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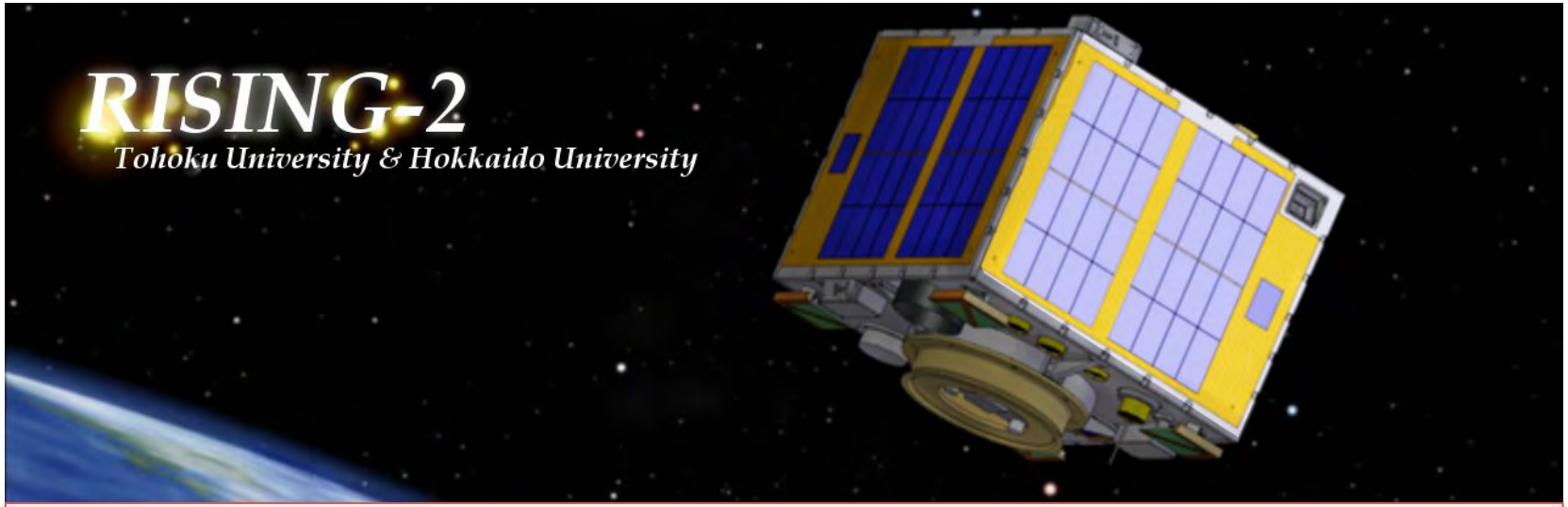

New observation system for disaster monitoring with ground lightning networks and micro-satellite constellation

Yukihiro Takahashi
Space Mission Center (SMC)
Creative Research Institution (CRIS)
Hokkaido University

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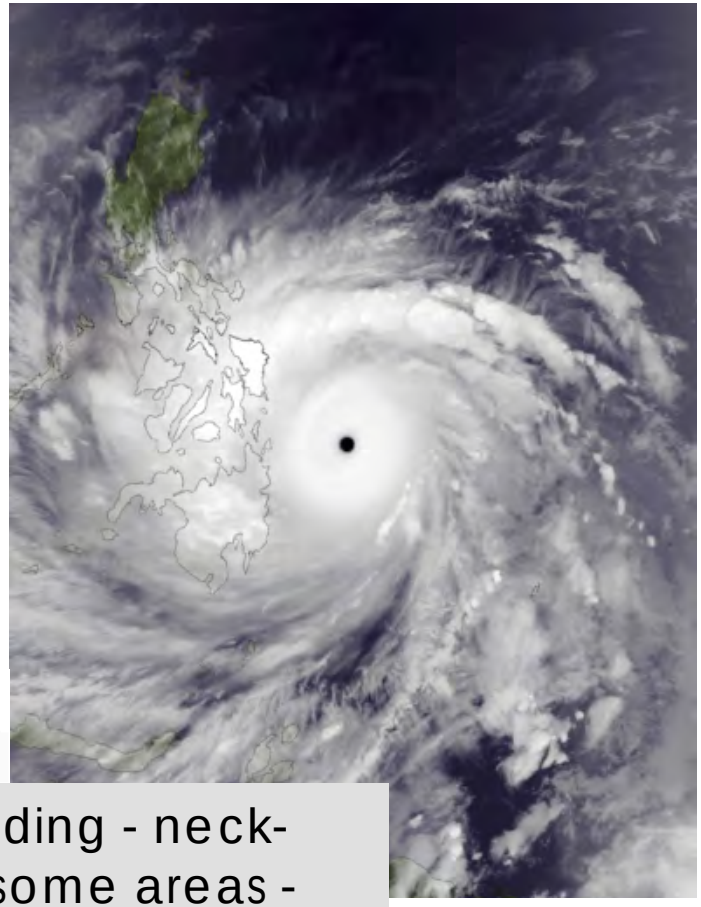
Torrential rainfall and Typhoon



BBC News Sport Weather
NEWS ASIA
Home UK Africa Asia Europe Latin America Mid-East US & Canada Busin

Floods paralyse Philippine capital Manila

BBC's Kate McGeown: "Roads have been turned into rivers"

"The flooding - neck-deep in some areas - forced tens of thousands of people to flee their homes, closing schools, offices and the stock exchange."

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Monitoring and understanding thunderstorm
is the key for disaster prevention of torrential rainfall and typhoon

Torrential rainfall
- flood, inundation

Typhoon energy source = thunderstorm
- flood, inundation
- violent wind
- high tide

Lightning
- one of the main causes of internet trouble
- electrical blackout
- human life
- wild fire

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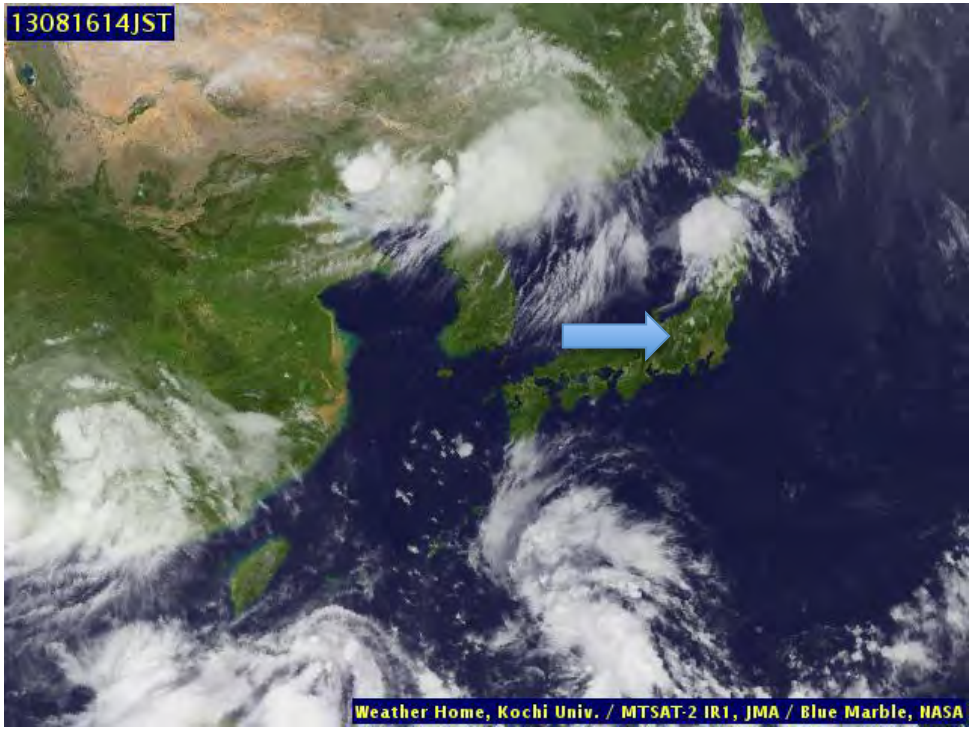
Thunderstorm is difficult object to observe

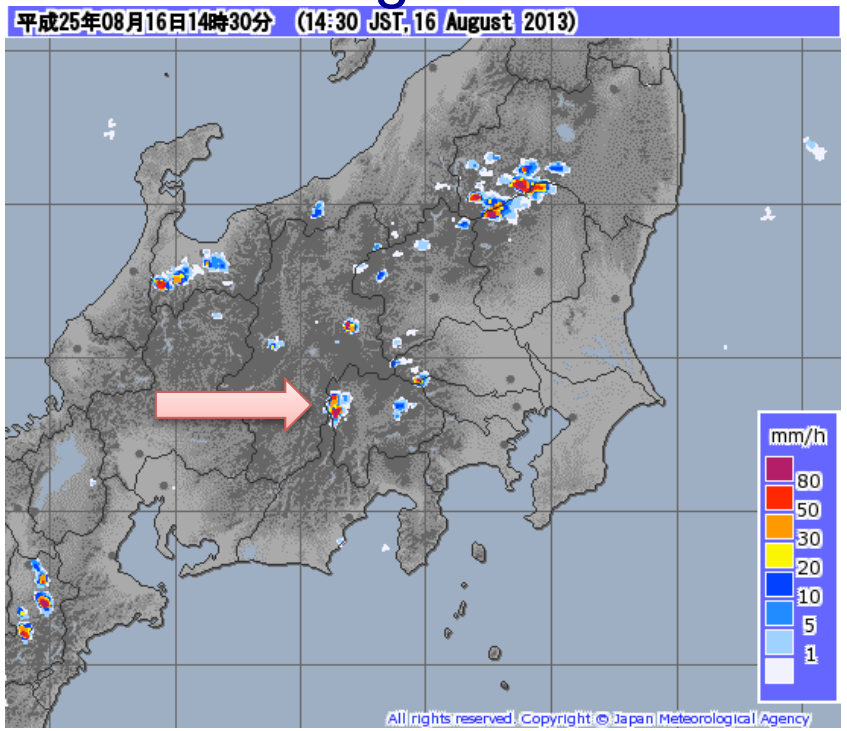
--- it's very strong but too tiny scale...

Geosynchronous Satellite Image



(C) JMA

Meteorological Radar



(C) JMA

Geostationary Meteorological satellite: 0.5-1.0 km

C band radar: resolution ~1-2 km

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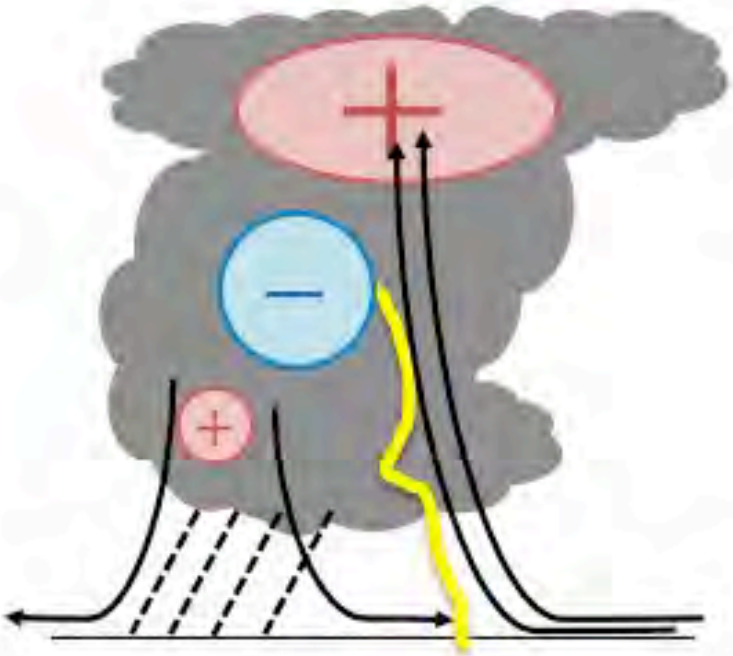
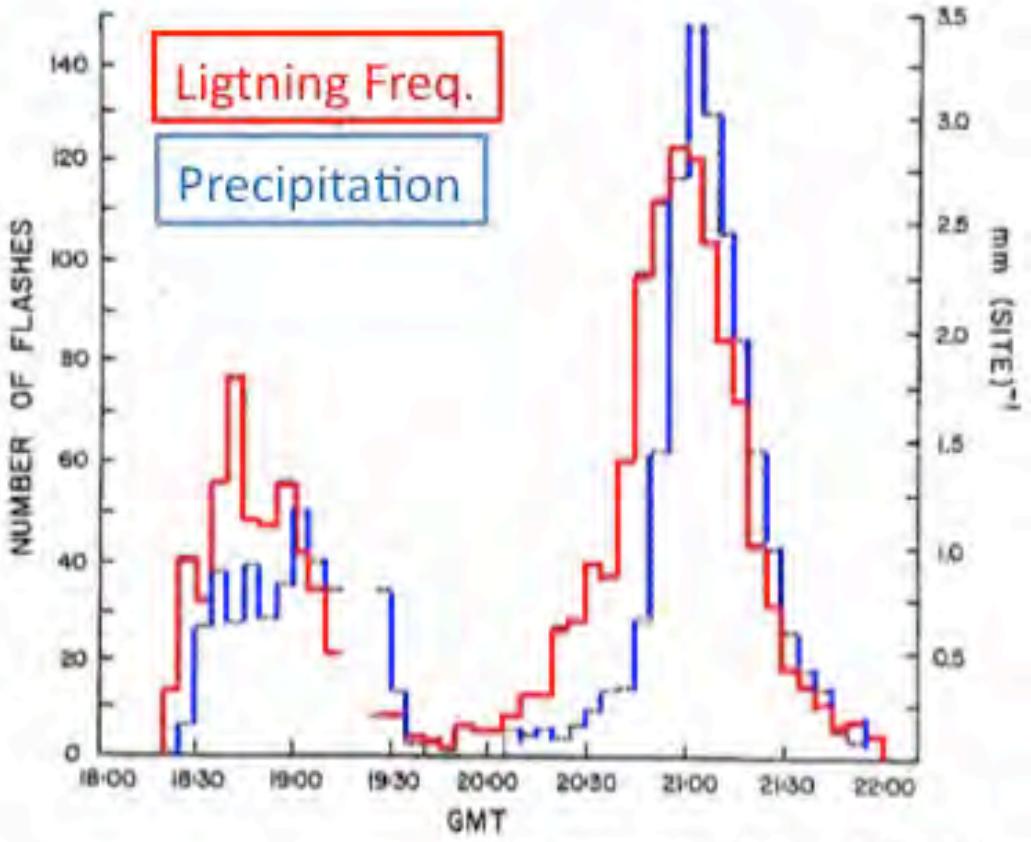
How to monitor thunderstorms?

