Moisture Cycling and *Urban Dry Islands* in Thunderstorm Environments

***G.S. Strong & Danny Brown*, Univ. of Alberta**

***J. Hanesiak & J. Brimelow*, Univ. of Manitoba**

***C.D. Smith, D. Sills, & N. Taylor*, Environment Canada**

Correspondence: geoff.strong.shaw.ca

43rd Annual CMOS Congress,

Halifax, NS

01-04 June, 2009

Background Photo: ***Hailstorm west of Caroline, AB during UNSTABLE-08, 17 July 2008*** (G. Strong)

OBJECTIVES

1. Revise the *multi-scale conceptual model of severe Alberta thunderstorms*[1] to include the interaction of *drylines* with *capping lids* over the foothills, and determine what role these play in storm initiation. - UNSTABLE objective

2. Determine the relative importance of daily evapotranspiration from grain crops to intensities and cycles of convective storms and drought. - DRI/UNSTABLE objectives

3. Investigate possible relationships between thunderstorms and drought regions, in this case a possible analogous relationship to that of drylines and thunderstorms. - DRI objective

[1] *Strong (1982, 1986, 2000)*

DATASETS

1. **11 July 1985 (LIMEX-85) –** (1) demonstrate strong orographic subsidence close to front range that maintains and moves the *dryline*.

2. **20 July – 08 Aug. 1992 (St. Denis)** - (2) detect *moisture gradient* across crop/grass and (3) estimate the *diurnal cycle in ET* (fixed µtransect).

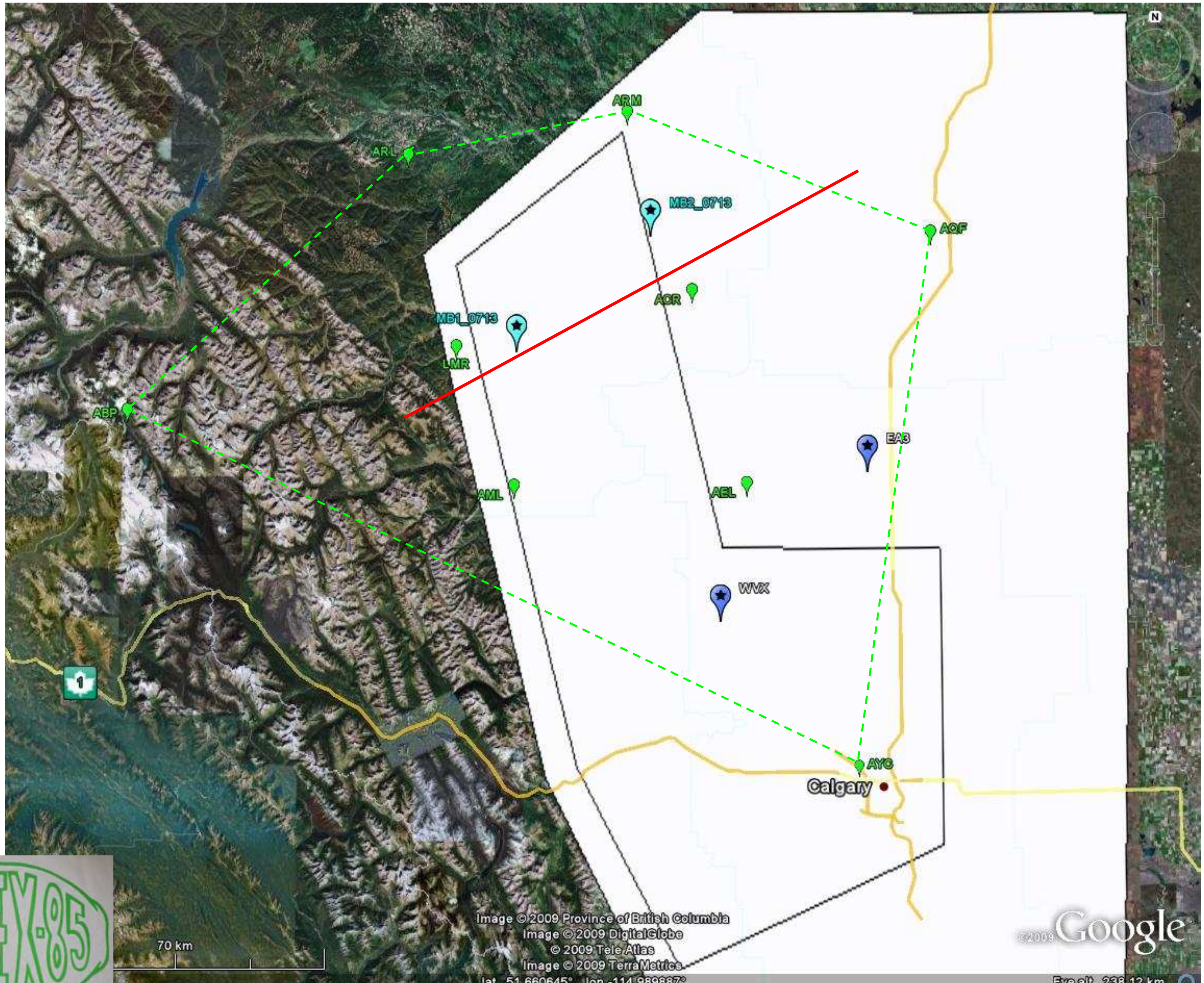
Regional Evaporation Study 1991
St. Denis - 1992

3. **13 July 2008 (UNSTABLE-‑08)** - (4) illustrate moisture cycling across rural/urban boundaries (the *urban dry island*), and (5) demonstrate the *dryline* discontinuity and how it can contribute to storm initiation.

