Cereal rust/wind trajectory event update

Summer 2015

June 5 to 10, 2015

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Agriculture and Agri-Food Canada
Environment Canada - Meteorological Service of Canada
Memorandum of Understanding for
Cooperative Weather, Water, Climate, Agriculture
and Related Environmental Information Activities Directed at Sustainable Agriculture in Canada

ANNEX C

Air Parcel Trajectories and Modelling

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Introduction

Cereal rusts represent a unique challenge for western Canadian cereal producers. In contrast to cereal leaf spot diseases and fusarium head blight, most cereal rusts do not typically overwinter in western Canada. Thus, crop rotation does not reduce the risk of rust outbreaks and as a consequence effective management of cereal rusts depends on either growing resistant varieties (if available) or applying an in-crop fungicide application for susceptible varieties. The choice of which variety to grow is a relatively easy decision, which can be made during the previous fall and winter. However, the decision to spray a fungicide can be difficult to make, especially during a busy growing season. Whether to spray a fungicide will depend on the when disease appears in the crop and its level, weather conditions, the variety being grown, crop yield potential, and commodity price. The ultimate goal of using a foliar fungicide is to protect green leaf area in the upper cereal canopy since these leaves contribute most to yield and grain filling. Routine scouting will be a key strategy to determine whether there is a risk of rust in any individual crop and whether fungicide is needed to protect the upper leaves of the cereal canopy.

In general, cereal rusts, especially for wheat and barley, will overwinter on cereals and grasses in the southern USA and northern Mexico, although stripe rust can also overwinter in the Pacific Northwest (PNW) and California (Menzies and Gilbert 2003; Wiese 1987). Rust spores (also known as urediniospores) are blown northward by wind currents, affecting successive northerly winter and spring cereal crops (Agrios 1988; Menzies and Gilbert 2003). In the prairie region, rust spores will typically arrive in mid to late June. Several scientific reviews provide more detail on long distance transport of cereal rust fungi and other plant pathogens (Aylor 2003; Aylor 1990; Brown and Hovmøller 2002; Chen 2005; Eversmeyer and Kramer 2000; Nagarajan and Singh 1990).

Spread of cereal rusts into western Canada from locations in the USA will depend on the following factors:

- Disease severity and pathotypes at the point of origin
- Release and turbulent transfer of spores into upper atmosphere air parcels
- Movement and direction of air parcels
- Spore survival during long distance transport
- Deposition of spores over at risk locations in western Canada
- Crop growth stage for at risk locations
- Prevailing weather conditions for at risk locations

Rust spore liberation from symptoms on infected cereal leaves is favoured by increased wind speeds and sudden wind gusts, while vertical movement into upper air parcels is favoured by convective wind currents resulting from surface heating and cooling during the 24 hour night/day cycle (Aylor 1990; Nagarajan and Singh 1990). Burleigh et al. (1967) found that the aerial concentration of rust spores increased when disease levels were increased in wheat crops below the collection points. Cereal rust spores can be found at altitudes of up to 3000 m and may travel several hundred kilometres before being deposited (Eversmeyer et al. 1984; Stakman 1923, 1934; Stakman and Christensen 1946). Deposition of cereal rust spores over at risk locations appears to primarily result from the "scrubbing action" of rainfall, where even light precipitation events may remove spores from the air (Nagarajan and Singh 1990; Rowell and Romig 1966). Successful infection of cereal crops and potential impact are then influenced by the weather conditions, host resistance, and crop growth stage (Chen 2005; Eversmeyer and Kramer 2000; Menzies et al. 2003; Wiese 1987).

Given the importance of long distance transport of cereal rust spores via wind currents from the USA, an initiative has been developed to identify wind trajectory events that may possibly bring rust spores into western Canada from epidemic areas in the central USA and the PNW. In 2006, an amendment was made to a joint memorandum of understanding (MOU) between Environment Canada, the Prairie Farm Rehabilitation Administration (PFRA), and Agriculture and Agri-Food Canada. The MOU for wind trajectory data was spear-headed by personnel from all three organizations, with Drs. O. Olfert and J. Soroka at AAFC Saskatoon overseeing the AAFC component.

Trajectories based on forecast and diagnostic wind fields

Three-altitude backward trajectory models (prognostic numerical model GEM [Global Environmental Model]) have been used to forecast potential movement of diamondback moth into western Canada (Braun et al. 2002; Dosdall et al. 2001; Hopkinson 1999). Currently, air parcel trajectories are being constructed from wind fields at discrete intervals and solved numerically to identify potential wind trajectory events that may carry rust spores from epidemic areas in the USA (D'Amours and Pagé 2001). The trajectories utilise wind fields of the Global Environmental Multiscale (GEM) model, which have a horizontal resolution of 33 km and 58 vertical levels over North America. The model is being run at three levels corresponding to starting points (forward – prognostic trajectories) or end points (backward – diagnostic trajectories) at approximately 500 m, 1500 m, and 2500 m above ground level (AGL) and follow parcels of air on curves denoting their successive positions in time. The forward trajectories are prognostic based on forecast wind fields while the backward trajectories are diagnostic and based on analyzed wind fields. By following trajectories for air parcels through time, potential wind events that may carry rust spores from source areas in the USA can be identified.

