Preparations for Assimilating Satellite Observations in the Next Generation Global Atmospheric Reanalysis at ECMWF - ERA6

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Overview

- The value of reprocessed and rescued data in reanalysis
  (‘synoptic accuracy’ and ‘mean state’ accuracy & continuity)
- C3S activities in reprocessing and rescue in advance of ERA6 :
  - Early (pre-1979) satellite data: data rescue
  - Reprocessing of operational mission data by EUMETSAT

ERA5 & its preliminary extension back to 1950: reforecast skill

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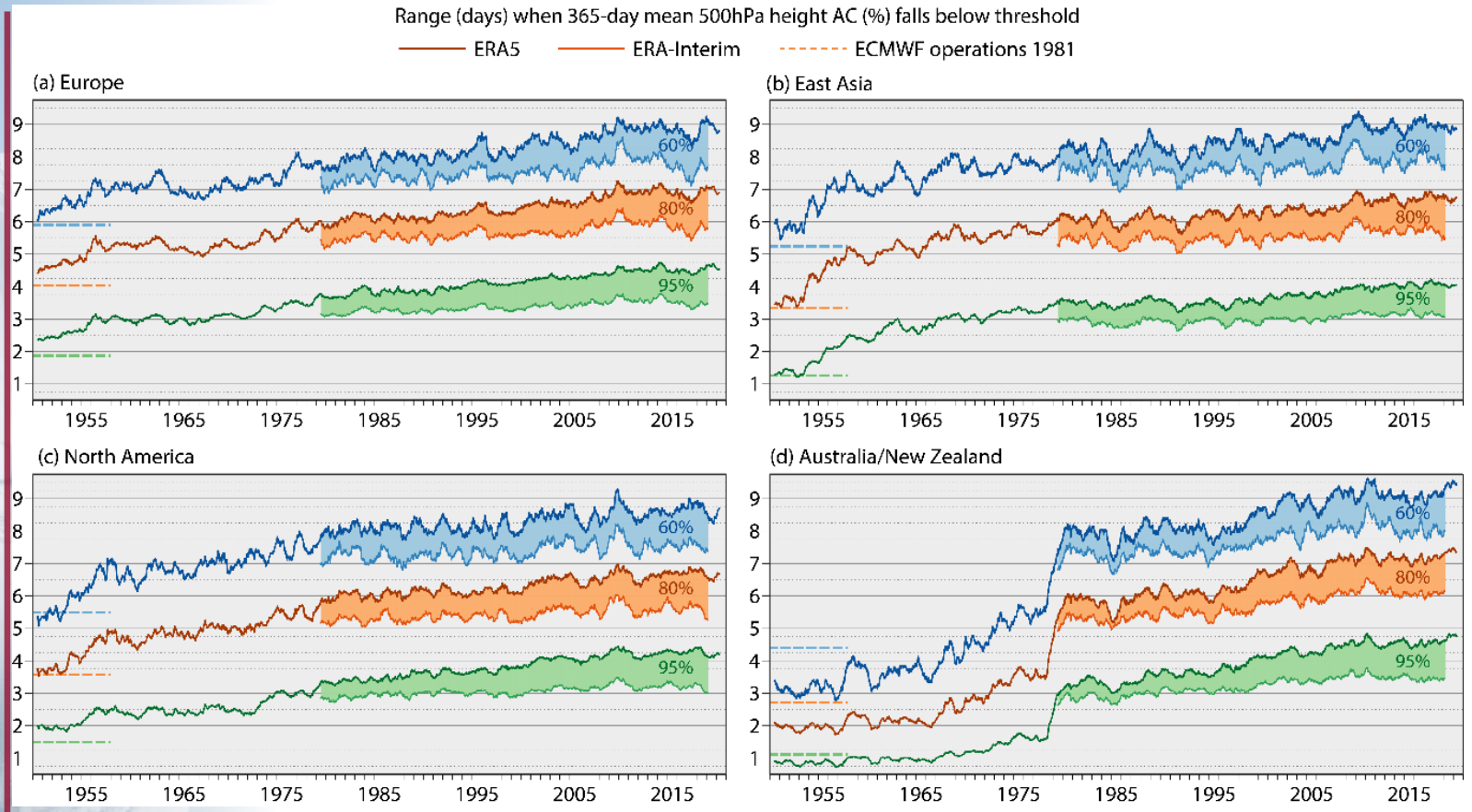

Hersbach *et al*, QJRMS, 2020, The ERA5 Global Reanalysis
Bell *et al*, QJRMS, 2021, The ERA5 Global Reanalysis, Preliminary Extension to 1950

Skill gains (ERA-Interim → ERA5) realised from:

- ↑ HPC power → higher resolution
- Model & DA improvements
- **Improved use of observations**

Skill gains vs time due to the evolving observing system:

- → Expect incremental gains through improved observations (reprocessing)
- → Expect (larger ?) gains from previously unused data (rescue) pre- and post-1979

