



Climate Change

The Assimilation of Radiance Data in the ERA5 Global Reanalysis

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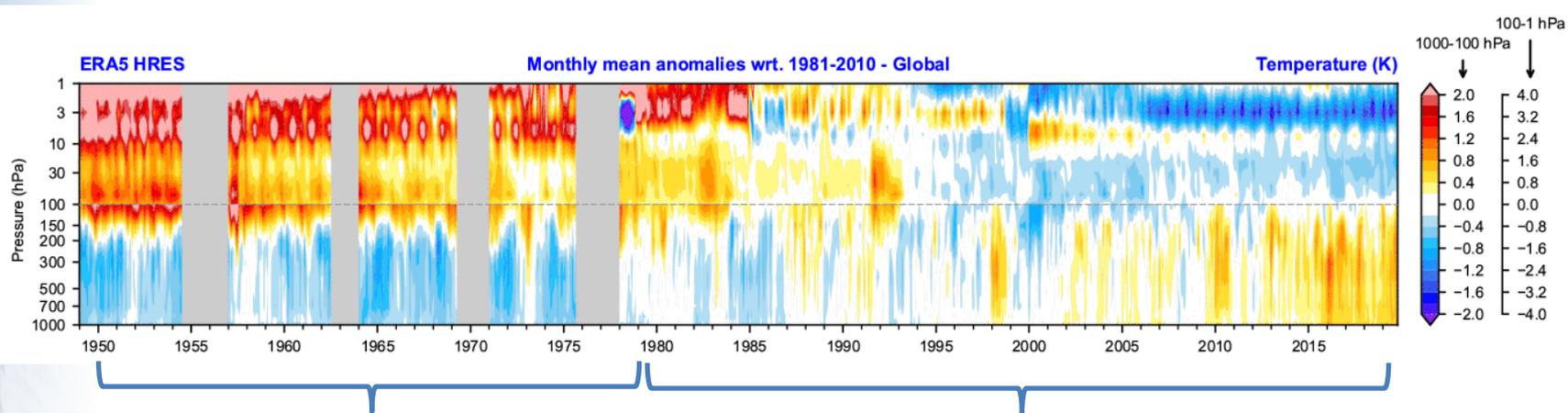
Overview

- The ERA5 global reanalysis
- Assimilating Vertical Temperature Profiling Radiometer (VTPR) radiance data
- Bias corrections in ERA5
- Summary & future perspectives



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ERA5 Production Status



1950 – 1979

due to complete Q1 2020

1979 – present

Complete. NRT stream runs RT – 1 day

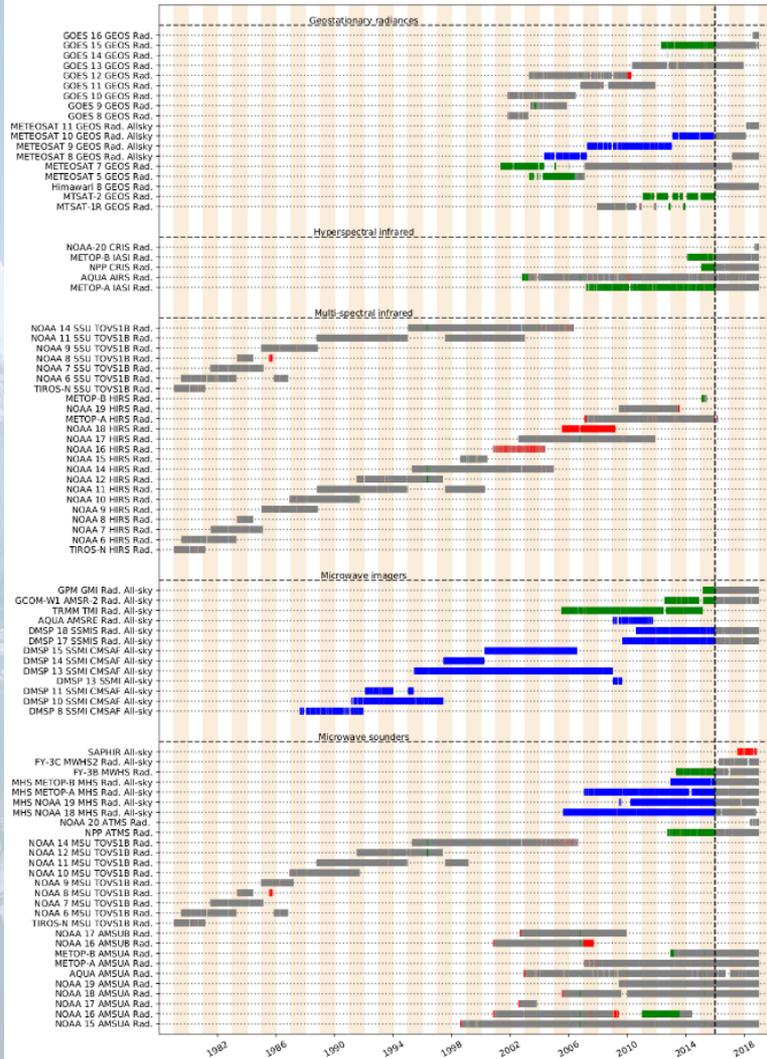
Improvements relative to ERA-Interim:

- 10 years of ECMWF model development (2006 to 2016)
- Resolution; **31km** versus 80km
- More, and better, input data
- Hourly output
- 10-member EDA-based uncertainty estimate (at 63km)
 - Perturbations to: SST, model tendencies & obs





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Radiance observations assimilated in ERA5 (1979-2018)

Reprocessed data, or significant change in processing since ERA-Int

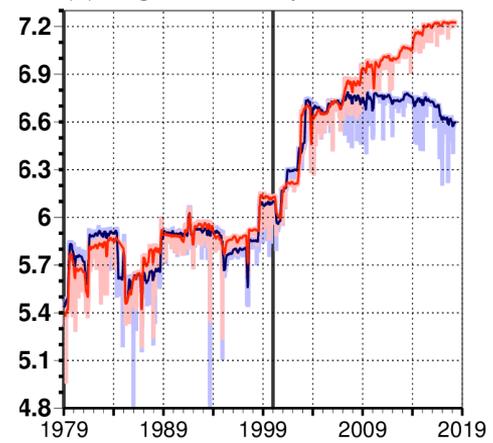
Same as ERA-Int

Not used in ERA5, but used in ERA-Int

Not used in ERA-Int, but used in ERA5

Number of used observations per day (log₁₀ scale) for **ERA5** and **ERA-Interim**

