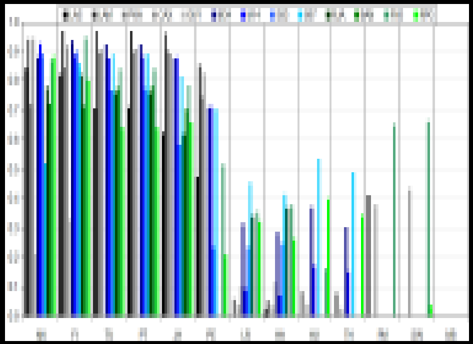
THE TROPICAL LAND–ATMOSPHERE WATER FLUX

measurements, models & controls for evapotranspiration in the Amazon



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LARGE SCALE BIOSPHERE–ATMOSPHERE EXPERIMENT (LBA)

TROPICAL *LE*

- Hadley cells, global climate, atmospheric circulation, sea surface temperature

  → Radiation, cloud formation, rainfall

  → *LE* recycling

- 2 problems:

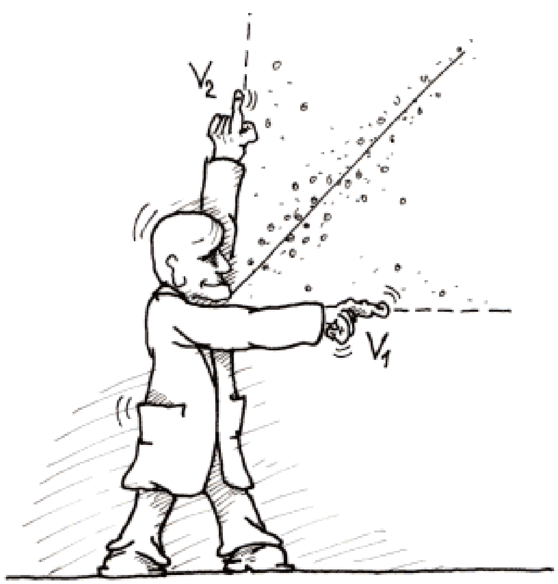
1) Understanding based on models, but models developed for temperature/agriculture
2) *LE* measurements → extrapolation

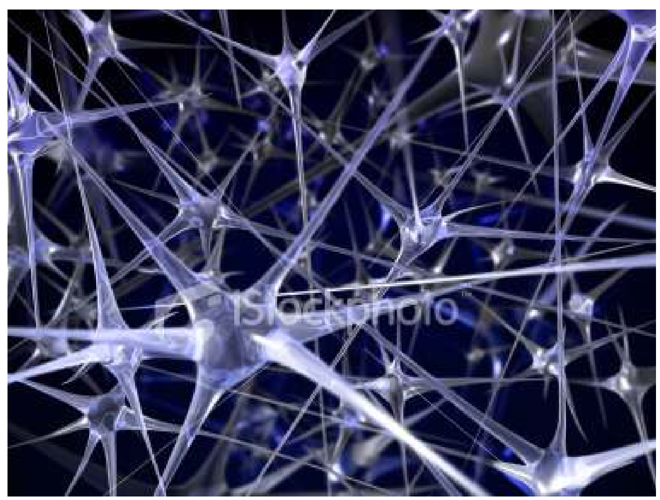
LE CONTROLS

- LAI
- Albedo
- Wind speed
- Precipitation
- Net radiation
- Soil moisture
- Soil resistance
- Air temperature
- Stomatal resistance
- Vapor pressure deficit
- Aerodynamic resistances
- Boundary layer resistance

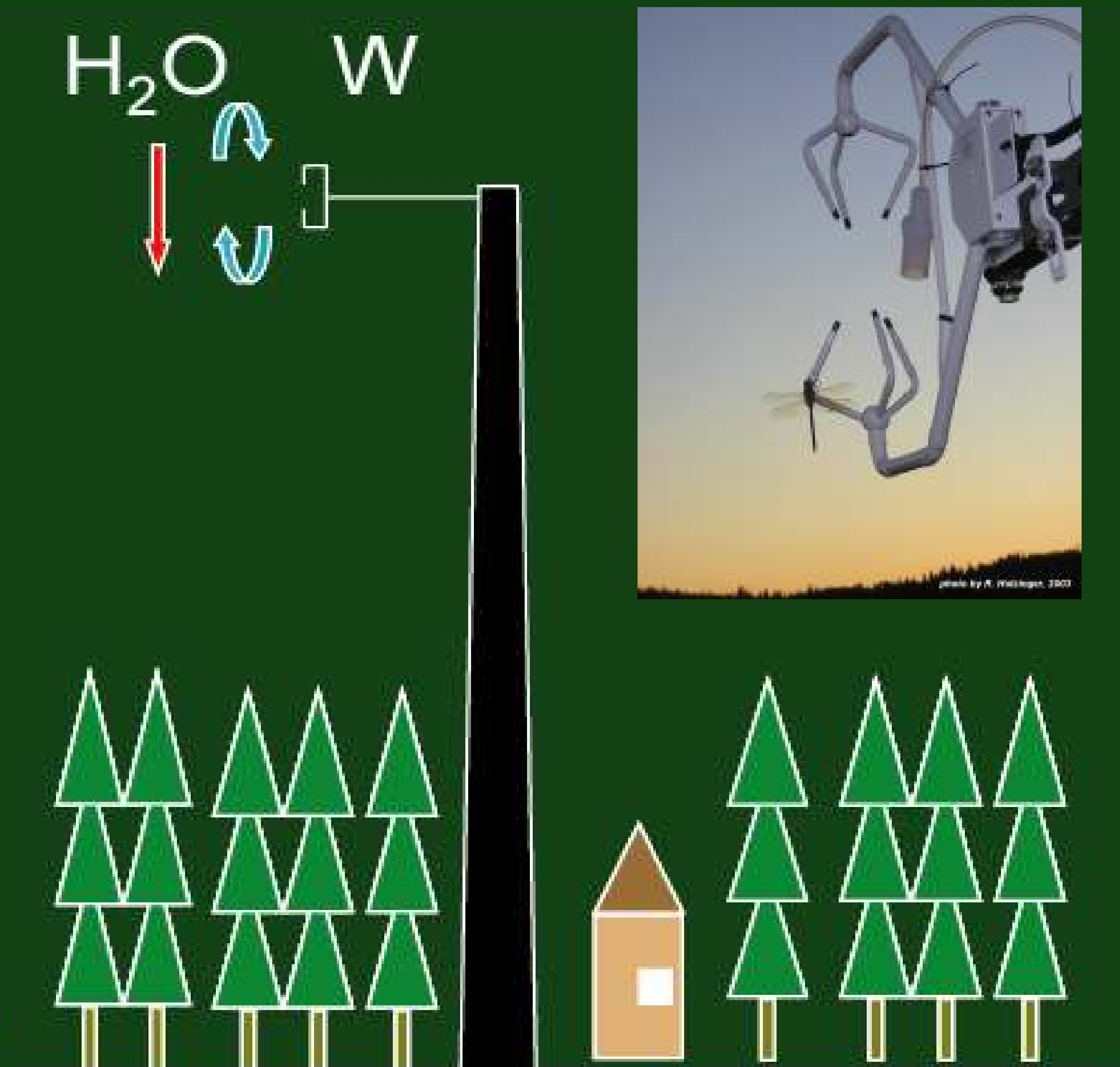
A N A L Y S I S

1) Correlations between potential controls & *LE*
2) Neural network neuron importance ranks
3) Performance evaluation for suite of models





