

Climate Science and the Hydrological Cycle

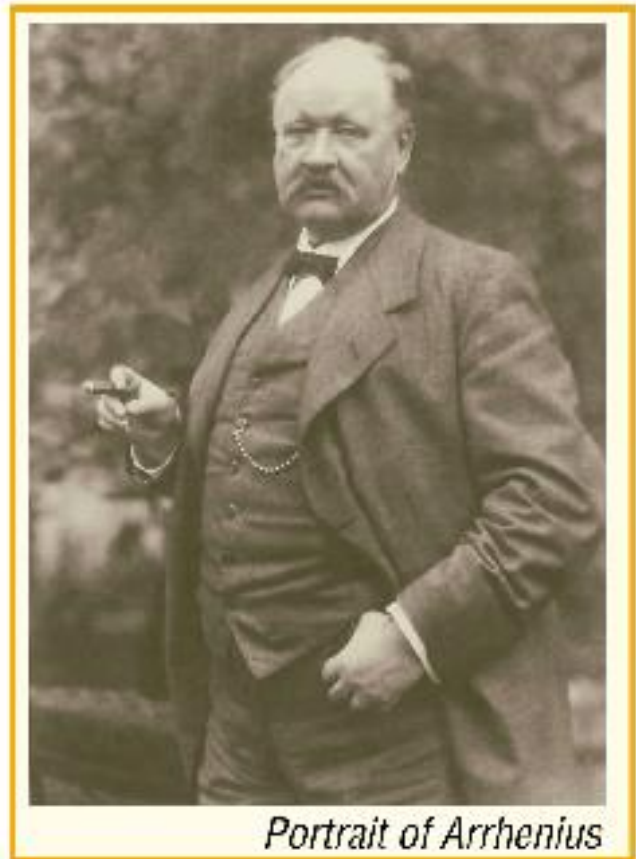
Antonio J Busalacchi

Chair, U. Maryland Council on the Environment
Director, Earth System Science Interdisciplinary Center

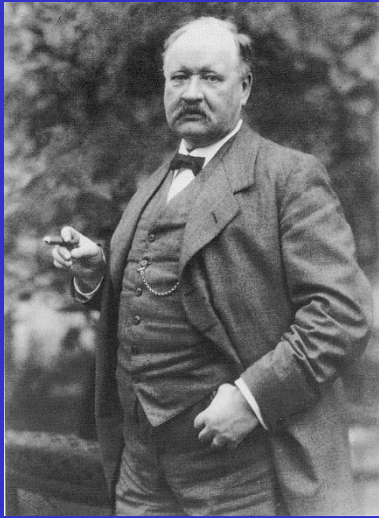


Climate change research has been around over 100 years.

- **S Arrhenius 1859-1927**
- Arrhenius, S., 1896. On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground. *Philosophical Magazine and Journal of Science* 41, 236-276.

