Satellite Rainfall Estimation

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Workshop on Regional Flash Flood Guidance System—South America

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Outline

- Motivation: Why Satellite?
- Satellite Rainfall Estimation Theory
- The NOAA/NESDIS Hydro-Estimator (H-E)
- Summary

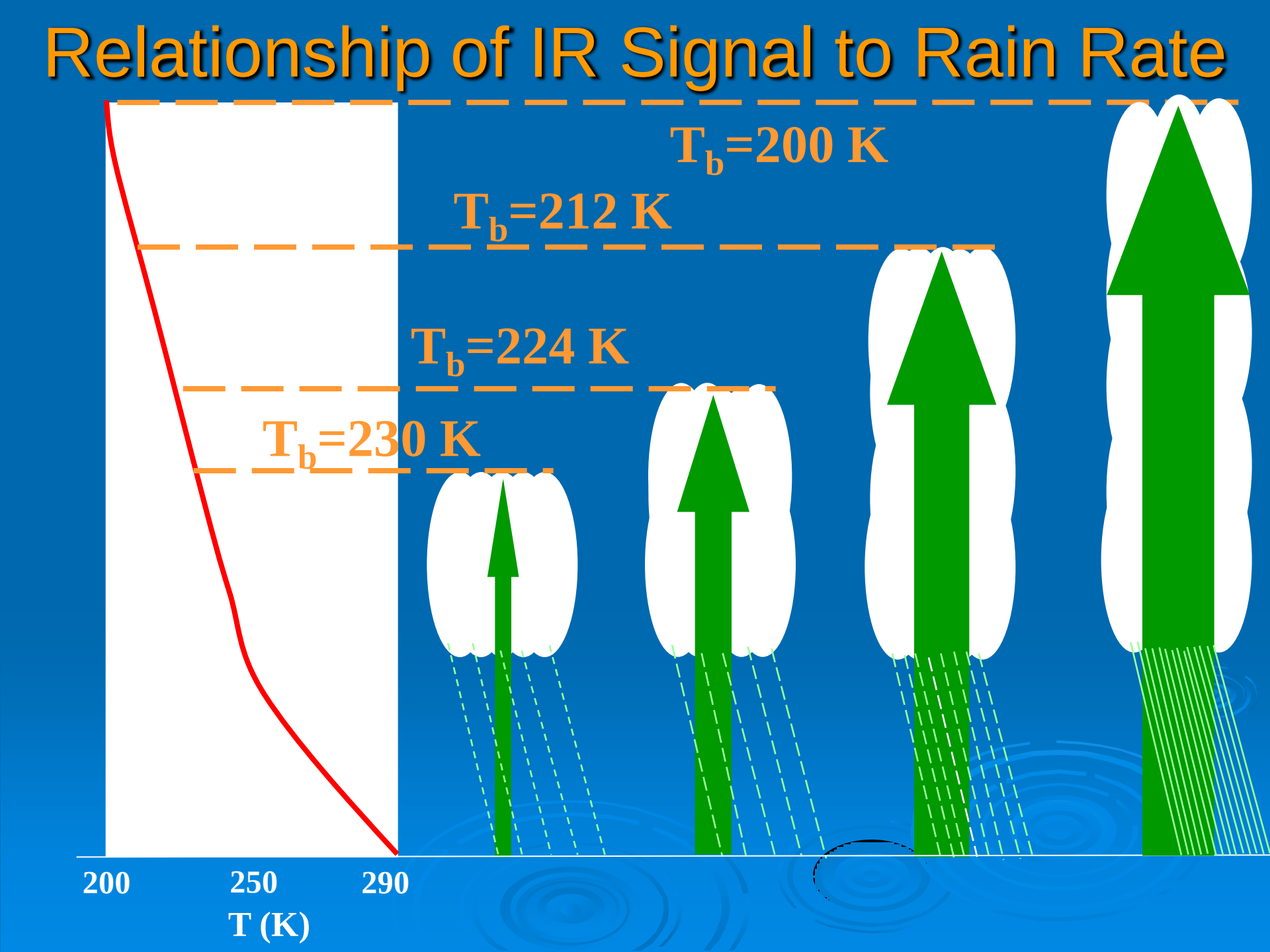
Motivation: Why Satellite?

- Spatial Coverage
  - Covers land areas away from gauges and/or radar
  - Over-water coverage for incoming storms
  - Spatially uniform coverage at high spatial (3-5 km) and temporal (15 min) resolution
- Latency
  - Potential data latency of less than half an hour
- This makes satellite rainfall estimates a critical input to FFG
- (Caveat)
  - Not as accurate as gauges, but quite good for convective rainfall

Satellite Rainfall Estimation Theory

- Basic assumptions:
  - Cloud-top brightness temperature (T_b) → cloud-top height (colder clouds have higher tops)
  - Cloud-top height → strength of convective updraft (higher-topped clouds have stronger updrafts)
  - Strength of convective updraft → rainfall rate (stronger upward moisture transport produces heavier rain)
- In essence:
  - Colder clouds are associated with heavier rain
  - Warmer clouds are associated with light or no rain

