ESA - MOST Dragon 2 Programme

2011 DRAGON 2 SYMPOSIUM

中国科技部-欧洲空间局合作 "龙计划"二期

"龙计划"二期2011年学术研讨会

Key Eco-Hydrological Parameters Retrieval and Land Data Assimilation System Development in a Typical Inland River Basin of China's Arid Region (ID. 5322)

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Delft University of Technology

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- Jiemin Wang (CAREERI)
- Zeyong Hu (CAREERI)
- Ling Lu (CAREERI)
- Mingguo Ma (CAREERI)
- Weizhen Wang (CAREERI)
- Tao Che (CAREERI)
- Rui Jin (CAREERI)
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European Investigators

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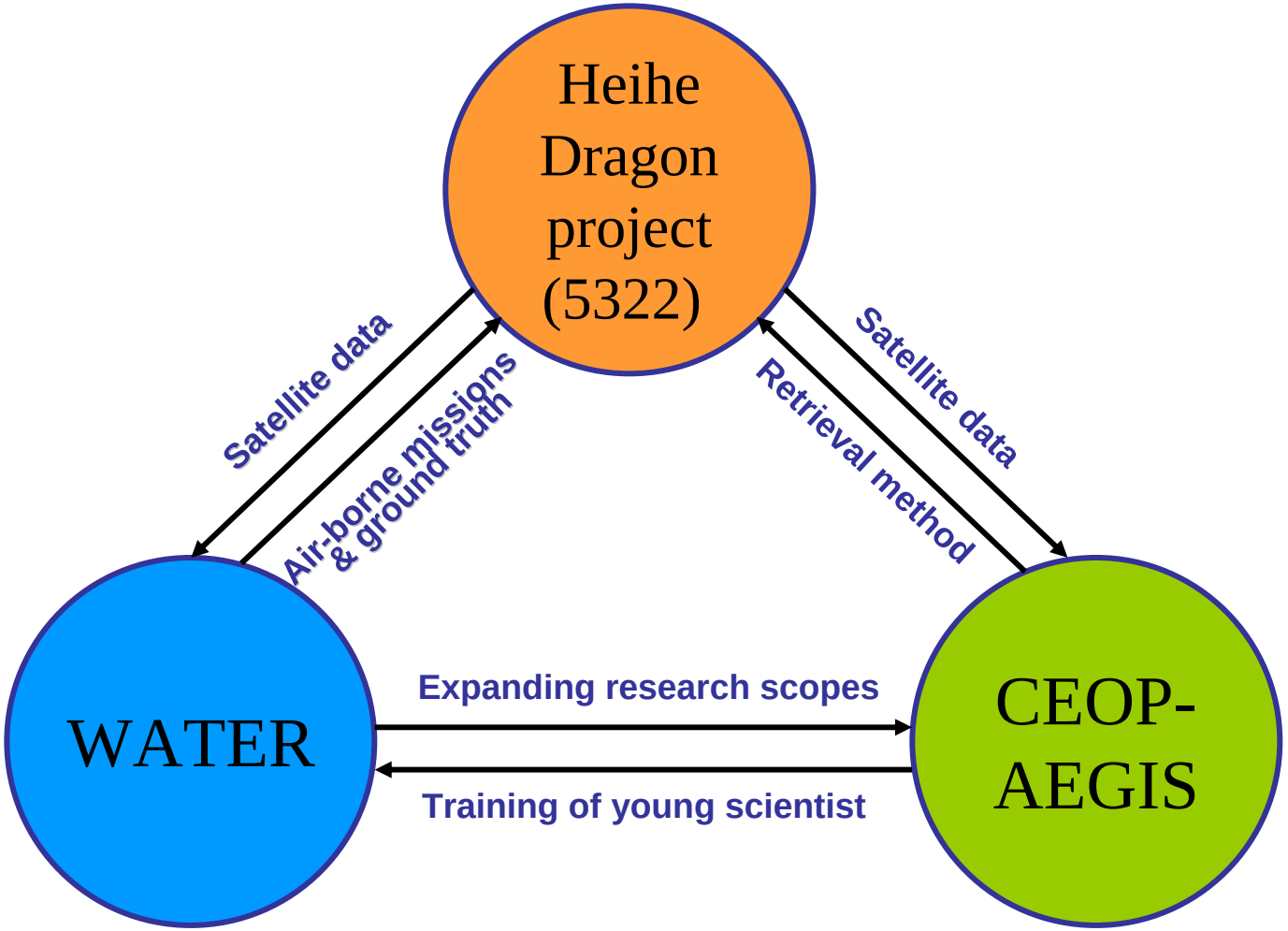
- Zhongbo Su (NL)
- Li Jia (NL)
- Frank Veroustraete (B)
- Fabio Maselli (IT)
- Sandro Brivio (IT)
- Zhaoliang Li (F)
- Run Wang (G)
- Xin Tian (NL)

Outline

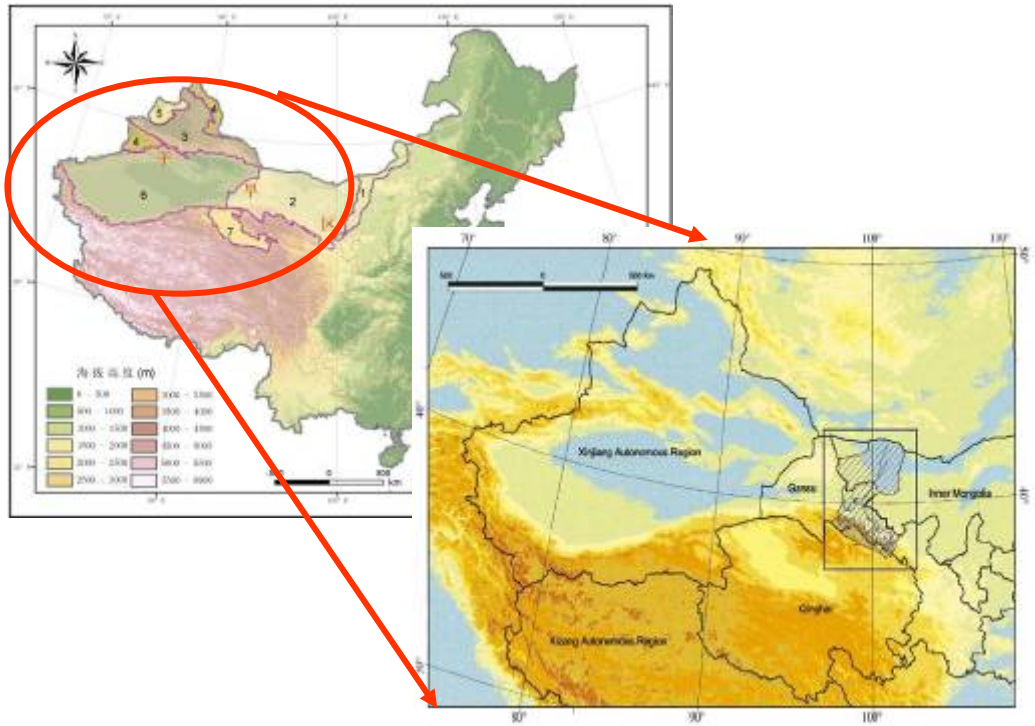
- Objective and background
- Progress on key eco-hydrological parameters retrieval
- Progress on HDAS
- Prevue of Hi-WATER
- Summary

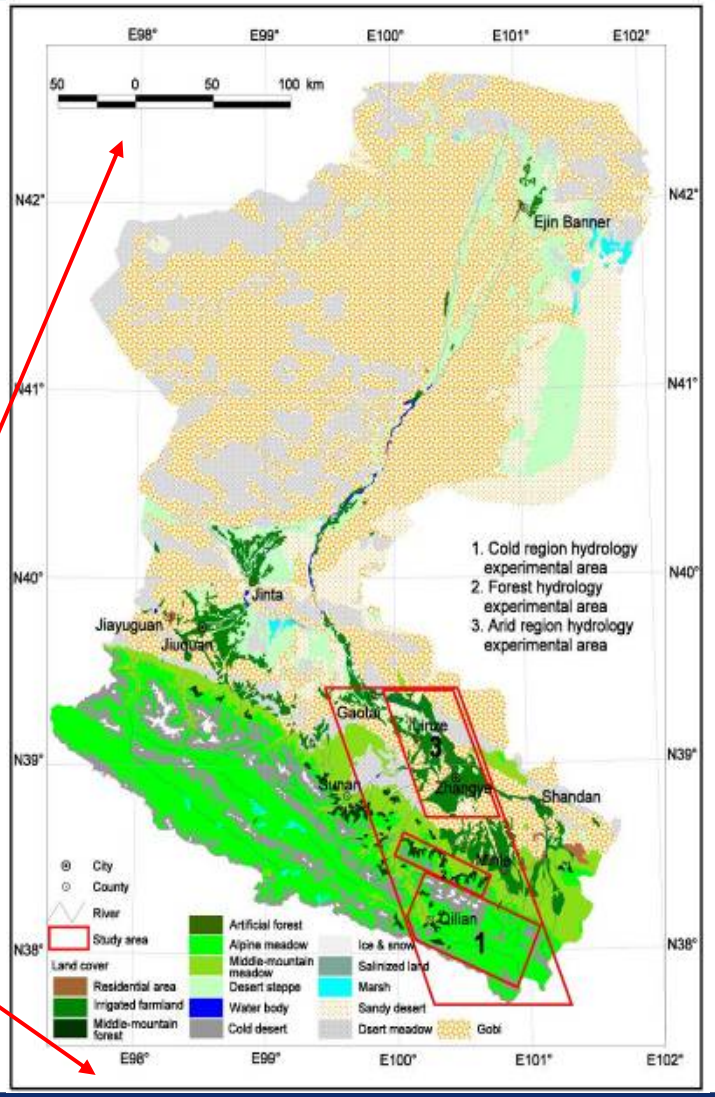
1.2 Background



Study area:

Heihe River Basin





The WATER Project

Watershed Allied Telemetry Experimental Research

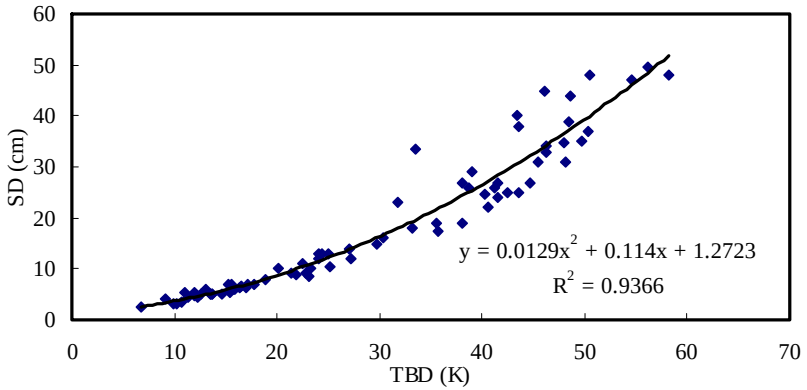
Watershed Allied Telemetry Experimental Research

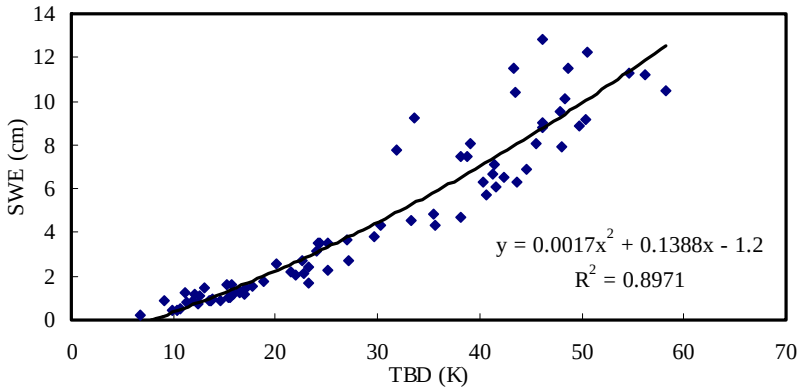
Xin Li[1], Xiaowen Li[2, 3], Zengyuan Li[4], Mingguo Ma[1], Jian Wang[1], Qing Xiao[2], Qiang Liu[2], Tao Che[1], Erxue Chen[4], Guangjian Yan[3], Zeyong Hu[1], Lixin Zhang[3], Rongzhong Chu[1], Peixi Su[1], Qinhuo Liu[2], Shaomin Liu[3], Jindi Wang[3], Zheng Niu[2], Yan Chen[5], Rui Jin[1], Weizhen Wang[1], Youhua Ran[1], Xiaozhou Xin[2], Huazhong Ren[3]

