Near Real Time Processing of Underway Salinity Data from Ships of Opportunity

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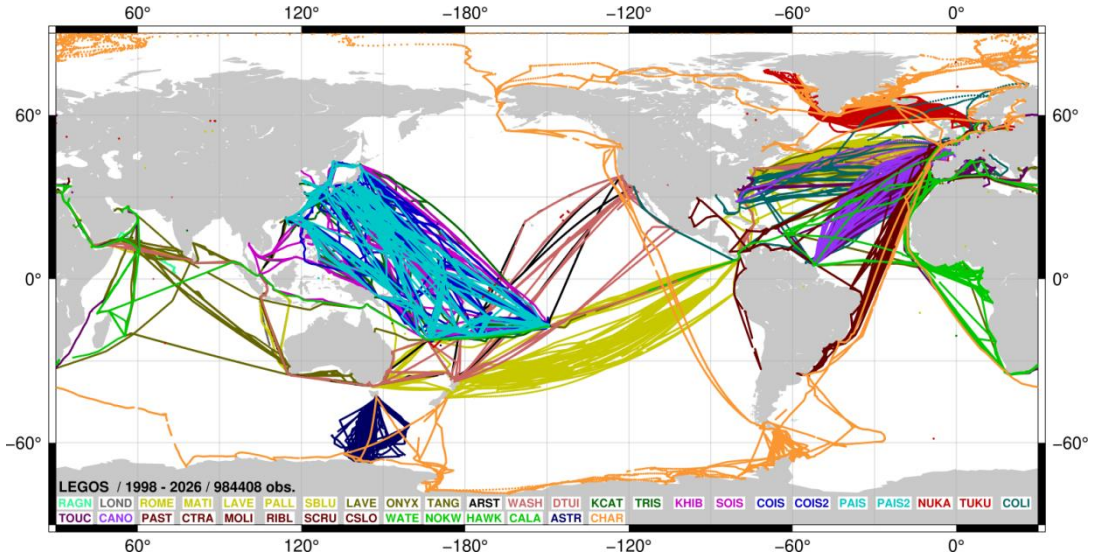
Alory et al., 2025, Journal of Operational Oceanography

The French SSS Observation Service



1998-2026

- A network of ships of opportunity initiated more that 50 years ago
- Nowadays 15 commercial ships instrumented with thermosalinographs (TSG)
- From tropics to pole
- Complementary to Argo: coastal regions, mesoscale, fronts (2 km alongtrack resolution)
- Useful for satellite validation (ESA salinity Pi-MEP)
- Real and delayed time data fluxes

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Real time (RT) processing

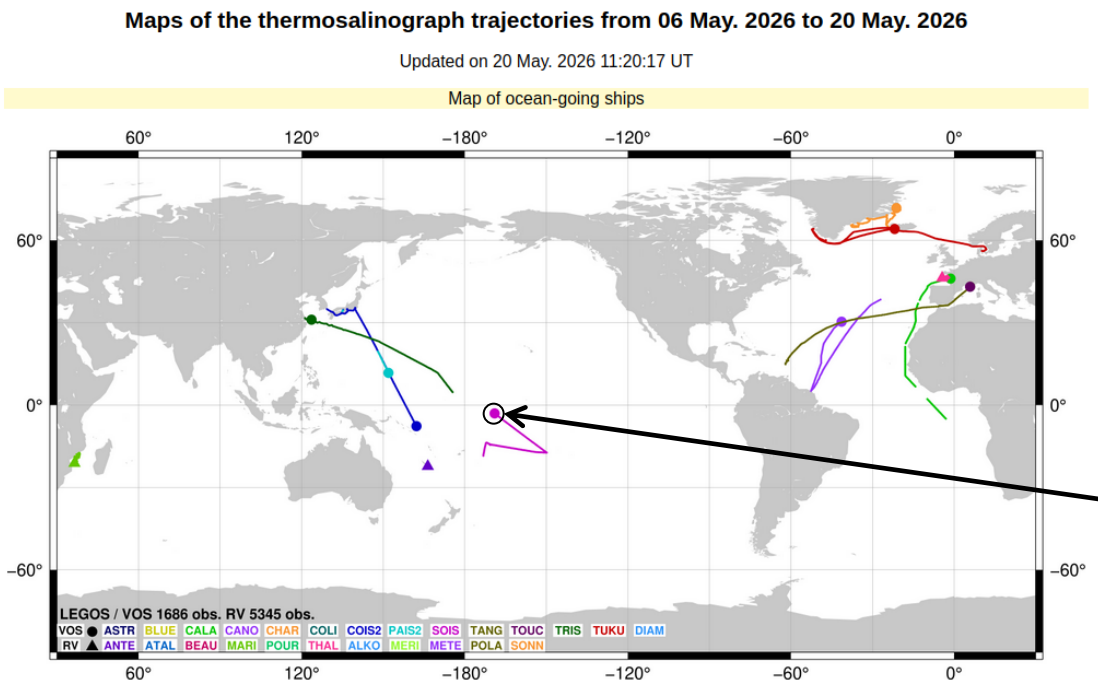
- Satellite transmission of hourly data twice a day
- Warning messages in case of potential problems
- Detection of instrumental problems
- Feeds **operational oceanography** database

