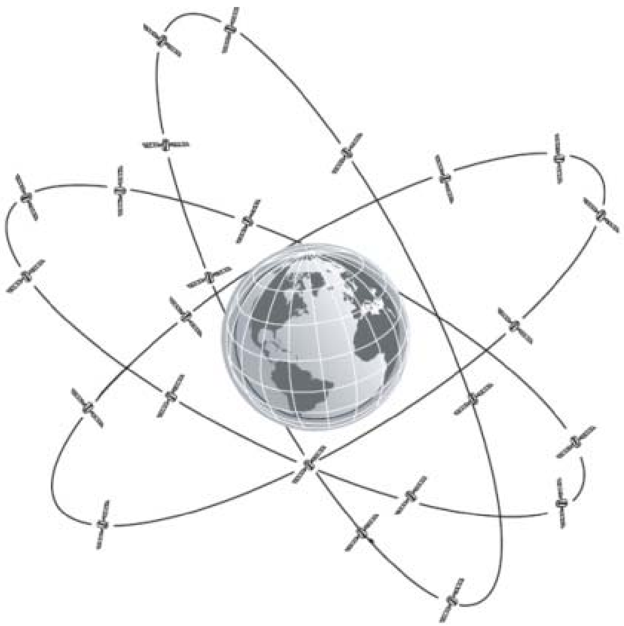
Precise Point Positioning

Performances under Ionospheric Scintillations



Matthieu Lonchay

University of Liège, Belgium
Geomatics Unit

University of Nottingham, UK
Nottingham Geospatial Institute

PhD Meeting
19 June 2012
NGI, The University of Nottingham

Handling

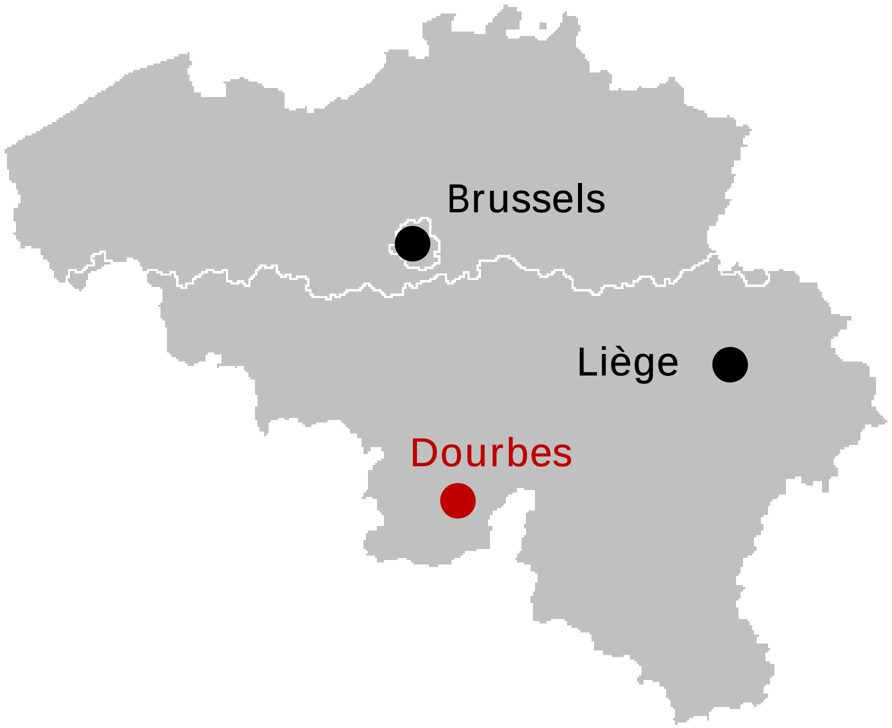
Project

Softwares

Geometry

Stochasticity

We installed two Septentrio receivers in the Geophysical Center of Dourbes (RMI)



SWANS Project

Geophysical Center of Dourbes (RMI)

Septentrio PolaRx3eG

Very Short Baseline

GioveA and GioveB (E1 – E5)

GPS 01/25 (L1 – L5)

1-year data set

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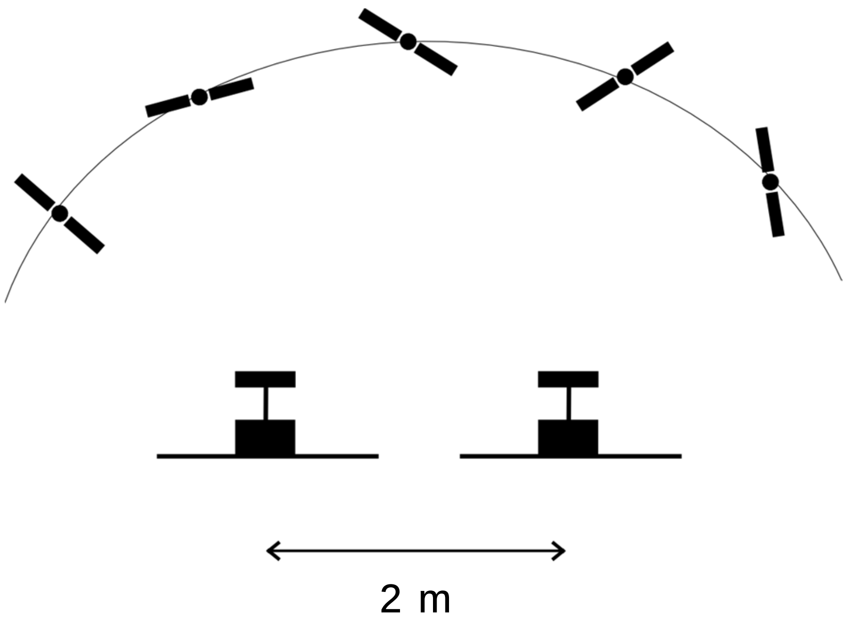


SWANS Project

Geophysical Center of Dourbes (RMI)

Septentrio PolaRx3eG

Very Short Baseline

GioveA and GioveB (E1 – E5)

GPS 01/25 (L1 – L5)

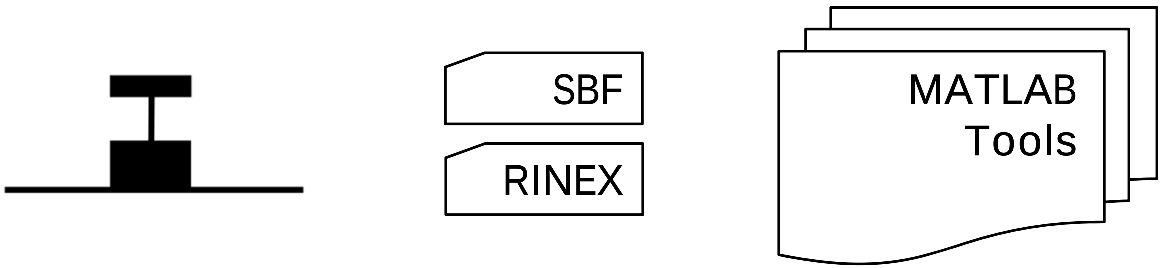
1-year data set

We designed a preprocessing method based on this new data set

Clock Slips Compensation

Cycle Slips Detection

Data Quality Assessment



Orbits
Observation
Geometry
RINEX
Other
...

Handling

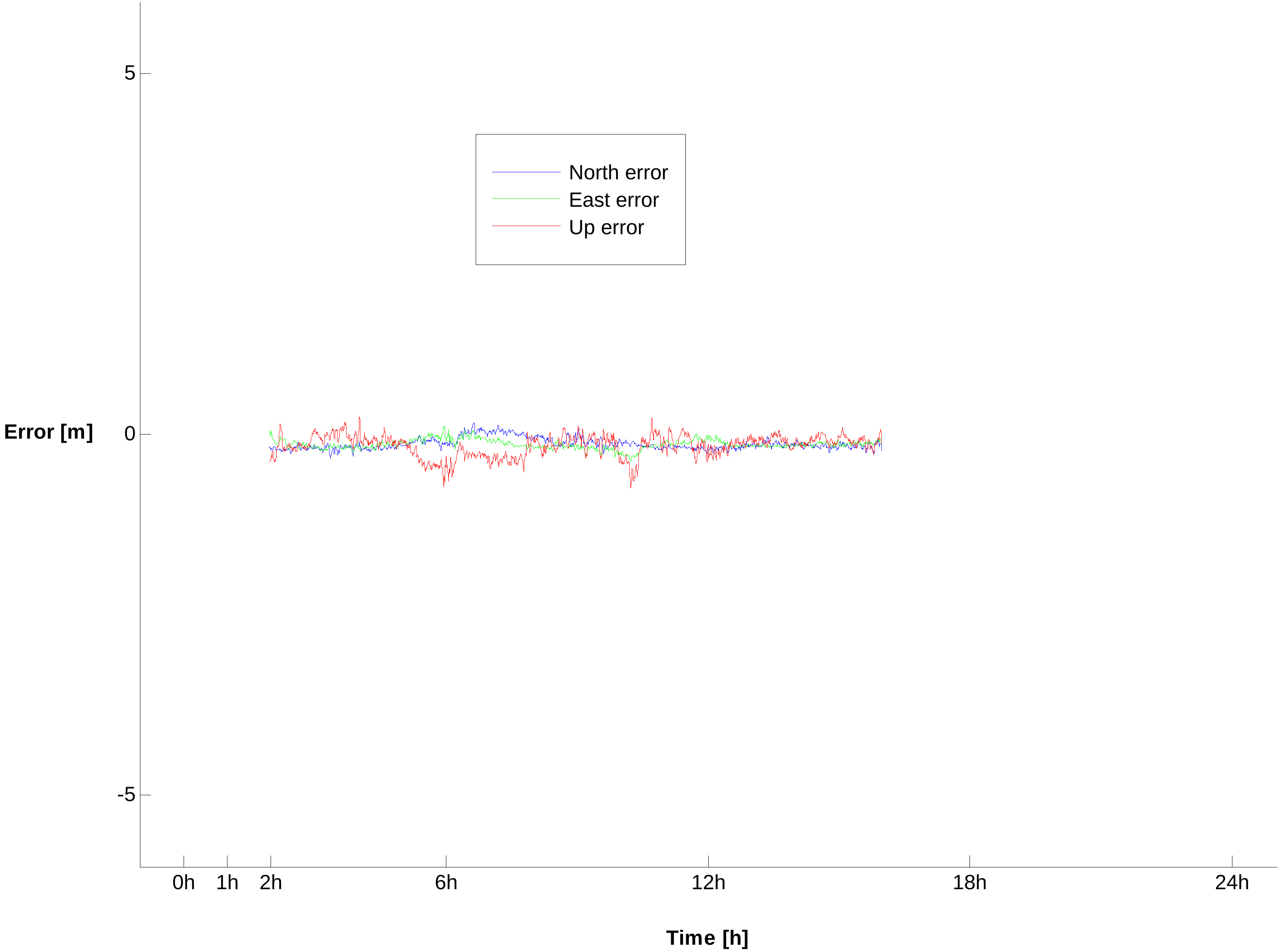
Project

Softwares

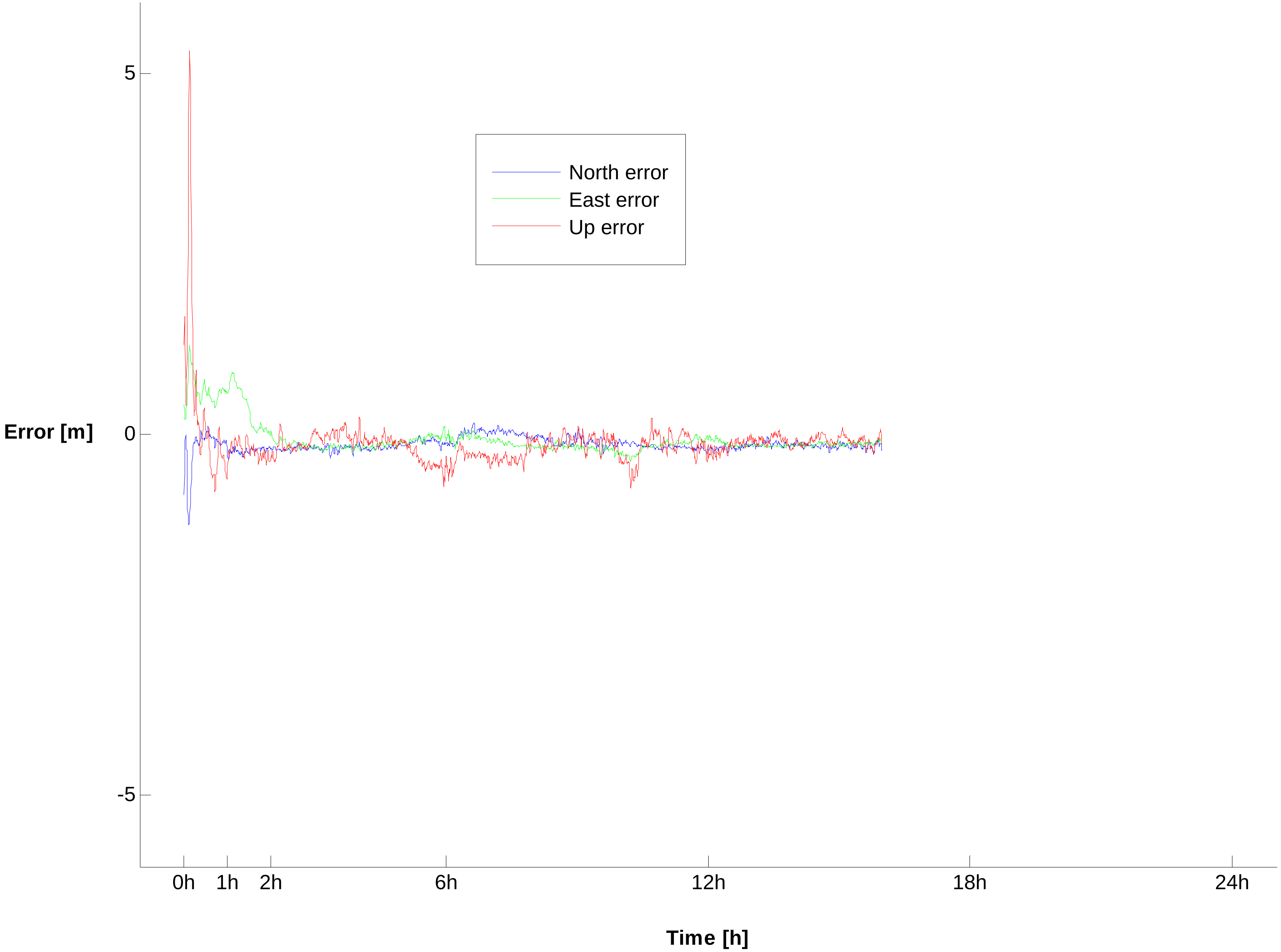
Geometry

Stochasticity

The PPP is a performant technique



The PPP suffers from several weaknesses



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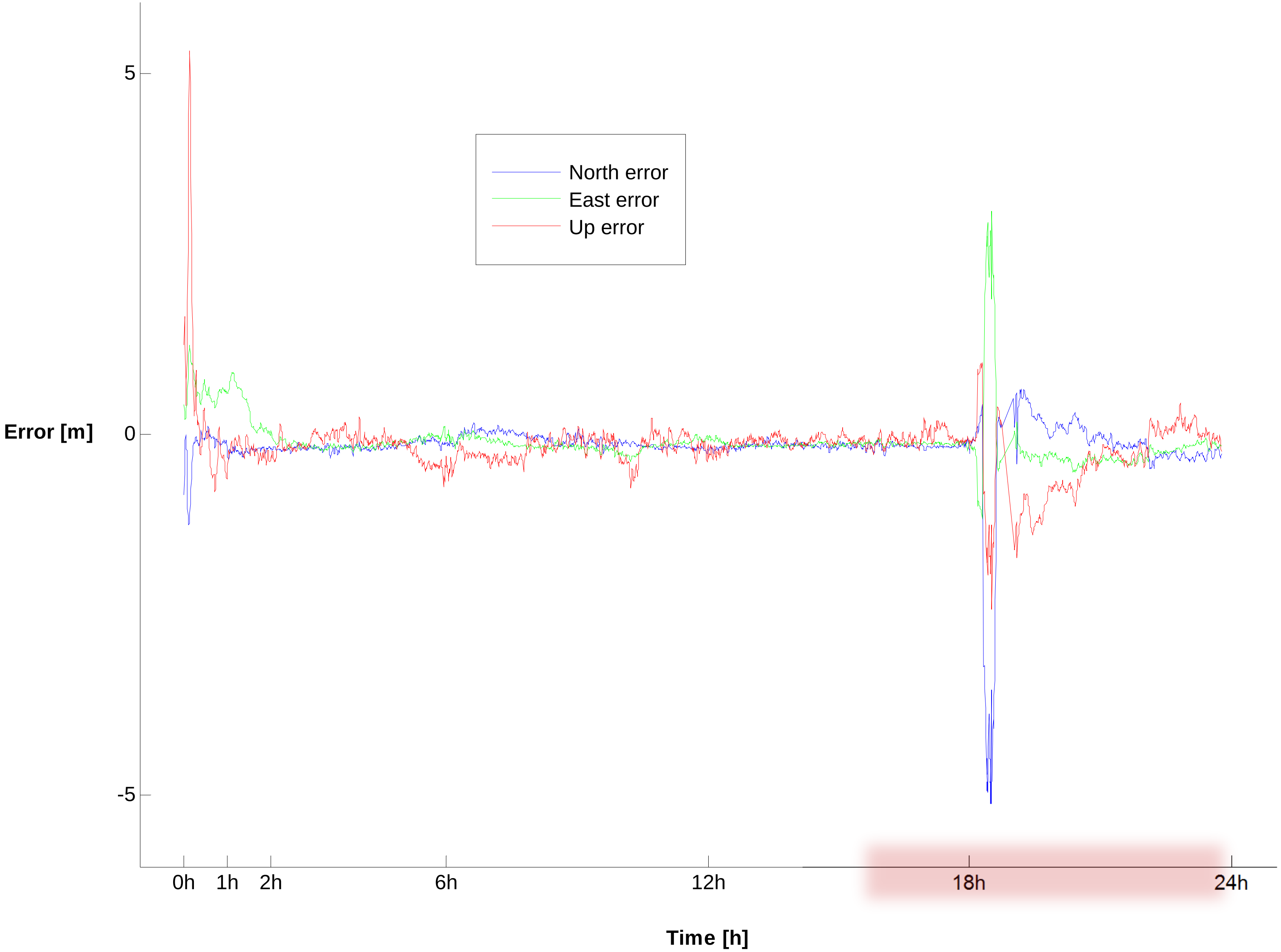
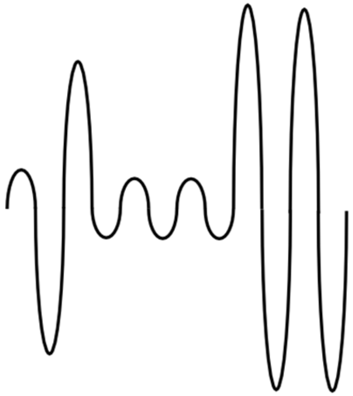


