Vermont State Climate Office
Initial Climate Impacts Summary
August 2011

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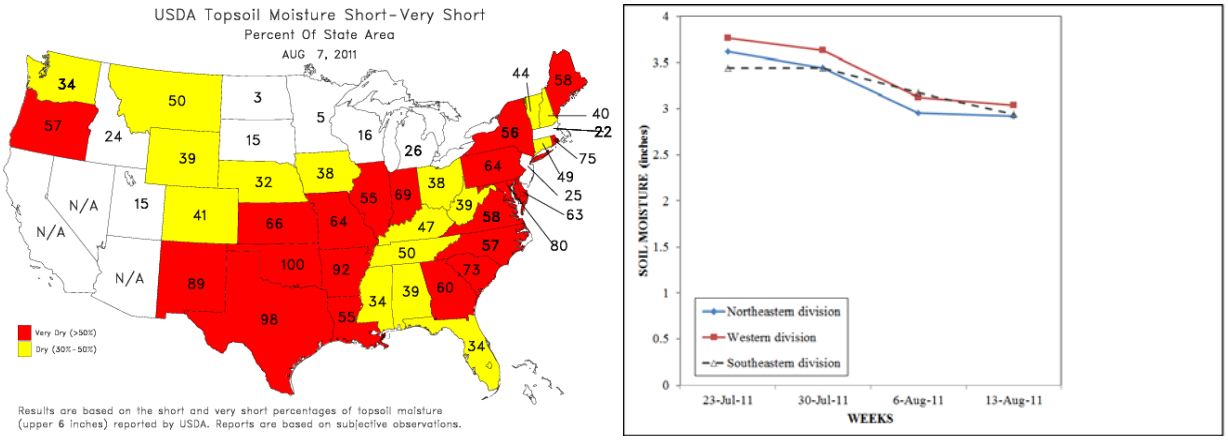
From a flash drought to the flooding rains of Tropical Storm Irene

August 2011 began with a marked precipitation deficit that had begun in July and which was exacerbated by the heat wave as that month ended. The precipitation shortfalls of July and August led to drying of the soils in western and northeastern Vermont. By 7 August, 2011 44% of Vermont's area was characterized by short to very short amounts of soil moisture in the upper 6 inches (Figure 1a). Drying in the lower parts of the soil column was also observed around the state by 13 August 2011 (Figure 1b). This loss of soil moisture in both the upper and lower parts of the soil profile was ultimately reflected in the drawdown of water bodies including Lake Champlain. By 3 August 2011, the National Weather Service reported that the Lake Champlain levels at the King Street Ferry Dock in Burlington had fallen to 96.02 feet from the record-setting 103.20 feet on 6 May 2011. Their records from this site indicate that the Lake rose 7.5 feet between 5 March and 6 May, 2011 followed by the 7.18 foot drop to the 96.02' level on 3 August (Figure 2).



(A) (B)

Figure 1: (A) Percent of a state's area with short-very short amounts of soil moisture in the uppermost 6 inches of the soil. Source: USDA. (B) Soil moisture values in the lower parts of the soil column across Vermont's three climate divisions. Source: NOAA/CPC

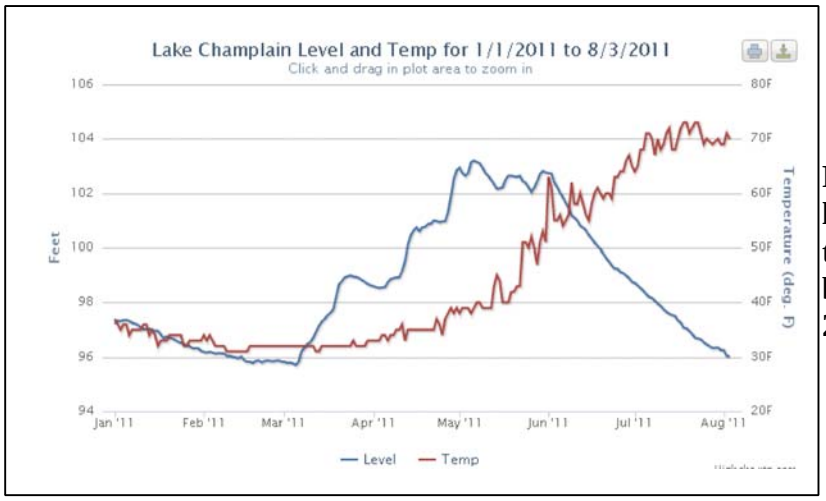


Figure 2: Lake Champlain levels and water temperature at the King Street Ferry Dock between January and August 2011. Source NOAA/NWS-BTV

