Perspective on the needs and opportunities for data rescue & reprocessing

Bill Bell[1], Hans Hersbach[1], Paul Berrisford[1], András Horányi[1], Joaquin Muñoz Sabater[1], Julien Nicolas[1], Raluca Radu[1], Dinand Schepers[1], Adrian Simmons[1], Cornel Soci[1], Adrien Oyono Owono[1], Roberto Ribas[1], Martin Suttie[1], Jörg Schulz[2], Viju John[2], Timo Hanschmann[2], Paul Poli[2], Pascal Prunet[3], Andrzej Klonecki[3], Carsten Standfuss[3], Jon Mittaz[4], Tom Hall[4], Bruno Six[5], Jérôme Vidot[6], Bruna Barbosa Silveira[6], Pascale Roquet[6], Emma Turner[7], Roger Saunders[7].

[1] ECMWF, Reading, UK.

[2] EUMETSAT, Darmstadt, Germany.

[3] Spascia, Toulouse, France.

[4] University of Reading, Reading, UK.

[5] ICARE, University of Lille, Lille, France.

[6] Météo-France -CNRS, Lannion, France.

[7] Met Office, Exeter, UK.

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Overview

- The value of reprocessed and rescued data in reanalysis
- Reprocessing and rescue in the EU's Copernicus Climate Change Service (C3S)
  - Conventional data
  - Early satellite data rescue
  - Reprocessed satellite data
- Opportunities and challenges
  - Resources
  - Collaboration
  - Scientific challenges

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ERA5 & its preliminary extension back to 1950: reforecast skill

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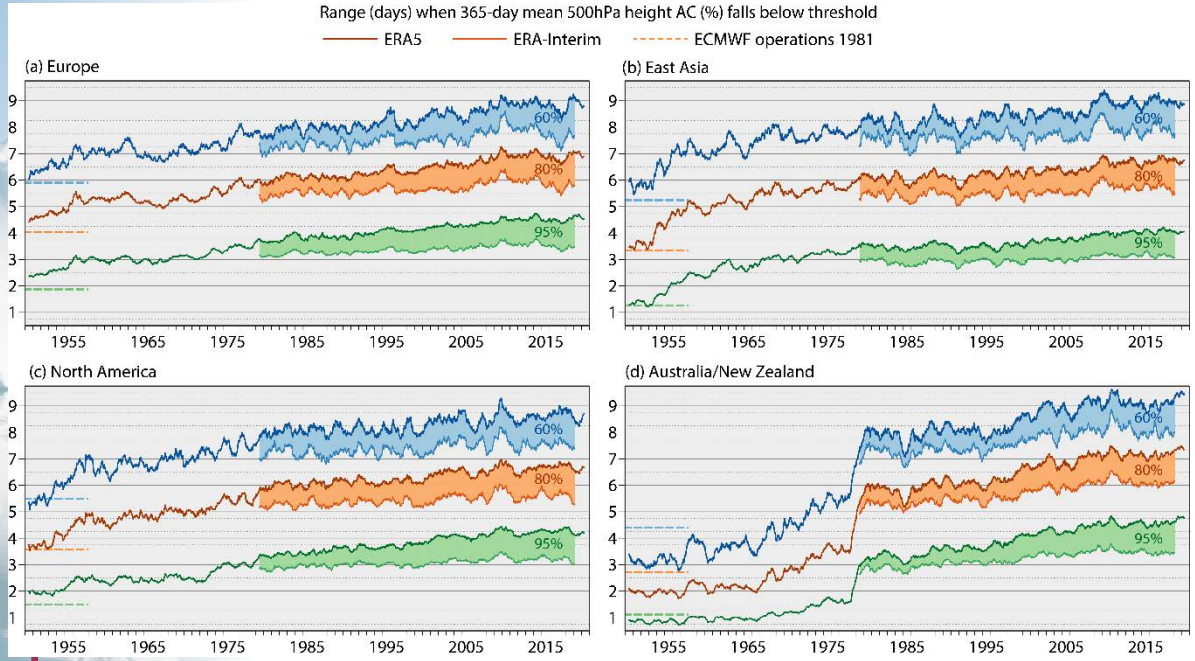

Skill gains (ERA-Interim → ERA5) realised from:

- ↑ 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)

