Ground-based lightning and AWS network system for alert of torrential rainfall and typhoon combined with micro-satellite constellation

Yukihiro Takahashi¹, Mitsuteru Sato¹, Hisayuki Kubota¹, Tetsuro Ishida¹, Meryl Algodon², Ellison Castro³, Loren Jay Estrebillo², Purwadi², Gay Perez³, Joel Marciano⁴, Kozo Yamashita⁵, Jun Matsumoto⁶, Jun-ichi Hamada⁶

¹. Faculty of Science, Hokkaido University, Japan
². Graduate School of Science, Hokkaido University, Japan
³. Institute of Environmental Science and Meteorology, University of the Philippines Diliman, Quezon City, Philippines
⁴. DOST-ASTI, Quezon City Philippines (now at PhilSA, Philippines)
⁵. Division of Electrical and Electronic Engineering, Ashikaga University, Ashikaga, Japan
⁶. Department of Geography, Tokyo Metropolitan University, Hachioji, Japan
SATREPS: Japan-Philippines joint project (JST-JICA, DOST)

e-ASIA: "Monitoring and prediction of extreme weather using lightning detection network and micro-satellites" (JST, BPPT, DOST)
Related programs

supported by DOST-PCIEERED

LAPAN A-4 satellite project (launch in 2020)
supported by LAPAN and BPPT

Core-to-core program (2016-2019. Mar) supported by JSPS
"Establishment of observing means for dynamics of the Earth environment
in Asia with micro-satellites"

SATREPS/ULAT (2017-2022) supported by JST-JICA
"Development of extreme weather monitoring and information sharing system in the Philippines"

AVON: Asia VLF observation network
GEON: global ELF observation network
Asian Micro-satellite Consortium: 9 countries in Asia
Background
Monitoring and understanding **thunderstorm** is the key for disaster prevention of torrential rainfall and typhoon.

**Thunderstorm and torrential rainfall**
- flood, inundation
- downburst
- tornado

**Typhoon**
- flood, inundation
- violent wind
- high tide

**Lightning**
- one of the main causes of internet trouble
- electrical blackout
- human life
Thunderstorm is difficult object to observe
--- very strong but its scale is too small ...

Geostationary Meteorological satellite: 0.5-1.0 km
C band radar: resolution ~1-2 km

Sample of **X-band radar** (250m resolution) observation
we cannot get information behind heavy rain area...

Typhoon
>24 hours prediction has been improved
for the **location** of typhoon center
But intensity prediction has **not** been improved...
Our purpose

To establish the new methodology of real-time monitoring and short term prediction for thunderstorm (0.5-1 hour) and typhoon (1-2 days).
1. LIGHTNING
Our AVON (Asian VLF Observation Network) for scientific research

- Indonesia
- Thailand
- Taiwan
- Vietnam
- Philippines
Figure. Dipole antenna (left panel) and loop antenna (right one) installed at Los Banos, Philippines.
Example of geolocation based on 3 stations observation.

Geolocation of lightning by Time-of-Arrival method

ΔT₁
Difference of arrival timing between Tainan and Saraburi

ΔT₂
Difference of arrival timing between Saraburi and Pontianak

ΔT₃
Difference of arrival timing between Pontianak and Tainan

accuracy ~30km
2. MICRO-SATELLITE
Personal computer

Micro-satellite

50kg

3-5M USD
Quick fabrication (One year)
On-demand operation based on User’s purposes

Super computer

Larger-satellite

300kg - 6000kg

> A few 100M USD
Long period (>10 years)
To carry heavy equipments
Conventional satellites

LANDSAT-8: pushbroom imaging

revisiting period: 16 days
Our micro-satellites: DIWATA, RISING-2, LAPAN A series, etc.

On-demand target pointing
DIWATA-1, the first Philippine micro-satellite and released from International Space Station (2016.4)
UNIFORM-1 satellite with Thermal Infrared sensor developed by Hokkaido University

Volcano eruption

Typhoon observation with RISING-2 satellite
Final goal: next generation disaster monitoring system
Lightning observation system installation and analysis
Lightning sensor (POTEKA) installation

POTEKA system with lightning sensor (Sapporo station)

Training in Japan

Serpong station
Typhoon network

Typhoon 24, Trami/Paeng
26 Sep 2018

~1500 km interval

+: geolocated lightning

VLF receiver

30 km accuracy for geolocation
6 sites completed
Nation-wide network

~300 km interval

VLF receiver
Infrasound (>0.01 Hz) + AWS

3 km accuracy for geolocation
>5 sites/10 sites completed
Metro Manila network

~4 km interval

Slow antenna (quasi static E field)
Field mil (static field)
Infrasound (>0.1 Hz)
+ AWS

100 m accuracy for geolocation
>32 sites/50 sites completed
Micro-satellite
- On-demand operation and 3-D imaging
- Development of thermal infrared
Stereo imaging by consecutive exposures
STEREO imaging by DIWATA-1

Catro master (2018) work (Hokkaido Univ)

The world’s first detailed 3-D cloud top structures observed by satellite
On-demand target pointing
Target pointing of typhoon eye

Typhoon 24, Trami/Paeng
26 Sep 2018
The world’s first precise 3-D image of typhoon eye processed by Hokkaido Univ.
LAPAN A-4 will be launched 3rd Quarter of 2020

Thermal Infrared Camera (TIS)

In order to estimate the cloud top temperature of thunderstorm
Heritages and on-going projects with 50-kg satellite

50-kg satellites (launching year)

SPRITE-SAT (2009)
RISING-2 (2014)
UNIFORM-1 (2014)
DIWATA-1 (2016): Philippines
DIWATA-2 (2018): Philippines
RISESAT (2019)
MicroDragon (2019): Vietnam
LAPAN A-4 (2020) Indonesia
Myanmar (2020-) x 2 Myanmar
MMSAT (2021-) x 2 Malaysia
Future scopes
Latitudinal range of the Philippines

Future scope
Latitudinal range of the Philippines

7,000 km
6,400 km
2,300 km
800 km
24 deg
Future scope
10 satellites in equatorial orbit
Asian Micro-satellite Consortium

to maximize the efficiency of space use, sharing data, toward the **super-constellation** realizing real-time monitoring

- sharing data, technology, and application
- standardizing sensor and operation system
- establishing ground validation

- involving **9 countries in Asia**
- signed by representatives of 16 universities/institutes
Super constellation under international collaboration

If we share ~50 satellites, continuous monitoring of disaster anywhere in the world will be possible.

Satellite + Ground = next generation earth monitoring