On 15-16 August, 2011 widespread and heavy rains were observed across most of Vermont (Figure 3) as a slow-moving upper level low pressure area and surface low pressure region tracked through. The system was associated with a deep layer of moisture which helped to produce precipitation totals in excess of 2" in central and eastern Vermont, with 1" totals in the Champlain Valley. This soaking rain was accompanied by low daytime high temperatures.

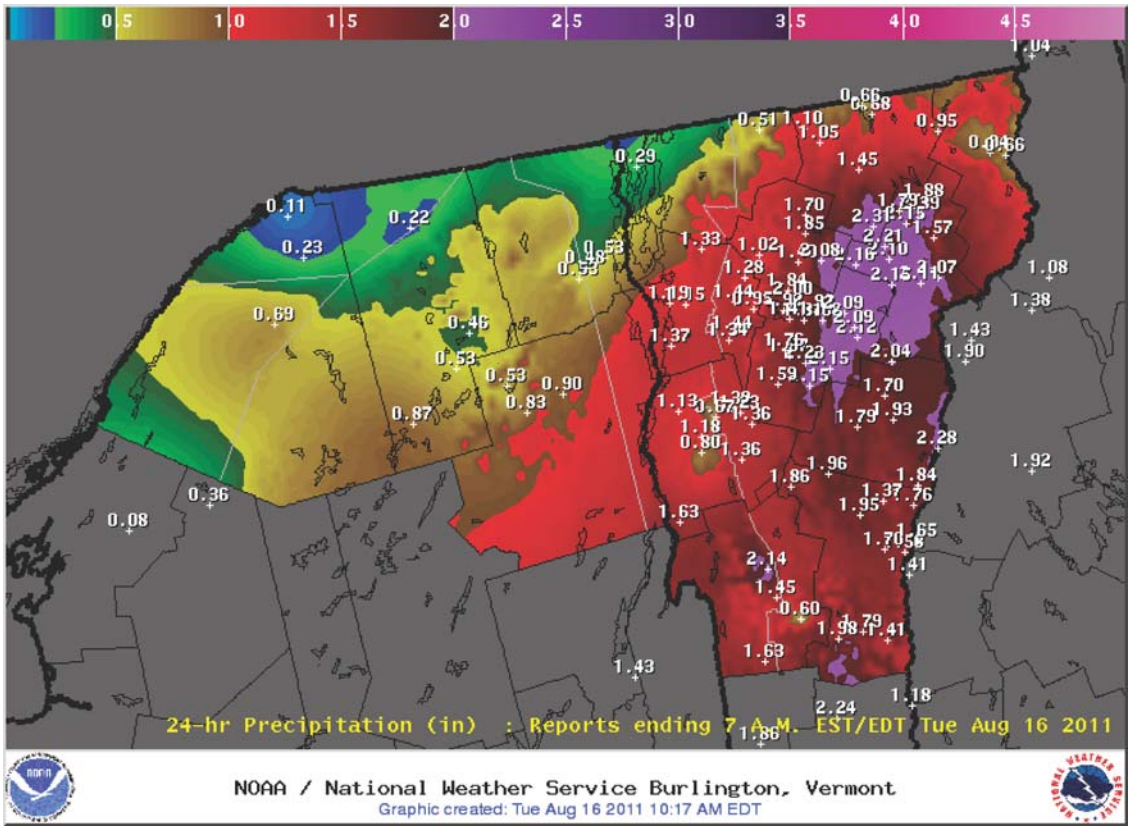


Figure 3: Precipitation totals observed across the NWS Burlington VT Forecast area as of 0700 EDT on 16 August, 2011.

