Tropical Meteorology
11:670:444

Instructor: Dr. Benjamin R. Lintner

Course Time/Location: MTh 12:35-1:55 pm/ENRS 223

Office Hours/Location: By arrangement/ENRS 250

Course page: http://envsci.rutgers.edu/~lintner/tropmet.html

Email: lintner[@] envsci[.]rutgers[.]edu

Catalogue Description:

The dynamics and thermodynamics of the tropics, including regional and large-scale tropical circulations and their role in the global general circulation, tropical wave dynamics, convection and convective systems, synoptic, intraseasonal, and seasonal variability; monsoons, the El Niño/Southern Oscillation, tropical cyclones and hurricanes.

Sandy

Sandy winds loop

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Prerequisites:

Thermodynamics of the Atmosphere [11:670:323]

Dynamics of the Atmosphere [11:670:324]

Course Text:

There is no formal course text, but the following are useful references:

Comet Program Distance Learning Module, *An Overview of Tropical Meteorology*

http://www.meted.ucar.edu/dl_courses/tropical_wmo/index.htm

[registration required]

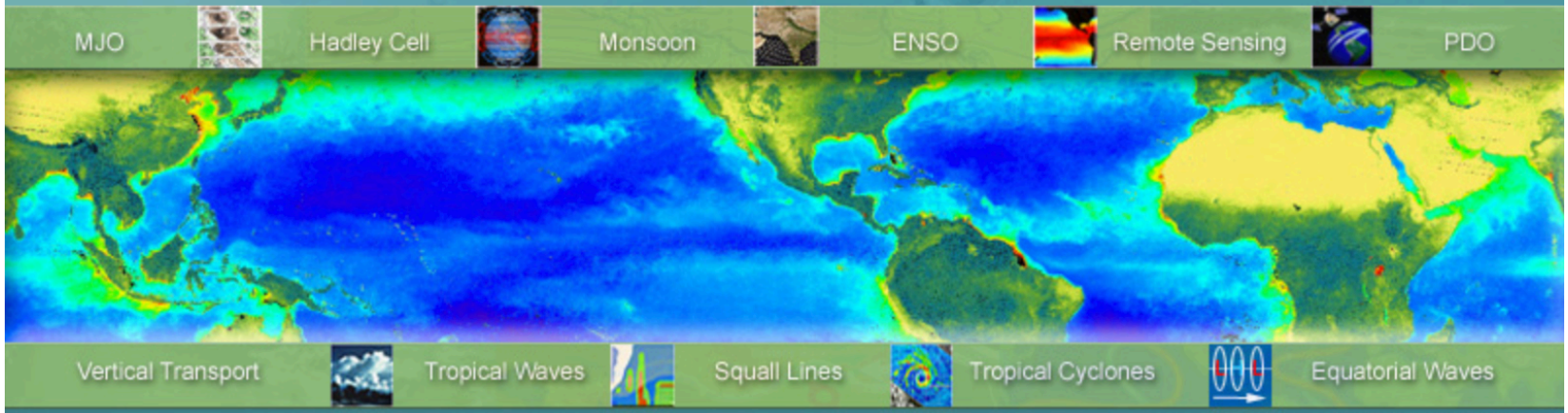
Holton, J.R., *An Introduction to Dynamic Meteorology*

Emanuel, K., Divine Wind: *The History and Science of Hurricanes*

Introduction to Tropical Meteorology *2nd Edition*

A Comprehensive Online & Print Textbook

Version 2.0, October 2011



Dr. Arlene Laing, Lead Author
The COMET Program and
National Center for Atmospheric Research

Dr. Jenni-Louise Evans, Co-author
The Pennsylvania State University

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MetEd Home
COMET Home

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Supporting Pages:

Tropical Meteorology
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Grading:

Homework Assignments [4 Total]: 20% [5% each]

Semester Exams [2 Total]: 50% [25% each]

Course Project and Paper: 30%

You will be assigned 4 homework sets, each comprising 5% of the total course grade. You are also asked to research a topic of interest and present an overview of your topic in class. This exercise, accounting for 30% of the course grade, is intended to expose you to problems, concepts, tools, and data products used in the study of tropical meteorology (more details to follow). Two semester exams, each accounting for 25% of the course grade, will be given. Make-up exams are permitted only if the exam is missed for documented serious emergencies or university-sanctioned conflicts. If you know in advance that you will miss an exam, please make arrangements to take the exam early.

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Learning Goals:

The learning goals for this course are:
(1) Develop a theoretical understanding of the thermodynamics and dynamics of the tropics;
(2) Apply quantitative principles to solve problems in tropical meteorology/climate;
(3) Research and discuss a problem of interest in tropical meteorology/climate.

Q: What [Where] are the Tropics?

- The region where the angle of declination can be 90°; whose outer limits are identified as the Tropic of Cancer and the Tropic of Capricorn, ±23.5° latitude, (Fig. 1.6).

- The region of surplus radiation where annual solar input minus terrestrial output is positive, ± 35 to 40° latitude, (Fig. 1.7).

- The region of net upward motion and surface low pressure (Fig. 1.8): positive net radiation sets air in motion leading to general upward motion and low pressure at the surface surrounded by sinking air and high pressure at the subtropics. This circulation is referred to as the Hadley cell in honor of George Hadley who, in 1735,[13] proposed that excess radiation in the tropics would lead to upward motion and corresponding subsidence at the poles. Later studies showed that his circulation model was incomplete as it did not account for the midlatitude westerlies and the indirect circulations known as the Ferrell cells.

- The region in which winds blow primarily from the east (approximately ± 30° latitude), except for the regional monsoon (Fig. 1.9). The easterly trade winds flow out of the subtropical high into the equatorial trough. They converge at the Intertropical Convergence Zone (ITCZ), which is usually identified as an intermittent band of clouds in the low pressure belt or equatorial trough.

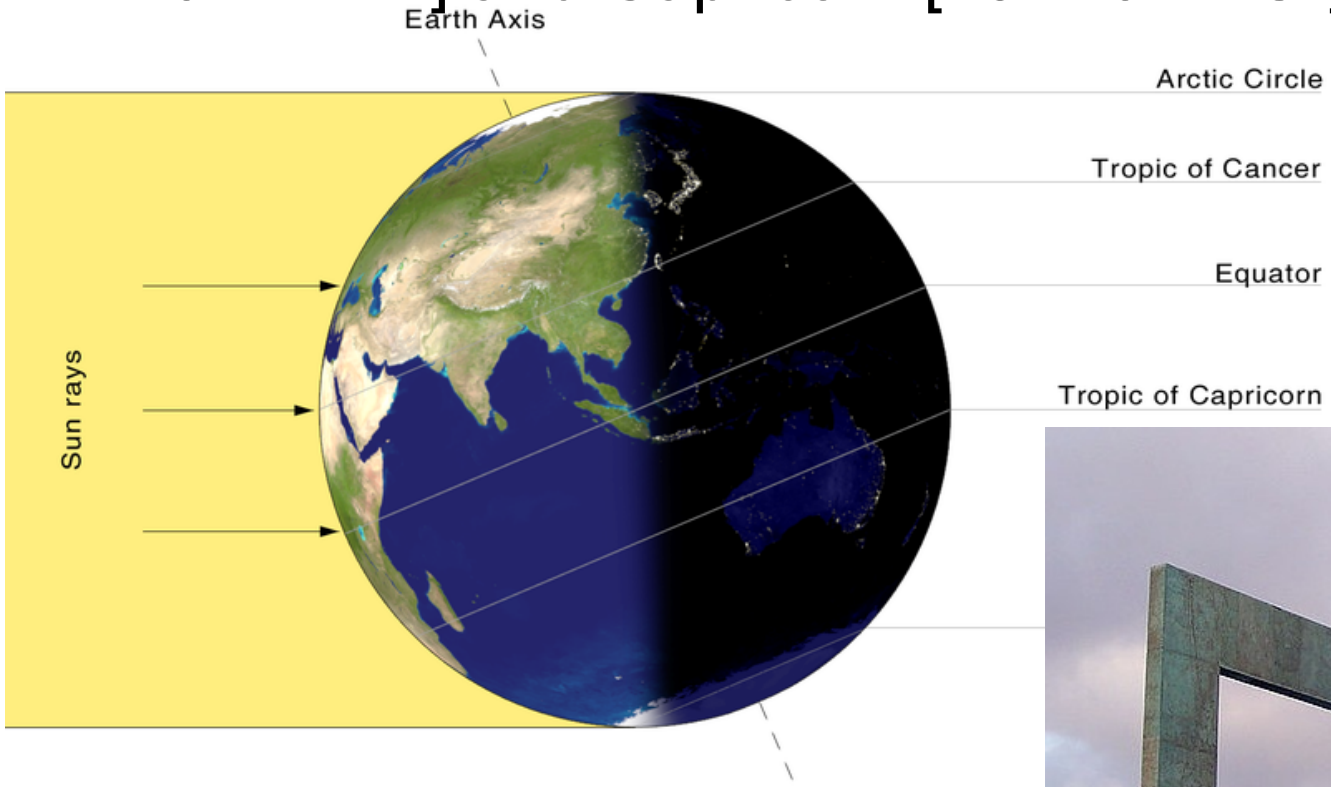
- The region where the annual range of temperature is less than or equal to the average daily range. We will examine the surface temperature distribution in Section 1.6 and focus sections at the end of the chapter.

