Beacon satellite symposium 2016
Space and Ground based TEC techniques and Measurements

An approach to study TEC gradients variability and their role in driving scintillations

Claudio Cesaroni – Trieste, 28 June 2016

GNSS TEC measurements and calibration

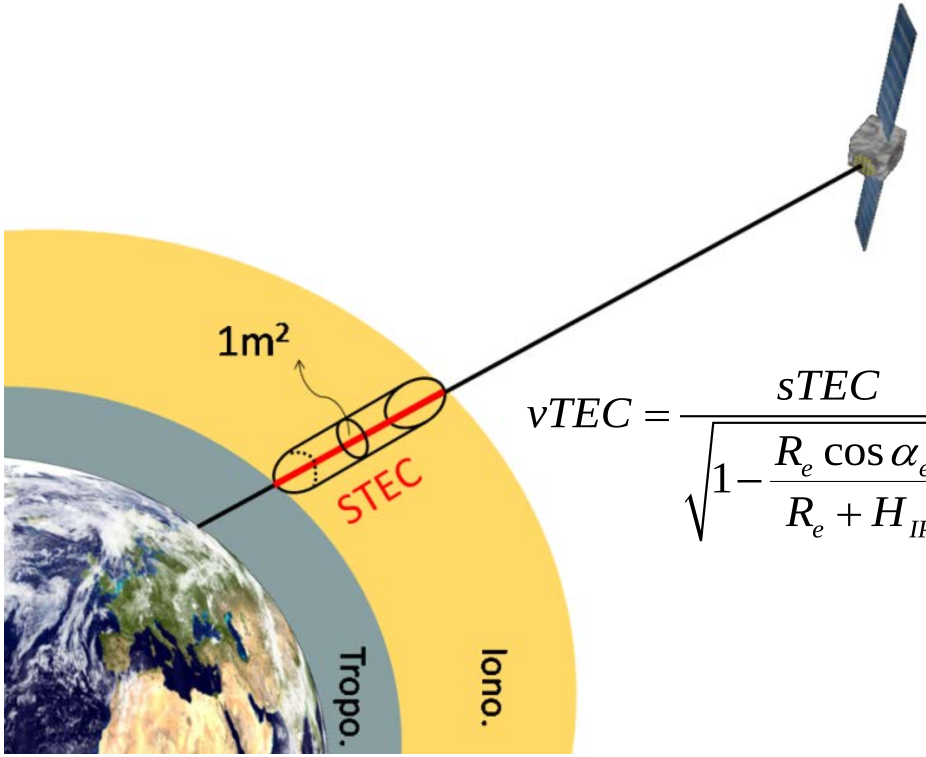
$$I_2 - I_1 = K\ STEC\left(\frac{1}{f_2^2} - \frac{1}{f_1^2}\right)$$

I_2, I_1 GNSS observable relative to f_2, f_1

Actually…

$$DGD = K\ STEC\left(\frac{1}{f_2^2} - \frac{1}{f_1^2}\right) + \Delta\beta + \Delta\gamma + \Delta m$$

$$DPD = K\ STEC\left(\frac{1}{f_2^2} - \frac{1}{f_1^2}\right) + \Delta\Omega$$



$$vTEC = \frac{sTEC}{\sqrt{1 - \frac{R_e \cos\alpha_{elev}}{R_e + H_{IPP}}}}$$

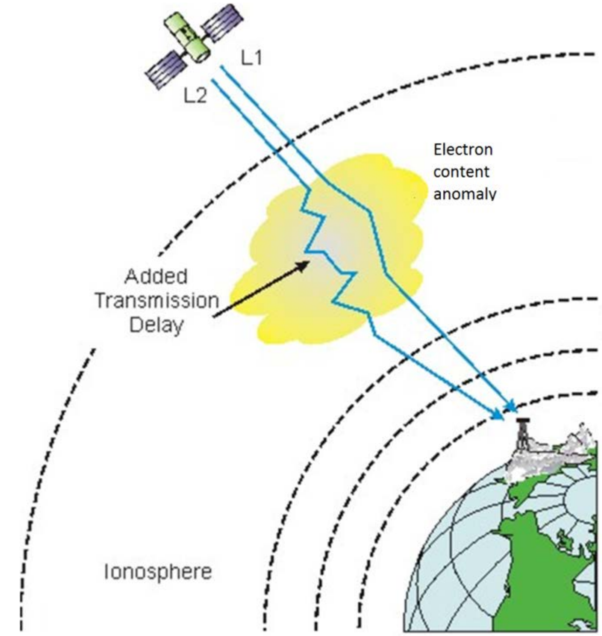
In order to cancel out biases and all non-zero mean error contributions we apply a calibration procedure based on phase and code measurements (*Ciraolo et al., 2007*)

Ionospheric Scintillation index

Scintillations

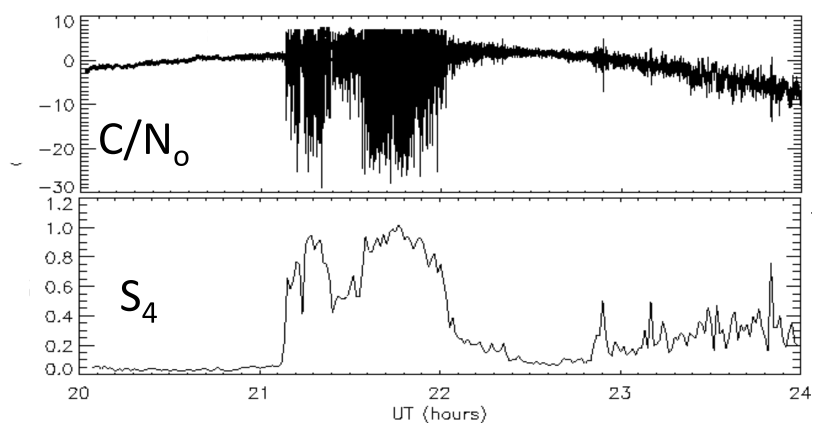
Sudden fluctuations of amplitude and phase of trans-ionospheric e.m. wave due to small scale electron (first Fresnel zone) density anomalies

$$S_4 = \sqrt{\frac{\langle I^2 \rangle - \langle I \rangle^2}{\langle I \rangle^2}}$$



