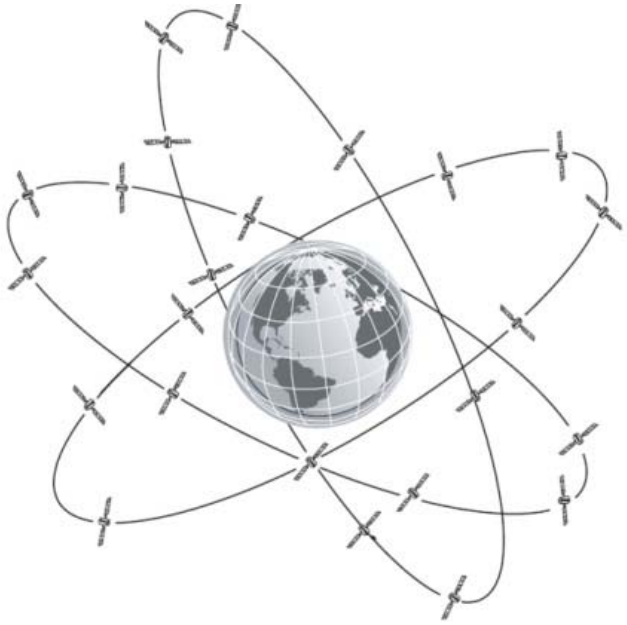
Precise Point Positioning

Performances under Ionospheric Scintillations



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New Navigator Seminar 2012
14 June 2012
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Project

Geometry

Stochasticity

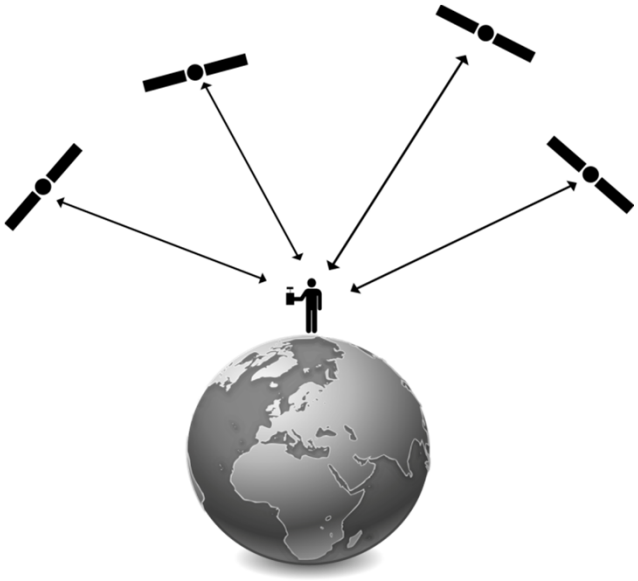
Project

Geometry

Stochasticity

The Precise Point Positioning – PPP - is an advanced satellite positioning technique

SPP – Standard Point Positioning



$$P_p^i = D_p^i + T_p^i + I_{p,m}^i + c(\Delta t^i - \Delta t_p) + \varepsilon_{p,m}^i$$

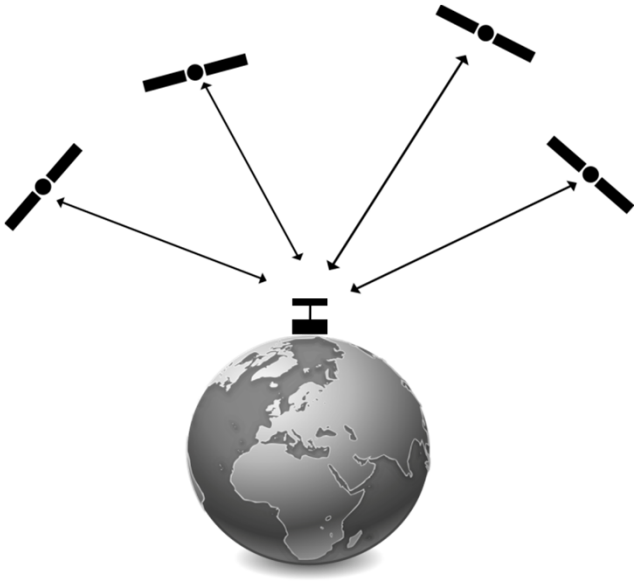
...

...

...

The Precise Point Positioning – PPP - is an advanced satellite positioning technique

PPP – Precise Point Positioning



$$i,p \begin{cases} P_{IF} = D + T + c(\Delta t^{i} - \Delta t_{p}) + \varepsilon_{P_{IF}} \\ \phi_{IF} = D + T + c(\Delta t^{i} - \Delta t_{p}) + N\lambda + \varepsilon_{\phi_{IF}} \end{cases}$$

Ionospheric Free (IF) model

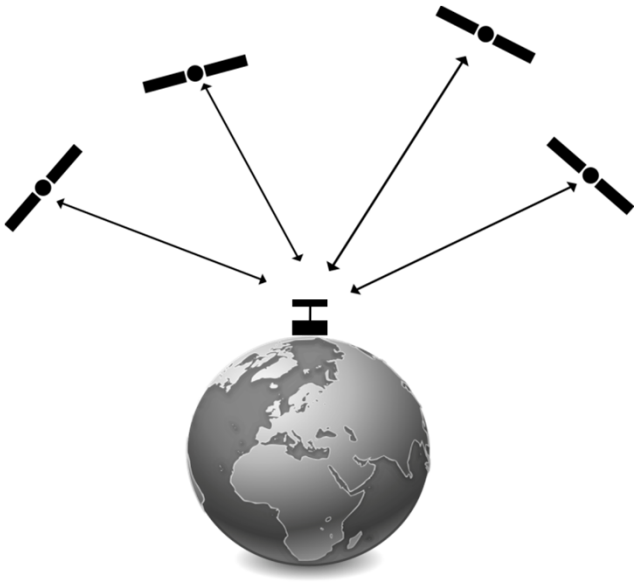
Tropospheric delay is estimated

Code pseudorange and carrier-phase

Precise satellite clock and orbits products

The Precise Point Positioning – PPP - is an advanced satellite positioning technique

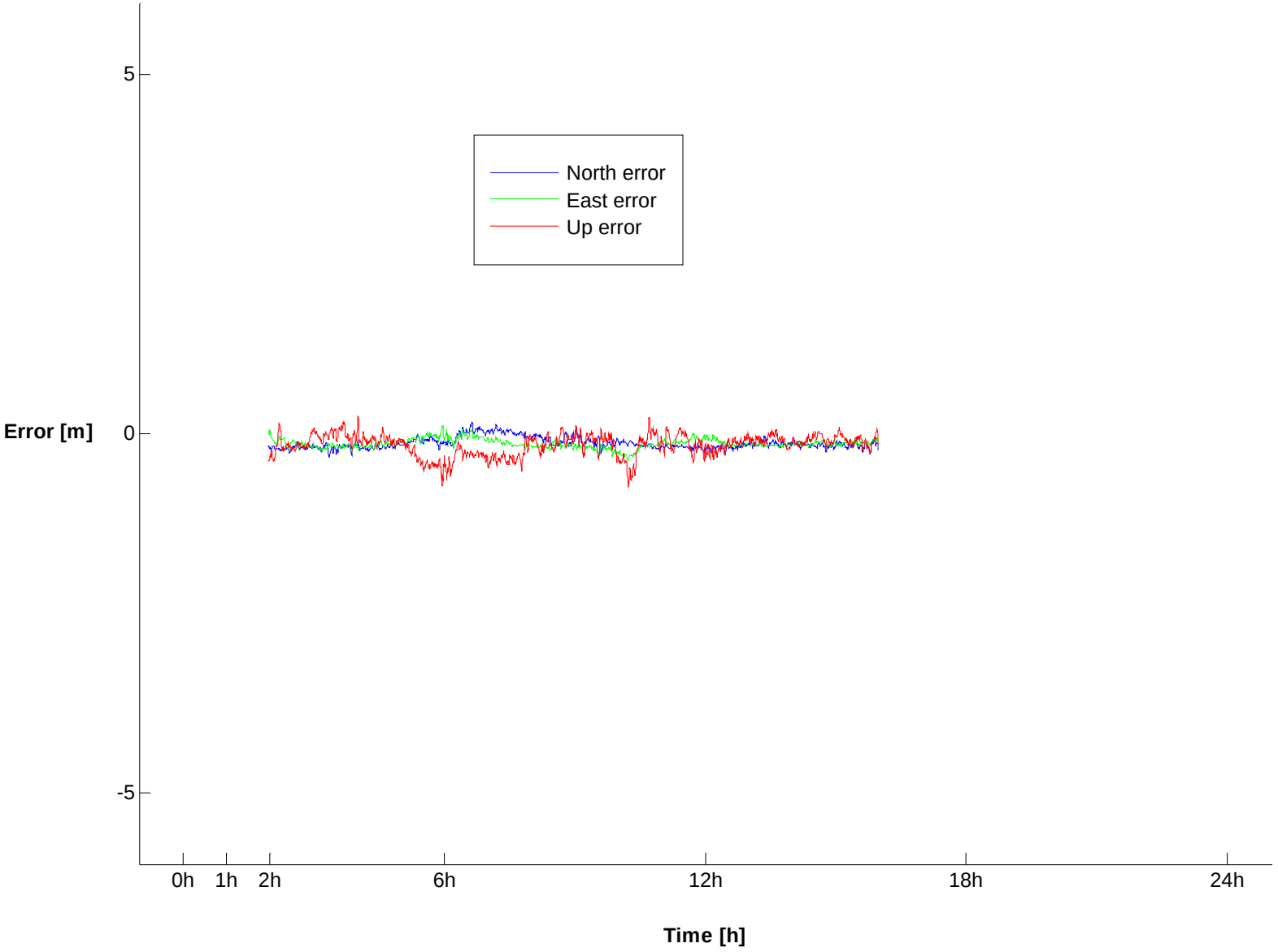
PPP – Precise Point Positioning



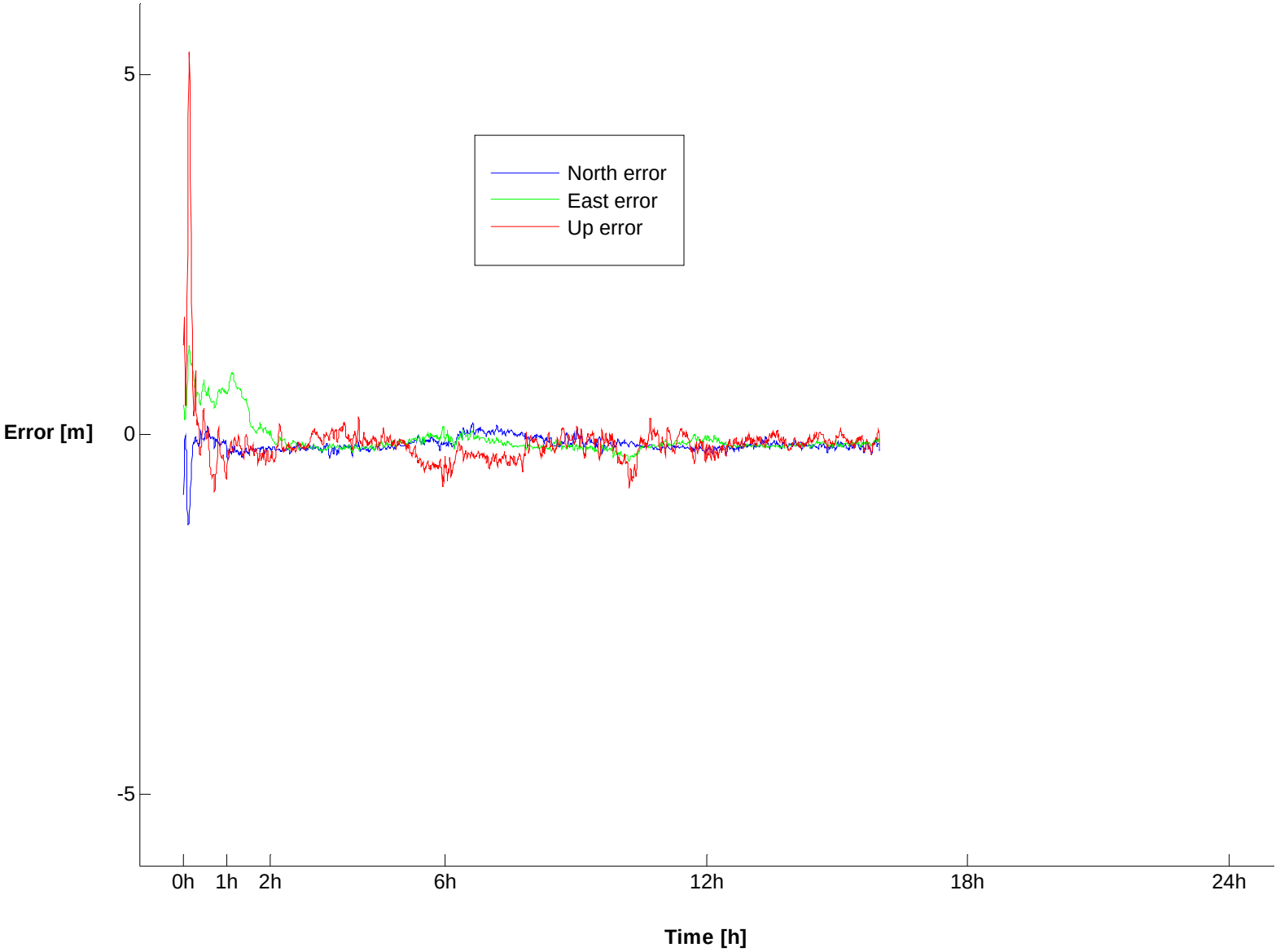
$$i,p \begin{cases} P_{IF} = D + T + c(\Delta t^i - \Delta t_p) + \varepsilon_{P_{IF}} \\ \phi_{IF} = D + T + c(\Delta t^i - \Delta t_p) + N\lambda + \varepsilon_{\phi_{IF}} \end{cases}$$

→ Iterative Least Square Adjustment (LSA)

