

Amazon River

The Superlative Amazon River

- Amazon is to rivers what Himalayas are to mountains or Challenger Deep is to trenches
- 20% of all river water is flowing in it
- The outpouring of water and sediment is so vast that the salinity and color of the Atlantic Ocean are altered for a distance of about 320 km from the mouth of the river.



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Orellano 1541-1542

- The first descent by a European of the mighty river was made by Francisco de Orellana in 1541, and the name Amazonas arises from the battle which he had with the Tapuya tribe where the women fought alongside the men, as was their custom. Orellana, no doubt, derived the name Amazonas from the ancient Amazons of Asia and Africa described by Herodotus and Diodorus.



http://www.pbs.org/conquistadors/orellana/orellana_flat.html

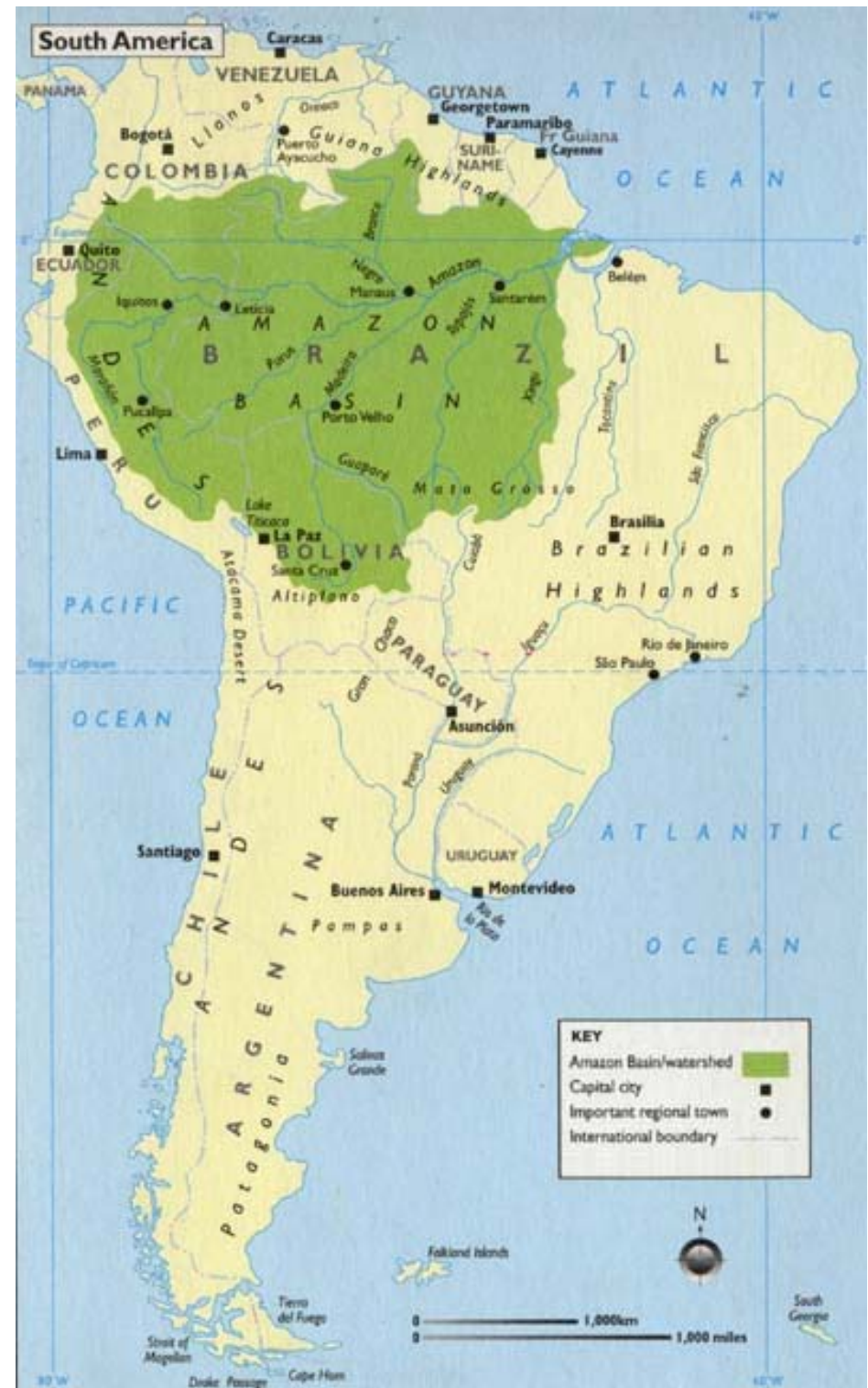
Great Rivers of the World

River	Length (km)	Discharge (cubic m/s)	Basin Area (km ²)	Discharge per area (m ³ / km ²)
Nile	6690	1,600	2,900,000	0.00055
Amazon	6296	180,000	7,000,000	0.026
Mississippi -Missouri	5970	17,500	2,980,000	0.0056
R. de la Plata	4700	19,500	2,650,000	0.0074
Congo	4700	42,000	3,822,000	0.011
Orinoco	2560	28,000	1,086,000	0.0258

<http://www.rev.net/~aloe/river/>

Amazon Drainage Basin

Its total drainage basin encompasses about one-third of South America, an area more than 10 times the size of Texas and nearly as large as the entire contiguous United States. Rain falls about 200 days each year, and total rainfall exceeds 80 inches per year. One result of so much rain is that Amazonia is covered by the largest tropical rain forest in the world.



THE AMAZON



<http://www.mbarron.net/Amazon/bigmap.htm>

The Superlative Amazon

Heavy rains drench the region especially between January and June. During the months of maximum precipitation, broad areas are flooded. In Brazil the width of the river ranges between 1.6 and 10 km (1 and 6 miles) at low water but expands to 48 km (30 miles) or more during the annual floods, when the water level rises 15 m (50 ft) above normal. To drain the vast mass of water, the Amazon has carved a deep bed in the plain through which it flows. In one section near Óbidos, the channel is more than 91 metres (300 ft) deep. The Amazon is often called the Ocean River and is navigable to ocean liners for two-thirds of its course. Transatlantic ships call regularly at Manaus, nearly 1,600 km upstream, and ships of 3,000 tons can reach Iquitos, Peru, 3,700 km from the river's mouth, the farthest point from sea of any port serving ocean traffic. The river is made up of over 1,100 tributaries, 17 of which are longer than 1000 miles, and two of which (the Negro and the Madeira) are larger, in terms of volume, than the Congo river. The Amazon enters the Atlantic through a broad estuary, 240 km (about 150 mi) wide. During new and full moon a tidal bore, or wave front from the ocean, sweeps some 650 km (more than 400 mi) upstream at speeds in excess of 65 km/hr (40 mph). This phenomenon often causes waves up to 5 m (16 ft) in height.

Q: Why is there so much water in the Amazon?

A: It rains more over the Amazon drainage basin than over other river basins

Q: Why does it rain so much here?

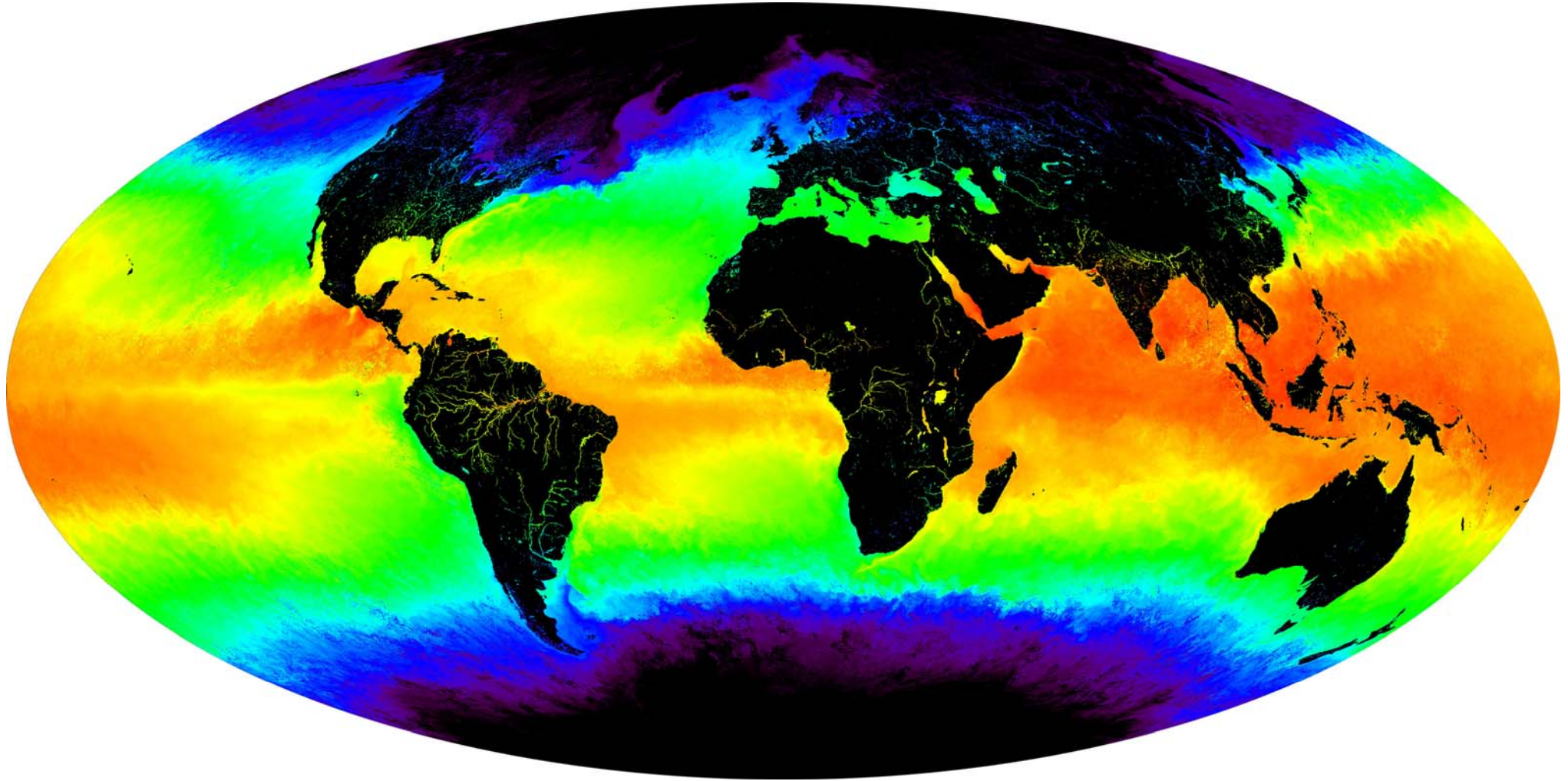
A: ITCZ and Orographic Effect.

Q: What's that?

Rain forms when warm, moist air rises

- Warm air holds more moisture (water vapor or water in gaseous state) than cold air.
- Air cools as it rises because of expansion.
- Cool air holds less water vapor than warm air.
- Excess water condenses out as droplets and falls to the ground as precipitation (rain or snow).
- Abundant rainfall over the Amazon Basin indicates there is a lot of air rising over the region.

