NWP spatio-temporal configuration for NWC/GEO CTTH

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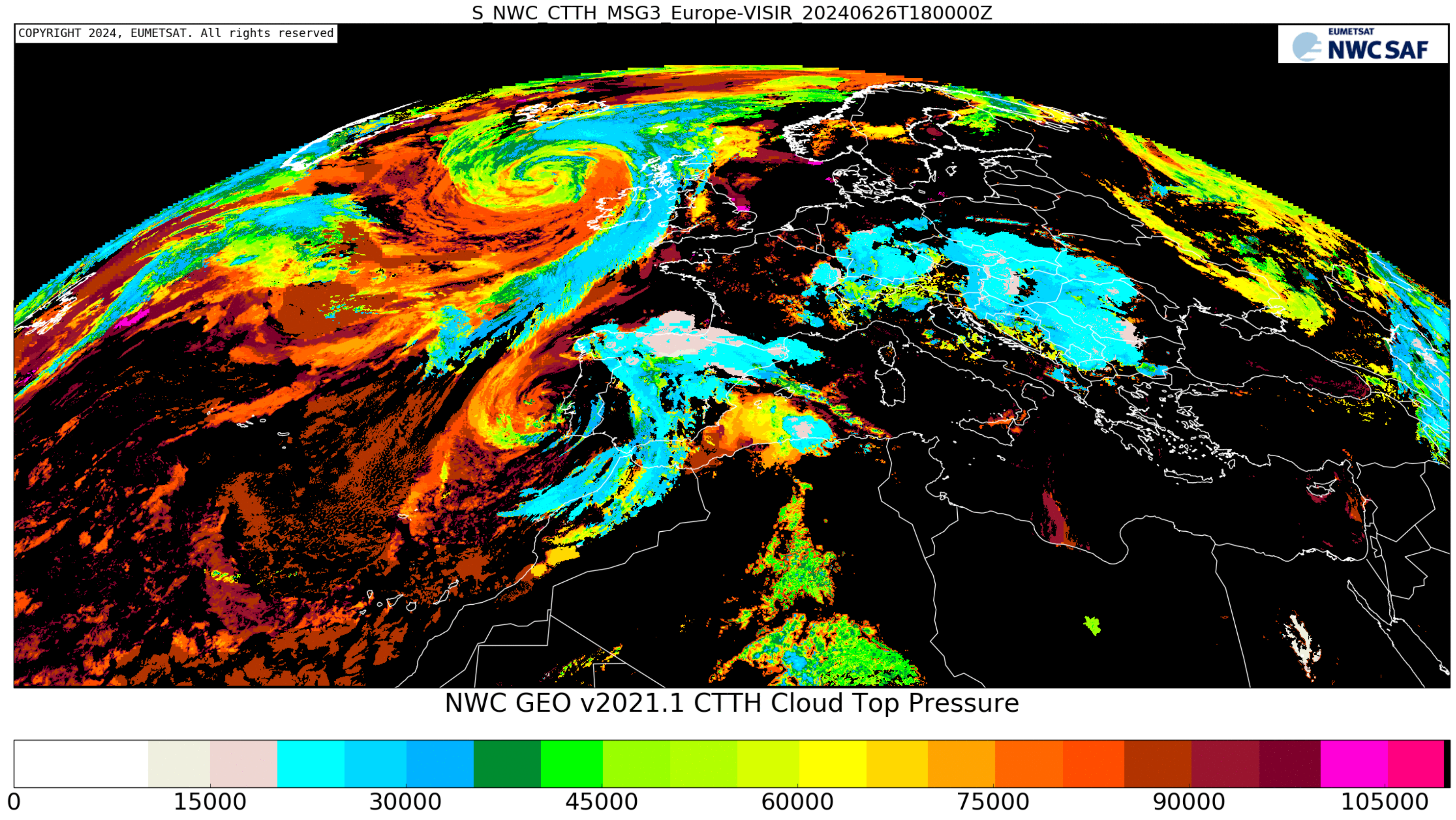
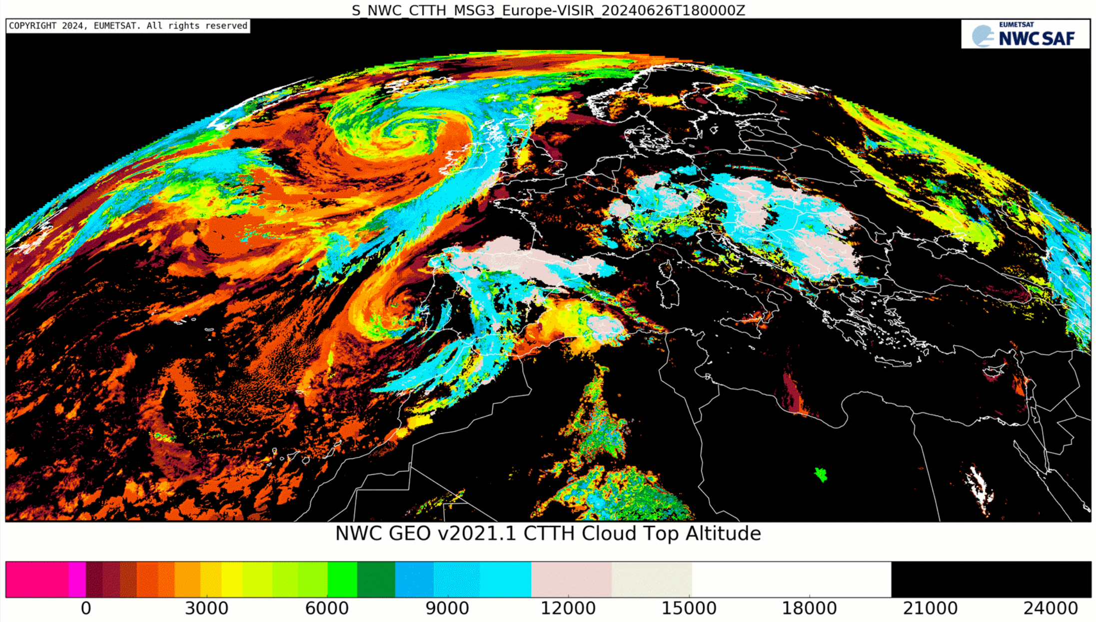
CTTH: Cloud Top Temperature and Height

