A Model for Estimating Hourly Lake Evaporation Rates

NWRI

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IP3 Study of Lake Evaporation :

Evaporation is the link between the energy and water budgets;

Meteorology, climate and hydrology models operate with short time steps; ~ 1 hr;

Open water evaporation responds differently than landsurface evapotranspiration;

<u>Need Open water evaporation model for hourly time steps.</u>

Evaporation Models are parameterizations of one or more of the conditions required for evaporation to occur:

For evaporation to occur there must be:

- a supply of water at the surface,

- a supply of energy to satisfy the requirement for the phase change, and

- a transport mechanism to carry the vapour away from the surface (wind, vapour gradient).

For Open Water:

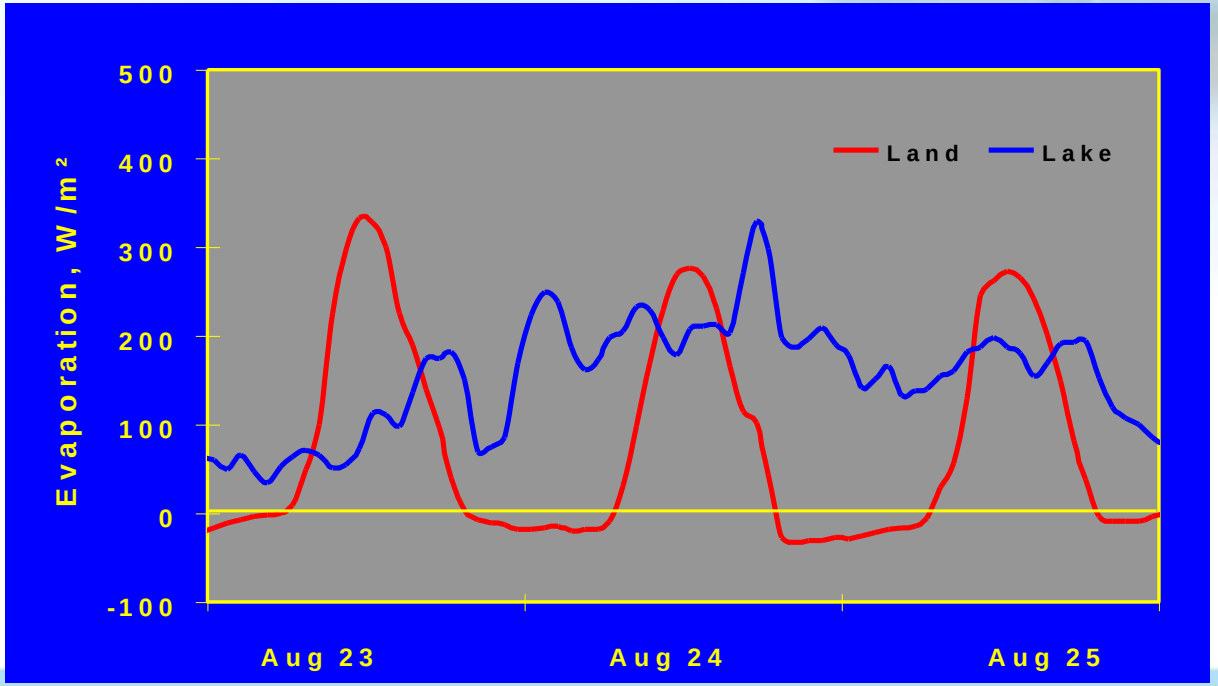
- The supply of water at the surface is not an issue.

The surface is saturated; this non-varying state does not provide useful information for the parameterization of the evaporation rate.

For Open Water:

- The **radiant energy** penetrates deeply and so is not immediately partitioned at the surface.

One should not expect a direct correspondence between net radiant and evaporation for short time periods.



Quill Lake, 1993

For Open Water:

- The transport mechanism remains as the single, most important condition which can be used to describe evaporation at sub-daily rates.

The governing parameters are:

- vapour gradient
- wind speed
- stability

The available observations are:

- water surface temp.(?), wind speed(?)

Evaporation from open water (lakes and ponds) involves *advection*:

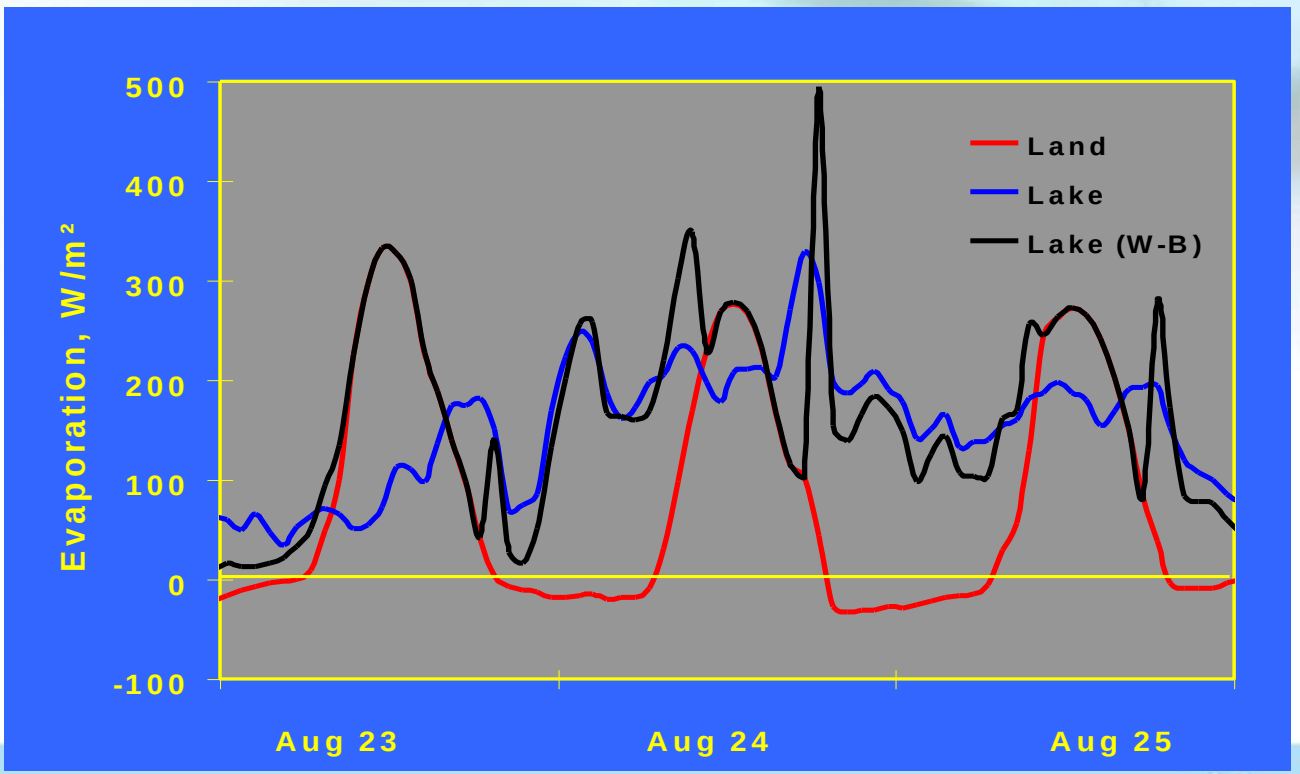
- Conditions over the water are affected by conditions over the adjacent land surface;

- Gradients of Water Vapour and Temperature over the water are affected by the *land-water contrast*.

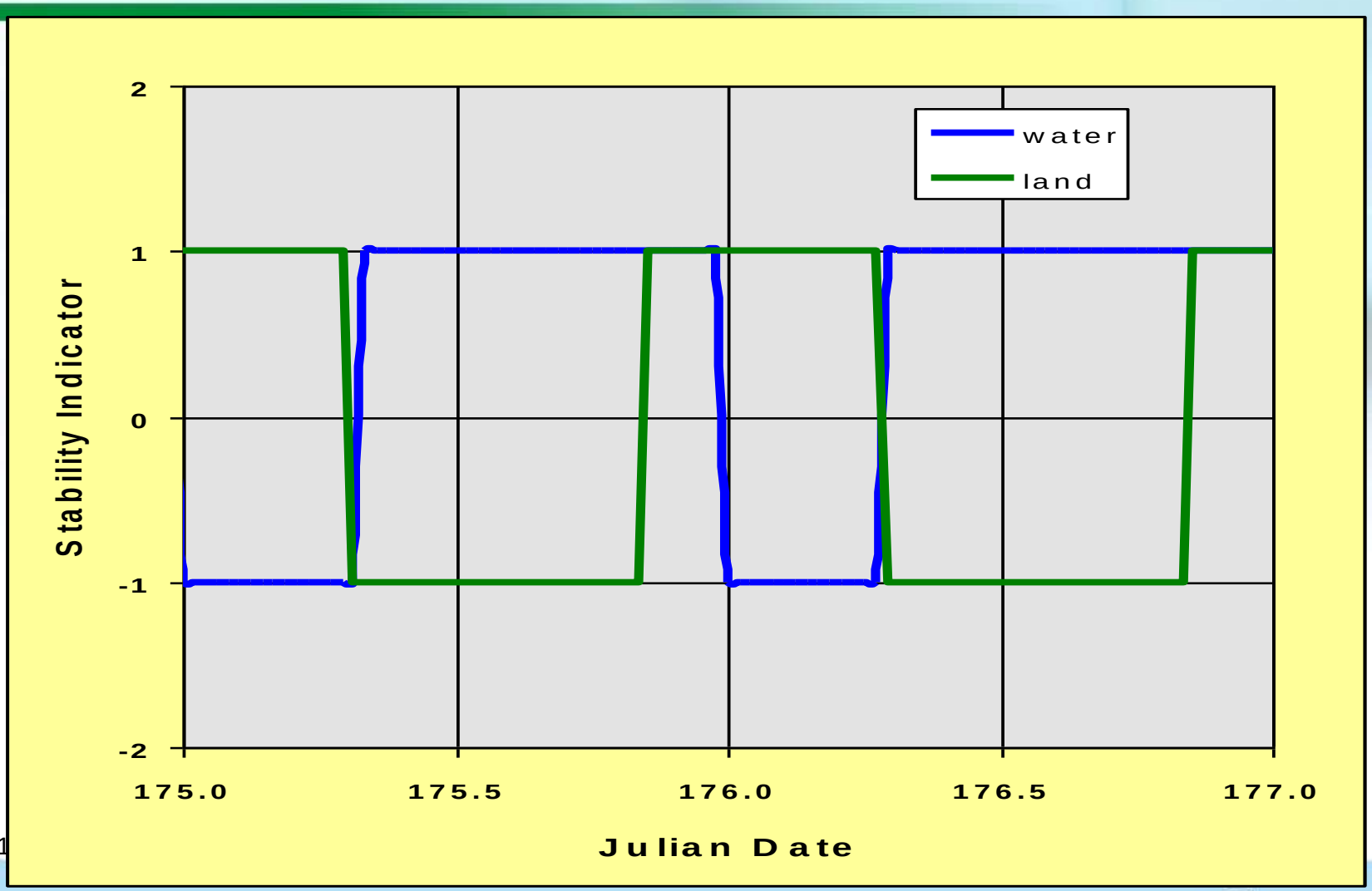
Weisman and Brutsaert (1973), using dimensional analysis, developed the following:

$$E_l = E_a + a\rho u_* \cdot (q_s - q_{as}) \cdot (X_f / Z_o)^{-b}$$

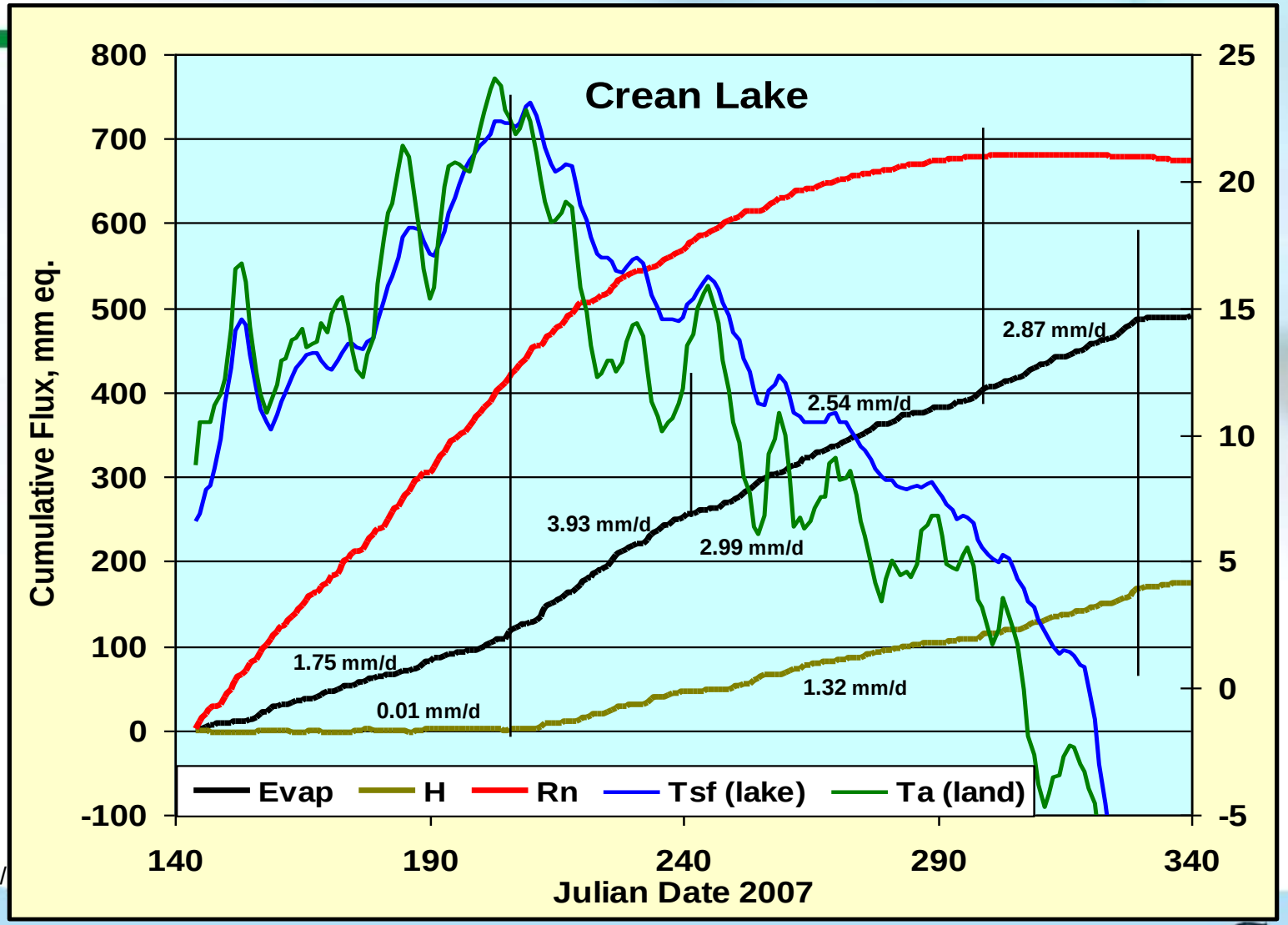
Where the coefficients *a* and *b* are related to dimensionless advection parameters.



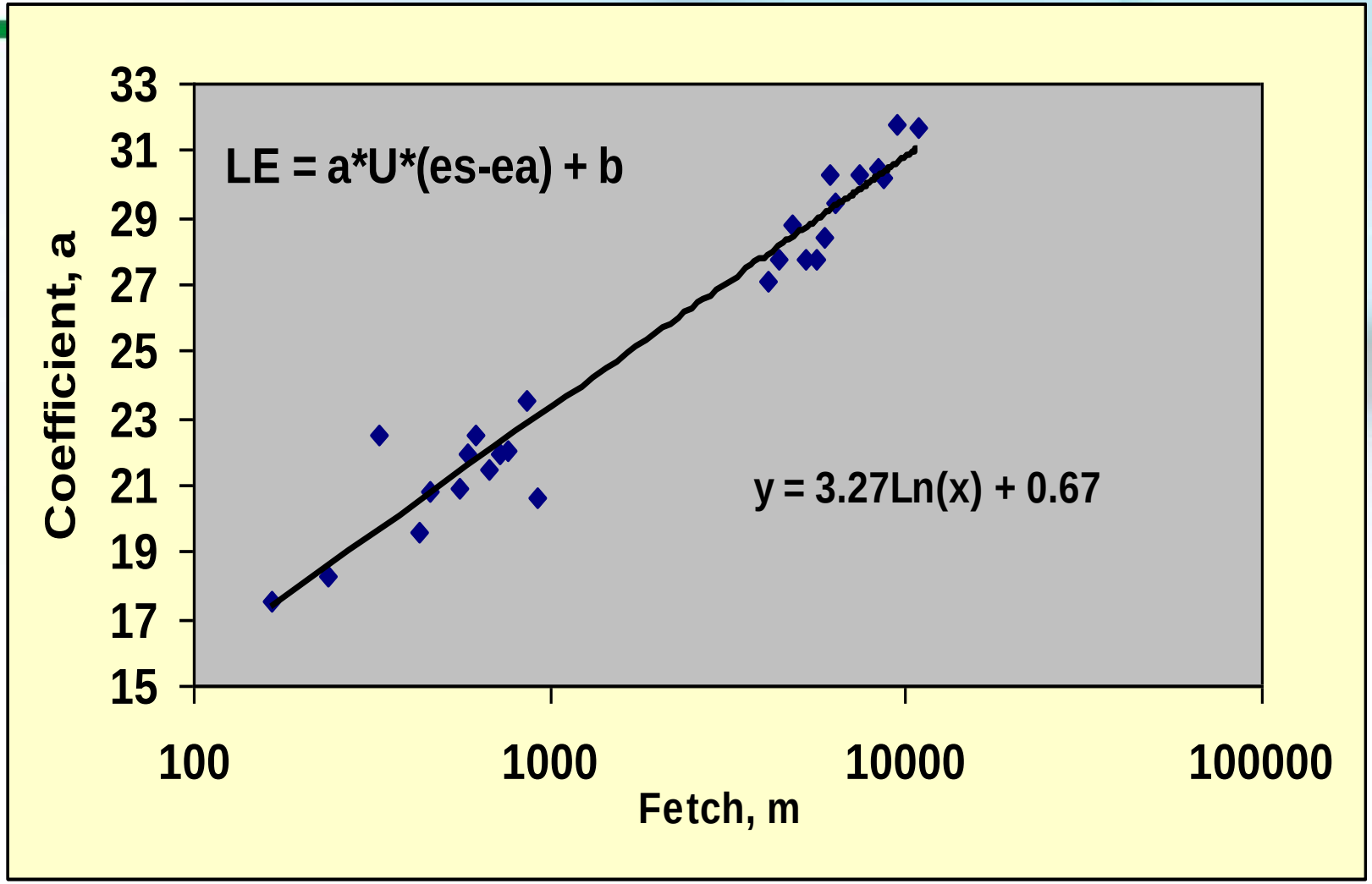
Diurnal Cycle of Stability: Land and Water



