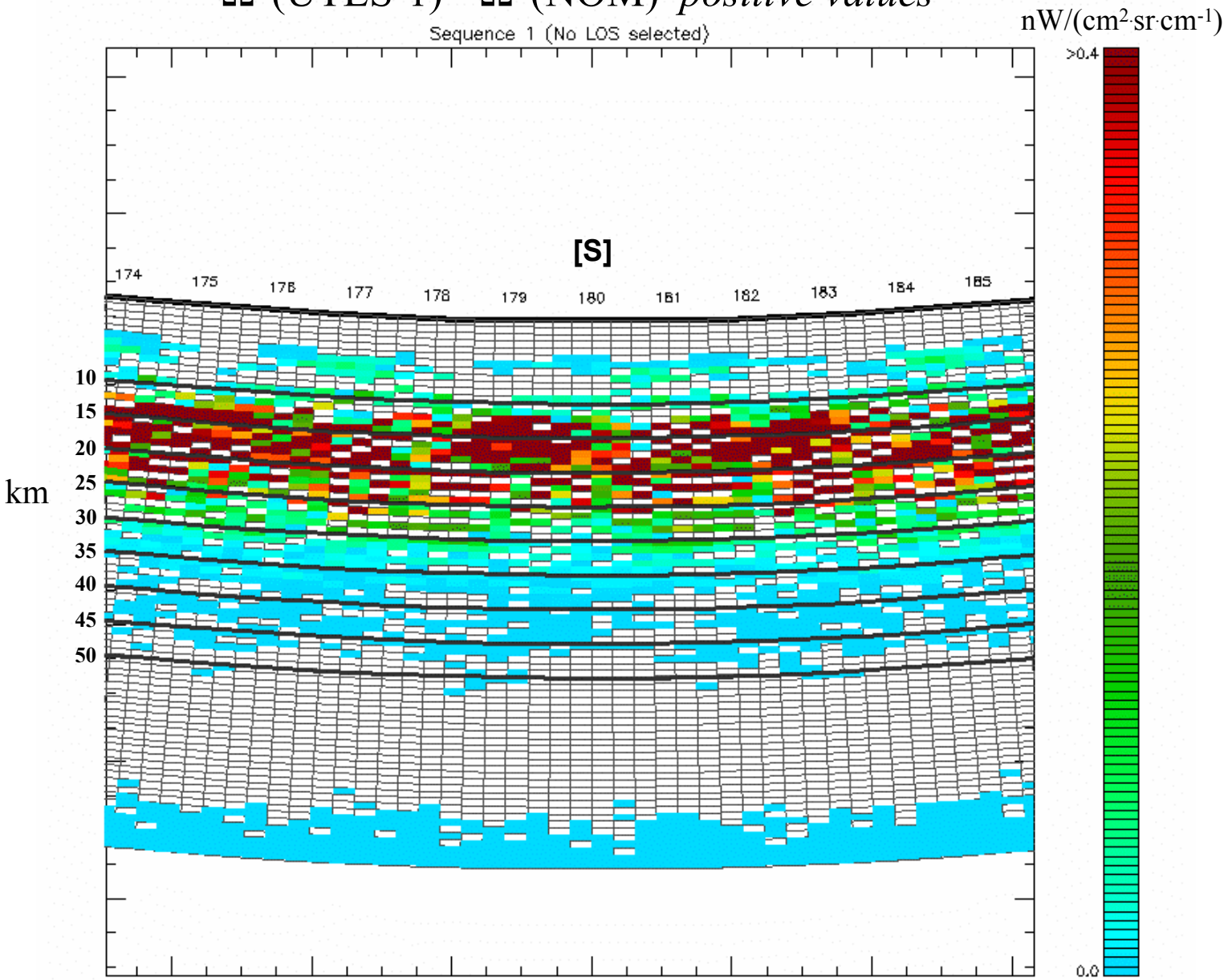
HNO_3

Ω (UTLS-1) - Ω (NOM) *positive values*



HNO_3

Ω (UTLS-1) - Ω (NOM) *positive values*



The information load analysis suggests that the performance of UTLS modes could be competitive with NOM in its full altitude range.

Simulated retrievals

comparison of the performance of

NOM, UTLS-1, UTLS-2

1- Generate simulated observations for obs. parameters of a real reference orbit,

2- add random noise using noise levels of the reference orbit,

3- perform the retrieval analysis starting from perturbed initial guess profiles,

4- evaluate the retrieval precision by comparing the retrieved values with the reference values used to generate the simulated observations,

5- evaluate the horizontal and the vertical resolution of the retrieval products by means of the 2D averaging kernels.

Simulated retrievals

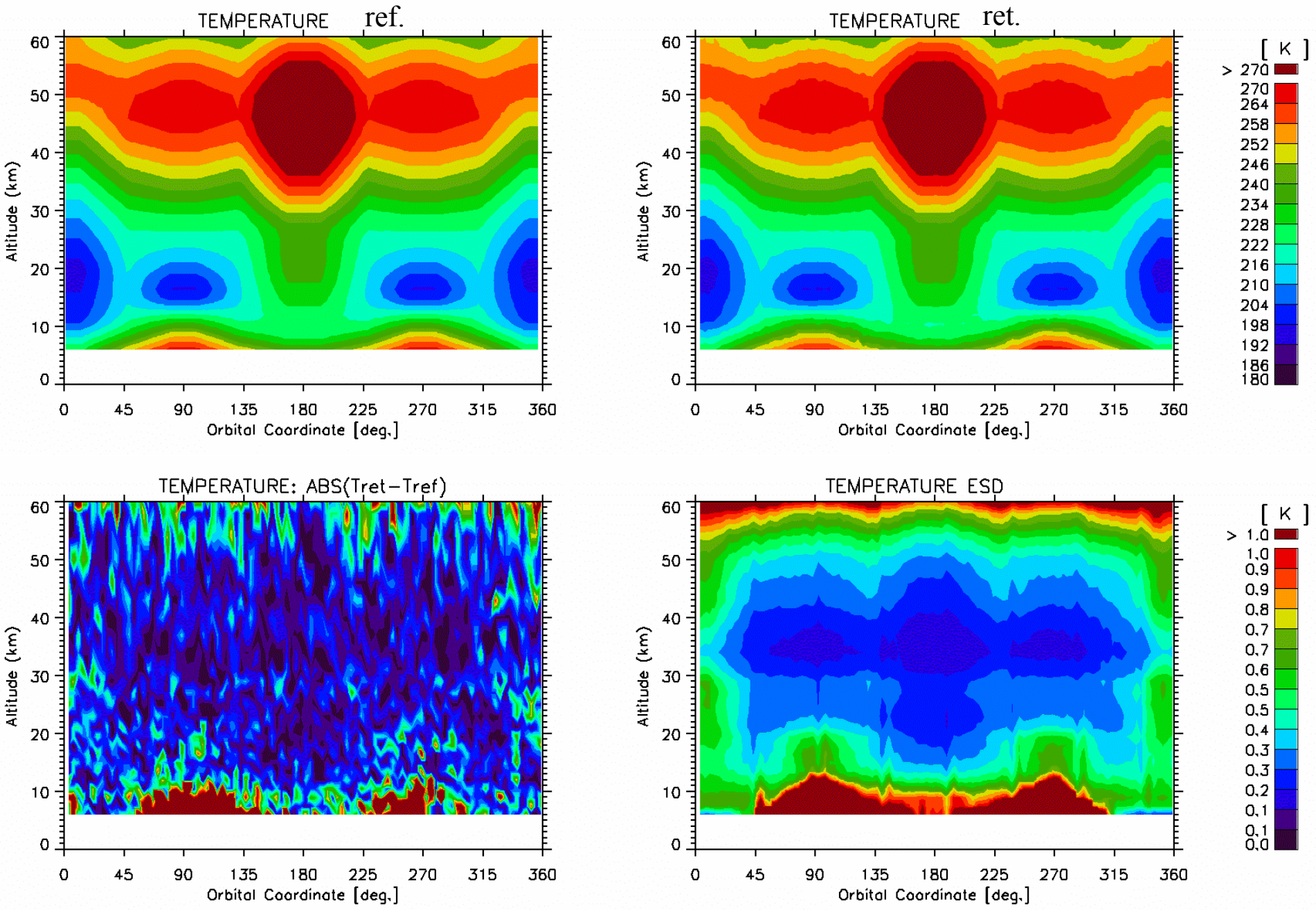
in the NOM retrieval grid

- vertical grid ≡ nominal altitudes of NOM (> 12 km for UTLS-2)
- horizontal grid ≡ average position of NOM limb-scans

