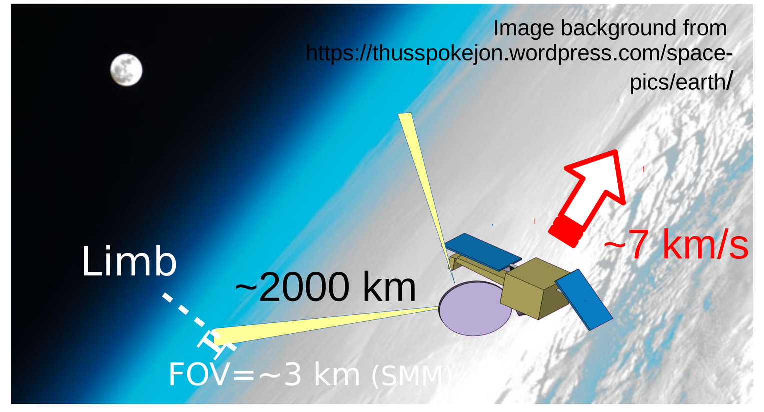

SMILES-2: Retrieval errors estimation

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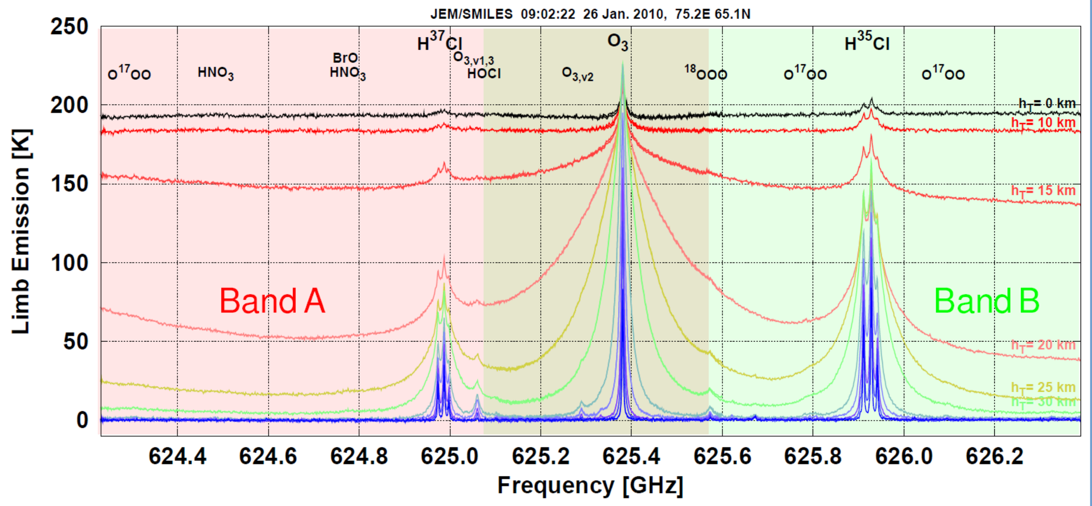
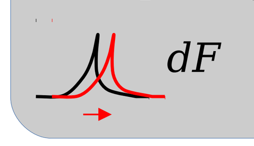
Context

- Sub-millimeter (SMM) limb sounding is a mature and efficient technique to measure temperature and trace gases from the upper troposphere to the lower thermosphere (MLS, Odin/SMR, JEM/SMILES) [1,2,3]
- Odin/SMR and MLS are being operated for more than 12 years, exceeding their expected lifetimes. No missions are planned to monitor the middle atmosphere when those missions stop.
- AURA/MLS and JEM/SMILES have demonstrated their potential for measuring winds in the upper-mesosphere (70-90 km) and in the stratosphere (30-60 km), respectively[4,5]. No other system has provided wind data in this range.
- The 4-K cooled instrument (**SMILES-2**) [6] is under study in Japan including SMM and THz channels for high precision measurements from the upper troposphere to the lower thermosphere:
  - Wind from 30–160 km (day and night)
  - Fundamental state of OI in the thermosphere (day and night)
  - Temperature from 10 to 160 km,
  - O3 related species *(O3, ClO, HCl, HO2, N2O, NO)* and dynamical tracers *(N2O, H2O, HNO3, CO)*

JEM/SMILES[3] spectra (Ochiai et al. 2015)

