UN ICG WG S Workshop on GNSS Interference Detection and Mitigation
Hilton Waikiki Beach, Honolulu, HI
15th April 2024

Ambient-Aware PNT

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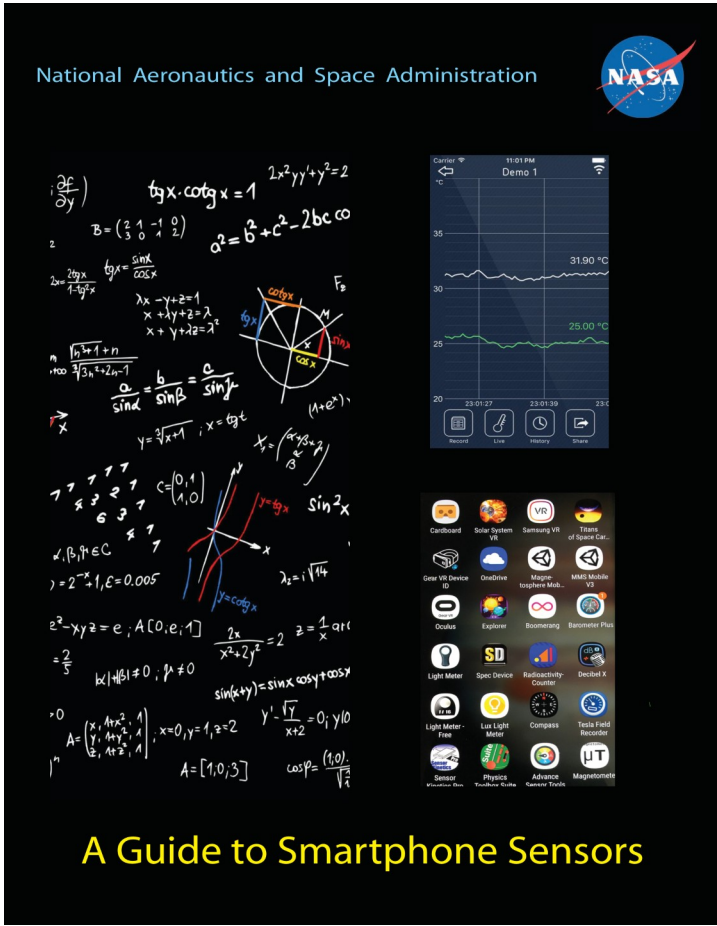
Ambient-Aware PNT (R Filjar, *Croatia*)

- Content of presentation

- Problem statement and motivation
- State-of-the-art
- Ambient-Aware (AA) GNSS-based PNT
- Implementation
- Validation
- Discussion

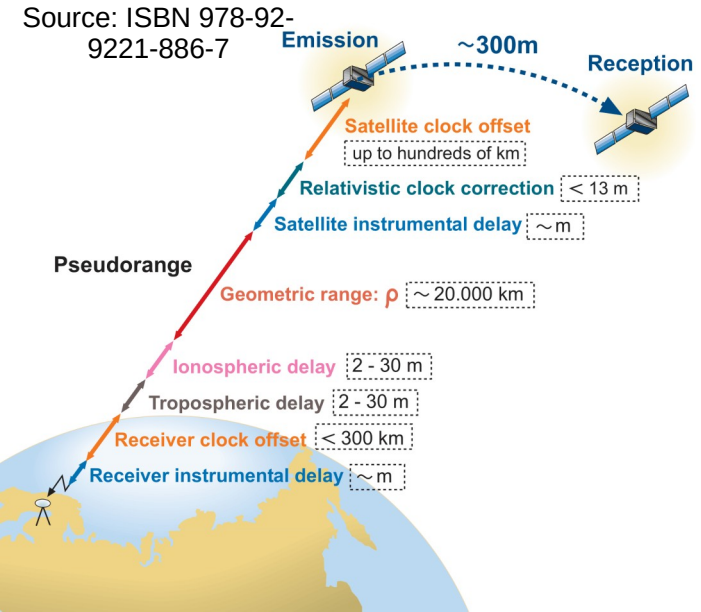
Source:
https://spacemath.gsfc.nasa.gov/Sensor/SensorsBook.pdf



