CO-LOCATION: GUIDING PRINCIPLE OF THE DORIS DEPLOYMENT

IDS WORKSHOP 2016

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WHEN IS A CO-LOCATION A CO-LOCATION?

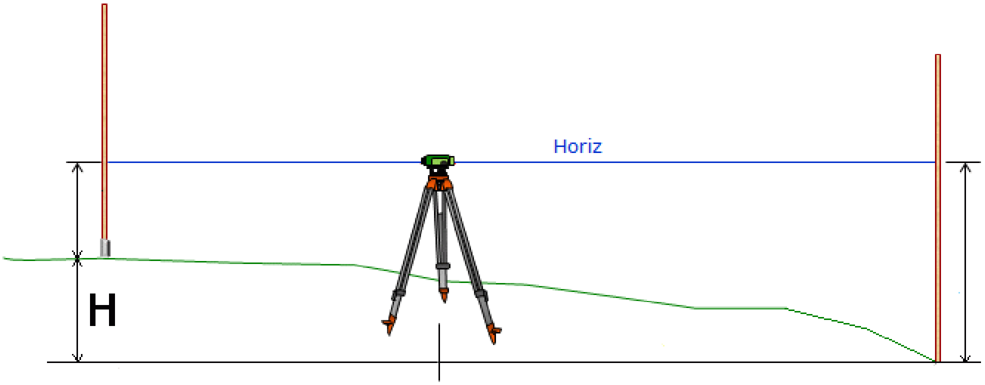
- **DEFINITION:**
  - Closeness of two or several instruments operating simultaneously (or not)
- **REQUIREMENTS:**
  - All instruments are part of core networks of global observing system: IDS, IGS, ILRS, IVS, GLOSS, PSMSL.
  - The spacing between instruments must meet the definition of a geodetic site: unique site identifier (DOMES* number)
  - All reference points can be linked by high precision local tie surveys

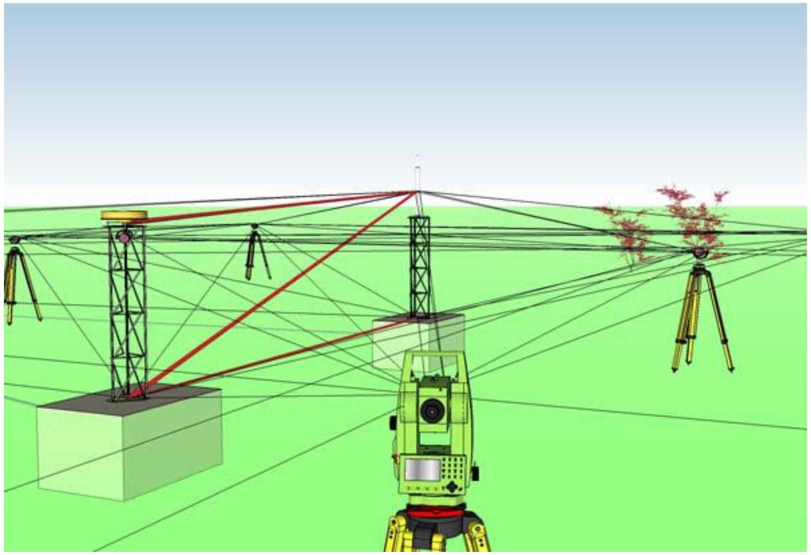
⇒ distance = ideally a couple hundred meters, in any case < 1km

DOMES: Directory of MERIT sites*
***MERIT: Monitoring of Earth Rotation and Intercomparison of Techniques*

HOW TO MAKE A CO-LOCATION EFFECTIVE?

- CARRYING OUT OF A CO-LOCATION SITE SURVEY
  - Combining terrestrial measurements of angles, distances and height differences
  - Computing differential coordinates expressed in a topometric frame
  - Referencing into a global frame (ITRF)
- ACHIEVING THE BEST POSSIBLE ACCURACY IN THE TIE VECTORS DETERMINING

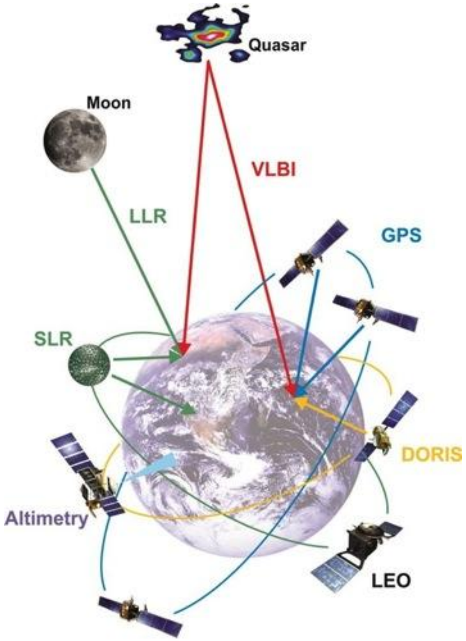




WHY DO WE NEED CO-LOCATIONS?

- **DORIS WITH OTHER IERS TECHNIQUES:**
  - ITRF is based on the data combination of the 4 space geodesy techniques: VLBI, SLR, GNSS, DORIS
  - Co-location sites are necessary for ITRF combination: terrestrial measurements (tie vectors) allow to connect the independent reference frames

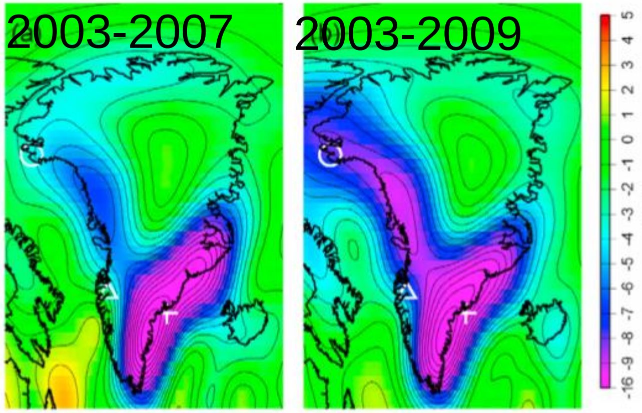
- **DORIS WITH TIDE GAUGES:**
  - Monitoring of sea level variations
  - Geophysical information about the stability of the coast
  - Absolute reference for the tide gauge measurements



EXAMPLE: CONTRIBUTION TO GEOPHYSICS

- ELASTIC REBOUND AT THULE (GREENLAND)

