



# Space Weather Effects on GNSS: Ionospheric Monitoring in South East Asia in the ERICA Study



*EQUATORIAL IONOSPHERE CHARACTERIZATION IN ASIA*

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# Motivations of the work

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- **Southeastern Asia** is a very interesting area from the ionosphere monitoring point of view.
- The **ionosphere-magnetosphere coupling** presents features which differ from other geographical sectors.
- The **lack of extended networks of monitoring stations** makes peculiarities in Southeastern Asian ionosphere not exhaustively known and understood.

# Objectives

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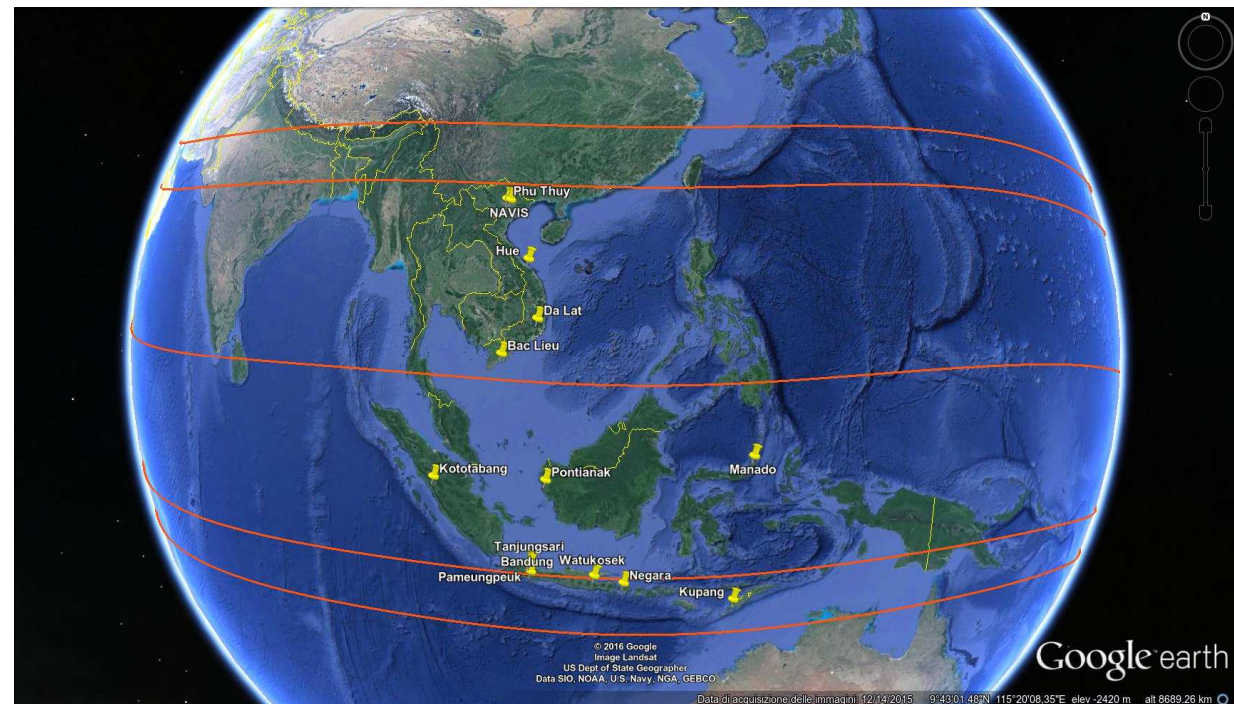
- To characterize the ionospheric variability of the Equatorial Ionospheric Anomaly (EIA) in SEA, in particular the variation of the plasma electron density in the EIA southern and northern crests and over the dip equator identified by the Equatorial Ionospheric Trough (EIT)
- To conduct an **ad hoc measurement campaign** with ground-based instruments at the footprints of EIA and EIT in Vietnam and Indonesia
- To provide training to the South East Asian researchers involved in the project



# Measurement Campaign

## Full Network

Location	GNSS (50Hz)	Magneto meter	Ionosonde
<i>Navis (Hanoi)</i>	X		
<i>Phu Thuy</i>	X	X	
<i>Hue</i>	X		
<i>Da Lat</i>		X	
<i>Bac Lieu</i>	X	X	
<i>Manado</i>	X		
<i>Kototabang</i>		X	
<i>Pontianak</i>	X		X
<i>Bandung</i>	X		
<i>Tanjungsari</i>		X	
<i>Pameungpeuk</i>		X	
<i>Watukosek</i>		X	
<i>Negara</i>		X	
<i>Kupang</i>	X		X