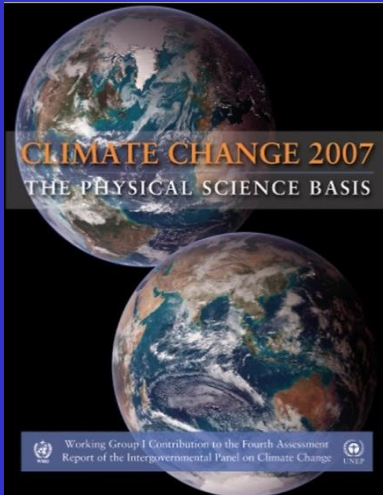


Projections of climate change



Svante Arrhenius, “Verldamas Utveckling”, 1906

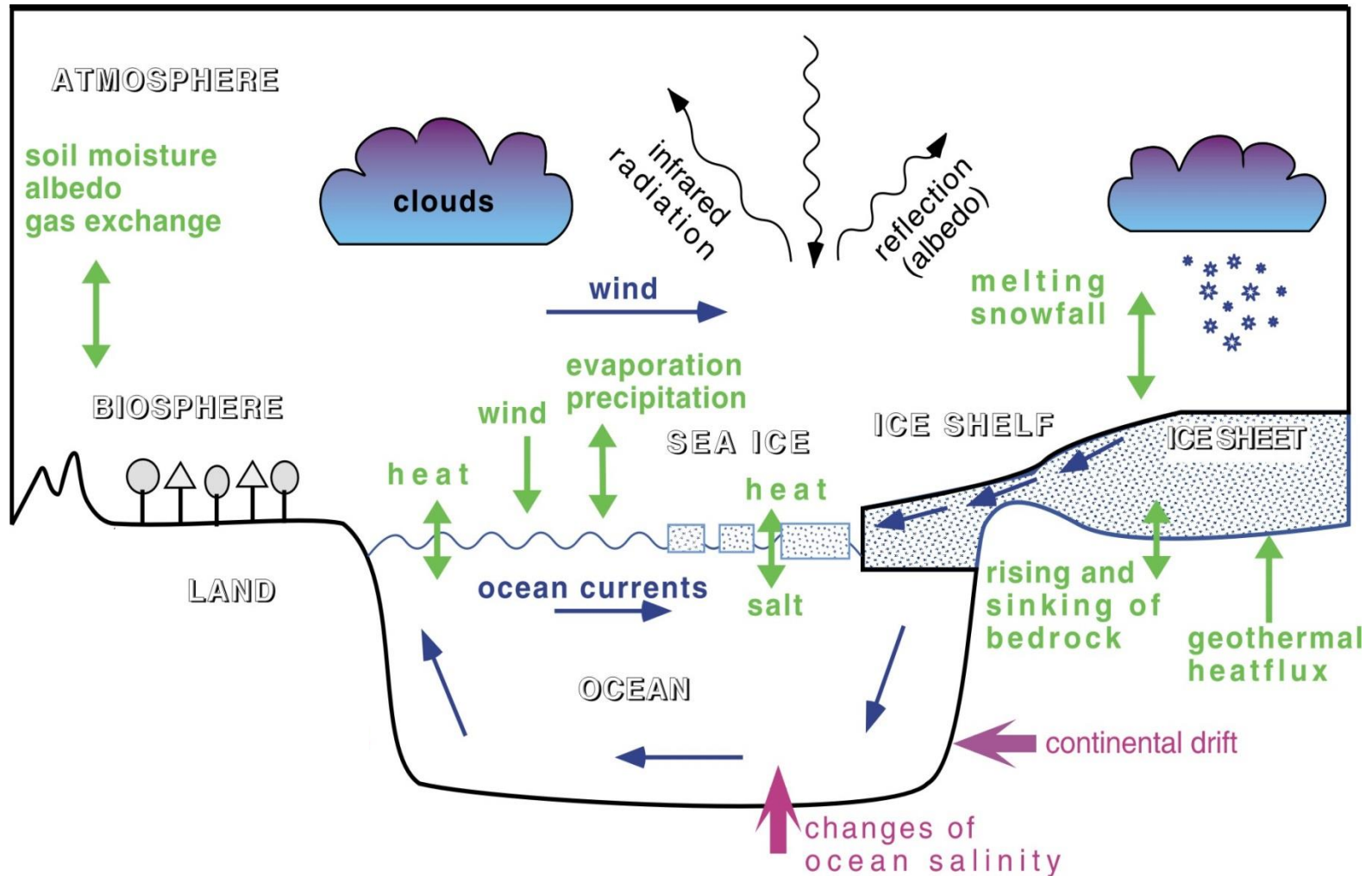
- ... any doubling of the percentage of carbon dioxide in the air would raise the temperature of the Earth's surface by 4°C.
- ... the percentage of carbonic acid in the atmosphere may, by the advances of industry, be changed to a noticeable degree in the course of centuries.



Intergovernmental Panel on Climate Change 2007 (IPCC)

- ... the best estimate of climate sensitivity to a CO₂ doubling is a warming of 3° C, with a likely range of 2 to 4.5° C.
- ... “business as usual” scenarios lead to CO₂ doubling over pre-industrial levels between 2050 and 2100.

The Physical Climate System



WCRP Grand Challenges

- **Regional Climate Information**
- **Regional Sea-Level Rise**
- **Cryosphere in a Changing Climate**
- **Clouds, Circulation, and Climate Sensitivity**
- **Changes in the Global Water Cycle**
- **Prediction and Attribution of Extreme Events**

* Climate Change is Water Change

Spruce Beetle Kill, San Juan Mountains, 2012

- * Heat Drives the Water Cycle - 1000 km³ evaporates daily from the oceans
- * The Water Cycle mixes heat from areas of too much to too little
- * As the Atmosphere Warms it Holds More Moisture: ~5F warming is 20% increase
- * Heating Up the Earth (and uneven heating) results in Water Cycle changes
 - * More Evaporation, More Precipitation, More Moisture
 - * Changes in weather patterns
 - * Wet Wetter, Dry Drier Standard Rule
 - * More Intense Floods and Droughts
- * All Kinds of Water Changes Already Noted
 - * More rain/less snow, Earlier Runoff, Higher Water Temps, More Intense Rain
- * Many of the most critical impacts of climate change will arise through water cycle changes driven by higher temps, not simply rising temperatures

April 2013 “showers” in Argentina

1 April 2013: Torrential rain Buenos Aires. Over night, rainfall records broken, >6 inches in less than two hours; flooding, killing eight people and leaving hundreds displaced. Buenos Aires Central Observatory

3 April 2013: Next storm 11 to 16 inches in some spots in La Plata Basin. Damage: >\$500Million



“Since the early ‘80s, the frequency of extreme weather events dumping over 100 millimeters of water has tripled,” Canziani

YEAR-TO-DATE RAINFALL TOTALS

Boulder



Source: RCC-ACIS.org - Applied Climate Information Systems
Boulder Station USC00050848

