Royal Observatory of Belgium

Solar-Terrestrial Centre of Excellence

Royal Meteorological Institute of Belgium

GNSS-derived water vapour observations at high latitudes

LONG-TERM VARIABILITY AND CONTRIBUTION TO WEATHER FORECASTING

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Long-Term IWV Variability

AT HIGH LATITUDES

Datasets

Ground-based, satellite-based, and NWP model data

GPS

Product: IGS repro 1 - Homogeneously reprocessed ZTD

Period: 1996-2010

Time res.: 5min (ZTD) → 6h (IWV)

Spatial res.: pointwise – worldwide

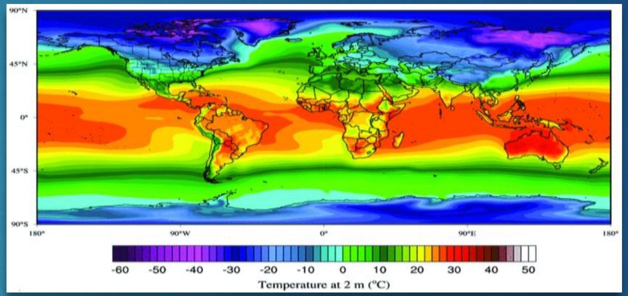
GOMESCIA

Product: UV/VIS IWV retrievals by GOME, GOME2, SCIAMACHY - “Climate dataset”, Beirle et al., 2018

Period: 1995-2015

Time res.: monthly means

Spatial res.: pixel - worldwide



ERA-Interim

Product: NWP model reanalysis from ECMWF

Period: 1979-2019

Time res.: 6 hour

Spatial res.: grid – worldwide

Datasets

Ground-based, satellite-based, and NWP model data

Different product characteristics (e.g. spatial and temporal resolutions) → harmonisation needed:

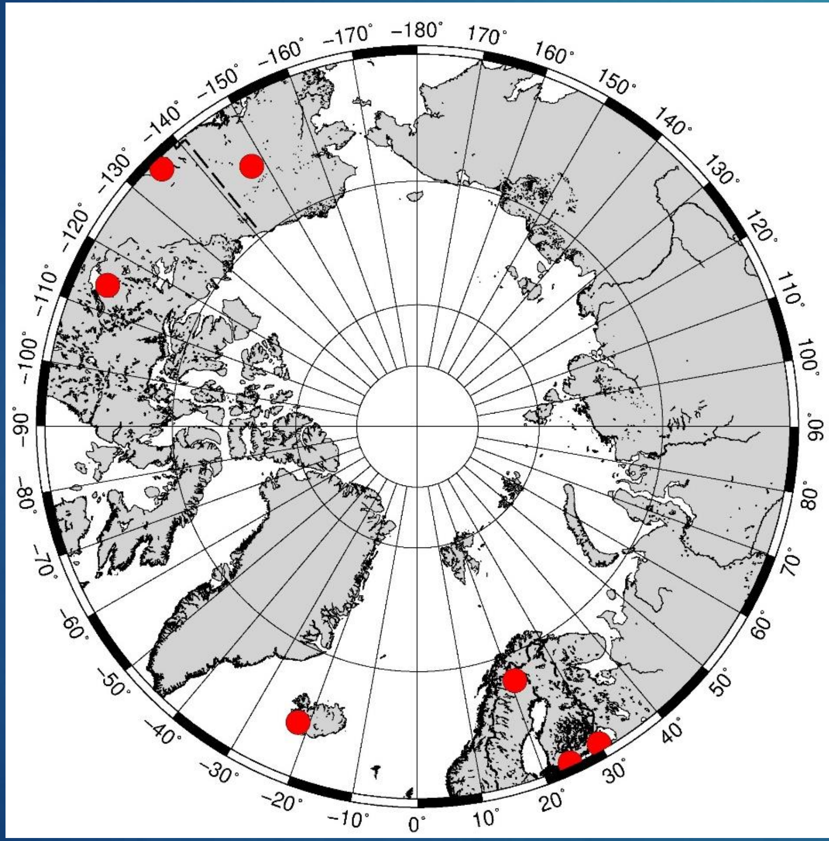
- Spatial resolution : at IGS station location
- Time resolution: monthly mean values, from 1996 to 2010