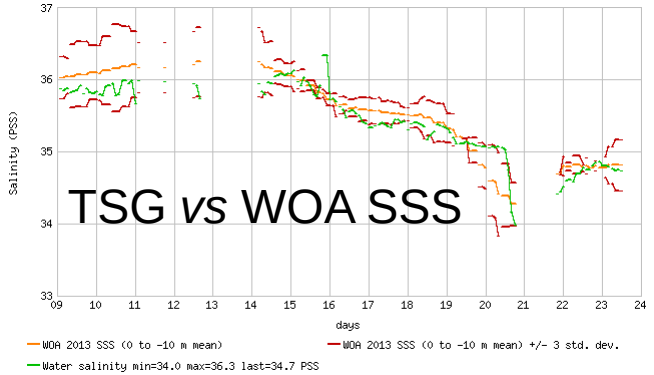
Coriolis OCEANOGRAPHIE OPERATIONNELLE

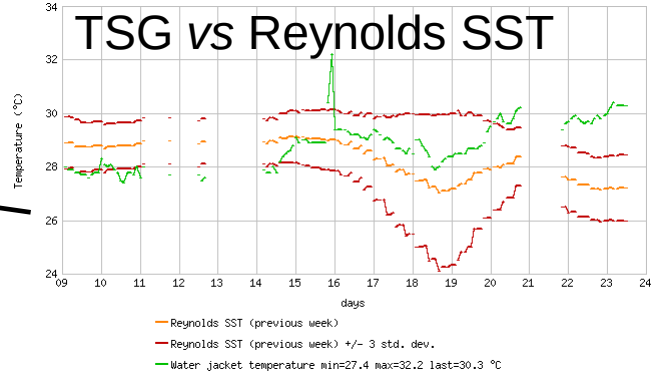
MERCATOR OCEAN INTERNATIONAL

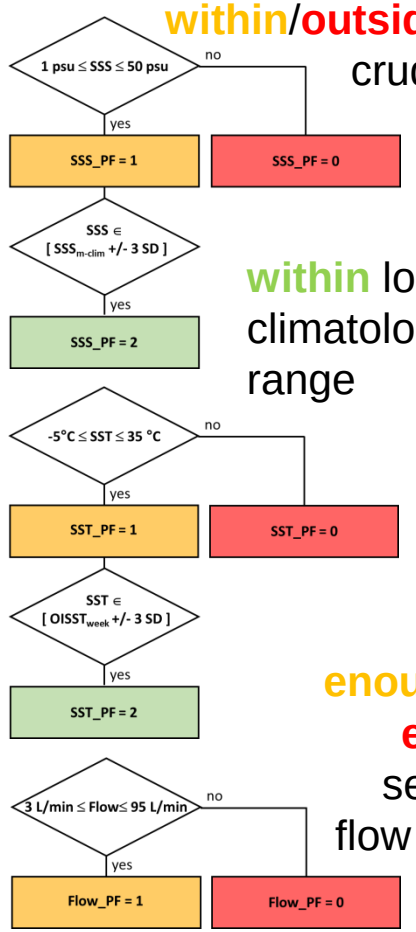
→ Allows to minimize data loss and plan maintenance operations at calls in Europe/New Caledonia

→ Attribution of internal processing flags (PF) on SST, SSS, flow, though unexploited in Coriolis QC









