Study of Medium-scale Traveling Ionospheric Disturbances (MSTID) with Sounding Rockets and Ground Observations

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Contents

- 2 Sounding rockets from Uchinoura/JAXA on July 20, 2013.
- Experiment plan & preliminary results.

S-520-27 & S-310-42 sounding rocket experiment based on Japan-US collaboration

Objective:

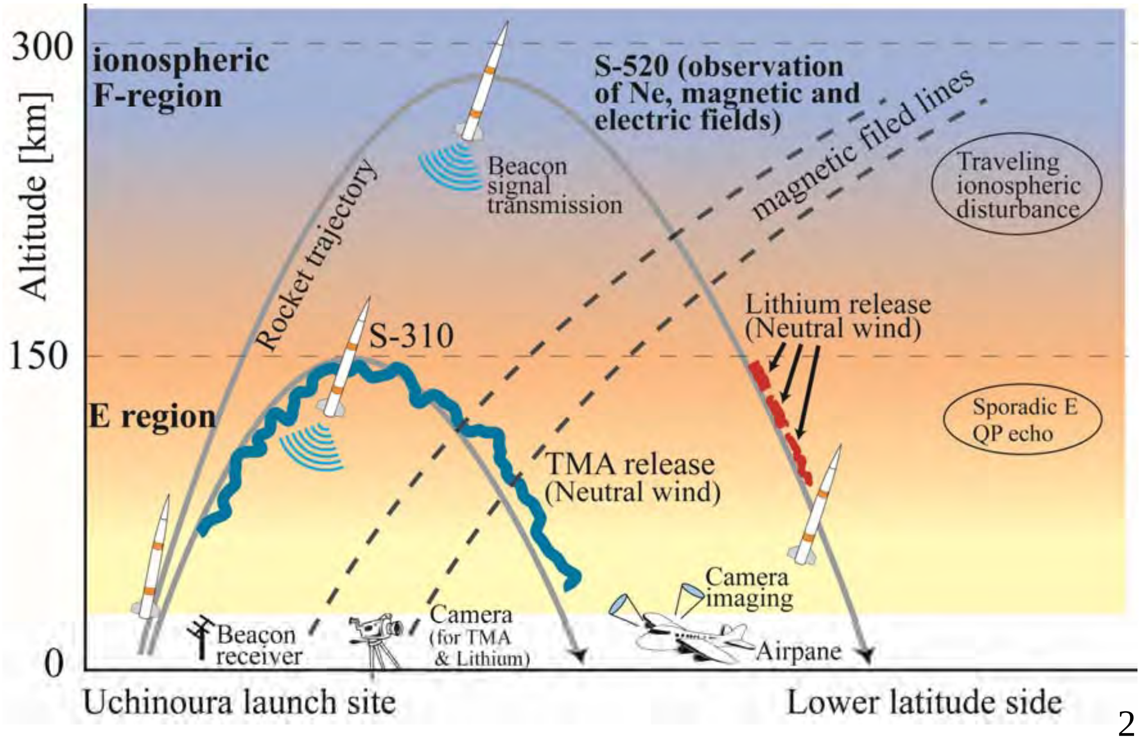
To elucidate generation mechanism of MS-TID by conducting comprehensive observation of the electromagnetic interaction between the ionospheric E and F region.

Summary of Rocket Launch:

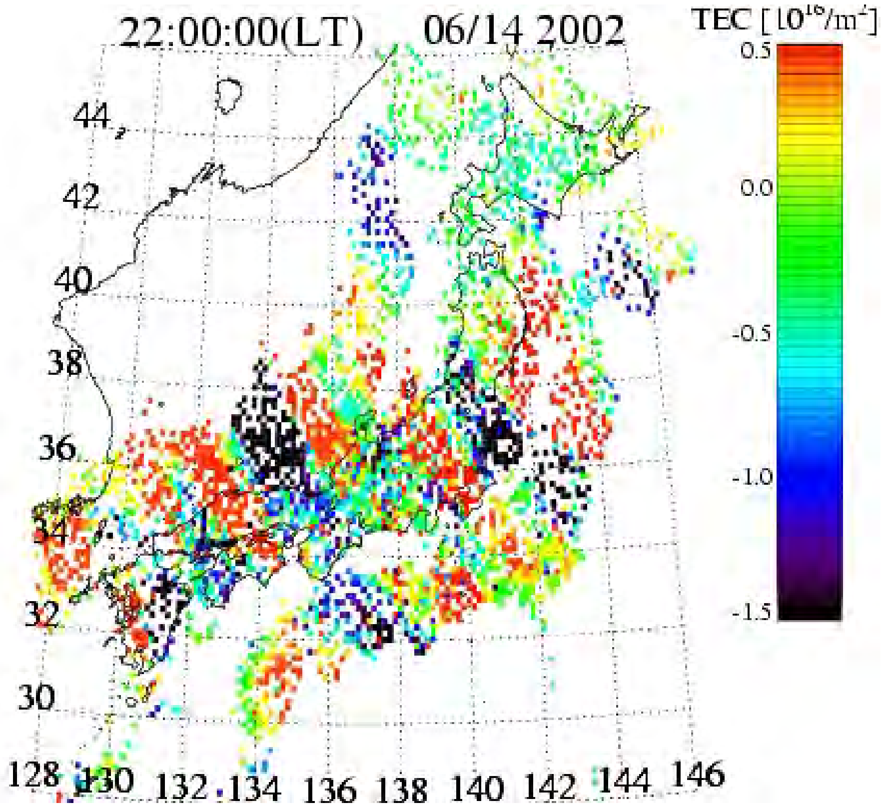
23:00 JST (S-310-42) and 23:57 JST (S-520-27) on July 20, 2013 under condition that MS-TID event was occurring over the launch site. A comprehensive measurement of plasma, neutrals, electric and magnetic fields was made with a suite of science instruments on the two rockets and on the ground to understand various interaction process existing in the mid-latitude ionosphere.

