The hydroclimate of Montana over the past half-century: comparison against global trends

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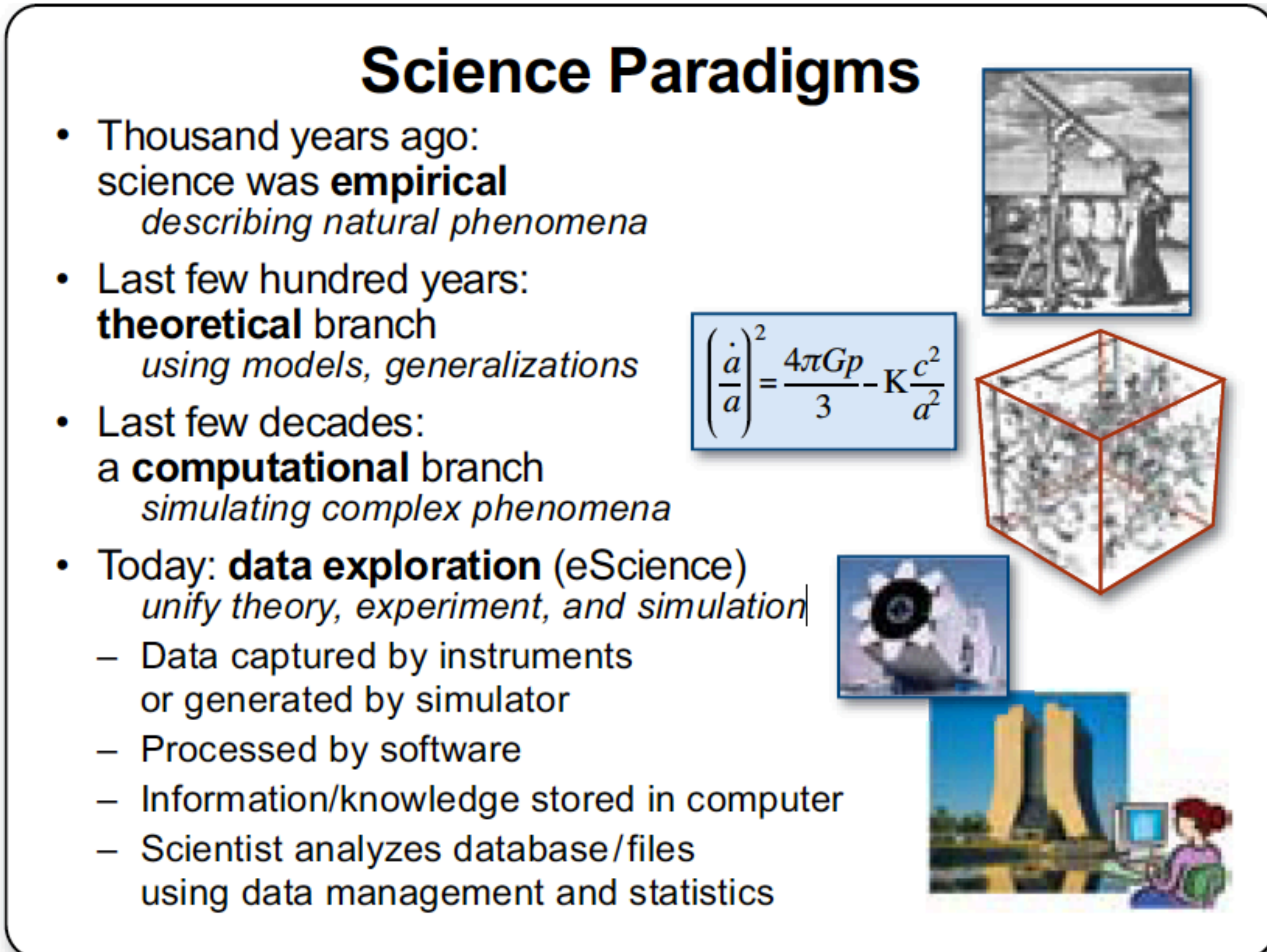
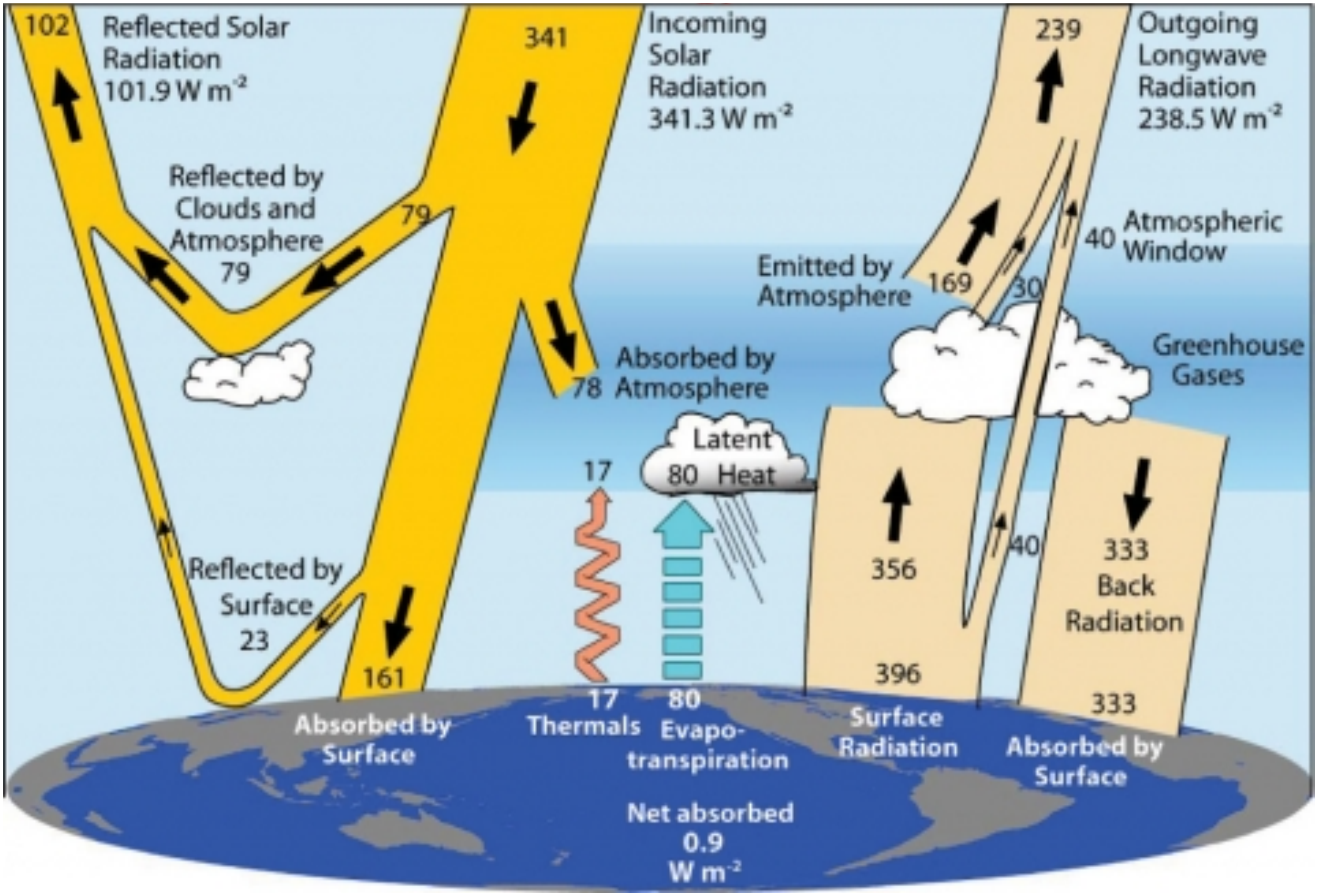
Motivation:



- Gray (2007)

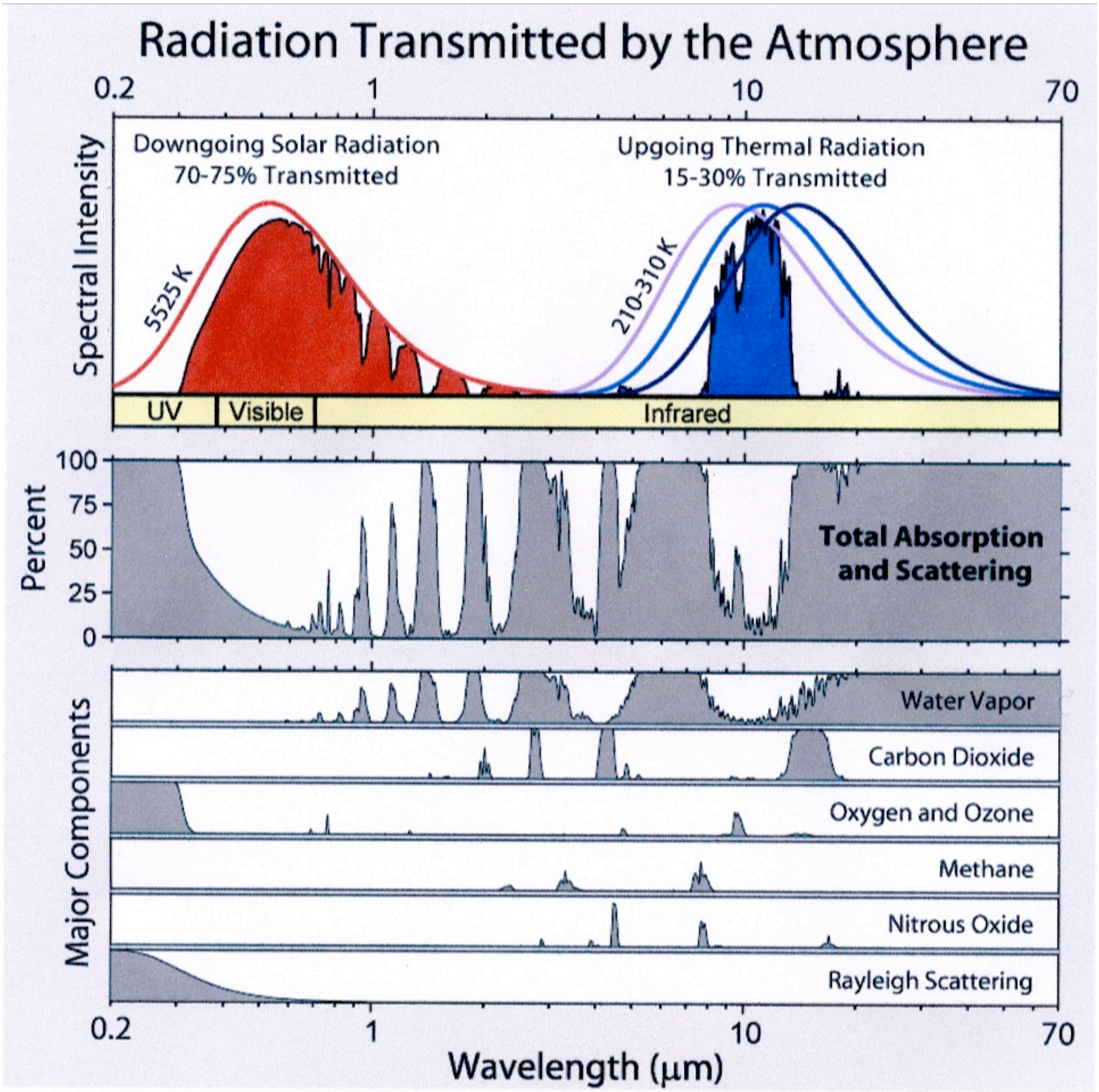
IPCC WG1 AR5 just released…but what about MT?

