A Development of Near-Real Time Drought Monitoring System in Ubon Ratchathani, Northeastern Thailand.
タイ北東部における干ばつの準リアルタイム モニタリングシステムの開発

By
Thammasat University
Asian Institute of Technology

Supported by
The Thailand Research Fund

Outline

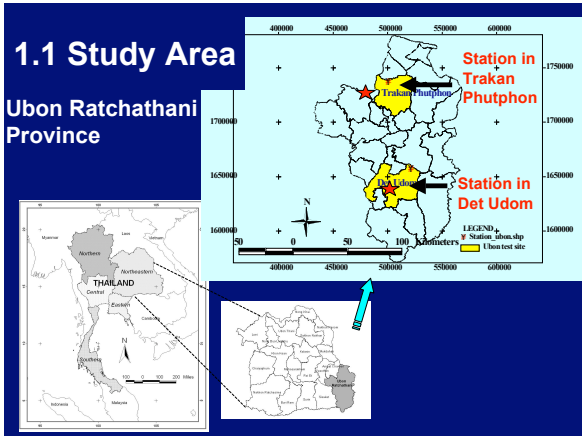
1. Introduction （導入）
2. System and Observation（システムと観測）
3. Analysis（解析）
4. Possible Application of this research results （この研究結果の応用可能性）
5. Summary （まとめ）
6. Future work （今後）

1. Introduction

- Drought（干ばつ） has hit many regions of Thailand and tends to occur and increases its severity（被害の程度) and duration(期間）.
- Most of the damages(被害） happened to rainfed rice （水稲）in Northeastern Thailand.
- Need : Real Time Monitoring and Early Warning System （警告システム）.
- Ubon Ratchathani was selected as the first target.

1.1 Study Area

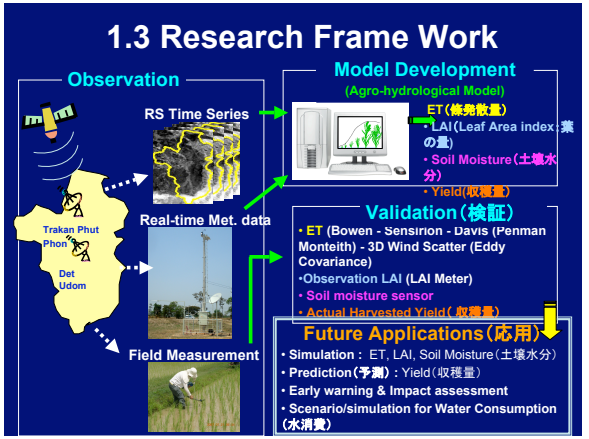
Ubon Ratchathani Province



1.2 Objectives（目的）

- To develop（開発） a method（方法） for drought（干ばつ） monitoring and impact assessment（影響評価） on rice crop in Ubon Ratchathani, based on agro-hydrological（農業-水収支） crop simulation （収量シミュレーション）.
  - To create near real time potential / actual(可能/実) evapotranspiration (ETp, ETa)（蒸発散量）, and water stress map （水ストレスマップ） using remote sensing.
  - To calibrate agro-hydrological crop model (SWAP) to simulate the impact of drought(干ばつ） on soil moisture （土壌水分） and on rice crop growth（成長）.
  - To validate(検証） simulation and impact assessment（影響評価） by field observation（地上観測）.