Significant ice melting since 2005 according to Khan et al., (2010) from GRACE



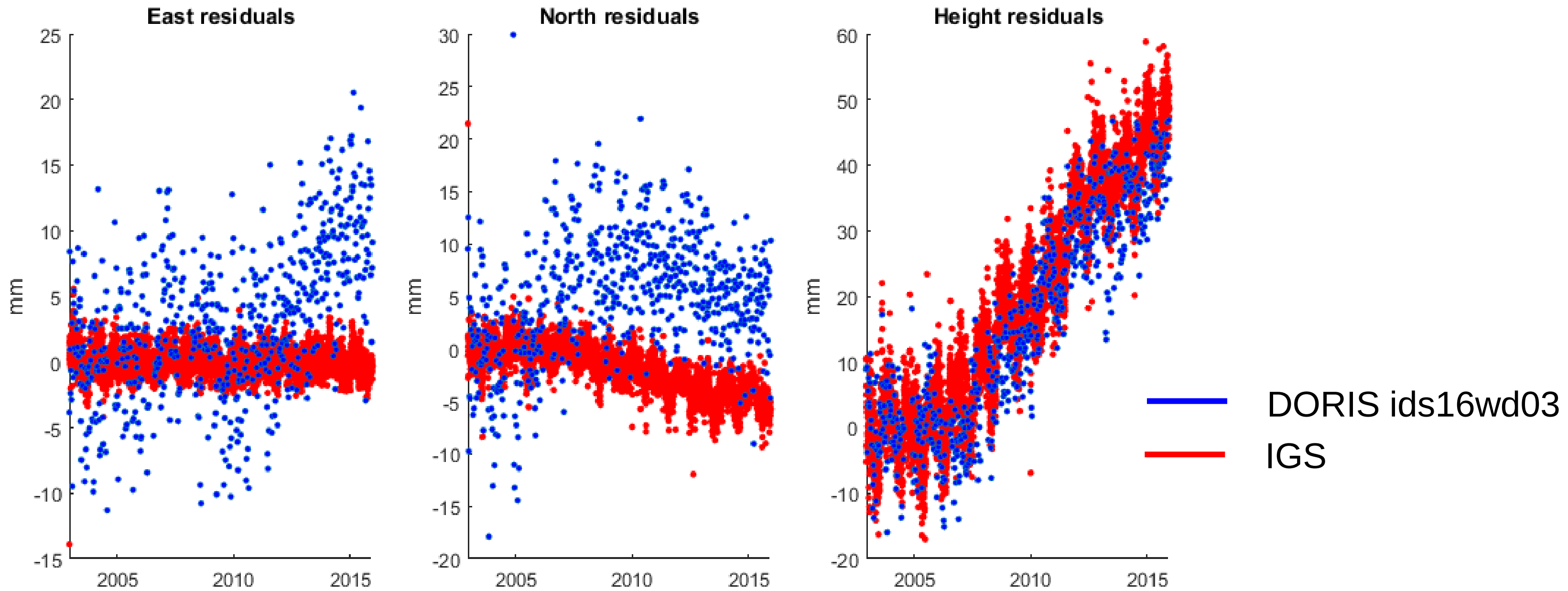
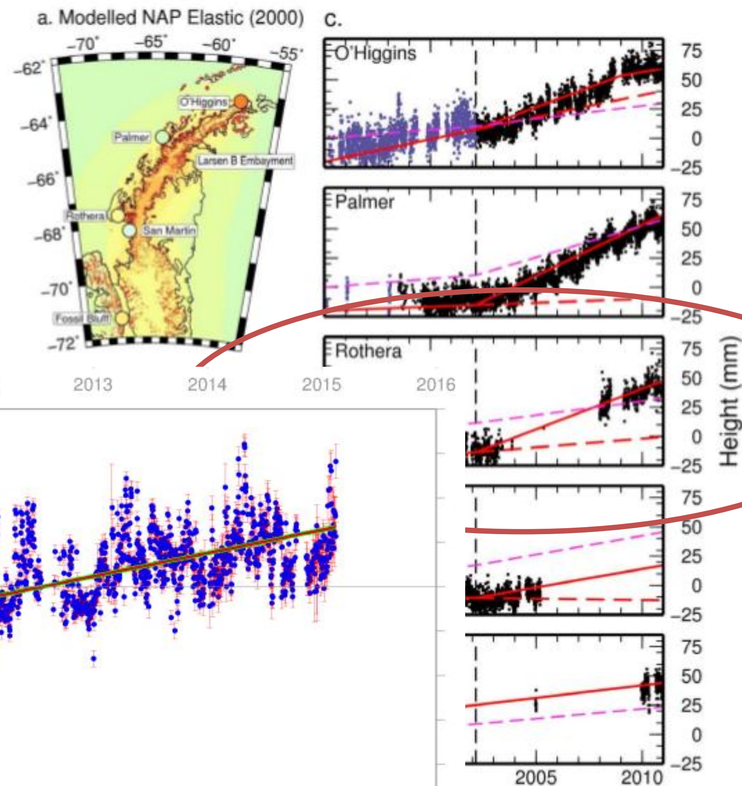


Fig: After removing estimated velocity before January 2006. Frame = ITRF2014

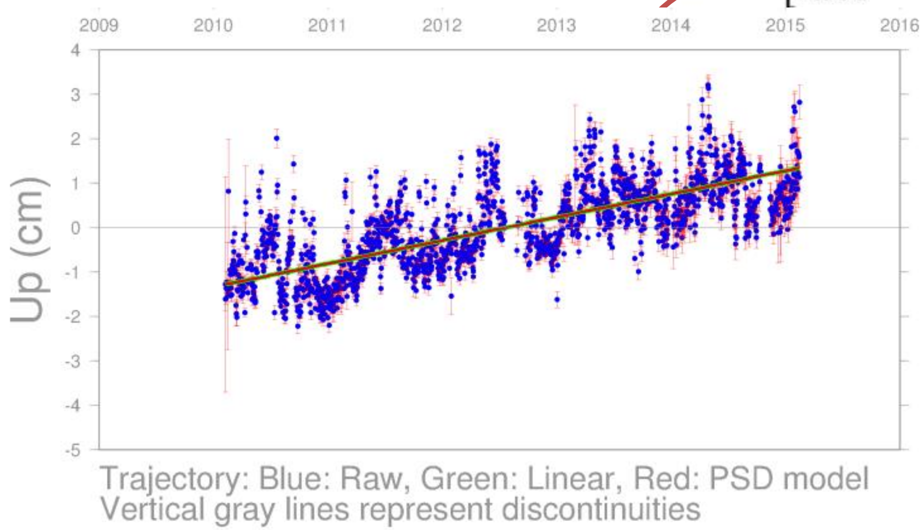
ANOTHER EXAMPLE: ROTHERA (ANTARCTICA) 1/3

ELASTIC REBOUND AT ROTHERA?

Thomas et al., GRL, 2011



Very small slope change according to forward model (pink)
But significant offset in GPS?



Only recent data in ITRF2014 but DORIS has a long history!