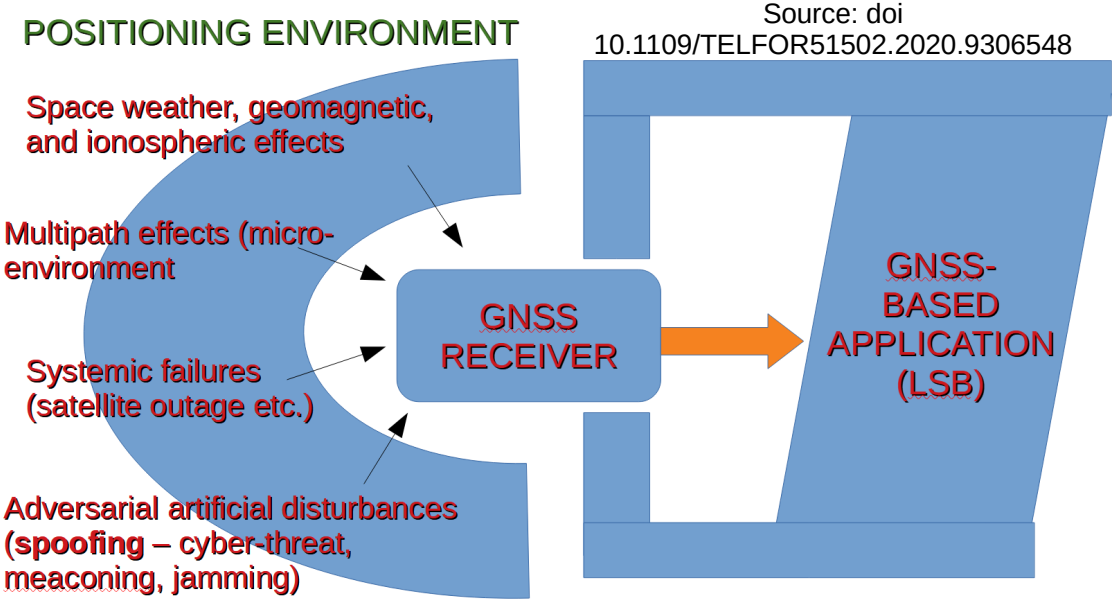
Problem statement and motivation

- Natural and artificial interference in the positioning environment (space weather/ionosphere, multipath, spoofing etc.)
- PNT process confined a black-box GNSS receiver
- GNSS PNT QoS guarantees required in the uncontrollable positioning environment
- GNSS PNT QoS and GNSS apps QoS requirements not aligned

Source: ISBN 978-92-9221-886-7



Source: doi 10.1109/TELFOR51502.2020.9306548



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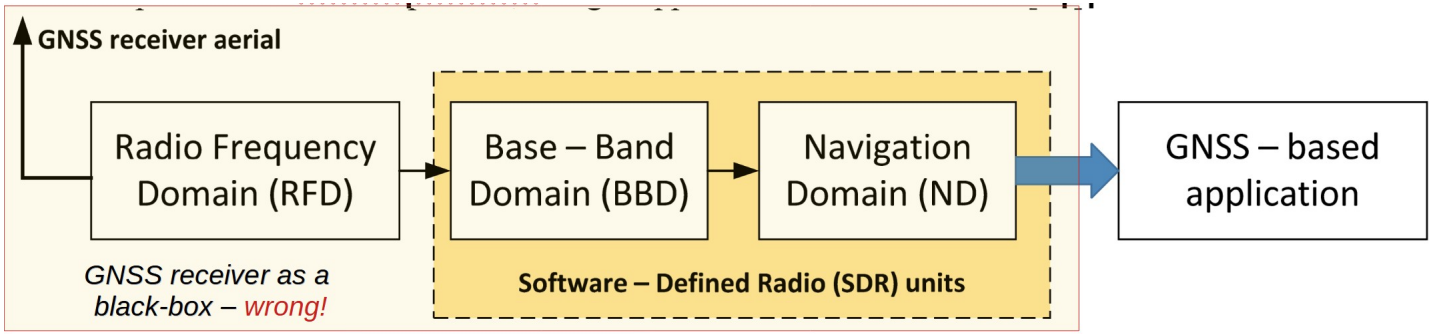
State-of-the-art

