New Algorithms for Real-time PPP and RTK GNSS positioning

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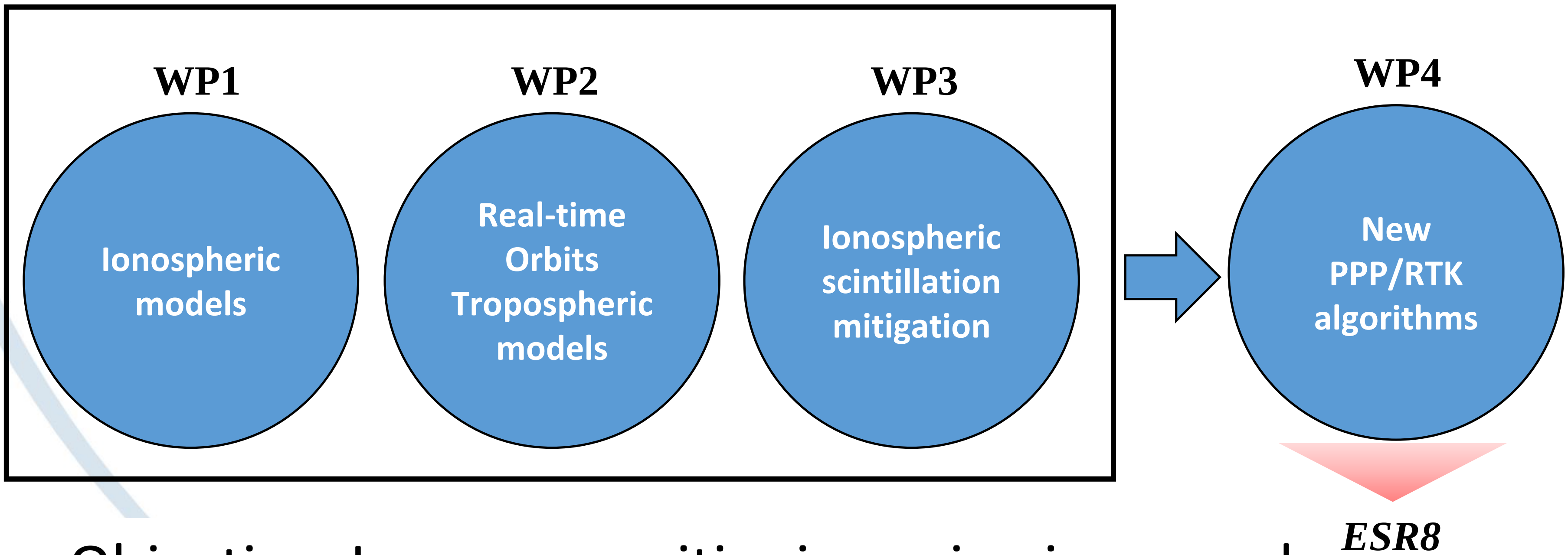
Outline

- PhD research objectives
- State of the art
- Preliminary findings
- Future research

PhD Research Objectives [1]

Title: <u>Real-time PPP and RTK algorithm development</u>

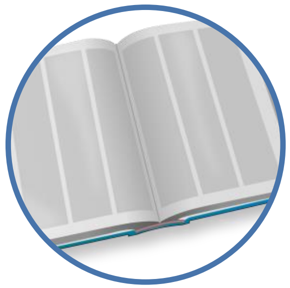


Objective: <u>Improve positioning using improved external information</u> (Example: Park et al 2016)

PhD Research Objectives [2]

Investigate

- WP1-4 topics
- PPP/RTK theory
- Data transmission

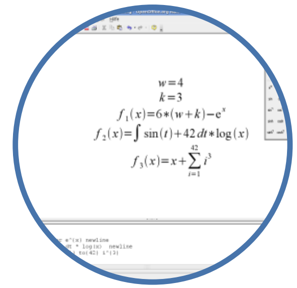


Study

- PPP/RTK algorithms
- PPP/RTK software
- RTCM standards

Collaborate

- WP1-3: inputs
- WP4: algorithms



Develop

- Algorithms which incorporate results from WP1-3

Research Roadmap

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PhD Research Objectives [3]

