FOUNDATIONAL COURSE

December 6, 2018

Satellite Foundational Course for JPSS (SatFC-J)

MICROWAVE

FOUNDATIONAL COURSE

Oxygen and Water Vapor Absorption Bands
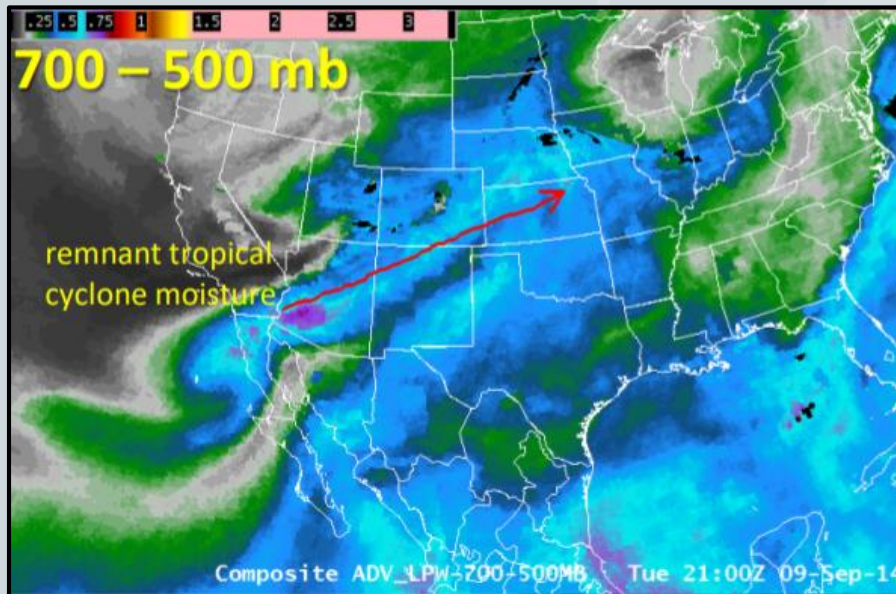
Learning Objectives

1. Identify the location of the oxygen and water vapor absorption regions in the microwave spectrum

2. Describe how varying levels of absorption/transmittance across the oxygen and water vapor absorption regions can be used in determining temperature and moisture profiles

oxygen absorption → temperature profile

water vapor absorption → moisture profile

Operational Usage

MICROWAVE

CONSTELLATION

APPLICATIONS

INITIATIVES

What do microwave temperature and moisture profiles inform?

Total and Layered Precipitable Water Products

.25 .5 .75 1 1.5 2 2.5 3

700 – 500 mb

remnant tropical cyclone moisture

Composite ADV_LPW-700-500MB   Tue 21:00Z 09-Sep-14

Advected Layer Precipitable Water Product Quick Guide

NUCAPS Soundings
(NOAA Unique Combined Atmospheric Processing System)

