Improvements to the MODIS ET model (MOD16) for regional applications

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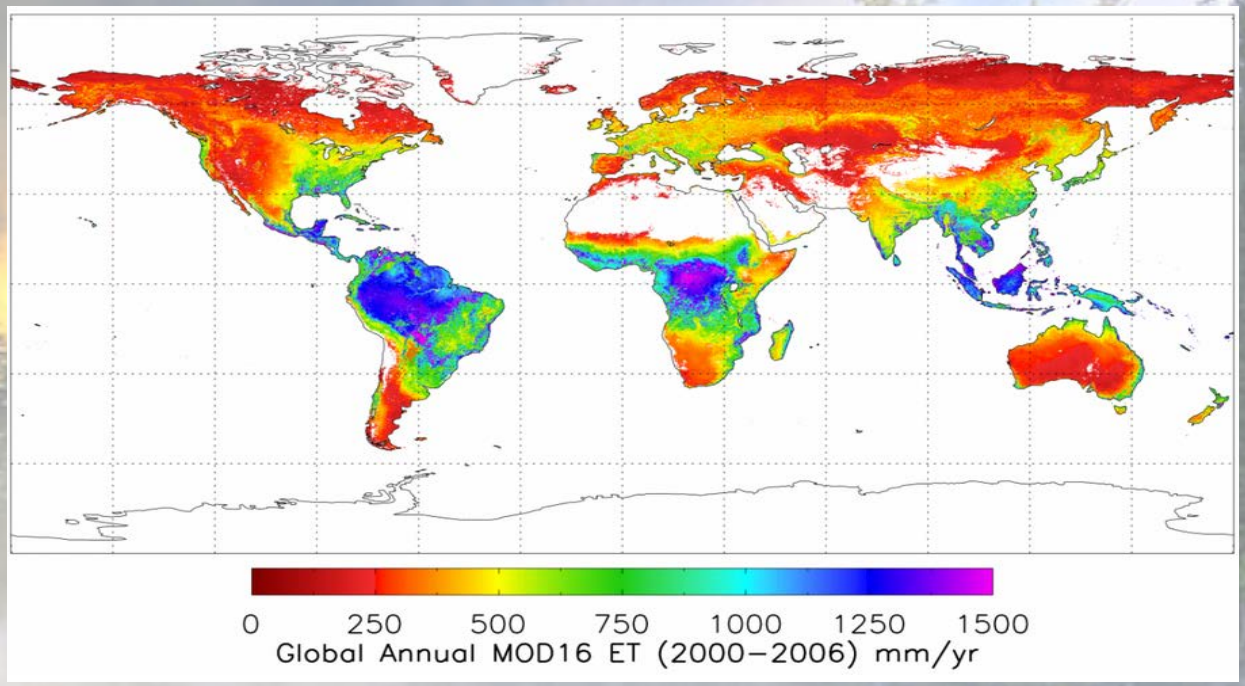
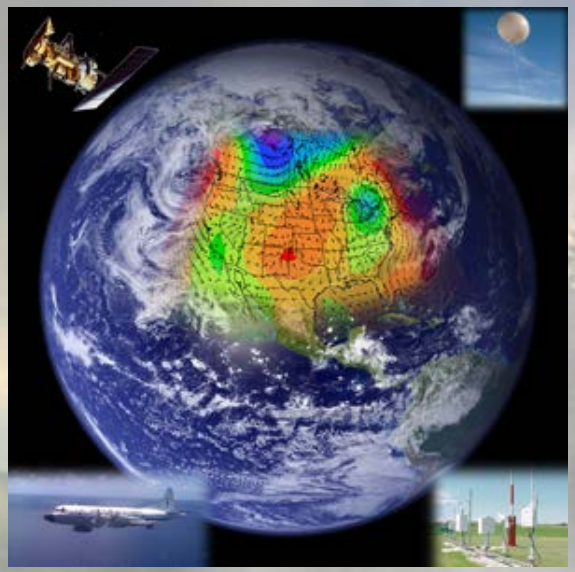
http://www.ntsg.umt.edu/project/mod16

