Meso−γ scale Water Vapor Distributions of the Rainfall Systems Estimated by the Tomography Method

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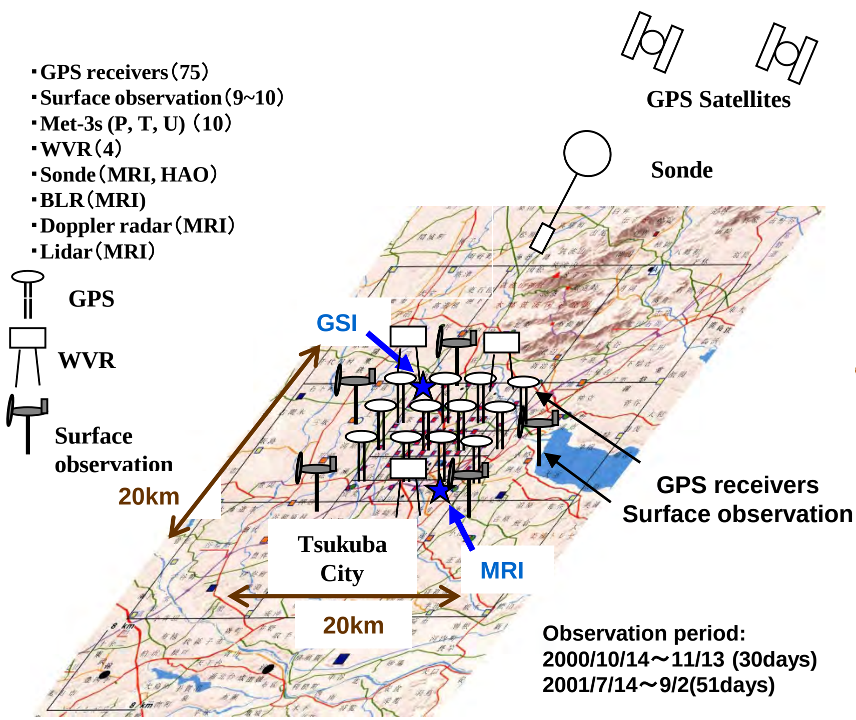
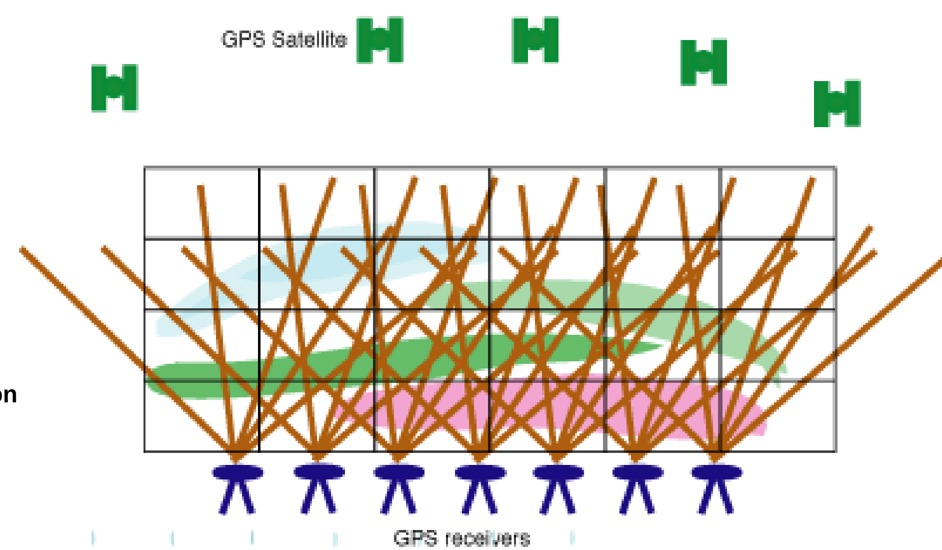