Ionospheric Scintillations involve physical effects on GNSS signals

Signal phase fluctuations



Signal amplitude fluctuations

Signal delay

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

- *Measurement noise*
- *Signal power fluctuations*

- *Lost signals*
- *Geometry troubles*

- *Signal delay*

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

PPP performances under Ionospheric Scintillations can be improved by using several strategies

WP0 – GNSS Tools

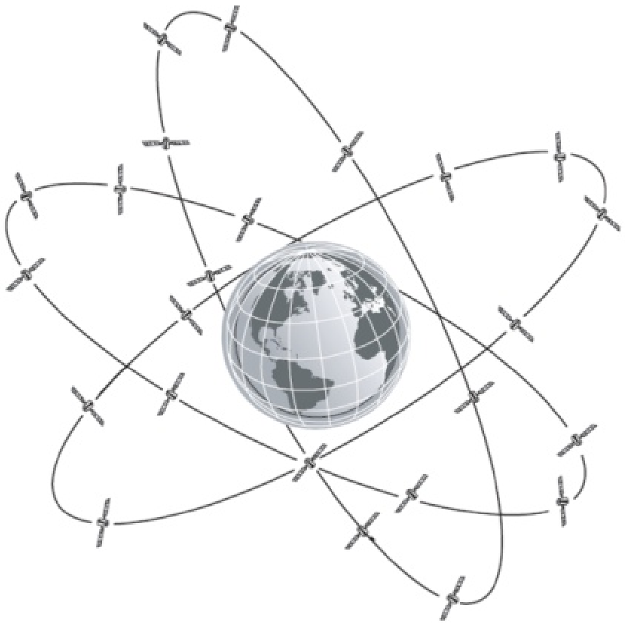
WP1 – Signals

WP2 – Geometry

WP3 – Stochasticity

WP4 – Model

WP5 – Ambiguity



Handling

Project

Softwares

Geometry

Stochasticity

gLAB is a free and open source multipurpose GNSS data processing and analysis software

ESA / gAGE (UPC)

GNSS Data Processing Tool

GNSS Data Analysis Tool

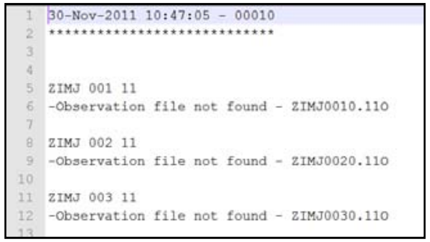
Support

Multipurpose

Scientific
Professional
Educational

AgLAB is a MATLAB software which exploits gLAB to process large network data sets

- Automatic downloading
- Processing (SPP/PPP)
- Output Data Format
- Report Files
- Errors Detection



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30-Nov-2011 10:47:05 - 00010
****************************



ZIMJ 001 11
-Observation file not found - ZIMJ0010.11O

ZIMJ 002 11
-Observation file not found - ZIMJ0020.11O

ZIMJ 003 11
-Observation file not found - ZIMJ0030.11O
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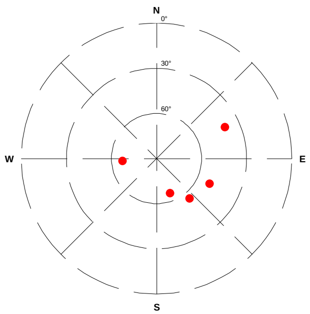

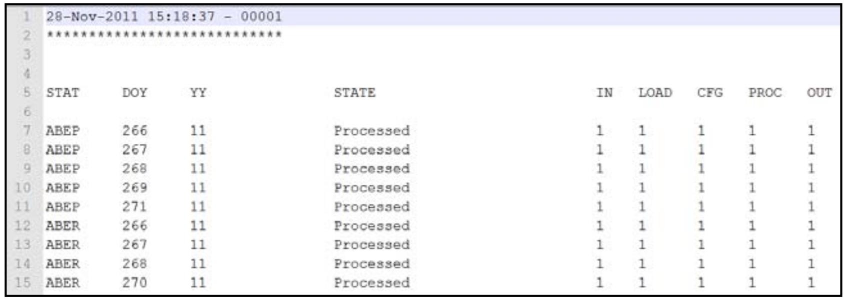

28-Nov-2011 15:18:37 - 00001
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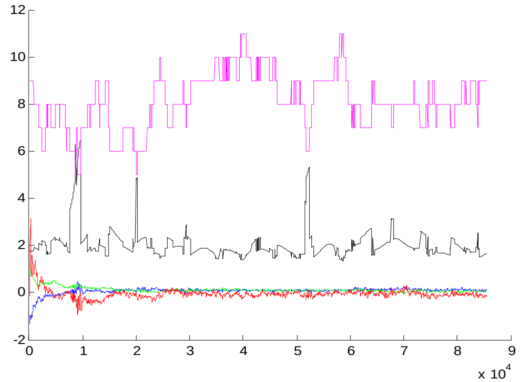
STAT	DOY	YY	STATE	IN	LOAD	CFG	PROC	OUT
ABEP	266	11	Processed	1	1	1	1	1
ABEP	267	11	Processed	1	1	1	1	1
ABEP	268	11	Processed	1	1	1	1	1
ABEP	269	11	Processed	1	1	1	1	1
ABEP	271	11	Processed	1	1	1	1	1
ABER	266	11	Processed	1	1	1	1	1
ABER	267	11	Processed	1	1	1	1	1
ABER	268	11	Processed	1	1	1	1	1
ABER	270	11	Processed	1	1	1	1	1



AgLAB is a MATLAB software which exploits gLAB to process large network data sets

Automatic downloading

Processing (SPP/PPP)

Output Data Format

Report Files

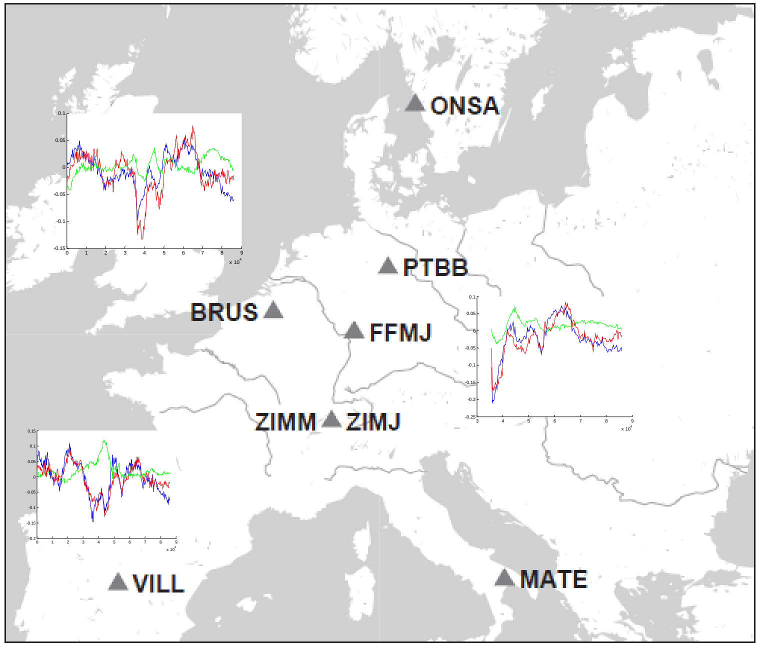
Errors Detection

Galileo?

Rinex v3.0?

Triple Frequency Data?

Simulated Data Processing?



Handling

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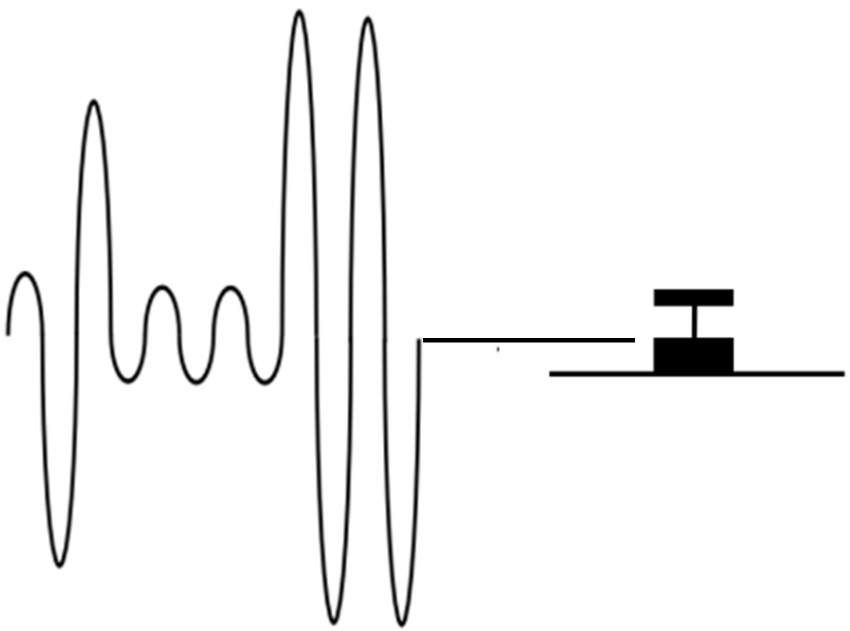
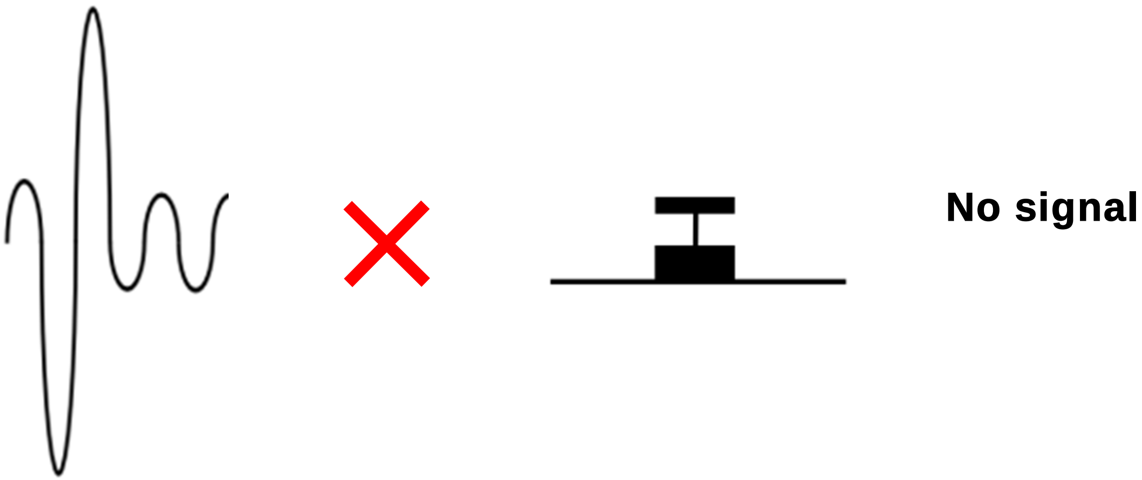
Ionospheric Scintillations
reduce the number of tracked satellites



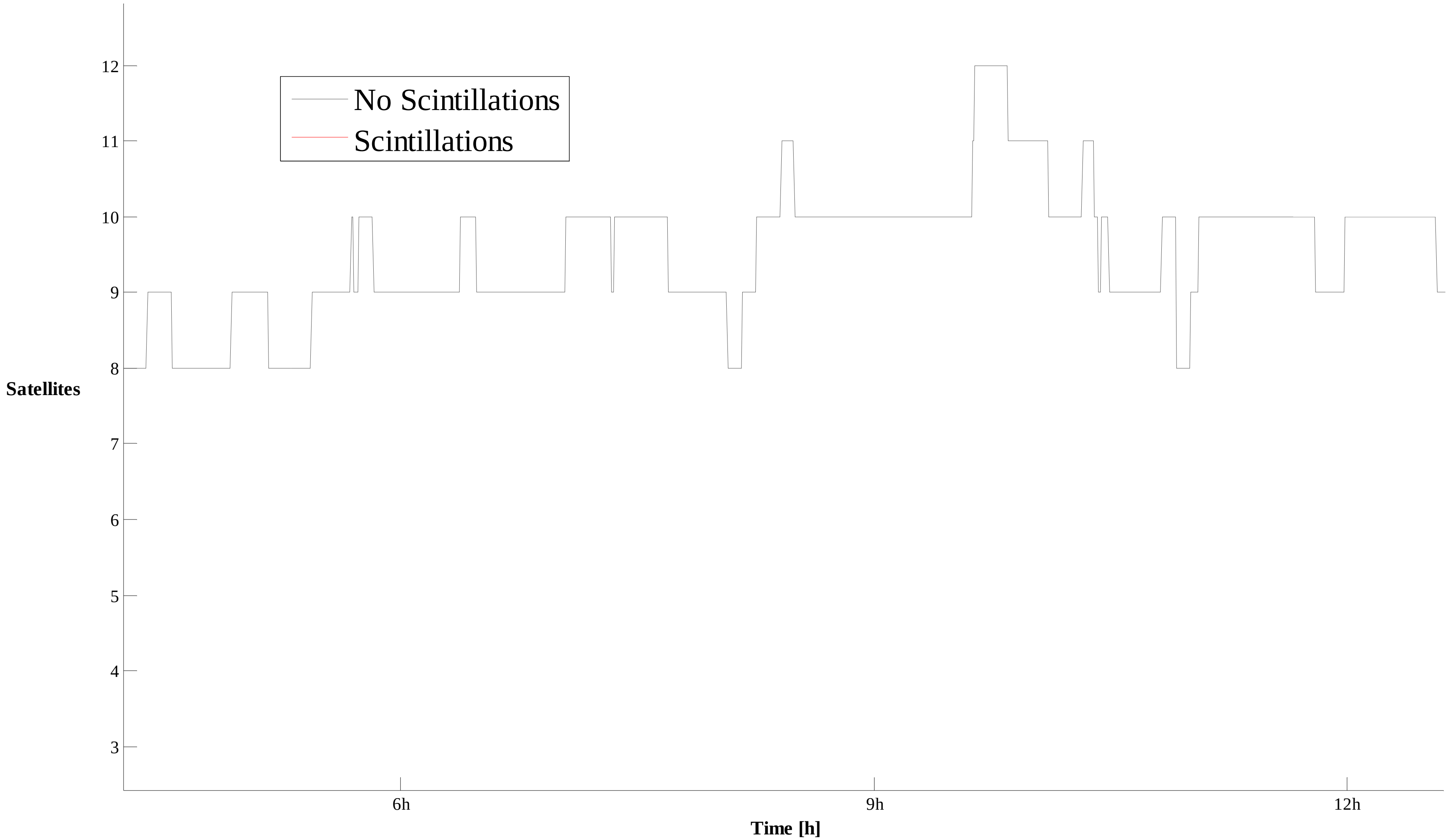
Signal amplitude fluctuations

Ionospheric Scintillations
reduce the number of tracked satellites



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

Ionospheric Scintillations reduce the number of tracked satellites



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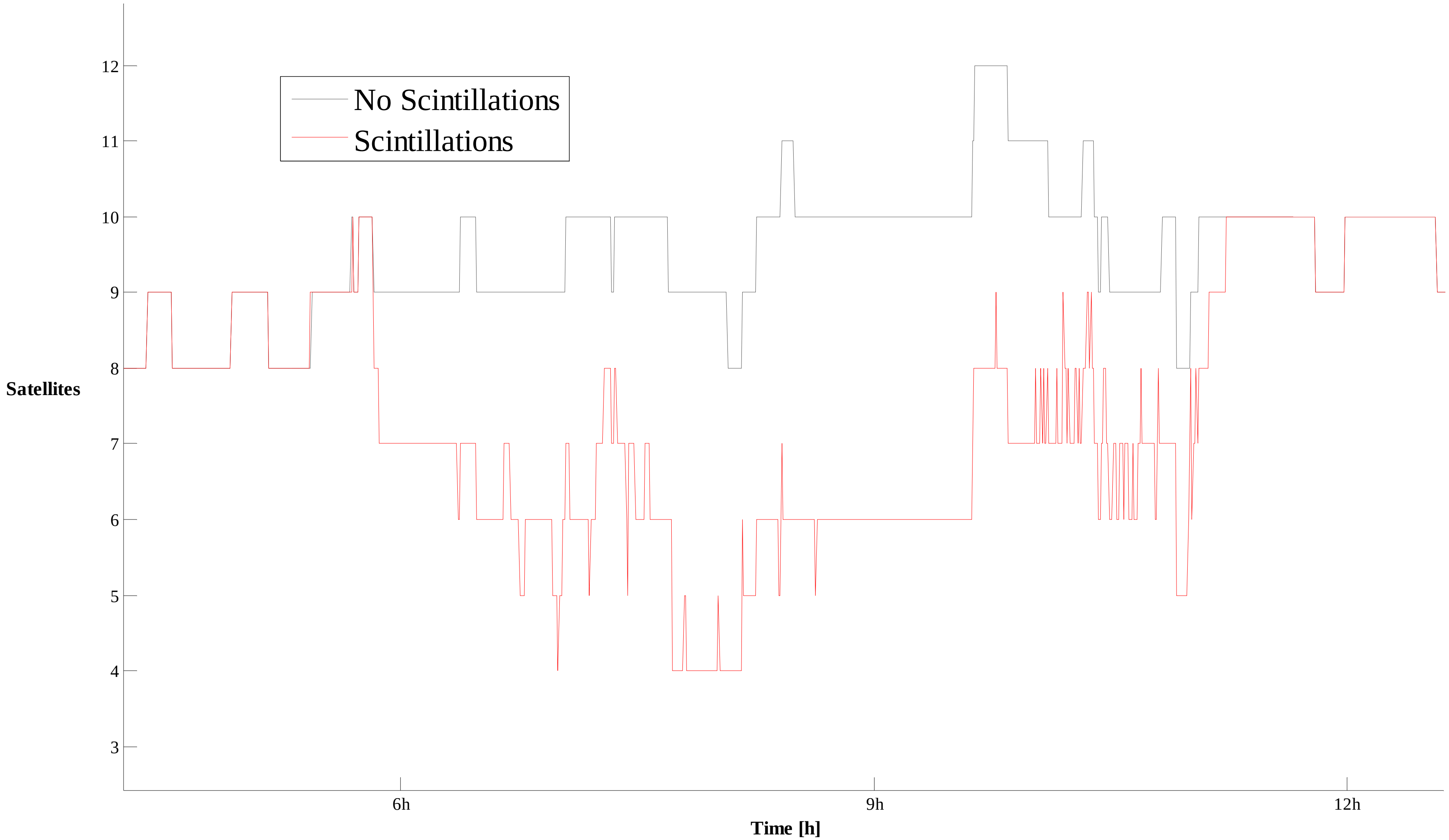
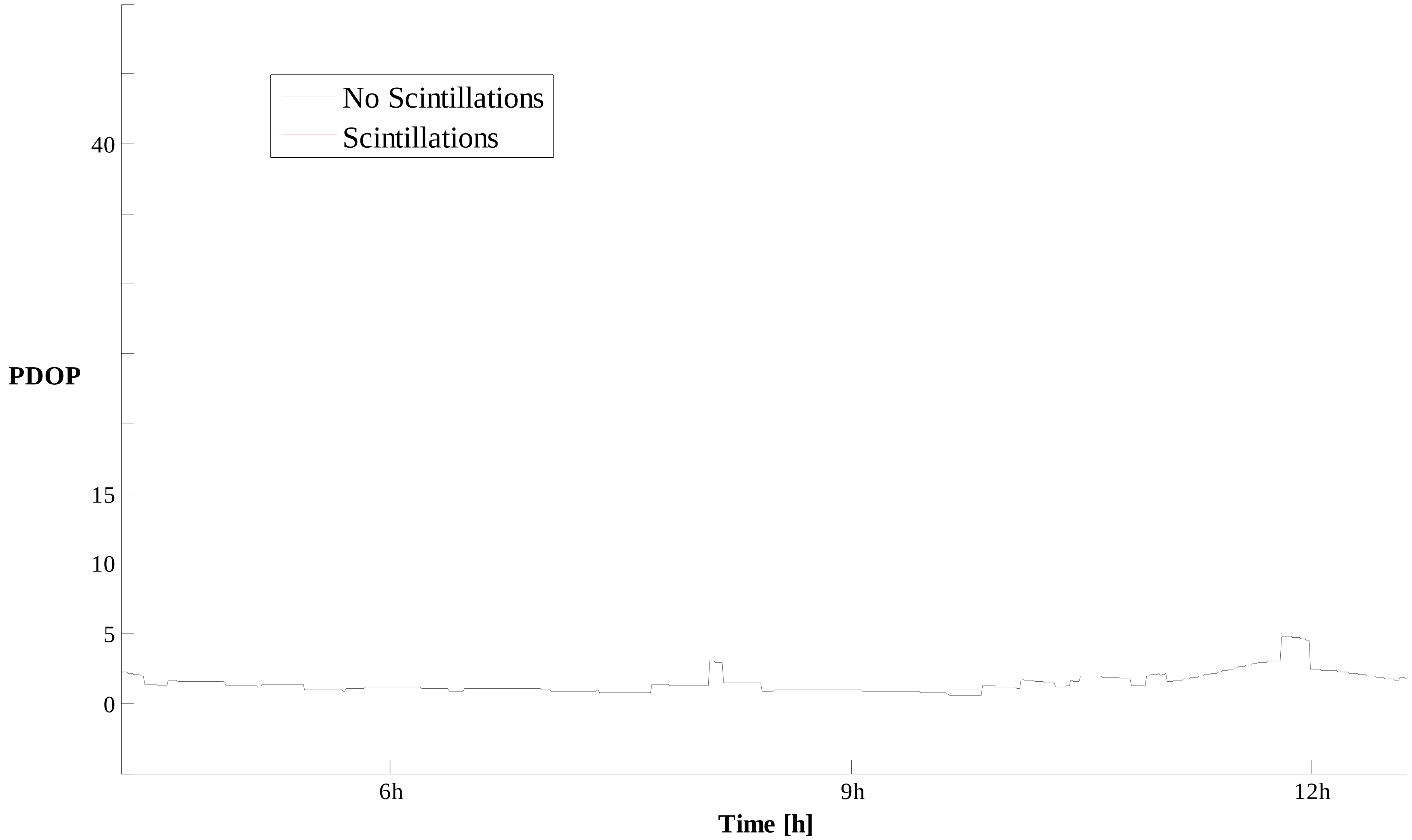


