# Preparations for ERA6: The assimilation of reprocessed and rescued radiance observations

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European Commission

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ITSC-24, Tromso

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# Preparations for ERA6: the assimilation of reprocessed and rescued radiance observations

- Preparations for ERA6 :  reprocessed & rescued satellite data
- Assimilation of IRIS hyperspectral radiances (1970)
  - SH analyses and forecasts;
  - Southern polar winter biases in the stratosphere
- Next steps:  testing weak constraint 4D-Var model error corrections using IRIS
- Summary

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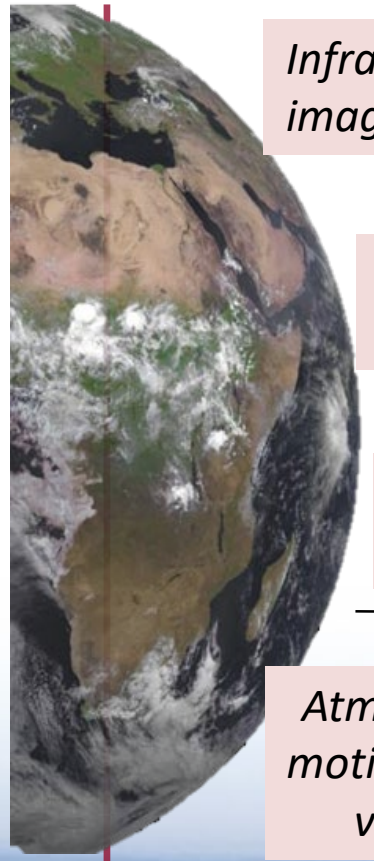
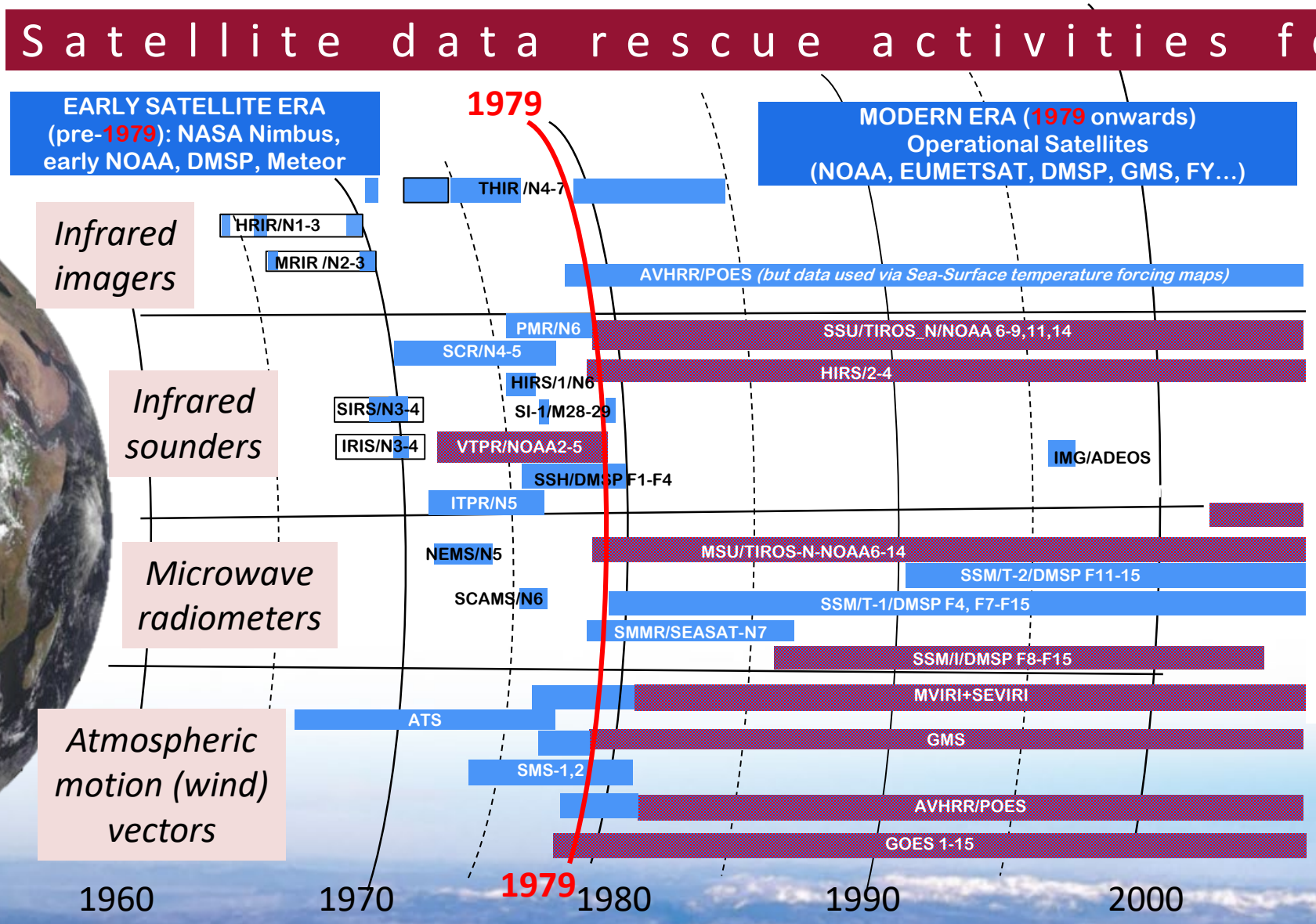
# Satellite data rescue activities for ERA6






**Preparations for ERA6 include:**

- **Reprocessing** of radiances from (post-1979) operational missions (HIRS, SSM/T, SSM/T-2, ATMS, MWHS-1/-2, MVIRI/SEVIRI, Japanese GEOs)
- **Rescue and Assessment** of radiance observation from pre-1979 sensors
- Aim is to improve the '***assimilation readiness***' of the data
- Example of the work on **Nimbus-4 IRIS** shown in the following slides
- **ERA6 (1989 or 1979 onward)** due to start mid-2024. **ERA6 (1950-1978/88)** due to start mid-2026.

*Data not yet assimilated in ERA*

*Original or earlier-reprocessed data version assimilated in ERA5*

**Data Rescue** (Spascia, C3S2_314): decoding original data, reformatting, archiving & QC

Reprocessing (EUMETSAT, C3S2_310): recalibration, navigation, quality assessment

Both activities aim to improve assimilation readiness of these datasets for ERA6 and high-resolution (regional) reanalyses, and also support ECV production

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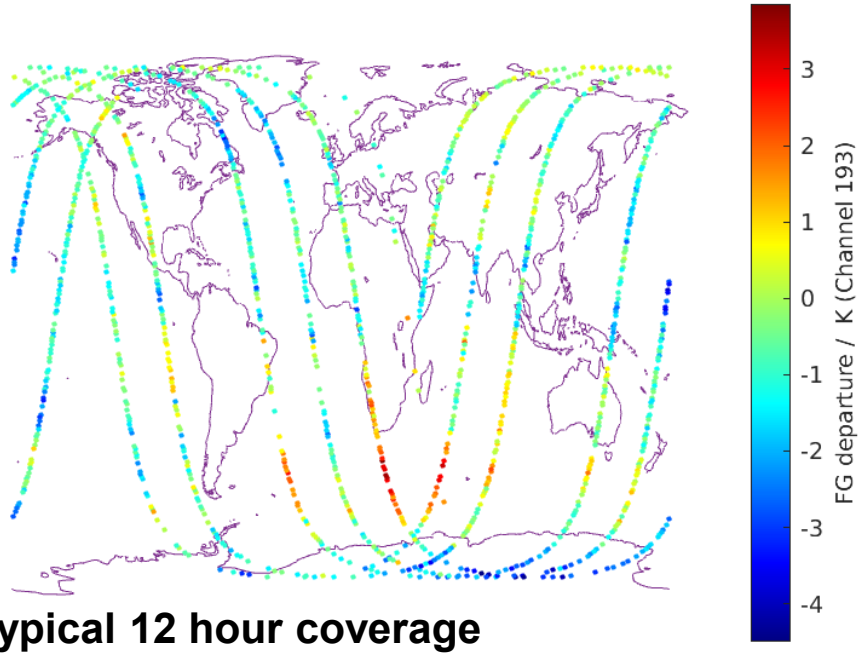
# Initial experiments assimilating IRIS in the IFS

