Weather monitoring Based on Collaborative Crowdsourcing

NAVISP Industry Days - ESTEC

DEFENCE AND SPACE

22nd January 2020

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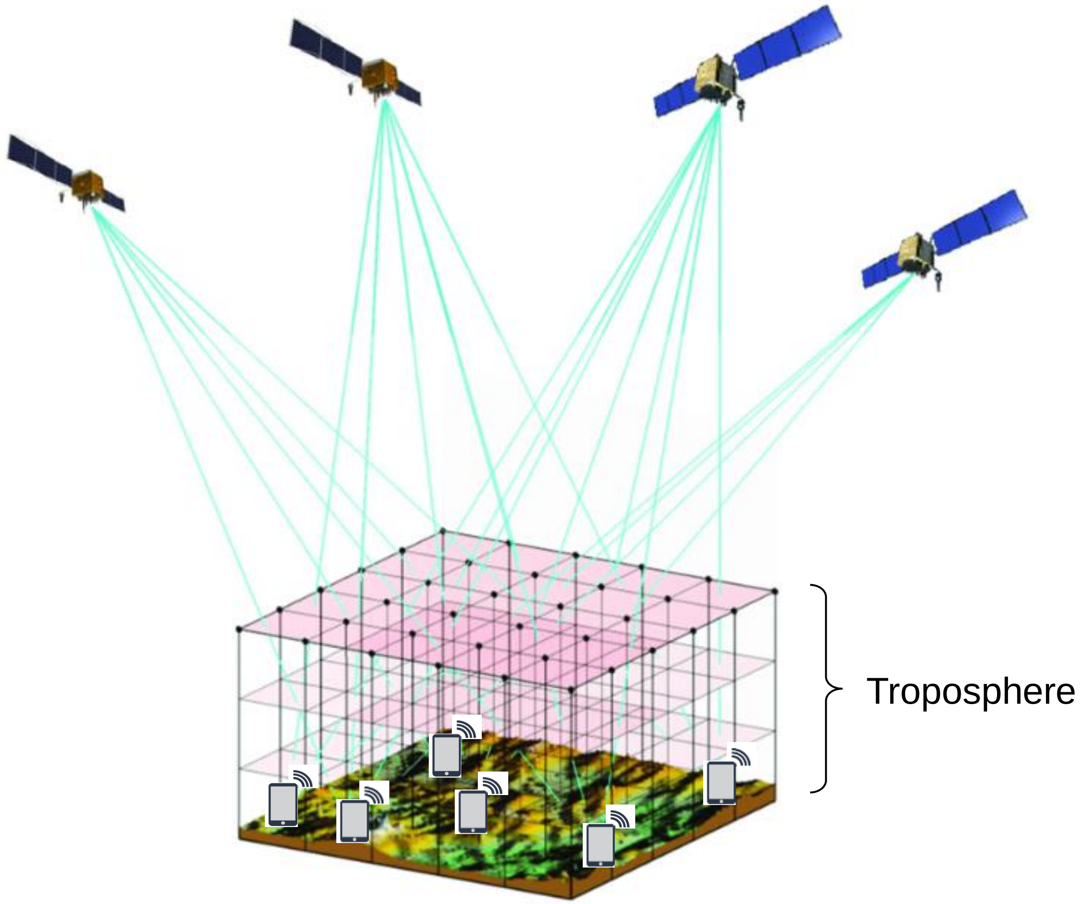
AIRBUS

Objectives and approach

GNSS receiver network

Collaborative crowdsourcing algorithms

Troposphere delays (ZWD) estimated for NWP



Content

1. **Project summary**

2. **Organization**

3. **Results**

4. **Conclusion/recommendations**

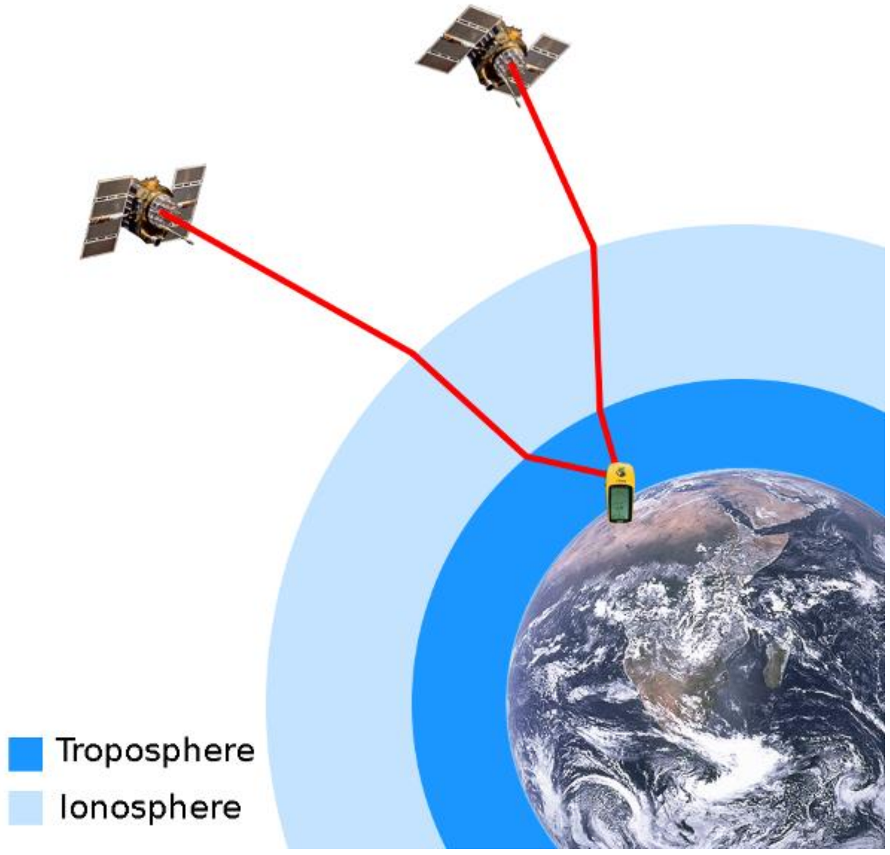
5. **Perspectives**

Introduction on troposphere

- Lowest part of the atmosphere, below ionosphere
- From the surface of the Earth to ~ 50km
- GNSS Slant Total Delay (STD) =

