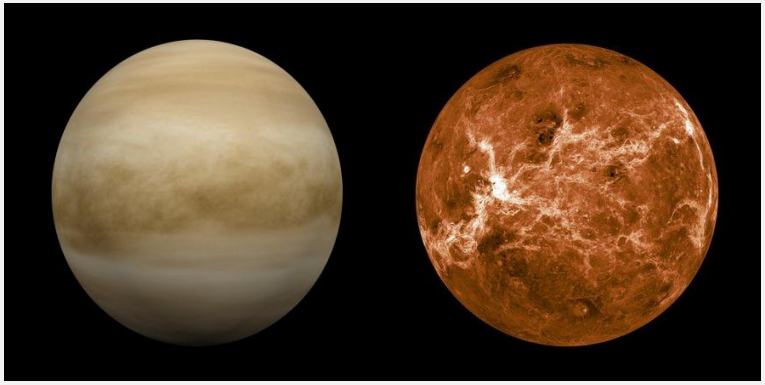


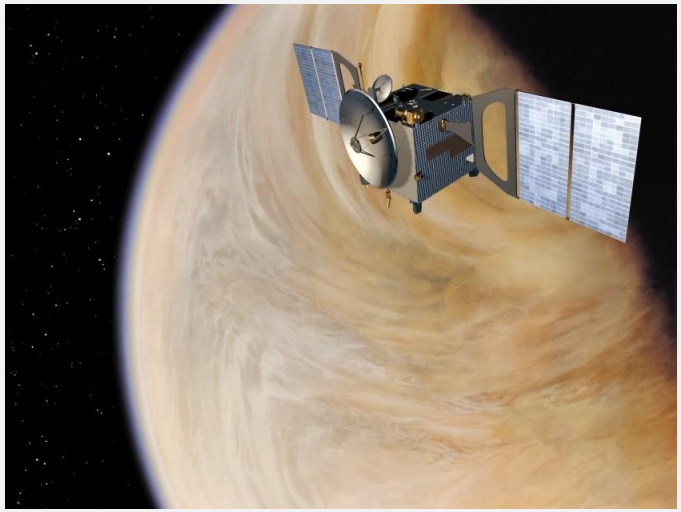
Retrieval of surface properties in the NIR nightside windows of Venus

Gabriele Arnold[1], Rainer Haus[2], David Kappel[1]

[1]Institut of Planetary Research, DLR, Rutherfordstr.2, 12489 Berlin, Germany; [2]Institut für Planetologie, WWU, 48129 Münster, Germany

Scope

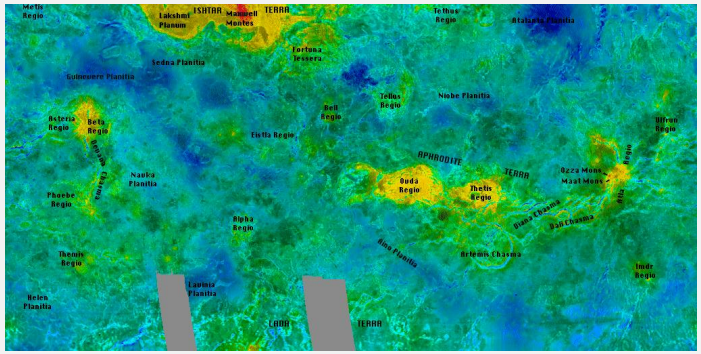
- *Obtain global scale deep atmosphere and surface information*
- *Use of Venus' spectra in the NIR nightside transparency windows*
- *Retrieve parameters from single-spectrum and multi-spectrum regularization*
- *Discussion of surface emissivity retrievals*



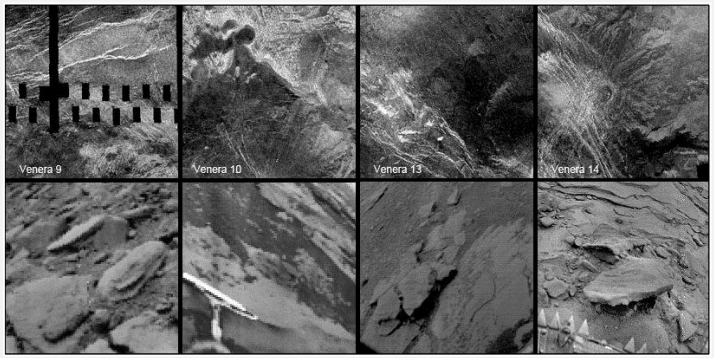
Venus Express

Background

- *Global view of surface topography by radar observations (Magellan)*
- *Global view of surface radar reflection and scattering (limited information about material and texture)*
- *Global surface composition properties poorly known*
- *In situ data from Venera and Vega landers (local/regional information)*