Sea surface temperature

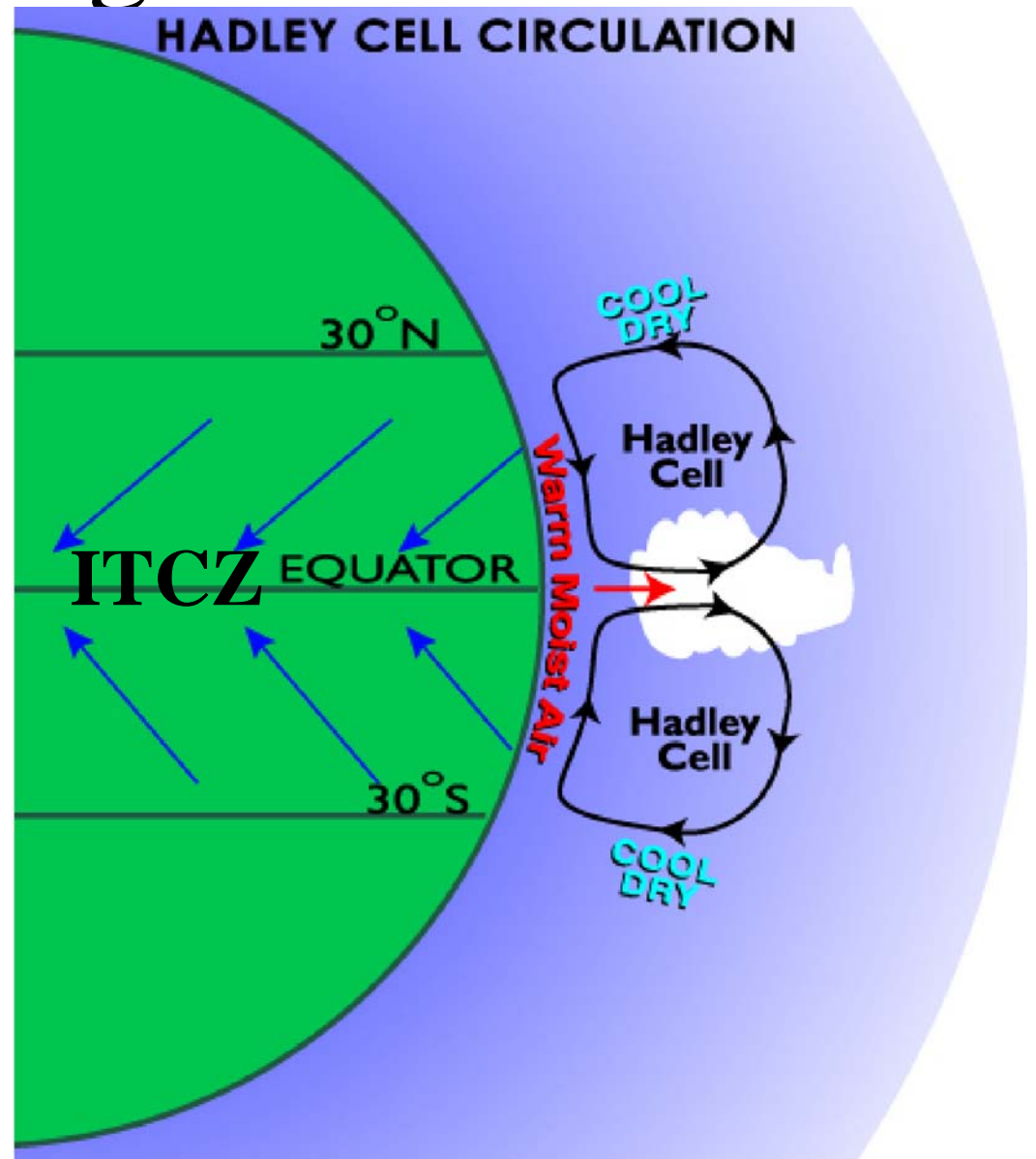


MODIS; Red = warm, blue = cold

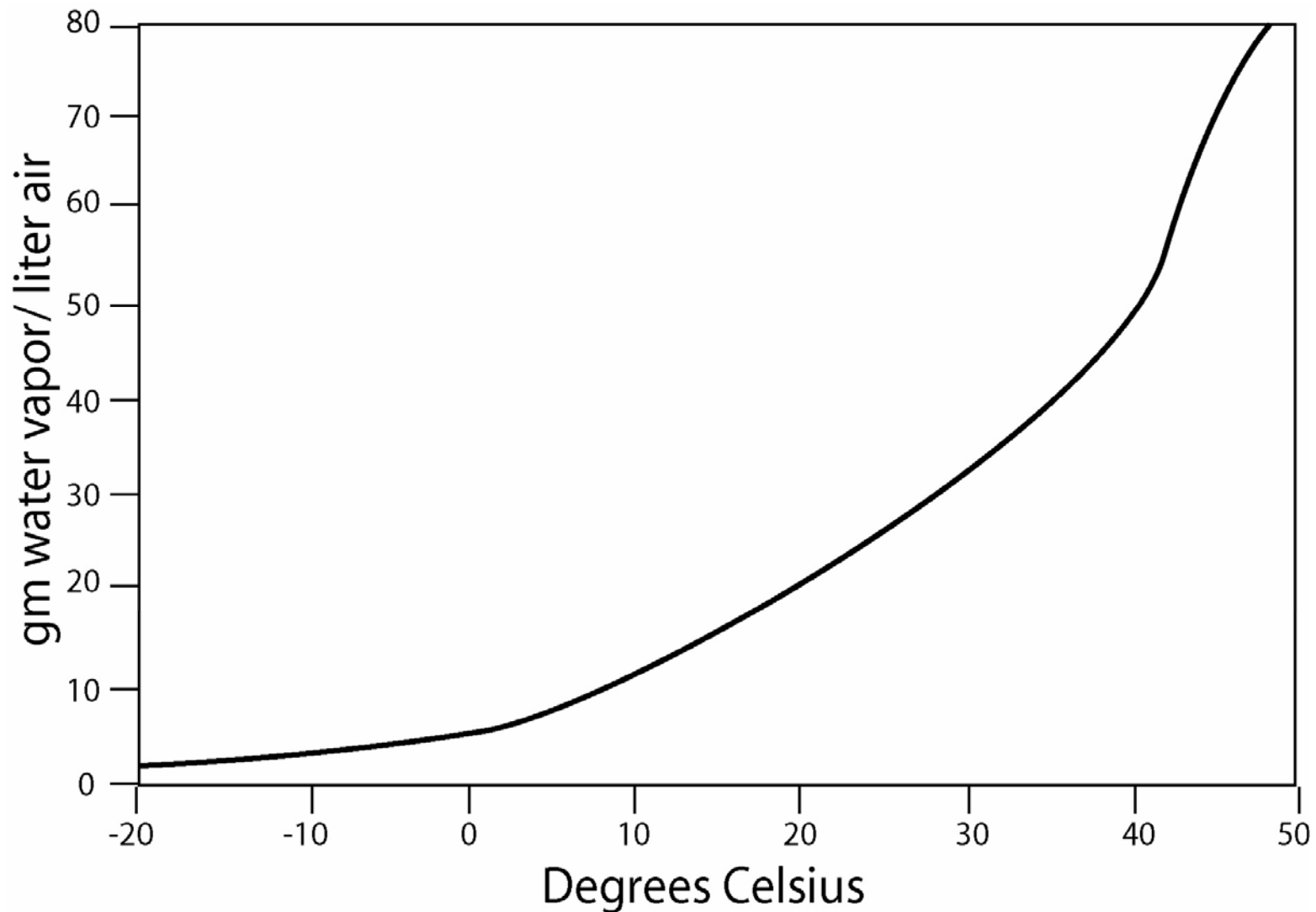
Hadley Cells and the Inter-Tropical Convergence Zone

Solar heating is greatest near the equator and air is warmed at the surface and rises. This creates a band of low air pressure, centered on the equator known as the **intertropical convergence zone (ITCZ)**. Air from the subtropics is drawn towards the ITCZ and rises. It rises to about 14 kilometers (top of the troposphere), and then begins flowing horizontally north and south. This rising air comprises one segment of a circulation pattern called the **Hadley Cell**. The Hadley Cell eventually returns air to the surface of the earth, near 30° N and S.

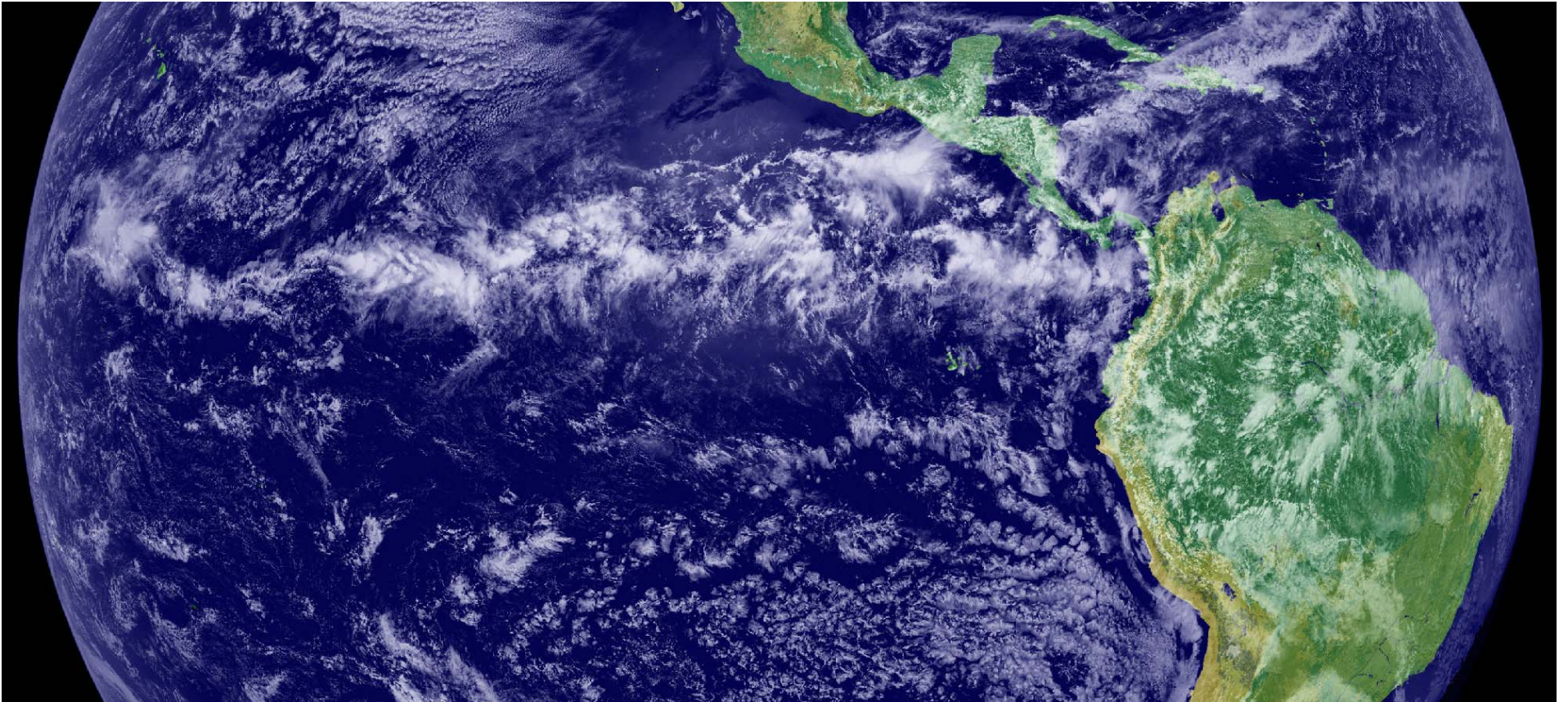
http://www.planearthsci.com/products/Hurricanes/tutorial%20pieces/Easterly_%20Waves/Trade_Winds/Trade_Winds.html



Warm air holds a lot of water vapor, cold air doesn't



Satellite image of ITCZ

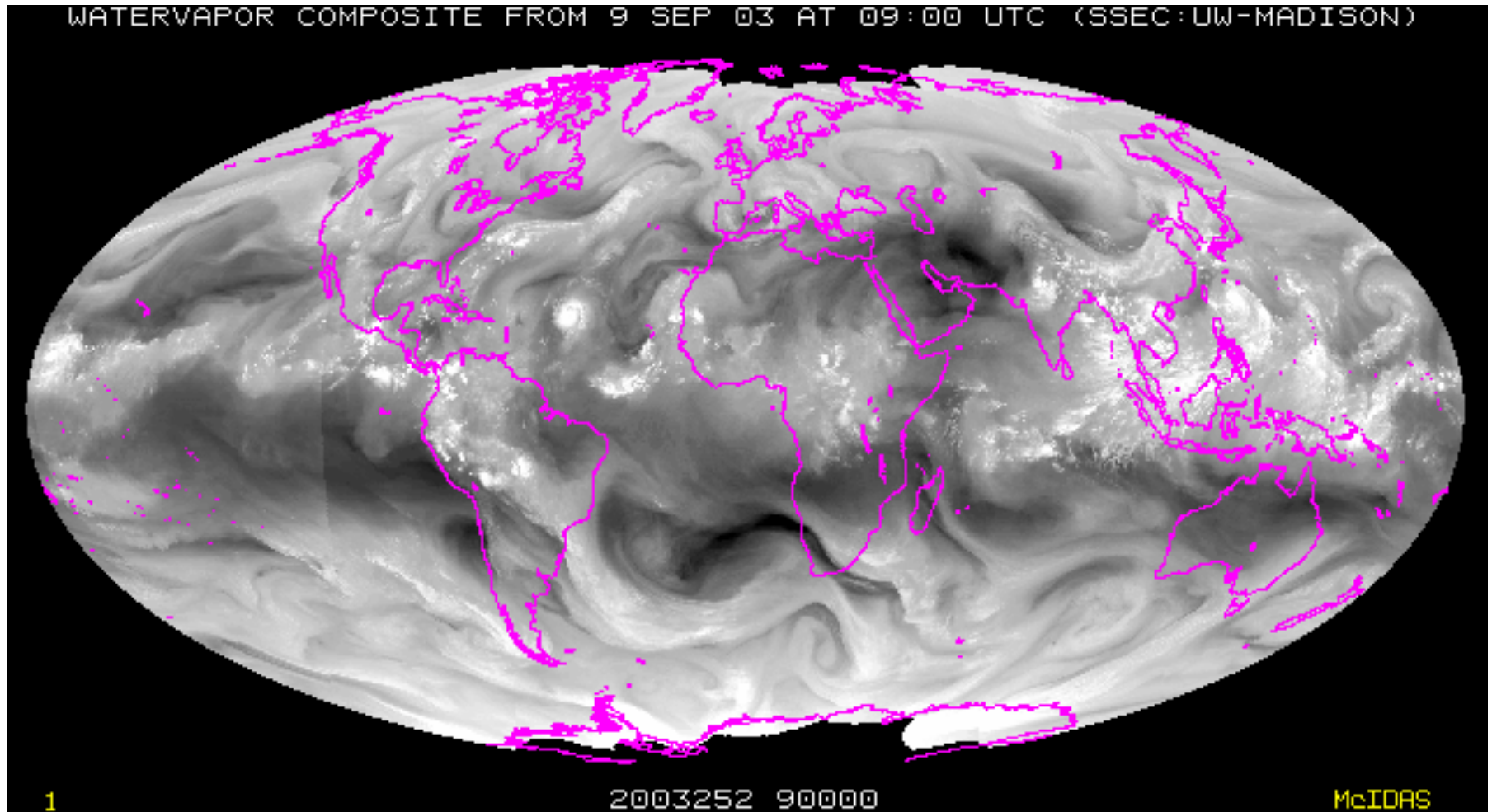


The ITCZ is the band of bright white clouds that cuts across the center of the image. This image is a combination of cloud data from NOAA's newest Geostationary Operational Environmental Satellite (GOES-11) and color land cover classification data.

<http://visibleearth.nasa.gov/cgi-bin/viewrecord?2100>

Global Water Vapor in Atmosphere

(white = high concentrations, dark = low concentrations)



<http://www.ssec.wisc.edu/data/composites.html>

NASA's Tropical Rainfall Mapping Mission (TRMM) has five instruments

■ Precipitation Radar

- The Precipitation Radar has a horizontal resolution at the ground of about 2.5 miles (four kilometers) and a swath width of 137 miles (220 kilometers). One of its most important features is its ability to provide vertical profiles of the rain and snow from the surface up to a height of about 12 miles (20 kilometers)

■ TRMM Microwave Imager

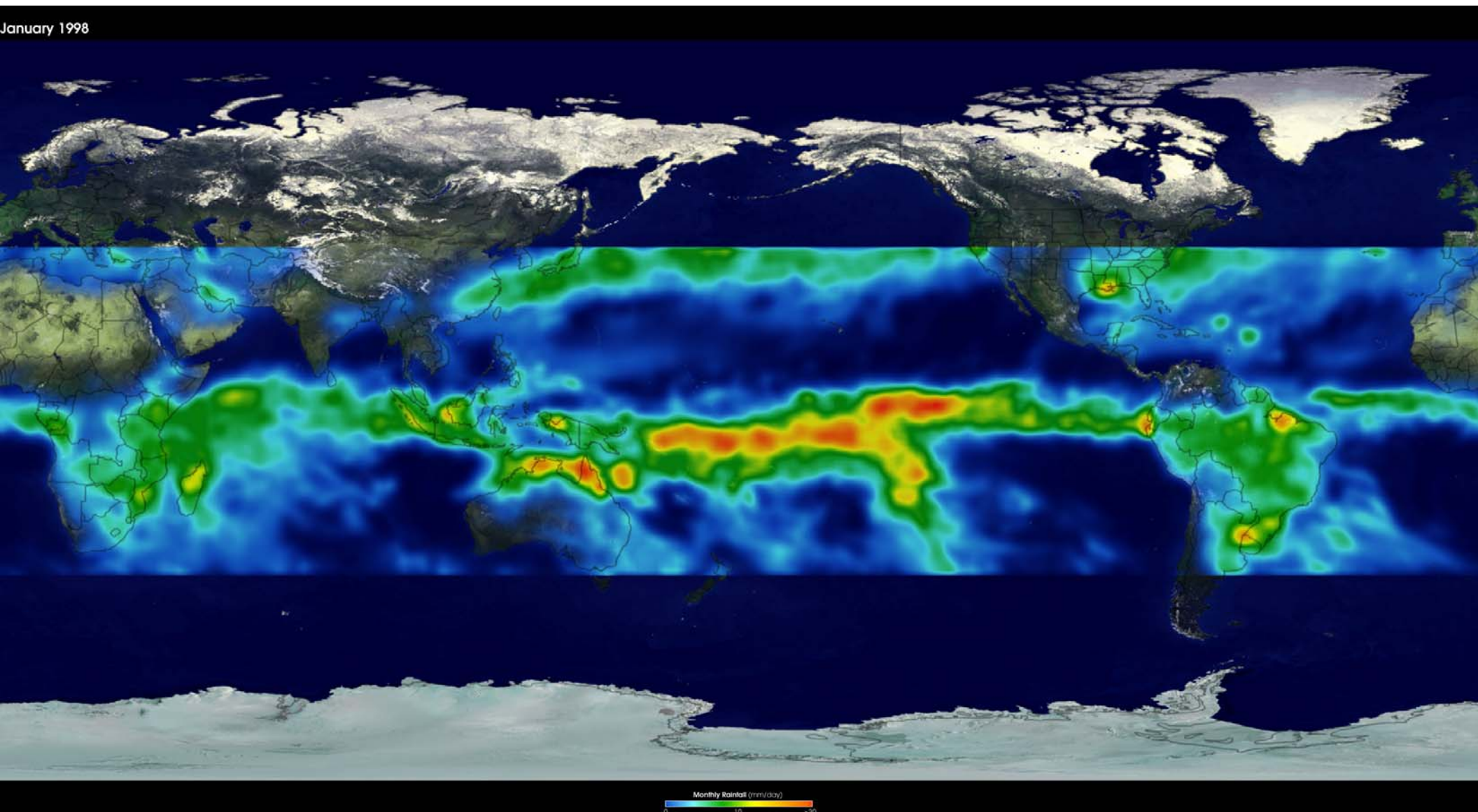
■ Visible Infrared Radiometer

■ Cloud and Earth Radiant Energy Sensor

■ Lightning Imaging Sensor



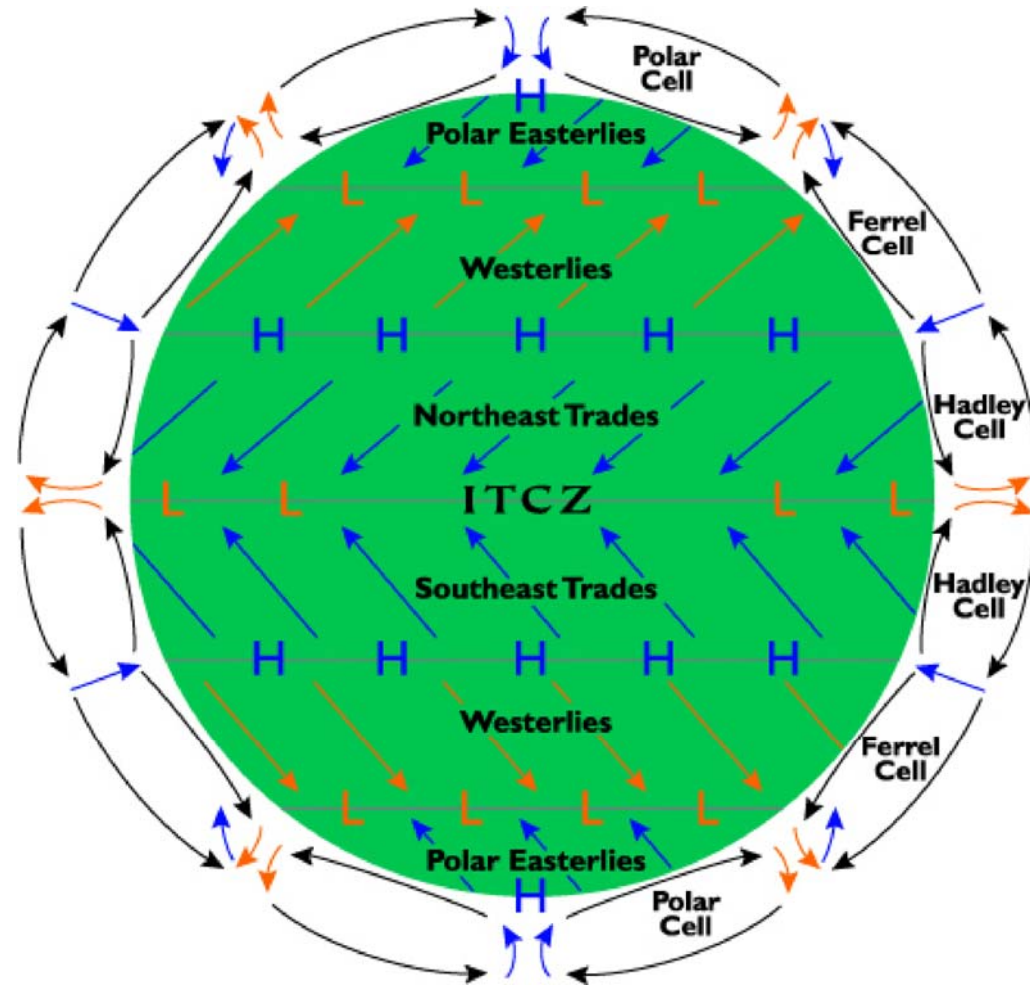
Rainfall (Jan. 1998 TRMM data)