- GNSS PNT confined in a non-transparent GNSS receiver black-box, detached from GNSS application



- Numerous advancements are not exploited *in full*: (i) Software-Defined Radio, (ii) statistical & machine learning, artificial intelligence, (iii) computational capacity of mobile devices, (iv) mobile platforms with SDR GNSS receivers & embedded sensors (smartphones, connected vehicles, IoT devices, etc.), (v) open access to position environment data in near-real time (space weather, geomagnetic, and ionospheric indices, spatial databases etc.), (vi) mobile internet and IoT

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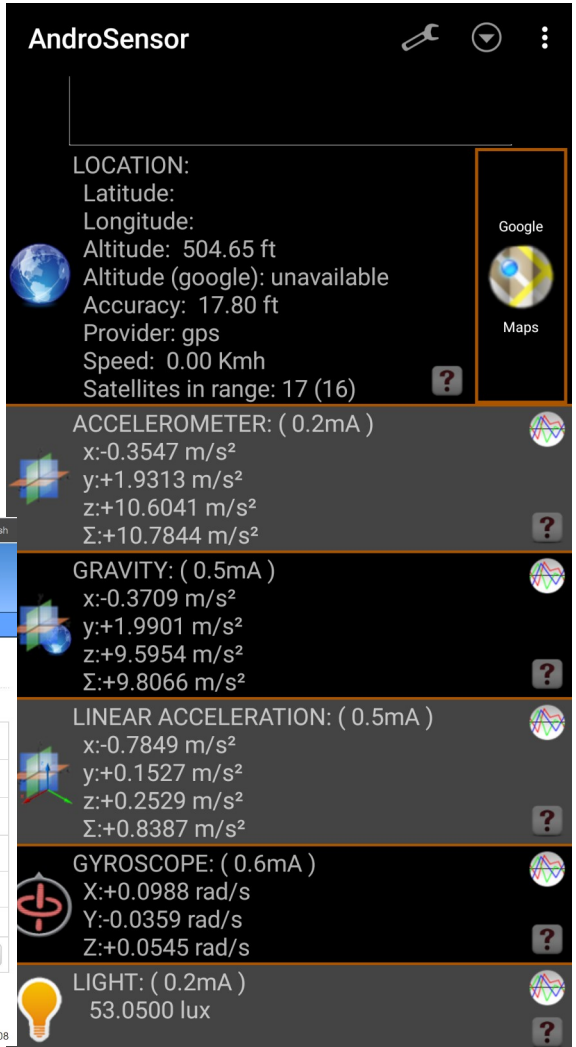
State-of-the-art – Ambient (space weather environment) awareness