25.04/-57.09 180920/05(Thu) NUCAPS
25.04,-57.09

TPW in Sounding: 1.57"
Mid-level RH: 53%

CIMSS Satellite Blog: https://cimss.ssec.wisc.edu/goes/blog/archives/29877
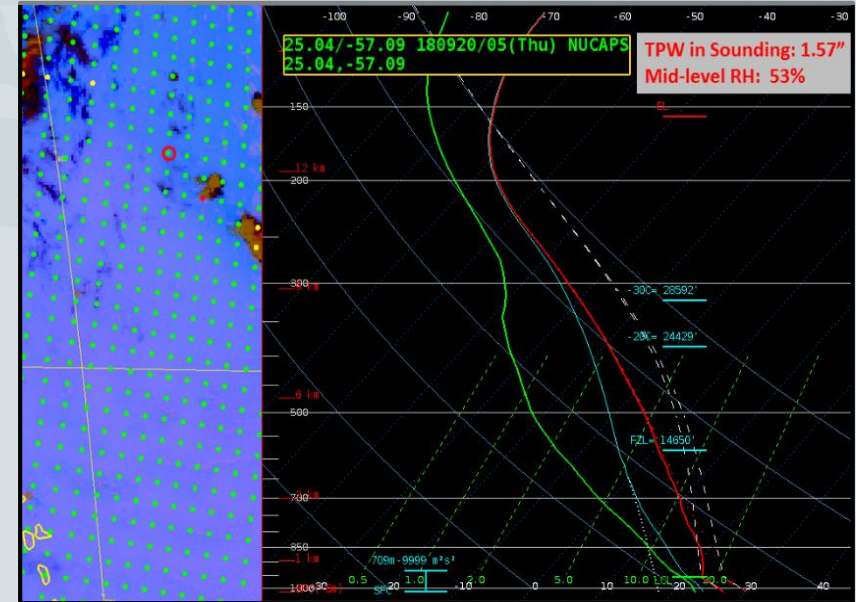
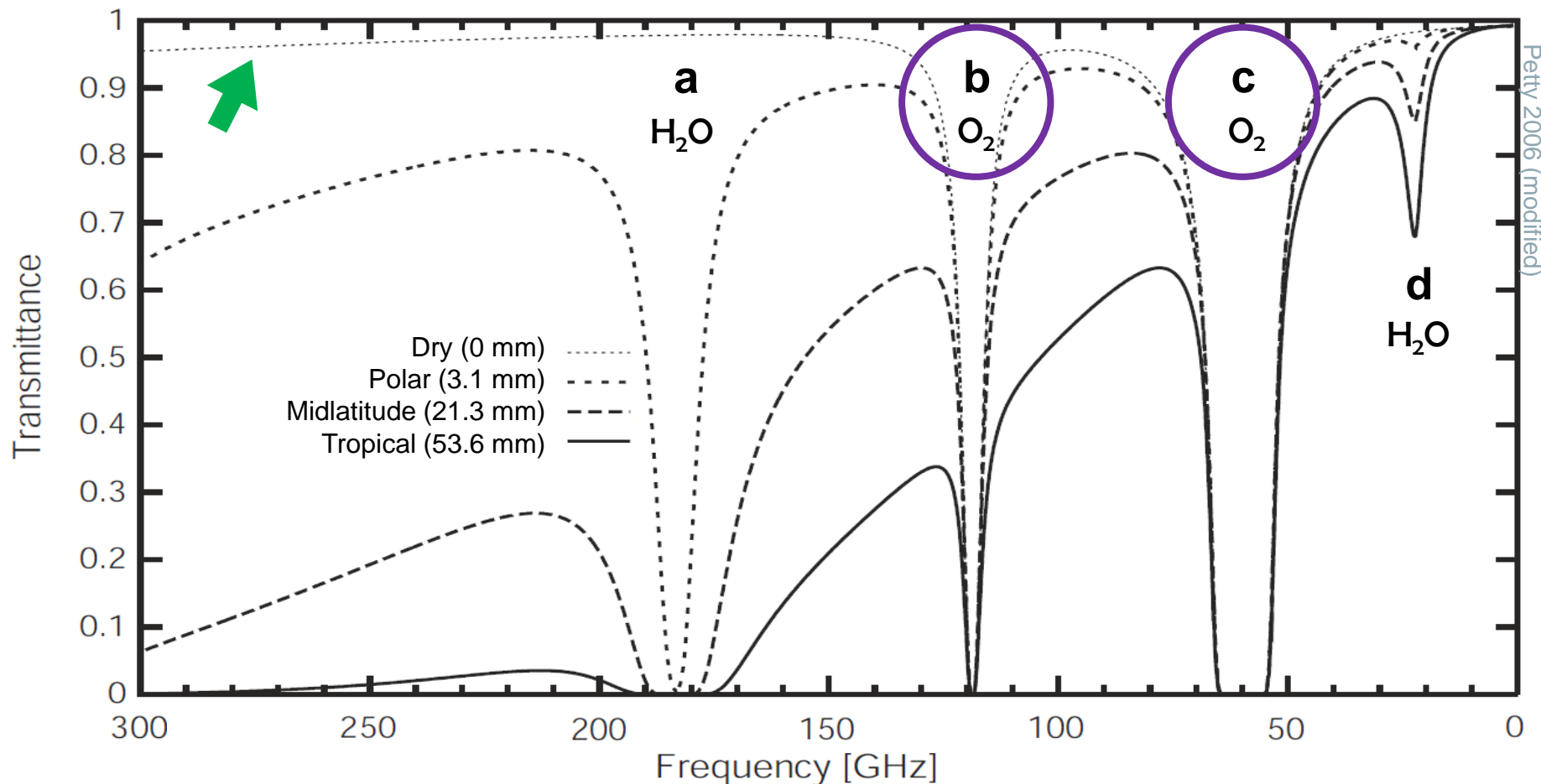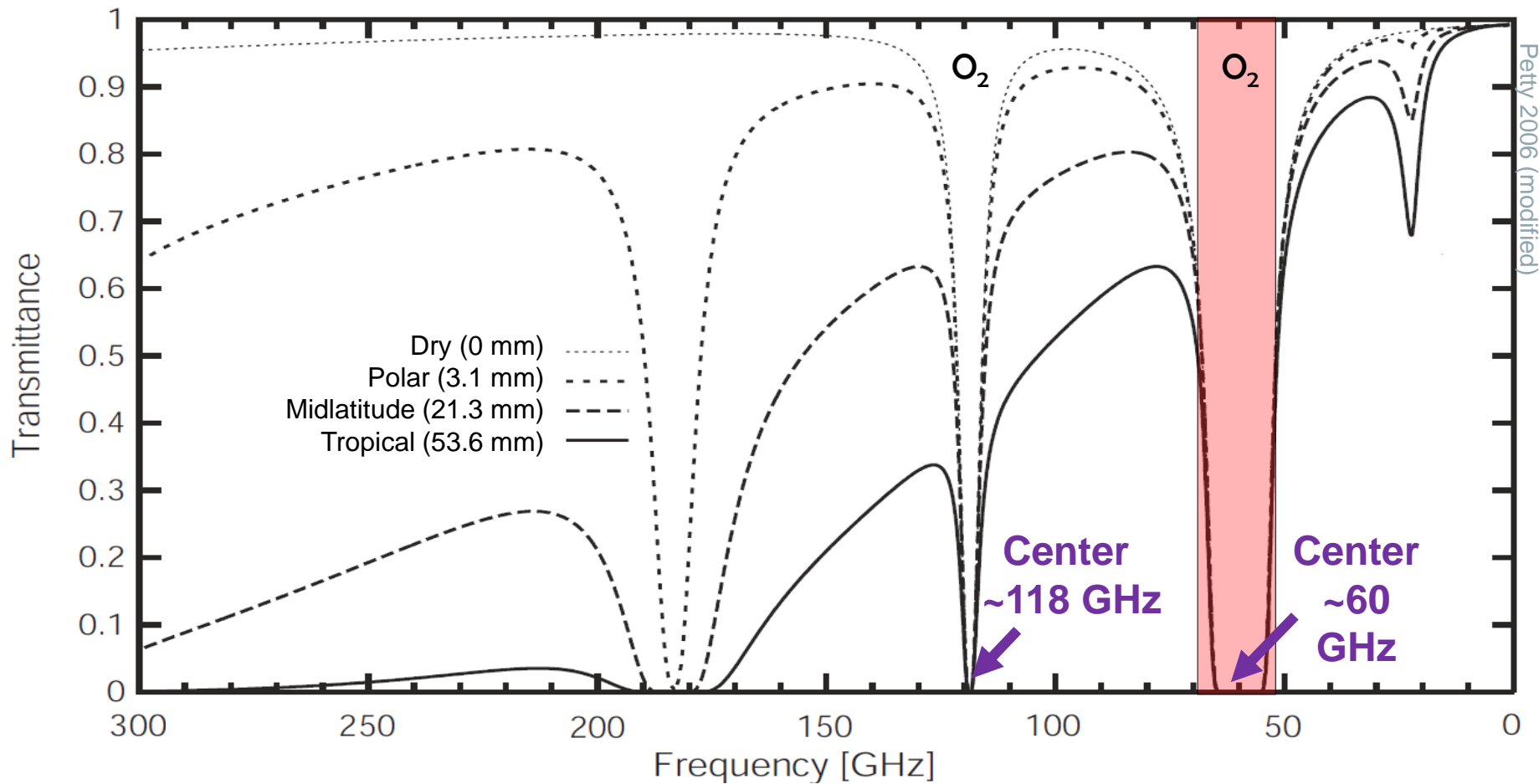## Numerical Weather Prediction

