Water – Where We Are Going

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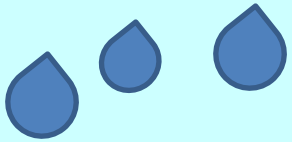
Summary of presentation for the City Council Work Session on Monday, Nov. 25th, 1 PM
by Vincent P. Gutschick*

Topics:

- Where the water is, globally
- Where water moves, globally
- Regional movement: our summer monsoon (and atmospheric rivers)
- How dry are we? Continents...and our local rain shed (rain in = (1/9) of potential evapotranspiration)
- Driver of dryness #1: the descending Hadley cell at this latitude
- Driver #2: cold California current and the rain shadow of the coastal mountain ranges
- How our precipitation and that of Colorado gets to our managed water supplies
- The main uses to which we put our water – surface and groundwater; most for irrigation and reservoir evaporation, small amount for energy production, middling for municipal and industrial
- Our water balance, for groundwater – negative, measured from orbit!
- Fundamentals of how crops and other plants must use copious water; switch to "virtual water"?
- Developing extremes for our area – and a note about our droughts and mega droughts
- Stalled storms
- Northward move of the Intertropical Convergence Zone
- The correlation of extreme weather with rising water content in warmer air
- Moisture convergence – the wet get wetter and the dry get drier
- The need for adaptation, given the inevitability of further climate change

- Prof., Emeritus, NMSU; Ph.D., Caltech, Chemistry/Chemical Physics; research, teaching, and public service record viewable at http://gcconsortium.com/about_us_founders_qualifications.html

Where water comes from... where it goes



Vince Gutschick

Presented at the 27 Sept. 2013 meeting of the
Sun Country de Las Cruces Kiwanis Club

Good Samaritan Village

Table 5.1

Water Volumes of Earth

Category	Volume (10^6 km^3)	Percent
Oceans	1348.0	97.39
Polar ice caps, icebergs, glaciers	227.8	2.010
Groundwater, soil moisture	8.062	0.580[a]
Lakes and rivers	0.225	0.020
Atmosphere	0.013	0.001
Total water amount	1384.0	100.0
Freshwater	36.00	2.60
Freshwater reservoirs as a percent of total freshwater		
Polar ice caps, icebergs, glaciers		77.2
Groundwater to 800-m depth		9.8[a]
Groundwater 800–4000-m depth		12.3[a]
Soil moisture		0.17[a]
Lakes (freshwater)		0.35
Rivers		0.003
Hydrated earth minerals		0.001
Plants, animals, humans		0.003
Atmosphere		0.040
Sum		100.000

[From Baumgartner and Reichel (1975).]

[a]Numbers uncertain.

Where the water is, on average

Where the water moves, globally

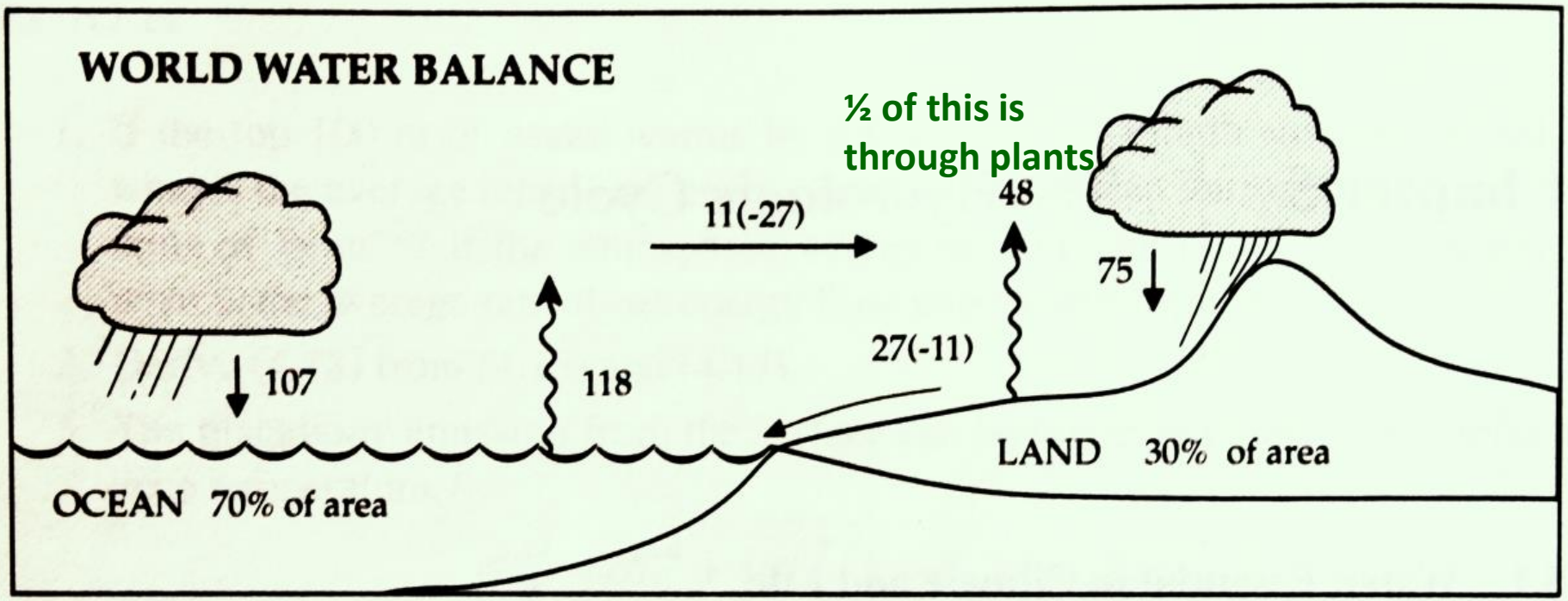
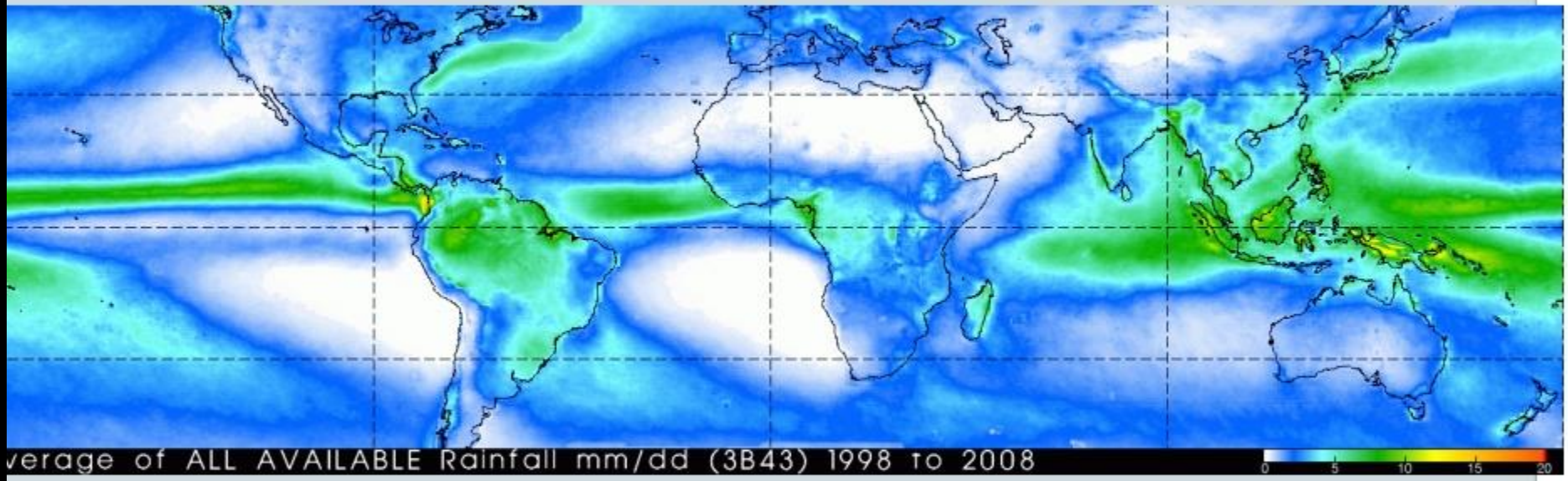


