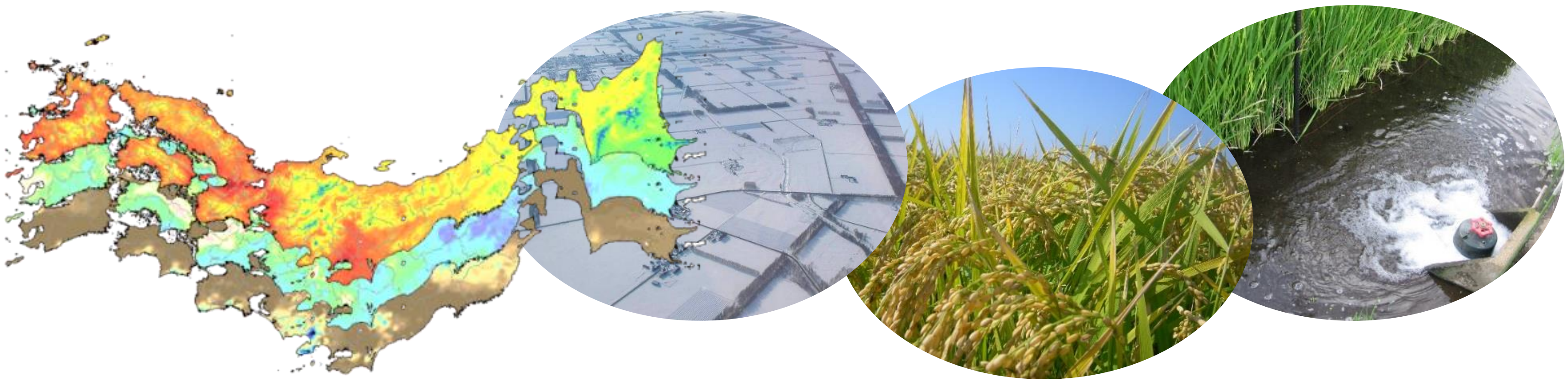


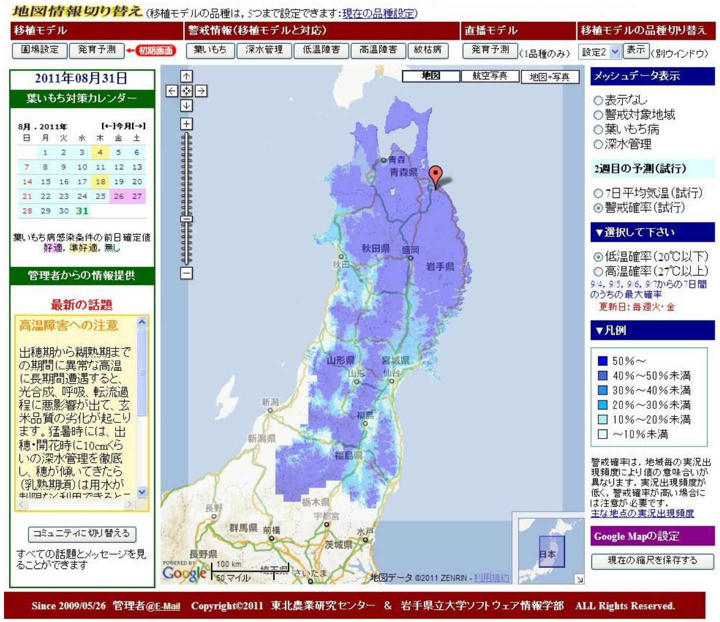
Recent Advances in Agro-Meteorological Services for Climate Change Adaptation

Atsushi MARUYAMA

Division of Climate Change Adaptation

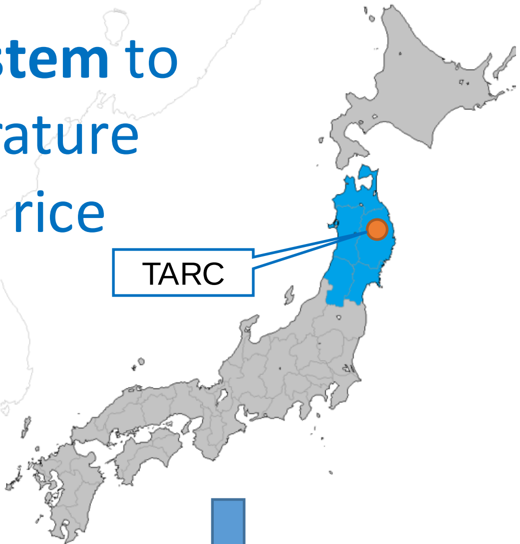
Institute for Agro-Environmental), NARO

History of AgroMet services in NARO, JAPAN

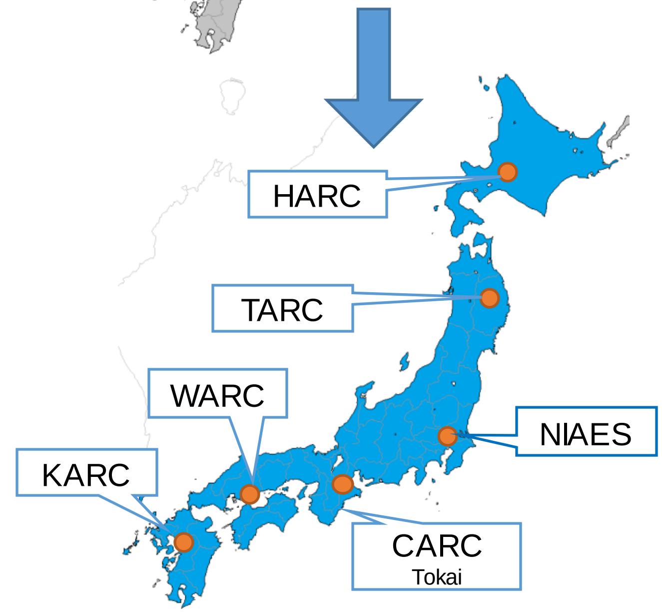


1993: cold summer

Early warning system to avoid low temperature damage of paddy rice in Tohoku region