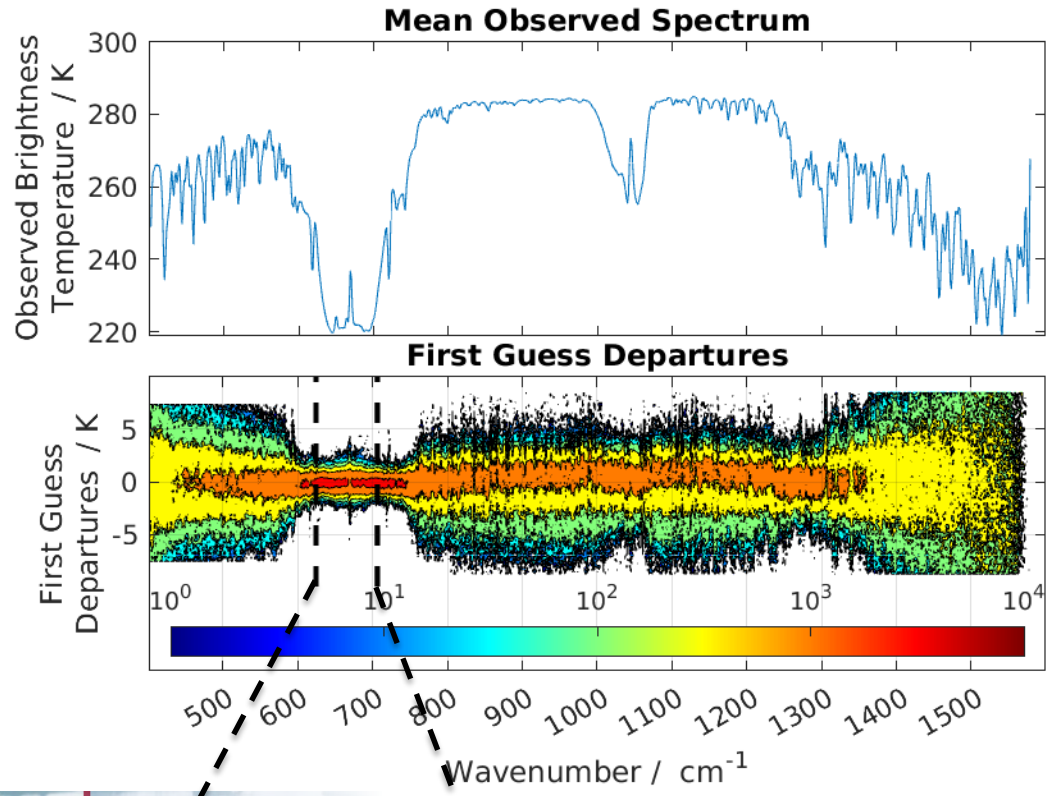


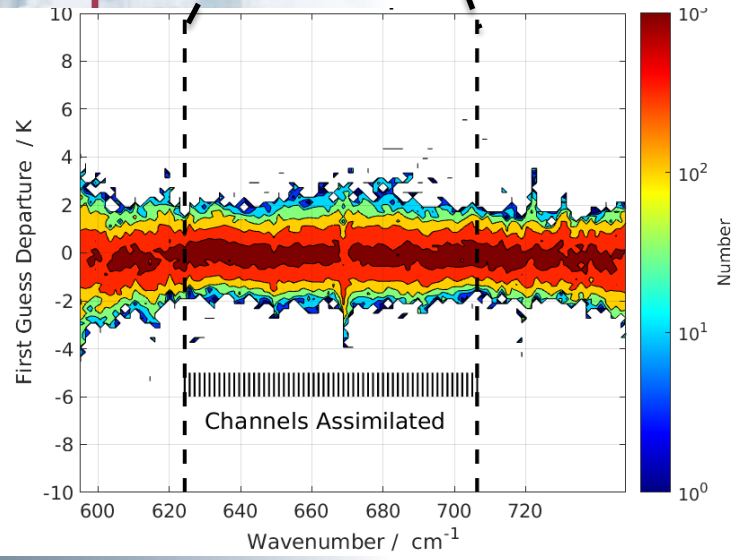

**Typical 12 hour coverage**

- Operated on Nimbus-4, from April 1970 – January 1971
- Nadir only observations. Spectral range 400 - 1600 $cm^{-1}$
- Resolution: 2.53 $cm^{-1}$ to 2.69 $cm^{-1}$
- 94 km footprint
- 13 s measurement time
- Coverage to 80°N to 80°S (rely on **B** to propagate information to poles)

**Daily time coverage / %**

| Year | Month | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1970 | 04 | | | | | | | | | 18 | 63 | 0 | 0 | 2 | 95 | 88 | 77 | 86 | 2 | 79 | 93 | 88 | 85 | 85 | 5 | 83 | 0 | 1 | 86 | 79 | 76 | |
| | 05 | 82 | 3 | 85 | 5 | 92 | 79 | 85 | 85 | 93 | 93 | 93 | 93 | 79 | 52 | 84 | 93 | 93 | 5 | 93 | 86 | 81 | 0 | 92 | 86 | 93 | 90 | 90 | 82 | 79 | 5 | 88 |
| | 06 | 90 | 0 | 90 | 77 | 59 | 59 | 71 | 70 | 86 | 63 | 77 | 79 | 93 | 93 | 91 | 93 | 6 | 90 | 0 | 3 | 93 | 93 | 93 | 93 | 5 | 93 | 91 | 0 | 91 | 93 | |
| | 07 | 93 | 1 | 90 | 93 | 93 | 85 | 85 | 5 | 0 | 89 | 89 | 68 | 92 | 73 | 4 | 76 | 94 | 3 | 0 | 0 | 4 | 86 | 5 | 94 | 94 | 79 | 79 | 1 | 0 | 0 | 89 |
| | 08 | 85 | 79 | 88 | 1 | 0 | 76 | 9 | 91 | 85 | 86 | 82 | 90 | 86 | 94 | 80 | 0 | 55 | 5 | 94 | 2 | 59 | 2 | 79 | 80 | 86 | 5 | 0 | 0 | 2 | 82 | 47 |
| | 09 | 86 | 88 | 2 | 88 | 95 | 80 | 95 | 86 | 95 | 2 | 0 | 91 | 89 | 80 | 94 | 5 | 75 | 0 | 47 | 36 | 3 | 0 | 0 | 0 | 96 | 94 | 88 | 89 | 93 | 94 | |
| | 10 | 2 | 85 | 61 | 63 | 58 | 85 | 95 | 86 | 6 | 0 | 0 | 0 | 4 | 21 | 93 | 80 | 5 | 89 | 1 | 90 | 63 | 3 | 88 | 94 | 88 | 4 | 4 | 85 | 78 | 0 | 0 |
| | 11 | 93 | 91 | 91 | 85 | 0 | 0 | 60 | 86 | 83 | 0 | 93 | 81 | 93 | 97 | 1 | 91 | 92 | 94 | 89 | 93 | 98 | 93 | 82 | 54 | 2 | 96 | 93 | 69 | 82 | 81 | |
| | 12 | 71 | 70 | 68 | 1 | 69 | 77 | 76 | 0 | 77 | 0 | 1 | 63 | 66 | 61 | 0 | 61 | 70 | 69 | 0 | 76 | 72 | 72 | 73 | 68 | 74 | 3 | 71 | 72 | 69 | 69 | 75 |
| 1971 | 01 | 0 | 70 | 64 | 73 | 63 | 69 | 0 | 0 | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | 52 | 0 | 36 | 42 | 46 | 0 | 35 | 44 | 46 | 0 | 40 | 40 | 48 | |




