Maps of the MY 25 Planet-encircling Dust Storm

Comparison of MOC-observed dust storms and FFSM eddies

John Noble[1,2], Robert M. Haberle[1], R. John Wilson[3], Bruce A. Cantor[5]
Jeffrey R. Barnes[4], Alison F. C. Bridger[1,2] Jeffery L. Hollingsworth[1], Melinda A. Kahre[1]
1. NASA/Ames Research Center, 2. San José State University, 3. NOAA Geophysical Fluid Dynamics Laboratory, 4. Oregon State University, 5. Malin Space Science Systems

Introduction

We have produced 42 daily, global dust opacity maps of the MY 25 planet-encircling dust storm (Ls=165-188°). These include dust storms and dust entrained in gravity waves. Gravity waves are included for both completeness, and because they may indicate dust transport. The maps use a new dust characterization scheme that classifies events by 1) category; 2) degree of (visual) structure; 3) water ice content. Water ice clouds are included for both completeness, and because they (sometimes) obscure dust storm structure below, which increases uncertainty of storm structure. We have also created a storm catalog that identifies storms by lat/lon coordinates and Mars Orbiter Camera (MOC) ID number. Duplicate storms in MOC imagery are also identified.

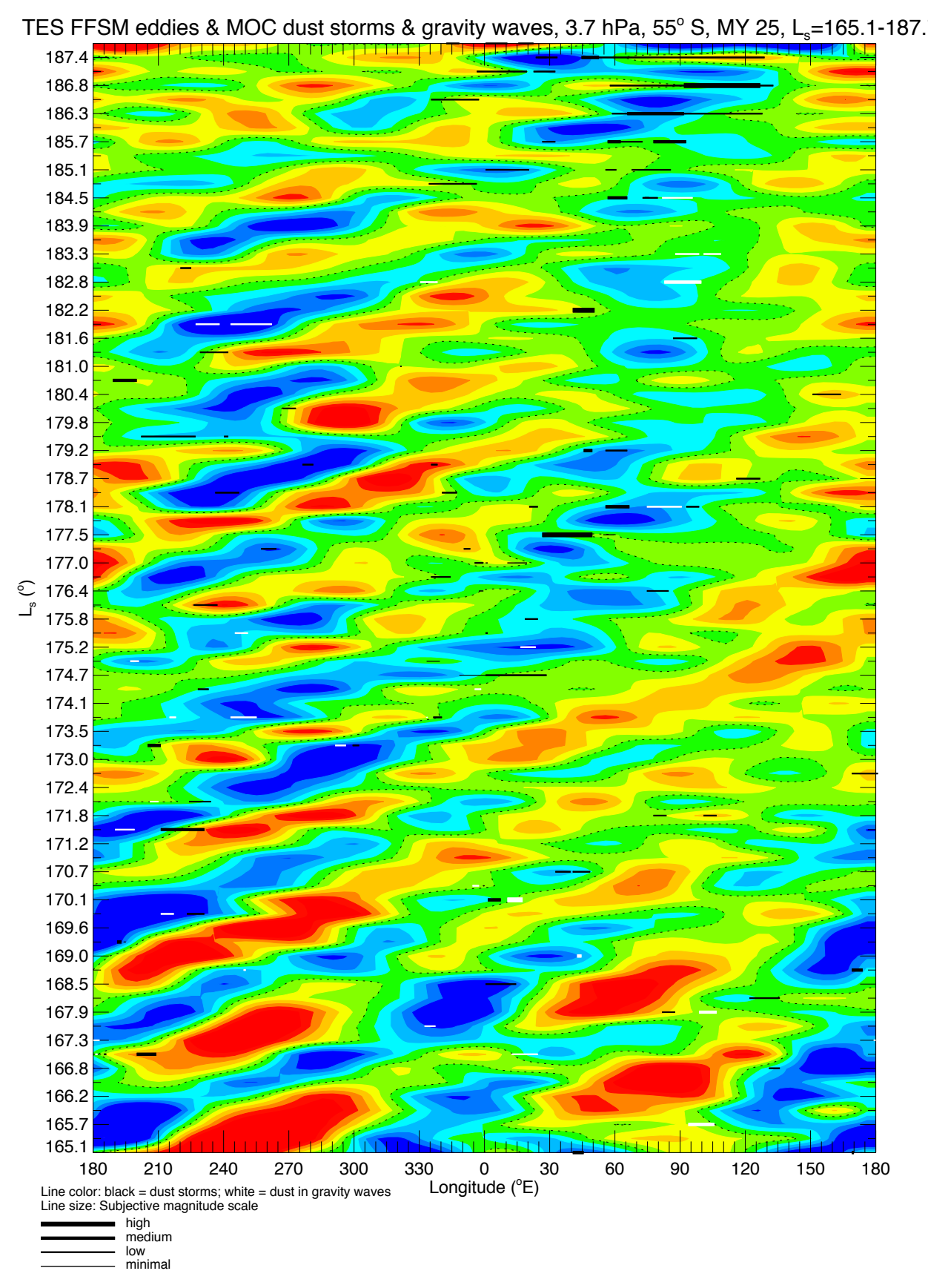
Motivation

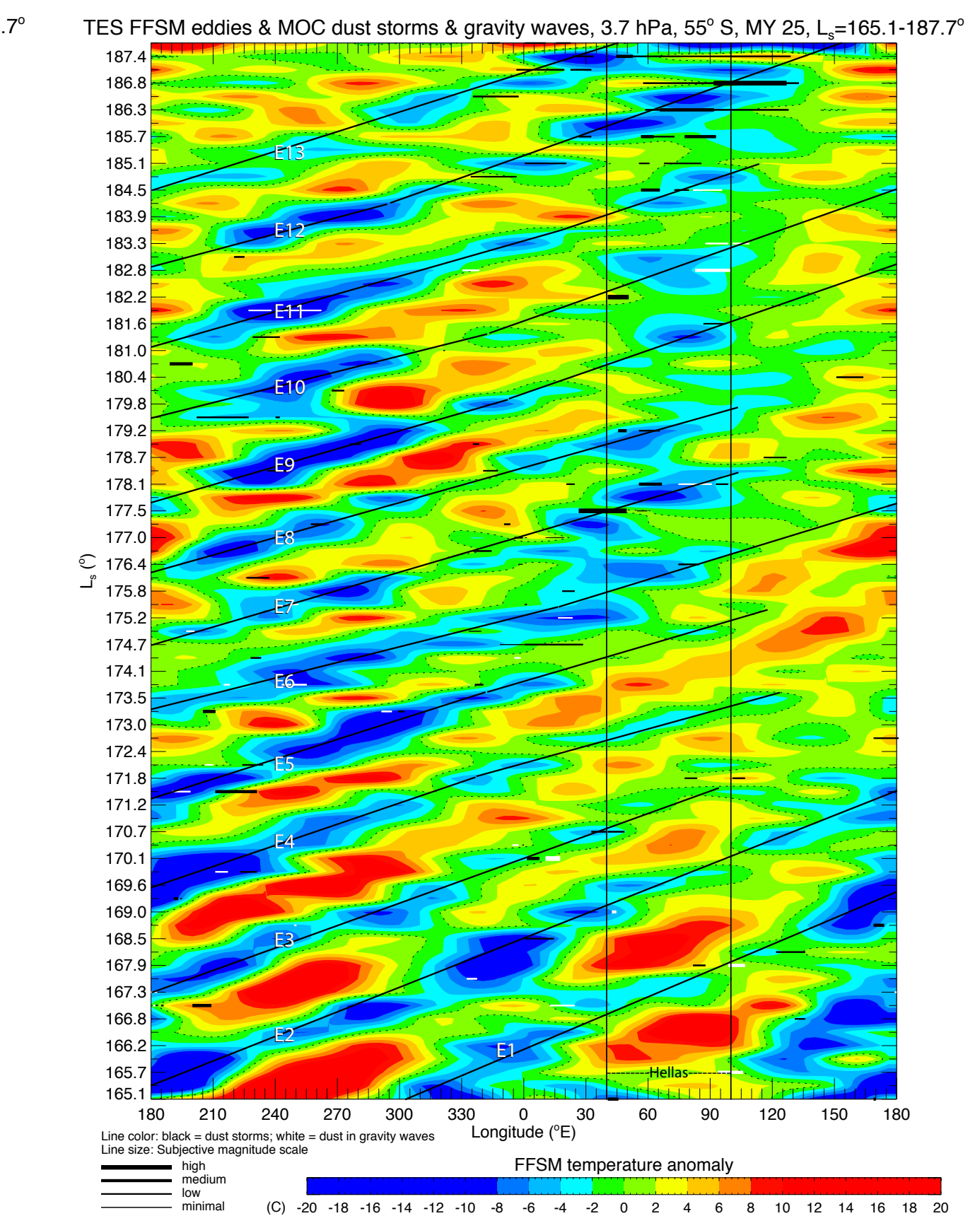
The motivation of this work is two-fold. 1) There is a need to better delimit the areal extent of dust storms observed by MOC in order to compare storm evolution with eddies observed in Fast Fourier Synoptic Mapping (FFSM) of Thermal Emission Spectrometer (TES) temperatures. FFSM analysis of TES 3.7 hPa thermal data shows the presence of eastward traveling waves from 40 - 60° S with a period of about three sols. Previous work was latitudinally imprecise (Noble *et al.* 2011). 2) Provide improved bases and constraints for modeling (Noble *et al.* 2007; Wilson *et al.* 2008).