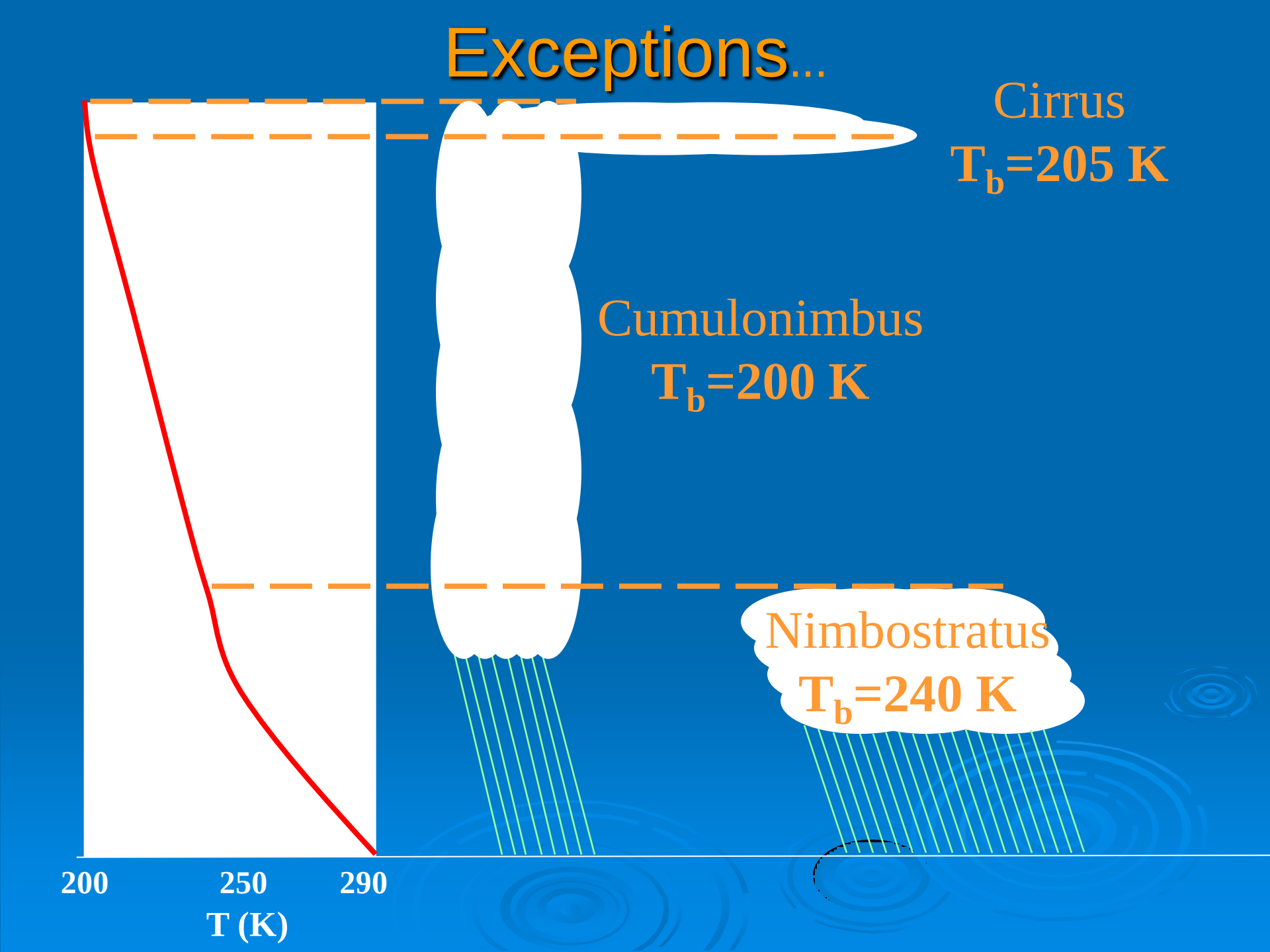
Relationship of IR Signal to Rain Rate



Satellite Rainfall Estimation Theory

- Reasonable assumption for convective clouds (i.e., warm season showers / thunderstorms)
- Poor assumption for
  - Stratiform clouds (i.e., cool-season long-duration rainfall)
    - Clouds are warm, but can produce significant rainfall)
  - Cirrus clouds (i.e., high, thin, wispy clouds)
    - Cold but do not produce any rain)

Exceptions…


Cirrus
T_b=205 K
Cumulonimbus
T_b=200 K
Nimbostratus
T_b=240 K
200
250
290
T (K)