Fig. 5.1 Schematic diagram showing the basic fluxes of water in the global hydrologic cycle. Units are centimeters per year spread over the area of the land or ocean. Since the areas of land and ocean are different, the land–ocean water exchanges by atmospheric transport and river runoff have different values depending on the reference area, as indicated by the parentheses. The smaller values are those referenced to the larger oceanic area.

Most of the precipitation is in the tropics, where the evaporation is highest

- For reference, the precip climatology from TRMM (1998-2008)



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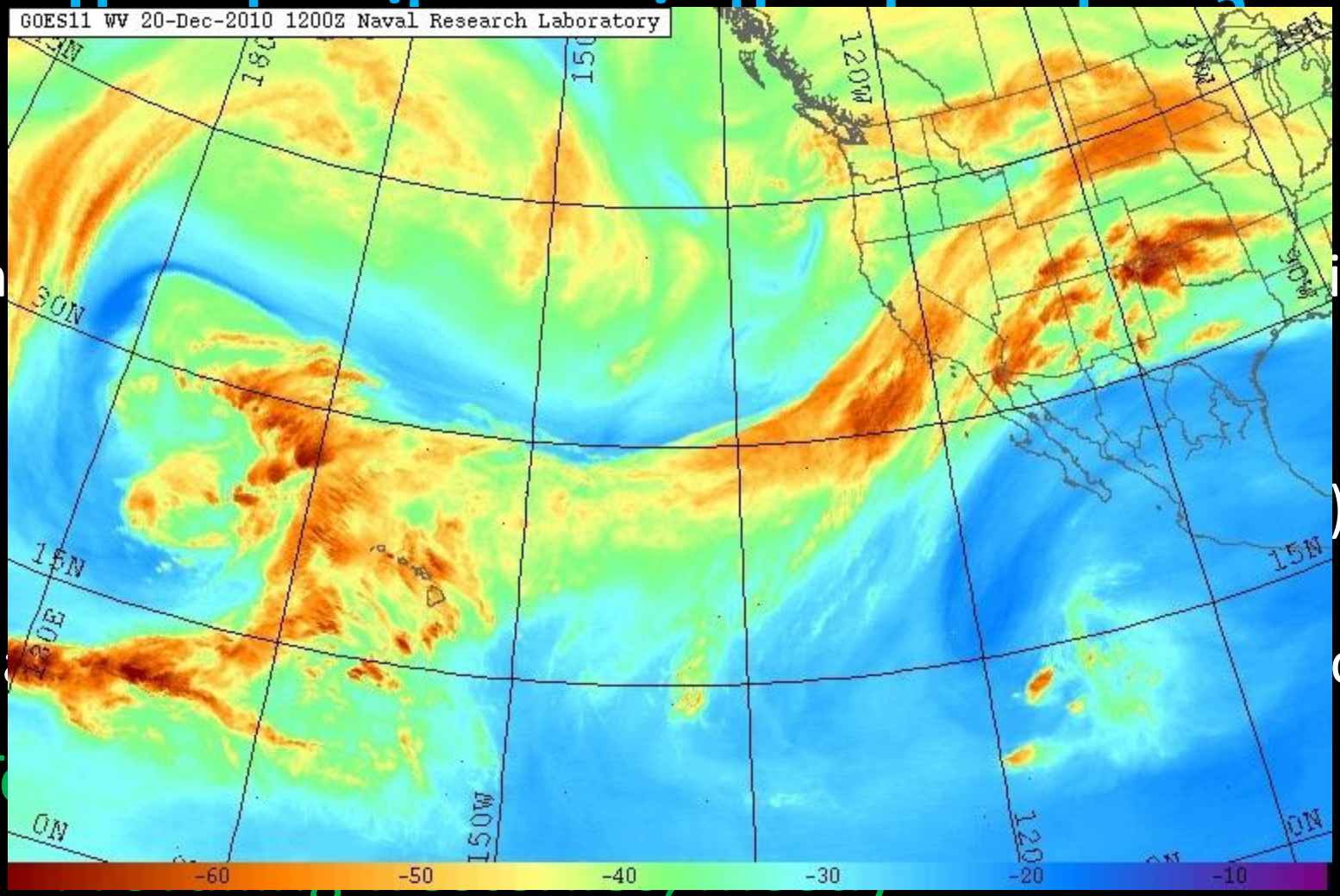