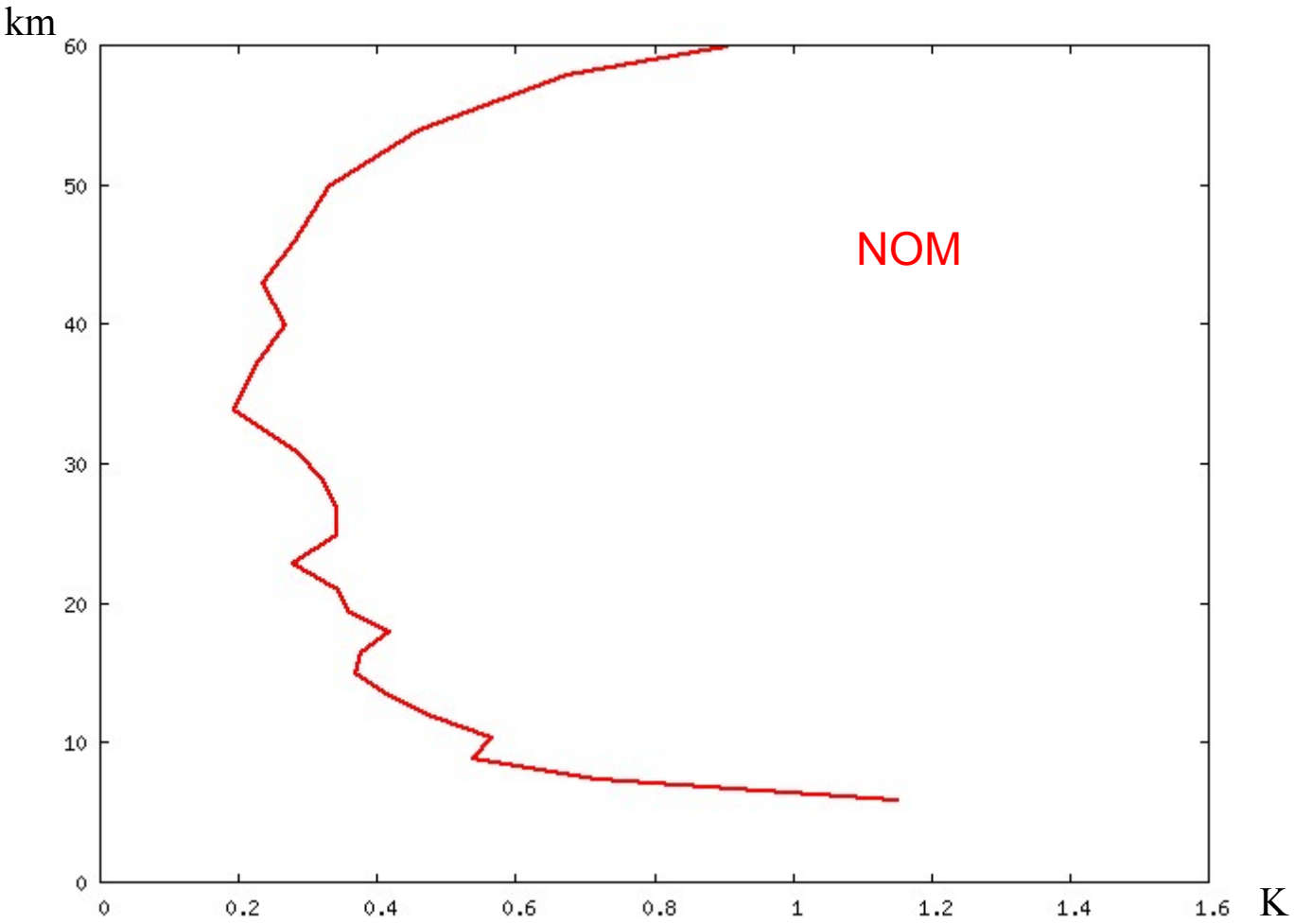
Common MWs and auxiliary data

NOM: 96 scans, UTLS-1: 125 scans, UTLS2: 213 scans

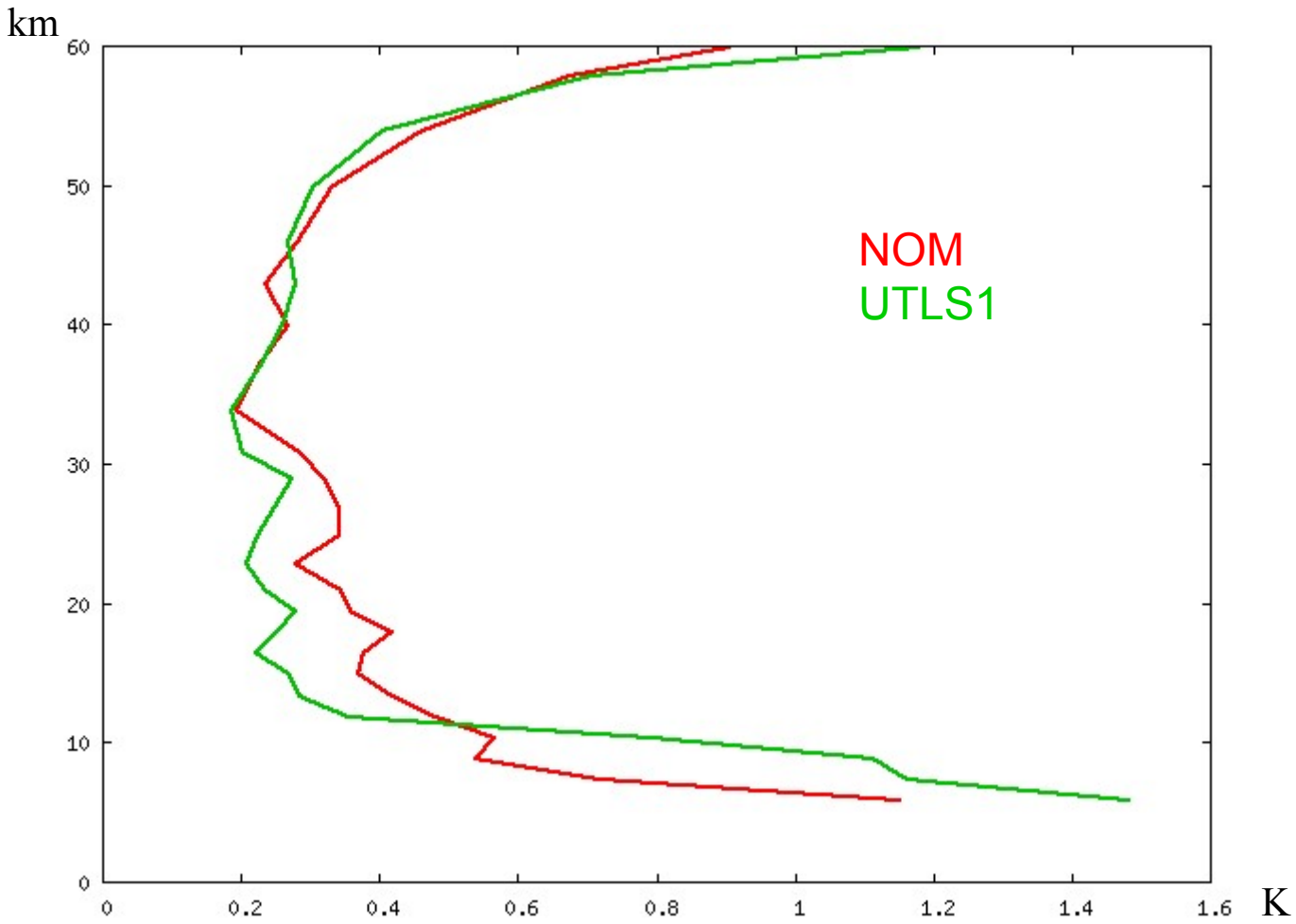
Nominal mode



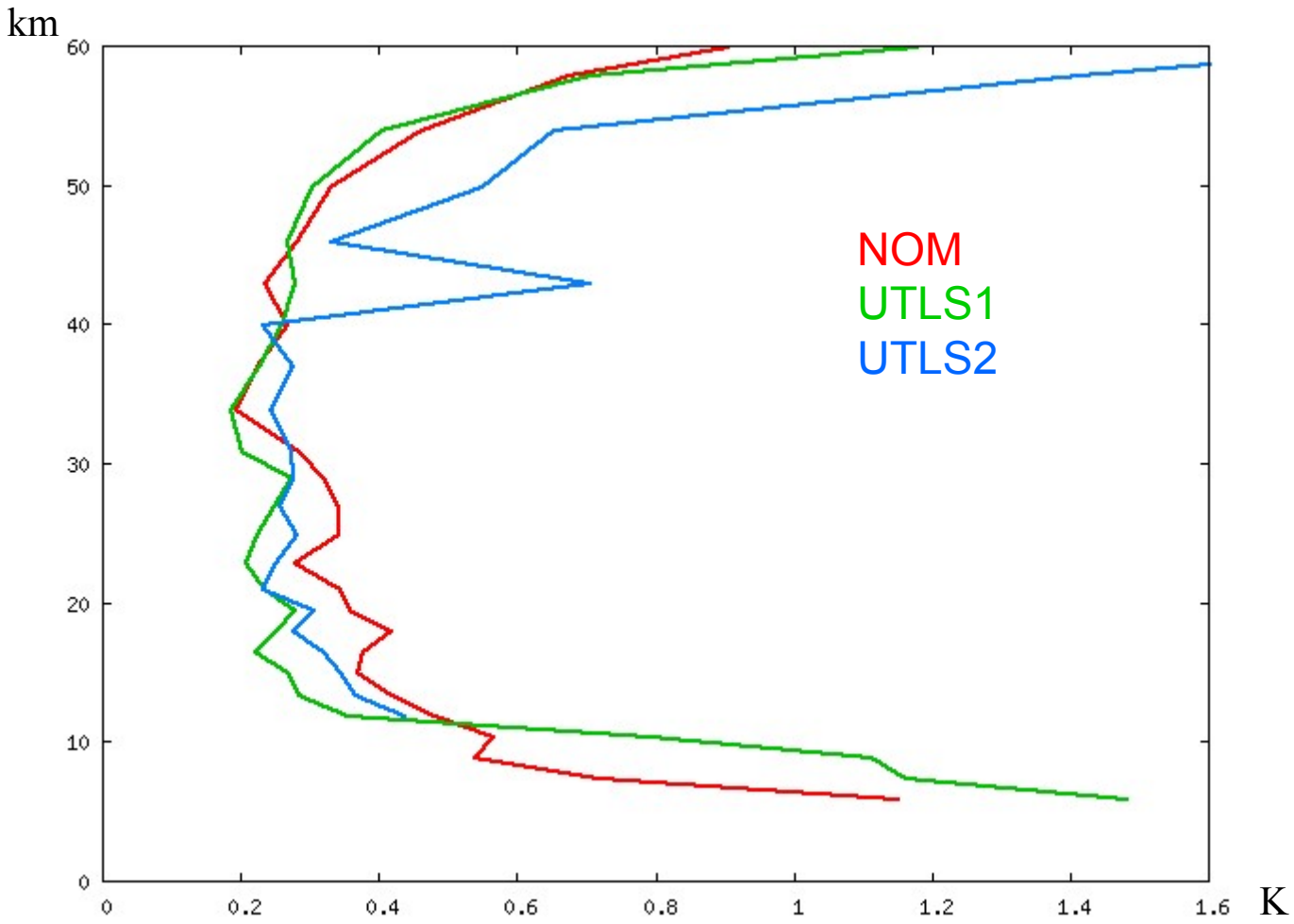
T St. Dev. of (ret.-ref.) over the orbit