GNSS models

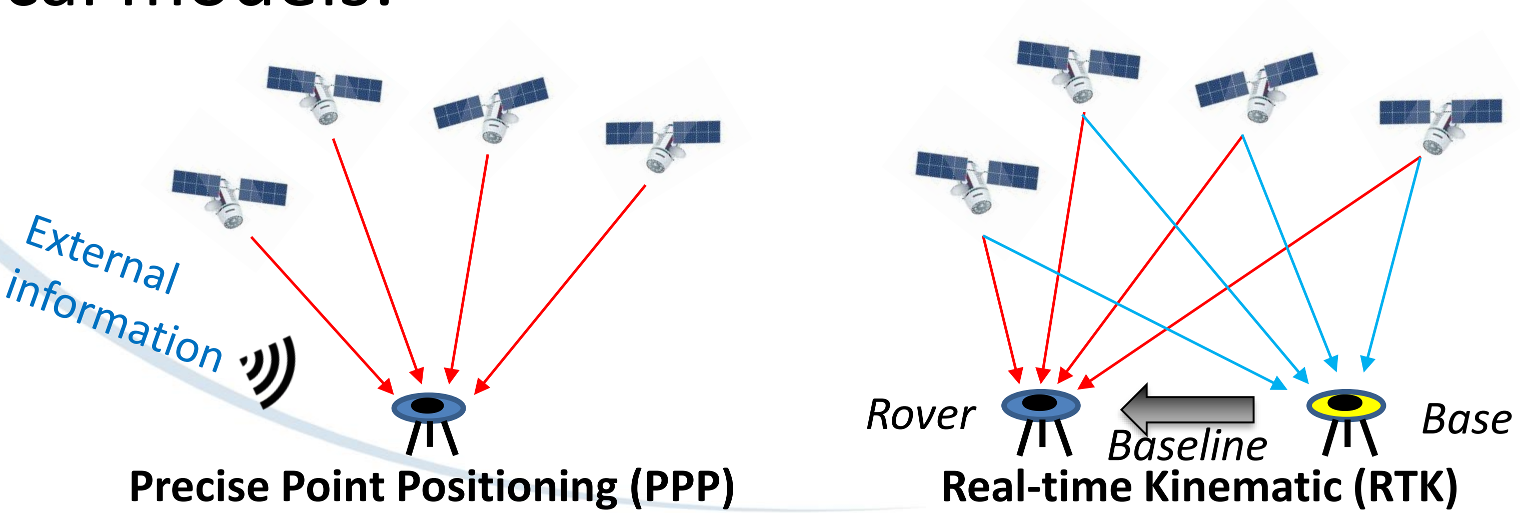
Mathematical models:

(Pseudorange) $$P_{gi}^{k} = \rho_i^k + ct_i^k + \frac{\mu_i^k}{f_g^2} + b_{gi}^k - e_{gi}^k$$

(Carrier-phase) $$L_{gi}^{k} = \rho_i^k + ct_i^k - \frac{\mu_i^k}{f_g^2} + B_{gi}^k + \lambda_g N_{gi}^k - \varepsilon_{gi}^k$$

(Geng 2010)

Physical models:



State of the art [1]

GNSS algorithms

Form linear combinations of observation models to create new observables (Hauschild 2017)

Combined observable	Purpose
Ionospheric	Isolate ionospheric term
Ionospheric-free	Eliminate ionospheric term
Wide-lane	Ambiguity resolution
Narrow-lane	Form Melbourne–Wübbena combination
Melbourne–Wübbena	Carrier-phase cycle slips
Multipath	Isolate multipath errors

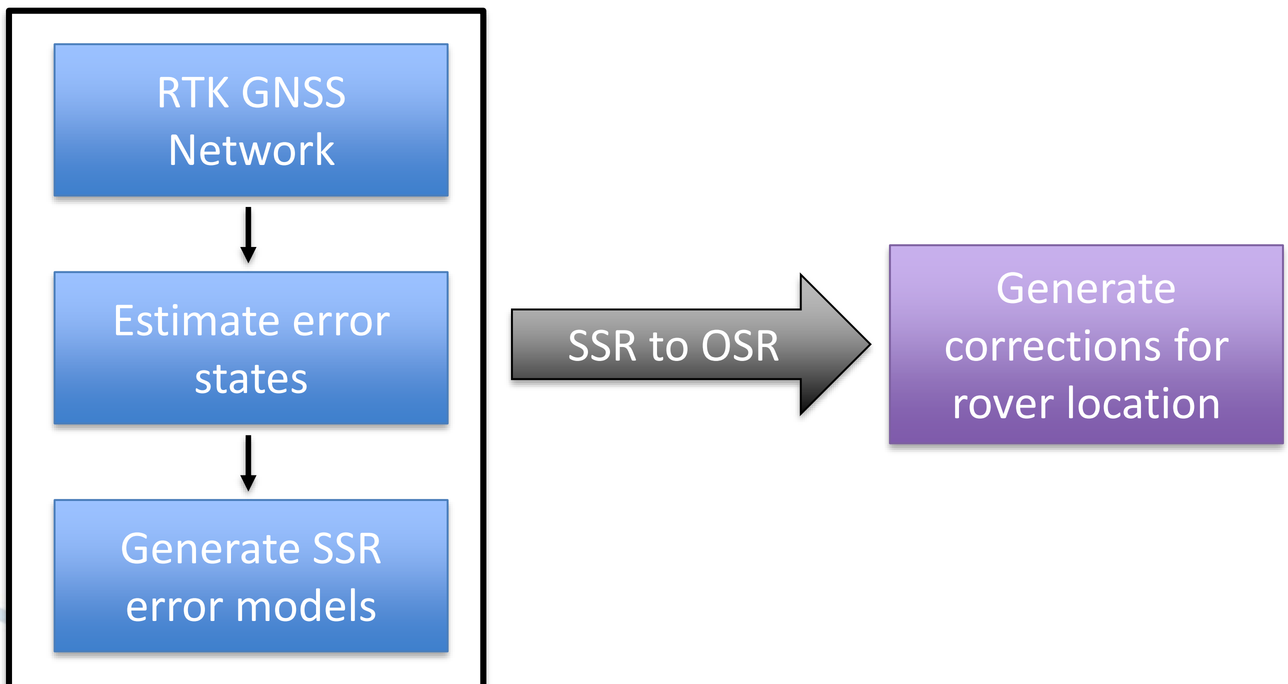
Note: Propagation error law results in noise amplification for new observables

State of the art [2]

GNSS data transmission

RTCM State-Space Representation (SSR)

- Method to correct observations at rover location



Preliminary findings [1]

