Field evaluation of the Maximum Entropy Production model

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Morais A., Parent A.C., Anctil F., and Music B.
Université Laval, Département de génie civil et de génie des eaux
Why Maximum Entropy Production model?
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Potential evapotranspiration based on empirical relationships that does not close the energy budget

Is there a simple model that would include the energy budget closure and provide evapotranspiration for use with conceptual models and a non-stationary climate?
Outline

- Model description
- Methodology
- Results
- Conclusion
The Maximum Entropy Model: Model derived from thermodynamics (Wang and Bras 2012)

- «Maximization of the transpiration/evaporation rate and the corresponding heat fluxes under the constraint of $Rn$ is the most probable and macroscopically reproducible thermodynamic process among all possible partition of energy fluxes.» (Wang and Bras, 2007)

- Based on the theory of maximum entropy production of Dewar (2005)

- With constraint of surface energy balance:

  Evaporation: $Rn = G + H + E\lambda$
  Transpiration: $Rn = T\lambda + H$
Equations of the 2 models:

**Evaporation**

\[
E = B(\sigma)H \\
G = \frac{B(\sigma) I_s}{\sigma} \frac{I_0 H|H|^{-\frac{1}{6}}}{H}
\]

\[
\sigma(T_s, q_s) = \frac{q_s}{T_s} \frac{\lambda^2}{c_p R_v T_s}
\]

**Transpiration**

\[
T = \frac{R_n}{1 + B^{-1}(\sigma)} \\
H = \frac{R_n}{1 + B(\sigma)}
\]

\[
B(\sigma) = 6 \left( \sqrt{1 + \frac{11}{36} \sigma} - 1 \right)
\]

\[
I_0 = \rho c_p \sqrt{C_1 \kappa z} \left( C_2 \frac{\kappa z g}{\rho c_p T_0} \right)^{-\frac{1}{6}}
\]

\[
I_s = \text{Thermal inertia of soil}
\]
The Canadian Land Surface Scheme (CLASS)

- Sophistic 1 D physical Land surface Scheme for use in atmospheric models
- Good reference since the model is well known and has been validated for a variety of land type.
- CLASS is only used as a comparison tool for the evaluation of the MEP model, if the MEP model gives similar outputs we will gain more confidence in his application.
Field evaluation

Experimental data

- Two micro-meteorological stations located in a potato field, St-Ubalde, Qc (N46 45', W72 20')
- Complete season: June 6th – October 8th 2013 (125 days)
- Observations of latent (Lv) and sensible (Ls) heat fluxes derived from the eddy covariance method

Models

- Maximum Entropy Production model (MEP) from Wang and Bras 2012
- Canadian Land Surface Scheme 3.5 (CLASS) from Vershegy 1992
Meteorological inputs

- Rain gauge CS700, Campbell SCI Precipitation (pr)
- Pyranometer SP-Lite, Kipp & Zonen Global radiation at the surface (rs)
- Net radiometer NR-Lite, Kipp & Zonen Net radiation at the surface (rn)
- Barometer 06103, R.M. Young Atmospheric pressure (ps)
- Heat flux plates HFP01SC, Hukse Flux Soil heat flux (G)
- IRGA LI-7500, LI-COR Water vapour and air temperature (qa, ta)
- 3-D sonic anemometer CSAT3, Campbell SCI 2m wind speed in 3D (v)

<table>
<thead>
<tr>
<th>MEP</th>
<th>CLASS</th>
</tr>
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<tbody>
<tr>
<td>rn, qa, ta</td>
<td>rs, rl**, qa, ta, v, pr, ps</td>
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** rl : Downwelling longwave radiation

How to distinguish between evaporation and transpiration?
The leaf area index (LAI)
Two indices to represent the LAI:

- fg : Ground fraction
- fc : Canopy fraction

100% Bare soil: $fg = 1, \quad fc = 0$

Bare soil and crops: $fg = (1 - fc), \quad fc = \mathcal{F}(LAI)$

100% crops: $fg = 0, \quad fc = 1$

$ETR = E$

$ETR = (fg \times E) + (fc \times T)$

$ETR = T$
Energy budget
Evapotranspiration and energy components
<table>
<thead>
<tr>
<th>Statistics</th>
<th>MEP</th>
<th>CLASS</th>
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<tbody>
<tr>
<td>Evapotranspiration based on LAI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RMSE Flux (W m(^{-2}) d(^{-1}))</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensible</td>
<td>39.20</td>
<td>40.63</td>
</tr>
<tr>
<td>Latent</td>
<td>32.00</td>
<td>33.99</td>
</tr>
<tr>
<td>Ground</td>
<td>22.15</td>
<td>15.73</td>
</tr>
<tr>
<td>RMSE ETR (mm d(^{-1}))</td>
<td>0.84</td>
<td>0.75</td>
</tr>
<tr>
<td>PBIAS Flux (%)</td>
<td>-79</td>
<td>13</td>
</tr>
<tr>
<td>Sensible</td>
<td>6</td>
<td>-72</td>
</tr>
<tr>
<td>Latent</td>
<td>-12</td>
<td>-10</td>
</tr>
<tr>
<td>Ground</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Latent heat flux

![Graph showing latent heat flux comparison between MEP and Observed, and MEP and CLASS models.](image-url)
Sensible heat flux

- MEP
- Observed

- MEP
- CLASS

$L_s$ (W/m²)

DOY

239 240 241 242 243 244 245 246 247 248 249 250
Ground heat flux

![Graph of Ground heat flux showing comparison between MEP and Observed data, as well as MEP and CLASS data. The x-axis represents DOY from 239 to 250, and the y-axis represents G (W m⁻²).]
Conclusion

- MEP gave encouraging results for use as an alternative evapotranspiration model
- Advantage of only requiring a few meteorological inputs and physiological parameters
- A simple and general model which may fit for global scales
Merci pour votre attention!

Thank you for your attention!