Magellan topography

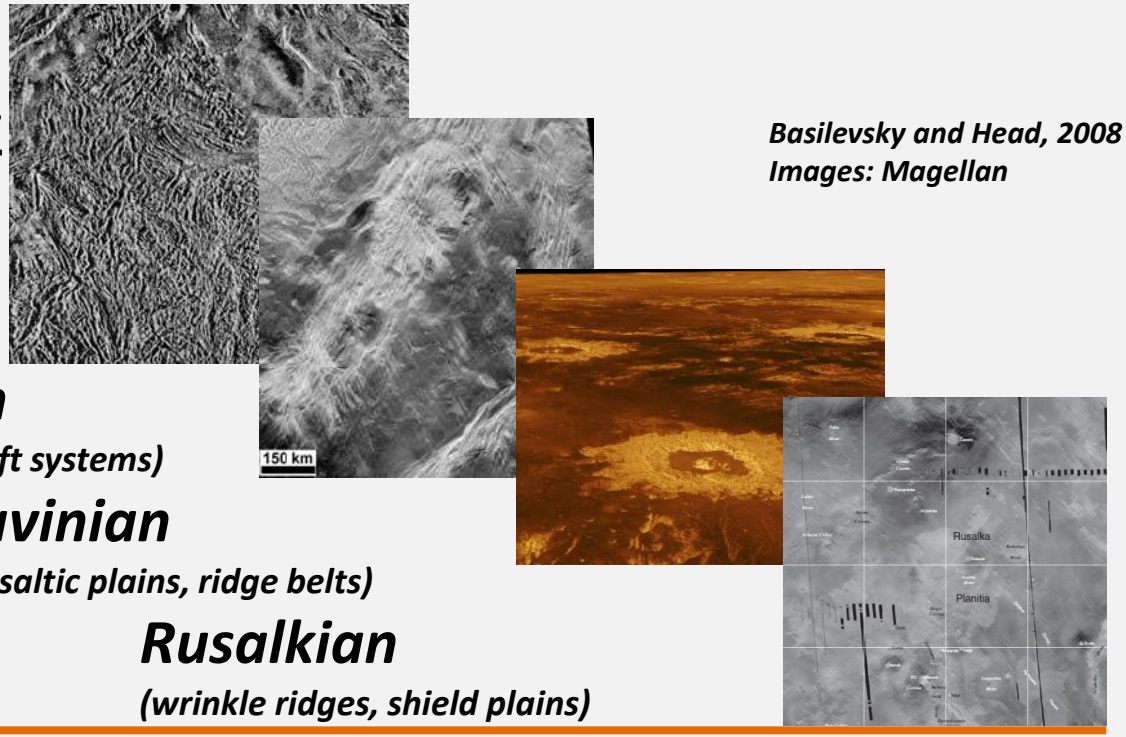


Basilevsky et al., 2004

Introduction

Geological surface units

Basilevsky and Head, 2008
Images: Magellan



Old area
Max. about 1 Gy

Fortunian
(Tesserae)

Sigrunian
(tectonic belt/rift systems)

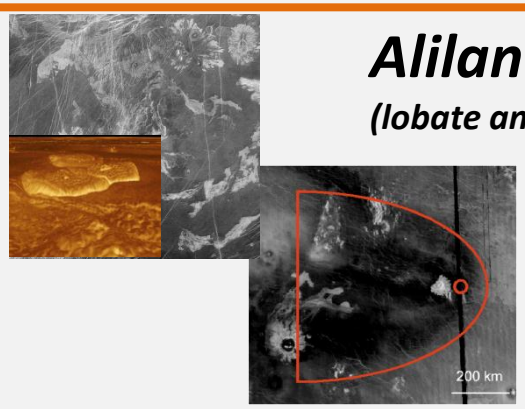
Lavinian
(basaltic plains, ridge belts)

Rusalkian
(wrinkle ridges, shield plains)

Middle age: 600-800 Mio. y

Alilan
(lobate and smooth plains, coronae)

Aurelian
(eolian impact sediments)



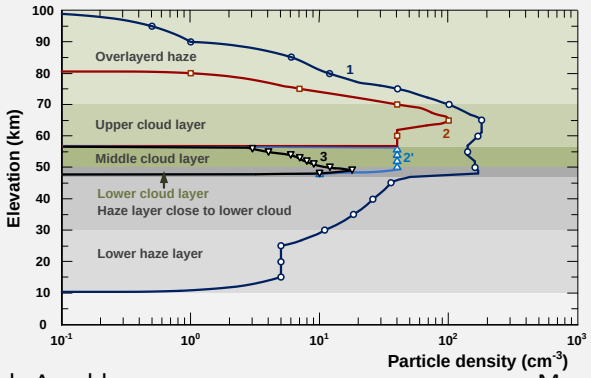
Young area

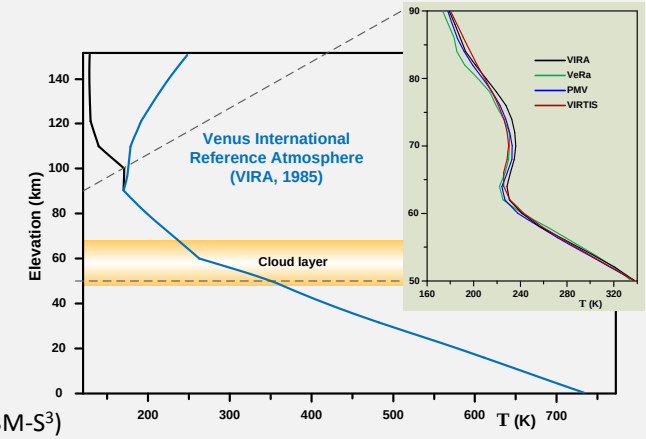
Surface material

- ***Basaltic plains- Tholeiide to basic basalt?*** ***(Morphology, basaltic volcanism, Venera-Vega landers composition:*** *Basilevsky and Head, 2003; Kuchinas et al., 1996; Ivanov et al., 1996; Basilevsky et al., 1995; Nikolaeva, 1989; Barsukov, 1992; Surov, 1997; Fegley et al., 1997; Klingelhöfer and Fegeley, 2000)*
- ***Steep-sided domes – different viscosity?*** *(Basilevsky and Head, 2009)*
- ***Tessera – more felsic?*** ***(above standing material and bright radar reflectance above 5 km altitude:*** *Pettengil et al., 1997 –* ***key to the older surface forming processes)***
- ***Weathering: Carbonate vs pyrite model?*** *(Fegely et al., 1997; Pettengill et al. 1983)*

Atmosphere and surface studies

- *Radar studies provide only limited results in respect to the global surface composition*
- *Studies at optical wavelengths require sophisticated methods to extract information about the lower atmosphere and surface of Venus on global scales*
- *New measurements of VIRTIS/VEX in the NIR nightside windows created a new data base for such studies*