Backward trajectories are the focus of the current cereal rust/wind trajectory updates. Backward trajectories follow a five day time frame backward in time for air parcels moving over at risk locations in western Canada. Backward trajectories forecast where air parcels have come from. Locations for backward trajectories and the disease issues of concern are summarized in Table 1 and Figure 1. Backward trajectory events were computed for specific areas in the USA including the PNW, Texas/Oklahoma region, and the Kansas/Nebraska region. Stripe rust would be the main rust issue affecting cereal crops in the PNW, while stem rust, leaf rust and stripe rust can affect crops in the Texas to Nebraska corridor (Table 1, Figure 1).

A note of caution regarding computation of the total number of backward trajectory events originating from source locations in the USA for various locations in western Canada. Calculation of the total number of events originating from source locations may result in a value that is greater than the total number of days with events originating from source locations in the USA. The model is being run at three levels corresponding to end points (backward – diagnostic trajectories) at approximately 500 m, 1500 m, and 2500 m above ground level (AGL) and follow parcels of air on curves denoting their successive positions in time. Thus, it is possible to have at least three separate trajectories that pass over an at risk location, i.e. one each with an endpoint of 500 m, 1500 m, and 2500 m AGL and where they have previously passed over a source location in the USA. In addition, if a particular trajectory is the result of a slow moving air mass the air parcel will take a longer period of time to pass over a source location in the USA. Under these circumstances, even though you have one trajectory end point, you may have several points in time where the trajectory passes over a source location/region, increasing the total number of events that are computed for an at risk location in western Canada. Regardless of whether you are looking at the total number of events or number of days with events, as both increase, the risk of rust spores being transported into the prairie region increases.

Source of events based on trajectories

Pacific Northwest (PNW)

❖ June 5 to 10, 2015

- From June 5 to 10, 2015 there were 19 of 29 locations in the prairie region where wind parcels previously passed over the Pacific Northwest (PNW) (Table 2)
  - Most wind parcels arrived over at risk locations in the Prairies from June 5 to 7, 2015
  - Most air parcels passed over the PNW at average elevations of >500 m above ground level (AGL), although some trajectories were as low as 26 m AGL (Table 2)
  - The average travel time for back-trajectories from the PNW into the Prairie region from June 5 to 10, 2015 ranged from 2.1 to 4.6 days, but some parcels arrived over at risk locations in the Prairies in as little as one day (e.g. Lethbridge, AB).
- The PNW region, where air parcels passed over, has a significant proportion of wheat production and where stripe rust epidemics can occur
  - http://www.wheatflourbook.org/p.aspx?tabid=50
  - http://www.agcensus.usda.gov/Publications/1997/Ag_Atlas_Maps/Crops%20and%20Plants/Field_Crops_Harvested/map236.gif

South and central Midwest USA

❖ June 5 to 10, 2015

- There were air parcels from the Texas/Oklahoma region that passed over two at risk locations in western Canada from June 5 to 10, 2015 (Table 3)
  - REGINA_SK, and RUSSELL_MB
- There were a number of events and days with events for 6 of 29 locations in the prairie region with wind parcels that passed over the Nebraska/Kansas region of the USA (Table 4)
  - BRANDON_MB, NAICAM_SK, PORTAGE_MB, REGINA_SK, RUSSELL_MB, and TISDALE_SK

  - Trajectories from the Nebraska/Kansas region passed over a number of locations in Manitoba, and central to eastern Saskatchewan, but no locations in Alberta (Table 4)
- The arrival date for the events from the Texas/Oklahoma region and the Nebraska/Kansas region was June 6, 2015 (Tables 3 and 4)
  - Air parcels passed over the Texas/Oklahoma region at average elevations of <400 m above ground level (AGL), although some trajectories were as low as 6 m AGL (Table 3)
  - Depending on locations, most air parcels passed over the Nebraska/Kansas region at average elevations of 52-1150 m above ground level (AGL), although some trajectories were as low as 3 m AGL (Table 4)
  - Over the period from June 5 to 10, 2015 average travel time for back-trajectories into western Canada ranged from 2.4 to 4.9 days from the Texas/Oklahoma and Kansas/Nebraska regions.
- The origin of events from Texas north to Nebraska includes regions that have a significant proportion of wheat production and where epidemics of stem rust, leaf rust and stripe rust can occur.

Risk interpretation

Stripe rust from the Pacific Northwest (PNW) – Low risk for June 5 to 10, 2015

During the period of June 5 to 10, 2015, 2 to 70 events occurred that resulted from air parcels passing over source locations in the PNW for 19 of 29 at risk locations in the Prairies. Locations including ANDREW_AB, LETHBRIDGE_AB, PROVOST_AB, VEGREVILLE_AB, and UNITY_SK, had from two to five days with events (Table 2). The most recent updates from the PNW indicate stripe rust development in 2015 has been limited in commercial winter wheat fields, with reports mainly from disease nurseries and other research trials, although very early development was reported in Oregon (http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB1.pdf, http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB2.pdf, http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB3.pdf, http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB4.pdf, http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB5.pdf, http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB6.pdf).

