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Possible shear instability in the daytime midlatitude sporadic-*E* observed with InSAR and GPS-TEC

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Summary

A coordinated observation of GPS total electron content (TEC) and space-borne interferometric synthetic aperture radar (InSAR) has been conducted to reveal both the large- and small-scale plasma structures of daytime midlatitude sporadic-*E* (Es). Both observations are used for the direct imaging of the plasma patches. GPS-TEC observations have shown a common frontal shape of Es elongated typically in the east-west (E-W) direction, while an interferogram derived from InSAR observation have revealed the small-scale (fine) structure of Es. Small-scale patches are aligned in the E-W direction which is the same azimuthal direction of dominant large-scale frontal structure. **We speculate that the Kelvin-Helmholtz instability with the vertical shear of meridional winds is considered to be the most likely candidate for the generation mechanism of the small-scale plasma patches aligned in the zonal direction**.

Slant TEC

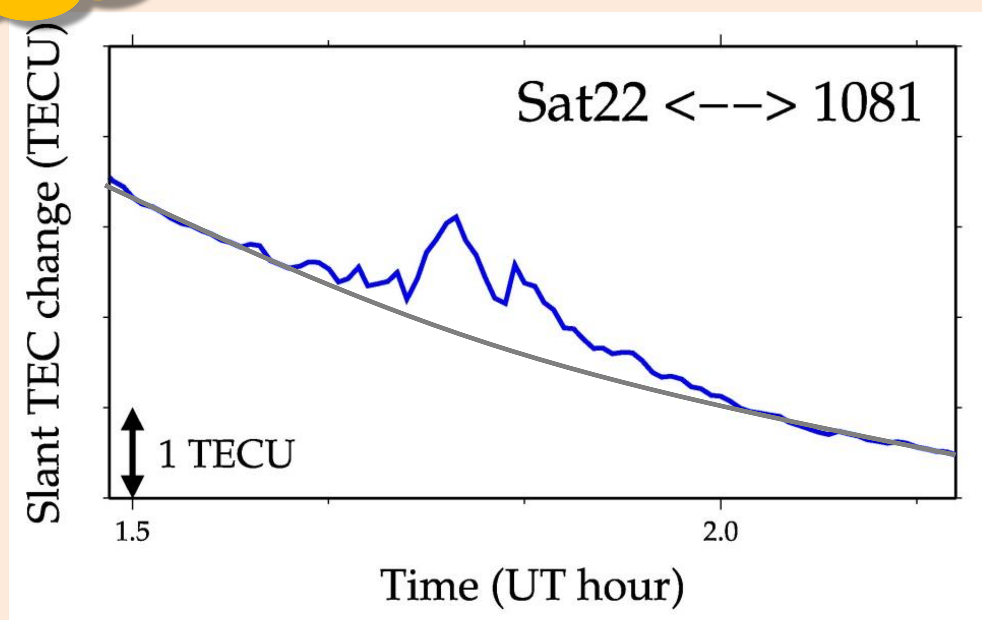
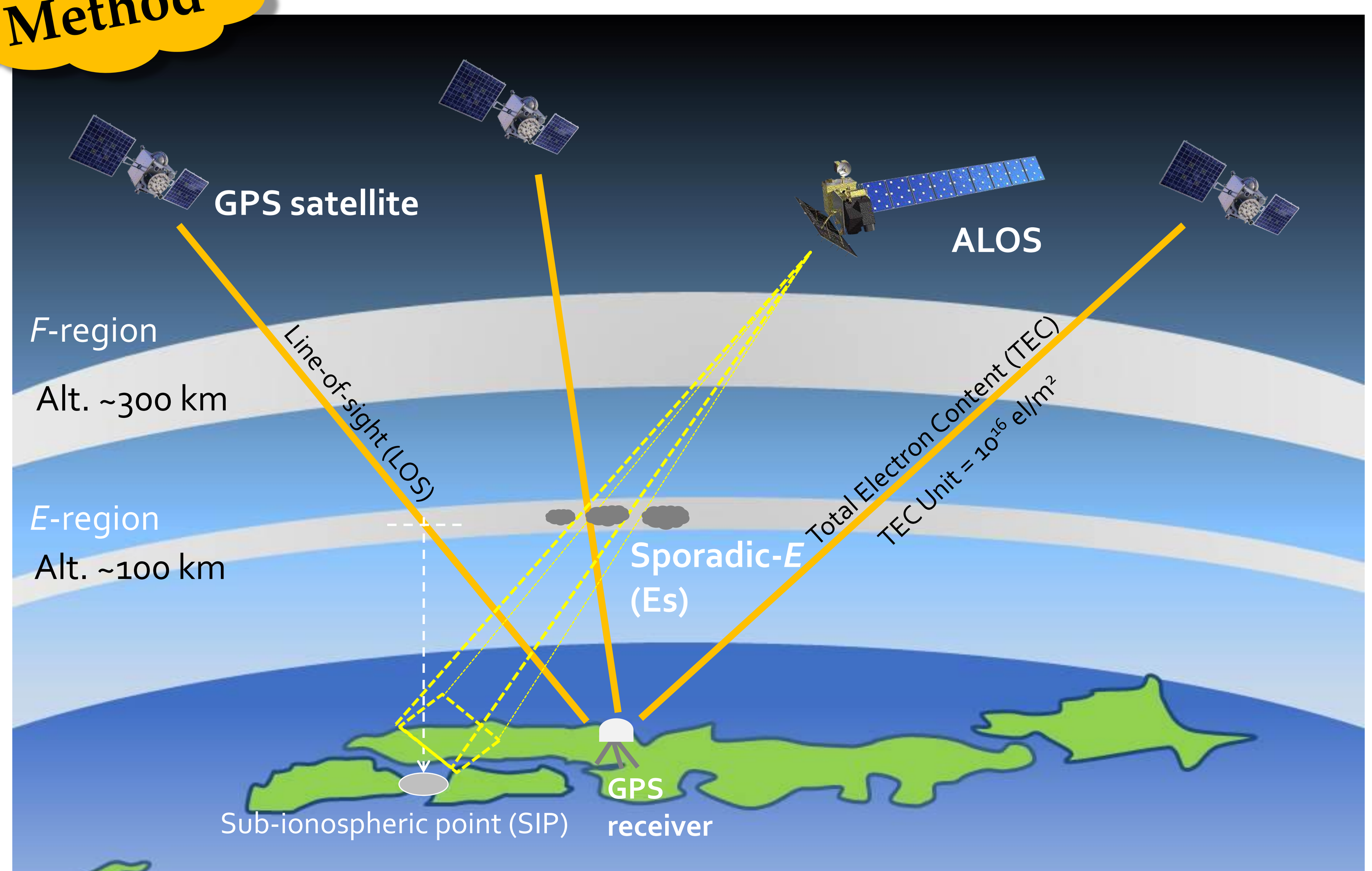


Fig.1 Slant TEC time series (observed / model). Es leaves peculiar signature of pulse-like positive TEC enhancement in the slant TEC time series. By analyzing the slant TEC time series with the corresponding SIP track, small-scale structures can also be inferred with GPS-TEC observation.

Method



"**Sporadic-*E***" is a densely ionized thin plasma patch that **sporadic**ally appears at an altitude of ~100 km (***E***-region of the ionosphere).

