“Confidential”

Cloud Top Height Estimation using Satellite Image and Ground Based Image

Oct.25th,2017

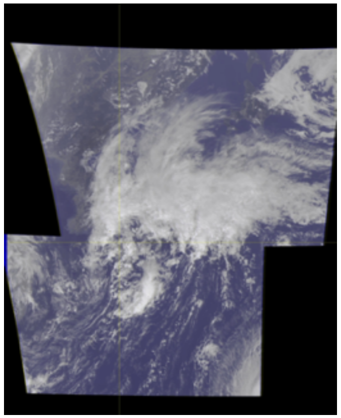
Takuro HANYU

Weathernews Inc.

weathernews *Always WITH you!*

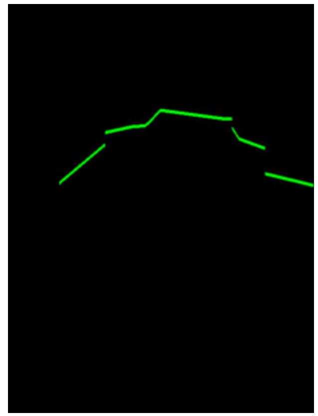
Conclusion

How wonderful is **novelty using ground based image** taken by you to get detailed information of the upper layer.



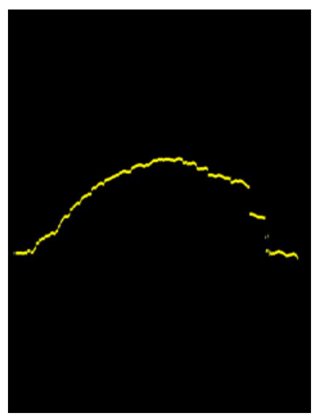
Satellite image

Standard atmosphere & Coordinate transformation

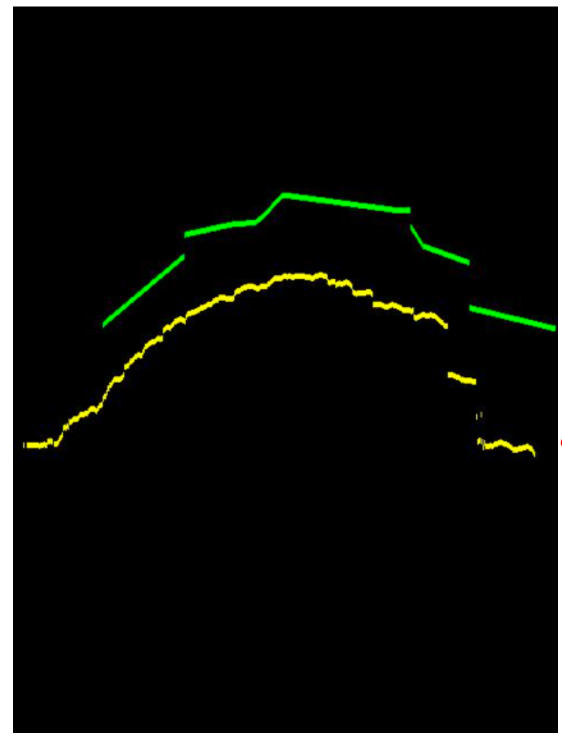


GPS azimuth elevation

Ground based image



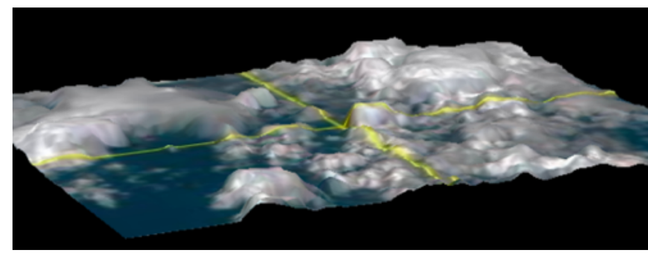
Skyline of screen image



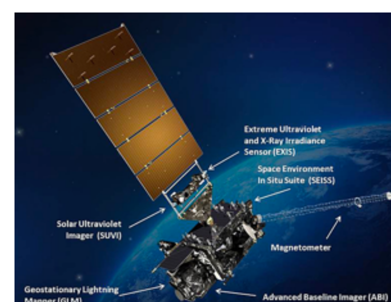
ex) Lower than estimation by satellite

Purpose

- **Benefits**
  - To use as observational data.
  - To correct of the upper temperature as initial value of NWP for data assimilation.
  - To correct the 3D form for visualization.