- The region that is better described by a wet and dry season than the four seasons of higher latitudes because annual rainfall varies much more from place to place than annual temperature. Temperature and precipitation characteristics of tropical climates are presented in Section 1.9.

Comet Textbook, Ch 1

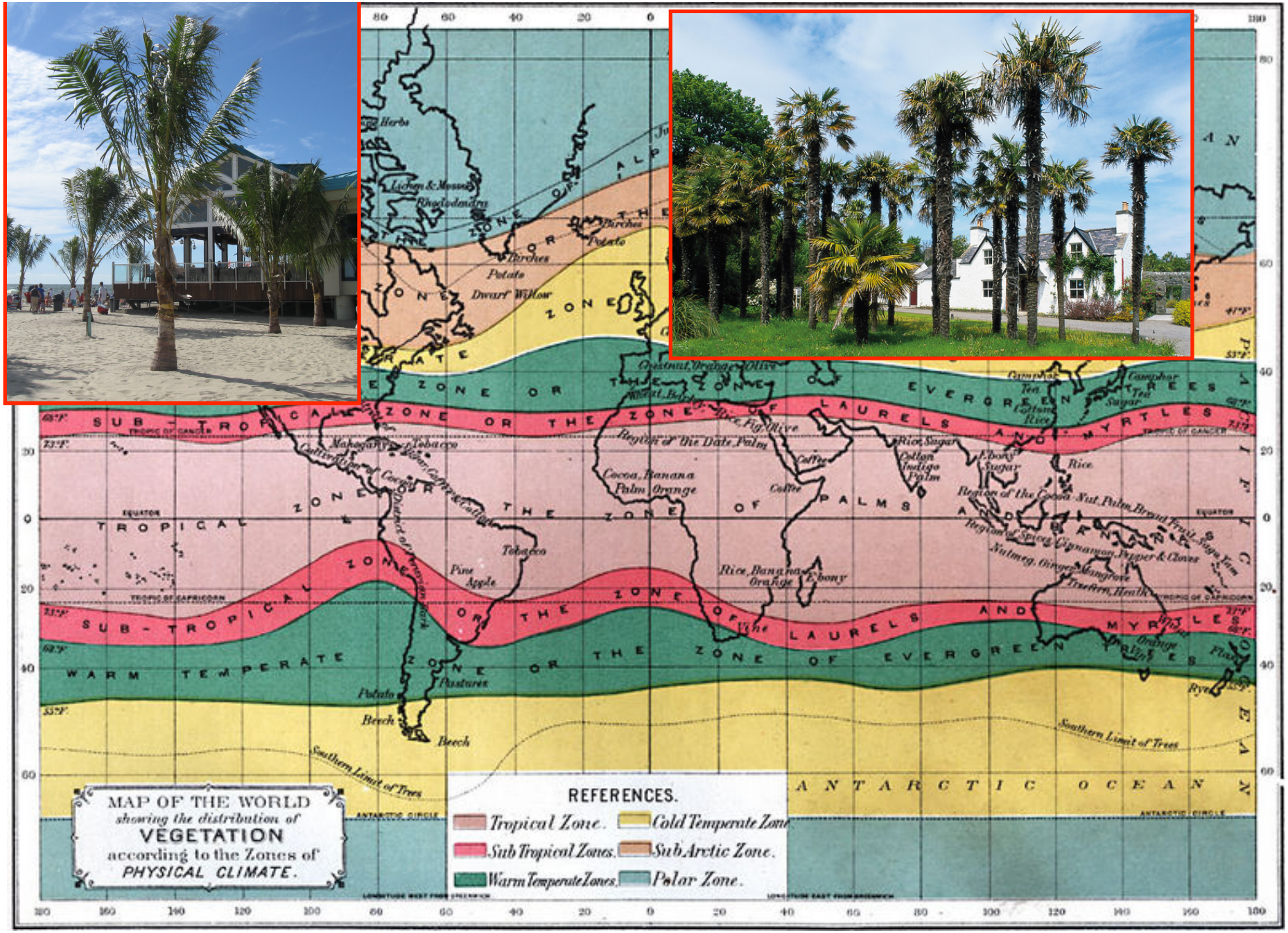
Q: What [Where] are the Tropics?

e.g.,the Torrid Zone: area between Tropics of Cancer [23° 26′ 22′′N*] and Capricorn [23° 26′22′S*]




Tropic of Capricorn north of Antofagasta, Chile

*These vary through time because of the changing obliquity of the earth.



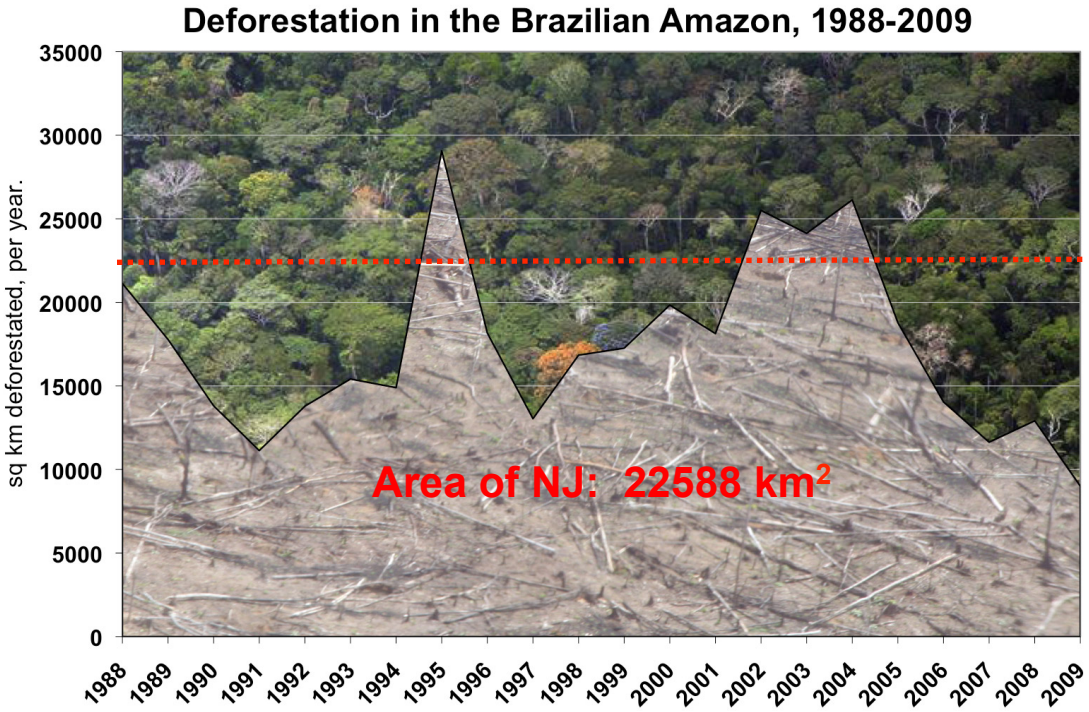
Edwin J. Houston, A. M., *The Elements of Physical Geography* (Philadelphia, PA: Eldredge & Brother, 1891)

The Tropics & New Jersey

- Tropical cyclones: Direct strikes are rare (~1 in 100-200 years); prior to Sandy, one intense hurricane in past 350 years (1821)…but remnant effects (especially flooding associated with heavy rains) can be substantial

The Tropics & New Jersey

- Amazonian deforestation: economic globalization



70% of formerly forested land in Brazil is used for livestock pasture but industrial-scale soybean production is a growing user of deforested land.

New York Times [01/21/01]:

Down the Shore; bringing the rainforest into a boardwalk battle

New York Times [06/24/07]:

Environment; rainforest politics strides onto boardwalk

Cape May County Herald [12/23/08]:

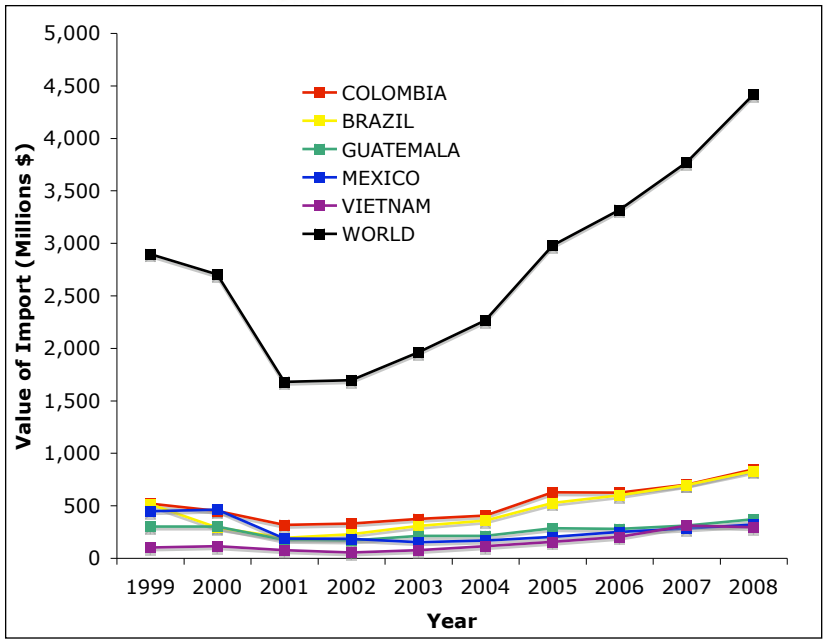
Wildwood opts for ipe wood over black locust in boardwalk construction

Cape May County Herald [01/16/09]:

Environmental and political issues collide over rainforest wood on boardwalk

The Tropics & New Jersey

- Coffee!