Rough Image

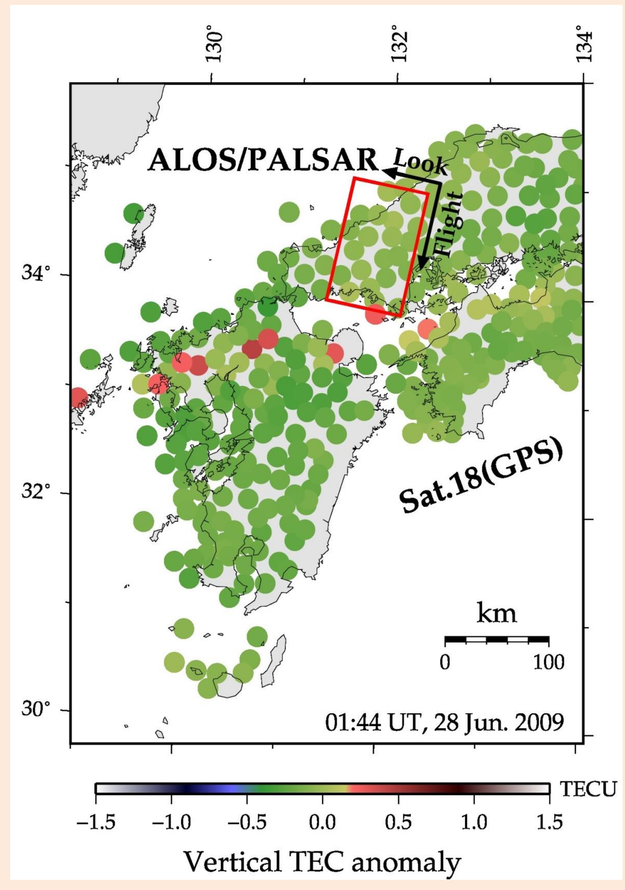


Fig.3 Vertical TEC anomaly map at 01:44 UT derived from GPS Satellite 18 when ALOS acquired the SAR image (red framed region). ALOS was on a descending orbit and observed Es looking the right side. Vertical TEC anomaly map shows a large-scale frontal structure which elongates over 250 km in the ENE-WSW direction. The SAR observation area corresponds to the eastern part of the frontal structure.