TROPICAL STORM IRENE

Rainfall associated with the remnants of Tropical Storm Irene began across southern Vermont during the night of Saturday 27 August, reaching northern Vermont during the early morning of the 28th. As the tropical system made landfall early Sunday, it moved north up the Hudson Valley into western Massachusetts and across extreme northeast Vermont by Sunday night. One of Irene's main characteristics was its large spatial extent (Figure 4a) and heavy rainfall totals. Twenty-four hour rainfall estimates at 0800 EDT on Monday 29 August ranged from 3 to 8 inches, affecting all rivers and basins across Vermont and surrounding states (Figure 4b).

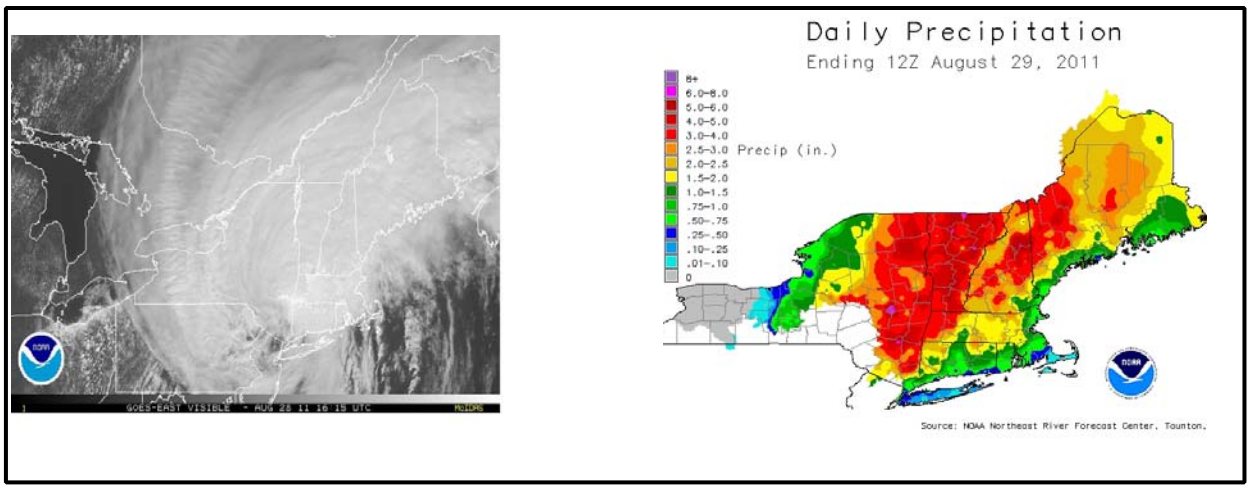


Figure 4: Cloud shield of Tropical Storm Irene at 1215 EDT on 28 August, 2011 (a). Twenty-four hour precipitation totals observed across the northeast as of 0800 EDT on 29 August, 2011 (b).

Across the state, rainfall totals ranged from 3.2"- 8.15", shattering records dating back to the summers of 1949, 1950 and 1971 as summarized in Table 1. This widespread, intense rainfall resulted in soils quickly becoming saturated. Flash flooding was common across central and southern Vermont, with slower riverine flooding being observed in much of the north. Saturated soils also primed the landscape for massive trees blow downs by winds associated with Irene's remnants .

Table 1: Twenty-four hour daily record rainfall (inches) totals for the August 28 & 29, as observed at 0800 EDT on the respective days

