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Properties of SF Observed with Digisonde at Different Latitudes

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Introduction

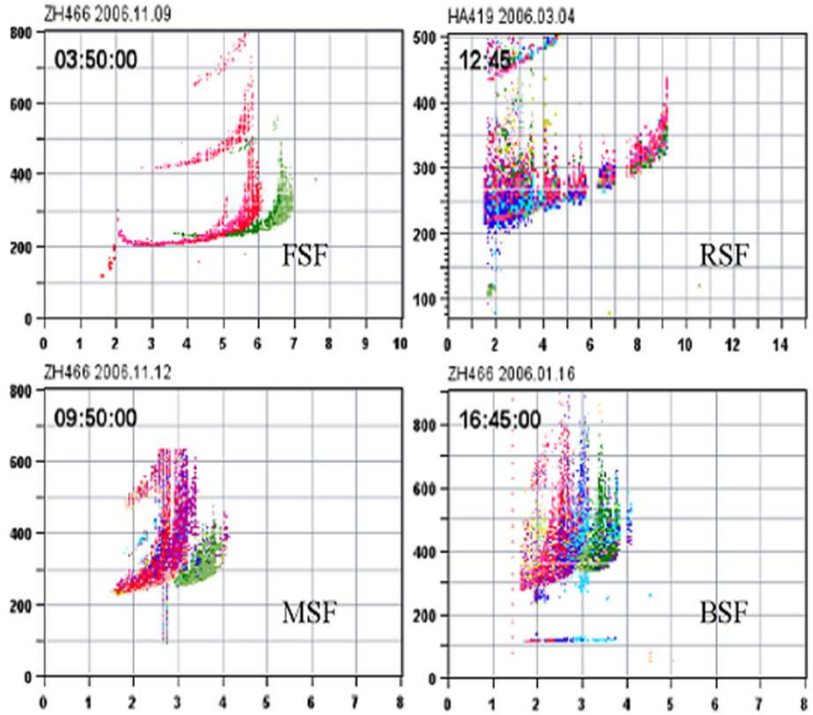
- The SF can be observed with
  --- ionosonde, 15 Mins or more or less
  to identify type of SF

  --- HF Doppler, continuously measurement
  without types

  --- ISR, no types

The ionosonde has advantage to measure and study the different type of SF

According to the URSI's book, Spread-Fs are divided into four types:



FSF: Frequency SF, spread increases with frequency, FoF2 not definable.

RSF: Range SF, diffuse echoes at lower frequency with clear FoF2.

MSF: Mixed SF, mixed by FSF and RSF.

BSF: Branch SF, RSF occurs under (or above) the other spread diffusion,

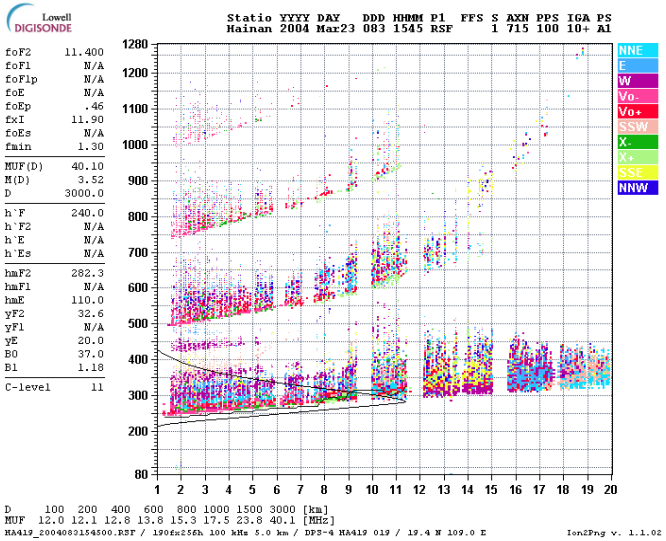
Some propeties of the SF in low latitude ionosphere

Hainan (dip. 9.1N, 109.1E**)**

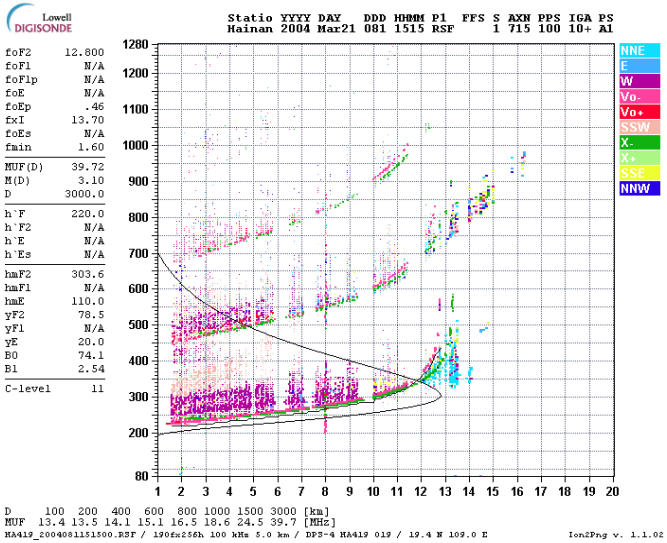
New type of SF:

In Hainan, we often observed another type of SF with DPS-4, which is drawn from the RSF. We call it as Strong range Spread-F (SSF) which has a characteristics of:

- diffuse echoes extend from low frequency to high frequency in ionograms
- the critical frequency is not definable
- the duration of Spread-F at least 1 hour

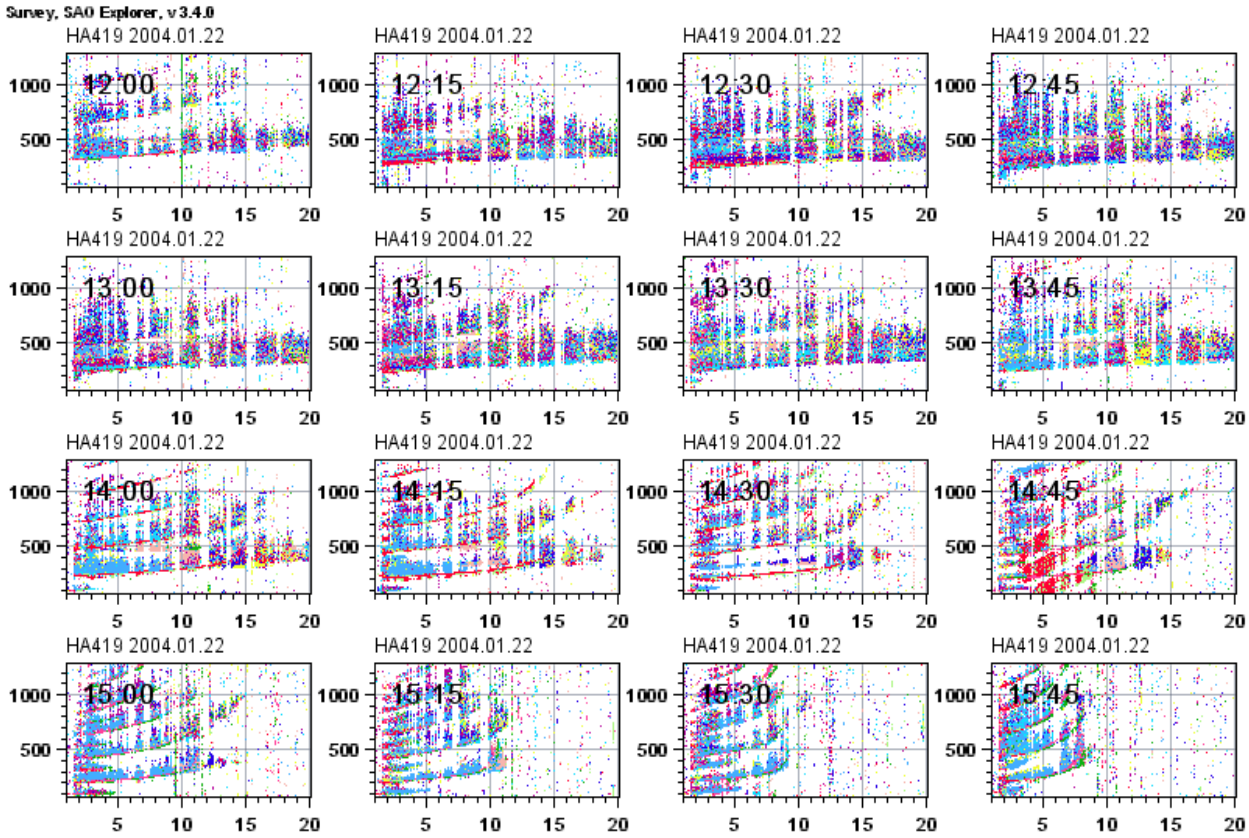


Strong SF (SSF)