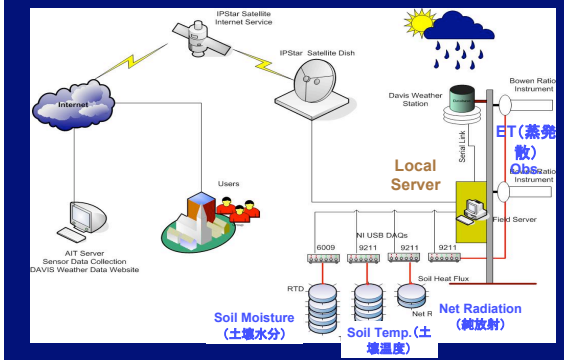
1.3 Research Frame Work



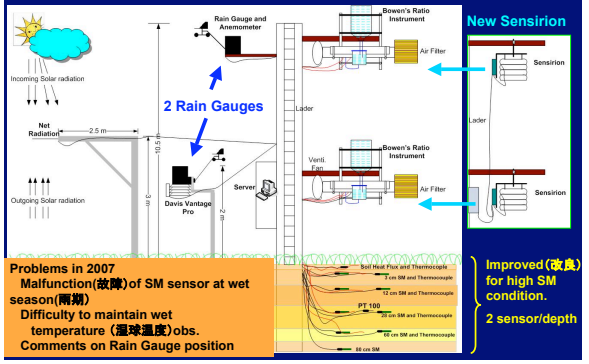
1.4 Expected Result(期待される結果)

- Methodology（方法論） to calibrate agro-hydrological model （農業ー水収支モデルの校正）using remote sensing
- Product （成果物）
  - Observation（観測） Data Set (Weather, Flux, SM, LAI..)
  - ETp, ETa, Water Stress （水ストレス）(Drought) Map in Ubon Ratchathani
- Technical（技術的な） knowledge（知識） on Real Time Monitoring and Early Warning（警告） System.
- Base for constructing（構築） Drought（干ばつ） Monitoring System

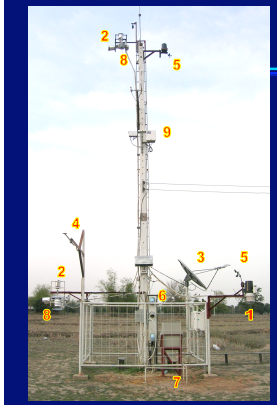
2. System and Observation



2.1 System Configuration



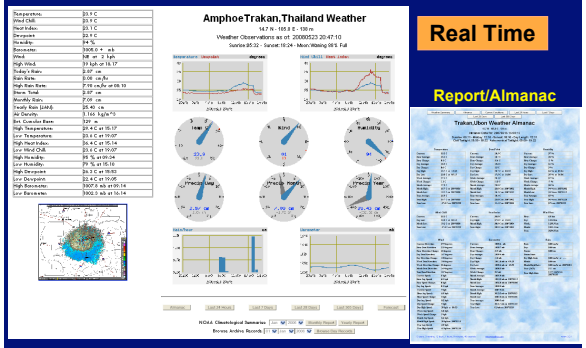
2.1 System Configuration (2)



1. Davis Weather Station
2. Bowen Ratio（蒸発率に関する量） Instrument (2m, 10m)
3. IP Star (Fix IP)
4. Net Radiometer(純放射) (2.5 m)
5. Wind speed (2 m, 10 m) and Wind direction (2 m) and + Rain gauge 2 m and 10m)
6. Control Box
7. Soil moisture sensors (2 sets for each station)
8. Sensirion sensors (2 m, 10 m)

2.2 Control Box

2.3 Web Base : Basic Weather Data



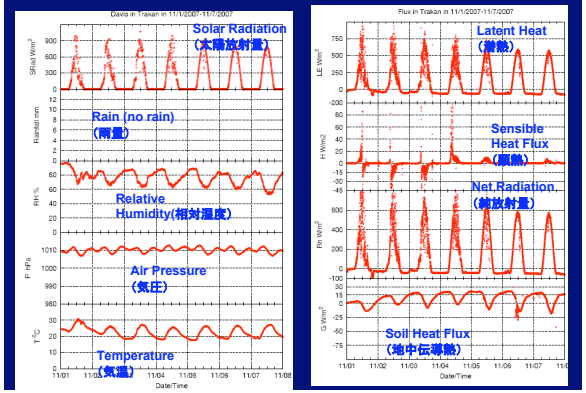
http://203.159.10.20/weather/trakan

2.4 Product - Data Visualization（可視化）

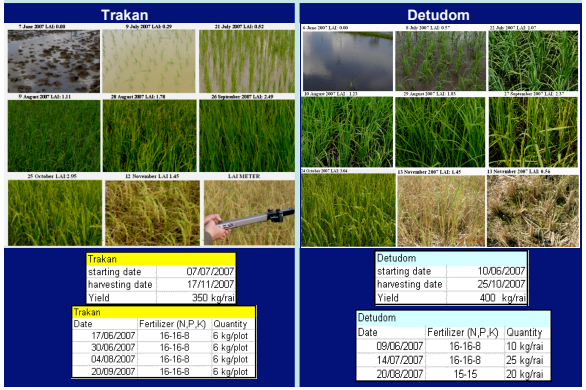
20(Observed観測) +6 (Derived計算結果)

