Greenhouse Gases

EES 2110

Introduction to Climate Change

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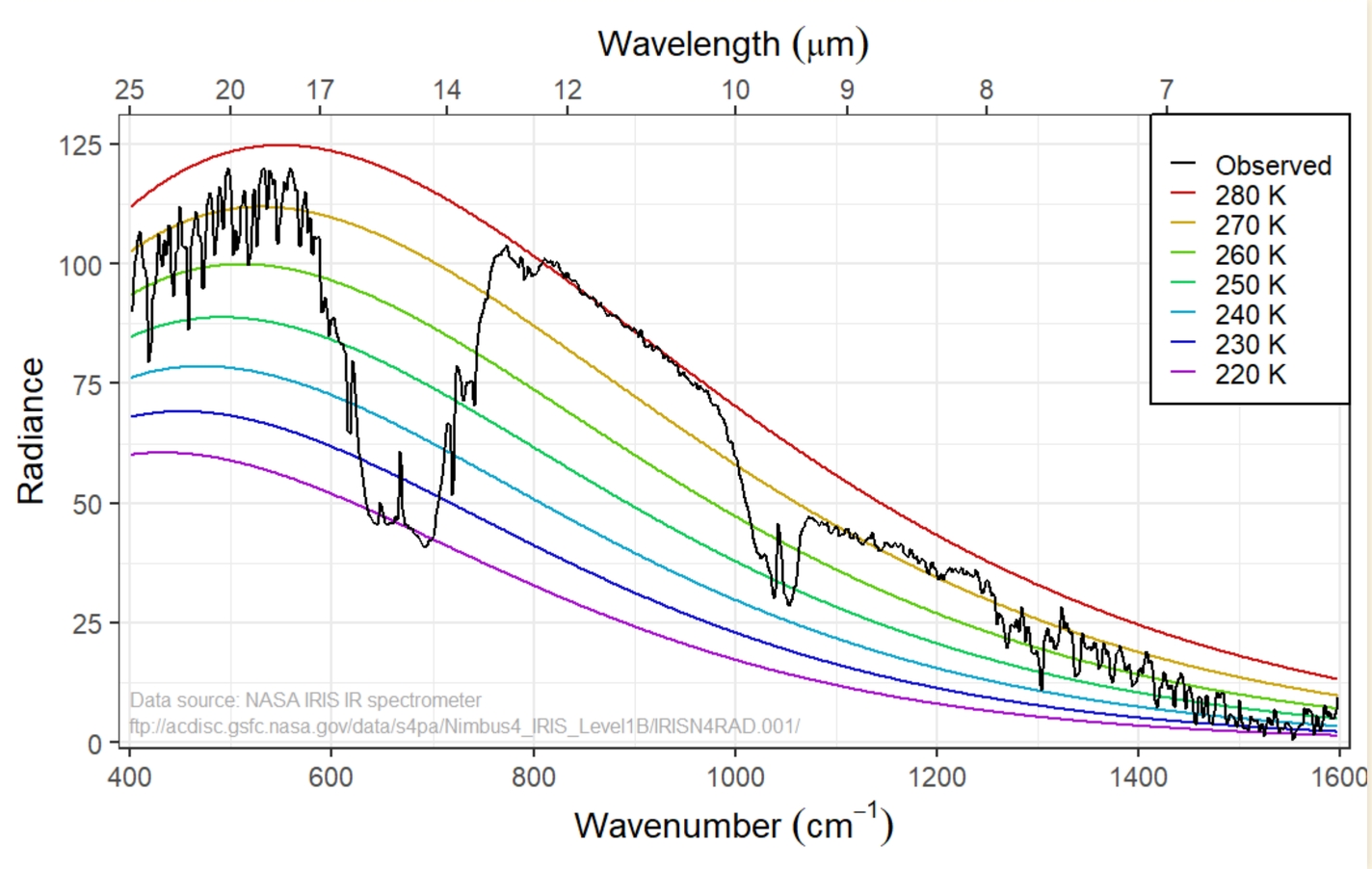
Class #5: Friday, January 20 2023