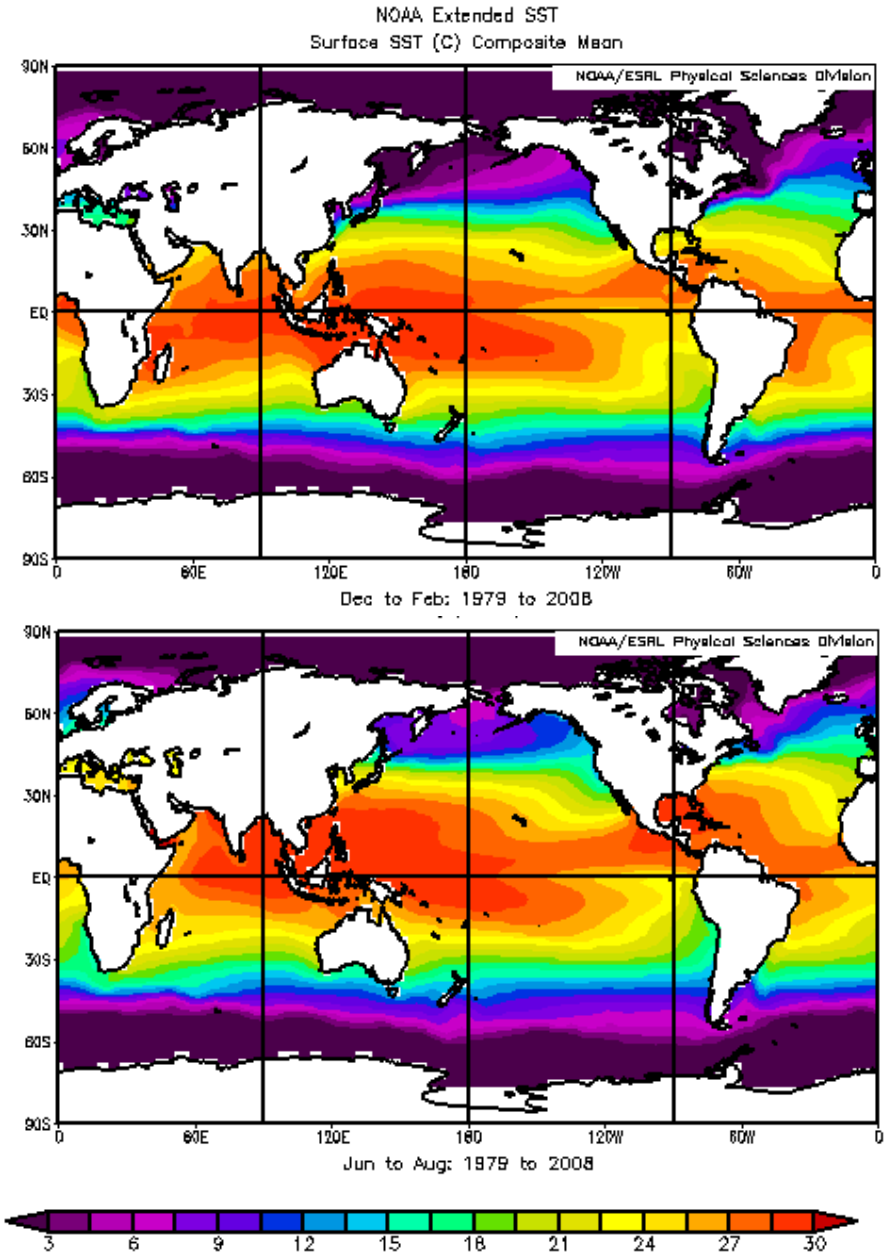
[Data from the Economic Research Service of the US Department of Agriculture]

Doka Estate Coffee Plantation, Alajuela Costa Rica

Overview of the Tropics

- Longitude-latitude maps
  - Climatologies
  - Daily snapshots
- Latitude-height cross-sections
- Köppen climate classification

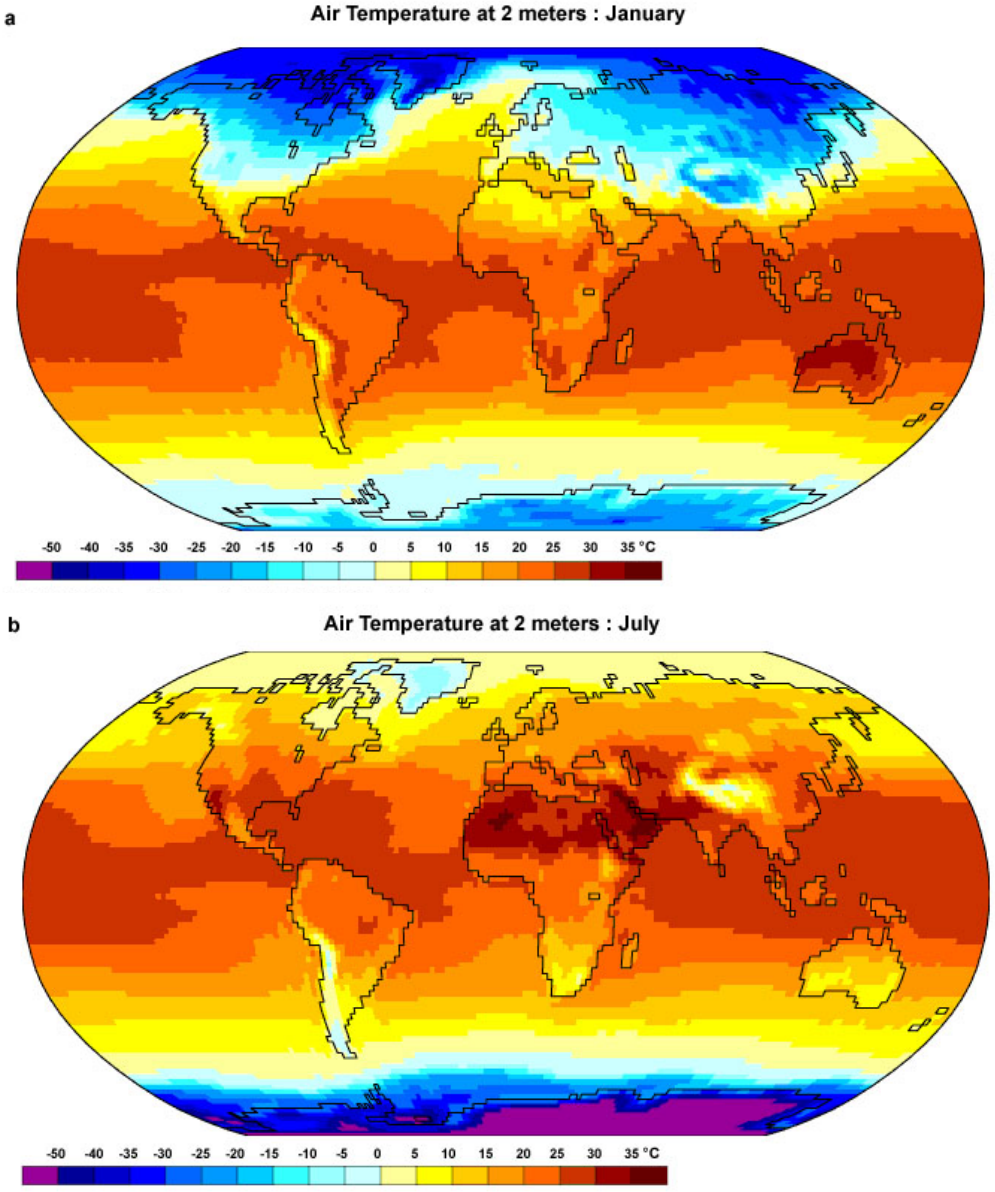
SST [in °C; NOAA ERSST]



- Warmest SSTs (~29C) typically in the Western Pacific warm pool
- "Tongues" of relatively cool SST along the equator in eastern Pacific/Atlantic