UNOTT GNSS software: *POINT*

- Products required for PPP processing

External Information	Description
RINEX	GNSS measurements
Navigation data	Broadcast ephemeris for GNSS SVs
Ocean tide loading	Displacement due to ocean load
Planetary ephemeris	Positions of planetary bodies
Earth orientation parameters	Rotational effects, polar motion
IGS SVs clock/orbit	IGS Precise SVs clock/orbit
Antenna calibration	Antenna phase center variation
Leap second	GPS time vs UTC time
Differential code biases (DCBs)	P1-C1, P1-P2 bias for each satellite

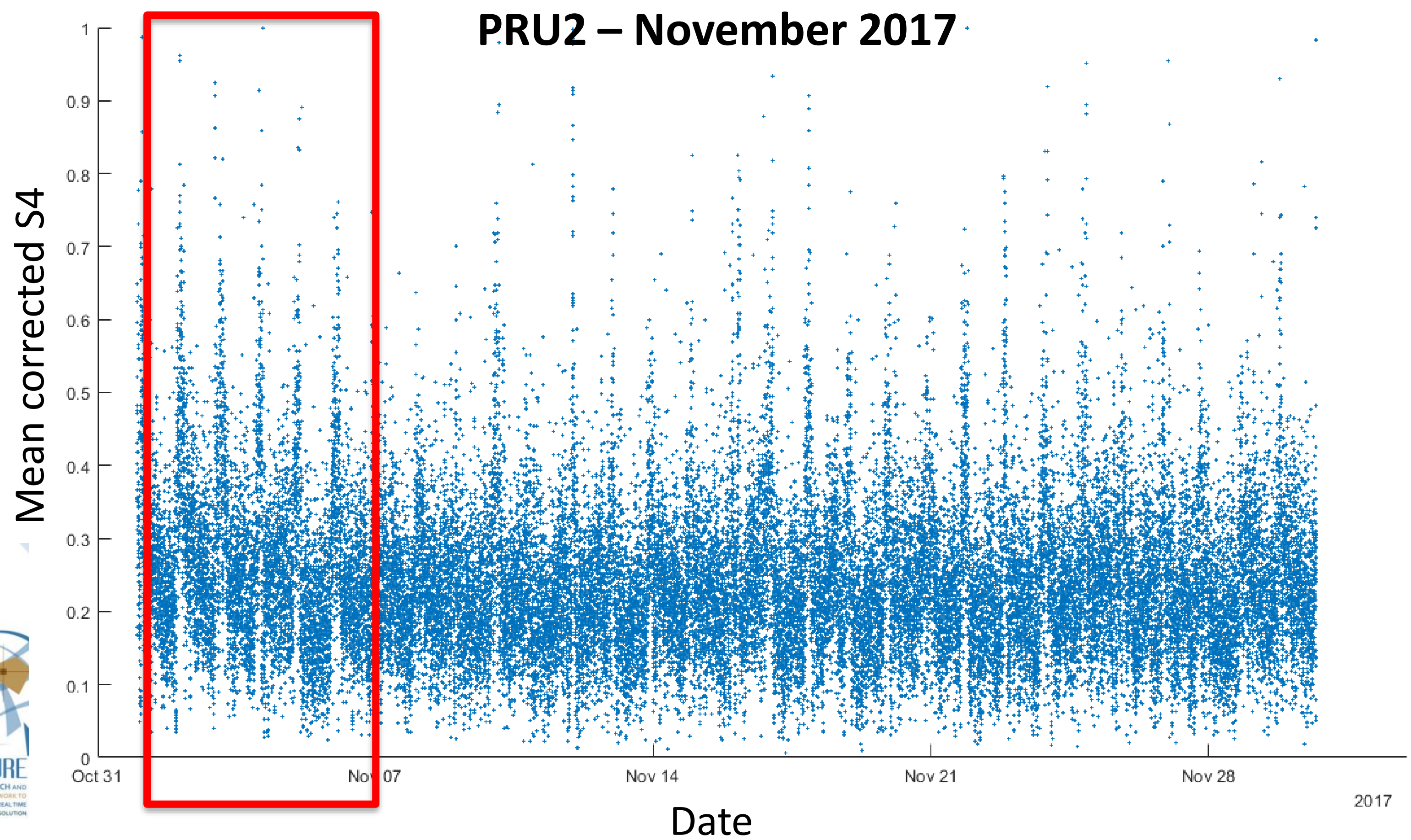
Preliminary findings [1]

UNOTT GNSS software: *POINT*

- Extended Kalman filter
- Existing weighting schemes
- Existing linear combinations
- (Float) ambiguity resolution
- Must use algorithms consistent with external products!

