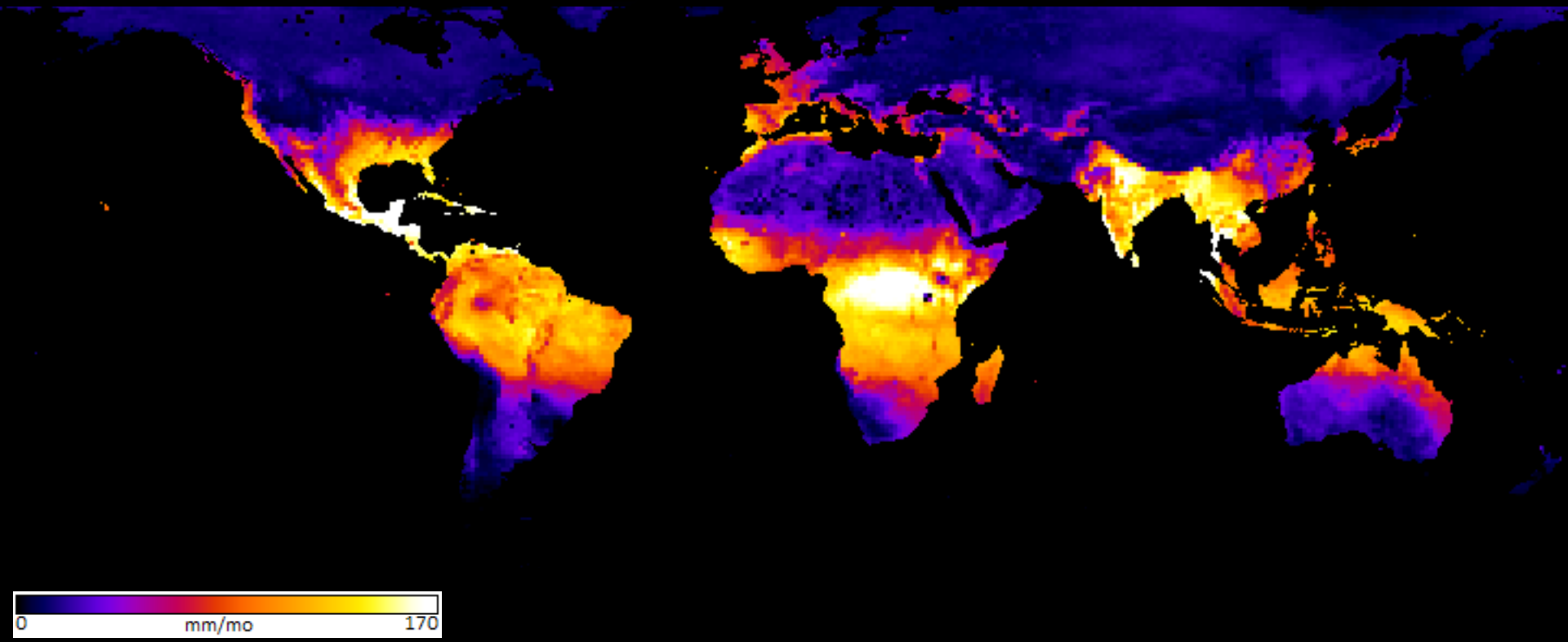
PT-JPL ET

ECOPHYSIOLOGICAL CONSTRAINTS DOWNSCALE PRIESTLEY-TAYLOR POTENTIAL TO ACTUAL EVAPOTRANSPIRATION

DR. JOSHUA B. FISHER

NASA JET PROPULSION LABORATORY (JPL)
CALIFORNIA INSTITUTE OF TECHNOLOGY (CALTECH)

PT-JPL GLOBAL ET



Fisher, J.B., Tu, K.P., Baldocchi, D.D., 2008. *Remote Sensing of Environment*.

MONTHLY, 0.5 DEGREE

PT-JPL ET

1/3

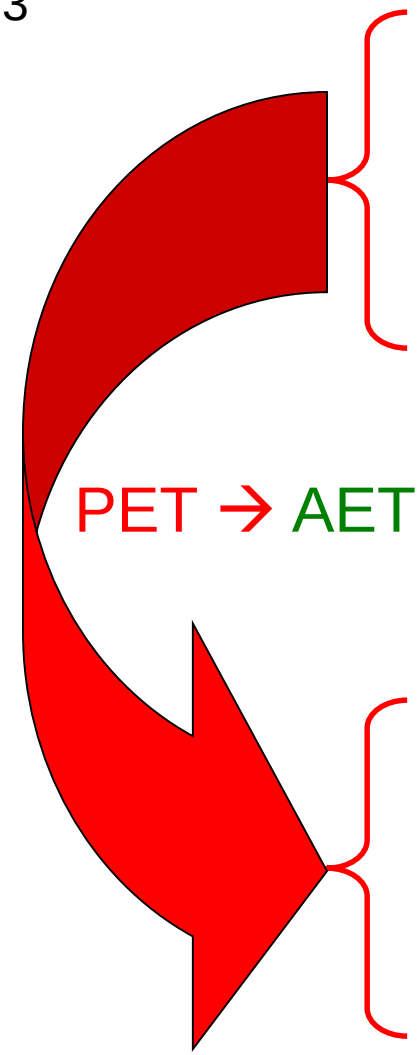
$$LE_{pot} = \alpha \frac{\Delta}{\Delta + \gamma} R_n$$

Priestley & Taylor (1972)

Fisher, J.B., et al., 2008: *Remote Sensing of Environment*.

PT-JPL ET

2/3



$$LE_{pot,canopy} = (1 - f_{wet})\alpha \frac{\Delta}{\Delta + \gamma} R_{nc}$$

$$LE_{pot,soil} = (1 - f_{wet})\alpha \frac{\Delta}{\Delta + \gamma} R_{ns}$$

$$LE_{pot,interception} = f_{wet}\alpha \frac{\Delta}{\Delta + \gamma} R_{n}$$

PT-JPL ET

3/3

$$LE_c = (1 - f_{wet}) f_g f_T f_M \alpha \frac{\Delta}{\Delta + \gamma} R_{nc}$$

$$LE_s = (f_{wet} + f_{SM}(1 - f_{wet})) \alpha \frac{\Delta}{\Delta + \gamma} (R_{ns} - G)$$

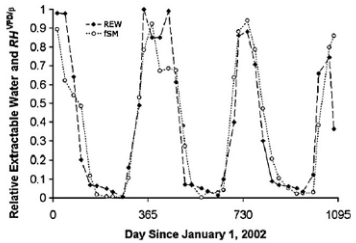


Fig. 1. Comparison of monthly f_{SM} to normalized volumetric water content (VWC), or relative extractable water – $REW = (VWC - VWC_{min})/(VWC_{max} - VWC_{min})$ – at an oak–savanna site.