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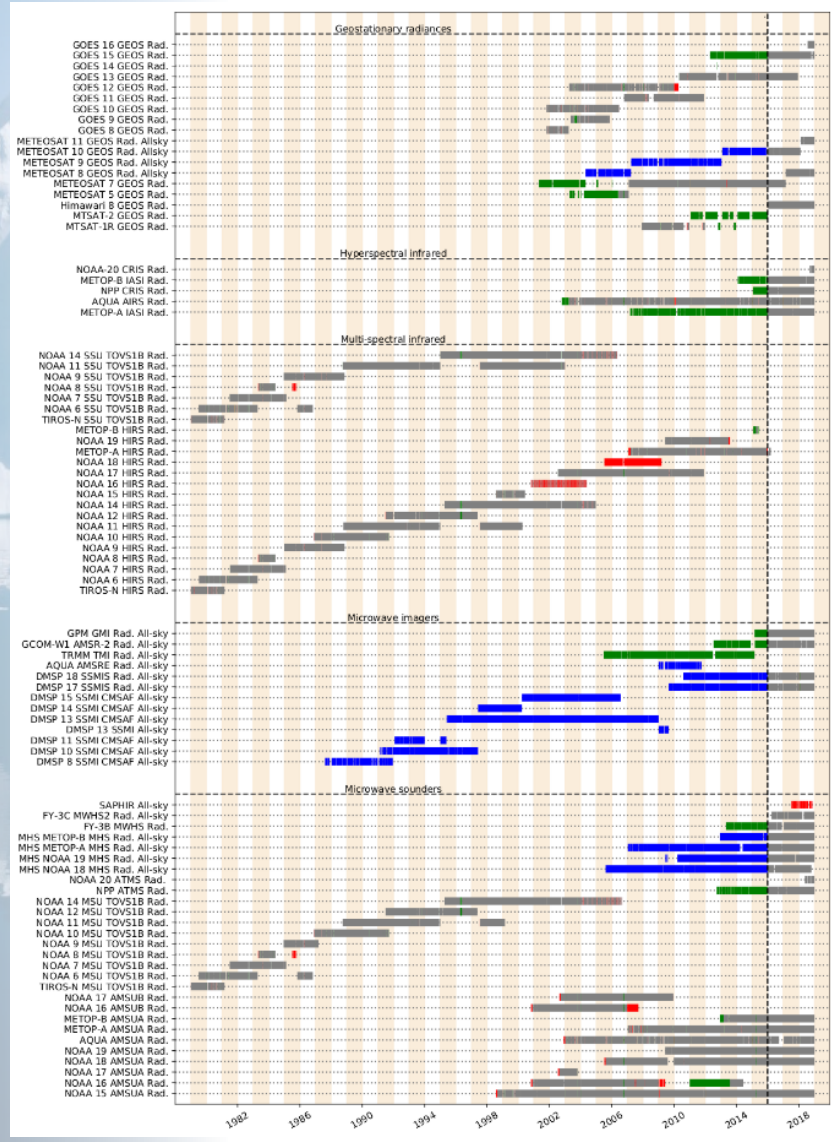
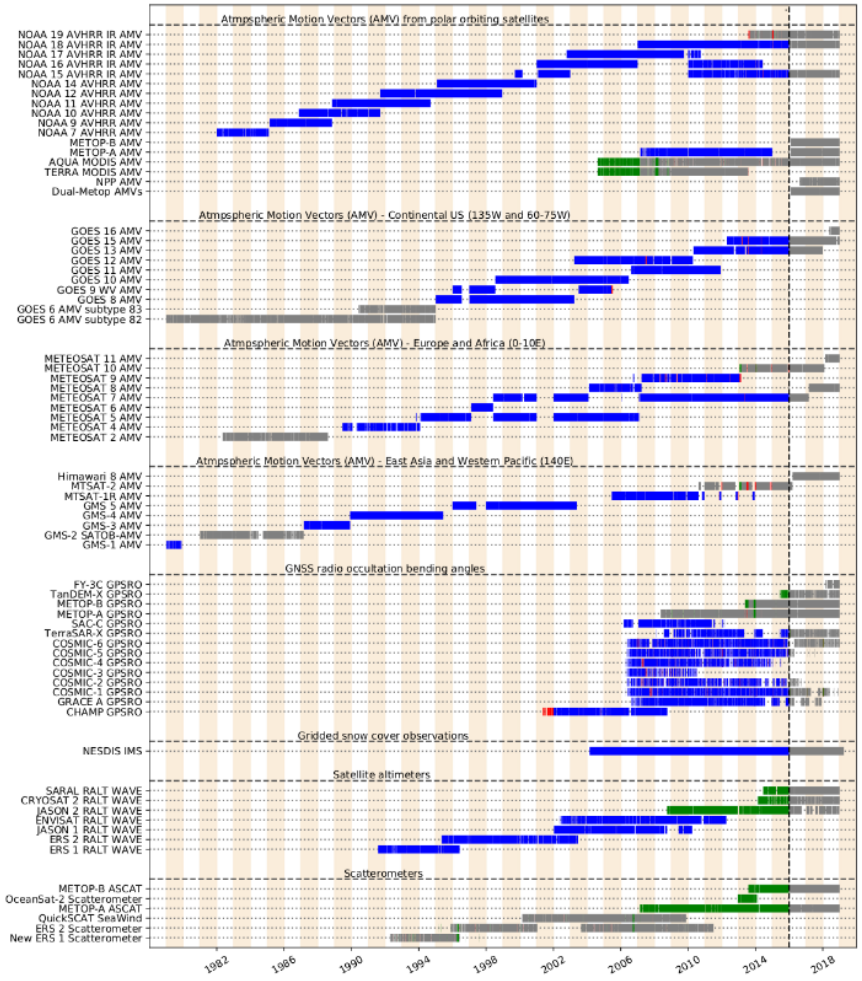
Satellite observations assimilated in ERA5

Satellite radiances 1979-2019



Satellite non-radiances 1979-2019



Reprocessed data, or change in processing since ERA-Int

Same as ERA-Int

Not used in ERA5, but used in ERA-Int

Not used in ERA-Int, but used in ERA5

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Impact of early-era sounding data in ERA5

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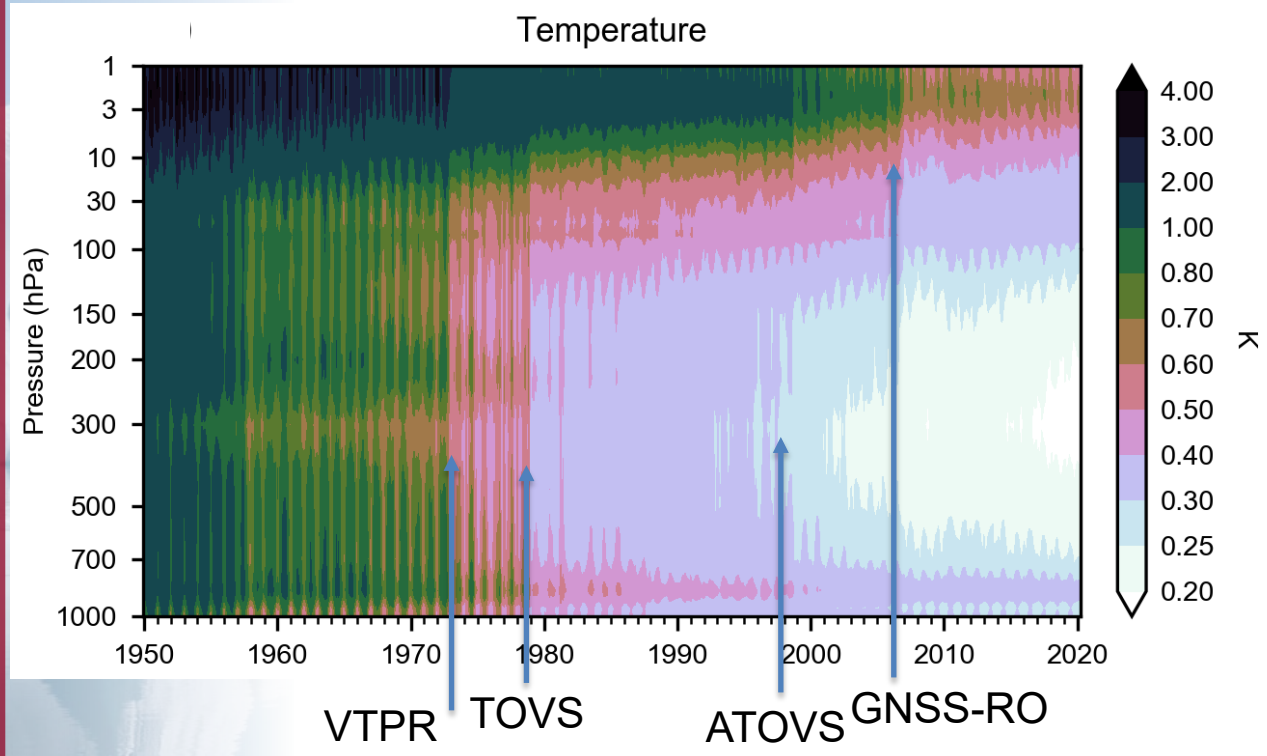
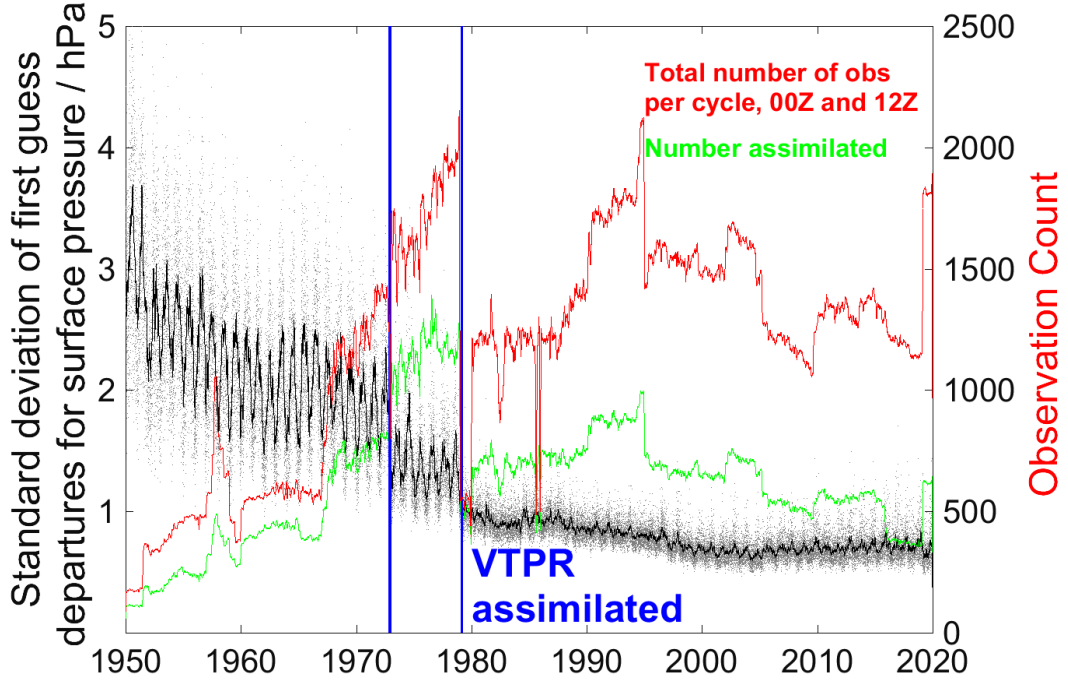
Ensemble of Data Assimilations (EDA) analysis spread