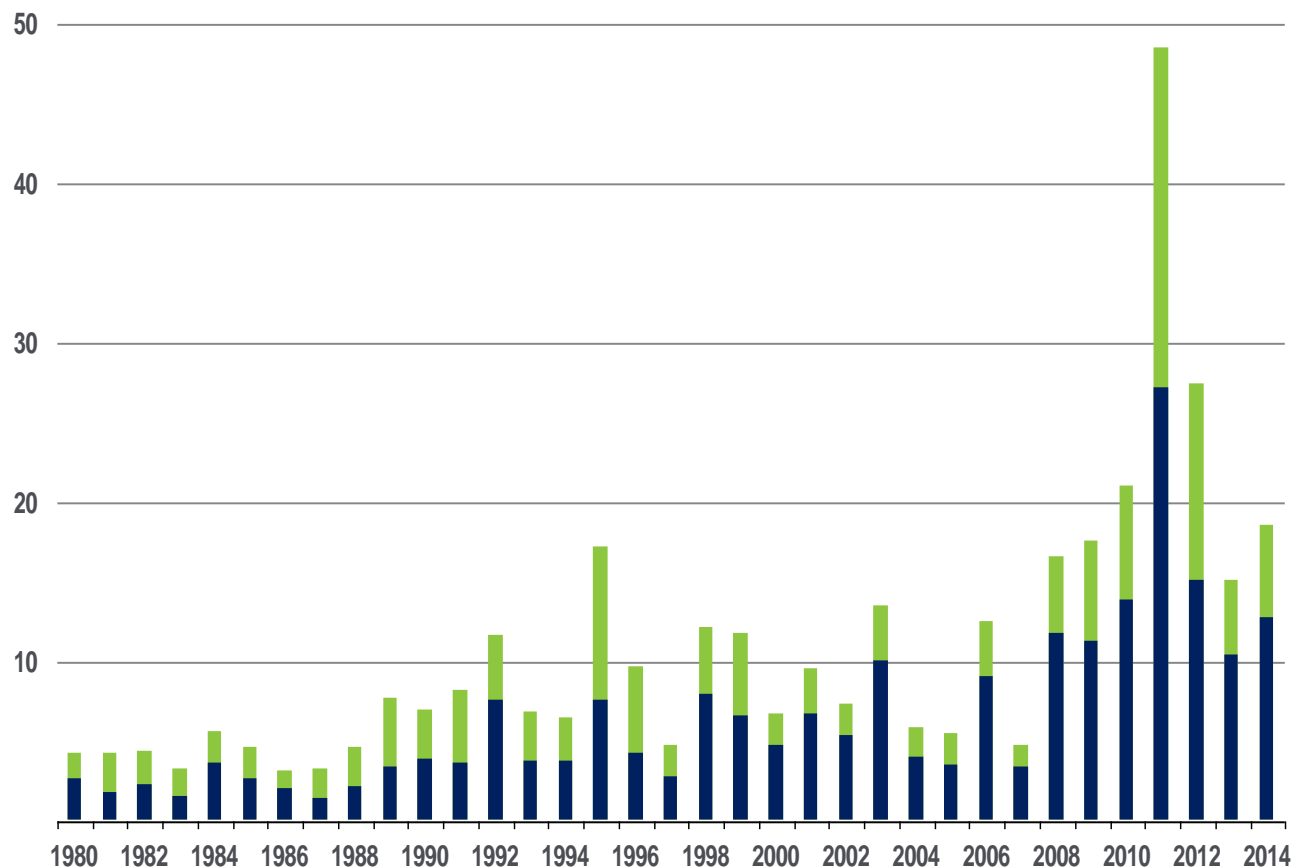
CLIMATE CENTRAL

The record is especially noteworthy since before Sept. 9, Boulder, along with much of eastern Colorado, was still mired in long-term drought conditions. As of Sept. 17, Boulder's monthly rainfall during September stood at 17.18 inches, all but 0.02 inches of which fell during the preceding week. The previous all-time monthly record was 9.59 inches in May of 1995.


