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# 2023 DRAG SYMPOSIUM 3<sup>rd</sup> YEAR RESULTS REPORTING 11-15 SEPTEMBER 2023

#### PROJECT ID. 57160

MONITORING WATER PRODUCTIVITY IN CROP PRODUCTION AREAS FROM FOOD SECURITY PERSPECTIVES



Dragon 5 3<sup>rd</sup> Year Results Project



**13 SEPTEMBER 2023** 

ID. 57160

#### **PROJECT TITLE: MONITORING WATER PRODUCTIVITY IN CROP PRODUCTION AREAS FROM FOOD SECURITY PERSPECTIVES**

#### PRINCIPAL INVESTIGATORS: ZHU LIANG, DONG QINGHAN CO-AUTHORS: WU BING FANG, MA ZONGHAN

**PRESENTED BY: ZHU LIANG** 



## Objectives



- Assess both the agricultural output and the water consumption for crop growth using satellite information and compute subsequently the water productivity
- The outcome of the research could be used as a scientific evidence for water use policy making





#### EO Data Delivery



Data access (list all missions and issues if any). NB. in the tables please insert cumulative figures (since July 2020) for no. of scenes of high bit rate data (e.g. S1 100 scenes). If data delivery is low bit rate by ftp, insert "ftp"

ESA Third Party Missions	No. Scenes	ESA, Explorers & Sentinels data	No. Scenes	Chinese EO data	No. Scenes
1.GeoEye-1/WorldView2	2	1.Sentinel 2	16	1.GF-1, GF-2	4
2.		2. MODIS		2. FY	
3.		3.		3.	
4.		4.		4.	
5.		5.		5.	
6.		6.		6.	
Total:	2	Total:	16	Total:	4



Schedule



#### • the project's schedule, planning & contribution of the partners

#### Monitoring water productivity in crop production areas from food security perspectives

#### Plan Duration 🖉 Actual Start 📕 % Complete 🎆 Actual (beyond plan) 📒 % Complete (beyond plan) Select a period to highlight at right. A legend describing the charting follows. **Period Highlight** PERIODS PLAN ACTUAL ACTUAL PERCENT ACTIVITY PLAN START DURATION START DURATION COMPLETE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 WP100 Field data collection Field data collection and pre-processing of remote sensing and meteorological 100% data - Season 1 + Season 2 24 24 9 2 2 100% TerraScope Training WP200 Crop type identification 9 16 16 100% Crop type mapping for the study regions - Season 1 + 2 9 26 2 26 Validation or comparison with the local official statistics - Season 1+2 2 100% MS1 100% Milestone 1 (MS1) – 1 ESA Dragon 5 Conference report 12 12 1 1 WP300 Crop Yield forecasting 100% 13 12 12 Crop yield modeling for the study regions - Season 1 + 2 13 100% Validation or comparison with the local official statistics - Season 1 + 2 25 2 25 2 MS1 Milestone 2 (MS2) – 1 conference report / 1 peer-reviewed Journal article 29 1 29 100% 1 WP400 Evapotranspiration and water productivity mapping (WPM) 100% Maps of actual ET per targeted crop - Season 1+2 27 3 27 3 Water productivity maps for each study region and for each crop - Season 1+2 30 3 30 3 100% 33 2 33 100% Validation or comparison with the local official statistics - Season 1+2 2 Milestone 3 (MS3) – 1 ESA Dragon 5 Conference report / 1 peer-reviewed MSR 100% 35 1 Iournal article 35 1 FR Final Report 36 1 36 1 100%







Characterizing earth surface with multi-source remote sensing data Quantifying fluxes between surface and atmospheric boundary layer Integration of energy balance, aerodynamics and water balance





**ETWatch Model** 



# ETWatch-operational remote sensing model





## **ETWatch Model**



# Sub-models

- Net-radiance model
- Surface soil heat flux model
- > Aerodynamic roughness length model
- > Atmospheric Boundary Layer model
- > Vapor pressure deficit model
- Canopy conductance model
- Sensible heat flux model
- > Latent heat flux model
- Bare soil evaporation model
- > Water surface evaporation model
- > Ice snow sublimation model
- Latent heat flux model
- > ET fusion model
- Coupling water and carbon processes Model
- > Field scale ET allocation model

#### Parametrized

- > Net-radiance model
- > Soil heat flux model
- Sensible heat flux model
- Latent heat flux model
- key parameters model
  - > Aerodynamic roughness length model
  - > Atmospheric Boundary Layer model
  - Vapor pressure deficit model
  - Canopy conductance model
- ET scale conversion model