Impact of VTPR
Background fits to surface pressure observations 1950-2020
Southern Hemisphere



Vertical Temperature Profiling Radiometer (VTPR)

- 8-channel IR sounder. 'HIRS predecessor'
- Flown on NOAA2 - 5 (Nov 1972 - Feb 1979)
- Same L1 data assimilated in ERA-40 & JRA-55
- Benefits from improved: cloud detection, observation errors, QC & RT modelling

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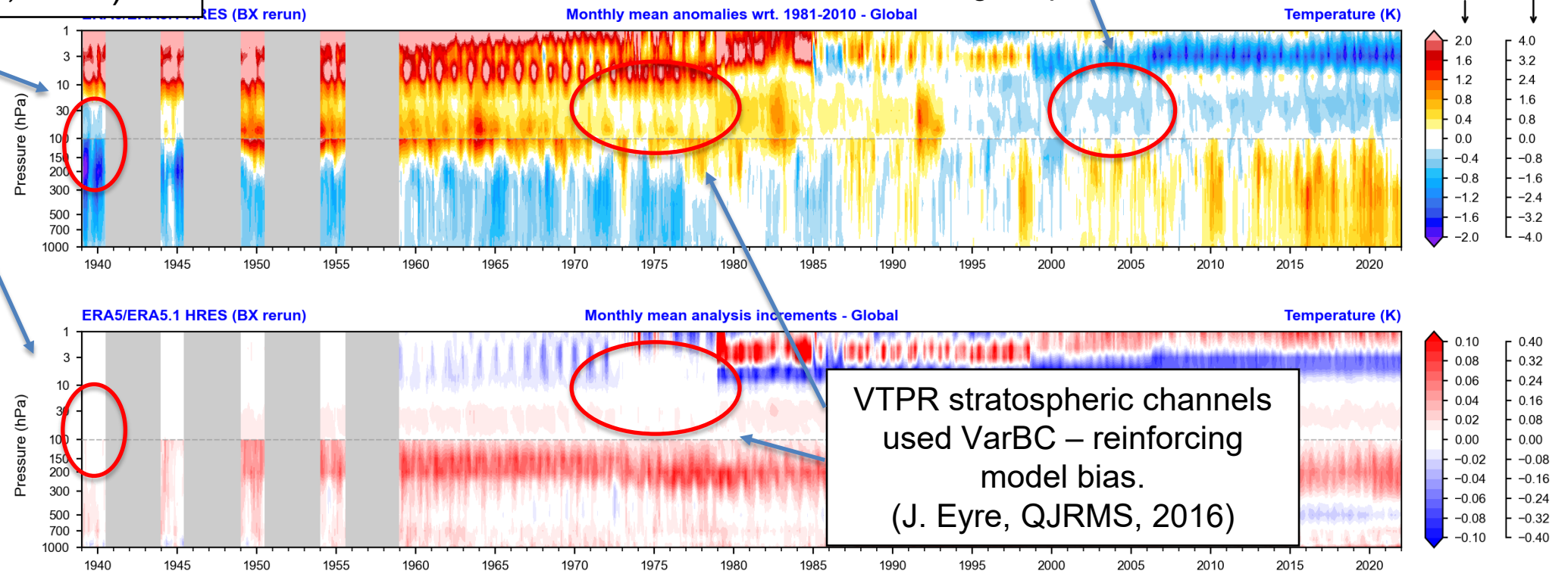
Extension of ERA5 to 1940
Few upper air observations
→ model bias exposed
(D. Dee, QJRMS, 2005)

The impact of model bias on stratospheric temperatures

lower stratospheric cold biases
in original production → ERA5.1



VTPR stratospheric channels used VarBC – reinforcing model bias.
(J. Eyre, QJRMS, 2016)

- Discontinuities most evident above 10 hPa
- Caused by interplay of model biases & changing observing system
- **Improved reprocessing of observations will play a role in minimising these effects**

Early satellite data rescue (focus on pre-1979)

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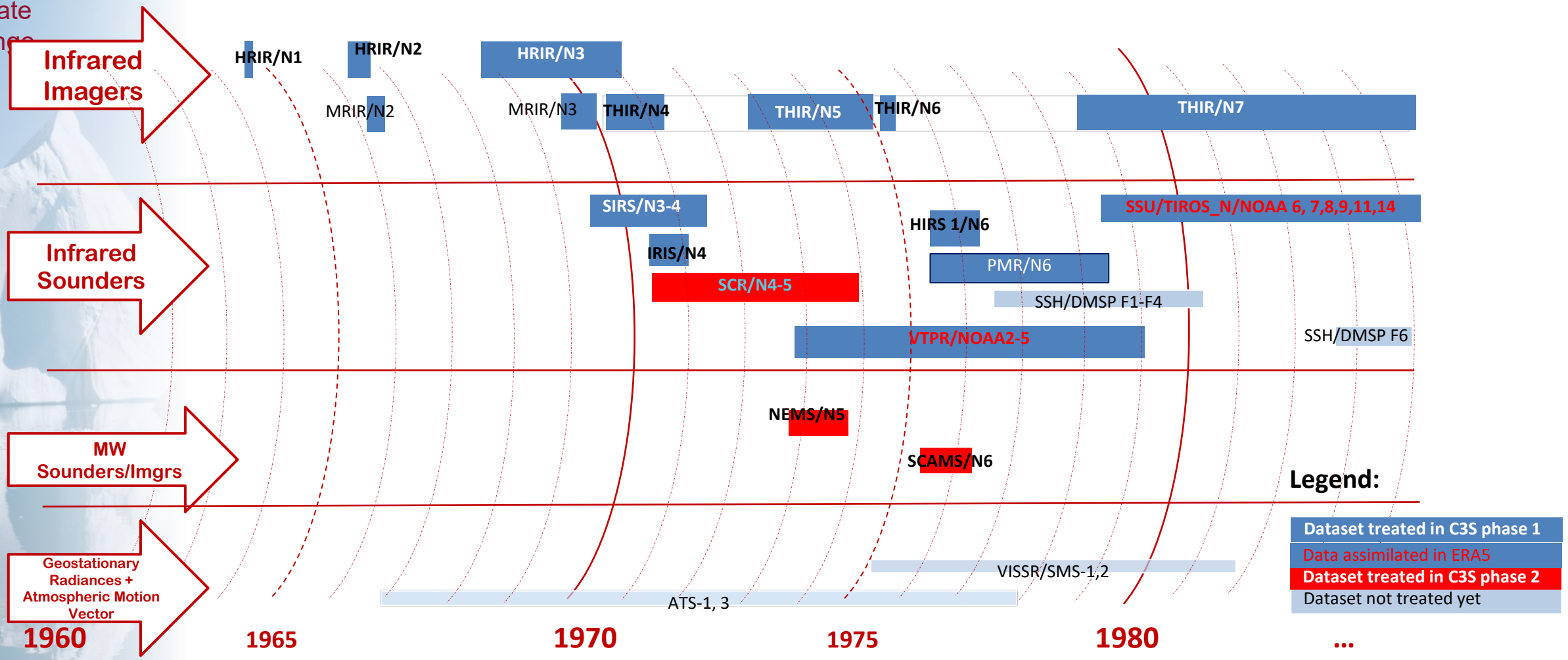