The PPP is a performant technique



The PPP suffers from several weaknesses



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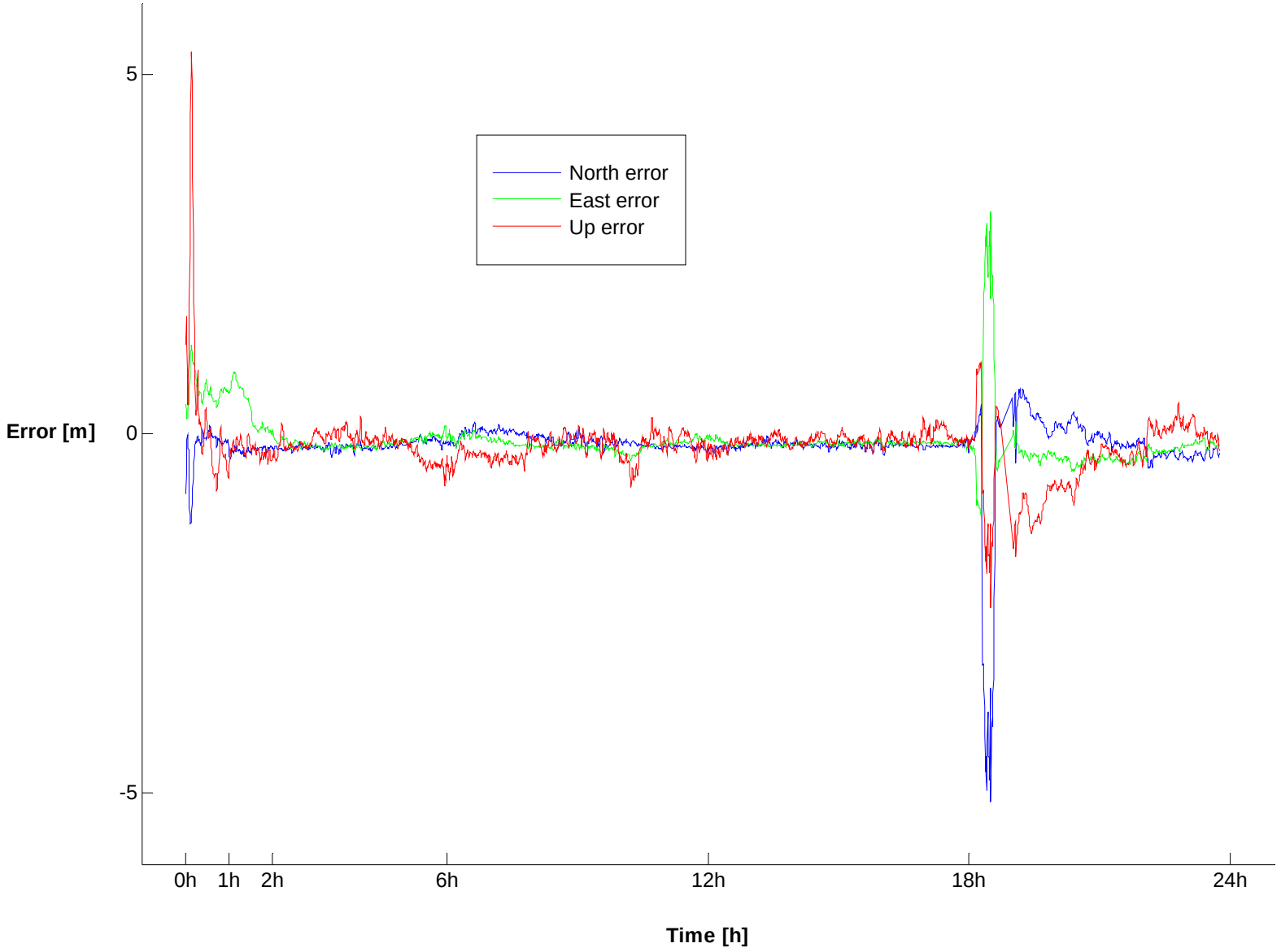
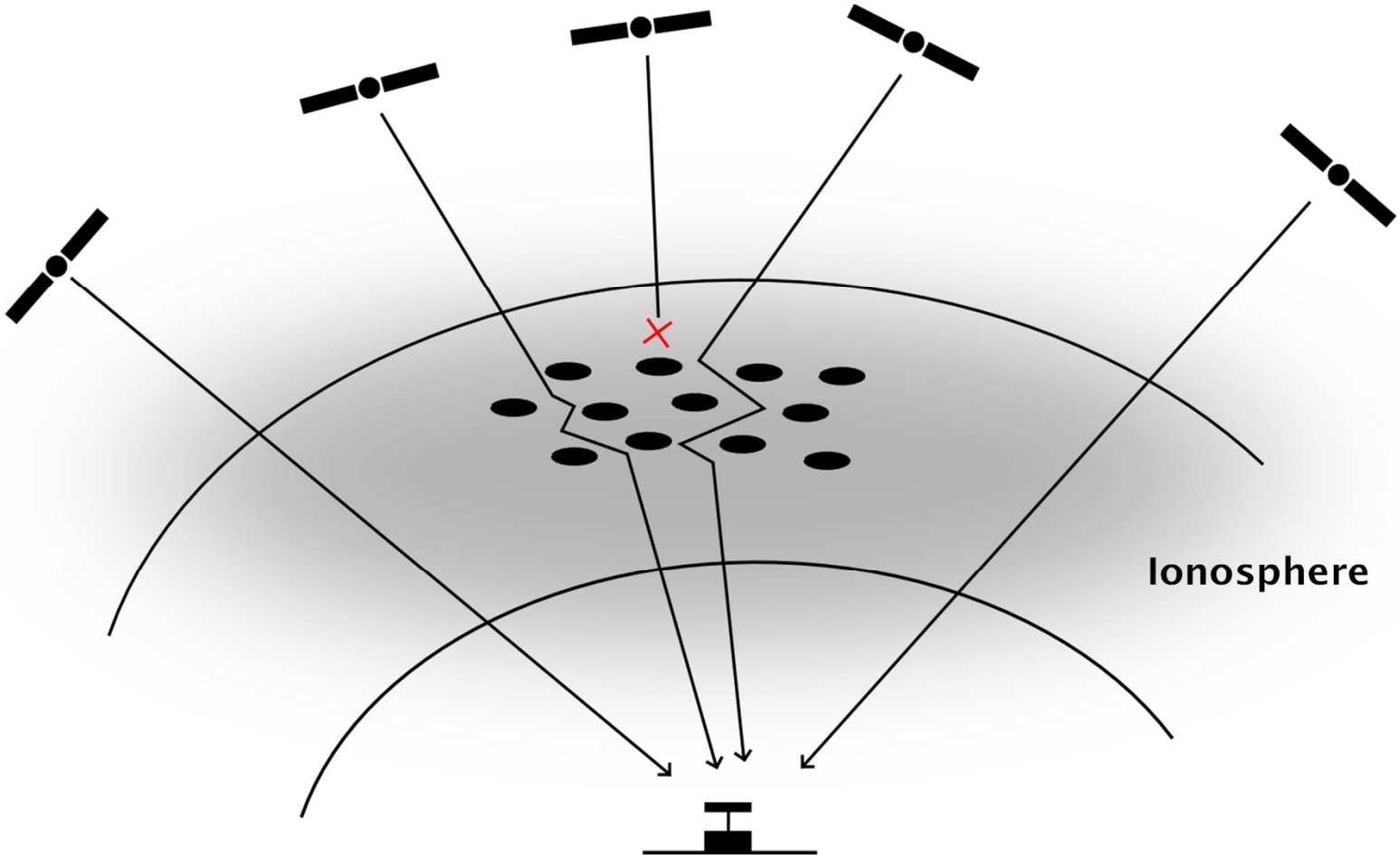
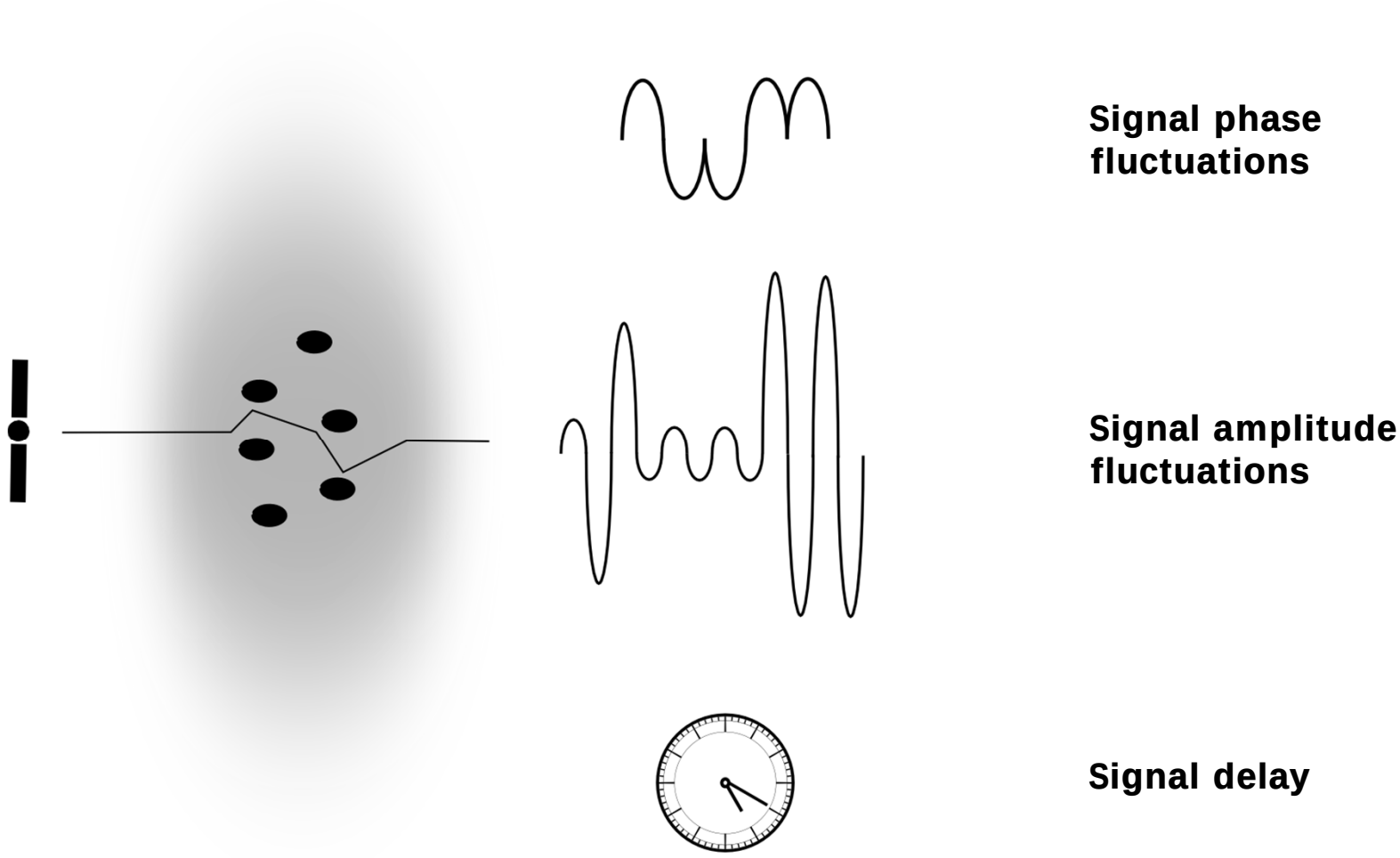


Ionospheric scintillations disrupt satellite signals propagation



Ionospheric scintillations degrade satellite signals quality



Signal phase fluctuations

Signal amplitude fluctuations

Signal delay

Ionospheric scintillations degrade satellite signals quality

Signal phase fluctuations

- *Cycle slips*
- *Ambiguity resolution processes*
- *Additional convergence time*

Signal amplitude fluctuations

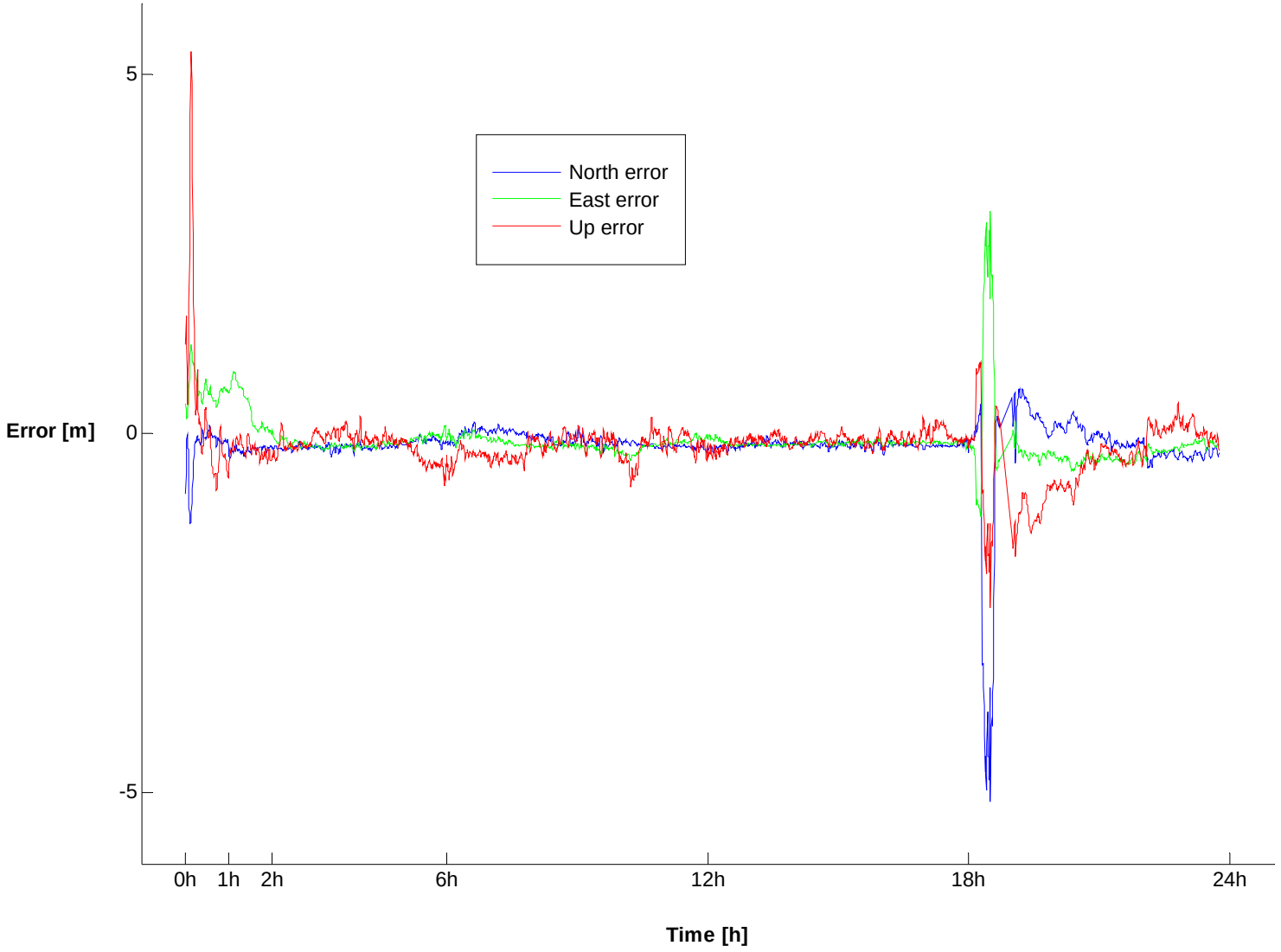
- *Measurement noise*
- *Signal power fluctuations*

