

# Weather Ingredients Involved in the 14 May 2013 Record Breaking Temperatures

## Event Synopsis

On Tuesday, 14 May 2013 afternoon temperatures soared into the triple digits, and the state high temperature record for Minnesota was set (preliminary 102°F at multiple locations). St Cloud set a record of 95°F, and the Minneapolis airport reached 98°F which also set a record. In fact, this is the earliest date in the 142 year climate record that Minneapolis has ever reached 98°F. There are three main ingredients that need to come together during the late afternoon hours in order for these record breaking heat events to occur. They are:

- 1) Warm air aloft
- 2) Dry conditions
- 3) Sunny skies

Warm Air Aloft - As air moves eastward across the Rocky Mountains, it sinks and warms. Also, sun heats the ground at the high elevations, and this warms the air near the ground. As this hot air moves eastward, the ground elevation decreases, so even though this air remains at the same level relative to sea level, it becomes elevated relative to the ground (Fig 1). This warm air was in place Monday morning, moved eastward, and was positioned directly across the Upper Midwest by midafternoon (Fig 2,3).

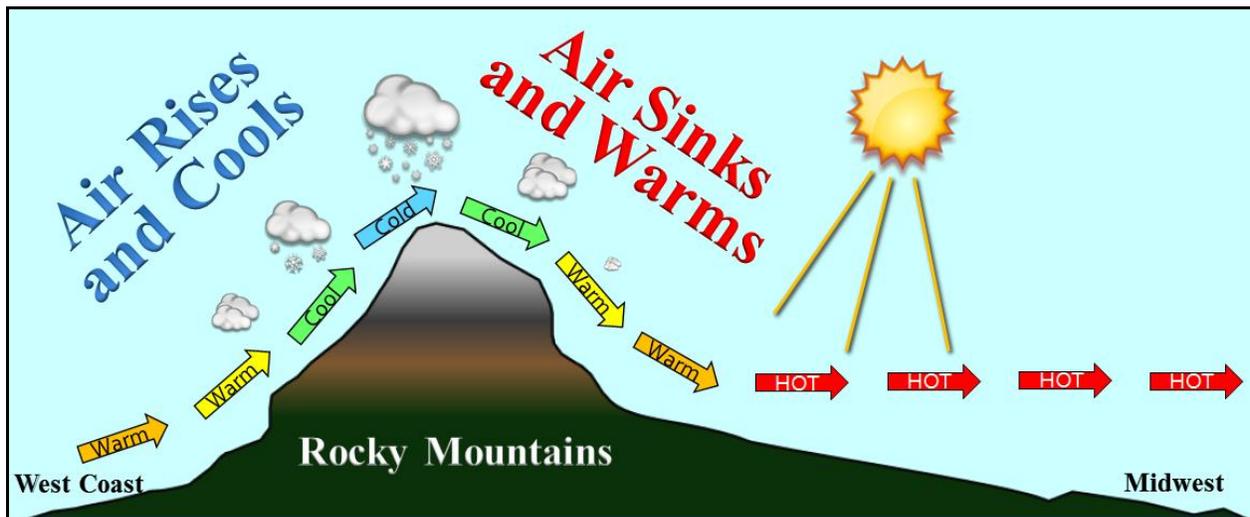


Figure 1: The image above shows a west (left) to east (right) cross section of the United States. As air moves up the Rocky Mountains, it rises, cools, and produces snow. After it crosses the peaks, it sinks, warms, and becomes hot. This hot air then continues eastward over the Upper Midwest. Meteorologists call this an “elevated warm layer”.

