



Preparations for assimilating sounding observations in the next generation global atmospheric reanalysis at ECMWF - ERA6



Climate Change

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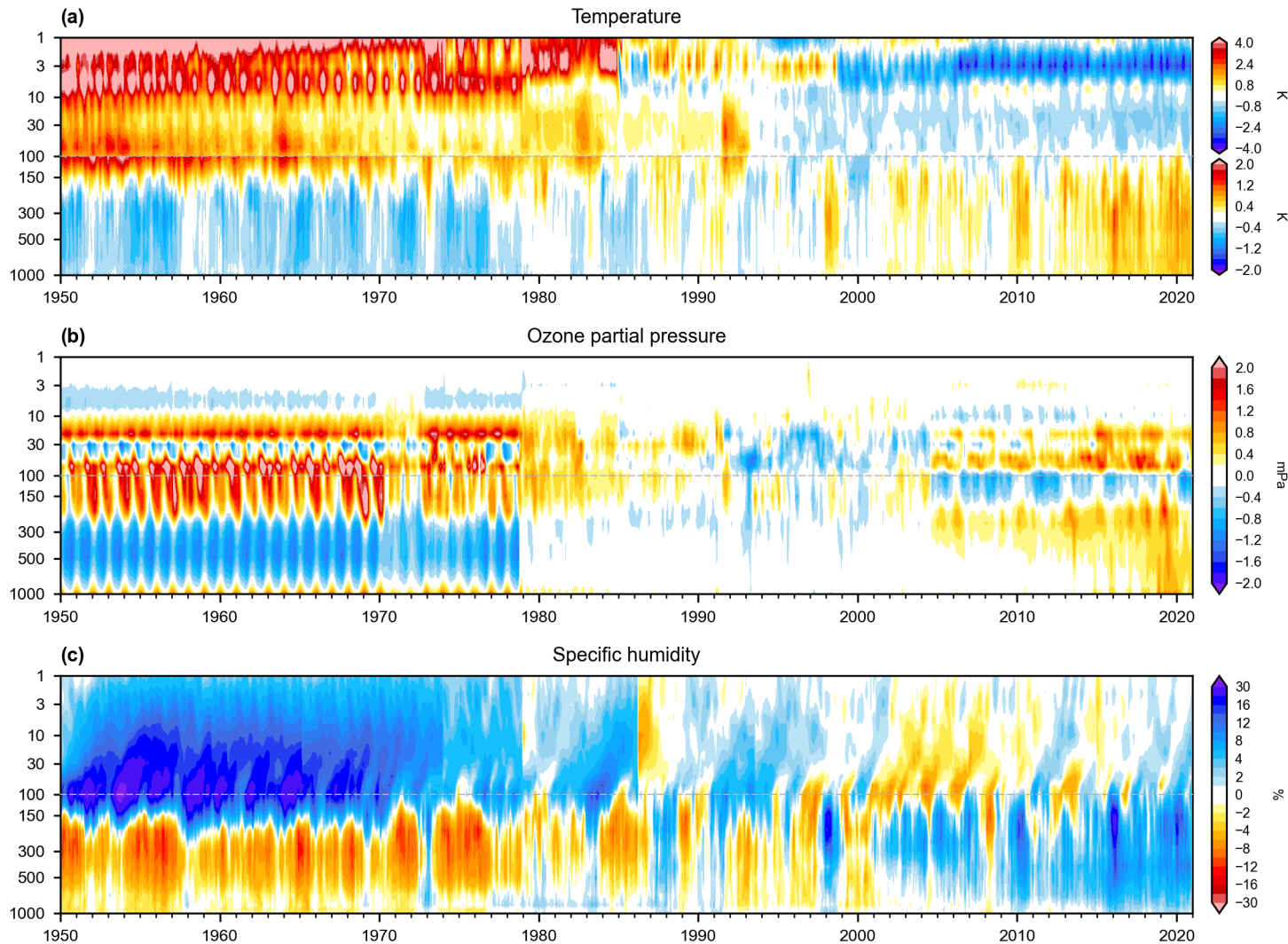


- ERA5 - status and some highlights
- The impact of sounding data in ERA5 & issues identified:
 - MSU / AMSU-A biases
 - CO₂ (t) for Adv IR sounders
 - SSU (see extra slides)
- Preparations for ERA6:
 - Reprocessed satellite data (e.g. HIRS from NOAA-6 / TIROS-N)
 - Rescued early satellite data (e.g. Nimbus-4 IRIS)



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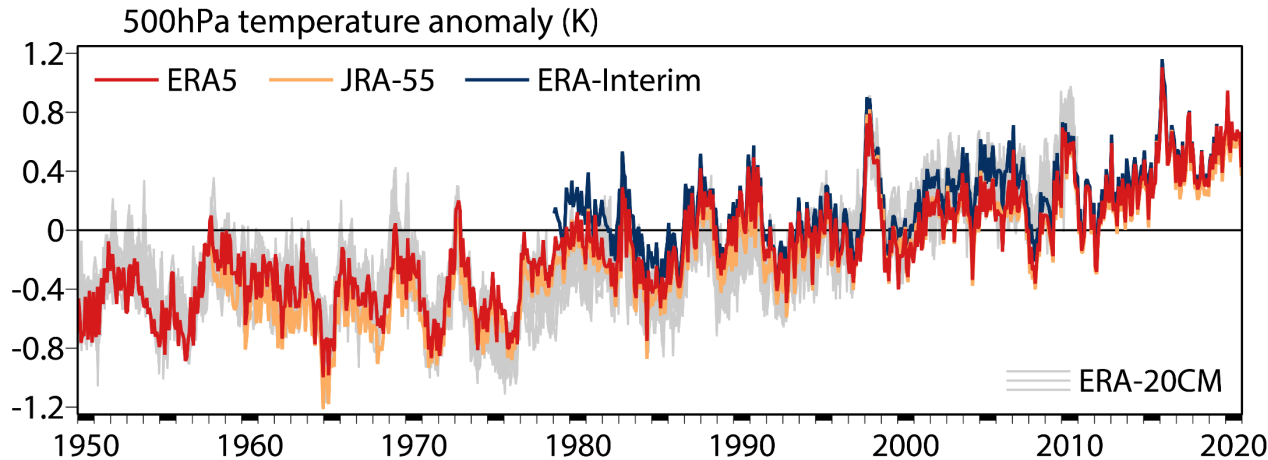
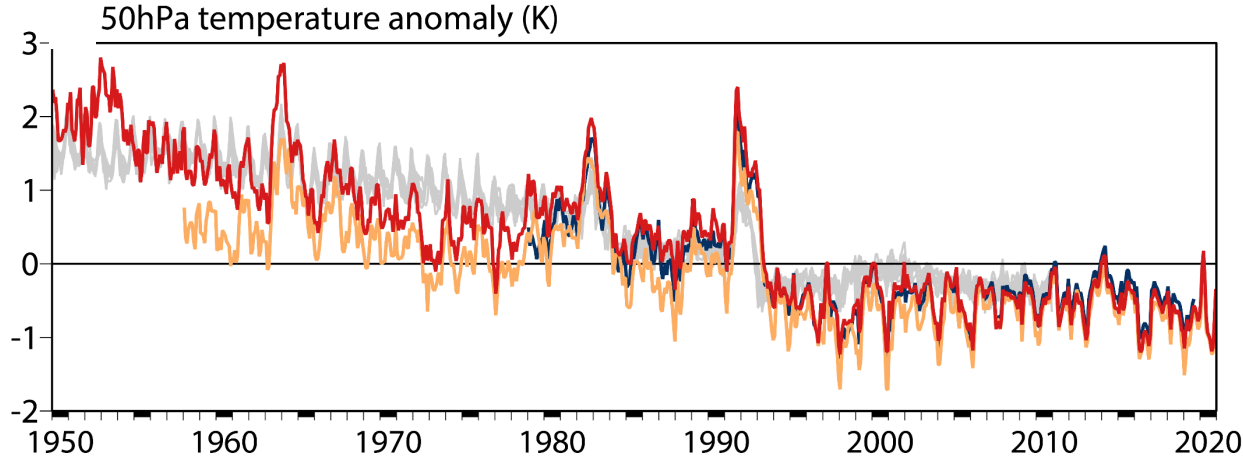
ERA5 1950 – 2021 Upper Air Anomalies Relative to 1981-2010 ERA5 Climate