Absorption and Window Regions

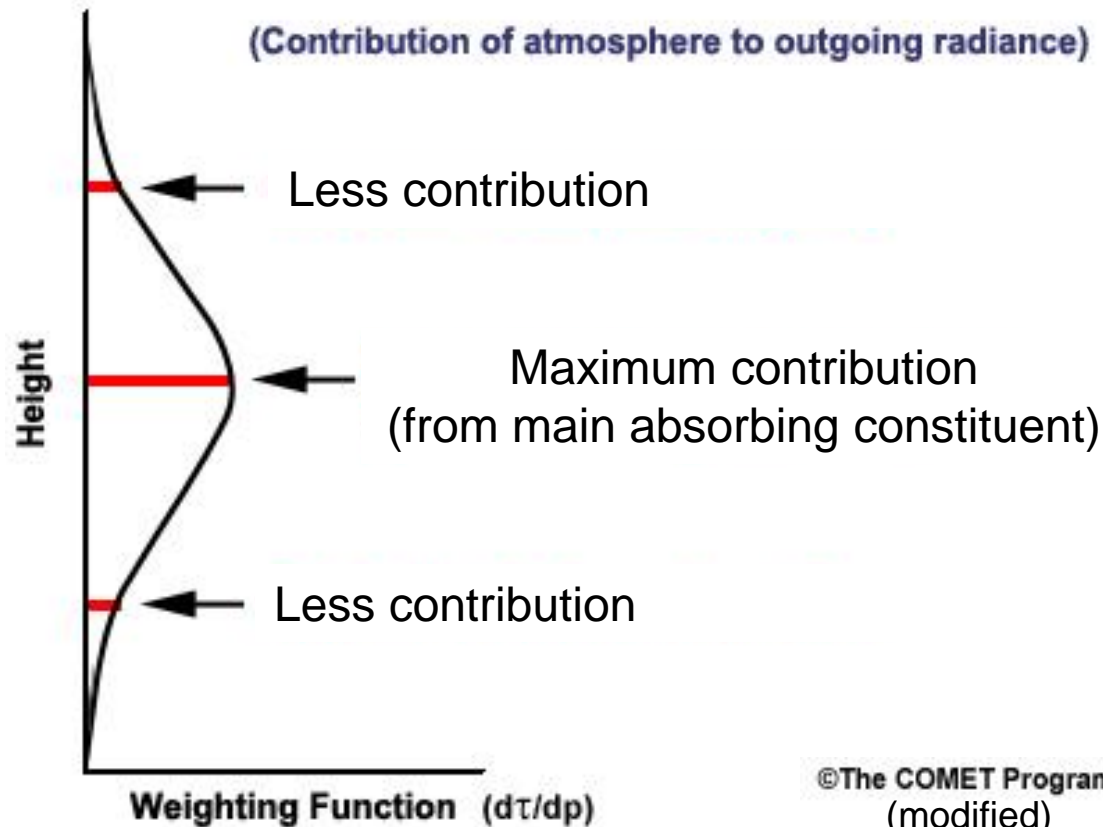▪ Zenith microwave transmittance depends on latitude (moisture)

Oxygen Absorption

- Used to profile atmospheric temperature
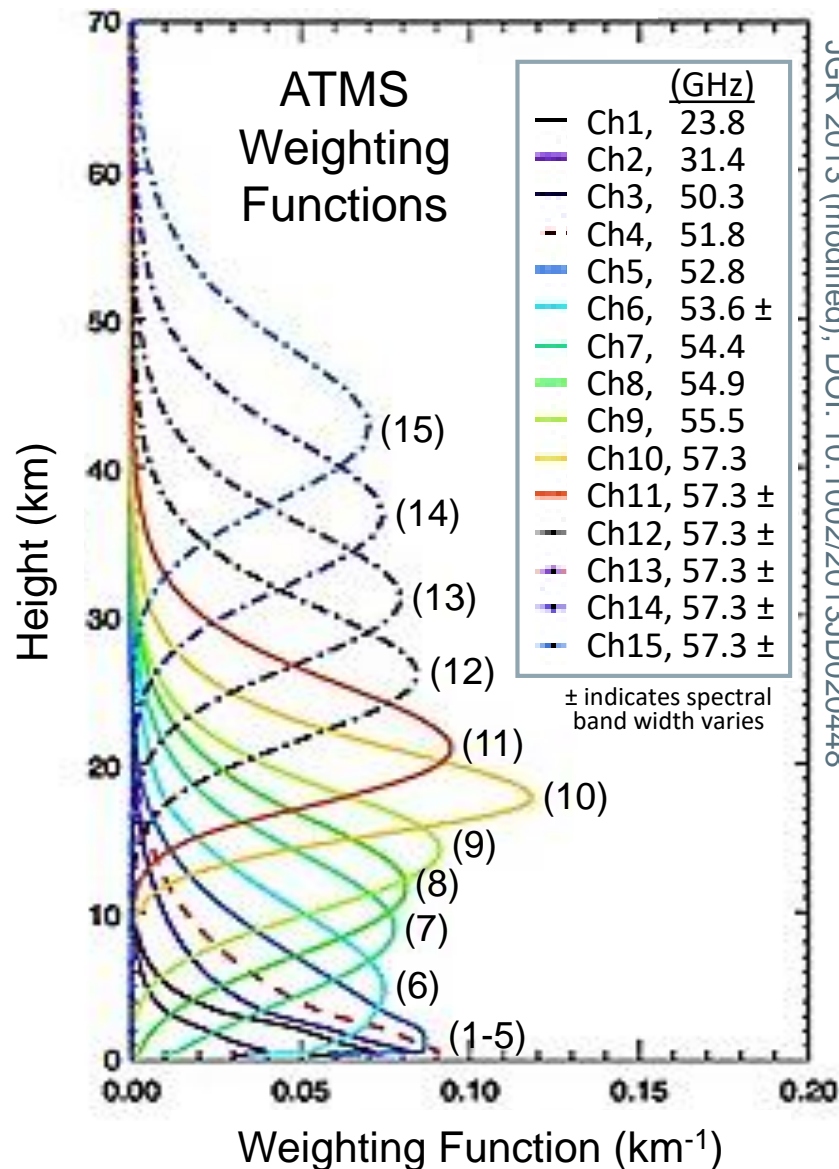
Weighting Function

- At a given frequency, the weighting function for radiation represents the contributions from different heights in the atmosphere.

(Contribution of atmosphere to outgoing radiance)

Less contribution

Maximum contribution
(from main absorbing constituent)

Less contribution

Height

Weighting Function ($d\tau/dp$)

©The COMET Program
(modified)

Spectral Selection: O$_2$ Absorption

- Advanced Technology Microwave Sounder (ATMS)

  – Channels 3-15 on edge of oxygen absorption region (center ~60 GHz)

  – Used to derive atmospheric temperature profiles

  – Weighting functions peak over a range of heights in the troposphere and stratosphere

  – Weighting function for maximum absorption for well-mixed O$_2$ peaks highest in the atmosphere

ATMS Weighting Functions

	(GHz)
Ch1,	23.8
Ch2,	31.4
Ch3,	50.3
Ch4,	51.8
Ch5,	52.8
Ch6,	53.6 ±
Ch7,	54.4
Ch8,	54.9
Ch9,	55.5
Ch10,	57.3
Ch11,	57.3 ±
Ch12,	57.3 ±
Ch13,	57.3 ±
Ch14,	57.3 ±
Ch15,	57.3 ±

± indicates spectral band width varies

Height (km)

Weighting Function (km^{-1})

for a standard mid-latitude atmosphere

JGR 2013 (modified), DOI: 10.1002/2013JD020448

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Loop of ATMS Channels 3-15: Oxygen Absorption