Ionospheric Scintillations reduce the satellite geometry quality



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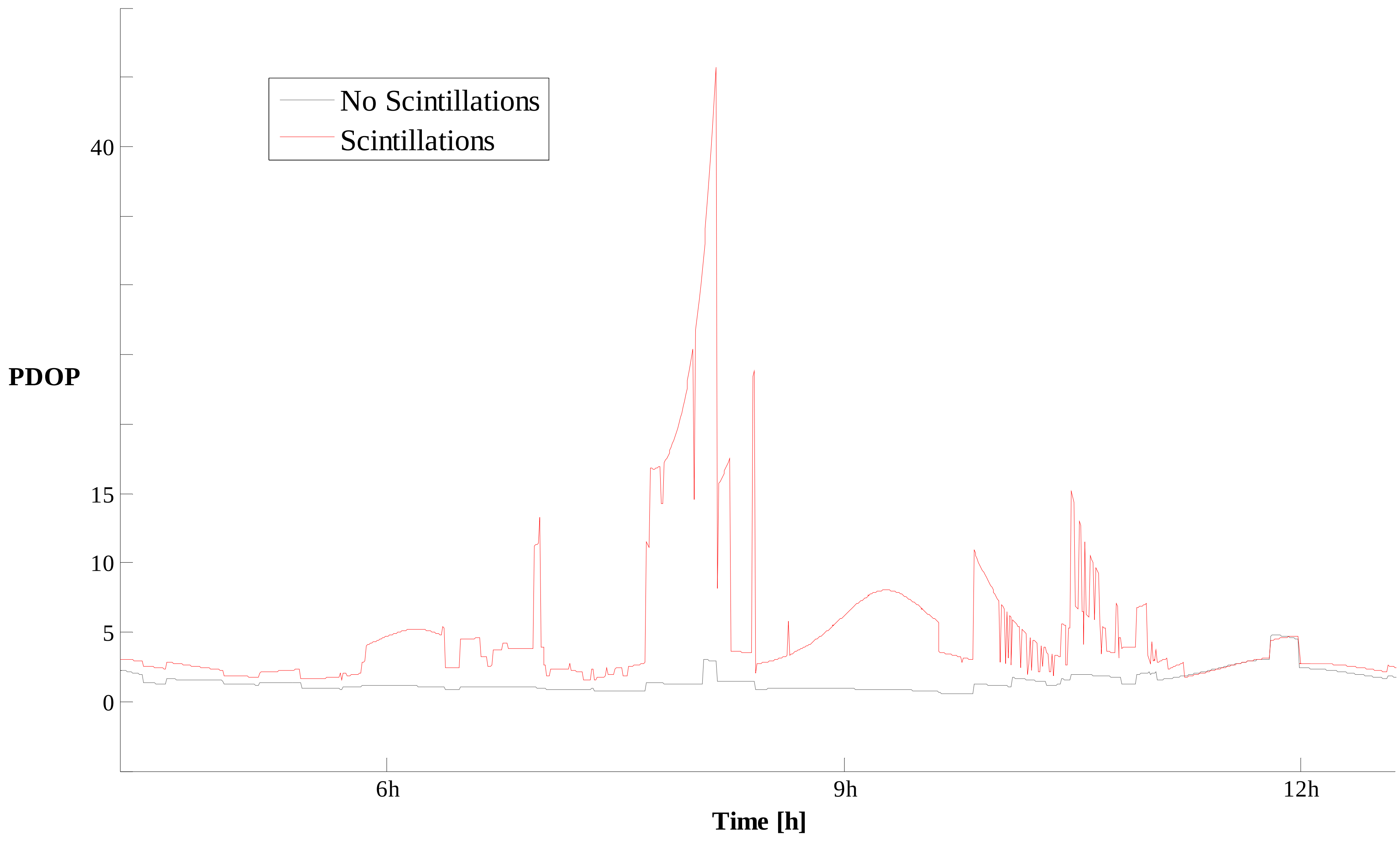
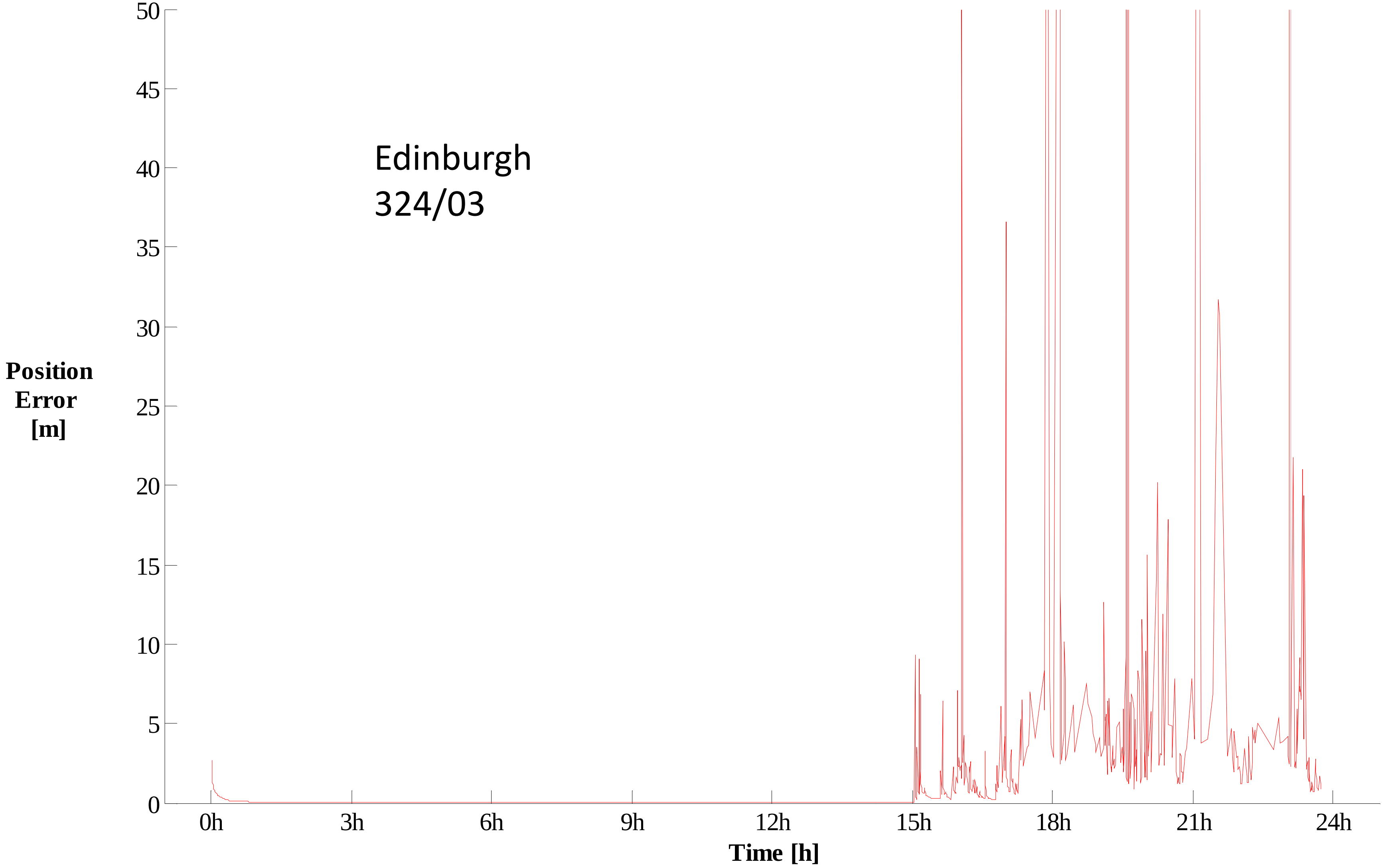


The geometric effect of Ionospheric Scintillations is a major effect for satellite positioning



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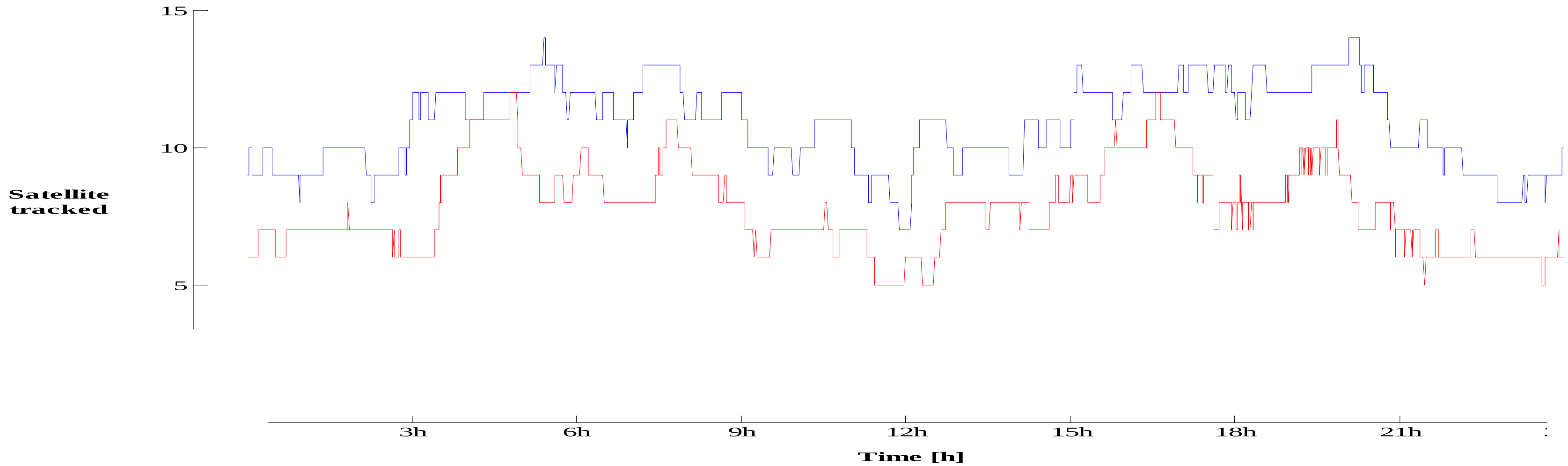