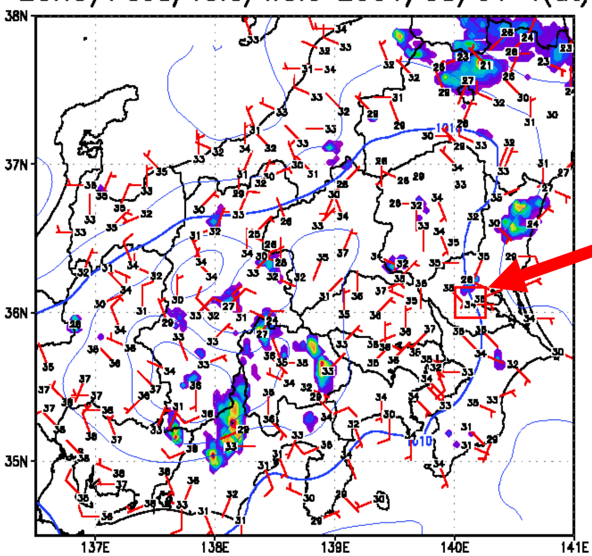
Tsukuba GPS Dense Net



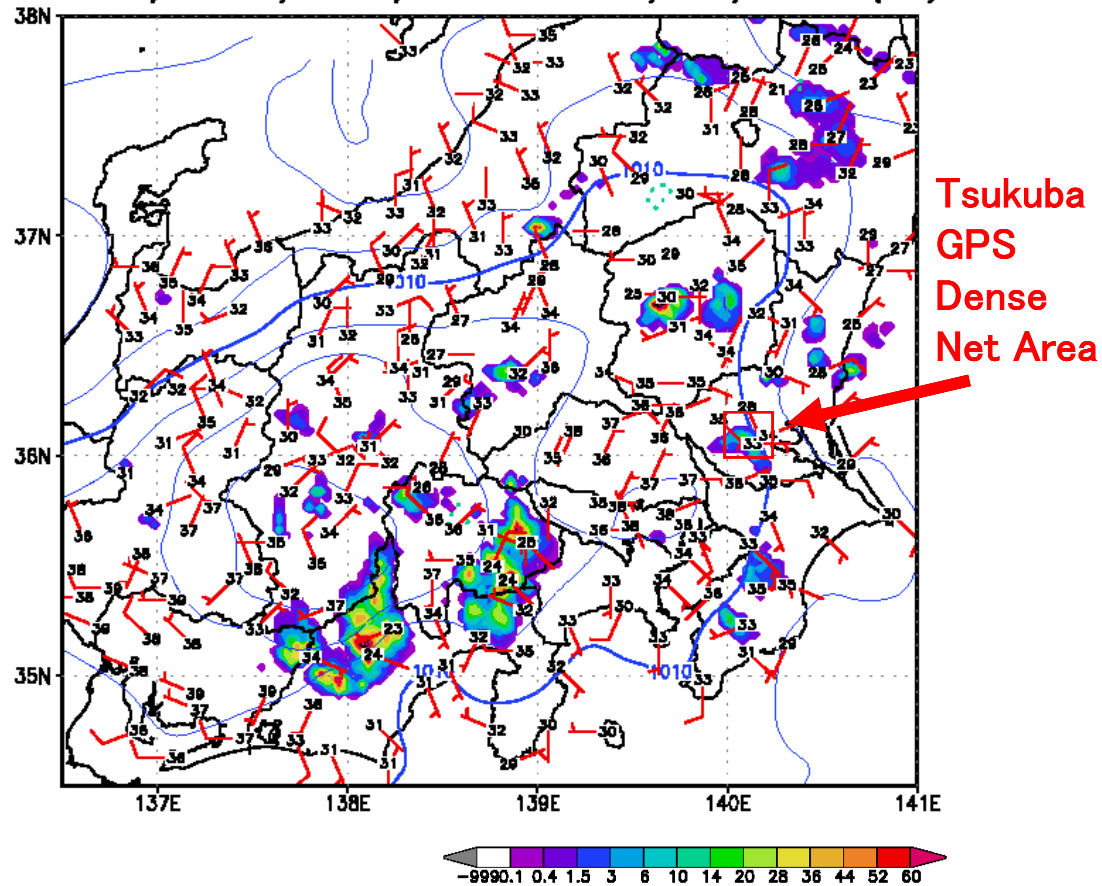
Tomography method

Thunderstorm event on 1st August 2001

ECHO/Psea/Tsfc/Wsfc 2001/08/01 4(ut)



ECHO/Psea/Tsfc/Wsfc 2001/08/01 5(ut)



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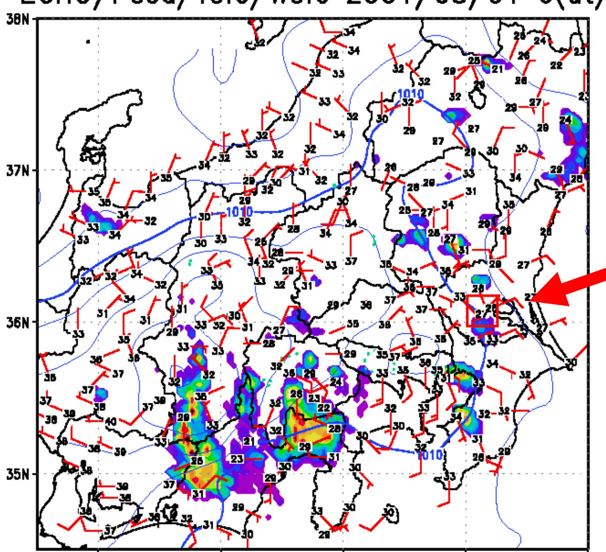
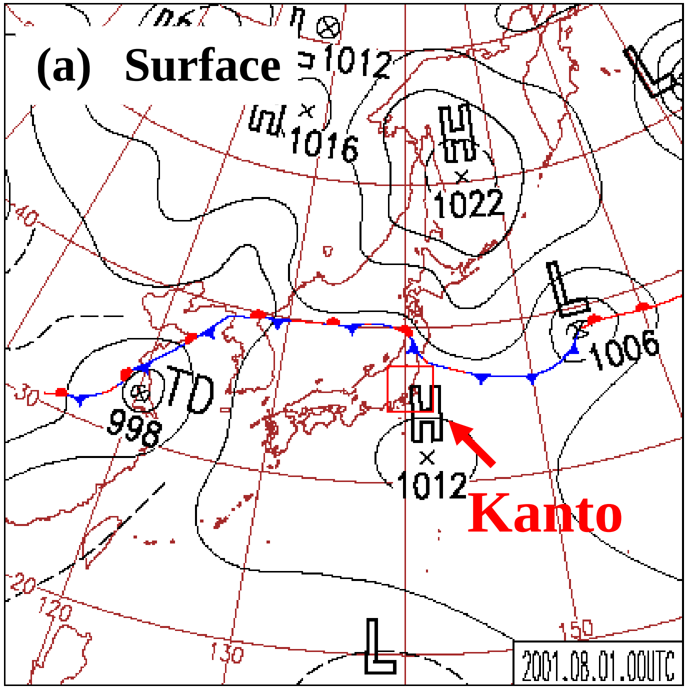
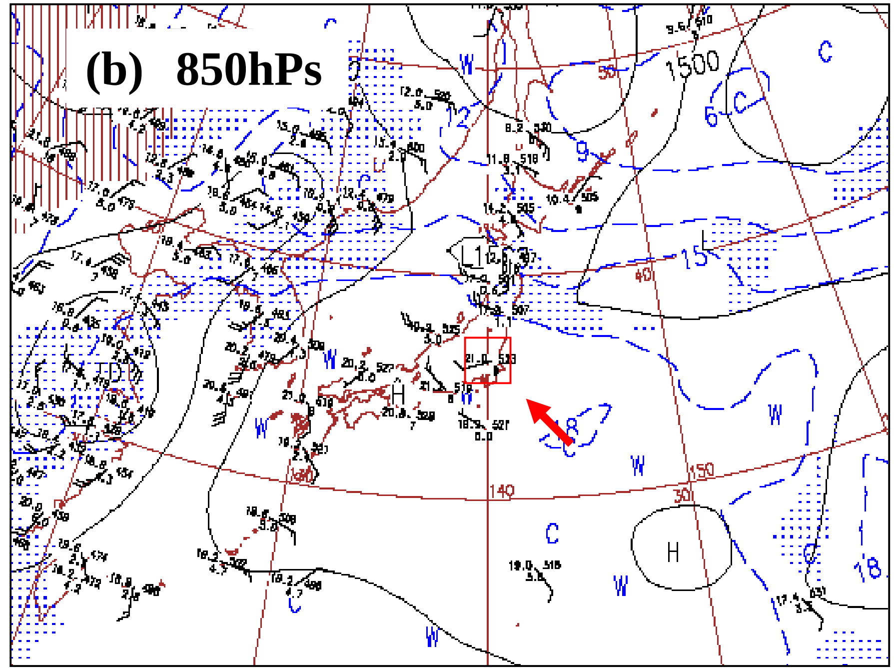
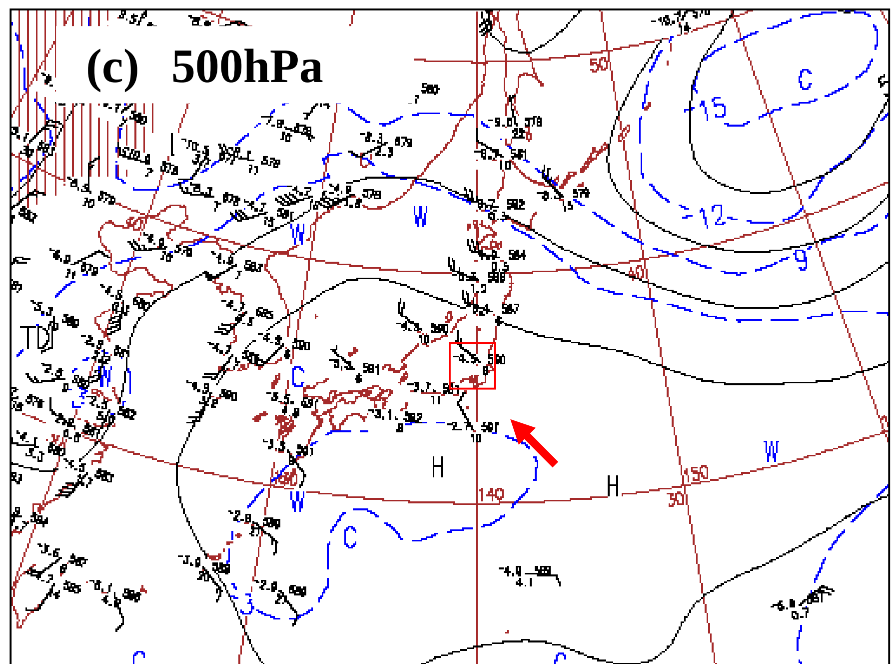


- Small thunderstorm developed at 14JST (=5UTC) and began decaying at 15JST over Tsukuba GPS Dense net area.