Convective loss events in the US

Overall and insured losses 1980 – 2014

bn US\$



 Overall losses
(in 2014 values)*

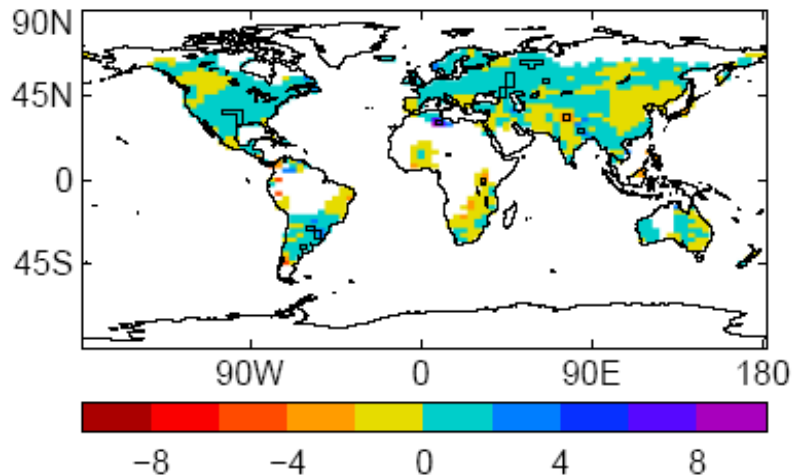
 Insured losses
(in 2014 values)*

Analysis contains:
severe storm,
tornado, hail,
flash flood and
lightning

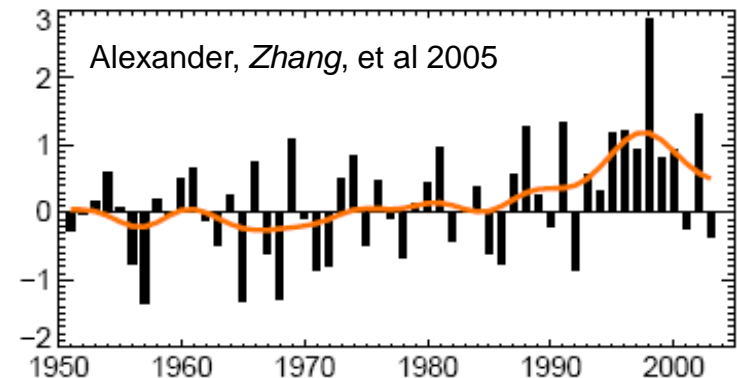
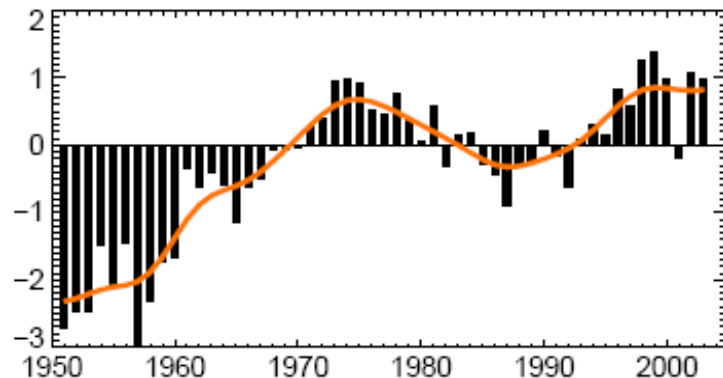
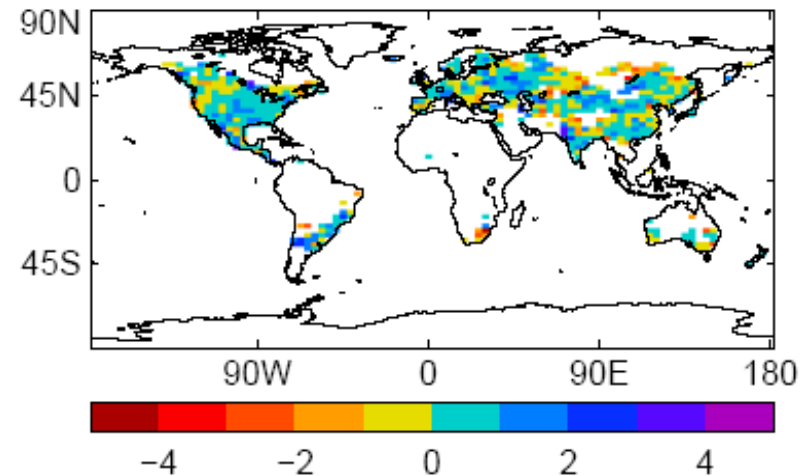
*Losses adjusted
to inflation based
on country CPI

Indices of precipitation “extremes”

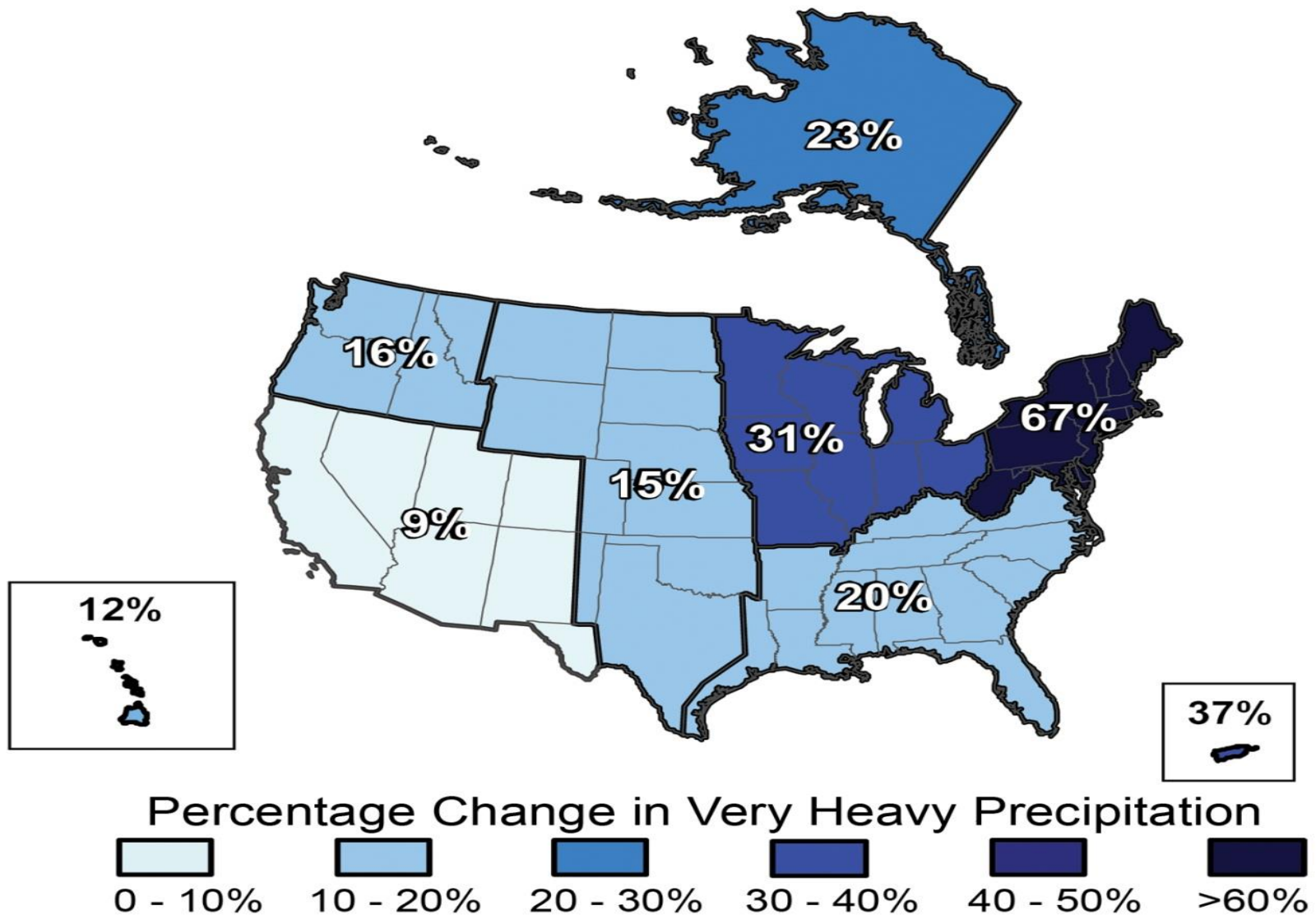
(a) Heavy precipitation days



(b) Contribution from very wet days



- Tendency is consistent with model results and physical understanding: shift in precipitation distribution



The map shows the percentage increases in very heavy precipitation (defined as the heaviest 1 percent of all events) from 1958 to 2007 for each region. There are clear trends toward more very heavy precipitation for the nation as a whole, and particularly in the Northeast and Midwest.

