MAVEN/IUVS Observations of Martian Mesospheric Clouds in 2017: A Persistent Longitudinal Asymmetry at Southern Mid-Latitudes

M.H. Stevens[1], S.K. Jain[2], J.S. Evans[3], J. Deighan[2] and N.M. Schneider[2]

[1]Space Science Division, NRL
[2]Computational Physics, Inc., Springfield, VA
[3]Laboratory for Atmospheric and Space Physics, University of Colorado

52nd ESLAB Symposium – 14 May 2018

Motivation

- **Martian mesospheric clouds are diagnostic of low temperatures, enabled by migrating and non-migrating thermal tides from 60-180 km altitude.**

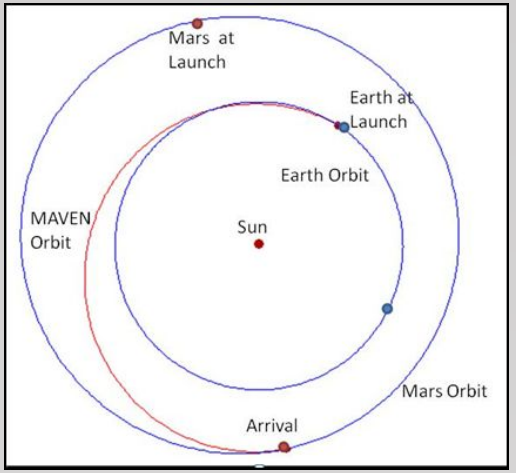
- **Prior to MAVEN, few mesospheric cloud observations existed in the southern hemisphere during nominal season (L_s<150º). MAVEN can observe at ALL local times, providing new insight to tidal oscillations over diurnal cycle.**

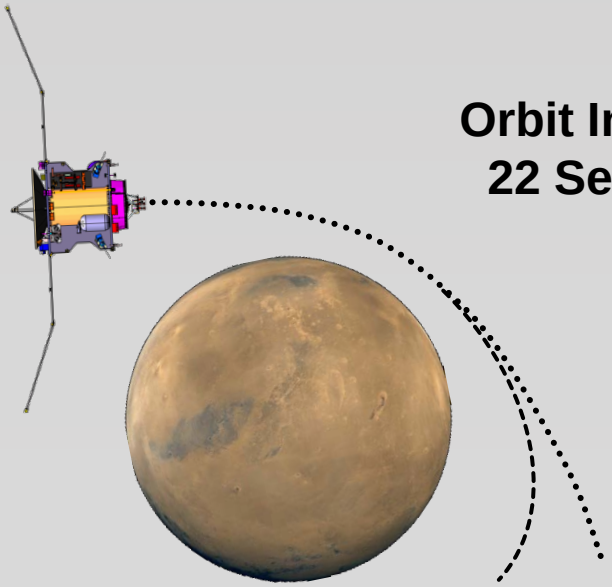
- **There is evidence that either CO_2 ice or H_2O ice comprise mesospheric clouds. MAVEN/IUVS can help disambiguate this.**

MAVEN Mission Timeline

Launch on November 18, 2013

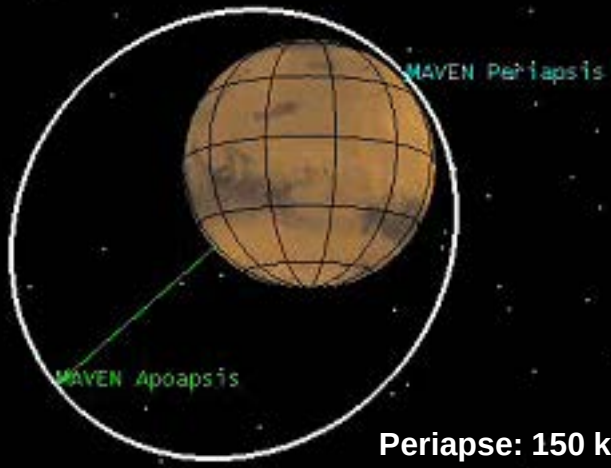
Ten-Month Ballistic Cruise to Mars





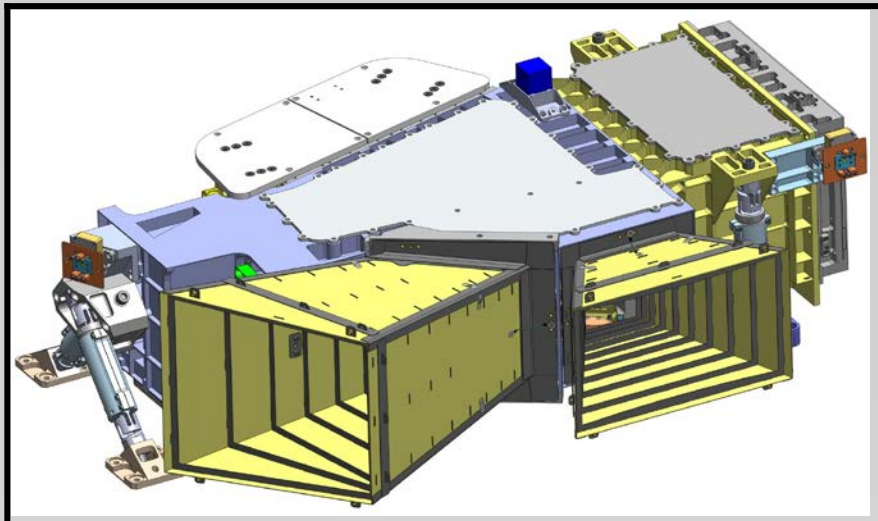
Orbit Insertion: 22 Sept 2014

Operational Ever Since



Periapse: 150 km
Apoapse: 6200 km

Imaging Ultraviolet Spectrometer (IUVS)
P.I. Nick Schneider, LASP

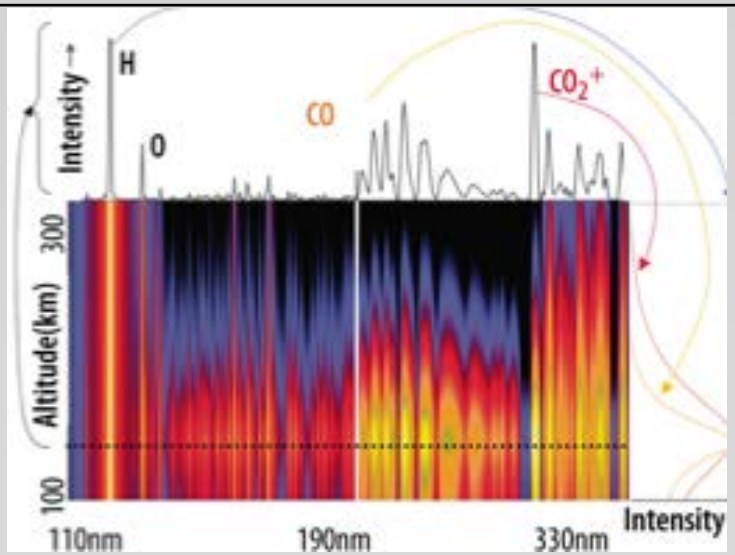


Measurement objectives:

- Vertical profiles of neutrals and ions through dayglow limb emissions and lower atmosphere properties from stellar occultations
- Disk maps from near apoapsis.
- D/H and hot oxygen coronal mapping
- Atmospheric properties below homopause

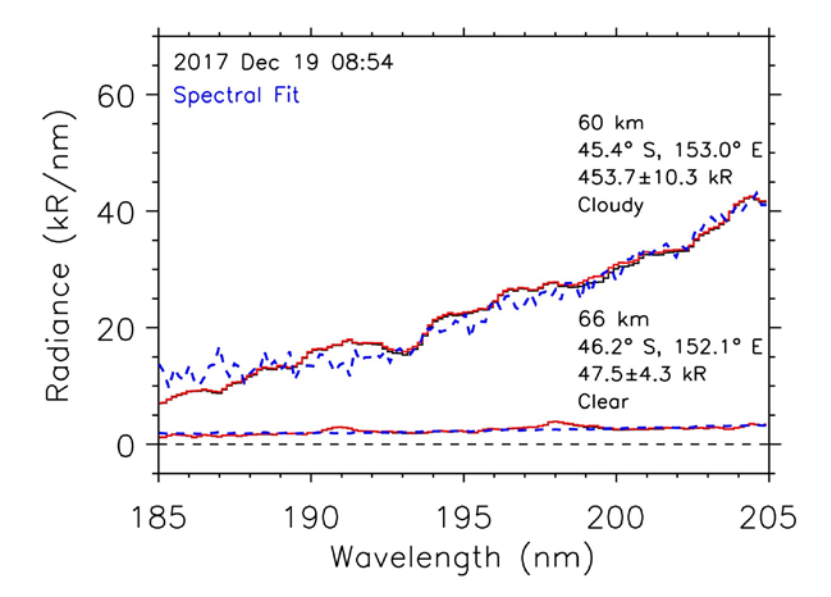
Technical details and heritage:

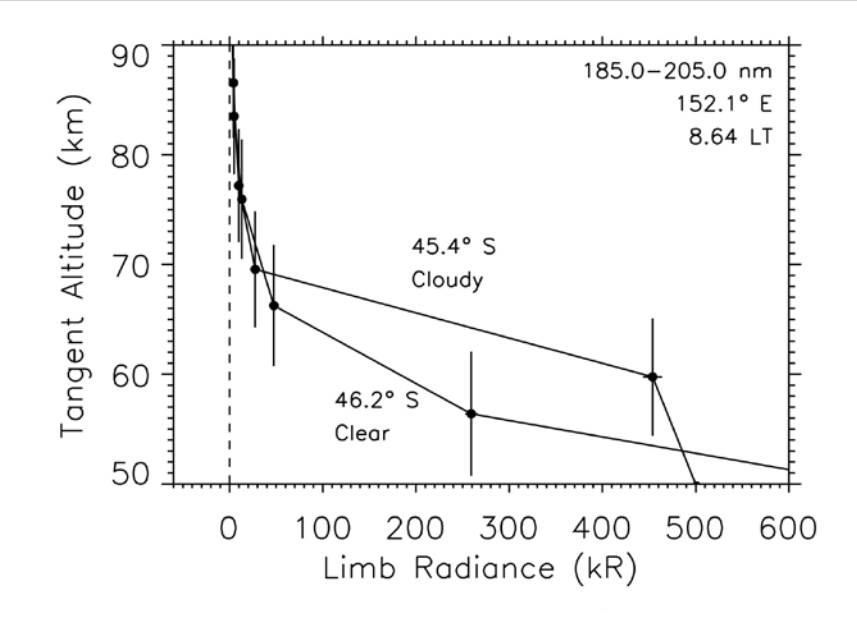
- Imaging spectroscopy from 110-340 nm, with resolution of ~1 nm in the MUV
- Vertical resolution of 6 km on limb
- Detectors: Image-intensified 2-D active pixel sensors
- Most recent heritage from NASA/AIM CIPS



Model spectra and derived profiles

Identification of Mesospheric Clouds on Limb with IUVS

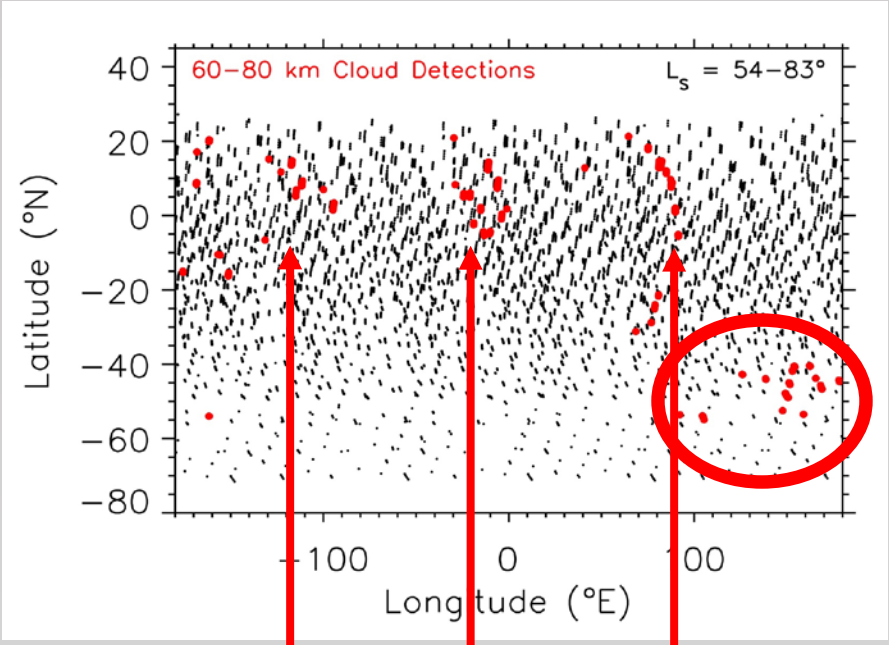


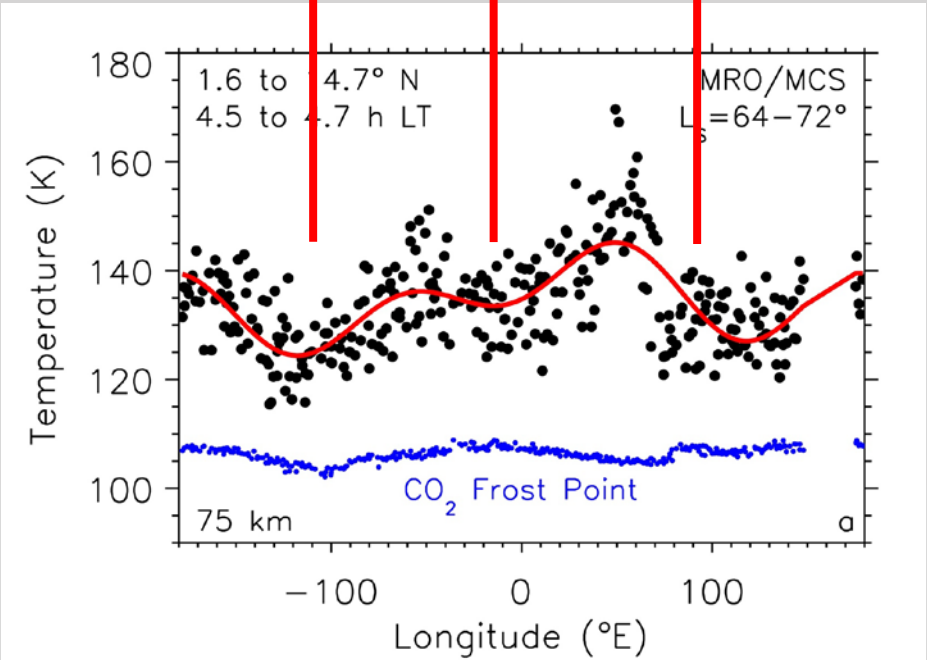


- Use “Level 1b” limb scans that sample below 60 km
- Fit limb spectrum with a spectrum of solar scattered light
- Identify clouds by excess solar scattering

- One profile shows ice particles along the line of sight. The other is “clear air”.
- This approach has heritage in identifying terrestrial noctilucent clouds [Thomas and Olivero, 1989; Bailey et al., 2005; Petelina et al., 2006; Stevens et al., 2009; Robert et al., 2009].

2015 MAVEN/IUVS Cloud Observations





Red = cloud

Black = clear

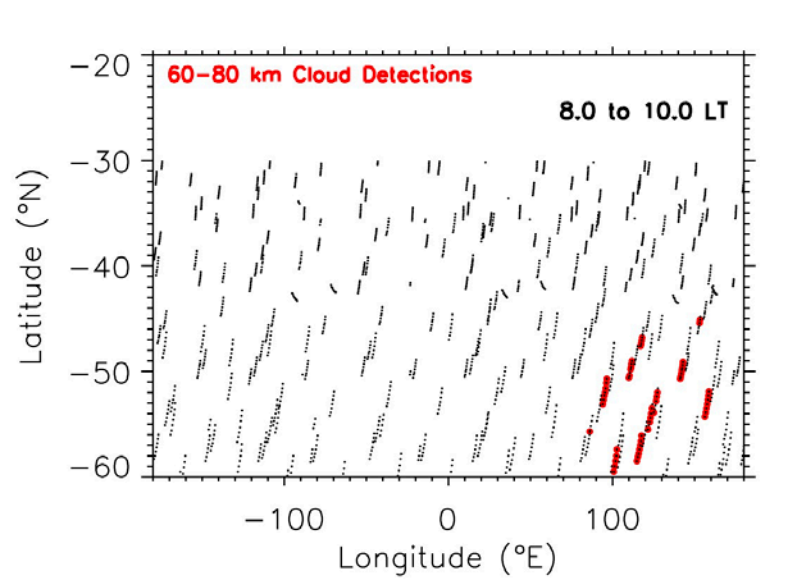
Both migrating and non-migrating thermal tides interact to produce cloud morphology observed by MAVEN/IUVS [Stevens et al., 2017].