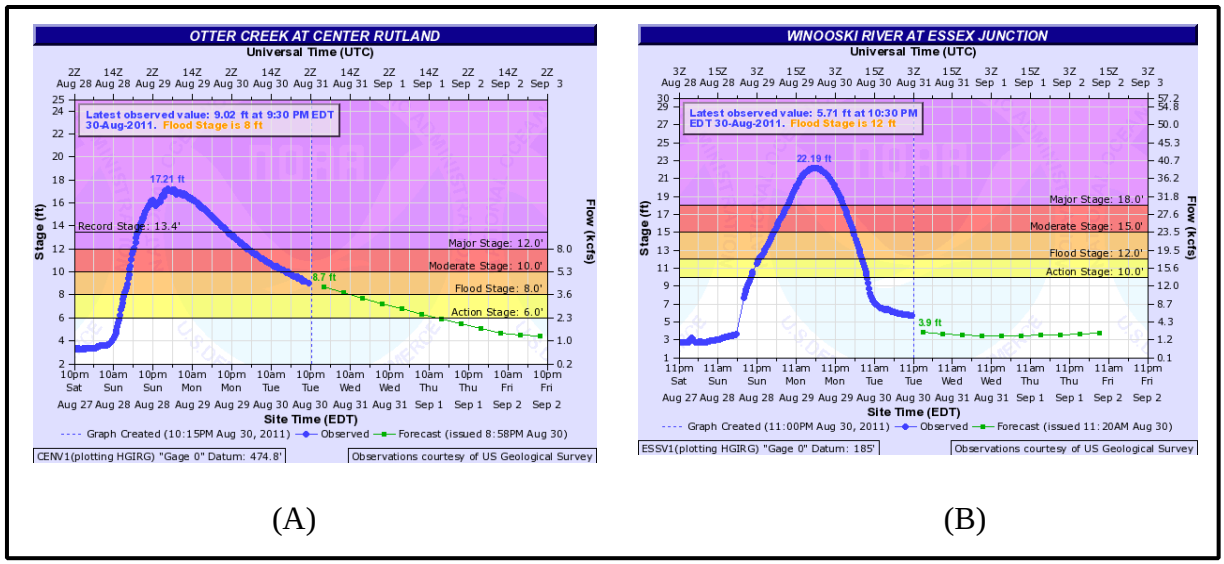
COUNTY	STATION	RAINFALL (in) 28 August	RAINFALL (in) 29 August
Addison	Salisbury 2 N	4.08 (2.52 in 1967)	
Caledonia	St. Johnsbury	4.83 (1.97 in 1971)	

Chittenden	Burlington airport	3.38 (2.38 in 1971)	
Bennington	Pownal 1NE	1.36 (0.92 in 1999)	
Franklin	Enosburg Falls	2.45 (0.94 in 1973)	
Orange	South Newbury	1.36 (0.92 in 1971)	
	Corinth	1.09 (0.53 in 1950)	
Windsor	Woodstock	1.7 (1.6 in 1971)	
Addison	South Lincoln		5.36 (1.58 in 1988)
Bennington	Pownal 1NE		3.49 (0.64 in 1987)
Lamoille	Mt. Mansfield		3.22 (2.0 in 1990)
Orange	South Newbury		2.33 (1.68 in 1971)
	Corinth		5.7 (1.34 in 1949)
	Union Village Dam		3.4 (1.98 in 1971)
Orleans	Newport		4.1 (2.1 in 1949)
Washington	Montpelier airport		2.32 (1.83 in 1949)
Windsor	Bethel 4 N		4.54 (2.22 in 1971)
	Woodstock		5.64 (1.97 in 1971)
Windham	Ball Mountain Lake		4.9 (1.79 in 1971)

Impacts due to Irene's passage

Human fatalities are the most important losses from natural disasters. Three people lost their lives in Vermont. A 21 year old female in the Wilmington Vermont area was swept away and drowned in the roaring Deerfield River. A male died while inspecting the inlet to Rutland's water system while his son's body was never found.

In west-central Vermont, the Otter Creek in Rutland crested at new record flood stage of 17.21 feet. Flood stage at this gauge is 8 feet. Flash flooding on this river (Figure 5a) and others in the vicinity led to the isolation of the city and wreaked severe damage to many of the local roads in the area including State Route 7. Further north, flooding continued on many rivers especially the main stem rivers. This included the Winooski River which flooded the State Complex in downtown Waterbury, leading to the evacuation of the Vermont Emergency Management headquarters and the new state office complex among others. Further downstream, the river continued to crest, flooding fields in the Richmond area and reaching a flood stage of 21.7 feet at the Essex Junction gauge (Figure 5b). Flood stage there is 12 feet.