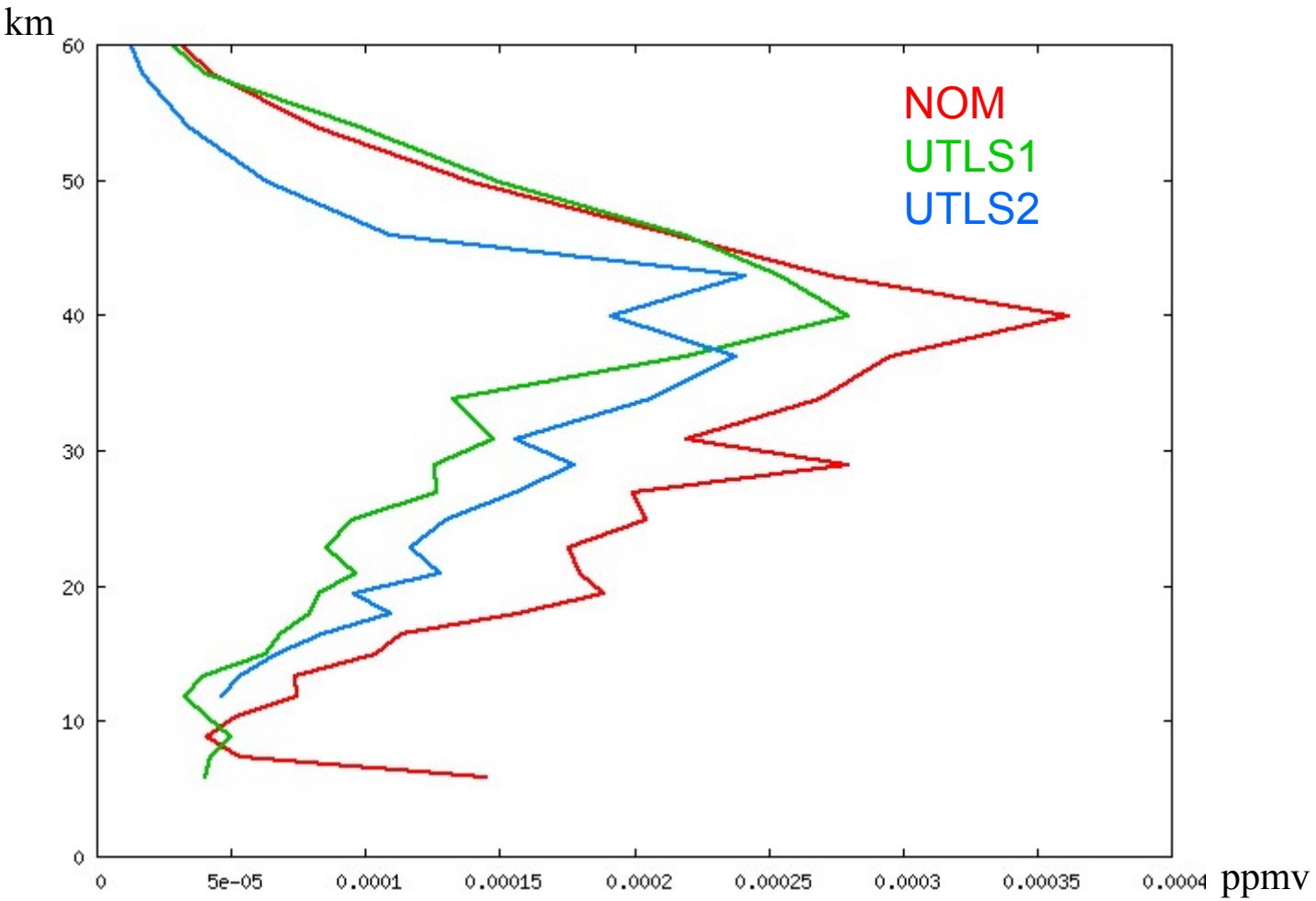
T St. Dev. of (ret.-ref.)



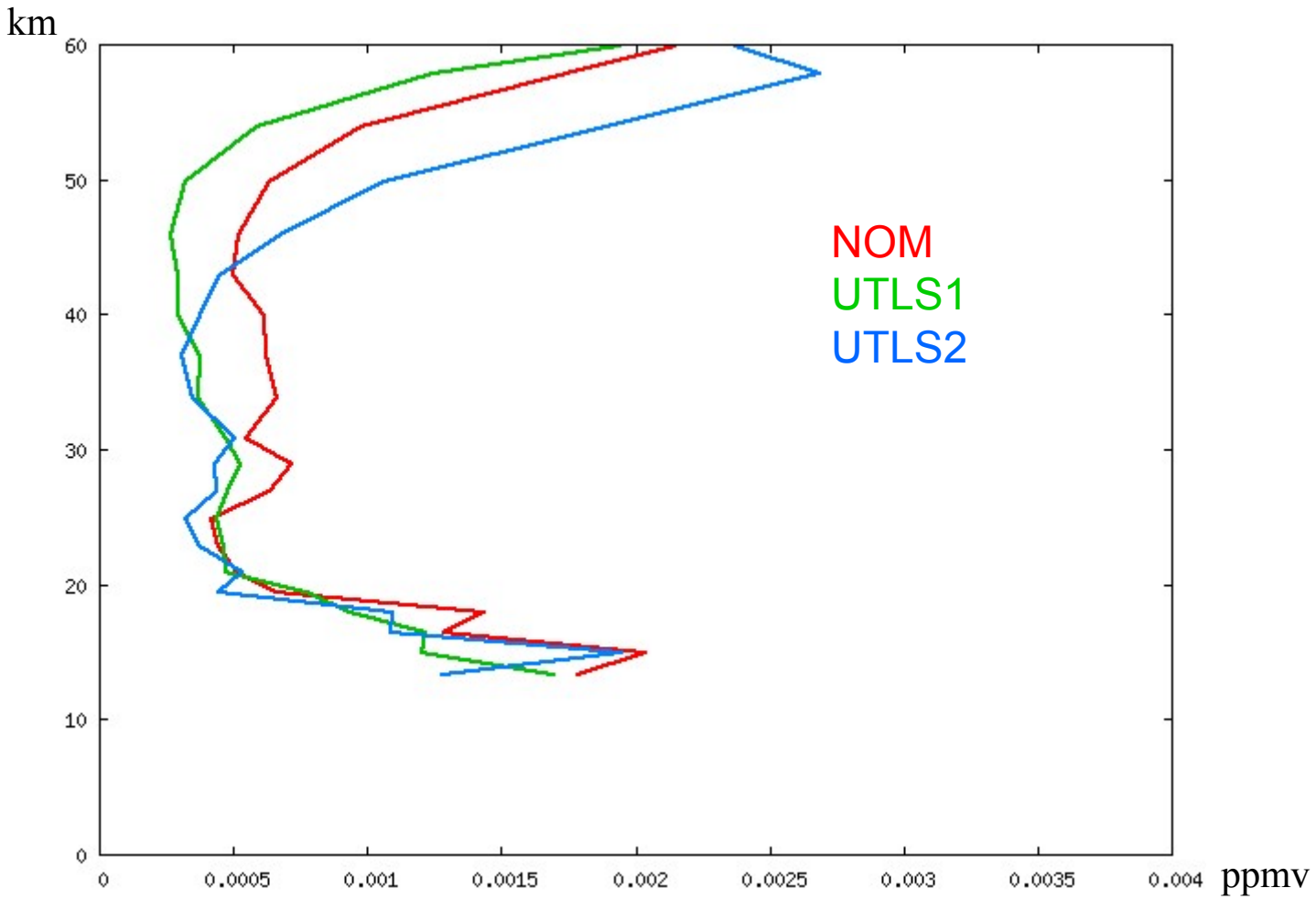
T St. Dev. of (ret.-ref.)



HNO_3 VMR St. Dev. of (ret.-ref.)



NO_2 VMR St. Dev. of (ret.-ref.)



Question 1: what mode provides the best performance in the full altitude range ?

U1 ≡ UTLS-1 U2 ≡ UTLS-2

	6 →13 km	13 →40 km	> 40 km
P,T	NOM	U1 ≅ U2	U1 ≅ NOM
H_2O	NOM	U1 ≅ U2	U1
O_3	NOM	U1 ≅ U2	U1 ≅ NOM
HNO_3	U1	U1	U2
CH_4	NOM	U1 ≅ U2	U1
N_2O	NOM	U1 ≅ U2	U1
NO_2	U1	U1 ≅ U2	U1

Answer: UTLS-1

Question 2

what mode provides the best performance in the UT/LS ?

Test 1

Simulated retrievals using geometrical separations:

- vertical grid ≡ NOM tangent altitudes up to 25 km (> 12 km for UTLS-2), altitude of tangent points above 25 km

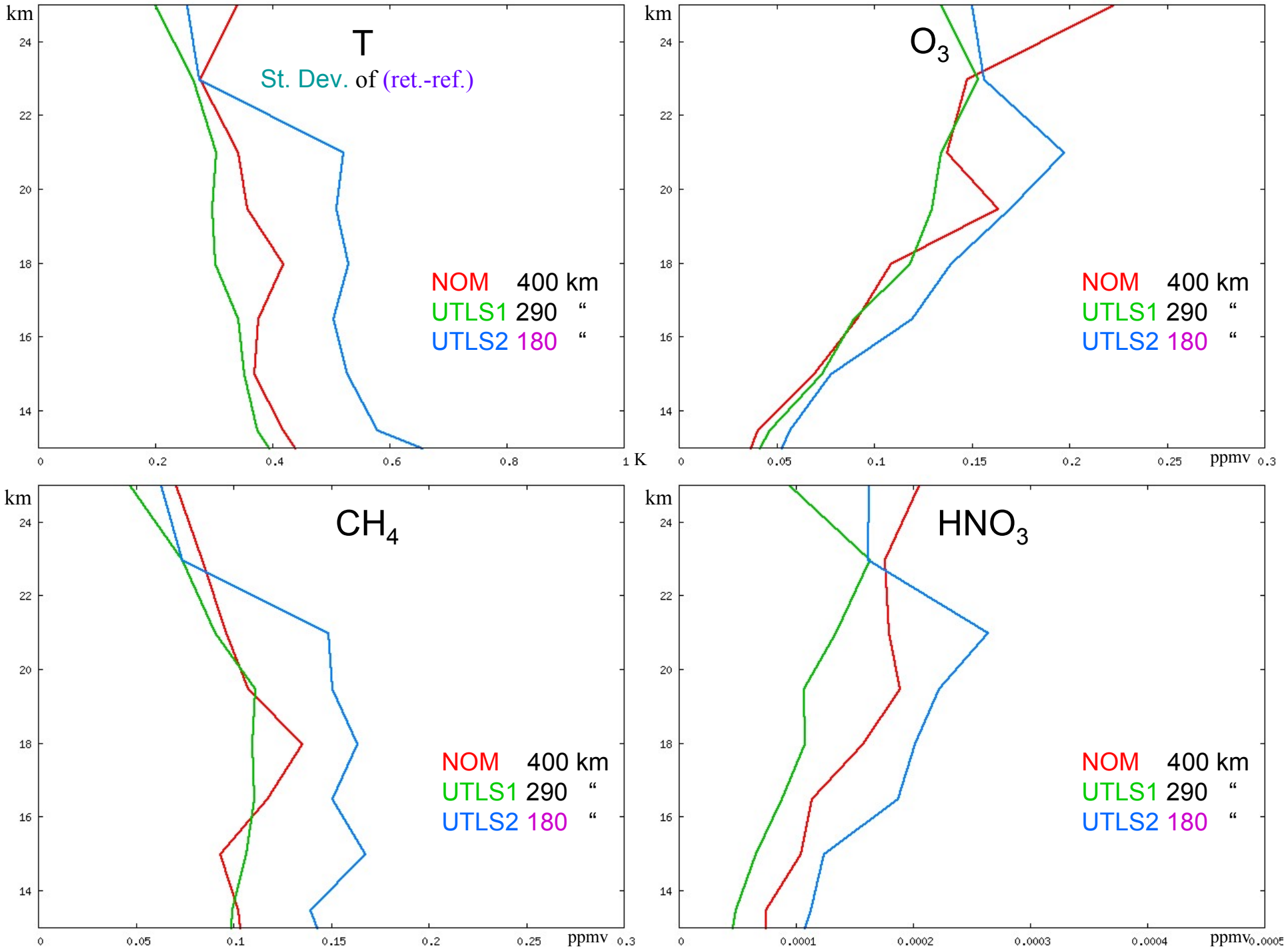
- horizontal grid ≡ average latitude of each limb-scan (*Natural grid*):