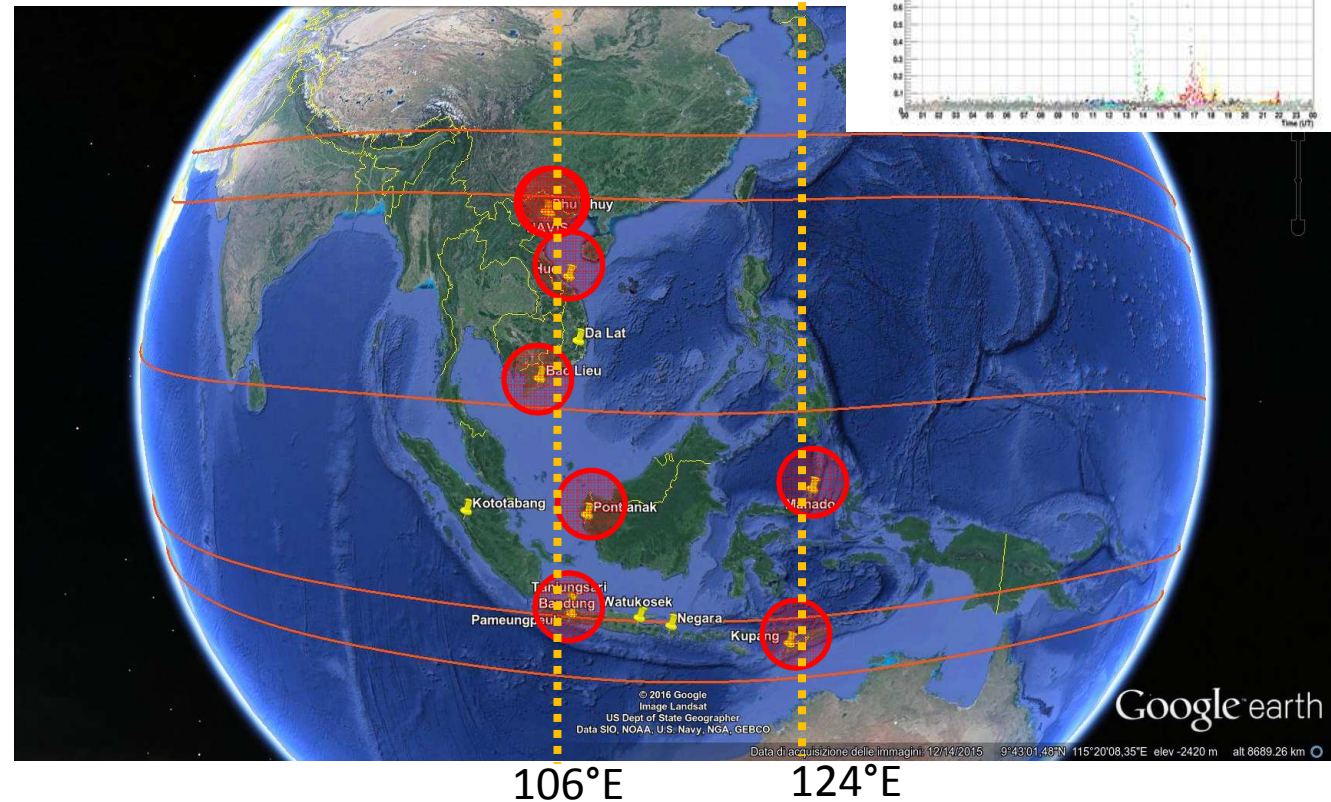


# Measurement Campaign

## Full Network

Location	GNSS (50Hz)	Magneto meter	Ionosonde
Navis (Hanoi)	X		
Phu Thuy	X	X	
Hue	X		
Da Lat		X	
Bac Lieu	X	X	
Manado	X		
Kototabang		X	
Pontianak	X		X
Bandung	X		
Tanjungsari		X	
Pameungpeuk		X	
Watukosek		X	
Negara		X	
Kupang	X		X

## GNSS



Examples of S4 time profile

Novatel  
Station6



Novatel  
GSV4004



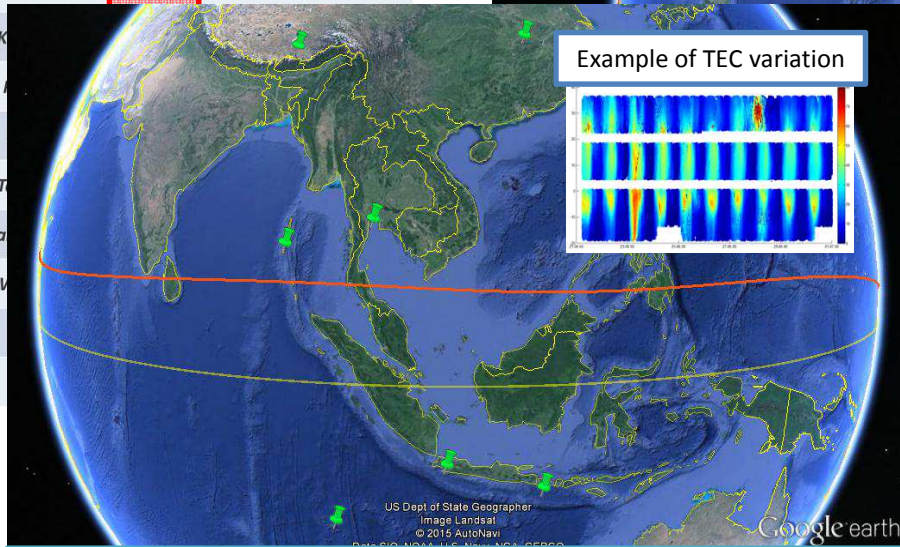
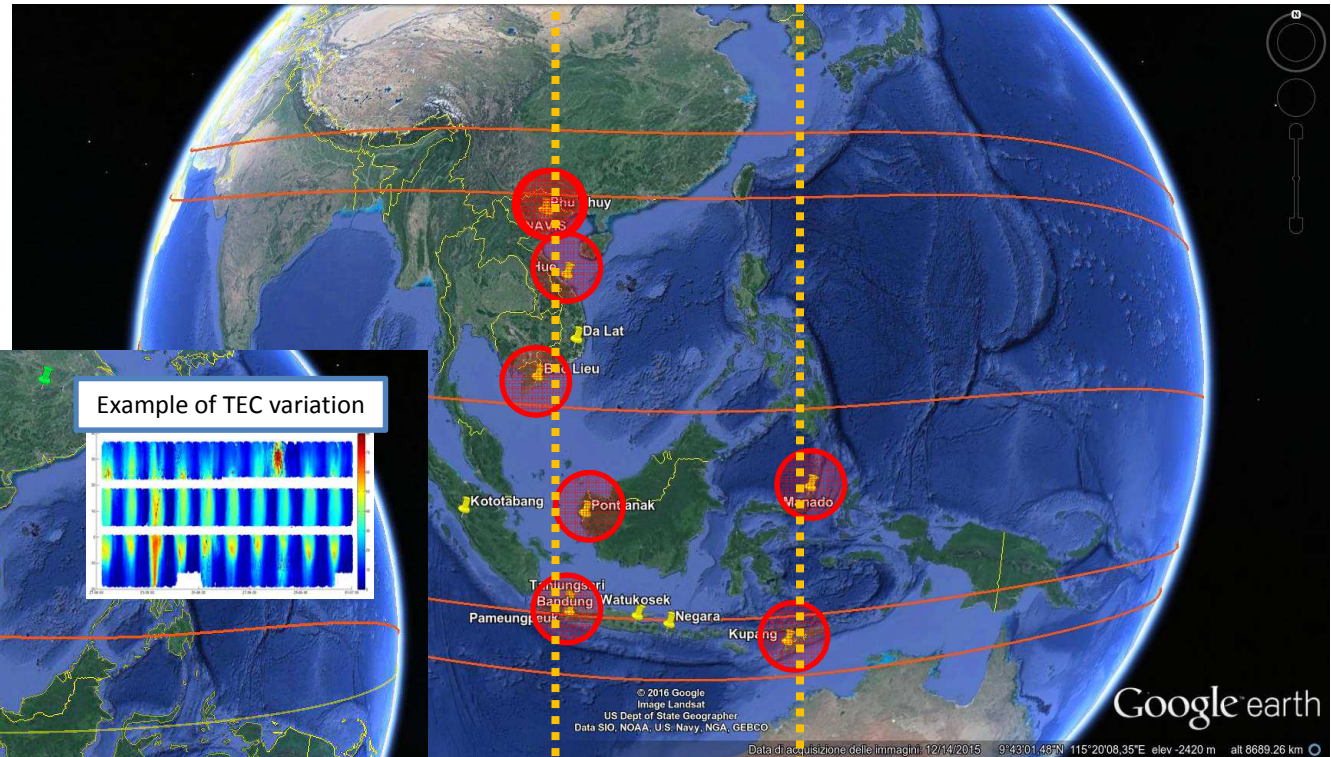
Software  
receiver

