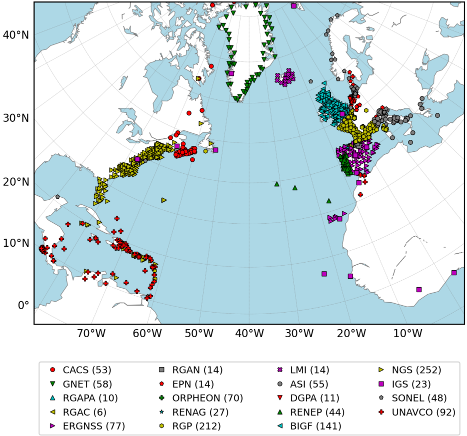

IWV retrieval from GPS receivers during NAWDEX

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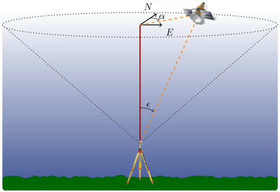
Recap : GPS meteorology concept



Troposphere propagation delay :

$$\Delta L_{\mathrm{tropo}}(\alpha,\epsilon) = \Delta L_h^z \cdot mf_h(\epsilon) + \Delta L_w^z \cdot mf_w(\epsilon) + m_\alpha(\epsilon)[\Gamma_{ns}\cos\alpha + \Gamma_{ew}\sin\alpha]$$

- $\Delta L_{\mathrm{tropo}}(\alpha,\epsilon)$: troposphere delay for a given direction
- ΔL_h^z: Zenith Hydrostatic Delay (ZHD) retrieved from ground pressure measurements.
- ΔL_w^z: Zenith Wet Delay (**ZWD**) estimated during the processing.
- Γ_{ns}, Γ_{ew}: horizontal **gradients**
- mf_h, mf_w, m_α: mapping functions for delays and gradients.

ZWD is closely linked to IWV:

$$IWV = k(T_m) \times \Delta L_w^z$$

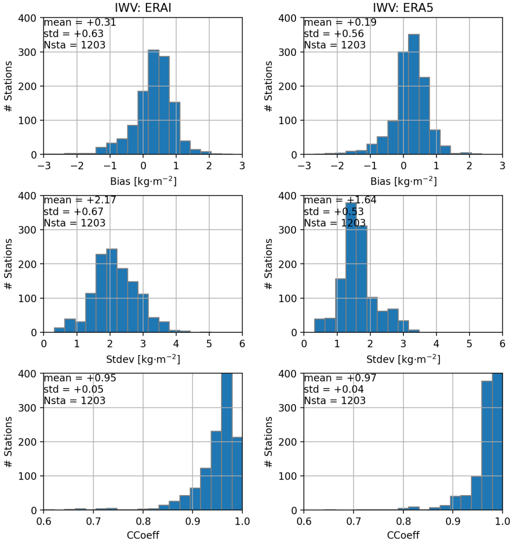
A short summary of work completed

- Retrieval of GPS IWV by the analysis of measurements from more than **1,200 GPS antenna** (sept. to nov. 2016).
- **Quality check** of GPS IWV using **intrinsic methods**.
- **Global & regional assessment** of IWV from **ERAI and ERA5 reanalysis** over the period using GPS IWV.
- Analysis of **GPS IWV and gradients** during two **high impact weather events** (related to Walpurga and Sanchez Cyclon / IOPs 5 and 9), assessment of ERAI and ERA5 IWV products.
- **Evaluation of Atalante IWV** using ERAI and ERA5 reanalysis, IWV from ground-based GPS antenna.

[Bin+20; Bos+20; Bos+21]

Global assessment

ERAI (←) & ERA5 (→) – GPS [Bos+21]



ERAI → ERA5 :

- Decrease of bias:
  $+0.33 \pm 0.69 \rightarrow +0.19 \pm 0.56\,\mathrm{kg\,m^{-2}}$
- Decrease of standard deviation:
  $2.16 \pm 0.67 \rightarrow 1.65 \pm 0.53\,\mathrm{kg\,m^{-2}}$
- Increase of correlation:
  $0.95 \pm 0.06 \rightarrow 0.97 \pm 0.04$

Regional assessment

ERAI & ERA5 – GPS [Bos+21]