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

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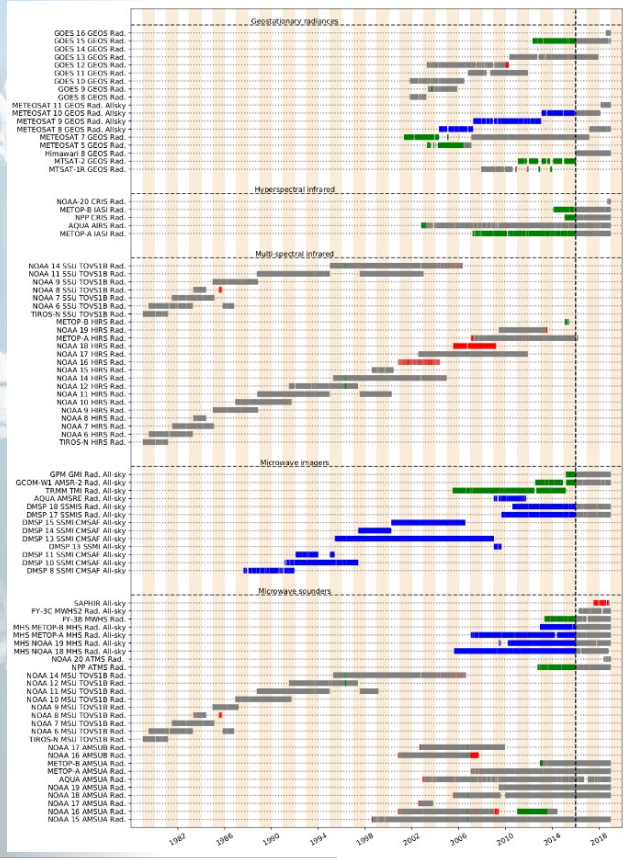
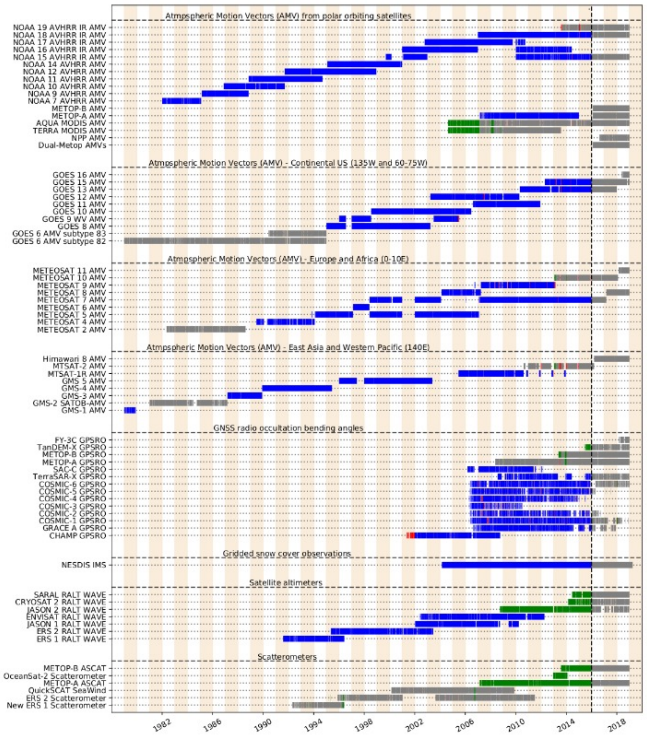
Observations assimilated in ERA5

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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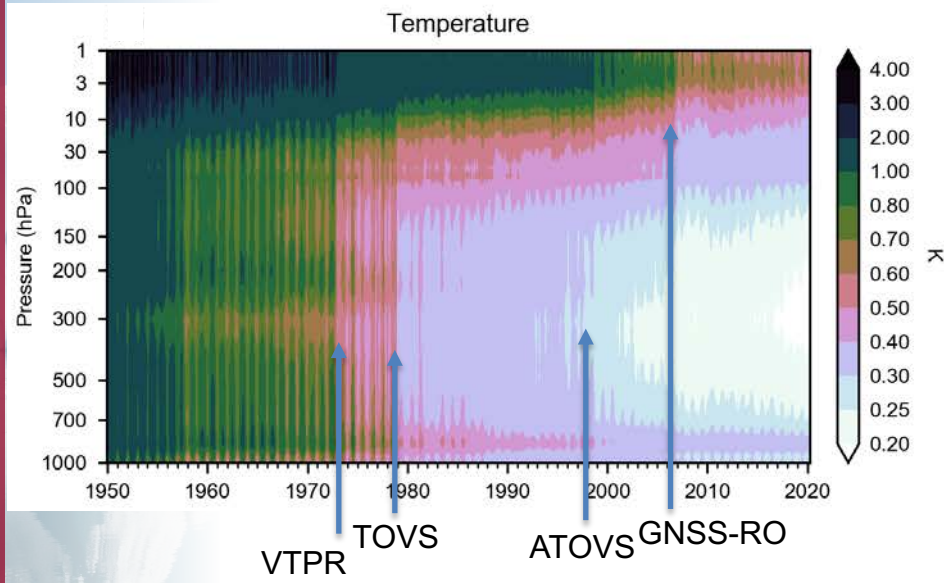
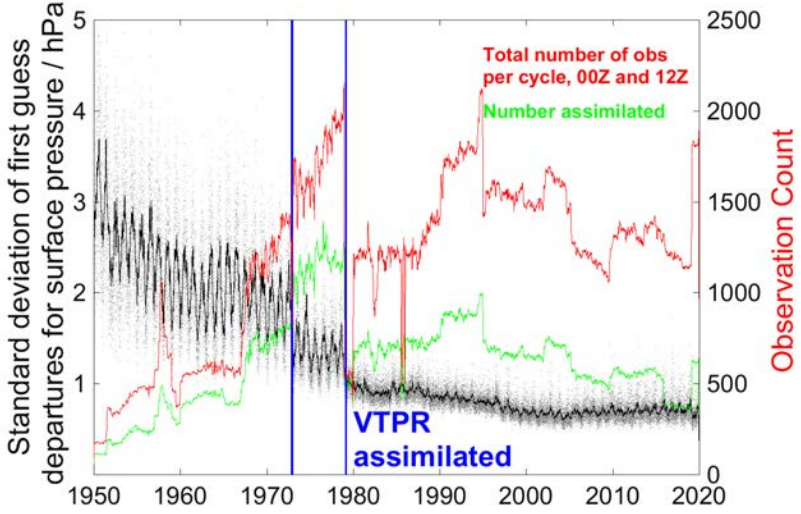
Ensemble of Data Assimilations (EDA) analysis spread