Japan-US collaboration:

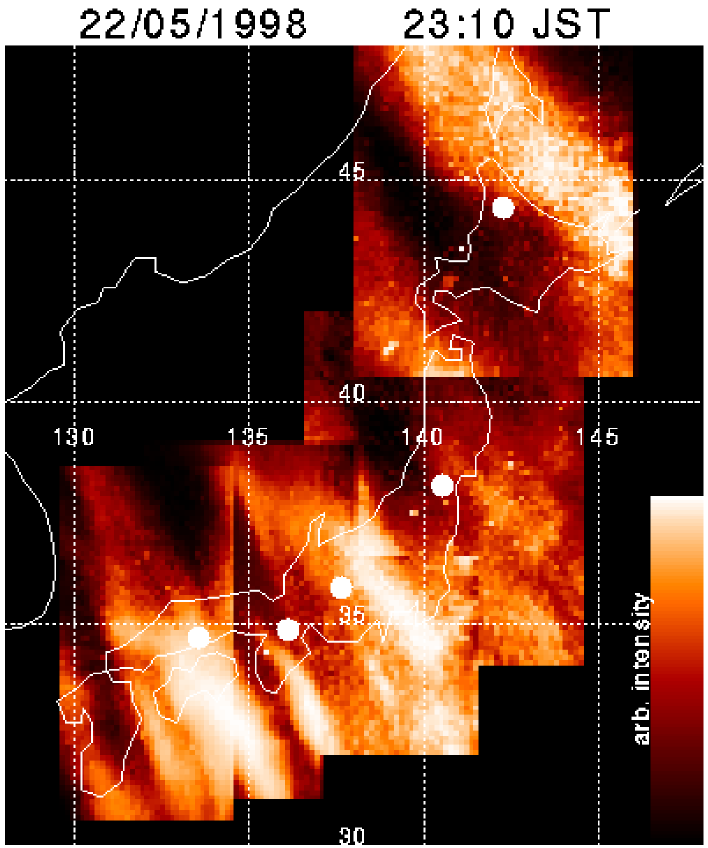
Clemson Univ. and NRL in US provided TMA canister and beacon transmitters onboard the rockets. They joined the experiment by visiting JAXA USC to conduct ground-based observations of Lithium and TMA emission imaging and beacon receiving.



Medium-Scale Traveling Ionospheric Disturbance (MSTID)



GPS-TEC patterns

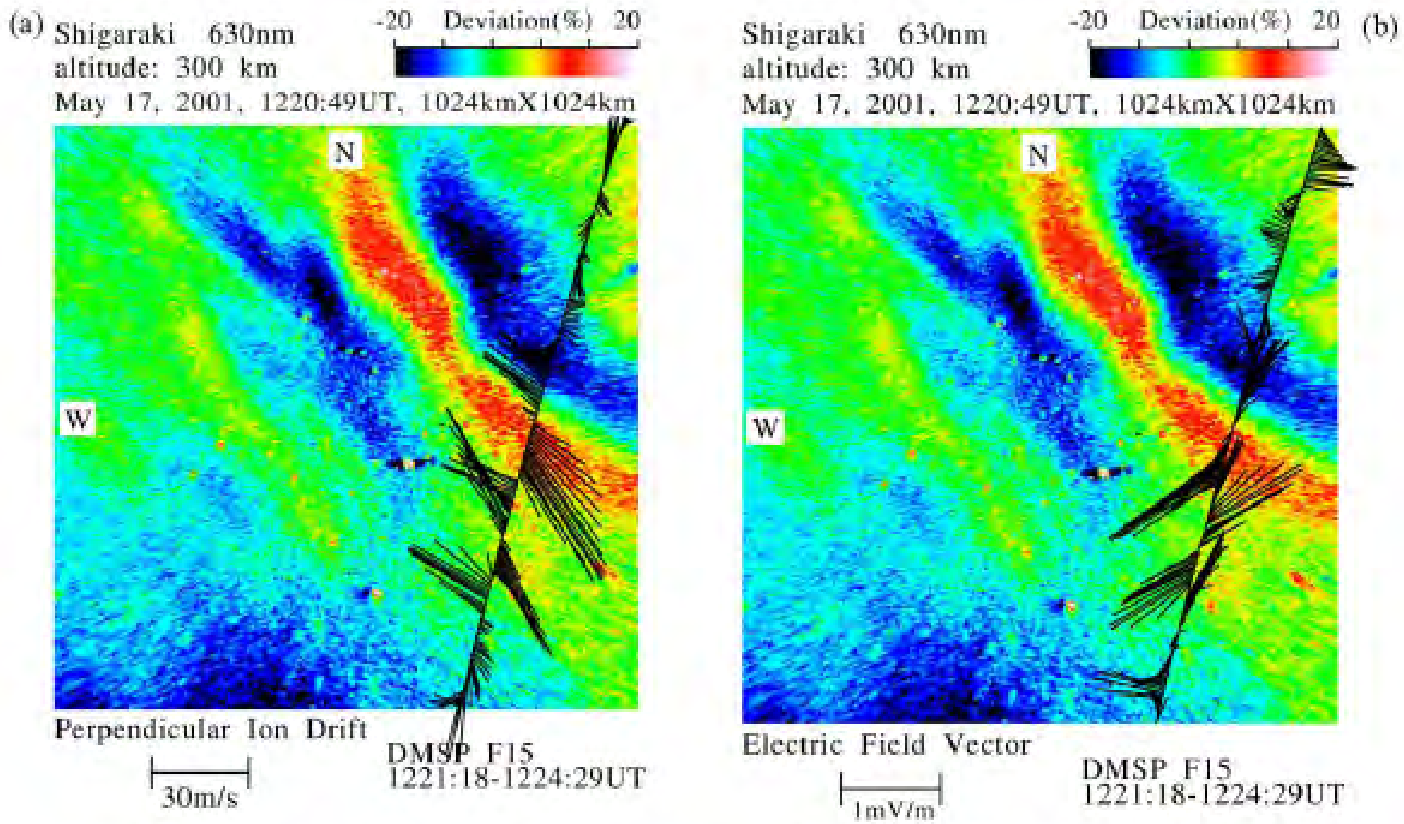


Airglow (630nm) imagers

MSTID: F-region TEC pattern of 1-2 hours, 100-200km wavelength, and maximizes in summer and propagates southwestward.