- **Background**
  - Satellite data upgrading : High resolution & High frequency
    - 2017 Nov. 30th~ GOES-16
    - 2015 Jul. HIMAWARI-8



Outline

- **Data**
  - Satellite image : HIMAWARI-8
  - Ground based image : weather report
- **Method**
  - Geometric approach : Coordinate transformation,
    Perspective projection, Cross-correlation function
- **Results**
  - error evaluation
    h_real - h_img > f (FOV, pix, G, AD), range, growth speed

Data

● Satellite image

Himawari-8 infrared (Band 13 : 10.4µm)

Resolution : 2km , Time frequency : 2.5min

● Ground based image

- Weather report

  Picture taken by supporter

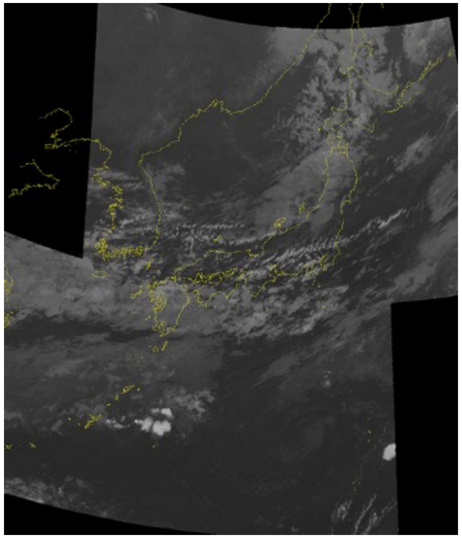
  GPS, azimuth, elevation

- Web camera

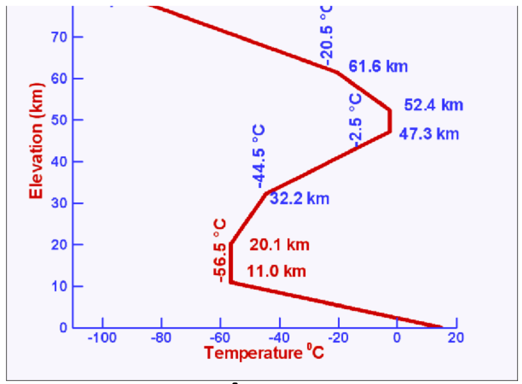
  Time frequency : 1min

  GPS, azimuth, elevation

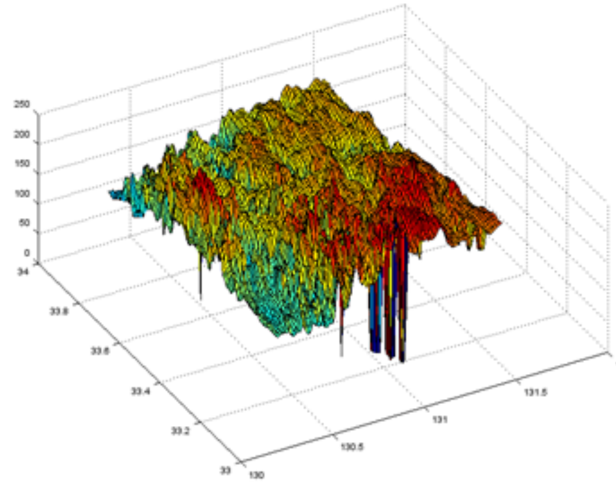
Pixel(x,y,brightness temerature) → lon, lat, height



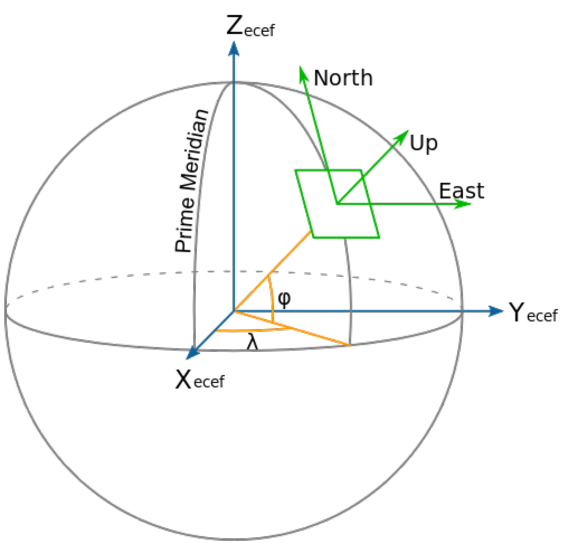
ISA (**I**nternational **S**tandard **A**tmosphere)