# IRIS initial IFS tests

- TCO399 (25km resolution), L137, weak constraint 4DVAr
- $CO_2$ temperature sounding channels actively assimilated (60 channels ~ 624 - 706 cm$^{-1}$)
- Adjacent channels used – no spectral thinning & no spatial thinning
- Diagonal errors: R = 1.0K
- VarBC on. Offset and 4 thickness predictors (10-1, 50-5, 200-50, 1000-300 hPa)
- *McNally & Watts* cloud detection, parameters as given in *Poli & Brunel (2016)*
- IRIS RTTOV coefficients include the effects of:
  - spectral shift - due to off-axis effects
  - $OPD_{MAX}$
  - self apodisation due to finite FOV
  - Hamming numerical apodisation
  - but no additional '*misalignment-induced*' apodisation

# Assimilating Nimbus-4 IRIS data: forecast Impacts

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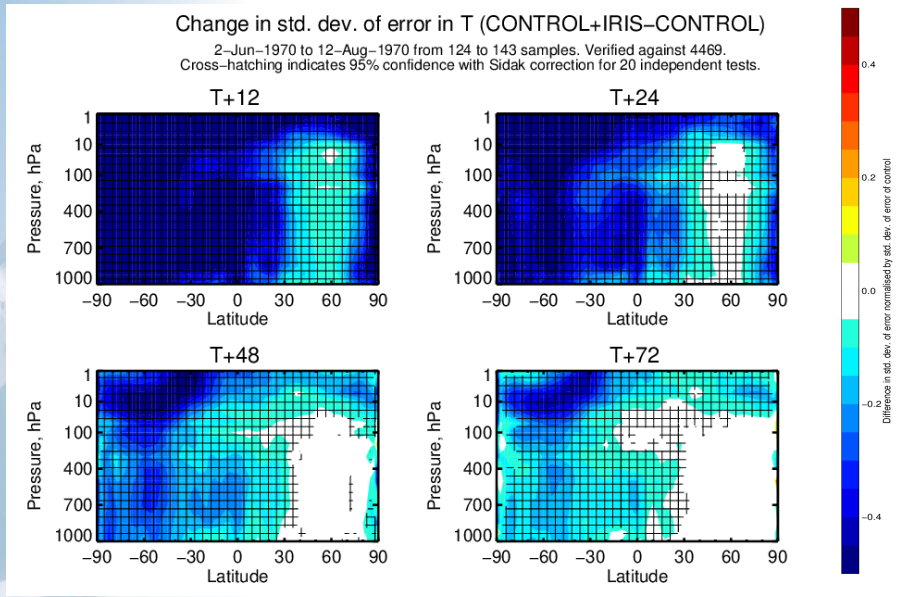
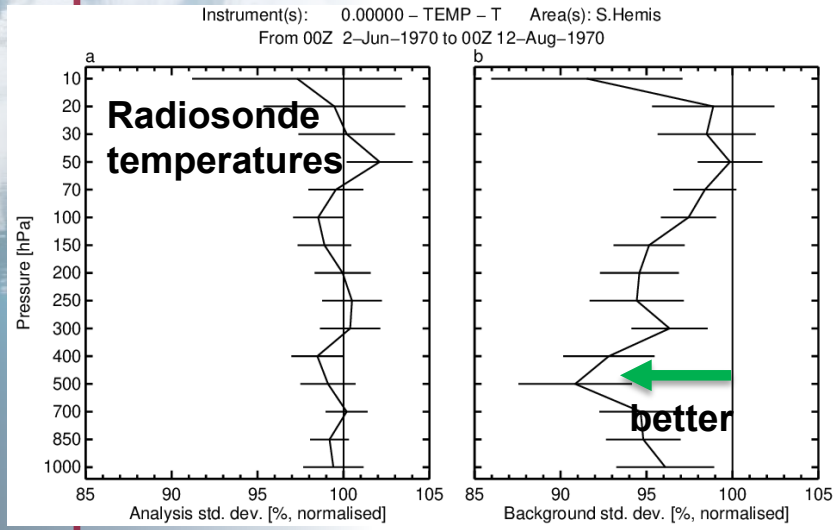
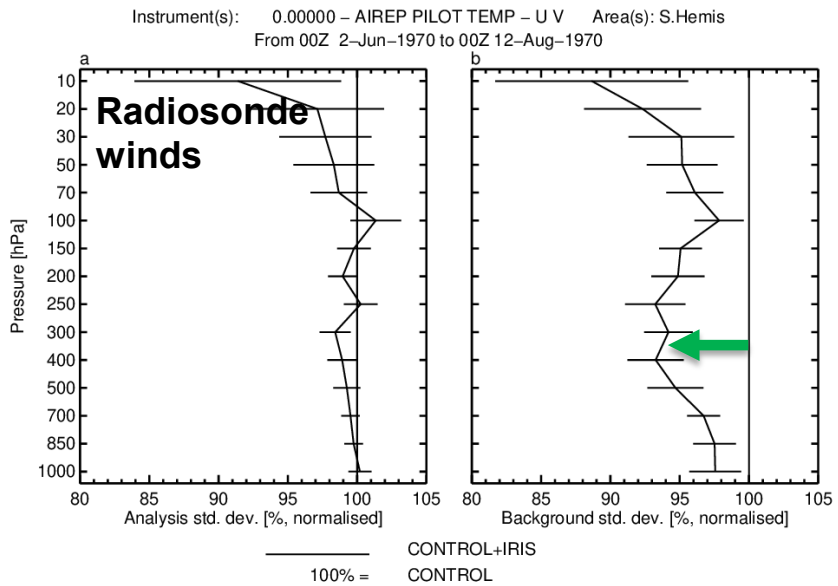
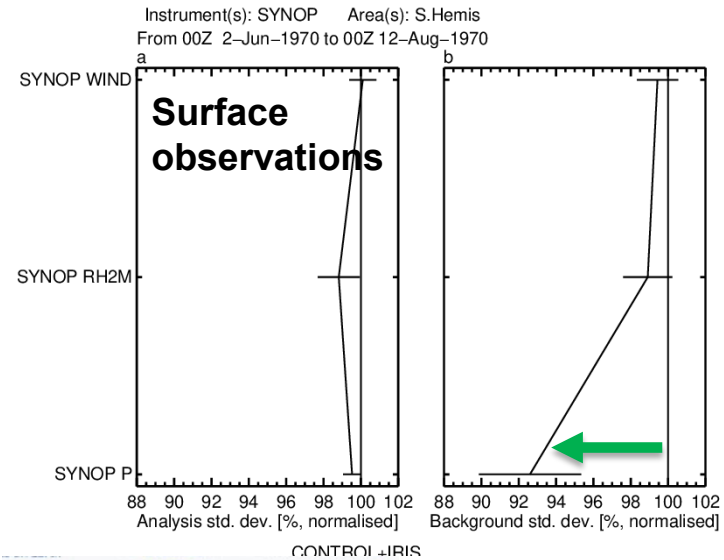



- **Control:** CY48R1 / **Experiment** assimilated IRIS data
- Background error covariances from ERA5 (so appropriate for 1970)
- 12Z 1st June 1970 – 00Z 12th August 1970
- **Significant improvements in southern hemisphere and stratosphere**
- **Improved background (and analysis) fits** to radiosonde temperatures and winds (~5%) and surface pressure obs (7%)