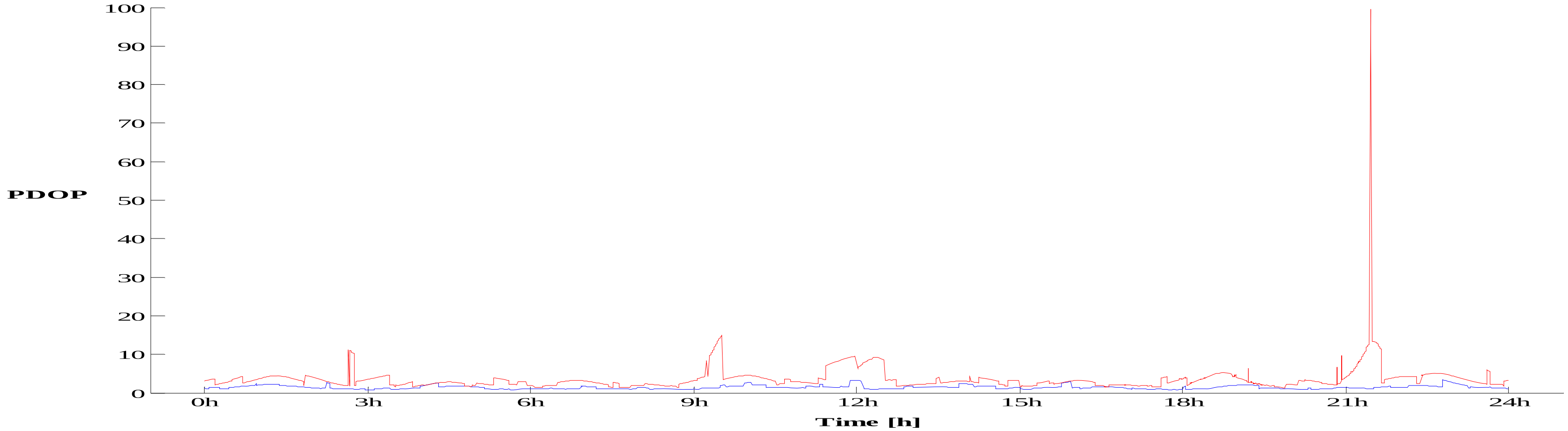

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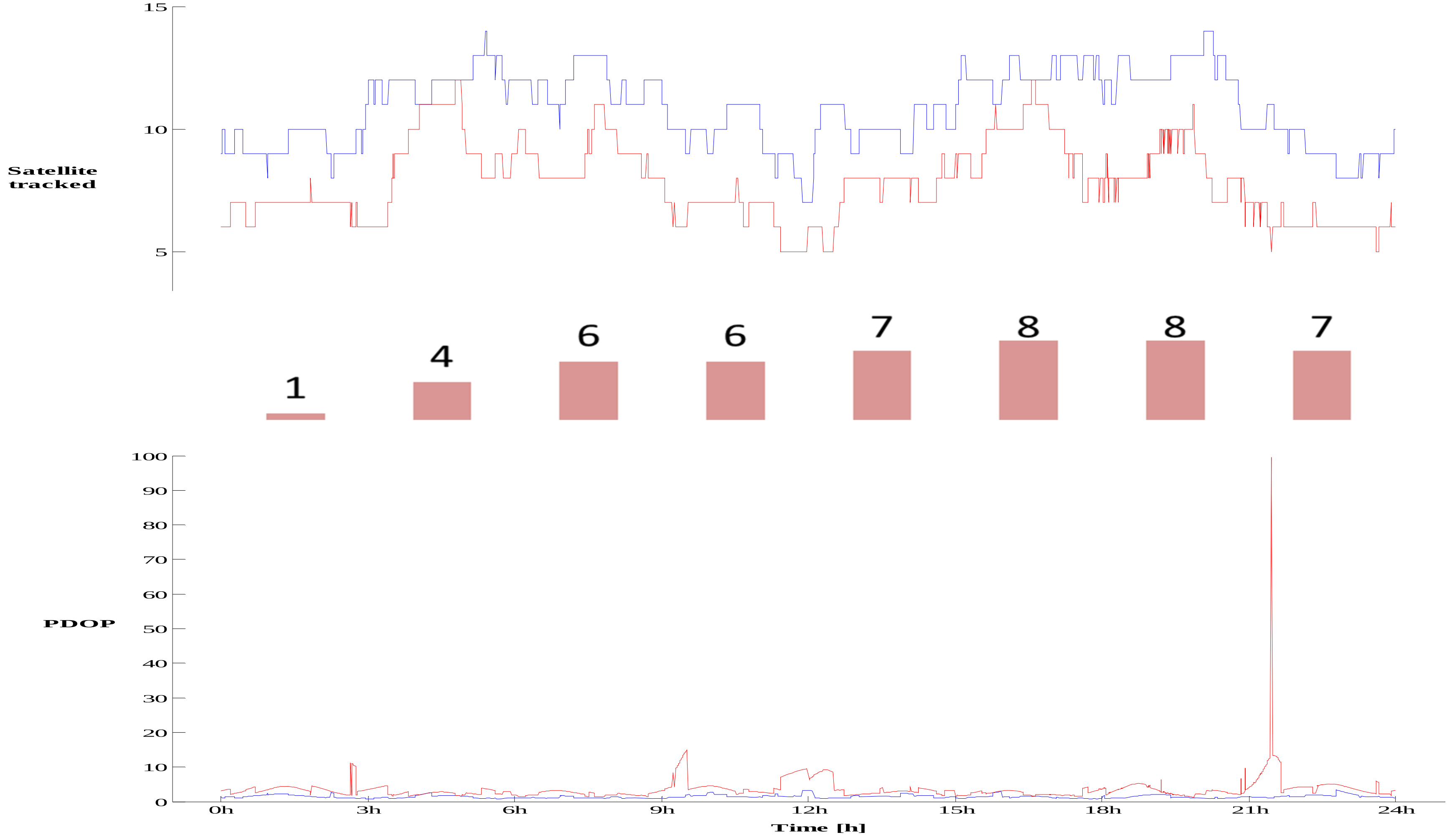
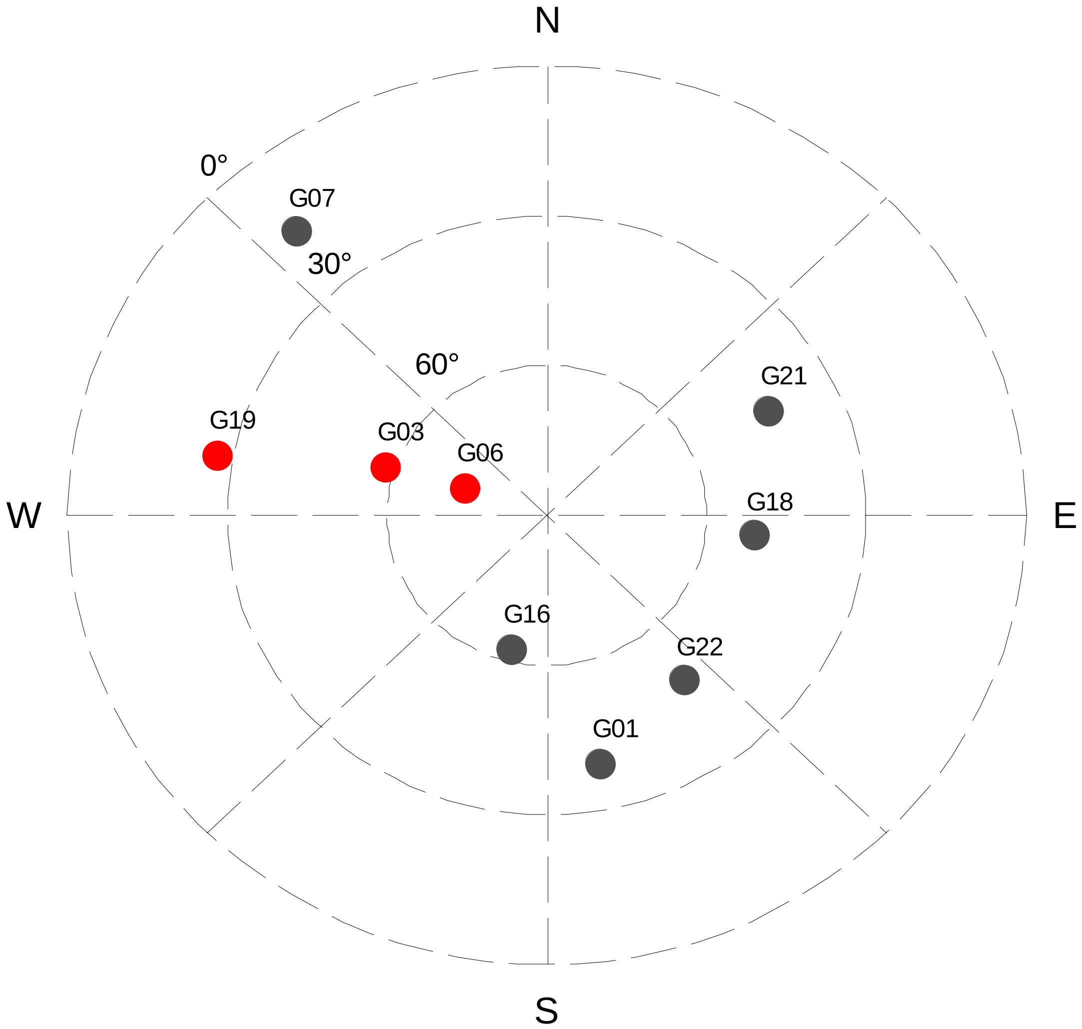
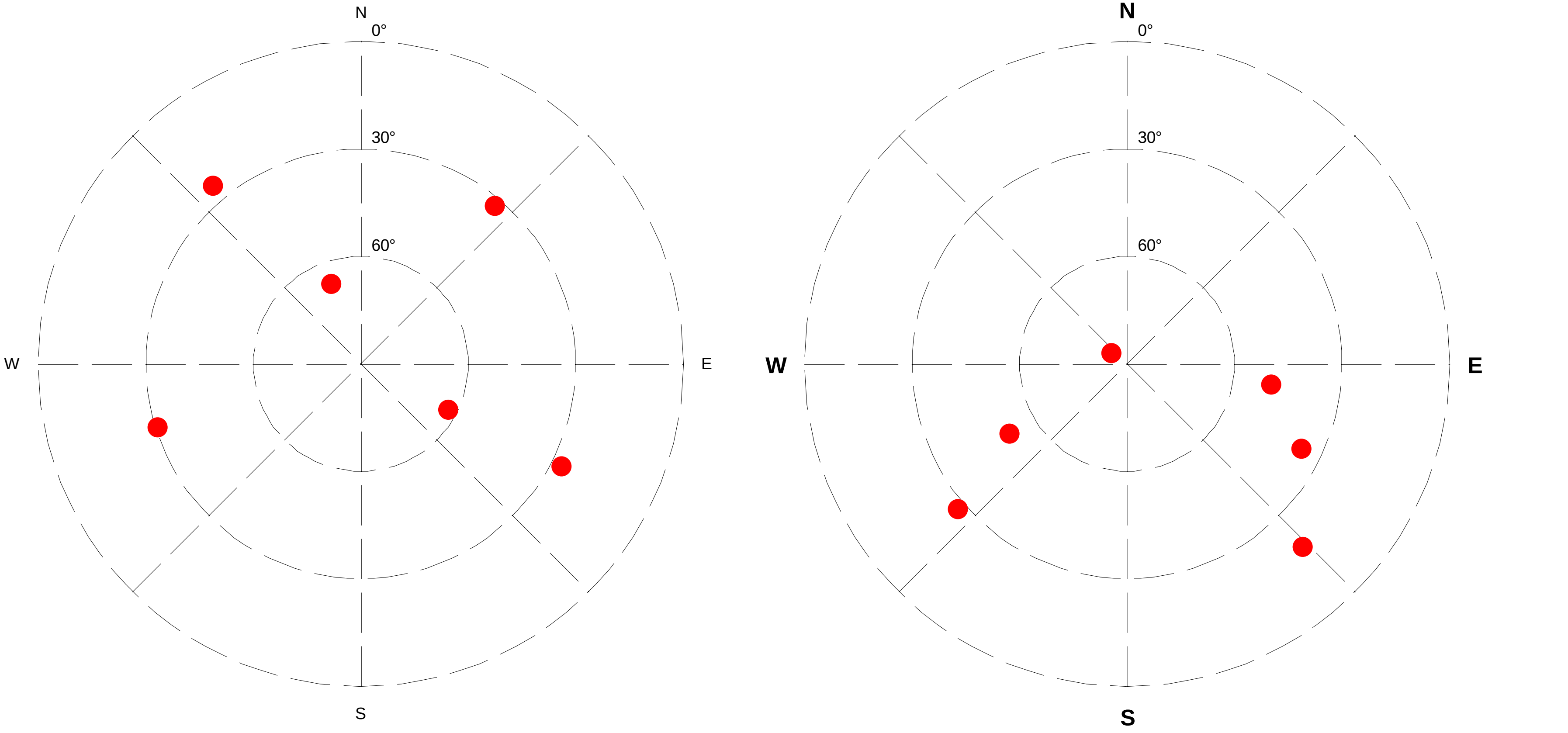


Ionospheric Scintillations produce unbalanced satellite geometry



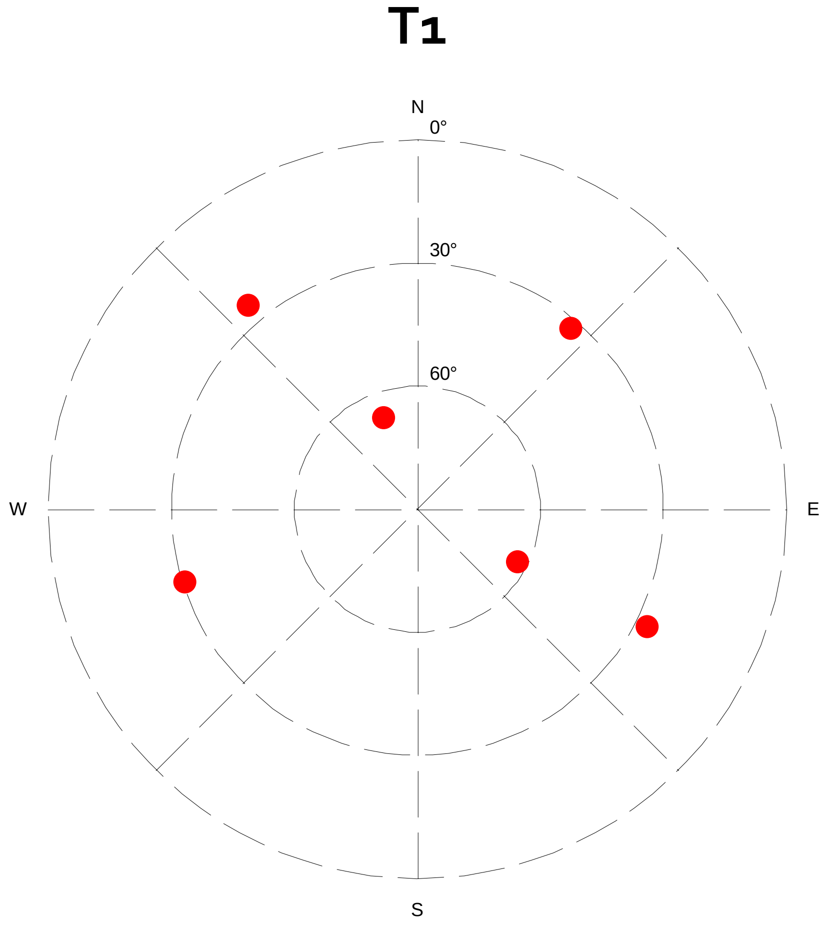
High DOP values are not only due to a small number of tracked satellites

T1 **T2**

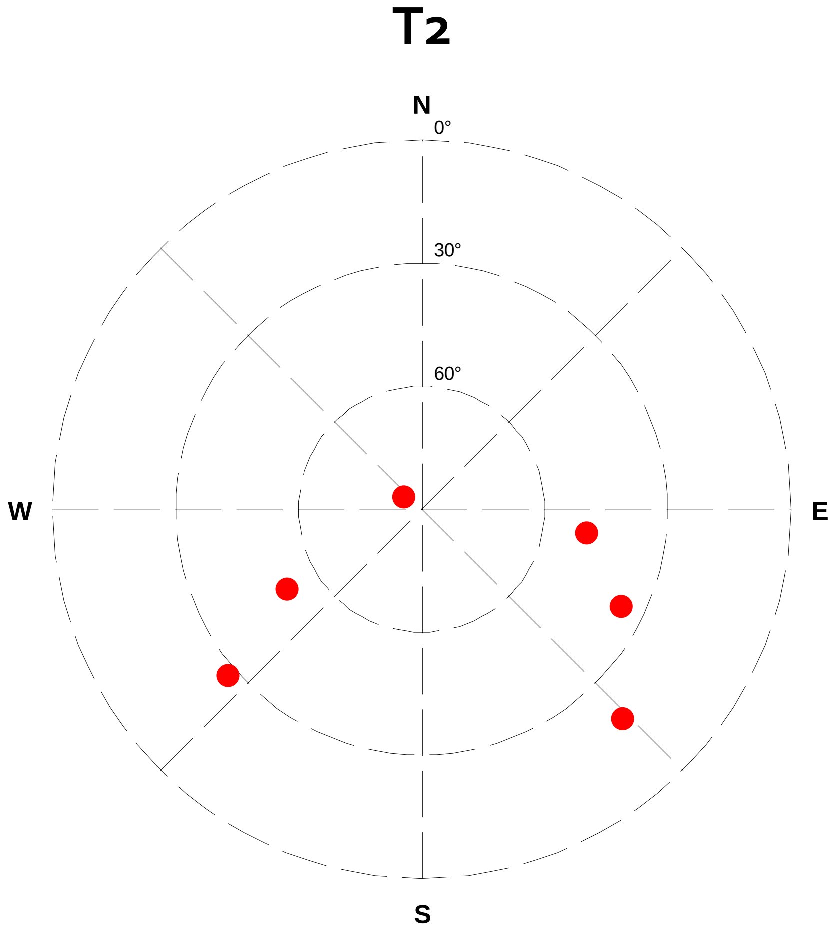


DOP = 2.36 **DOP = 13.78**

High DOP values are correlated to a normal matrix close to a singular state



$$|N| = 3.47$$



$$|N| = 0.04$$

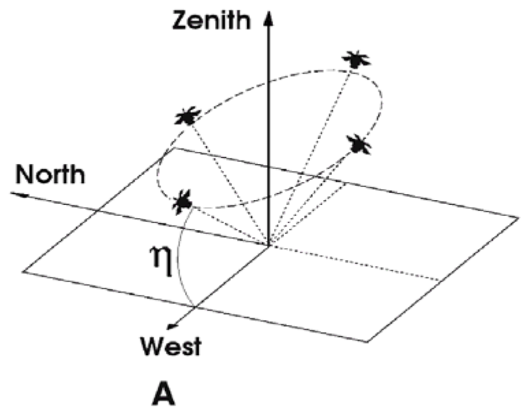
A conical satellite geometry drives the DOP to infinite values

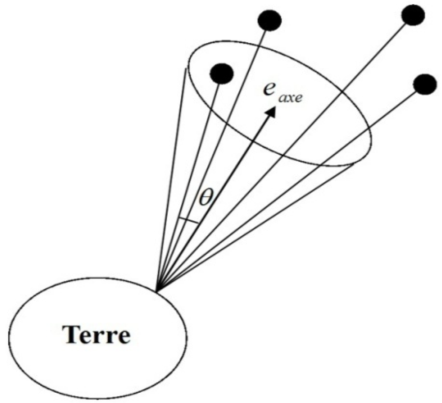
$$\left| N \right| = 0$$

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

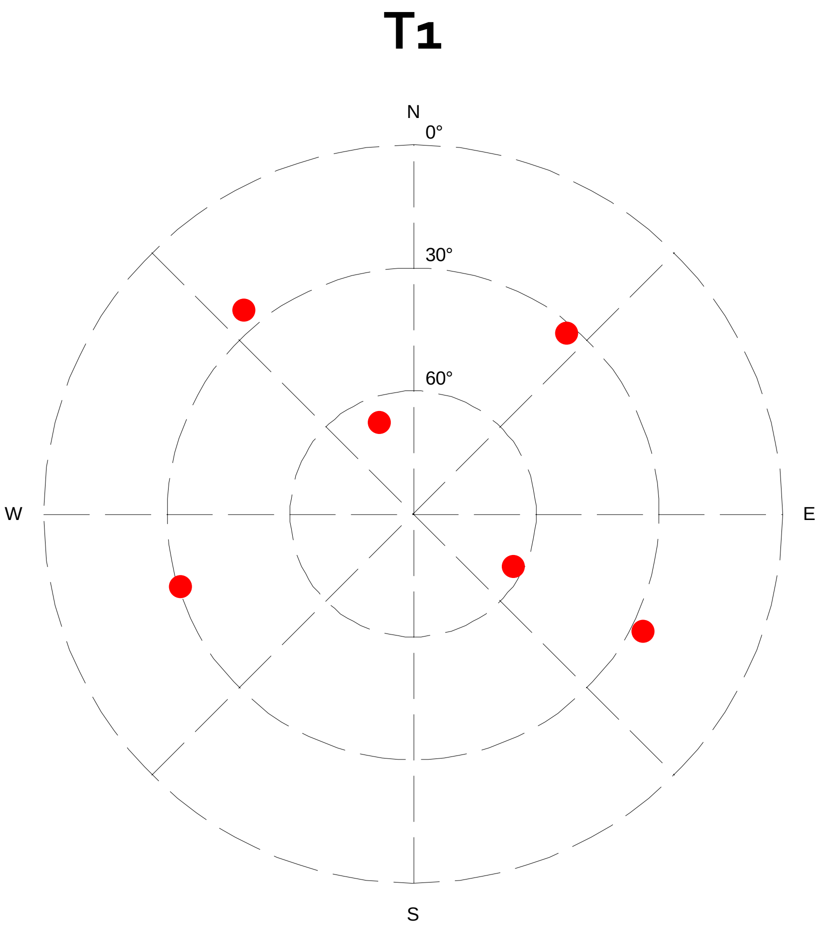
$$A = \begin{bmatrix} -\cos\eta^1 \sin\chi^1 & -\cos\eta^1 \cos\chi^1 & -\sin\eta^1 & 1 \\ -\cos\eta^2 \sin\chi^2 & -\cos\eta^2 \cos\chi^2 & -\sin\eta^2 & 1 \\ \dots & \dots & \dots & \dots \\ -\cos\eta^n \sin\chi^n & -\cos\eta^n \cos\chi^n & -\sin\eta^n & 1 \end{bmatrix}$$

Any linear dependence?

