IWV retrieval from shipborne GPS receiver on hydrographic ship Borda

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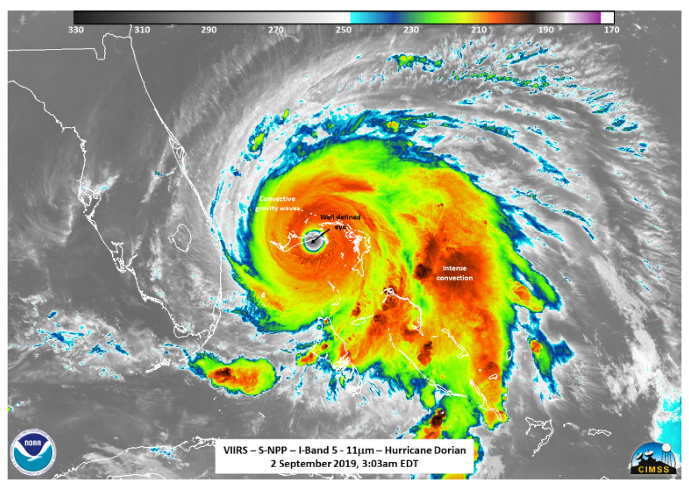
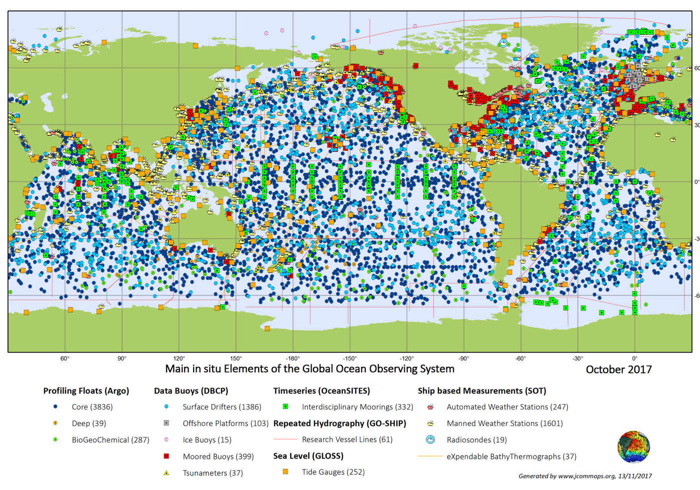
Context & Objectives

Why use offshore GNSS measurements for IWV retrieval ?

- Origin of severe weather events.
- Area limited to surface observations or satellite remote sensing.

Left : Infrared view of Dorian Cyclone (NASA-NOAA Suomi) - Right Global Ocean Observing System (WMO).

Benefit of offshore GNSS IWV retrievals:

- **Meteorology**: potential of ships of opportunity.
  Requirement for accuracy/latency: 2kg·m^{-2}, 15 minutes for 1h-forecast.
- **Climatology**: potential of research vessels, already equipped.
  Requirement for accuracy: 1-2kg·m^{-2}.
- **Hydrography**: Better estimatation of height.
  Requirement for accuracy: 20 to 40mm (antenna position).

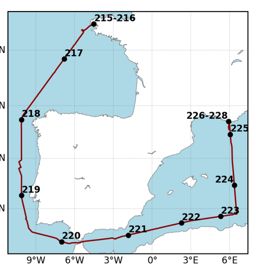
State-of-the-art

	Mode, software Constellation	Area Period	RMS (wrt)
[Roc+05]	PPP, BGSW GPS	Caribbean Sea 2 wks (2003)	1.4kg·m^{-2} (RS) 2.6kg·m^{-2} (WVR)
[Fuj+08]	PPP, RTNet GPS	Indian Ocean 7 days (2007)	2.8kg·m^{-2} (RS) 2.1kg·m^{-2} (RTNet)
[Bon+12]	PPP_AR, RTNet GPS	Mediterranean Sea 4 mths	2;3kg·m^{-2} (CORS) 2.4kg·m^{-2} (Aladin) 3.1kg·m^{-2} (Modis)
[Fuj+14]	PPP_AR, RTNet GPS, Glonass, QZSS	Japan 1 mth (2013)	3.6kg·m^{-2} (RS/GPS) 2.0kg·m^{-2} (RS/GNSS)
[Sho+17]	PPP_RTK, RTKlib GPS, Glonass, QZSS	Japon 10 mths (2016-2017)	2,8 kg·m^{-2} (RS)
[Wan+19]	PPP_AR, Panda GPS, Glonass, Galileo	Arctic Ocean 20 days (2016)	1.0kg·m^{-2} (CORS) 1.2kg·m^{-2} (ERAI) 1.2kg·m^{-2} (RS) 1.9kg·m^{-2} (SARALL)
[Liu+19]	PPP_AR, Panda GPS, Glonass,	Indian Ocean 3 days (2014)	1.0kg·m^{-2} (HY-2A)
[Fou+19]	PPP_AR, GPSPPP GPS	Mediterranean Sea 2 mths (2012)	3.0kg·m^{-2} (Arome-WMED)