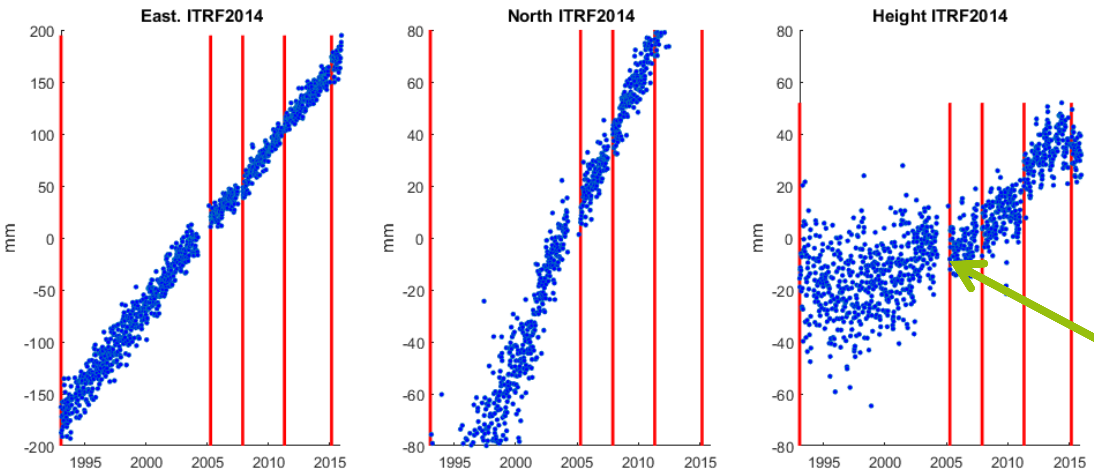
ANOTHER EXAMPLE: ROTHERA (ANTARCTICA) 2/3

- **5 DORIS STATIONS : ROTA, ROTB, ROUB, ROVB AND ROWC**

- **DATA USED:**

  - IDS16wd03 (expressed in ITRF2014) downloaded at ftp://doris.ensg.ign.fr/pub/doris/products/stcd/

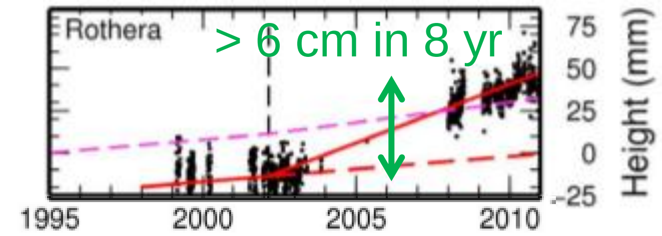
  - ITRF2014 SINEX files dowloaded at http://itrf.ign.fr/local_surveys.php + ftp://cddis.gsfc.nasa.gov/pub/doris/cb_mirror/stations/DORIS_int_ties_20160902.txt



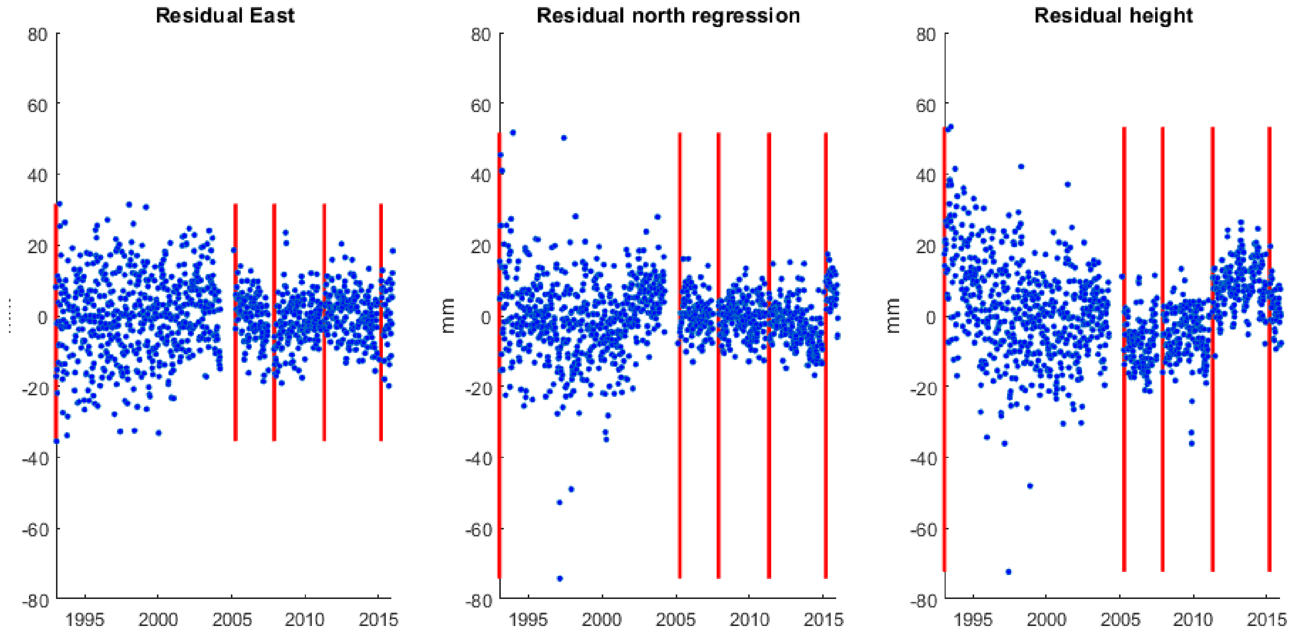
Local tie vector (ΔX) added at each station change

ANOTHER EXAMPLE: ROTHERA (ANTARCTICA) 3/3

- ELASTIC REBOUND AT ROTHERA?



Solution ids16wd03
After removing a trend computed using data before 2002



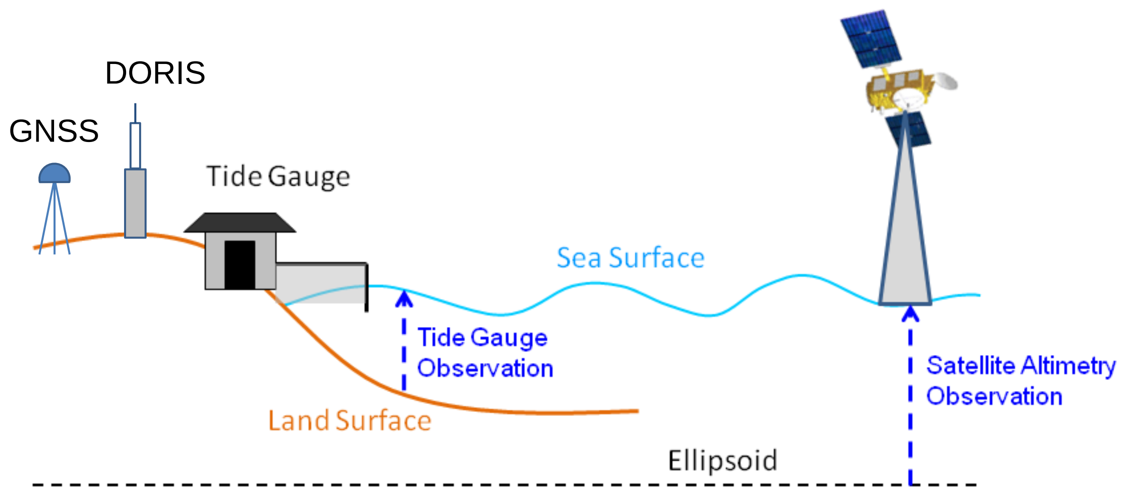
➢ No acceleration detected but uncorrected offset at antenna changes (same behavior in ign16wd03 for instance)