PT-JPL ET

$$LE = LE_s + LE_c + LE_i$$

R_n	MODIS | CERES | SRB | ISCCP
T_a	MODIS | AIRS
e_a [*RH*, *VPD*]	MODIS | AIRS
Vegetation fraction	MODIS | Landsat

NET RADIATION

The retrieval of R_n involves the integrated retrieval of individual radiation balance components: downwelling shortwave radiation (R_{SD}), upwelling shortwave radiation (R_{SU}), downwelling longwave radiation (R_{LD}), and upwelling longwave radiation (R_{LU}):

$$R_N = (R_{SD} - R_{SU}) + (R_{LD} - R_{LU}) \quad (1)$$

R_{SD} is calculated from an atmospheric radiative transfer model, the Forest Light Environmental Simulator (FLiES) [*Iwabuchi*, 2006; *Kobayashi and Iwabuchi*, 2008; *Ryu et al.*, 2011; *Ryu et al.*, 2012]. FLiES uses: 1) solar zenith angle; 2) aerosol optical thickness at 550 nm; 3) cloud optical thickness; 4) land surface albedo; 5) cloud top height; 6) atmospheric profile type; 7) aerosol type; and, 8) cloud type. FLiES inputs are provided from MODIS products: MOD04 (aerosol optical thickness, aerosol type), MOD06 (cloud top height, cloud type), MCD43B2 and MCD43B3 (land surface albedo) [*Roesch et al.*, 2004; *Wind et al.*, 2010; *Bi et al.*, 2011; *Chen et al.*, 2011].

R_{SU} is calculated from broadband surface albedo (a), which integrates black and white sky albedo, and R_{SD}:

$$R_{SU} = \alpha R_{SD} \quad (2)$$

R_{LD} is calculated from Stefan-Boltzmann's Law:

$$R_{LD} = \sigma \varepsilon_A T_a^4 \quad (3)$$

where σ is the Stefan-Boltzmann constant (5.67×10^{-8} W m^{-2} K^{-4}), ε_A is the atmospheric emissivity, and T_a is air temperature. ε_A is calculated from total atmospheric precipitable water (ζ) [*Prata*, 1996]:

$$\varepsilon_A = 1 - (1 + \xi)\exp(-(C + D\xi)^{0.5}) \quad (4)$$

where C and D are coefficients with values of 1.2 and 3, respectively. ζ is available from MODIS product MOD05.

R_{LU} is also calculated from Stefan-Boltzmann's Law:

$$R_{LU} = \sigma \varepsilon_S T_S^4 \quad (5)$$

where ε_S is the surface emissivity and T_S is the radiometric surface temperature in Kelvin. ε_S and T_s are available from MODIS product MOD11L2 [*Coll et al.*, 2009].

Water vapor pressure (e_a) is derived from the dew point temperature (T_D) using the Clausius-Clapeyron relationship between the saturation vapor pressure and temperature:

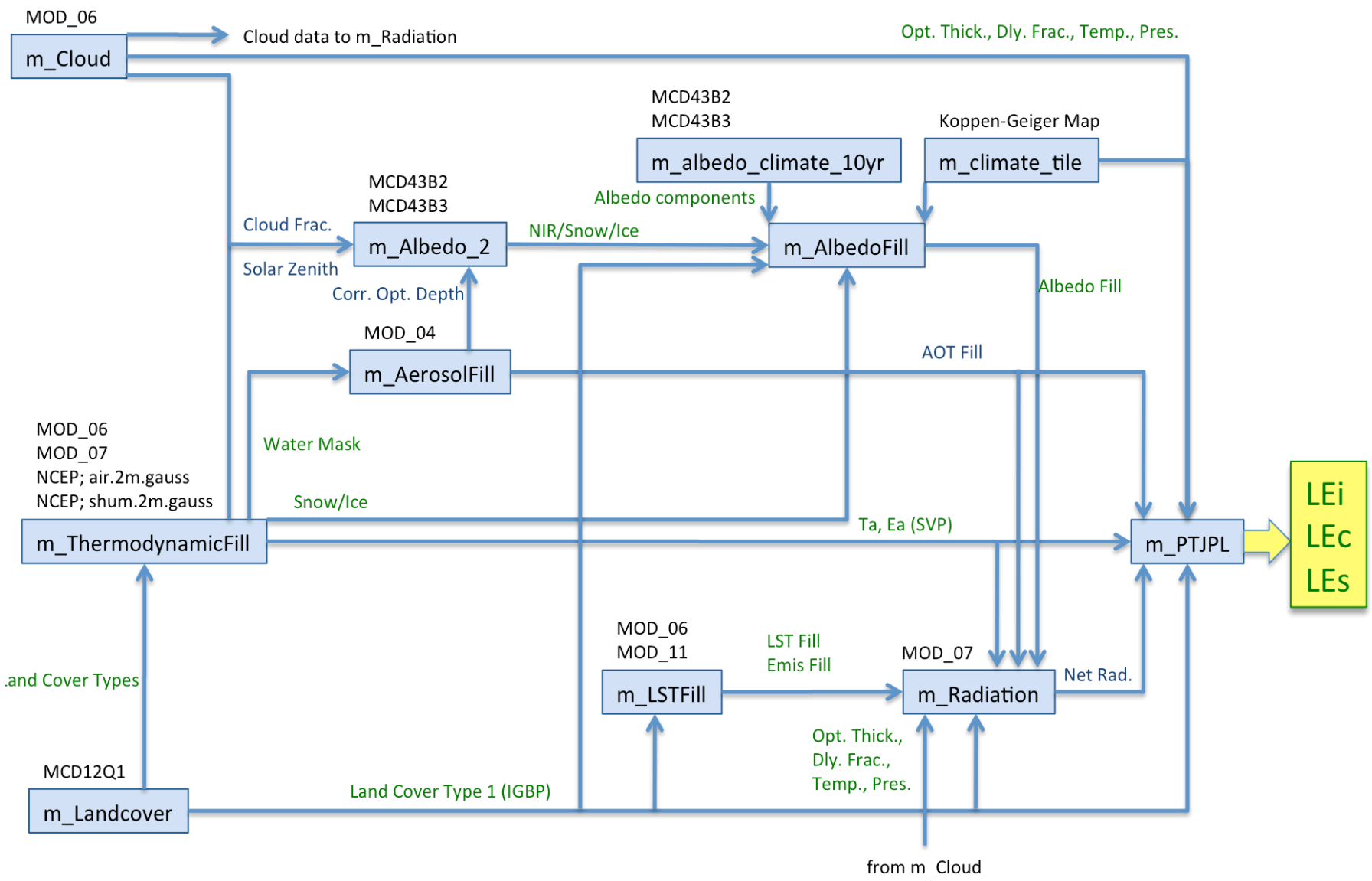
$$e_a = 6.13753 e^{\left(\frac{17.27 T_D}{T_D + 237.3}\right)} \quad (6)$$

T_D is available from MODIS product MOD07 [*Chen et al.*, 2011]. Near surface air temperature (T_a) is a direct MODIS product, MOD07 [*Chen et al.*, 2011].