NOM: 96 scans → profiles separated by ≅ 400 km

UTLS-1: 125 scans → profiles separated by ≅ 290 km

UTLS-2: 213 scans → profiles separated by ≅ 180 km

Common MWs and auxiliary data


T
St. Dev. of (ret.-ref.)
NOM 400 km
UTLS1 290 “
UTLS2 180 “
km
K
O3
ppmv
CH4
HNO3

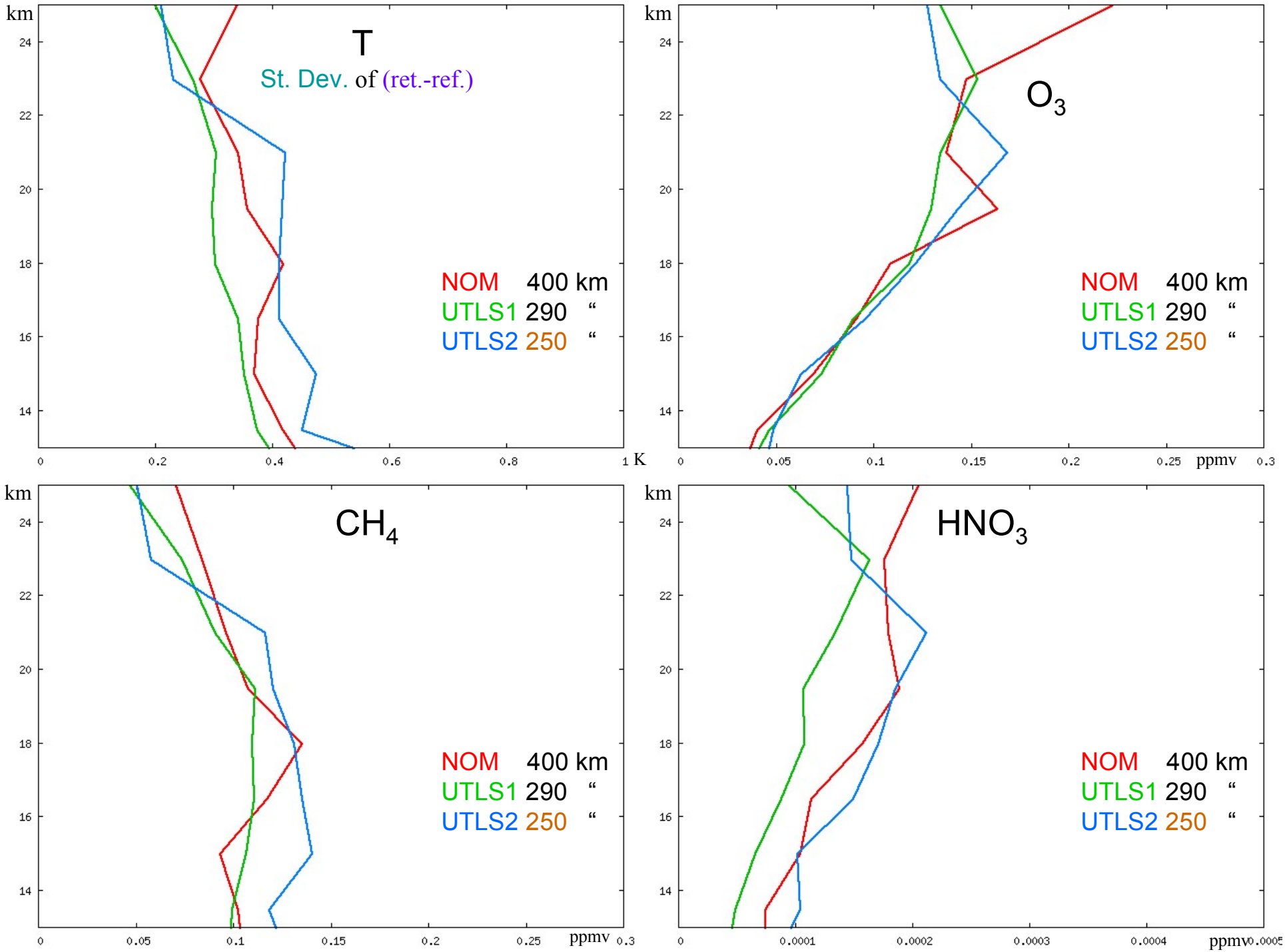
- UTLS-1 gives precision similar to NOM but with a finer *Horizontal Geometrical Separation (HGS),*
- UTLS-2 gives worse precision than NOM.

How much must the profiles separation must be incresed in UTLS-2 in order to get the same precision as NOM ?

Test 2

Simulated retrievals on UTLS-2 *using*:

- vertical grid ≡ NOM tangent altitudes up to 25 km (> 12 km for UTLS-2), altitude of tangent points above 25 km
- horizontal grid ≡ spread out to obtain the same precision as NOM.


T
St. Dev. of (ret.-ref.)
NOM 400 km
UTLS1 290 “
UTLS2 250 “
km
K
O3
ppmv
CH4
HNO3

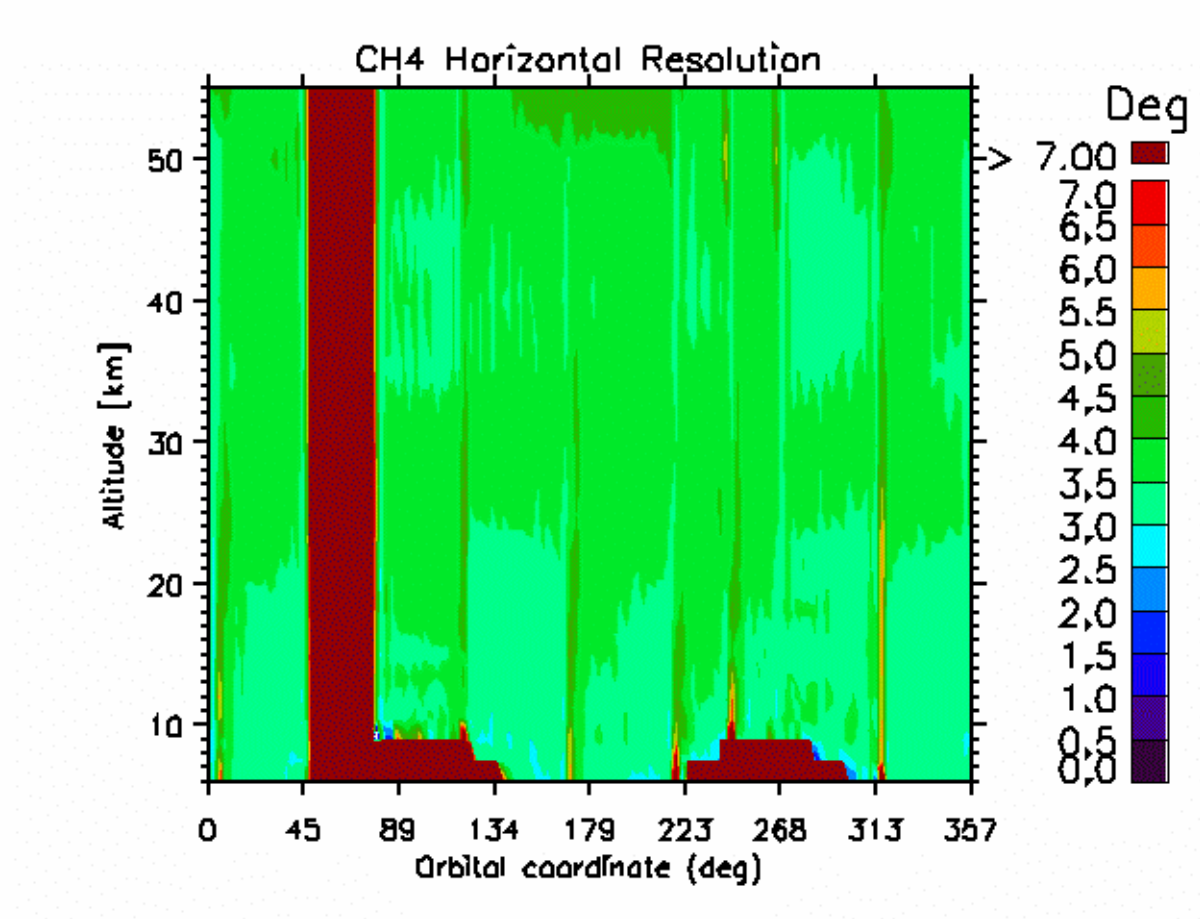
Can we further reduce the profiles separation in UTLS modes
to achieve a better horizontal resolution ?