# Measurement Campaign

## Full Network

### GNSS

Location	GNSS (50Hz)	Magnetometer	Ionosonde
Navis (Hanoi)	X		
Phu Thuy	X	X	
Hue	X		
Da Lat	X	X	
Bac Lieu	X	X	
Manado	X		



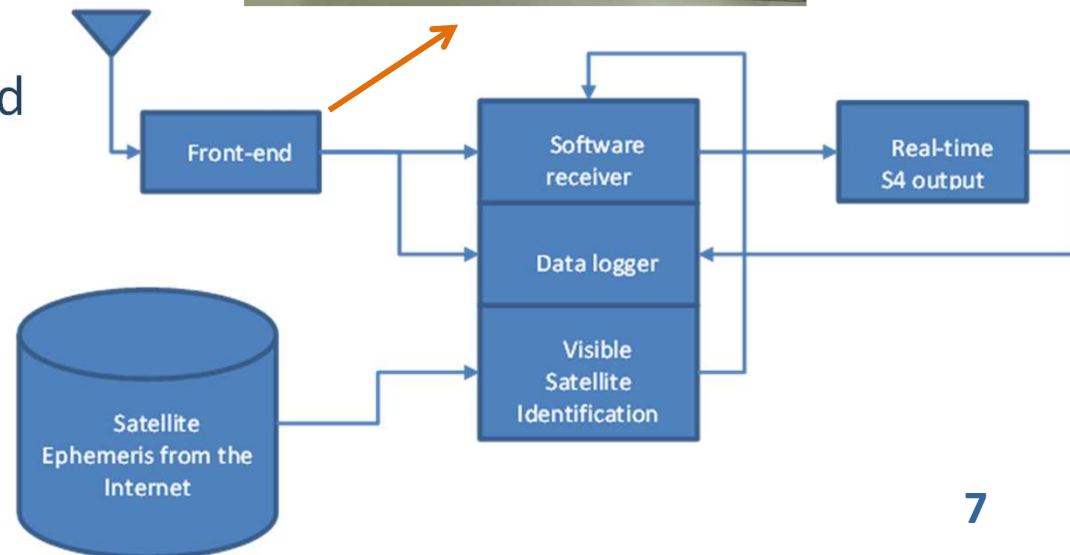
IGS receivers used to obtain TEC over the area of interest



# Measurement Campaign

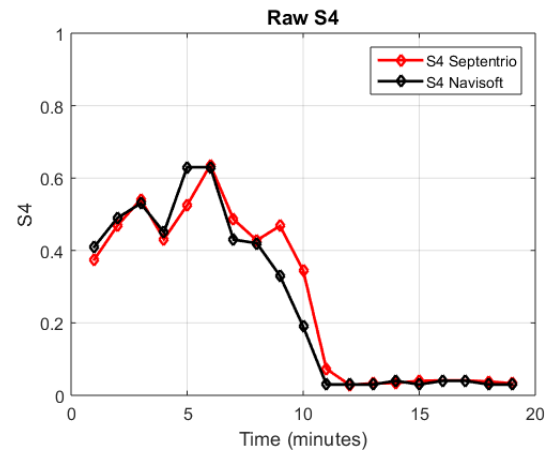
**GNSS raw data** was envisioned to complement the measurements obtained from co-located professional receivers in Vietnam and Indonesia.

- ✓ Front-end built with flexible configuration of frequency bands.
- ✓ Data processing by means of software receiver.
- ✓ Large amount of data (1minute=1GB). Data recorded only upon detection of scintillation indexes above a threshold.

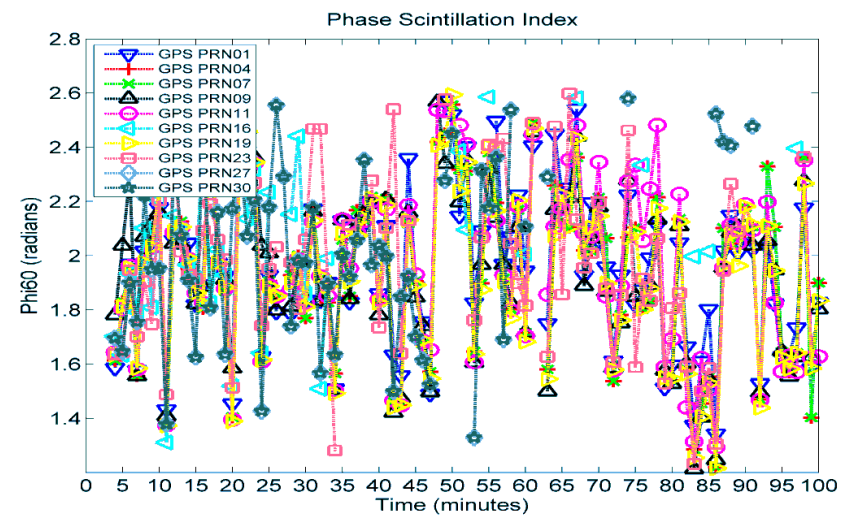
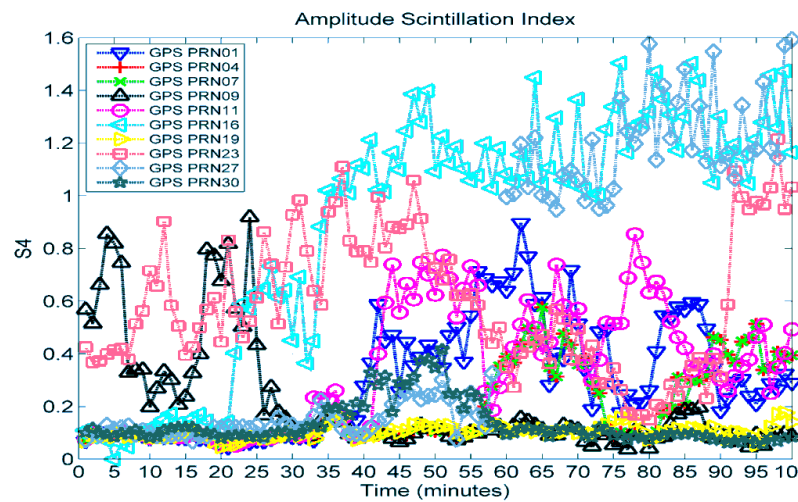


# Measurement Campaign

✓ Scintillation estimations were initially validated against those of professional receivers.