Started in **1996**



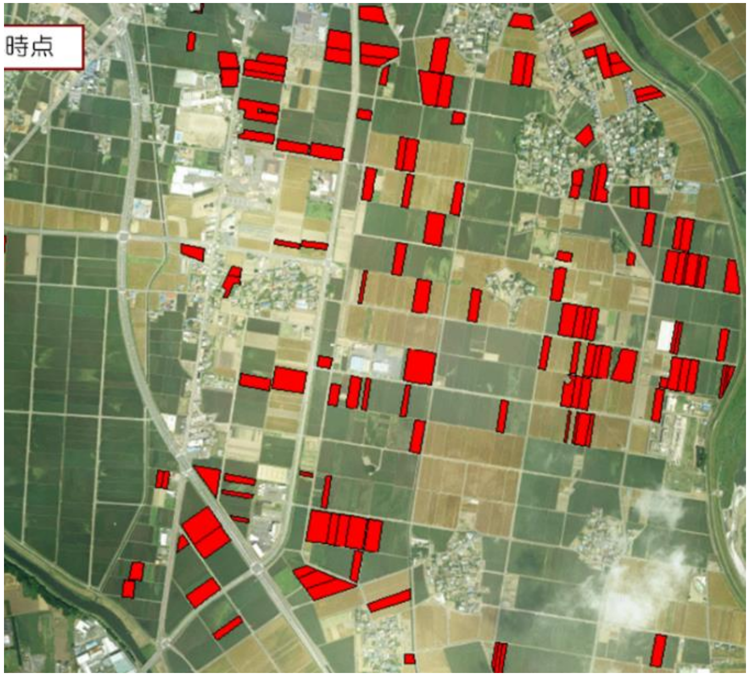
after **2011**

Nationwide early warning and **Decision support system** to reduce weather risk in field crop production

Why "decision support" ?

Socio-economic change of agriculture in Japan

- Farm scale growing due to farmer population decreasing and aging
- Different crop species, cultivars, cropping seasons to level the seasonal variation of working hours
- Crop calendar changes every year by climate change



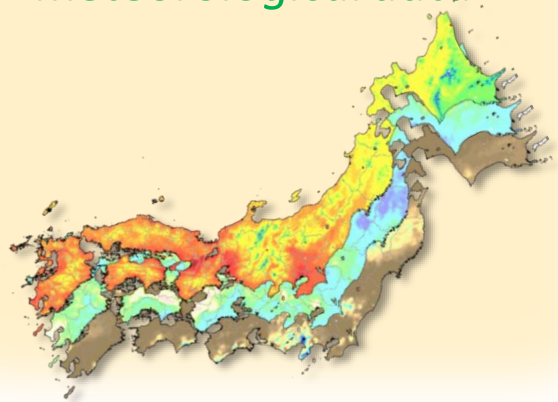
An example of many scattered fields managed by one farmer (total >100 ha)

Decision support by agrometeorological services is useful to solve complex "**puzzles**" in large-scale farming

AgroMet services in NARO (Decision support system)

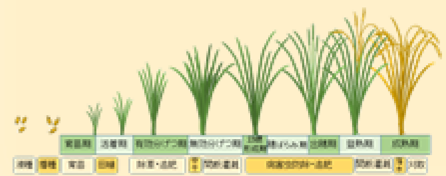
Meteorological Data

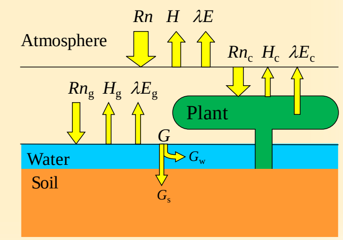
- *1km-resolution grid meteorological data*



Simulation models

- *Crop growth model*
- *Disease/pest development model*
- *Microclimate model*

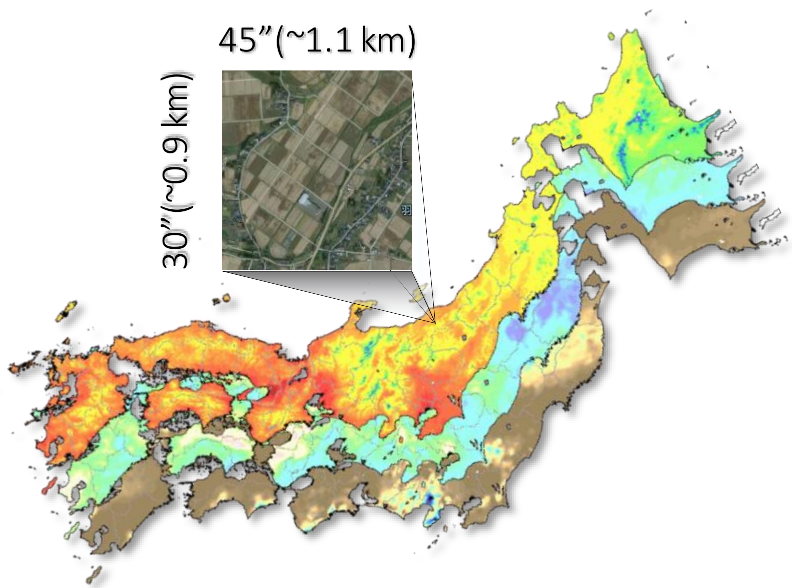




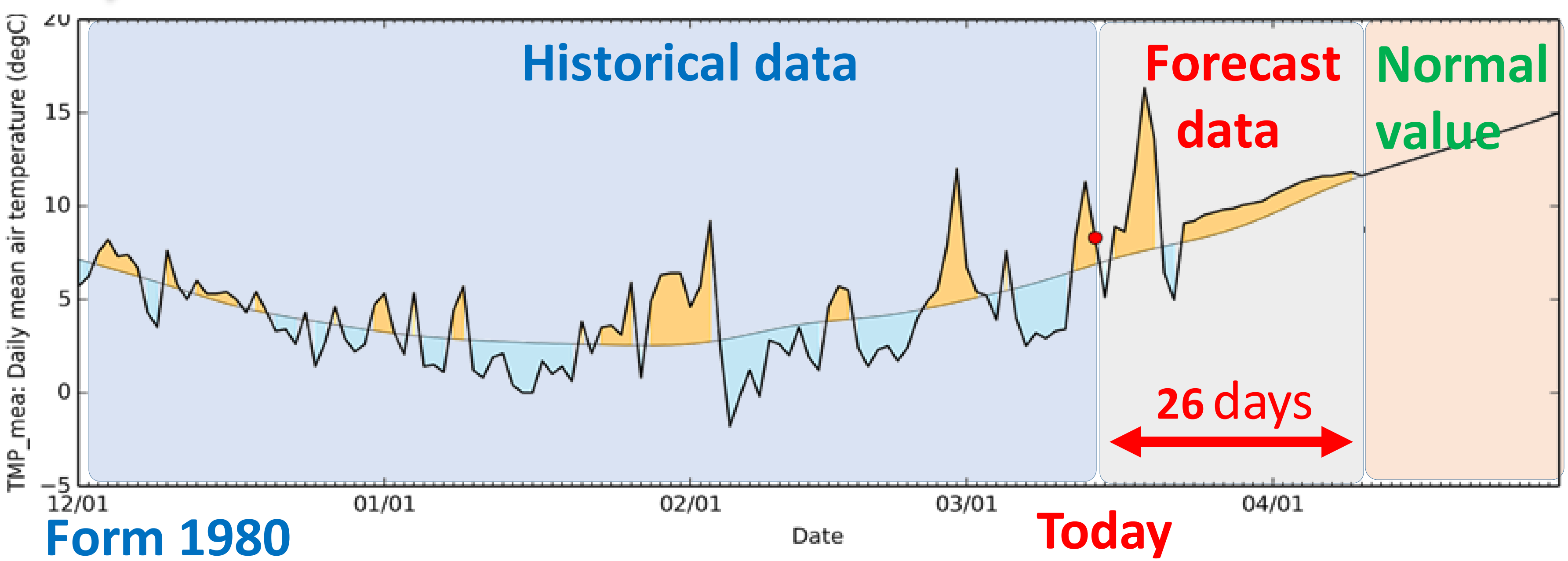
Decision support information / advisories