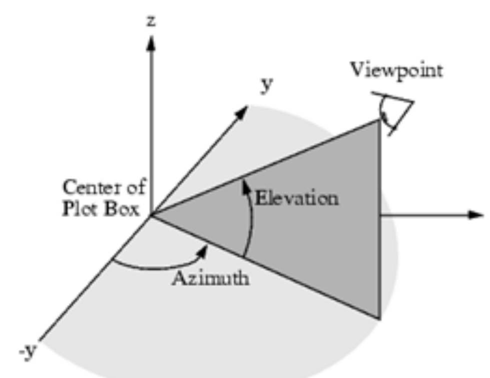
6.5K/1000m



→ Earth-fixed coordinate system

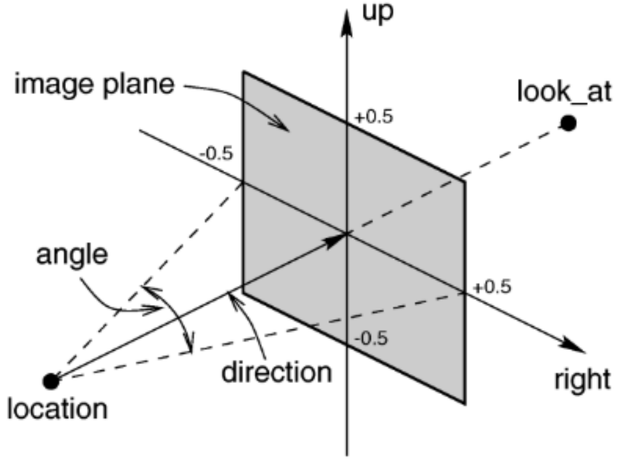


→ Viewpoint coordinate system



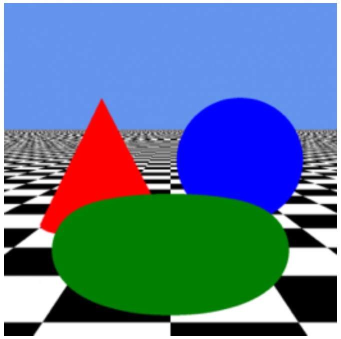
→ **Perspective projection**

(to reproduce like a image taken by smartphone)



→ **Shadow processing**

(to get the skyline from image)



→ **Skyline image from satellite**

Processing (3/3)