✓ Performance of the complete setup was fully validated under scintillation activity over Hanoi.

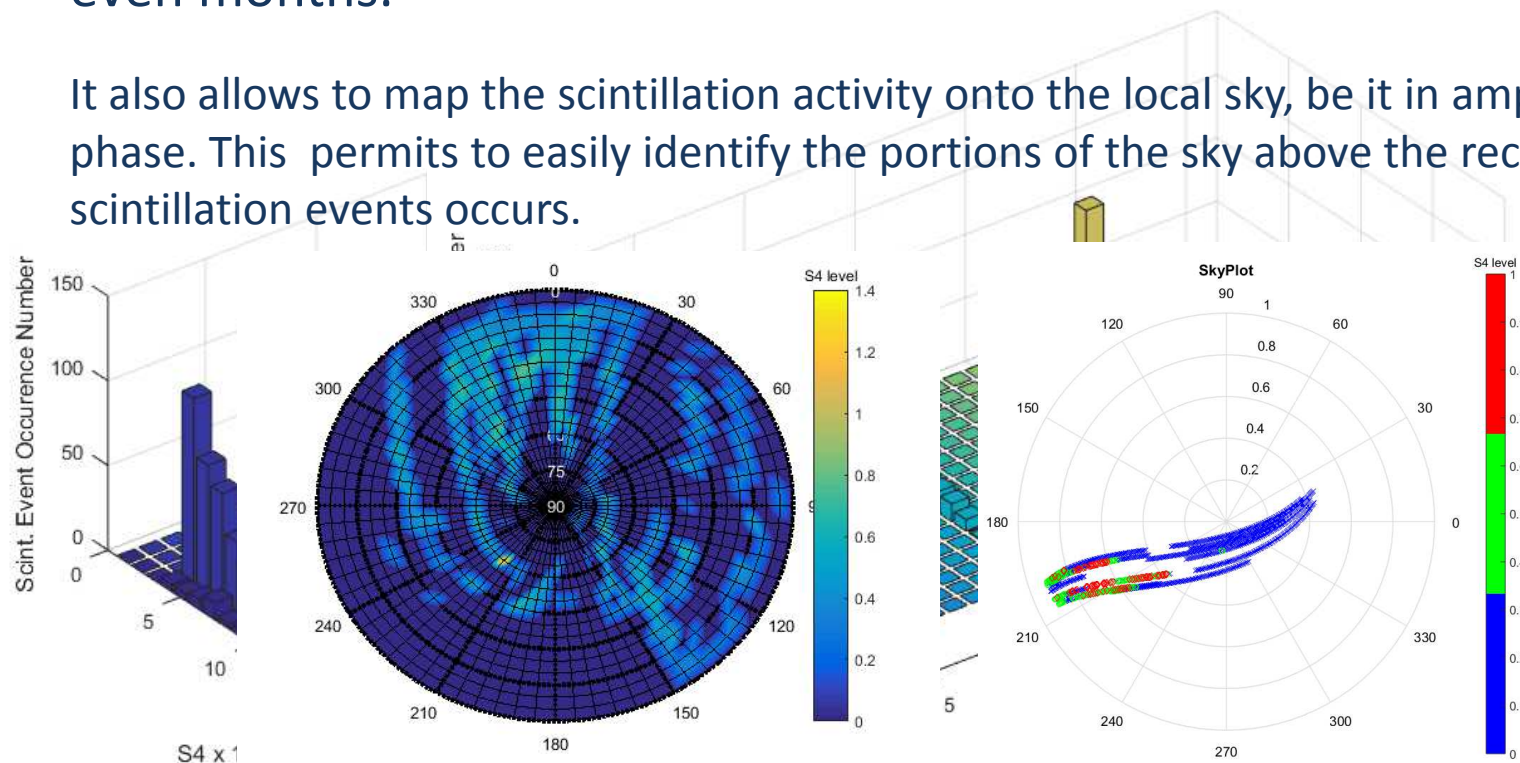




# Measurement Campaign

The developed graphical interface allows a quick snapshot of the scintillation activity of selected satellites during spans of hours, days, or even months.

It also allows to map the scintillation activity onto the local sky, be it in amplitude or phase. This permits to easily identify the portions of the sky above the receiver where scintillation events occurs.



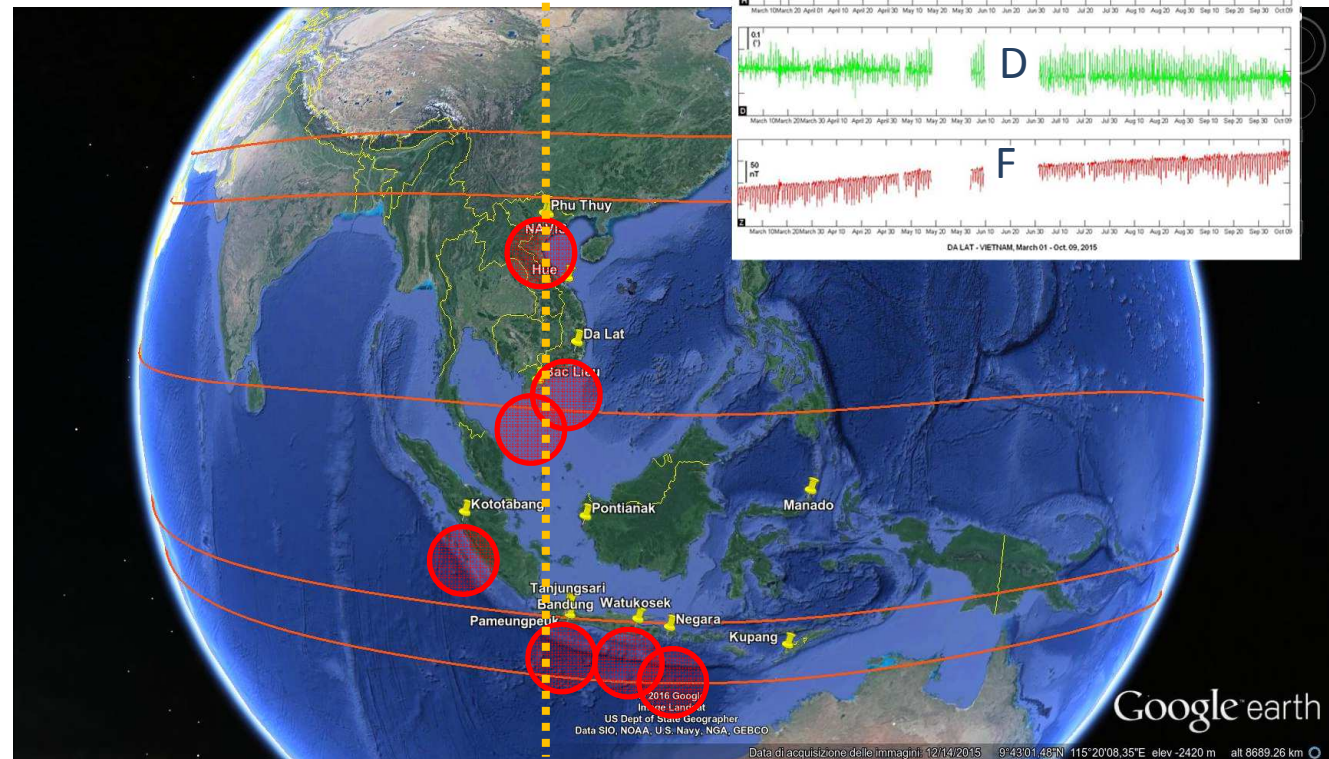
Scintillation activity location  
Statistical Analysis: S4 x Day

