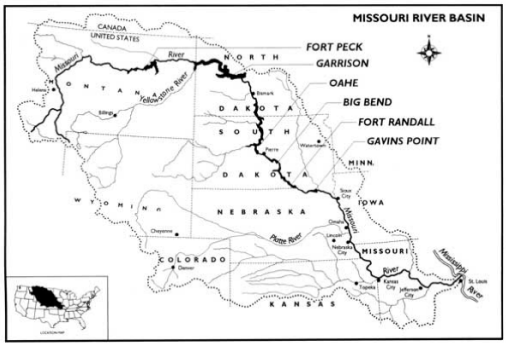
Explaining Climate Extremes

An Assessment of the 2011 Missouri River Basin Flood

In early 2011, the Missouri River Basin experienced devastating flooding, which caused significant property loss and threatened thousands of lives. January-May was the wettest recorded in the region since 1895, and the annual runoff above Sioux City, Iowa surpassed the previous record.

Researchers from the National Oceanic and Atmospheric Administration (NOAA) pursued a scientific study on the meteorological causes for the flood event with hopes to better understand its causes and assess its predictability. An assessment report has been completed, following peer review, and below are highlighted the major scientific findings.



The Missouri River Basin, the Missouri River, and the main U.S. Army Corps of Engineers reservoirs. The Upper (Lower) Basin is the region generally located in a west-east line above (below) Gavins Point near Sioux City Iowa. (Image courtesy Missouri Department of Natural Resources)

Major Findings

The factors immediately responsible for flooding were found to be a sequence of events that included:

- Pre-existing wet conditions – a particularly cold and wet 2010-2011 winter that led to unusually high snow pack, and
- Record-setting rains in late spring

The late spring rains were almost certainly the most critical in the meteorological sequence for understanding the historic proportion of Missouri Basin flooding.

The wintertime cold and wet conditions were shown to be consistent with those occurring in the upper Missouri Basin during La Niña events, and in this sense NOAA's La Niña Advisory issued on 5 August 2010 provided early warning for these types of winter conditions. However, La Niña in general, and the particular ocean conditions in 2011 specifically, were found not to materially alter the risks for a wet spring in the upper Missouri Basin.

The report suggests that neither the NOAA La Niña Alert Status nor subsequent exact knowledge of the details of the ocean conditions could have forewarned of extreme heavy spring rains.

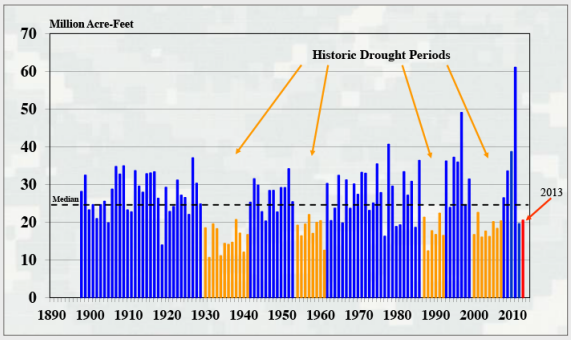
61 million acre-feet (maf) of runoff above Sioux City, Iowa beat the prior record by 12 maf

The analyses in the report indicate that the record-setting amount of water from the Upper Missouri Basin could not have been anticipated before the heavy spring rains set in, and it could almost certainly not have been anticipated at long seasonal (6-9 month) lead times.