Rn/ET Product Statistics

The following summarizes current data product usage in the Net Radiation and Evapotranspiration (Rn/ET) code, which will be used to generate L3/L4 ECOSTRESS products.

Type	Collection Name	Brief Description	Layers Of Interest	Level	Resolution		Projection	File Format	Source	Remarks
					Spatial	Temporal				
MODIS Land	MCD12Q1	MODIS Land Cover Type (Terra and Aqua, combined)	*Land_Cover_Type_1*	3	500 m	1 year	Sinusoidal, 2400 x 2400	HDF-EOS	LP-DAAC MCD12Q1	IGBP global vegetation classification scheme
	MCD43B2	MODIS BRDF/Albedo Quality, Snow Conditions (Terra and Aqua, combined)	*BRDF_Albedo_Quality* *Snow_BRDF_Albedo*	3	1 km	16 day (produced every 8 days)	Sinusoidal, 1200 x 1200	HDF-EOS	LP-DAAC MCD43B2	
	MCD43B3	MODIS Albedo (Terra and Aqua, combined)	*Albedo_BSA_shortwave* *Albedo_BSA_vis* *Albedo_BSA_nir* *Albedo_WSA_shortwave* *Albedo_WSA_vis* *Albedo_WSA_nir*	3	1 km	16 day (produced every 8 days)	Sinusoidal, 1200 x 1200	HDF-EOS	LP-DAAC MCD43B3	
	MOD11_L2	MODIS Land Surface Temperature and Emissivity 1 km	*LST* *Emis_31* *Emis_32* *QC*	2	*See Remarks*	*See Remarks*	Swath, 2330km x 2000km @ 1km	HDF-EOS	LP-DAAC MOD11_L2	1km (U.S.), 5 km (world) @ 1 day regridding, sinusoidal projection at NERSC
	MOD13A1	MODIS Vegetation Indices	*500m 16 days NDVI* *500m 16 days EVI*	3	500 m	16 day	Sinusoidal, 2400 x 2400	HDF-EOS	LP-DAAC MOD13A1	
	MOD15A2	MODIS Leaf Area Index (LAI) and Fraction of Photosynthetically Active Radiation (FPAR)	*Fpar_1km* *Lai_1km*	4	1 km	8 day	Sinusoidal, 1200 x 1200	HDF-EOS	LP-DAAC MOD15A2	
MODIS Atmosphere	MOD04_L2	MODIS Aerosol	*Longitude* *Latitude* *Corrected_Optical_Depth_Land* *Quality_Assurance_Land*	2	*See Remarks*	*See Remarks*	Swath, 135 x 203 @ 10 km	HDF-EOS	MODIS Atmosphere	1km (U.S.), 5 km (world) @ 1 day regridding, sinusoidal projection at NERSC
	MOD05_L2	MODIS Precipitable Water	*Water_Vapor_Near_Infrared* *Quality_Assurance_Near_Infrared*	2	*See Remarks*	*See Remarks*	Swath, 1354 x 2030 @ 1km, 270 x 406 @ 5 km	HDF-EOS	MODIS Atmosphere	1km (U.S.), 5 km (world) @ 1 day regridding, sinusoidal projection at NERSC
	MOD06_L2	MODIS Cloud Products	*Surface_Pressure* *Surface_Temperature* *Cloud_Top_Temperature_Day* *Cloud_Fraction_Day* *Cloud_Phase_Infrared_Day* *Cloud_Optical_Thickness* *Cloud_Effective_Radius* *Cloud_Water_Path* *Cloud_Top_Pressure_Day* *Quality_Assurance_1km* *Quality_Assurance_5km*	2	*See Remarks*	*See Remarks*	Swath, 1354 x 2030 @ 1 km, 270 x 406 @ 5 km	HDF-EOS	MODIS Atmosphere	1km (U.S.), 5 km (world) @ 1 day regridding, sinusoidal projection at NERSC
	MOD07_L2	MODIS Atmospheric Profiles	*Longitude* *Latitude* *Surface_Pressure* *Retrieved_Temperature_Profile* *Retrieved_Moisture_Profile* *Quality_Assurance* *Surface_Temperature* *Cloud_Mask* *Total_Ozone* *Solar_Zenith* *Sensor_Zenith* *Scan_Time* *Sinusoidal_X* *Sinusoidal_Y*	2	*See Remarks*	*See Remarks*	Swath, 270 x 406 @ 5 km	HDF-EOS	MODIS Atmosphere	1km (U.S.), 5 km (world) @ 1 day regridding, sinusoidal projection at NERSC
NCEP	air.2m.gauss	6-Hourly Forecast of Air Temperature at 2 m	*air*	NCEP-DOE Reanalysis-2	192 x 94 (global)	4x daily	Gaussian, T62	NetCDF	ESRL, NCEP-DOE Reanalysis 2	NCEP air temperature fills MOD07 Ta


MOD_06
m_Cloud
Cloud data to m_Radiation
Opt. Thick., Dly. Frac., Temp., Pres.
MCD43B2
MCD43B3
m_albedo_climate_10yr
Koppen-Geiger Map
m_climate_tile
MCD43B2
MCD43B3
Albedo components
Cloud Frac.
m_Albedo_2
NIR/Snow/Ice
m_AlbedoFill
Solar Zenith
Albedo Fill
Corr. Opt. Depth
MOD_04
m_AerosolFill
AOT Fill
MOD_06
MOD_07
NCEP; air.2m.gauss
NCEP; shum.2m.gauss
Water Mask
Snow/Ice
m_ThermodynamicFill
Ta, Ea (SVP)
m_PTJPL
LEi
LEc
LEs
MOD_06
MOD_11
LST Fill
Emis Fill
MOD_07
.and Cover Types
m_LSTFill
m_Radiation
Net Rad.
Opt. Thick.,
Dly. Frac.,
Temp., Pres.
MCD12Q1
m_Landcover
Land Cover Type 1 (IGBP)
from m_Cloud

