AMVs from FengYun Geo. Stereo View -System and Bias Analysis

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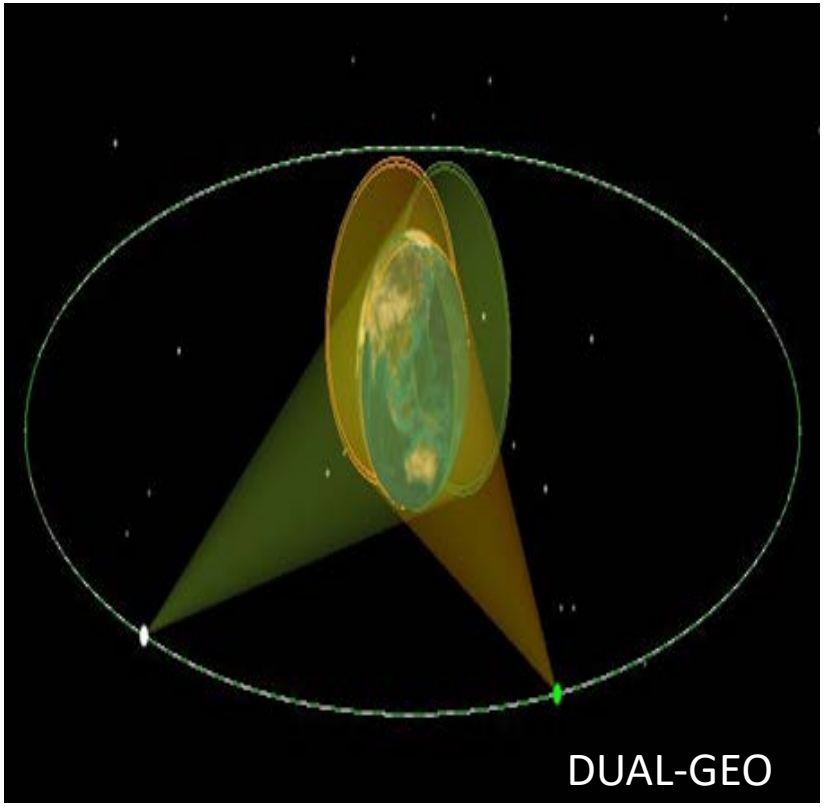
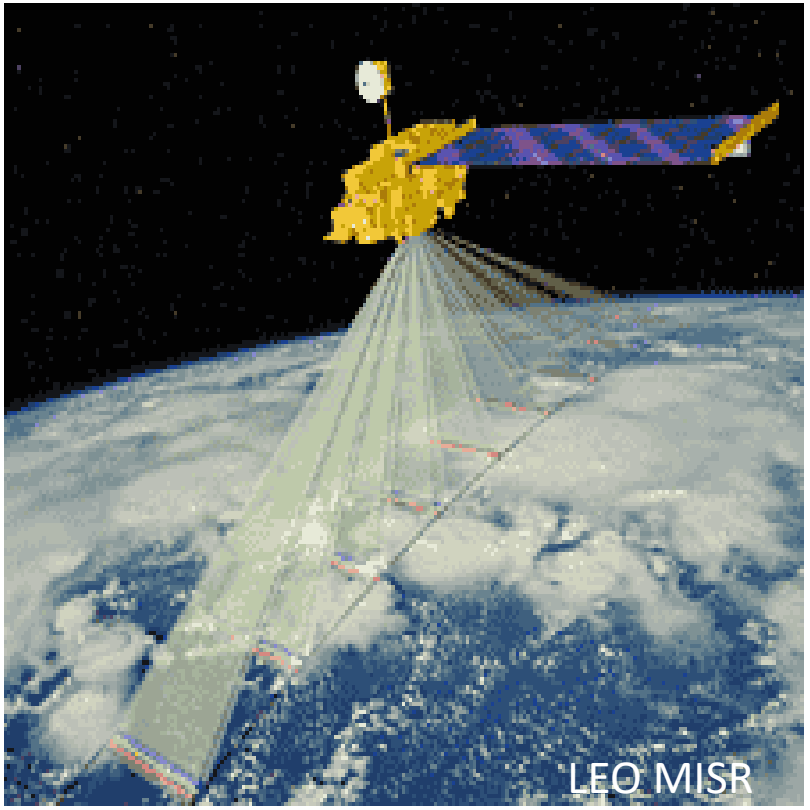
Parallax*

Apparent displacement, or difference in the apparent position, of an object, caused by actual change (or difference) of position of the point of observation; spec. the angular amount of such displacement or difference of position, being the angle contained between the two straight lines drawn to the object from the two different points of view, and constituting a measure of the distance of the object."



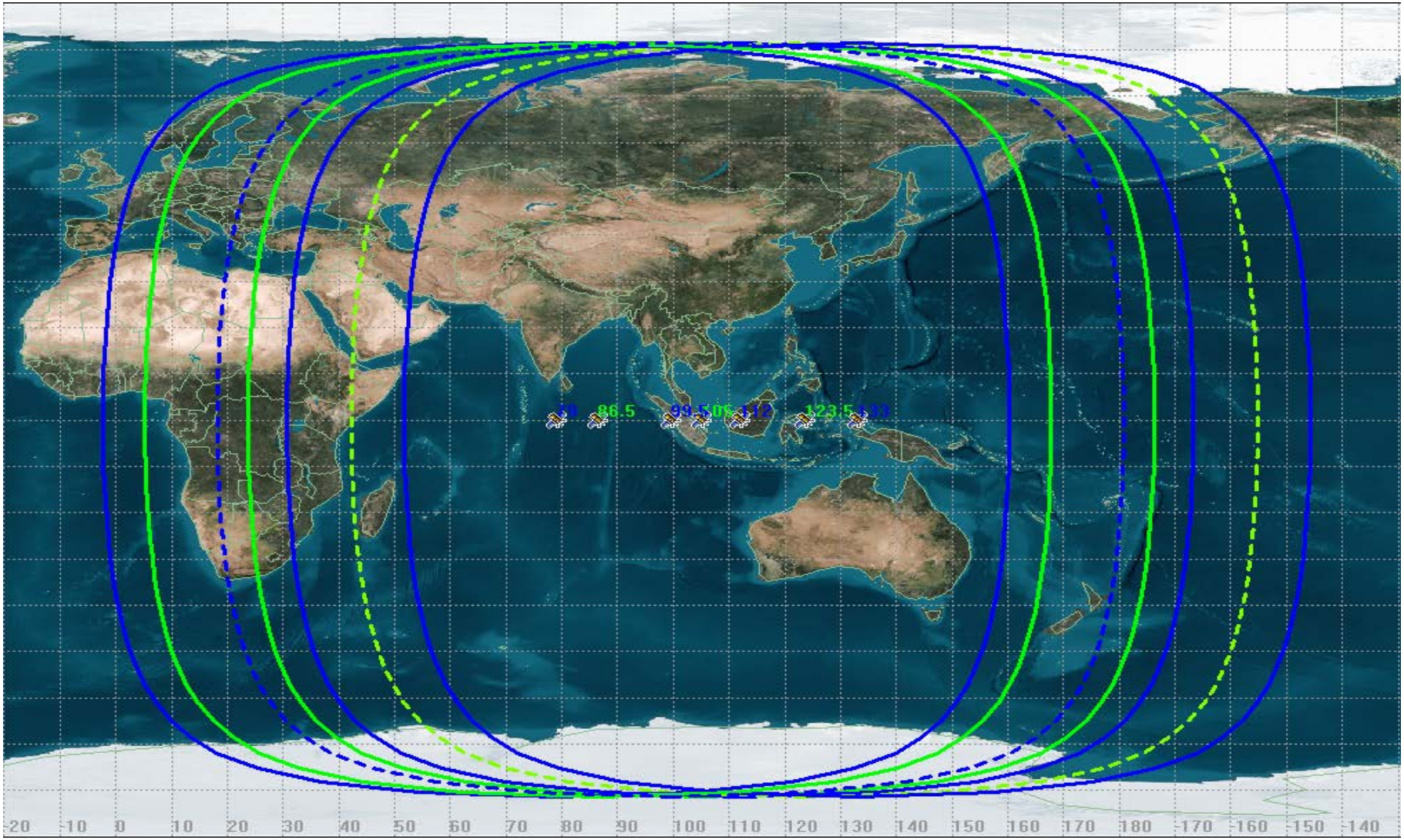


**Oxford English Dictionary* (Second Edition ed.). 1989.

Benefits of Dual-Geo. In Visible CMV Retrieval

1) Not rely on NWP data for height assignment.
2) Good accuracy in cloud height assignment, especially for low level cloud.
3) Good temporal resolution.
4) Good spatial coverage.