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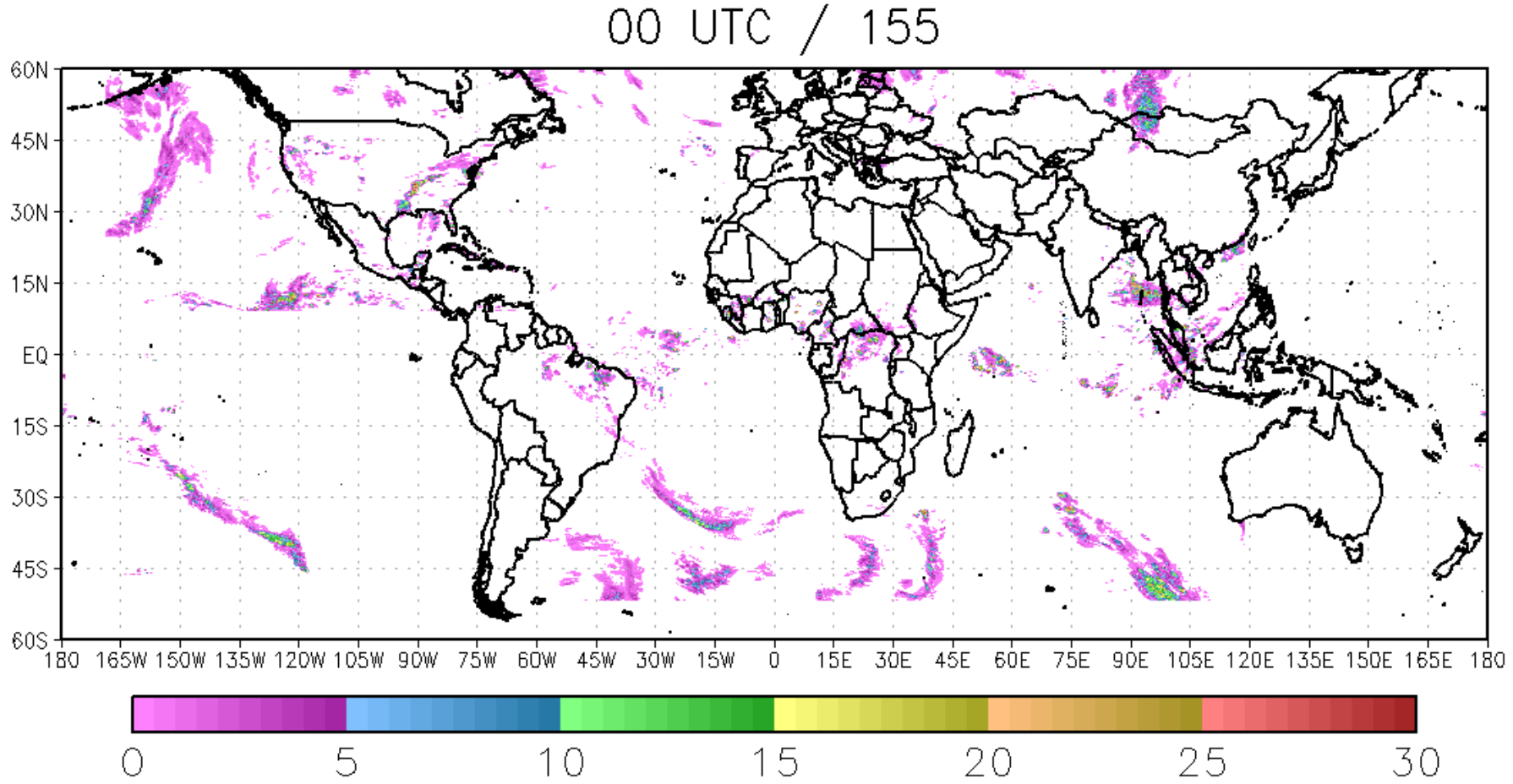
Hydro-Estimator (H-E) Description

- Operational at NOAA/NESDIS since August 2002
- Produced in real time for the entire globe between 60°N and 60°S using
  - GOES-11/13 (Western Hemisphere)
  - MTSAT-1 (Western Pacific)
  - METEOSAT-9 (Europe and Africa)
  - METEOSAT-7 (Central Asia)
- Information, real-time images, and data at

  http://www.star.nesdis.noaa.gov/smcd/emb/ff/HydroEst.php

HE Example



Hourly rainfall estimates for 0000-2300 UTC 4 June 2009

H-E Description

- Uses IR window T_b (10.7 μm) to determine raining areas and rain rates
  - Assigns rain only to regions where $T_{10.7}$ is below local average (cloud top is higher above surrounding clouds); i.e., active precipitating cores