The occurrence of a number of events from the PNW into the prairie region from June 5 to 10, 2015 may be of concern for winter wheat fields, especially for areas around ANDREW_AB, LETHBRIDGE_AB, PROVOST_AB, VEGREVILLE_AB, and UNITY_SK, while 14 of the other at risk locations may also have some limited risk as they had one day with events from the PNW. However, these events may be of little relevance given the current reports of "relatively low levels of stripe rust" in the PNW, especially in commercial winter wheat fields, while crop development in the prairie region would be limited, especially for spring seeded cereals (X. Chen, Stripe rust update, May 21, 2015, http://x-160-94-131-250.crl.umn.edu/fmi/webd#CRS-mail and USDA Cereal Rust Bulletin, May 27, 2015, http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB5.pdf, and http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB6.pdf). Dr. Chen indicates that lower levels observed in PNW winter wheat are likely due to resistance in the varieties being grown, fungicide application with the herbicides, and dry conditions in April and the first part of May. For the Prairie region, limited rainfall occurred over most of Saskatchewan and Alberta, while some areas of SE Saskatchewan and southern Manitoba had between 10 to over 50 mm of rainfall (Figure 2). At the time of preparation of this report only rainfall data for June 3 to 9, 2015 were available from Environment Canada so it will be important to look at local and regional sources of information regarding the occurrence of rainfall on a daily basis and how this may affect the risk of spore deposition and subsequent disease development. However, even though a number of trajectories from the PNW passed over 19 of 29 at risk locations in the Prairies, there was limited development of stripe rust in the PNW, and thus likely limited inoculum available to be blown up into the prairie region. Nevertheless as a precaution, winter wheat producers may want to monitor winter wheat fields and spring wheat fields, especially those planted to susceptible varieties and in regions where trajectory events from the PNW and localized rainfall occurred from June 5 to 10, 2015. Stripe rust may also potentially overwinter in the western Prairie region on winter wheat, especially during mild winters (Conner et al. 1988; Xi et al. 2006). Unfortunately, there have been several reports of potential overwintering of stripe rust in winter wheat fields in the spring of 2015 in southern Alberta, the Olds and Lacombe region, and the Stony Plain, Edmonton area (M. Harding, D. Pittman, A. Laroche, E. Amundsen, K. Xi, and K. Kumar, J. Paly personal communications). In late May, Dr. Henry Klein-Gebbinck at AAFC Beaverlodge indicated the development of stripe rust in winter wheat research plots at Beaverlodge, AB in the Peace region. Significant symptom development was observed on the lower leaves with infections appearing to spread to the middle part of the canopy. On June 4, 2015, Henry reported that the winter wheat at Beaverlodge is now in the boot stage and stripe rust symptoms are appearing on the penultimate and the third leaf from the head (Figure 5). Given the appearance of stripe rust so early in the 2015 season, the pathogen that causes stripe rust has likely overwintered in these Alberta winter wheat fields. As a consequence producers and agronomists are encouraged to monitor winter wheat fields planted to susceptible varieties and where stripe rust was observed in the fall of 2014.

Cereal rusts from the central Midwest regions of the US (mainly Kansas and Nebraska) – moderate risk for stripe rust (Manitoba and central to eastern Saskatchewan especially), and limited-low risk for leaf and stem rust, June 5 to 10, 2015

For 1 of 29 locations and 6 of 29 locations there were a number of events over a single day (June 6, 2015) where trajectories from the Texas/Oklahoma and Nebraska/Kansas regions, respectively passed over a number of locations in western Canada. Reports from earlier in May indicated that levels of leaf rust had been relatively low in Kansas and Nebraska, but recent reports suggest increasing severity in Kansas. In addition, reports from mid to late May indicated leaf rust being more widespread in Texas and Oklahoma. Stripe rust has been more of a concern with widespread development in Kansas in late April and early May, with reports from mid to late May indicating the presence of significant stripe rust in south central regions of Kansas as well as reports from central and western regions with concerns that further development were favoured by favourable weather conditions (May 19, 2015, Stripe and leaf rust update – Kansas, E. De Wolf, http://x-160-94-131-250.crl.umn.edu/fmi/webd#CRS-mail). In Nebraska, stripe rust

has been reported to be widespread throughout the southern parts of the state, but was reported in the eastern areas of Nebraska, and there were concerns that further stripe rust development was favoured by lower temperatures wet conditions (May 20, 2015, Rust update – Nebraska, S. Wegulo, http://x-160-94-131-250.crl.umn.edu/fmi/webd#CRS-mail). On May 27, 2015 significant development of stripe rust was observed from the southeast to southwest regions of Nebraska (May 28, 2015, Stripe rust update - Nebraska, S. Wegulo, http://x-160-94-131-250.crl.umn.edu/fmi/webd#CRS-mail). Stripe rust was reported in Texas and Oklahoma, but reports from mid to late May suggest leaf rust is becoming more predominant. Recently on May 29, 2015, stripe rust was reported to be prevalent in Oklahoma, while leaf rust could be found on wheat varieties susceptible to leaf rust, but resistant to stripe rust (May 29, 2015, Wheat disease update, Bob Hunger, http://x-160-94-131-250.crl.umn.edu/fmi/webd#CRS-mail). Note that for both Texas and Oklahoma, crop development has progressed towards maturity and thus fields in these states likely no longer represent a potential source of inoculum. In early June 2015, stripe was reported from both South and North Dakota (June 1, 2015, Stripe rust found in North Dakota, Andrew Friskop and June 5, 2015, Stripe rust increasing in South Dakota, Emmanuel Byamukama, http://x-160-94-131-250.crl.umn.edu/fmi/webd#CRS-mail). Limited stem rust has occurred in the Texas to Nebraska region with some reports, but mainly from nursery sites. Maps showing the distribution of stripe rust and leaf rust are shown in Figures 3 and 4, respectively, while more detailed information regarding the current rust situation can be found in the Cereal Rust Bulletins
(http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB1.pdf,
http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB2.pdf,
http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/12CRB3.pdf,
http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/12CRB4.pdf,
http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB5.pdf,
http://www.ars.usda.gov/SP2UserFiles/ad_hoc/36400500Cerealrustbulletins/15CRB6.pdf).