MOD16: Objective

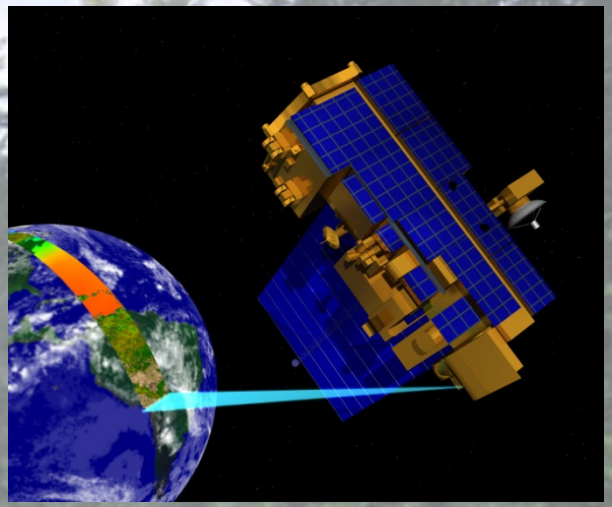


Estimate <u>global</u> terrestrial evapotranspiration, which may be used in calculations of regional water and energy balances to help quantify trends in climate change, primary productivity and drought.

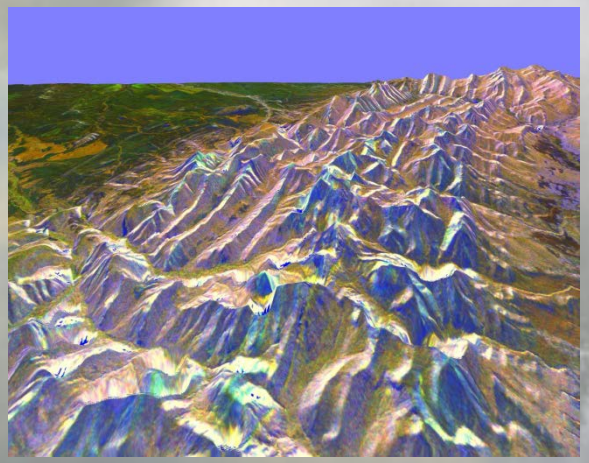
MOD16: Inputs



MERRA Reanalysis Meteorological Variables



MODIS LAI/FPAR, Albedo, Land Cover Type

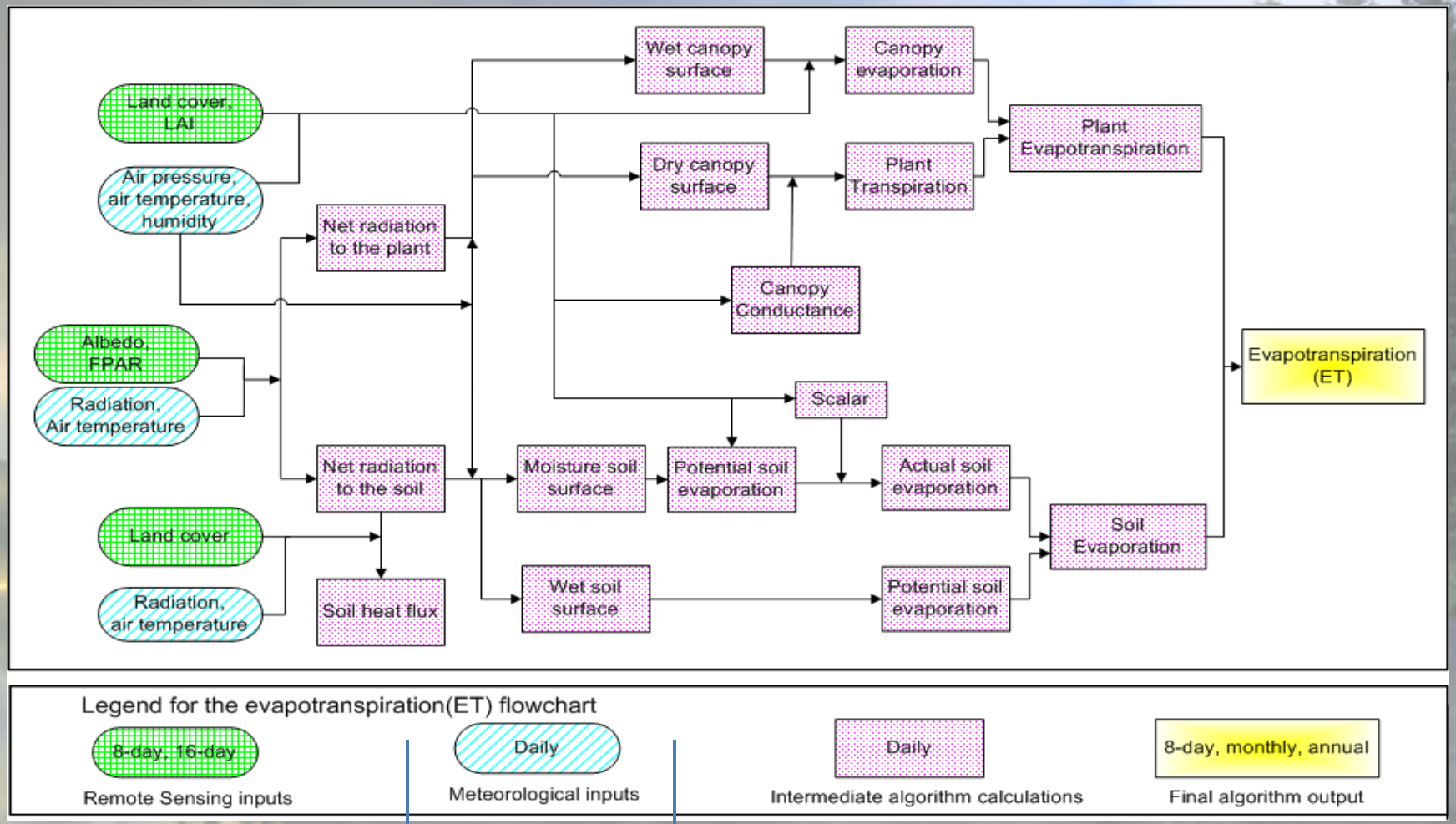


SRTM Elevation

Biome Property Look- Up Table (BPLUT)

PARAMETER	*OSH*	WL
T_{min_open} (°C)	8.80	11.39
T_{min_close} (°C)	-8.00	-8.00
VPD_{close} (Pa)	4400	3500
VPD_{open} (Pa)	650	650
gl_sh ($m\ s^{-1}$)	0.04	0.08
gl_e_wv ($m\ s^{-1}$)	0.04	0.08
Cl (m/s)	0.0065	0.0070