Mars Climate Sounder (MCS) temperature observations on NASA's Mars Reconnaissance Orbiter (2006-present).

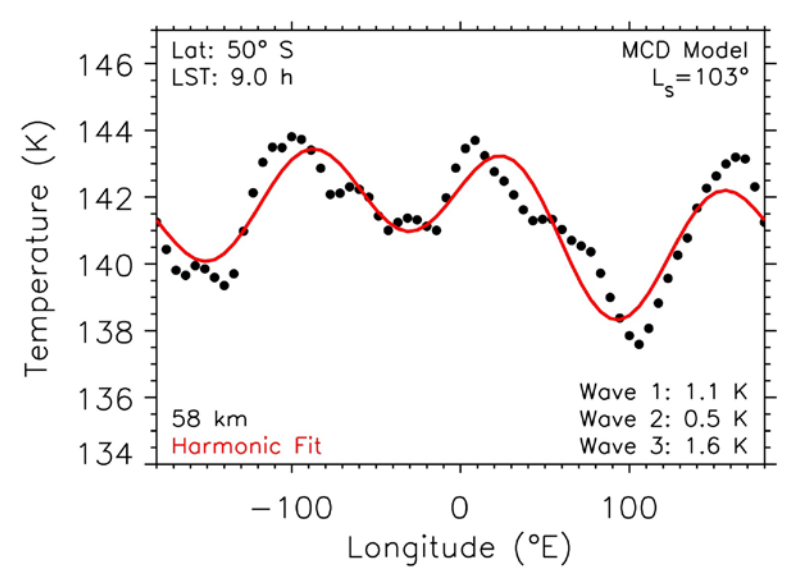
IUVS clouds are near the troughs, as expected.

What about the clouds at southern mid-latitudes?....

2017 Mid-Latitude SH Clouds: Comparison with MCD Model Temperatures



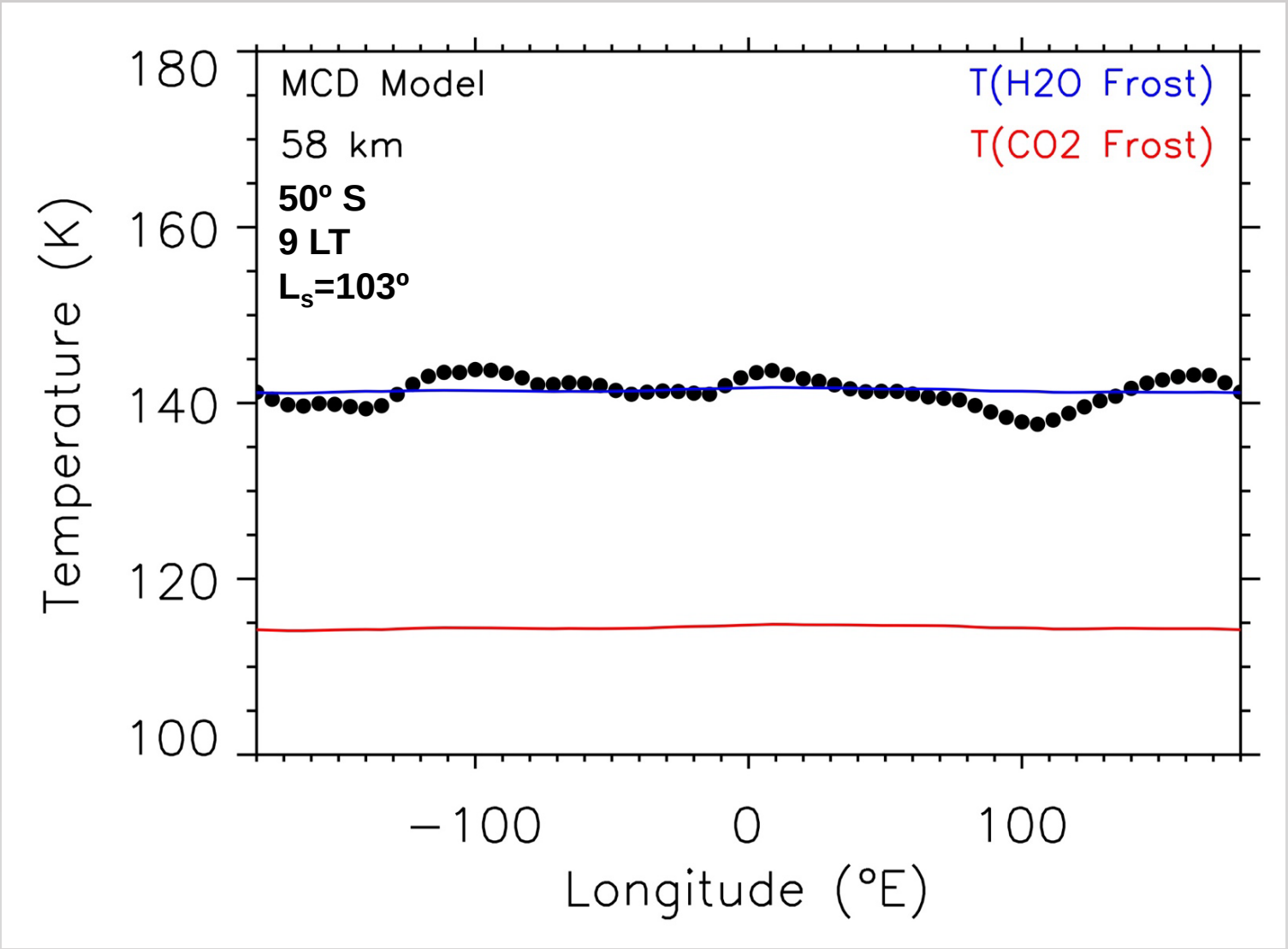
There is a localized cluster of clouds at southern mid-latitudes at the same local time as the 2015 observation (8-10 h).



Mars Climate Database (MCD) model results for same conditions as above observations. **Red** = harmonic fit to the MCD results.

Clouds are only observed where there is a temperature minimum in model results.

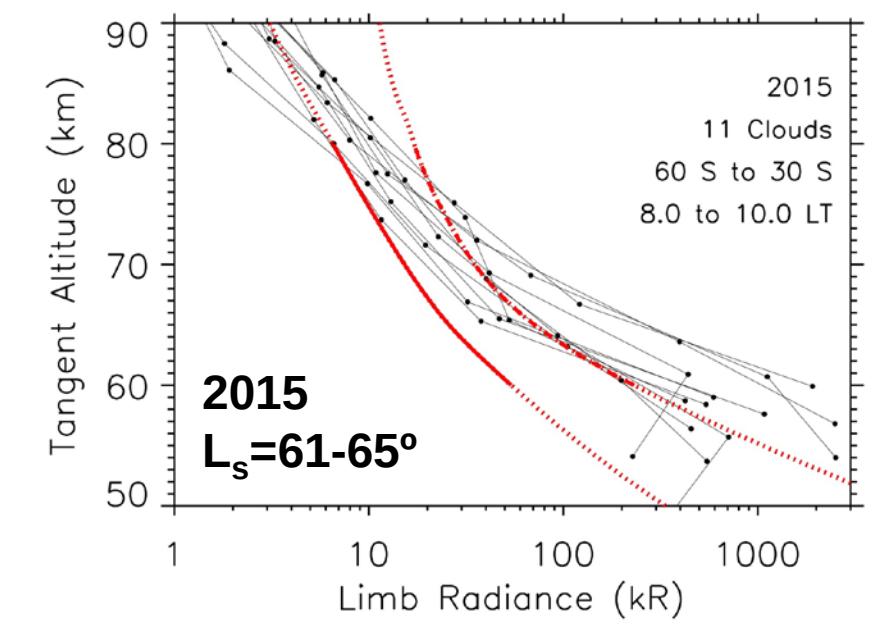
MCD Model Results Indicate H_2O Ice at 58 km