Basic Weather Data (Davis)	Temperature	Observed	Soil Moisture	SM at 3cm	Observed
	Pressure	Observed		SM at 12cm	Observed
	RH	Observed		SM at 28cm	Observed
	Rainfall	Observed		SM at 60cm	Observed
	Wind Speed & Direction	Observed			
Flux	Soil Heat Flux	Observed	Temp. and Humidity	Dry Temp. at 2m	Observed
	Net Radiation	Observed		Dry Temp. at 10m	Observed
	Sensible Heat	Derived		RH at 2m	Derived
	Latent Heat	Derived		RH at 10 m	Derived
Soil Temperature	Soil temp. at 2 cm	Observed	Temp. Difference	Wet temp at 2m	Derived
	Soil temp at 3cm	Observed		Wet temp at 10m	Derived
	Soil temp at 12 cm	Observed		Dry-wet at 2m	Observed
	Soil temp at 28cm	Observed		Dry –Wet at 10m	Observed
	Soil temp at 60cm	Observed		Dry2m – Dry 10m	Observed

Downloadable PDF (as per TRF permission)



2.5 Rice Cultivation(耕作) Observation



Trakan	
starting date	07/07/2007
harvesting date	17/11/2007
Yield	350 kg/rai

Trakan		
Date	Fertilizer (N,P,K)	Quantity
17/06/2007	16-16-8	6 kg/plot
30/06/2007	16-16-8	6 kg/plot
04/08/2007	16-16-8	6 kg/plot
20/09/2007	16-16-8	6 kg/plot

Detudom	
starting date	10/06/2007
harvesting date	25/10/2007
Yield	400 kg/rai

Detudom		
Date	Fertilizer (N,P,K)	Quantity
09/06/2007	16-16-8	10 kg/rai
14/07/2007	16-16-8	25 kg/rai
20/08/2007	15-15	20 kg/rai

3. Analysis（解析）

3.1 General Analysis – Climate(気候), Rice observation
- 3.1.1 Climate Observation Overview
- 3.1.2 Field LAI (実測のLAI) vs Satellite LAI（衛星データからのLAI ）
  LAI:葉の量に関する指標

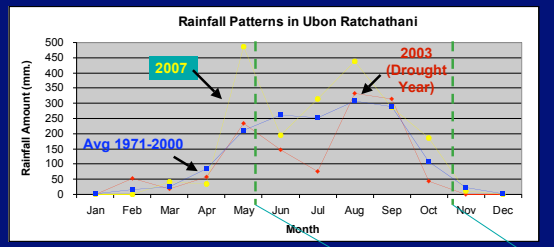
3.2 ET Observation and Analysis
- 3.2.1 Energy Balance
- 3.2.2 ETa from Bowen Ratio（蒸発しやすさに関する値より）
- 3.2.3 ETa from Sensirion and Bowen's Equipment Comparison
- 3.3.4 ET from Penman-Montieth Method（ペンマン法）

3.3 Satellite Remote Sensing

3.4 Data Assimilation（データ同化）

3.5 Validation of Observed ETa

3.1.1 Climate Observation Overview

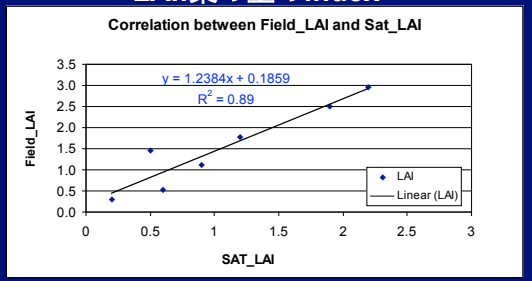


- Onset(発現) of rainfall always at beginning of May
- Peak of rainfall always appear at mid of August