- Lightning observation on the ground
- On demand operation with micro-satellite

Charge distribution inside thunderstorm





(Piepgrass et al., 1982)

Difficult to detect the inner structure of thunderstorm by existing networks

- AMEDAS (10 min., ~17 km)
- C band radar (5 min., ~1km)

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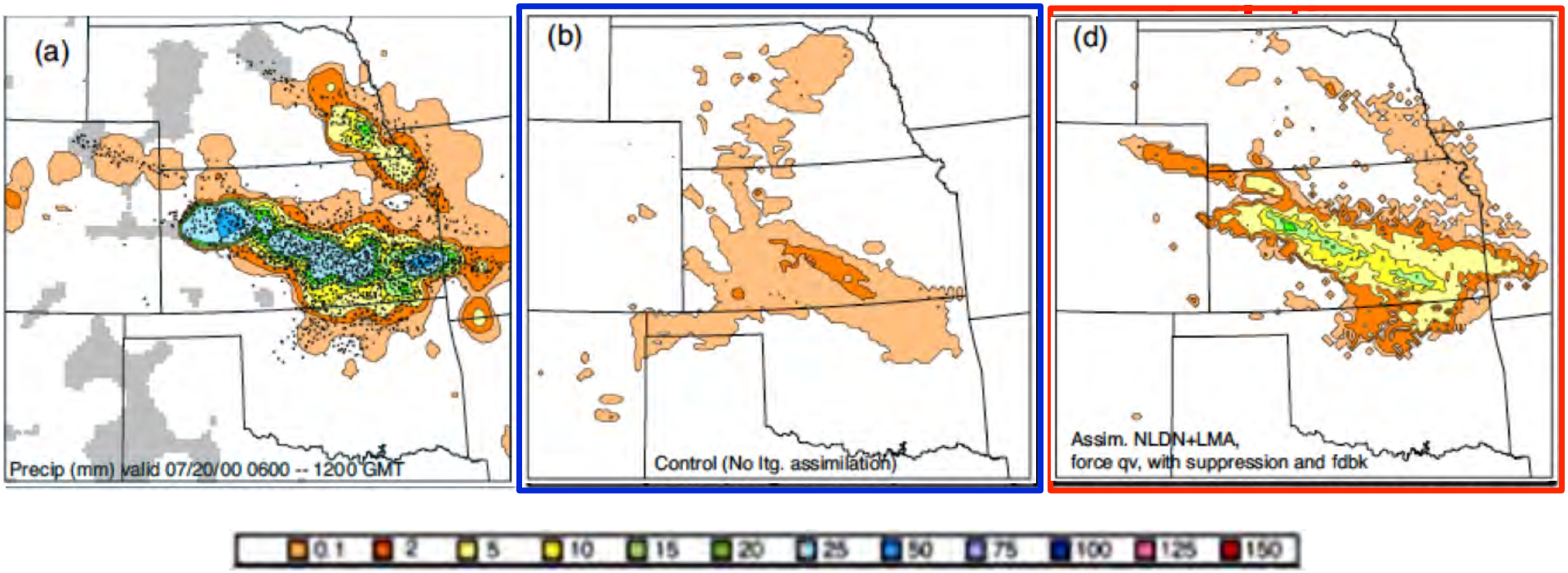
Lightning data assimilation for meteorological forecast model

Observed data

Non-lightning data

Lightning data



Successful in aspect of rain intensity and distribution in US

[*Mansell et al*., 2007]

Typhoon predicted by lightning？

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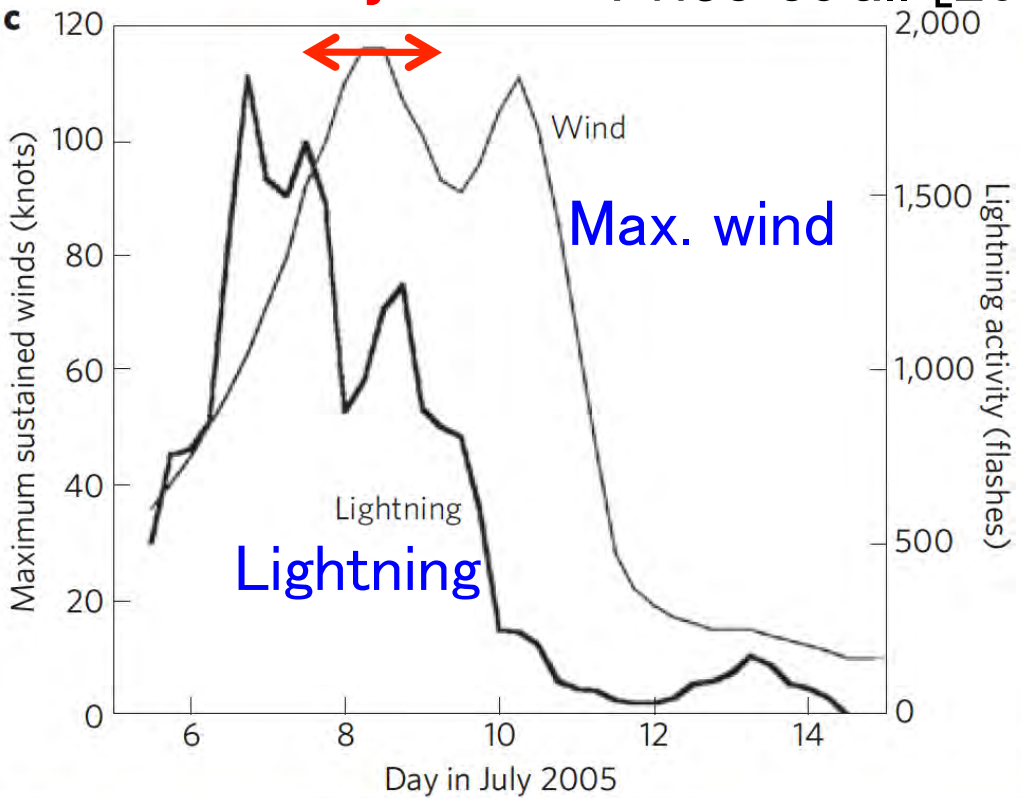
1 or 2 days shift Price et al. [2007]



- Correlation ~0.82 ！

We could predict intensity 1-2 days before.

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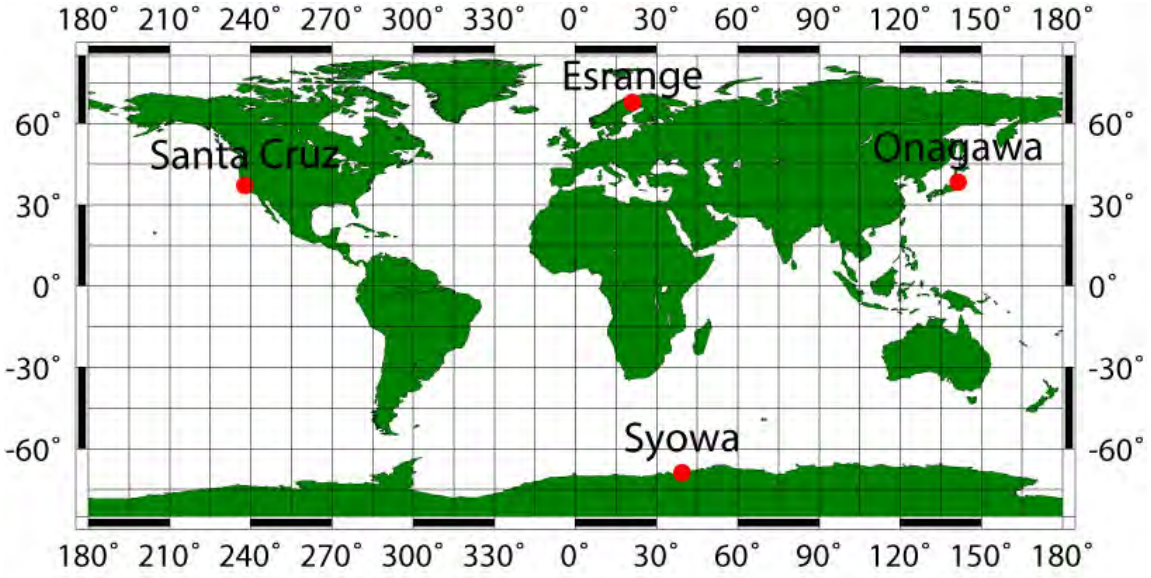
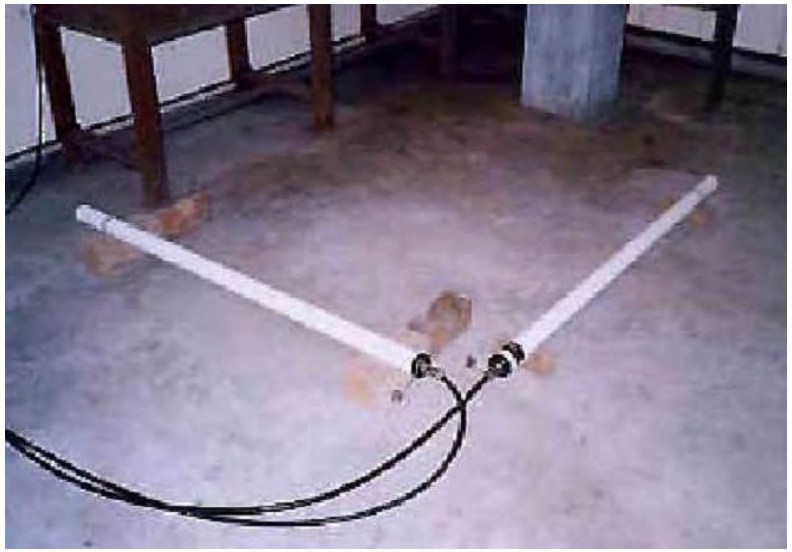
Global ELF Observation network: GEON



GEON sites



GEON Sensors

	Syowa(SYO)	Onagawa(ONG)	Esrange(ESR)
Location	39.506°E, 69.018°S	141.483°E, 38.433°N	21.100°E, 67.833°N
Declination angle	-48.489°	-7.7°	-
Sampling frequency	400Hz		
Low pass filter	100Hz		
High pass filter	1Hz		
Data span	2003/08/01～2004/7/31 (Observation day: 300 days)		

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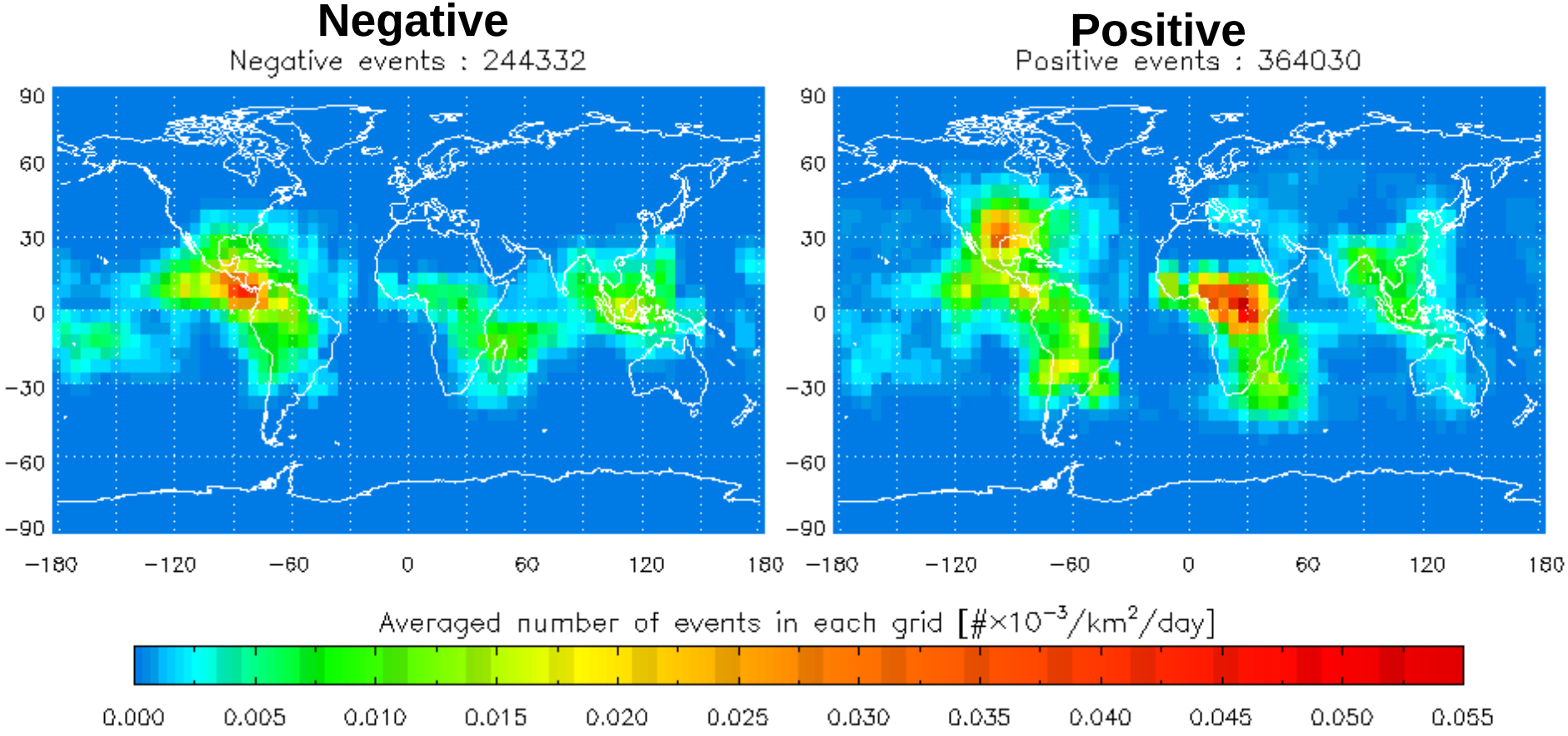
Global CG distribution (one year) by GEON

>950C-km

2003. 8- 2004.7



Number of events: Positive CG: 364,030, Negative CG: 244,332

Yamashita, Dr. Thesis, 2011

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Outdoor system

Dipole antenna:
To measure electric field

Loop antenna:
To measure magnetic field

Figure. Dipole antenna (left panel) and loop antenna (right one) installed at Los Banos, Philippines.

10 K USD / site

Geolocation of lightning by Time-of-Arrival

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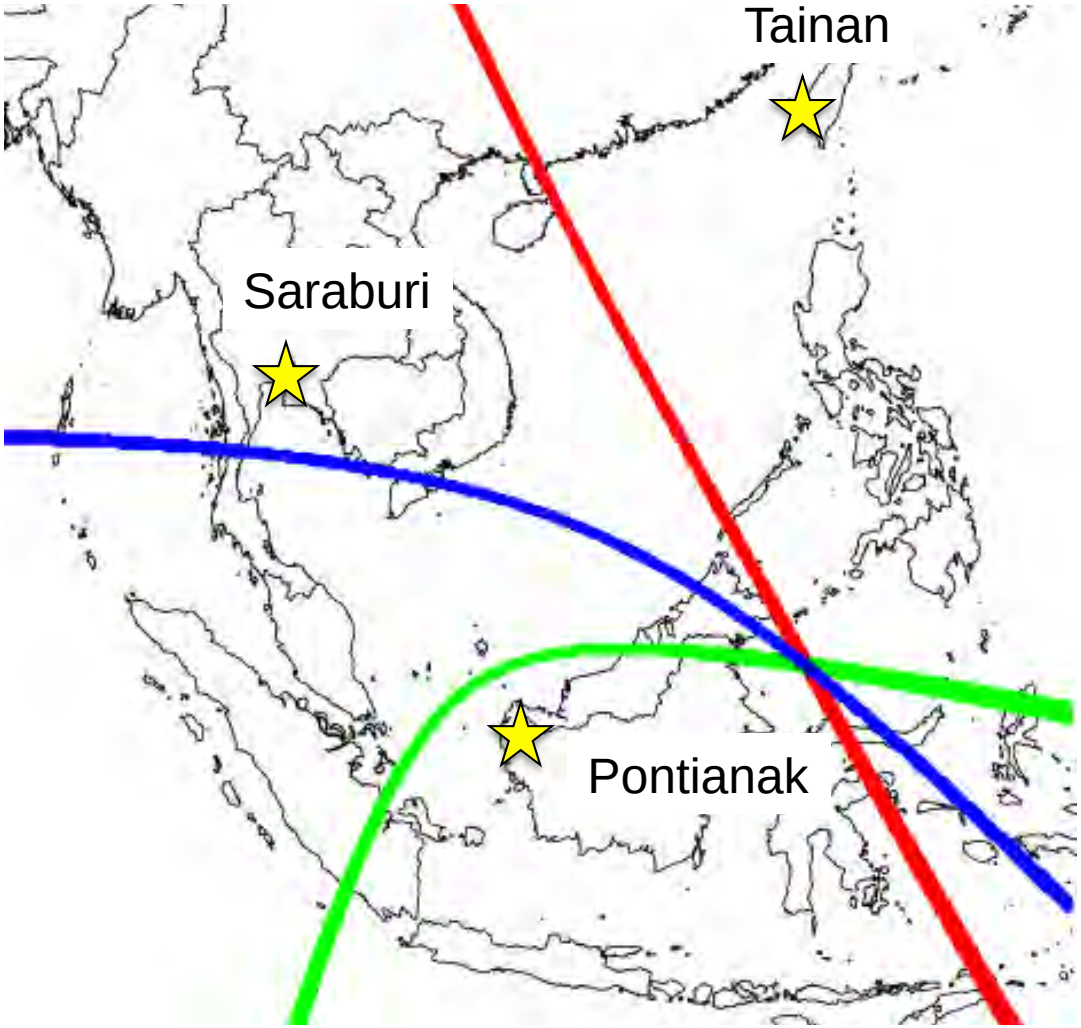

ΔT_1

Difference of arrival timing between Tainan and Saraburi

ΔT_2

Difference of arrival timing between Saraburi and Pontianak

ΔT_3

Difference of arrival timing between Pontianak and Tainan

Example of geolocation based on 3 stations observation.