Greenhouse Gases

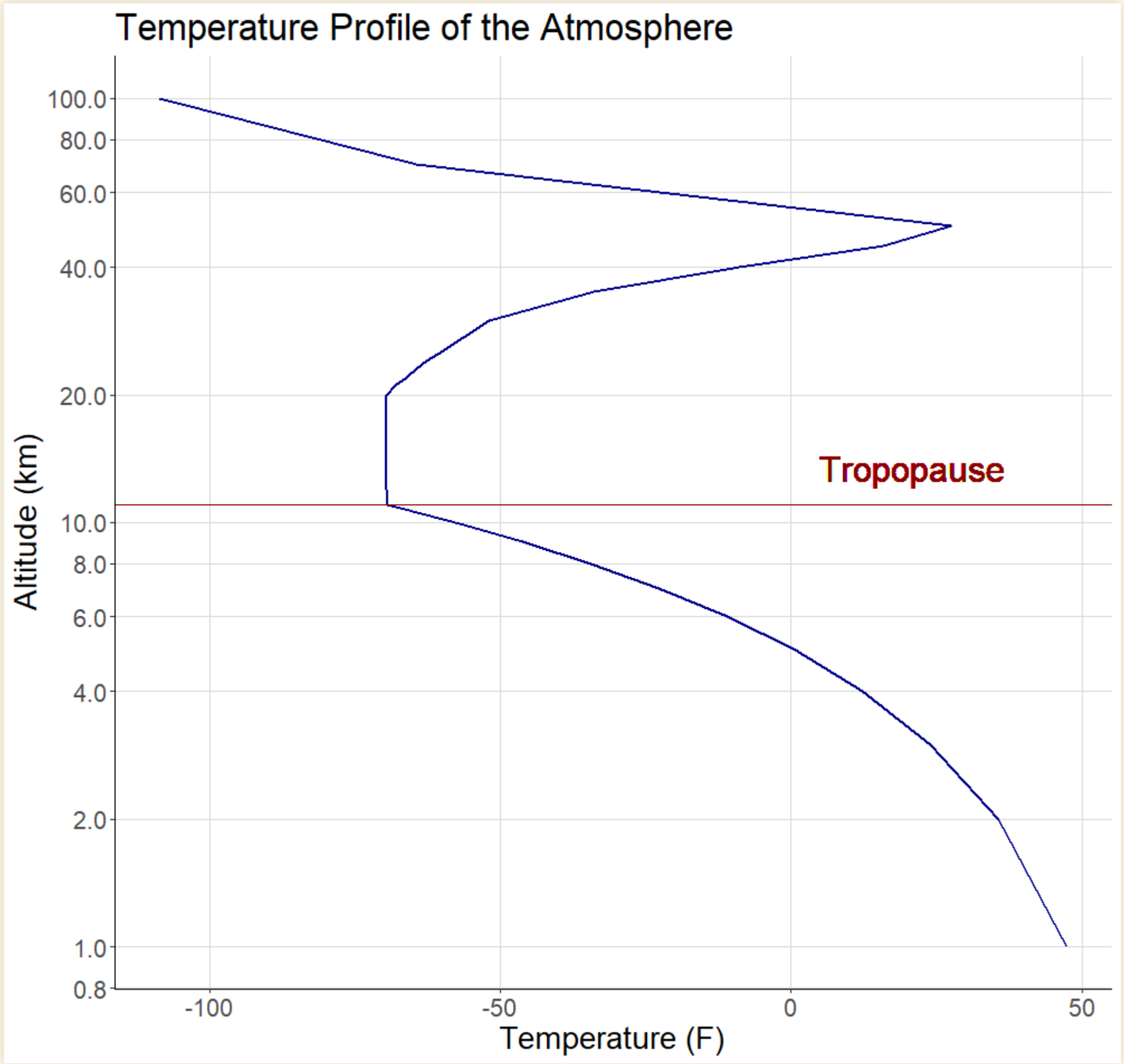
Greenhouse Gases

Layer model was too simple:

- Emissivity ε, varies with wavelength
- Temperature varies with altitude



Temperature in the Atmosphere



Longwave Light in the Atmosphere

Greenhouse Gases

- At wavelengths where gases in the atmosphere absorb longwave:
  - Atmosp
  - Like fog
- For light t
  too many
  - The str
    wavele
  - or the g
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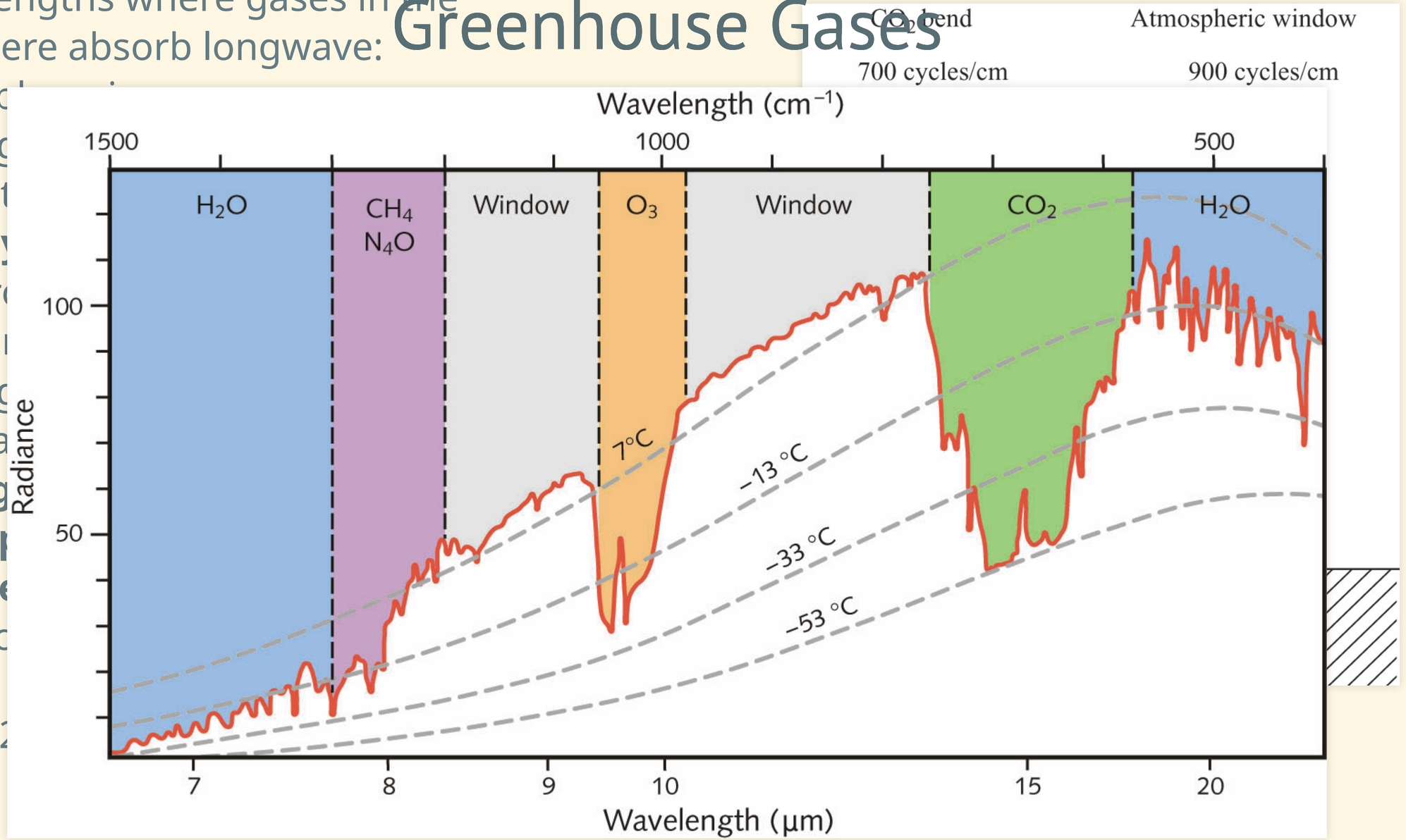
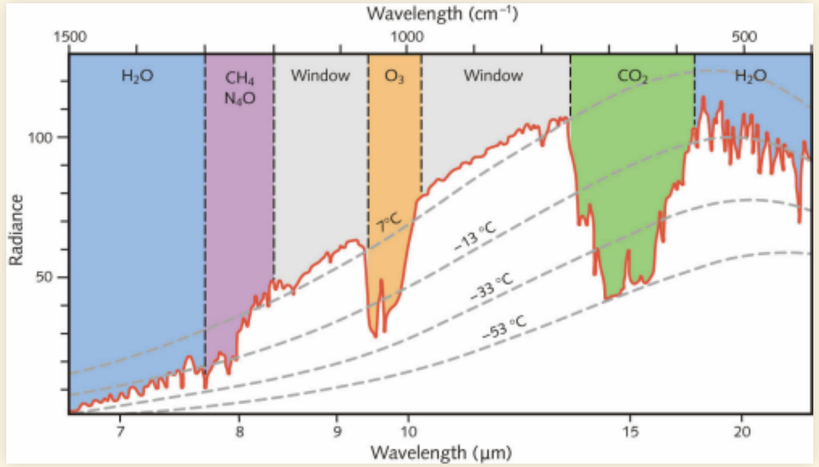
  - **the hig**
    atmosp
    opaque
- The tropo
  go.
  - 6.5K (12
  - Colder