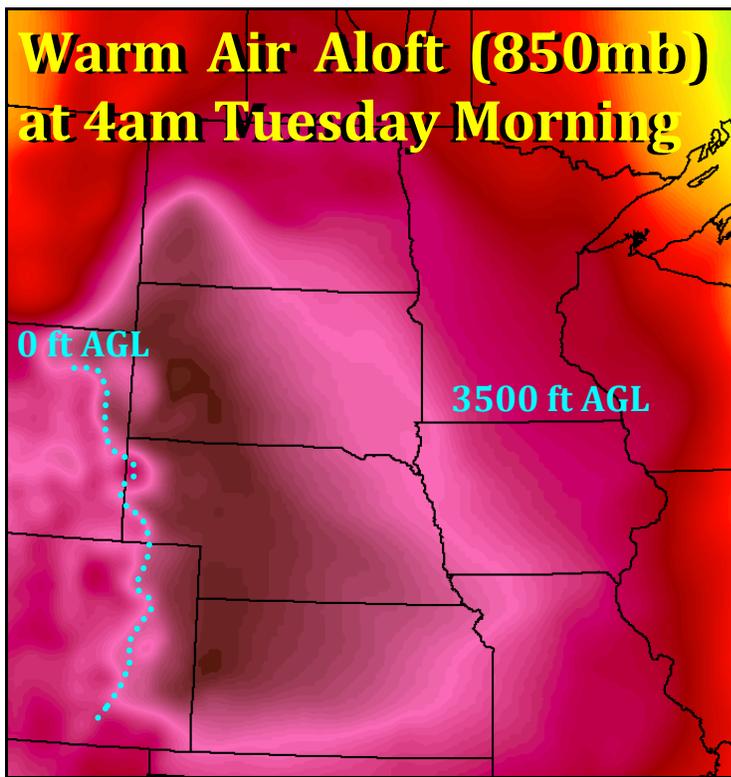
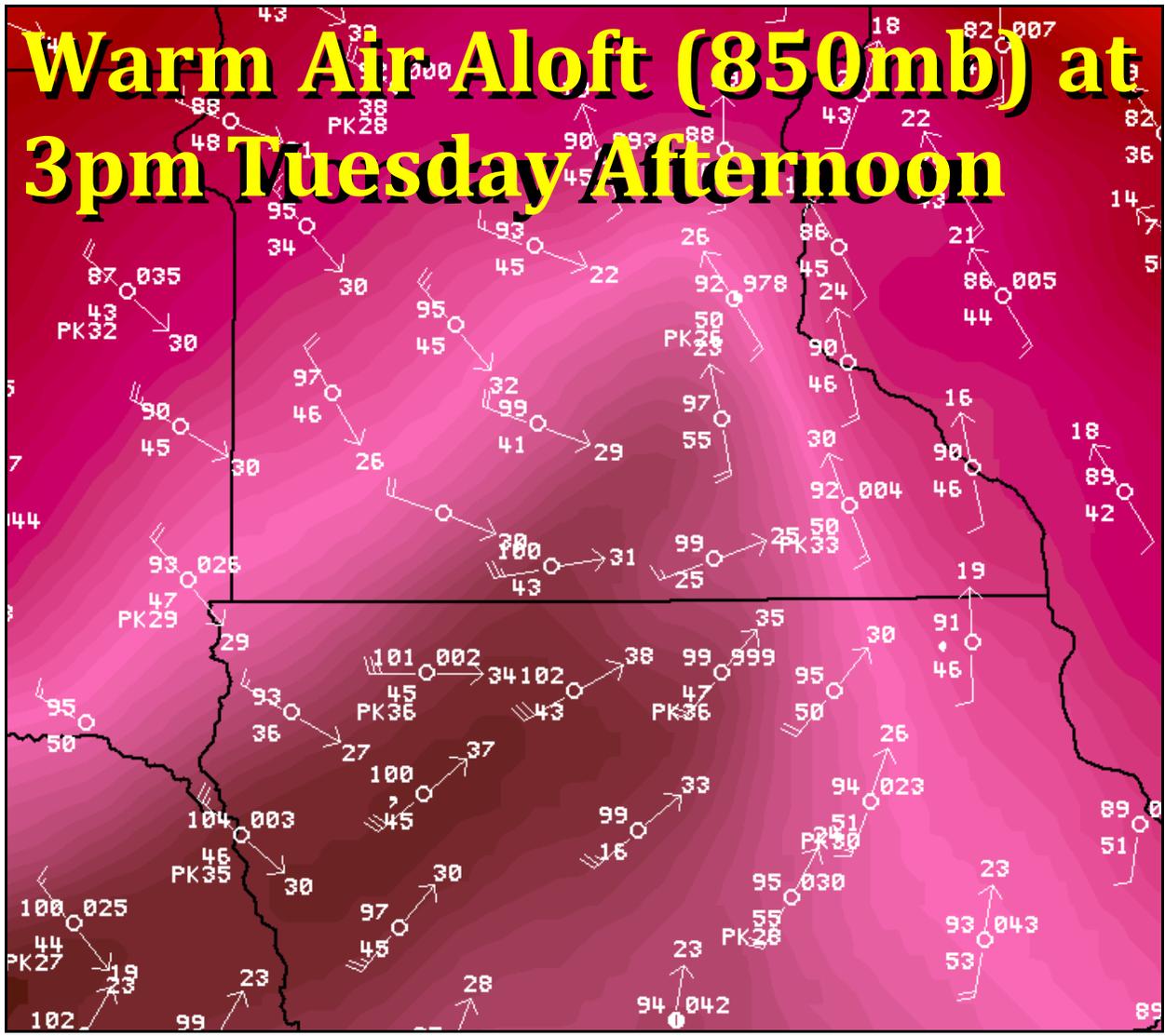