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 NOAA-2-5 (Nov 1972 - Feb 1979)
- Same L1 data assimilated in ERA-40 & JRA-55
- Benefitted from collaboration with JMA on:
  - cloud detection, observation errors, QC & RT modelling

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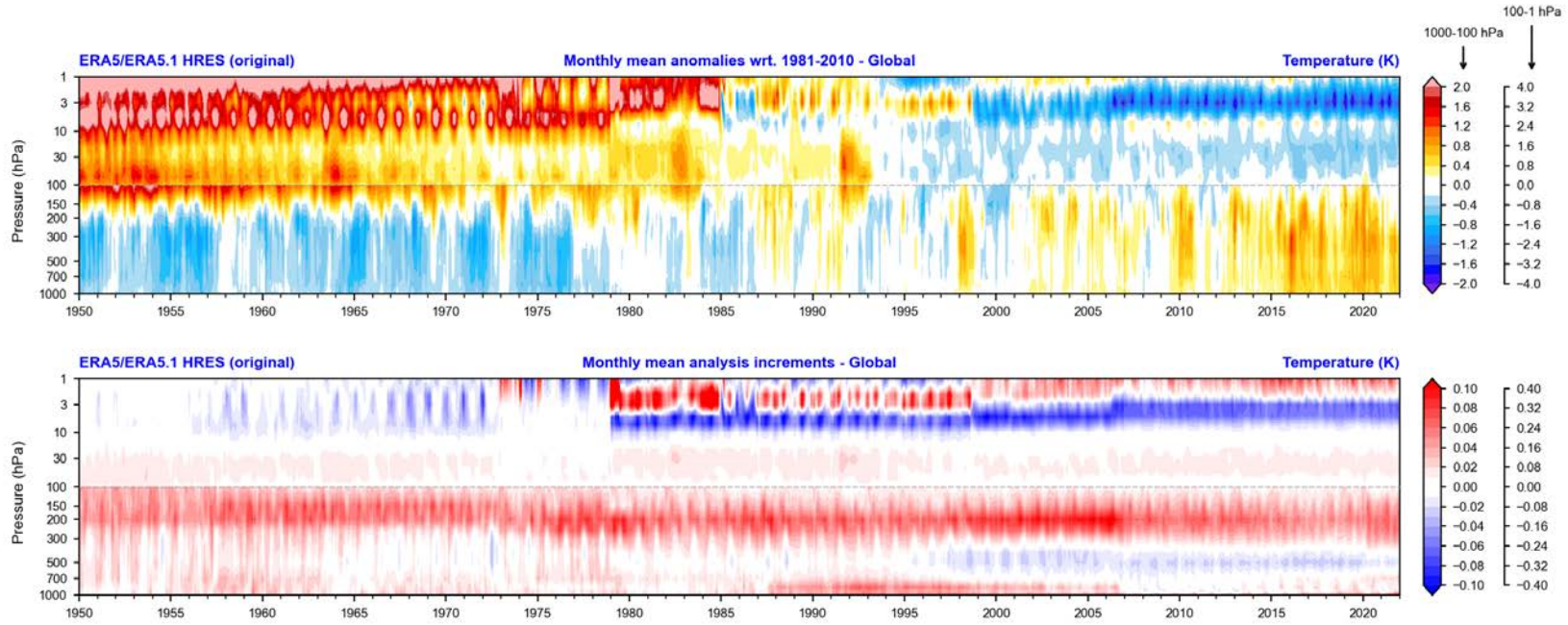
Evolution of the mean state



- Discontinuities most evident above 10 hPa
- Caused by interplay of model biases (see Patrick's talk) & changing observing system
- Same effects likely at lower levels (*e.g.* lower stratospheric biases & ERA5.1)
- Improved reprocessing of observations will play a role in minimising these effects

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C3S Approach: external partners provide long-term support in data rescue and reprocessing

Conventional Observations

- Surface and upper air meteorological data
- Facilitating data rescue
- Improving data records
- Common data standards
- Archiving data in CDS

Early Satellite Observations

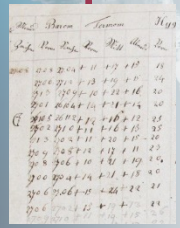
- Focus on pre-1979, mainly Nimbus
- Builds on NASA / NOAA activities
- Data formatting, QA and archiving

↓

- Evaluation relative to ERA5 (O-A)
- Evaluation of bias models

Reprocessed Satellite Observations

- Focus on long-term operational missions
- Mainly post-1979
- Delivered by EUMETSAT
- Programme defined through a comprehensive review of requirements