Orbital positions for FengYun Geo.



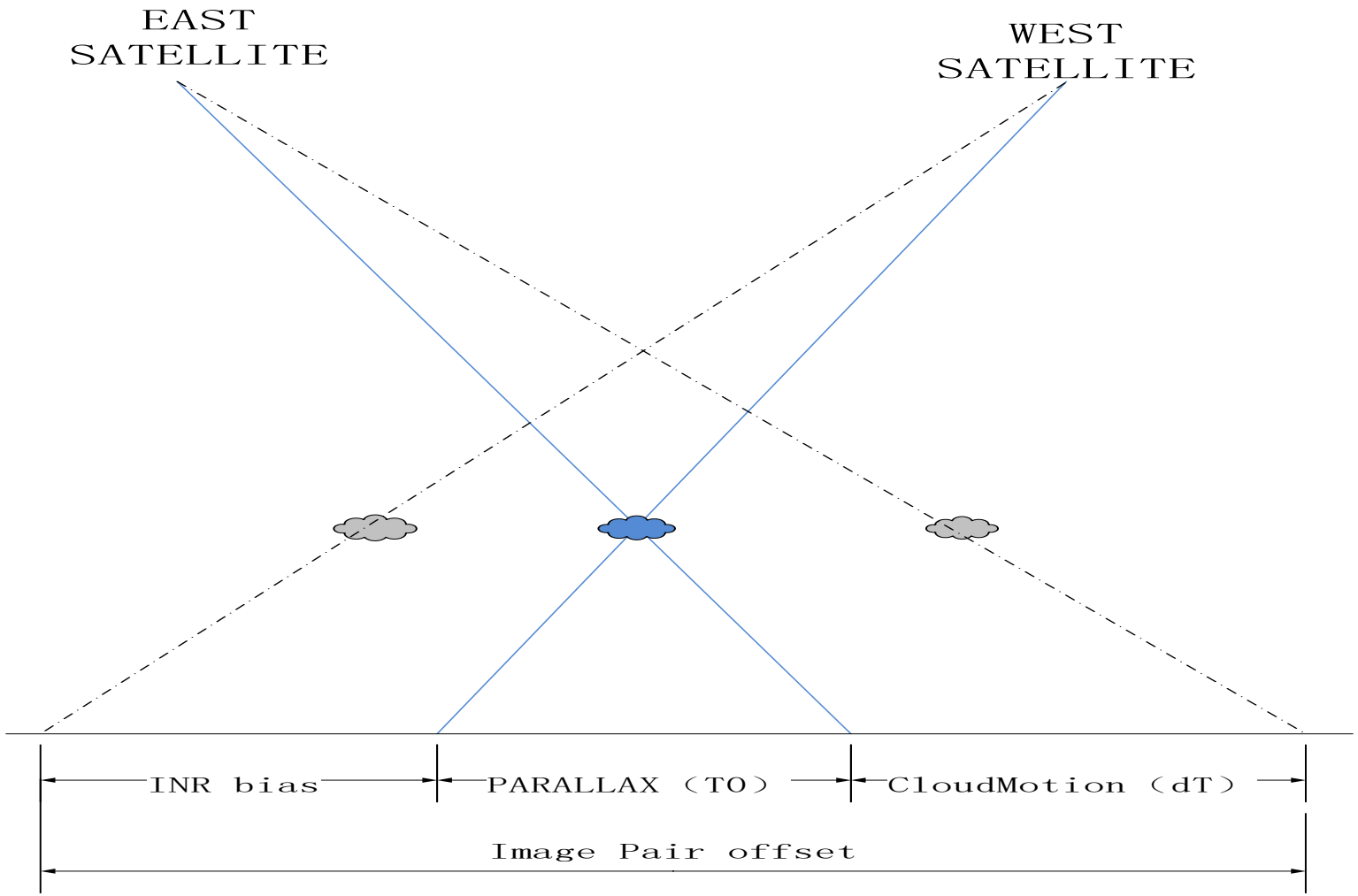
Current positions from FY-2 86.5E,105E and 112E

New positions to apply 79E,99.5E

Revised 2018

FengYun DUAL-Geo. CMV

Image Pair Offset = INR Bias +Parallax (T0) +Cloud motion(dT)



The two FengYun Geo. satellite make observation asynchronous

1) FY-2 Dual-Geo CTH Capability

For FY-2 Vis channel,

86.5+112.0E dual-geo could recognize CTH >750 meters

86.5+123.5 dual-geo could recognize CTH >500 meters

79.0+133.0 dual-geo could ·recognize CTH >400 meters.

2) Coverage

86.5+123.5 dual-geo covers China and most of Asian Pacific region

3)Operational Possibility

2018

FY2F have been positioned over 112E for regional scan.

FY2E have been positioned over 85E for regional scan.

FY2F have been repositioned

The FY2H ,to be launched on Jun,2018, and positioned over 79E.

The FY-4A will repositioned in 105E and provide observations since May 2018

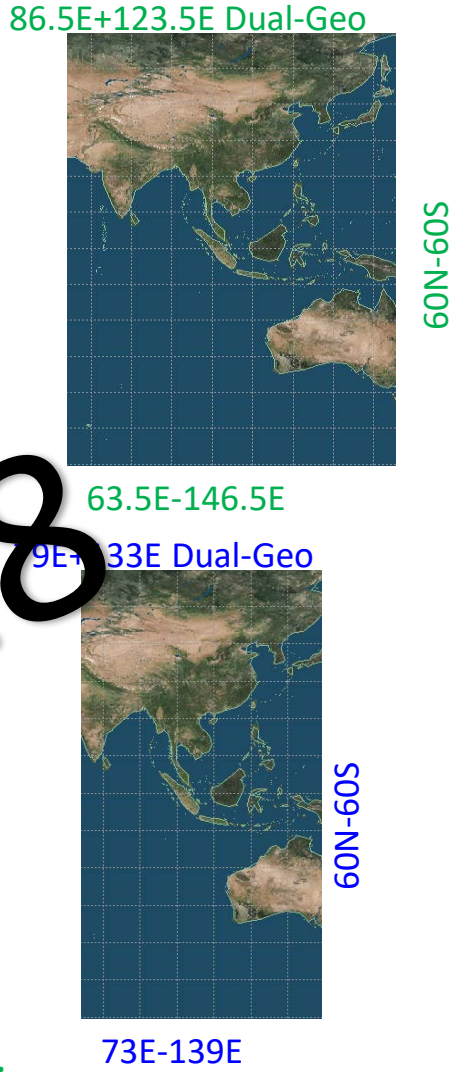
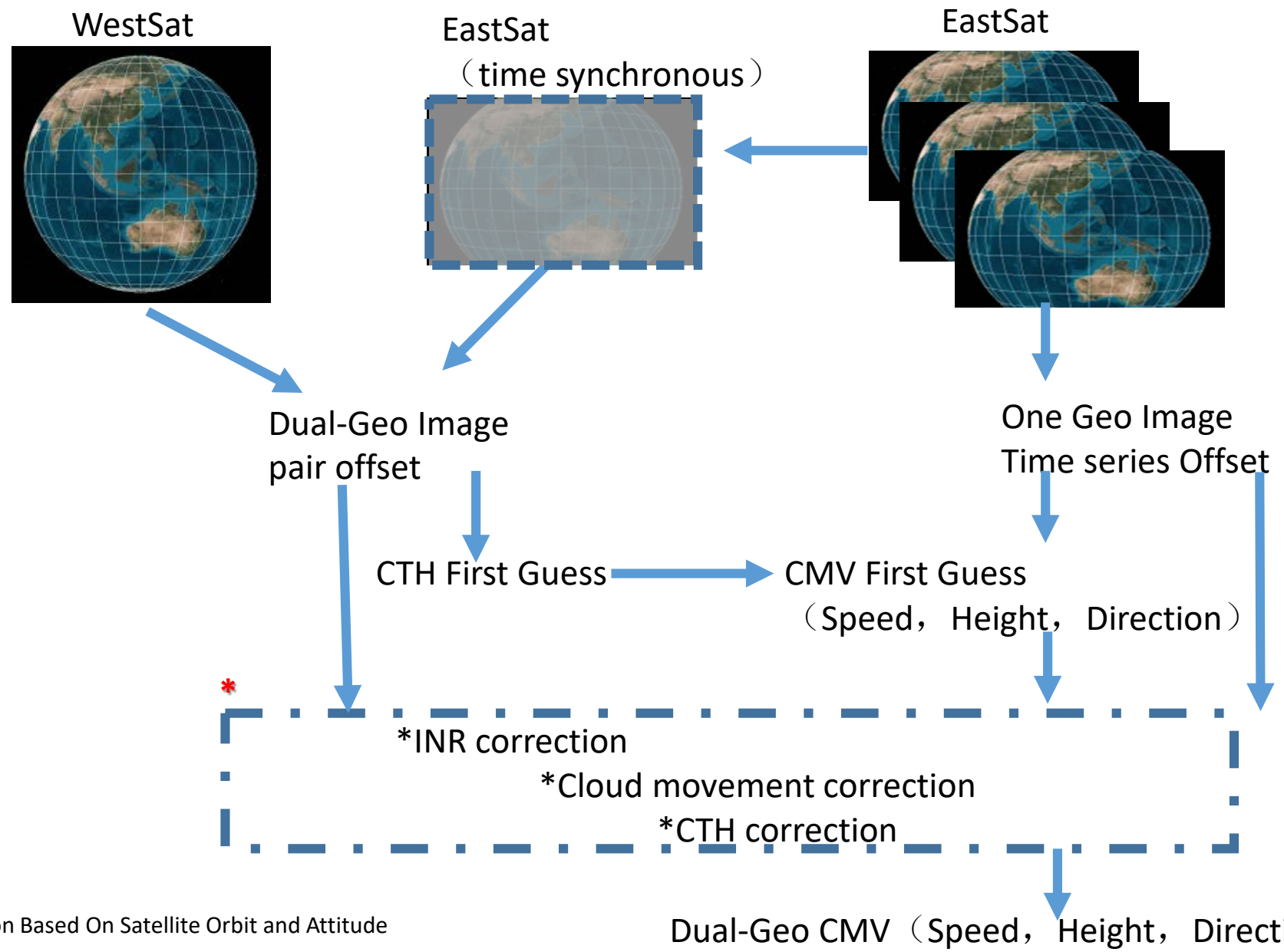
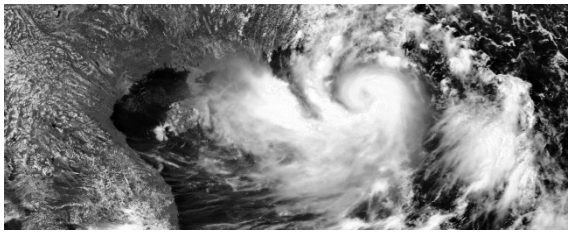