(A) (B)

Figure 5: Flood hydrographs for the Otter Creek at Center Rutland (a) and Winooski River at Essex Junction for 27-30 August, 2011

Road and Bridge washouts

One of the most striking aspects of the Irene-related damage was the spatial extent and magnitude of the damage to the transportation sector especially in central and southern Vermont. Three historic covered bridges have been washed away or extensively damaged, including a) a 141 year old bridge in Rockingham washed out by the Williams River; b) the Quechee covered bridge that was left in "tatters" (Figure 6) and c) the Northfield Falls Cox Brook covered bridge that was severely damaged.

Figure 6: Covered bridge in Quechee on 28 August 2011 [Photo credit: Associated Press]

A number of towns were cutoff from the rest of Vermont including Wilmington in Windham county as the raging Deerfield River flooded. Initial estimates of road washouts or closures across the state included 260 roads with at least 18 state highway bridges being washed out or extensively damaged.

Power Outages

The widespread heavy rainfall and river flooding were accompanied by wind gusts between 30 and 60 mph. The highest wind gust of 85 mph was reported on the summit of Mt Mansfield. These combination of these winds with the loose saturated soil resulted in power lines being blown down and uprooted trees which also took down power lines (Figure 7). At one point in time up to 60,000 customers were without power in Vermont. By the afternoon of 29 August, about 35,000 customers were without power. Generators were required to provide power to hospitals and those requiring assistance. In addition, up to 3000 customers had limited or no phone service.

Figure 7: Downed tree in Burlington, VT on 28 August 2011. [Photo credit: Burlington Free Press]

Protective State and Local Actions

‣ National Guard mobilized along with cold water rescue units and deployed. Several emergency evacuations and recues were required during the storm by local responders.
‣ Portions of I-91 (southeast Vermont) closed during height of storm and flooding as well as exit 11 on I-89
‣ Emergency shelters opened in; Barre, Bennington, Brattleboro, Bristol, Enosburg, Hartford, Middlebury, Rutland, St Albans, St Johnsbury, Springfield. As of late Monday, only the shelters in Rutland, Brattleboro, Barre and Hartford remain operational. At the height of the storm, approximately 500 people were sheltered.
‣ Power crews requested from other states to help with power restoration. One of the biggest challenges will be ability to access sites due to road closures.
‣ As noted above, numerous state and local roads closed. Some of the more significant road closures are listed below as of Monday afternoon.
‣ Chester was especially hard hit with State Routes 11, 103, 35, and 10 closed or washed out. A number of local streets were also closed.
‣ Grafton reported Route 121 closed and the Wrights Foot Bridge washed out. Numerous local streets were also closed.
‣ A number of east-west roads across southern Vermont were washed out and closed causing travel difficulty. In particular, Route 9 which connects Bennington with Brattleboro and Route 4 which connects Rutland with White River Junction.
‣ Route 11 was severely affected in the Andover area as well as Routes 12 and 8 in Readsboro.

‣ In Ludlow, Routes 103 and 100 were closed, as well as in Wilmington which remained isolated by flood waters.
‣ Across northern Vermont, the west-east connector Route 2 was closed in several places especially in the Richmond and Bolton areas.
‣ Route 5 was closed in several places between St Johnsbury and Newport.

ADDITIONAL RESOURCES

http://www.uvm.edu/~vtstclim/?Page=Irene_flooding_2011.html	Irene one-stop page for background, recovery, data
http://vthistory.org/journal/70/vt701_204.pdf	Hazards in Vermont including hurricanes
http://www.erh.noaa.gov/btv/events/Irene2011/#	NWS/Burlington initial summary of Irene
http://www.mass.gov/czm/chc/meetings/present/vallee_hurricanes_6-12-06.pdf	New England hurricanes
http://vem.vermont.gov/	Vermont Emergency Management
http://crisislanding.appspot.com/?crisis=2011_flooding_vermont	VTrans-GOOGLE partnership for road closures
http://www.whitehouse.gov/the-press-office/2011/08/29/president-obama-signs-vermont-emergency-declaration	Presidential Emergency Declaration