RBL_MIN ($s\ m^{-1}$)	20.0	15.0
RBL_MAX ($s\ m^{-1}$)	45.0	45.0

MOD16: Methods



MOD12Q1	Land Cover (c4)
MOD15A2	FPAR/LAI
MCD43B3	White Sky
MCD43B2	Albedo (10th Band)
SRTM30	Elevation

T_{avg}	T_{min}
AVP_{day}	AVP_{night}
SWrad	SWGDN
$LWrad_{day}$	$LWrad_{night}$
T_{day}	T_{night}

(MERRA)

+ Biome Properties Look-Up Table

Evergreen Needleleaf Forest	Evergreen Broadleaf Forest
Deciduous Needleleaf Forest	Deciduous Broadleaf Forest
Mixed Forest	Woody Savannas
Closed Shrubland	Open Shrubland

Grassland, Urban and Built-up (sparsely vegetated)
Cropland

Penman-Monteith Logic

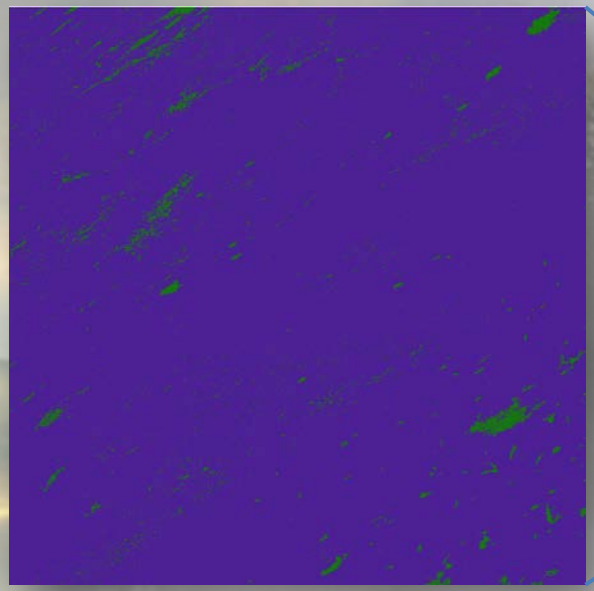
$$\lambda E = \frac{s * A * \rho * C_p * \frac{(e_{sat} - e)}{r_a}}{s + \gamma * (1 + \frac{r_s}{r_a})}$$