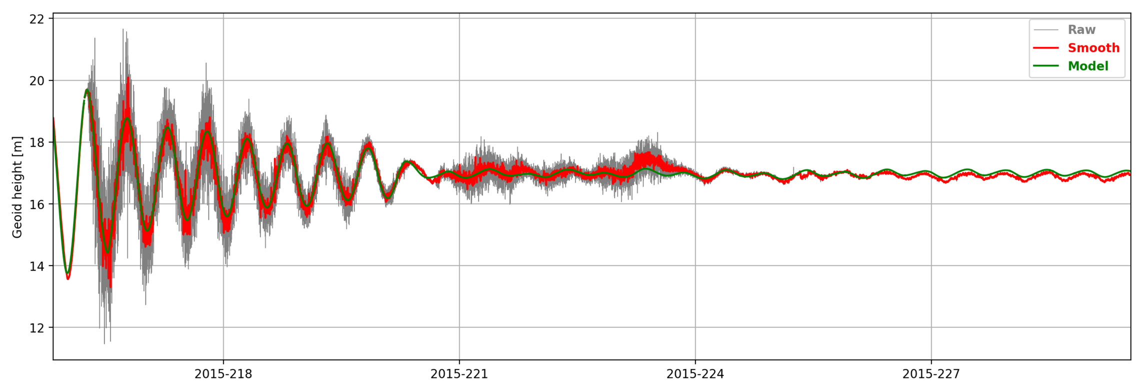
RMS computed wrt : **RS** : radiosounding, **WVR** : ground radiometer, **CORS** : GNSS Continuously Operating Reference Station, **Aladin**, **ERAI**, **Arome** : Numerical Weather Prediction models, **Modis**, **SARAL**, **HY-2A** : satellite radiometer.

Borda cruise

- Route from Brest to Toulon (Fr, Aug. 2015).
- PPP_AR using Gipsy-Oasis II 6.4.
- 2 GPS antennas (BRDA + BRD2).
- VMF model (a priori & mapping function).




➡ GPS+EGM2008 Geoid height estimates for BRDA antenna compared to FES2014 model:



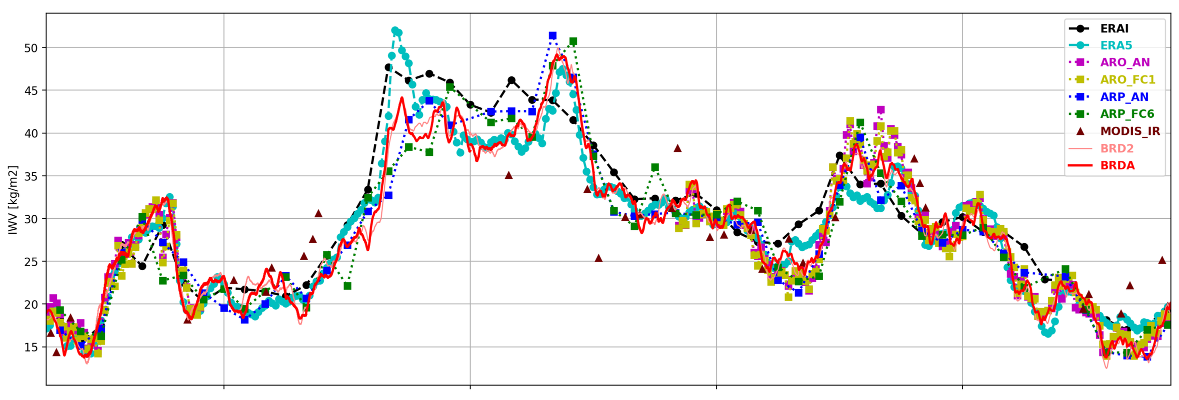
(Smoothing using a 10min median filter)