Data Recovery: decoding original archives, storing in modern format, review of historical literature, characterisation of errors (radiometric, digitalisation, …), quality analysis, correction of geolocation and time errors, analysis of O-B biases, cloud filtering, bias reduction models

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Geolocation problems with early satellite data

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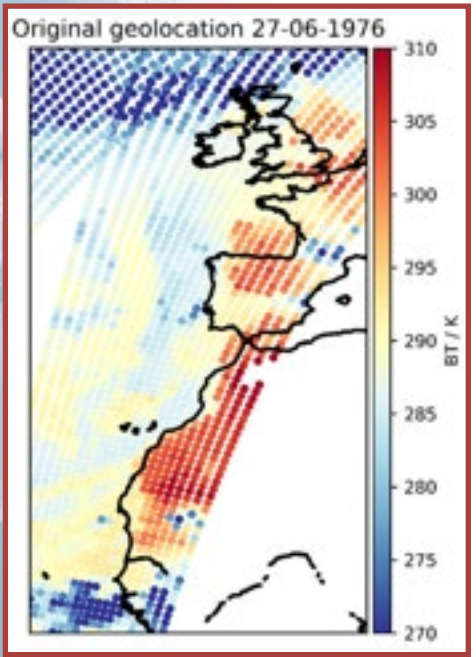
- VTPR exhibits geolocation errors of up to 400 km.
- For the Nimbus sensors such as THIR, there are often problems with the anchor points used for geolocation at the poles.
- These problems can be fixed by recalculating the geolocation using modern software.

VTPR geolocation errors

Original geolocation

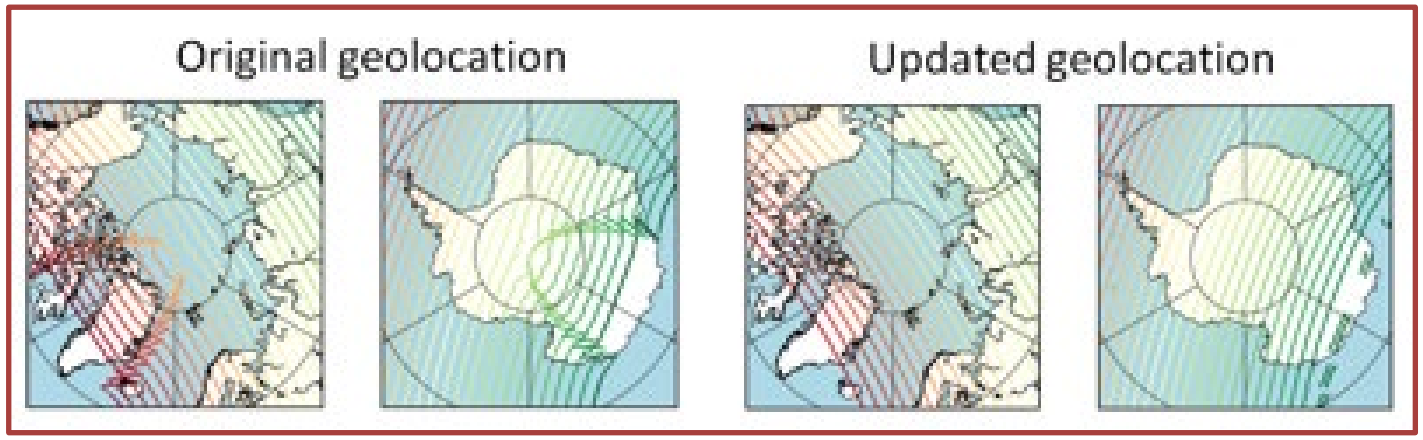


BT (K) for VTPR window channel (11.97 µm)

Corrected geolocation

Coming in Copernicus C3S Phase 2

THIR Nimbus 4



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ERA5 temperature biases in the polar winter stratosphere – as observed by early satellite sensors (SIRS and IRIS)