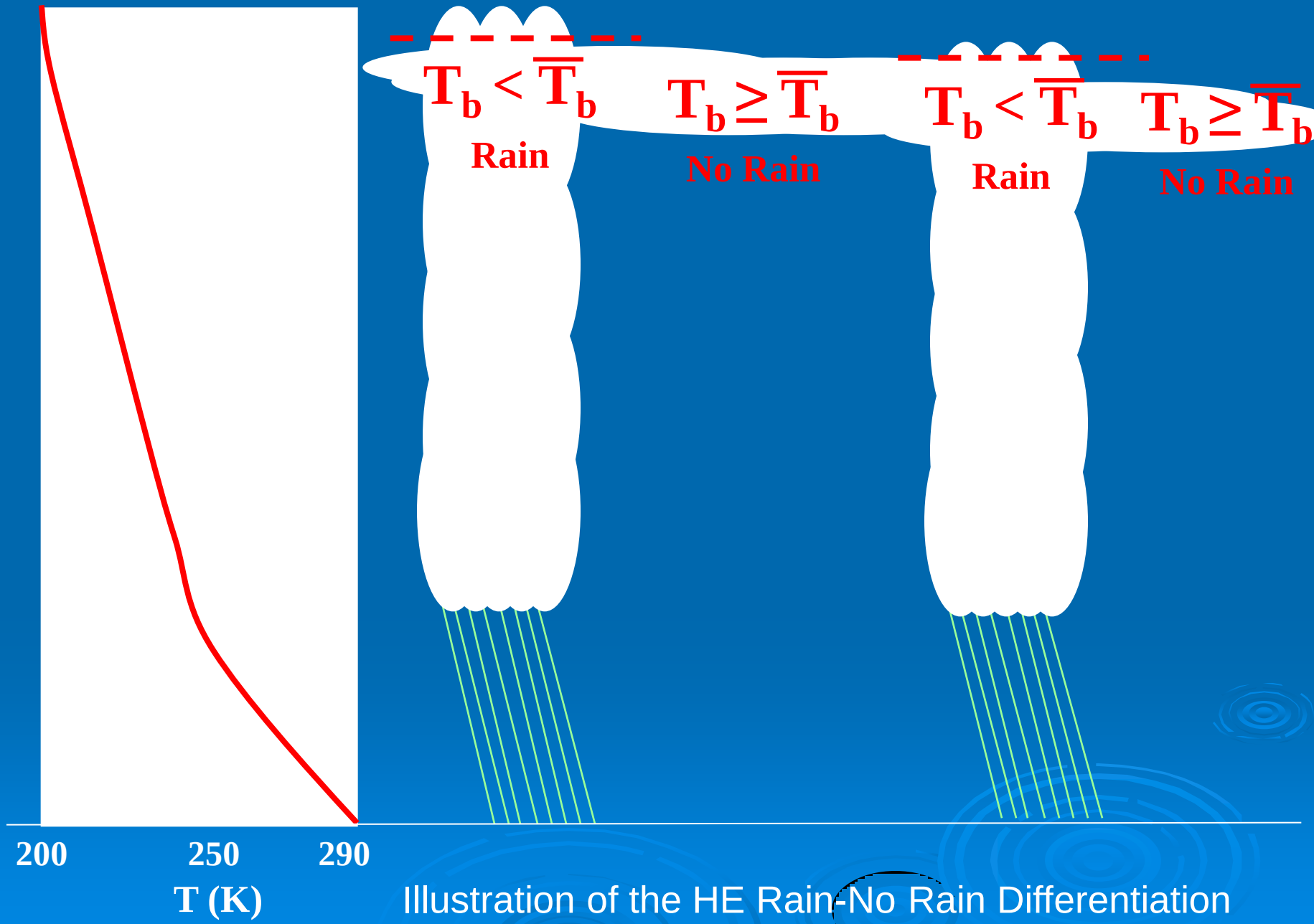
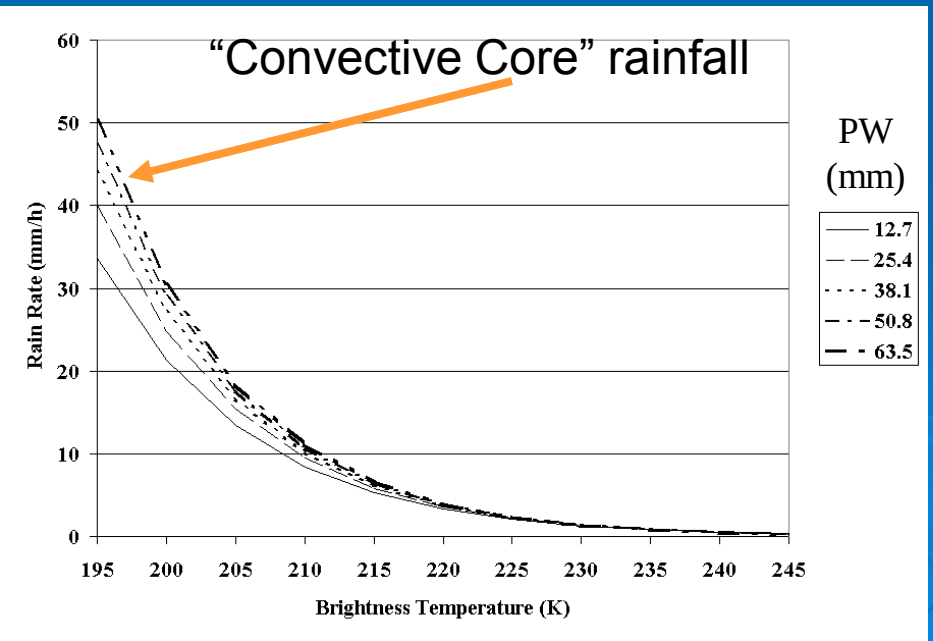
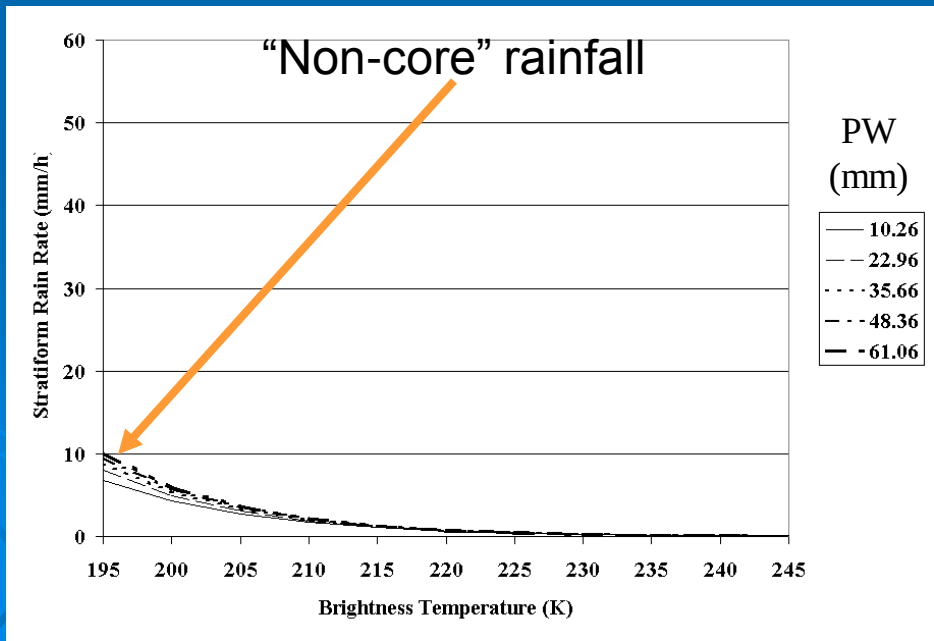