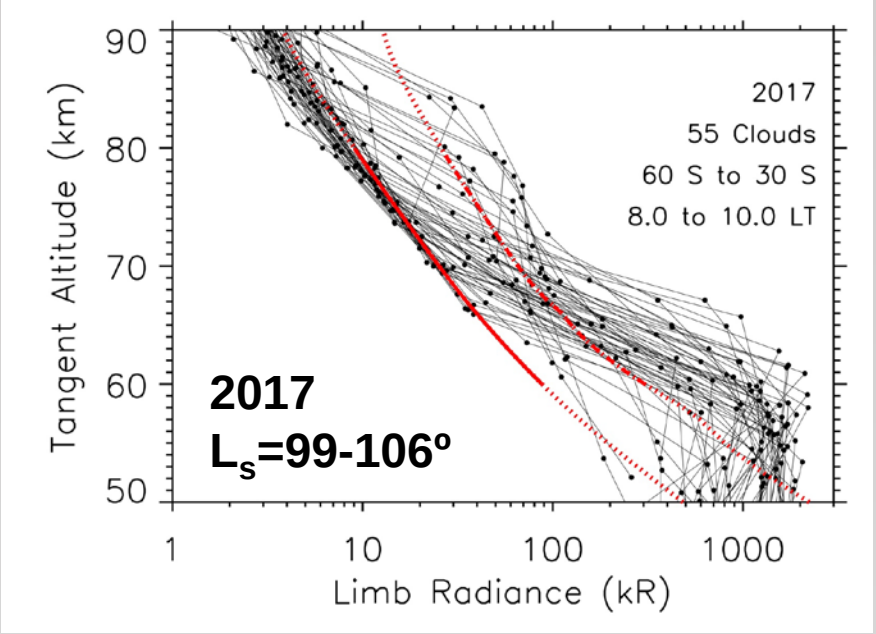


Model temperatures are too high to make CO_2 ice for 2017 SH cloud observations.

What can we say about composition using the IUVS mesospheric cloud data?...

Southern Mid-Lat Profiles: 2015 and 2017

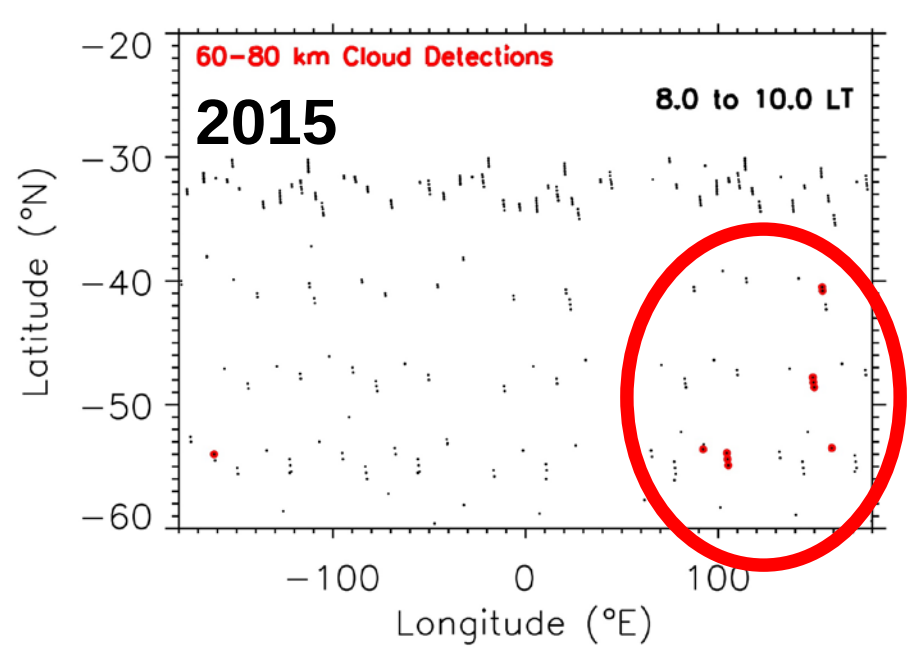


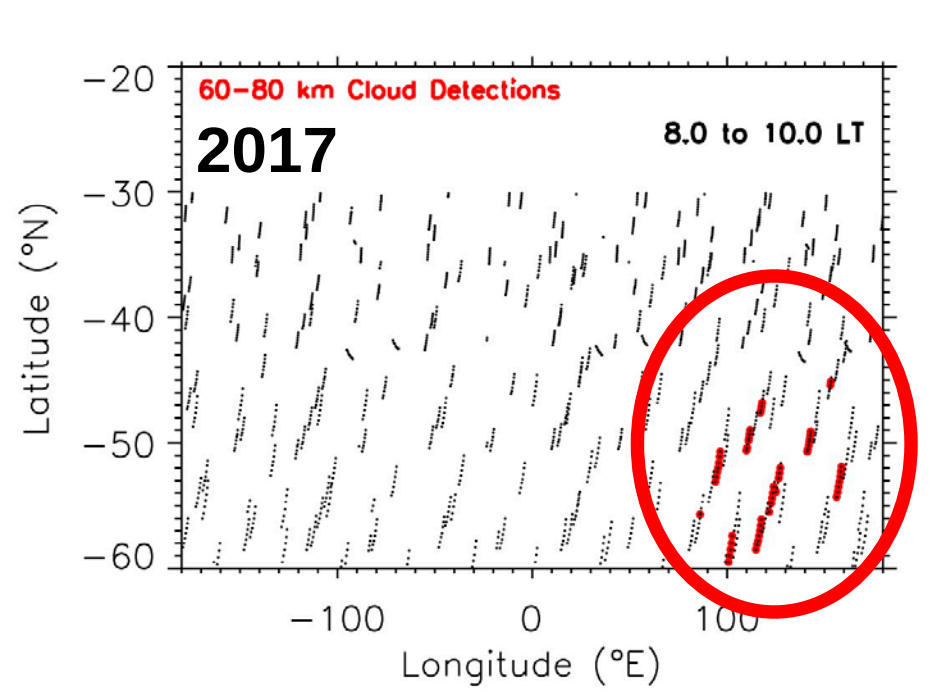


- **Red solid = clear air average**
  Broken red = detection limit
  Dashed red = altitude region of study

- **More SH clouds detected in 2017 due to larger sampling.**

More Complete Southern Coverage in 2017





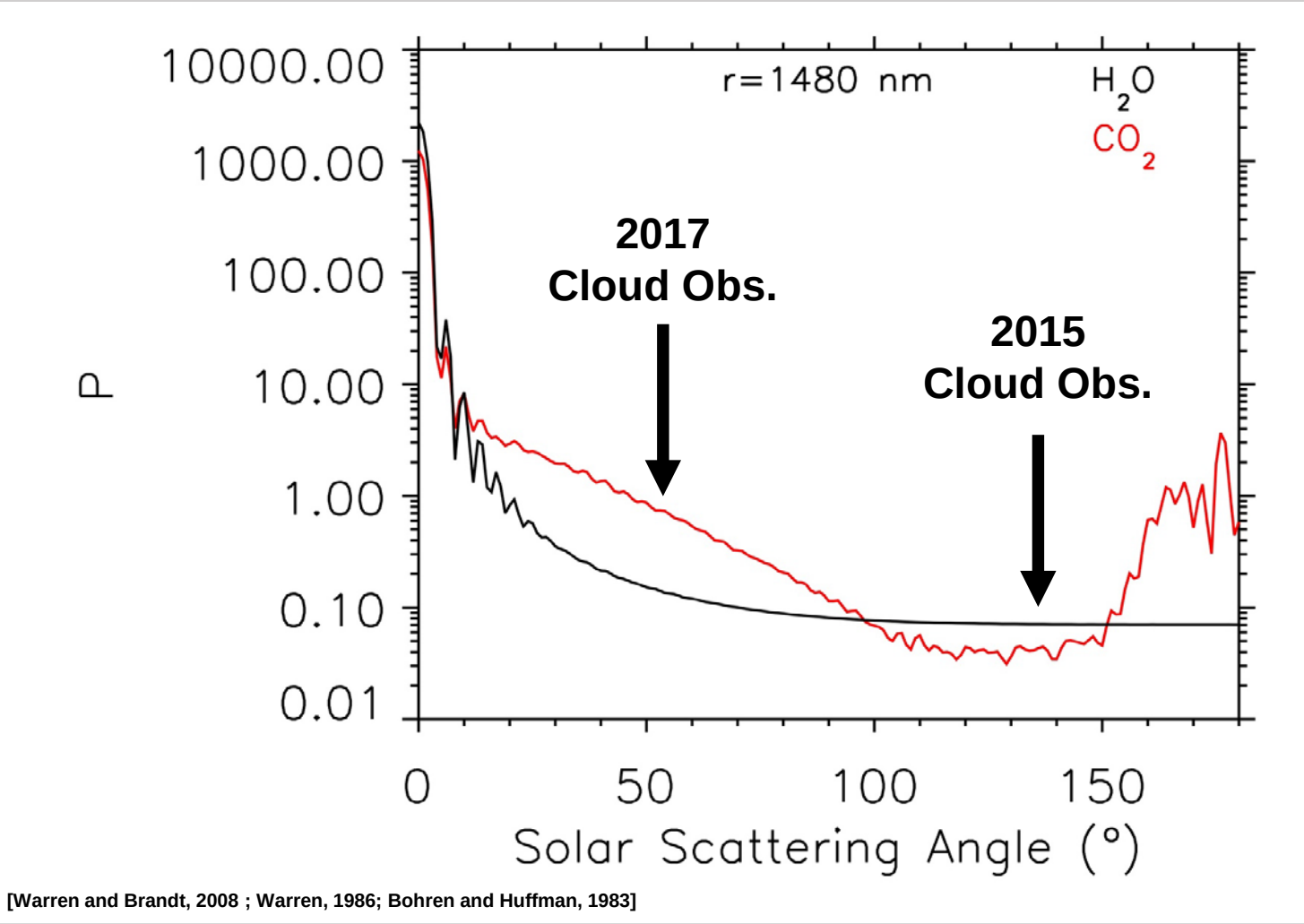
- **Distribution of SH mid-latitude clouds in 2015.**
- **Red are detections. Black are non-detections.**