- ERA5 1979 → completed Q1 2019
- Continues at RT+1 day (avail. RT+5 days)
- ERA5 1950–1978 – completed* Q1 2020
- 31km resolution HRES. Hourly output. L137
- > 100 Billion observations assimilated
- [‘Synoptic’] uncertainties from EDA
- > 50,000 users
- Hersbach *et al* (QJRM, 2020) for ERA5 1979 - 2019
- Bell *et al* (QJRM, submitted) for ERA5 1950 – 1978
- ERA6 production will start 2024. Preparations underway



Climate trends: Temperature at 50 hPa, 500 hPa and T2m



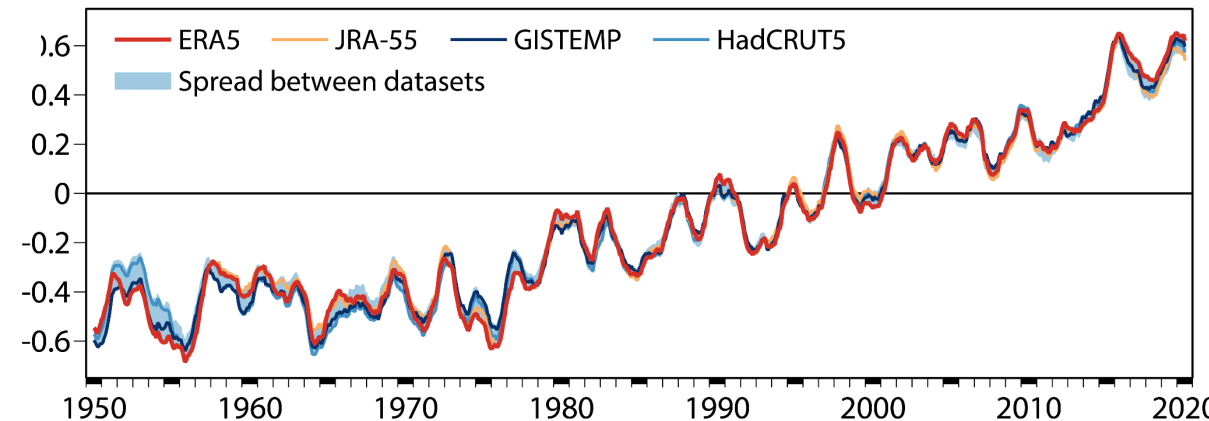
Upper air temperatures at 50 and 500 hPa:

- Stratospheric cooling (1950 – 1995)
- Tropospheric warming (late 1970s onwards)
- Reasonable agreement between reanalyses

Surface temperatures at 2m:

- Good agreement between reanalyses & obs
- Spread increases pre-1980

12 month running mean surface temperature anomaly (K) relative to 1981-2010
Global