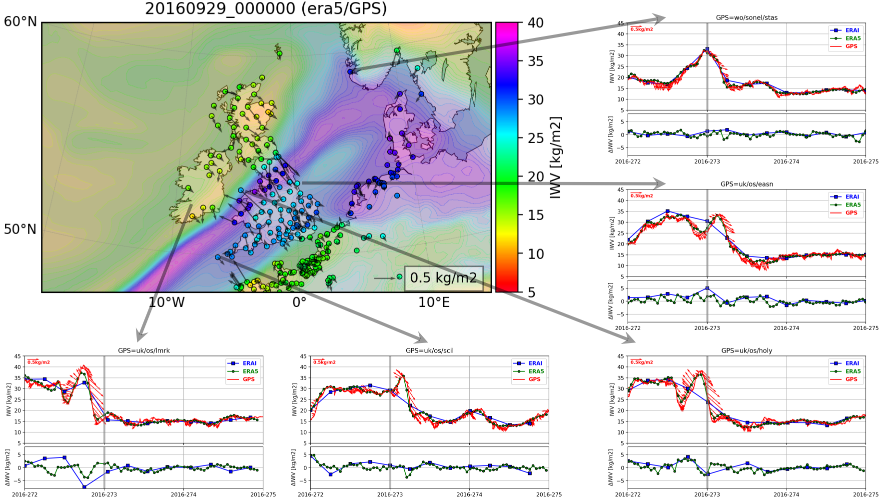
(1) Caribbean Sea (2) Nothern America East Coast
(3) Greenland - Arctic Circle (4) Western Europe

Area	N_{sta}	mean IWV		m [kg m^{-2}]	σ [kg m^{-2}]	ρ
Overall	1203	23.26±13.11	ERAI	0.31±0.63	2.17±0.67	0.95±0.05
			ERA5	0.19±0.56	1.64±0.53	0.97±0.04
(1)	121	48.71± 7.68	ERAI	-0.36±0.91	3.26±0.42	0.84±0.09
			ERA5	-0.66±0.70	2.73±0.24	0.89±0.06
(2)	276	25.66±13.46	ERAI	0.01±0.54	2.39±0.48	0.98±0.02
			ERA5	0.26±0.44	1.71±0.34	0.99±0.01
(3)	89	8.24± 5.00	ERAI	0.33±0.33	0.90±0.28	0.96±0.02
			ERA5	0.08±0.24	0.70±0.19	0.97±0.01
(4)	442	20.05± 7.34	ERAI	0.55±0.46	2.20±0.40	0.94±0.02
			ERA5	0.36±0.40	1.65±0.22	0.97±0.01

- Strong fluctuations in mean IWV and standard-deviation in the 4 regions
- Negative (dry) bias in the Caribbean VS positive (wet) bias in other regions ; higher standard-deviation & lower correlation in the Caribbean.
  ➥ Nature of data assimilated ?
- ERA5 drier than ERAI (about 0.2-0.3 kg m^{-2}) except in (2).

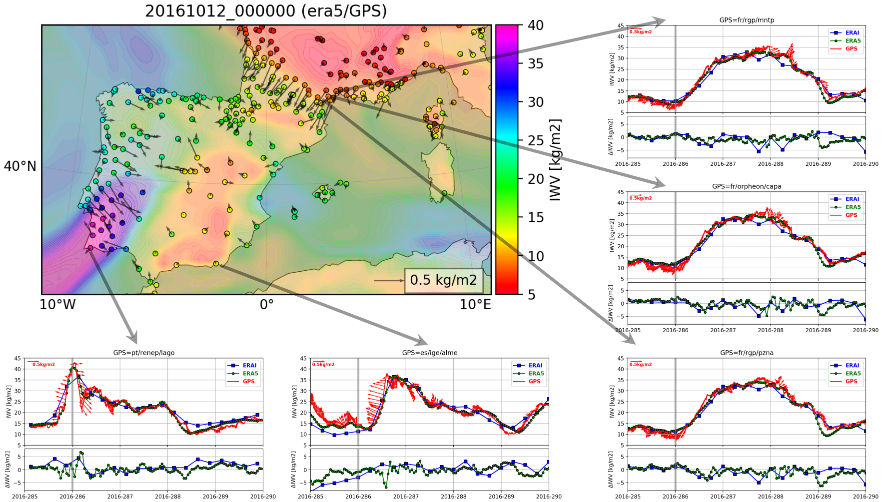
Case study: Walpurga / IOP 5

GPS IWV + gradient, ERAI, ERA5 (+colormap)



Case study: Sanchez Cyclon / IOP 9 [Bin+20]

GPS IWV + gradient, ERAI, ERA5 (+colormap)



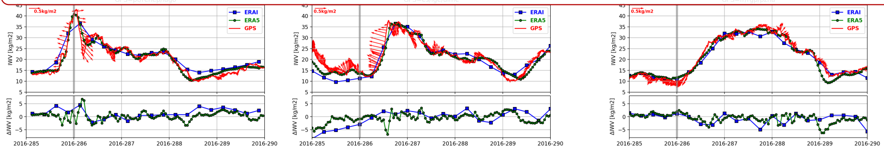
Case study: Sanchez Cyclon / IOP 9 [Bin+20]

GPS IWV + gradient, ERAI, ERA5 (+colormap)