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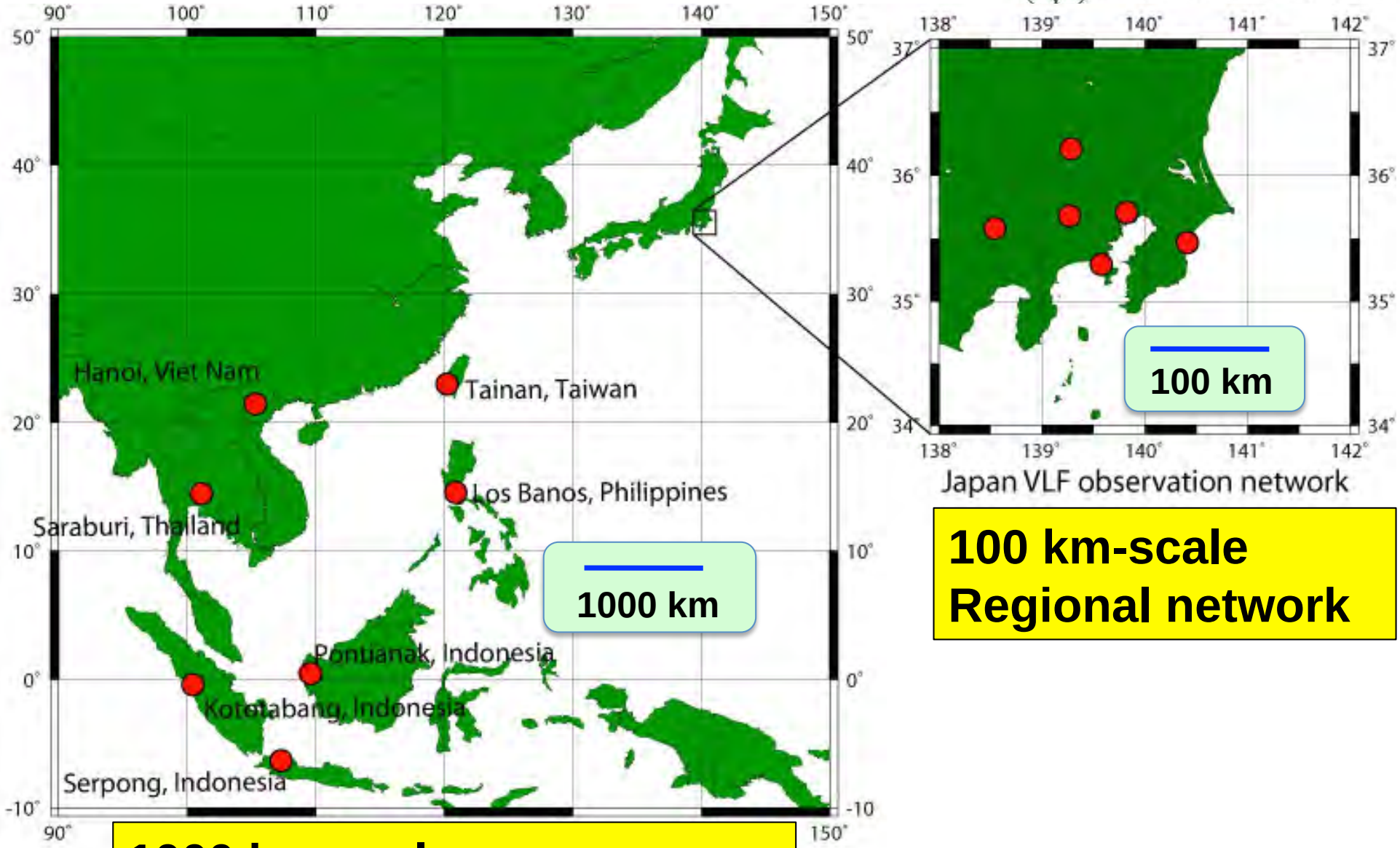

1000 km-scale
Asia / Nation-wide network

100 km-scale
Regional network

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Lighting and Cloud

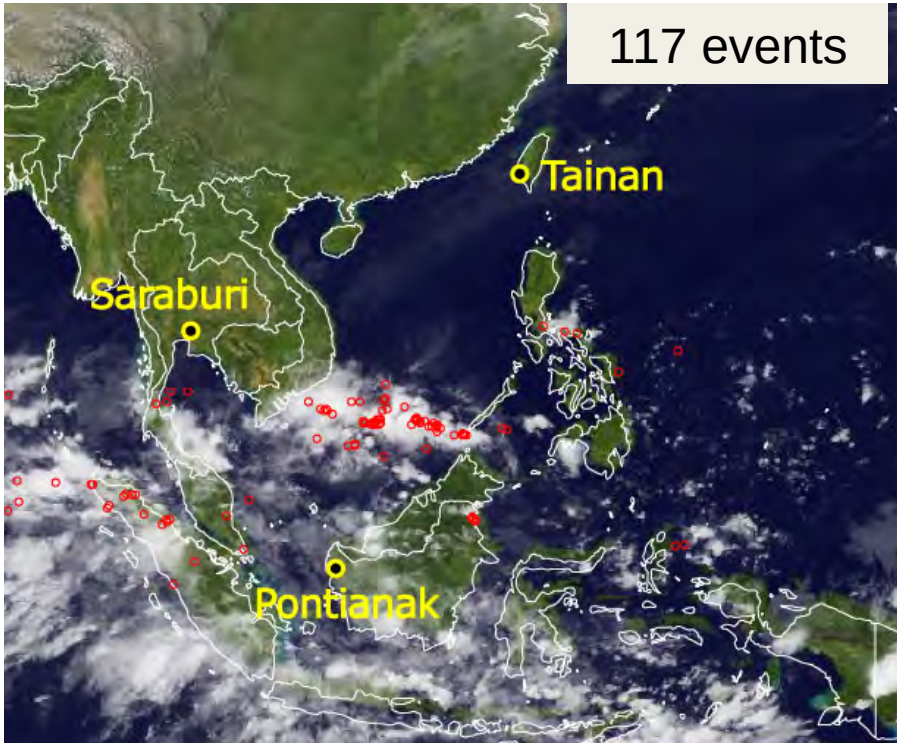


Figure. Lightning mapping on cloud data during 2010/12/01 17:00-18:00

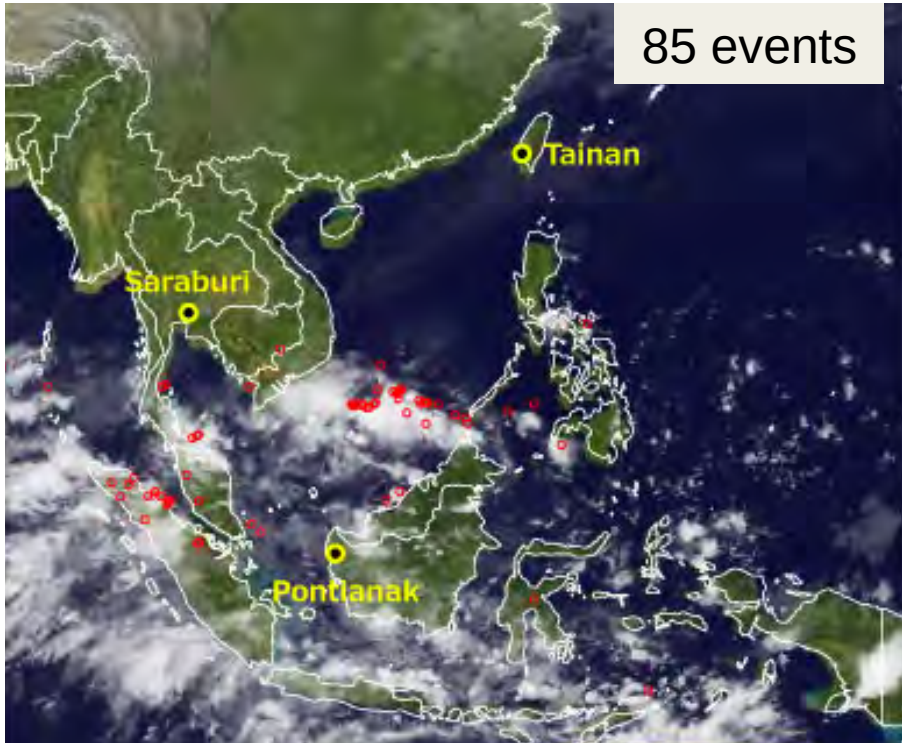


Figure. Lightning mapping on cloud data during 2010/12/01 18:00-19:00

- Span: 2010/12/0117:00-19:00
- Analyzed events: 202 events

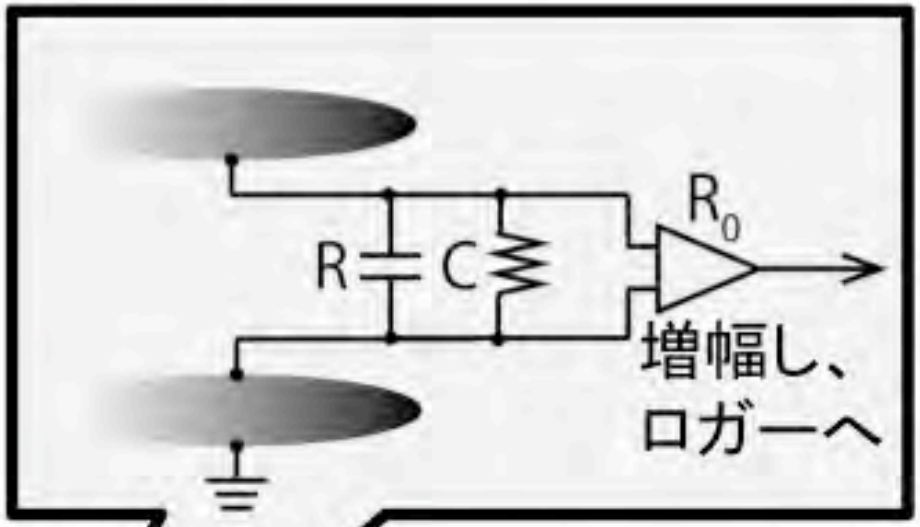
by Kozo Yamashita

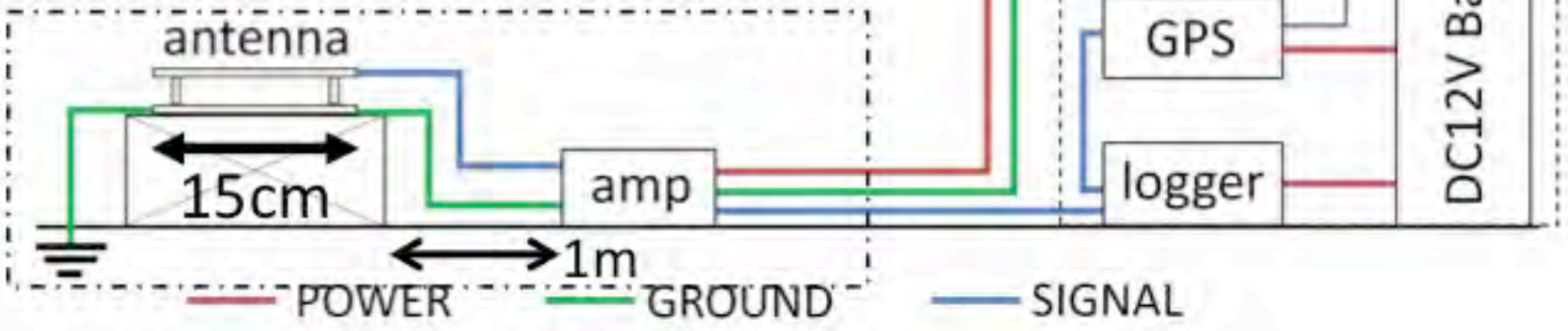
More detail observation with simpler and cheaper sensors

Plate-type sensor

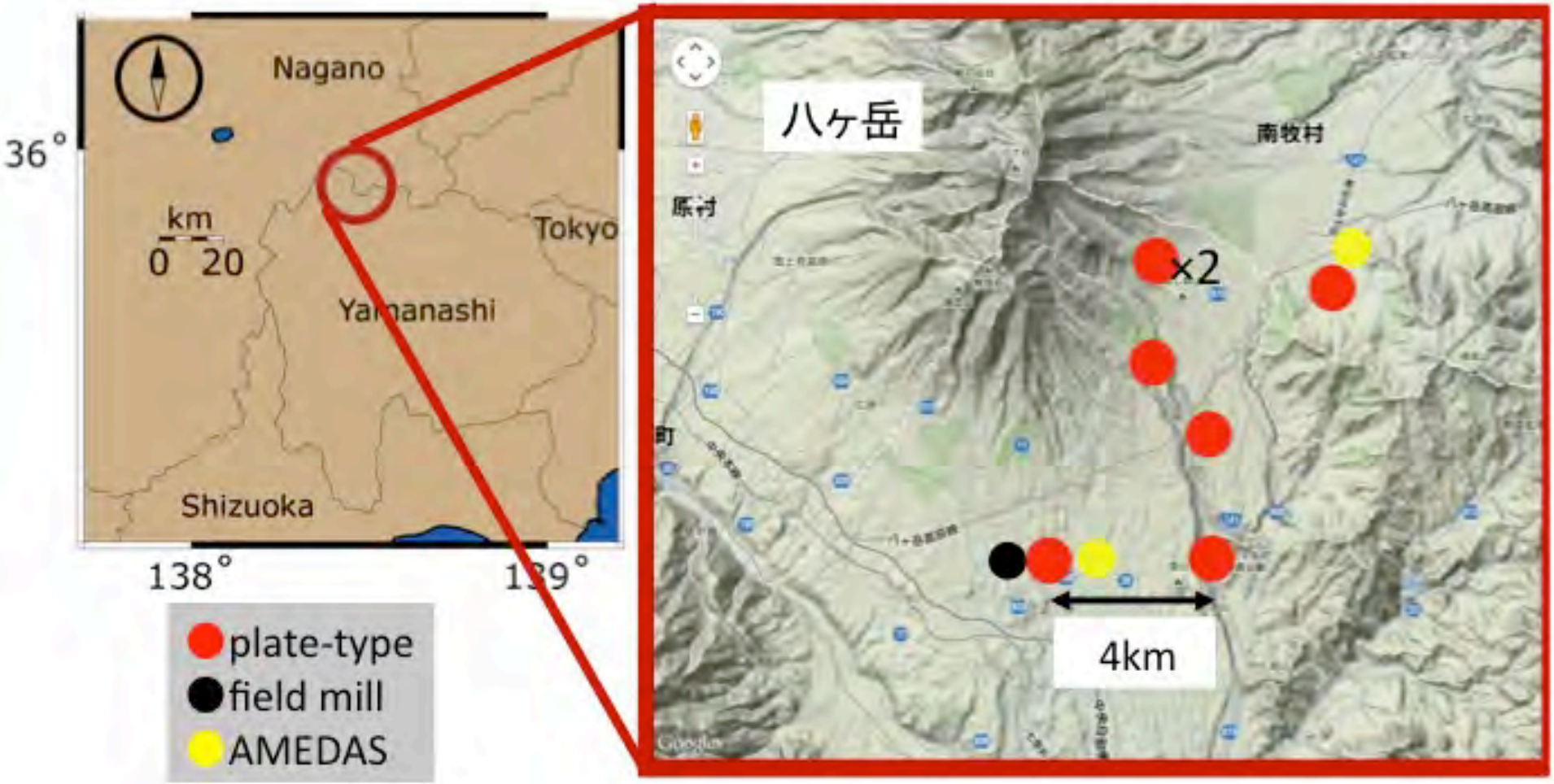
100 USD / site

- time constant (RC) : 100ms
- sampling interval : 10ms
- height from ground : 15cm