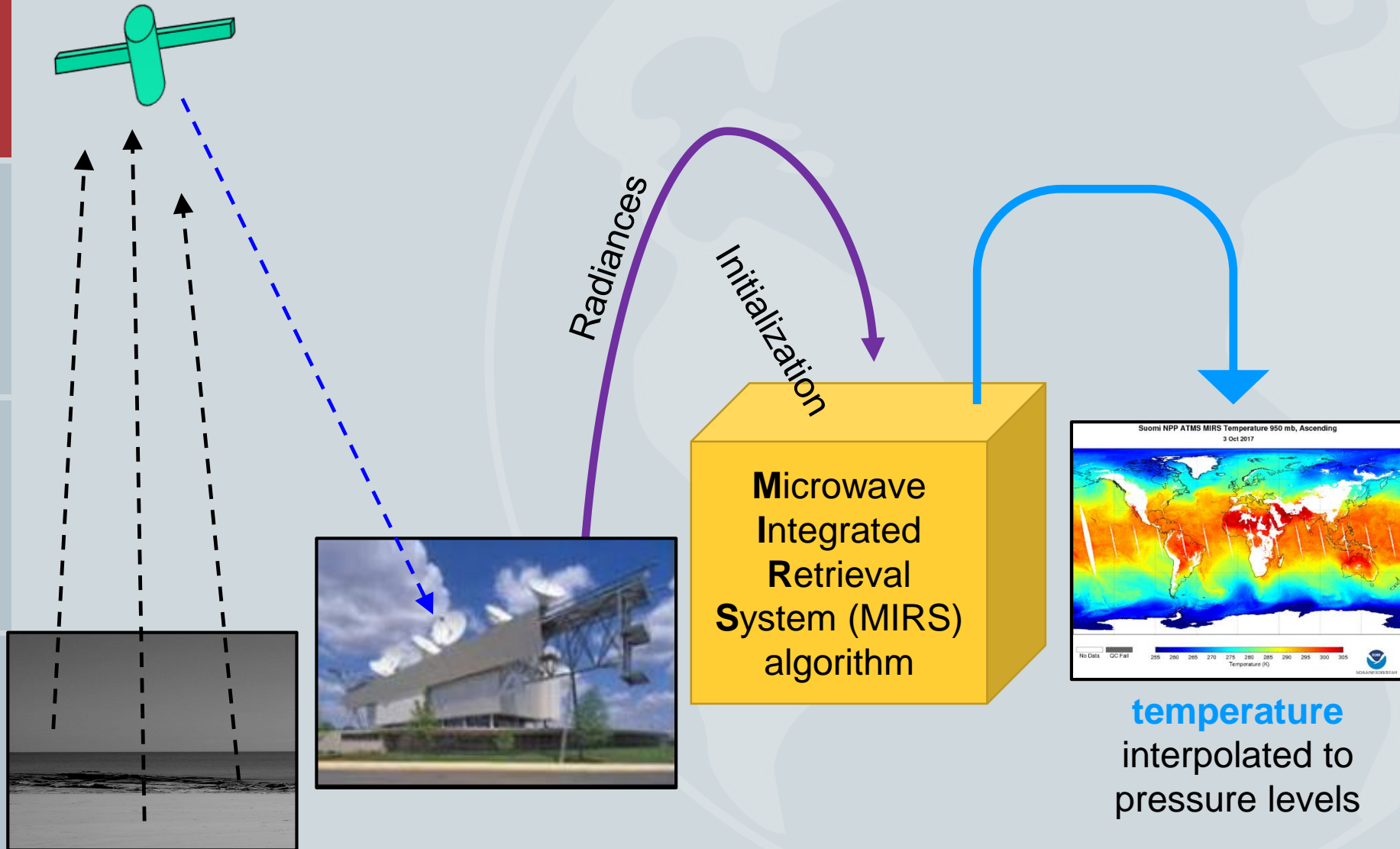ATMS Ch 3 (50.3 GHz) Ascending: 3 Oct 2017
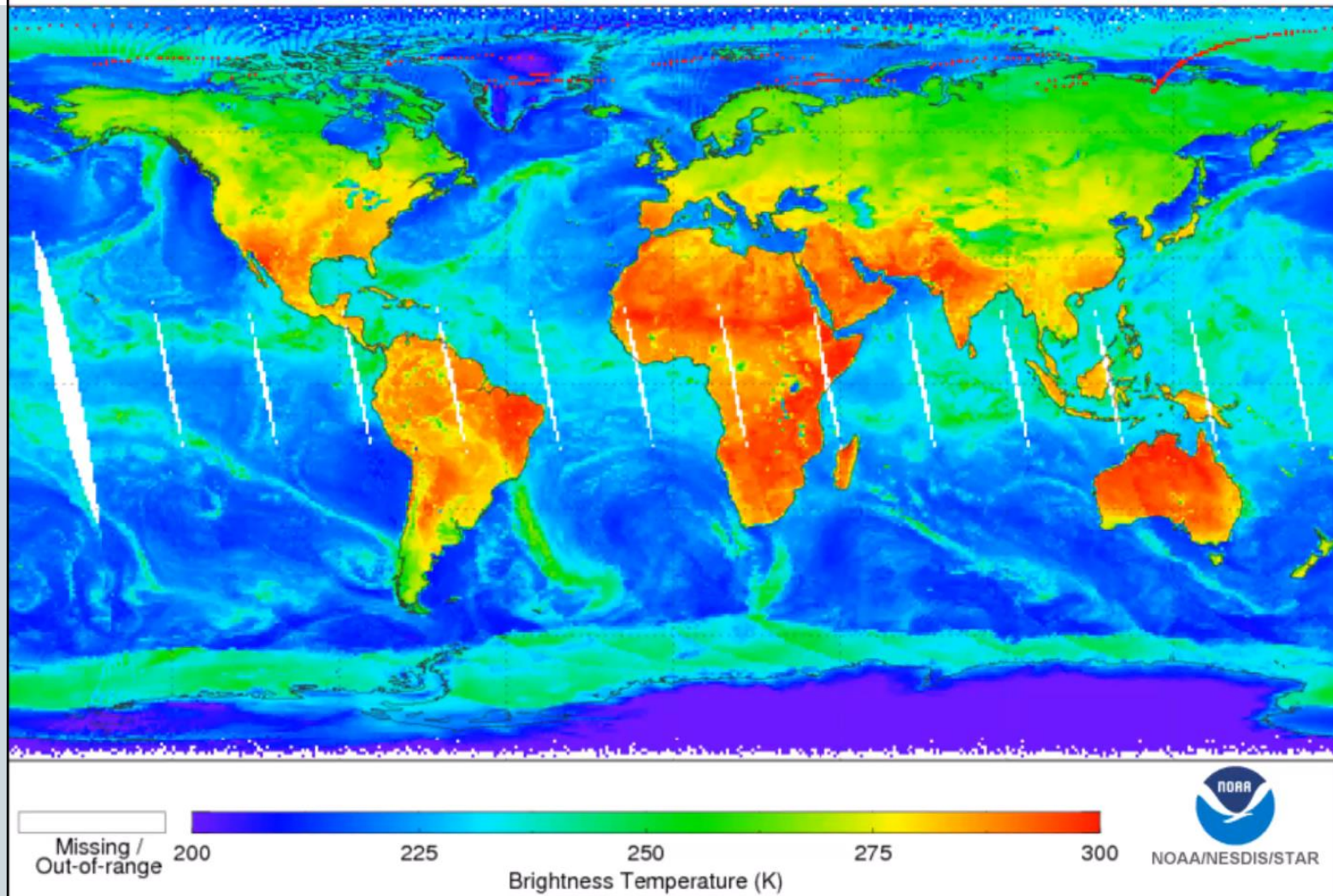
http://rammb.cira.colostate.edu/templates/loop_directory.asp?data_folder=visitview/custom/ATMS_20171003_3to15
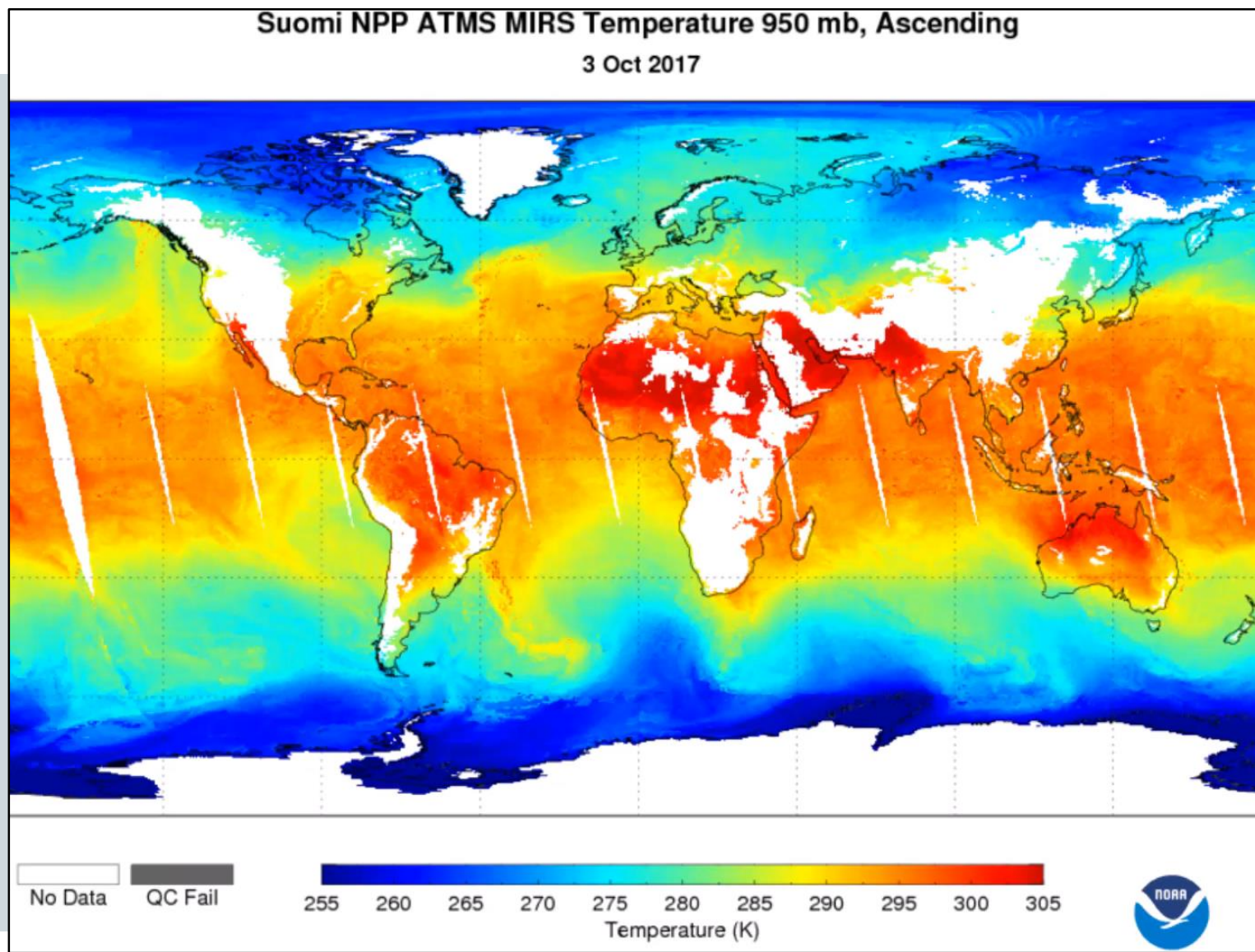
Imagery Source: NOAA/NESDIS/STAR JPSS Environmental Data Records (parameter = ATMS Limb-Corrected TDR)
https://www.star.nesdis.noaa.gov/jpss/EDRs/products_ATMS_LC.php