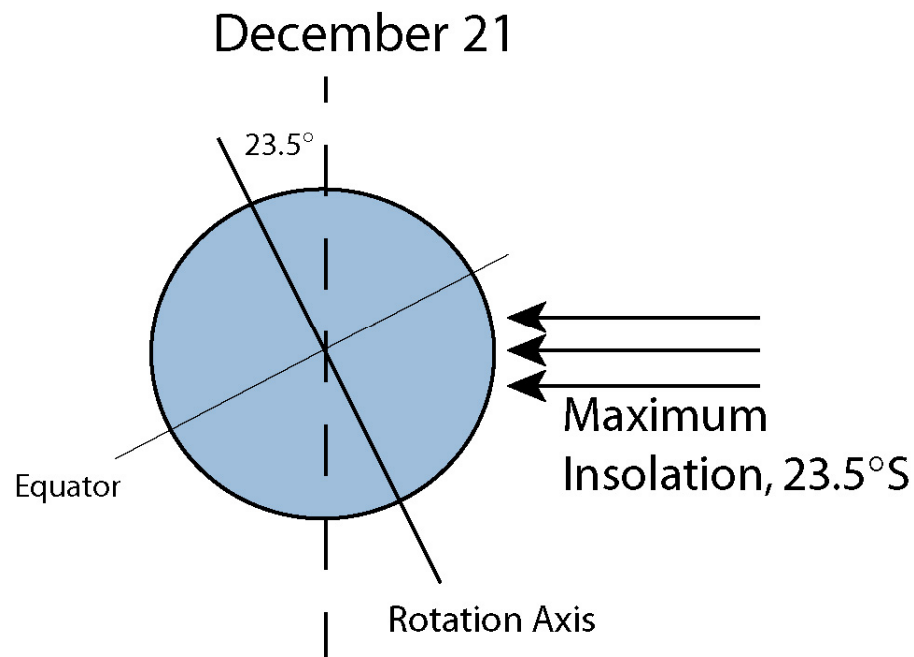
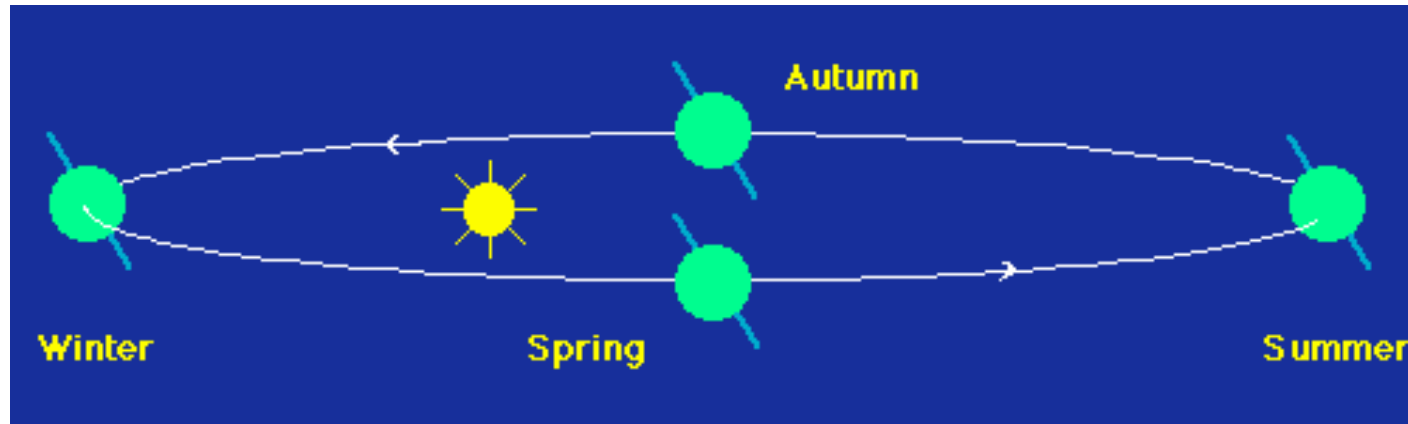
The ITCZ and the Trade Winds

Because air rises along the ITCZ into the upper atmosphere due to solar heating, air from north and south flows in to replace the rising air. Because of Earth's rotation, these winds are deflected to flow west, forming the trade winds.

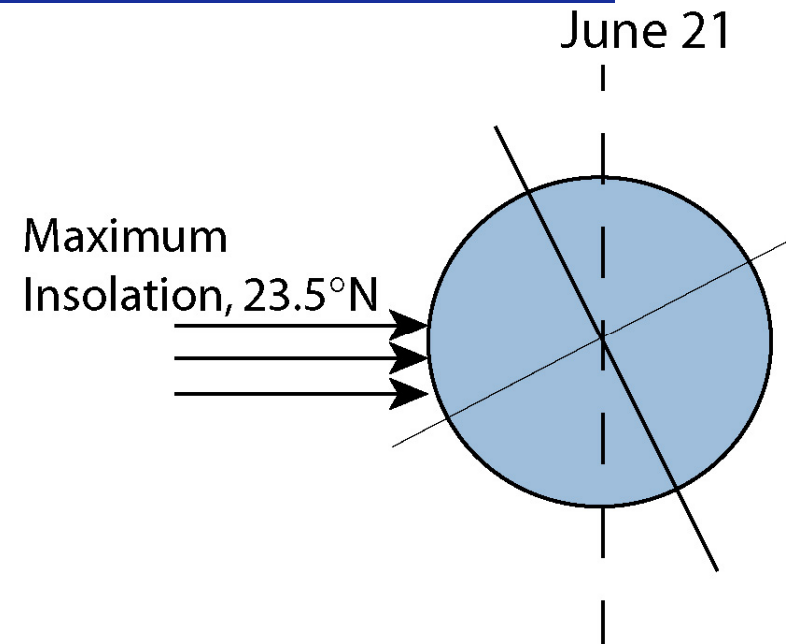
http://www.planearthsci.com/products/Hurricanes/tutorial%20pieces/Easterly_%20Waves/Trade_Winds/Trade_Winds.html



ITCZ migrates with the seasons

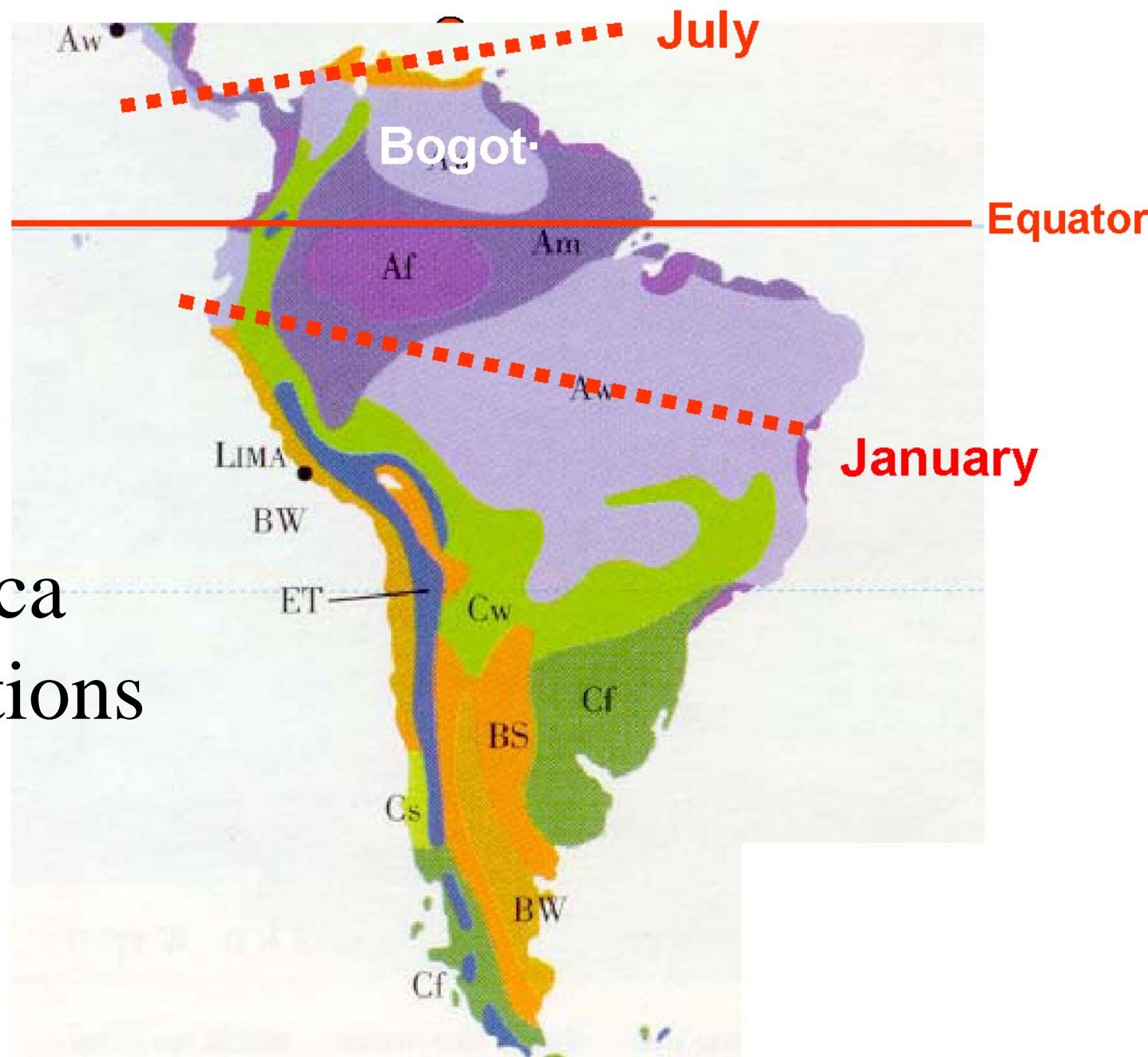


ITCZ moves south



ITCZ moves north

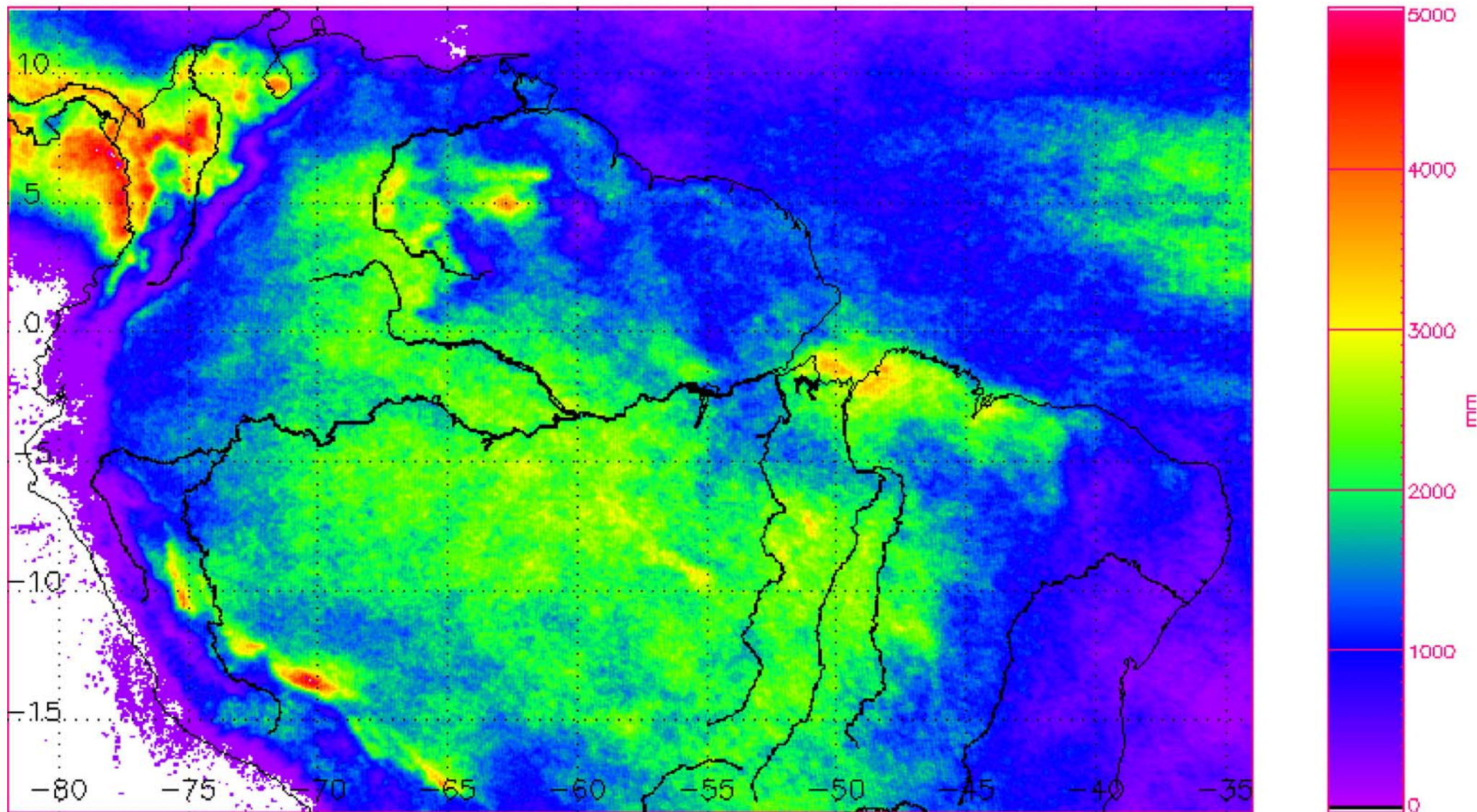
Latin America ITCZ migrations



The Migrating ITCZ (TRMM)