IGN

CONTRIBUTION TO SEA LEVEL MONITORING

- THE VERTICAL LAND MOVEMENTS (VLM) SIGNALS ARE DIRECTLY INCLUDED IN SEA LEVEL RECORDS FROM TIDE GAUGES

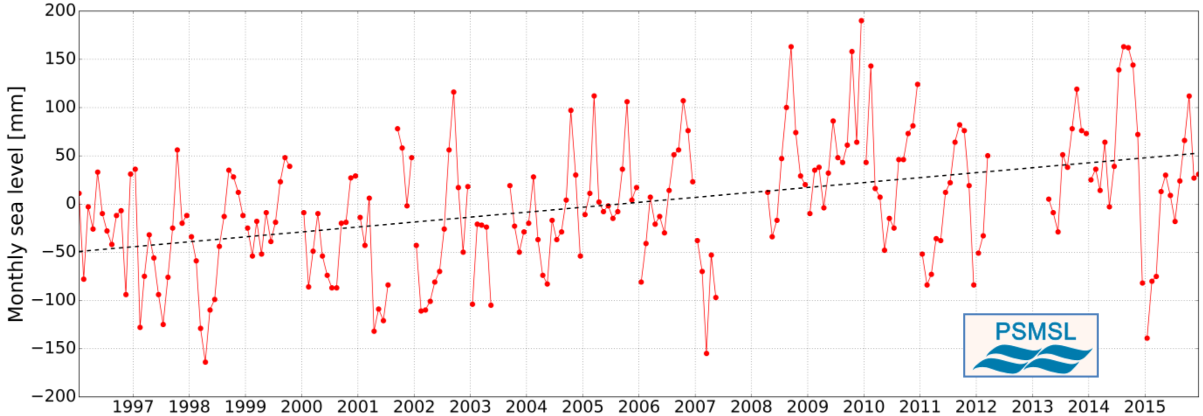
- DETERMINATION OF VLM: MODELING VS. MONITORING
  - Monitoring = Space Geodesy: DORIS, GNSS



Absolute sea level trend can be derived from altimetry or DORIS/GNSS corrected sea level records from tide gauges

EXAMPLE: PONTA-DELGADA (AZORES, PORTUGAL)

VLM CORRECTION IN SEA-LEVEL RECORDS



Relative sea-level trend over [1996-2016]: 5.12 +/- 0.74 mm/yr

VLM estimates

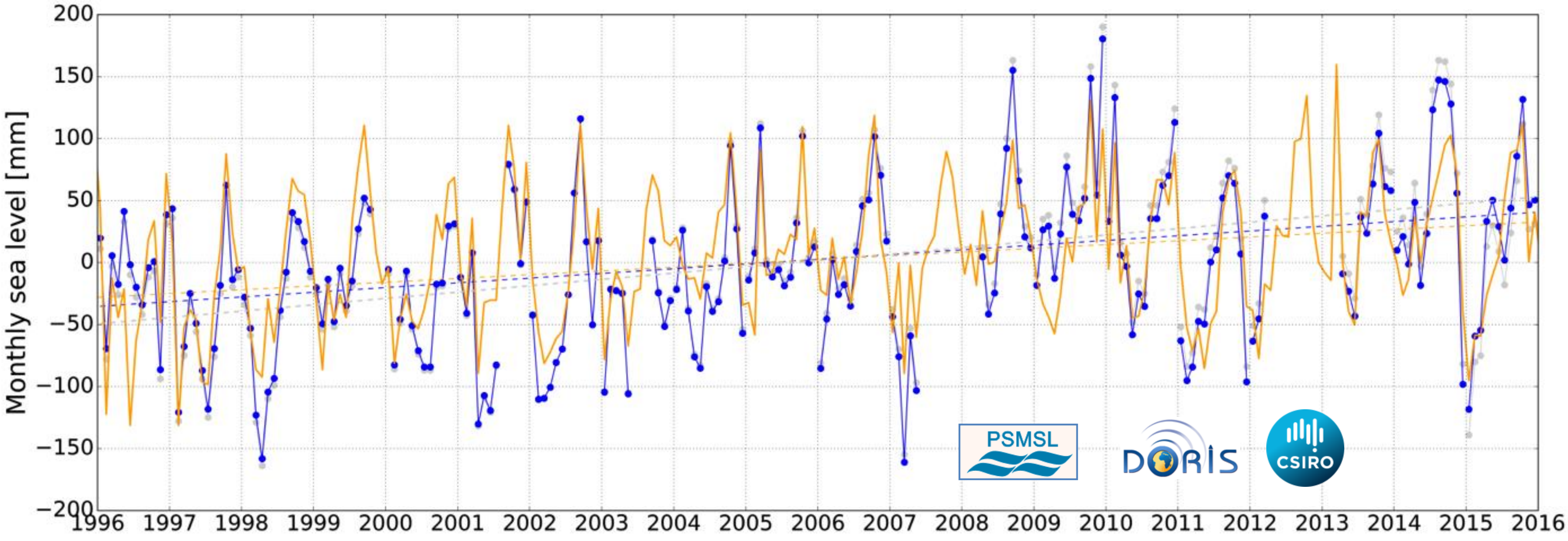
DORIS (PDMB)
-1.32 +/- 0.45 mm/yr
Source: ITRF2014, itrf.ign.fr

GPS (PDEL)
-1.51 +/- 0.16 mm/yr
Source: SONEL, www.sonel.org

Absolute sea-level trend over [1996-2016]:
3.80 +/- 0.87 mm/yr

EXAMPLE: PONTA-DELGADA (AZORES, PORTUGAL)