=> Focus only at IGS station's locations with abs(latitude) > 60°

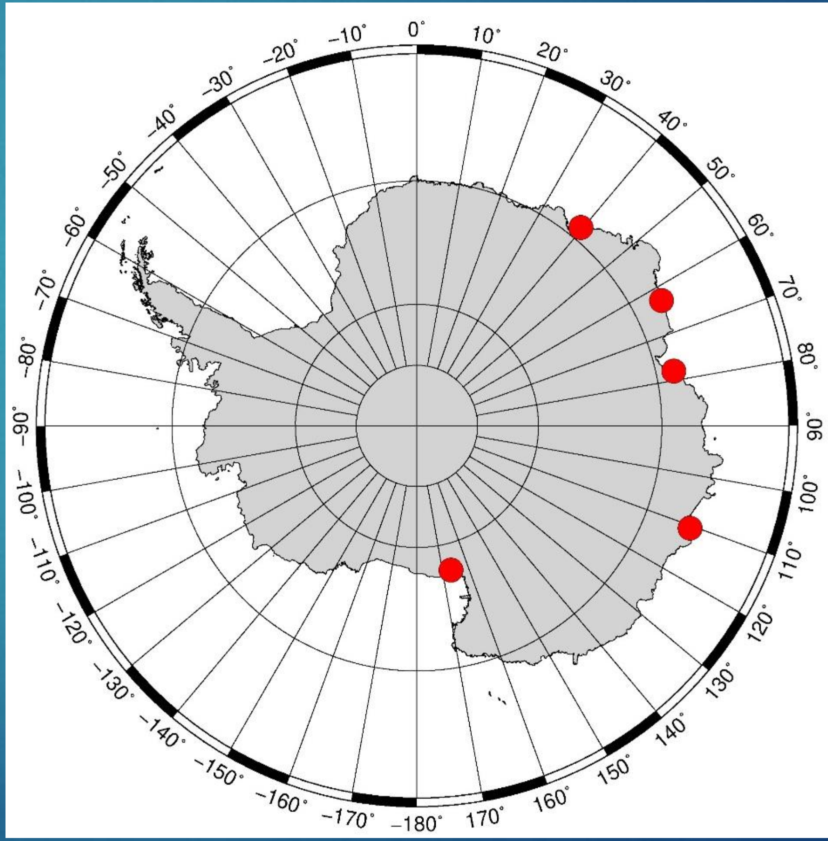
Datasets

12 IGS station locations in IGS repro1 have abs(latitude)>60°

Artic (#7)

