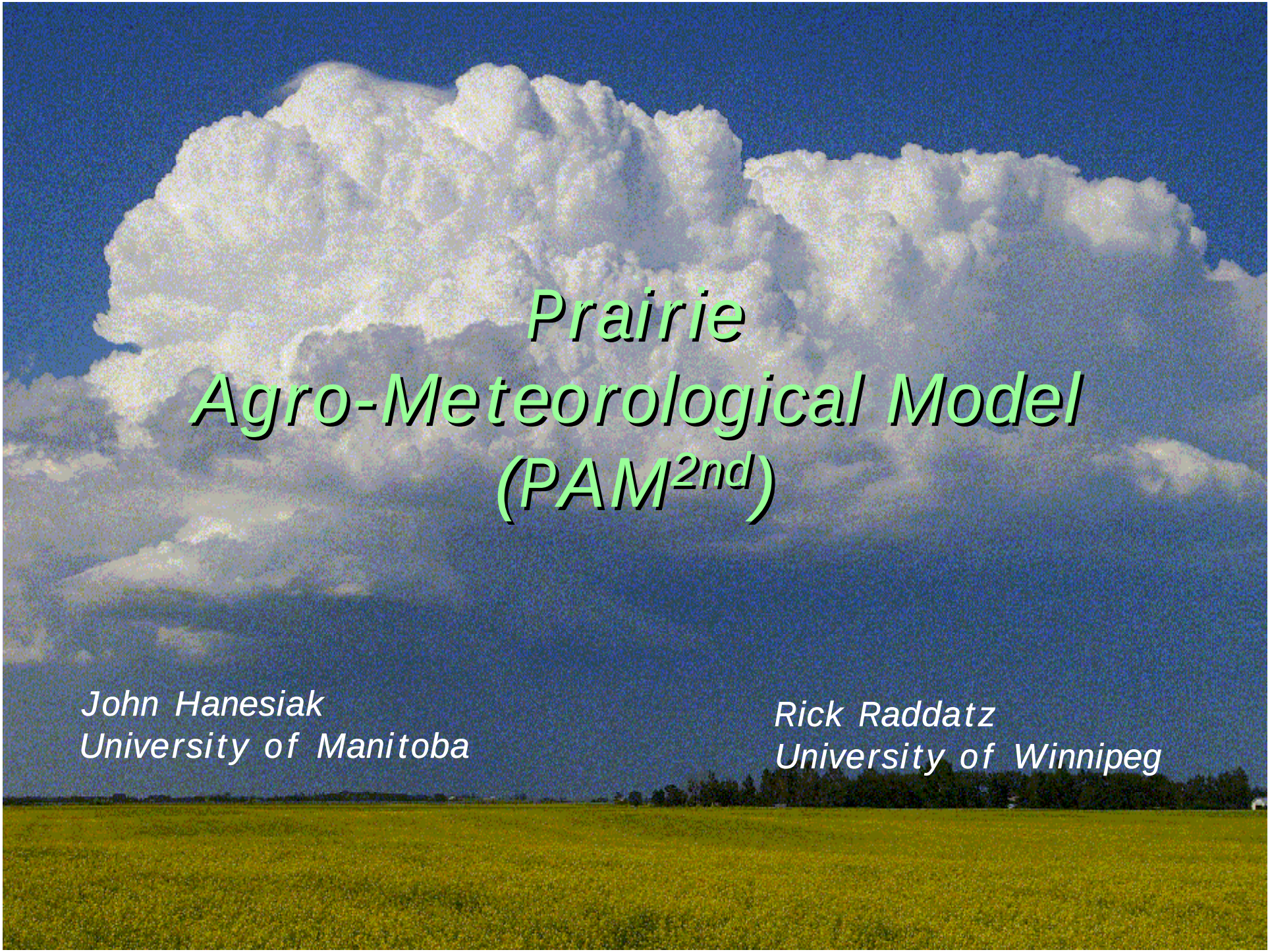
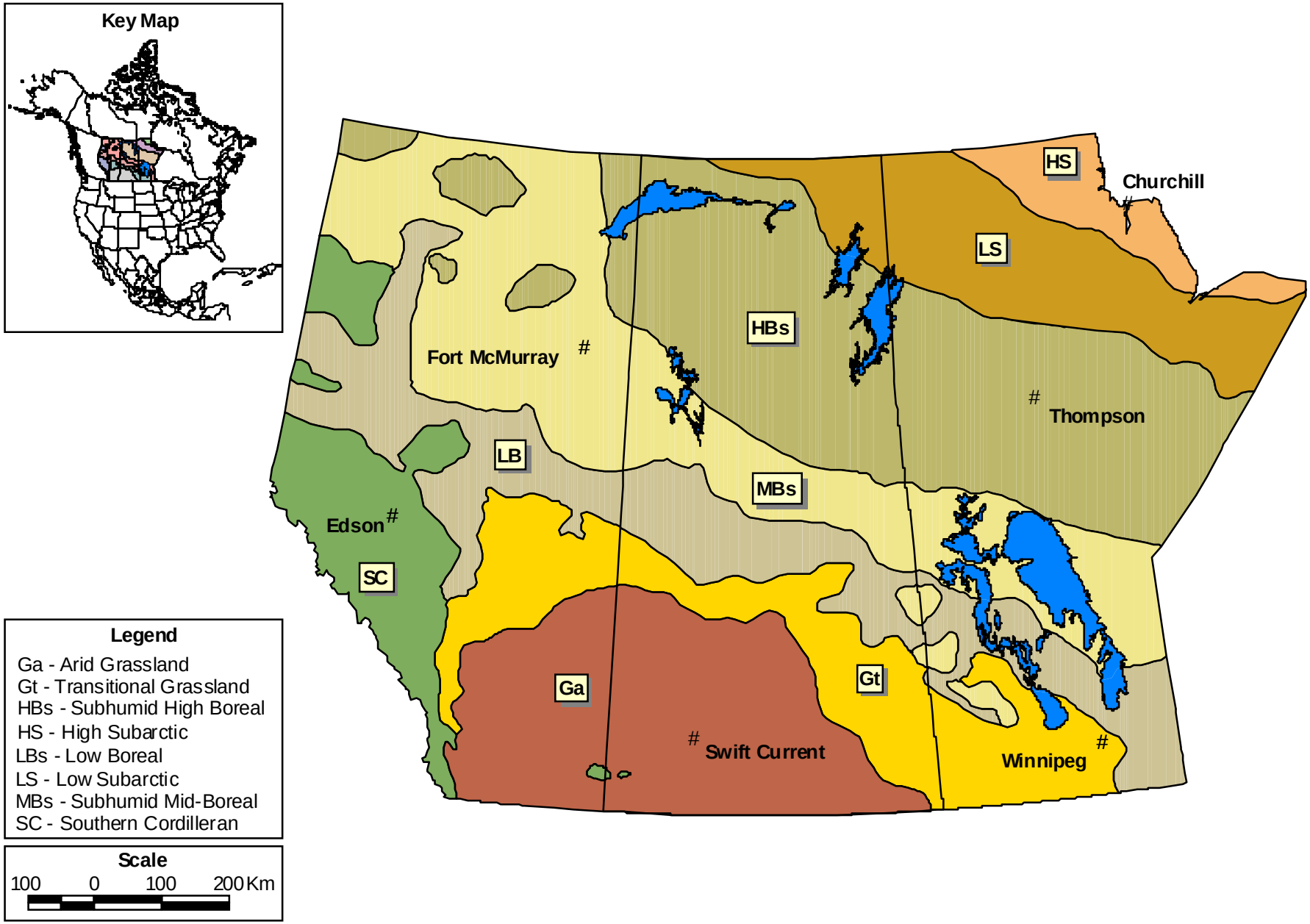
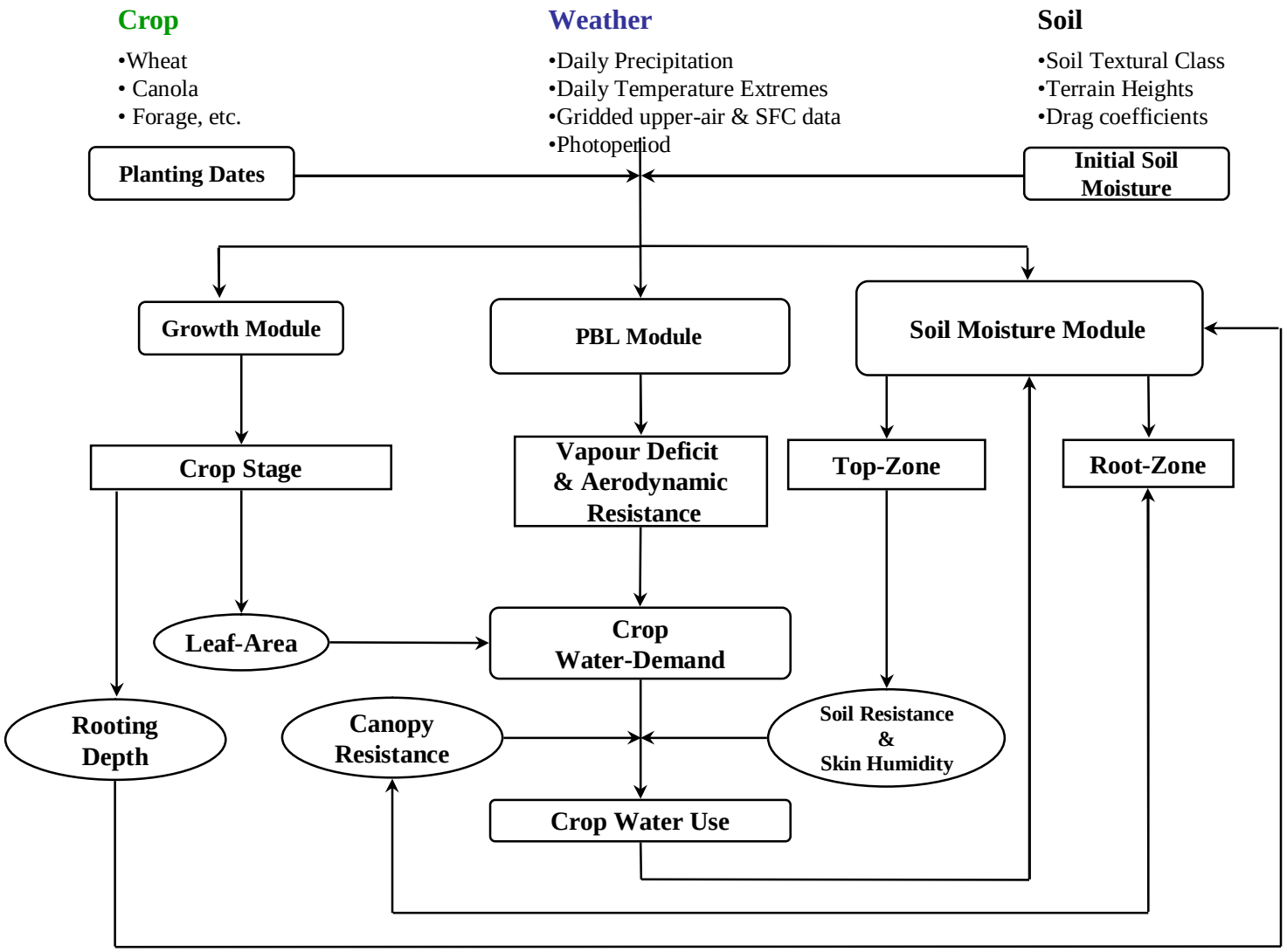