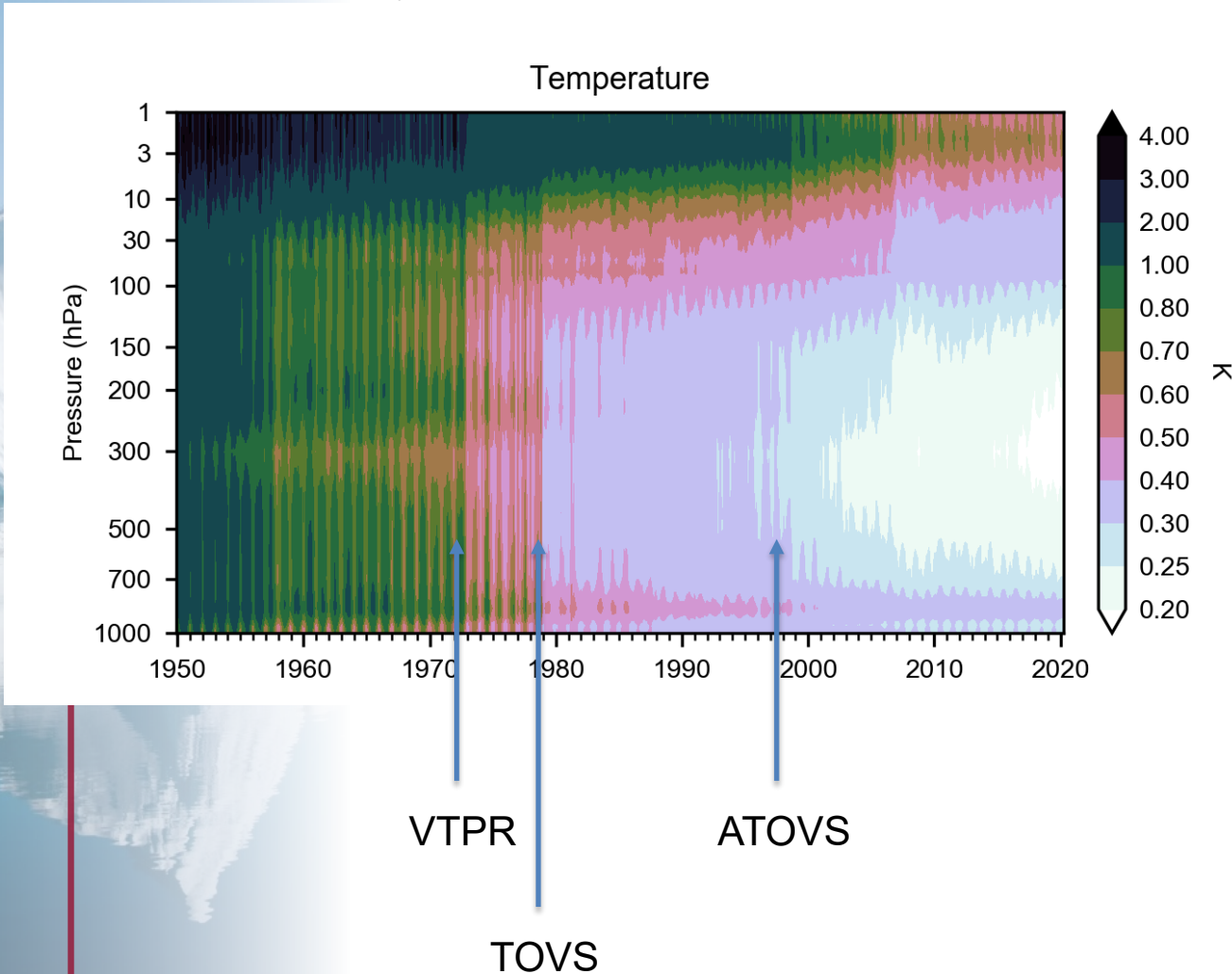




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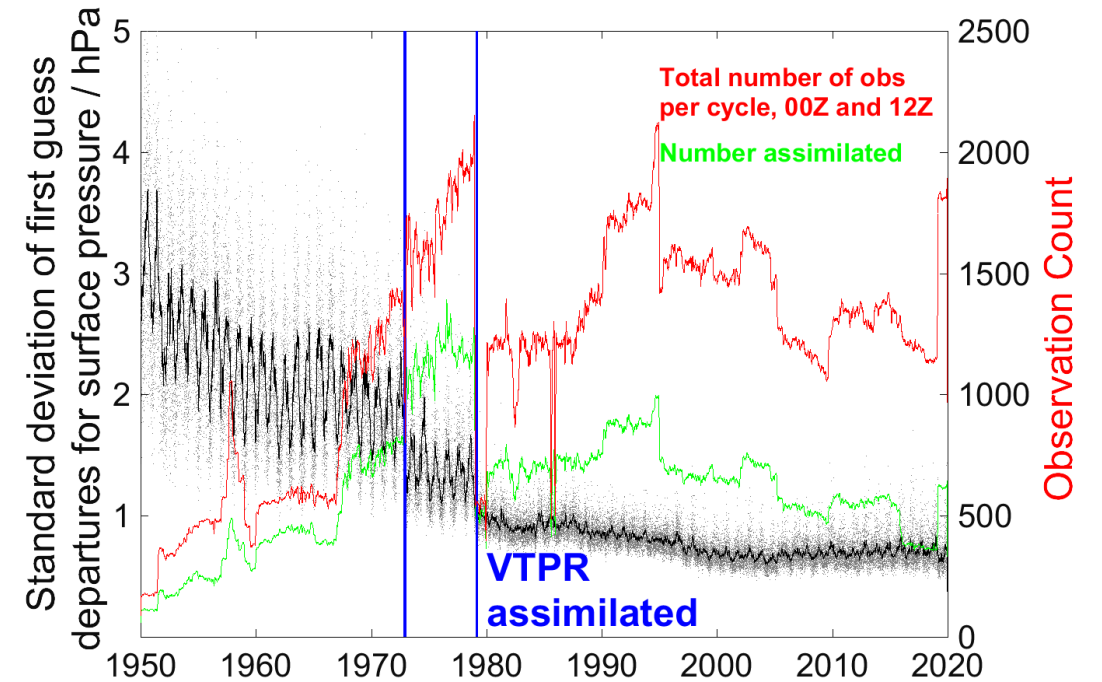
Impact of sounding data in ERA5