Trusted third-parties

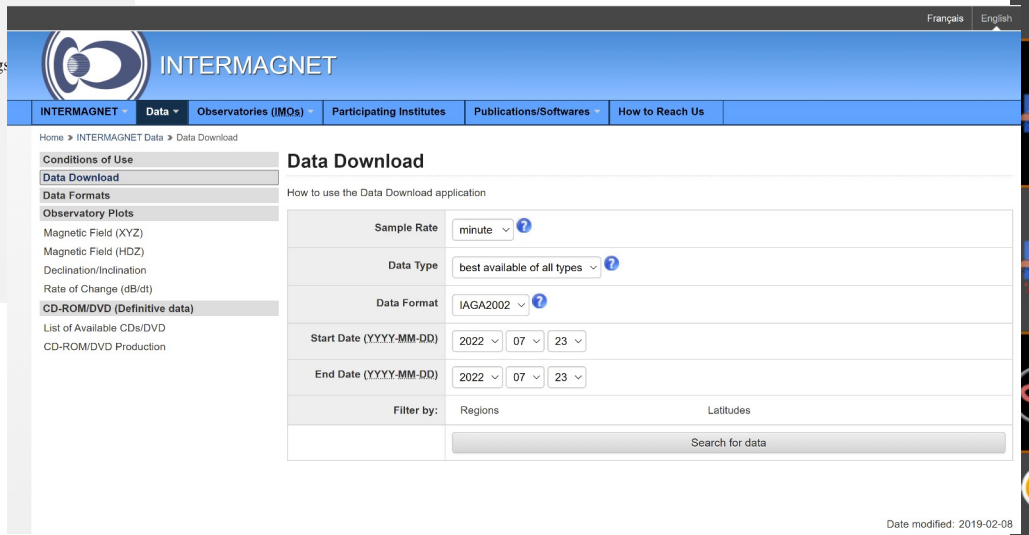
Source: https://omniweb.gsfc.nasa.gov/form/dx1.html

Direct access to embedded sensors

(Motorola *moto 30 edge*, with AndroSensor application)



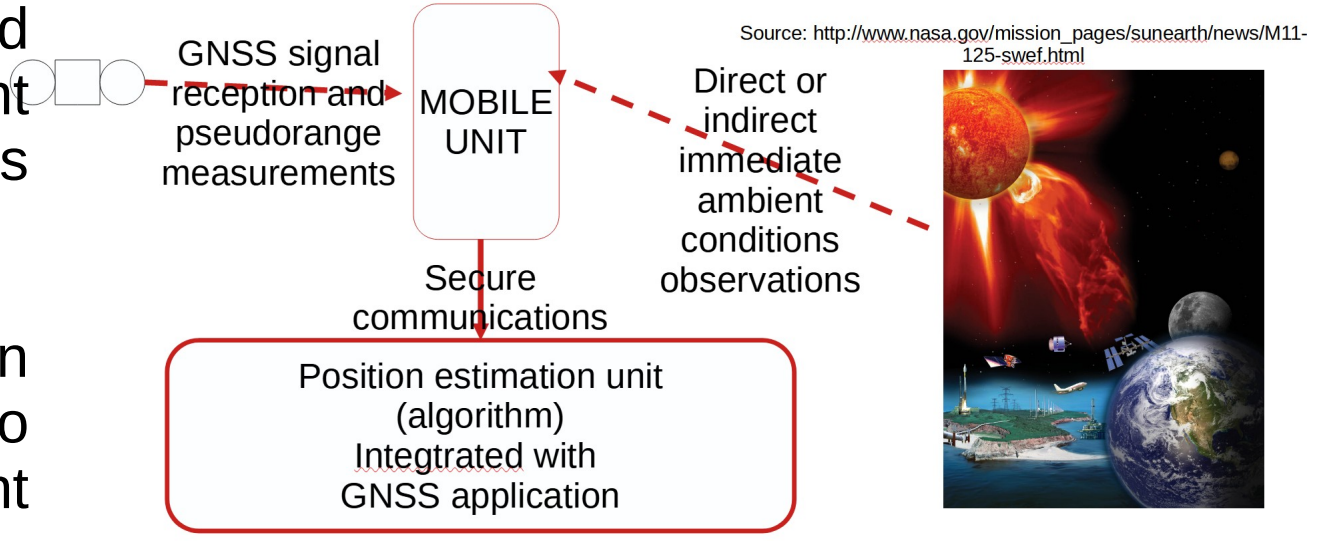
Source: https://www.intermagnet.org/data-donnee/download-eng.php

