Information Content of Limb Radiances from MIPAS

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Nadir v Limb Radiances

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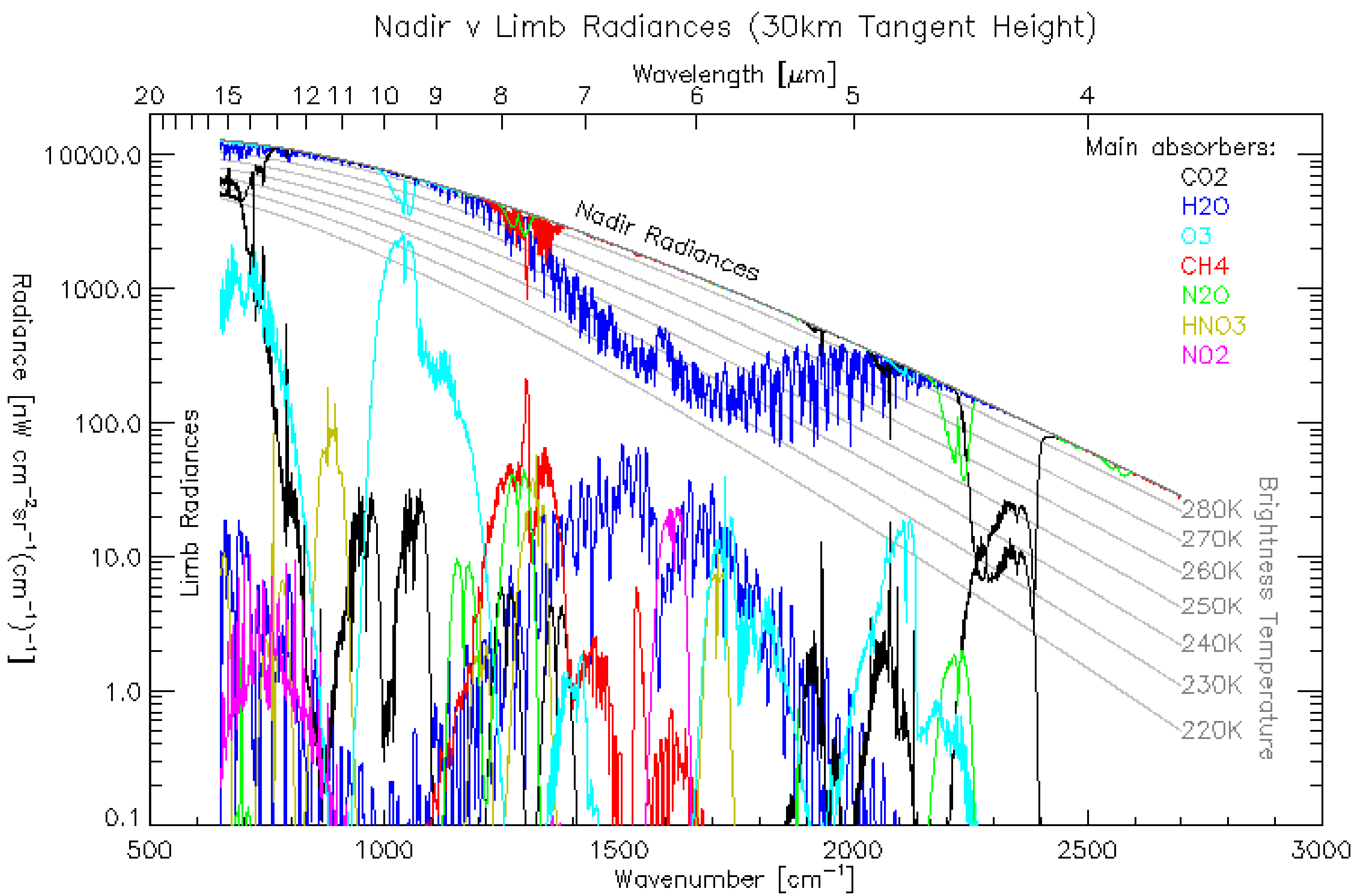
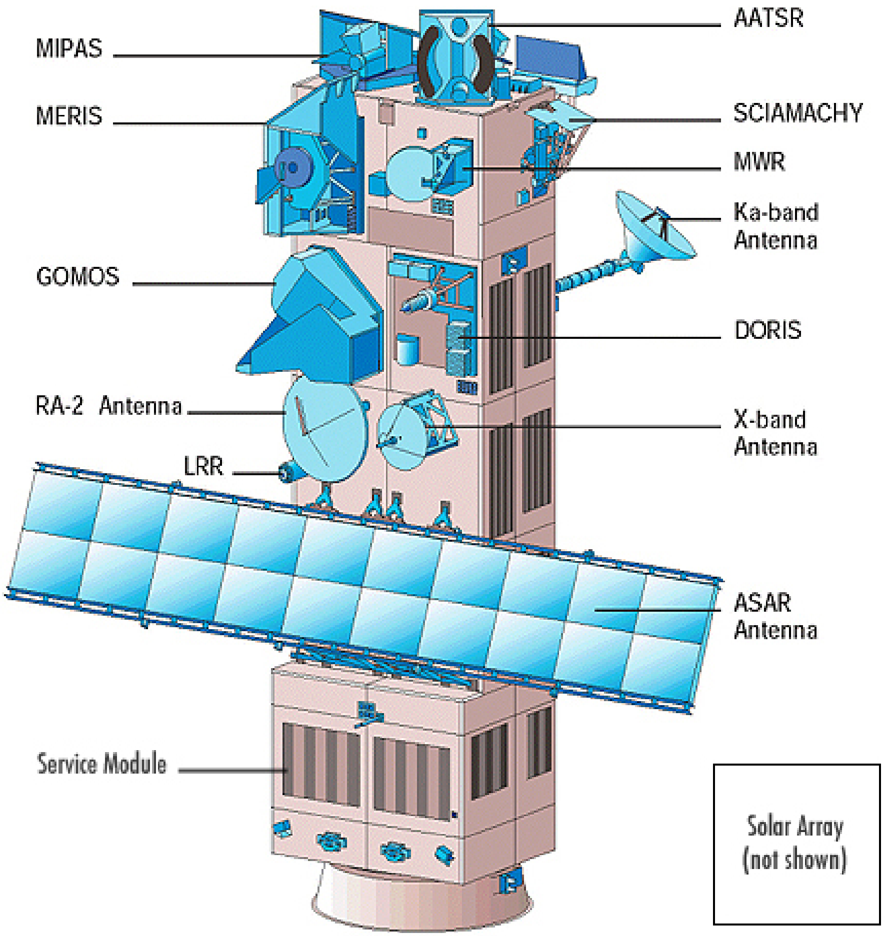


ENVISAT



- ESA Satellite
- Payload of 10 instruments monitoring the earth's surface and atmosphere
- Launched 1st March 2002
- Sun Synchronous Orbit
- Period 101 minutes
  $\Rightarrow$ 14.25 Orbits per day

MIPAS

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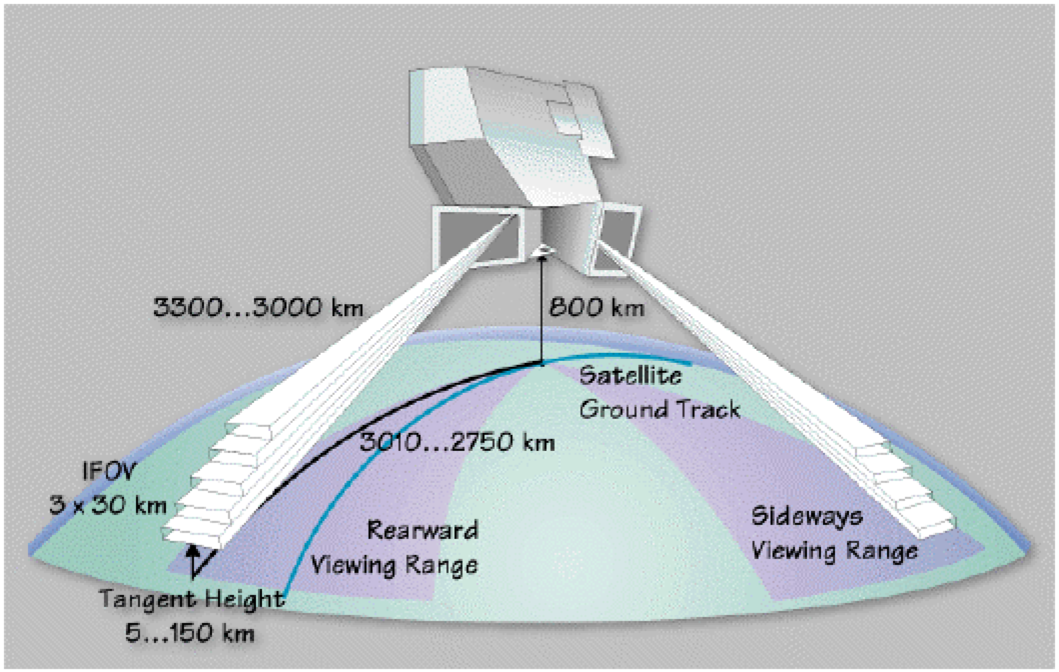
Michelson Interferometer for Passive Atmospheric Sounding



- Fourier Transform Spectrometer
- Spectrum 685-2410cm^{-1} at 0.025cm^{-1} resolution in 4.5s
- Limb scan in 17 steps from 68-6km in 85s (~500km)
- 72 profiles per orbit
- ~1000 profiles per day

MIPAS Nominal Scan

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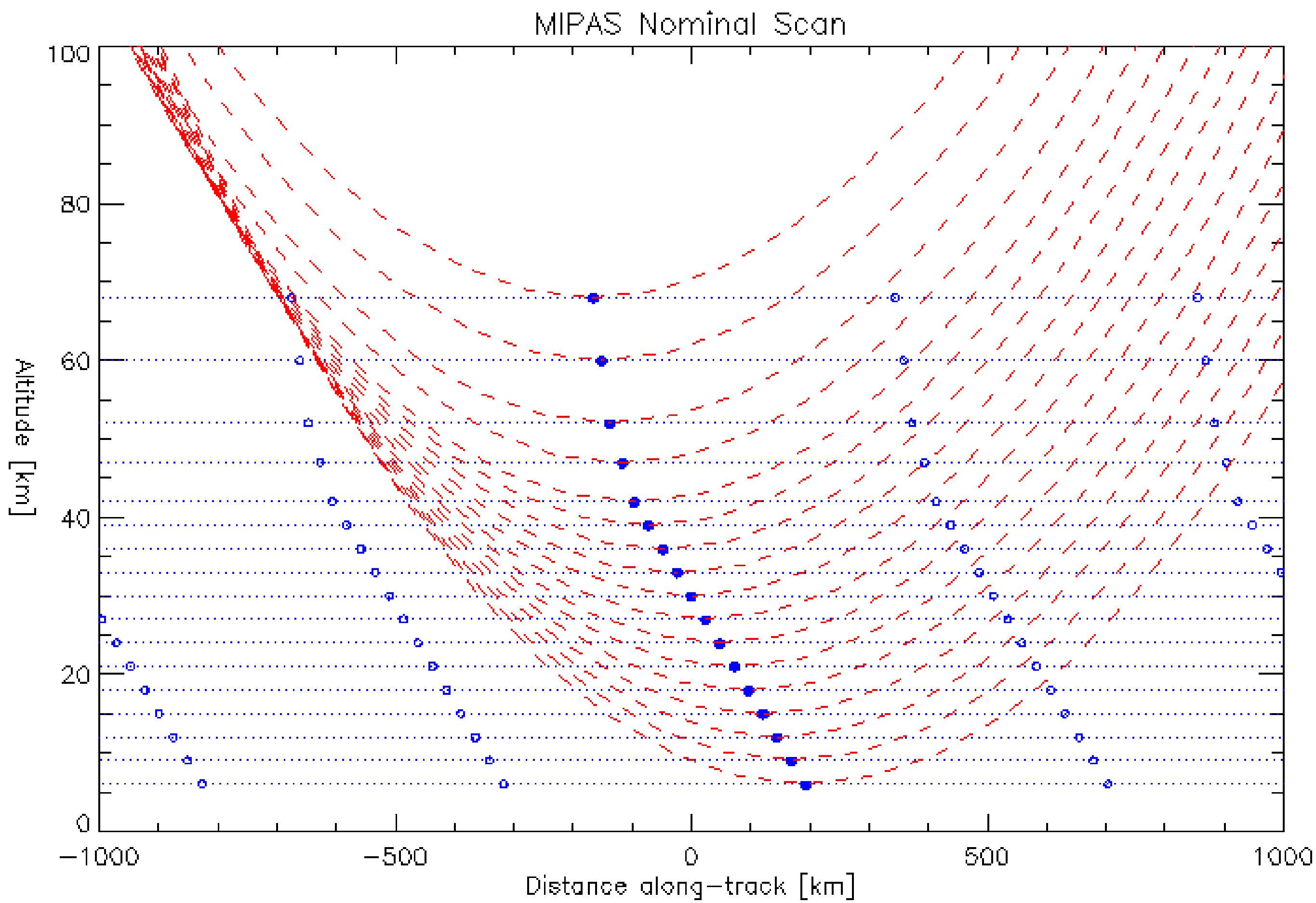