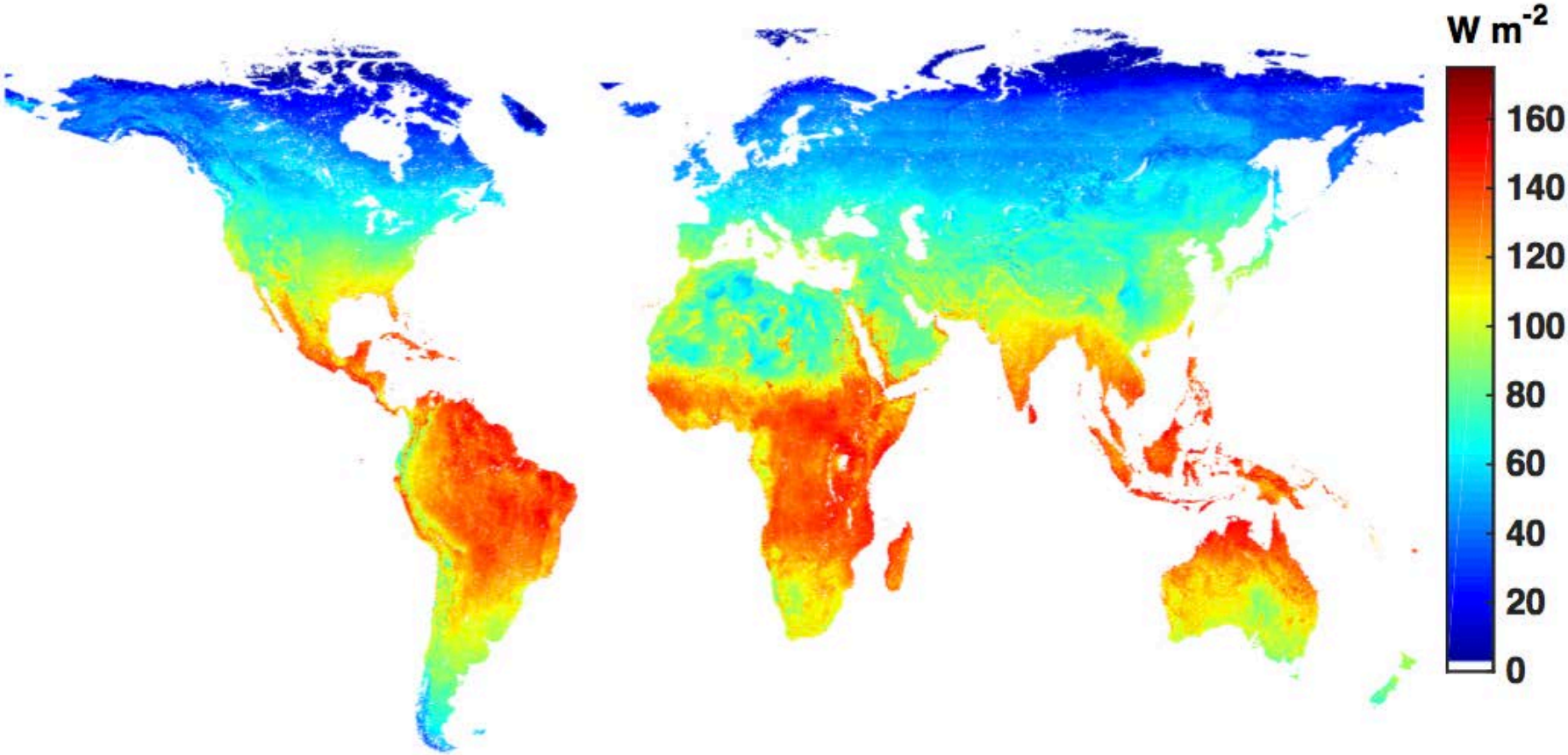
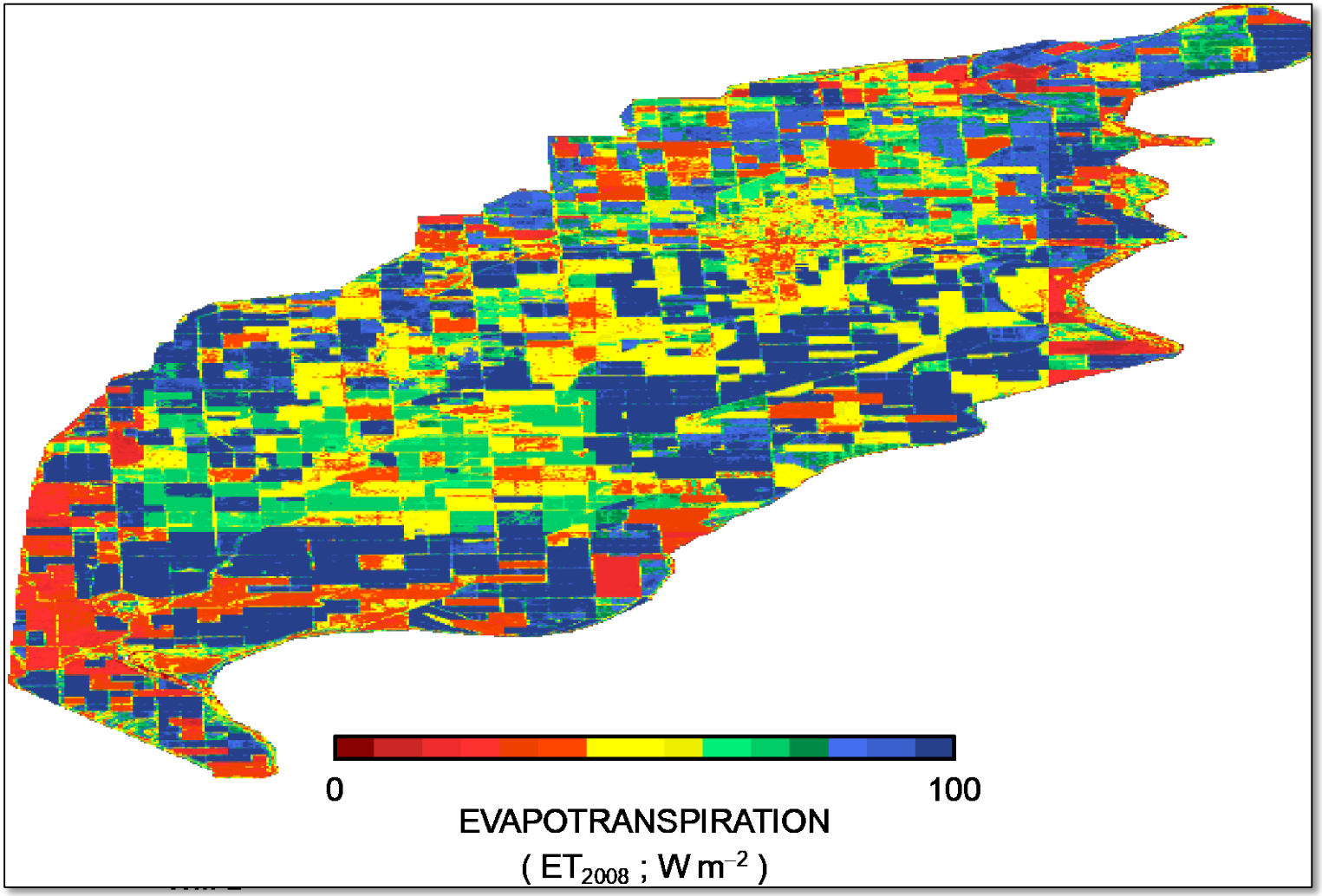
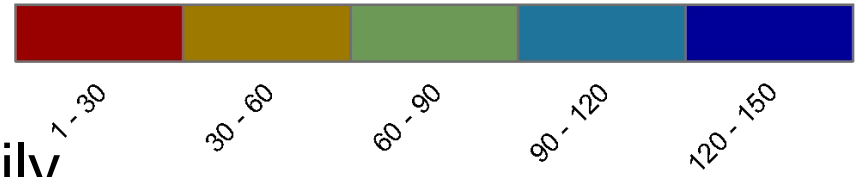