- VLM CORRECTION IN SEA-LEVEL RECORDS



Relative sea-level trend: 5.12 +/- 0.74 mm/yr

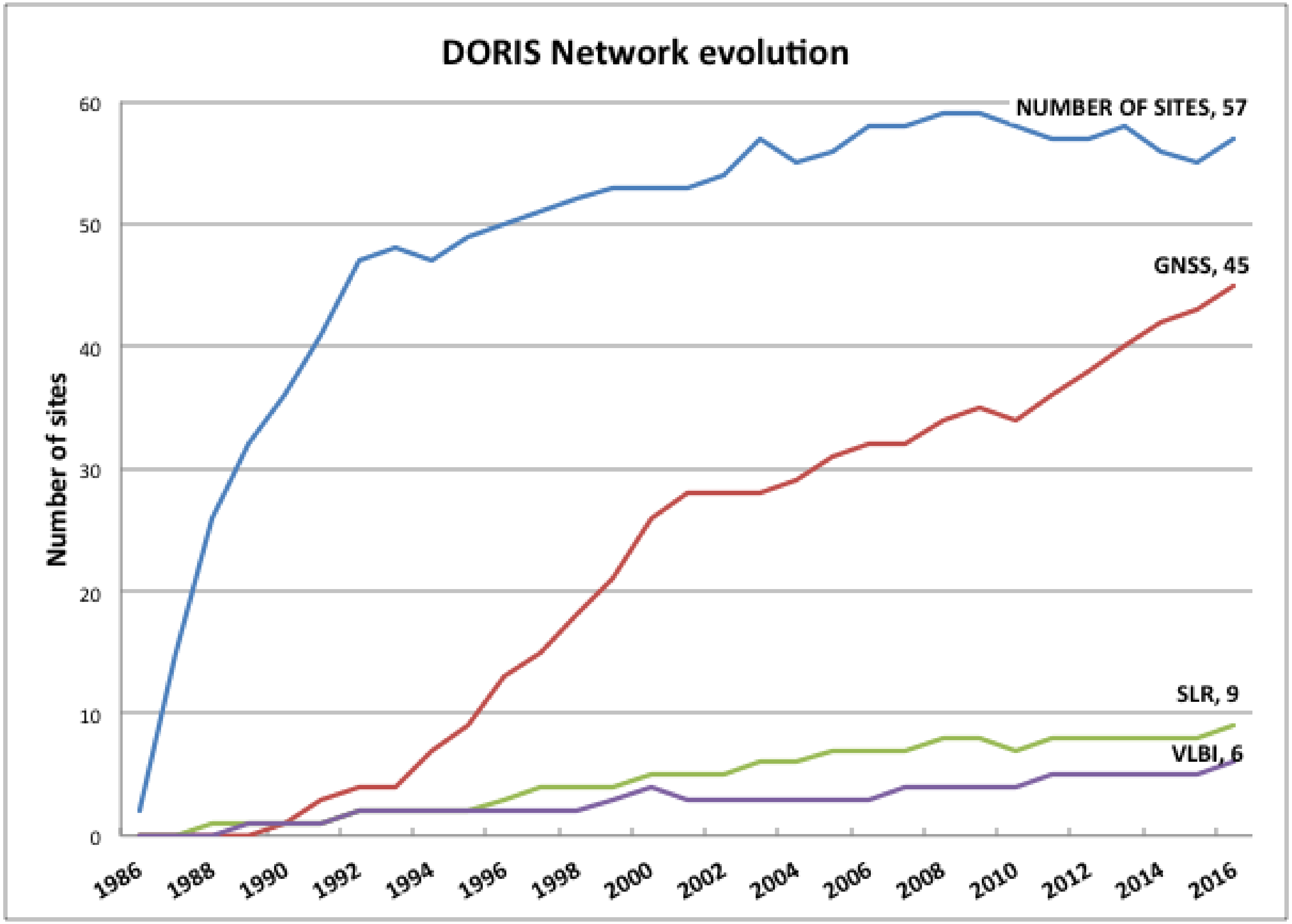
Absolute sea-level trend (DORIS corrected): 3.80 +/- 0.87 mm/yr

Absolute sea-level trend (altimetry): 3.04 +/- 0.51 mm/yr

CO-LOCATION WITH OTHER IERS TECHNIQUES:

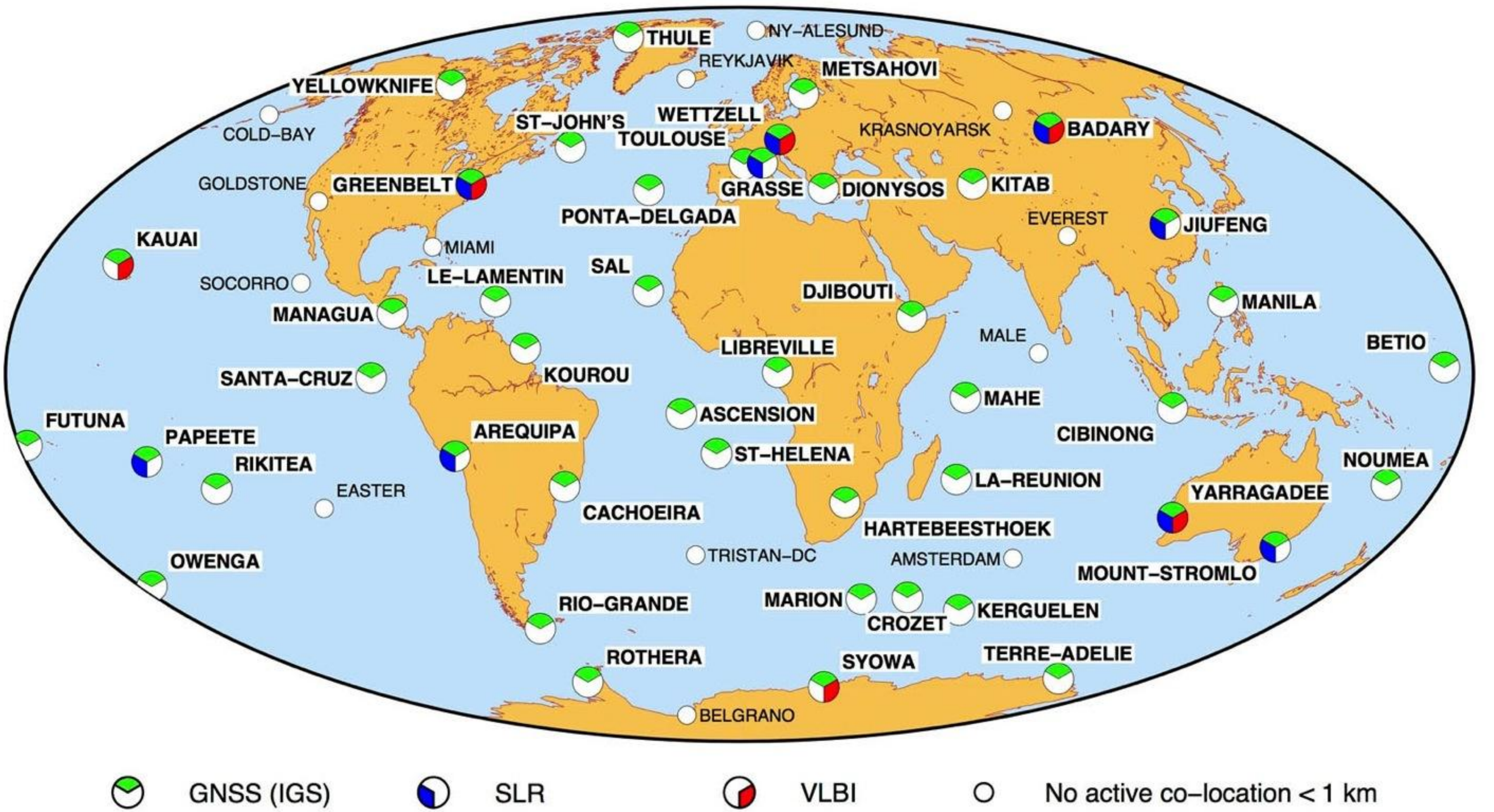
ASSESSMENT

CO-LOCATION HISTORY



CO-LOCATION EVOLUTION

DORIS co-locations today: 45 co-located sites out of 57



CURRENT STATUS

- **45 CO-LOCATIONS OUT OF 57 DORIS SITES**
- **GOOD NORTH-SOUTH DISTRIBUTION:**
  - North: 23 GNSS / 5 SLR / 4 VLBI
  - South: 22 GNSS / 4 SLR / 2 VLBI
- **4 SITES WITH THE 4 TECHNIQUES**
  - Greenbelt (2000)
  - Yarragadee (2011)
  - Badary (2011)
  - Wettzell (2016)

SITE SURVEY METHODS / ACCURACY

- **CONVENTIONAL SURVEYING**
  - Terrestrial measurements of angles and distances
  - Accuracy: 1 mm

- **GPS SURVEYING**
  - GPS relative positioning (indirect method)
  - Long observations + post-processing
  - Accuracy: 3 mm (horizontal) / 6 mm (vertical)

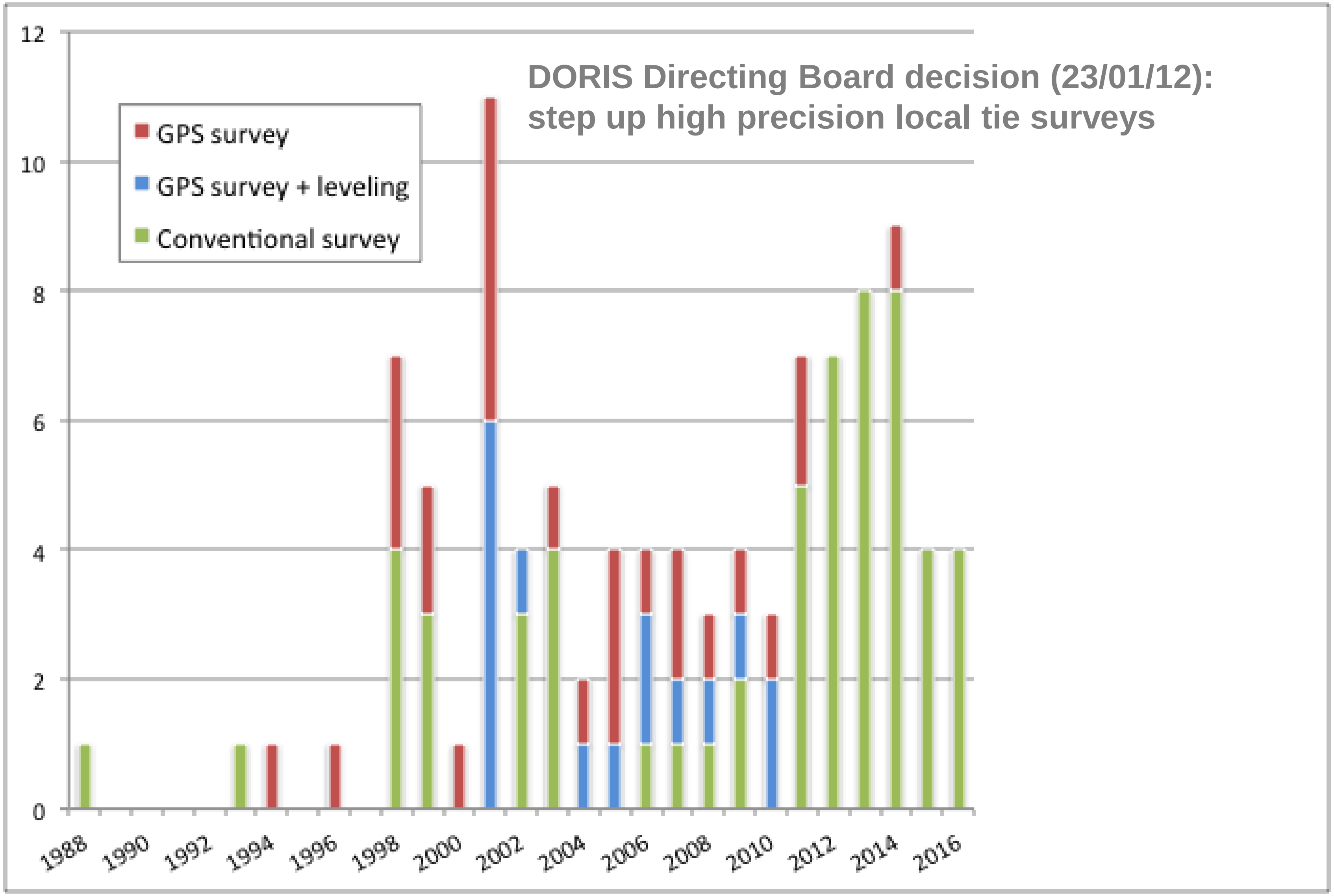
- **GPS SURVEYING + LEVELING**
  - Leveling is used to increasing the vertical accuracy of the GPS survey
  - Accuracy: 3 mm

- **OTHER INFLUENCING FACTORS**
  - Distance
  - Observation time
  - Observation conditions
  - Geometry
  - Survey date

SITE SURVEYS ASSESSMENT

- **FULL REVIEW ON THE TIE VECTORS**
  - NEW Complete list of tie vectors DORIS -> Others_Techniques since 1988
  - 175 tie vectors: 135&GNSS / 29&SLR / 11&VLBI
  - 75% of site surveys performed by IGN-F
- **RE-QUALIFYING OF THE TIE VECTORS**
  - Site survey methods: 57% conventional / 16% GPS + leveling / 27% GPS
  - Re-qualifying of the tie vectors (surveys carried out in the past)
  - On-going action: re-computing of old site surveys; SINEX cleaning and completing
- **GRADUAL IMPROVEMENT IN THE TIE VECTORS DETERMINATION**
  - 51% of the tie vectors (since 1988) have been determined with mm accuracy
  - 82% of the mm accuracy tie vectors have been determined in the last 10 years