Global Energy Balance (W m^{-2})



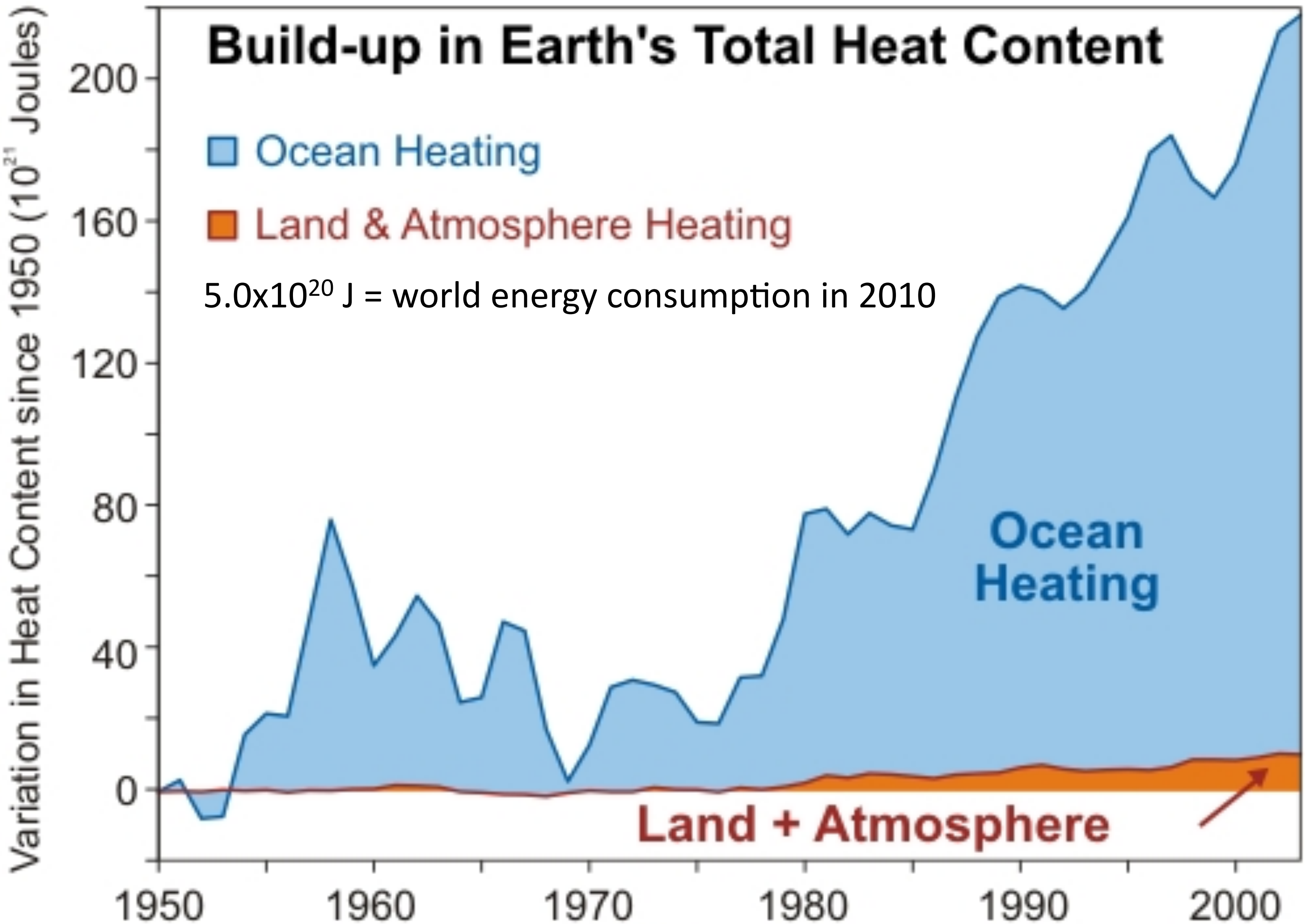
-Ultimately following Kiehl and Trenberth (1997) *BAMS* 78:197-208.

Changes to atmospheric transmissivity in the infrared



www.barrettbellamyclimate.com

Global Change vs. Global Warming



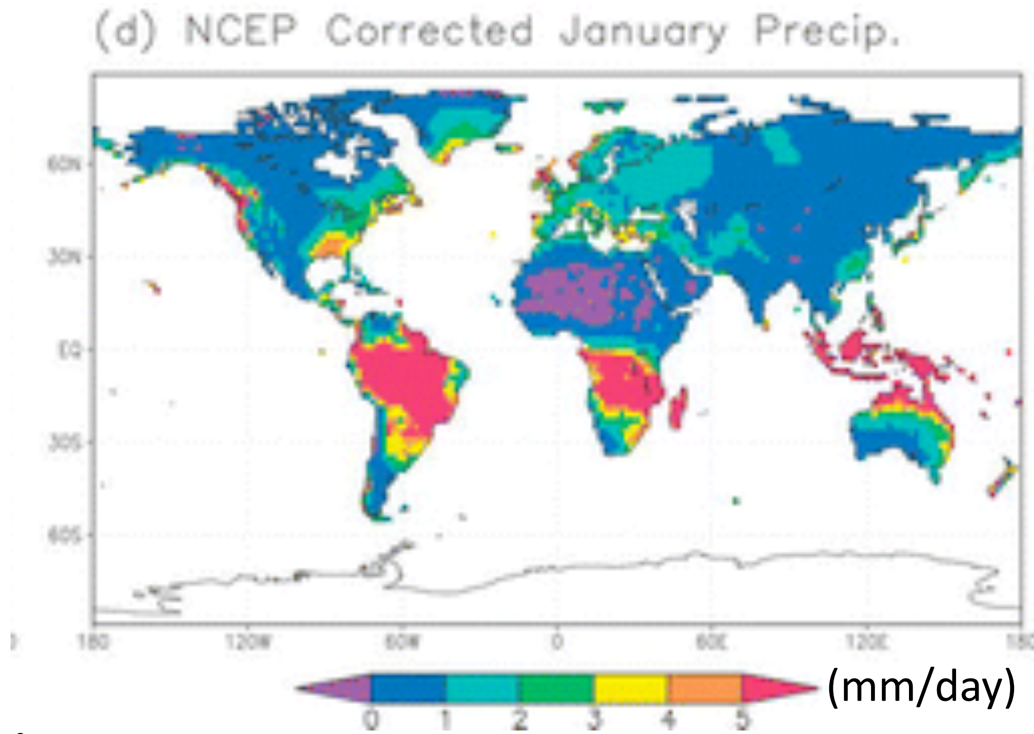
From Church et al. 2011

What does it all mean for water resources in MT?