Range SF (RSF)

SSF observed on Jan. 22, 2004 at Hianan

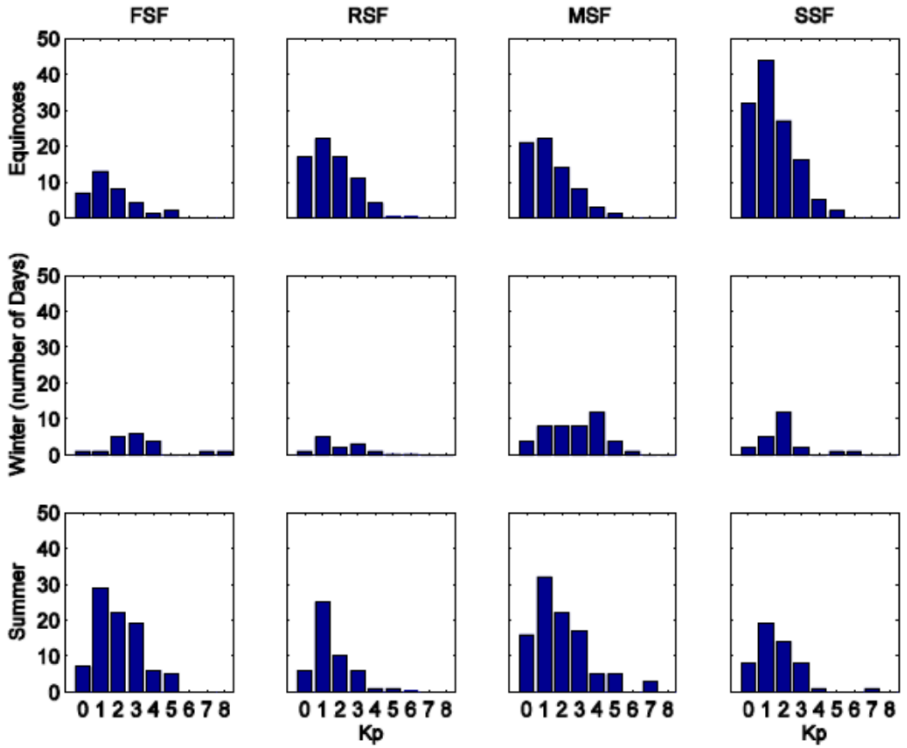


- Duration of the SSF was about 2 hours (from 12:00 to 14:00).
- Frequency extend over FoF2 which could not to be defined.

The SSF was often observed in Low latitude ionosphere Hainan, however, the BSF never observed in Hainan.

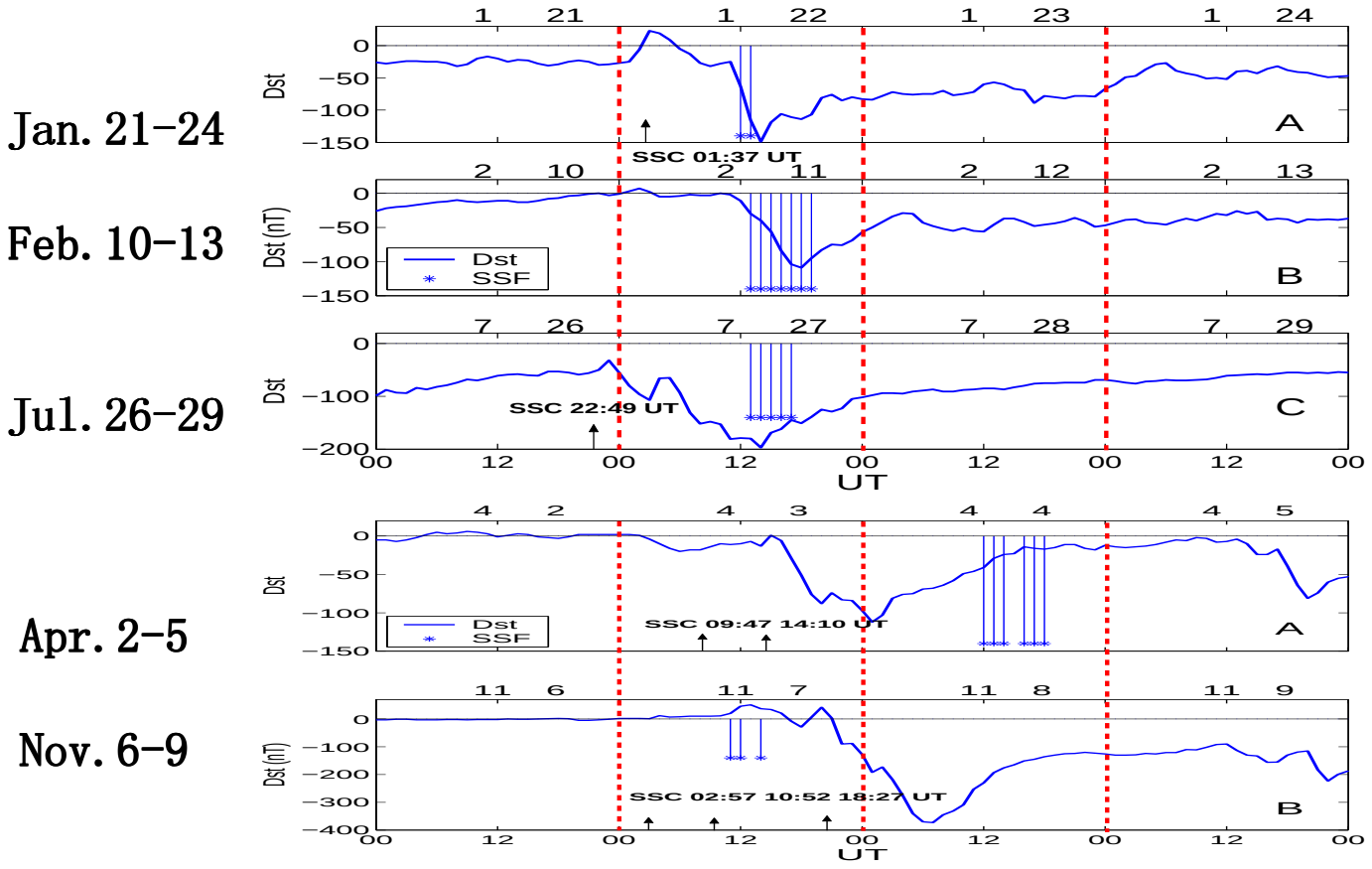
SF versus Kp

(Wang et al, Ann. Geophy, .2010)



- When Kp <5, all type SF are more easy to take place
- In equinoxes and summer, the max occurrence is with Kp=1
- In the winter, the occurrence is low and the max occurrences with Kp seems complex
- The SSF has a same properties as others

SF in storm time



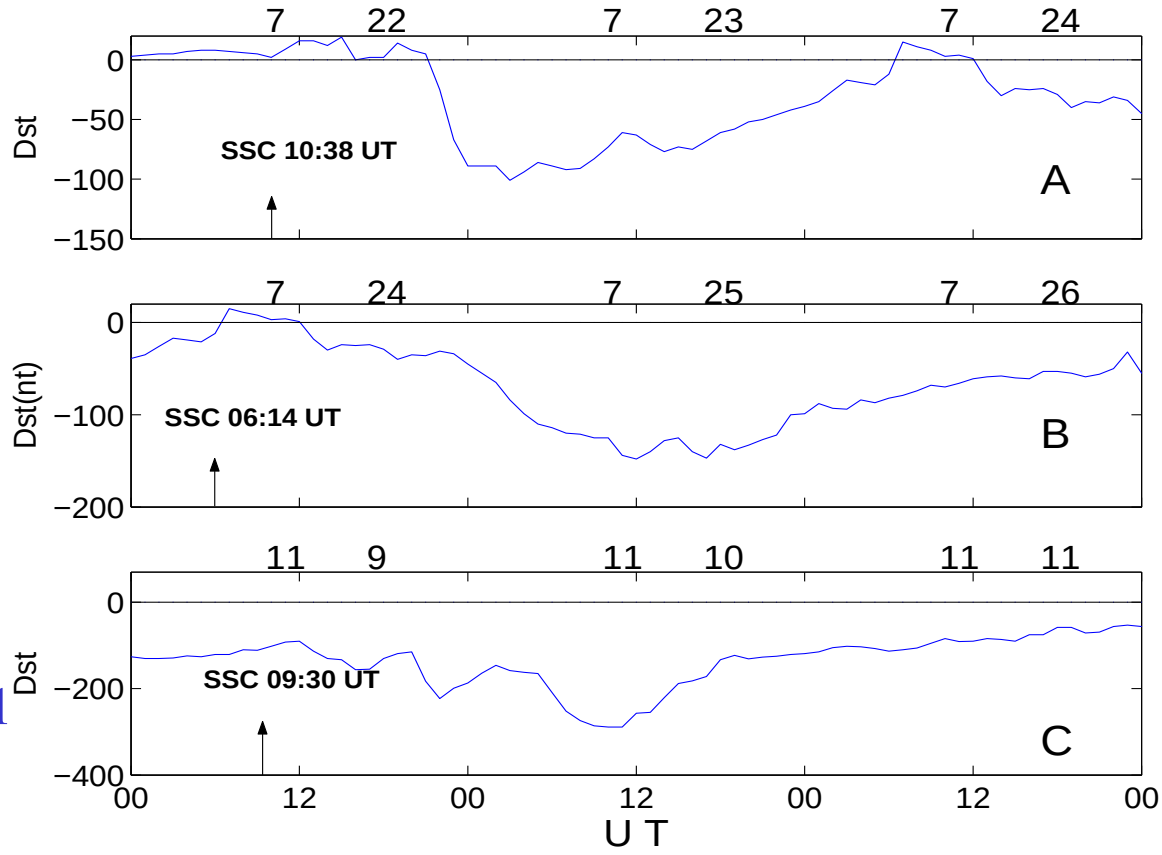
SF can occur during storm time in SC, main and recovery phase