Greenhouse Gases

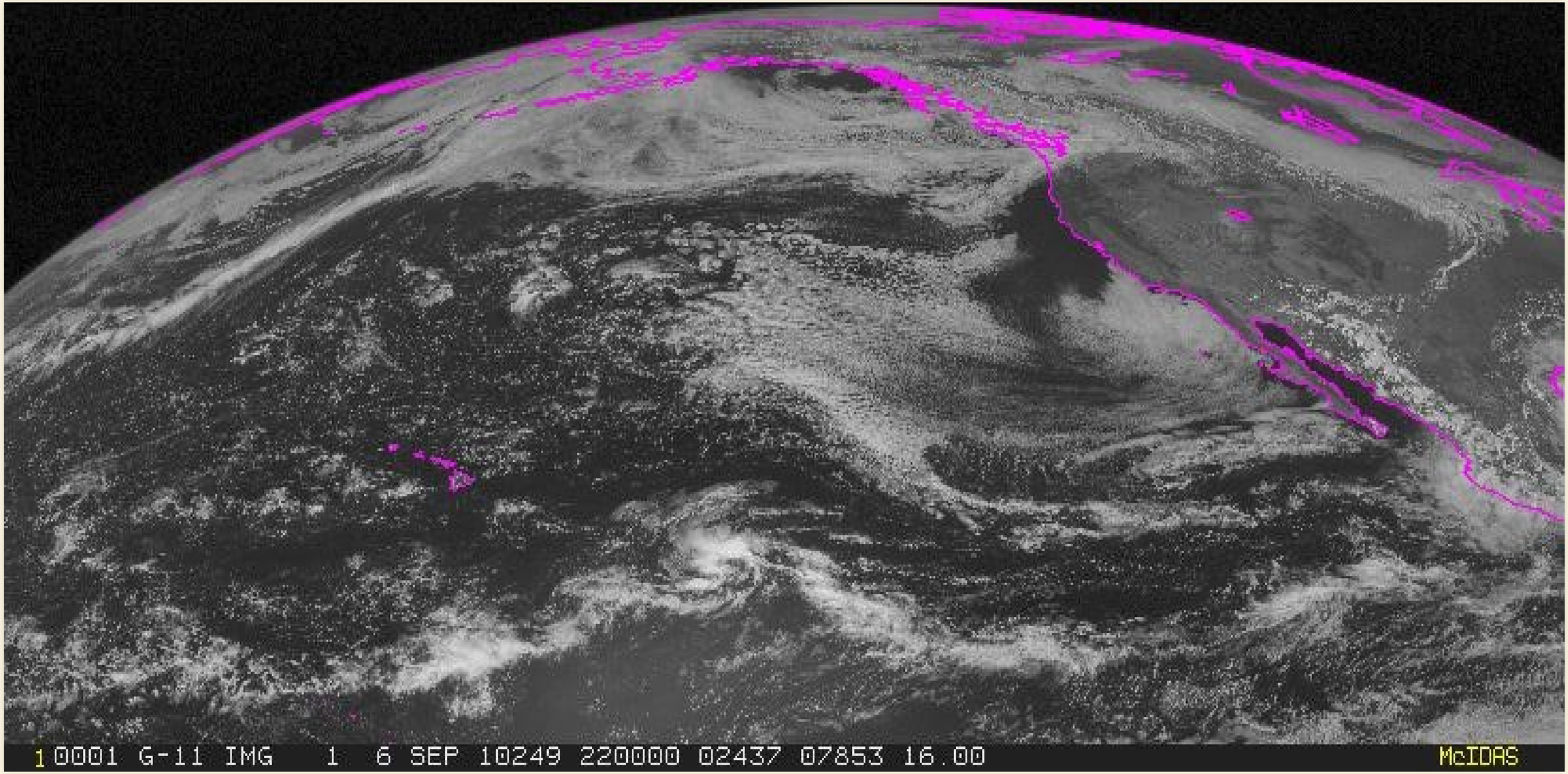


- Brightness: Stefan-Boltzmann law:
  - $I = \varepsilon \sigma T^4$
  - $\varepsilon = 1$