Summer monsoon, from the Caribbean

Why are we so dry?

Compare us to others, first

Table 5.2

Water Balance of the Continents and Oceans (in mm/year)

Region	E	P	Δf	$\Delta f/P$
Land				
Europe	375	657	282	0.43
Asia	420	696	276	0.40
Africa	582	696	114	0.16
Australia	534	803	269	0.33
North America	403	645	242	0.37
South America	946	1564	618	0.39
Antarctica	28	169	141	0.83
All land	480	746	266	0.36
Ocean				
Arctic Ocean	53	97	44	0.45
Atlantic Ocean	1133	761	−372	−0.49
Indian Ocean	1294	1043	−251	−0.24
Pacific Ocean	1202	1292	90	0.07
All ocean	1176	1066	−110	−0.10
Globe	973	973	0	

[From Baumgartner and Reichel (1975).]

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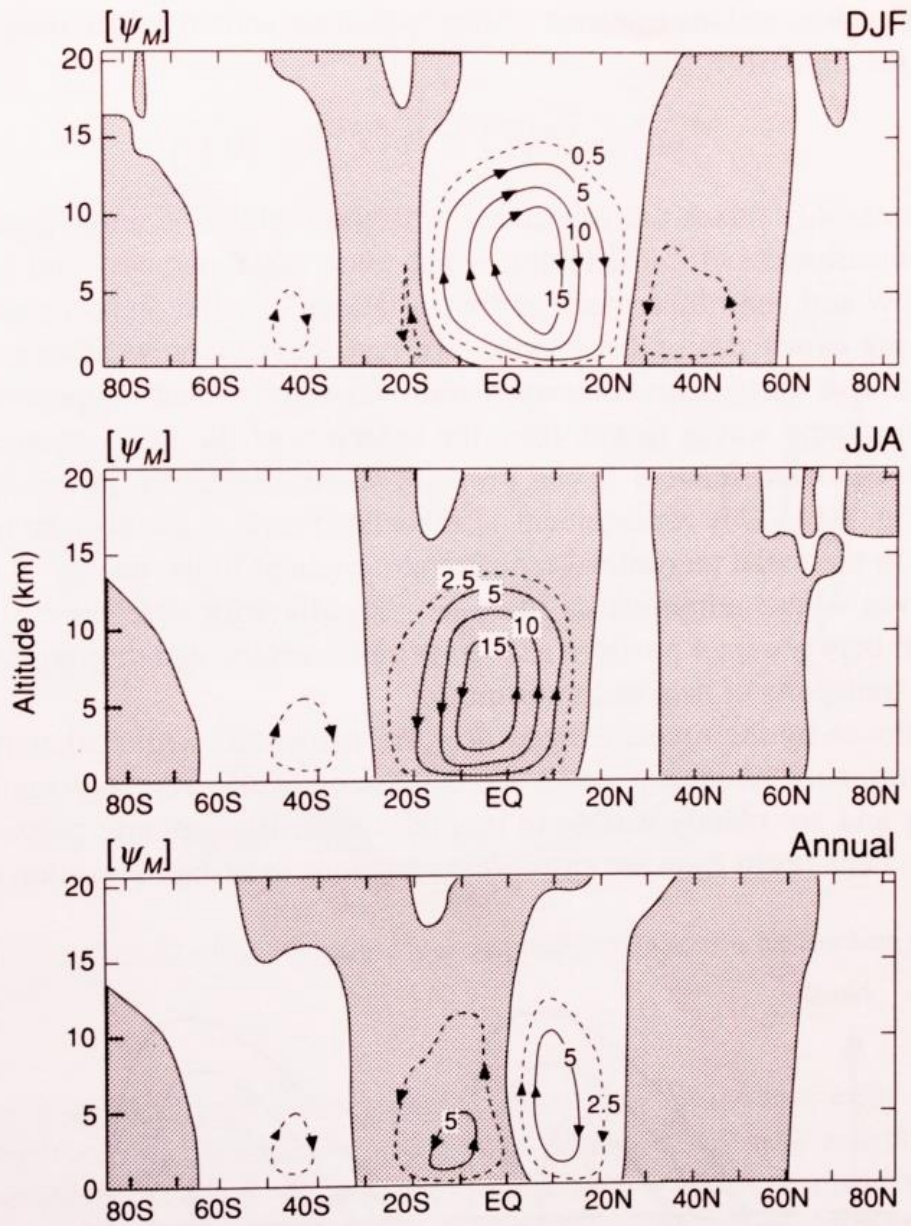
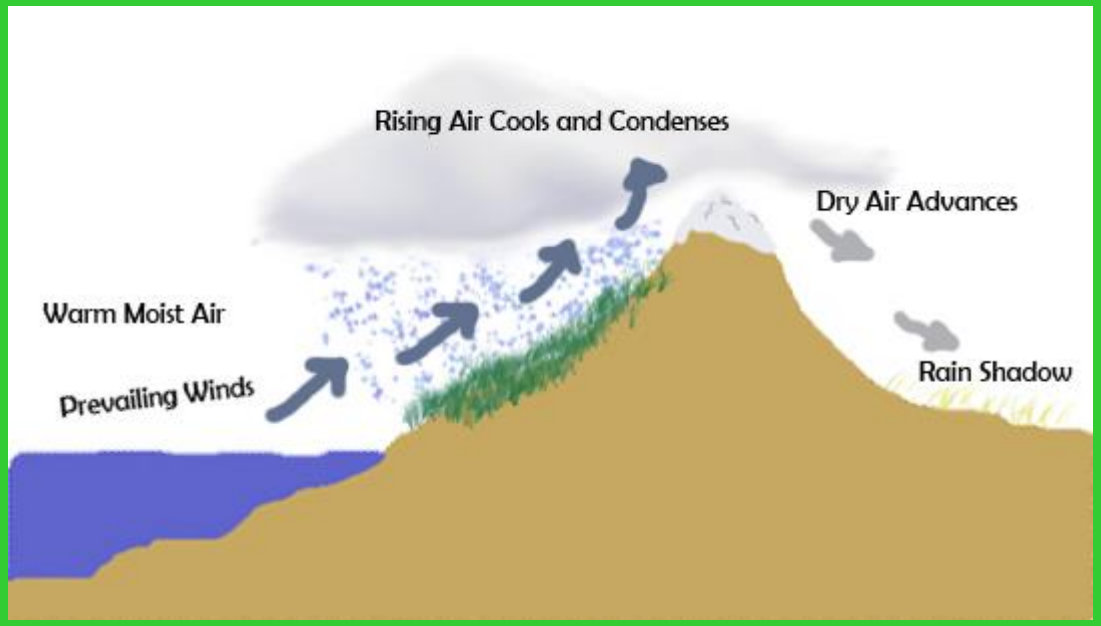