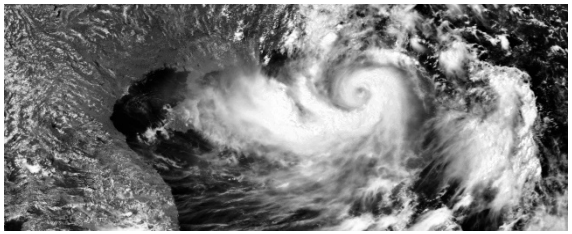
Diagram of FengYun Dual-Geo CMV

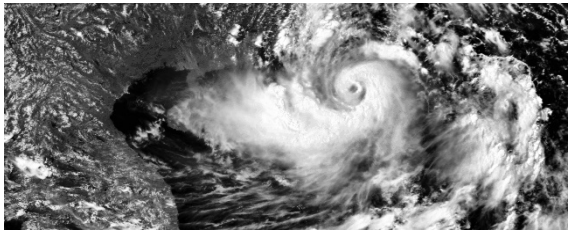


*Iteration Based On Satellite Orbit and Attitude

Satellite observations for this study
Typhoon Hato, Aug 22-23,2017
A maximum category 10 storm

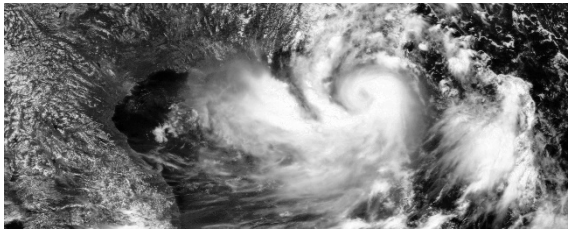


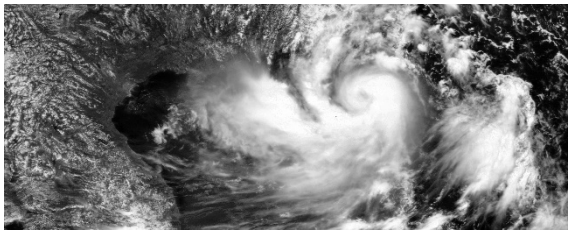


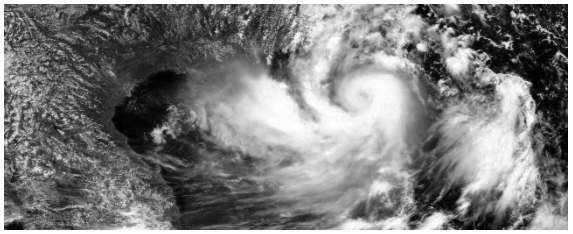


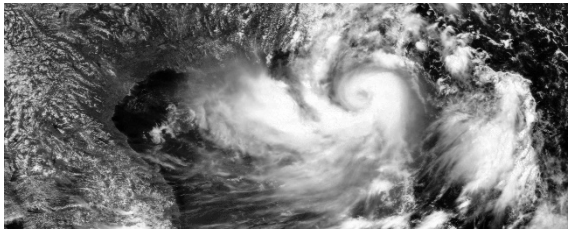
FY-2E 86E hourly

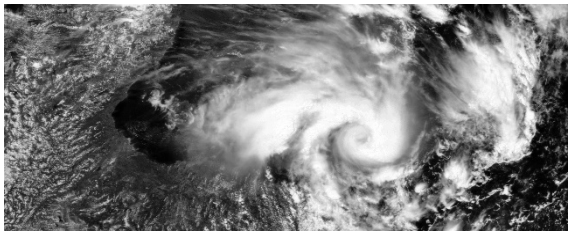
Dt<60s











FY-2F 112E 6 minute interval

1.Image tracking:

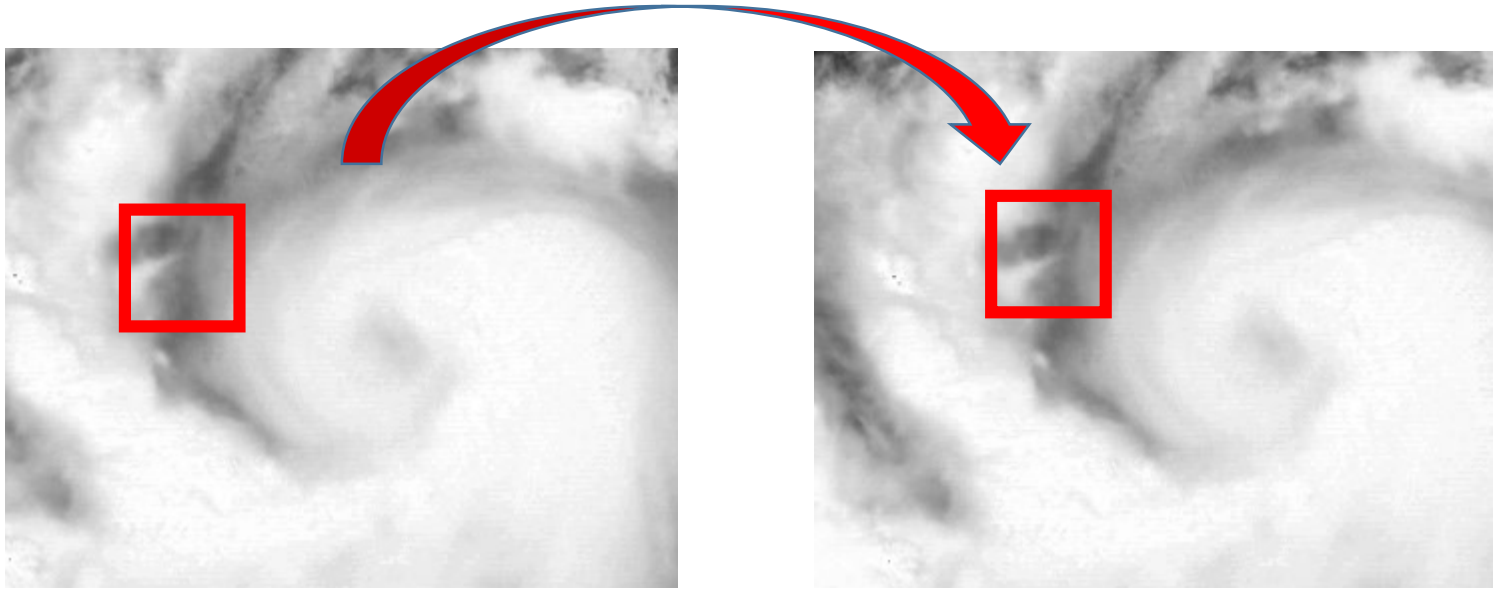


Image at time t

Image at time t+dt

σεϖεραλ ασσυμπτιονσ:

1. **Τηε ταργετ ιτσελφ δο νοτ χηανγε**(*βριγητνεσσ ανδ σηαπε*) *βετωεεν τωο φραμεσ*,
2. **Τηε ταργετ μοϖεμεντ ισ σμαλλ**
3. **Πιξελσ ωιτηιν τηε Τραχκινγ βλοχκ ηαϖε σιμιλαρ μοτιον**.

Optical Flow (1)

- $E(x, y, t)$ = irradiance at time t at the image point (x, y).
- $u(x, y)$ and $v(x, y)$ = optical flow vector at that point
  - *find a new image for a point where the irradiance will be the same at time* $t + \delta t$

$$E(x + u\delta t, y + v\delta t, t + \delta t) = E(x, y, t)$$

- If brightness varies smoothly with x, y and t we can expand the left hand side as a Taylor series to obtain:

$$E(x, y, t) + \delta x \frac{\partial E}{\partial x} + \delta y \frac{\partial E}{\partial y} + \delta t \frac{\partial E}{\partial t} + e = E(x, y, t)$$

- e = second and higher order terms in δx ...
  - *With* $\delta t \rightarrow 0$

$$\frac{\partial E}{\partial x}\frac{dx}{dt} + \frac{\partial E}{\partial y}\frac{dy}{dt} + \frac{\partial E}{\partial t} = 0 \qquad u = \frac{dx}{dt}\ ;\ v = \frac{dy}{dt}$$

Lucas-Kanade method for optical flow

Lucas-Kanade

Recall scalar equation with two unknowns:

$$\begin{bmatrix} I_x & I_y \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} = -I_t$$

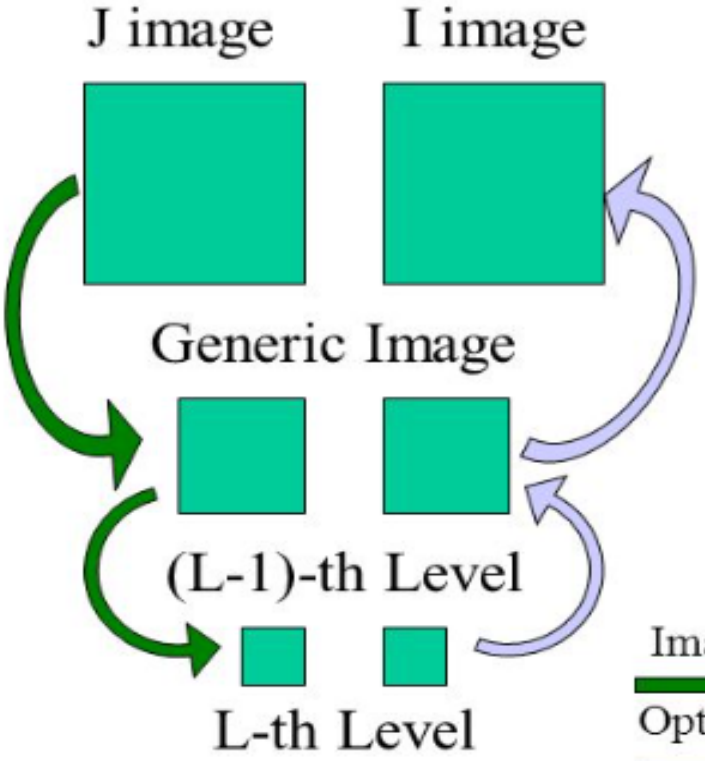
Assume neighboring pixels have same motion:

$$\begin{bmatrix} I_x(\mathbf{x}_1) & I_y(\mathbf{x}_1) \\ I_x(\mathbf{x}_2) & I_y(\mathbf{x}_2) \\ \vdots & \vdots \\ I_x(\mathbf{x}_N) & I_y(\mathbf{x}_N) \end{bmatrix} \begin{bmatrix} u \\ v \end{bmatrix} = - \begin{bmatrix} I_t(\mathbf{x}_1) \\ I_t(\mathbf{x}_2) \\ \vdots \\ I_t(\mathbf{x}_N) \end{bmatrix}$$

where N is the number of pixels in the window

Pyramidal Implementation of the optical flow algorithm

Image Pyramid Representation



Iterative Lucas – Kanade Scheme

Location of point u on image $u^L = u/2^L$

Spatial gradient matrix $G = \sum \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$