Spatial resolutions can be calculated from the 2D Averaging Kernels (AK) matrix

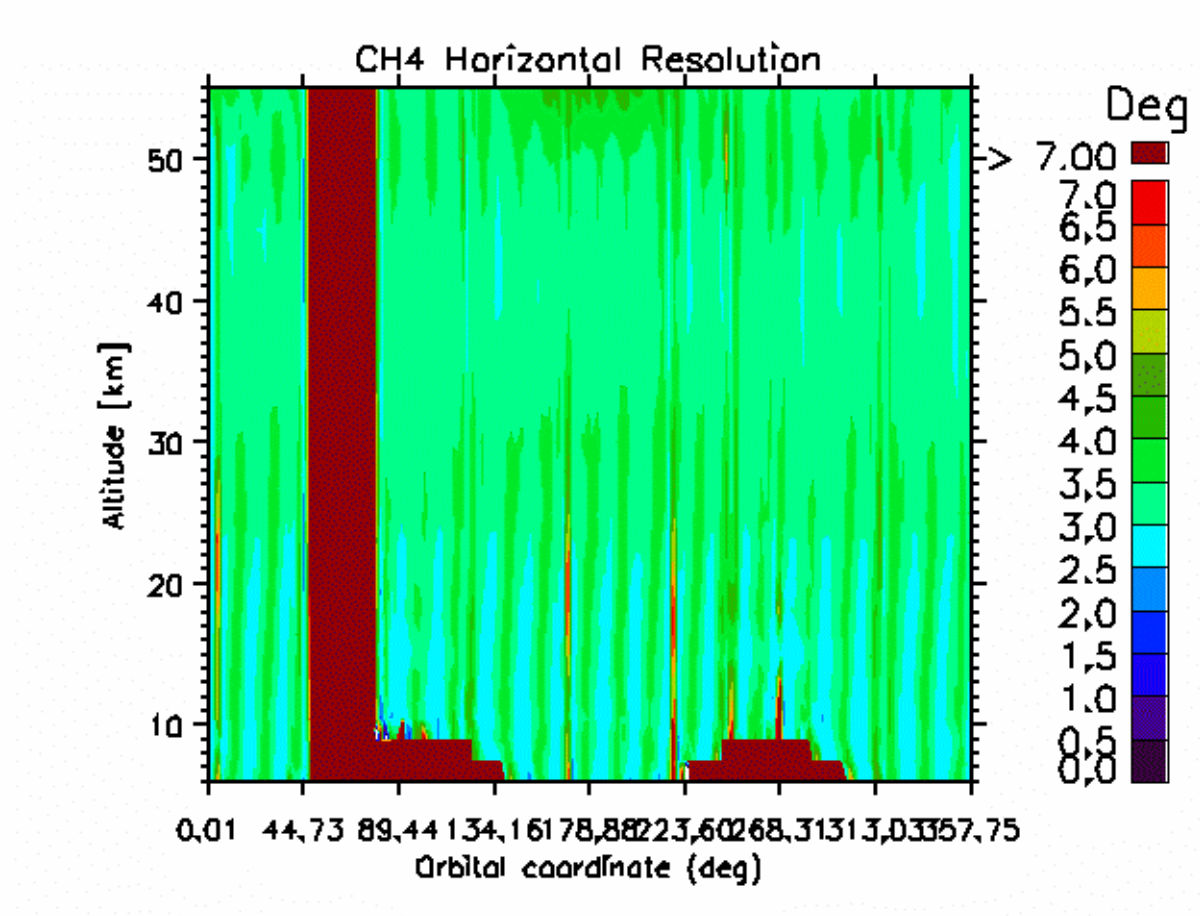
The *vertical* resolution (VR) of a retrieval parameter at OC θ_k is the FWHM of the subset of elements of the AK *column* that correspond to OC θk.

The *horizontal* resolution (HR) of a retrieval parameter at altitude z_k is the FWHM of the subset of elements of the AK *row* that correspond to altitude z_k.

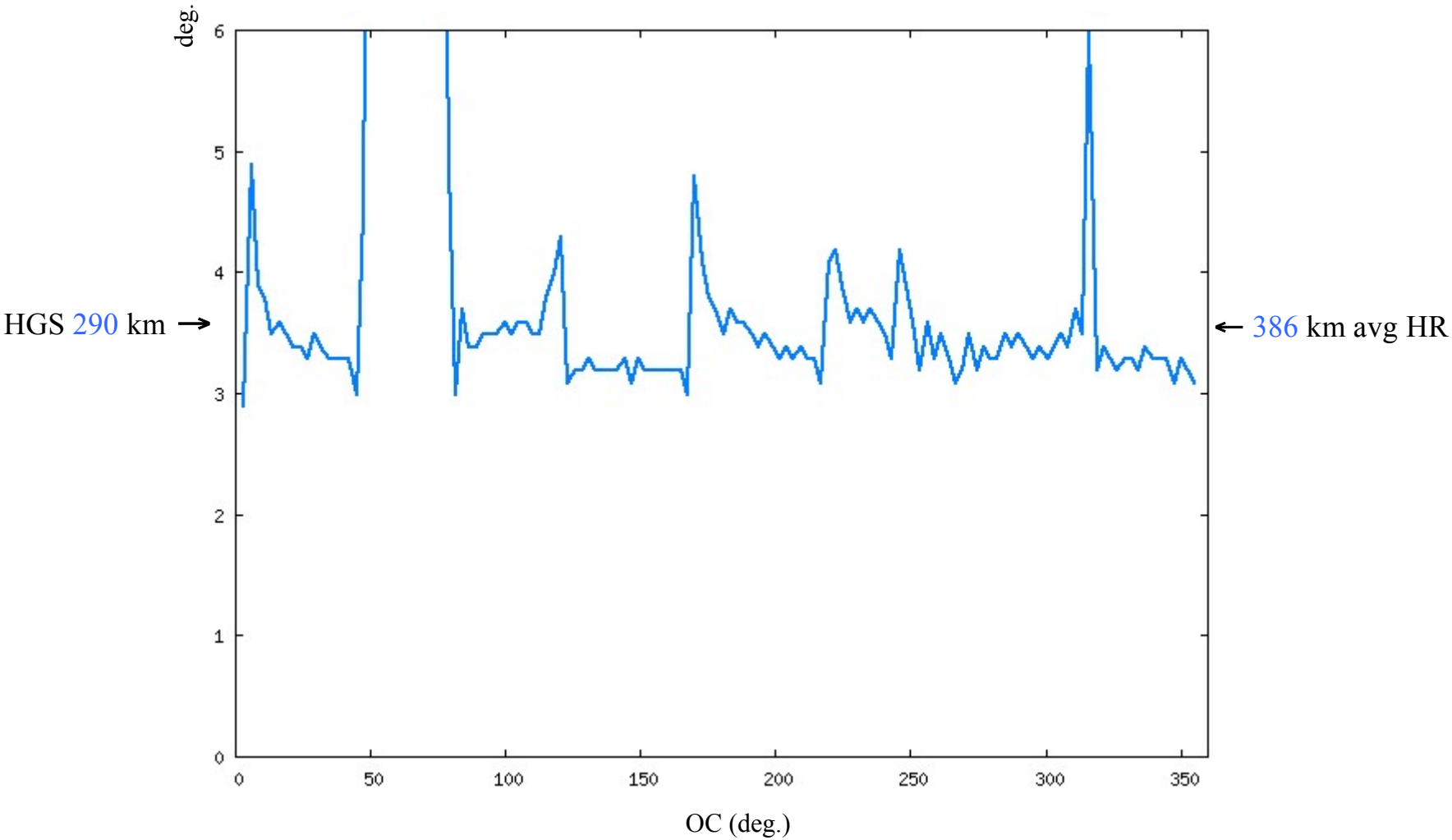
UTLS-1 horizontal resolution for CH_4 using HGS = 290 km (*Natural grid*)



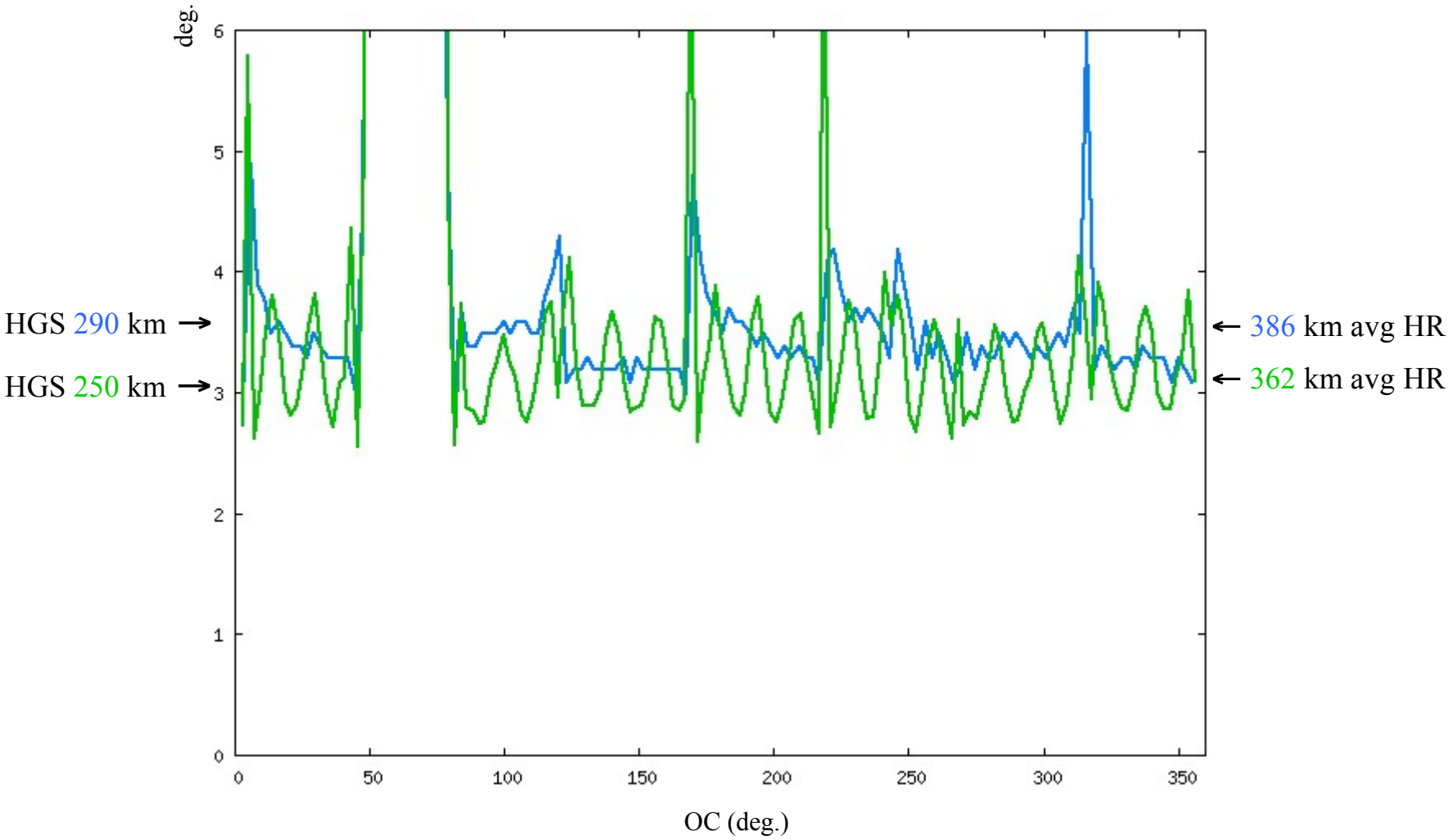
UTLS-1 horizontal resolution for CH_4 using HGS = 250 km



