Development of an in-house DORIS processing software

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Dionysos DORIS Beacon

Dionysos Satellite Observatory (DSO) has been hosting a DORIS beacon in its facilities since 1989. First setup equipped with an `Alcatel` antenna (1a), upgraded in May 2006 to `Starec` (1b).

(a) DORIS Beacon DIOA (Alcatel)

(b) DORIS Beacon DIOB (Starec)

Figure 1: DORIS beacon hosted hosted at DSO facilities

Involvement in IDS & Motivation

Since late 2021, DSO has decided to expand its involvement in the DORIS community by developing its own, in-house processing software for POD and positioning using the DORIS system.
The software is designed and build from scratch, adopting recent developments in DORIS analysis and Satellite Geodesy.

- expand out knowledge-base and expertise (research activity & academic services),
- follow and apply state-of-the-art technologies in Satellite Geodesy and expand & modernize our research activity,
- contribute to the DORIS/IDS community, and get involved ongoing/future projects,
- fulfill PhD dissertation requirements

Background

Up to now, DSO has mainly be involved in precise GNSS positioning, primarily for monitoring the crustal dynamics of Greece, a region of complex tectonic & volcanic background.

- since 2015 we have established a monitoring platform using continuous GNSS stations,
- daily, routine analysis of an extensive dataset,
- contribution to EUREF/EPN Densification (SINEX submission),
- time-series analysis (modeling of crustal dynamics)

All in all, we have extensive knowledge of GNSS analysis but a limited understanding of DORIS technology.

Plan Outline

Our goal is to develop a DORIS free and open-source analysis software for POD & positioning.
We follow an incremental approach, integrating one component at a time. As a first step, we are targeting:

- POD-only
  - Jason-3 satellite
    - adopt & implement simple models initially; gradually increase complexity (e.g. gravity model)
  - ✓ gradually incorporate more satellites . . .
- ✓ introduce positioning once POD is acceptable

Design Considerations (1/2)

- Core software development using the **C++** programming language (exploiting its speed, robustness & versatility)
- Various minor, peripheral parts developed using **Python**, allowing development speed and ease of use (for developers & users)
- Follow a **modular** design pattern, with different parts developed individually, serving specific needs, thus favoring composability & reusability
- Strive for **minimum dependencies**; when unavoidable, we only use open-source software
- Developed in an "**open**" fashion, using public repositories on `github`

Design Considerations (2/2)

- RINEX-only processing
- We try to follow, as close as possible, the latest IDS recommendations published as "*IDS Recommendations and suggestions for ITRF 2020 reprocessing*"[1] or design for their easy adoption later on
- In general, consulting the extensive documentation on the IDS website "*Documents for the data analysis*"[2]
- Handling of DORIS observations follows the approach outlined in Lemoine et al. [2016] (range-rate)
- Estimation performed via Extended Kalman Filtering, Tapley et al. [2004] (later adopt a more sophisticated approach)

