Key Lessons on Water, Carbon, & Energy Fluxes for the Semiarid Landscapes of Inner Mongolia

NEWS 2004 NRA: NN-H-04-Z-YS-005-N

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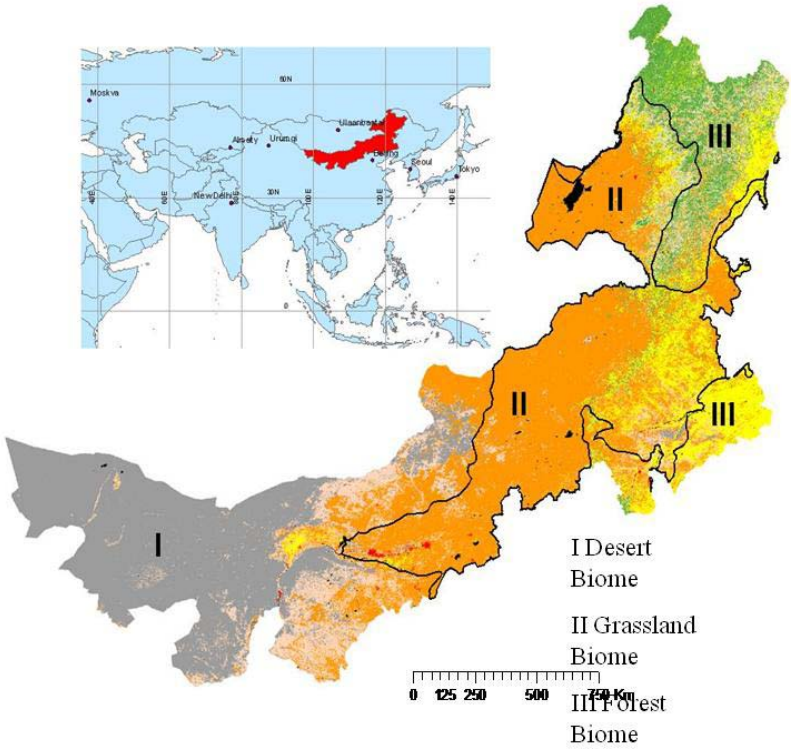
Ranjeet John, Nan Lu, and Burkhard Wilske, Changliang Shao, Ge, Sun, Dennis Ojima, Xiangming Xiao, and others



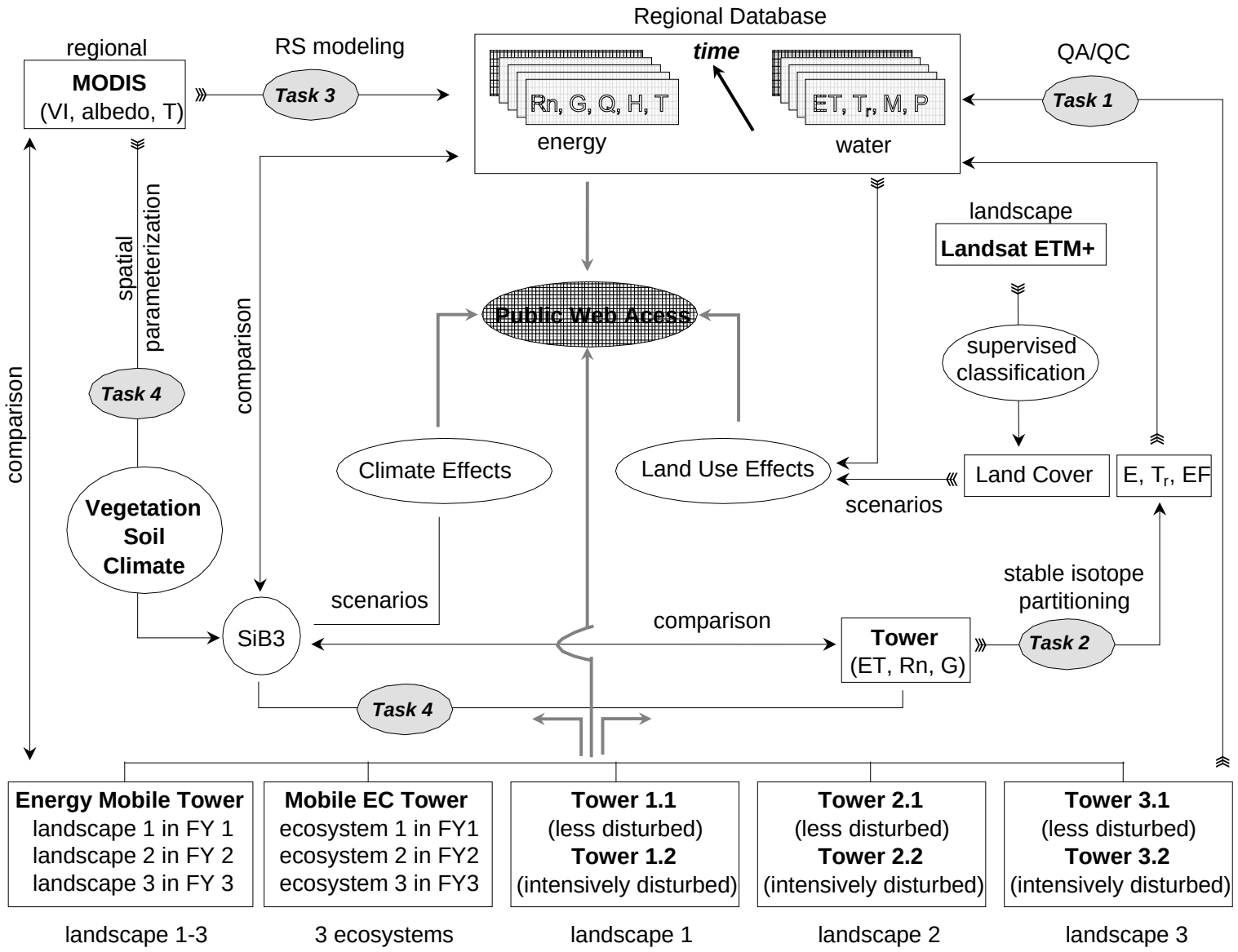
Objectives

- Mechanistically explain the variability of energy (Rn, L, G, Q, H, T) and water (ET, E, EF, Tr, LWSI, Wleaf, M) fluxes along a climatic and land use gradient,

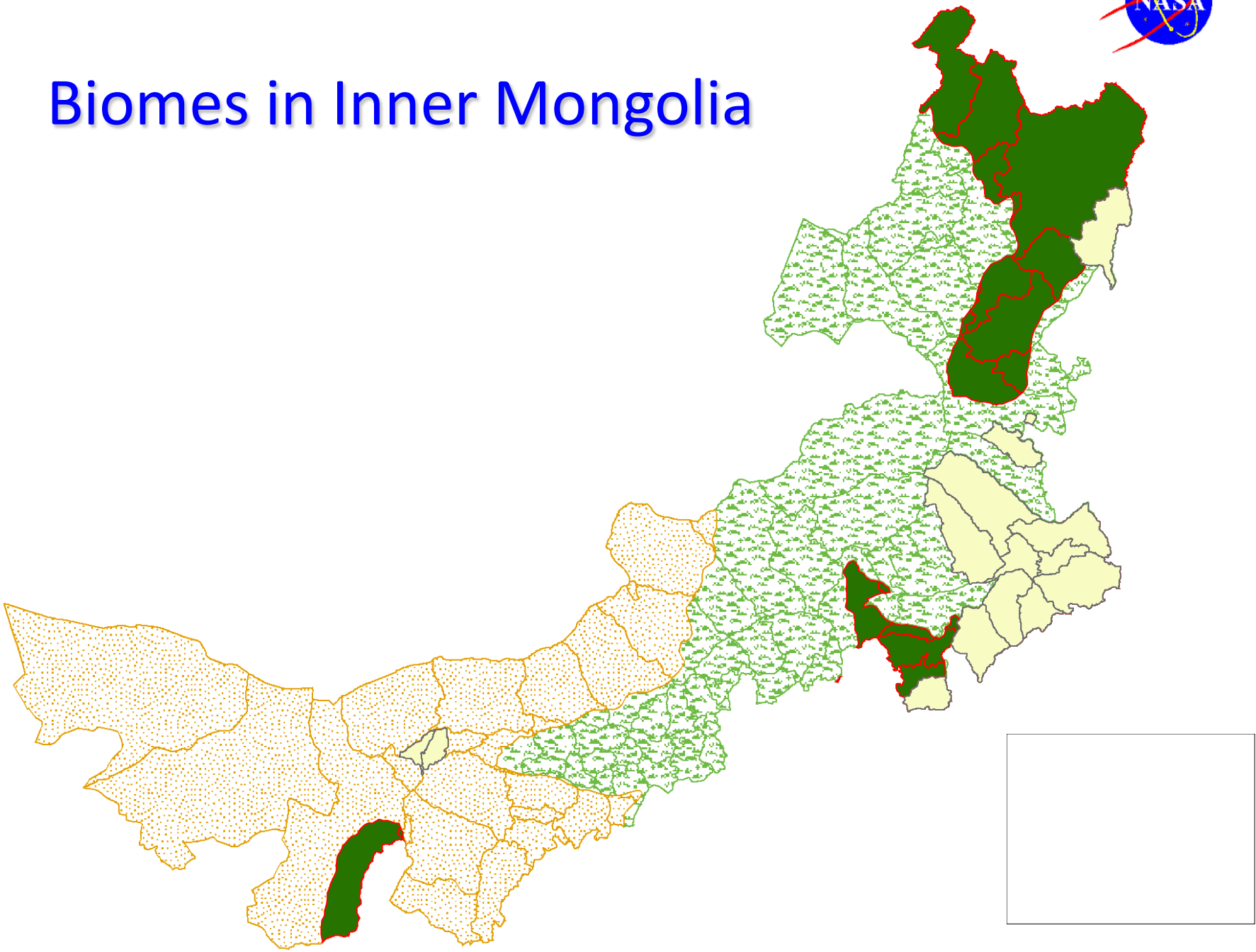
- Develop and validate MODIS-based models for water fluxes,

- Evaluate and improve biophysical models for regional simulations of water and energy fluxes at multiple spatial & temporal scales.