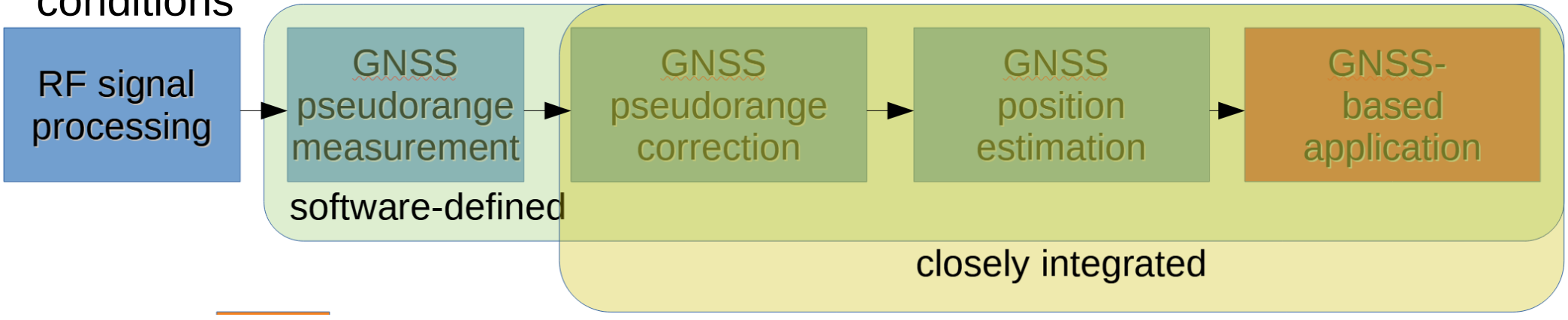


Ambient-Aware (AA) GNSS PNT

- Mobile unit as pseudorange and positioning environment conditions observations device

- Self-adaptation of position estimation algorithm to immediate real-time ambient conditions