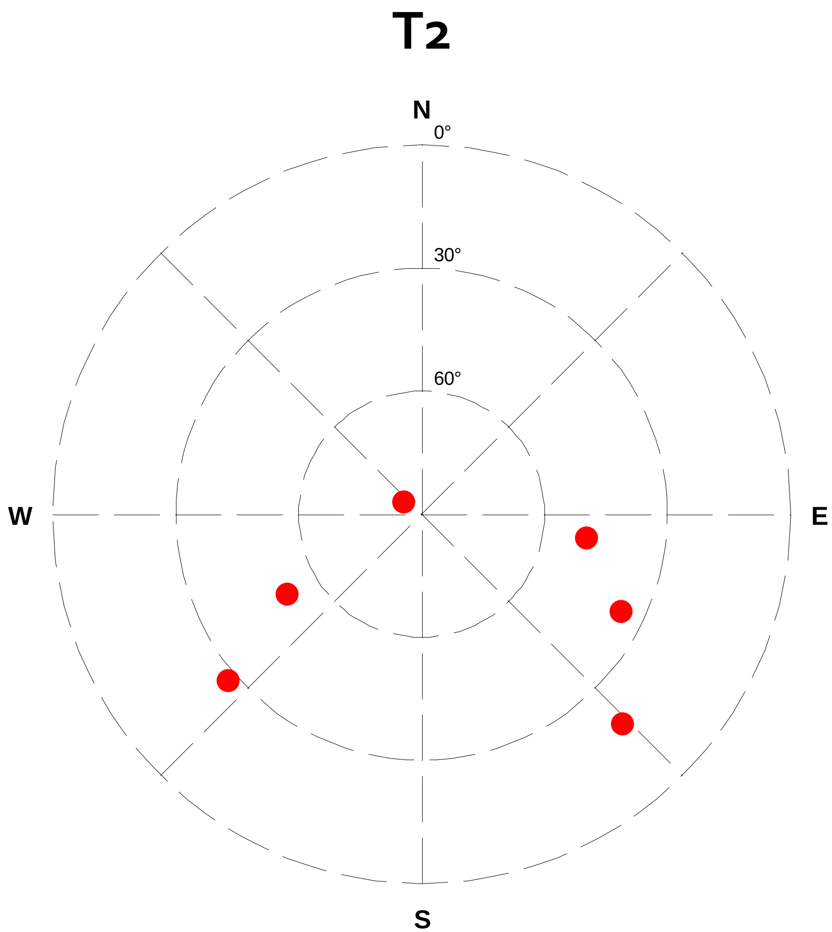




High DOP values are not only due to a small number of tracked satellites

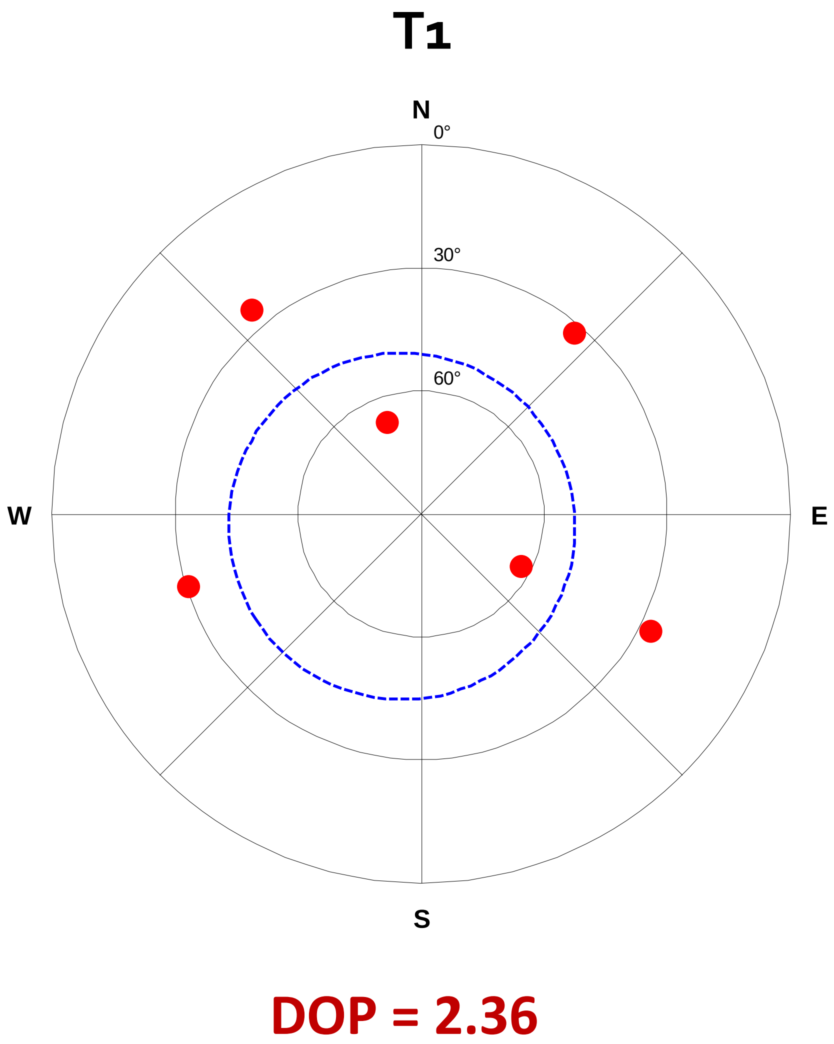


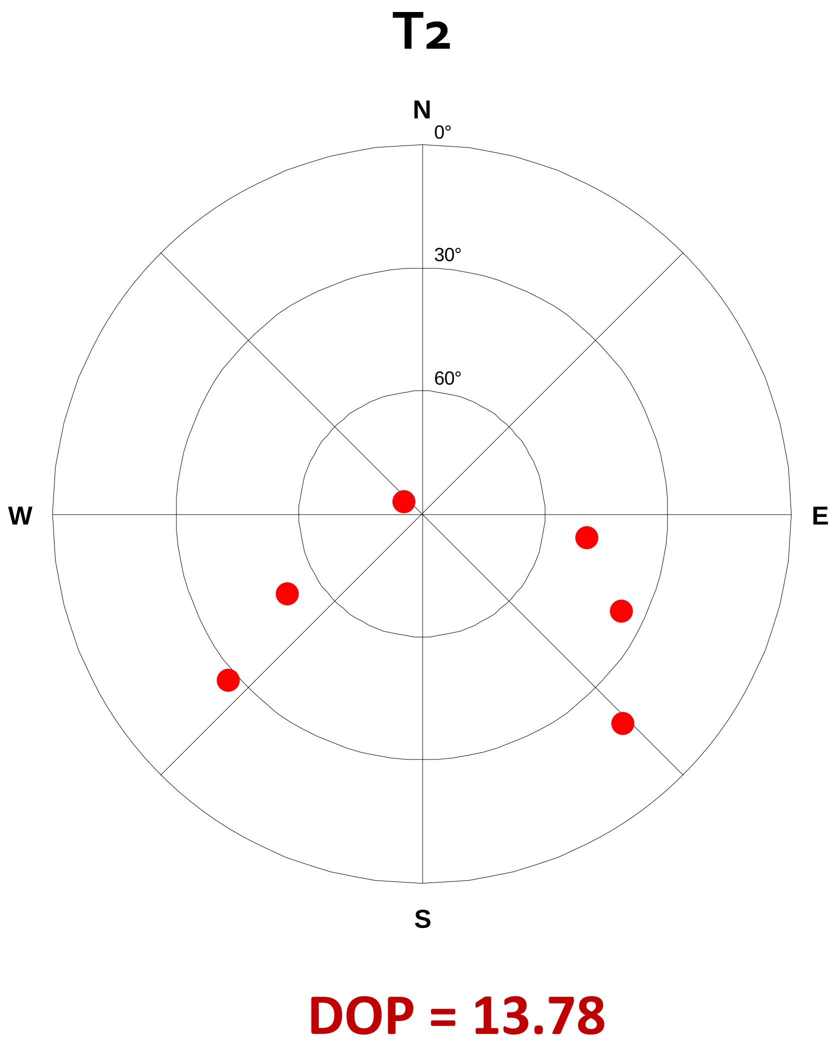
DOP = 2.36



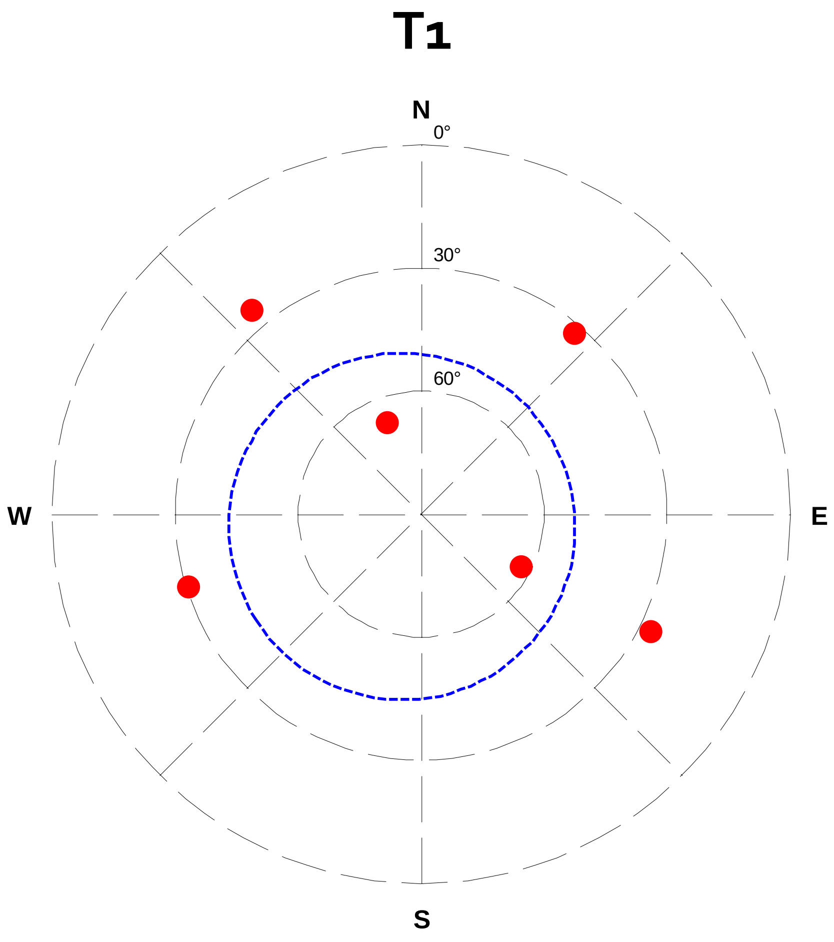
DOP = 13.78

A nearly conical satellite geometry drives the DOP to critical values

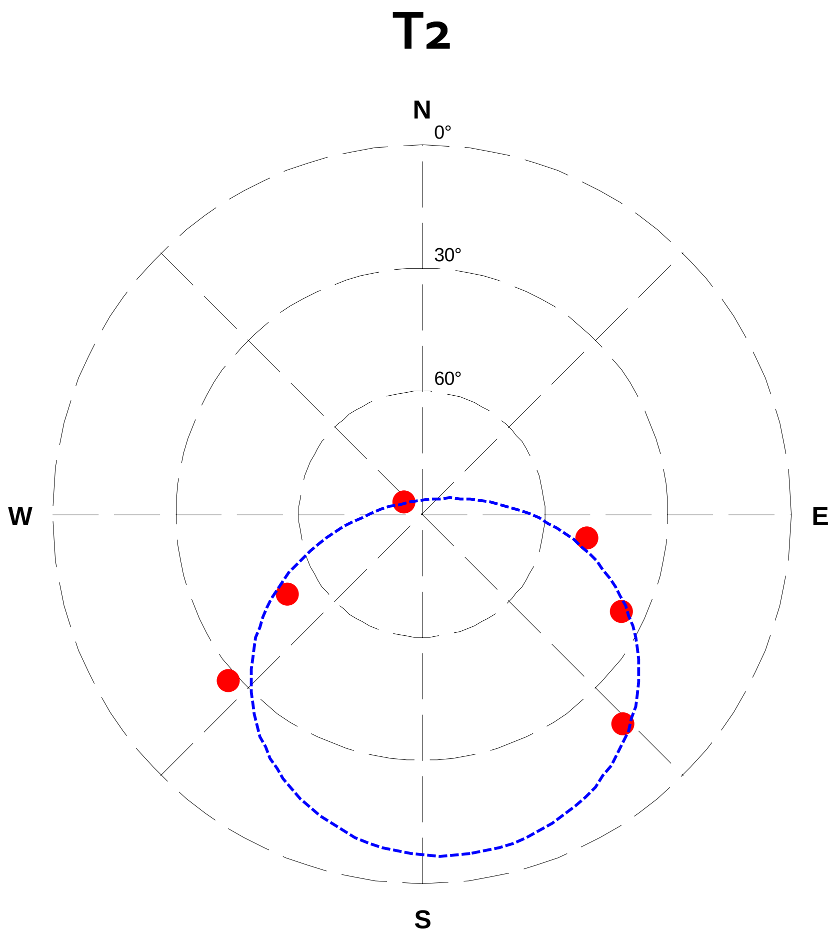




A nearly conical satellite geometry deteriorates the satellite geometry quality

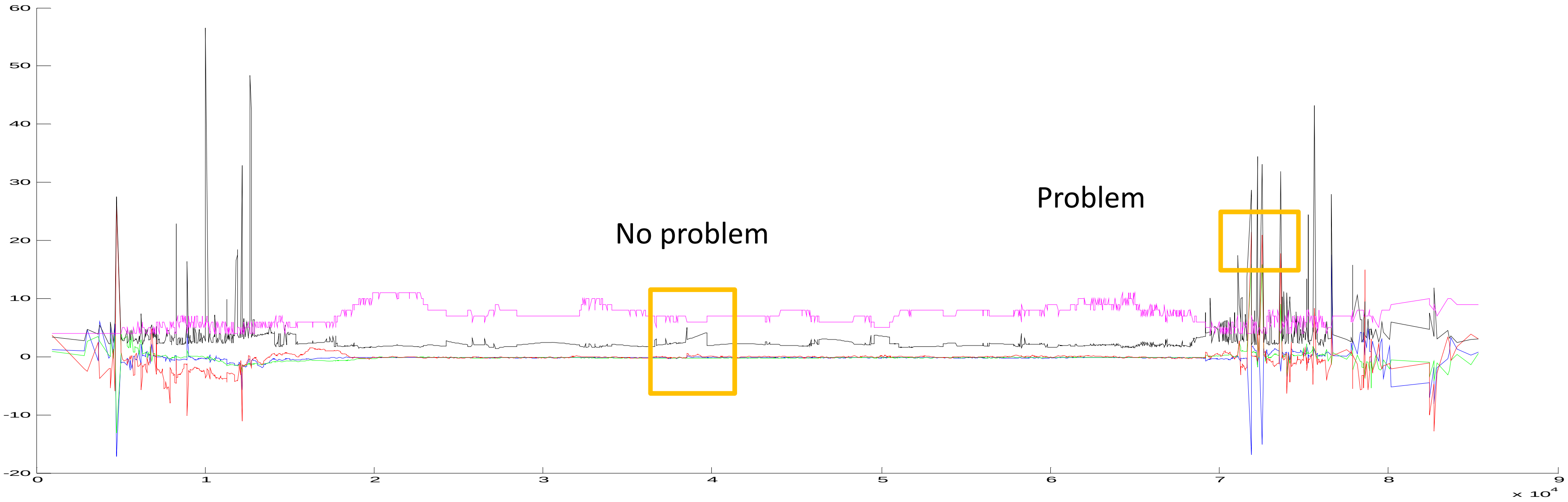


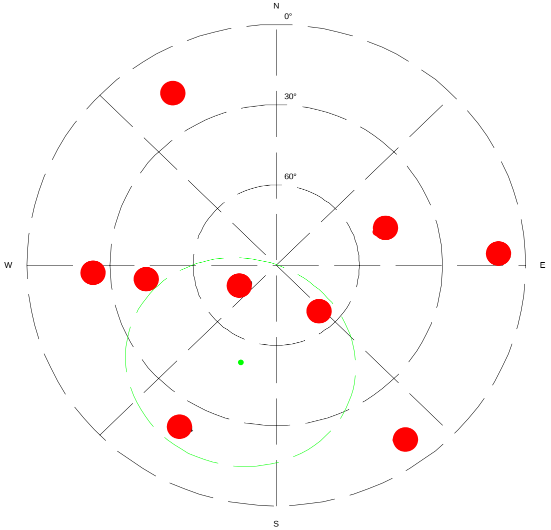
DOP = 2.36

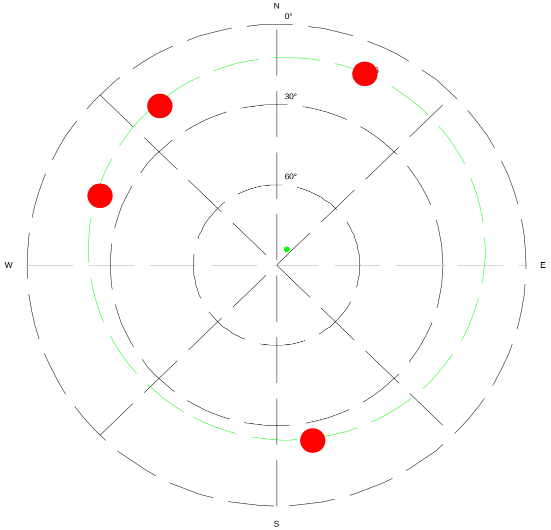


DOP = 13.78

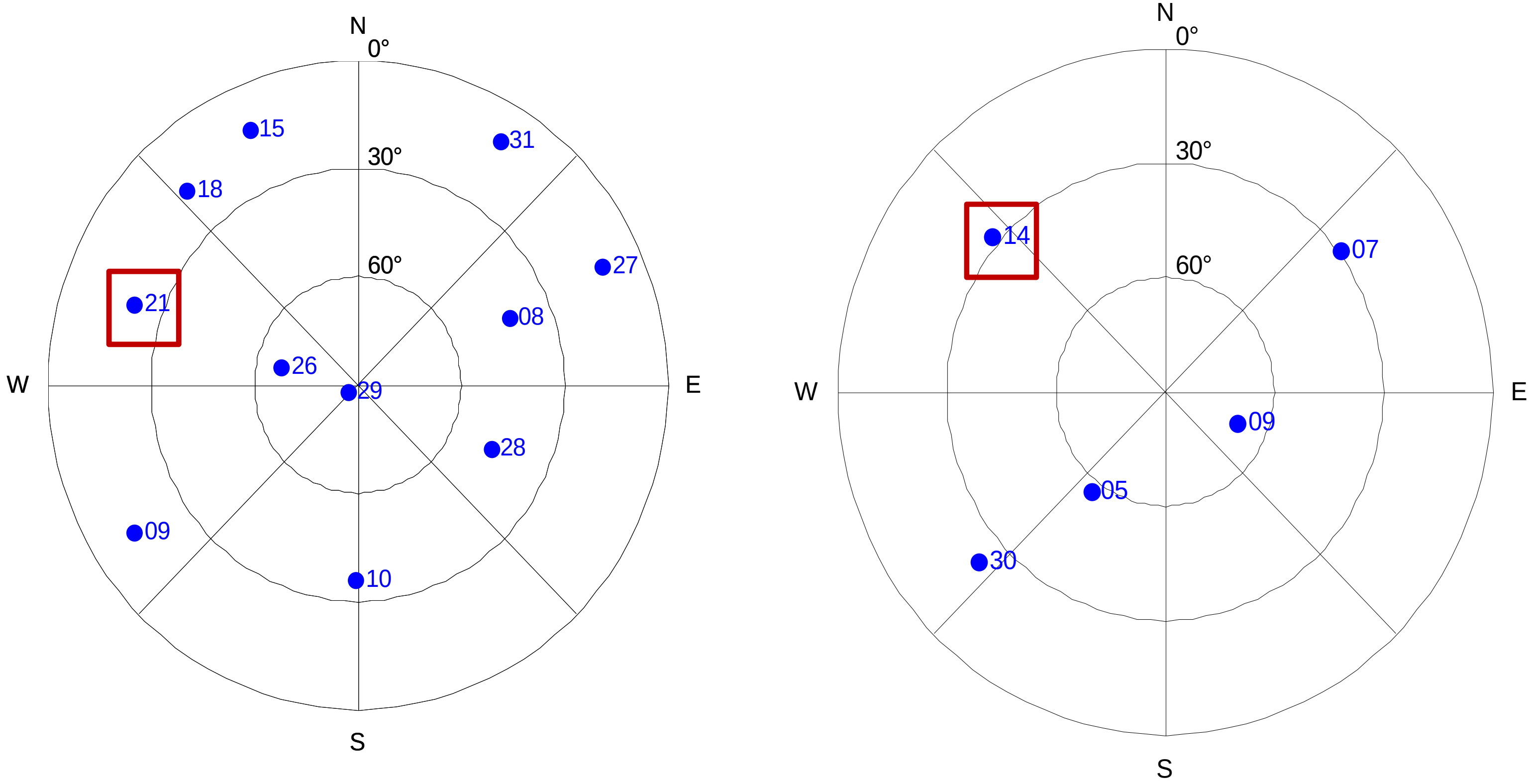
Ionospheric Scintillations increase the probability to encounter conical satellite geometries