- .Global
- Amazon Precipitation

Estimated mean rainfall (in mm) for 2000

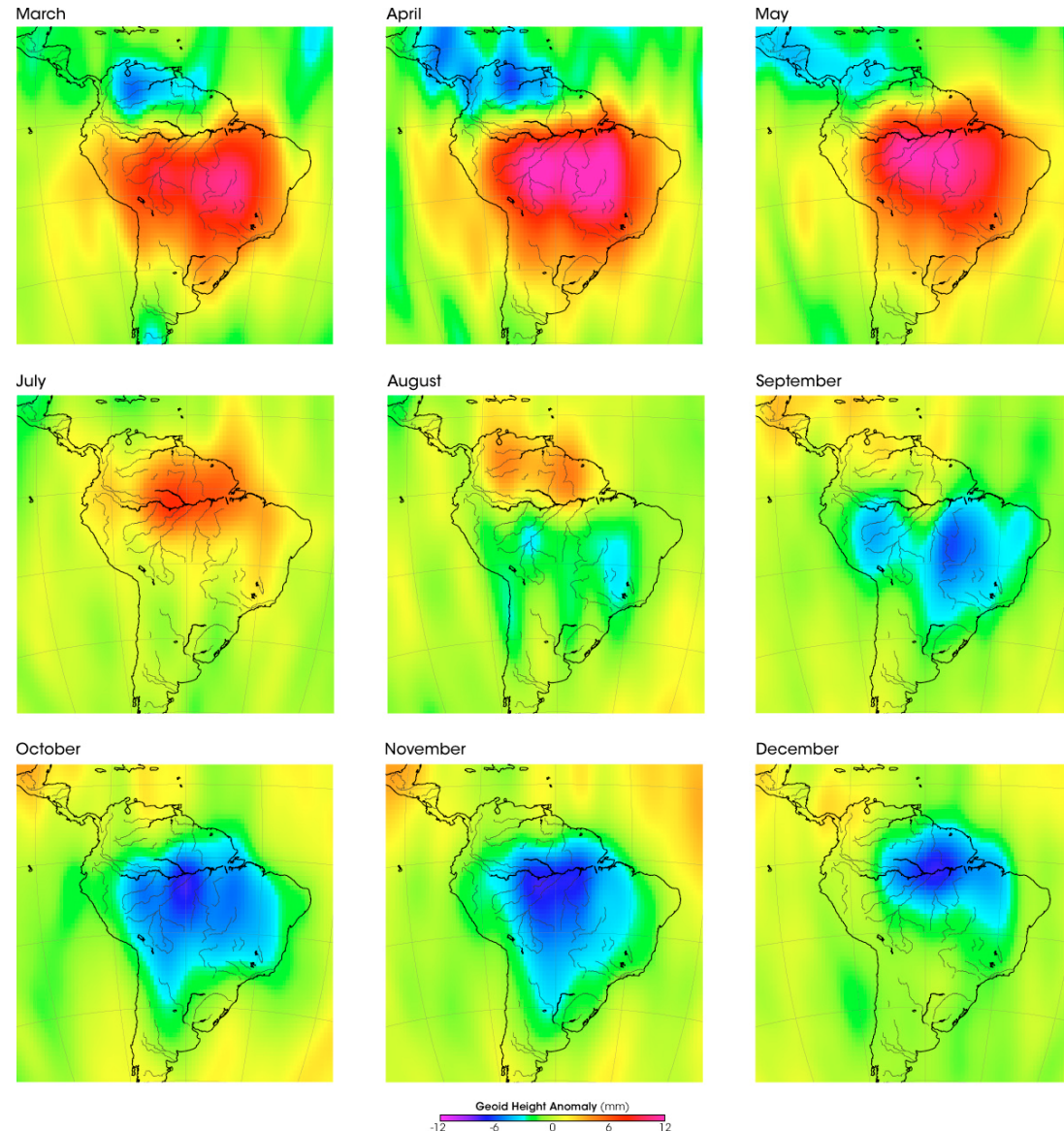


Estimated mean rainfall (in mm) for 2000 using GOES IR with TMI calibration (A. Negri, GSFC)

These images show monthly changes in gravity detected by NASA's Gravity Recovery and Climate Experiment (GRACE) between March and December 2003. Changes in gravity are due to changes in the amount of water on or below the surface. Each shows the difference between that month's gravity and the region's average gravity. Orange, red, and pink show areas of higher-than-average gravity (more water) while green, blue, and purple have lower-than-average gravity (less water).

<http://earthobservatory.nasa.gov>

Amazon Basin water measured from space

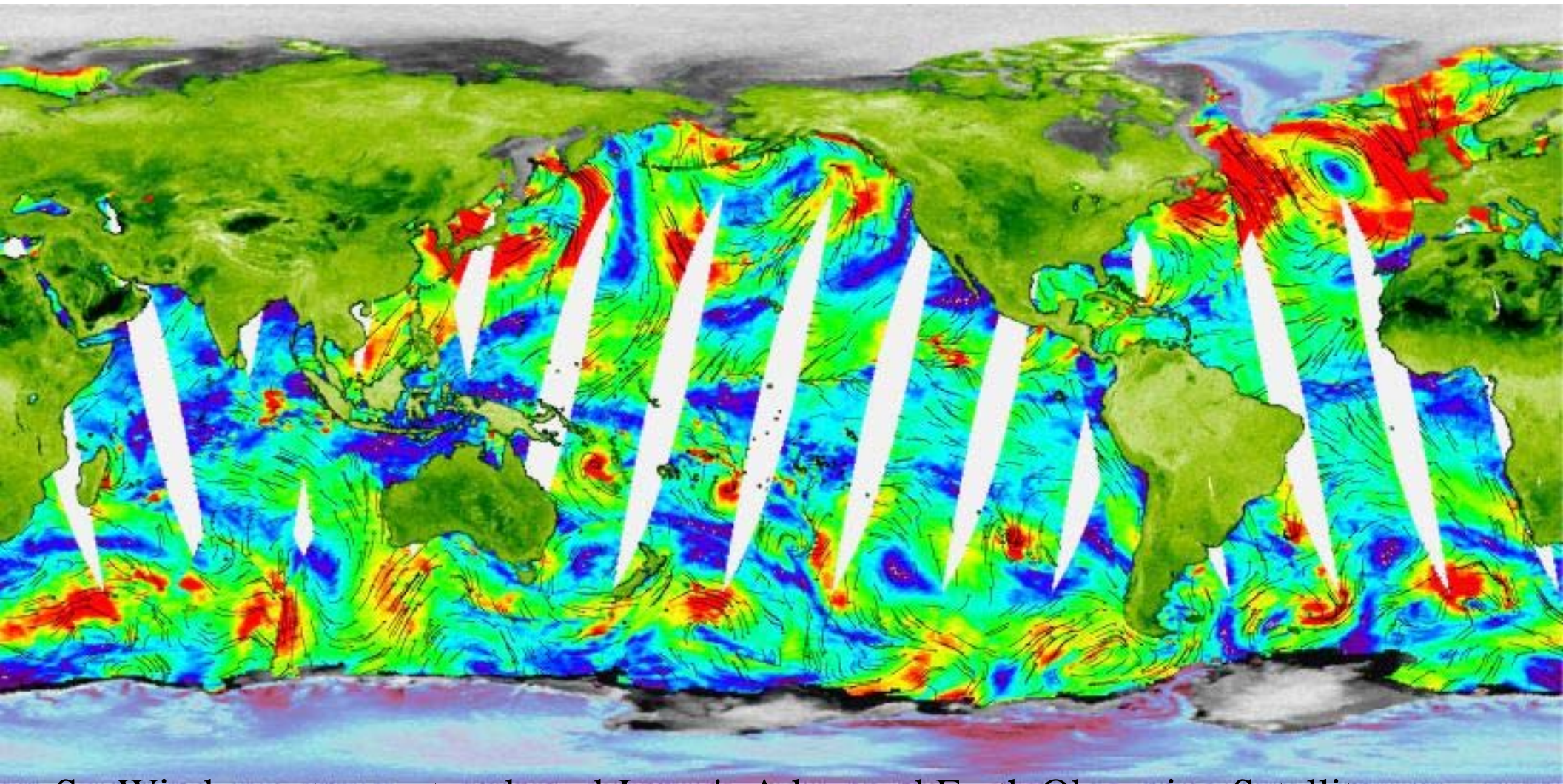


Water Budget of the Amazon Basin

The Amazon Basin receives an average of around 2 meters of rainfall, equivalent to 13,303 cubic km of water. Approximately 60% of this amount is recycled by evapo-transpiration, and the other 40% ends as runoff feeding the Amazon River. About 5,324 cubic km of fresh water is delivered annually at an average rate of 170,000 cubic m/sec to the Atlantic Ocean (~10x discharge of Mississippi River).

<http://www.geocities.com/CapeCanaveral/Hangar/5047/amazonia.htm>

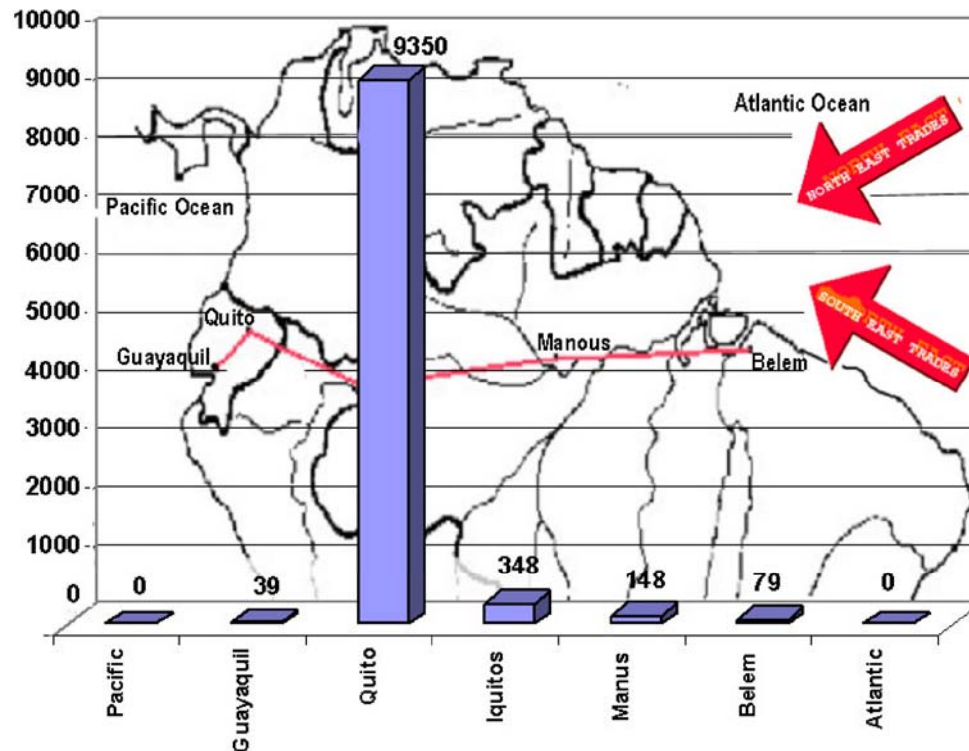
Amazon Basin lies in the Trade Winds belt



SeaWinds scatterometer aboard Japan's Advanced Earth Observing Satellite (Adeos) 2--now renamed Midori 2. Ocean surface wind speeds, measured during a 12-hour period on January 28, are shown by colors, with blues corresponding to low wind speeds and reds to wind speeds up to 15 meters per second (30 knots). Black arrows denote wind direction.

<http://photojournal.jpl.nasa.gov/catalog/PIA03896>

Orographic Precipitation in the Andes

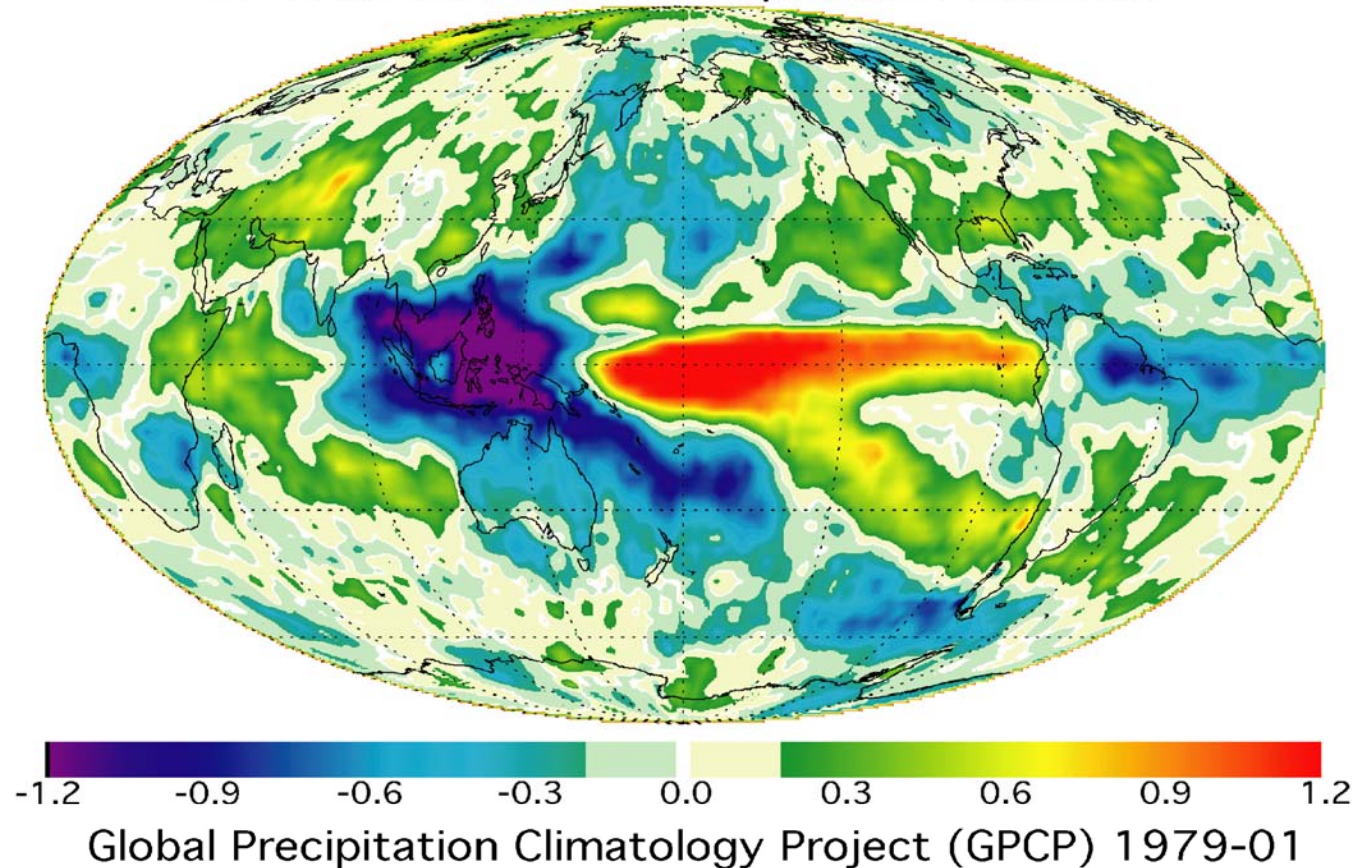


The orographic effect on the eastern slope of the Andes accounts for the largest share of the precipitation that flows into the Amazon. The map and the graph - which plots rainfall along the E-W transect (red line) - show the orographic effects of South American landform distribution. Warm wet trade winds cross over Belem with an elevation of only 89 feet, more than 1500 miles to the west, the elevations achieved by the air mass is about 3500 feet. Then the moisture of the air mass is squeezed out as the air rises more than 10,000 feet in about 200 miles to cross the Andes. This is reflected in the low latitudes by the difference between the nearly 200 inches of rain east of the Andes and the less than 10 inches along the coast.