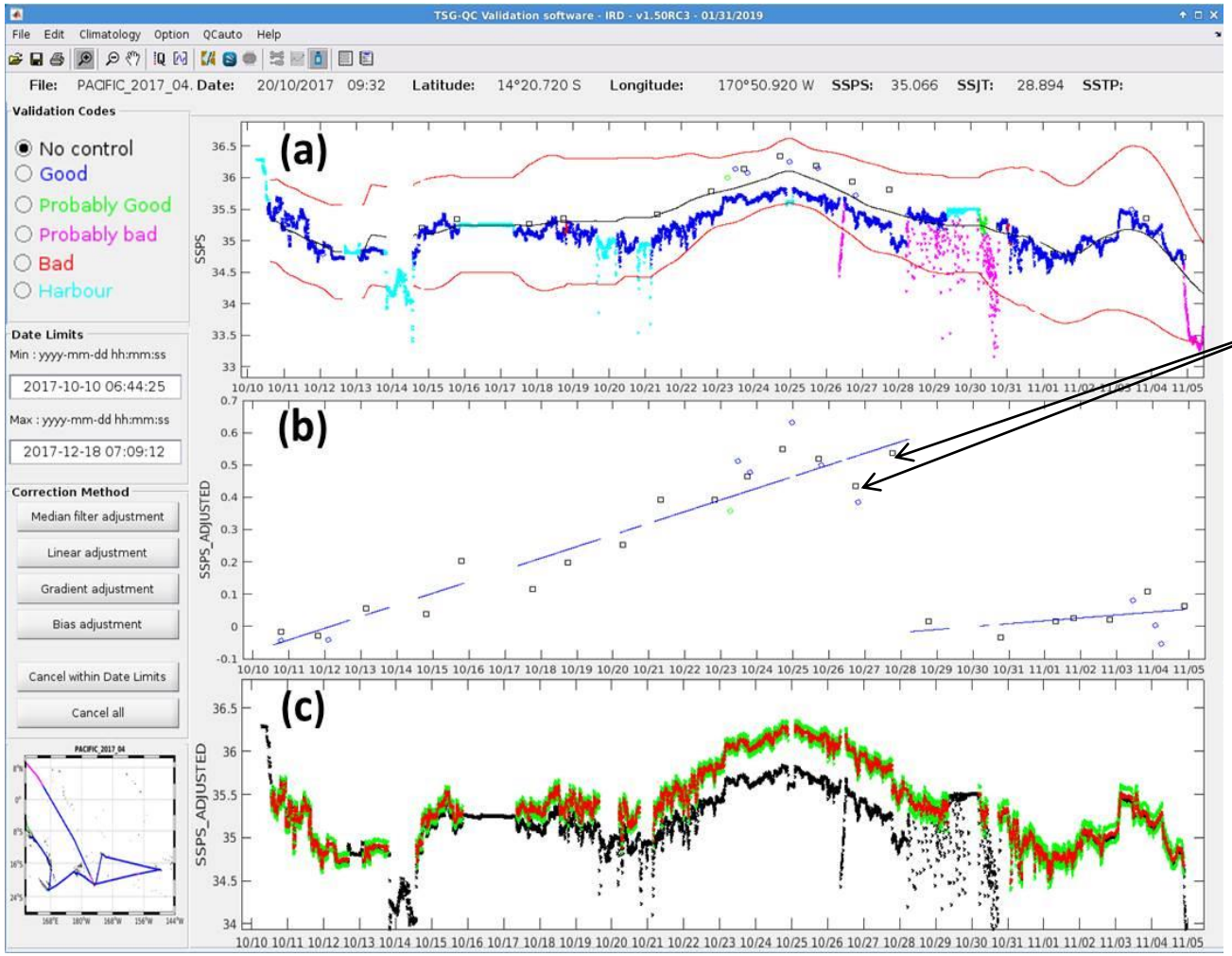
within/outside global crude range

within local climatological range

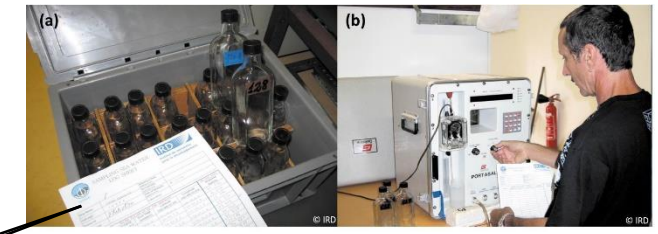
enough/not enough seawater flow in TSG

Delayed time (DT) processing

5-min measurements retrieved at harbour calls



TSG
+/- 0,02 psu



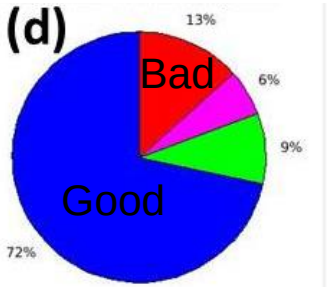
Salinometer
+/- 0,005 psu

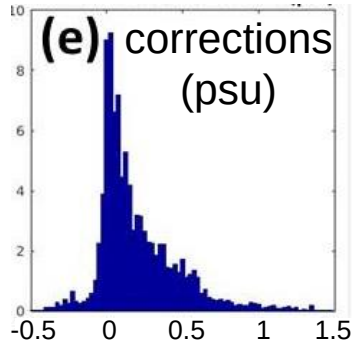
Manual attribution of QC flags by comparison with climatology and flowmeter, correction of instrumental drifts/shifts (fouling, dirty habours) with daily water samples, estimation of errors

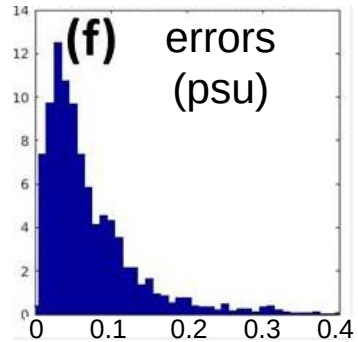
Delay: 6 months to 1 year
For research purposes