Exploring the Sheffield et al. (2006) meteorological forcing dataset

Daily global 0.5° data product

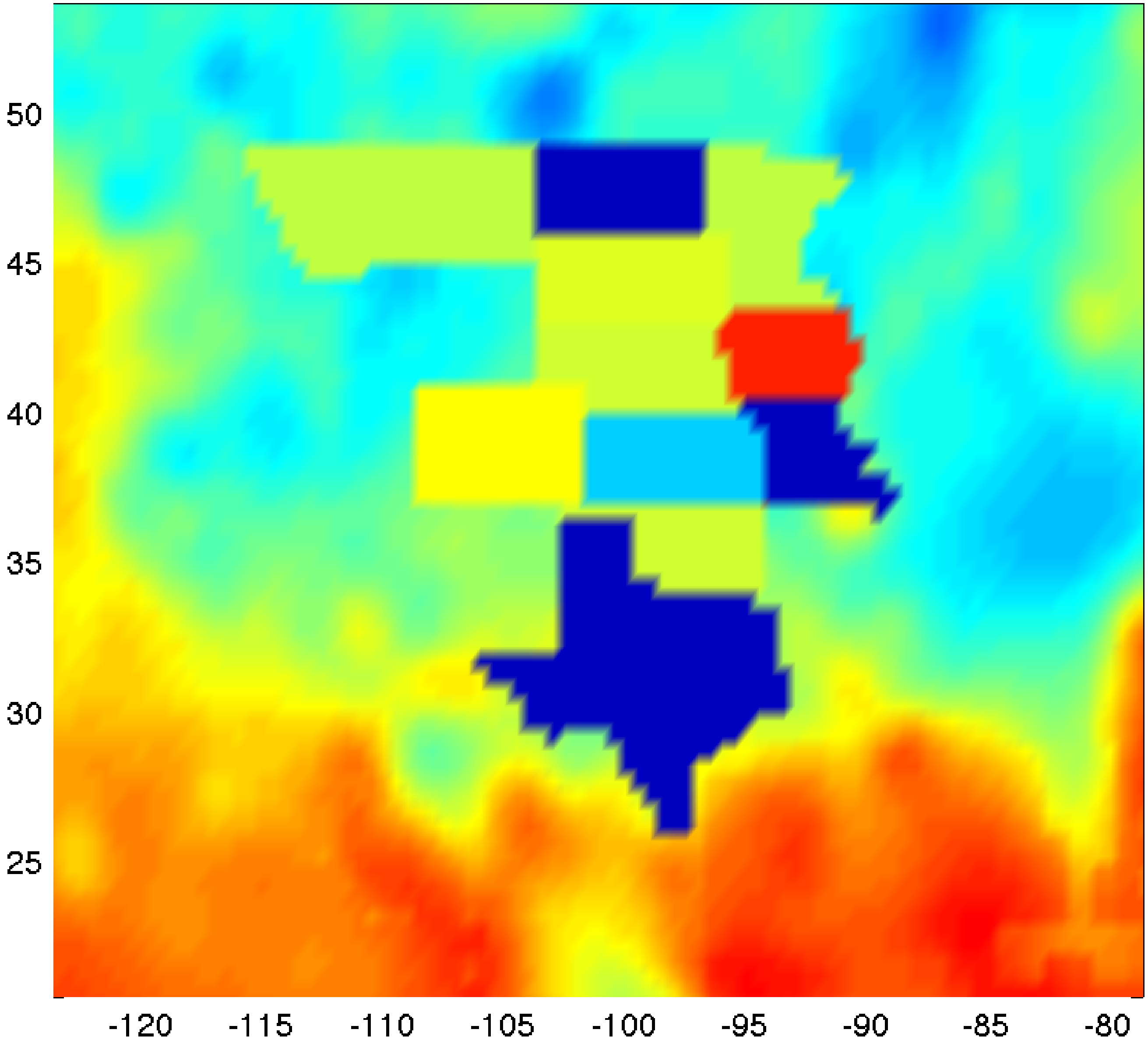
Designed for hydrology:
-Precipitation
-Air temperature
-Specific Humidity
-Air Pressure
-Wind speed
-Incident shortwave radiation
-Downwelling longwave radiation



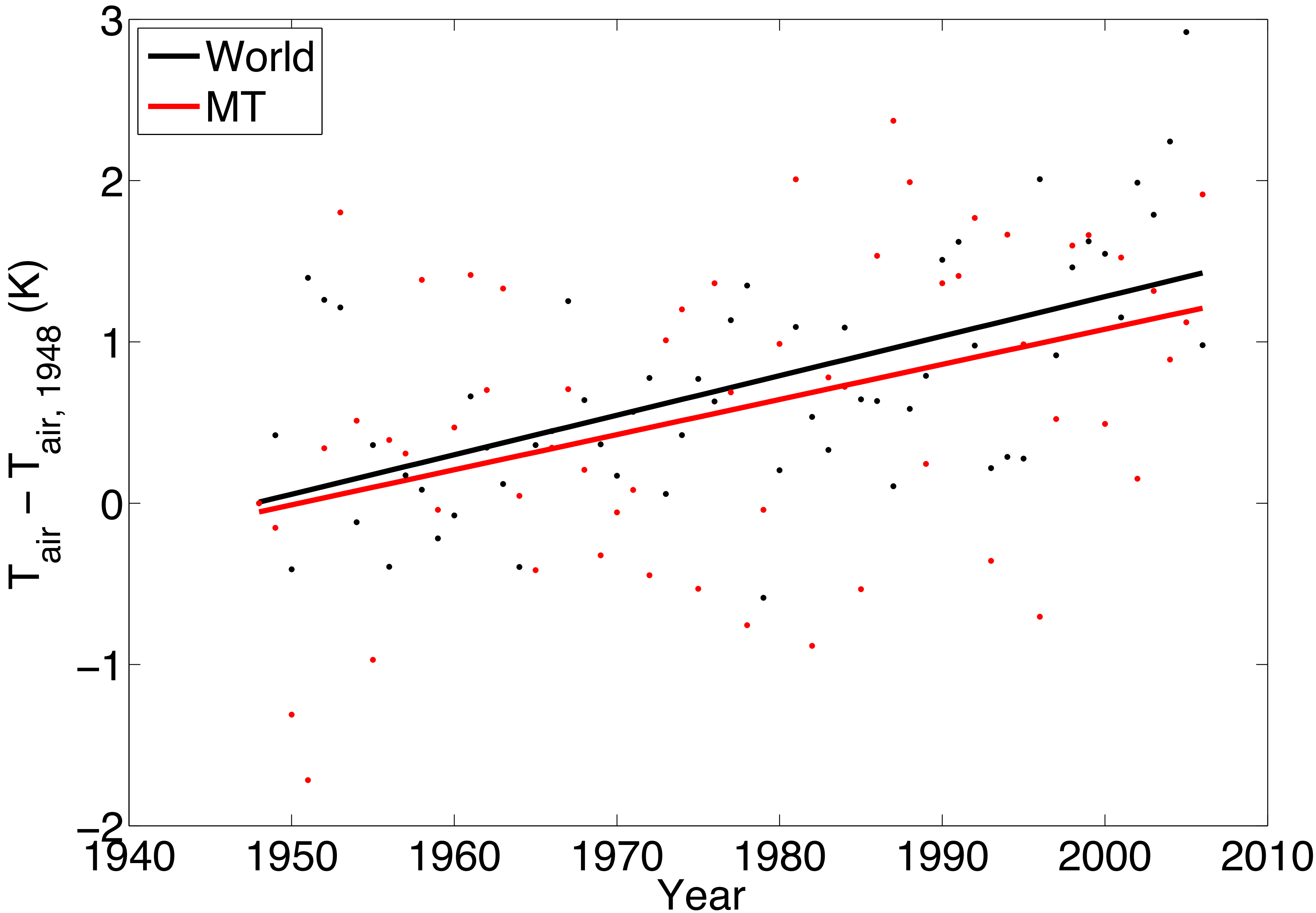
(mm/day)