# Measurement Campaign

## Full Network

Location	GNSS (50Hz)	Magneto meter	Ionosonde
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Da Lat		X	
Bac Lieu*	X	X	
Manado	X		
Kototabang		X	
Pontianak	X		X
Bandung	X		
Tanjungsari		X	
Pameungpeuk		X	
Watukosek		X	
Negara		X	
Kupang	X		X

## Magnetometers



106°E

- Vector magnetometers for the recording of the field variations in the three-dimensions.
- Scalar magnetometers for the recording of F, the amplitude of the field.

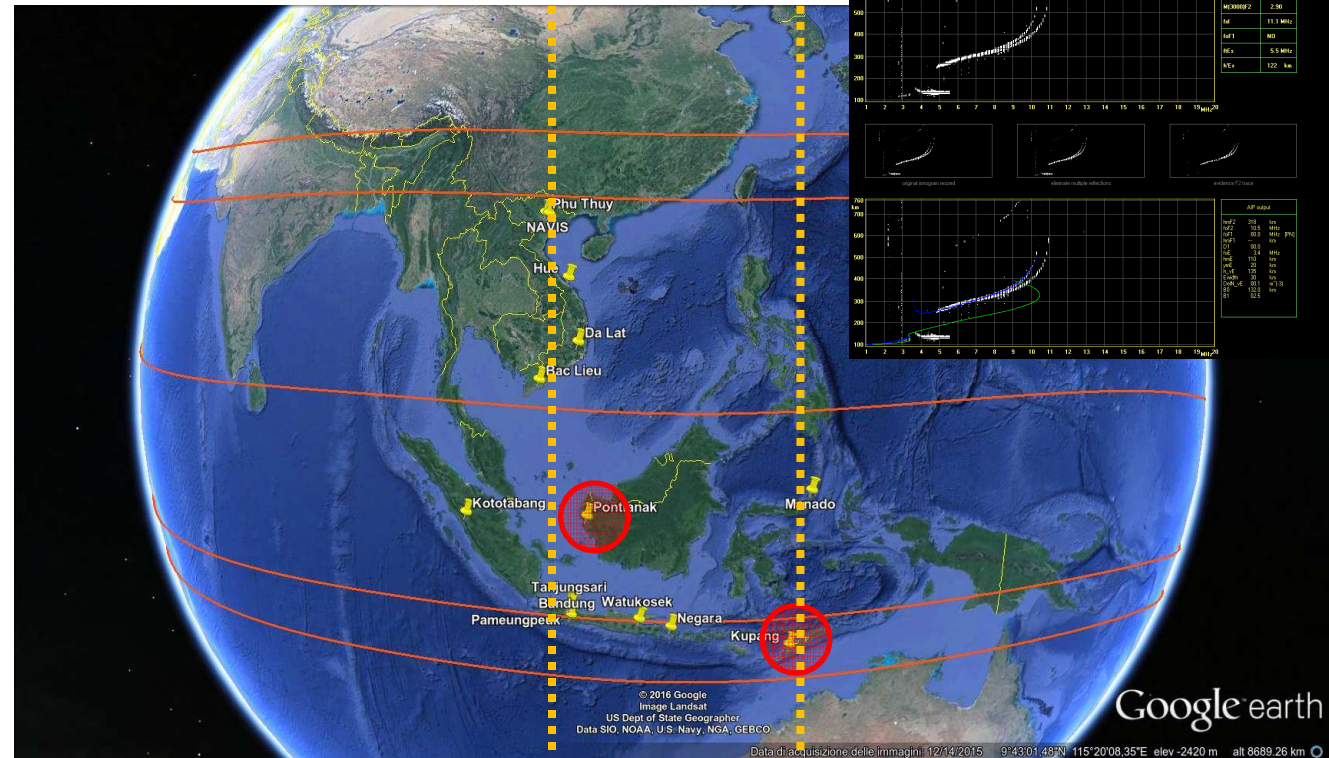
\*only variational data

# Measurement Campaign

## Full Network

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Pontianak	X		X
Bandung	X		
Tanjungsari		X	
Pameungpeuk		X	
Watukosek		X	
Negara		X	
Kupang	X		X

## Ionosondes



Examples of ionogram (Kupang)