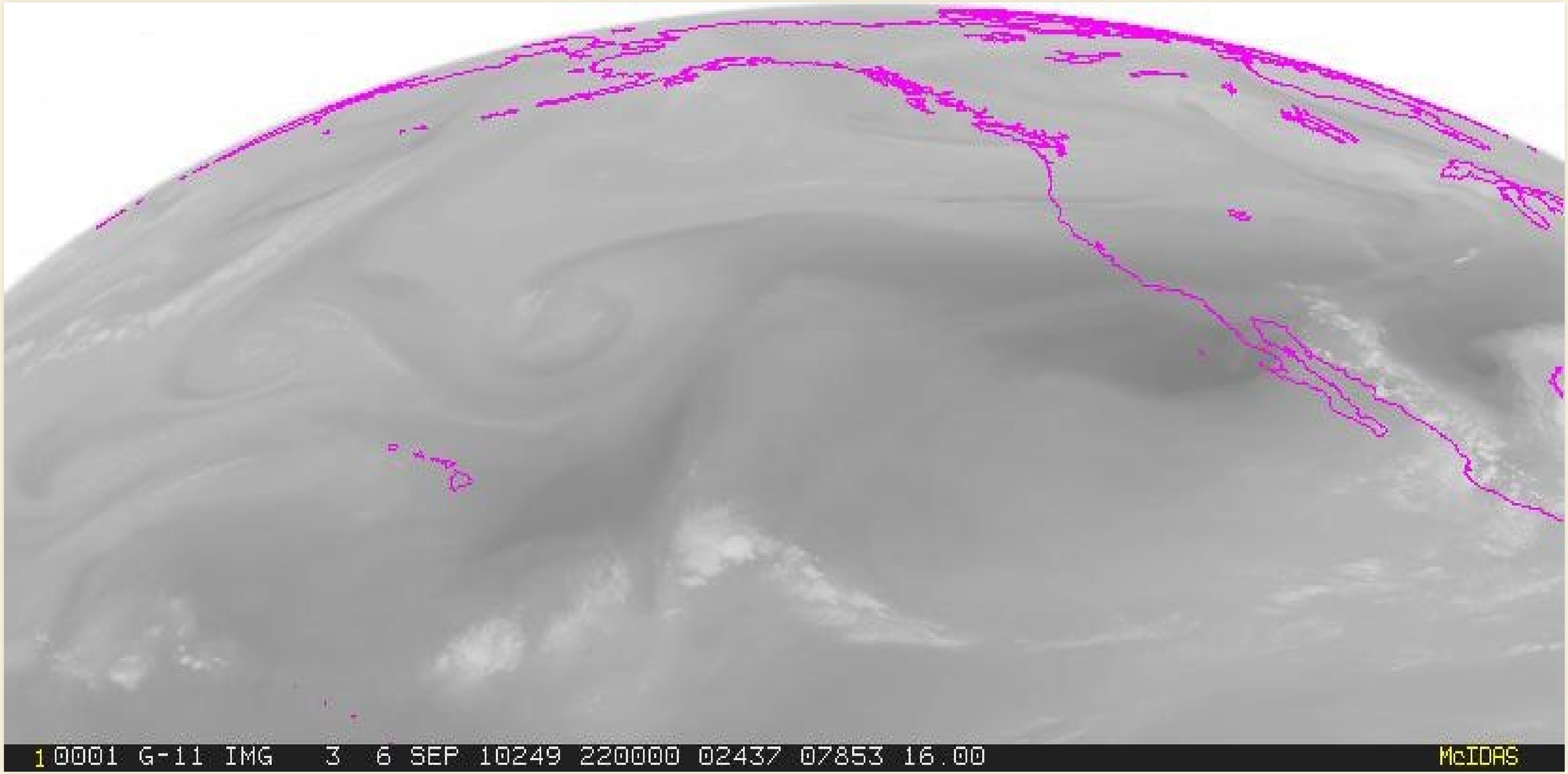
- Brighter = Hotter
- Hotter = closer to ground
  - Satellite can see through atmosphere to low altitude (hot, bright) in “window” region.
  - Satellite can see to middle-troposphere (cold, dimmer) in “water vapor” region
  - Satellite can’t see past top of troposphere (very cold, very dim) in CO_2 region.