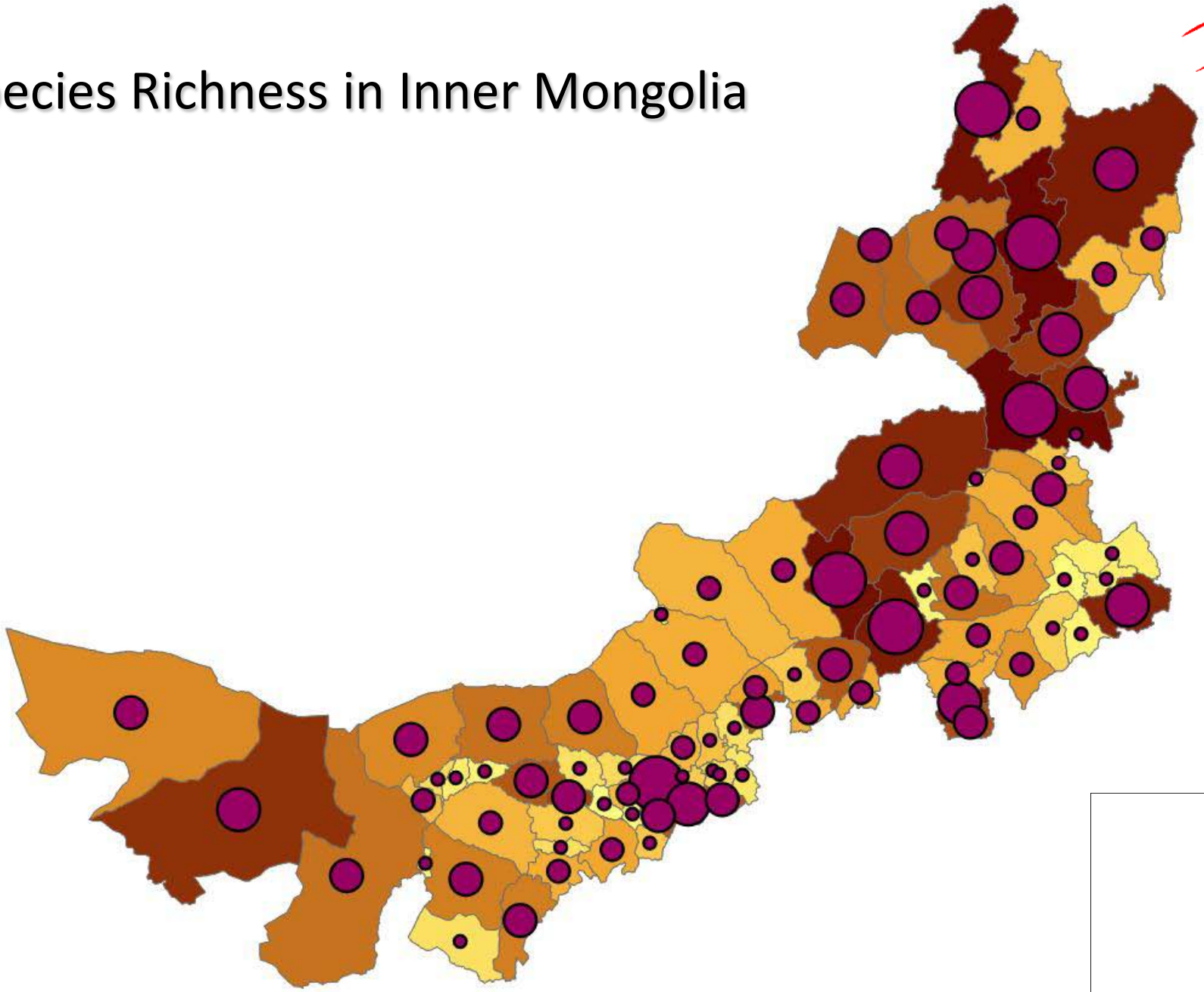
The Conceptual Framework

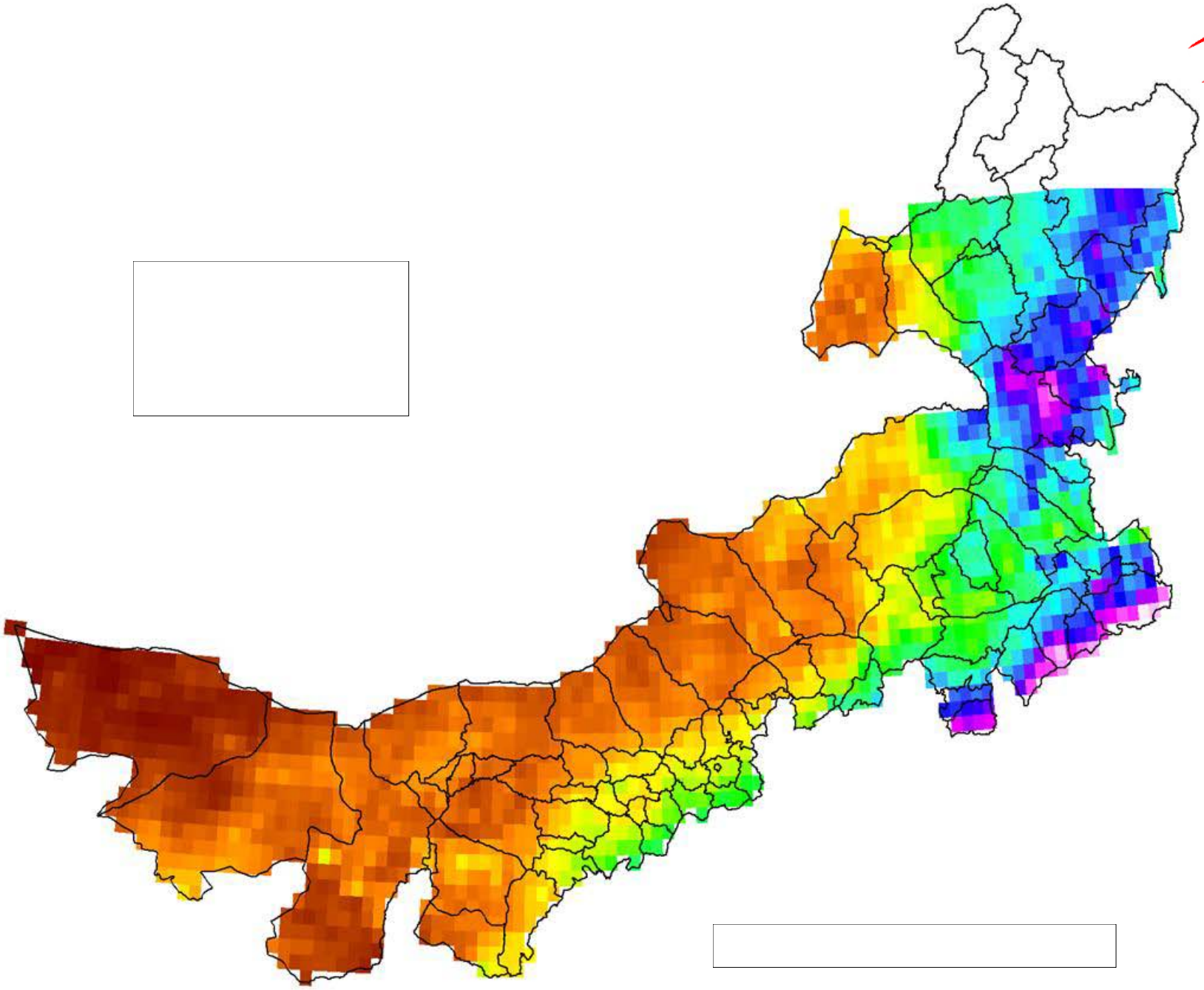


Biomes in Inner Mongolia



Species Richness in Inner Mongolia





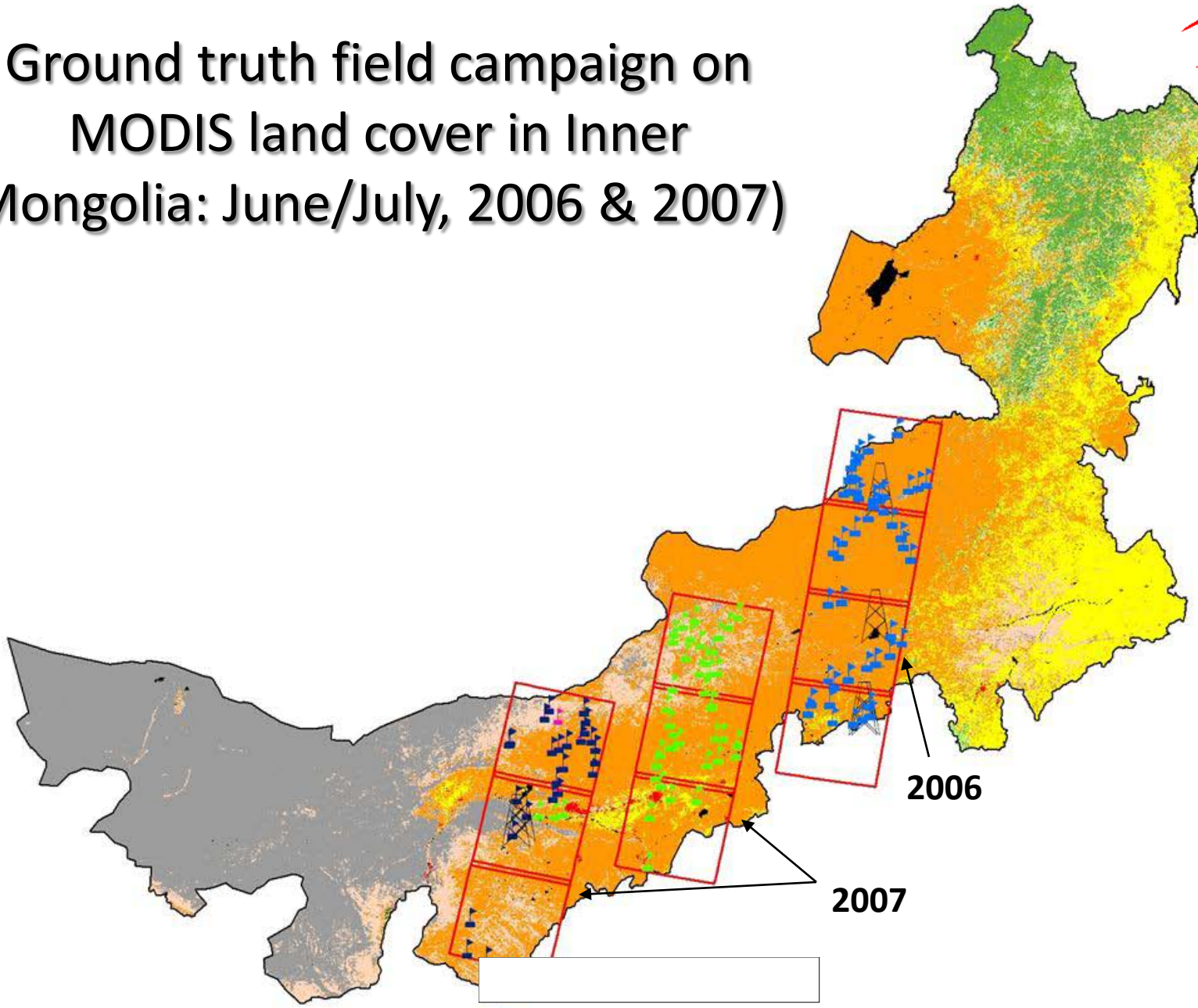
Typical grassland in Dongwu

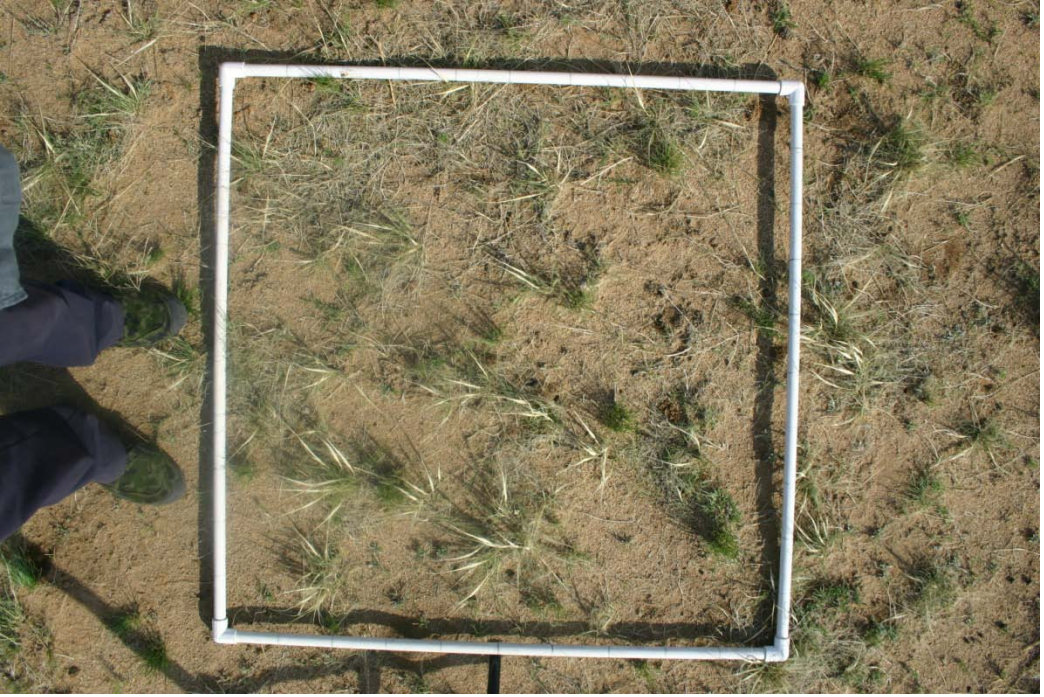
Degraded grassland in Xilinhot

Stipa krylovii grassland in Duolun

Cropland in Duolun

Ground truth field campaign on MODIS land cover in Inner Mongolia: June/July, 2006 & 2007)