Slant Hydrostatic delay (SHD) + **Slant Wet delay** (SWD)

$\Rightarrow$ **SWD contains troposphere water vapor content information**



GNSS signal propagation in ionosphere and troposphere

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Motivations

- **Limited area NWP: AROME Model example**

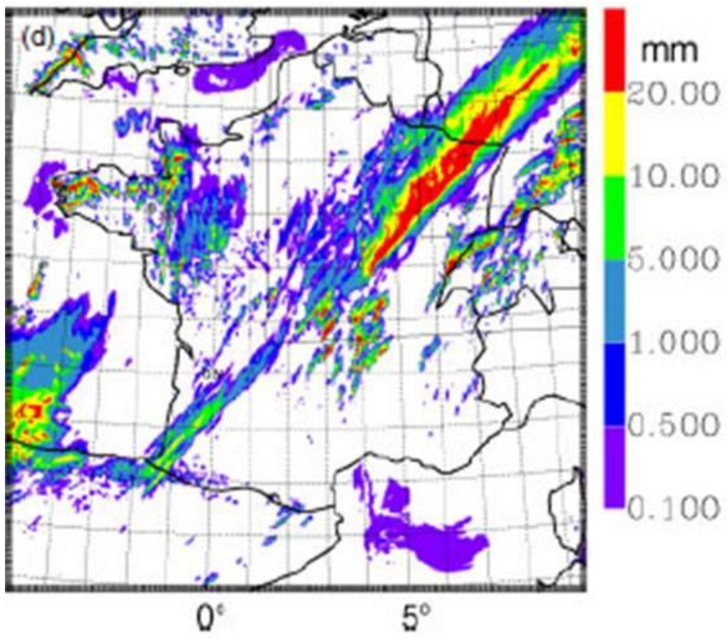
Conventional sensors (radiometers)