Earth Seen by Satellites

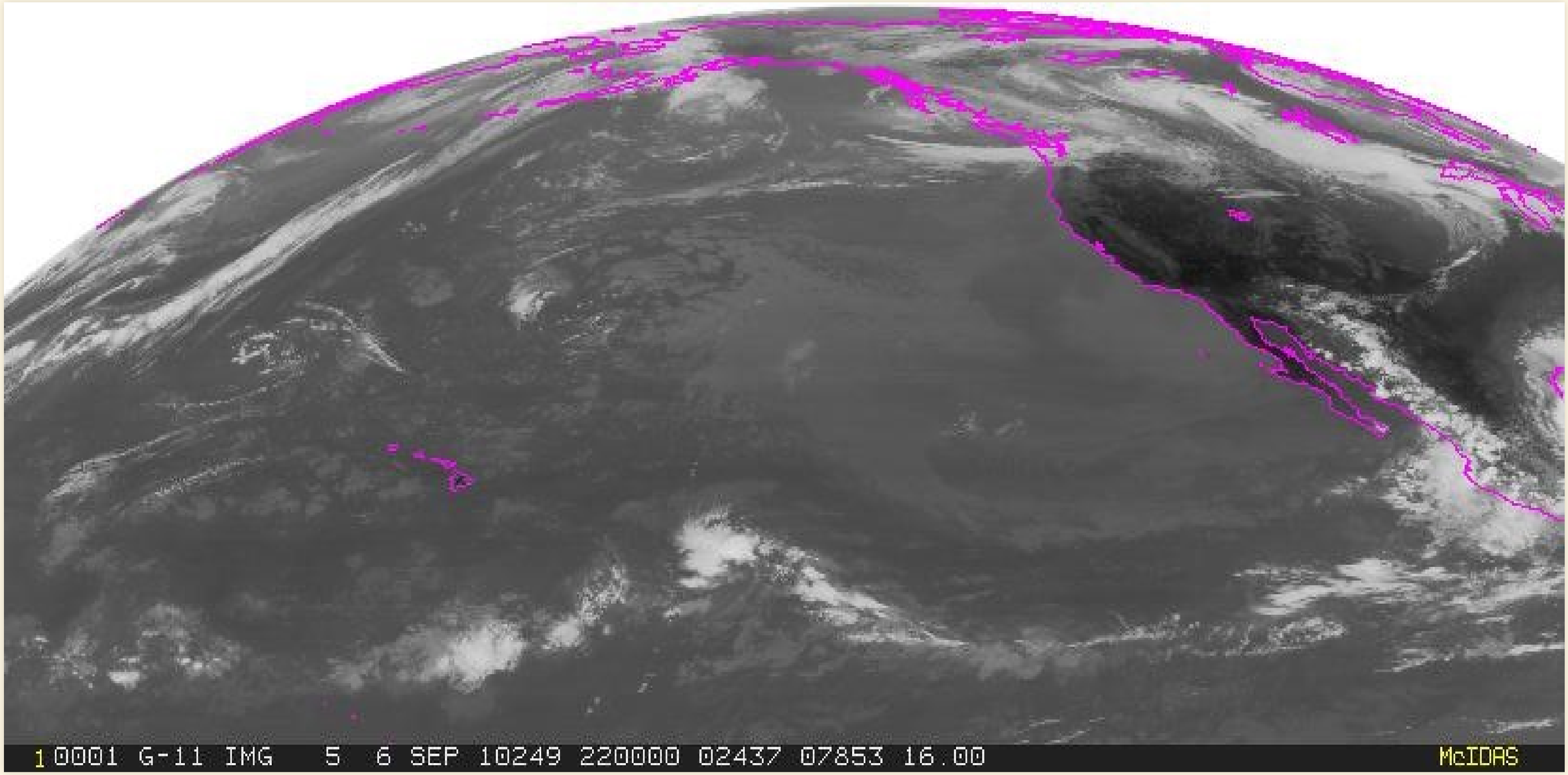
Visible



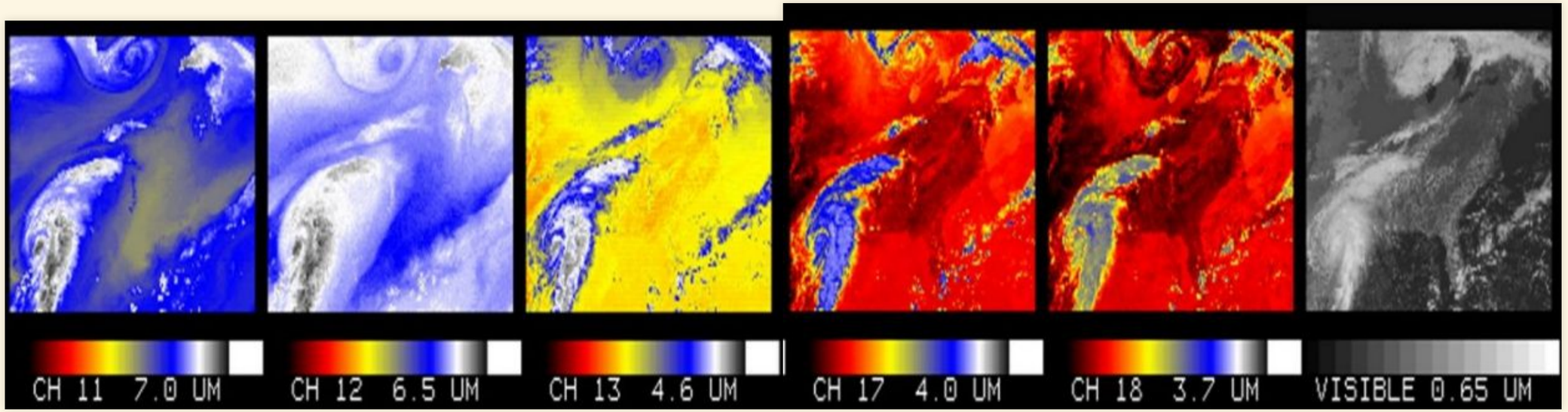
6.8 μm (Water Vapor)



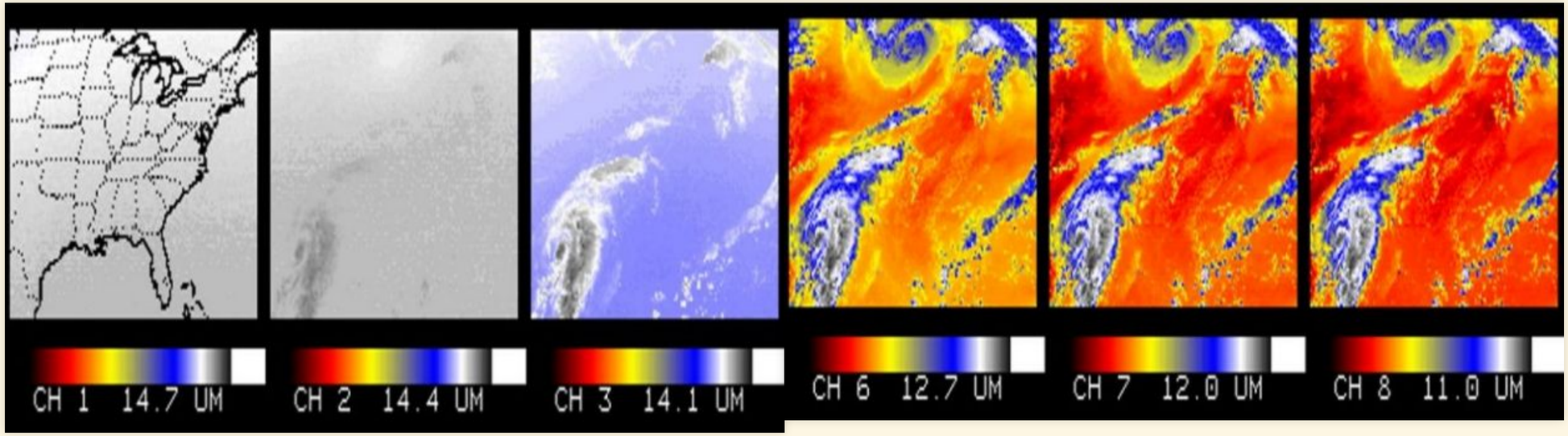
12.0 μm (Window)