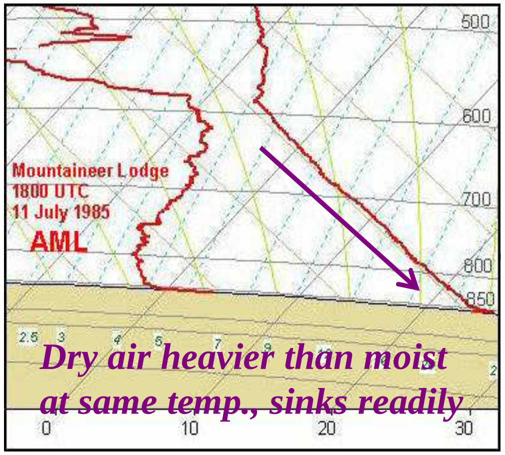
4. **14 July 2000 (Pine Lake *tornadic* Storm** - (6) hypothesize how *drought-source air* can contribute to storms in analagous ways to the *dryline*.

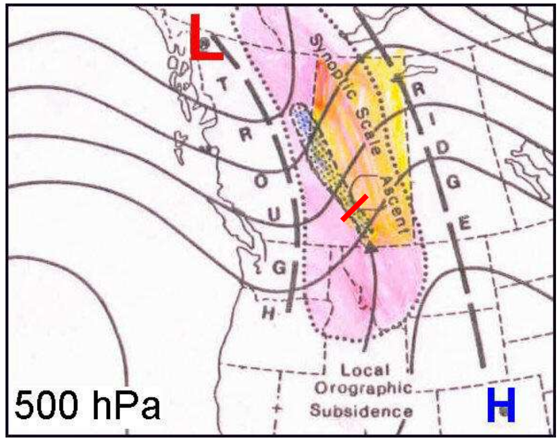
Environment Canada Environnement Canada

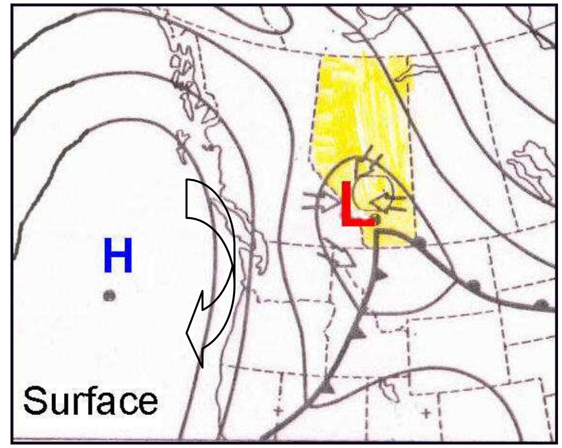
LIMEX-85 and UNSTABLE-08 Radiosonde Sites



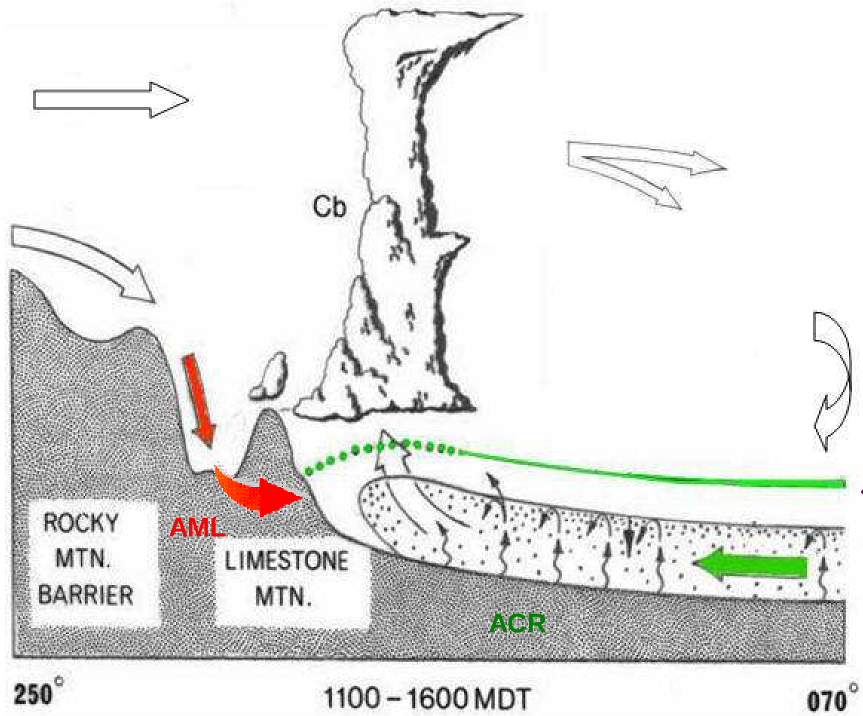
The *Alberta Multiscale Severe Thunderstorm Conceptual Model*