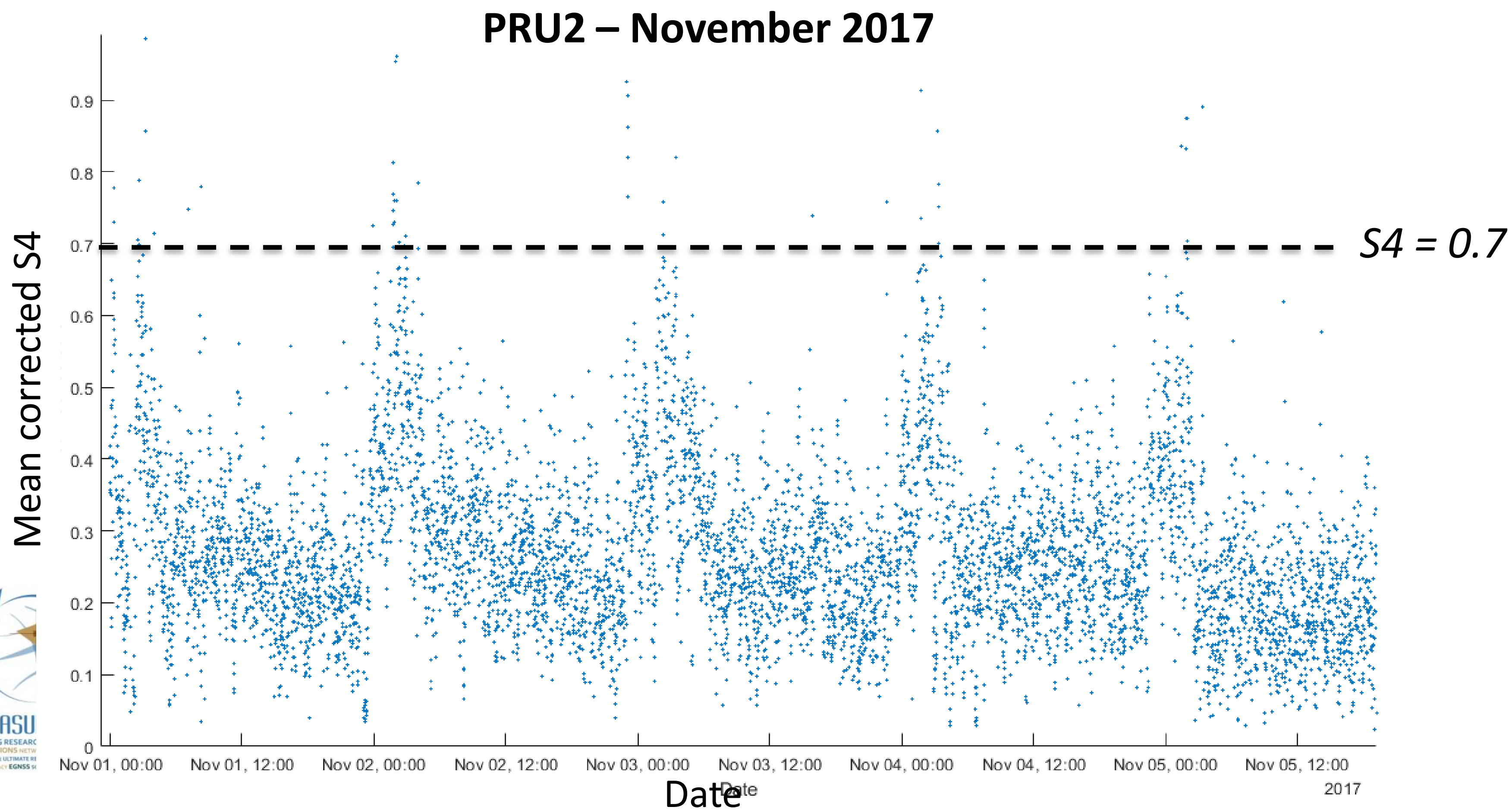
Preliminary findings [2]

Secondment: ISMR analysis



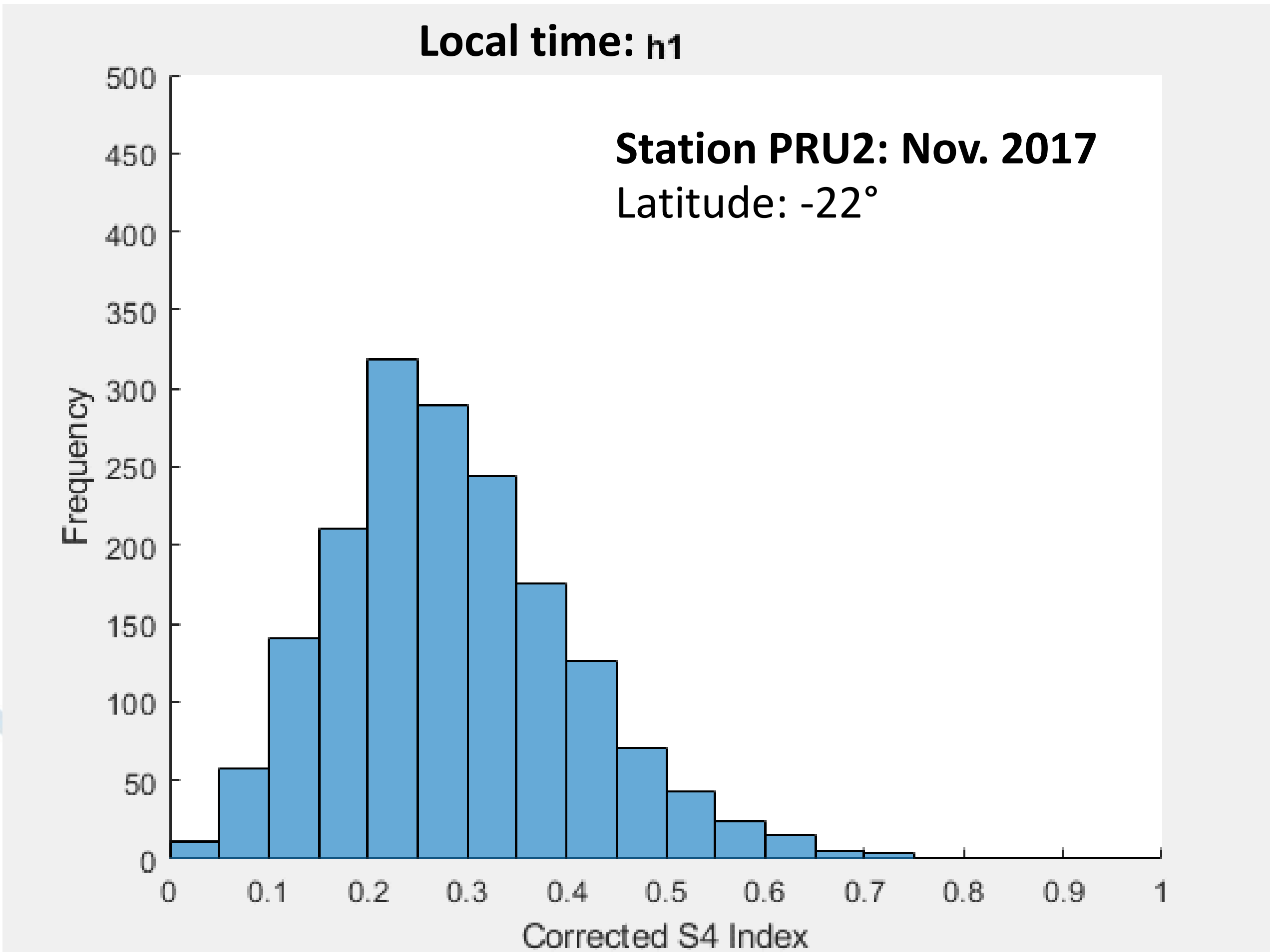
Preliminary findings [2]