- *Lost signals*
- *Geometry troubles*

Signal delay

- *Signal delay*

Ionospheric scintillations decrease PPP performances



PPP performances under ionospheric scintillations can be improved

WP0 – GNSS Tools

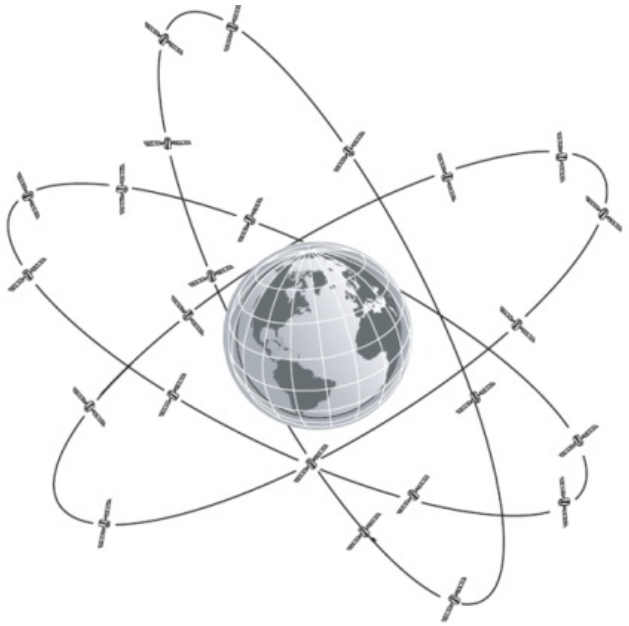
WP1 – Signals

WP2 – Geometry

WP3 – Stochasticity

WP4 – Model

WP5 – Ambiguity

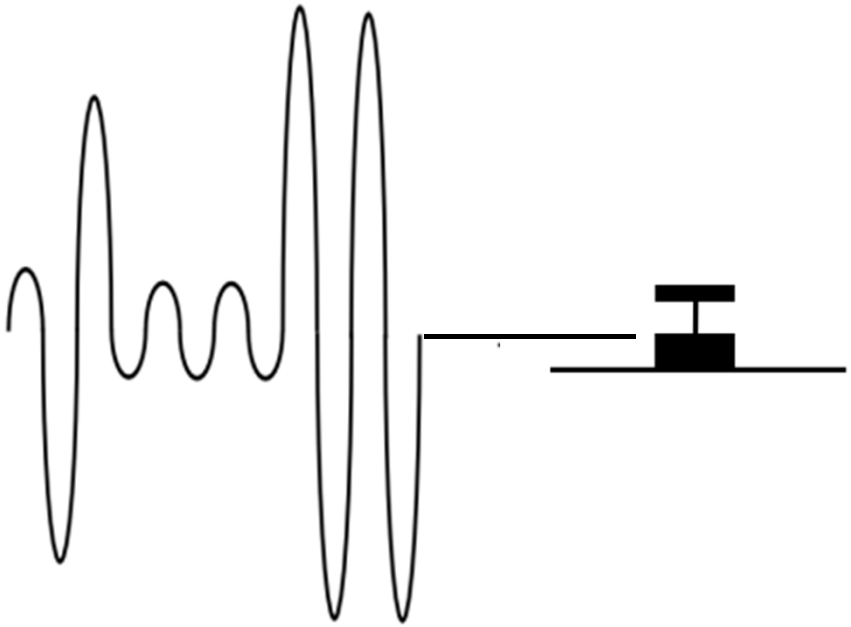


Project

Geometry

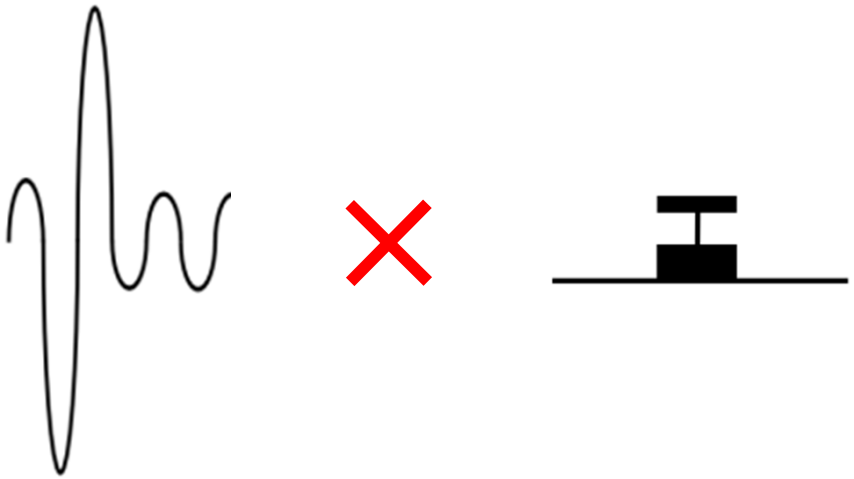
Stochasticity

Ionospheric scintillations reduce the number of available satellites



Signal amplitude fluctuations

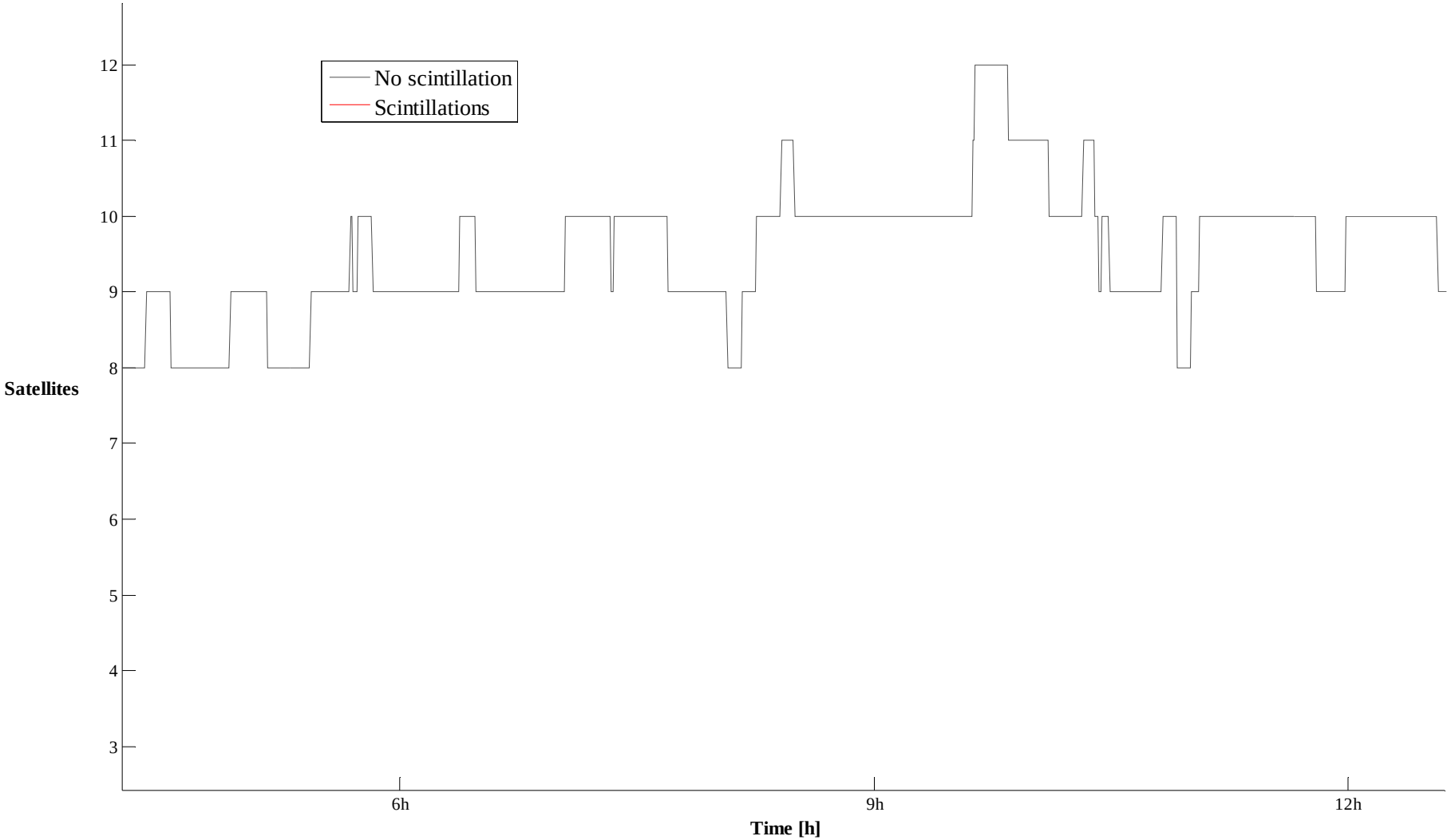
Ionospheric scintillations reduce the number of available satellites



No signal

$$\sigma_{POS} = DOP \times \sigma_P$$

Ionospheric scintillations reduce the number of available satellites



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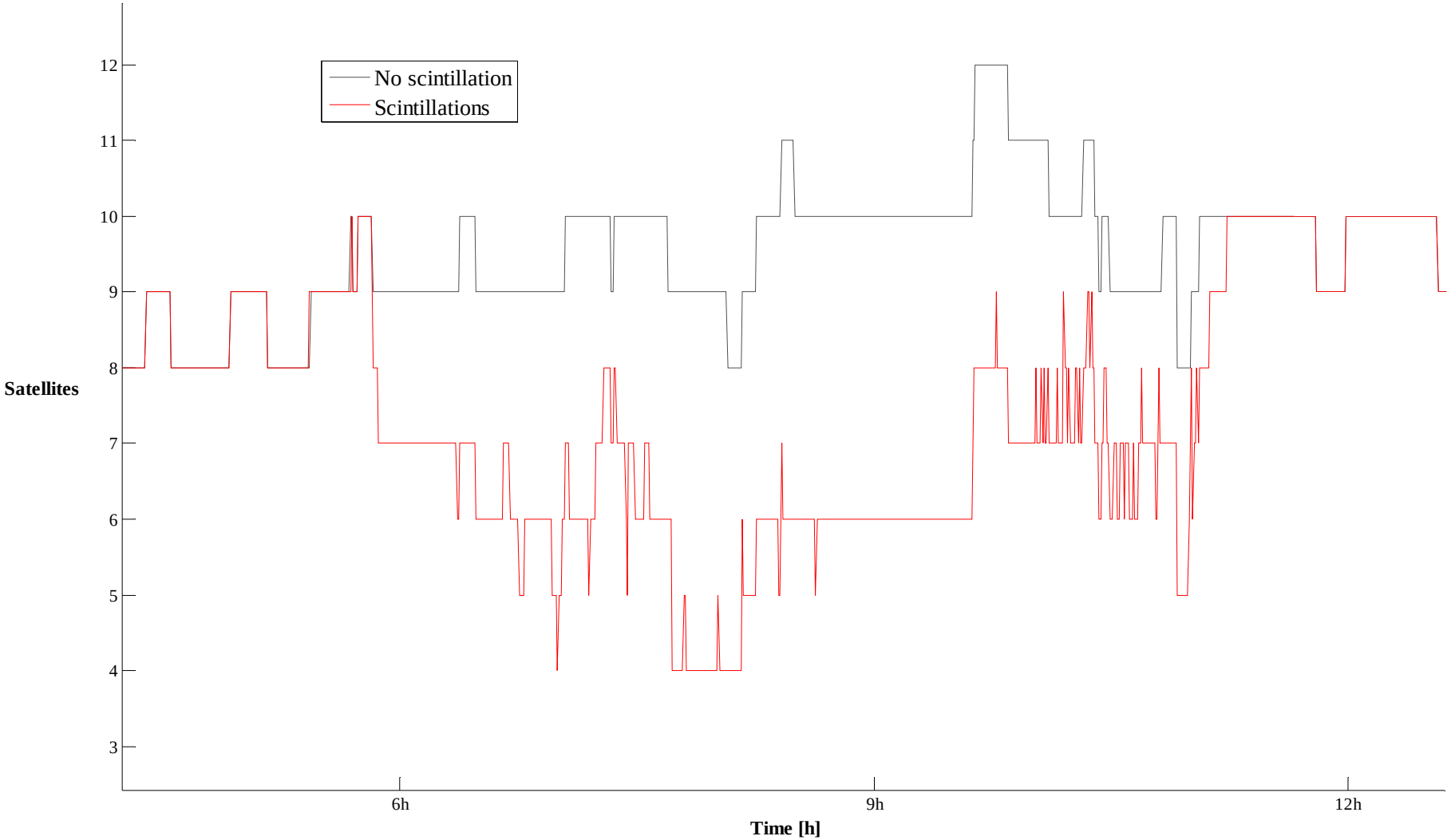