Prairie
Agro-Meteorological Model
(PAM2nd)
John Hanesiak
University of Manitoba
Rick Raddatz
University of Winnipeg


Key Map
HS
Churchill
LS
HBs
Fort McMurray
Thompson
LB
MBs
Edson
SC
Ga
Gt
Swift Current
Winnipeg
Legend
Ga - Arid Grassland
Gt - Transitional Grassland
HBs - Subhumid High Boreal
HS - High Subarctic
LBs - Low Boreal
LS - Low Subarctic
MBs - Subhumid Mid-Boreal
SC - Southern Cordilleran
Scale
100 0 100 200 Km

Prairie Agrometeorological Model (PAM 2nd)



Evapotranspiration

Transpiration & Evaporation calculated separately:

$$T = L_A \left[\rho_s(T_a) - \rho(Td_a) \right] / (r_a + r_c)$$

$$E = (1 - L_A) \left[h(\rho_s(T_a)) - \rho(Td_a) \right] / (r_a + r_g)$$

Evapotranspiration

Driven by vapor density gradient with surface of leaves & soil at air temperature (T_a):

$\rho_s(T_a) - \rho(Td_a)$ Assumes good coupling between small crop leaves and atmosphere

Modulated by resistances:

1. Canopy: $r_c = [r_{c(min)} / L_A] [(W - W_x) / (W_f - W_x)]^{-1}$

2. Aerodynamic: $r_a = [\ln(Z_{pbl} / Z_o)]^2 / [\sigma k^2 (V_{mbl} - V_{sfc})]$

3. Water Supply to Soil Surface: $r_g = r_{g(min)} [(w - w_x) / (w_f - w_x)]^{-2.5}$

Daily Evapotranspiration

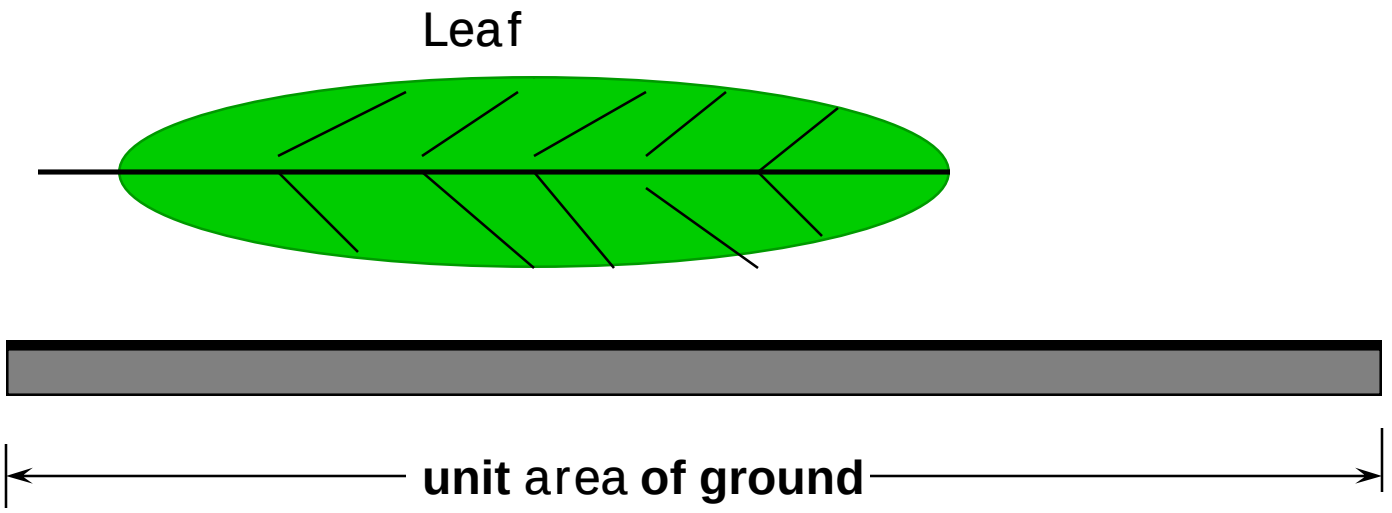
1. Max Hourly ET derived from Tmax, 0000Z Standard Level GRIB data and modeled PBL