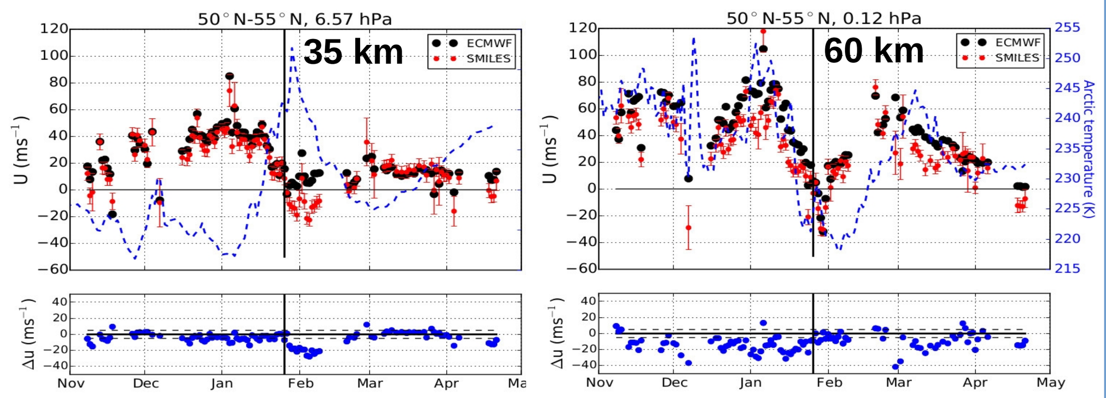


LOS wind υ is derived from the Doppler shift frequency:



υ = 5 m/s → *dF* = 0.01 MHz for λ = 0.5 mm

Zonal winds from the JEM/SMILES O3 line at 625.4 GHz[ref 5,7]



[1] Barath, F.T. et al., 1993: JGR, 98(D6), 10751–10762
[2] Murtagh, D. et al., 2002: Can. J. Phys., 80(4), 309–319.
[3] Kikuchi, K. et al, 2010: J.G.R. 115, D23306
[4] Wu at al., 2008: Advanced in Space Research, 42, 1246-1252
[5] Baron, P. et al., 2013: ACP 13(13), 6049–6064
[6] Suzuki, M. et al., 2015: Proc. SPIE, 9639, 96390M
[7] Baron, P. et al., 2015: Proc. SPIE, 9639, 96390N
[8] Baron et al., 2013: Proc. ESA Symposium

SMILES-2 payload [Ref 6]

4 double-side-band (DSB) receivers **cooled at 4K**

3xSIS-mixers, System temp. (Tsys) of **125 K**

THz HEB mixer, System temp. of **1000 K**

SIS-1: 487/525 GHz
T, Wind, O_2, $\mathbf{H_2O}$, O_3, HO_2, BrO, $\mathbf{NO_2}$, $\mathbf{H_2CO}$, $\mathbf{N_2O}$, HO_2, etc

SIS-2: 625/650 GHz
O_3, HCl, BrO, HNO_3, HO_2, $\mathbf{N_2O}$, HOCl, $\mathbf{CH_3Cl}$, ClO, HO_2, BrO, **NO**

SIS-3: 556/576GHz
H2O, CO, O3

HEB: 1.8/2.0 THz switching
- 1.8 THz: **OH**, $\mathbf{H_2O}$, O_3
- 2.06 THz: **O-atom**

Antenna diameter of 1 m:

SMM-EFOV ~ 1.8 km

THz-EFOV ~ 0.8 km

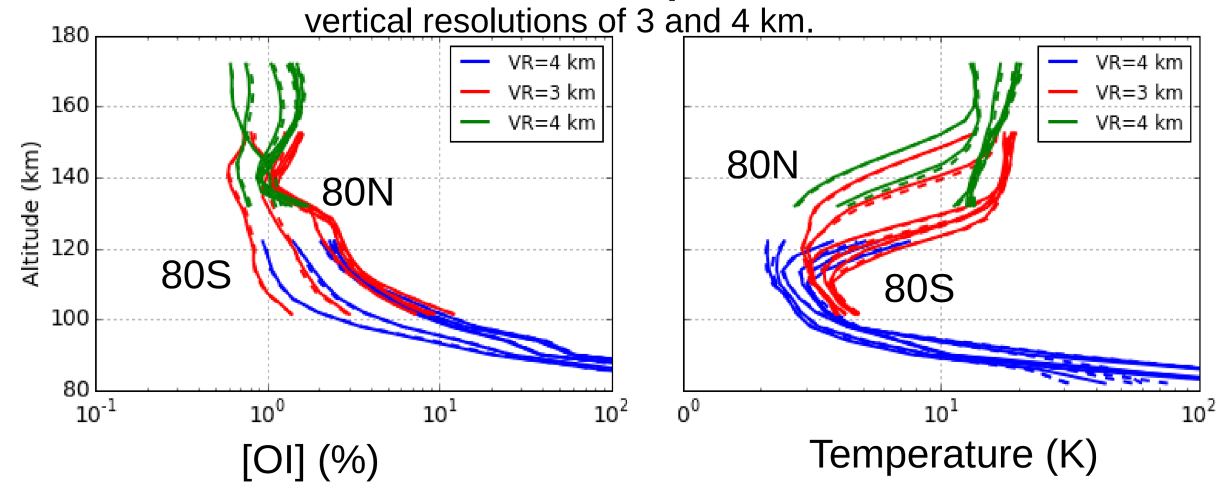
SIS: Superconductor Insulator Supero
HEB: Hot Electron Bolometer

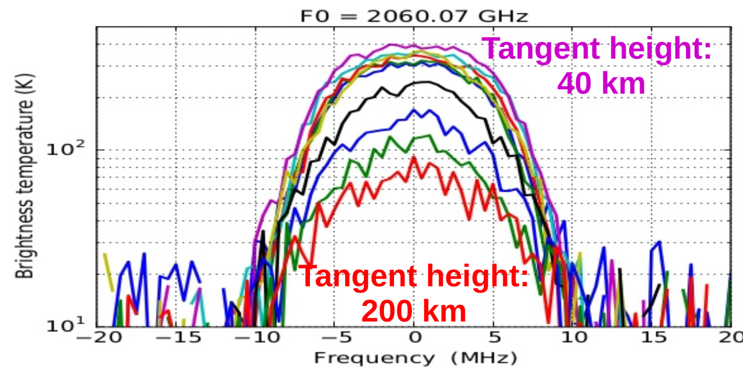
Atomic oxygen (OI) 2-THz line

- One of the strongest signal in the **lower thermosphere**
- Would be the first time global observation of the **fundamental state of OI**
- Allows for the retrievals of [OI], wind and temperature
- Day and night measurement with similar performances (thermal emission).

Retrieval errors

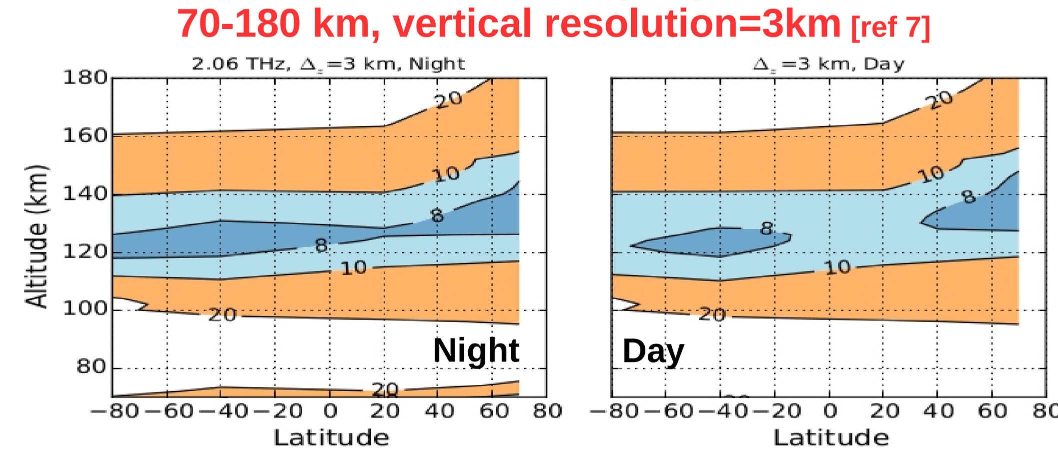
OI concentration and temperature errors
vertical resolutions of 3 and 4 km.





Simulation of SMILES-2 OI spectra for tangent heights between 40 and 200 km. Zeeman-splitting of the line is not taken into account.