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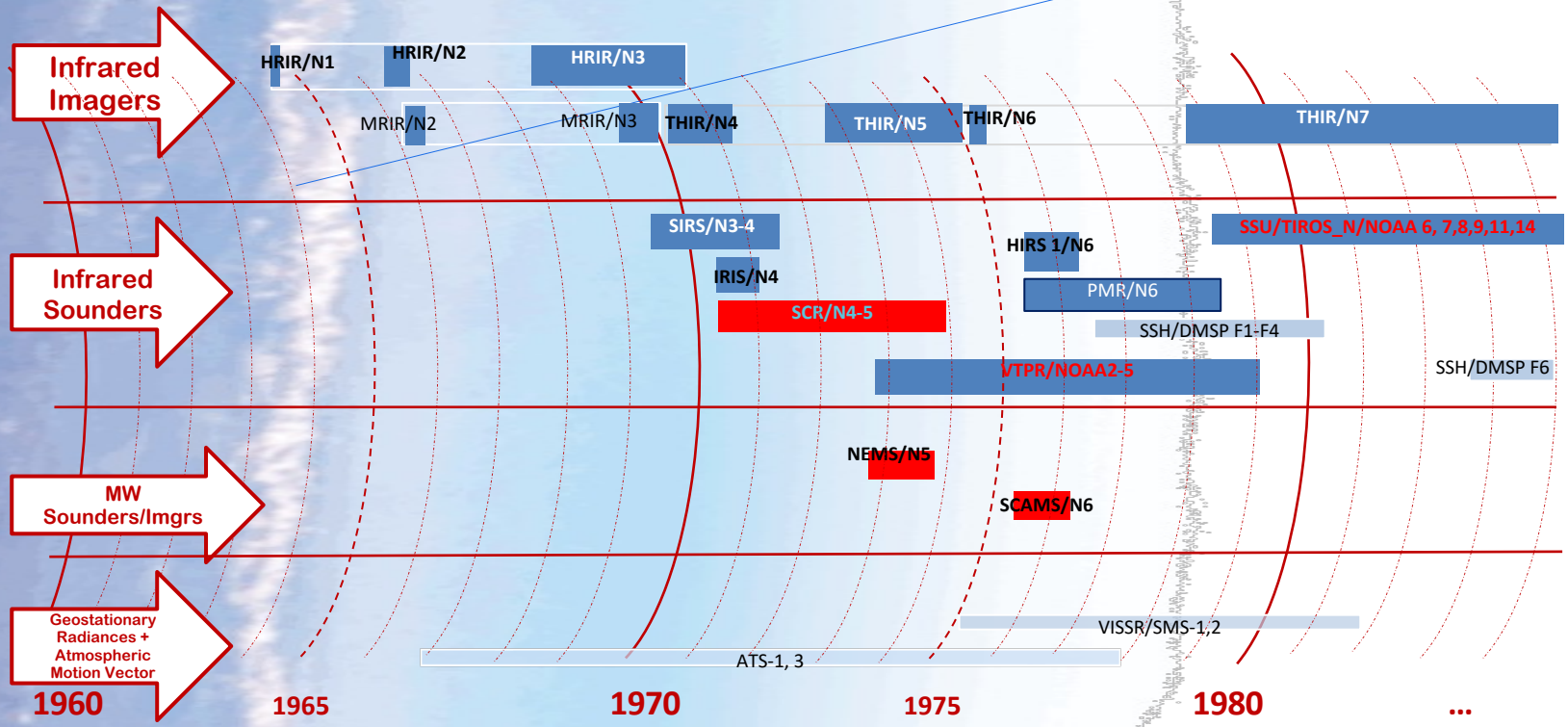
Early Satellite Data Rescue (focus on pre-1979)



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

Legend:

- Dataset treated in C3S phase 1
- Data assimilated in ERA5
- Dataset treated in C3S phase 2
- Dataset not treated yet

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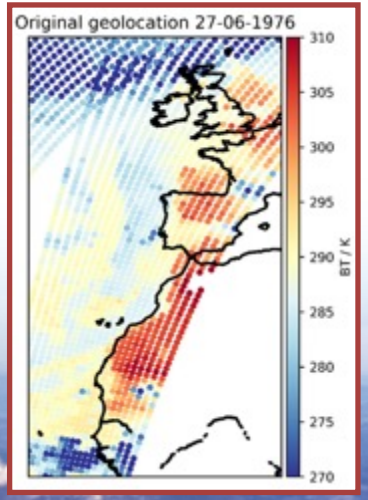
Geo-location issues for early satellite sensors