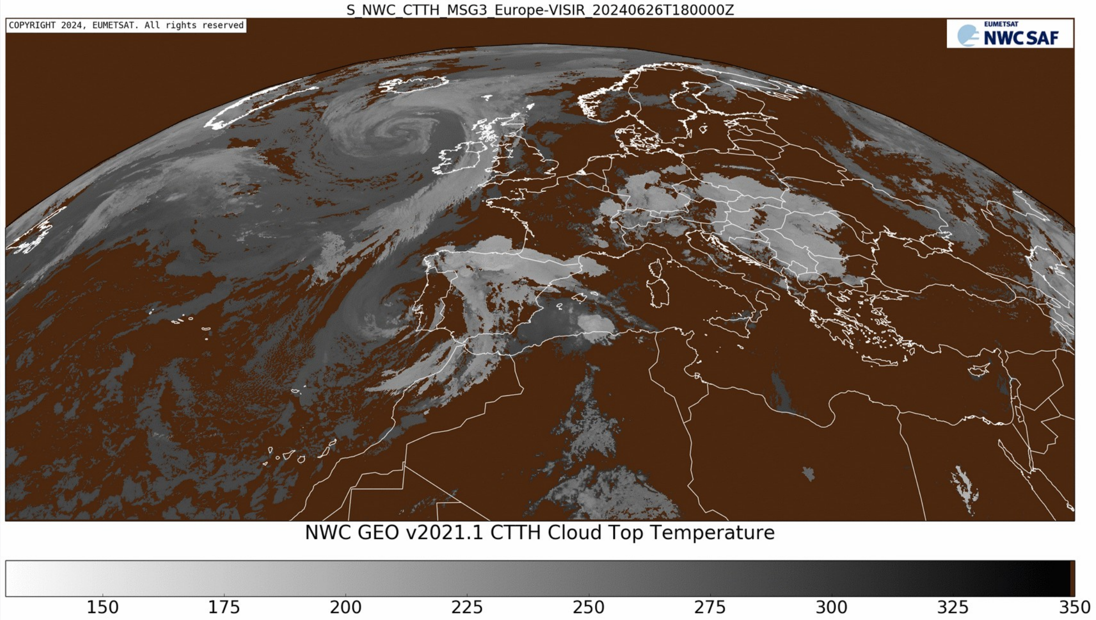


Cloud Top Pressure

Introduction

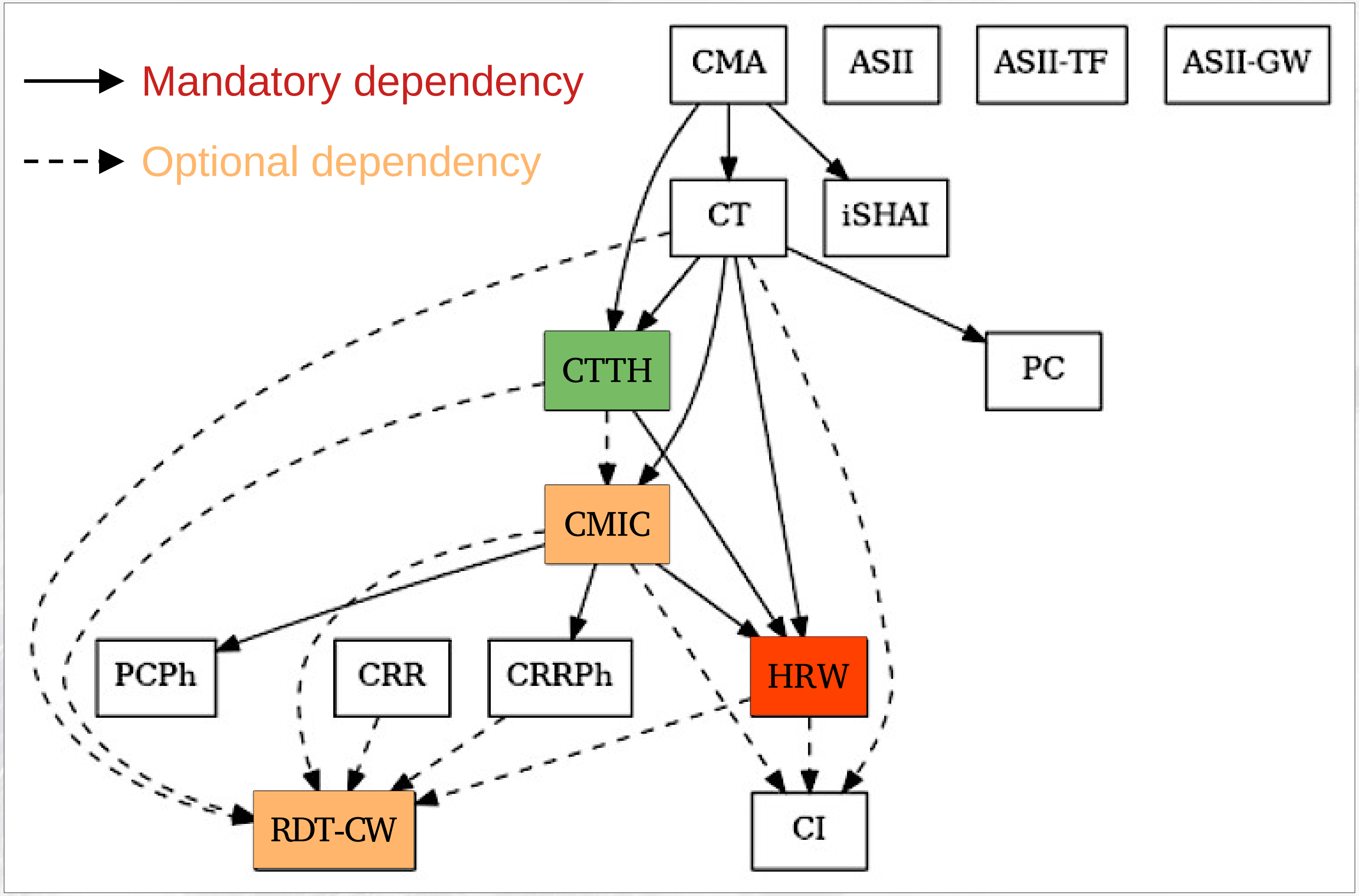


Cloud Top Altitude



Cloud Top Temperature

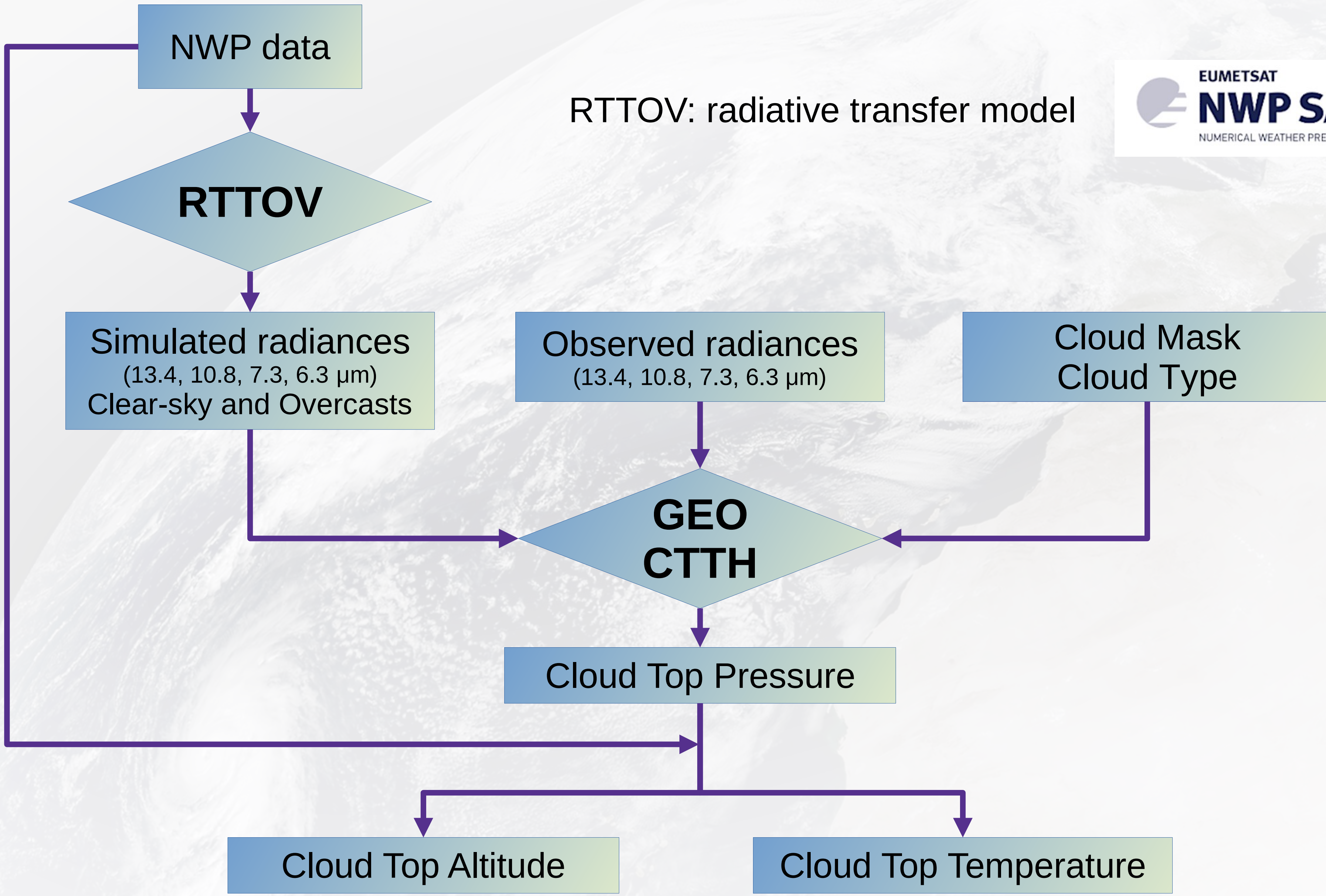
Introduction



CTTH is the 3rd product in the GEO software process. It is **mandatory for High Resolution Wind product (HRW)**, and optional for Cloud Microphysics (CMIC) and Rapid Detecting Thunderstorm – Convection Warning (RDT-CW) products.

Introduction

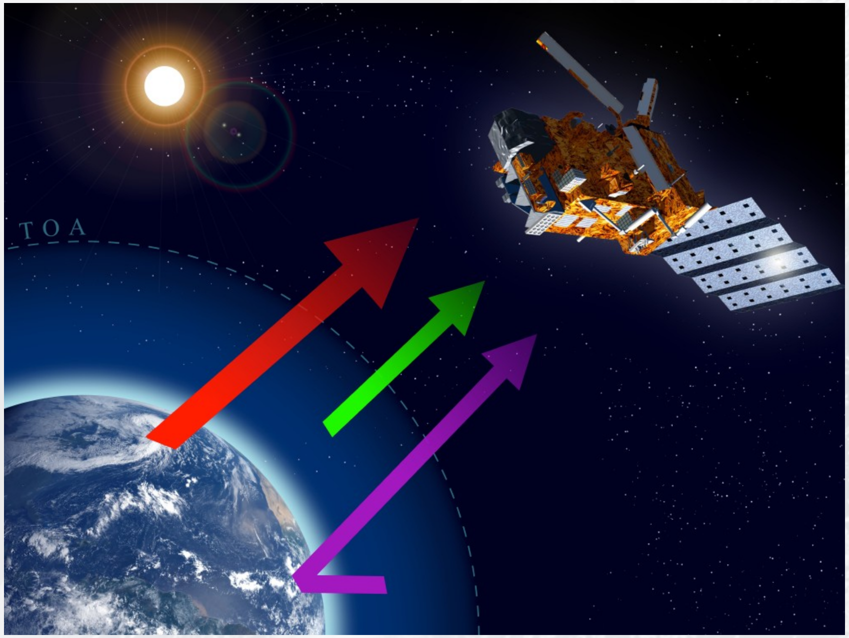
RTTOV: radiative transfer model



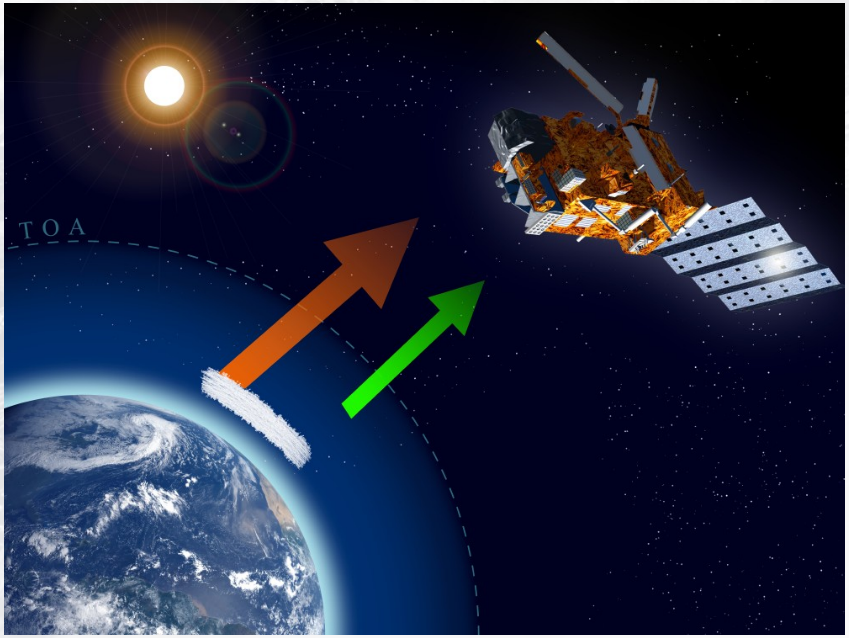
Introduction

RTTOV simulates in particular radiances in **clear sky** and **overcast** conditions.

Clear sky conditions



Overcast conditions



For each NWP level, an overcast simulation is produced by positionning an **opaque cloud** at this level which blocks radiation from the earth's surface and the atmosphere beneath the cloud.

Introduction

nwp_conf_file: configuration file for NWP data used as input

- NWP pressure levels

```
# List of available Pressure Levels in NWP model
# ----------------------------------------------
AV_PRESSURE_LEVELS 10 ,20 ,30 ,50 ,70 ,100 ,150 ,200 ,250, 300, 400, 500, 600, 700, 800, 850, 900, 925, 950, 1000
```

- Temporal frequency of NWP data

```
# Maximum allowed period between slot and NWP forecast validity time
# -----------------------  WARNING!!-----------------------------
# The use of periods greater than 6 hours can produce quality-degraded products
NWP_MFVAL 6
```

To what extent do these parameters have an impact on the CTTH retrieving?

Introduction

Outline

Outline

I --- Introduction

II --- Experiments 1 & 2: NWP vertical resolution

III --- Experiment 3: NWP temporal frequency

IV --- Conclusion

Experiment 1: vertical resolution
Lower top level

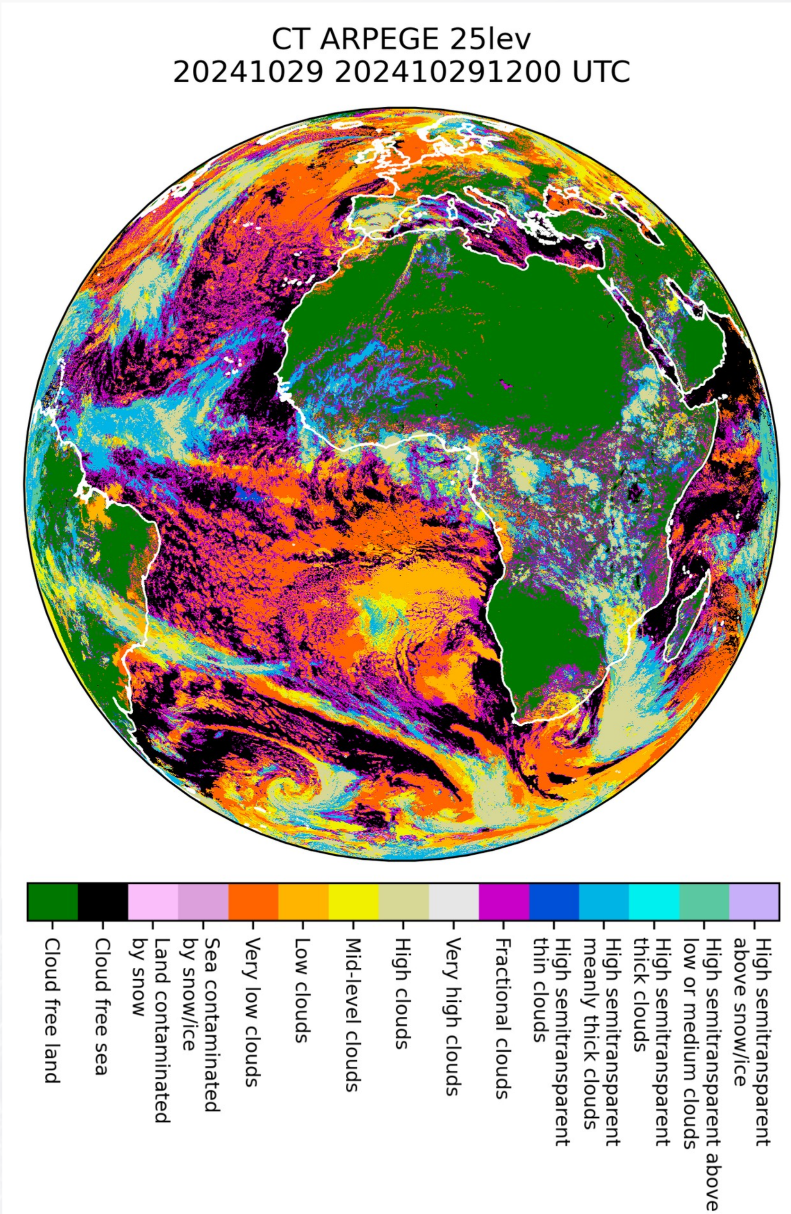
Satellite data: MSG3 for the 29/10/2024 at 1200 UTC
NWP data: ARPEGE 00Z (+12h)

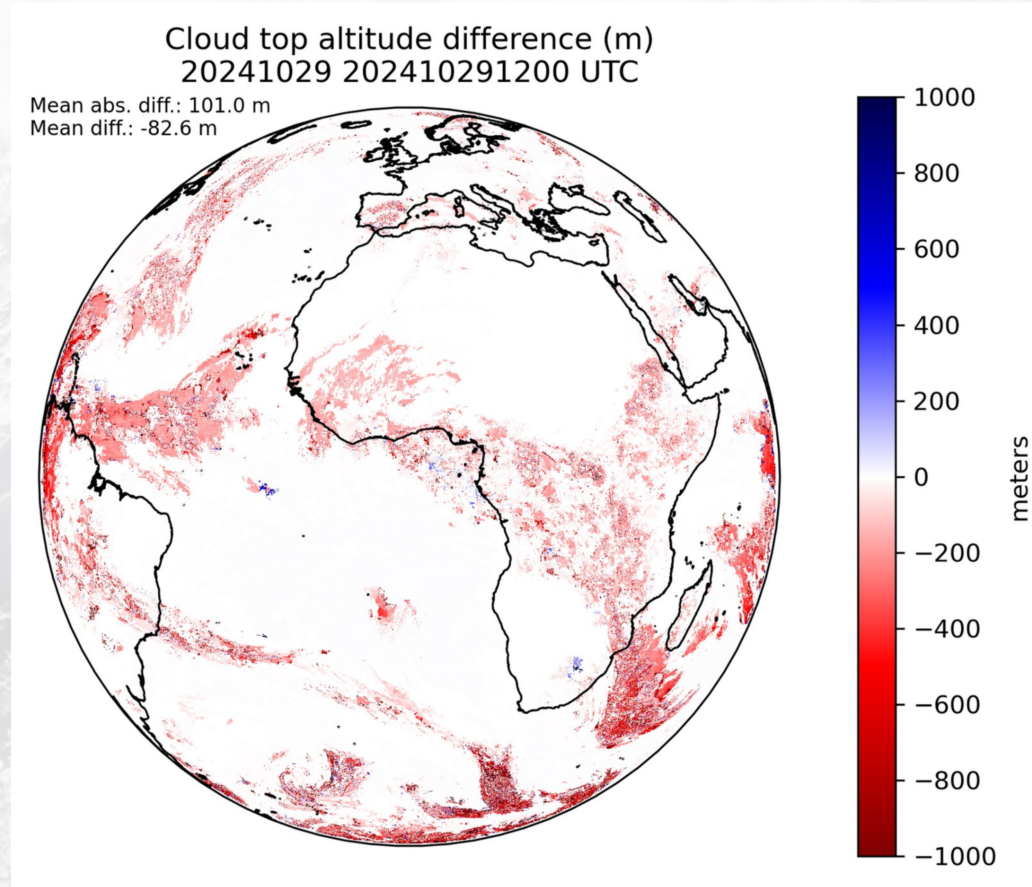
NWP vertical configurations:

- **Reference**
  25 levels (hPa): 1, 2, 3, 5, 7, 10, 20, 30, 50, 70, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 850, 900, 925, 950, 1000

- **Lower top level**
  20 levels (hPa): 1, 2, 3, 5, 7, 10, 20, 30, 50, 70, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 850, 900, 925, 950, 1000

Experiment 1: vertical resolution
Lower top level



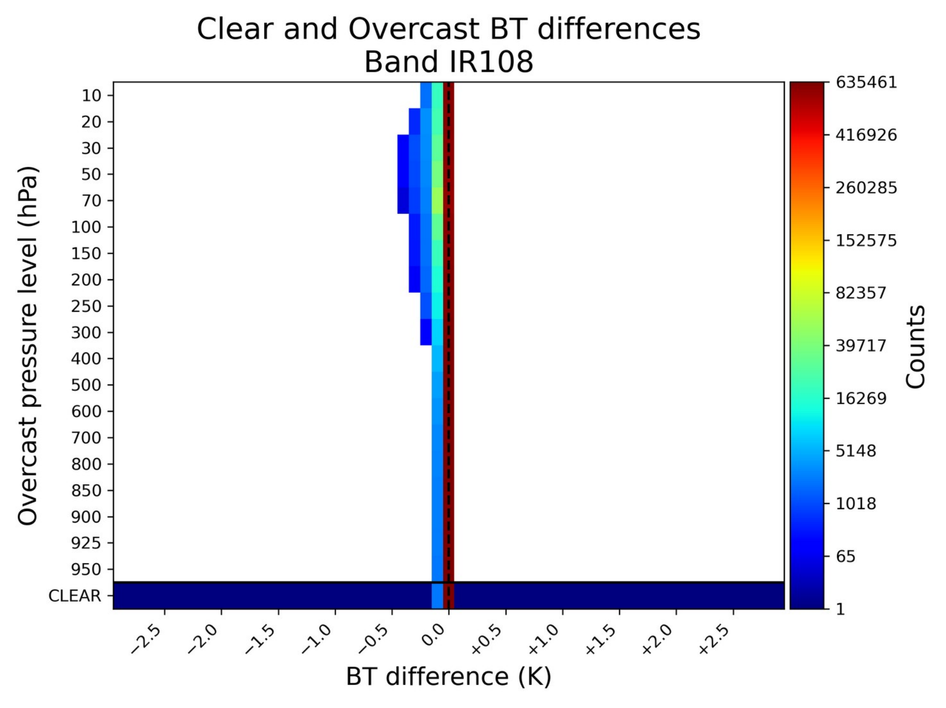


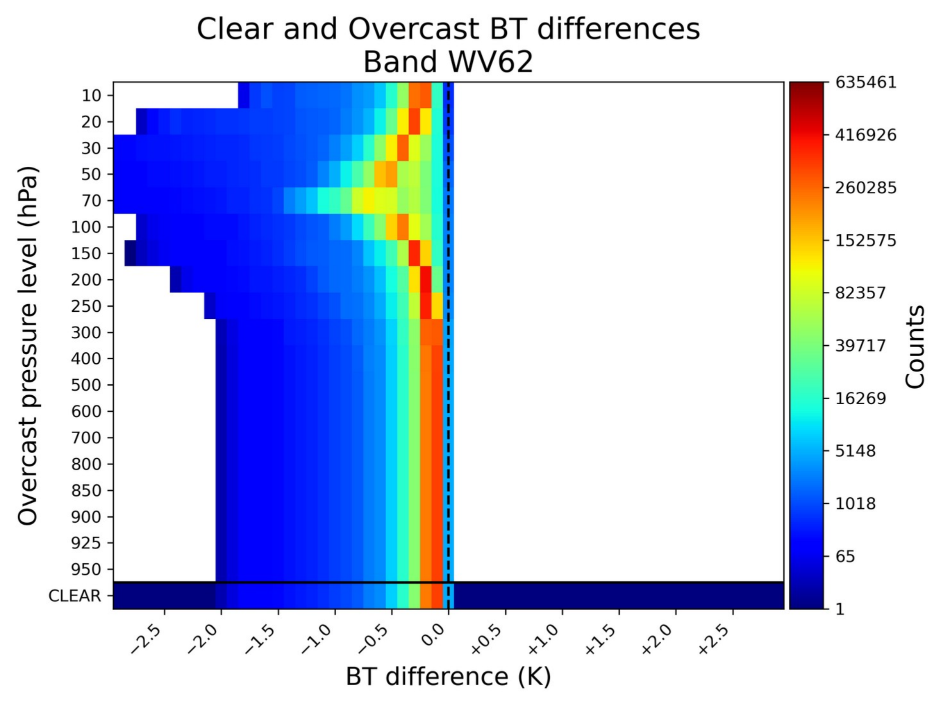
When the highest NWP levels are removed, **altitude of highest clouds** (blueish colors on CT) **is systematically underestimated** (reddish colors on difference). Almost no impact on mid-level and low opaque clouds.

Experiment 1: vertical resolution
Lower top level

Methods used for estimating the altitude of high semi-transparent clouds are based on the comparison of observed radiances with simulated radiances in **clear** and cloudy (**overcast**) conditions in **2 channels** (IR108 and a sounding channel).

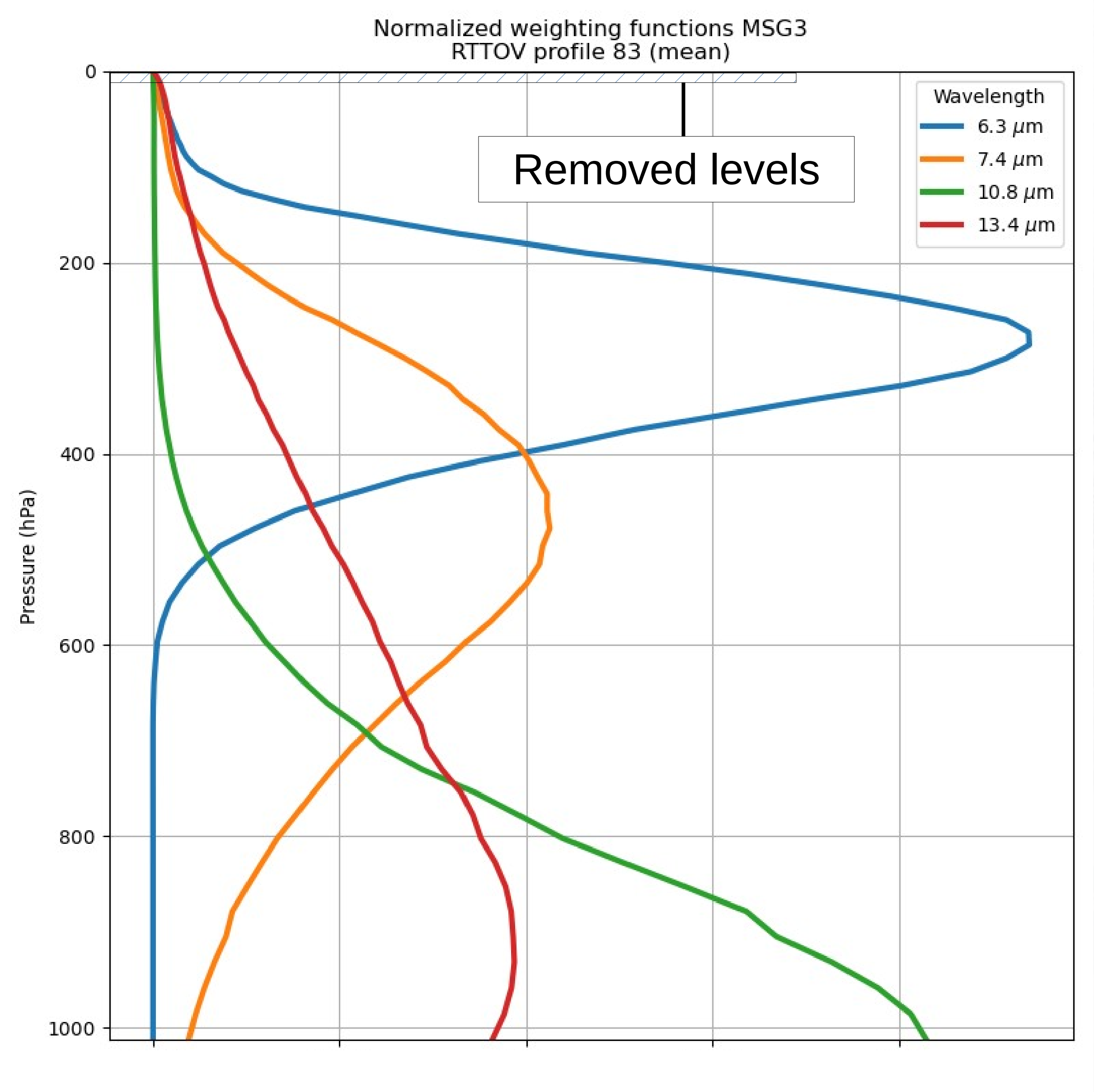
BT differences: 20 levels (lower top level) − 25 levels (reference)





When highest NWP levels are removed, almost no impact on simulated BT in window channels (IR108) but **cold bias in sounding channels** (WV62, WV73 and IR134) especially around 50 / 100 hPa.

Experiment 1: vertical resolution
Lower top level

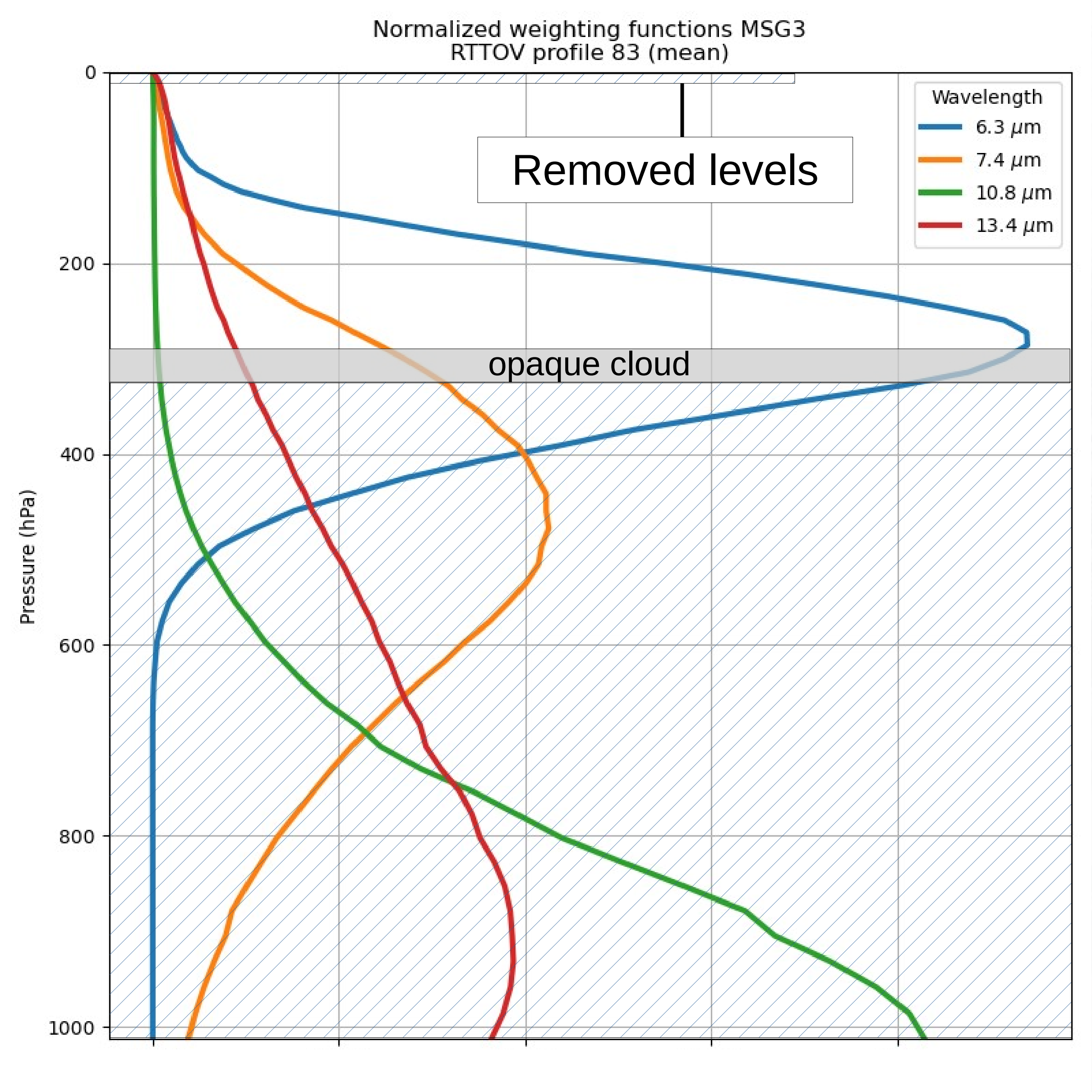


The behaviors of overcast biases can be explained thanks to the weighting functions of the MSG channels for clear sky.