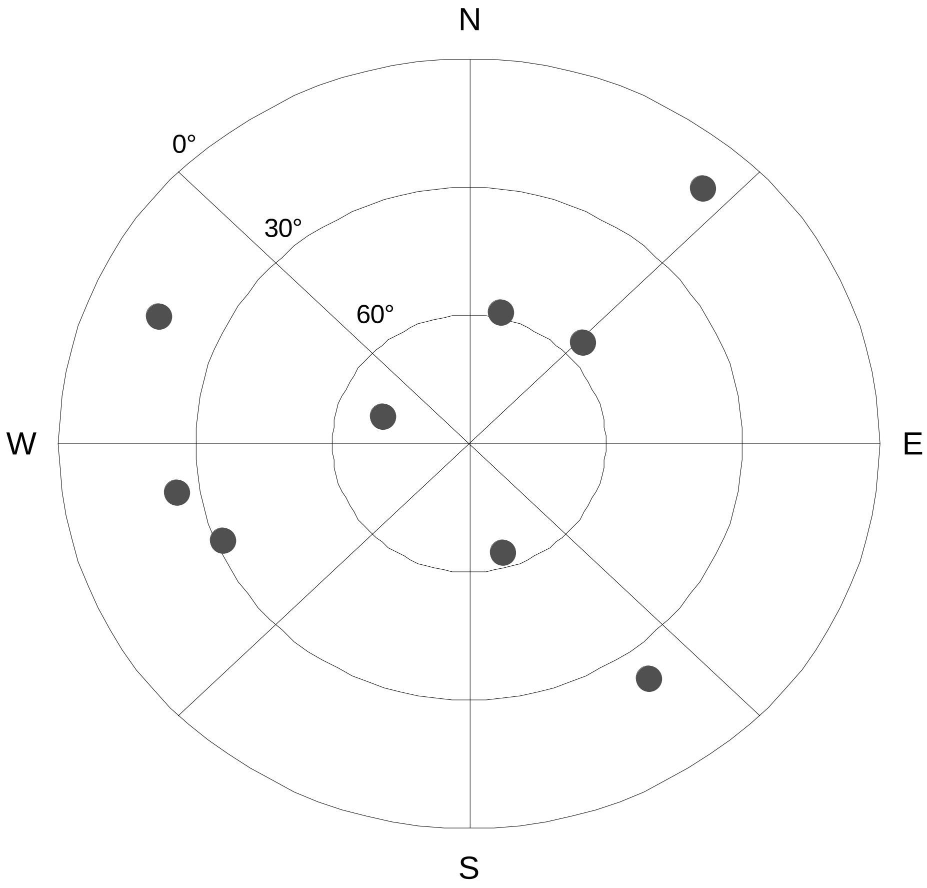




Coherent Observation Weigthing Scheme
is essential to correctly combine observations



The combined use of GPS and Galileo satellites improves the satellite geometry quality



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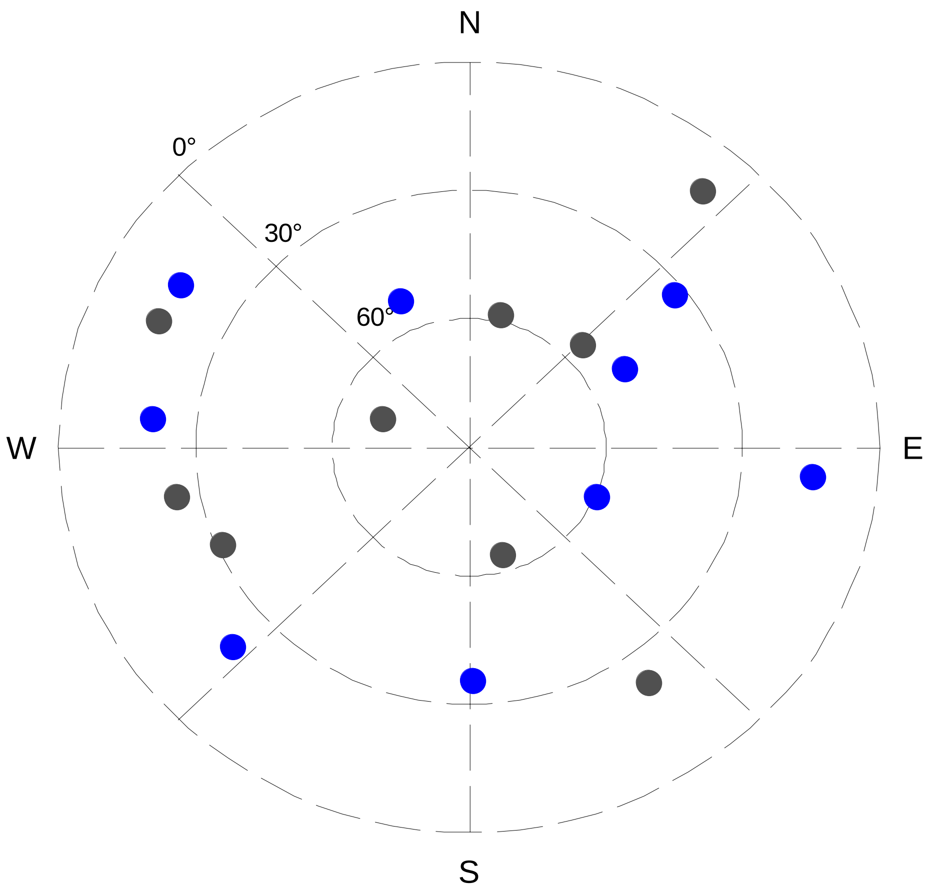

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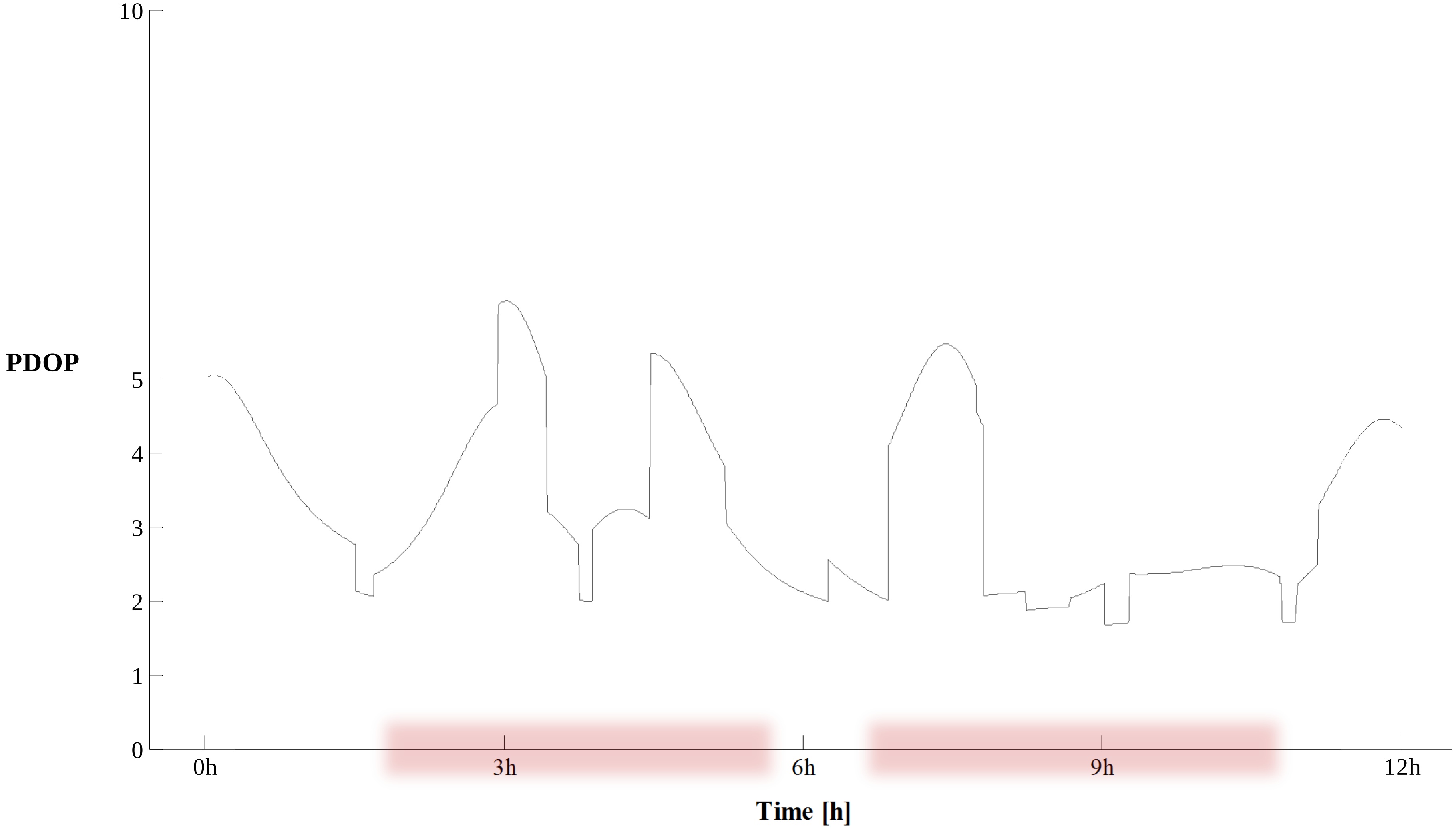

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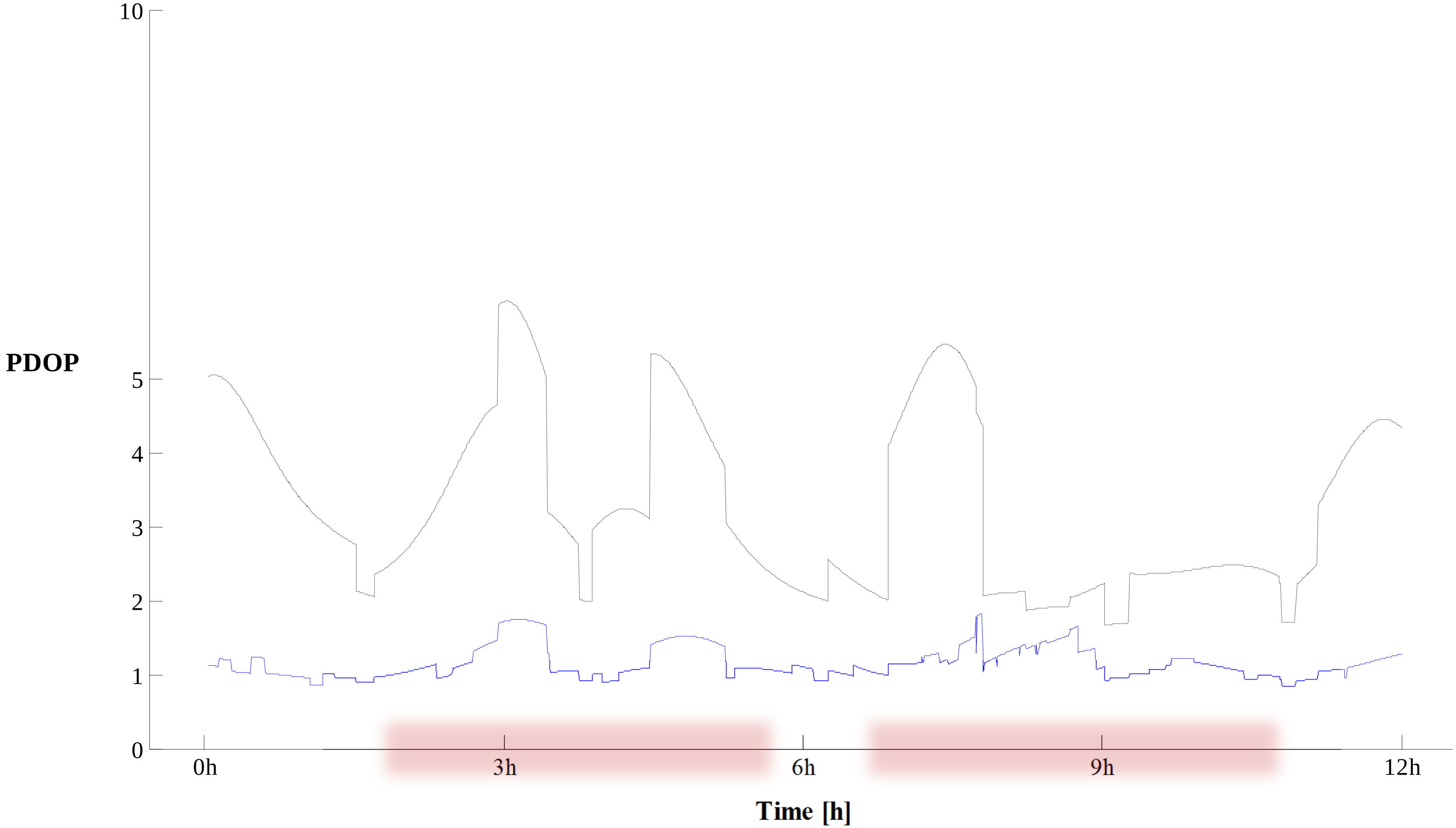


Scintillations/Geometry/WP2/Objectives

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

- Precision
- Time convergence
- Reliability

Ionospheric Scintillations

Handling

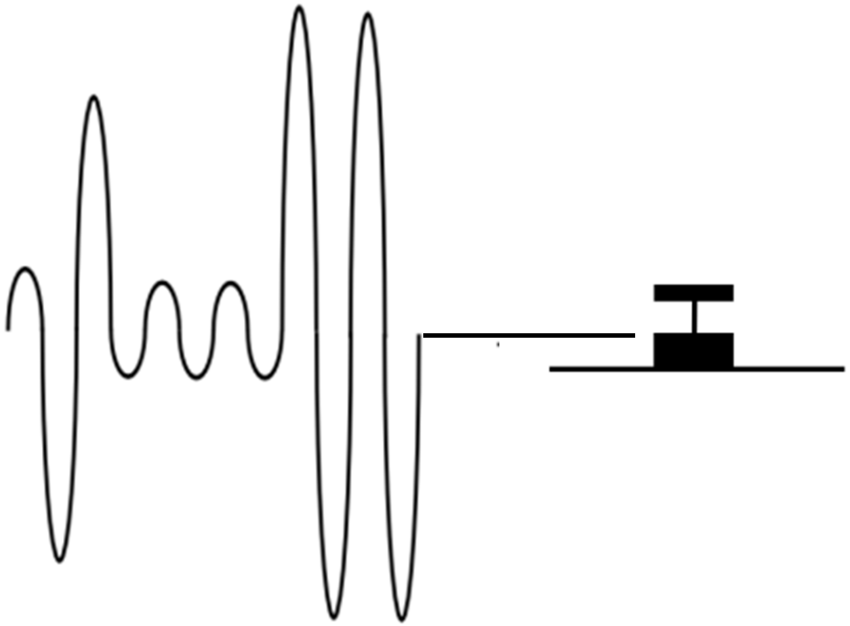
Project

Softwares

Geometry

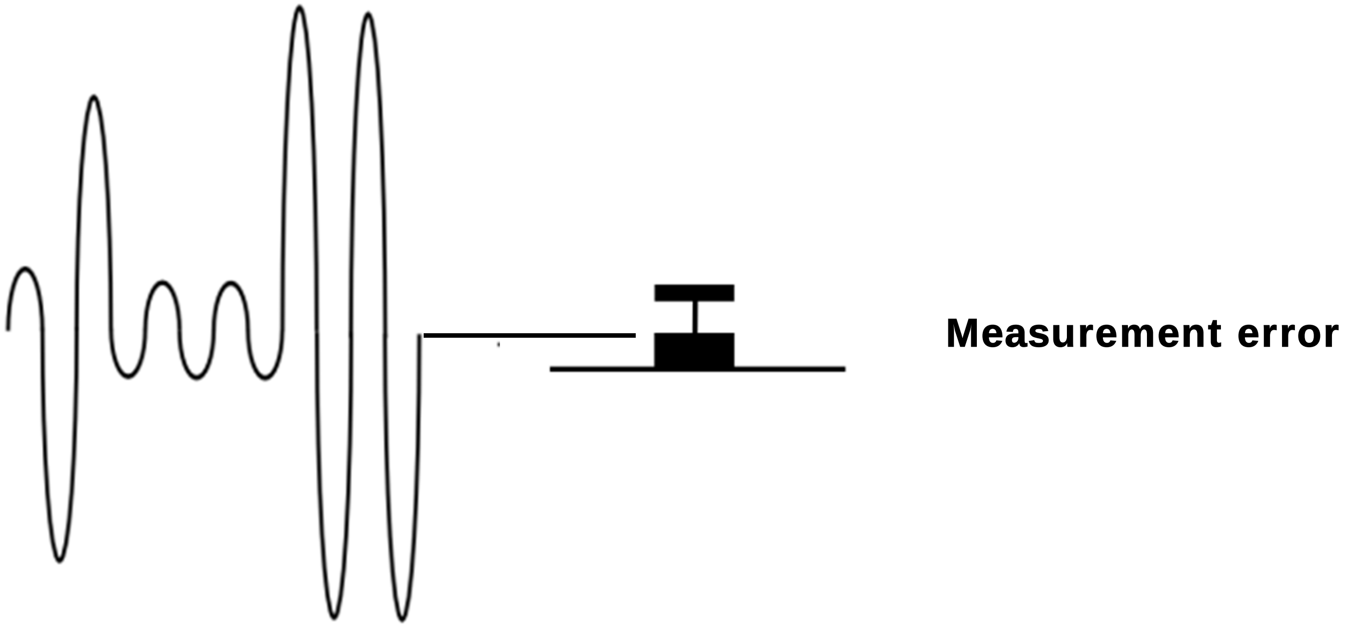
Stochasticity

Ionospheric Scintillations degrade satellite signal quality



Signal amplitude fluctuations

Ionospheric Scintillations degrade receiver measurement precision



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

The PPP stochastic model considers receiver measures to be independent/uncorrelated

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

The PPP stochastic model considers receiver measures to be independent/uncorrelated