→Data of GPS Dense Net contains the information of the evolution of this thunderstorm.

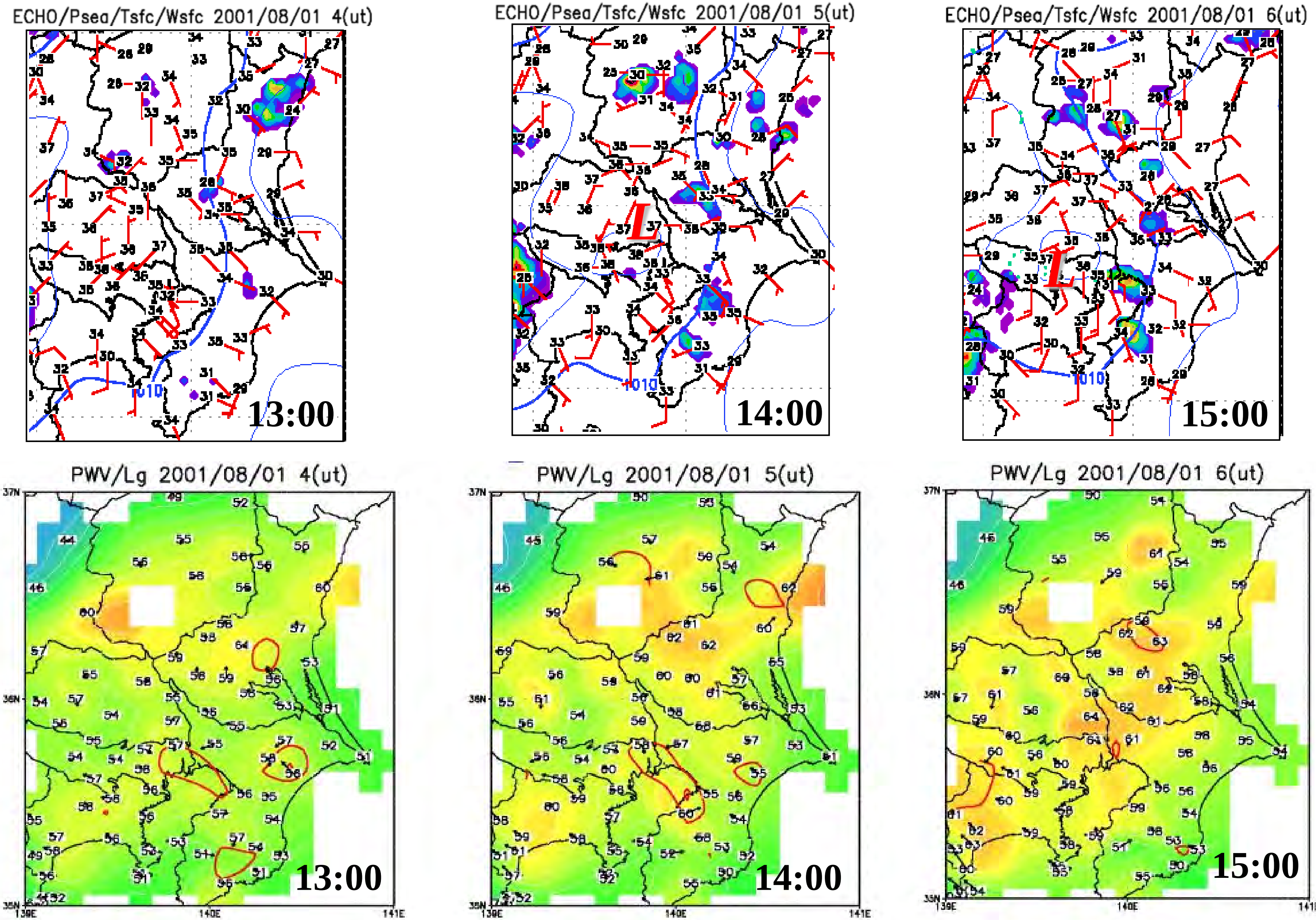




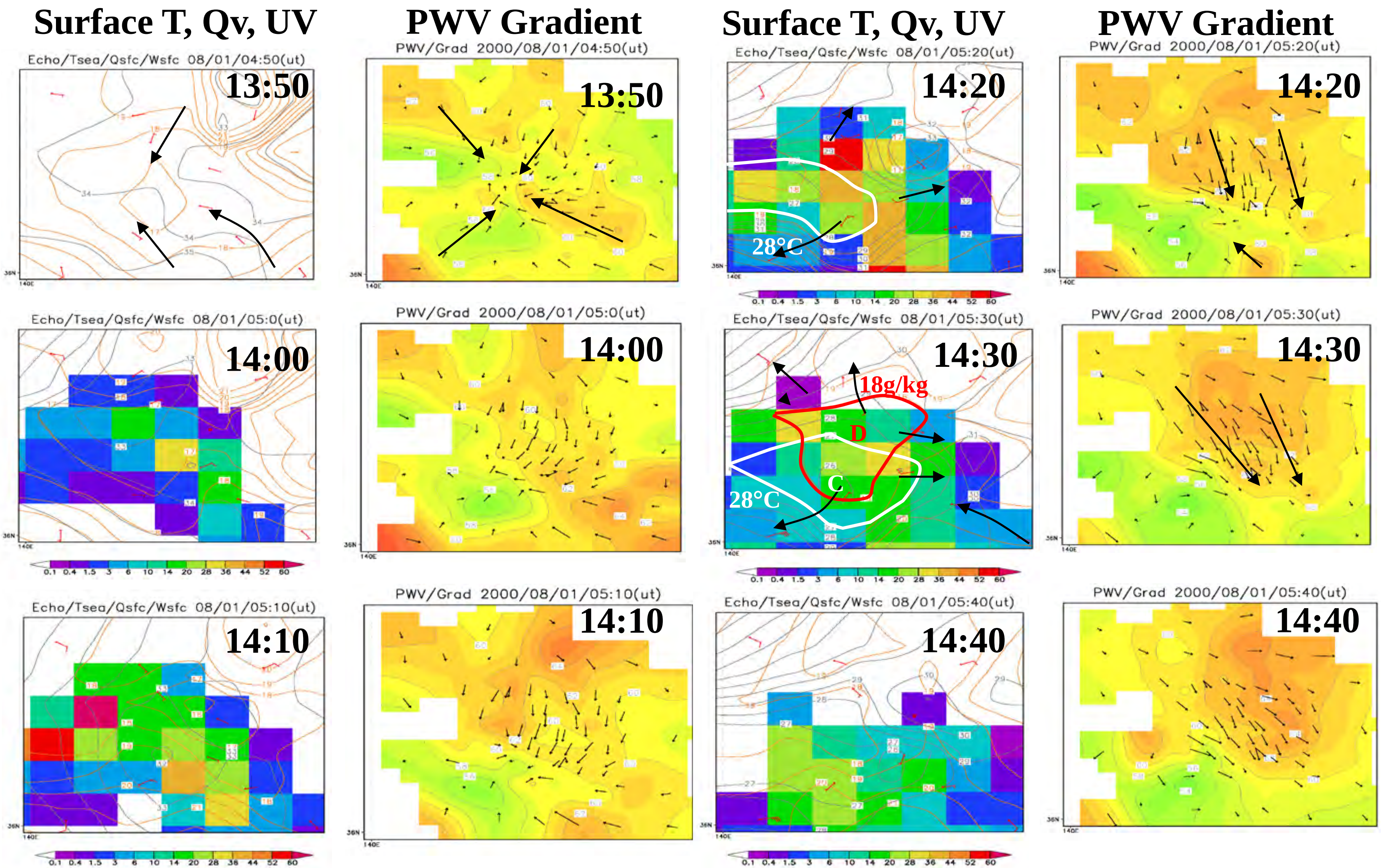


Synoptic scale features

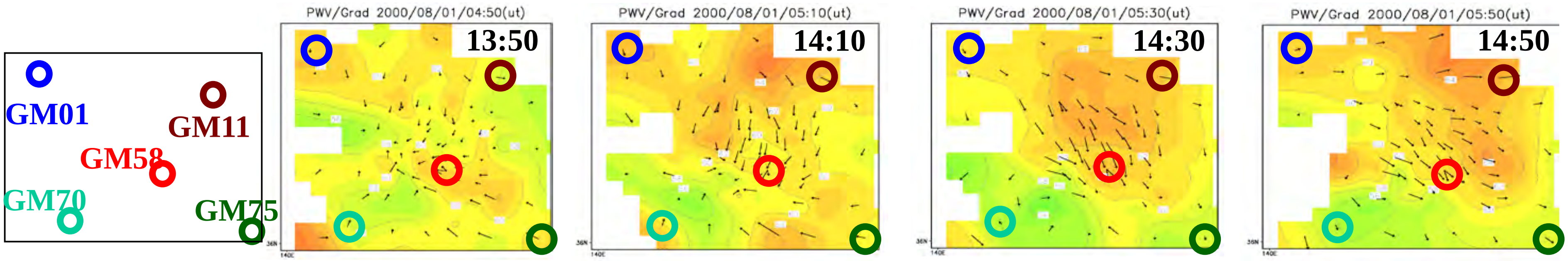
- High pressure area covered Kanto region, Japan.
- Thunderstorm was not associated with low pressure or front system.

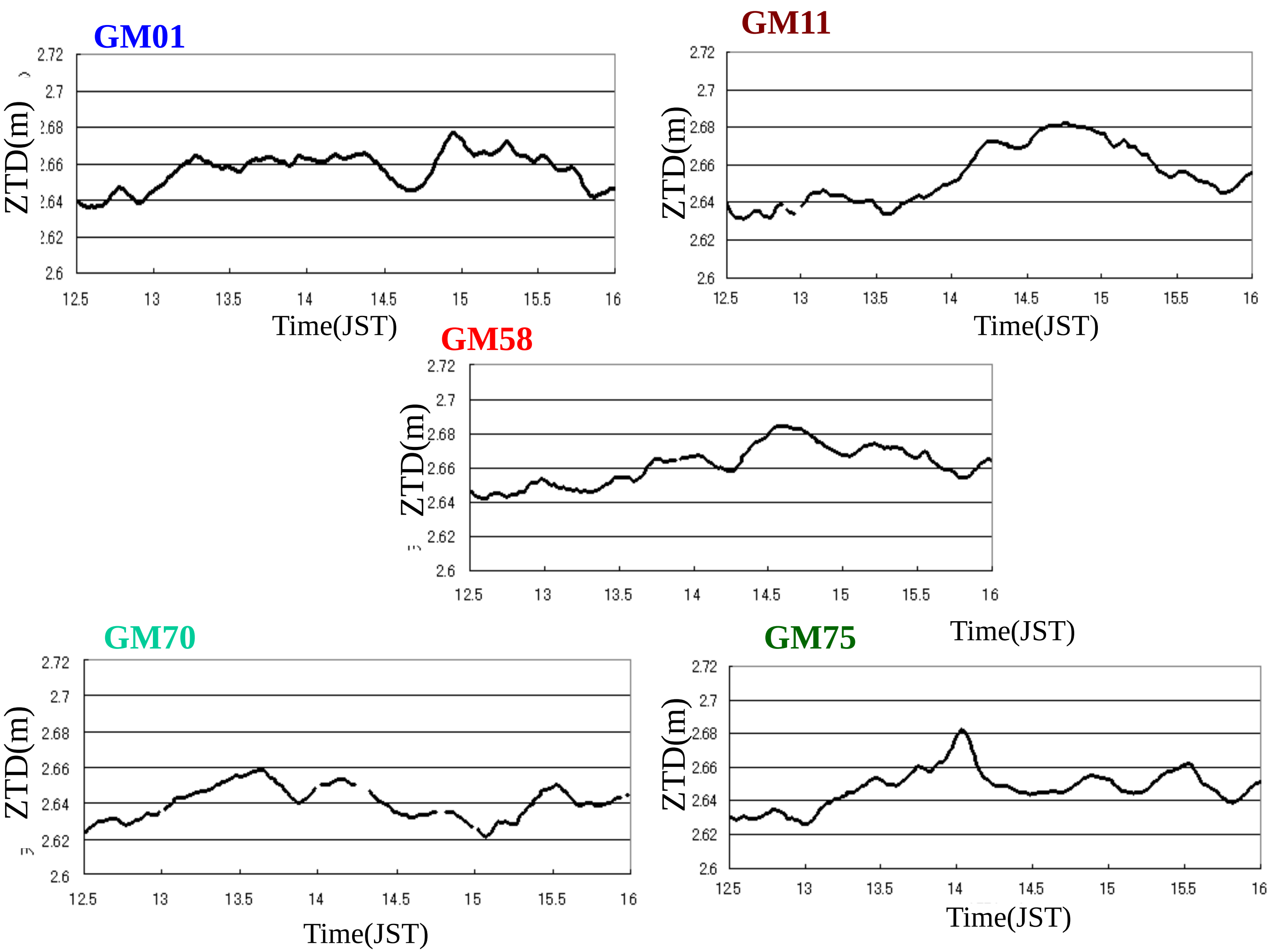


- Large PWV was distributed over the Kanto region
- Water vapor moved toward Low pressure area near Tokyo.
- Around Low pressure, large PVW and precipitation areas were generated.



- Precipitation in the southern part decreased surface T, Qv and PWV.
- Surface flows converged (diverged) at 1350JST (1430JST).
- Gradient parameters in the northern part pointed to the south.