Some time, there is no SF taking place during the storm times

Jul.22-24

Jul.24-26

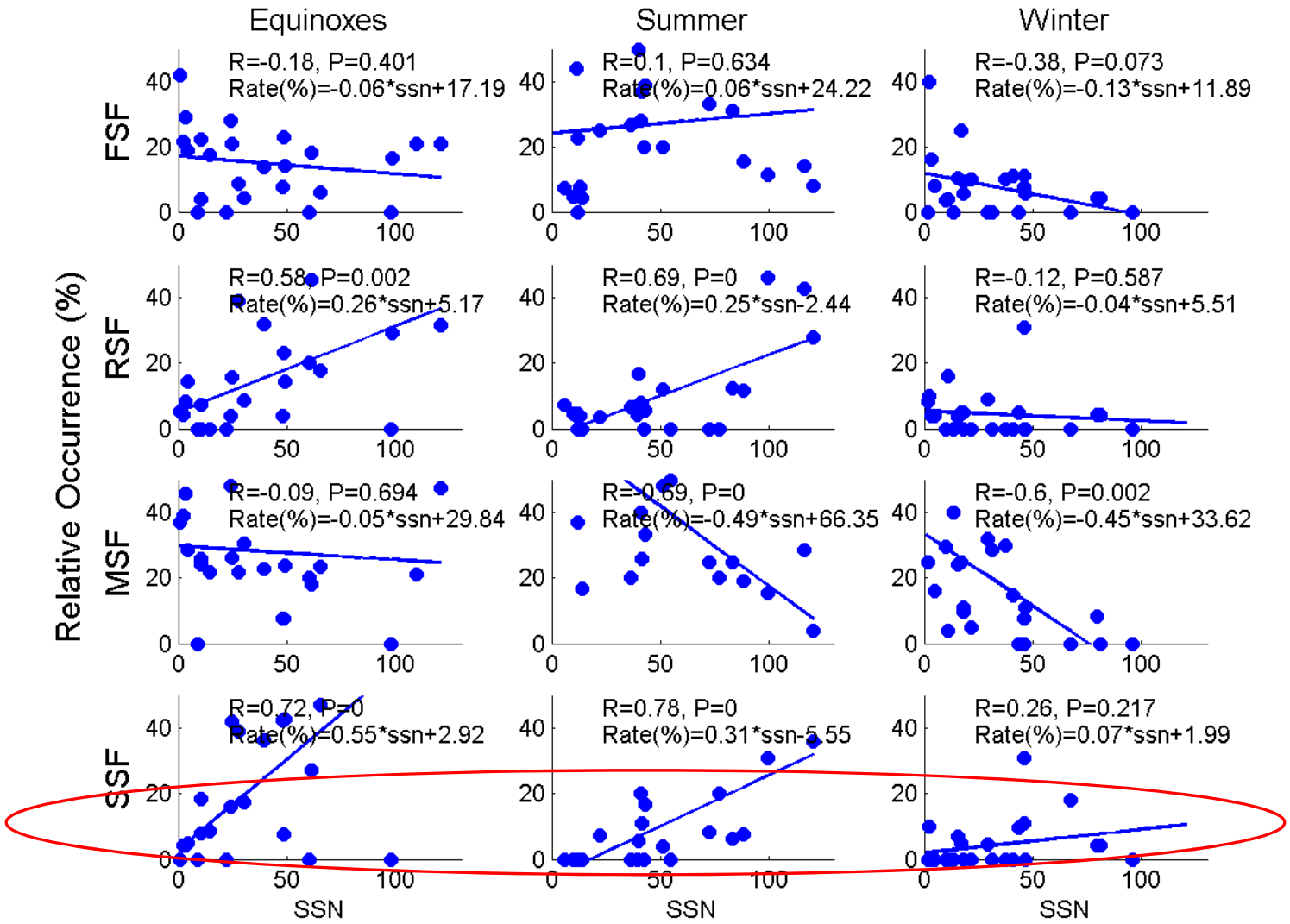
Nov. 9-11



Some time the storm restrains the SF and some time the storm enhances the SF.

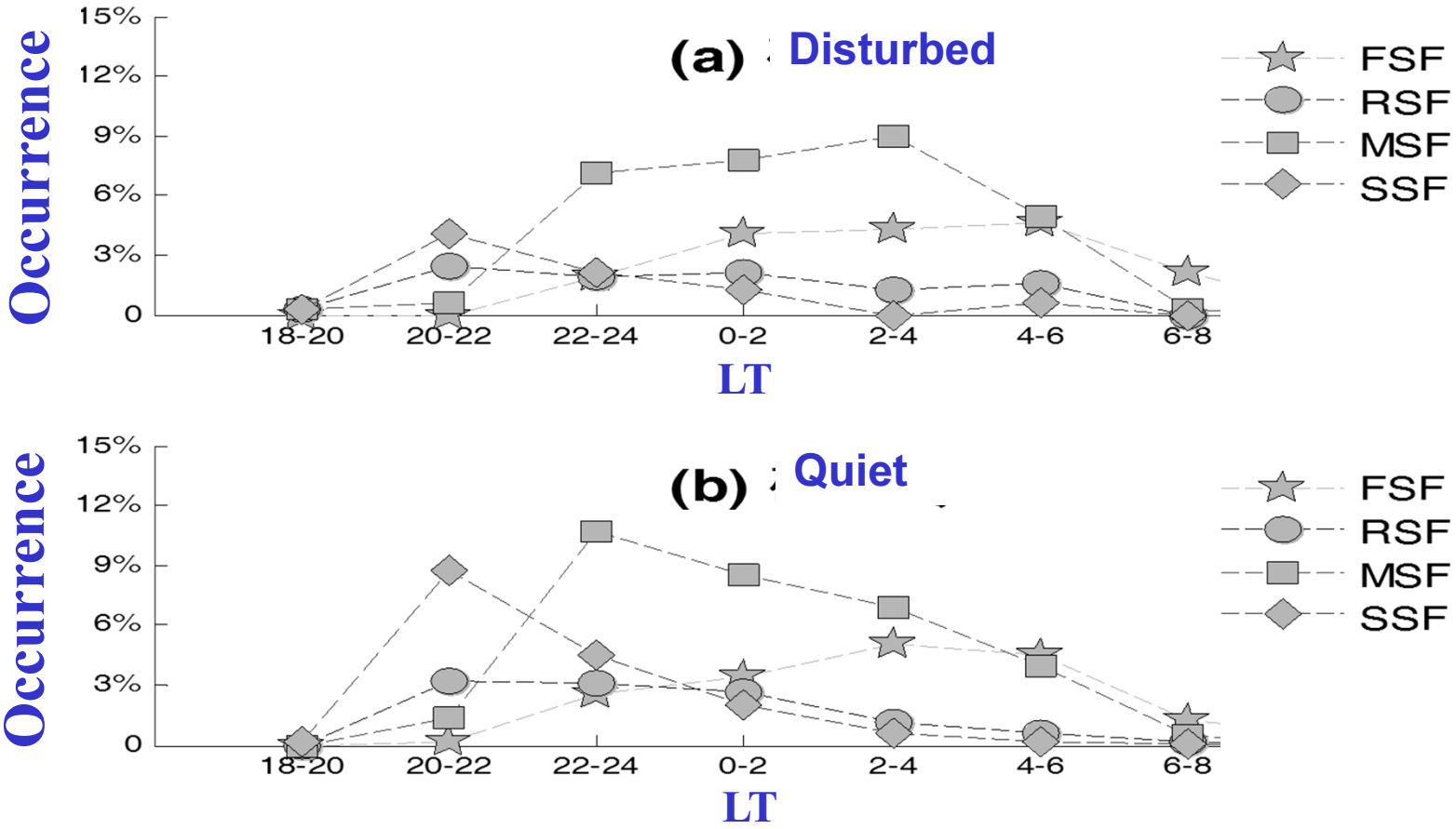
SF variation with SSN in different season