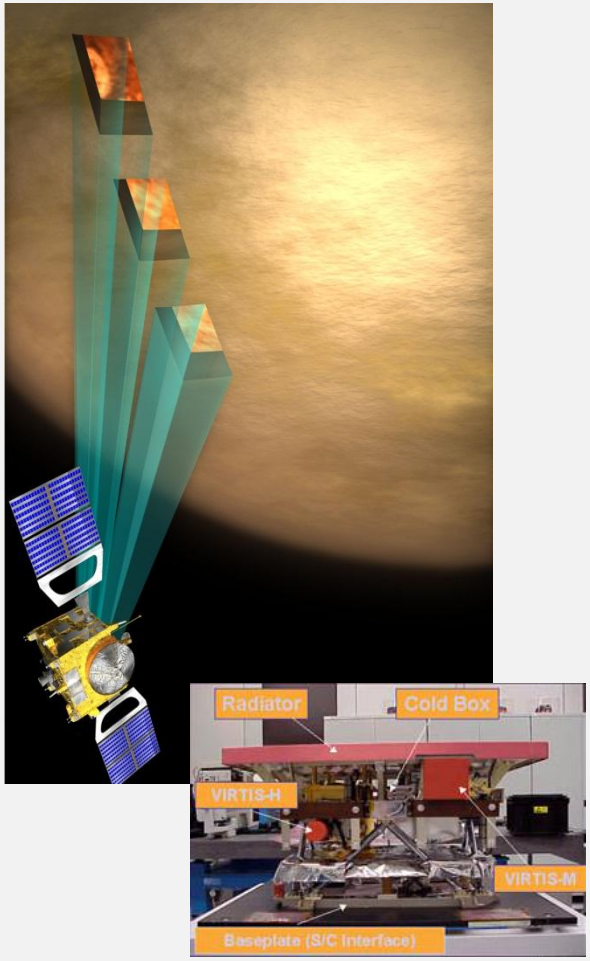




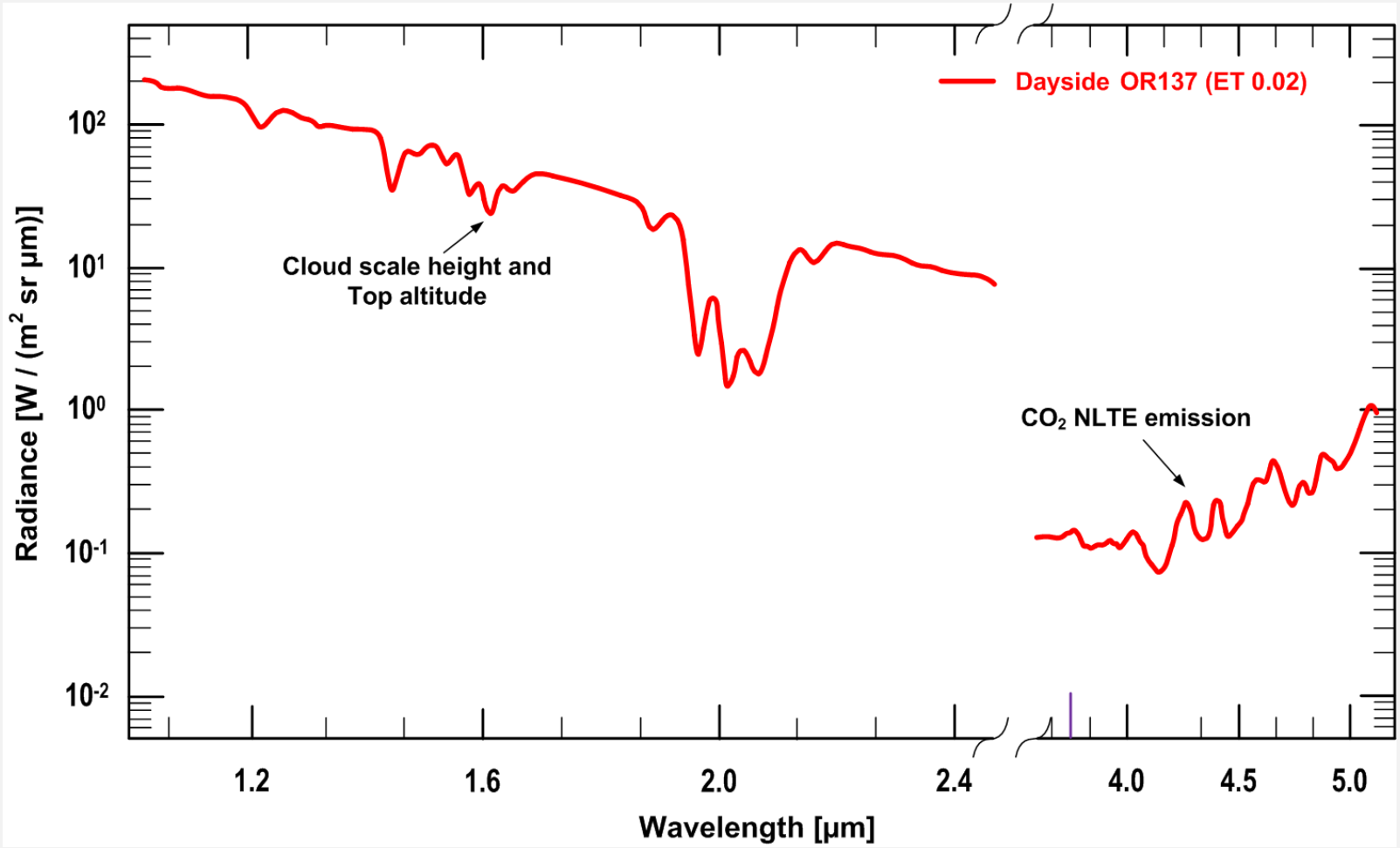
VIRTIS/VEX data base

Spectral measurements

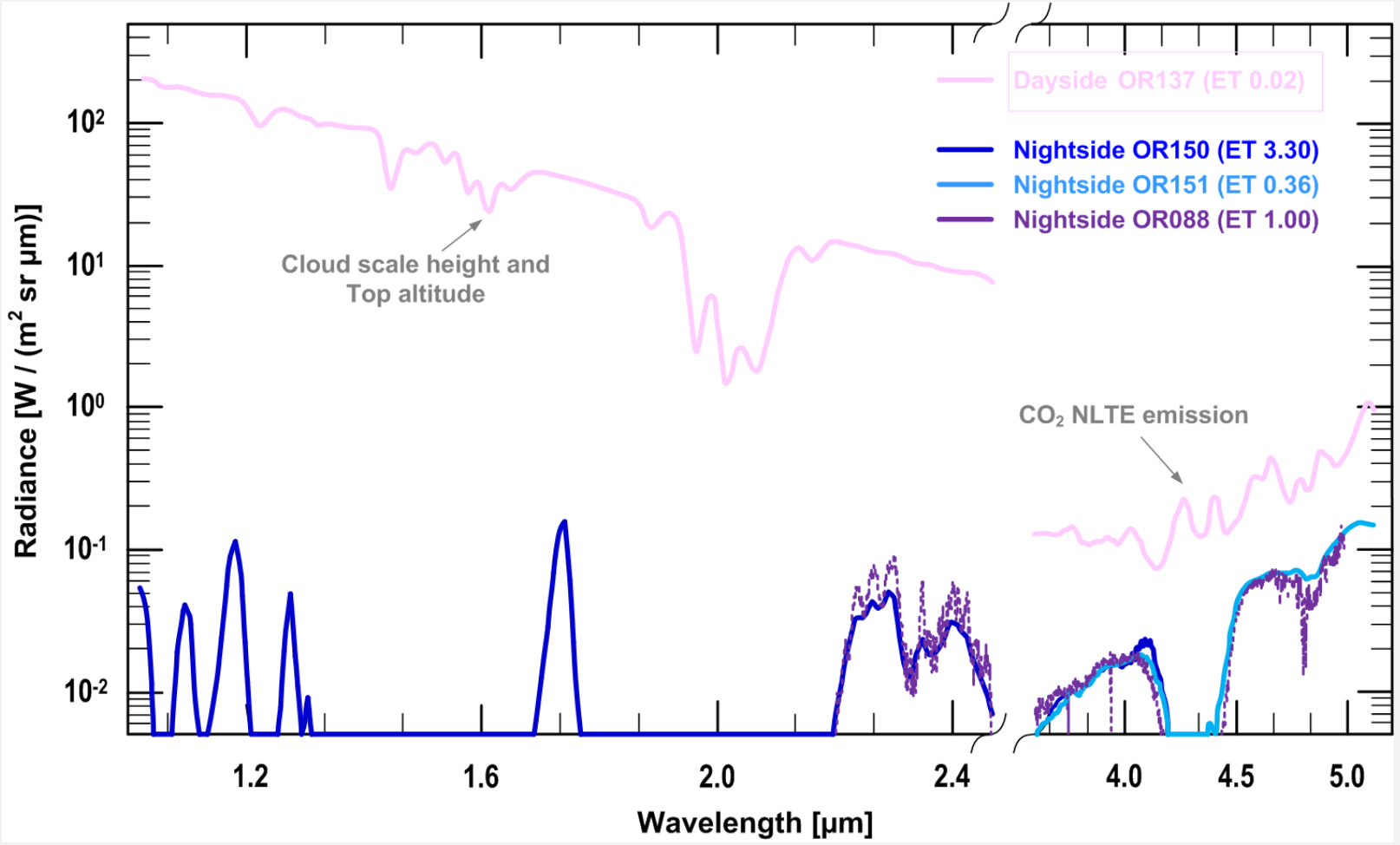
- ***Systematic atmospheric and surface mapping by VIRTIS/VEX***
- ***Data base: VIRTIS-M-IR subsystem***
  - 1.0 – 5.1 µm
  - 2D imaging + spectral + temporal dimension
- ***Spectral observation in the NIR nightside transparency windows permits atmospheric sounding from the ground to the base of thermosphere***