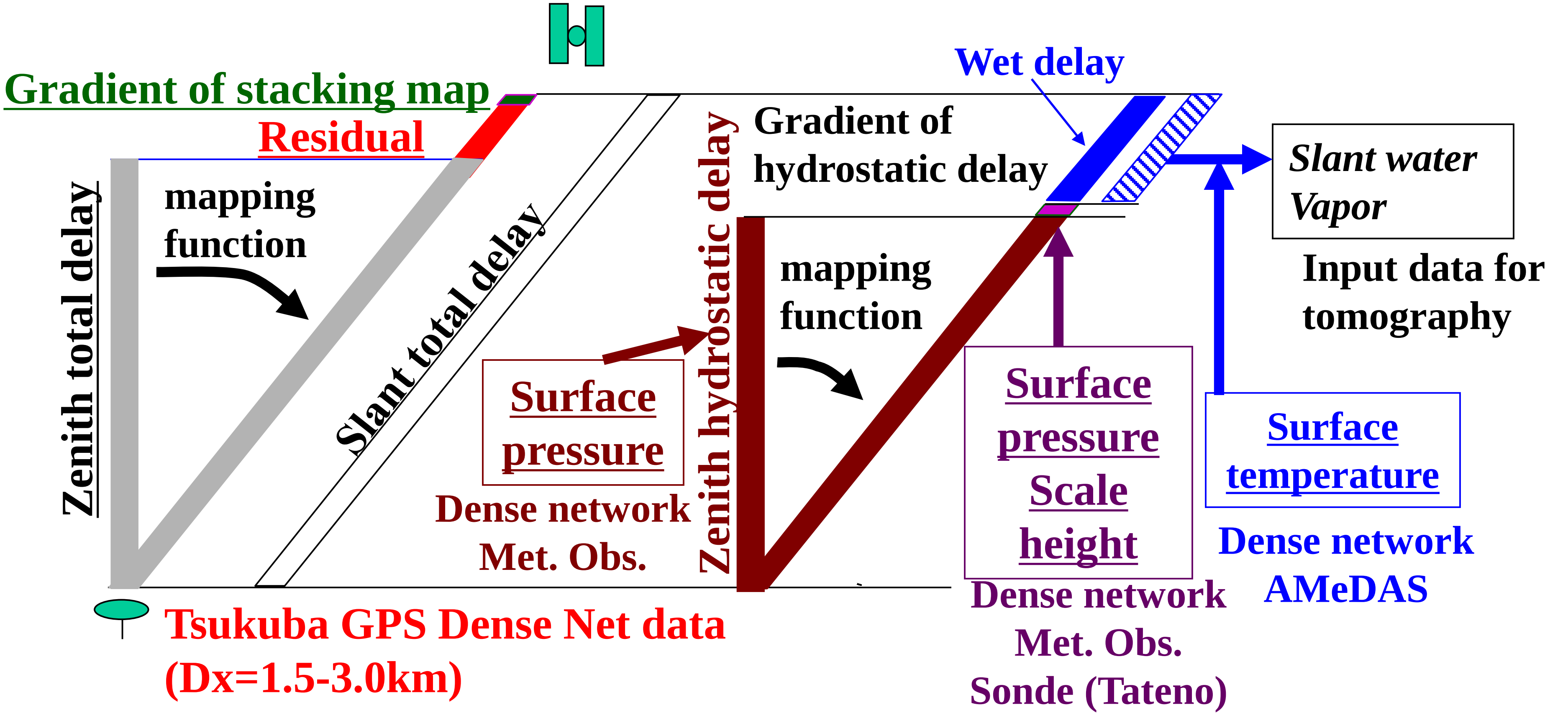
- Variation of ZTD depended on the location of the GPS receivers

↓

Small scale variation of ZTD caused by Thunderstorm.

- ZTD increased and decreased in the period of 20–40 minutes.

Estimation of slant water vapor (Tsukuba GPS Dense Net)



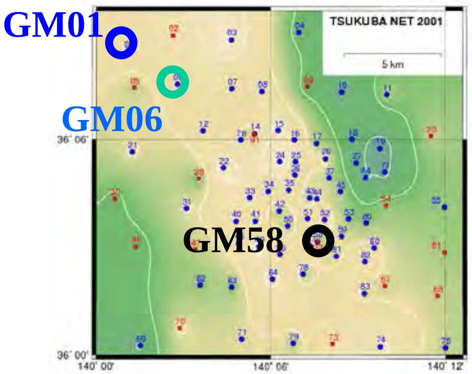
Slant total vapor was estimated from following data:

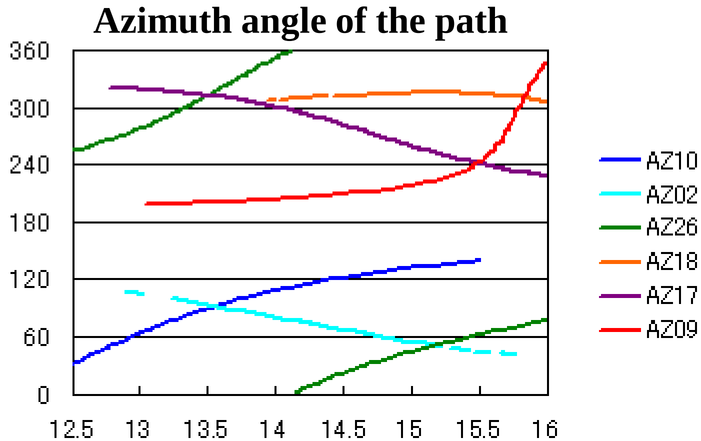
- Tsukuba GPS Dense Net , Met. Observatory, AMeDAS, Sonde

Automated Meteorological Data Acquisition System

Following effects are taken into consider.

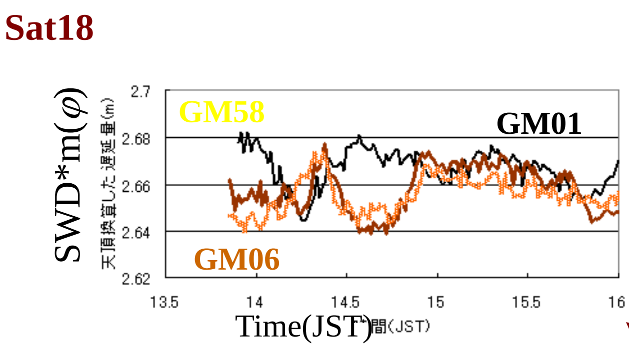
- Gradient of stacking map → climatologic distribution of delay.
- Gradient of hydrostatic delay ← $\nabla_H P_{surf}$ ∗ scale height.