- **Distribution of SH mid-latitude clouds in 2017.**
- **<u>Persistent</u> longitudinal asymmetry is clarified with improved coverage.**

Summary of 2015 and 2017 Southern Mesospheric Cloud Observations

	2015	2017
# Clouds Detected	11	55
Wavelength	185-205 nm	185-205 nm
Altitude	50-80 km	50-80 km
Local Time	8-10 h	8-10 h
Latitude	40-55º S	45-60º S
Longitude	92-198º E	86-159º E
L_s	61-65º	99-106º
Avg. Solar Scattering Angle	135º	53º
Avg. Radiance@60 km (kR)	544	662

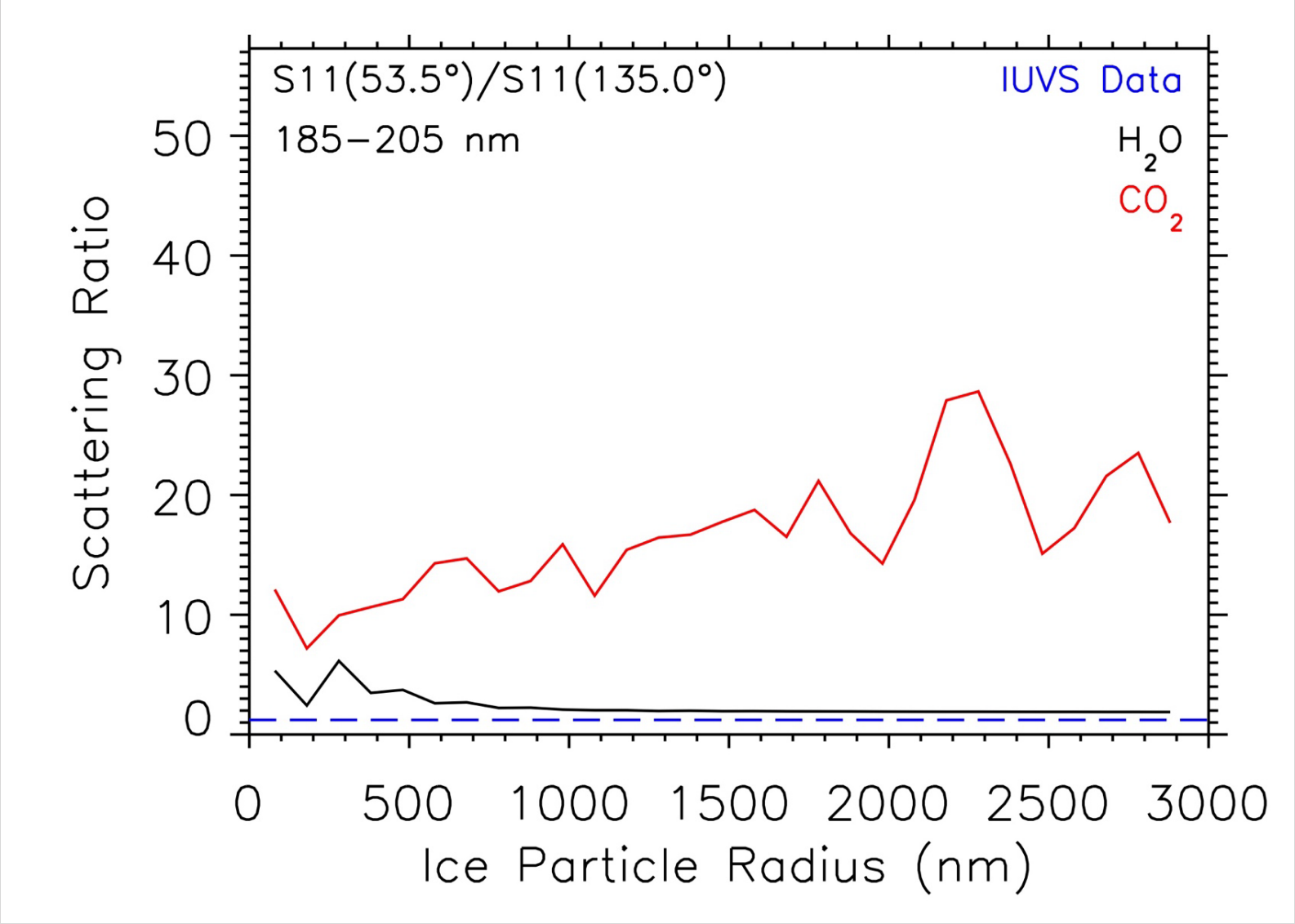
Phase Functions for CO_2 Ice and H_2O Ice



[Warren and Brandt, 2008 ; Warren, 1986; Bohren and Huffman, 1983]

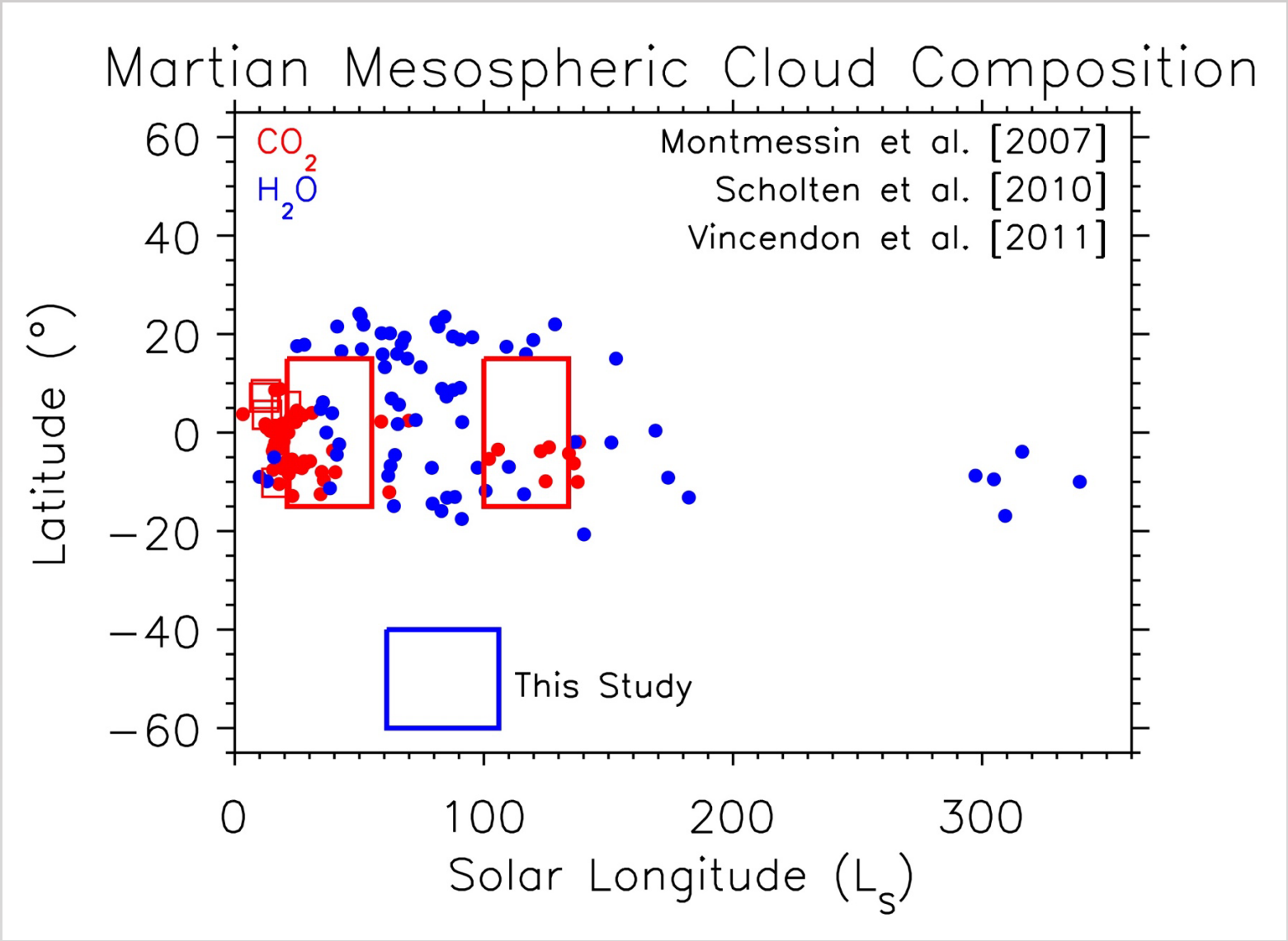
- Typical monodisperse ice particle radius used for a mesospheric cloud.
- Solar scattering angles sampled leverage steep CO_2 phase function.