<http://sis.spsu.edu/SouthAmer.htm>

Effect of El Niño on Amazon rainfall

El Niño minus La Niña Composites
of Global Normalized Precipitation Anomalies

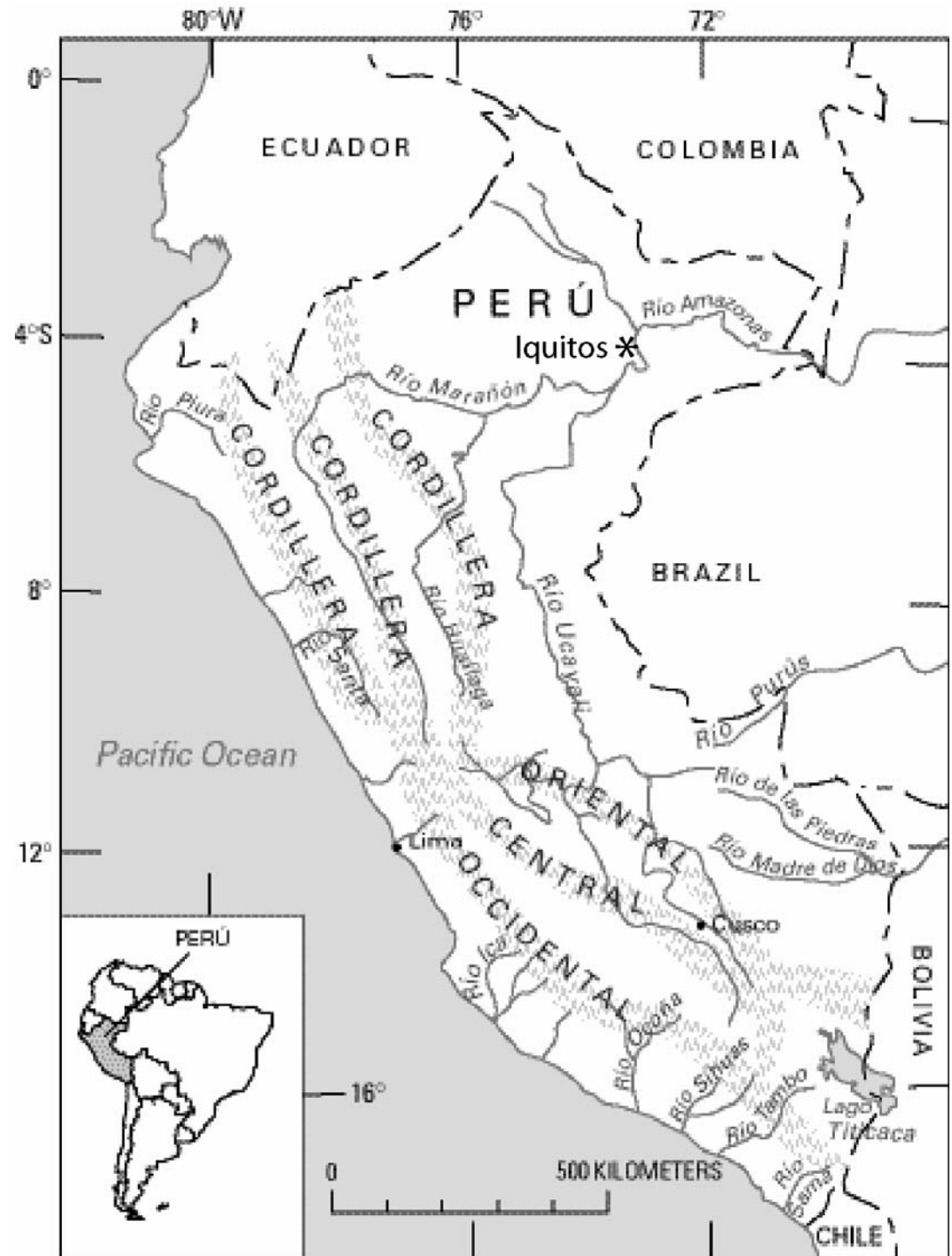


Curtis, S., and R. F. Adler, 2003. The evolution of El Niño-precipitation relationships from satellites and gauges. *JGR-Atmospheres*, 108, NO. D4, 4153, doi:10.1029/2002JD002690, 2003

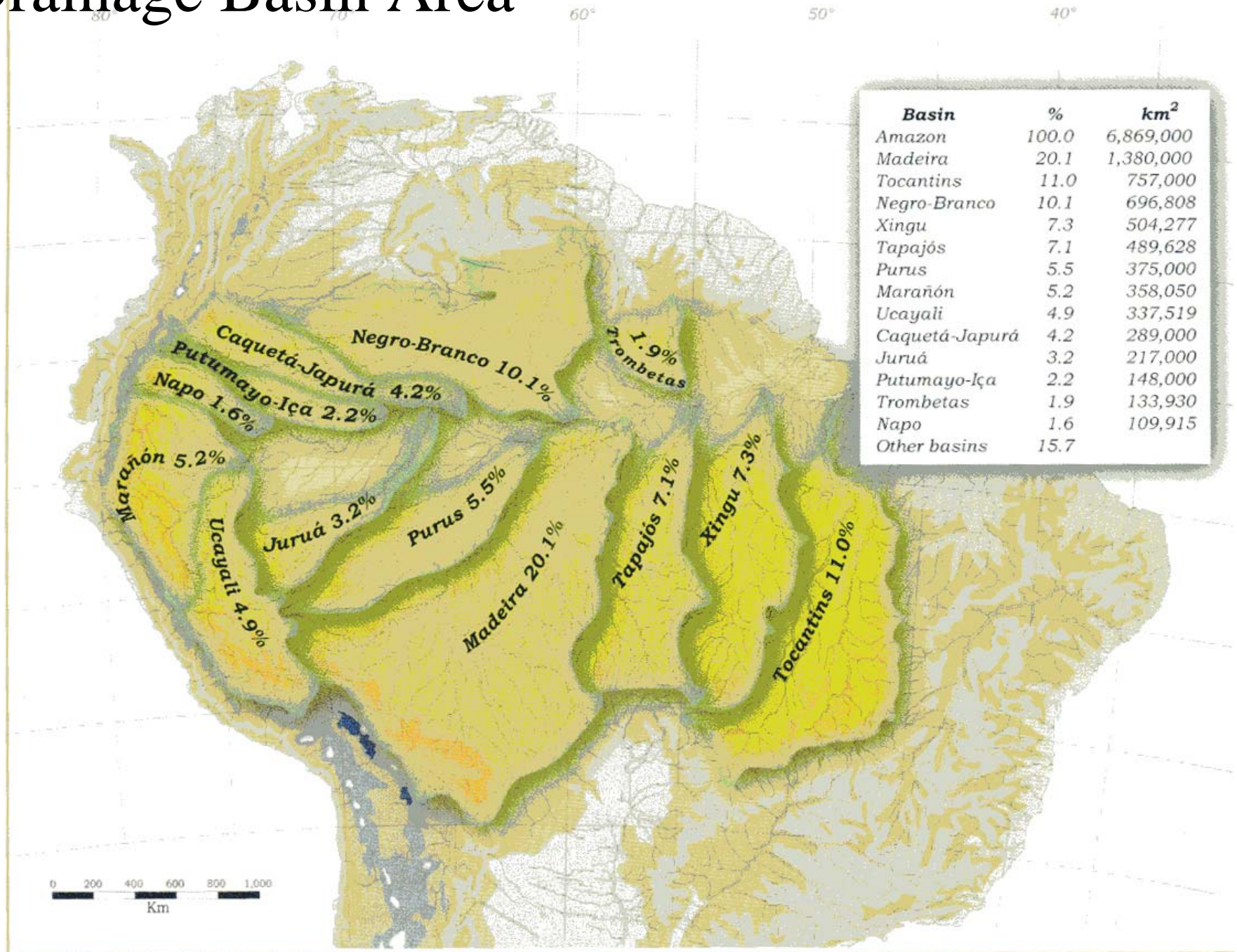
Headwaters of the Amazon in Peru

The great river begins as hundreds of tiny streams high in the Peruvian Andes, some of them within 100 miles of the Pacific Ocean. Rushing down the slopes, stream after stream continues to merge to form larger and larger rivers. Near Iquitos in eastern Peru, the northeastward flowing Ucayali and the Rio Marañon, the two main headwaters of the Amazon, unite to form a truly major river. Iquitos is the point farthest upstream that shallow draft-freighters and passenger vessels can penetrate (deep-water ships can reach as far as Manaus in central Brazil).

Figure from Morales-Arnan in
USGS Prof. Paper 1386I

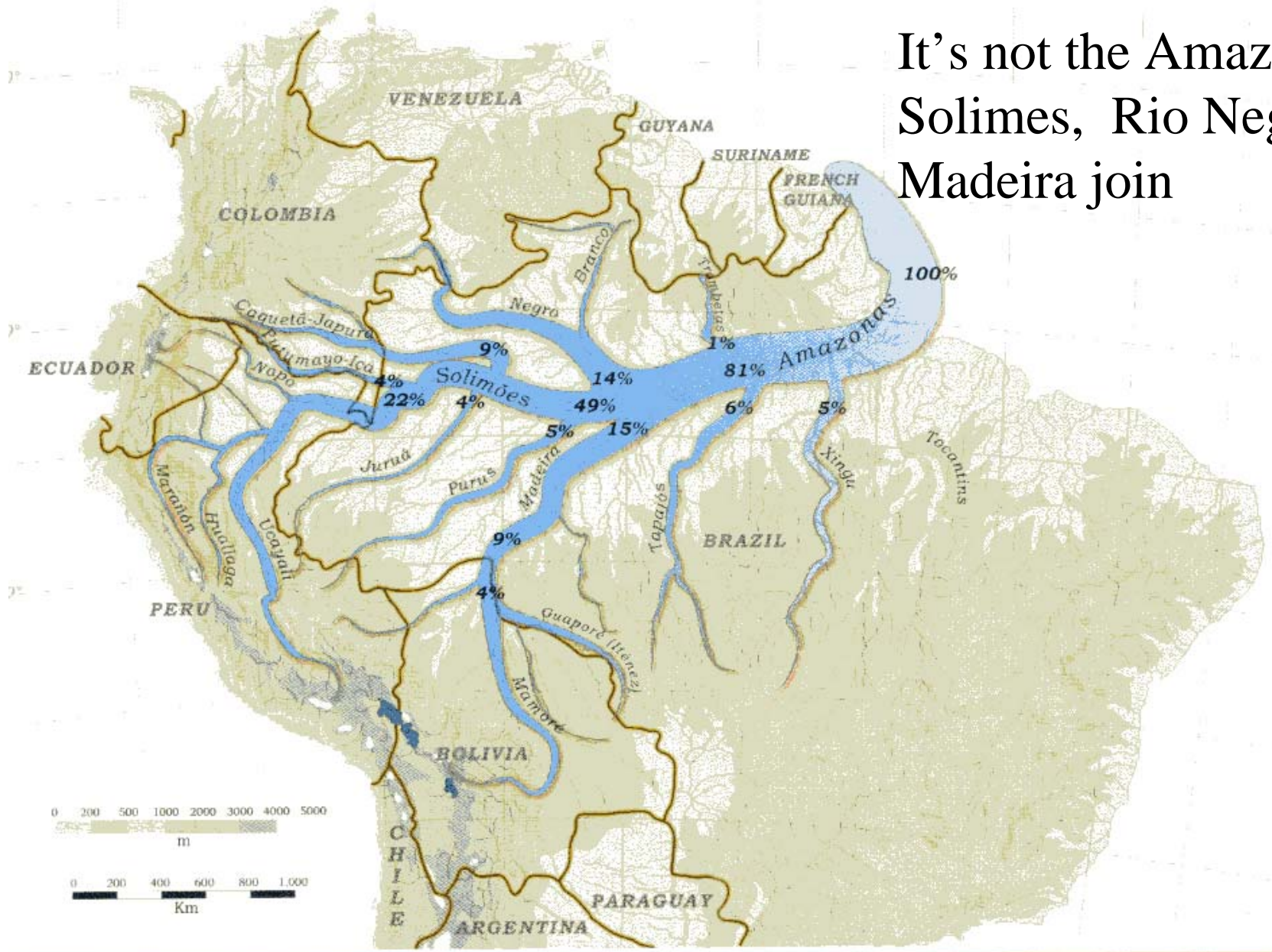


Drainage Basin Area



Contribution of Tributaries (% water)

It's not the Amazon until the Solimões, Rio Negro, and Madeira join



Source of the Amazon - headwaters of the Ucayali



Lago Lauricocha, Peru

Nevado Mismi, Peru



Mountain rivers of Peru



Rio Huallaga



Rio Urumbaba

http://www.virtualperu.net/peru_phys_geo_amazonas.html

Iquitos to Manaus

Beyond Iquitos the river changes both its character and course. Turning abruptly eastward, it more or less parallels the equator as it meanders over lowland plains. At Iquitos the river also changes its name. Locally it is known as the Solimoes from Iquitos to its junction with the Rio Negro at Manaus, and is called the Amazon only from Manaus to the sea.



Iquitos and a view of the Solimoes
http://www.virtualperu.net/peru_phys_geo_amazonas.html