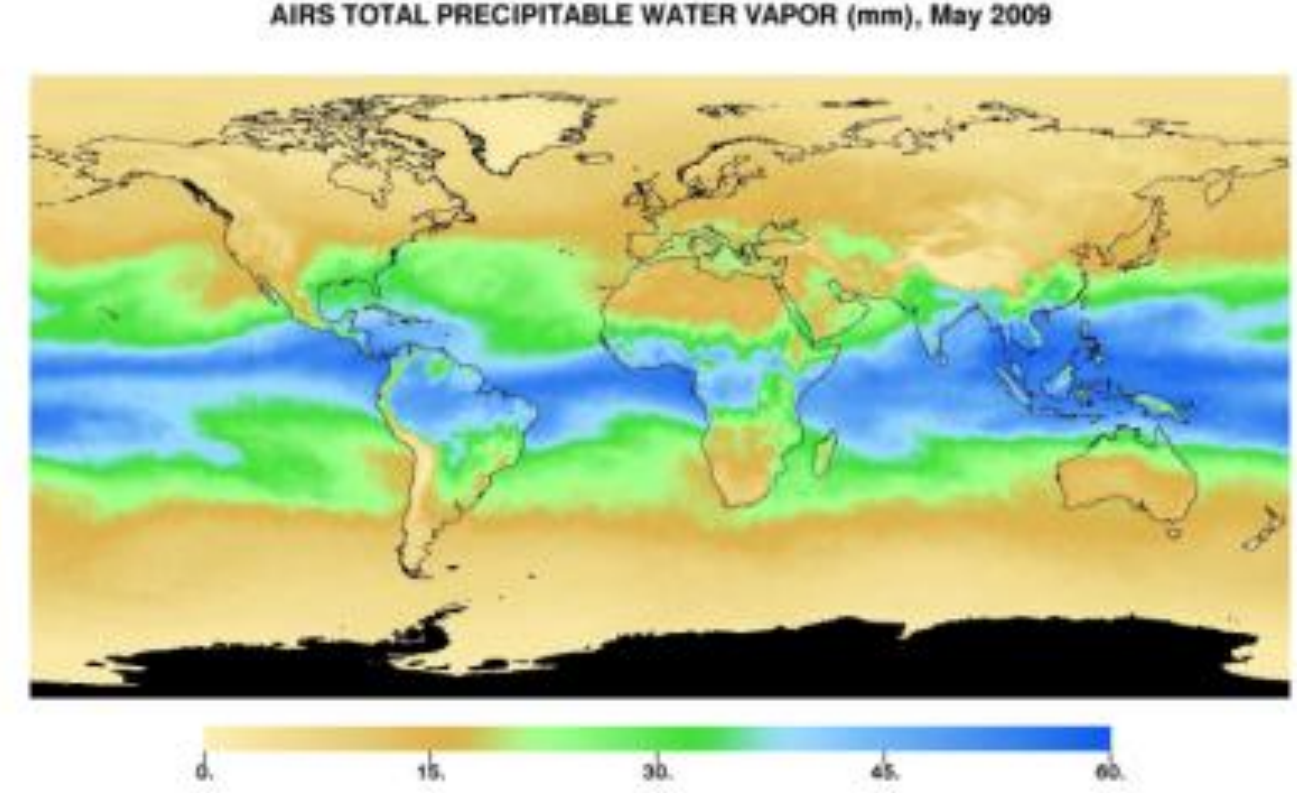
We must ultimately consider the coupled ocean-atmosphere [and land-atmosphere] system in the Tropics!

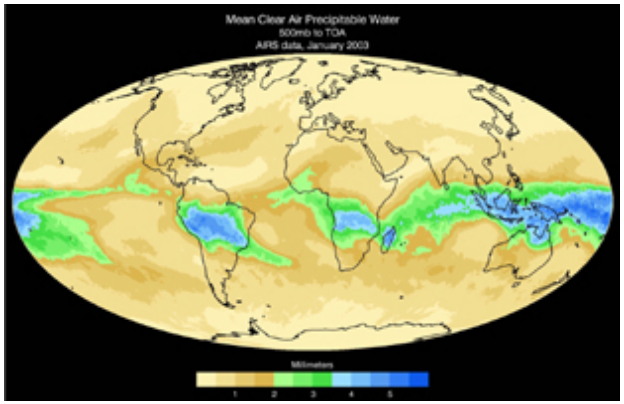
Temperature @ 2m [in °C; NCEP R1

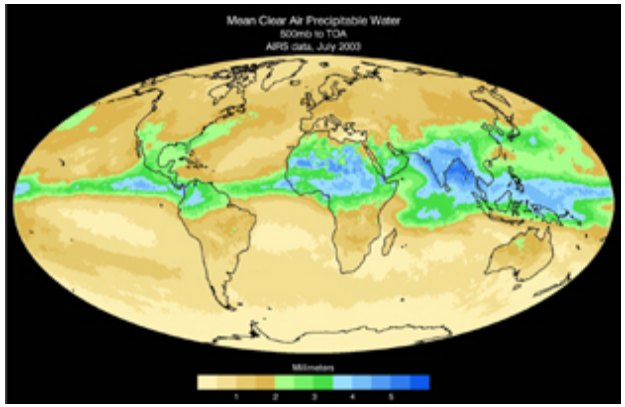


- Maxima over the tropical continents
- Regional influences of ocean currents and topography
- Small seasonal temperature range

Precipitable Water [in mm; AIRS]