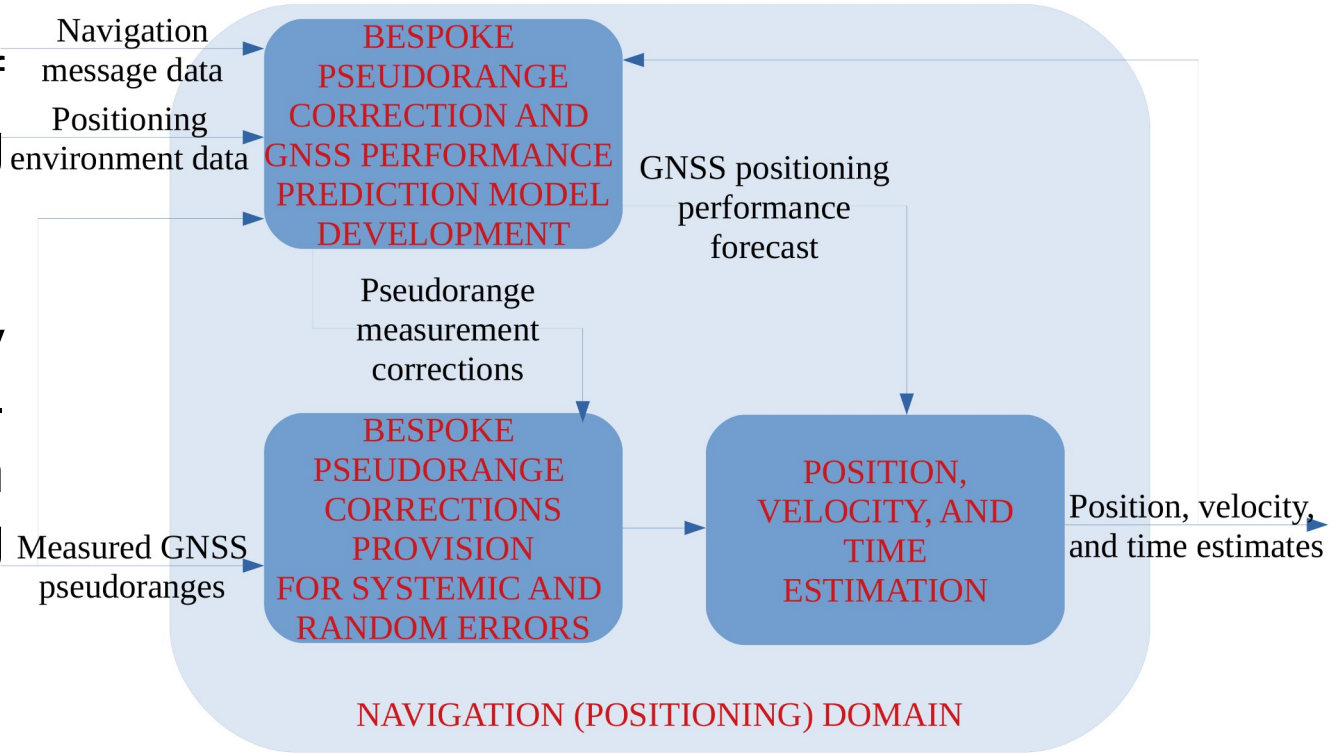
Ambient-Aware (AA) GNSS PNT

- Mitigation of space weather/ionospheric effects on GNSS PNT performance:

  - direct observations of immediate positioning environment

  - trusted third-party data (stream, server-application access), with optional processing (interpolation)

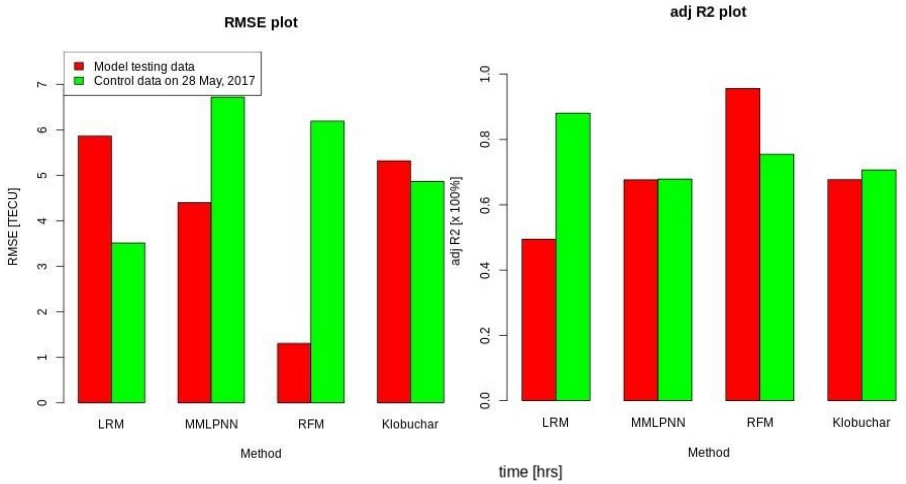
Sources: ISBN 978-613-9-90118-0,
doi:10.1088/1757-899X/1032/1/012001