Statistics

QC flags





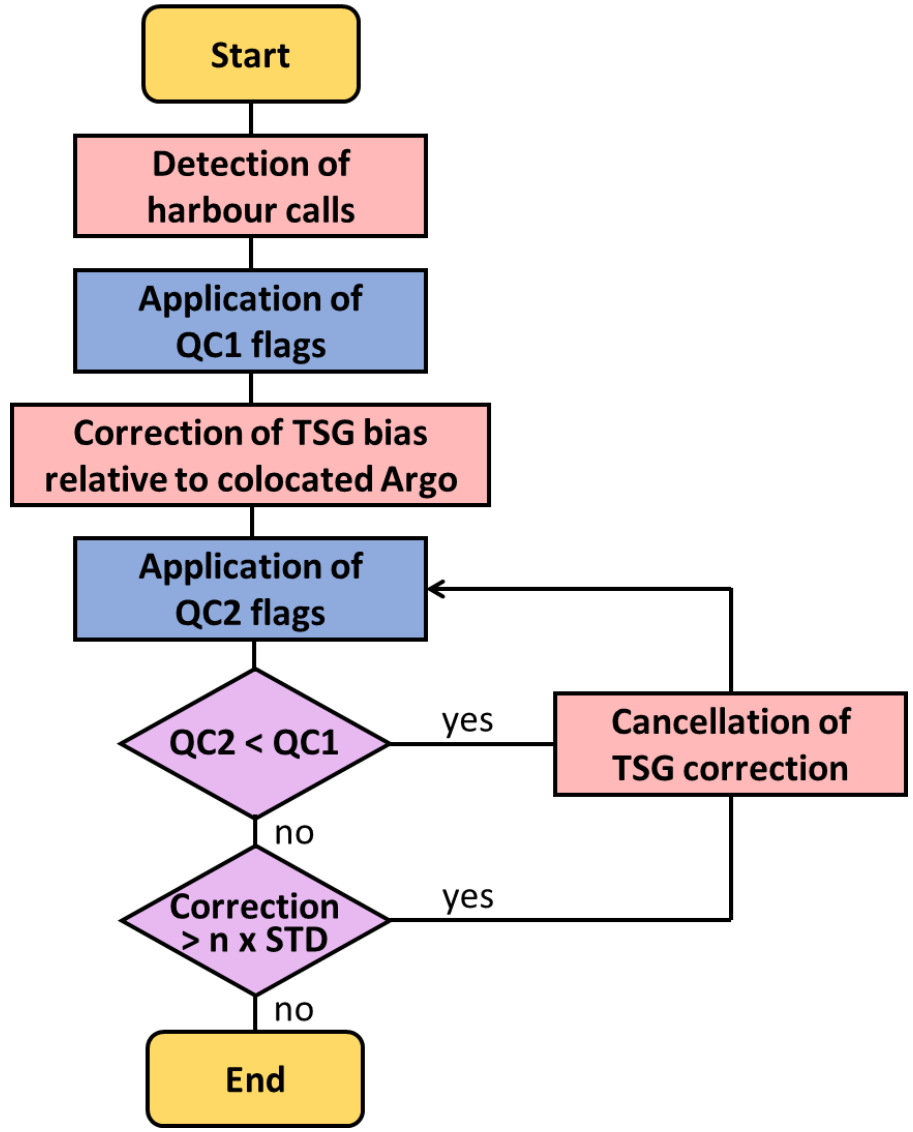


Alory et al., 2020

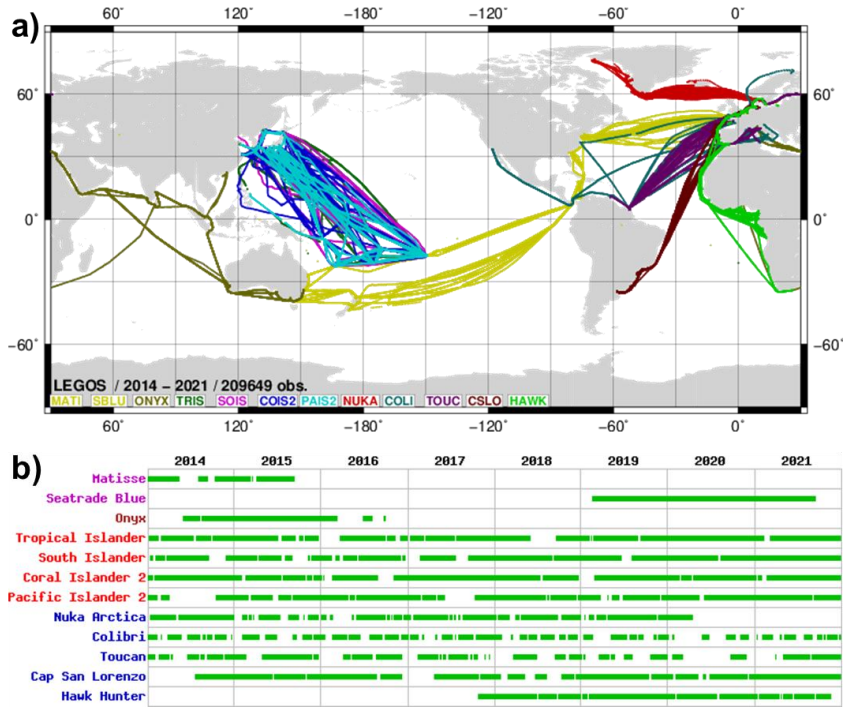
New algorithms for automatic validation/correction

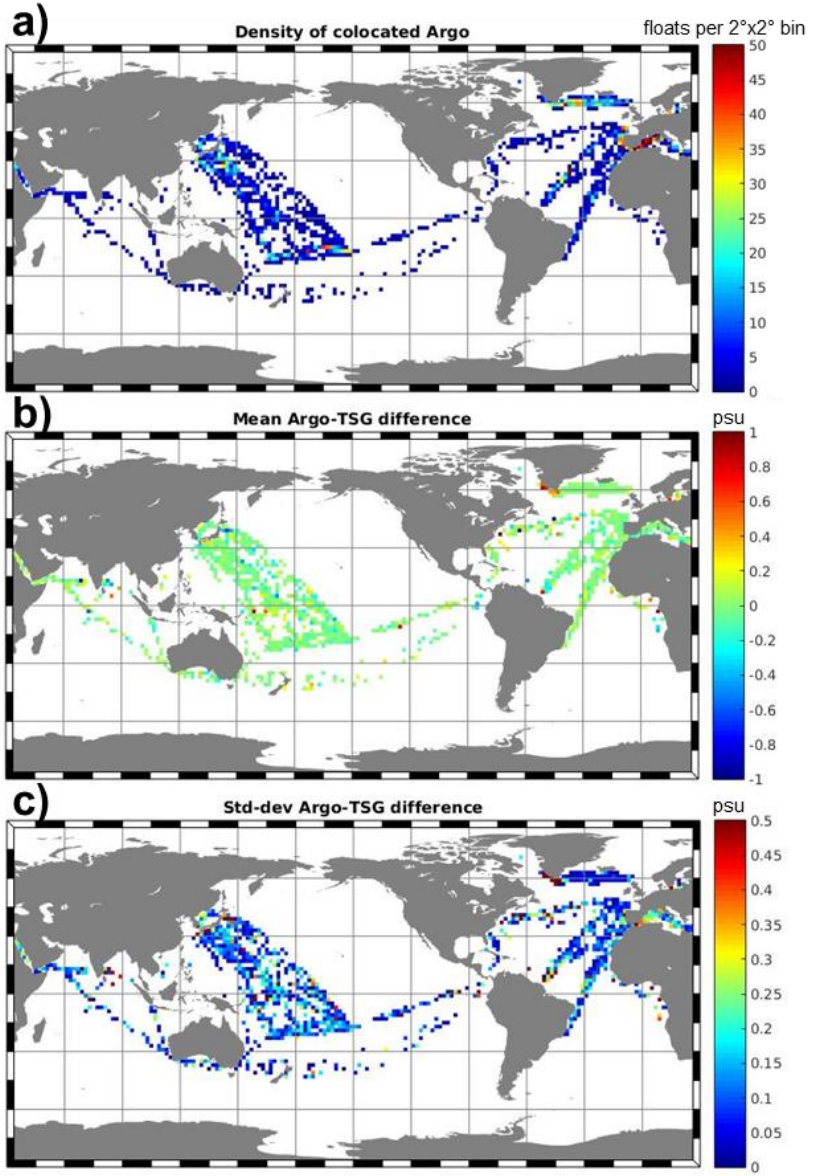
- QC flags applied by Coriolis mostly defined for Argo floats
- TSG often rejected in Mercator assimilation systems due to biases (only removed in DT)
- Unexploited RT processing flags
- Argo surface data colocated with ship trajectories routinely extracted in RT at Coriolis (+/- 100 km, 5 days)

→ **Need and potential to develop automatic processing that can be applied in Near Real Time (NRT)**