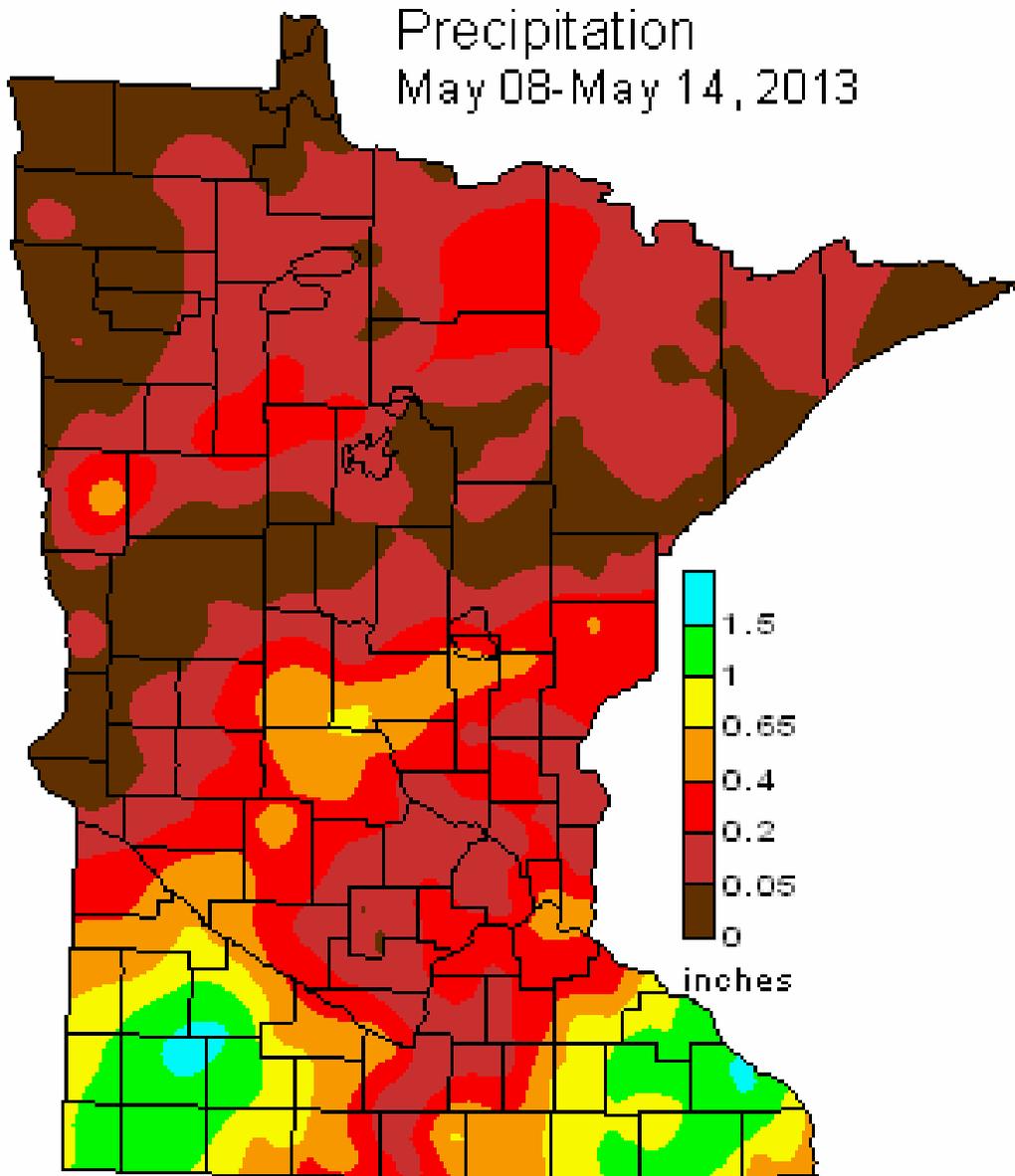


