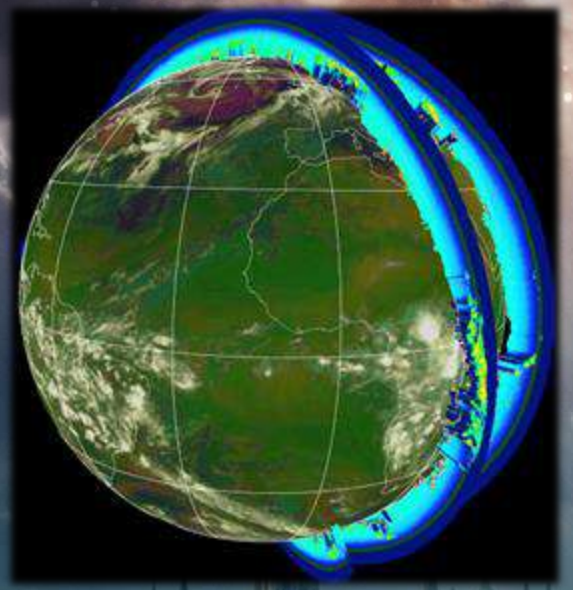


EarthCARE 2026 Science and Validation workshop

8–12 June 2026 | Rhodes House | Oxford, UK

An update on the assimilation of EarthCARE ATLID cloud observations in ECMWF's global NWP system – assessing model biases

By Michael Rennie, Mark Fielding, Kamil Mroz and Richard Forbes

11/06/2026

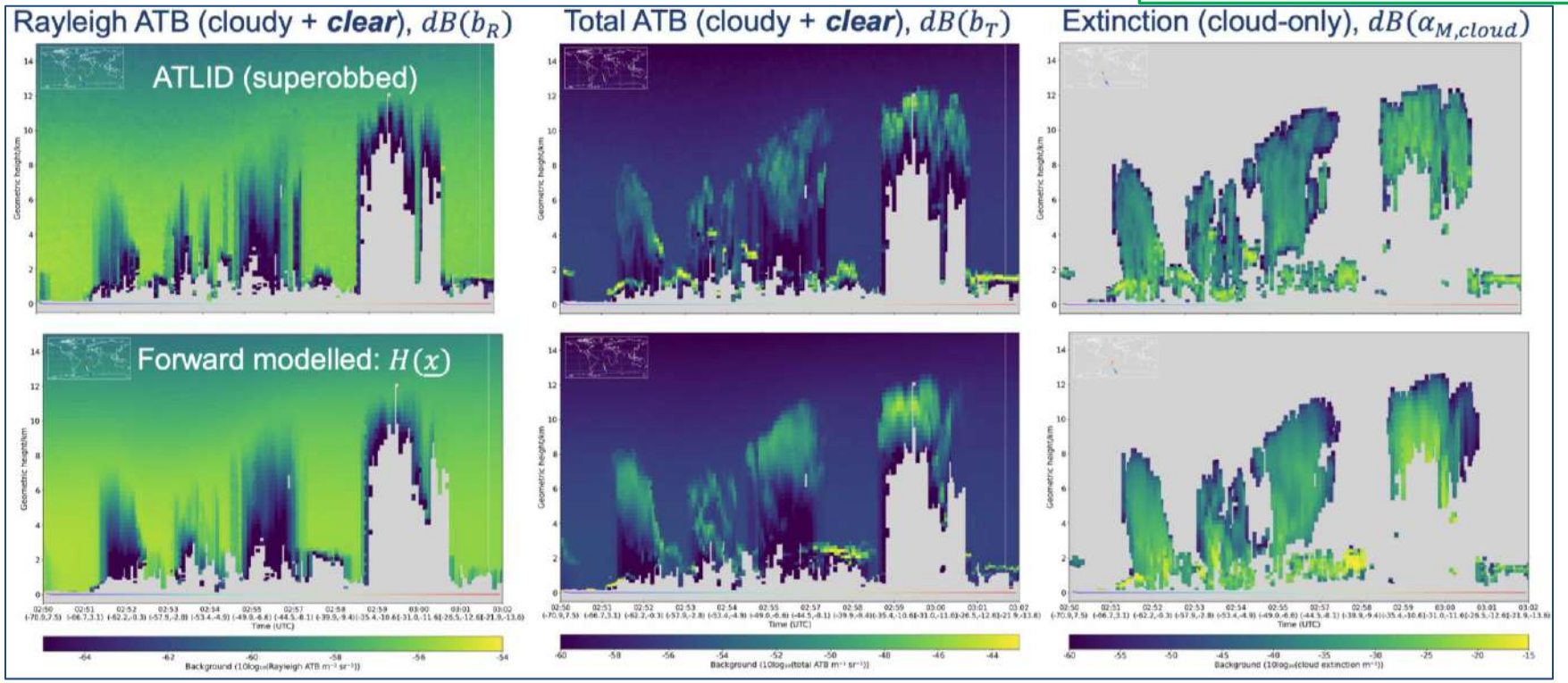
Aim to improve ECMWF forecasts by assimilation of **ATLID cloud information**