Growing(成長) season (Seeding(種まき) - Harvesting(収穫))

3.1.2 Field LAI vs Satellite LAI

LAI:葉の量のindex



Correlation(相関) between Field LAI and Sat LAI = 0.89 (Strong correlation)

Satellite Data can be used to estimate ground LAI

3.2 ET（蒸発散）Observation and Analysis

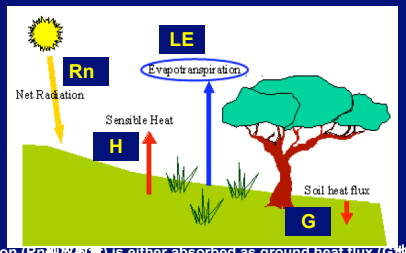
3.2.1 Energy Balance（エネルギー収支）

3.2.2 ETa (蒸発散) from Bowen Ratio (ボーエン比)

3.2.3 **ETa from** Sensirion and Bowen's Equipment Comparison

3.3.4 ET from Penman-Montieth Method（ペンマン法）

3.2.1 Energy Balance



Net radiation (Rn 純放射量) is either absorbed as ground heat flux (G 地中伝導熱) or transferred to the air above in the form of sensible heat flux (H 顕熱：対流等よる) and latent heat flux (LE 潜熱 ：水が蒸発する時奪われる熱量).

Rn-G = H+LE

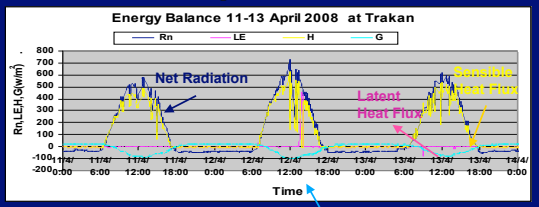
Bowen Ratio B = H / LE （ボーエン比：顕熱／潜熱）

B = gamma * deltaT / delta (Vapor Pressure（水蒸気圧）)

Partitioning of Rn-G into H and LE

Energy Balance from Bowen Ratio

Dry condition

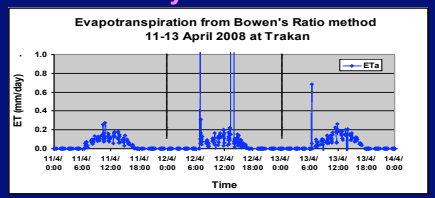


Soil Heat Flux

- At noon time, Maximum Soil Heat Flux (G) goes down.
- Bowen Ration is high, meaning almost of energy goes to H (sensible Heat 顕熱) and very less energy goes to LE(潜熱)
- In dry condition, ETa is far less than ETp

3.2.2 ETa from Bowen Ratio

Dry Condition



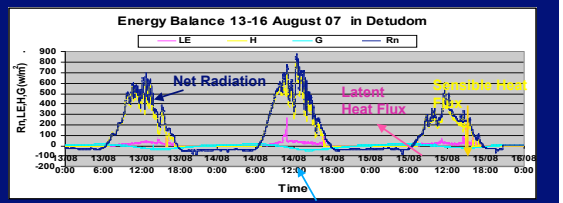
Date	SM 3CM	SM12CM	SM28CM	SM 60CM
12/05/2008	0.030	0.165	0.139	0.244
13/05/2008	0.023	0.159	0.136	0.238
Difference	0.007	0.006	0.003	0.006

✓ ETa from Bowen < 0.1mm/day, while SM shows 3mm/day

✓ Our ETa observation is too less→ need to improve/recheck

Energy Balance from Bowen Ratio

Wet condition

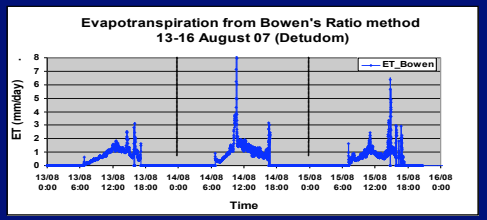


Soil Heat Flux

- Bowen Ration is higher than dry condition.
- More energy goes to LE(潜熱).
- Eta(蒸発散)estimated from this LE(潜熱) is lower than PM ETa