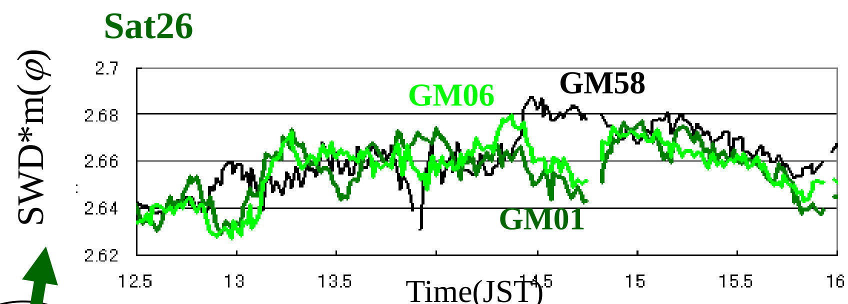


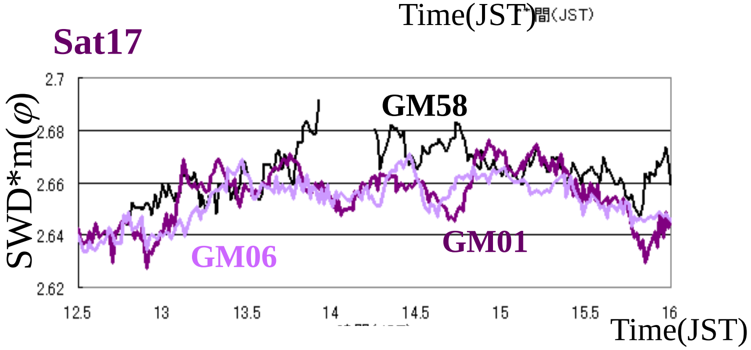


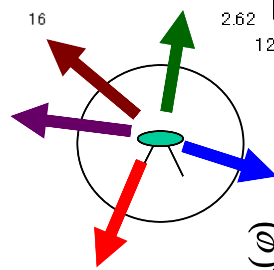
- Slant water vapor between the adjacent GPS receivers are correlated.

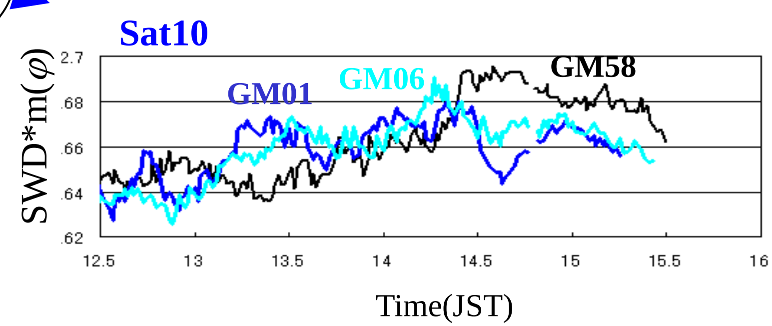
→ SWV contains the signal of water vapor.