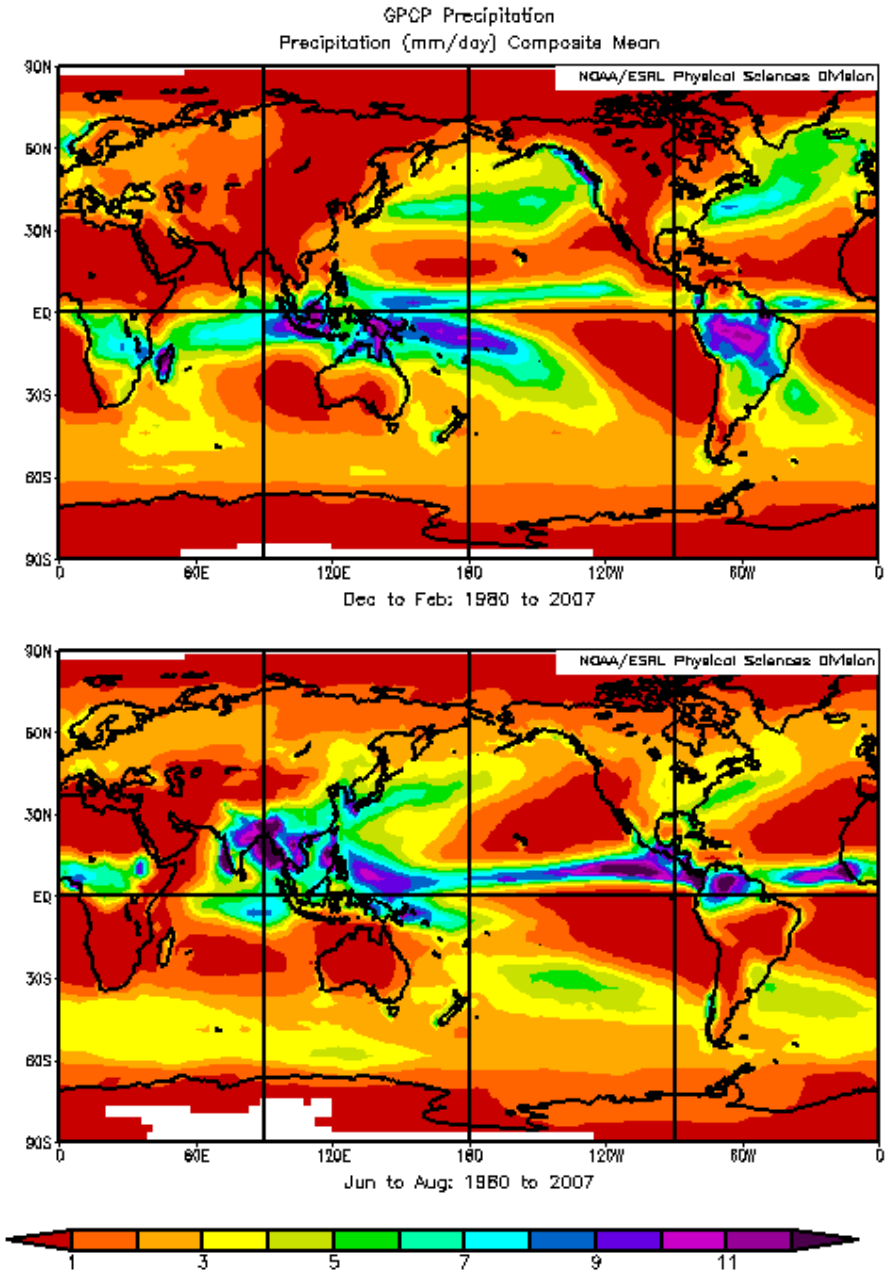






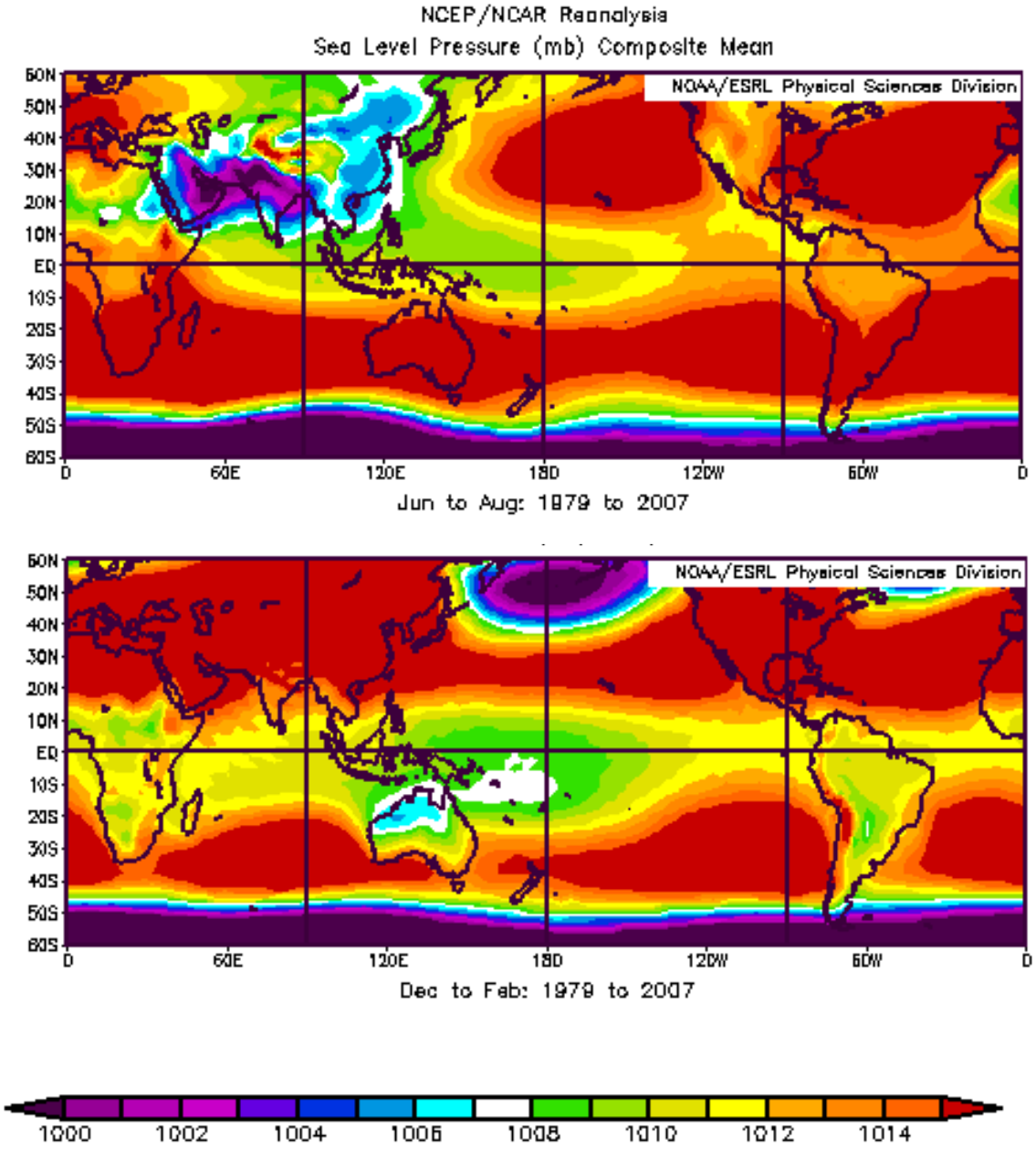
- Top [May 2009]: High values (~60 mm) centered near equator, some regionally sharp gradients, especially over oceans
- Bottom [2003 *left January*; *right July*]: northward displacement of maxima from January to July

Prec [in mm day^{-1}; GPCP]



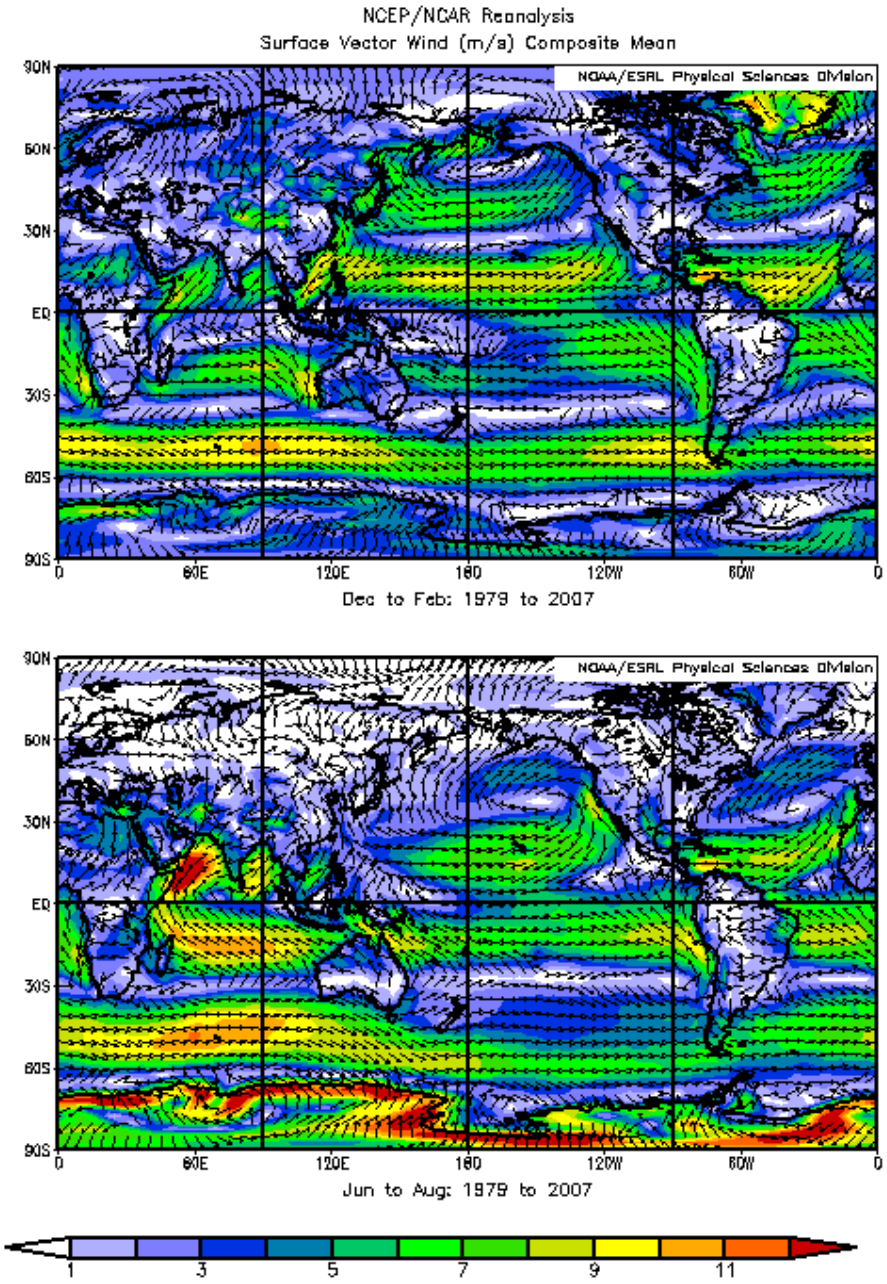
- Near-equatorial oceanic precipitation organized in relatively narrow bands (Intertropical Convergence Zones or ITCZs)
- NW-SE diagonal bands of precipitation extending toward higher latitudes in SH in DJF
- Broader zones of intense precipitation over tropical continents

SLP [in mb; NCEP]



- Relatively low SLP near the equator
- Lowest pressures in continental summer monsoon regimes

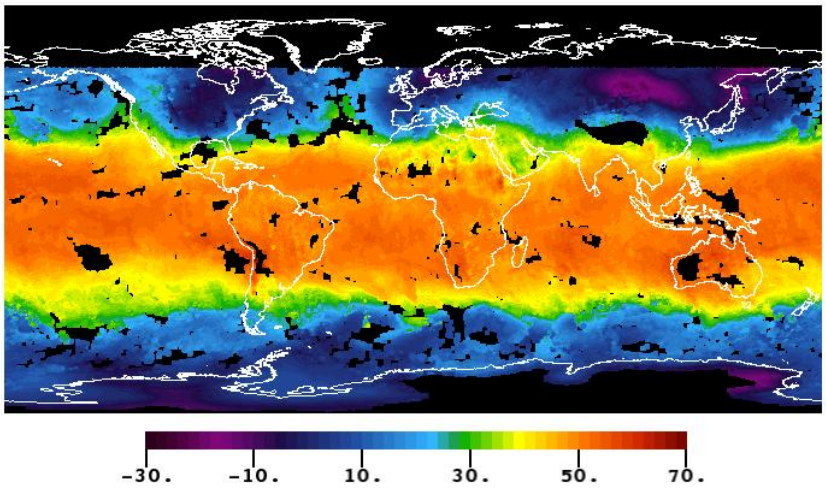
Surface Winds [in ms^{-1}; NCEP]