ETa from Bowen Ratio

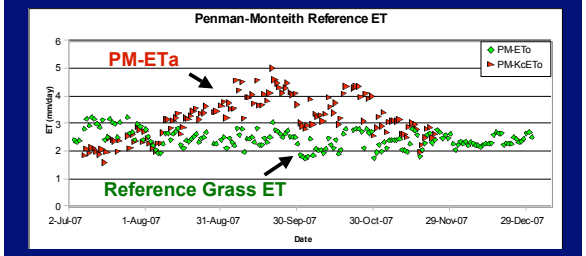
Wet condition



It showed higher ETa than dry condition

3.2.4 ET from Penman-Montieth Method（ペンマン法：熱収支法の近似解）

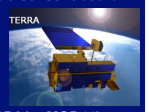
- PM-ETo : Penman-Monteith Reference ET– Wet Grass Condition
- PM-ETa : Penman-Monteith ETo x crop coefficient (Kc)



3.3 Satellite Remote Sensing Analysis

MODIS Overview

MODIS (Moderate Resolution Imaging Spectroradiometer) is a sensor aboard the TERRA and AQUA satellites.



Spectral Resolution（波長分解能） : 0.405 – 14.385 μm

Spectral Band （波長帯数） : 36 bands

Spatial Resolution （空間分解能） : 250m, 500m & 1 km

Temporal Resolution （観測頻度分解能）: every 1-2 days

Standard Data Products （標準成果物） : 44 products (MOD01 – MOD44)

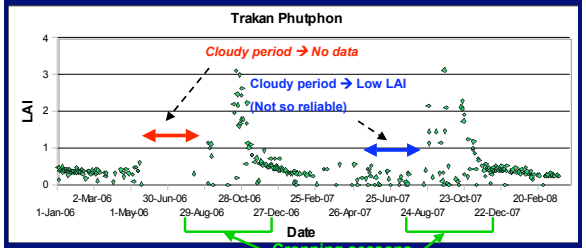
Data Archive : 2000 – present

Data used for estimating（推定） LAI and ET（蒸発散）:

1. MODIS Daily Surface Reflectance Product（地表面反射率） (MOD09GA) 500 m
   Band 1 to Band 7 & Solar Zenith Angle（太陽天頂角度）
2. MODIS Daily Land Surface Temperature （地表面温度） Product (MOD11A1) 1 km
   Land Surface Temperature & Emissivity （放射率）

Data Range : 2006 – present

3.3.1 LAI Estimation from MODIS

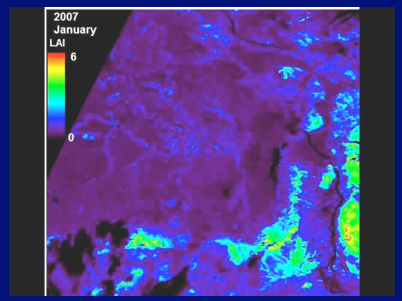


It is observed that Satellite LAI of rice goes up to 3.

Limitation : No data or less reliable(信頼できる) LAI in rainy/cloudy period.

Combination with Model Calibration -> Reliable Result

LAI map from MODIS



Satellite LAI in Animation : for the year 2007 (lai.wmv).

3.3.2 ETa Estimation from MODIS

Surface Energy Balance Algorithm for Land (SEBAL) is used to estimate ETa from Satellite images.

Surface Energy Balance $Rn = G + H + LE$

Iterative process（繰り返し処理）

- Thermal Band（熱赤外）
- Aerodynamic(空気力学)
- Hot & Cold pixels

- Sensible Heat Flux（顕熱）
- Evaporative Fraction（蒸散率）
- Actual ET（実際の蒸発散量）

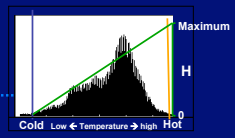
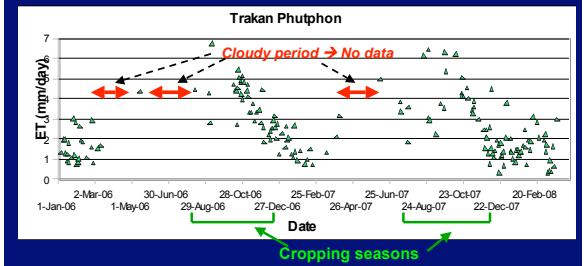


Figure. Thermal histogram & Assumption of Sensible Heat（顕熱）at Hot and Cold pixels.