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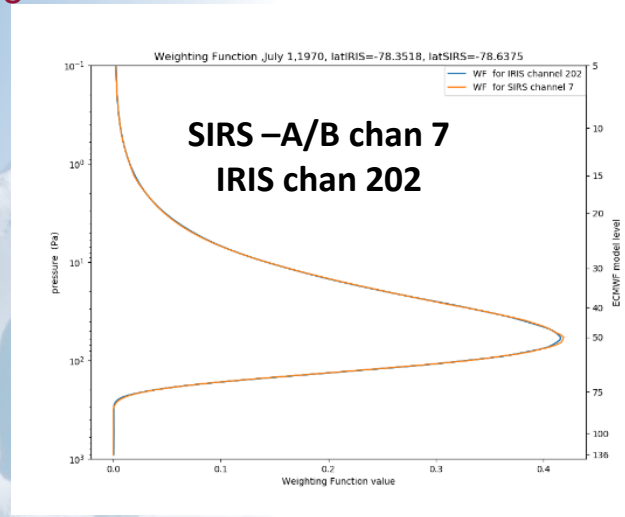
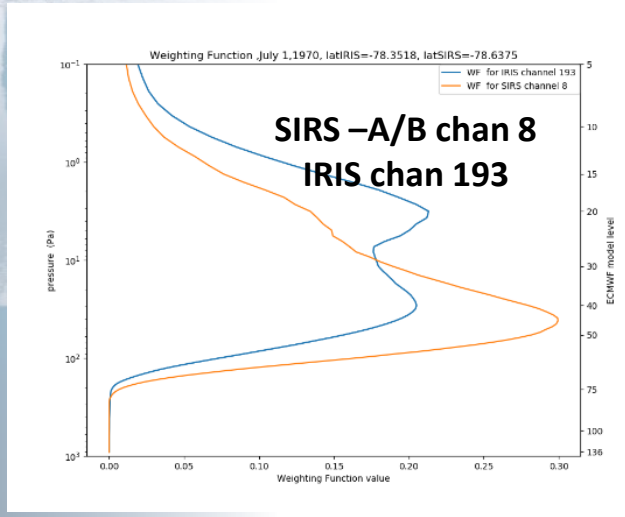
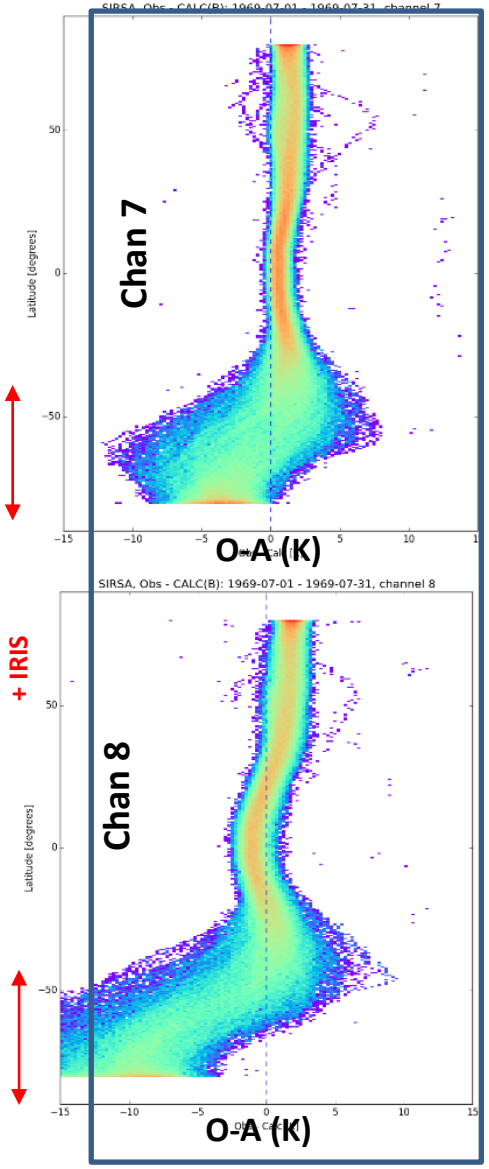
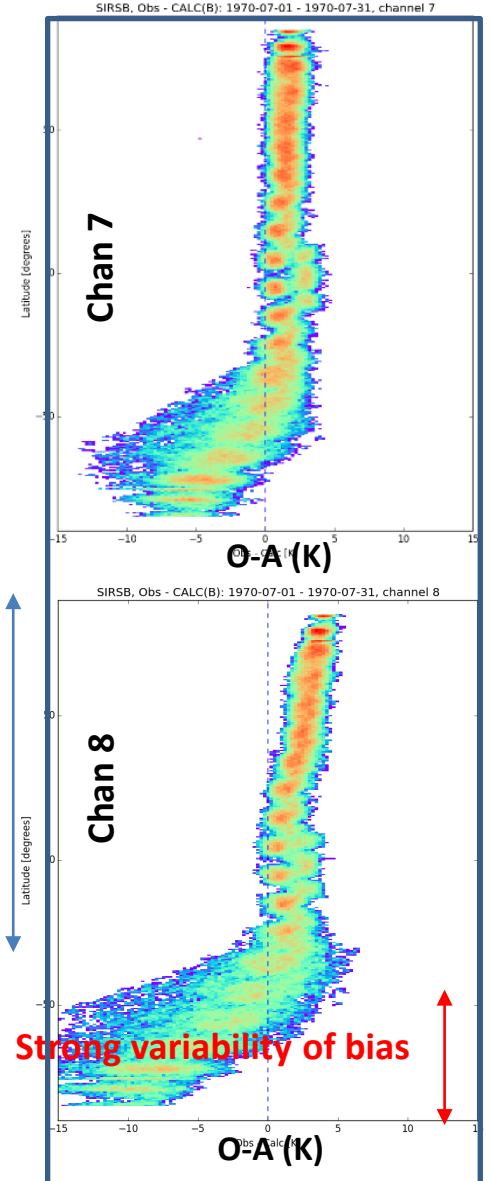