A World of Drought

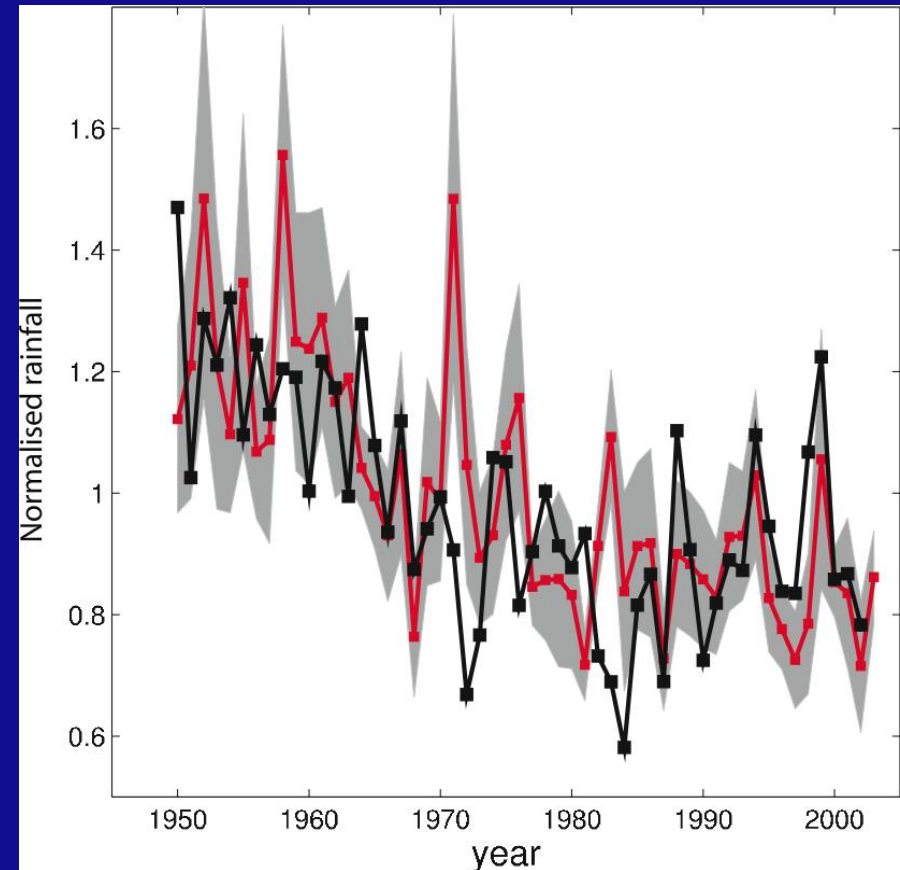


Many dry areas are getting drier.

Observed sea surface temperature (SST) and links to the pattern of rain in Africa

SSTs and Sahelian rainfall have varied in the past.

Some studies suggest links to widespread ocean SST trends and global warming.
Physical understanding of regional changes worldwide (snowpack? evaporation?) is needed for projections/attribution.....