EDDY COVARIANCE



$$F_{H2O} = \overline{w' \, H_2O'}$$

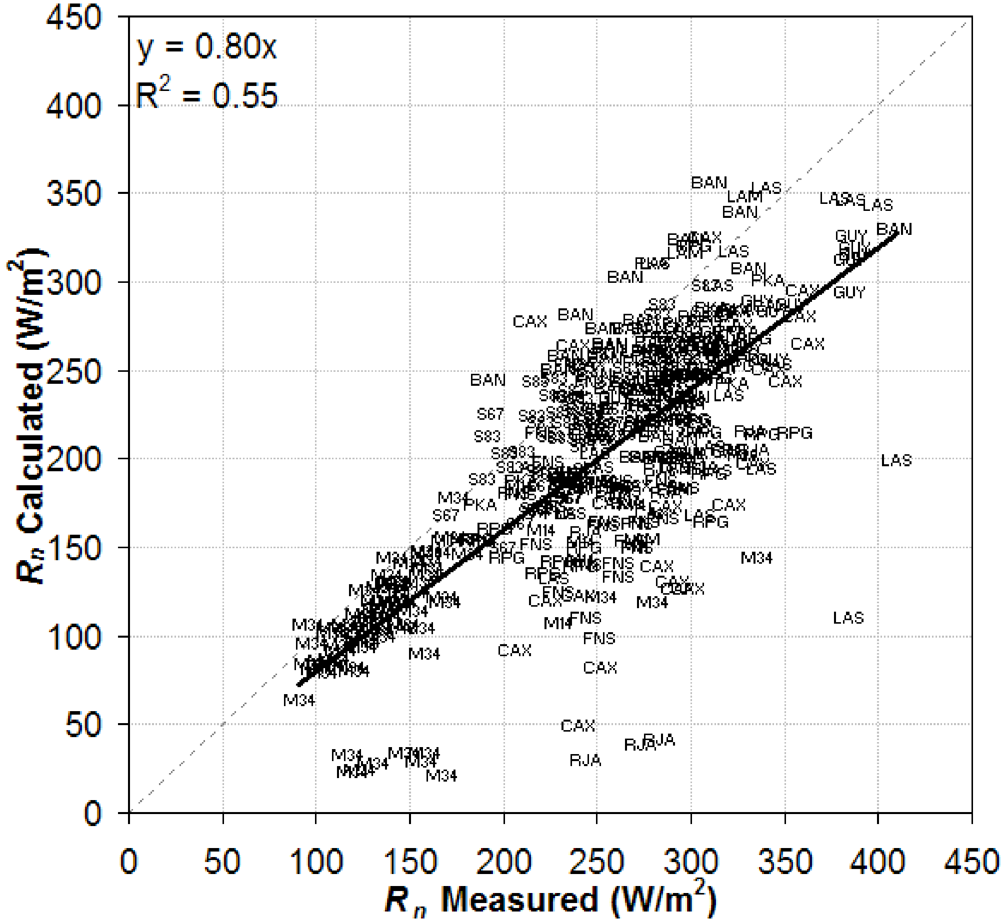
Flux = time avg. covariance of vertical wind and H_2O concentration

Adapted from A. Goldstein

EDDY FLUX SITES

R_n CLOSURE

$$R_n = LE + H + G + S$$



LE MODELS

Thornthwaite (1948) – TH

$$1.067\Lambda\left(\frac{10T_a}{S_T}\right)^A$$

Penman-Monteith (1965) – PM

$$\frac{\Delta R_n + c_p \rho VPD / r_a}{\Delta + \gamma + \gamma (r_c / r_a)}$$

Penman (1948) – PE

$$\frac{\Delta R_n + 73.64 VPD \rho \gamma (1 + 0.54u)}{\Delta + \gamma}$$

Priestley-Taylor (1972) – PT

$$\alpha \frac{\Delta}{\Delta + \gamma} R_n$$

Turc (1961) – TU

$$\frac{0.313 T_a (R_s + 2.1)}{T_a + 15}$$

McNaughton-Black (1973) – MB

$$\frac{c_p \rho VPD}{\gamma r_c}$$

Hamon (1963) – HA

$$\frac{715.5 \Lambda 0.61121 e^{\frac{17.502 T_a}{T_a + 240.97}}}{T_a + 273.2}$$

Jensen-Haise (1963) – JH

$$0.41 R_s (0.025 T_a + 0.078)$$

Hutyra et al. (2005) – HU

$$1.9 * 30 (0.3764 T_a - 6.7084)$$

Fisher et al. (this study) T_a linear regression – LR

$$10 T_a - 105$$

Shuttleworth-Wallace (1985) – SW

$$PM_c C_c + PM_s C_s$$

$$PM_c = \frac{\Delta R_n + (c_p \rho VPD - \Delta r_b R_{ns}) / (r_a + r_b)}{\Delta + \gamma (1 + r_c / (r_a + r_b))}$$

$$PM_s = \frac{\Delta R_n + (c_p \rho VPD - \Delta r_w (R_n - R_{ns}) / (r_a + r_w))}{\Delta + \gamma (1 + r_s / (r_a + r_w))}$$

$$C_c = \left(\frac{1 + R_c R_a}{R_s (R_c + R_a)}\right)^{-1}$$

$$C_s = \left(\frac{1 + R_s R_a}{R_s (R_s + R_a)}\right)^{-1}$$

$$R_a = (\Delta + \gamma) r_a$$

$$R_s = (\Delta + \gamma) r_w + \gamma r_s$$

$$R_c = (\Delta + \gamma) r_b + \gamma r_c$$

Fisher et al. (this study) Neural Network – NN

$$((((0.2*((2.1 NDVI - 1.5) + (0.02 R_n - 4.4) + (0.002 T_a - 0.04) + (-0.4 VPD + 0.5) + (-0.2u + 0.3) - 1.2) + 0.08)/2) + 0.5)*426.3) + 3.8$$

FC MODEL

Parameter	Description	Equation	
LE	Evapotranspiration	$LE_s + LE_c + LE_i$	
LE_c	Canopy transpiration	$(1 - f_{wet}) f_g f_T f_M \alpha \frac{\Delta}{\Delta + \gamma} R_{nc}$	
LE_s	Soil evaporation	$(f_{wet} + f_{SM}(1 - f_{wet}))\alpha \frac{\Delta}{\Delta + \gamma}(R_{ns} - G)$	
LE_i	Interception evaporation	$f_{wet} \alpha \frac{\Delta}{\Delta + \gamma} R_{nc}$	RS derived – *f(R_s, a, clouds)*
f_{wet}	Relative surface wetness	RH^4	RS derived – *f(ea)*
f_g	Green canopy fraction	$\frac{f_{APAR}}{f_{IPAR}}$	RS derived – *f(NDVI)*
f_T	Plant temperature constraint (June et al., 2004)	$\exp\left(-\left(\frac{T_{max} - T_{opt}}{T_{opt}}\right)^2\right)$	RS derived – *f(T_s)*
f_M	Plant moisture constraint	$\frac{f_{APAR}}{f_{APARmax}}$	RS derived – *f(NDVI)*
f_{SM}	Soil moisture constraint	$RH^{VPD/\beta}$	RS derived – *f(ea)*