- VTPR has 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

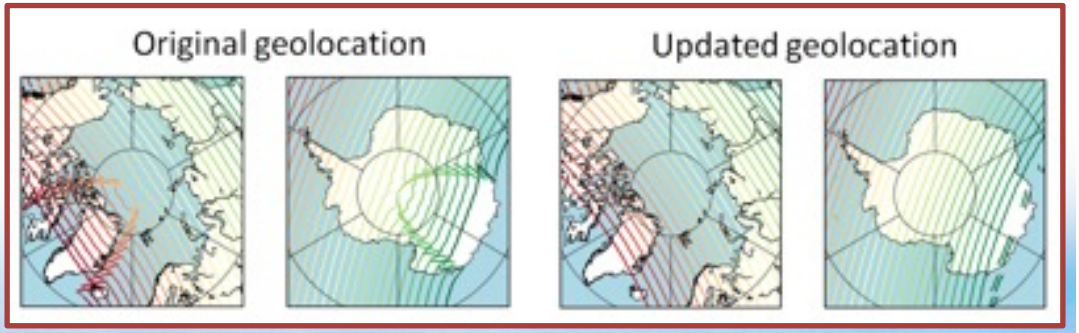


Corrected geolocation

Coming in Copernicus
C3S
Phase 2

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

THIR Nimbus 4



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

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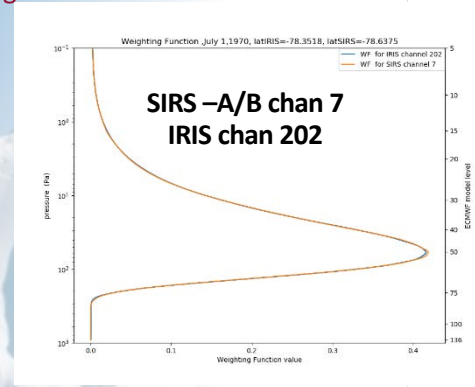
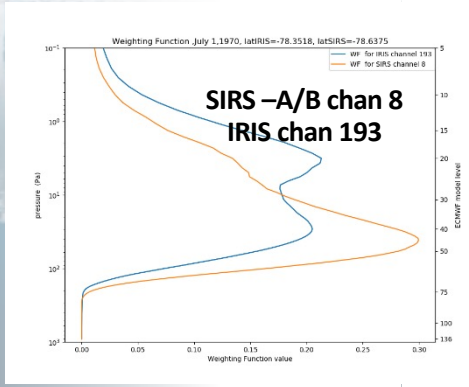
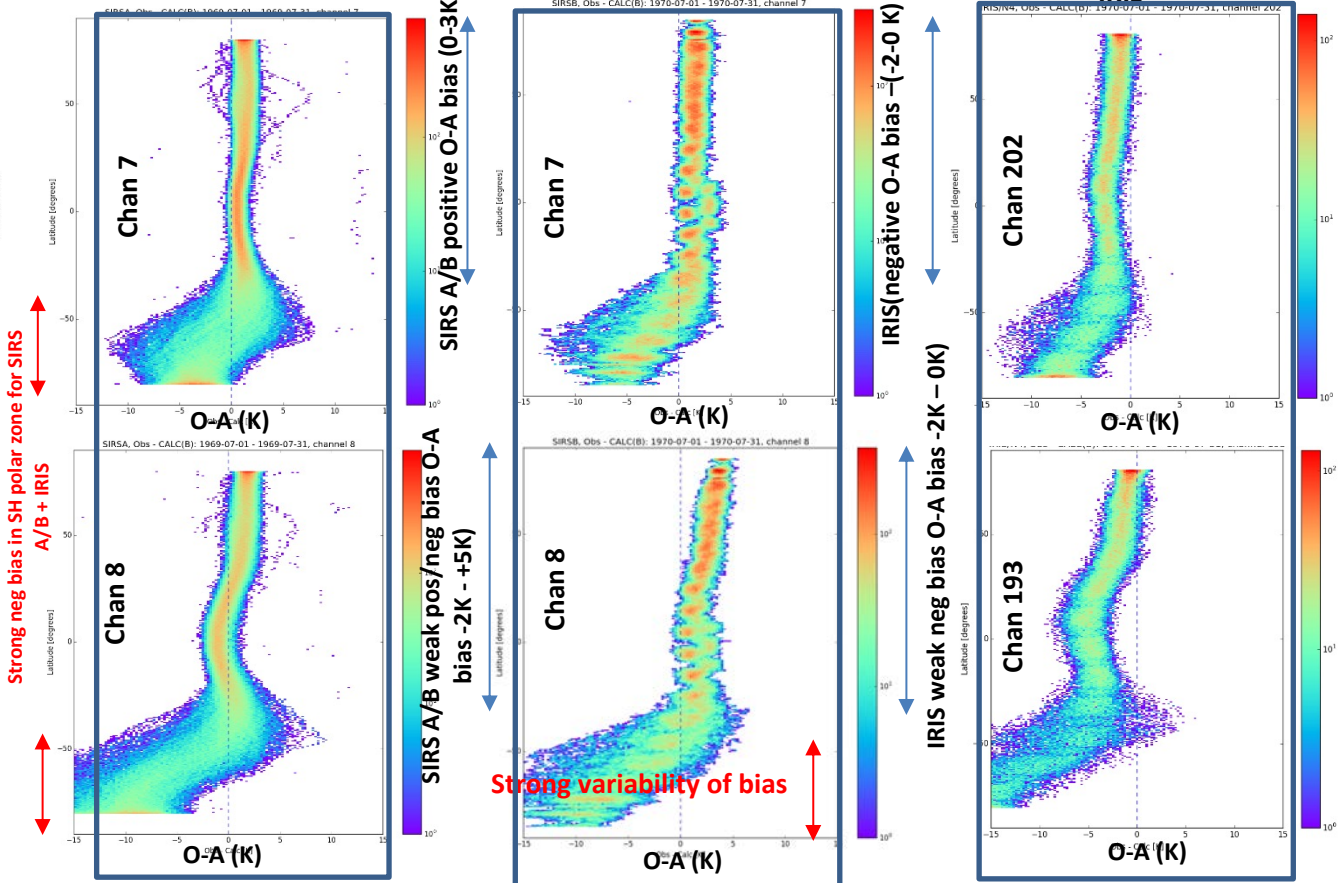