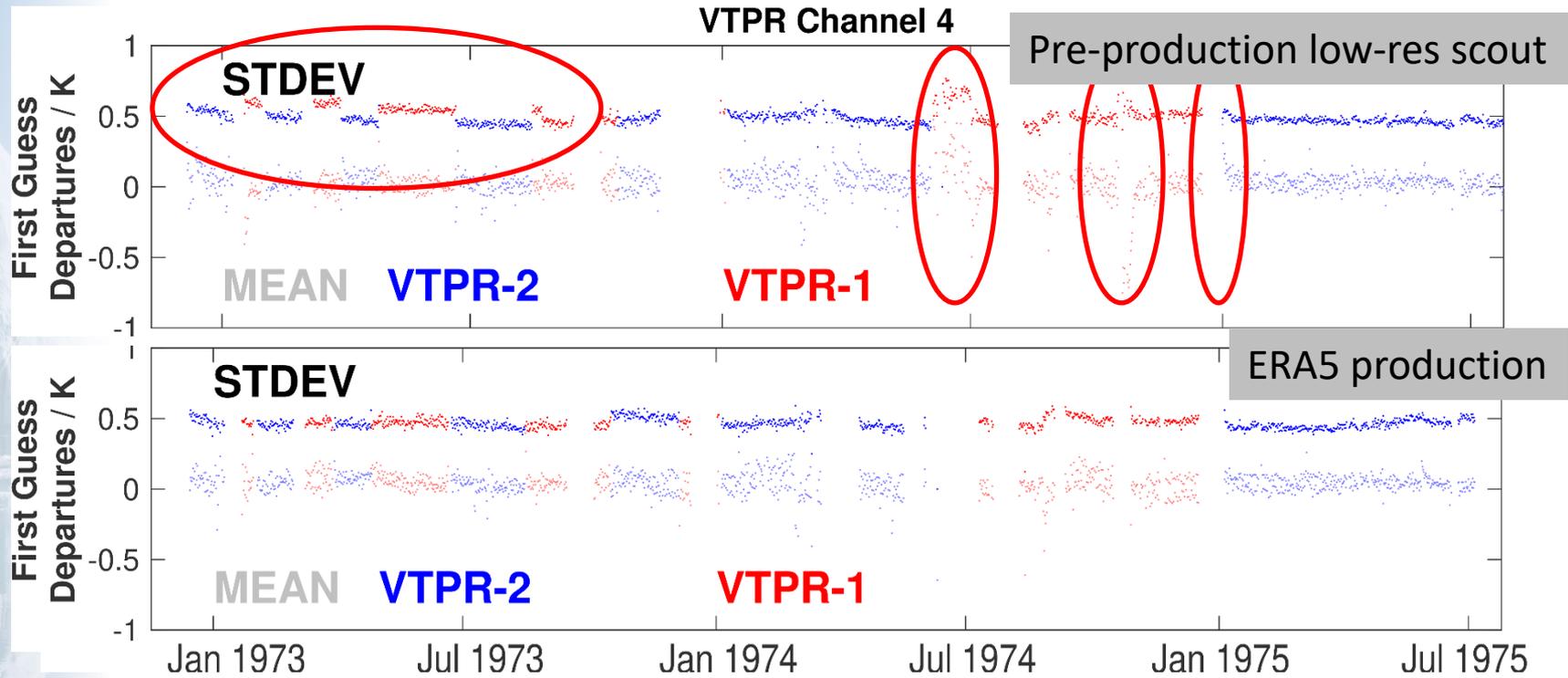
(a) Brightness Temperature





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VTPR (1972 - 1979) in ERA5



Relative to ERA-40

- New cloud detection scheme
- RT coefficient optimisation
- Blacklisting periods of degraded data quality
- Observation error tuning (Desroziers , reduced obs errors)