Multi-point observation campaign (2013/08/11-08/23)



©Google map

- distributed at 4 km distance in 7km×7km range in mountain area
- 7 plate-type sensors and 1 field mill sensor
- lightning and rain drops are recorded on 3 days

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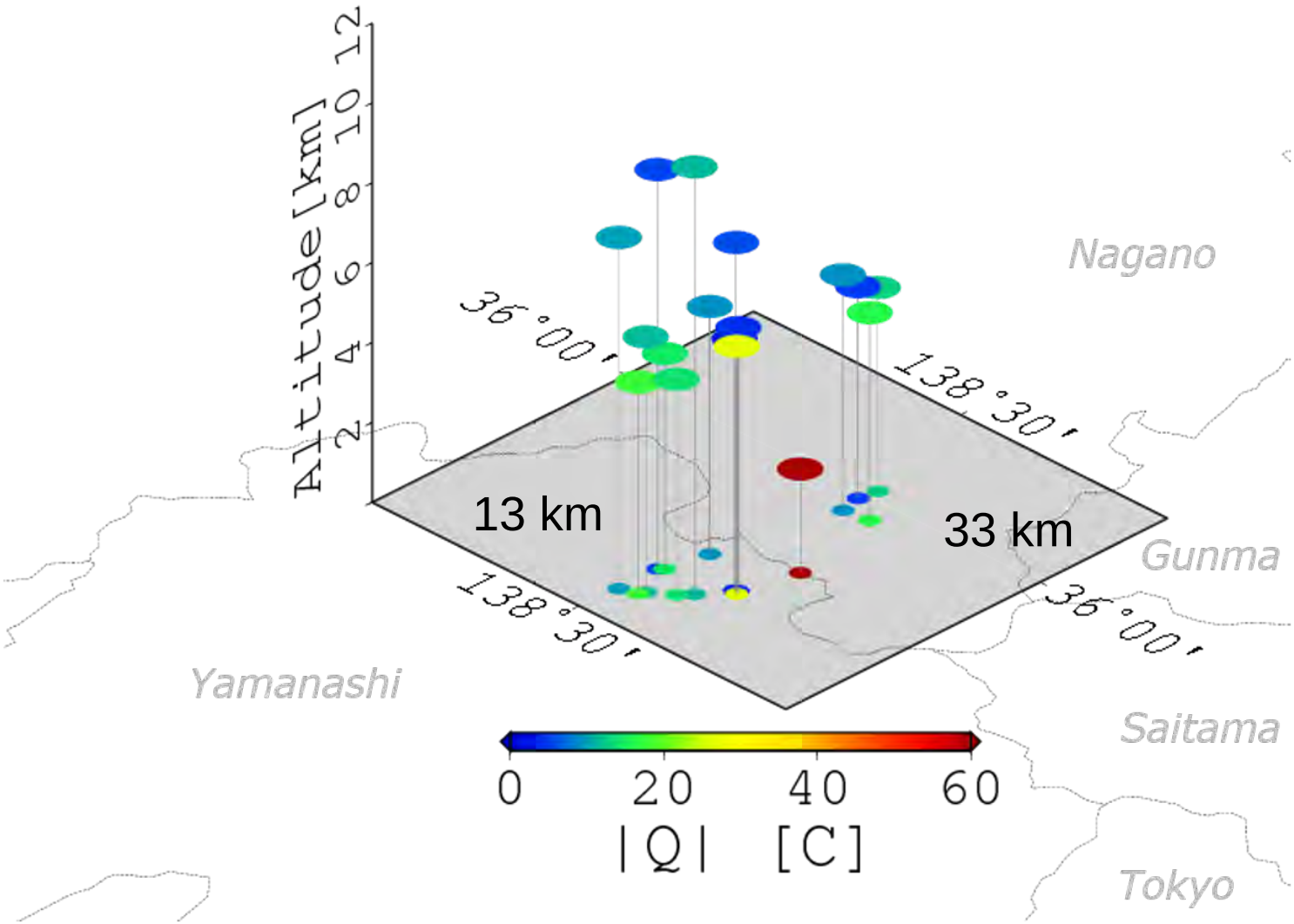
estimated locations of discharges (2013/08/15, 12:00-15:00)



Negative pulses recorded at 4 sites

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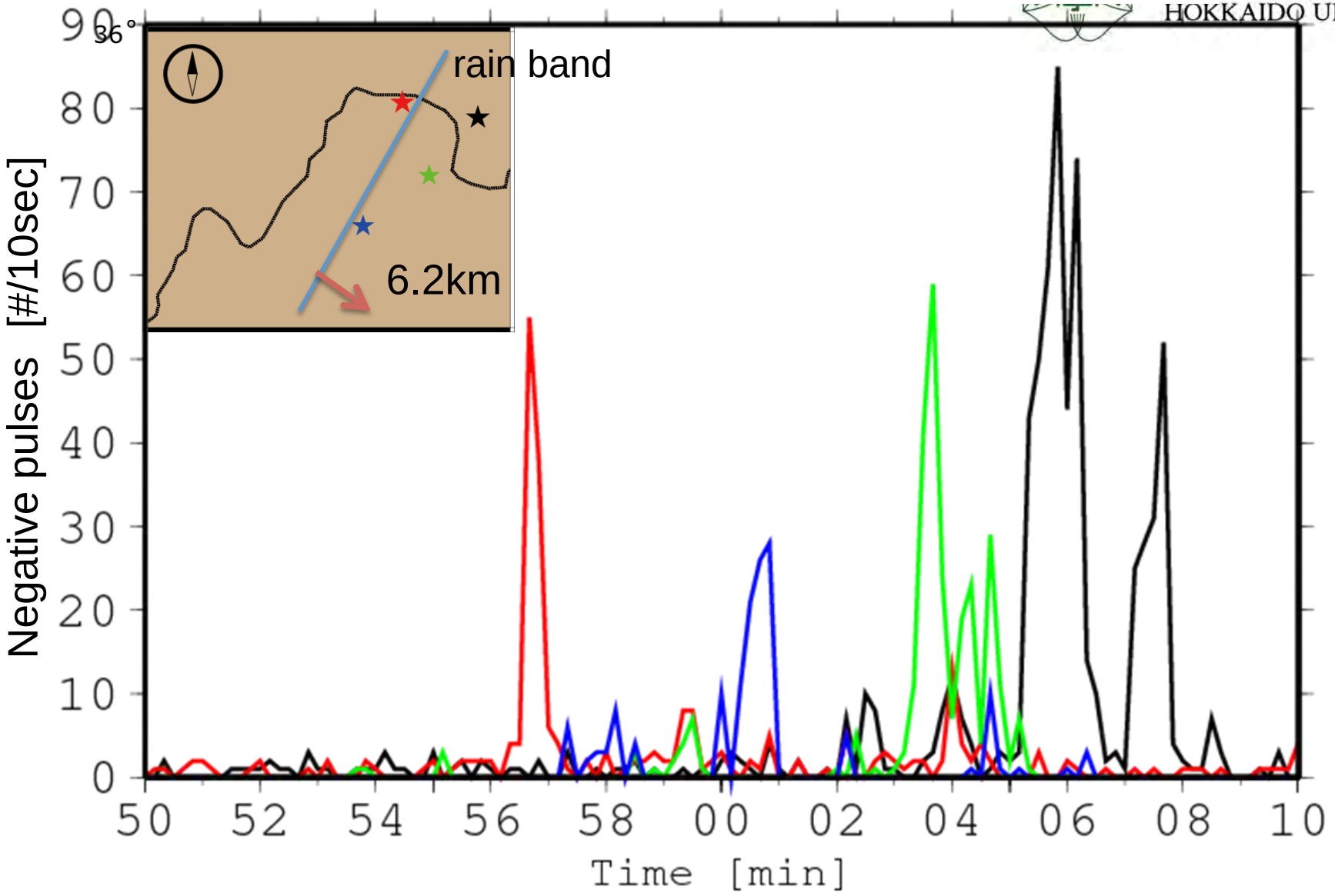

- Estimated velocity of rain band motion: 34m/s
- spatial resolution is an order of few 100s m.

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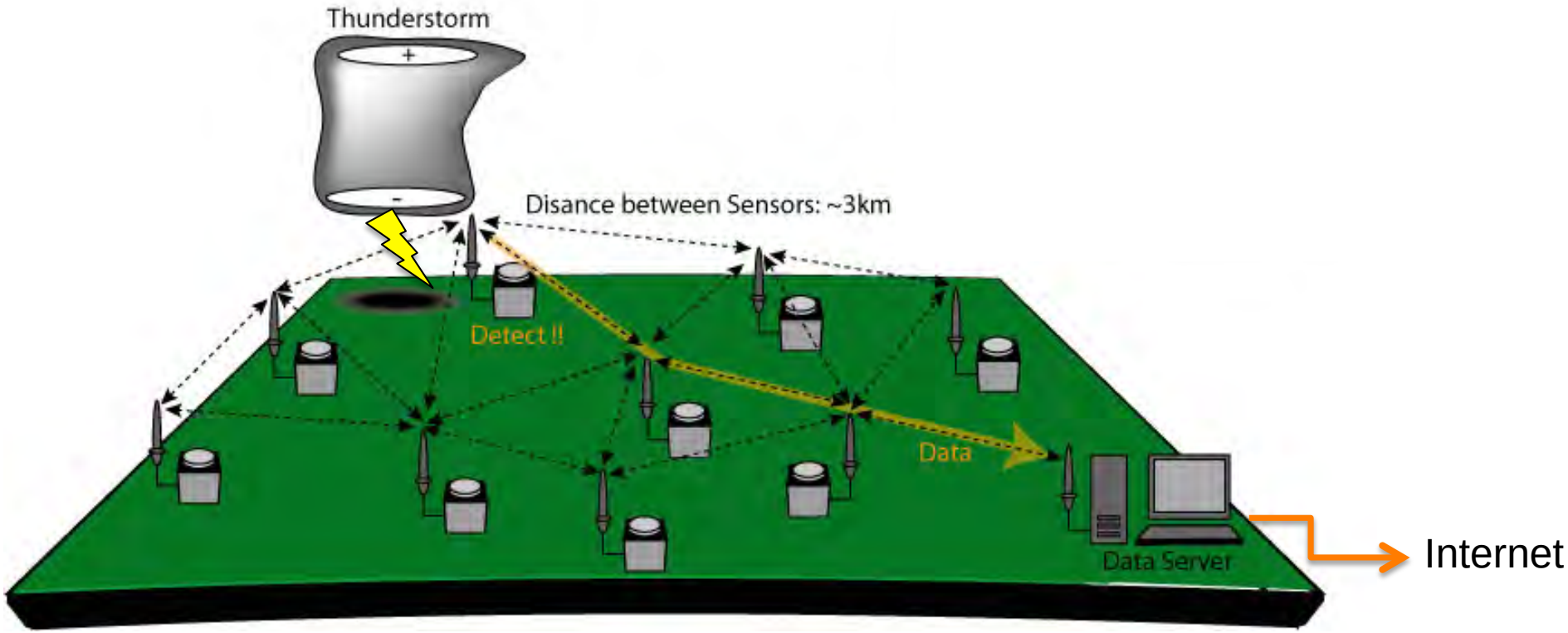
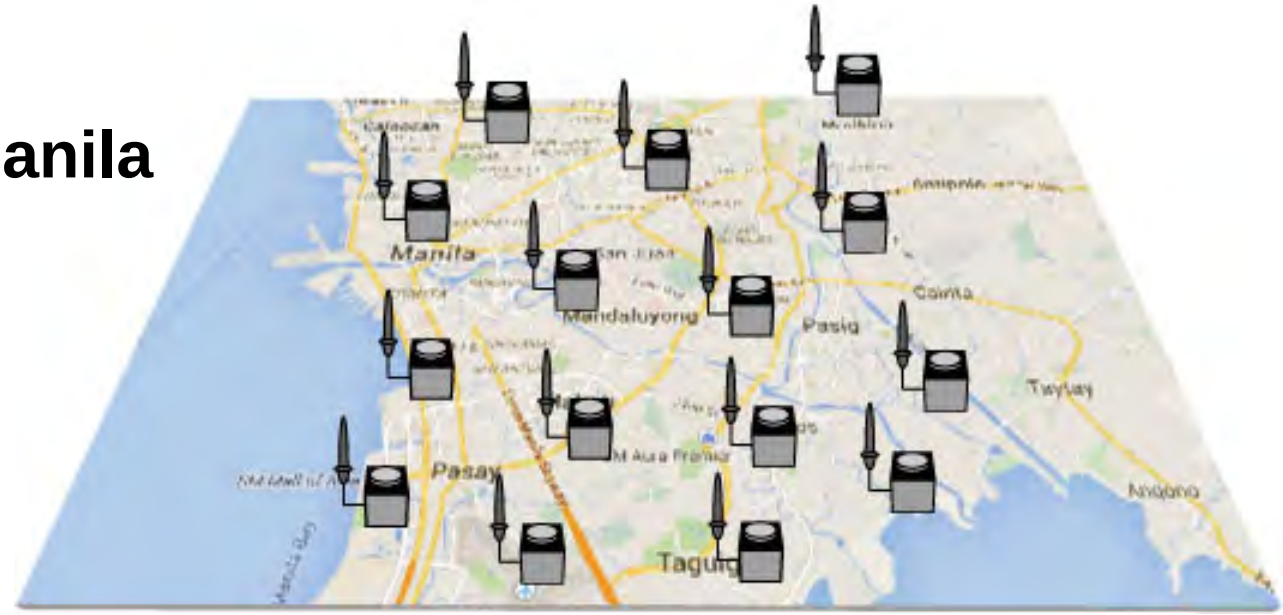