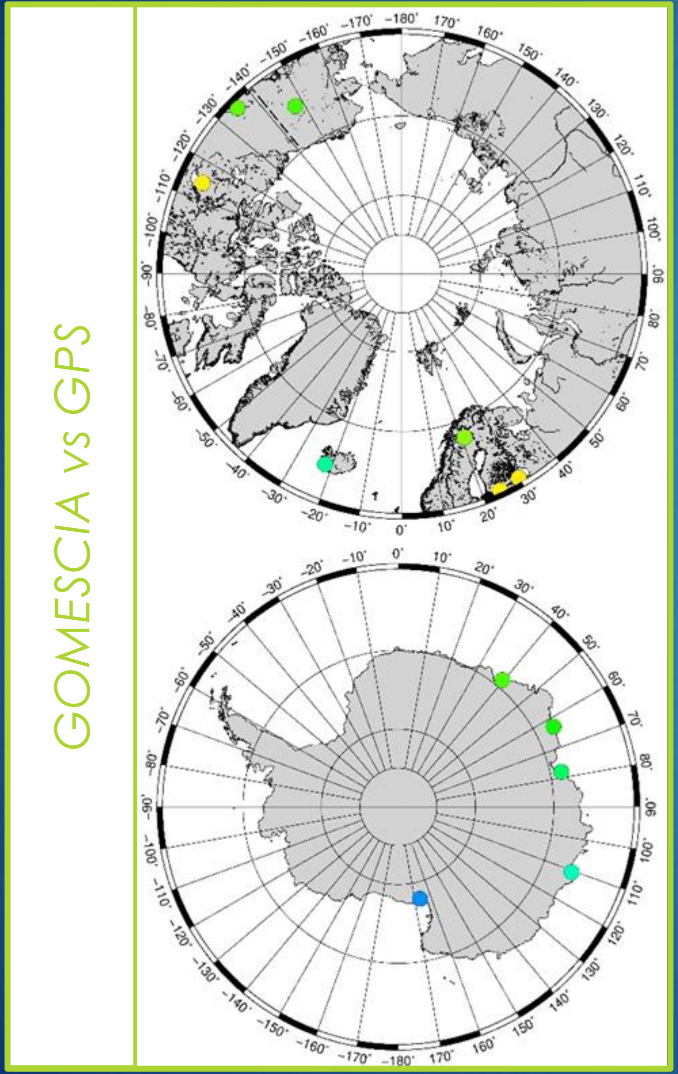


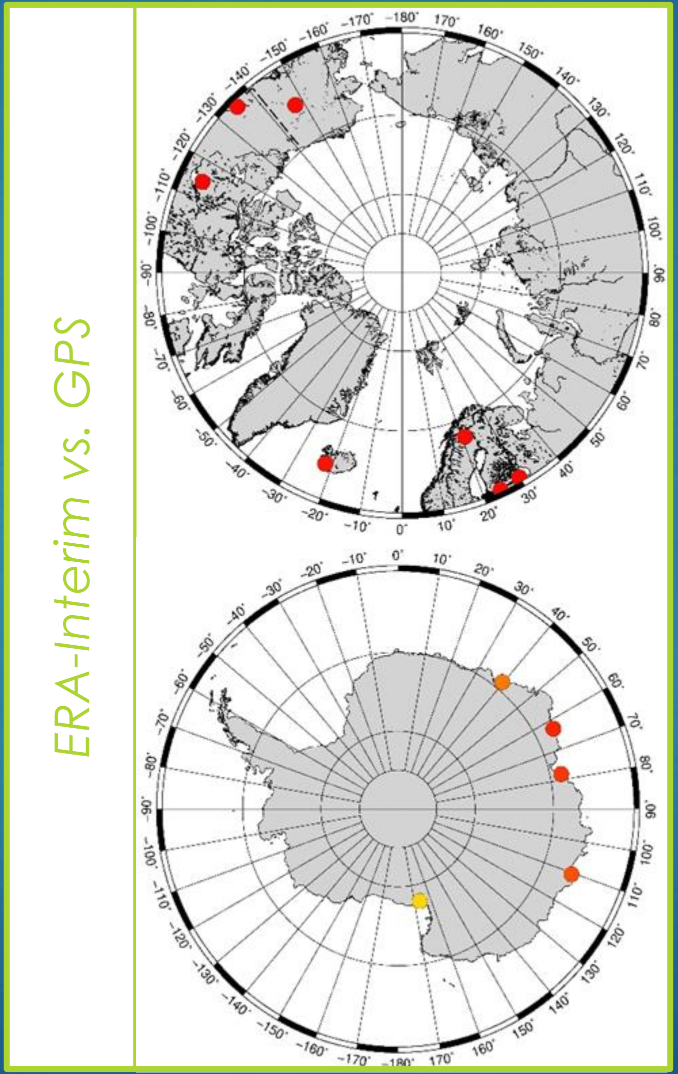
Antarctic (#5)



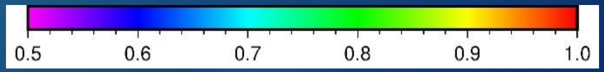
Overall Agreement Between Datasets

➤ Long-term IWV Variability





Correlation Coefficients of Monthly Means



Overall Dataset Agreements

Main Findings

- The datasets compare better to each other for the Artic than for the Antarctic sites

- The agreement between GPS and ERA-Interim is better than the one between GPS and GOMESCIA. (Note that no ground-based GPS measurement is assimilated in ERA-Interim!)