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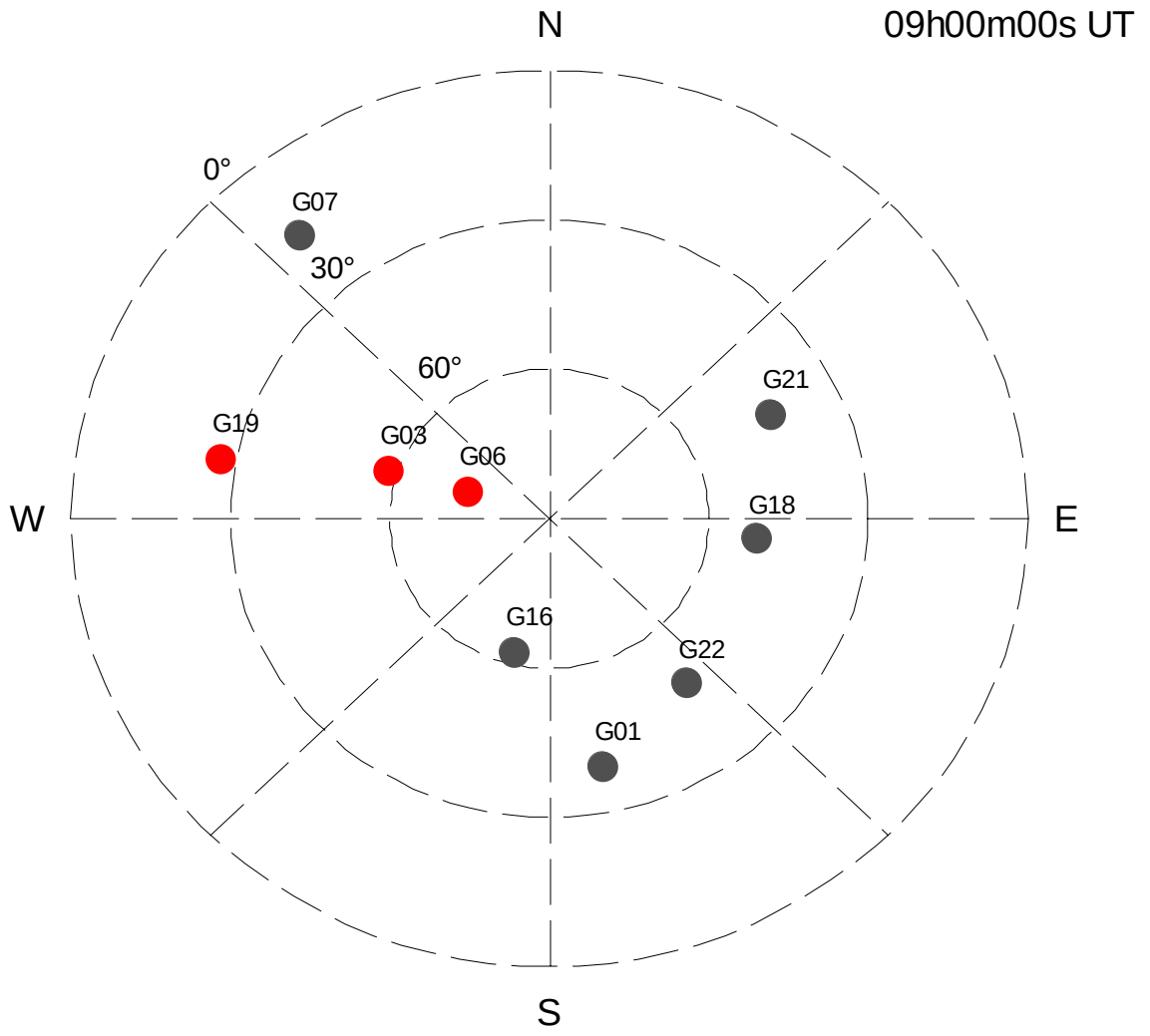
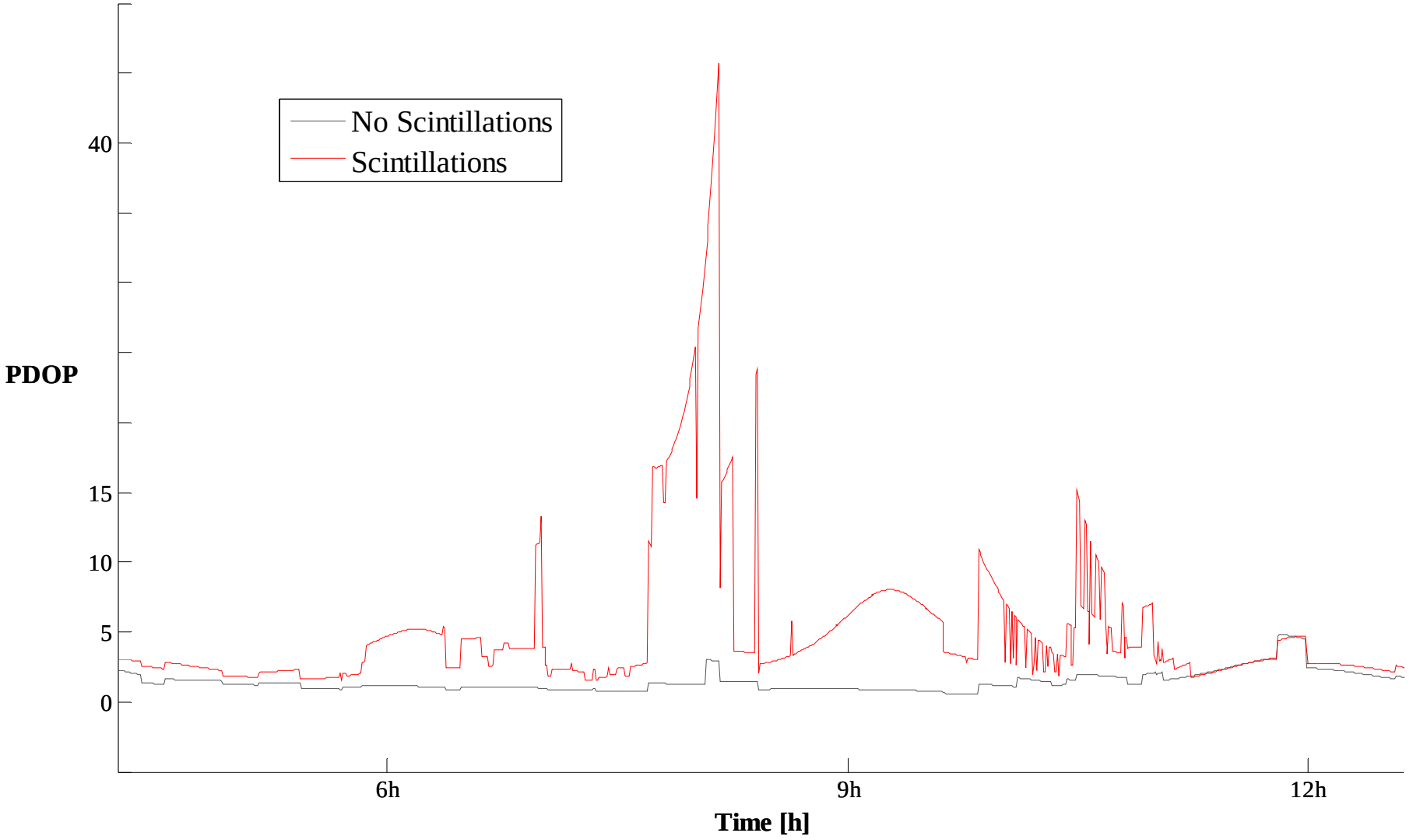
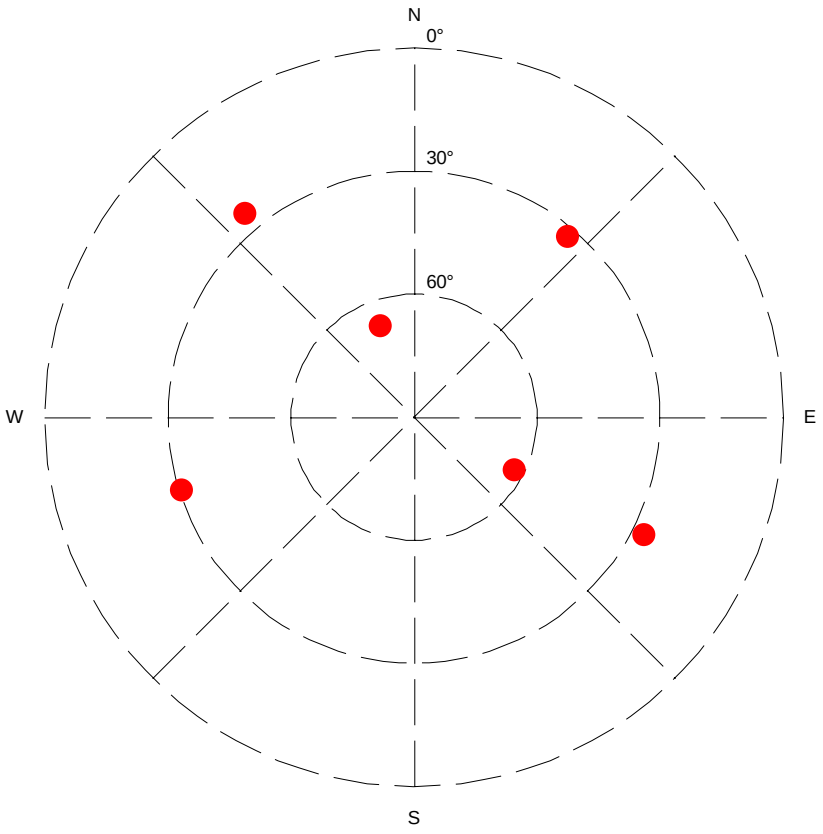


Ionospheric scintillations reduce the satellite geometry quality



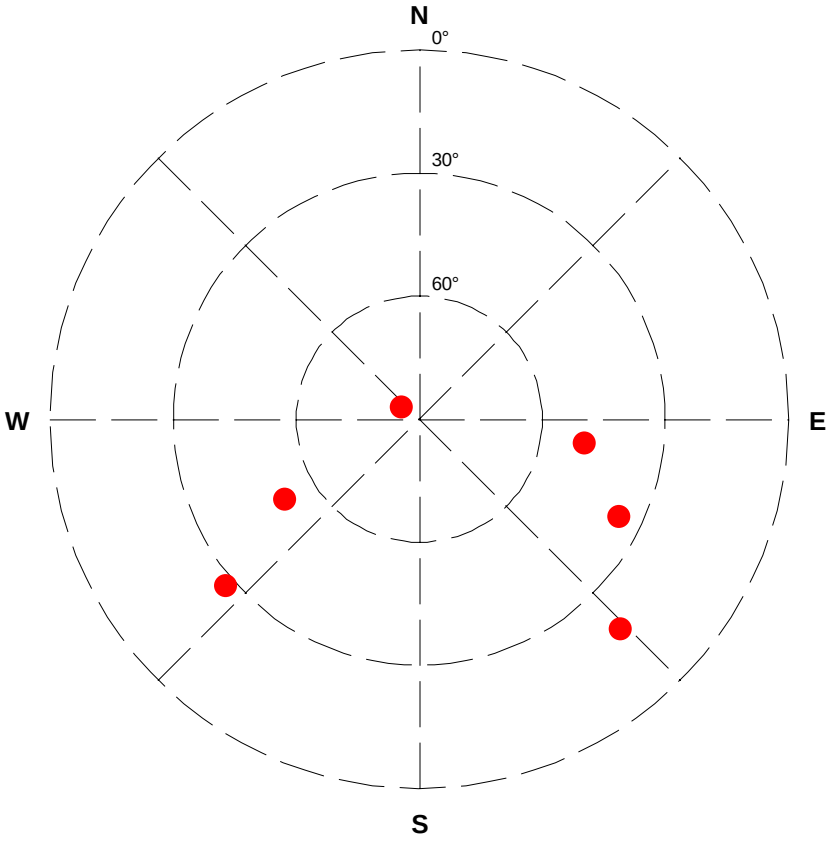
The high DOP values are not only involved by the low number of satellites

T1



DOP = 2.36

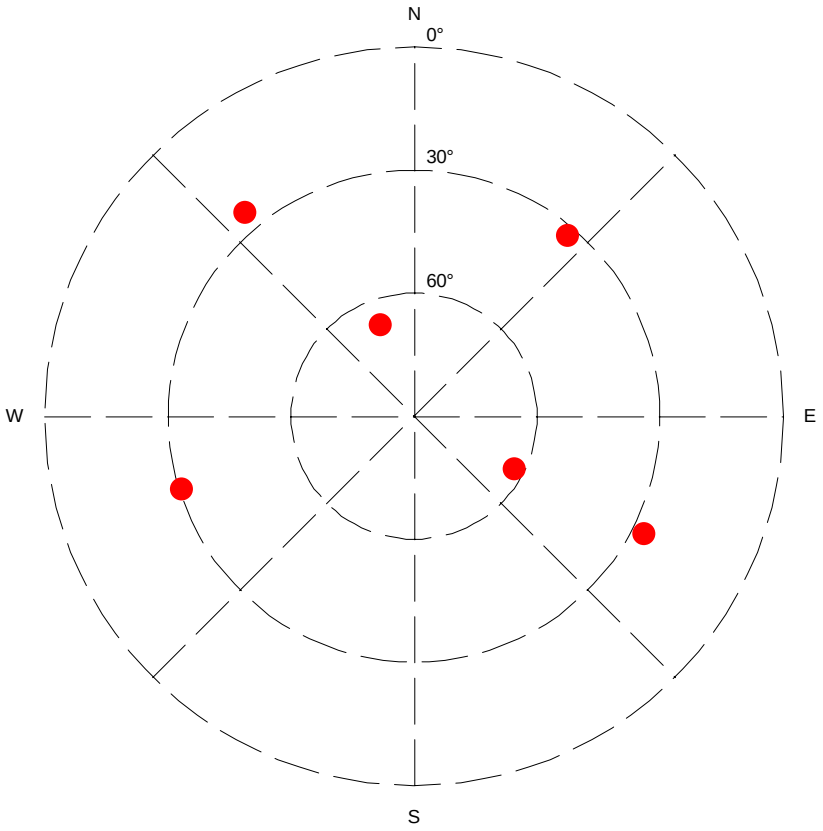
T2



DOP = 13.78

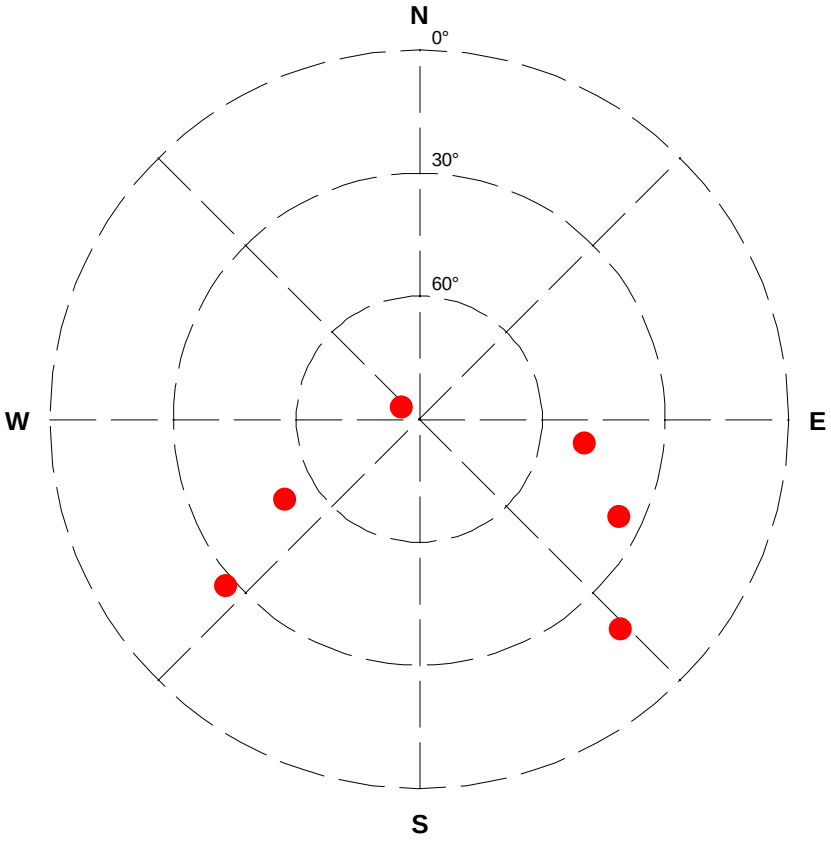
The high DOP values are not only involved by the low number of satellites