~15 sites are enough to cover big city area

Jakarta

Manila



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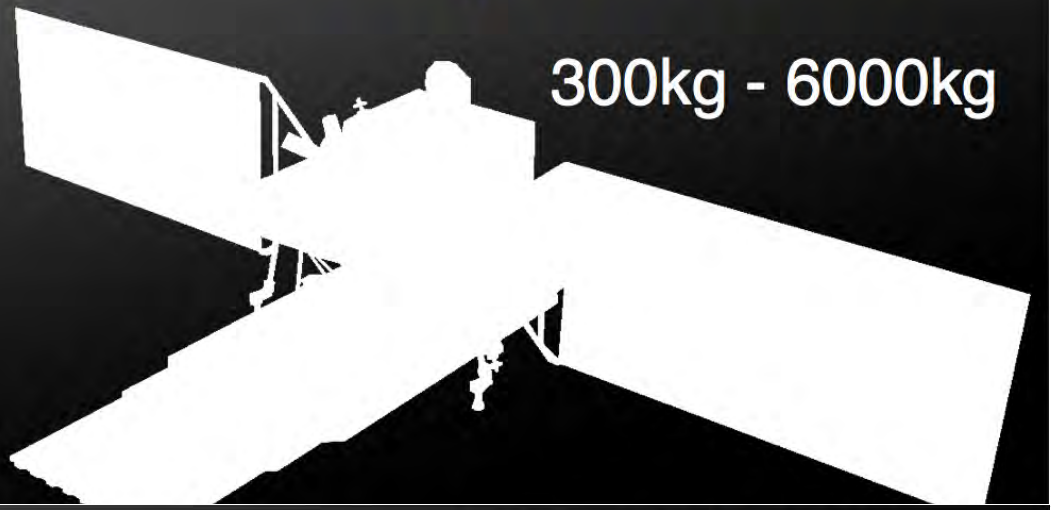
Breakthrough occurred in 2014 in utilization of very small satellites

Micro-satellite

50kg

Larger-satellite

300kg - 6000kg



3-5M USD

Quick fabrication (One year)

On-demand operation based on User's purposes

> A few 100M USD

Long period (>10years)

To carry heavy equipments

GiFT

RISING-2 satellite

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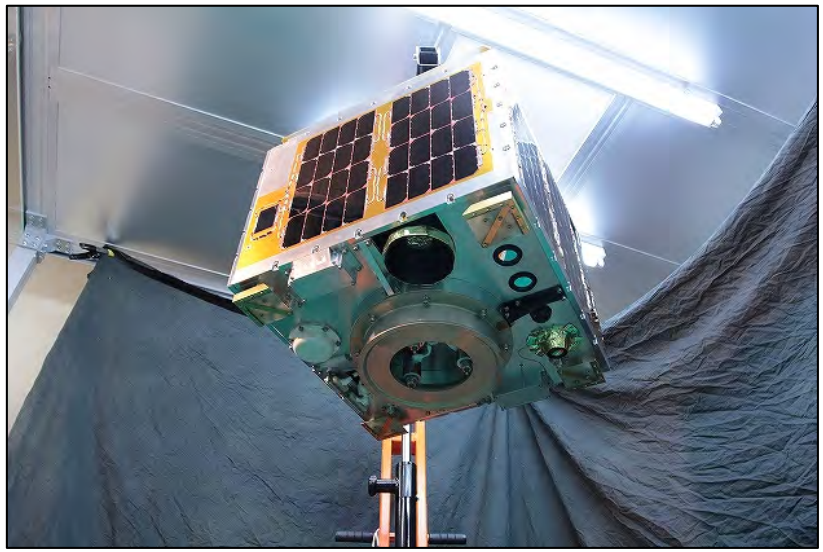
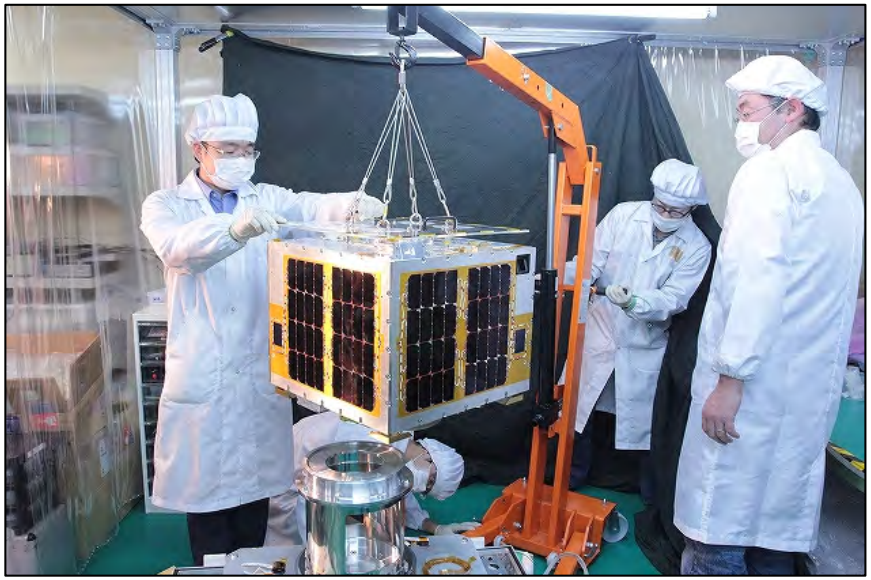
survived the big earthquake on the table of a building in Tohoku University





RISING-2 (launched May 24, 2014)

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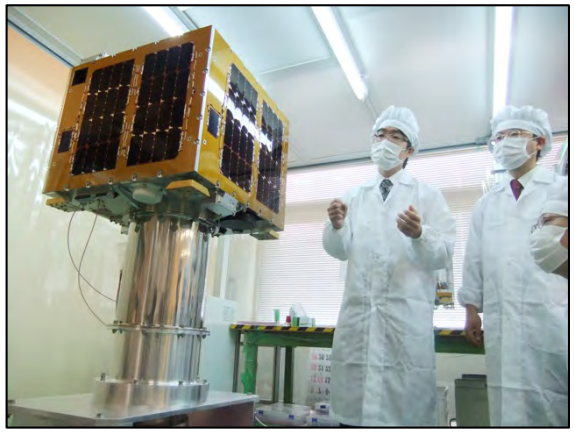
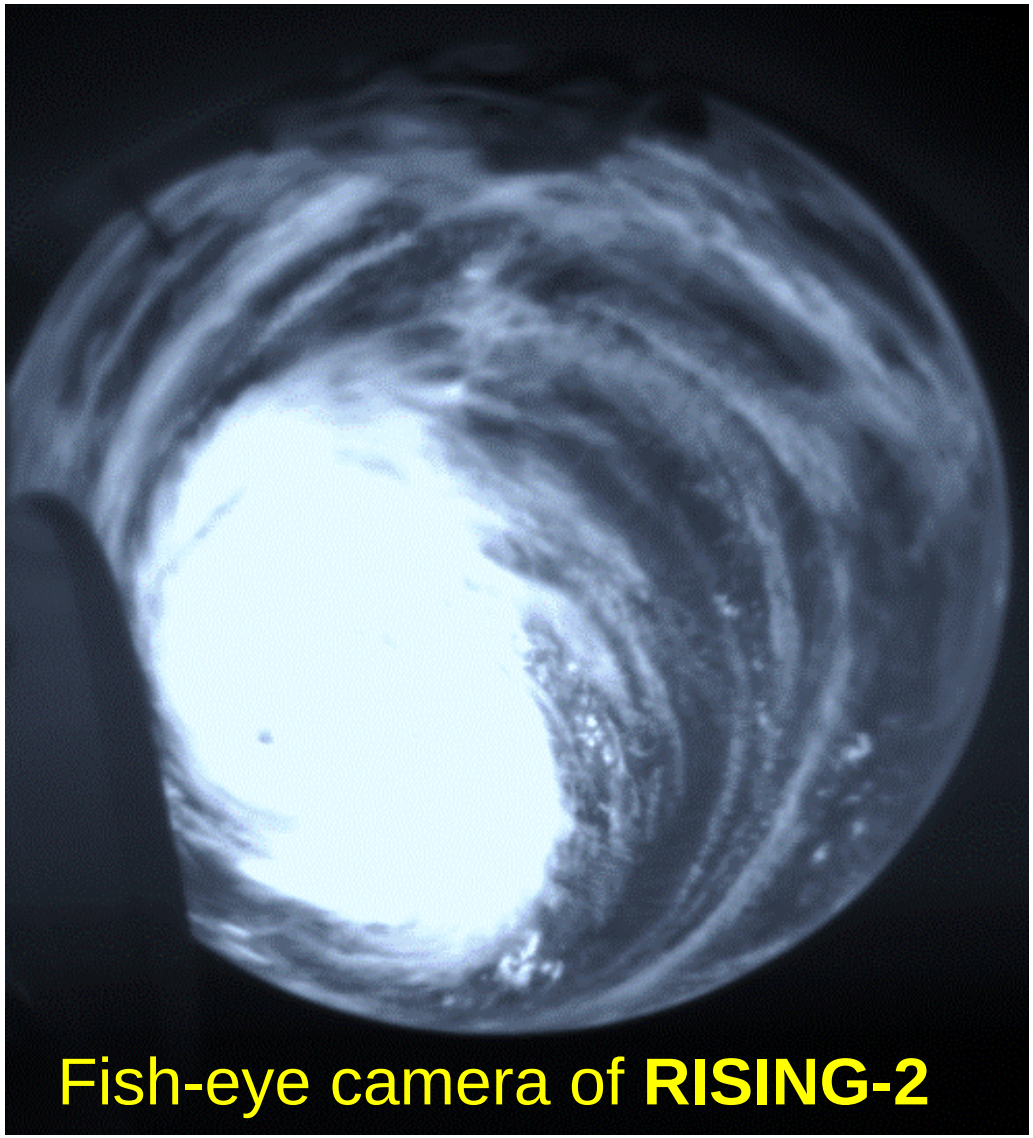
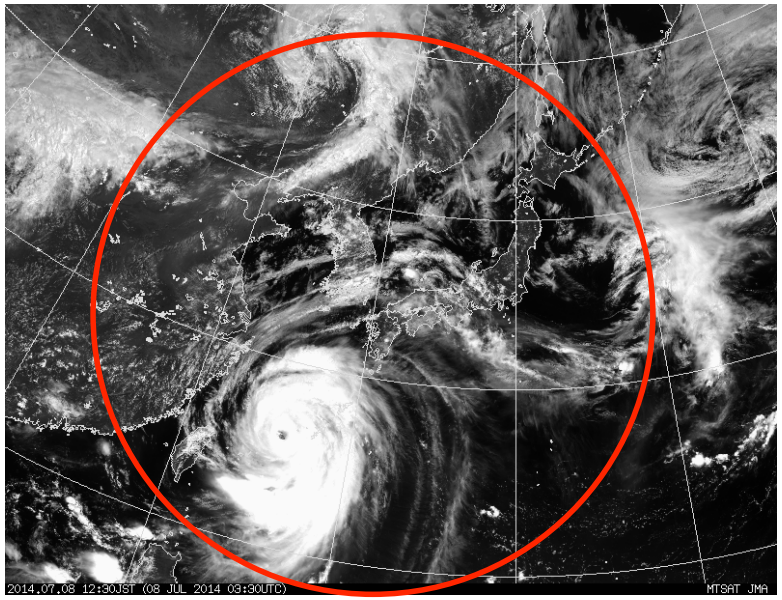


Operation at lab. (or at home)

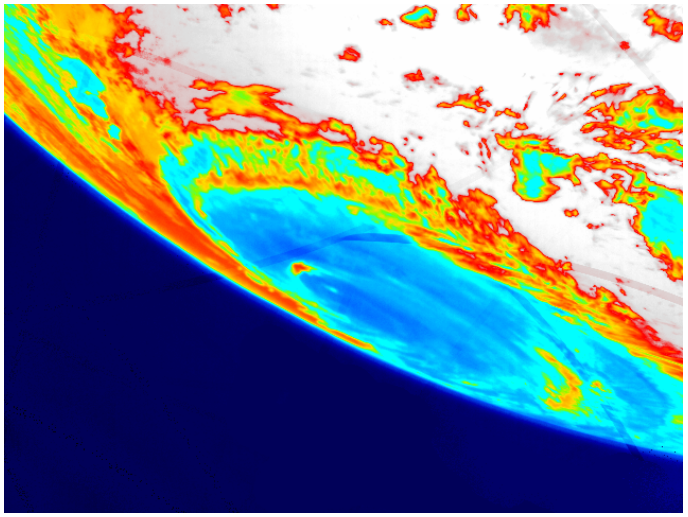
(C) JAXA

Typhoon 2014-#8 Nogree





from geosynchronous orbit



Thermal Infrared Image
by **RISING-2**

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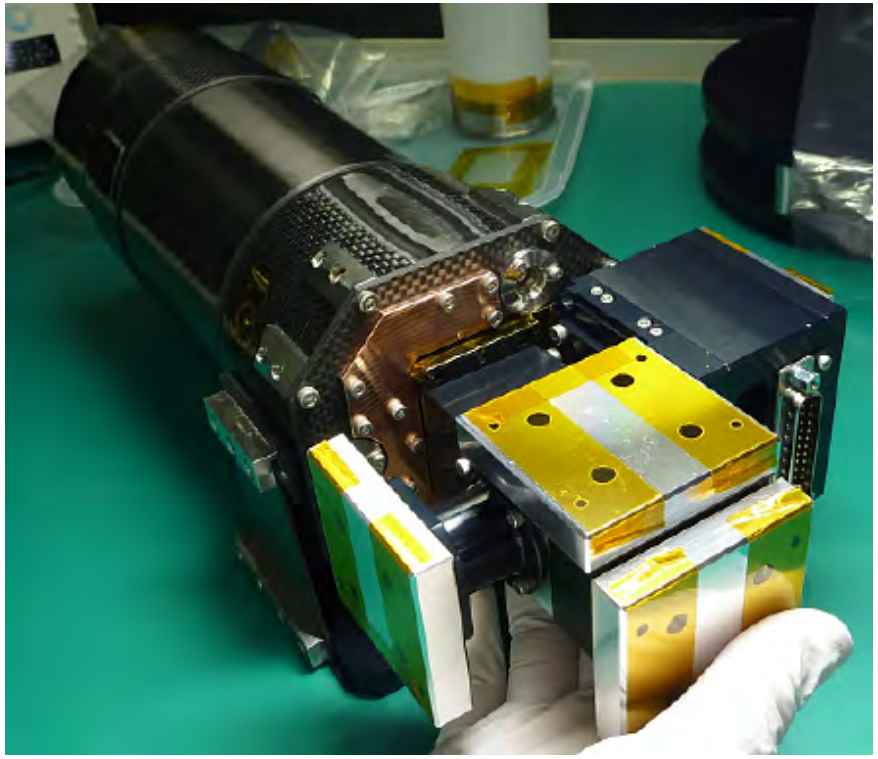
5m resolution color image
one of the best with 50 kg-class satellite

High Precision Telescope with Liquid Tunable Filter (HPT with LCTF)

the world first super multicolor LCTF imager in space



- Size: W380xD161xH124mm
- Weight: < 3.0 kg

- 1-m focal length, 10-cm dia. (F10), Case grain telescope
- 5-m resolution (659 x 494 pixels)
- 3-CCD (R,G,B) + Multi spectrum CCD
- Liquid Crystal Tunable Filter (LCTF)
  - range: 650 - 1050nm
  - 1-nm step selection (400 wavelengths)
  - order of 10s-msec switching time