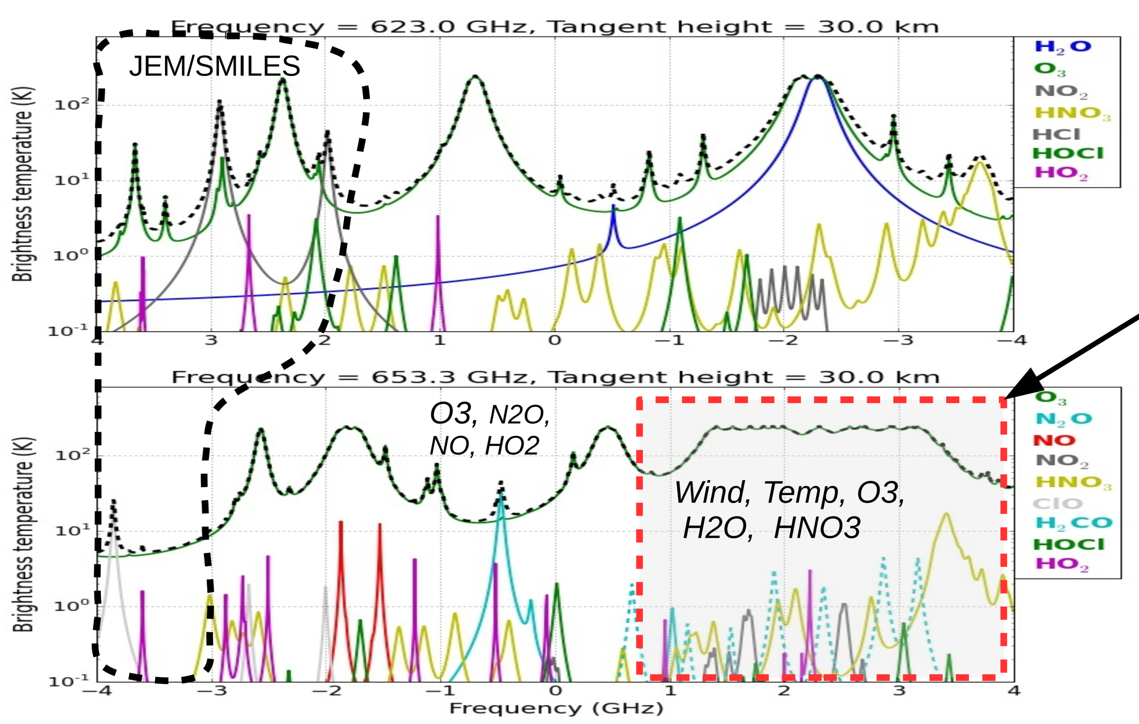
Wind error (m/s)
70-180 km, vertical resolution=3km [ref 7]



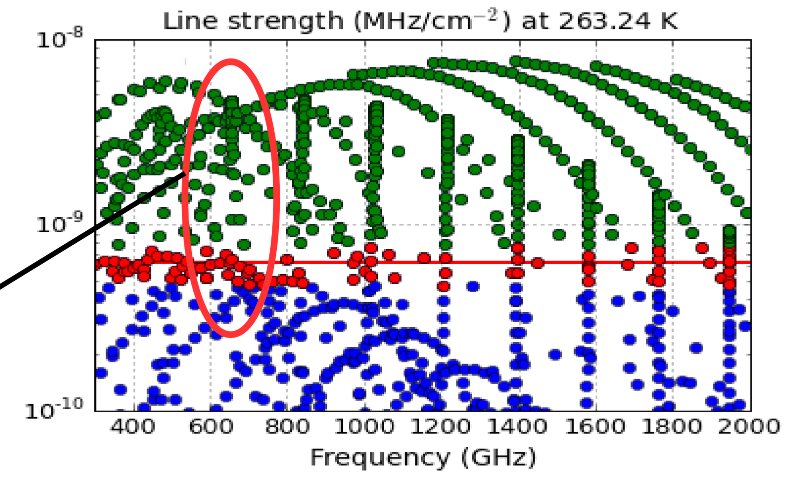
Simulations are performed with a winter climatology (DJF, 2009-2010) using the GAIA model for [OI] and the thermosphere, and MLS observations in the middle atmosphere (10-90 km). See ref 7 for details.

The Tsys is increased by 20% to account for the additional noise raising from the intensity calibration.