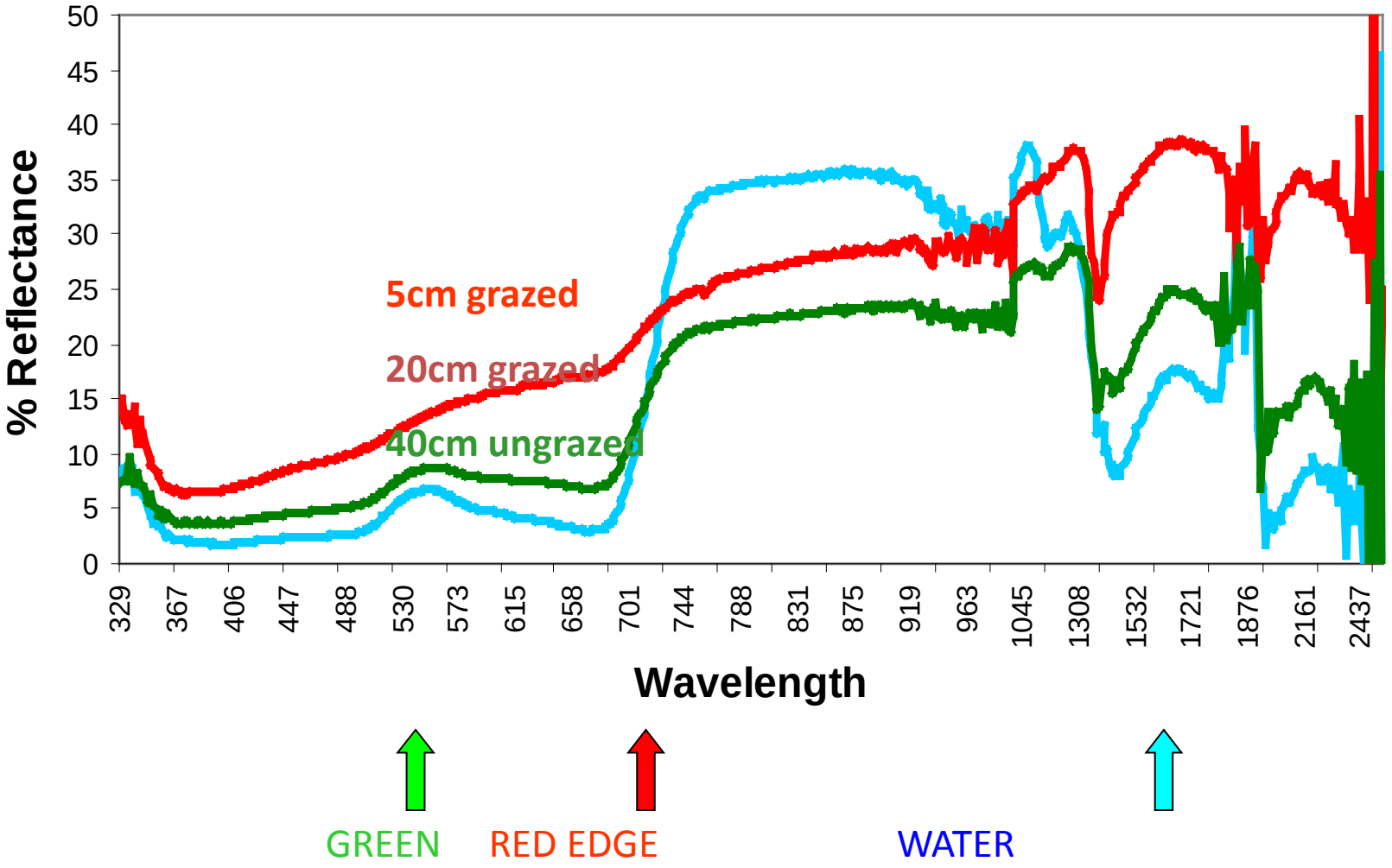


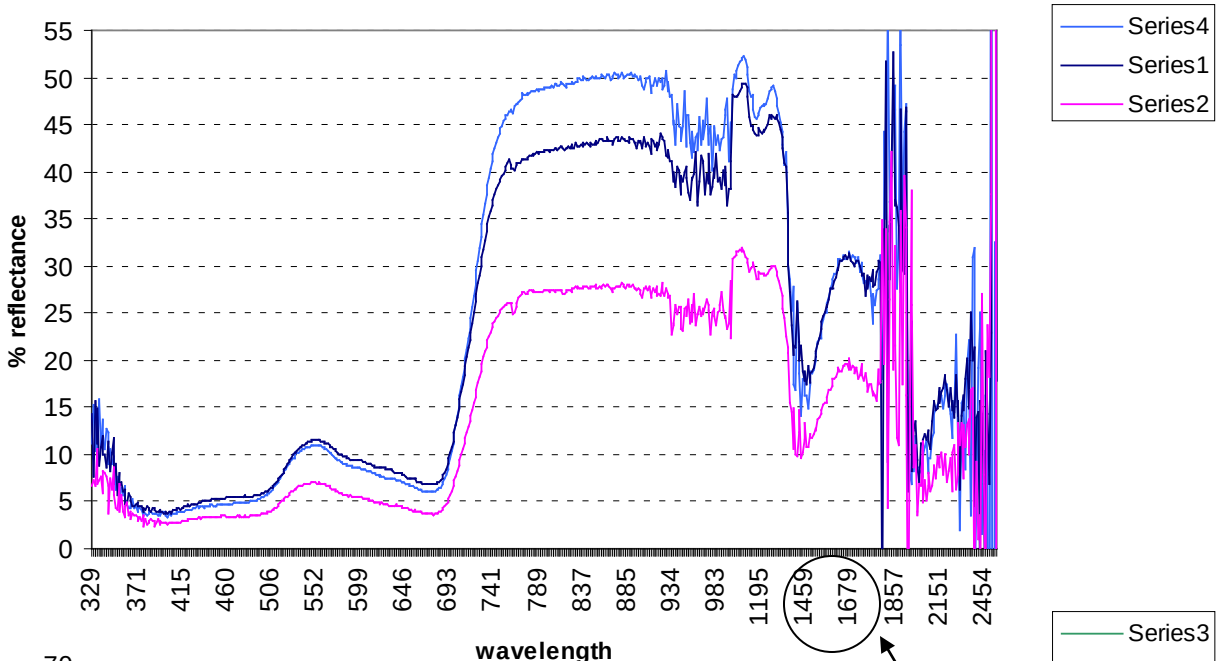


Direct measurements of surface reflectance

Direct measurements of vegetation and soil properties

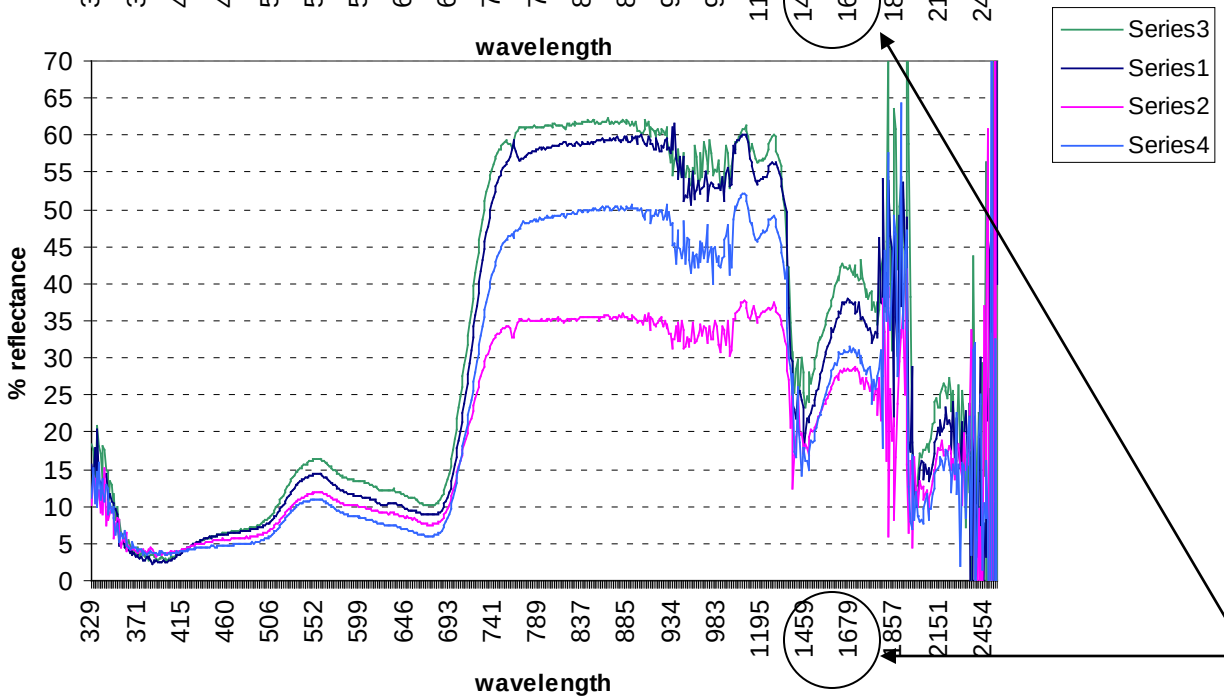
Reflectance (GER 3700) varying by grass height on grazed anc ungrazed prairies in Inner Mongolia





Examples of radiometer spectral signatures

Healthy vegetation



757 spectra from 2006

331 & 748 spectra from 2007

Foliar nitrogen

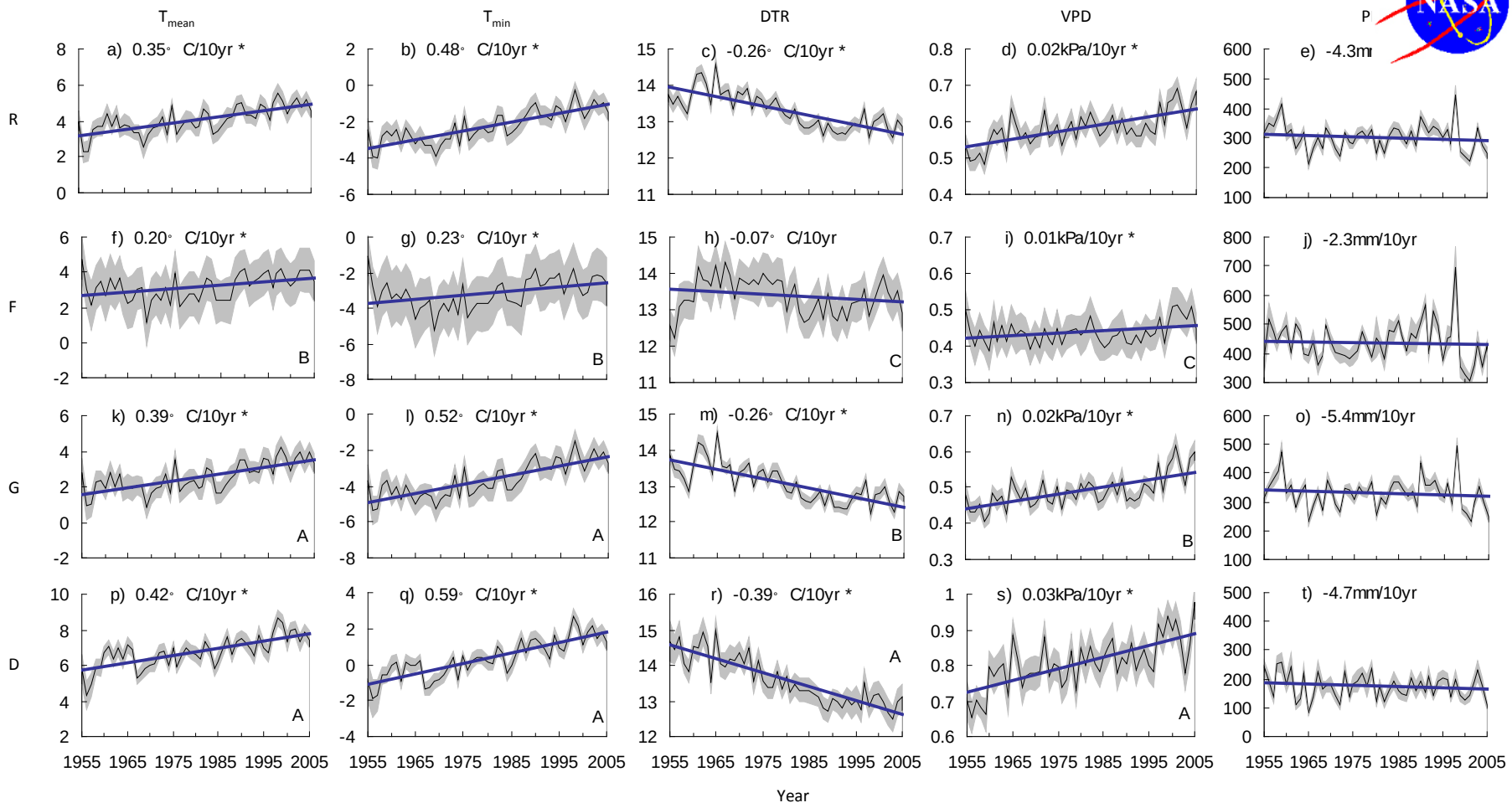
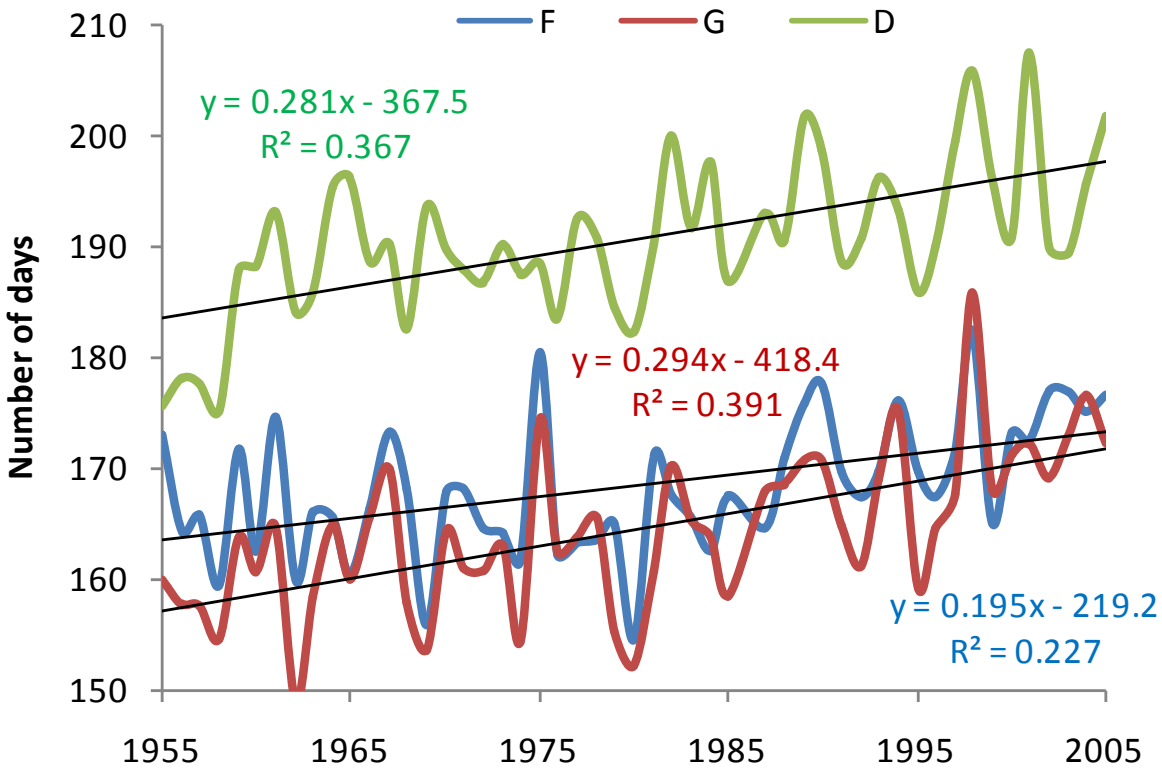
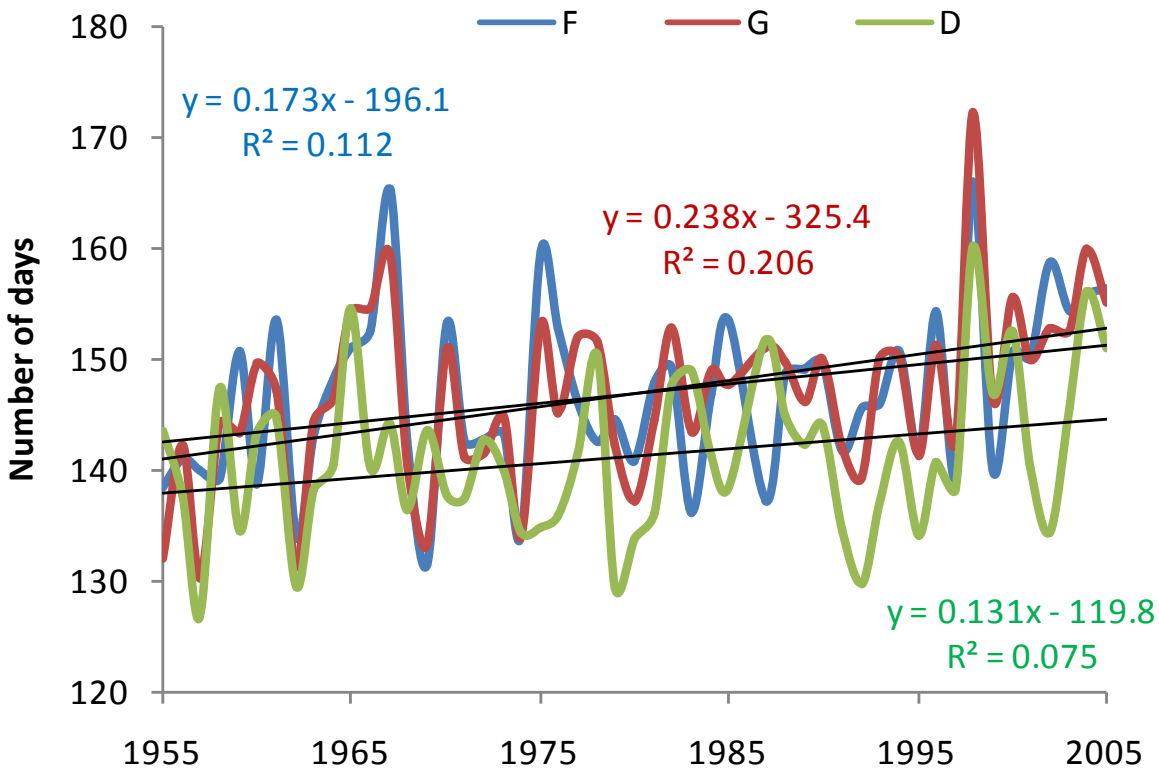


Figure 1. 50-year oscillation of annual mean T_{mean}, T_{min} DTR (˚C), VPD (kPa) and annually accumulated precipitation (mm), averaged for the 51 weather stations (R-region) and those in each biome (F-forest, G-grassland, D-desert), respectively. The shaded area was mean plus/minus standard error. The bold solid line represented the trend. Stars meant slopes were significant at the level of 0.05. Capital letters A, B and C referred to the slope differences among biomes.