- λE: Latent heat of evaporation; Latent heat flux
- s: $\frac{\Delta e_{sat}}{\Delta temp}$
- A: Available energy partitioned between sensible heat, latent heat and soil heat fluxes
- ρ: Air density
- C_p: Specific heat capacity of air
- e_{sat}: Saturated H_2O vapor pressure
- e: Actual H_2O vapor pressure
- $(e_{sat} - e)$: VPD
- r_a: Aerodynamic resistance
- r_s: Surface resistance to evaporation from the land surface and transpiration from the plant canopy
- $\gamma = \frac{C_p * P_a * M_a}{\lambda * M_w}$
  - M_a: Molecular mass of dry air
  - P_a: Atmospheric pressure
  - M_w: Molecular mass of wet air
  - λ: Latent heat of evaporation

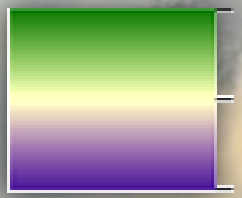
$$\lambda E = \lambda E_{wet\_canopy} + \lambda E_{transpiration} + \lambda E_{soil}$$

Sample Output

*.exe MOD12Q1_h09v05.MODIS SRTM30.h09v05.DEM MOD15A2_ h09v05_2009.MODIS MCD43B3_h09v05_2009.MODIS MCD43B2_ h09v05_2009.MODIS 2009



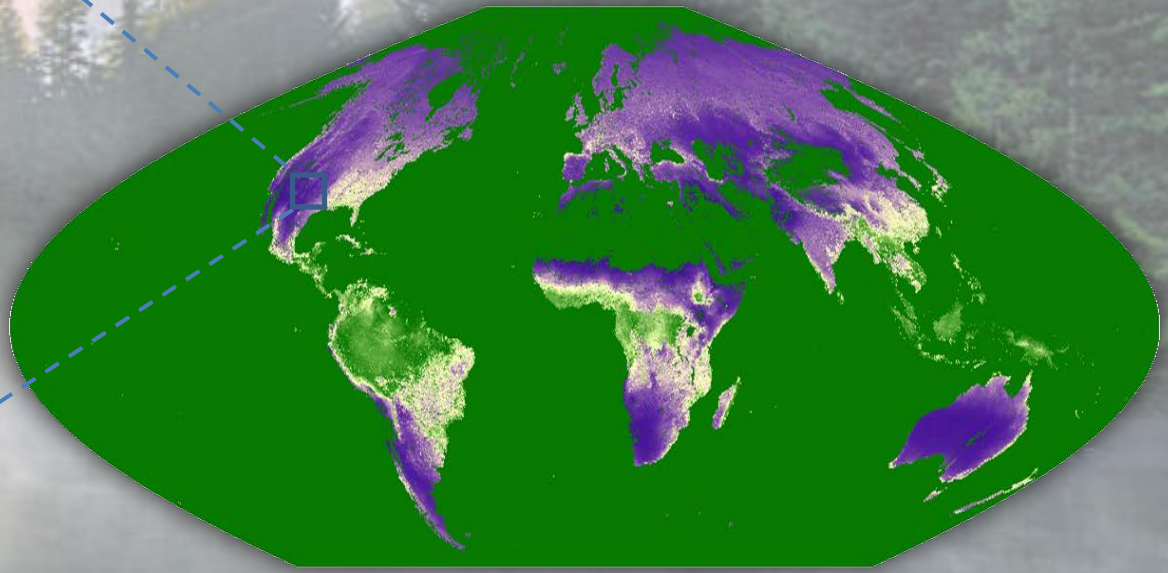
August 13-21 h09v05

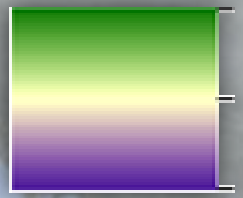


High: 32766

Low: 0

2009 Annual Evapotranspiration





High: 65535

Low: 27

MOD16: Limitations

- Static MODIS land cover map
- Wind and **Precipitation** are **not used in the calculations of ET**
- **Relative Humidity controls % of saturated soil (standing water) and % canopy intercepted standing water**
- **MERRA meteorological inputs**