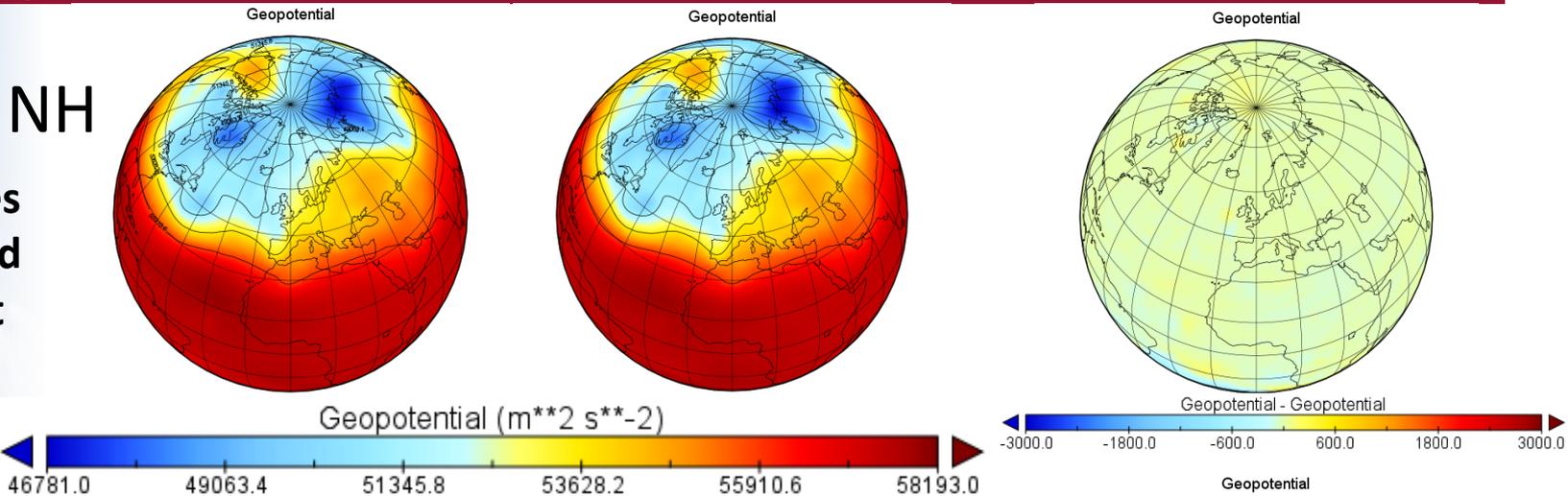




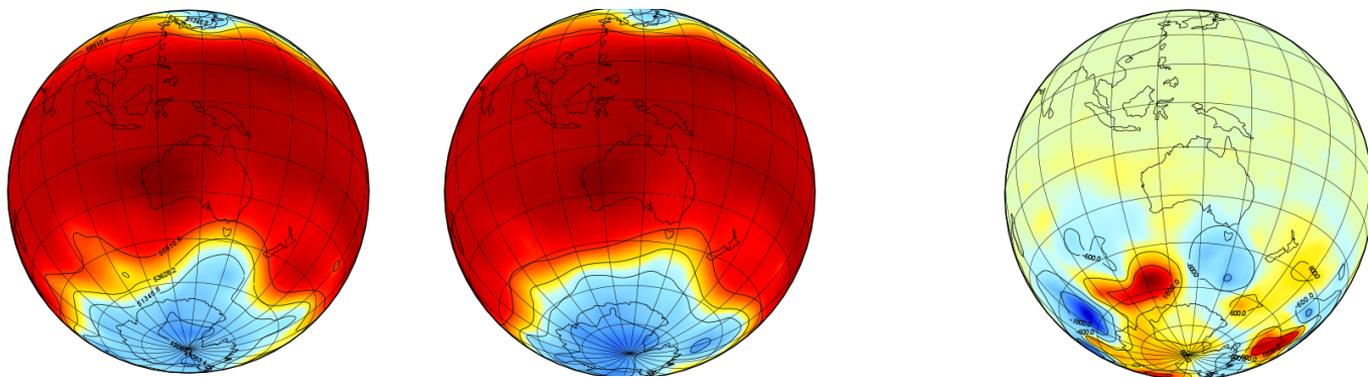
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Impact of VTPR assimilation SH/NH

NH
Analyses with and without VTPR



SH



VTPR assimilated

VTPR not assimilated

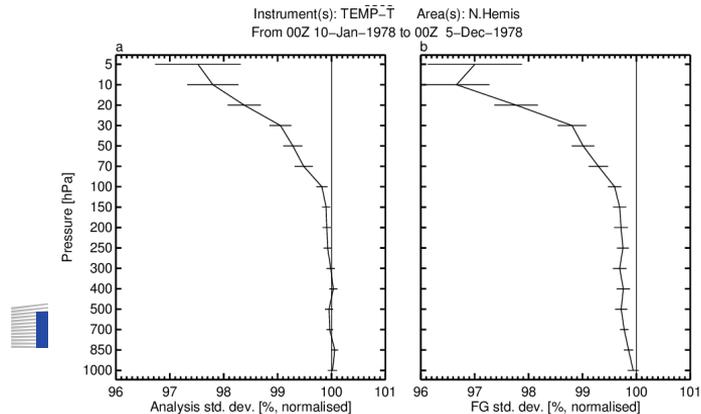
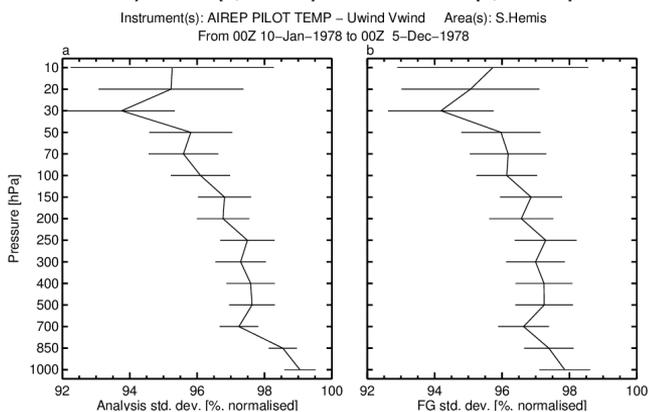
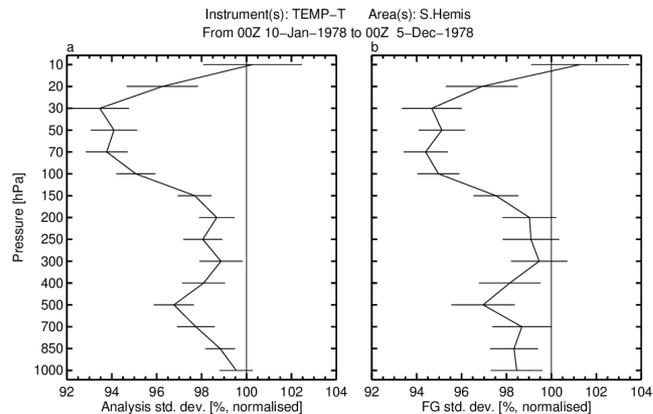
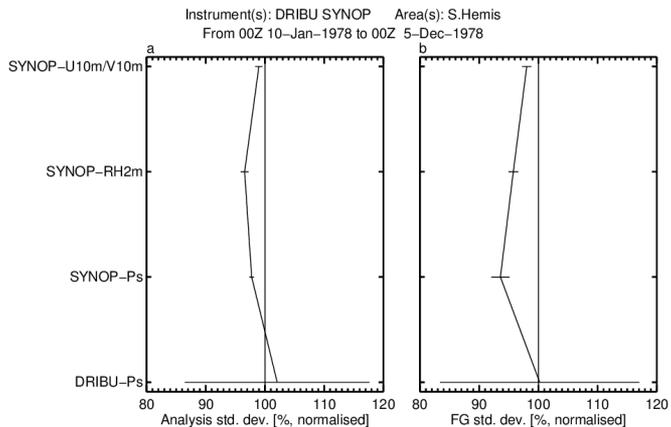
Difference in geopotential