MSTID detected in 630nm airglow and simultaneous DMSP ion-drift/electric-field

(Shiokawa et al., JGR, 2003)



- Electric-fields were found in good association with MSTID patterns. The structure resembles to that of Perkins instability.
- Growth rate of Perkin instability is, however, too small to explain the observations. → Needs more mechanism.

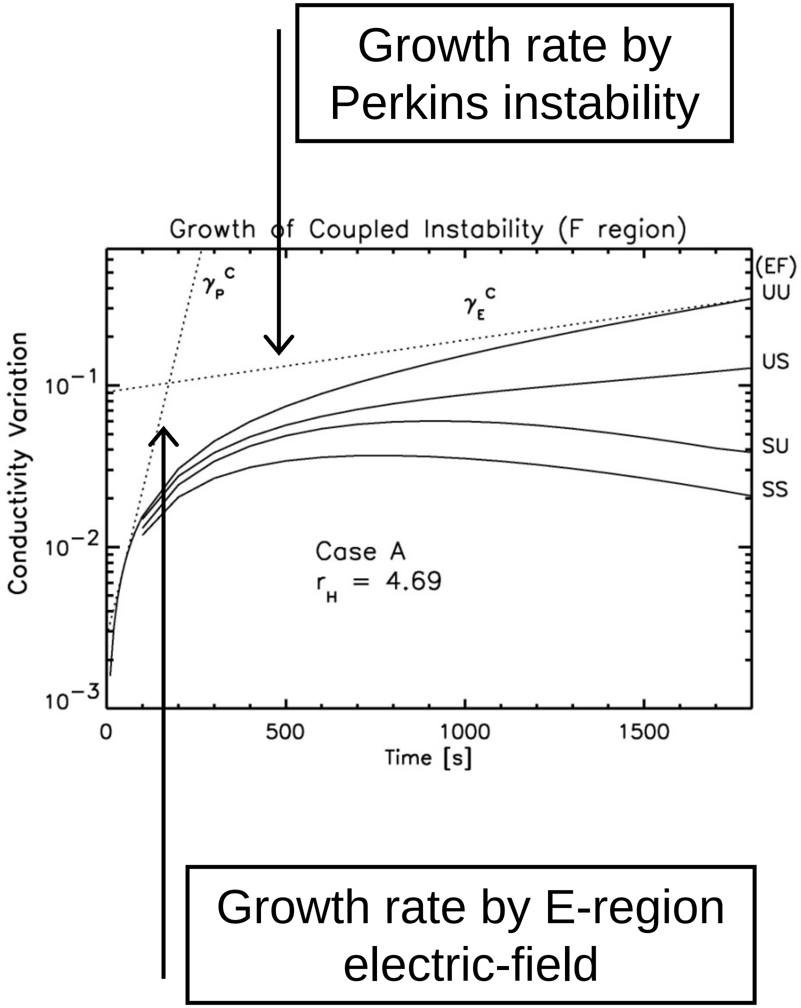
E- and F-region Coupling

- Couplings occur through polarization electric-field mapping.
- Observations in the past
  - Comparison of F-region TID and Sporadic-E (Es) layer
    - Ionosonde traces for E and F-regions [e.g., Chen et al., 1972]
    - 630 nm airglow image ⇔ Es-layer patch [Kelley et al., 2003]
- Theoretical study
  - Perkins instability (F-region) ←→ Azimuth-dependent Es-layer instability (E-region) [Cosgrove et al., 2004]

FERIX (F- and E-Region Ionosphere Coupling Study)

- Direct observation of coupling between F- and E-region FAIs
- Instruments
  - MU radar for F-region FAI
  - LTPR (portable radar) for E-region FAI
  - GPS receiver network for F-region TID
  - Airglow imager network for F-region TID and E-region structures
  - Ionosonde network for spread-F and basic ionosphere parameters

3D simulation of E-/F-region coupling



Scenario of MSTID generation proposed from 3D simulation by Yokoyama et al (2009)

(A) Fluctuations in the F-region, while they are small, rapidly grow by intense E-region polarization electric fields.

(B) When F-region fluctuations become large, they more grow according to the growth rate of Perkins instability.

(C) NW-SE pattern of MSTID is determined by the Es-layer instability mechanism.

(D) Southwestward propagation of MSTID is explained by southward wind in E-region.