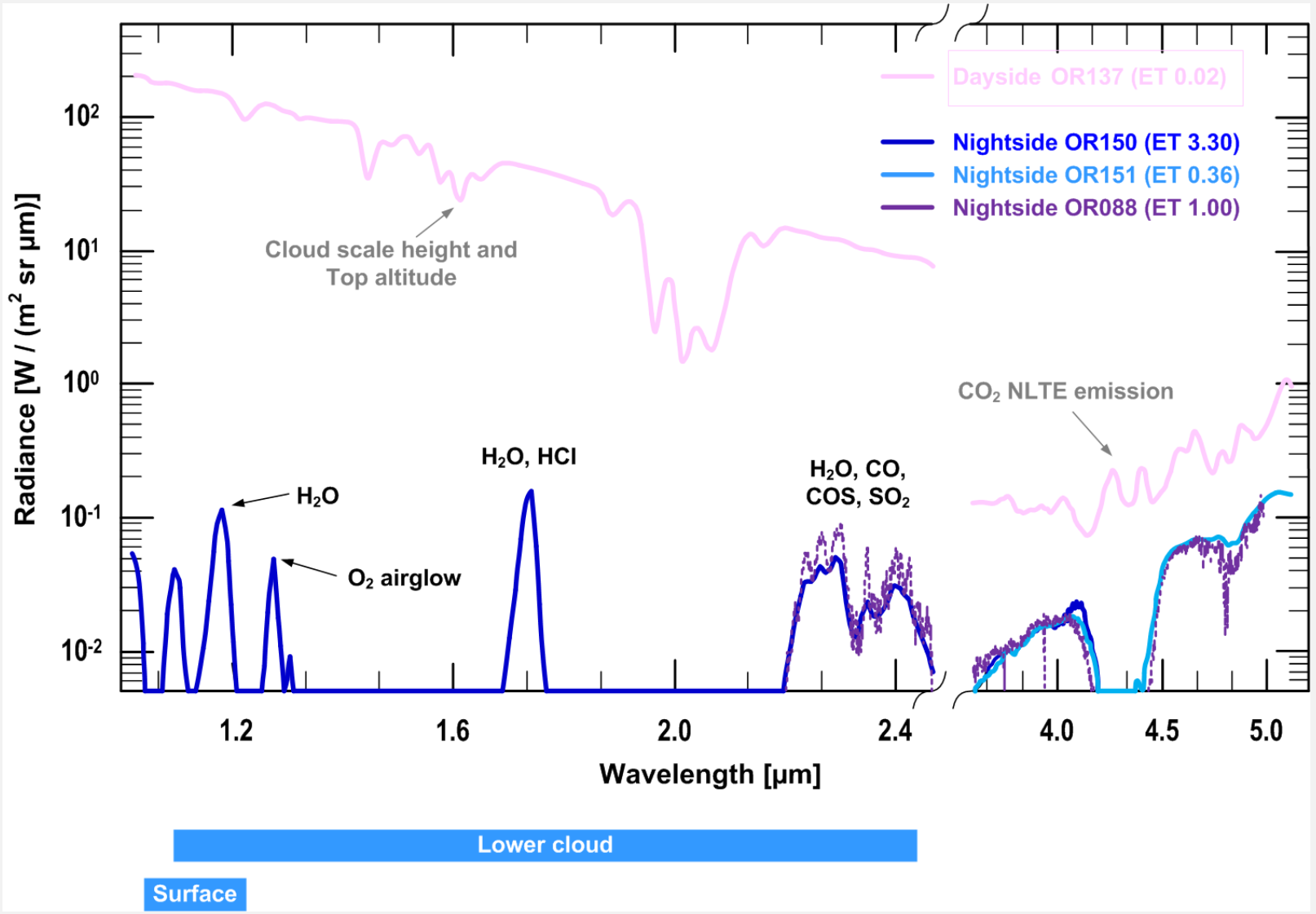
VITIS-M-IR spectral data (dayside)