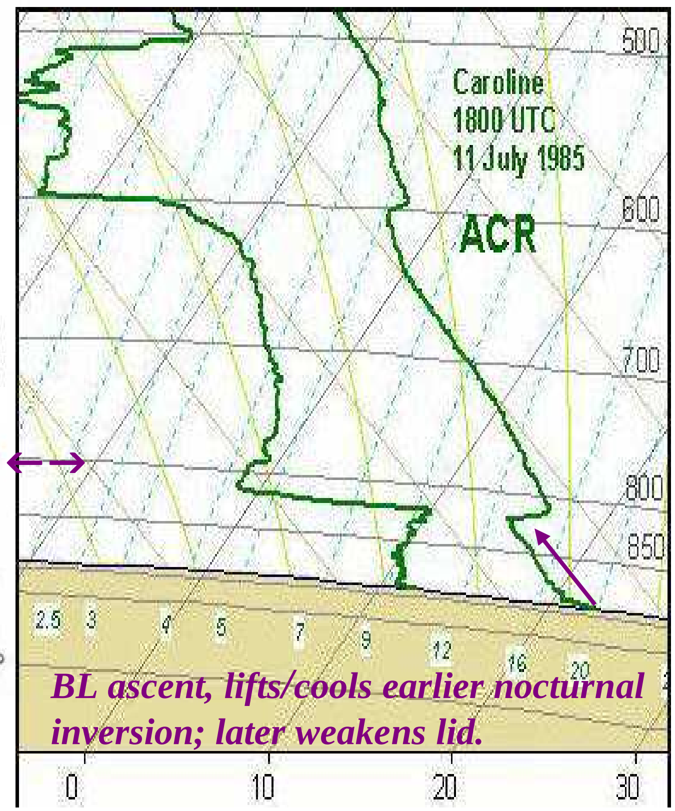






- the orographic subsidence often causes a '*dryline*' to form over the foothills

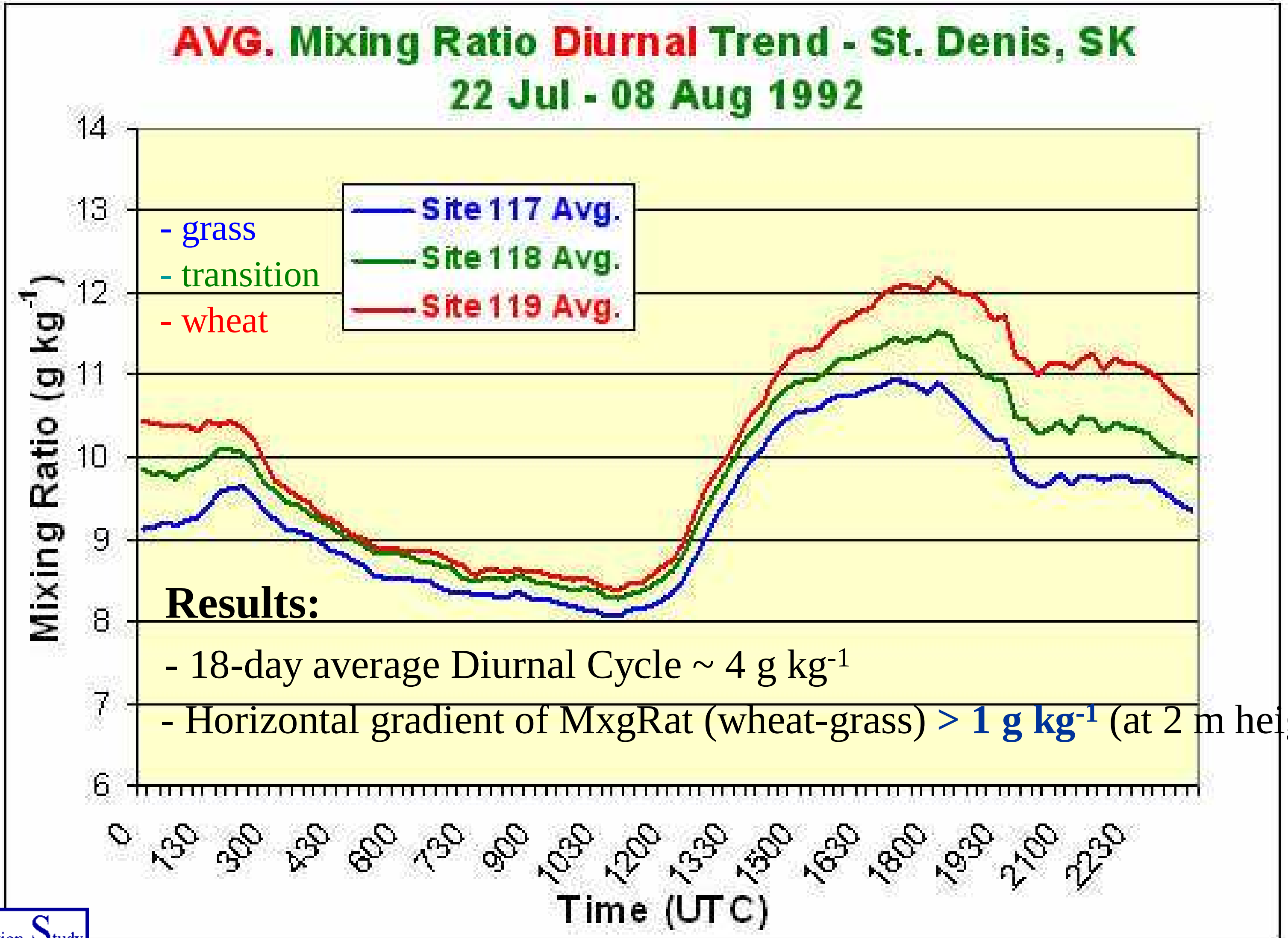




. . . next, look at the role of ET from grain crops

St. Denis, SK Crop/Grass ET Field Tests, July-Aug., 1992

(18-day average for each half hour, sites on 180-m baseline)