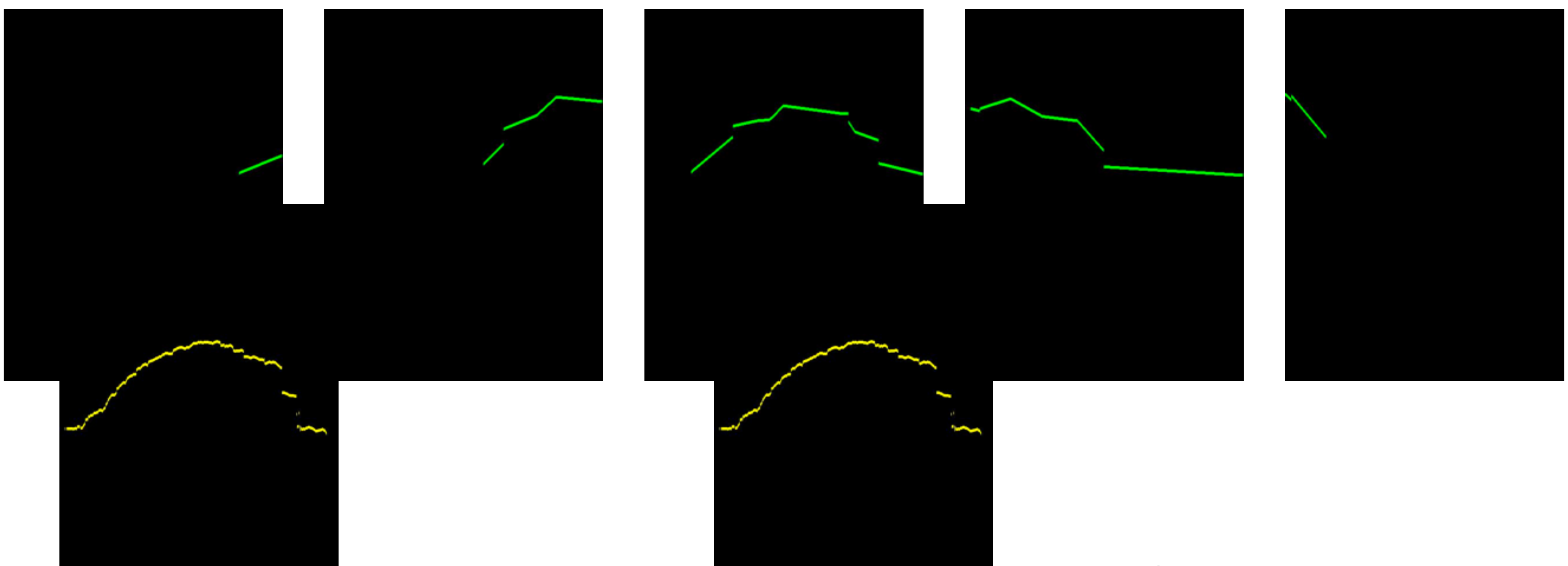
→ Cross-correlation function

(Azimuth with the highest correlation is taken as positive)

$$\phi_{xy}(m) = \frac{1}{N}\sum_{n=0}^{N-1} x(n)y(n+m)$$

$$r_k = \frac{\sum_{i=1}^{n-k}(x_i - m1_k)(y_{i+k} - m2_k)}{\sqrt{\sum_{i=1}^{n-k}(x_i - m1_k)^2}\sqrt{\sum_{i=1}^{n-k}(y_{i+k} - m2_k)^2}}$$

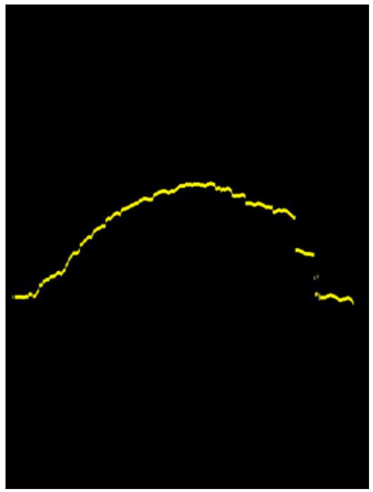
$$m1_k = \sum_{i=1}^{n-k} x_i \Big/ (n-k) \quad , \quad m2_k = \sum_{i=1}^{n-k} y_{i+k} \Big/ (n-k)$$



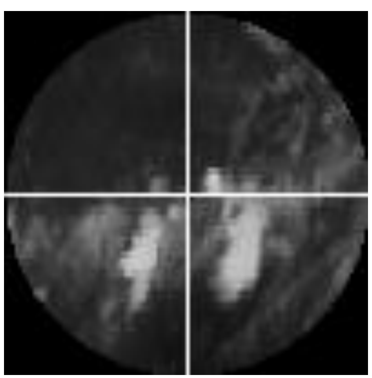
Sample results (1/3)

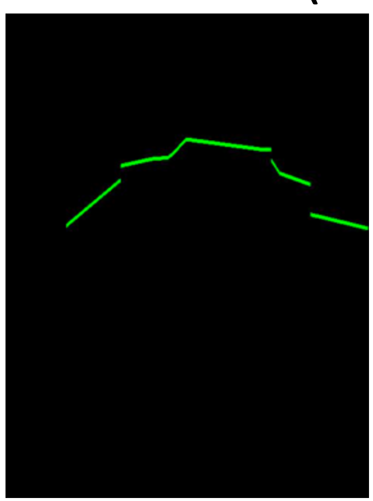
<INPUT>

report 2015-08-03 07:52:01(UTC)



satellite 2015-08-02 07:51:44(UTC)