We want to confirm this scenario by the rocket/ground observation

3D simulation of E-/F-region coupling

”Es layer with random pattern” + “E-region southward wind”

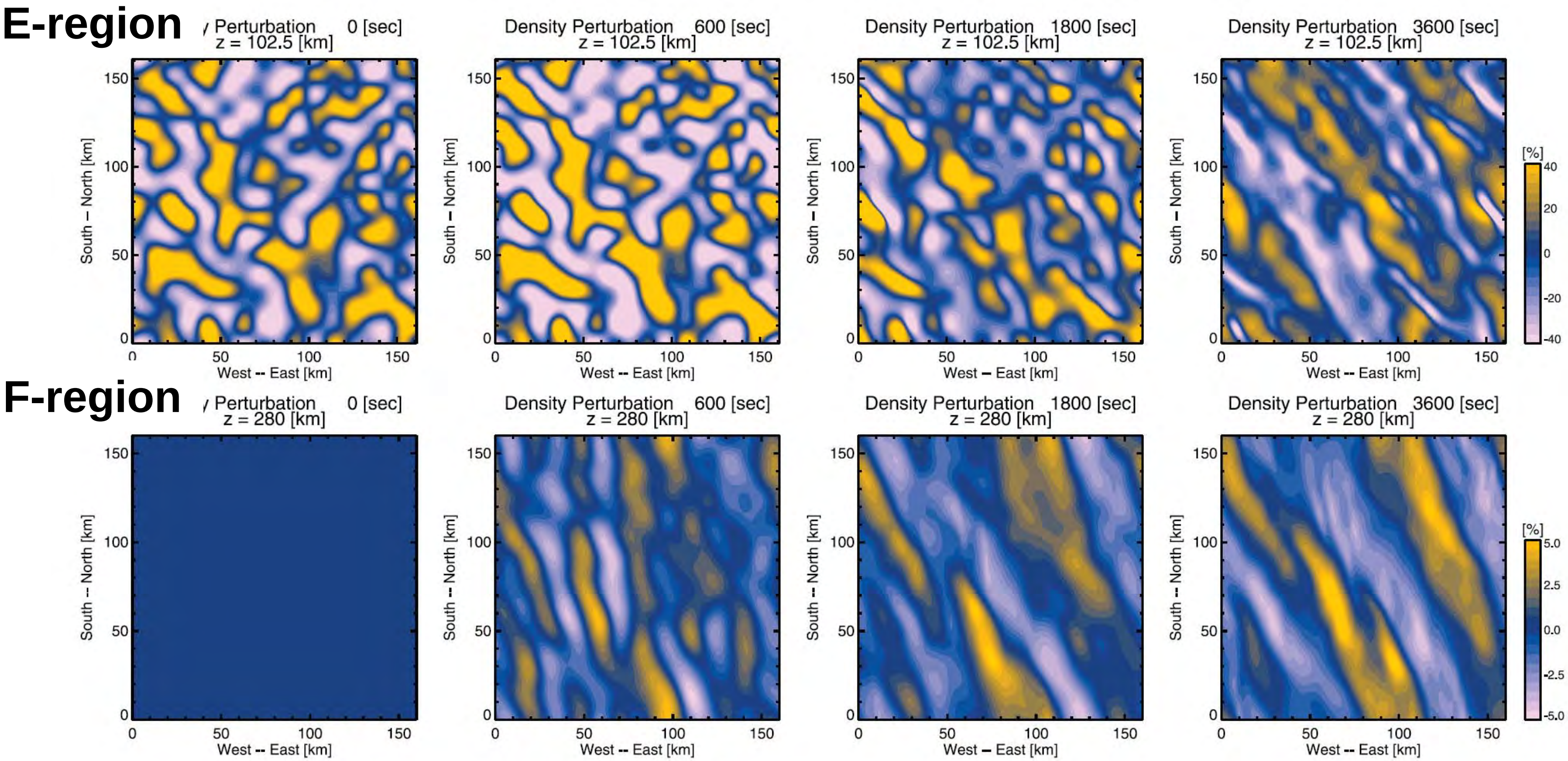
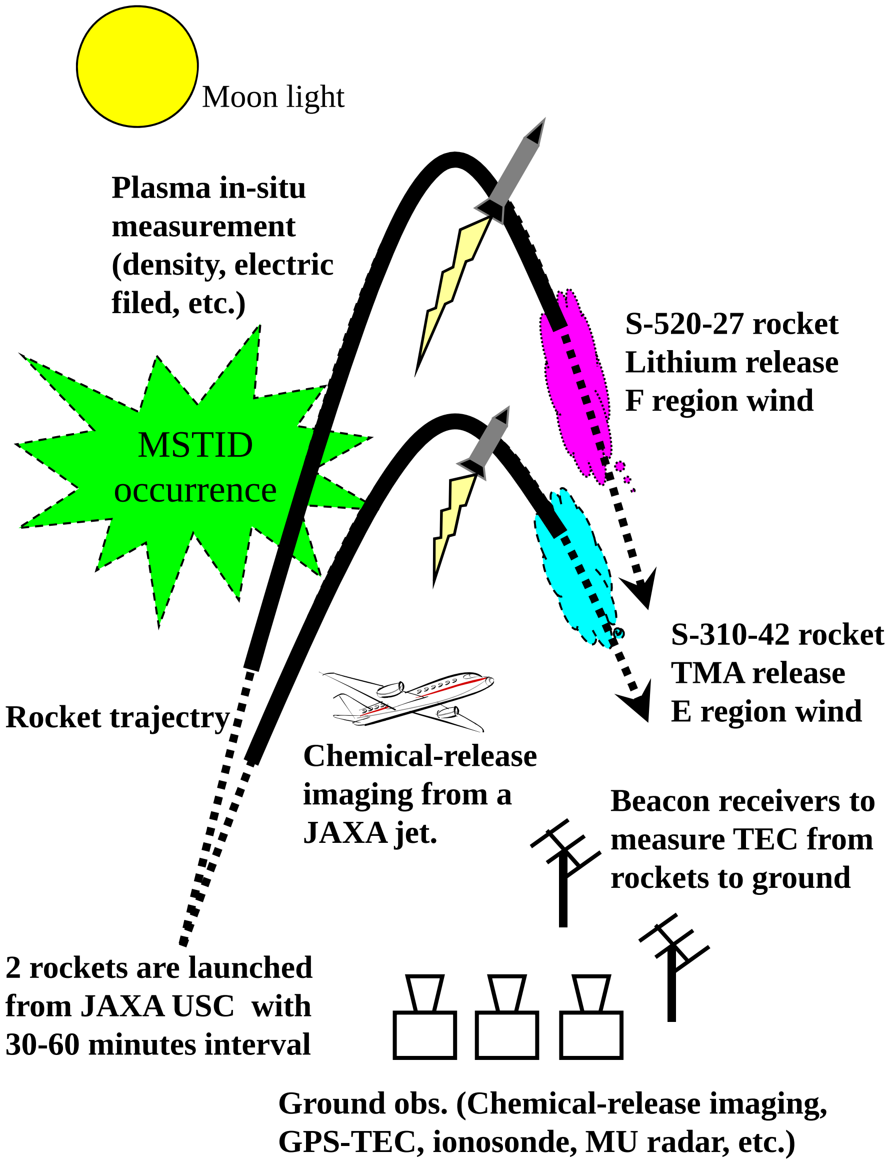