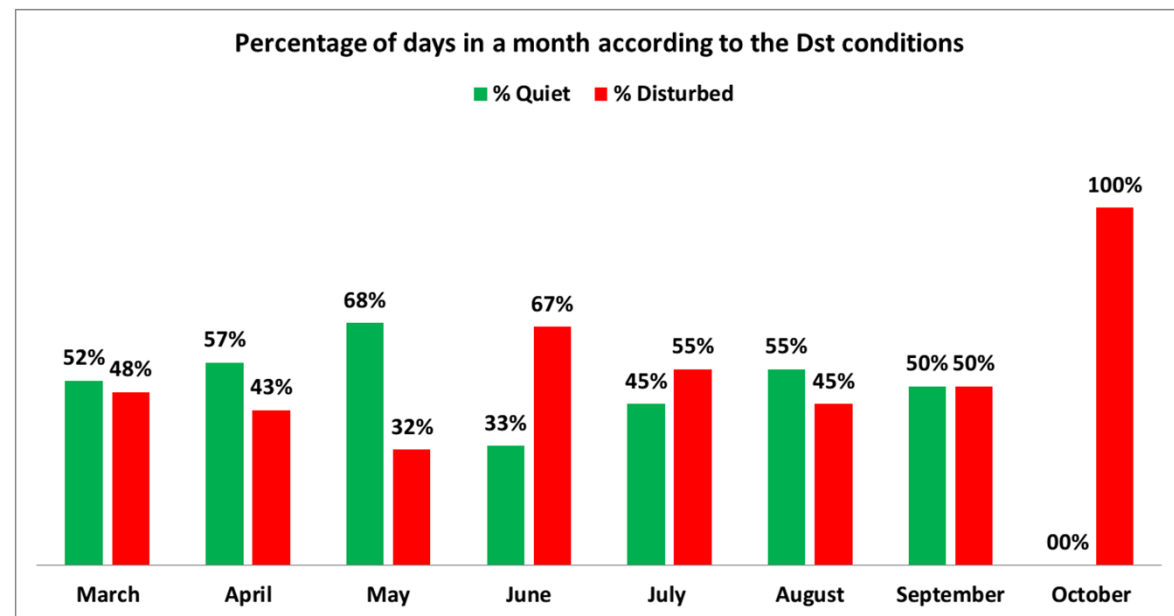
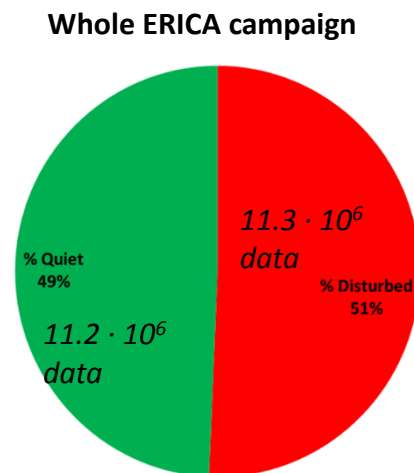
- Two Indonesian stations equipped with Canadian Advanced Digital Ionosondes (CADI)
- Sounding repetition rate of 15 minutes
- Sweeping frequency range from 1 to 20MHz



# Analysis of collected data

## Climatological assessment of the ionosphere

- **CLIMATOLOGY**: assessment of the general recurrent features of the ionospheric irregularities dynamics and temporal evolution on long data series
- GNSS grouped into quiet and disturbed conditions according to Dst index and local K index.
- A good balance in the number of days with quiet and disturbed conditions for reliable climatology was achieved.



# Analysis of collected data

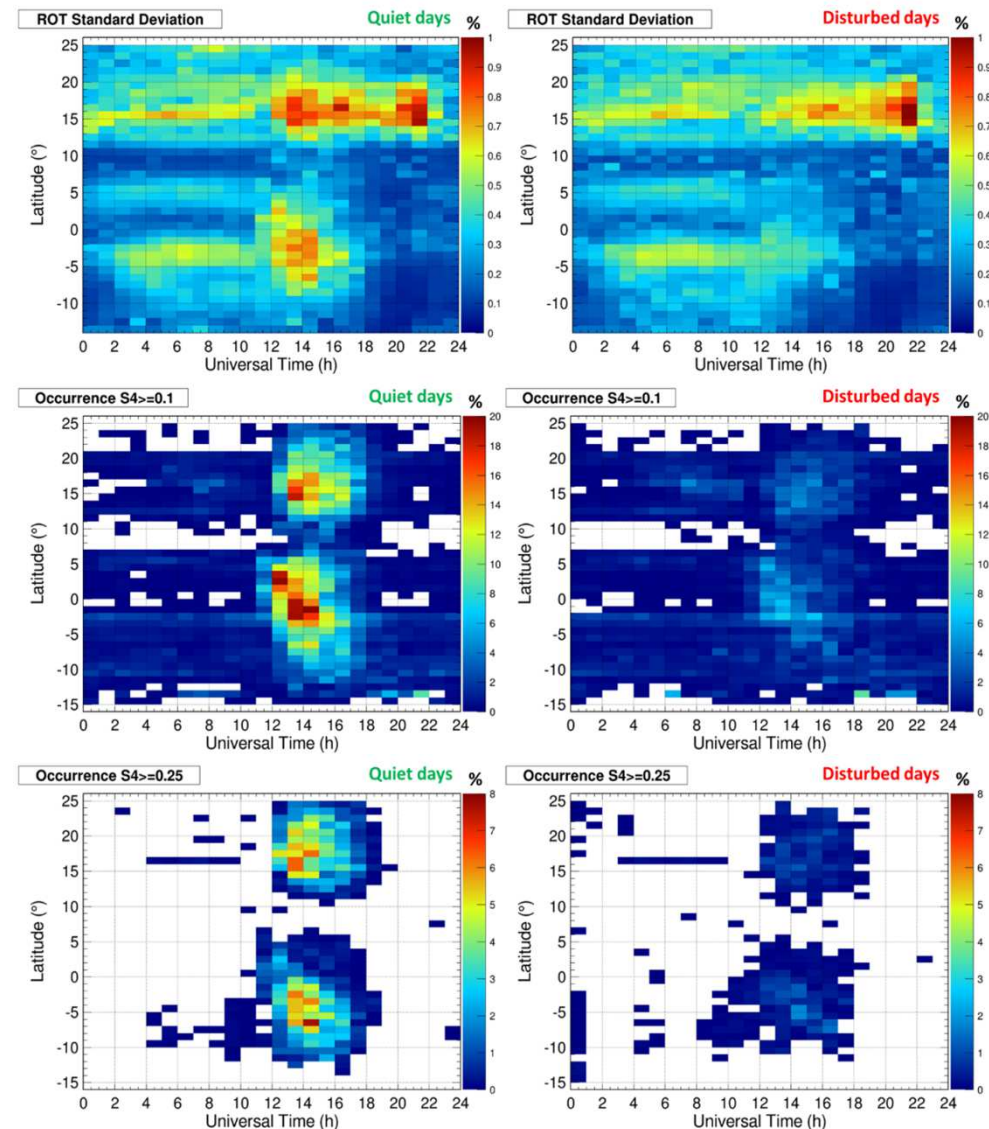
## Climatological assessment of the ionosphere

### Ground Based Scintillation Climatology

- GBSC maps describe the variation of occurrence in geographic latitude and UT.
- Calculated over 1-minute interval, from all the satellites in view above 30° of elevation
- Thresholds are chosen in order to distinguish between different scintillation scenarios

