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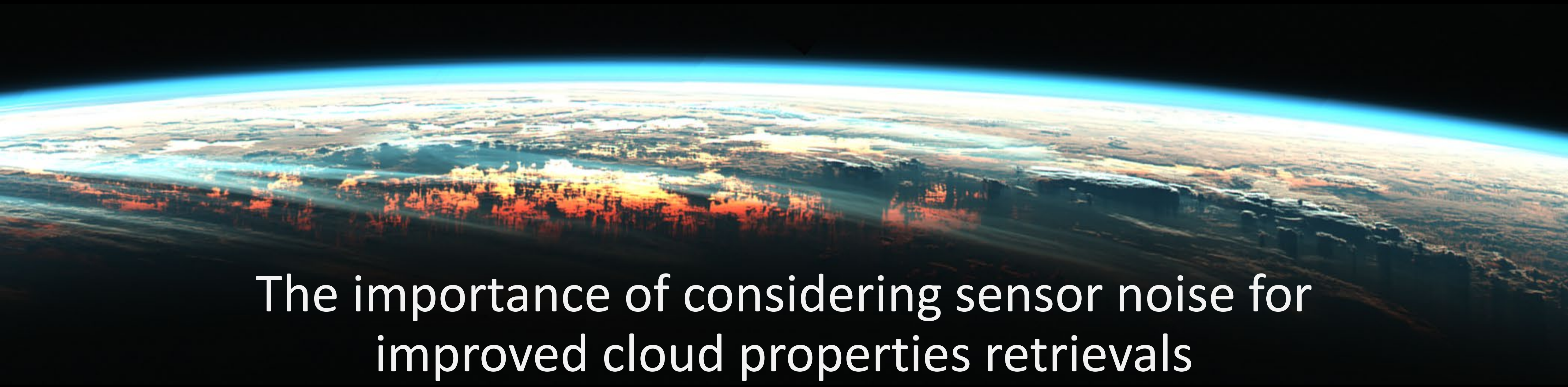

The importance of considering sensor noise for improved cloud properties retrievals

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UKRI Science and Technology Facilities Council

RAL Space

Background

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ORAC / CC4CL is a framework for retrieving cloud and aerosol properties from passive vis/IR satellite imagers.

Open source: https://github.com/ORAC-CC/orac

GEO and LEO a wide range of instruments are supported, here we focus on Meteosat-11 / SEVIRI.

Using optimal estimation, ORAC retrieves cloud optical depth, effective radius, cloud top temperature and, from ERA5 atmospheric profiles, cloud top pressure and height.

Optimal estimation allows a comprehensive consideration of uncertainty, and channel information is weighted by their uncertainty.

This requires information sensor noise characteristics and instrument calibration.

Sensor noise

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For most sensors, noise values are given by:
- The signal to noise ratio (SNR) for visible channels
- The normalised equivalent delta temperature (NEdT) for thermal channels.

For IR, noise is given at a specific temperature and is NOT valid at other temperatures.

Solution:

Convert NEdT to radiance (NEdR), which is constant, and apply at temperature measured by satellite:

$$NEdT_{meas} = \frac{\left(\frac{dB}{dT}\right)_{Tref}}{\left(\frac{dB}{dT}\right)_{Tmeas}} NEdT_{ref}$$

Channel	Wavelength (µm)	Type	Radiometric Noise	At
VIS 0.6	0.64	VIS	> 14.3	1%
VIS 0.8	0.81	VIS	> 9.7	1%
IR 1.6	1.64	VIS	> 3	1%
IR 3.9	3.92	Mixed	< 0.35	300K
WV 6.2	6.25	IR	< 0.75	250K
WV 7.3	7.35	IR	< 0.75	250K
IR 8.7	8.70	IR	< 0.28	300K
IR 9.7	9.66	IR	< 1.5	255K
IR 10.8	10.80	IR	< 0.25	300K
IR 12.0	12.00	IR	< 0.37	300K
IR 13.4	13.40	IR	< 1.8	270K
HRV	0.75	VIS	> 4.6	1%