Ensemble of Data Assimilations (EDA) analysis spread



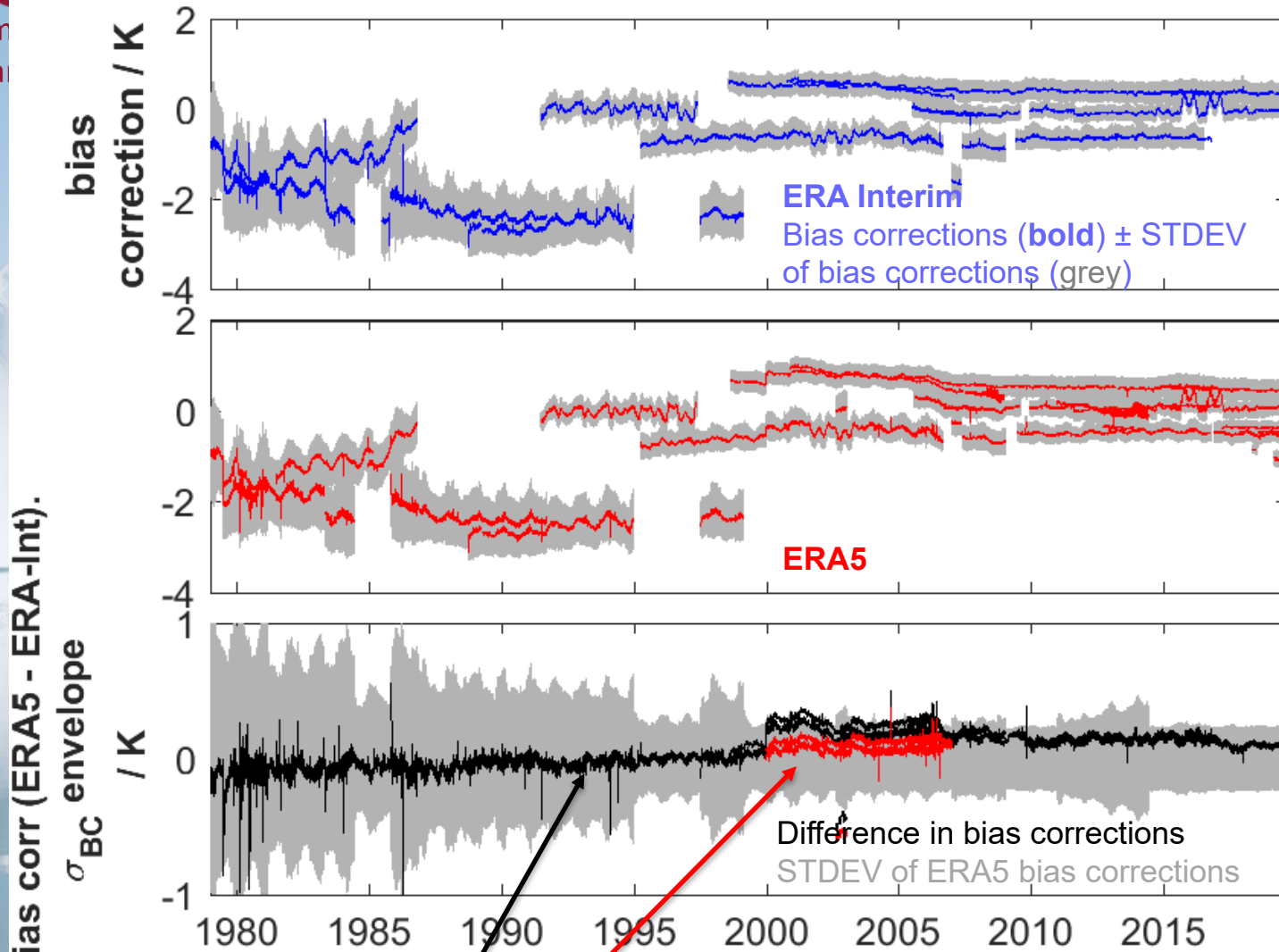
Impact of VTPR

Background fits to surface pressure observations 1950-2020 Southern Hemisphere





MSU-3 / AMSU-A7 / ATMS-8 Bias Corrections



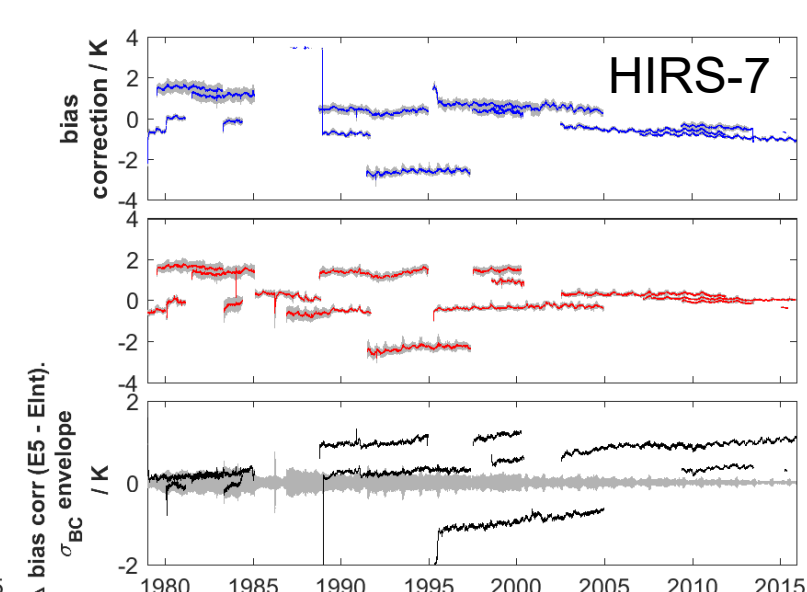
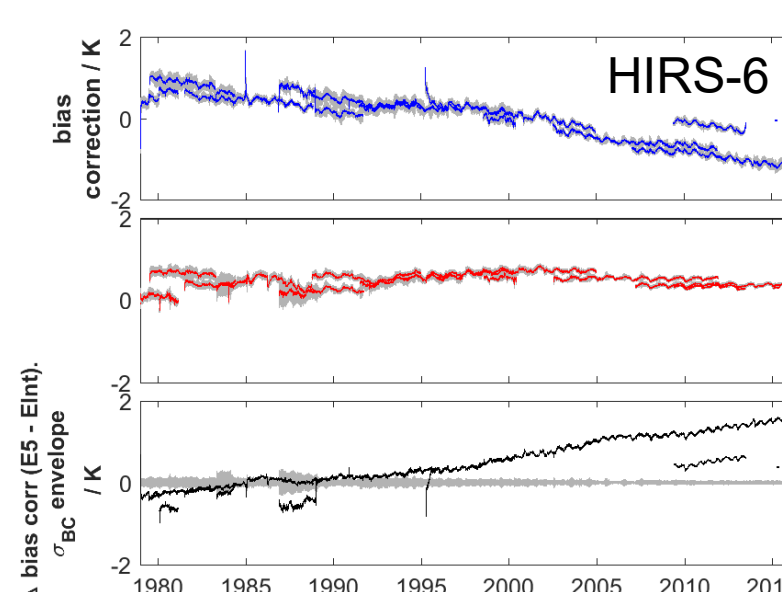
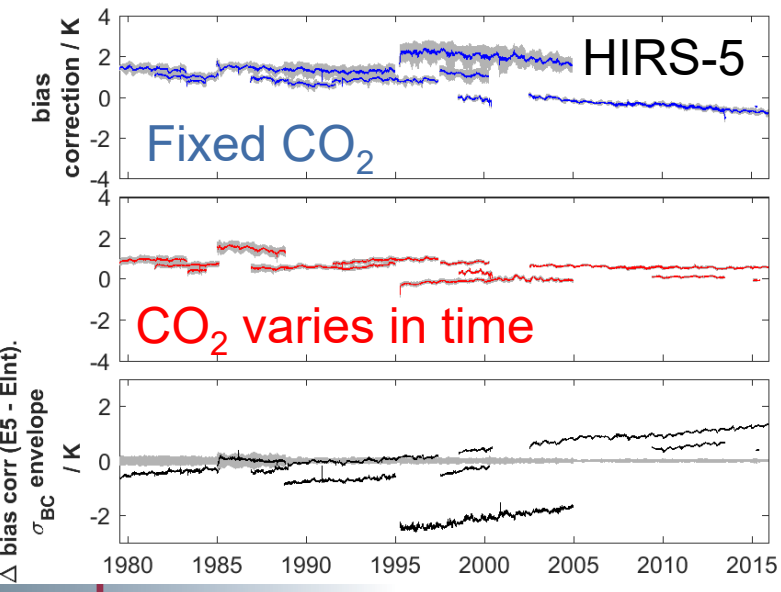
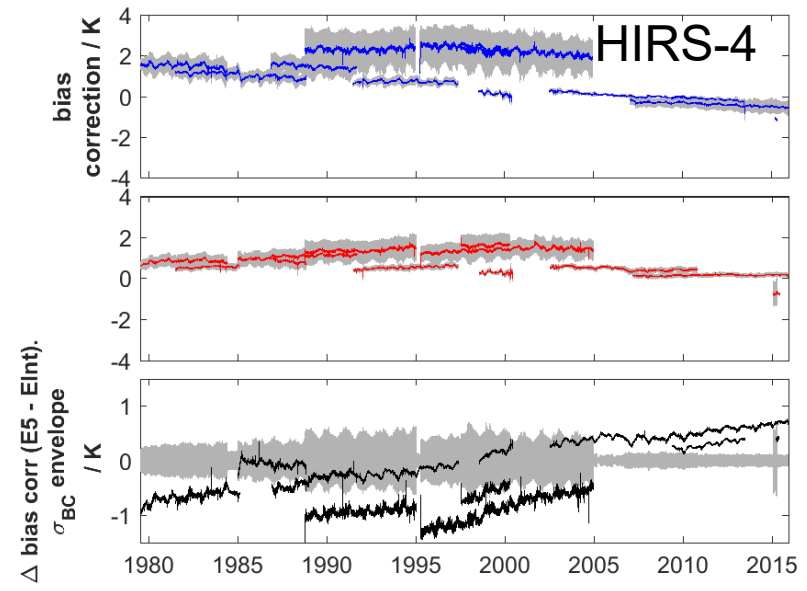
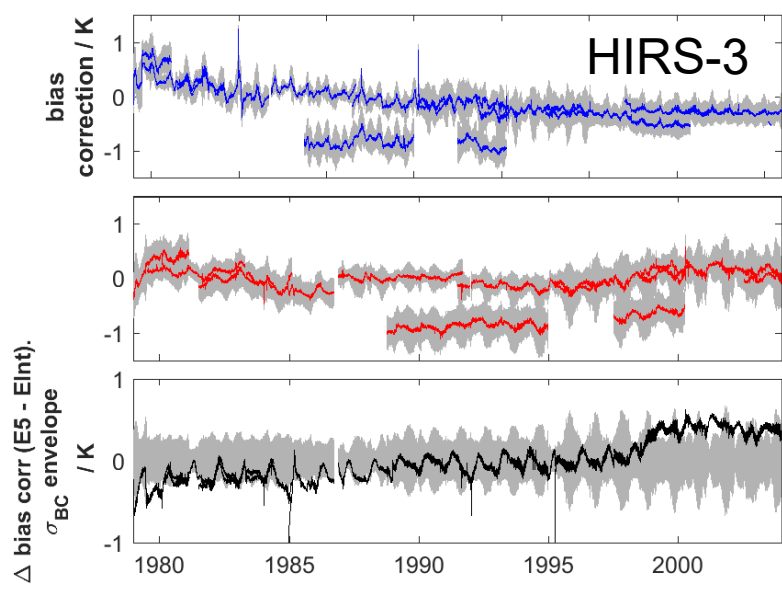
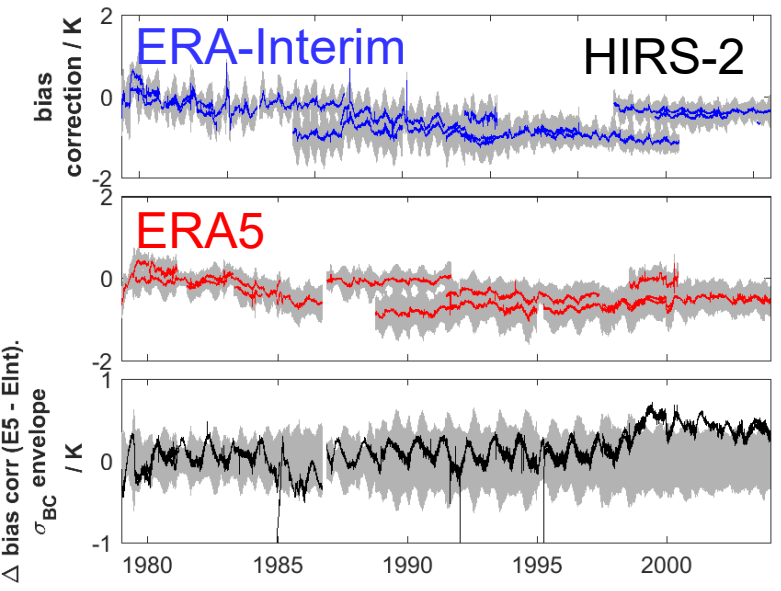
ERA5 – ERA Interim
ERA5.1 – ERA Interim