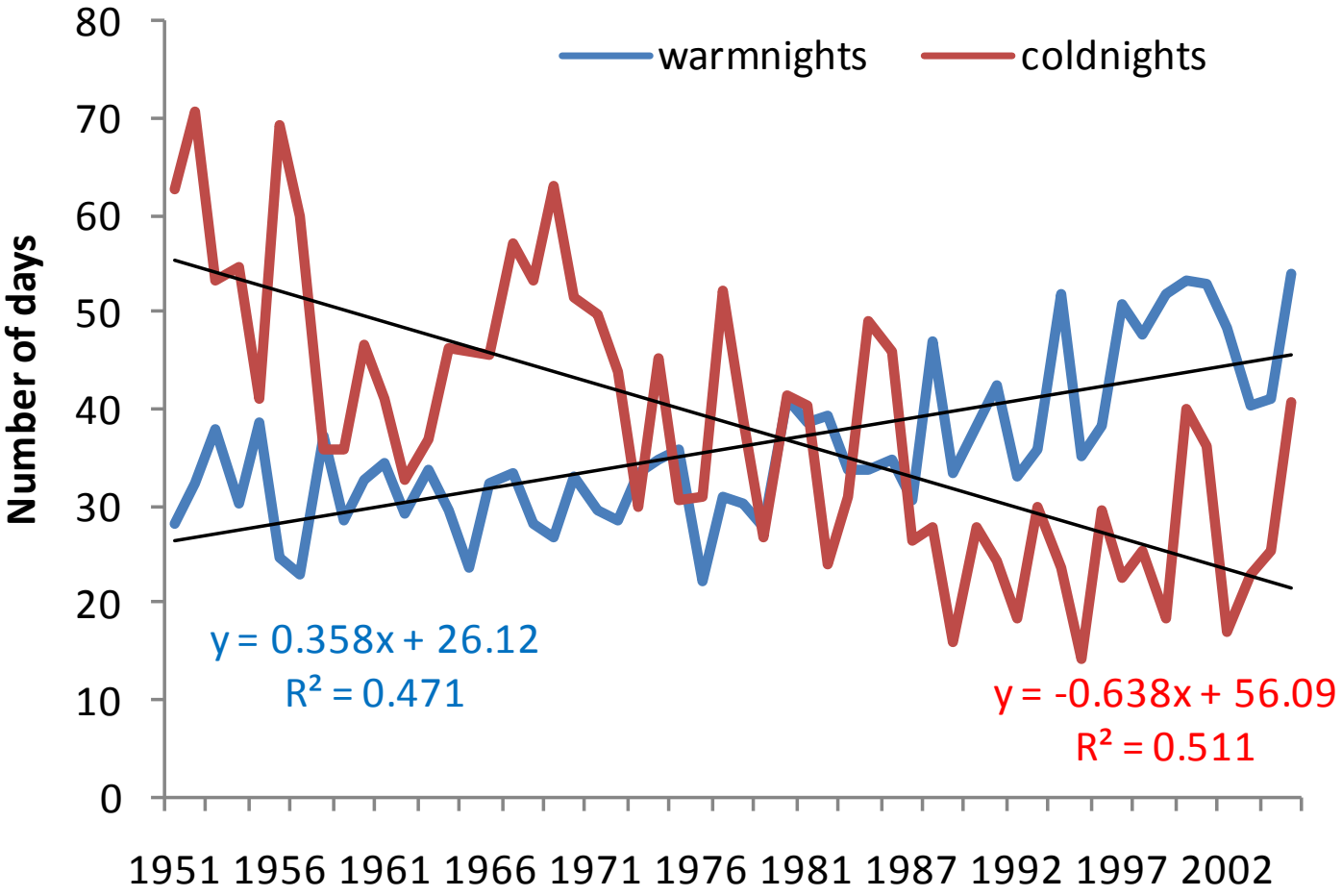
Comparison of trend in growing season length (GSL among three biomes



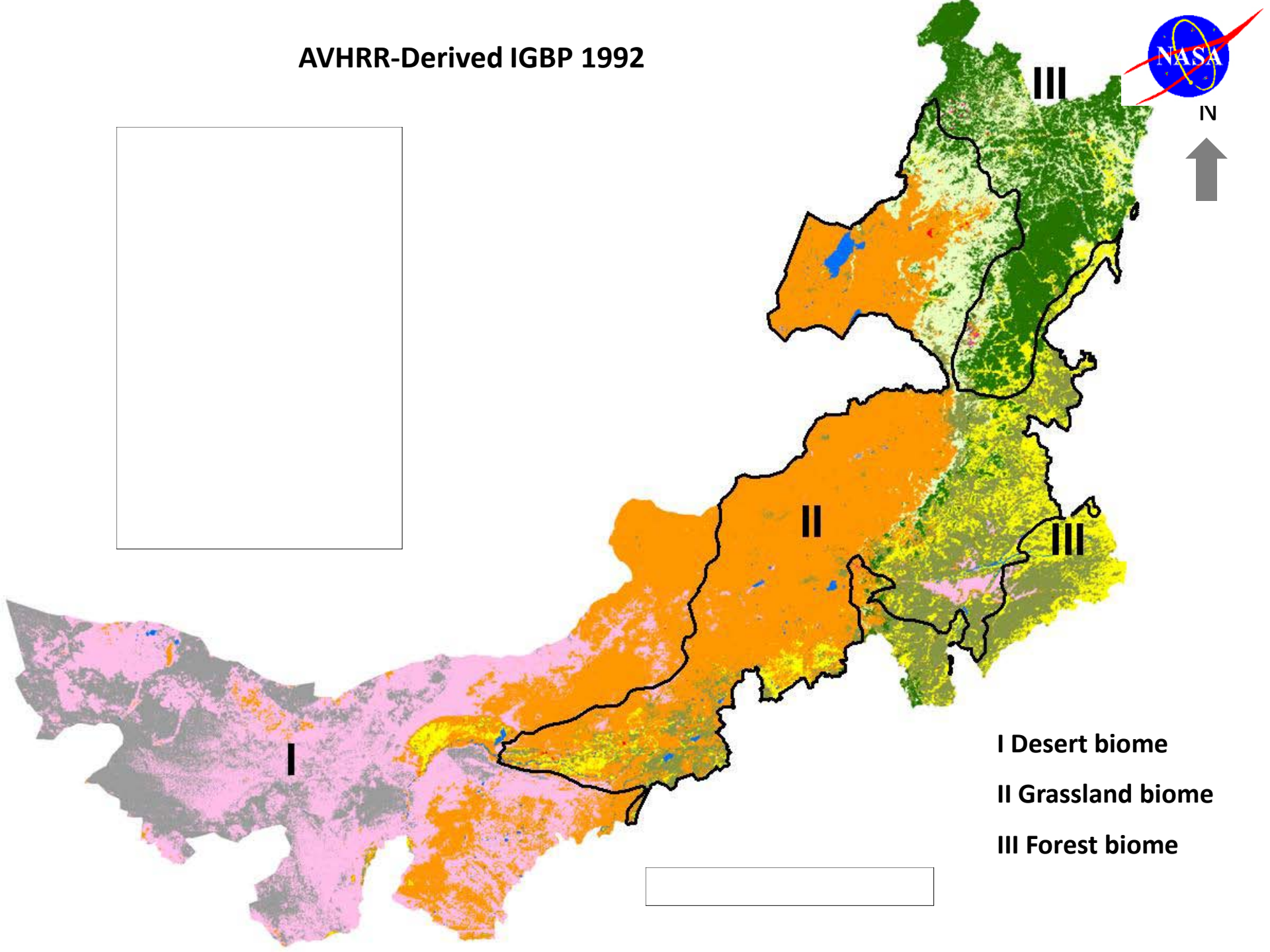
Comparison of trend in heat wave duration index (HWDI) among three biomes