July 1969
SIRS -A

July 1970
SIRS -B

July 1970
IRIS



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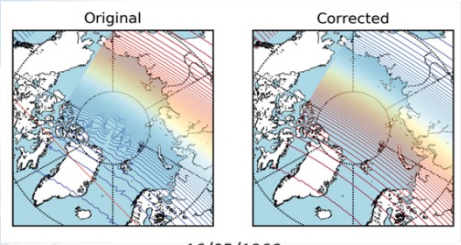
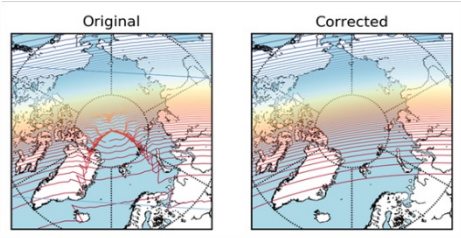
Assessment of the Medium Resolution Infrared Radiometer (MRIR) data

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

Nimbus 2

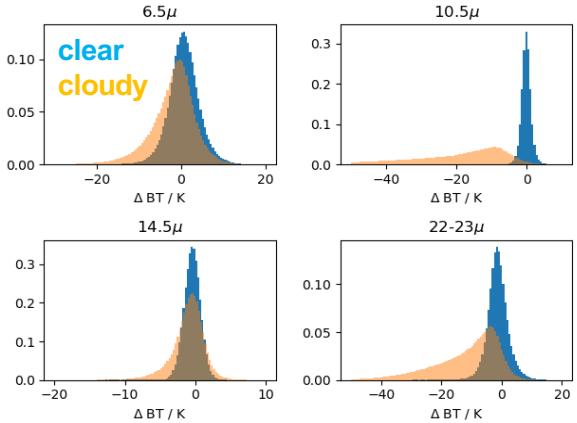


Nimbus 3

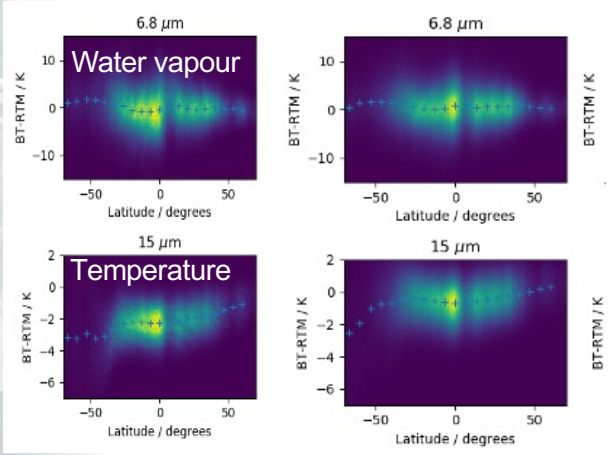


Development of cloud screening methods, based on visible albedo, from 0.2-4.0 μm vis-NIR channel

OBS-CALC, based on ERA5

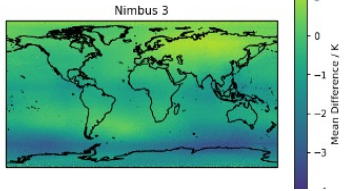


Analysis of bias characteristics, relative to ERA5

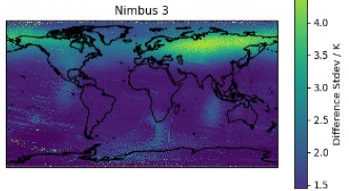


Nimbus-2 Nimbus-3

MEAN O - Calc / K



STDEV O - Calc / K



15μm channel

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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