Altitude Constraint

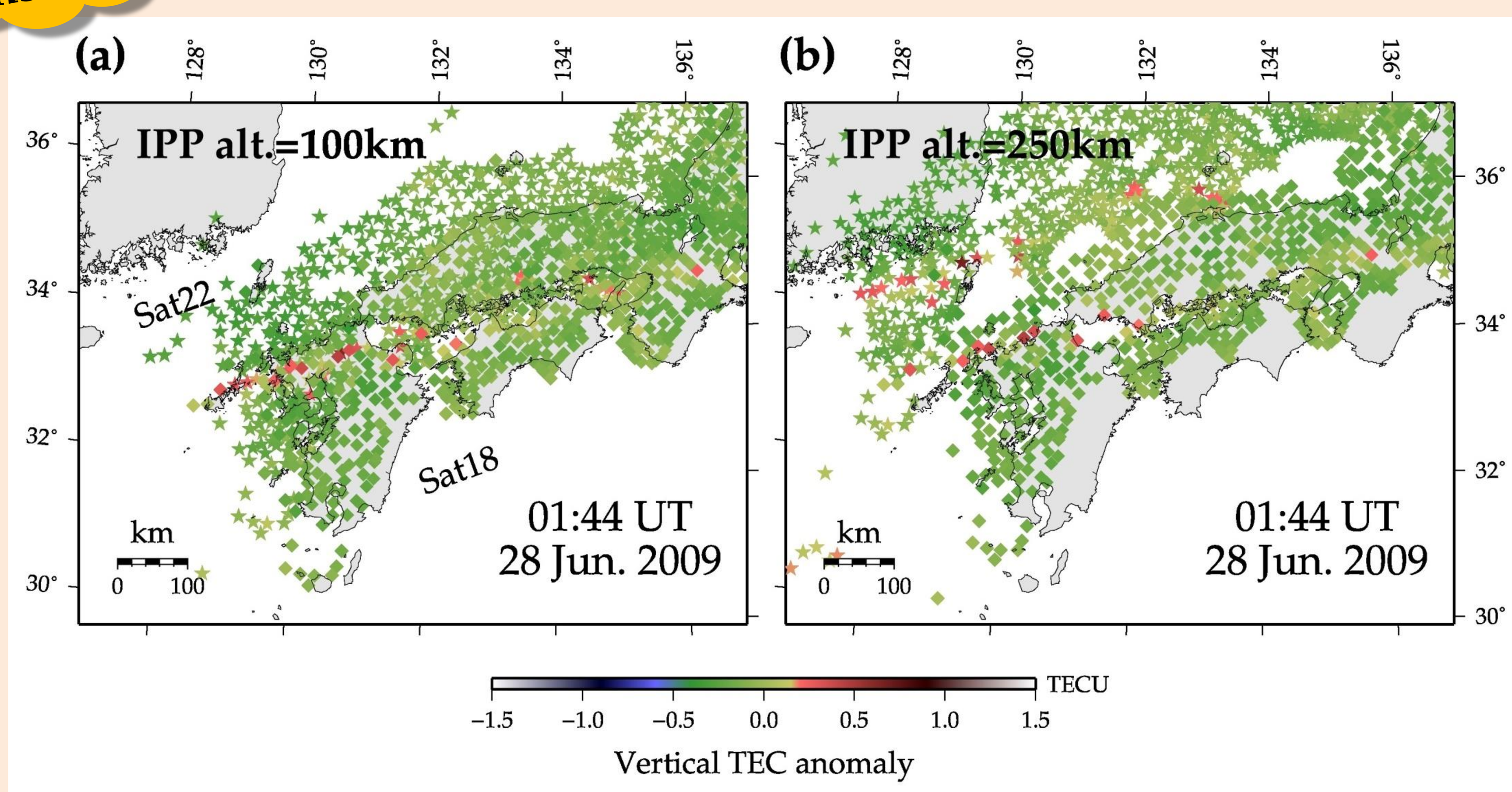


Fig.2 Altitude constraint with 2 different satellite (i.e., Satellite 18 & 22). Changing the altitudes of ionospheric points (IPP) at 100 km (E-region) and at 300 km (F-region), two frontal (linear) structures elongated in the E-W direction coincide at 100 km (Fig.2a) while gaps emerge at 300 km (Fig.2b). This demonstrates that the frontal structure exists in the E-region of the ionosphere, hence the positive TEC anomaly is attributed to Es.

Fine Image !