Li Xin et al., 2009, JGR

2. Progress on key eco-hydrological parameters retrieval

Estimating snow depth and SWE using K and Ka-bands microwave radiometers

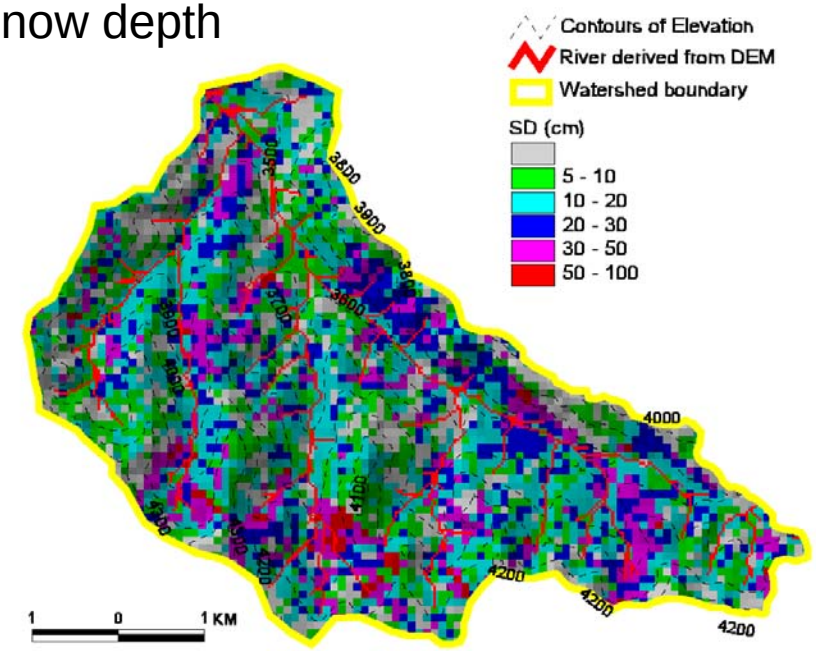




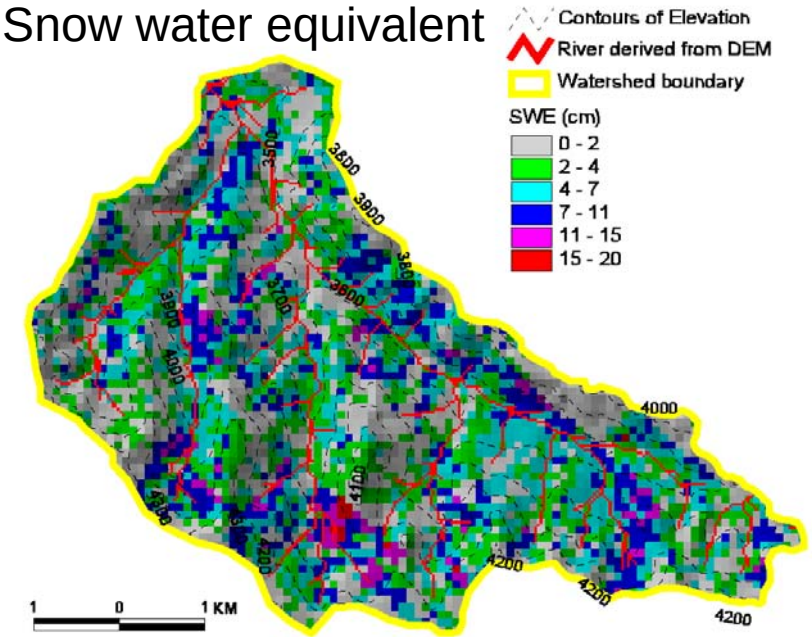
$SD = 0.0129*TBD^2+0.114*TBD+1.2723$

$SWE = 0.0017*TBD^2+0.1388*TBD-1.2$

Snow depth



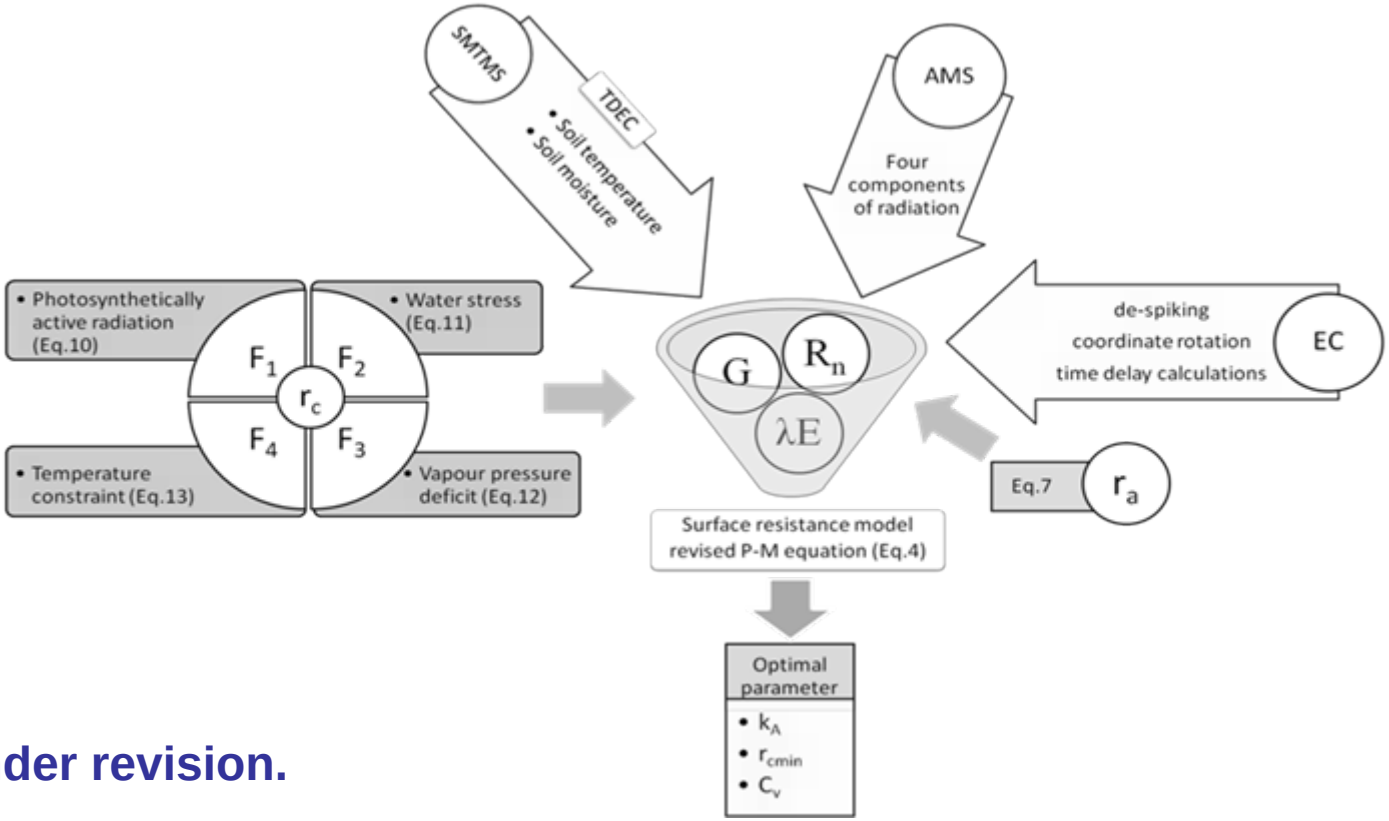
Snow water equivalent



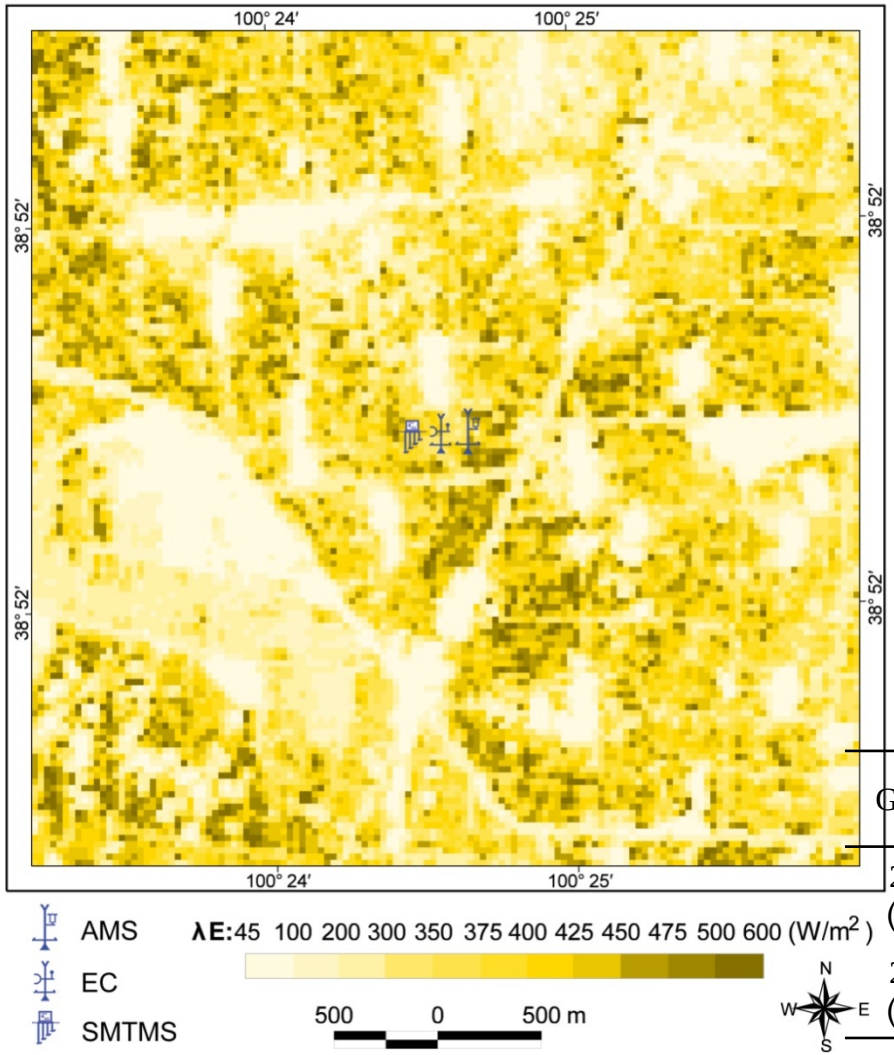
Che *et al.*, JAG, 2011, Under revision.

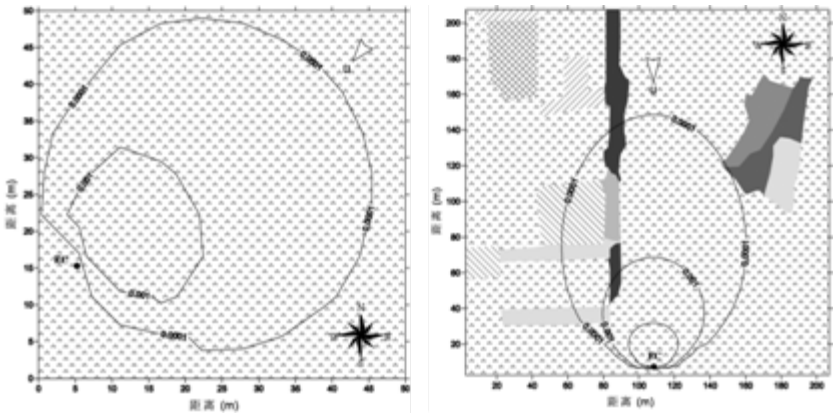
A biophysics-based surface resistance model for estimating latent heat flux from remotely sensed data

Four factors (radiation, soil water content, saturated vapour pressure deficit (VPD) and air temperature) that affect the ET are taken into the algorithm.



Song, *et al.*, JAG, Under revision.





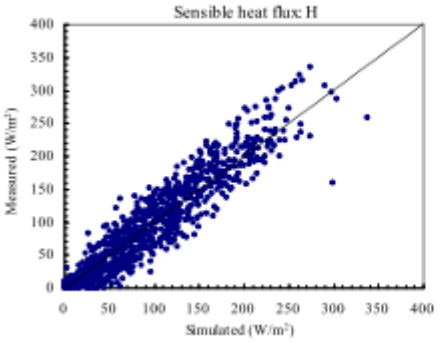
（080629 11:42） （080707 11:42）

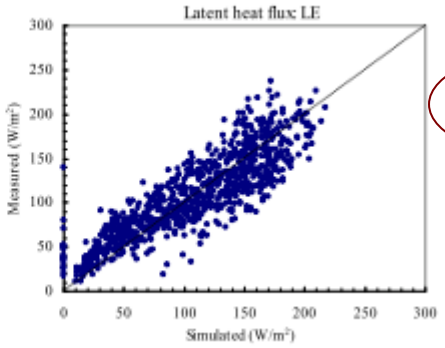
图4 EC 足迹 Fig. 4 EC footprint

Validation of λE (Wm^{-2})

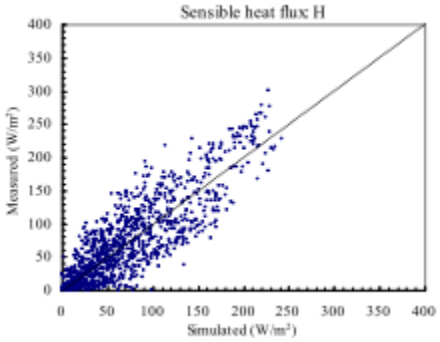
Ground truth (EC)	Estimate (footprint)	Estimate (one pixel)	Ground truth (EC)
20080629 11:45 (Beijing Time)	448	479	441
20080707 11:42 (Beijing Time)	407	476	396

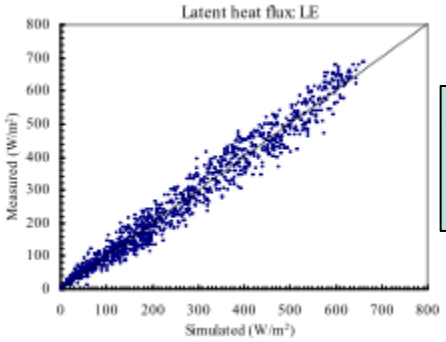
Heat fluxes estimation using directional thermal-infrared (TIR) data and the two-layer model