(Wang et al, Ann. Geophy, .2010)



SF occurrence period

Hainan Station at low latitude



- The SSF has a highest occurrence at 20:00 to 22:00 LT
- All type of the SF take place from 18:00 to 08:00(+1) LT

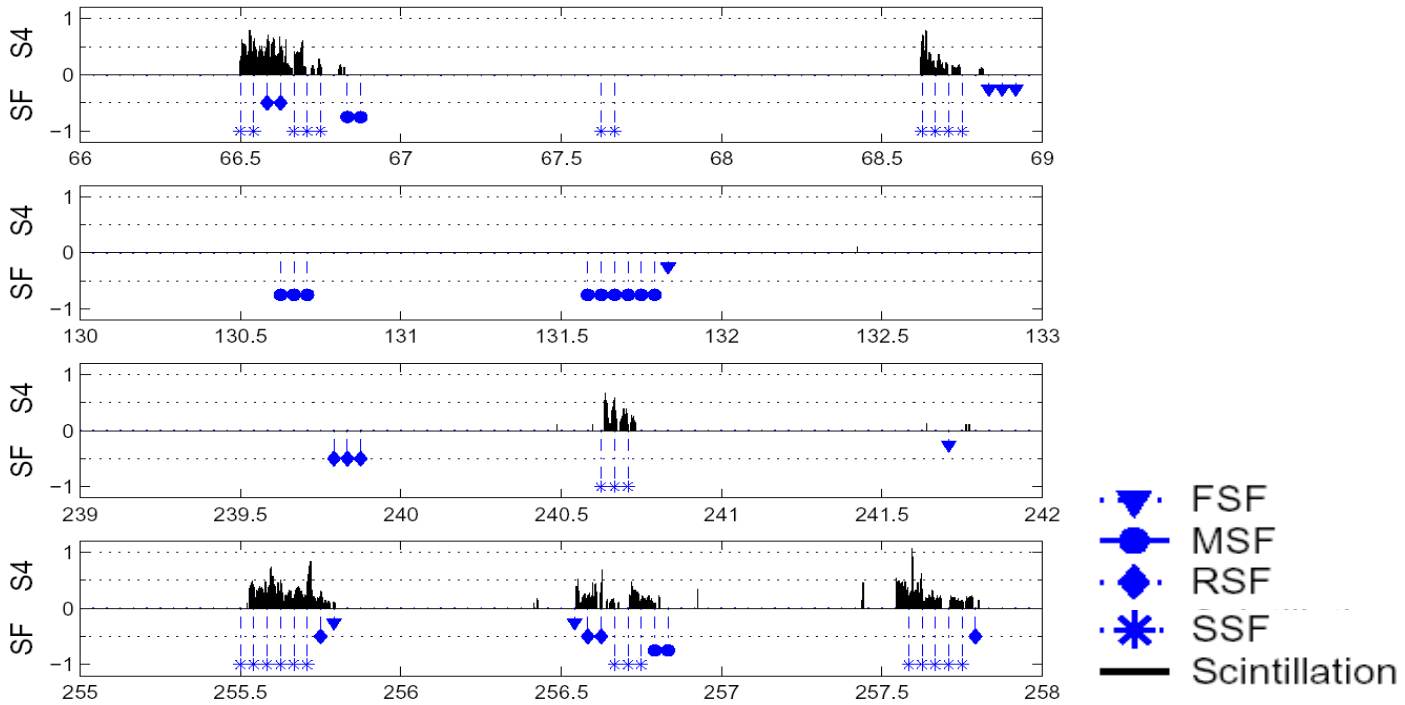
SSF has a good correlation with scintillation

3/6-3/8, 2004

5/9-5/11, 2004

8/26-8/28, 2004

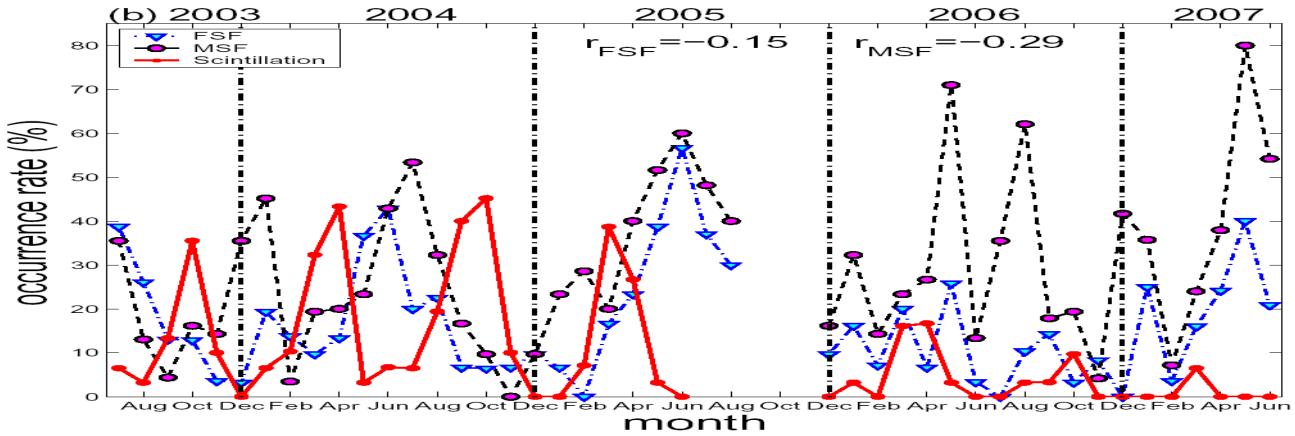
9/11-9/13, 2004



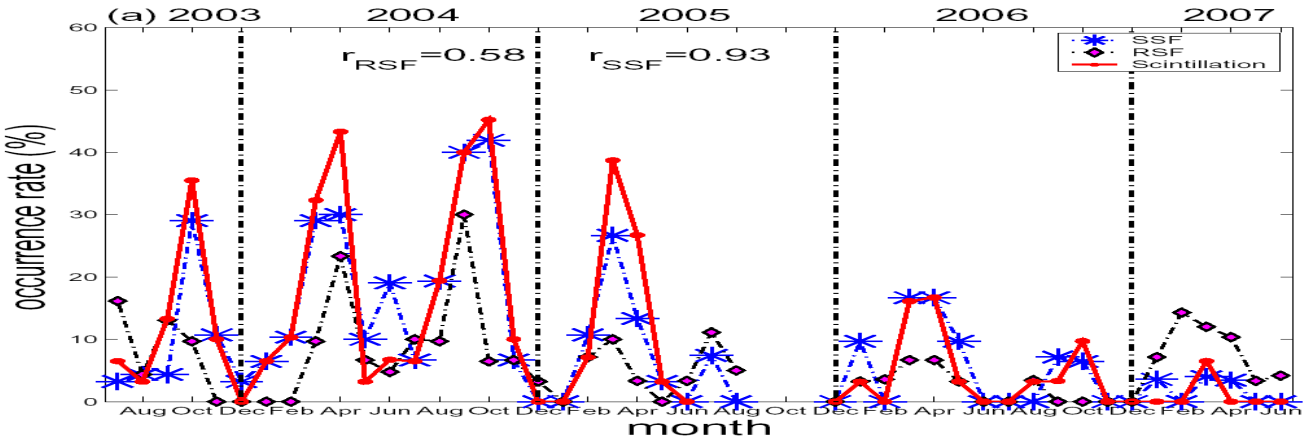
Examples of SF and GPS L-band scintillations observed in Hainan

- **Scintillation is always with SF, But SF is not always with scintillation**
- **SSF is often accompanied with scintillation**

Shi. J. K. et al, JGR, 2012



The FSF (blue), MSF (black) and scintillation (red) occurrence



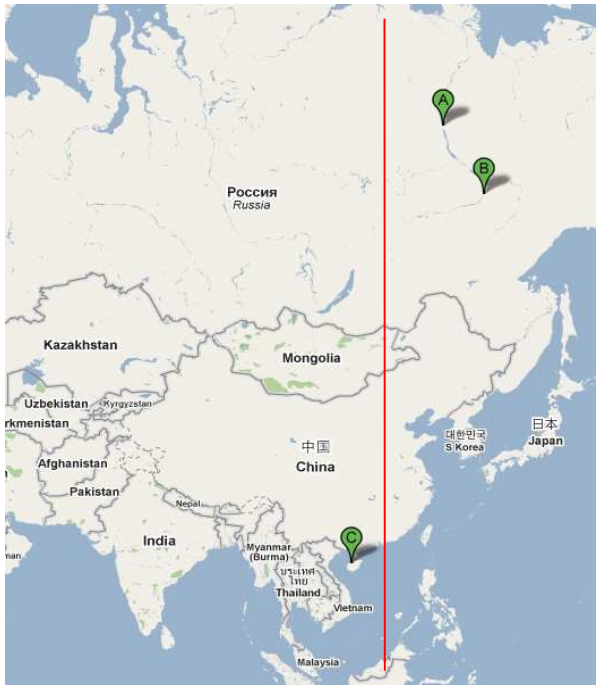
RSF (Black), SSF (Blue) and scintillations (red) occurrence.