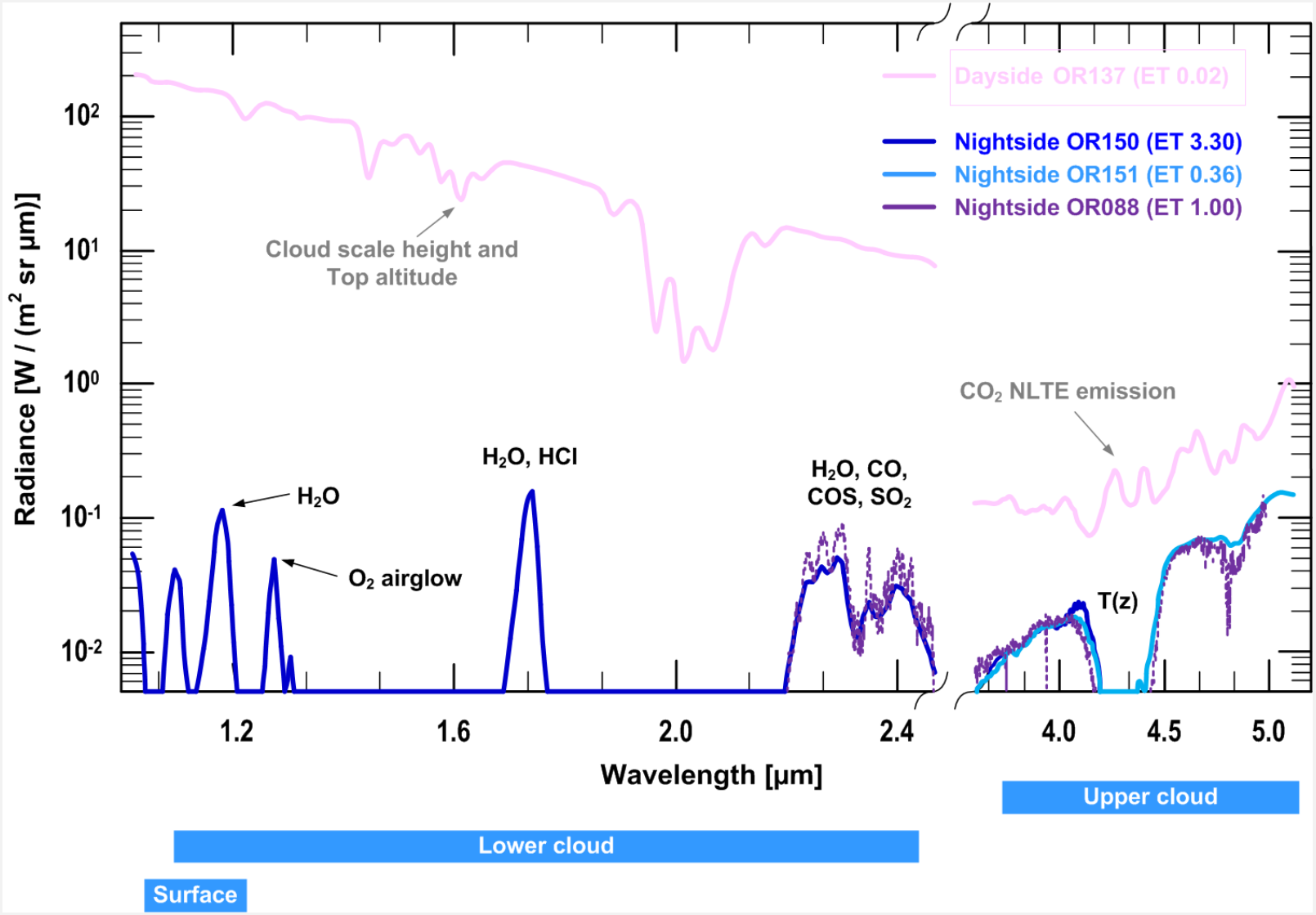
VITIS-M-IR spectral data (nightside)



VITIS-M-IR spectral data (nightside, troposphere)



VITIS-M-IR spectral data (nightside, +mesosphere)



Methods – Radiative Transfer Model (RTM)

Haus and Arnold, 2010

Multi-Window Retrieval Technique (MWT)

Elements of RTM-MWT

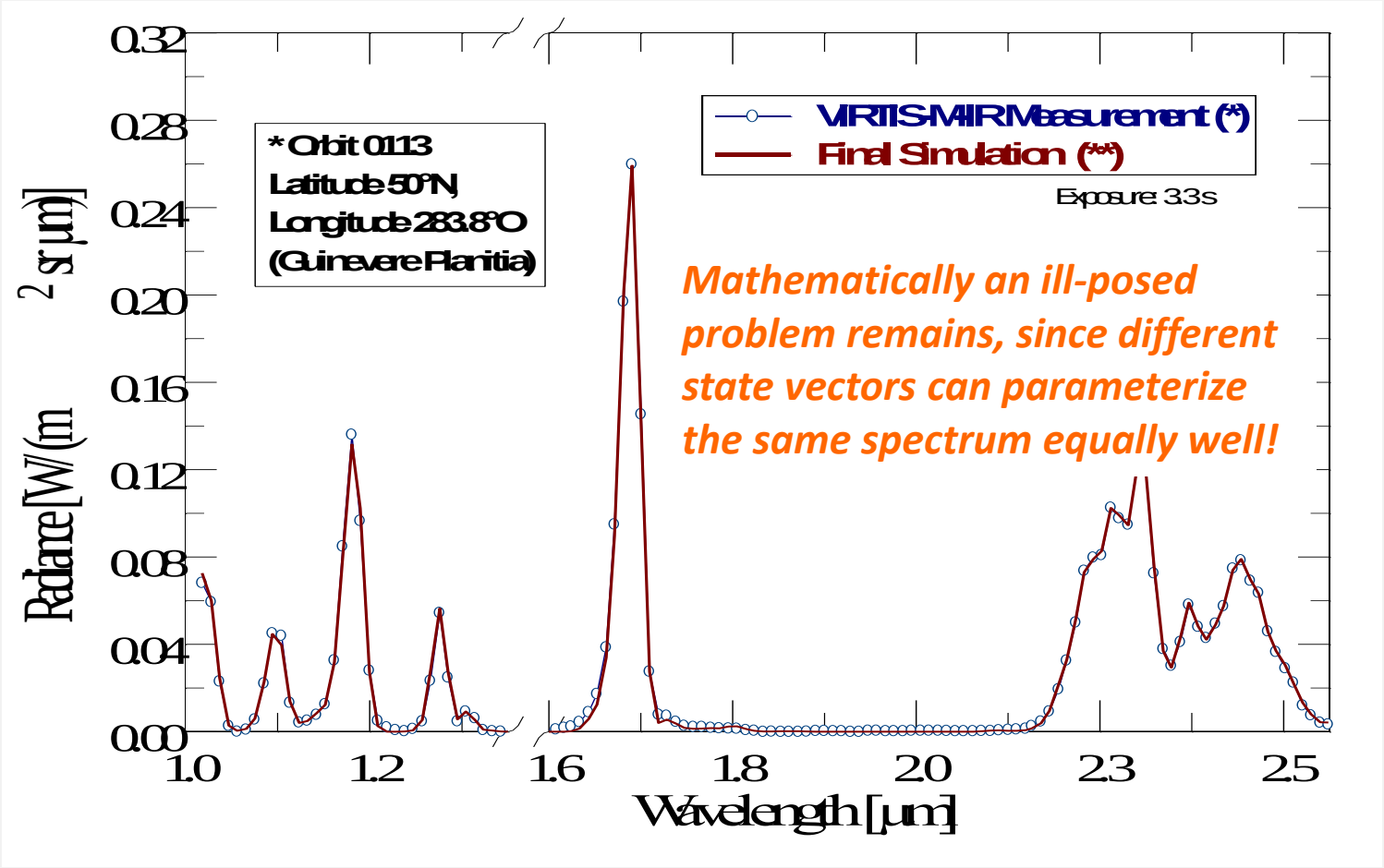
- *RTM simulates observed radiances in dependence of atmospheric and surface parameters*
- *RTM key elements are absorption, emission and multiple scattering by gaseous and particulate constituents*