An alternative setting for the SIS-2 band: 625/655 GHz (8 GHz bandwidth)



The 655 GHz O3 lines

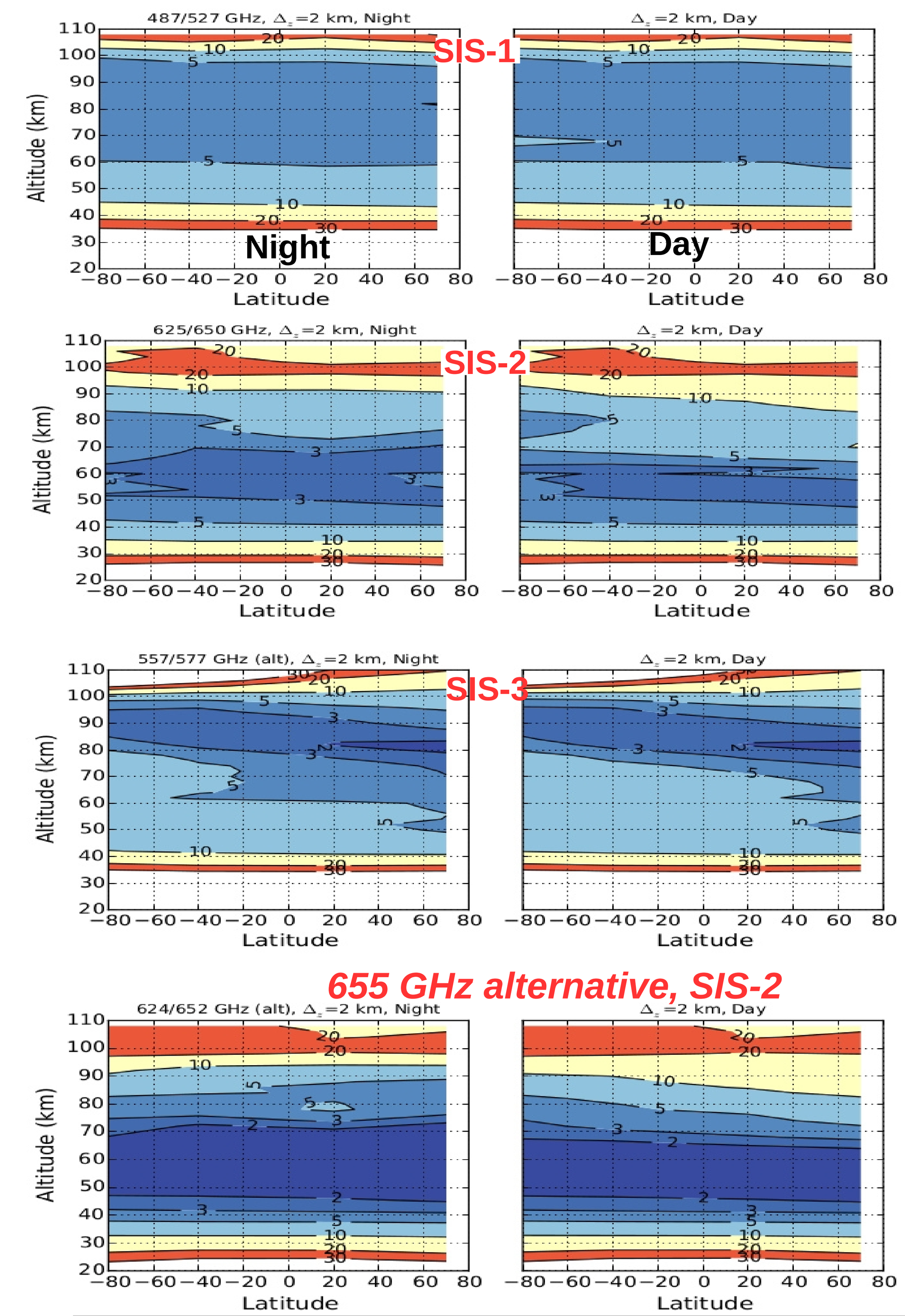


Ozone lines
The red circles indicate lines with a strength similar to the JEM/SMILES line at 625 GHz. The strengths are weighted with the inverse of the line-frequency to **account for the linear increase of Tsys with the frequency.**

Using wide spectrometer bandwidth (>8 GHz) allows for the optimal exploitation of **clusters of strong O3-lines** (655, 840, 1100 GHz). Such clusters provide:

- Best wind sensitivity with a factor 2 improvement near 40 km compared to any other bands [Ref 8],
- Good sensitivity to temperature without the use of an O2 line
- High sensitivity for O3 even with a non-cryogenic receiver.
- Systematic errors from spectroscopic parameters are reduced.
- The range near 655 GHz is rich in lines from important O3 related species (O3, ClO, HCl, BrO, HO2, N2O, NO) and dynamical tracers (N2O, H2O, ...)