2. Min Hourly ET derived from Tlow, 1200Z Standard level GRIB data and modeled PBL

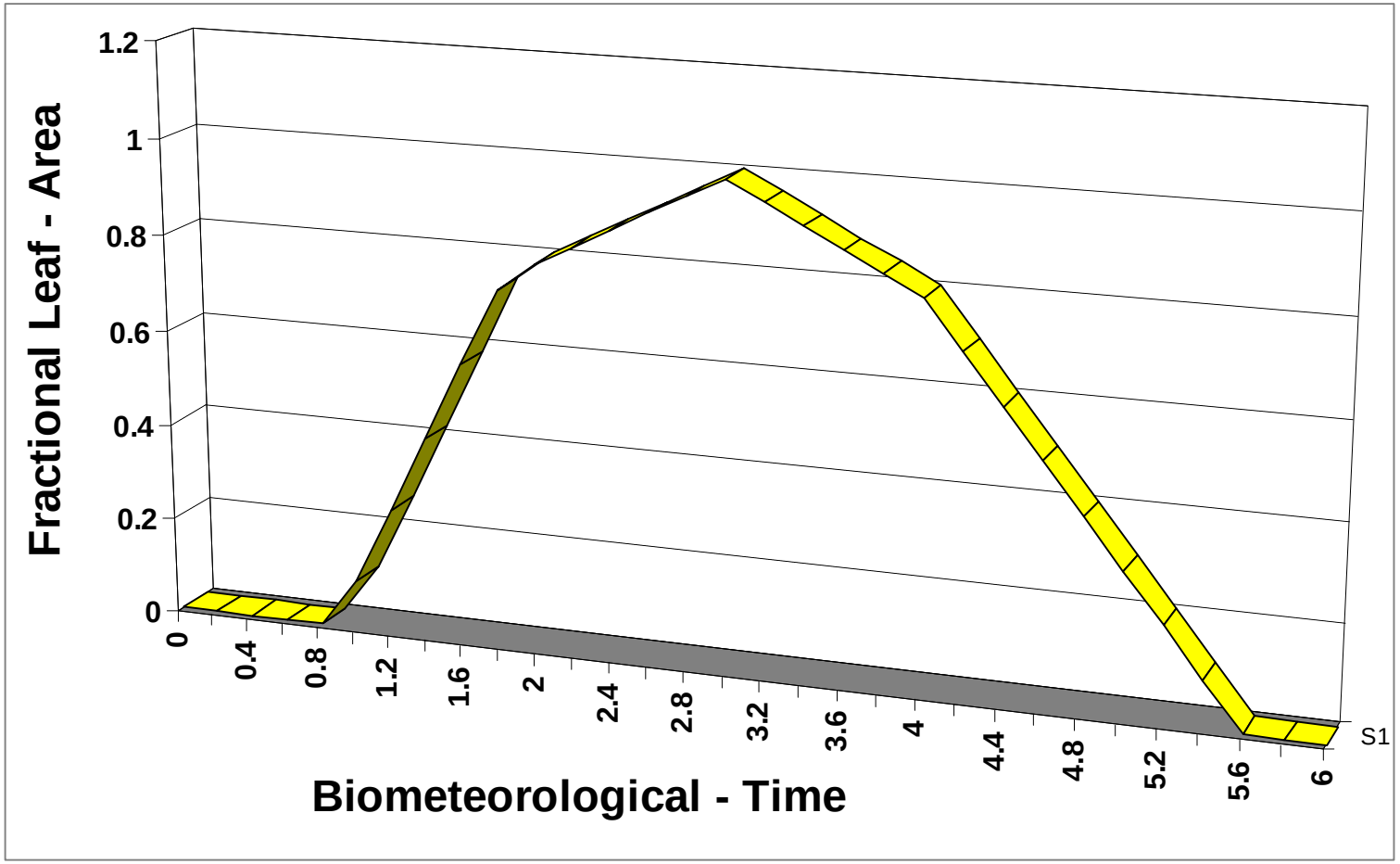
3. ET values for other daylight hours derived by fitting sinusoidal curve.

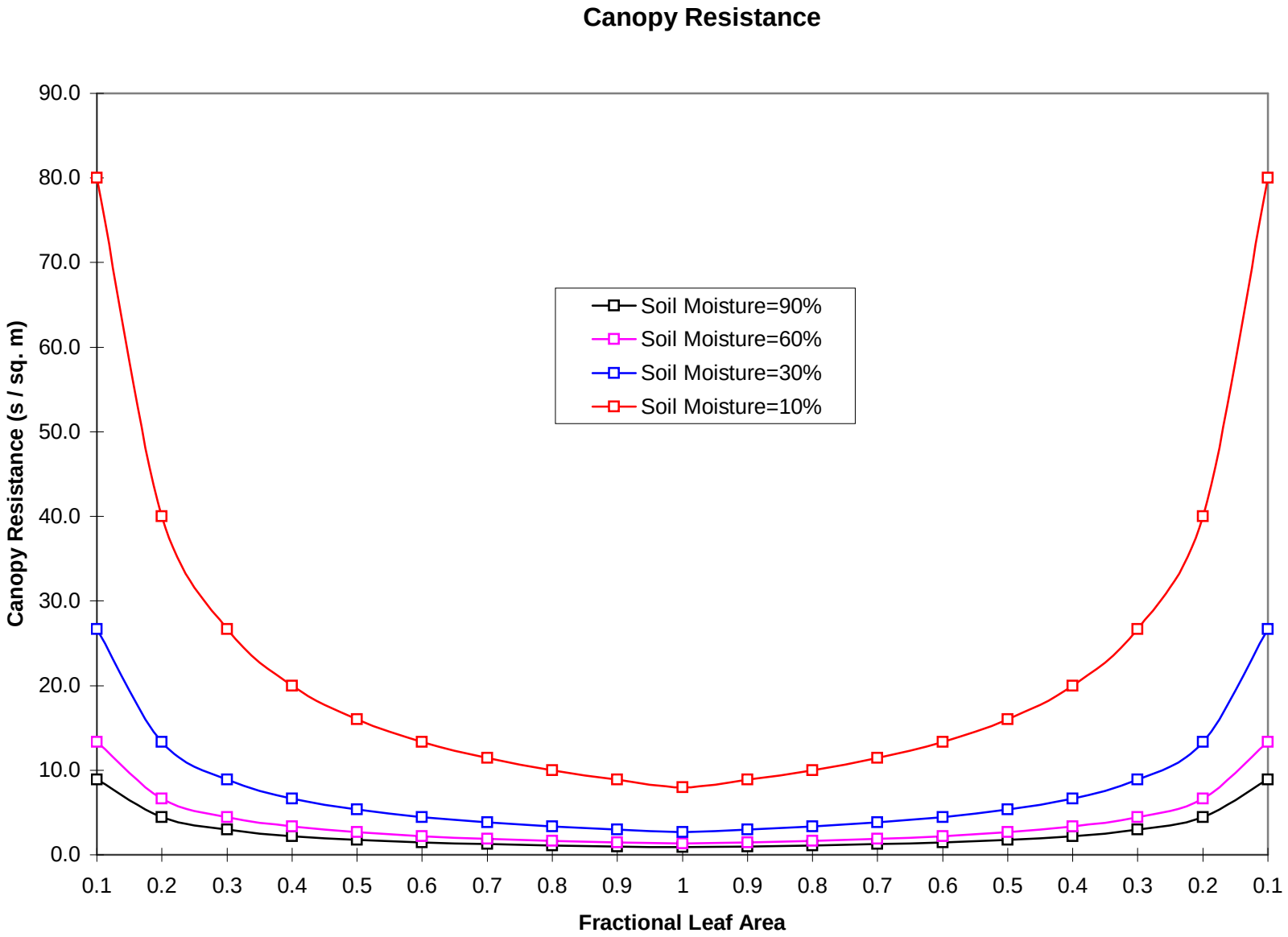
4. Hourly values from sunrise to sunset added to get daily ET.