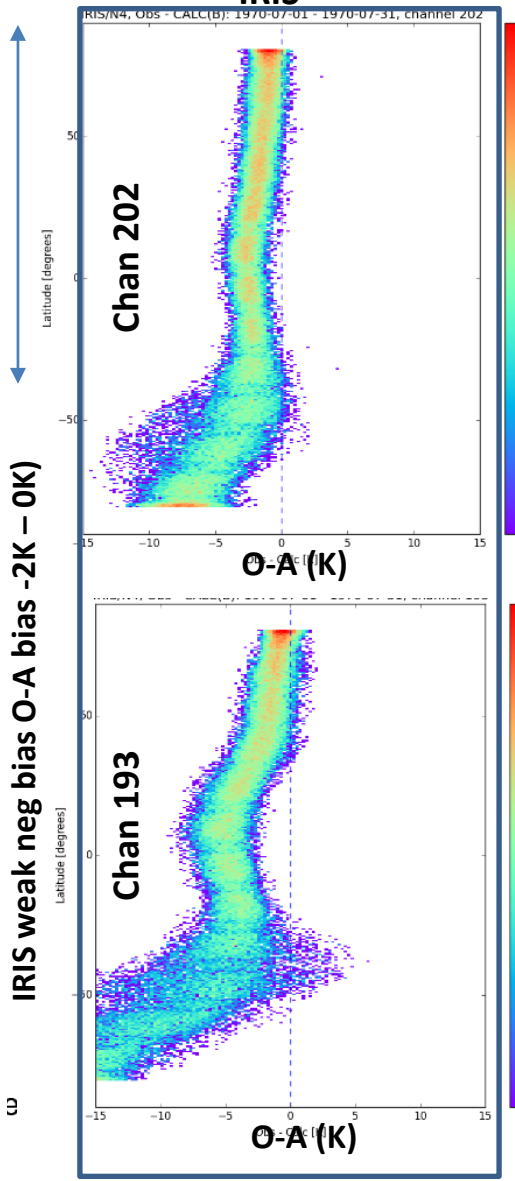
July 1969
SIRS -A



July 1970
SIRS -B



July 1970
IRIS



Assessment of the Medium Resolution Infrared Radiometer (MRIR) data

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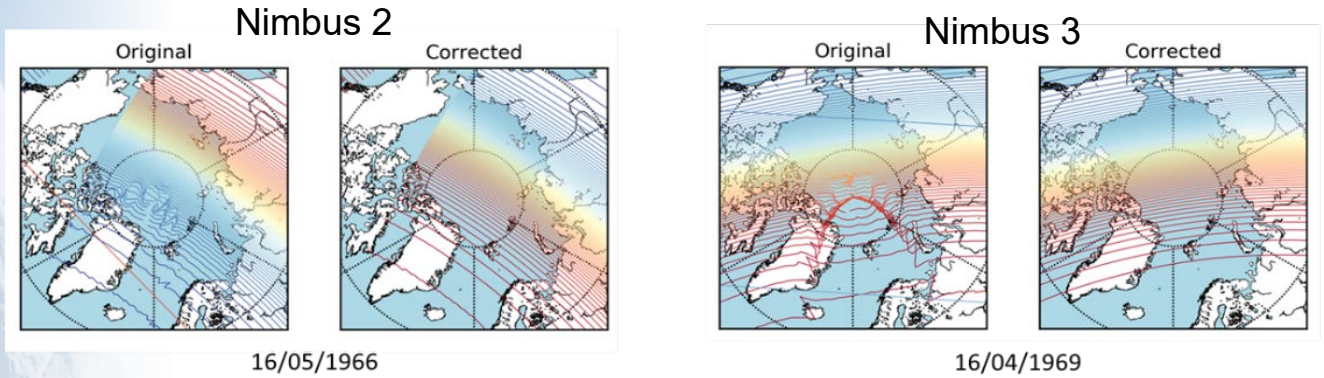
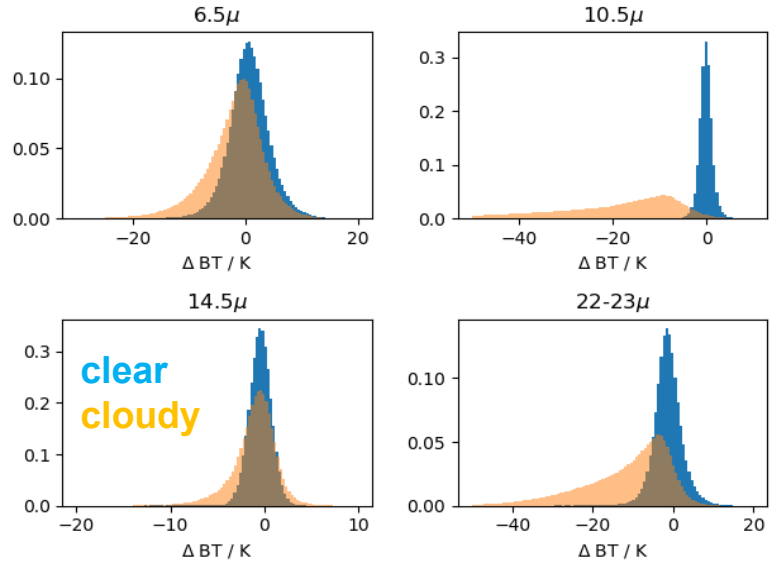
Improved geolocation, relative to original data, using two line elements (TLEs)

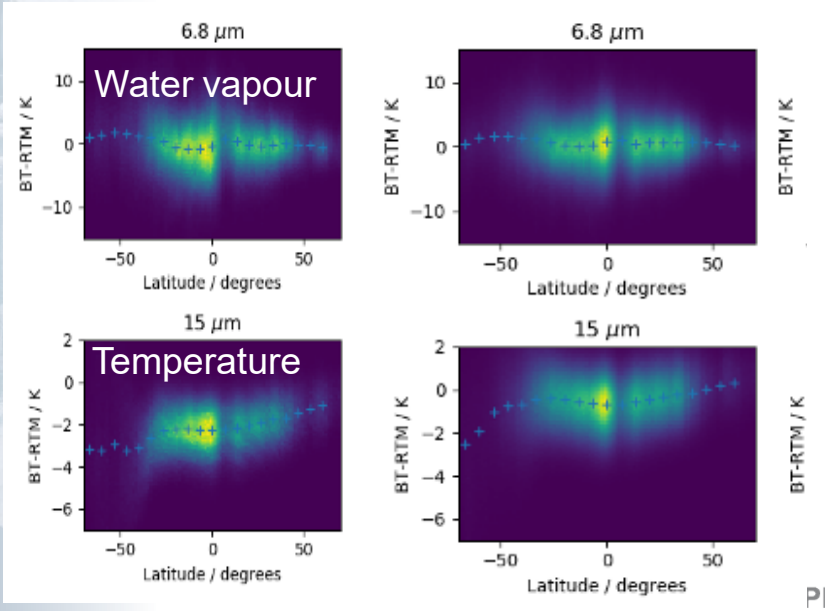


Development of cloud screening methods, based on visible albedo, from 0.2-4.0 µm vis-NIR channel

OBS-CALC, based on ERA5



Analysis of bias characteristics, relative to ERA5



Nimbus-2

Nimbus-3

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Evaluation of reprocessed satellite data

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During 2016-2021 EUMETSAT developed several reprocessed datasets for assimilation in ERA6:

Radiances

- **MHS** (Metop-A and –B, 2007-2018)
- **ATMS** (NPP & JPSS-1, 2012-18)
- **MWHS-1/-2** (FY-3A-D, 2008-18)
- **HIRS** (Nimbus-6, TIROS-N, NOAA-6 and MetOp-B, 1975 – 2018)
- **MVIRI and SEVIRI** (Meteosat, 1982-2020)
- **SSM/T-2** (DMSP, 1994-2004)