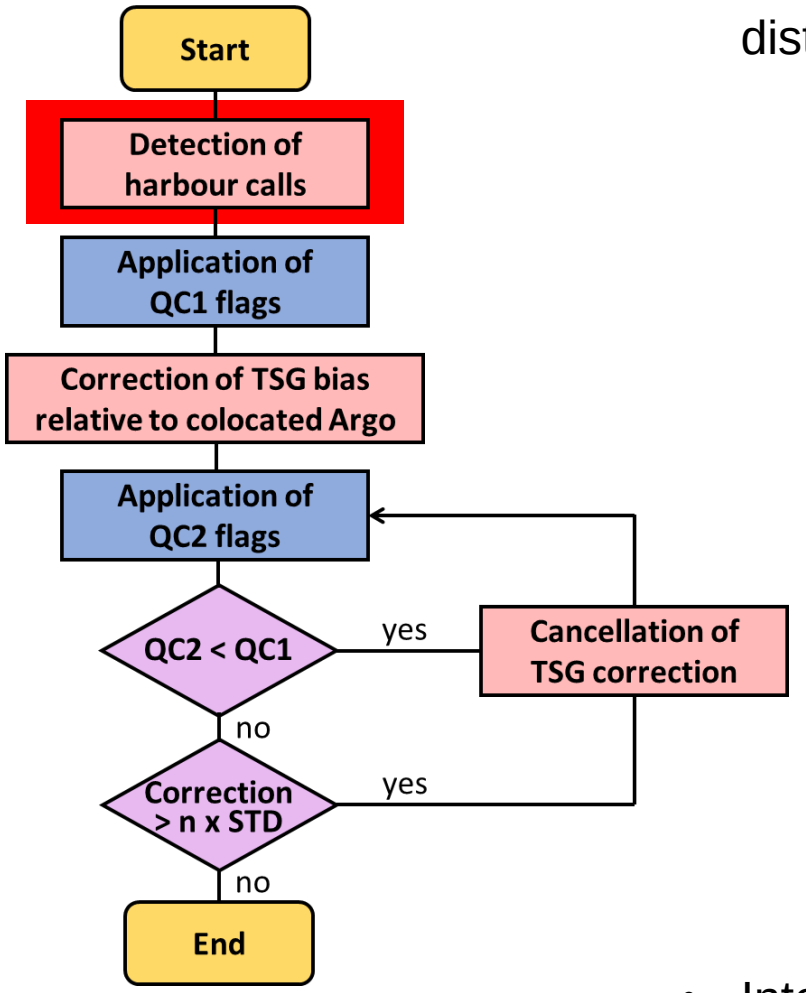
Database for evaluation of algorithms





- Subset of ships equipped with flowmeters over 2014-2021 for retrospective application and evaluation of NRT of algorithms
- Set of colocated Argo for SSS comparison
- TSG-Argo differences (in mean and STD) generally small except in frontal regions (Gulf Stream eddies, Greenland shelf)

Methodology: Detection of harbour calls



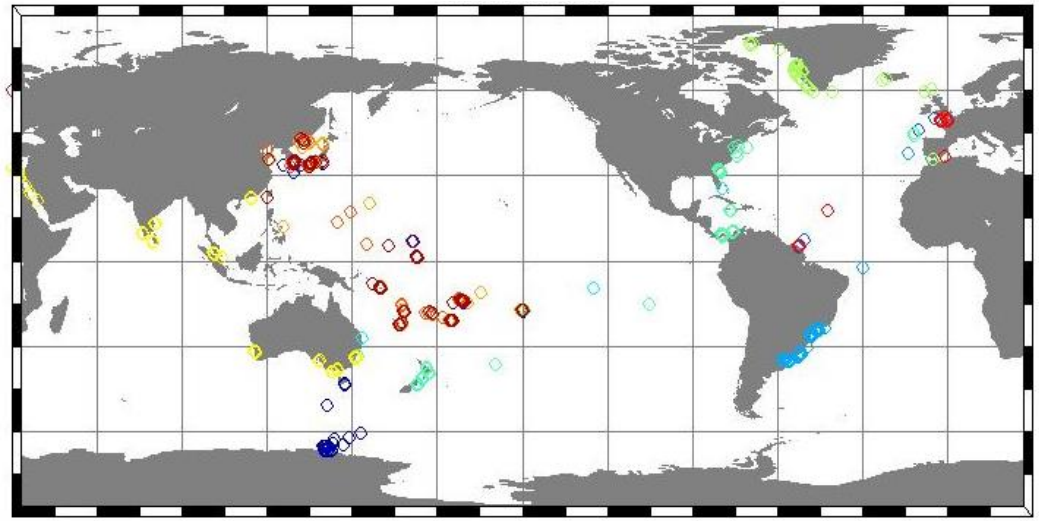
- Based on time since last message received (T_{last}), ship's velocity (V_{ship}) and distance to nearest coastline (D_{coast}) :

  (T_{last} > 5 h & V_{ship} < 5 kn & D_{coast} < 60 km)

  or (V_{ship} < 1 kn & D_{coast} < 25 km)

