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Application of remote sensing data in global evapotranspiration (ET) estimate

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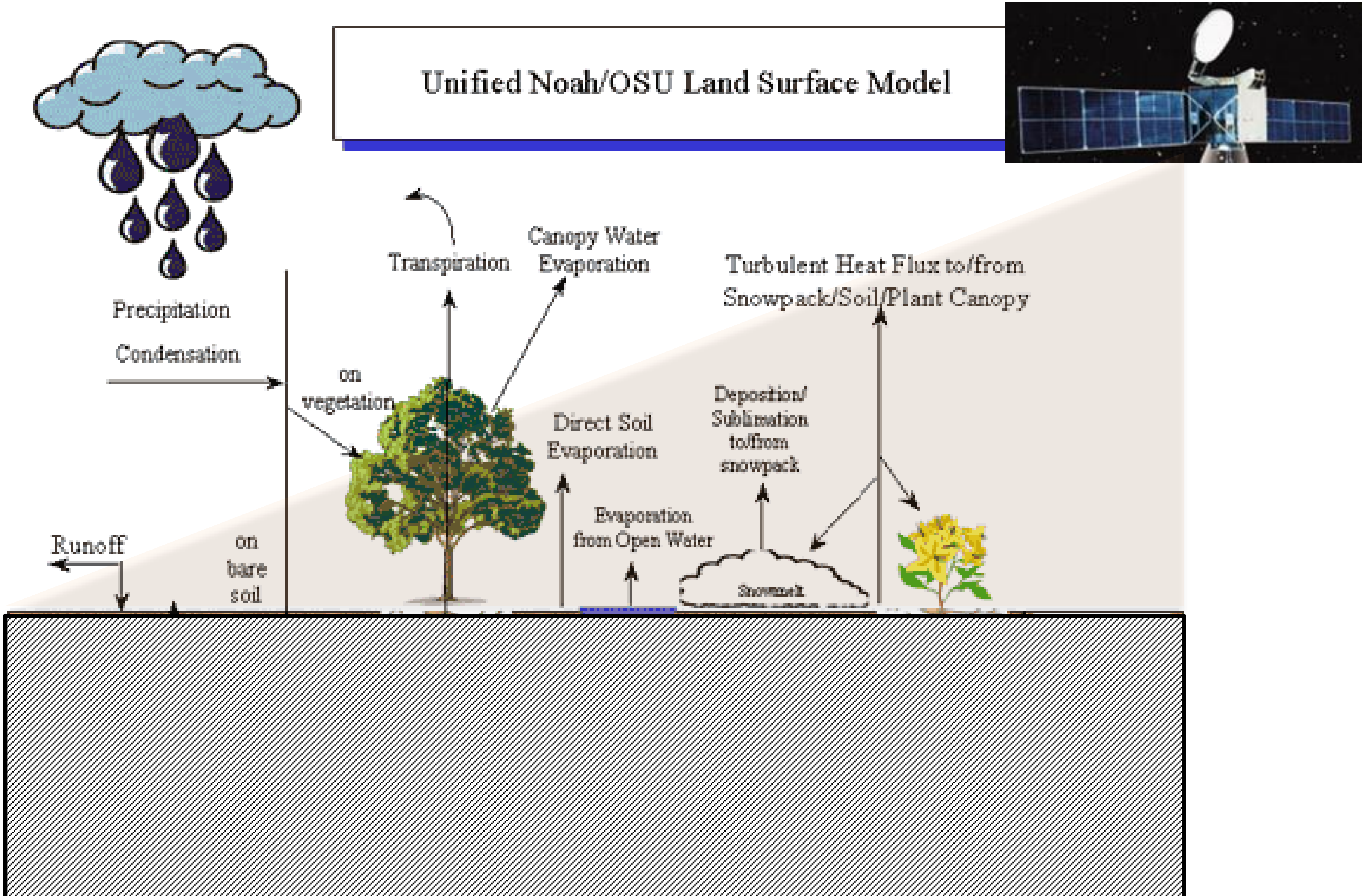
CONTENTS

- 1. Why the remote sensing data is important for global land surface energy balance and evapotranspiration (ET) studies?
- 2. Applications of satellite data in ET estimate
- 3. Conclusions

ET produced by land surface process model and reanalysis data

	Method	Spatial resolution	Temporal resolution
GSWP-2	Land surface model	≈1 deg.	6 hours
GLDAS	Land surface model&data assimilation	≈0.25 deg.	3 hours
ERA-int	Reanalysis	≈0.125 deg.	3 hours
NCEP	Reanalysis	≈1.25 deg.	6 hours
MERRA	Reanalysis	≈0.5 deg.	
JRA-25	Reanalysis	≈1.25 deg.	6 hours


Unified Noah/OSU Land Surface Model
Precipitation
Condensation
on vegetation
on bare soil
Runoff
Transpiration
Canopy Water Evaporation
Direct Soil Evaporation
Evaporation from Open Water
Deposition/ Sublimation to/from snowpack
Snowpack
Turbulent Heat Flux to/from Snowpack/Soil/Plant Canopy

Remote sensing based Global ET product

	Algorism	Input dataset	Grid size	Temporal resolution	Time span	References	Data source
MOD16-ET	Penman-Monteith	daily temperature, actual vapor pressure, solar radiation, LAI, NDVI, and LST	1 km	Daily	2000-2011	Mu et al. (2007)	GMAO, MODIS
Zhang-ET	PM of Vegetation + PM Soil evaporation	daily temperature, Net radiation, NDVI,	8 km	monthly	1983-2006	Zhang et al. (2010)	NCEP/NCAR, GEWEX SRB, GIMMS
GLEAM	Priestley & Taylor	Net Radiation, Precipitation, Air temperature, Vegetation optical depth, Snow water equivalents, Soil Moisture, Skin Temperature	0.25 deg.	daily	1984-2007	Miralles et al. 2011	GEWEX SRB, CMORPH NSIDC, ISCCP, TMMI+AMSR-E

➢2. Applications of satellite data in evapotranspiration estimate

- SEBS model introduction
- CASE1: Landsat TM/ETM used in mountainous area
- CASE2: MODIS LST used in China landflux and ET
- CASE3: Remote sensing data applied in Global ET

SEBS model equations

- $Rn = (1 - \alpha)\, SWD + LWD - LWU$ **Radiation balance**
- $Rn = G0 + H + LE$ **Energy balance**
- $H = u_* \rho C_p (\theta_0 - \theta_a)[\ln\left(\frac{z-d}{z_{0h}}\right) - \Psi_h\left(\frac{z-d}{L}\right) + \Psi_h\left(\frac{z_{0h}}{L}\right)]^{-1}$

MOST

$$G_0 = R_n \cdot \left[f_c \cdot \Gamma_c + (1 - f_c) \cdot \Gamma_s \right]$$

Su et al. 2002

Heat roughness length parameterization

$$z_{0h} = \frac{z_{0m}}{\exp(kB^{-1})},$$

$$kB^{-1} = {f_c}^2 * kB_c^{-1} + {f_s}^2 * kB_s^{-1} + 2 * f_c * f_s * kB_m^{-1},$$

Canopy | Soil | Canopy+Soil

Su02

SY02

$$z_{0hs} = \frac{70\,\vartheta}{u_*} \exp(-7.2\, {u_*}^{0.5} {\theta_*}^{0.25}),$$

$$kB_s^{-1} = \log\left(\frac{z_{0ms}}{z_{0hs}}\right),$$

Yang 02

$$z_{om} = HC * (1 - d/HC) * \exp(-k\,\beta),$$

$$HC = HC_{min} + \frac{HC_{max} - HC_{min}}{(NDVI_{max} - NDVI_{min})} * (NDVI - NDVI_{min}),$$

$$\beta = C_1 - C_2 * \exp(-C_3 C_d * LAI),$$

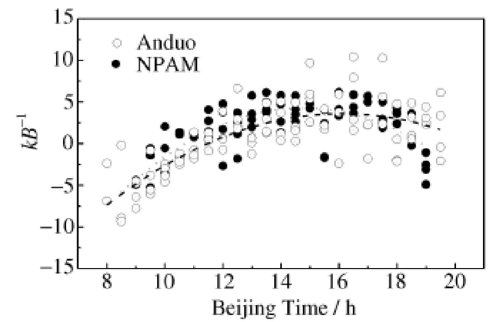
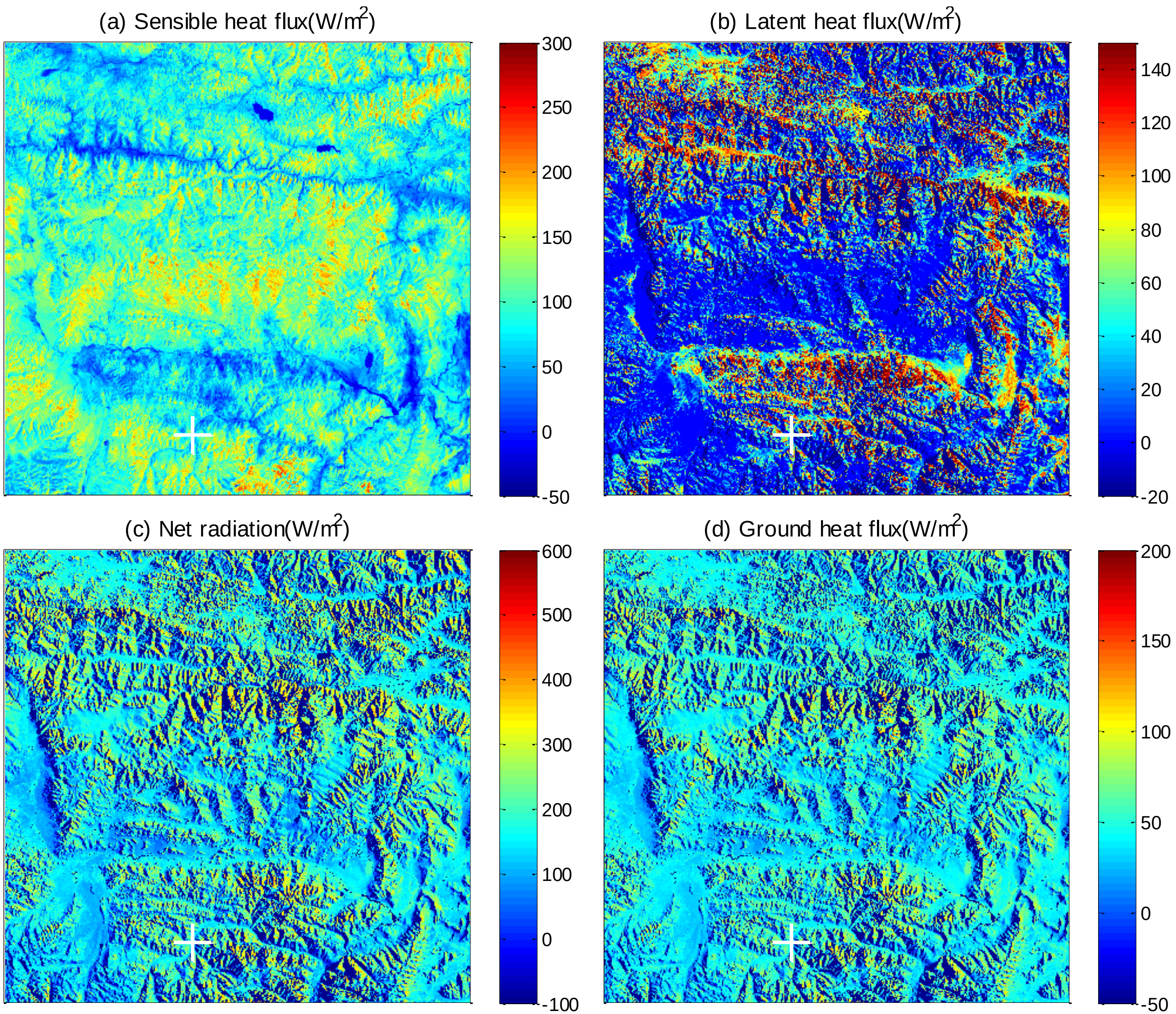


Fig. 2. Diurnal variations of the excess resistance to heat transfer kB^{-1} of Anduo Station and NPAM Station.