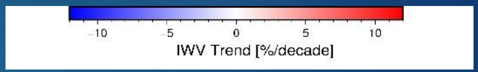
Normalized Linear IWV Trends

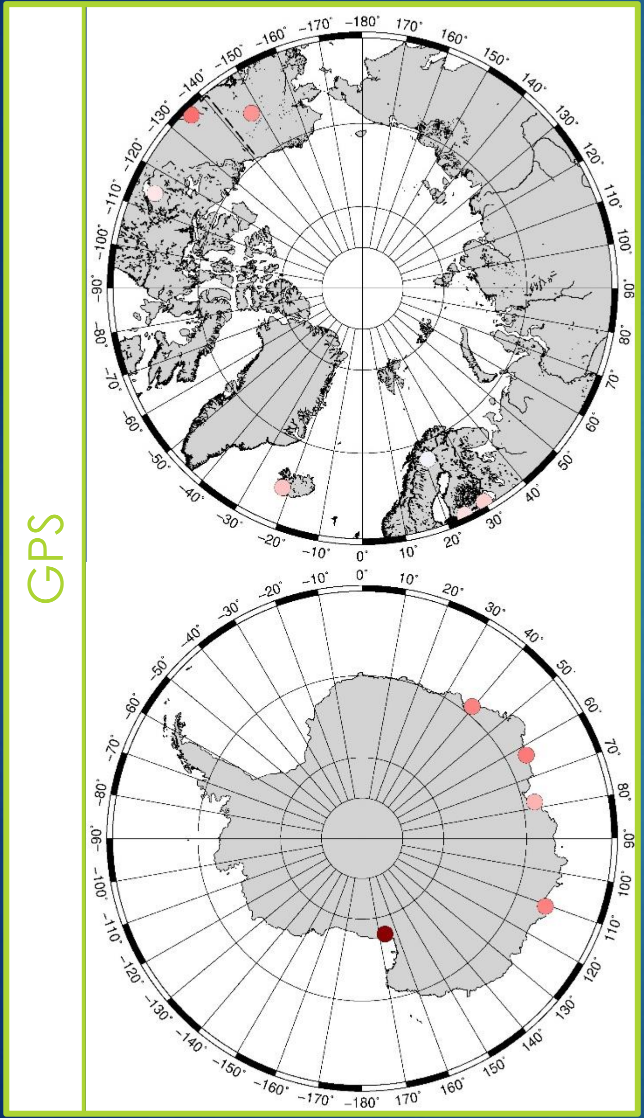
Foreword

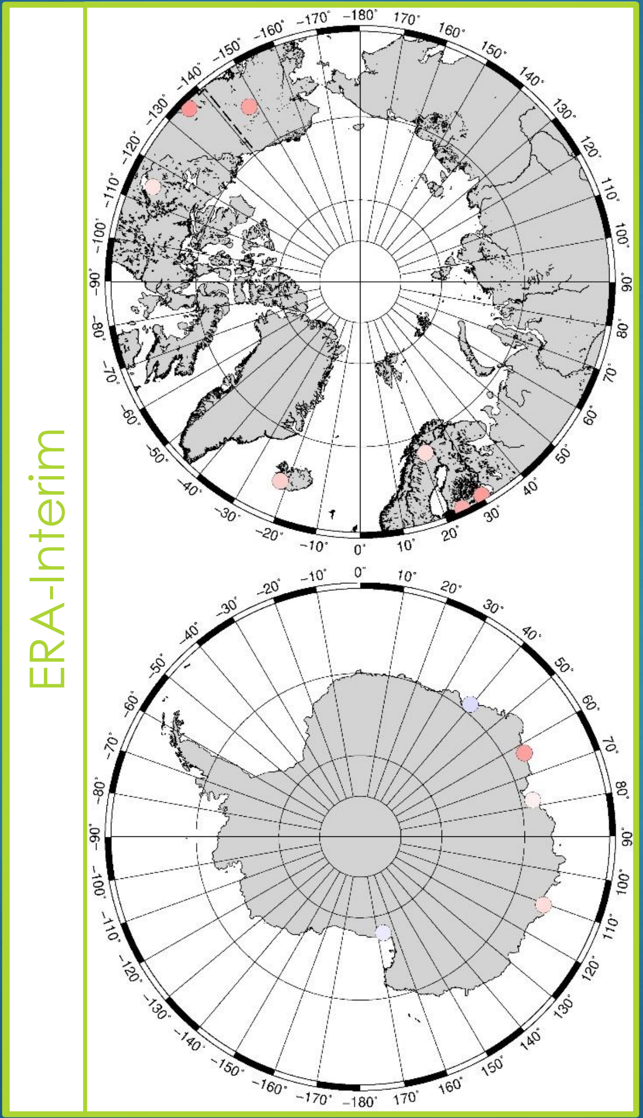
- Linear trend are calculated as the slope of the linear regression line that was fitted (by minimising the least-squares) through the monthly anomaly time series during the period 1996-2010

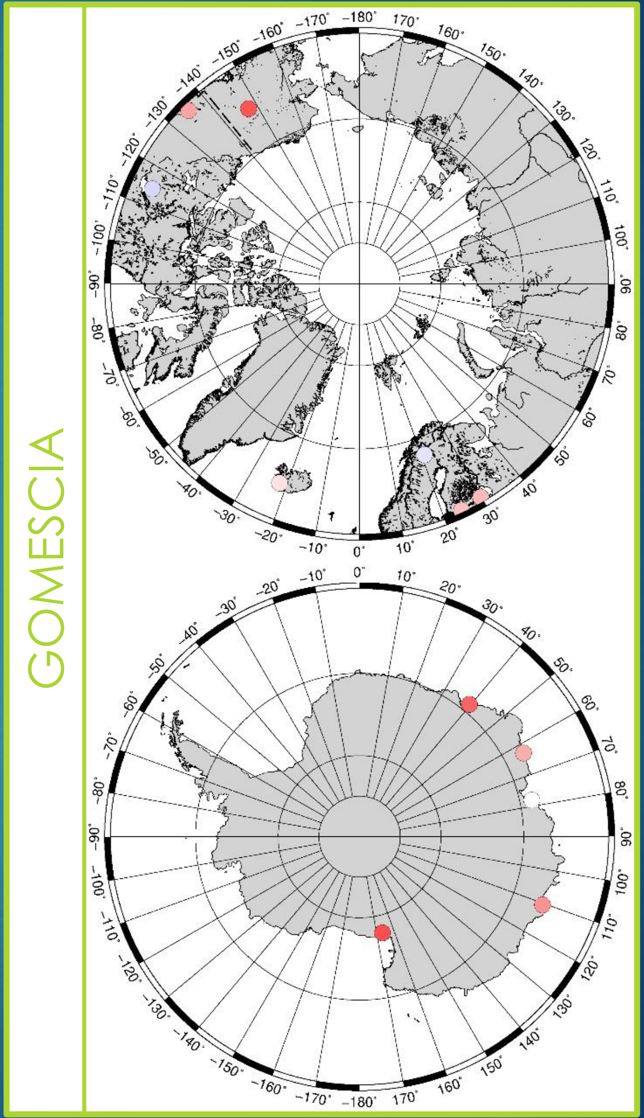
- Normalized by the climatological mean and expressed as %/decade

Normalized Linear IWV Trends









➢ Long-Term IWV Variability

Normalized Linear IWV Trends

Main Findings

- The spatial consistency of the trend (sign and magnitude) seems higher between GPS and GOMESCIA, at both Artic and Antarctic sites.
  - Parracho et al 2018: "uncertainties in current reanalysis like ERA-Interim remain quite high above Antarctica, and the spread between models is important".
  - Rinke et al; 2019 found that 4 reanalysis agree on the spatiotemporal trend pattern for the Artic but substantially disagree on regional trend magnitude.