- *Prediction of best harvesting time*
- *Prediction of crop yield*
- *Crop disease forecast*
- *Early warning of high/low temperature damage (Web-based)*
- *Climate smart irrigation (IoT-based)*

1km-resolution grid meteorological data



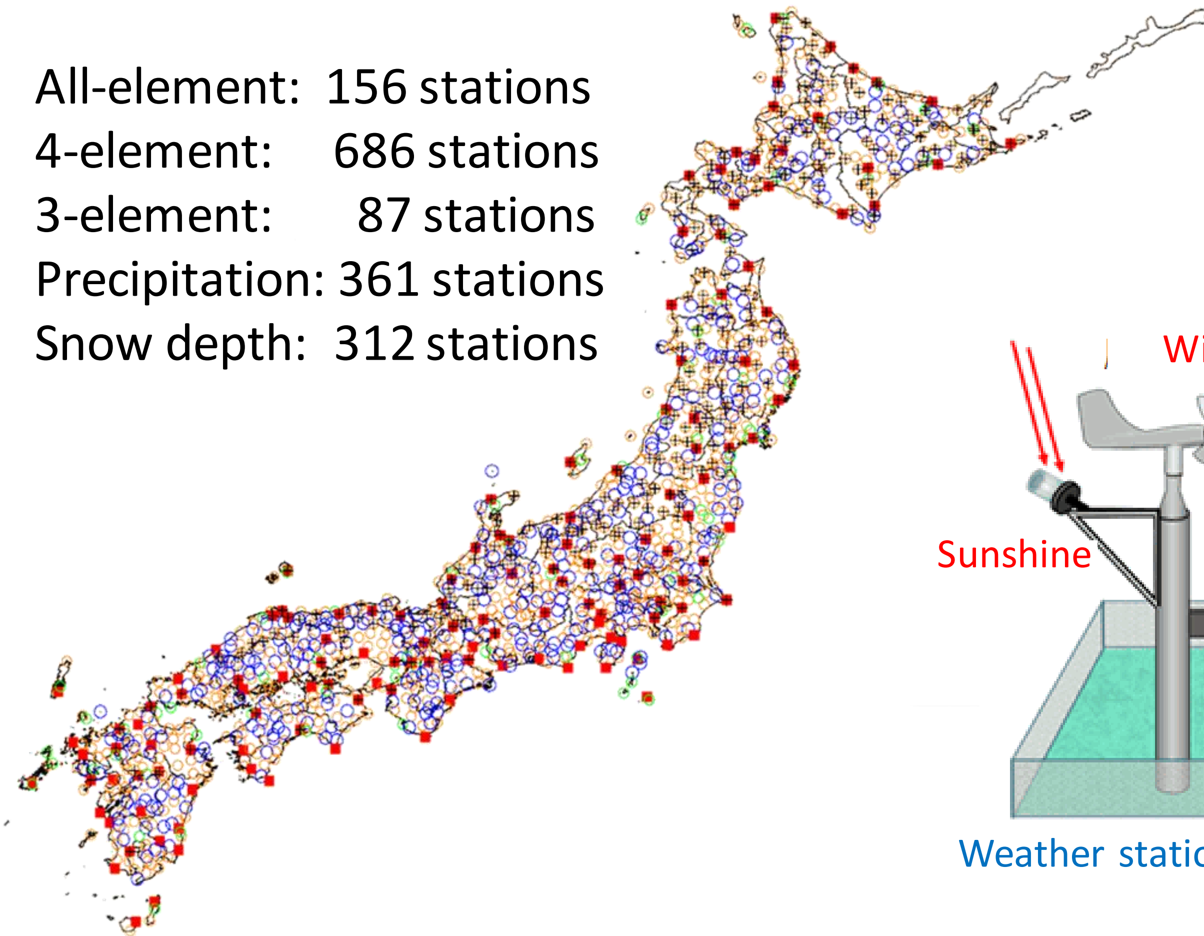
- **System provide the daily data with the spatial resolution of about 1km.**
- **Historical data, forecasted data, and climatic normal values are seamlessly connected.**

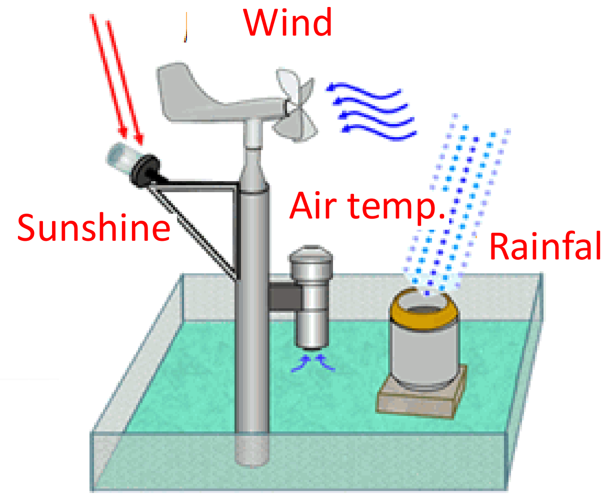


Data source to create Historical data (Observation)

1,300 weather stations by Japan Meteorological Agency (JMA)
(1 station / 20 km x 20 km)

- ■ All-element: 156 stations
- ○ 4-element: 686 stations
- ○ 3-element: 87 stations
- ○ Precipitation: 361 stations
- \+ Snow depth: 312 stations





