Natural Hazards and Disaster

MITIGATION & ADAPTATION RESEARCH INSTITUTE
MARI
OLD DOMINION UNIVERSITY

Natural Hazards and Disaster

Class 18: Lab
- Case Study 2
- Floods

Class: Floods
- Water (Energy) cycle
- Flood Risk Management
- Largest Floods
- Deadliest Floods
- River floods
- Flash Floods
- Monsoon
- Water-Energy Cycle: Atmospheric Rivers
- Changing Flood Risk

Lab: Floods

Floods are the leading cause of death and property damage around the world. The most damaging floods are caused by hurricanes, typhoons, and stalled tropical storms which can drop heavy rain that lasts for several days. Coastal storm surge, including tsunami waves, often causes massive destruction to coastal communities. Flooding is also caused by rapid ice melting, which can dam rivers upstream creating lakes that subsequently break through the ice dam and swamp valleys downstream.

River flooding is often quoted in relation to a 100-year flood recurrence. This is often interpreted to mean that the flood of a stated magnitude has a 1 in 100 chance of occurring in any year. However, that is somewhat miss-leading. Floods are well represented by the Poisson distribution, which we discussed earlier. It does not mean that a flood of the specified magnitude will only occur every 100 years and it does not mean that a flood of that magnitude must occur every 100 years. It could happen next week, a dozen times over the next years, or not at all for 20 years.

The probability of flooding is based on past historical records. The 100-year flood recurrence datum will change if the frequency of flood recurrence changes significantly.

Discharge Q is the volume of water with time that passes a particular marker, usually the same location as the stage measurements, such as a bridge. Discharge is given in m^3/s. It is calculated from the width W and height) of the river channel and the average water velocity V at the measurement point:

$$Q = W \text{ x } H \text{ x } V$$

For example, a river channel with width of 3.2 m, height of 1.8 m, and average water velocity of 4.0 m/s will have a discharge Q of 3.2 x 1.8 x 4 = 23 m^3/s.

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Question: The largest flood known is the Kuray ice-dam failure, which had a peak discharge of 18,000,000 m^3/s. If at a certain location the average depths was 30 m and the average velocity 30 m/s, what must have been the average width of this flood?

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Question: One of the largest meteorological flood took place in 1953 in the Amazon basin, with a peak discharge of 370,000 m^3/s. If at a certain location the average depths was 10 m and the average width was 3 km, what was the average velocity at this location?

Lab: Floods

A substantial amount of historical data from previous flooding is needed to determine the recurrence interval of river floods. The river's 'stage' is its surface height *H* above a fixed point, measured by using a gauge. Observation of a river's stage over time leads to a "normal" stage for that river at that location, and flooding is generally recorded in meters or feet above the normal stage.

If the discharge rate increases, perhaps due to increased storm-water run-off, and the river valley's width cannot change, then the stage (H) must increase and the river will likely overflow its banks. Similarly, if the water continues to travel at the same velocity but becomes funneled downstream into a narrower river valley or culvert, then the stage must increase to accommodate the volume of water and flooding can result.

Lab: Exercises

On the following slides, fur exercises are defined. Please, submit these exercises to me by November 14, 2017.

The total number of points you can get is 170. If you achieve more than 100 Points, the points above 100 will be counted as extra credits.

For Exercise 3, group work is strongly recommended to reduce the work load. If you submit a group exercise for Exercise 3, please indicate who handled which of the three data sets.

Lab: Floods

The flooding recurrence interval R is calculated from

$$R = \frac{(N + 1)}{M}$$

where N is the number of years in the record, and M is the ranked order of the flood discharge, from greatest to least (see table below). Several years of maximum flood discharge data are required for this calculation to be meaningful.

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Table 1. Sample Discharge Table

Discharge rates are ranked in order of the magnitude of discharge. The period of analysis for this hypothetical sample set is 114 years (from 1902 to 2016).

Month	Year	Discharge (m^3/s)	Rank order
January	1936	8,500	1
December	2004	6,400	2
February	1920	6,000	3
January	1958	4,600	4
March	1983	2,900	5
January	2006	2,800	6
March	1939	2,500	7
November	1902	2,000	8

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From the sample data, the recurrence interval for a flood discharge of 6,000 m^3/s (ranked #3) or more is given by:

$$R = \frac{(114+1)}{3} = 38.33 \text{ years}$$

Thus a discharge rate of 6,000 m^3/s (or more) could be considered to be a 38-year flood. However, it is important to note that the time intervals for the three highest flood years (1920, 1936, 2004) are not equally spaced at 38.33 years apart. Moreover, having only three events is a poor basis to compute the recurrence interval.

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10 points

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Flood recurrence interval is not the same as probability of flooding. The probability p of a flood of a specified discharge rate in any given year is given by:

$$p = 1/R$$

In the example, the probability of a flood with discharge rate of 6,000 m^3/s or more in a given year is:
$p = 1/38.33 = 0.026$ or 2.6%

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Exercise 1: Using the sample data in Table 1, calculate the percent probability of a flood with a discharge rate of 2,900 m^3/s or larger.

p =____________%

10 points

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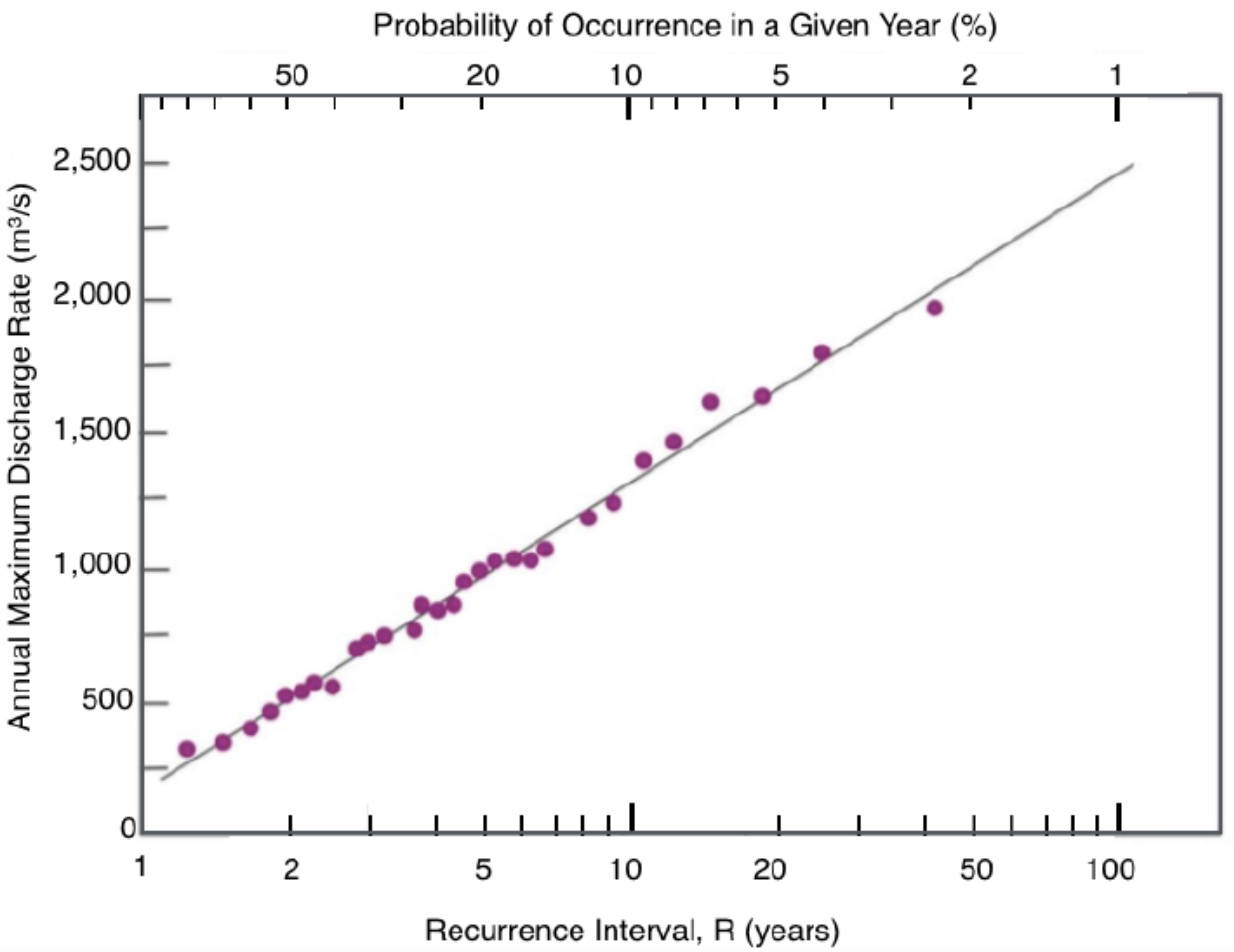
p =____________%

10 points

Of course, real floods do not occur with simple, round number discharge rates. If there are sufficient available historical data, a probability graph can be useful. The recorded discharge rate *Q* is plotted against *R*, the recurrence interval. *Q* is plotted on a linear scale but both *R* and *p* are plotted on log scales (this is called a semi-log plot). A trend line analysis, which is the line of best fit through the data, allows the probability of any discharge volume occurrence in a given year to be read from the graph. Smaller volume floods naturally occur more frequently than very large discharge volume floods and so the trend line, and therefore the probability prediction, is much more accurate for small volume floods.



Graph shows 50 years of annual maximum discharge rate data measured at the same point on a river, plotted against the calculated recurrence interval.

Exercise 2: Using the semi-log probability graph, estimate the probability of a discharge rate of 750 m^3/s and 1,600 m^3/s, respectively, in any given year.

10 points

Lab: Floods

The data tables are actual data from the U. S. Geological Survey's National Water Information System for the Roanoke, Virginia Gauge Station on the New River. Data records began in 1878 when the river went into major flood stage. Water stage gauges were installed and river stage and discharge measurements were recorded over the next 60 years.

In 1939, the gauge was replaced and the gauge datum (base line "normal" stage) was changed. This change affected all of the stage readings for the Roanoke station from that time forward. Therefore there are really two sets of data in the records: pre-1939 and post-1939. It is generally advantageous to use the entire discharge record as this gives the longest period of measurement. However, the change in gauge datum complicates the situation.

Exercise 3: What effect, if any, did the change in gauge datum have on the flood recurrence calculations or the probability assessment for future floods?

100 points

U.S. Geological Survey
National Water Information System

This file contains the annual peak streamflow data for
USGS site 03171000 NEW RIVER AT RADFORD, VA

agency	site no	peak date	peak streamflow (cfs)	gage height (ft)
USGS	03171000	1878-09-15	217000	37.4
USGS	03171000	1896-04-01	52400	13.0
USGS	03171000	1897-02-22	67200	16.0
USGS	03171000	1898-09-23	37200	9.6
USGS	03171000	1899-03-05	50600	12.6
USGS	03171000	1900-03-01	34000	8.6
USGS	03171000	1901-05-22	147000	26.8
USGS	03171000	1901-12-29	111000	22.6
USGS	03171000	1903-03-23	65200	15.6
USGS	03171000	1904-03-08	18300	8.0
USGS	03171000	1905-07-13	79800	21.6
USGS	03171000	1906-01-23	60200	18.0
USGS	03171000	1907-06-13	70400	20.0
USGS	03171000	1908-01-12	41600	14.0
USGS	03171000	1909-05-21	46200	15.0
USGS	03171000	1910-06-14	31000	11.0
USGS	03171000	1911-04-06	21900	8.8
USGS	03171000	1912-03-16	30500	10.8
USGS	03171000	1913-03-27	46200	15.0
USGS	03171000	1914-02-21	14000	7.0
USGS	03171000	1914-12-05	38700	13.6
USGS	03171000	1916-07-16	200000	35.7
USGS	03171000	1917-03-05	32000	8.0
USGS	03171000	1918-01-29	38500	10.0
USGS	03171000	1918-10-26	69400	16.5
USGS	03171000	1920-04-03	19600	5.0
USGS	03171000	1921-02-12	24200	6.0
USGS	03171000	1921-11-02	31000	7.7
USGS	03171000	1923-06-13	27500	6.7
USGS	03171000	1924-01-17	42600	10.9
USGS	03171000	1924-12-09	22800	5.7
USGS	03171000	1926-01-19	37000	9.7
USGS	03171000	1926-11-16	34500	9.1
USGS	03171000	1928-08-17	55700	13.8
USGS	03171000	1929-03-01	28000	6.8
USGS	03171000	1929-10-02	76200	17.7
USGS	03171000	1931-08-23	19600	5.0
USGS	03171000	1932-05-02	20100	5.1
USGS	03171000	1932-10-18	34000	8.7
USGS	03171000	1934-03-28	24200	6.0
USGS	03171000	1934-11-29	44800	11.4
USGS	03171000	1936-02-15	38500	10.0
USGS	03171000	1937-01-21	32000	8.0
USGS	03171000	1937-10-20	47500	12.0
USGS	03171000	1939-02-17	15300	4.0

Lab: Floods

USGS	03171000	1940-08-14	218000	35.96
USGS	03171000	1940-12-29	13200	4.96
USGS	03171000	1942-05-22	31300	10.13
USGS	03171000	1942-12-31	22500	7.85
USGS	03171000	1944-02-18	32100	10.32
USGS	03171000	1945-09-18	62700	17.00
USGS	03171000	1946-01-08	44400	13.07
USGS	03171000	1947-01-20	34500	10.86
USGS	03171000	1948-02-14	34500	10.86
USGS	03171000	1949-08-29	40800	12.31
USGS	03171000	1949-11-02	15200	5.58
USGS	03171000	1950-12-08	62200	16.86
USGS	03171000	1952-03-11	28100	9.30
USGS	03171000	1953-02-21	34900	11.00
USGS	03171000	1954-03-01	48000	13.90
USGS	03171000	1955-04-15	32100	10.26
USGS	03171000	1956-04-16	33300	10.63
USGS	03171000	1957-04-06	54400	15.33
USGS	03171000	1958-05-08	19700	7.02
USGS	03171000	1958-12-29	40300	12.16
USGS	03171000	1959-10-01	71000	18.64
USGS	03171000	1961-05-12	48400	13.95
USGS	03171000	1961-12-12	39800	12.06
USGS	03171000	1963-03-13	46600	13.62
USGS	03171000	1964-03-06	24000	8.15
USGS	03171000	1965-03-27	35800	11.23
USGS	03171000	1966-02-14	55700	15.57
USGS	03171000	1967-03-08	23400	8.04
USGS	03171000	1968-03-13	22700	7.86
USGS	03171000	1968-10-20	21700	7.58
USGS	03171000	1970-08-10	31400	10.12
USGS	03171000	1971-05-14	15800	5.80
USGS	03171000	1972-06-21	80600	20.21
USGS	03171000	1973-05-28	79300	20.02
USGS	03171000	1974-04-05	41000	12.36
USGS	03171000	1975-03-15	48000	13.92
USGS	03171000	1976-06-21	49600	14.26
USGS	03171000	1977-04-05	60000	16.46
USGS	03171000	1977-11-07	108000	24.10
USGS	03171000	1979-09-22	53900	15.23
USGS	03171000	1980-04-15	41300	12.42
USGS	03171000	1981-05-29	25700	8.64
USGS	03171000	1982-02-03	40100	12.15
USGS	03171000	1983-04-10	47700	13.79
USGS	03171000	1984-02-15	39000	11.87
USGS	03171000	1985-08-18	19100	6.71
USGS	03171000	1985-11-05	46800	13.60
USGS	03171000	1987-03-01	54100	15.12
USGS	03171000	1987-11-17	11200	4.48
USGS	03171000	1989-09-23	92600	21.73
USGS	03171000	1989-11-16	38600	11.79
USGS	03171000	1991-03-30	24400	8.16
USGS	03171000	1992-06-05	74100	18.81
USGS	03171000	1993-03-24	70900	18.24
USGS	03171000	1994-08-18	59300	16.12
USGS	03171000	1995-01-15	108000	24.04
USGS	03171000	1996-01-19	79900	19.76
USGS	03171000	1996-12-02	33500	10.50
USGS	03171000	1998-04-20	43400	12.89
USGS	03171000	1999-05-15	12500	4.80
USGS	03171000	2000-04-18	13600	5.13
USGS	03171000	2001-07-30	22800	7.73
USGS	03171000	2002-03-18	32500	10.25
USGS	03171000	2003-02-23	53900	15.08
USGS	03171000	2003-11-20	80000	19.77
USGS	03171000	2005-03-29	28700	9.28
USGS	03171000	2006-06-28	34900	10.87
USGS	03171000	2006-11-16	18400	6.50
USGS	03171000	2007-10-26	21900	7.45
USGS	03171000	2009-05-08	23100	7.77
USGS	03171000	2010-01-25	40000	11.92
USGS	03171000	2011-03-06	50600	14.36
USGS	03171000	2011-12-08	31800	9.96
USGS	03171000	2013-01-31	89300	21.13
USGS	03171000	2014-02-21	22900	7.72
USGS	03171000	2015-04-20	58700	16.16

Exercise 3: What effect, if any, did the change in gauge datum have on the flood recurrence calculations or the probability assessment for future floods?

To answer this question, you will work in teams using Excel to compare the separate and combined data sets, and to discuss the relative accuracy of flood predictions using these available data.

Use only the data set that you have been assigned (this will be one of the following data sets: 1878 to 1939 (45 data rows); or 1940 to 1977 (38 data rows); or 1977 to 2015 (38 data rows).

A. Open Excel and select New Workbook. Give the workbook the title of New River, Radford, VA and be sure to add your name, class ID#, and the date range of your data set in the title cells (top row of the worksheet).

B. You will enter your data into three columns titled: Year; Peak Streamflow data (also known as the peak Discharge Rate Q), which is given in cubic feet per second (cfs); and the gauge (gage) height, which is given in feet.

C. Now add 3 more columns: one for the Recurrence Interval R, one for $\log_{10}R$, and a third column for the % probability p, of a recurrence of a flood of that magnitude in any given year. Use the Excel formulas (or calculate by hand, if you prefer) and enter the respective calculations for each year in these three columns.

D. Use the chart tool provided in Excel to create an X-Y scatter plot for your data set, with $\log_{10}R$ data on the X-axis and Q data on the Y-axis. Be sure to title your chart with the year-range of your data set and the locality (Roanoke, VA).

E. Use the Trend tool in the Excel chart menu to add a Straight Line trend line to your scatter plot. You should now have a chart that looks something like the sample graph shown above in Exercise 2, except that you have already calculated the $\log_{10}R$ values so that they can be plotted on linear graph paper.

F. Now comes the interesting part! Compare your chart with those from the other two data sets. What explanations are there for the differences? In which data set - if any - would you have the most confidence?

G. Combine the three original data sets onto one new worksheet (copy and paste works fine, just be sure to add the new data below existing data and not in new columns!)

H. Create a new chart for $\log_{10}R$ versus Q with a new trend line that uses all the data.

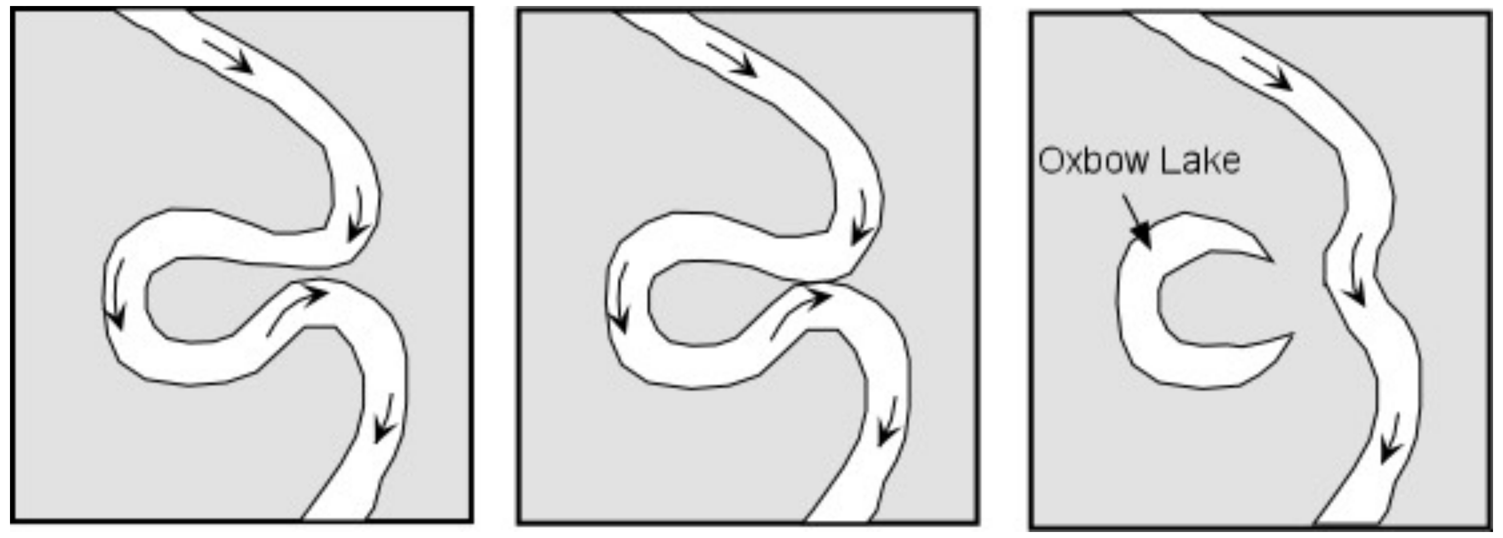
I. Does this combined data set improve the probability (p) predictions? Discuss what you see.

J. Which data set(s) for the New River in Virginia would you recommend that the USGS uses in future? Give reasons for your answer.

Exercise 4. Meander cut-offs by flooding events

The geological map on the next page was created in 1944 for the Office of the President's Mississippi River Commission. It shows the different meanders (curves) that the Mississippi River made over time along this section of its length. Each meander became abandoned as an ox-bow lake during a flood event, when the river broke across the narrowest part of the loop to take a more direct route to the ocean.