☒ Low spatial resolution

+

Network of GNSS receivers

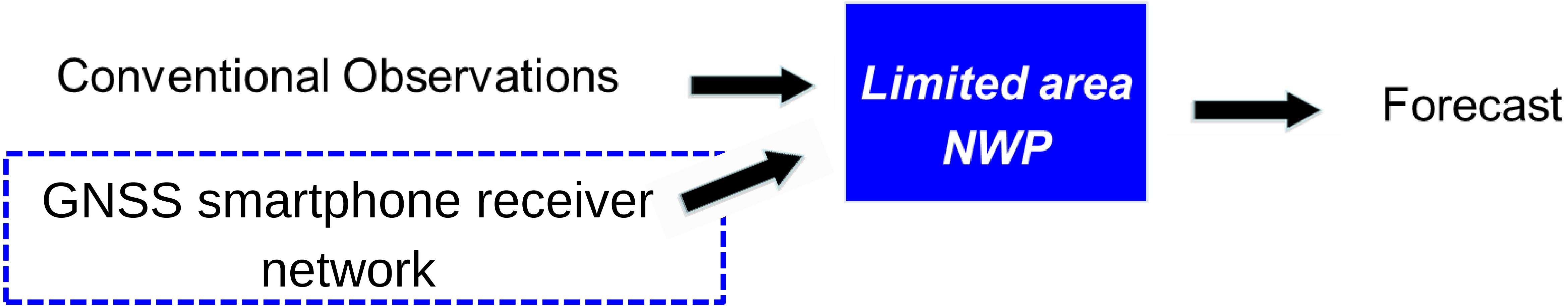
☑ High spatial and temporal resolution



Accumulated precipitation (mm) on 19 July 2007 AROME forecast

Motivations

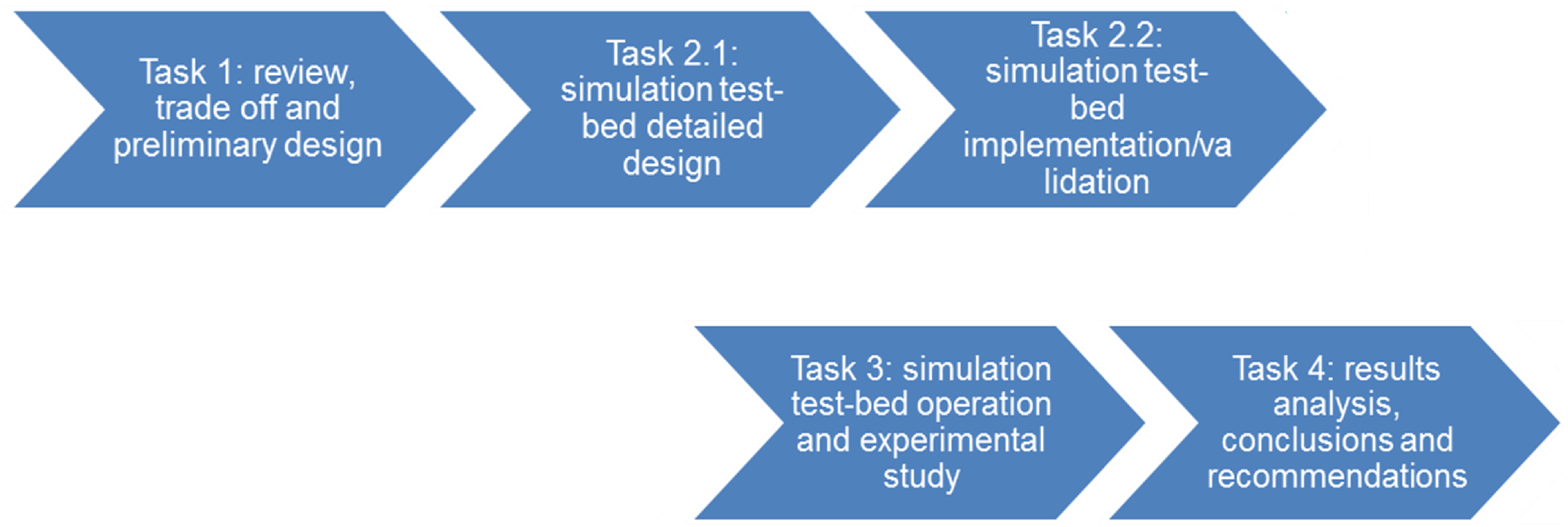
- **Objective of the project**



⇒ Collaborative crowdsourcing approach

Organization

➢ Work steps



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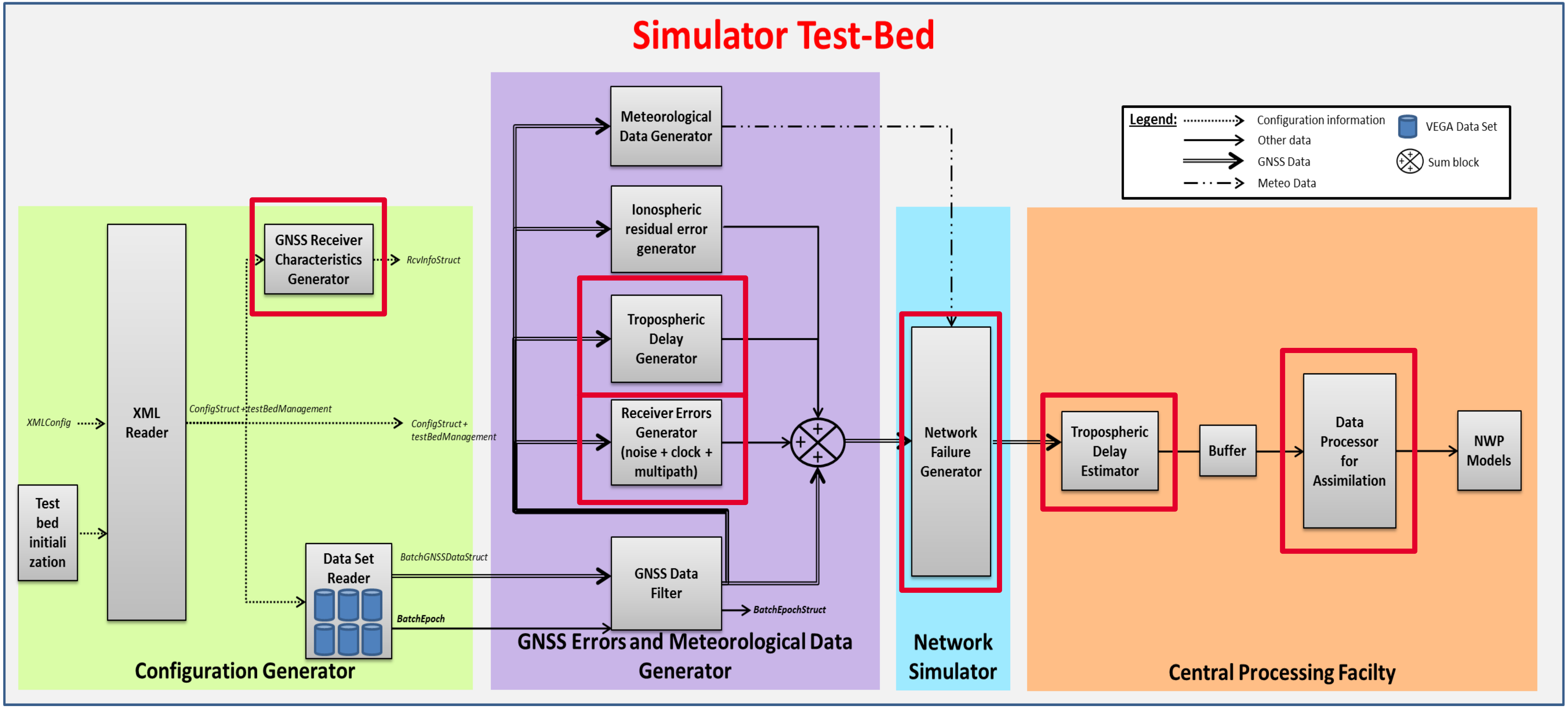
Simulation test-bed