- **High-resolution** optical properties for **optically thin clouds** and **optically thick cloud tops**
  - Use **L2a EBD** product
    - Cloudy- and clear-sky; avoiding aerosol
  - **Three** assimilation options:
    - b_R, Rayleigh attenuated backscatter (ATB)
    - $b_T = b_R + b_{M,\parallel} + b_{M,\perp}$, total ATB
    - $\alpha_{M,cloud}$, extinction (thanks to HSRL)

$$b_{\mathrm{R}}(z) = \beta_{\mathrm{R}}(z)\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$

$$b_{\mathrm{M},\parallel}(z) = \beta_{\mathrm{M},\parallel}(z)\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$

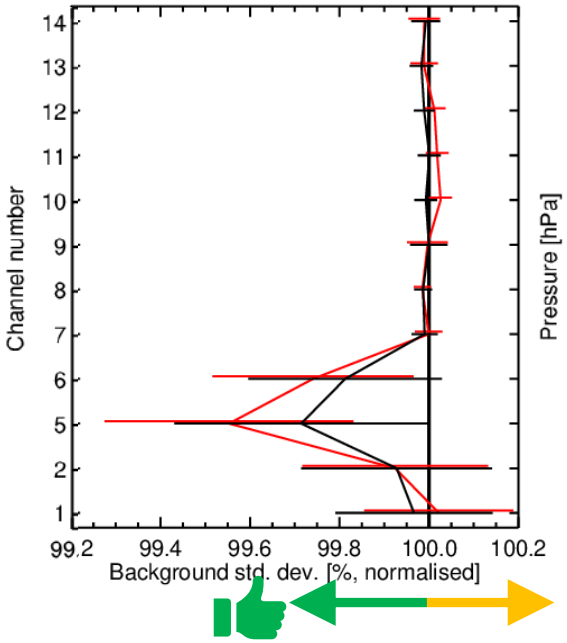
$$b_{\mathrm{M},\perp}(z) = \beta_{\mathrm{M},\perp}\exp\left[-2\int_{z_{\mathrm{lid}}}^{z}\left(\alpha_{\mathrm{M}}(z') + \alpha_{\mathrm{R}}(z')\right)\mathrm{d}r(z')\right]$$



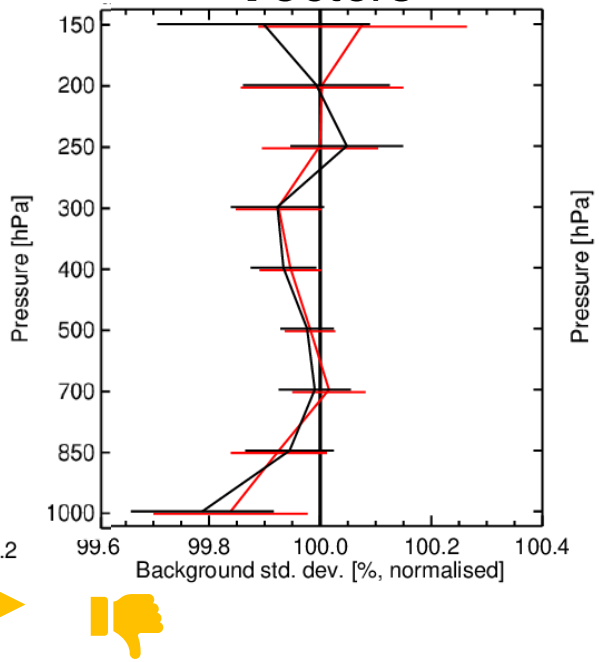
ATLID total attenuated backscatter **O**bserving **S**ystem **E**xperiments show some positive impact, but mostly neutral