- *MWT makes simultaneous use of information from different atmospheric windows of an individual spectrum*
- *MWT provides an iterative optimization of atmospheric and surface parameters until the simulated spectrum well fits the measurement for all utilized windows*

Methods – Radiative Transfer Model

Haus and Arnold, 2010

Comparison of VIRTIS-M-IR data and fitted simulation



Methods – Multi-Spectrum retrieval Technique

Kappel et al., 2012

Multi-spectrum retrieval Technique (MST)

- ***Regularization of retrieval by incorporation of available a priori mean values and standard derivations of the parameters to be retrieved***
- ***Incorporation of physically reasonable spatial-temporal a priori information on atmospheric parameters***

  → *Context of adjacent measurements is considered: Each spectrum can be related to its adjacent measurements (not only single measurements are analyzed)!!!*
- ***Determination of common parameters***

  → ***Considerable enhancement of reliability of retrieved emissivity!***

Methods – Multi-Spectrum retrieval Technique

Multi-spectrum retrieval Technique (MST)

- ***Input: Standard spectrum to analyze***
- ***Jacobians – derivatives of simulations for perturbations***
- ***Total cloud abundance from 1.31 µm window***
- ***Modal abundances from 1.30-2.30 µm***
- ***Cloud mode altitude profiles from Haus et al., 2012 – in preparation***
- ***Assumptions on deep atmosphere temperature variations***

Kappel et al., 2012

Kappel et al., 2012 (Cospar)

Multi-spectrum retrieval Technique (MST)

Impact on retrieved surface emiss. for wrong assumptions on ...

Neglected parameter	Assumed perturb.	Impact	Action
Cloud mode 1 abundance	50%	21%	wider spect. range ?
Cloud 1 & 2 bottom or top	1 km	$\leq$ 1%	neglect
Cloud 1 & 2' & 3 bottom, 2' & 3 top	1 km	$\leq$ 5%	2.55 µm peak
H_2SO_4 concentration	75%–85%	9%	wider spect. range ?
Surface elevation	100 m	8%	
Temperature profile around 0 km	1 K	13%	lat. trends in emiss.?
Temperature profile around 25 km	1 K	8%	
CO_2 opacity correction	tbd.	tbd.	multi-spectrum retr.
Minor gases	tbd.	tbd.	V-H

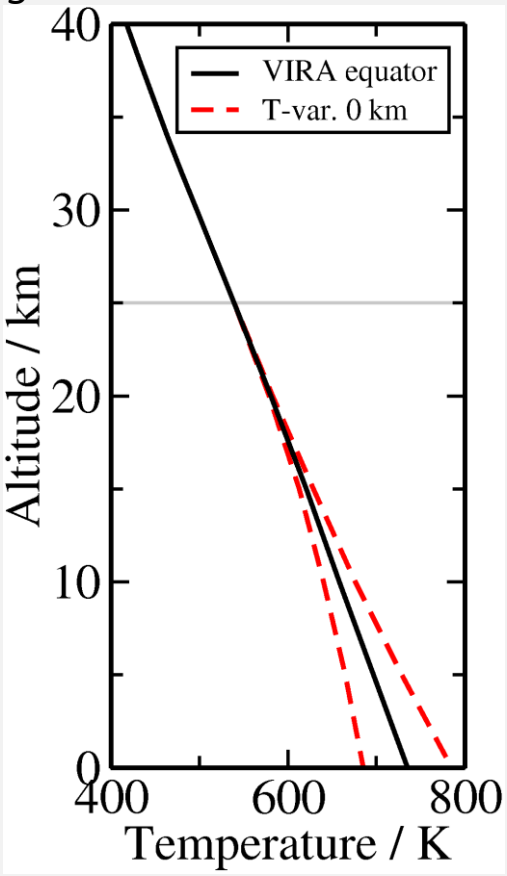
Noise impact: $\approx$ 10% for Gaussian noise with 2 · std. dev. = 1 mW/(m^2 sr µm)

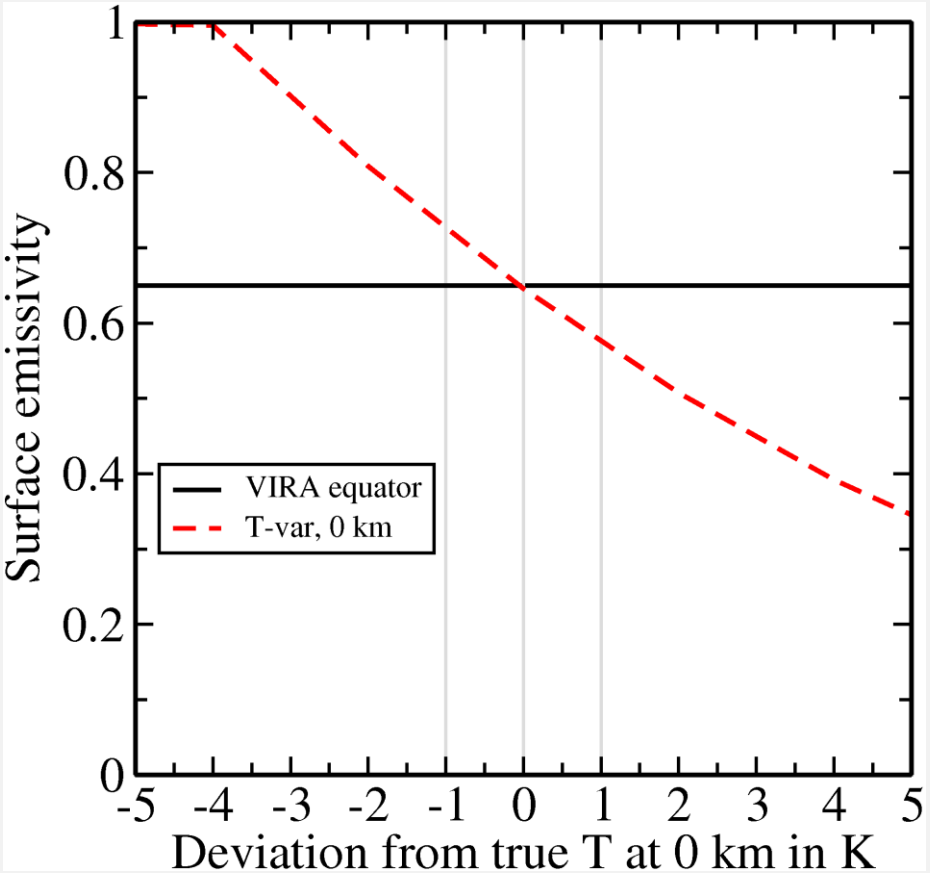
Outlook:

- Utilize wider spectral range. Retrieve emissivity as parameter common to measurements repeatedly covering a surface spot

Methods – Multi-Spectrum retrieval Technique

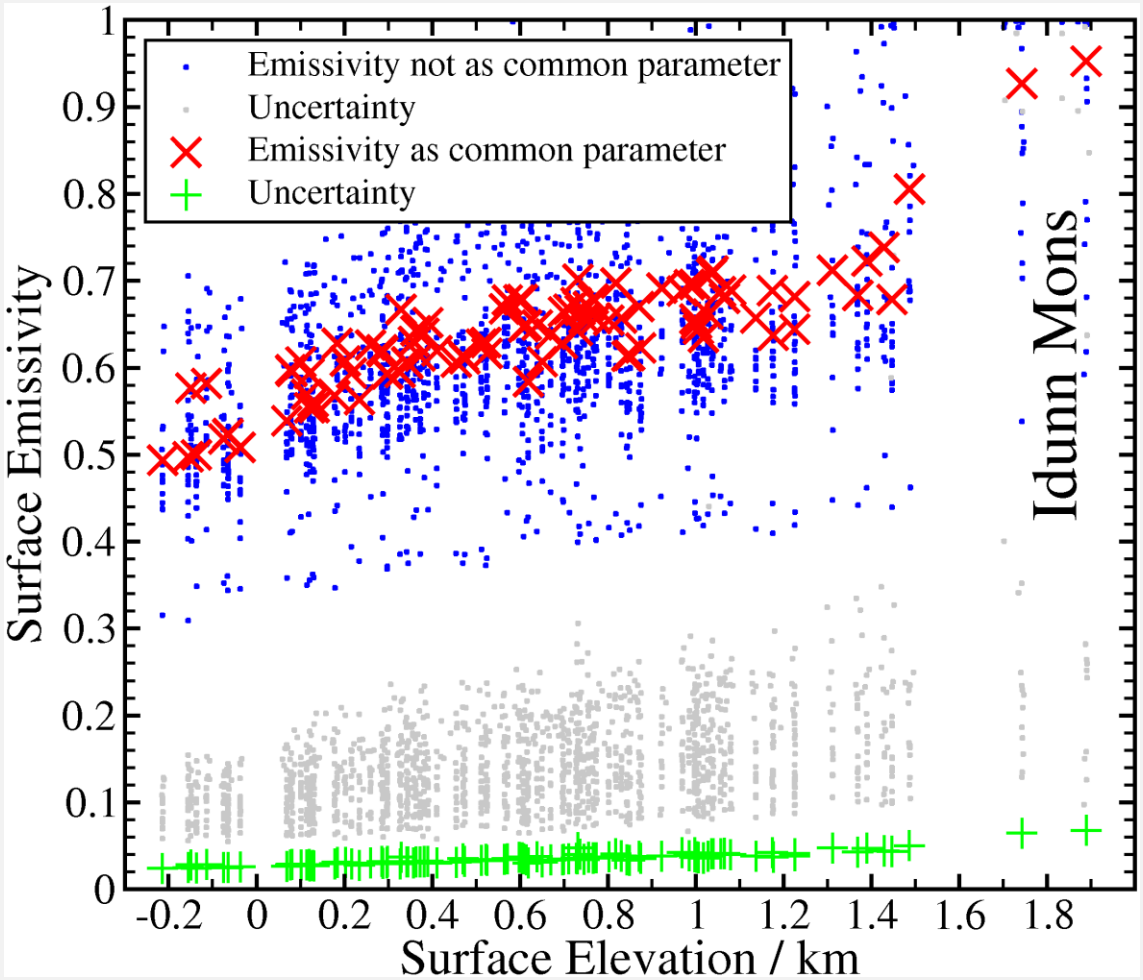
Example for retrieved surface emissivity as a function of deep atmospheric temperature profile *(not well known below 40 km):*
In situ data only close to the equator; VIRA below 32 km extrapolated; GCM suggests latitude trend