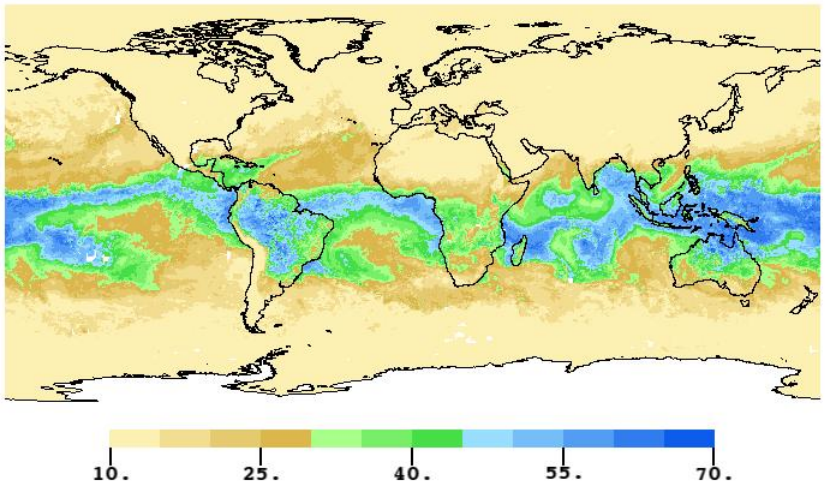
- Trade wind regimes in low latitudes, with northeasterly (southeasterly) flow in the NH (SH)
- Slight asymmetry with respect to the equator in the eastern Pacific/Atlantic
- Strong reversing cross-equatorial flow in monsoon regions

Synoptic Snapshots [AIRS]

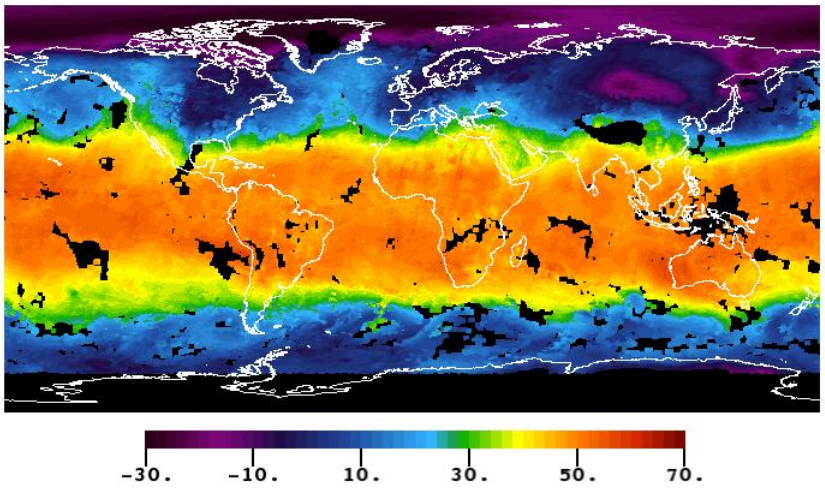
AIRS DAILY AIR TEMPERATURE (F) AT 700mb 20100107-20100109



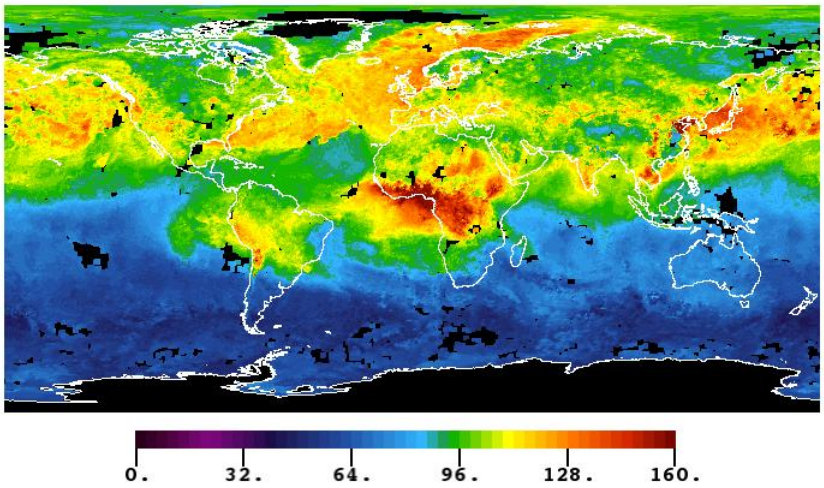
AIRS TOTAL PRECIPITABLE WATER VAPOR (millimeters) 20100107-20100109



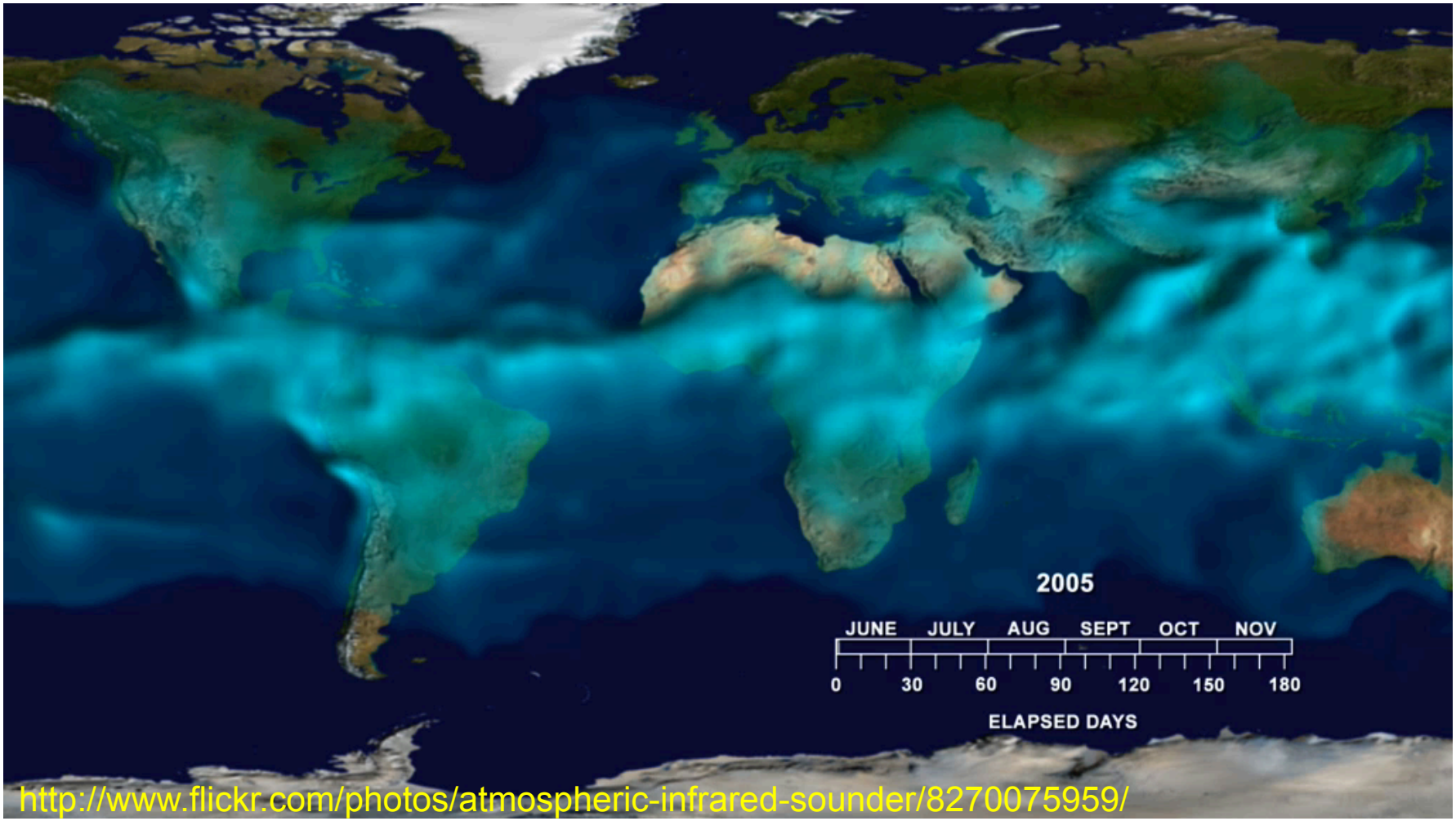
AIRS NIGHTLY AIR TEMPERATURE (F) AT 700mb 20100107-20100109