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Impact of VTPR in ERA5: background and analysis fits

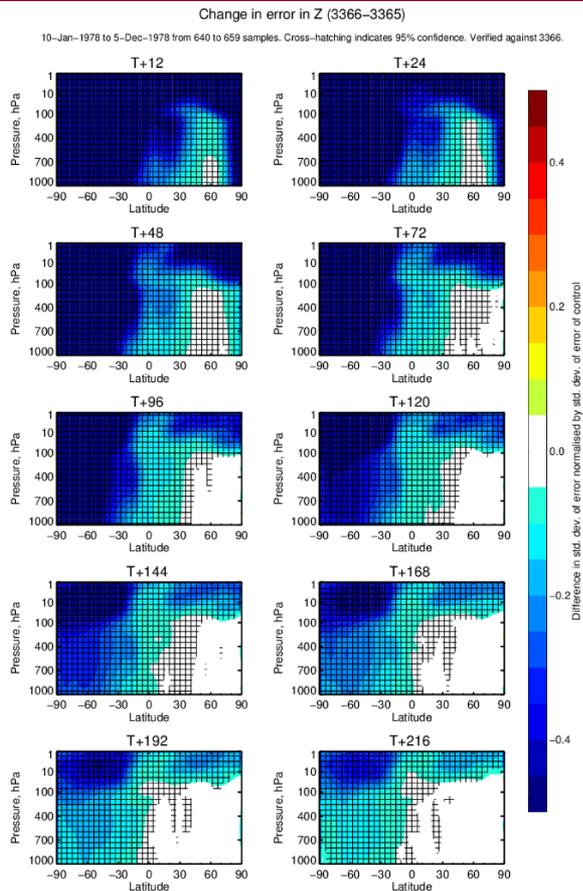
VTPR in vs out





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Impact of VTPR in ERA5: Forecast impact versus control with no VTPR



11 months of verification
(verified against analysis with VTPR assimilated)

Consistent with change in background fits to
independent observations:

- SH improved surface -> stratosphere
- NH improved in the stratosphere

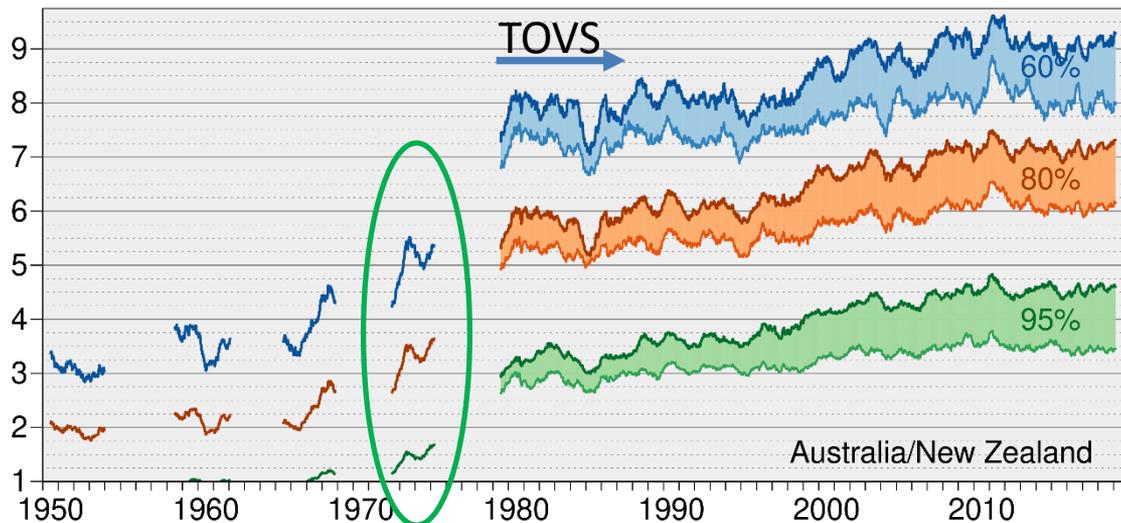


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Performance of ERA5 Reforecasts

Range (days) when 365-day mean 500hPa height AC (%) falls below threshold

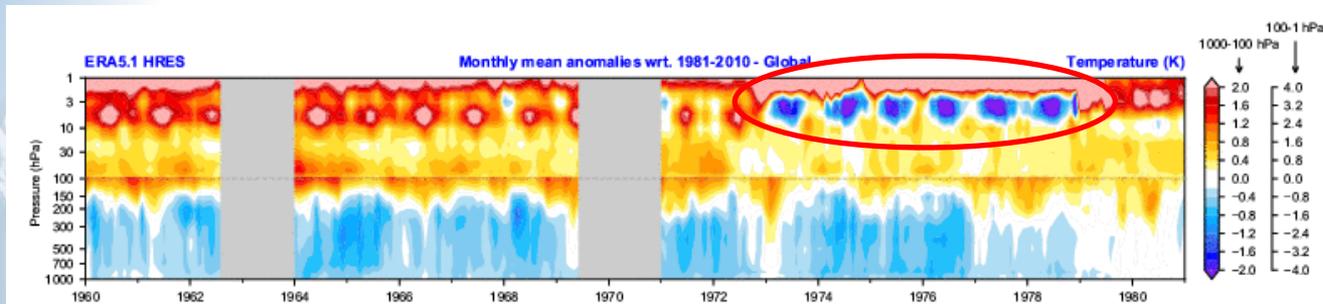
— ERA-Interim — ERA5



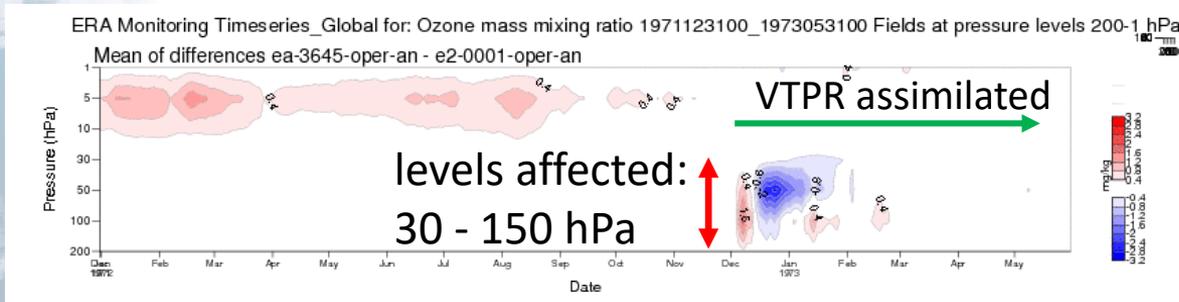


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Challenges



Large temperature anomalies 3-10hPa.
 Due to B_{CLIM} - solved in final production.