Figure 2,3: The image to the left shows the 850mb temperature at 4am Tuesday morning. The pink/brown areas are where the warmest air is located at the 850mb level. This is very close to the ground out west at the foothills of the Rockies. However, the 850mb level is roughly 3500ft above ground level across the Upper Midwest (blue). The image below shows the same 850mb temps at 3pm Tuesday afternoon. Notice how the warmest air is directly overhead at this time. Surface temps (white) were able to reach 100 across the region. For reference, the top number next to the observation is the air temperature ( $^{\circ}\text{F}$ ), the bottom number is dewpoint ( $^{\circ}\text{F}$ ), and the number at the end of the arrow is the wind gust (kt).



Dry Conditions - When the sunlight is absorbed at the surface some of the energy goes into warming the ground, and some of the energy is used to evaporate water. Lack of rain across Minnesota this past week allowed the topsoil to dry out in that region (Fig 4). Therefore more of the sun's energy could be converted into heating the ground, and the air next to the ground. Also, this year's late spring has kept vegetation from greening up, especially when compared to last year. Plants that are in full foliage pump water from the ground into the air through a process called "evapotranspiration". Since dry air warms up more easily than moist air, the two factors described above support the hot temperatures we saw on Monday. The two satellite comparison images contrast the vegetation maturity between this year and last (Fig 5,6).



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*Figure 4: The red and brown colors show that most of the state received less than a half an inch of moisture over the past week leading up to Monday's record breaking temperatures. Image courtesy of Minnesota State Climate Office.*