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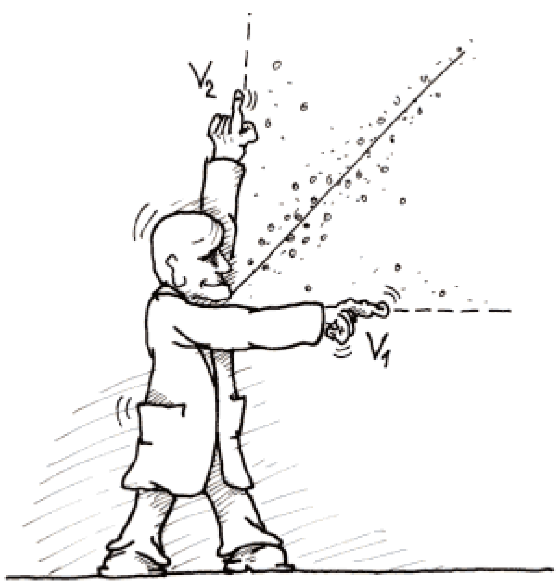
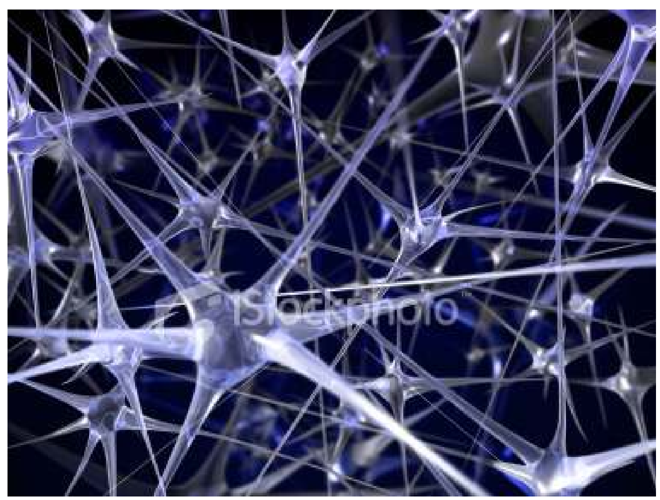
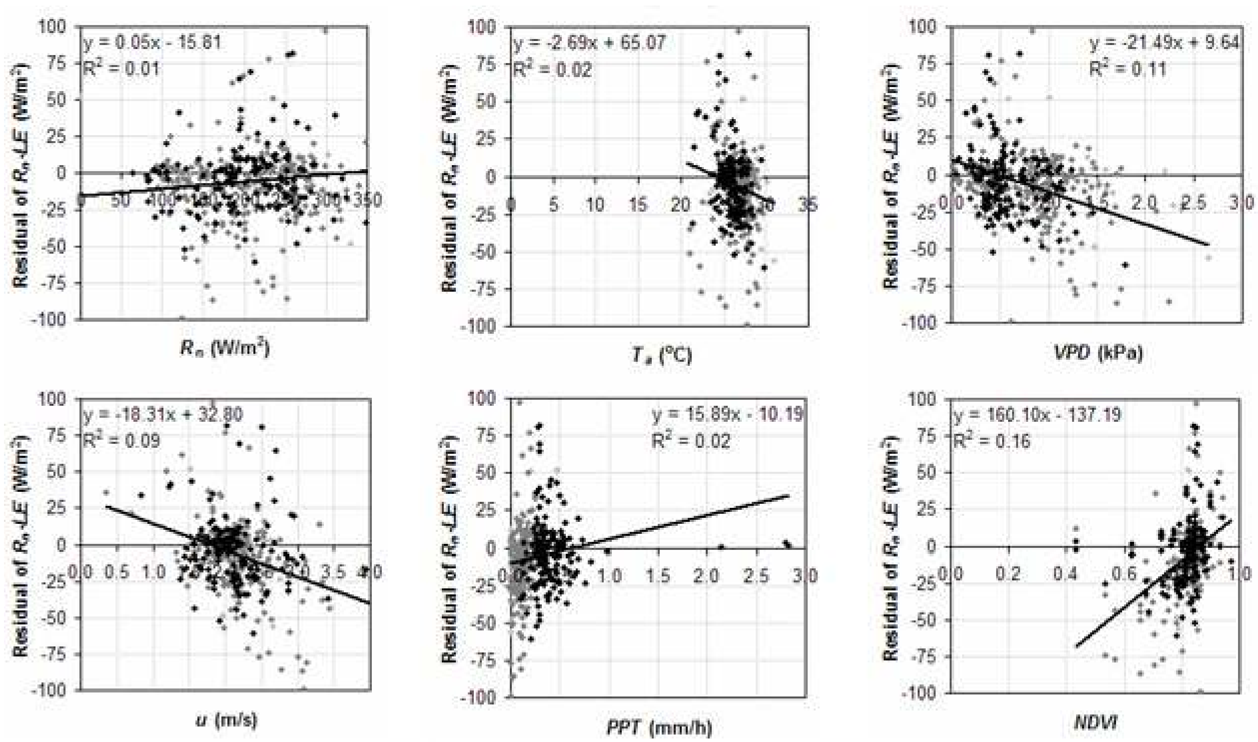




LE VS. CONTROLS



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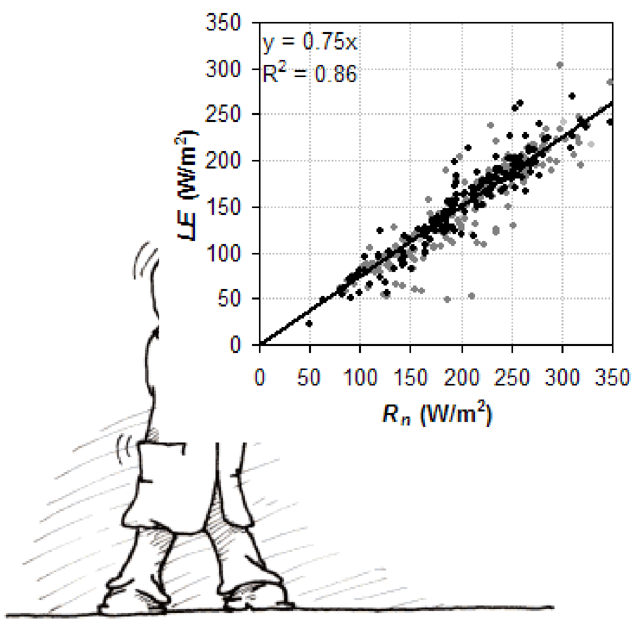