Results:

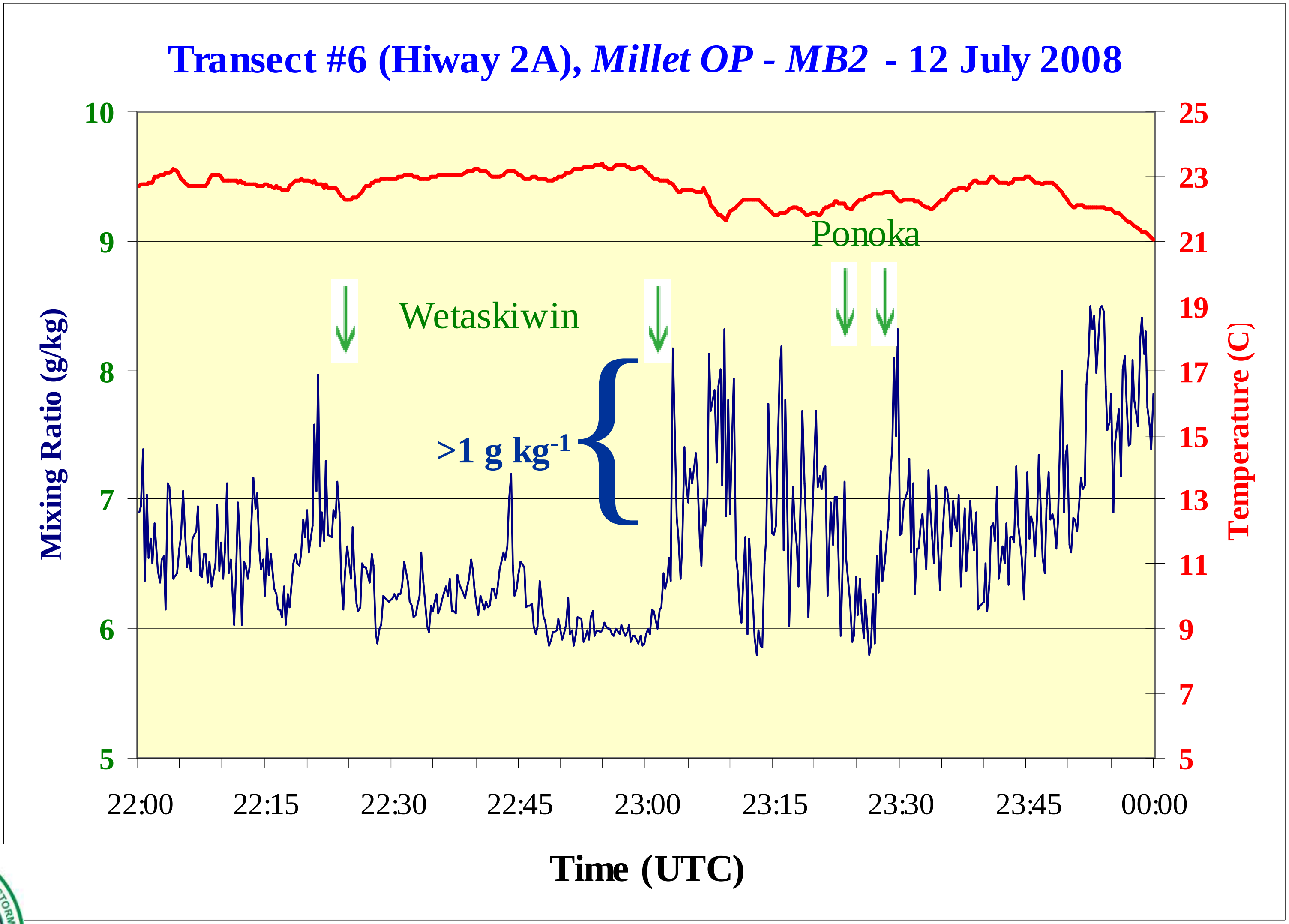
- 18-day average Diurnal Cycle ~ 4 g kg^{-1}
- Horizontal gradient of MxgRat (wheat-grass) **> 1 g kg^{-1}** (at 2 m height)

- after Hrynkiw & Strong (1992)