Meteosat / SEVIRI noise requirements

Sensor noise

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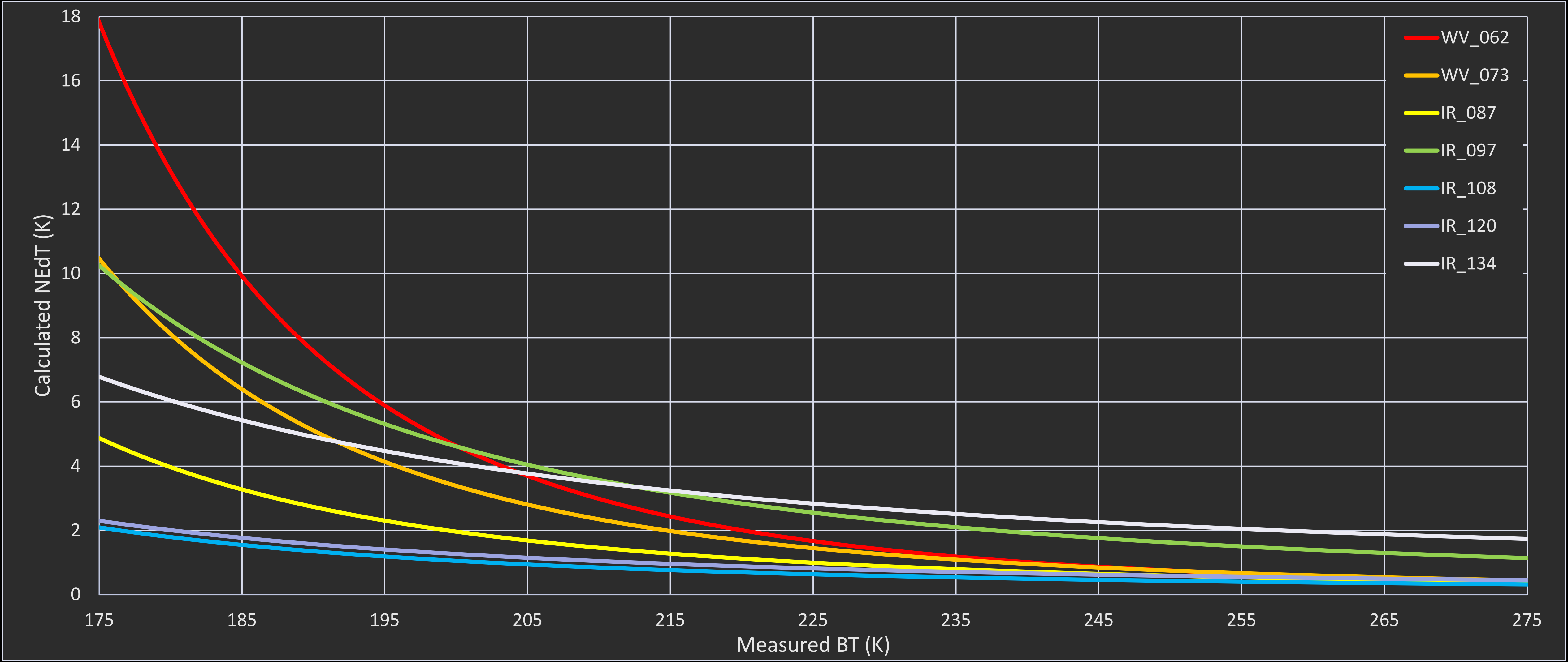

Example Meteosat-11 / SEVIRI noise values as a function of varying brightness temperature

