Satellite Foundational Course for JPSS (SatFC-J)
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

What do microwave temperature and moisture profiles inform?

**Total and Layered Precipitable Water Products**

NUCAPS Soundings (NOAA Unique Combined Atmospheric Processing System)


Numerical Weather Prediction
Absorption and Window Regions

- Zenith microwave transmittance depends on latitude (moisture)

![Graph showing transmittance vs. frequency with regions labeled a, b, c, and d.]

- **a** and **b** likely represent different absorption regions.
- **c** might indicate an oxygen (O₂) absorption region.
- **d** could be another absorption region, possibly related to water vapor (H₂O).

Petty 2005 (modified)
Oxygen Absorption

- Used to profile atmospheric temperature

![Graph showing oxygen absorption frequencies with different midlatitudes and polar regions.](image-url)

- Dry (0 mm)
- Polar (3.1 mm)
- Midlatitude (21.3 mm)
- Tropical (53.6 mm)

Frequency [GHz]:

- Center ~118 GHz
- Center ~60 GHz
Weighting Function

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

Spectral Selection: O$_2$ Absorption

Weighting Function (km$^{-1}$)

<table>
<thead>
<tr>
<th>Channel</th>
<th>Frequency (GHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ch1</td>
<td>23.8</td>
</tr>
<tr>
<td>Ch2</td>
<td>31.4</td>
</tr>
<tr>
<td>Ch3</td>
<td>50.3</td>
</tr>
<tr>
<td>Ch4</td>
<td>51.8</td>
</tr>
<tr>
<td>Ch5</td>
<td>52.8</td>
</tr>
<tr>
<td>Ch6</td>
<td>53.6</td>
</tr>
<tr>
<td>Ch7</td>
<td>54.4</td>
</tr>
<tr>
<td>Ch8</td>
<td>54.9</td>
</tr>
<tr>
<td>Ch9</td>
<td>55.5</td>
</tr>
<tr>
<td>Ch10</td>
<td>57.3</td>
</tr>
<tr>
<td>Ch11</td>
<td>57.3 ±</td>
</tr>
<tr>
<td>Ch12</td>
<td>57.3 ±</td>
</tr>
<tr>
<td>Ch13</td>
<td>57.3 ±</td>
</tr>
<tr>
<td>Ch14</td>
<td>57.3 ±</td>
</tr>
<tr>
<td>Ch15</td>
<td>57.3 ±</td>
</tr>
</tbody>
</table>

$\pm$ indicates spectral band width varies for a standard mid-latitude atmosphere.
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
Measured Radiance to Display Information

**Microwave Integrated Retrieval System (MIRS) algorithm**

Radiance → Initialization → Temperature interpolated to pressure levels
Loop of MIRS Temperature (Interpolated to Pressure Levels 950-100 mb)

Imagery Source: NOAA/NESDIS/STAR JPSS Environmental Data Records (parameter = Temperature)

http://rammb.cira.colostate.edu/loop_directory.asp?data_folder=visitview/custom/ATMS_20171003_MIRS_Temp
https://www.star.nesdis.noaa.gov/jpss/EDRs/products_MiRS.php
Water Vapor Absorption

- Used to profile atmospheric moisture

Graph showing the transmittance of water vapor absorption at different frequencies for different atmospheric conditions. The graph indicates absorption centers at approximately 183 GHz and 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

± indicates spectral band width varies

for a standard mid-latitude atmosphere
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
Measured Radiance to Display Information

Microwave Integrated Retrieval System (MIRS) algorithm

water vapor content interpolated to pressure levels
Loop of MIRS Water Vapor (Interpolated to Pressure Levels 950-100 mb)

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
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 $\rightarrow$ temperature profile
  - Water vapor absorption $\rightarrow$ 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](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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