Daily Coverage

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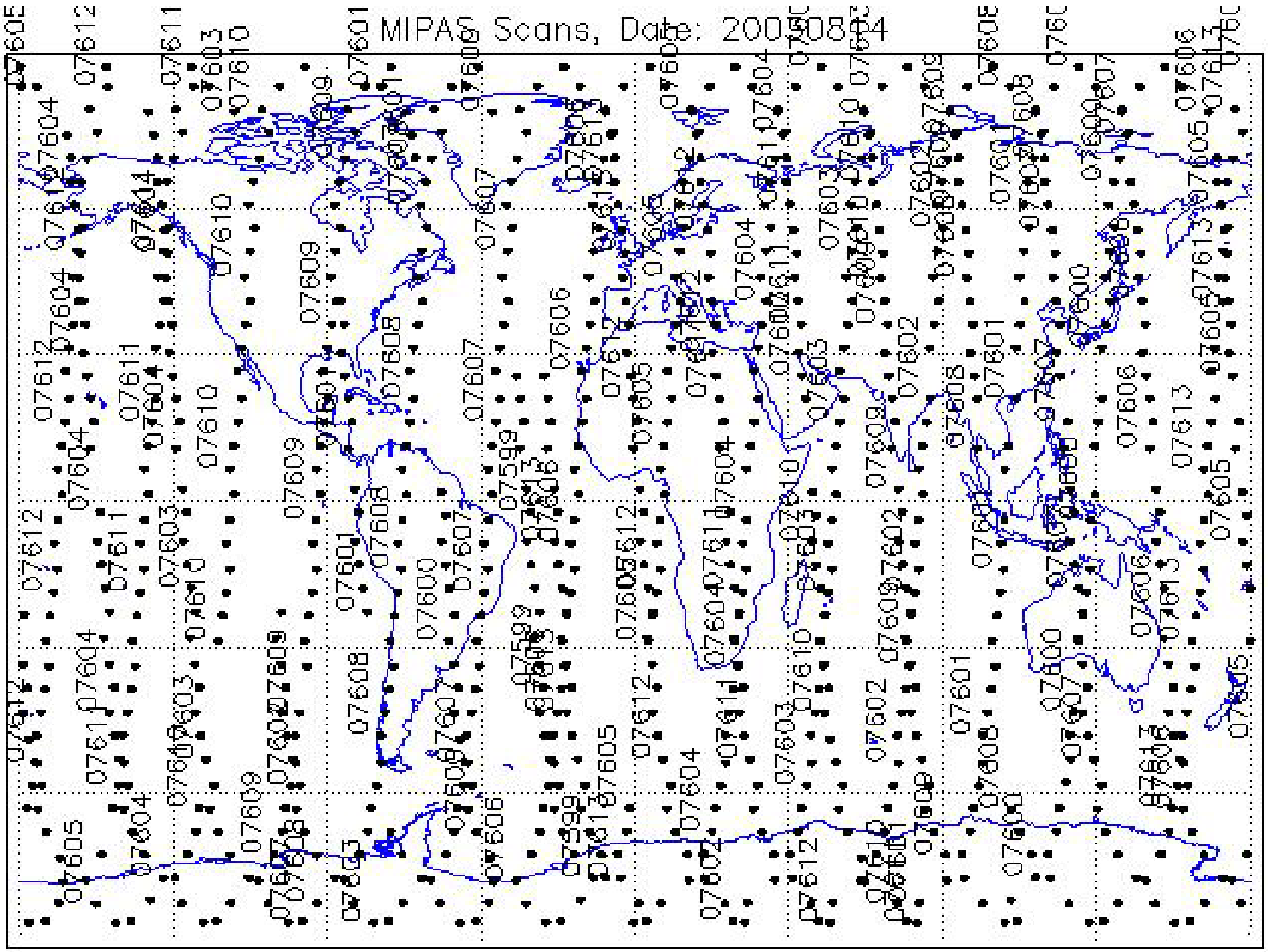

ESA Products

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- ESA produce both Near Real Time and Off Line retrievals
- Main difference is the altitude range, eg OFL extended down to 6km where possible, NRT always truncated at 12 km
- Sequential: pT, then H2O, O3, HNO3, CH4, N2O, NO2
- Only siginificant change in retrieval algorithm since launch is the introduction of cloud detection (Jul'03)

Reduced Resolution

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- Instrument switched off on 26 March 2004 due to problems with interferometer mirror movement

- Current plan is to reactivate instrument operating at 40% original spectral resolution, i.e. 0.0625cm-1 instead of 0.025cm-1

- If the limb scan in 17 steps from 68-6km is maintained, this may mean twice as many profiles along the orbit, alternatively pairs of spectra may be averaged

- S/N is actually improved by reduced resolution so no decrease in retrieval quality is expected

ESA RETRIEVAL

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Iterative non-linear least-squares fit:

- Find solution (ie profile) **x** which minimises

$$\chi^2 = (\mathbf{y} - \mathbf{K}\,\mathbf{x})^T\, \mathbf{S}_y^{-1}\, (\mathbf{y} - \mathbf{K}\,\mathbf{x})$$

Where **y** is the vector of measurements, noise covariance $\mathbf{S}_y$, and **K** is the matrix of Jacobians d**y**/d**x**

- Standard solution:

$$\mathbf{x} = \mathbf{G}\,\mathbf{y} \quad \text{where } \mathbf{G} = (\mathbf{K}^T\, \mathbf{S}_y^{-1}\, \mathbf{K})^{-1}\, \mathbf{K}^T\, \mathbf{S}_y^{-1}$$

Covariance $\mathbf{S}_x = \mathbf{G}\,\mathbf{S}_y\,\mathbf{G}^T = (\mathbf{K}^T\, \mathbf{S}_y^{-1}\, \mathbf{K})^{-1}$

Information

- No explicit *a priori*

- Define some climatological *a priori* $\mathbf{S}_a$ for the purposes of establishing the relative information represented by the retrieval.

$$H = -1/2 \log_2 (| \mathbf{S}_x \mathbf{S}_a^{-1} |)$$

- Maximising information ⇒ using measurements which …
  - Minimise $\mathbf{S}_x = (\mathbf{K}^T \mathbf{S}_y^{-1} \mathbf{K})^{-1}$
  - Maximise $\approx K^2 / S_y$
  - Maximise (sensitivity to target parameter x)/Noise

Temperature Sounding

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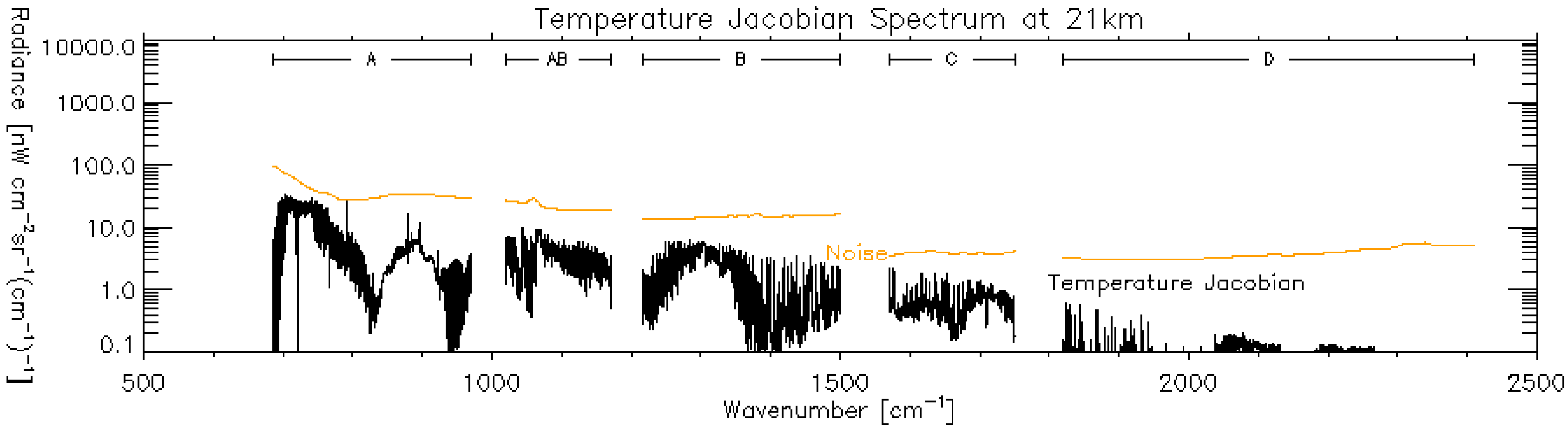

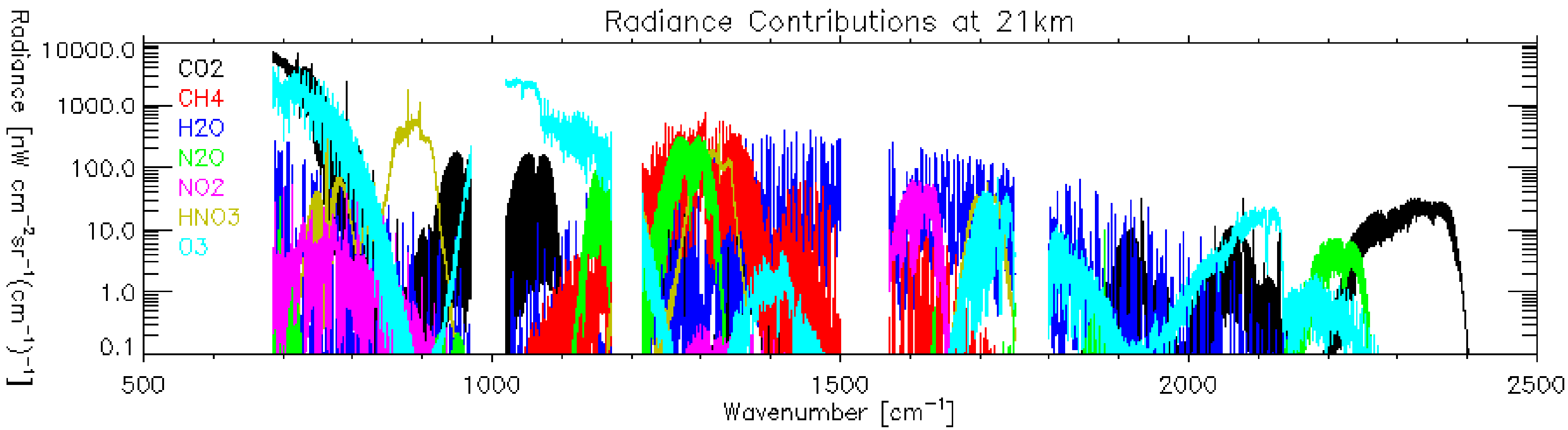

Total Error

- Problem is that the only source of error considered is the random measurement noise.

- Define 'Total Retrieval Error'

$$\mathbf{S}_x^{tot} = \mathbf{S}_x^{rnd} + \sum_i \mathbf{S}_x^{i} = \mathbf{S}_x^{rnd} + \mathbf{S}_x^{sys}$$

$$= \mathbf{G}\,(\mathbf{S}_y^{rnd} + \sum_i \mathbf{S}_y^{i})\,\mathbf{G}^T = \mathbf{G}\,(\mathbf{S}_y^{rnd} + \mathbf{S}_y^{sys})\,\mathbf{G}^T$$

where 'rnd' are the previous random noise contributions and 'sys' are contributions from various *systematic* error sources i.