Fig. 6.5 Latitude–height cross section of the mean meridional mass circulation. Shaded values are negative; units are 10^{10} kg s^{-1}. [Data from Oort (1983).]

Reason #2 for why we are dry:

We're in the rain shadow of the West Coast mountain ranges



...and (#3) the air coming off the ocean by California has low water content; the California current in the ocean is cold, adding little moisture to the air

OK, once it gets to us as rain, how does it get to us in managed water supplies

Runoff and collection into:

Rivers, above ground

Aquifers, below ground

And as artifact of our tapping aquifers:

Reverse flow from rivers to aquifers

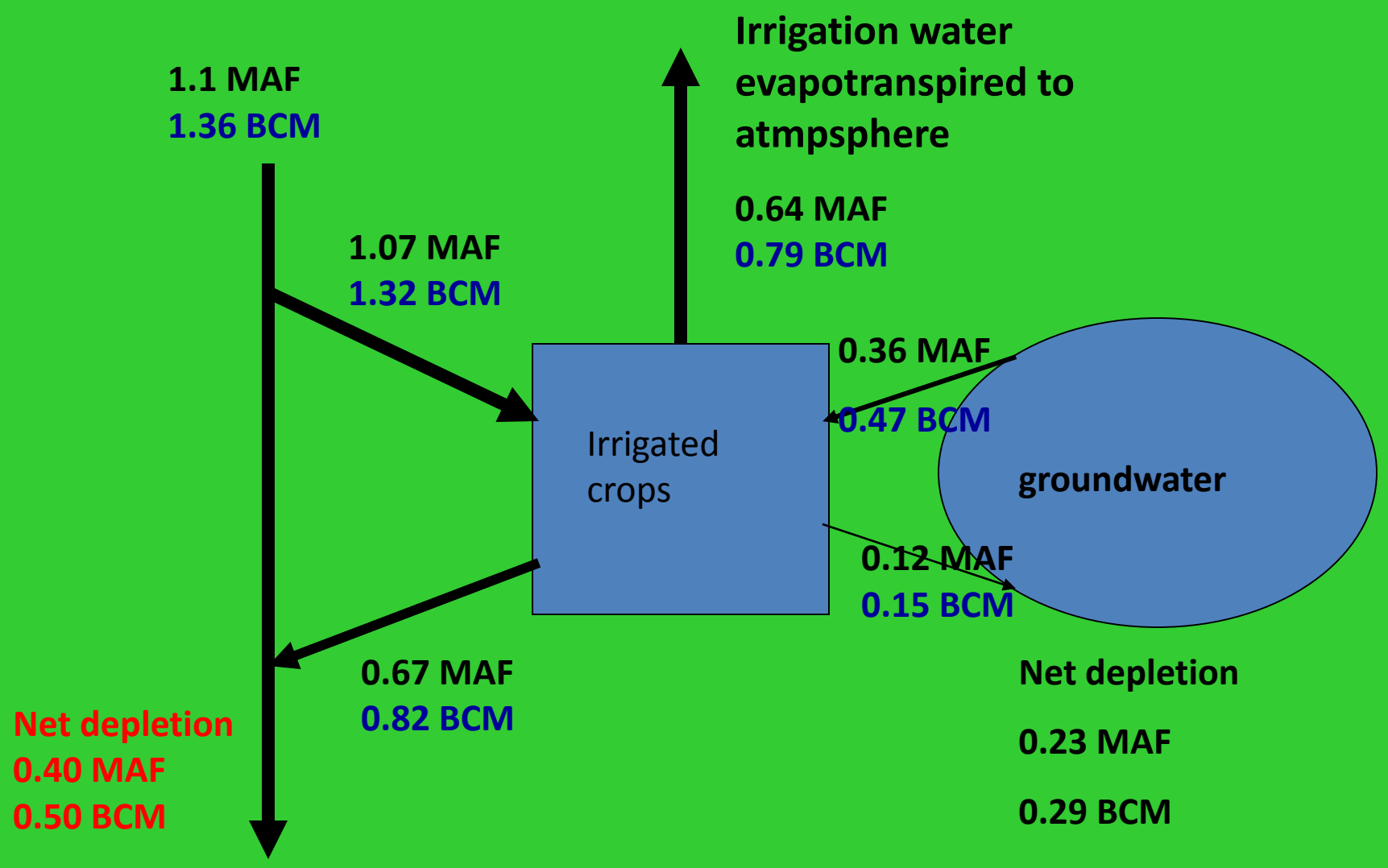
How do we tap into these supplies?