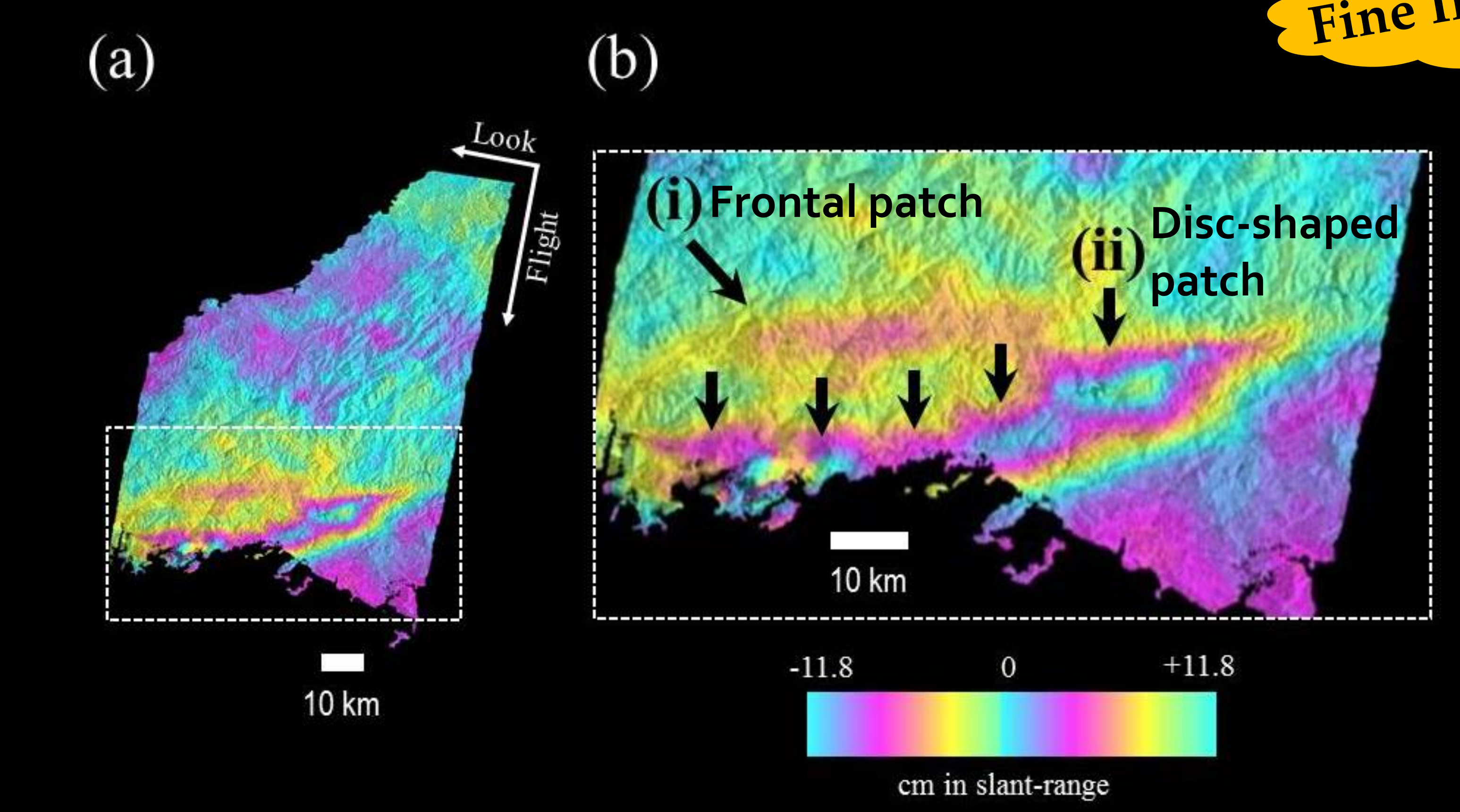


Fig.4 Interferogram derived from ALOS/PALSAR data (Path-frame: 72-2920~2930). The phase changes are shown as slant range changes in centimeter. Beginning with pale blue, the color changes into purple and into yellow represent positive and negative slant range changes, respectively. In an enlarged image in (b), (i) a frontal patch (pointed by a slant arrow) and (ii) a chain of disc-shaped patches (pointed by short black arrows) are clearly seen.