# Upper stratospheric biases in ERA5: Temperature anomalies relative to ERA5 climate

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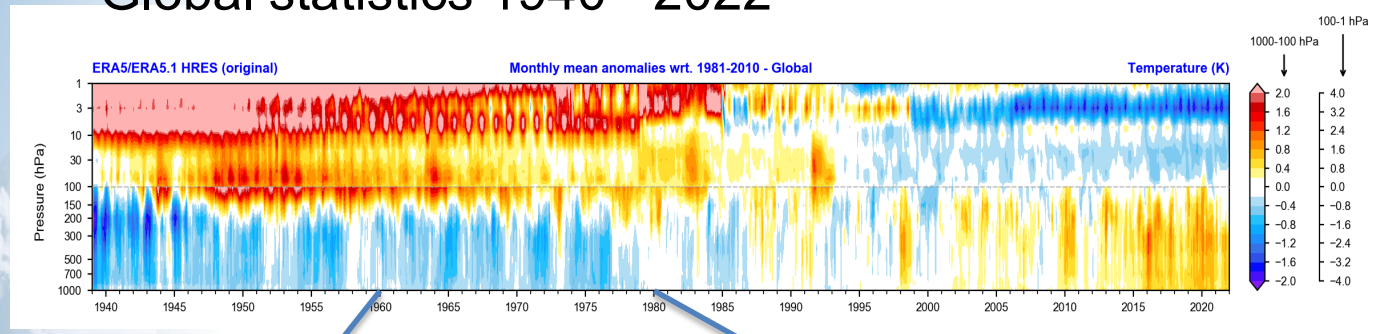
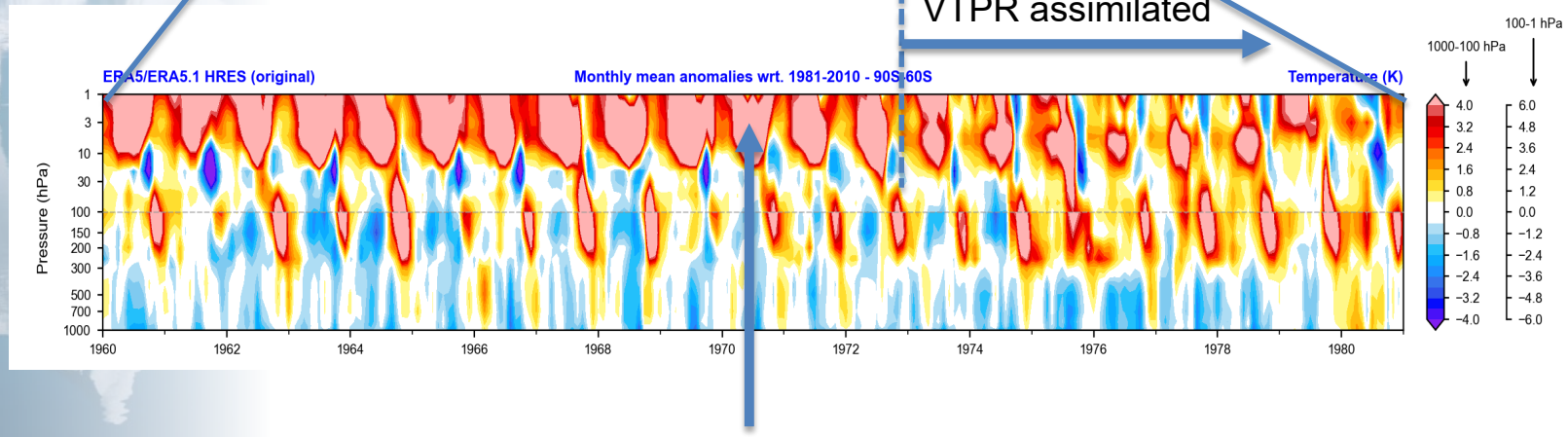
## Global statistics 1940 - 2022




## Southern polar statistics 1960 - 1980




IRIS experiments

- Generally, ERA5 temperature analyses above 10 hPa exhibit biases and discontinuities
- Particularly large biases evident in southern polar winter (>> 6K in the plot shown)
- Repeatable from year-to-year (before 1972)
- Reduced following the assimilation of VTPR data (Nov 1972 - Jan 1979)

# Evaluation of IRIS radiances relative to ERA5, rocketsondes & SIRS radiances (Andrzej Klonecki *et al* , Spascia)

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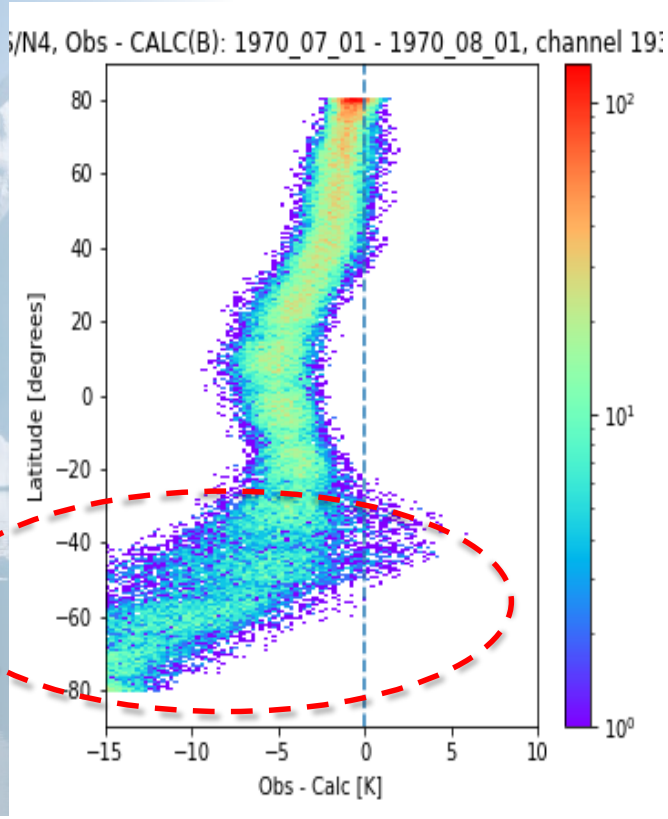
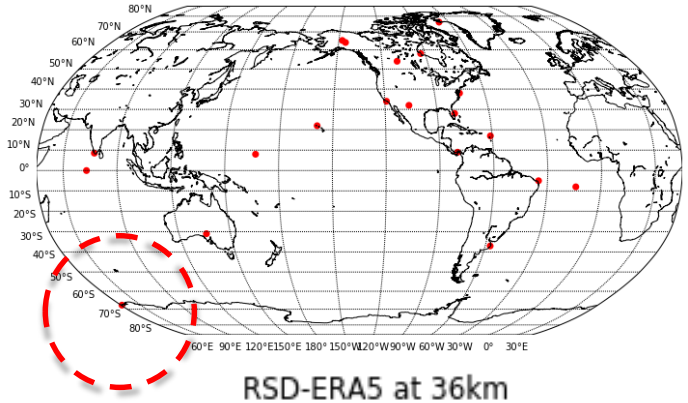
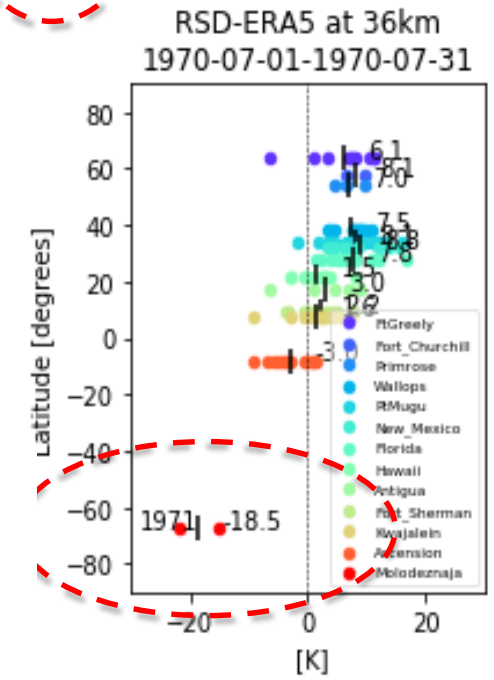
## IRIS Obs vs ERA5 channel 193 peaking at 3 - 40hPa