Chen et al. JAMC 2013

CASE 1: A land surface energy balance study using Landsat



Only 8 TM/ETM images can be used because of cloud noise.

ET? Not possible

Chen et al. 2013 HESS

CASE2: MODIS LST used in China land ET estimate

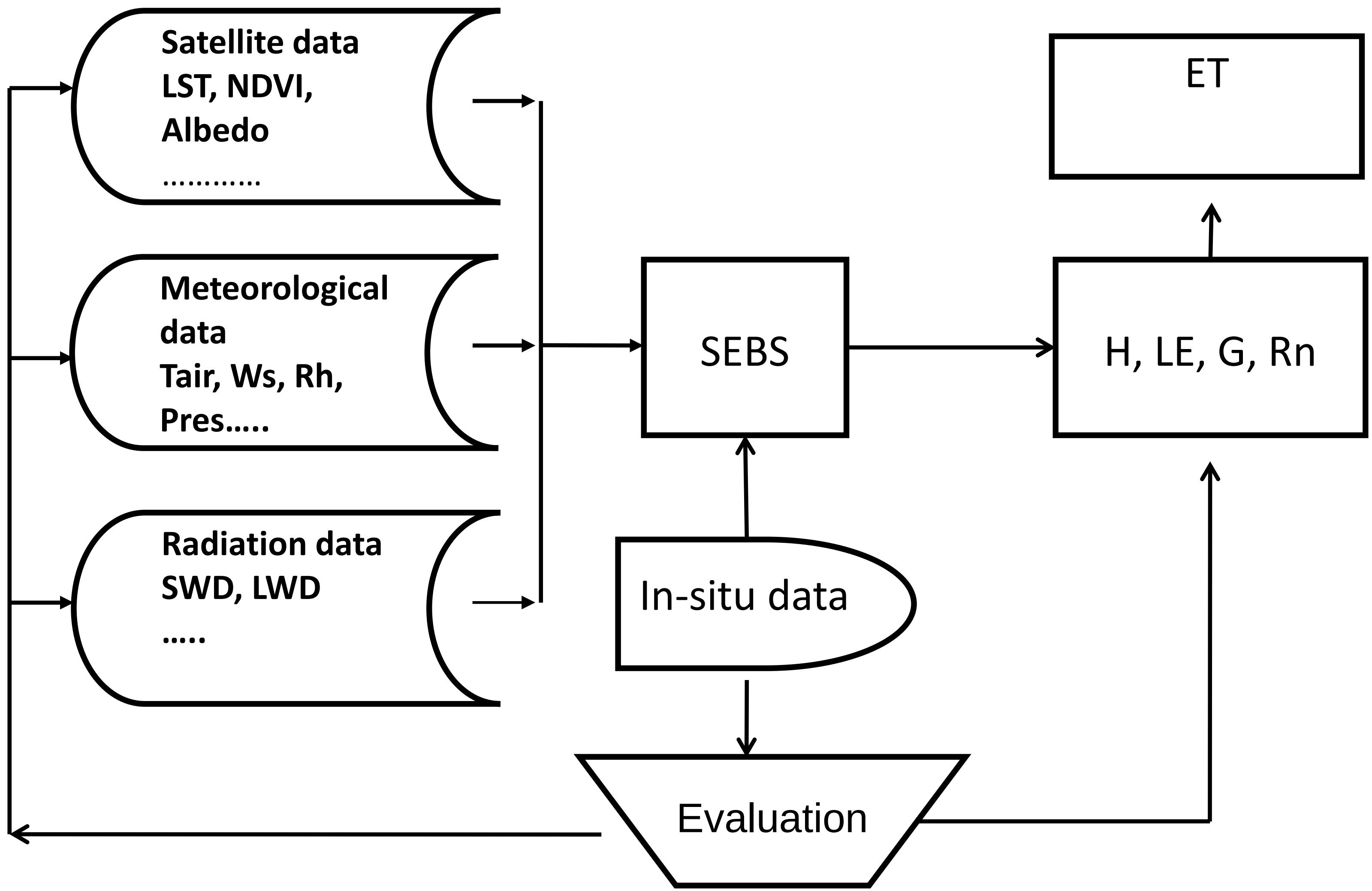
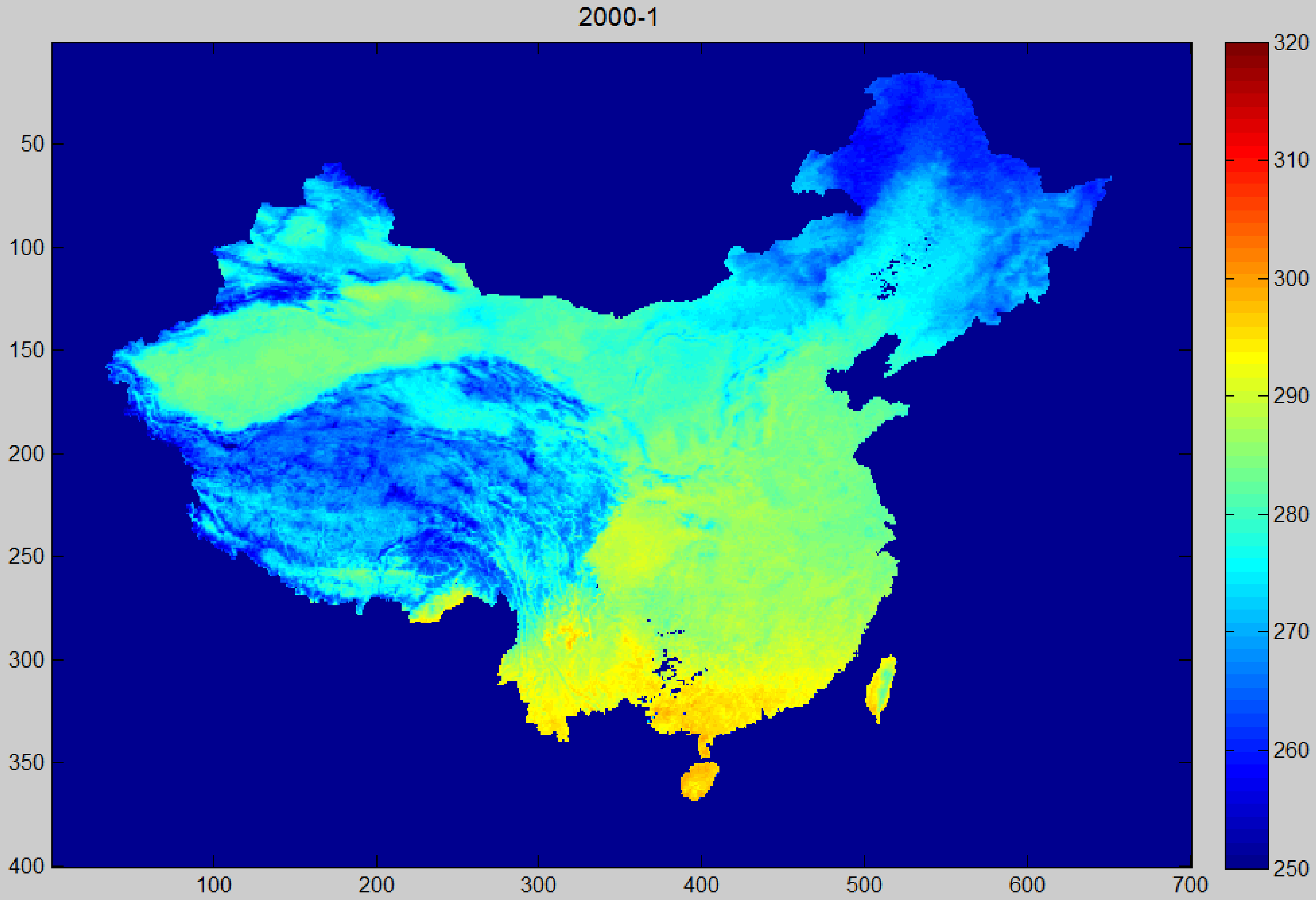


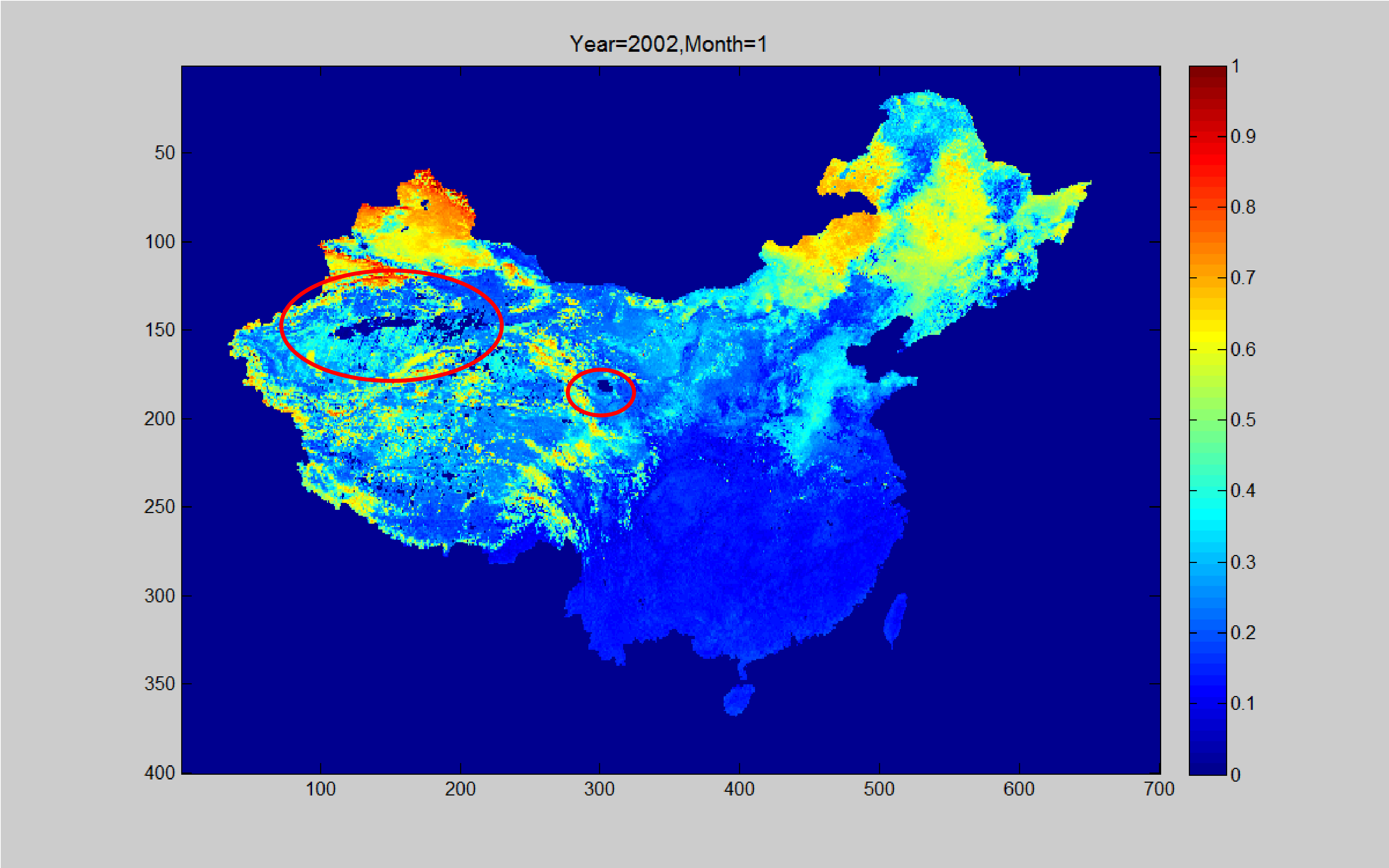
Table 1. Input data sets used for calculating China land energy fluxes