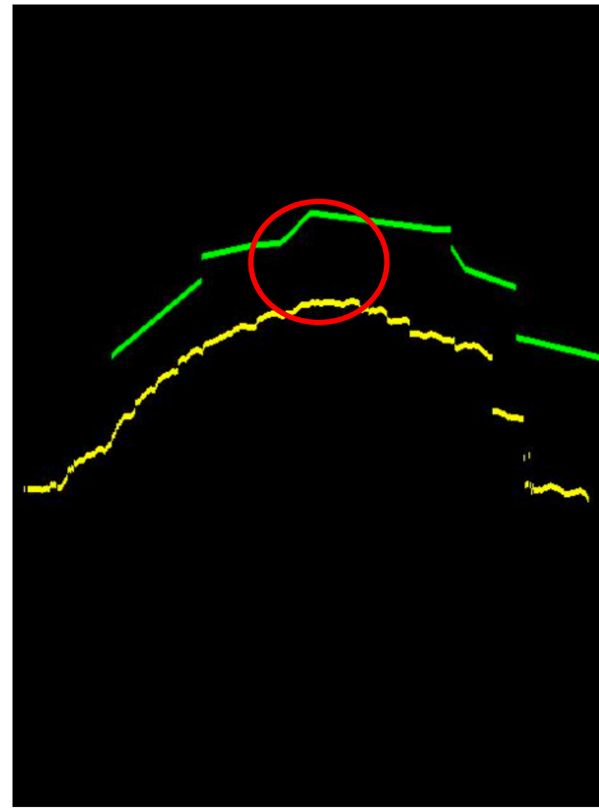




Azimuth : ENE / Elevation : 39.8 °

<OUTPUT>

cross-correlation coefficient : 0.82

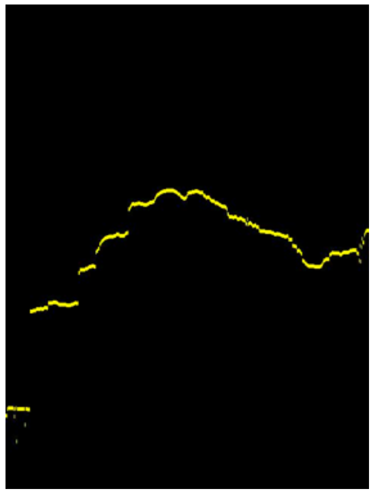


h_img(satellite)	**8,567m**
h_real(report)	**7,310m**
brightness temp	**232.5K**

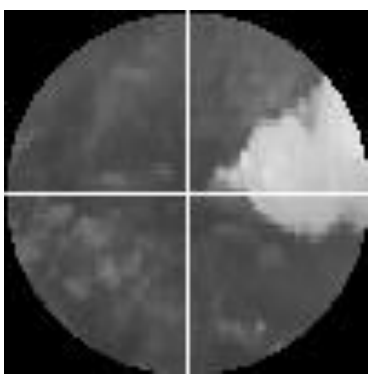
Sample results (2/3)

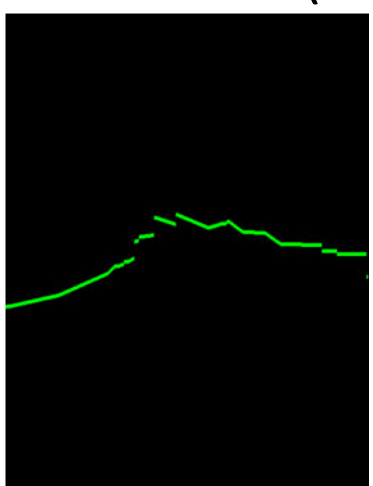
＜INPUT＞

report 2017-08-19 06:42:53(UTC)



satellite 2017-08-19 06:41:46(UTC)