Standard Lucas – Kanade scheme for optical flow computation at level L d^L

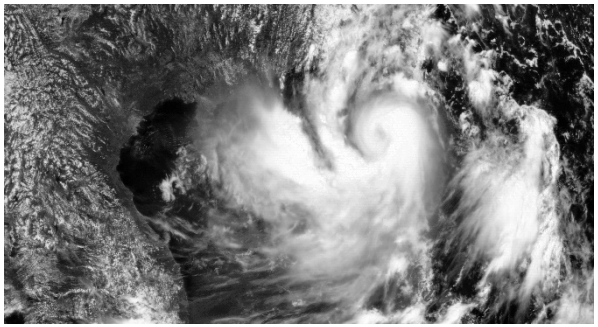
Guess for next pyramid level L – 1

$$g^{L+1} = 2(g^L + d^L)$$

Finally, $d = d^0 + g^0$

$$V = U + d$$

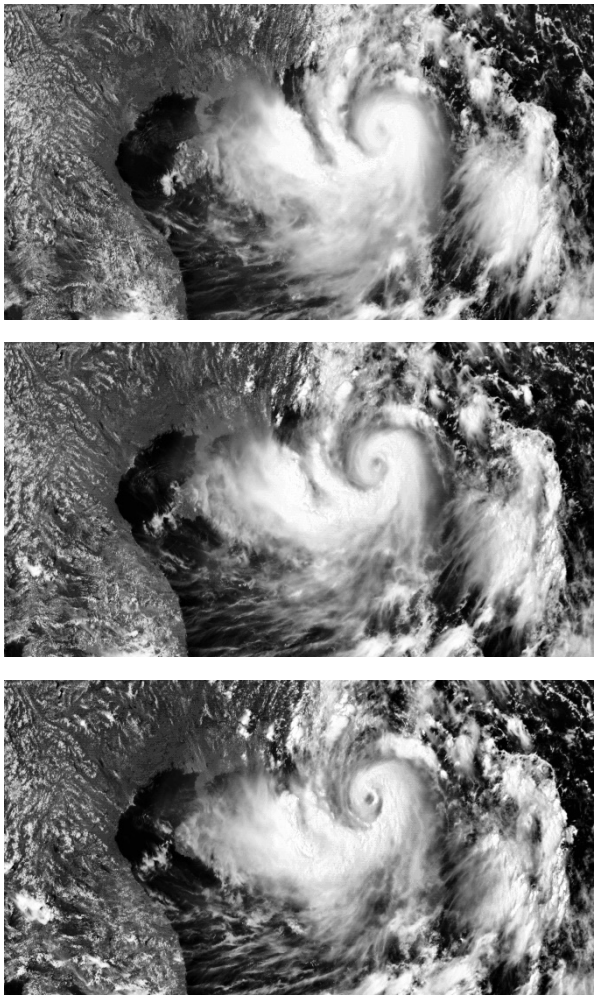
1. Image adjustment



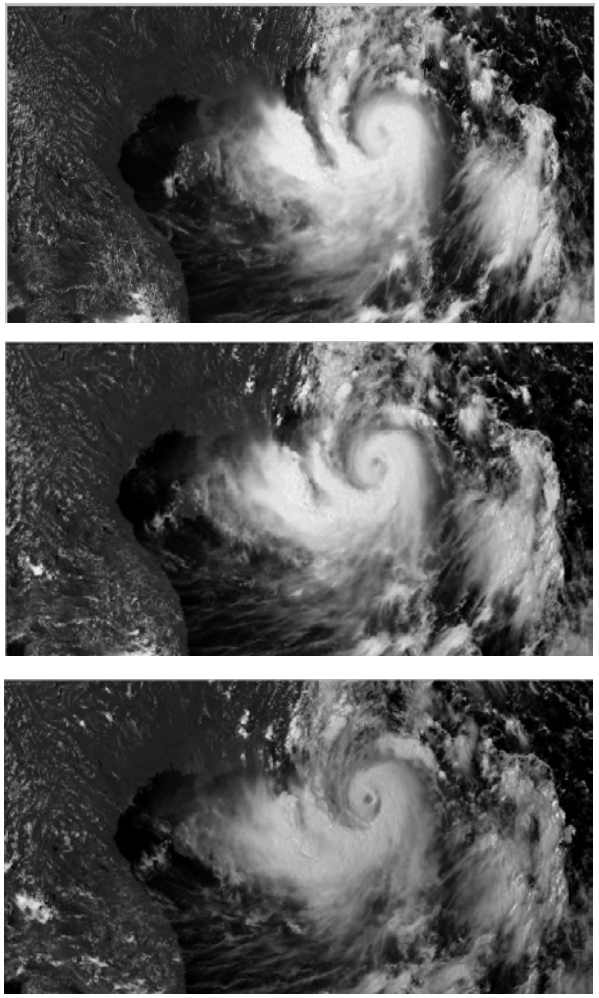
FY2F

1) Solar Zenith angle correction

2) Histogram adjustment



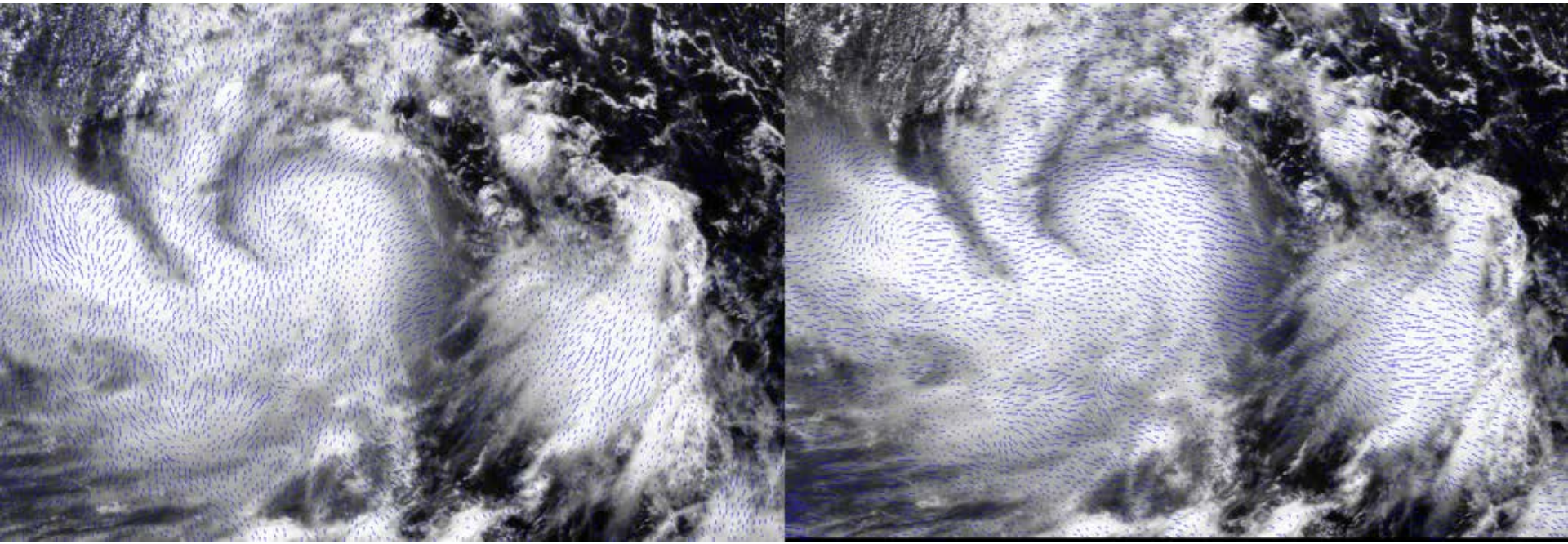
FY2E



Before adjustment(FY2E)

1. Image adjustment(continue)

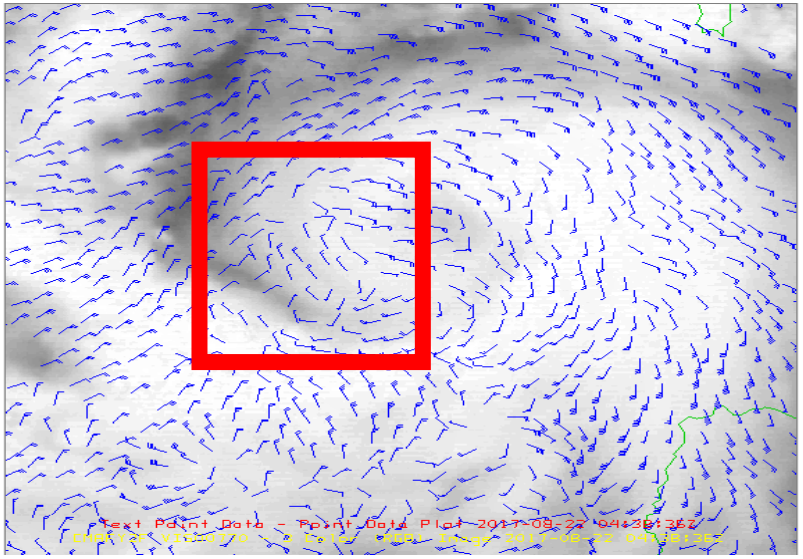
Two satellite Stereo Image pair tracking