Illustration of the HE Rain-No Rain Differentiation

H-E Description

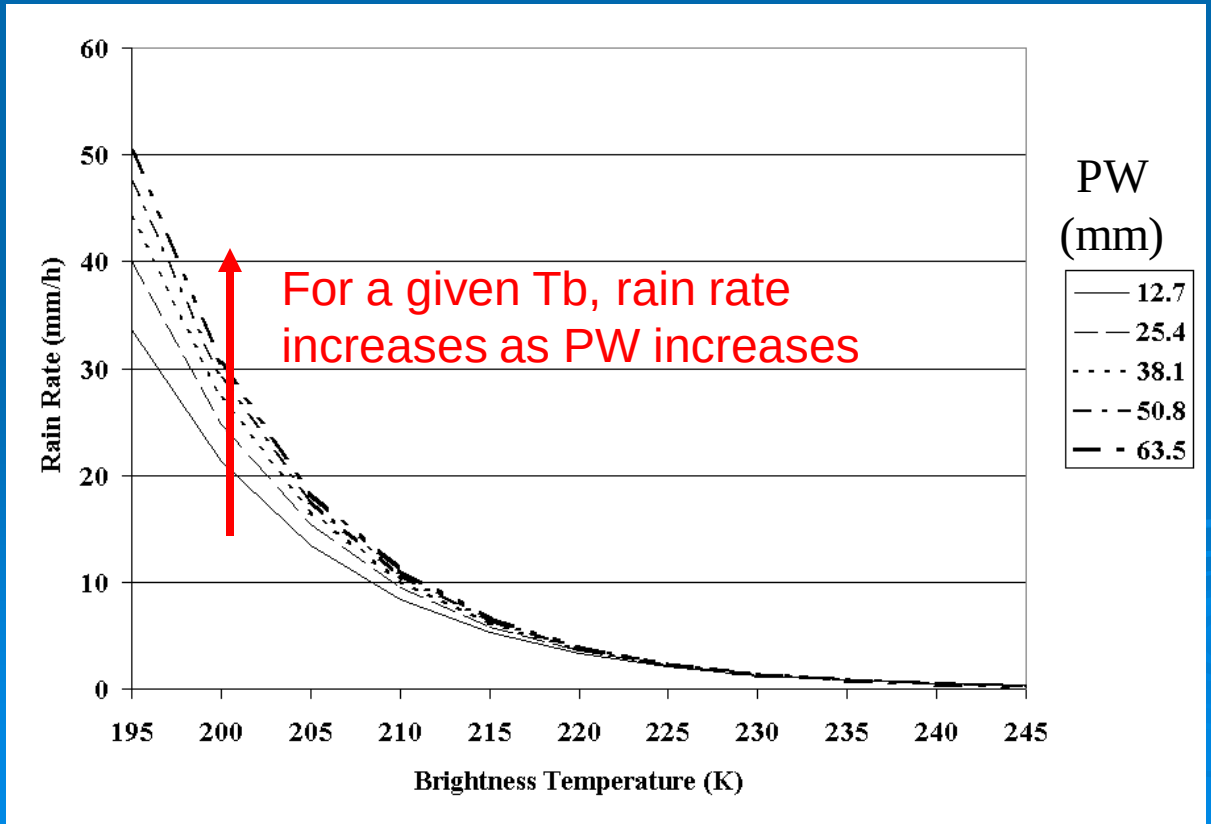
- Uses IR window T_b (10.7 μm) to determine raining areas and rain rates
  - Rain rates are a function of both $T_{10.7}$ and its value relative to the local average— enhances rain rates in precipitating cores