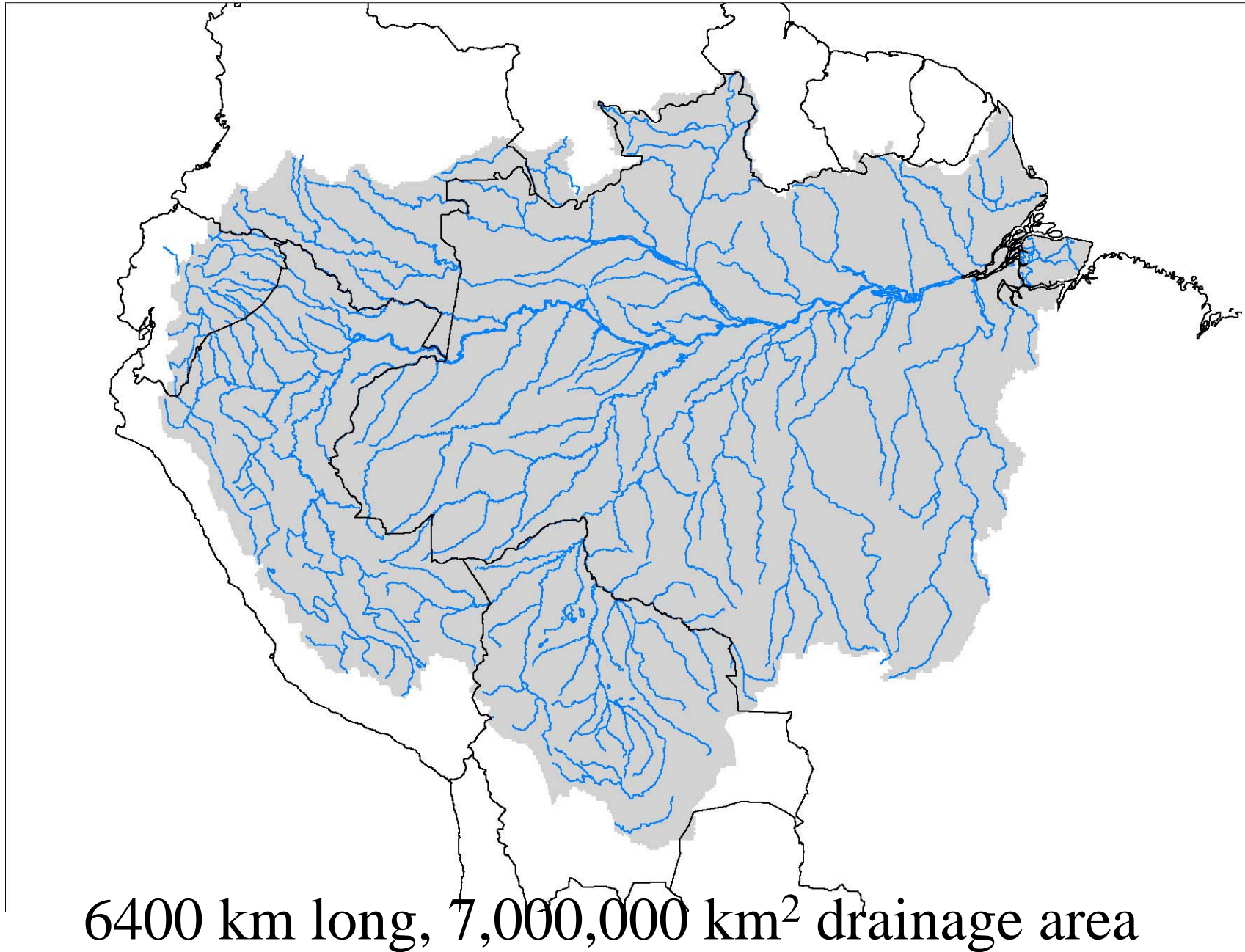
Tributaries of the Amazon

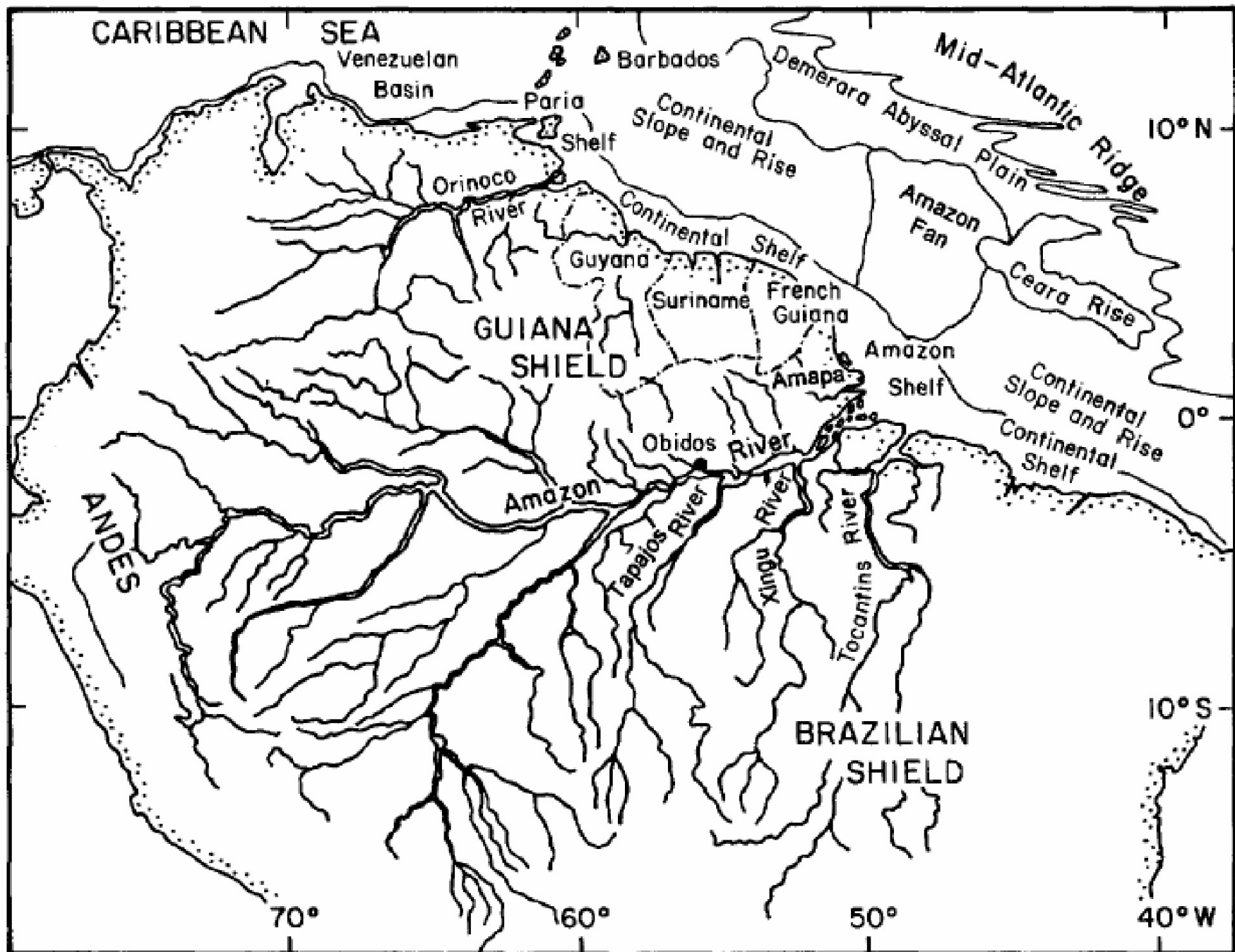
All along the course of the river there are seasonal floods. Tributaries flowing from the south tend to reach their highest stages from February to April (when the ITCZ lies south of the equator), while those coming from the north tend to crest in June and July (when the ITCZ is north of the equator).

On its long journey to the sea, the Amazon also varies in color. Some of its tributaries are called "white" rivers, though their color is more often a murky yellow or tan. Others are known as "black" rivers, their waters dark but crystal clear. The white rivers rise in the Andes, and their turbidity results from the heavy loads of mud and silt they carry. The black rivers, in contrast, rise in areas of ancient basement rock where little sediment remains to be washed away; only dissolved organic matter stains their clarity.

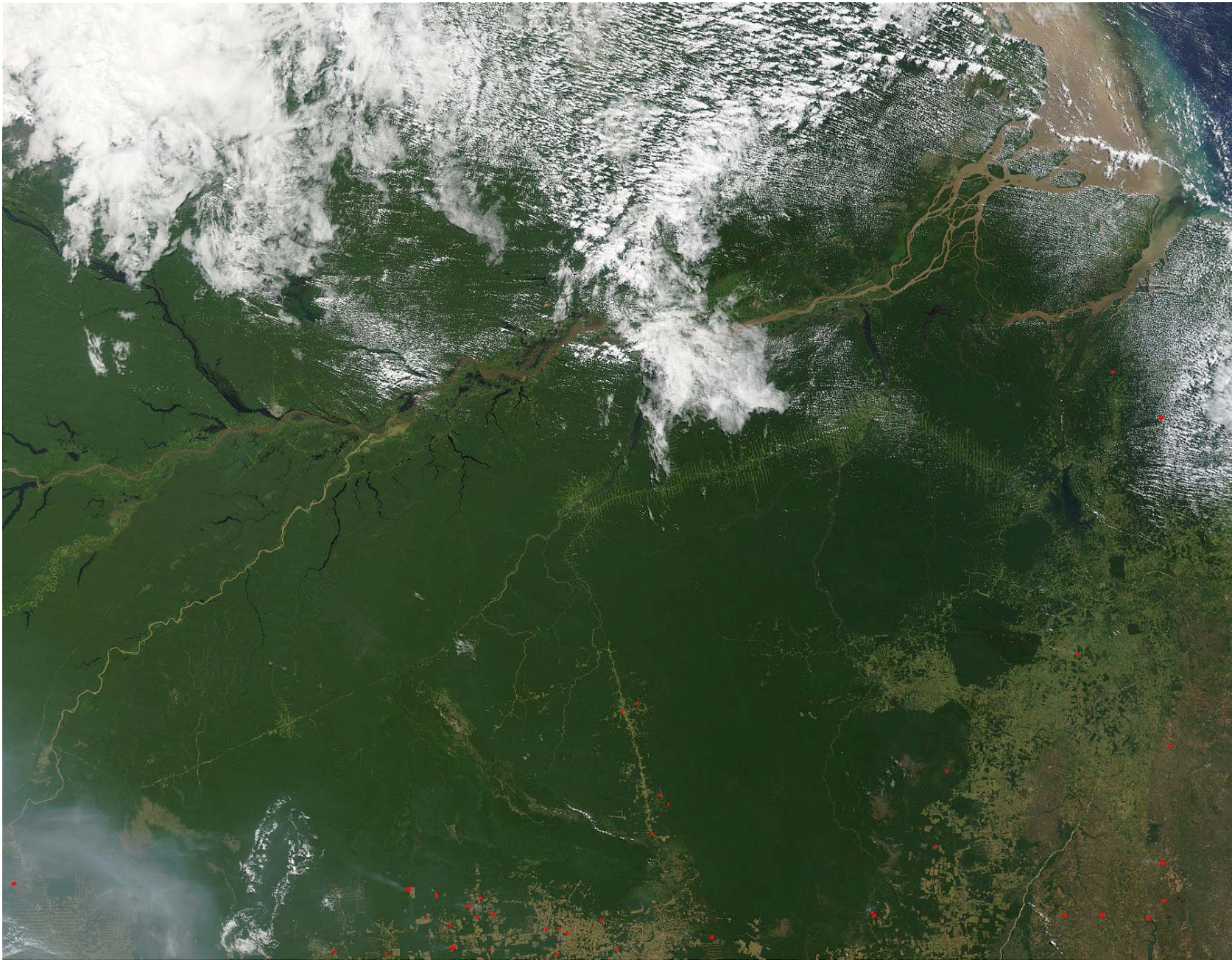
<http://www.sci.mus.mn.us/greatestplaces/notes/amazon.htm>

Amazon Basin and Tributaries



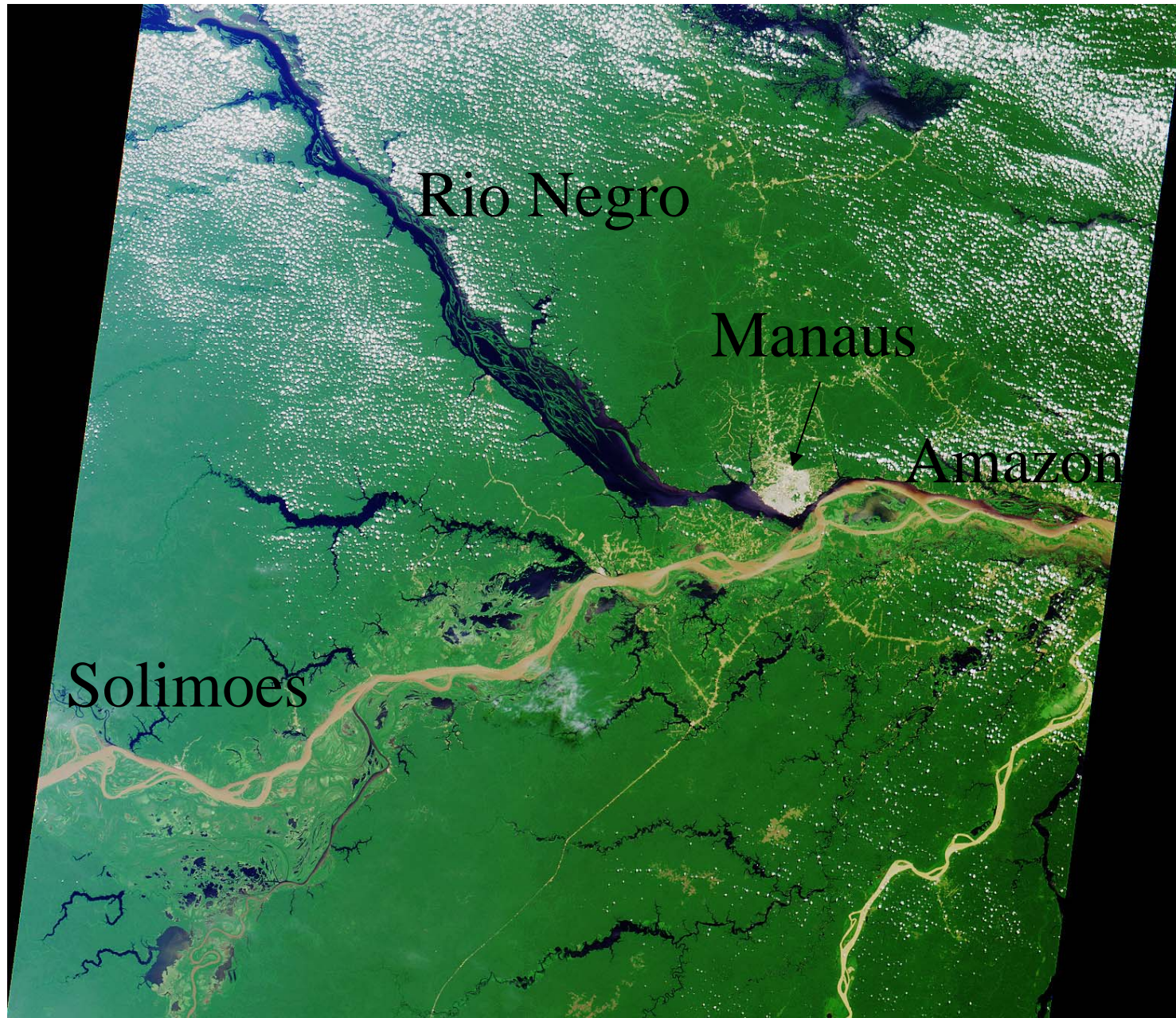


Nittrouer et al. 1995 Marine Geology



Eastern part of the Amazon River, which flows into the scene at the center left edge, a meandering brown line that widens as first the dark waters of the Rio Negro join it from the north and then the Madeira joins it from the south. MODIS image from Earth Observatory.

MISR image of Solimoes & Rio Negro



Meeting of the Waters



Close by the city of Manaus, Brazil, the Rio Negro, colored like black coffee, flows into the beige-colored Amazon main stream. For fifty miles downstream, the waters from the two rivers retain their distinct identity, yet flow together. This is called the 'Meeting of Waters' and is one of the area's main tourist attractions.

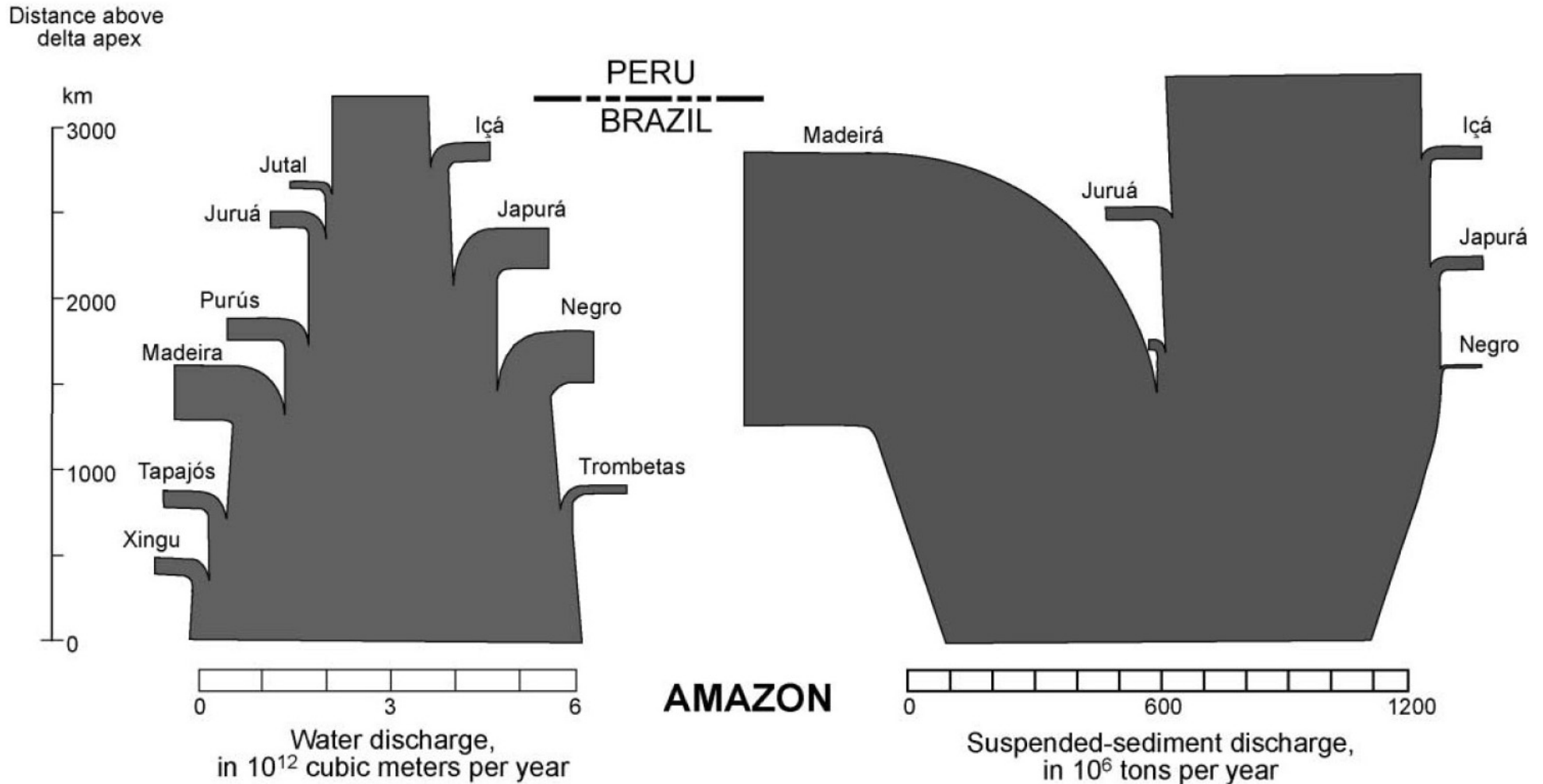
<http://www.junglephotos.com/scenery/river/mtgwtrs.html>