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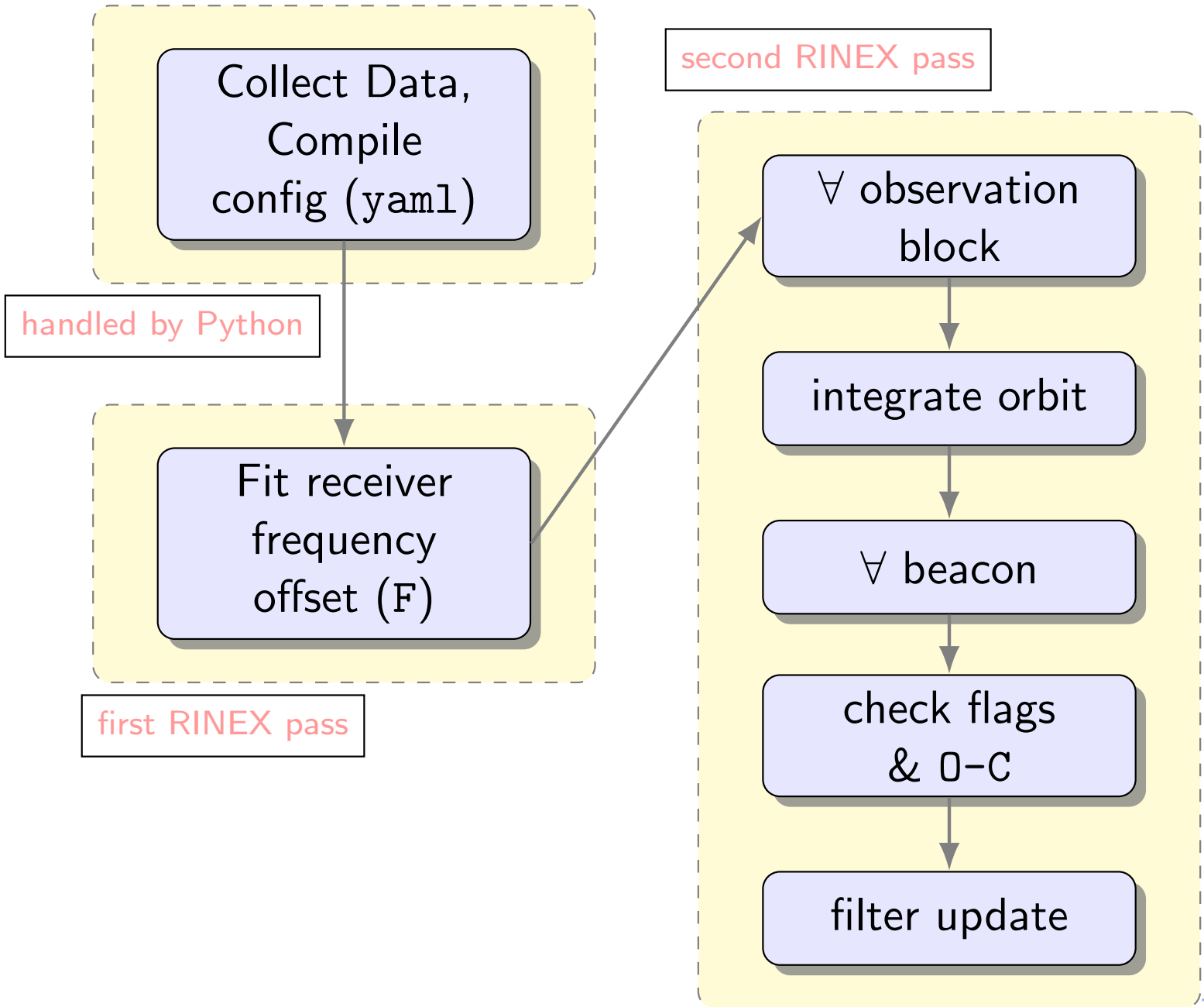
[1] `https://ids-doris.org/images/IDS_RecommendationsITRF2020_04.02.2020.pdf`

[2] `https://ids-doris.org/analysis-coordination/documents-related-to-data-analysis.html`

Currently Implemented (Key Points)

- orbit integration (using "variational equations")
- GPT3/VMF3 (Landskron and Böhm [2018]) tropospheric delay modeling
- quaternions for attitude (via published files)
- atmospheric drag force modeling, using the *NRLMSISE00* model Picone et al. [2002]
- strive for adherence to the latest IERS standards (*IERS2010*, Petit and Luzum [2010])
- linear model for relative frequency offsets
- static gravity model (ICGEM-format)
- elevation-dependent weighting
- use of observation flags extracted from RINEX files (?)

Flowchart


Collect Data, Compile config (yaml)
handled by Python
Fit receiver frequency offset (F)
first RINEX pass
second RINEX pass
∀ observation block
integrate orbit
∀ beacon
check flags & O-C
filter update

Thank you

Thank you for your attention!

References I

Daniel Landskron and Johannes Böhm. Vmf3/gpt3: refined discrete and empirical troposphere mapping functions. *Journal of Geodesy*, 92(4):349–360, Apr 2018. ISSN 1432-1394. doi: 10.1007/s00190-017-1066-2. URL https://doi.org/10.1007/s00190-017-1066-2.

Jean-Michel Lemoine, Hugues Capdeville, and Laurent Soudarin. Precise orbit determination and station position estimation using DORIS RINEX data. *Advances in Space Research*, 58(12): 2677–2690, December 2016. doi: 10.1016/j.asr.2016.06.024.

Gérard Petit and Brian J. Luzum, editors. *IERS Conventions (2010)*, volume 36 of *IERS Technical Note*, 2010. International Earth Rotation and Reference Systems Service (IERS), International Earth Rotation and Reference Systems Service (IERS).

References II

J. M. Picone, A. E. Hedin, D. P. Drob, and A. C. Aikin. NrlmsiseÂ-00 empirical model of the atmosphere: Statistical comparisons and scientific issues. *Journal of Geophysical Research: Space Physics*, 107(A12):SIA 15–1–SIA 15–16, 2002. doi: https://doi.org/10.1029/2002JA009430. URL `https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2002JA009430`.

Byron D. Tapley, Bob E. Schutz, and George H. Born. *Statistical Orbit Determination*. Academic Press, Elsevier Inc., 2004. ISBN 978-0-12-683630-1.