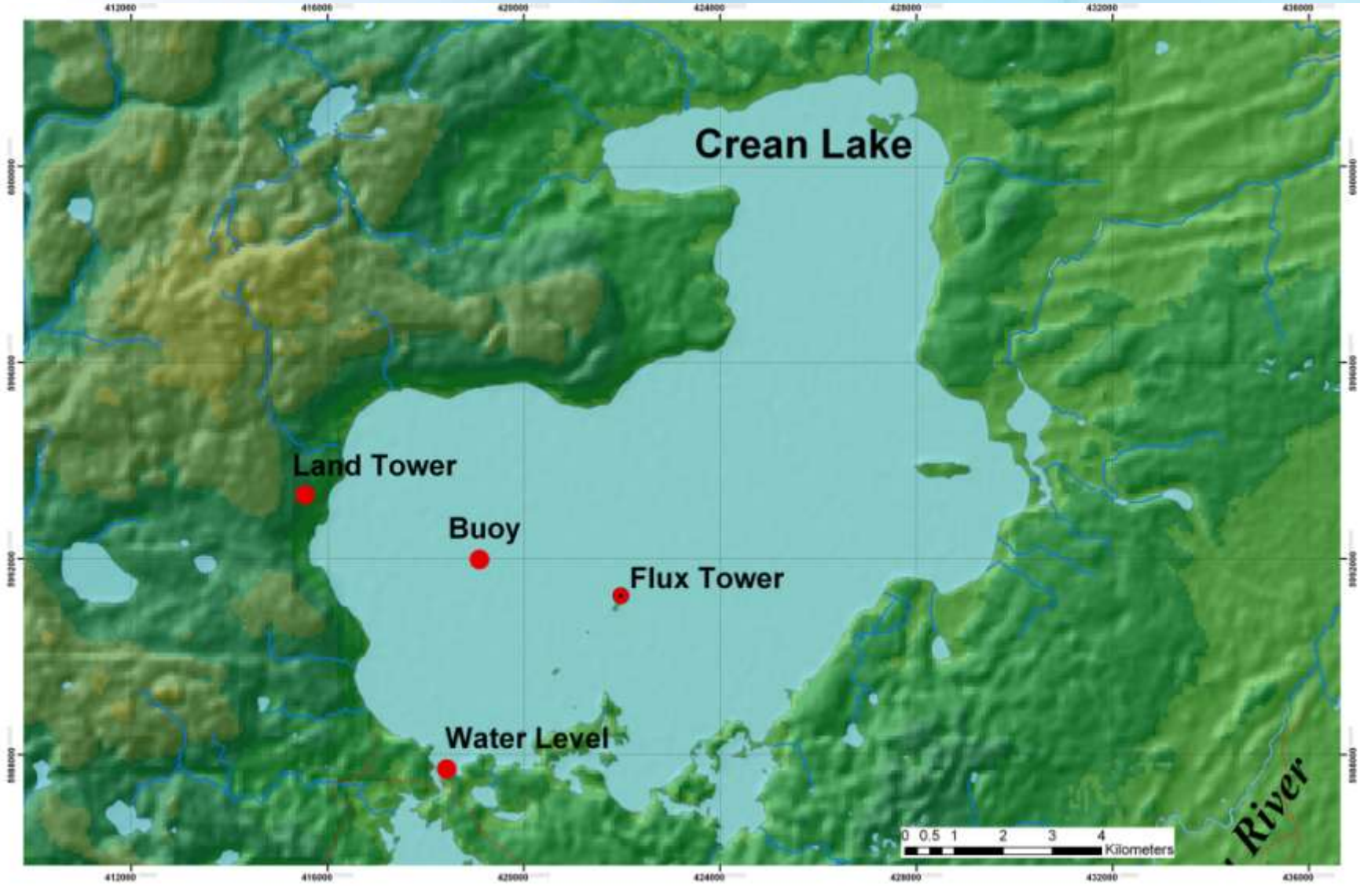
Seasonal Cycle of Stability



Effect of Fetch on Evaporation



Crean Lake, PANP, 2006



Crean Lake, 2006

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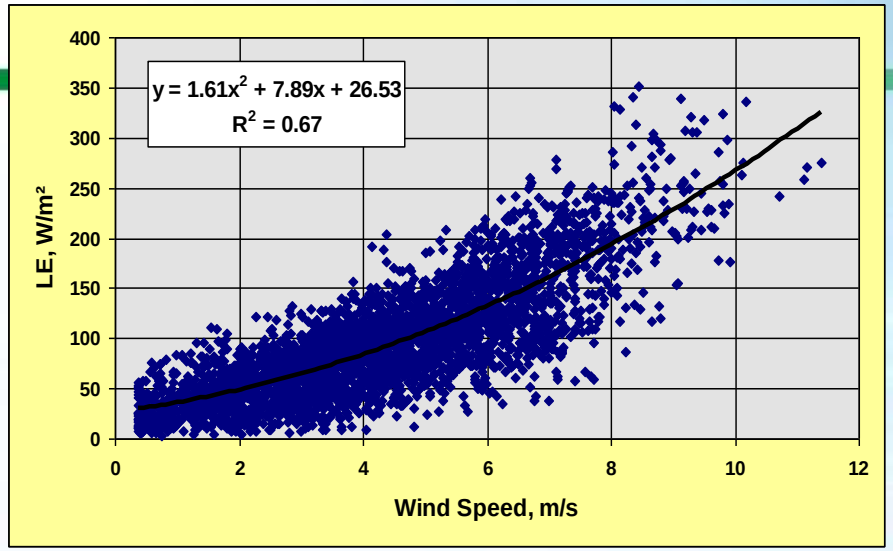
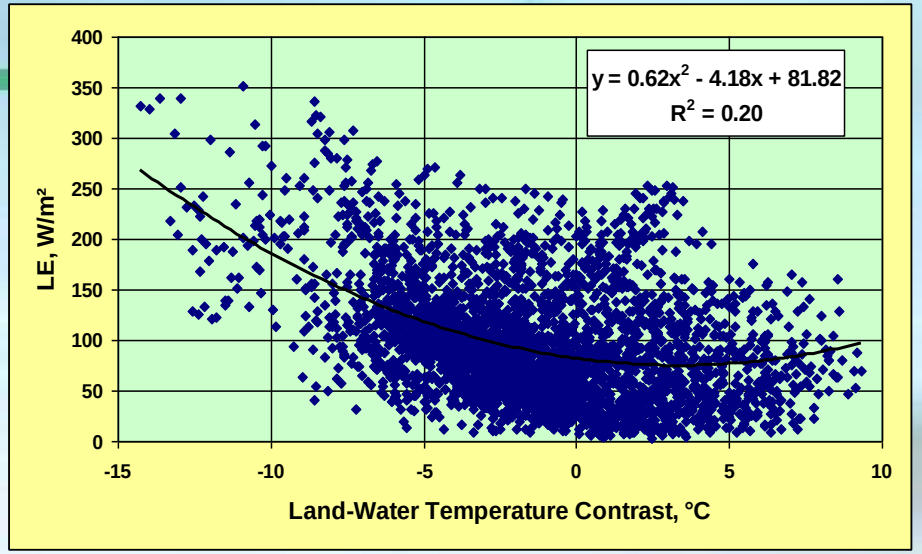
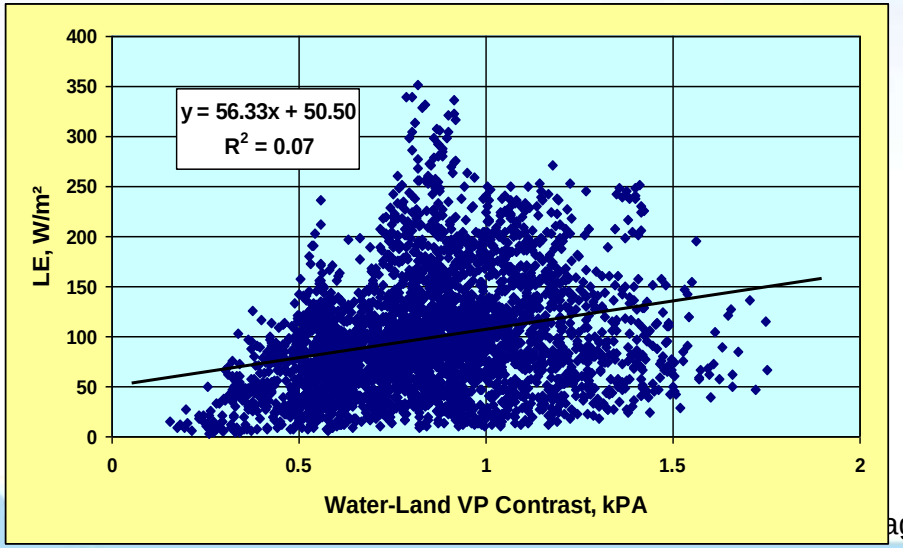
Landing Lake, NWT, 2007

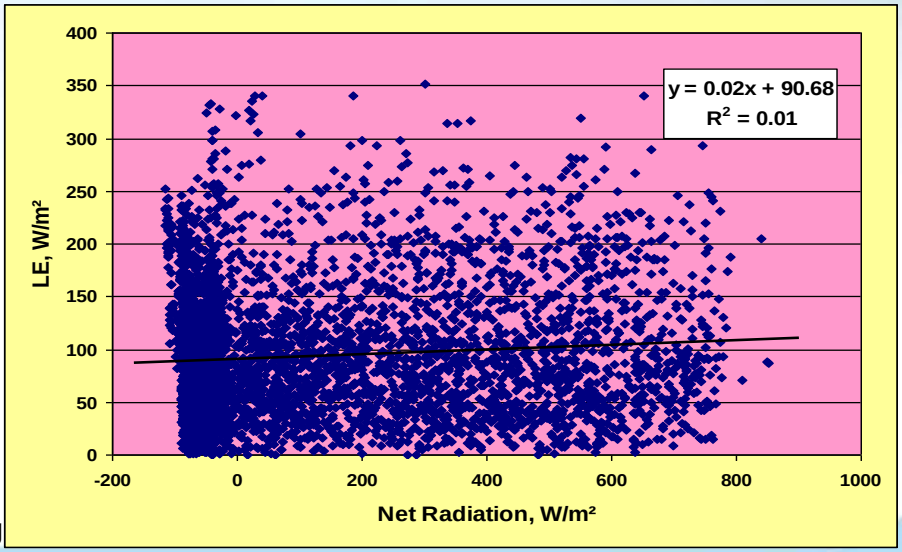
Landing Lake, NWT, 2007

Effect of Wind, T, VP and Rn on Lake Evaporation









Modeling Hourly Lake Evaporation

Approach using the development of relationships based on:

- Vapour gradient
(land-water VP contrast)
- wind speed,
- stability
(land-water temperature contrast)
- distance from shore

Modeling Hourly Lake Evaporation

Data from Crean Lake (2006-2008) and Landing Lake (2007-2008) were sorted into:

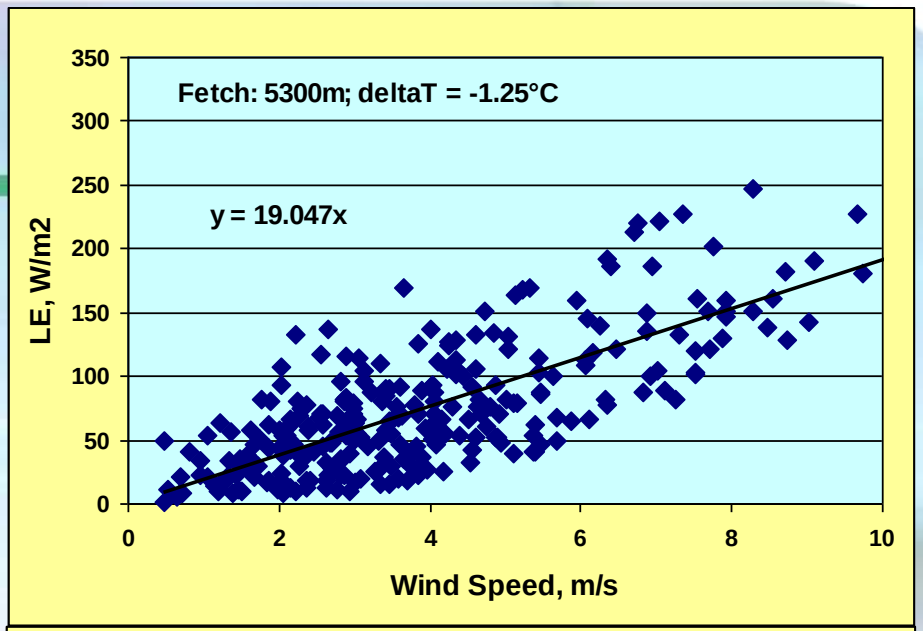
- stable and unstable categories
- distance from shore (fetch)
- land-water temperature contrast