Systematic Errors

Instrument characterisation

- Radiometric gain uncertainty +/-1% (GAIN)
- Spectral calibration uncertainty +/-0.001 cm-1 (SHIFT)
- Instrument lineshape uncertainty +/- 2% width (AILS)

Forward model assumptions

- Climatological variability of 28 species
- Non-LTE effects (NONLTE)
- Spectroscopic database uncertainties (SPECDB)
- Modelling gaseous continua: 25% uncertainty (CTMERR)
- CO2 line mixing (CO2MIX)
- Horizontal temperature gradients +/-1K/100 km (GRA)
- High altitude column (HIALT)
- (constituent retrievals) pT retrieval uncertainties of +/-2%, +/-1K respectively

Temperature Sounding

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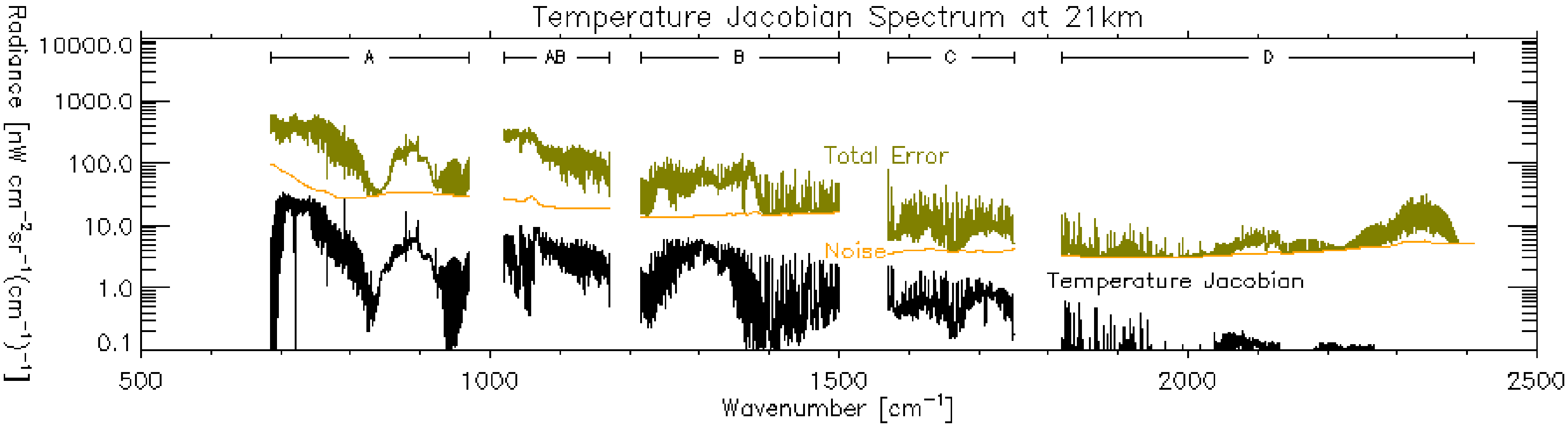

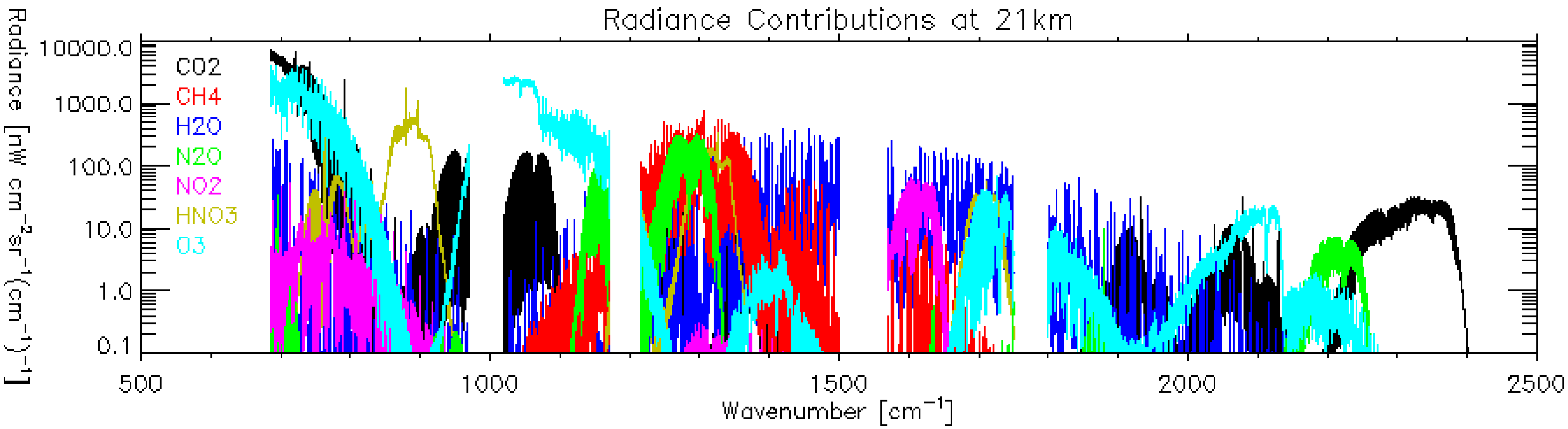

Negative Information

- Note that **G**, defined by the ESA retrieval, is still

$$\mathbf{G} = (\mathbf{K}^T (\mathbf{S}_y^{rnd})^{-1} \mathbf{K})^{-1} \mathbf{K}^T (\mathbf{S}_y^{rnd})^{-1}$$

$\Rightarrow$Non-optimal weighting

- Consequence is some measurements will reduce total information, ie contribute negative information.

- Aim is to select measurements which maximise total information but allowing for ‘incorrect’ weighting in retrieval

- Achieve this by selecting measurements which minimise, or even cancel, systematic errors

Microwindows

- The measurement domain for limb sounders can be considered to be a 2D array, tangent height v spectral channel

- Rather than pick isolated points, prefer to use microwindows which represent rectangles in this domain.

- Advantages:
  - Numerically more efficient for forward model
  - Allows continuum-like emissions to be fitted/eliminated
  - Allows systematic errors to be reduced

Microwindows

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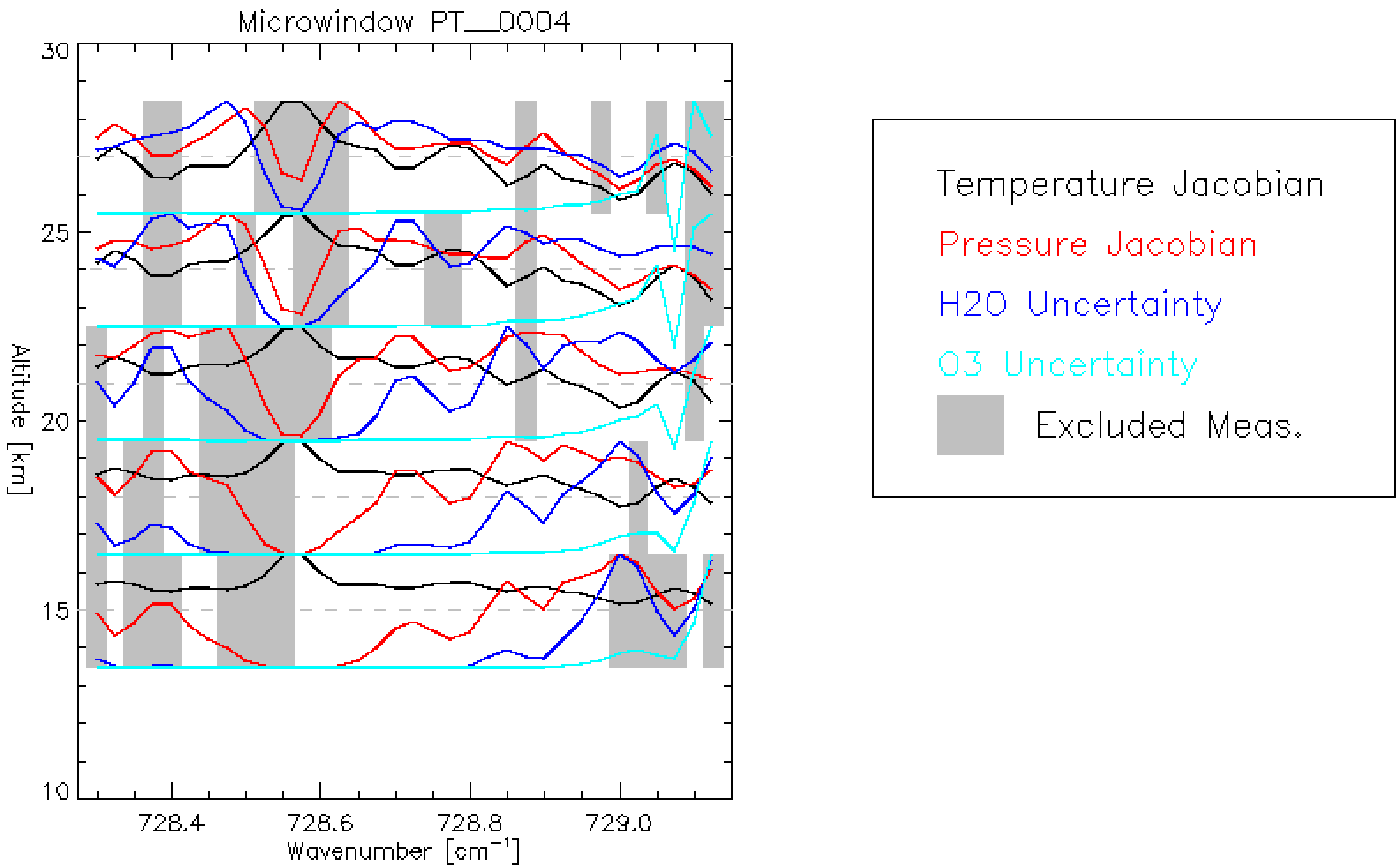
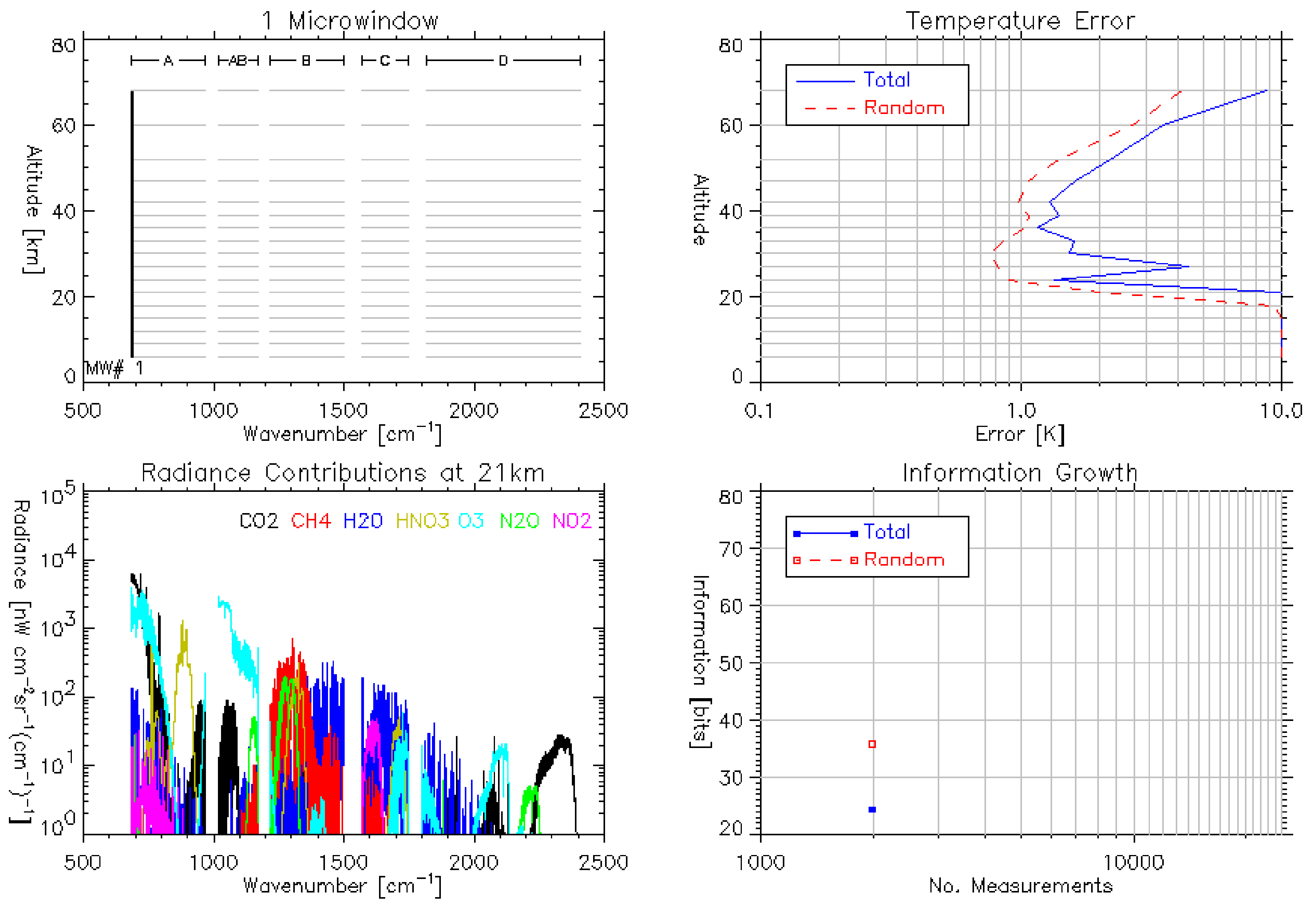
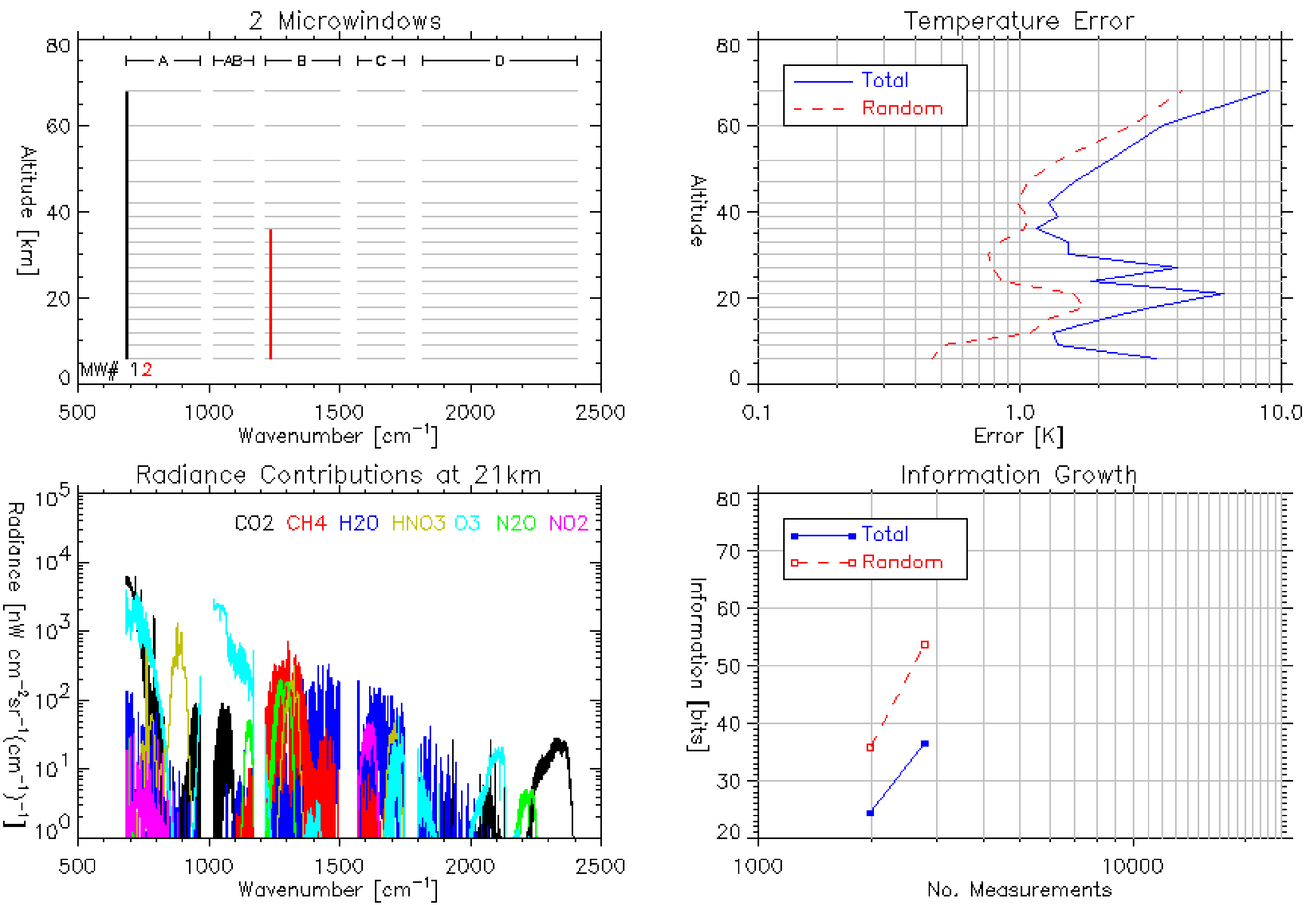