Figure 4. Mean daily (24-hour) global net-radiation (2001 to 2007) from MODIS.

Verma, M., **Fisher, J.B.**, Mallick, K., Ryu, Y., Kobayashi, H., Guillaume, A., Moore, G., Ramakrishnan, L., Hendrix, V., Wolf, S., Sikka, M., Kiely, G., Wohlfahrt, G., Gielen, B., Roupsard, O., Toscano, P., Arain, M.A., in revision. Global daily surface net-radiation at 5 km from MODIS. *Remote Sensing of Environment*.





Current JPL ET:

- Global, 1 km, daily
- Running multiple algorithms: PT-JPL, PM-MOD16, SEBS, PMBL

Geosci. Model Dev., 9, 283–305, 2016
www.geosci-model-dev.net/9/283/2016/
doi:10.5194/gmd-9-283-2016
© Author(s) 2016. CC Attribution 3.0 License.
Geoscientific Model Development

The GEWEX LandFlux project: evaluation of model evaporation using tower-based and globally gridded forcing data

M. F. McCabe[1], A. Ershadi[1], C. Jimenez[2], D. G. Miralles[3], D. Michel[4], and E. F. Wood[5]

Agricultural and Forest Meteorology 187 (2014) 46–61
Contents lists available at ScienceDirect
Agricultural and Forest Meteorology
journal homepage: www.elsevier.com/locate/agrformet

Multi-site evaluation of terrestrial evaporation models using FLUXNET data

A. Ershadi[a,*], M.F. McCabe[b], J.P. Evans[c,d], N.W. Chaney[e], E.F. Wood[e]

Remote Sensing of Environment 115 (2011) 801–823
Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

Global estimates of evapotranspiration for climate studies using multi-sensor remote sensing data: Evaluation of three process-based approaches

Raghuveer K. Vinukollu[a,*], Eric F. Wood[a], Craig R. Ferguson[a], Joshua B. Fisher[b]

Remote Sensing of Environment 140 (2014) 279–293
Contents lists available at ScienceDirect
Remote Sensing of Environment
journal homepage: www.elsevier.com/locate/rse

Comparison of satellite-based evapotranspiration models over terrestrial ecosystems in China

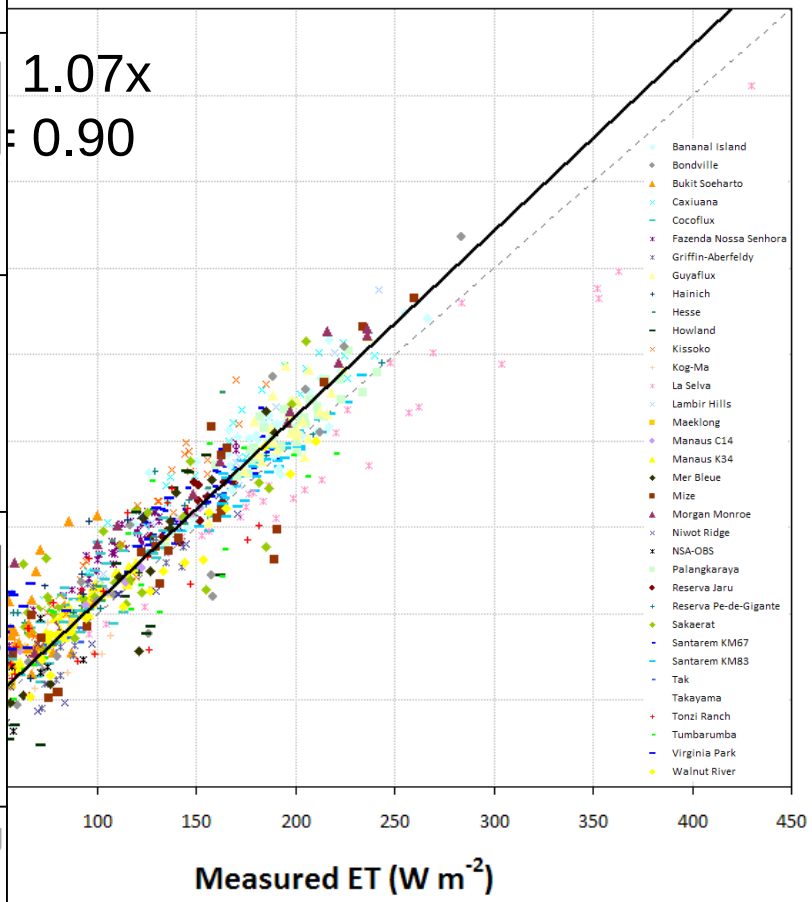
Yang Chen[a,b], Jiangzhou Xia[a,b], Shunlin Liang[h,c], Jinming Feng[a,d], Joshua B. Fisher[e], Xin Li[f], Xianglan Li[b], Shuguang Liu[g], Zhuguo Ma[d], Akira Miyata[h], Qiaozhen Mu[i], Liang Sun[j], Jianwei Tang[k], Kaicun Wang[a,b], Jun Wen[l], Yueju Xue[i], Guirui Yu[m], Tonggang Zha[n], Li Zhang[o], Qiang Zhang[k], Tianbao Zhao[d], Liang Zhao[p], Wenping Yuan[a,q,*]

Hydrol. Earth Syst. Sci. Discuss., 12, 10739–10787, 2015
www.hydrol-earth-syst-sci-discuss.net/12/10739/2015/
doi:10.5194/hessd-12-10739-2015
© Author(s) 2015. CC Attribution 3.0 License.
Hydrology and Earth System Sciences Discussions

This discussion paper is/has been under review for the journal Hydrology and Earth System Sciences (HESS). Please refer to the corresponding final paper in HESS if available.