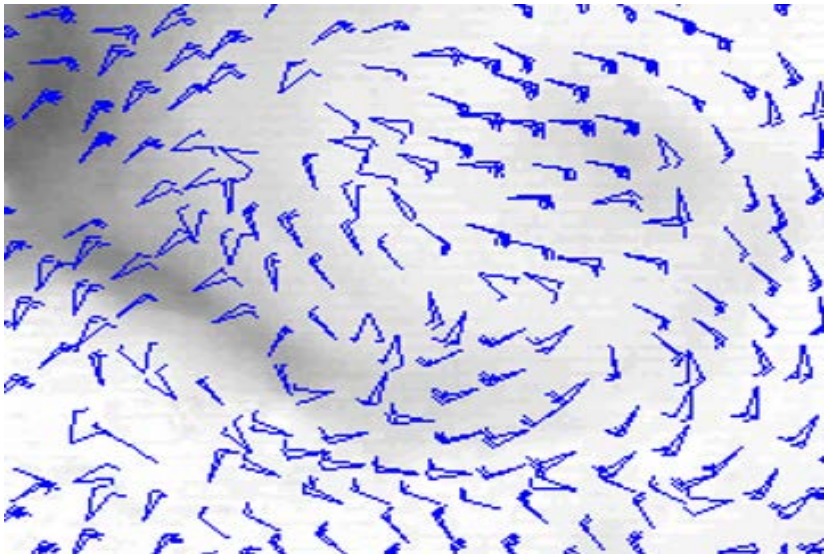
Before INR correction

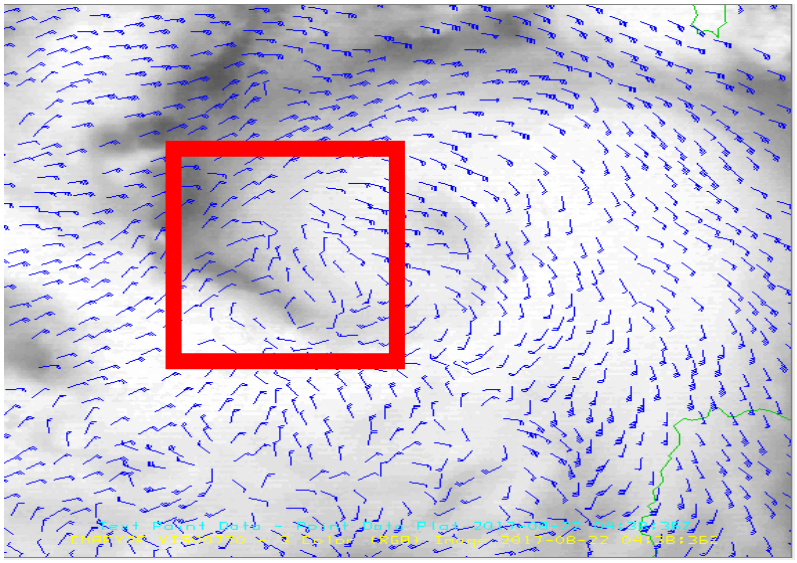
After INR correction

2.Subpixel accuracy target selection

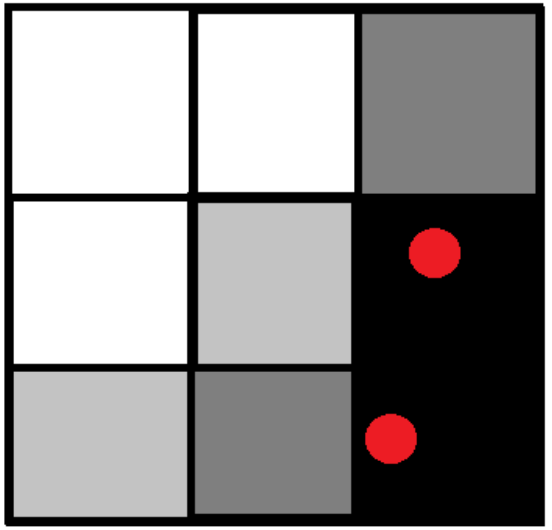


pixel tracking





subpixel tracking

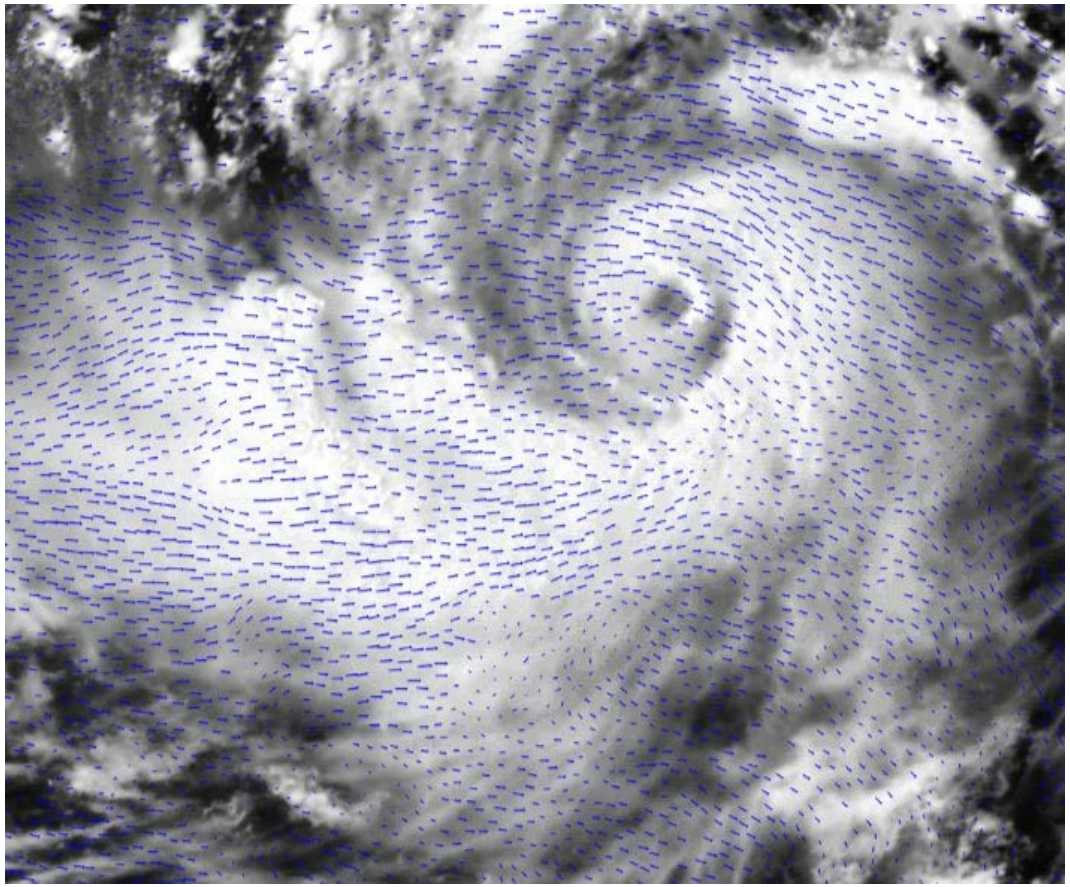


3.Parallax to altitude transformation

$$H = \frac{P}{P_{10}} \times 10 \ km$$

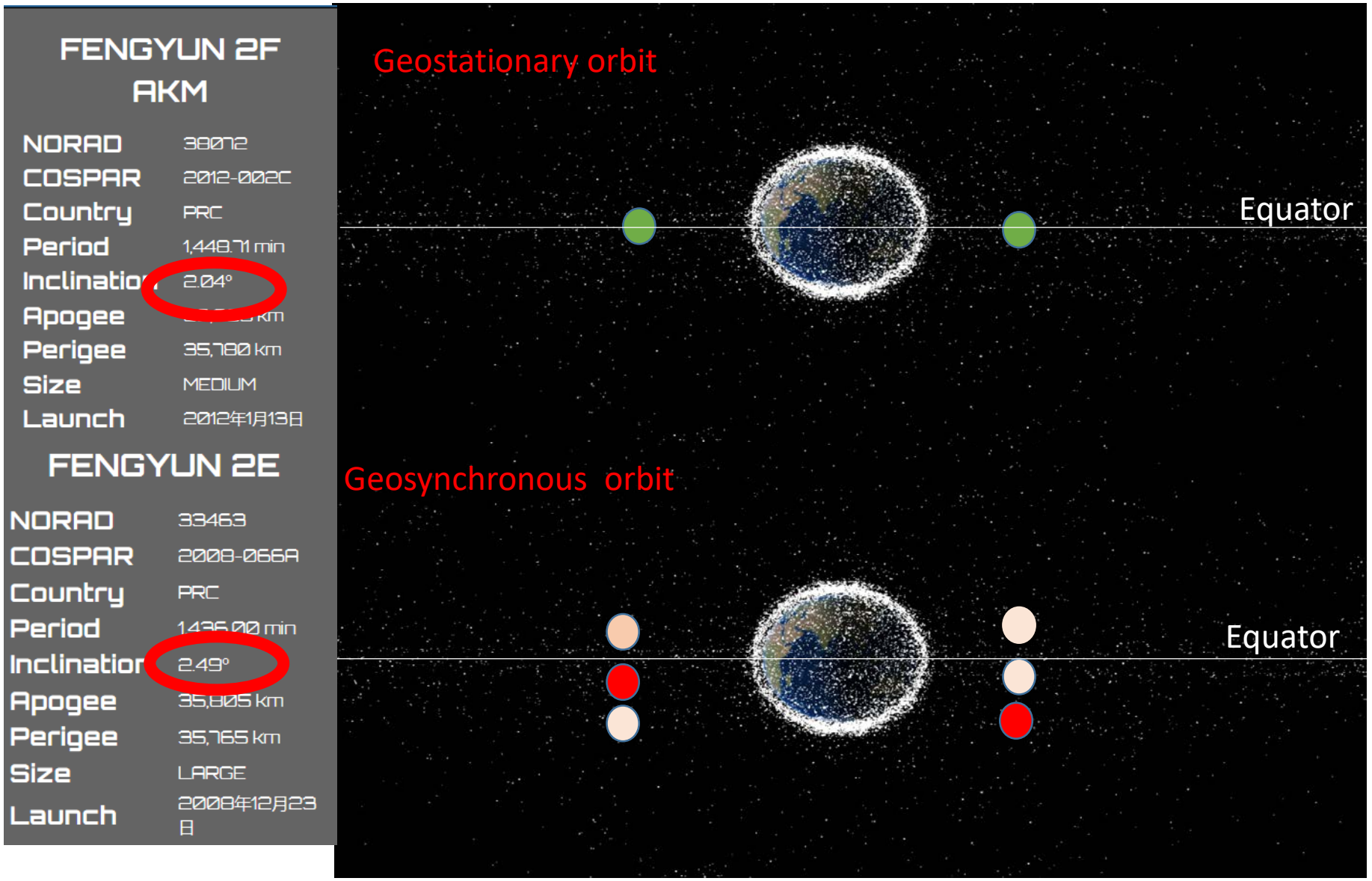
The common algorithm for stereo/height transform.