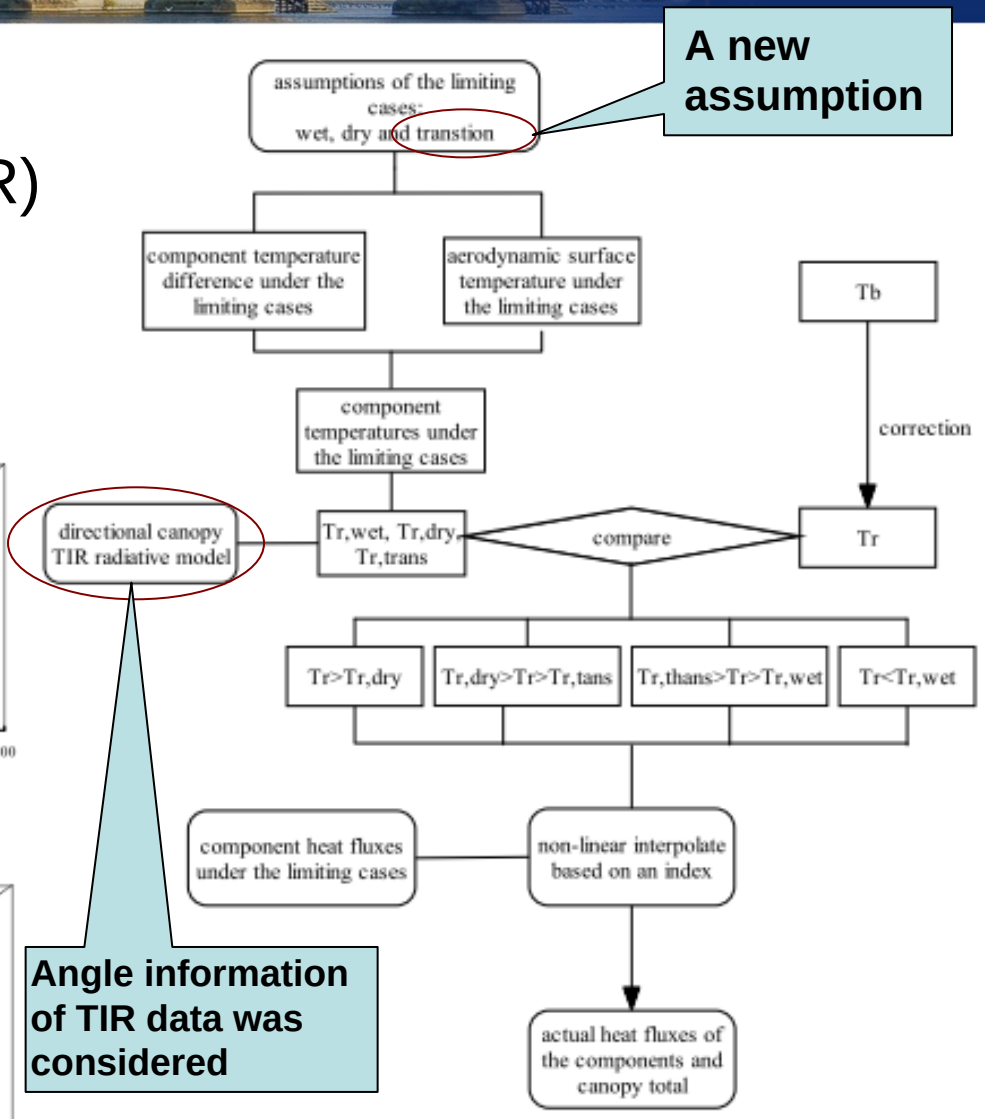


Winter wheat





Maize

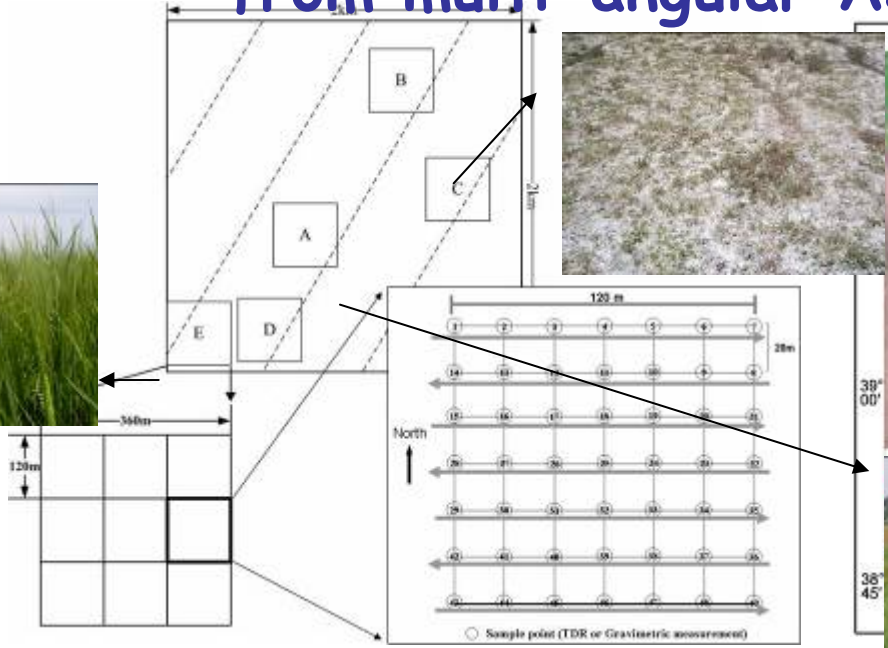


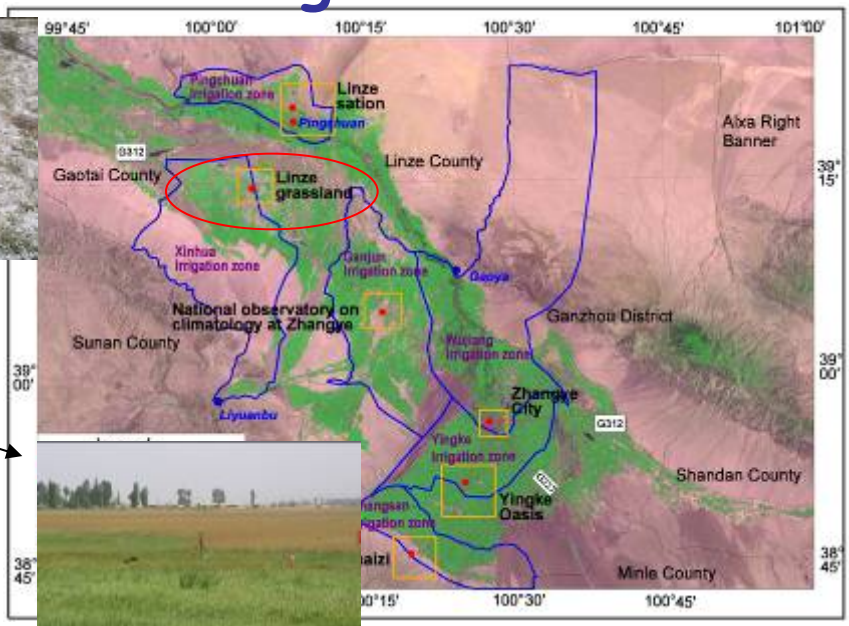
A new assumption

Angle information of TIR data was considered

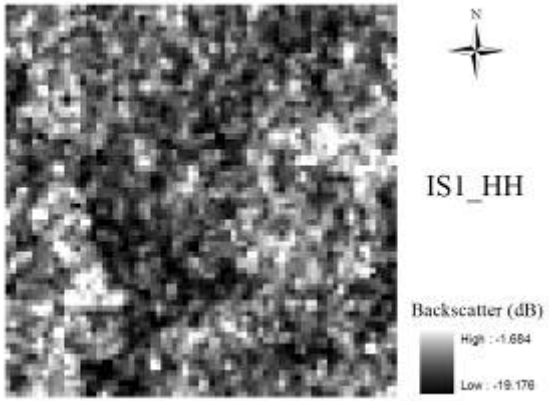
Xin et al., 2010, HESS

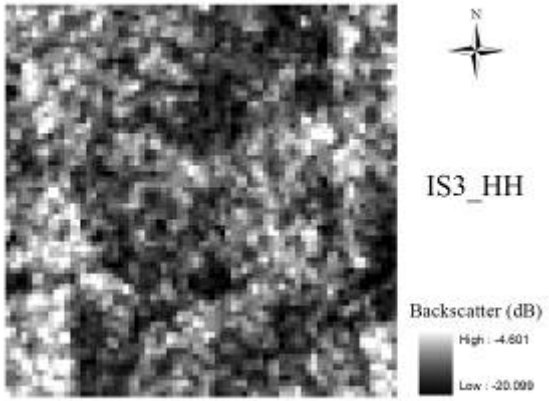
Estimation of surface soil moisture and roughness from multi-angular ASAR images





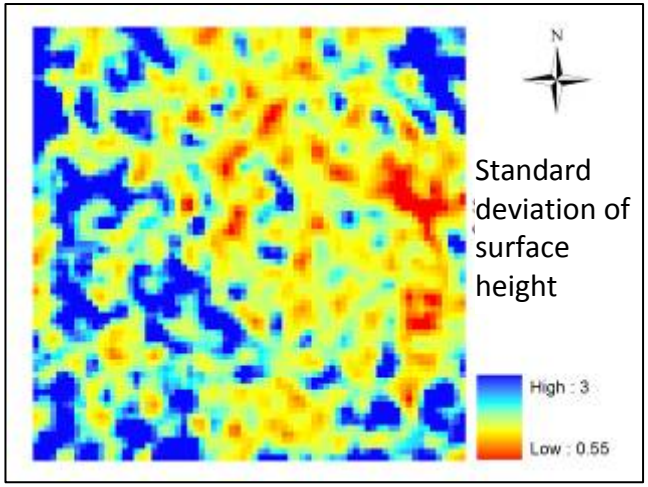
This study develops and evaluates an operational method that explores surface roughness based solely on multi-angle ASAR data.

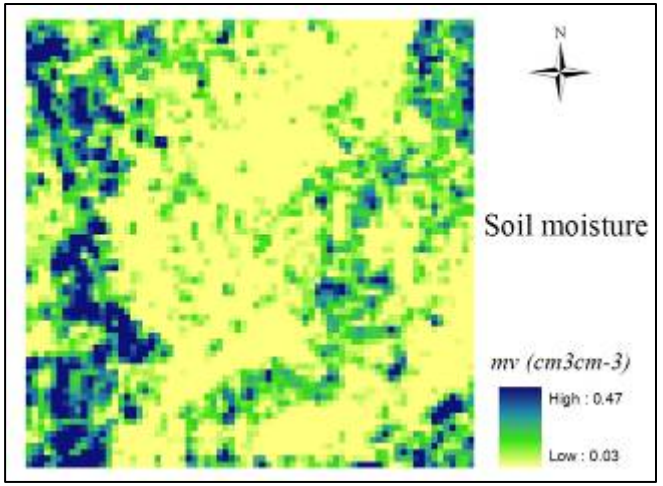




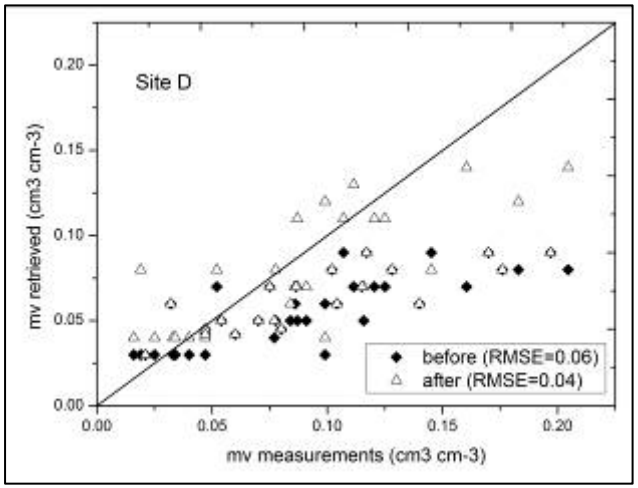
Estimation of surface soil moisture and roughness from multi-angular ASAR images

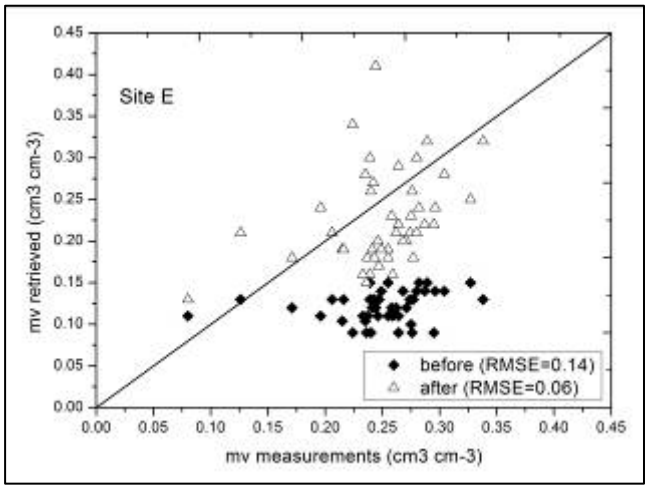
Retrieved results





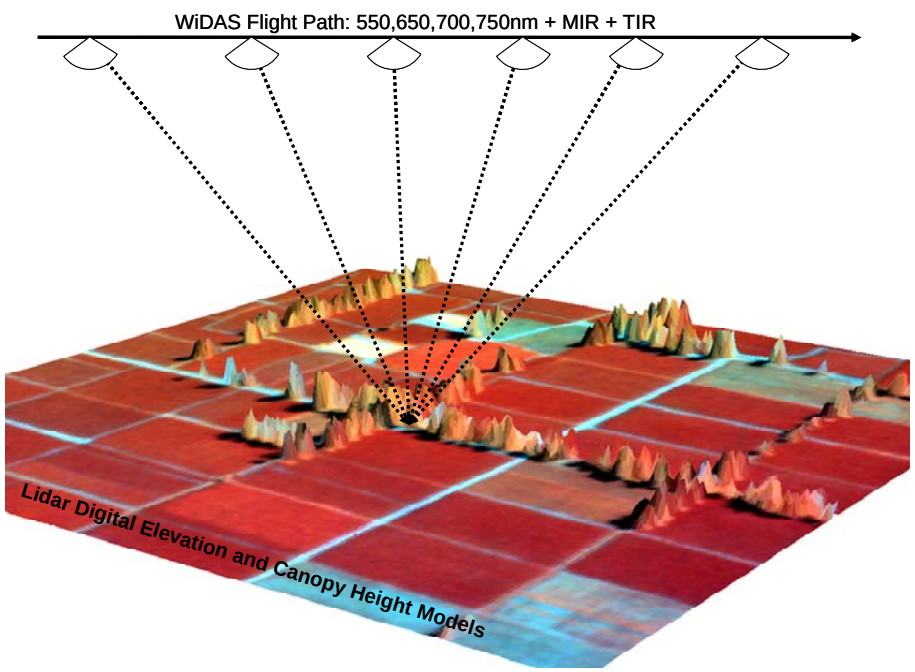
Soil moisture validation



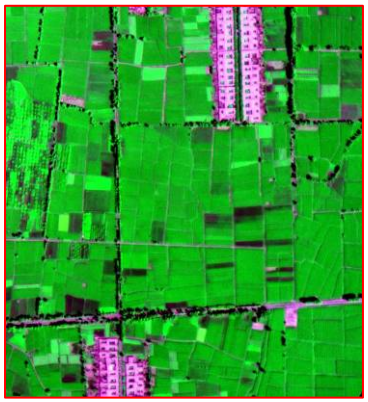


Wang *et al.*, HESS, 2011

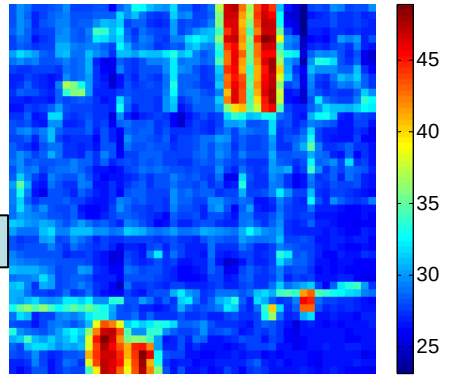
Separating vegetation and soil temperatures using airborne multi-angular remote sensing image data



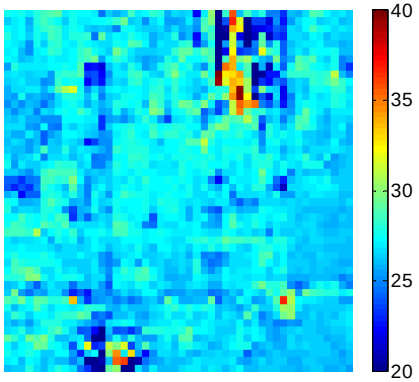
Multi-angular measurements for a given target of known 3D structure



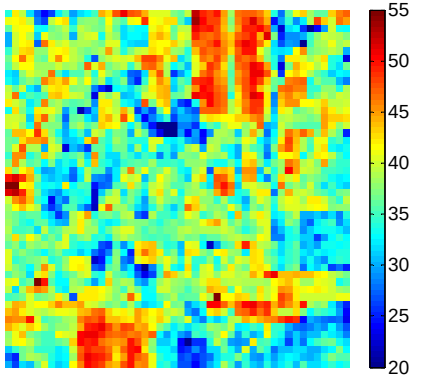
WiDAS VNIR image (Resolution 1.25 m)



WiDAS TIR image (Resolution 7.5 m)



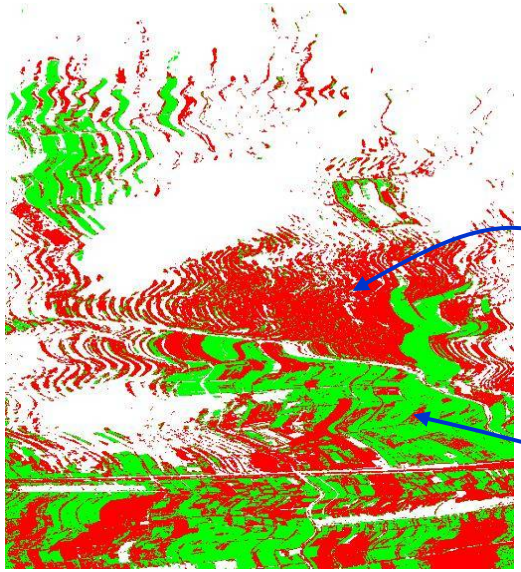
Vegetation BT

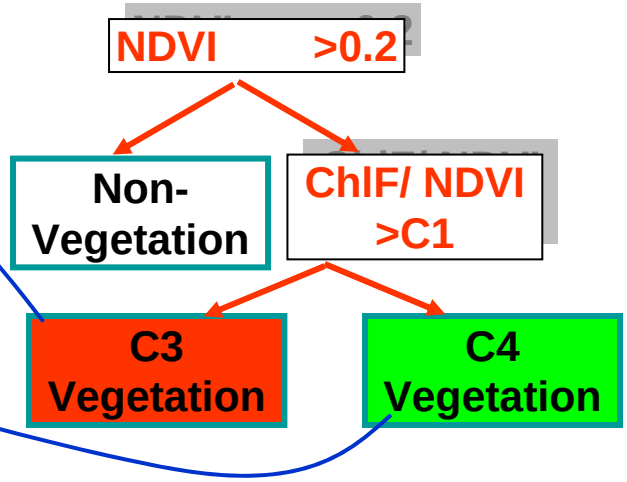


Soil BT

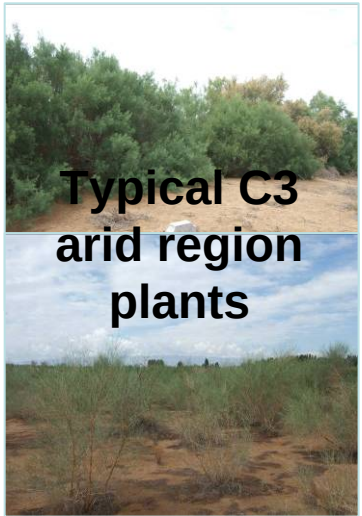
Liu Qiang et al., JAG, 2011

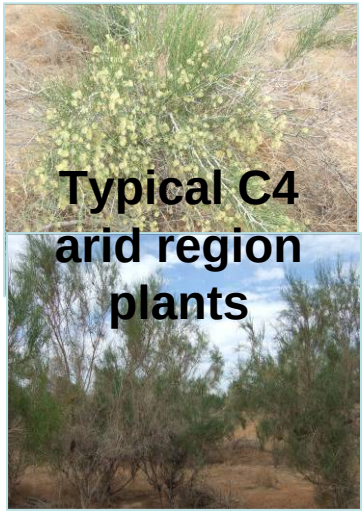
Mapping C3 and C4 plant functional types using separated solar-induced chlorophyll fluorescence from hyperspectral data