Combination of observational and reanalysis data products
Bias correction for precipitation gage undercatch

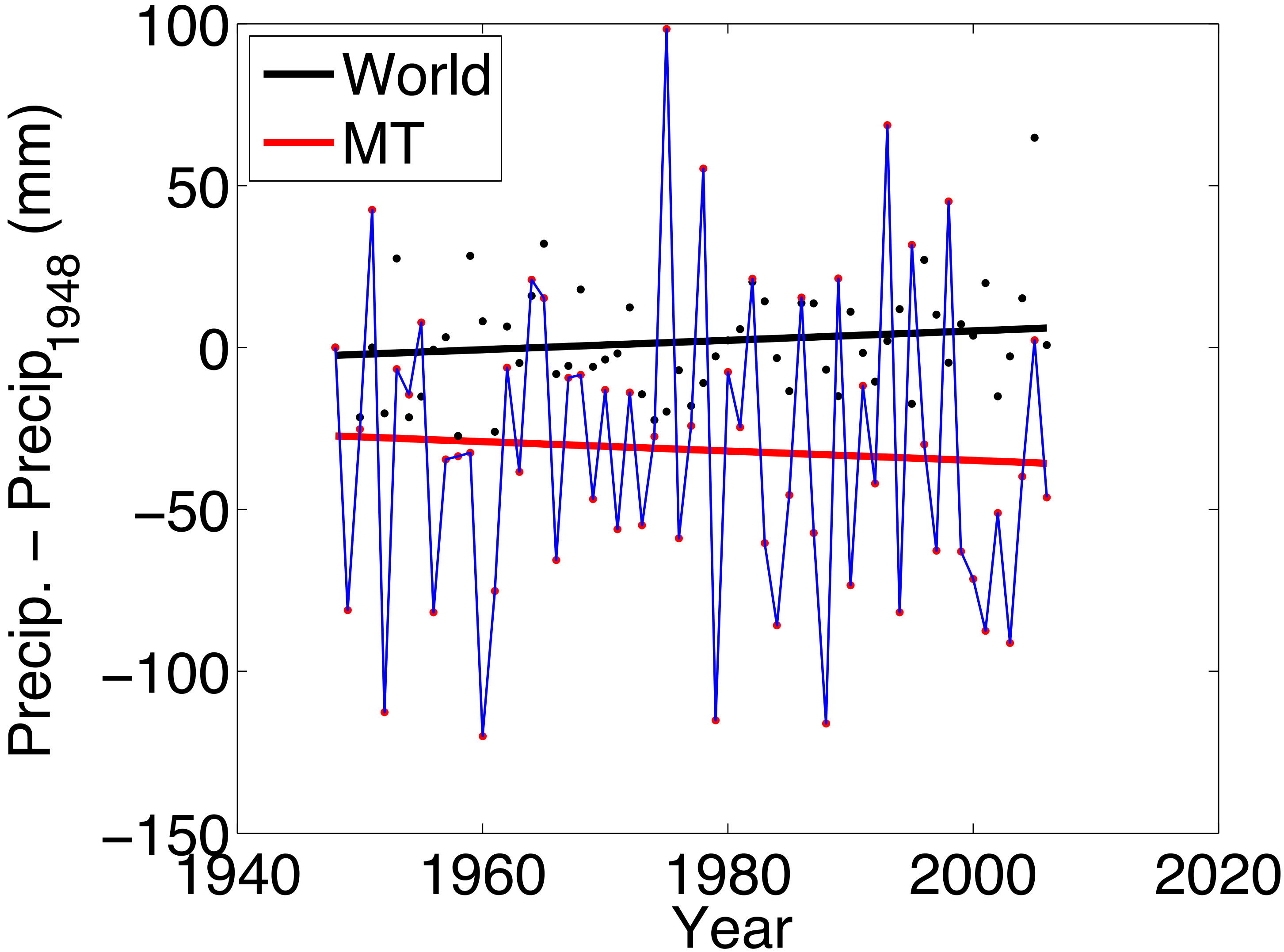
Defining areas belonging to MT from Sheffield et al.