Over time, the river gradually carved out new meanders and deposited new sediments in its river bed on the outermost banks of the meanders.



The Legend on the right of the map below shows the relative ages of each abandoned meander. Information about their relative ages comes from the age of the sediments deposited within the meander cut-offs. Where the ages cannot be determined with precision, it is still possible to tell which is the younger of two abandoned ox-bow meanders by looking at the superposition of sediments, such as gravels which indicate fast-moving water deposited on top of muds, which indicate slow-moving or still water.

Lab: Floods

A. Examine the map and using a green pencil trace out the path that the river took in 1880 (unit #19, light green color at top of the legend list).

B. Now use a red pencil to trace out the path of the river before the 1880 segments were deposited (dark red, unit #18)

C. Identify and clearly label where the river at the time unit #19 sediments were deposited must have abandoned a meander filled with sediments of unit #18. This abandoned meander would have been an ox-bow lake when the river flow was cut-off.

D. Identify and trace out units #8 and #9 (light pink) as far as you can. Are there any abandoned meanders in these units? If so, locate them and label them on the map.

E. Two small towns, Hayti (labeled H) and Caruthersville (C) are situated on the Missouri side of the river, near the top edge of the map. You can see them on GoogleEarth if you zoom in to Lat 36.21°N, Lon -89.7°W. What would you advise the officials of these two towns (if you were asked) about the wisdom of further property development, given the history of the Mississippi River's course in this region? What information do you think they should be aware of?

50 points

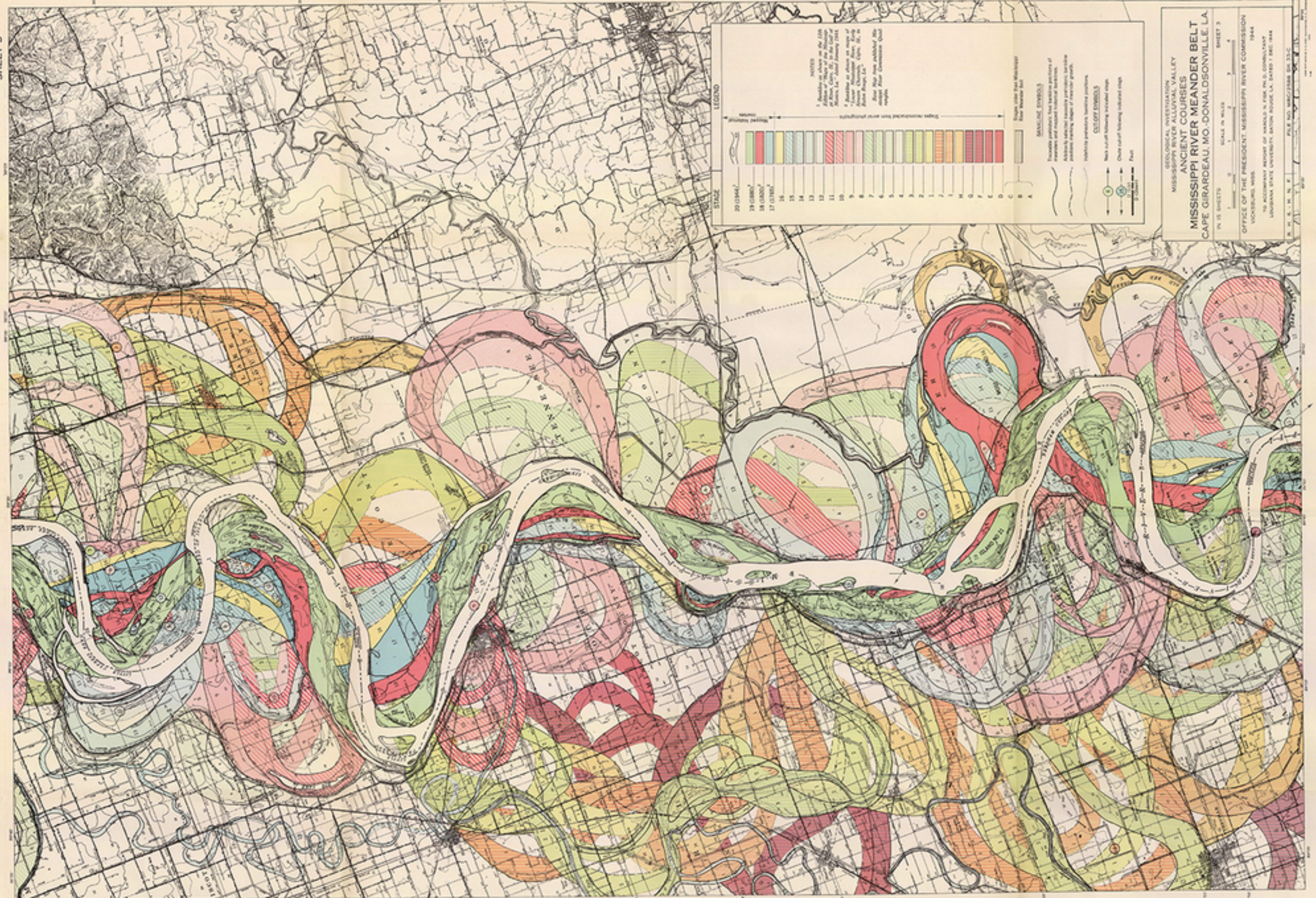


PLATE 22
SHEET 3
GEOLOGICAL INVESTIGATION
MISSISSIPPI RIVER ALLUVIAL VALLEY
ANCIENT COURSES
MISSISSIPPI RIVER MEANDER BELT
CAPE GIRARDEAU, MO.-DONALDSONVILLE, LA.
OFFICE OF THE PRESIDENT, MISSISSIPPI RIVER COMMISSION
VICKSBURG, MISS.
1944
LEGEND

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Floods Risk Management

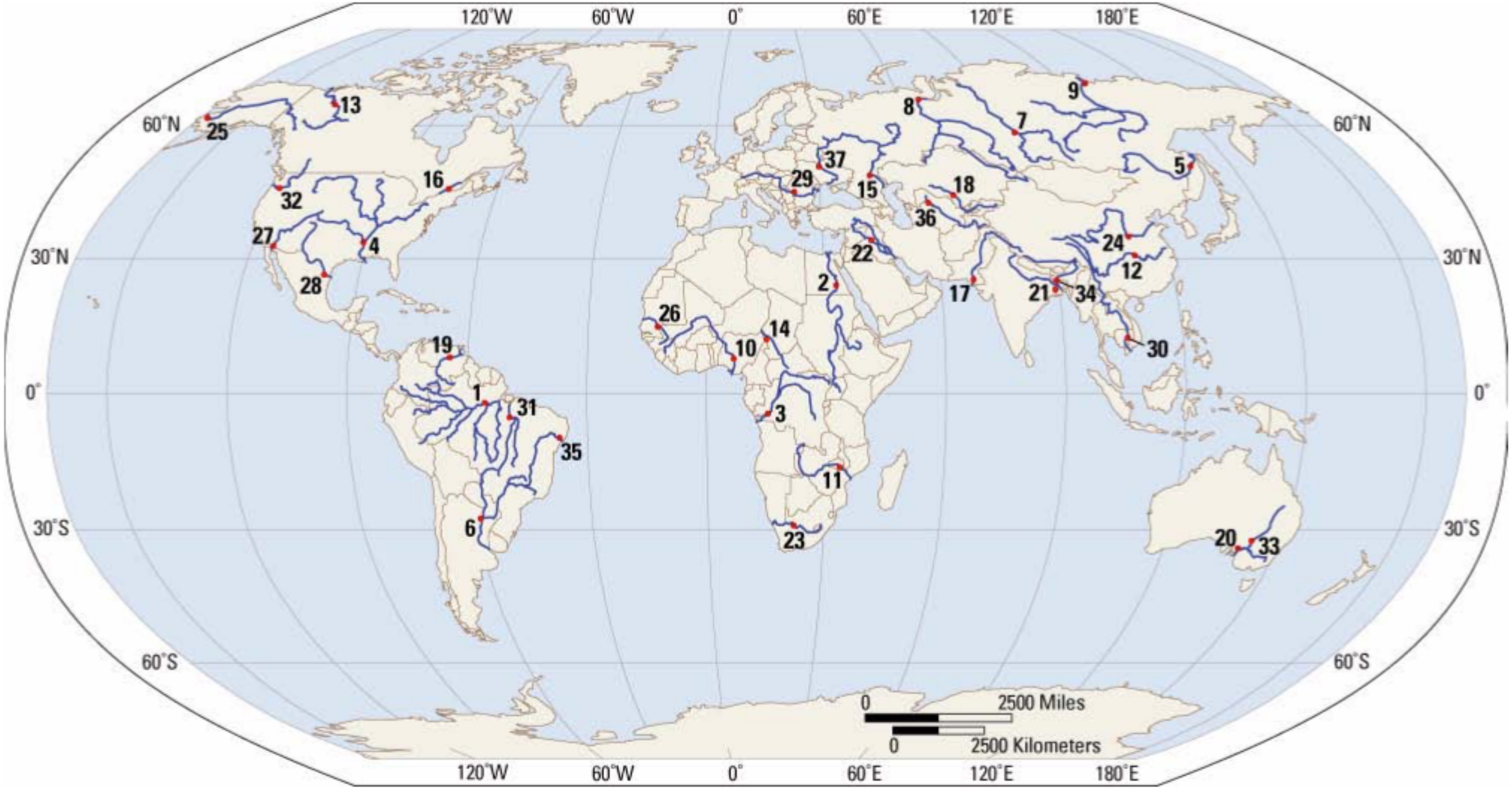


Figure 5. This map shows rivers with drainage basins larger than 500,000 square kilometers. Map numbers are keyed to table 2.

Connor and Costa, 2011

Floods Risk Management

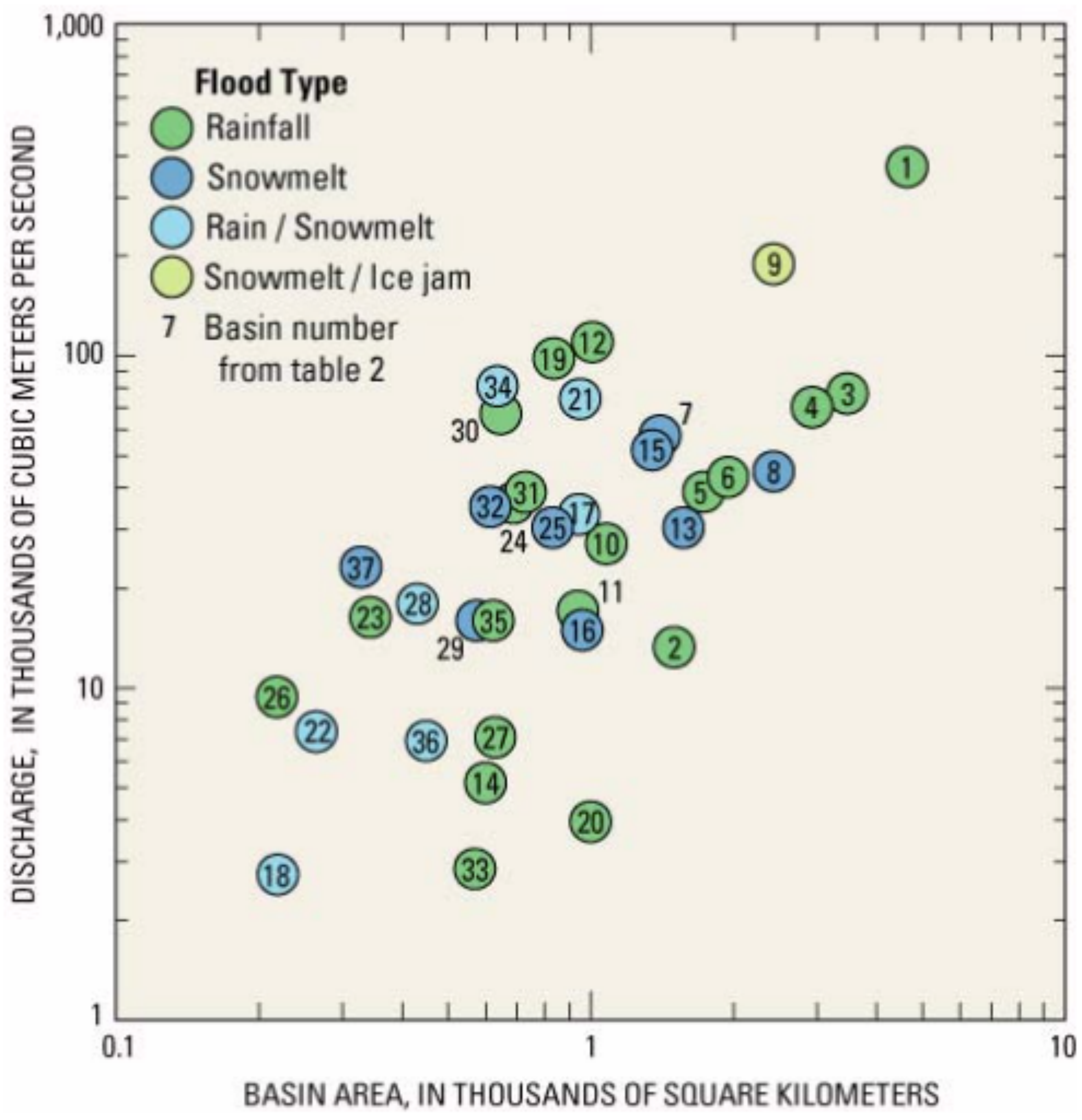
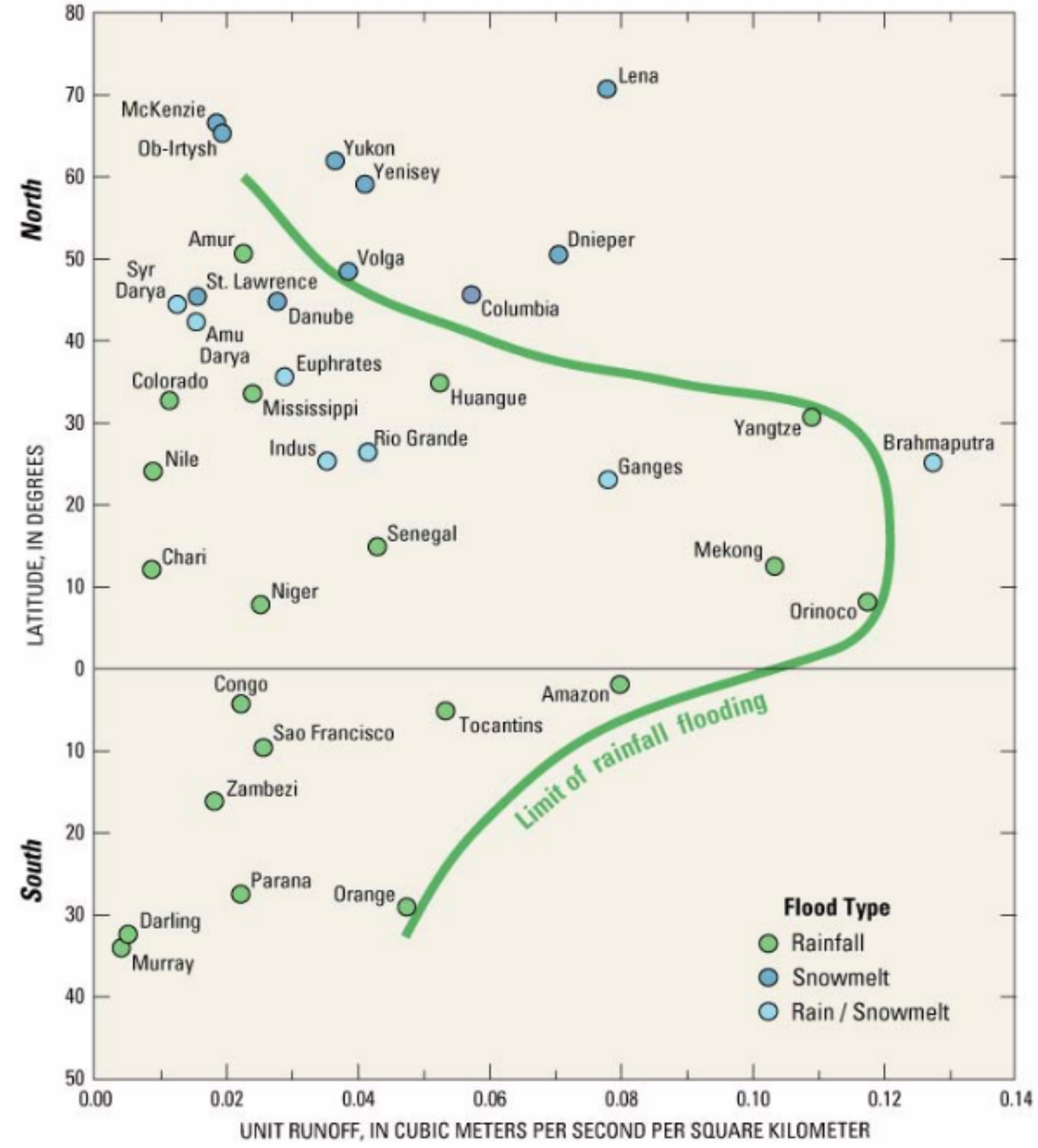


Figure 6. In general, larger river basins produce larger floods, but larger unit discharges in the moist tropics can result in floods of disproportionately large size. Numbers refer to basin numbers in figure 5 and table 2.

Figure 7. Nearly all of the largest floods caused by rainfall have occurred in basins south of latitude 40 degrees N. North of that, snowmelt- and ice-jam-related floods have predominated. Data from table 2.



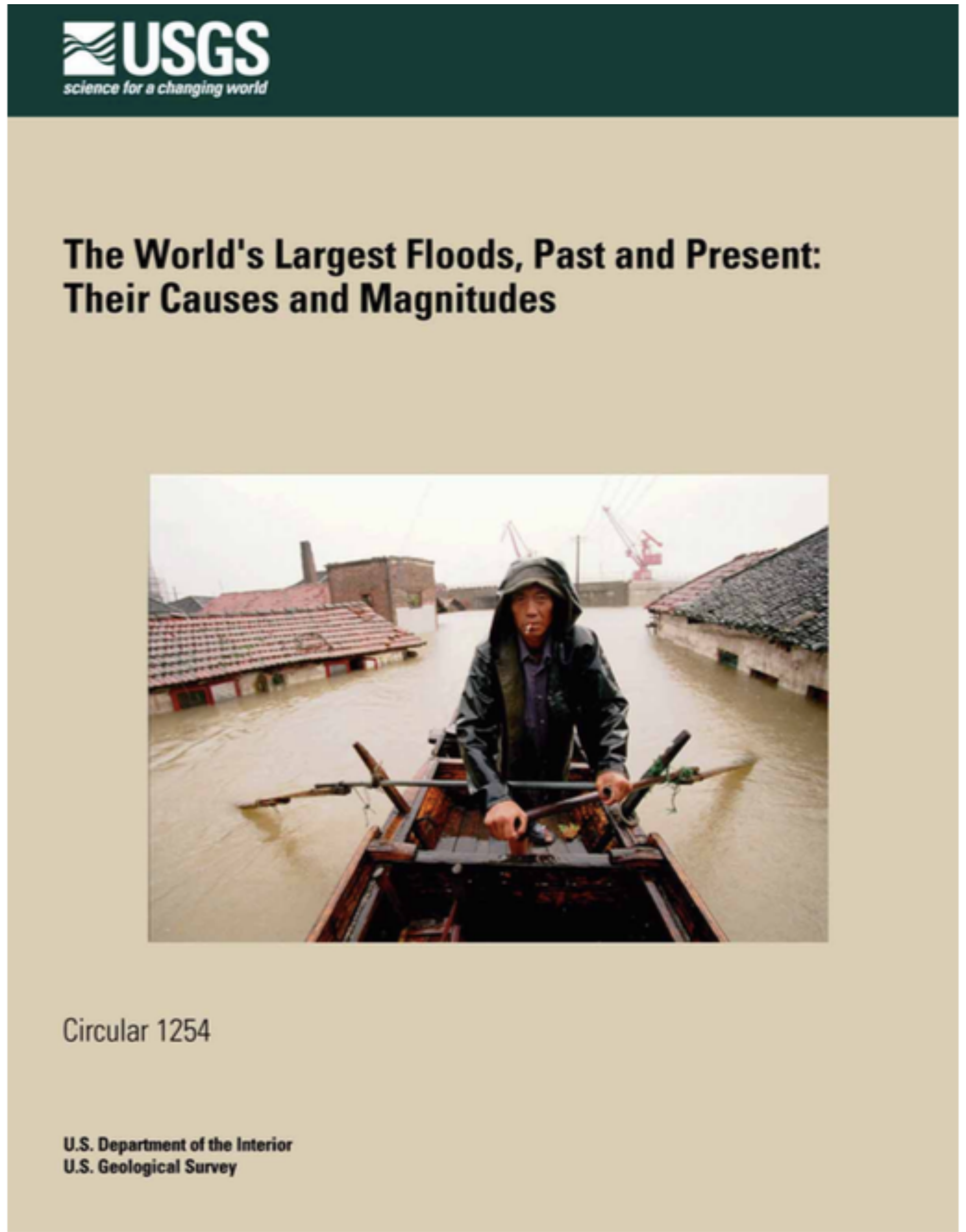
Connor and Costa, 2011

Largest Floods

Table 2. Largest meteorologic floods from river basins larger than about 500,000 square kilometers.