Only SSF has a good correlation with scintillation

Some propeties of the SF
In high latitude ionosphere

- we use the digisonde data to investigate properties of different type of SF in the high latitude ionosphere

- The data are from
  - --- DPS-4 digisonde
  - --- obtained in 2006.
  - --- from two stations



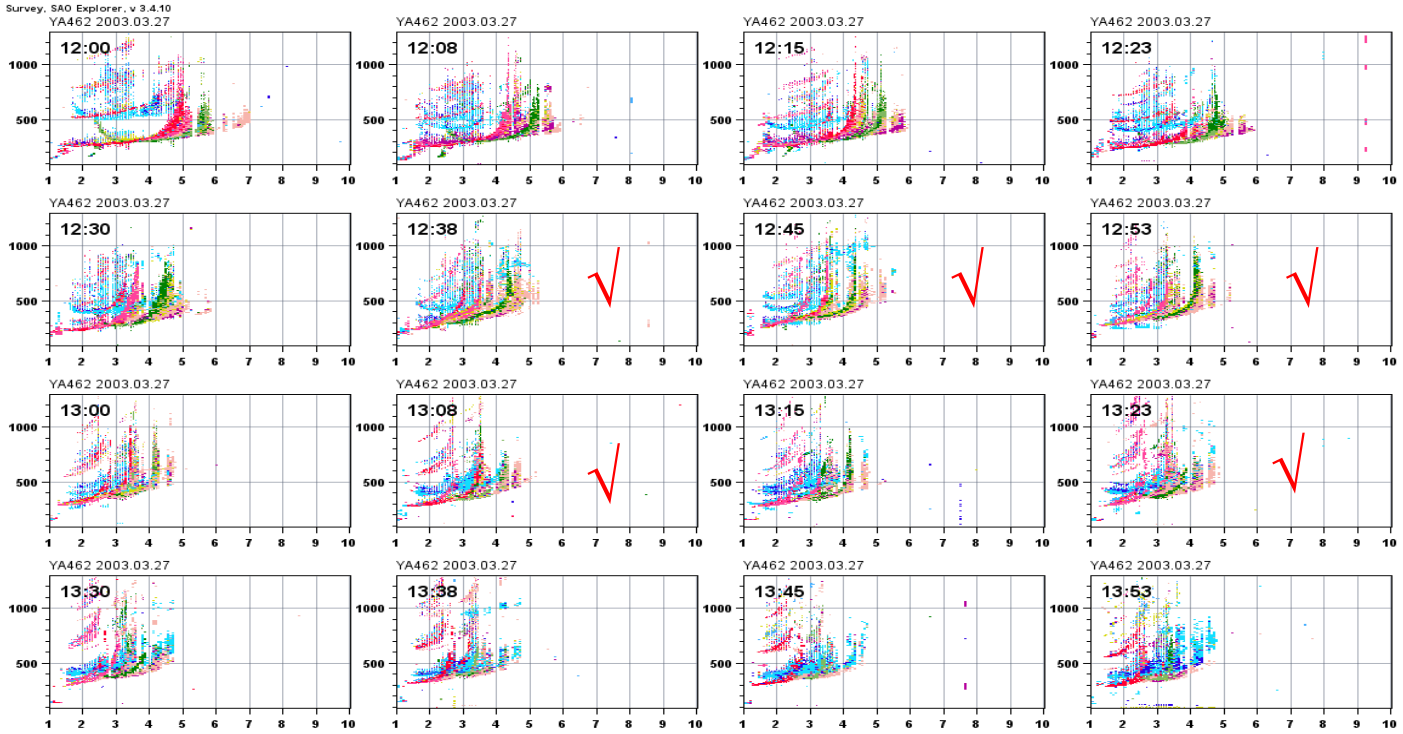
A: Zhigansk (dip 56.2N, 123.4E)
B: Yakutsk (dip 53.1N. 129.6E)
C: Hainan (dip. 9.1N, 109.1E)

SF types

► At high latitude stations

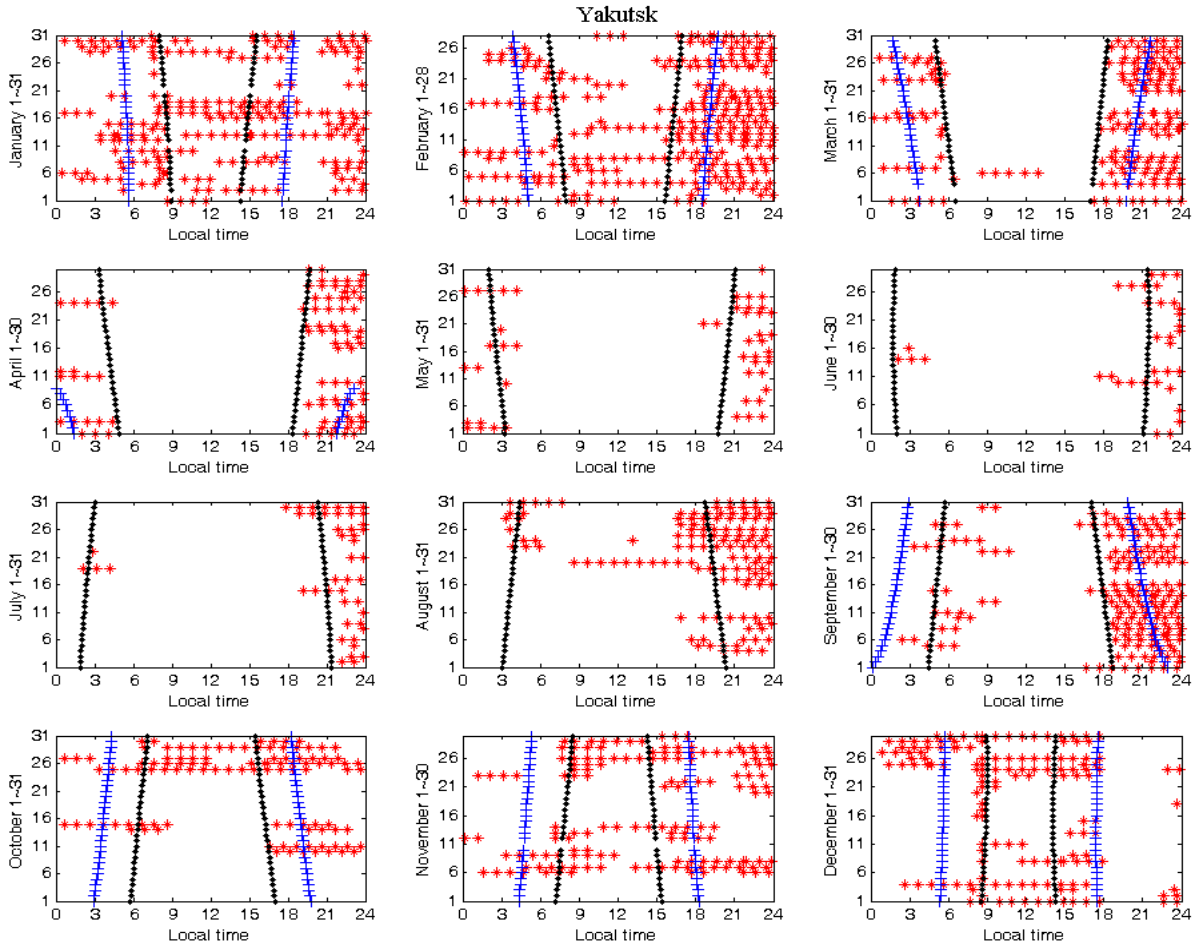
not only FSF, MSF, and RSF, but also BSF can be observed