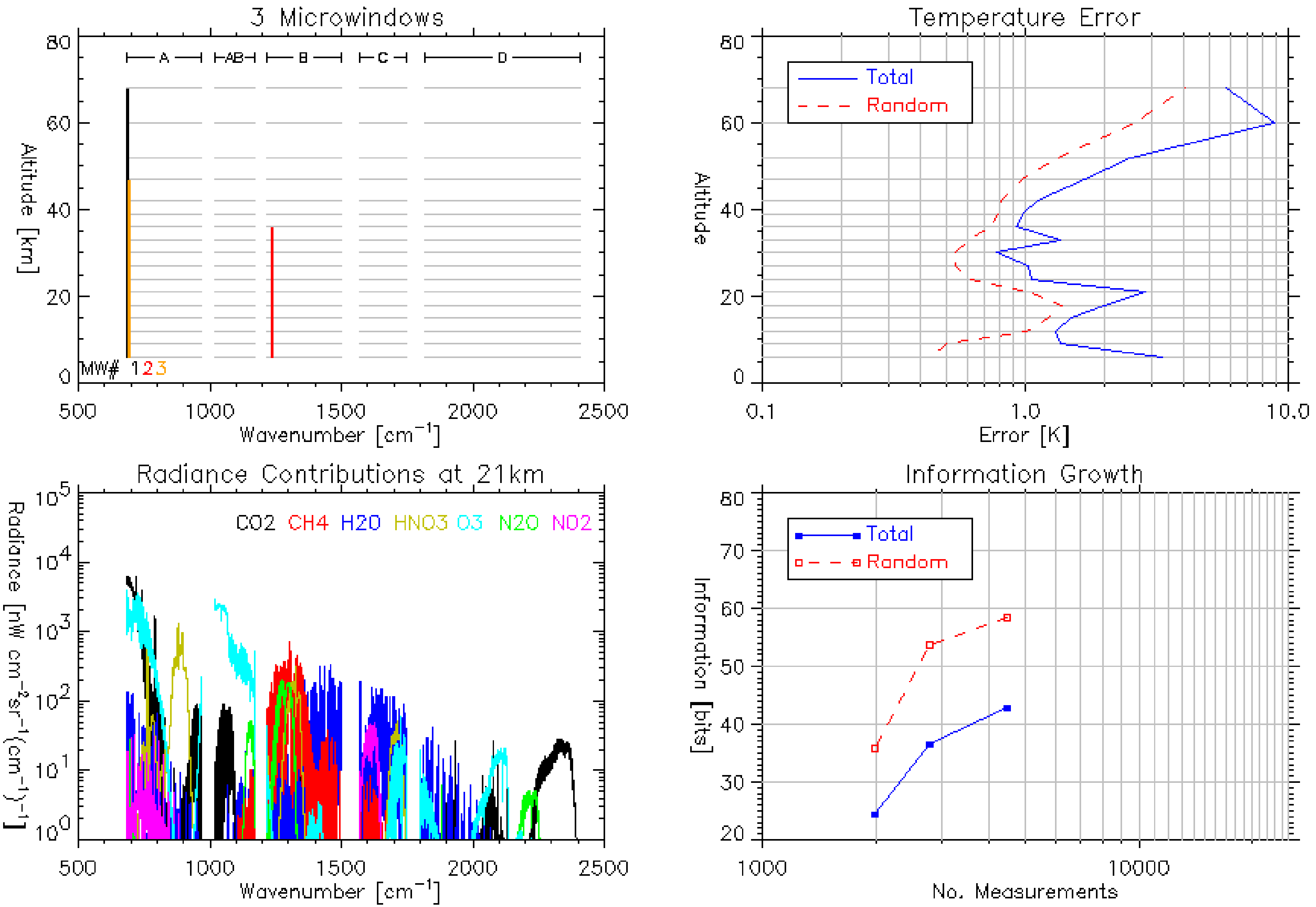
1 Microwindow



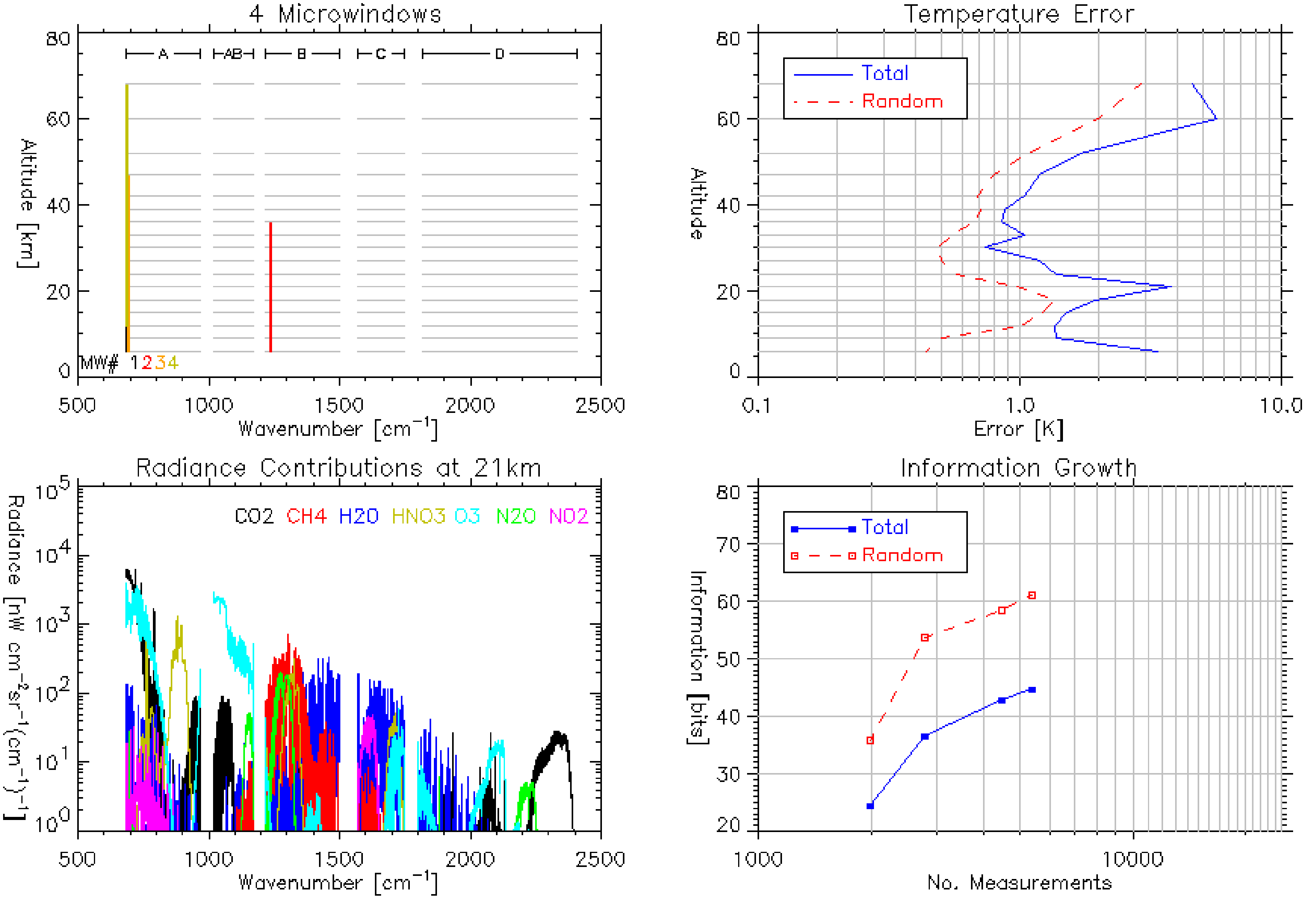
2 Microwindows



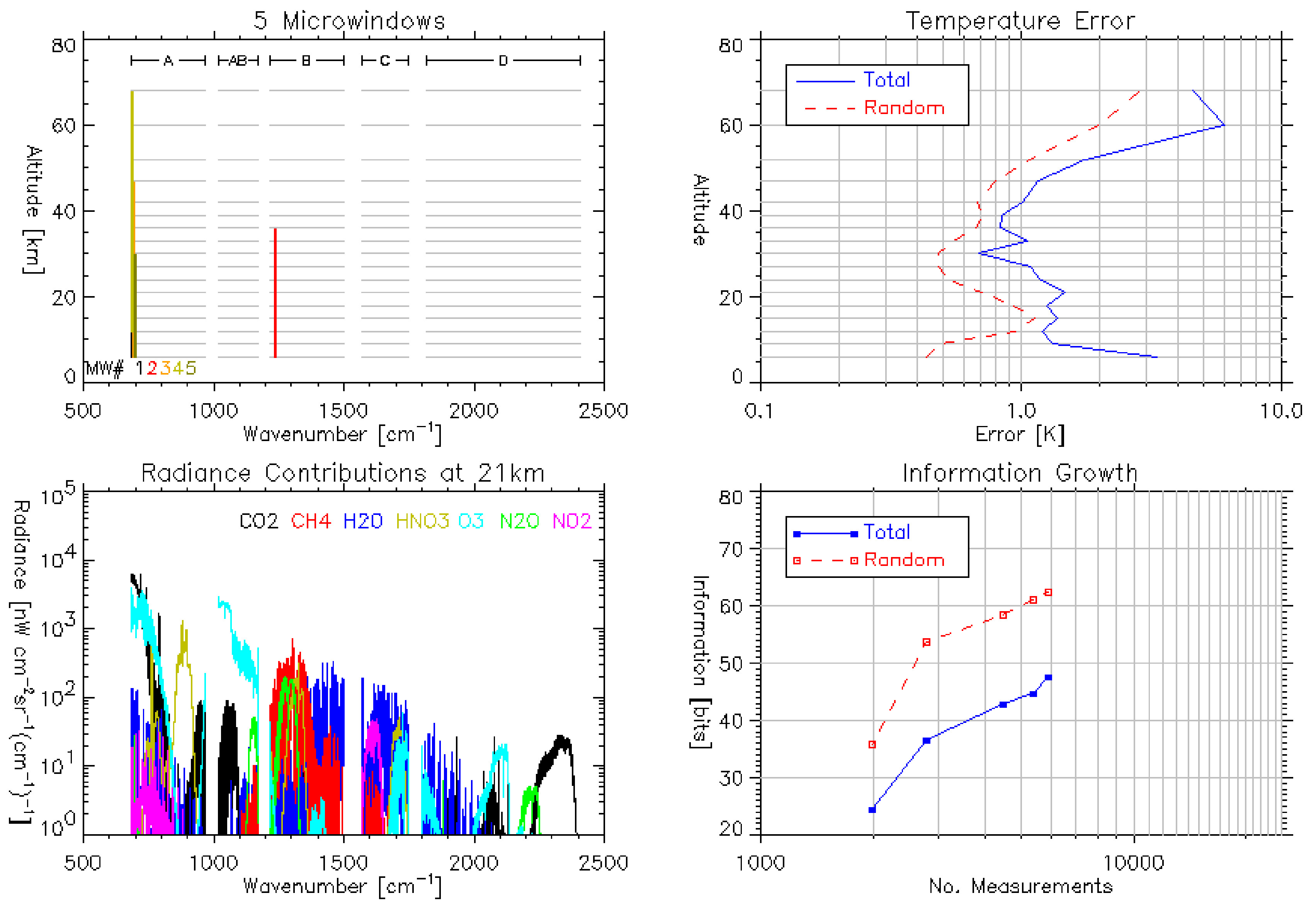
3 Microwindows



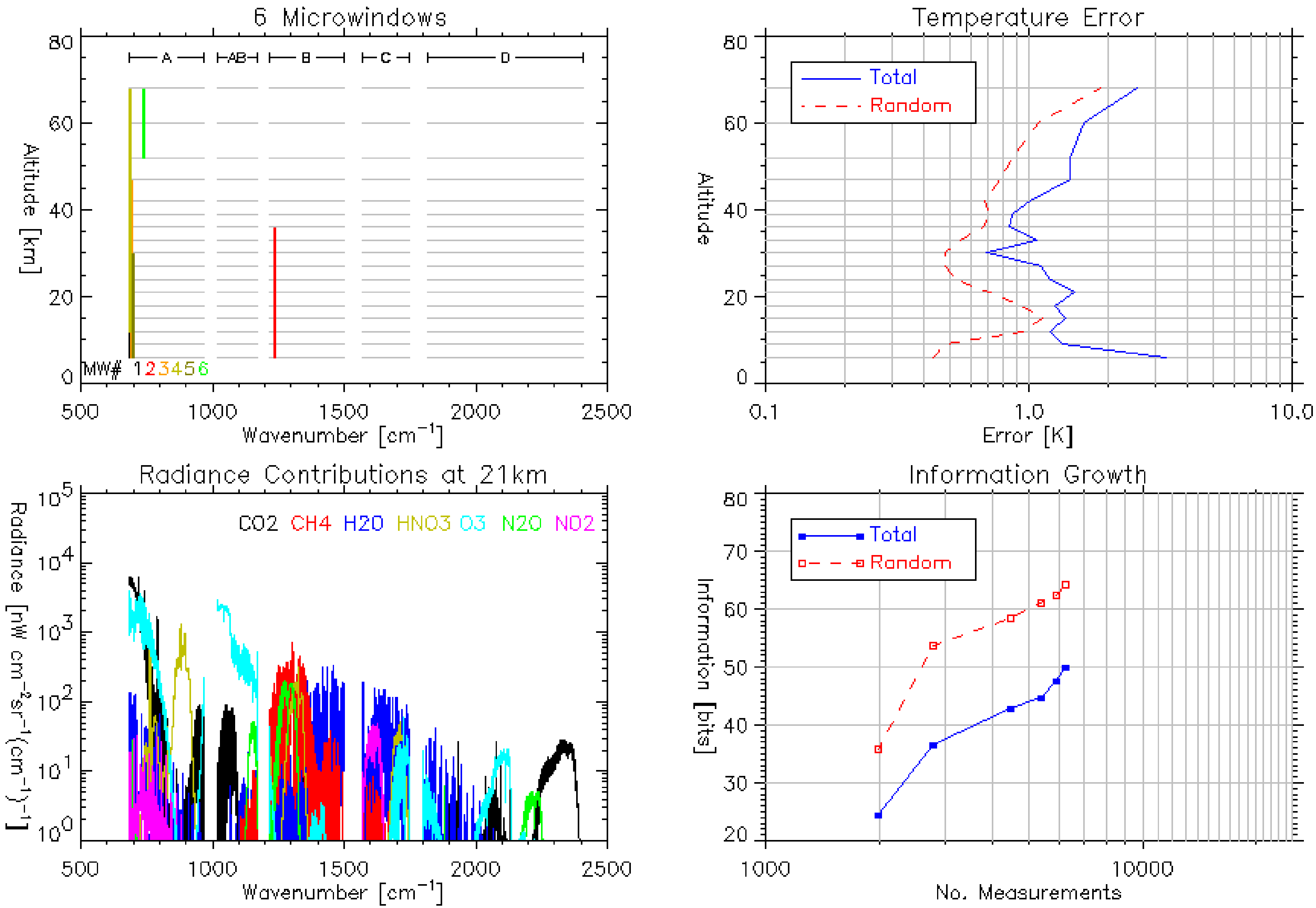
4 Microwindows



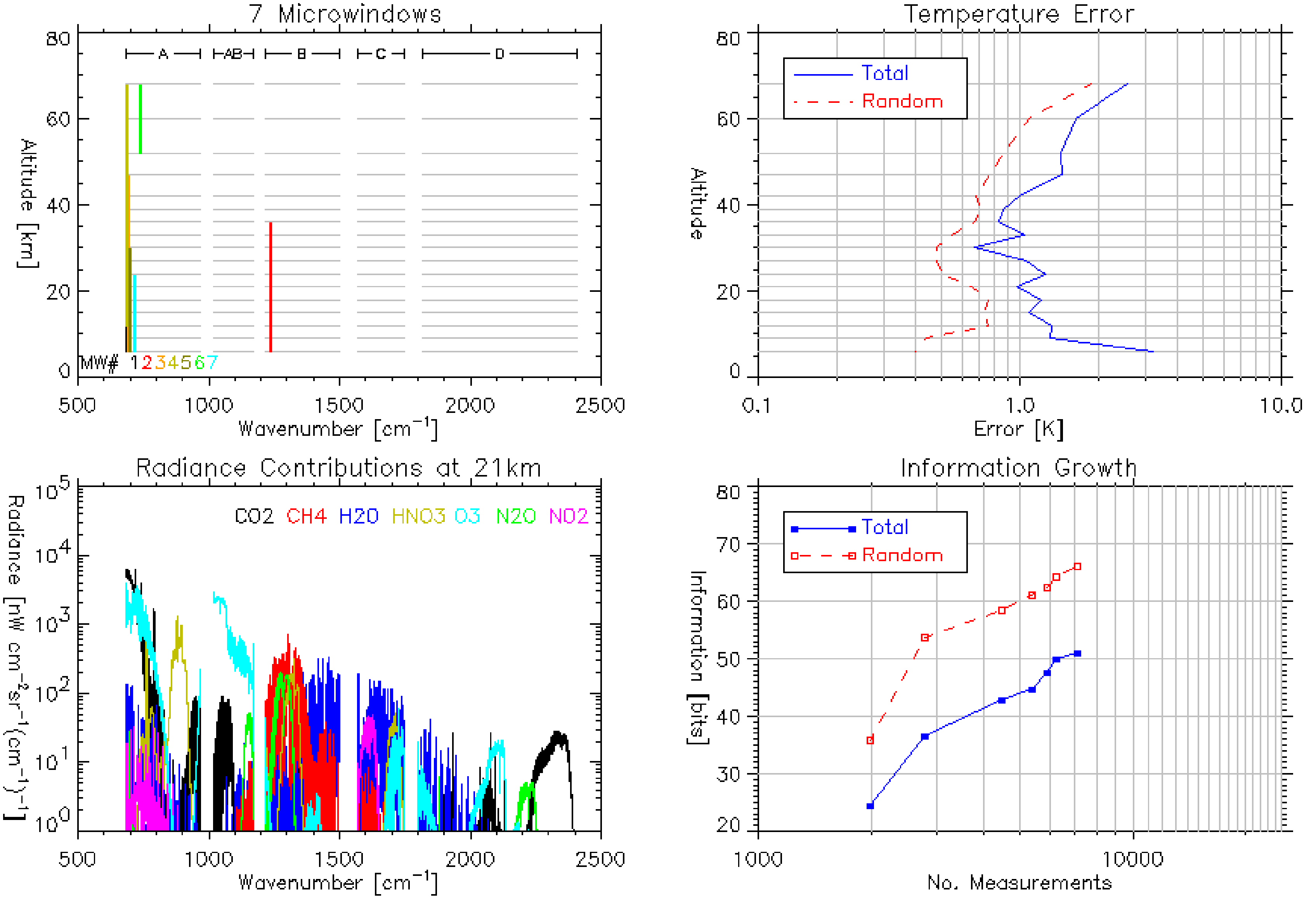