The WACMOS-ET project – Part 1: Tower-scale evaluation of four remote sensing-based evapotranspiration algorithms

D. Michel[1], C. Jiménez[2,3], D. G. Miralles[4,5], M. Jung[6], M. Hirschi[1], A. Ershadi[7], B. Martens[5], M. F. McCabe[7], J. B. Fisher[8], Q. Mu[9], S. I. Seneviratne[1], E. F. Wood[10], and D. Fernández-Prieto[11]



ET VALIDATION

D., 2008.

ECOSTRESS

ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

An Earth Venture Instrument-2 Proposal

Submitted in response to

AO NNH12ZDA006O EVI2

Prepared for

National Aeronautics and Space Administration
Science Mission Directorate

PI — Simon Hook (JPL)

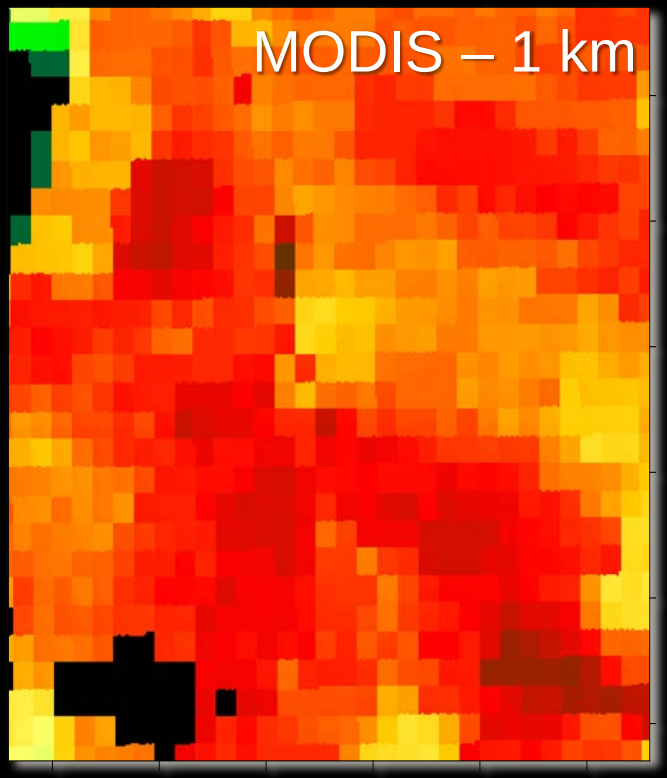
SCIENCE LEAD — **Joshua B. Fisher** (JPL)

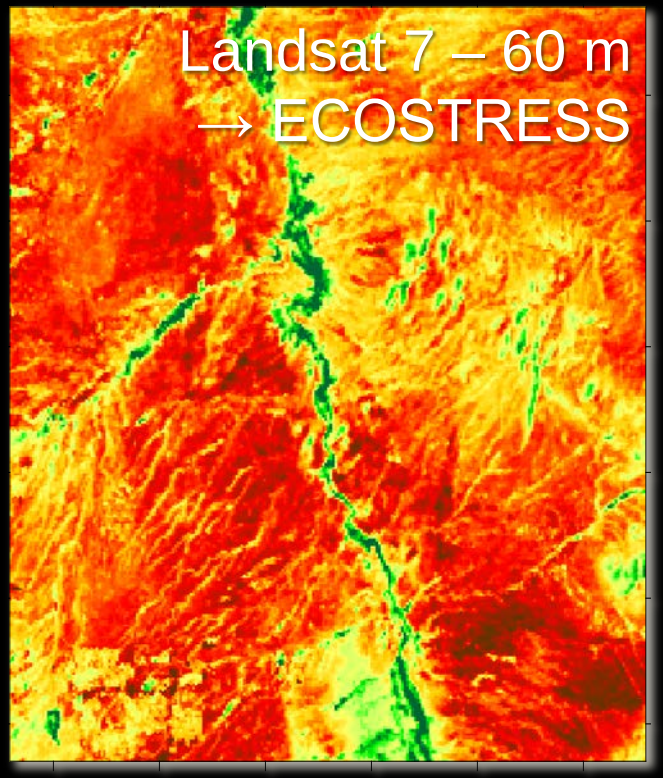
SCIENCE TEAM — Rick Allen (U. Idaho)
Martha Anderson (USDA)
Andy French (USDA)
Chris Hain (UMD)
Glynn Hulley (JPL)
Eric Wood (Princeton U.)

