Principles of Sounding

RETRIEVAL OF TEMPERATURE AND MOISTURE PROFILE FROM SOUNDER

INTRODUCTION

- Atmospheric sounding is one of the most important applications of satellite measurements in meteorology, which involves retrieving vertical profiles of temperature and trace-gas concentrations, especially water vapor and ozone, using observations at wavelengths that have significant attenuation in atmosphere.

For this we need to know the variation of temperature with altitude, and the variation of the density of atmospheric gases with altitude, such as carbon dioxide, water vapour and ozone

Conventional Method

- Releasing a balloon carrying a suitable instrument

Package that would sense the parameter and transmit

The data to a ground station.

- RS data have their own inherent errors due to solar radiation during day time and infrared cooling at night.

BASIC PRINCIPLES

The upwelling radiation sensed by a satellite sensor is governed by

a) emission from the earth's surface transmitted through the atmosphere and

b) emission from the atmospheric layers transmitted through the outer layers of the atmosphere.

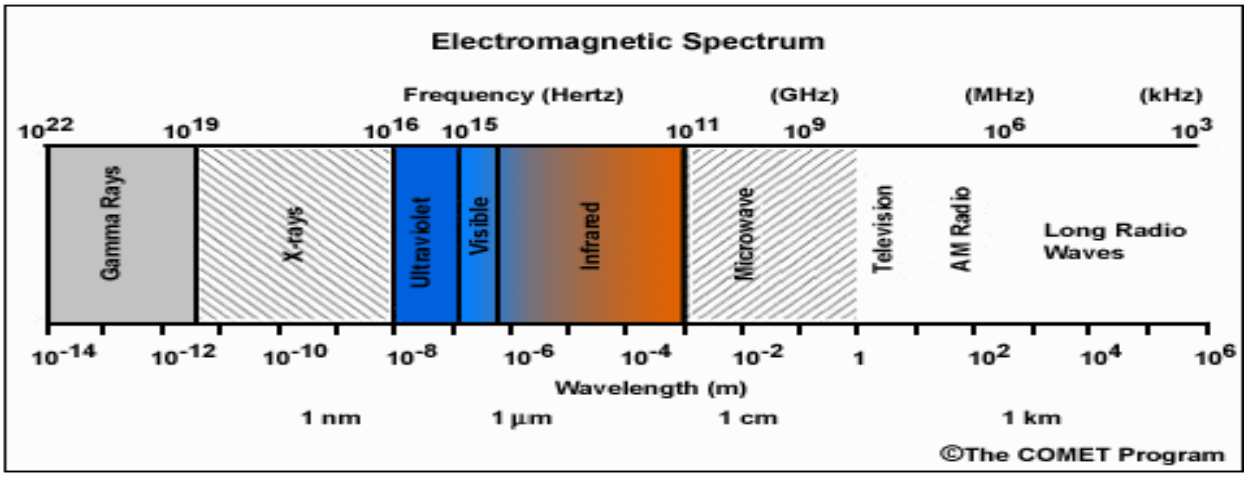
- Satellite radiometers can “see” in a wide range of electromagnetic spectral intervals. These intervals are called windows, channels or spectral bands.
- The three most common channels: visible light (0.6 microns), longwave infrared (10 to 12 microns), and a special channel near one of the infrared absorption bands of H_20 (6.7 microns) that we call the “water vapor channel.”

- Polar orbiting satellites provide information about the earth and our atmosphere via the visible, infrared, *and* microwave regions of the electromagnetic spectrum.
- The radiation from the earth surfaces,Cloud top and atmospheric constituents are received at satellite through the process of

REFLECTION –VIS EMISSION -IR SCATTERING-VIS,MW

- The microwave portion of the spectrum covers the range from approximately 1cm to 1m in wavelength. Because of their long wavelengths, compared to the visible and infrared, microwaves have special properties that are important for remote sensing.
- Longer wavelength microwave radiation can penetrate through cloud cover, haze, dust. so microwave radiometers don't need clear skies to produce images.
- Sounding is accomplished with a group of spectral bands selected to detect radiation emitted from successively lower layers of the atmosphere.