- High sensitive (ISO8000)
- 1/50,000s min. exposure time
- light and strong stiffness CFRP structure
- zero-expansion high stiffness ceramic mirror (ZPF)

Liquid Crystal Tunable Filter camera

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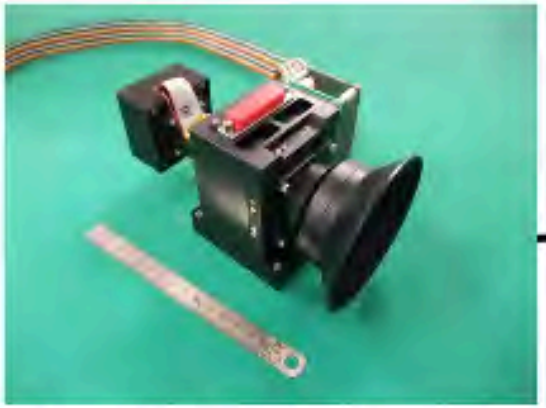
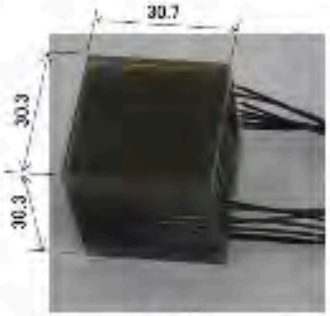
Airborne Multicolor Imager (AMI)



Multispectral Camera
- Wide FOV lens
- High-sensitive CCD
- Liquid Crystal Tunable Filter (LCTF) for Visible
- 190 x 100 x 100 mm
- 1.3 kg

Camera controller
- 100-240 V AC input
- USB 2.0 interface
- 300 x 200 x 60 mm
- 2.0 kg



LCTF

Specifications	
Wavelength range	420 - 700 nm
Band width (FWHM)	8 - 25 nm
Response time	< 0.3 sec
Frame rate	> 1 frame /sec
Number of pixels	659 x 494
Field of view	92 degree

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Aircraft (UAV) campaign with AMI in Java （2012/10/29-31）

UAV developed and owned by **BPPT**

10/31 ~18:40
forest in the target area

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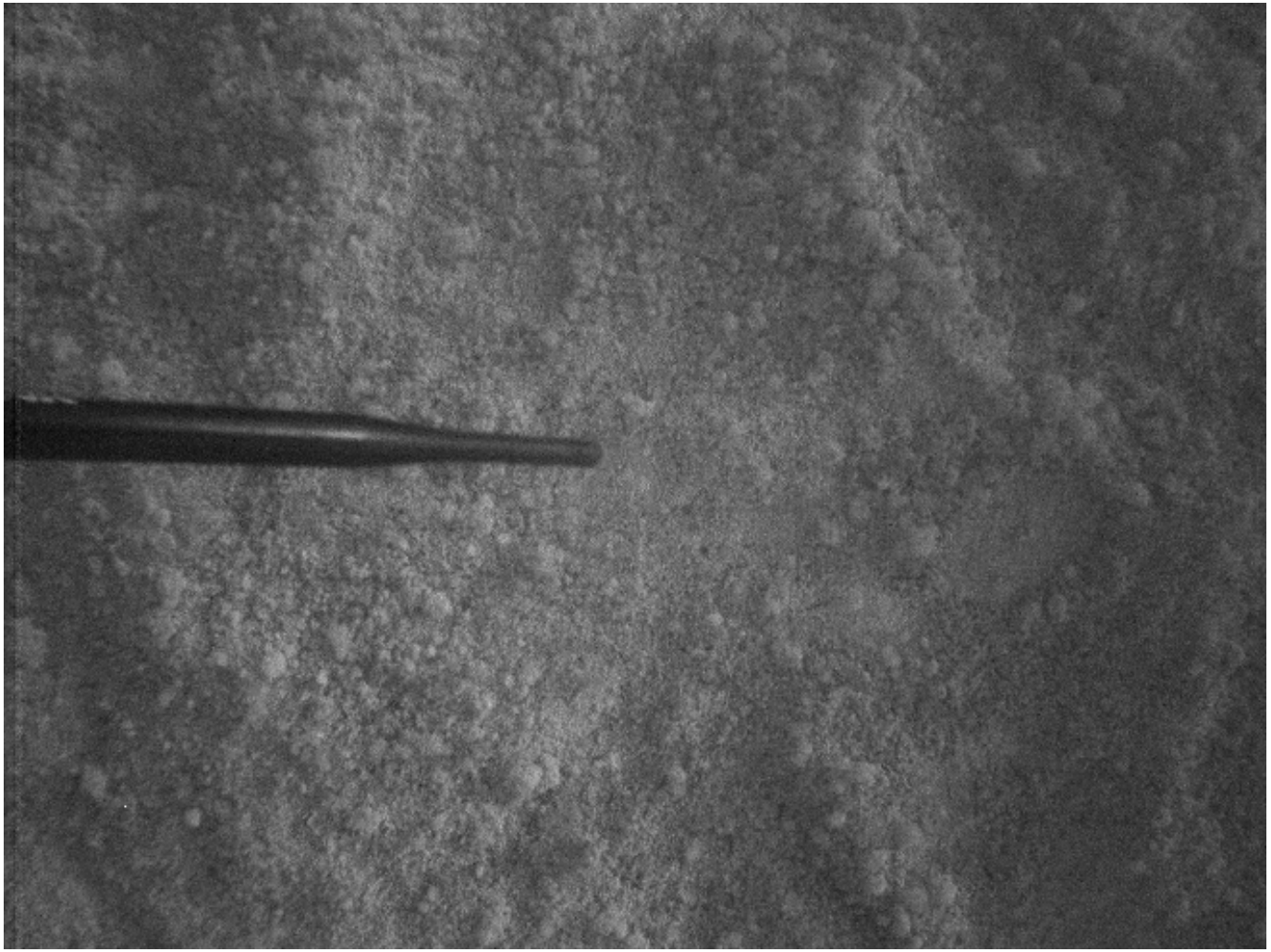

flight direction
of UAV
~ 30 m/s

2.5 m/pixel

~1.2 km

@420 nm

18h:40m:08s:918ms

~1.6 km

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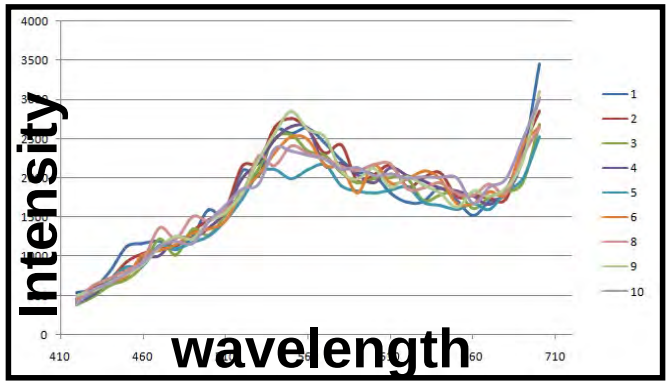
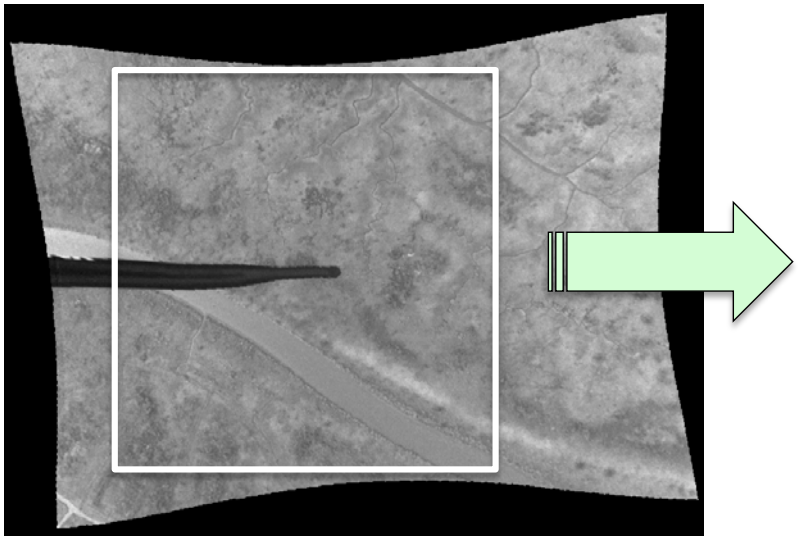
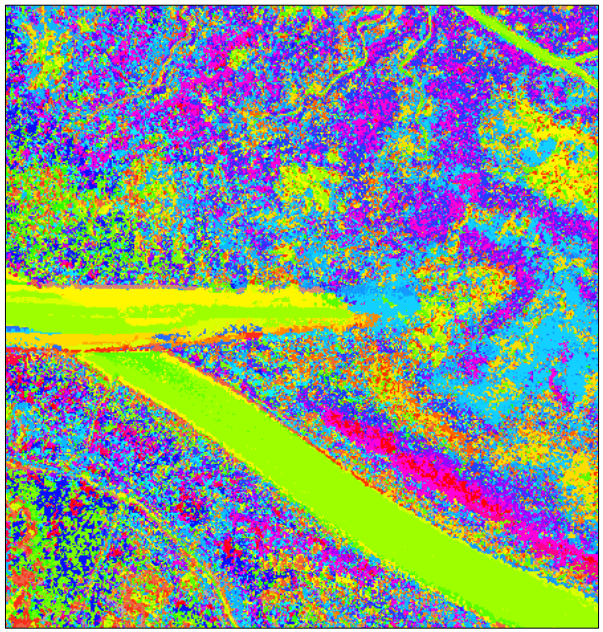


from 30 wavelengths

900 m





classification of species or monitoring condition for each tree...

”disaster” and ”usual environment”

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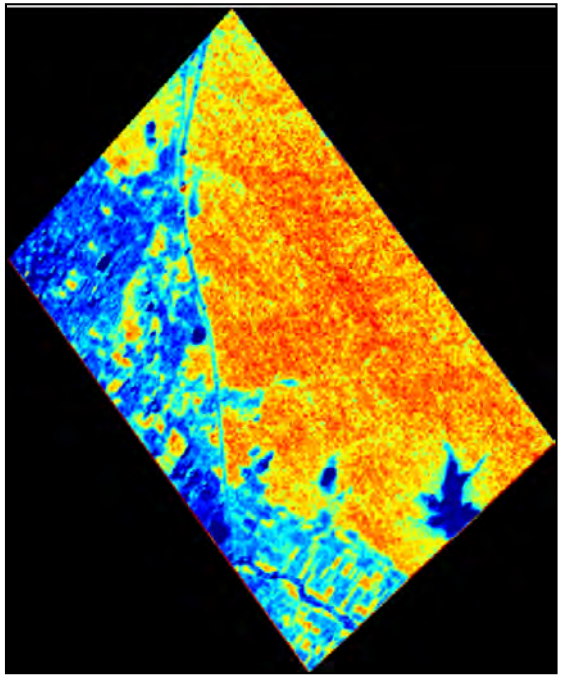
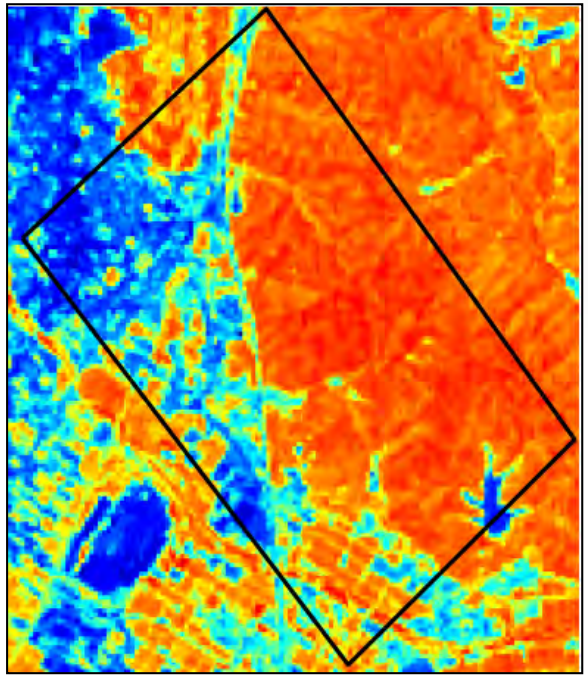
NDVI (vegetation index) = forest and crops
based on precise spectral imaging



RISING-2 (2014/9/14)



Landsat-8 (2013/8/14)

Hikone city

the detection of detail effects of disaster, such as tsunami, sea water, volcano ... pollution caused by disaster, on crops or environment.

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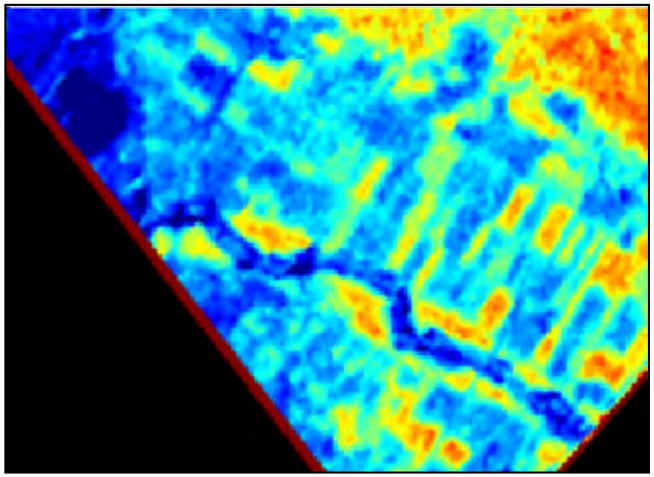
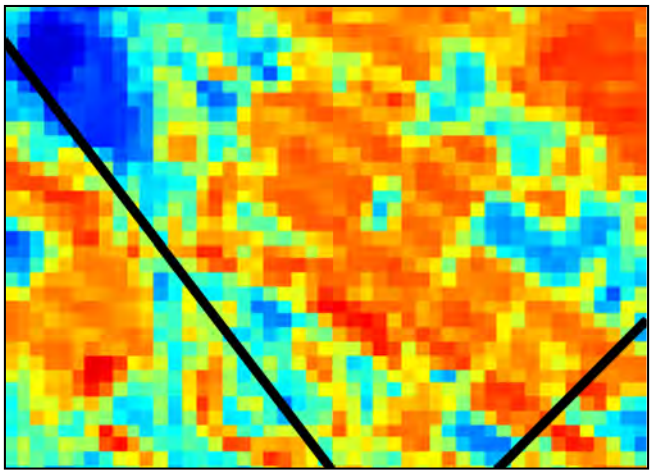
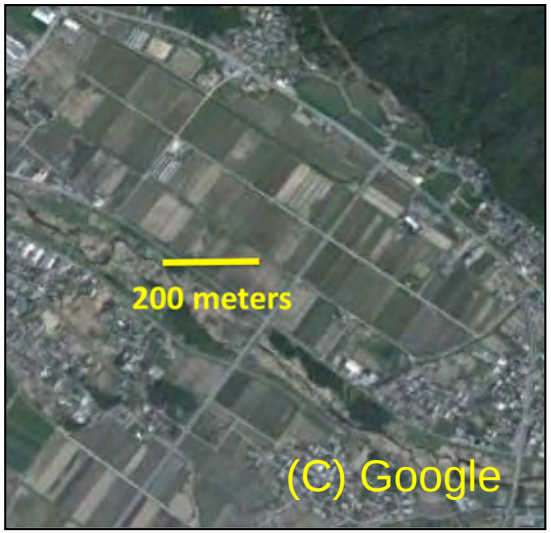
The world's best resolution of spectral imaging