Normalized Linear IWV Trends

Main Findings

- If we average out the different IWV trend estimates, we found the highest moistening over Antarctica but a closer agreement between mean moistening values in Artic:

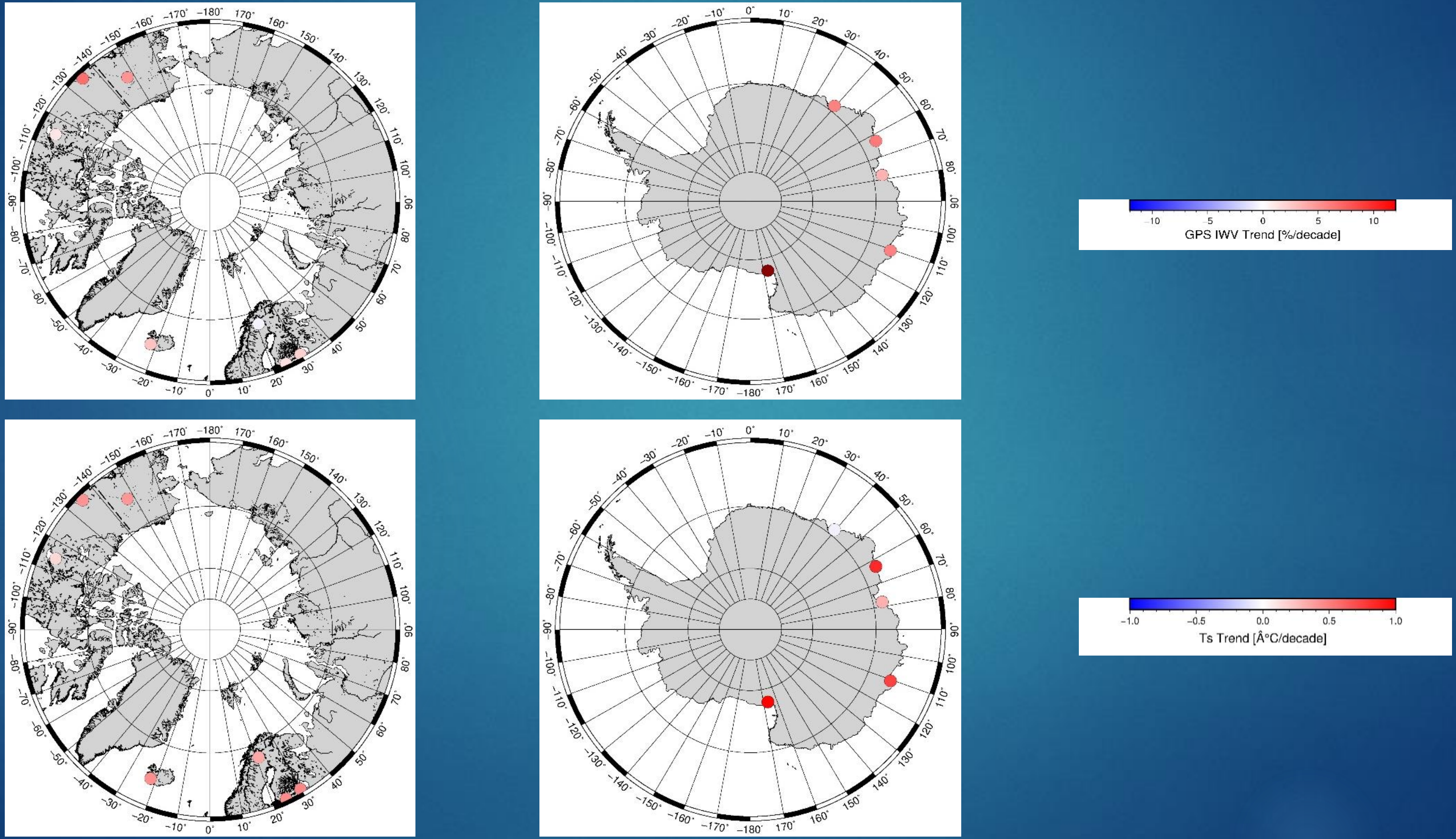
	GPS	GOMESCIA	ERA-Interim
Arctic	2.7±2.3 %/dec	2.4±3.0 %/dec	3.3±2.2 %/dec
Antarctic	7.4±3.2 %/dec	4.9±4.2 %/dec	0.8±2.5 %/dec

Normalized Linear IWV Trends

Moistening seems associated with a warming

GPS
IWV Trend (%/decade)

Ts Trend (C°/decade)



Normalized Linear IWV Trends

A Word of Caution

- Taking into account the effect of auto-correlation and variability (e.g. Weatherhead et al. 1998), 15 years of monthly data are not enough to detect a trend with a magnitude of 0.3 mm/decade (largest Arctic reanalysis median trend, Rinke et al., 2019) at 95% confidence level with probability 0.90

Inter-Annual IWV Variability

Foreword

- Therefore, we concentrate our research on the interpretation of the inter-annual variability, which is not necessarily dominated by the linear trend.
- By using a stepwise multiple linear regression (Van Malderen et al. 2018): the monthly means of IWV are fitted by the sum of

Long-term means

Linear trend

Monthly mean time series of explanatory variables

Var 1

Var 2

...