- **Weather satellite instruments initially used detectors that sensed energy at visible and infrared wavelengths from 0.4-15 µm (10^{-6} m).**
- **Microwave instruments sense much longer wavelengths, expressed in units of frequency called gigahertz (GHz).**
- **The frequencies for meteorological observations fall in the range from about 5 to 200 GHz.**



frequency(GHz)	monitoring target
around 1	ocean waves
around 3	geology
around 5	soil moisture content
around 10	rainfall
around 14	wind,ice,geoid
around 17	vegetation
around 35	snow
around 75	cloud

Satellite Sounding in the infrared region

- The infrared region of the spectrum we can use CO2 spectral bands at 15 and 4.3 microns to give us information on the temperature structure of the atmosphere.
- Information on water vapour content can be gained from a large number of H2O lines between 5 and 8 microns.
- In addition, parts of the infrared spectrum are sensitive to ozone (8.9-10.1 micron band).

THEORETICAL BACKGROUND

Atmospheric sounding techniques exploit all three phenomena that play important role in radiative transfer:

- absorption,
- scattering and
- thermal emission.

- Most observations are made in the thermal infrared and microwave bands. At infrared wavelengths scattering due to atmospheric gases is negligible, hence it is not considered in the radiative transfer process.
- So for vertical sounding at infrared wavelengths the significant

terms in the radiative transfer equation (RTE) are absorption

and thermal emission.

$$R_v = (I_0)_v \tau_v(z_0) + \int_{z_0}^{\infty} B_v\{T(z)\} \frac{d\tau_v(z)}{dz} dz$$

- Assumed that there are no clouds in the atmosphere, there is

no scattering and earth surface is a black body. The outgoing

radiance at frequency v reaching the satellite can be

expressed as a sum of two terms: In this eq. The first term on the right hand side is spectral Radiance I_0 at frequency v emitted by earth surface, denoted by Z_0 and attenuated by the atmosphere. The second term is the Integrated spectral radiance at frequency v emitted by various Layers of the atmosphere and attenuated by the atmosphere.

Bv is the plank function for frequency v and temperature T at

Hight z, and is the transmittance from level z to the top of the atmosphere.

The simplified form of RTE can be written as

$$R_v = (I_0)_v \tau_v(z_0) + \int_{z_0}^{\infty} B_v\{T(z)\} K_v(z) dz$$

K_v = weighting function

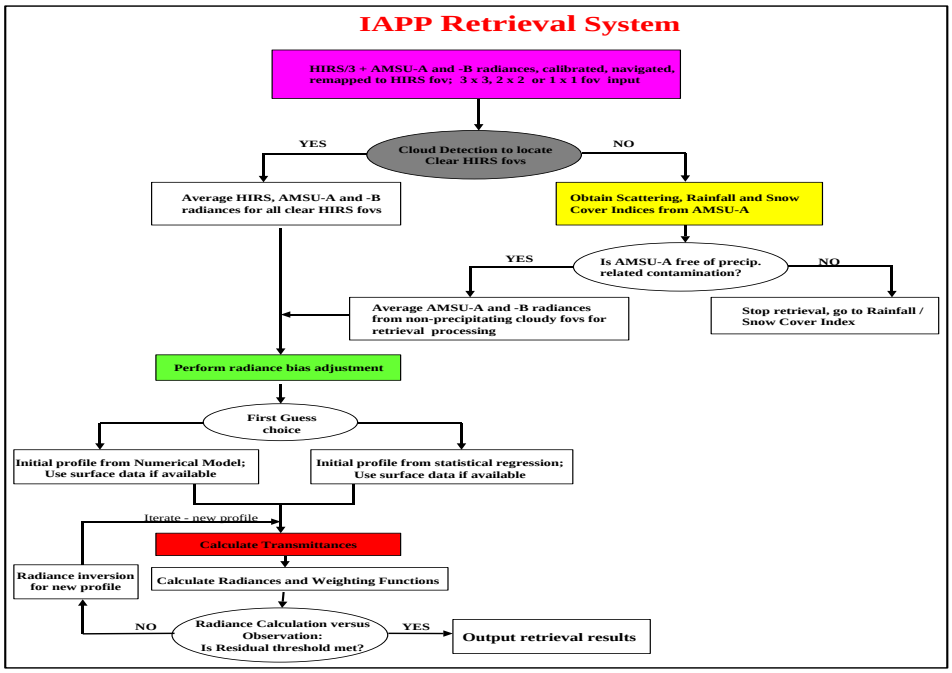
Retrieval of Products from Sounder

International TOVS Working Group (ITWG) Activities

- ITWG
  - Is a sub group of the Radiation Commission within the International Association of Meteorology and Atmospheric Physics (IAMAP)
  - Serves as an International Forum for Operational and Research users of (A)TOVS and other Sounder data to exchange information and ideas and optimal use of satellite sounder data
  - Holds the International (A)TOVS Study Conferences every 18 months
  - Provides recommendations to guide the directions of future research and to influence relevant programs of WMO and other agencies (NOAA/NESDIS, NASA, EUMETSAT, JMA, CMA)
  - Through collaborations, develops and distributes software packages for use with Direct Broadcast radiance data
    - ITPP
    - 3I
    - AAPP
    - IAPP
    - ICI