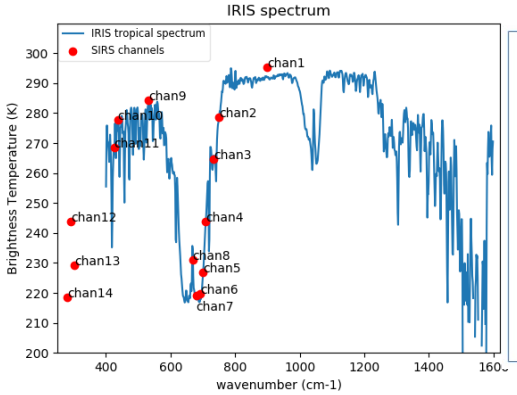


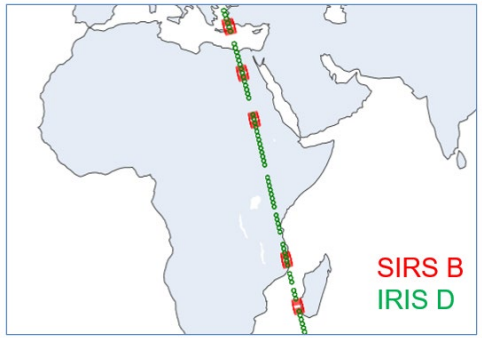

## rocket sondes vs ERA5

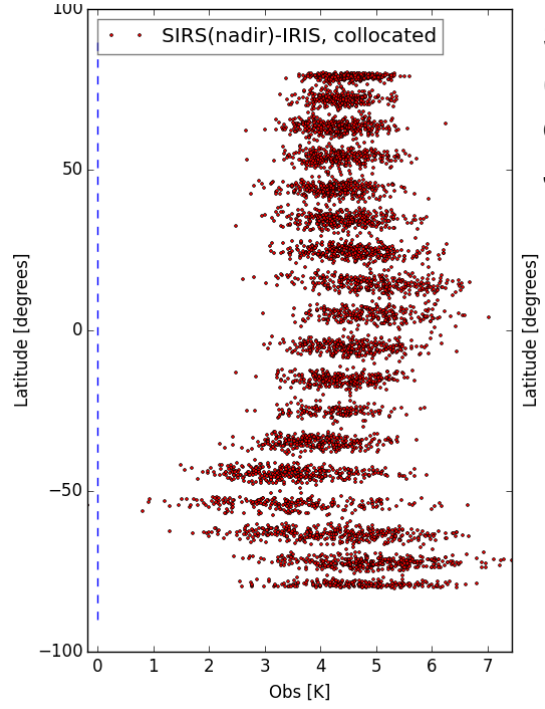





## Nimbus-4 IRIS vs SIRS




SIRS / IRIS (ch 8 / ch 193) colocations for July 1970

In summary, relative to :

- Its own climate (1981-2010);
- IRIS observations;
- SIRS observations; and
- Rocket-sonde data

**ERA5 exhibits a warm bias, at 36km / 5hPa, of ~15K**

# Impact of assimilating IRIS on southern polar stratospheric biases

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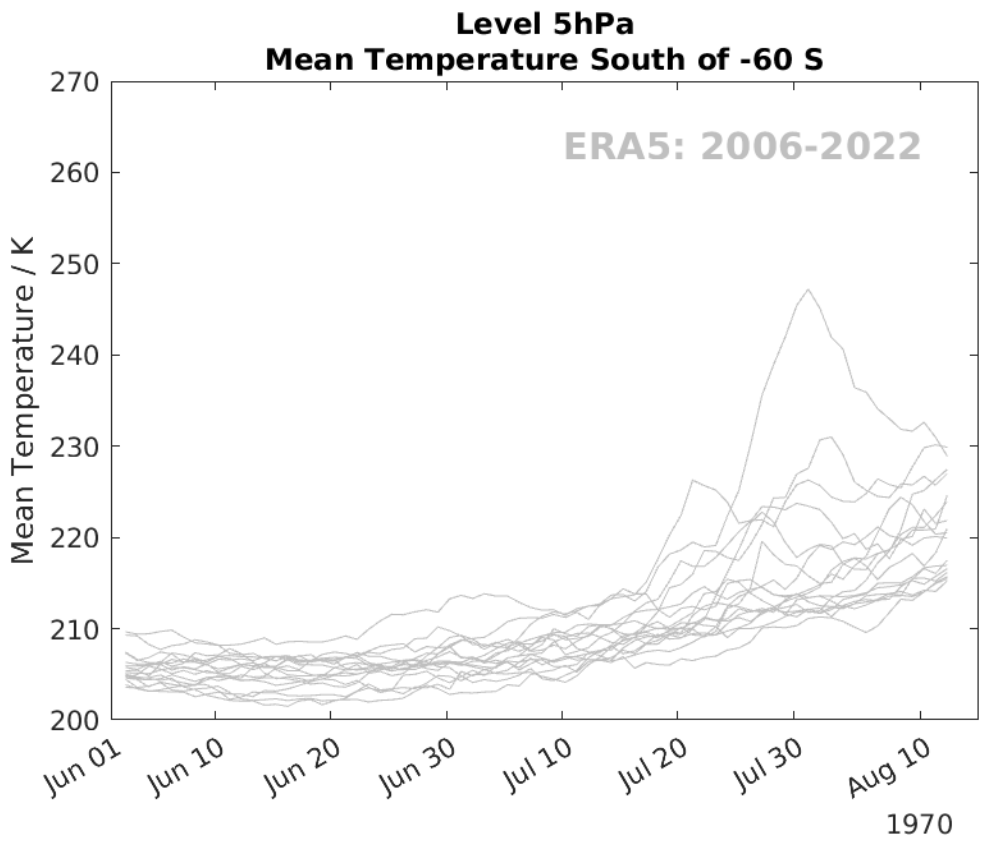


- During the GNSS-RO era (2006 - ) the stratospheric temperature analysis is realistic