[Data from Rodier and Roche (1984) except as noted. River and station locations shown on figure 5. Station area: $10^3 km^2$, thousand square kilometers. Station latitude and longitude: N, north; S, south; E, east; W, west. Peak discharge: m^3/s, cubic meters per second]

Basin number	River basin[a]	Country	Basin area (10^3 km^2)[b]	Station	Station area (10^3 km^2)	Station latitude (degrees)	Station longitude (degrees)	Peak discharge (m^3/s)	Date	Flood type
1	Amazon	Brazil	5,854	Obidos	4,640	1.9S	55.5W	370,000	June 1953	Rainfall
2	Nile	Egypt	3,826	Aswan	1,500	24.1N	32.9E	13,200	Sept. 25, 1878	Rainfall
3	Congo	Zaire	3,699	Brazzaville B.	3,475	4.3S	15.4E	76,900	Dec. 27, 1961	Rainfall
4	Mississippi[c]	USA	3,203	Arkansas City	2,928	33.6N	91.2W	70,000	May 1927	Rainfall
5	Amur	Russia	2,903	Komsomolsk	1,730	50.6N	138.1E	38,900	Sept. 20, 1959	Rainfall
6	Parana	Argentina	2,661	Corrientes	1,950	27.5S	58.9W	43,070	June 5, 1905	Rainfall
7	Yenisey	Russia	2,582	Yeniseysk	1,400	58.5N	92.1E	57,400	May 18, 1937	Snowmelt
8	Ob-Irtysh	Russia	2,570	Salekhard	2,430	66.6N	66.5E	44,800	Aug. 10, 1979	Snowmelt
9	Lena	Russia	2,418	Kasur	2,430	70.7N	127.7E	189,000	June 8, 1967	Snowmelt/Ice Jam
10	Niger	Niger	2,240	Lokoja	1,080	7.8N	6.8E	27,140	Feb. 1, 1970	Rainfall
11	Zambezi	Mozambique	1,989	Tete	940	16.2S	33.6E	17,000	May 11, 1905	Rainfall
12	Yangtze	China	1,794	Yichang	1,010	30.7N	111.2E	110,000	July 20, 1870	Rainfall
13	Mackenzie	Canada	1,713	Norman Wells	1,570	65.3N	126.9W	30,300	May 25, 1975	Snowmelt
14	Chari	Chad	1,572	N'Djamena	600	12.1N	15.0E	5,160	Nov. 9, 1961	Rainfall
15	Volga	Russia	1,463	Volgograd	1,350	48.5N	44.7E	51,900	May 27, 1926	Snowmelt
16	St. Lawrence	Canada	1,267	La Salle	960	45.4N	73.6W	14,870	May 13, 1943	Snowmelt
17	Indus	Pakistan	1,143	Kotri	945	25.3N	68.3E	33,280	1976	Rain/Snowmelt
18	Syr Darya	Kazakhstan	1,070	Tyumen'-Aryk	219	44.1N	67.0E	2,730	June 30, 1934	Rain/Snowmelt
19	Orinoco	Venezuela	1,039	Puente Angostura	836	8.1N	64.4W	98,120	Mar. 6, 1905	Rainfall
20	Murray	Australia	1,032	Morgan	1,000	34.0S	139.7E	3,940	Sept. 5, 1956	Rainfall
21	Ganges	Bangladesh	976	Hardings Bridge	950	23.1N	89.0E	74,060	Aug. 21, 1973	Rain/Snowmelt
22	Shatt al Arab	Iraq	967	Hit(Euphrates)	264	34.0N	42.8E	7,366	May 13, 1969	Rain/Snowmelt
23	Orange	South Africa	944	Buchuberg	343	29.0S	22.2E	16,230	1843	Rainfall
24	Huanghe	China	894	Shanxian	688	34.8N	111.2E	36,000	Jan. 17, 1905	Rainfall
25	Yukon	USA	852	Pilot Station	831	61.9N	162.9W	30,300	May 27, 1991	Snowmelt
26	Senegal	Senegal	847	Bakel	218	14.9N	12.5W	9,340	Sept. 15, 1906	Rainfall
27	Colorado[c]	USA	808	Yuma	629	32.7N	114.6W	7,080	Jan. 22, 1916	Rainfall
28	Rio Grande[c]	USA	805	Roma	431	26.4N	99.0W	17,850	1865	Rain/Snowmelt
29	Danube	Romania	788	Orsova	575	44.7N	22.4E	15,900	April 17, 1895	Snowmelt
30	Mekong	Vietnam	774	Kratie	646	12.5N	106.0E	66,700	Sept. 3, 1939	Rainfall
31	Tocantins	Brazil	769	Itupiranga	728	5.1S	49.4W	38,780	April 2, 1974	Rainfall
32	Columbia[c]	USA	724	The Dalles	614	45.6N	121.2W	35,100	June 6, 1894	Snowmelt
33	Darling	Australia	650	Menindee	570	32.4S	142.5E	2,840	June 1890	Rainfall
34	Brahmaputra[d]	Bangladesh	650	Bahadurabad	636	25.2N	89.7E	81,000	Aug. 6, 1974	Rain/Snowmelt
35	São Francisco	Brazil	615	Traipu	623	9.6S	37.0W	15,890	April 1, 1960	Rainfall
36	Amu Darya	Kazakhstan	612	Chatly	450	42.3N	59.7E	6,900	July 27, 1958	Rain/Snowmelt
37	Dnieper	Ukraine	509	Kiev	328	50.5N	30.5E	23,100	May 2, 1931	Snowmelt



[a]Basins larger than 500,000 square kilometers for which reliable data were not available include the Nelson River in North America; the Jubba, Irharhar, Araye, Tafassasset and Qattar Rivers in Africa; and the Kolyma and Tarim Rivers in Asia.

[b]Basin areas from Vörösmarty et al. (2000).

[c]Station and discharge data from U.S. Geological Survey National Water Information System (http://water.usgs.gov/nwis).

[d]Station area and drainage basin data from Global Runoff Data Centre in the Federal Institute of Hydrology, Germany (http://www.bafg.de/grdc.htm).

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Largest Floods

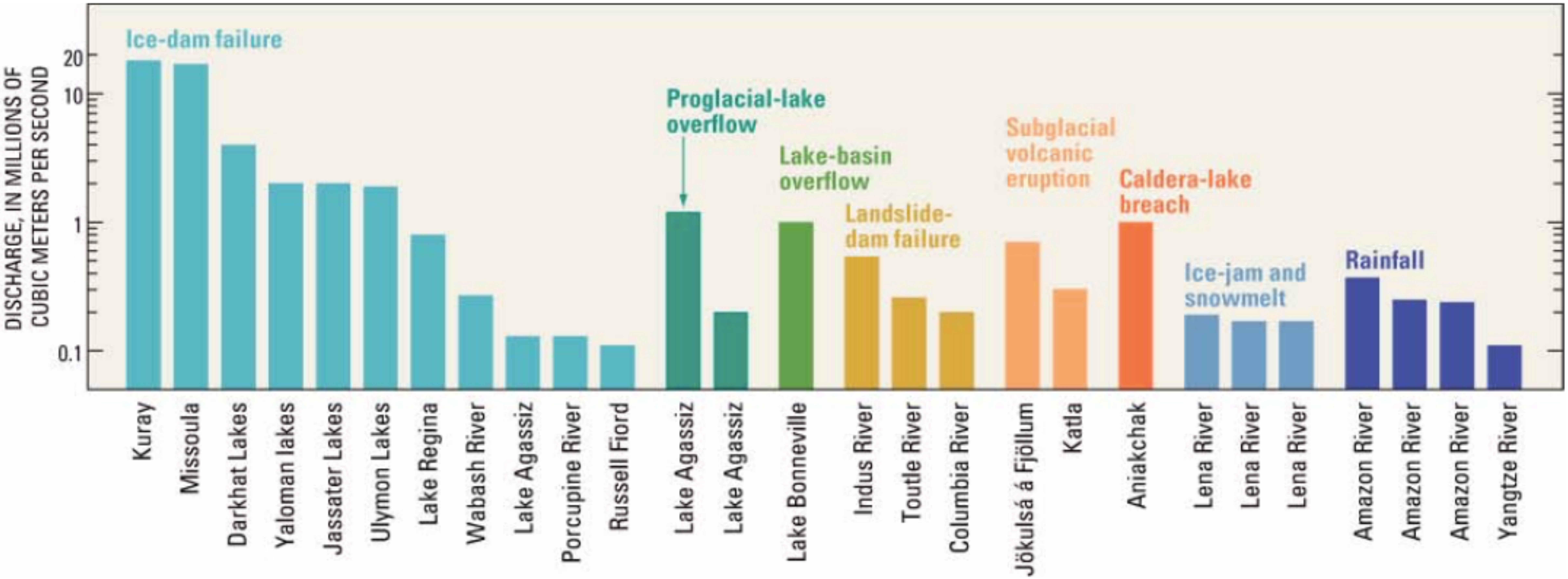

Figure 1. Most of the largest known floods of the Quaternary Period resulted from breaching of dams formed by glaciers or landslides. See table 1 for details of each flood.

Connor and Costa, 2011

Largest Floods

Table 1. Quaternary floods with discharges greater than 100,000 cubic meters per second

[Pleistocene, about 1.8 million to 10,000 years ago; Holocene, about 10,000 years ago to present. Peak discharge: $10^6 m^3/s$, million cubic meters per second]

Flood/River	Location	Date	Peak discharge ($10^6 m^3/s$)	Mechanism	Reference
Kuray	Altai, Russia	Late Pleistocene	18	Ice-dam failure	Baker et al., 1993
Missoula	Northwestern USA	Late Pleistocene	17	Ice-dam failure	O'Connor and Baker, 1992
Darkhat Lakes	Mongolia	Late Pleistocene	4	Ice-dam failure	Rudoy, 1998
Jassater Lakes	Altai, Russia	Late Pleistocene	2	Ice-dam failure	Rudoy, 1998
Yaloman Lakes	Altai, Russia	Late Pleistocene	2	Ice-dam failure	Rudoy, 1998
Ulymon Lakes	Altai, Russia	Late Pleistocene	1.9	Ice-dam failure	Rudoy, 1998
Lake Agassiz	Alberta, Canada	Early Holocene	1.2	Proglacial-lake overflow	Smith and Fisher, 1993
Aniakchak	Alaska, USA	Late Holocene	1.0	Caldera-lake breach	Waythomas et al., 1996
Lake Bonneville	Northwestern USA	Late Pleistocene	1.0	Lake-basin overflow	O'Connor, 1993
Lake Regina	Canada/USA	Late Pleistocene	.8	Ice-dam failure	Lord and Kehew, 1987
Jökulsá á Fjöllum	Iceland	Early Holocene	.7	Subglacial volcanic eruption	Waitt, 2002
Indus River	Pakistan	1841	.54	Landslide-dam failure	Shroder et al., 1991
Amazon River	Obidos, Brazil	1953	.37	Rainfall	Rodier and Roche, 1984
Katla	Iceland	1918	.3	Subglacial volcanic eruption	Tomasson, 1996
Wabash River	Indiana, USA	Late Pleistocene	.27	Ice-dam failure	Vaughn and Ash, 1983
Toutle River	Northwestern USA	Late Holocene	.26	Landslide-dam failure	Scott, 1989
Amazon River	Obidos, Brazil	1963	.25	Rainfall	Rodier and Roche, 1984
Amazon River	Obidos, Brazil	1976	.24	Rainfall	Rodier and Roche, 1984
Columbia River	Northwestern USA	About 1450	.22	Landslide-dam failure	O'Connor et al., 1996
Lake Agassiz	Canada/USA	Early Holocene	.20	Proglacial-lake overflow	Teller and Thorliefson, 1987
Lena River	Kasur, Russia	1967	.19	Ice jam and snowmelt	Rodier and Roche, 1984
Lena River	Kasur, Russia	1962	.17	Ice jam and snowmelt	Rodier and Roche, 1984
Lena River	Kasur, Russia	1948	.17	Ice jam and snowmelt	Rodier and Roche, 1984
Lake Agassiz	Canada/USA	Late Pleistocene	.13	Ice-dam failure	Matsch, 1983
Porcupine River	Alaska, USA	Late Pleistocene	.13	Ice-dam failure	Thorson, 1989
Yangtze River	China	1870	.11	Rainfall	Rodier and Roche, 1984
Russell Fiord	Alaska, USA	1986	.10	Ice-dam failure	Mayo, 1989

Connor and Costa, 2011

Deadliest Floods

Rank	Death toll	Event	Location	Year
1	1,000,000 – 4,000,000	1931 China floods	China	1931
2	900,000–2,000,000	1887 Yellow River flood	China	1887
3	500,000–800,000	1938 Yellow River flood	China	1938
4	231,000	Banqiao Dam failure, result of Typhoon Nina. Approximately 86,000 people died from flooding and another 145,000 died from subsequent disease.	China	1975
5	145,000	1935 Yangtze river flood	China	1935
6	100,000+	St. Felix's Flood, storm surge	Netherlands	1530
7	100,000	Hanoi and Red River Delta flood	North Vietnam	1971
8	up to 100,000[citation needed]	1911 Yangtze river flood	China	1919
9	50,000–80,000	St. Lucia's flood, storm surge	Netherlands	1287
10	60,000	North Sea flood, storm surge	Netherlands	1212
11	40,000 [1]	1949 Eastern Guatemala flood	Guatemala	1949
12	36,000	St. Marcellus flood, storm surge	Netherlands	1219
13	30,000	1954 Yangtze river flood	China	1954
14	28,700	1974 Bangladesh flood due to monsoon rain	Bangladesh	1974
15	25,000–40,000	St. Marcellus flood / Grote Mandrenke, storm tide	Netherlands, Germany, Denmark	1362
16	20,006	1999 Vargas mudslide	Venezuela	1999
17	20,000	All Saints' Flood, storm surge	Netherlands	1570
18	20,000	1939 Tianjin flood	China	1939

Deadliest Floods

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5	145,000	1935 Yangtze river flood	China	[illegible]
6	100,000+	St. Felix's Flood, storm surge	Netherlands	[illegible]
7	100,000	Hanoi and Red River Delta flood	North Vietnam	[illegible]
8	up to 100,000[citation needed]	1911 Yangtze river flood	China	[illegible]
9	50,000–80,000	St. Lucia's flood, storm surge	Netherlands	[illegible]
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Deadliest natural hazard (discounting pandemics and famines) recorded in recent centuries.

Deadliest Floods

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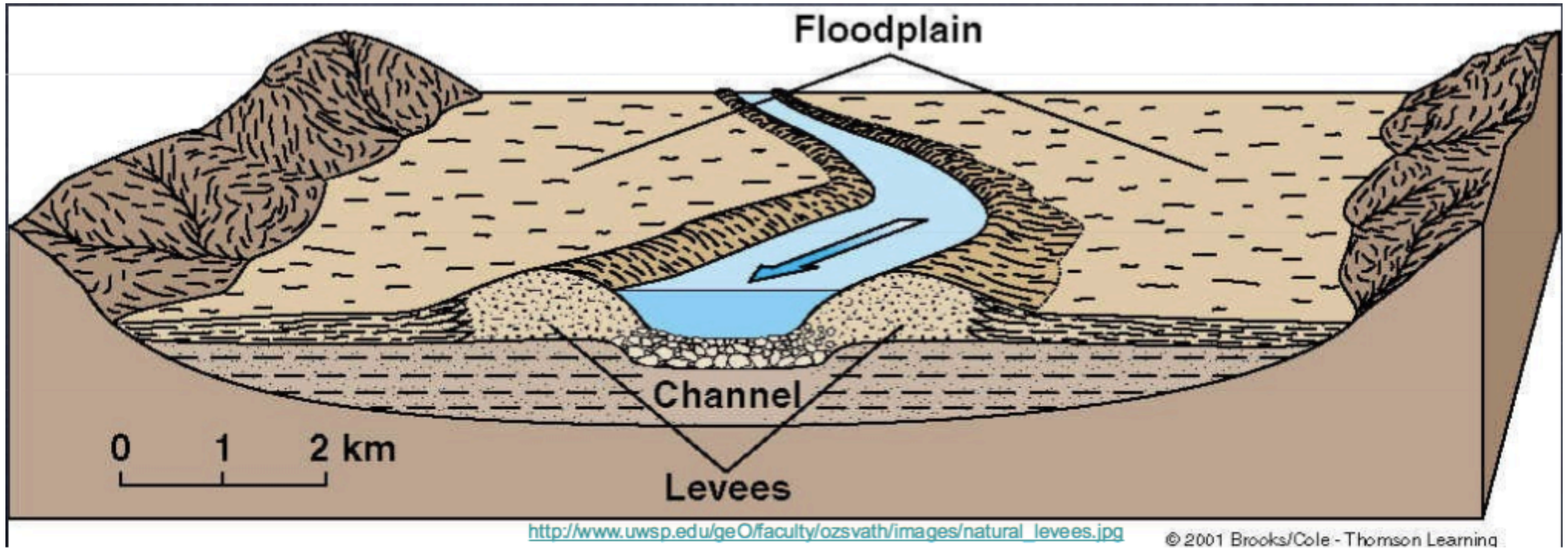
Deadliest Floods

19	14,000	Christmas flood, storm surge	Netherlands, Germany, Denmark	1717
20	10,000–100,000	St. Elizabeth flood, storm surge	Netherlands, Belgium	1421
21	8,000–15,000	Burchardi flood	Germany, Denmark	1634
22	10,000	Great Iran Flood	Iran	1954
23	10,000	1824 St. Petersburg flood	Russia	1824
24	several thousands	North Sea flood, storm surge	Netherlands	1014
25	several thousands	St. Juliana flood, storm surge	Netherlands	1164
26	several thousands	St. Agatha flood, storm surge	Netherlands	1288
27	several thousands	St. Clemens flood, storm surge	Netherlands	1334
28	several thousands	St. Mary Magdalene's flood	Central Europe	1342
29	several thousands	All Saints flood, storm surge	Netherlands	1532
30	several thousands	North Sea flood, storm surge	Netherlands	1703
31	5,700 [2]	2013 North India floods	India	2013
32	6,200	Sichuan, Hubei, Anhui flood	China	1980
32	5,000	Cojup valley, Cordillera Blanca mountain range, landslide by massive avalanche	Peru	1941
33	5,000–10,000	Rajputana flood	India	1943
34	4,892 [1]	1968 Rajasthan, Gujarat monsoon rain	India	1968
35	4,800	1951 Manchuria flood	China	1951
36	3,838	1998 Eastern India, Bangladesh monsoon rain	India, Bangladesh	1998

Deadliest Floods

36	3,838	1998 Eastern India, Bangladesh monsoon rain	India, Bangladesh	1998
37	3,814	1989 Sichuan flood	China	1989
38	3,800	1978 Northern India monsoon rain	India	1978
39	3,656	1998 Yangtze river flood	China	1998
40	3,500	1948 Fuzhou flood	China	1948
41	3,084	1993 South Asian monsoon rain	Nepal, India, Bangladesh, Pakistan	1993
42	3,076	2004 Eastern India, Bangladesh monsoon rain	India, Bangladesh	2004
43	3,000	1992 Afghanistan flood, mainly, Gulbahar, Kalotak, Shutul, Parwan, flash flood, mudslide	Afghanistan	1992
44	2,910	1950 Pakistan flood	Pakistan	1950
45	1,828	2011 Southeast Asian floods	Asia	2011
46	2,775	1996 China flood, torrential floods, mud-rock flows	China	1996
47	2,566	1953 Japan flood, mainly Kitakyushu, Kumamoto, Wakayama, Kizugawa, massive rain, flood, mudslide	Japan	1953
48	2,400	North Sea flood, storm surge	Netherlands	838
49	1,000-8,000	2016 Indian floods by monsoon rain	India	2016
50	2,379	1988 Bangladesh monsoon rain	Bangladesh	1988
51	2,209	Johnstown Flood	United States (Pennsylvania)	1889
52	2,142	North Sea flood of 1953 storm surge	Netherlands, United Kingdom, Belgium	1953

River Floods



Floodplains are flat areas adjacent to rivers where previous floods have left silty deposits.

Rivers meander across their floodplains over time, leaving abandoned meander channels.

Top: 1944 geological map of prior meanders of the Mississippi River. Colors are abandoned meander loops from different times. Bottom: Satellite image of same area in 2014. The river has abandoned one of its 1944 meanders (dashed line at bottom of image).

River Floods

Levees are natural or man-made barriers along river banks. They work until a flood exceed the design level and breaches the levee.

A breached levee on the Ganges River is repaired one bowlful of dirt at a time, after Cyclone Aila in July 2009 caused the river to breach the barrier.

Flood water breached the 17th Street Canal levee in New Orleans, on August 29, 2005. This breach was one of more than 50 levee failures around the city.

A breached levee on the Elbe river in Germany in June 2013.

River Floods

Flooding in the Mississippi River system can affect the entire region shaded pale green, between the Rocky Mountains in the west and Appalachians in the east.

Left: Mississippi River flooding in Memphis, TN, in Spring 1927. Flood waters breached 145 levees, caused 246 deaths in seven U.S. states, and displaced 700,000 people for several months. Right: In December 2015, the Mississippi River inundated broad areas of its floodplain, including these homes in Pacific, MO.

Evacuation by canoe from Arnold, MO, after levee failure along the Mississippi in December 2015.

River Floods

Great Mississippi and Missouri Flood of 1993: April to October 1993; 78,000 km^2 flooded, $15 billion damage

Jefferson City, Missouri, near the Missouri Capitol building during the "Great Flood of 1993".

Aerial view of the Missouri River flooding on July 30, 1993, in the vicinity of Cedar City and Jefferson City Memorial Airport immediately north of Jefferson City, Missouri, looking south (photograph from the Missouri Highway and Transportation Department).

Confluence of Mississippi and Missouri Rivers, August 1993. Extensive floods in the Mississippi River Basin during the spring and summer of 1993 caused $20 billion in damages. (Photograph, Srenco Photography, St. Louis, Mo.)

Flooding of the Mississippi River in late July, 1993. Top: At the confluence with the Missouri River, near St. Louis. Bottom: Near Cedar City, MO.