- The removed levels have almost **no weight in IR108**.

Experiment 1: vertical resolution

Lower top level



The behaviors of overcast biases can be explained thanks to the weighting functions of the MSG channels for clear sky.

- The removed levels have almost **no weight in IR108**.
- In the other channels, their weight are very low but **their relative contribution increase when adding an opaque cloud** (overcast simulation). The higher the cloud, the greater the relative contribution of the highest levels.

The different behaviors in sounding and windows channels are responsible for altitude biases of high semi-transparent clouds when highest levels are removed.

Experiment 2: vertical resolution
Coarser resolution near the surface

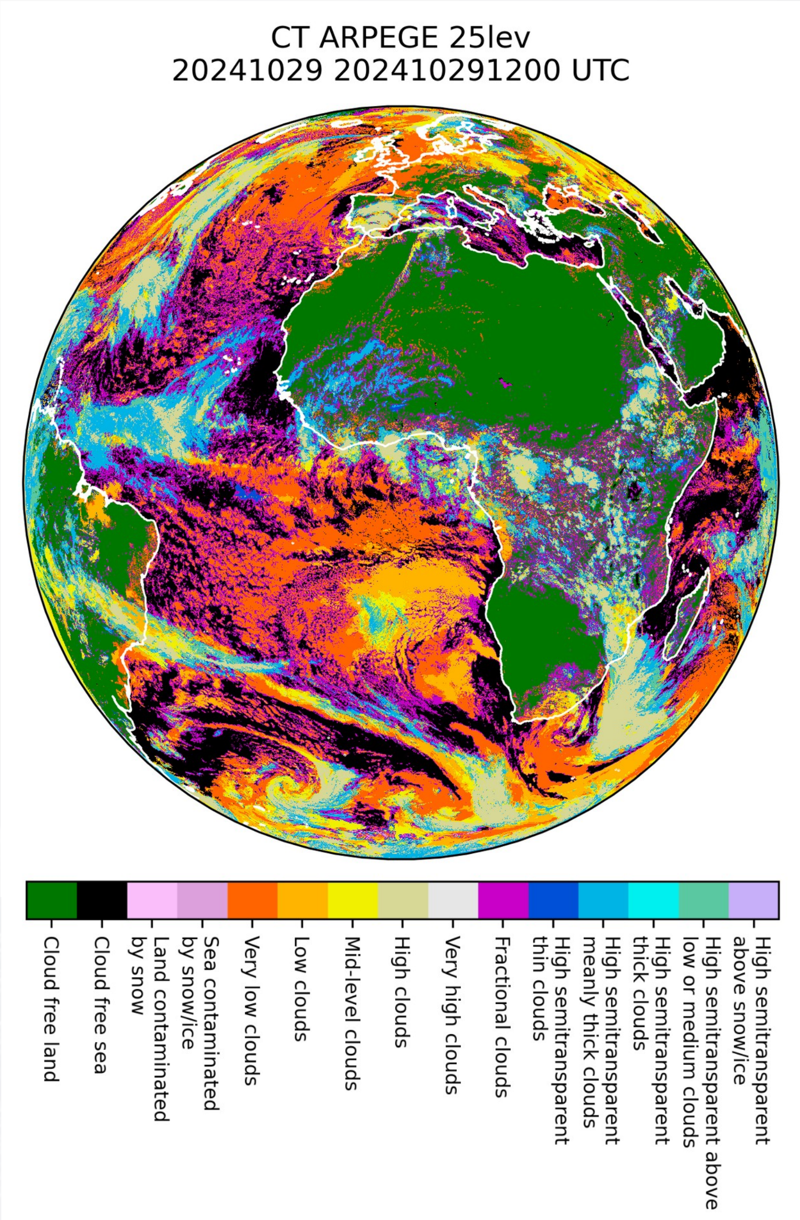
Satellite data: MSG3 for the 29/10/2024 at 1200 UTC
NWP data: ARPEGE 00Z (+12h)

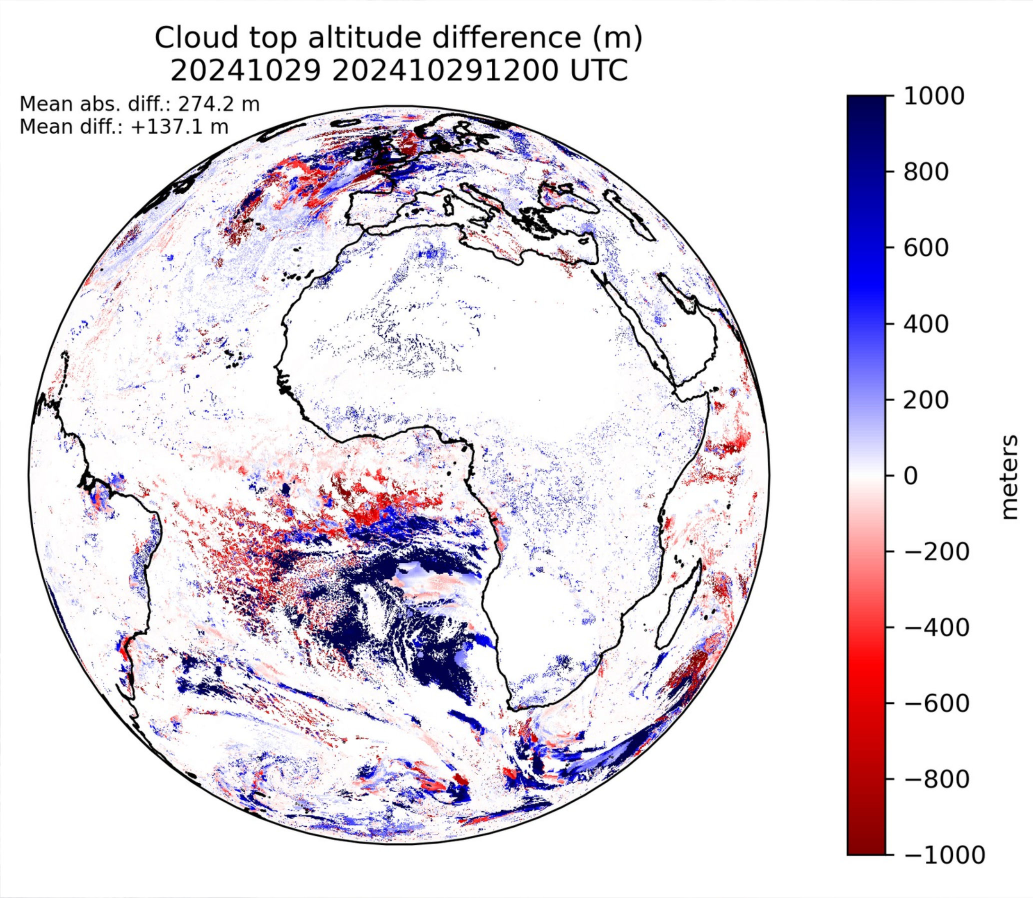
NWP vertical configurations:

- **Reference**
  25 levels (hPa): 1, 2, 3, 5, 7, 10, 20, 30, 50, 70, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 850, 900, 925, 950, 1000
- **Coarser resolution near the surface**
  21 levels (hPa): 1, 2, 3, 5, 7, 10, 20, 30, 50, 70, 100, 150, 200, 250, 300, 400, 500, 600, 700, 800, 850, 900, 925, 950, 1000

Experiment 2: vertical resolution

Coarser resolution near the surface

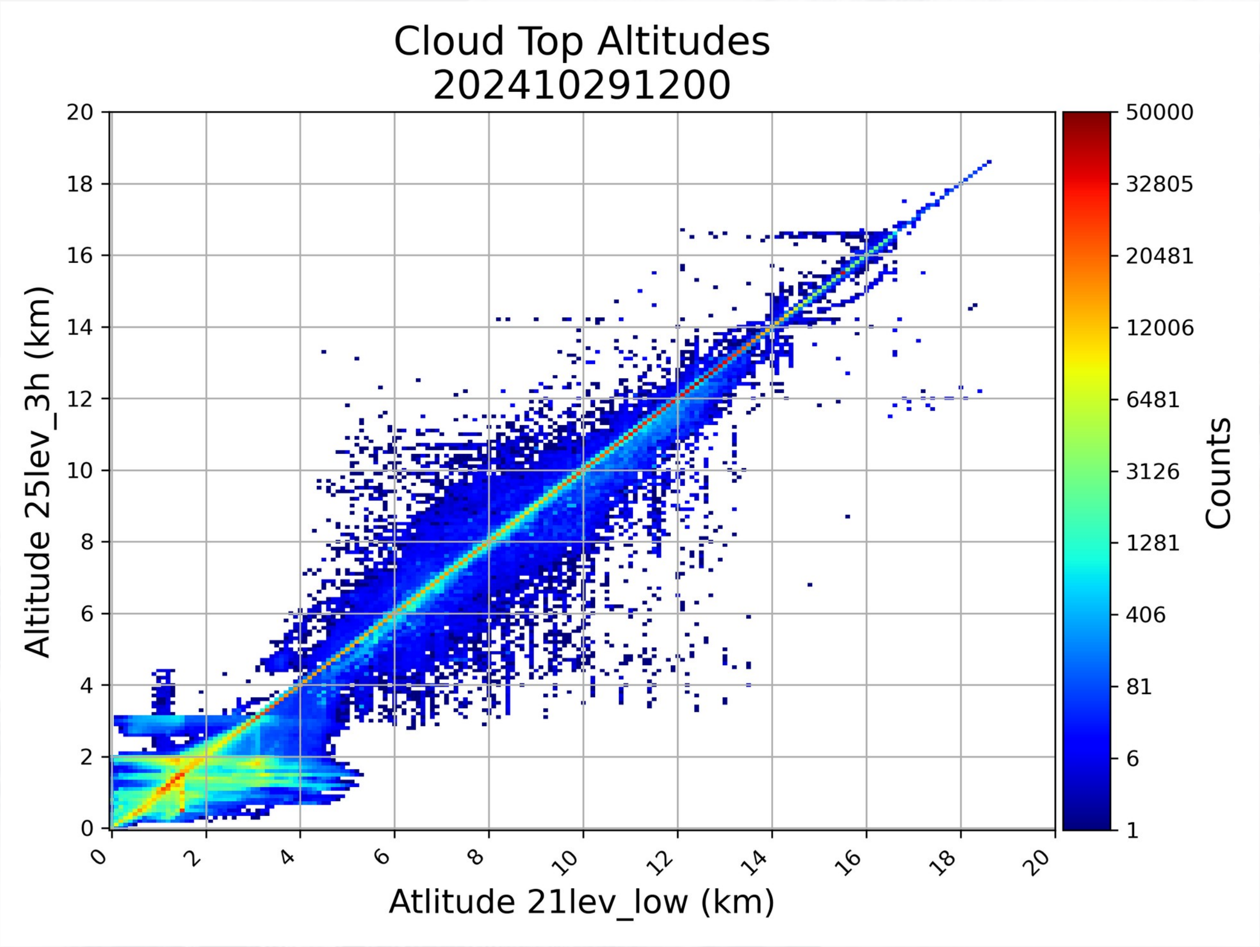




Most of the differences concern low clouds. Cloud top altitudes are generally overestimated.