T1



$$|N| = 3.47$$

T2



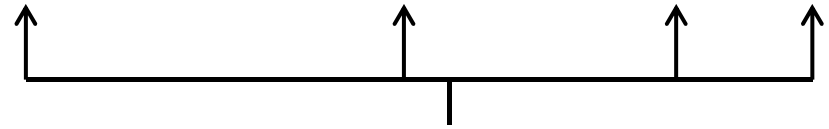
$$|N| = 0.04$$

A conical satellite geometry involves infinite DOP values

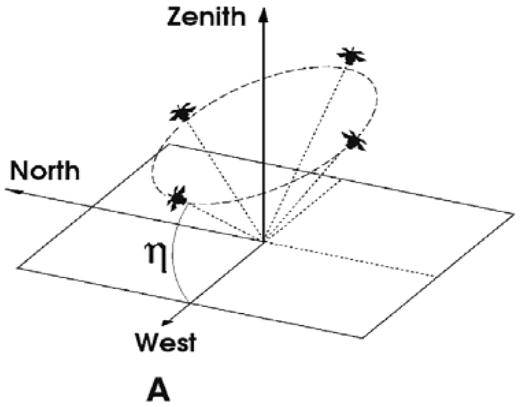
$$|N| = 0$$

$$Q_{\hat{x}} = N^{-1} = (A^T A)^{-1}$$

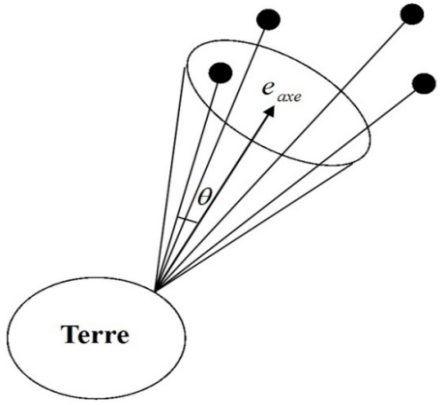
$$A = \begin{bmatrix} -\cos\eta^1 \sin\chi^1 & -\cos\eta^1 \cos\chi^1 & -\sin\eta^1 & 1 \\ -\cos\eta^2 \sin\chi^2 & -\cos\eta^2 \cos\chi^2 & -\sin\eta^2 & 1 \\ \dots & \dots & \dots & \dots \\ -\cos\eta^n \sin\chi^n & -\cos\eta^n \cos\chi^n & -\sin\eta^n & 1 \end{bmatrix}$$



Any linear dependence?



A



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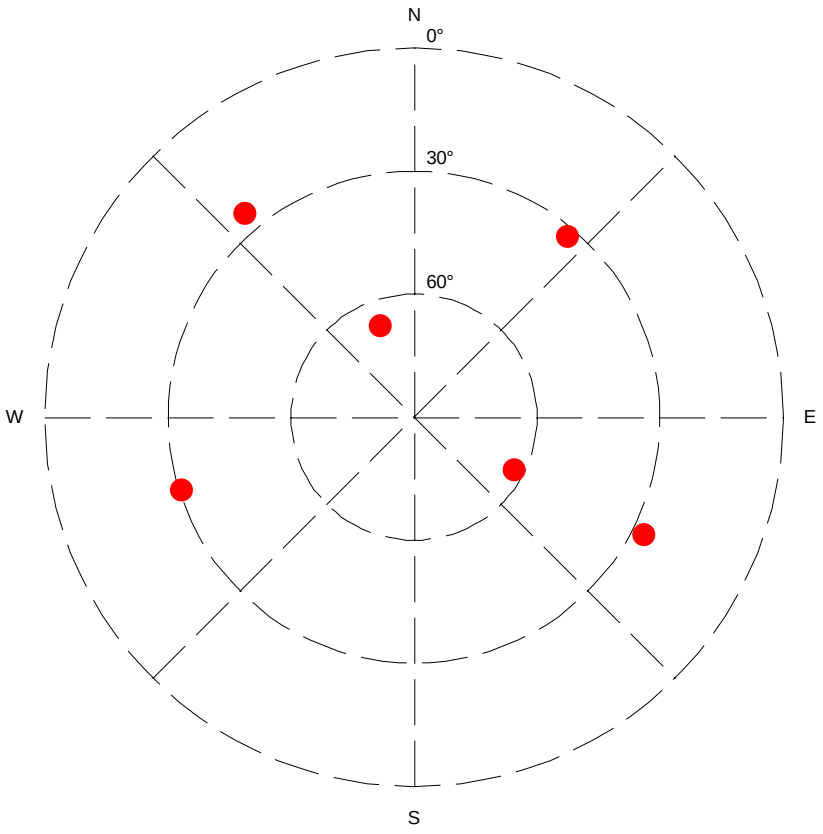

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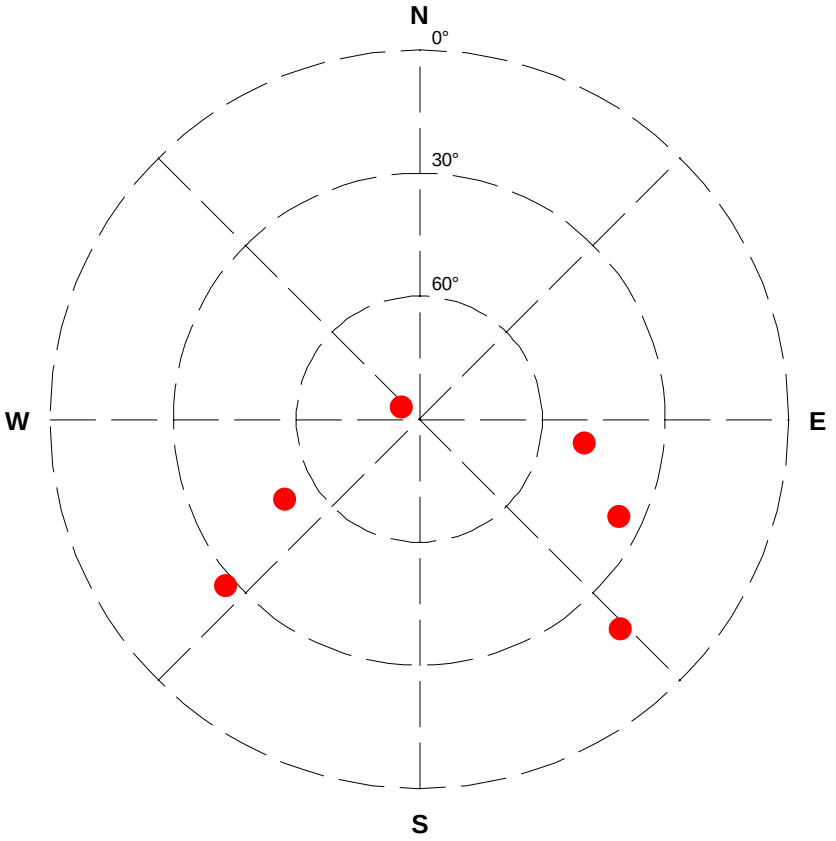
T2



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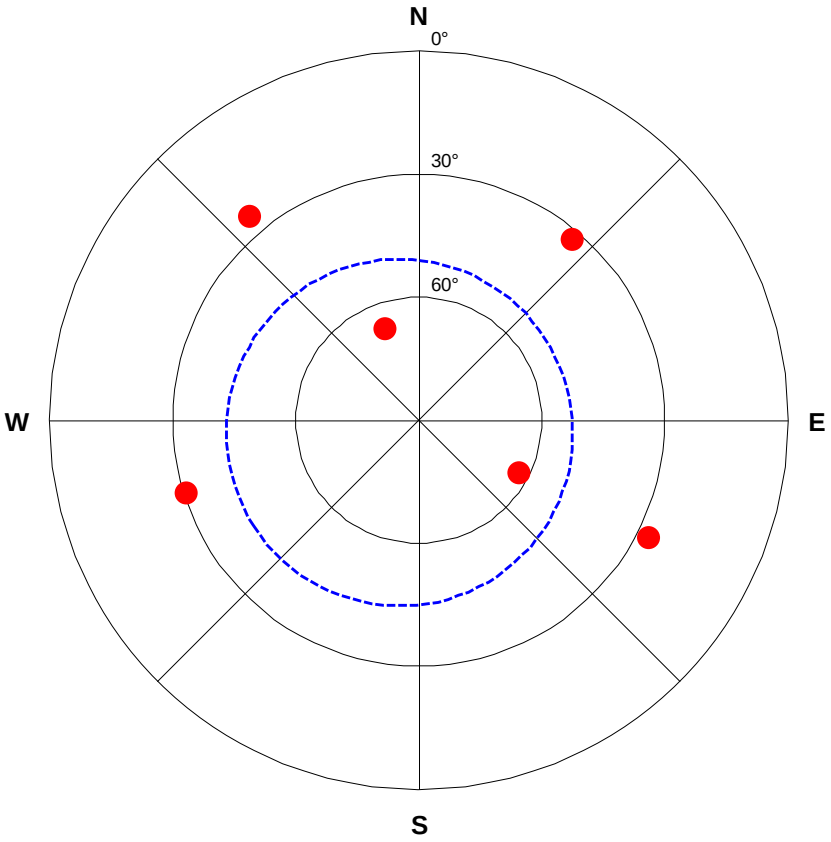

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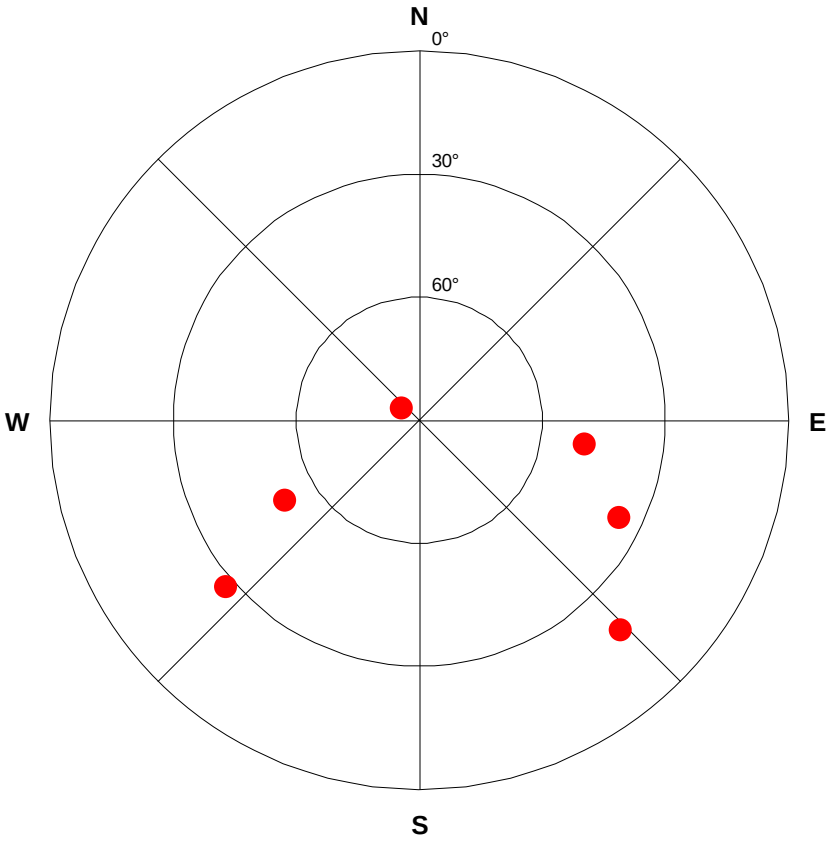

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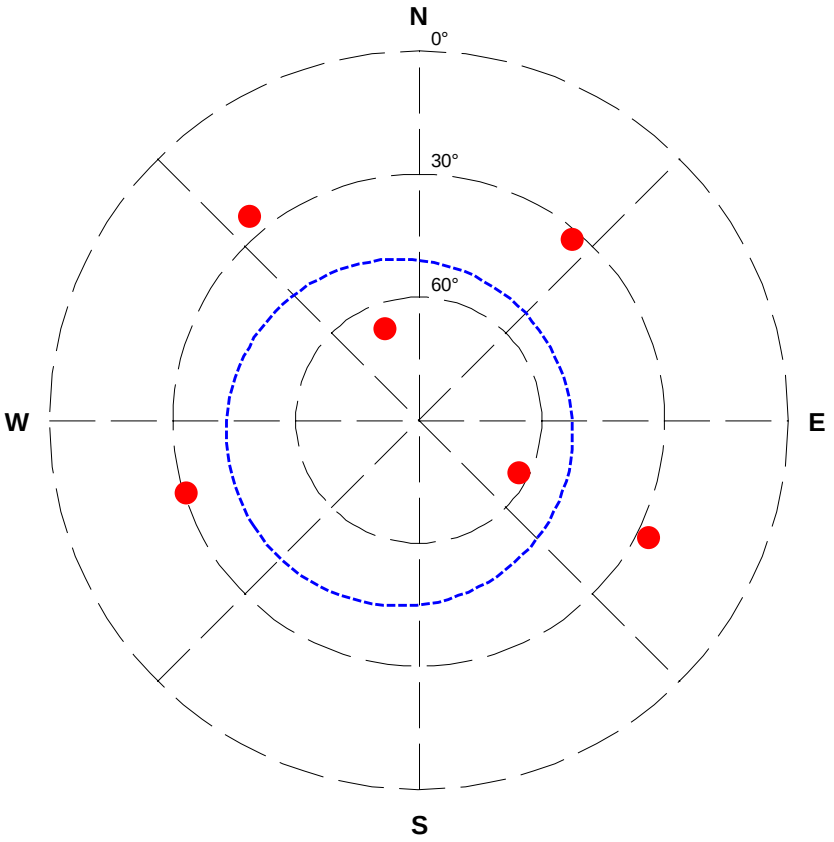