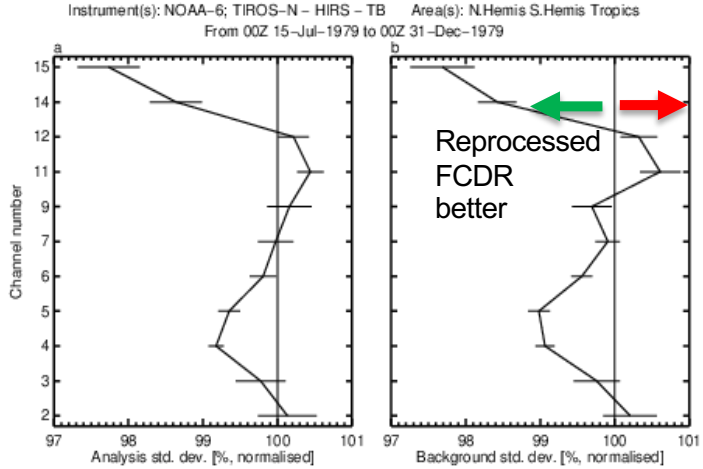
- **GRAS , COSMIC , CHAMP & GRACE**

Atmospheric Motion Vector Winds

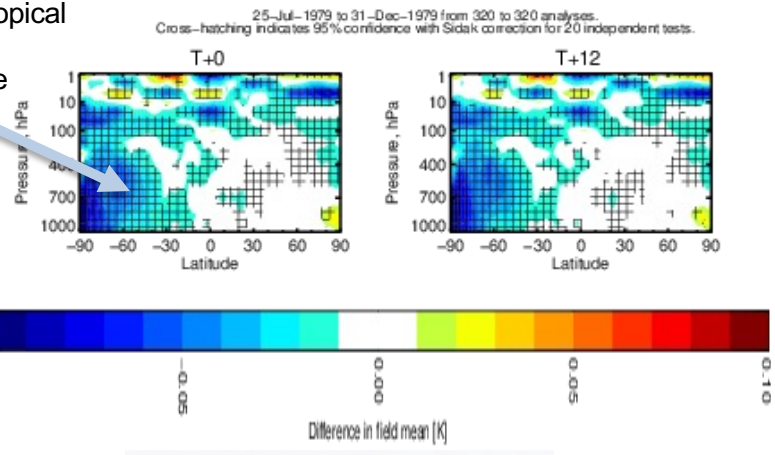
- **MVIRI, SEVIRI and AVHRR**

Scatterometer data

- **ASCAT**



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



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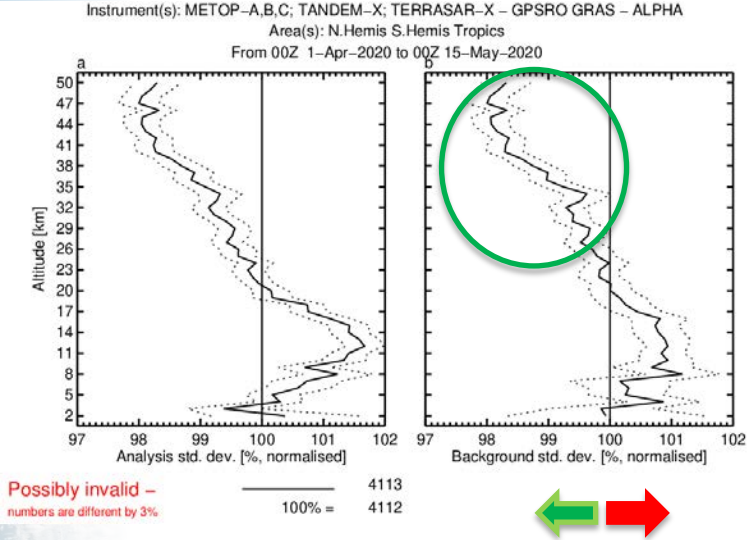
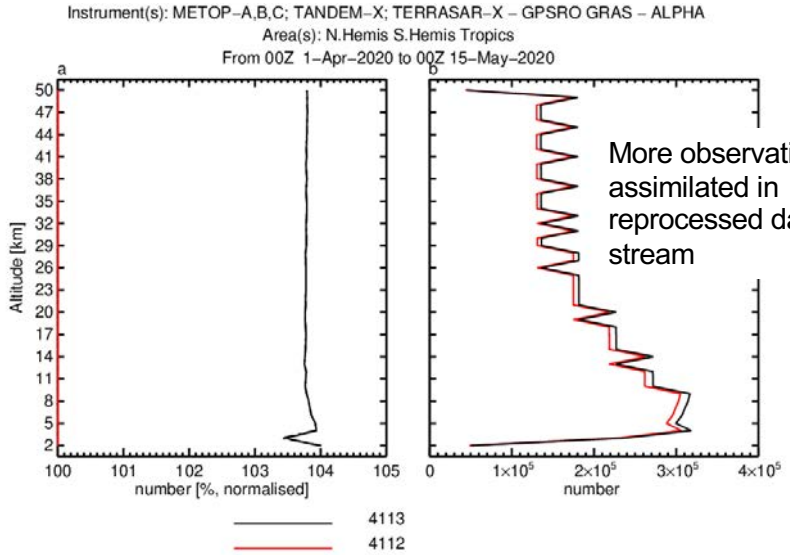
Improved GRAS-A RO fits and observation counts





More observations assimilated in reprocessed data stream

Reprocessed GRAS-A RO data better

Operational GRAS-A RO data better

- Results consistent with RD testing of equivalent updated processing for operational RT data stream
- Experiments underway to assess reprocessed COSMIC, CHAMP and GRACE data