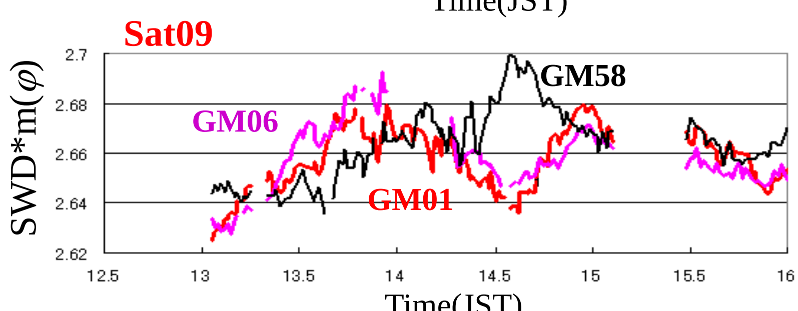


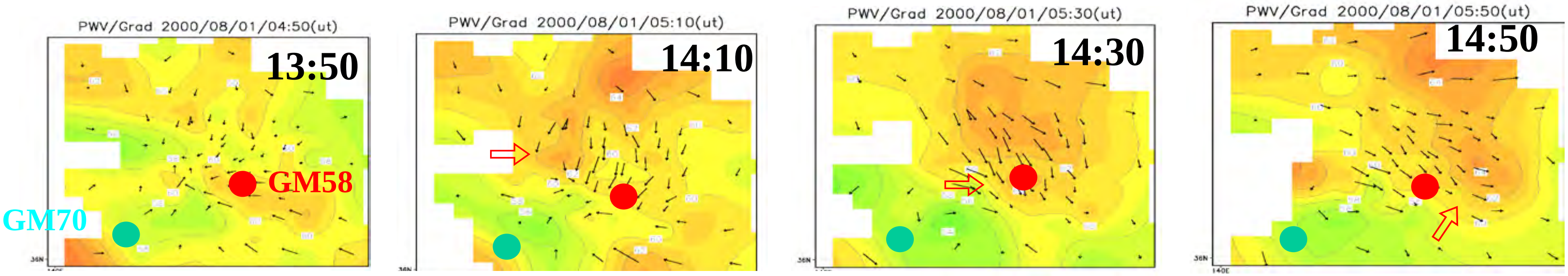


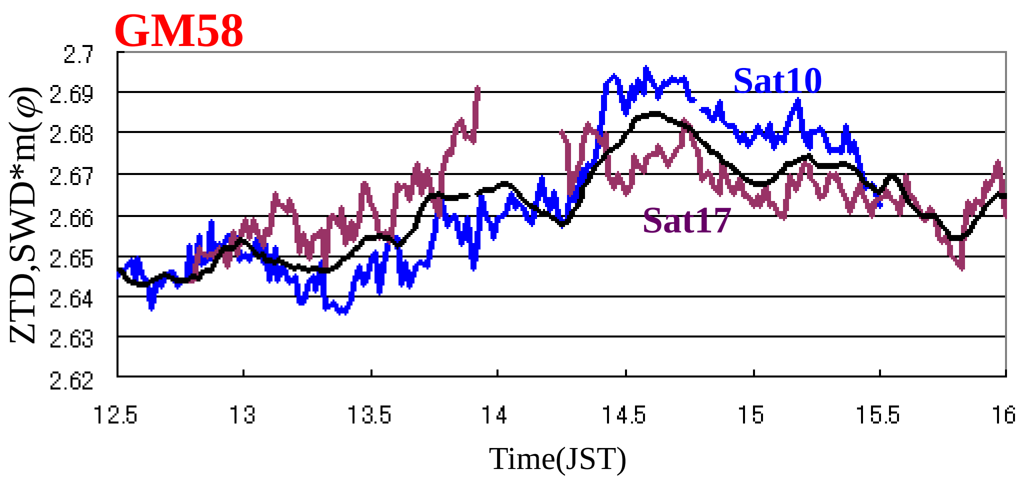


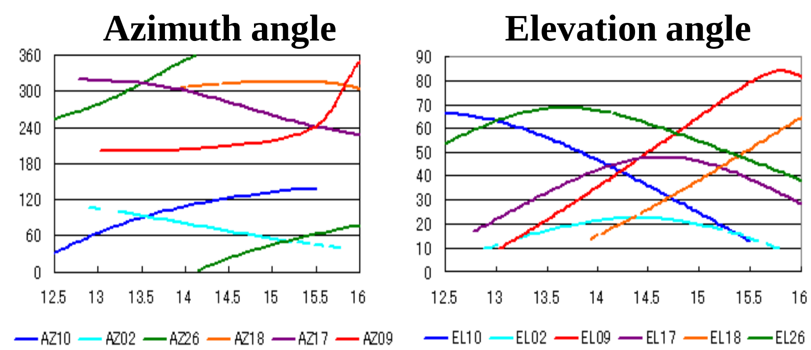






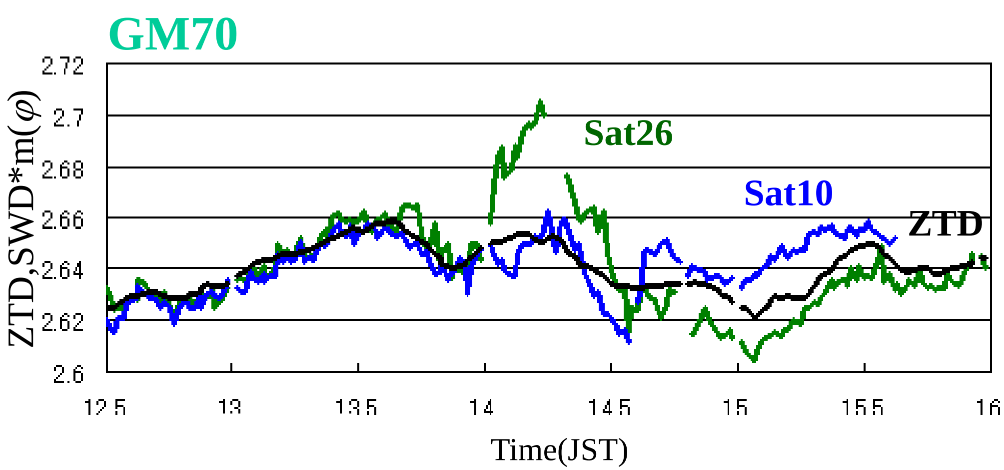






- Large PWV region (⇨)passed GM58 at 1430JST.

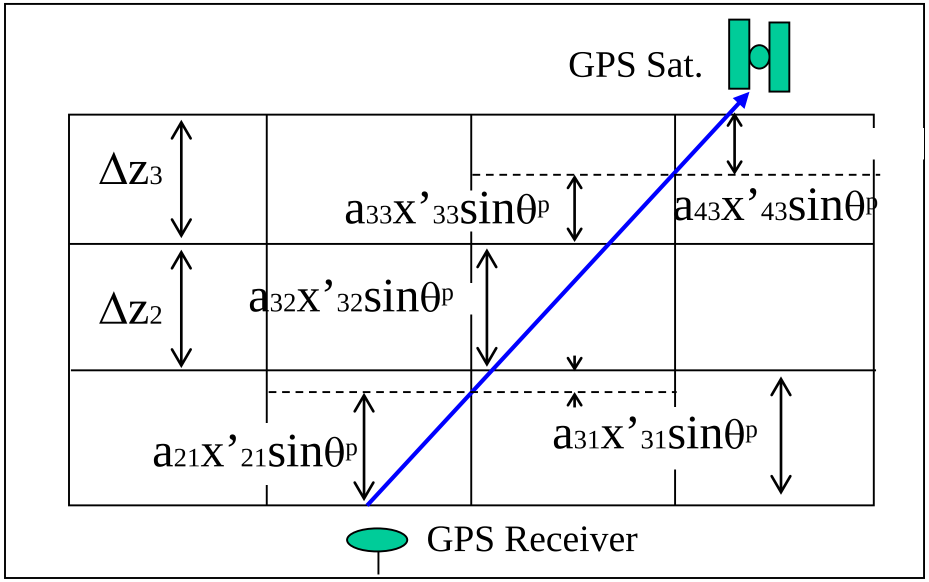
→ SWV of satellite 10 (17) at GM58, which pointed to SE (NW), increased (decreased) at 1430 JST.



- SWV of satellite 26 at GM70, which pointed to north, decreased rapidly at 1430JST.

Method of tomography

Observation equation



- Water vapor along the slant path b^p is used as input data of tomography method

- Atmosphere is divided into the boxes.
  Water vapor is assumed to be uniform in each box (→Box method)

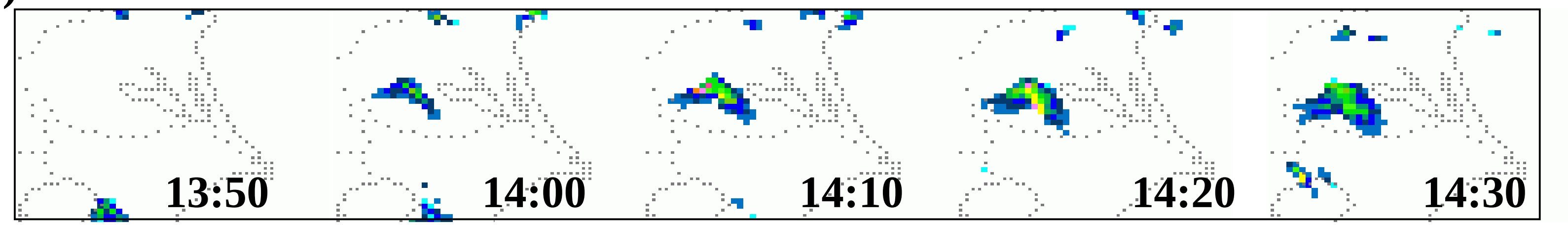
- Water vapor along the slant path b^p is expressed as follows;

  $a_{21}x_{21} + a_{31}x_{31} + a_{32}x_{32} + a_{33}x_{33} + a_{43}x_{43} = b^p$,

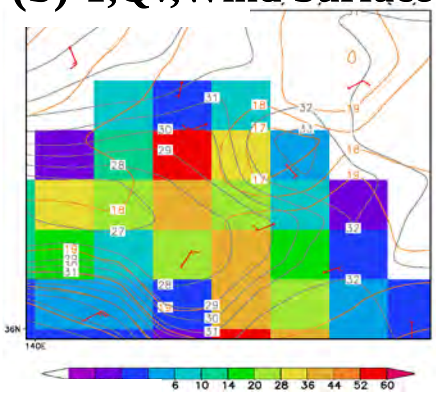
  where x_{ij} is water vapor density and a_{ij} is path length.