GNSS-Radio Occultation data

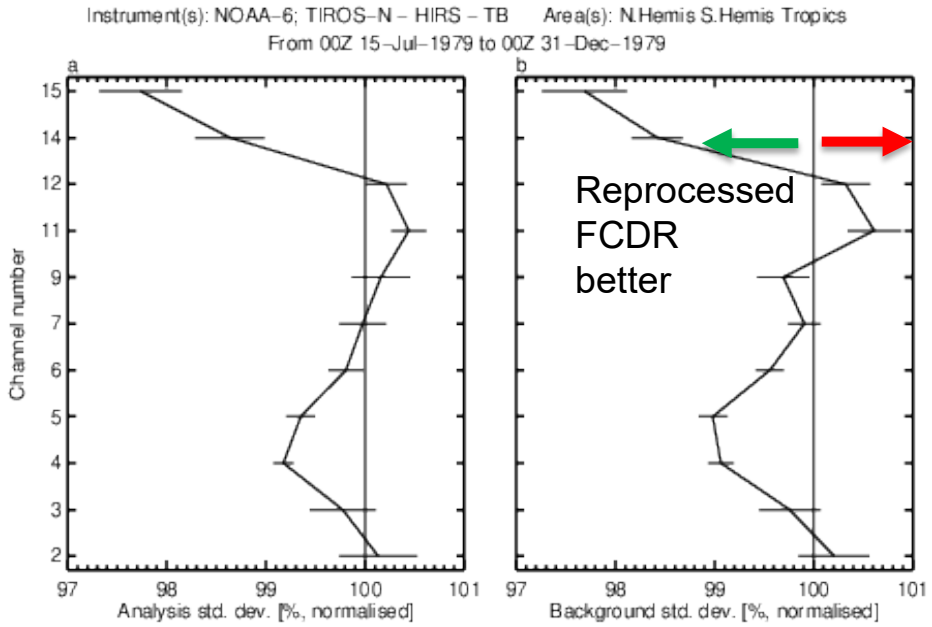
- **GRAS , COSMIC , CHAMP & GRACE**

Atmospheric Motion Vector Winds

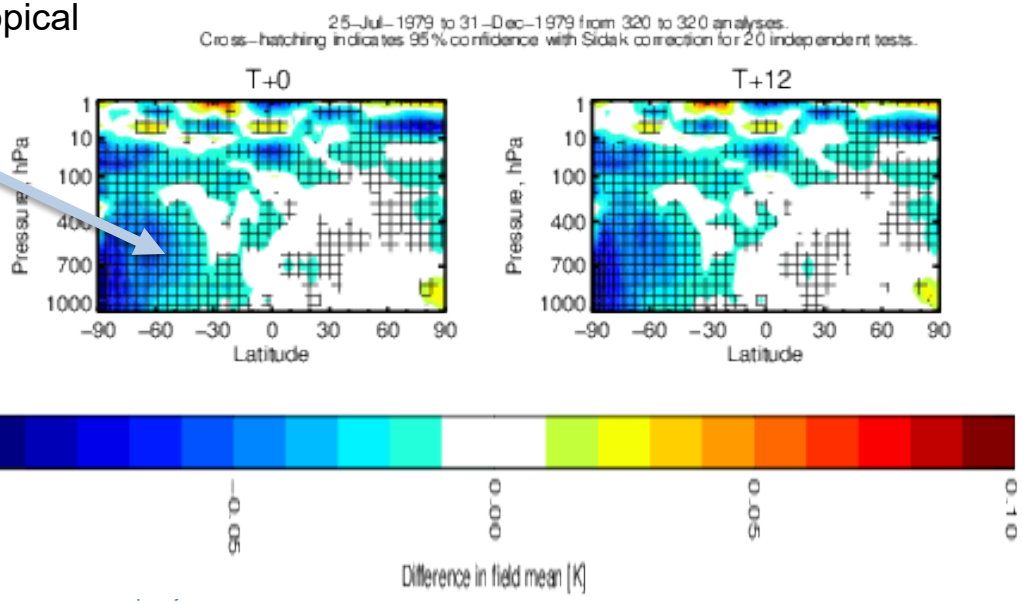
- **MVIRI, SEVIRI and AVHRR**

Scatterometer data

- **ASCAT**



SH extra-tropical mid-lower troposphere analysis colder by ~0.05K



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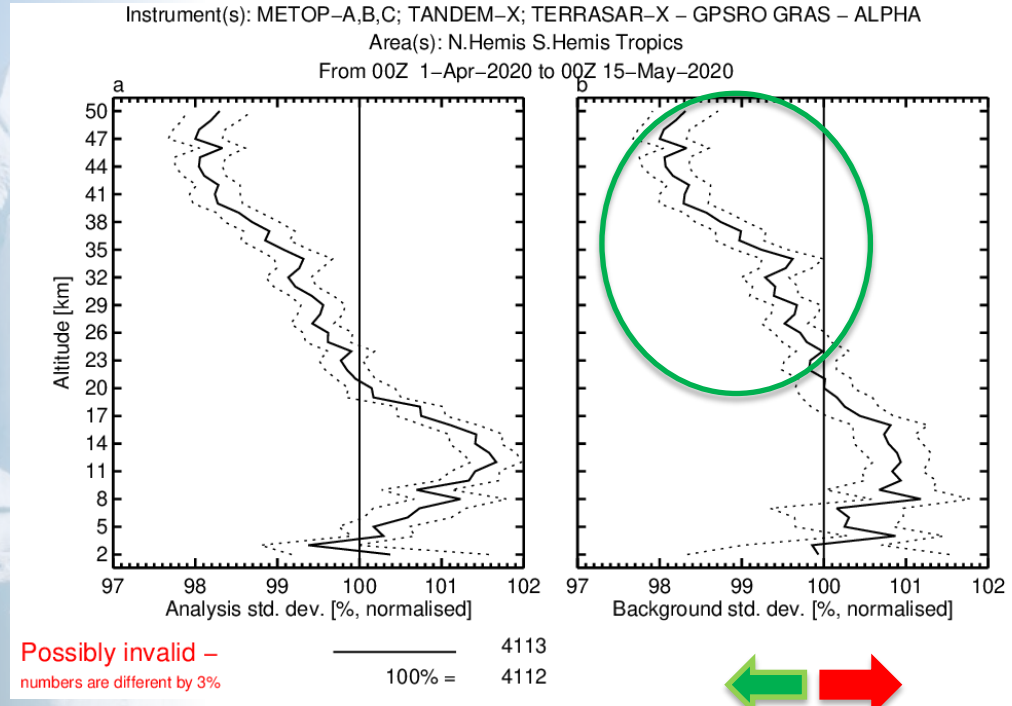
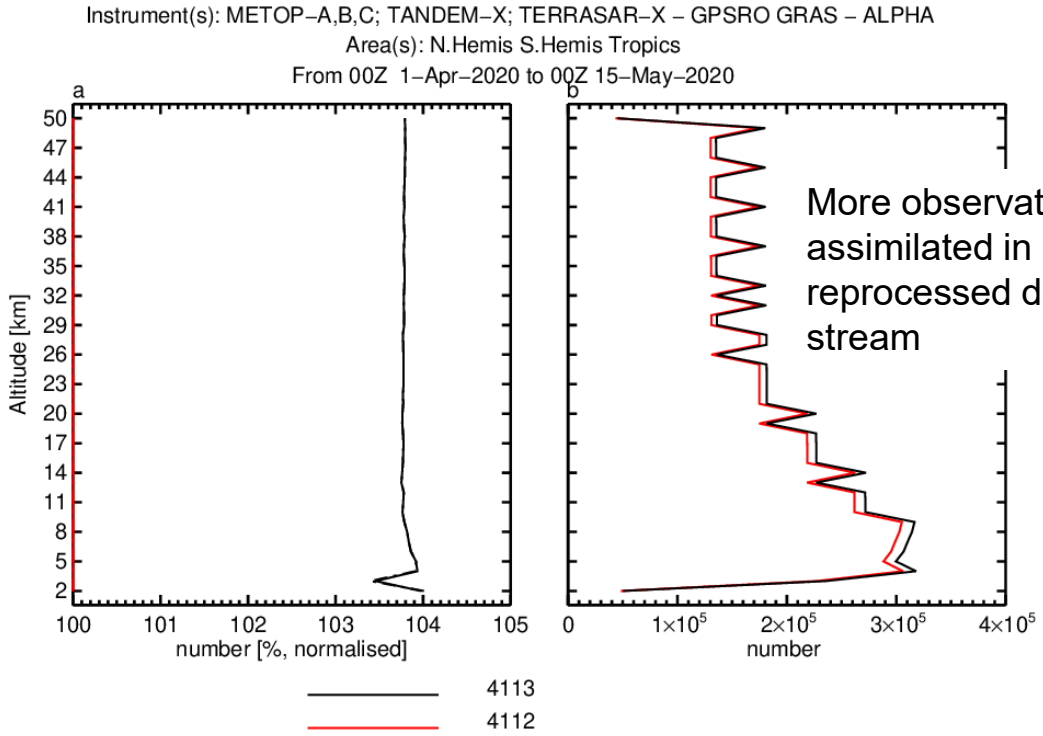
Improved GRAS-A RO fits and observation counts