RISING-2
5 m/pixel



LANDSAT-8
30 m/pixel



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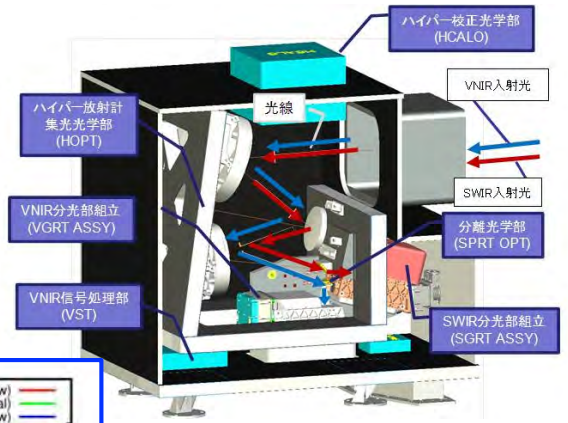
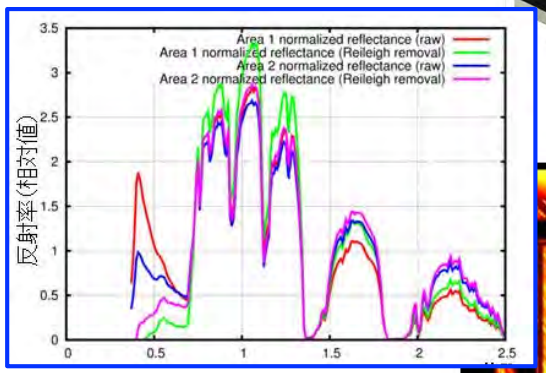
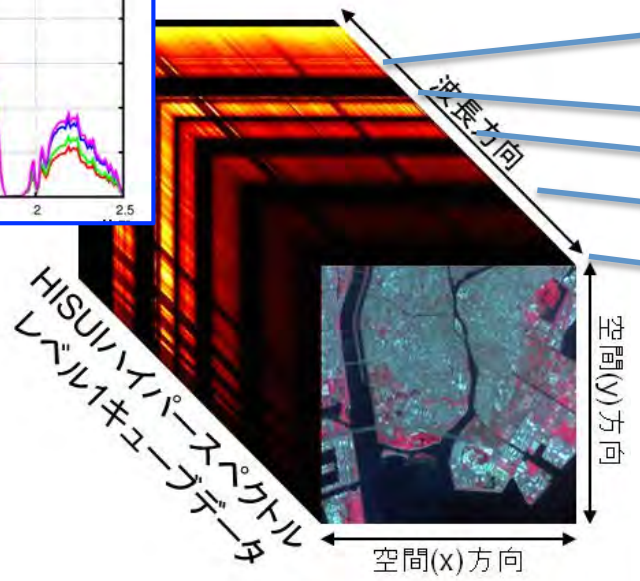
Hyperspectral sensor

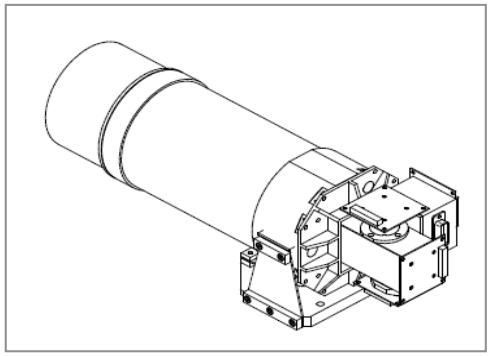


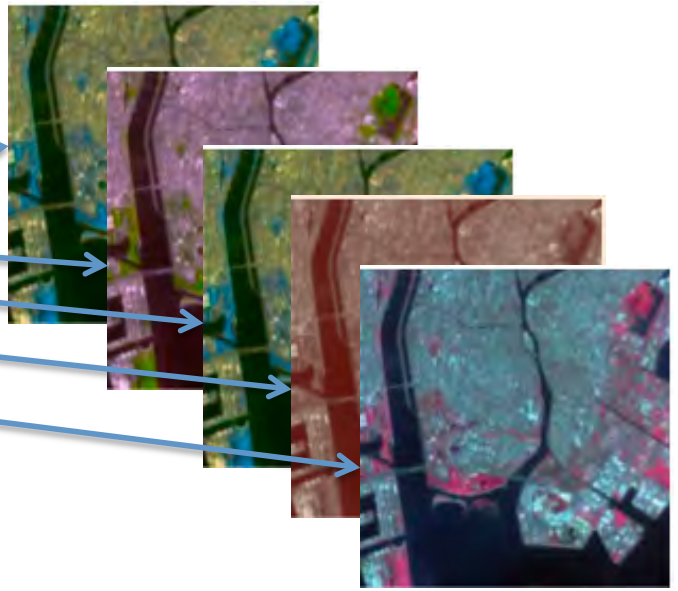




185 wavelengths, 30 m/pixel

LCTF camera





< 10 wavelengths, 5m/pixel

UNIFORM-1 satellite

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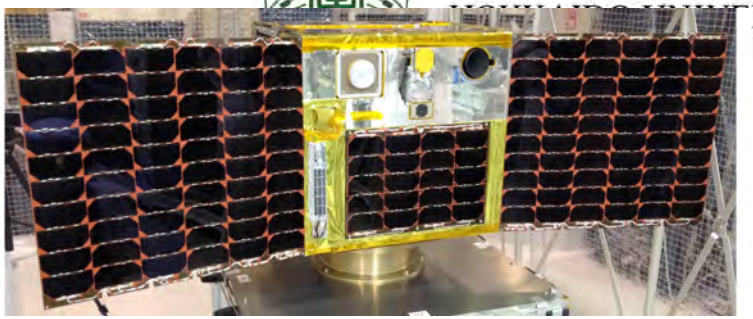
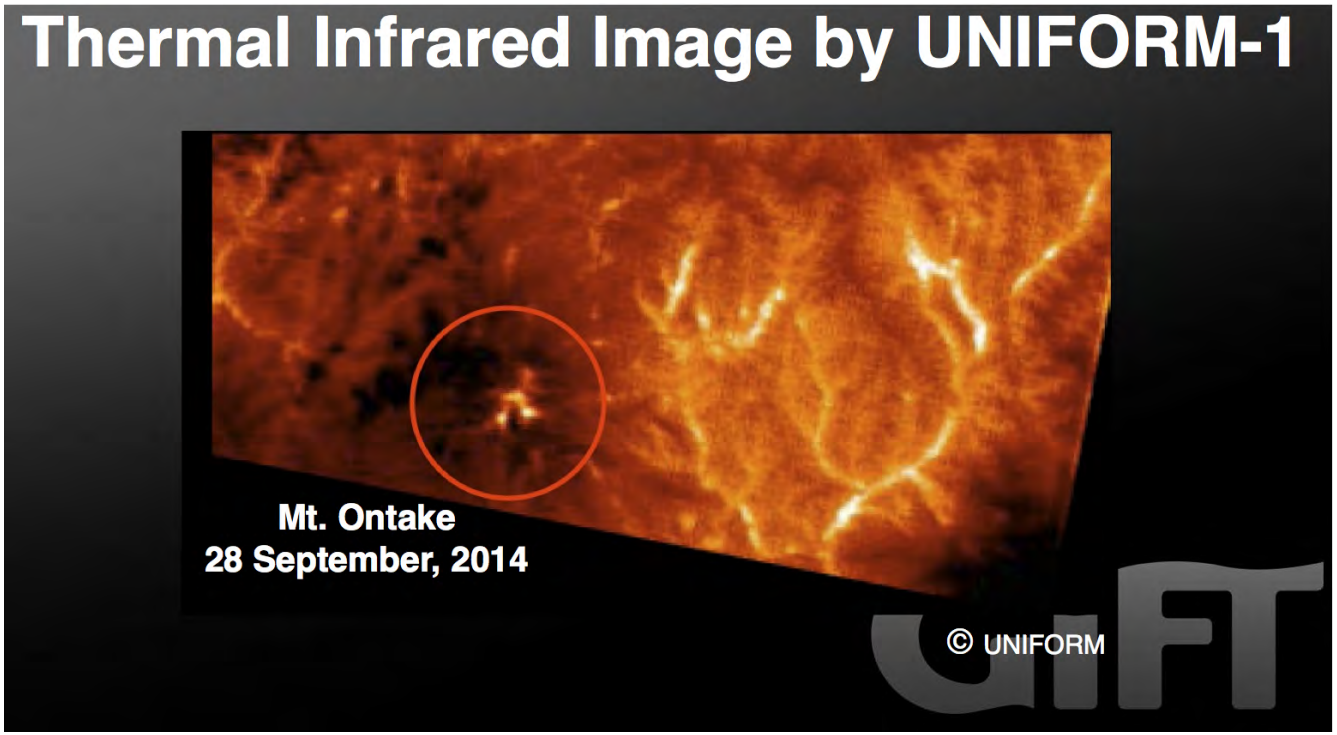


by University Union in Japan
launched in May, 2014
HU is in charge of sensor and data analysis

dedicated to forest fire detection + monitoring of volcano

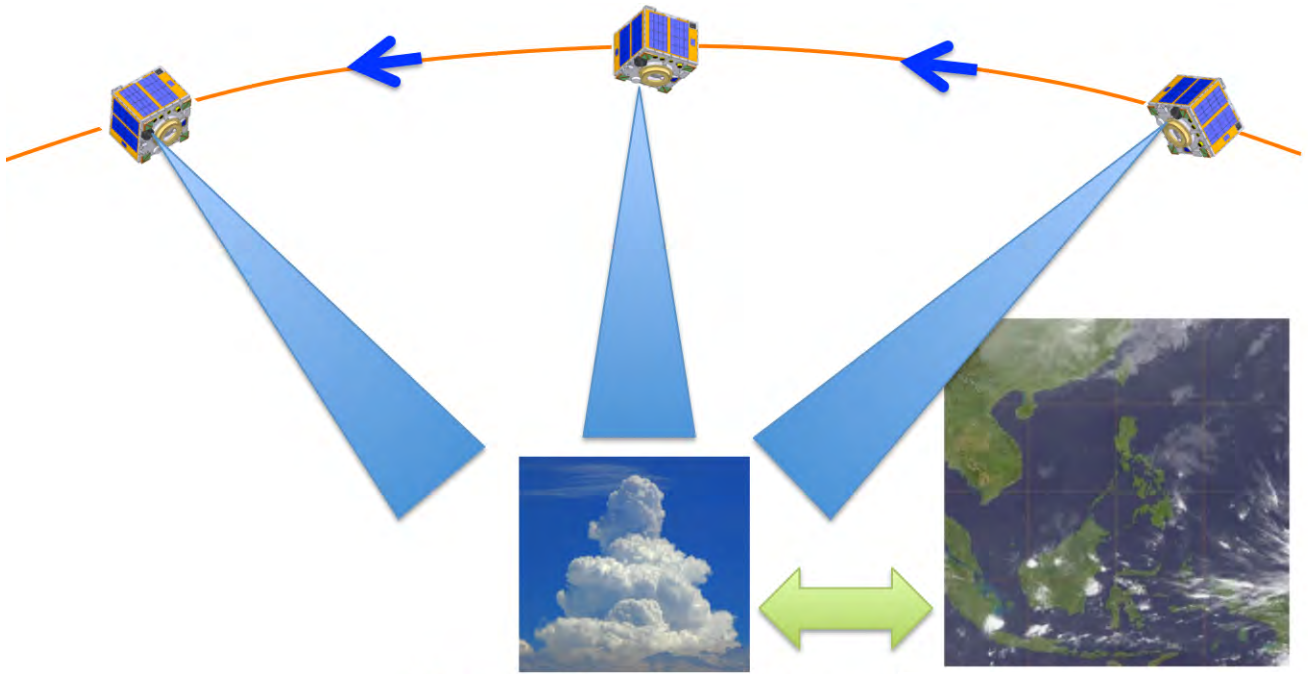


the earliest satellite report at infrared wavelength

Target Pointing by precise attitude control

... most of big satellites make pushbroom scan
by orbital motion...**1 time / 16 days**

- Flexible on-demand operation
  covering from nadir to horizon (>5000 km in diameter)
  enables frequent visiting (**2 times / day** in daytime)
- 3-D reconstruction



10m resolution by micro-sat. 0.5-1km res. by meteorological sat.

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~50 satellites realize continuous monitoring

- usually used for environmental research or agriculture/fisheries...
- once disaster happened, concentrate on the disaster area
  under international consortium

Asian Micro-satellite Consortium

sharing technologies, data and application methods

establishing **standardization** of sensors and BUS operating system

collaboration in making **ground validation**

AMC 48 Asian Micro-satellite Consortium 48

being contacted universities, space agency, and government in Asian countries.

To be started with ~10 countries officially soon.
(now under the final correction of MOU)