### Highlights

- Inhibition of the scintillation occurrence during post sunset hours
- Penetration of electric fields from auroral latitudes during storm periods may inhibit the formation of the two crests of the EIA
- Not all TEC spatio-temporal scales are effective in producing scintillation-leading irregularities in the ionosphere



# Analysis of collected data

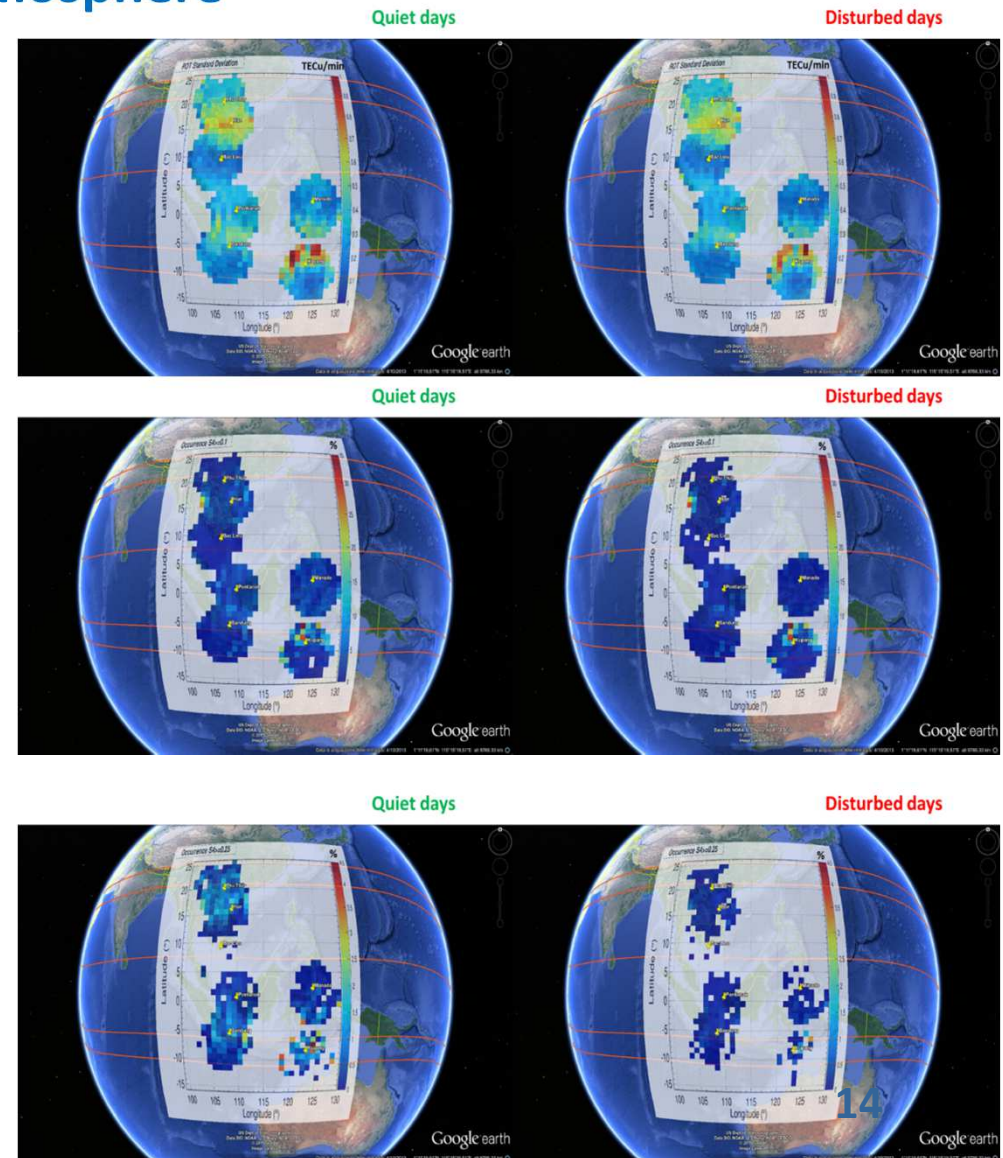
## Climatological assessment of the ionosphere

### Ground Based Scintillation Climatology

- GBSC maps describe the variation of occurrence in geographic coordinates

### Highlights

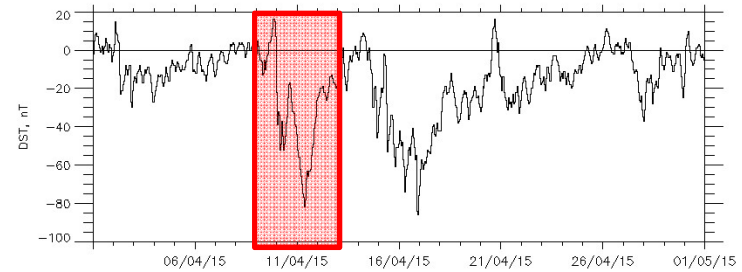
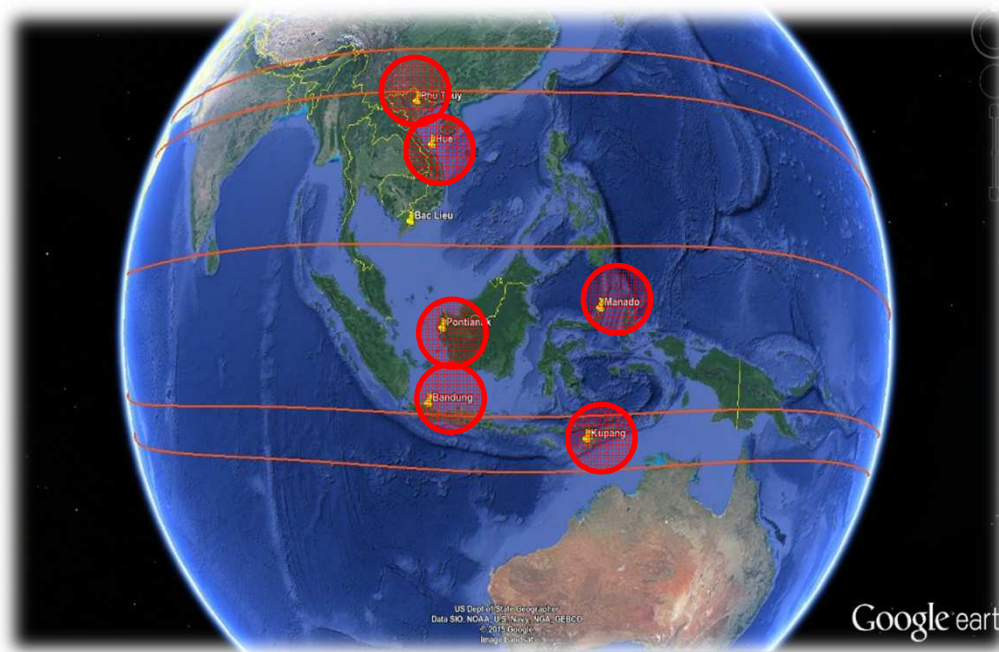
- Inhibition of the scintillation occurrence during post sunset hours
- Dip equator and the  $\pm 15^\circ$ - $20^\circ$  magnetic parallels (orange curves) provide a clear portrait of the EIA crests and trough