Secondment: ISMR analysis



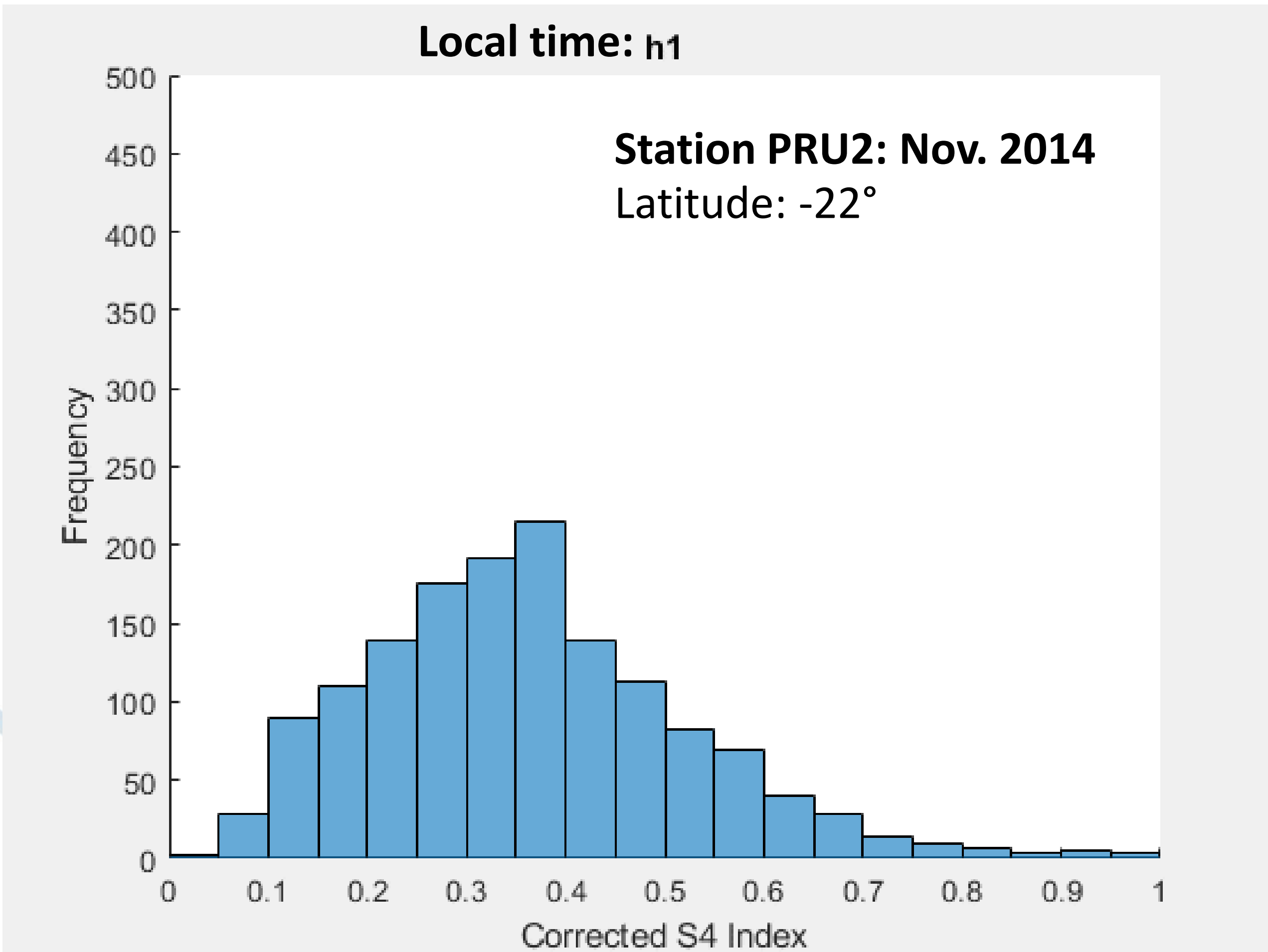
Preliminary findings [2]