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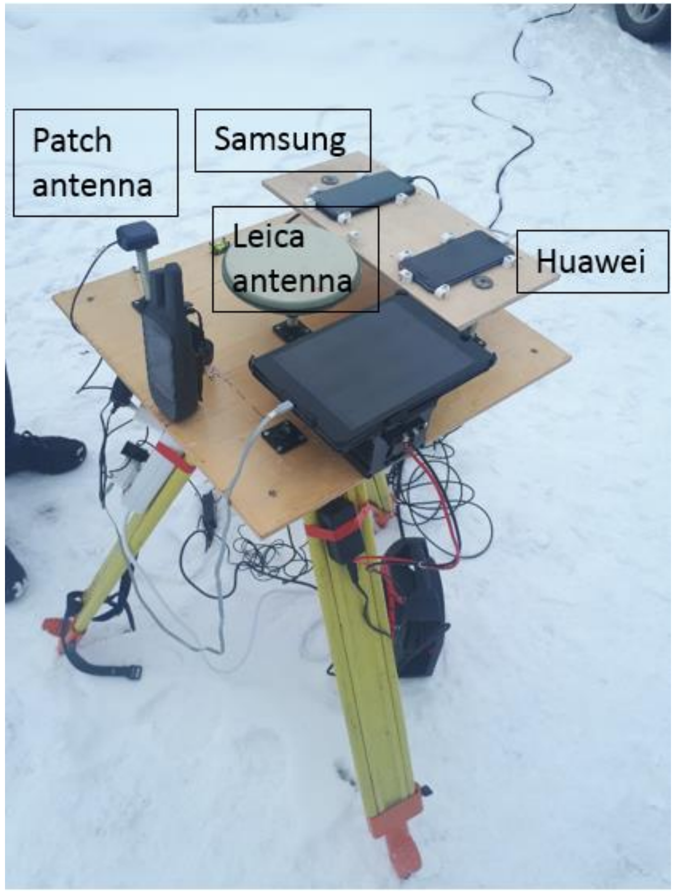
WMCC test-bed

➢ Receiver error generator

Measurement combination to extract and model:

- Receiver clock offset
- Noise+multipath effects

Receiver grade	GNSS signal	Multipath environment
Smartphone (Samsung S8)	GPS L1 Galileo E1 GLONASS L1	Open sky + semi-urban
Medium (uBlox)		
High grade (Septentrio)		



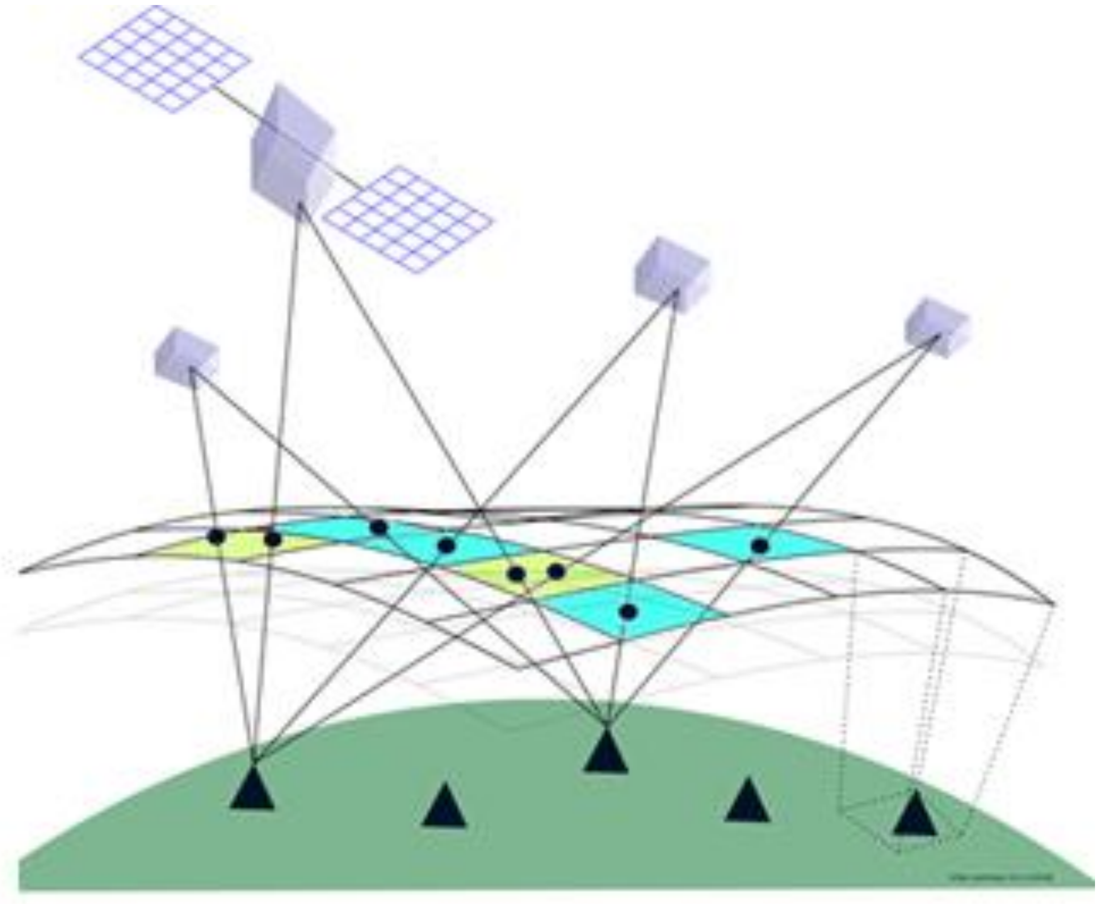
Experimental set-up

WMCC test-bed

➢ Tropospheric delay estimator

- **Estimate:**
  - Tropospheric zenithal wet delays (ZTD)
  - Standard deviation of the estimation error

- **Methodology:**
  - Feed forward loop implementation of **PPP and tomography**