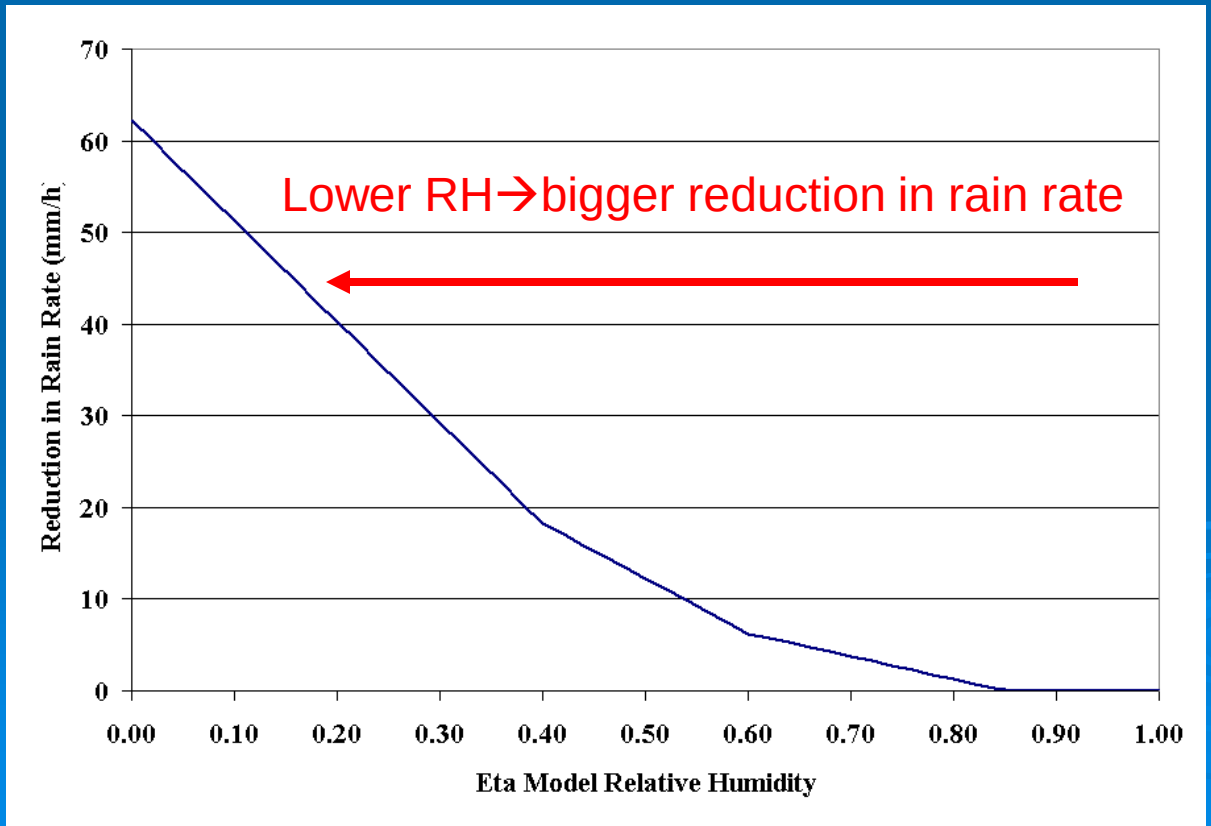
H-E Adjustments

- Precipitable water (PW) from numerical models to enhance rainfall in regions of high moisture availability



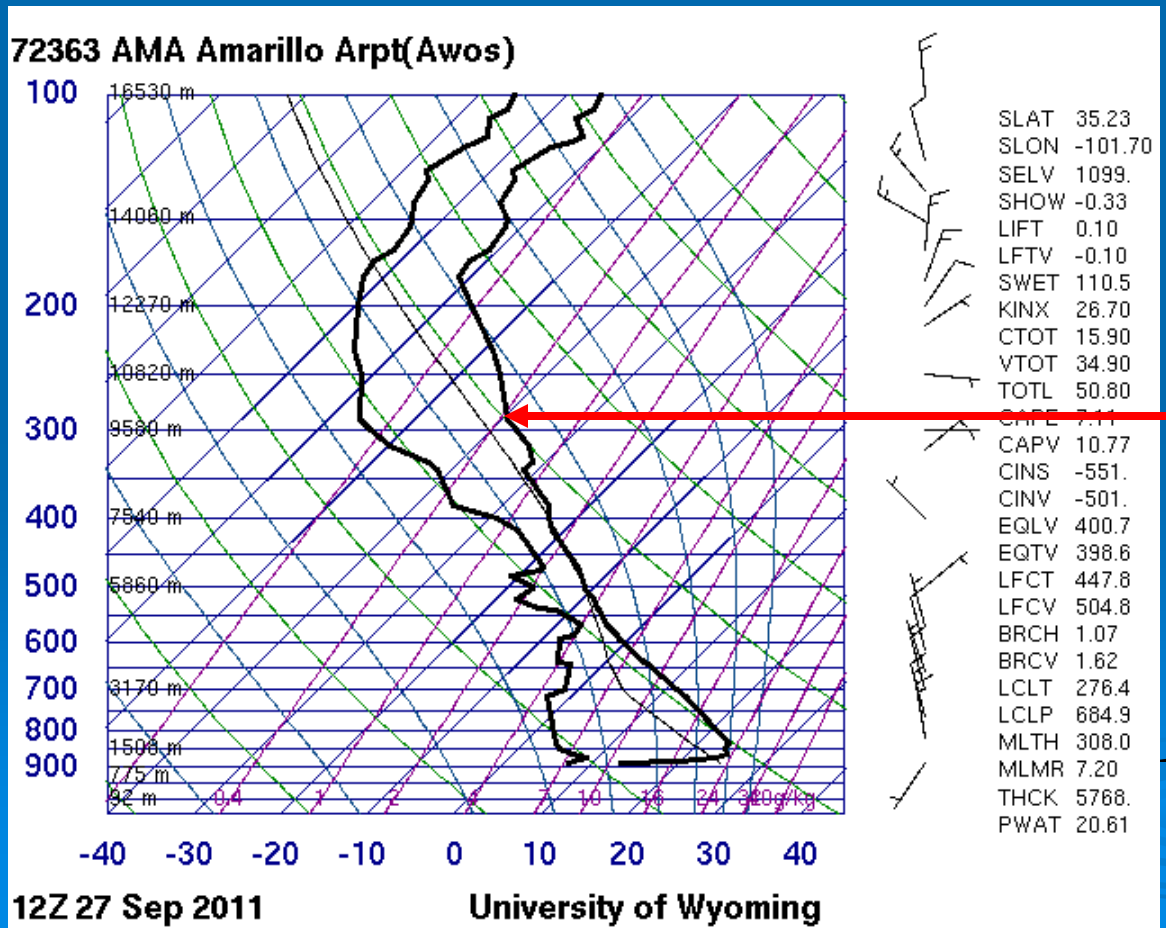
H-E Adjustments

- Relative humidity (RH) from numerical weather models reduces precipitation in arid regions