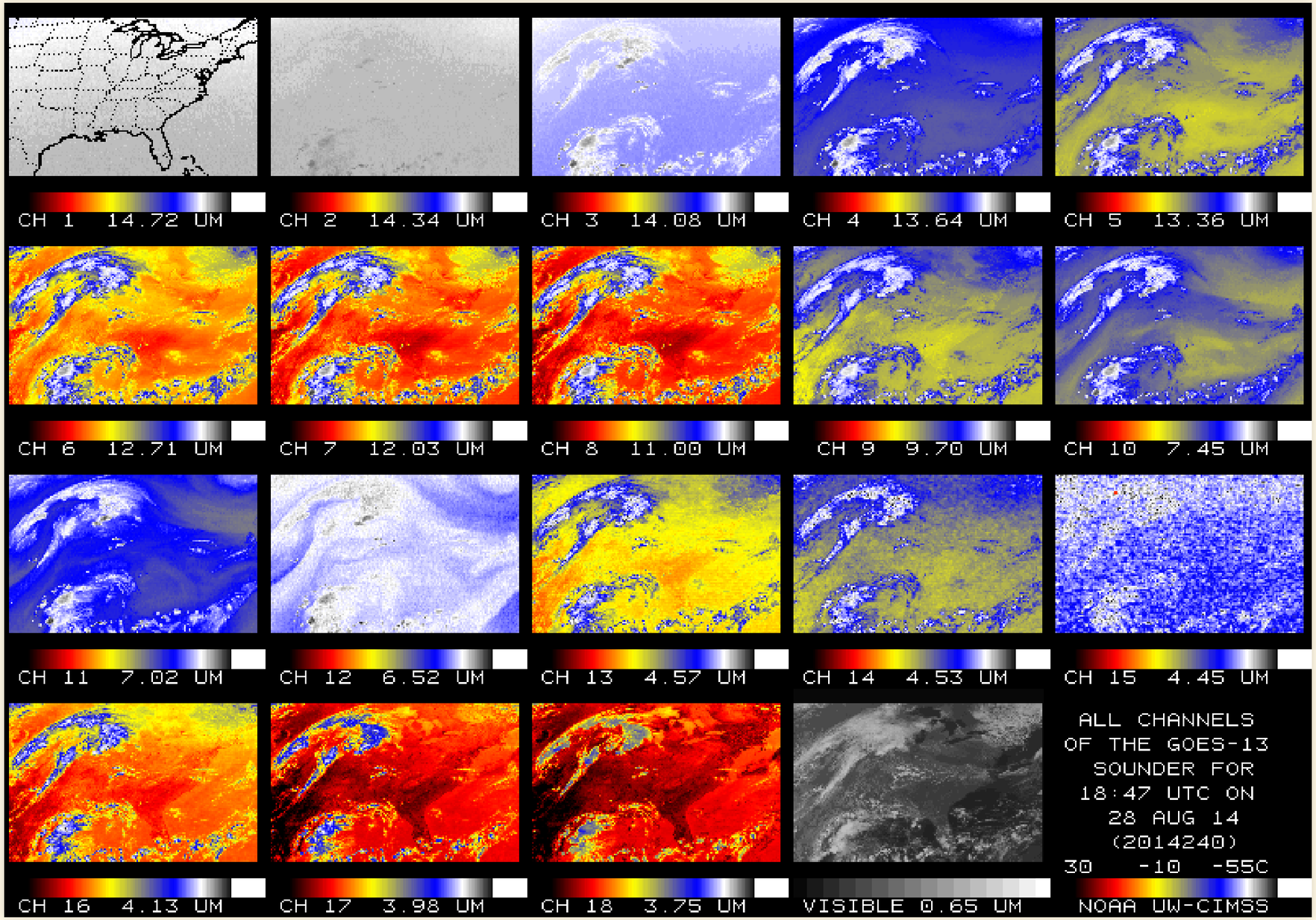
Water, Window, Visible



CO_2 peak vs. Window

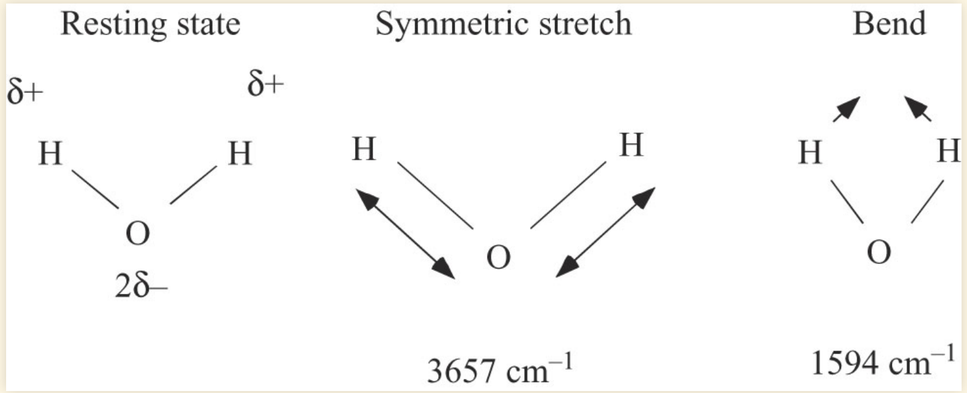


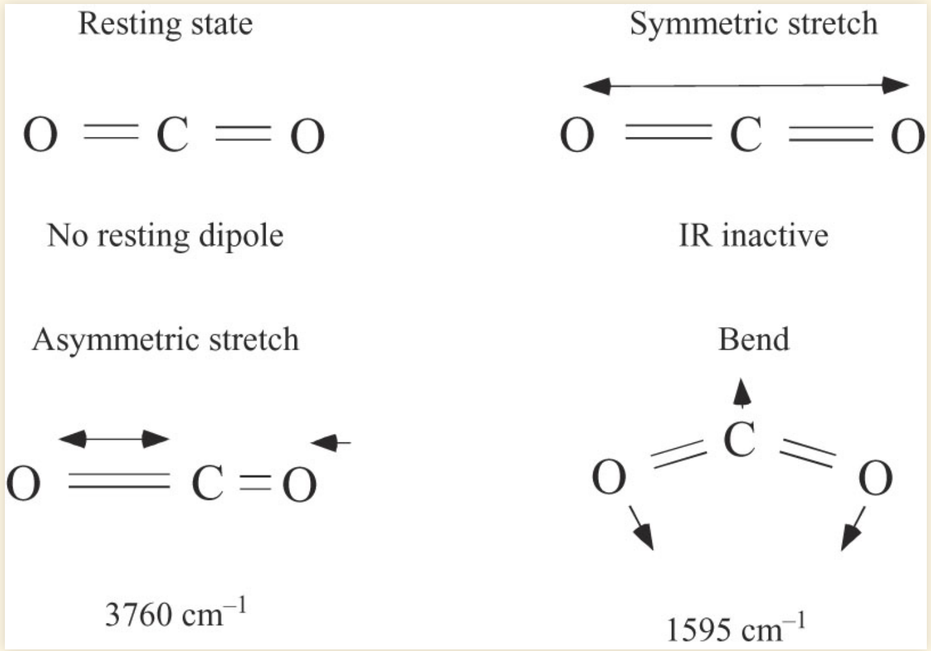
All Wavelengths



Understanding Greenhouse Gases

Molecular Structure

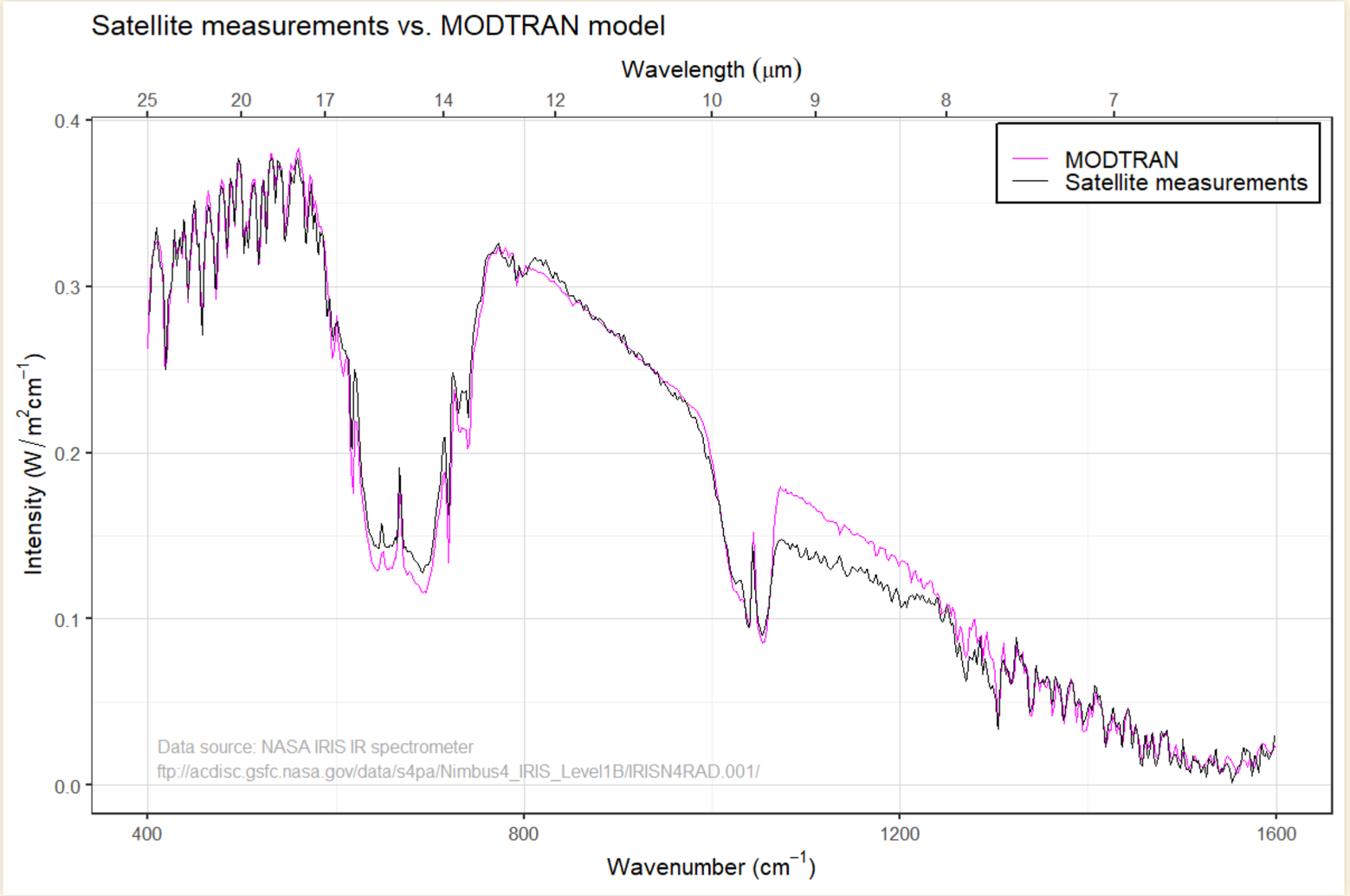




- Electromagnetic radiation is produced by asymmetric motion of positive and negative electric charges in atoms.
- Single atoms & two-atom molecules with the same atom (O_2, N_2) have little or no longwave absorption
- Molecules with:
  - two different atoms (CO, NO) absorb (simple stretch)
  - three or more atoms (CO_2, O_3, H_2O) absorb strongly (multiple stretching & bending modes)
  - More atoms, more different kinds → stronger absorption (CH_4, $C_2F_3Cl_3$ aka CFC 113)

Models and Observations

Models and Observations



Checking MODTRAN model: It looks very similar to real life.

MODTRAN Computer Model

What is MODTRAN?

- Pure radiative calculation
  - Air does not move:
    - No wind or convection
- Only calculates infrared heat flux
  - Does not give equilibrium ground temperature
- Only calculates one spot
  - Does not give global averages
- You specify:
  - Ground temperature
  - Composition of atmosphere
- Modtran computes:
  - Longwave radiation at different altitudes
  - Total radiation to space

Running MODTRAN

- Go to http://climatemodels.uchicago.edu/modtran/
- Next

Exercise: Double CO_2

- Set Locality to “Tropical Atmosphere”
- Click “Save This Run to Background”
- Note the Upward IR heat flux
- Double the amount of CO_2
- Adjust T offset until new heat flux = background flux
- What is the new ground temperature?