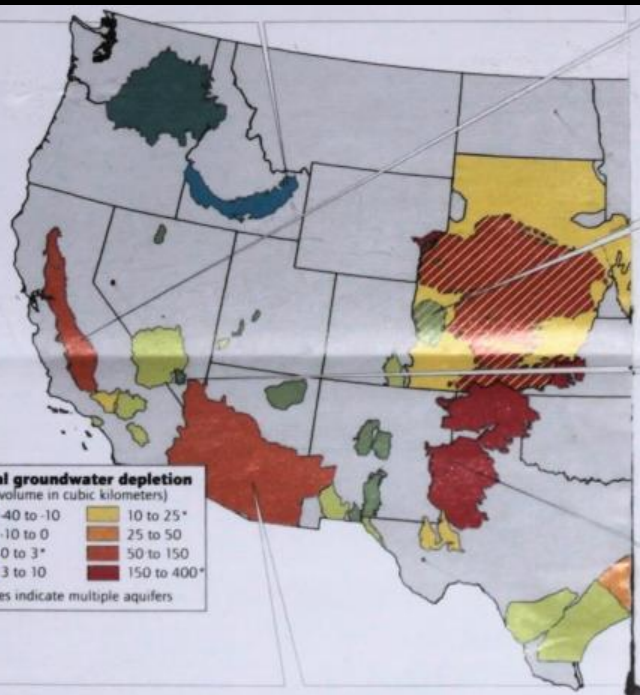
Municipal water use is about 8% of total water use
Industrial use is about 14% of total water use
- **About 2% is used for energy generation**
- **Fracking might consume a similar amount (but contamination of larger amounts is a concern)**

Together they account for 11% of *river flow...*
- **while most is indirect use, tapping groundwater replenished largely by reverse flow from the river**

Irrigation accounts for 78% of consumptive water use

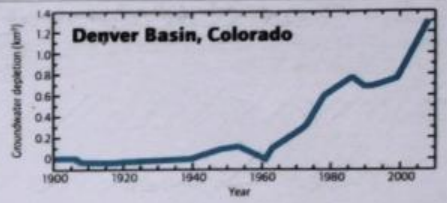
Irrigation water usage





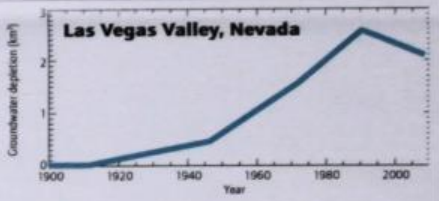
Beneath the Denver Basin, the shallow aquifers that irrigators rely on have begun to drain more slowly. That's because the state now regulates that supply, recognizing its connection to carefully divvied-up surface water, and because wet years in the '80s and '90s helped slow water loss. But the depletion of unregulated deep aquifers has sped up as the region grows, since new subdivisions often lack surface-water rights and thus must drill for a source. New subdivisions exploded in the early 2000s, just as the latest drought began, further increasing the drawdown.

The suburb of Castle Rock, where well production has flagged by 7 to 10 percent each summer since the mid-2000s, recently joined nine other South Denver water providers in a pact with Denver and Aurora to pipe water from the South Platte River.



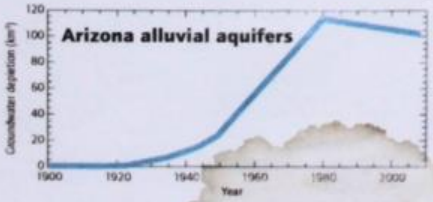
Despite its reputation for excess, Sin City's conservation plan fines local water wasters, prohibits new turf in front yards, and offers coupons for water-recycling car washes. Between 2002 and 2011, southern Nevada cut per-person use by 29 percent, likely helped by the recession.

Vegas is well aware of its limited groundwater, and in 1987 began using part of its share of Colorado River water, drawn from Lake Mead, to recharge the aquifer that fed its early growth. But Mead has dropped more than 100 feet since 2000, and the Bureau of Reclamation recently projected that water levels could plunge enough to come close to triggering a federal shortage declaration by next autumn -- meaning potential cutbacks. To secure future supplies, the Southern Nevada Water Authority is pushing for a groundwater pipeline from rural east-central Nevada, despite its possible impacts on springs and creeks used by ranchers and wildlife.



In Arizona, tighter groundwater management, starting in 1980, and the 1985 Central Arizona Project, which transports Colorado River water to Tucson and Phoenix, have helped ease the pressure on aquifers.

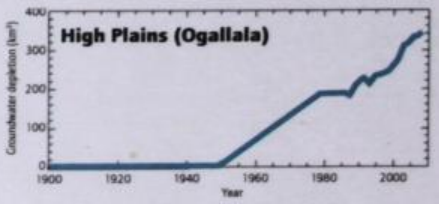
But the state still doesn't legally recognize that groundwater and surface water are connected, and draining the desert water table has transformed rivers like Tucson's Santa Cruz from verdant waterways lined with cottonwoods and mesquite into sand-filled valleys. Now, state-approved wells from a 7,000-unit housing development threaten to de-water the San Pedro, one of the healthiest remaining Southwest rivers and an oasis for migrating birds and other wildlife.