IUVS Data are Consistent with H_2O Ice



- **IUVS cloud data is $4\pi I(2017)/4\pi I(2015)$ at 60 km. H_2O ice is indicated.**
- **If CO_2 ice, observed scattering ratio would be over a factor of 10 larger**

The Reported Cloud Composition is Either H_2O or CO_2



- **IUVS probes latitudes (40-60º S) and local times (8-10 h) where compositional data are limited heretofore.**

Summary

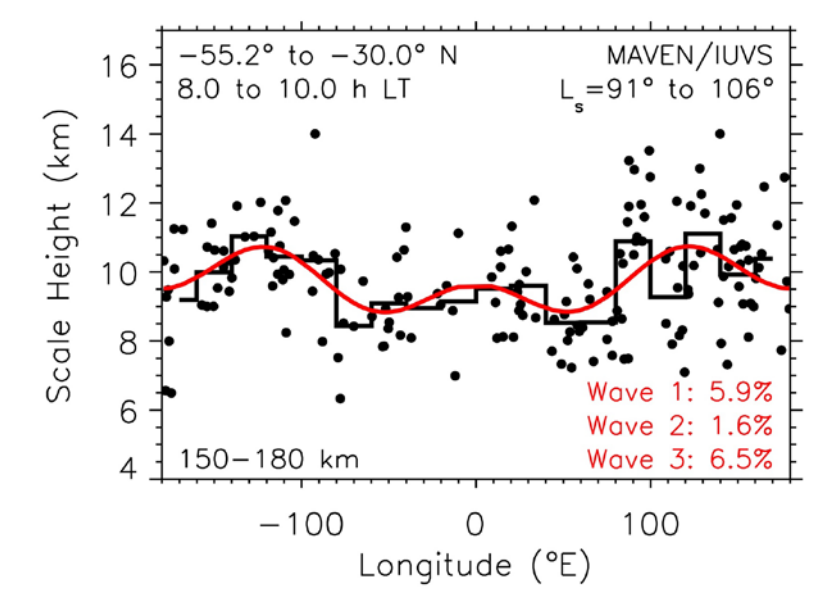
- **IUVS has detected mesospheric clouds in 2015 and 2017 at southern mid-latitudes (40-60º S) and at local times (8-10 h) sparsely sampled heretofore.**

- **The clouds show a persistent longitudinal asymmetry such that they appear between 80-170º E.**

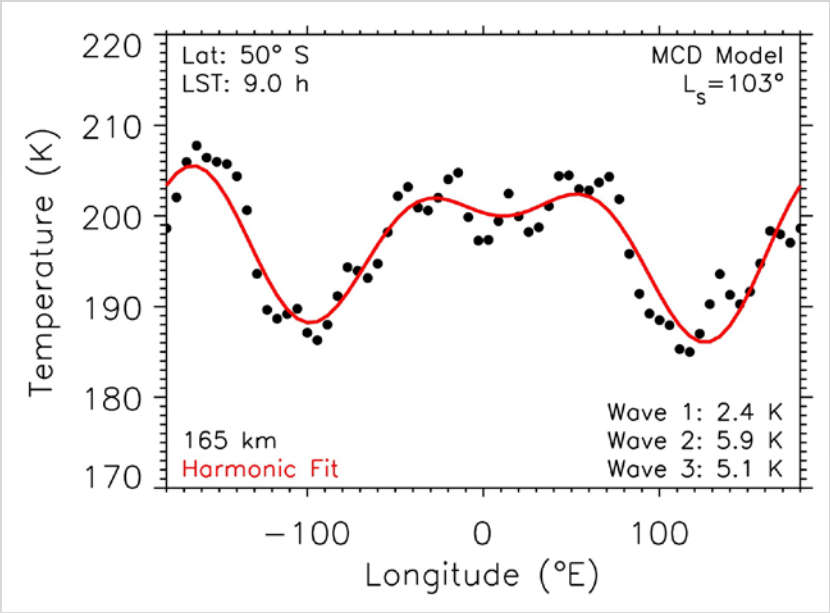
- **Spectroscopic analysis indicates that the SH mesospheric clouds are composed of H_2O ice.**

Extra Slides

Comparison of IUVS Data and MCD Temperatures



IUVS Data in Thermosphere

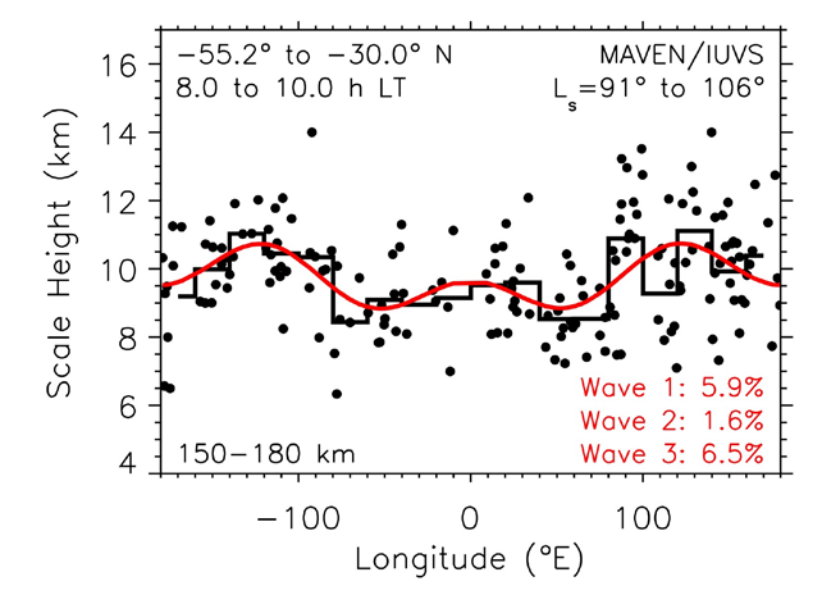


Model Results in Thermosphere

Wave structure preserved in model at same thermospheric altitudes.

Phase/components slightly different in model compared to IUVS data.