Weather station of 4-element

(Source: http://www.jma.go.jp/jma/kishou/know/amedas/kaisetsu.html)

Data processing to create Historical data (Interpolation)

Seino (1993); Ohno et al. (2016)

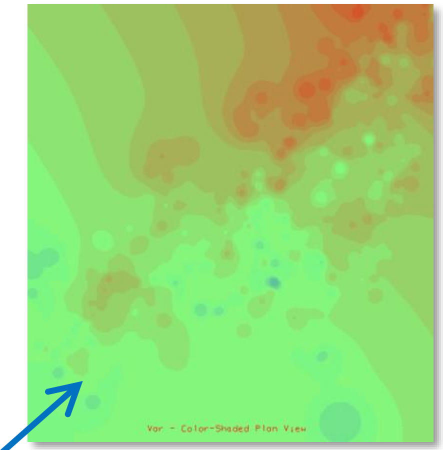
Weather stations

name	lat	lon	Diff
沓形	45.1783	141.138	1.49871
浜頓別	45.125	142.35	1.39098
歌登	44.8417	142.48	0.113136
中頓別	44.965	142.28	0.623808
豊富	45.1067	141.765	1.06162
沼川	45.2483	141.852	0.943466
宗谷岬	45.52	141.935	0.563242
浜鬼志別	45.335	142.17	0.822798
本泊	45.2417	141.187	1.0531
声問	45.4033	141.8	0.480562
礼文	45.305	141.045	1.02551
美深	44.48	142.342	0.922987
名寄	44.37	142.457	0.948408
下川	44.3017	142.623	1.47098
士別	44.1867	142.417	2.02439
上川	43.8467	142.753	4.50726
富良野	43.3333	142.4	5.00928
朝日	44.1183	142.595	3.27112
比布	43.875	142.48	2.86071
美瑛	43.5883	142.493	4.4406
和寒	44.0283	142.41	1.43181
東川	43.7017	142.508	4.45858
志比内	43.6433	142.582	4.87527
幾寅	43.1683	142.568	4.28407
占冠	42.9783	142.395	5.19254
上富良野	43.455	142.465	5.4635
江丹別	43.87	142.26	3.8559
音威子府	44.7267	142.265	0.42145
中川	44.8283	142.077	1.65347
麓郷	43.3017	142.522	5.41236
東神楽	43.67	142.447	3.99308
幌加内	44.01	142.16	3.12586
朱鞠内	44.2817	142.162	1.4306
天塩	44.8933	141.762	2.21531
遠別	44.7183	141.807	3.17394
増毛	43.8483	141.51	3.39999
焼尻	44.4283	141.422	3.78057
初山別	44.5233	141.77	3.23905
達布	44.0483	141.857	4.04409

Observed values

name	lat	lon	Diff
沓形	45.1783	141.138	1.49871
浜頓別	45.125	142.35	1.39098
歌登	44.8417	142.48	0.113136
中頓別	44.965	142.28	0.623808
豊富	45.1067	141.765	1.06162
沼川	45.2483	141.852	0.943466
宗谷岬	45.52	141.935	0.563242
浜鬼志別	45.335	142.17	0.822798
本泊	45.2417	141.187	1.0531
声問	45.4033	141.8	0.480562
礼文	45.305	141.045	1.02551
美深	44.48	142.342	0.922987
名寄	44.37	142.457	0.948408
下川	44.3017	142.623	1.47098
士別	44.1867	142.417	2.02439
上川	43.8467	142.753	4.50726
富良野	43.3333	142.4	5.00928
朝日	44.1183	142.595	3.27112
比布	43.875	142.48	2.86071
美瑛	43.5883	142.493	4.4406
和寒	44.0283	142.41	1.43181
東川	43.7017	142.508	4.45858
志比内	43.6433	142.582	4.87527
幾寅	43.1683	142.568	4.28407
占冠	42.9783	142.395	5.19254
上富良野	43.455	142.465	5.4635
江丹別	43.87	142.26	3.8559
音威子府	44.7267	142.265	0.42145
中川	44.8283	142.077	1.65347
麓郷	43.3017	142.522	5.41236
東神楽	43.67	142.447	3.99308
幌加内	44.01	142.16	3.12586
朱鞠内	44.2817	142.162	1.4306
天塩	44.8933	141.762	2.21531
遠別	44.7183	141.807	3.17394
増毛	43.8483	141.51	3.39999
焼尻	44.4283	141.422	3.78057
初山別	44.5233	141.77	3.23905
達布	44.0483	141.857	4.04409

Normal values



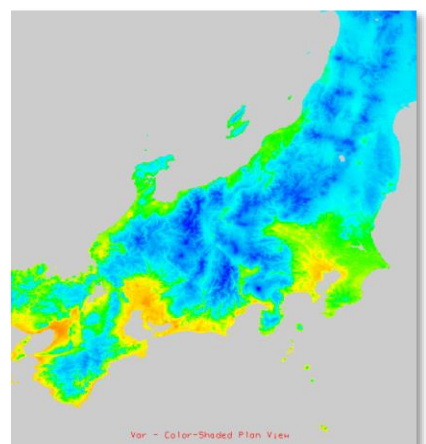
Gridded differences

Interpolated with

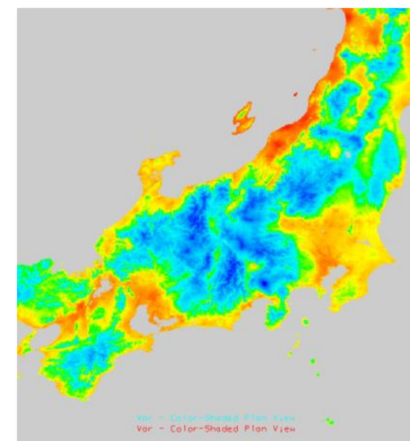
Inverse Distance Weighting (IDW)