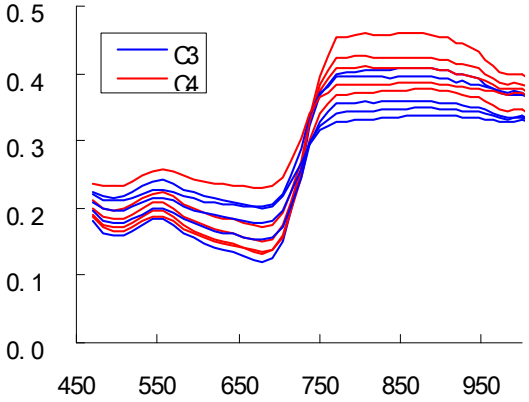




Overall accuracy 92%,
Kappa 0.84



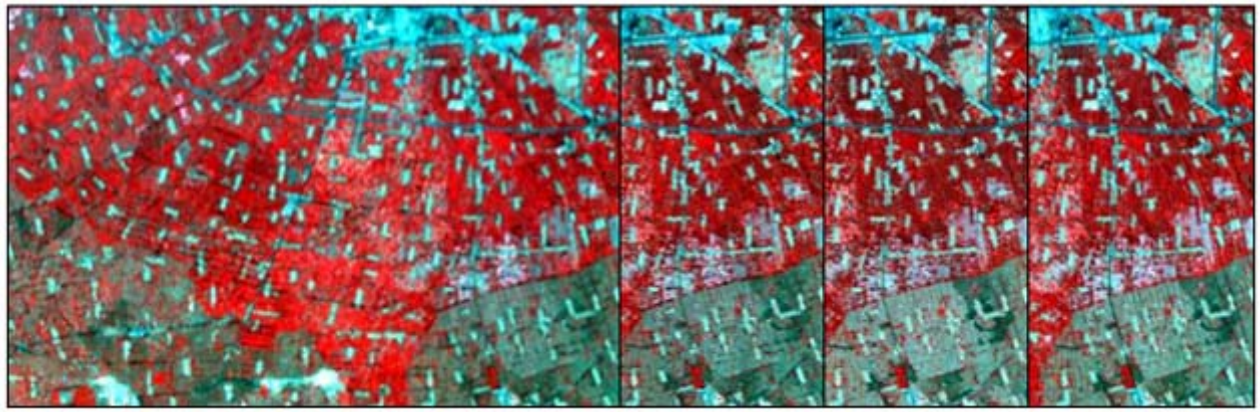




Spectral refletances of C3/C4 plants

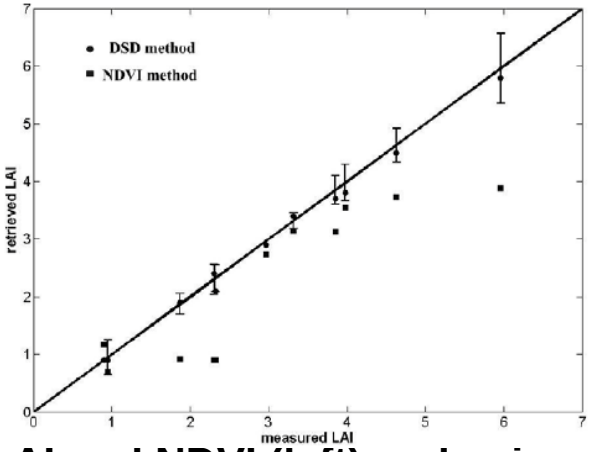
Liu Liangyun et al., 2010

LAI derived from CHRIS



CHRIS data of the study area after geometric correction

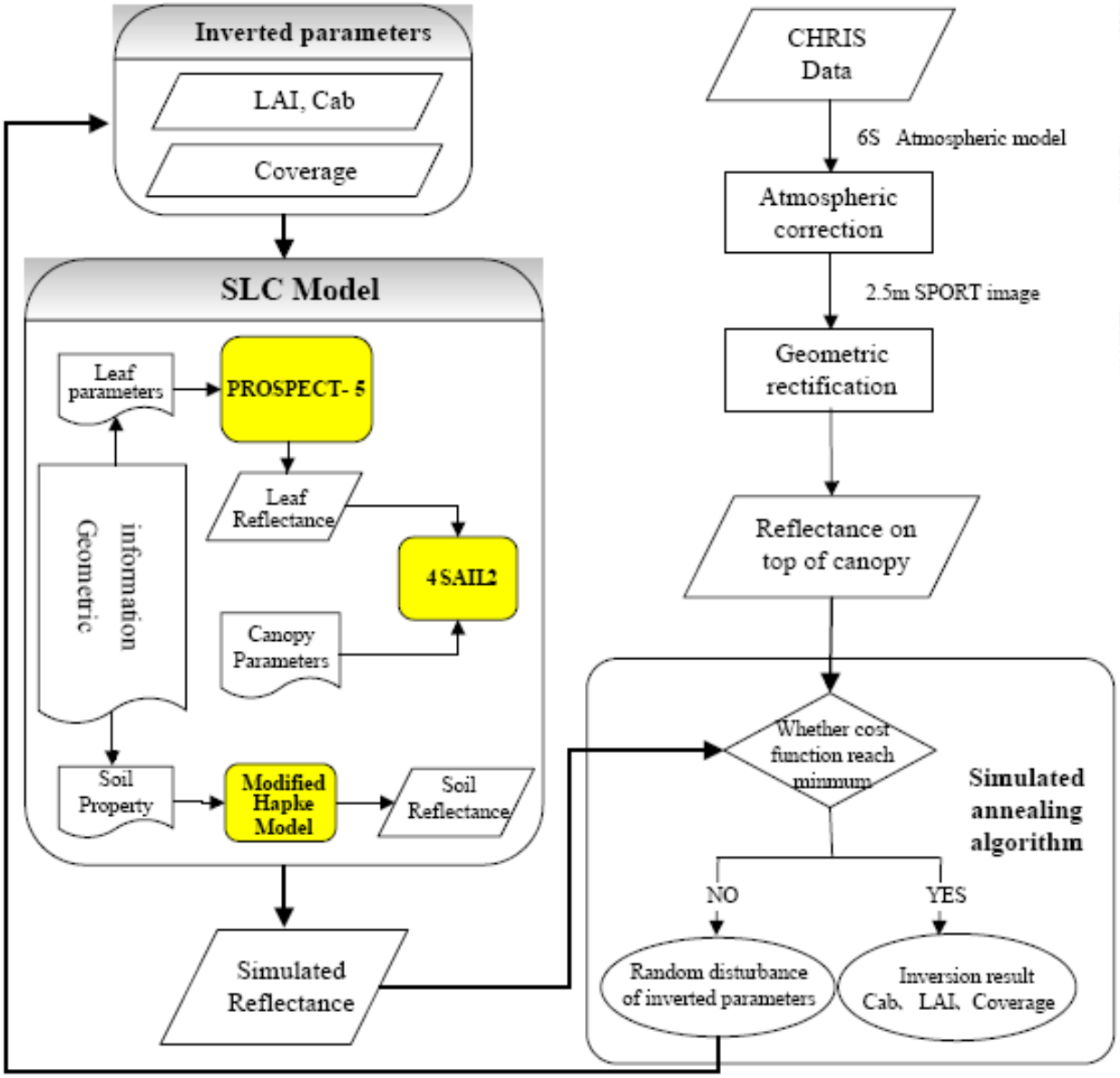
A new hybrid canopy reflectance model was developed and applied it to estimate LAI from CHRIS/PROBA.

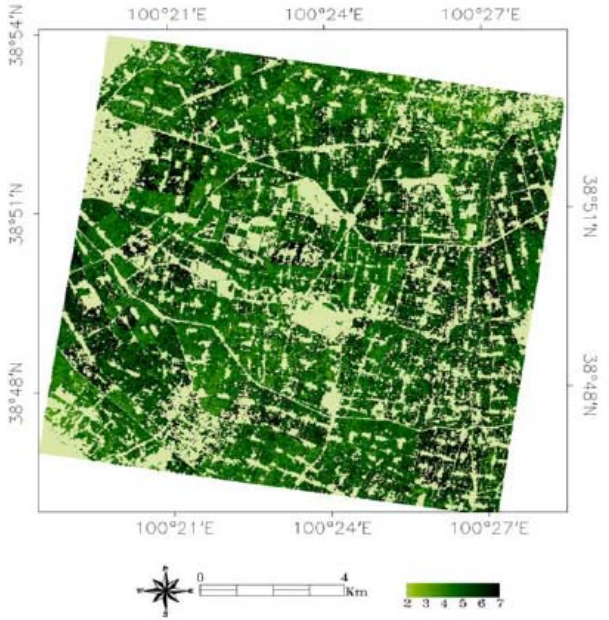


LAI map retrieval based on the empirical relationship between LAI and NDVI (left) and using DSD (directional second derivative) method (right)

Fan et al., 2010, HESS

Retrieval of Leaf Area Index, Leaf Chlorophyll Content Based on SLC Model and CHRIS Data

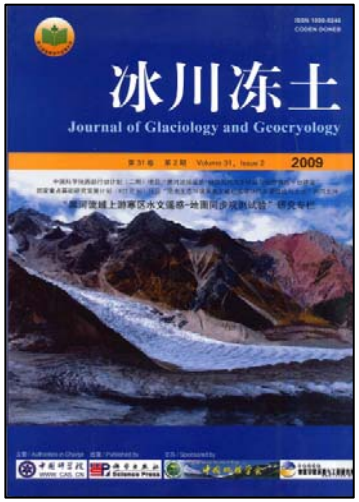


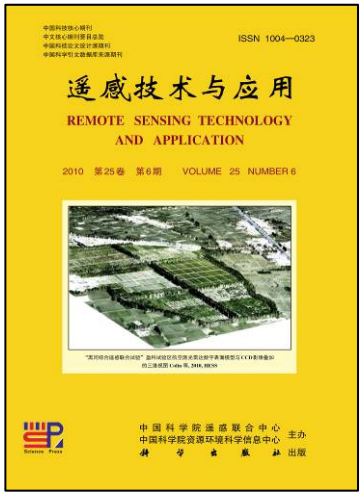


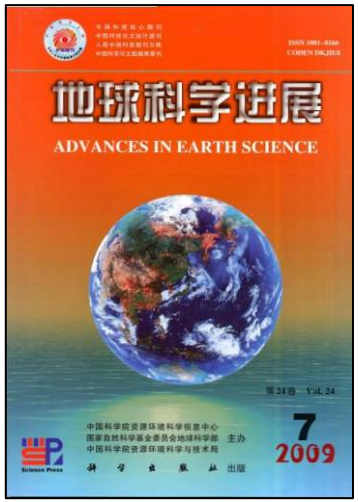
A forward model, Soil-Leaf-Canopy (SLC) model, was used to estimate LAI and Cab in this paper. Simulated annealing method was adopted as inversion algorithm.

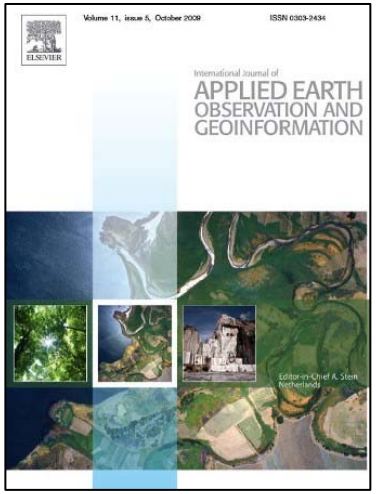
Tan et al., 2010, IITA-GRS

Publications of WATER









HESS - Special Issue

Observing and modeling the catchment-scale water cycle
Editor(s): Xin Li, Xiaowen Li, K. Roth, M. Menenti, and W. Wagner

Parameterization of a coupled CO_2 and H_2O gas exchange model at the leaf scale of *Populus euphratica* 05 Mar 2010
G. F. Zhu, X. Li, Y. H. Su, and C. L. Huang
Hydrol. Earth Syst. Sci., 14, 419-431, 2010
Abstract | Final Revised Paper (PDF, 1679 KB) | Discussion Paper (HESSD)

The Two-layer Surface Energy Balance Parameterization Scheme (TSEBPS) for estimation of land surface heat fluxes 12 Mar 2010
X. Xin and Q. Liu
Hydrol. Earth Syst. Sci., 14, 491-504, 2010
Abstract | Final Revised Paper (PDF, 515 KB) | Discussion Paper (HESSD)

Frozen soil parameterization in a distributed biosphere hydrological model 23 Mar 2010
L. Wang, T. Koike, K. Yang, R. Jin, and H. Li
Hydrol. Earth Syst. Sci., 14, 557-571, 2010
Abstract | Final Revised Paper (PDF, 1269 KB) | Discussion Paper (HESSD)

Estimation of evapotranspiration in the Mu Us Sandland of China 24 Mar 2010
S. Liu, J. Bai, Z. Jia, L. Jia, H. Zhou, and L. Lu
Hydrol. Earth Syst. Sci., 14, 573-584, 2010
Abstract | Final Revised Paper (PDF, 1897 KB) | Discussion Paper (HESSD)

Groundwater response to leakage of surface water through a thick vadose zone in the middle reaches area of Heihe River Basin, in China 07 Apr 2010
X.-S. Wang, M.-G. Ma, X. Li, J. Zhao, P. Dong, and J. Zhou
Hydrol. Earth Syst. Sci., 14, 639-650, 2010
Abstract | Final Revised Paper (PDF, 1116 KB) | Discussion Paper (HESSD)

Evaluation of Penman-Monteith model applied to a maize field in the arid area of northwest China 29 Jul 2010
W.-Z. Zhao, X.-B. Ji, E.-S. Kang, Z.-H. Zhang, and B.-W. Jin
Hydrol. Earth Syst. Sci., 14, 1353-1364, 2010
Abstract | Final Revised Paper (PDF, 505 KB) | Discussion Paper (HESSD)

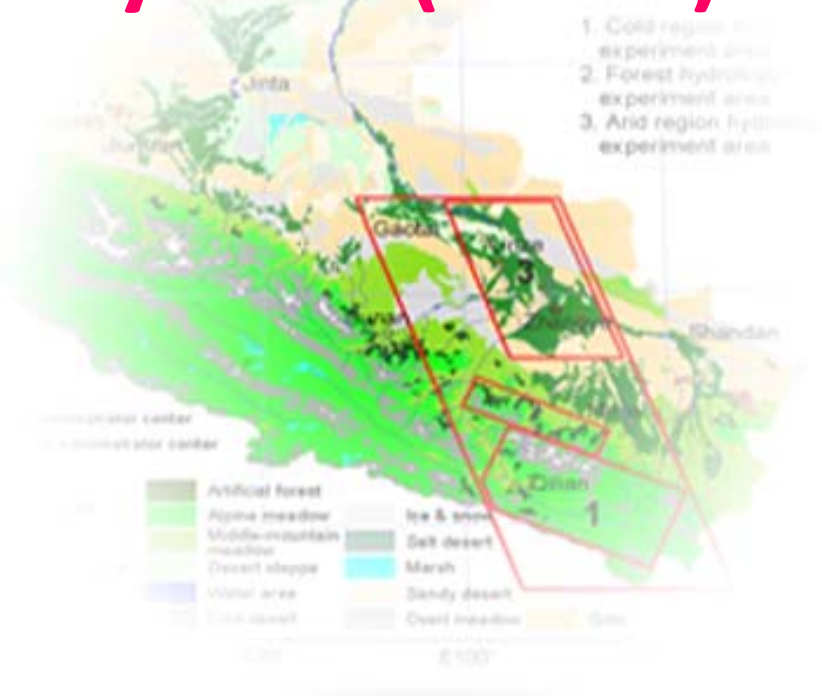
Accurate LAI retrieval method based on PROBA/CHRIS data 10 Aug 2010
W. J. Fan, X. R. Xu, X. C. Liu, B. Y. Yan, and Y. K. Cui
Hydrol. Earth Syst. Sci., 14, 1499-1507, 2010
Abstract | Final Revised Paper (PDF, 2935 KB) | Discussion Paper (HESSD)

The benefits of gravimeter observations for modelling water storage changes at the field scale 01 Sep 2010
B. Creutzfeldt, A. Güntner, S. Vorogushyn, and B. Merz
Hydrol. Earth Syst. Sci., 14, 1715-1730, 2010
Abstract | Final Revised Paper (PDF, 2184 KB) | Discussion Paper (HESSD)

Responses of snowmelt runoff to climatic change in an inland river basin, Northwestern China, over the past 50 years 19 Oct 2010