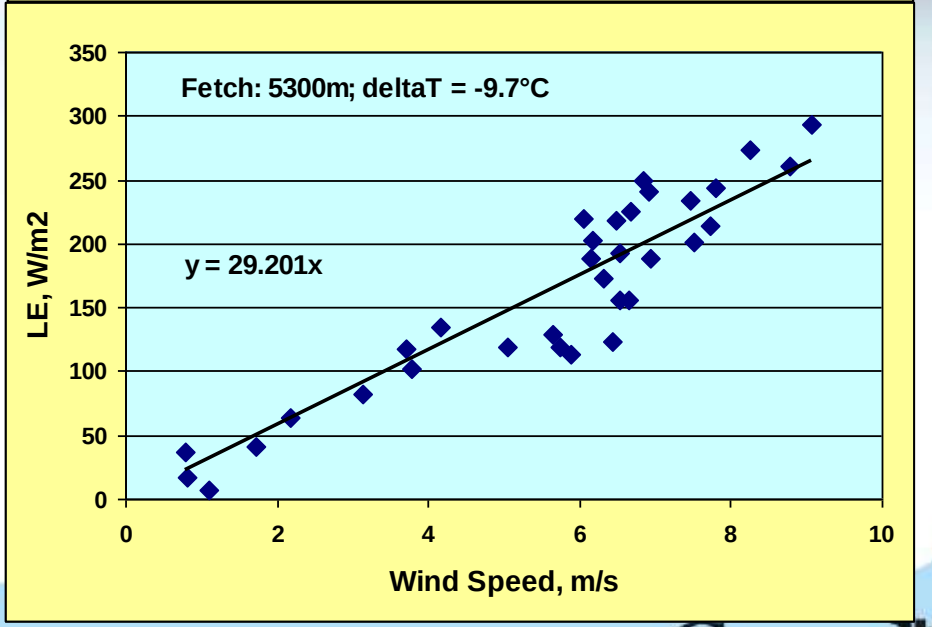
- LE related to wind speed

Modeling Hourly Lake Evaporation

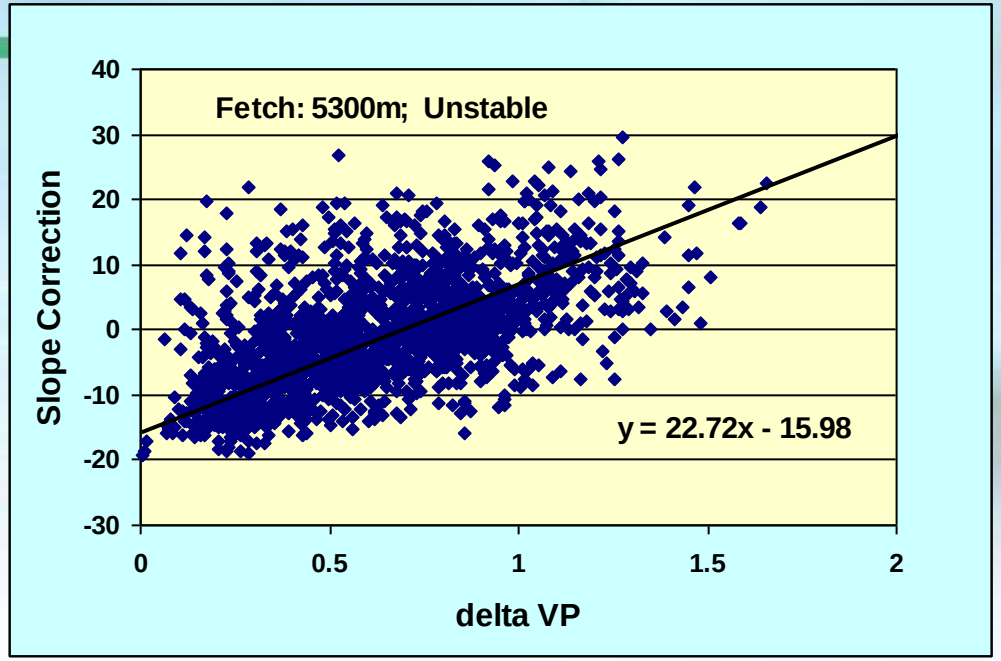
- LE = a*U

- a = f(dT, X)





Modeling Hourly Lake Evaporation



- LE = a*U
  a = f(dT, X)

Refine the slope (a) relationship

a = f(dT, dVP, X)

Hourly Lake Evaporation Model

$LE = a * U$; $a = f(dT, dVP, X)$

$a = b + m * dT + n * dVP$

$b, m, n = f(X)$

b, m, n values for stable, unstable

Hourly Lake Evaporation Model

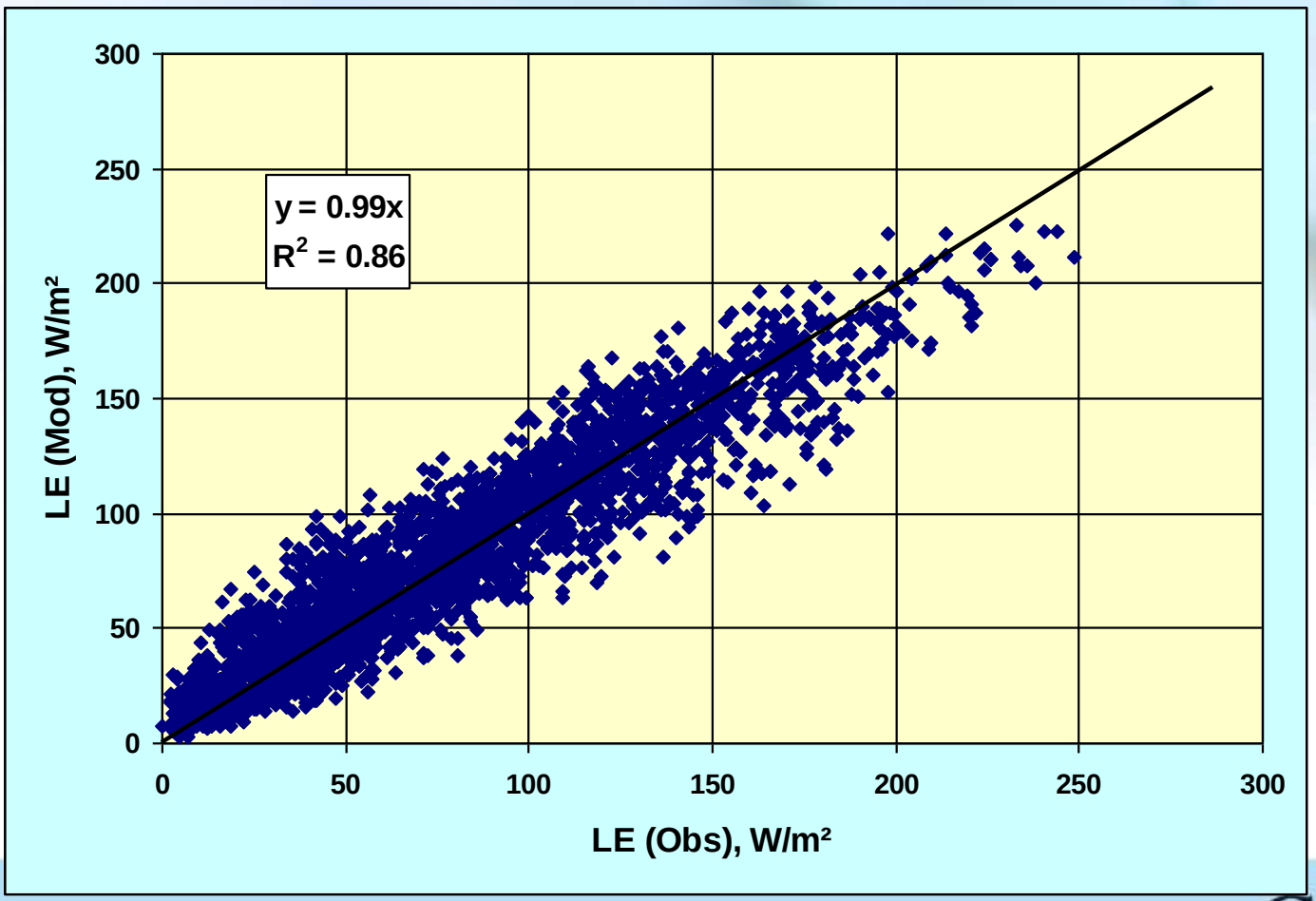
Verification data sets :

Crean 2005 (land data from mixedwood site)

Quill 1993 (Heatmex data)

Hourly Lake Evaporation Model

Verification results *Crean 2005*



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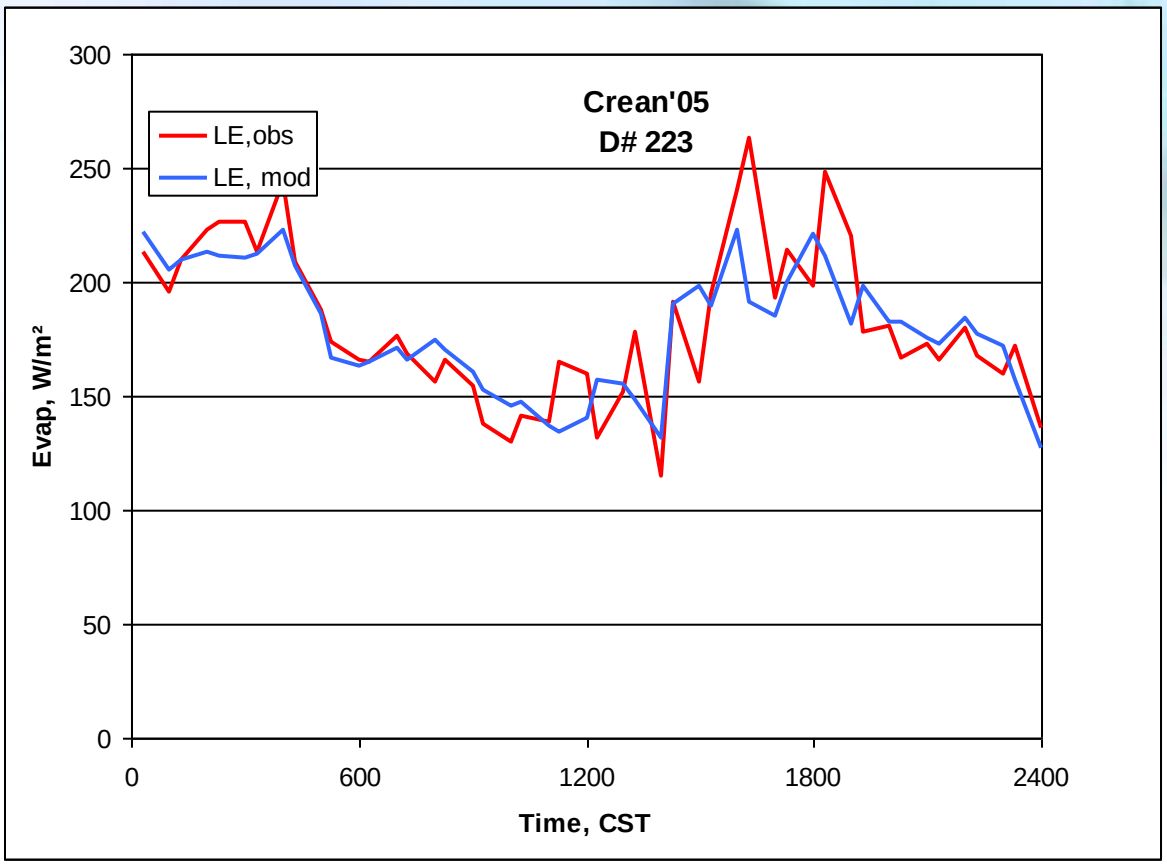