Regional Evaporation Study
1991
St. Denis - 1992

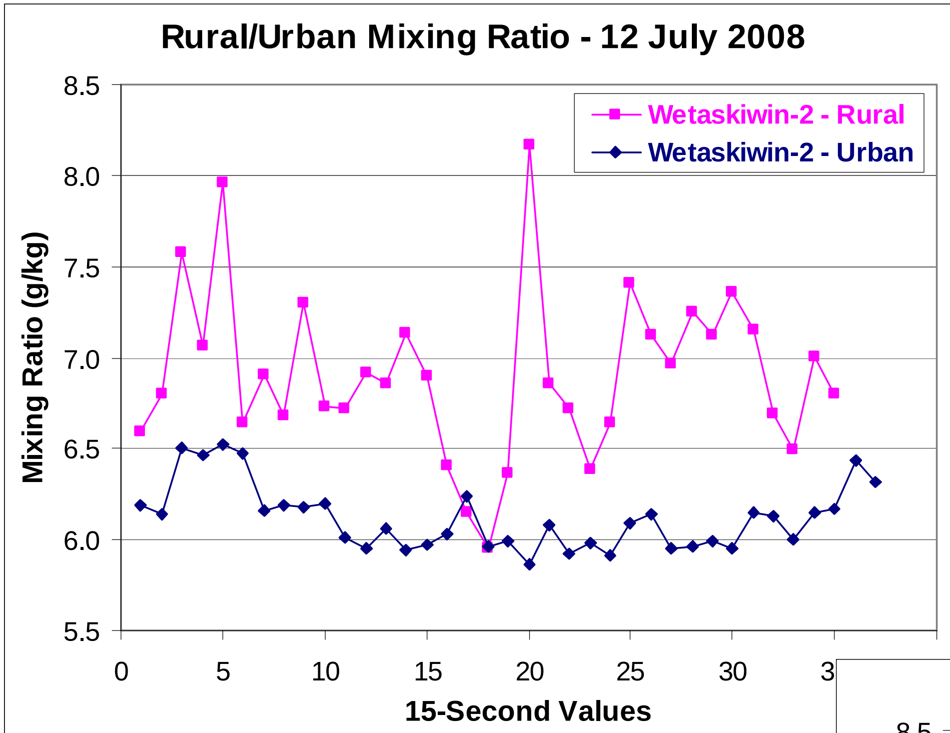
Urban *Dry Islands* in Small Alberta Towns

- Mobile transect through **Wetaskiwin/Ponoka**, 12 July 2008
- 15-second output of Temperature and Mixing Ratio