H-E Adjustments

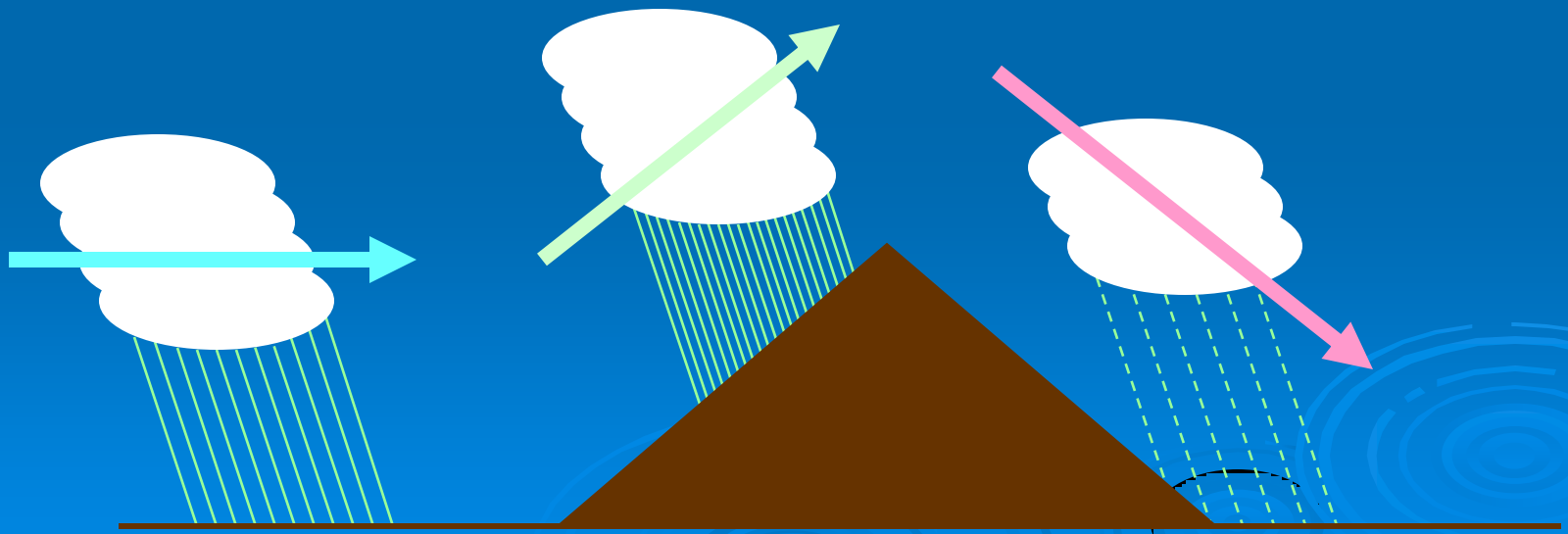
- Convective Equilibrium Level adjustment based on numerical weather model data



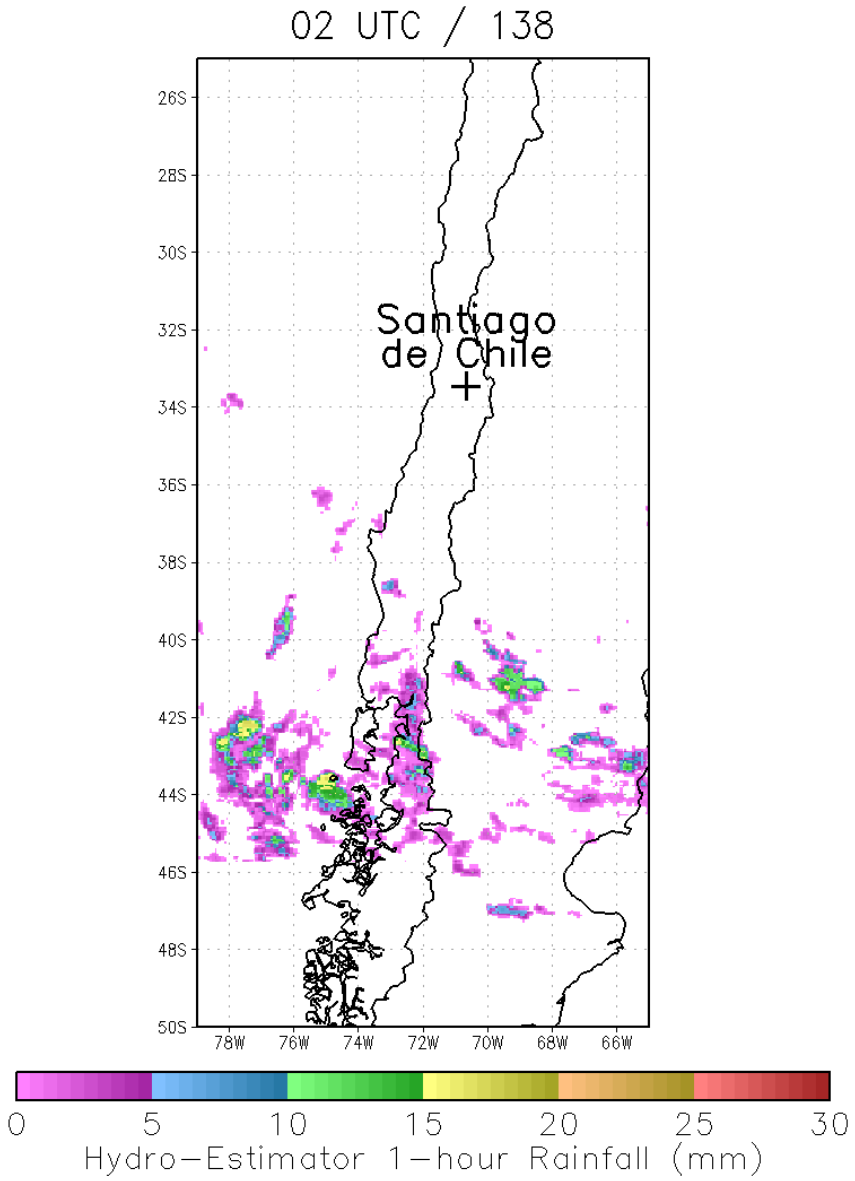
Instability (LI=-5 K; CAPE = 860 J/kg) BUT convective equilibrium level of 293 hPa = 231 K → 2 mm/h rainfall rate!