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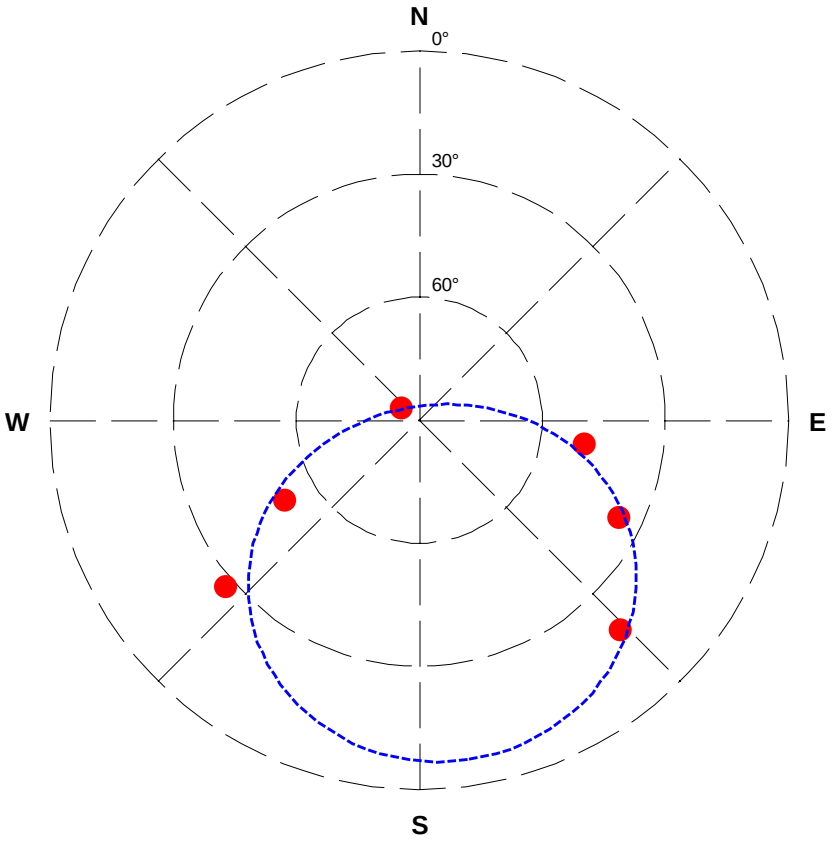
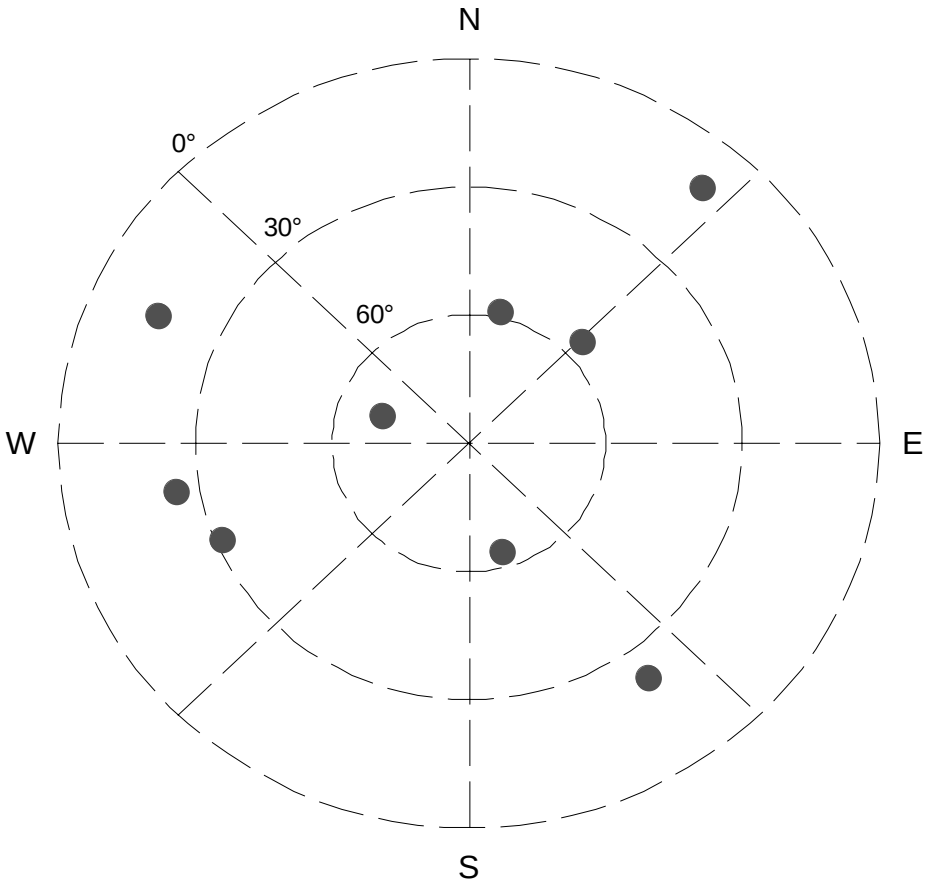
T2



DOP = 13.78

The combined use of GPS and Galileo strongly improves the satellite geometry



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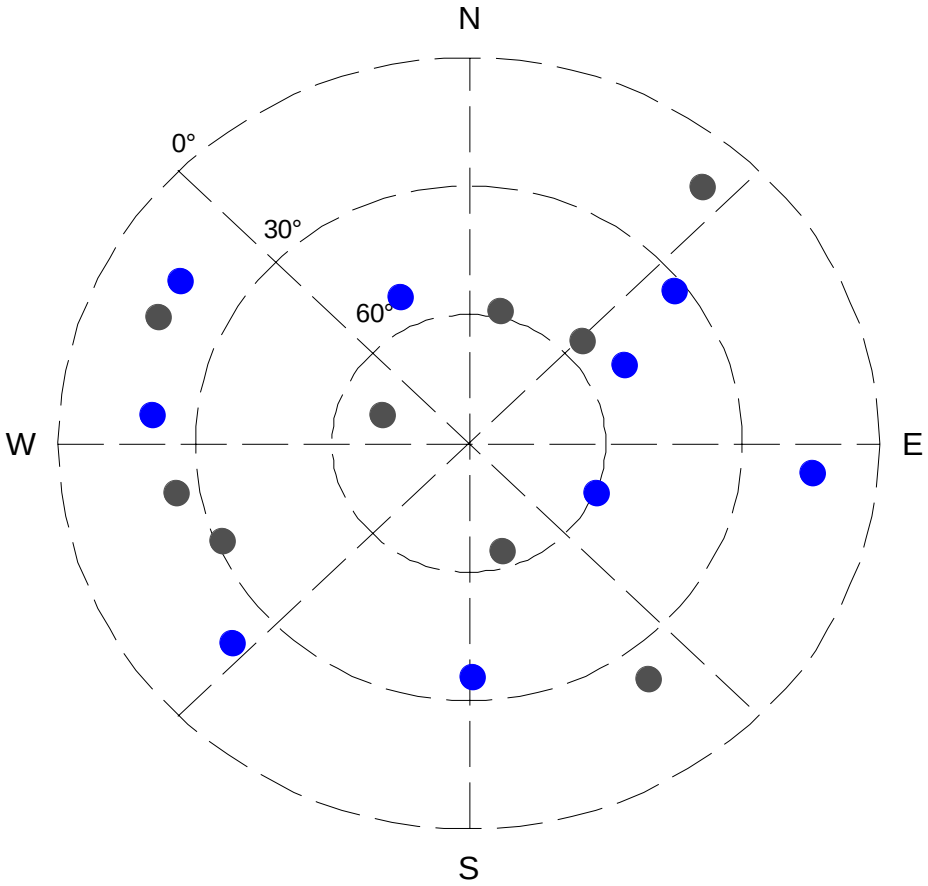

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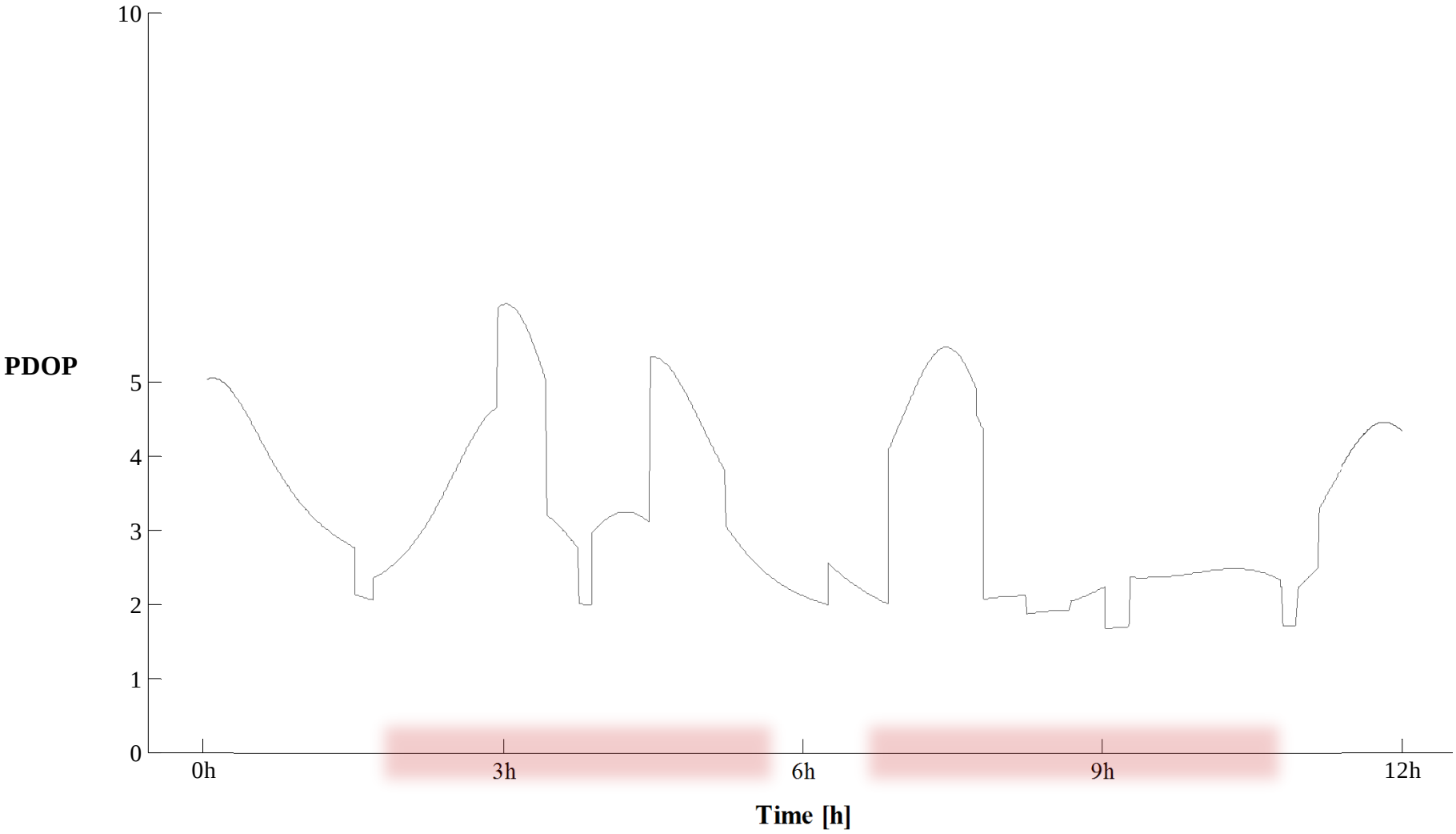

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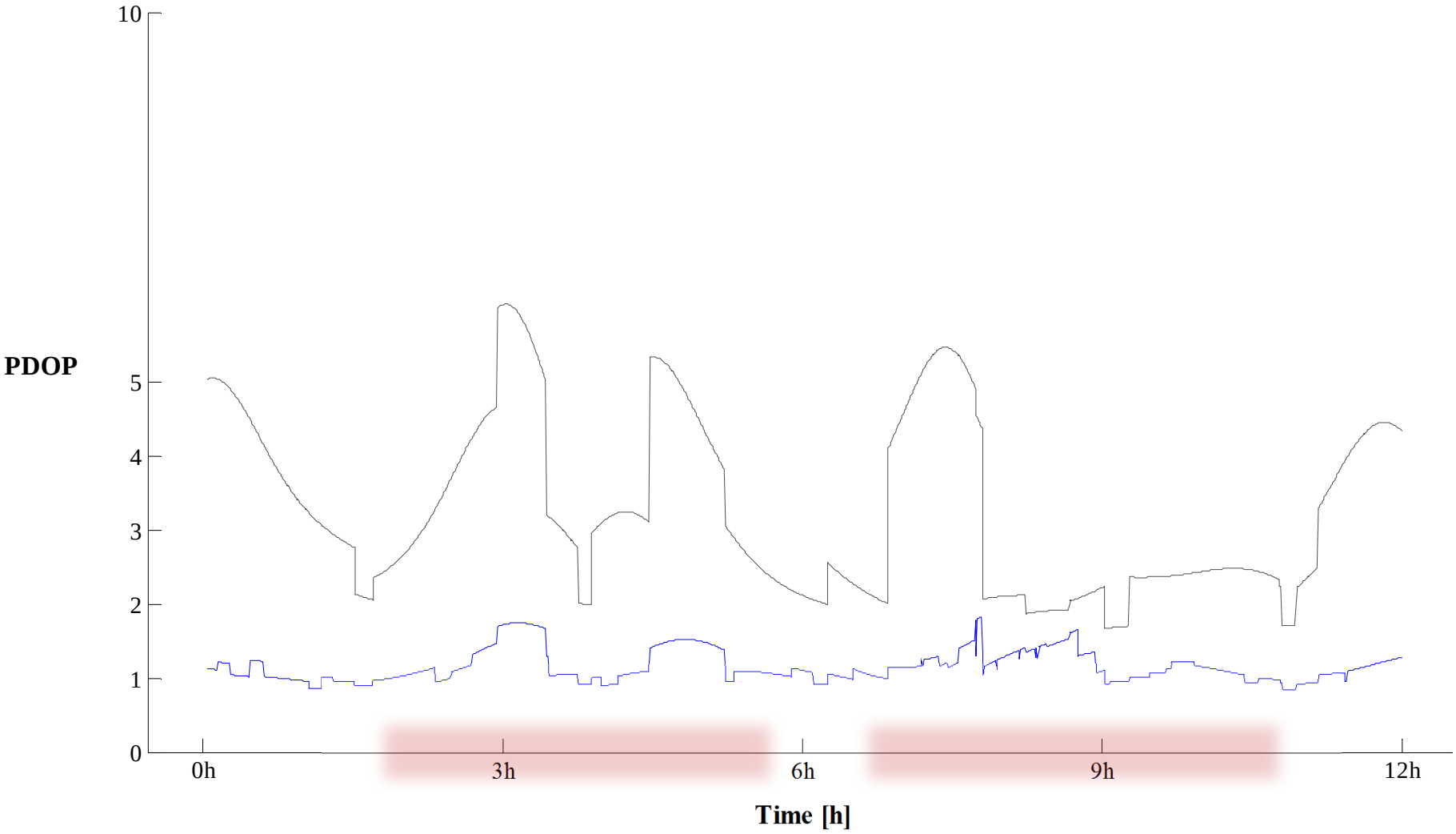