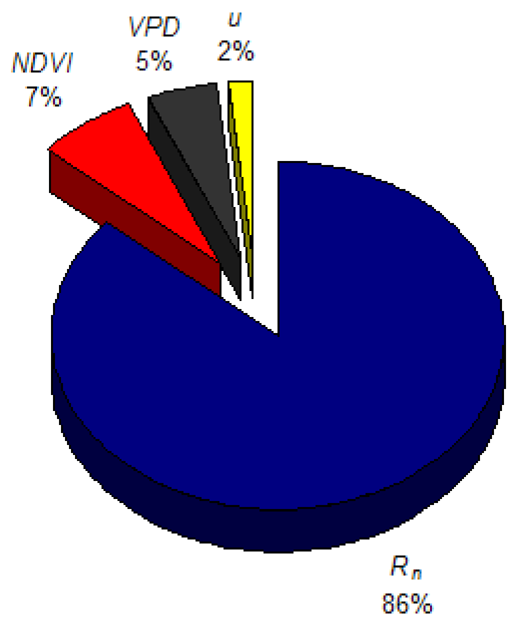

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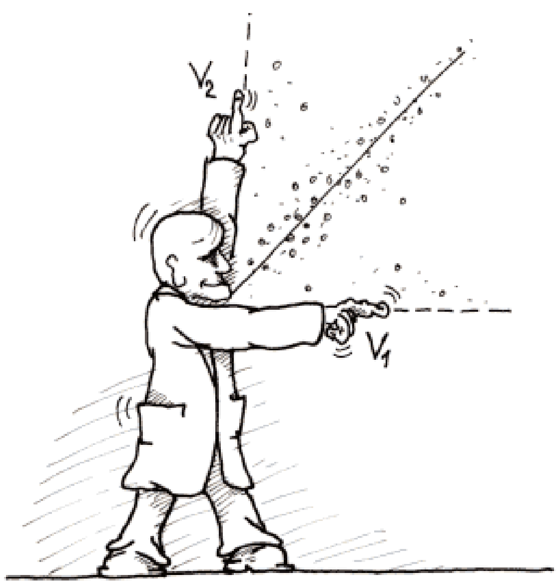
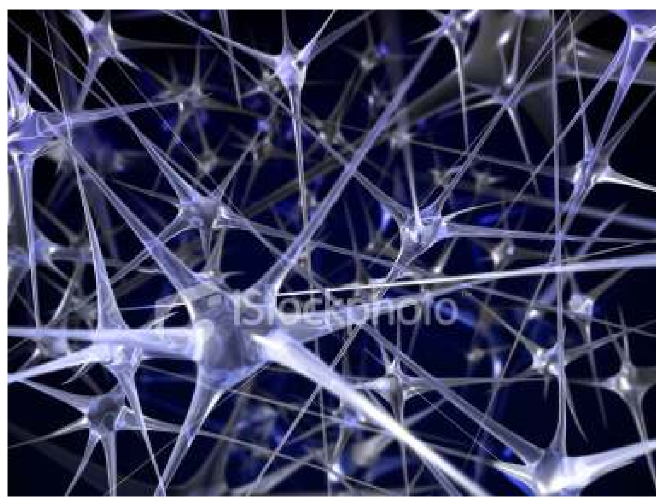
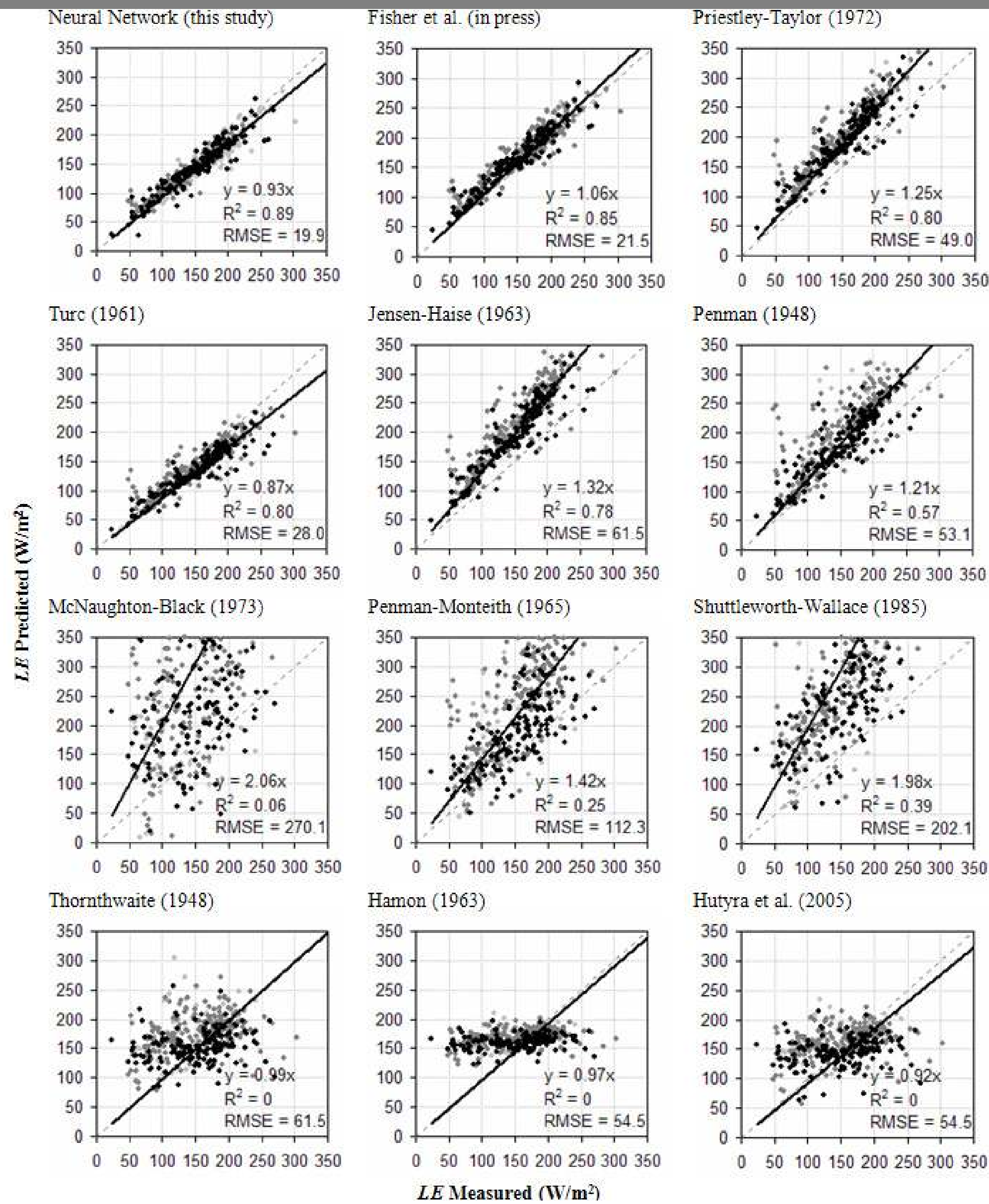