Effects on retrievals

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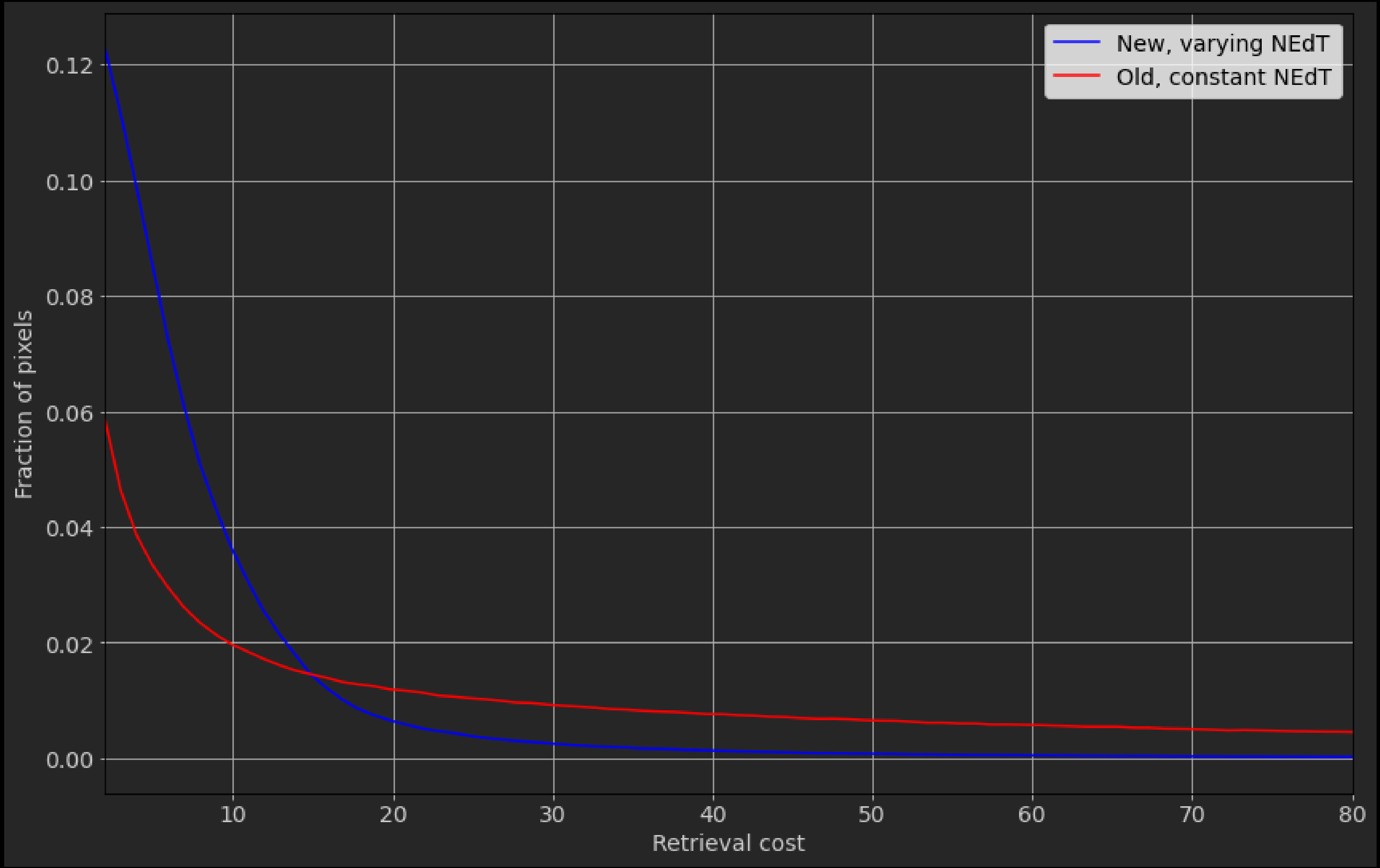
Overall, the addition of varying IR noise reduces retrieval cost.