Regional trend of warm nights and cold nights



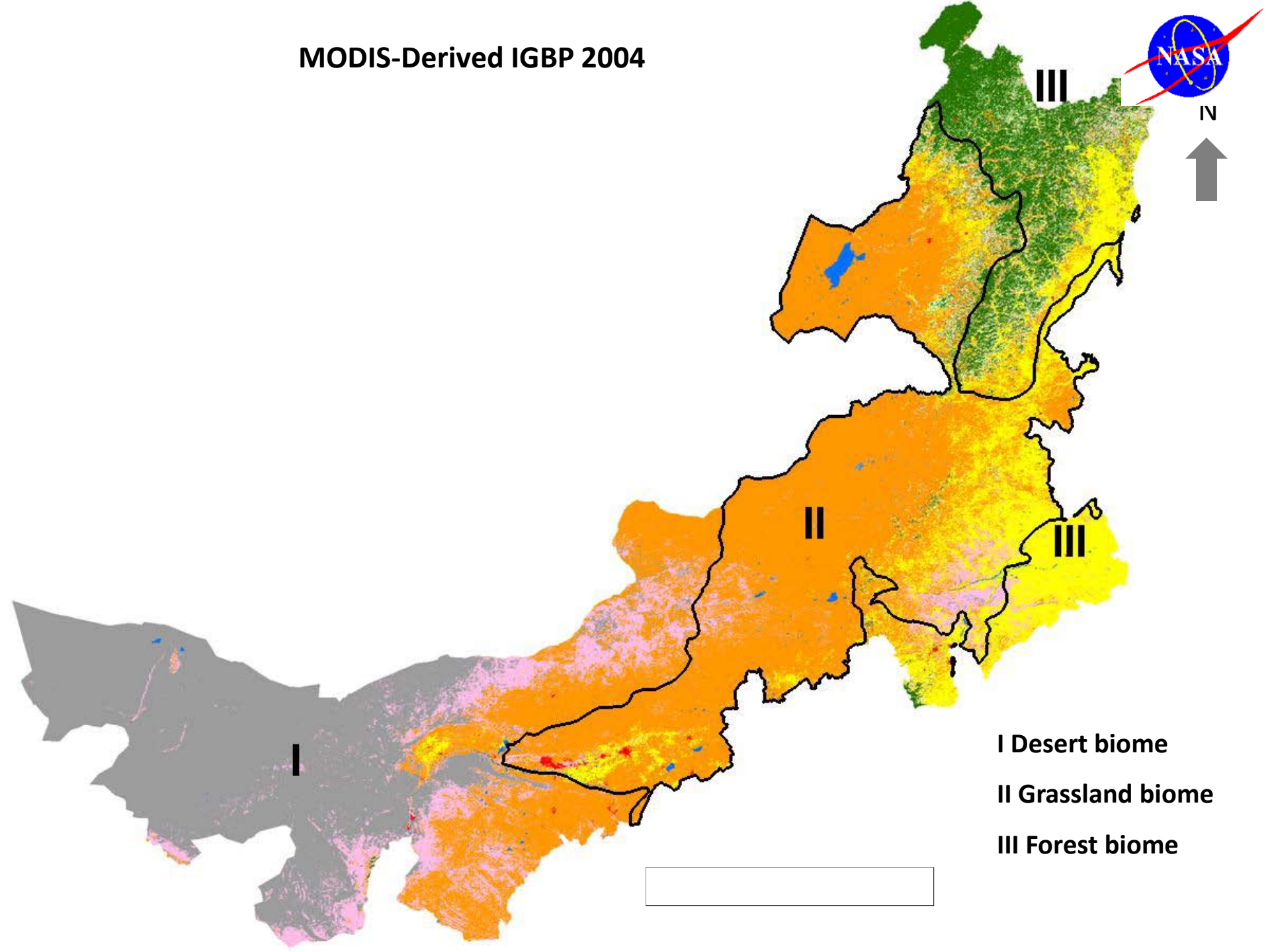
AVHRR-Derived IGBP 1992



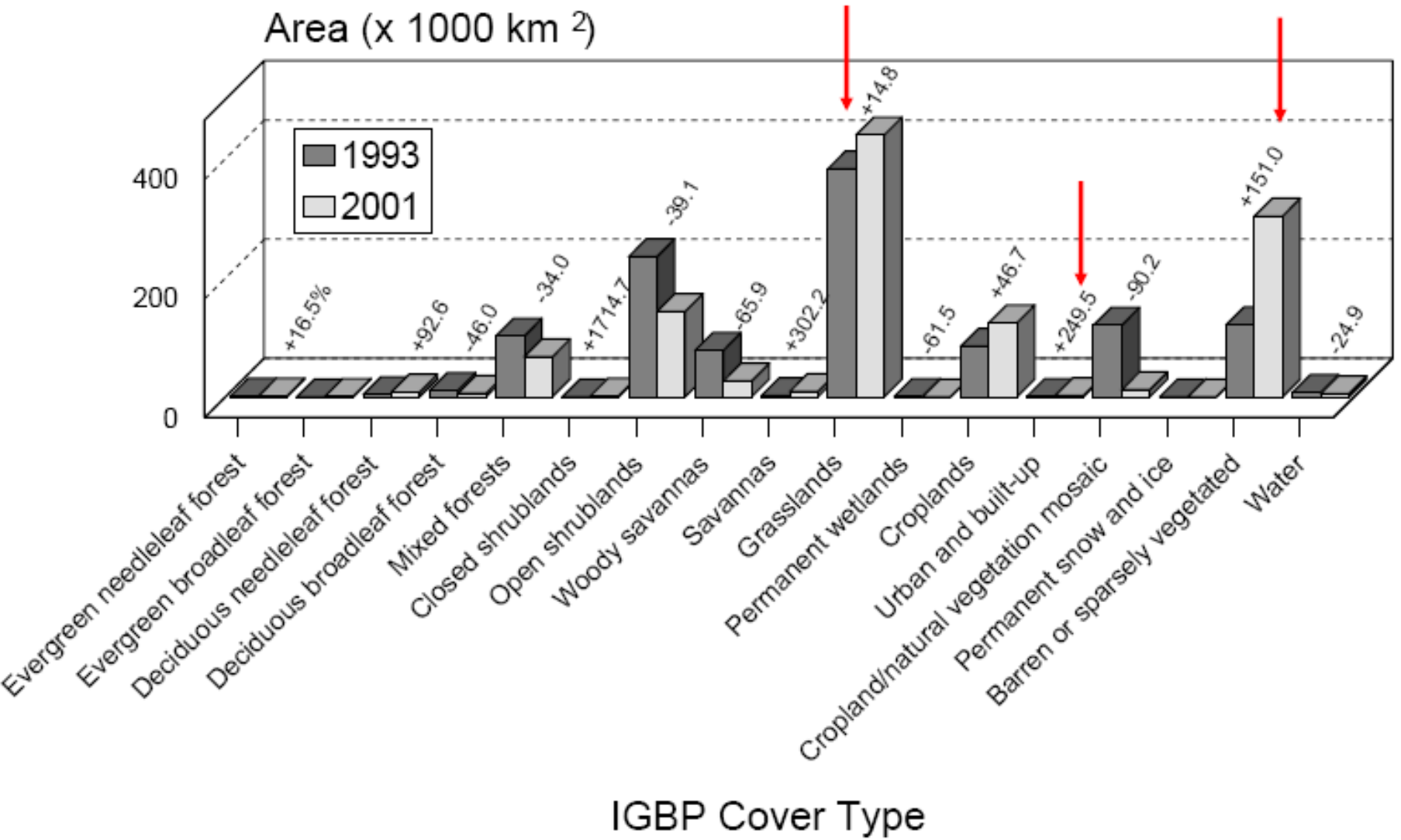
I Desert biome

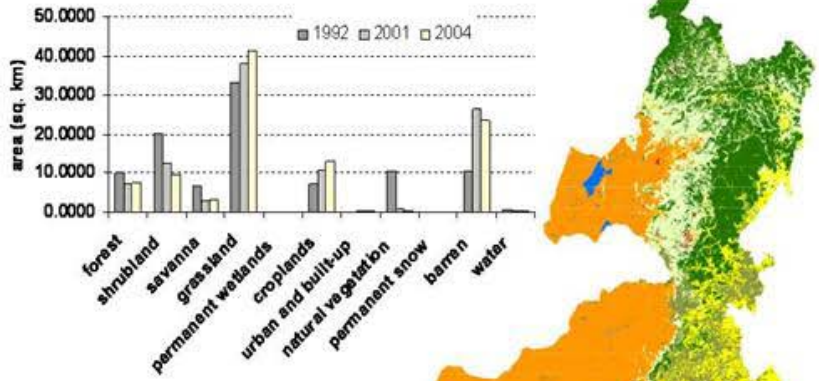
II Grassland biome

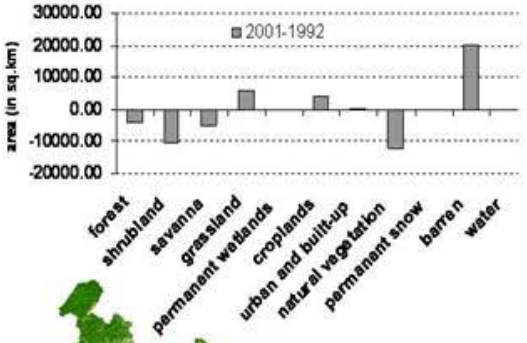
III Forest biome

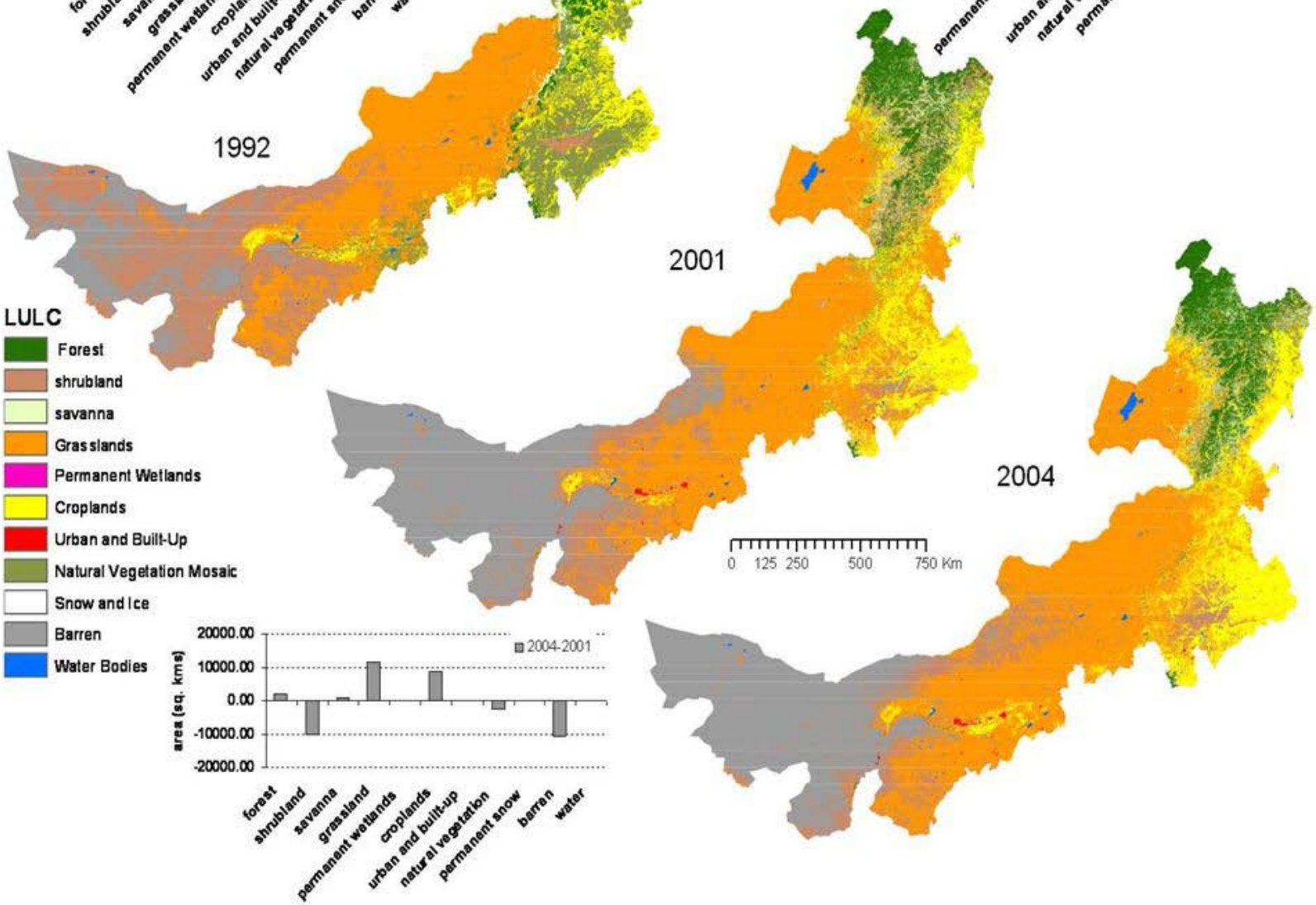

MODIS-Derived IGBP 2004
III
II
III
I
N
I Desert biome
II Grassland biome
III Forest biome

Land cover change between 1993 and 2001 in Inner Mongolia. The numbers are net percent change with negative sign indicating a decrease.




50.0000
40.0000
30.0000
20.0000
10.0000
0.0000
area (sq. km)
1992
2001
2004
forest
shrubland
savanna
grassland
permanent wetlands
croplands
urban and built-up
natural vegetation
permanent snow
barren
water


30000.00
20000.00
10000.00
0.00
-10000.00
-20000.00
area (in sq.km)
2001-1992
forest
shrubland
savanna
grassland
permanent wetlands
croplands
urban and built-up
natural vegetation
permanent snow
barren
water


1992
2001
2004
LULC
Forest
shrubland
savanna
Grasslands
Permanent Wetlands
Croplands
Urban and Built-Up
Natural Vegetation Mosaic
Snow and Ice
Barren
Water Bodies
0 125 250 500 750 Km

20000.00
10000.00
0.00
-10000.00
-20000.00
area (sq. kms)
2004-2001
forest
shrubland
savanna
grassland
permanent wetlands
croplands
urban and built-up
natural vegetation
permanent snow
barren
water

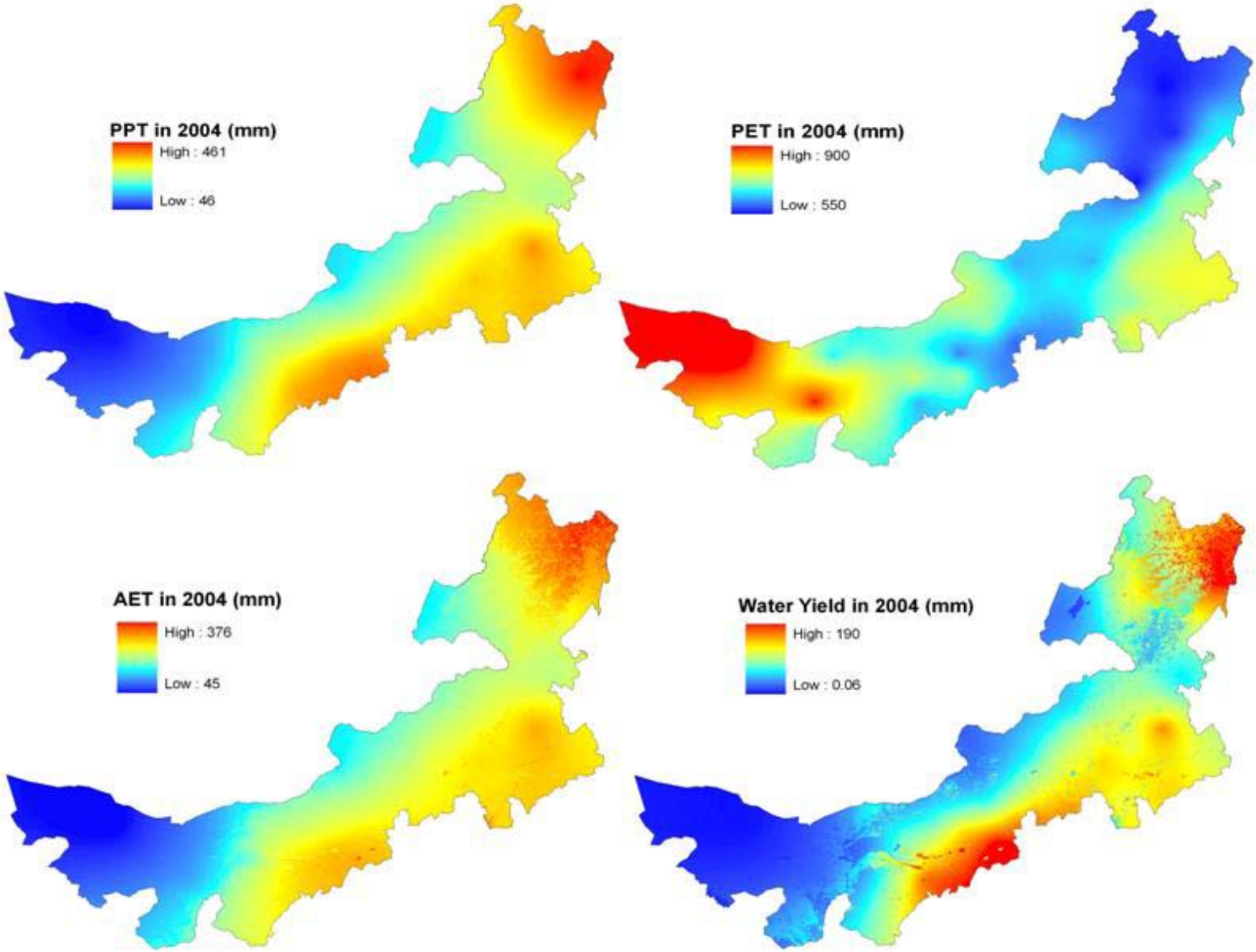
Overall Approaches

- Eddy-covariance flux towers (6 paired-towers since 2005) for time series and validation

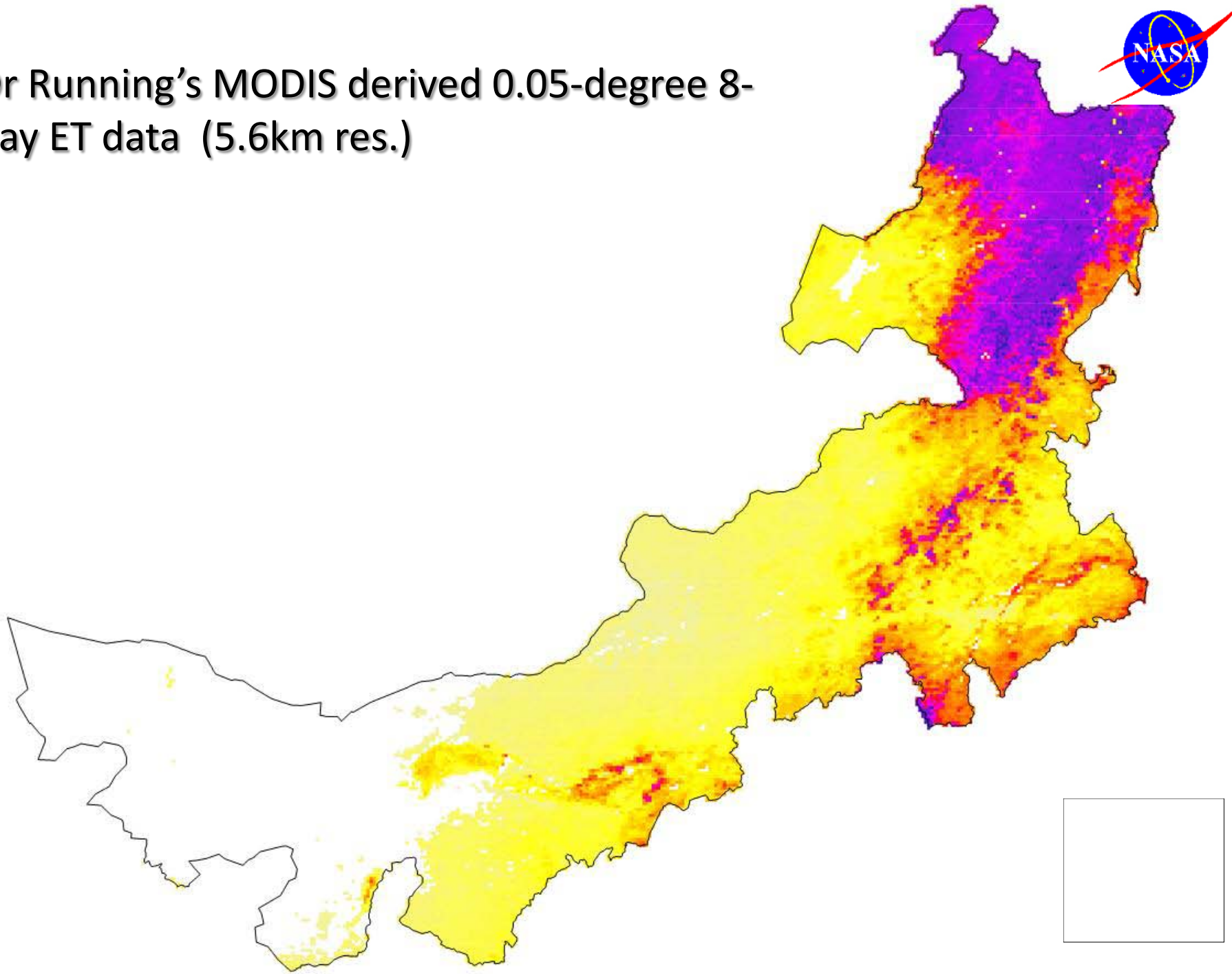
- Biophysical models (Monteith, SSEB, VPM) and statistical models) for predictions

- RS modeling (MODIS, TRMM, TM) for spatial coverage

Temporal changes in PPT, PET, water yield and AET (mm) in IM during 1955 to 2005.