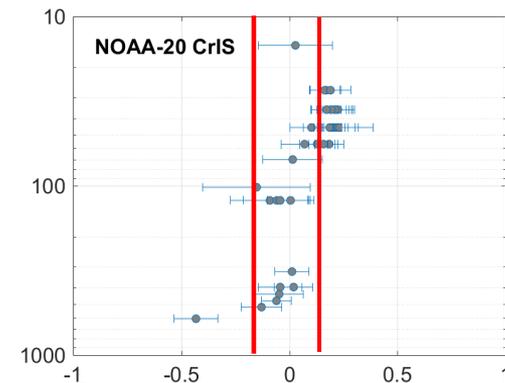
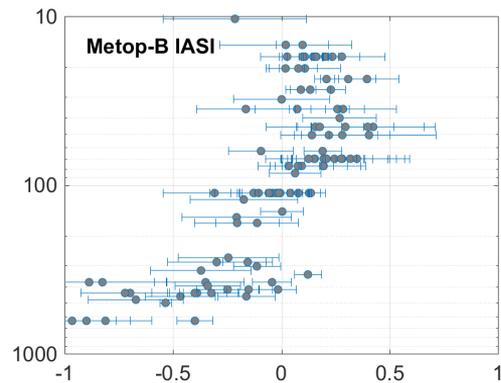
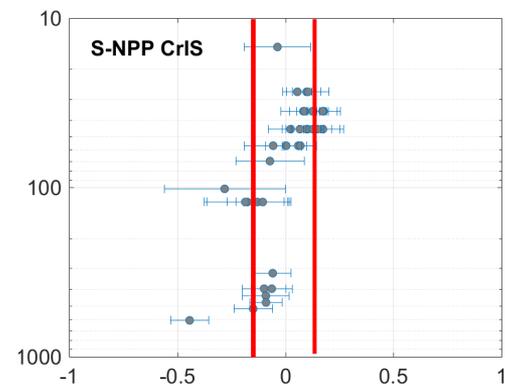
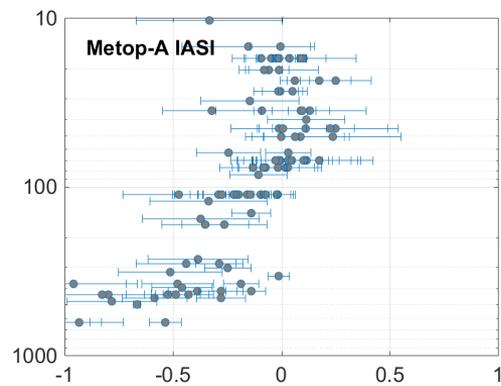
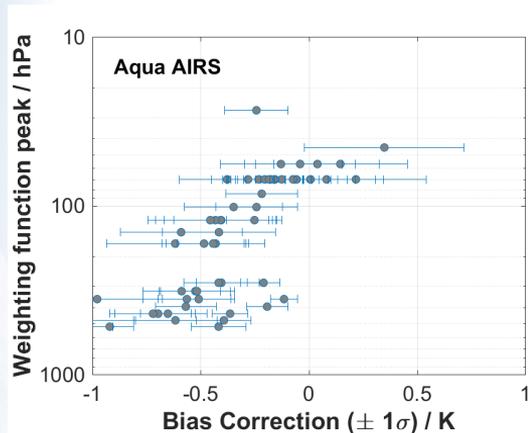


Anomalies in O_3 .
 Due to O_3 sensitivity of T-sounding chans of VTPR, lack of other O_3 obs, and large B . Solved in final production.



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ERA5 Bias corrections



- Metop-A IASI \sim Metop-B IASI
& S-NPP CrIS \sim NOAA-20 CrIS
- Radiometric uncertainties for CrIS shown (0.14K at 3σ)

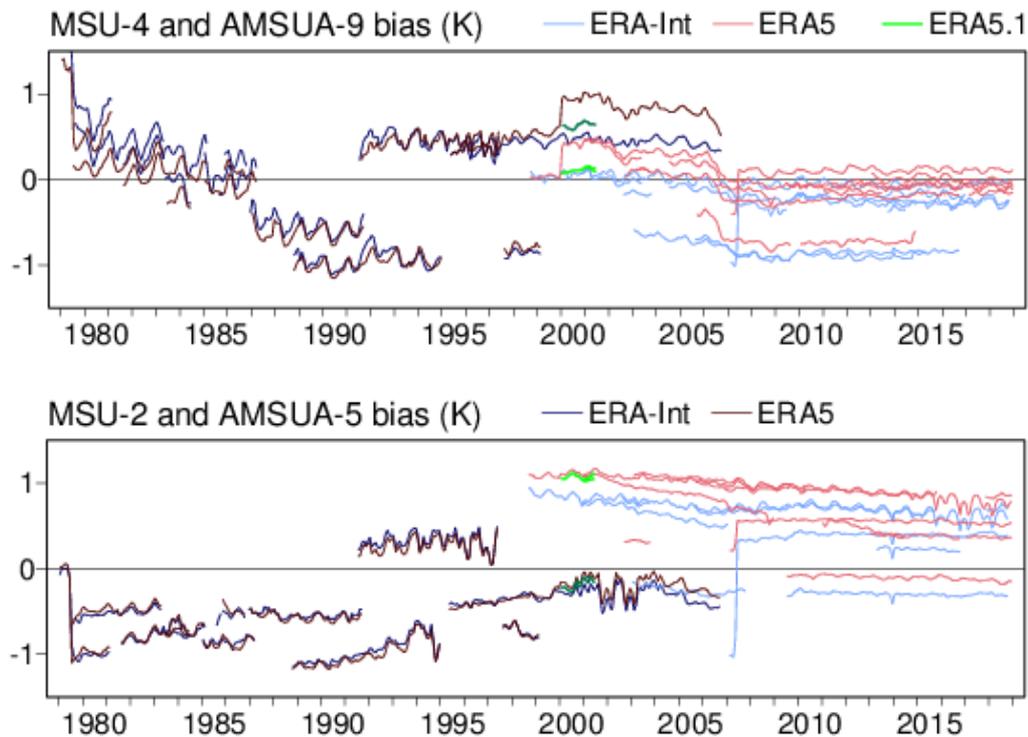
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Bias corrections for microwave sensors