MODELS EVALUATION



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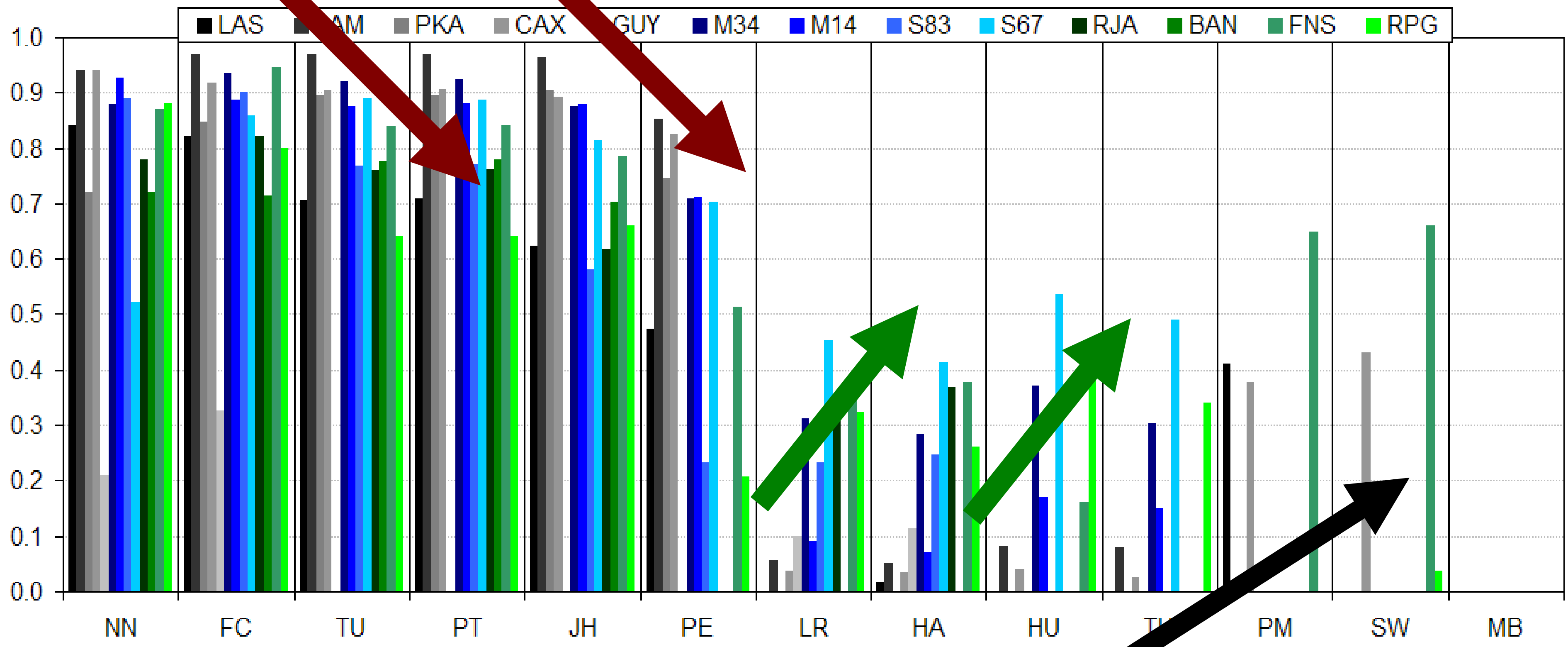