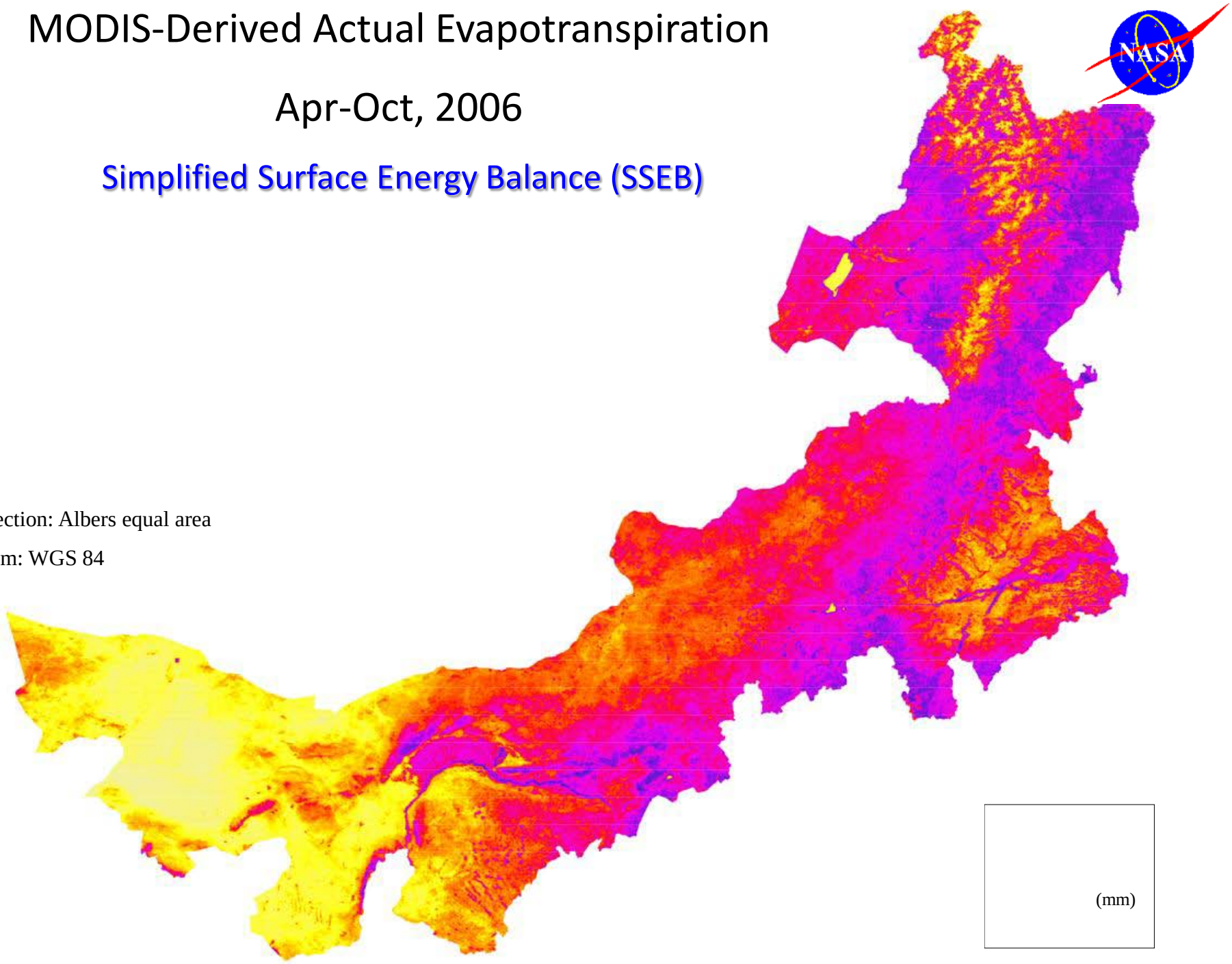
Dr Running's MODIS derived 0.05-degree 8-day ET data (5.6km res.)



MODIS-Derived Actual Evapotranspiration

Apr-Oct, 2006

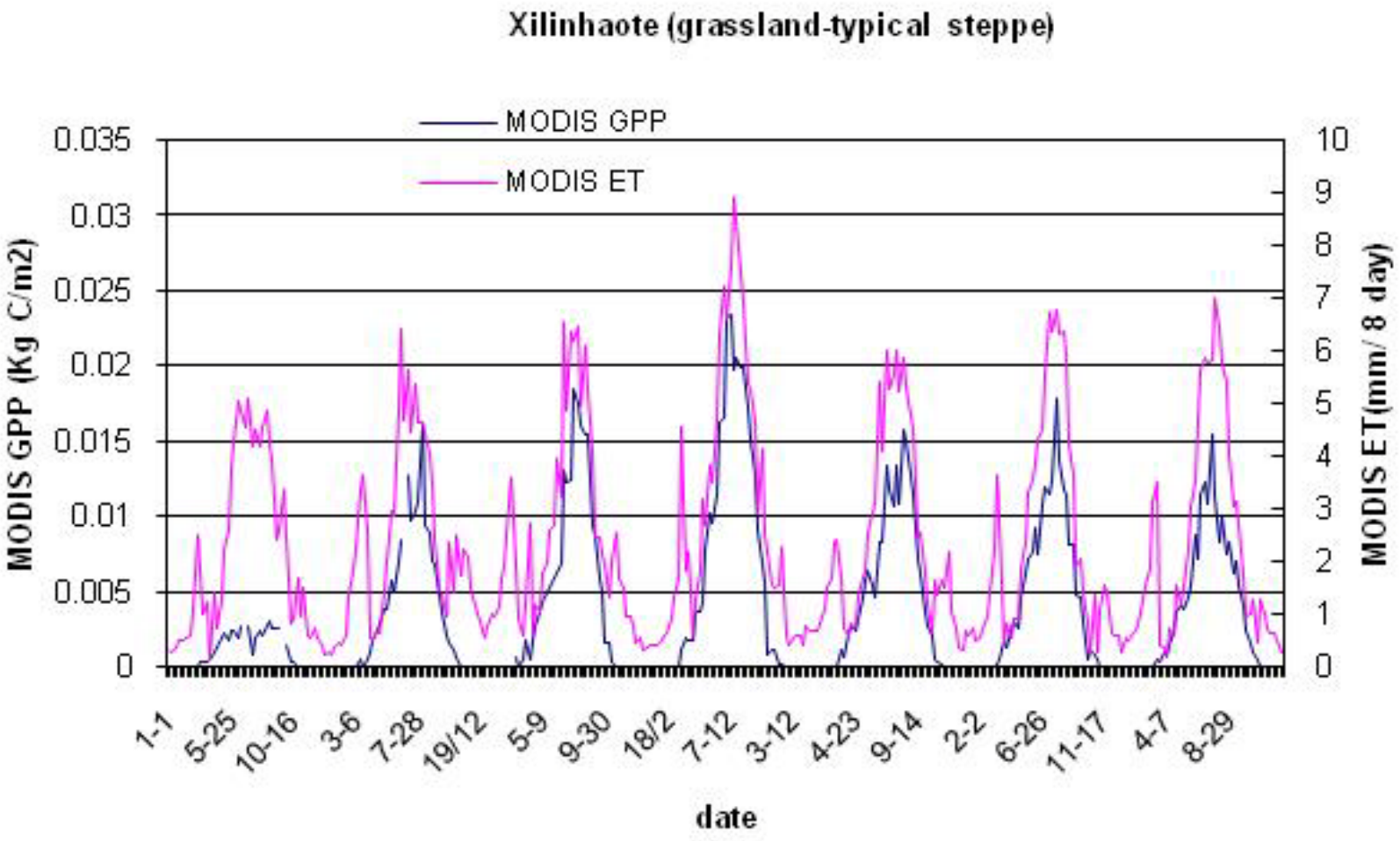
Simplified Surface Energy Balance (SSEB)