For the two cases :

- ERA5 VS ERAI :
  - Global consistency between GPS and ERA5 IWV distribution
  - Better adequation with ERA5 ; some differences remain (upto 5 $\mathrm{kg\,m^{-2}}$)
  - Large benefit of the higher time resolution with ERA5
- Peaks in IWV time series as the moist flow passes
- High magnitude of gradients during the passage of moist flow; inversion of gradient direction at max IWV.
- High values of IWV 2 days during the events ($> 30 \mathrm{kg\,m^{-2}}$)

➥ These results could be extended on more cases



Future work

- EUREC^{4}A :
  - Retrieval of GPS IWV by the analysis of measurements from ground-based GNSS stations in Caribbean Sea.
    - Investigation of the moisture environment of mesoscale cloud patterns in the Tradewinds
    - Feedback on the large-scale circulation and energy budget
  - Retrieval of GPS IWV by the analysis of measurements from shipborne GNSS antennas (R/Vs Atalante, Maria S. Merian, Meteor):
    - Assessment of shipborne GNSS IWV, using more traditional techniques.
- CADDIWA

References

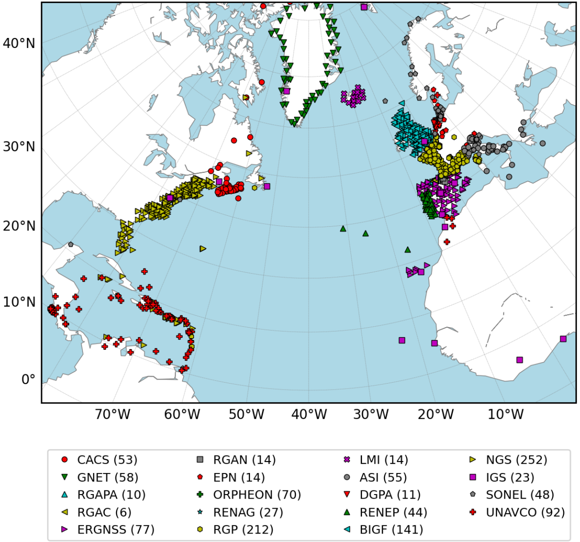
H. Binder et al. “Dynamics of forecast error growth along cut-off Sanchez and its consequence for the prediction of a high-impact weather event over southern France”. In: **submitted to Quarterly Journal of the Royal Meteorological Society** (2020).

P. Bosser et al. “IWV retrieval from ground and shipborne GPS receivers during NAWDEX”. In: **EGU General Assembly 2020**. Vienna, Austria, 2020. DOI: 10.5194/egusphere-egu2020-6956.

P. Bosser et al. “IWV retrieval from ground GNSS receivers during NAWDEX”. In: **Advances in Geosciences** 55 (2021), pp. 13–22. DOI: 10.5194/adgeo-55-13-2021.

Backup slides

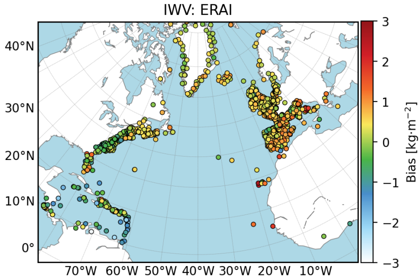
Networks

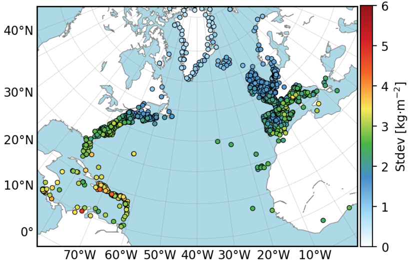


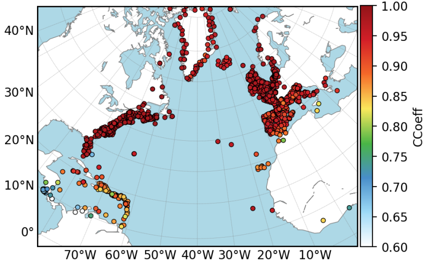
40°N
30°N
20°N
10°N
0°
70°W
60°W
50°W
40°W
30°W
20°W
10°W
CACS (53)
GNET (58)
RGAPA (10)
RGAC (6)
ERGNSS (77)
RGAN (14)
EPN (14)
ORPHEON (70)
RENAG (27)
RGP (212)
LMI (14)
ASI (55)
DGPA (11)
RENEP (44)
BIGF (141)
NGS (252)
IGS (23)
SONEL (48)
UNAVCO (92)

ERAI – GPS

Bias (←) / Standard-deviation (→) / Correlation (↓)







ERA5– GPS

Bias (←) / Standard-deviation (→) / Correlation (↓)