- BPLUT calibrated for the MOD17 GPP/NPP algorithm, though it's used in MOD16 as well
- Validations comparing two different approaches to calculate ET while using similar data as drivers are acceptable

MERRA

- Gridded models of meteorological variables using satellite, weather station, radiosonde, weather balloons, etc
- Provided every 6 hours at 0.5°x 0.67° resolution
- Assimilation routine is “frozen” and will not be updated for newer instrument suites
- Quality will degrade as current instruments expire

High(er)-resolution meteorology

TopoWx: 1km gridded data

temperature only (humidity coming soon)

U of I METDATA: 4km gridded data

temperature, precipitation, humidity, shortwave radiation, and wind

Daymet: 1km gridded data

temperature, precipitation, humidity and solar radiation

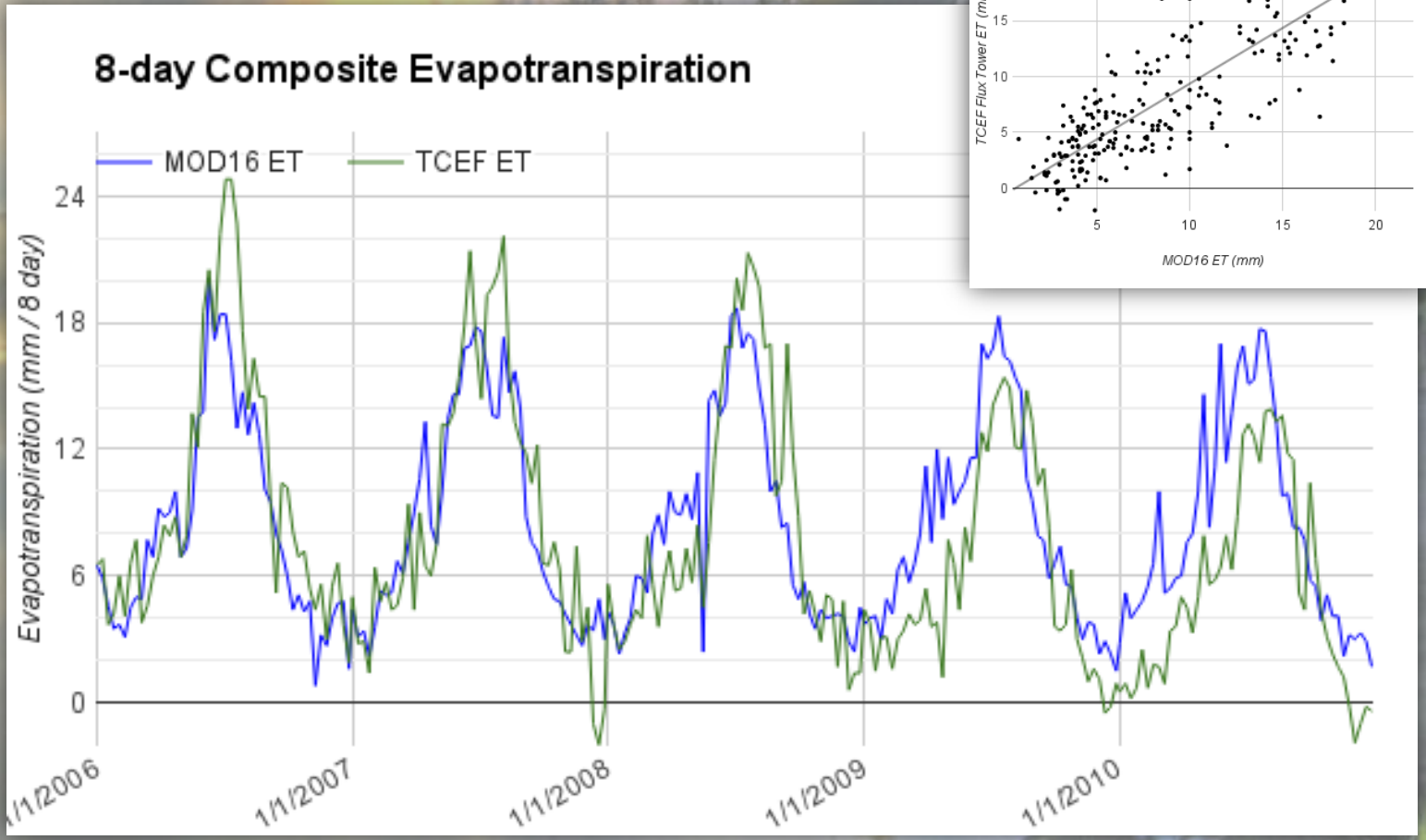
Addition of a Precipitation Component and bucket model for soil moisture