The occurrence of a number of events, especially from the Kansas to Nebraska corridor is of concern for winter wheat fields and spring wheat fields for six at risk locations in central to eastern Saskatchewan and Manitoba as indicated in Table 4. Although leaf rust levels appeared to be lower initially, leaf rust has become more common in Texas and Oklahoma, while stripe rust was more prevalent and widespread, especially in Kansas and Nebraska, with recent reports of stripe rust in the Dakotas. Thus, there was potential for both stripe inoculum, and to a certain extent leaf rust inoculum, to be available for dispersal into the central to eastern Prairie region from June 5 to 10, 2015. For the Prairie region, limited rainfall occurred over most of Saskatchewan and Alberta, while some areas of SE Saskatchewan and southern Manitoba had between 10 to over 50 mm of rainfall (Figure 2). At the time of preparation of this report only rainfall data for June 3 to 9, 2015 were available from Environment Canada so it will be important to look at local and regional sources of information regarding the occurrence of rainfall on a daily basis and how this may affect the risk of spore deposition and subsequent disease development. These rain events could have deposited stripe rust spores blown in from Nebraska and Kansas and created conditions favourable for infection and disease development for areas in the region of the at risk Prairie locations as indicated in Table 4. Farmers and agronomists in those at risk areas where trajectories from the USA occurred are encouraged to actively scout for stripe and perhaps leaf rust symptoms, especially in winter wheat fields and spring wheat fields planted to susceptible varieties. Information regarding variety reactions to stripe and leaf rust can be found in the prairie variety guides (links provided below). Another potential risk for winter wheat producers in the prairie region is the potential overwintering of stripe rust inoculum especially in winter wheat fields planted to susceptible varieties and where stripe rust was observed in the fall of 2014. In Alberta, there have been several reports from winter wheat fields of early season stripe rust appearance and development from the southern part of the province to the Edmonton region in April and early May; while there was a recent report from Beaverlodge in the Peace region of Alberta. Farmers and agronomists are encouraged to monitor winter wheat fields in the spring for any signs of overwintering of stripe rust.

Information on cereal rusts and on the use of fungicides for management of cereal rusts can be found at the following websites:

http://www.ars.usda.gov/Main/docs.htm?docid=9854

http://www.mtagalert.org/alertDocs/Stem%20Rust%20Man%20MT.pdf

http://www.mtagalert.org/alertDocs/Rust%20Diseases%20MT.pdf

http://www1.agric.gov.ab.ca/$department/newslett.nsf/all/agnw23602

http://www.gov.mb.ca/agriculture/crops/plant-diseases/index.html

http://www.gov.mb.ca/agriculture/crops/plant-diseases/print,stripe-rust-puccina-pathway.html

https://cropwatch.unl.edu/documents/1841/8062087/2015+Fungicide+Efficacy+Table/21306ea6-794d-44a9-87e0-03756baf8af8

https://www.google.com/url?q=http://www.uidaho.edu/~/media/Files/Extension/Cereals/SCSE%2520Idaho/Cereal%2520Disease%2520Projects%2520and%2520Info/Stripe%2520Rust/Fungicide_with_Herbapp.ashx&sa=U&ei=XuFUVcXLIZGTNsHagegC&ved=0CBIQFjAH&client=internal-uds-cse&usg=AFQjCNEO6nyyhuzbcXupUuVBcYdgnIvQCg

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/prm4515

http://www.gov.mb.ca/agriculture/crops/guides-and-publications/pubs/crop-protection-guide-disease.pdf

http://www.agriculture.gov.sk.ca/Guide_to_Crop_Protection

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex32

http://striperust.wsu.edu/diseaseManagement/stripe-rust-considerations.html

http://striperust.wsu.edu/diseaseManagement/stripe-rust-fungicide.html

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Table 1. Locations for backward (diagnostic) and forward (prognostic) trajectory events, western Canada and the United States of America, 2015.

Reverse trajectory location	Prov.	Pest issue*
ANDREW	AB	Stripe rust
BEISEKER	AB	Stripe rust
FORT VERMILLION	AB	**
GRANDE PRAIRIE	AB	**
LETHBRIDGE	AB	Stripe rust
MANNING	AB	**
OLDS	AB	Stripe rust
PROVOST	AB	Stripe rust
RYCROFT	AB	**
SEDGEWICK	AB	Stripe rust
VEGREVILLE	AB	Stripe rust
WANHAM	AB	**
BRANDON	MB	Stem rust, leaf rust, stripe rust
CARMAN	MB	Stem rust, leaf rust, stripe rust
DAUPHIN	MB	Stem rust, leaf rust, stripe rust
PORTAGE	MB	Stem rust, leaf rust, stripe rust
RUSSELL	MB	Stem rust, leaf rust, stripe rust
SELKIRK	MB	Stem rust, leaf rust, stripe rust
GAINSBOROUGH	SK	Stem rust, leaf rust, stripe rust
GRENFELL	SK	Stem rust, leaf rust, stripe rust
KINDERSLEY	SK	Stripe rust
NAICAM	SK	Stem rust, leaf rust, stripe rust
NORTH BATTLEFORD	SK	Stripe rust
REGINA	SK	Stem rust, leaf rust, stripe rust
SASKATOON	SK	Stem rust, leaf rust, stripe rust
TISDALE	SK	Stem rust, leaf rust, stripe rust
UNITY	SK	Stripe rust
WATROUS	SK	Stem rust, leaf rust, stripe rust
YORKTON	SK	Stem rust, leaf rust, stripe rust