Experiment 2: vertical resolution

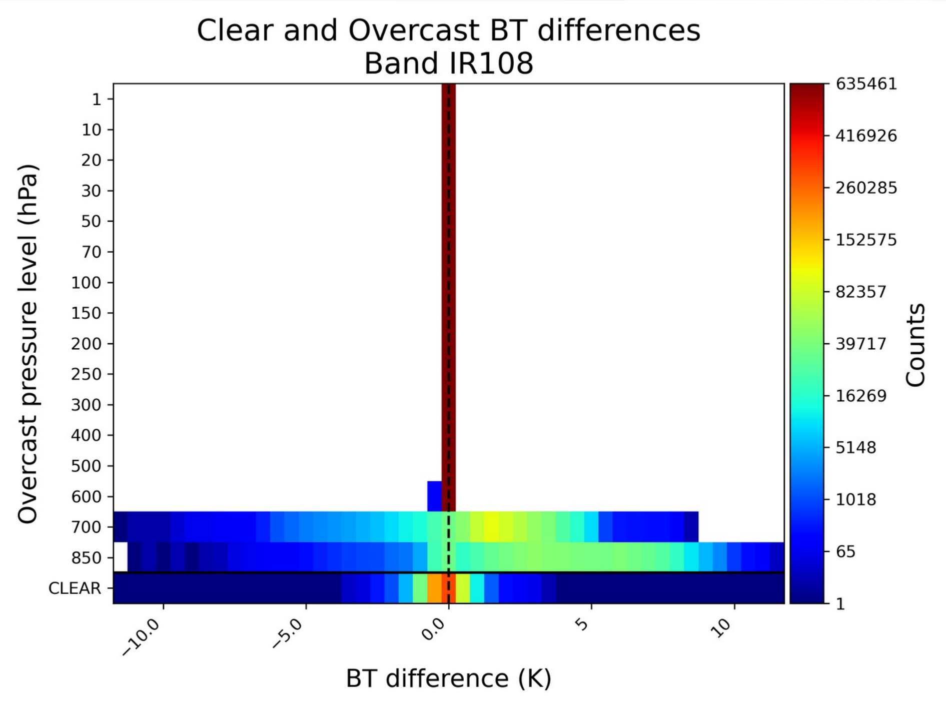
Coarser resolution near the surface

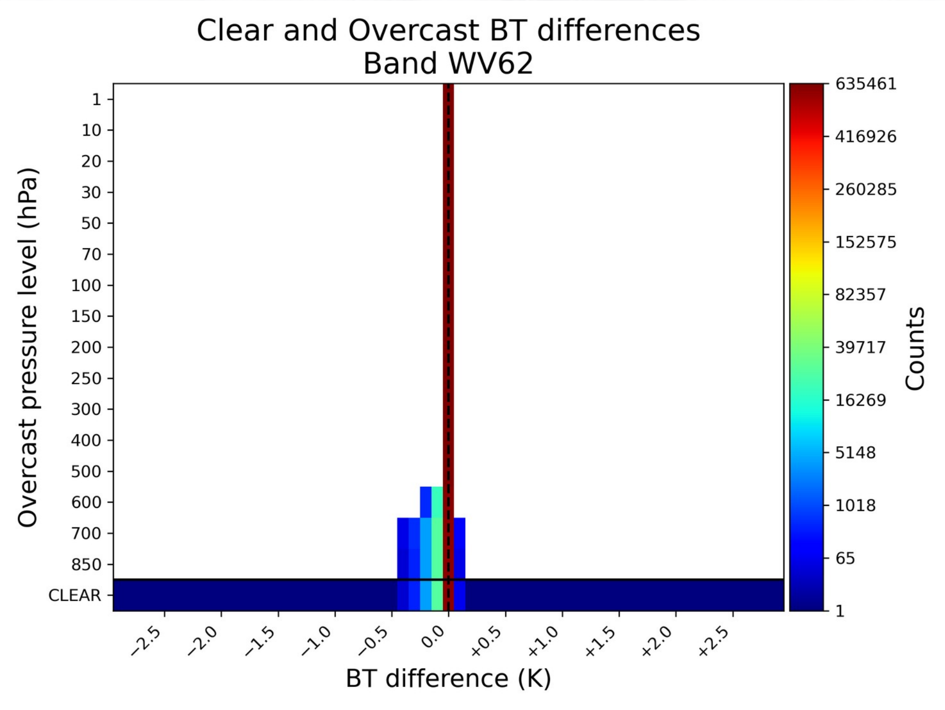


Most of the differences concern clouds below 3000 m (~700 hPa), where some NWP levels have been removed.

Experiment 2: vertical resolution
Coarser resolution near the surface

BT differences: 21 levels (coarser resolution near the surface) − 25 levels (reference)



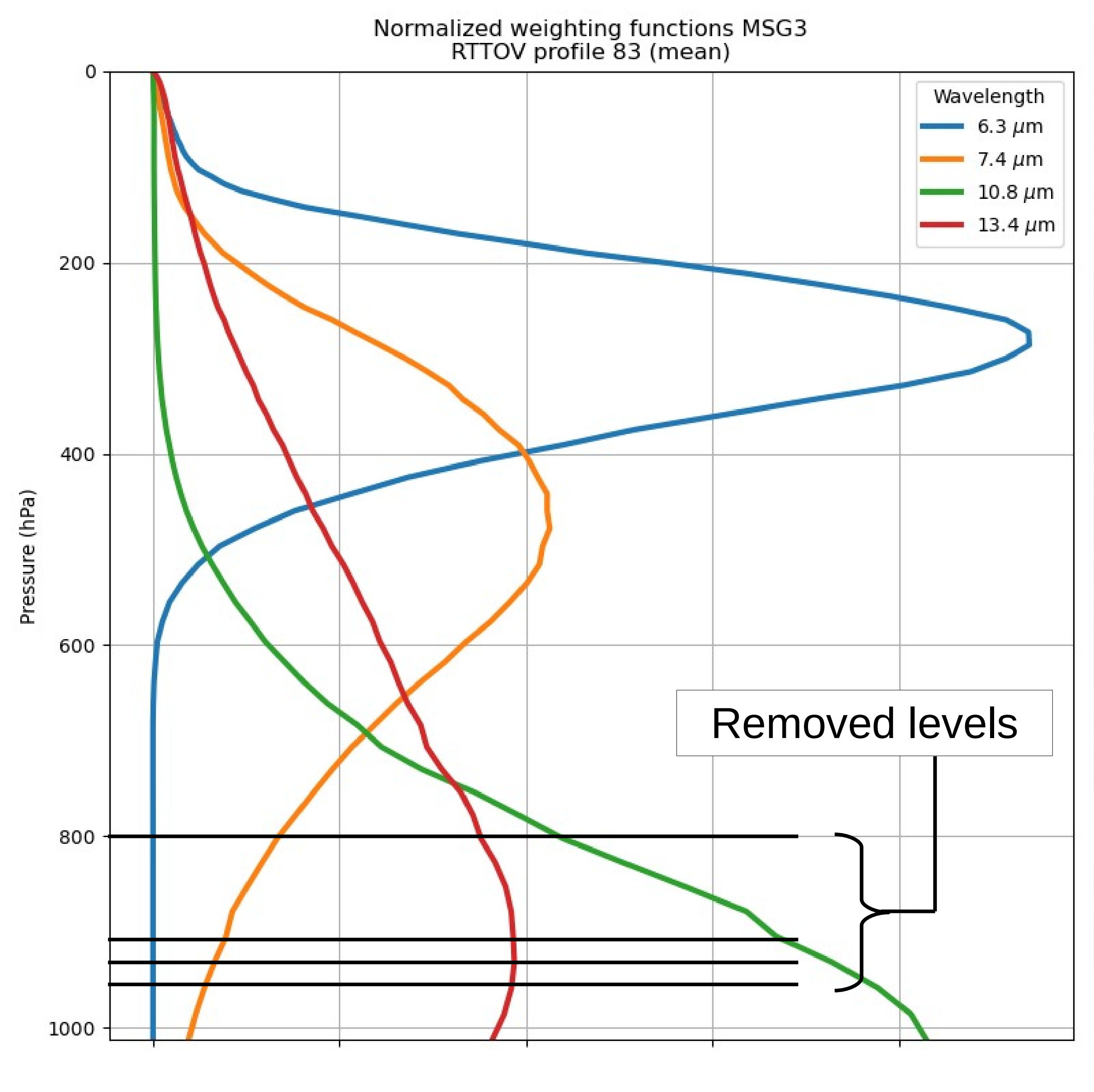


When some low levels are removed, almost no impact on WV62, but moderate cold bias on lower levels of WV73 (not shown) and **significant warm bias on lower levels of IR134 (not shown) and IR108**.

The altitude biases observed for high clouds are due to the biases in clear sky radiance simulations.

Experiment 2: vertical resolution

Coarser resolution near the surface

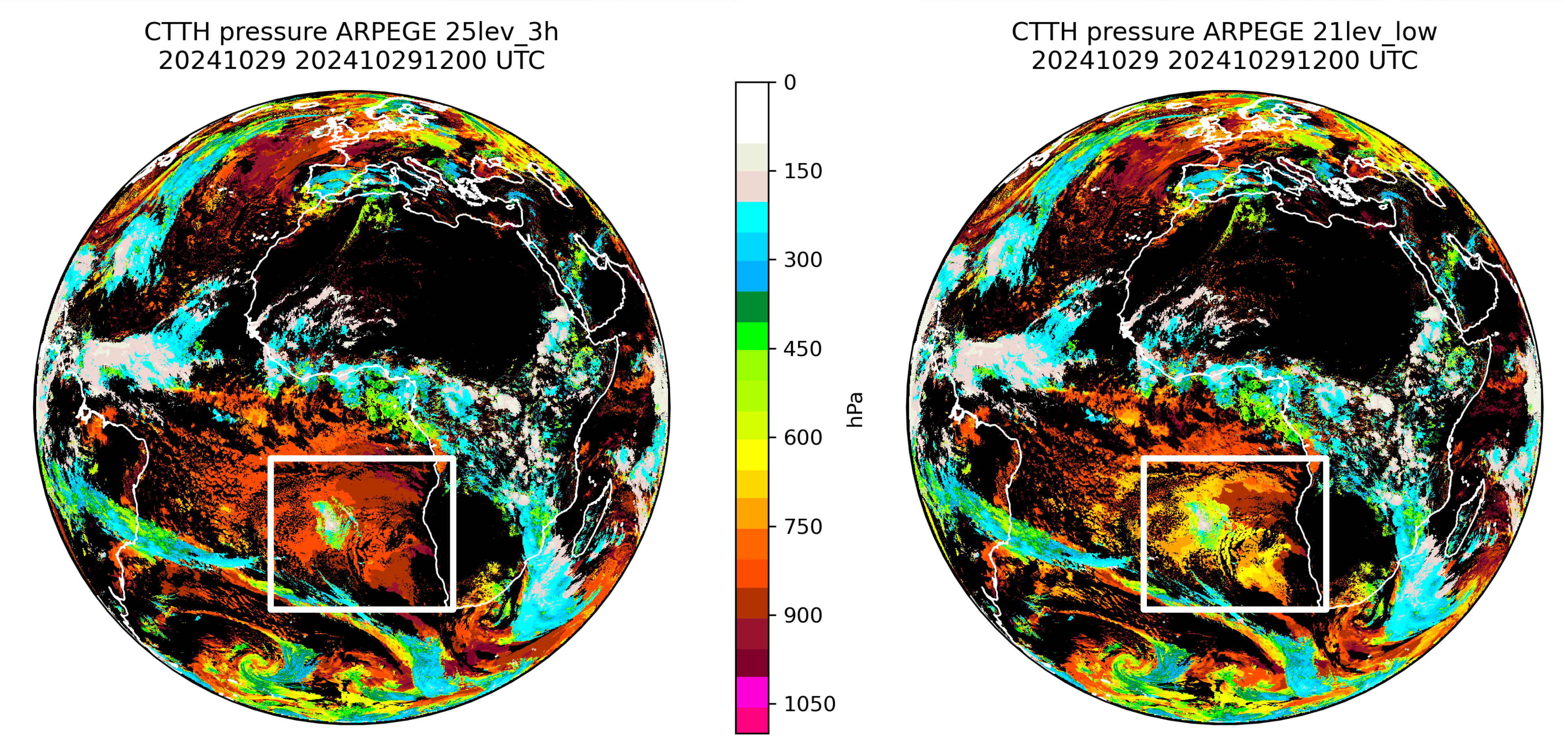


The behaviors of overcast biases can be explained thanks to the weighting functions of the MSG channels for clear sky.

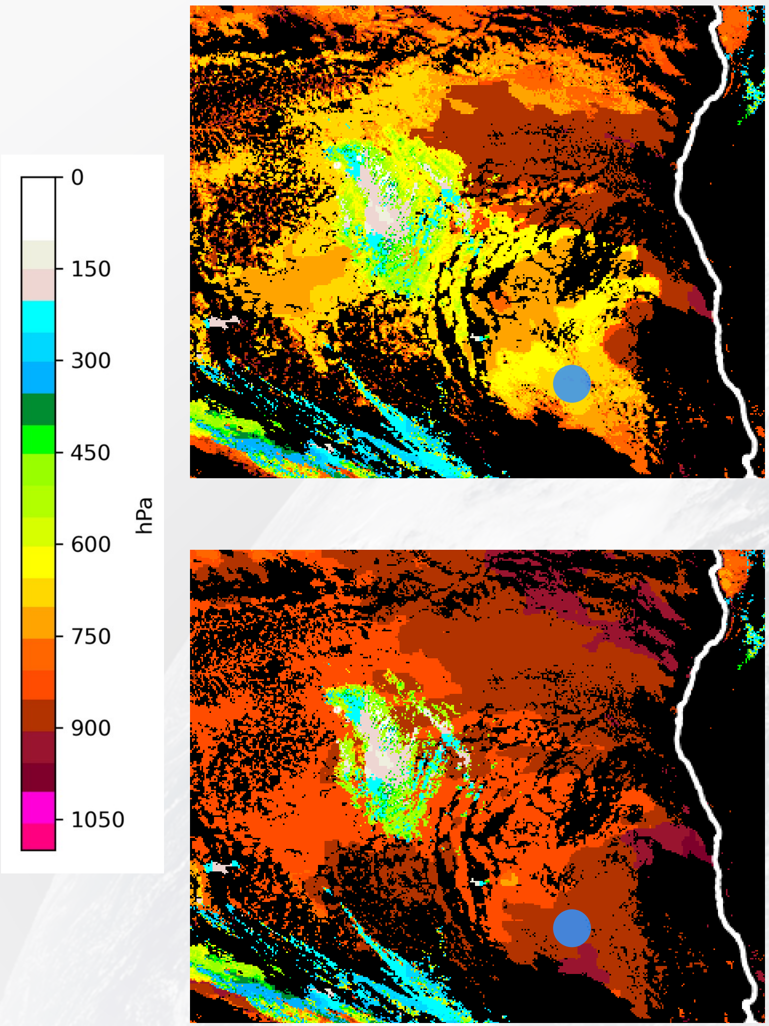
- The removed levels have almost **no weight in WV63**.
- In the other channels, **their weight are very significant**, especially for IR108 and IR134.