HESS special issue:
Http://www.hydrol-earth-syst-sci.net/special_issue116.html

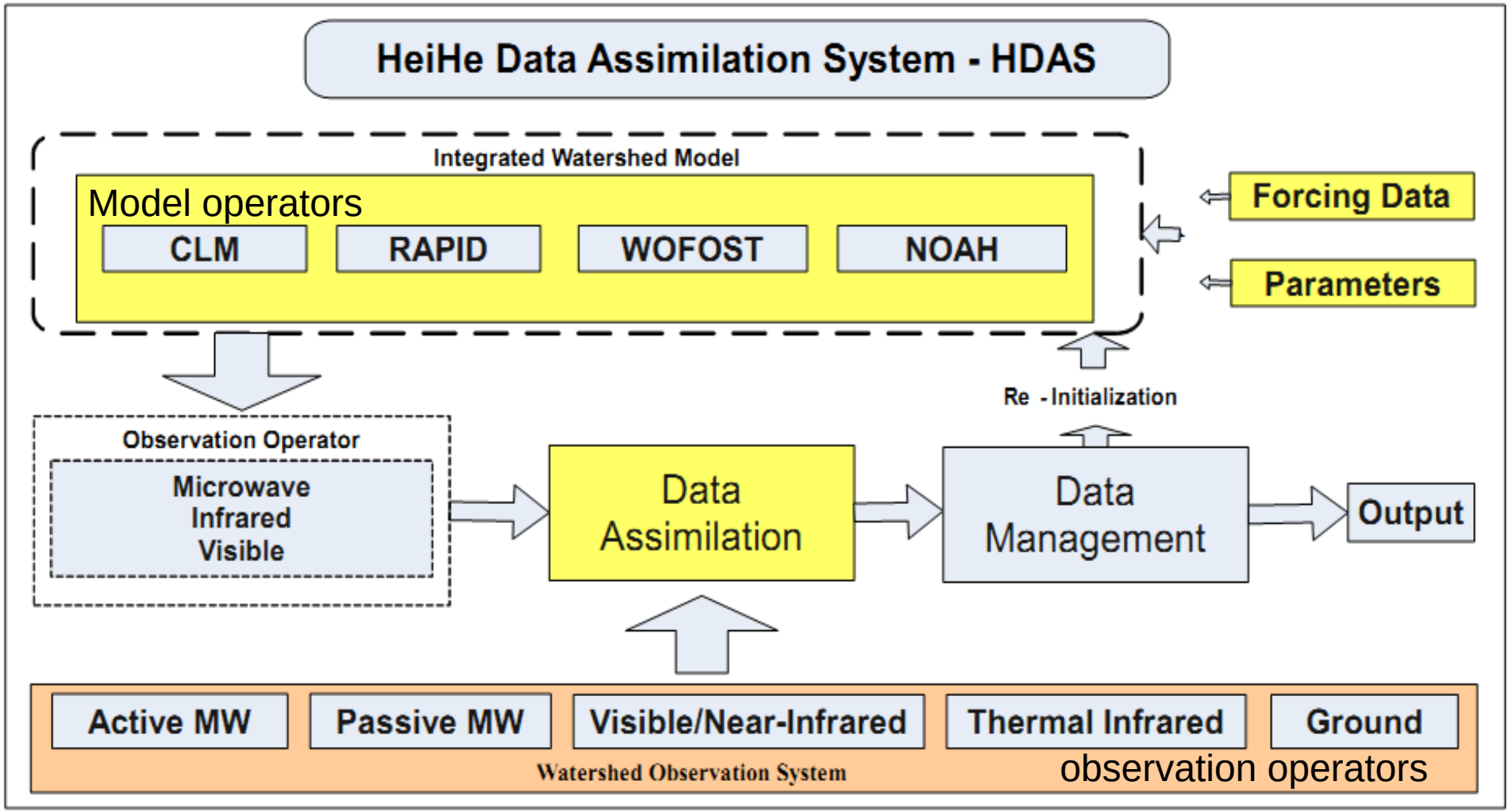
3. Progress on Heihe data assimilation system (HDAS)



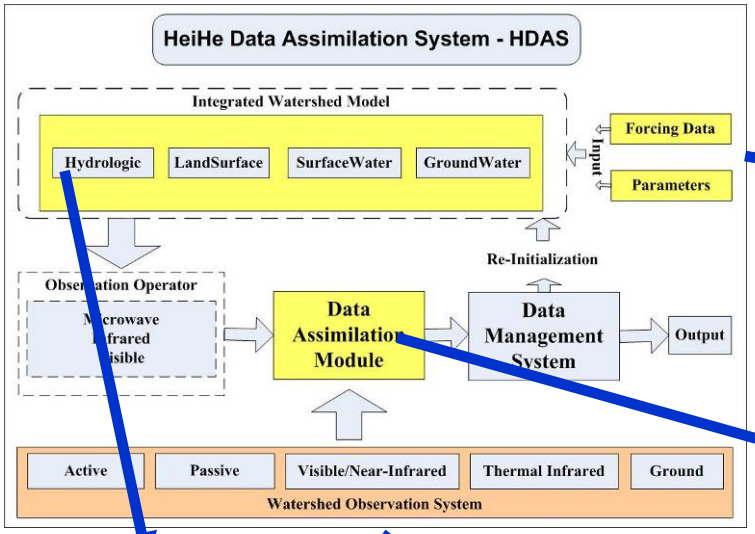
3.1 Objective

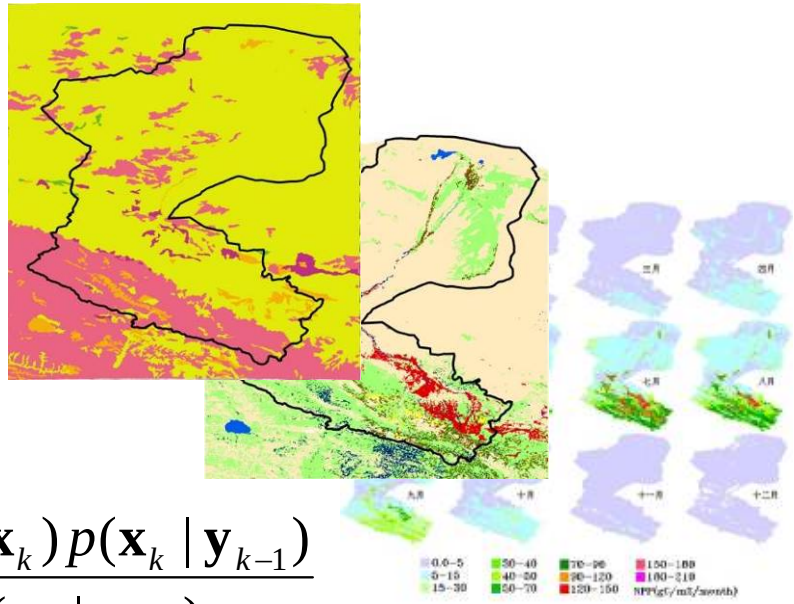
- To implement the real-time monitoring system of the watershed
- To improve the predictability of water cycle at catchment scale
- To integrate the multi-source watershed observation systems within a data assimilation framework to produce improved water and energy fluxes

3.2 Implemented system structure

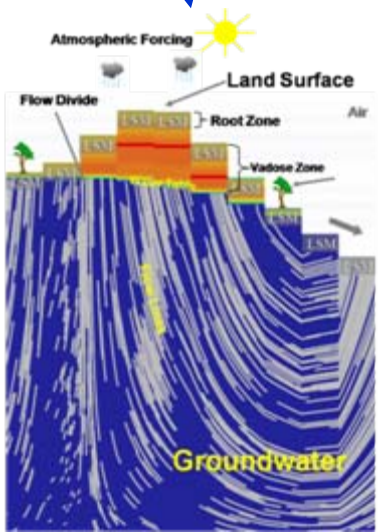


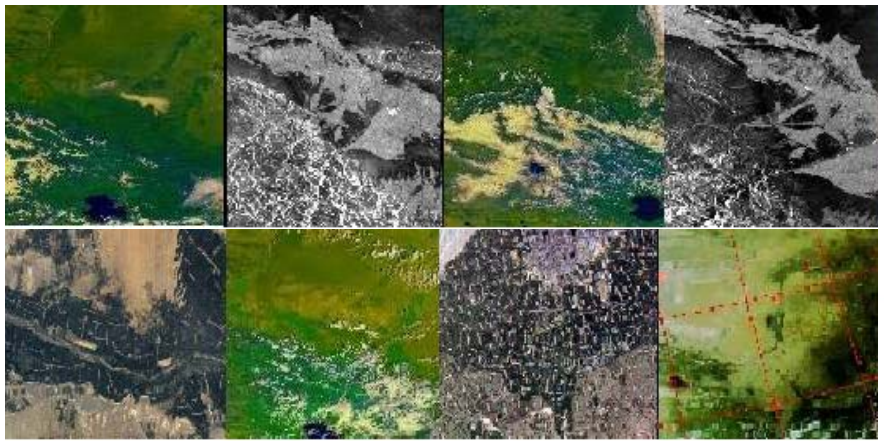
3.3 General framework





$$p(\mathbf{x}_k \mid \mathbf{y}_k) = \frac{p(\mathbf{y}_k \mid \mathbf{x}_k)\, p(\mathbf{x}_k \mid \mathbf{y}_{k-1})}{p(\mathbf{y}_k \mid \mathbf{y}_{k-1})}$$

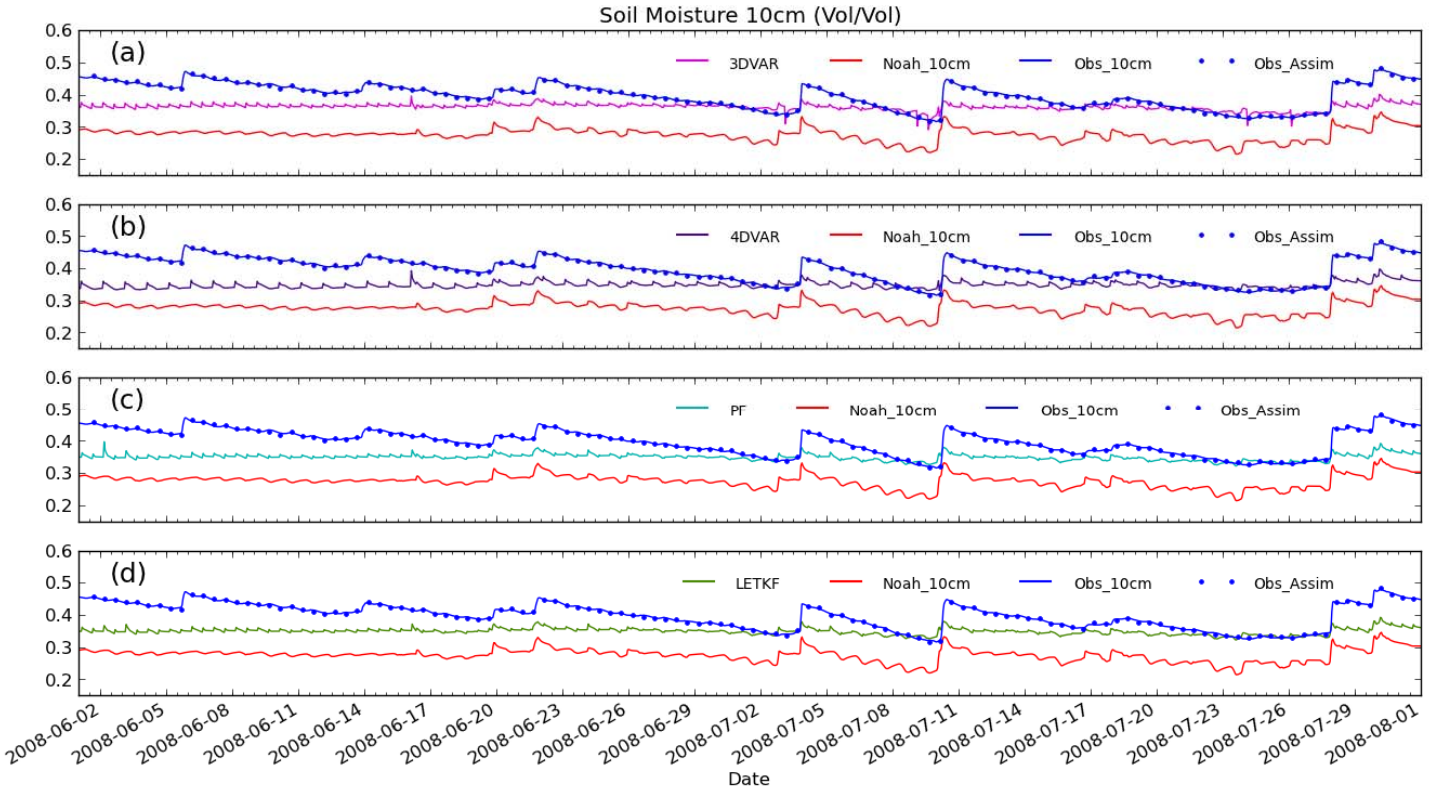




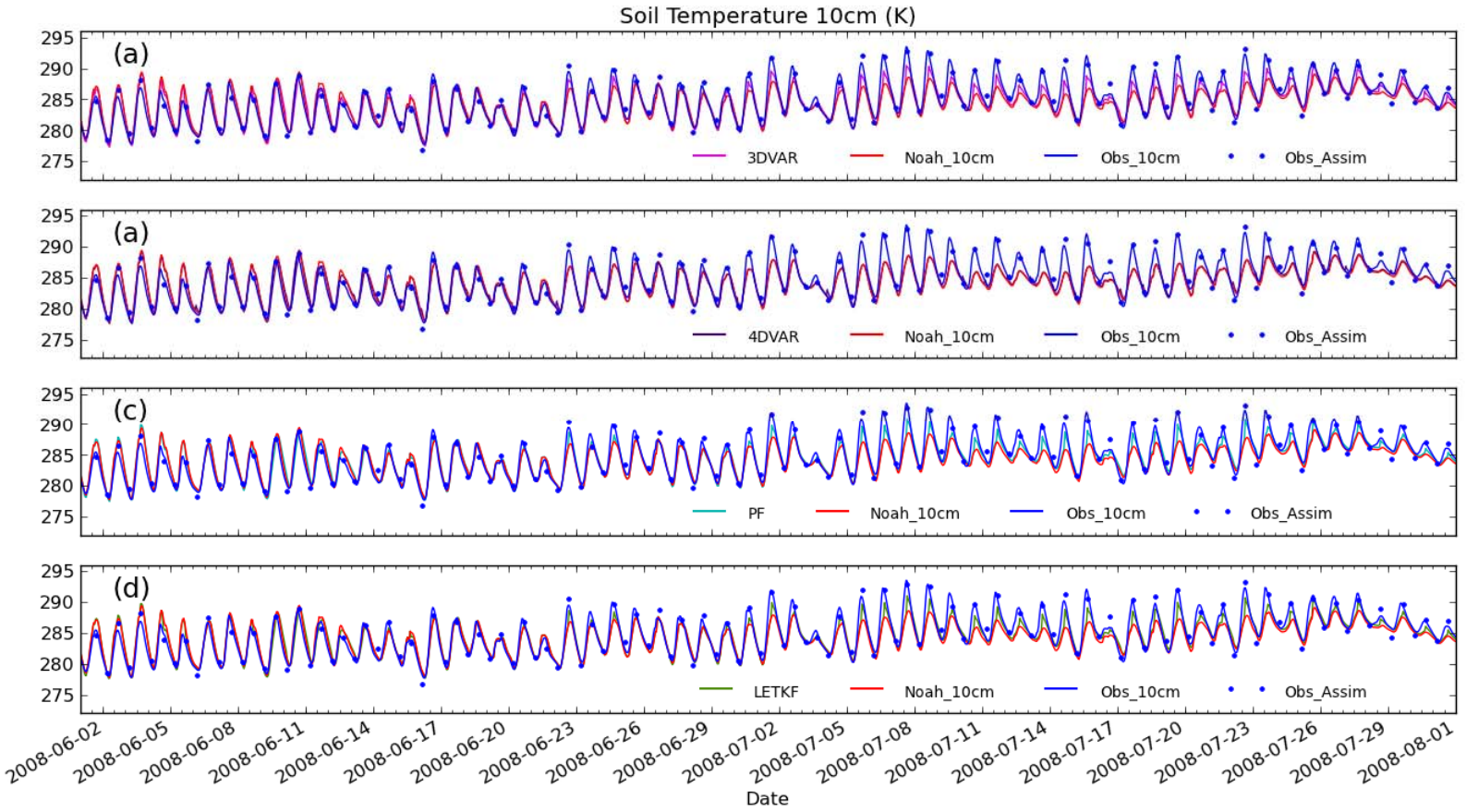
3.4 Comparison of assimilation algorithms

3DVAR (three-dimensional variational) 4DVAR (four-dimensional variational)

PF (Particle Filter) LETKF (Local Ensemble Transform Kalman Filter)