Figure 11. Plasma density perturbation at altitudes of (top) 102.5 and (bottom) 280 km at $t = 0$, 600, 1800, and 3600 s in case RP1. The top images are shifted along the meridional direction so that the same coordinate points are connected by **B**.

(Yokoyama et al., JGR, 2009)

Rocket experiment for E-F coupling



Simultaneous sounding rocket and ground observations.

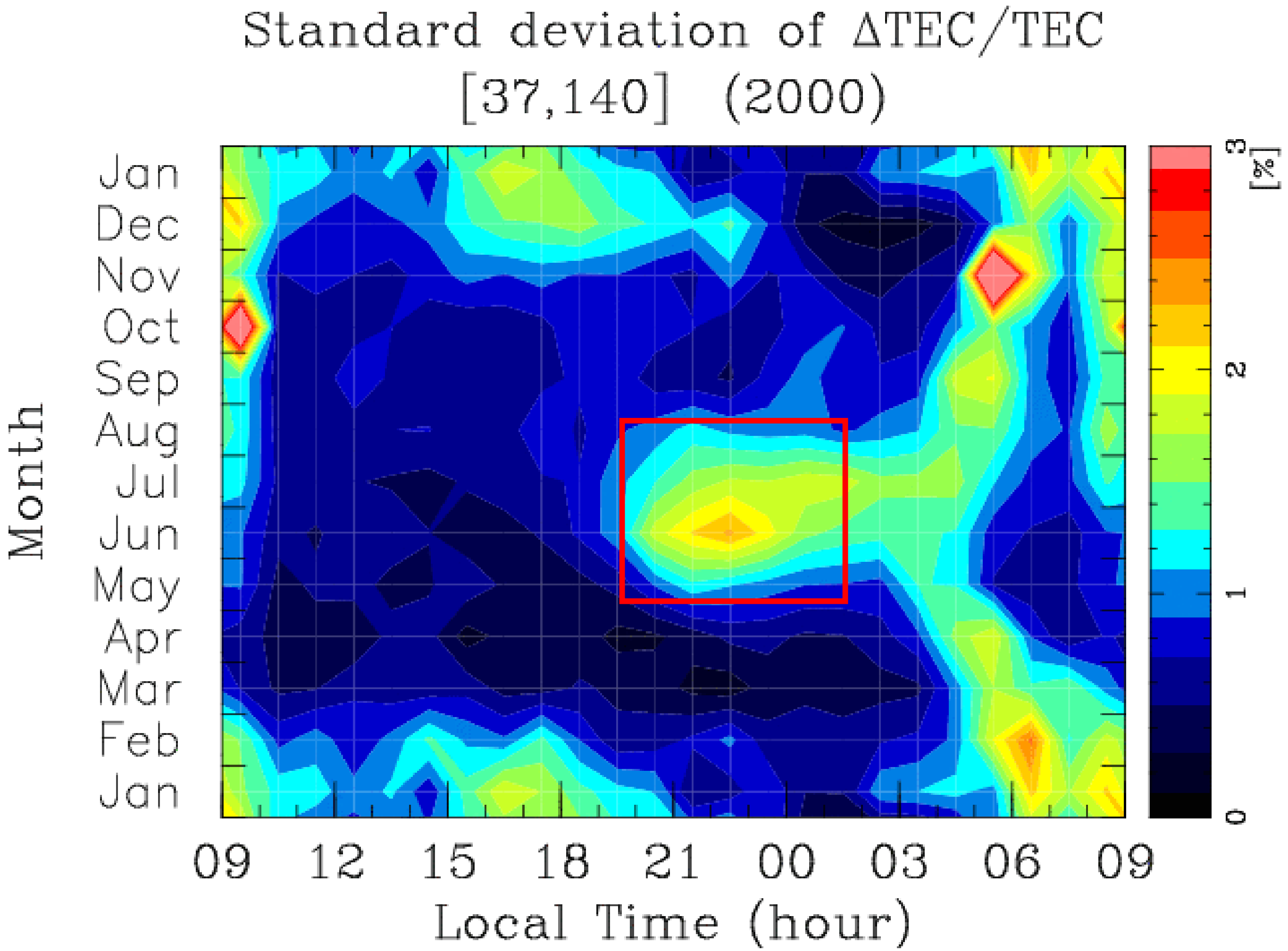
Rockets provide both plasma parameters and neutral winds in E-region and F-region.

MSTID tends to occur at night (21-24 LT) in summer. We need to measure winds in the nighttime.

→ We have to try Lithium-release experiment with the moonlight.

We need to decide the rocket launch by confirming MSTID is active in the F-region.