MSU-3 / AMSU-A7 / ATMS-8
(54.96 / 54.94 / 54.94 GHz) - w.fn. peak at 270 hPa

- Improvements MSU -> AMSU-A -> ATMS
- Little change from ERA-Interim to ERA5
- Suggests model bias and RT related biases are less significant than instrument biases
- MSU & AMSU-A possible mechanisms identified:
 - Radiometer non-linearities. Zou *et al* (JTECH, 2010)
 - Spectral shifts. Zou *et al* (JGR, 2011), Lu and Bell (JTECH, 2013)
- But disappointing results in NWP testing so far (for AMSU-A, Lupu *et al*, ECMWF TM 770, 2016)
- Further work planned in C3S in COP2 (2021-2027)



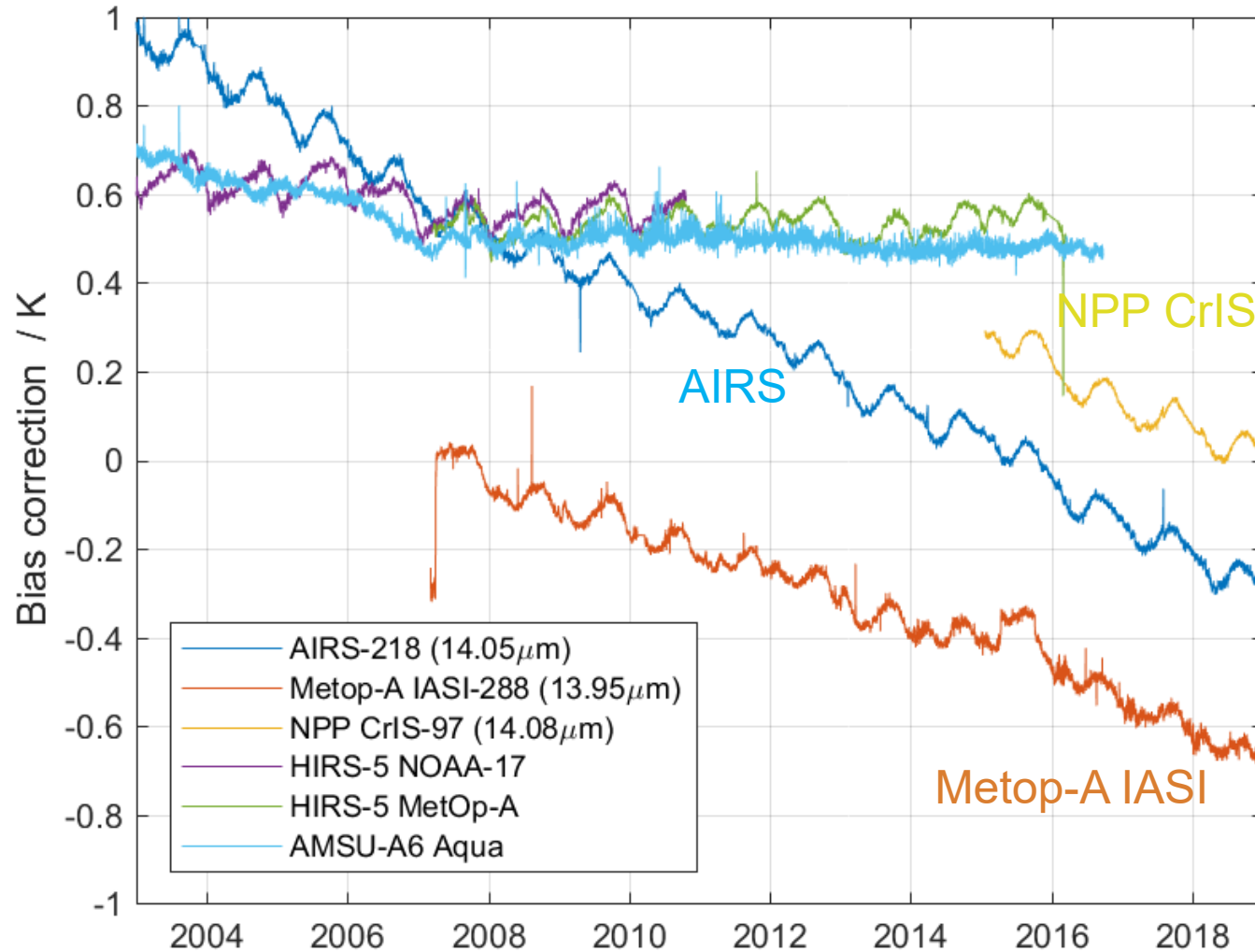
Improvements in RT modelling: HIRS Temperature Sounding Channels 2 - 7



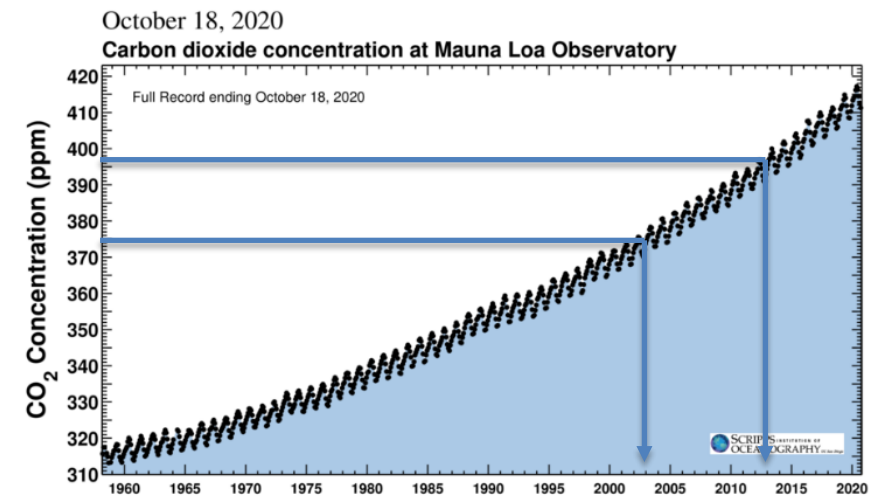


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Improvements in RT modelling: bias corrections for Adv. IR Sounders in ERA5



- AIRS, IASI and CrIS channels shown at $\sim 14\mu\text{m}$ ($710 - 717\text{ cm}^{-1}$) & peak in the range 430 - 480 hPa
- AIRS & IASI: assume $[\text{CO}_2] = 376\text{ ppm}$
CrIS assumes $[\text{CO}_2] = 396\text{ ppm}$
- HIRS (& SSU & VTPR): assume time varying $[\text{CO}_2]$