$$y = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i}$$

$$w_i = \frac{1}{d_i^p}, \qquad p = 3$$



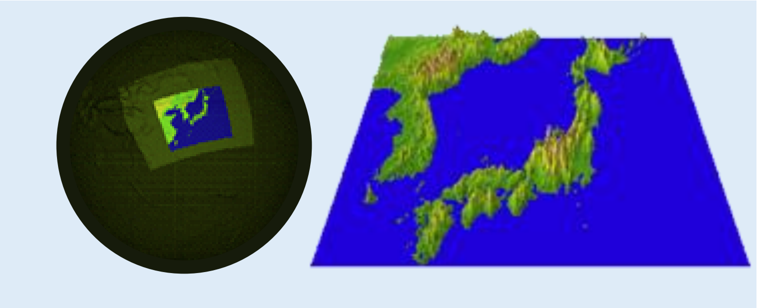
Gridded normal values

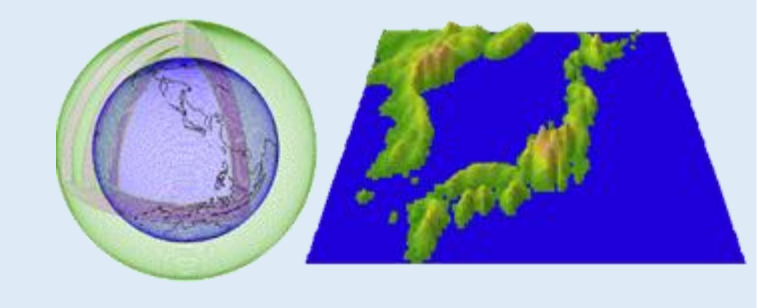


Historical data

Data sources to create Forecast data

(source: http://pfi.kishou.go.jp/material/nwp50th-ann.pdf)





1. JMA's Meso-Scale Model (MSM)

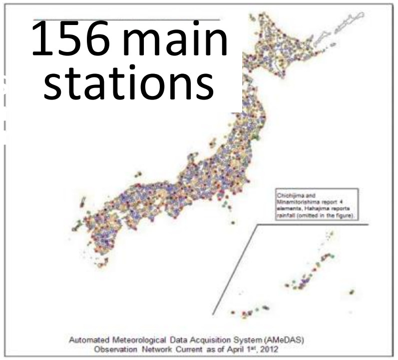
- Regional model
- Approx. 5 km grid
- 1.5-day forecast (for **day 1**: today)

2. JMA's Global Spectral Model (GSM)

- Global model
- Approx. 20 km grid
- 9-day forecast (for **day 2 - 9**)

3. Model Output Statistic (MOS) Guidance for 1-month by JMA

- Empirical forecast using 30 ensemble data
- Forecast for 156 points
- 4-week forecast (for **day 10 - 26**)

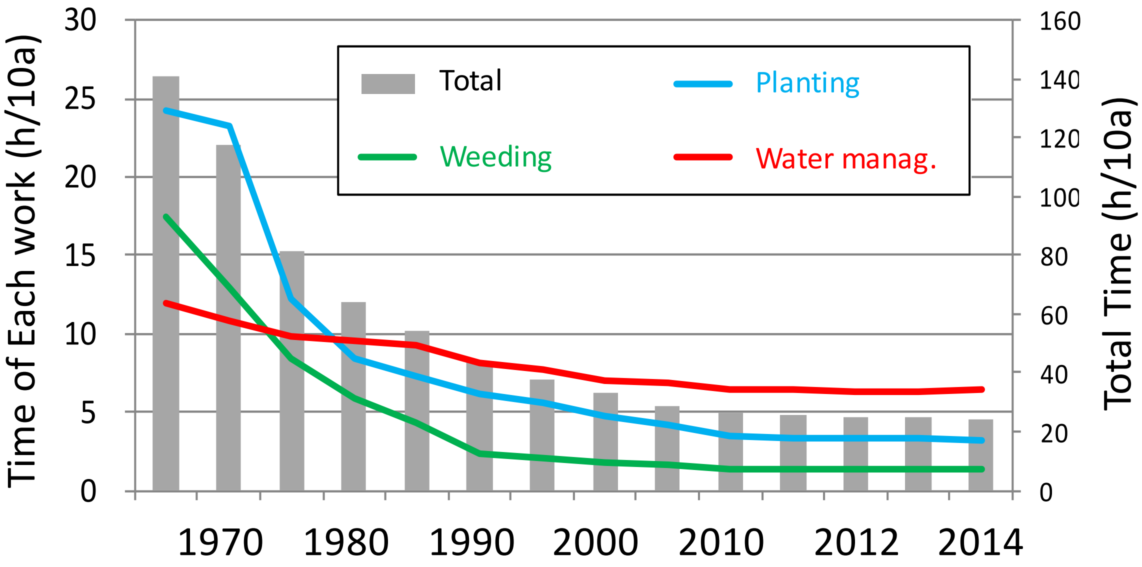


List of data provided by the system

Meteorological factors	Historical	Forecast
Mean air temperature	1980 -	- 26 days in the future
Maximum air temperature	1980 -	- 26 days in the future
Minimum air temperature	1980 -	- 26 days in the future
Precipitation	1980 -	- 26 days in the future
Relative humidity	2008 -	- 9 days in the future
Wind speed	2008 -	- 9 days in the future
Sunshine duration	1980 -	- 9 days in the future
Shortwave radiation	1980 -	- 9 days in the future
Longwave radiation	2008 -	- 9 days in the future
Snow depth	2008 -	- 9 days in the future

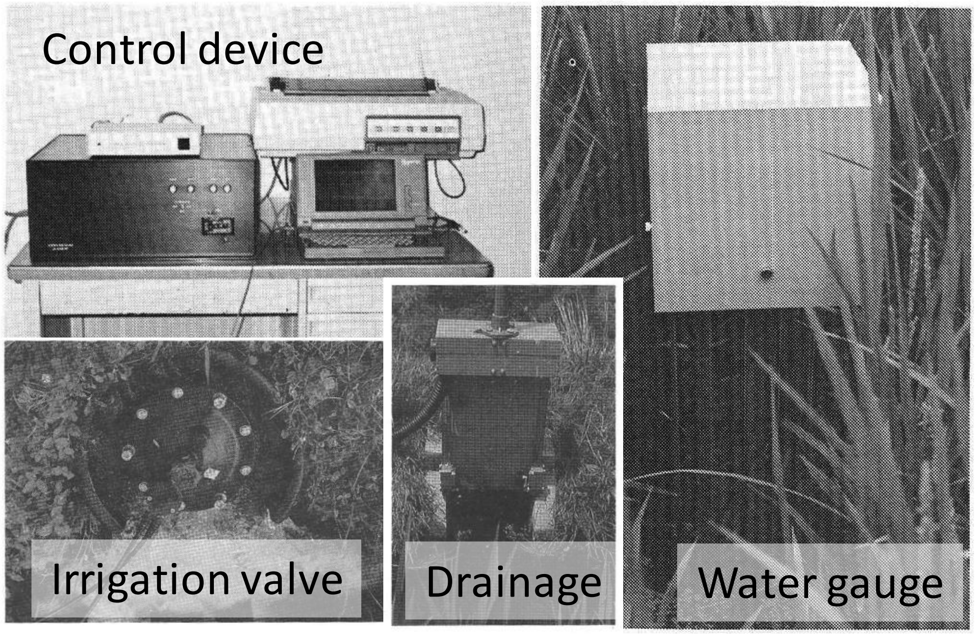
Climate Smart Irrigation

Current issues of field irrigation in Japan



- Field irrigation practices are not mechanized unlike other works
- 30% of working time for rice cultivation is water management
- Farm size is growing due to decrease in farmer population

