Copernicus
Europe's eyes on Earth

Climate Change Service
climate.copernicus.eu

Satellite data rescue for climate reanalysis: C3S_311c_Lot1

Thomas W. Hall[1], Jonathan P. D. Mittaz[1,2], Pascal Prunet[3], Andrzej Klonecki[3], Carsten Standfuss[3]
[1]Department of Meteorology, University of Reading, [2]National Physical Laboratory, [3]SPASCIA

This project is a part of a larger C3S data rescue effort:

Current EO activities in C3S

C3S_311a	Data rescue activities	Lot1: Coordination of data rescue activities	Started 2017Q2/ End 2021Q2
		Lot2: Harmonised access to Global Data Archives	Started 2017Q2 / End 2021Q2
		Lot3: Harmonised access to data from reference networks	Started 2017Q2 / End 2021Q2
C3S_311c		Lot1: Satellite data rescue, mainly prior to 1978	Started 2018Q4 / End 2021Q2
		Lot2 : Upper-air data rescue	Started 2018Q4 / End 2021Q2
C3S_311b	Reprocessing	Reprocess of EUMETSAT L1 satellite data	Started 2016Q3 / End 2021Q2

Project Objective: to recover, assess and prepare a selection of early satellite data records (mainly 1964-1979) for use in climate reanalysis.

Context:

- ERA5 - reanalysis currently run for periods 1950-present
- ERA6 - next generation centennial reanalysis scheduled for 2023 start
- Very little satellite data pre-1979 is currently assimilated into climate reanalyses (only VTPR assimilated in ERA5)
- Several satellite missions from before 1979 identified as potentially important for reanalysis. However, important work needed to bring them to a sufficient level of readiness

Sensor	Time period	Channels	Function
HRIR	1964-1970	Single 3.4-4.2 µm channel (Nimbus 1&2) and additional 0.7-1.3 µm component (Nimbus 3)	Map night-time cloud clover and cloud top temperature
MRIR	1966-1970	6.7 µm water vapour, 10.5 µm window, 15 µm CO_2, 5-30 µm, 0.2-4.0 µm visible	Detect surface and stratospheric temperature, water vapour, reflected solar energy
SIRS	1969-1971	7 channels in CO_2 band and 1 window channel (Nimbus 3) and extra 6 channels in water vapour band (19-35 µm) on Nimbus 4	Atmospheric sounding (220km footprint)
IRIS	1970-1971	862 channels in 400-1600 cm^{-1} (6.25-25 µm) interval	Early hyperspectral sounder with surface sensing capability
THIR	1970-1977	6.7 µm water vapour and 11.5 µm window	Map cloud cover, cloud top temperature, surface temperature, relative humidity
VTPR	1972-1979	8 channels in window, CO_2 and water vapour bands (11.9-18.7 µm)	Atmospheric temperature sounding
PMR	1975-1978	2 channels (cells) in 15 µm CO_2 band	Uses pressure modulation to sense at different heights in stratosphere (45-90 km)
SSU	1978-2006	3 channels (cells) in 15 µm CO_2 band	Retrieval of temperature in stratosphere (29-44 km)

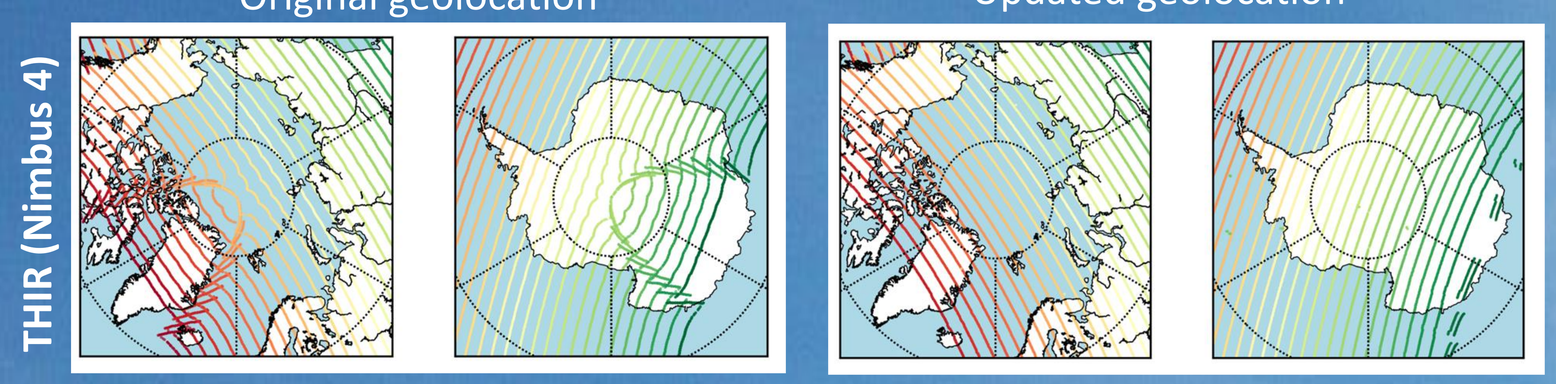
Project data rescue activities:

1) Develop and maintain an up-to-date global inventory of known satellite data records that require data rescue
2) Obtain and provide access to the datasets. Development of readers for historical binary formats and conversion to modern formats (netCDF4)
3) Error characterisation based on available documentation, identification of bias parameters, ranking instruments in terms of their interest for assimilation.
4) Assess available RTTOV coefficients and creation of new coefficients, improve RT modelling where possible and estimate uncertainties
5) Develop QC schemes based on step 3 and timing/geolocation corrections to improve data quality
6) Characterise uncertainties and determine dominant sources of error (biases) and apply bias corrections
7) Large scale calculations of the difference between observations and model values from ERA5 (O-B). Assess performance of bias models currently used in ERA5. Develop bespoke VarBC models to correct the observations during assimilation.

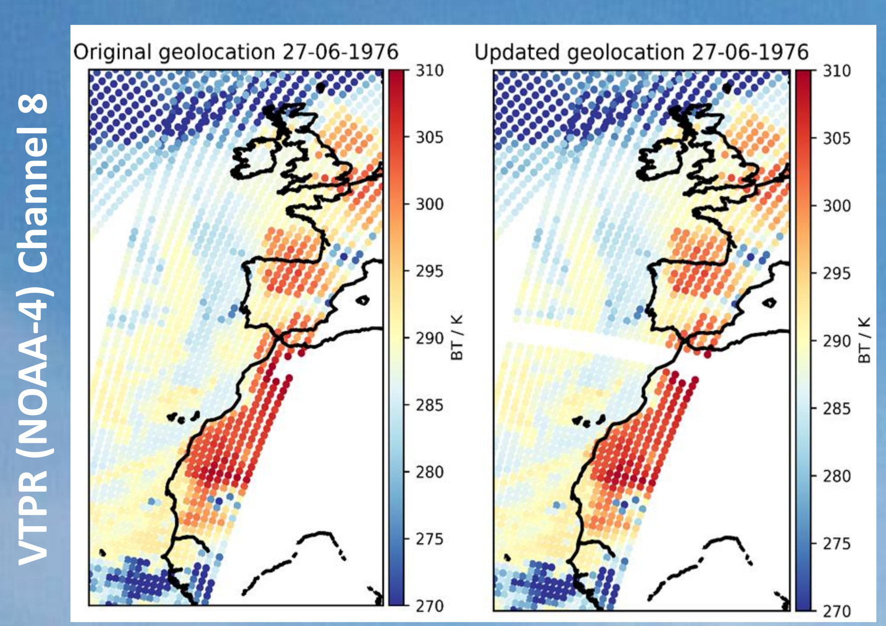
Geolocation corrections:

- Geolocation quality studied for each historic sensor and corrections made where necessary
- Two-line element (TLE)-based approach using Pyorbital Python package:

- For most sensors, this significantly improves the geolocation accuracy
- Data that would be unusable can be recovered in some cases:
  - Correction of IRIS orbit tracks in January 1971
  - Clear improvements at Poles for THIR and MRIR where there are discontinuities in the original anchor points