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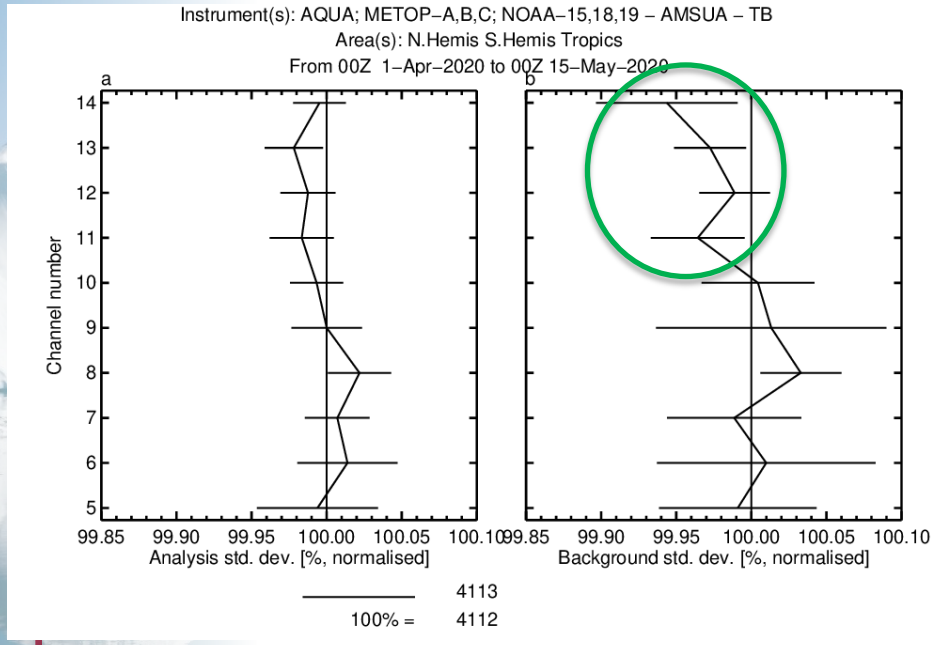
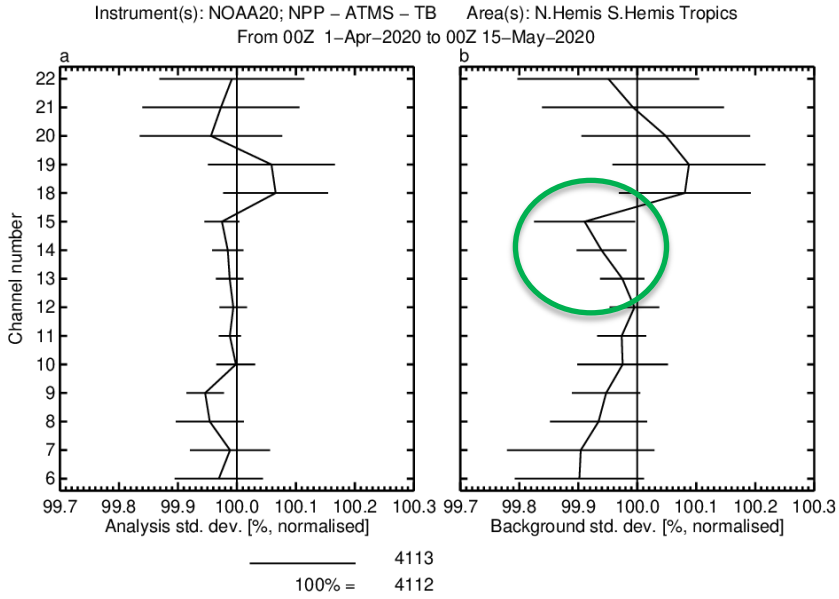
Improved background fits to AMSU-A and ATMS





Reprocessed GRAS-A RO data better

Operational GRAS-A RO data better

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EUMETSAT contribution to C3S reprocessing efforts 2021-2027

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

- 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

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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

xx Satellite-years expected in deliverable (F)CDR

CM SAF Close collaboration

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Opportunities & Challenges I

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Most significant advances for the field of reanalysis in 5-10 years?

- Performance (coupling, synoptics & mean state trends) will continue to improve in next-gen reanalyses
- Reanalysis established as an ever more powerful and widely used tool for climate monitoring, including:
  - Greater focus on performance at ever smaller scales (global → continental → national / regional)
  - Greater focus on '*higher order*' statistics of anomalies (means → extremes → full pdfs) – scientific & technical value
- These trends will bring increased scrutiny to our uncertainty estimates
- *Peak-carbon* is probably > 10 years away, next 5-10 years is the time to build capabilities to respond to this scrutiny
- Progress in unexplored aspects of this problem (*e.g.* mean-state uncertainties – see WCRP WS) is likely
- Improved quality of, & understanding of, observational data will play a key role in this

What do you see are the most significant barriers to progress in the field of reanalysis?

- **Resources**
  - Compared to much larger effort focussed on operational NWP, resources devoted to reanalysis are small
  - Some significant scientific challenges for reanalysis are less of a priority for NWP, *e.g. :*
    - Mean-state uncertainties
    - Developing & testing observation operators and DA configurations for historical sensors
      - Pre-1979 satellite data
      - More recent Research / Operational missions never fully exploited in NWP (SSMIS upper-strat & mesospheric channels, Windsat, limb-sounders, …)

- **Establishing effective modes of collaboration**

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Opportunities & Challenges II

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Which collaborations are currently working and which collaborations need to be fostered?

- Compared to NWP, reanalysis is a relatively solitary activity ! (? …)
- Re. Satellite data. For NRT aspects, ITWG (~200), IROWG (~40), IWWG (~50), IPWG (~50) are very effective
- No (formal) equivalent for conventional observations
- Components related specifically to historical observations of relevance for reanalysis are currently fringe, and could be strengthened.
- Other groups exist (GSICS, CEOS WGCV) and are very active (*e.g.* in reprocessing) but are less DA-focussed than ITWG, IROWG, .. etc. How to strengthen links ?
- Post-pandemic modes of meeting offer an opportunity to strengthen reanalysis focussed collaborations
- What's the appetite for greater collaboration ?

What are the critical requirements for consistent Earth system reanalysis?

- Consistency in time: improved treatment of biases (model & observation) and estimation of uncertainties
- Consistency across variables - improved coupling across domains

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Opportunities & Challenges III

What observational datasets are required to support these requirements?

- Improved reprocessed & rescued data (see talk)
- Interface observations (to support coupling)
- [General point: Engagement of reanalysis communities in specifying next generation observing systems. Requirements not identically aligned with NWP requirements]

How is uncertainty quantified for your application?

- Synoptic uncertainties from EDA
- Mean-state uncertainties not evaluated (except through comparison with independent datasets)

Are there significant barriers for quantifying uncertainty in your field?

- Mean state uncertainties - needs new approaches, building on work in climate / EPS communities

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Thanks for listening !

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