Variables	Source	Temporal resolution	Availability	Domain	Spatial Resolution	Method
SWD	ITPCAS	3 hours	1979-2010	China land	0.1 deg.	Satellite&Reanalysis
SWU	ITPCAS&GlobAlbedo	3 hours	2000-2010	China land	0.1 deg.	Satellite&Reanalysis
LWD	ITPCAS	3 hours	1979-2010	China land	0.1 deg.	Satellite&Reanalysis
LWU	MOD11C3	1 month	2000-pre.	China land	0.05deg.	Satellite
Ta	ITPCAS	3 hours	1979-2010	China land	0.1 deg.	Reanalysis
Q	ITPCAS	3 hours	1979-2010	China land	0.1 deg.	Reanalysis
Ws	ITPCAS	3 hours	1979-2010	China land	0.1 deg.	Reanalysis
P	ITPCAS	3 hours	1979-2010	China land	0.1 deg.	Reanalysis
LST	MOD11C3&MYD11C3	1 month	2000-pre.	Global	0.05deg.	Satellite
h_c	GLAS&SPOT VEGETATION	1 month	2000-2012	China land	0.01deg.	Satellite
α	GlobAlbedo	1 month	2000-2010	Global	0.05deg.	Satellite
NDVI	SPOT VEGETATION	10 days	1998-2012	Global	0.01deg.	Satellite
LAI	MOD15A2& MCD15A2	8 days	2000-2012	Global	0.01deg.	Satellite

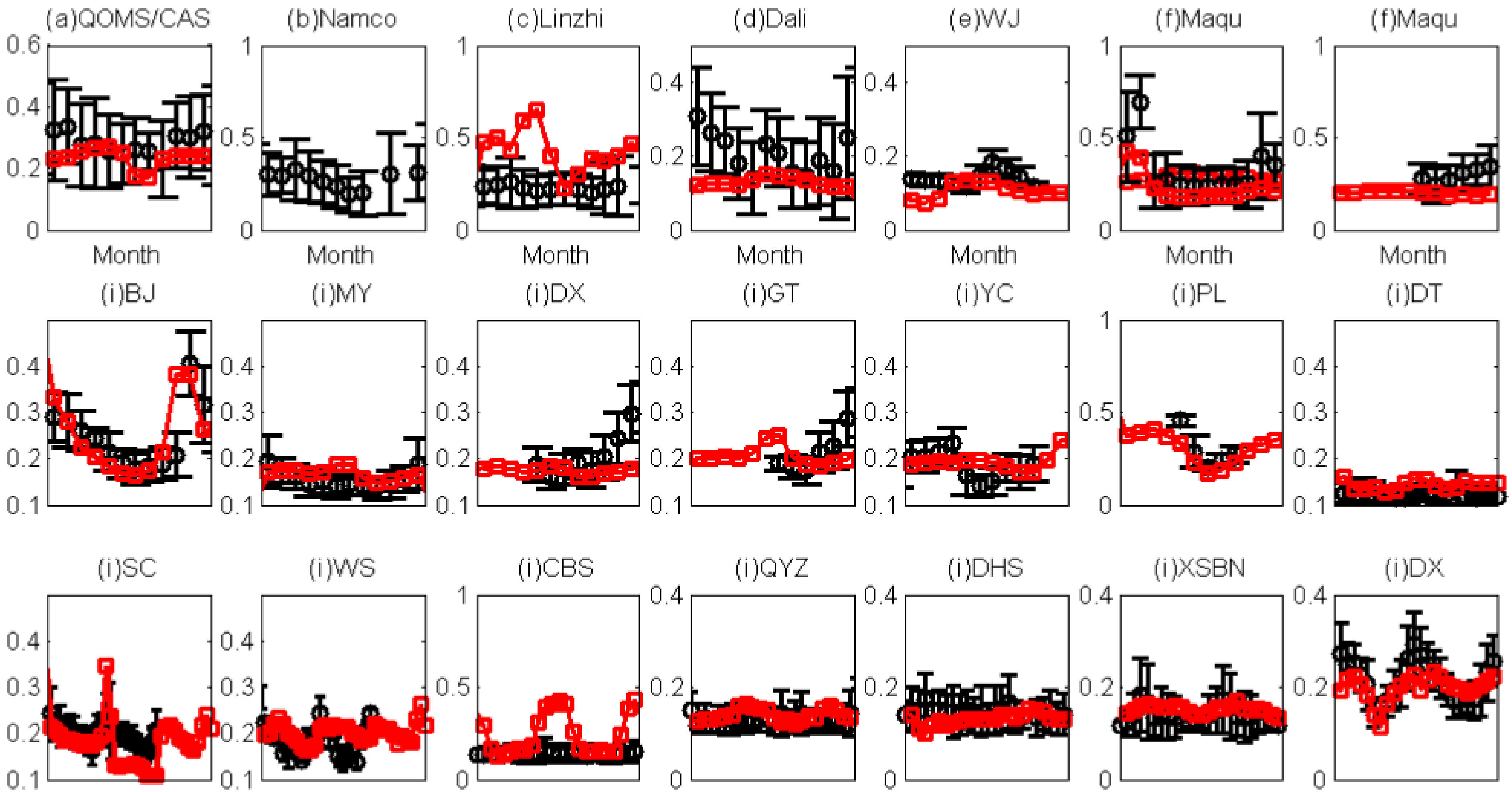
MODIS monthly LST



GlobAlbedo over China landmass

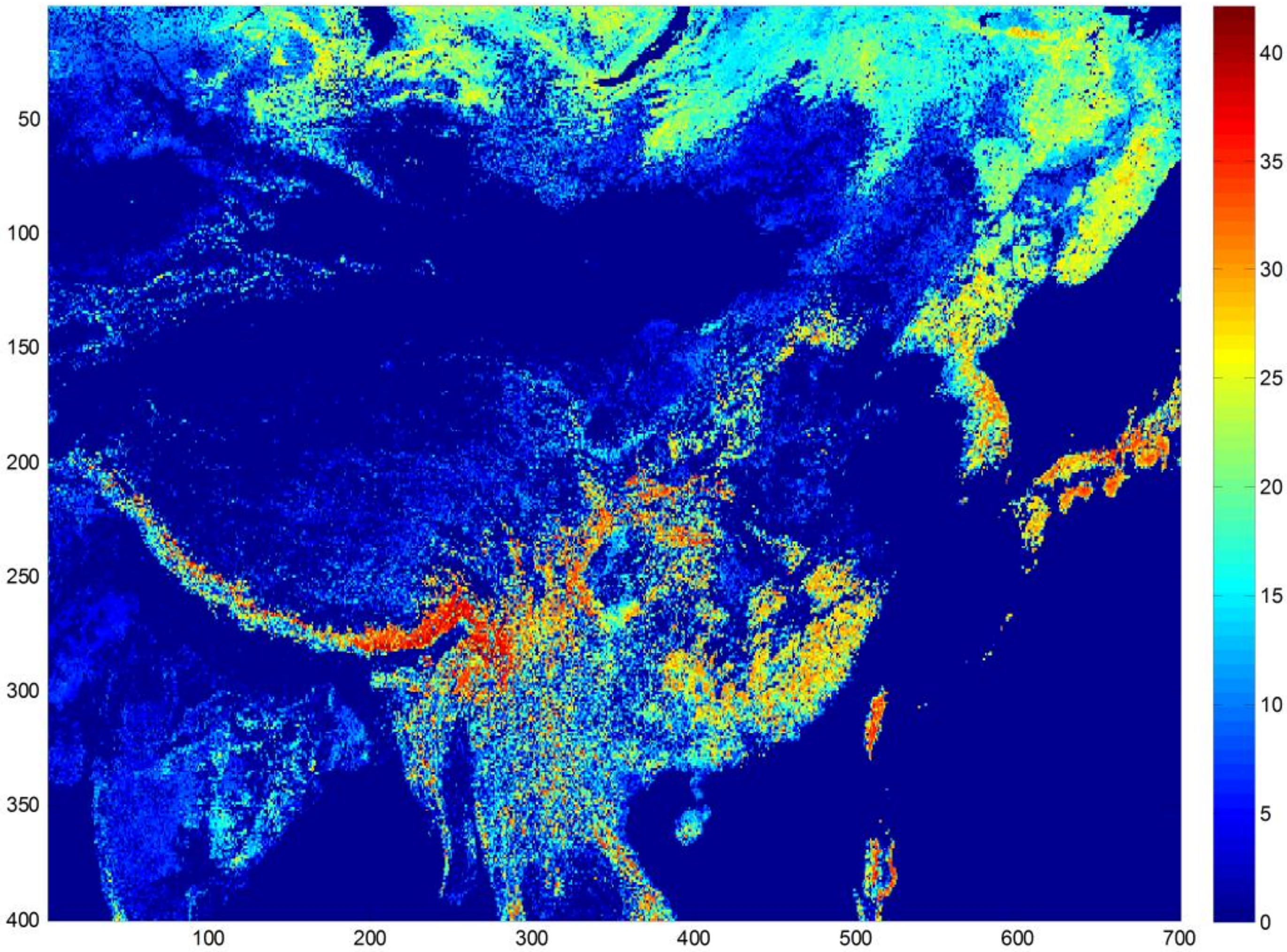


GlobAlbedo performance at 21 flux stations in China



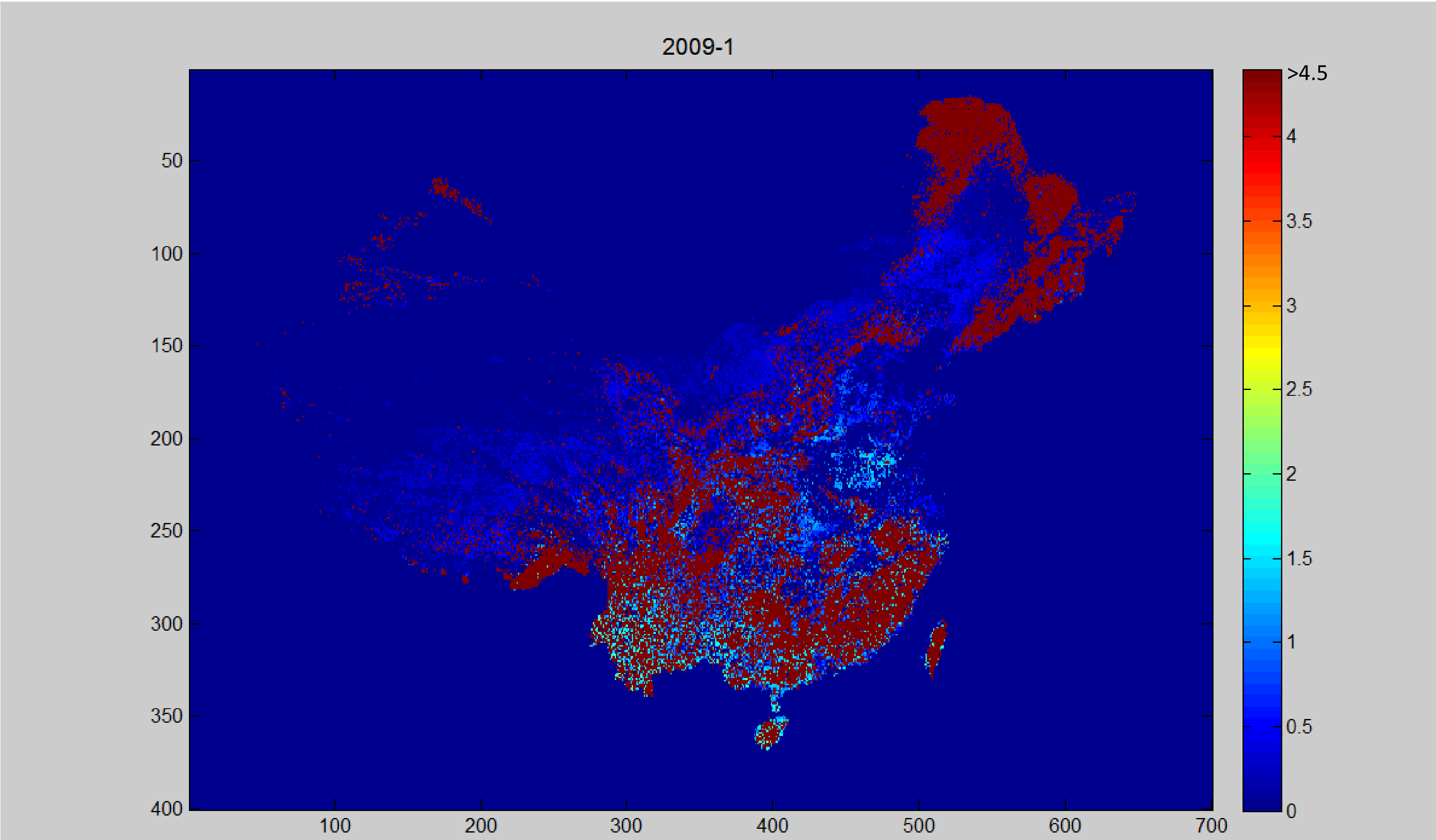
Red square- GlobAlbedo, Error bar- in-situ measurement