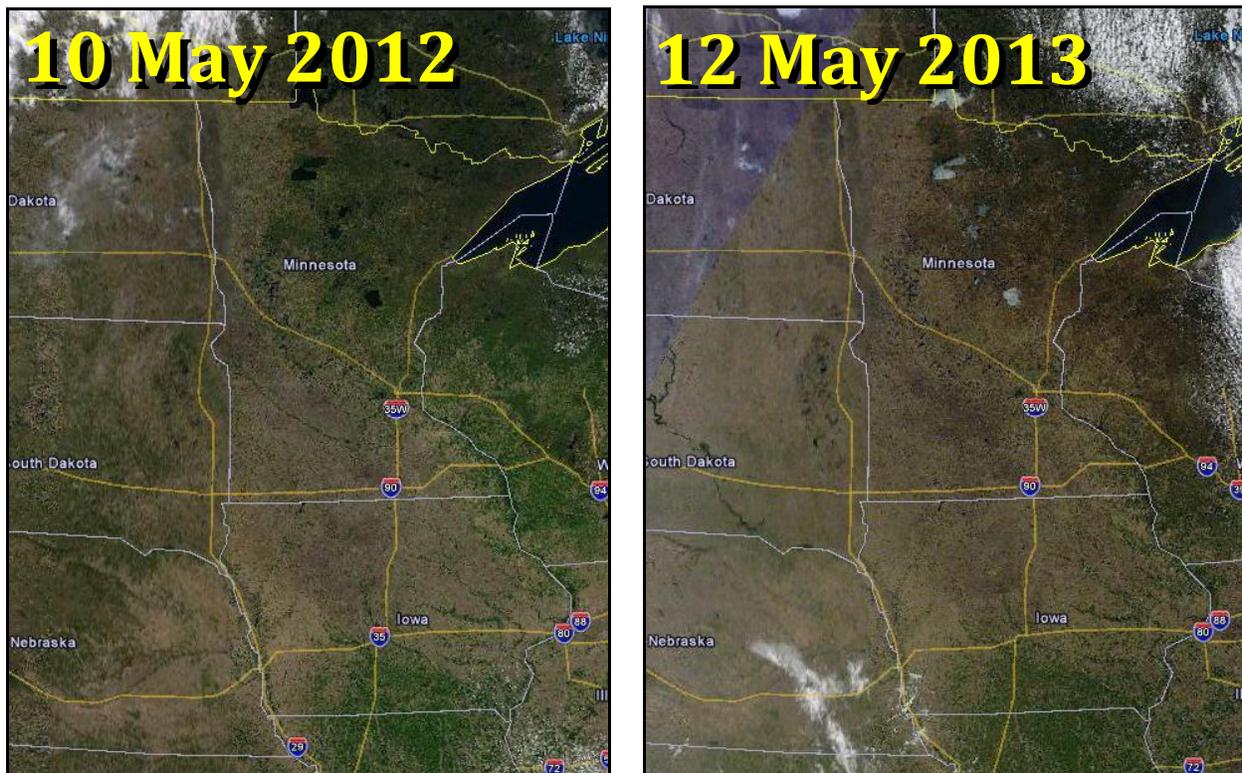


Figure 5,6: Notice the stark contrast between the MODIS true color satellite image from May 10th 2012 (left), and May 12th 2013 (right). The vegetation free ground is generally drier, and able to warm faster. Another unrelated, but still interesting feature is the ice covered lakes this year across northern Minnesota. Images courtesy of SSEC at UW Madison.

Sunny Skies - The last main ingredient for record breaking heat is clear skies during the peak afternoon heating hours. Some midlevel clouds were present across the region during the morning, but these quickly moved southeast allowing the sun to warm the surface (Fig 7). As the surface warms, it mixes with the warm air aloft and often temperatures skyrocket as was the case on Monday.

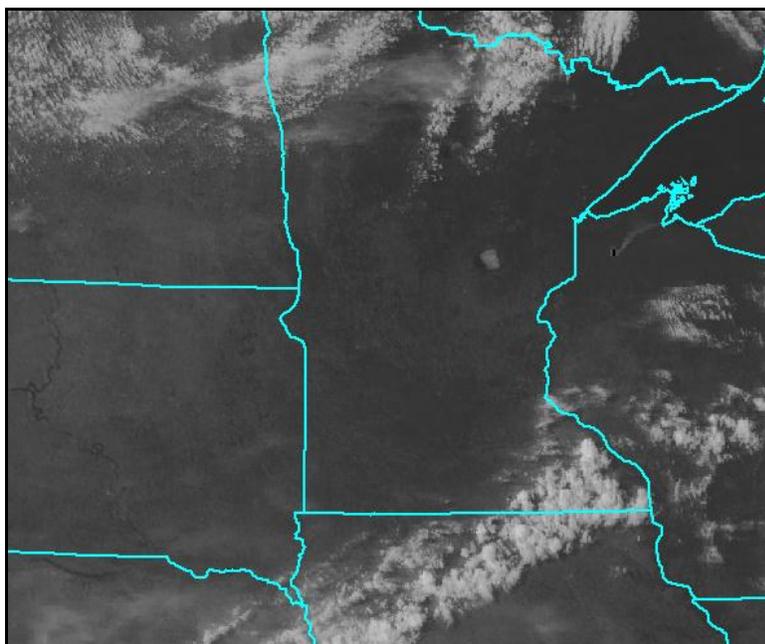


Figure 7: The visible satellite image from 415pm shows clear skies across all but the extreme corners of Minnesota. This was shortly after the time that Minneapolis set its all-time record of 98°F.