Fujita T.T., 1982: Principle of stereographic height computations and their and their applications to stratospheric cirrus over severe thunderstorms. *J. Meteor.Soc. of Japan*, **60**, 355-368.

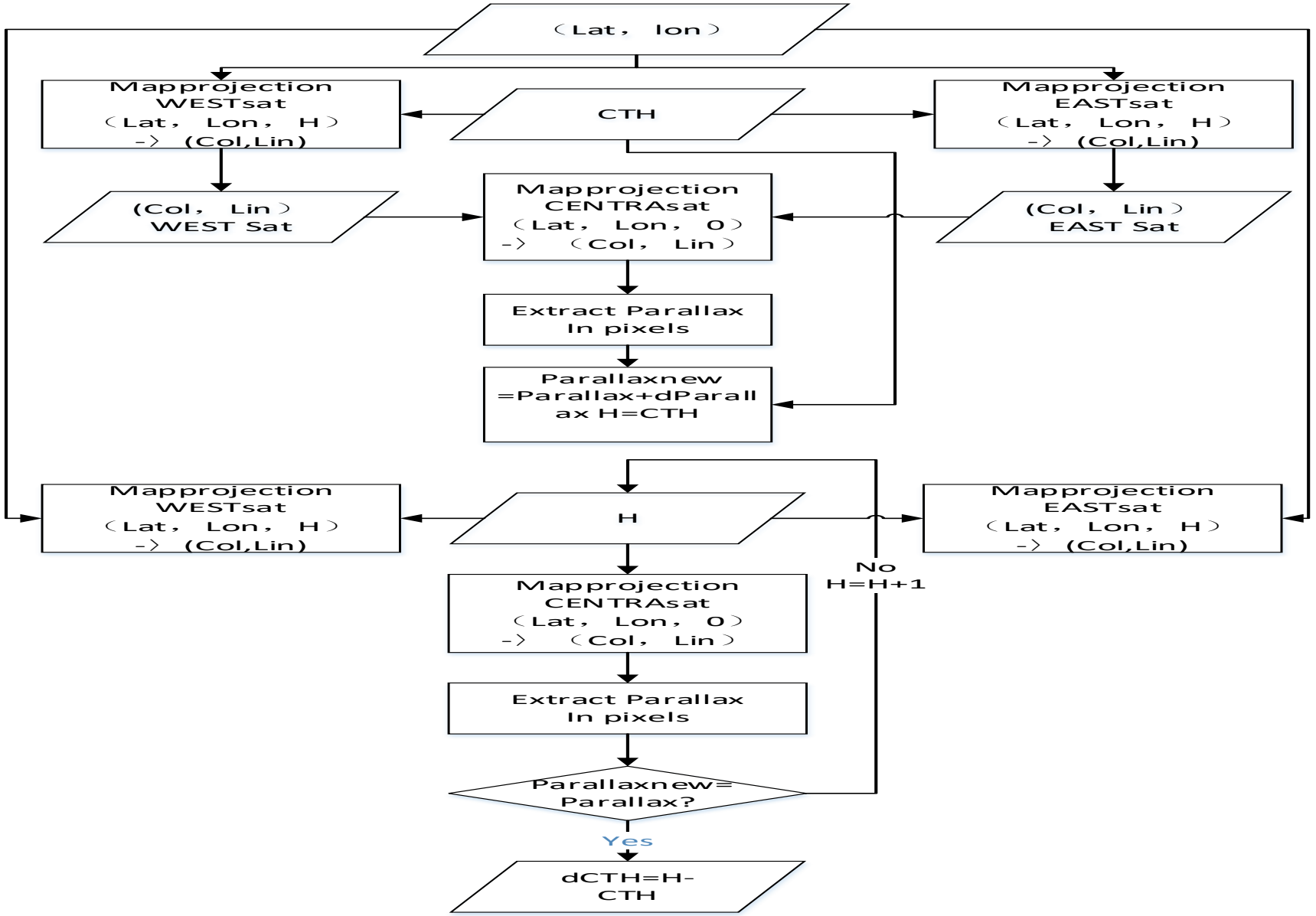


The parallax offset from FENGYUN Geo are different.