UTLS-1 horizontal resolution for CH_4 at 16.5 km

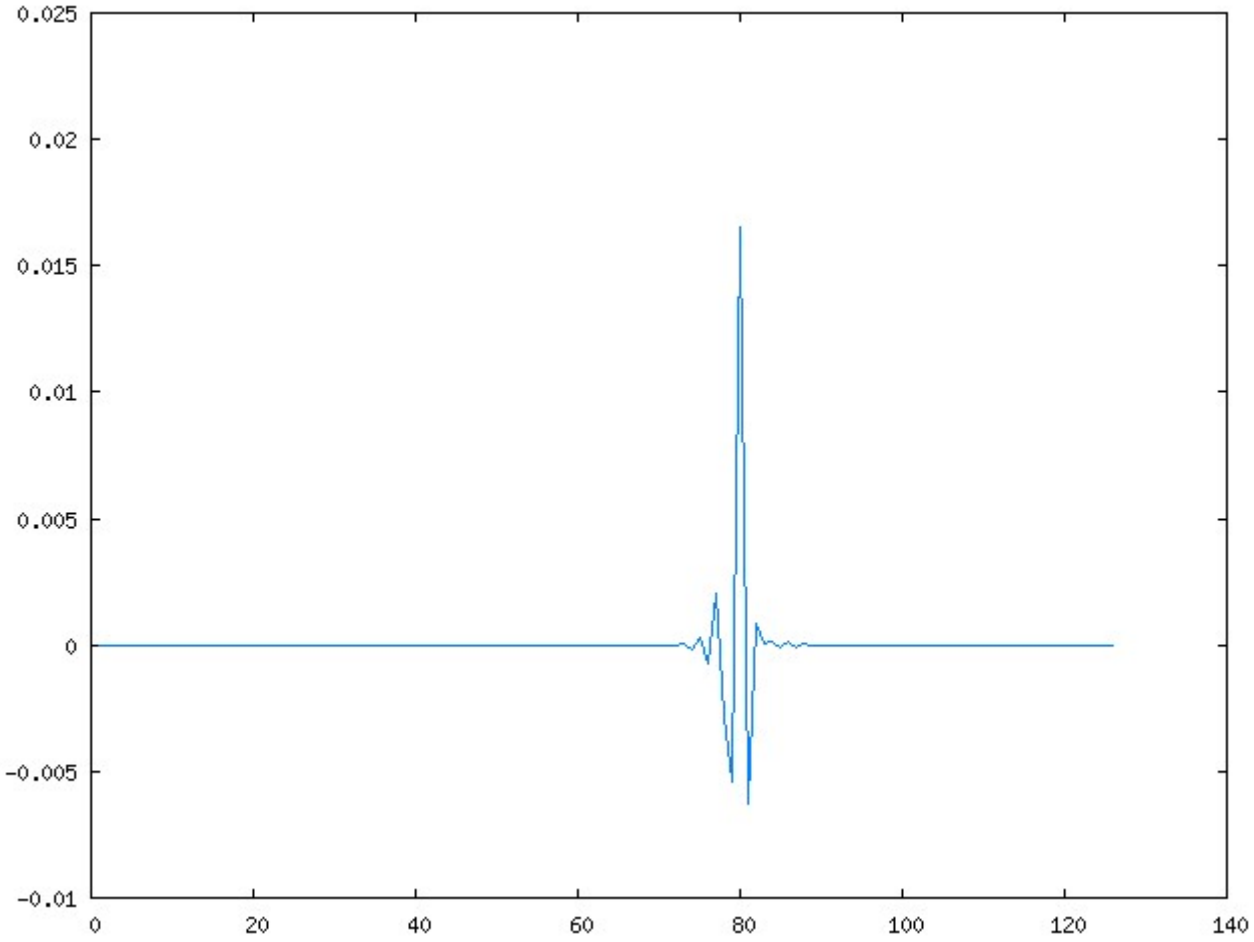


UTLS-1 horizontal resolution for CH_4 at 16.5 km



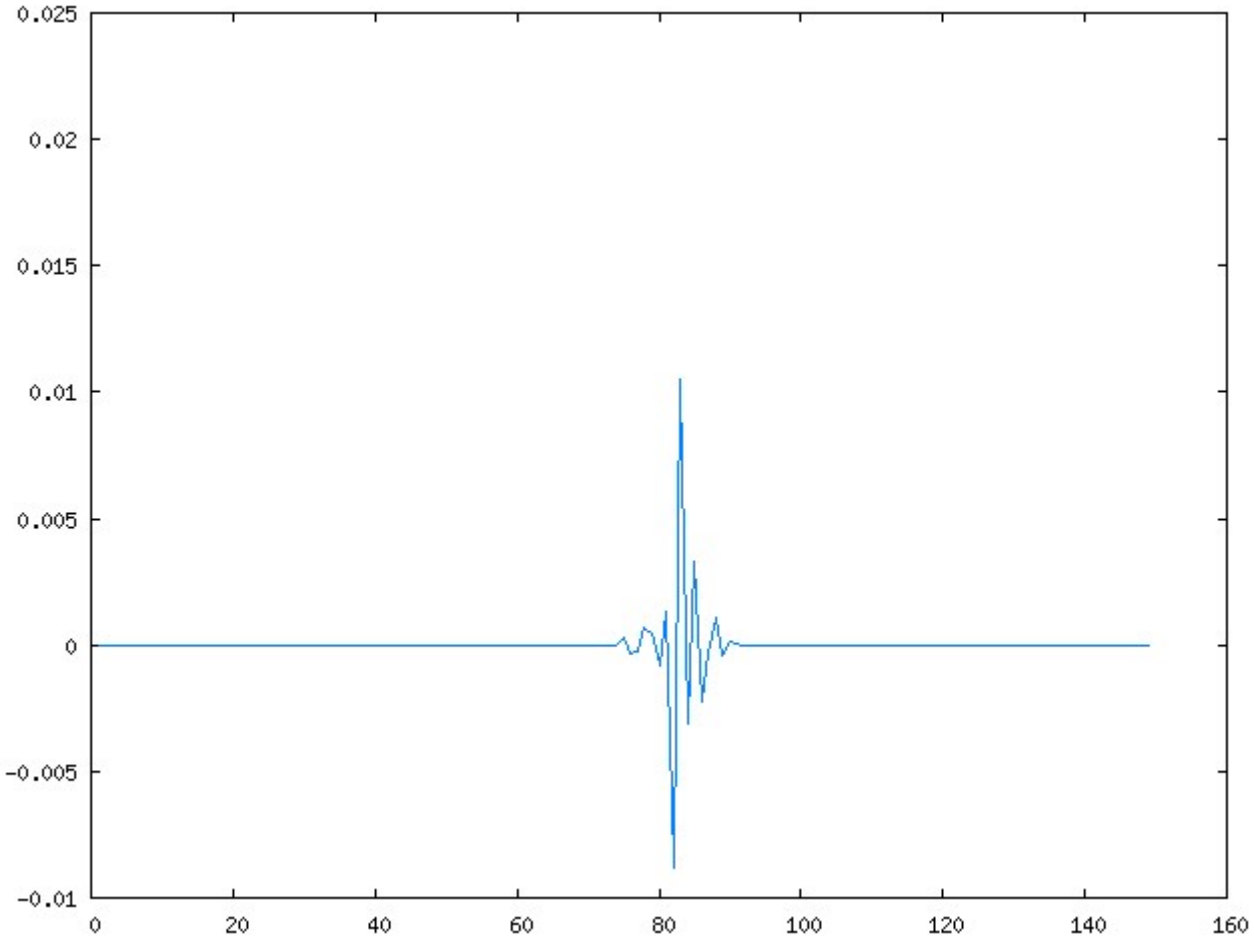
UTLS-1 HGS = 290 km

row of AK for CH_4 at 16.5 km

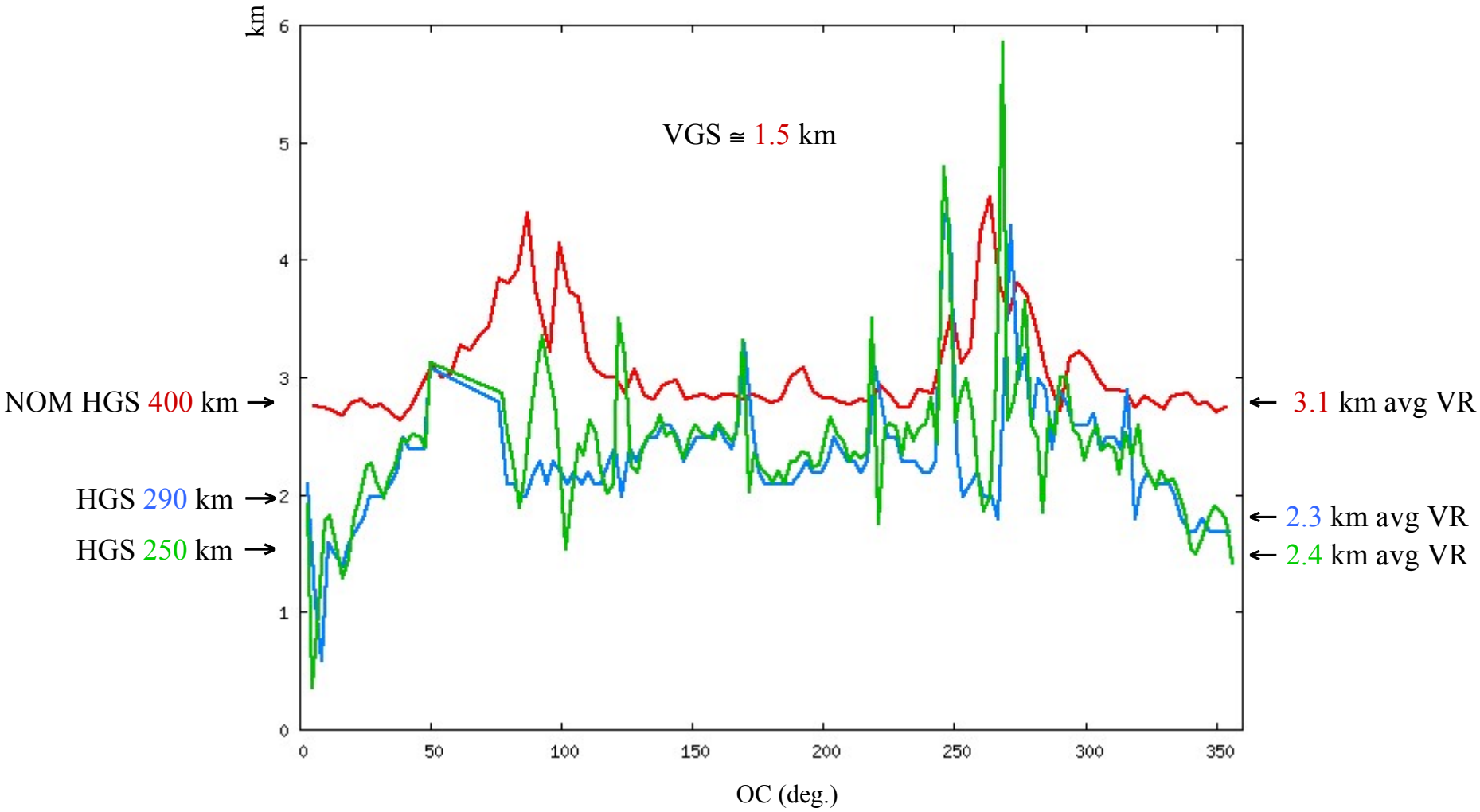


UTLS-1 HGS = 250 km

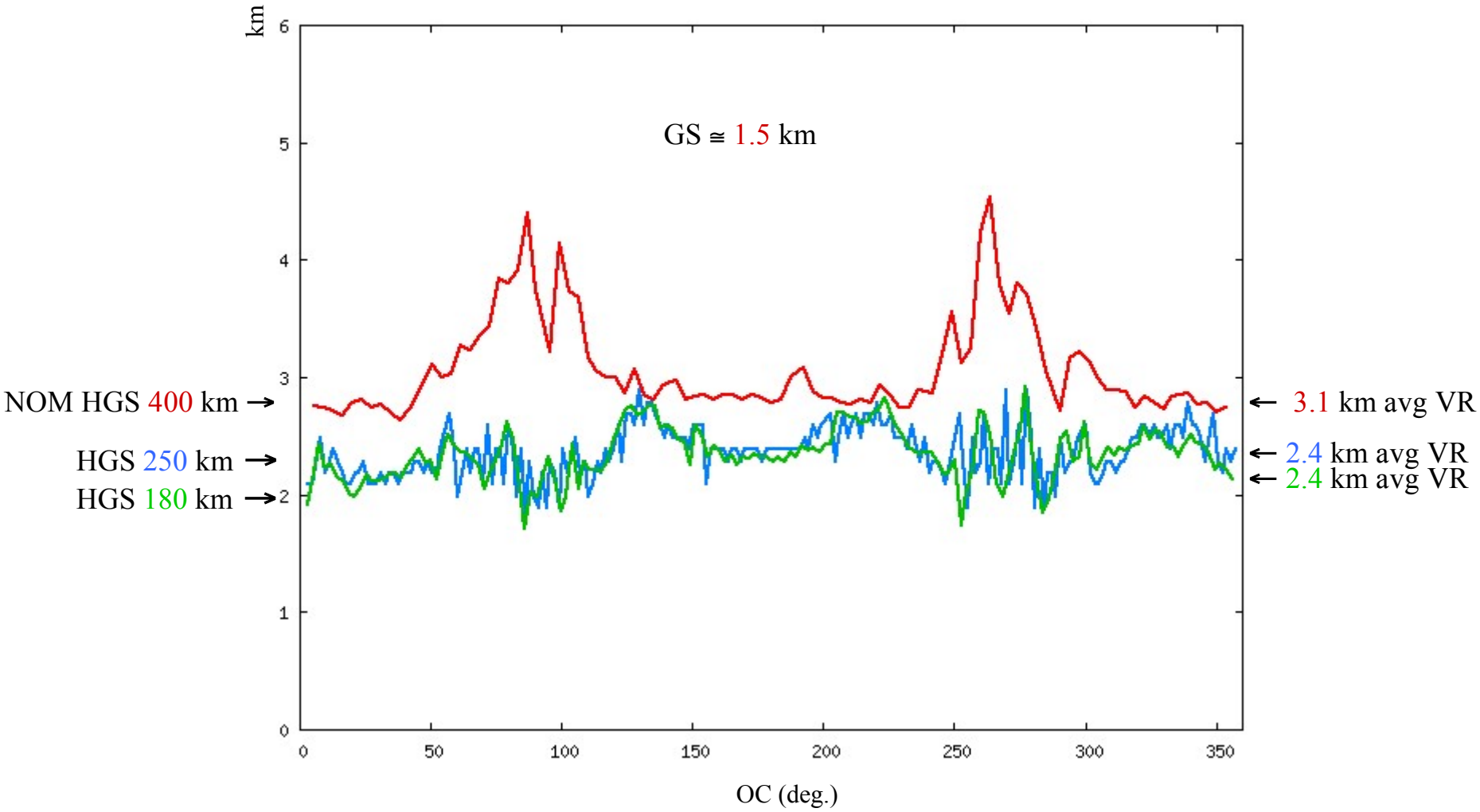
row of AK for CH_4 at 16.5 km



UTLS-1 vertical resolution for CH_4 at 16.5 km



UTLS-2 vertical resolution for CH_4 at 16.5 km



CONCLUSIONS

- In the full altitude range the best performance is provided by UTLS-1,