Experiment 2: vertical resolution

Coarser resolution near the surface

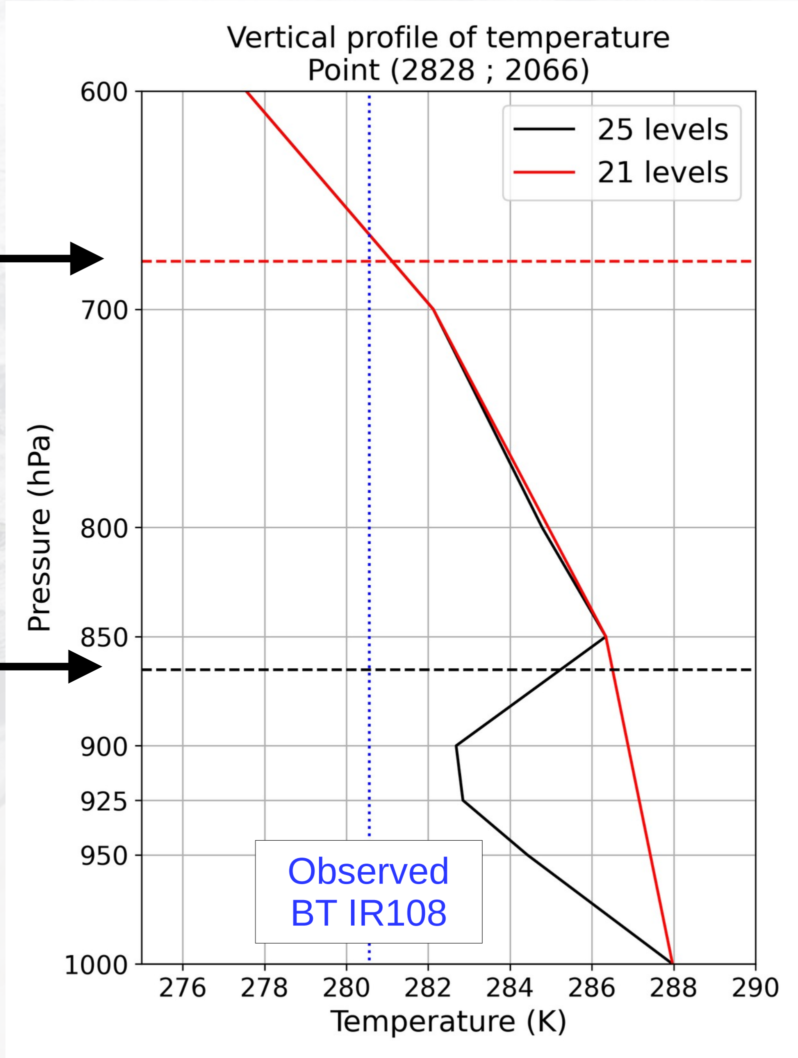


Experiment 2: vertical resolution
Coarser resolution near the surface



Cloud Top Pressure
21 levels: 678 hPa

Cloud Top Pressure
25 levels: 865 hPa



With a coarser vertical resolution near the surface, thermal inversions can be fully missed, leading to an overestimation of the cloud top altitude.

Introduction

Outline

Experiment 3: temporal resolution

Satellite data: MSG3 for the 29/10/2024 between 0600 and 1800 UTC
NWP data: ARPEGE 00Z (+6 to +18h)

2 NWP temporal configurations:

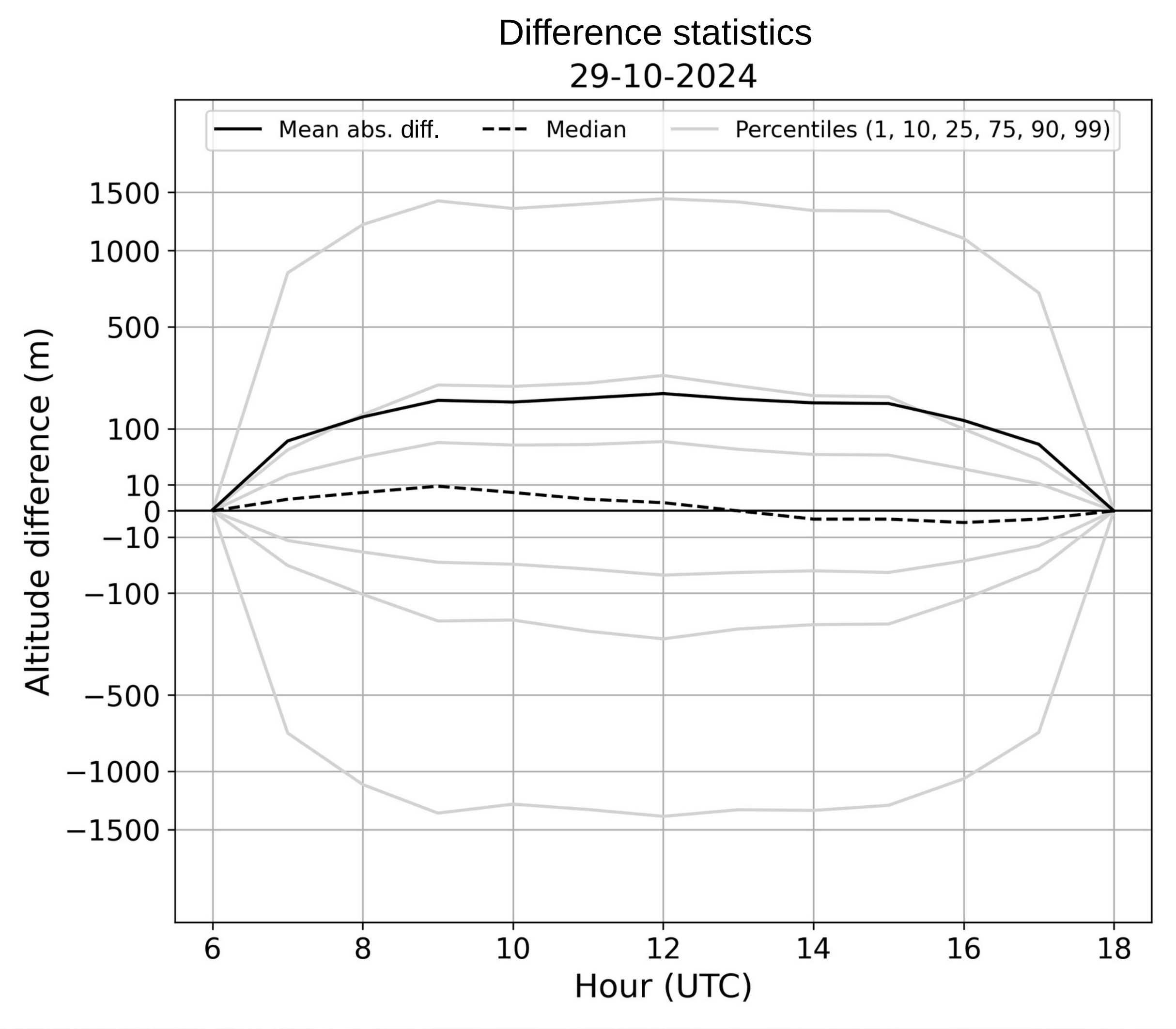
- **Reference**
  3-hour time step resolution: +6, +9, +12, +15 and +18h forecasts

- **12-hour time step resolution**: +6 and +18h forecasts

In GEO software, NWP data are temporally interpolated to the time slot.

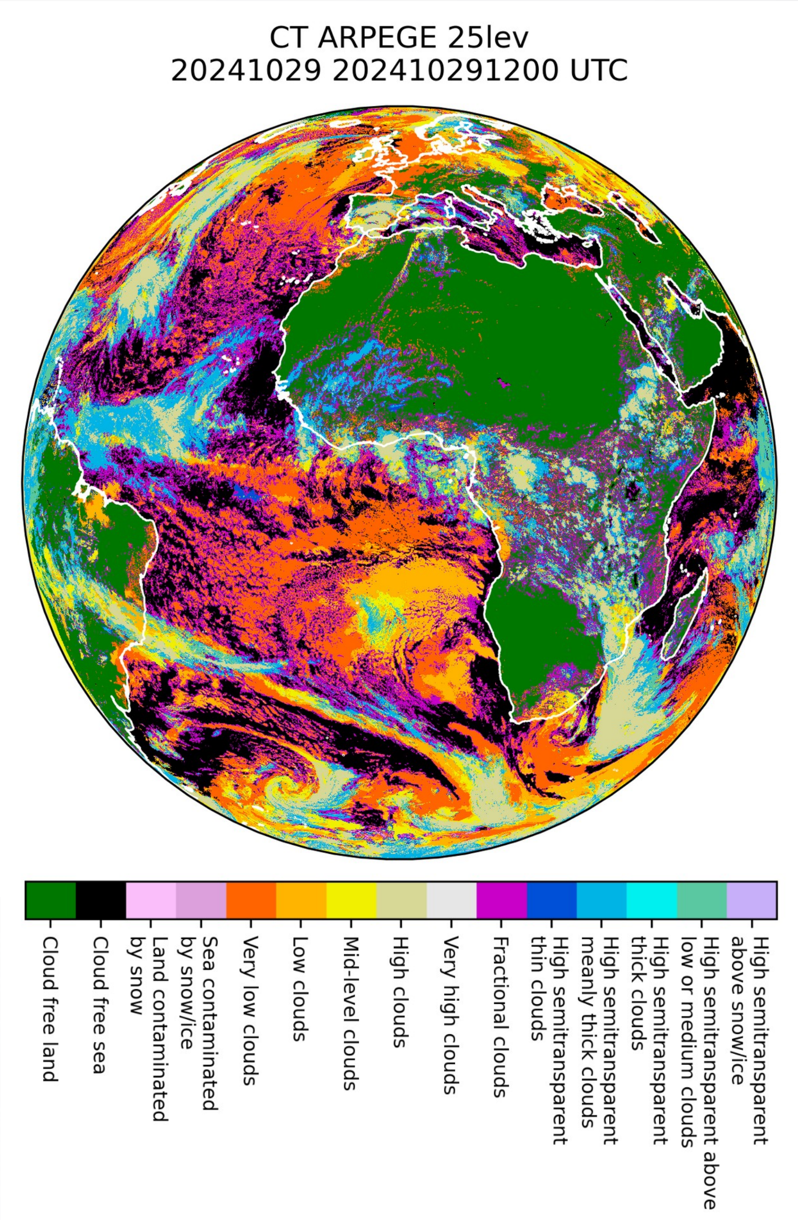
Experiment 3: temporal resolution

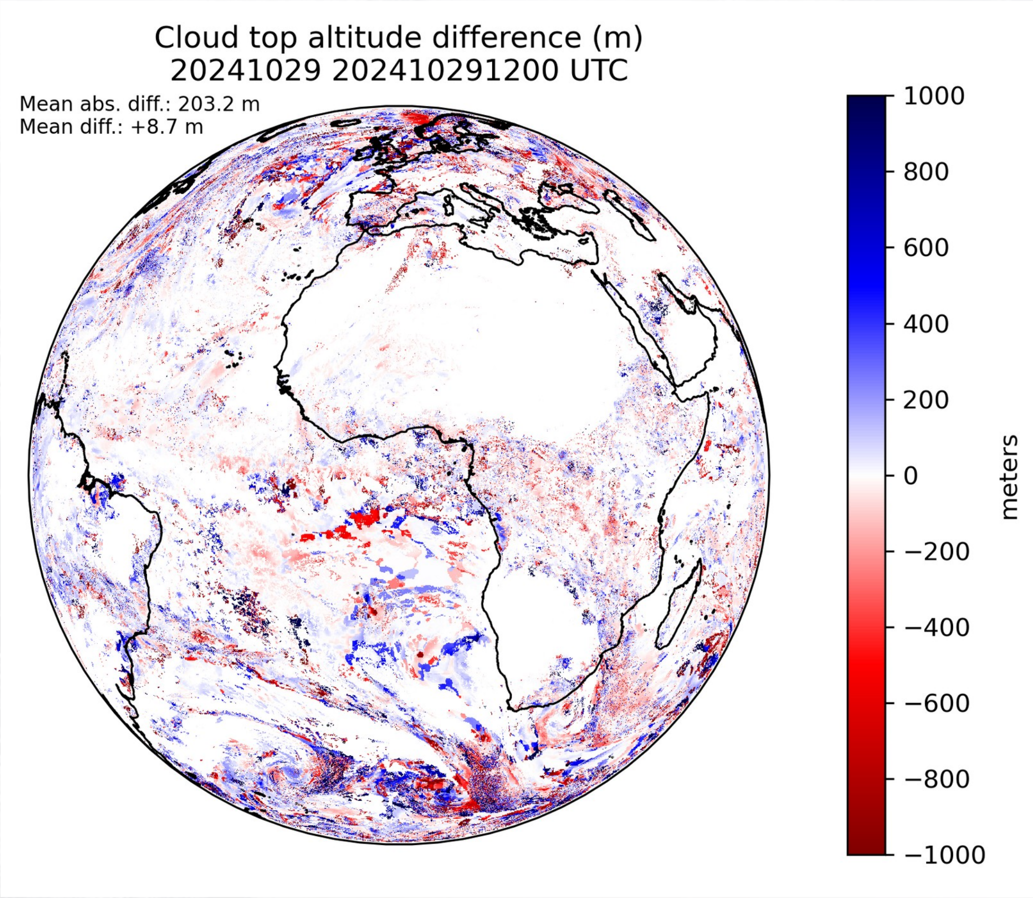
12-hour time step resolution



- Differences increase rapidly when we are away of the NWP output times.
- Differences are strongest at the middle of the period separating the NWP outputs (12 UTC).
- Mean of absolute differences reaches 200 meters at 12 UTC.