AIRS CO AT 505mb (ppbv) 20100107-20100109

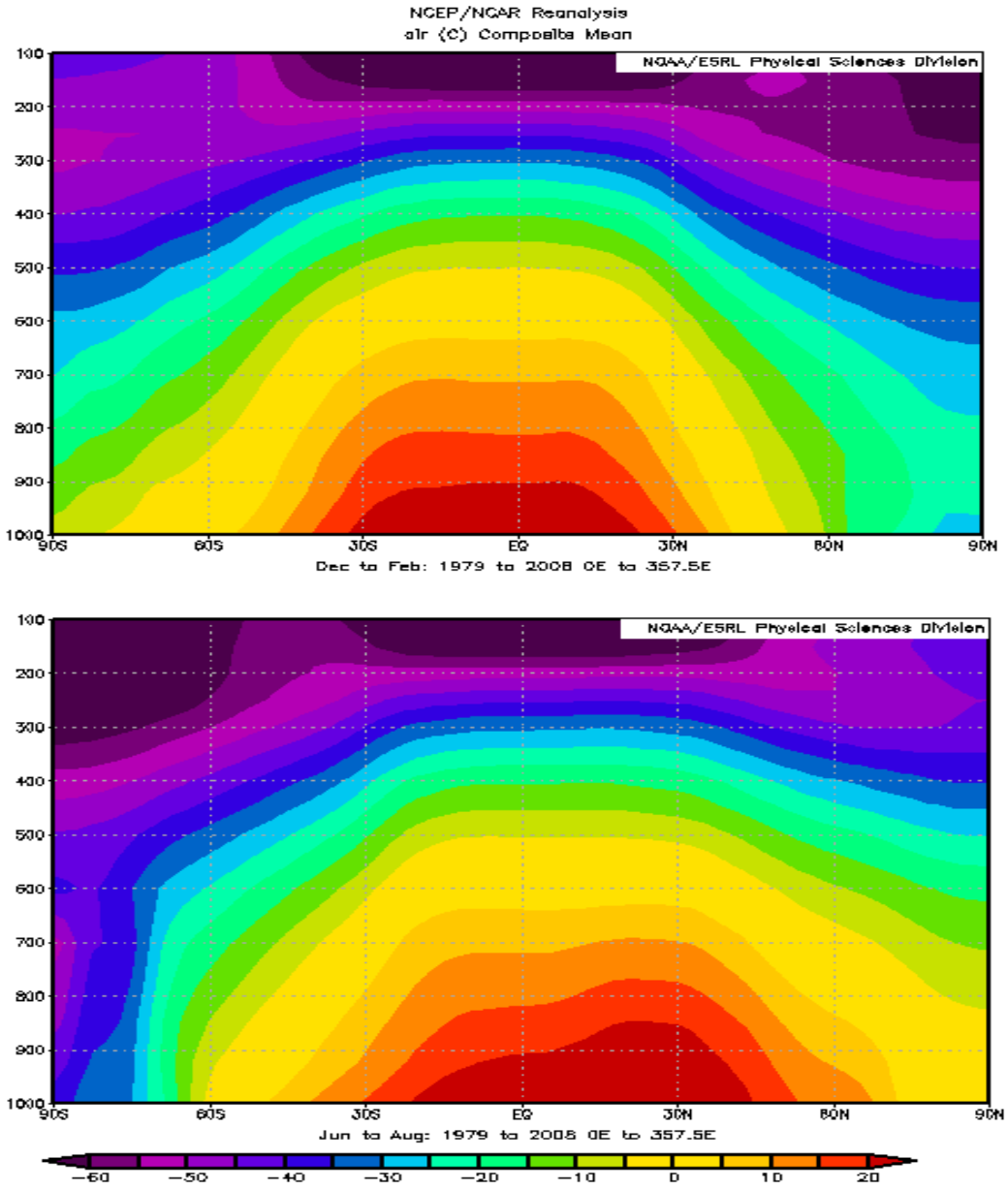


Water vapor transport [based on AIRS and AMSU data]



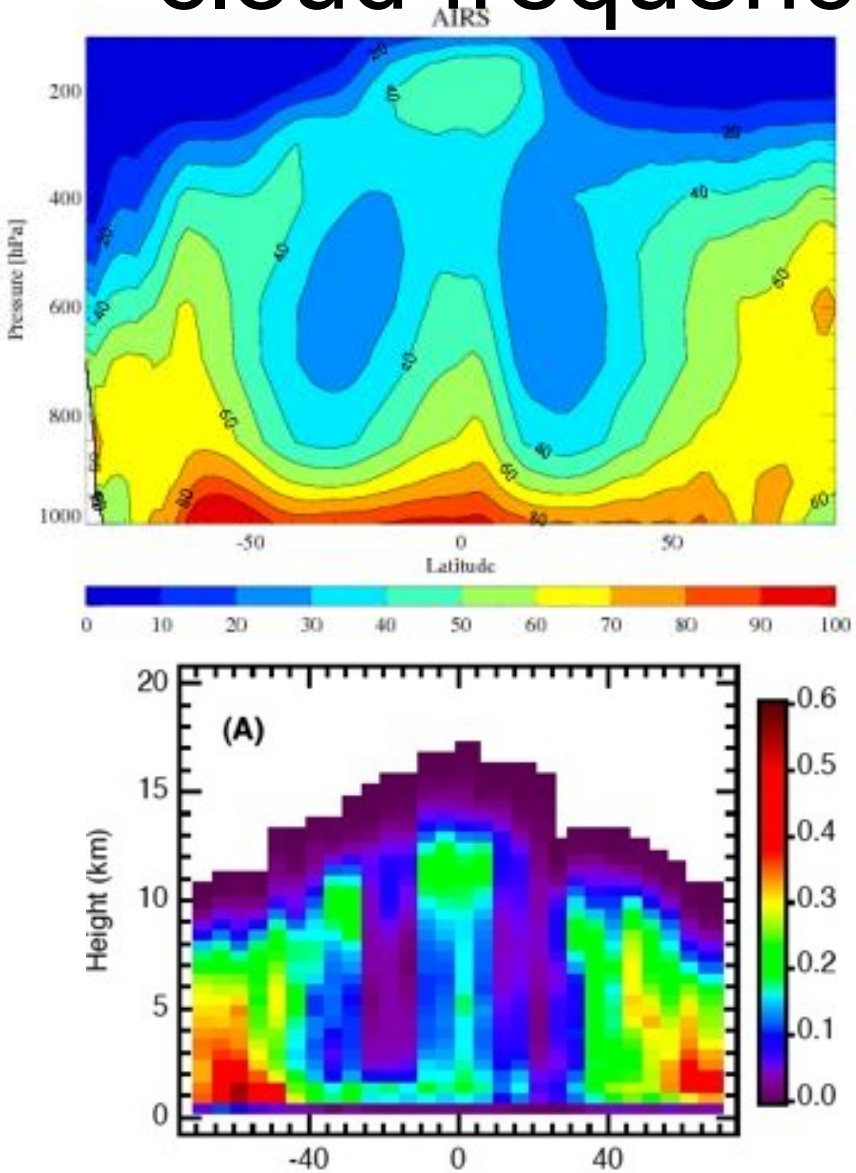
NASA JPL AIRS Project

Temp vertical structure [in °C; NCEP]



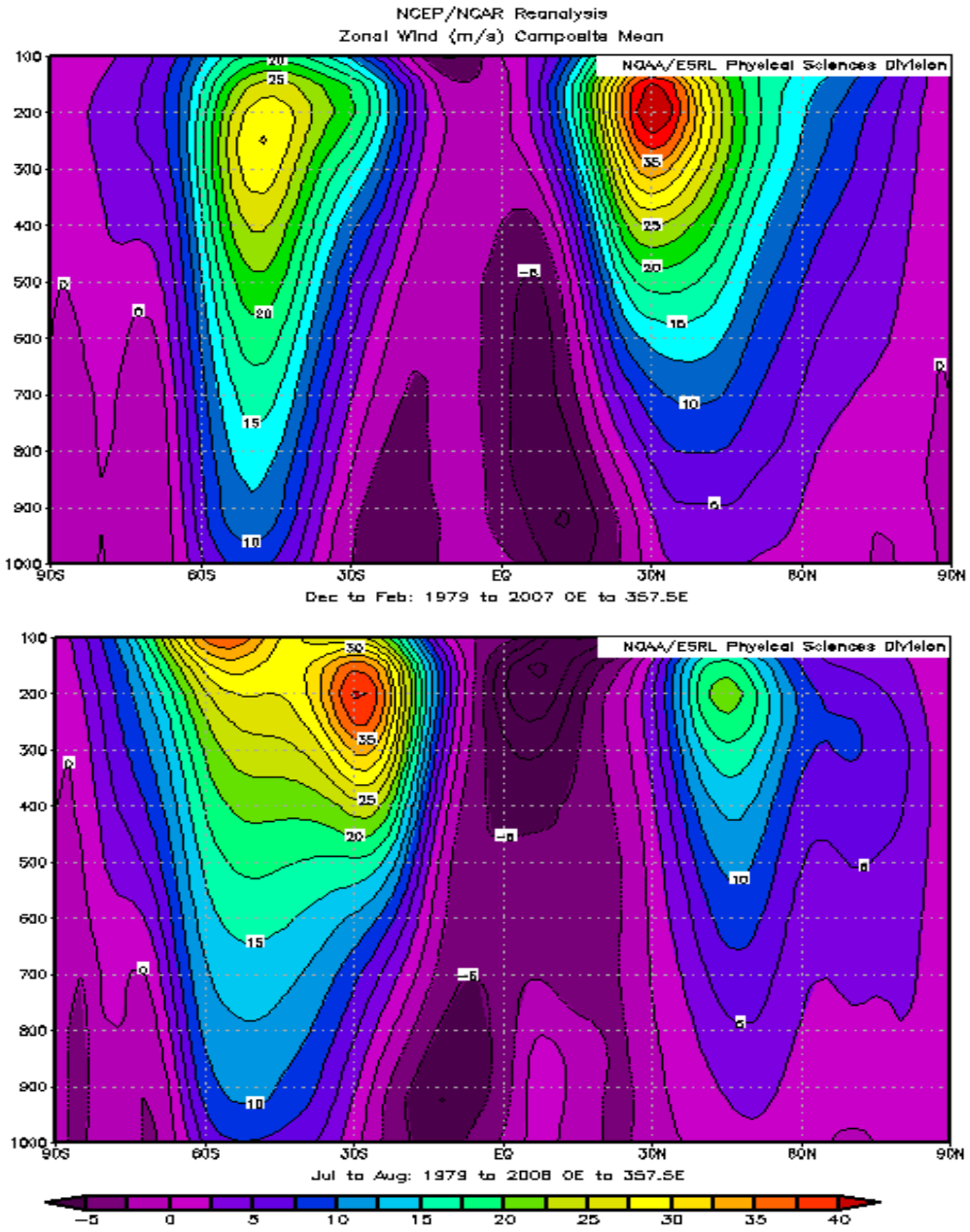
- Upward bowing of tropical isotherms [higher tropopause]
- Relatively flat isotherms in tropics [small gradients]