Sahelian rainfall decline is reproduced in many models

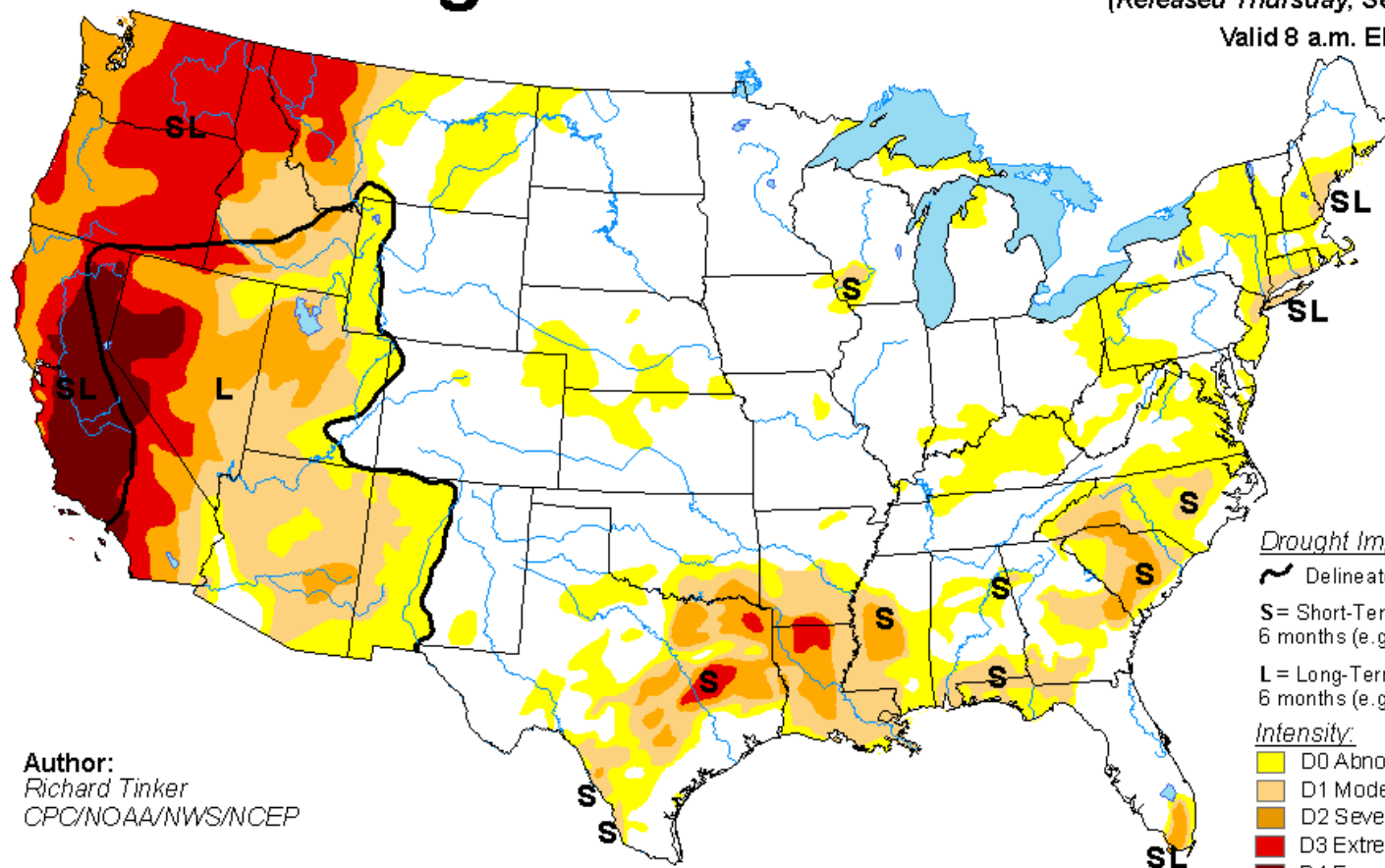
Drought: Tools and Resources

U.S. Drought Monitor

September 8, 2015

(Released Thursday, Sep. 10, 2015)

Valid 8 a.m. EDT



Author:
Richard Tinker
CPC/NOAA/NWS/NCEP

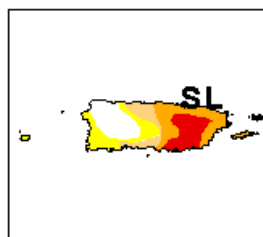
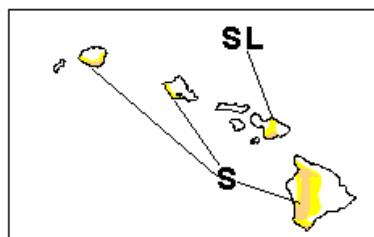
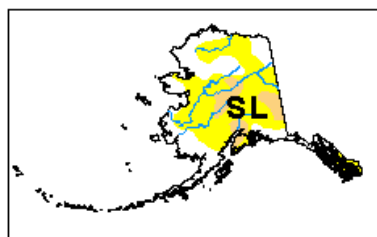
Drought Impact Types:

- ~ Delineates dominant impacts
- S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)
- L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.



<http://droughtmonitor.unl.edu/>

Maps of CMIP5 IPCC climate projections: multi-model mean results

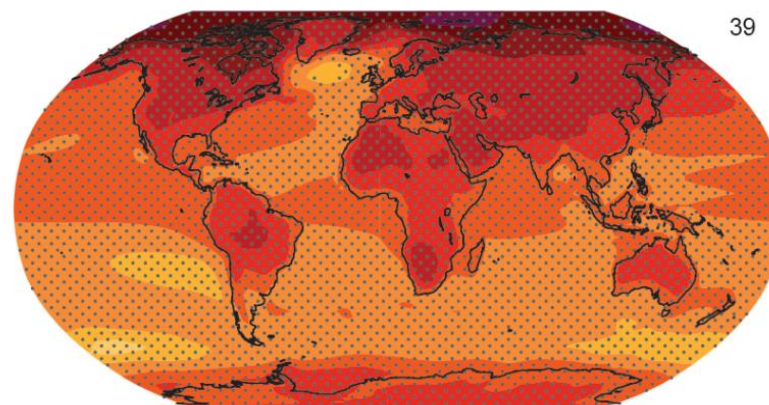
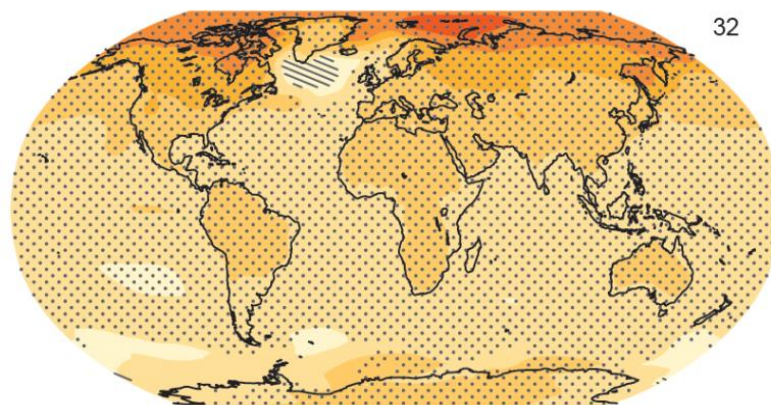
RCP 2.6