Secondment: ISMR analysis



Preliminary findings [2]

Secondment: ISMR analysis



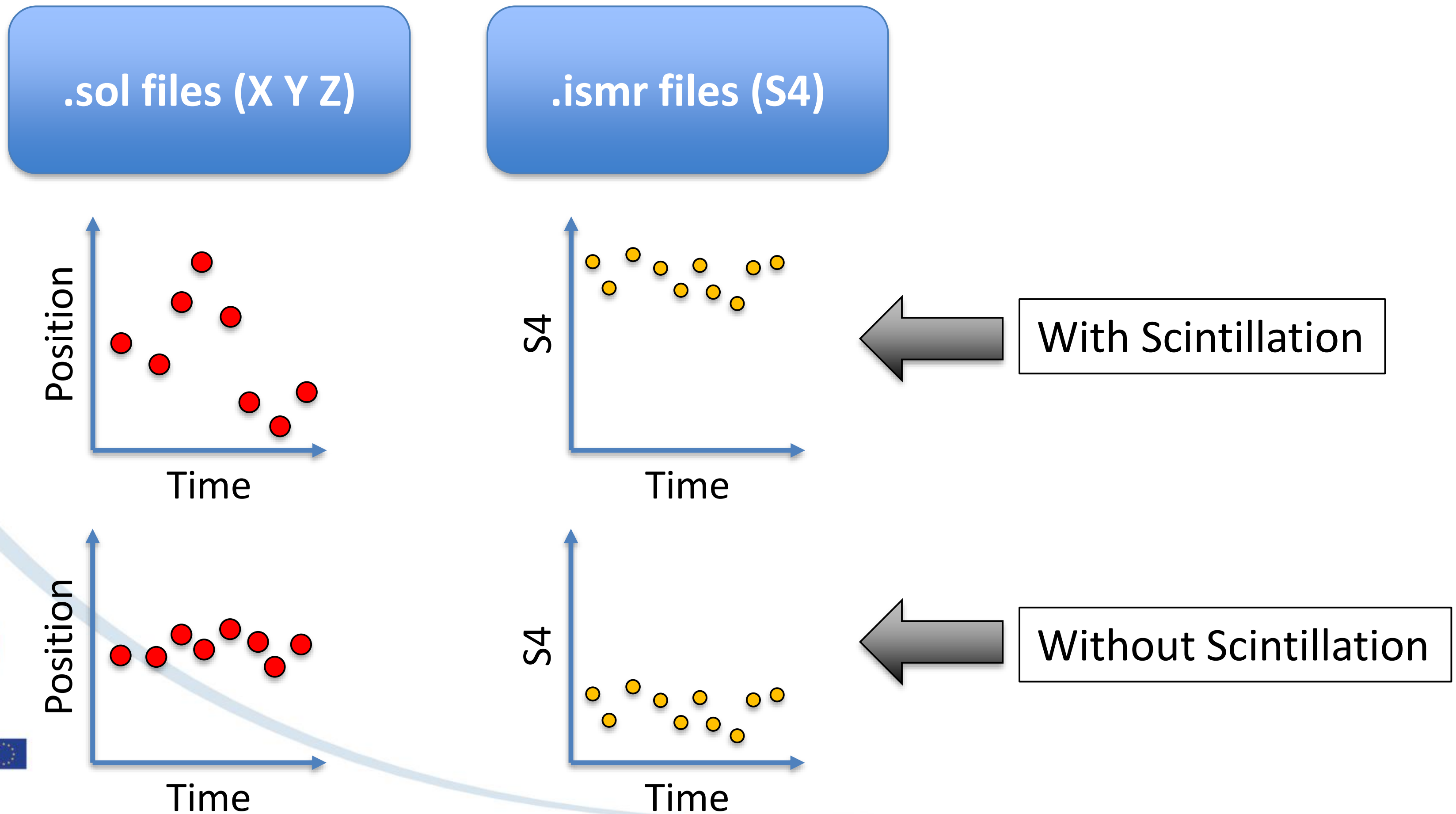
Preliminary findings [2]

Secondment: positioning and scintillation

- Two perspectives:
  - (1) Real-time network base stations
    - Maximize useable observations (DD algorithms)
    - Mitigate scintillation for position estimates
  - (2) Roving receivers
    - Require ionospheric scintillation information
    - Scintillation mitigation strategy

Preliminary findings [2]

Secondment: positioning and scintillation



Preliminary findings [2]