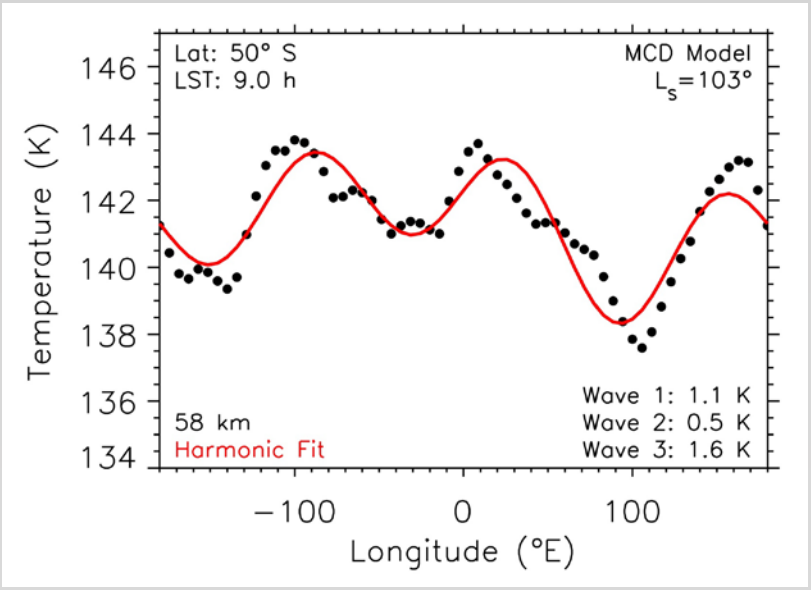
Wave Structure Propagates to Thermosphere



IUVS Data in Thermosphere

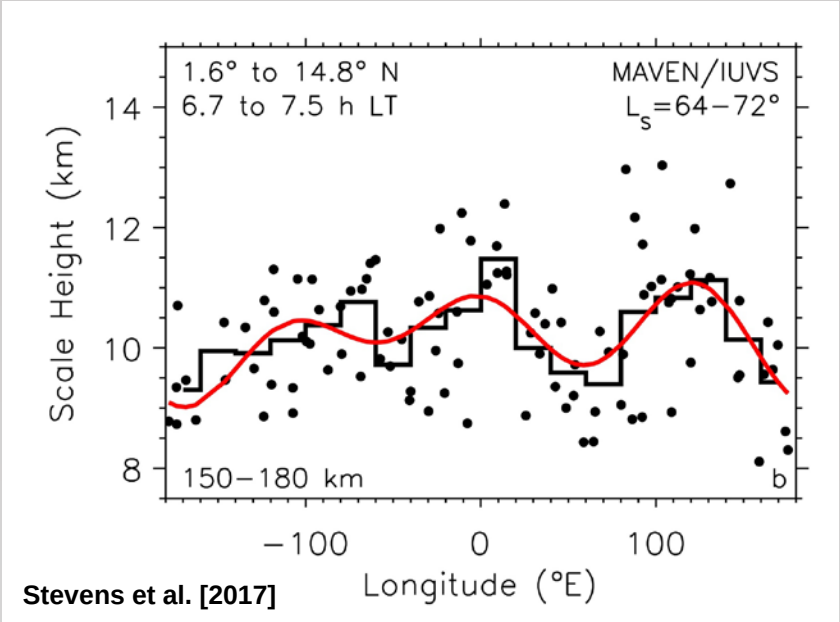
Waves 1 and 3 persist 100 km above mesosphere, consistent with analysis of equatorial clouds [Stevens et al., 2007].

Black symbols: IUVS data
Black histogram: Binned avg. of IUVS data
Red: Harmonic fit to IUVS data



Model Results in Mesosphere

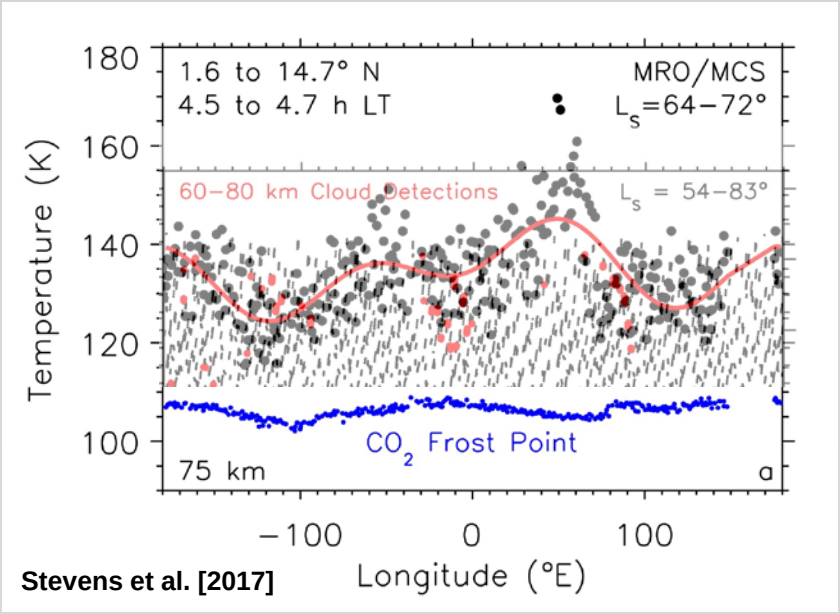
Non-Migrating Tides: Which Modes Dominate?



Stevens et al. [2017]

IUVS 165 km scale heights: Nov 2015
Diagnostic of temperatures
Black histogram=avg.

Red Curve = 3 Component fit:
Wave 3: 5%
Wave 2: 4%
Wave 1: 3%



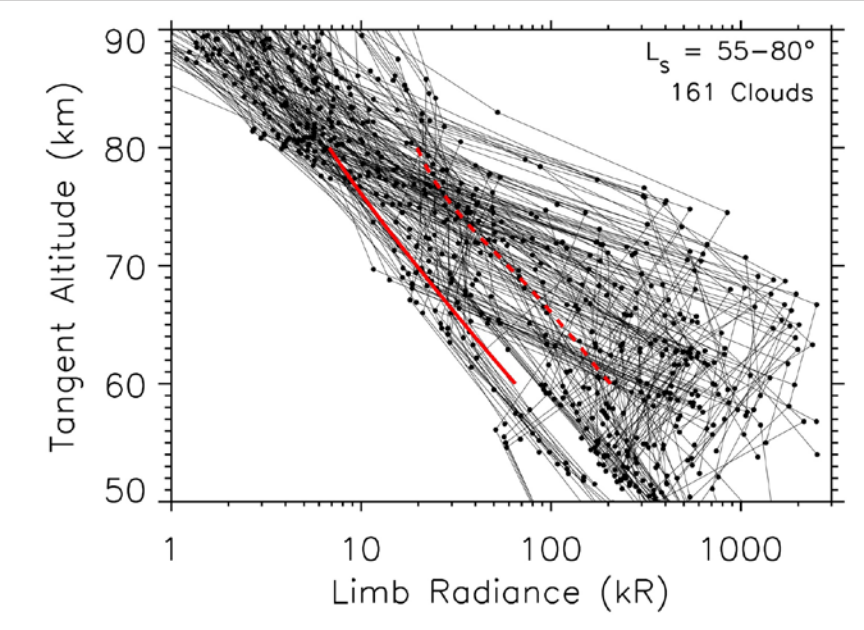
Stevens et al. [2017]

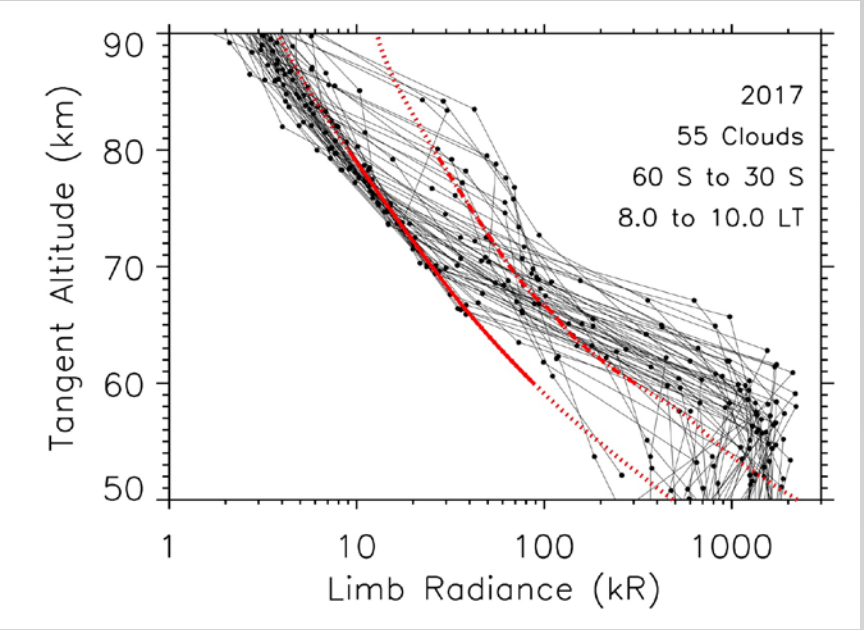
MCS 75 km temperatures: Nov 2015
Temps out of phase with IUVS H
IUVS clouds observed near cold troughs

3 Components are fit:
Wave 3: 5.6 K
Wave 2: 3.2 K
Wave 1: 4.5 K

Wave 3 is strongest from <u>75-180 km</u>.