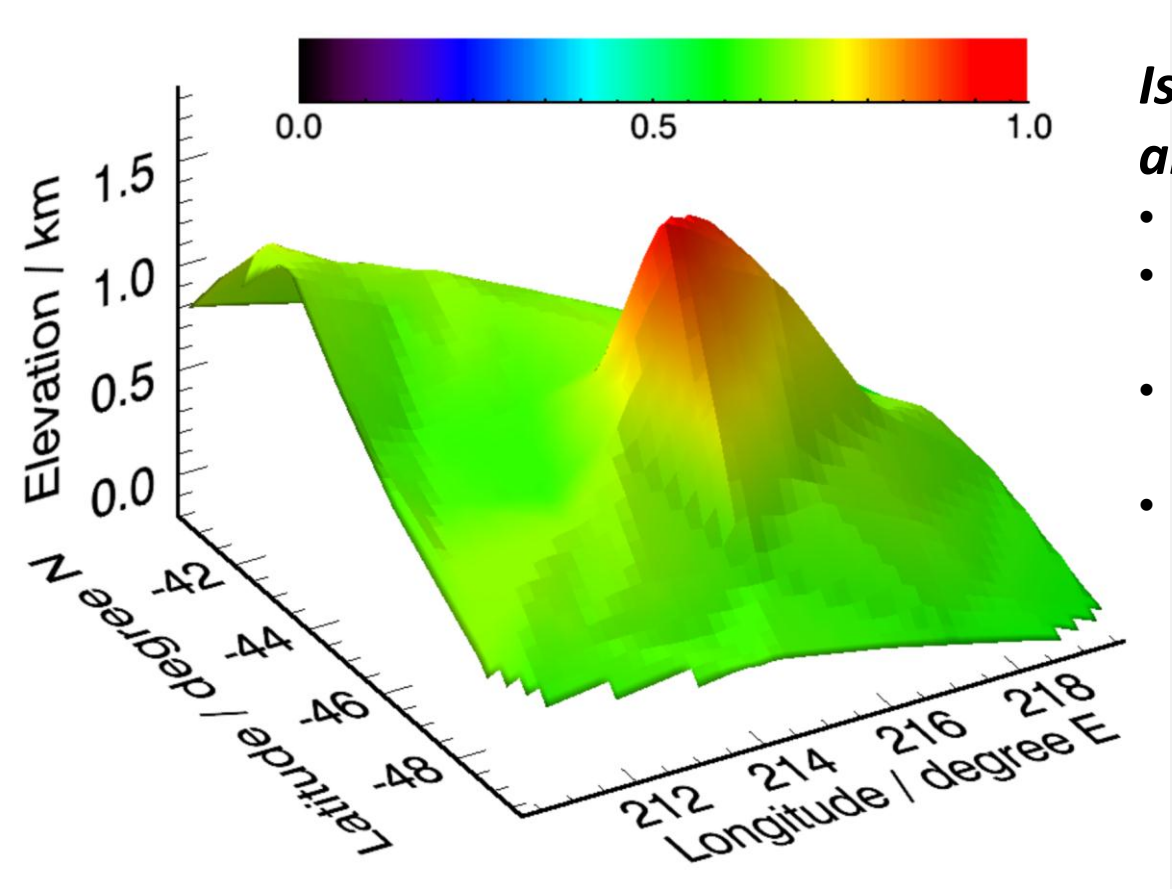
New results – surface emissivity

Scatterplot – Emissivity retrieval at 1.02 µm in the region of Idunn Mons as a function of surface elevation: Emissivity is considered as common parameter



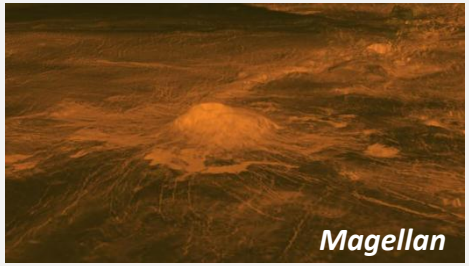
New results – surface emissivity

Topography near Idunn Mons, overlayed with retrieved common 1.02 µm surface emissivity map *(99 surface bins with about 15 repetitions)*



Isolated emissivity anomaly:

- *Recent volcanic activity?*
- *Different surface material?*
- *Different surface texture?*
- *Different weathering conditions?*



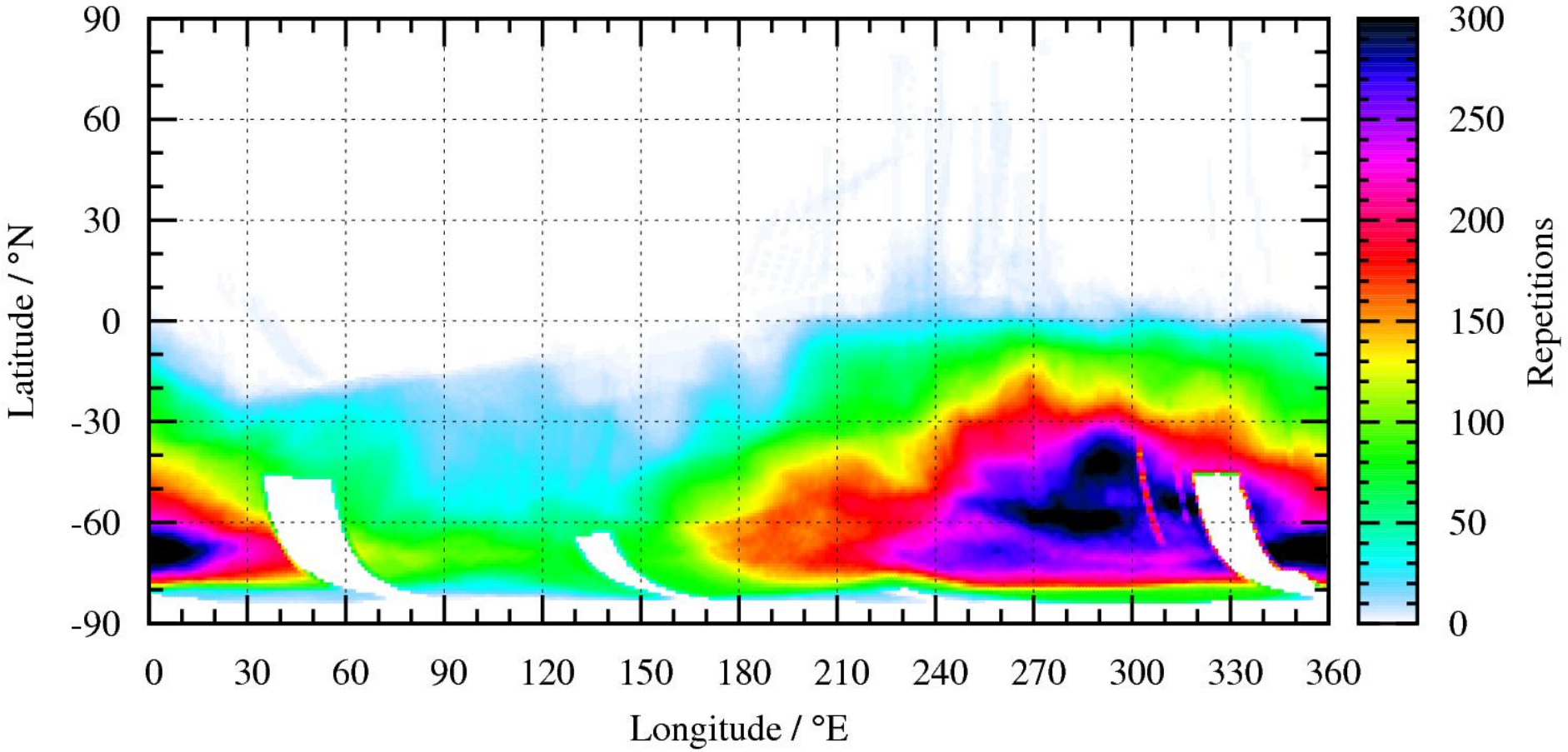
Summary and outlook

Summary

- ***RTM-MWT** results show a good agreement of simulated and measured spectra*
- ***MST** enhanced reliability for quantitative deep atmosphere/surface data coming from the Venus' nigtside emission – first 2D maps of REAL surface emissivity at 1.02 µm*

Outlook

- *Better disentanglement of cloud modes; utilize wider spectral range; retrieve emissivity as common parameter from repeated measurements covering the same surface spot*

Summary and outlook

Next target areas