never SSF was pbserved

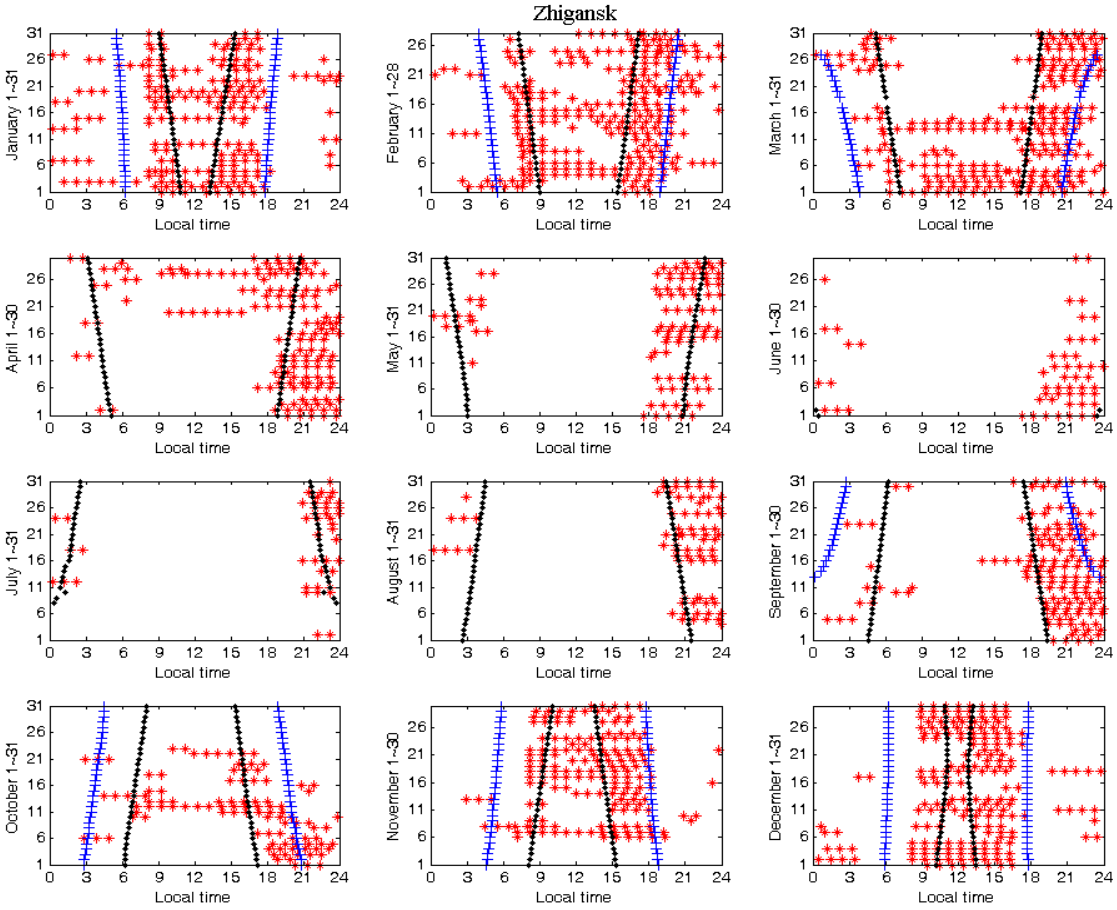


The branch SF was observed at Yakutsk.

SF occurrence period Statistics: (2006)



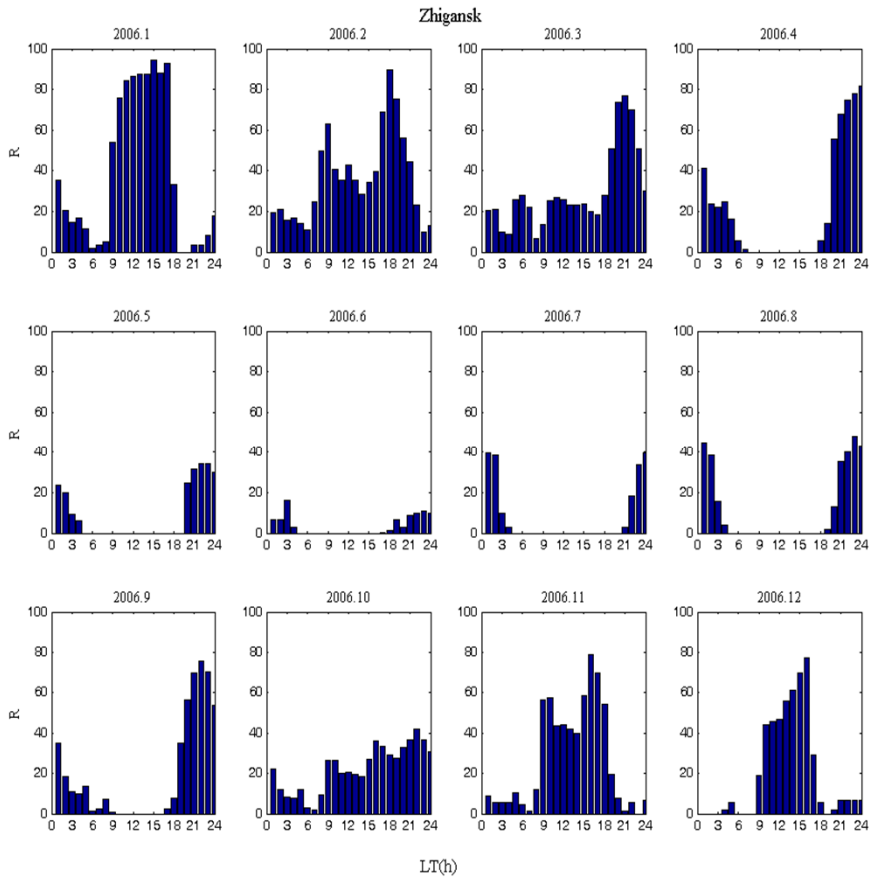
- Most of the SF were observed in night time
- It also can be observed in day time



- Most of the SF were observed in night time
- It also can be observed in day time

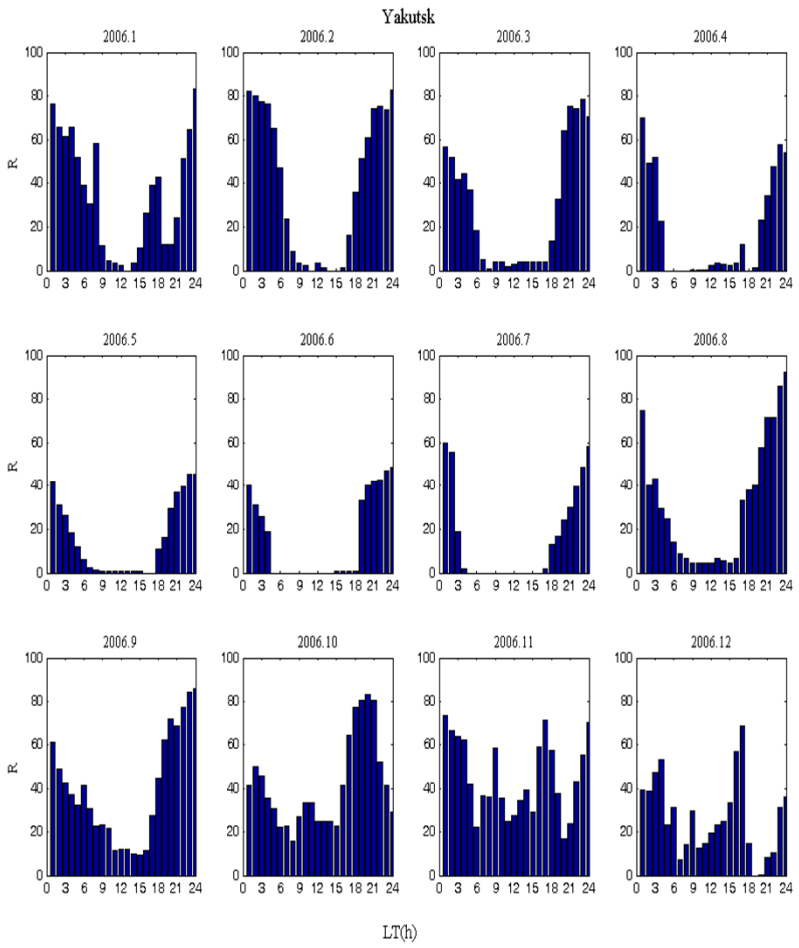
SF seasonal appearance

Zhigansk, high latitude



- In the winter, early spring and later autumn, SF has high occurance in day and night time
- In late spring and early autumn, the SF only in night time with high occurance
- In the summer, the SF mainly occur in night time and with low occurance