More observations assimilated in reprocessed data stream

Reprocessed GRAS-A RO data better

Operational GRAS-A RO data better

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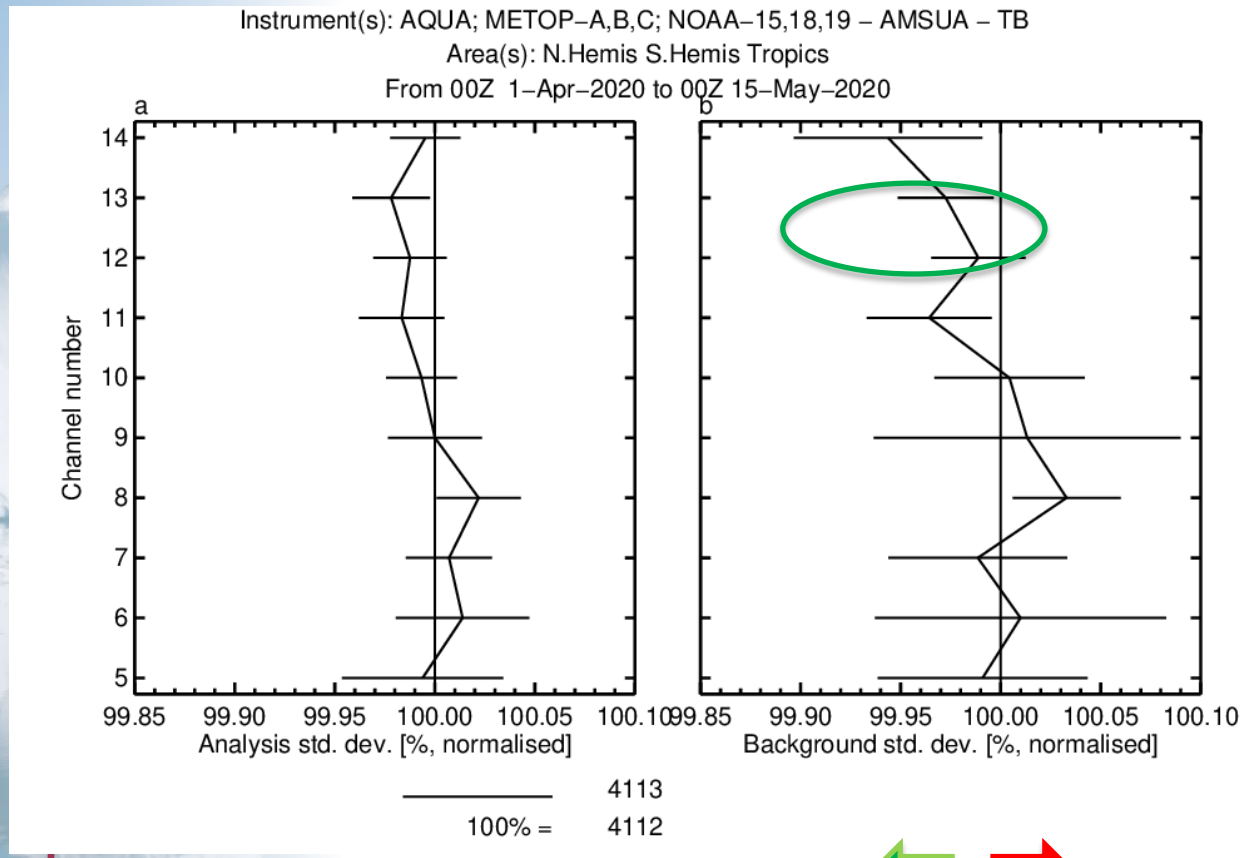
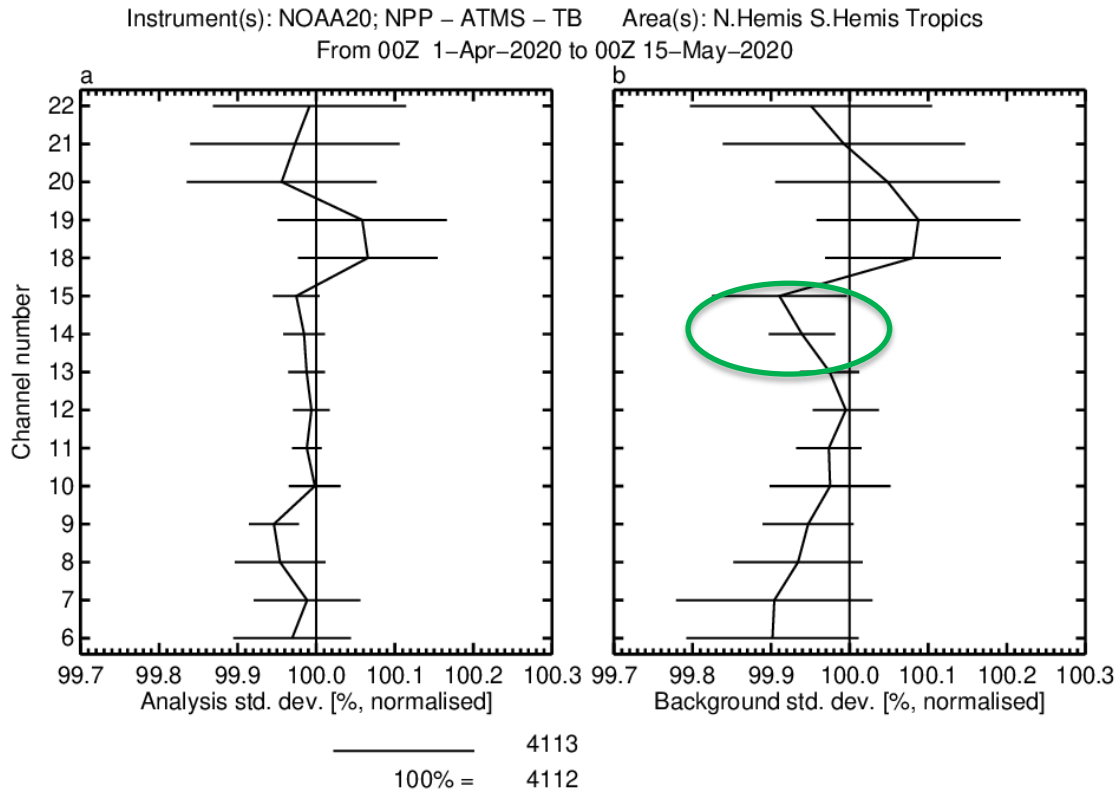
Improved background fits to AMSU-A and ATMS





Reprocessed GRAS-A RO data better

Operational GRAS-A RO data better

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EUMETSAT contribution to C3S reprocessing efforts 2021-2027

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For ERA6

- HIRS: infrared soundings (1978-2021) — 130
- SSMT: microwave soundings (1991-2005) — 25
- SSMIS: microwave soundings (2003-2021): addressing T/q sounding channels — >3
- Japanese GEO radiances (1978-2015): assimilation readiness — 0

CM SAF

Delivery and assessment 2023

For European and Arctic high-resolution reanalyses

- METEOSAT: radiances & AMV from 1st & 2nd Gen. Rapid-Scan — MVIRI AMV — 11 — 15
- AVHRR (Metop) LAC Polar AMV Release 3 (2006-2023) — 31

For early satellite era

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- SMMR: microwave imager (1978-1987) — 9
- SSH: infrared soundings (1977-1980) — 5
- SI-1: infrared spectra (1977, 1979) — <1
- THIR: Polar AMV (1970-1985) — 12

xx Satellite-years expected in deliverable (F)CDR

Uncertainty-characterised MW FCDR

- MSU: microwave soundings (1978-2006) — 55
- AMSU-A: microwave soundings (1998-2021) — 100
- (A)MSU uncertainty assessment towards FIDUCEO
- ATMS: microwave soundings (2011-2021) FIDUCEO-type analysis, all channels — 14

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Summary

- ERA5 made extensive use of reprocessed satellite observations, and this contributed to performance improvements over ERA-Interim. Same expected for ERA6

- For reanalysis, impacts on 'synoptic accuracy' and 'mean state' accuracy & continuity are important - improved observations contribute to both

- In advance of ERA6 (7, 8, 9 …) C3S has supported activities in data reprocessing and rescue:

  - Jointly these activities are targeting the highest priority datasets for ERA6
  - **Rescue**: detailed assessment has resulted in significant improvements in pre-1979 data
  - **Reprocessed**: data produced are already showing positive impacts in pre-production testing for ERA6

See related presentations:

T. Hall, B4.01.3, Satellite data Rescue for Earth observation missions of the 1960s and 1970s
J. Schulz, A5.02.1, Sustainable provision of climate data for research and climate services by EUMETSAT
P. Poli, A5.01.1, Minding the gap between FCDRs and model gridded datasets
J. Schulz, A 5.03.1, Development of a quasi-global Fundamental Climate Data Record from observations from geostationary satellites

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Thanks for listening !

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