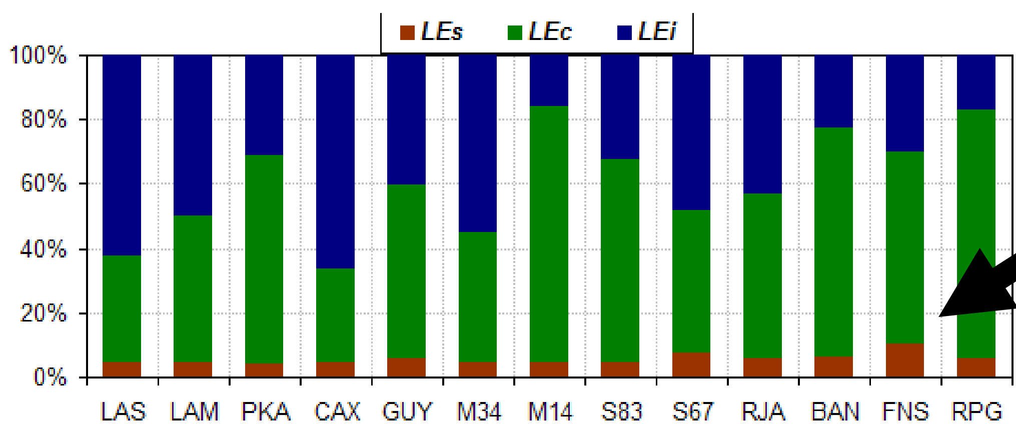

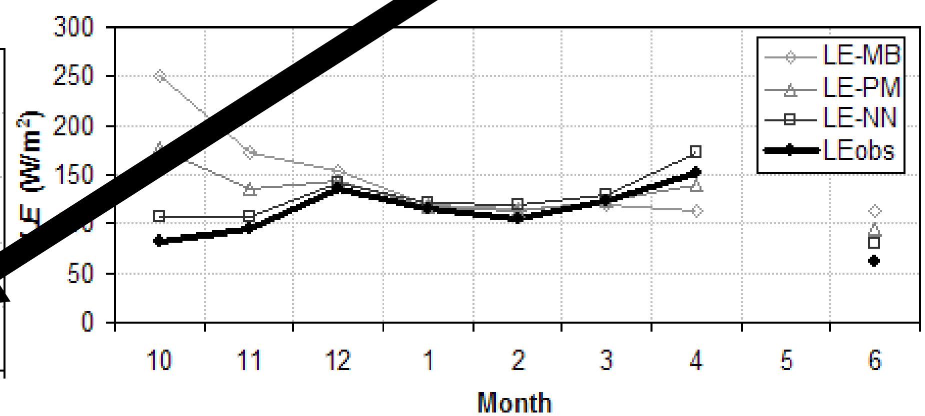

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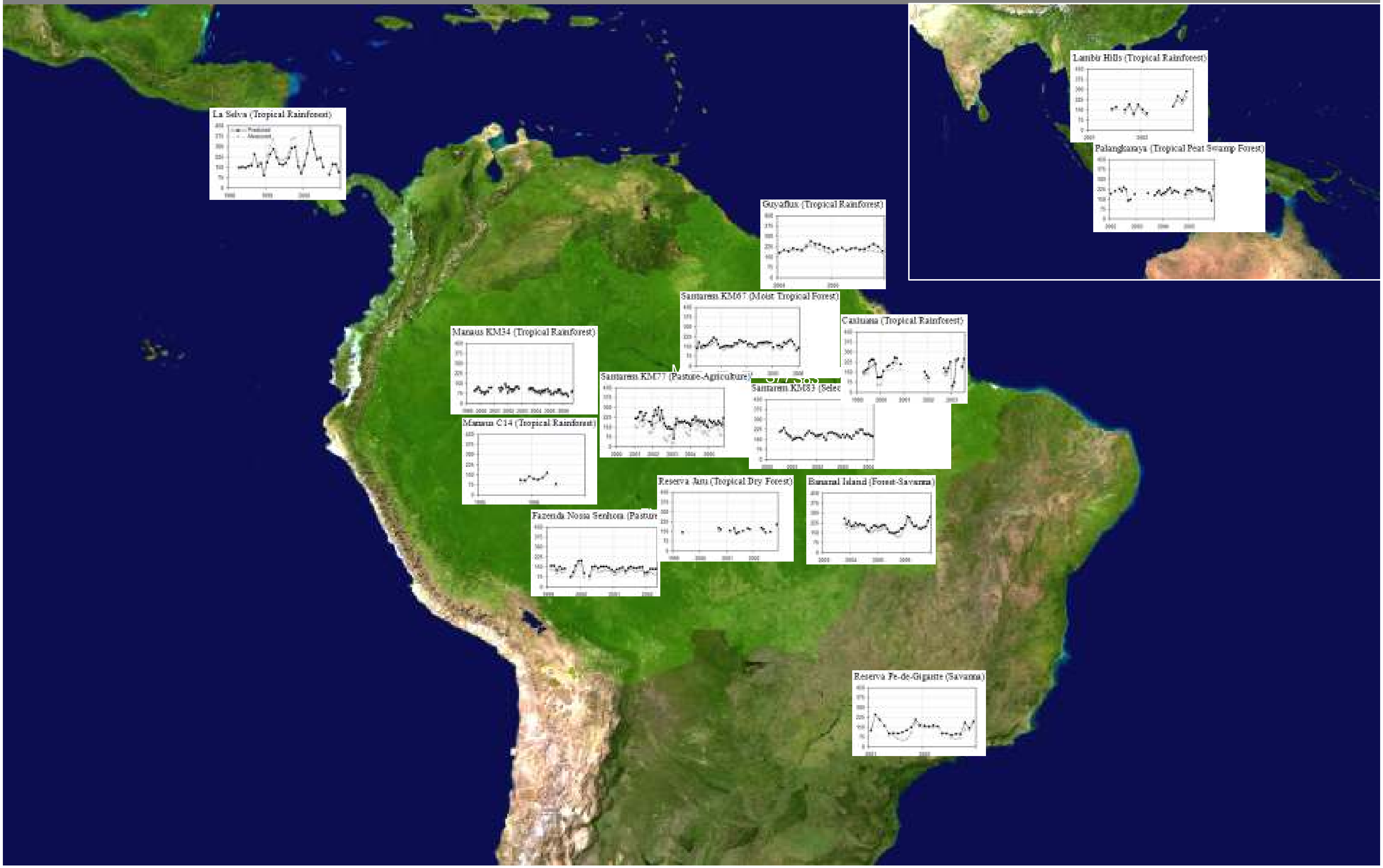