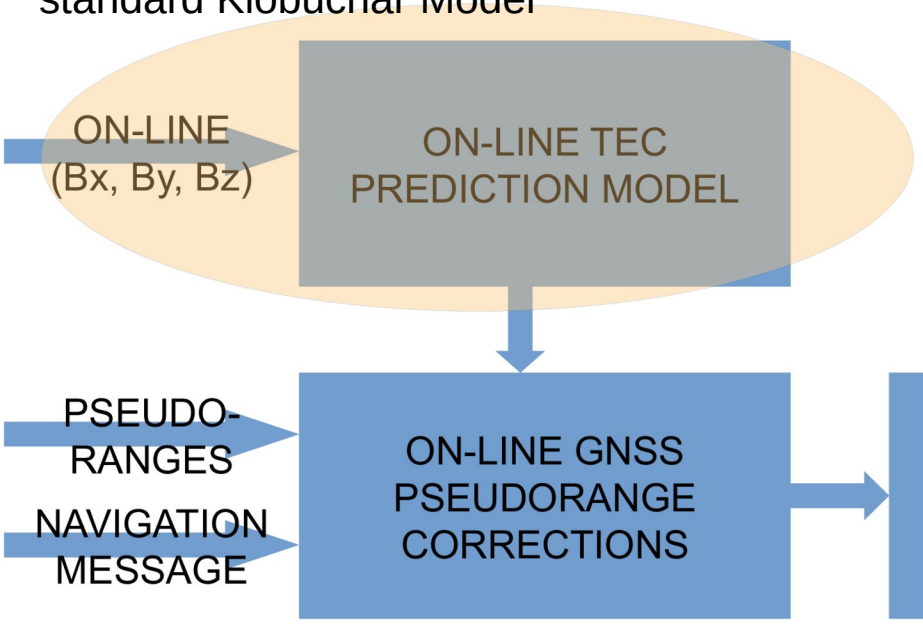
Implementation & Demonstration

- Case-study of a short-term rapidly developing geomagnetic storm in sub-equatorial area (Darwin, NT)

LRM … Linear Regression Model, MMLPNN … Monotone Multi-layer Perceptron Neural Network Model, RFM … Random Forest Model, Klobuchar … standard Klobuchar Model



Reference model: global Klobuchar model



Tailored framework developed in the open-source R environment for statistical computing

Validation (source: doi: 10.33012/2022.18247)

- Case-study of short-term rapidly developing geomagnetic storm in sub-equatorial area (Darwin, NT)
- Single-frequency GPS-based position estimation, no additional infrastructure utilised → GPS position estimation process self-adapted to the immediate environment conditions
- Ionospheric corrections: (i) Klobuchar model (reference/benchmark), (ii) geomagnetic field density-based statistical learning Linear Regression Model (LRM) (alternative)

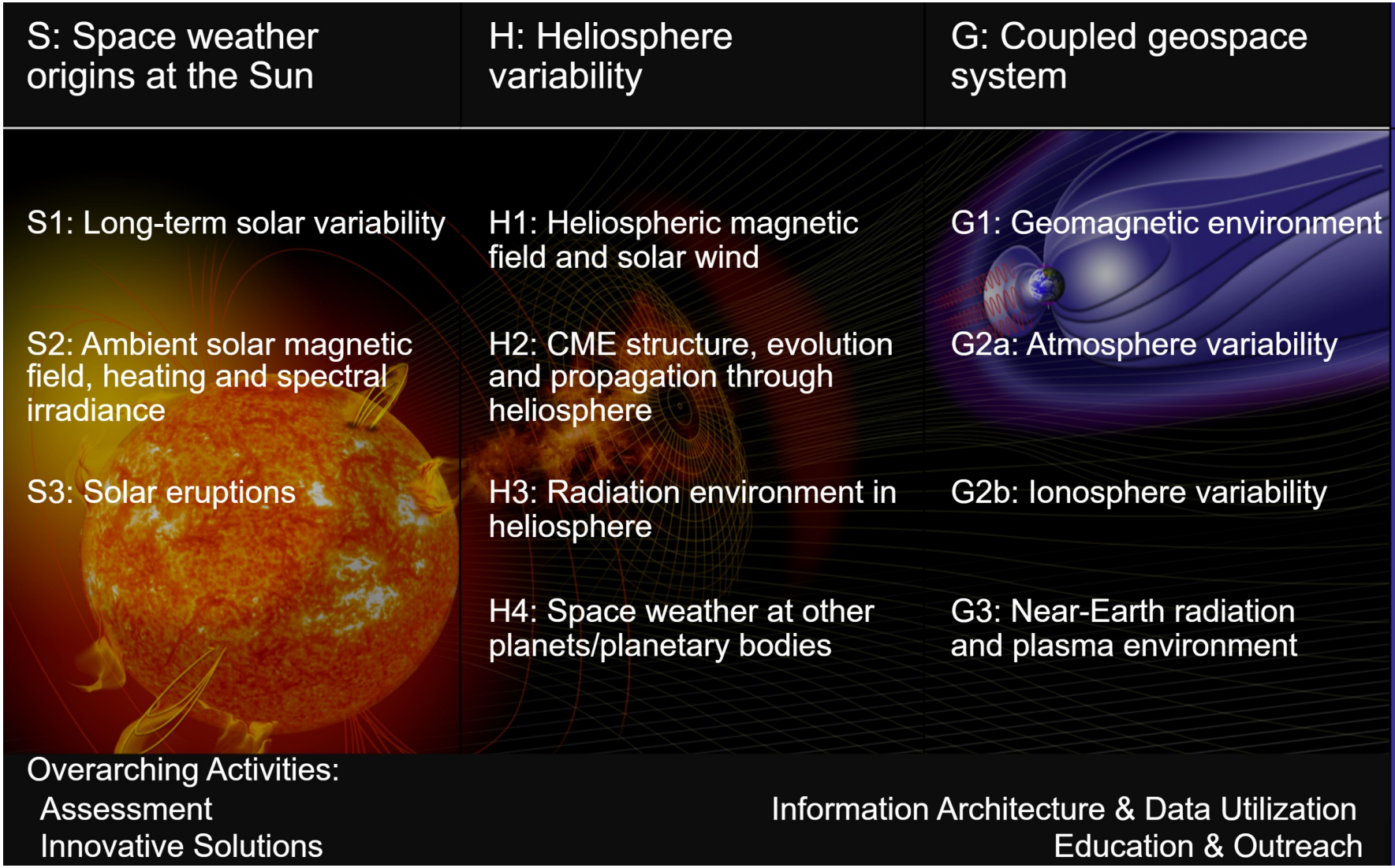
in [m]	mean		standard deviation	
	Klobuchar corrections	self-adaptive corrections	Klobuchar corrections	self-adaptive corrections
northing error	-1.5368	-0.1098	2.24106	1.088705
easting error	0.72717	-0.02663	1.878769	0.9983062
vertical error	0.2225	-0.09773	1.29891	0.510632