Exercise: Double CO_2

Different Gases

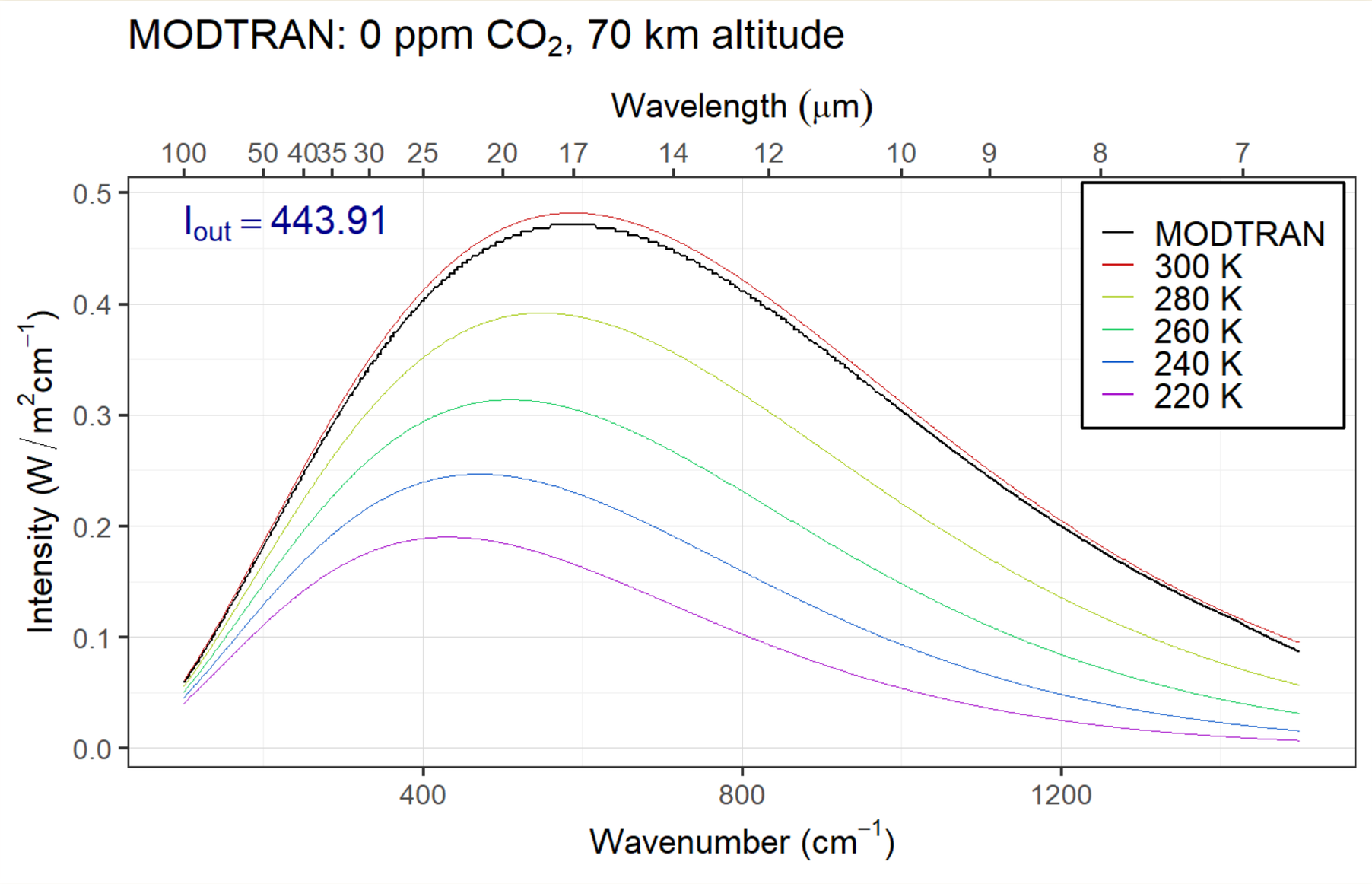
Different Gases

Measuring Greenhouse Effect:

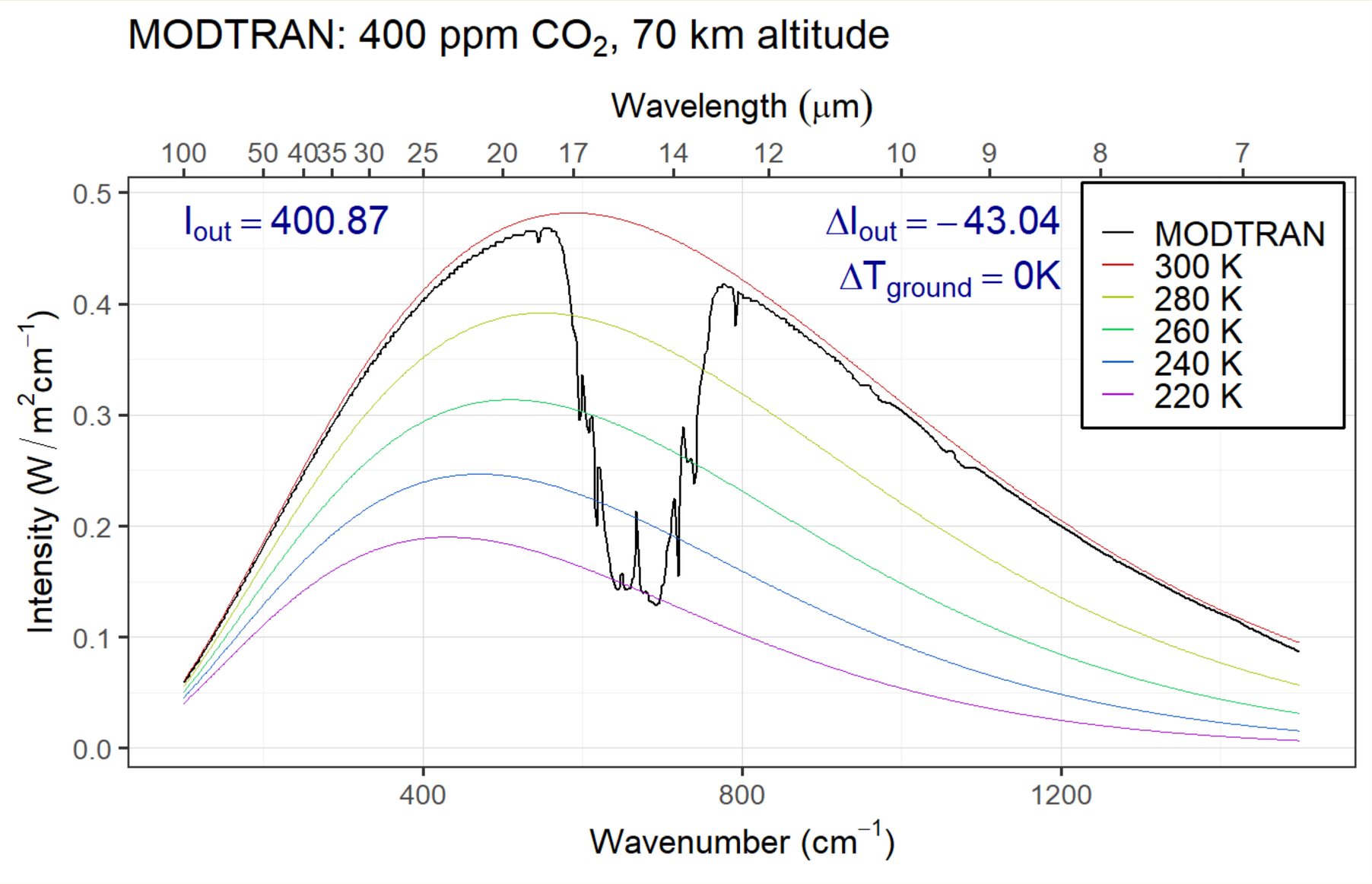
Measuring Greenhouse Effect:

- Go to MODTRAN, set CO_2 to 0 ppm, and set all other gases to zero.
- Set altitude to 70 km and location to “Tropical Atmosphere”.
- Press “Save this run to background”
- Note I_{out}
- Set CO_2 to 400 ppm and note the change in I_{out}
- Adjust the temperature offset to make the difference in $I_{\text{out}}(\text{New} - \text{BG})$ equal zero.

No Greenhouse Gases



400 ppm


MODTRAN: 400 ppm CO_2, 70 km altitude
Wavelength (μm)
100 50 40 35 30 25 20 17 14 12 10 9 8 7
$I_{out} = 400.87$
$\Delta I_{out} = -43.04$
$\Delta T_{ground} = 0K$
MODTRAN
300 K
280 K
260 K
240 K
220 K
Intensity (W / m^{2}cm^{-1})
0.0 0.1 0.2 0.3 0.4 0.5
400 800 1200
Wavenumber (cm^{-1})

Adjust temperature