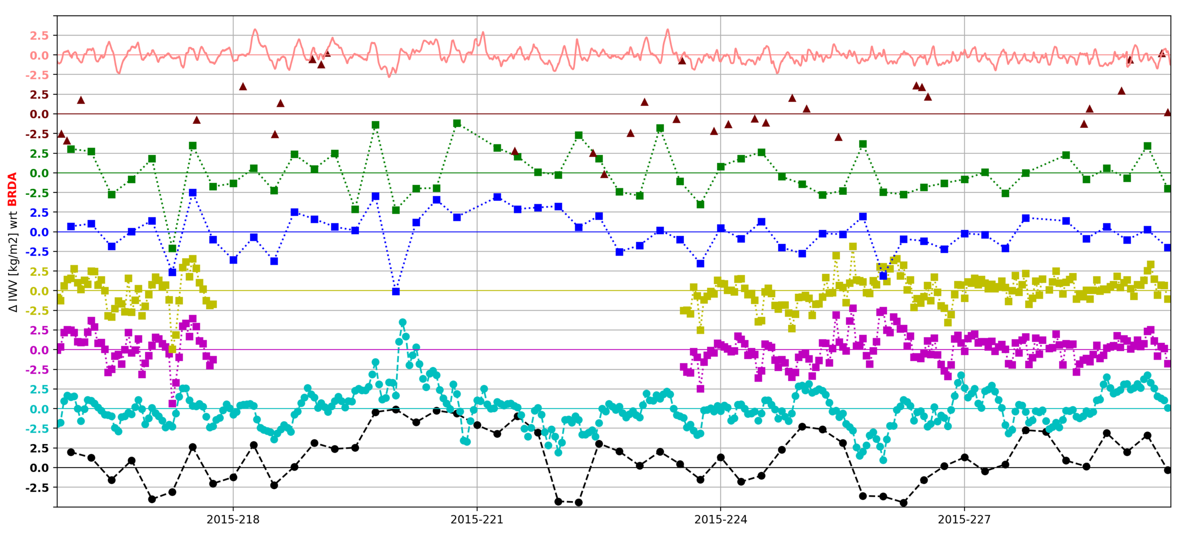
➡ Mean differences wrt FES2014 model:

Raw	-0.031 ± 0.351m
Smoothed	-0.032 ± 0.164m

IWV evaluation

BRDA (ref) / BRD2	30s GPS IWV for antennas BRDA and BRD2 using VMF T_m and ERA5 P_{msl}
ERAI	ECMWF reanalysis, 6h × 0.75deg (∼ 60-80km)
ERA5	ECMWF reanalysis, 1h × 0.25deg (∼ 20-30km)
ARO_AN / ARO_FC1	Meteo-France small scale NWP Arome, analysis and 1h-forecast, 1h × 1.3km
ARP_AN / ARP_FC6	Meteo-France global NWP Arpege, analysis and 6h-forecast, 6h × 7.5km
MODIS_IR	Satellite radiometer MODIS, infrared IWV within 20 km & 450s range





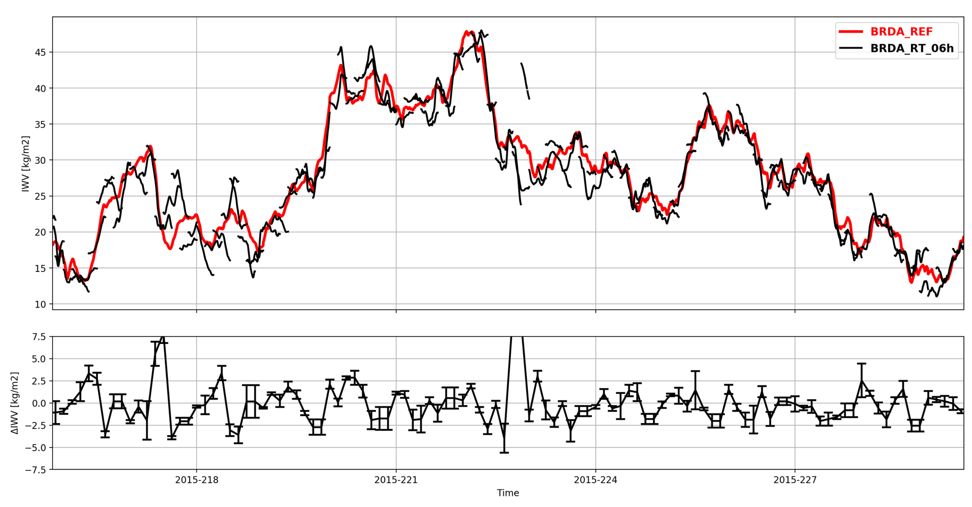
	N	$b \pm \sigma$ [kg·m^{-2}]	$\Delta \leq \pm 2$ kg·m^{-2}
ERAI	55	+1.44 ± 3.26	38.2%
ERA5	329	+0.06 ± 2.36	63.5%
ARO_AN	190	+0.14 ± 1.87	75.8%
ARO_FC1	190	+0.06 ± 1.91	77.9%
ARP_AN	53	-0.12 ± 2.56	60.4%
ARP_FC6	53	-0.04 ± 3.00	47.2%
MODIS_IR	33	+0.82 ± 3.89	36.4%
BRD2	39408	-0.12 ± 0.87	97.0%

