Progress Towards Calculating Actual Evaporation over the Canadian Prairie Region during Drought

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Canada Dry

‘What a difference a year makes: satellite images reveal drought's impact on Alberta farms and ranches’

By Steven Fick and Eric Harris

http://www.canadiangeographic.ca/Magazine/mj03/alacarte.asp

Landsat 7 images: Wainwright, Alta

Rainy July 2001

Dry July 2002

Evaporation: Land ↑, water ↓

Biomass less than normal

Parched veg; ponds disappearing

Evaporation: Land ↓, water ↑
Region and Time Period of Interest

- Prairie “agricultural” region: Alta, Sask, Man
- Growing period: May – August (2001/02)
Modeling Approach

- Integrate climate and remote sensing data with a physically-based evaporation model
  - Estimate daily actual evaporation approximately once every 16 days (i.e. 2x per month)
  - Map spatial patterns of actual evaporation
  - Relative to normal conditions: instructive description of drought
Intro to Estimating Regional Evaporation

- **3 basic methods that use remote sensing data**
  - Iterative energy balance inversion
  - Residual energy budget (Jackson et al., 1977)*
  - Parameterized model inputs

- **Basic limitations of the models**
  - Iterative solutions require detailed descriptions of soil-vegetation system and complex physics
  - Residual method: energy budget terms estimated directly except for evaporation*
  - Input parameterizations often empirically-based

* Bussières et al (1997)
Physically-Based Approach

- Granger complementary/feedback model (Granger and Gray, 1989; Granger & Pomeroy, 1997)
  - Extension of Penman’s “potential evaporation” model
  - Daily estimates of actual evaporation obtained directly
  - Does not require soil moisture data to derive parameters
  - Can be coupled with soil moisture data for estimates of soil water limited actual evaporation

- Basic principles of complementary/feedback relationships
  - Drying surface: actual evaporation ↓, potential evaporation ↑
  - Surface/atmospheric conditions reflections of each other: Surface temp (Ts) ↑, vapour pressure deficit ↑
Data Requirements and Sources

- **Atmospheric data**
  - Air temp, humidity, wind speed, ↓shortwave, ↓longwave, reference value of daily net radiation
  - Remote sensing data – Midday images (~1900h UTC)
  - Albedo, surface temperature, surface roughness

- **Consistent and reliable regional datasets?**
  - Environment Canada stations (coarsely distributed)
  - North American Regional Reanalysis (32 km gridded forecast / fitted outputs)
  - MODIS (1 km albedo; 1 km surface temp)
  - AVHRR (1km land cover data; 12 and 31 classes)
Environment Canada Data

- **Hourly obs: Temp, humidity, wind speed, pressure**
  - Approx. 95 stations across Prairie agricultural region

- **Observations to region interpolation problem?**
  - Kriging: Area vs # of stations? → too much smoothing
  - Theissen Polygons/Isolines from polygons
  - Minimum Curvature Spline
Comparison of Air Temp: Interpolated Data (Spline) vs Environment Canada Obs

- Overall good fit with observations
  - Noticeable anomalies: result of missing data values
  - Possible to fill missing station data with NARR data
NORTH AMERICAN REGIONAL REANALYSIS (Mesinger et al., 2006)

Courtesy of Ouranos / DAI:

- Follow up to NCEP–NCAR Global Reanalysis
- NARR: improved resolution and accuracy
  - 32 km gridded data; 3-hour forecasts
- Surface observations assimilated
  - Pressure, wind, precipitation
- Surface observations not assimilated
  - Air temperature – “detrimental to forecast”!?
NARR Output vs Environment
Canada Observations (3-hour)

- Pressure (2 m): systematic underestimate (correctable)
- Wind speed (10 m): less sensitivity than roughness height
- Air temp (2 m): tendency to overestimate (correctable)
- Dewpoint temp (2 m): tendency to underestimate (correctable)
Cell by Cell Comparison of Temp (°C)

- Interpolated 32 km raster (Spline) vs NARR gridded output (May 9, 2001)
  - Generally poor agreement between grid cells not influenced by climate station observations

![Comparison of Spline Interpolated and NARR Gridded Data](image)

$R^2 = 0.6$
Processed MODIS Land Surface Temp (1 km)

Data courtesy of Andrew Davidson (NLWIS-AAFC)

July 12, 2001

July 12, 2002
Other MODIS and AVHRR Imagery

- **CCRS MODIS Bi-directional reflectance data (1 km)**
  - Obtainable from GeoGratiss (NRCan)
  - Available for 2000 – 2004
  - 16-day composites
  - Algorithms for deriving BRDF/Albedo data

- **AVHRR land cover data product (1 km)**
  - Latifovic and Pouliot (2005)
  - “spatially and temporally consistent land cover maps”
  - 12 classes and 31 classes available
  - Application: deriving roughness heights
Case Study at St. Denis, Sask (2007)

- G-D model (same as in Cold Regions Hydrological Model)

Validation site

Eddy Cov
E = 2.2 mm

Granger-Gray
E ≈ 2.6 mm
Conclusions

- Development of regional scale dataset achievable
  - Interpolated daily temp: Environment Canada; correct and substitute NARR data for missing data; Spline surface
  - Daily pressure and wind: NARR
  - Midday shortwave ↓, longwave ↓: NARR
  - Midday imagery of albedo and surface temp: MODIS
  - Roughness heights: AVHRR
  - Reference site for daily net radiation value: Lethbridge (Ameriflux)

- Reference all data to common GRID: LCC / NAD 83; build and run model in ArcGIS

- Projected time for completion of evaporation mapping of drought – this winter.