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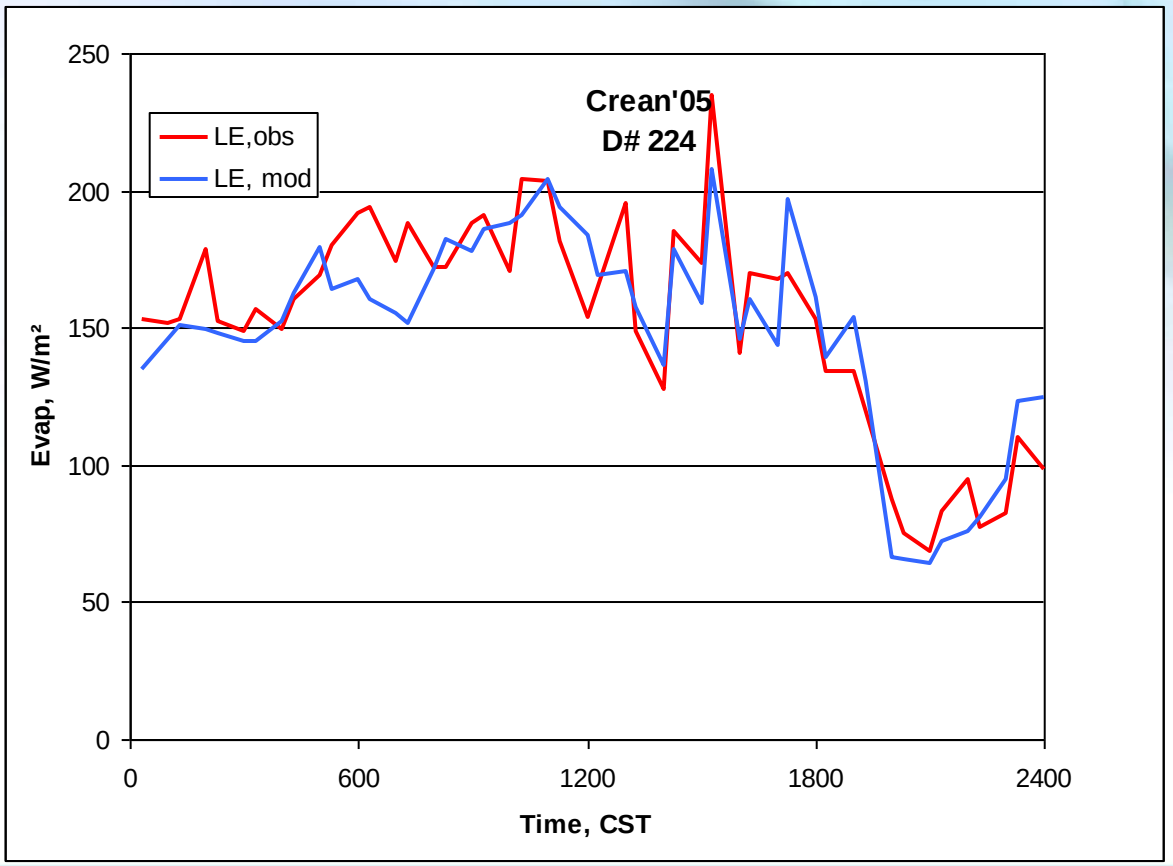

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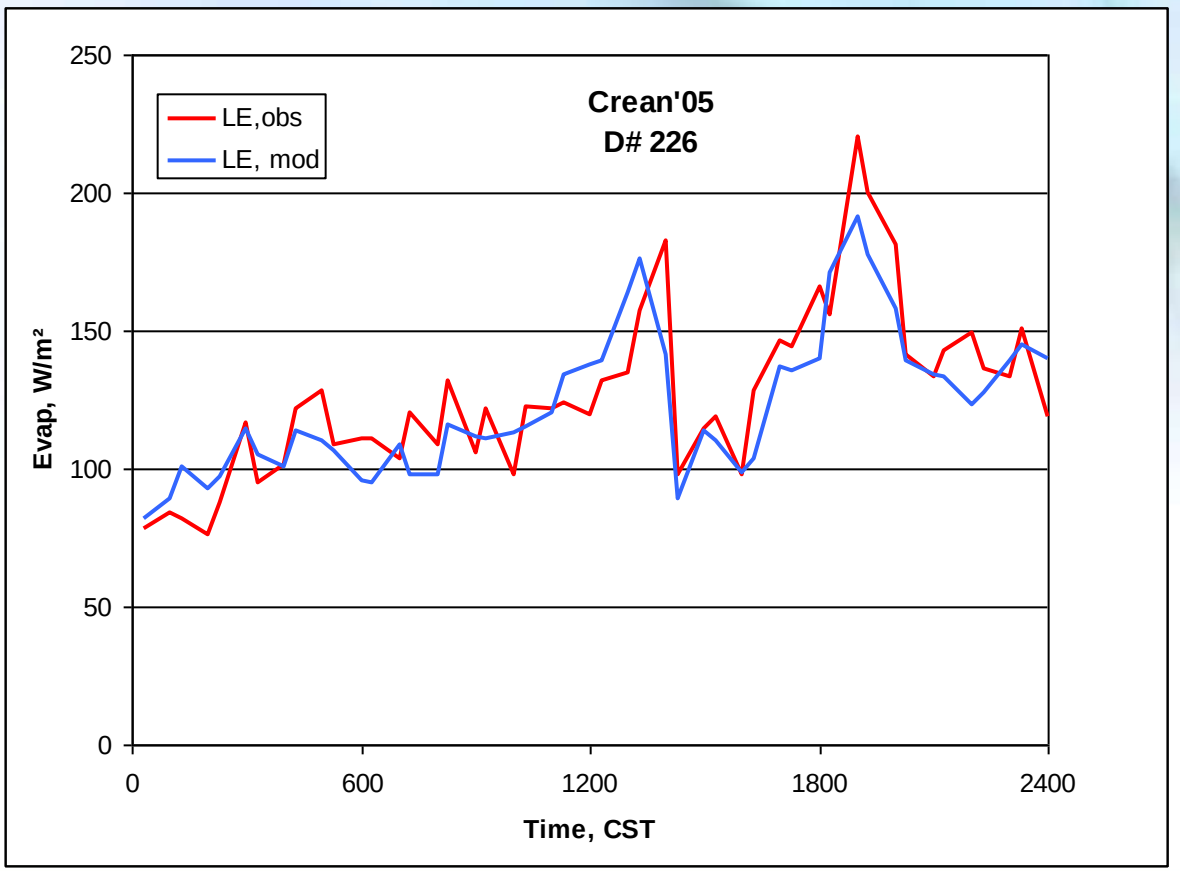

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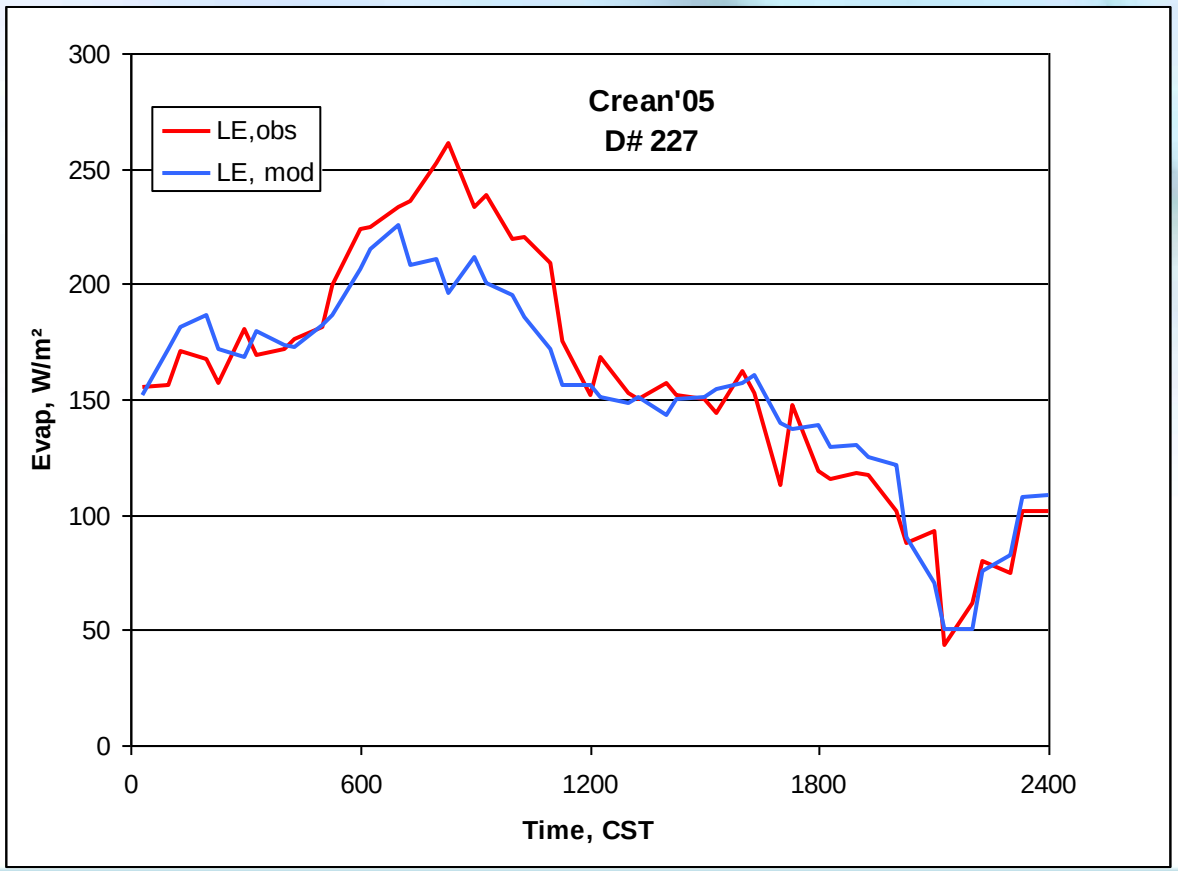