Effects on retrievals

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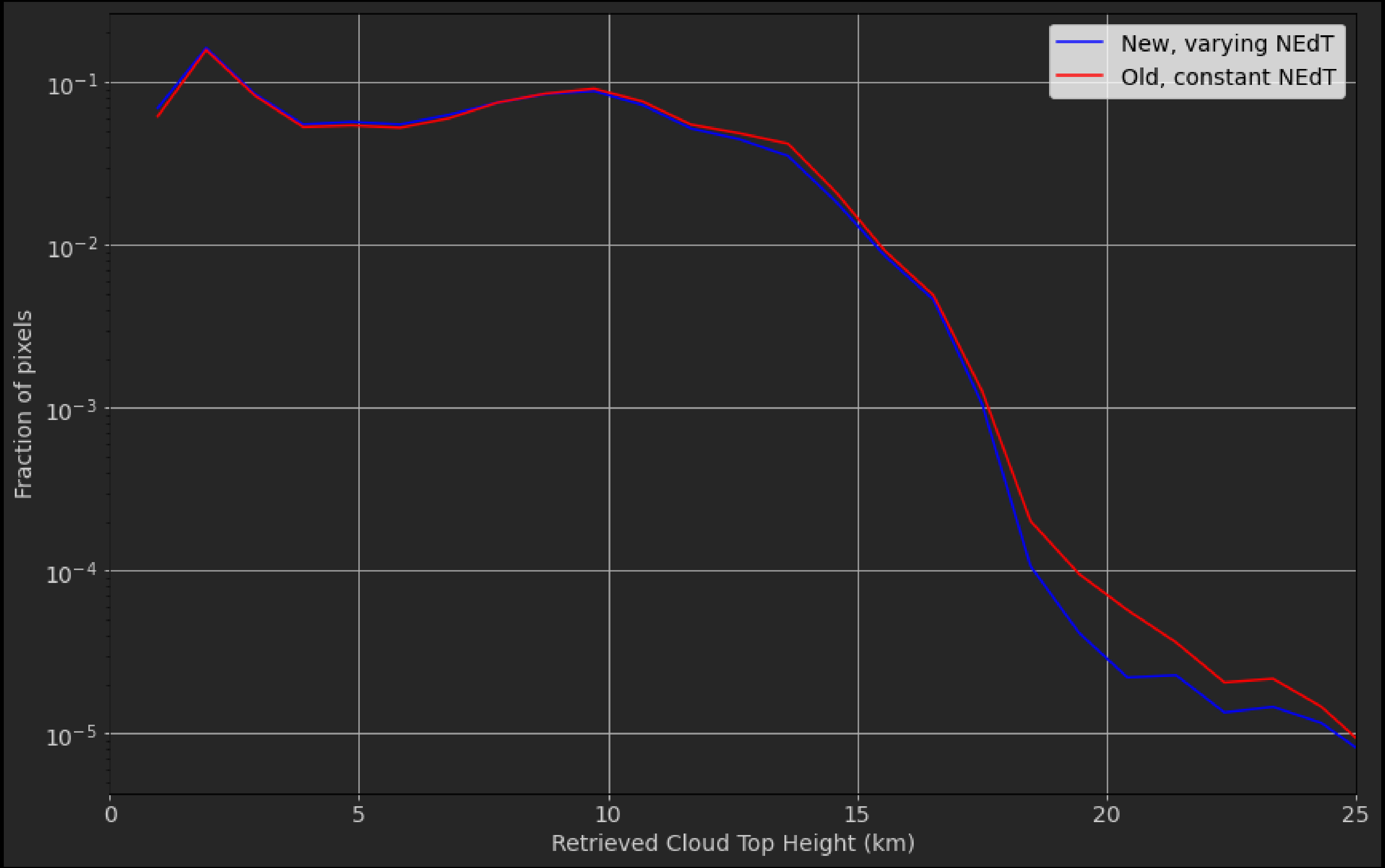
The faction of anomalously high cloud top heights is reduced.