Tomography grid model

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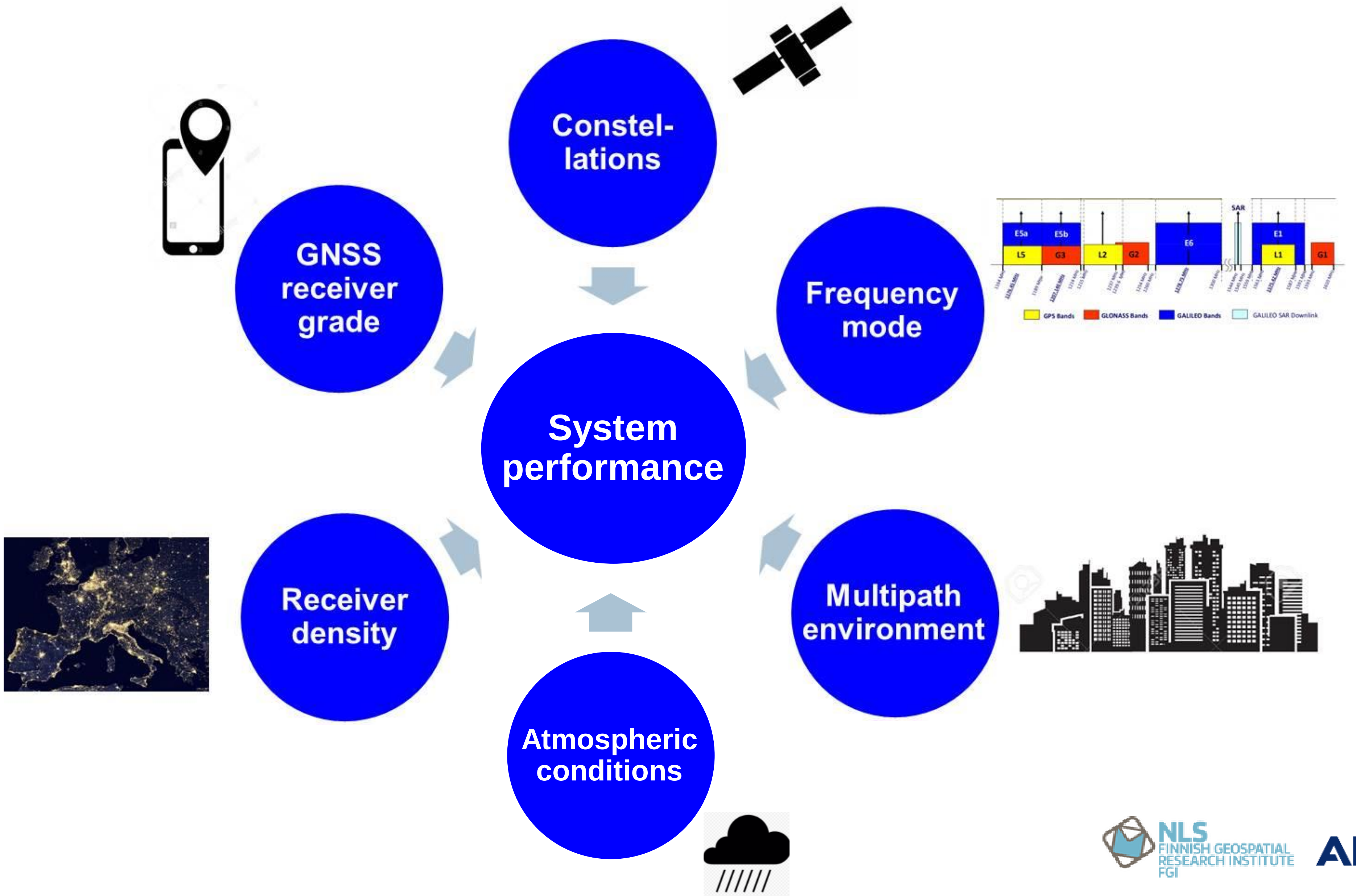
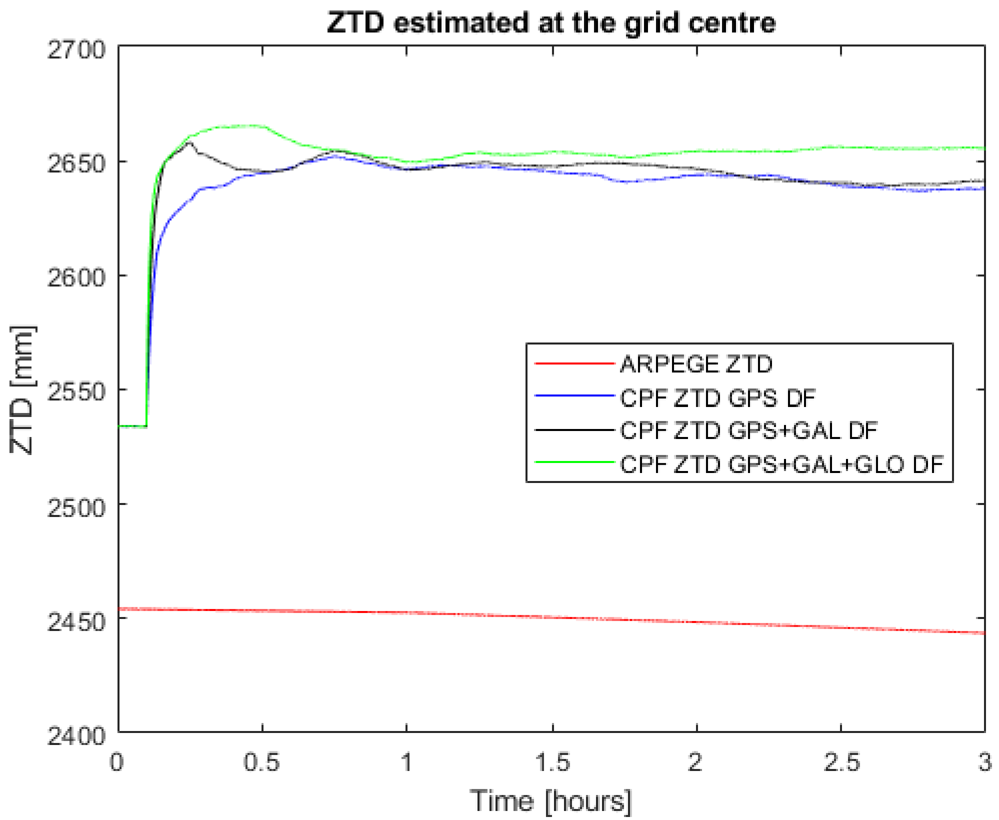
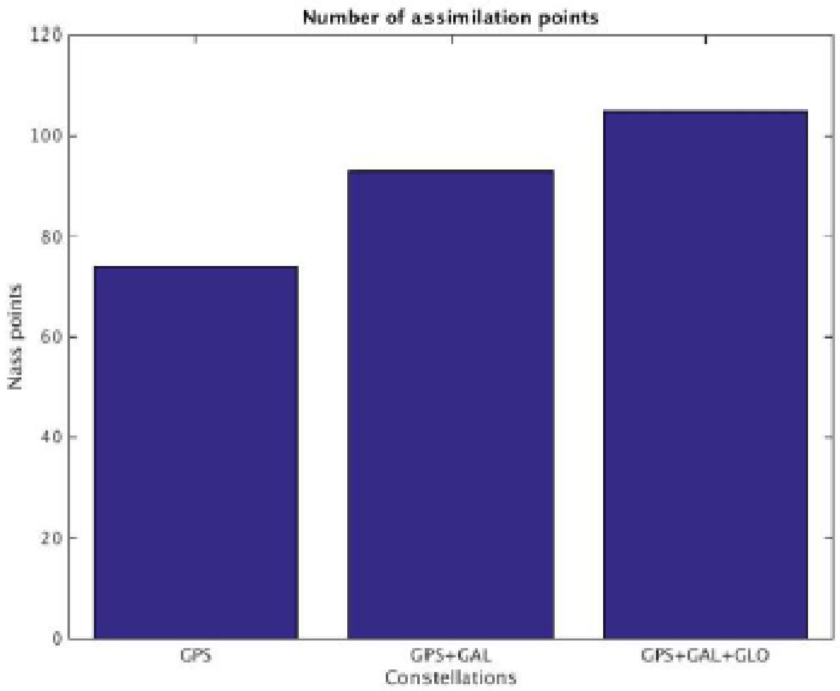
Results: Performance contributors