*Specified pest issue(s) reflect the relative importance of particular disease issues for the reverse and forward trajectory locations. Some locations were chosen based insect pest concerns, especially diamond back moth.

** Primarily chosen based on insect concerns.

Table 2. Reverse trajectory locations, arrival dates, number of events, and elevation for backward trajectory events originating from the Pacific Northwest region of the USA, June 5 to 10, 2015.

			Metres above ground level at source location (PNW)		
Location	**Arriving Date**	**Number of events**	**Average**	**Minimum**	**Maximum**
ANDREW_AB	05-Jun-15	2	988	812	1164
ANDREW_AB	06-Jun-15	10	1733	172	2753
BEISEKER_AB	05-Jun-15	12	2664	2301	3030
BRANDON_MB	07-Jun-15	5	3095	2908	3382
FORT_VERMILION_AB	05-Jun-15	4	815	472	1354
GAINSBOROUGH_SK	07-Jun-15	7	738	142	1459
GRENFELL_SK	07-Jun-15	5	1102	343	1515
KINDERSLEY_SK	06-Jun-15	5	900	628	1188
LETHBRIDGE_AB	05-Jun-15	20	1911	649	2984
LETHBRIDGE_AB	06-Jun-15	5	80	26	172
LETHBRIDGE_AB	07-Jun-15	3	624	494	726
LETHBRIDGE_AB	09-Jun-15	9	90	49	206
LETHBRIDGE_AB	10-Jun-15	33	1152	68	2760
MANNING_AB	05-Jun-15	7	682	115	1406
NORTH_BATTLEFORD_SK	06-Jun-15	5	2795	2602	3022
OLDS_AB	05-Jun-15	13	2161	97	3383
PROVOST_AB	05-Jun-15	4	2886	2610	3199
PROVOST_AB	06-Jun-15	4	1209	1114	1327
RUSSELL_MB	07-Jun-15	4	3772	3573	4055
SEDGEWICK_AB	05-Jun-15	6	2075	1471	3040
TISDALE_SK	07-Jun-15	4	2854	2653	3028
UNITY_SK	05-Jun-15	1	2938	2938	2938
UNITY_SK	06-Jun-15	3	437	415	461
VEGREVILLE_AB	05-Jun-15	8	2245	1744	2878
VEGREVILLE_AB	06-Jun-15	1	3091	3091	3091
WANHAM_AB	05-Jun-15	4	1339	1028	1508
YORKTON_SK	07-Jun-15	2	3438	3415	3461

Table 3. Reverse trajectory locations, arrival dates, number of events, and elevation for backward trajectory events originating from the Texas/Oklahoma region of the USA, June 5 to 10, 2015.

			Metres above ground level at source location (KS and NB)		
Location	**Arriving Date**	**Number of events**	**Average**	**Minimum**	**Maximum**
REGINA_SK	06-Jun-15	7	9	6	13
RUSSELL_MB	06-Jun-15	12	351	223	547

Table 4. Reverse trajectory locations, arrival dates, number of events, and elevation for backward trajectory events originating from the Nebraska/Kansas region of the USA, June 5 to 10, 2015.					
			Metres above ground level at source location (KS and NB)		
Location	**Arriving Date**	**Number of events**	**Average**	**Minimum**	**Maximum**
BRANDON_MB	06-Jun-15	3	463	325	600
NAICAM_SK	06-Jun-15	1	192	192	192
PORTAGE_MB	06-Jun-15	5	708	552	904
REGINA_SK	06-Jun-15	26	52	3	236
RUSSELL_MB	06-Jun-15	11	321	130	480
TISDALE_SK	06-Jun-15	5	1150	1076	1220