Remote control irrigation system

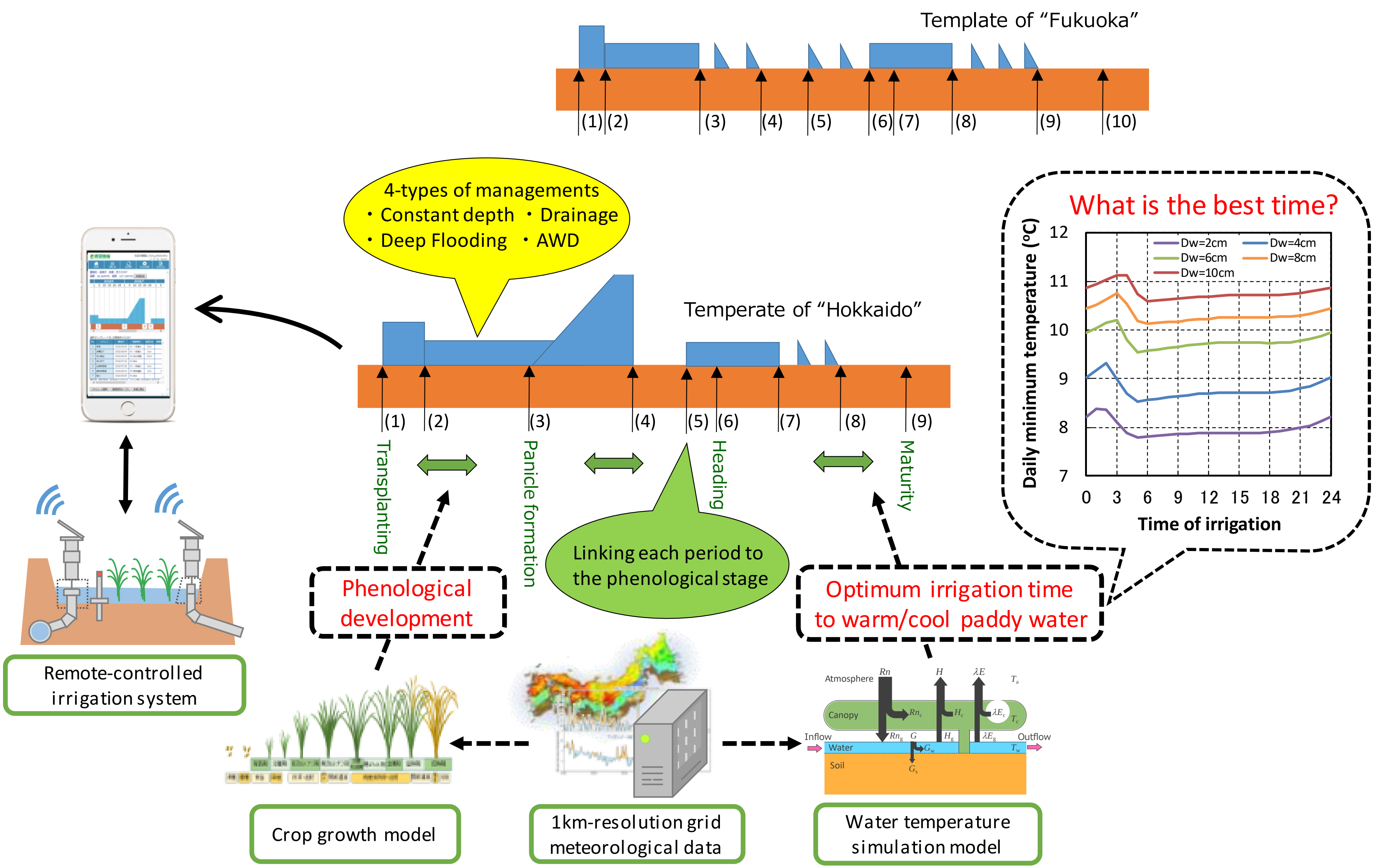


Remote control irrigation devices (MAFF, 1994)

Field irrigation system (NARO, 2017)

Development of ICT

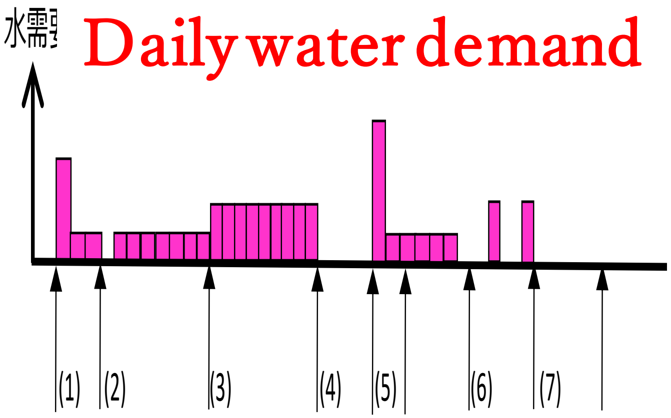
Climate smart irrigation (Software of the field irrigation system)