Pop. Wetaskiwin < 11,000

Pop. Ponoka < 6,500



Wetaskiwin Population: 12,000

Variable	Average (Urban - Rural)
Mixing Ratio	-0.8 g kg^{-1}
Temperature	+0.4 C

← *urban dry island*

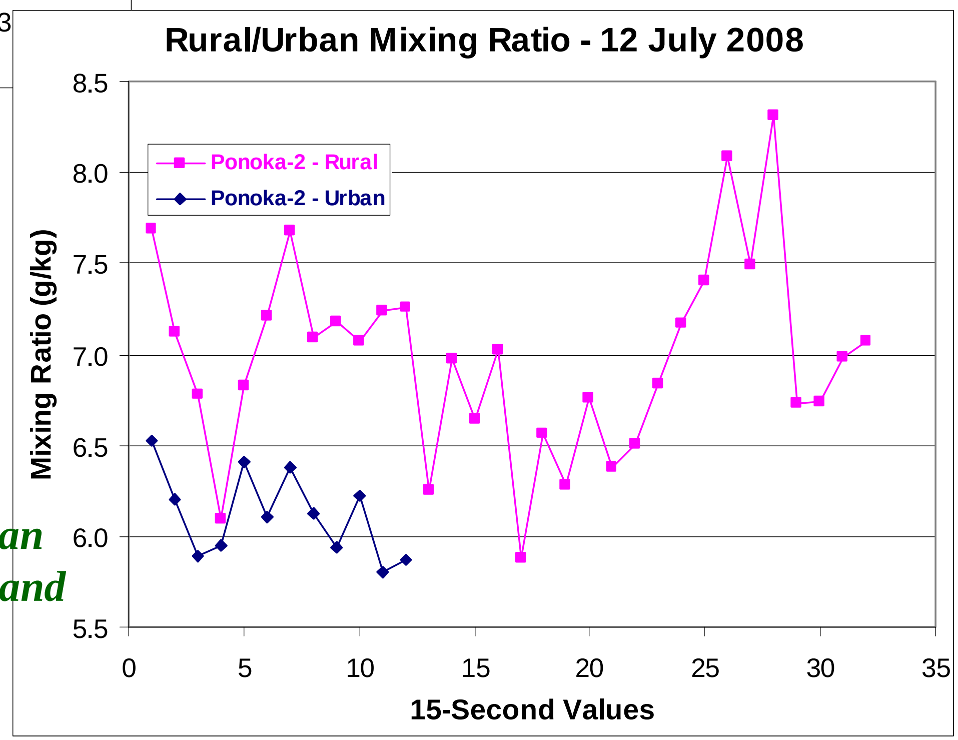
Removed data points –

1) *within 200 m of town boundaries;*
2) *when vehicle speed was below 25 kph.*

Ponoka Population: 6,500

Variable	Average (Urban - Rural)
Mixing Ratio	-0.9 g kg^{-1}
Temperature	+0.0 C

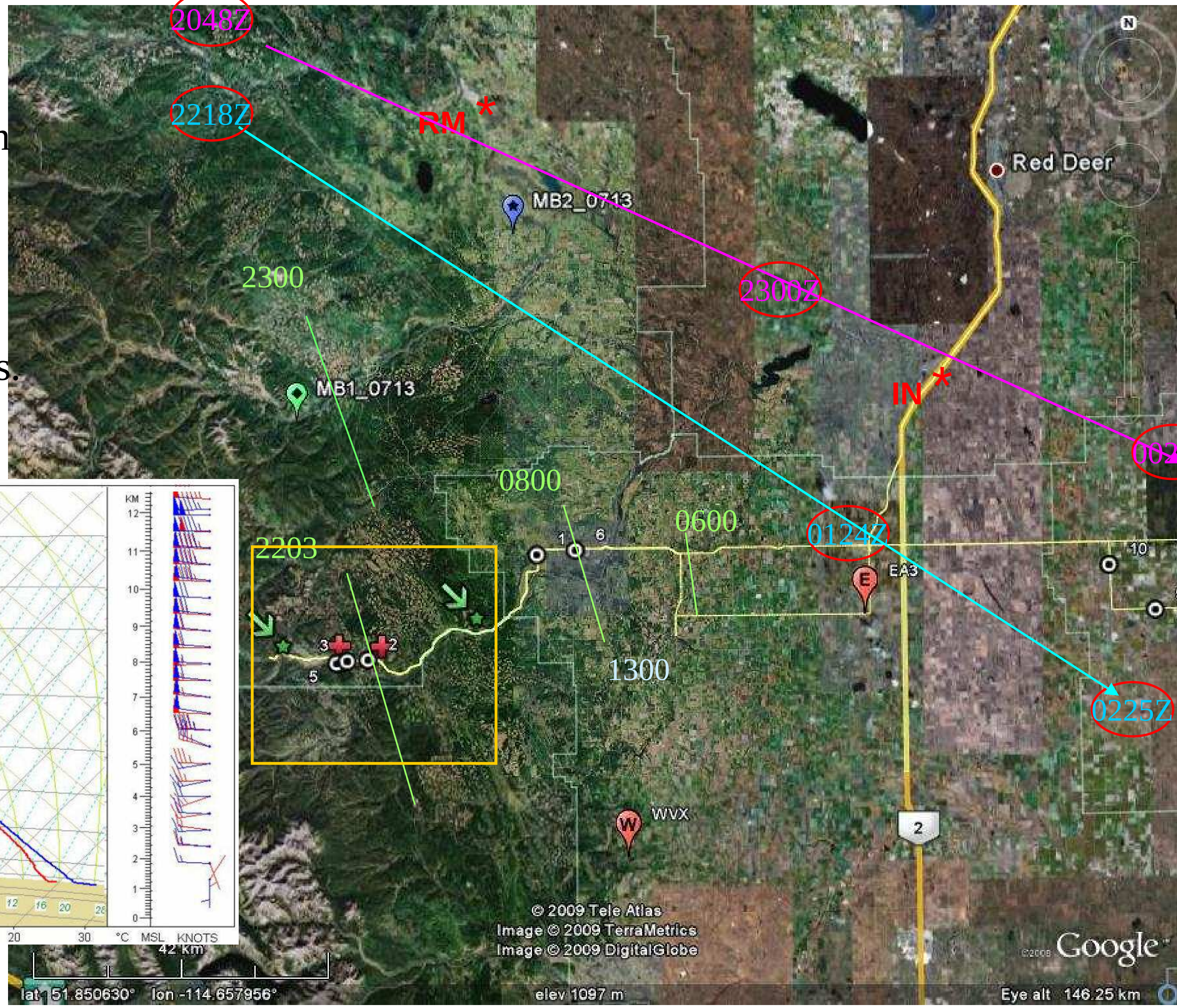
← *urban dry island*

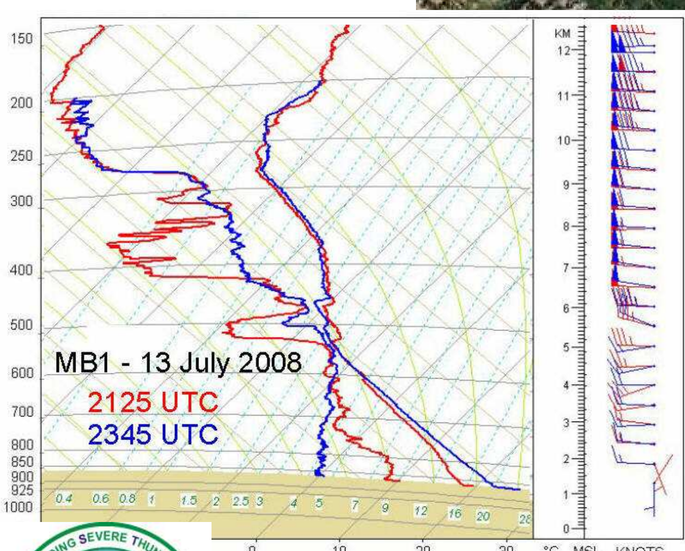


UNSTABLE-2008 *Dryline* of 13 July 2008

Green lines with times indicate ‘known’ progression of the *dryline*.

Magenta and light blue lines are two primary storm tracks.