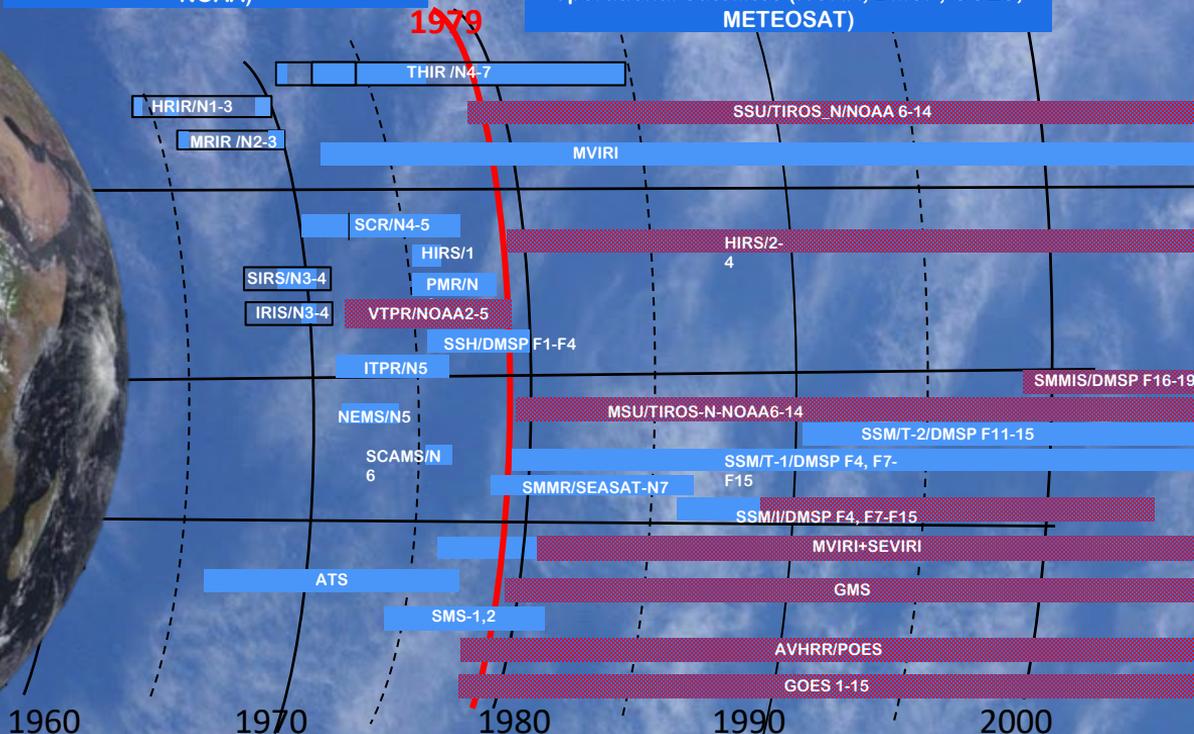
European
Commission



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)



Infrared Imagers

Infrared Sounders

Microwave Sounders/
Imagers

Atmospheric
Motion Vector

Data Recovery: reading bands,
 storing in modern format

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

Legend:

Data not yet assimilated

Data assimilated in ERA5





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Summary, and future perspectives

- **ERA5 is currently in production**, 1979 - present is complete, and 1950-1979 will be complete Q1 2020. ERA5 performs well wrt ERA-Interim (for which production has now stopped)
- **ERA5 assimilates satellite data from VTPR (1972-1979)**, this required some development work, including:
 - A new cloud detection scheme
 - careful blacklisting
 - observation error tuning
 - RT coefficient tuning
- **VTPR significantly improves the analysis**, esp. in the SH.
- **CrIS bias corrections are bounded by radiometric uncertainties**. 'Benchmarking' in future reanalyses ?
- **C3S supports data rescue and reprocessing** and we expect to use many new & improved datasets in the next global reanalysis (ERA6, 2023)





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More information

The ERA5 Global Reanalysis

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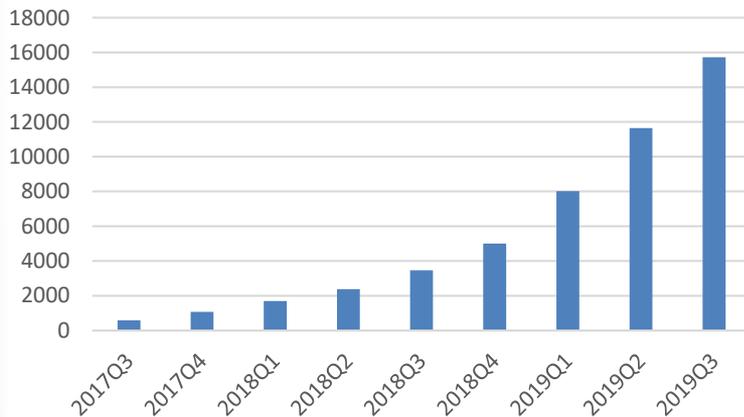
³ The Norwegian Meteorological Institute, Oslo, Norway

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- Submitted September 2019 to QJRMS
- In the meantime, see: Hersbach *et al* 2018, *Operational global reanalysis: progress, future directions and synergies with NWP*
<https://www.ecmwf.int/en/publications/>