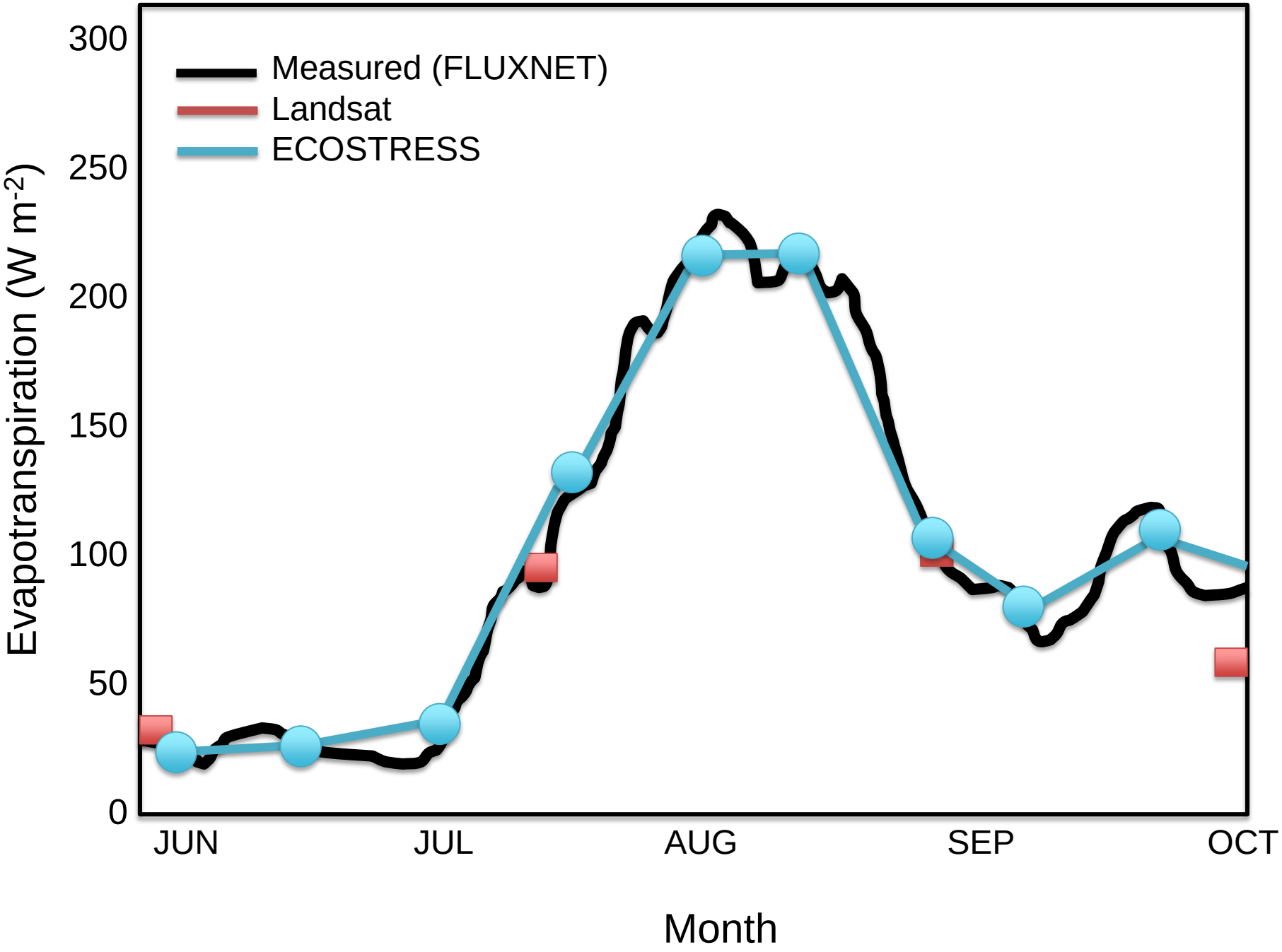
November 25, 2013

© 2014 California Institute of Technology. Government sponsorship acknowledged.

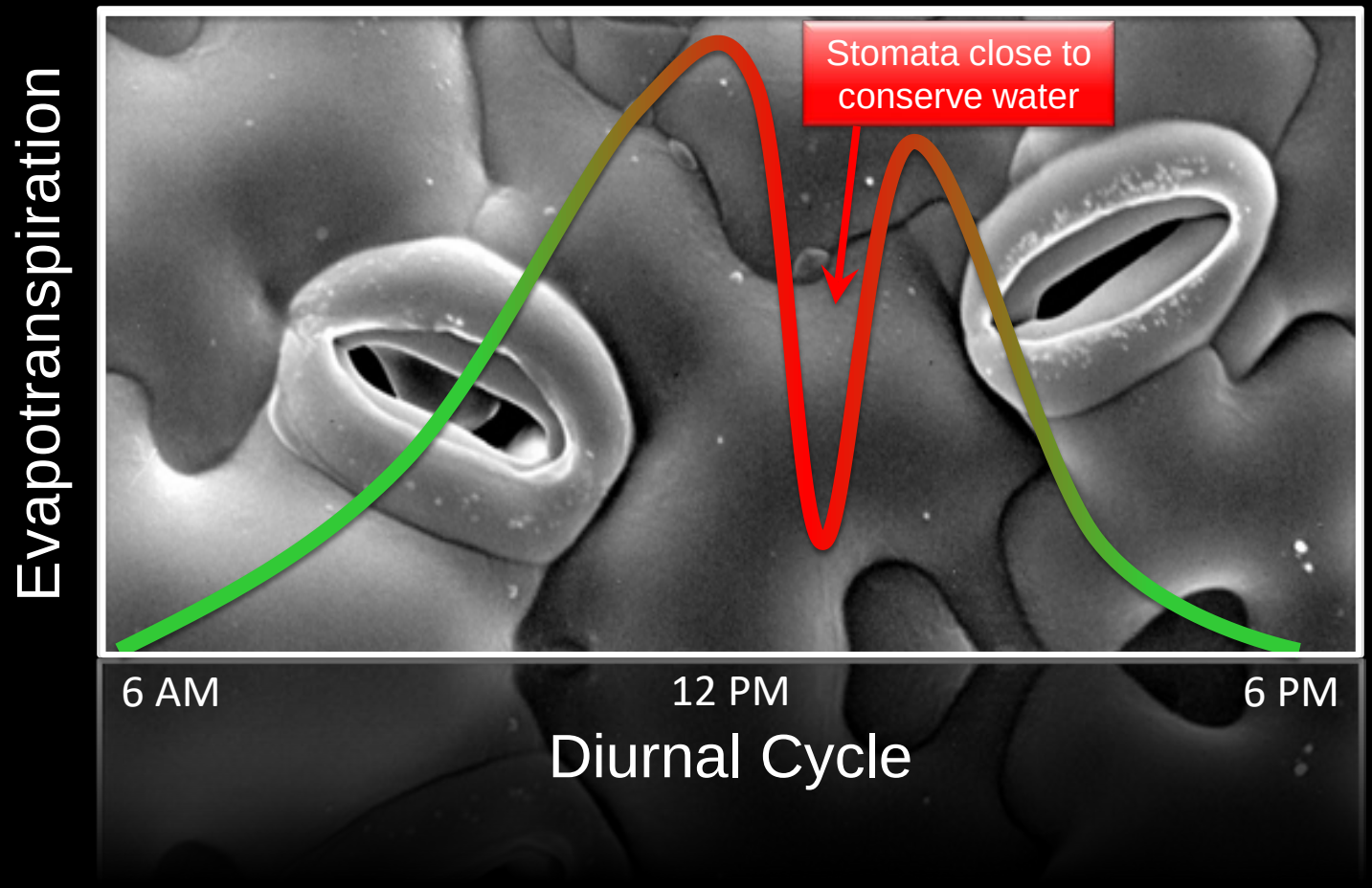
What we need: accurate, high spatial, high temporal, diurnal cycle, global, ET.