MT *versus* global temperature trends

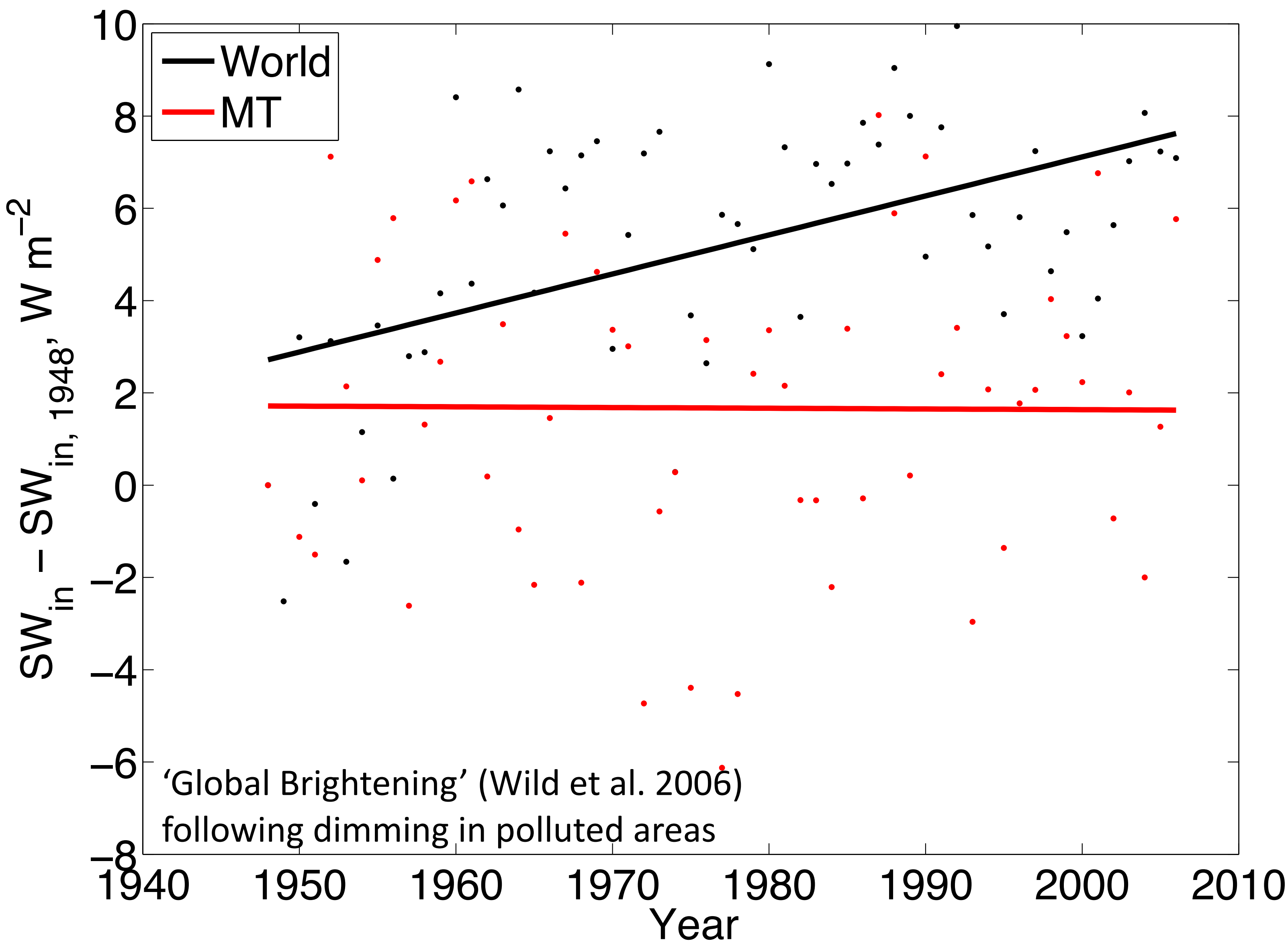


MT *versus* global precipitation trends

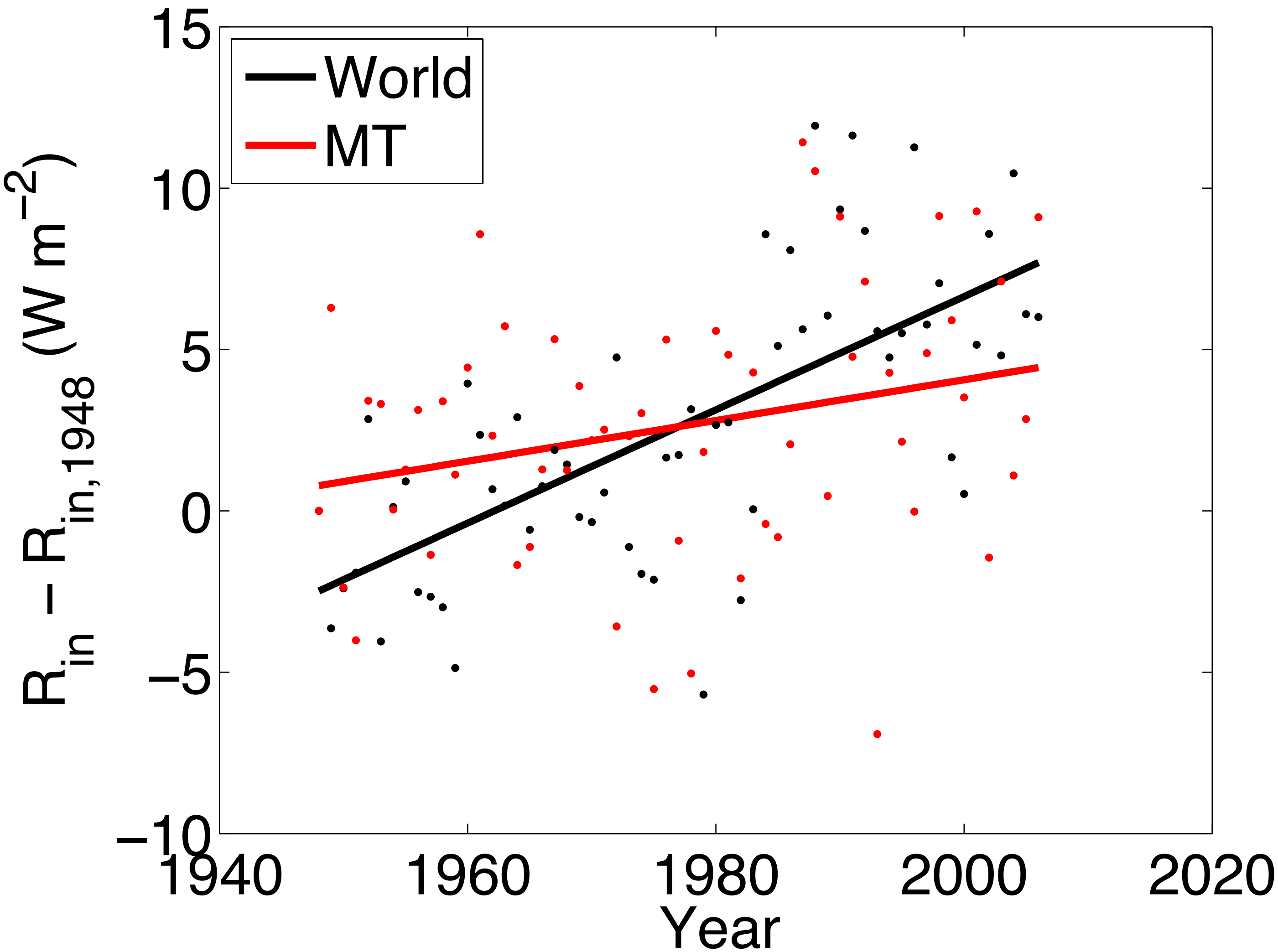


Sheffield et al. (2012) Little change in global drought over the past 60 years. Nature doi:10.1038/nature11575