Datasets

- TES measurements of atmospheric temperature, 9-μm dust opacity, and water ice opacity (normalized) (Smith *et al.* 2001)
- MOC daily global maps (DGM) produced by Malin Space Science Systems (Cantor 2007).
- Fast Fourier Synoptic Mapping of TES temperatures. FFSM is a spectral analysis method that creates synoptic maps from asynoptic data, maintaining full space-time resolution without distorting or smoothing higher frequency (~1–3 sols) weather signals (Barnes 2001, 2003, 2006). This process removes the time mean, zonal mean, and westward diurnal tide.
- GCM-derived dust opacity estimates (normalized) (Wilson *et al.* 2011)

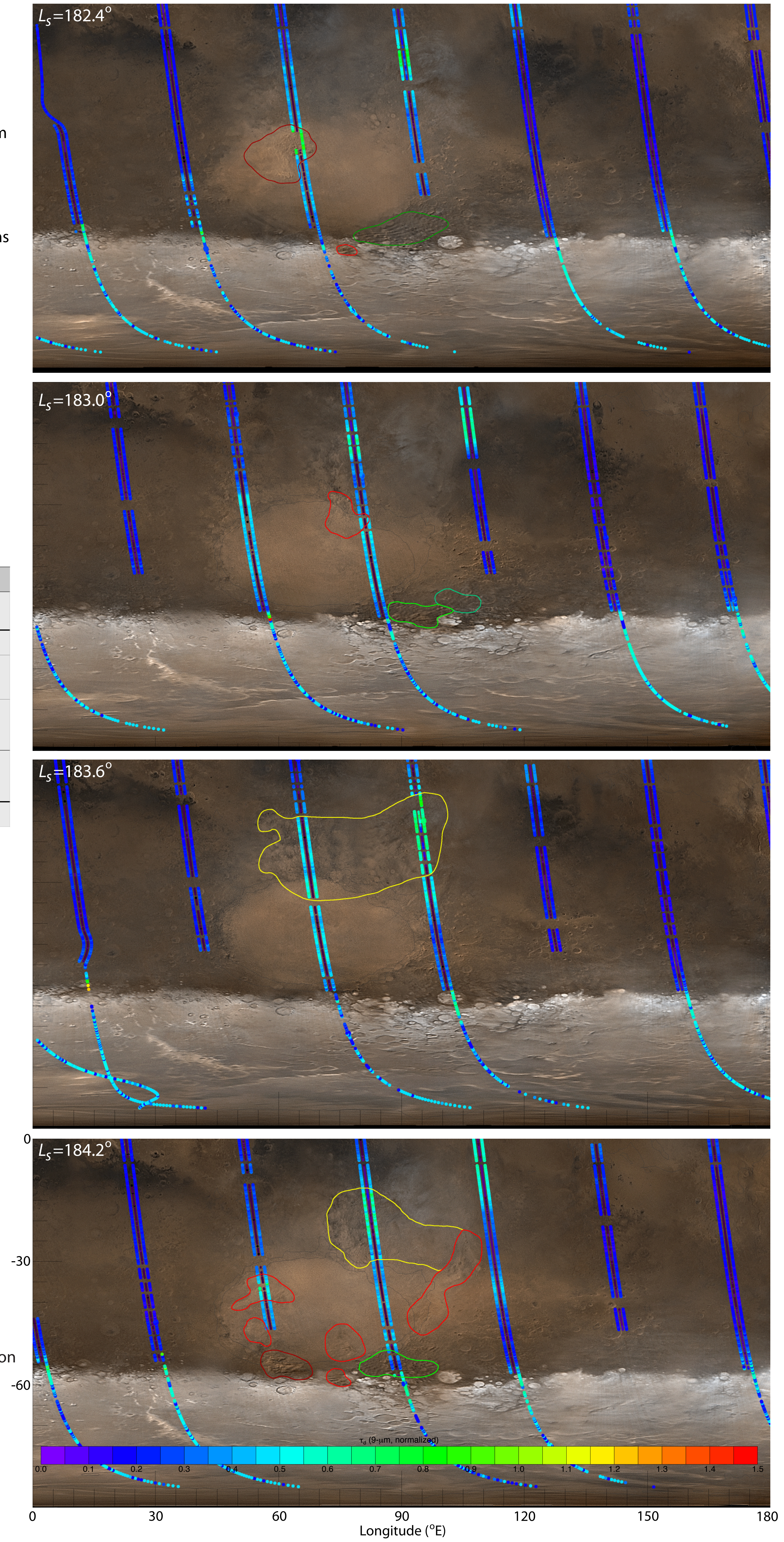
										Convective structure Dust storms, category 1	Opacity, qualitative (apparent visual obscuration) Dust storms, category 1	Opacity, quantitative τ_d (9-μm) approximation Dust storms, category 1
Category:	1) Dust storms • near major lifting sites (Hellas, Claritas)			2) Category 2 [working characterization] • Different morphology from category 1 (except struc 0) • more spatially intermittent: surface often visible among clouds • more 'cloud'-like, 'puffy' (certain cases)			3) Gravity waves					
struc = 3	63, 0, 0 3F0000 113	123	133	255, 153, 0 FF9900 213	223	233	0, 63, 0 003F00 313	323	333	convective structure = high • large kanoobs • strong shadows/contrast	visually opaque • surface features completely obscured	$\tau_d \geq 1.0$