Forest canopy height information



Simard,et. al., 2011, Geoscience Laser Altimeter System (GLAS) aboard ICESat

Canopy height (forest + short canopy)

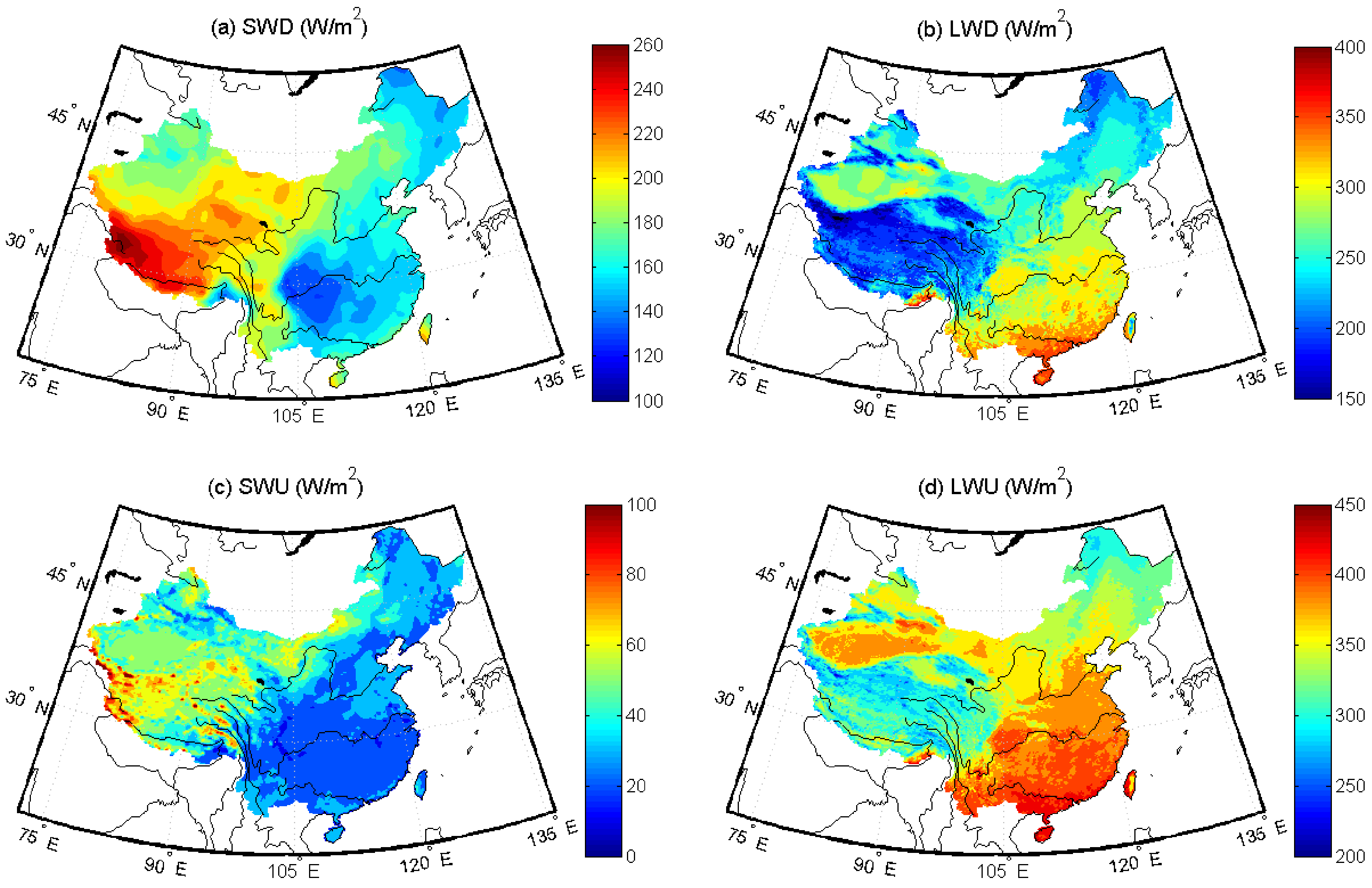


Short canopy height:

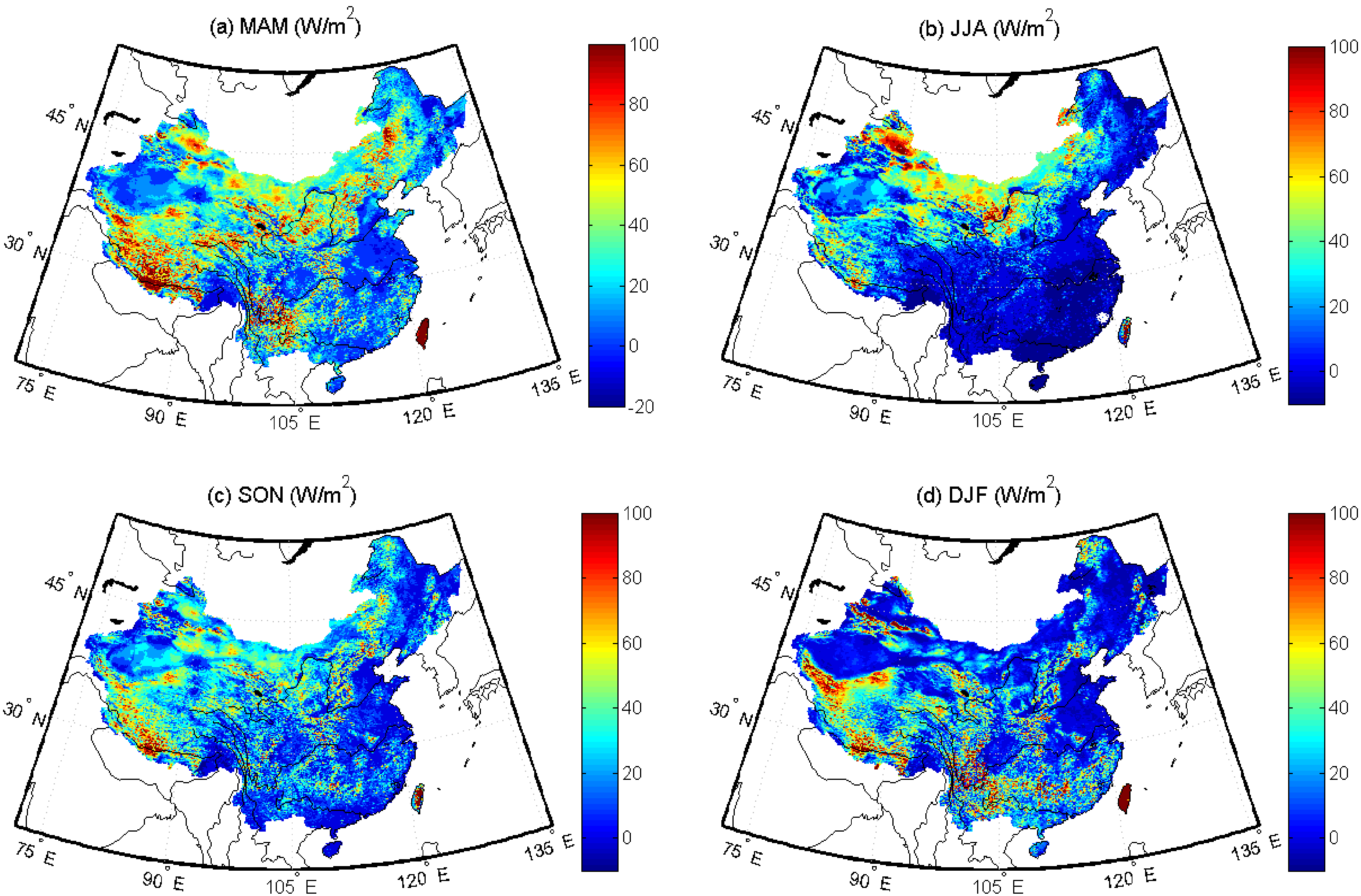
$$HC = HC_{min} + \frac{HC_{max} - HC_{min}}{(NDVI_{max} - NDVI_{min})} * (NDVI - NDVI_{min}),\ HC_{max} = 2.5, HC_{min} = 0.0012$$

Chen et al. 2013 JAMC

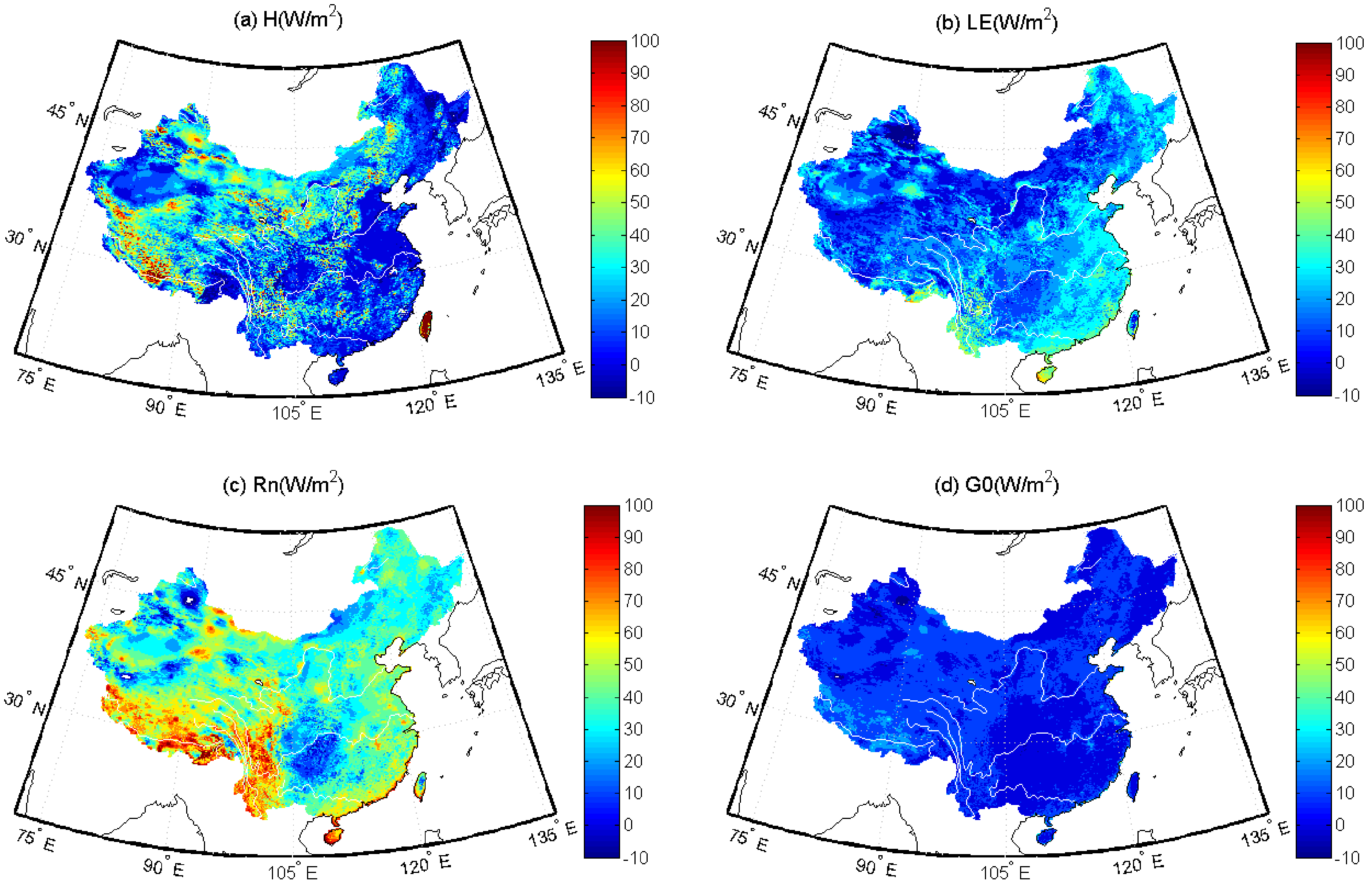
Yearly average maps of (a) downward shortwave radiation (SWD), (b) downward longwave radiation (LWD), (c) upward shortwave radiation (SWU), (d) upward longwave radiation (LWU) from 2000 to 2010.