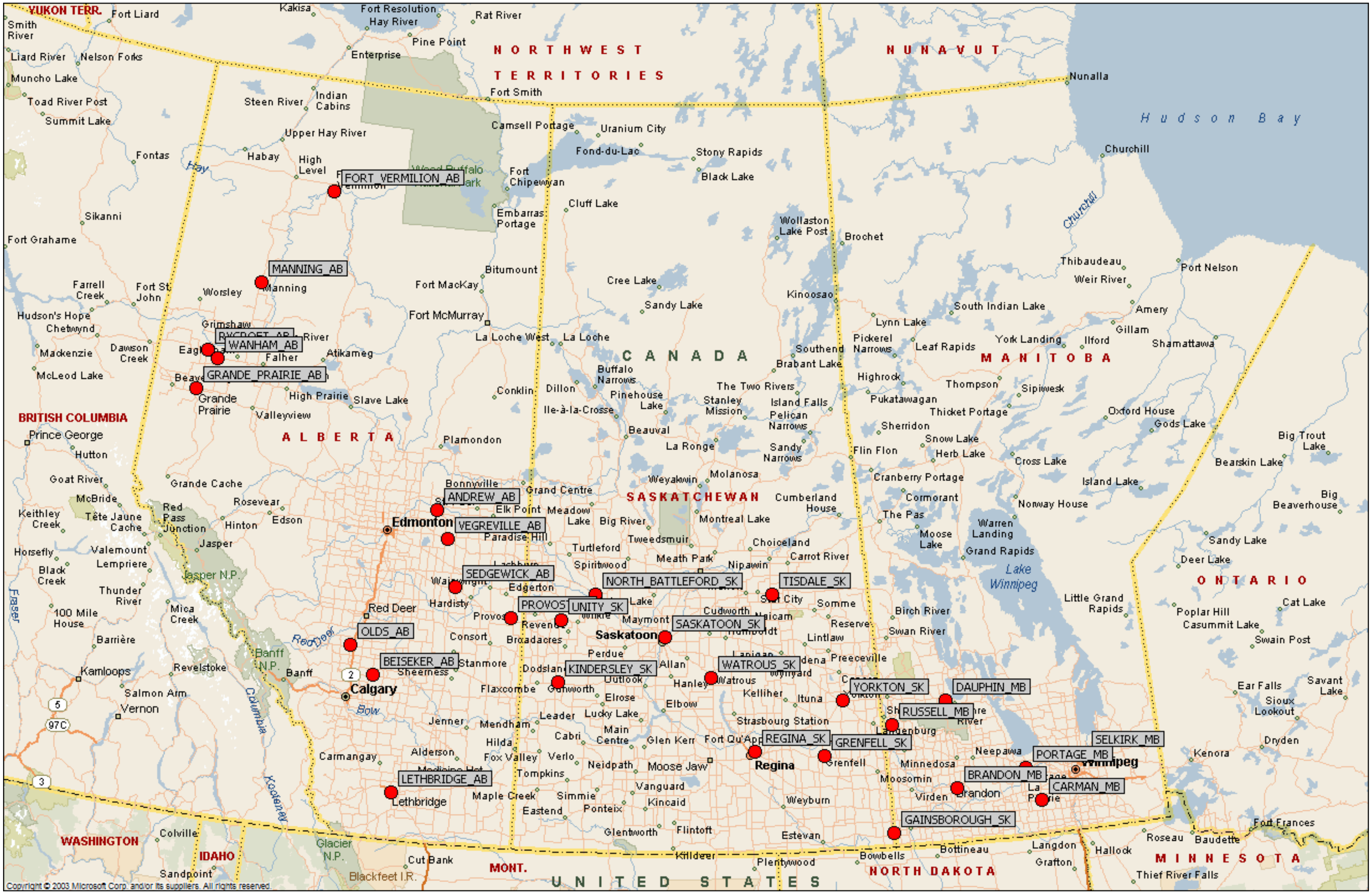

Figure 1. Locations for backward (diagnostic) trajectory events, western Canada, 2015.