C3S ERA5: total number of users



For ERA5 data from the C3S
Climate Data Store:

<https://cds.climate.copernicus.eu>





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Extra Slides

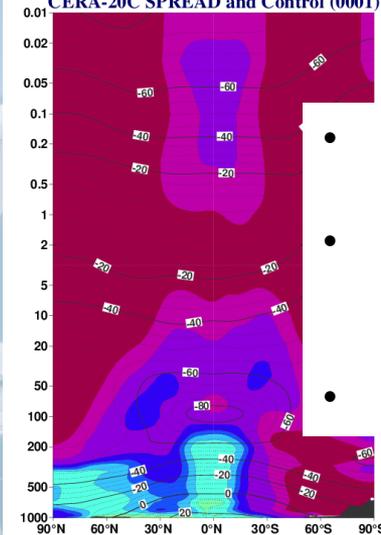




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Ensemble spread (temperature)

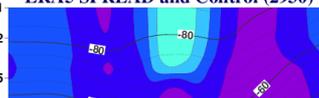
Temperature (Celsius) in MAM 1971
CERA-20C SPREAD and Control (0001)



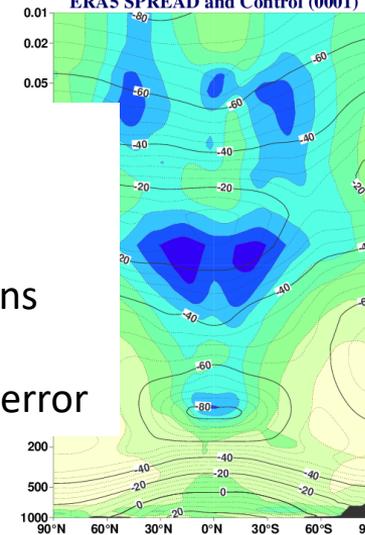
Temperature (Celsius) in MAM 1971
ERA5 SPREAD and Control (3580)



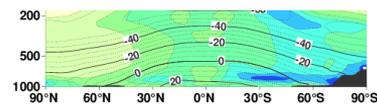
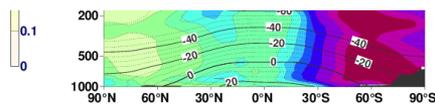
Temperature (Celsius) in MAM 1980
ERA5 SPREAD and Control (2930)



Temperature (Celsius) in MAM 2018
ERA5 SPREAD and Control (0001)



- Application of GUM terminology to analyses is *inexact*
- Ensemble spread is analogous to stdev of measurements obtained under *reproducibility* conditions
- Doesn't (fully) represent the systematic component of error



1971 CERA-20C:
Surface pressure,
marine wind, only

1971 ERA5:
Upper-air data

1980 ERA5:
Early-satellite era

2018 ERA5:
Current observing system

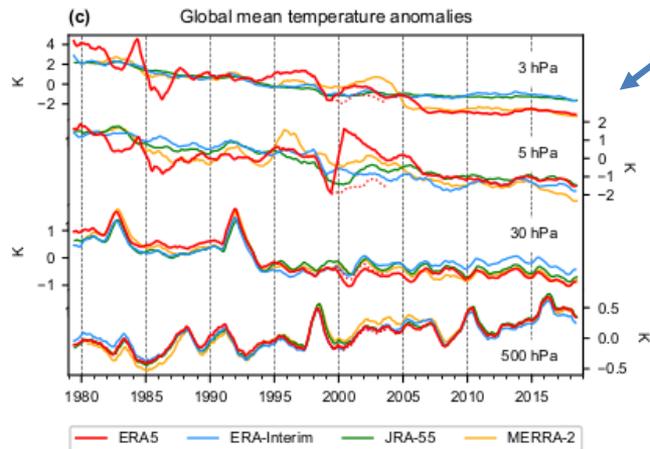
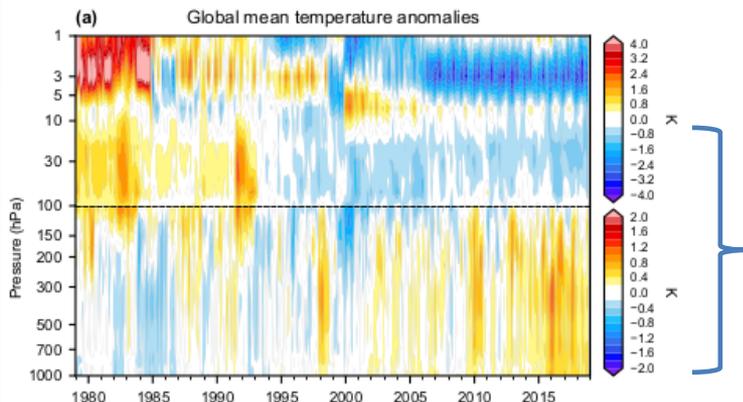




Upper air anomalies in ERA5

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Anomalies
relative
to monthly
mean
climate
1981-2010

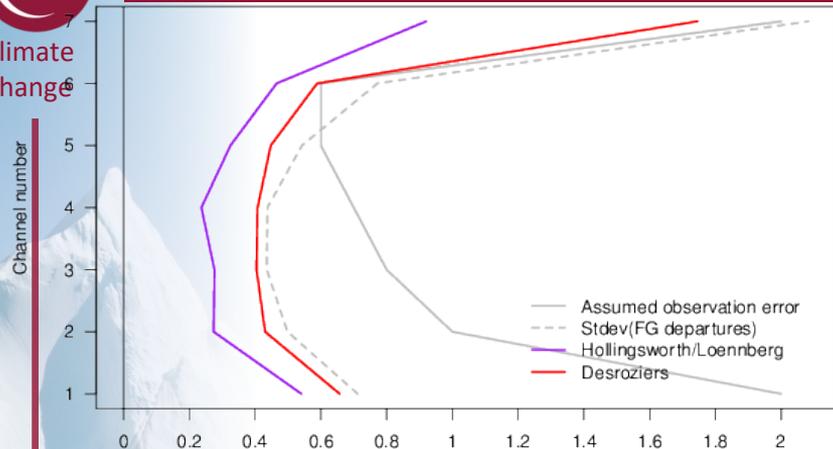


- Below 10hPa the ERA5 temperatures are relatively continuous, and ...
- in reasonable agreement with other reanalyses, but ...
- above 10hPa there are significant discontinuities until 2006 (RO), due to change in B_{CLIM} & observing system changes
- Partly solved in ERA5.1 (...)