Yakutsk, high latitude

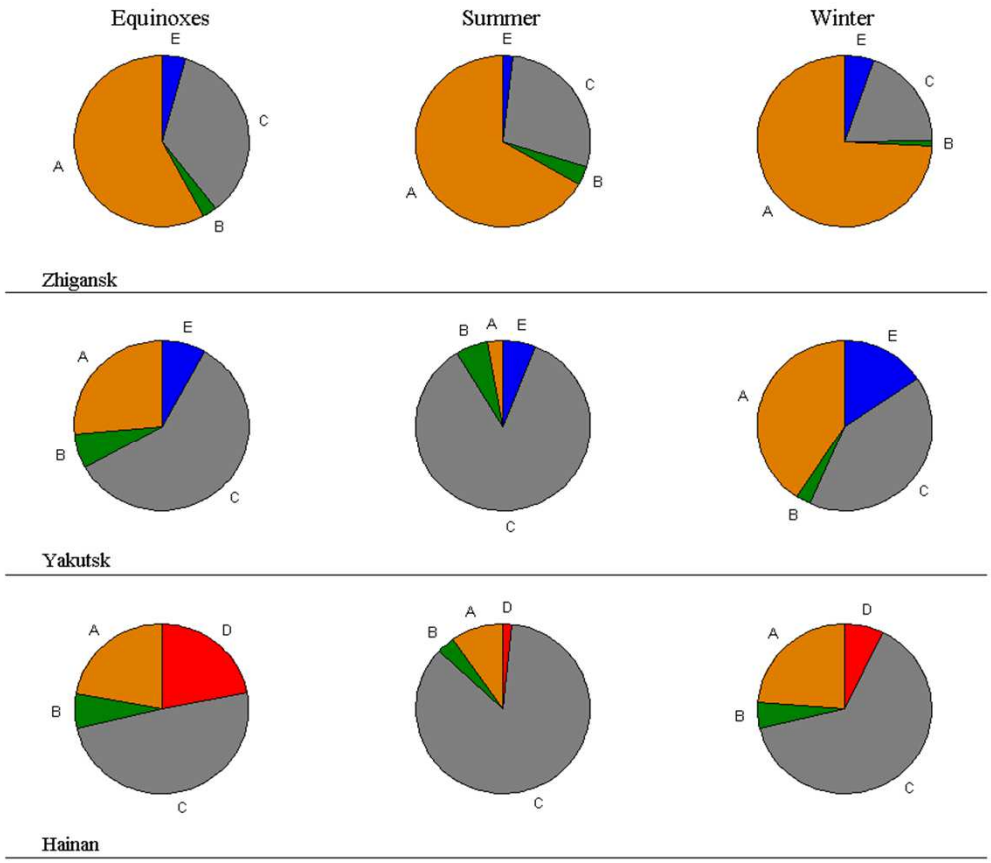


- In the winter, and equinoxes, SF has high occurance in night time and and low occurance in day time.
- In the summer, the SF maily occur in night time with a lower occurance
- The differnce between the Zhigansk and Yakutsk needs to be further investigated.

Comparative between the low and high latitude ionosphere

(1) SF types

► SF Occurrence (statistics, 2006)



A --FSF

B --RSF

C --MSF

D --SSF

E --BSF

- High latitude: FSF, MSF, RSF, and BSF, no SSF
- Low latitude: MSF, FSF RSF and SSF, no BSF

► We suggest:

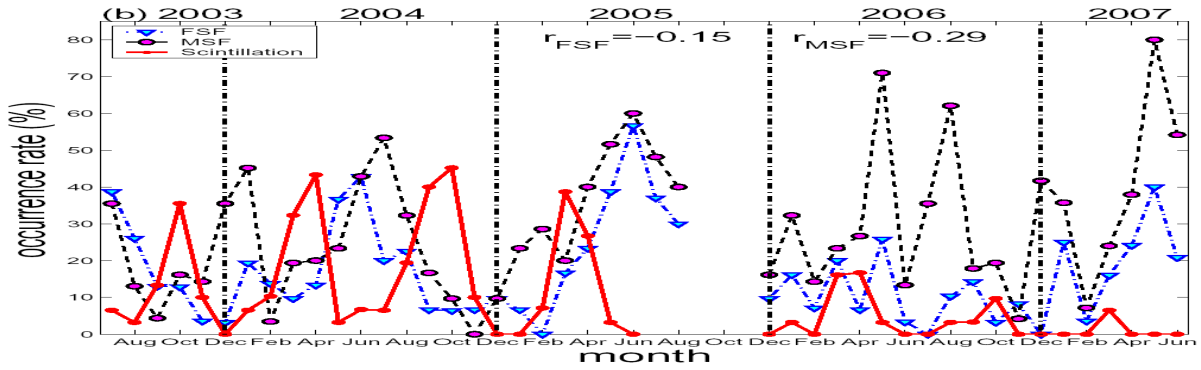
- In low latitude ionosphere, SF can be divided into 4 types:
  --- FSF, Perkins instability, or coupled E/F region electrodynamics
  --- RSF, Rayleigh-Taylor instability or the ExB drift
  --- MSF, mergence of the mechanisms of FSF and RSF
  --- SSF, concerning the EQ plasma bubbles, R-T instability

- In high latitude ionosphere, SF can be divided 4 types:
  --- FSF
  --- RSF
  --- MSF
  --- BSF
  The same as URSI,s definition.