SITE SURVEYS EVOLUTION



TIE VECTORS FILE

- **AVAILABLE ON THE IDS DATA CENTERS**
  - ftp://doris.ign.fr/pub/doris/cb_mirror/stations/DORIS_ext_ties_20161021.txt

```
## File date:   Fri October 21 2016
# DORIS tie vectors between DORIS and others IERS techniques (GNSS:SLR:VLBI)
# This table is provided and maintained by IGN-France
#
# Key (Fn is field number n, all fields are separated by spaces):
# F1: DORIS Acronyme
# F2: DORIS DOMES number (Point 1)
# F3: Longitude
# F4: Latitude
# F5: Co-located Technique
# F6: Technique Acron/CDP
# F7: Technique DOMES number (Point 2)
# F8: Co-location Start Date
# F9: Co-location End Date
# F10: Survey Date
# F11: dX from Point 1 to Point 2, ie. X2-X1 (m)
# F12: dY from Point 1 to Point 2, ie. Y2-Y1 (m)
# F13: dZ from Point 1 to Point 2, ie. Z2-Z1 (m)
# F14: tie precision at one sigma (m)
#
OWEC:50253S002:-176.22:-44.02:GNSS:OWNG:50253M001:20141120:20160307:20141129:-14.393:-11.579:18.737:0.001
OWFC:50253S001:-176.22:-44.01:GNSS:OWMG:50253M004:20160310::20160603::-2.205:-6.428:5.710:0.001
PAPB:92201S007:210.24:-17.35:GNSS:TAHI:92201M006:19970407:19980413:19980417:11.033:-16.403:-0.416:0.002
PAPB:92201S007:210.24:-17.35:SLR:7124:92201M007:19970801:19980413:19980417:173.077:-311.887:-37.063:0.002
PAQB:92201S008:210.24:-17.35:GNSS:TAHI:92201M006:19980419:20071001:19980417:-154.718:277.292:62.581:0.002
PAQB:92201S008:210.24:-17.35:GNSS:THTI:92201M009:19981122:20071001:19980417:-1.129:6.358:-2.366:0.002
PAQB:92201S008:210.24:-17.35:SLR:7124:92201M007:19980419:20071001:19980417:7.326:-18.193:25.933:0.002
PATB:92201S010:210.24:-17.35:GNSS:THTI:92201M009:20071002:20091116:20071001:-1.119:6.358:-2.363:0.001
PATB:92201S010:210.24:-17.35:SLR:7124:92201M007:20071002:20091116:20071001:7.322:-18.193:25.935:0.001
PAUB:92201S010:210.24:-17.35:GNSS:THTG:92201M016:20110113::20110113::-1.470:4.333:-2.838:0.001
PAUB:92201S010:210.24:-17.35:GNSS:THTI:92201M009:20091119::20071001::-1.119:6.358:-2.363:0.001
PAUB:92201S010:210.24:-17.35:SLR:7124:92201M007:20091119::20071001::7.322:-18.193:25.935:0.001
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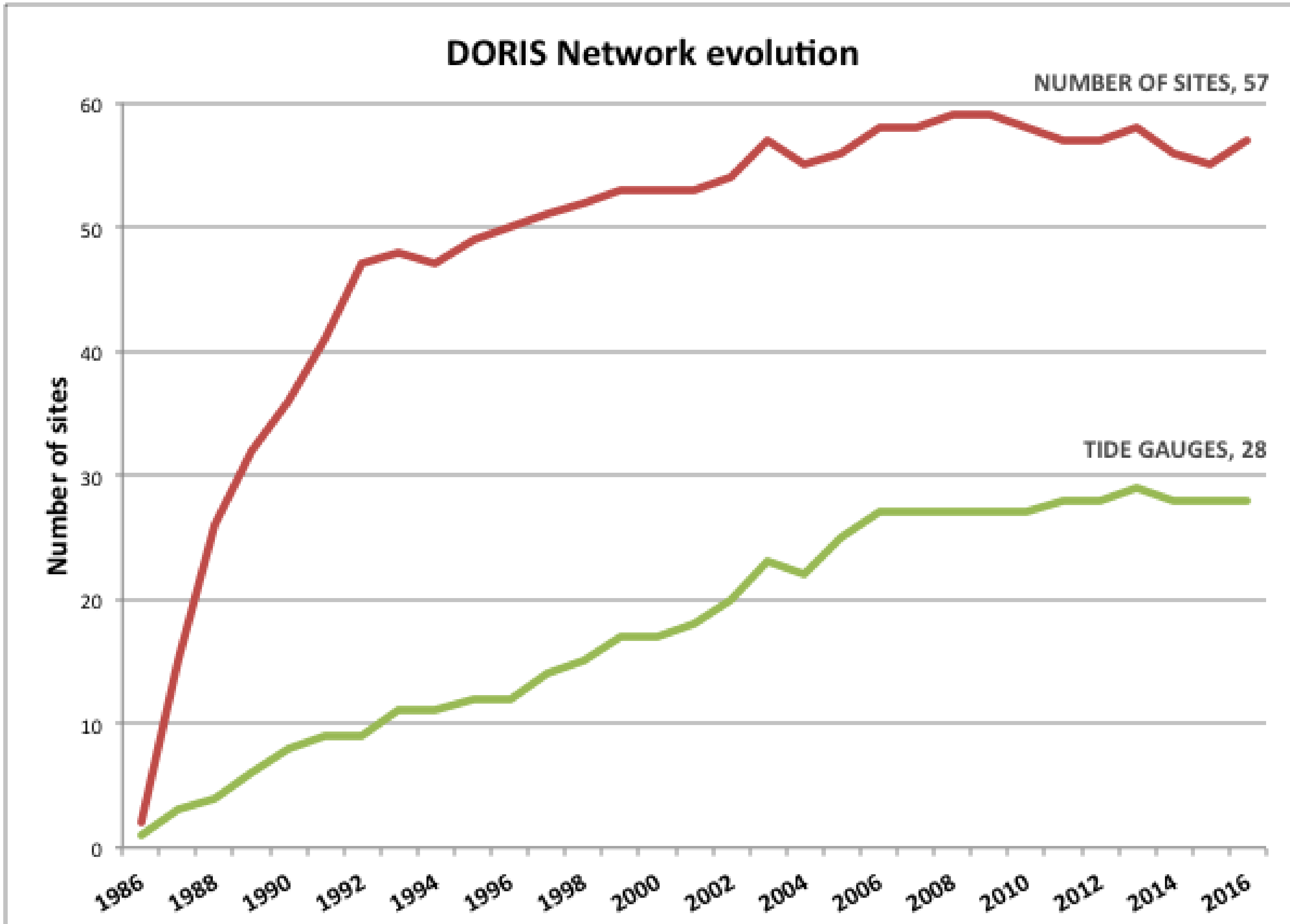
CO-LOCATION WITH TIDE GAUGES:

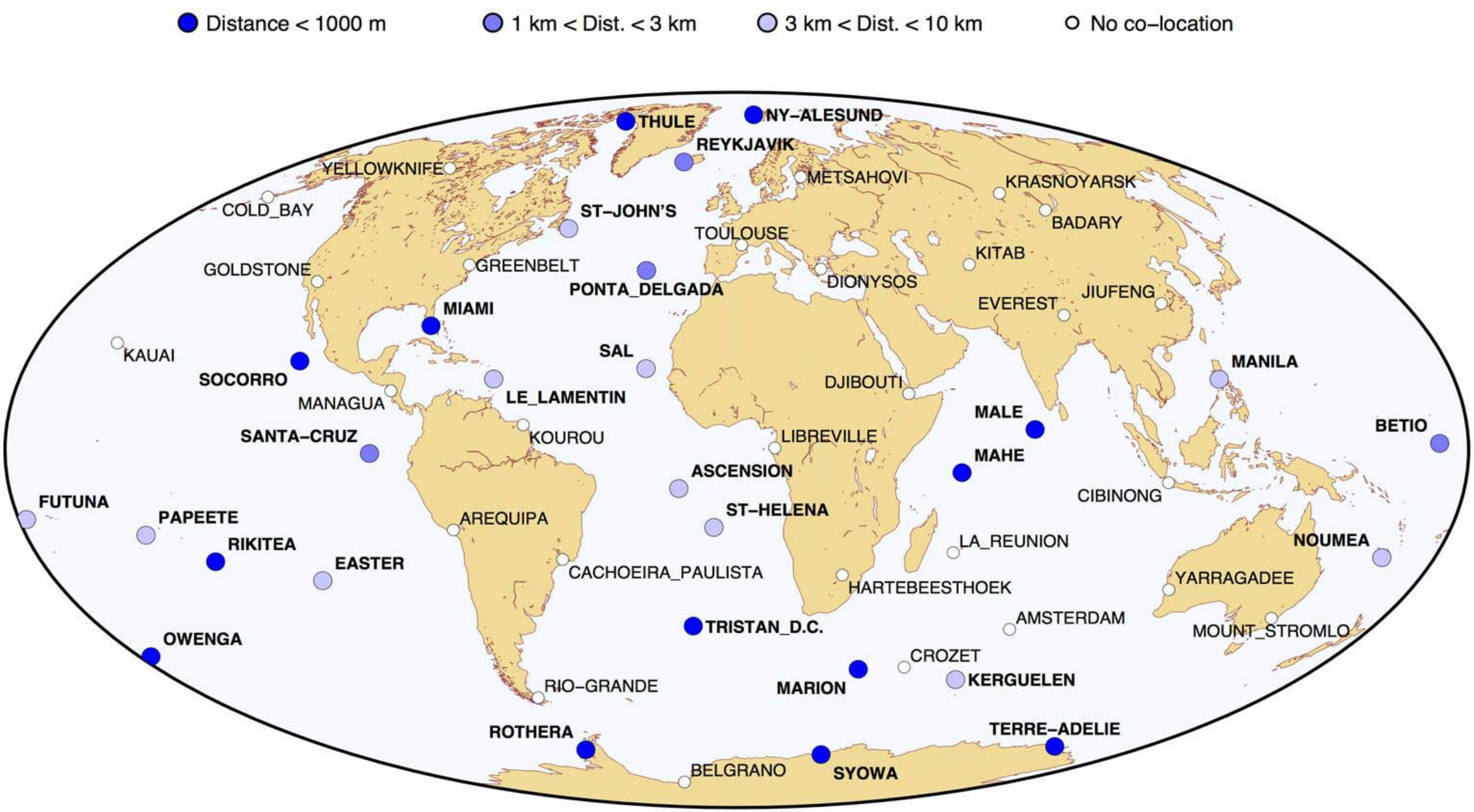