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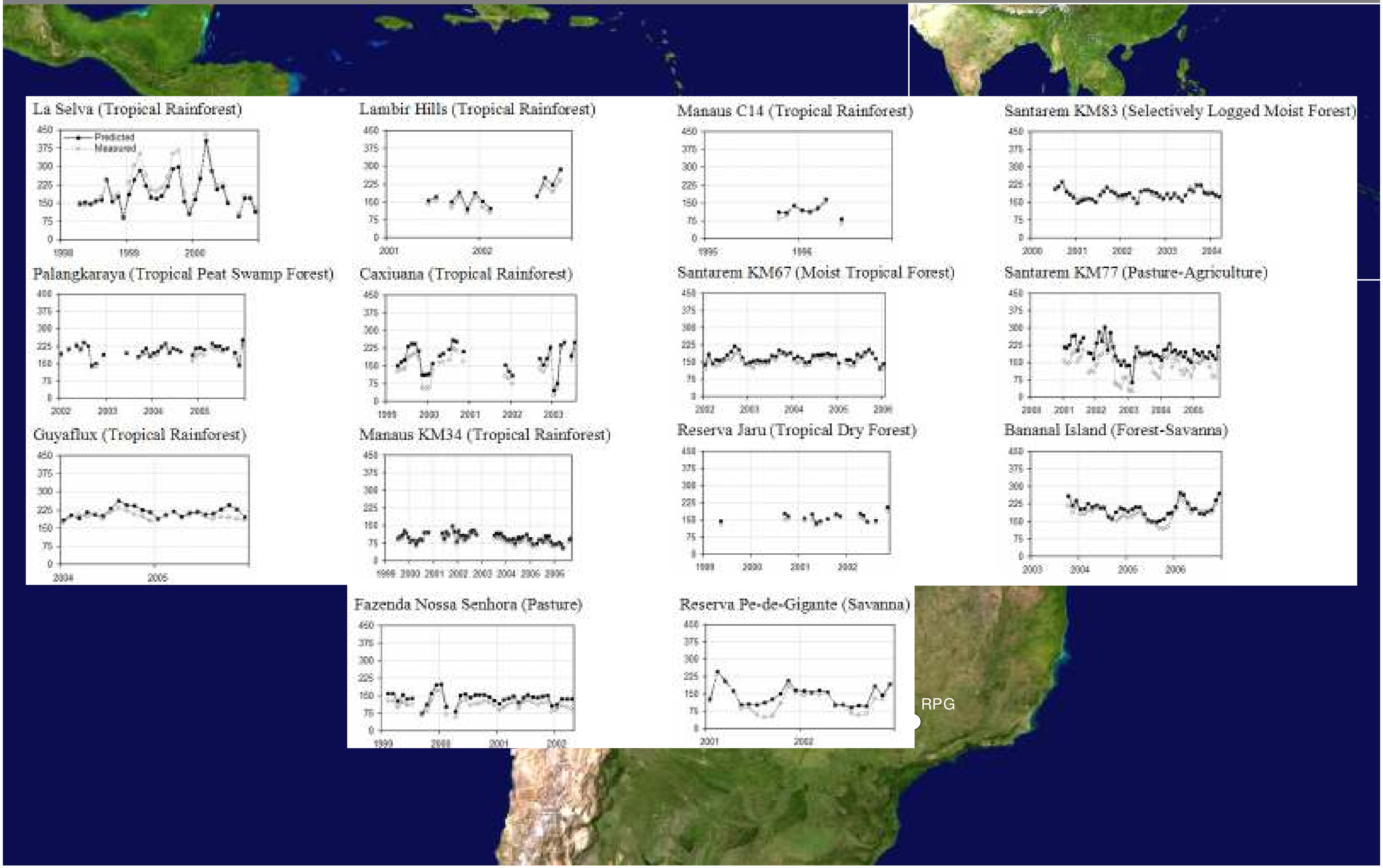
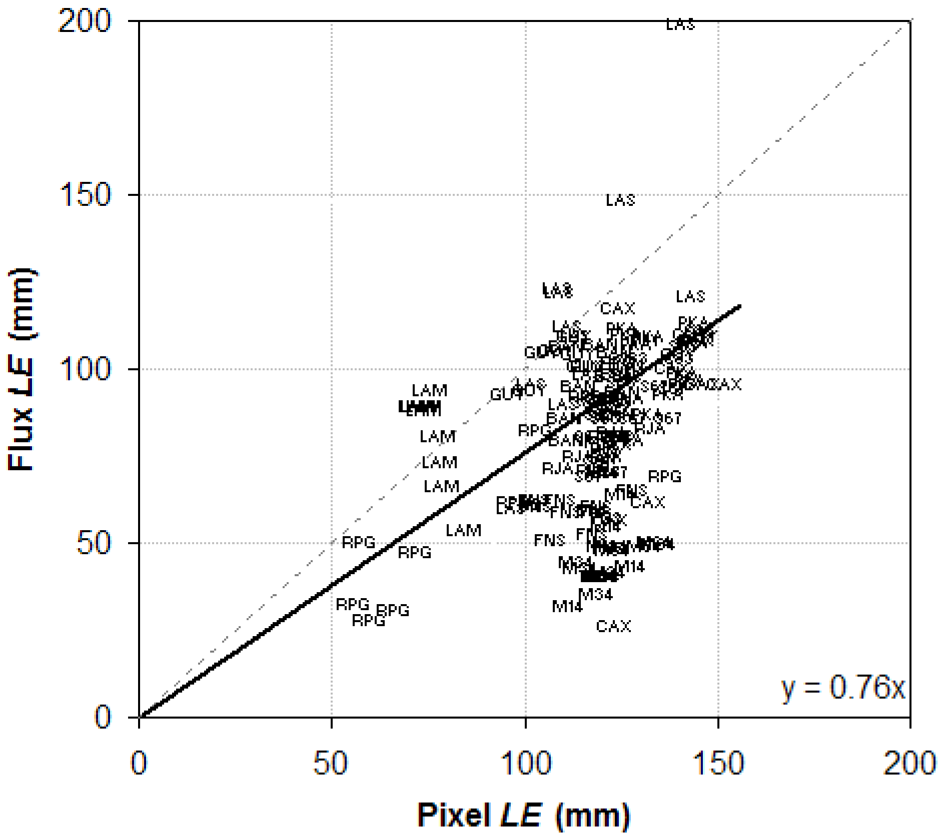
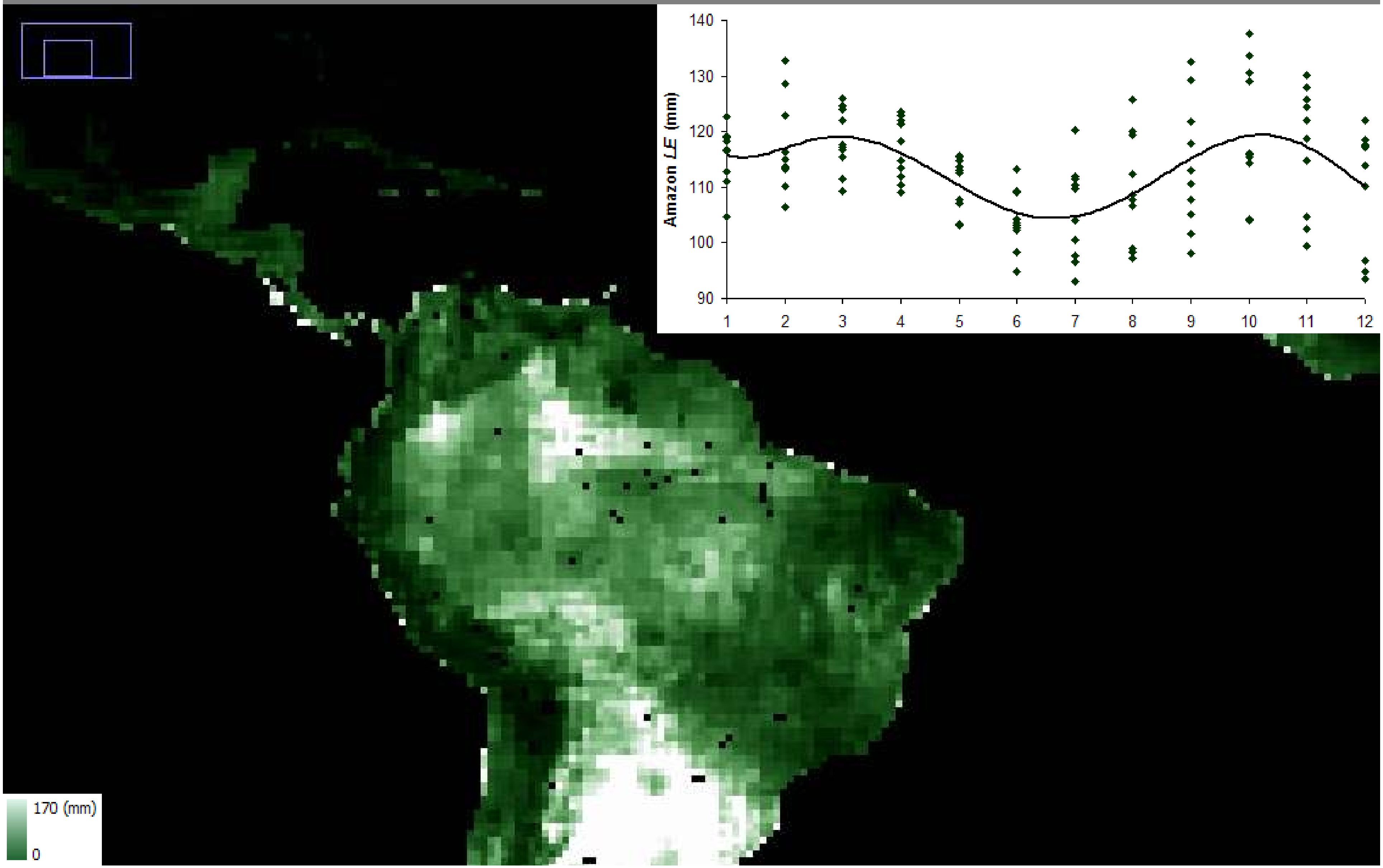