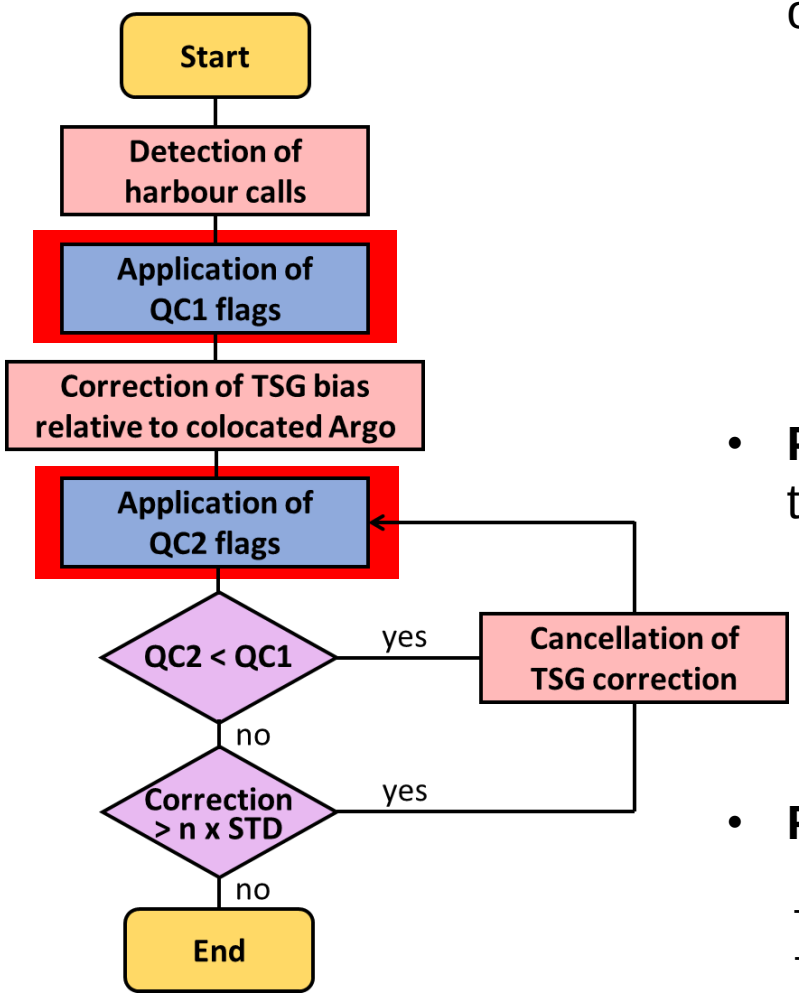
  or (T_{last} > 6 d)

Detected calls

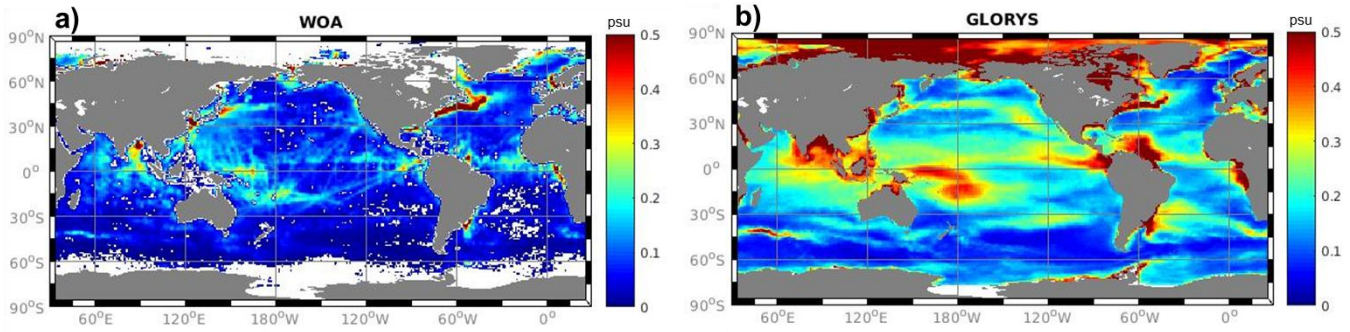


- Intervals between 2 ports of call (where shifts generally occur) define a **section** where a constant correction can be applied

Methodology: QC flagging



- Conversion of preliminary processing flags (PF), attributed from WOA or GLORYS reanalysis climatology, into quality flags



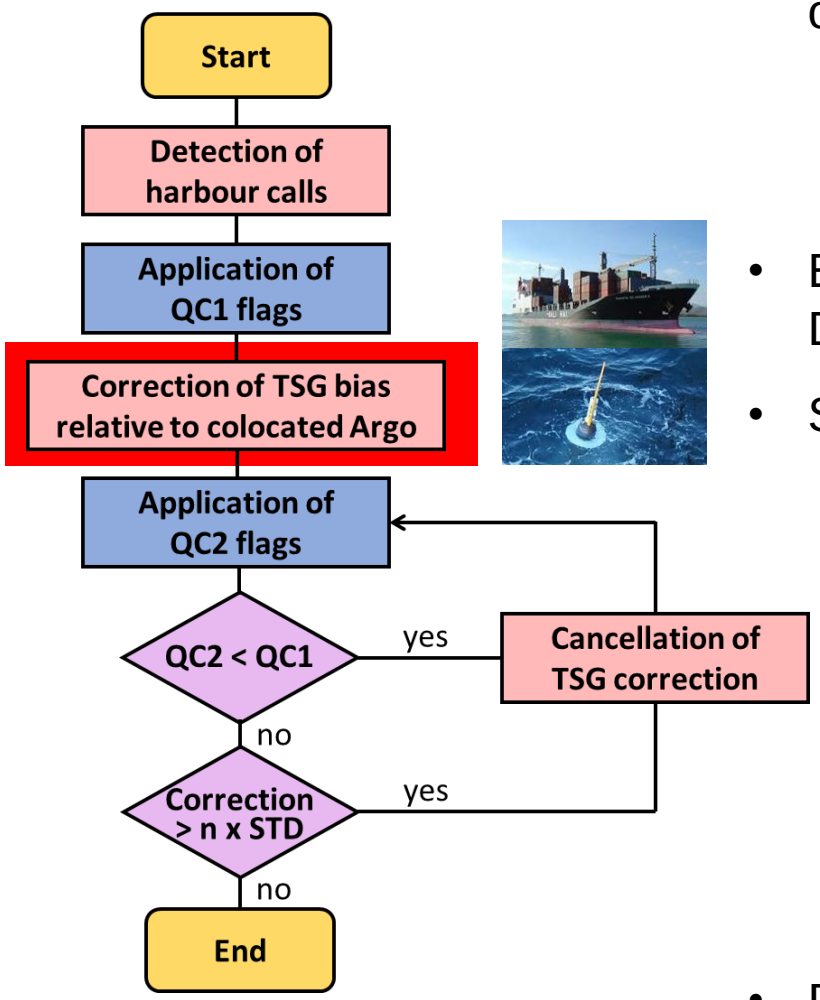
- **Preliminary flagging (QC1)**, permissive to keep *(Probably) Good* data that can potentially be corrected :