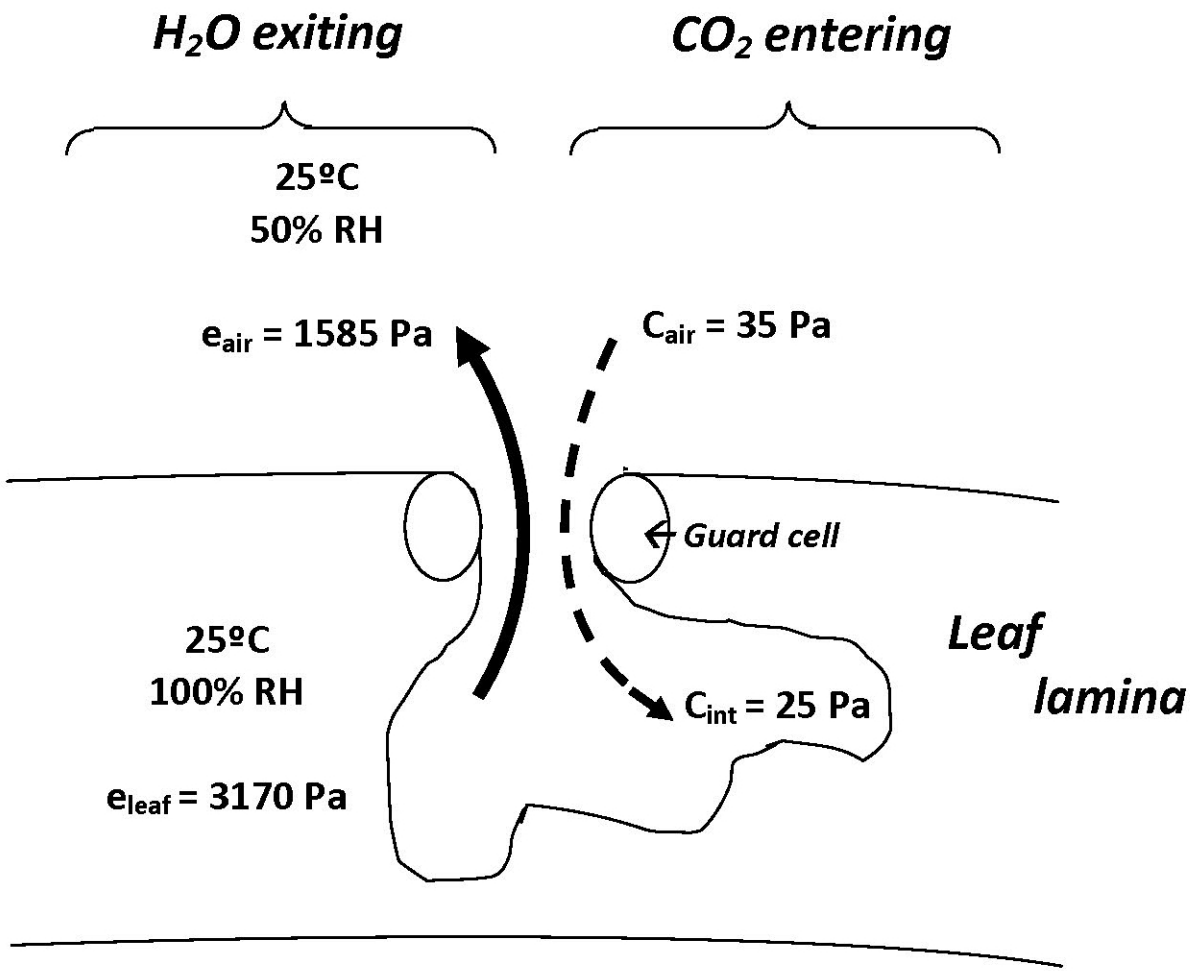


USGS

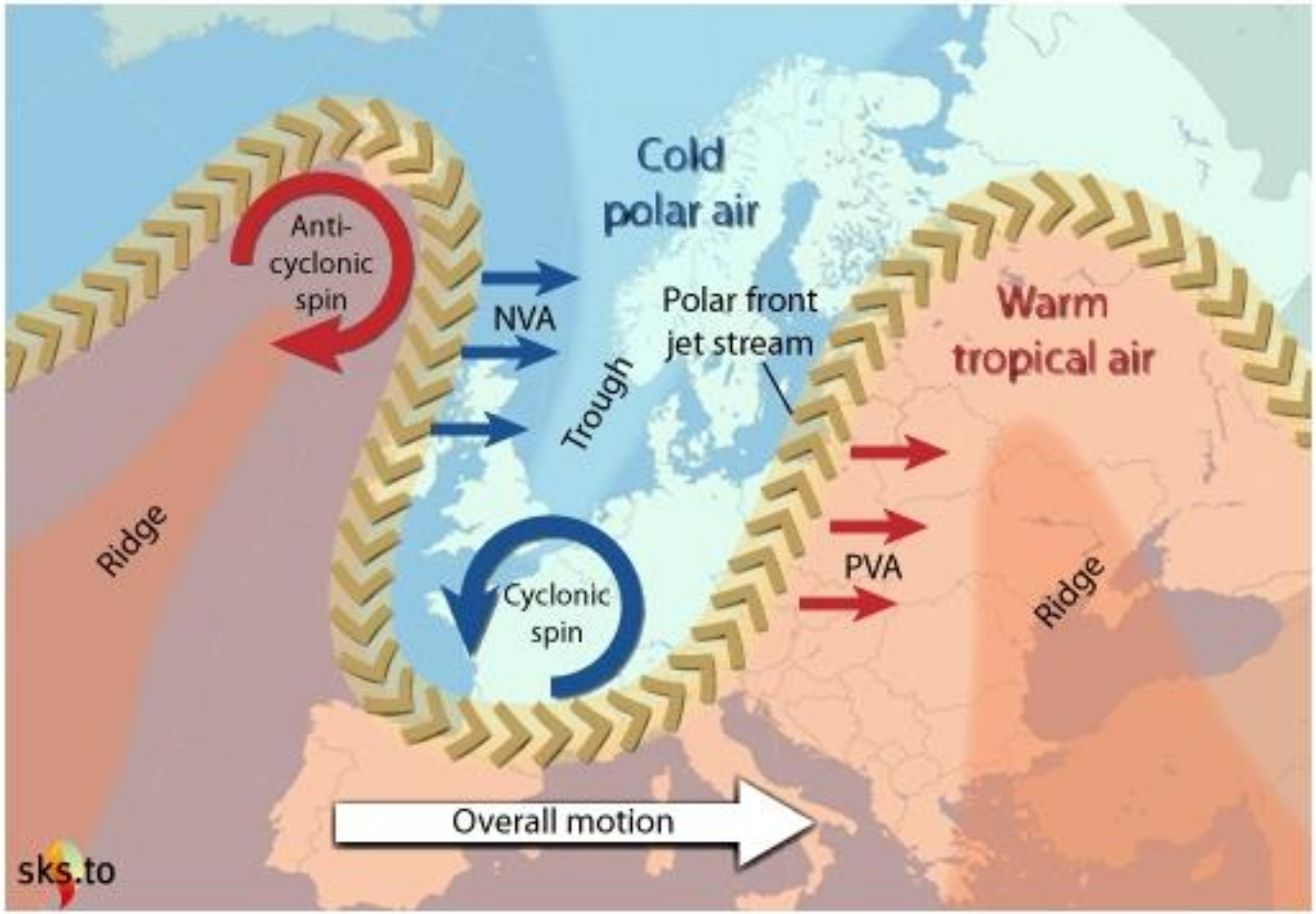
The High Plains, or Ogallala, aquifer -- which stretches from South Dakota to Texas -- accounts for about 34 percent of all U.S. groundwater depletion since 1900. A whopping 24 percent of that loss occurred between 2001 to 2008, likely helped by decreased rainfall and increased pumping for larger corn plantings, spurred by higher corn prices.

Irrigators are already seeing the consequences in Texas and Kansas, where the aquifer replenishes much more slowly than up north. Dried-up wells are now pumping up sand along with dwindling well water, and drought-stricken farmers have been forced to fallow their fields. According to a 2012 study in the Proceedings of the National Academy of Sciences, 35 percent of the southern High Plains will be unable to support irrigation within the next 30 years if current pumping rates