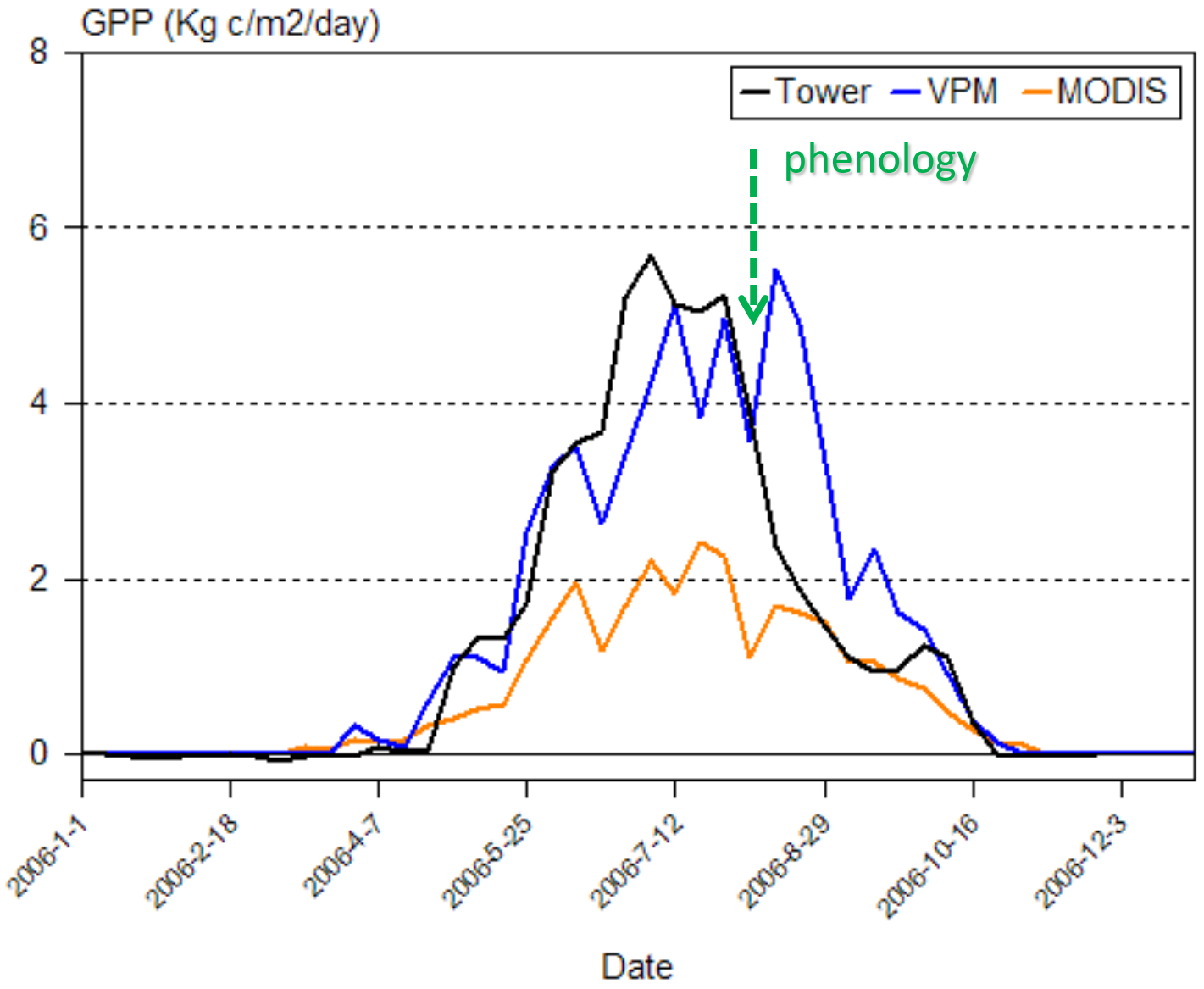
Projection: Albers equal area

Datum: WGS 84

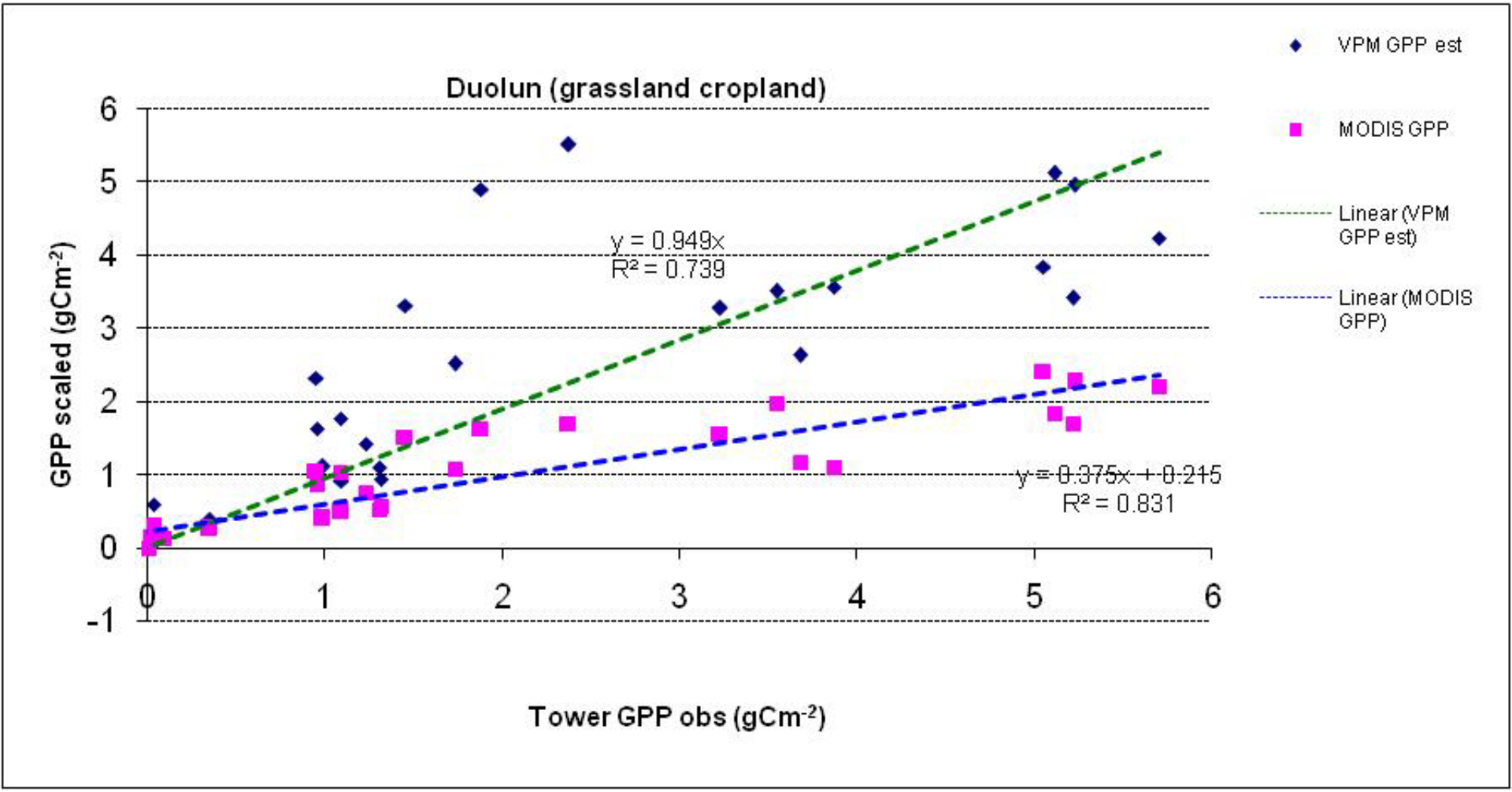
Intra-annual GPP, ET, and WUE



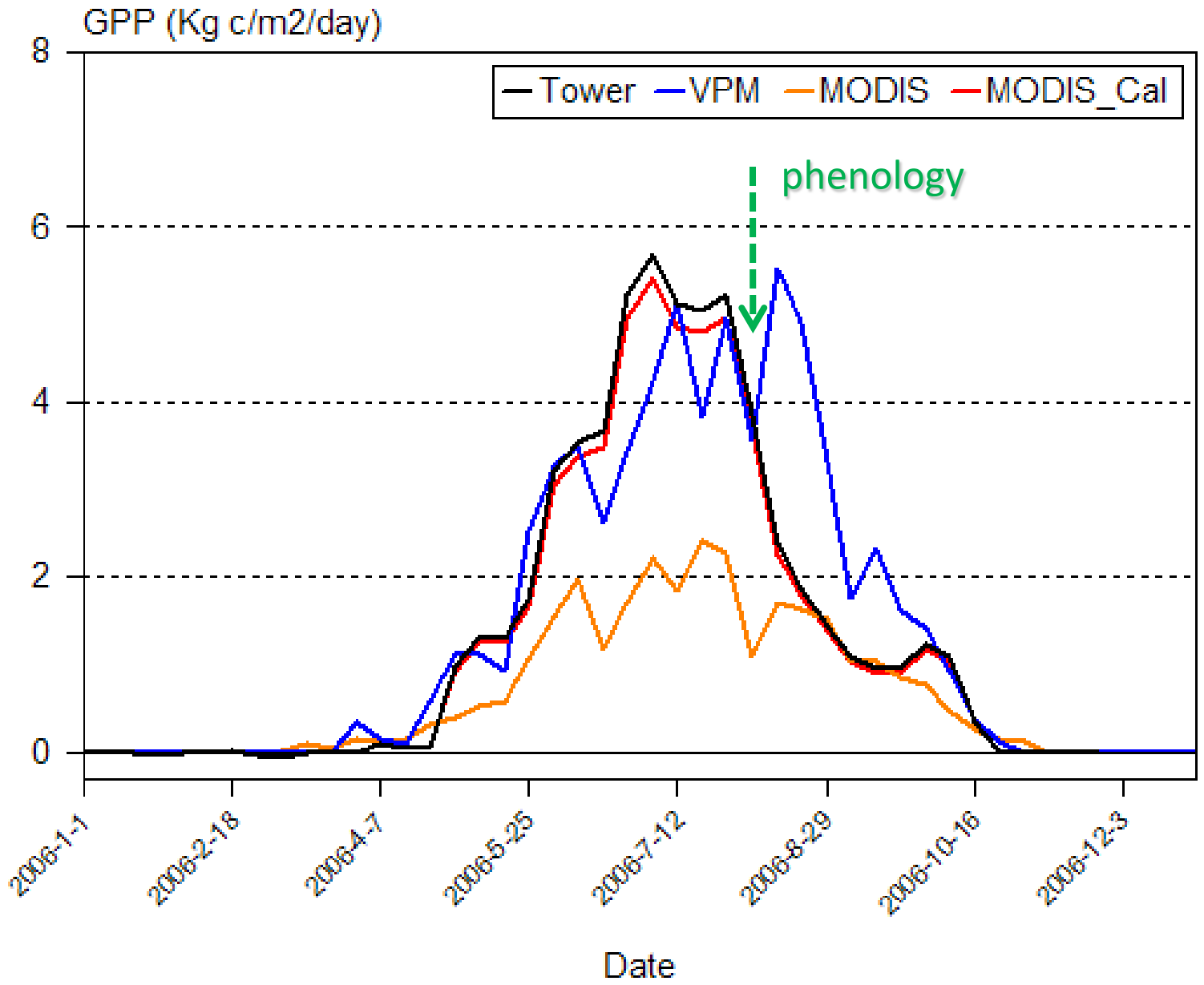
Seasonal changes of GPP from eddy-covariance tower, VPM, MODIS in 2006 in Duolun steppe



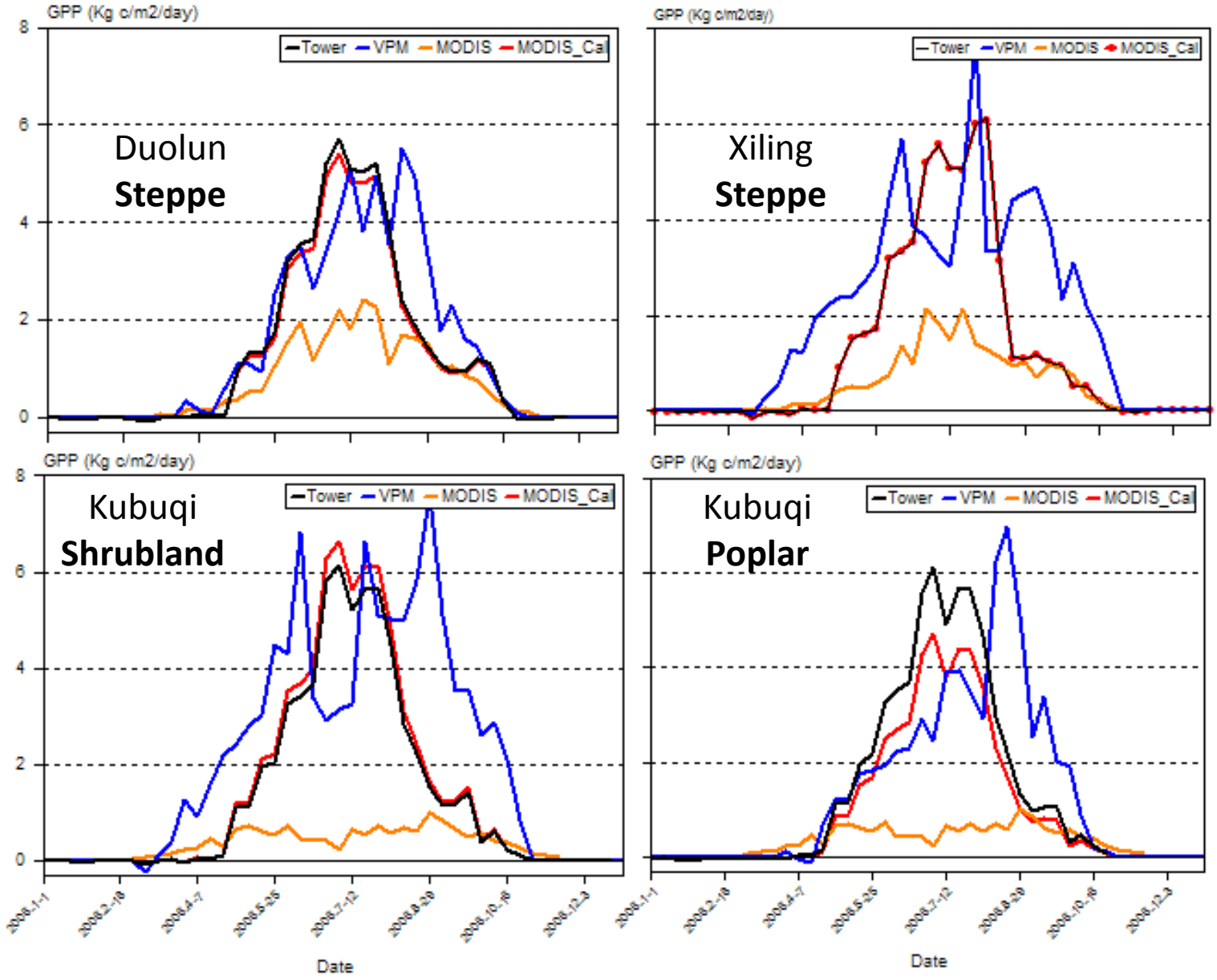
Linear relationship between MODIS and VPM GPP and tower-based GPP in 2006, showing a very tight correlation for MODIS



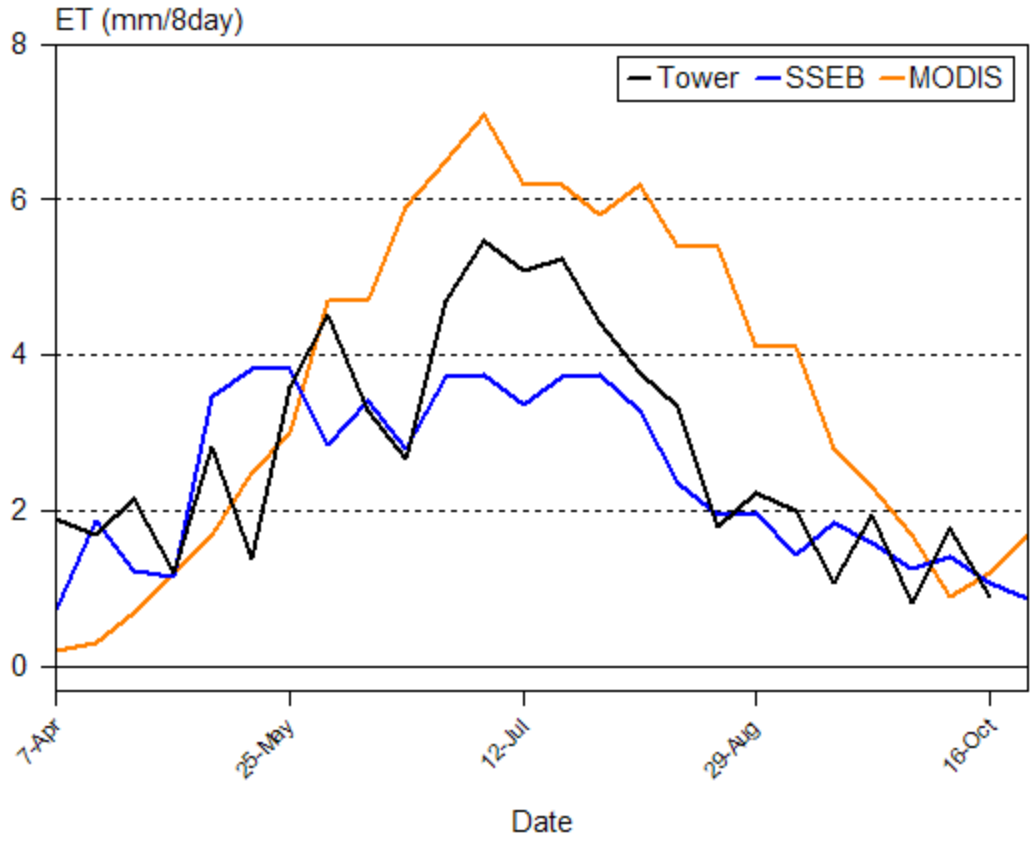
Seasonal changes of GPP from eddy-covariance tower, VPM, MODIS in 2006 in Duolun steppe