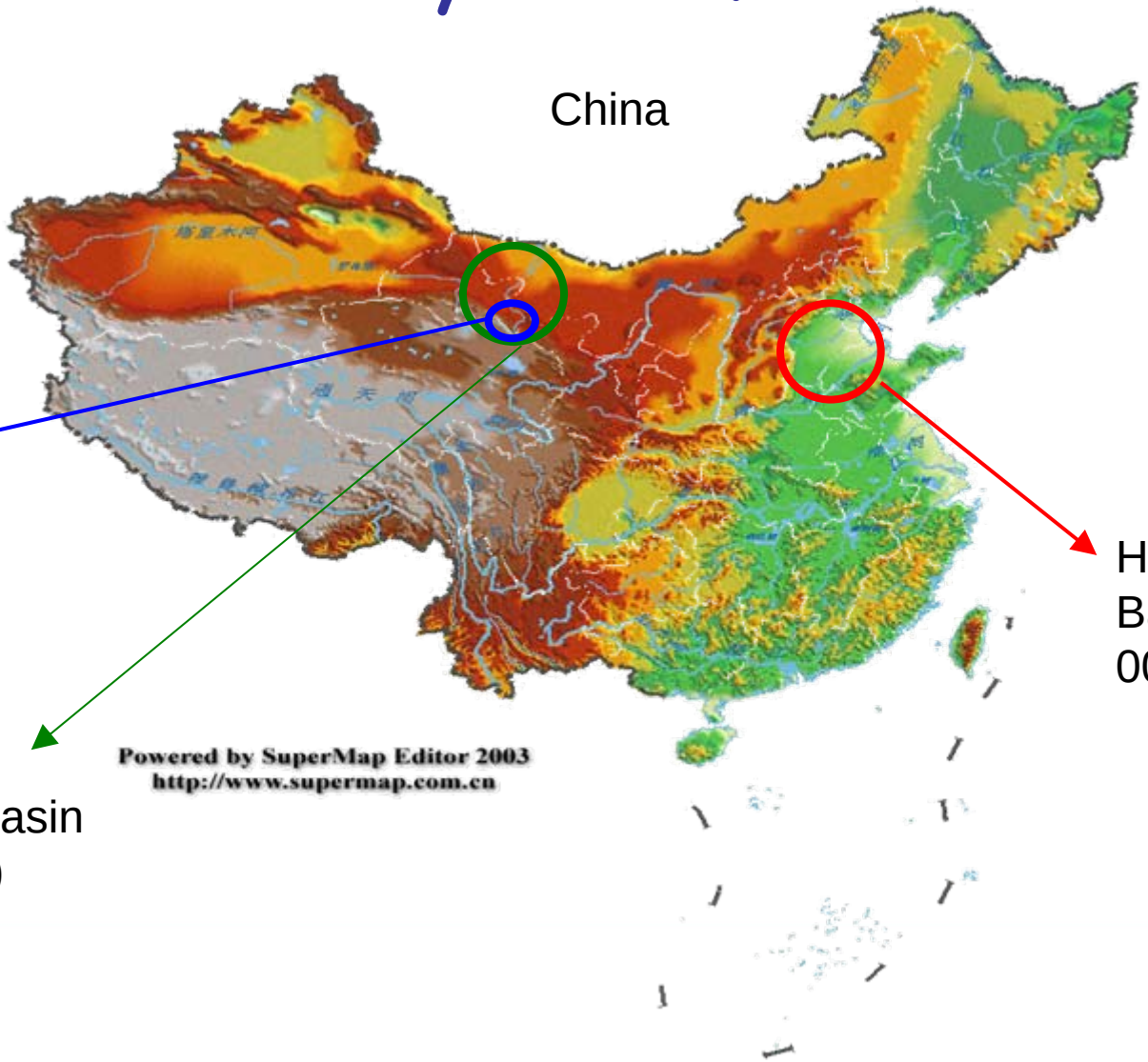


3.4 Comparison of assimilation algorithms



LETKF > PF > 3DVAR > 4DVAR

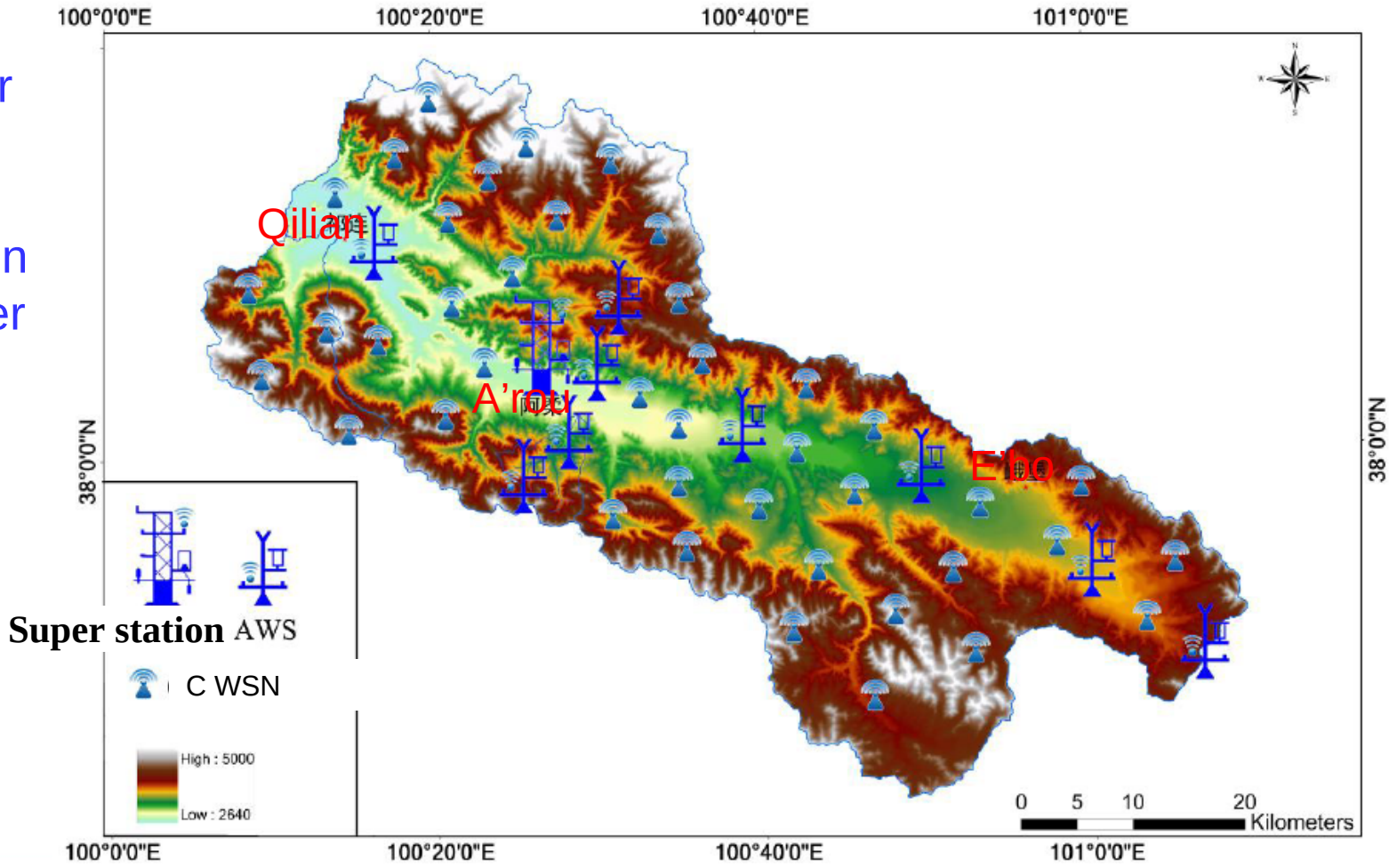
3.5 Study area of HDAS



3.6 Sensors and data sets

- **Remote Sensing**
  - **MODIS**: LAI, Land Surface Temperature, Snow Cover
  - **AMSR-E, SMOS**: Brightness Temperature or Soil Moisture
  - **ASAR, PALSAR**: Backscattering Coefficients
  - **GRACE**: Groundwater Variations
- **Ground Based**
  - **Wireless Network**: Moisture, Temperature
  - COsmic-ray (COSMOS): Moisture, Snow

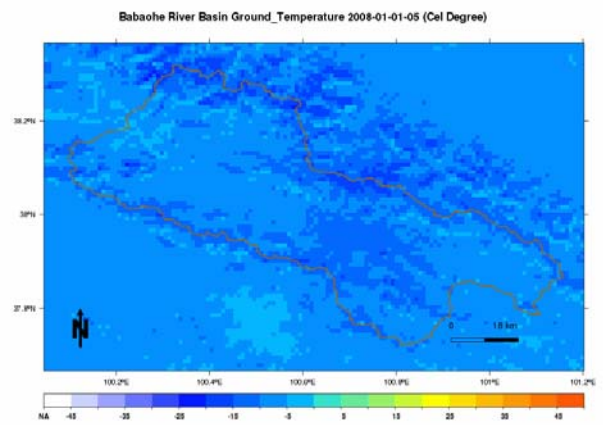
Observation system in the Babaohe River Basin, which belongs to the upper stream in the Heihe River Basin