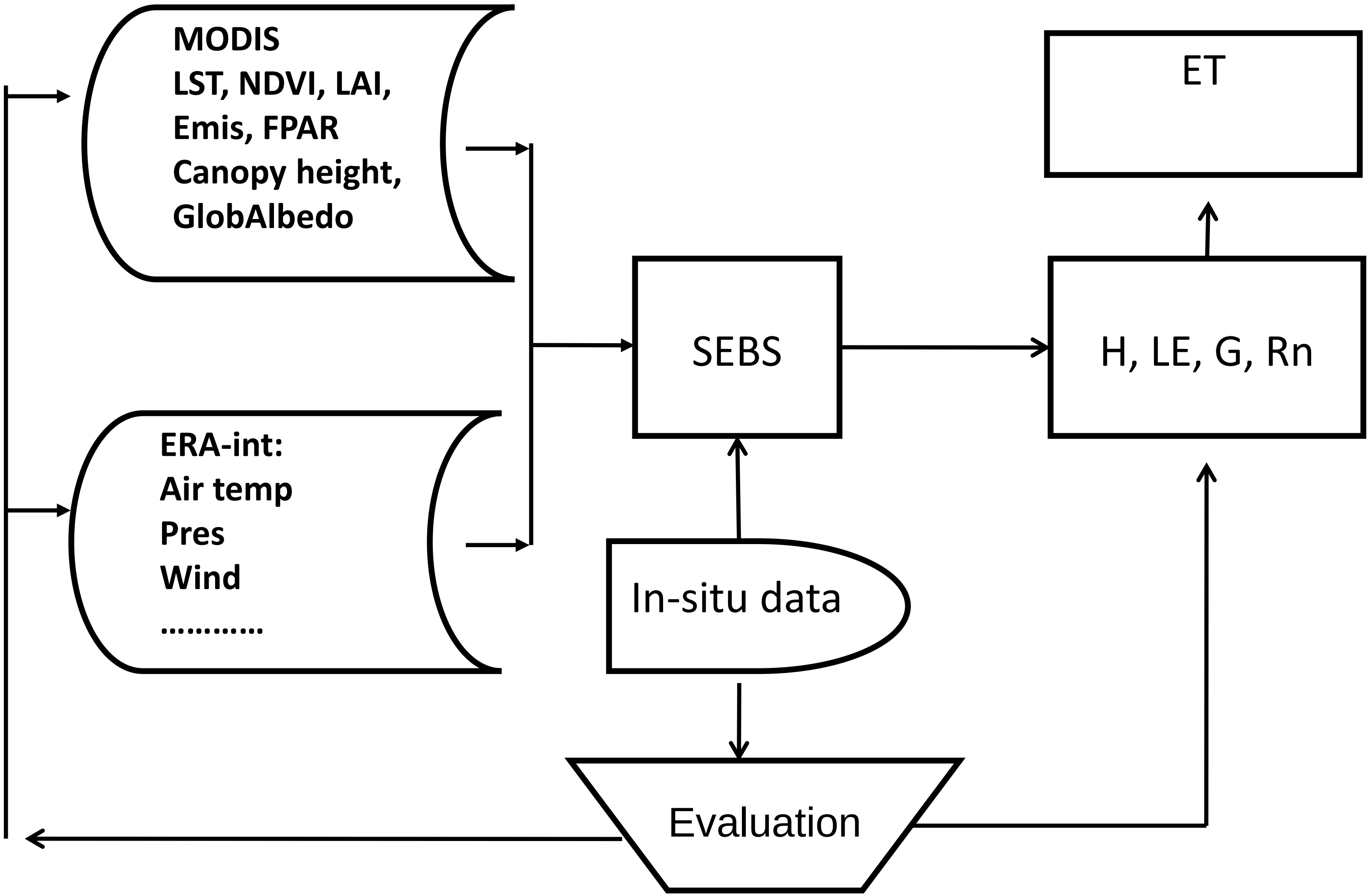
Seasonal average maps of sensible heat flux (H), (a) Mar-May, (b) Jun-Aug,(c) Sep-Nov, (d) Dec-Feb



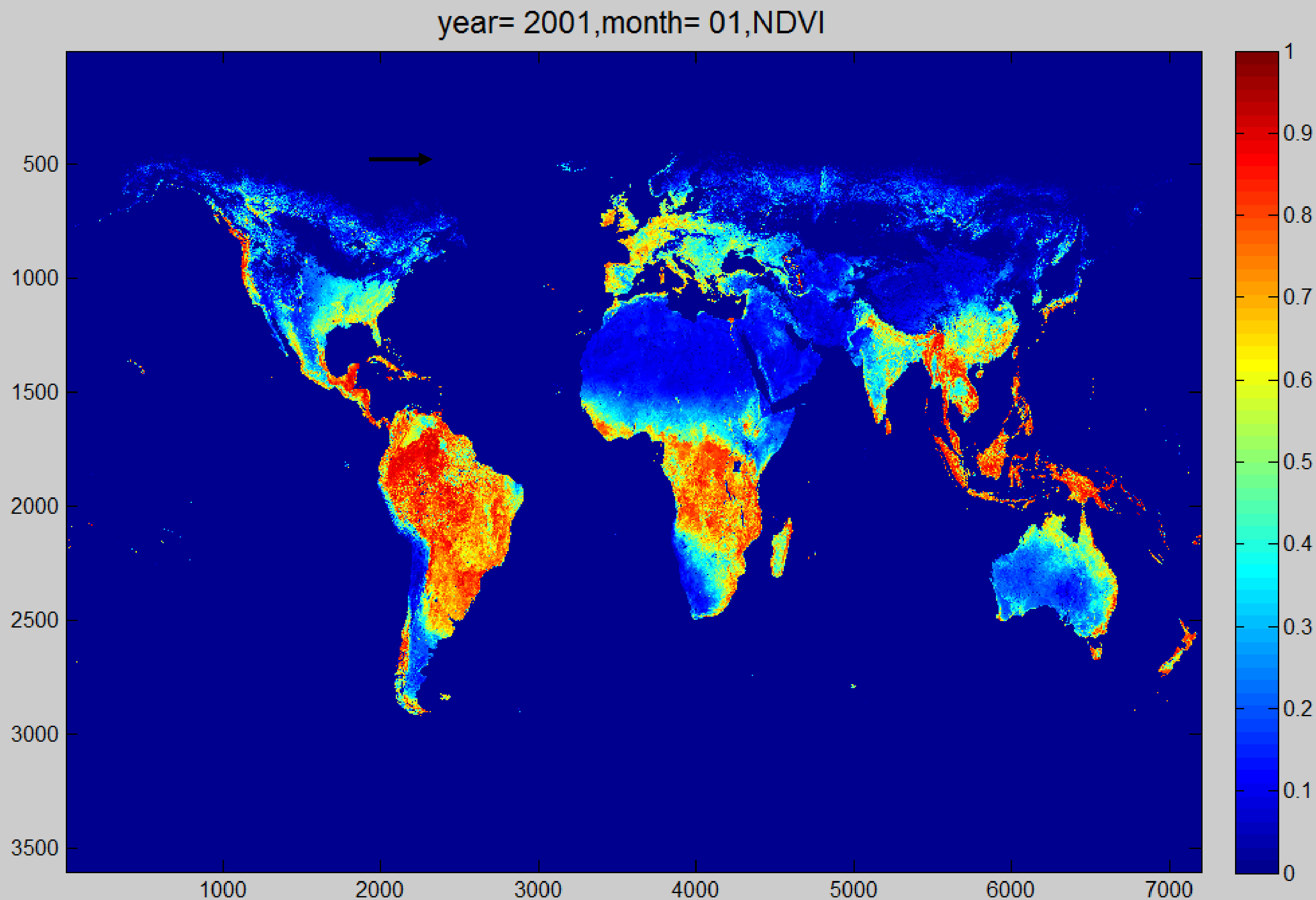
Maps of multiyear (2000-2010) mean of (a) sensible heat flux (H), (b) latent heat flux (LE), (c) net radiation (Rn), (d) ground heat flux (G0)