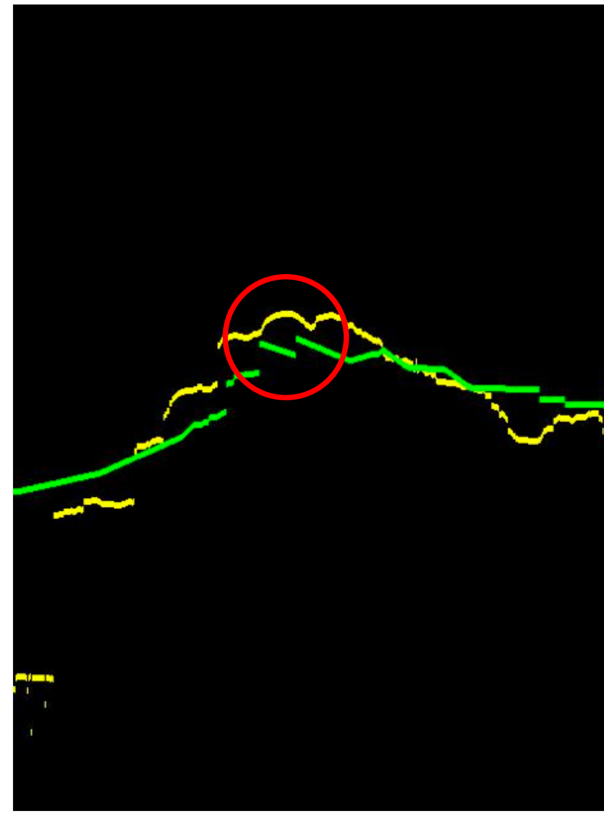




Azimuth : ENE / Elevation : 24.5 °

＜OUTPUT＞

cross-correlation coefficient : 0.88

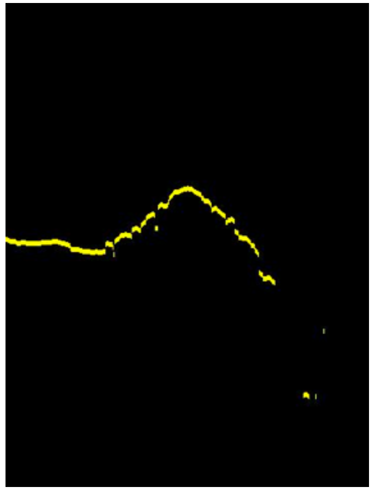


h_img(satellite)	**7,897m**
h_real(report)	**8,793m**
brightness temp	**236.8K**

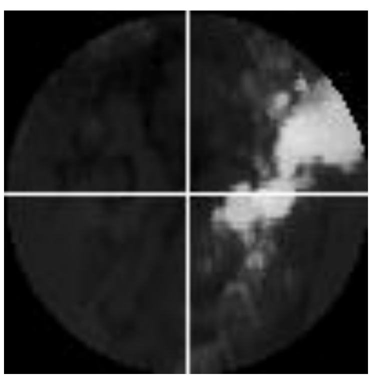
Sample results (3/3)

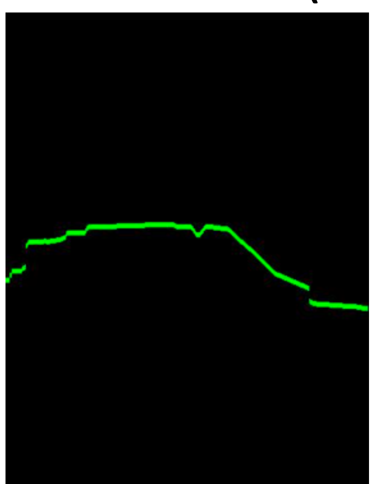
＜INPUT＞

report 2015-08-02 06:05:24(UTC)



satellite 2015-08-02 06:01:49(UTC)

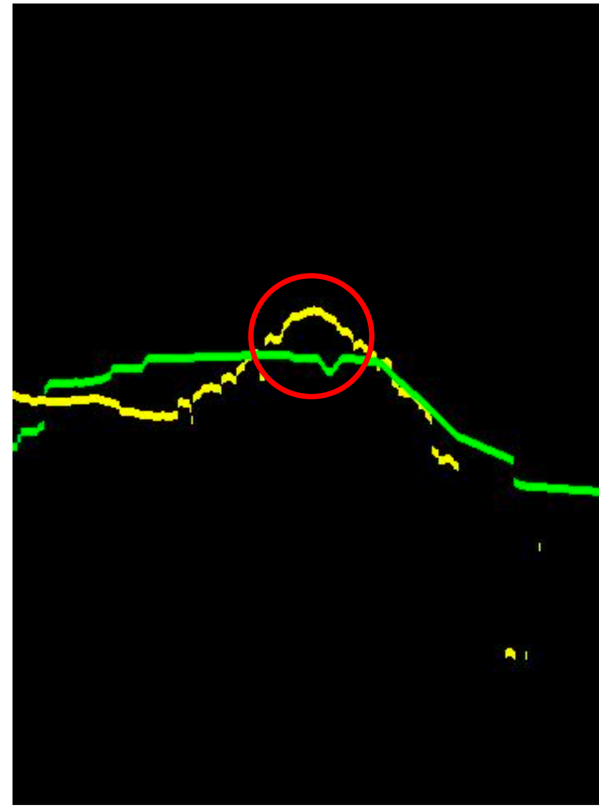




Azimuth : ESE / Elevation : 23.2 °

＜OUTPUT＞

cross-correlation coefficient : 0.58



h_img(satellite)	8,712m
h_real(report)	10,146m
brightness temp	231.5K

Consideration : error evaluation

weathernews Always WITH you!

h_real - h_img

> f (FOV, pix, G, ADC) +range, +growth speed

(1) (2) (3) (4)