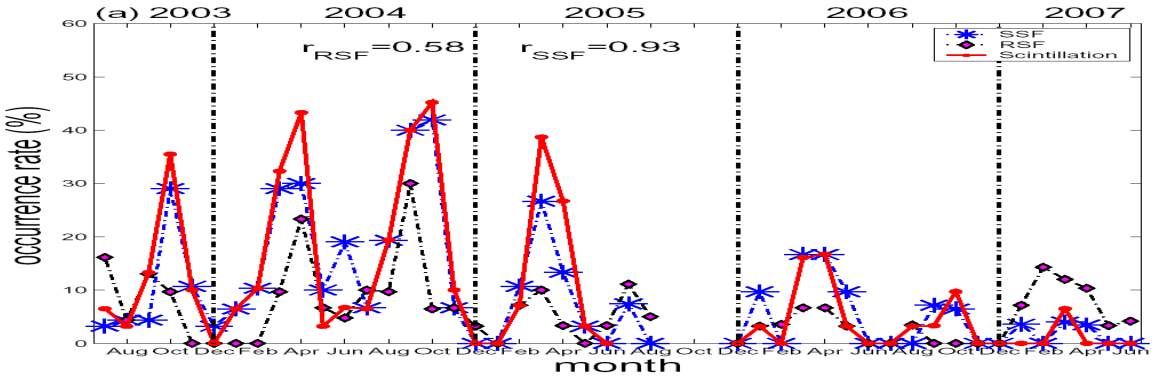
(2) SSF and Scintillation

---- Hainan

The FSF (blue), MSF (black) and scintillation (red) occurrence



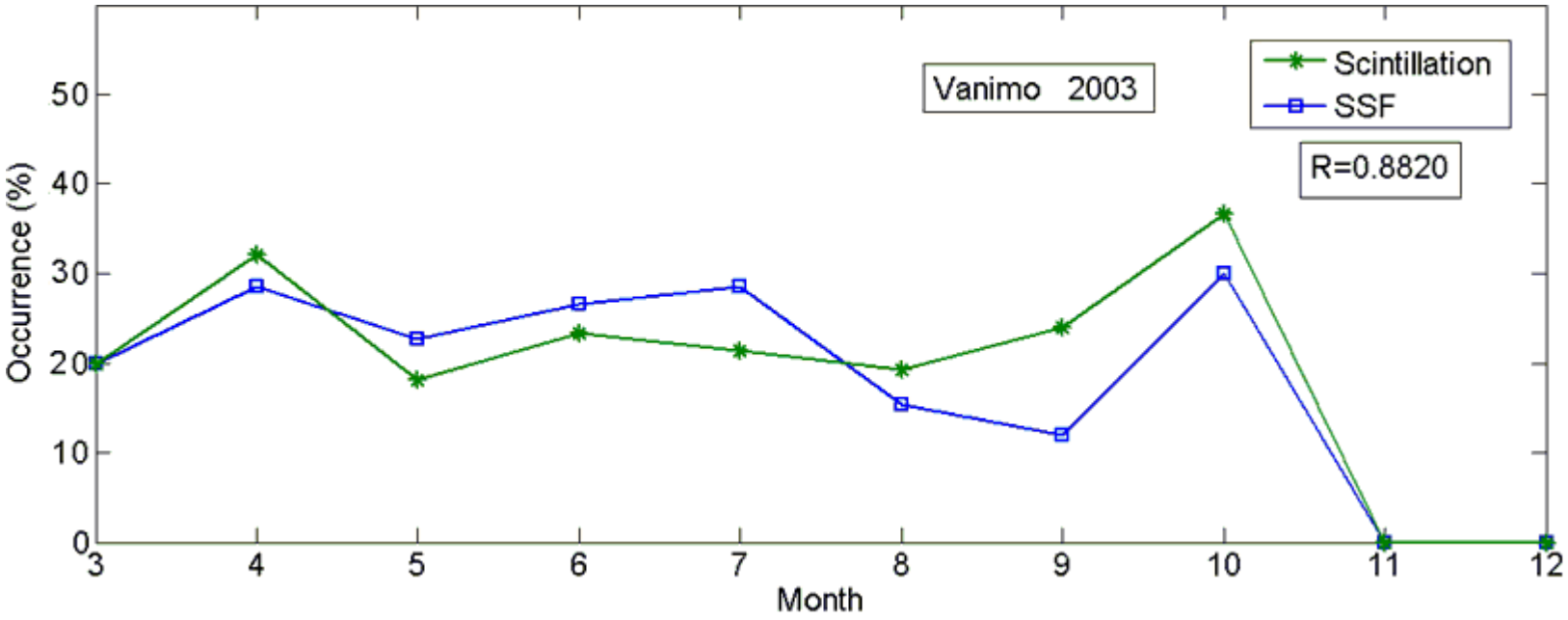
RSF (Black), SSF (Blue) and scintillations (red) occurrence.



SSF has close correlation with scintillations Shi. J. K. et al, JGR, 2012

---- **Vanimo** (141.3° E, dip 11° S)

Monthly occurrence of scintillation and SSF (2003)



- Monthly occurrence: scintillation (**green**), strong SF(**blue**) ;
- They had a good correlation, the correlation coefficient was 0.8820.

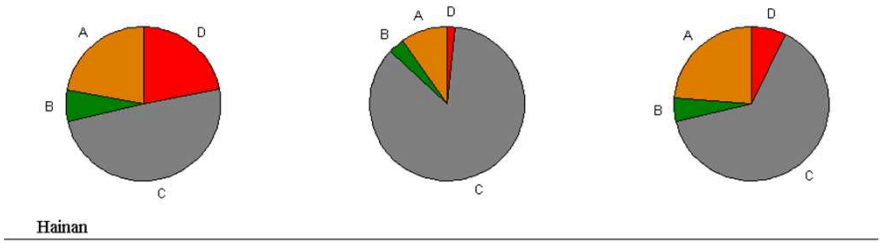
◆ Discussion

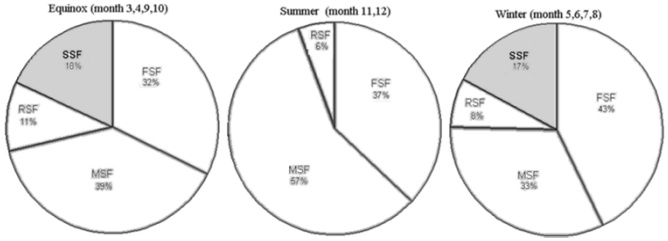
ISR

ESF and equatorial plasma bubbles (Scintillations) are registered after sunset during quiet or disturbed times INDEPENDENTLY!

Why ？

A --FSF, C --MSF, D --SSF, E --BSF





- ISR couldn't identify the type of the SF
- Ionosonde can identify the type of SF, more important , we divide the SSF from the SF

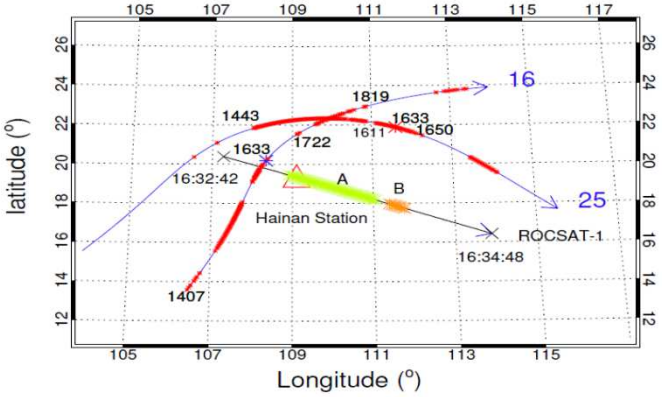
--- Tucumán station (26.9° S, 294.6° E; mag. latitude 15.5° S), Southern hemisphere

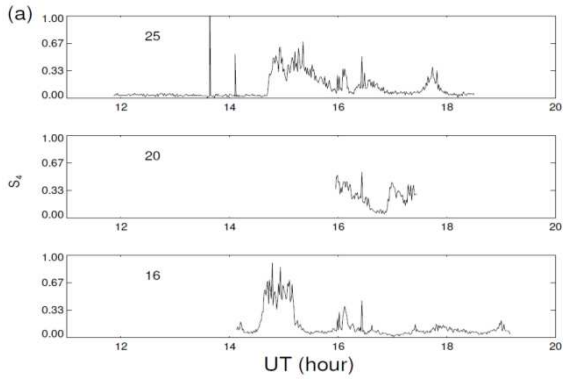
--- October 2010 to September 2011,

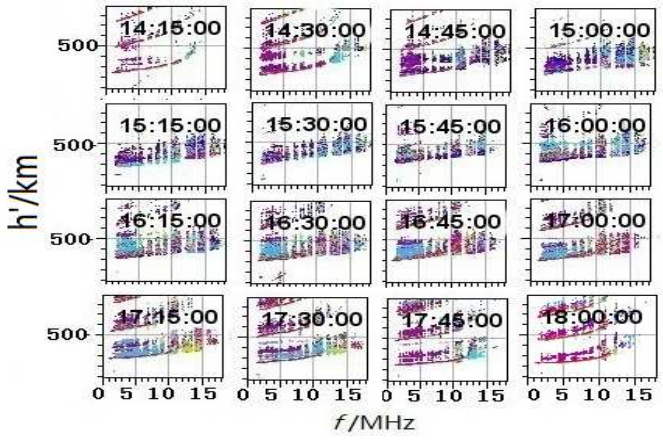
--- Alfonsi *et al*. (2013) also consider RSF, SSF, FSF, MSF, and also found that there was close association between SSF and scintillation.

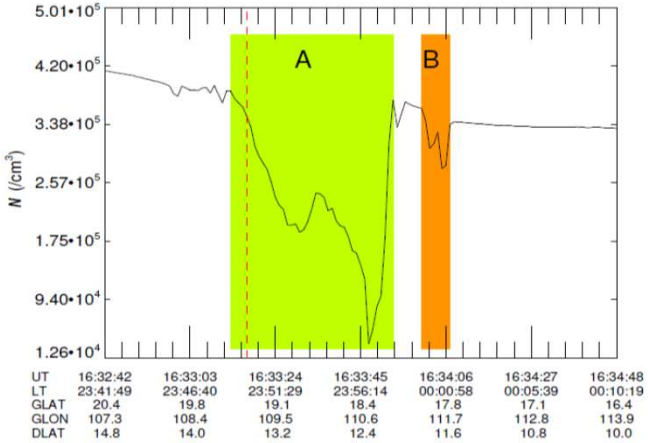
The high correlation between the SSF and scintillation suggests that the physical mechanism of the SSF is different from the RSF.

The plasma bubbles observed by ROCSAT-1 from 16:32:42 to 16:34:48 UT on 23 April 2004 over Hainan station, the GPS Scintillation, and the SSF were concurrently observed and Hainan station.









This further shows that the SSF is caused by the equatorial plasma bubbles

Conclusion

(1) A New type of the SF was proposed for low latitude ionosphere

i.e., Strong Range SF with properties of

--- Diffuse echoes extend from low to high frequency

--- The critical frequency is not definable

--- The duration of Spread-F is at least 1 hour

(2) The SF types are different in the different latitude ionosphere

--- Low latitude: FSF, RSF, MSF and SSF

--- High latitude, FSF, RSF, MSF and BSF

(3) The high correlation between the SSF and scintillation suggest that the SSF was also caused by Equatorial plasma bubbles.

This gives a example of the advantage of the digisonde observation.

谢谢！

Thank you !