Experiment 3: temporal resolution
12-hour time step resolution





Differences affect all areas but seem a bit stronger in higher latitudes.

Outline

Conclusion

CTTH is a **data fusion product** in which NWP data play a key role.

To reduce the computation time when running GEO software operationnally or over a large amount of data, it could be necessary to reduce the **spatio-temporal resolution of NWP data**. Before doing that, keep in mind that:

- removing higher NWP levels (even well beyond the tropopause!) has a significant impact on the cloud top altitude retrieved for **semi-transparent clouds**.
- a low vertical resolution of NWP data close to the surface (< 700 hPa) can largely modify the cloud top altitude estimation of **low clouds** in particular because of the poor representation of thermal inversions.
- degrading temporal resolution of NWP data impacts all cloud top altitudes retrieved, especially in **areas where the spatio-temporal variability of vertical profiles is significant** (mid and high latitudes)
- CTTH is used as **input for HRW, CMIC and RDT-CW** products.

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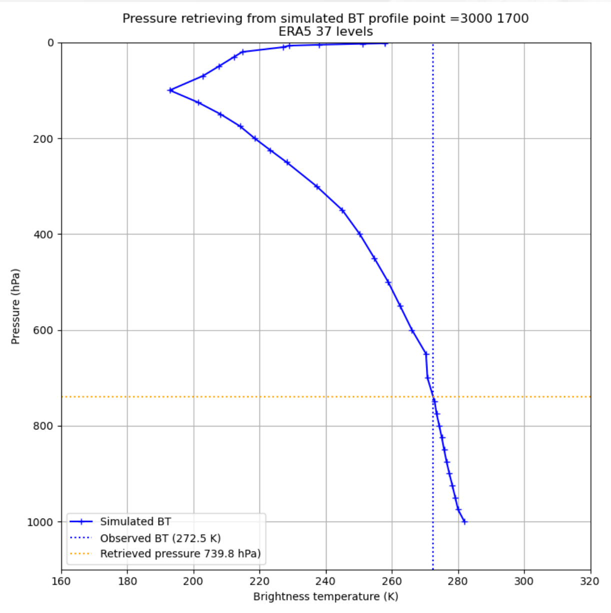
CTTH retrieving methods

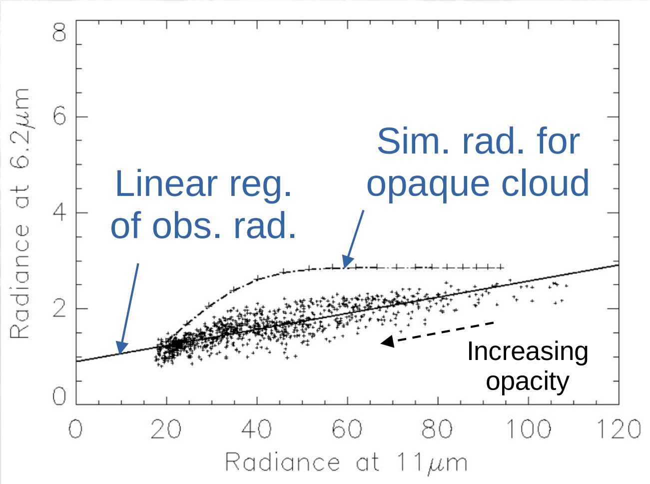
3 different methods are used when RTTOV simulations are available:

- **Intercept between IR108 brightness temperature and simulated overcast BT profile**:



for very low, low and mid-level clouds (CT 5 to 7), and for high and very high clouds (CT 8 and 9) if no result with radiance ratioing technique

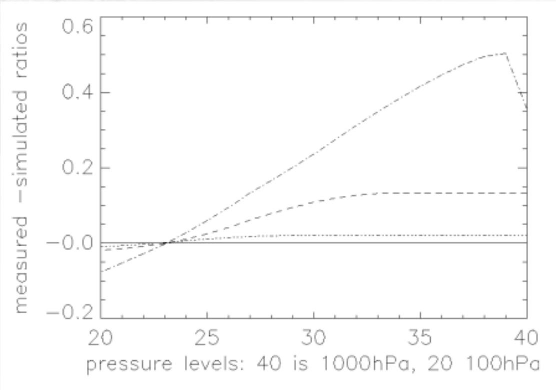
- **Intercept method between IR108 and a sounding channel** (IR134, WV062 or WV073) (Schmetz et al., 1993)



for semi-transparent clouds (CT 11 to 15)

- **Radiance radioing technique** (Menzel et al., 1983)

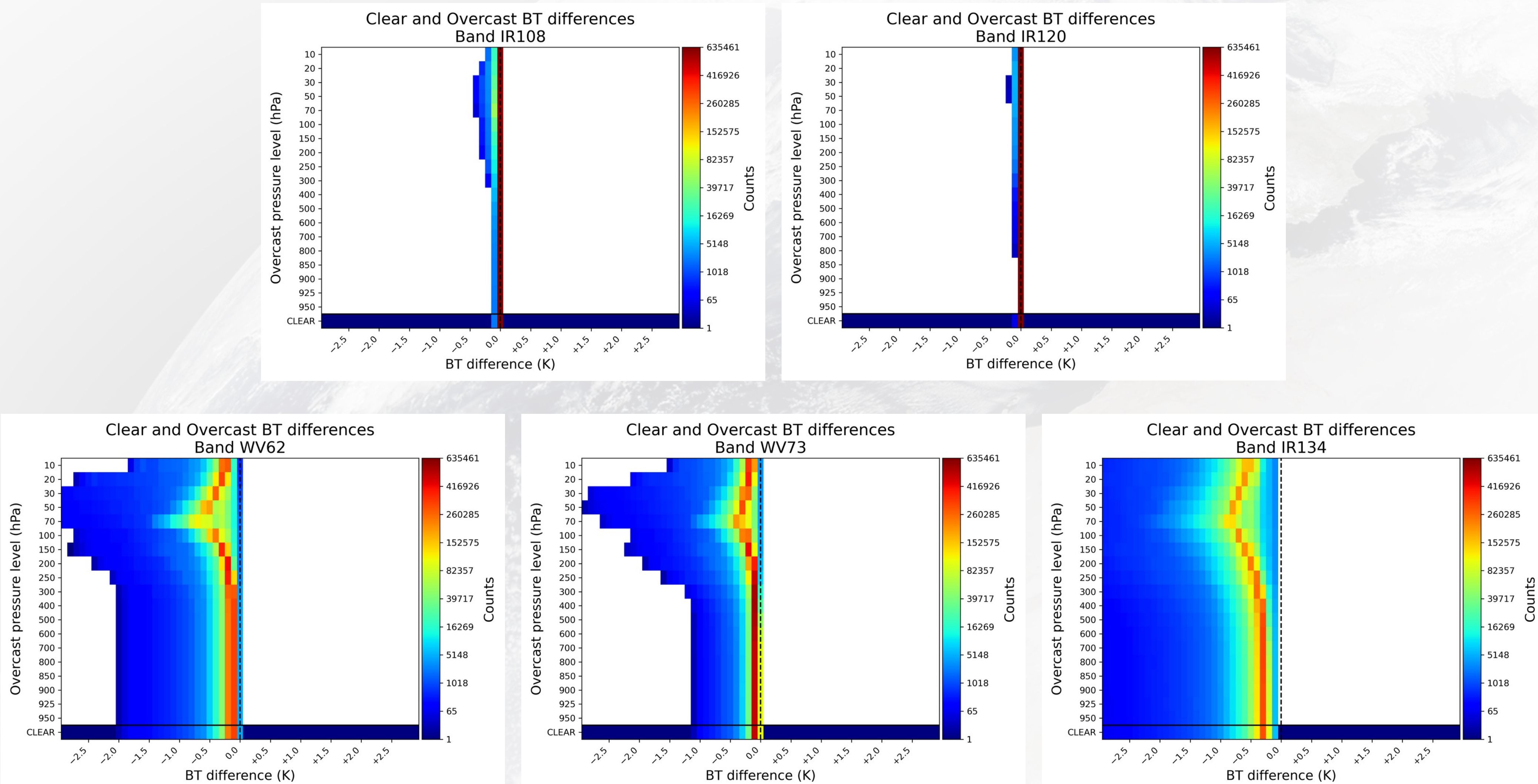
$$\frac{R_{m1} - R_{clear1}}{R_{m2} - R_{clear2}} = \frac{N\varepsilon_1 (R_{op1} - R_{clear1})}{N\varepsilon_2 (R_{op2} - R_{clear2})}$$



for high and very high clouds (CT 8 and 9), and for semi-transparent clouds (CT 11 to 15) if no result with intercept method

Experiment 1: vertical resolution
Lower top level

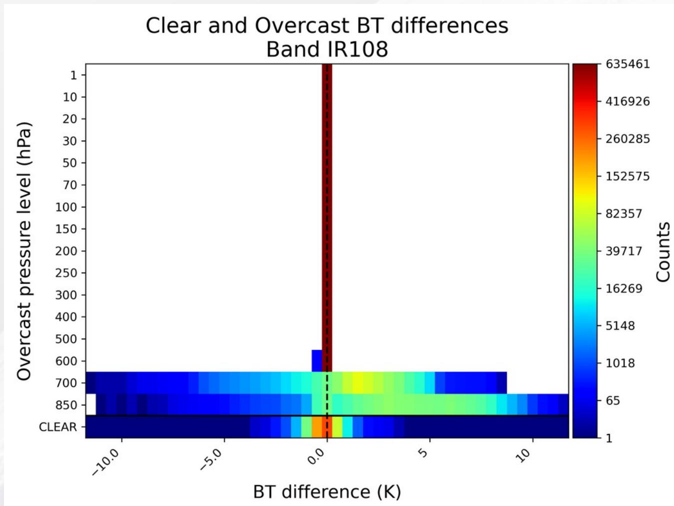
BT differences: 20 levels (lower top level) − 25 levels (reference)