Fractional Leaf Area

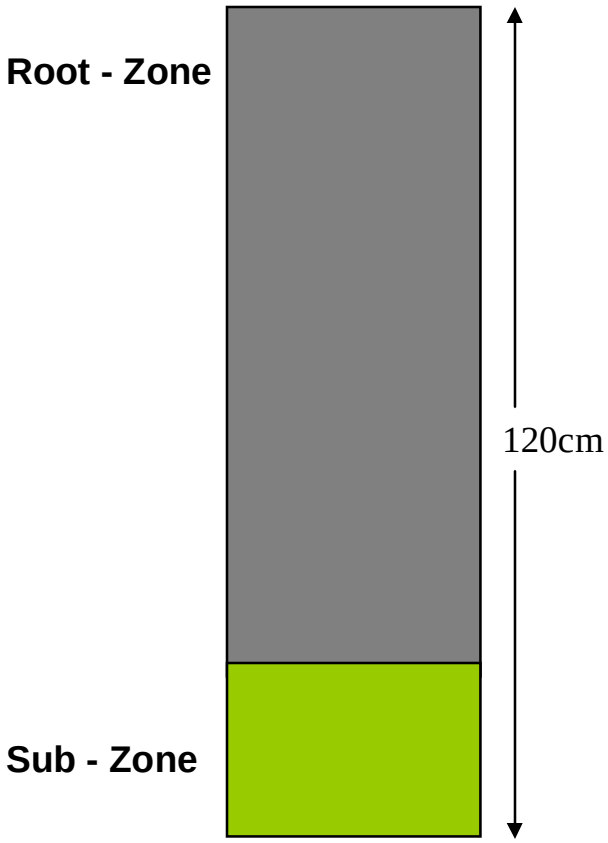


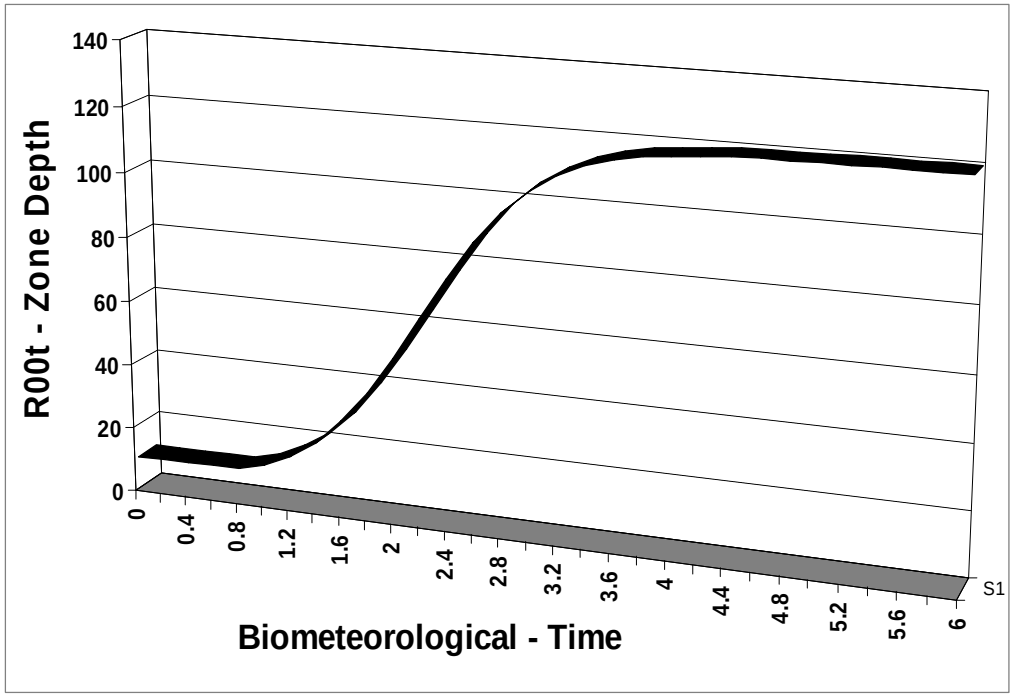
Wheat


Fractional Leaf - Area
1.2
1
0.8
0.6
0.4
0.2
0
0
0.4
0.8
1.2
1.6
2
2.4
2.8
3.2
3.6
4
4.4
4.8
5.2
5.6
6
Biometeorological - Time
S1


Canopy Resistance
Canopy Resistance (s / sq. m)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
Soil Moisture=90%
Soil Moisture=60%
Soil Moisture=30%
Soil Moisture=10%
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Fractional Leaf Area

Root - Zone Growth & Soil Layers

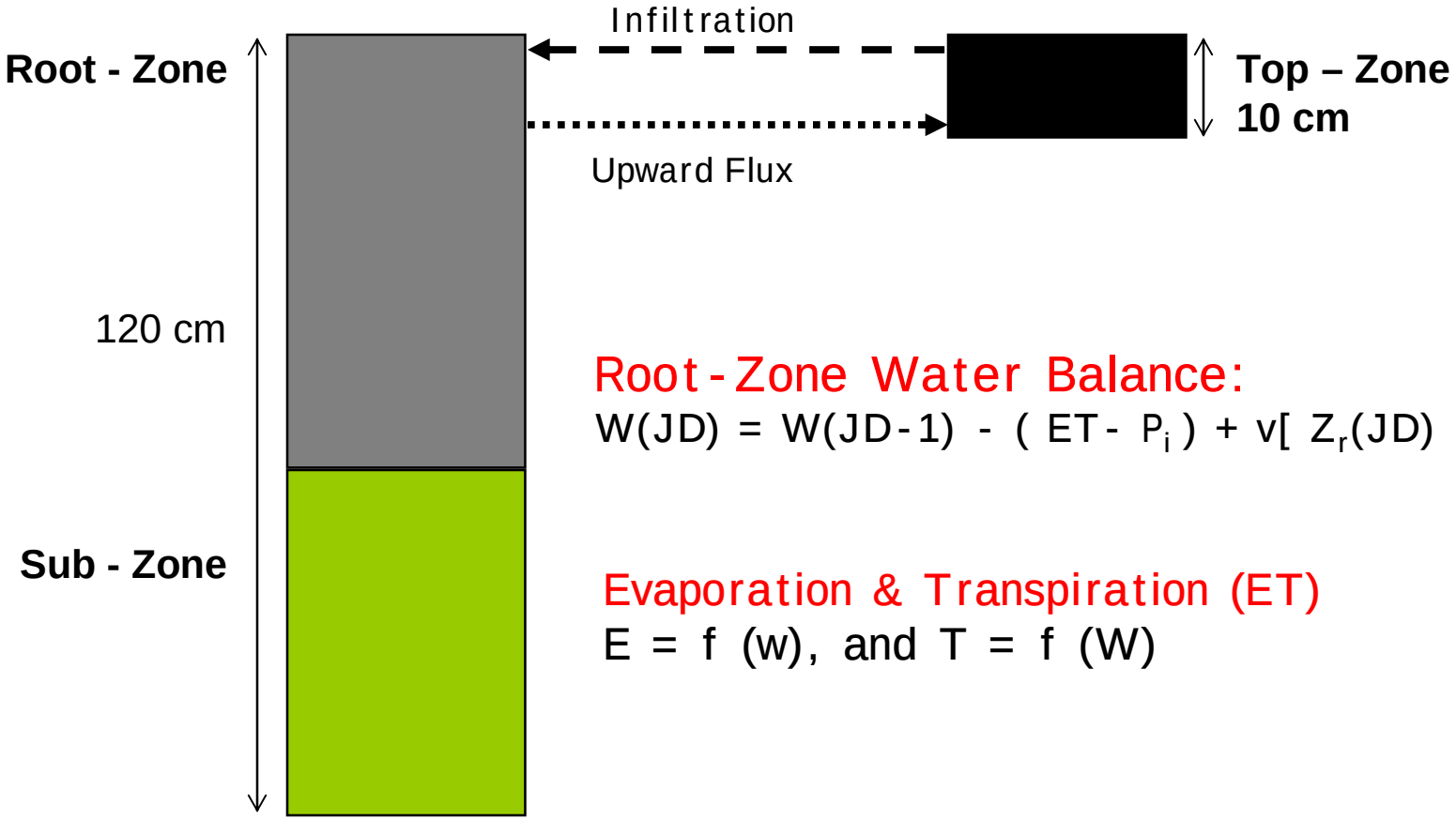




Two Water Balances

Top-Zone Water Balance:

$$w(JD) = w(JD-1) - (C_1 ET - P_i) - \tau C_2 (\upsilon - \Omega)$$

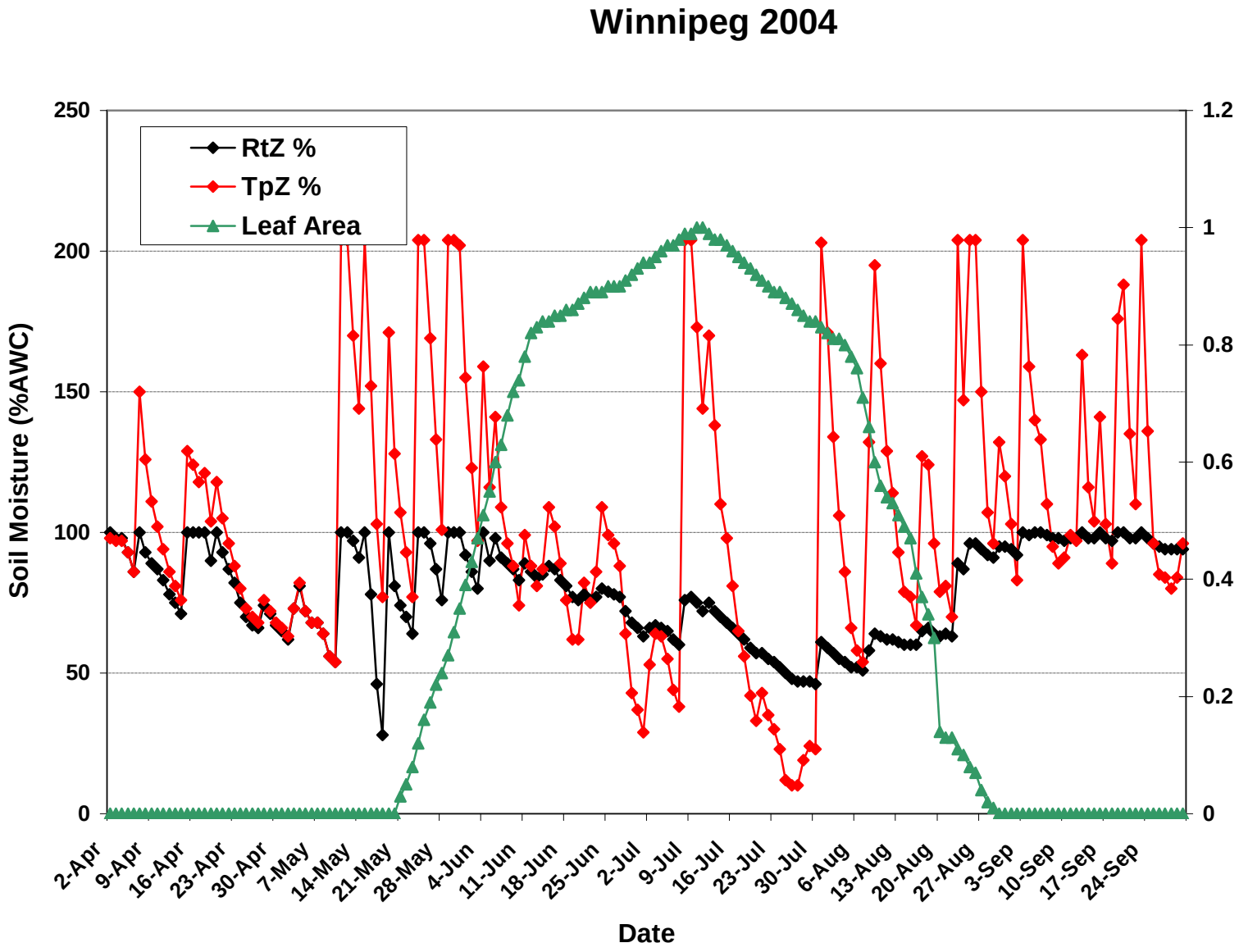


Root-Zone Water Balance:

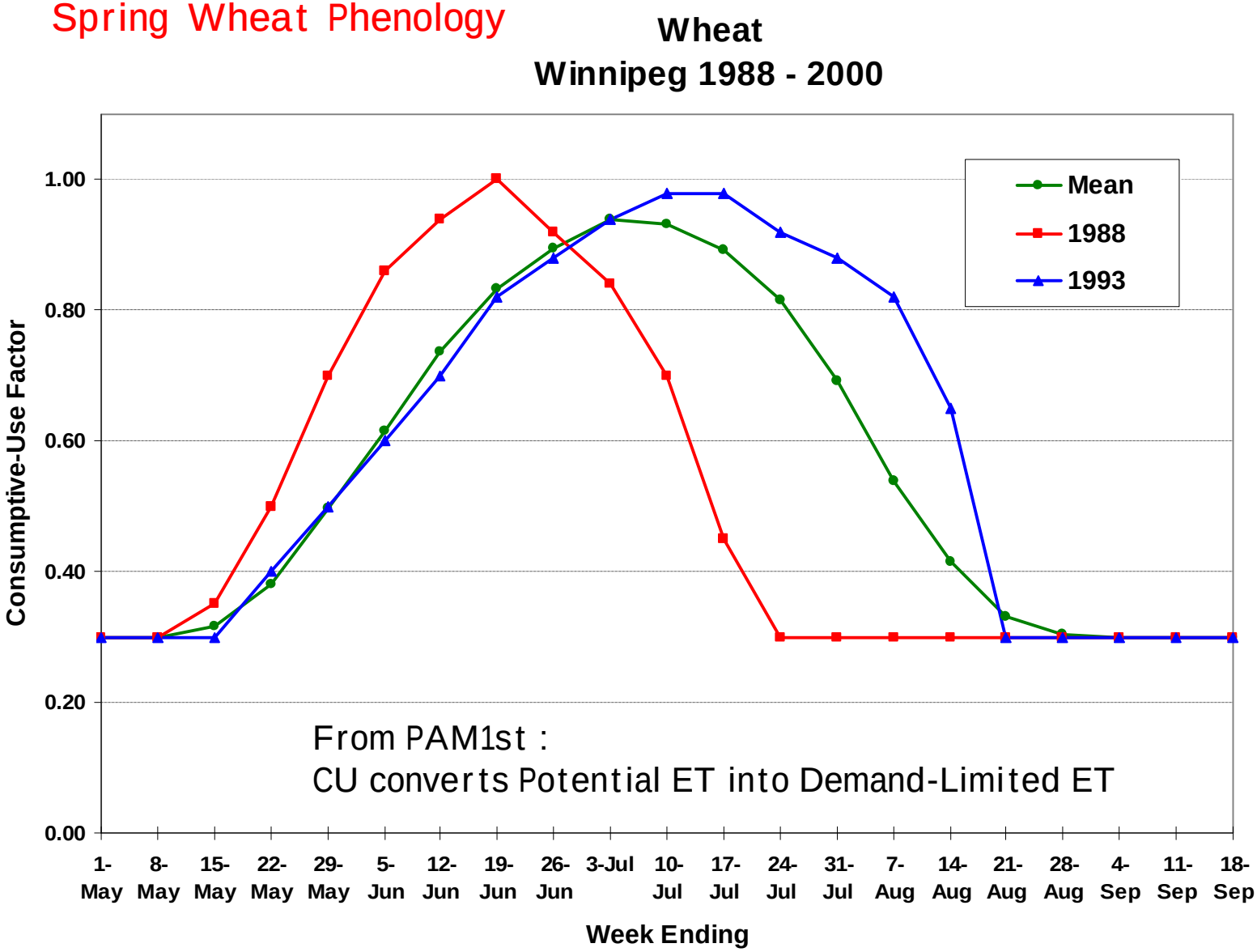
$$W(JD) = W(JD-1) - (ET - P_i) + v[Z_r(JD) - Z_r(JD-1)]$$