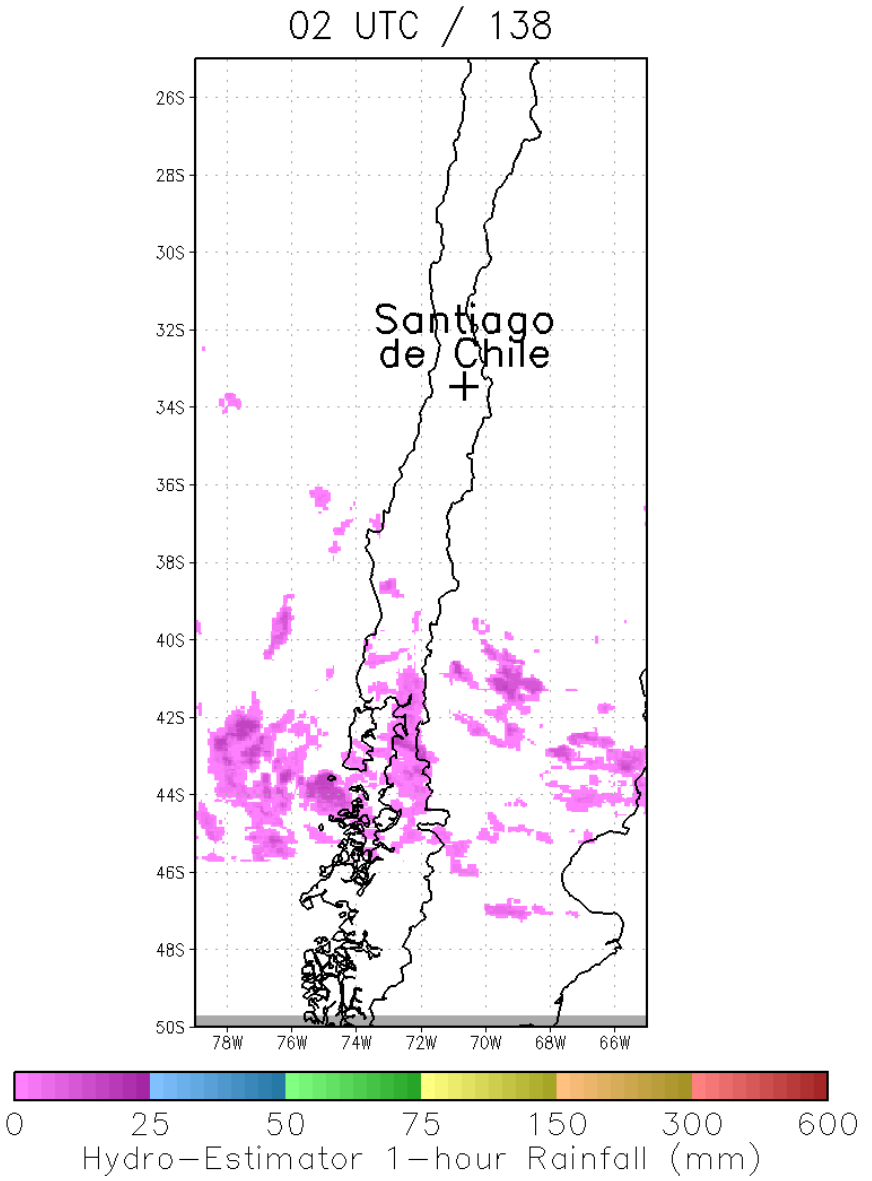
H-E Continued

- Wind fields and digital topography for orographic effects where wind blows:
  - up slope (moistening / enhancement of rain)
  - down slope (drying / reduction of rain)



Example: May 2008 Chile Floods





Summary

- Satellites provide spatially uniform coverage and low data latency for rainfall rate estimation—critical features for supporting FFG.
- The NOAA/NESDIS Hydro-Estimator provides real-time global coverage between 60˚S and 60˚N.
- The estimates assume a relationship between cloud-top temperature and rainfall rate
  - Work best for convective rainfall…
  - …not as well for cool-season rain and snow, but gauges can be used to “fine-tune” the algorithm.

Questions?

More information at

http://www.star.nesdis.noaa.gov/smcd/emb/ff/HydroEst.php

or e-mail Bob.Kuligowski@noaa.gov