- Global consistency between all techniques
- Noticeable deviations over certain periods for certain models (e.g. around doy 220 or 226)
- Significant differences with MODIS_IR
- Improvements from ERA5 with respect to ERAI
- Analysis better than forecast (ARO & ARP)
- Very good consistency between the 2 antennas

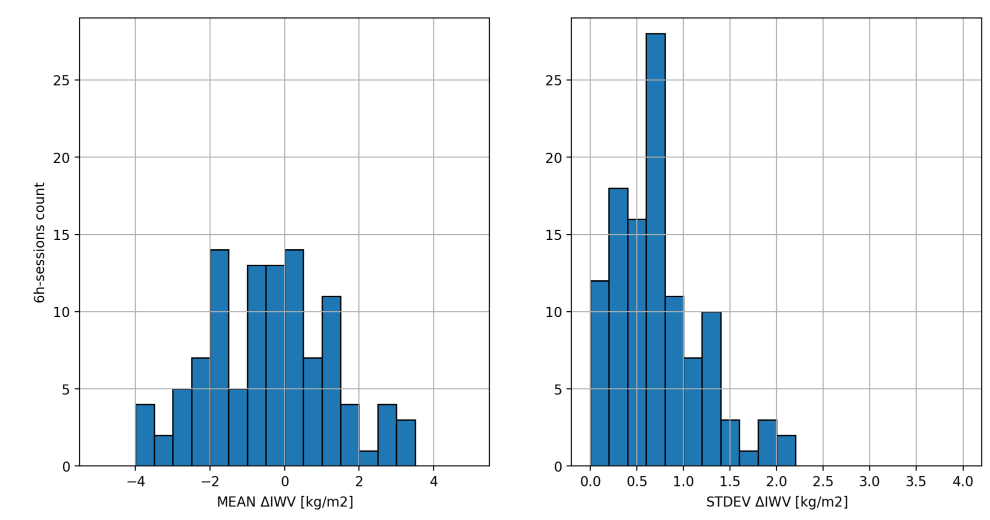
IWV evaluation in a NRT context

Investigation of the possibility of an analysis at h+15min with error inferior to 2kg·m^{-2} for a forecast at h+60min:

- Use of real-time products from IGS (IGC1) archived by CDDIS
- PPP using Gipsy-Oasis II 6.4 (w/o AMB fixing)
- 6h sessions every 3h (short sessions may be required if transmission rates are limited)
- GPT/GMF model
- Screening of estimates: $\sigma_{ZTD} > 4$ mm (0.2% of estimates)



- Mean deviations : -0.37 ± 2.20 kg·m^{-2}
- 68.0% of differences inferior to 2 kg·m^{-2}



- Maximum deviations ∼ 11 kg·m^{-2}
- Some very biased sessions (> 4 kg·m^{-2})

Conclusion & Perspectives

- Interest of **shipborne GNSS** for **meteorology** and **climatology**
- **Accuracy levels similar to CORS** (uncertainty < 2kg·m^{-2}) could be reached
- **Near-real time** is still ambitious, but the **results are encouraging** (standard deviation just over 2kg·m^{-2}for 6-hour sessions).
- **Methology** for analysis still should **clarified** (contribution of mGNSS, ambituity, stochastic modeling, etc.)
- **Near-real time** application still required a **robust means of communication** for retrieving shipborne data.

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