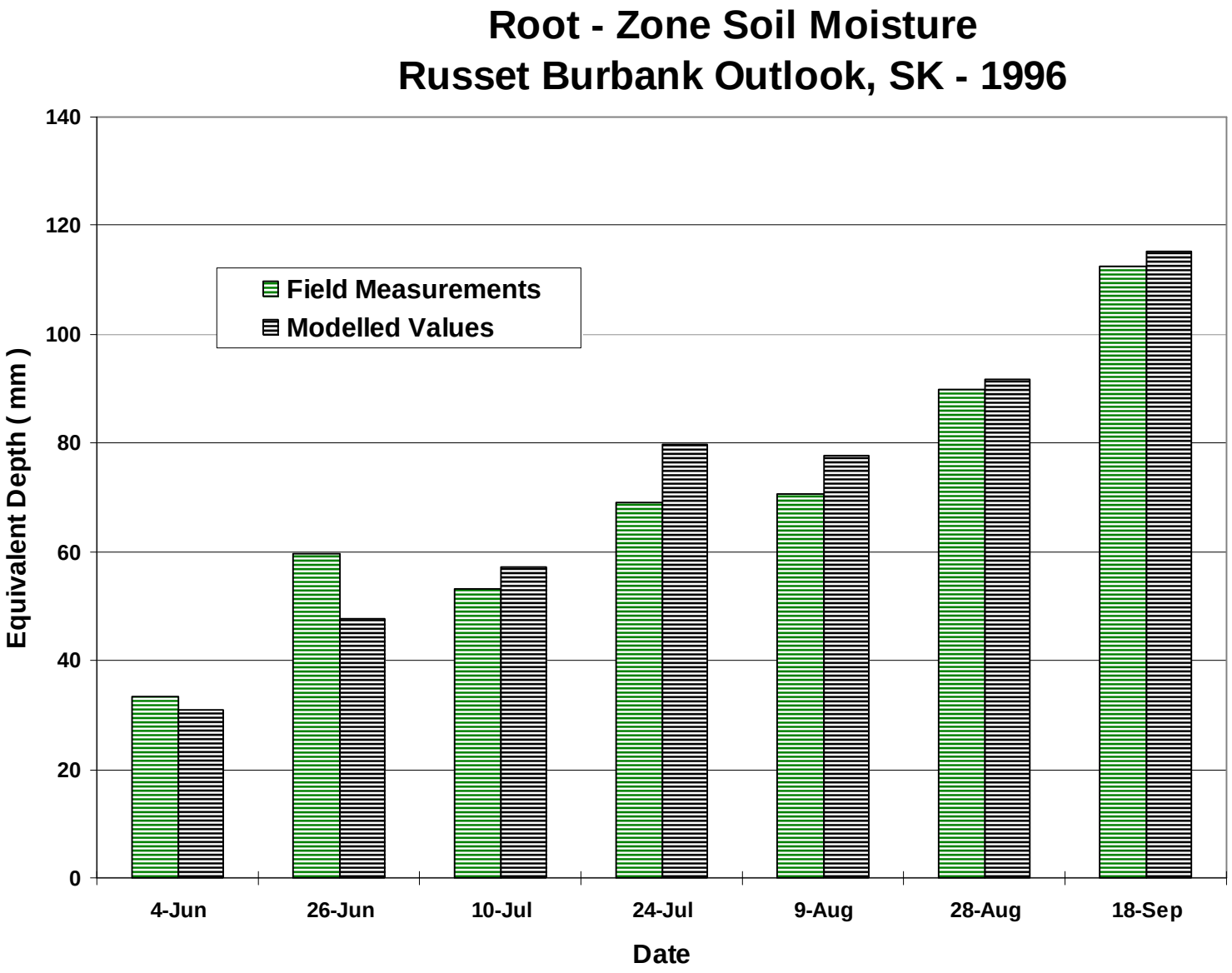
Evaporation & Transpiration (ET)

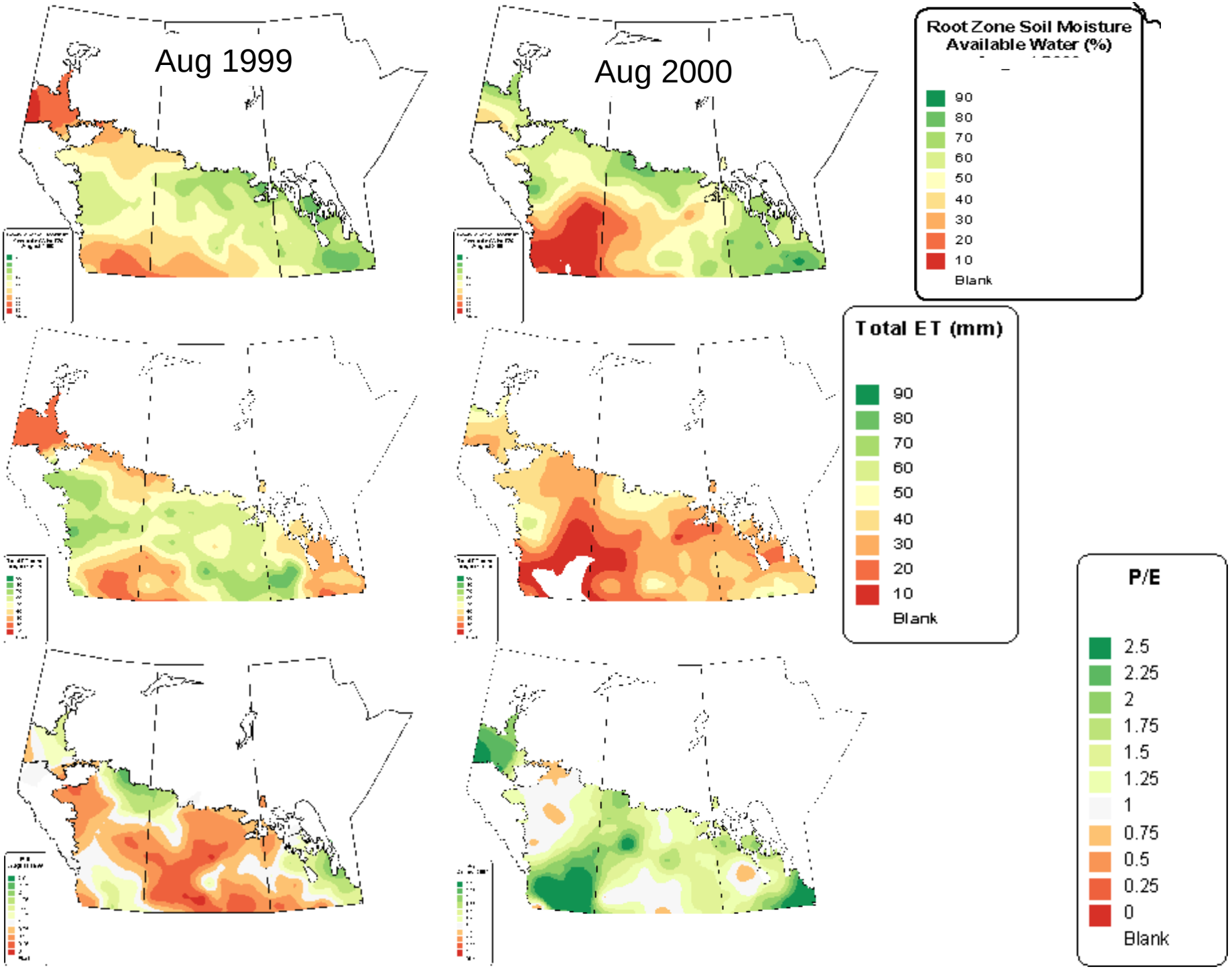
$$E = f(w), \text{ and } T = f(W)$$

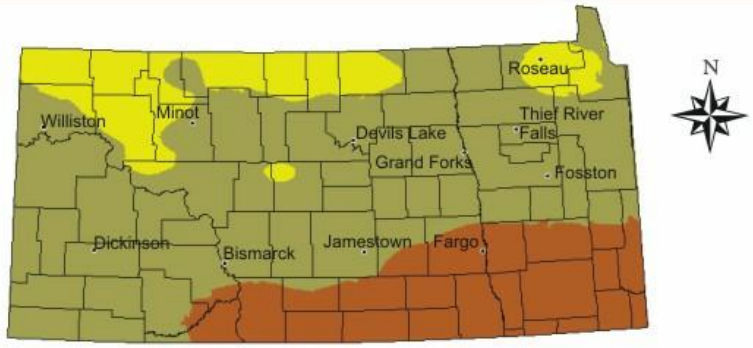

Winnipeg 2004
RtZ %
TpZ %
Leaf Area
Soil Moisture (%AWC)
250
200
150
100
50
0
1.2
1
0.8
0.6
0.4
0.2
0
2-Apr
9-Apr
16-Apr
23-Apr
30-Apr
7-May
14-May
21-May
28-May
4-Jun
11-Jun
18-Jun
25-Jun
2-Jul
9-Jul
16-Jul
23-Jul
30-Jul
6-Aug
13-Aug
20-Aug
27-Aug
3-Sep
10-Sep
17-Sep
24-Sep
Date