RCP 8.5

All Figures © IPCC 2013

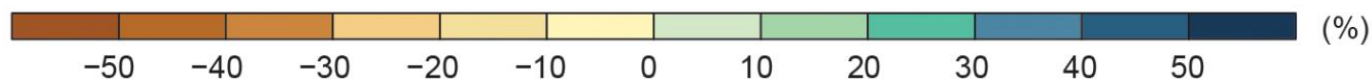
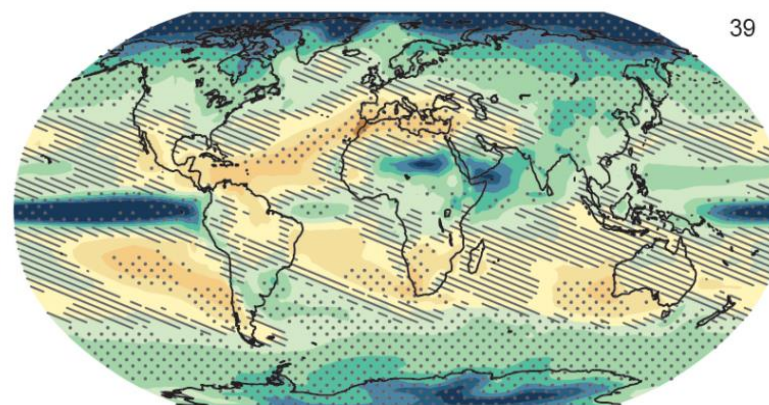
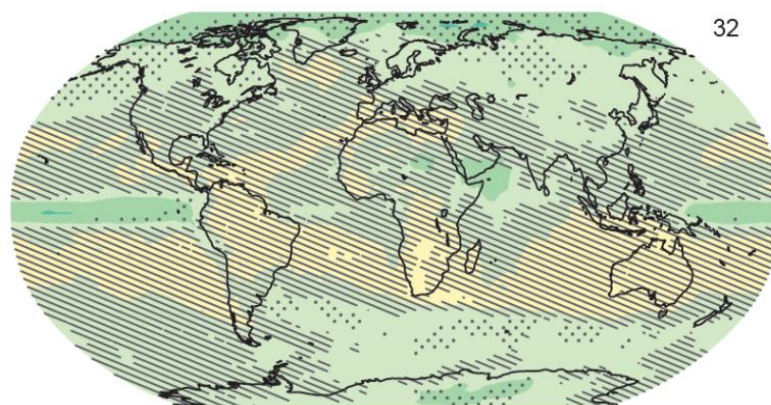
(a) Change in average surface temperature (1986–2005 to 2081–2100)

T



(b) Change in average precipitation (1986–2005 to 2081–2100)

P



7 The cooled and more dense air pushed aside by the rising column begins to sink.

6 Eventually, the density of the rising air equals the density of the surrounding air and it stops rising. This newly arrived air displaces air already at the same altitude, causing it to spread sideways.

5 As the air rises through the surrounding regions of greater density, it begins to cool and contract, becoming more dense.

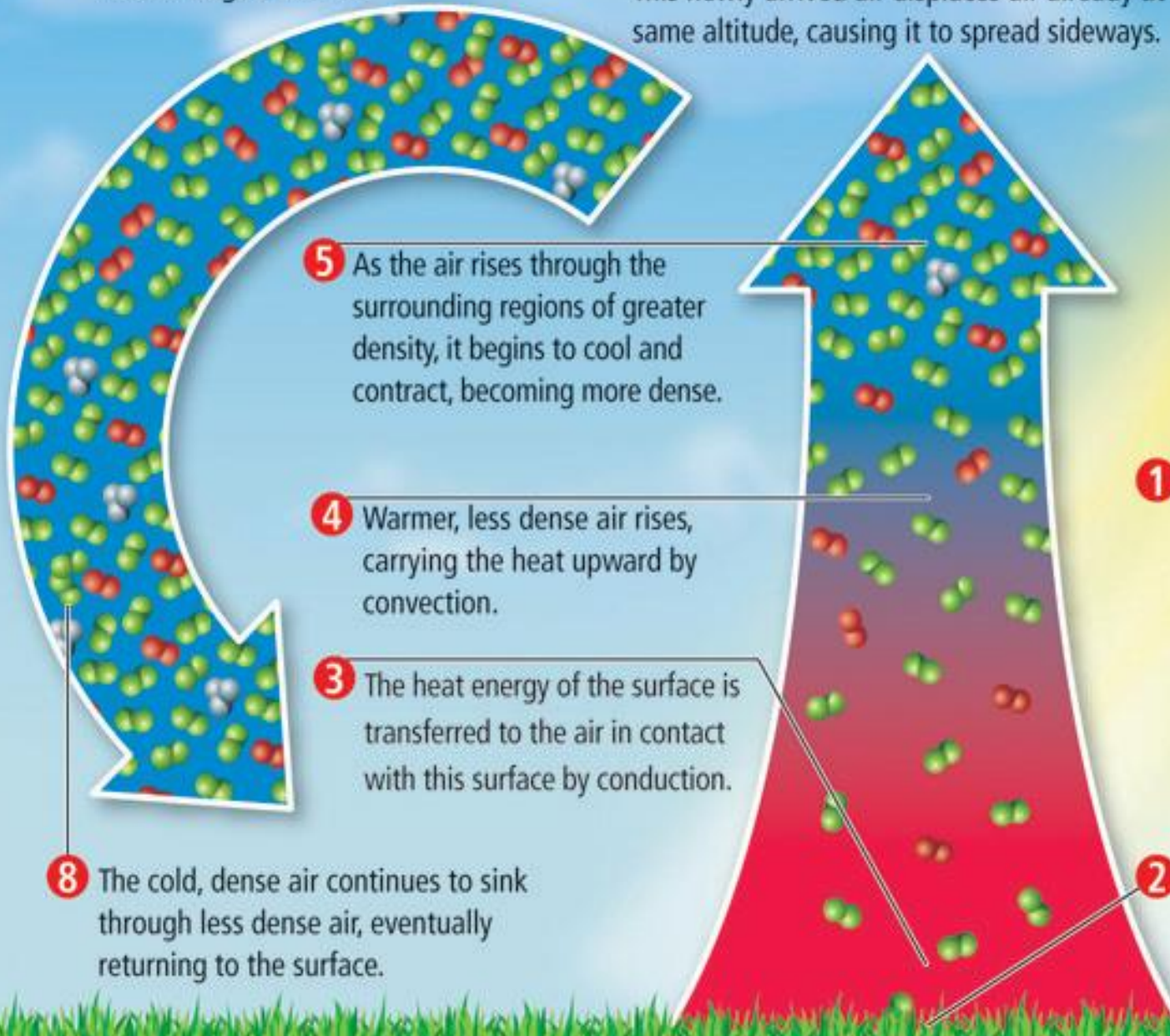
4 Warmer, less dense air rises, carrying the heat upward by convection.