Muddy, Clearwater, and Blackwater Rivers

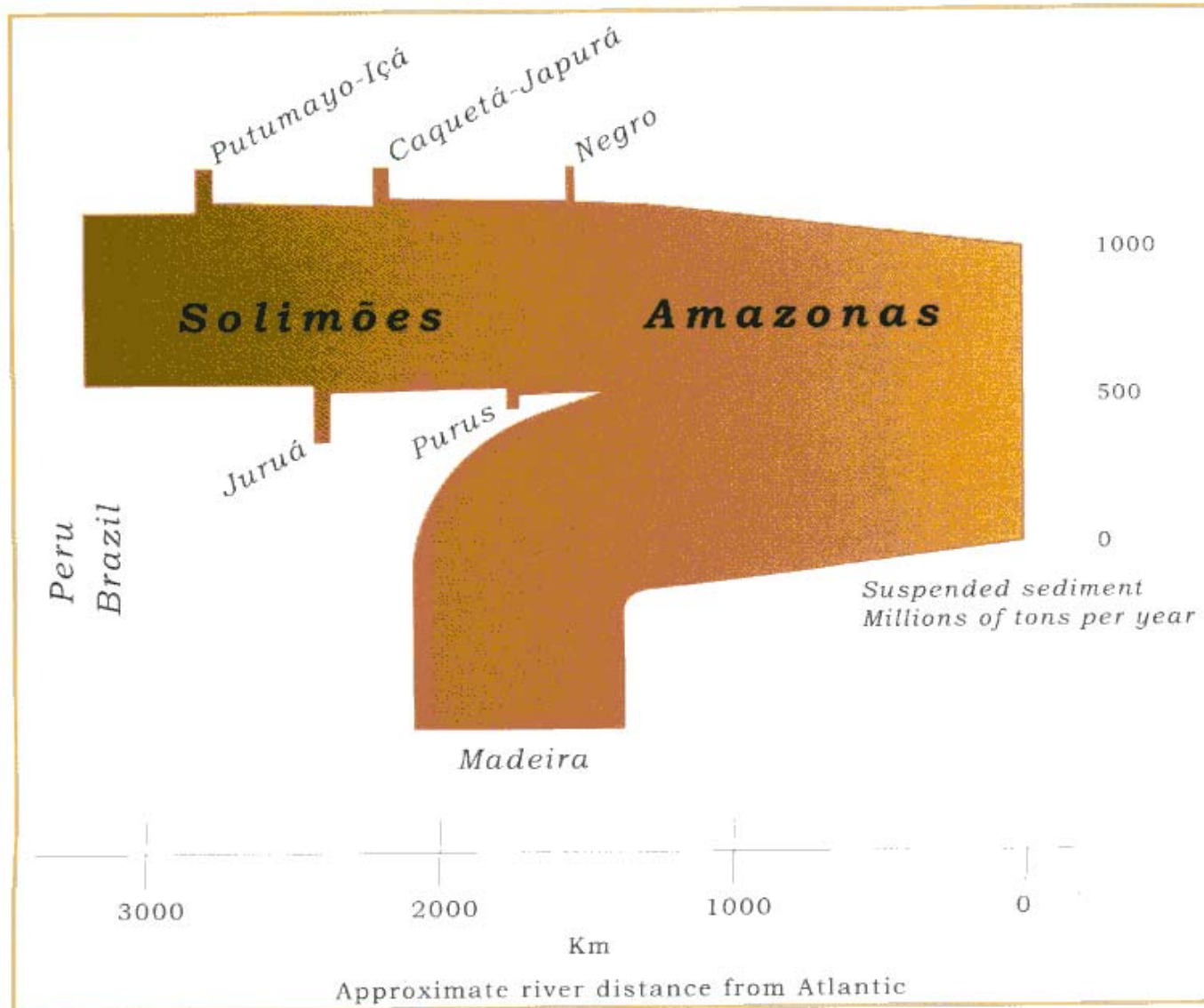
- Muddy rivers carry lots of sediments and originate in the Andes: Solimoes & Madeira



Amazon tributaries carry different proportions of sediment and water



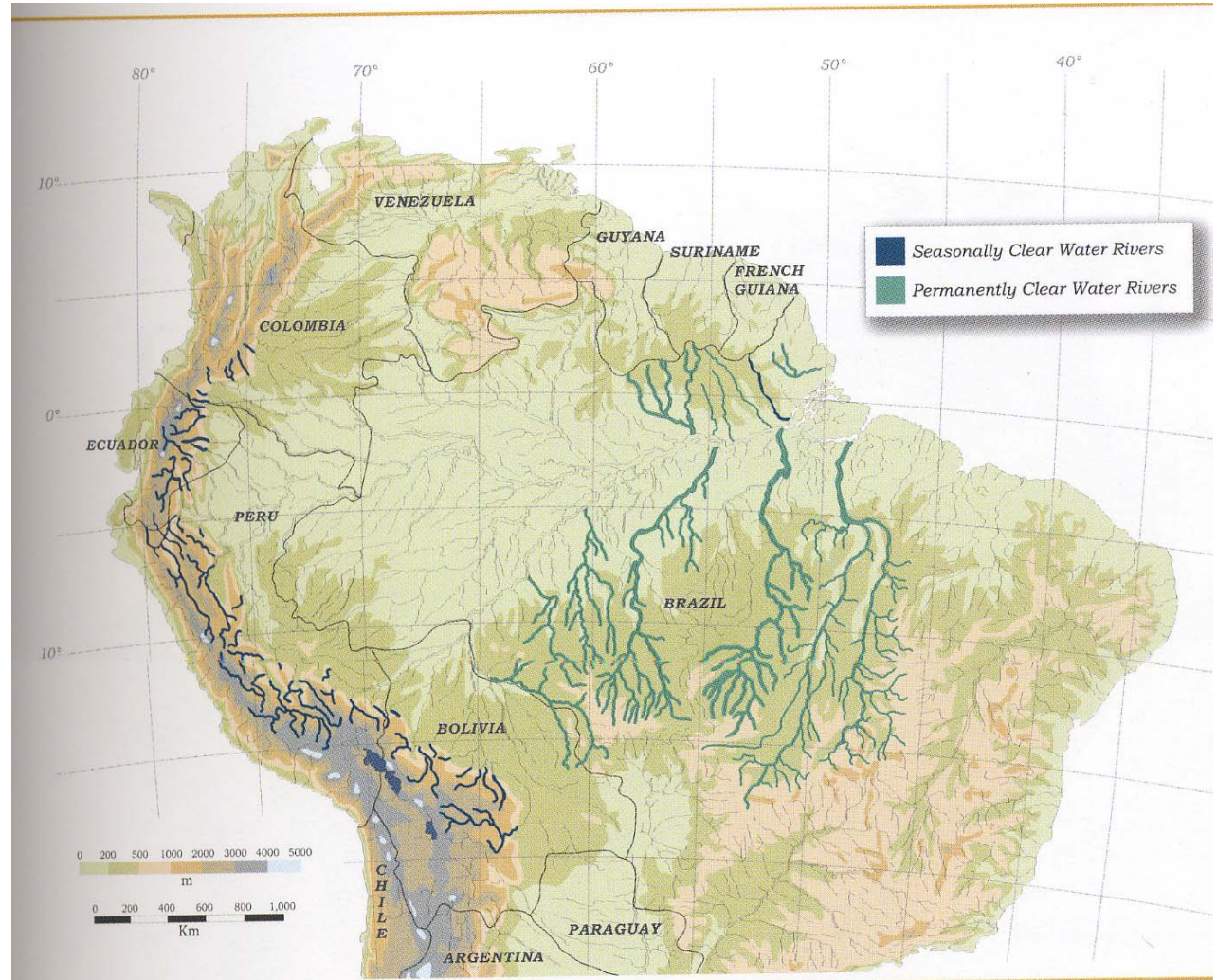
Sediment contributions



Most of the sediment carried by the Amazon comes from the big muddy rivers, especially the Solimoes & Madeira rivers.

Clearwater Rivers

- Have little sediment
- Mostly drain the Brazilian Shield to the south and the Andes above 400m elevation: Tapajos and Xingu rivers.



Atlas of the Amazon, 2003

Blackwater Rivers

- Dominated by organic compounds dissolved in water
- Mostly drain the Guyana Shield:
- Rio Negro





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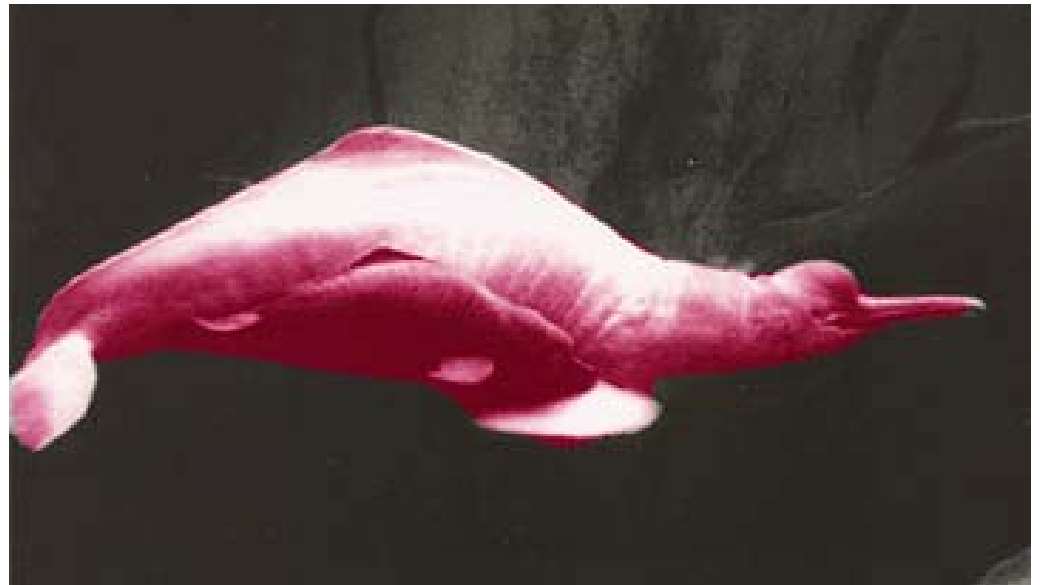
Rio Purus



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South American Dolphin



The South American dolphin, *Inia geoffrensis*, inhabits the Amazon and Orinoco rivers and fluctuates in color from bright pink to gray, depending on age and environmental factors such as sunlight, water temperature, and stress. **Size:** 2.5 to 3 meters (8.25 ft to 9.75 ft) and 90 kilograms (200 lbs.). Also called **boto**.



ISS005E21757

Amazon Manatee



The Amazonian Manatee is the largest aquatic mammal in the Amazon Basin. It can reach a length of 3 meters and weigh up to 300 kg. Manatees are gentle and slow-moving. They spend most of their time eating, resting, and in travel. Manatees are herbivorous and consume up to 15% of their body weight daily in vegetation. One calf is born every two to five years. The Amazonian Manatee is an endangered species. <http://www.yaqupacha.de/enmanati.htm>



ISS005E21762

ISS005-E-21762

Anaconda

The largest-known snake in the world is the Anaconda, or *Eunectes murinus*, of South America. They are agile swimmers but sometimes prefer to let the river's current carry them downstream with only their nostrils above the watery surface. Once they are satisfied with the change in scenery, they simply drift to the river's edge. Anacondas are more often found in swamps and calmer waters than in swift-moving rivers.



One specimen in eastern Colombia in the 1944 measured 37 1/2 feet in length. Do they grow bigger? According to Colonel Percy H. Fawcett, a former British Army officer, surveyor and adventurer in the early 1900's, they do:

We were drifting easily along on the sluggish current not far below the confluence of Tigor and the Rio Negro when almost under the bow there appeared a triangular head and several feet of undulating body. It was a giant anaconda. I sprang for my rifle as the creature began to make its way up the bank, and hardly waiting to aim smashed a .44 soft-nosed bullet into its spine, ten feet below the wicked head. At once there was a flurry of foam, and several heavy thumps against the boat's keel, shaking us as though we had run on a snag...

Fawcett examined the body. Though he had no ruler, he guessed the length of the creature at sixty-two feet with a twelve-inch diameter. "Such large specimens as this may not be common, but the trails in the swamps reach a width of six feet and support the statements of Indians and rubber pickers that the anaconda sometimes reaches an incredible size dwarfing that shot by me. The Brazilian Boundary Commission told me of one exceeding eighty feet in length!" <http://www.unmuseum.org/bigsnake.htm>

Piranha



The piranha (also known as the caribe) is a ferocious, schooling, fresh-water fish. It is native to warm lowland streams and lakes in South America, east of the Andes Mountains. Piranhas range in color from yellow to steel-gray to bluish to partly red to almost black. They range from 1/2 to 2 feet (15-60 cm) long. Piranhas have been introduced to other places, including Northern Brazil, Hawaii, and parts of Central and North America. There are many species of piranha; they belong to the genera *Pygocentrus* and *Serrasalmus*.



ISS004E6068

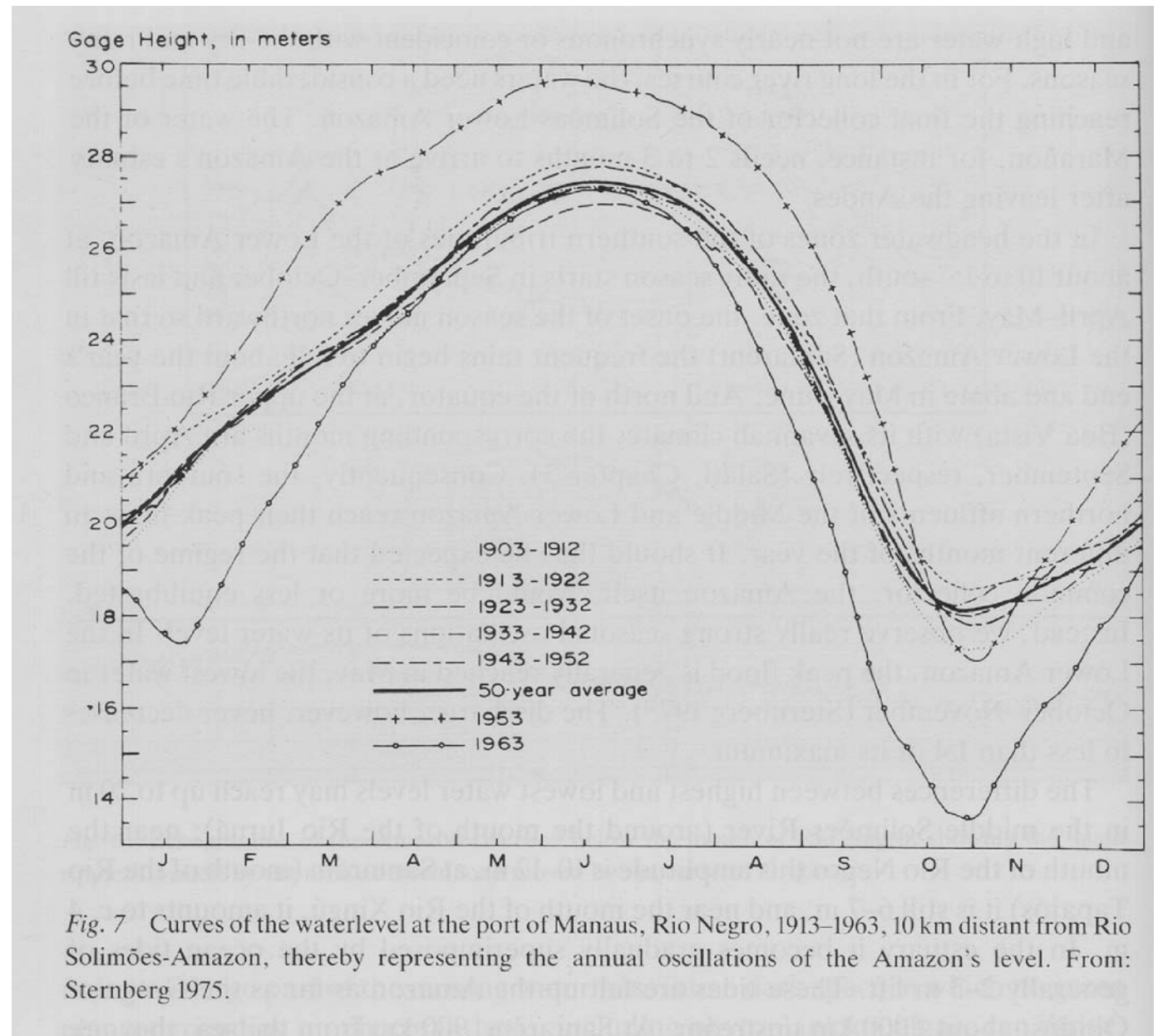
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Peacock Bass



The peacock bass is one of the most ferocious freshwater fish you'll find anywhere. They are known as pavon in Venezuela and Colombia or tucunare in Brazil and Peru. Interestingly enough, the "bass" portion of the fish's name is incorrect. Peacocks are actually members of the cichlid family. A common characteristic shared by all peacocks is the black circular "eye spot" - dramatically rimmed in gold - on the base of the caudal fin. This spot closely resembles the tail plume of a peacock fowl.