MT *versus* global incident shortwave trends



MT *versus* global incident radiation trends



Increases in aridity

Not Changing

Aridity index = Precipitation / Potential Evapotranspiration

Increasing as a function of incident radiation

Conclusion:

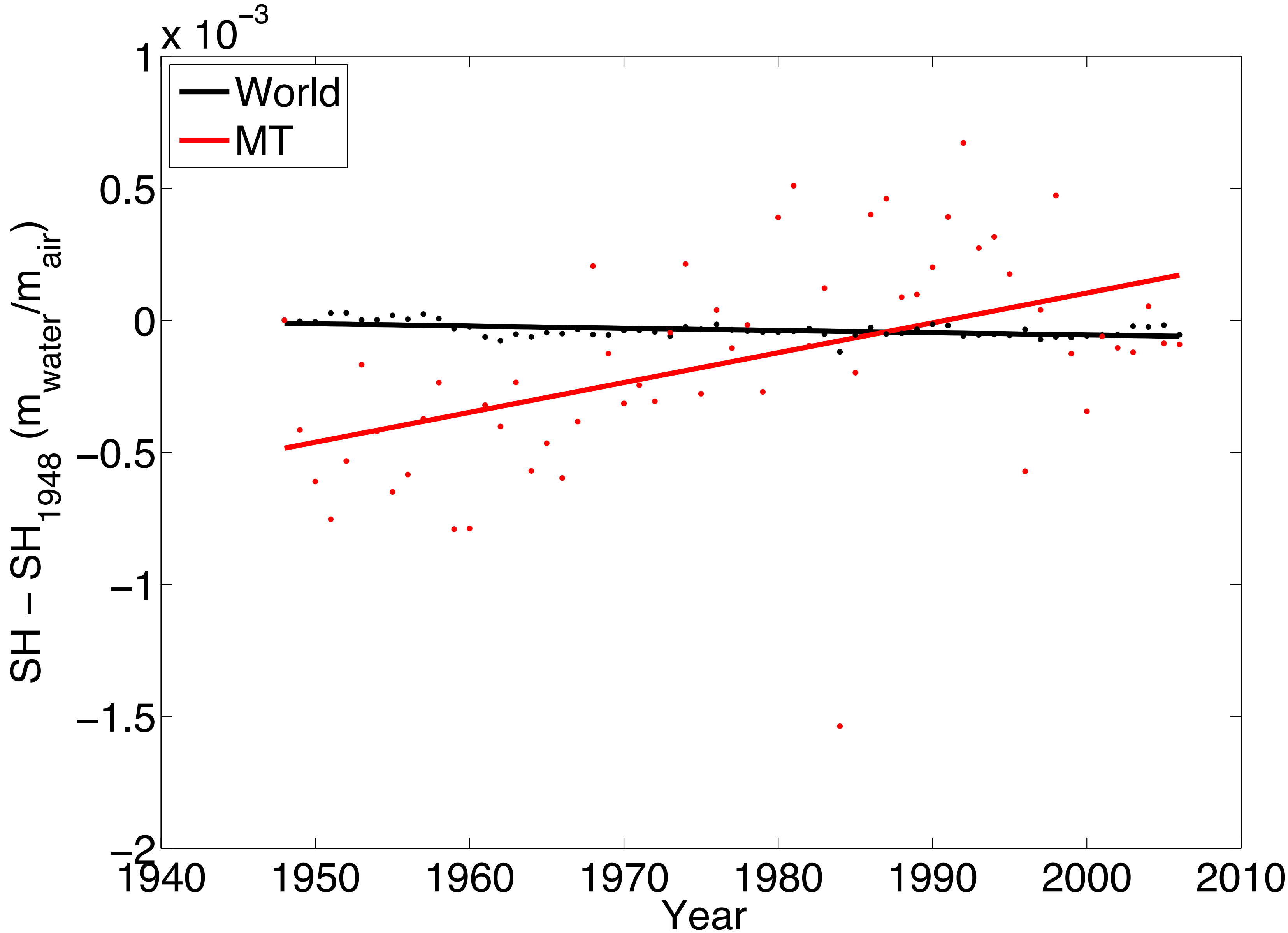
When making water use decisions we must recognize that there is now more energy to move water to the atmosphere.

Trends in MT are not as acute as the global mean, but MT has less available water than the global mean.

Sheffield et al. data inputs

Dataset	Variables	Temporal coverage	Spatial coverage	Source
NCEP–NCAR reanalysis	P, T, SW, LW, q, Ps, w	1948–present, 6 hourly	Global, ~2.0° × 2.0°	Kalnay et al. (1996)
CRU TS2.0	P, T, Cld	1901–2000, monthly	Global land excluding Antarctica, 0.5° × 0.5°	MCJHN
GPCP	P	1997–present, daily	Global, 1.0° × 1.0°	Huffman et al. (2001)
TRMM	P	Feb 2002–present, 3 hourly	50°S–50°N, 0.25° × 0.25°	Huffman et al. (2003)
NASA Langley SRB	LW, SW	1983–95, monthly	Global, 1.0° lat × 1.0°–120° lon	Stackhouse et al. (2004)

MT *versus* global specific humidity trends



The zero-dimensional climate model
(Global change is simple, regional change is difficult)