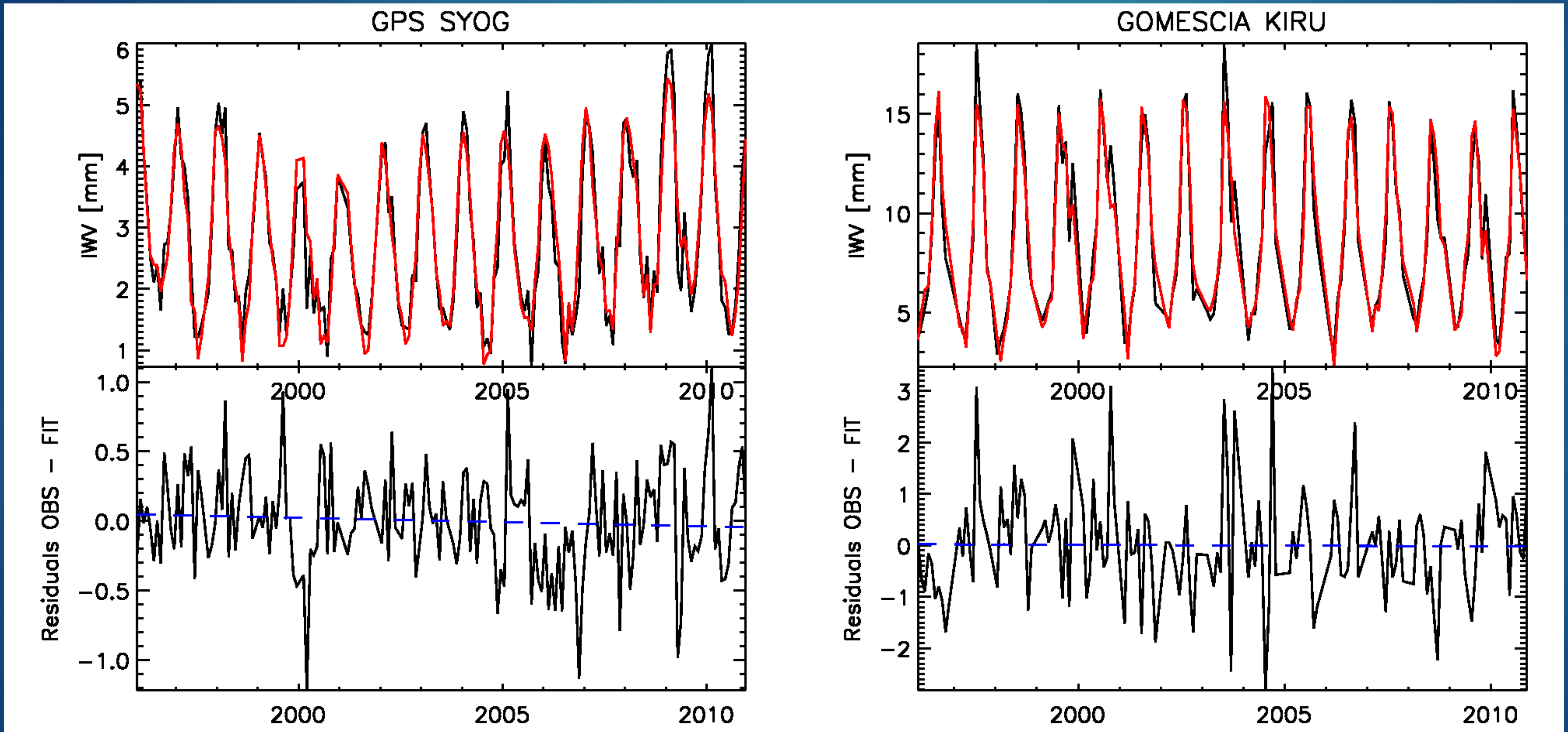
Inter-annual IWV Variability

Explanatory variables

- Surface meteorological variables (e.g. Temperature, pressure, precipitation...)
- Teleconnection patterns or climatic/oceanic indices (e.g. The North Atlantic Oscillation (NAO), the El Niño Southern Oscillation (ENSO)...)