Rn = Net Radiation（純放射）
G = Soil Heat Flux（土壌熱フラックス）
H = Sensible Heat Flux（顕熱）
LE = Latent Heat Flux （潜熱）

3.3.2 ETa Estimation from MODIS (2)

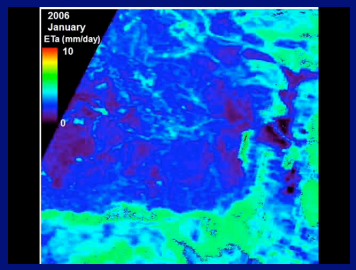
SEBAL calculate ETa assuming the climate condition is clear for the whole day.



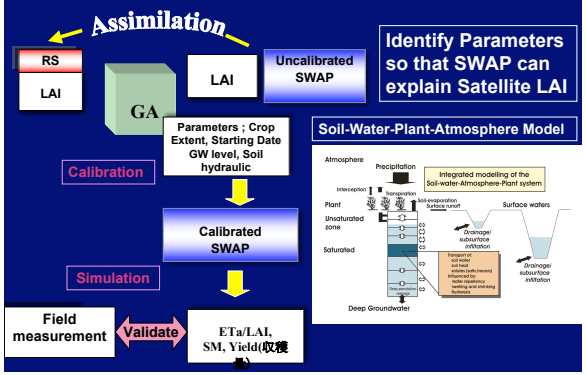
From Satellite, ETa of rice rises up to 6 mm/day in cropping season.
Combination with Model Calibration for reliable estimation

Eta（蒸発散）Map from MODIS

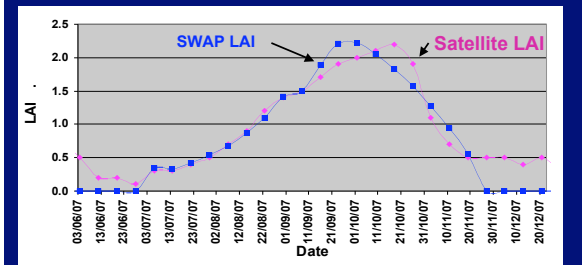
ETa map animation from January 2006 to March 2008 (ETa_3frame.wmv).



3.4 Data Assimilation/Simulation

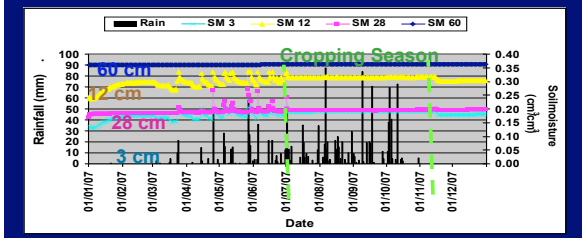


3.4.1 Assimilation Result



➢ **Simulated LAI shows a good match pattern with Satellite LAI**

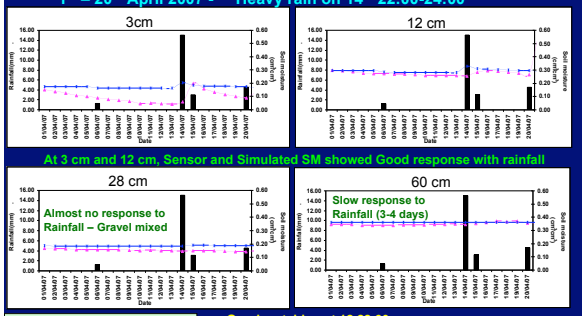
3.4.2 SWAP – Soil Moisture Simulation



- Soil was saturated during cropping season.
- Saturated soil moisture is not more than 0.6 (based on the sensor manual)