ETWatch Model



# Input data

Parameter	Description	Data Source	Clear day	Cloud day	
LST	Land surface temperature	MODIS/FY3	0	×	
Albedo	Surface reflectivity of solar radiation	MODIS/FY3/Sentinel-2	0	• With Filter method	
LAI	Leaf Area Index MODIS/FY3/Sent		0	• With LAI-NDVI	
Meteo parameters	Relative Humidity, Wind Velovity, Sun Shine Hours, Air Presure, Air Temperature	Meteo	0	0	
PBL	Air temperature, Wind Velovity, Air Presurre and Humidity of Boudary Layers	ARIS	0	• With Filter method	
VPD_es	Instantaneous near-surface saturated vapour pressure	MODIS/FY3	0	⊖ With gap filing	
VPD_ea	Instantaneous near-surface actual vapour pressure	MODIS/FY3	0	• With gap filing	
Gc	Canopy Conductance	MODIS/FY3	0	○ With gap filing	
Rnl	Net longwave radiation	MODIS/FY3+meteo	0	○ With gap filing	





#### Complex underlying surface within pixel of remote sensing does not match the homogeneous underlying surface which is assumed with ET model

- Parameter values for specific underlying surface types are not suitable for mixed pixels  $\checkmark$
- Models with high uncertainty and poor regional applicability  $\checkmark$



Types	Maximum canopy height (m)	Minimum vegetation canopy resistance (m/s)	VPD sensitive parameter (1/hPa)
Forest land	20	100	0.025
Grassland	0.2	40	0.0155
Wetland	0.01	150	0.0155
Cultivated land	2	40	0.023
Bare land	0.05	50	-



Parametric values assumed by pure feature type are not suitable for mixed pixels







- Surface soil heat flux is the key to increasing the monthly energy closure rate, which seriously affects the accuracy of monthly and seasonal evapotranspiration (about 5-10%)
  - > Existing evapotranspiration models all assume that the daily surface soil heat flux is zero
  - > Daily surface soil heat flux models is proposed based on the daily diurnal surface temperature
  - Improved monthly energy balance closure rate, monthly evapotranspiration accuracy can be increased by 3-5%





•Zhu WW, Wu B F, et al. 2014. A method to estimate diurnal surface soil heat flux from MODIS data for a sparse vegetation and bare soil. Journal of Hydrology, 511, 139-150.





Canopy stomatal conductance model is proposed, and the empirical value of the maximum stomatal conductance is replaced by a mathematical model to reflect the spatial heterogeneity of vegetation types and the influence of the atmospheric environment.





Xu J M, Wu B F, et al. 2021. A Canopy Conductance model with temporal physiological and environmental factors. STOTEN. 791, 148283

Xu J M, Wu B F, et al. 2020. Quantifying the contribution of biophysical and environ. factors in uncertainty of canopy conductance. Journal of Hydrology, 592:125612





Aerodynamic roughness is a key variable that affects evapotranspiration. If the influence of topography, micro-topography and canopy structure is not considered, it is easy to cause large evapotranspiration errors on complex underlying surfaces such as non-growing seasons, mountainous areas, and urban areas.







BRDF Model:

$$\rho(\theta_s, \theta_v, \phi) = k_0 + k_1 F_1(\theta_s, \theta_v, \phi) + k_2 F_2(\theta_s, \theta_v, \phi)$$

The bi-directional reflectance characteristics fitting based on RossThick and LiSparseR kernel

BRDF\_ $R = k_2/k_0$ 

The factor R can reflect the heterogeneity of surface geometric structure





Daman in the middle reaches of Heihe River Basin



Conclusion: the BRDF information of near-infrared or shortwave band is suitable to estimate temporal aerodynamic roughness length over farmland with equivalent effect.

Wu Bingfang\*, Xing Qiang, Yan Nana, Zhu Weiwei, Zhuang Qifeng. A linear relationship between temporal multiband MODIS BRDF and aerodynamic roughness in HiWATER wind gradient data, IEEE Geoscience and Remote Sensing Letters, 2015, 12, 507–511.





- Two dimensional RMSH Definition
- Input data: DEM

$$\overline{z} = \frac{1}{LxLy} \int_{-Lx/2}^{Lx/2} \int_{-Ly/2}^{Ly/2} z(x, y) dxdy$$

$$\overline{z^2} = \frac{1}{LxLy} \int_{-Lx/2}^{Lx/2} \int_{-Ly/2}^{Ly/2} z^2(x, y) dxdy$$

$$RMSH = (\overline{z^2} - \overline{z}^2)^{1/2}$$

$$\overline{z} : \text{Average of the image}$$

$$\overline{z^2} : \text{Two moment}$$

$$RMSH: \text{ Root-mean-square height}$$





Wu Bingfang, Zhu Weiwei, Yan Nana, Xing Qiang, Xu Jiaming, Ma Zonghan, Wang Linjiang. Regional actual evapotranspiration estimation with land and meteorological variables derived from multi-source satellite data. Remote Sensing, 2020, 12, 332