3 The heat energy of the surface is transferred to the air in contact with this surface by conduction.

8 The cold, dense air continues to sink through less dense air, eventually returning to the surface.

1 Solar energy reaches Earth's surface via radiation.

2 Energy is absorbed by Earth's surface causing it to warm.



Heavy Downpours are Increasing Exposure to Disease

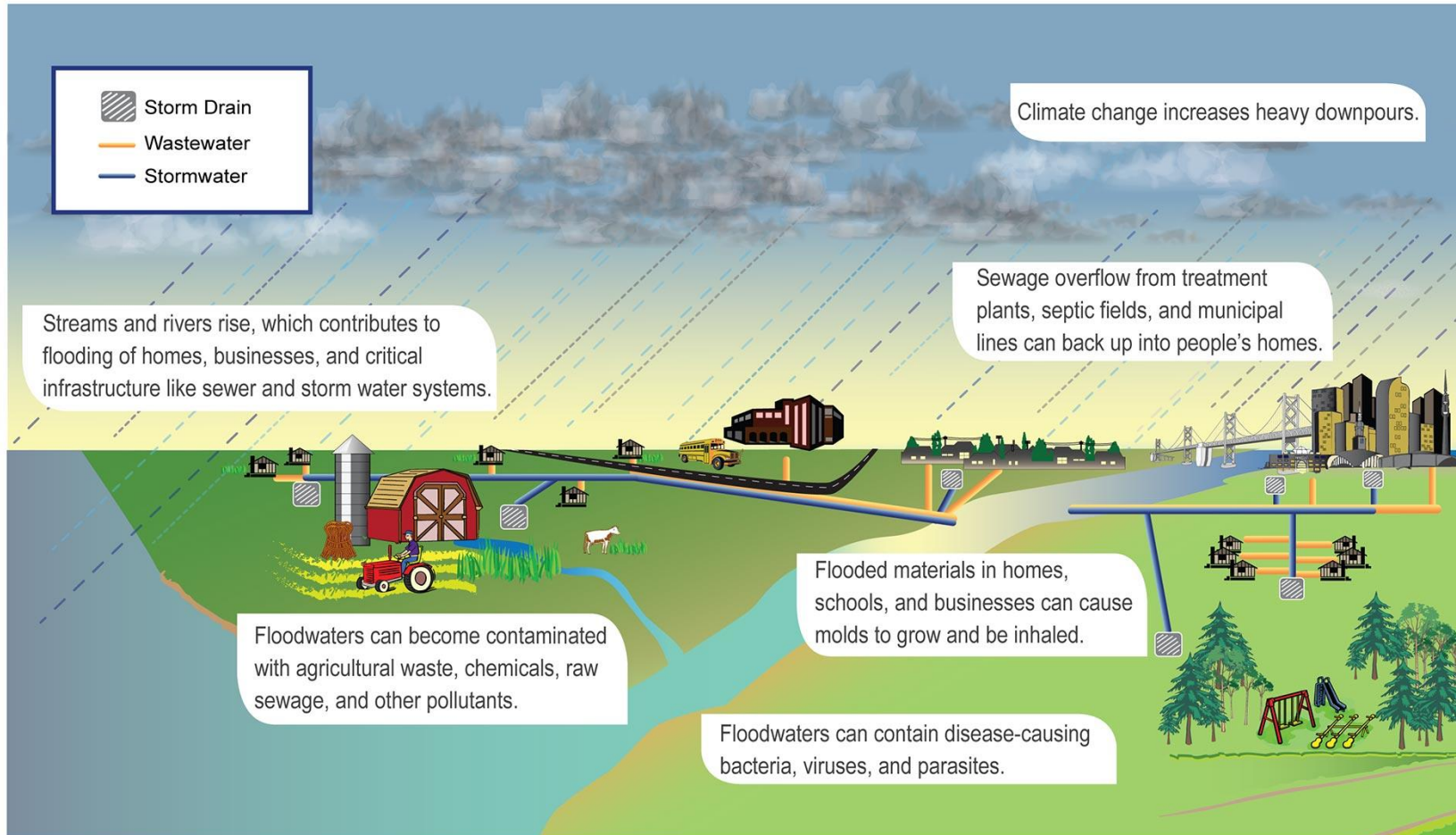


Figure 9.7: Heavy downpours, which are increasing in the United States, have contributed to increases in heavy flood events (Ch. 2: Our Changing Climate, Key Message 6). The figure above illustrates how people can become exposed to waterborne diseases. Human exposures to waterborne diseases can occur via drinking water, as well as recreational waters. ¹(Figure source: NOAA NCDC / CICS-NC)