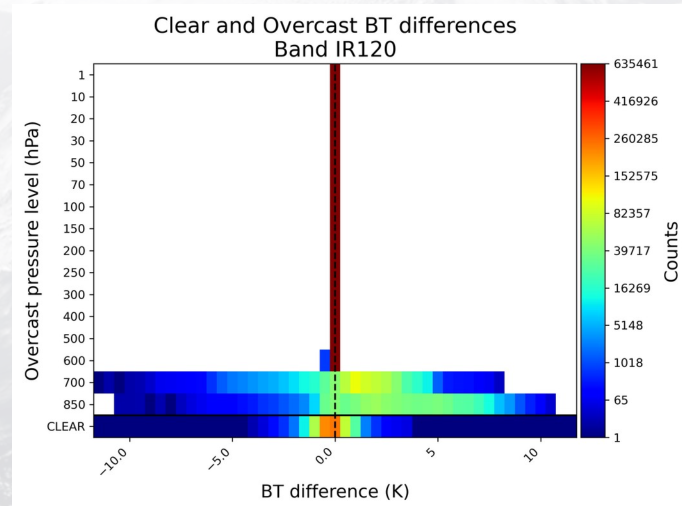


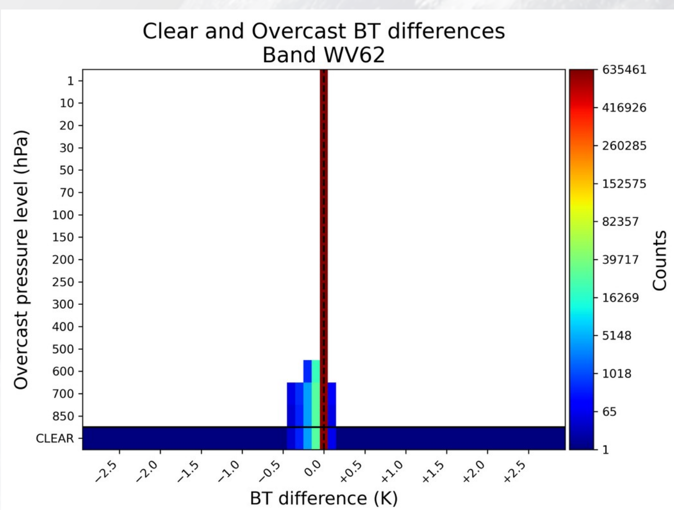
Experiment 2: vertical resolution

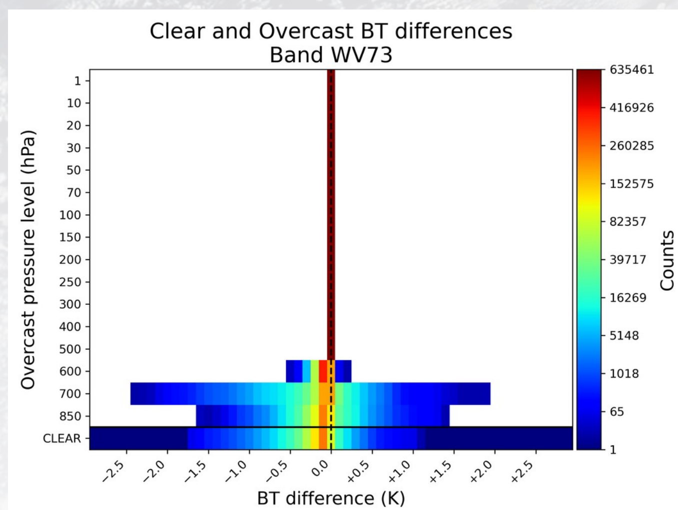
Coarser resolution near the surface

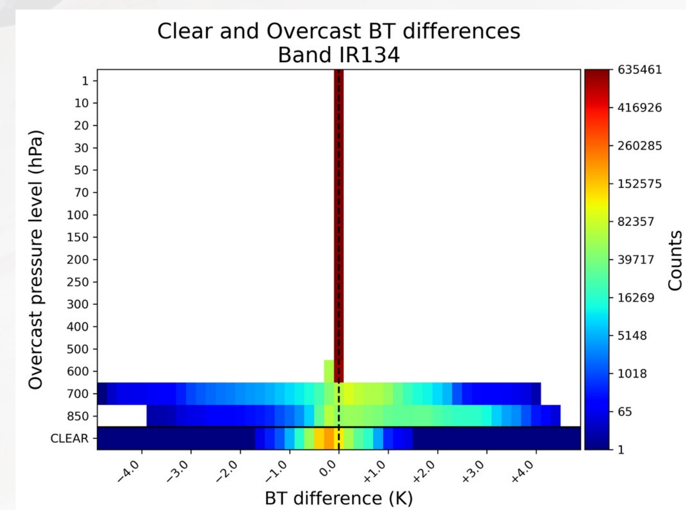
BT differences: 21 levels (coarser resolution near the surface) − 25 levels (reference)





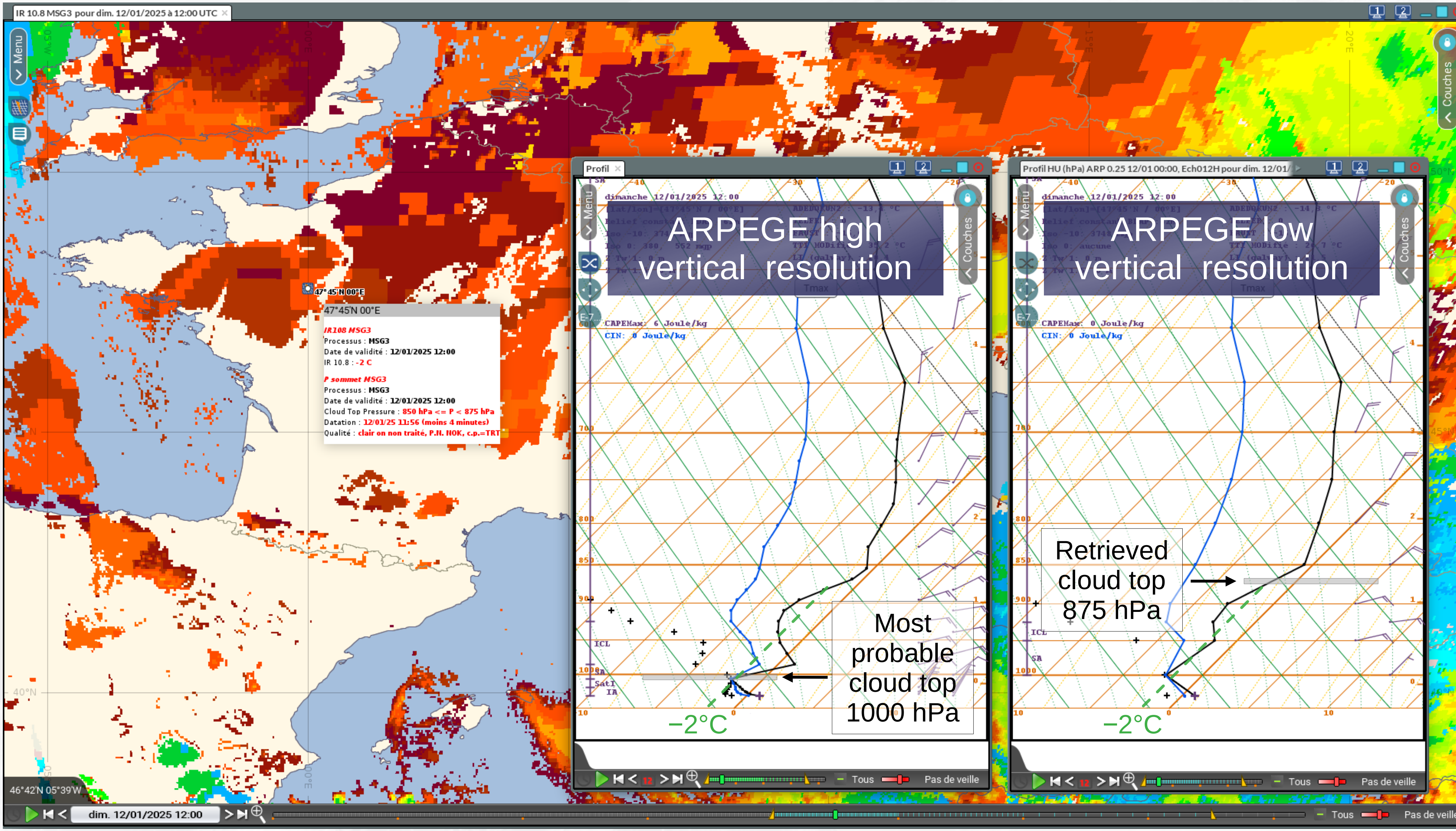






Experiment 2: vertical resolution

Coarser resolution near the surface



Experiment 3: temporal resolution

Satellite data: MSG3 for the 29/10/2024 between 0600 and 1800 UTC
NWP data: ARPEGE 00Z (+6 to +18h)

3 NWP temporal configurations:

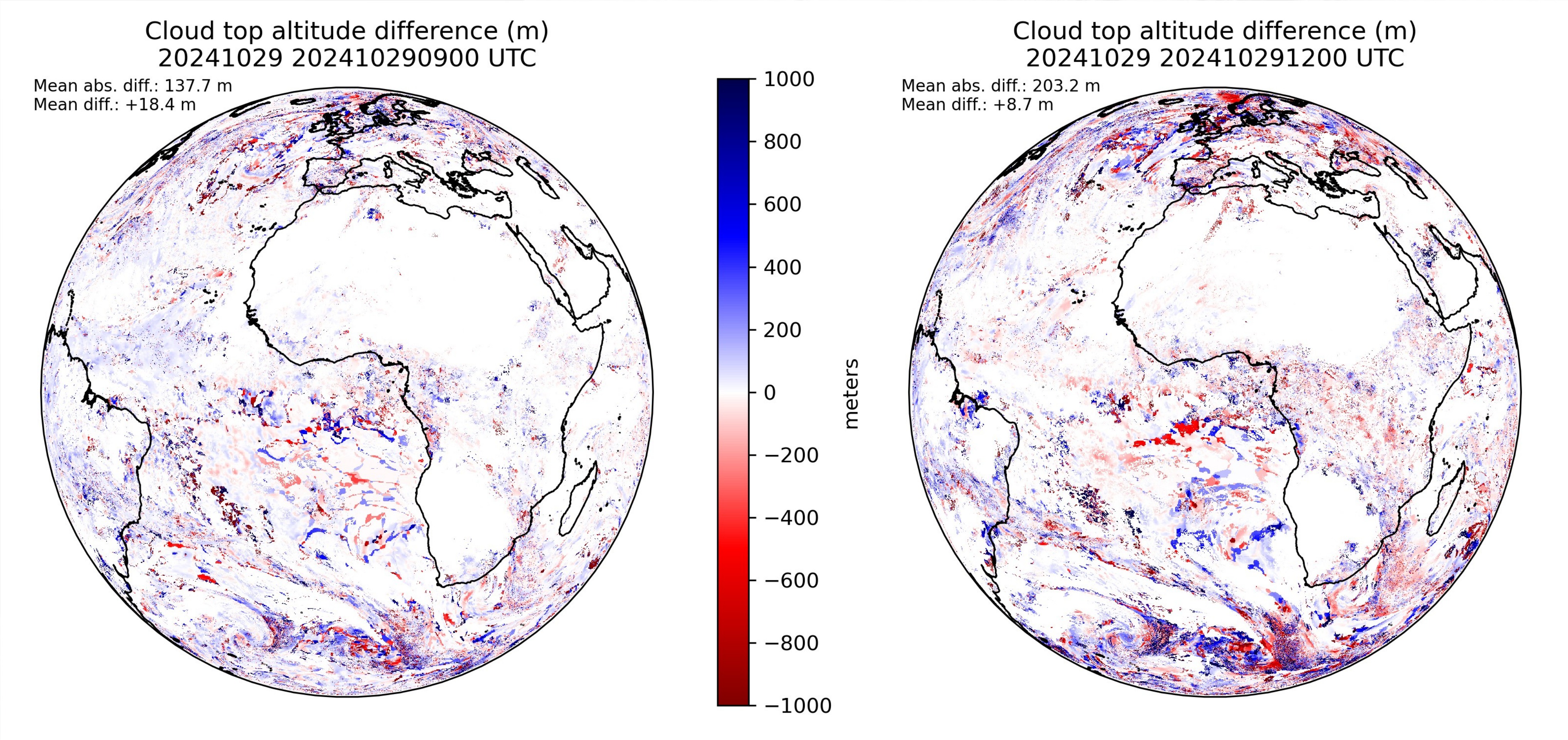
- **Reference**
  3-hour time step resolution: +6, +9, +12, +15 and +18h forecasts
- **6-hour time step resolution**: +6, +12 and +18h forecasts
- **12-hour time step resolution**: +6 and +18h forecasts

In GEO software, NWP data are temporally interpolated to the time slot.

Experiment 3: temporal resolution

6-hour time step resolution

12-hour time step resolution



Differences affect all areas but seem a bit stronger in higher latitudes.

Experiment 3: temporal resolution

12-hour time step resolution

Difference statistics

Statistics	Time slot (UTC)												
	6	7	8	9	10	11	12	13	14	15	16	17	18
Q01	0	-729	-1106	-1349	-1270	-1317	-1378	-1319	-1325	-1280	-1060	-725	0
Q10	0	-44	-103	-179	-176	-214	-242	-206	-191	-189	-115	-50	0
Q25	0	-13	-25	-39	-42	-50	-61	-56	-53	-56	-37	-18	0
Q50	0	+2	+5	+9	+5	+2	+1	0	-1	-1	-2	-1	0
Q75	0	+19	+43	+69	+64	+65	+71	+56	+47	+46	+26	+11	0
Q90	0	+55	+137	+234	+229	+241	+271	+231	+196	+192	+99	+39	0
Q99	0	+837	+1211	+1419	+1350	+1392	+1439	+1410	+1332	+1327	+1097	+702	0
Mean	0.0	+4.5	+13.9	+19.6	+15.5	+12.0	+8.7	+7.7	+1.3	+0.5	-3.5	-2.3	0.0
Abs. mean	0.0	72.3	130.5	180.5	174.8	188.5	203.2	184.7	172.3	170.3	120.8	65.5	0.0

Experiment 3: temporal resolution

6-hour time step resolution

Difference statistics

		Time slot (UTC)												
		6	7	8	9	10	11	12	13	14	15	16	17	18
Statistics	Q01	0	-551	-992	-1193	-958	-513	0	-564	-906	-1118	-913	-555	0
	Q10	0	-26	-59	-101	-57	-25	0	-32	-72	-118	-75	-34	0
	Q25	0	-7	-13	-21	-14	-7	0	-11	-24	-38	-26	-13	0
	Q50	0	+3	+6	+10	+6	+2	0	0	0	0	-1	-1	0
	Q75	0	+15	+33	+52	+32	+14	0	+9	+20	+32	+19	+8	0
	Q90	0	+41	+98	+164	+91	+37	0	+29	+68	+123	+67	+27	0
	Q99	0	+636	+1027	+1180	+940	+583	0	+569	+889	+1105	+911	+530	0
	Mean	0.0	+7.5	+13.7	+18.4	+11.5	+5.5	0.0	-0.1	-0.5	+1.4	-2.3	-0.8	0.0
	Abs. mean	0.0	54.2	98.5	137.7	94.9	49.6	0.0	50.3	89.7	129.2	90.9	49.4	0.0

Experiment 3: temporal resolution