# The geometric roughness keeps stable for one fixed land cover usually Input data: radar backscattering data



#### Inversed Geometric Roughness

Wu Bingfang, Zhu Weiwei, Yan Nana, Xing Qiang, Xu Jiaming, Ma Zonghan, Wang Linjiang. Regional actual evapotranspiration estimation with land and meteorological variables derived from multi-source satellite data. Remote Sensing, 2020, 12, 332





- Coupled with multi-dimensional data such as optics, infrared, microwave, topography, etc., an aerodynamic roughness model is proposed, which reveals the daily change process of aerodynamic roughness, and significantly reduces the evapotranspiration error in non-growing seasons, mountainous areas, and urban areas, ensuring daily and Ten-day evapotranspiration error <7%.</p>
  - > The overall components of the composited aerodynamic Roughness

 $A_{z0m} = (Z_{0m}^{v} + Z_{0m}^{nir}) \cdot (1 + (slope - a_1) > 0/a_2) + Z_{0m}^{r}$ 

> The vegetation component based on NDVI

 $Z_{0m}^{v} = b_1 + b_2 \cdot \left( (NDVI) > 0 / NDVI_{max} \right)^{b_3}$ 

> The geometric structure based on near-infrared R factor

$$Z_{om}^{nir} = e^{c_1 \cdot \frac{f_{geo}}{f_{iso}} + c_2}$$

> The hard surface roughness based on radar backscattering coefficient

 $\mathbf{Z}_{0m}^{r} = \mathbf{e}^{d_1 \cdot \text{sigma}_0 + d_2}$ 

Wu B F, et al. 2020. Regional actual evapotranspiration estimation with land and meteorological variables derived from multi-source satellite data. Remote Sens, 12(2), 332. Wu B F, et al. 2015. A Linear Relationship between temporal multiband MODIS BRDF and aerodynamic roughness. IEEE GRSL, 12(3), 507-511. Yu M Z, Wu B F, et al. 2016. A method for Estimating the Aerodynamic Roughness Length with NDVI and BRDF Signatures. Remote Sensing, 9(6), 2017



#### Validation of Aerodynamic roughness length



roughness

· e esa





- *Multicollinearity problem between key variables in ET models.* The same VI is redundantly used to calculate several key variables in ET models.
  - ✓ NDVI was used to calculates net radiation, soil heat flux, roughness in the SEBAL model
  - ✓ LAI is used to calculate net radiation, soil heat flux, roughness, KB-1 in the SEBS model
- There is high correlation between key variables, leading to unstable parameter estimates, large systematic bias and inter-annual variability.



Key variables such as NDVI, LAI from a single sensor are reused many times in the existing remote sensing ET models





- Clouds are a key factor affecting net radiation and it is difficult to accurately quantify surface solar radiation using MODIS /LandSat data
  - Sunshine hours and net daily radiation models are proposed based on the hourly cloud data products of geostationary meteorological satellites
  - It solves the problem of accurately describing the changes in the temporal and spatial distribution of daily shortwave radiation, daily net longwave radiation, and daily net daily radiation, and also solves the problem of calculating daily net radiation on cloudy and rainy days.



Wu B F, et al. 2017. An Improved Approach for Estimating Datity Net Radiation over the Hethe River Basin. Sensors, 17, 86. Wu B F, et al. 2016. A Method to Estimate Sunshine Duration Using Cloud Classification Data from a Geostationary Meteorological Satellite (FY-2D) over the Heihe River Basin. Sensors, 16, 1859





- The characteristic of the atmospheric boundary layer height is a key factor in the ET process. Other remote sensing ET models use a fixed boundary layer height value, which seriously affects the interannual stability of evapotranspiration.
  - Atmospheric boundary layer height models are proposed to accurately describe the spatial heterogeneity of boundary layer parameters based on atmospheric profile data
  - With this method, we can reduce the sensitivity of ETWatch to the thermal character of ground, then improve the accuracy of ET model



Xueliang Feng, Bingfang Wu, Nana Yan, Weiwei Zhu. Method to derived mixed boundary layer height from MODIS atmospheric profile data product at Heihe river basin. Atmosphere 2015, 6, 1346-1361; doi: 10.3390/atmos609134





Vapor pressure deficit models are proposed to accurately describe the spatial heterogeneity of Vapor pressure deficit based on atmospheric profile data and atmospheric precipitable data products