Amazon hydrograph



Amazon Delta



STS097-370-17

Flooded forests of the Amazon

Every year, during the wet season, the rivers in the Amazon Basin overflow and flood nearly 100,000 sq km of forests. The floods can raise water levels by 12m and submerge the trees for 6 months of the year. Instead of killing the trees, this annual flood results in a thriving flooded forest. The seasonal flood brings in a huge load of nutrients to feed trees and plants as well as aquatic creatures. These in turn attract a fascinating migration of animals into the flooded forest. These unique conditions spawned specialist animals which are found nowhere else. There is so much food that many of these specialists are giants!

Many flooded forest fish have developed adaptations to eat fallen fruit. They have come to depend on the annual flood to build up fat reserves so as to survive the leaner dry season of low water levels. The trees in turn, have grown to rely on the fish to disperse their seeds. Some seeds cannot germinate unless they have been processed through the gut of a fish. Many fish have developed especially large mouths to eat large fruits. Others have powerful jaws that can even crack Brazil nuts. Some piranha species even specialize in fruits, abandoning the bloody habits of their relatives.

<http://www.szgdocent.org/ff/f-wflood.htm>

The Giant Royal Waterlily

This has the largest floating leaf, reaching a diameter of 2m. This leaf is very strong, often demonstrated by having a small child stand on a leaf. The leaf's strength comes from the arrangement of radiating ribs and cross-veins, which also contain airspaces to help the leaf float. The leaf is protected underneath by very sharp spines to discourage vegetarians like the manatee. A young leaf bud is a tight ball with the spines facing upwards, which unrolls on the surface, spiny side down. The Royal Water Lily has upturned edges so it looks like a frying pan! This not only prevents water from covering the leaf, but also pushes aside other water plants. Each leaf unfurls rapidly (at up to half a square meter a day), and one plant can put out 40-50 in one growing season! The Royal Water Lily depends on a particular species of beetle to pollinate it. When it first opens in the evening, the lily flower is white and smells powerfully of pineapples. As the beetles feast on the nectar throughout the night, the lily closes about them. During the day, the male anthers ripen and dust the trapped beetles with pollen. The beetles are released only the next evening when the flowers reopen. This time, the flowers turn pink.





ISS004E12206

ISS004-E-12206

The Amazon and the Atlantic Ocean

About 600 miles from the coast, at Obidos, the ocean begins to affect the river. Tides are able to penetrate this far upstream because of the extremely gentle slope of the land. Beyond the point where the Zingu flows in from the south, the Amazon splits up into a maze of channels clogged by larger and larger islands. (Marajo, the biggest island in the delta, is about the size of Vermont and New Hampshire combined.) Finally, beyond its several mouths, the river merges with the sea where a powerful ocean current bends it northwestward along the coast. Upon mixing with salt water and depositing brown silt along the continental shelf, the Amazon slowly loses its tan and becomes part of the much more massive South Equatorial Current. Particles of clay smaller than 4 microns, still held in suspension, tinge the current gray until it passes beyond the Guianas (French Guiana, Suriname, and Guyana). And, even after the waters clarify, dissolved nutrients from Amazonia travel as far as the Grand Banks of Newfoundland.

<http://www.sci.mus.mn.us/greatestplaces/notes/amazon.htm>

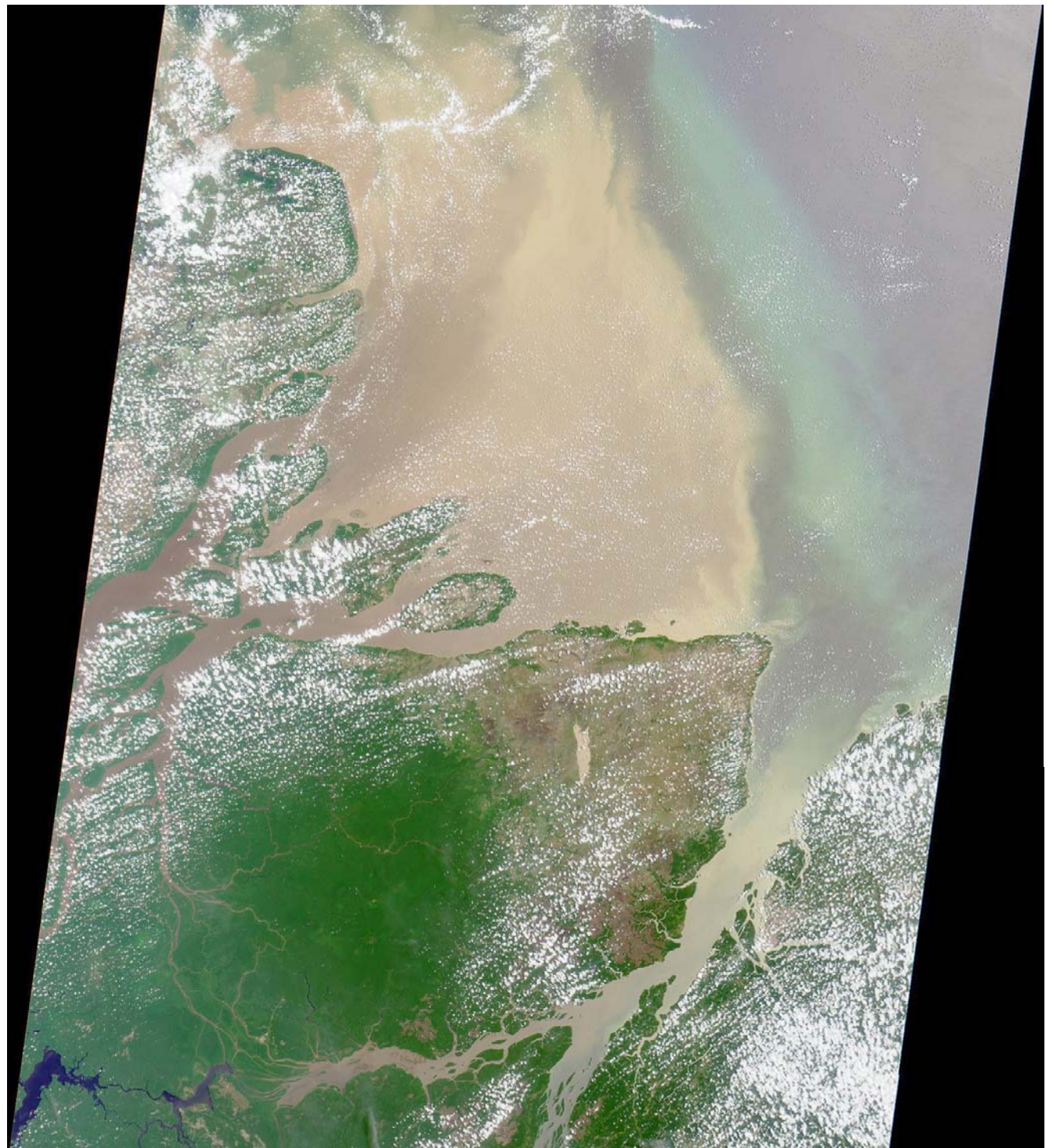
Tocatins & Amazon rivers



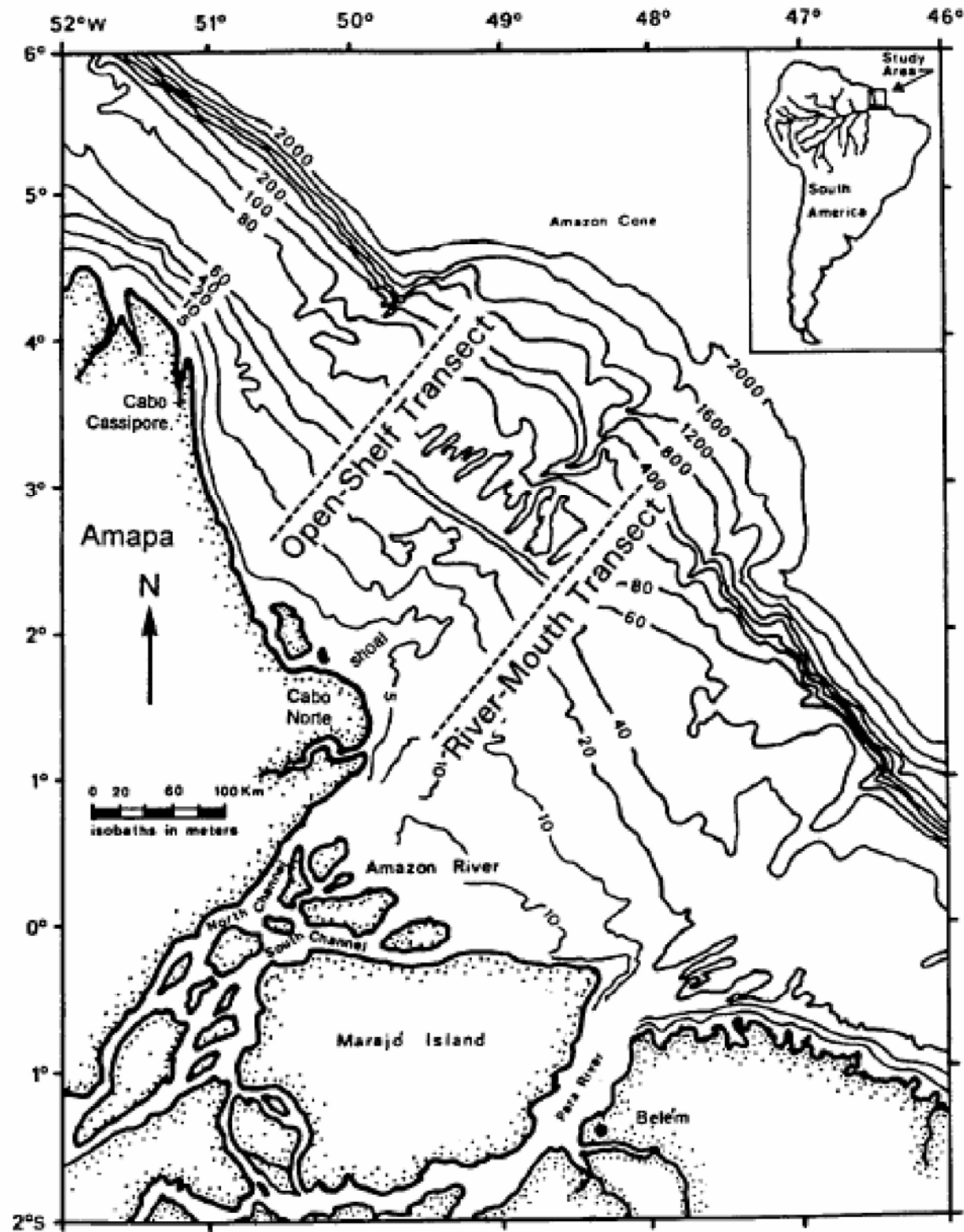
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MISR image (Amazon & Tocantins)



380 km

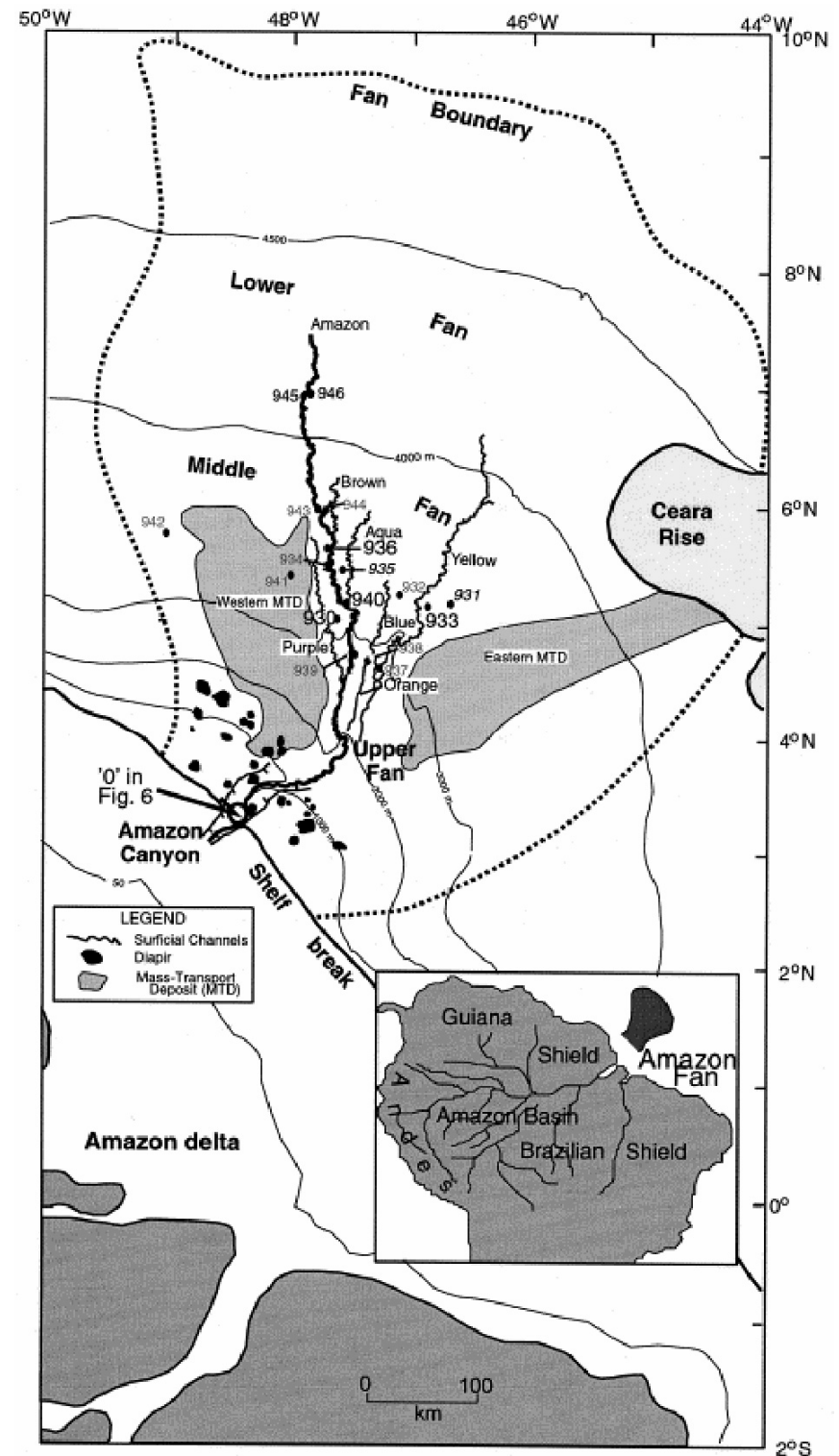


Submarine Amazon Fan

Nittrouer et al.
1995 Marine
Geology

Submarine Amazon Fan

Map of the Amazon Fan showing location of Ocean Drilling Project Sites (in bold larger font). ODP sites also referred to in the text are shown in lower case, bold, italic font. Channel names (Amazon, Brown, Aqua, Purple, Blue, Yellow and Orange) are in order of increasing age (Normark et al., 2002)



A third of the sediment carried by the Amazon is transported NW as far as the Orinoco delta