- Path length increases as elevation angle θ^p decreased.
  To remove this effects, the equation is multiplied by $\sin\theta^p$

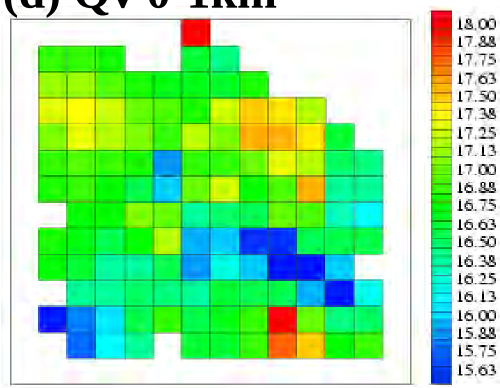
(a) Radar



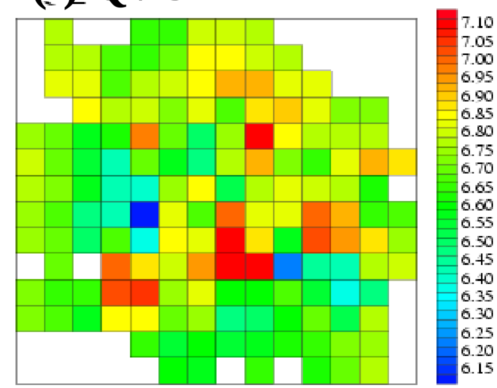
(b) T,Qv,Wind Surface



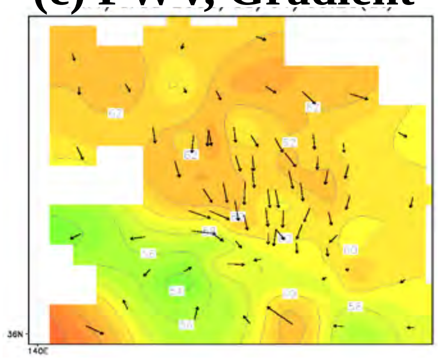
(d) Qv 0-1km



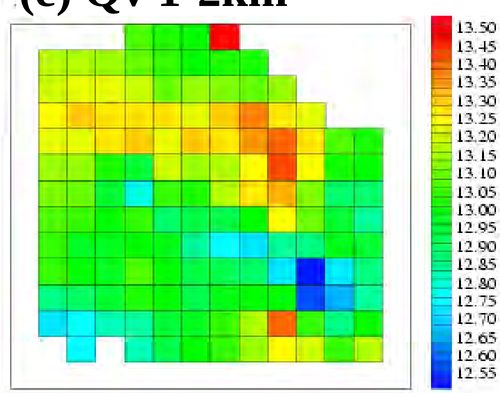
(f) Qv 3-4km



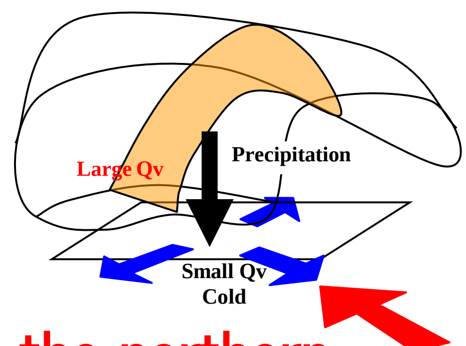
(c) PWV, Gradient



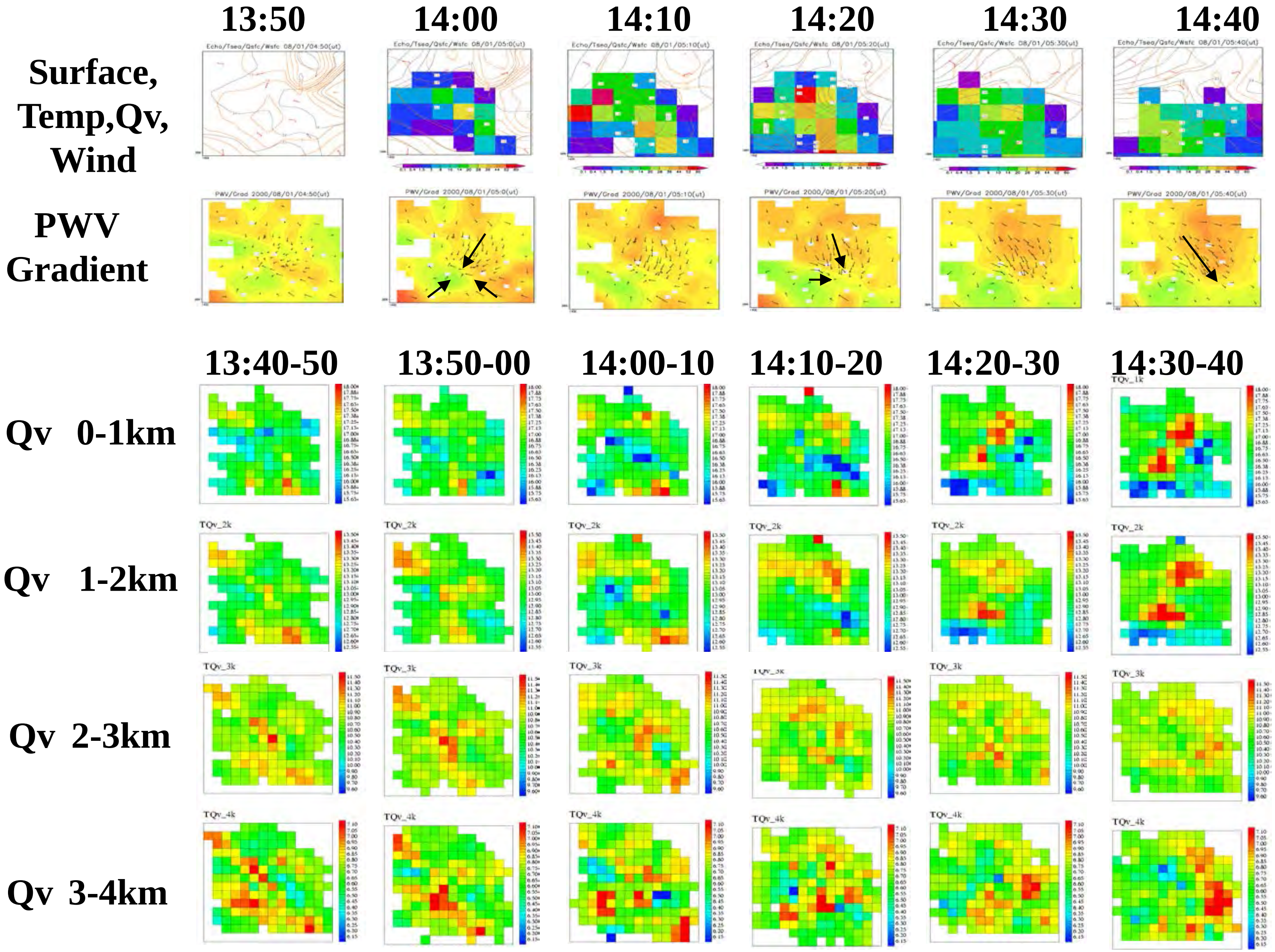
(e) Qv 1-2km



(g) Schematic illustration of precipitation system



- Region of large (small) water vapor existed on the northern side of precipitation region (at precipitation region).
- Large water vapor region in the upper layer existed in southern part. This distribution is consistent with gradient parameter.



- Time variation of water vapor shows that the water vapor deviation did not jump to faraway place.

Summary

- GPS slant water vapor has the signal of the meso-γ scale (~10km) thunderstorm.

- Water vapor variations of the thunderstorm observed by Tsukuba GPS Dense Net:

1) Water vapor decreased under the developed thunderstorm due to the low temperature.
2) Regions of large water vapor at $z>3.5$km correlated to the intense reflectivity regions of 10minutes later.
3) From 10–20 minutes before the appearance of the echo, water vapor began to increase where the echo would appear, especially $z>3.5$km.
4) Most of large water vapor regions at $z>3.5$km correlated to the updraft regions.