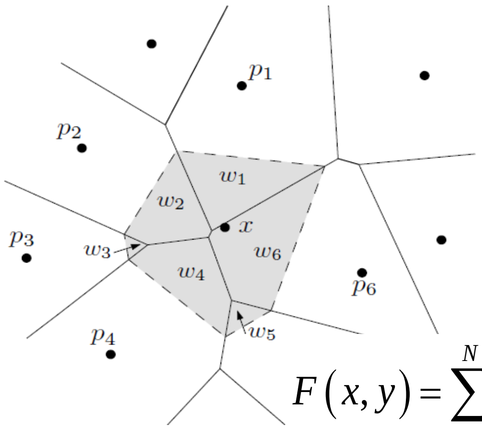
GNSS receivers for scintilliations

- High sampling frequency (50 Hz)
- Multi frequency
- Multi constellation (GPS,GLONASS , GALILEO)

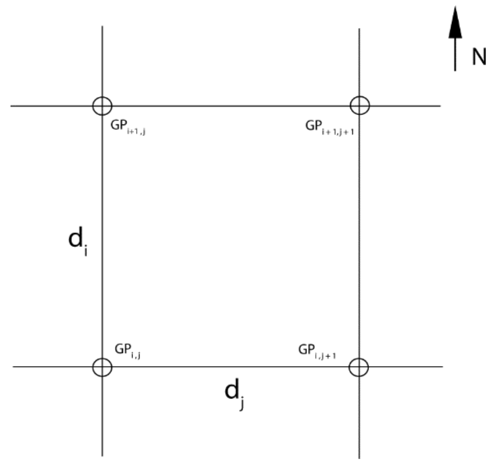


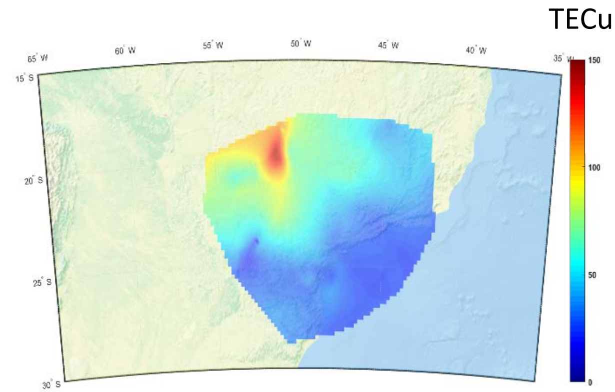
An approach to study TEC gradients variability and their role in driving scintillations

TEC interpolation over a regular grid



$$F(x,y)=\sum_{i=1}^{N} w_i f_i$$



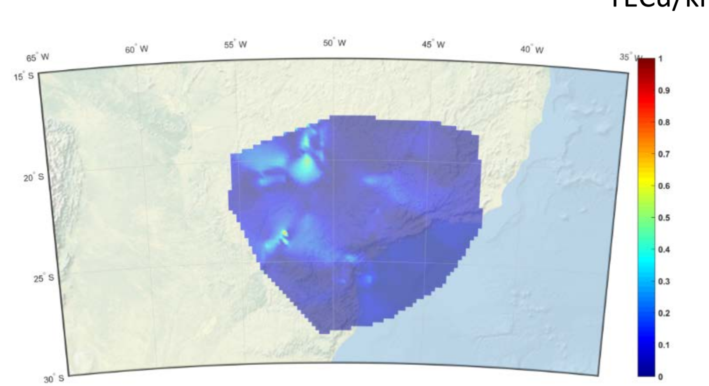


Natural Neighbor interpolation is a good technique to treat regional TEC data (Foster and Evans,2008; Cesaroni, 2015)

TEC meridional and zonal gradients

$$\Delta TEC_{N-S}\left(GP_{i,j}\right)=\frac{TEC\left(GP_{i+1,j}\right)-TEC\left(GP_{i,j}\right)}{d_i}$$

$$\Delta TEC_{E-W}\left(GP_{i,j}\right)=\frac{TEC\left(GP_{i,j+1}\right)-TEC\left(GP_{i,j}\right)}{d_j}$$



Cesaroni et al., 2015 SWSC

Ground Based Scintillation Climatology

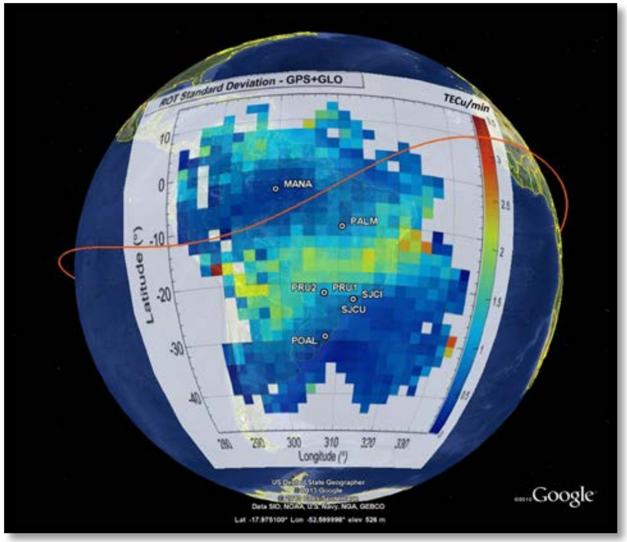
Maps of ionospheric scintillation and TEC derived parameters