Discussion

- Proposed utilisation of ambient awareness of immediate GNSS PNT environment conditions for Ambient-Adaptive (AA) PNT.
- Ambient-Adaptive GNSS PNT is inherently infrastructure-agnostic → no further investments in infrastrciture is needed!
- GNSS positioning performance demonstrated in the case of short-term rapidly developing ionospheric disturbance.
- The need for space weather/geomagnetic/ionospheric observations and indices data standardisation (access, structure and format) and availability.
- Optimisation of ML/AI-based algorithms for ambient effects correction and PNT
- International activities, in collaboration with International Space Weather Action Teams (ISWAT, COSPAR)

Ambient-Aware PNT (R Filjar, *Croatia*)

Source: https://www.iswat-cospar.org/



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Recommendations

- 1. Ambient (SW/iono) conditions awareness to improve GNSS NT algorithm, as well as GNSS PNT performance and resilience against adverse SW/iono effects.
- 2. Ambient-Adaptive ML/AI-based GNSS ionospheric correction model to be developed based on SW/iono conditions awareness for every PNT process/receiver.
- 3. Ambient (SW/iono) conditions awareness to be obtained by: (i) direct SW/iono observations in the immediate vicinity of receiver, and/or (ii) link to trusted third-party sources.
- 4. International co-operation to be facilitated, established, and operated to:
- 4.1 develop standards for ambient SW/iono data structure, formats, and protocols for internet-based data exchange;
- 4.2 collect, assemble, aggregate, collate, and allow access to location-based real-time and archived ambient SW/iono observations;
- 4.3 foster infrastructure-agnostic Ambient-Adaptive (AA) PNT correction model development, validation, and standardisation;
- 4.4 develop inter-/multi-disciplinary expertise/capacity in support of transition to infrastructure-agnostic Ambient-Aware (AA) GNSS-based PNT.

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In appreciation of your attention, and
with invitation to participate to

Baška SIF (Spatial Information Fusion) Forum 2024

Baška, Krk Island, Croatia, 16th – 18th June, 2024

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