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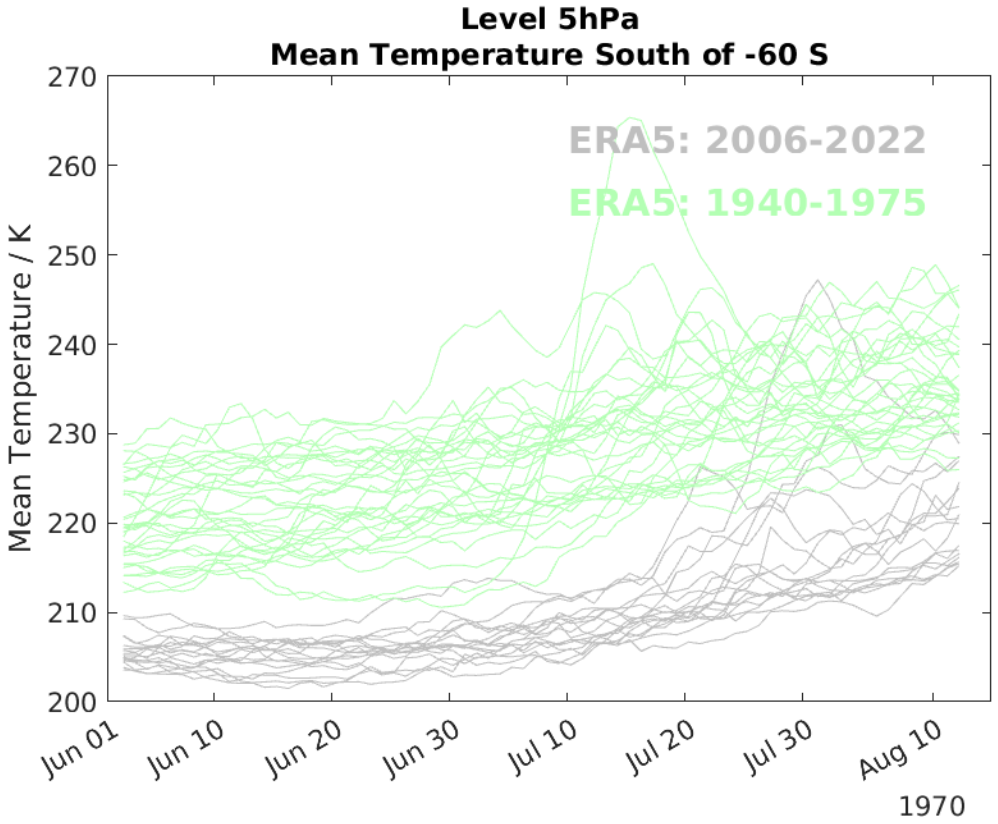
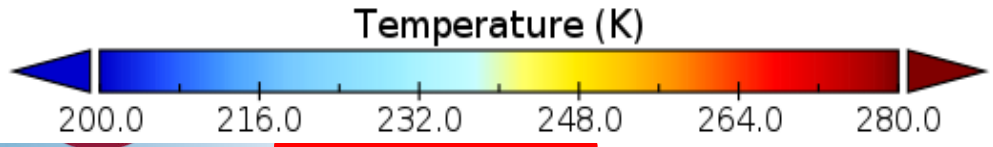
# Impact of assimilating IRIS on southern polar stratospheric biases

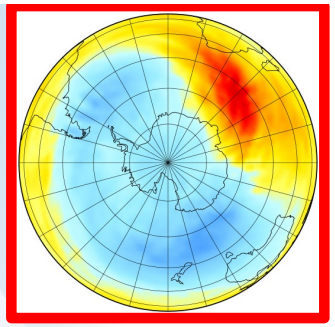



- During the GNSS-RO era (2006 - ) the stratospheric temperature analysis is realistic
- In the early period (1940-75) of the reanalysis, few observations constrain the analysis ⇒ model biases are exposed. At 5hPa, temperatures are **10 – 25 K warmer** in mid-winter, relative to 2006-2022

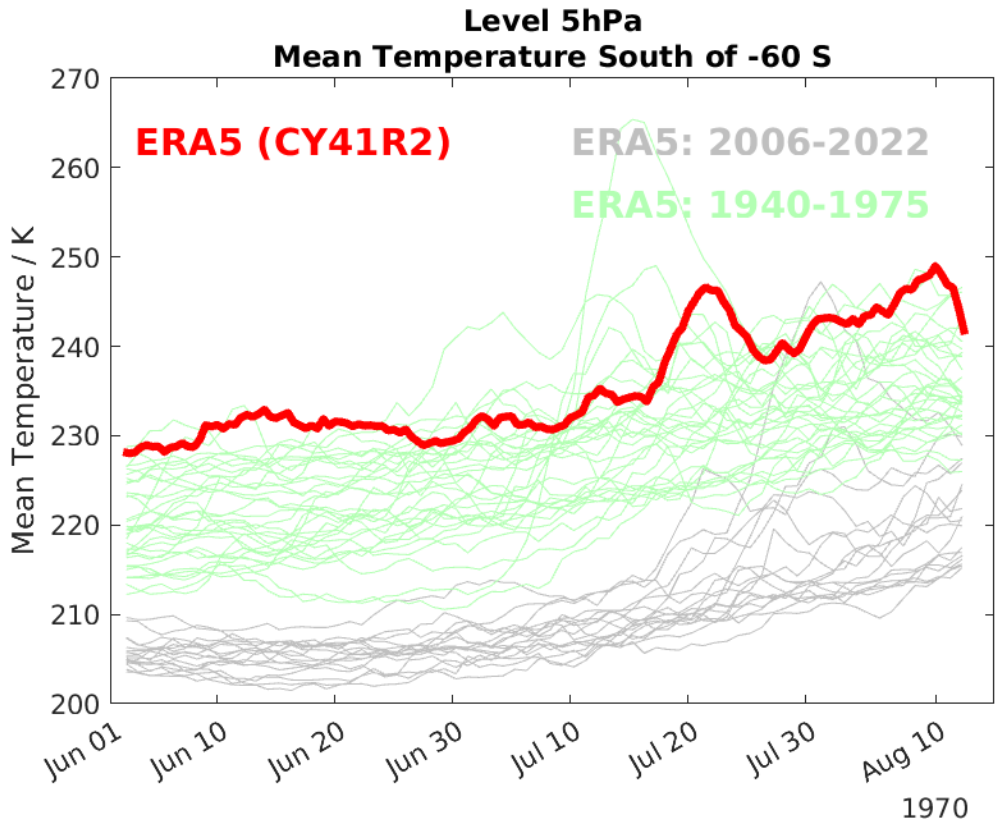
# Impact of assimilating IRIS on S. polar stratospheric biases

Climate Change



5 hPa temperature
10th July 1970, 00Z

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# Impact of assimilating IRIS on S. polar stratospheric biases

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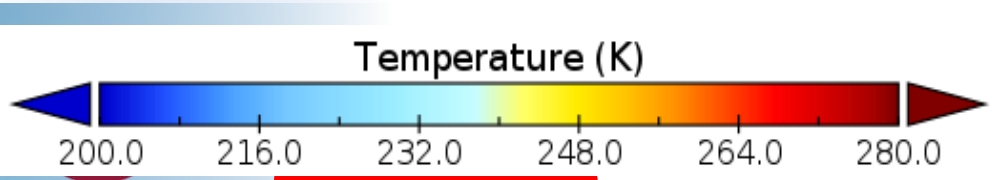