Inter-annual IWV Variability

Examples of SYOG (East Ongle Island, Antarctica) and KIRU (Kiruna, Sweden)



Black : time series
Red: Fit

Inter-annual IWV Variability

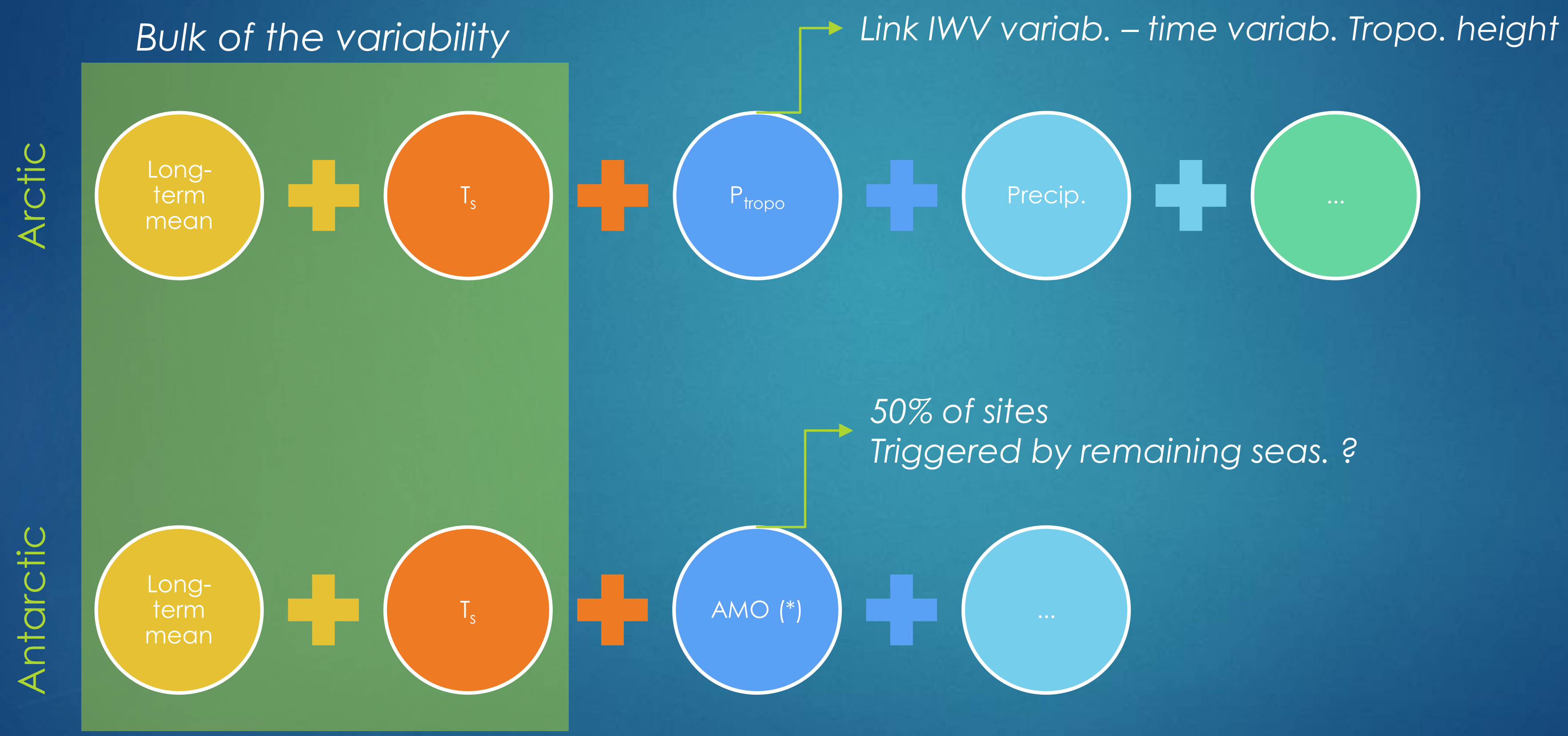
Main Findings

- The multiple linear regression fits explain a very high percentage of the IWV variabilities, both in the Arctic and the Antarctic

	GPS	GOMESCIA	ERA-Interim
Arctic	97.25%	93.12%	97.51%
Antartic	91.59%	91.50%	94.73%