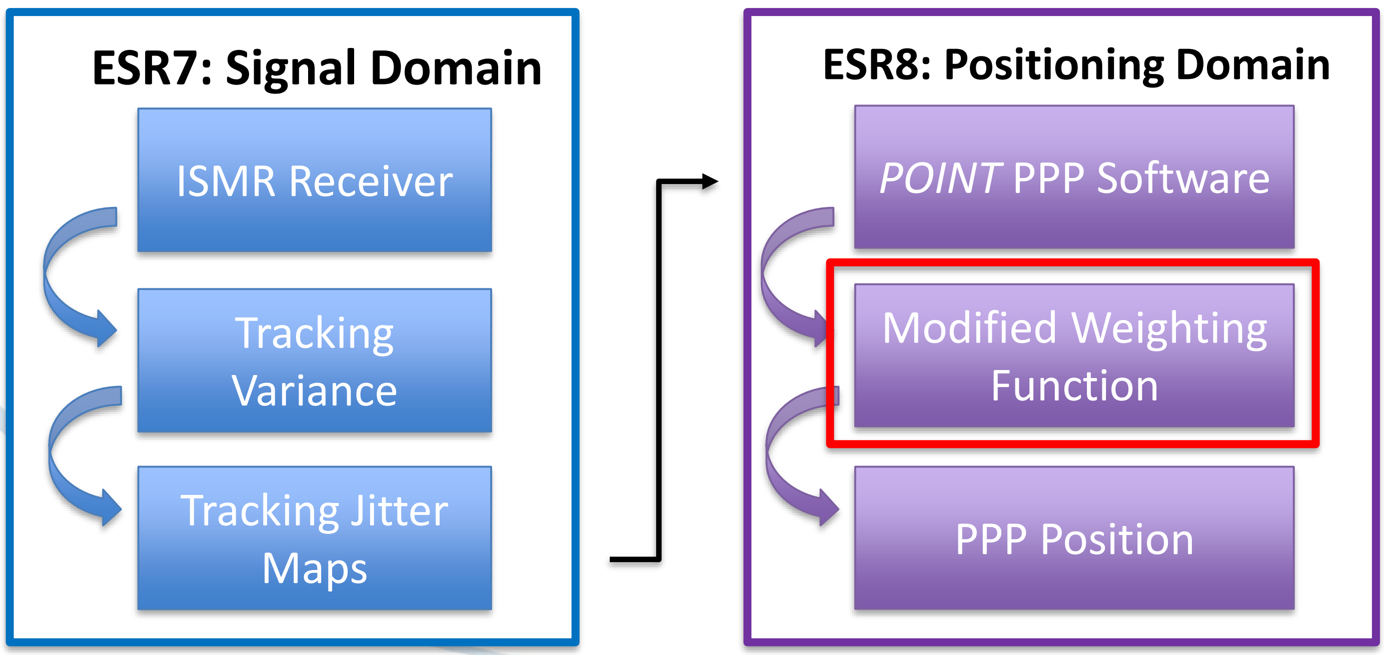
Secondment: positioning and scintillation

- Problems:
  - 1-hr positions compared to 1-min S4 values
  - Data availability (RTN and ISMR)
  - Missing spatial correlation of data
- Benefits:
  - Performance of RTN software during scintillation
  - TREASURE collaboration opportunity

Preliminary findings [3]

Ionospheric scintillation mitigation

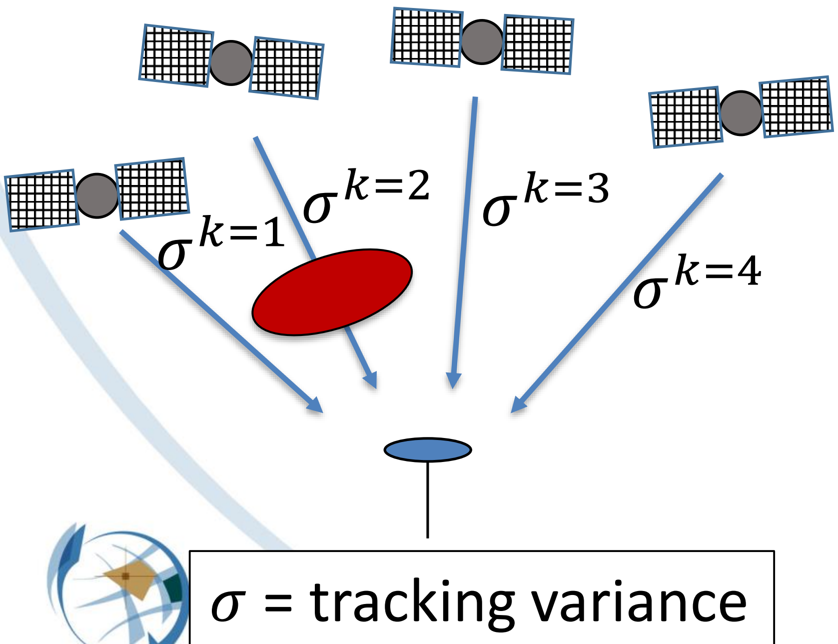
- Collaboration with ESR7
- Tracking variance based weighting scheme



Preliminary findings [3]

Ionospheric scintillation mitigation

- Improve stochastic model



Weight matrix:

$$\begin{bmatrix} \frac{1}{(\sigma^{k=1})^2} & 0 & 0 & 0 \\ 0 & \frac{1}{(\sigma^{k=2})^2} & 0 & 0 \\ 0 & 0 & \frac{1}{(\sigma^{k=3})^2} & 0 \\ 0 & 0 & 0 & \frac{1}{(\sigma^{k=4})^2} \end{bmatrix}$$

Preliminary findings [3]

Ionospheric scintillation mitigation

In collaboration with ESR7

- Real or simulated data
  1. Grid containing scintillation parameters
  2. Calculate tracking loop variance (Conker)
  3. Verticalize tracking loop variance
- Analyse positioning domain during scintillation

Preliminary findings [4]