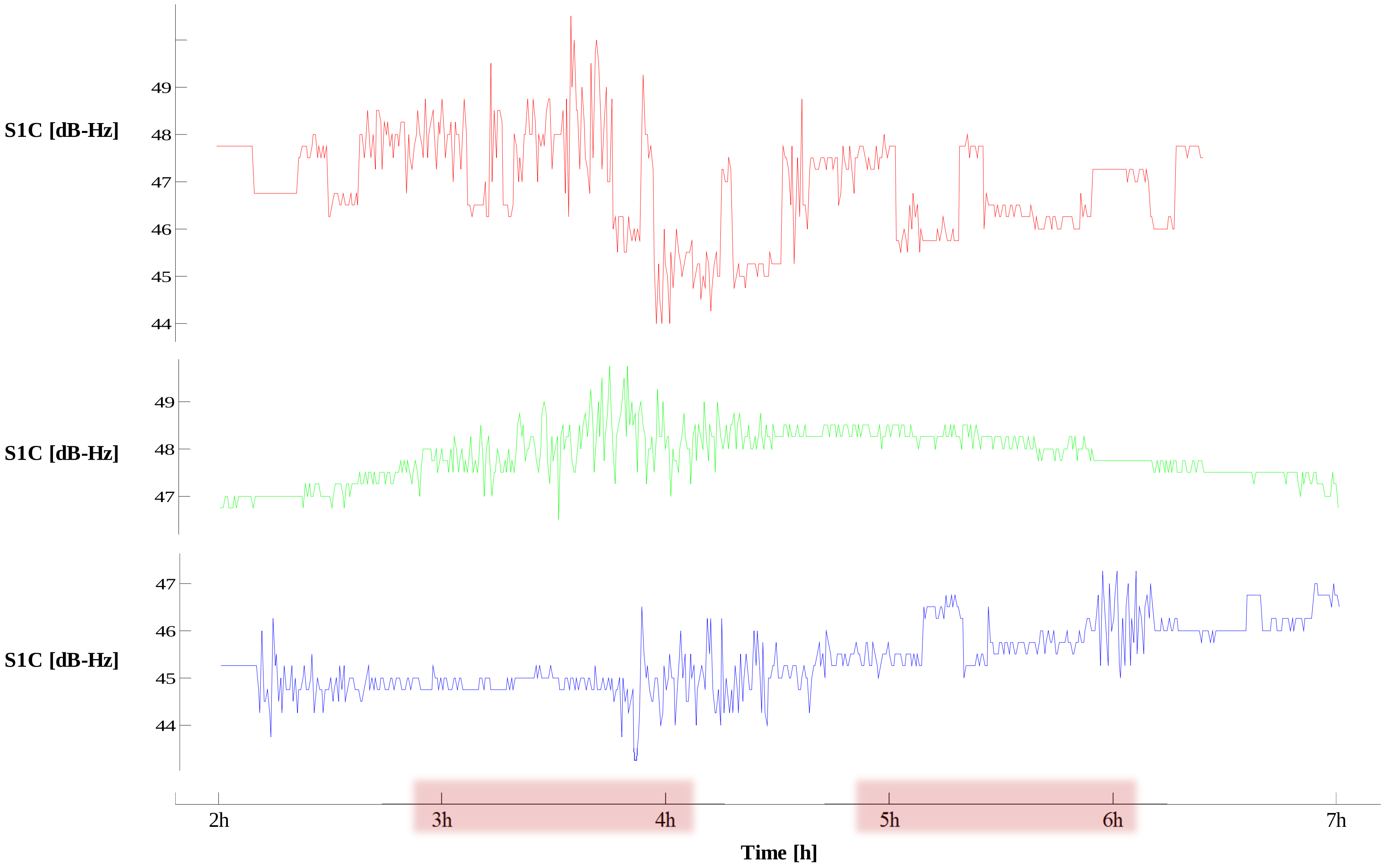
$$\Sigma = \begin{pmatrix} \sigma_1^2 & 0 & .. & 0 \\ 0 & \sigma_2^2 & .. & 0 \\ .. & .. & ... & ... \\ 0 & 0 & ... & \sigma_n^2 \end{pmatrix}$$

First law of Geography…

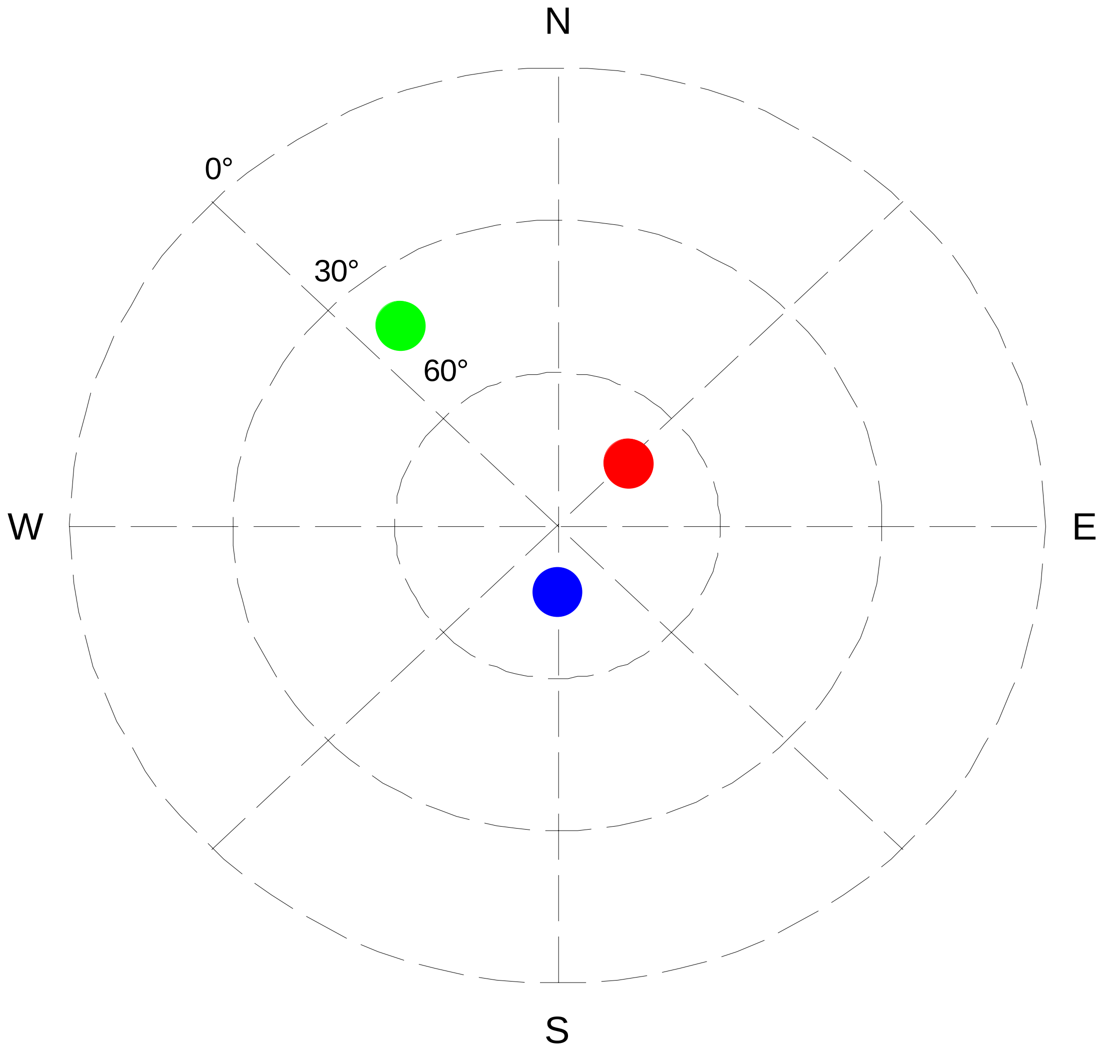
"Everything is related to everything else, but near things are more related than distant things."

Waldo Tobler

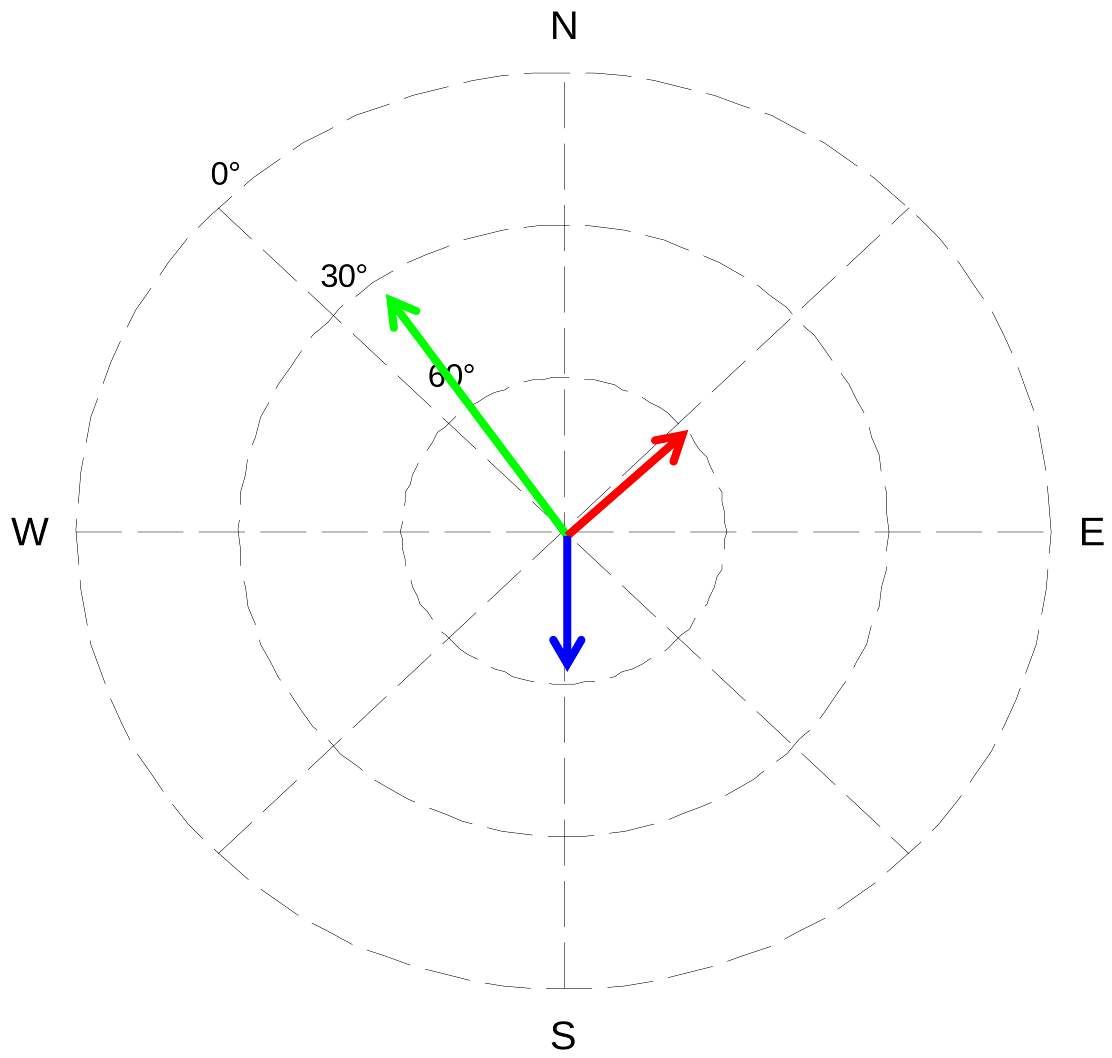
Satellite Signals are affected differently by Ionospheric Scintillations



Satellite Signals are affected differently by Ionospheric Scintillations



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



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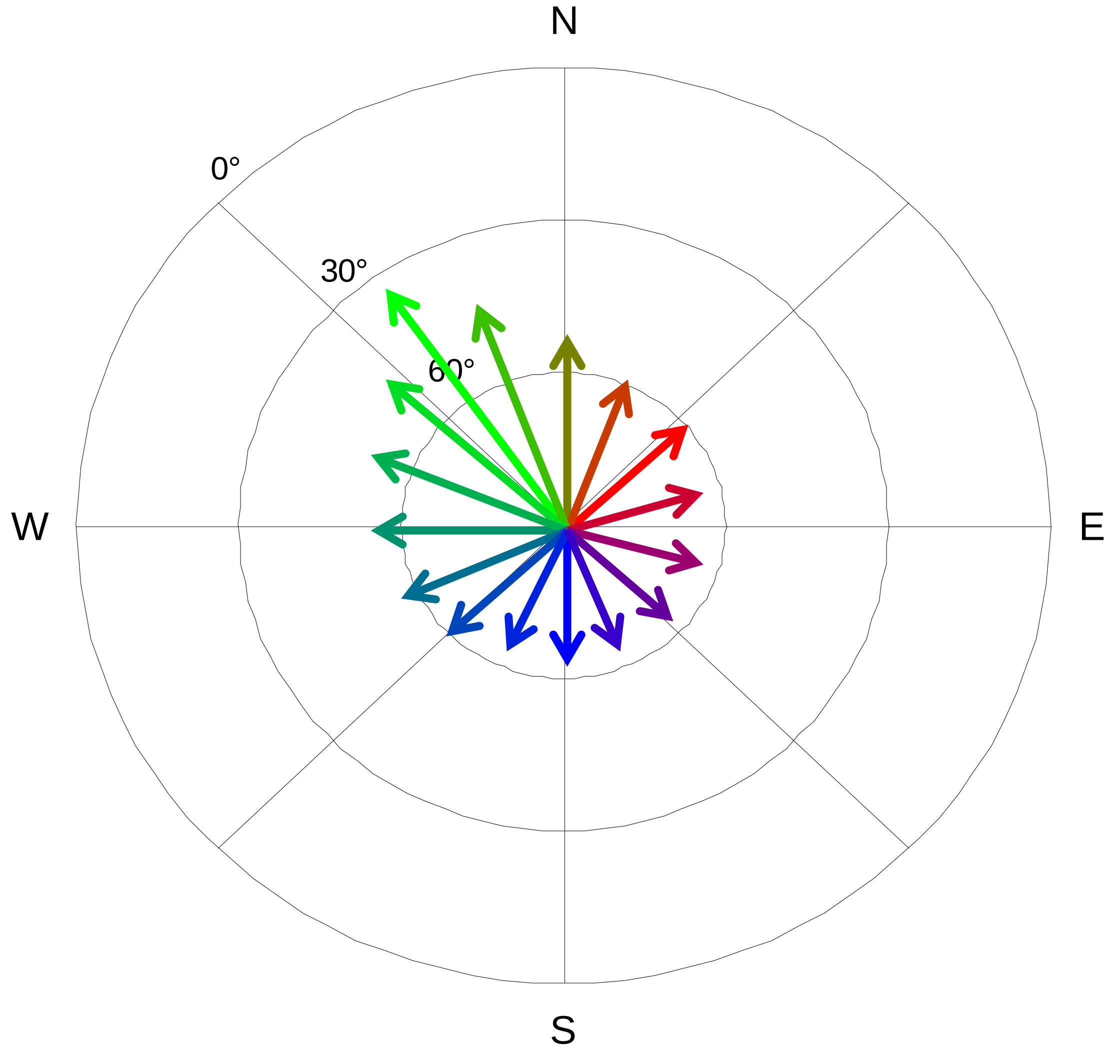

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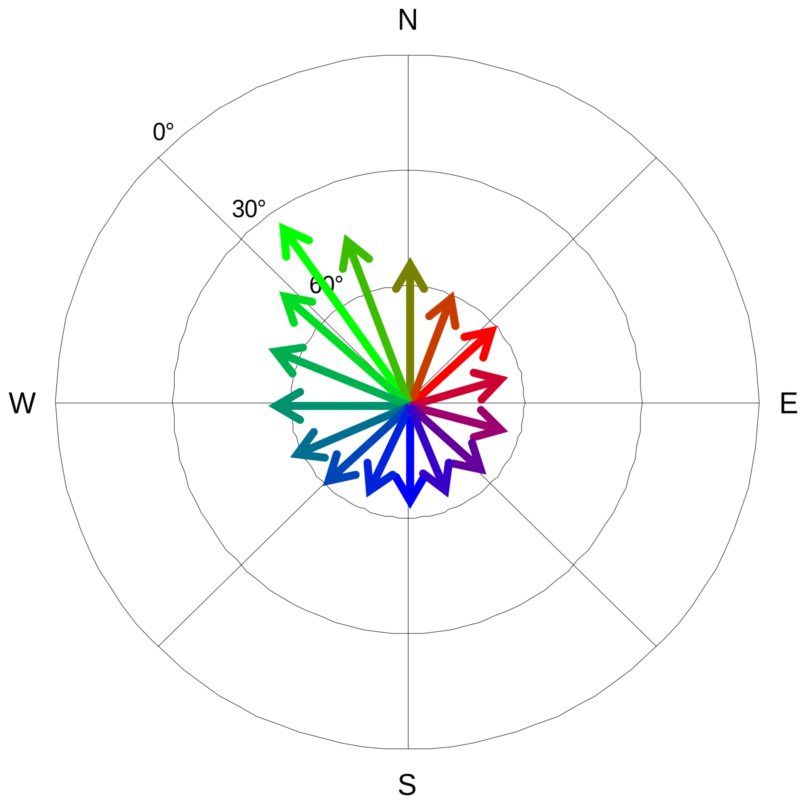

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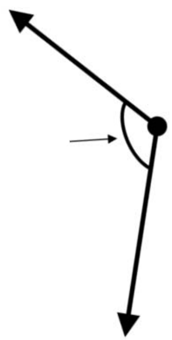
Spatial Auto-Correlation (SAC) is measured by computing SAC indices on satellite geometries

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

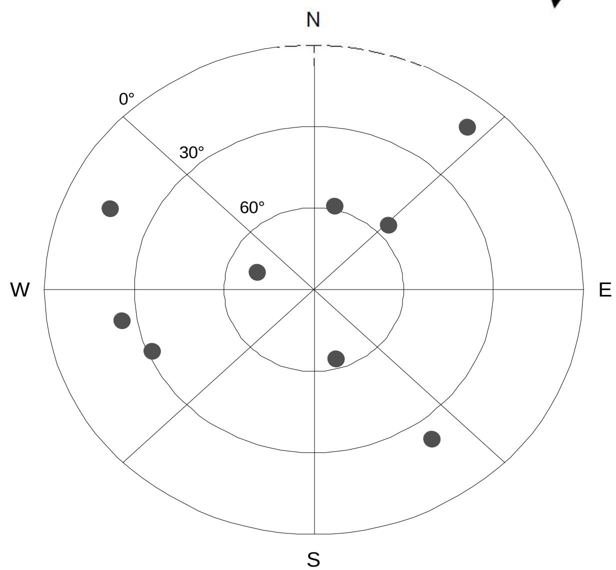
$$v_i = S1C_i$$

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



$-SAC$ $random$ $+SAC$

-1 ⟵ 0 ⟶ 1



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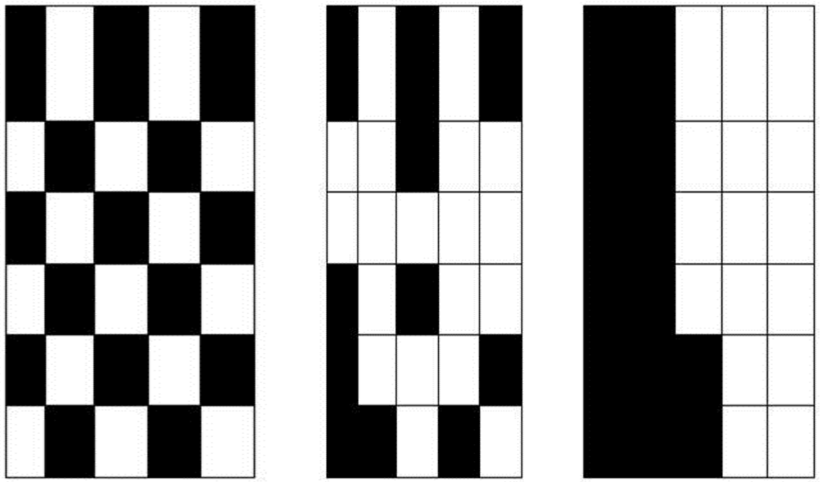
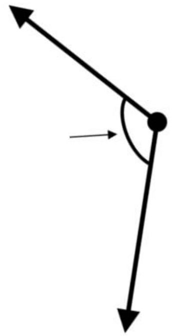
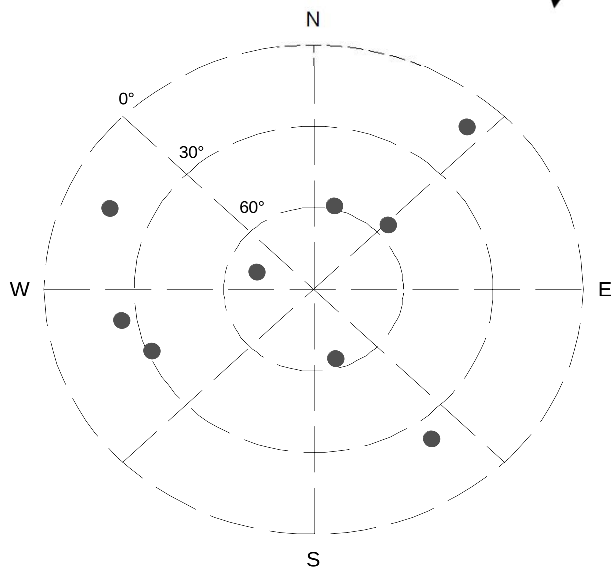
$$v_i = S1C_i$$