Inter-annual IWV Variability

Main Findings – Explanatory Variables



(*) AMO: Atlantic Multidecadal Oscillation

Operational GNSS Processing

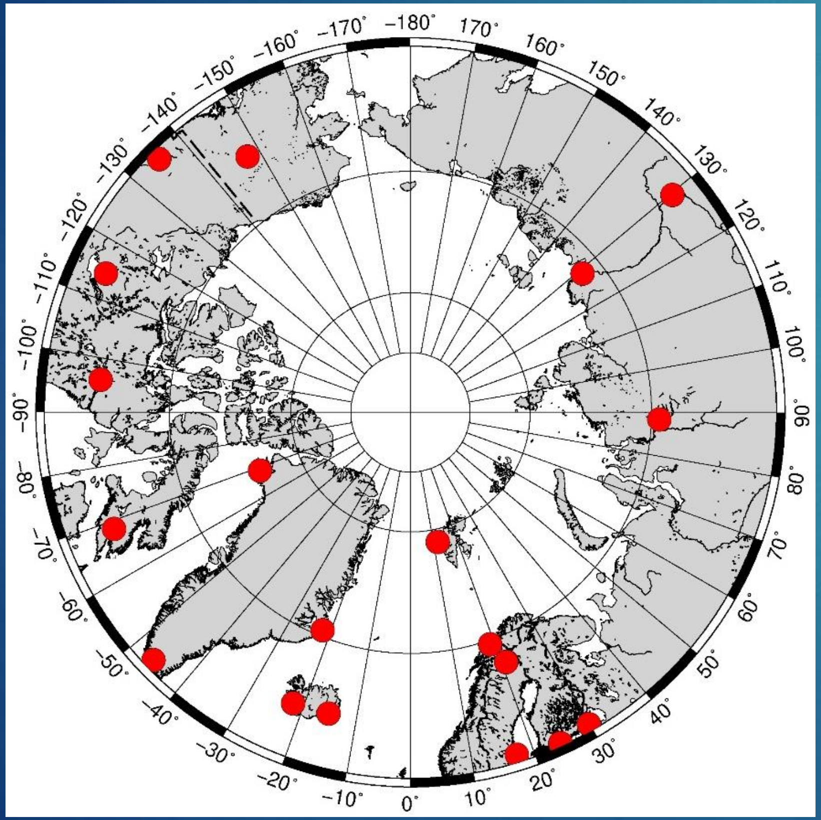
CONTRIBUTION TO WEATHER MODELS

24x7 GNSS Analysis Centre for E-GVAP

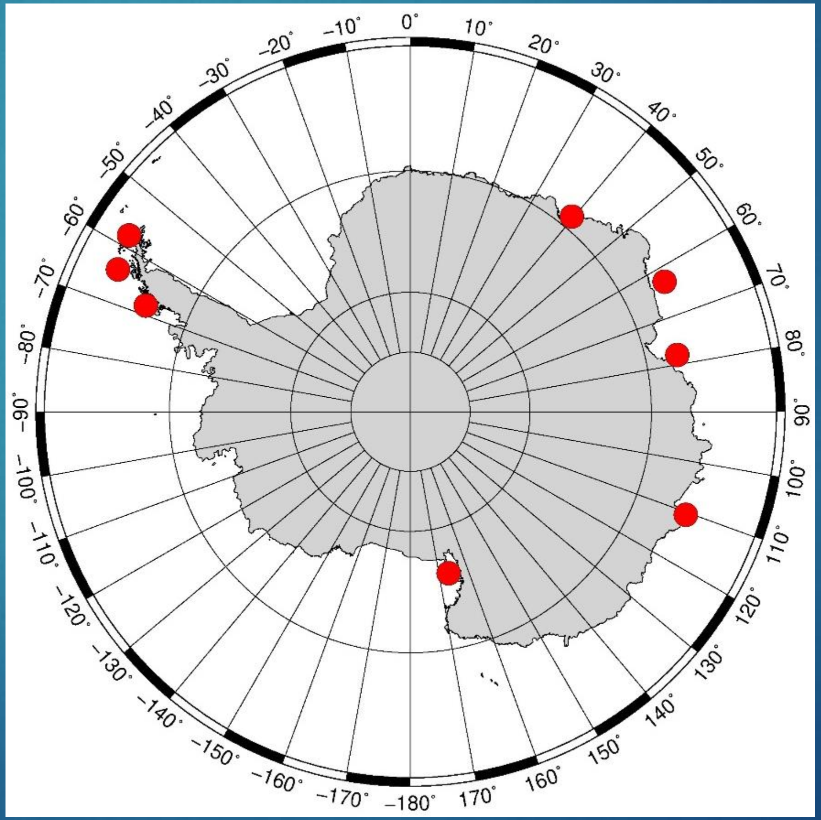
Operational hourly updated ZTD for data assimilation in NWP models

- Long-term IWV Variability

Arctic (#25)



Antarctic (#9)



Jones J. et. al, 2020

EUMETNET

Conclusions

Long-Term Variability

- We used long-term (1996-2010) GPS-derived time series at 7 Arctic and 5 Antarctic sites + satellites IWV retrievals and model reanalysis output.
- We found that the three datasets are rather consistent in representing the IWV variability, although e.g. trend differences occurs between datasets at a couple of sites.
- We concluded the Antarctic moistening seems predominantly driven by surface warming, while the Arctic IWV variability can be explained by a combination of Ts, Tropopause pressure., precipitation and the North Atlantic Oscillation.

Conclusions

Weather Forecasting

- Hourly-updated monitoring of the water vapour in the Arctic and Antarctic zones, these products used for data assimilation in global NWP models (via E-GVAP)

- Higher quality products, including more stations, can be made available upon request for specific studies in the Arctic and Antarctic zones

- Looking for more GNSS stations (providing at least hourly RINEX) to be included in these regions

Thank you…

References

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