continue. "There's so much talk about making things sustainable," says study author Bridget Scanlon. "Some things can't be sustainable."





Partial pressure difference:	1585 Pa	10 Pa
Flux:	g_w*(1585Pa)/P_{air}	0.62*g_w*(10 Pa)/P_{air}
Relative flux :	256	1

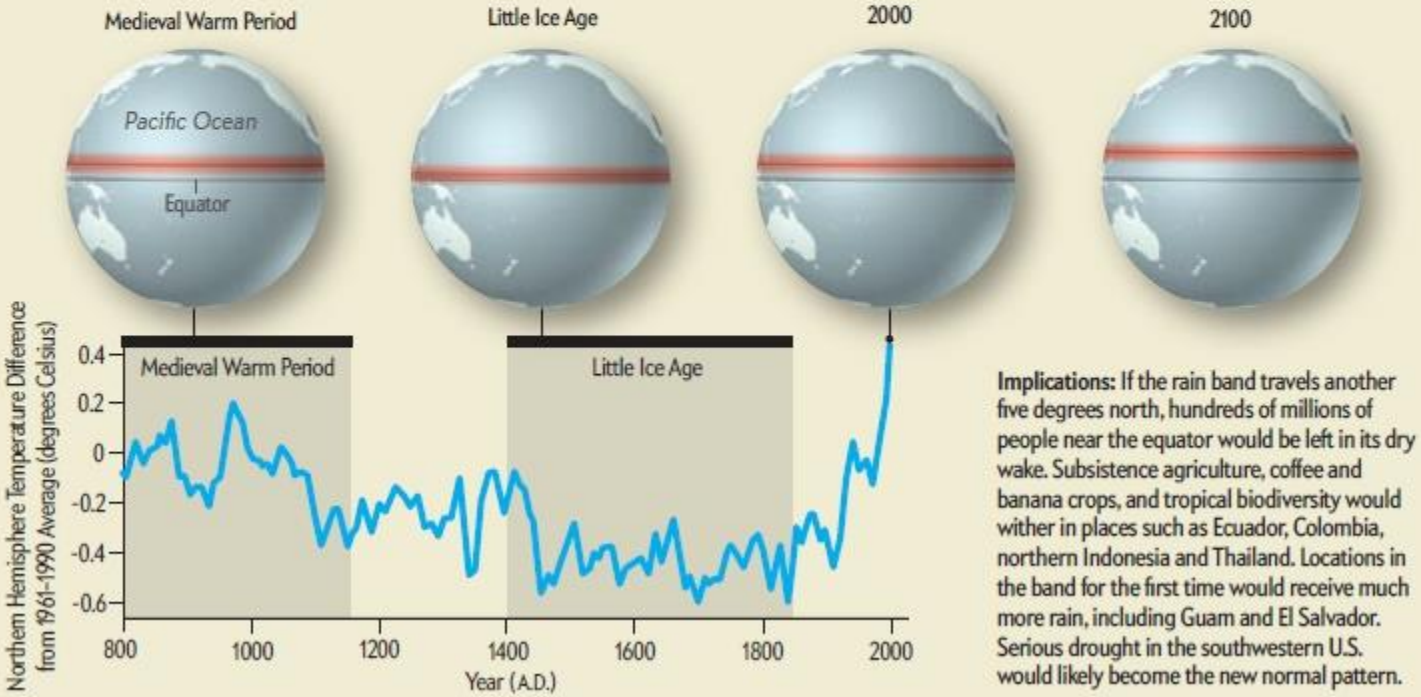


The slowing of the west to east flow of the jet stream produces large meandering lobes that can stall, resulting in long periods of unchanging weather. Source: Skeptical Science

As Temperature Rises, So Does the Rain Band

The Intertropical Convergence Zone (*red*), which circles the earth, is formed by opposing trade winds that create low pressure above equatorial water heated by the sun. The water evaporates, rises and condenses as rain—lots of it. The low pressure also creates adjacent, massive high-pressure cells that circulate atmospheric heat toward higher latitudes, driving weather systems there.

