Passive Microwave Band Basics

Key Frequency Bands for Precipitation

- **10–19 GHz (Low-Frequency Window):** Used primarily over **oceans** to detect rain through *emission*. These bands are highly sensitive to liquid water.
- **37 GHz (Mid-Frequency Window):** A versatile band used for detecting moderate-to-heavy rain over oceans and identifying frozen hydrometeors aloft via scattering.
- **50–60 GHz (Oxygen Absorption Complex):** Particularly the **54 GHz** region is used for "opaque" sensing. These bands help retrieve precipitation profiles by measuring atmospheric temperature and identifying glaciated (frozen) precipitation.
- **85–92 GHz (High-Frequency Window):** The primary band for detecting precipitation **over land**. It relies on *scattering* from ice particles in clouds, which causes a decrease in brightness temperature.
- **150–183 GHz (Water Vapor Absorption):** Used to detect **snowfall** and light precipitation. The **183.31 GHz** band is critical for profiling humidity and sensing frozen precipitation over both land and sea.

Retrieval Methods by Surface Type

- **Over Ocean:** Algorithms utilize the high contrast between the low-emissivity ocean surface and the high-emissivity rain drops (emission-based).
- **Over Land:** Land surfaces have high, variable emissivity that mimics rain emission. Sensors must rely on the scattering signatures of ice particles (scattering-based) or opaque bands to filter out surface noise.

Polarization

Passive microwave (PMW) precipitation sensing relies on polarization differences to distinguish precipitation from surface backgrounds, particularly over land. Higher frequencies (e.g. 85.5GHz) use ice scattering-induced reduction in polarization to identify convection, while lower frequencies (e.g. 10-37 GHz detect surface emission changes. Horizontal polarization (H-pol) is generally more sensitive to scattering and surface changes, while vertical polarization (V-pol) is often used for stability in emission-based algorithms.

Key Aspects of Passive Microwave Polarization in Precipitation Bands:

- **Scattering vs. Emission:**
  - **High Frequencies (> 35 GHz, e.g., 85.5 GHz):** Primarily detect scattering by ice aloft, resulting in low brightness temperatures. These channels show significant polarization reduction (polarization difference decreases) in convective cores.
  - **Low Frequencies (~ 10 – 37 GHz):** More sensitive to emission from liquid rain droplets. These are often used for detecting precipitating clouds over ocean backgrounds, which are relatively "warm" or "cold" depending on the emission.

- **Convective-Stratiform Discrimination:** Polarization-based methods (e.g., at 85.5 GHz) are highly effective at distinguishing convective, heavy rainfall (low , low polarization) from stratiform rain, which has higher polarization in ice-scattered regions.
- **Surface Effects and Polarization:** Over complex land surfaces, the high background emissivity makes it hard to distinguish rain. Polarization difference (e.g., 10.6 GHz V-H) is used to detect water, whereas strong ice scattering at 85.5 GHz masks the surface, allowing for better identification of convective cells.
- **Sensor Utilization:** Instruments like the GPM Microwave Imager (GMI) and earlier SSM/I or TRMM-TMI, as well as experimental sensors like the NASA PSR/CX, utilize multi-polarization (vertical and horizontal) to enhance detection of rain over both land and water.
- **Wind and Water Vapor:** Strong winds reduce polarization, while water vapor increases and reduces polarization, requiring careful calibration in rainfall retrieval algorithms.

Polarization in Precipitation Retrieval

Polarization (the orientation of the electric field) is a critical discriminator for identifying precipitation structure and surface types:

- **Surface Discrimination:** Water surfaces have high polarization differences (the difference between vertical and horizontal Tb), whereas rain and land surfaces tend to depolarize the signal.

- **Ice Scattering Signal:** Significant polarization at high frequencies (e.g., **85.5 GHz**) often indicates horizontally oriented, non-spherical ice particles, which helps distinguish between **convective** (stronger scattering) and **stratiform** (weaker scattering) precipitation.
- **Dual-Polarization Benefits:** Sensors like the GPM Microwave Imager (GMI) use dual-polarization (V and H) across multiple bands to improve the accuracy of rainfall intensity and type classification.

Polarization Strengths:
- **H-Polarization:** Typically shows stronger scattering signals from ice, providing better identification of convective precipitation.
- **V-Polarization: Generally offers higher, more stable brightness temperatures and is less sensitive to small-scale surface variations, making it better for emission-based rain identification.**

Applications and Limitations

- **Retrieval over Land:** Challenging because warm land surfaces mimic the emission of rain; algorithms like GPROF use high-frequency scattering and dynamic surface information to overcome this.
- **Hydrologic Monitoring:** Beyond just rain, L-band and Ka-band data are used to monitor river discharge and flood areas by analyzing polarization ratios.

Passive Microwave Bands for Sea Surface Temperatures

Passive microwave bands used for sea surface temperature (SST) retrieval mainly include 6.925-7.3 GHz and 10.65 GHz which offer low atmospheric interference and good sensitivity to sea surface emission. These low-frequency channels, particularly 6.9 GHz, are crucial for producing all-weather, cloud-penetrating SST data.

- **Key Bands/Frequencies:**
    - **6.925 GHz and 7.3 GHz (C-band):** Primary channels used by instruments like AMSR2 and AMSR3 for measuring SST. The 7.3 GHz channel is used to mitigate radio-frequency interference (RFI).
    - **10.65 GHz (X-band):** Used to retrieve SST, sea surface wind speed, and, at higher frequencies (18.7/36.5 GHz), sea ice concentration and snow parameters.
    - **Low Frequencies (L-band):** While often used for salinity, L-band instruments (like SMAP) can provide complementary surface information.

Passive Microwave Bands for Ocean Winds

Passive microwave radiometers measure ocean surface winds, especially in storms, using frequencies ranging from
~1.4 GHz to **~35 GHz** is preferred for high-wind accuracy because it is less affected by rain. Other, higher-frequency bands are also used for broader, multi-sensor wind products. Key frequency bands for measuring ocean surface winds include:

- **~1.4 GHz:** Used by satellites like **SMAP** (Soil Moisture Active Passive) to measure high-wind speeds (hurricanes) due to high sensitivity to sea surface roughness and minimal signal attenuation from rain.
- **~4-8 GHz:** Used by instruments such as **AMSR3** to measure wind speed and direction.
- **~8-12 GHz:** Used by sensors like **WindSat** and **AMSR3** to detect wind speed and polarimetric signals for direction.
- **~18-40 GHz:** Used by **COWVR** and **AMSR3** for comprehensive vector wind observations.
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These sensors measure the "brightness" of the ocean surface (thermal emission), which directly relates to roughness caused by wind