Severe Weather and Crop-Atmosphere Interactions

Figure 1: *An approaching severe storm with a defined shelf cloud and extreme downburst winds.*
(credit: J. Hanesiak)

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What is going on?

Severe convective storms can have profound impacts on society, mainly due to loss of life and infrastructure/property damage, including agriculture impacts from hail, strong winds, tornadoes and heavy precipitation. For example, Figure 1 depicts a well-defined shelf cloud and strong downburst winds of a supercell storm that also generated large hail. On average, 221 severe events are reported in the Prairies each summer[1]. Since 1980, Public Safety Canada estimates 51 significant events have taken place, costing more than $2 billion in damage within the Prairies[2]. For instance, Alberta sees the most hail storms in Canada and has experienced many damaging events to agriculture and property. Assessing long-term trends in severe events and attributing them to global climate variability is problematic due to reporting/population biases[3,4] and similar issues arise when attempting to use insurance losses. Canadian severe-event data suffer from these same biases and our temporal database is shorter. Various methods are being considered to overcome such biases[5] with some focusing on how severe storm *ingredients* may change in a future climate[6].

There are four basic ingredients for *severe* summer convective storms: (1) enhanced low level moisture; energy (fuel) for storms, (2) atmospheric instability; air near the surface, when sufficiently lifted, remains upwardly buoyant throughout the troposphere, (3) a trigger to initiate storms; a front or other boundary that will lift air upwards in the lower atmosphere, and (4) wind shear; strong wind speed and direction changes with height. The wind shear primarily determines the *mode* of convection (i.e. type of convective system) that ensues. It has been shown that slight increases in low-level moisture, and thus greater potential storm energy, have taken place in many parts of the world, including Canada, mainly due to increases in temperature[6,7]. Trapp et al.[6] showed that these increases will only be further enhanced in a future U.S. climate, including enhanced atmospheric instability.

What is coming up?

Future North American changes in storm triggers can partially be linked to changes in the occurrence/intensity of low pressure systems in summer. Most studies show either no change[6] or slight decreases in both occurrence/intensity[8], hence, storm trigger mechanisms may not change or slightly decrease in the future. There is good evidence and theory to suggest that there will likely be a future decline in wind shear in summer primarily due to a weakening of the upper jet stream/pole-equator temperature contrast[6,9], however, increased intensity of the low-level jet in the future may enhance low level wind shear[10], which can be important for tornadoes. There is some early evidence of the northern hemisphere upper jet already slowing down, affecting the upper level wave pattern and progression[11]. In summary, recent (future) increases in moisture and instability have occurred (are likely) in North America, however, the lack of any historic trends (and future uncertainties) in triggers and wind shear suggest that we are currently unable to determine whether severe convective weather has changed, or will change in the future[9,12].

Does this matter?

Agriculture plays an important role in weather and climate. Agricultural land, such as crops and forage land, can *primarily* influence severe convective storms through evapotranspiration that adds moisture to the lower atmosphere as well as affecting instability. For example, the phenological development of crops has been linked to the seasonal timing peak of tornadoes[13]. Spatial variations in evapotranspiration (and its associated magnitudes) due to water-stressed crops versus non-stressed crops can determine the timing of and where deep convective cloud forms, and how severe the storms may become[14-17]. Figure 2 shows an example of how lightning occurrence (and hence deep convective clouds) (blue dots) can decrease over severely water stressed regions (i.e. low root-zone soil moisture) (orange and red) compared to other areas that are not water-stressed (green colors). An analysis of tornado/hail days over the Prairies shows a reduced number of days during drought periods[18]. In addition, Betts et al.[19] have shown that Canadian Prairie land use changes (fallow to annual crops) may have contributed to changes in the diurnal cycle climate and increased humidity over the region since the early 1950s. Hence, any future changes to Prairie agricultural practices and/or long-term soil moisture regimes could have profound effects on summer severe storms via the influence they have on low-level moisture supply. Clearly, this is a possible feedback situation, and demonstrates that our weather and surface conditions are tightly linked. Understanding the coupling of the atmosphere and agricultural surfaces is an important area of research, especially for the Prairies.

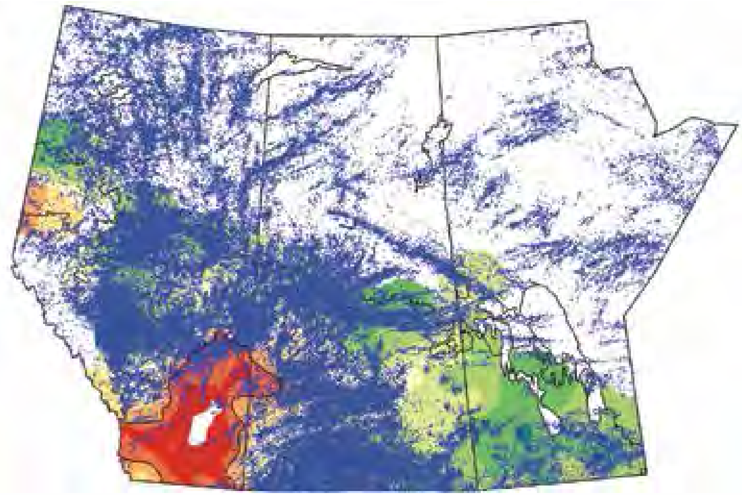

Figure 2: *July 2000 lightning strikes (blue dots) and root-zone soil moisture (dark orange/red < 30%; dark green > 75%) via the PAM-II crop model.*

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