5 Microwindows



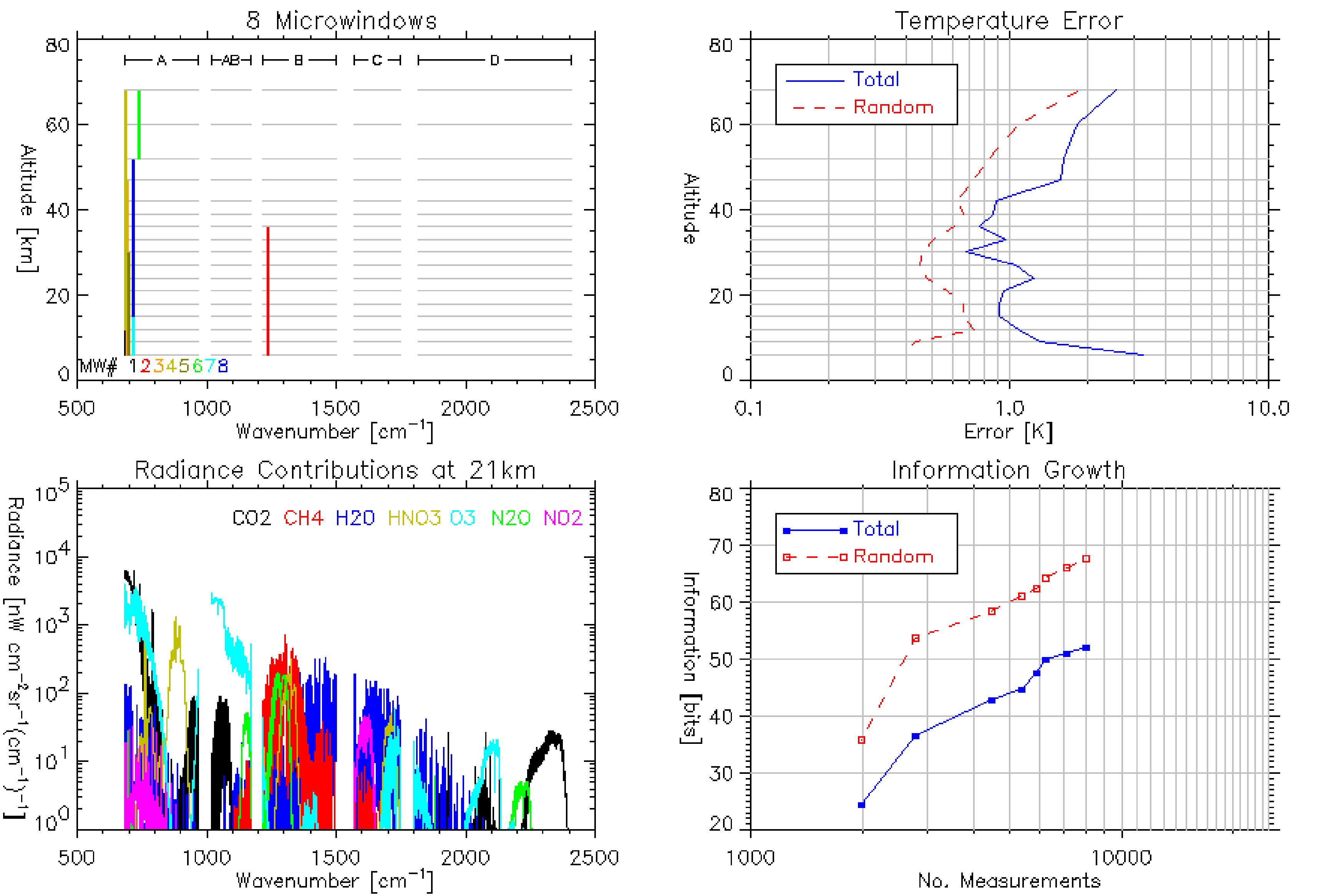
6 Microwindows



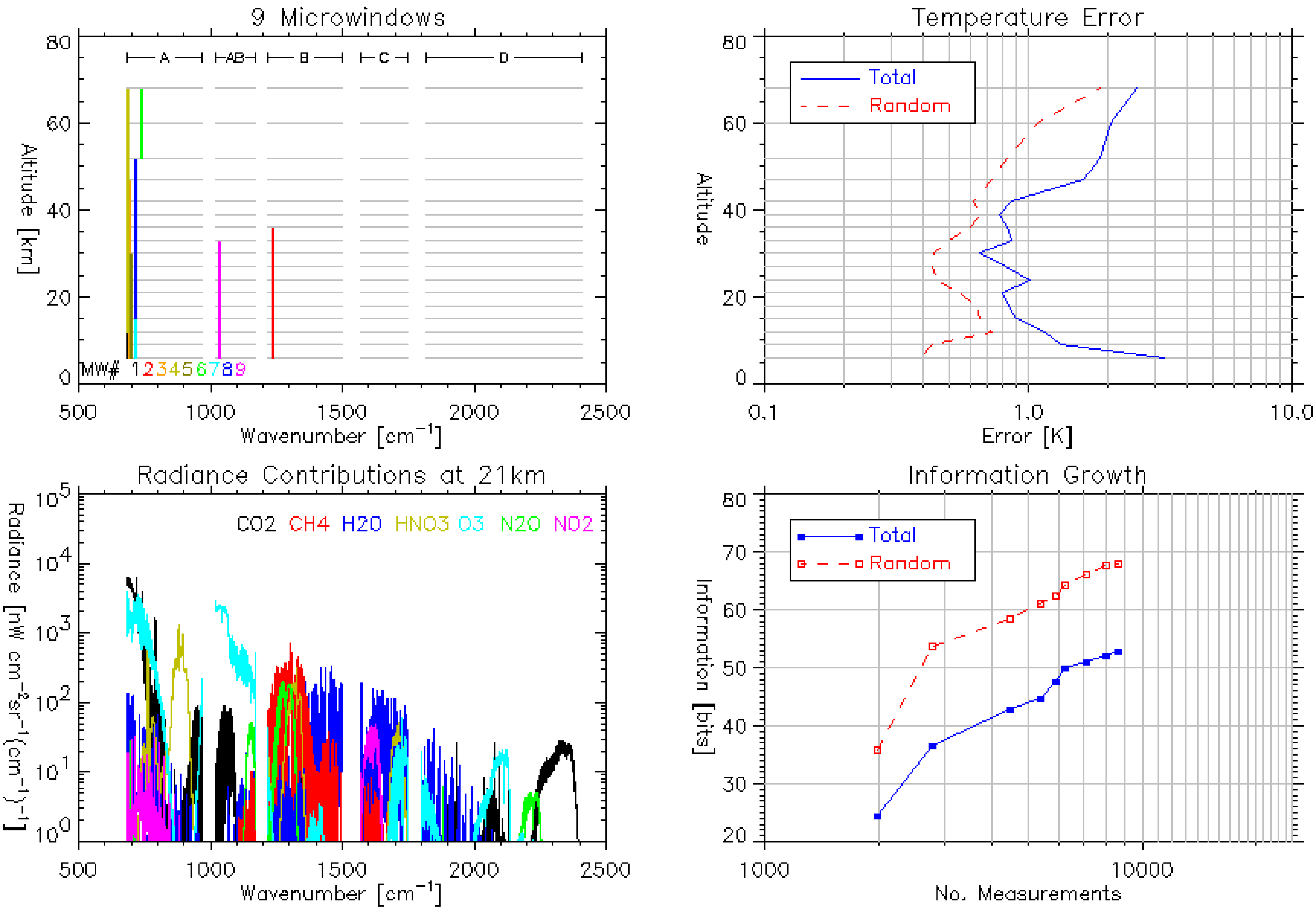
7 Microwindows



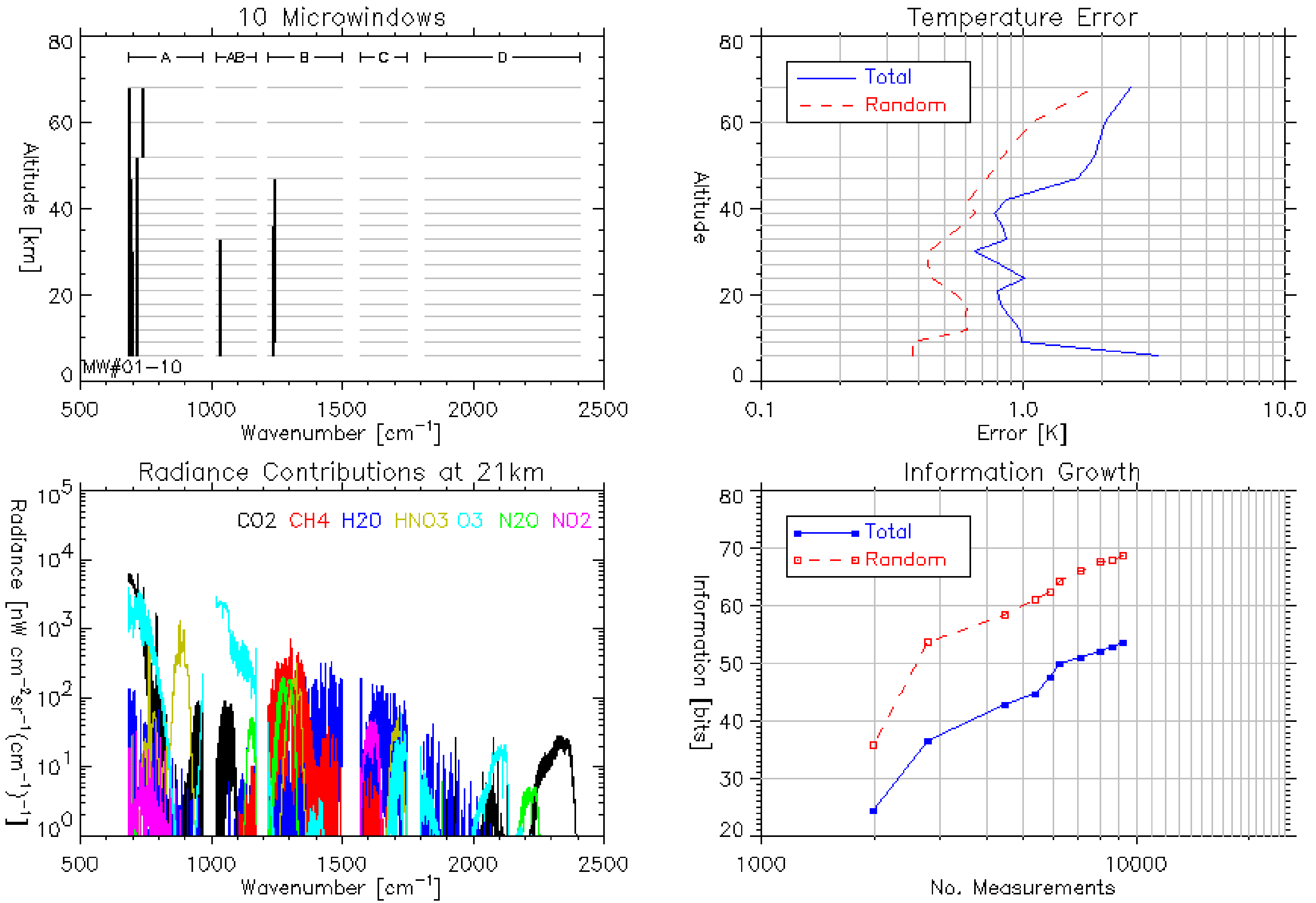
8 Microwindows



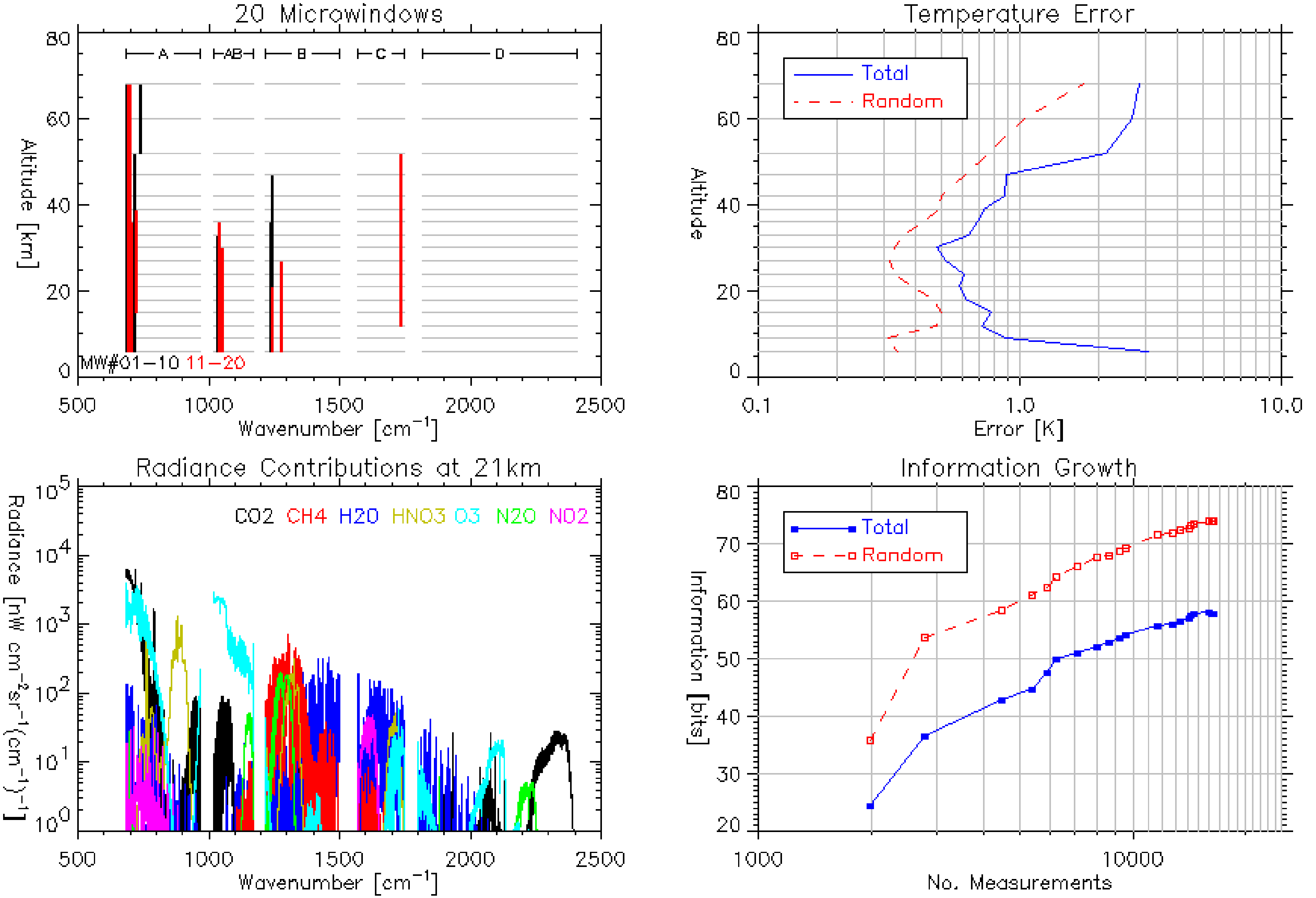
9 Microwindows