Flashfloods

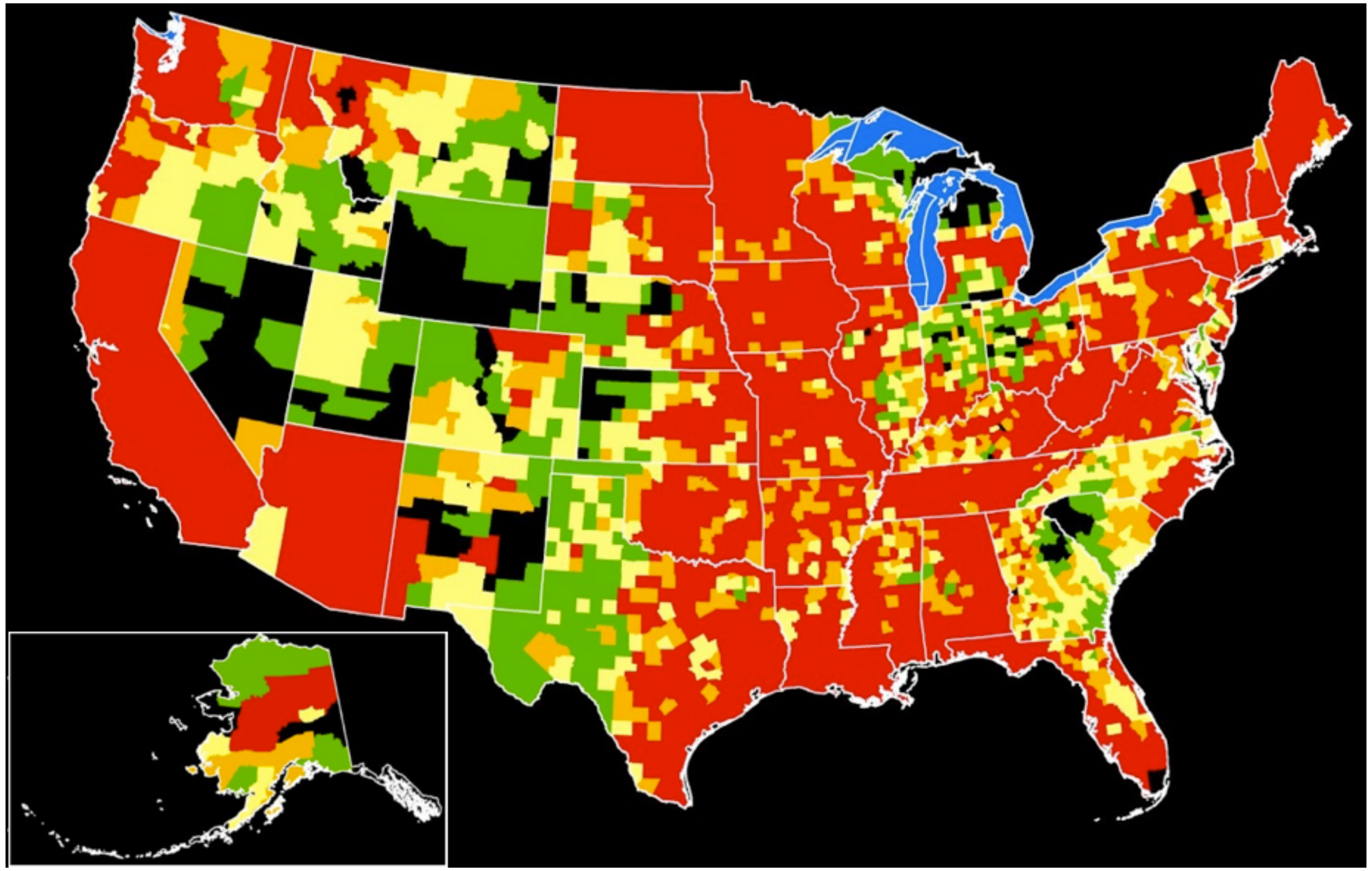
Flash floods occur unpredictably.after severe thunderstorms or a sudden release of snow melt.

The village of Boscastle in Cornwall, U.K. inundated by a flash flood on August 16, 2004 after thunderstorms dropped heavy rain several km away, in the catchment area of the normally small stream.

A flash flood in Toowoomba, near Brisbane, Australia, in January 2011 carried away cars that were parked by a stream and caused more than 20 deaths in the area. In Brisbane city the flood crest was 4.46 m, a little lower than record crests in the 1890’s.

Flashfloods

Flash Floods In The Desert: Otherwise dry rivers in desert regions flood when surface runoff exceeds river channel capacity.



U.S. presidential disaster declarations related to flooding by region for 1965-2003. Green = 1; yellow = 2; orange = 3; red = 4 or more.

The Blanco River, TX, rose by almost 8 m in a day on May 24, 2015 during a flash flood, sweeping away roads, trees, and houses.

Snowmelt Floods

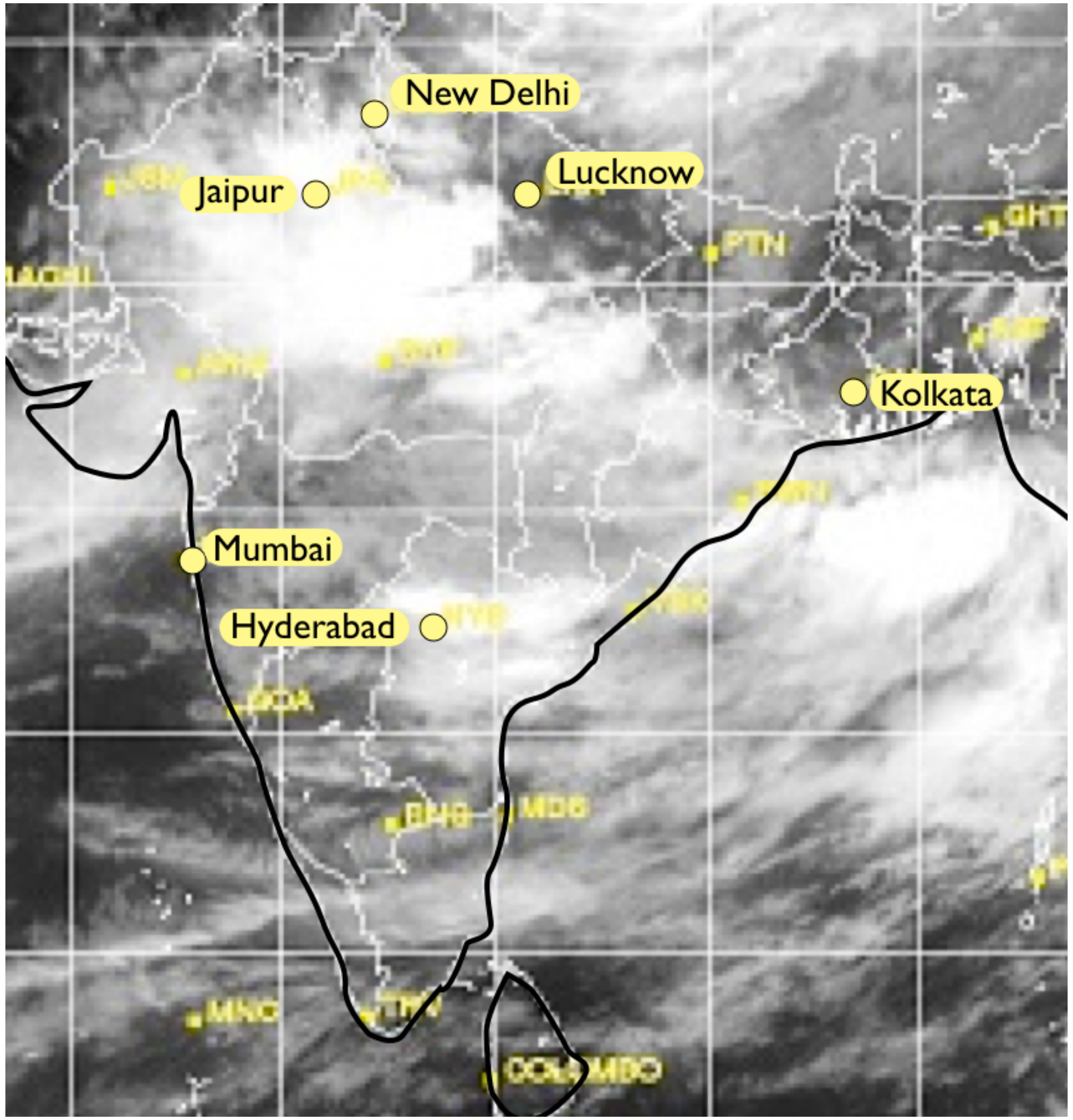
Rapid snowmelt during exceptional warm periods or heavy rain often causes floodplain inundation.

Unlike the Missouri and Mississippi Rivers, which drain southward, the Red River of the North drains northward, into Lake Winnipeg, Canada.

The Red River of the North breached levees and inundated Grand Forks, ND in April 1997. Several other cities, including Fargo, ND and Manitoba, Canada, were also flooded.

Monsoon

Monsoons are seasonal prevailing winds that bring heavy summer rains to southeast Asia.



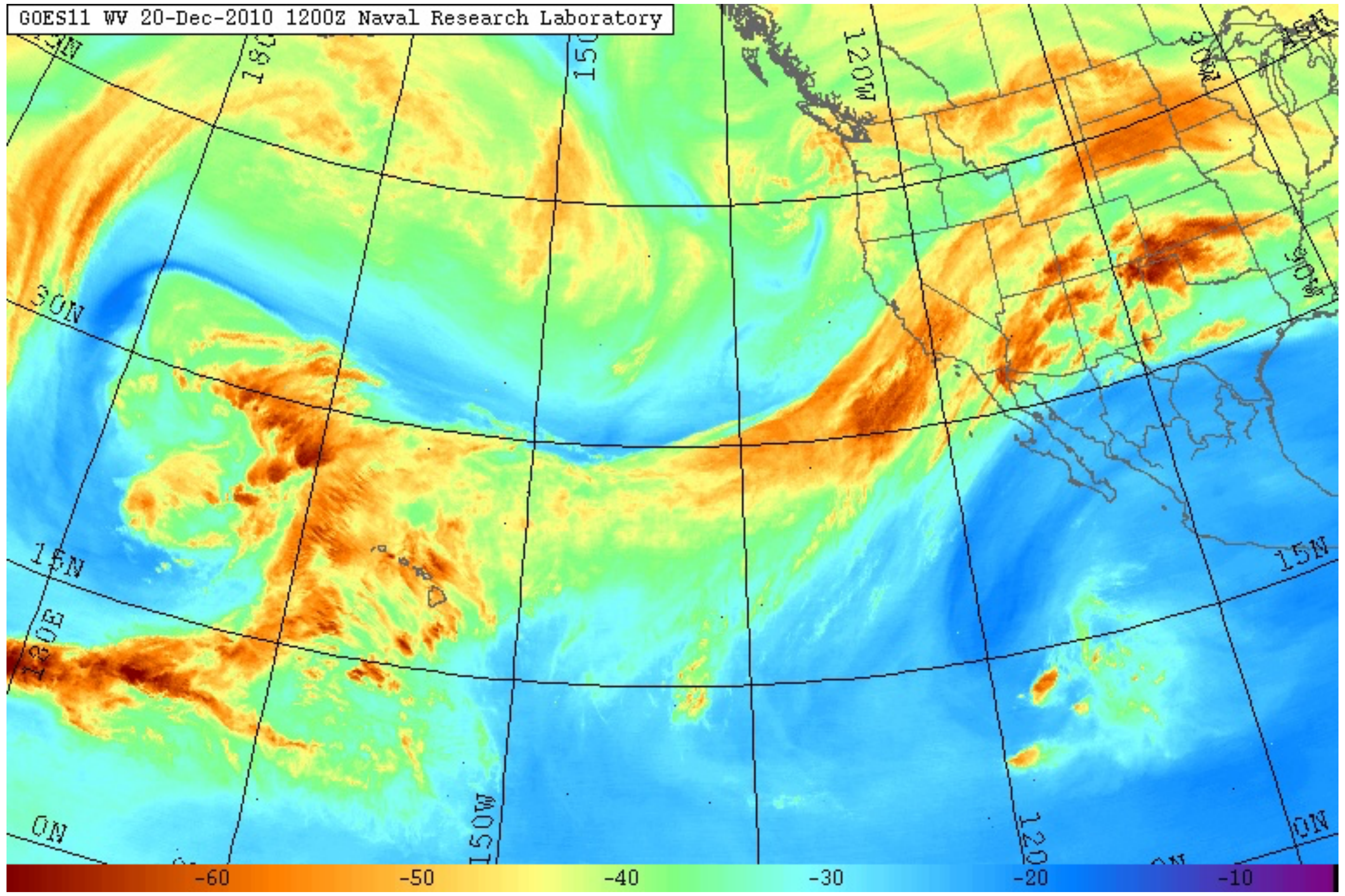
Monsoon rain clouds over India, July 2012.

Monsoon rain disrupts New Delhi, July 2015.

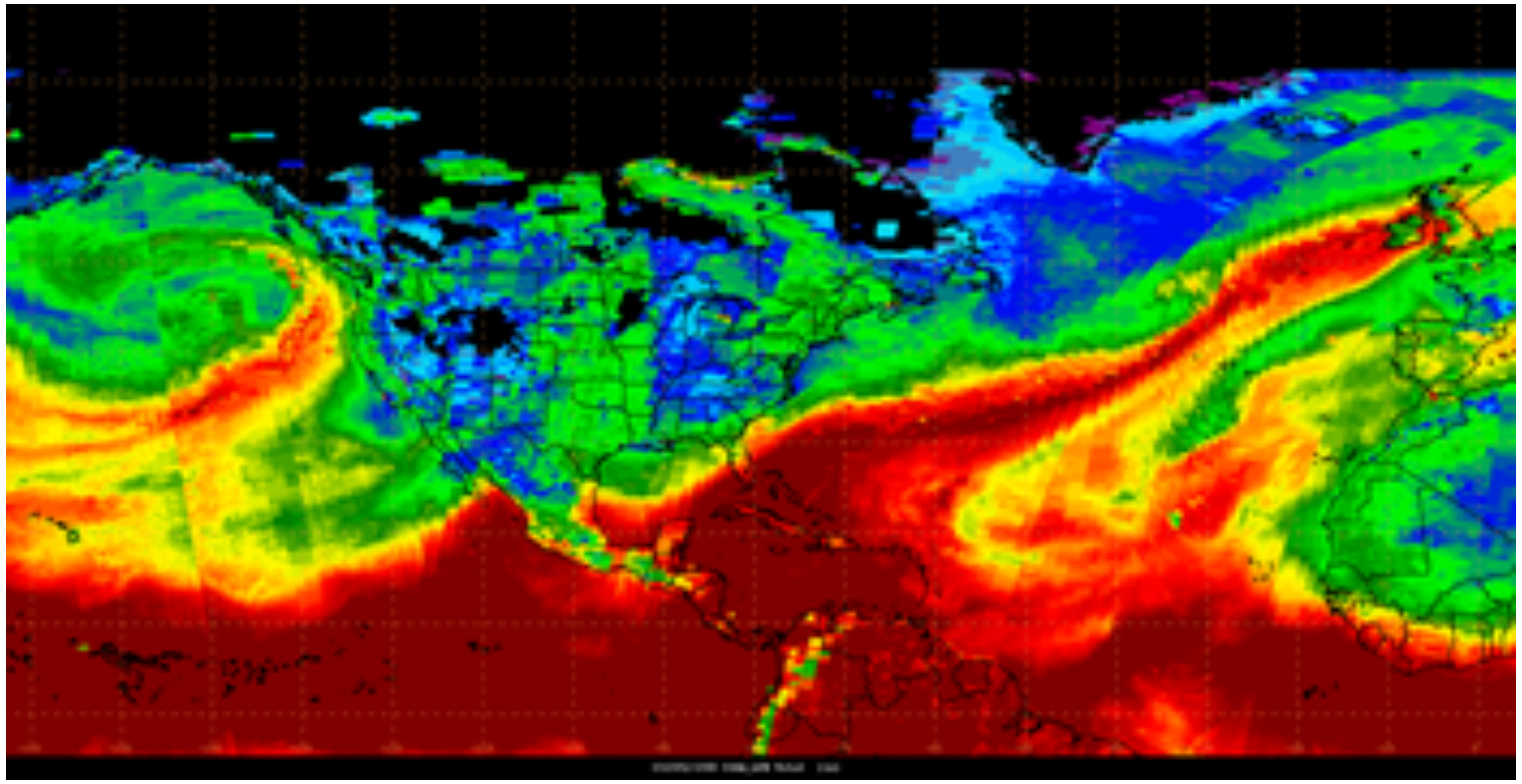
Part of a village in Uttarakhand, India, destroyed by flash flooding of the Ganges River in June 2013 after exceptionally heavy monsoon rains.

Water-Energy Cycle

Energy flows determine flows in the Water Cycle …



Imagery of water vapor in the atmosphere above the Pacific Ocean from NOAA's GOES11 satellite in December 2010. The narrow band of high water vapor (red, arrowed) was moving northeastward.

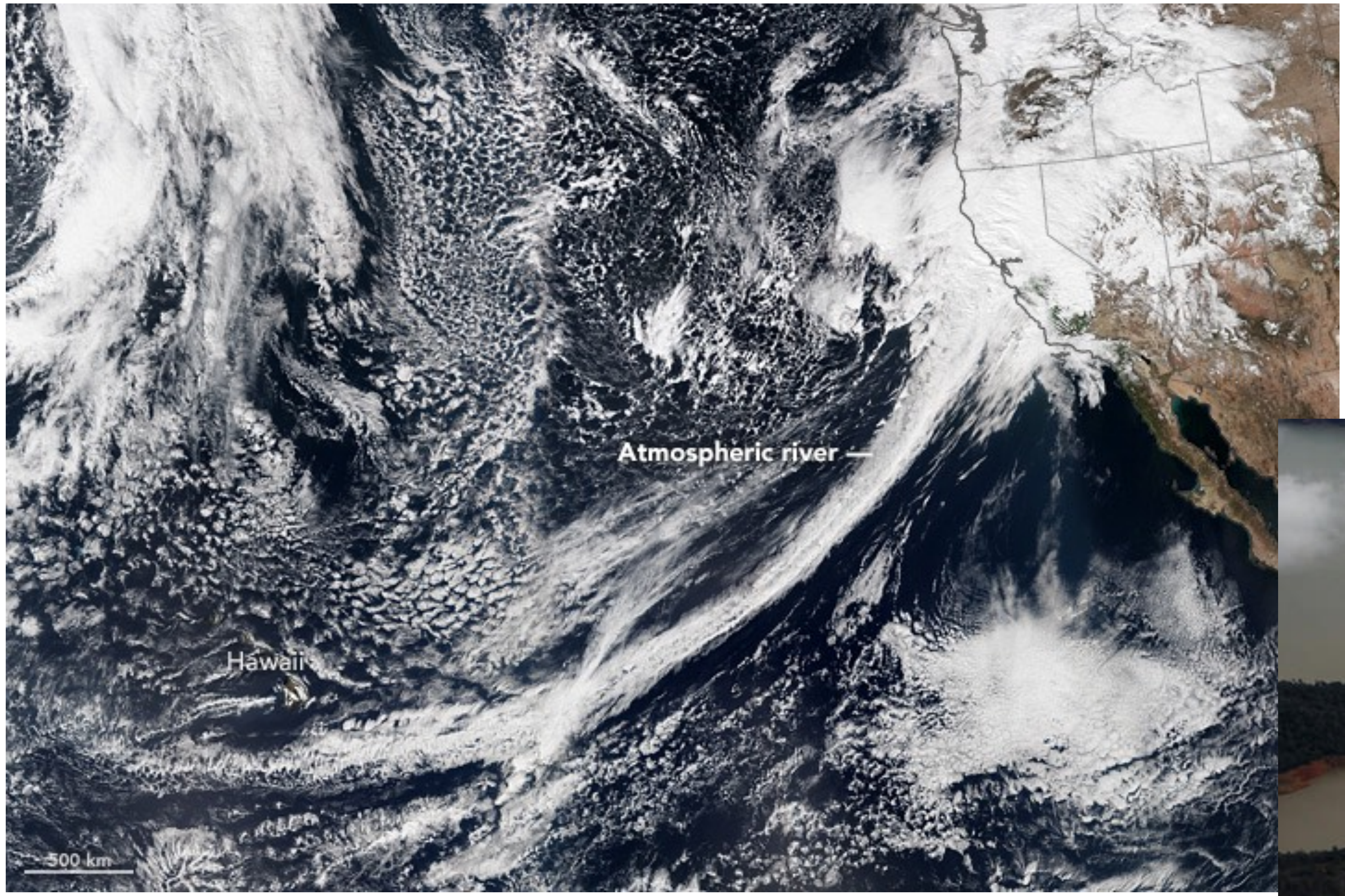


Satellite water vapor image for December 5, 2015, shows an intense atmospheric river (red color) moving across the north Atlantic toward the U.K.

Flooding in Cumbria, UK, in December 2015 caused by rain from the atmospheric river in the Figure above and associated Extratropical Storm Desmond.