Inter-annual variability of Spring Wheat Phenology




Root - Zone Soil Moisture
Russet Burbank Outlook, SK - 1996
Field Measurements
Modelled Values
Equivalent Depth (mm)
140
120
100
80
60
40
20
0
4-Jun
26-Jun
10-Jul
24-Jul
9-Aug
28-Aug
18-Sep
Date

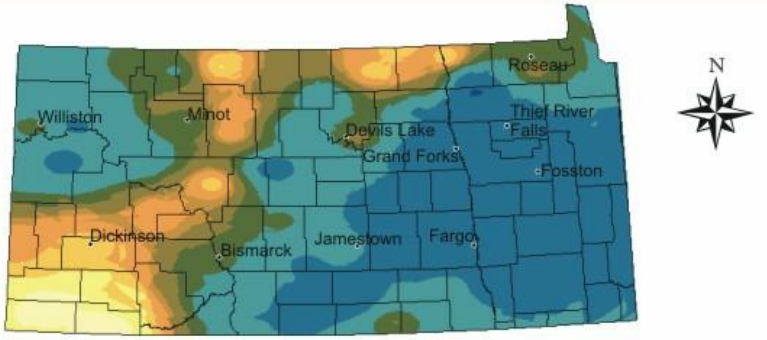

Aug 1999
Aug 2000
Root Zone Soil Moisture Available Water (%)
90
80
70
60
50
40
30
20
10
Blank
Total ET (mm)
90
80
70
60
50
40
30
20
10
Blank
P/E
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
Blank



Legend
- Seedling (0-142 GDD)
- Rosette - 3rd Leaf (142-220 GDD)
- Rosette-4th Leaf (221-404 GDD)
- Early Bud (404-460 GDD)
- Late Bud (460-518 GDD)
- Early Flower (518-647 GDD)
- Late Flower (647-776 GDD)
- Early Ripening (776-908 GDD)
- Late Ripening (908-1041 GDD)
- Ripe (>1041 GDD)

Growing Degree Days in Canola for the Period Ending July 11th, 2002

Growing degree days (GDD) is a measure of accumulated heat used to determine plant growth stages. This map uses 50% planting dates as a starting point for the growth model. GDDs are calculated for each day using the maximum daily temperature, the minimum daily temperature and a base temperature of 41 °F (5 °C). Unless stressed by other environmental factors, the rate of development of canola crops from their planting to maturity is dependant mainly upon the temperature during the growth phase.

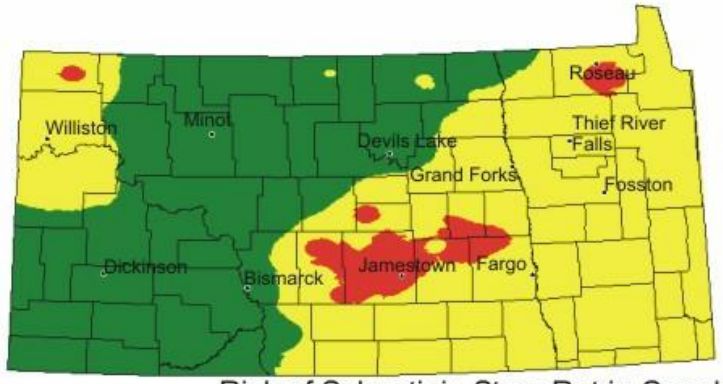


Legend
- 0-25% Capacity
- 25-50% Capacity
- 50-70% Capacity
- 70-90% Capacity
- 90-100% Capacity
- 100-125% Capacity
- 125-150% Capacity
- 150-200% Capacity
- 200-250% Capacity
- 250-350% Capacity

Top Zone (0-4 inch) Soil Moisture for the Period Ending July 11th, 2002

Relationship of Soil Moisture to Sclerotinia Risk

Fruiting bodies develop from sclerotia that are near the soil surface when soil conditions are suitable (moisture ≥100% field capacity , temperature 59-64°F) for 10-14 days. Apothecia form from germinated sclerotia and release spores. Temperatures of 59-64°F are optimum but apothecia can form in soils at temperatures of 40-86°F which means they can be produced throughout the growing season if moisture is sufficient.



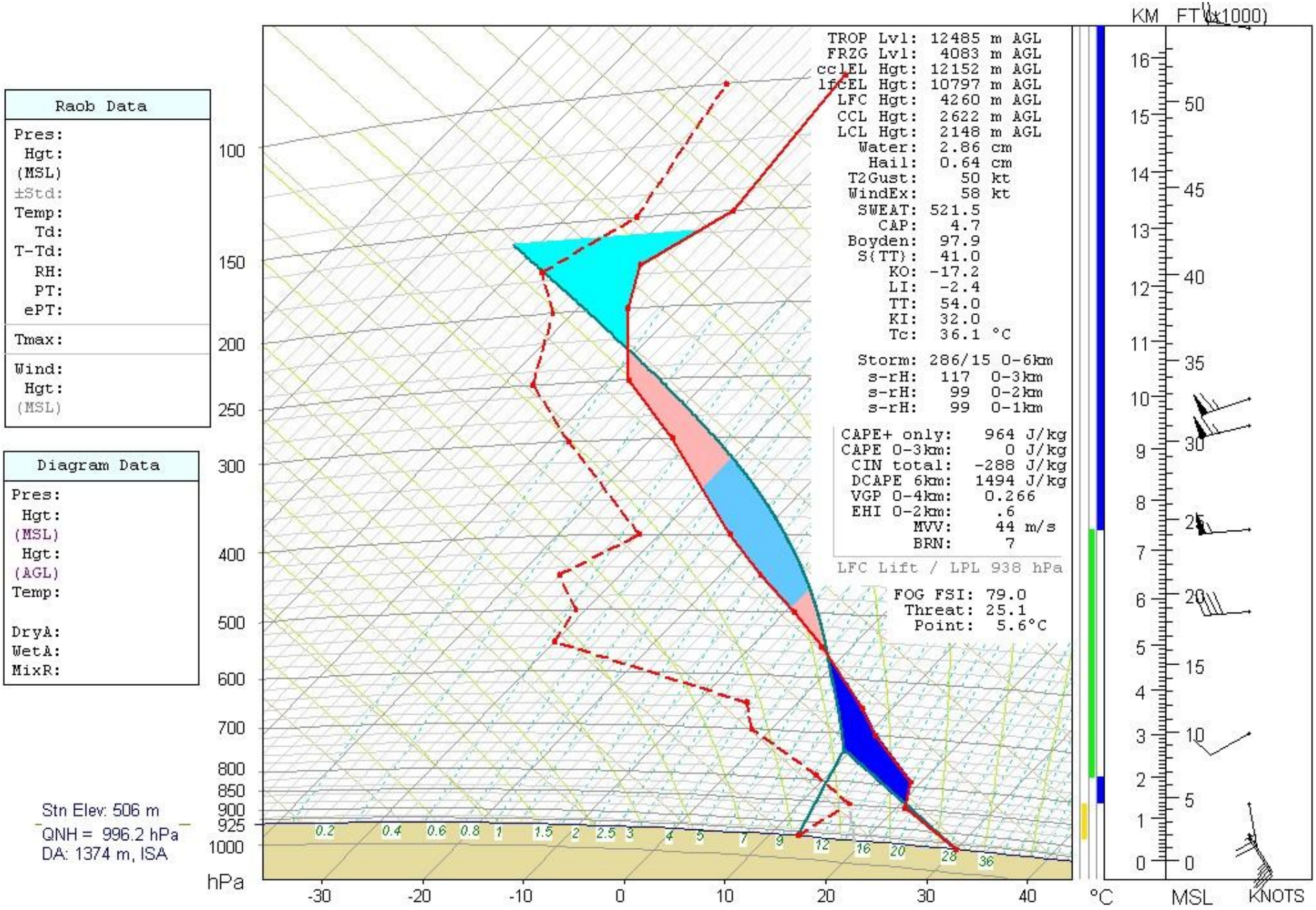
Risk of Sclerotinia Stem Rot in Canola for the Period Ending July 11th, 2002