MODIS – 1 km

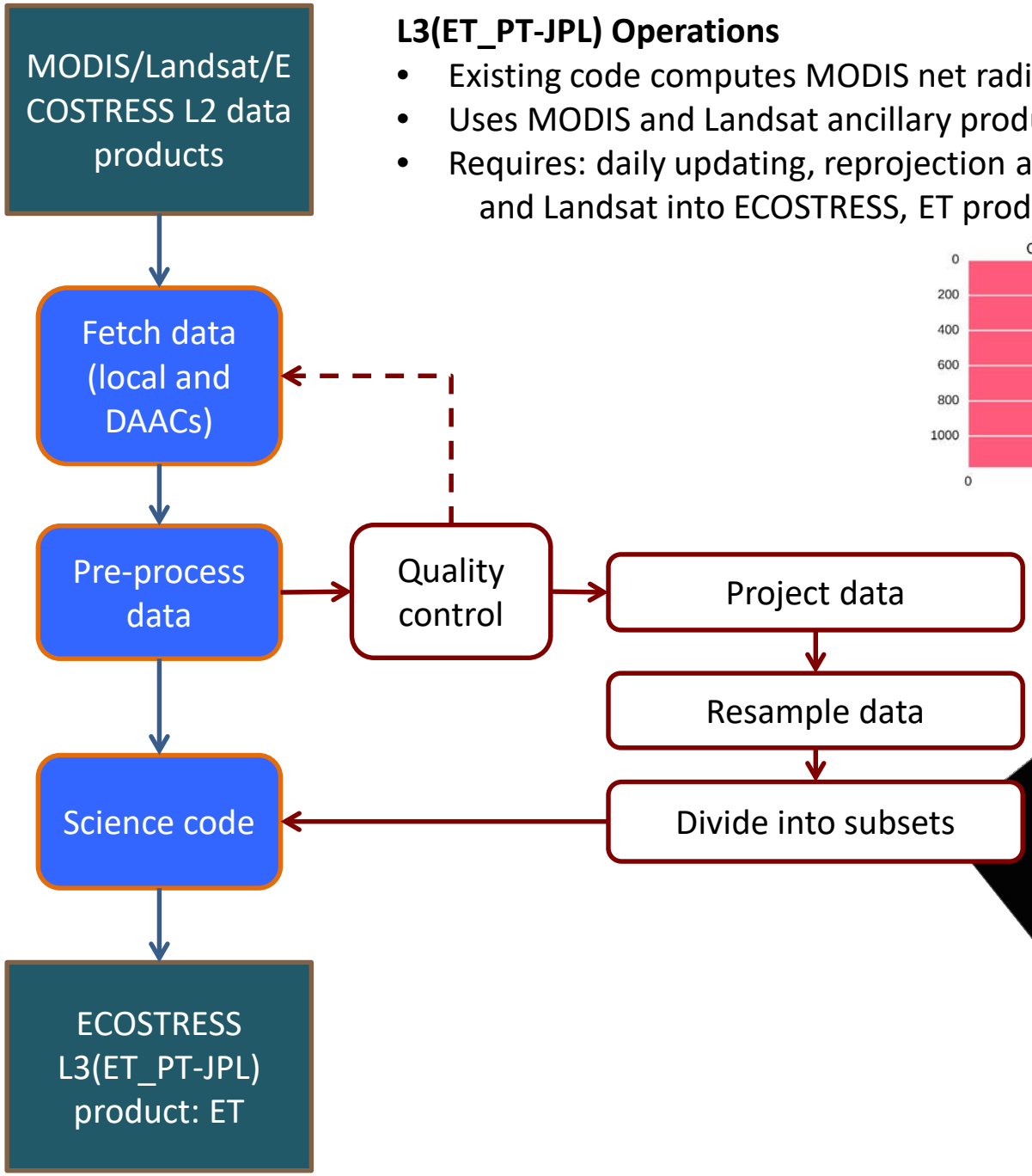
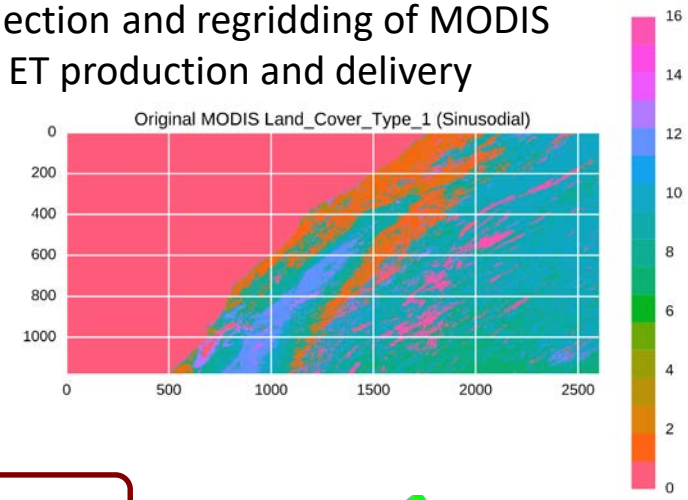
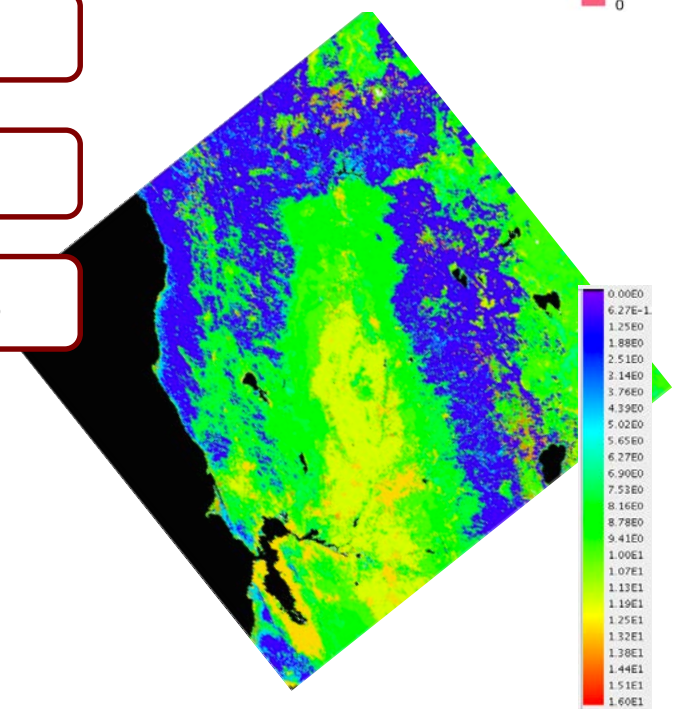

Landsat 7 – 60 m
→ ECOSTRESS


Measured (FLUXNET)
Landsat
ECOSTRESS
Evapotranspiration (W m-2)
300
250
200
150
100
50
0
JUN
JUL
AUG
SEP
OCT
Month

Water Stress Drives Plant Behavior



The International Space Station (ISS)

L3(ET_PT-JPL) Operations

- Existing code computes MODIS net radiation and evapotranspiration
- Uses MODIS and Landsat ancillary products + ECOSTRESS LST&E
- Requires: daily updating, reprojection and regridding of MODIS and Landsat into ECOSTRESS, ET production and delivery