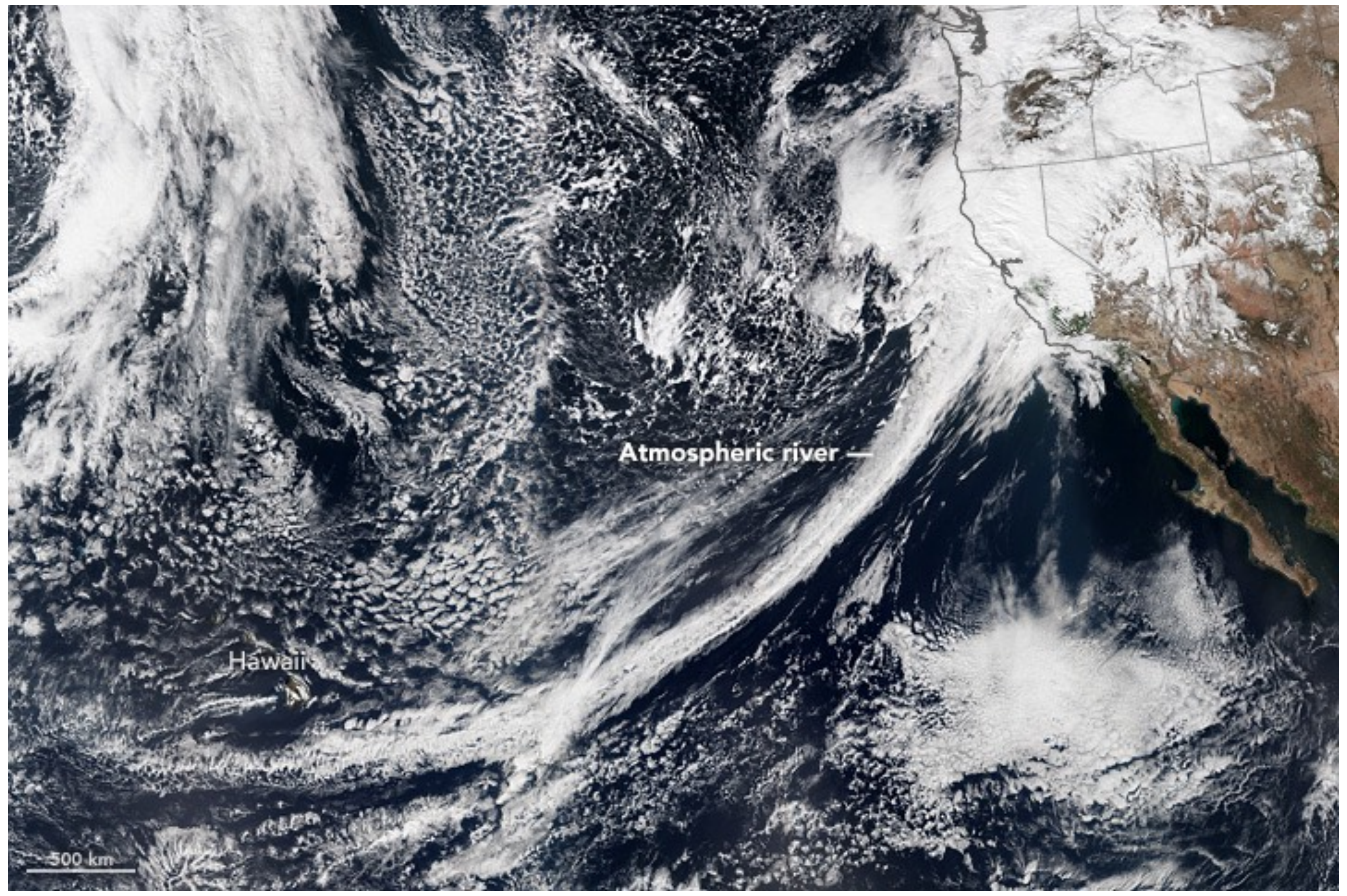
Water-Energy Cycle

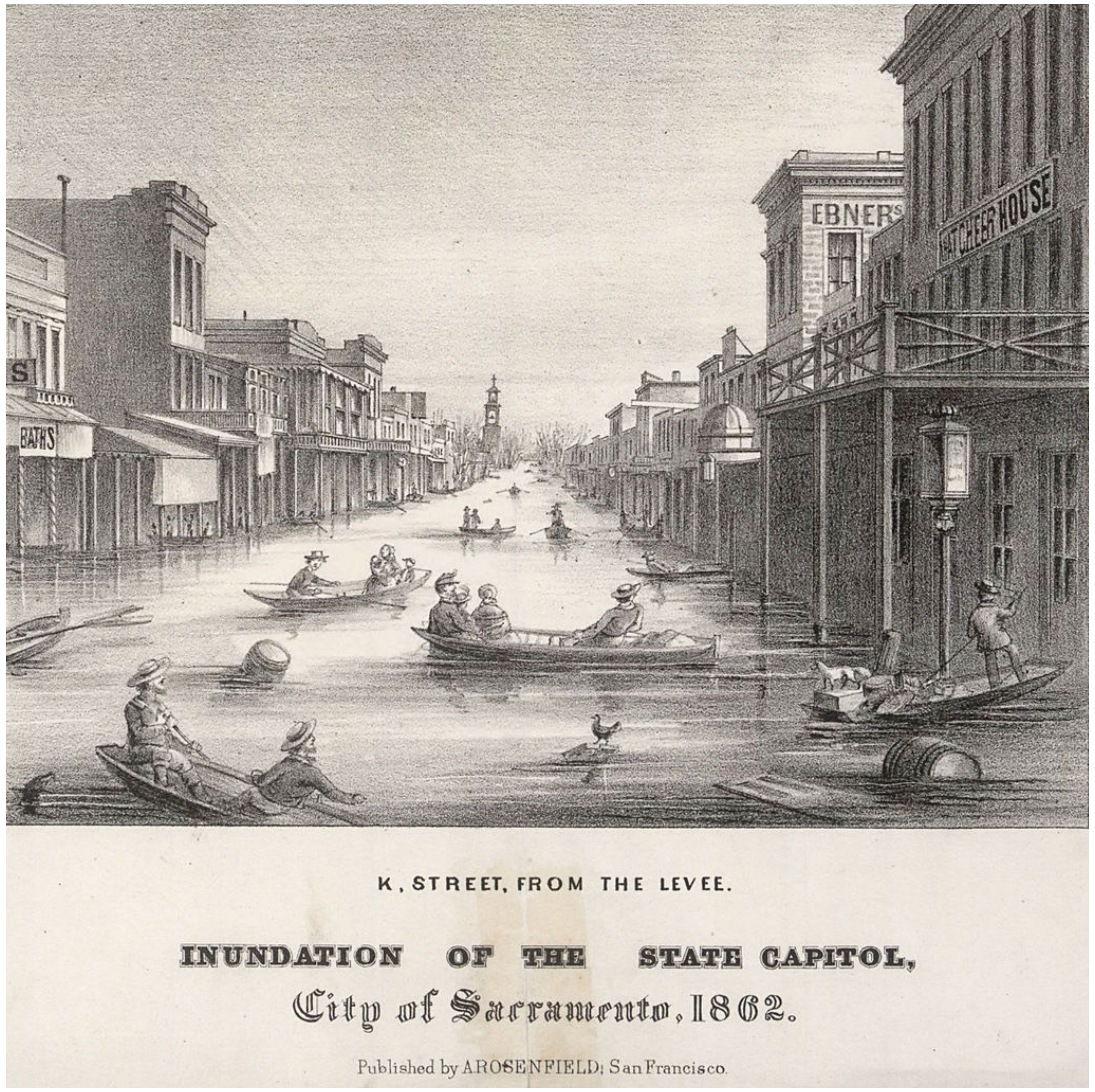
Energy flows determine flows in the Water Cycle … Atmospheric Rivers can cause mega floods

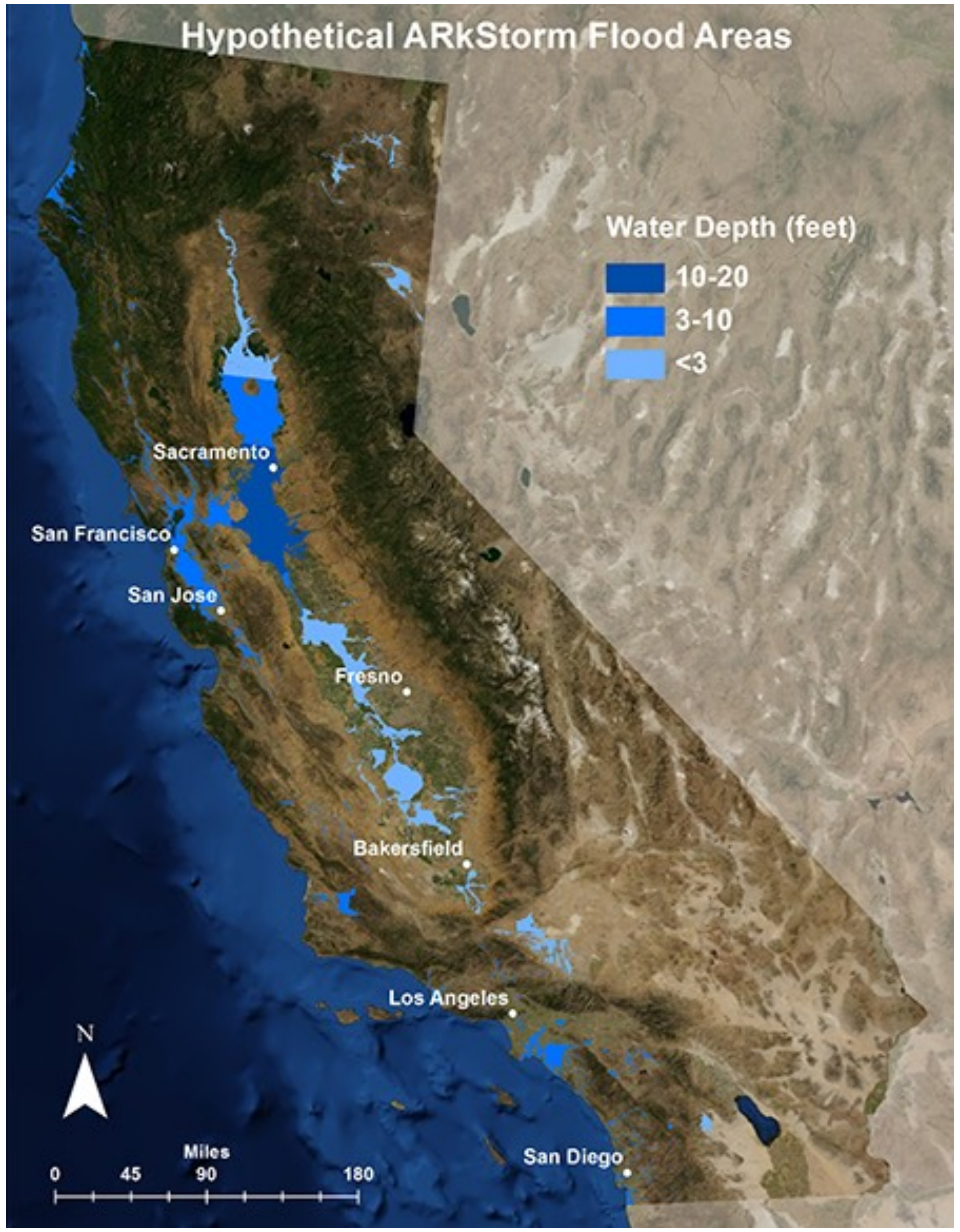


Energy flows determine flows in the Water Cycle …

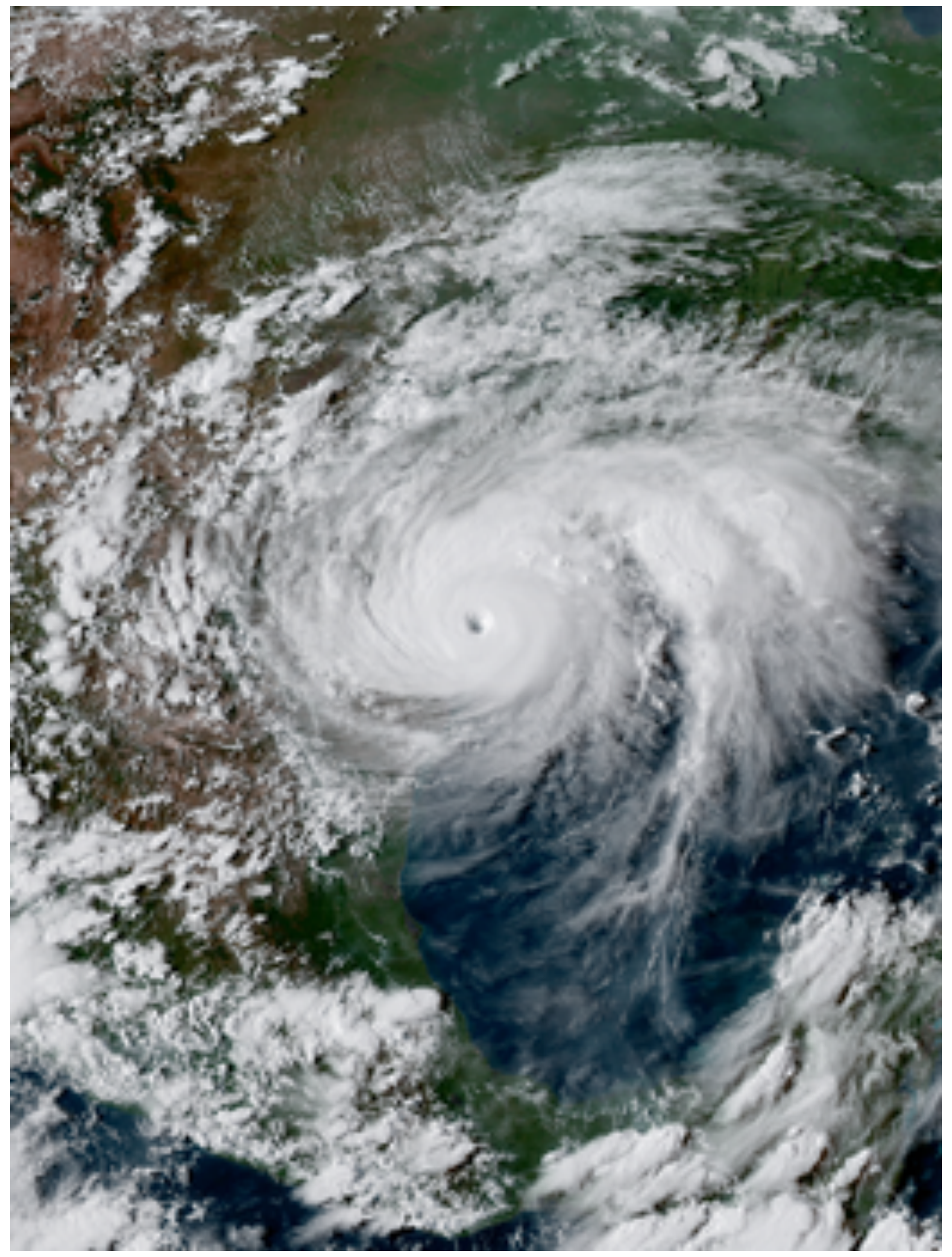
Atmospheric Rivers can cause mega floods