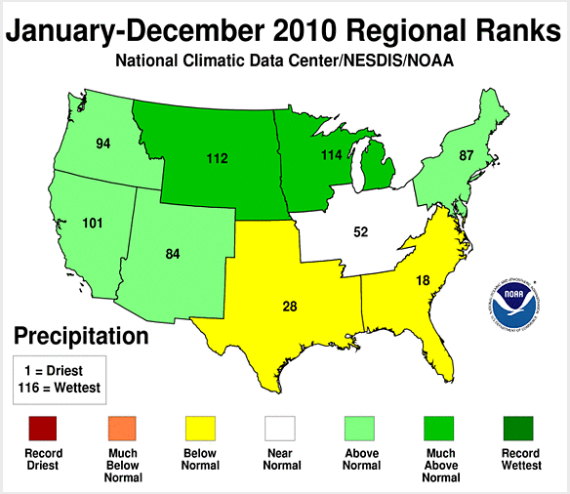
Conclusions

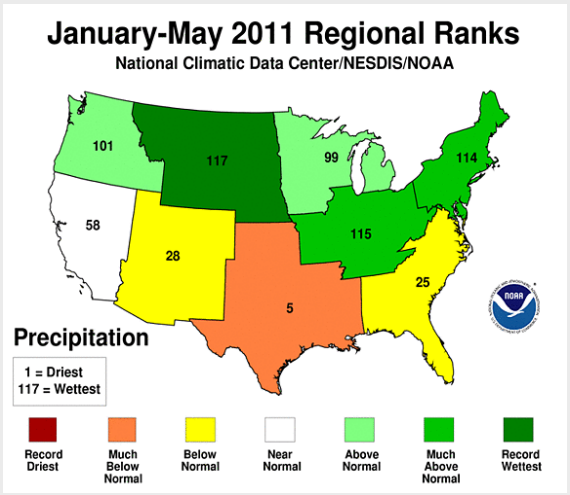
The report found that the record flooding was consistent with the physical response of basin runoff to a sequence of naturally occurring climate conditions, the majority of which resulted from random atmospheric variations, which could not have been predicted with current scientific knowledge. Due to the unusual sequence of extreme weather events, a flood of this magnitude

Annual Runoff above Sioux City, Iowa



Time series of the annual Missouri River runoff (million acre-feet) above Sioux City, Iowa for 1898-2012. The 2013 value (red bar) is a preliminary estimate. Regimes of persistent low flows, denoted by orange bars, denote hydrologic droughts within the basin. Horizontal line shows the historical median value. Data source is USACE.





The historical ranking of regional precipitation for annual 2010 conditions (top), and for the subsequent January-May 2011 conditions (bottom). Over the Missouri River Basin region, 2010 ranked 5th wettest since 1895, whereas the subsequent 5-month period January-May 2011 ranked as the historical wettest since 1895. Note the dramatic contrast between conditions in the Missouri Basin versus those immediately south. Data source is NOAA.

was a rare occurrence, and a comparable event has low probability for recurring in the immediate future.

A caveat to the conclusion that the flooding was the result of a sequence of naturally occurring climate conditions is the fact that annual flow in the Upper Missouri Basin has been more volatile in recent decades compared to prior decades dating to 1898. Specifically:

- Nine of the ten highest annual runoffs in the Missouri Basin historical record were found to have occurred after 1970, and
- Year-to-year variability of annual runoff has increased dramatically in recent decades principally due to an increase in high flow events.

The report does not address the underlying cause for post-1970 increase in the frequency of high runoffs events, but recommends further investigation of possible factors in order to better inform decision makers on the risks for future severe flooding events in the Missouri River Basin.

Given these events and the hydrology of the Missouri Basin, it was reasonable to expect that the subsequent 2012 year would also be susceptible to flooding. The previous five years had experienced above-average annual precipitation in the upper basin, resulting in progressively higher annual runoff from 2008-2011. However, the observed 2012 annual runoff in the Missouri Basin was below normal. The climate conditions themselves had not changed much between 2011 and 2012, and the concentrations of human-caused greenhouse gases were basically the same.

The fate of 2012 Missouri River runoff was apparently not set by the pre-existing conditions of 2011 anymore than pre-existing conditions determined the fate of 2011. Instead, in both 2011 and 2012 annual runoff depended primarily on meteorological factors, which abruptly returned the basin from flooding conditions in 2011 to drought conditions in 2012. The similar large-scale climate conditions of 2011 and 2012 serve as a lesson on the power of short-term variations in weather to cause contrasting impacts on the Missouri River Basin's annual runoff.

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