- Daily total precipitation will become a required input variable (University of Idaho METDATA- 4km)
- 20 cm soil water capacity across all biomes
- Soil water will gradually deplete until the next precipitation event
- If mostly non-vegetated, soil evaporation module will be affected
- If mostly vegetated, transpiration module will be affected
- Canopy evaporation will continue to assume interception based upon relative humidity thresholds and will evaporate at the potential evaporation rate

Major Assumptions

- Type and duration of precipitation events are undetermined
- Initial conditions: the bucket is “half full”
- Overflow and runoff disappear; no lateral flow between adjacent pixels*
- No throughfall from canopy*
- No snowpack (sublimation, lag between precip and bucket recharge, etc.)*
- Canopy interception still depends on RH thresholds*
- BPLUT will NOT be recalibrated*

Tenderfoot Creek Experimental Forest

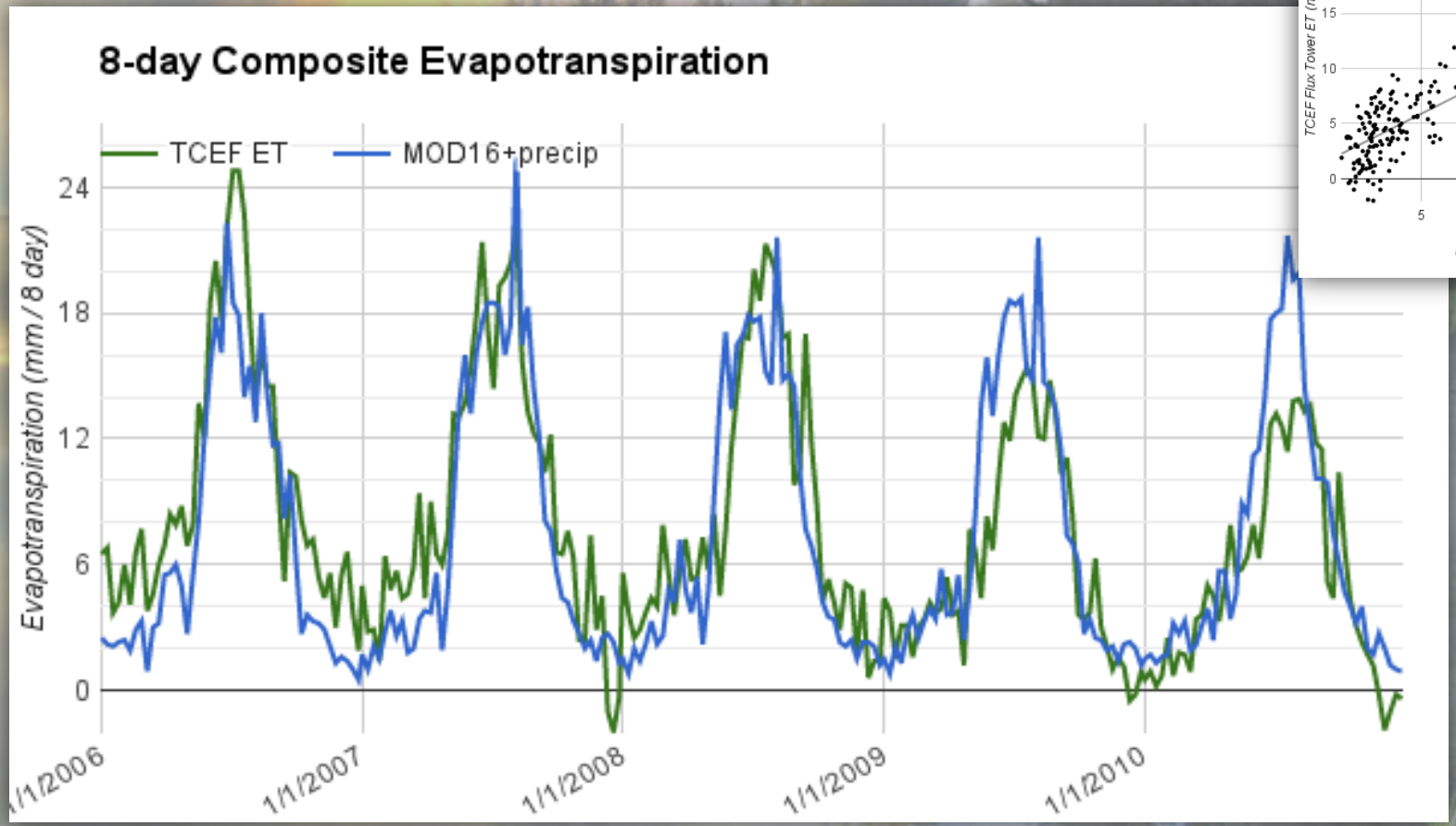


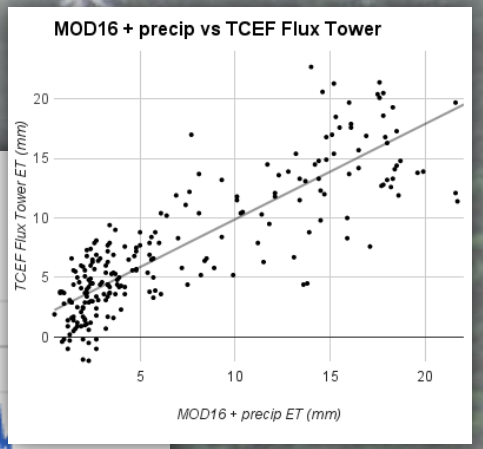
Correlation of original MOD16 estimates and TCEF measurements:

Y2006: r = 0.91
Y2007: r = 0.88
Y2008: r = 0.85
Y2009: r = 0.84
Y2010: r = 0.81

Y2006 – 2010: r = 0.82

TCEF and MOD16+precip comparison





Correlation of MOD16+precip estimates and TCEF measurements:

Y2006: r = 0.93
Y2007: r = 0.92
Y2008: r = 0.85
Y2009: r = 0.87