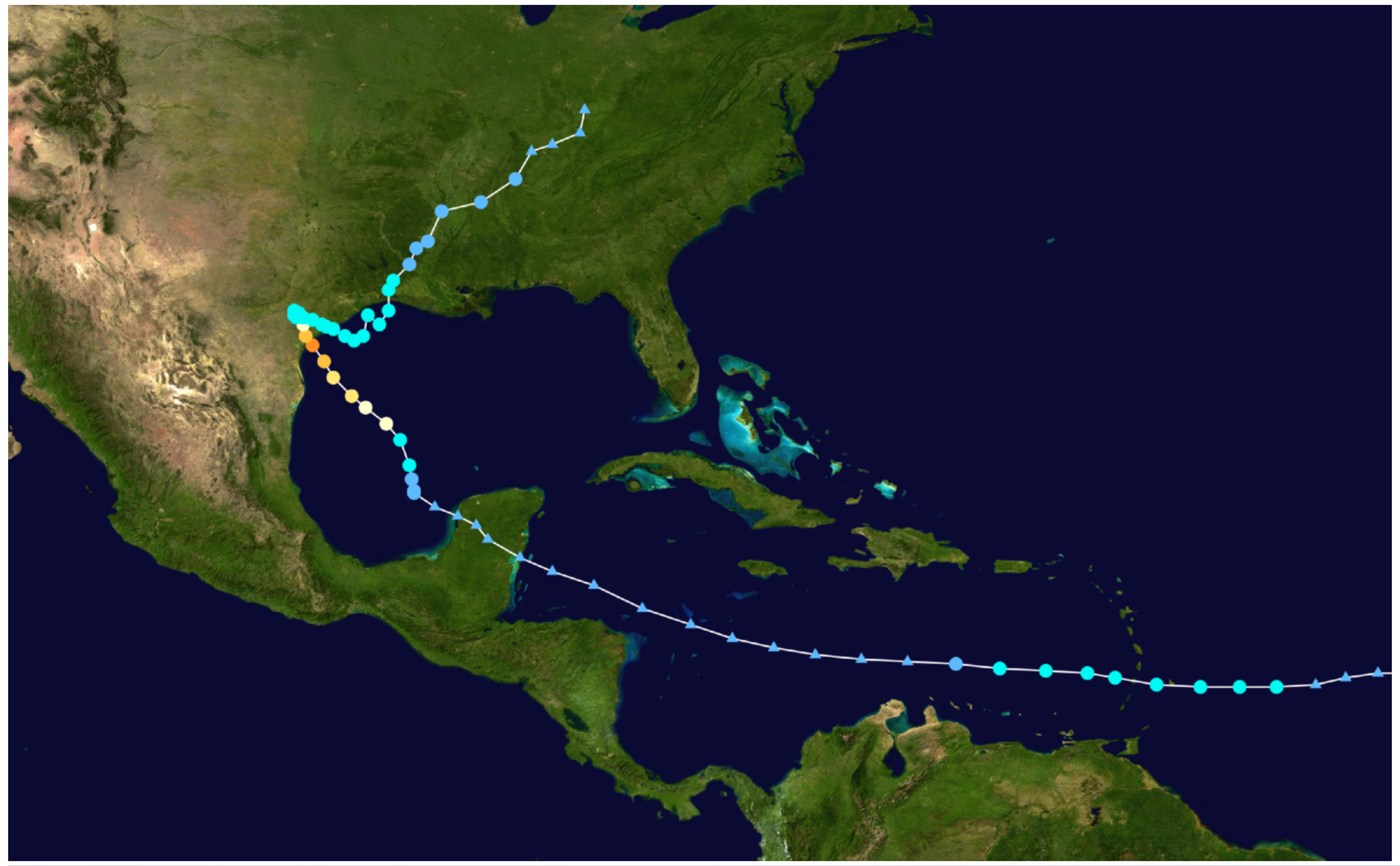




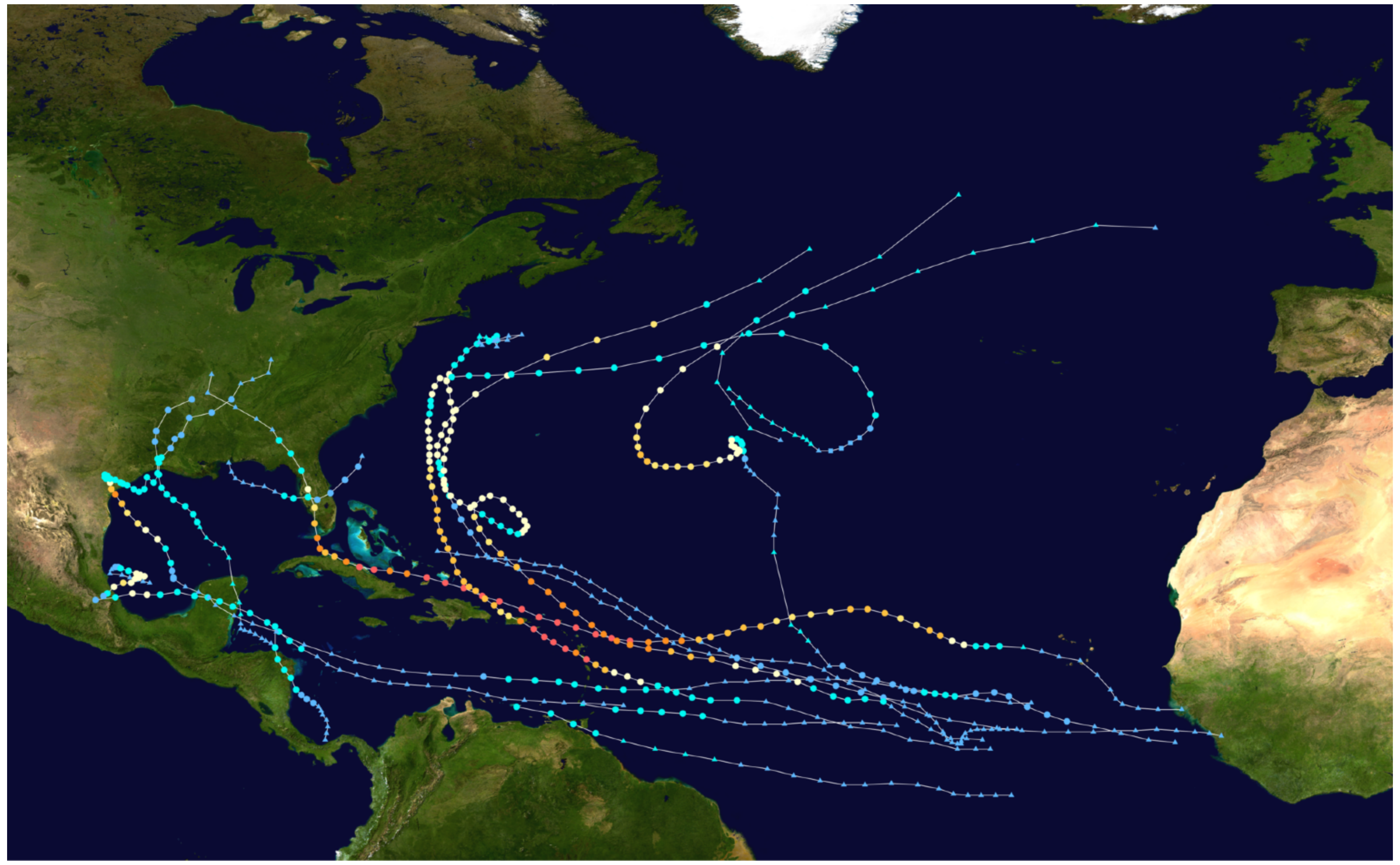


Energy flows determine flows in the Water Cycle …





A warming ocean can cause more and stronger hurricanes



Water-Energy Cycle

We are replacing homeostasis with disequilibrium

Water-Energy Cycle

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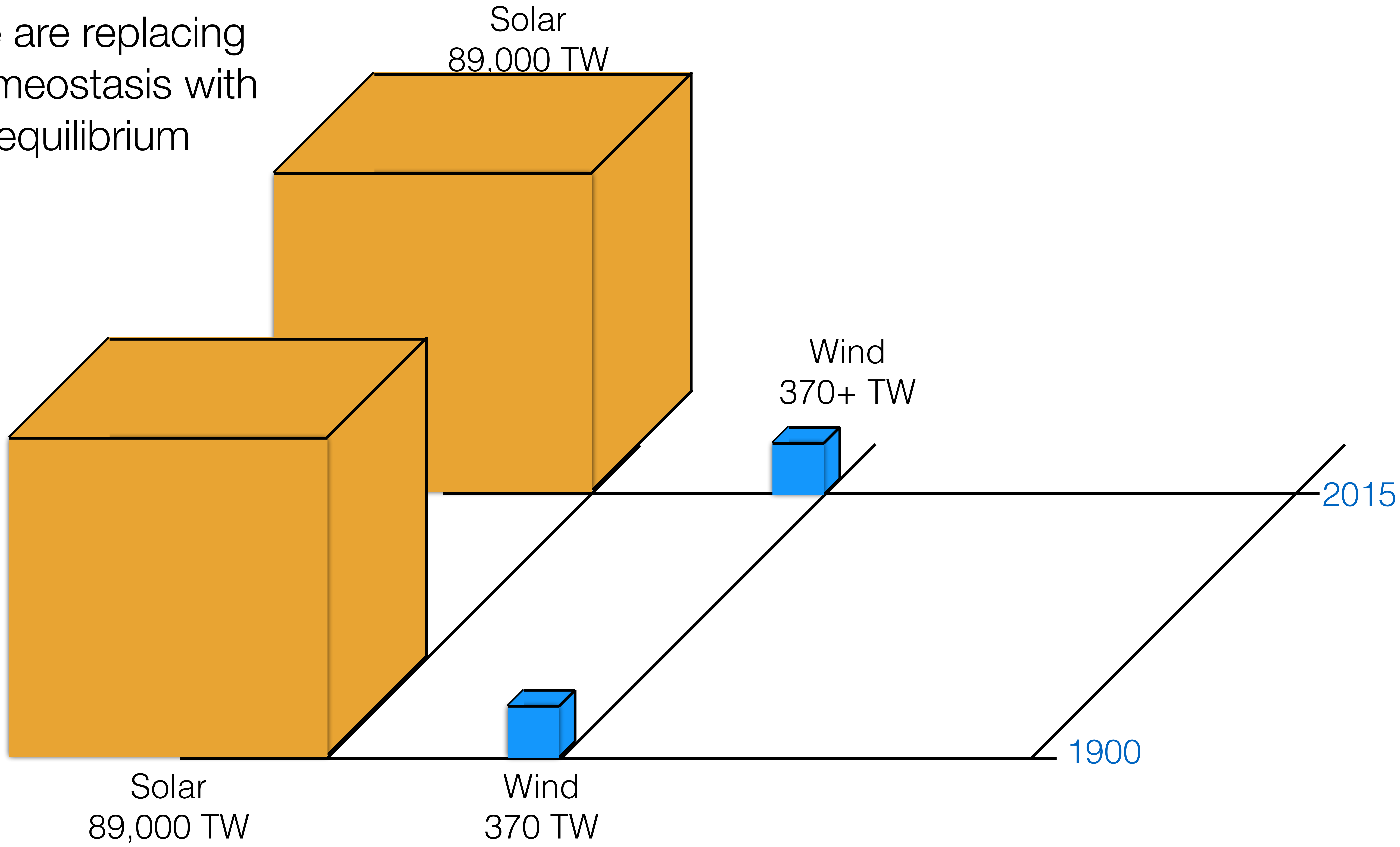
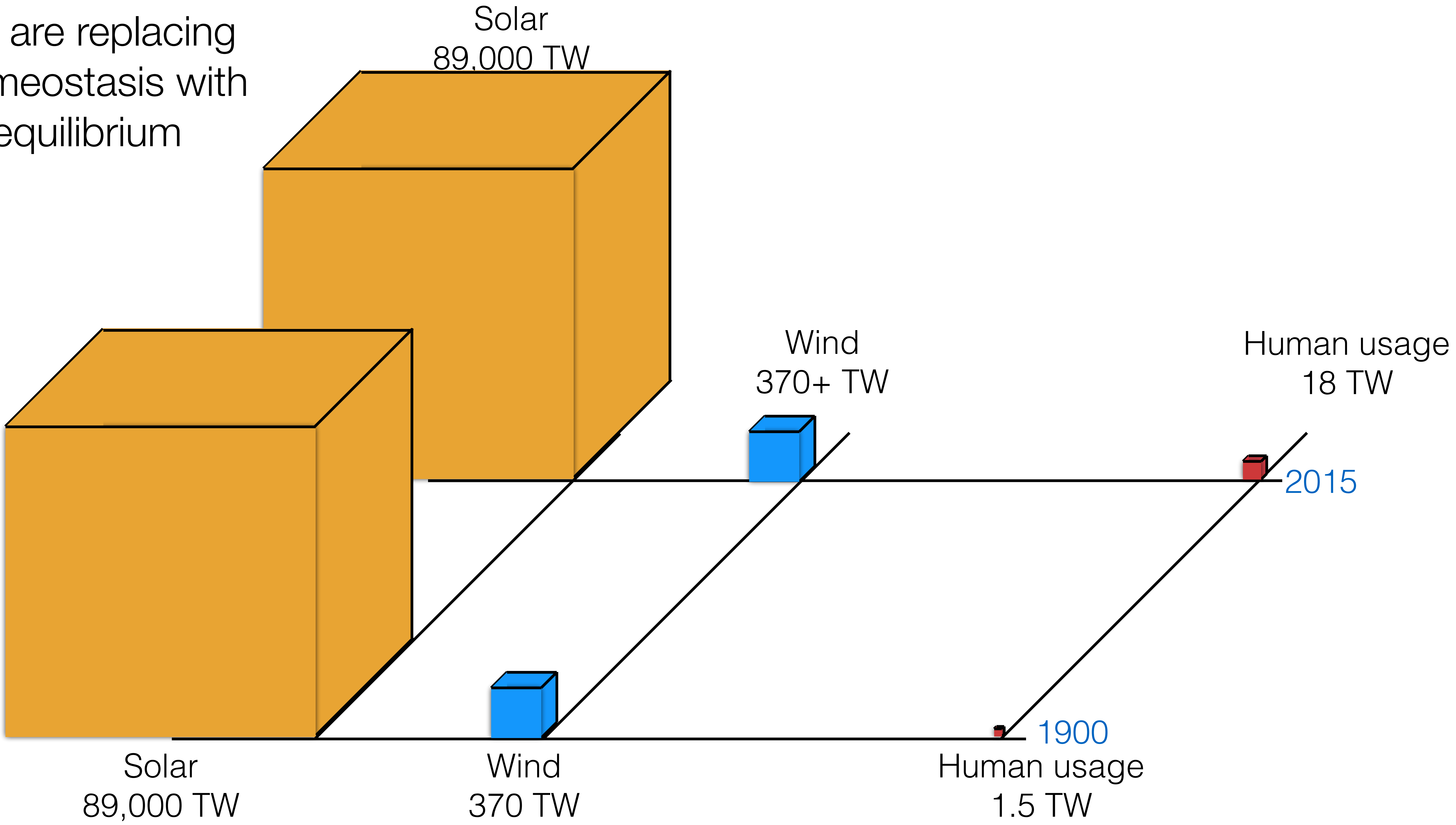


Water-Energy Cycle

We are replacing homeostasis with disequilibrium



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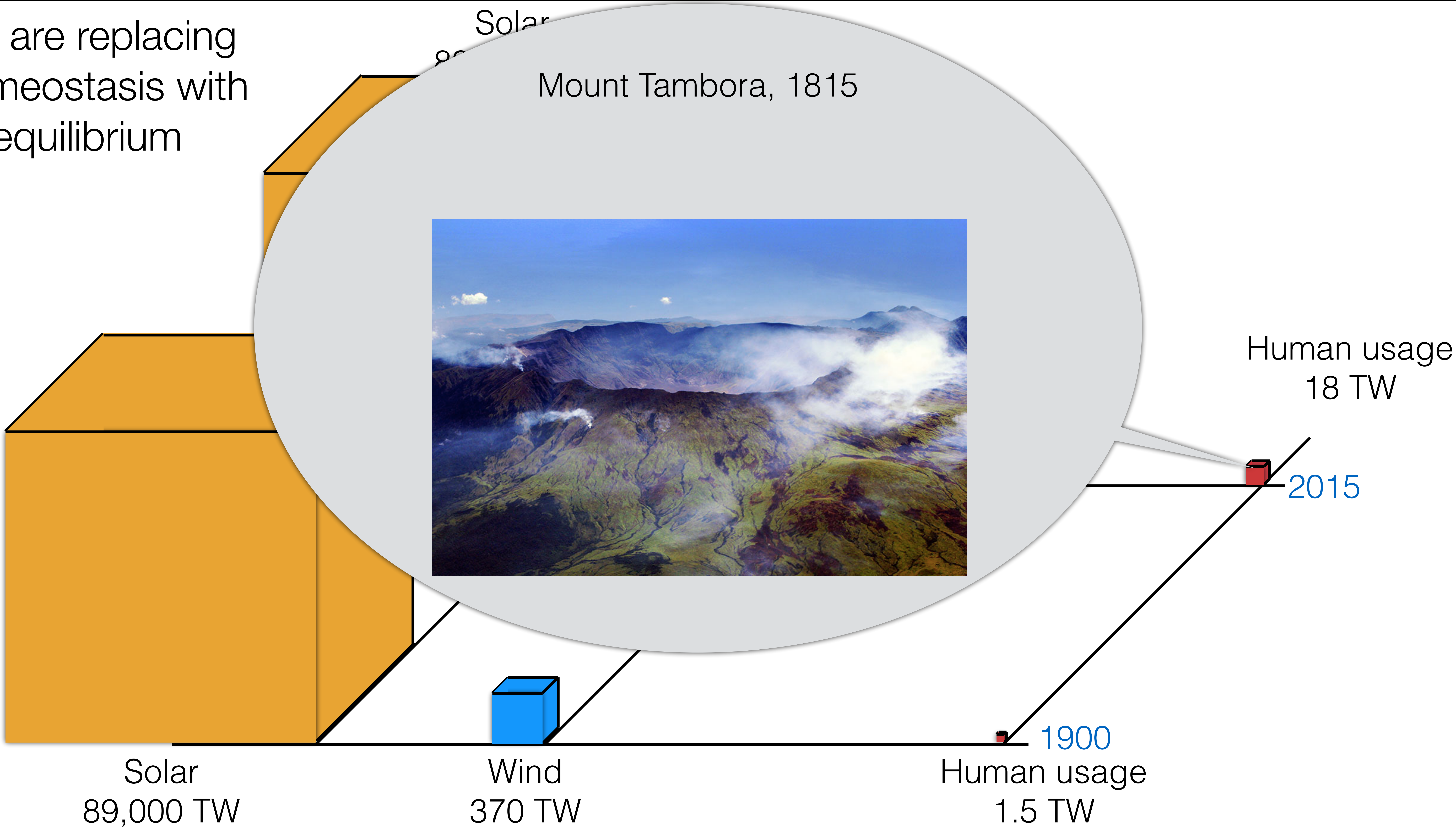

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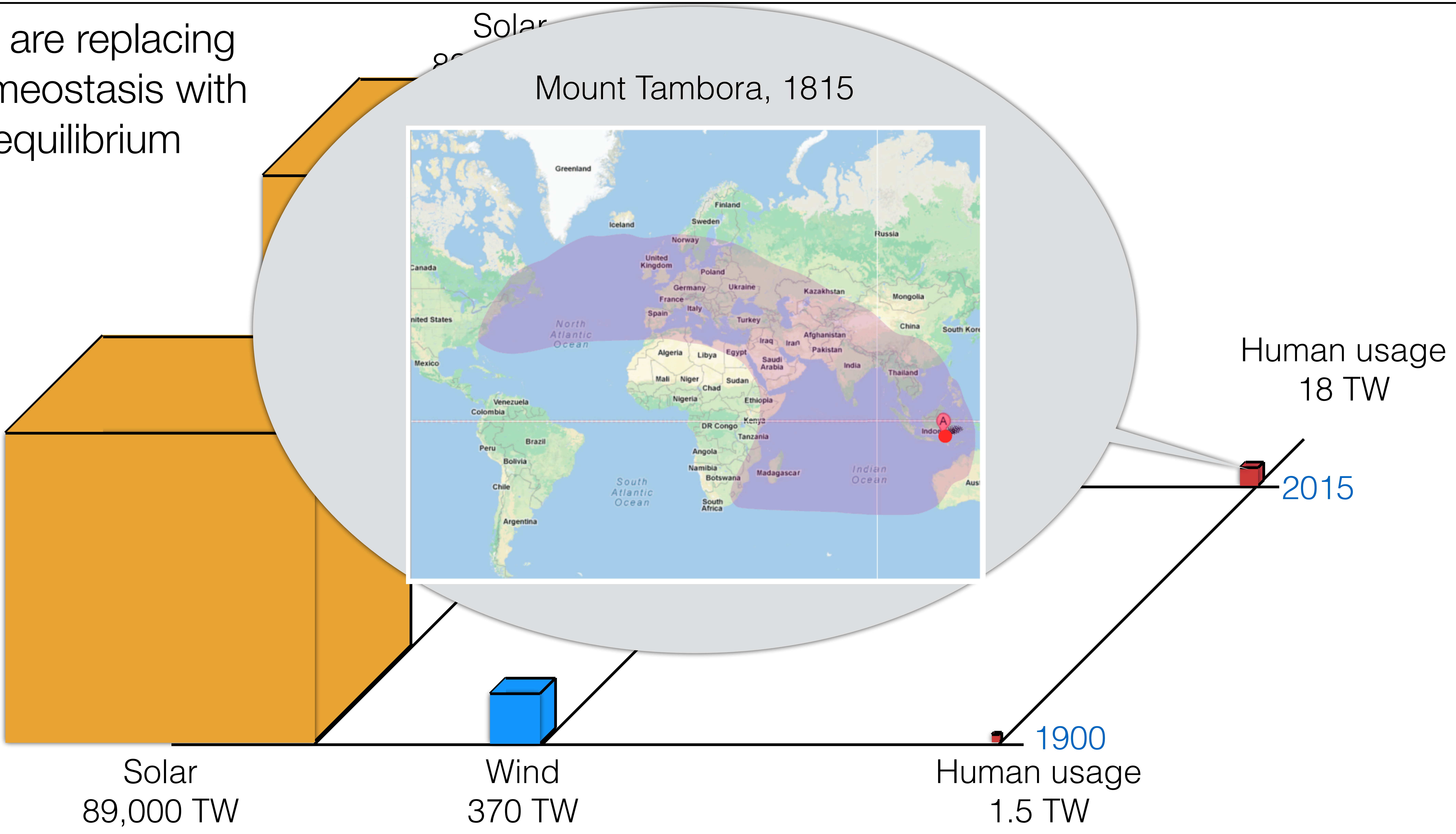

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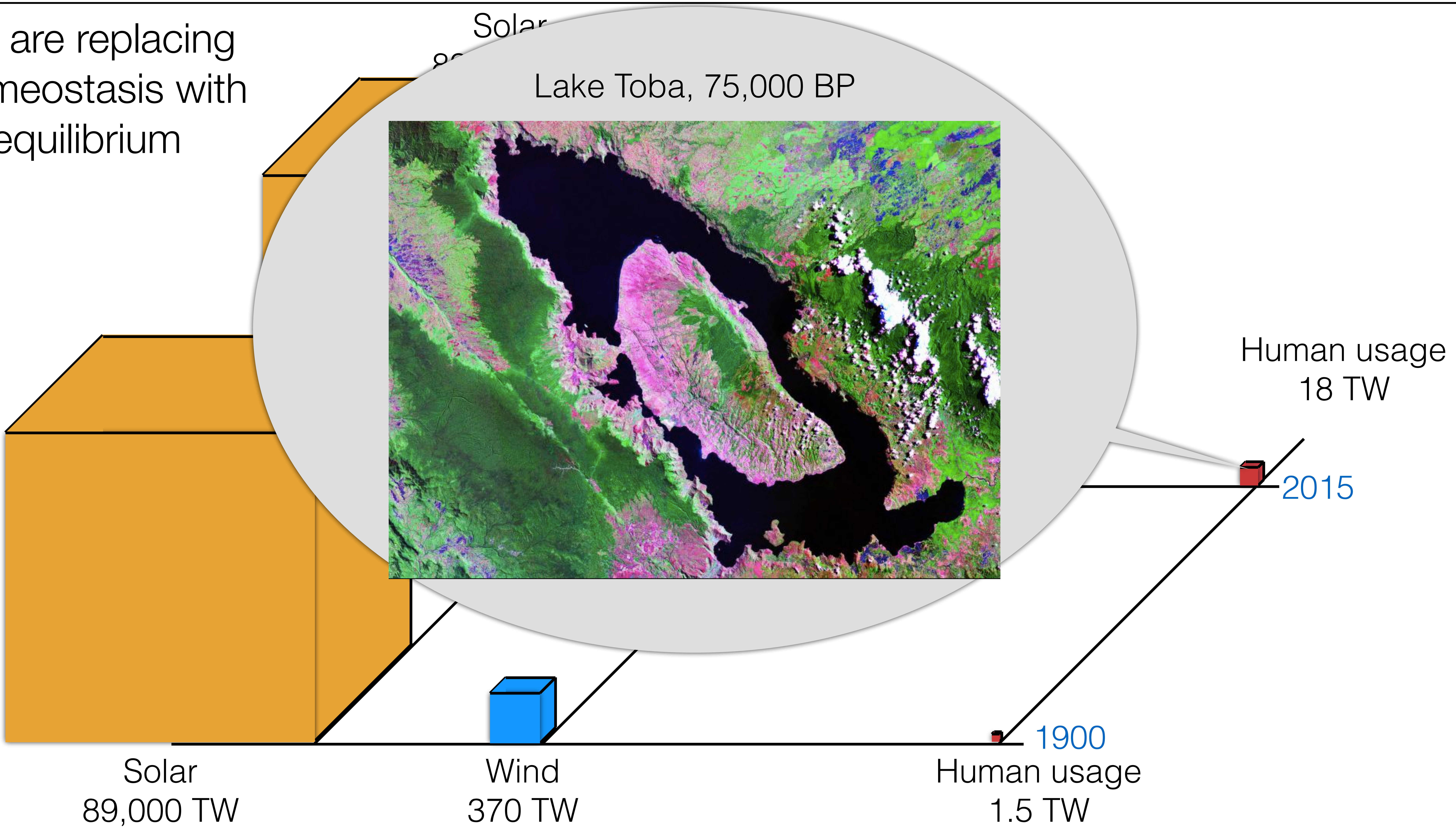

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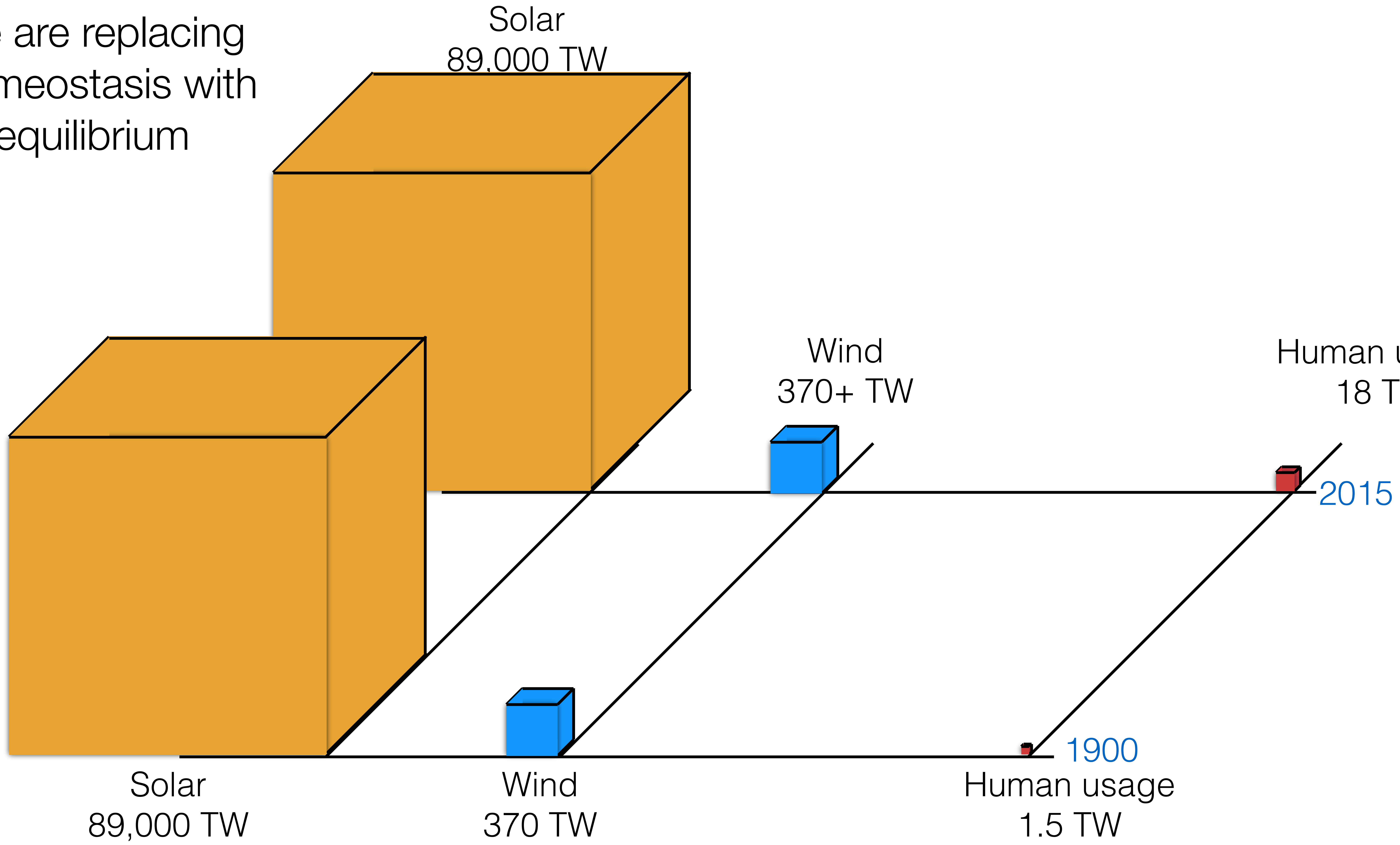