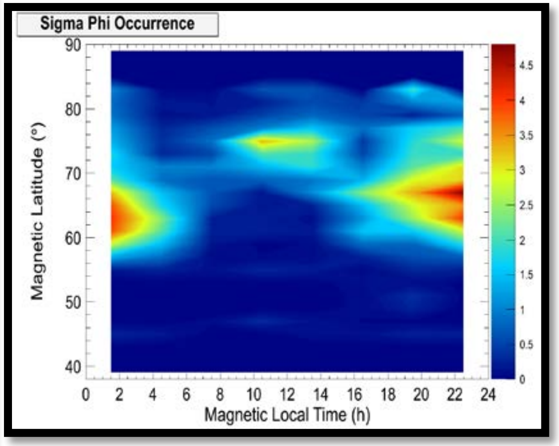
1. Mean value and standard deviation
2. Occurrence

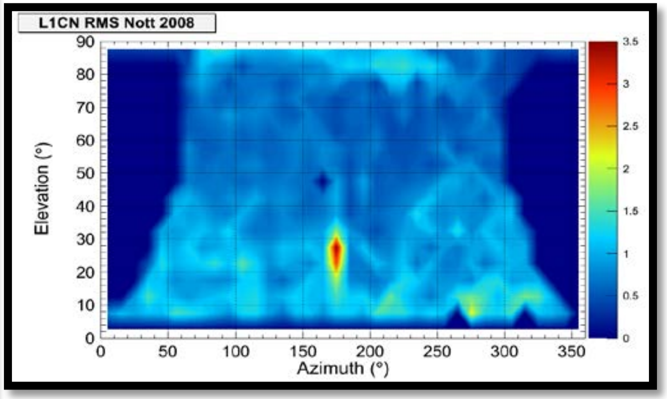
System of reference: Geographic and geomagnetic coordinates (AACGM), Universal and Magnetic Local Times*, Azimuth, Elevation

*Expressed@ the IPP

Different geomagnetic conditions can be selected (Kp, IMF, Dst)

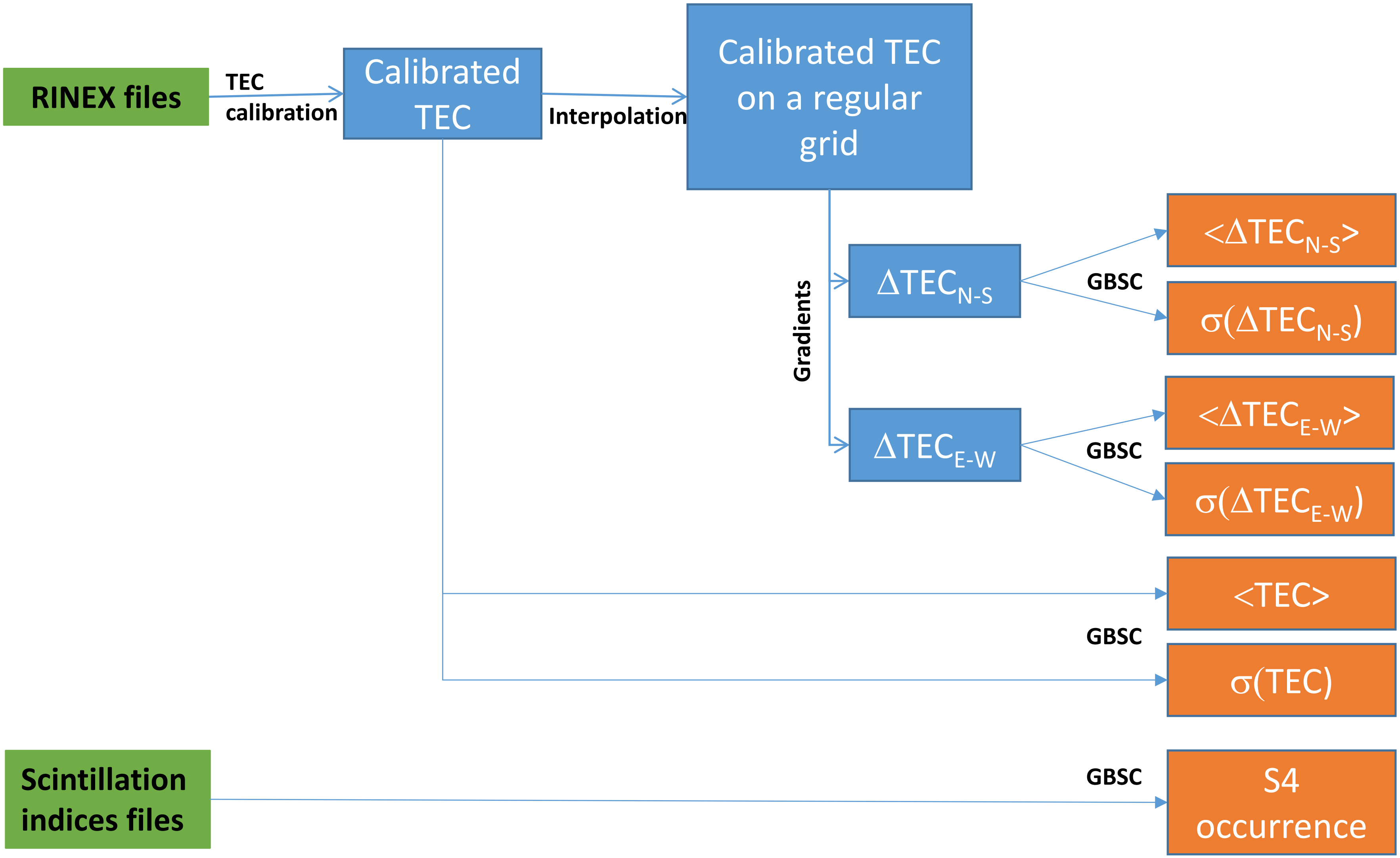






*Spogli L., Alfonsi Lu., G. De Franceschi, V. Romano, M. H. O. Aquino, A. Dodson, Climatology of GPS Ionospheric Scintillations over high and mid-latitude European Regions, Ann. Geophys., 27, 3429–3437, 2009.