struc = 2	159, 0, 0 9F0000 112	79, 31, 79 4F1F4F 122	132	255, 204, 0 FFCC00 212	222	232	0, 159, 0 009F00 312	0, 127, 79 007F4F 322	332	convective structure = medium • medium kanoobs • medium shadows/contrast • dust spatially intermittent (minimal) •	visually opaque • surface features obscured (or partially) • ..	$\tau_d \geq 1.0$ $\tau_d \geq 0.5$
struc = 1	255, 0, 0 FF0000 111	127, 51, 127 7F337F 121	0, 102, 255 0066FF 131	255, 255, 0 FFFF00 211	127, 127, 127 7F7F7F 221	0, 0, 255 0000FF 231	0, 255, 0 00FF00 311	0, 204, 127 00CC7F 321	0, 153, 255 0099FF 331	convective structure = low • [small kanoobs] • small shadows/contrast (but present) • dust spatially intermittent • plumes ('small' plumes in craters)	visually diffuse • surface features visible (or partially) • ..	
struc = 0	255, 191, 191 FFBFBF 110	120	130	255, 255, 204 FFFFCC 210	220	230	N/A	N/A	N/A	Convective structure = 0 => Range of possibilities, from: • optically thin haze • optically visible/thick dust • no shadows/contrast • optically thin haze	Full range possible: • surface features visible (optically thin haze) • surface features obscured (optically thick dust)	$\tau_d \leq 0.35$ (optically thin haze) $\tau_d \geq 1.0$ (optically thick dust)
Structure ↑ / τ_{ice} →	$\tau_{ice} < 0.15$ low	$\tau_{ice} \geq 0.15$ medium	$\tau_{ice} \geq 0.25$ high	$\tau_{ice} < 0.15$ low	$\tau_{ice} \geq 0.15$ medium	$\tau_{ice} \geq 0.25$ high	$\tau_{ice} < 0.15$ low	$\tau_{ice} \geq 0.15$ medium	$\tau_{ice} \geq 0.25$ high			