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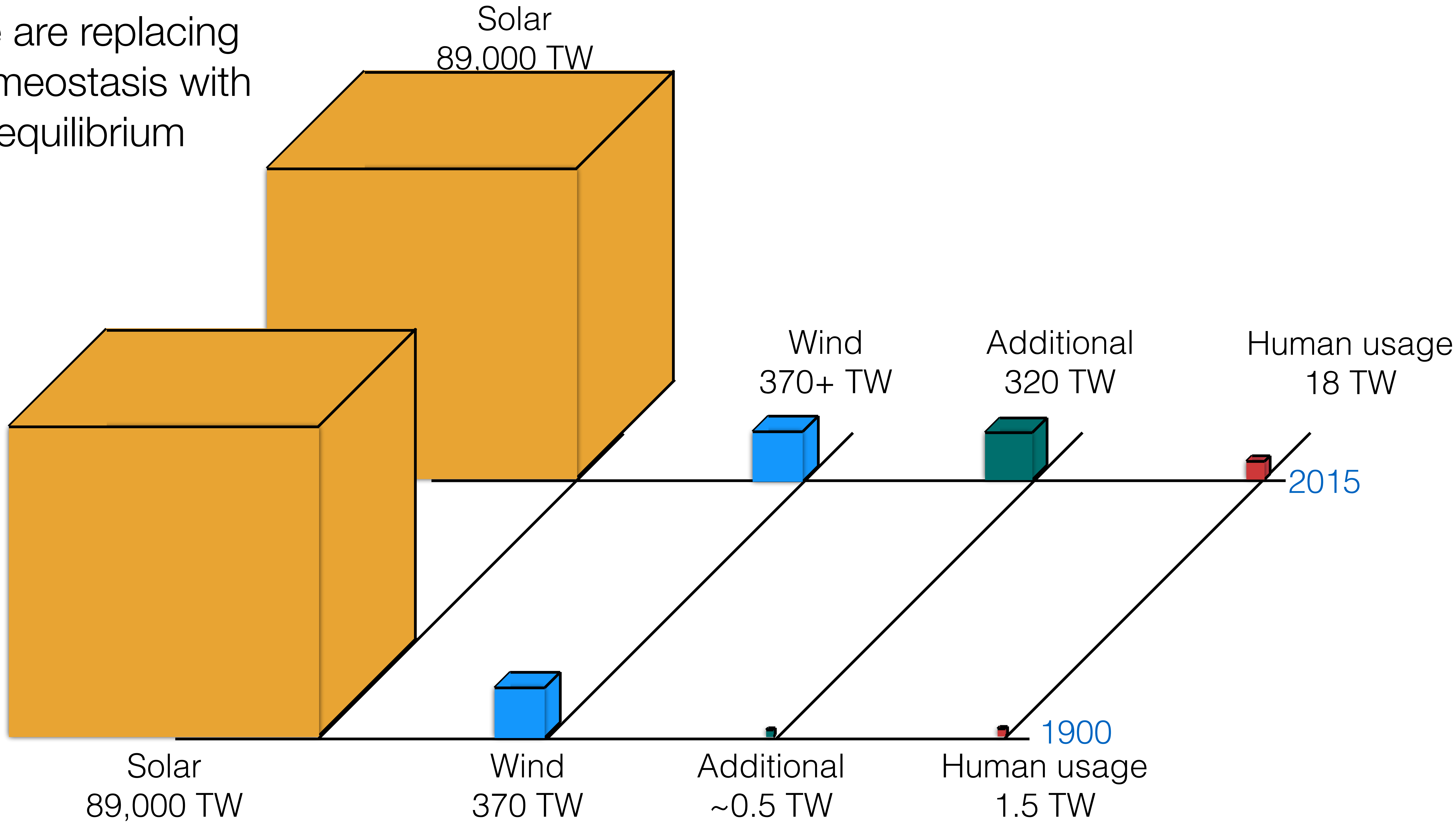

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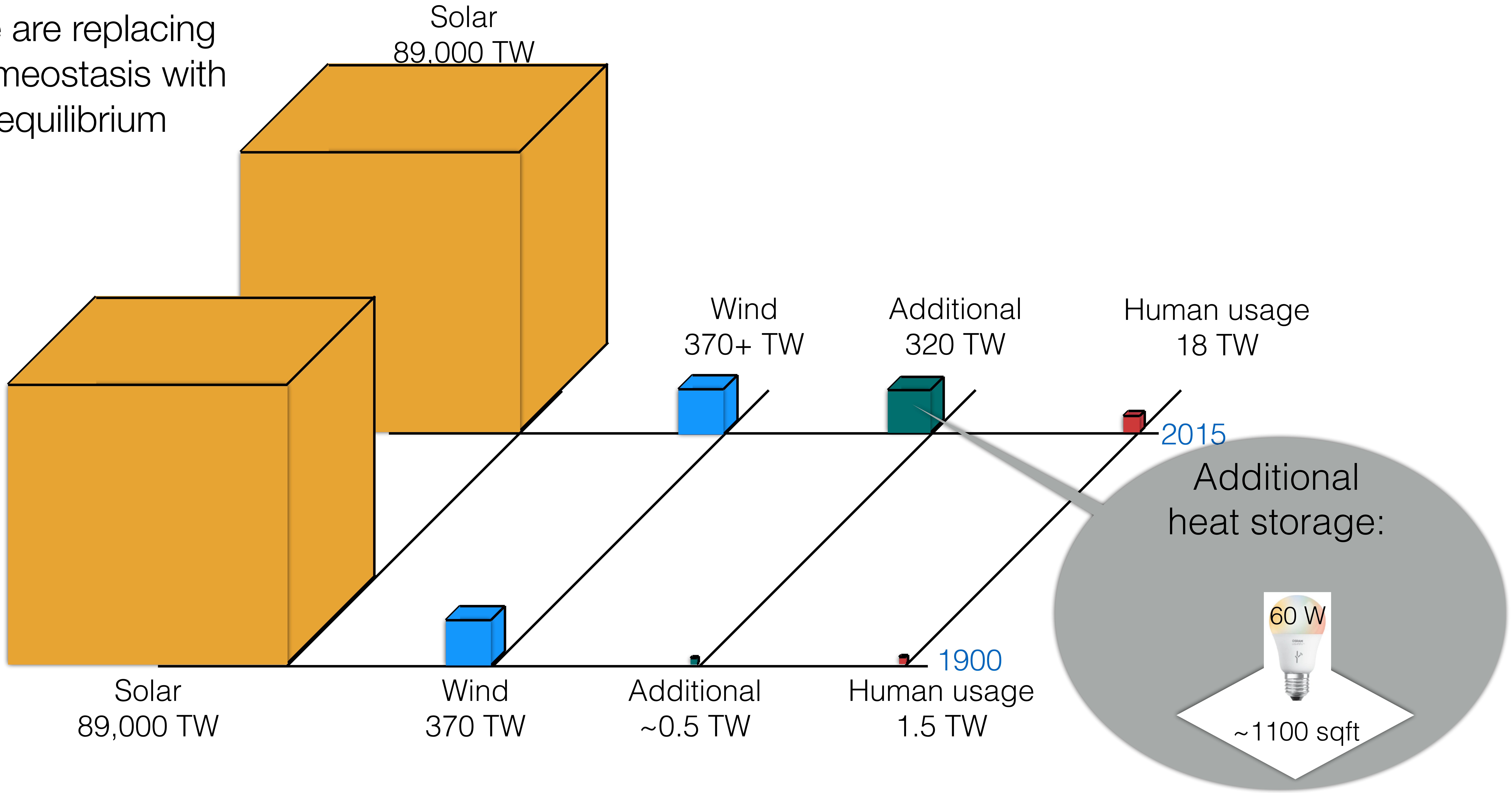

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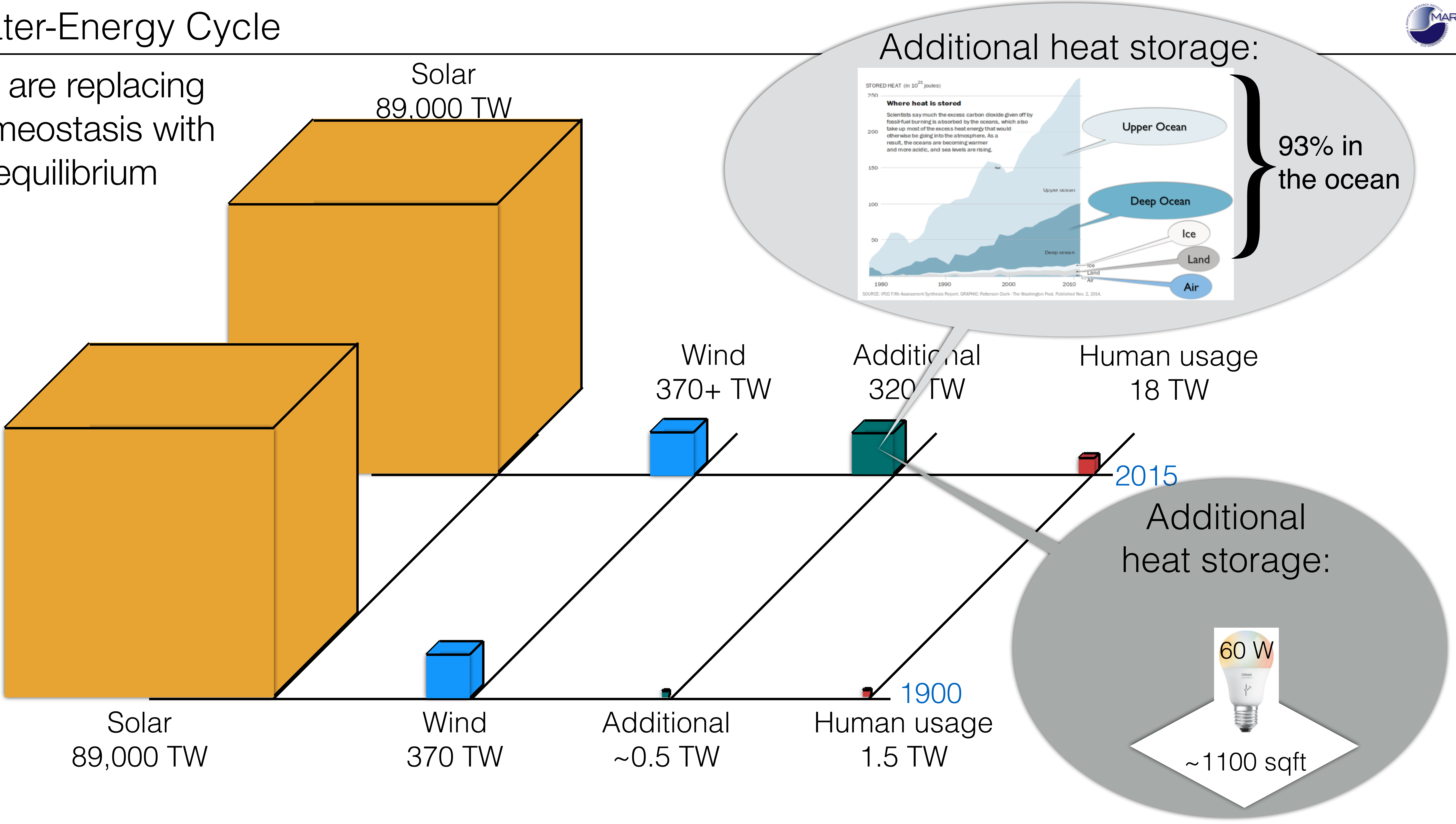

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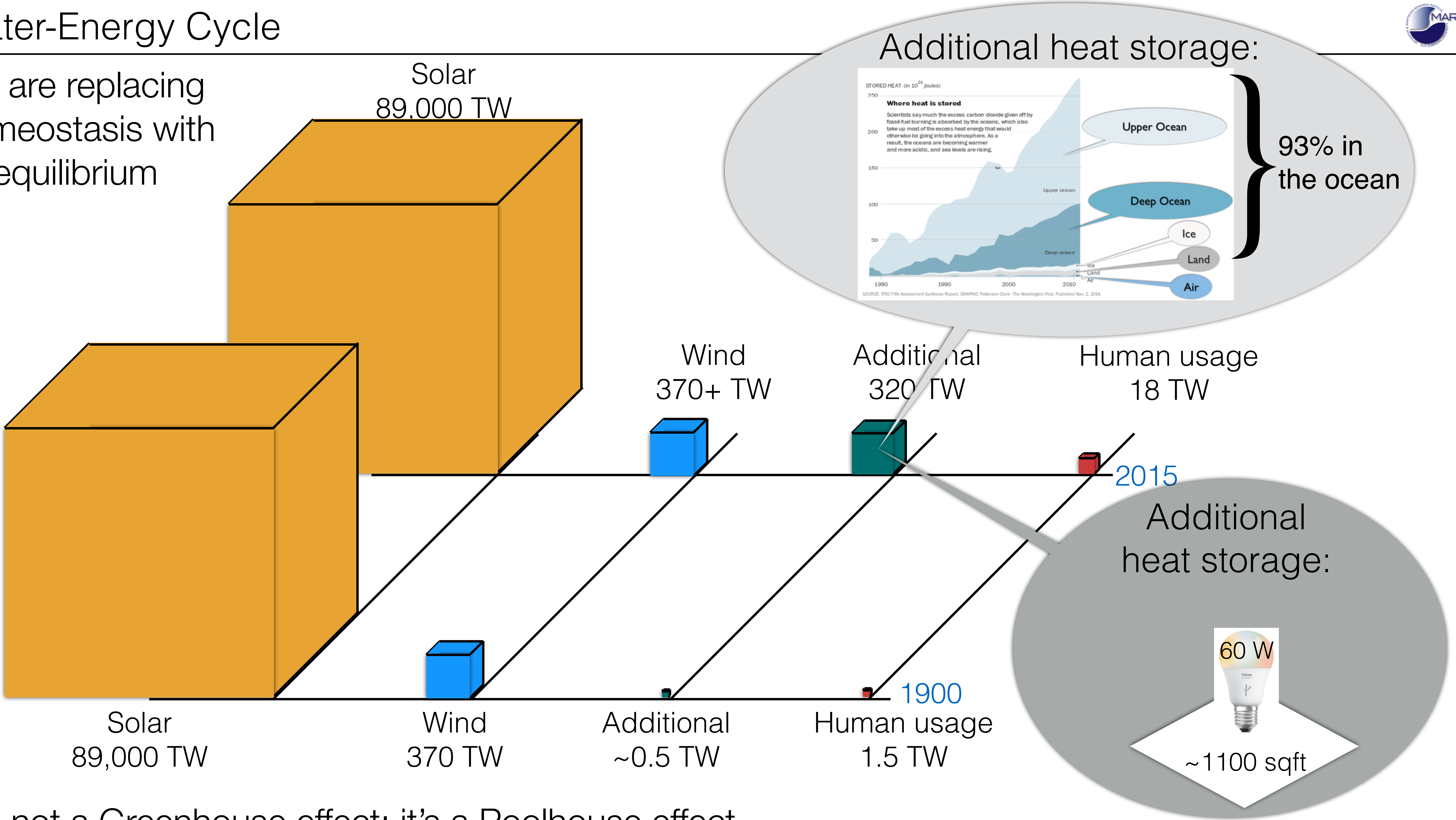

It’s not a Greenhouse effect; it’s a Poolhouse effect

Water-Energy Cycle

In a Dissipative System, small changes can change the characteristics of the system …

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Energy flows from fossil fuels => humanity => life-support system.

This impacts other flows in a “re-engineered” system and amplifies imbalances:

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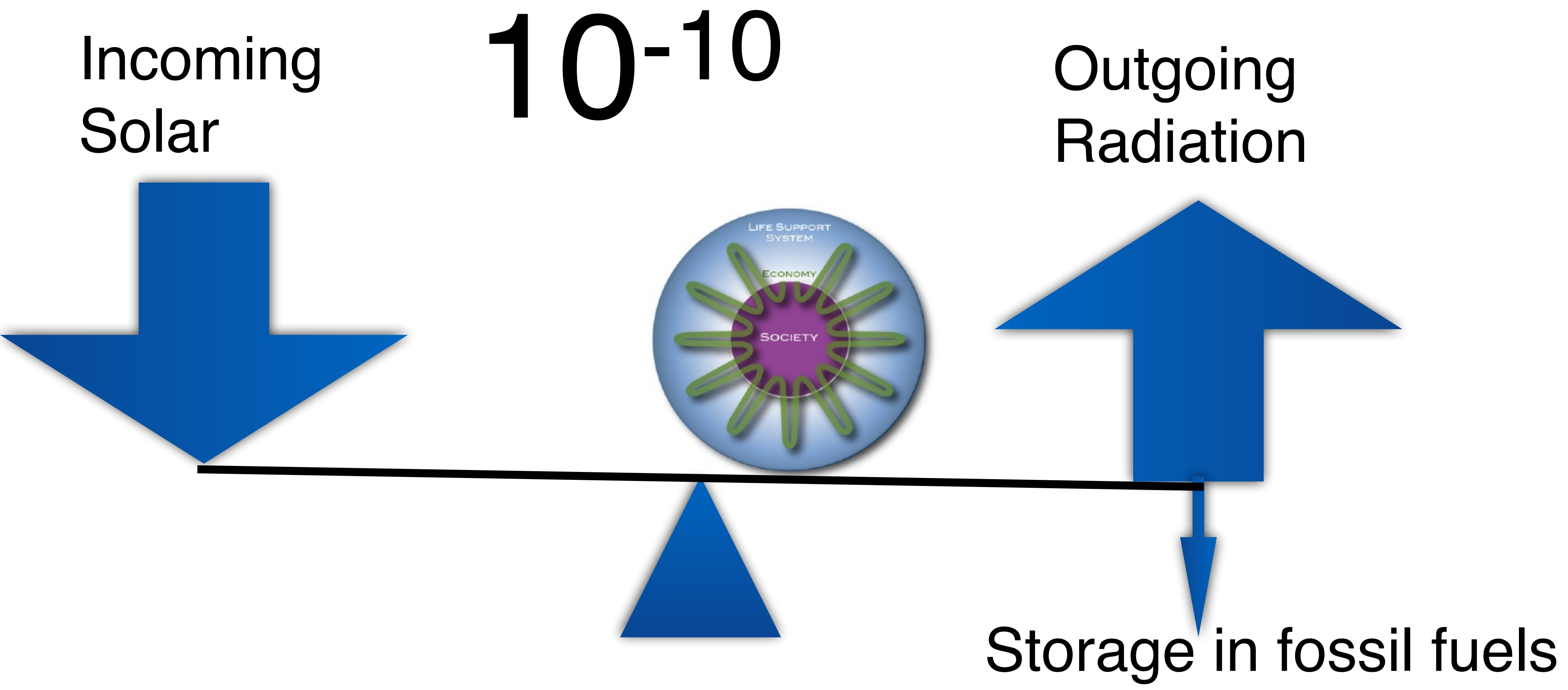

Imbalance on the order of 10^{-10}

Last 200 Million years

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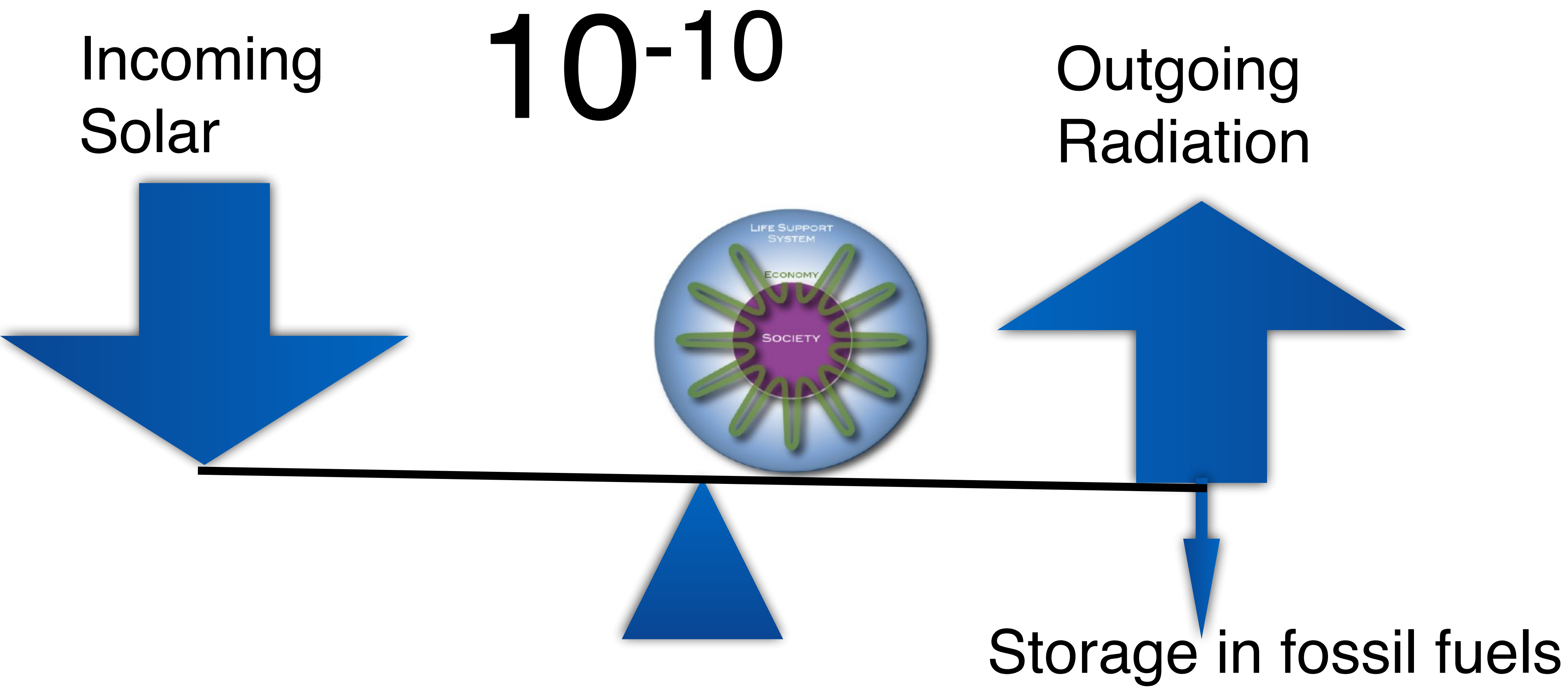