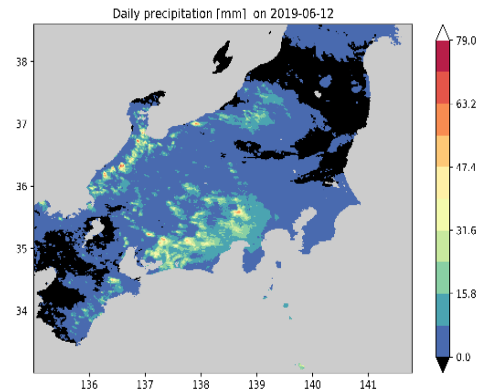


Future challenges

- **Water saving in rice cultivation**

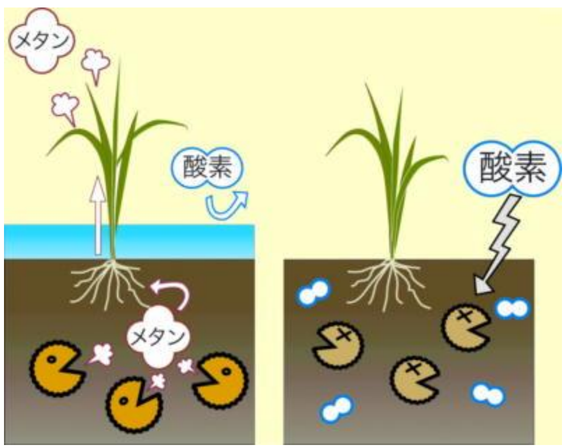
Daily water demand





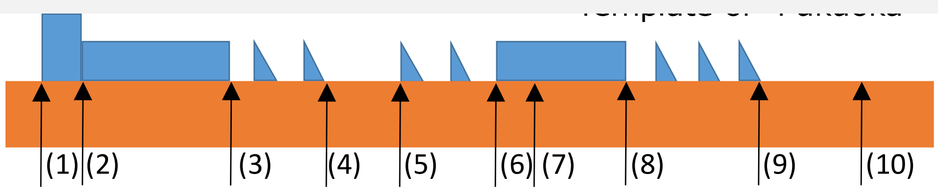
Precipitation forecast data

- **Climate change mitigation by reducing methane (CH4)**



NIAES(2000)

Template for "methane (CH4) generation control."



3-globe thermometer

A new thermometer

- **Having multiple spherical sensors (thermocouples)**
- **Does not require radiation shield**

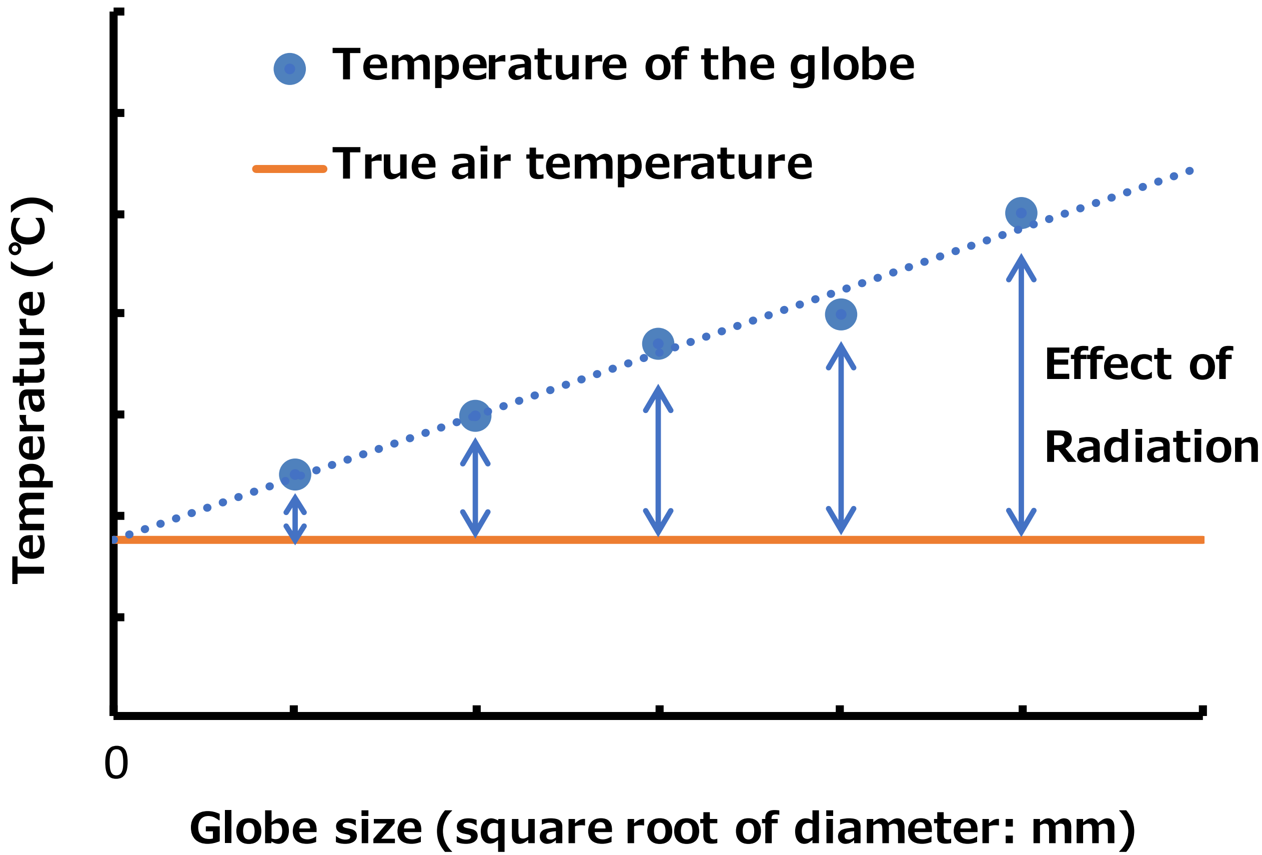
How to measure air temperature accurately