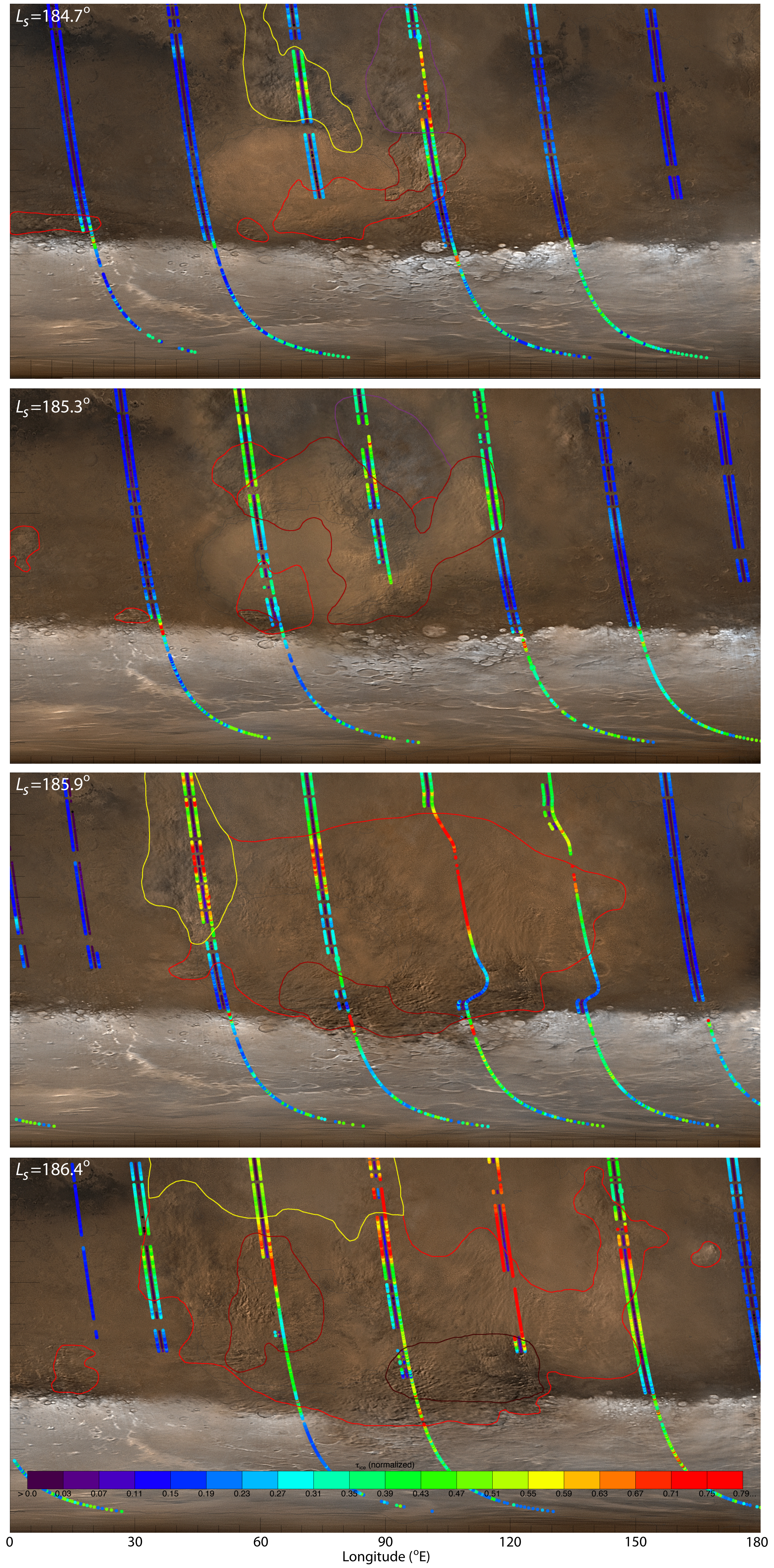


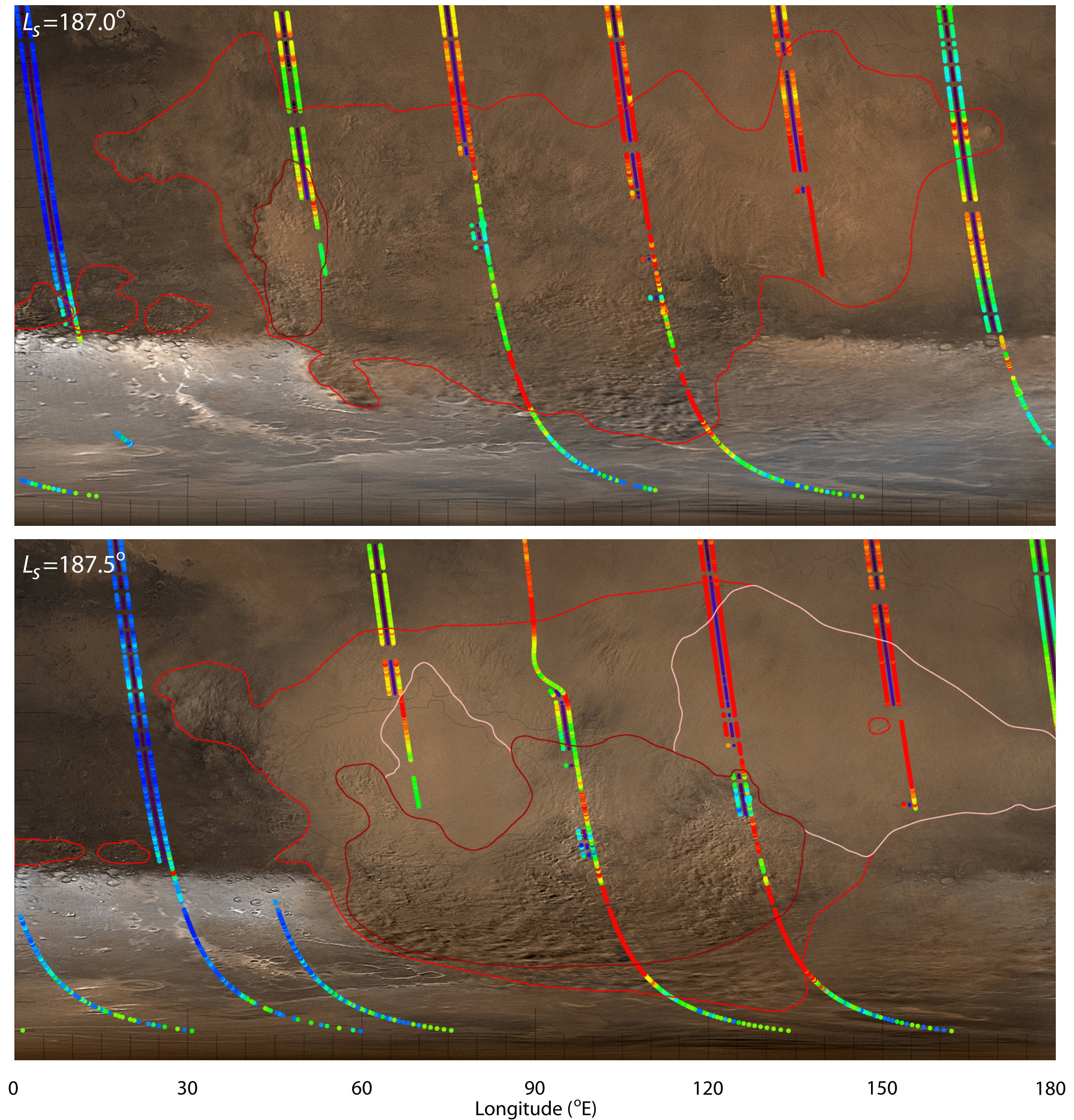


Working Hypothesis

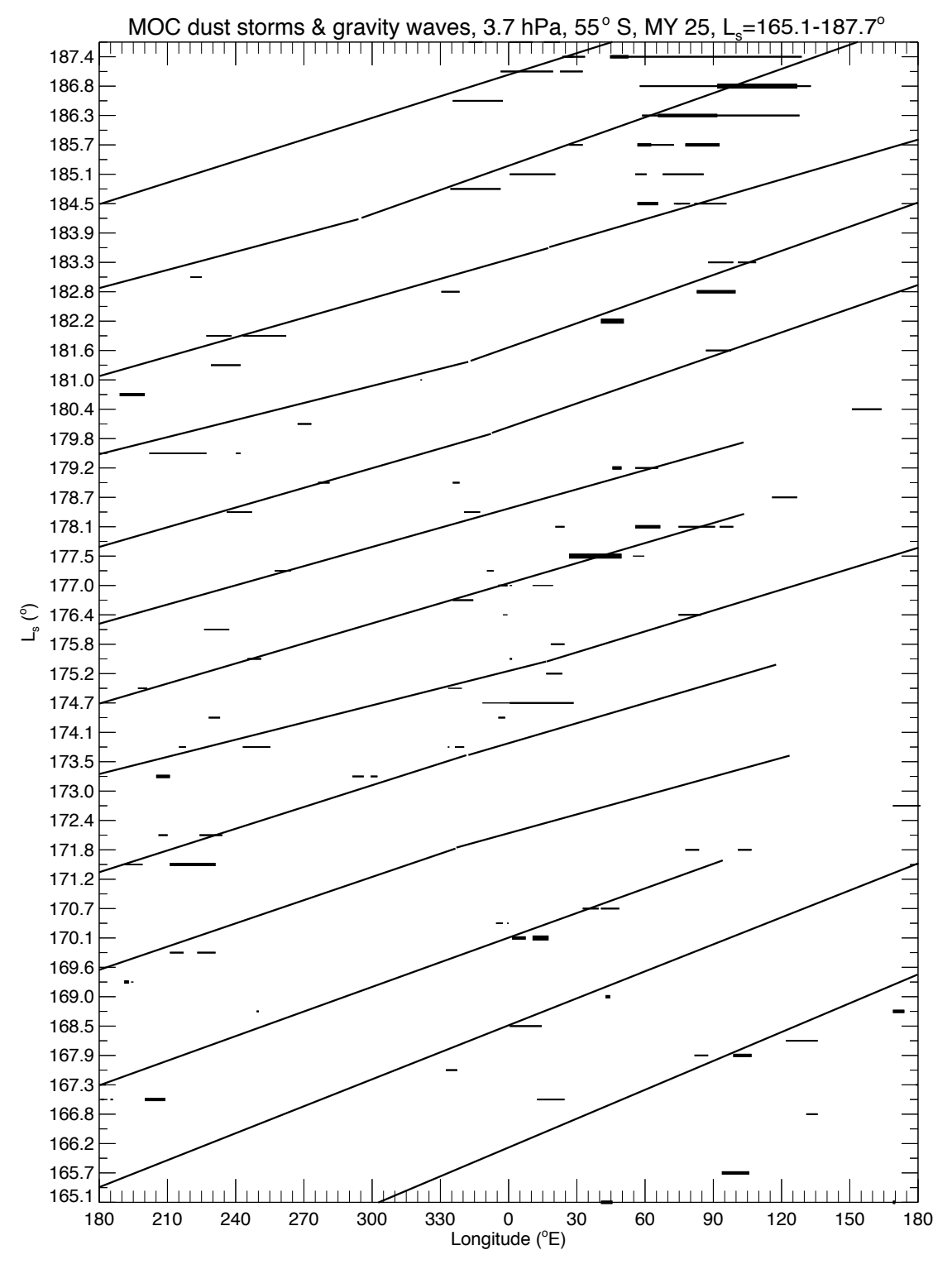
- Six eastward-traveling baroclinic eddies (E6-E11) triggered the precursor storms due to the enhanced dust lifting associated with their low-level wind & stress fields. E12 & E13 contributed to storm expansion
- The sustained series of high-amplitude eddies in MY 25 was a factor in PDS occurrence that year.
- Increased opacity and temperatures from dust lifting associated with eddies E6-E8 enhanced thermal tides which supported further storm initiation and expansion out of Hellas.
- Constructive interference of eddies and other circulation components may have led to the initiation and expansion of precursor storms. These include: CO_2 sublimation flow, anabatic winds, diurnal tides, and dust-induced thermal tides. Constructive interference increases surface stresses capable of lifting dust (through the wind field)
- Non-dynamical factors in PDS interannual variability include dust sources and sinks