Elevated Northern Hemisphere temperatures moved the rain band north during the Medieval Warm Period (*left*); cooler temperatures shifted it south during the Little Ice Age. Today the band is as far north as it has ever been in the past 1,200 years. The projected rise in global greenhouses gases could bump it another five degrees northward by 2100.



Implications: If the rain band travels another five degrees north, hundreds of millions of people near the equator would be left in its dry wake. Subsistence agriculture, coffee and banana crops, and tropical biodiversity would wither in places such as Ecuador, Colombia, northern Indonesia and Thailand. Locations in the band for the first time would receive much more rain, including Guam and El Salvador. Serious drought in the southwestern U.S. would likely become the new normal pattern.

Wet Gets Wetter, Dry Gets Drier

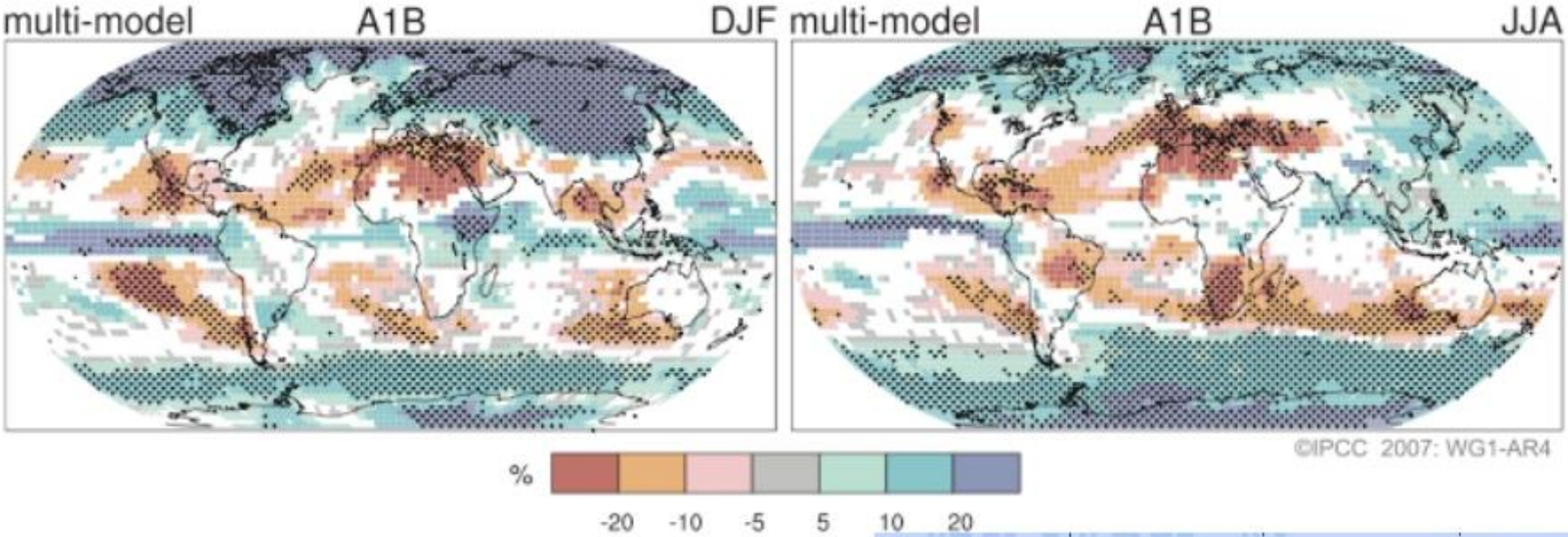
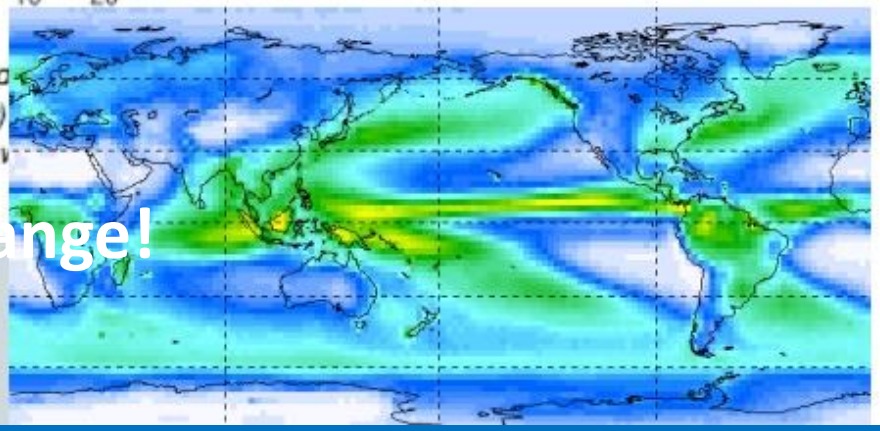


Figure SPM.7. *Relative changes in precipitation (in percent) for the period*
averages based on the SRES A1B scenario for December to February (left)
66% of the models agree in the sign of the change and stippled areas are w
change. {Figure 10.9}



Work to limit climate change!