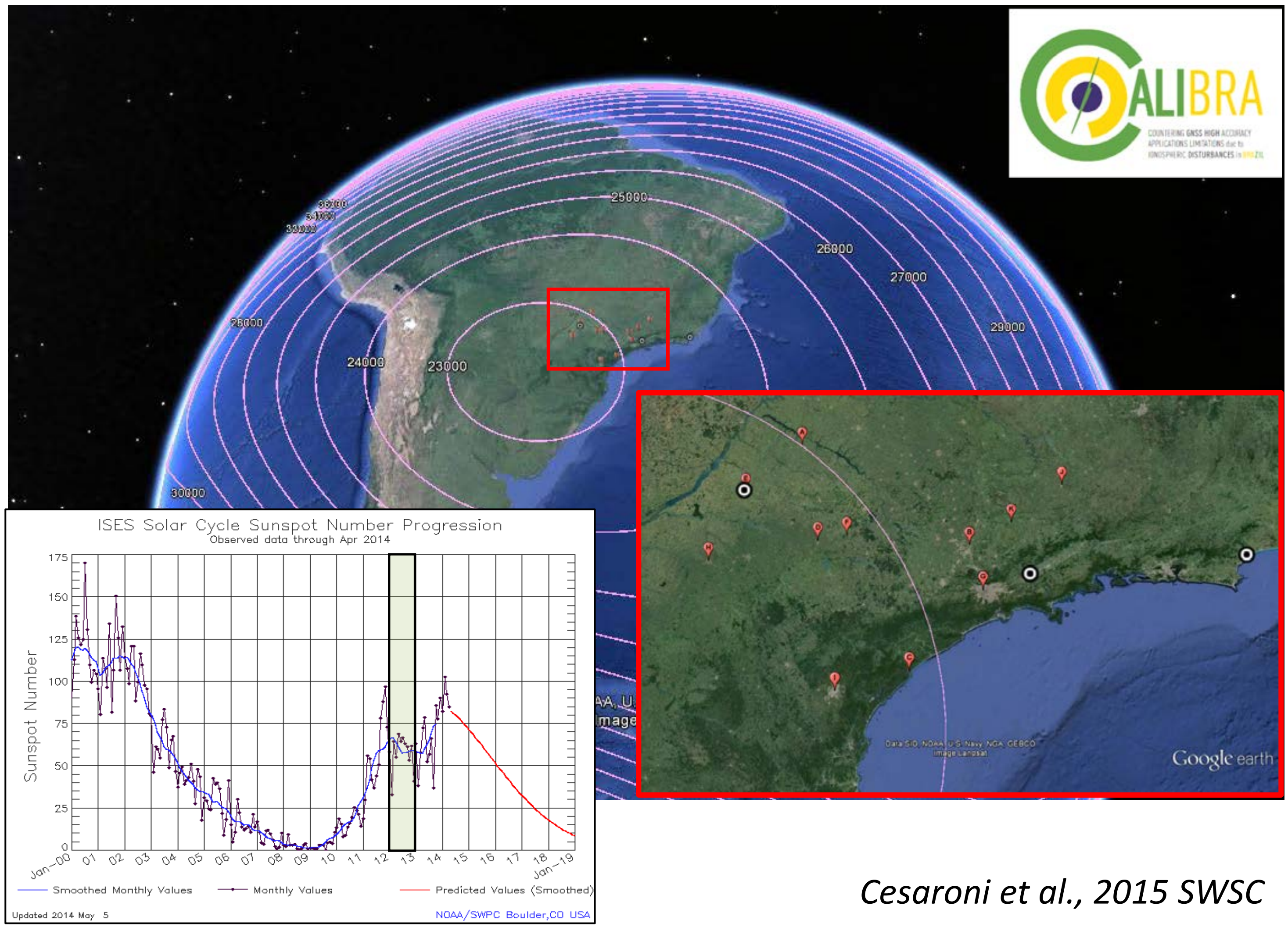
Block diagram of the TEC and scintillation algorithm



Stations in São Paulo state region (URTKN)

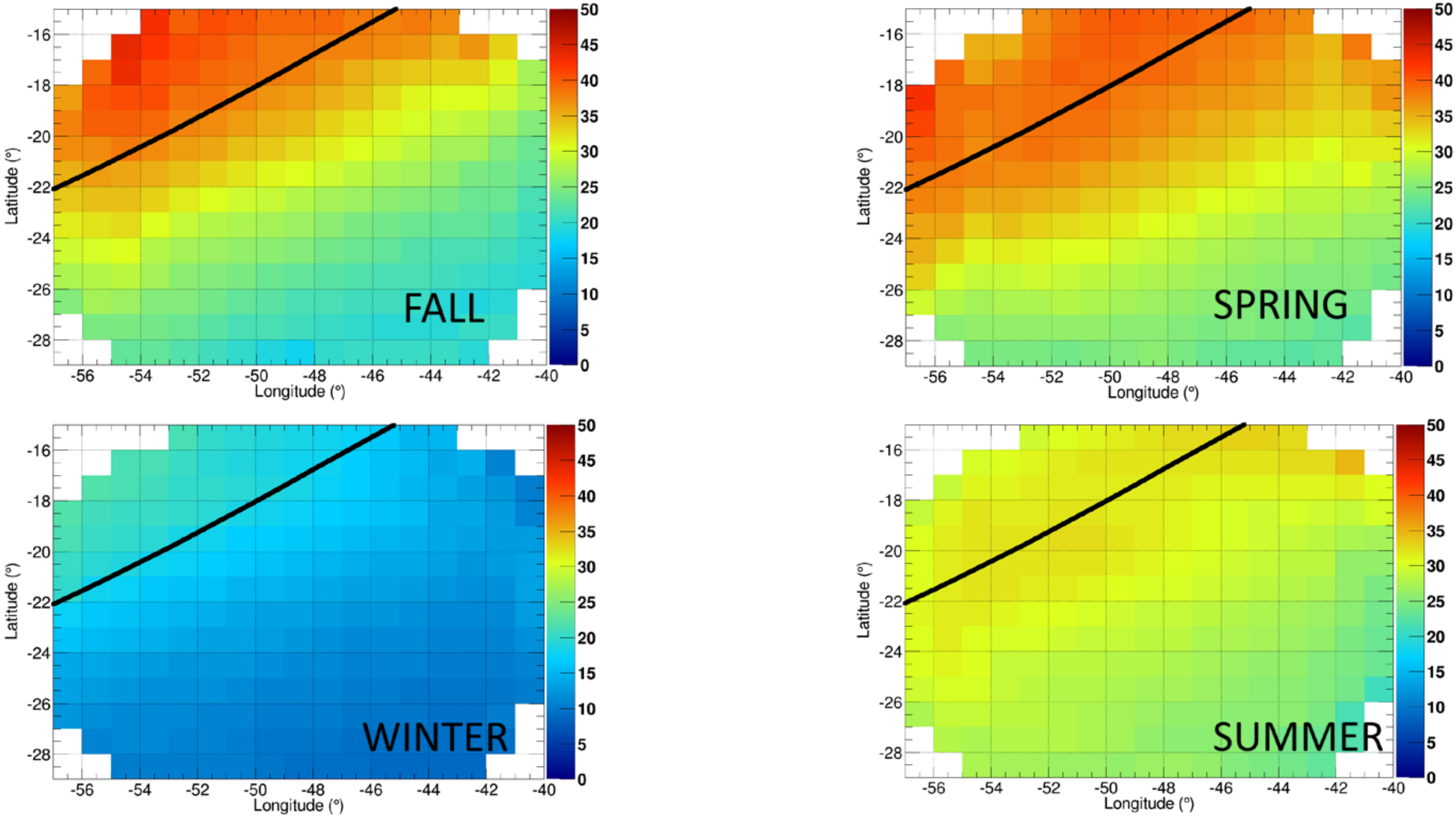
URTK network GNSS receivers collecting 1Hz data (11 stations for geodetic purpose)