Project - WP2 Geometry - Objectives

Quantify the improvement of PPP's performances involved by the expanded GPS-Galileo satellite geometry

- Precision
- Time convergence
- Reliability

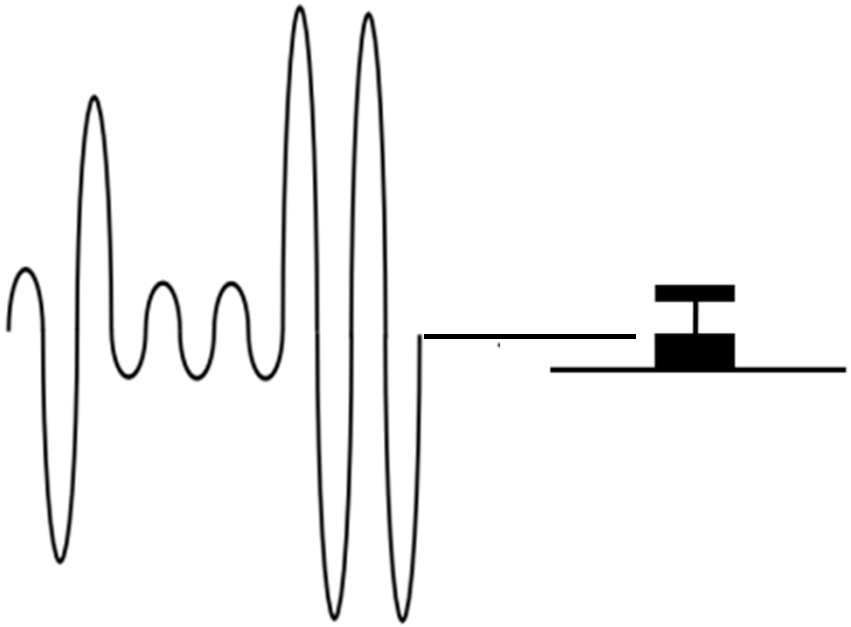
} Ionospheric Scintillations

Project

Geometry

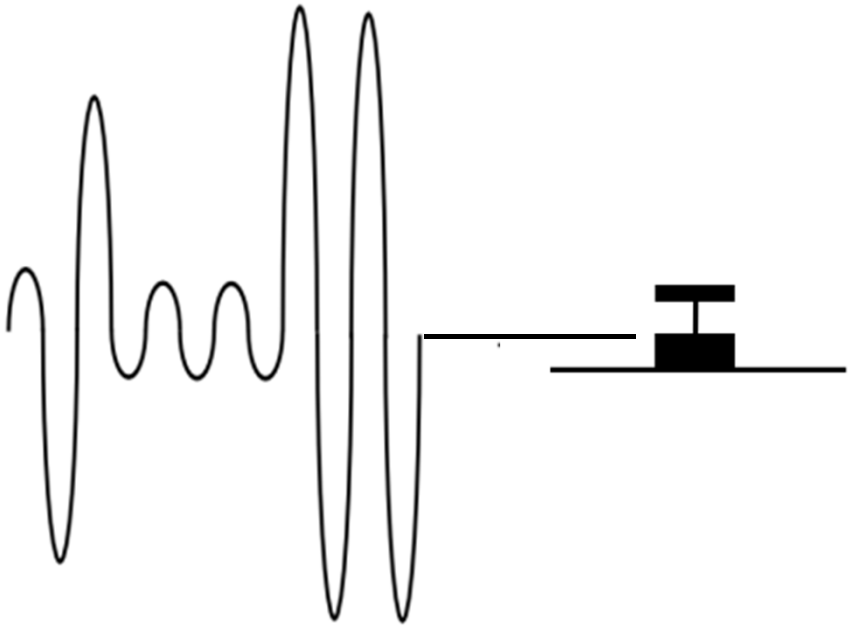
Stochasticity

Ionospheric Scintillations degrade satellite signal quality



Signal amplitude fluctuations

Ionospheric Scintillations degrade receiver measurement precision



Measurement error

$$\sigma_{POS} = DOP \times \sigma_P$$

The PPP stochastic model considers receiver measures to be independent

$$\Sigma = \begin{pmatrix} \sigma_1^2 & \sigma_{12} & .. & \sigma_{1n} \\ \sigma_{21} & \sigma_2^2 & .. & \sigma_{2n} \\ .. & .. & ... & ... \\ \sigma_{n1} & \sigma_{n2} & ... & \sigma_n^2 \end{pmatrix}$$

The PPP stochastic model considers receiver measures to be independent

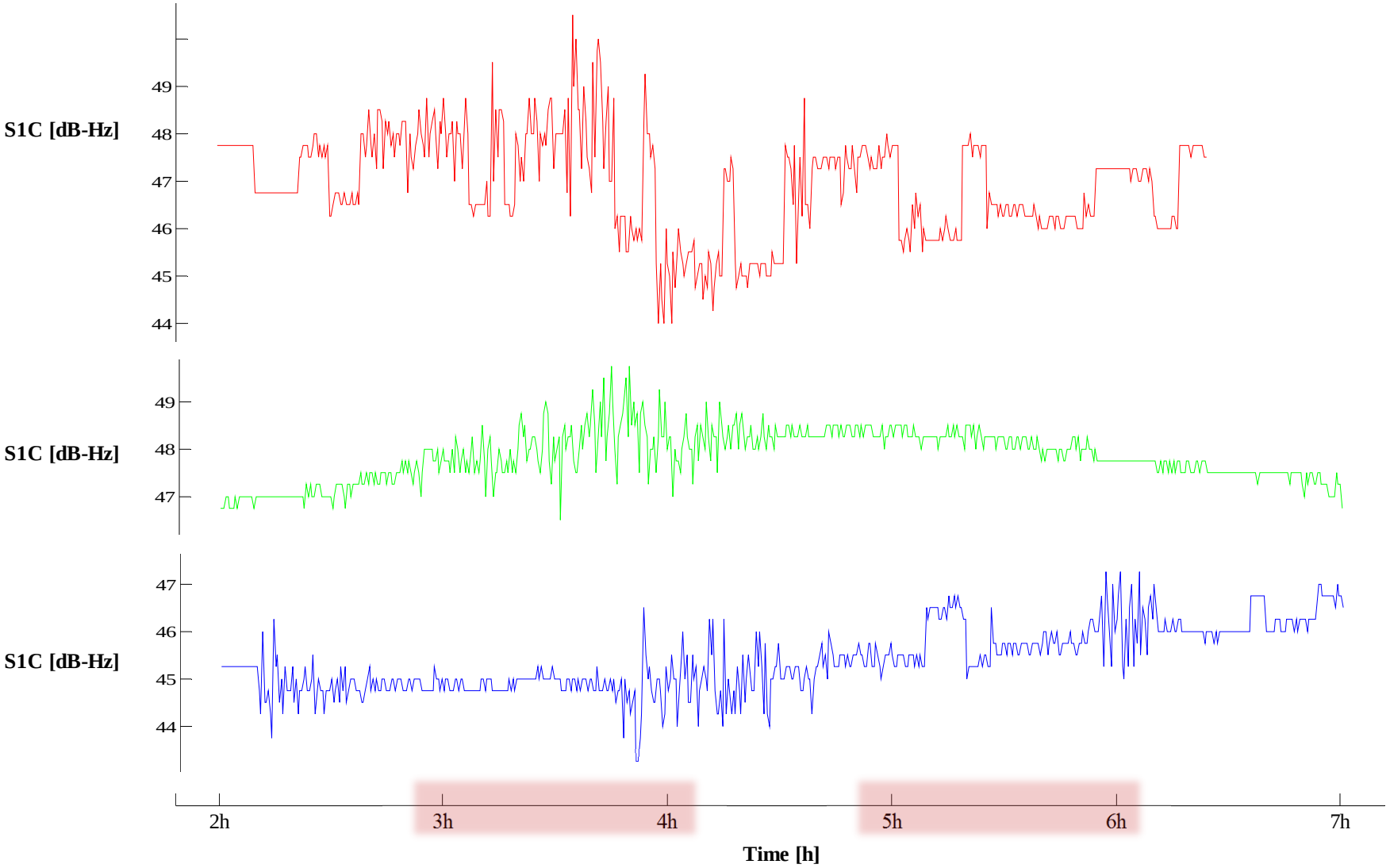
$$\Sigma = \begin{pmatrix} \sigma_1^2 & 0 & .. & 0 \\ 0 & \sigma_2^2 & .. & 0 \\ .. & .. & ... & ... \\ 0 & 0 & ... & \sigma_n^2 \end{pmatrix}$$

First law of Geography…

"Everything is related to everything else, but near things are more related than distant things."

Waldo Tobler

Satellite signals are affected differently in case of scintillations



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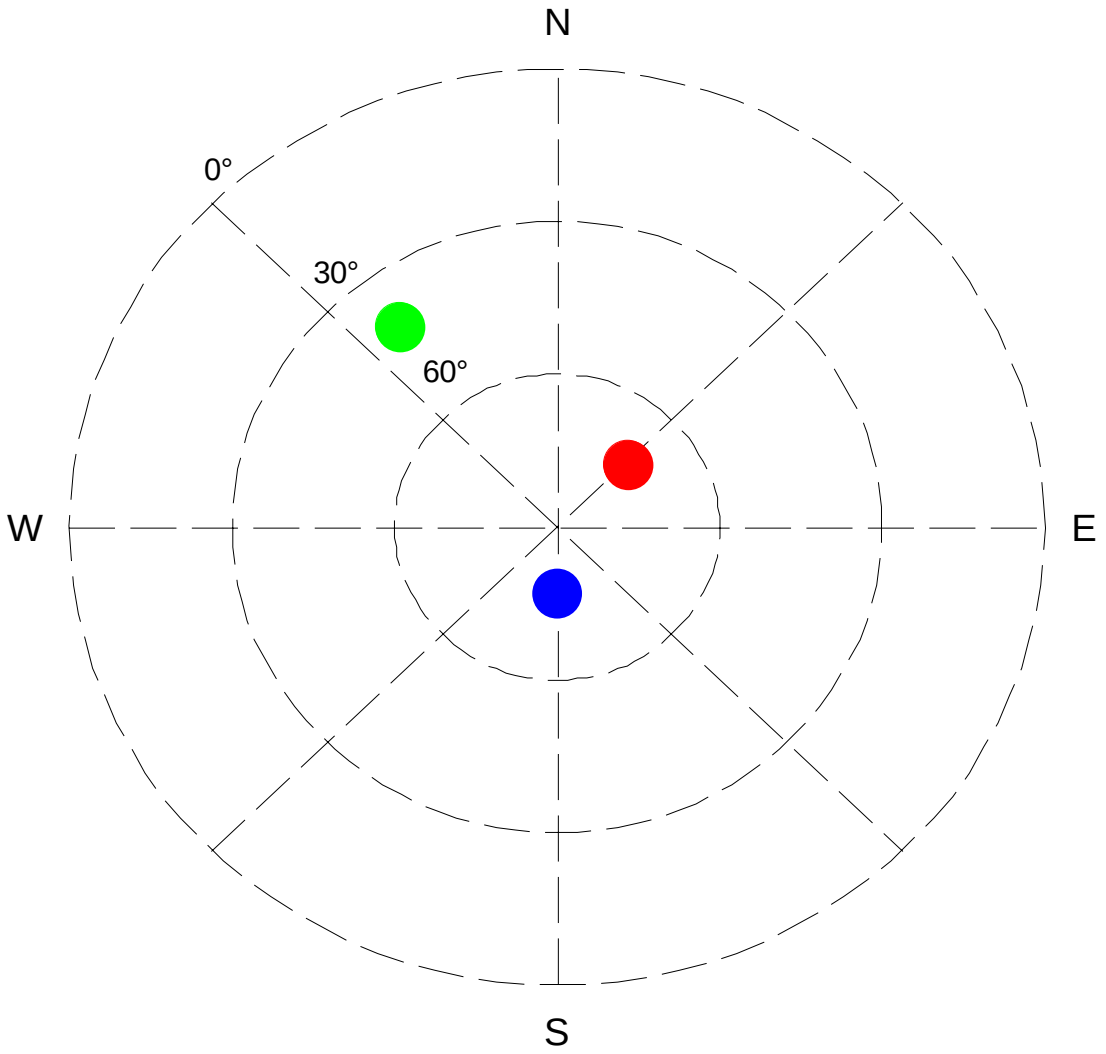
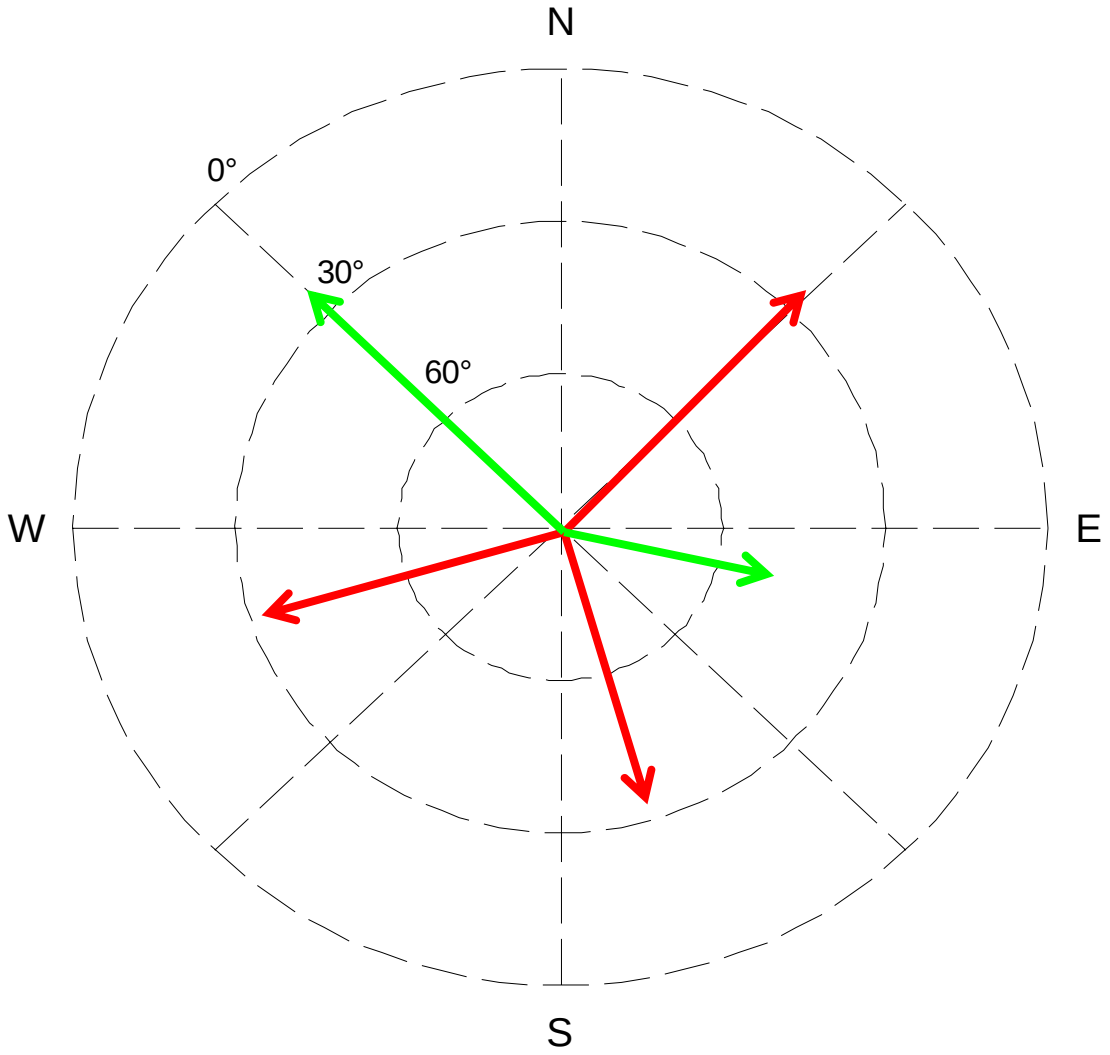