CASE3: Remote sensing data applied in Global ET

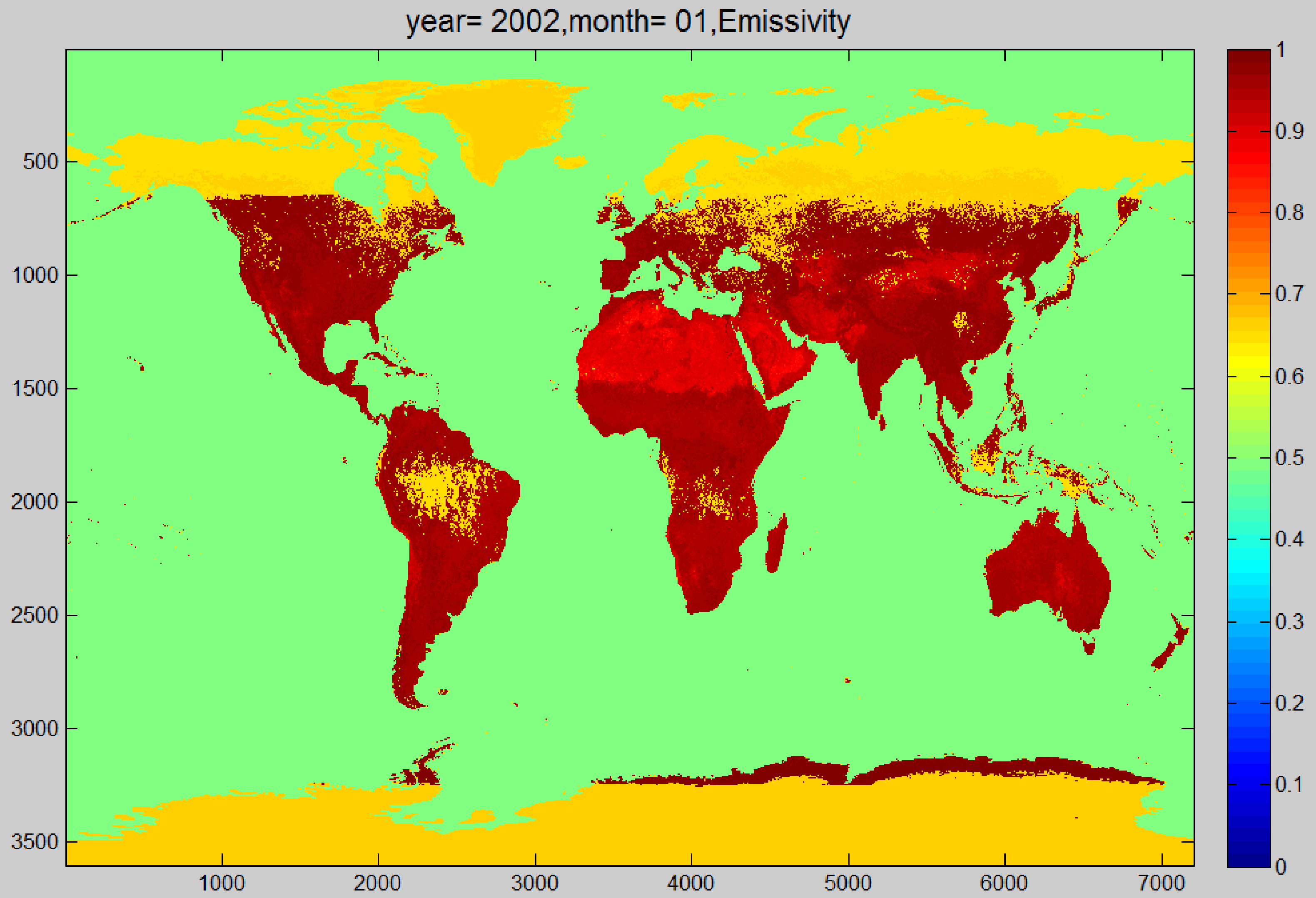


Remote sense observed input data for Global ET



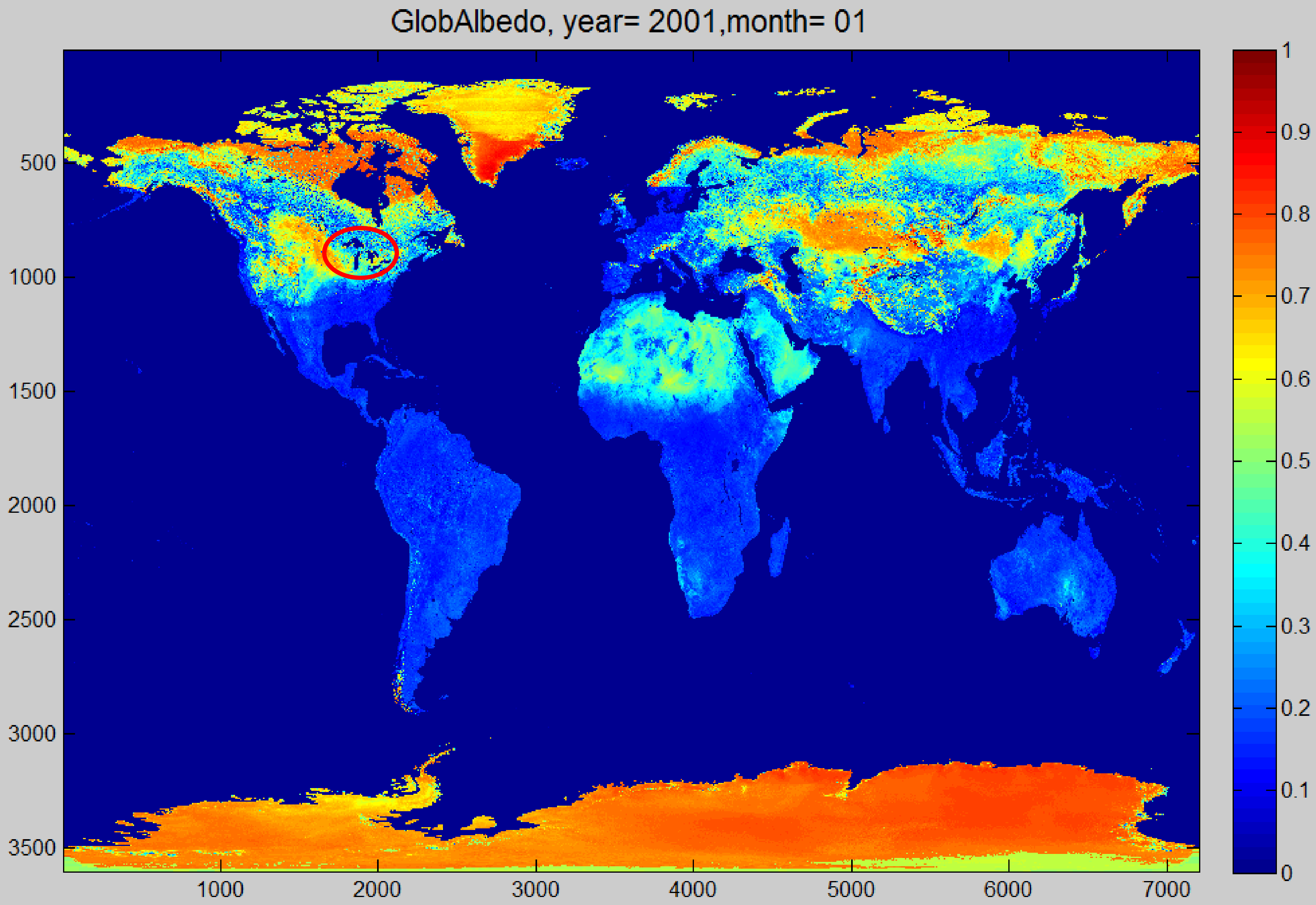
MODIS NDVI

Remote sense observed input data for Global ET

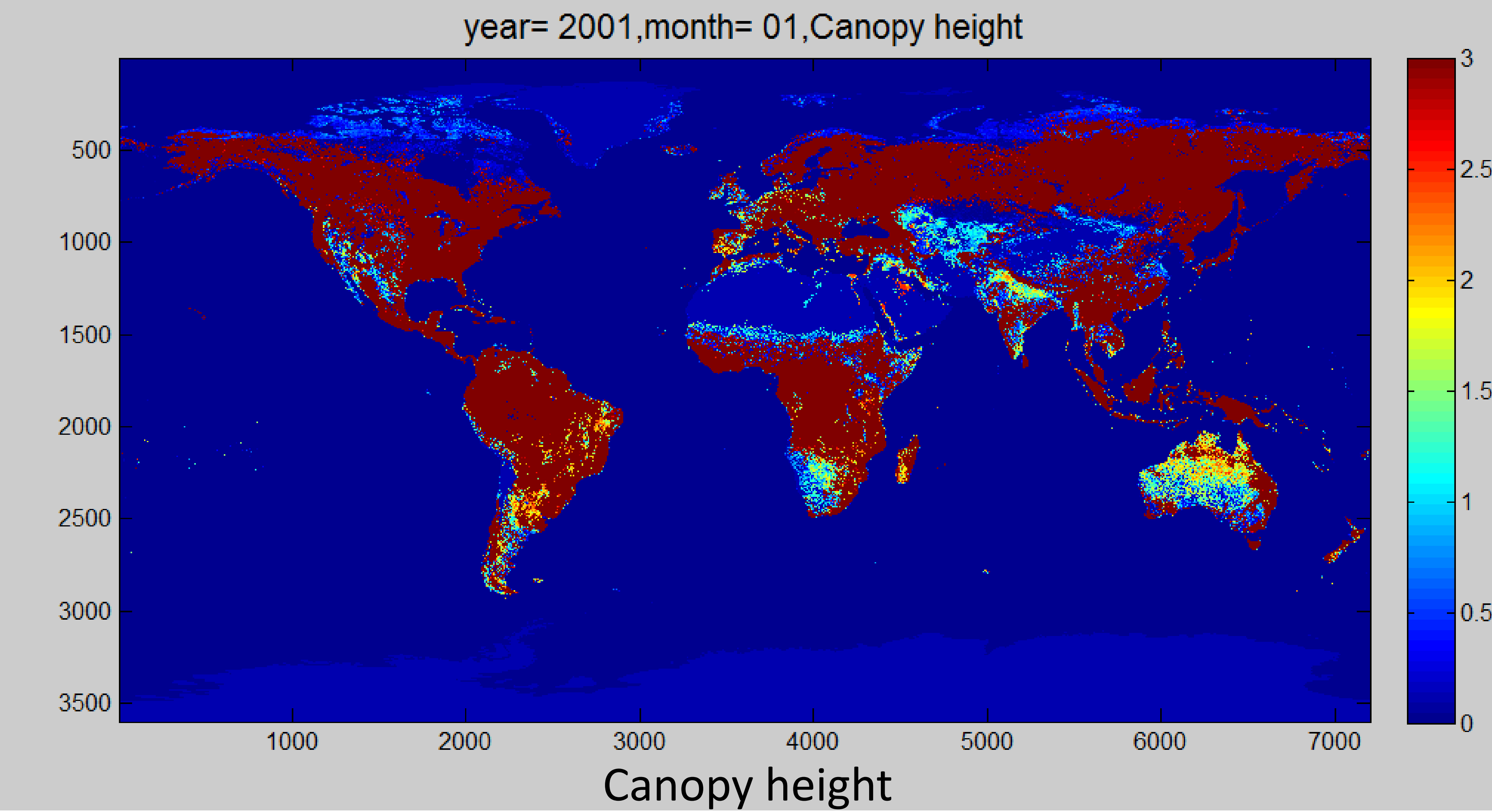


MODIS Emissivity

Remote sense observed input data for Global ET

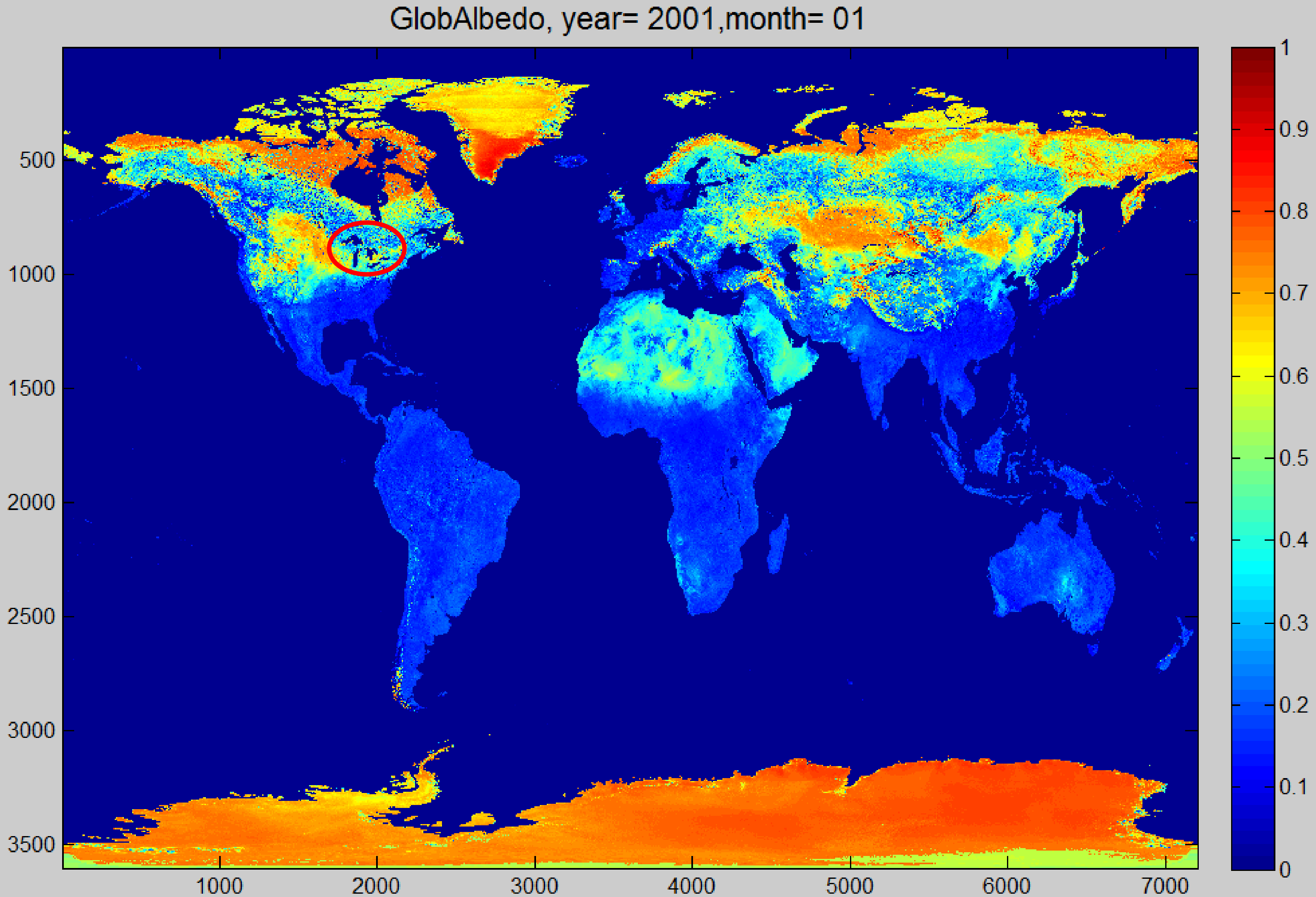


Remote sense observed input data for Global ET

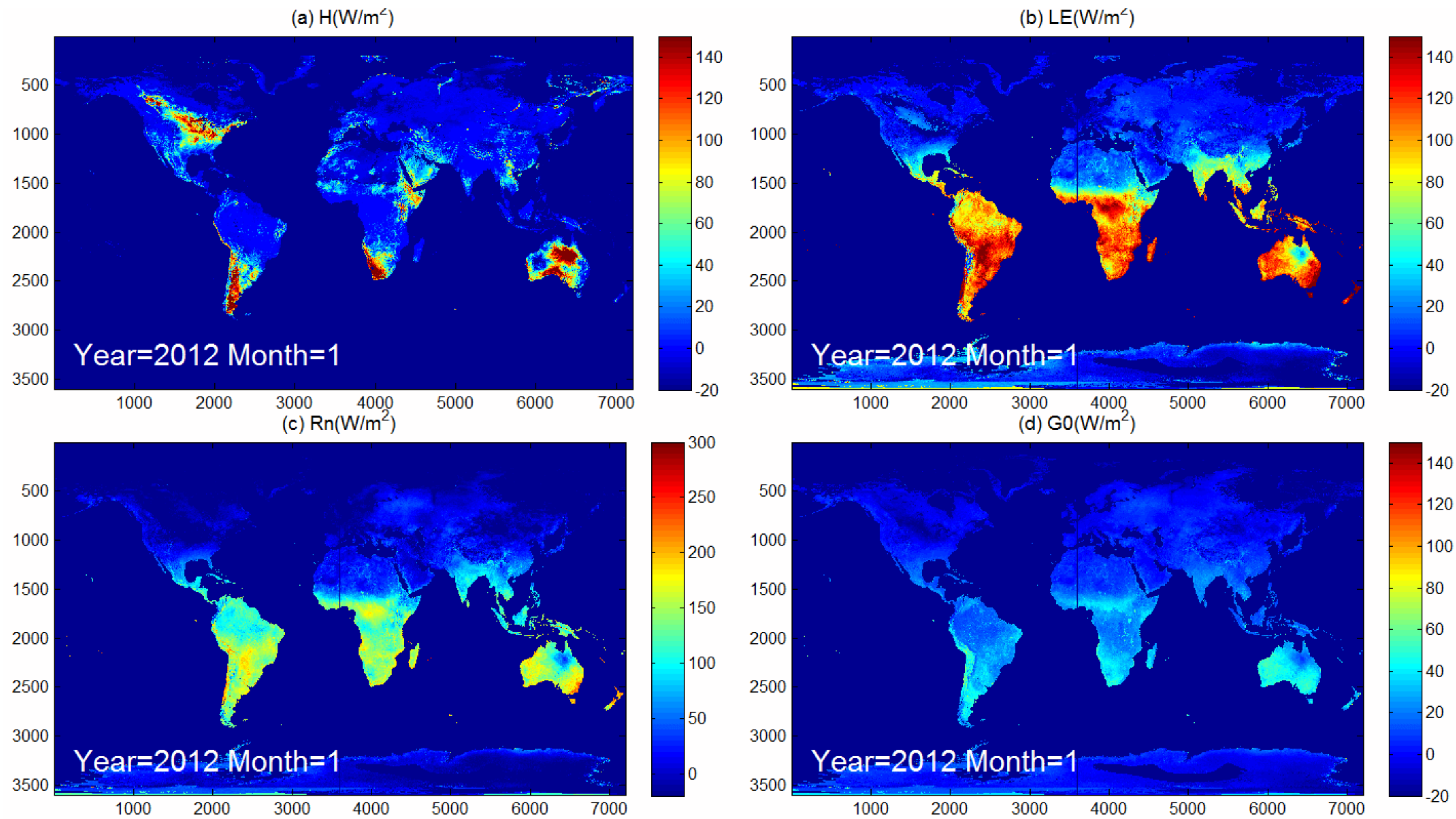


Canopy height

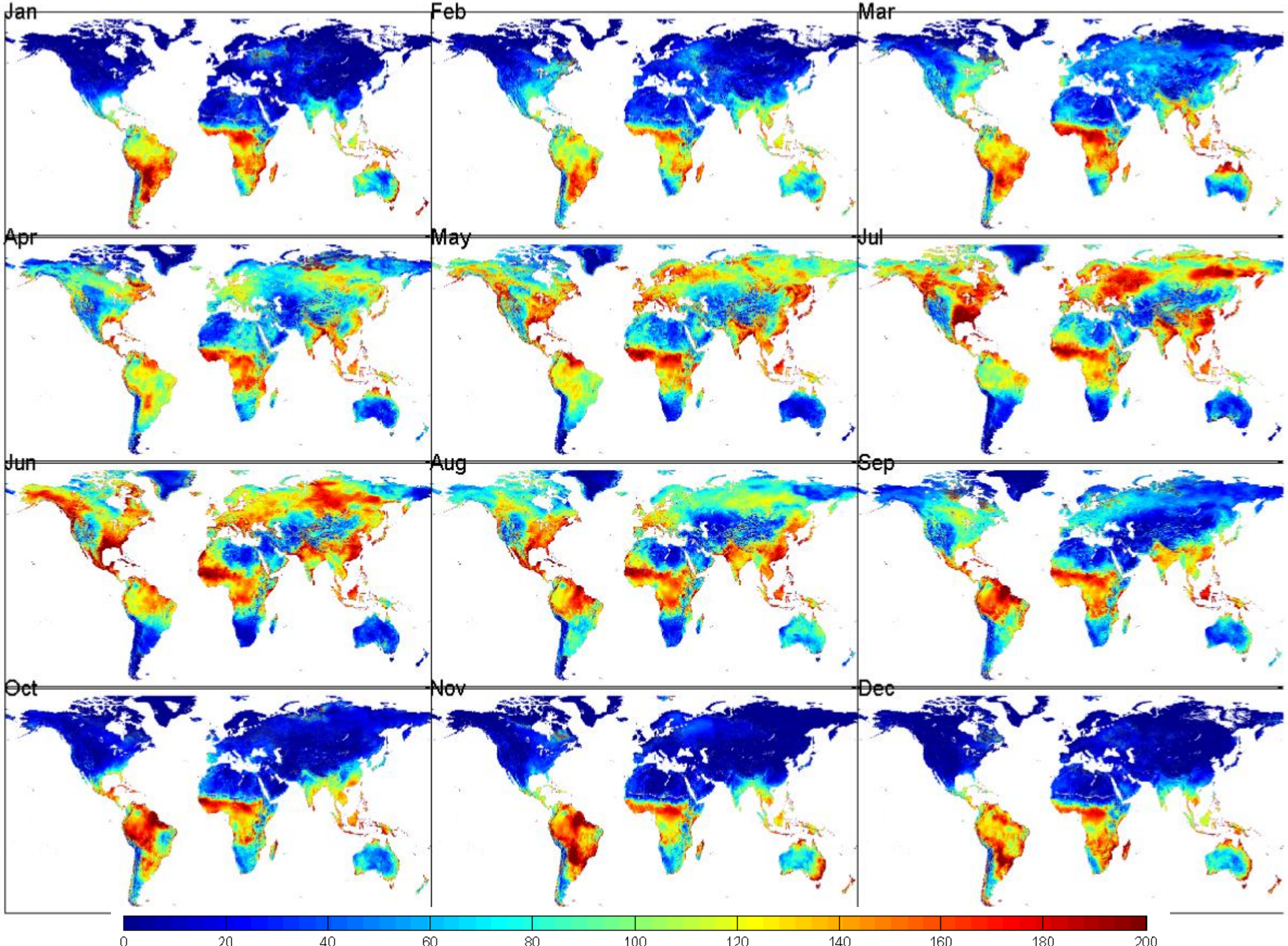
Remote sense observed input data for Global ET



Global monthly land surface fluxes derived from MODIS products



Global monthly ET(mm) in 2008



Global ET product

	Algorism	Input dataset	Grid size	Temporal resolution	Time span	References	Data source
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Zhang-ET	PM of Vegetation + PM Soil evaporation	daily temperature, Net radiation, NDVI,	8 km	monthly	1983-2006	Zhang et al. (2010)	NCEP/NCAR, GEWEX SRB, GIMMS
GLEAM	Priestley & Taylor	Net Radiation, Precipitation, Air temperature, Vegetation optical depth, Snow water equivalents, Soil Moisture, Skin Temperature	0.25 deg.	daily	1984-2007	Miralles et al. 2011	GEWEX SRB, CMORPH NSIDC, ISCCP, TMMI+AMSR-E
Chen-ET	Surface energy balance	Downward/upward shortwave/longwave,albedo, NDVI, FPAR, LAI, canopy height, Air temperature, humidity, pressure wind speed, LST, soil Moisture (ET partition)	5 km 1 km	Monthly Daily (in future)	2000-2014	Chen et al. 2014	ERA-I, MODIS, GlobAlbedo, ESA CCI,

CONCLUSIONS

- Land surface process model is complex and difficulty to be used at global scale.
- Remote sensing provide an easier way for global ET estimation.
- Application of remote sensed dataset in global water and energy studies has several issues need to be addressed in future.

References

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- **Chen, X**., Su, Z., Ma, Y., Liu, S., Yu, Q., and Xu, Z., **2014**: Development of a 10 year (2001–2010) 0.1° dataset of land-surface energy balance for mainland China, Atmos. Chem. Phys. Discuss., 14, 14471-14518, doi:10.5194/acpd-14-14471-2014, 2014.
- Su, Z.: The Surface Energy Balance System(SEBS) for estimation of turbulent heat fluxes, Hydrology and Earth System Sciences, 6, 85-99, 2002.