(1)resolution from camera spec

ex) ～25m

(2)elevation from accelerometer

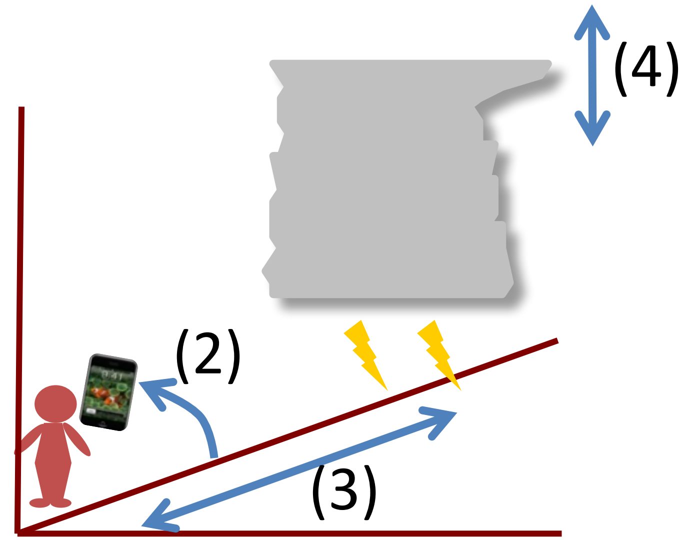
ex) ～90m

(3)range

ex) 3km～ (need to see the cloud top of cg, cb)

(4)growth speed

ex) ～480m/1min (The case of the earliest cumulonimbus)



Resolution from camera spec

(example)

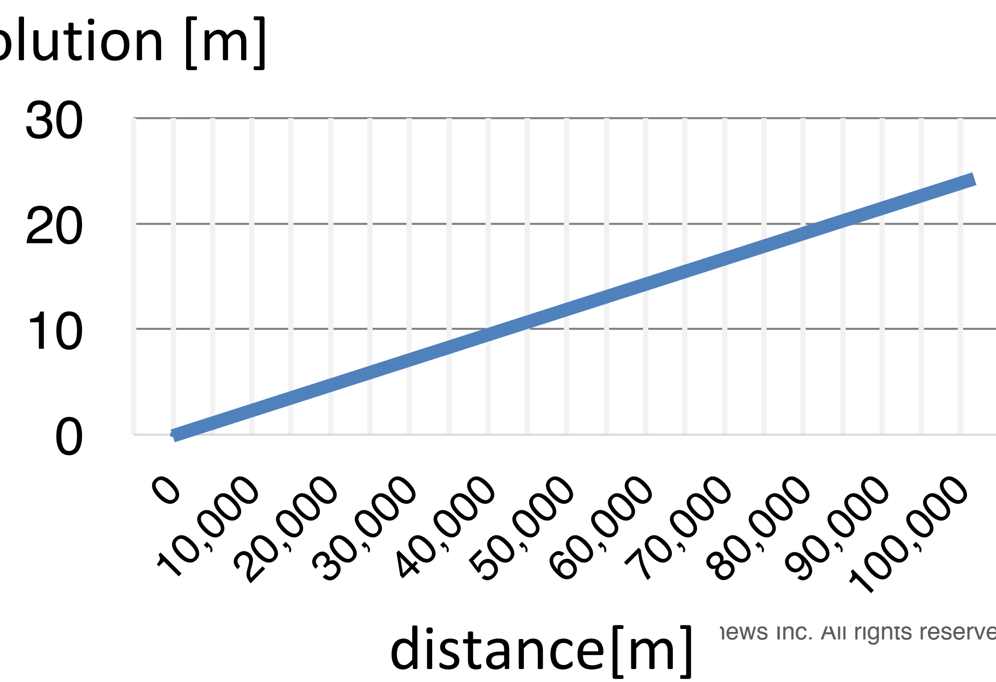
- Model : iPhone6 plus
- Image size : width 2448pix , height 3264pix
- Focal length : 29mm
- FOV : 73° (horizontal 64° : vertical 45°)