# Analysis of collected data

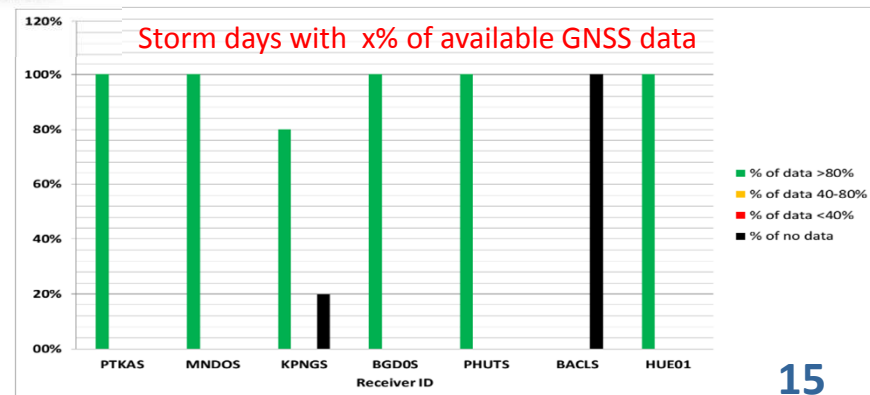
## The case of April 09-13 2015



$D_{st}$  variations show the occurrence of two moderate storms occurred on the 10<sup>th</sup> and 11<sup>th</sup> of April 2015.

flag	meaning	color
0	no data	black
1	data < 40%	red
2	data 40-80 %	yellow
3	data > 80%	green

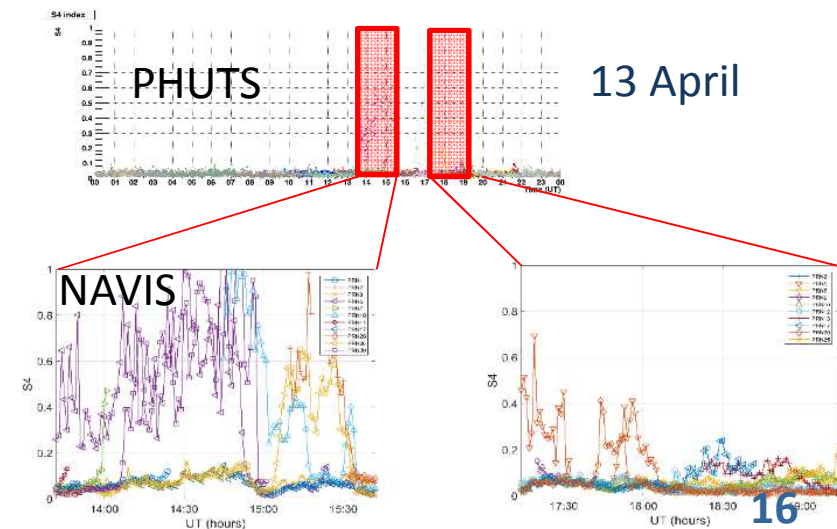
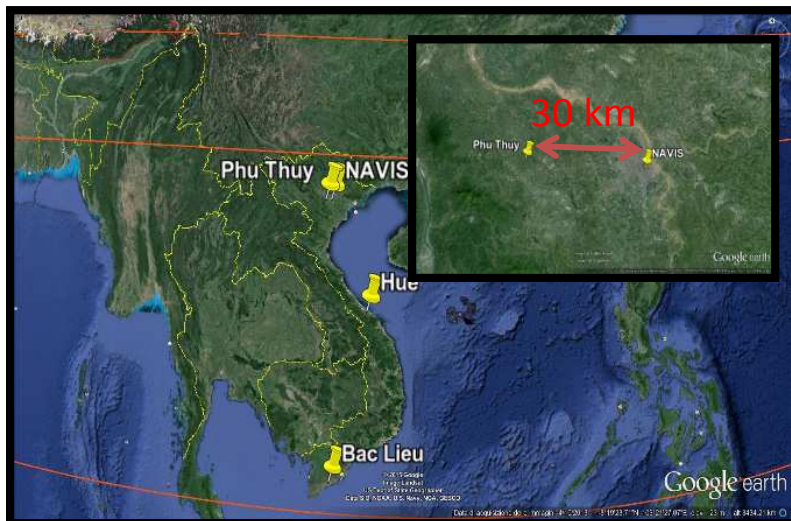
YY	MM	DD	PTKAS	MNDOS	KPNGS	BGDOS	PHUTS	BACLS	HUE01
2015	04	09	3	3	3	3	3		3
2015	04	10	3	3	3	3	3		3
2015	04	11	3	3		3	3		3
2015	04	12	3	3	3	3	3		3
2015	04	13	3	3	3	3	3		3



# Analysis of collected data

## The case of April 09-13 2015

- ✓ Raw datasets were recorded about 30 km far from PHUTS station (Phu Thuy) at Hanoi
- ✓ Both receivers have recorded amplitude scintillations on several satellites in view between April 09 and 13.
- ✓ In the inhibition phase of the storm, the lack of scintillation activity resulted in a gap of software-radio receiver data.



# Conclusions

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- Crucial importance of **accessing regional data** to properly characterise the ionospheric environment for both climatological and weather assessment (SEA regions are unevenly covered by ionospheric and geomagnetic measurements)
- The twofold approach (**ionospheric climatology** plus **deeper investigation of specific events**) has proved to be effective in better understanding the local features of the ionosphere, although there are still open issues about ionosphere behaviour over SEA.
- Significant analysed phenomena:
  - inhibition of the formation of the two crests of the EIA
  - corresponding inhibition of the scintillation on L-band signals
  - asymmetry of the scintillation patterns between the northern and southern crests of the EIA



# ERICA

## EquatoRial Ionosphere Characterization in Asia



[www.ismb.it](http://www.ismb.it)



Thank you!

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