MICROWAVE

CONSTELLATION

APPLICATIONS

INITIATIVES

Radiances

Initialization

Microwave **I**ntegrated **R**etrieval **S**ystem (MIRS) algorithm

Suomi NPP ATMS MIRS Temperature 950 mb, Ascending
3 Oct 2017

No Data   QC Fail   255 260 265 270 275 280 285 290 295 300 305
Temperature (K)

temperature interpolated to pressure levels

Loop of MIRS Temperature (Interpolated to Pressure Levels 950-100 mb)

Suomi NPP ATMS MIRS Temperature 950 mb, Ascending
3 Oct 2017

Imagery Source: NOAA/NESDIS/STAR JPSS Environmental Data Records (parameter = Temperature)
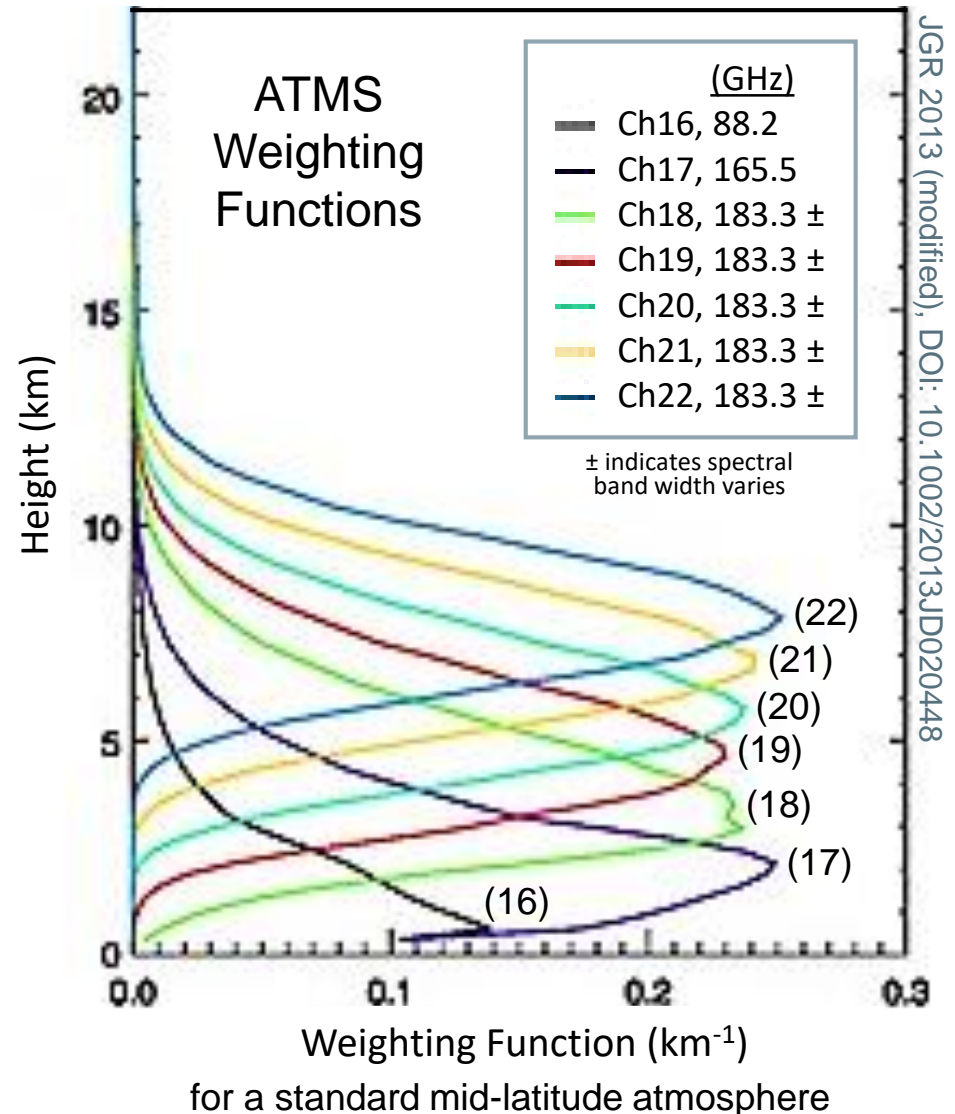https://www.star.nesdis.noaa.gov/jpss/EDRs/products_MiRS.php

Water Vapor Absorption
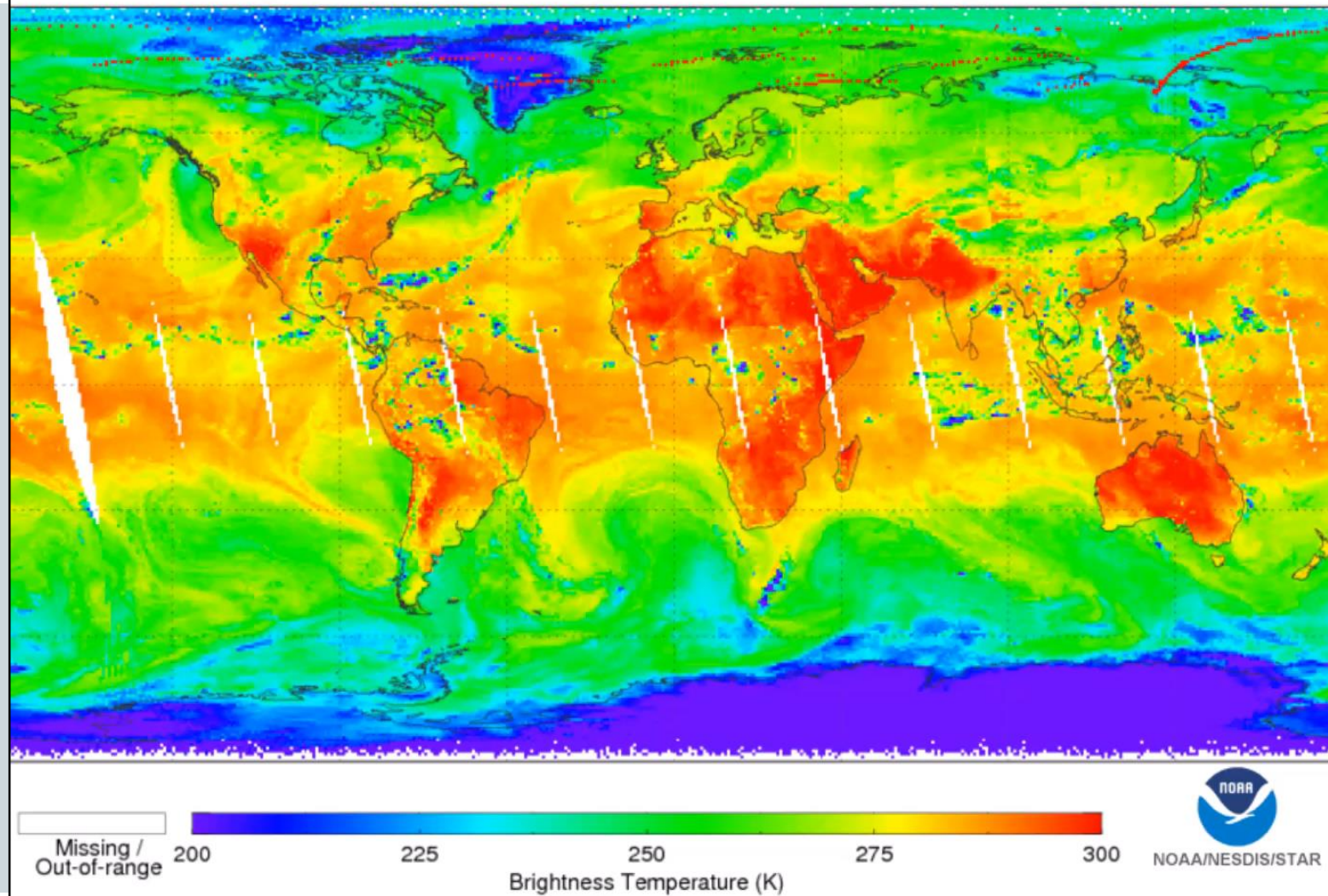
- Used to profile atmospheric moisture
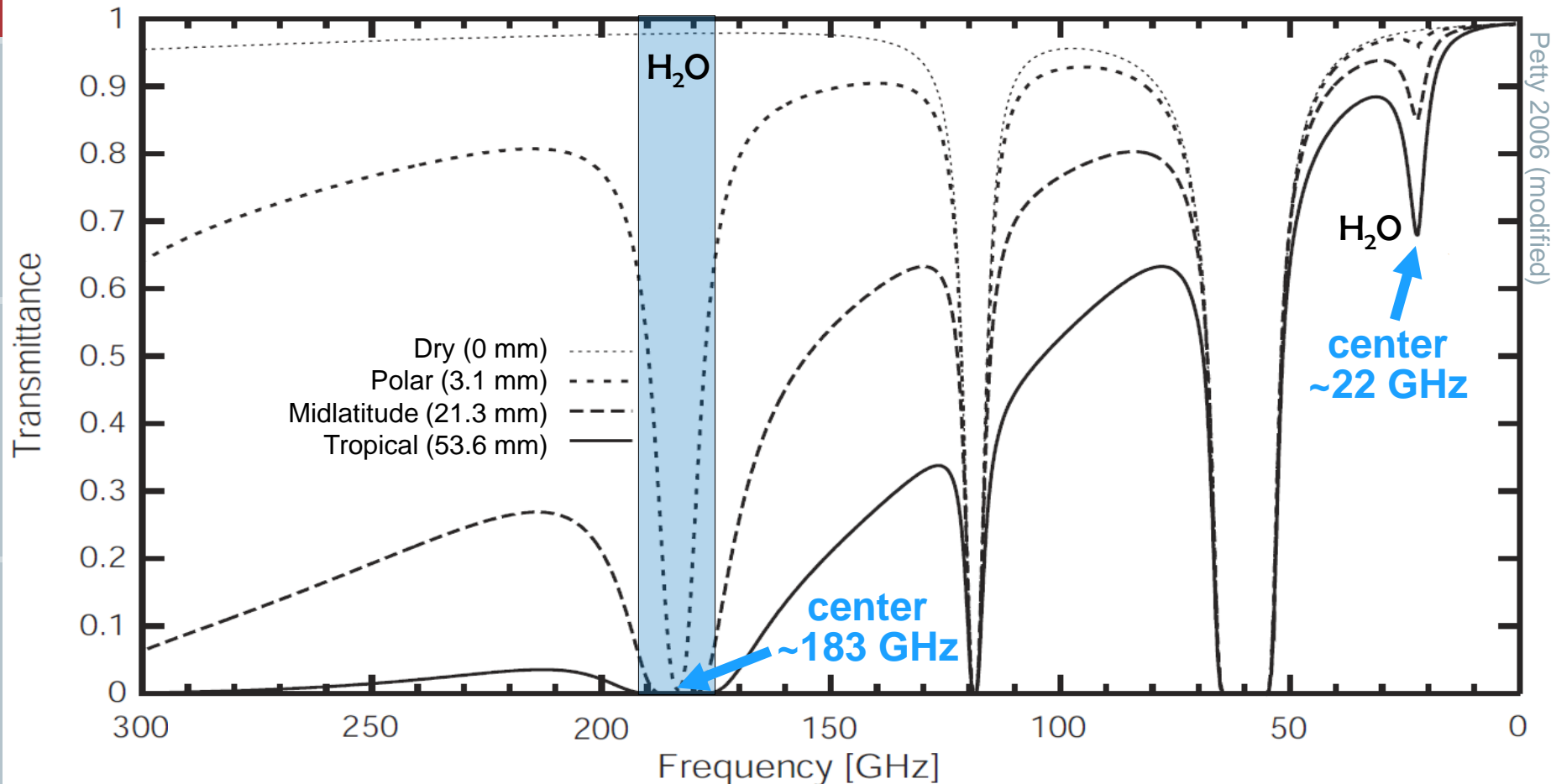
Plot of Transmittance vs Frequency [GHz] (Petty 2006 modified). Legend: Dry (0 mm), Polar (3.1 mm), Midlatitude (21.3 mm), Tropical (53.6 mm). Labels: H_2O center ~183 GHz, H_2O center ~22 GHz.