Relative humidity [in %; AIRS] and cloud frequency [in %; CloudSat]



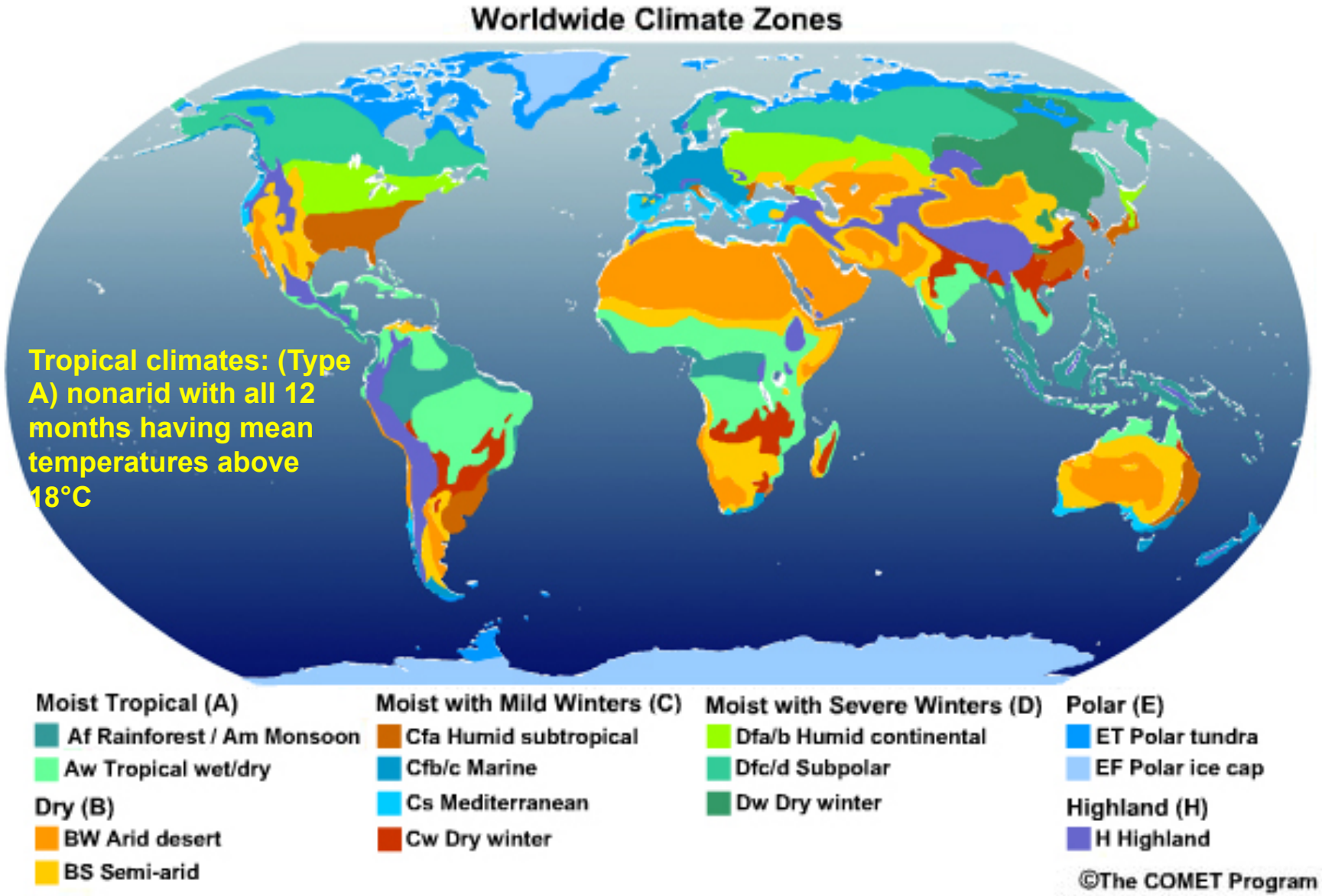
- Top [DJF RH]: Strong vertical gradient in the Tropics; high RH bulging upward near equator, flanked by low midtropospheric values; high tropical tropopause
- Bottom [DJF cld freq]: Many cloud frequency characteristics correspond to RH field, e.g., upper troposphere maximum in RH with relatively high cloud frequency

Zonal Wind [in ms^{-1}; NCEP]



- Strong westerly jets in upper troposphere between 30-60 degrees, especially in the winter hemisphere
- Weak easterlies across the Tropics

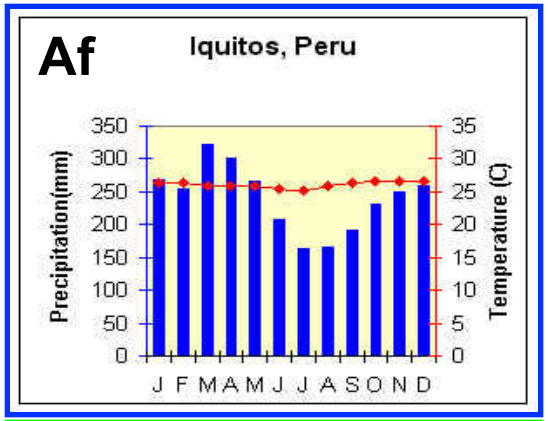
Köppen Climate Classification

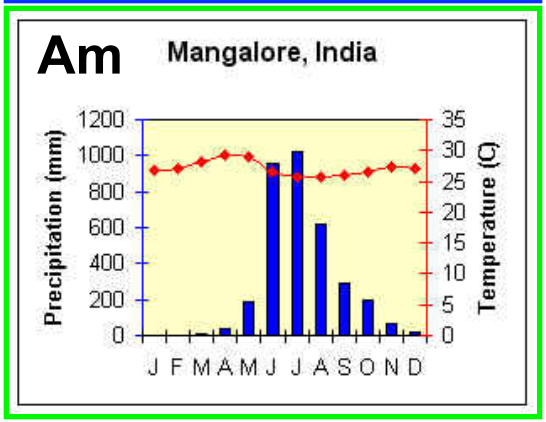


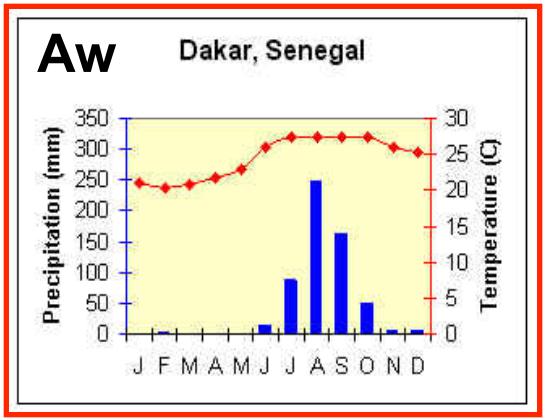
Köppen Type A Climates

- Tropical Rainforest (Af)
  - P ≥ 60 mm for each month
  - Typically 5-10º of equator
- Tropical Monsoon (Am):
  - Dominated by monsoonal, i.e., seasonally-reversing circulation, with distinct wet/dry seasons
  - Driest month [close to winter solstice] has (100 mm - Annual P [in mm]/25) < P ≤ 60 mm
- Tropical Savanna (Aw):
  - Driest month has P ≤ (100 mm - Annual P [in mm]/25)

Examples


Af
Iquitos, Peru
Precipitation(mm)
Temperature (C)
J F M A M J J A S O N D


Am
Mangalore, India
Precipitation (mm)
Temperature (C)
J F M A M J J A S O N D


Aw
Dakar, Senegal
Precipitation (mm)
Temperature (C)
J F M A M J J A S O N D

Tropics *vs* Extratropics

0) Weak Coriolis [vanishes along equator]
1) Higher T & q [but weak horizontal T and Pressure gradients]
2) More unstable [higher near-surface T but lower T in upper troposphere (higher tropopause)]
3) Easterly zonal mean winds
4) Seasonality often defined in terms of rainfall [wet & dry seasons]
5) Weather dominated by local and mesoscale systems more so than midlatitudes
6) Historically data sparse but vastly improved data coverage with remote sensing
7) High biodiversity and endemism
8) 40% of the world's population [2008] but 60% by 2060 [according to GeoHive.com]