Massive GNSS processing in double difference in the framework of the EPOS-IP project

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The EPOS project (in brief)

Project phases:

Project objectives:
• Establish an research infrastructure for solid Earth sciences
• Give access to data and products and services generated by different communities
• Facilitate multidisciplinary scientific research

Project architecture:
Prototype solution, established in 2016

Data set stored on a distributed management system: IRODS (in UGA, France):
- **600 sites**
- **16 years (2000-2015)**
- ~**1 850 000 RInEx files**
- ~**750 G**
New solution: on-going processing

Data set stored on a distributed management system: IRODS (in UGA, France):

- 1360 sites
- 18 years (2000-2017)
- ~3 600 000 RInEx files
- ~1800 G
- Data set processed in double difference with GAMIT/GLOBK software
- Massive data set was split into sub-networks
- Large number of small independent processes
- High performance computing platform used (CIMENT)
Daily processing: division in N sub-networks

- For each day independently, the network is split into sub-networks (4-29)
- Subnetworks consist in ~40 stations + 2 overlapping stations
- Define parameters of the jobs to launch on a distributed system

Example of division in 29 sub-networks for the day 100 in 2017. The tying sub-network (in black) consists in a set of stations couples belonging to the 28 others sub-networks.
All sub-network processing

- Processing conducted independently for each day and for each subnetwork
- Use of a high computing platform hosted at UGA
- ~99,120 jobs to launch
- Best-effort mode
- Identical format
  - Walltime = 2h
  - Mean job duration = 25min

Daily combination

- ~6,500 short jobs
- Job duration = a few minutes

Daily processing

GAMIT h-file for each couple day/sub-network

Daily solution in the form of a SINEX file (The whole SINEX file set ~280G)
Products: Time series combination, Pyacs

The PYACS software (developed in OCA, by J.M. Nocquet) was used to compute the time series. By using a chaining method, it allowed an easy automatic analysis. We successively:

- **Visualize** the time series
- **Detrend** it
- **Remove the outliers**
- **Estimate and correct for the jumps** associated with material changes using the information contained in the meta-data.

*Example of ACOR*
Products: Time series comparison, DD vs PPP example of BORJ

Time series generated with PYACS using the protocol described before for both DD and PPP solutions:

- **Detrend** it
- Remove the **outliers**
- Estimate and correct for the **jumps** associated with material changes using the information contained in the meta-data
We test 2 different ways to compute the velocity field for ~600 stations, over 11 year:

**GLOBK:**
- Developed in the MIT by Herring, King, Floyd and McClusky
- Kalman filter
- Combine various geodetic solutions (GPS, VLBI, SLR) from the processing of primary data (space-geodetic or terrestrial observations)
- Input data : SINEX files
- Time consuming (more than 100h for our data set)
- No splittable

**MIDAS:**
- Developed in NGL by Blewitt, Kreemer, William, Hammond and Gazeaux
- Statistical method based on a set of position pairs separated by 1 year
- Automatic estimator of position time-series trend
- Input data : time series
- Robust to outliers, steps, seasonality
- Fast (less than 1min for our data set)

We adopt MIDAS to compute our new velocity field (~1360 stations, over 18 years)
Preliminary results: velocity field (MIDAS)
The aim: strain rate map computation within the whole area (automatically ??)

The problem: heterogeneous density of stations

Potential solution: The VISR software (developed in UCLA by Shen et al.) is currently tested for the strain rate derivation.

- Program implemented in FORTRAN
- Distance dependant weighting
- Varying smoothing distance
+ varying grid step …
Preliminary results: vertical velocity field (MIDAS)

Post-glacial rebound

Subsidence in Venice
Preliminary results: Alpes

Horizontal velocity field (MIDAS)

Vertical velocity field (MIDAS)

Strain rate (VISR)
Preliminary results: Appenins

Horizontal velocity field (MIDAS)

Vertical velocity field (MIDAS)

Strain rate (VISR)
Preliminary results: Time series, co-seismic signal

L’Aquila (Mw 6.3) seismic sequence, 2009
Preliminary results: Time series, co-seismic signal

Emilia (Mw 5.9) seismic sequence, 2012
Preliminary results: Time series, co-seismic signal

Amatrice (Mw 6.2) & Norcia (Mw 6.1) seismic sequences, 2016
Preliminary results: Time series, co-seismic signal

To facilitate the analysis of the time series, these later are accessible via an interactive map on the project web page (on the ISTerre website).

Mw 6.4 seismic, Aegean Sea, 2014
Conclusions & perspectives

- We succeeded in this **up scaling challenge** and generated from a **big data** set the usual GNSS products: position **time series** + horizontal and vertical **velocity fields**

- Automatic derivation of strain rate is well on the way
- Real time processing, ...
- We are almost ready to make GNSS products available to advance research in Earth Science domain !!!
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