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Evaluation of reprocessed radiances

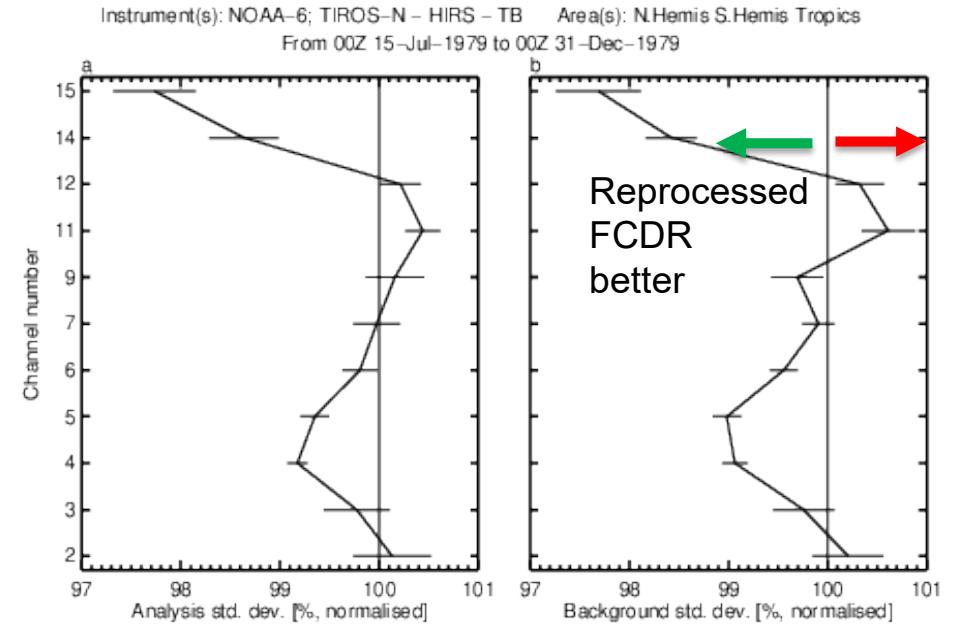
During 2016-2021 EUMETSAT developed reprocessed FCDR radiances:

- **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)

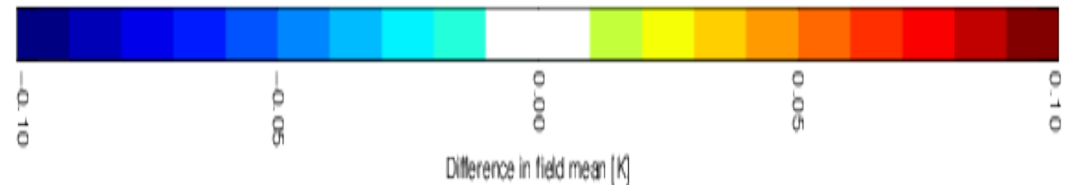
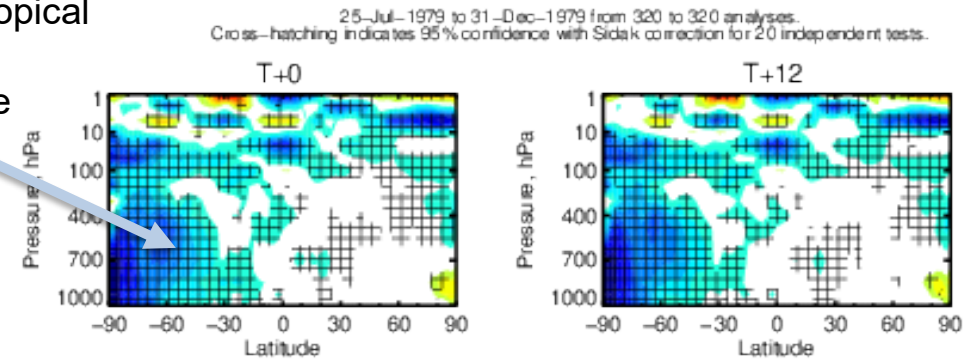
✓ Currently being assessed at ECMWF, prior to ERA6.

So far:

- Forecast impacts close to neutral
- Data quality generally improved
- Fits to independent obs neutral or better
- Impacts on analysis mean state non-zero



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





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EUMETSAT contribution to C3S 2021-2027

For ERA6

■	HIRS: infrared soundings (1978-2021)		130
■	SSMT: microwave soundings (1991-2005)		25
3	SSMIS: microwave soundings (2003-2021): addressing T/q sounding channels		>30
■	Japanese GEO radiances (1978-2015): assimilation readiness		

For European and Arctic high-resolution reanalyses

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

For early satellite era

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

Uncertainty-characterised MW FCDR

■	MSU: microwave soundings (1978-2006)	55
■	AMSU-A: microwave soundings (1998-2021) Both reprocessings to include NEDT	100
4	(A)MSU uncertainty assessment towards FIDUCEO	
■	ATMS: microwave soundings (2011-2021)	
4	FIDUCEO-type analysis, all channels	14

■ Baseline ■ Option #

Close collaboration

■ Some uncertainty of realization, related to availability and quality of the sensor data

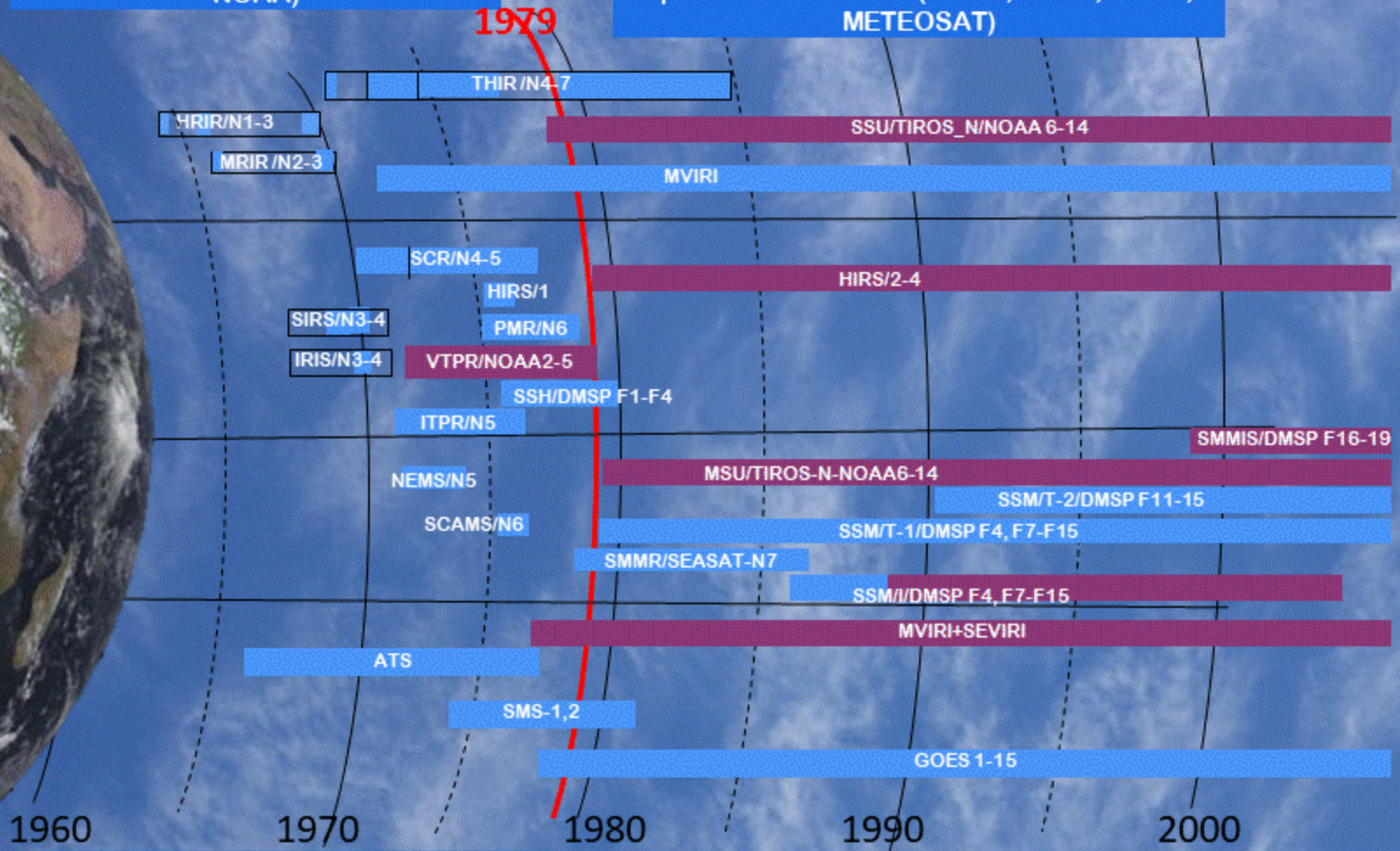
XX Satellite-years expected in deliverable (F)CDR