  - ***Bad*** : SST_PF = 0 **or** SSS_PF = 0
  - ***P. Bad*** : SST_PF = 1 **and** SSS_PF ≠ 0 **and** Flow_PF=0
  - ***P. Good*** : (SST_PF = 1 **and** SSS_PF = 1 **and** Flow_PF=1) **or** (SST_PF = 2 **and** SSS_PF = 1)
  - ***Good*** : (SST_PF = 1 **and** SSS_PF = 2 **and** Flow_PF = 1) **or** (SST_PF = 2 **and** SSS_PF = 2)

- **Final flagging (QC2)** of corrected data, more restrictive :

  - ***Bad*** : SST_PF = 0 **or** SSS_PF = 0
  - ***P. Bad*** : (SST_PF = 1 **and** SSS_PF = 2 **and** Flow_PF=0) **or** (SST_PF =1 **and** SSS_PF = 1) **or** (SST_PF =2 **and** SSS_PF = 1)
  - ***P. Good*** : (SST_PF = 1 **and** SSS_PF = 2 **and** Flow_PF=1) **or** (SST_PF = 2 **and** SSS_PF = 2 **and** Flow_PF=0)
  - ***Good*** : SST_PF = 2 **and** SSS_PF = 2 **and** Flow_PF = 1

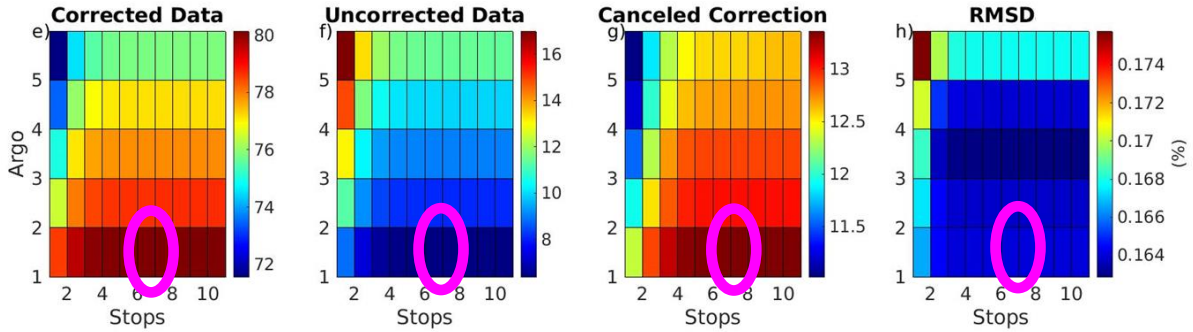
Methodology: Correction



- Application of corrections, always constant between 2 harbour calls, based on differences with colocated Argo data:

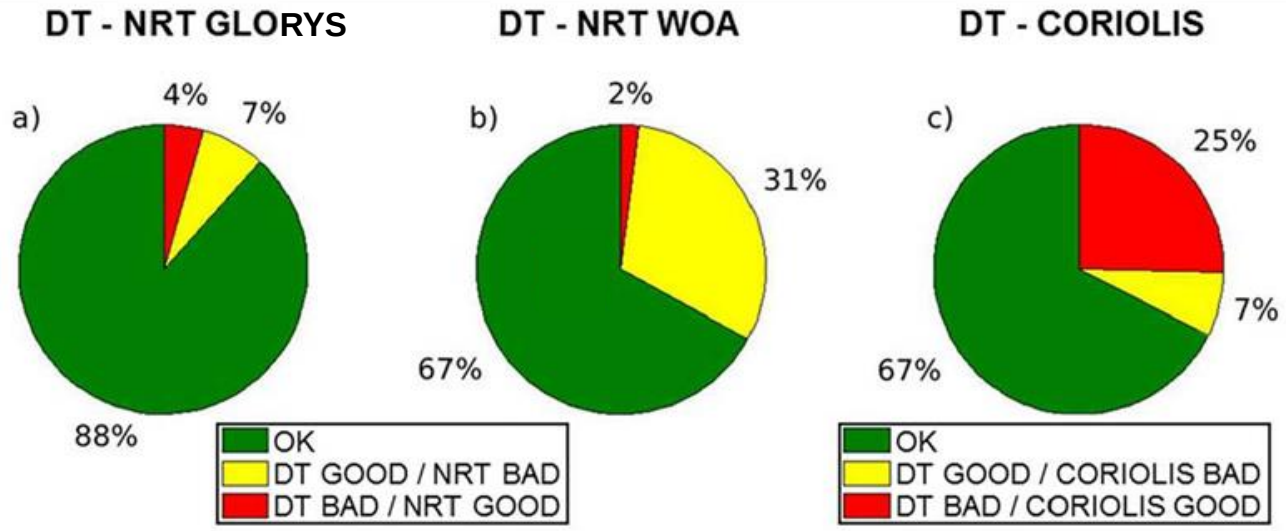
$$\Delta S_{\text{correction}} = \left[\sum_{i=1}^{N \geq N_{\min}} \frac{(\text{SSS}^{i}_{\text{Argo}} - \text{SSS}^{i}_{\text{TSG}})}{N} \right]^{\text{now}}_{\text{7 sections or 90 days max before}}$$

- Evaluation of corrections by comparison of NRT corrected data to reference DT corrected dataset – objective : minimize RMSD
- Sensitivity tests to:
  - minimum number of Argo data required (N_{min}=1)
  - maximum number of sections (7) and time (90 days) backward to search for Argo
  - spatial (100 km) and temporal (5 days) colocation radius



- Possible cancellation of correction, if there are less *(Probably) Good* Data after QC2 than after QC1, or if correction is very large.