- Advanced Technology Microwave Sounder (ATMS)

  – Channels 17-22 on edge of water vapor absorption region (center ~183 GHz)

  – Used to derive atmospheric moisture profiles

  – Weighting functions peak in the troposphere

ATMS Weighting Functions

(GHz)
- Ch16, 88.2
- Ch17, 165.5
- Ch18, 183.3 ±
- Ch19, 183.3 ±
- Ch20, 183.3 ±
- Ch21, 183.3 ±
- Ch22, 183.3 ±

± indicates spectral band width varies

Height (km)

Weighting Function (km^{-1})
for a standard mid-latitude atmosphere

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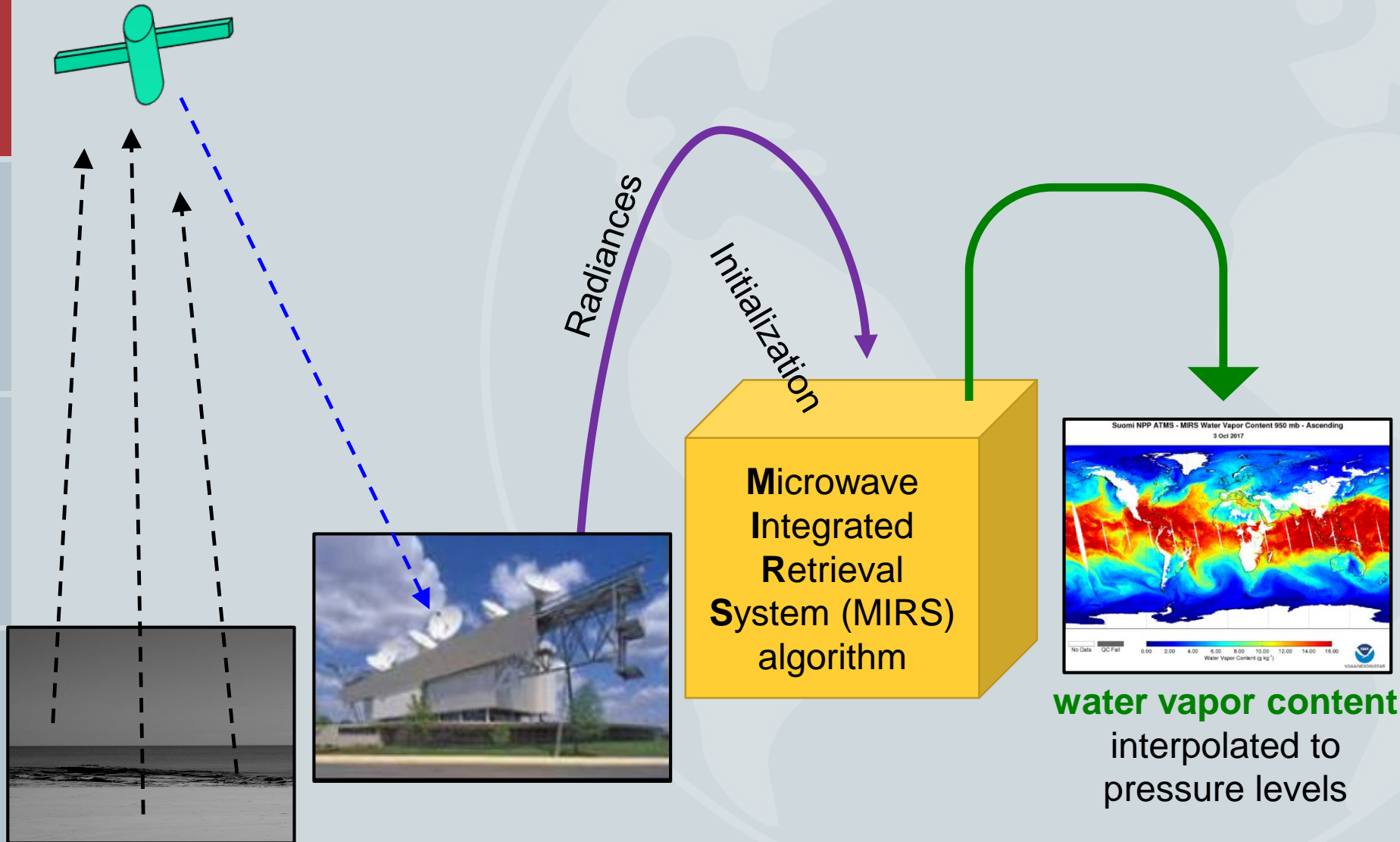# Loop of ATMS Channels 17-22: Water Vapor Absorption