3.4.3 SM simulation and comparison

1st – 20th April 2007 - Heavy rain on 14th 22:00-24:00



At 3 cm and 12 cm, Sensor and Simulated SM showed Good response with rainfall

Good matching at 12,28,60cm
SWAP may supply excess water from water table
More detail tuning of assimilation process
SWAP is concerned the total amount of daily rainfall(量)

4. Possible Applications（応用可能性）

4.1 Decision Support System（意思決定システム） for Drought（干ばつ）

4.2 Decision Support System for Rice Disease（病気）

4.3 Real Time Sensor Network

4.1 Decision Support System for Drought

- **Simulation :** ET, LAI, Soil Moisture
- **Prediction（予測）:** Yield(収穫量)

➢ **Monitor Water Stress** in near real time – wide area
➢ **Impact assessment(影響評価) to yield(収穫)**

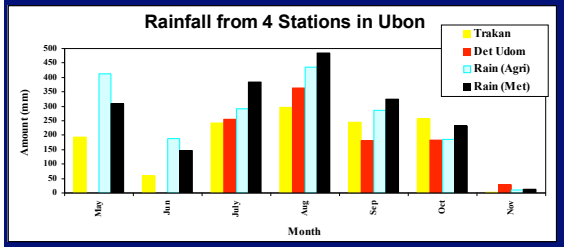
❑ A good basis for undertaking（試み）drought disaster preparedness(干ばつ災害への対策） and mitigation(緩和） activities at provincial level.

➢ **For drought concerned agencies : Agriculture Regional office, Local Administrators: CEO, Disaster Prevention and Mitigation Regional office (Land Development Regional offices, and Irrigation Regional office)**

4.2 Decision Support System for Rice Disease

- **The outbreak（大発生）of some rice diseases（病気） depend very much on weather (temperature, rainfall, moisture/humidity, soil moisture and also the stage of growth（成長）.**
- **In Ubon Ratchathani, Rice Blast Ddisease is a leading constraint to rice production. It is mostly found in high moisture area at flowering stage(開花時期)**
- **Real-time Met. data from our Agro-Met station could give a good basis for disease prediction（予測） and Early Warning to reduce the losses (production, yield, income).**

4.3 Real Time Sensor-Network



- High Variability（変動性）of Rainfall（雨）
- Need of High Density Observation Network for DSS
- Need of Low-Cost and Easy to Use Sensor Network System

5. Summary

- Our observation（観測） system → Improved（改良された）
- New Sensirion sensor has stable observation and shows satisfied（条件を満たした） data→ support old Bowen's Ratio equipment
- Good assimilation（同化） result of SWAP LAI → Achieved（得られた）
- Good simulated Soil Moisture from SWAP → Achieved
- Preliminary Validation（検証） using many Eta（蒸発散量）, LAI and Soil Moisture → have to do more validation and continue developing.
- The different patterns of Met. data from various(多くの) stations in Ubon → higher density simple Met. stations

6. Future Work

- Continue observation and maintenance – improve and closely observe SM observation at 3 cm, 60 cm
- Model developing is going on for better assimilation/simulation of ETa, Soil Moisture, LAI and Yield（収穫量）
- More Validation – ET and New system (sensirion) and results from model
- Yield estimation (depends on fluctuation of weather)
- Complete all dataset
- Publishing Report / Papers / Distribution under TRF's agreement

Research Team

- **Dr. Daroonwan Kamthonkiat** – Thammasat University (Principle Investigator)
- **Associate Prof. Dr. Kiyoshi Honda** - Asian Institute of Technology (Main researcher)
- **Col. Dr. Surat Lertlum** - Chulachomklao Royal Military Academy (Project consultant)
- **Dr. Mizoguchi Masaru** - University of Tokyo (External collaborator)
- **Dr. Yann Chemin** - International Rice Research Institute, Philippines (Post Doctoral, IRRI)
- **Dr. Putchong Uthayopas** - Kasetsart University (External collaborator)
- **Prof. Takaharu Kameoka** - Mie University (External collaborator)

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- Farmers/Workers – taking care the stations

Thank you