Spatial Auto-Correlation (SAC) can be used to generate a new PPP stochastic model



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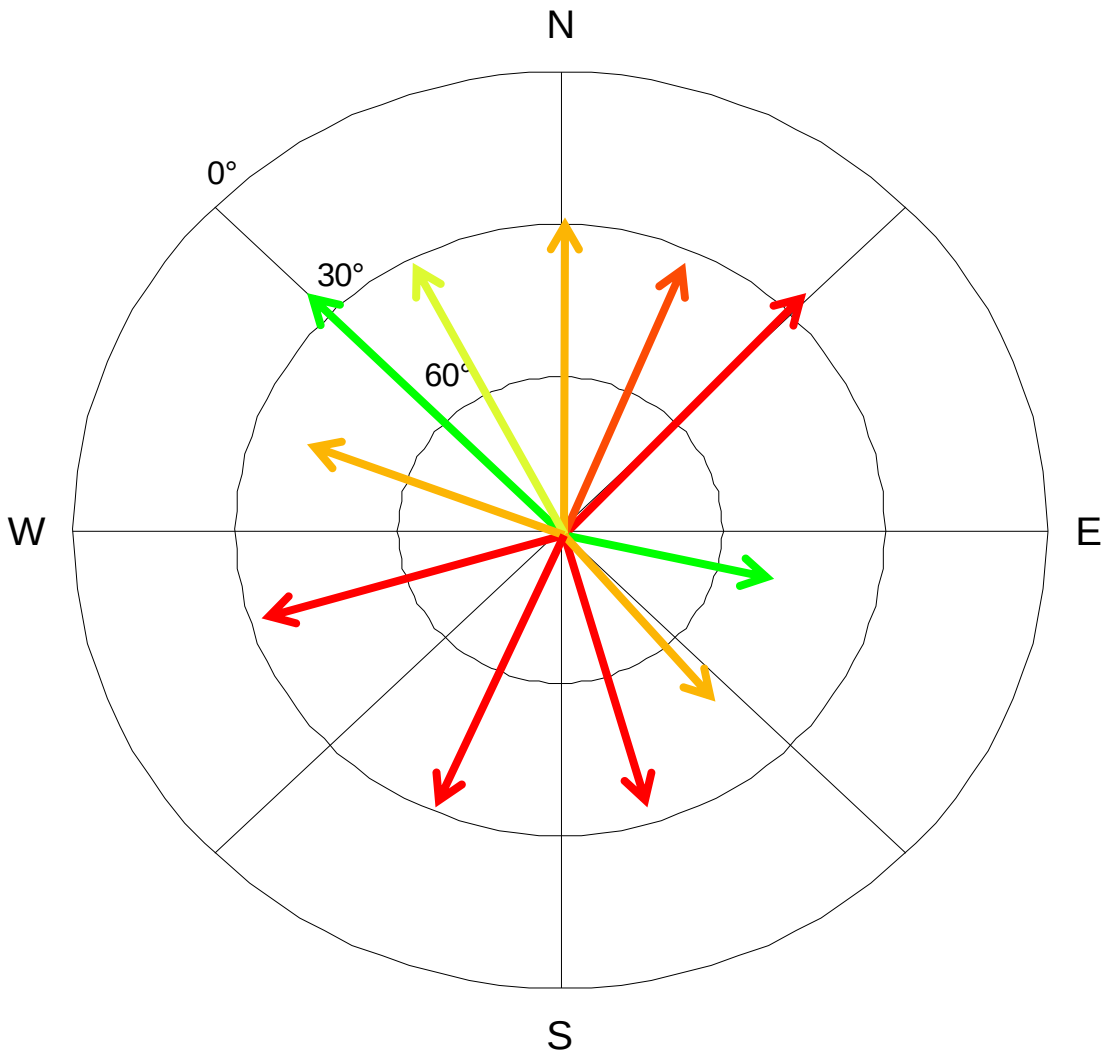
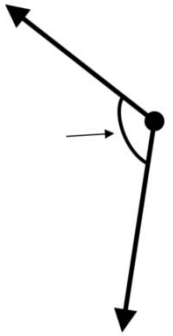


Spatial Auto-Correlation index are computed on satellite geometry

$$I = \frac{N}{\Sigma_i \Sigma_j w_{ij}} \frac{\Sigma_i \Sigma_j w_{ij} (v_i - \bar{v})(v_j - \bar{v})}{\Sigma_i (v_i - \bar{v})^2}$$

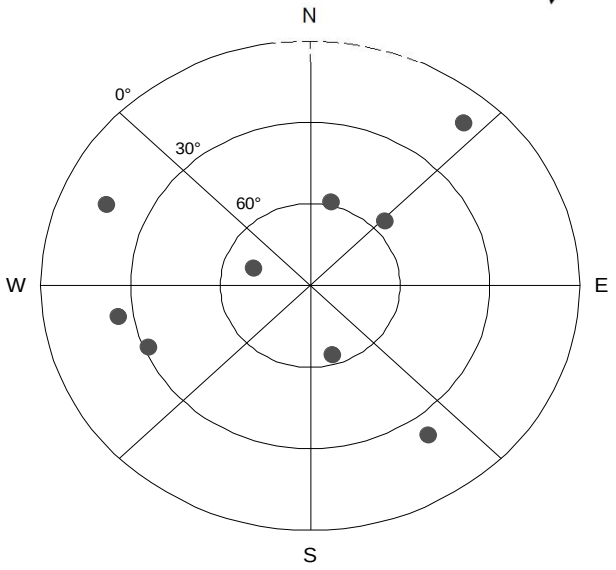
$$v_i = S1C_i$$

$$w_{ij} = \frac{1}{d_{ij}}$$

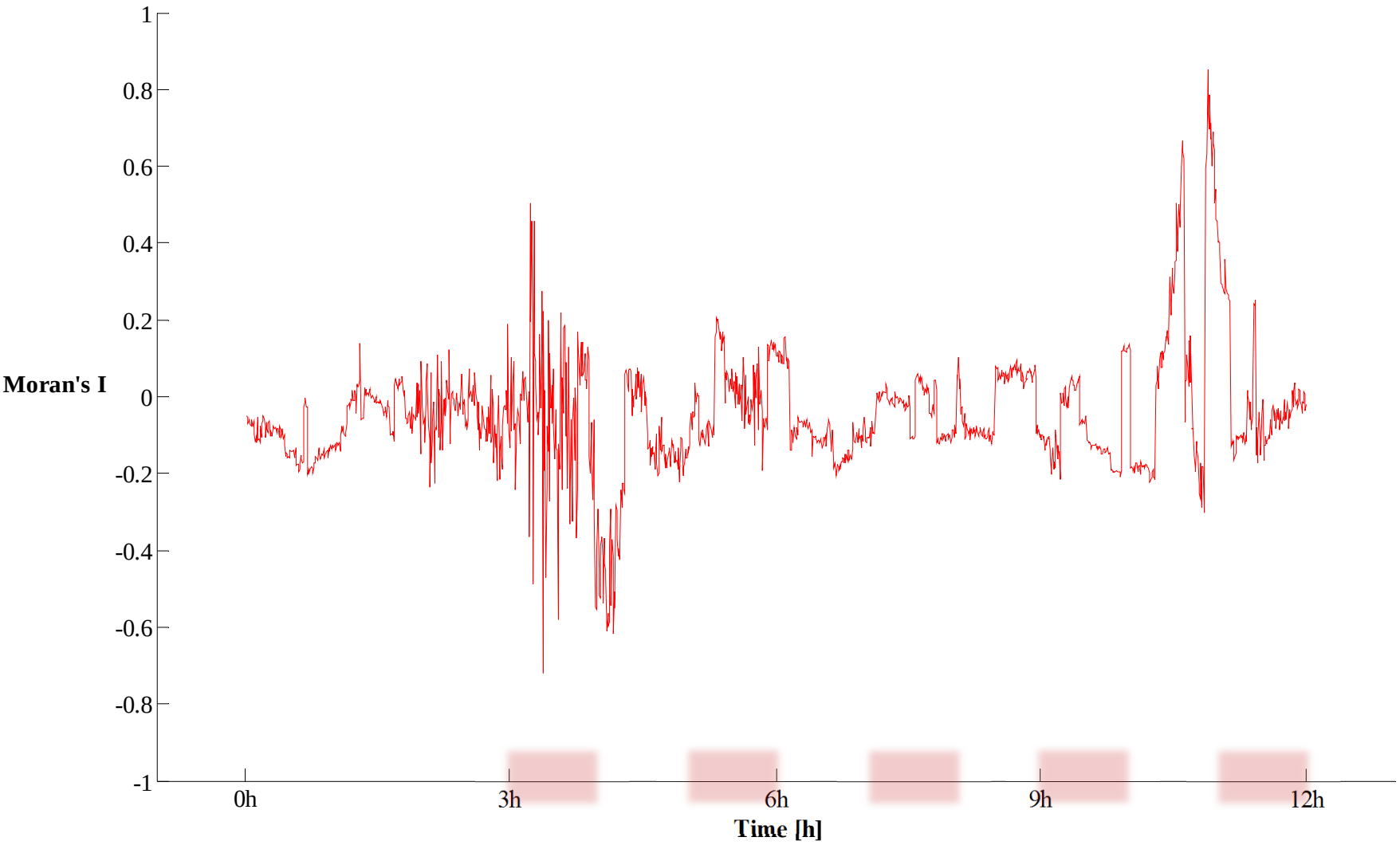


$-SAC \qquad random \qquad +SAC$

-1 ⟵ 0 ⟶ 1



Spatial Auto-Correlation is fluctuating



Spatial Auto-Correlation research will be expanded

Perspectives

- Other SAC indices (Geary'C, ...)
- Realistic simulations
- Tracking error vs. Power signal
- ...

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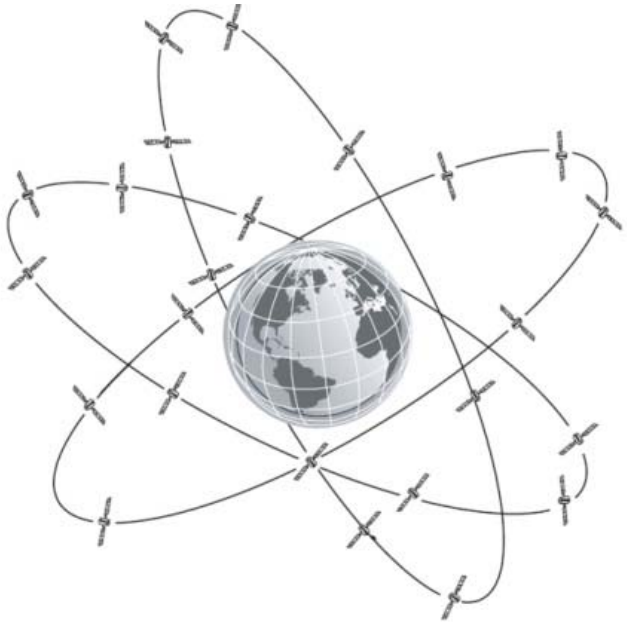

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René Warnant - ULg

New Navigator Seminar 2012

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