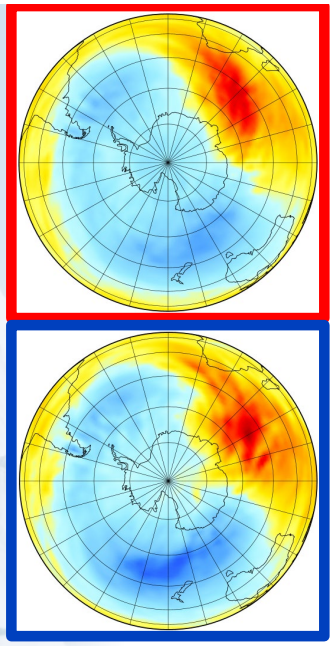

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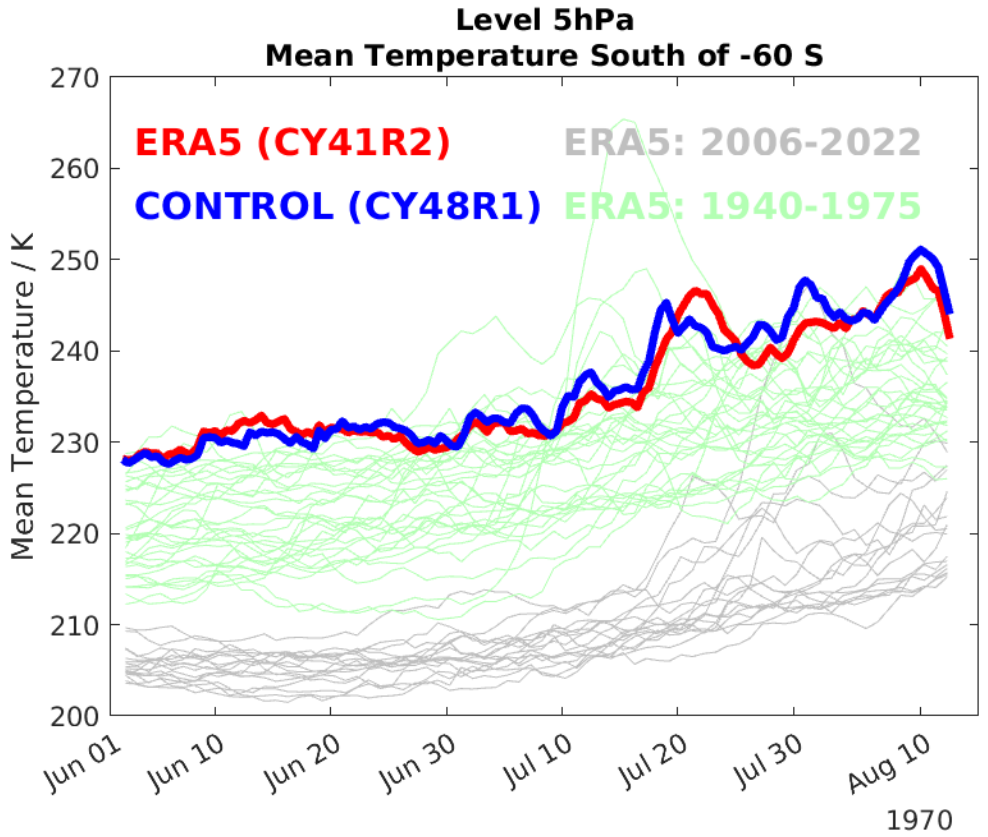


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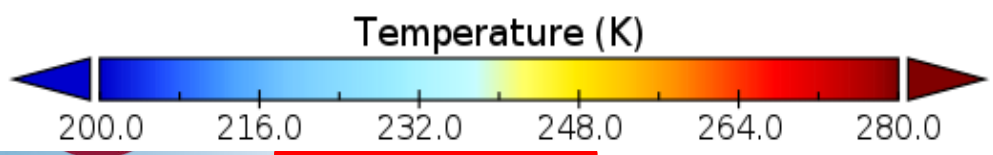


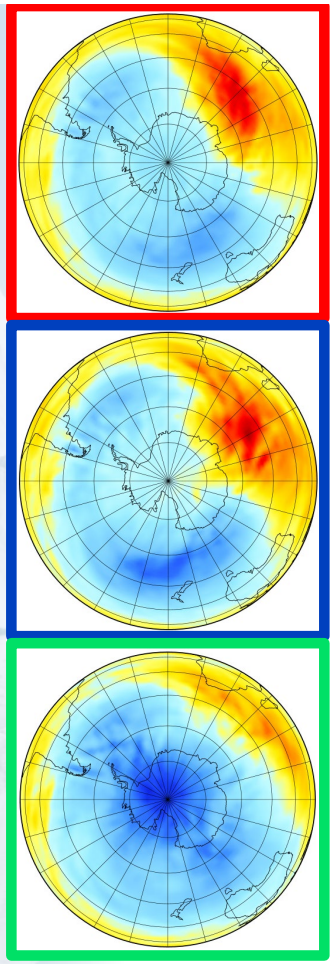

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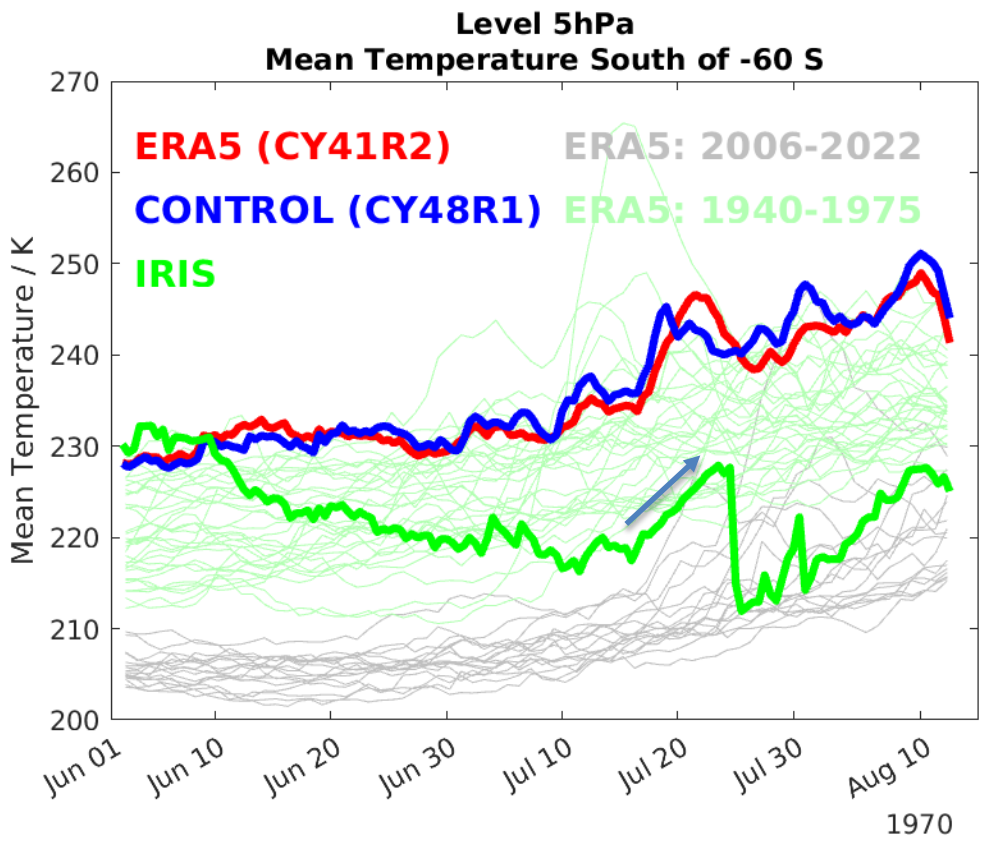


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- **Assimilating IRIS** *gradually* brings temperatures to more realistic values. Note: increase (↗) from 16th-24th July is associated with an **outage** of IRIS observations

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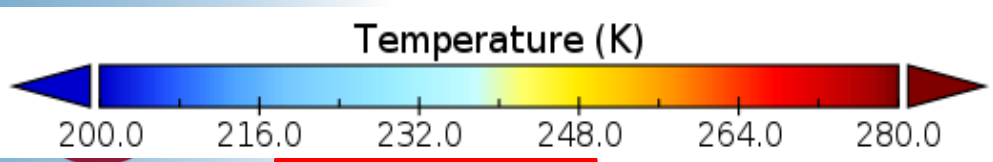
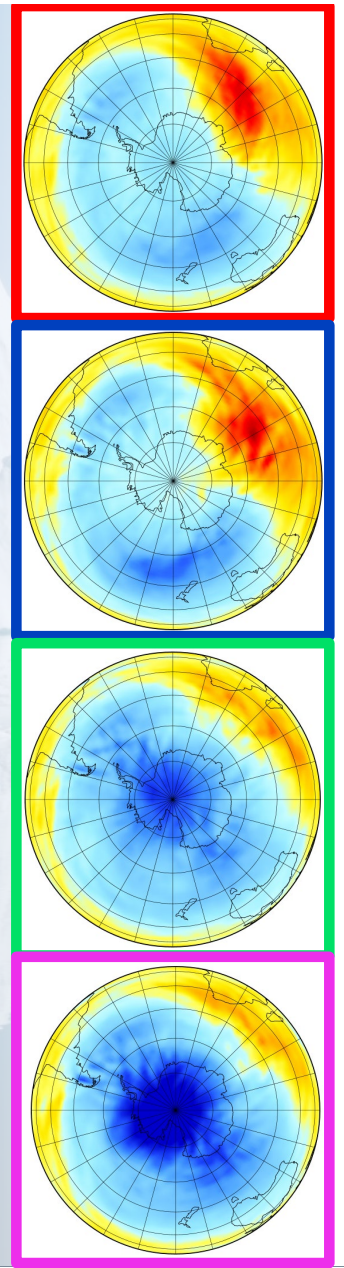
Climate Change