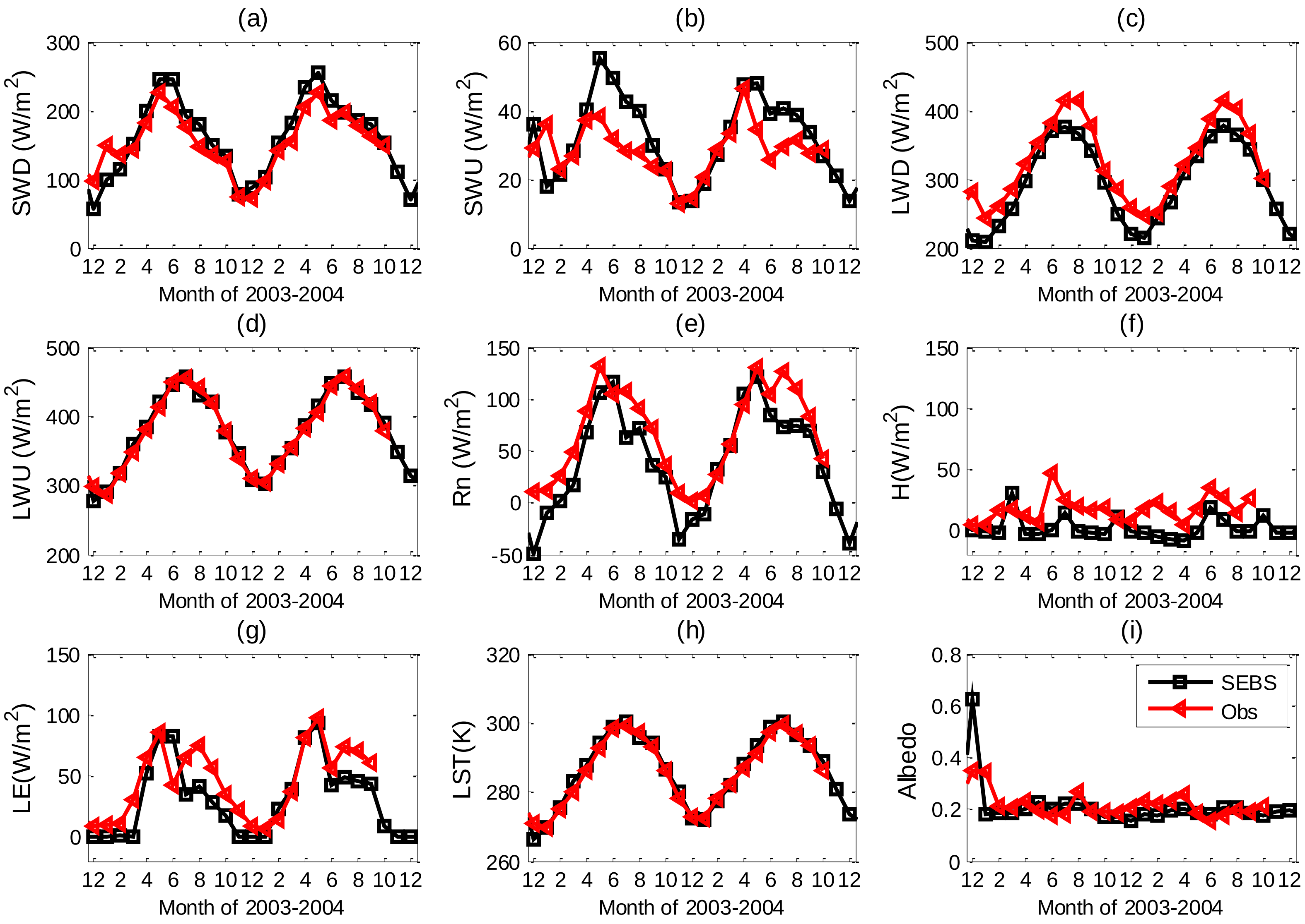
Thank you!

4. Evaluations

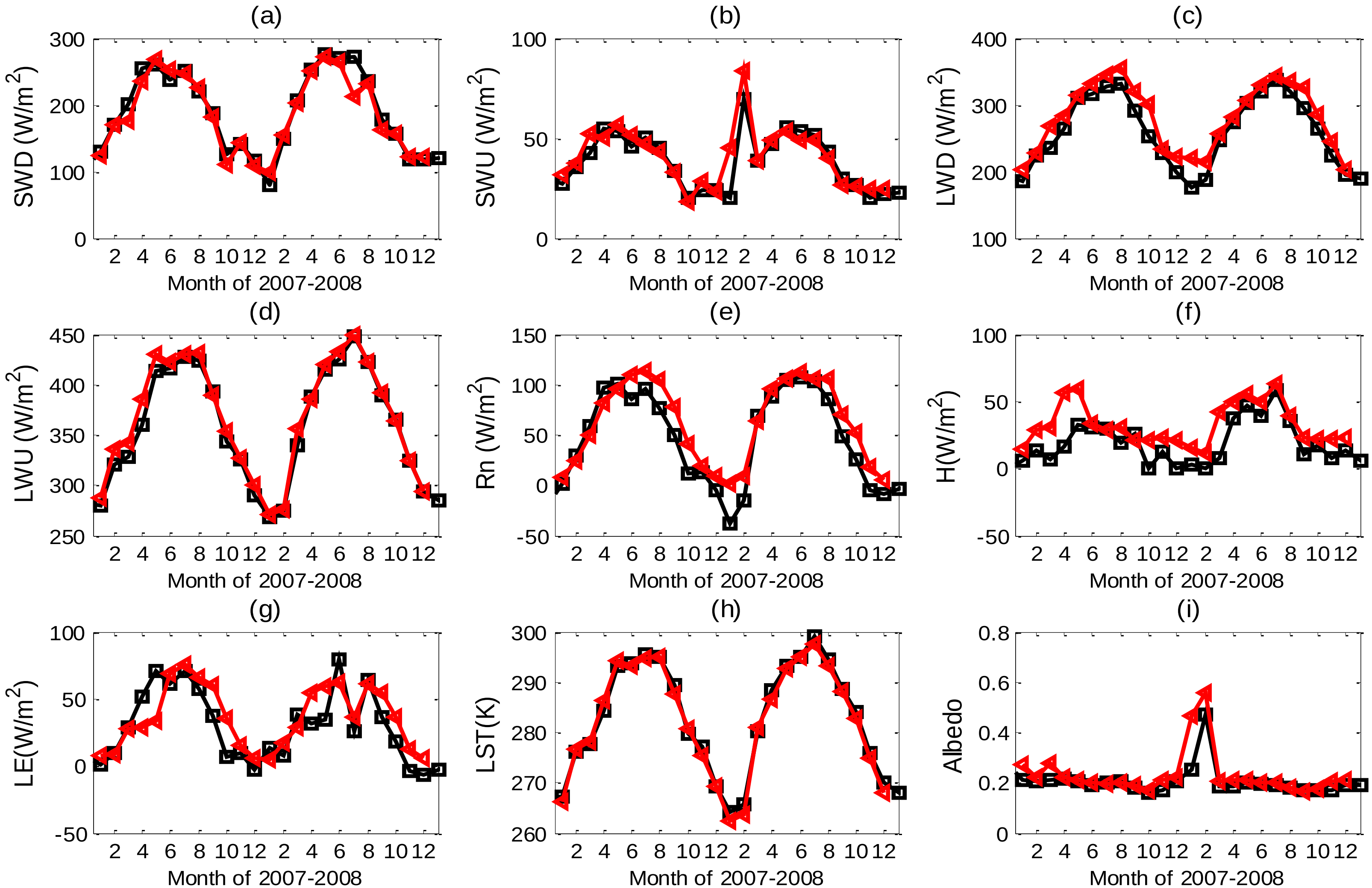
Table 2. Flux sites used for the product validation.

	Lat[deg]/ Lon[deg]	Land cover	Measurement period	Elevation (m)	Reference
WJ	30.4200N/ 103.5000E	Crop	Mar 2008 - Aug 2009	539 m	Zhang et al. (2012)
MQ	33.8872N/ 102.1406E	Alpine meadow	Apr 2009 - May 2010	3439 m	Wang et al. (2013)
AL	33.3905N/ 79.7035E	Bare soil	Jul 2010 - Dec 2010	4700m	Ma et al. (2008b)
BJ	31.3686N/ 91.8986E	Alpine grass	Jan 2008 - Dec 2010	4520 m	Ma et al. (2011)
MY	40.6038N/ 117.3233E	Orchard	Jan 2008 - Dec 2010	350 m	Liu et al. (2013a)
DX	39.6213N/ 116.4270E	Crop	Jan 2008 - Dec 2010	100m	Liu et al. (2013a)
GT	36.5150N/ 115.1274E	Crop	Jan 2008 - Dec 2010	30 m	Liu et al. (2013a)
YC	36.9500N/ 116.600E	Crop	Oct 2002 - Oct 2004	13 m	Flerchinger et al. (2009)
DT	31.5169N/ 121.9717E	Wetland	Jan 2005 - Dec 2007	5 m	Zhao et al. (2009)
SACOL	35.95N/ 104.133E	Dry land	Jan 2007 - Dec 2008	1965 m	Huang et al. (2008)
WS	36.6488N/ 116.0543E	Winter wheat / summer maize	Jan 2006 - Dec 2008	30 m	Lei and Yang (2010a)

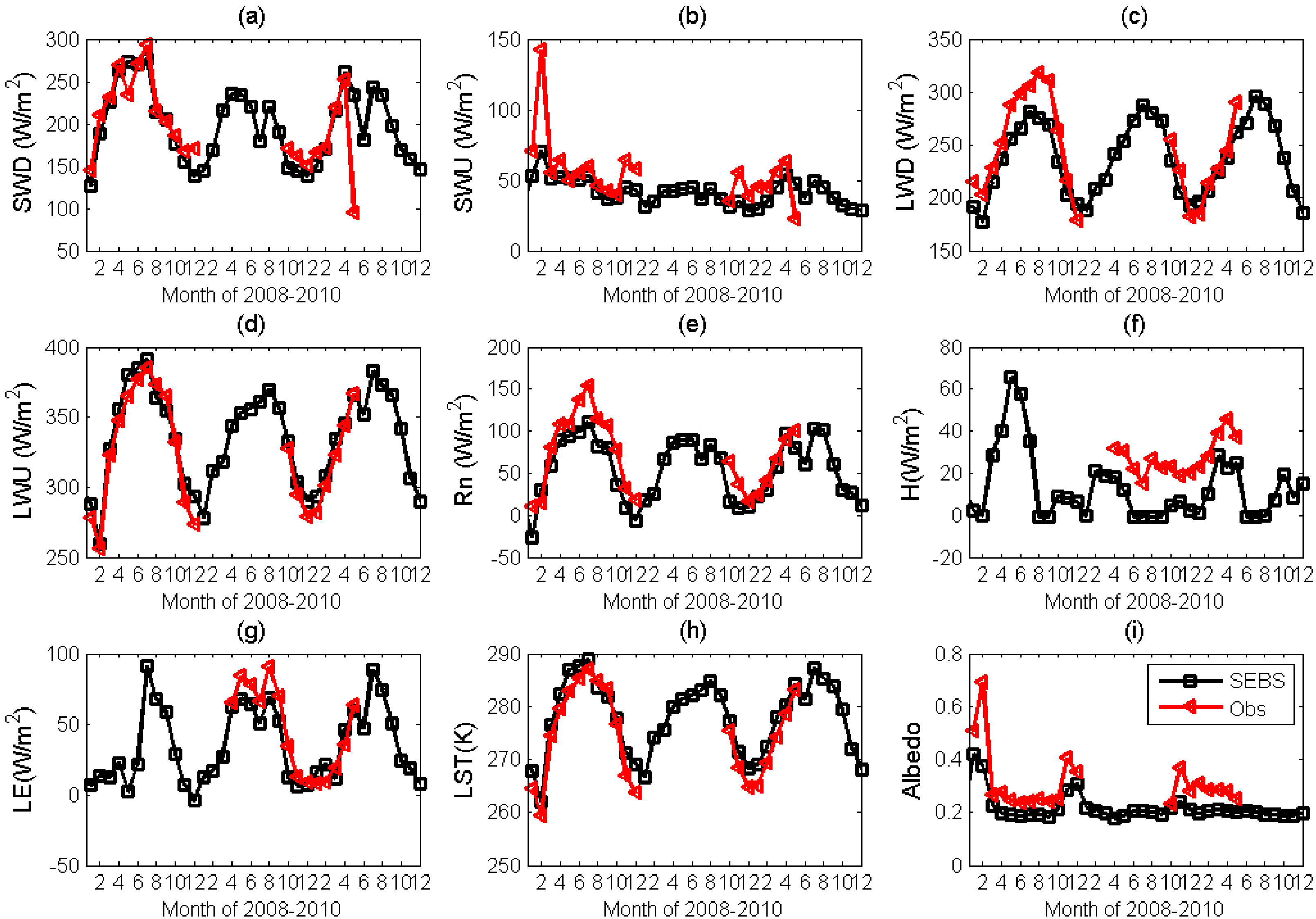
SEBS input and output variables vs measurement at Yucheng station winter wheat and summer maize



SEBS input and output variables vs measurement at SACOL station
(Semi-Arid Climate and Environment Observatory of Lanzhou University (SACOL)



SEBS input and output variables vs measurement at Maqu station in the eastern Tibetan Plateau



SEBS input and output variables vs measurement at BJ station in the central Tibetan Plateau