Results: QC flagging

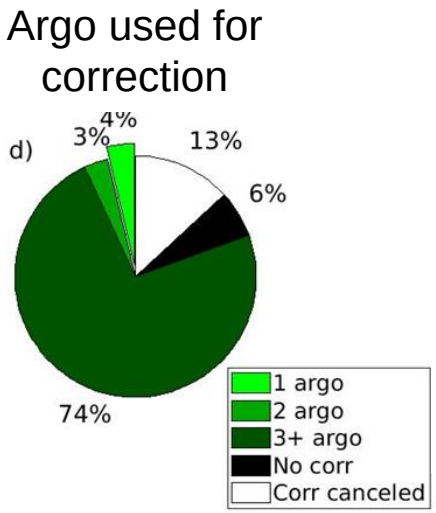


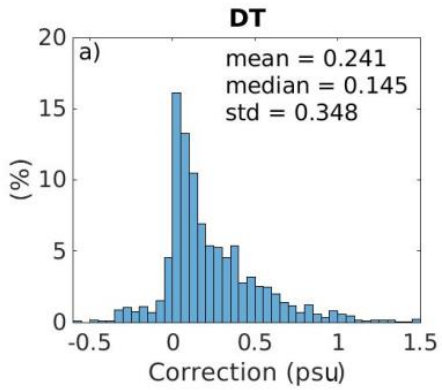
Comparison of (N)RT / DT QC flags

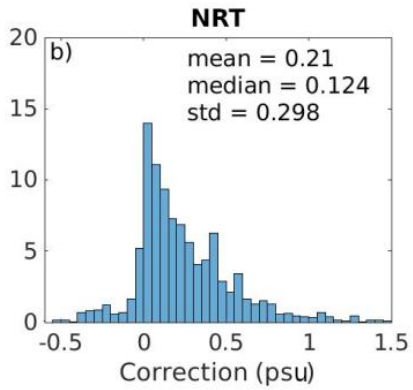
- From 67% to 88% agreement
- Philosophy: better to underestimate than overestimate data quality
- QC with GLORYS improves on QC with WOA climatology, which improves on Coriolis QC
- GLORYS Mercator reanalysis may better capture SSS dynamics especially at the coast

Results: Corrections

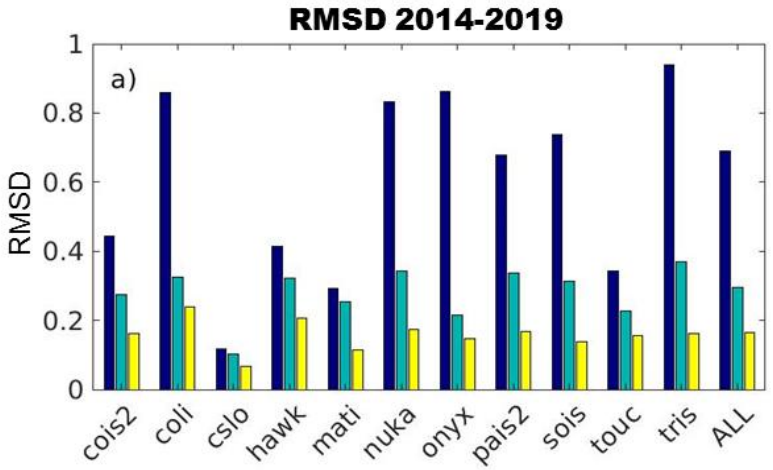
- More than 80% of TSG data are corrected, 74% with 3+ Argo data
- Very similar distribution of NRT and DT corrections

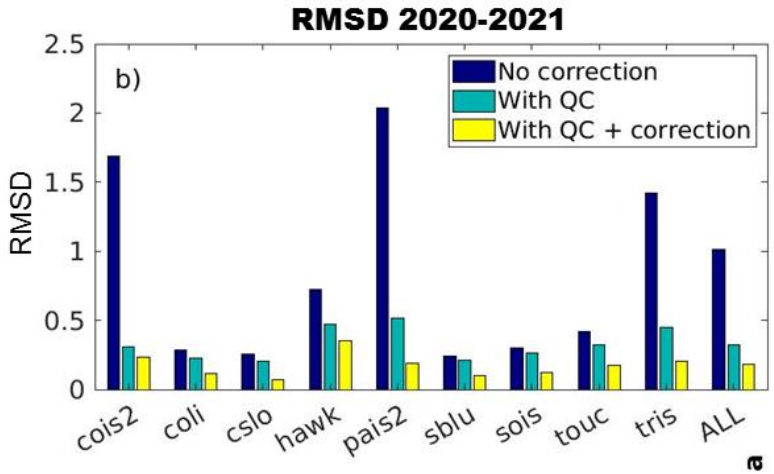






- RMSD between the DT/NRT SSS data decreases at each stage of the NRT processing on the 2014-2019 calibration period: by 75% (0.7 to 0.17 psu) from **all raw data** to **all *Good* data** to corrected *Good* data
- Similar results for the independent 2020-2021 validation period





Take home message

- New algorithms for Near Real Time processing of TSG underway data from commercial ships
- Inspired by Delayed Time processing, automated in Real Time: best of both worlds!
- Water samples replaced by colocated Argo data for correction
- Simple algorithms, 100% AI-free
- ~90% agreement between NRT and DT quality flags with climatology
- Differences with DT data divided by 3 or 4 after correction
- Also attribution of errors based on dispersion of TSG- ARGO differences
- NRT correction applied daily in a one-week window, can change every day as new Argo data appear, though NRT/DT differences only marginally decrease after the first 24 hours (-3 % within the next week)
- NRT data soon distributed through Coriolis operational oceanography database
- Automatic algorithms can be used in DT for retrospective corrections of TSG datasets

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