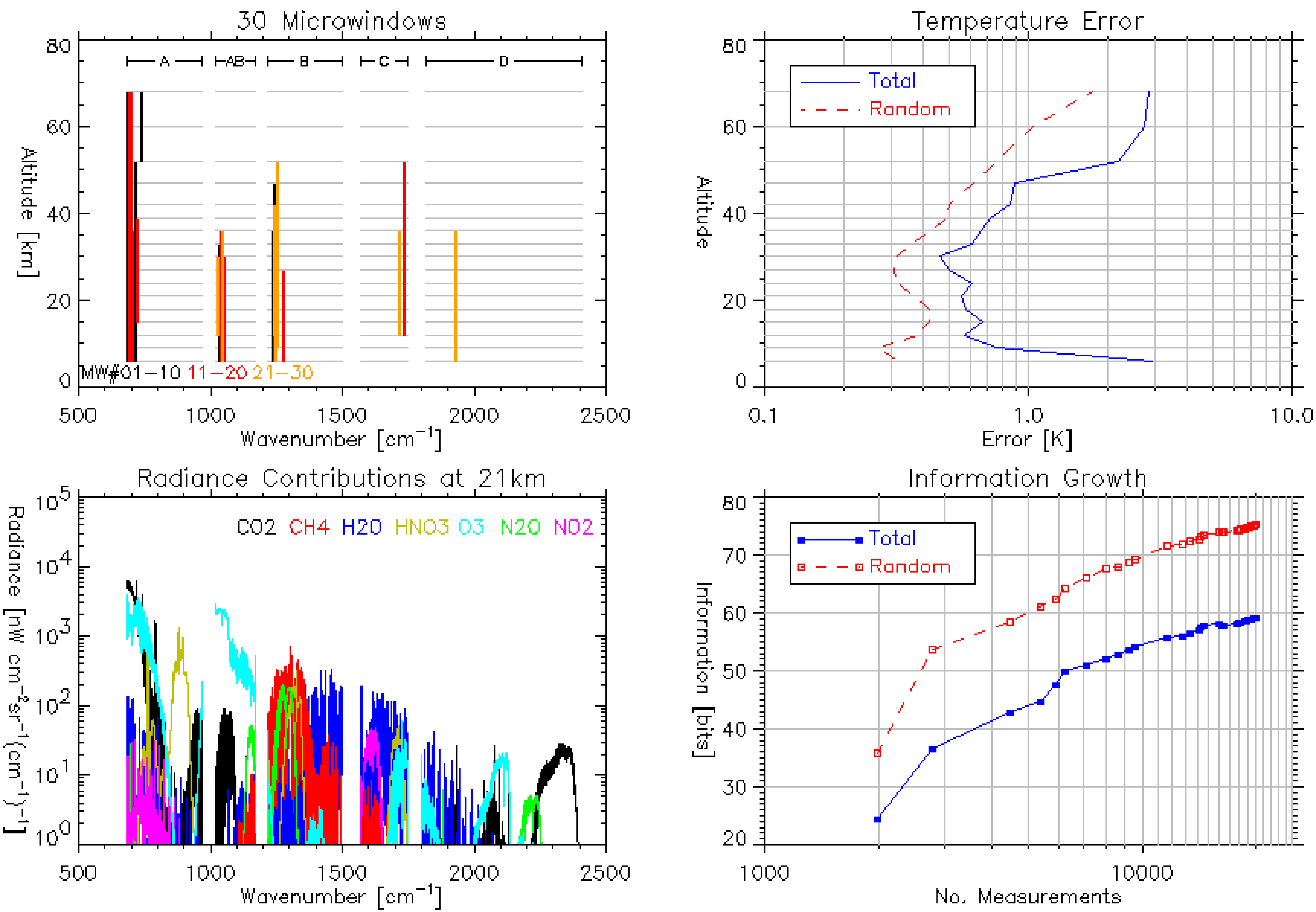
10 Microwindows



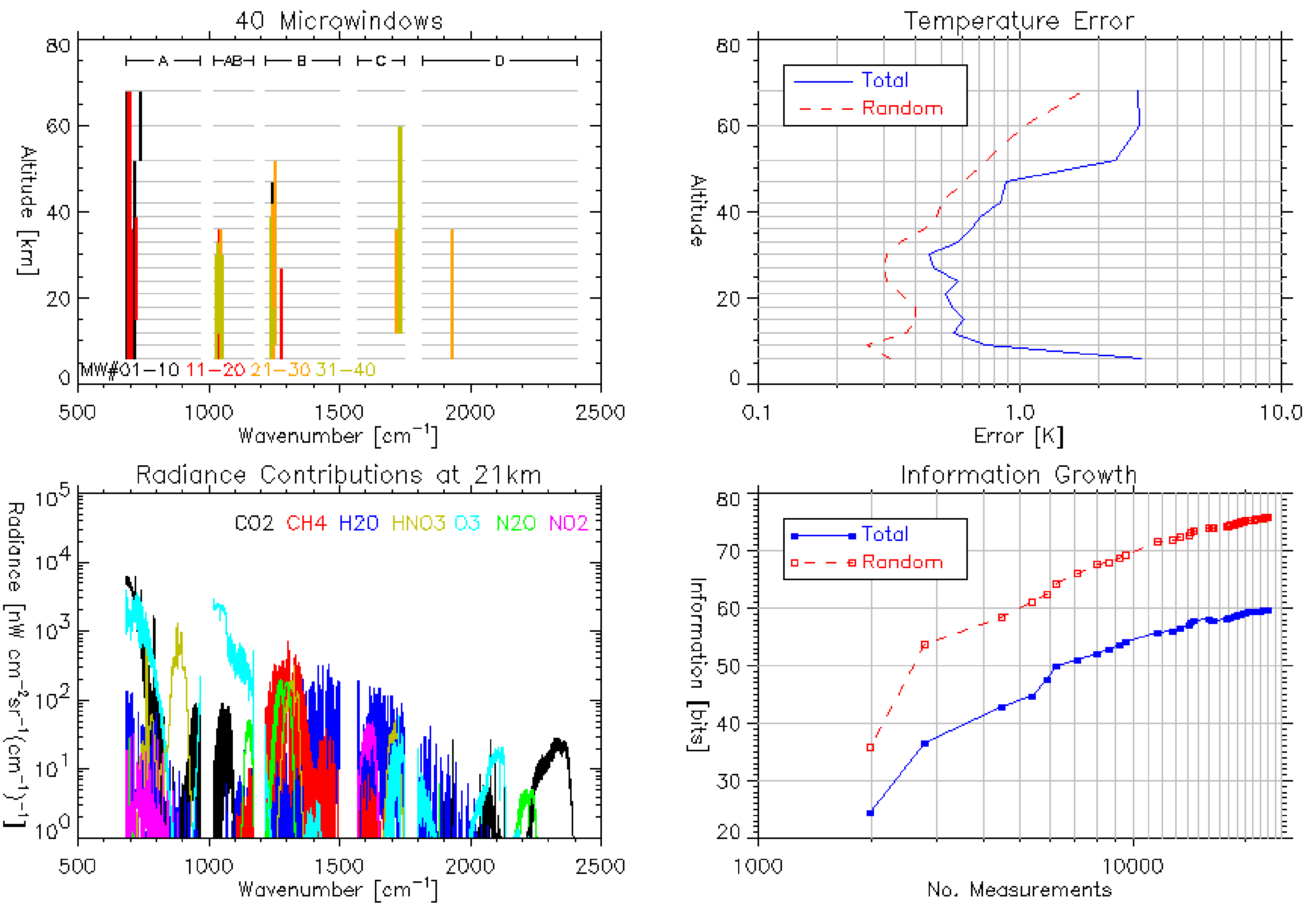
20 Microwindows



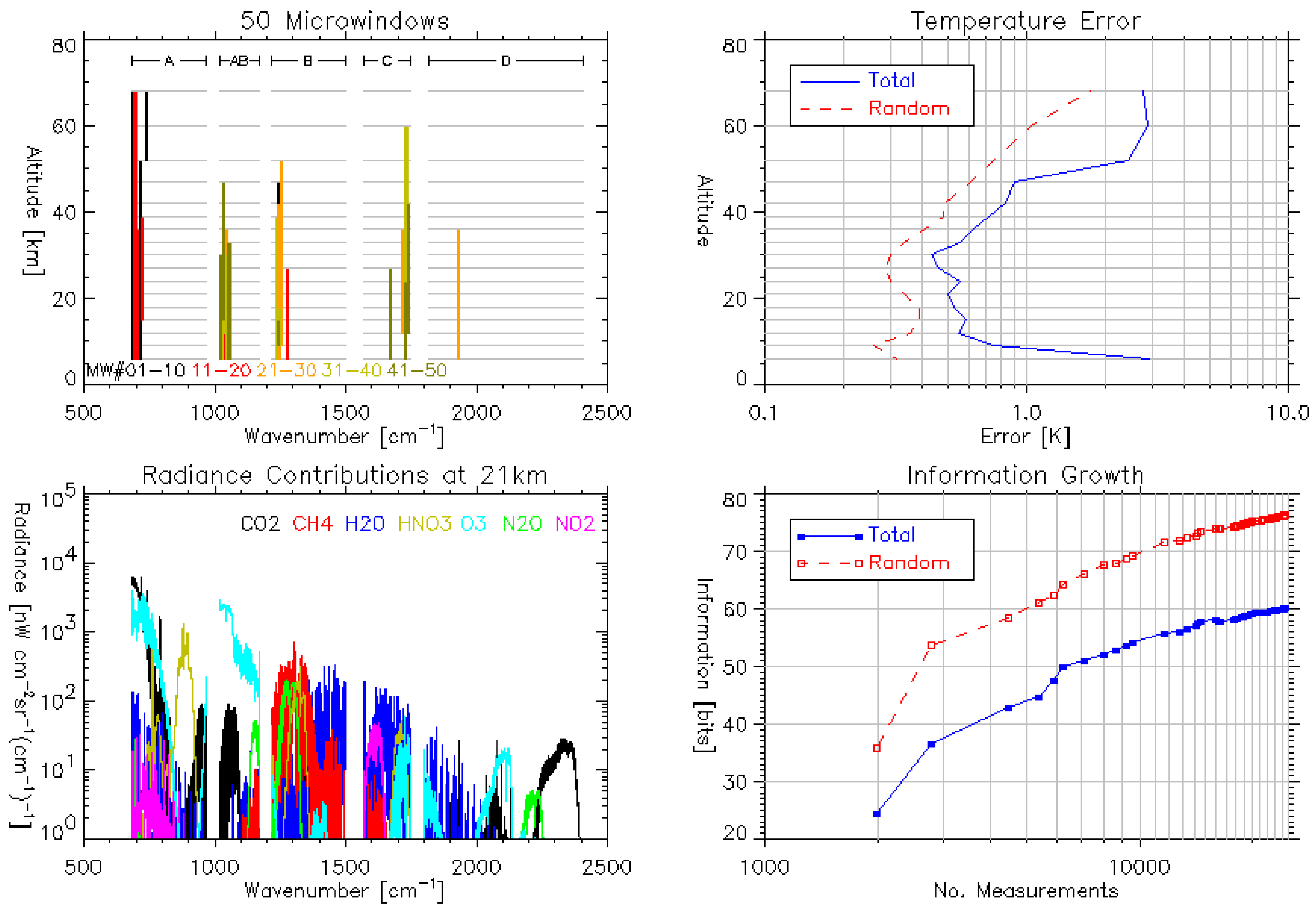
30 Microwindows



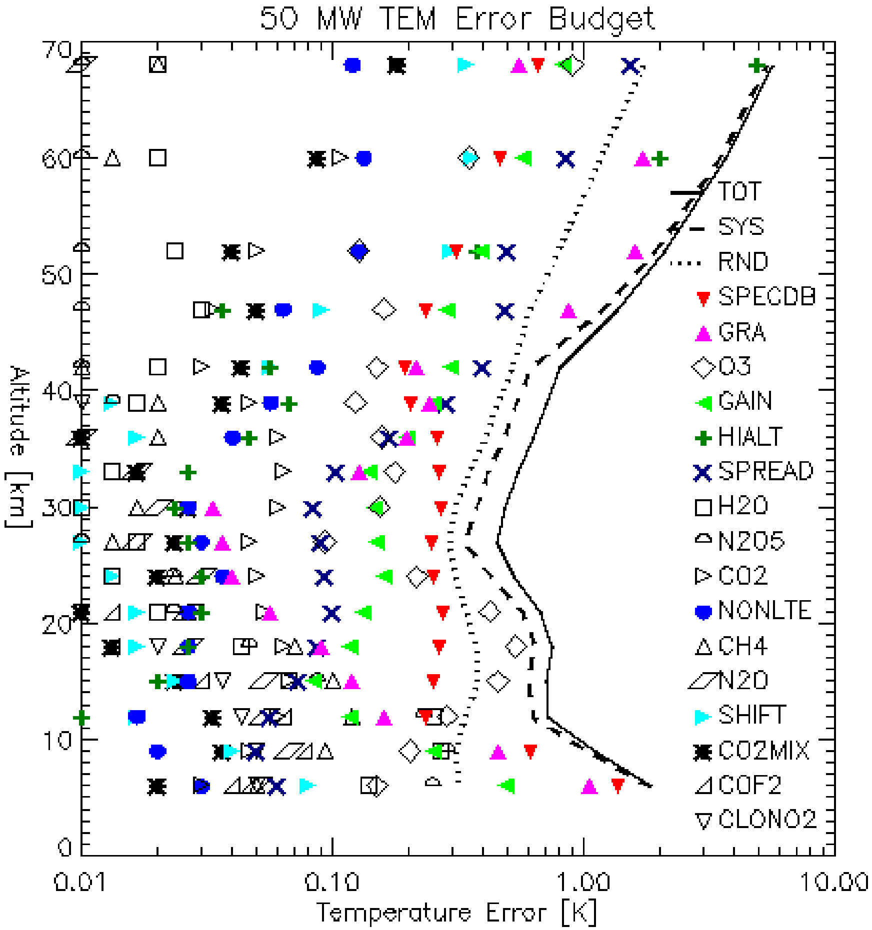
40 Microwindows

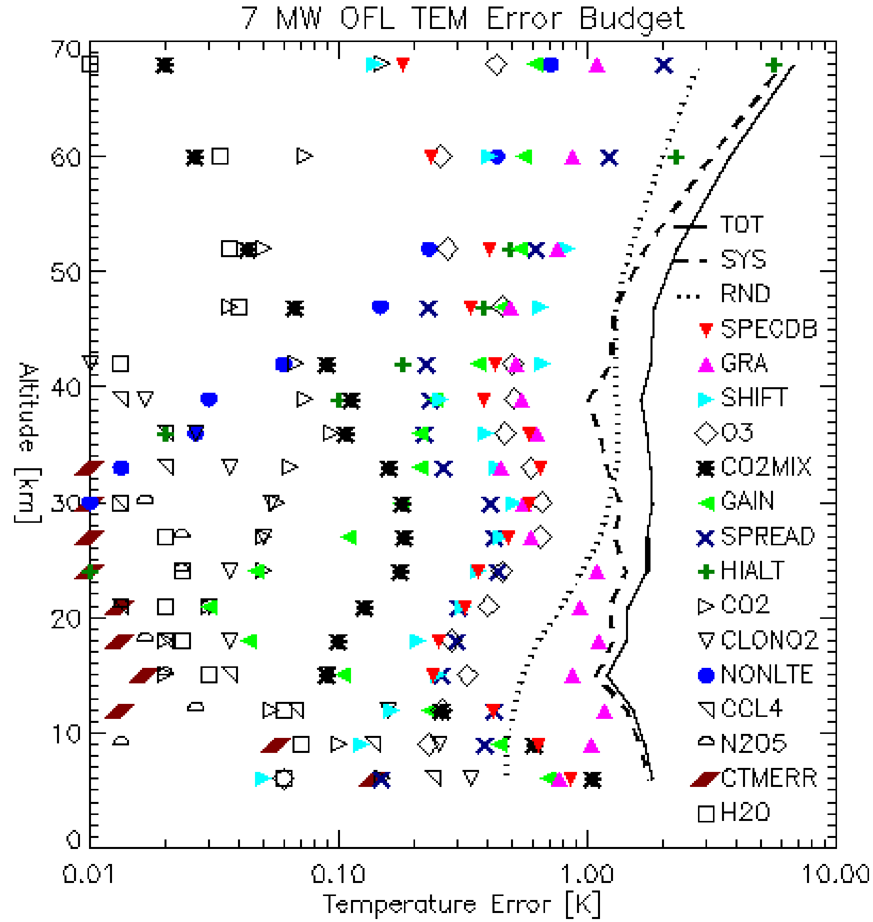