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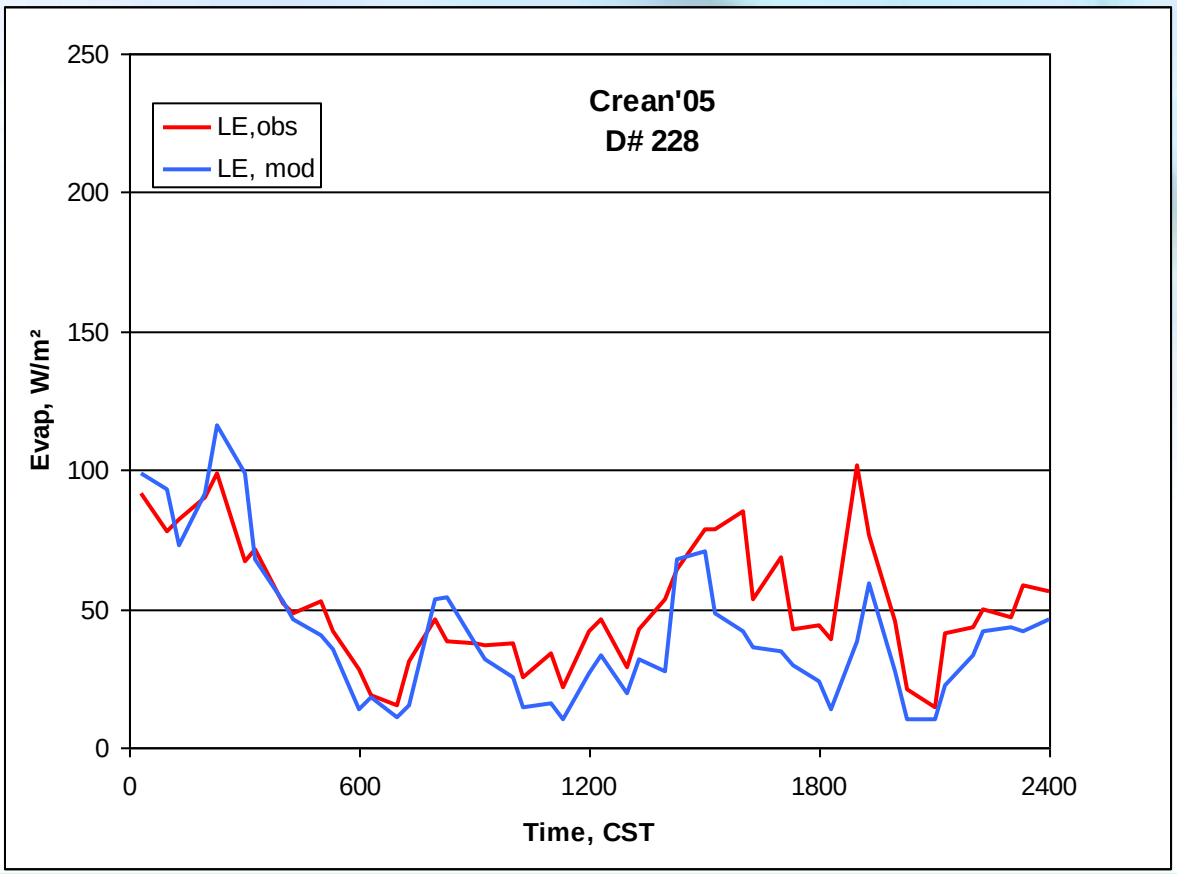

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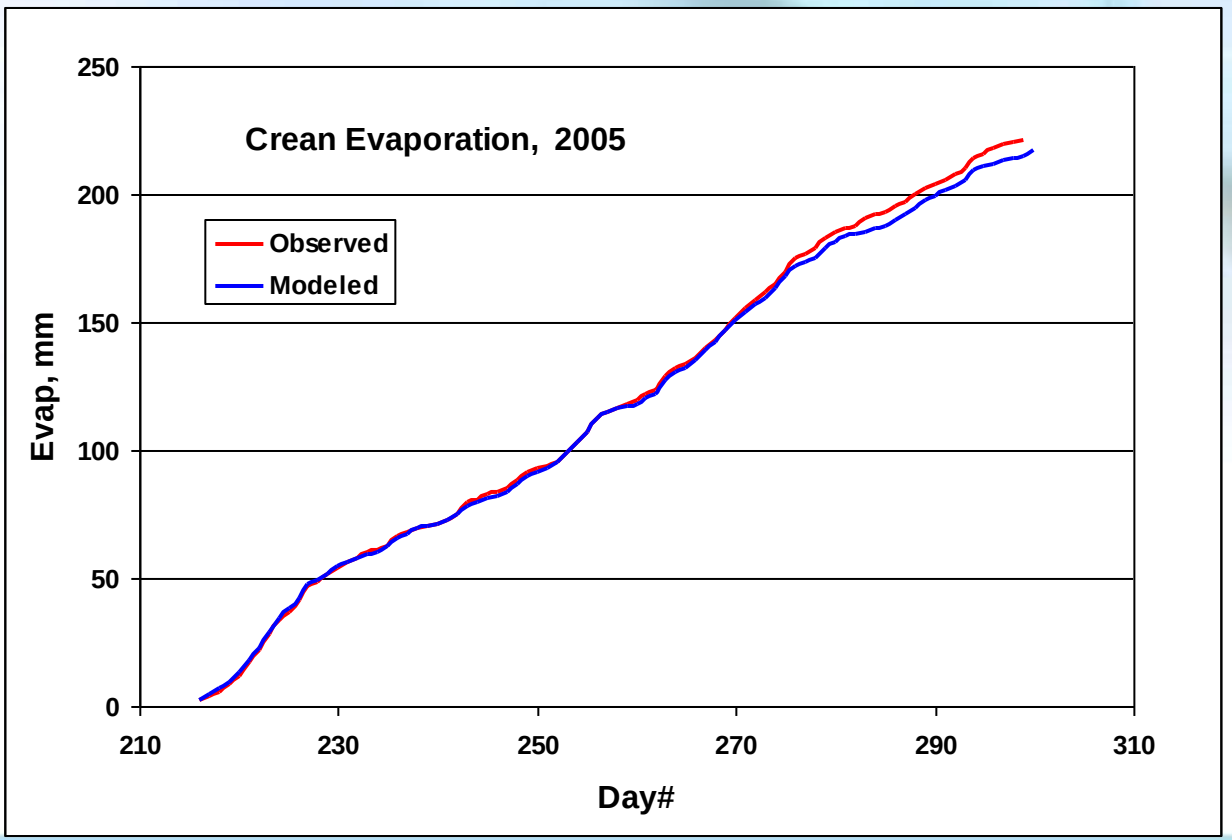
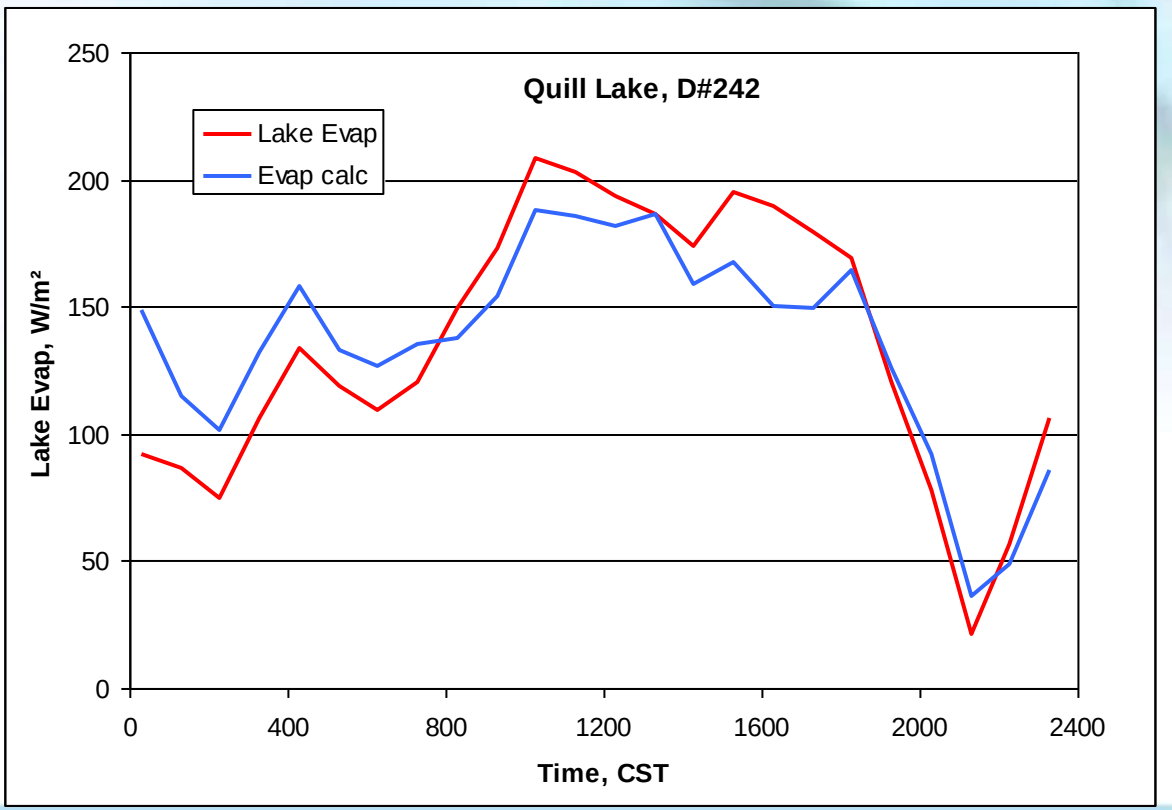


Hourly Lake Evaporation Model

Verification results *Quill 1993*



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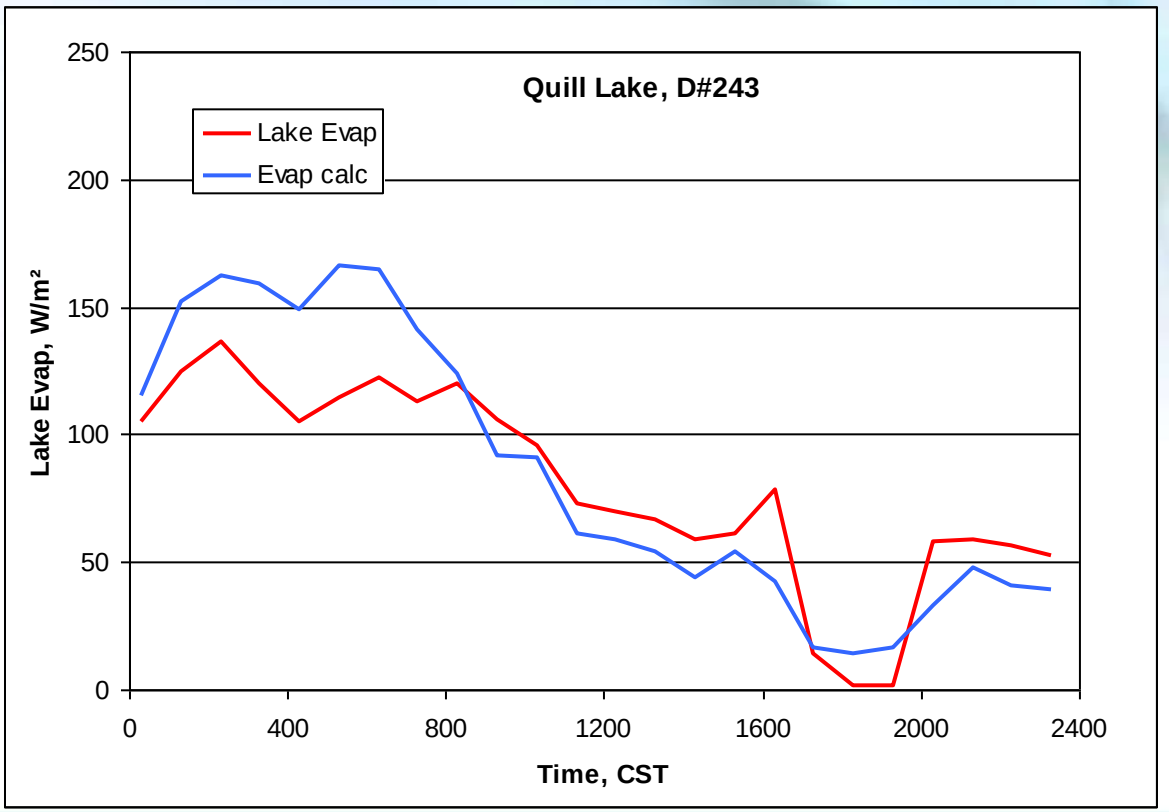