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

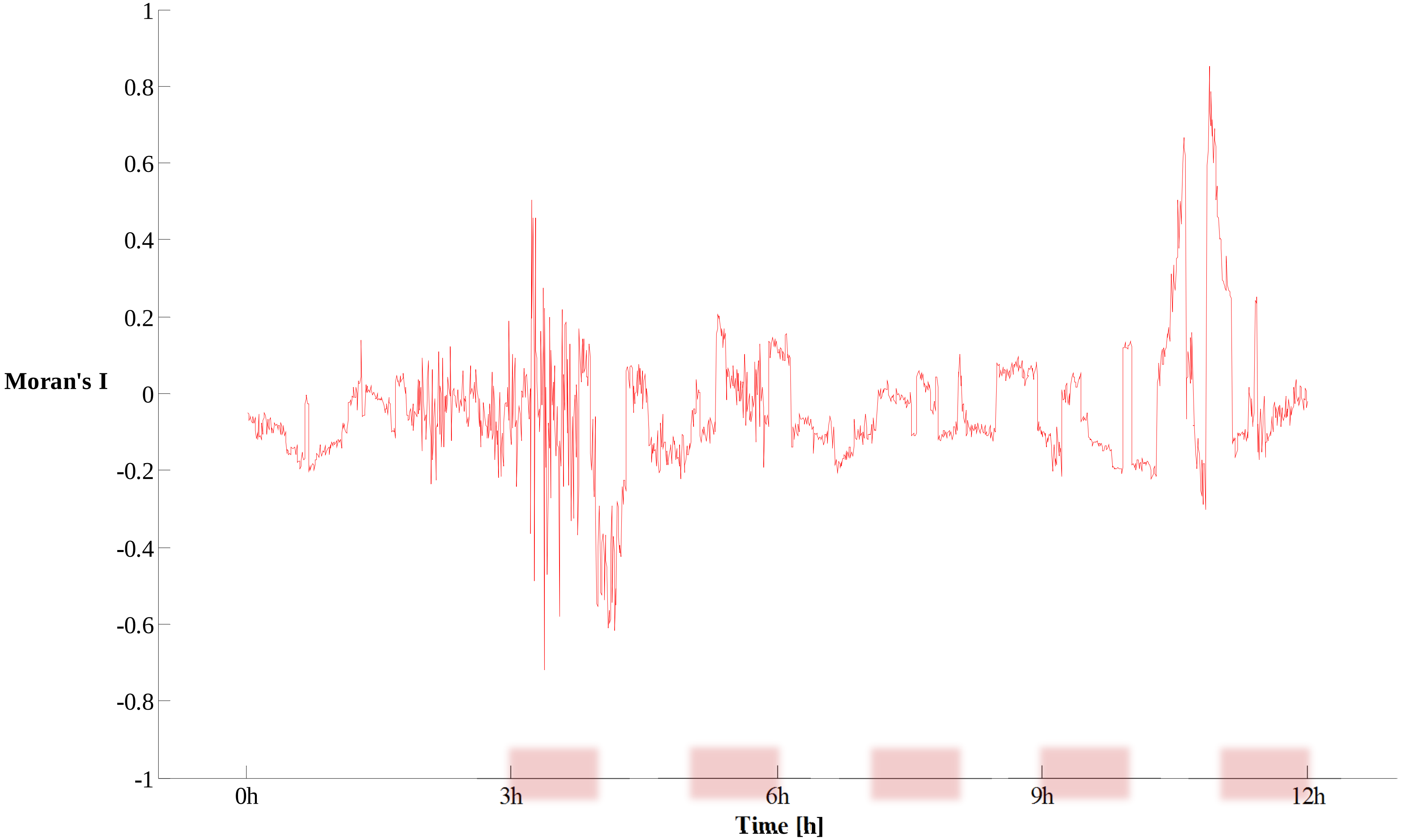






Negative S. A. **Neutral S. A.** **Positive S. A**

Spatial Auto-Correlation (SAC) is fluctuating in time



Perspective 1: several SAC indices exist with their own specificities

Moran's I

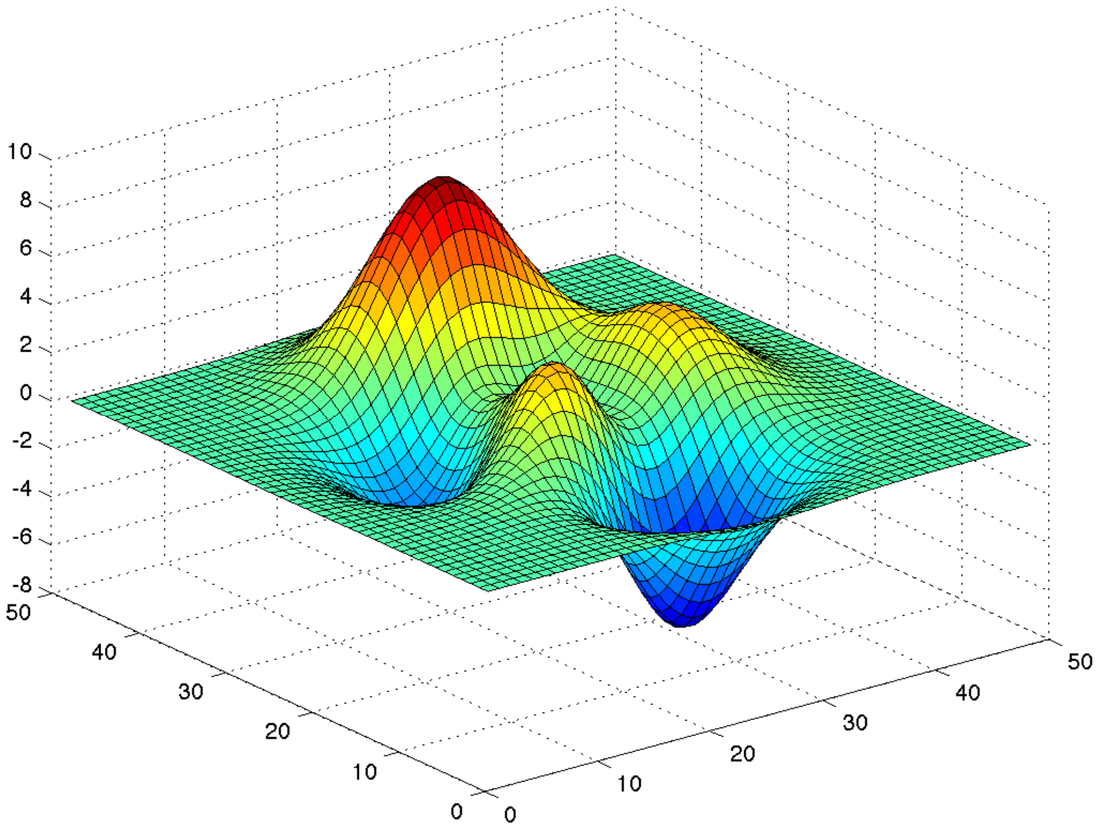
Geary's C

Mantel's Γ

Getis and Ord's index

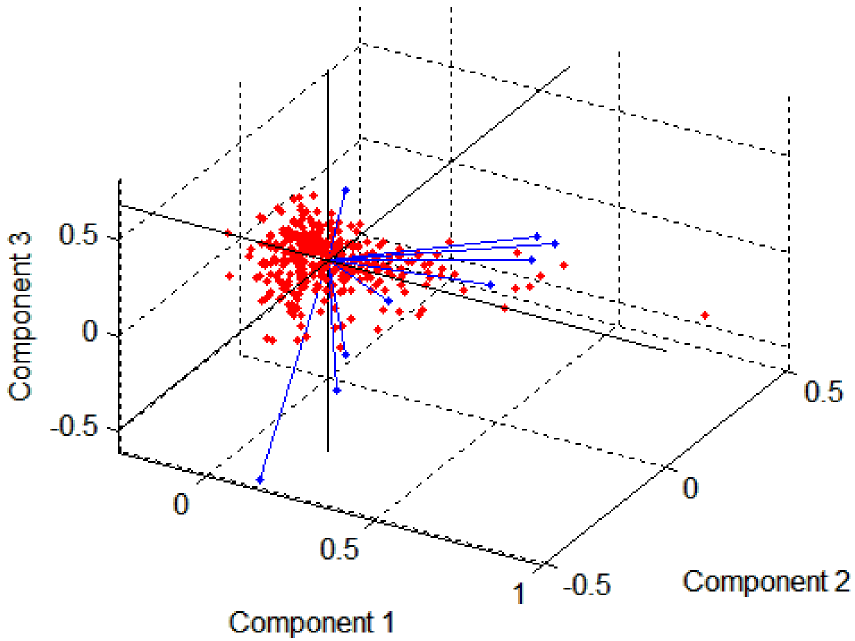
LISA tests

Perspective 2: a Least Square Adjustment to fit a polynomial surface on satellite geometries



$$S = f(\chi, \eta)$$

Perspective 3: a Principal Components Analysis (PCA) to study the correlation between variables



1	χ_1	η_1	v_1
2	χ_2	η_2	v_2
...	...	...	...
n	χ_n	η_n	v_n

$\rho_{\chi v} = ?$ $\rho_{\eta v} = ?$

Perspective 4: a SAC detection based on other observables

Signal Strength (S1C)

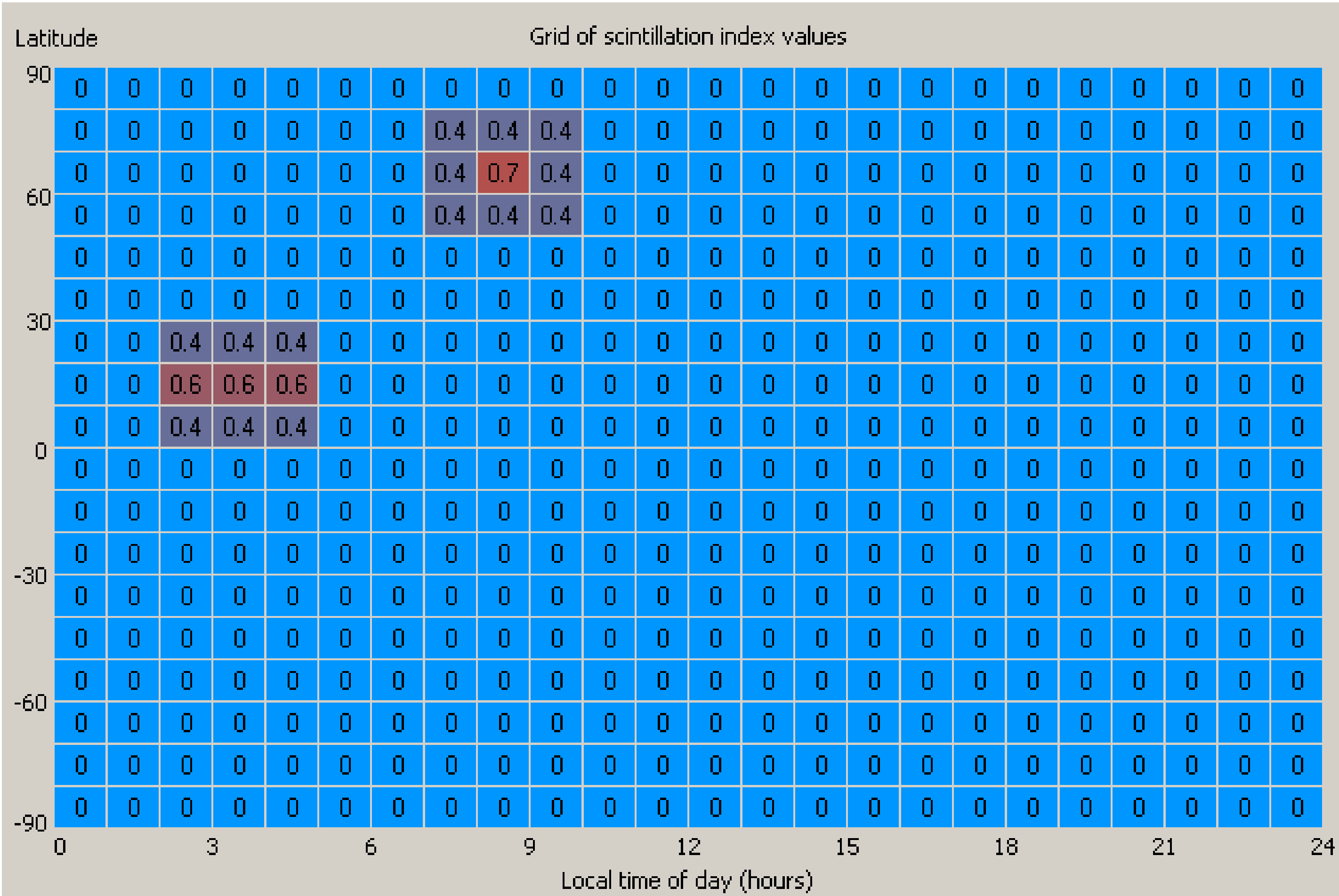
Tracking error (Conker model)

S_4

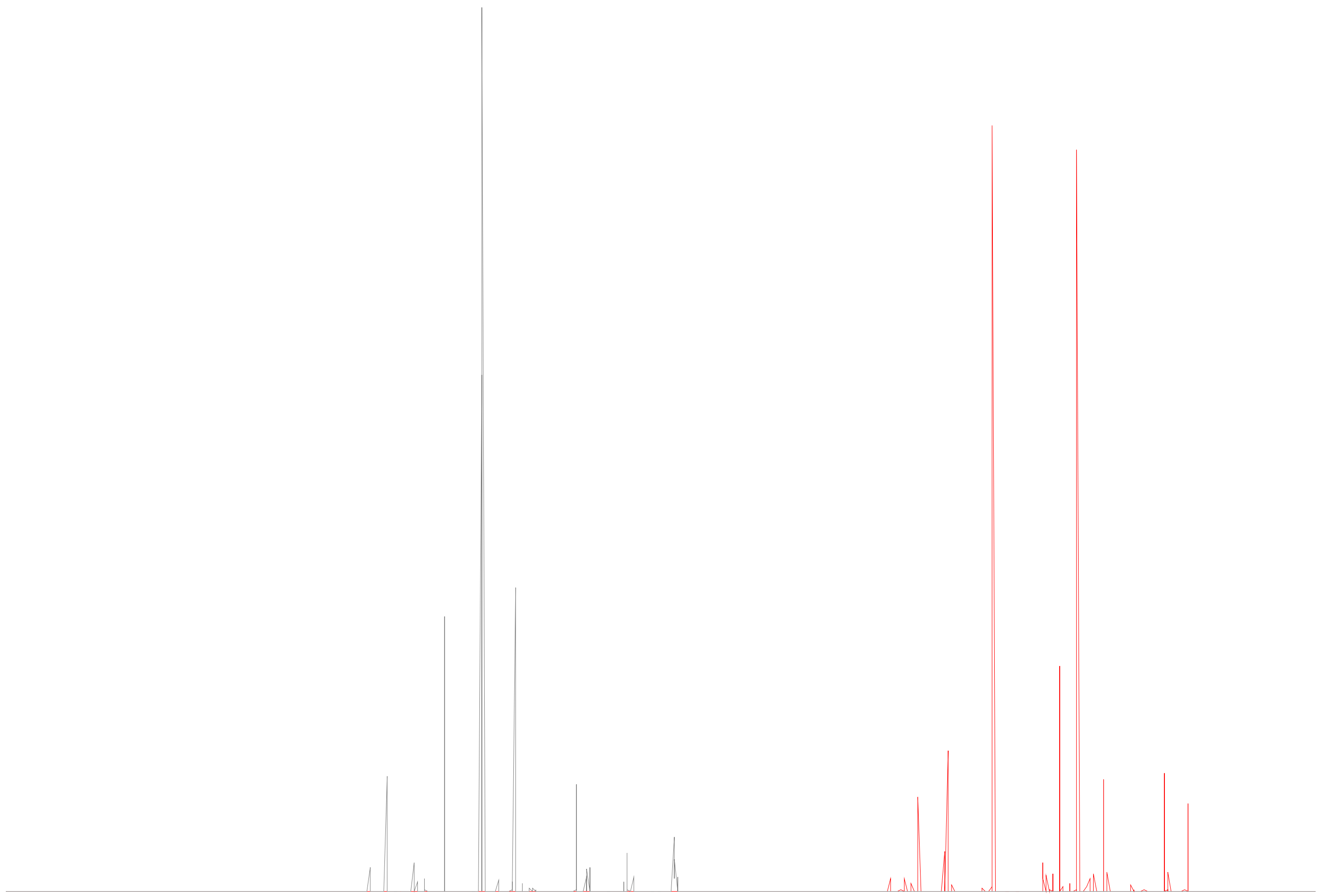
σ_φ

…

Perspective 5: more realistic simulations with potentially more tracked satellites



Perspective 6: a Correlation in Time?



Handling

Project

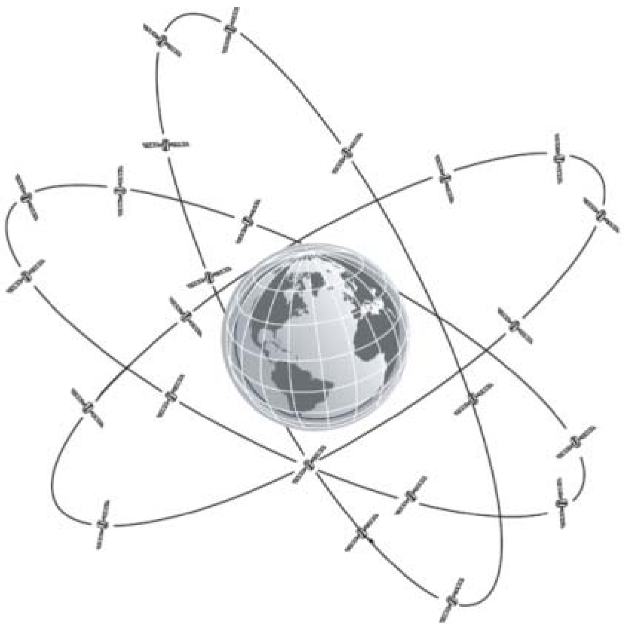
Softwares

Geometry

Stochasticity

Precise Point Positioning

Performances under Ionospheric Scintillations



Matthieu Lonchay

University of Liège, Belgium
Geomatics Unit

University of Nottingham, UK
Nottingham Geospatial Institute

PhD Meeting
19 June 2012
NGI, The University of Nottingham

Université de Liège

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