Early Satellite Data Rescue (pre-2000)

EARLY SATELLITE ERA (pre-1979)
 Research satellites (NIMBUS 1-7, NOAA)

MODERN ERA (1979-2000)
 operational Satellites (NOAA, DMSP, GOES, METEOSAT)



Data Recovery: reading bands, storing in modern format

Reprocessing (recalibration, navigation, ...), Quality assessment

Infrared Imagers

Infrared Sounders

Microwave Sounders/
Imagers

Atmospheric
Motion Vector

Legend:

Data not yet assimilated

Data assimilated in ERA5



Plans for satellite sounding data rescue 2021-2025

Sensor	Task					
	2 Data provision	3 Quality assessment	4 RT modelling	5 Quality control	6 Uncertainty assessment	7 Bias modelling
Early infrared sensors						
PMR [1]						
IRIS [2]						
VTPR [3]						
HRIR* [4]						
THIR* [5]						
MRIR [6]						
SIRS [7]						
SSH	EUMETSAT	EUMETSAT	✓	EUMETSAT	EUMETSAT	EUMETSAT
SI-1	EUMETSAT	EUMETSAT	✓	EUMETSAT	EUMETSAT	EUMETSAT
SCR	✓	✓	✓	✓	✓	✓
Early microwave sensors						
SMMR	CM SAF	CM SAF	✓	EUMETSAT	EUMETSAT	EUMETSAT
SMM/T	EUMETSAT	EUMETSAT	✓	EUMETSAT	EUMETSAT	EUMETSAT
SSM/T-2	EUMETSAT	EUMETSAT	✓	EUMETSAT	EUMETSAT	EUMETSAT
NEMS	✓	✓	✓	✓	✓	✓
SCAMS	✓					✓
ESMR N5	✓	✓	✓	✓	✓	✓
Reprocessed radiance data						
HIRS-1, 2, 3, 4	EUMETSAT	EUMETSAT	✓	EUMETSAT	EUMETSAT	EUMETSAT
SSU [8]						
SSMIS [9]		EUMETSAT	✓	EUMETSAT		EUMETSAT
MSU*	EUMETSAT	EUMETSAT	✓	EUMETSAT	EUMETSAT	✓

Completed 2019-2021:
assimilation experiments
planned 2021-2023

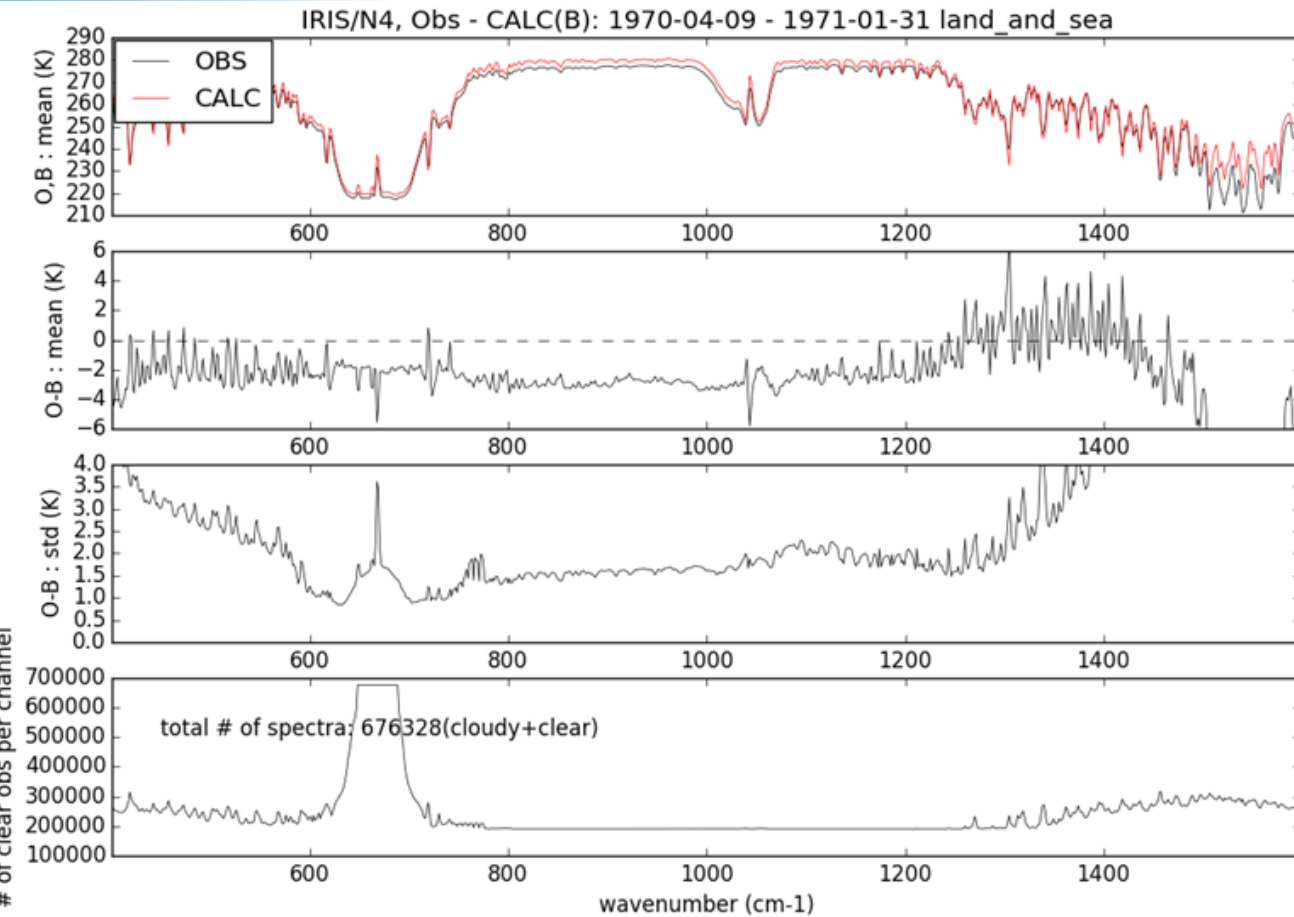
New work planned 2021-2024

- Includes data recovery and reformatting to NetCDF & archiving at ICARE server
- Quality assessment uses NWPSAF RadSim & ERA5 to compute analysis departures (as well as collocation approaches)
- Bias modelling assesses effectiveness of current bias models used in VarBC