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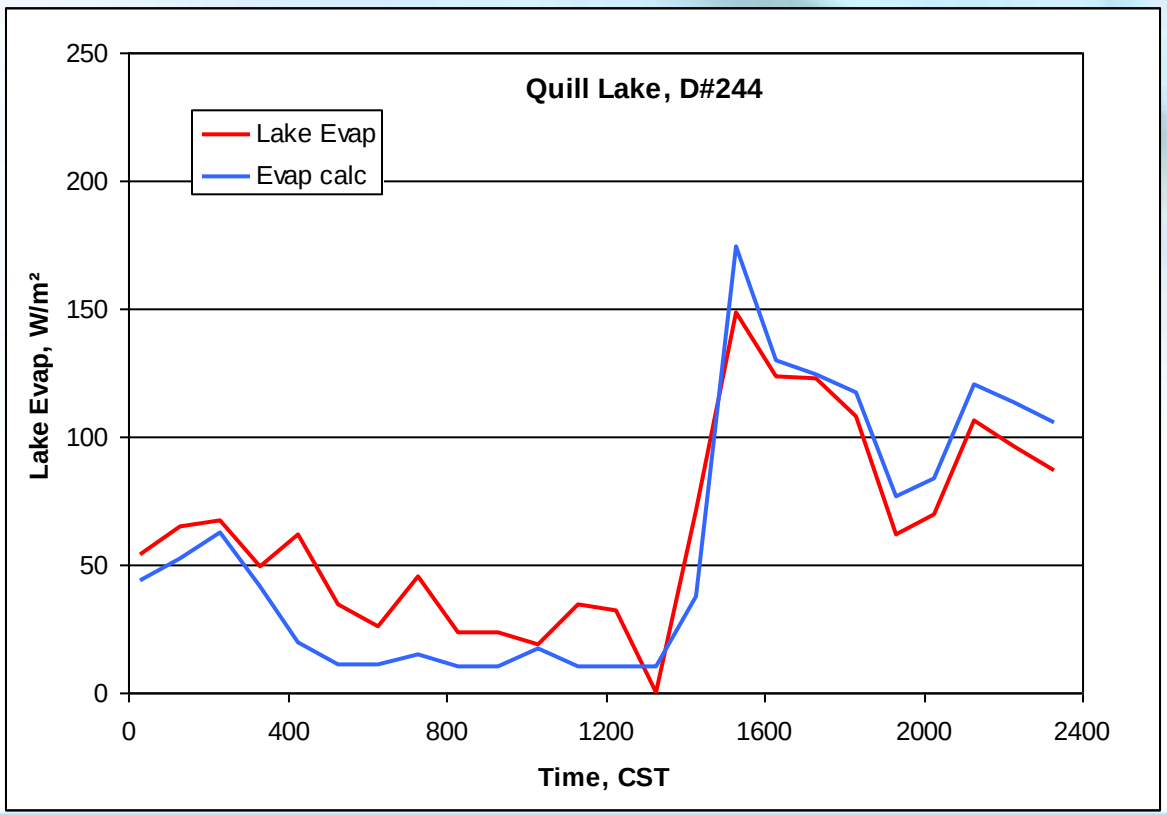

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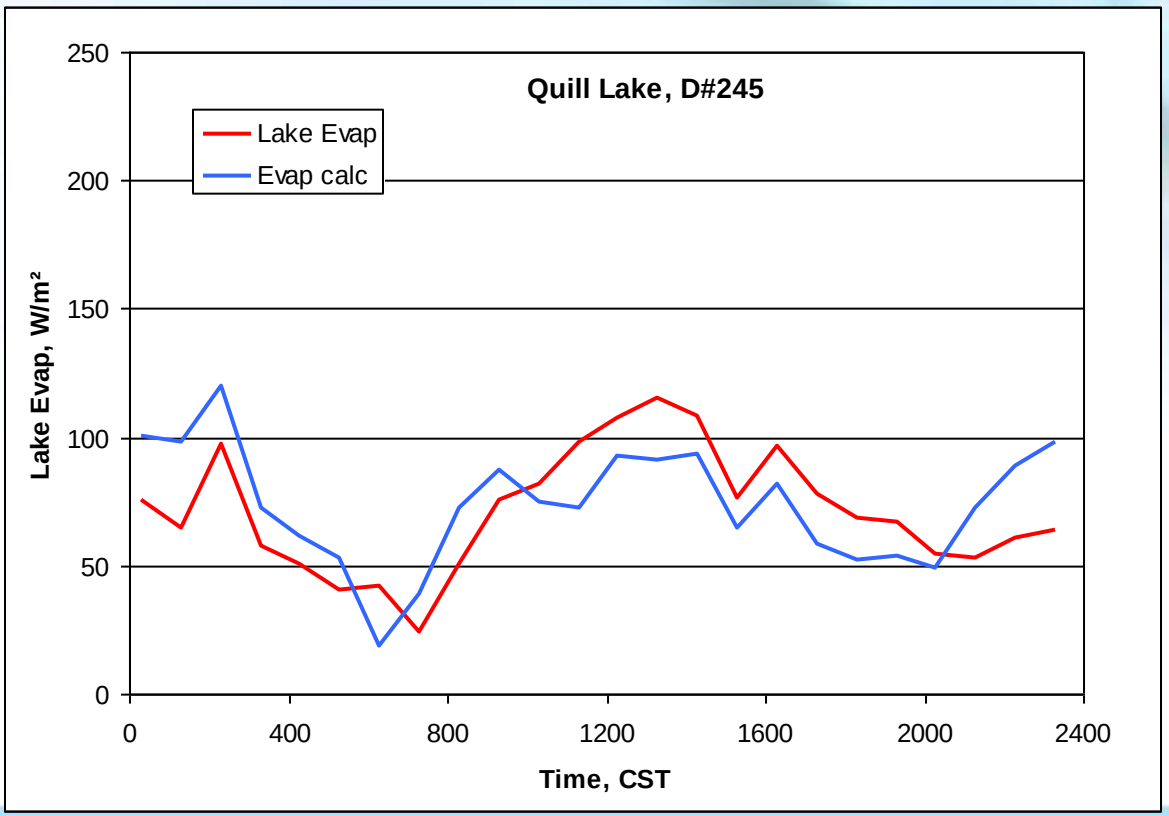

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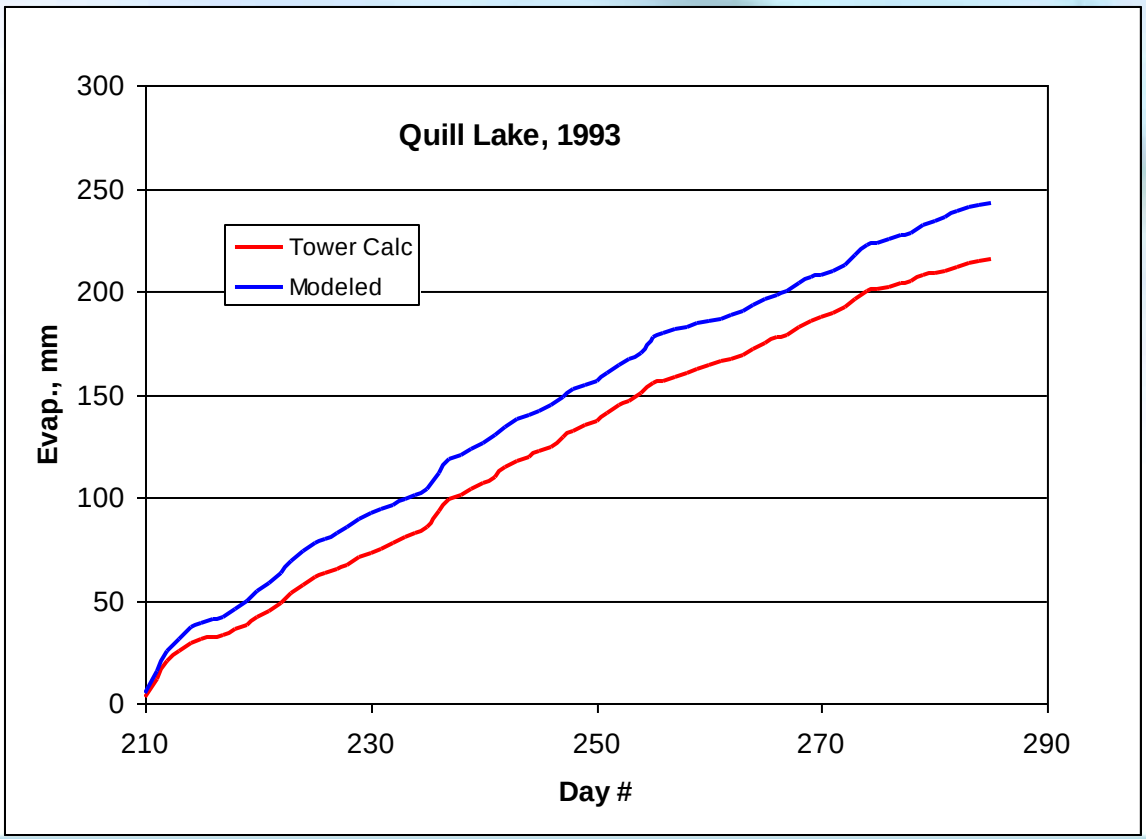


Conclusions

- First-generation model for ***Hourly Lake Evaporation.***

- Relatively simple, reliable
- Requires land data: Ta, VP, Udir
- Requires lake data: Tsf, U, Fetch