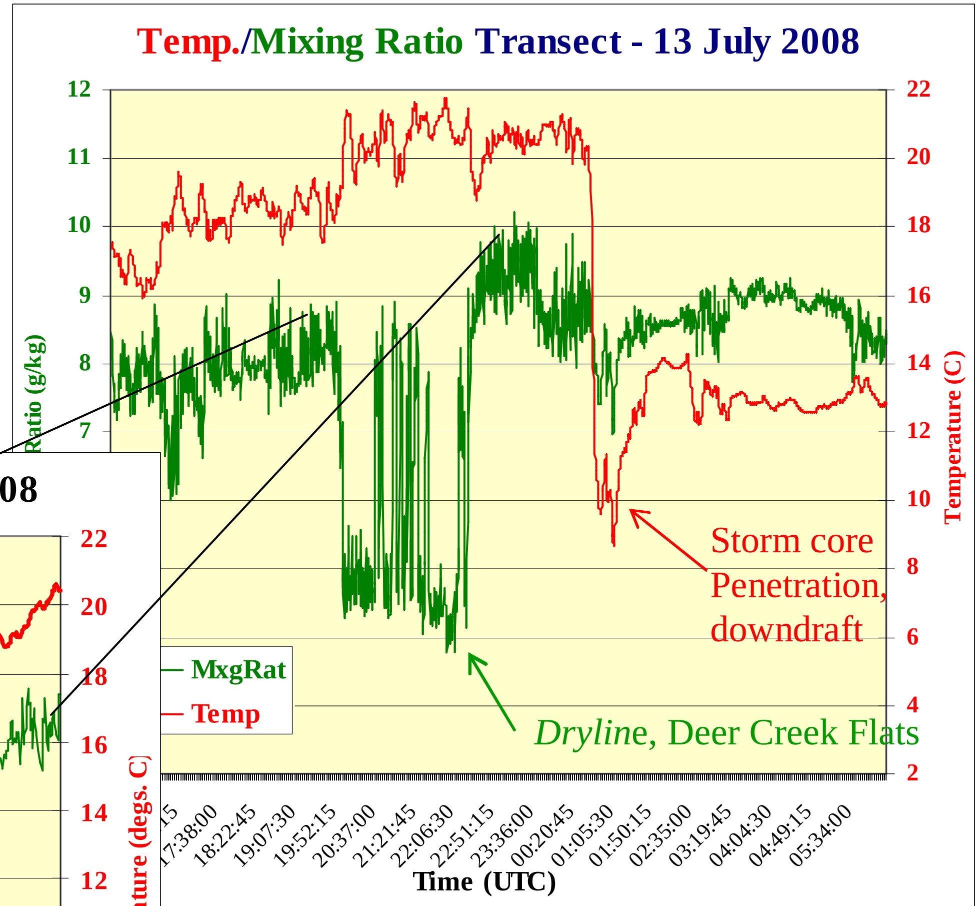


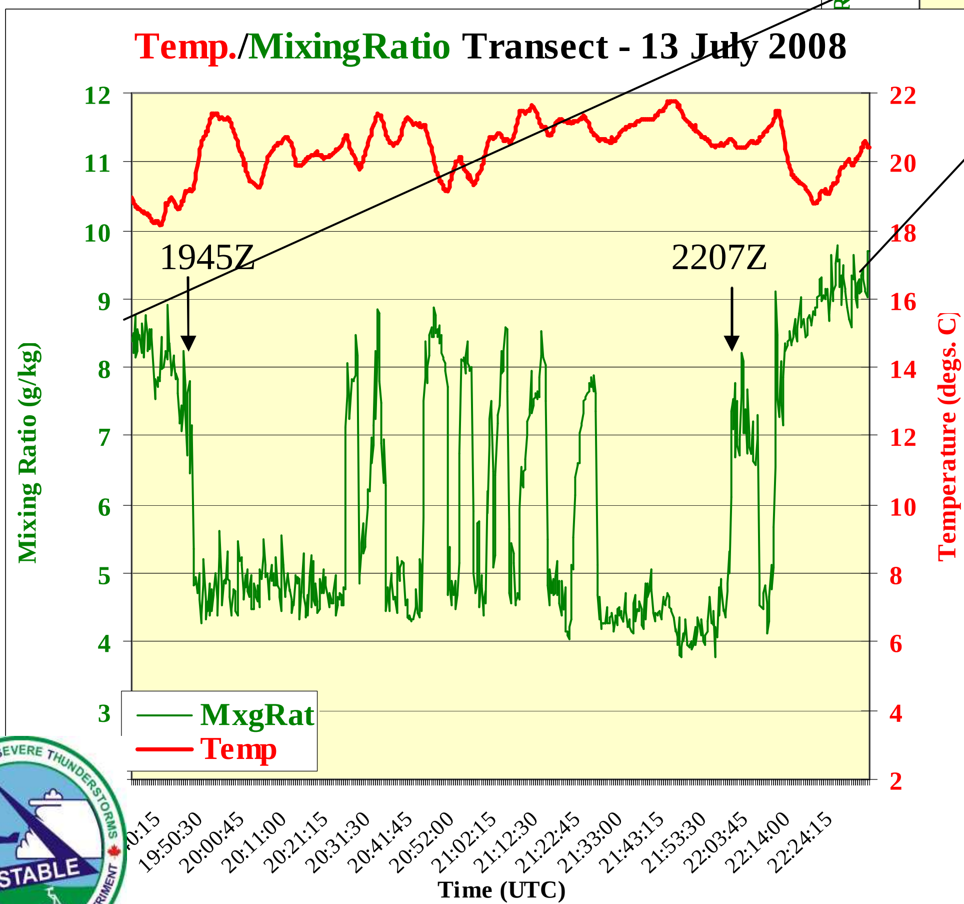
2) UNSTABLE-2008 *Dryline* of 13 July 2008