REMOTE SENSING

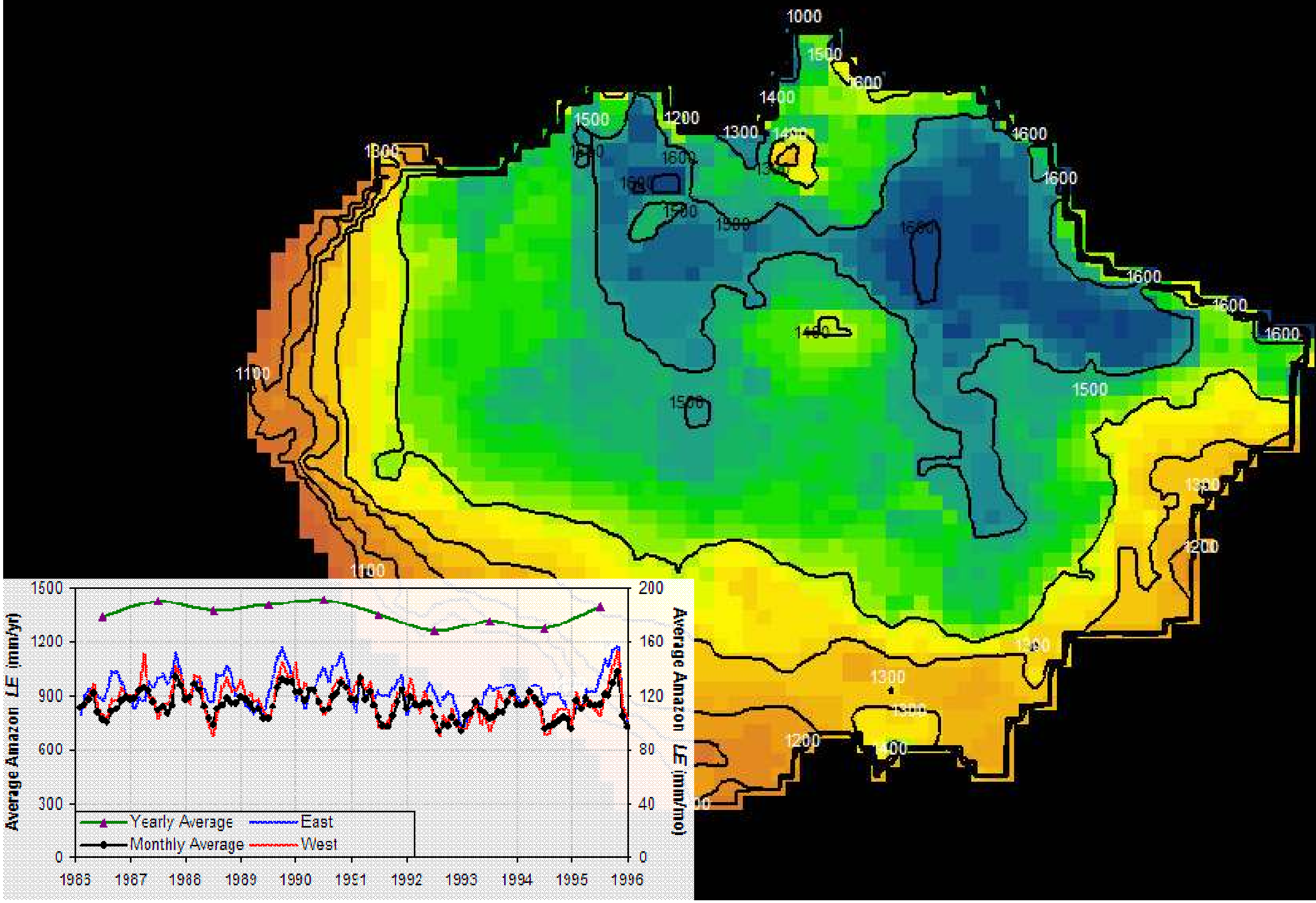
PIXEL VS. TOWER



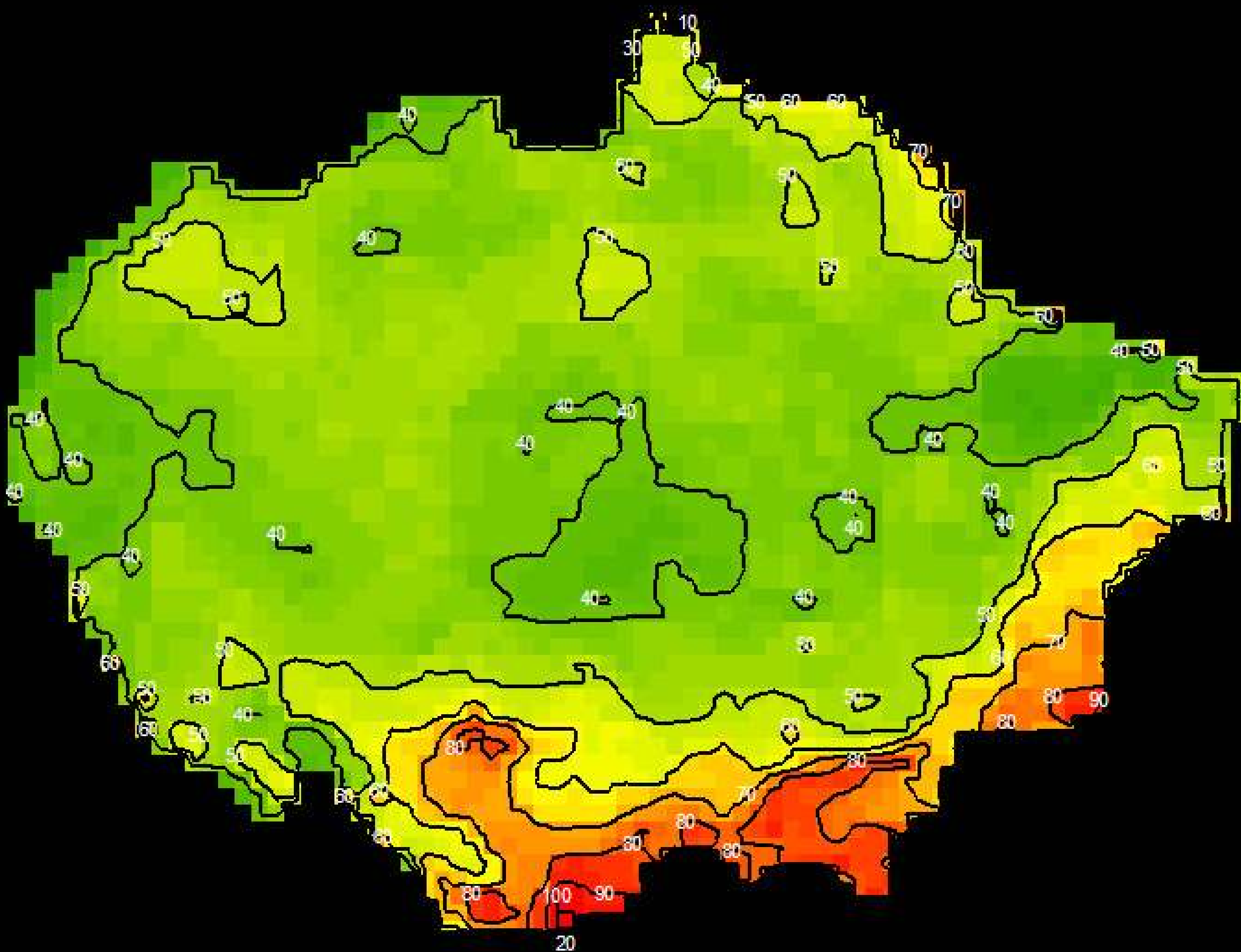
AMAZON MONTHLY *LE*



10-YEAR MEAN *LE*



10–YEAR *LE* AMPLITUDE



CONCLUSIONS

- *LE* uses 75% of R_n
  - 67% in central Amazon (Malhi et al. 2002); 73% in eastern Amazon (Sommer et al. 2002); seasonality?
- *VPD*, *NDVI* links
  - Malhi et al. 2002, Myneni et al. 2007, Williams et al. 1998
- *PPT*, T_a NOT linked in moist tropics; seasonality
  - Malhi et al. 2002, Costa & Foley 1997, Nepstad et al. 1994 for *PPT*
- NN not significantly better than FC
  - T_a-based models performed poorly
- Energy balance: 80%
  - Pixel-to-flux ratio: ~80%; NN ($R_{n,calc}$-trained)-to-FC ratio: ~80%
- Amazon *LE* 10-year mean: 1370 mm
  - Assumptions about energy balance; ISLSCP-II and FC model