50 Microwindows



Error Analysis





NRT Microwindows

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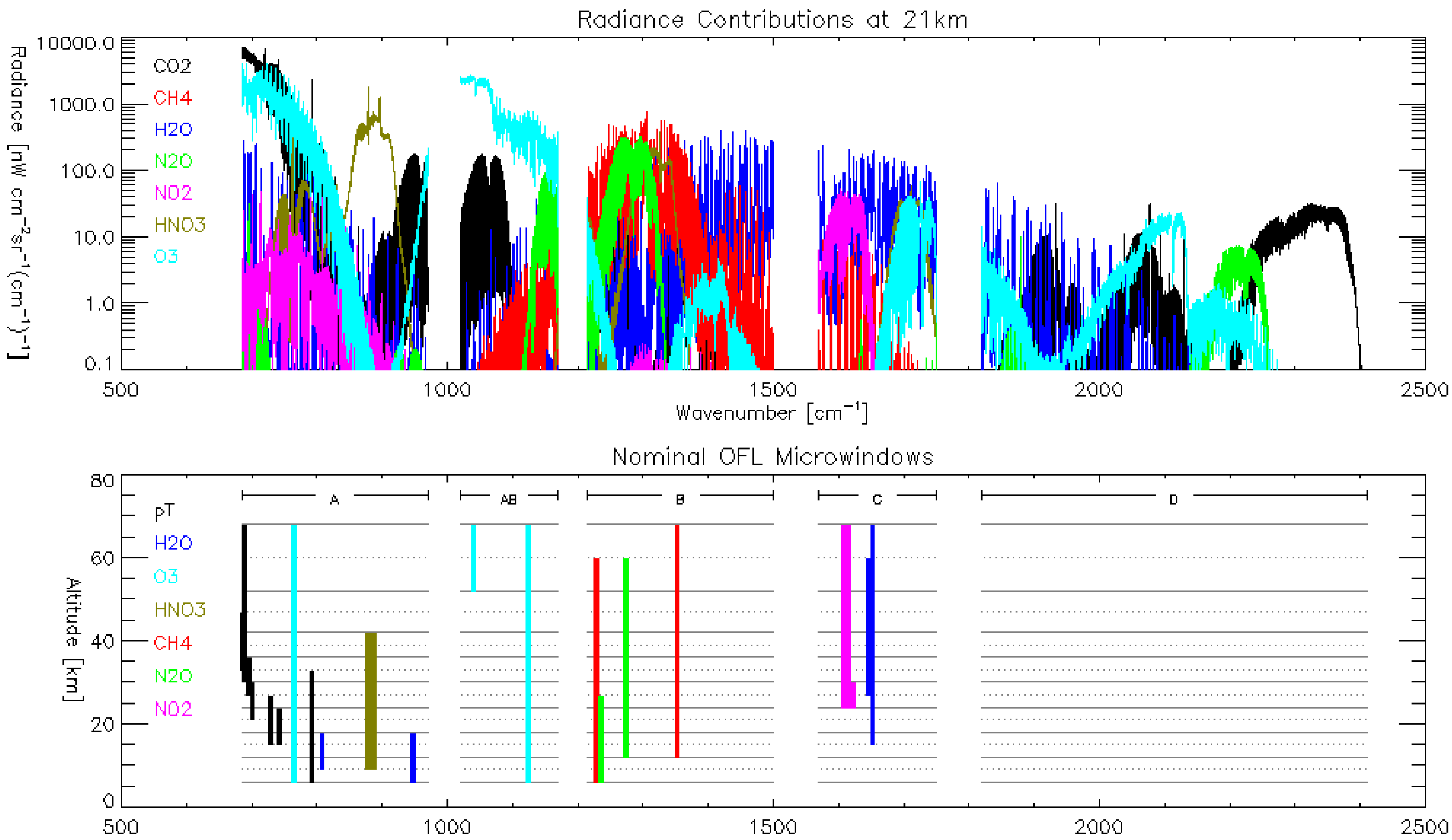

Summary

- The information content of MIPAS spectra is defined to include systematic as well as random (S/N) errors

- These systematic errors represent known limitations in the retrieval, forward model and instrument characterisation

- This allows microwindows to be selected which minimise the total retrieval error even though the retrieval itself considers only random noise errors