Seasonal variation of MSTID activity



Occurrence probability of night-time MS-TID has the maximum in summer solstice and winter solstice

Instrumentation - 1

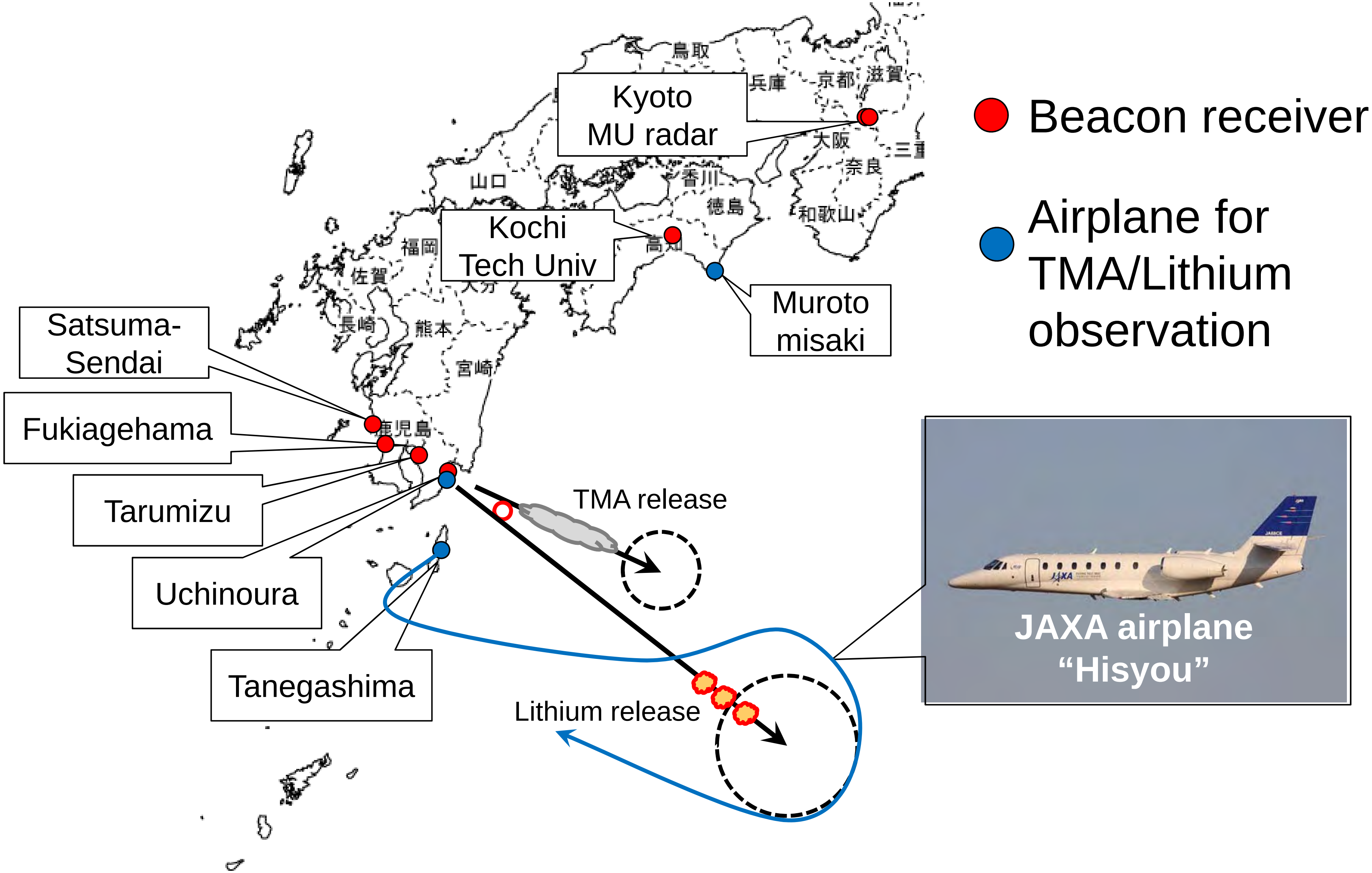
- **S-520-27 rocket (covering up to 300 km)**
  - Electric field by double probe (EFD)
  - Plasma density by impedance probe (NEI)
  - Density fluctuation by fixed-bias probe (FBP)
  - High-sensitivity magnetometer (MGF)
  - Dual-band beacon transmitter (DBB)
  - Star sensor (IAF)
  - Moon sensor (MAS)
  - Lithium release canister (LES)

Instrumentation - 2

- **S-310-42 (covering up to 140 km)**
  - TMA release canister (TMA)
  - Dual-band beacon transmitter (DBB)
  - GPS receiver

- **Ground observations**
  - Camera sites for Lithium/TMA emission
  - DBB beacon receiver
  - GPS-TEC mapping