GNSS scintillation receivers collecting 50 Hz data (7 stations, some of them almost colocated)



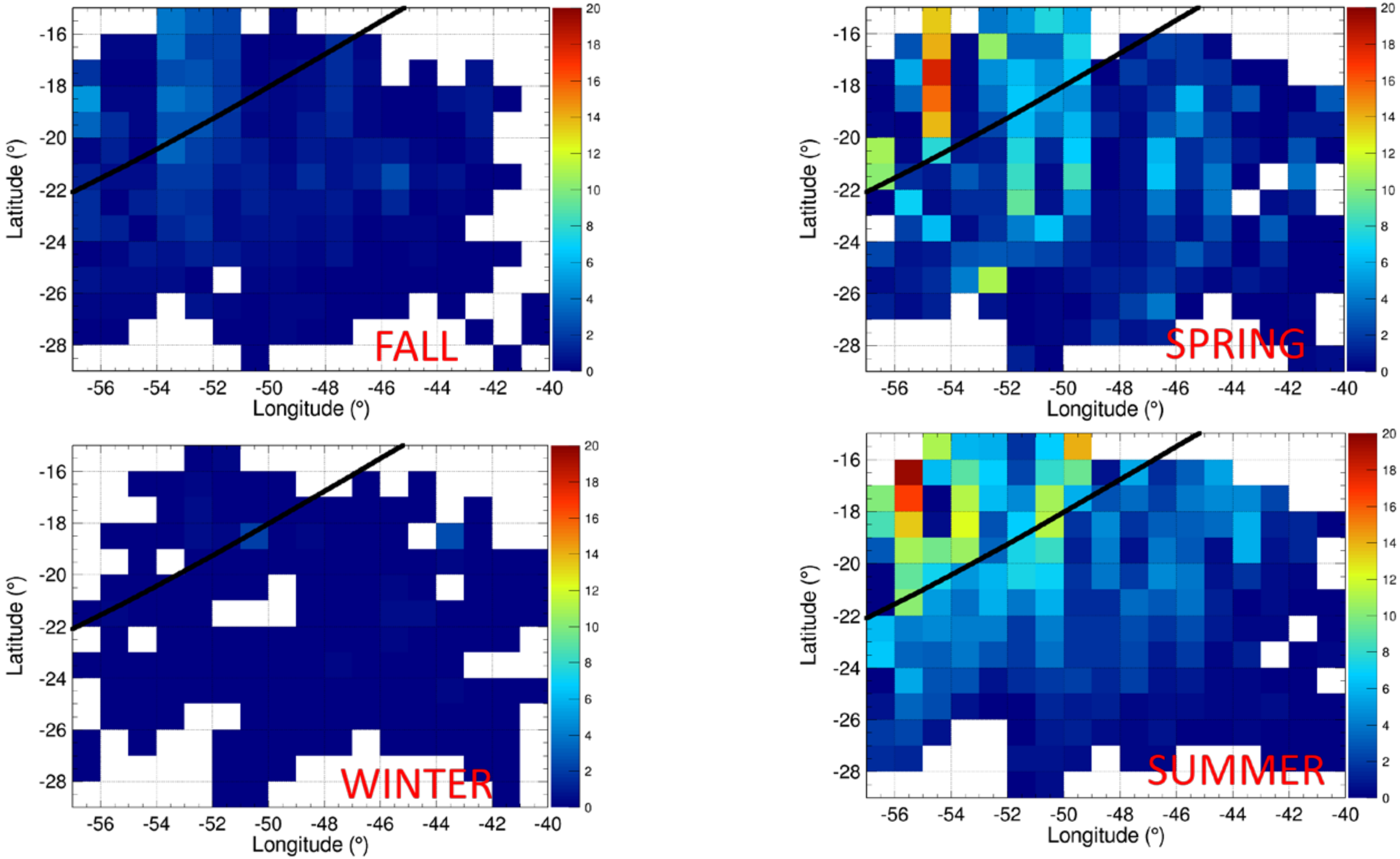
Cesaroni et al., 2015 SWSC

Seasonal variation of TEC during 2012



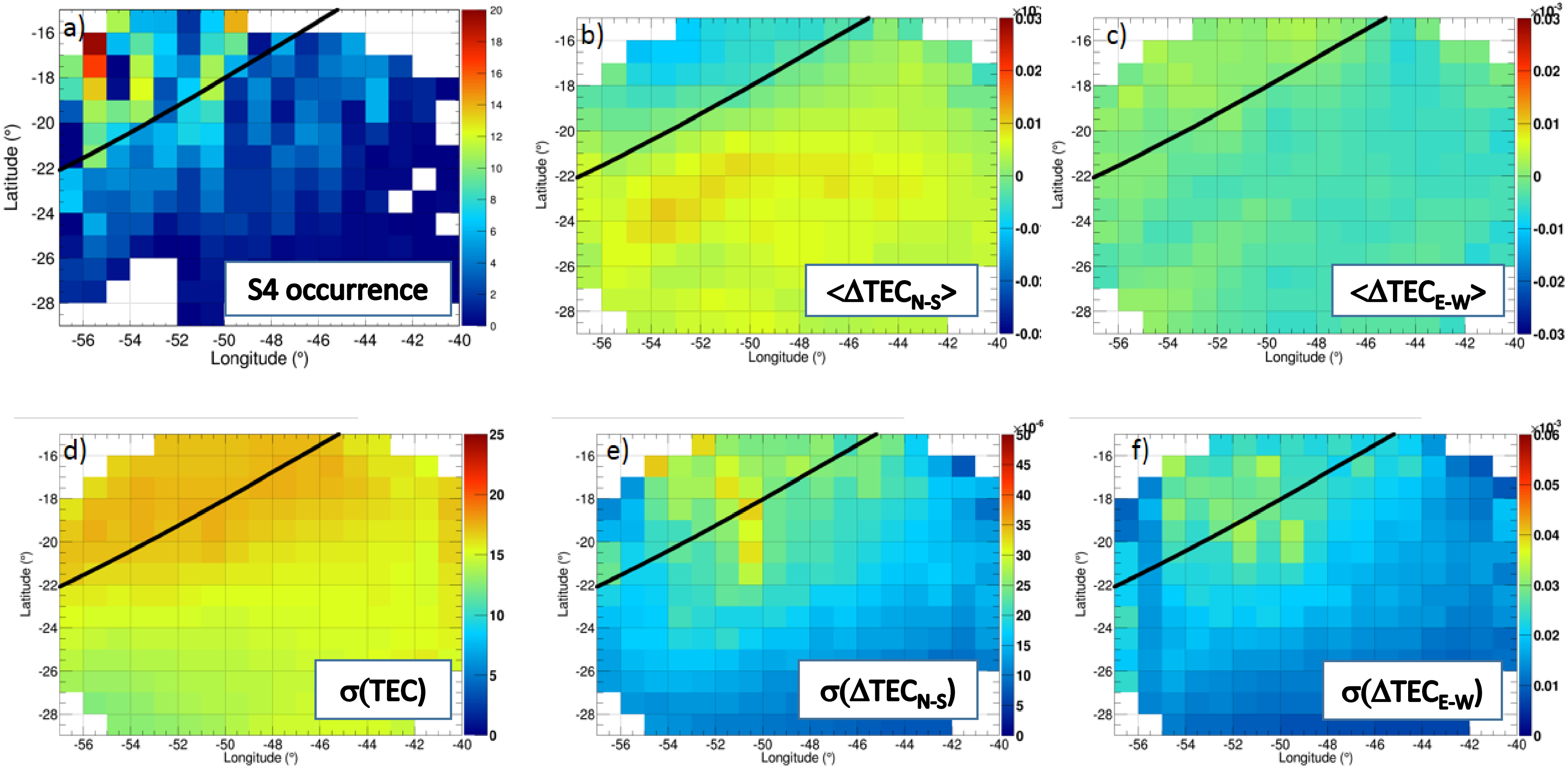
- TEC reaches its maximum during equinox
- Southern crest of EIA (at least in the SA sector) moves northwards during Fall and Winter