GNSS constellation impact on system performance



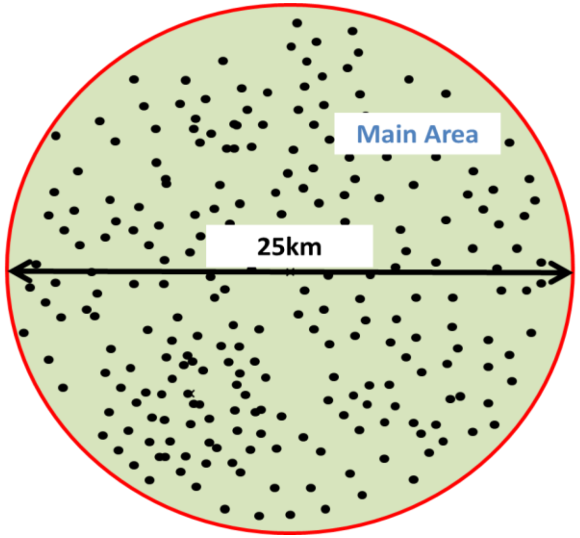
Local coverage, dual-frequency. After tropospheric delay estimator. In red, the reference value



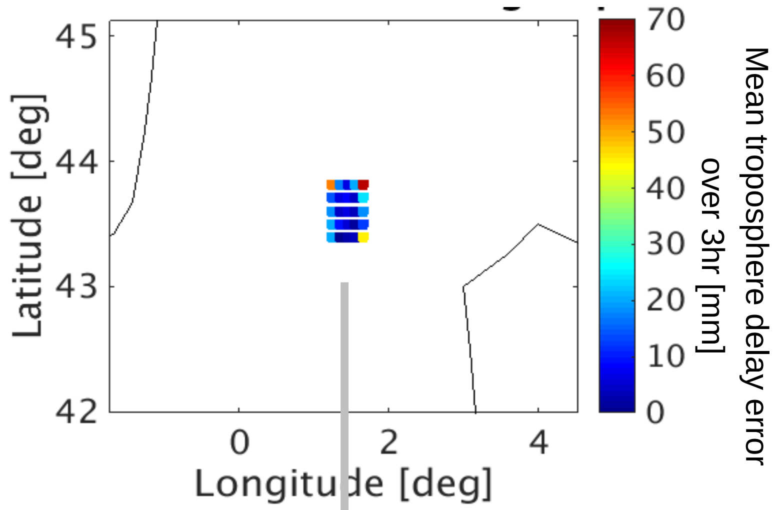
- The number of assimilated ZTD increases with the number of constellations

Results: Optimal conditions

- 3 constellations
- Dual frequency receivers
- Near-future smartphones
- Open-sky environment
- ~ 1 smartphone / km²



Test bed algorithms



- **~ 10mm error**
- **Can be used in NWP**

Recommendations

Configuration	GPS SF	GPS+GAL+GLO SF	GPS DF	GPS+GAL+GLO DF
Recommended?	(red)	(yellow)	(yellow)	(green)
Remark	ZTD estimation error > 10 cm (*)	ZTD estimation error < 10 cm (*)	Performance slightly better than multi-constellation in SF	In local coverage, ~1 cm (*) ZWD error

- (green) Recommended and can be used
- (yellow) Sub-optimal but can be used
- (red) Not recommended

Configuration	Network failures on every RCV	Semi-urban multipath environment	Duty cycles on 50% RCV	High residual ionospheric errors (SF)	Low-grade receiver
Recommended?	(red)	(yellow)	(yellow)	(yellow)	(yellow)
Degradation of the number of ZTD assimilated in NWP w.r.t nominal conditions	70%	40%	30%	25%	20%