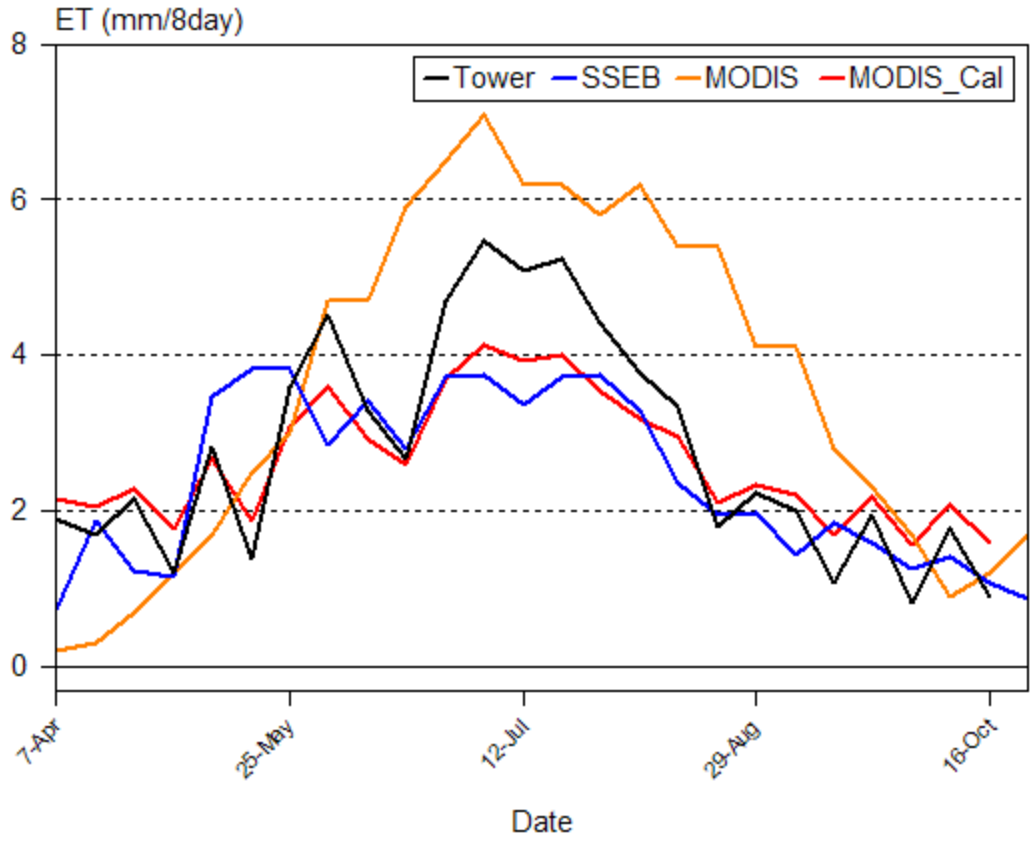
Empirical scaling-up from MODIS using EC towers provide very accurate GPP at all four flux measurement sites in Inner Mongolia



Predicting ET from SSEB, MODIS, and EC Towers

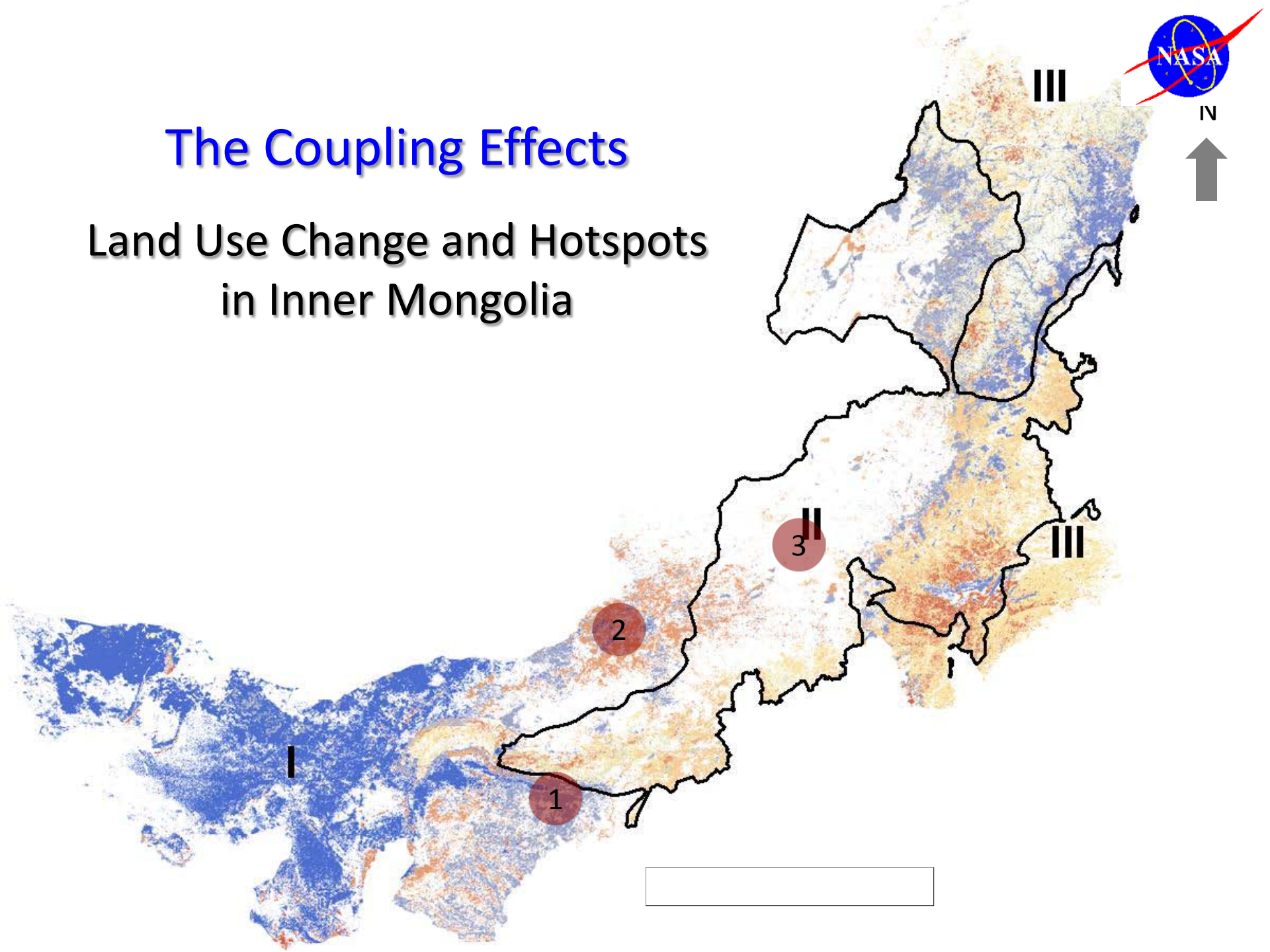


Predicting ET from SSEB, MODIS, and EC Towers



The Coupling Effects

Land Use Change and Hotspots in Inner Mongolia



Repeated ANOVA tests: Coupled Effects of Climate and Landuse on GPP & ET

(1) Gross Primary Production (GPP)

	SSE	%
Type	2.8924	64.3
Year	1.20423	26.8
Year*type	0.40085	8.9
total	4.49748	

2.4

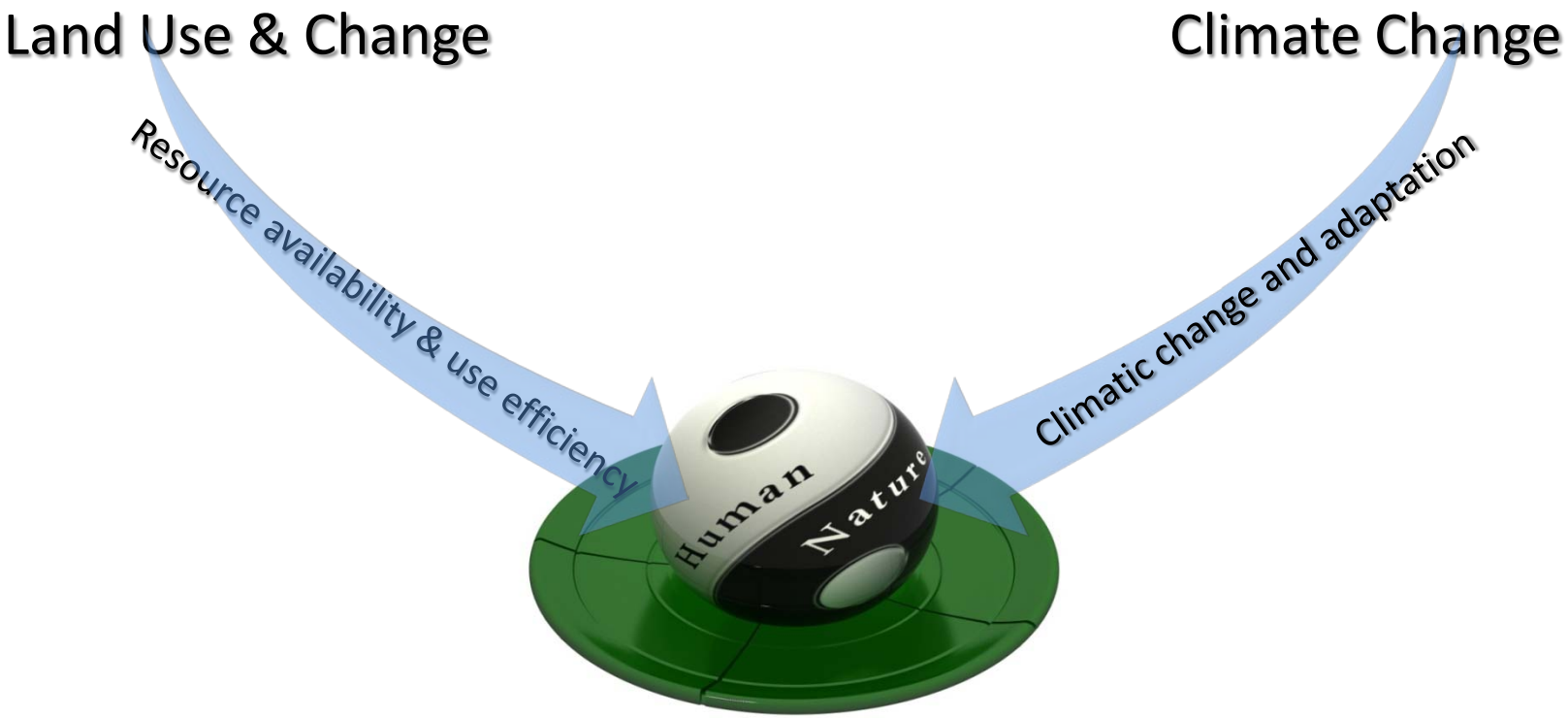
(2) Evapotranspiration (ET)

	SSE	%
Type	11425.4	83.6
Year	1981.1	14.5
Year*type	257.1	1.9
total	13663.6	

5.77

Moving Forward: Mongolia Plateau

- Two contrasting counties (IM & MG)
  - Adaptation as the central focus
  - Natural and Human System as one



谢 谢 ！

Publications (available upon request)

Zhang, F., J. Chen, et al. Predicting community structure using spectrometry in IM. *RSE* (draft manuscript)

Shao, C., J. Chen, and L. Li. Ecosystem responses to mowing in an Inner Mongolia prairies. Ecological Applications *(in review)*

Shao, C. J. Chen, and L. Li. Role of net radiation on energy balance closure in grassland ecosystems. *Journal of Geophysical Research-Atmosphere* (in review)

Wilske, B., H. Kwon, L. Wei, S. Chen, N.Lu, G. Lin. J. Xie, W, Guan, E. Pendall, B. E Ewers**,** J. Chen. Evapotranspiration (ET) and regulating mechanisms in two semiarid Artemisia-dominated shrub steppes at opposite sides of the globe. *Journal of Arid Environments* (in review)

Lu, N., B. Wilske, J. Ni, R John, **J. Chen**. Temporal and spatialvVariability of climate extremes in Inner Mongolia from 1955 to 2005. *International Journal of Climatology* (in review)

John, R., N. Lu, B. Wilske, and J. Chen. Land Cover /land use change and their ecological consequences. *Environmental Research Letter* (accepted)

Lu, N., B. Wilske, J. Ni, John, R. and J. Chen. Climate change in Inner Mongolia from 1955 through 2005. *Environmental Research Letter* (accepted)

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Wilske B., N. Lu, L.Wei, S. Chen, T. Zha, C. Liu, W. Xu, A. Noormets,J. Huang, Y. Wei, J. Chen, Z. Zhang, J. Ni, G. Sun, K. Guo, S. McNulty, R. John, X. Han, G. Lin, **J. Chen**. 2009. Poplar plantation has the potential to alter water balance in semiarid Inner Mongolia. *Journal of Environmental Management* 90: 2762-1770.

Zhang, W.L., S.P. Chen, J. Chen, L. Wei, X.G. Han, G.H. Lin. 2007. Biophysical regulations of carbon fluxes of a steppe and a cultivated cropland in semiarid Inner Mongolia. *Agricultural and Forest Meteorology 146: 216-229.*

Cheng, X., S. An, J.Chen, B. Li, Y. Luo, J. Chen, S. Liu, and Y. Liu. 2007. Spatial relationships among species, aboveground biomass, N, and P in disturbed prairie communities*. Journal of Arid Environment 68: 652-667.*

Simple Surface Energy Balance (SSEB)

- LE = Rn - G – H
- ET frac = TH – Tx / TH –TC (where Th & Tc are hot and cold pixels)
- ET act = ETfrac * ETref (where ET ref is USGS EROS PET)

Senay, G.B, M. Budde, J.P. Verdin, A.M. Melesse 2007. A Coupled Remote Sensing and Simplified Energy Balance Approach to Estimate Actual Evapotranspiration from Irrigated Fields. *Sensors,* 7, 979-1000.

Vegetation photosynthesis model (VPM)

- Xiao, X. M., Hollinger, D., Aber, J. D., Goltz, M., Davidson, E. A., & Zhang, Q. Y. (2004). Satellite-based modeling of gross primary production in an evergreen needle leaf forest. Remote Sensing of Environment, 89,

  519–534.

- Xiao, X., Zhang, Q., Braswell, B., Urbanski, S., Boles, S.,Wofsy, S. C., et al. (2004). Modeling gross primary production of temperate deciduous broadleaf forest using satellite images and climate data. Remote Sensing of Environment, 91, 256–270.