Effects on retrievals

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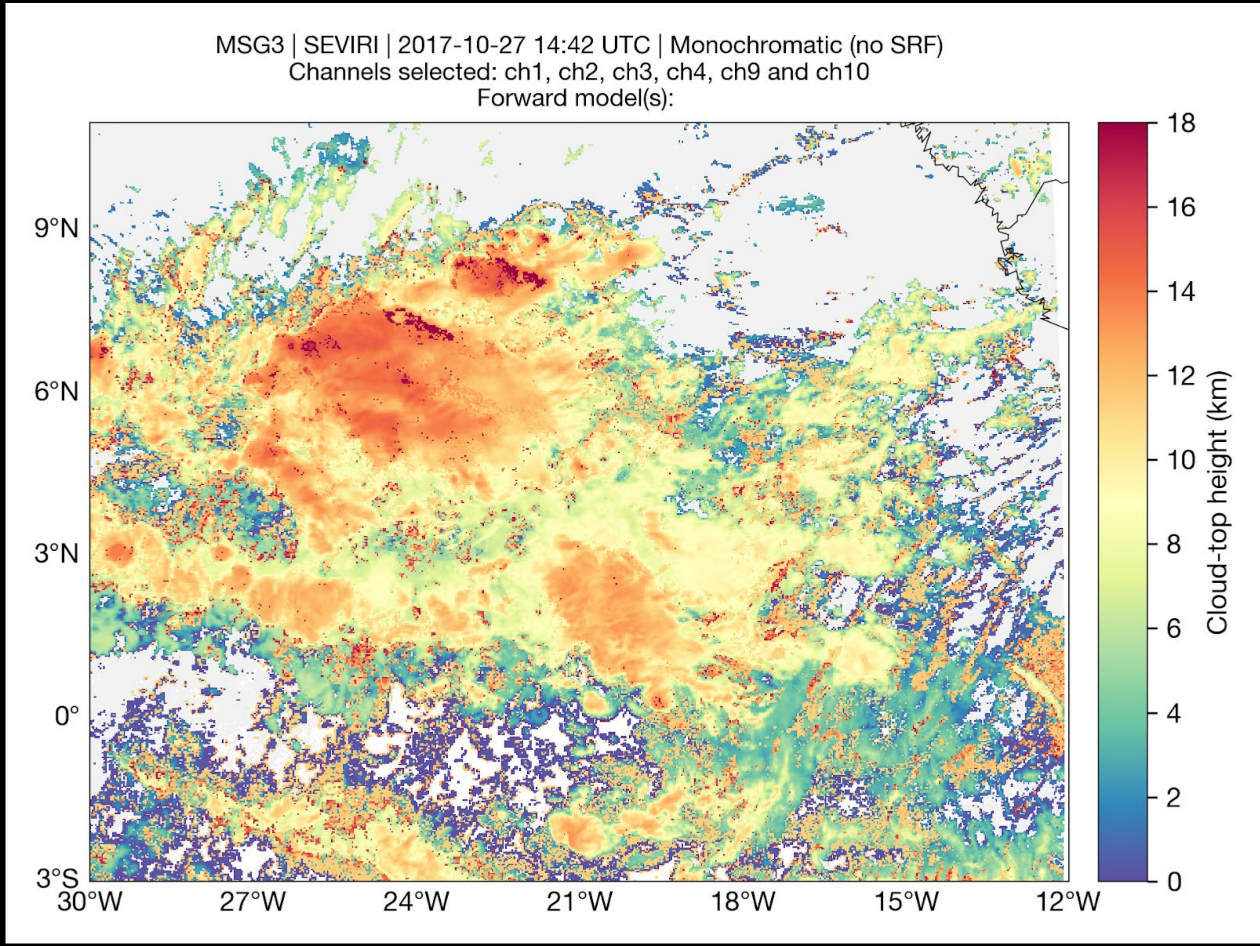
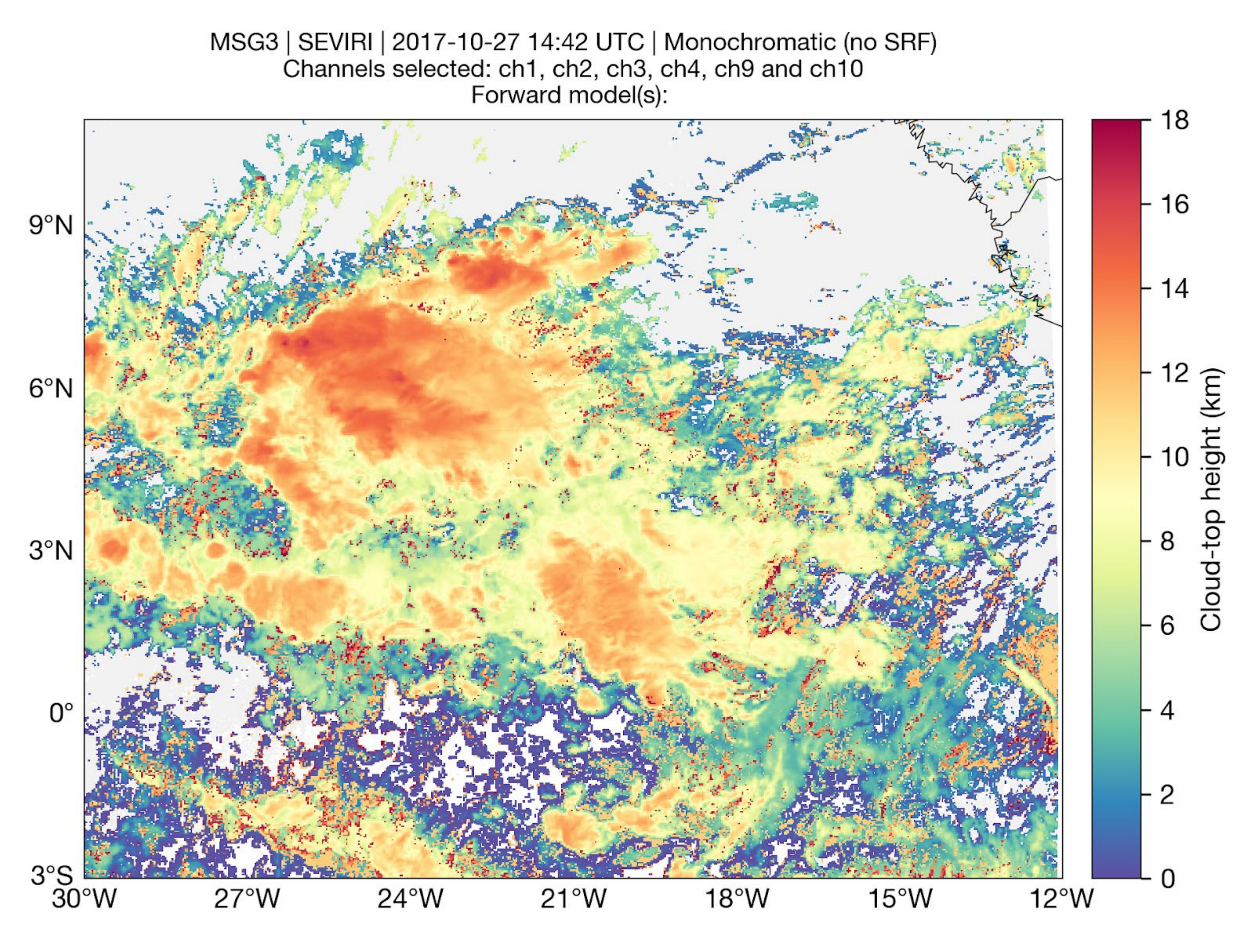
Fixed BT uncertainty.