IAPP Retrieval

- Developed for Direct Readout and 1-B data
- AAPP Pre-processing (from Eumetsat)
- Uses HIRS/3 and AMSU-A and -B radiances as input

- AMSU is remapped to HIRS/3 FOV
- 3 x 3, 2 x 2, or 1 x 1 fov can be used for retrieval
- NetCDF output file
- 

- Cloud Detection and Removal
- Bias Adjustment
- Regression Retrieval
- Non-linear, Iterative, Physical Retrieval (Li, et al, 1999, 2000)

AMSU & HIRS

The Advanced Microwave Sounding Unit (AMSU) on the NOAA-15 and 16 satellite, has a total of 20 channels in the microwave. The Advanced TOVS (ATOVS) is composed of Advanced Microwave Sounding Unit (AMSU) and High-Resolution Infrared Sounder (HIRS)/4, and flies on the National Oceanic and Atmospheric Administration (NOAA) polar-orbiting satellites.

- The AMSU-A is a cross-track, stepped-line scanning total power radiometer. The instrument has an instantaneous field-of-view of 3.38 at the half-power points providing a nominal spatial resolution at nadir of 48 km.

Channel	Wavelength (μm)	Meteorological application
HIRS		
1–7	14.9–13.4	Temperature soundings
8	11.1	Surface temperature
9	9.6	Total ozone
10	12.4	Moisture soundings
11, 12	6.5, 7.3	Moisture soundings
13–17	4.13–4.57	Temperature soundings
18, 19	3.76–4.13	Surface temperature
20	0.7	Cloud detection
Channel	**Frequency (GHz)**	**Meteorological application**
AMSU-A		
21, 22	23.8, 31.4	Total water content
23	50.3	Surface characteristics
24–34	52.8–57.3	Temperature soundings
35	89.0	Surface characteristics
AMSU-B		
36, 37	89.0, 150.0	Surface characteristics
38–40	183.0	Moisture soundings

Geophysical Products derived from NOAA/MODIS/METOP

- *Atmospheric temperature profile*
- *Atmospheric water vapour profile*
- *Surface emmissivity*
- *Surface Temperature*
- *Fractional cloud cover*
- *Cloud Top Temperature*
- *Cloud Top Pressure*
- *Tropopause height*

- *Cloud Liquid Water Content*
- *Total Column Precipitable Water*
- *Cloud Type (including Fog)*
- *Total Ozone from GOME*
- *Total Ozone from HIRS*
- *Ozone Profiles*
- *Land Surface Temperature*
- *Sea Surface Temperature*
- *Normalized Difference Vegetation Index (NDVI)*
- *Fog detection*

MODIS Level 2 geophysical products (Terra and Aqua)

- *MODIS cloud mask (MOD35)*
- *MODIS cloud top properties (MOD06CT)*
- *MODIS atmospheric profiles, precipitable water and stability indices (MOD07)*
- *MODIS aerosol product (MOD04)*
- *MODIS Sea Surface Temperatures (IMAPP product)*
- *Normalized Difference Vegetation Index (NDVI)*
- *Enhance Vegetation Index (EVI)*
- *Land Surface Temperature (LST)*

Future Sounding Instruments

Present

- ❖ **Polar orbiting**
  - – **AMSU** (NOAA & EPS/Metop) — **Metop → 2023**
  - – **IASI** (EPS/Metop)
  - – **AIRS** (Aqua)
  - – **SSMIS** (DMSP) & **AMSR-2** (GCOM-W1) — **DMSP → 2018**
  - – **GRAS** (EPS/Metop) & **COSMIC** & **TerraSAR-X**
- (❖ **Geostationary** – **MSG** — **MSG → 2020**)

Future

- ❖ **Polar orbiting**
  - – **ATMS** (Advanced Technology Microwave Sounder) & **CrIS** (Cross-track Infrared Sounder)
    - » **Suomi NPP** — **Oct 2011**
    - » **NPOESS (now JPSS)** — **2016 onwards?**
  - – **EPS-SG** — **2020 timeframe**
    - » **IAS MWS RO MWI ICI**
- ❖ **Geostationary**
  - – **Meteosat Third Generation (MTG)** — **MTG-S 2020 →**
    - » **MTG Sounder (Infrared)**