ASSESSMENT

CO-LOCATION HISTORY



CO-LOCATION EVOLUTION

Co-location with tide gauges on 01-11-2016



SITE SURVEY METHODS / ACCURACY

- DIFFERENTIAL LEVELING
  - Precise level + graduated staff : direct method for height measurements
  - Accuracy: <1 mm
- TRIGONOMETRIC LEVELING
  - Tachometer + prism : indirect method (angle and distance measurements)
  - Accuracy: 1 mm
- GPS SURVEY
  - Accuracy: 6 mm
- OTHER INFLUENCING FACTORS
  - Distance
  - Observation time
  - Observation conditions
  - Difference in height
  - Survey date

SITE SURVEYS ASSESSMENT

- **LEVELING METHOD USED**

← Better Accuracy

	Differential	Trigonometric	GPS	No Survey
Dist. < 1000m	3	2	6	2
1km < Dist. < 3km	0	1	3	0
3km < Dist < 10km	0	0	11	0

- **SOME SITES (WHERE TIDE GAUGE < 1000M) NEEDS BETTER HEIGHT DIFFERENCES DETERMINATION**
  - But differential leveling is difficult to implement in remote areas

- **MOST OF THE TIE VECTORS ARE AVAILABLE ON:**
  - www.sonel.org/?lang=en

PROSPECTS

CONCLUSION

FAVORABLE CONTEXT

- **GGOS (GLOBAL GEODETIC OBSERVING SYSTEM):**
  - Global geodetic network infrastructure through intergovernmental cooperation: core sites with the 4 techniques in progress
  - IERS Working Group “Site surveys and co-location”
- **REGINA (RÉSEAU GNSS POUR L’IGS ET LA NAVIGATION):**
  - Global GNSS real-time network for scientific purposes : deployment of about 30 stations co-located with DORIS from 2011
- **SONEL (SYSTÈME D’OBSERVATION DU NIVEAU DES EAUX LITTORALLES):**
  - Deployment of GNSS stations co-located with tide gauges from 2014

⇒ ***this context increases possibilities for multiplying co-locations***

⇒ ***increases opportunities for IGN to perform high precision local ties surveys***

CO-LOCATION: PERMANENT OBJECTIVE

- **THROUGHOUT THE DORIS NETWORK DEPLOYMENT**
  - Deployment: look for sites with other space geodetic techniques or tide gauges
- **THROUGHOUT THE DORIS NETWORK EVOLUTION**
  - Opportunities to move: site closure, drop in performance, local constraints…
  - Densification: geographic coverage improvement
- **TODAY MORE THAN EVER, INCREASING CO-LOCATION IS A GUIDING PRINCIPLE FOR THE DORIS NETWORK EVOLUTION**
  - Supported by CNES and IGN

FUTURE CO-LOCATIONS

2020