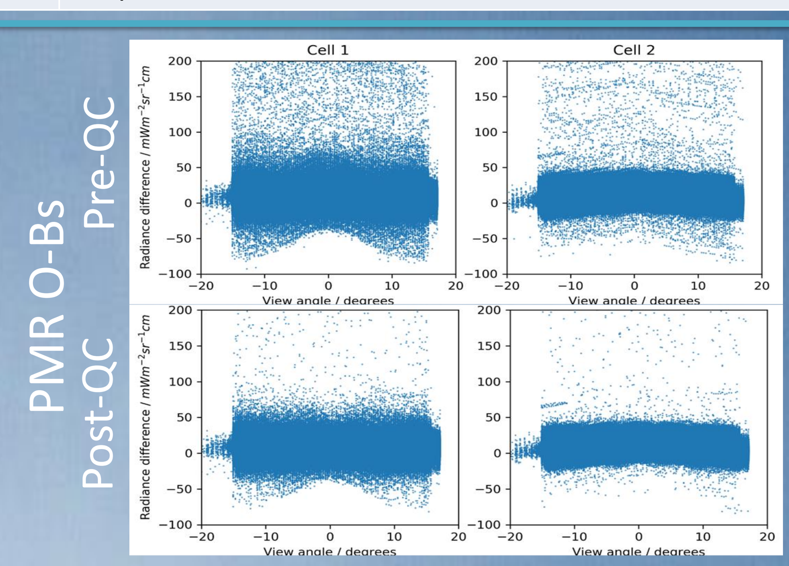
- However, geolocation errors up to 400km evident for VTPR, even with TLE correction:



- These errors are complex and highly variable
- Potentially due to satellite pitch errors but attitude data is unavailable
- A more detailed study is required to quantify these errors on a case-by-case basis

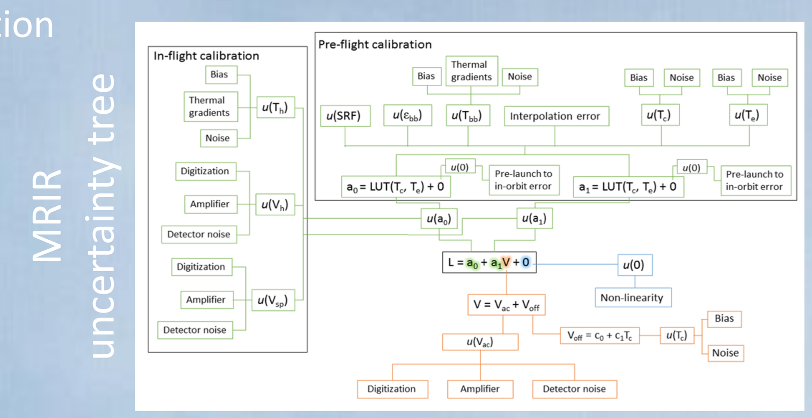
Data QA:

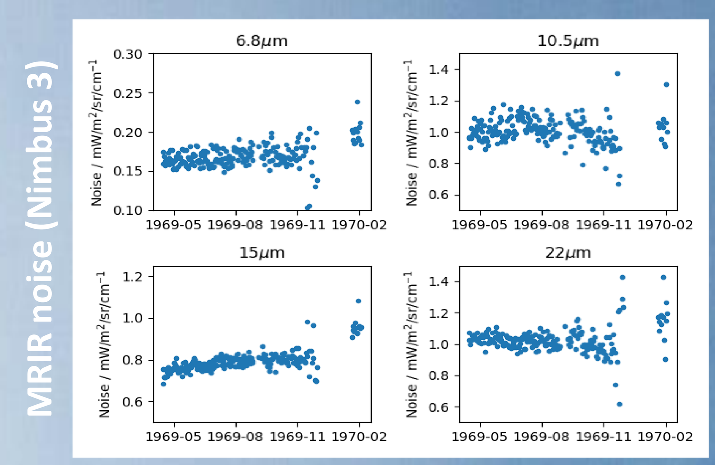
- Analysis of data quality to improve the usability of the data
- We have developed additional quality flags based on observations only and on O-Bs



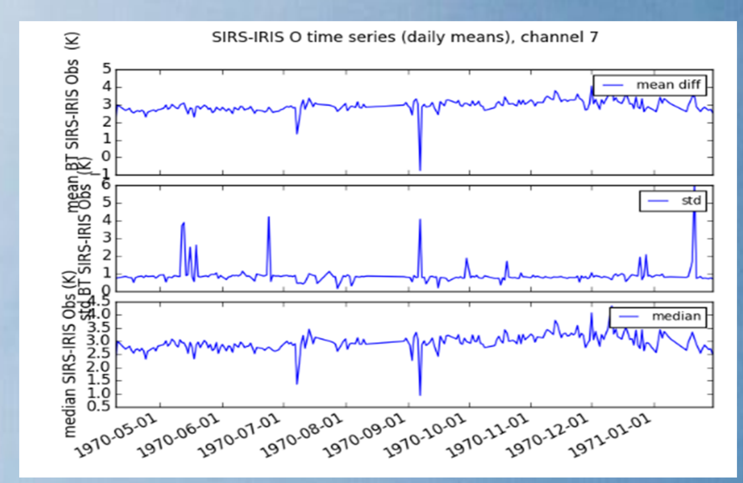
Error characterisation:

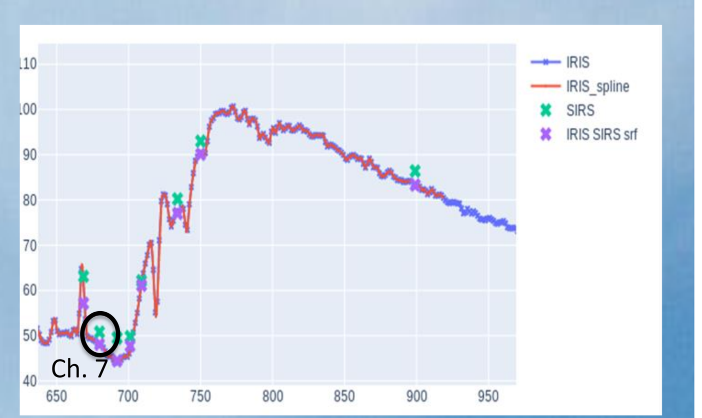
- Uncertainty tree analysis to study impact of all identifiable sources of error
- Estimates of instrument noise from local standard deviation

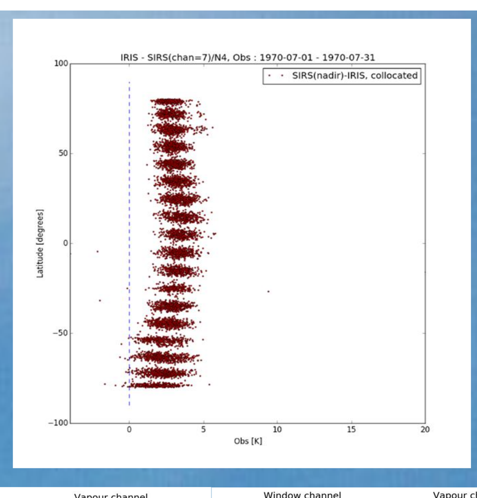




- **Sensor intercalibration** is a powerful tool to understand instrument behaviour and study observational biases
- IRIS spectra are convolved with SIRS SRFs. 11 SIRS channels covered by IRIS data
- Collocation criterion: ΔT<2s between SIRS (nadir only) and IRIS
- Results show a consistent bias between the two instruments, with IRIS being lower by 1-5 K depending on channel. The results are consistent with previous studies.
- Example for channel 7:

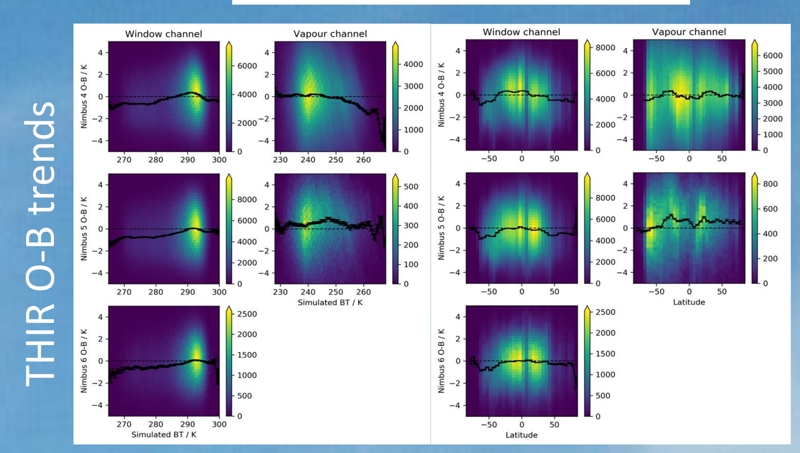






Bias modelling from O-B analysis

- We can infer instrumental effects/biases from analysis of O-Bs as a function of potential bias model parameters e.g. scene temperature, latitude, satellite zenith angle
- We have developed cloud screening algorithms for surface and tropospheric channels



SPASCIA Met Office METEO FRANCE European Commission Copernicus Europe's eyes on Earth ON BEHALF OF ECMWF FOR THE EUROPEAN COMMISSION icare University of Reading Capital High Tech