Variable BT uncertainty.



Varying visible channel noise

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VIS channel noise also a function of signal. This is not yet fully implemented in ORAC.

For instruments without onboard calibration:

$$(\delta \mathrm{R}_X)^2 = \frac{R_x^2}{SNR^2} + 2(\alpha \delta C)^2$$

Where:

δR_x is the noise in terms of reflectance.
R_x is the measured TOA reflectance.
SNR is the signal-to-noise ratio.
α is the radiometric gain value supplied in the L1 data
δC is a constant with value $1 / \sqrt{12}$

NB. Assumes no uncertainty on Solar irradiance.

Effects of calibration choice

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Data from GEO sensors often comes with two sets of calibration coefficients.
Typically:
- One from the satellite operator's ground segment and
- One from GSICS cross-calibration with hyperspectral LEO instruments

Channel	Difference @ 190K	Difference @ 300K
IR_039	1.35K	0.02K
WV_062	-0.47K	-0.12K
WV_073	2.19K	0.01K
IR_087	0.26K	-0.13K
IR_097	0.36K	0.05K
IR_108	0.16K	0.03K
IR_120	0.24K	-0.11K
IR_134	0.12K	-0.04K

Example of 'nominal' to 'GSICS' calibration differences for MSG4 / SEVIRI

Effects of calibration choice

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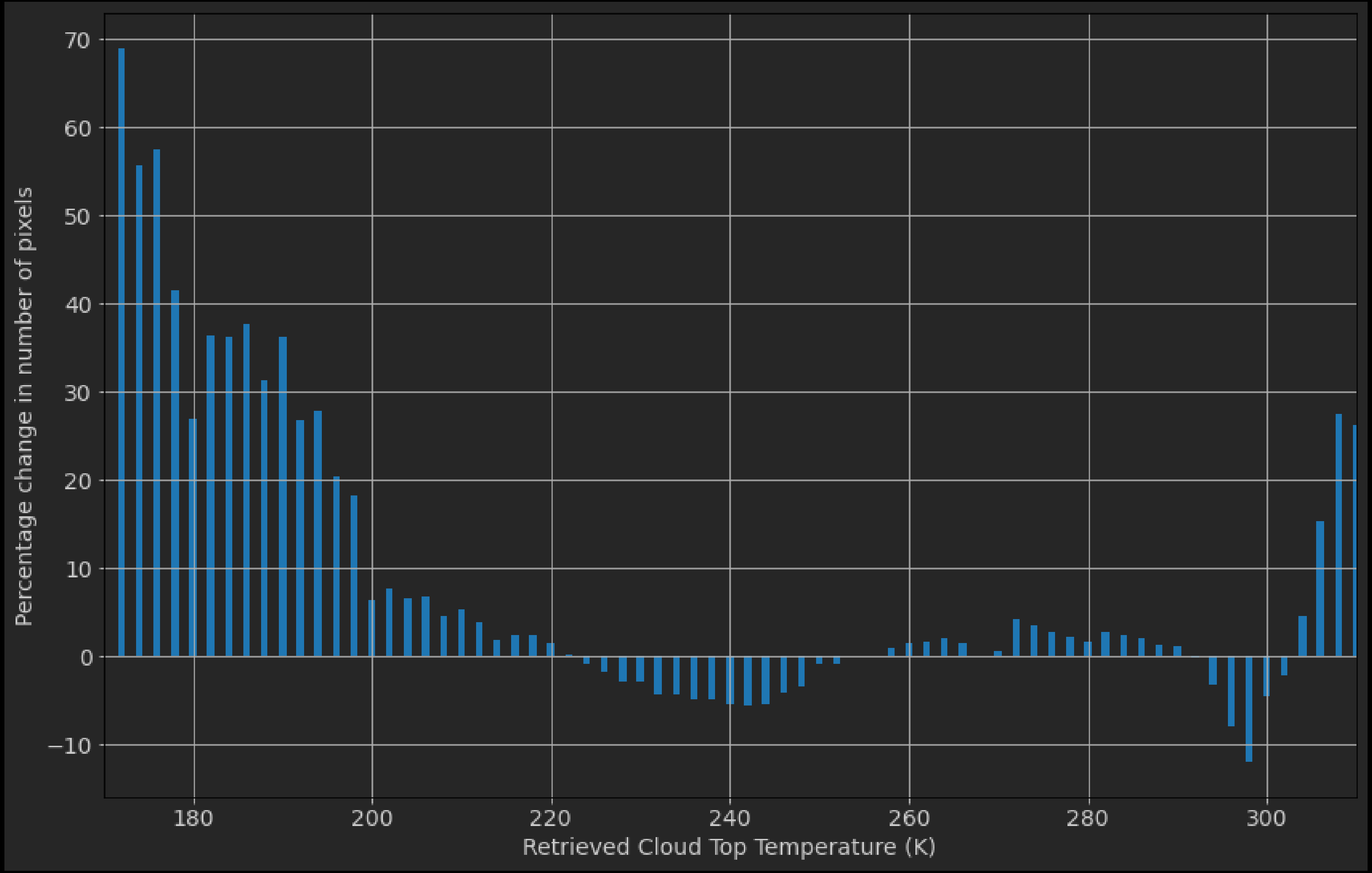
For SEVIRI, the GSICS calibration increases the number of cold (high) clouds and warm (low) clouds while decreasing the number of mid level clouds.



Is this more accurate?

Next step: Comparison to LIDAR cloud top heights.

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Questions?