Y2010: r = 0.89

Y2006 – 2010: r = 0.86

TCEF vs. MOD16

	TCEF vs. MOD16	TCEF vs. MOD16+precip
2006	0.91	0.93
2007	0.88	0.92
2008	0.85	0.85
2009	0.84	0.87
2010	0.81	0.89
2006 – 2010	0.82	0.86

Future work

- Validation across multiple biomes and climate gradients
- Incorporation of other high resolution meteorological variables (TopoWx, METDATA)
- Distribution of 8-day, high resolution (1km meteorological drivers) MOD16+precip data for Montana, then conterminous USA
- Incorporation of MOD16+precip into MOD17 NPP/GPP estimates as a measure of water stress

Acknowledgements

- North Central Climate Science Center
- Montana EPSCoR
- Montana Climate Office

- Dr. Steve Running
- Dr. Jared Oyler, Ruben Behnke
- Dr. Kelsey Jencso, Dr. Ashley Ballantyne

Formulas

$$stomatal\ conductance = \textbf{mean potential stomatal conductance per unit LAI} \times m(Tmin) \times m(VPD) \times m(SWC)$$

$$m(SWC) = \begin{cases} 1.0 & current\ SWC \geq \mathbf{20\ cm} \\ \dfrac{current\ SWC}{\mathbf{20\ cm}} & 0.0 < current\ SWC < \mathbf{20\ cm} \\ 0.0 & current\ SWC \leq 0.0 \end{cases}$$

$$AET\ soil = \begin{cases} precip \geq PET & PET * 0.60 \\ precip < PET & potential\ evaporation \times \left(\dfrac{0.3}{days\ since\ precip\ event^2}\right) \end{cases}$$

$$current\ soil\ water\ content = current\ SWC + precipitation\ amount - calculated\ ET$$