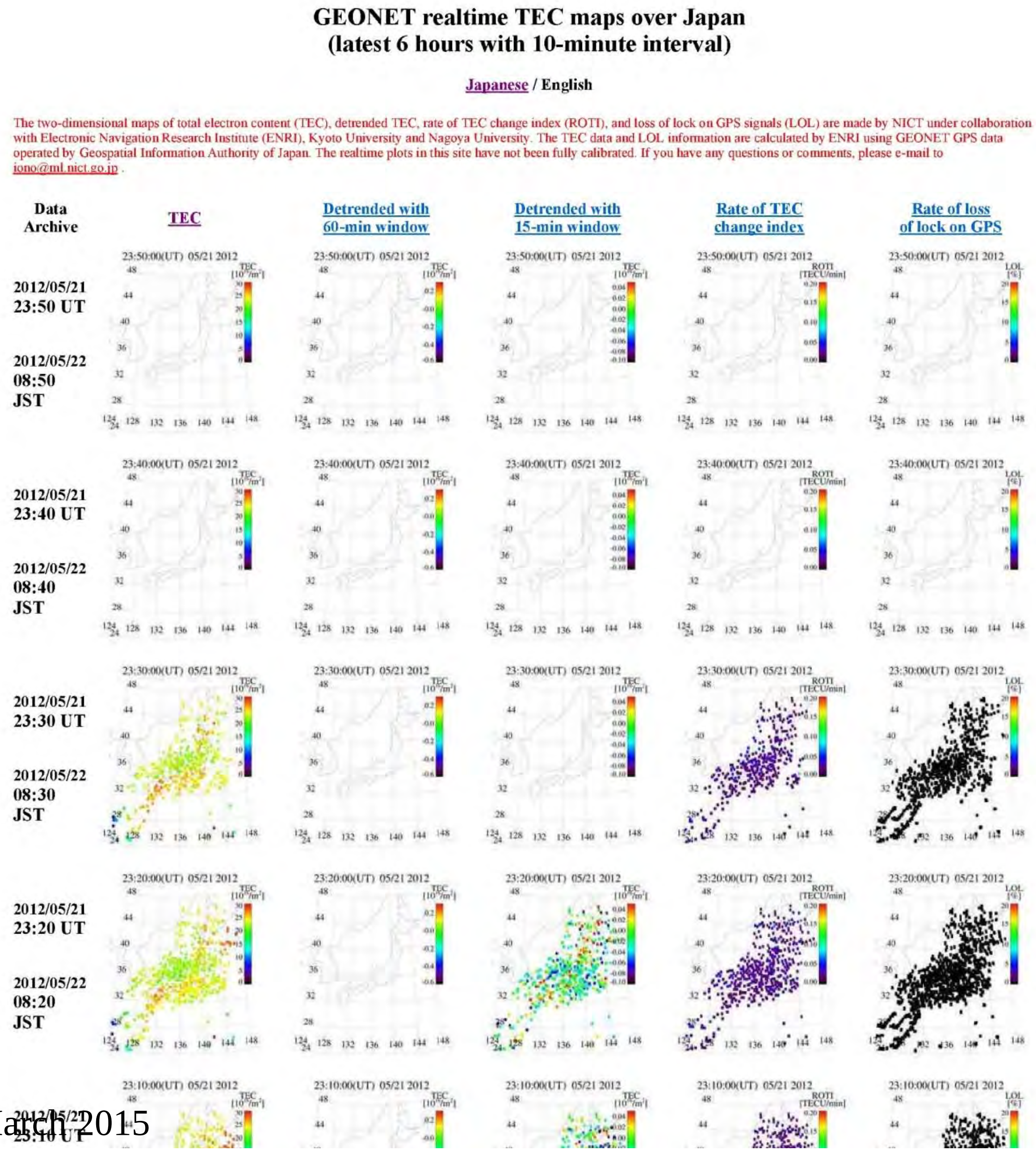
Location of the ground-based and airplane observation



Launch Criteria

- Phenomena
  - MSTID
    （July～August, 2300-2400 LT）
    - Real-time monitoring of GPS-TEC data
- Launch window
  - Full moon (July 23) ±3 days
- Weather
  - Clear sky in the remote site (for Lithium/TMA observation)

Near real-time GPS-TEC mapping



S. Saito (ENRI), T. Tsugawa (NICT), etc. developed “near real-time” mapping of GPS-TEC over Japan. They use 1s-reslution data from GEONET.

This figure is taken their test site for services.

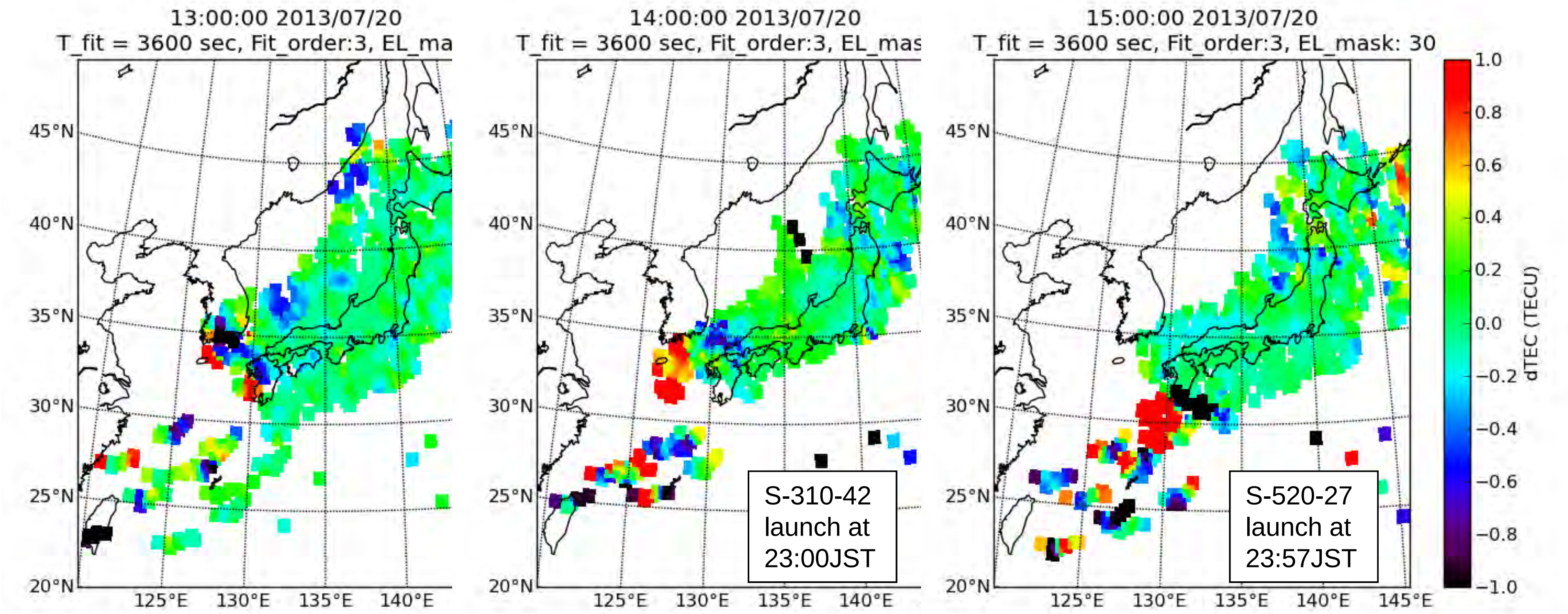
GPS-TEC real-time monitoring helped determine the launch timing (every 5-min renew, 3-min delay).