Legend
- Low Risk
- Moderate Risk
- High Risk

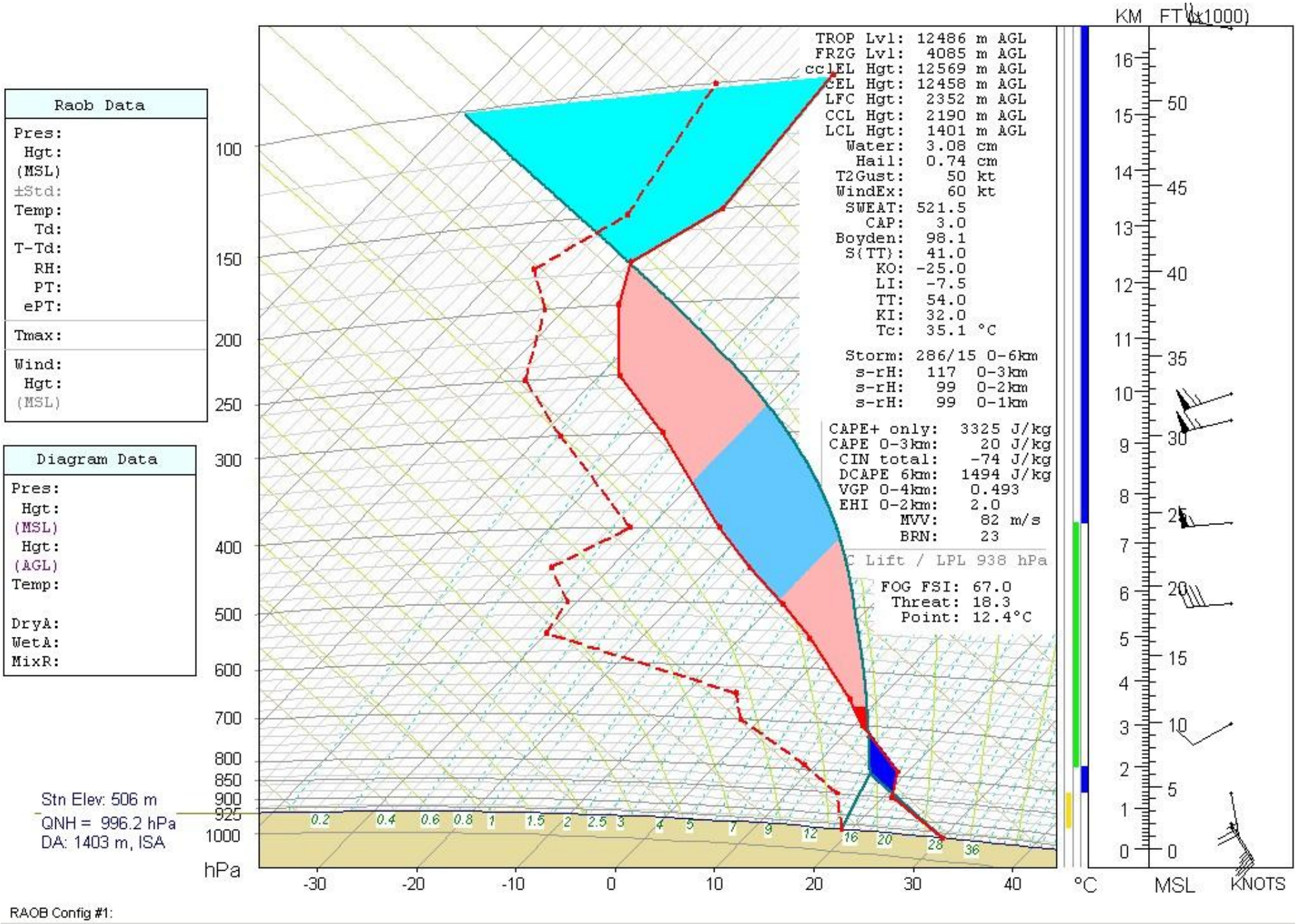
Sclerotinia Risk

Areas appearing in red are at high risk for developing sclerotinia based on consideration of the past 10 days of soil moisture data to 4 inches. Areas in yellow are at moderate risk for development of the spore releasing apothecia. Areas in green are at low risk for disease development.

This risk map is of a regional nature. Further field inspection of the canola crop should occur with regard to growth stages. Risk applies only to canola in flower.



RAOB Config #1:


Raob Data
Pres:
Hgt:
(MSL)
±Std:
Temp:
Td:
T-Td:
RH:
PT:
ePT:
Tmax:
Wind:
Hgt:
(MSL)
Diagram Data
Pres:
Hgt:
(MSL)
Hgt:
(AGL)
Temp:
DryA:
WetA:
MixR:
TROP Lvl: 12486 m AGL
FRZG Lvl: 4085 m AGL
ccLEL Hgt: 12569 m AGL
CEL Hgt: 12458 m AGL
LFC Hgt: 2352 m AGL
CCL Hgt: 2190 m AGL
LCL Hgt: 1401 m AGL
Water: 3.08 cm
Hail: 0.74 cm
T2Gust: 50 kt
WindEx: 60 kt
SWEAT: 521.5
CAP: 3.0
Boyden: 98.1
S{TT}: 41.0
KO: -25.0
LI: -7.5
TT: 54.0
KI: 32.0
Tc: 35.1 °C
Storm: 286/15 0-6km
s-rH: 117 0-3km
s-rH: 99 0-2km
s-rH: 99 0-1km
CAPE+ only: 3325 J/kg
CAPE 0-3km: 20 J/kg
CIN total: -74 J/kg
DCAPE 6km: 1494 J/kg
VGP 0-4km: 0.493
EHI 0-2km: 2.0
MVV: 82 m/s
BRN: 23
C Lift / LPL 938 hPa
FOG FSI: 67.0
Threat: 18.3
Point: 12.4°C
KM FT (x1000)
100
150
200
250
300
400
500
600
700
800
850
900
925
1000
hPa
-30
-20
-10
0
10
20
30
40
°C
MSL
KNOTS
Stn Elev: 506 m
QNH = 996.2 hPa
DA: 1403 m, ISA
RAOB Config #1:

Atmospheric Effect of ET

- In all situations, incrementally increasing the surface dew point temperature via ET increases the CAPE (and storm cloud top) that can, in some cases, significantly increase storm severity
- Also lowers the CIN, CCL, LCL and LFC that effectively decreases the amount of lift required to initiate convection
- Hence, ET can be a significant factor for storm initiation and severity depending on the quantity of added low level moisture and depth of the MBL.

Some Considerations:

1. Maximize spatial resolution with available inputs.

2. Initial soil moisture, post snow-melt, based on modeled fall soil moisture and Freshet Model.

3. Data assimilation system includes near real-time planting-dates. Crop phenology based on accumulated BMT.

4. Stability adjusted aerodynamic resistance (r_a) based on entire PBL, not just surface turbulent layer.

5. Interception / re-evap assumed to operate on a shorter time-step than model's daily water balance, thus neglected.

6. Good coupling assumed between small crop leaves and atmosphere, thus To = Ta.

7. Infiltration stopped by saturation of top-zone of soil.

8. Upper flux of moisture from root to top zone uses force-restore formulation.

9. In near-real time application, provides past and forecast output.