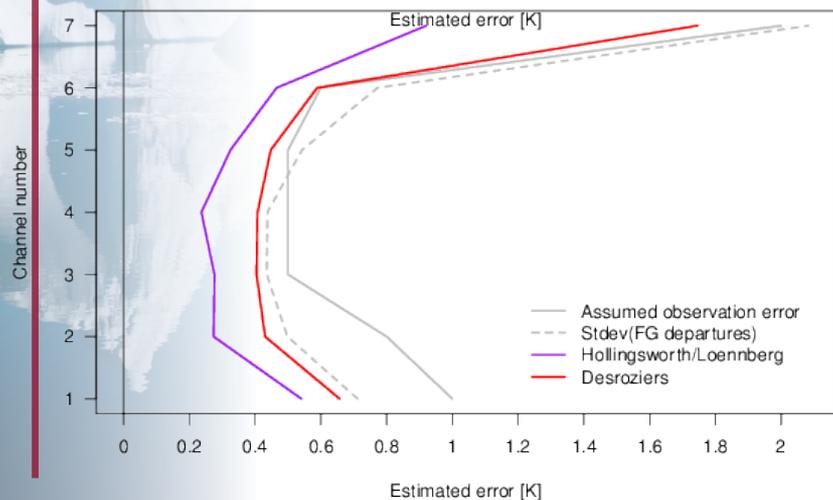


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Retuned Observation Errors for VTPR



Initial experiment (3366)

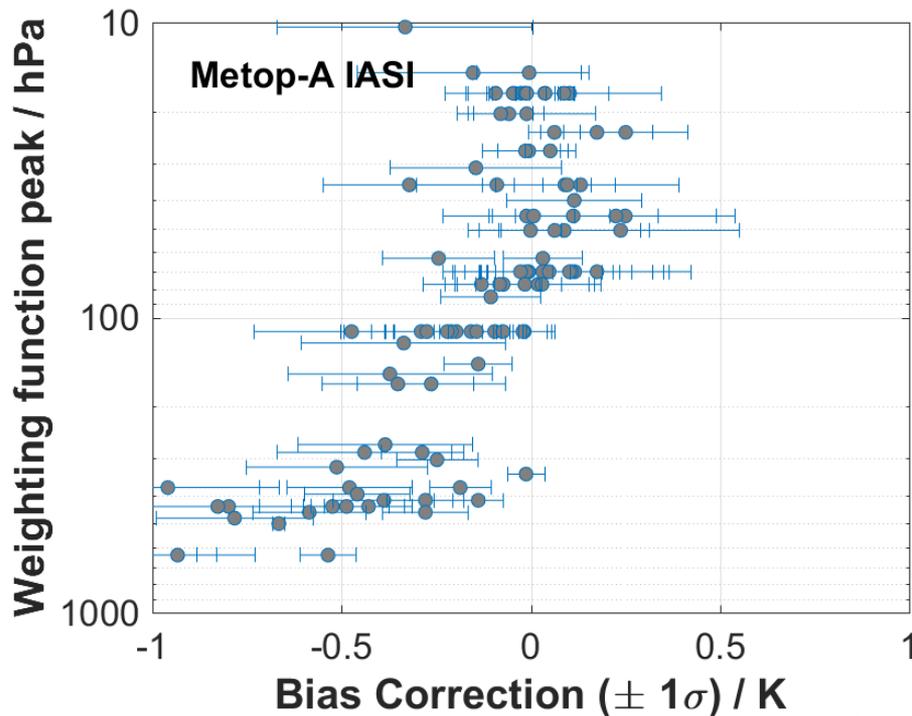


Retuned ob errors experiment (3396)



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ERA5 Bias corrections

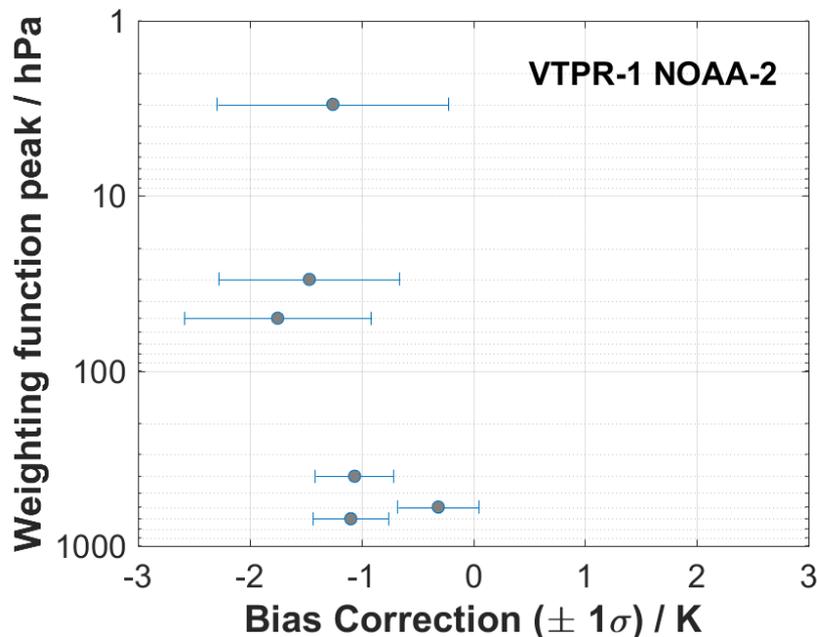


- One assimilation cycle
00Z 12/06/2019
- Temperature
sounding channels shown
($\lambda > 10\mu\text{m}$)
- Error bars represent
variation ($\pm 1\sigma$) of applied bias
corrections for all
observations assimilated



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VTPR Bias corrections (25th January 1973)



- T- sounding channels shown (CO_2 band)
- Bias corrections larger, at 1-2K typically
- Radiometric uncertainties unknown