3.Parallax to altitude transformation



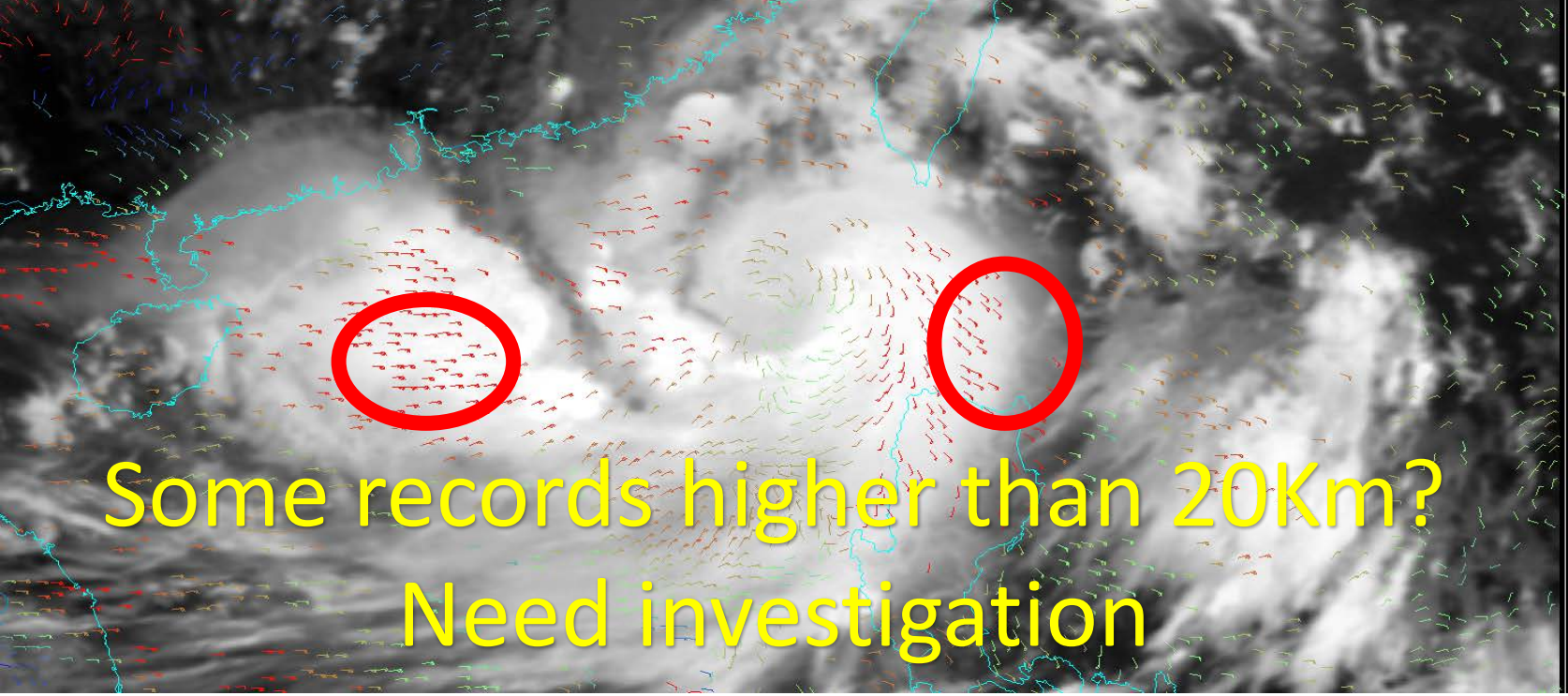
3.Parallax to altitude transformation



results

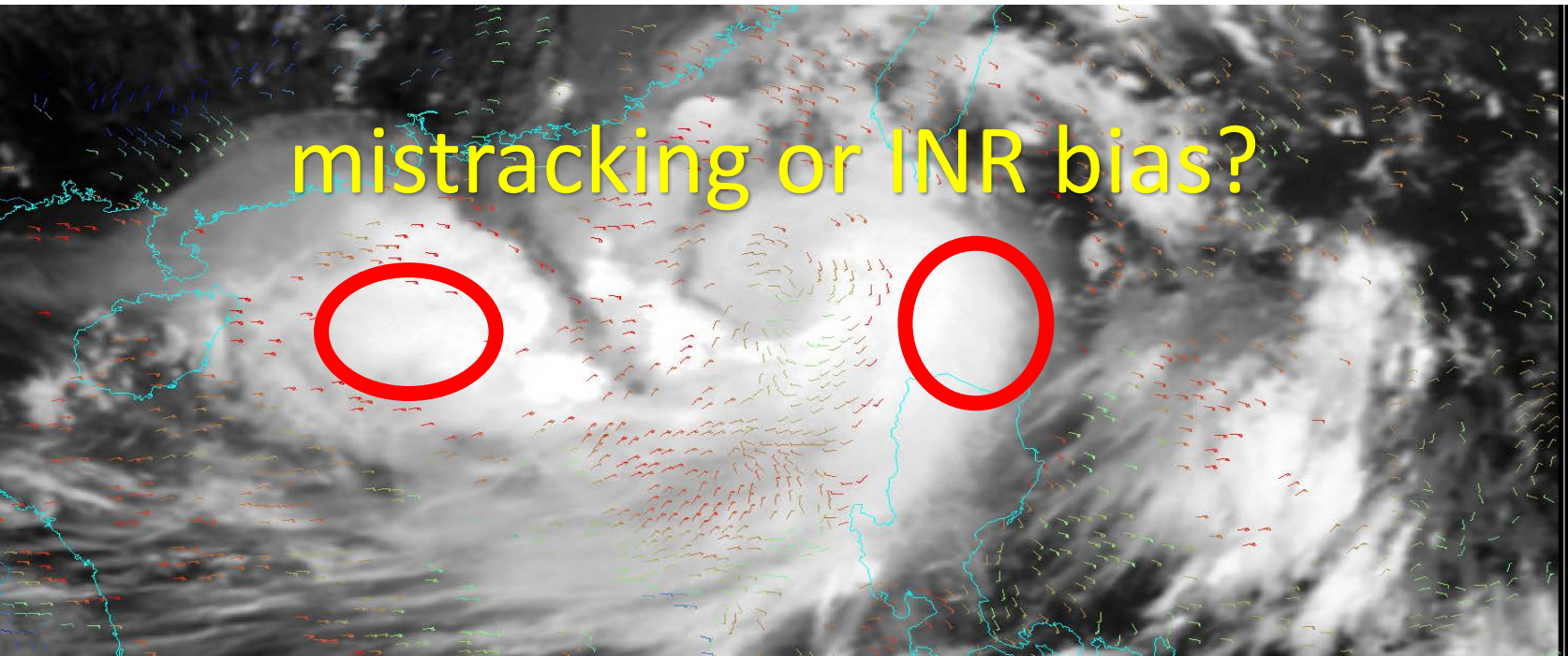
Tracking size=32x32

The stereo view for CMV could also be applied for Infrared channels. This is case is WV band



Some records higher than 20Km?

Need investigation



mistracking or INR bias?

Summary

- AMVs from FengYun Geo. Stereo View was generated using FENGYUN 86.5E and Feng 112E asynchronous observation
- The Optical flow technique was applied for image tracking
- The image navigation, sun zenith angle and time asynchronous bias was eliminated.
- Stereo heights from simulated IR cloud images are better represented by the height weighted by mass profiles.

Future Work

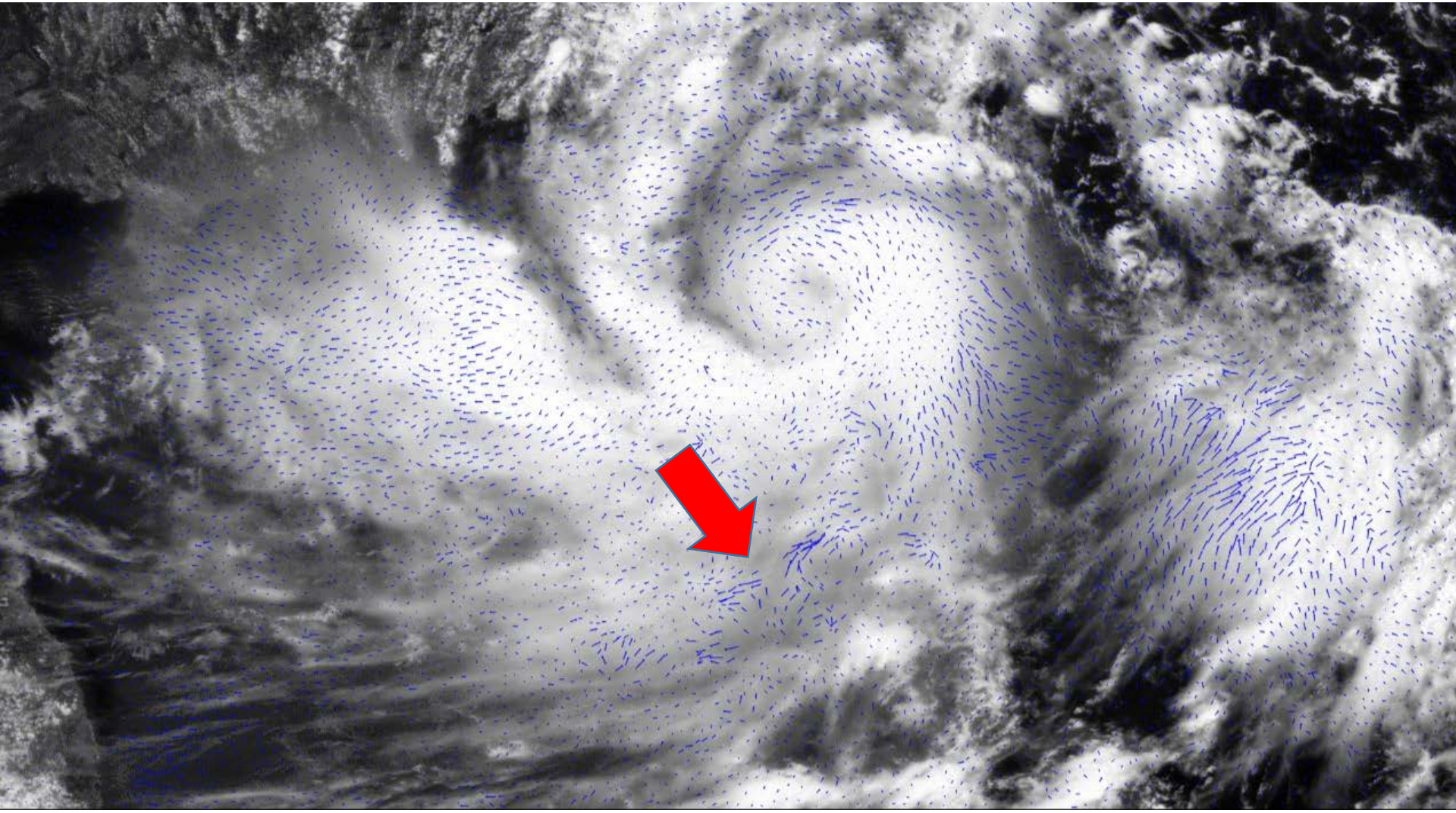
1) FY-2H launched in Jun 2018, will be located over 79.0E and the FY-2F over 112E will keep Rapid Scan service, try stereo wind on the daily basis

2) Wind and cloud top height validation

3)Extending the Dual-GEO observations, using more imaging channels and extending geographic coverage.

4) Apply the tracking technique for FY-4 GIIRS


Thank you
for your attention
Lufeng@cma.gov.cn



CH00770 small tracking box need more quality control try Nested tracking?