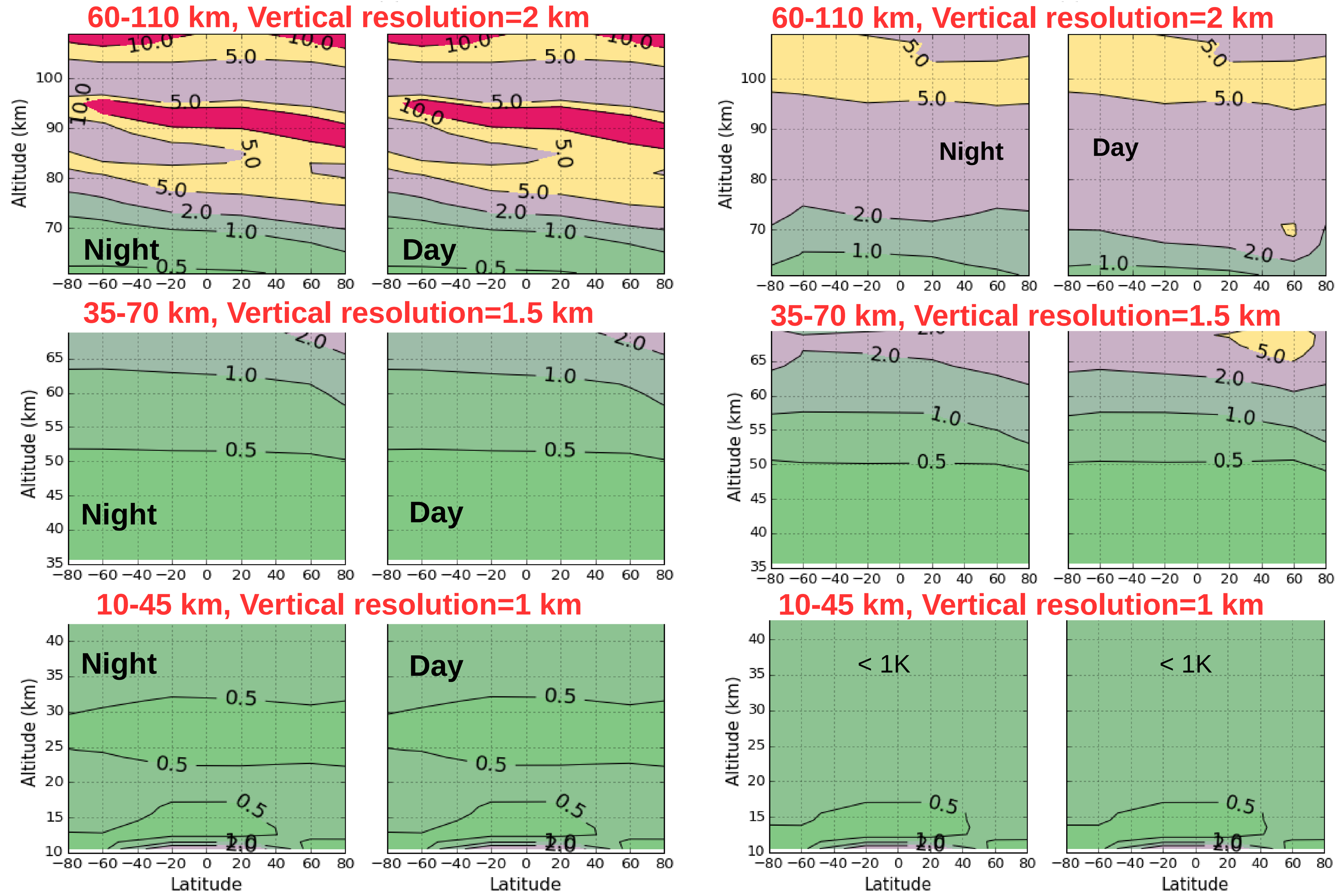
Wind error (m/s) [Ref 7]
20-120 km, vertical resolution=2km



Sub-millimeter bands: Wind and temperature retrieval errors

Temperature error (K)

SIS-1 (O2 line)   *655 GHz alternative*



Bandwidths of 8 GHz are considered for SIS-1 and SIS-2.