Migration

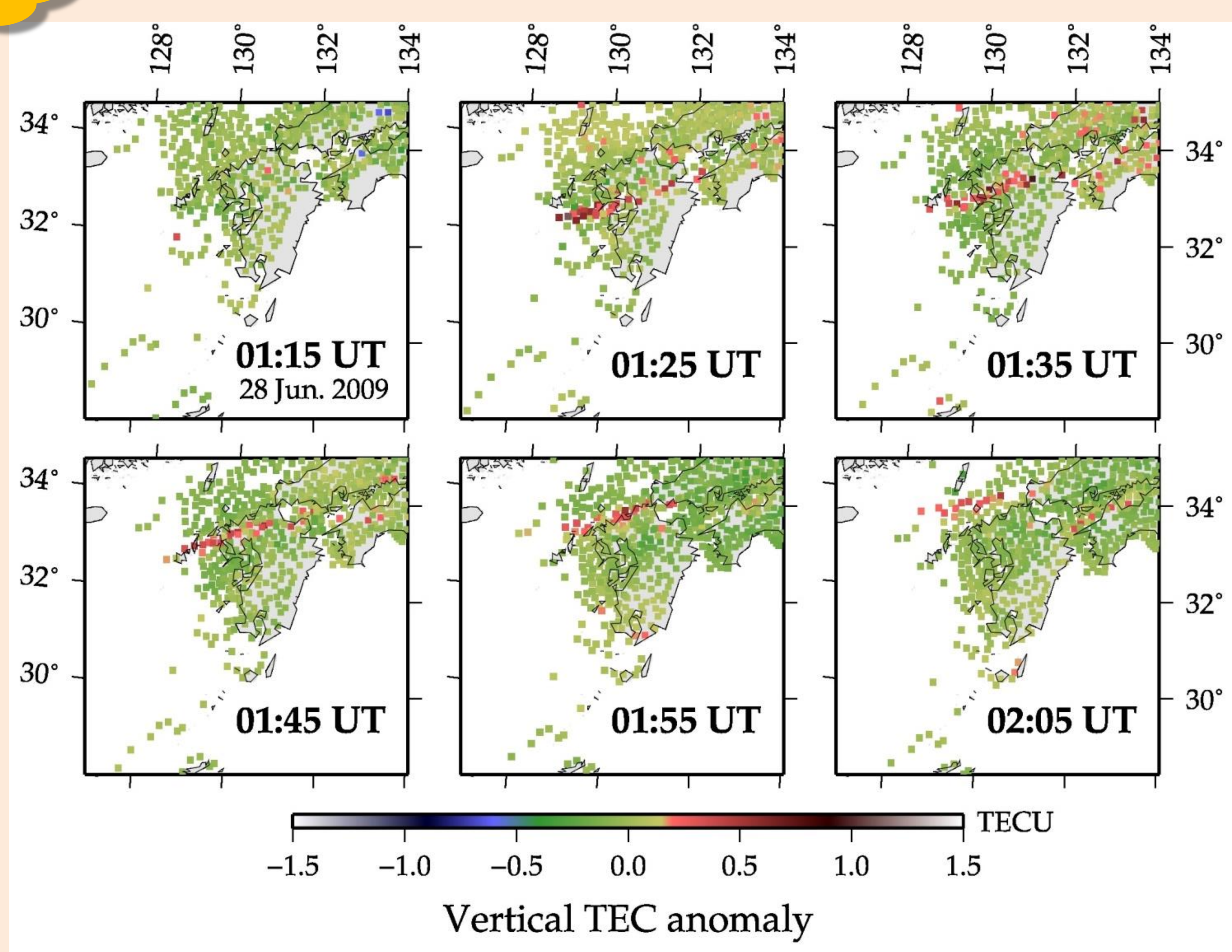
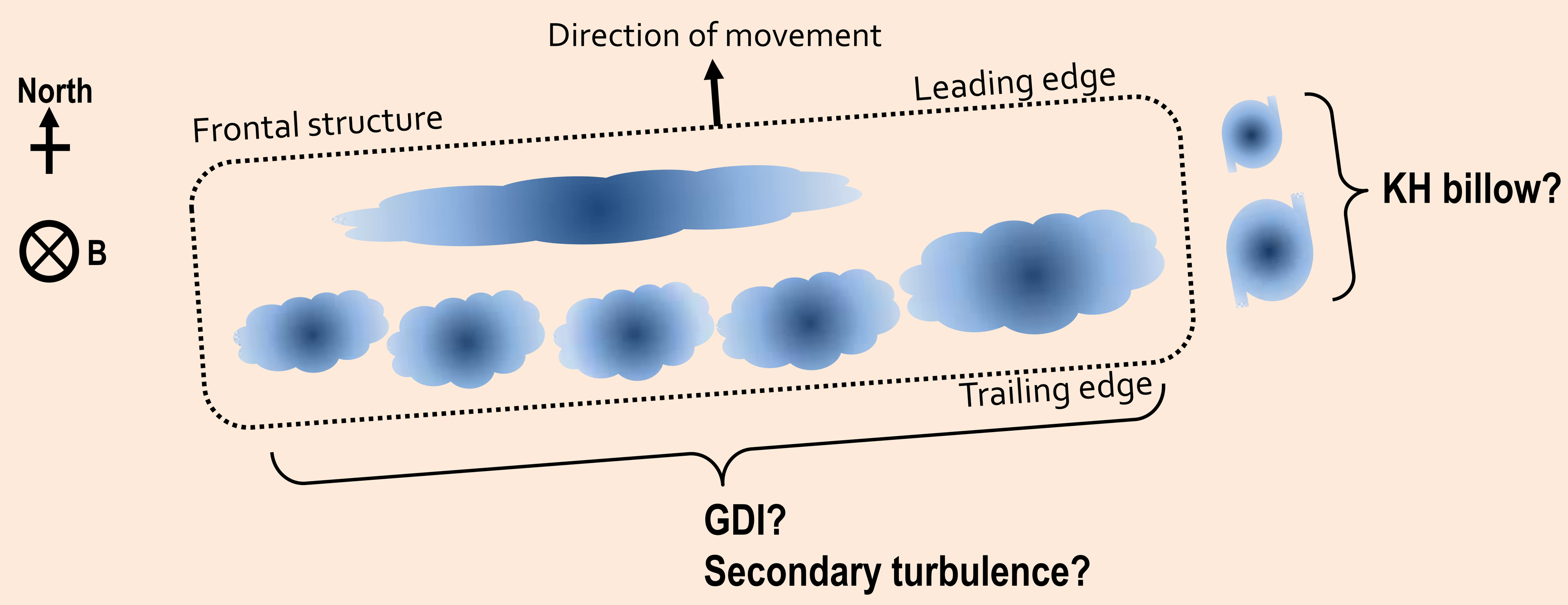