=

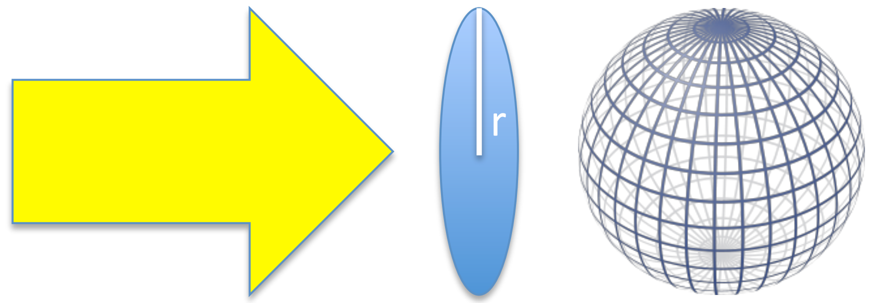
Energy in

Energy out

At steady state

Energy in = solar energy

A disk of solar radiation of size πr^2 hits Earth



$$E_{in} = \pi r^2 S_c (1 - \rho)$$

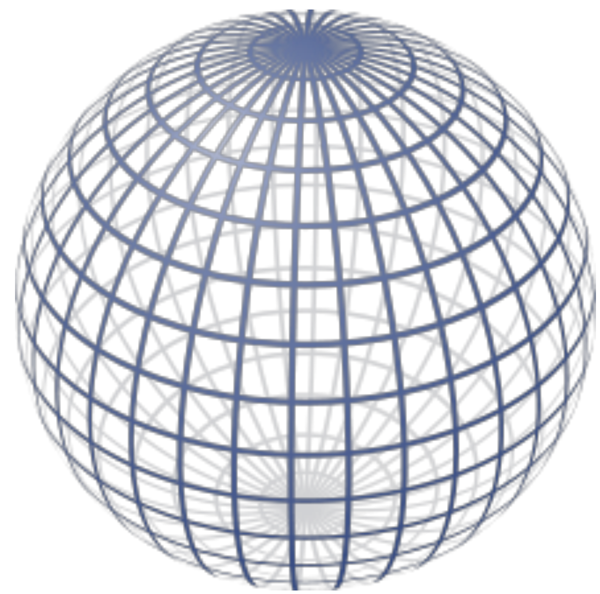
$$A_{circle} = \pi r^2$$

Energy out = planetary emittance

Stefan-Boltzmann Law

$$A_{sphere} = 4\pi r^2$$

$$E_{out} = A\varepsilon\sigma T^4$$



$$E_{out} = 4\pi r^2 \varepsilon\sigma T^4$$

Planetary energy balance

Energy in = Energy out

$$E_{in} = E_{out}$$

$$\pi r^2 S_c(1-\rho) = 4\pi r^2 \varepsilon\sigma T^4$$

$$\frac{S_c}{4}(1-\rho) = \varepsilon\sigma T^4$$

Solving for T

$$T^4 = \frac{S_c(1-\rho)}{4\varepsilon\sigma}$$

$$T = \sqrt[4]{\frac{S_c(1-\rho)}{4\varepsilon\sigma}}$$

Constants

σ= 5.67×10^{-8} J K^{-4} m^{-2} s^{-1}

Somewhat Constants

S_c=1367 W m^{-2}

ρ=0.31

The temperature of blackbody Earth

$$T^4 = \frac{1367 Jm^{-2}s^{-1}(1-0.31)}{4 \times 1 \times 5.67 \times 10^{-8} JK^{-4}m^{-2}s^{-1}} = 254K = -19^{\circ}C$$

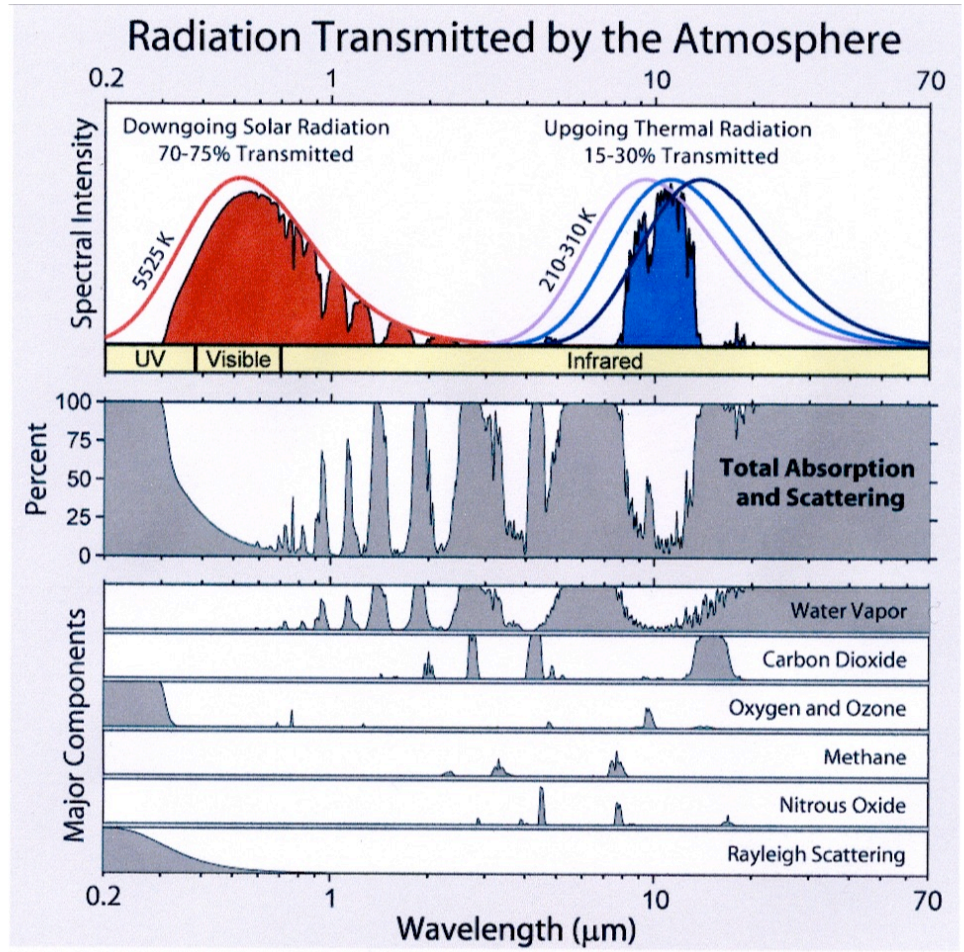
The temperature of real Earth ~ 14°C

Why? The effective emissivity of Earth is less than 1.
This is the greenhouse effect

Solving for (effective) emissivity

$$\varepsilon = \frac{S_c(1-\rho)}{4\sigma T^4} \approx 0.6$$

Recall:



Using T = 14 °C

Kirchoff's Law of Radiation

$$\varepsilon(\lambda) \propto \alpha(\lambda)$$

Albedo, emissivity and the solar constant determine global temperature

Why?
They determine
the energy balance.