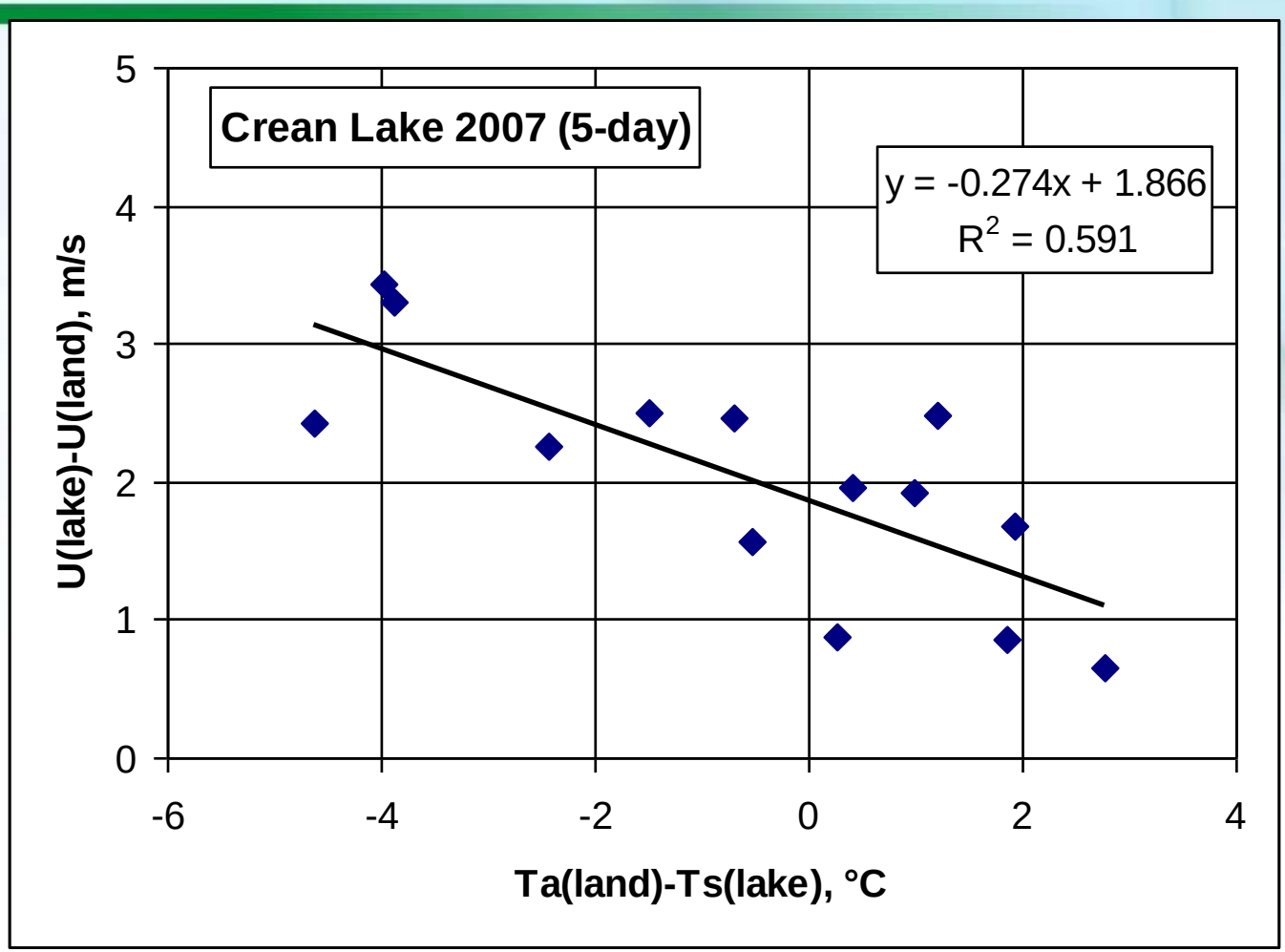
Things to do

- Relationship between Lake and Land windspeeds
- Verification with Whiteswan Lake
  - Fill fetch gap
- Apply to total lake area.
  - (Effective fetch vs Wind Direction)
- Test in model framework (RCM?, MESH?)
- Redo and simplify Weisman-Brutsaert advection analysis with better parameterizations for stable conditions.

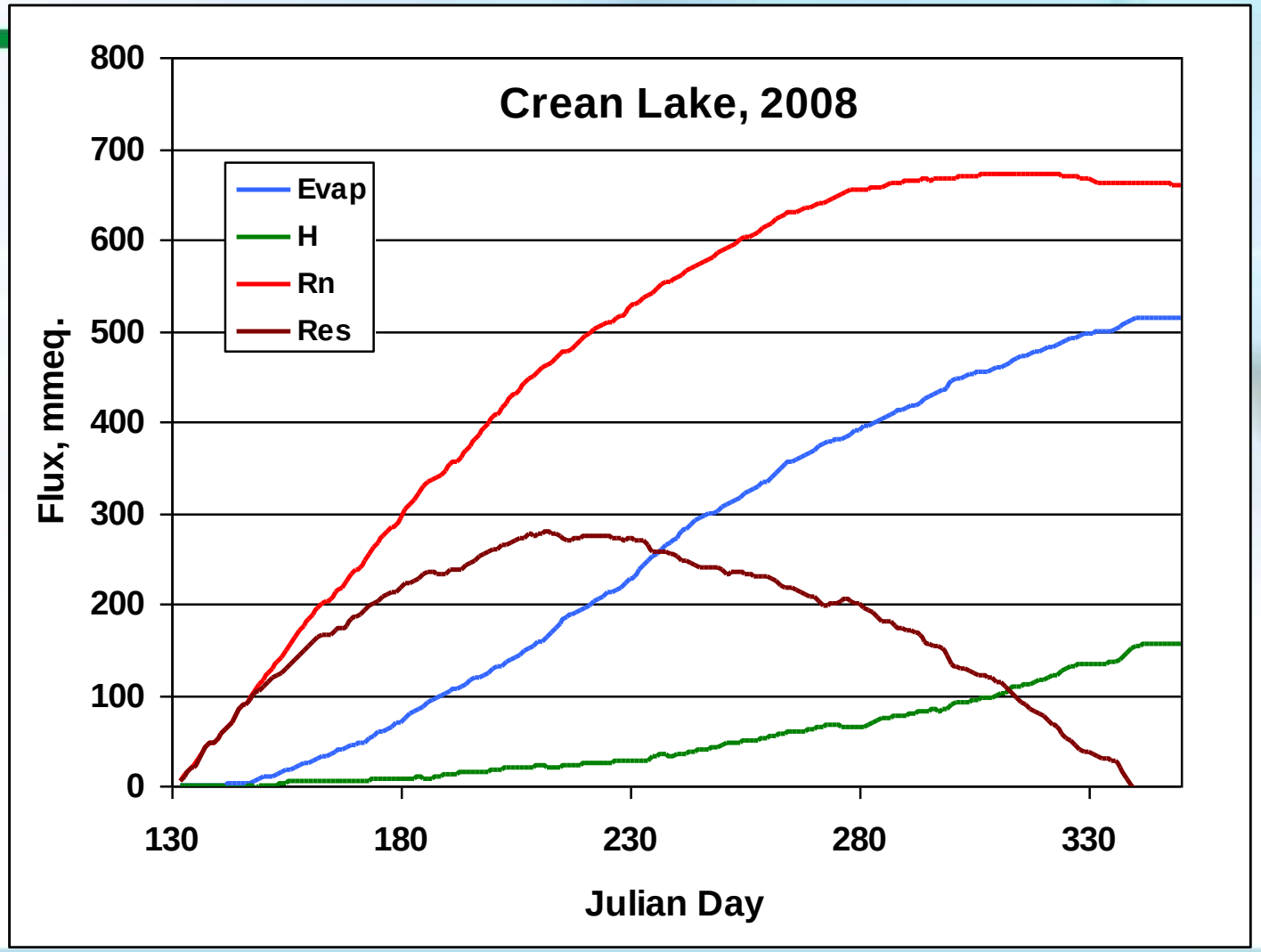
Thank you!

- IP3, IPY ($$)
- Chris Spence (Baker Creek Land data)
- PANP (logistics support)

Effect of Stability on Lake Wind Speed



Crean Lake Energy Balance, 2008



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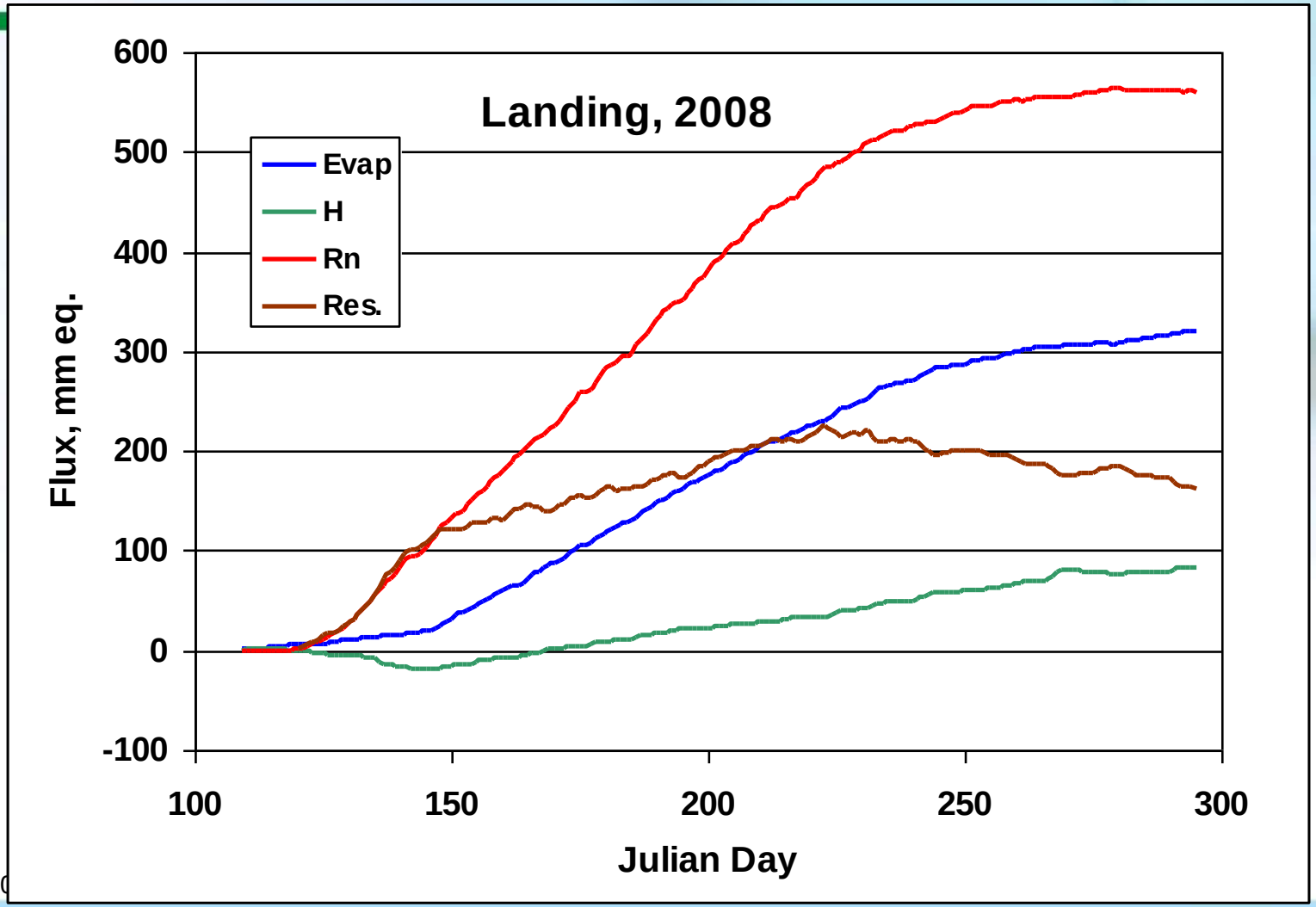
Landing Lake Energy Balance, 2008



Ratio of transfer coefficients : stable conditions