- Instantaneous near-surface vapor pressure:  $R = \frac{(RH_{700} + RH_{600} + RH_{500}) / 3}{RH_{850}}$   $A_{1} = 0.91 + 0.1 * \left(1 - \frac{(RH_{500} + RH_{400})/2}{(RH_{700} + RH_{600} + RH_{500})/3}\right)$   $A_{2} = 0.51 + 0.128 \ln(R)$   $a = TPW \cdot A_{1} \cdot 10000 / (H_{500 hPa} - H) / A_{2}$   $e_{a} = 0.125 \cdot a \cdot (1 + T_{a}/273 .15)$
- Instantaneous near-surface air temperatures and VPD calculation:

$$T_{s} - T_{a} = k_{0} + k_{1} \cdot NDVI + k_{2} \cdot W$$
$$VPD = e^{*}(T_{a}) - e_{a}$$



#### **Estimation and Validation of VPD**





Hongmei Zhong, Bingfang Wu, et al. An improved satellite-based apporach for estimating vapor pressure deficit from MODIS data. Journal of Geophysical Research: Atmospheres. 119, 12256-12271





































![](_page_29_Picture_0.jpeg)

![](_page_29_Picture_2.jpeg)

#### **APIs List**

![](_page_29_Figure_4.jpeg)

![](_page_30_Picture_0.jpeg)

![](_page_30_Picture_2.jpeg)

#### **Call APIs and MyCollection**

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![](_page_31_Picture_0.jpeg)

![](_page_31_Picture_2.jpeg)

#### Setting own project

![](_page_31_Picture_4.jpeg)

![](_page_32_Picture_0.jpeg)

![](_page_32_Picture_2.jpeg)

#### **API Add and Run**

![](_page_32_Figure_4.jpeg)

![](_page_33_Picture_0.jpeg)

![](_page_33_Picture_2.jpeg)

- ET resolution is from 5m to 1km in global scale or regional scale
- Multi-party independent validation: annual accuracy of 97%, daily accuracy of 90-93%
- Model
  - Quantifying fluxes between land surface, soil, vegetation, and the atmospheric boundary layer using multi-source satellite data
  - Solve the problem of large uncertainty and poor regional applicability of remote sensing ET model on the complex underlying surface
  - > Reduces the multicollinearity problem between multiple key variables in ET models
  - Solve the mismatch problem between the spatial and temporal resolution of remote sensing data and the timecontinuous process of evapotranspiration, and obtain multi-scale remote sensing ET data with high spatiotemporal resolution
  - > ET downscaling and field scale ET allocation at agricultural parcel and hydrological element for high resolution with support of multi-temporal optical satellite data

![](_page_34_Picture_0.jpeg)

![](_page_34_Picture_1.jpeg)

![](_page_34_Picture_2.jpeg)

- **ET** data in North China region and some European countries were produced using ETWatch model
  - Field data from 2 field stations (Guantao, Huailai) in Hebei provice in China was used for accuracy validation
  - RMSE is about 1 mm/day, the R<sup>2</sup> is about 0.8. The result of accuracy validation shows that the ETWatch model can well estimate ET. The data can be used for spatio-temporal characteristics analysis.

![](_page_34_Figure_6.jpeg)

![](_page_35_Picture_0.jpeg)

**Key Results** 

![](_page_35_Picture_2.jpeg)

#### Spatio-temporal characteristics analysis of ET in China and Europe

- > The North China region has a high vegetation cover, vegetation transpiration resulted in low ET in this area.
- > Significant difference was exisited in East and West of North China region
- > Average ET in Belgium is 12.75 mm, and the ET in south of Belgium is lower than north

![](_page_35_Figure_7.jpeg)

![](_page_36_Picture_0.jpeg)

**Key Results** 

![](_page_36_Picture_2.jpeg)

#### Spatio-temporal characteristics analysis of ET in China and Europe

![](_page_36_Figure_4.jpeg)

![](_page_37_Picture_0.jpeg)

#### Key Results

N

土壤蒸发 (mm)

1000

![](_page_37_Picture_2.jpeg)

![](_page_37_Figure_3.jpeg)

![](_page_37_Picture_4.jpeg)

NorthEast China

罗马尼亚

N

土壤蒸发 (mm)

![](_page_37_Figure_6.jpeg)

Spain

![](_page_37_Figure_8.jpeg)

![](_page_37_Figure_9.jpeg)

Romania

200

![](_page_38_Picture_0.jpeg)

![](_page_38_Picture_2.jpeg)

Name	Institution	Poster title	Contribution including period of research
Ilina Kamenova	Space Research and Technology Institute, Bulgarian Academy of Sciences	Evapotranspiration estimation using Sen-ET SNAP Plugin for study area in Bulgaria (ID:249)	ET in cropland in Bulgaria

![](_page_39_Picture_0.jpeg)

![](_page_39_Picture_1.jpeg)

# **Thanks for your attention**

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