All Profiles 2015 and SH Mid-Lat Profiles 2017

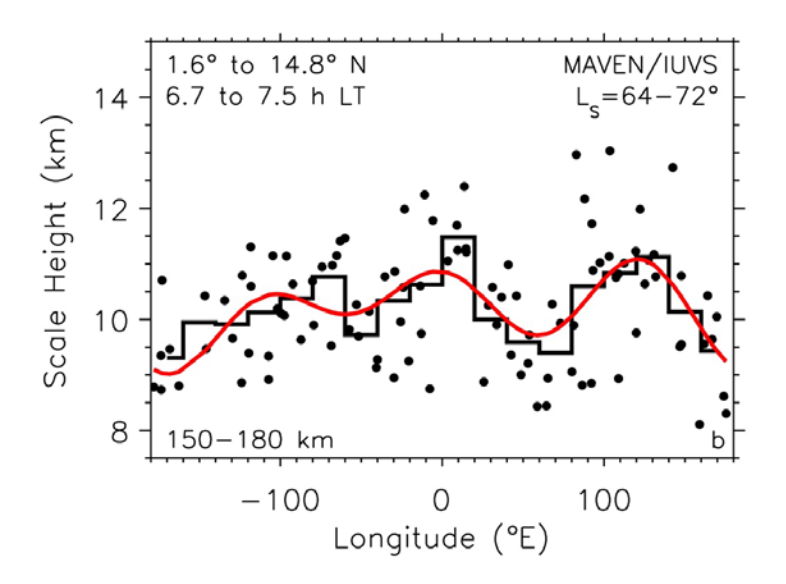




The 2015 cloud observations are mostly equatorial and peak between 60-70 km on average [Stevens et al., 2017].

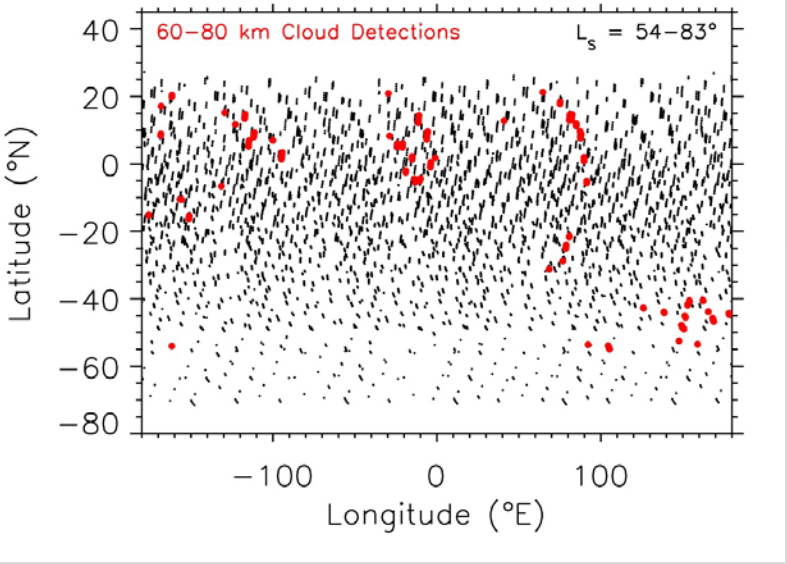
The 2017 SH mid-latitude observations peak at 58 km altitude on average.

2015 Equatorial Clouds: Wave 3 Dominates



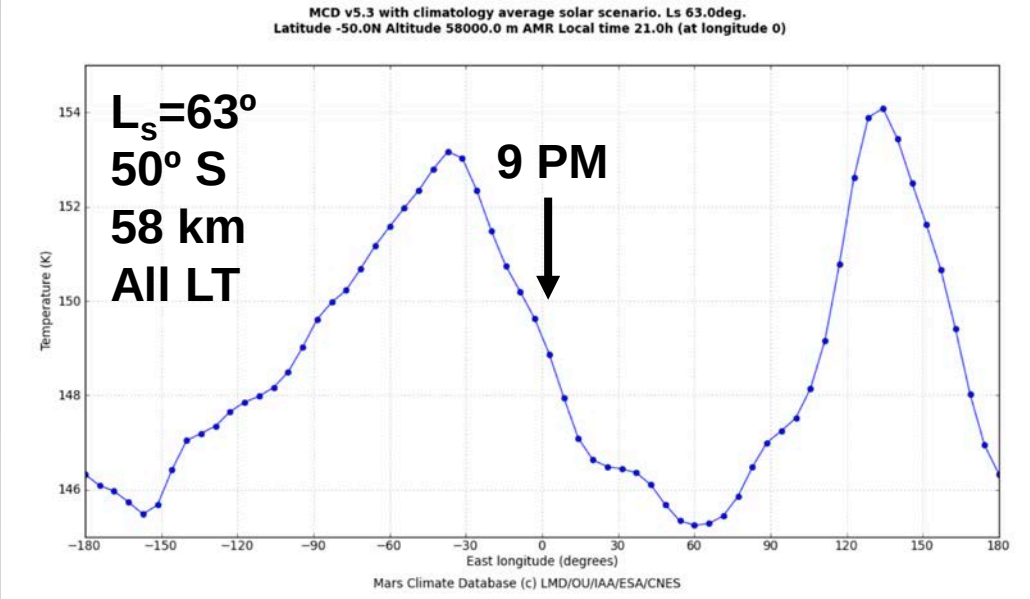
IUVS observations of upper atmospheric scale heights (150-180 km) near equator.

Black points = observations
Black histo = averages
Red curve = fitted wave components
Wave 1: 3%
Wave 2: 4%
Wave 3: 5%

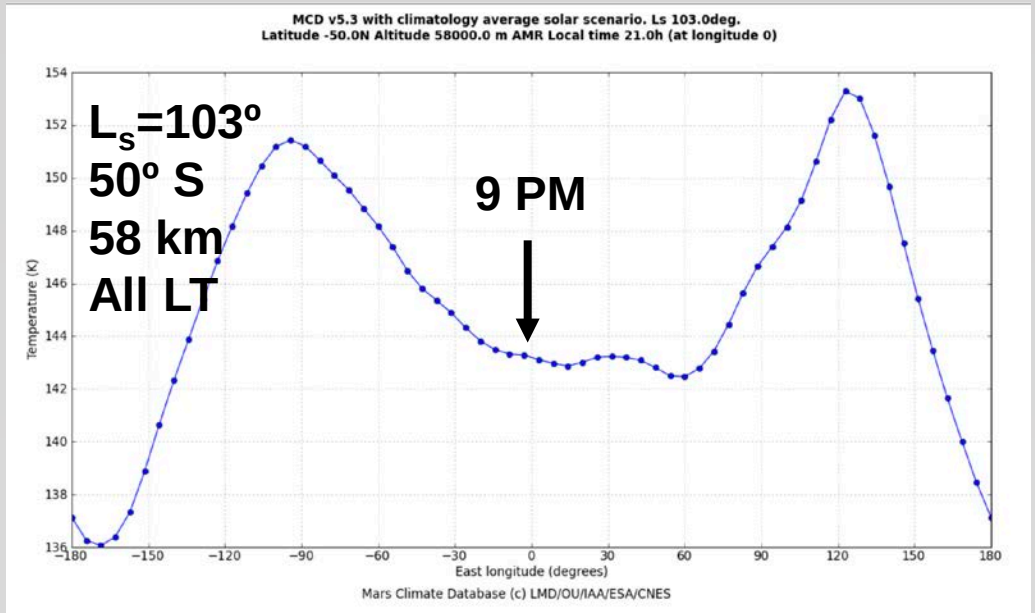


The dominant wave 3 pattern in the clouds at the equator also appears in the upper atmosphere, showing coupling of thermal tides throughout the atmosphere [Stevens et al., 2017].

MCD Temperatures: IUVS 2015 and 2018 Observations



IUVS 2015
T(min)=145 K
T(max)=154 K



IUVS 2017
T(min)=136 K
T(max)=154 K