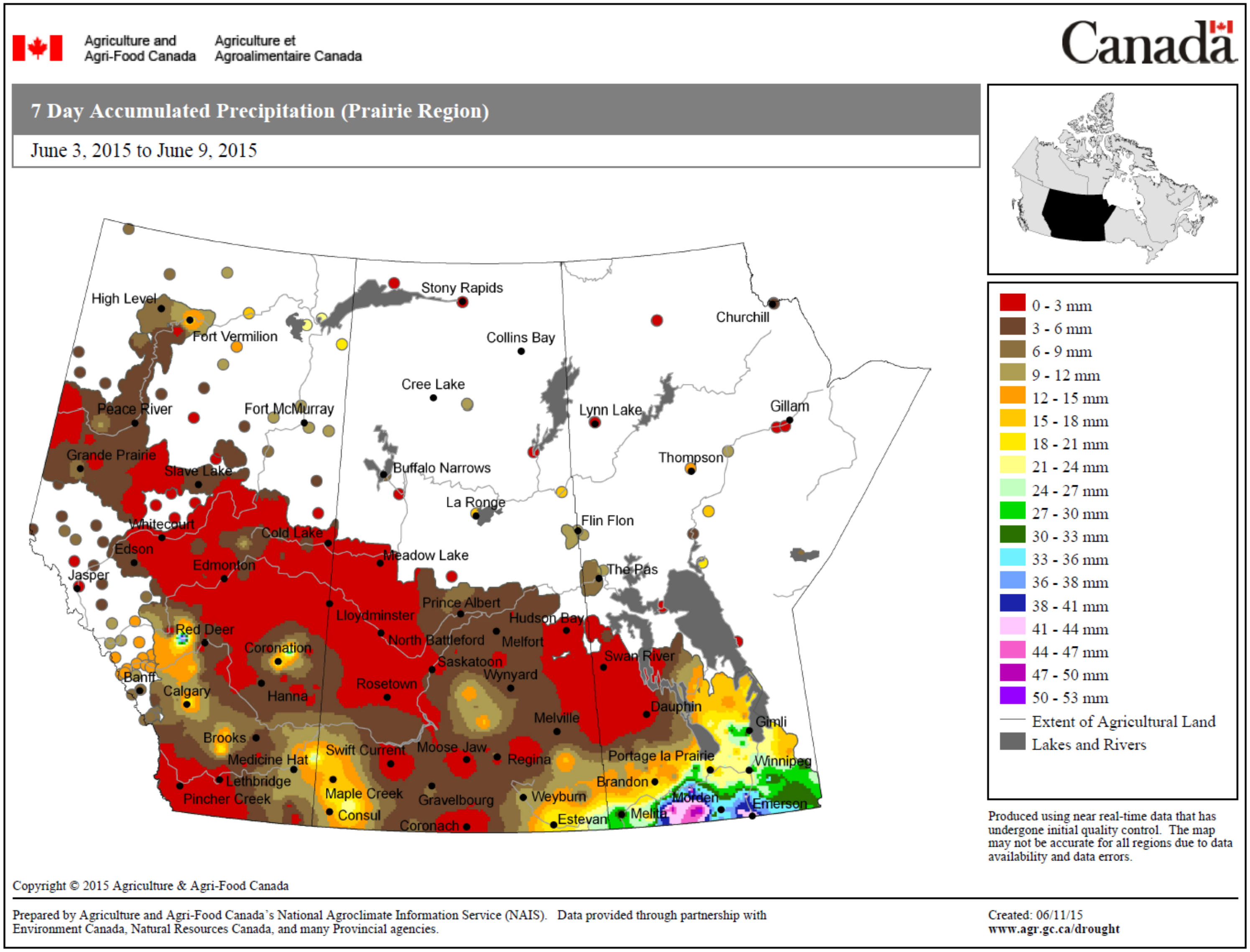

Figure 2. Seven day accumulated precipitation (Prairie Region), June 3 to 9, 2015 (http://www5.agr.gc.ca/resources/prod/doc/pfra/maps/nrt/pr_07_ac_d_e.pdf, http://www5.agr.gc.ca/DW-GS/current-actuelles.jspx?lang=eng&jsEnabled=true).

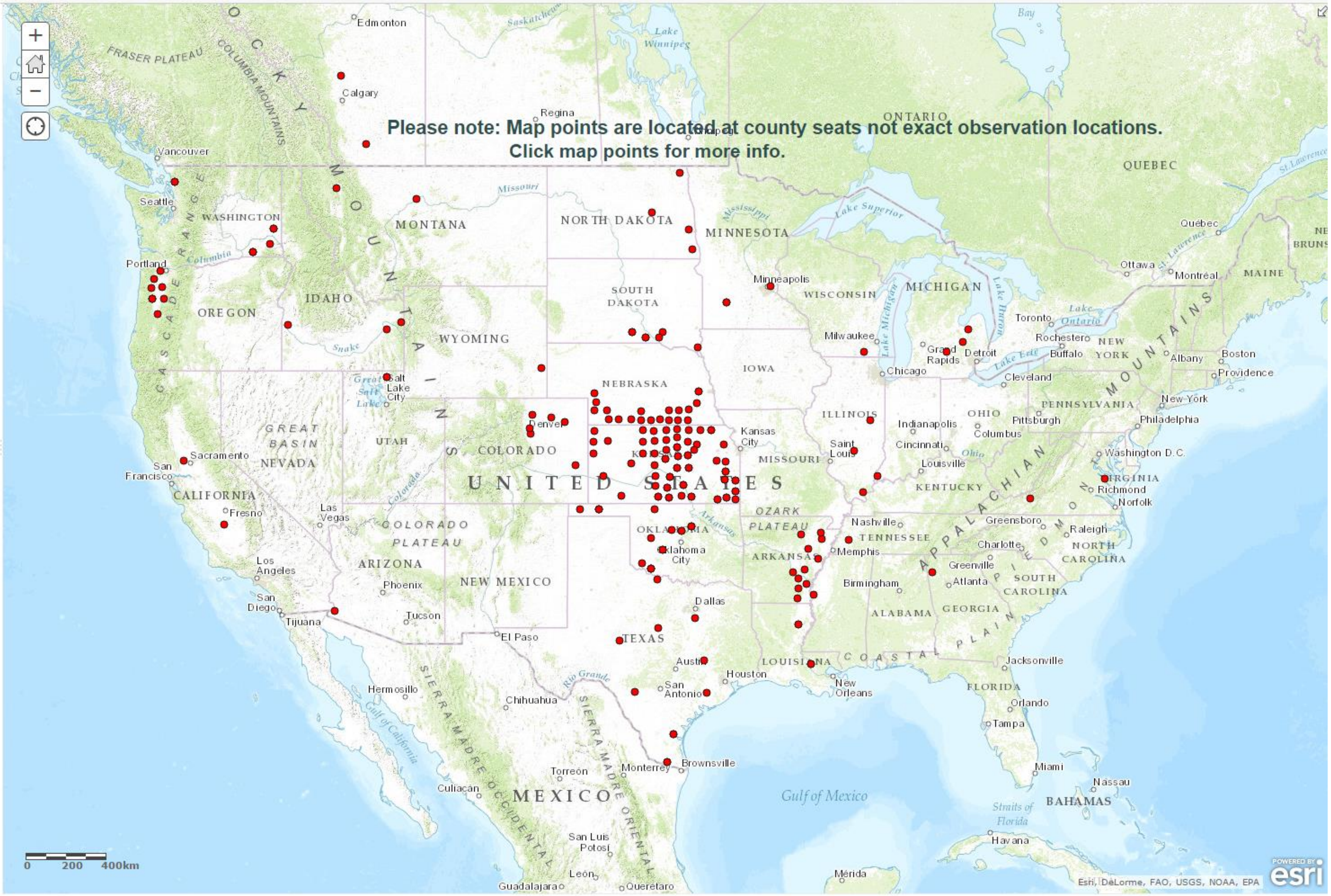

Figure 3. ArcGIS 2015 stripe rust observations, USA and Canada, up to June 11, 2015, USDA-ARS, Cereal Rust Situation Reports and Cereal Rust Bulletins Cereal Disease Laboratory, St. Paul, MN, (http://www.arcgis.com/home/webmap/viewer.html?webmap=aa8bcfd29fe94fd1ad397992ae76c3a1&extent=-128.7289,16.2924,-67.601,56.3614).