GPS-TEC data before and after the rocket launch

Saito (ENRI), Tsugawa (NICT)

July 20, 2013

22JST 23JST 24JST



By receiving GEONET data at 200 points, TEC distribution over Japan was distributed every 5 minutes (developed by Saito (ENRI))

⇒ Two rockets were launched at 23:00JST and 23:57JST by confirming existence of the ionospheric disturbance.

Photos from the ground

Sky was clear during the experiment.
These are example photos from Satsuma-sendai city.

TMA
downleg

TMA
upleg

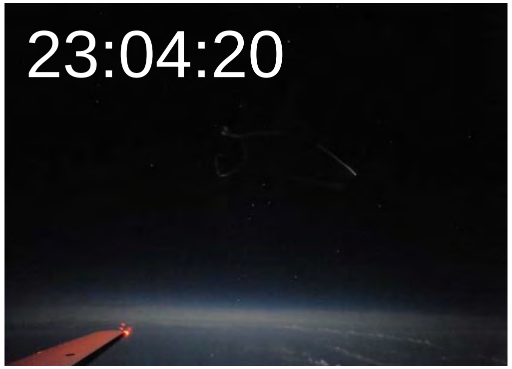
Photos by Hayamizu and
Ando at Sendai Uchu-kan

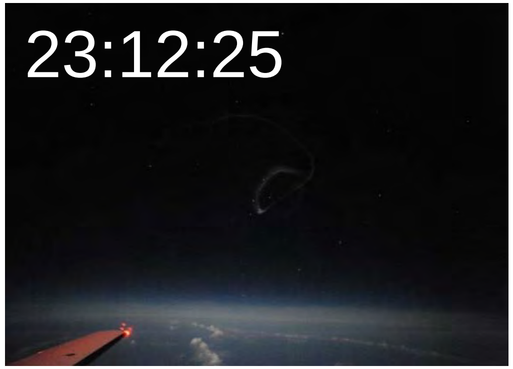
http://sendaiuchukan.jp/data/gallery/ex/1307-TMA.html

S-310-42
launch

Lithium and TMA photos

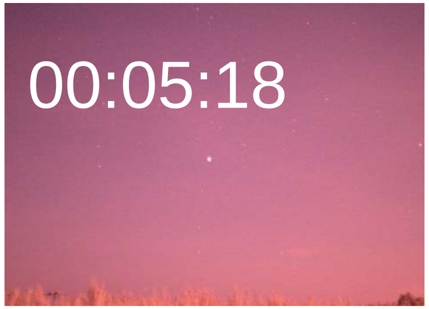
Masa-Yuki Yamamoto (KUT), H. Habu (ISAS/JAXA),
S. Watanabe (Hokkaido Univ.), M. Larsen (Clemson Univ.)

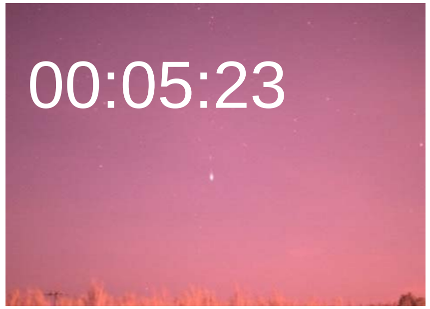


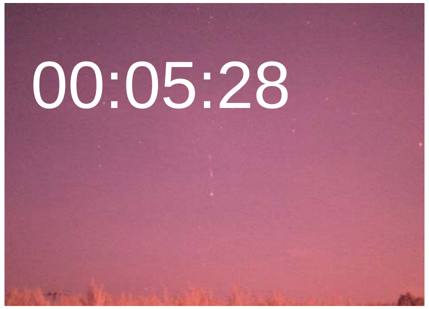


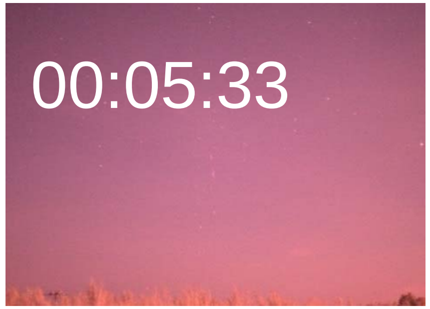
TMA: from airplane

Lithium : from airplane









Lithium : Tanegashima, Lithium from the ground

Summary

Rocket experiment of MSTID + E/F coupling

- Two sounding rockets were launched on July 20, 2013 to study MSTID and E-F coupling.
- GPS-TEC real-time monitoring helped determine the launch timing (every 5-min renew, 3-min delay).

Results from experiment (still on-going)

- Lithium imaging from airplane under the full moon.
- Wind from TMA shows strong shear with Es (as usual).
- We found large spatial variation of F-region electron density and electric field, which is consistent with Perkins instability.