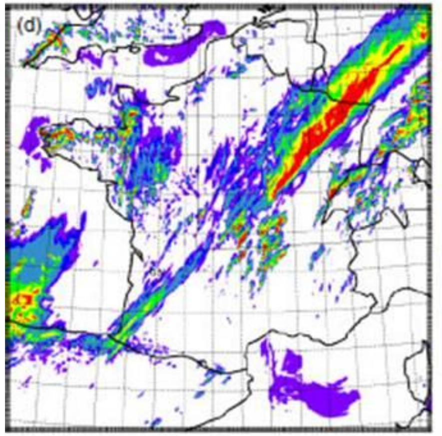
- SF: Single Frequency (L1 and E1)
- DF: Dual Frequency (L1/L2 for GPS and GLONASS, E1/E5a for GALILEO)
- RCV: receiver

Performance improvement →

(*): before bias removal

Way forward

- **Consolidate system performance analyses**
  - Adapt to moving smartphones
  - Test on real data



- **Assess performance improvement on weather forecast**

- **Develop operating system**
  - Develop near-real time processing facility to support crowdsourcing algorithms

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Publications

"Combinations of Measurements for Modeling Smartphone and Higher End GNSS Receiver Performance". V. V. Lehtola, S. Söderholm, M. Koivisto, L. Montloin, MDPI, July 2019

"Towards Tropospheric Delay Estimation Using GNSS Smartphone Receiver Network". Tiago Marques; Maija Makela; Leslie Montloin; Terhi Lehtola; Sarang Thombre; Ville Lehtola, proceedings of 7th ESA colloquium - Scientific and Fundamental aspects of GNSS , September 2019
Submitted to Special Issue on GNSS for Science of Elsevier - ASR

"Tropospheric tomography with a network of roving GNSS receivers". Ville V. Lehtola, Maija Makela, Tiago Marques, Leslie Montloin, to be published this year

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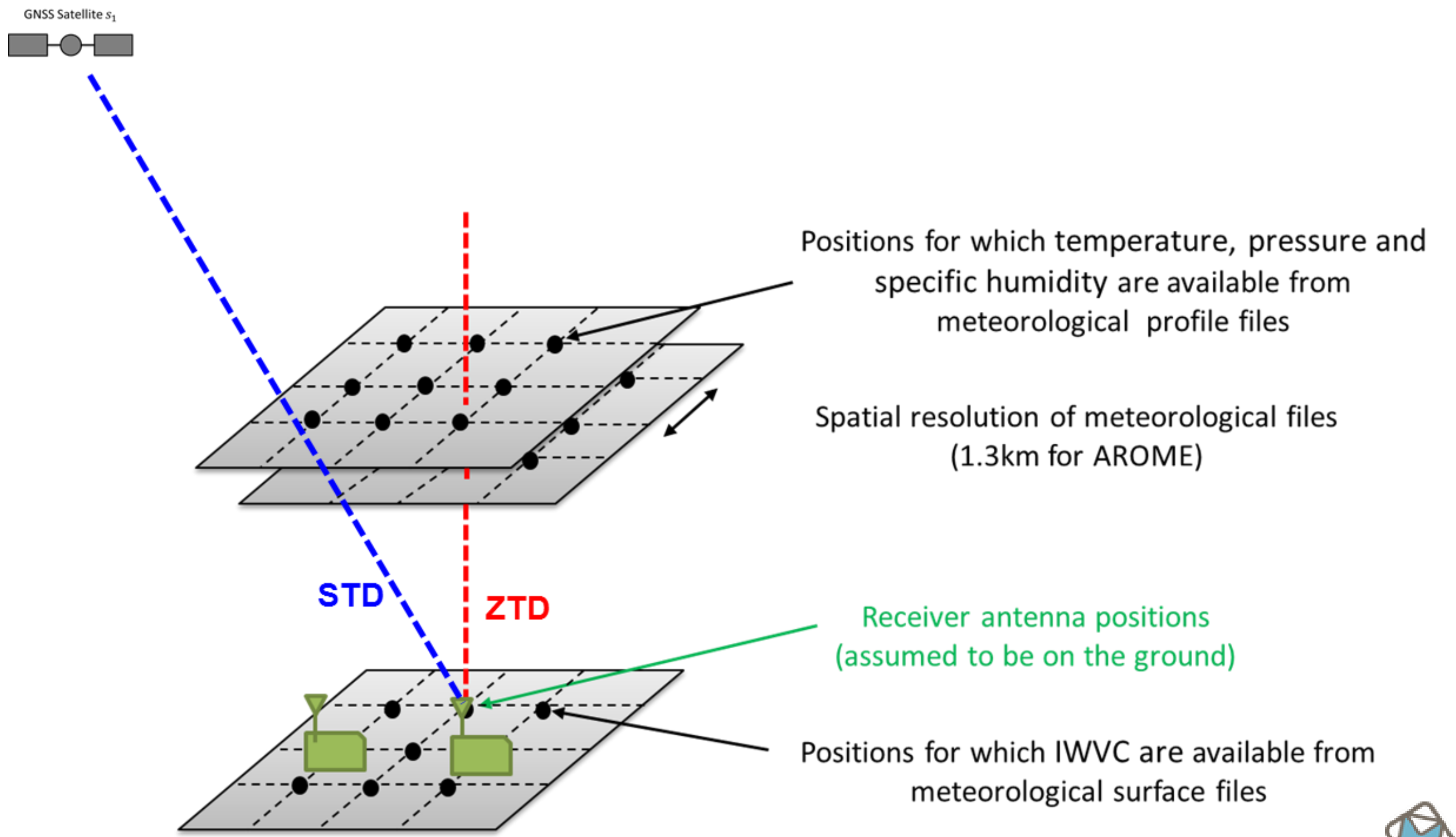
Back-up