Seasonal variation of S4 > 0.25 occurrence during 2012



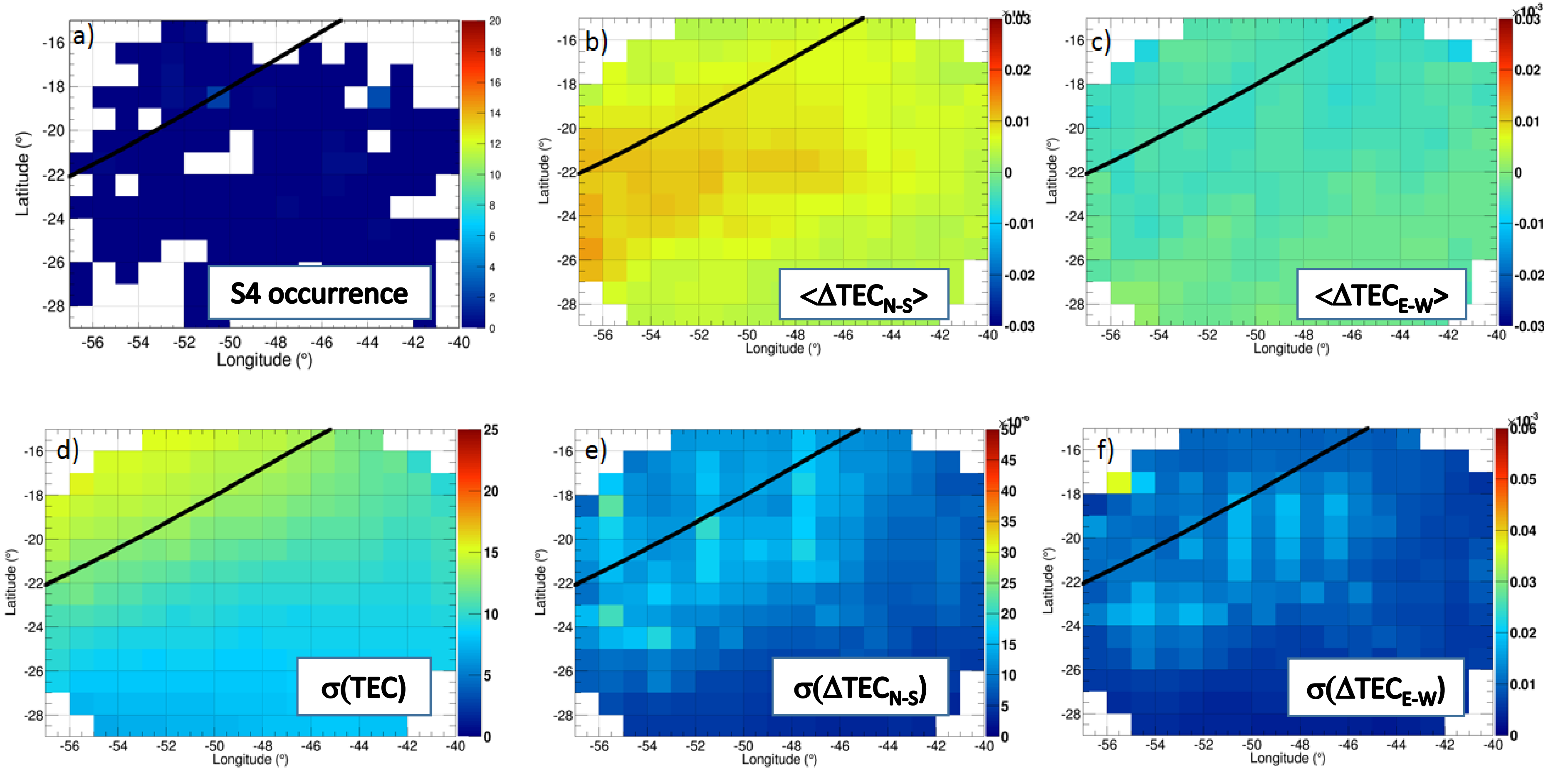
- Amplitude scintillation occurrence maximizes in Spring and Summer in correspondance with EIA southern crest

SUMMER



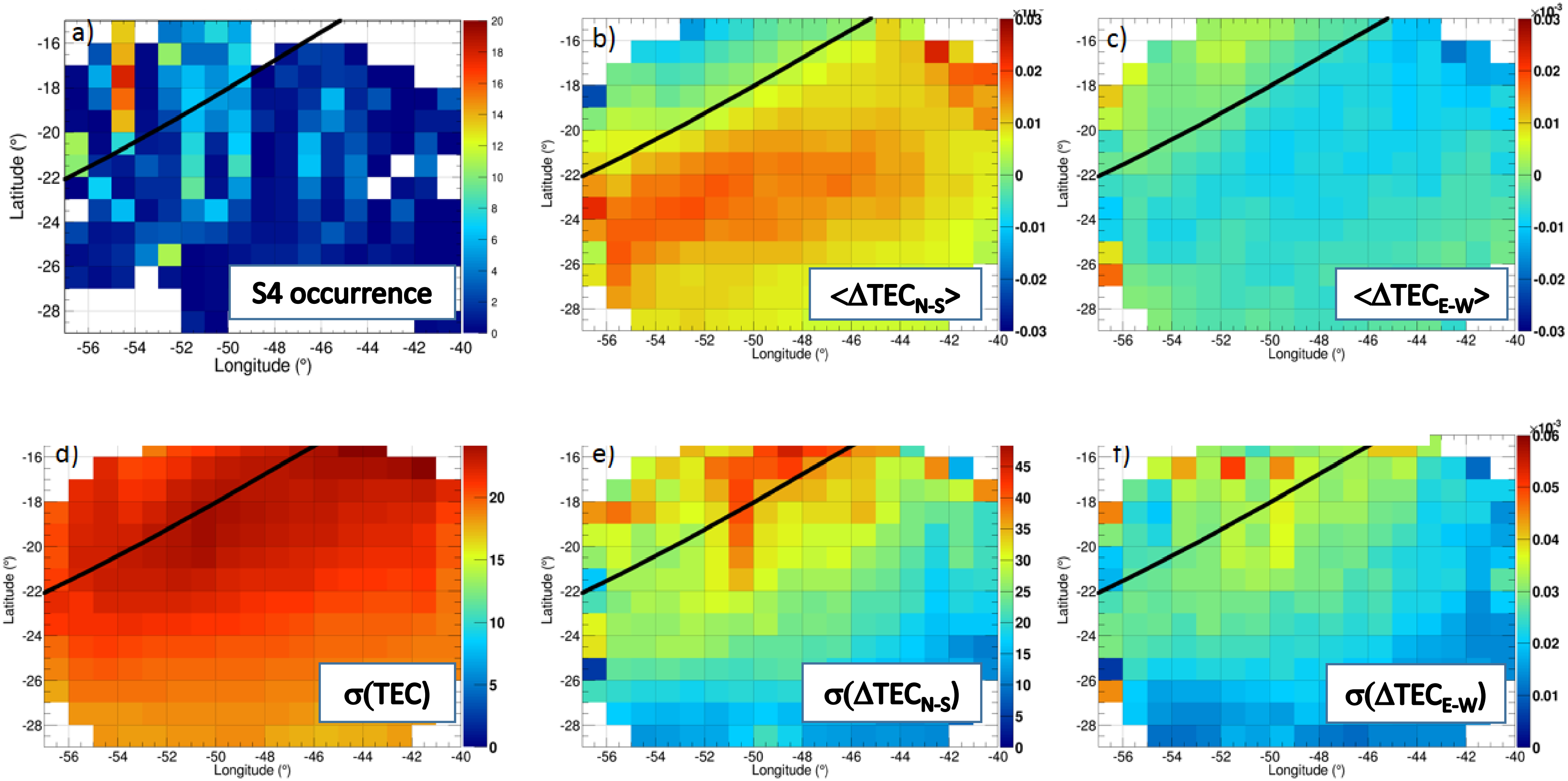
- Meridional gradients are significantly larger than the zonal ones
- Variabilty of the TEC spatial gradients give a signature of the S4 occurrence pattern

WINTER



- Even if the magnitude of the σ(TEC), <$\Delta TEC_{N\text{-}S}$> and <$\Delta TEC_{E\text{-}W}$> are comparable with that ones measured in Summer, σ($\Delta TEC_{N\text{-}S}$) and σ($\Delta TEC_{E\text{-}W}$) are neglectable confirming the role of the TEC spatial gradients variability in driving scintillations.