- Radiation shield
- Ventilation
- Power supply

Difficult to obtain commercial power in farmland

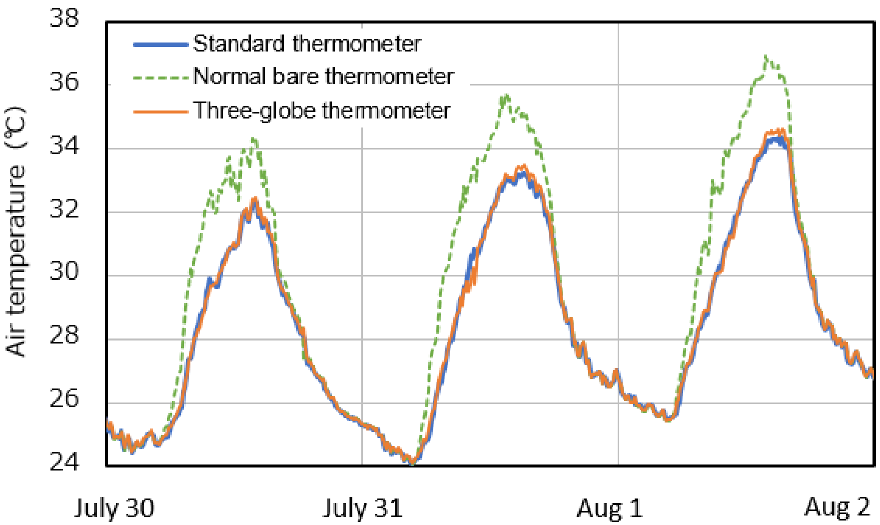
Principle

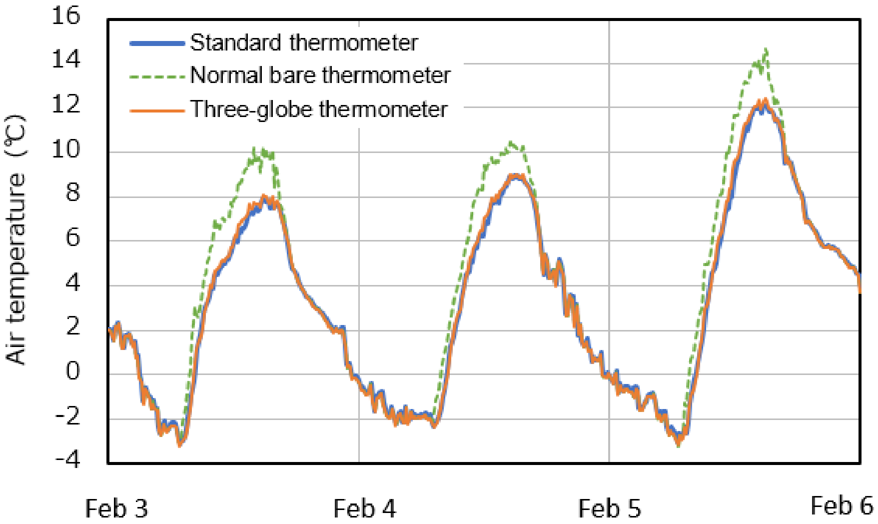
- Principle is based on the energy balance
- Radiation effects are eliminated using multiple sensors



- Optimum combination of diameter was 0.25, 1 and 4 mm

Comparison with a standard instrument



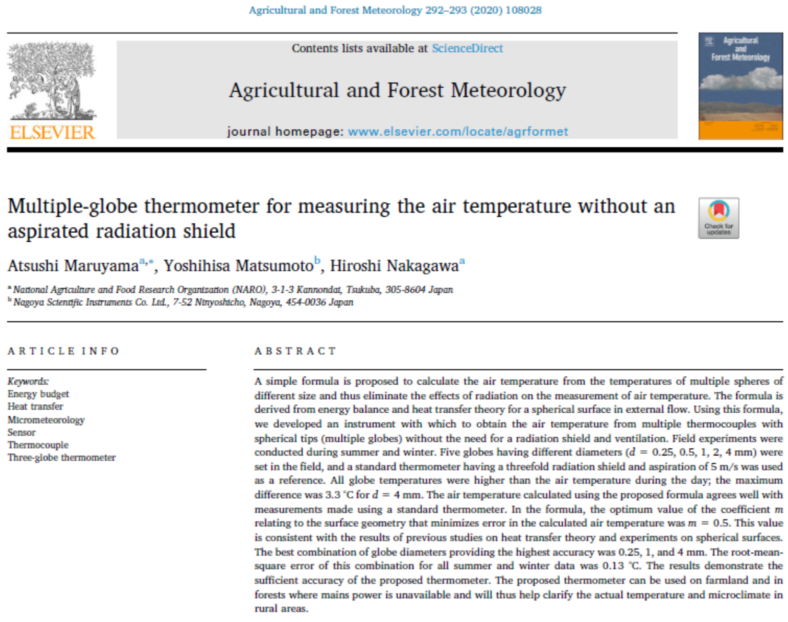


RMSE = 0.13 °C

Formula in 3-globe thermometer

$$T_a = T_1 + \frac{1}{2}(T_2 - T_3)$$

T_a : True air temp.
T_1 : Small globe temp.
T_2 : Medium globe temp.
T_3 : Large globe temp.



Agricultural and Forest Meteorology 292–293 (2020) 108028

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

Multiple-globe thermometer for measuring the air temperature without an aspirated radiation shield

Atsushi Maruyama[a,*], Yoshihisa Matsumoto[b], Hiroshi Nakagawa[a]

[a] National Agriculture and Food Research Organization (NARO), 3-1-3 Kannondai, Tsukuba, 305-8604 Japan
[b] Nagoya Scientific Instruments Co. Ltd., 7-52 Ninyoshicho, Nagoya, 454-0036 Japan

ARTICLE INFO

Keywords:
Energy budget
Heat transfer
Micrometeorology
Sensor
Thermocouple
Three-globe thermometer

ABSTRACT

A simple formula is proposed to calculate the air temperature from the temperatures of multiple spheres of different size and thus eliminate the effects of radiation on the measurement of air temperature. The formula is derived from energy balance and heat transfer theory for a spherical surface in external flow. Using this formula, we developed an instrument with which to obtain the air temperature from multiple thermocouples with spherical tips (multiple globes) without the need for a radiation shield and ventilation. Field experiments were conducted during summer and winter. Five globes having different diameters (d = 0.25, 0.5, 1, 2, 4 mm) were set in the field, and a standard thermometer having a threefold radiation shield and aspiration of 5 m/s was used as a reference. All globe temperatures were higher than the air temperature during the day; the maximum difference was 3.3 °C for d = 4 mm. The air temperature calculated using the proposed formula agrees well with measurements made using a standard thermometer. In the formula, the optimum value of the coefficient m relating to the surface geometry that minimizes error in the calculated air temperature was m = 0.5. This value is consistent with the results of previous studies on heat transfer theory and experiments on spherical surfaces. The best combination of globe diameters providing the highest accuracy was 0.25, 1, and 4 mm. The root-mean-square error of this combination for all summer and winter data was 0.13 °C. The results demonstrate the sufficient accuracy of the proposed thermometer. The proposed thermometer can be used on farmland and in forests where mains power is unavailable and will thus help clarify the actual temperature and microclimate in rural areas.

Maruyama et al. (2020)
Agric. For. Meteorol.

A prototype is available from Nagoya Scientific Instruments Co., Japan.


Thank you for your attention!

Acknowledgment

This work is supported by

- JSPS KAKENHI Grant Numbers 24780246 and 19H03084.
- Cross-ministerial Strategic Innovation Promotion Program (SIP), “Technologies for Smart Bio-industry and Agriculture” (funding agency: Bio-oriented Technology Research Advancement Institution)
- Ministry of Agriculture, Forestry and Fisheries「Research project for technologies to strengthen the international competitiveness of Japan‘s agriculture and food industry」 (funding agency: National Agriculture and Food Research Organization)