Asian Micro-satellite Consortium

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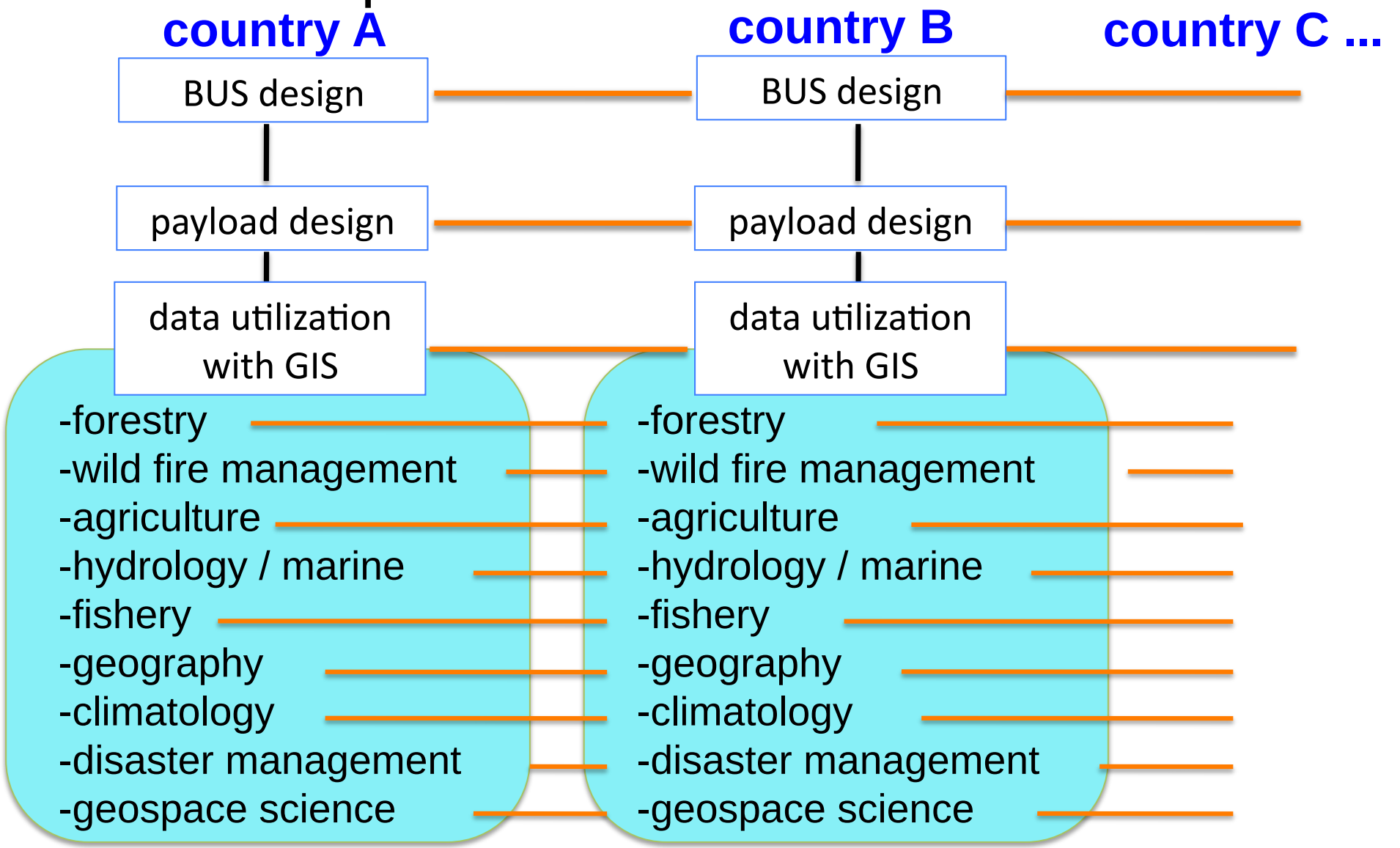
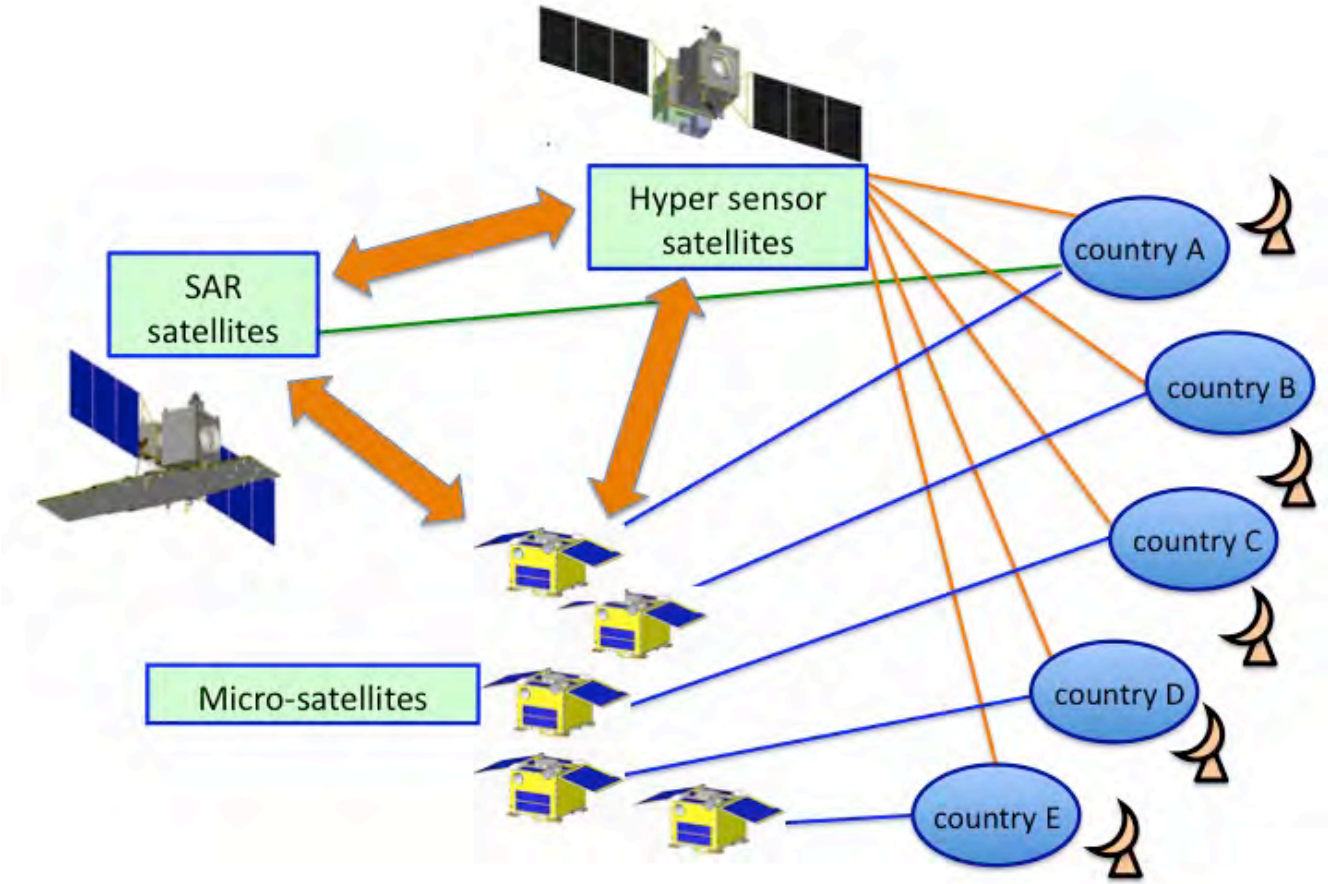
- to maximize the efficiency of space use

- to realize the super-constellation

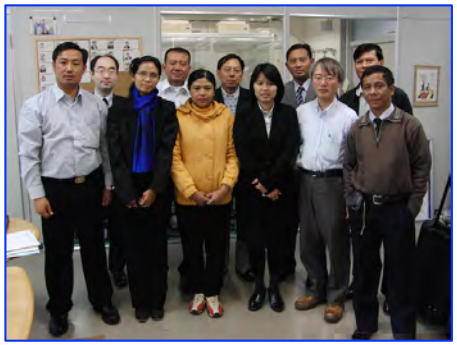


Space Remote-sensing Alliance

promoted by Asian Micro-satellite Consortium



Philippines



Myanmar

representatives from 6 countries

Space Mission Center (SMC) of H.U.

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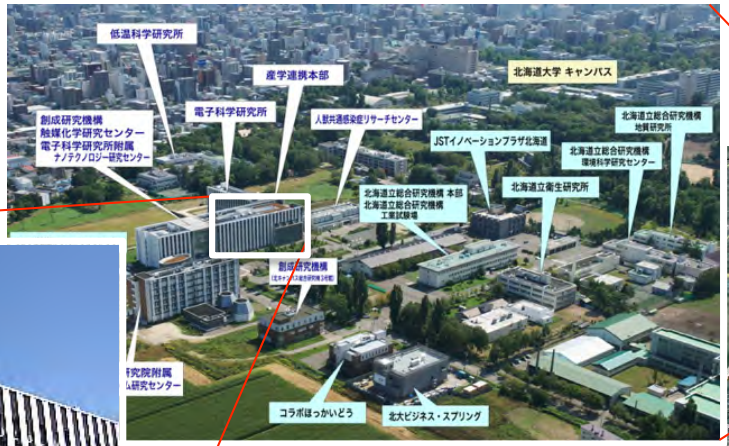

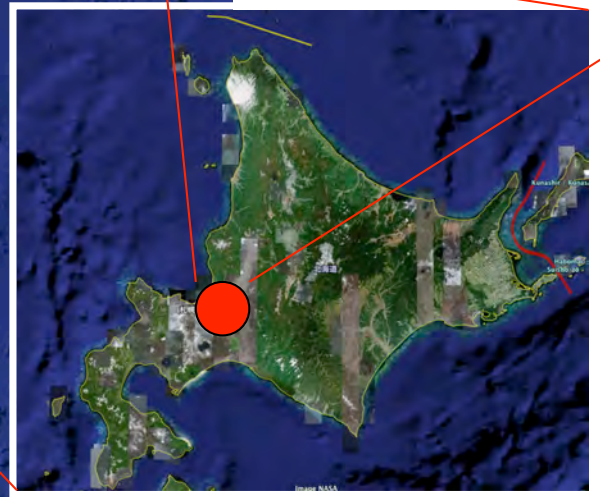

Facilities for development and testing in microsatellite development lab.

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One stop site for micro-satellite development

■ Thermal chamber

■ Thermal vacuum chamber

■ Class 100 clean booth and darkroom

■ Vibration test facility,
■ Shock test facility,
■ Radio wave darkroom are available at Hokkaido Research Organization

Next generation disaster monitoring and prediction system

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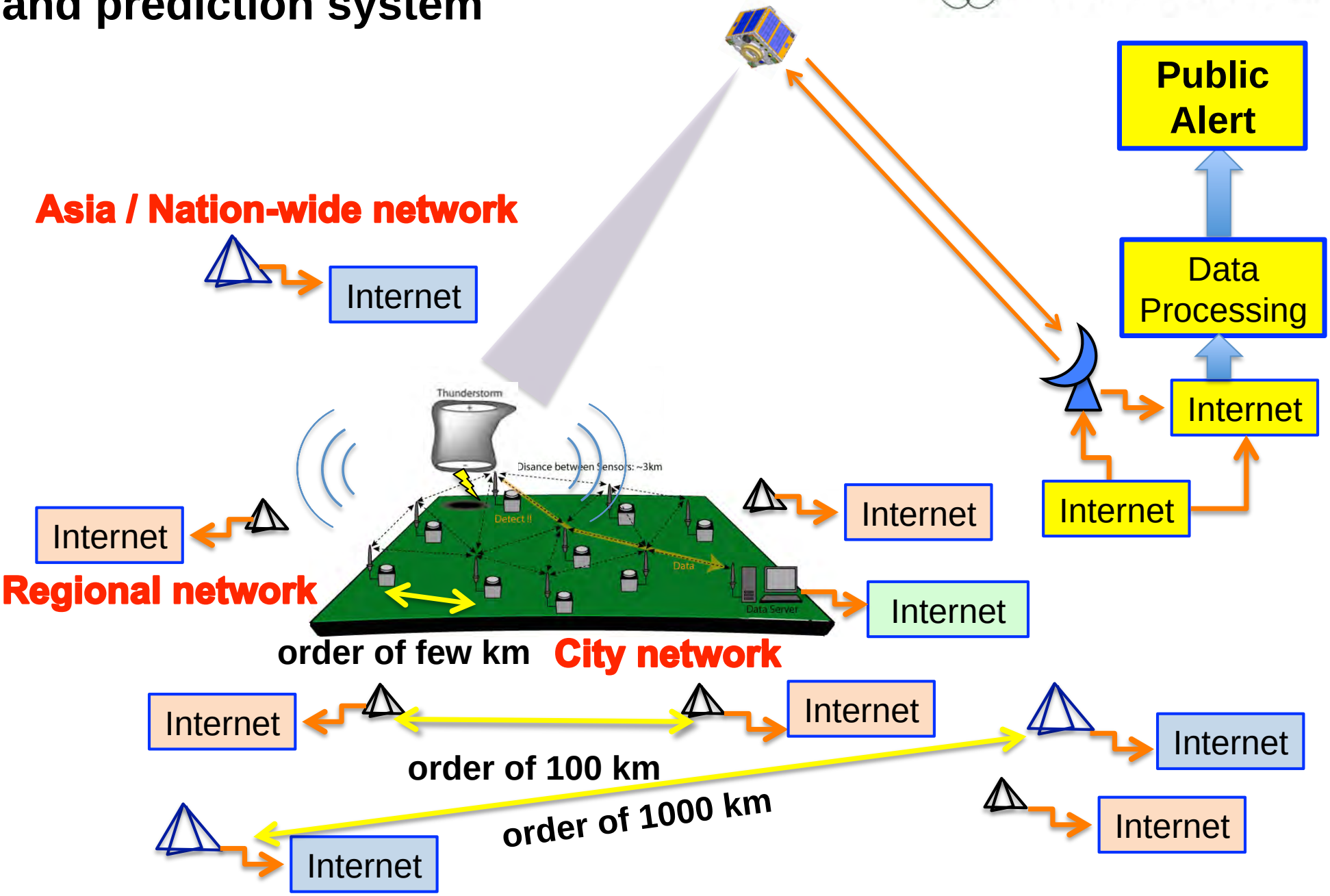

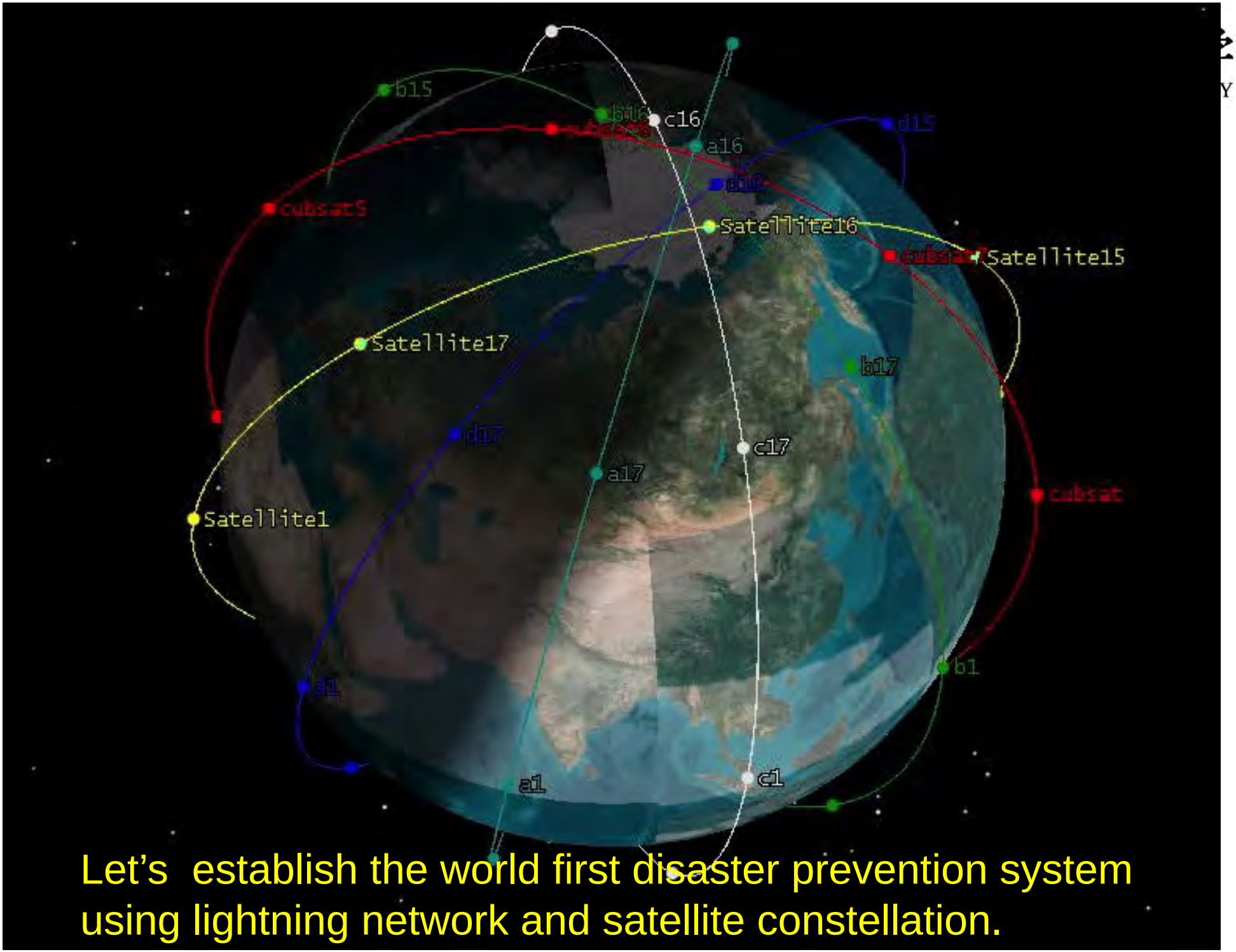

Let’s establish the world first disaster prevention system using lightning network and satellite constellation.