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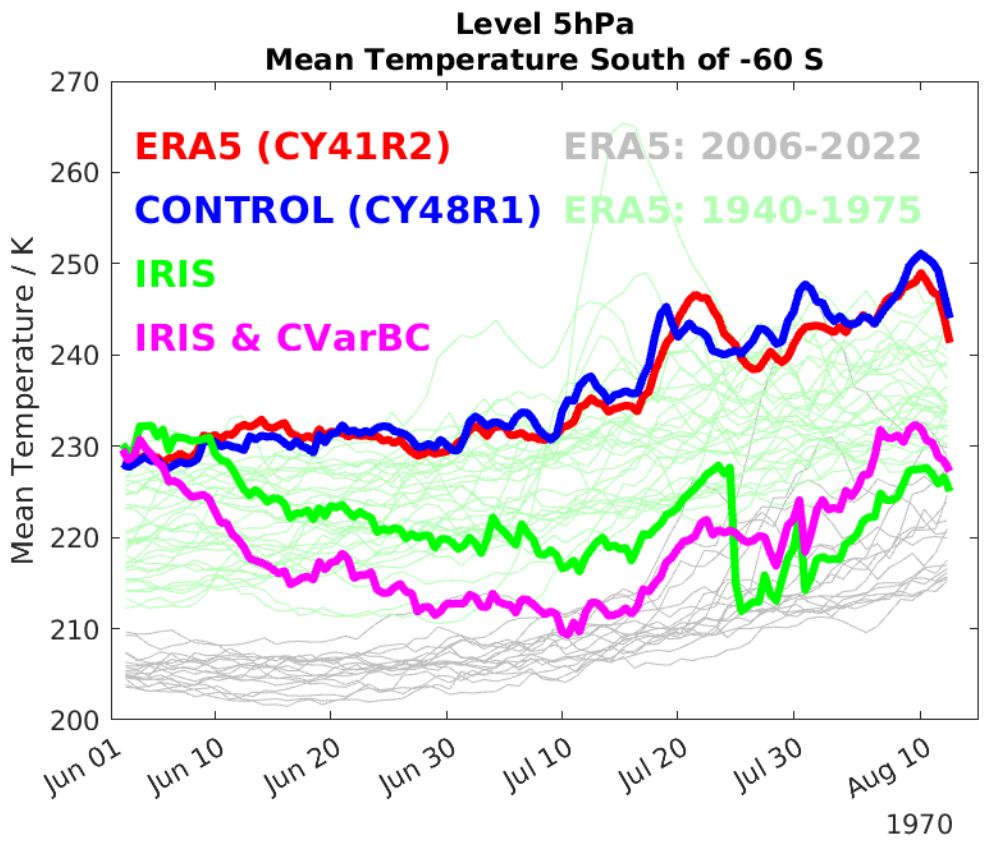


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- Using **Constrained VarBC** (Han & Bormann) reduces the bias absorbed by VarBC, and accelerates cooling of the analysis towards more realistic values.

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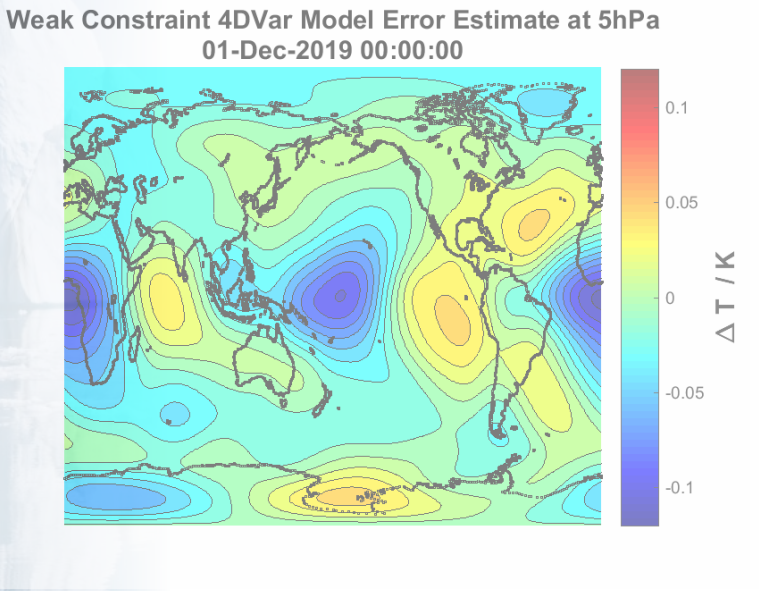
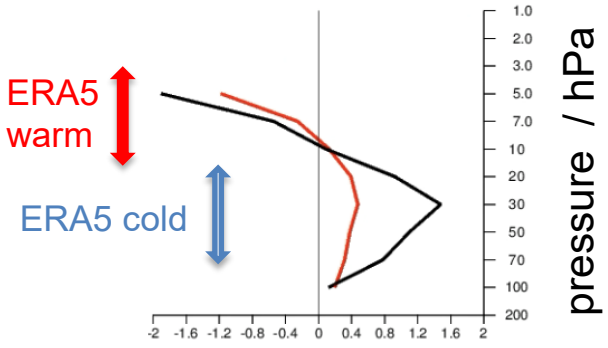
# Treatment of stratospheric biases using Weak Constraint 4D-Var

- Weak constraint 4D-Var analyses large scale biases in the stratosphere, operational since 2020
- Effective in reducing temperature biases in the stratosphere
- Several options under test for ERA6 (*e.g.* WC 2006 → present, WC model error used before 2006)



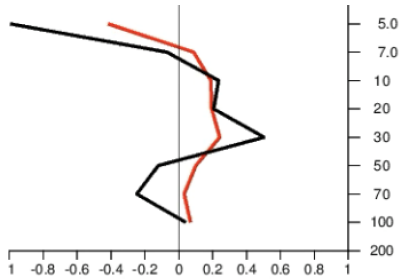

Strong Constraint 4D-Var
'ERA5-like' configuration




O – B / K
('O' from RO T-retrievals)

Using WC model error
'ERA6-like' configuration

Full observing system
No stratospheric observations




→ amplitude of T biases reduced by a factor of 2-3 in the stratosphere when using WC 4D-Var model error forcing (MEF)

→ remains to be seen how well WC MEF will work in the early period of the reanalysis.
**IRIS observations will be key in assessing this.**

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# Summary

- Preparations for ERA6 include the evaluation of many reprocessed (EUMETSAT) & rescued satellite radiance datasets (EUMETSAT and Spascia). See:
  - Jon Mittaz's talk (5.02) on *Investigating possible sources of error in the calibration of the Microwave Sounding Instrument &*
  - Timo Hanschmann's talk (5.03) on *Applying inter-satellite Harmonisation to various Microwave Humidity Sounders*
- The example of Nimbus-4 IRIS shows:
  - This very early (**36 years before IASI** ! & only **13 years after Sputnik !** ) hyperspectral sounding data is of high quality & bears testament to the skill of the scientists and engineers who built, launched & operated this instrument & took care of the data over the last 53 years !
  - The assimilation of this data provides significant benefit on analyses & forecast quality in the SH, but perhaps the most significant benefit is …
  - Validating the general treatment of model biases (e.g. using WC-4DVar MEF) with unique observational data in ERA6 and future reanalyses