Dist. between

Stars	Crosses	-
27.8	6.1	km

Mobile Transect 1520 – 0535Z 13-14 July 2008





Summary of 13 July 2008 *Dryline*:

	Time (mins.)	Width of *Dryline* front (km)	Abs. Val. MxgRat Change	Abs. Val. Distance Gradient (g kg^{-1} km^{-1})	Abs. Val. Distance Gradient (g kg^{-1} 100m^{-1})	Abs. Val. Time Gradient (g kg^{-1} min^{-1})
AVERAGE	**1.0**	**0.5**	**2.9**	**12.1**	**1.2**	**4.0**
MAX	4.50	1.9	4.4	50.1	5.0	12.3
MIN	0.25	0.04	1.1	1.9	0.2	0.8

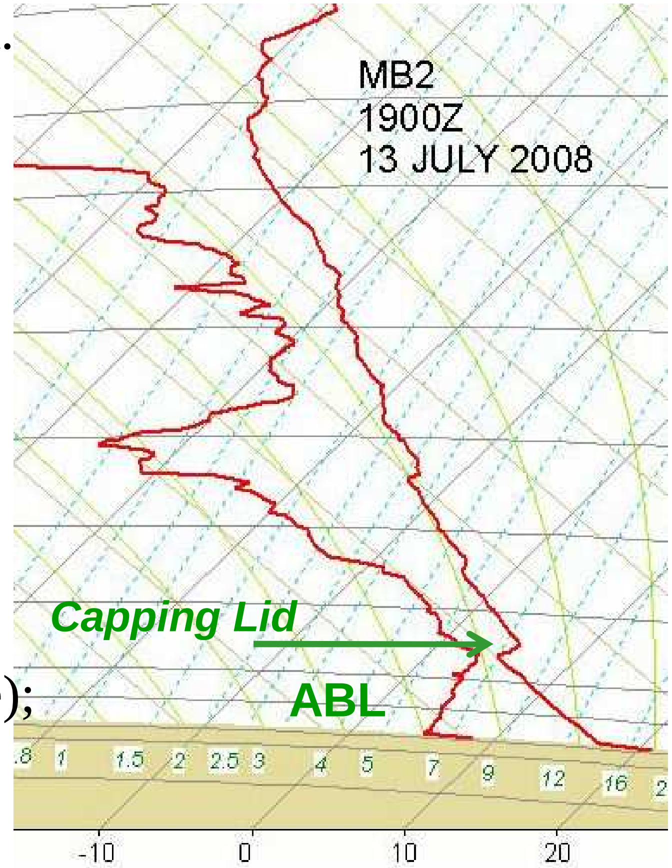
Data Collection Interval - 15 seconds
After 13 July - 5 seconds

What is the role of the *dryline*, and how does this relate to drought?

1. Dry air is denser (heavier) than moist air, hence its propensity to subside down along the front range of the Rockies (RE AML/LMW LIMEX soundings.

2. The continuing flow of dry air downslope from the mountains helps maintain its character at the dryline, while transferring momentum (from mountain-top level) to the boundary layer, giving the *dryline* its motion.

3. The dryline, being denser than the moist air just downstream, readily undercuts and lifts the moist air waiting beneath the capping lid.



Drought Scenario:

4. Stagnant dry air sitting over a drought area -

- typically drier than the air outside the region;
- high pressure typically dominates;
- subsidence prevails over the drought area;
- transfers momentum to surface (similar to dryline);
- the dry air, on moving out of the drought region, undercuts (being denser) and lifts any moisture it encounters.

CONCLUSIONS

I. Regional ET and Moisture Cycling from Grain Crops

1. Average evapotranspiration from mixed crop/grass vegetation with adequate soil moisture on the prairies is 4 g kg^{-1}, ~ 1 g kg^{-1} higher over grain crops than grasses. ➔ **KEEFEX**

2. Mobile transects show that the efficiency of ET from grain crops results in perturbations in mixing ratio of $\pm$1 g kg^{-1} over rural Alberta agriculture districts.

3. Induces '*urban dry islands*' of ~1 g kg^{-1} (mixing ratio) over urban centres within agricultural districts, including small towns; may divert or otherwise negatively influence convective storms (can reduce CAPE by 300-400 J kg^{-1}).

II. Role of Dry Air Initiating Severe Thunderstorms

4. **The *dryline***, gravity-induced subsidence of dry air from the Rocky Mountains, **can be a sharper discontinuity than previously believed**, with mixing ratio gradients as strong as 5 g kg^{-1} $(100\ m)^{-1}$. Mobile drylines add convergence/ascent at the back edge of moist air beneath a *capping lid*, thus helping to initiate convective storms over the foothills.

5. The **Pine Lake storm** of 14 July 2000 may have been initiated by a *dryline* over the foothills, but its intensification into a tornadic storm after crossing Highway 2 may also have been assisted by the southwesterly flow of dry air previously stagnant over drought-stricken southern Alberta. The mechanics of this is similar to that of the dryline.

END

Acknowledge Funding and Data from:

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

DRI
Drought Research Initiative
Réseau de recherche sur la sécheresse

Geomatics Engineering
University of Calgary

Understanding Severe Thunderstorms and Alberta Boundary Layers Experiment
UNSTABLE

Weather Modification Inc.

Environment Canada Environnement Canada