- In the stratosphere, UT/LS modes provide an altitude coverage of Ω generally better than that of Nominal Mode,

- UTLS-2 generates uniform distributions of Ω in the horizontal domain:
this allows to select the retrieval grid on the basis of only the trade-off between precision and spatial resolution,

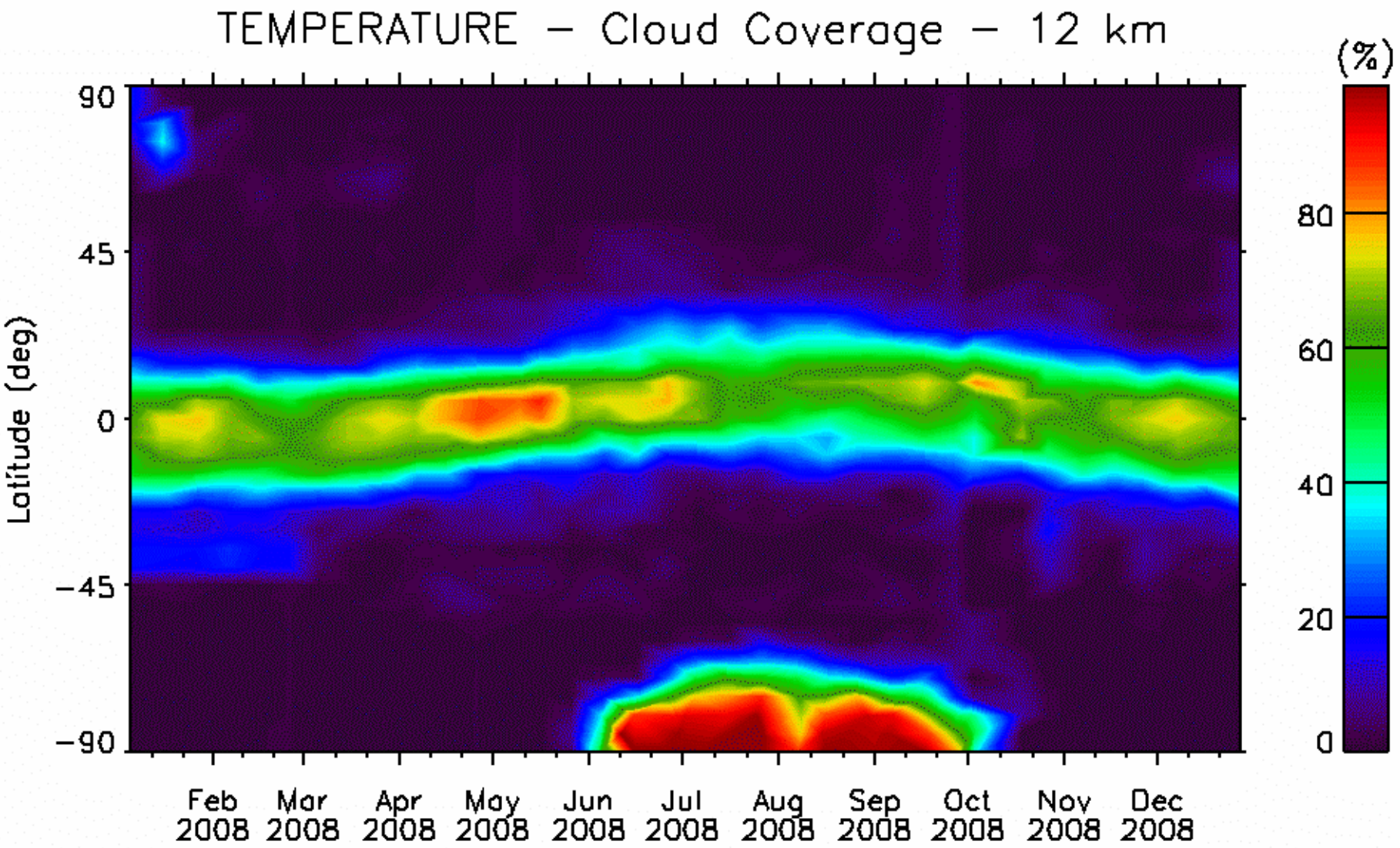
In the UT/LS

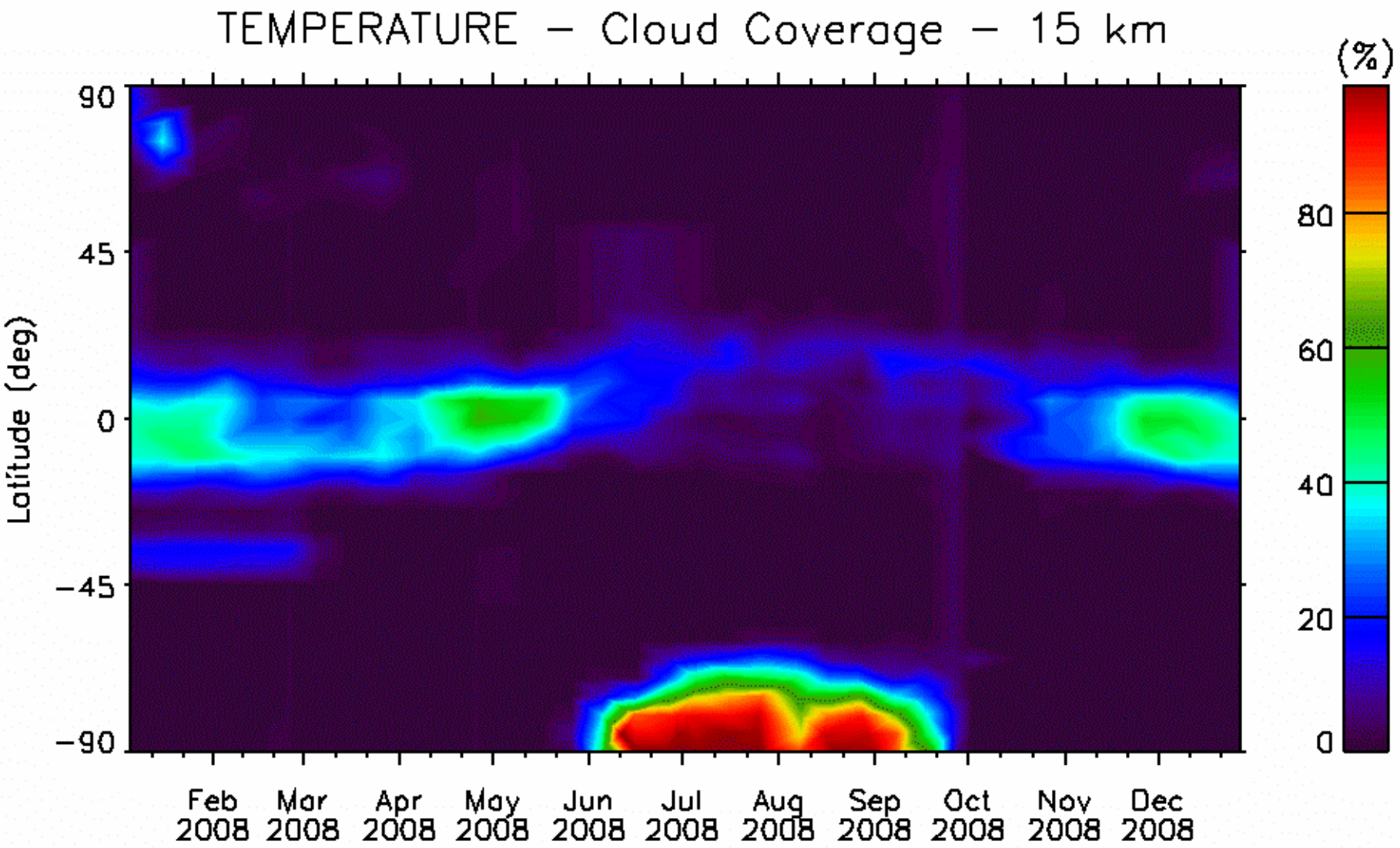
- the precision performance of Nominal Mode can be obtained by UTLS-1 with:
about 1.2 times better horizontal resolution,
about 1.3 times better vertical resolution.