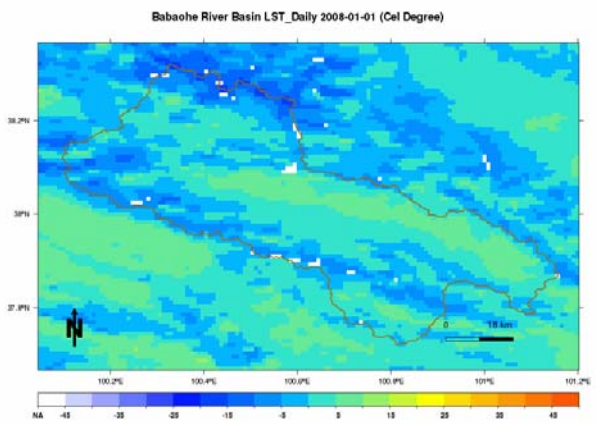
Constructed before October, 2011

3.7 MODIS LST and SCF Assimilation

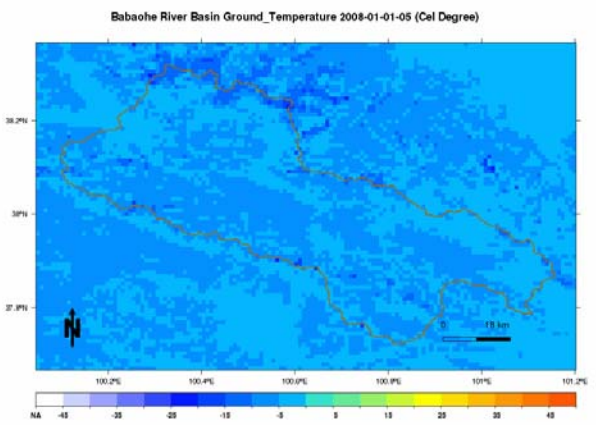
MODIS LST



CLM

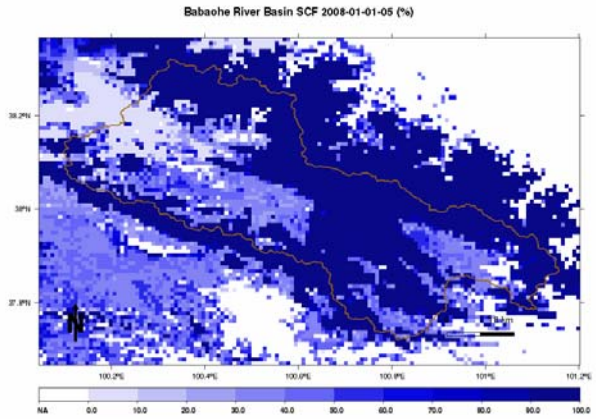


MODIS

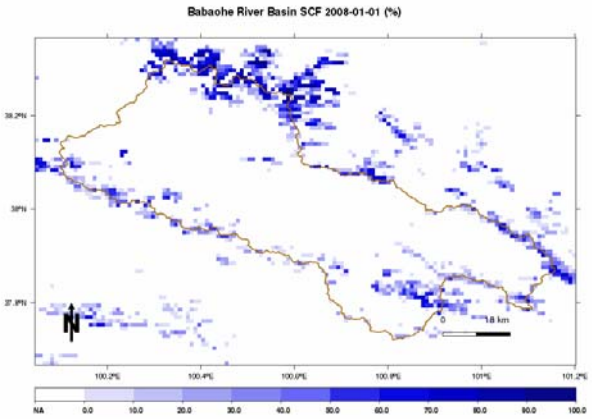


Assimilation

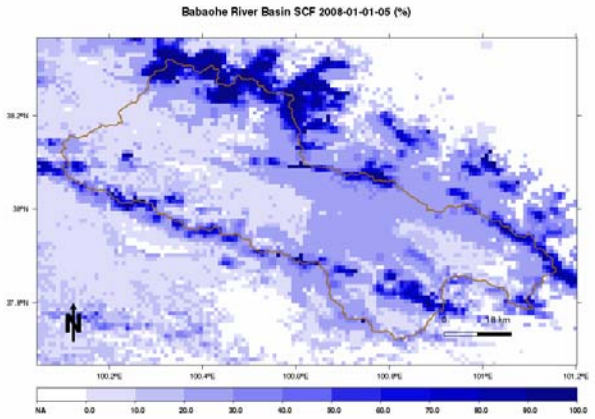
MODIS SCF



CLM



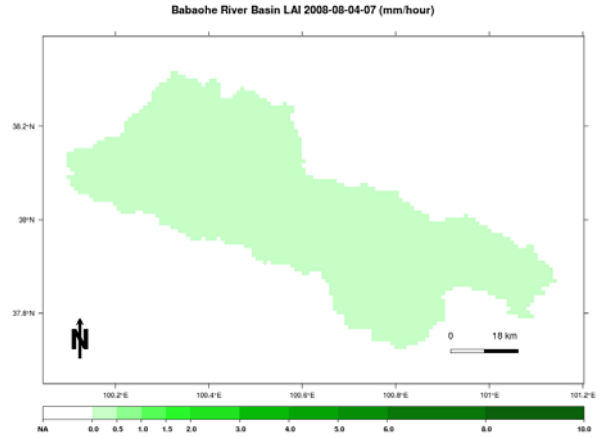
MODIS



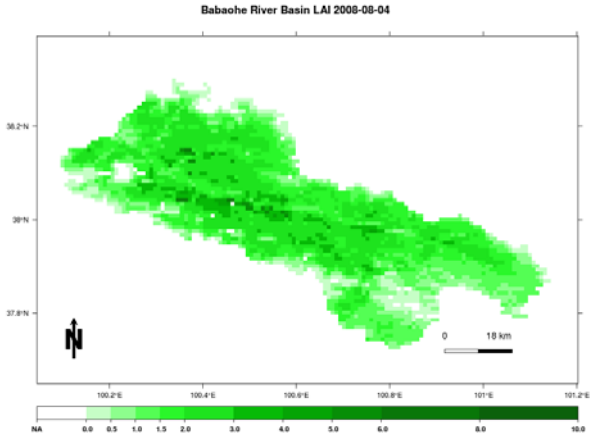
Assimilation

3.8 MODIS LAI Assimilation

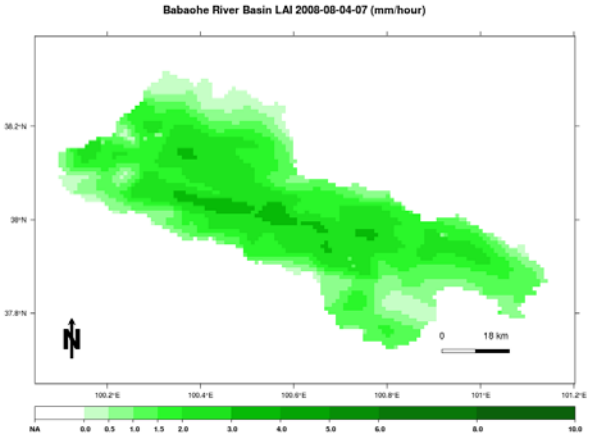
MODIS LAI 2008-08-04



CLM

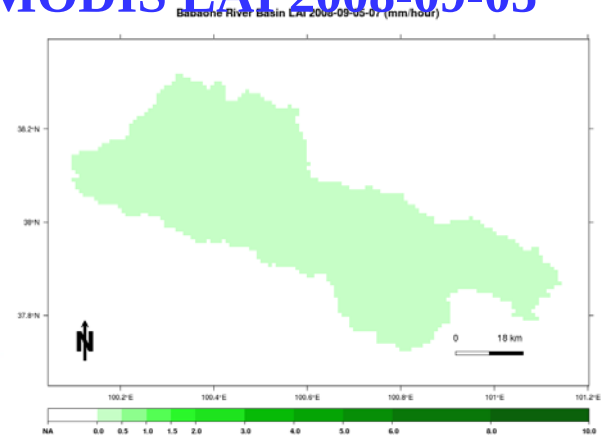


MODIS

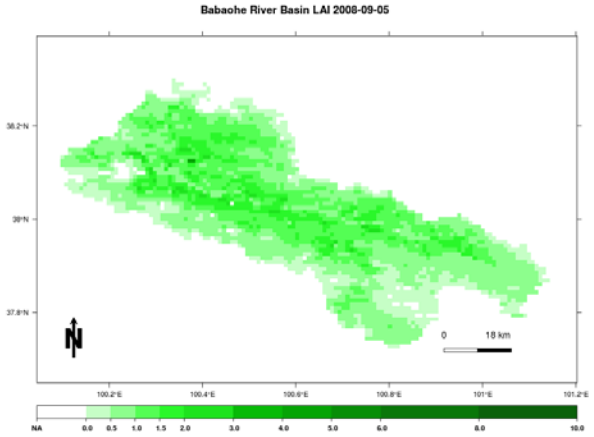


Assimilation

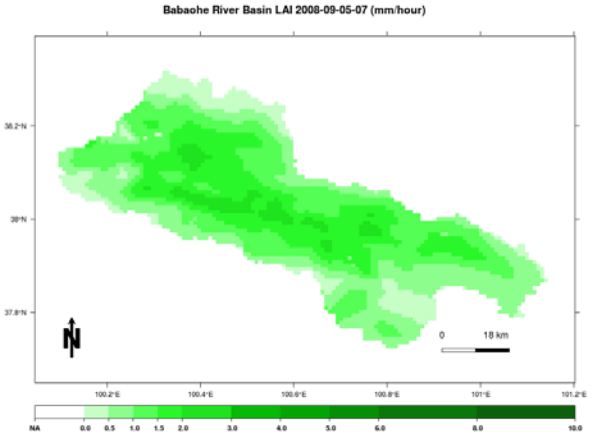
MODIS LAI 2008-09-05



CLM



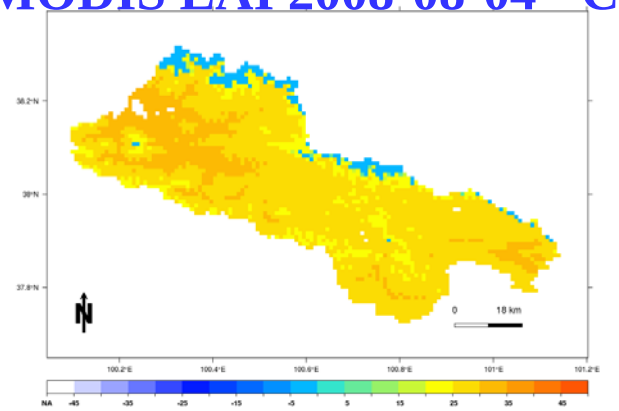
MODIS



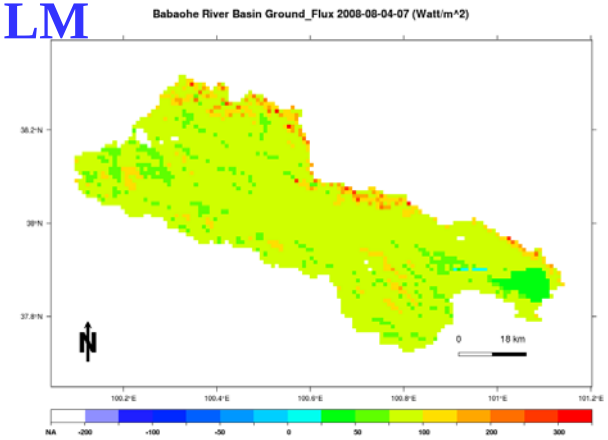
Assimilation

3.8 MODIS LAI Assimilation

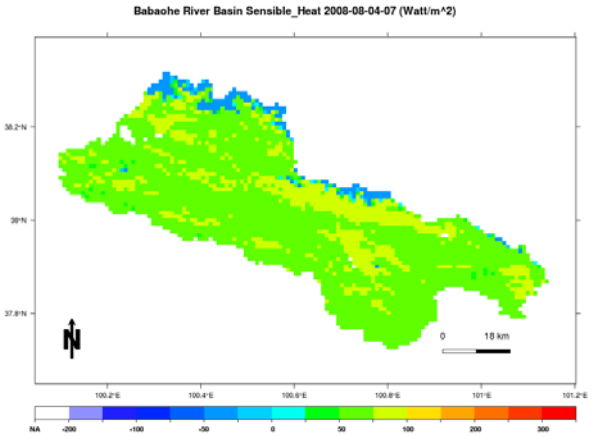
MODIS LAI 2008-08-04 - CLM



Ground Temperature

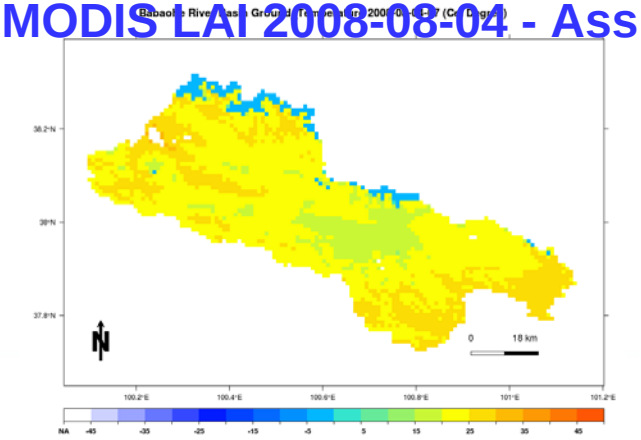


Ground Flux

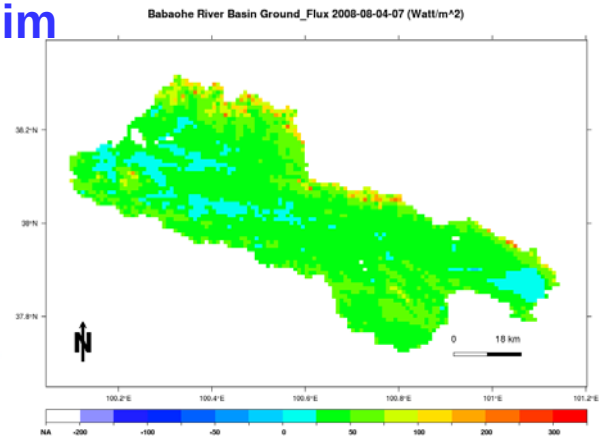


Sensible Flux

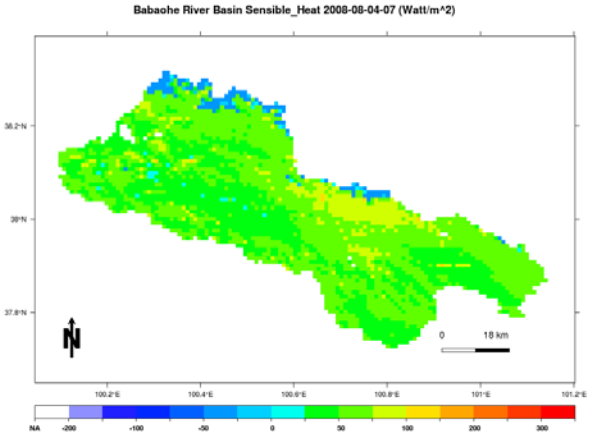
MODIS LAI 2008-08-04 - Assim



Ground Temperature

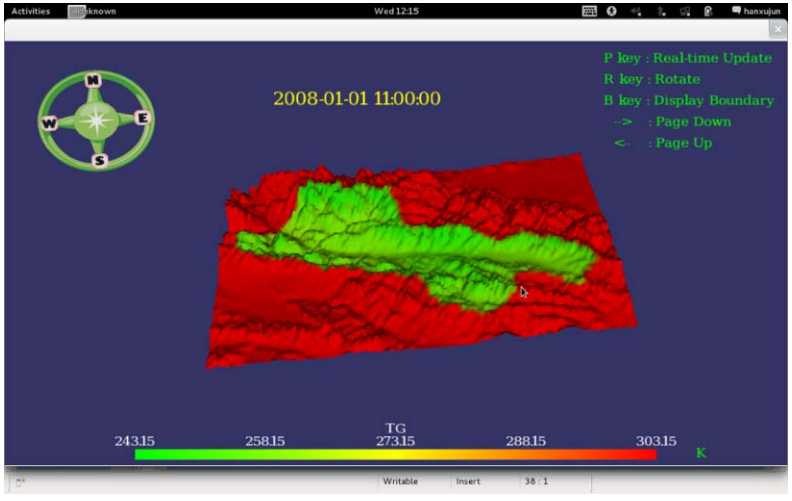


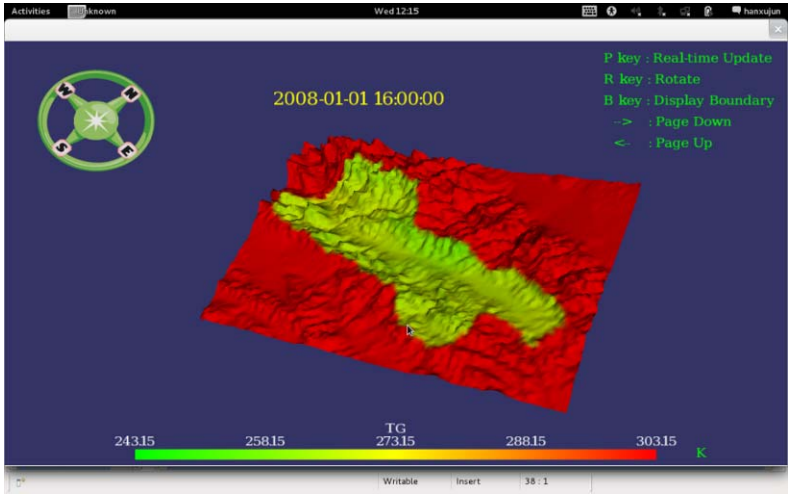
Ground Flux

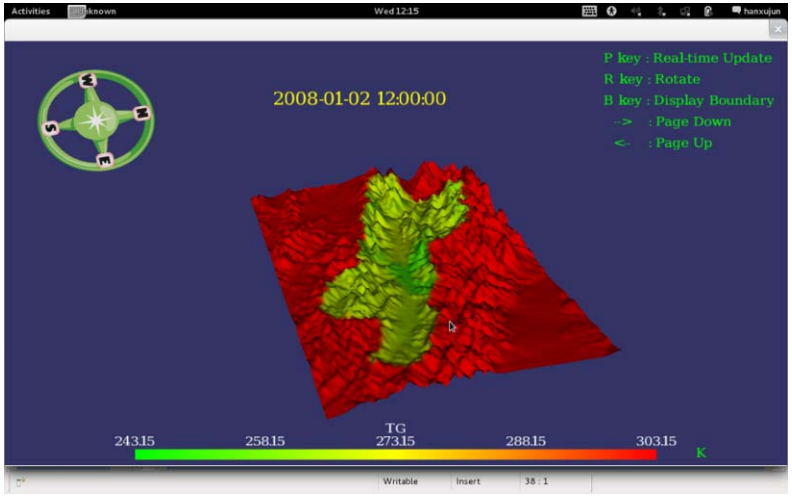


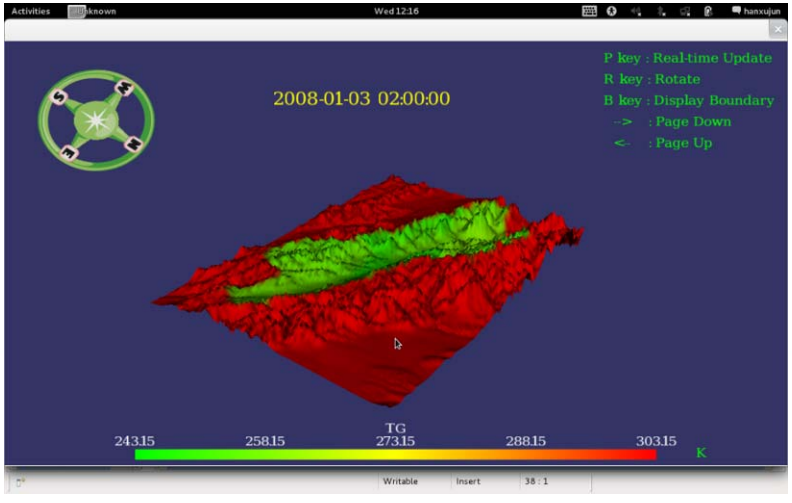
Sensible Flux

3.9 Visualization

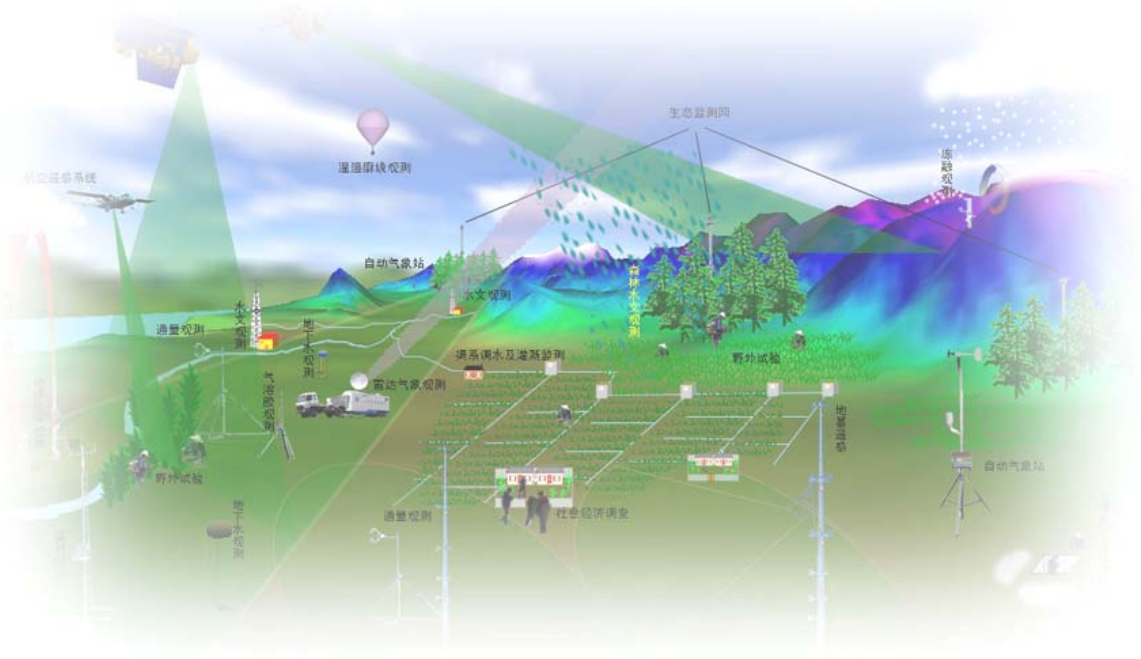








4. Prevue of Hi-WATER



Heihe Watershed Allied Telemetry Experimental Research

- **Comprehensive and multi-disciplinary**: satellite – airborne - ground based, ecology – hydrology - atmosphere
- **Multi-scale**: isotope - sub-meter - meters level…..catchment – sub-basin - basin
- **Collaboration:** other projects in the Heihe plan, international & domestic collaborations.
- **Hi:** Heihe, experimental area; hello, open platform; high, higher and stronger

4.2 Overall objective

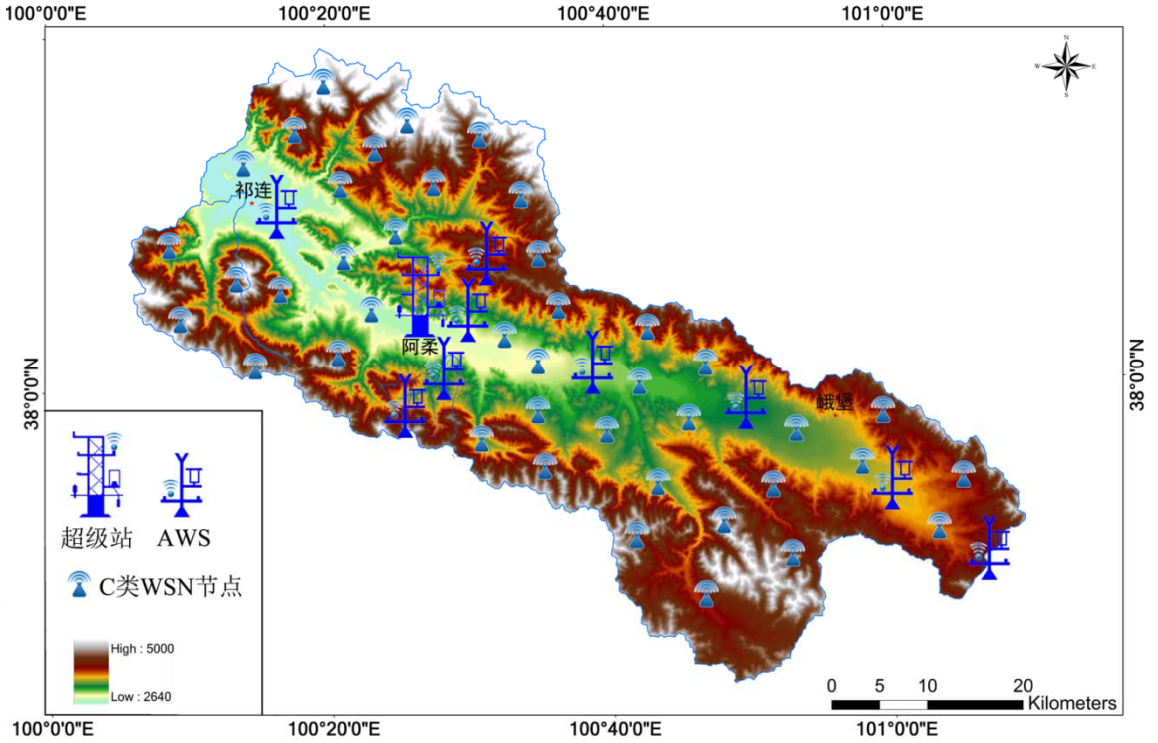
The overall objective of Hi-WATER is to improve the observability of hydrological and related ecological processes and build a leading river basin observing system to serve the watershed science (earth system science in a river basin scale).