WMCC test-bed

➢ Tropospheric delay generator

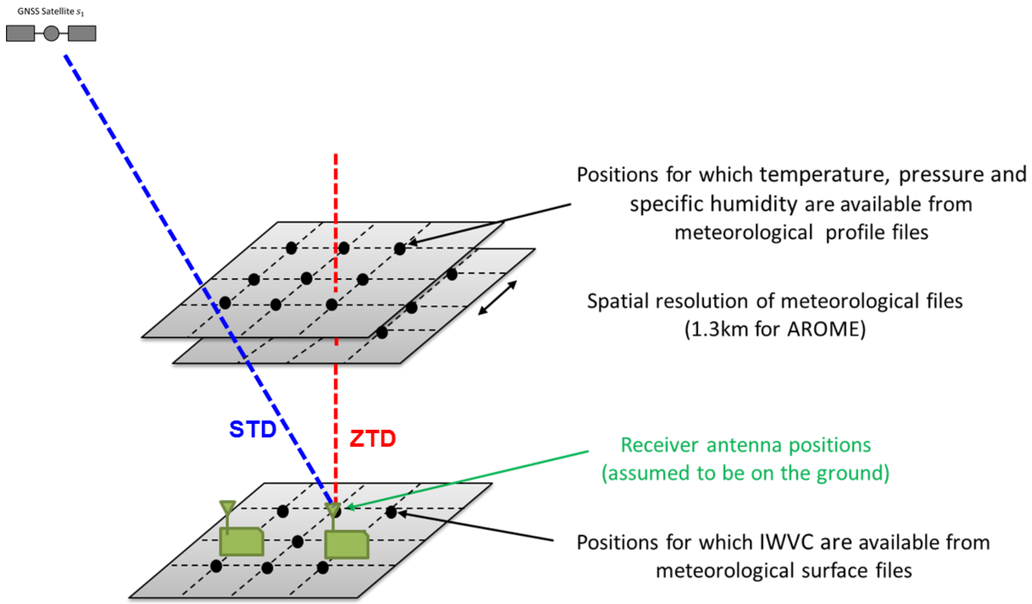
- **Objective**: Generate reference GNSS tropospheric slant total delays between smartphones and GNSS satellites
- **Constraint**: Need to represent **small-scale** and **short-term** tropospheric delay variations



WMCC test-bed

➢ Tropospheric delay generator

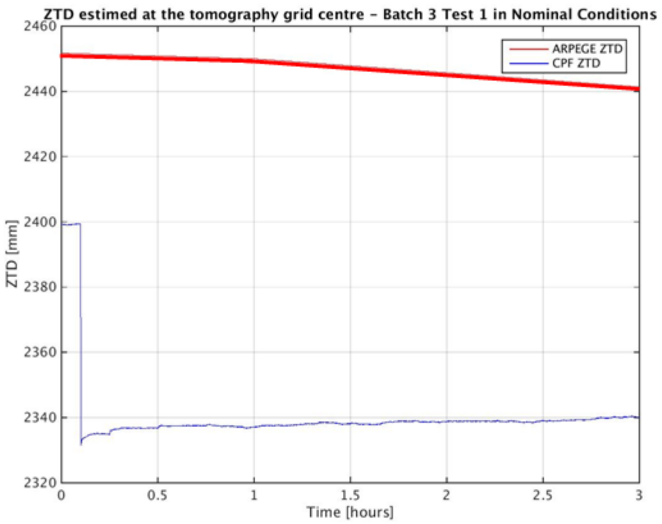
- **Methodology:**
  - **1st step** : compute the reference **ZTD** by using a vertical integration of the **high resolution AROME/ARPEGE** meteo fields above the smartphone location
  - **2nd step** : compute the wet and hydrostatic mapping functions **VMF1** using tropospheric files (VMF1 parameter files from Vienna University)
  - **3th step**: compute the reference **STD**



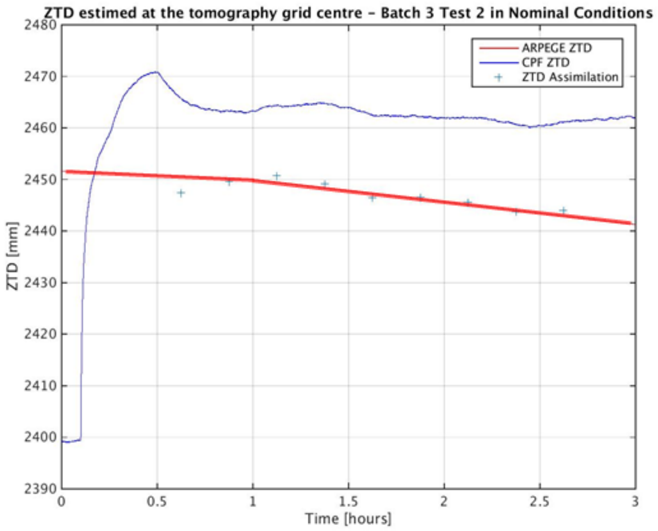
- **Accuracy:**
  - IGS ZTD and AROME ZTD comparison => [mm] level accuracy of AROME ZTD

Frequency mode impact on system performance

Single Frequency



Dual Frequency



Local coverage,GPS+GAL

Blue line: ZTD after tropospheric delay estimator

Blue cross: ZTD after data processor for assimilation

Red line: Reference value

Conclusions

- It is recommended to use dual frequency, the estimation of the ZTD error is significantly better comparing to single frequency mode
- Number of assimilated points when using single frequency is too low

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