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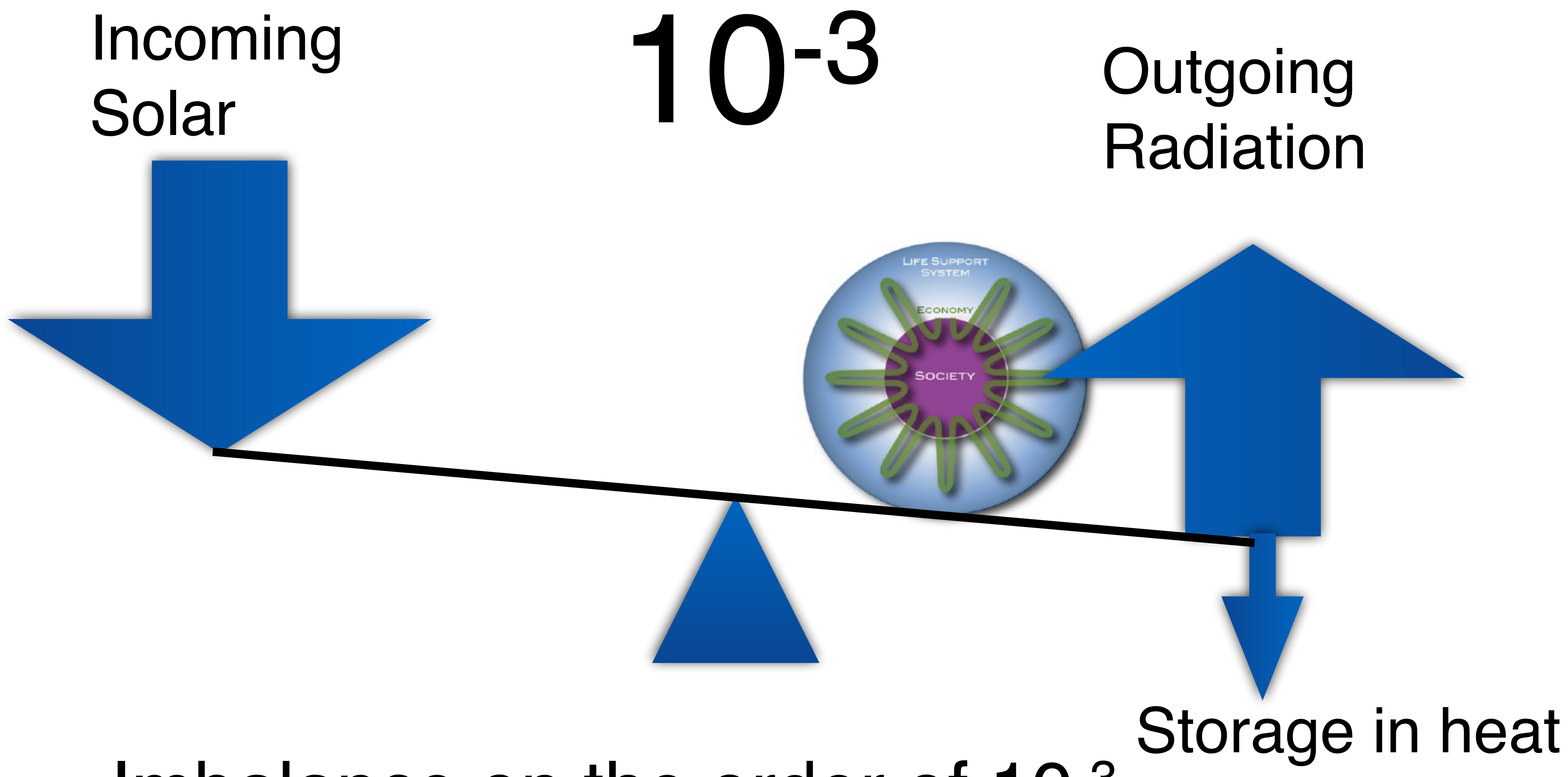
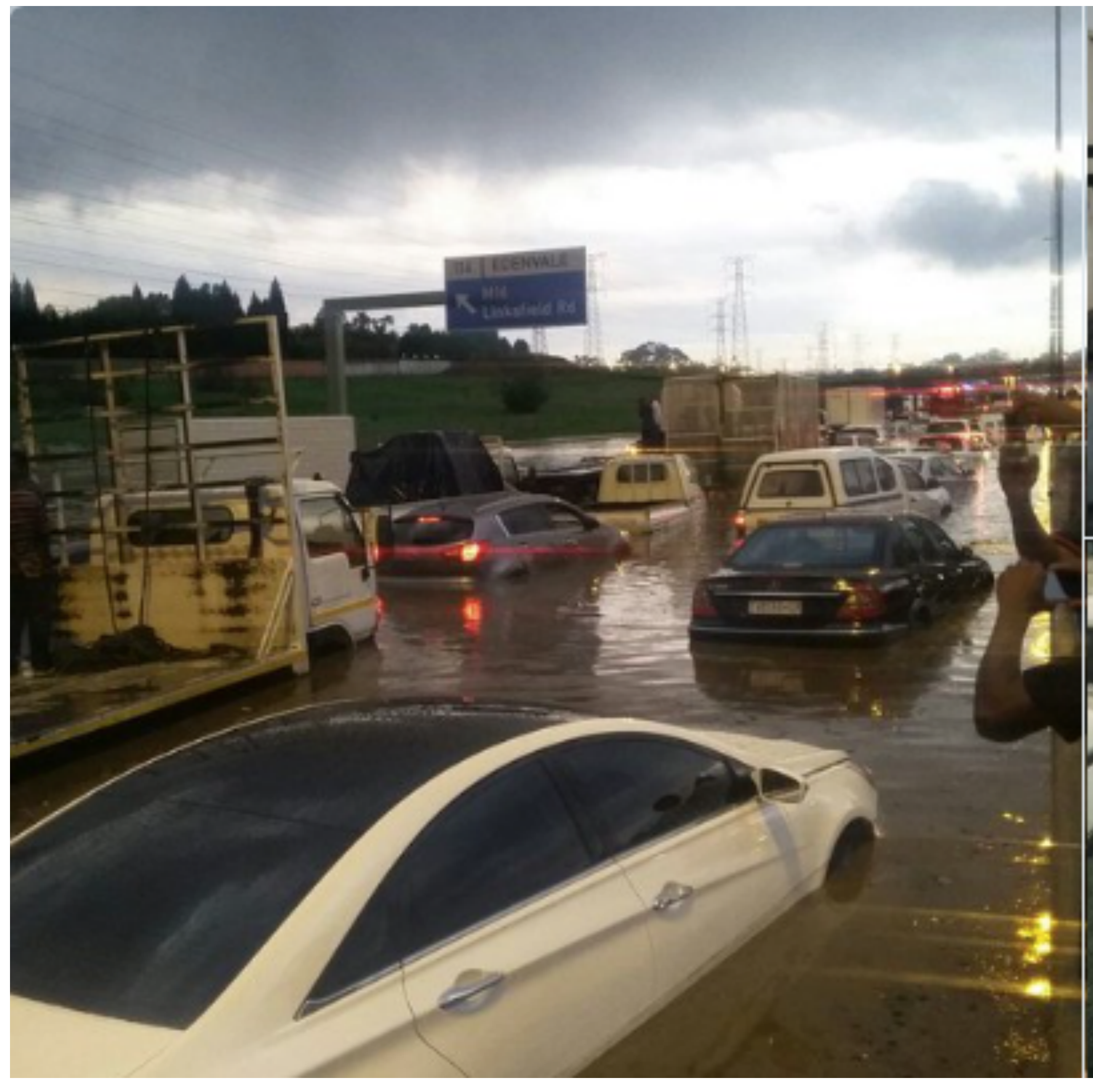


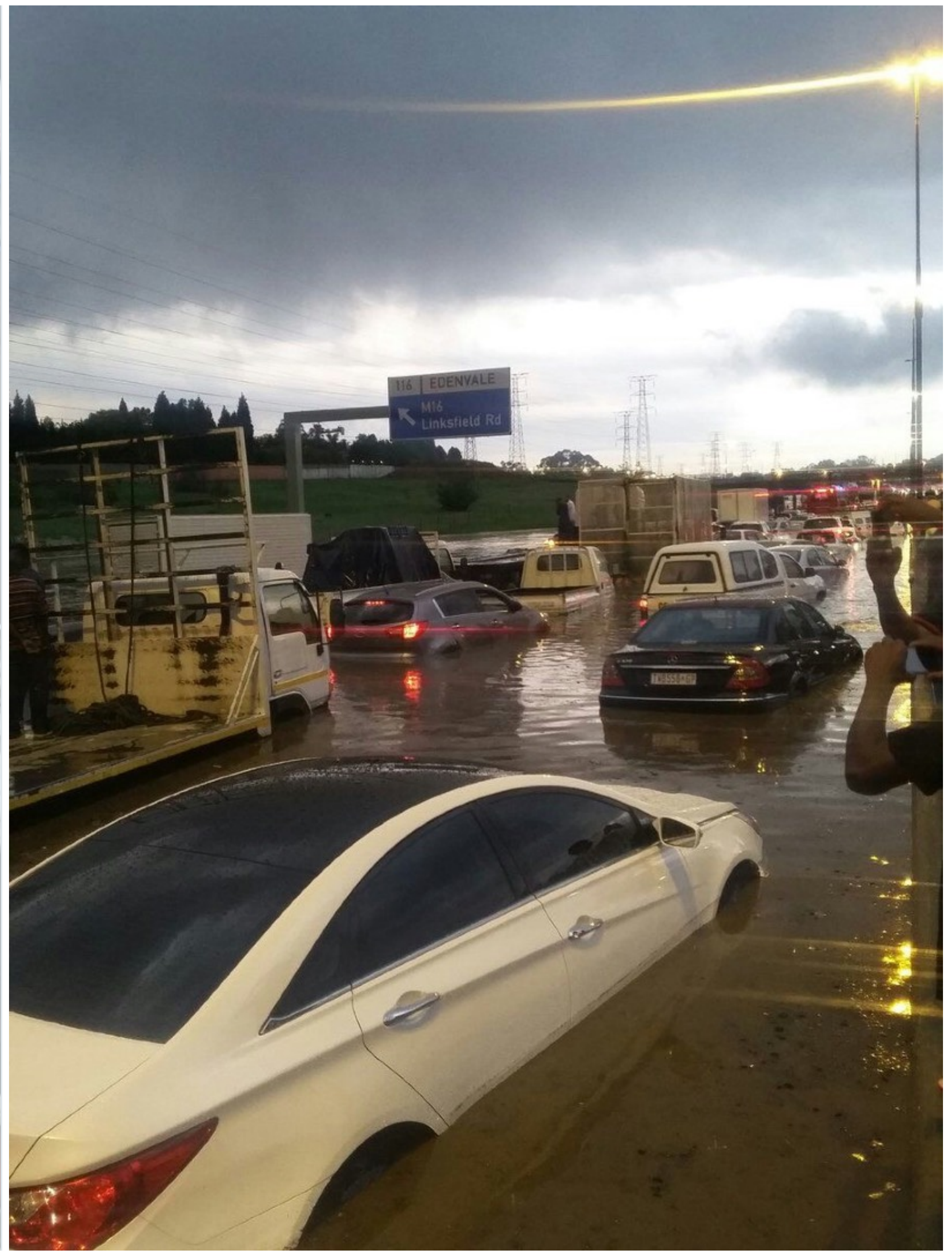
Imbalance on the order of 10^{-3}

Last 70 years

Preparing for Surprises: Extreme flood in Gauteng, South Africa, November 10-11, 2016






Preparing for Surprises: Extreme flood in Gauteng, South Africa, November 10-11, 2016

THE CONVERSATION

19 OCTOBER 2017

South Africa: Why Cape Town's Drought Was So Hard to Forecast

Tagged: Climate • Environment • Science • South Africa • Southern Africa • Sustainable Development

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Photo: Ashraf Hendricks/GroundUp

Theewaterskloof Dam in drought stricken Western Cape on 11 May 2017.

ANALYSIS

By Bruce Hewitson, University of Cape Town, Chris Jack and Piotr Wolski

Cape Town's drought and associated water shortage has officially escalated to the level of a disaster. The hope for a natural solution ended with the close of the main rainy season in September, and it is clear that water in the dams supplying the city will not last until the next rains in May-June next year.

The city had promised alternative sources of supply, the plans are not entirely realistic. Its main strategy now is to severely restrict water use through rationing.

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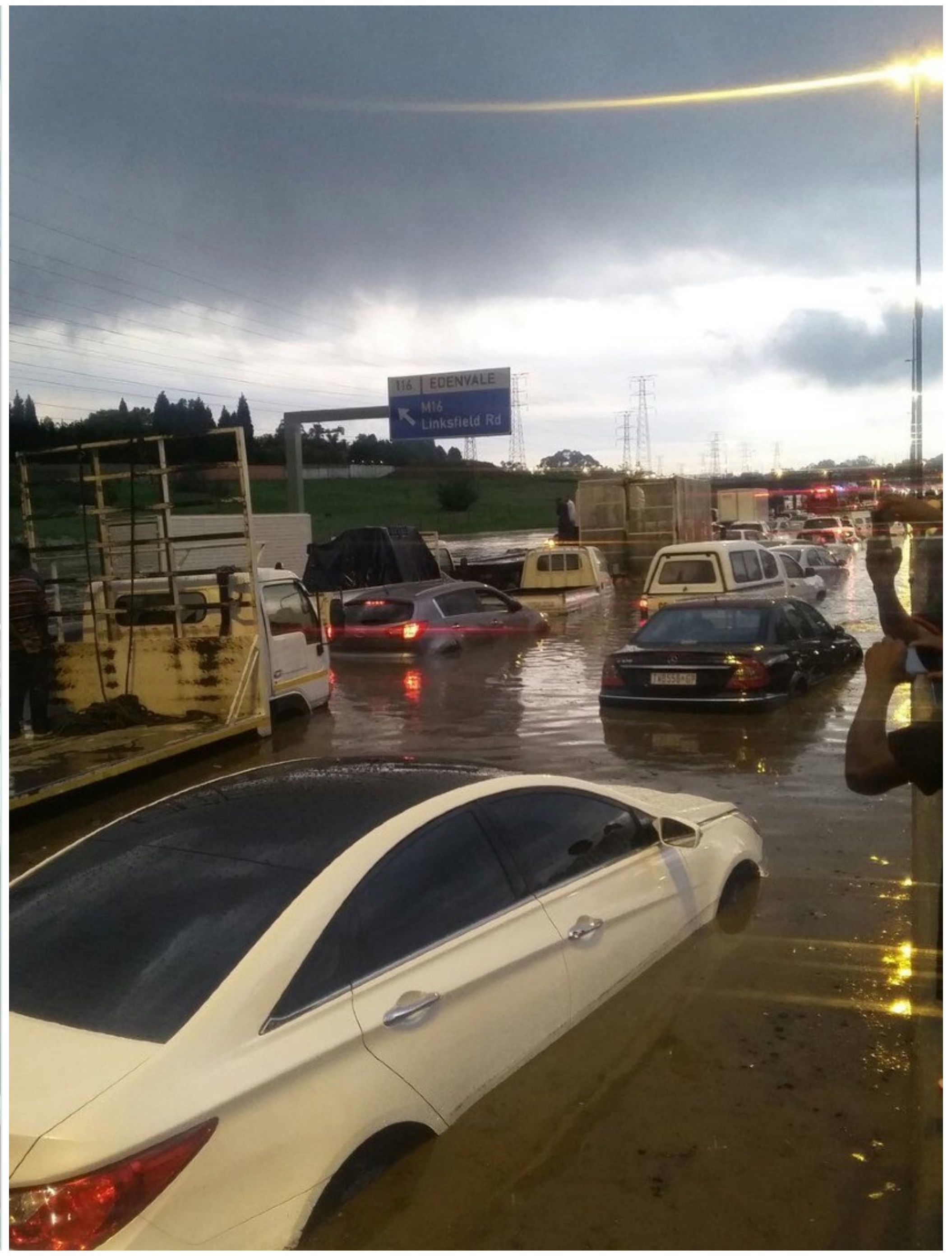

St Vincent and the Grenadines: Preparing for surprises

Changing Flood Risk

St Vincent and the Grenadines: Preparing for surprises

- Carry out high-resolution LIDAR survey
- Identify possible flood zones and landslide areas under extreme events
- Advice/regulate new constructions to be in safe areas

Changing Flood Risk

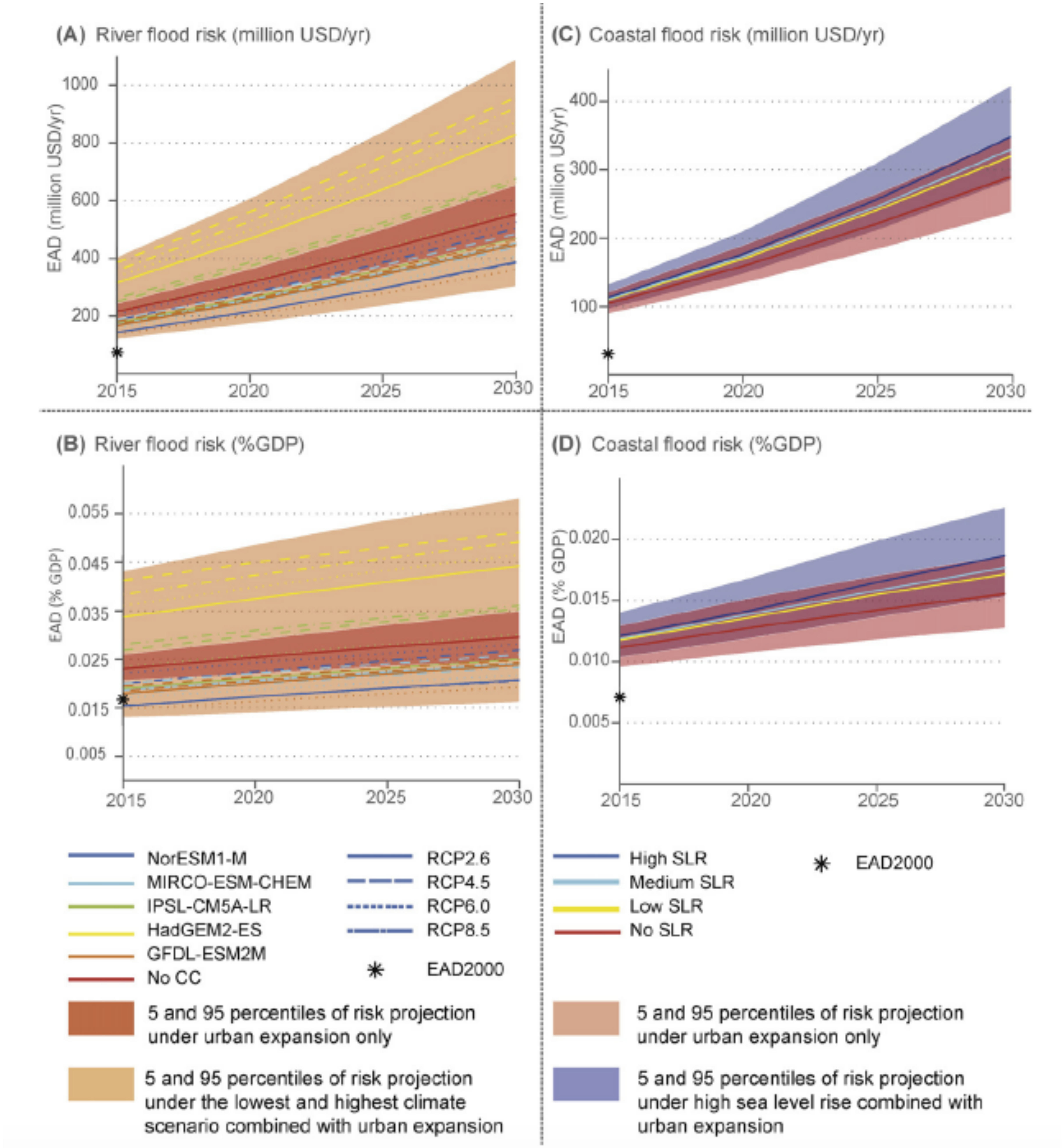

Fig. 6. Projections of changes in flood risk (EAD; expected annual damage) between 2015 and 2030. River flood risk is shownunder 20 different projections of climate change (5 GCMSand 4 RCPs) and for all projections of urban expansion. Absolute values are shown in (A), while values normalized to GDP are shown in (B). The light red shaded band shows the 5th–95th percentiles for the projections with no climate change (i.e. urban expansion only). The light orange shaded band shows the 5th–95th percentiles over the lowest and highest risk projection when the urban projections are combinedwith the 20 climate change projections. Coastal flood risk is shown under different scenarios of sea level rise (SLR) and for all projections of urban expansion using absolute values (C) and normalized to GDP (D). The red shaded band shows the 5th–95th percentiles for the projectionswith no SLR (i.e. urban expansion only). The blue shaded band shows the 95th percentile and 5th percentile when the urban projections are combined with high SLR.

Muis et al., 2015