Challenge 1:
Distributed ground observations to capture the heterogeneity

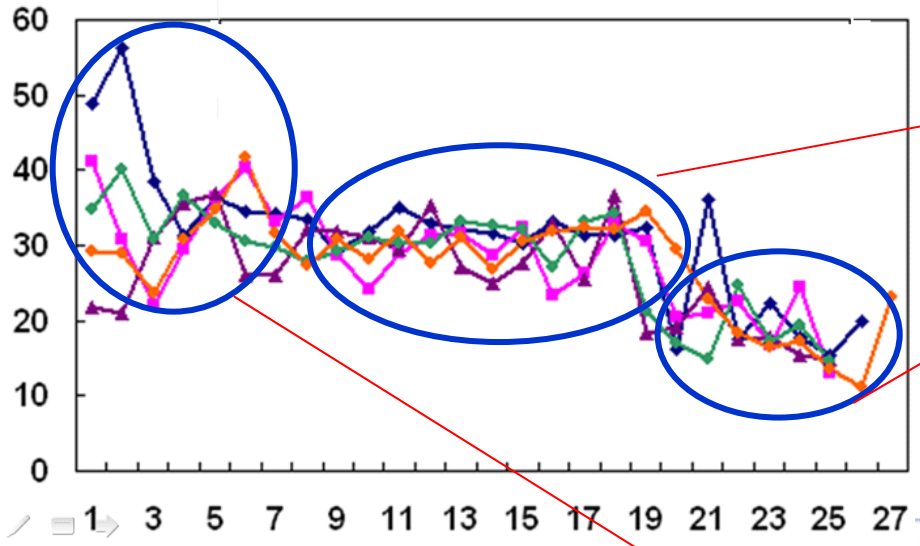
How to observe hydrological and ecological process in a river basin scale, instead of point scale?

4 hierarchic subsystems

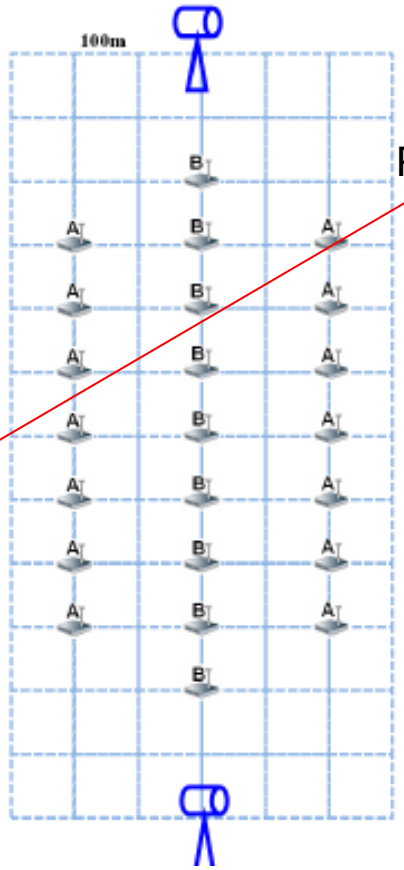
(1) The A'rou super station.
(2) A distributed AMS network.
(3) Three validation plots.
(4) A watershed soil moisture/temperature observing network.

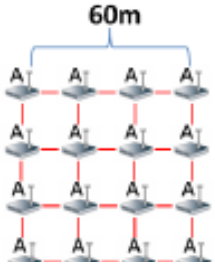


A'rou Validation plots for Remote Sensing



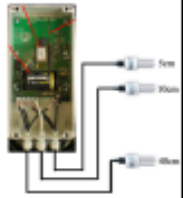
LAS



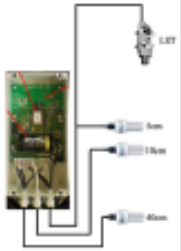


First valley terrace

A WSN



B WSN



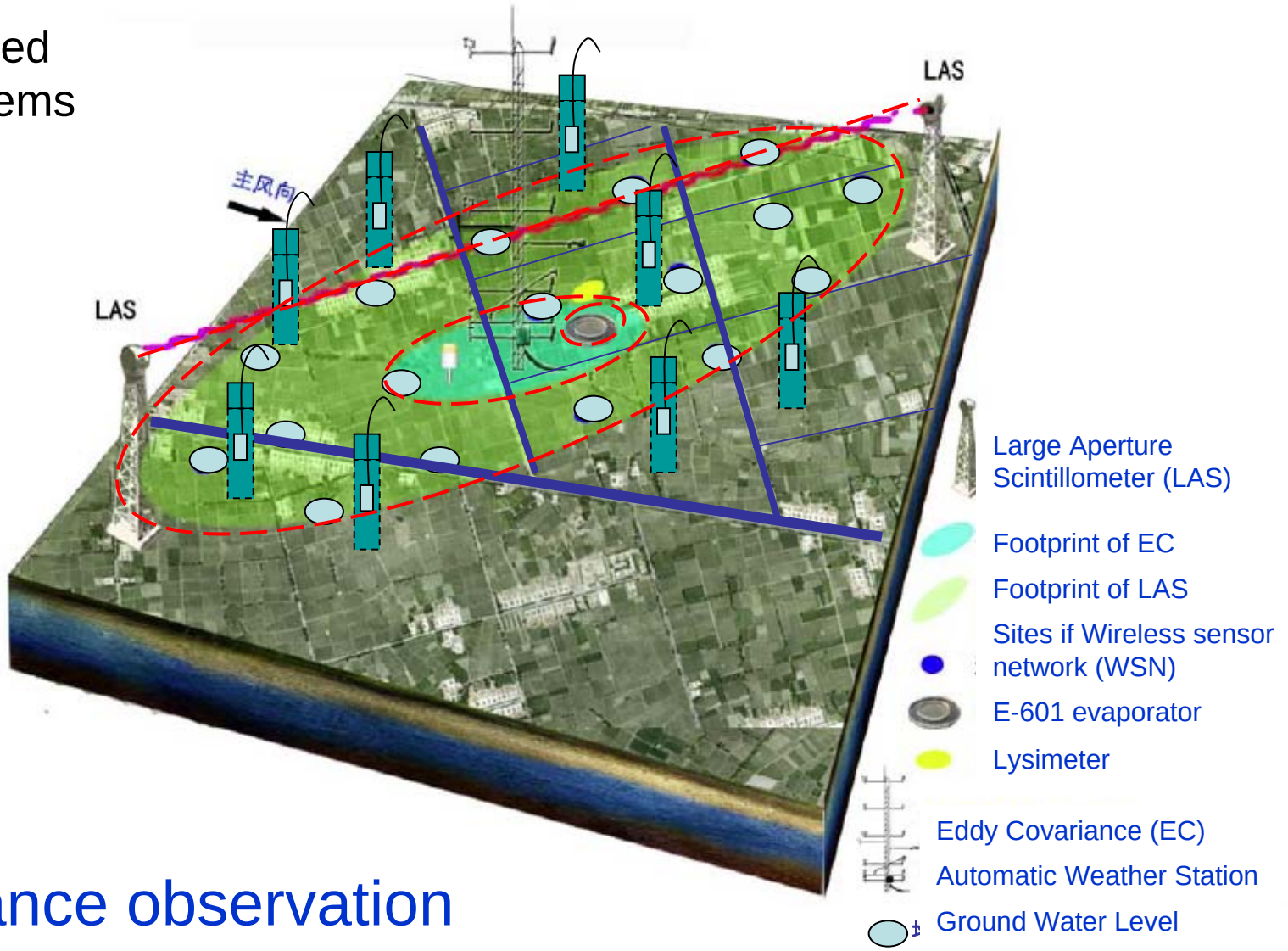
Second valley terrace

Third valley terrace

Challenge 2: Spatial representativeness of ground observations

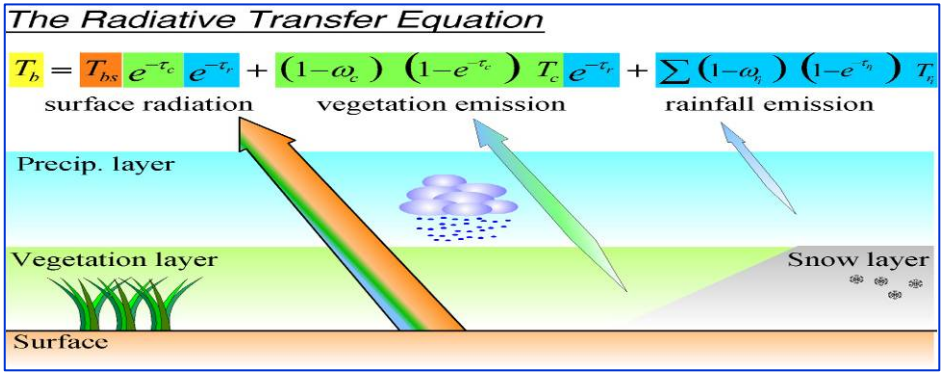
- Spatial representativeness of ground observations, i.e., their temporal and spatial variation characteristics (Probability Density Function, footprint) should be analyzed.
- Relationship between different scales (observation operator) should be obtained.
- Uncertainties related with spatial representativeness and scaling should be quantified.

Multi-scale nested observation sytems



Water Balance observation in irrigation region scale

Challenge 3: Development of radiative transfer models for heterogeneous pixel/land surface to improve the observability (mathematical viewpoint) of remote sensing



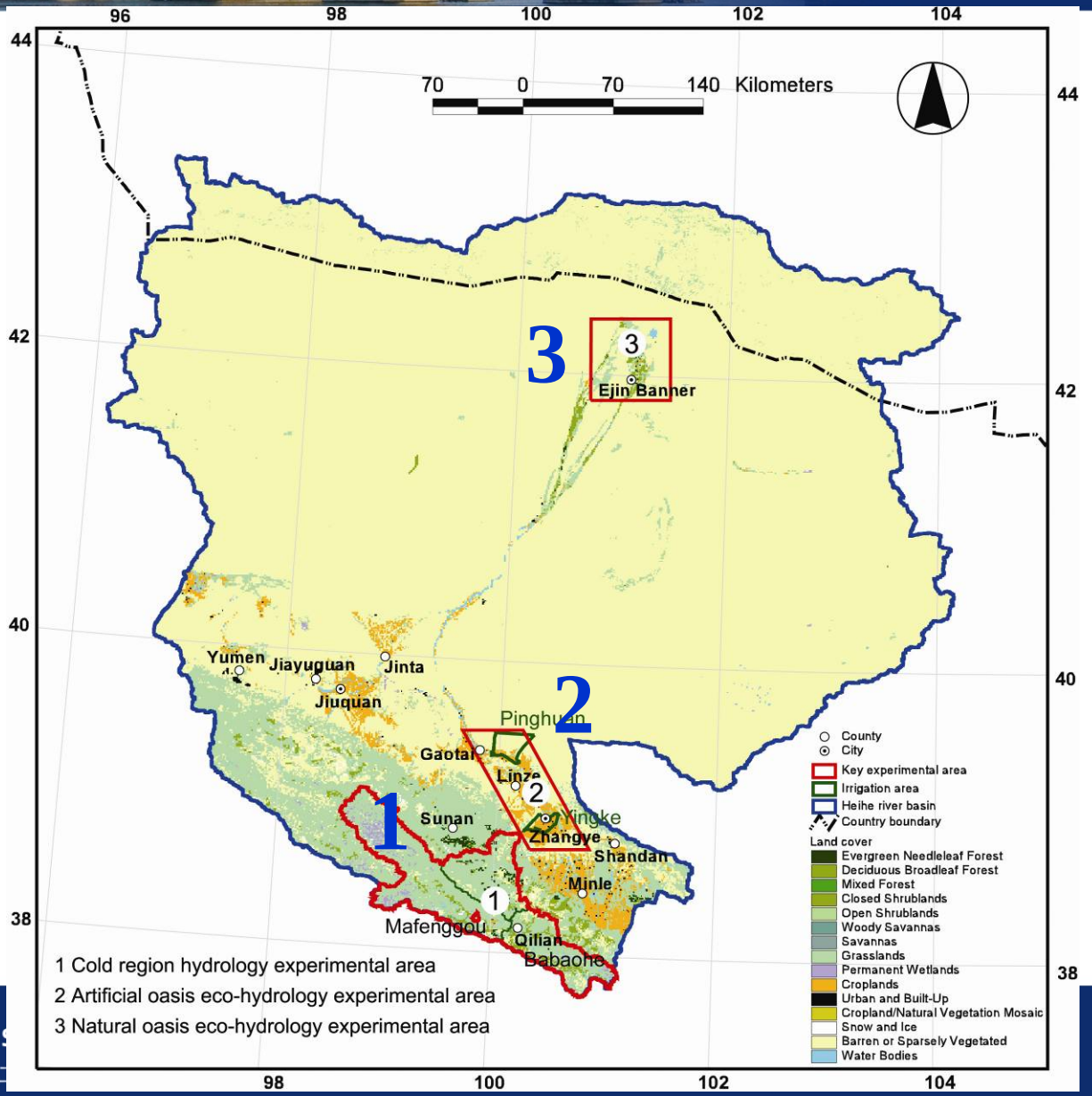
A quasi-homogeneous pixel

A heterogeneous pixel

- The relationship between remote sensing observations and surface ecological or hydrological variables is implied, so observations are indirect. In general, the forward model is a complex nonlinear model. This leads to very difficult or even illposed inversion.
- RTM for heterogeneous pixel needs to be developed.
- Inversion strategies for heterogeneous pixel.
- Related uncertainties with the above operators.
- How to design the ground sampling scheme which is more appropriate for remote sensing validation?

4.3 Experimental areas

Three key experimental areas (KEAs) are identified to conduct intensive and long-term observations. Within each KEA, nested experimental areas, i.e., the foci experimental area (FEA), the experiment site (ES) and the elementary sampling plot (ESP) will be established to carry out multi-scale observations based on different objectives.



To provide and validate the remote sensing products

Remote sensing product	Spatial resolution	Internal satellite/sensors	International satellite/sensors
LAI	30-1000 m	HJ-1，FY-3	MODIS, MISR, VEGETATION, POLDER, MERIS, MSG
Chlorophyll content	30-1000 m	HJ-1	MERIS
Precipitation	5-25 km	FY-3	TRMM, AMSR-E, GMS
Soil moisture	1-25 km	FY-3	SMOS, EnviSat, SMAP, AMSR-E
Snow Water Equipment	1-25 km	FY-3	CoReH2O, SLCP, AMSR-E
…	…	…	…

4.4 Experimental duration

- Intensive observation period (IOP): 2012-2014, a one year intensive observation will be conducted in each KEA.

Please pay attention on the detailed and latest information at our website.

http://water.westgis.ac.cn

5. Summary

- We introduce a few case studies of using airborne and satellite-borne remote sensing data (most from Dragon II project) obtained during WATER for retrieval of hydrological and ecological variables/parameters.
- Ground truth collected in WATER field campaignes are tested to be useful in validation of the models/algorithms for retrieval of hydrological and ecological parameters.
- Multi-source remote sensing data assimilation system is established and obtained preliminary results, further efforts need to be make in the next step.

5. Summary

- Catchment scale hydrological experiments should therefore be encouraged (e.g., Hi-WATER). In designing this kind of an experiment capturing multi-scale heterogeneity must be taken into account so that the knowledge obtained can eventually be scaled up to sub-basin and basin scales.
- Hi-Water has insistent demands on the Satellite data.

Thank you !

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