http://rammb.cira.colostate.edu/templates/loop_directory.asp?data_folder=visitview/custom/ATMS_20171003_17to22
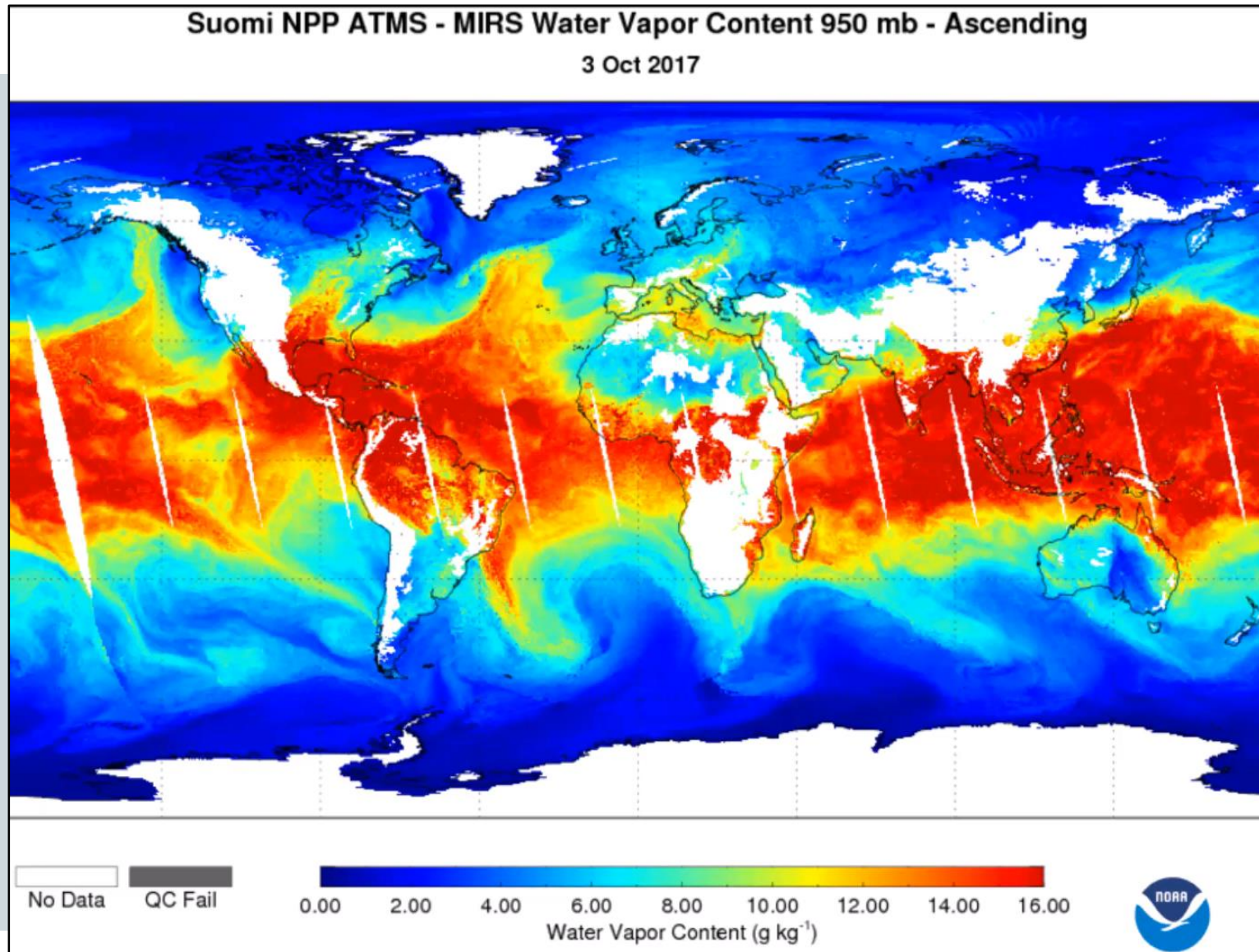
Imagery Source: NOAA/NESDIS/STAR JPSS Environmental Data Records (parameter = ATMS Limb-Corrected TDR)
https://www.star.nesdis.noaa.gov/jpss/EDRs/products_ATMS_LC.php

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water vapor content
interpolated to pressure levels

Loop of MIRS Water Vapor (Interpolated to Pressure Levels 950-100 mb)

Suomi NPP ATMS - MIRS Water Vapor Content 950 mb - Ascending
3 Oct 2017

http://rammb.cira.colostate.edu/templates/loop_directory.asp?data_folder=visitview/custom/ATMS_20171003_MIRS_WV

Imagery Source: NOAA/NESDIS/STAR JPSS Environmental Data Records (parameter = Water Vapor)
https://www.star.nesdis.noaa.gov/jpss/EDRs/products_MiRS.php

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Summary

- The microwave spectrum has strong atmospheric absorption regions due to:
  - Well-mixed oxygen (~60 GHz)
  - Variable water vapor (~183 GHz)

- Channel selection on microwave sounders takes advantage of absorption regions and weighting functions in deriving vertical profiles
  - Oxygen absorption → temperature profile
  - Water vapor absorption → moisture profile

Microwave temperature and moisture profiles inform NUCAPS soundings, precipitable water products, and numerical weather prediction.

Resources

- Microwave Remote Sensing: Clouds, Precipitation, and Water Vapor
https://www.meted.ucar.edu/training_module.php?id=226#.WYjODIjyvcs

- Satellite Meteorology: An Introduction (Kidder and Vonder Haar 1995)

- A First Course in Atmospheric Radiation, 2nd Ed. (Petty 2006)

"These **retrievals provide indispensable information** about the current state of the atmosphere to numerical weather prediction models. Without the availability of satellite-derived temperature structure data, accurate medium- and long-range forecasts (three days and beyond) would be impossible almost everywhere, and even shorter-range **forecasts would be of questionable value** over oceans and other data sparse regions." (Petty 2006, pp. 232-233)

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