RTCM-SSR demonstrator

- Tool to demonstrate data transmission for new algorithms or new information

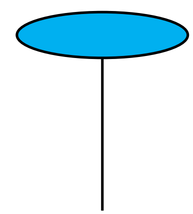
State-space modelling

Server

New RTCM-SSR messages:

- Tracking loop variance parameters
- New tropospheric model parameters
- New ionospheric model parameters

Examples for future research



Rover

Future research [1]

UNOTT GNSS software: *POINT*

- Implement and test tracking variance based weighting method (WP3)
- Incorporate results from WP1-3 (ionospheric and tropospheric models) in new algorithms
  - Collaboration with ESRs in WP1-2
- Investigate *POINT* real-time capabilities

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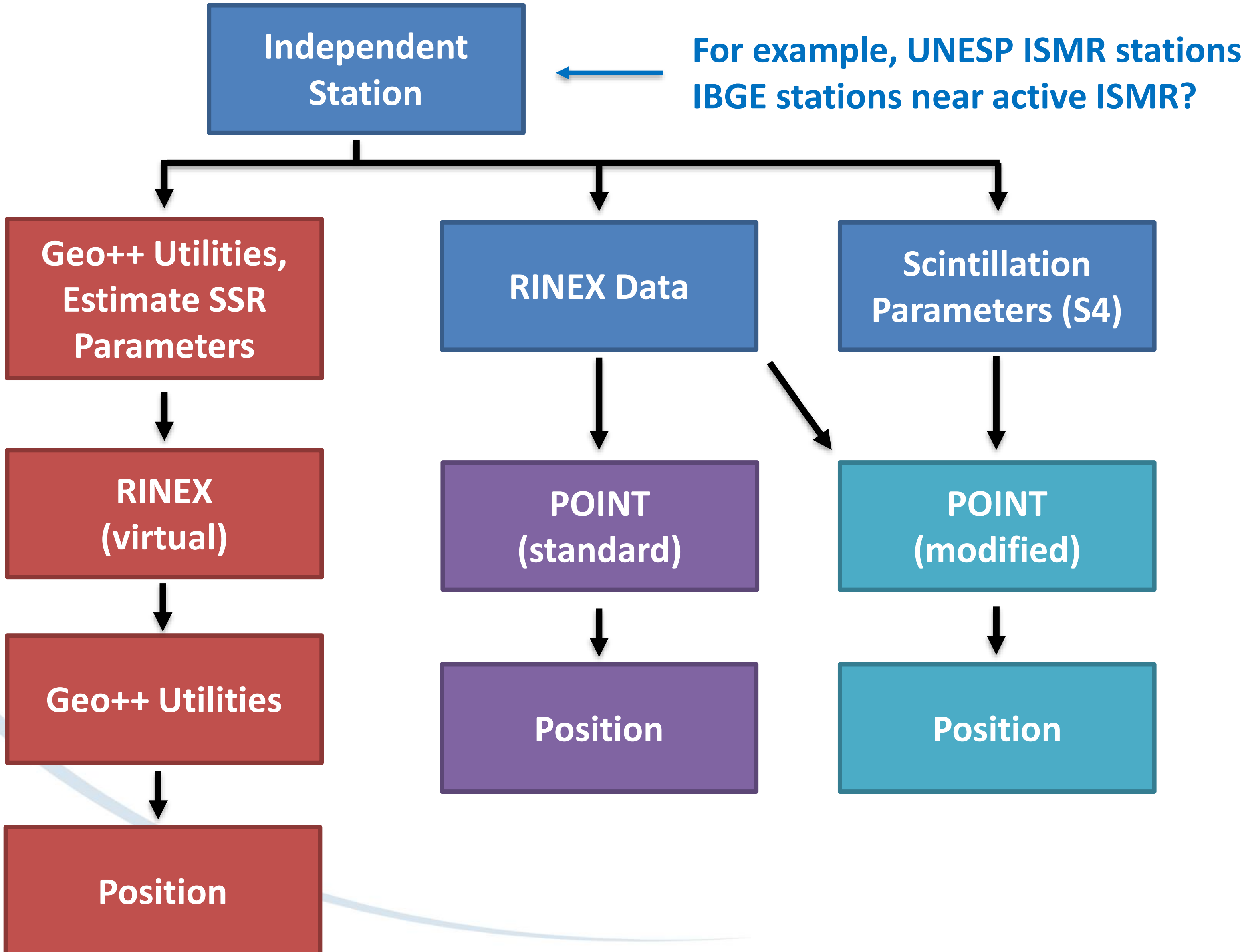
Future research [2]

RTCM-SSR demonstrator

- Develop demonstrator for compact SSRZ format
- Develop new message to transmit tracking variance map information
- Modify existing messages based on results from WP1-3

Future research [3]



Questions?

References:

Geng, J. (2010). Rapid Integer Ambiguity Resolution in GPS Precise Point Positioning. Nottingham, University of Nottingham.

Hauschild, A. (2017). Combinations of Observations. Springer Handbook of Global Navigation Satellite Systems. P. Teunissen and O. Montenbruck. Berlin**:** 590-591.

J. Park, V. S., M. Aquino, C. Cesaroni, L. Spogli, A. Dodson, G. De Franceschi (2016). "Performance of ionospheric maps in support of long baseline GNSS kinematic positioning at low latitudes." **51**(5).

Acknowledgements:

TREASURE project network

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In collaboration with TREASURE ESRs 7 & 10

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