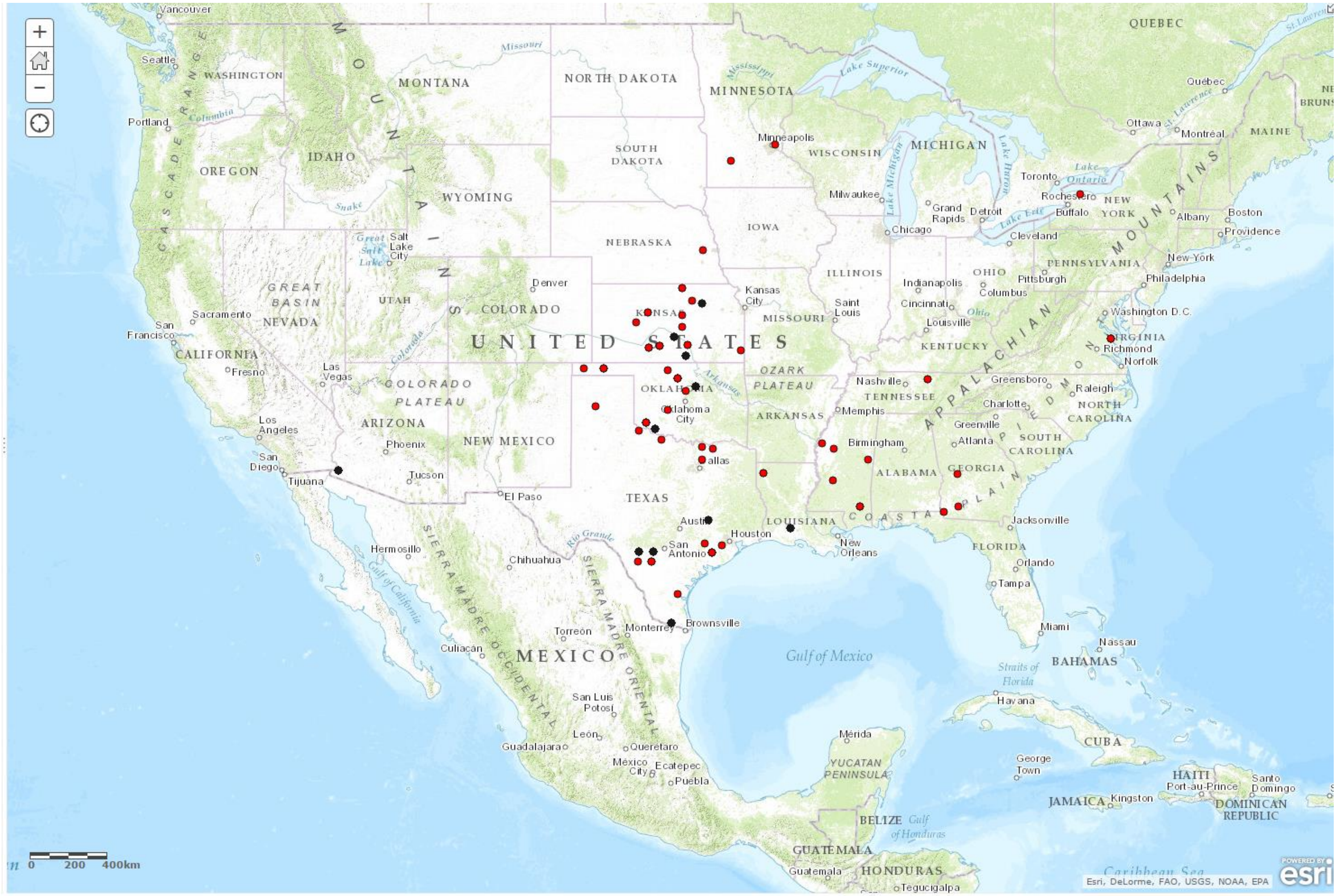

Figure 4. ArcGIS 2015 leaf rust observations, USA and Canada, up to June 9, 2015, USDA-ARS, Cereal Rust Situation Reports and Cereal Rust Bulletins Cereal Disease Laboratory, St. Paul, MN, http://www.arcgis.com/home/webmap/viewer.html?webmap=2c390053d2ca4cb3a2f333091bcdf671&extent=-125.2482,9.717,-70.8439,52.4341). Note that the red dots indicate where no pathogen race id has been done, while the black dots indicate those observations were a pathogen race id is available.

Figure 5. Symptoms of stripe rust on upper canopy leaves, winter wheat plants, AAFC winter wheat plots, boot stage of development, Beaverlodge, AB, June 4, 2015, Dr. Henry Klein-Gebbinck, AAFC Beaverlodge.