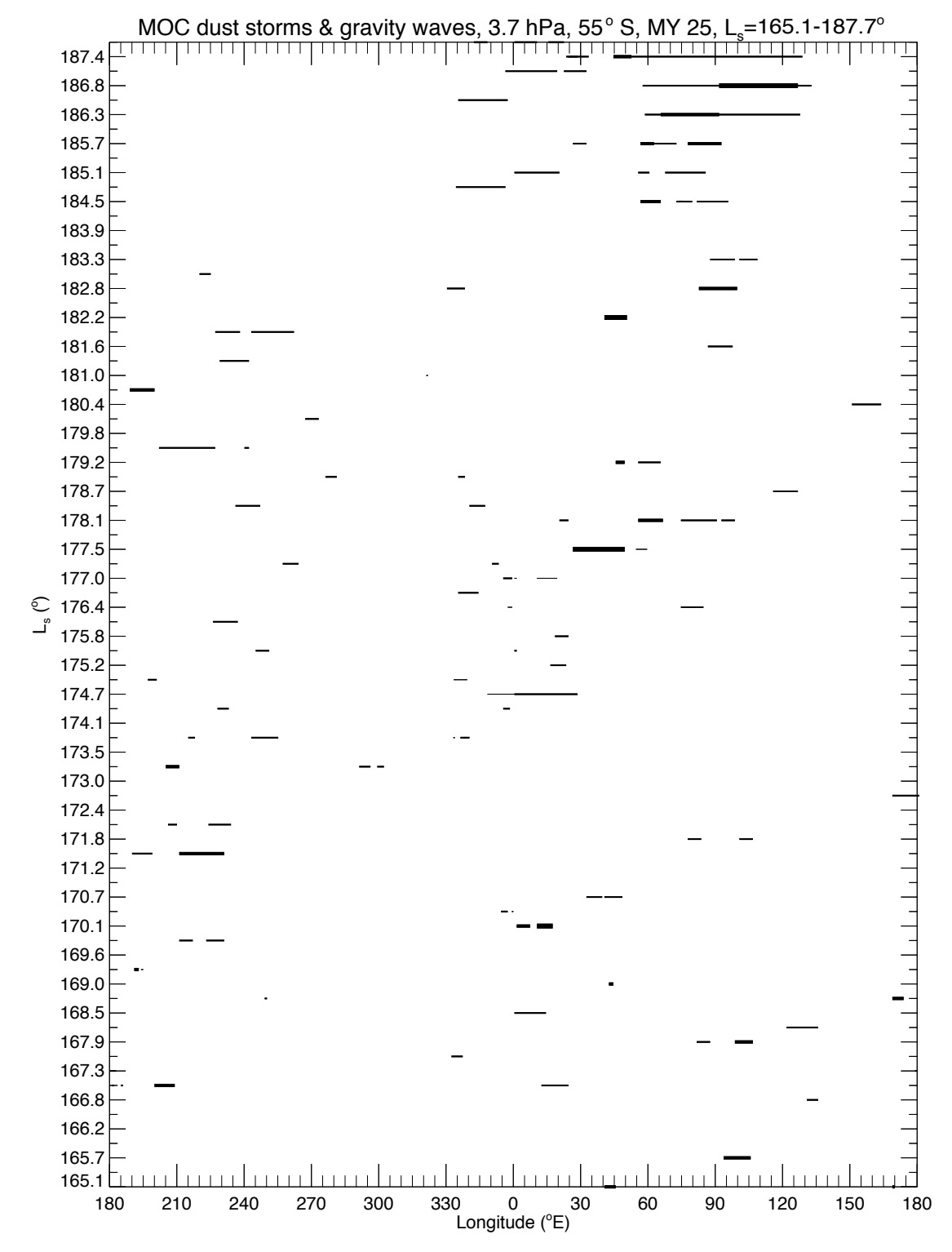






MOC daily global maps courtesy of Malin Space Science Systems





References

Cantor, B. A., 2007: MOC observations of the 2001 Mars planet-encircling dust storm. *Icarus* , 186, 60-96

Noble, J., R. M. Haberle, A. F. C. Bridger, J. Wilson, J. R. Barnes, J. Murphy, J. Hollingsworth, M. C. Malin, B. A. Cantor, M. Smith, and T. Martin, 2007: Integration of MGS Observations of the 2001 Global Dust Storm on Mars: Implications for Atmospheric Modeling. *AGU Fall Meeting* , San Francisco, CA, USA, American Geophysical Union.

Noble, J., R. J. Wilson, R. M. Haberle, J. L. Hollingsworth, M. A. Kahre, J. R. Barnes, A. F. C. Bridger, and B. A. Cantor, 2011: Comparison of TES FFSM Eddies and MOC Storms, MY 24-26. *Fourth International Workshop on the Mars Atmosphere: Modelling and observations* , Paris, France, CNES, ESA, NASA

Wilson, R. J., R. M. Haberle, J. Noble, A . F. C. Bridger, J. Schaeffer, J. Barnes, and B. Cantor, 2008: Simulation of the 2001 planet-encircling dust storm with the NASA/NOAA Mars general circulation model. *Third International Workshop on the Mars Atmosphere: Modeling and Observations* , Williamsburg, VA, USA.

Wilson, R . J., J. Noble, and S. J. Greybush, 2011: The derivation of atmospheric opacity from surface temperature observations. *Fourth International Workshop on the Mars Atmosphere: Modelling and Observations* , Paris, France.