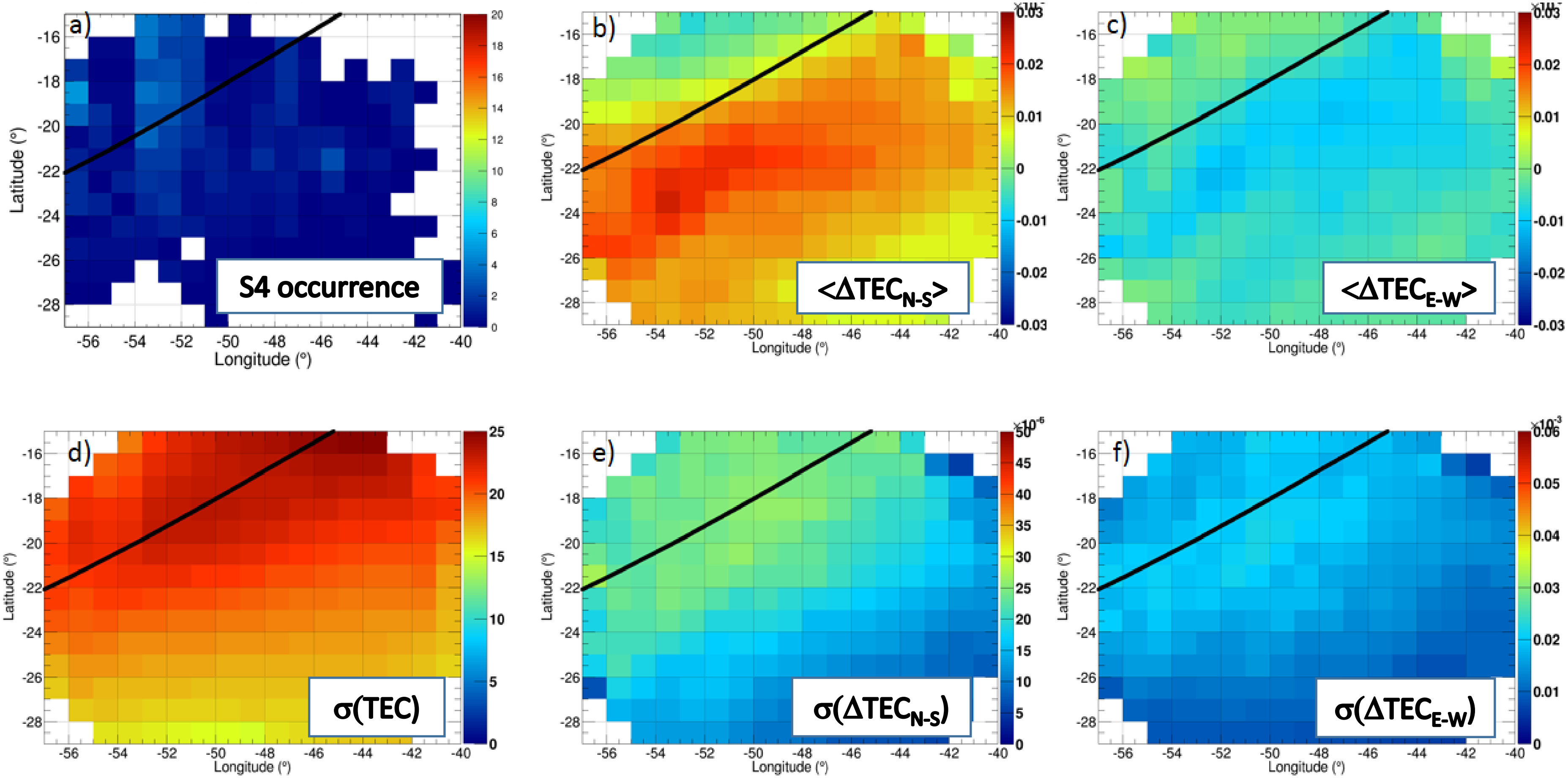
SPRING



- Meridional gradients are significantly larger than the zonal ones
- Variabilty of the TEC spatial gradients give a signature of the S4 occurrence pattern

An approach to study TEC gradients variability and their role in driving scintillations

FALL



- σ(TEC), $\langle \Delta TEC_{N-S} \rangle$ and $\langle \Delta TEC_{E-W} \rangle$ reach their maximum on Fall but their variability is neglectable (small $\sigma(\Delta TEC_{N-S})$ and $\sigma(\Delta TEC_{E-W})$). This lead to a low scintillation occurrence, $\sigma(\Delta TEC_{N-S})$ and $\sigma(\Delta TEC_{E-W})$ are neglectable confirming the role of the TEC spatial gradients variability in driving scintillations.

Remarks

- The technique here descrbed seems to able to catch the relationship between TEC climatological features and scintillation occurrence.
- Southern crest of EIA (at least in the SA sector) moves northwards (i.e. equatorwards) during Fall and Winter with respect to Spring and Summer.
- Amplitude scintillation occurrence maximizes in Spring and Summer in correspondance with EIA southern crest.
- Amplitude scintillations occur manly at the edge of gradient patterns and are mainly driven by the variability (high standard deviation) of N-S gradient
- Amplitude scintillation occurrence is low when the variability (standard deviation) of the TEC spatial gradients even if the TEC spatial gradients itself are very high.


Thank you!