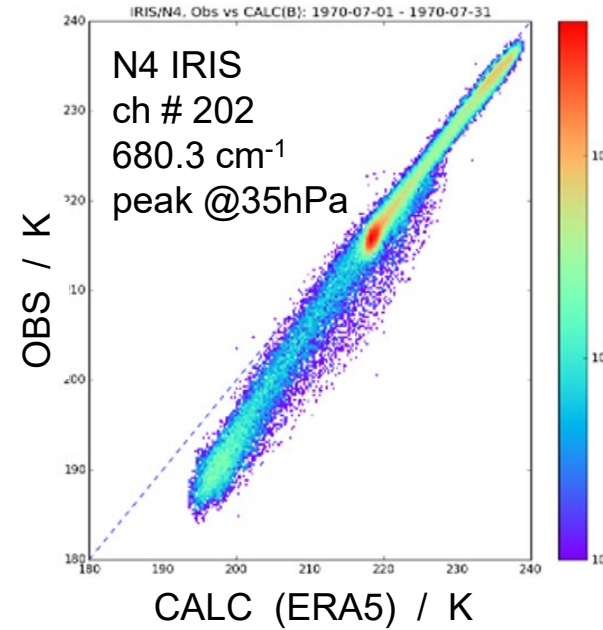


Example: Nimbus-4 IRIS

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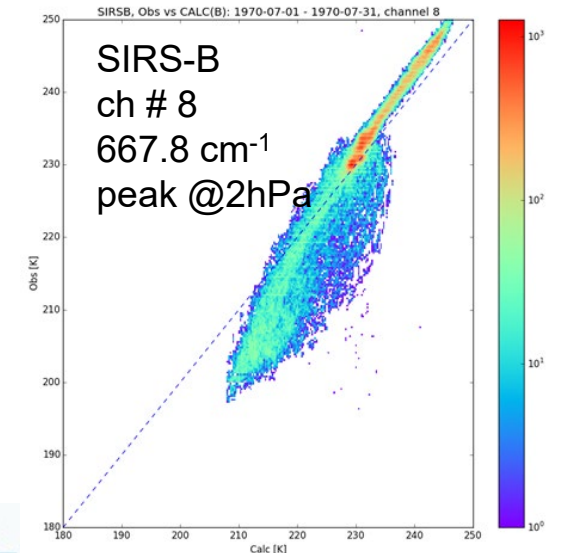
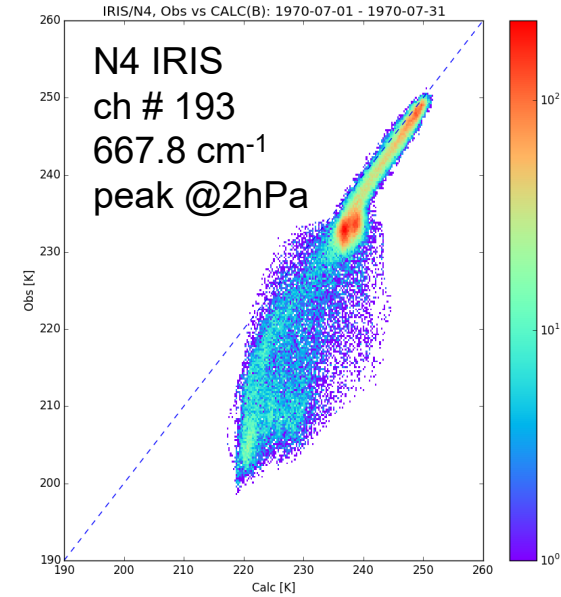


- IRIS spectra of good quality
- Obs - Calc STDEV ~ 1K at 700 cm-1



Rescued obs are highlighting potential issues in ERA5 in southern polar night - analysed temperatures too high

Effect seen in both IRIS and SIRS





Summary

- The ERA5 global reanalysis now covers 1950-present & is publicly available
- Trends from ERA5 are in good agreement with other reanalyses and with observational data (T2m)
- Early sounding data (VTPR) improves the quality of the reanalysis in the early period, 1973-1978
- Preparations are underway for ERA6, due to start 2024, which will include:
 - Assimilation of reprocessed data provided by EUMETSAT during 2016-2021 & 2021-2025 (radiances, but also AMVs, RO and SCAT data)
 - Assimilation of early satellite data rescued as part of phases 1 & 2 of the Copernicus Climate Change Service, 2019-2025 (C3S)



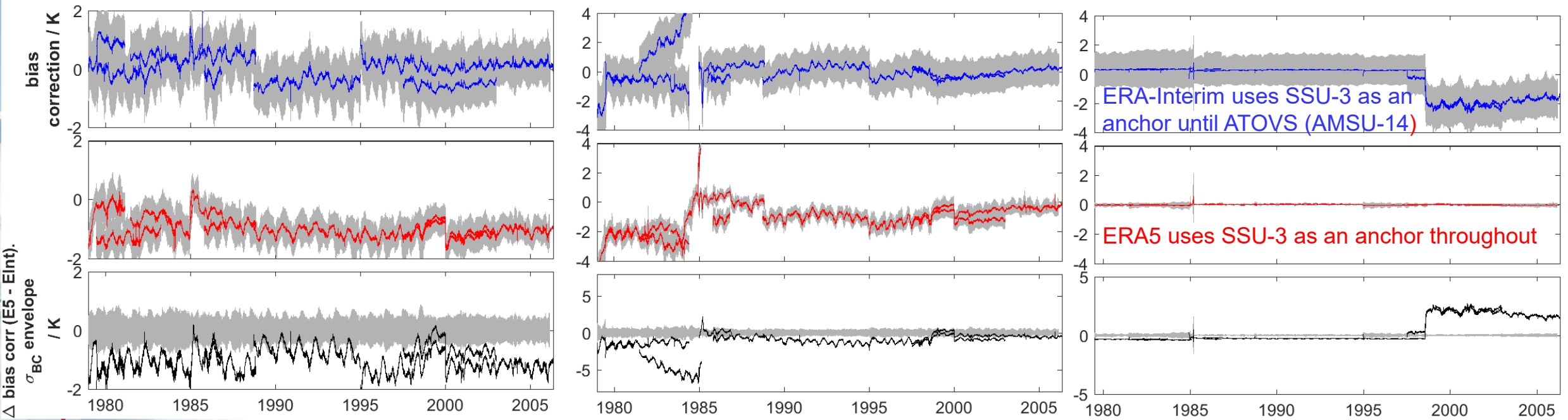
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Improved RT modelling : SSU Bias Corrections

SSU-1
peak 29km

SSU-2
peak 38km

SSU-3
Peak 44 km



Improved treatment of RT (cell pressure leaks) in ERA5:

- Reduced inter-satellite biases
- Reduced variance in bias corrections
- Reduced drift in biases (NOAA-7 during 1982-1985)
- Much improved wrt ERA0-Int – but transition period around 1985 remains a problem