Fig.5 A time series of vertical TEC anomaly maps derived from GPS Satellite 18 and 22 during 01:15–02:05 UT, including the observation time of SAR at 01:44 UT. The large-scale frontal structure migrated northward at the speed of 50-60 m/s. This indicates that the northern (southern) edge represents the leading (trailing) edge.

Discussion

Kelvin-Helmholtz (KH) instability

In the present case, two plasma structures, i.e., the frontal patch and disc-shaped patches, are considered to be generated at the two nodes of K-H billows under the condition that the Richardson number is lower than 0.25, making the neutral atmosphere unstable to the K-H instability. Since the axes of K-H billows are perpendicular to the shear direction, two structures which are aligned in the ENE-WSW direction are suggested to be caused by a wind shear in the NNW-SSE direction. Thus the K-H instability with the vertical shear of meridional winds is considered to cause ion perturbations in the neutral atmosphere, forming two K-H billows aligned in the zonal direction.



Gradient-drift instability

In addition to the primary structuring of the two dominant structures, it is suggested that there could be a secondary instabilities operating in the southern disc-shaped patches. In Figure 4b, it is shown that disc-shaped patches are more structured than the frontal patch in terms of the development of undulation in the northern leading edge and large electron density gradient. Gradient-drift instability achieves the maximum growth rate when the direction of electron density gradient and the direction of Es patch movement are parallel. In this sense, plasma clouds in propagating Es with steep electron density gradient are supposed to be under the condition of gradient-drift instability.

More details?

Here's the references!

Maeda, J., T. Suzuki, M. Furuya, and K. Heki (2016), Imaging the midlatitude sporadic *E* plasma patches with a coordinated observation of spaceborne InSAR and GPS total electron content, *Geophys. Res. Lett.*, *43*, 1419–1425, doi:10.1002/2015GL067585.

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Acknowledgments

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