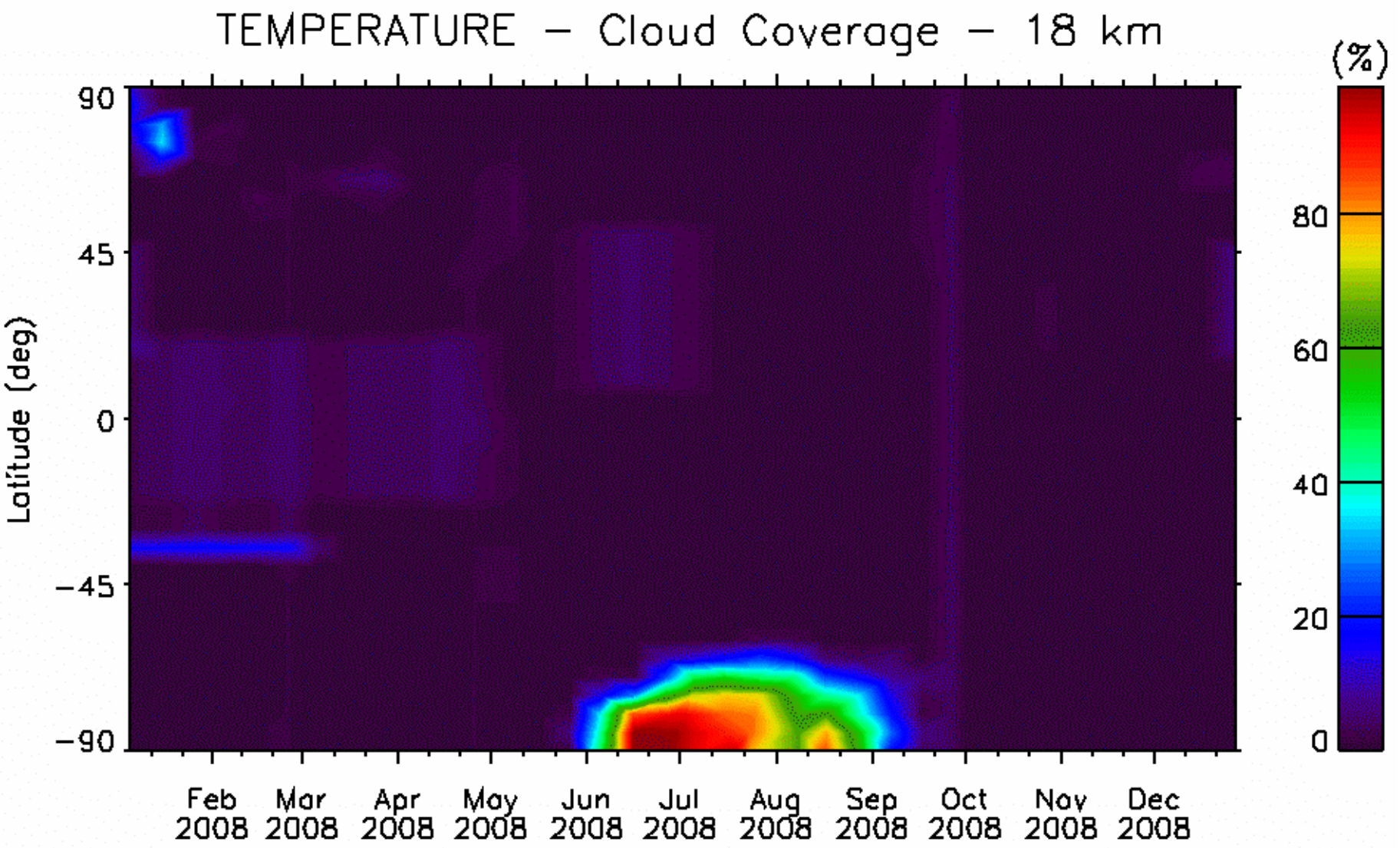
- the precision performance of Nominal Mode can be obtained by UTLS-2 with:
about 1.4 times better horizontal resolution,
about 1.3 times better vertical resolution.

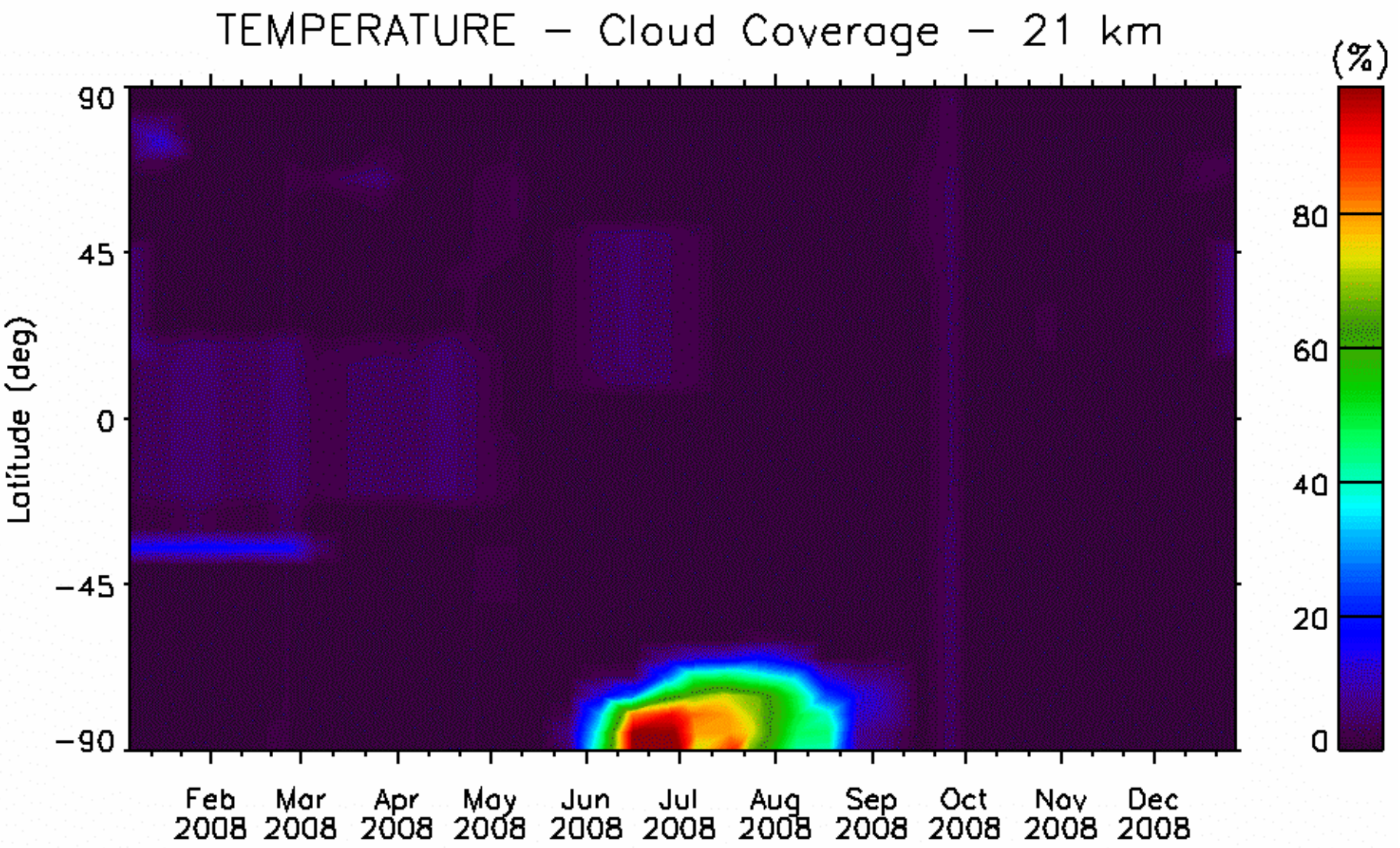
- In the UT/LS the best performance is provided by UTLS-2.

cloud coverage in the UT/LS


TEMPERATURE – Cloud Coverage – 12 km
(%)
90
45
0
−45
−90
Latitude (deg)
80
60
40
20
0
Feb 2008
Mar 2008
Apr 2008
May 2008
Jun 2008
Jul 2008
Aug 2008
Sep 2008
Oct 2008
Nov 2008
Dec 2008


TEMPERATURE – Cloud Coverage – 15 km
(%)
90
45
0
−45
−90
Latitude (deg)
80
60
40
20
0
Feb 2008
Mar 2008
Apr 2008
May 2008
Jun 2008
Jul 2008
Aug 2008
Sep 2008
Oct 2008
Nov 2008
Dec 2008


TEMPERATURE – Cloud Coverage – 18 km
(%)
90
45
0
−45
−90
Latitude (deg)
80
60
40
20
0
Feb 2008
Mar 2008
Apr 2008
May 2008
Jun 2008
Jul 2008
Aug 2008
Sep 2008
Oct 2008
Nov 2008
Dec 2008


TEMPERATURE – Cloud Coverage – 21 km
(%)
90
45
0
−45
−90
Latitude (deg)
80
60
40
20
0
Feb 2008
Mar 2008
Apr 2008
May 2008
Jun 2008
Jul 2008
Aug 2008
Sep 2008
Oct 2008
Nov 2008
Dec 2008