- Resolution

$= \text{Distance} \times \tan\theta$

$\approx$ ~25m

$\theta = \text{FOV/pix} = 0.0138°$

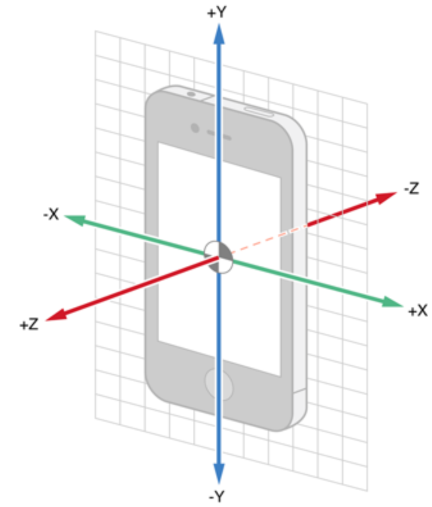


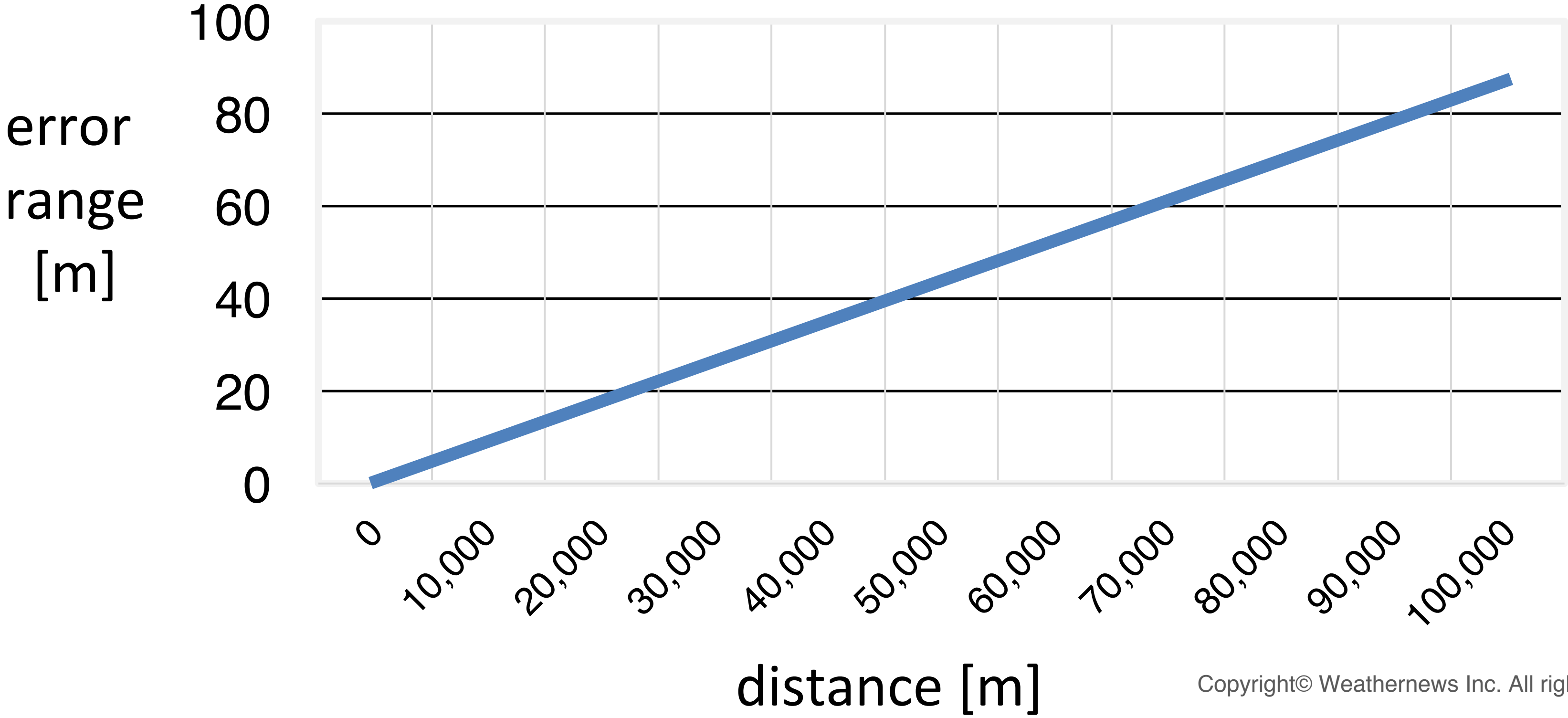
Accelerometer

(example : iPhone6 plus)

- ADC range : 14bit
- Acceleration range : ±2g

→ error range = ±1mg = ±0.05°





Summary

- Conclusion

  Proposal new method to estimate cloud top height
  & correct the temperature of the upper layer.

- Method

  To correct the height compared to the skyline between satellite and ground based image by geometric approach.

- Consideration (Error evaluation)

  h_real - h_img > f (FOV, pix, G, AD)+ range, +growth speed

Observation + Eye-Servation

weathernews Always WITH you!