Short-range forecast fit to other observations

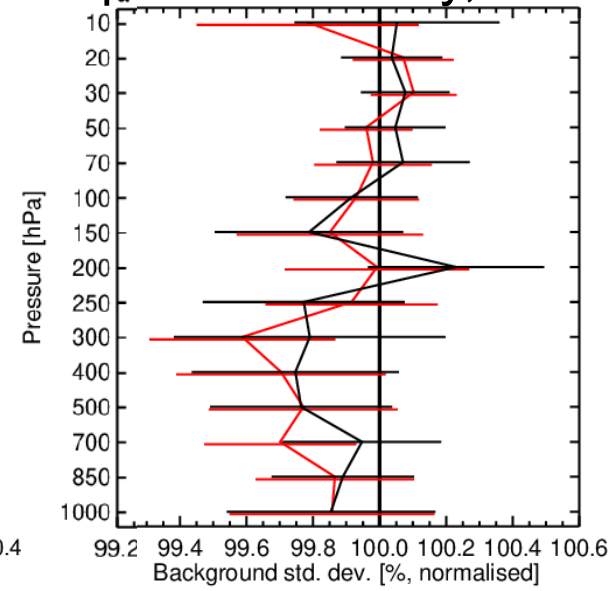
All sky AMSU-A



Atmospheric **M**otion **V**ectors

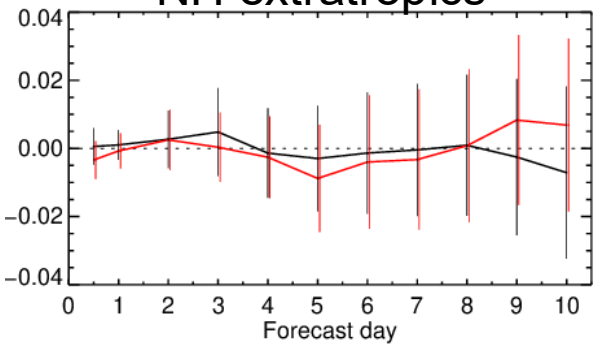


Radiosonde/aircraft specific humidity, SH

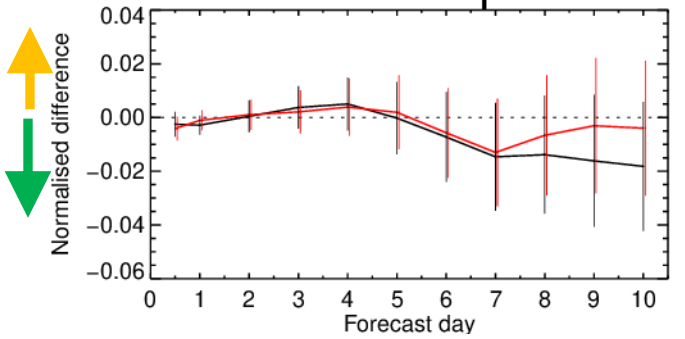


500 hPa geopotential forecast impact

NH extratropics



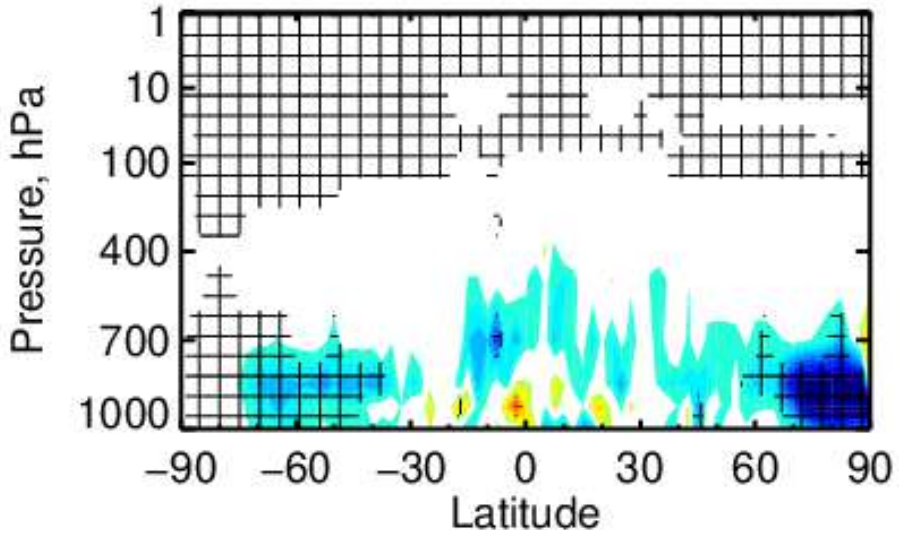
SH extratropics



Systematic analysis changes, indicate biases between observations and model

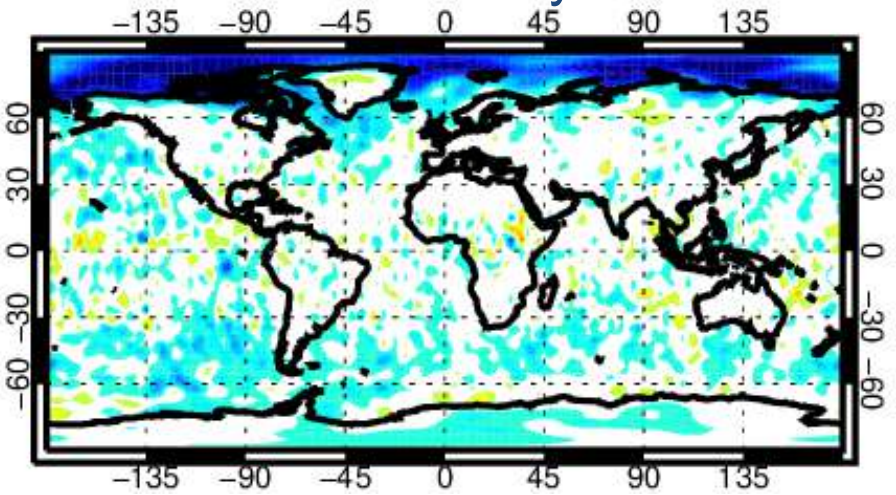
Total ATB OSE: ATLID “on” minus control

Zonal mean change of specific humidity



-0.02 g/kg +0.02 g/kg

Mean change of 850 hPa relative humidity



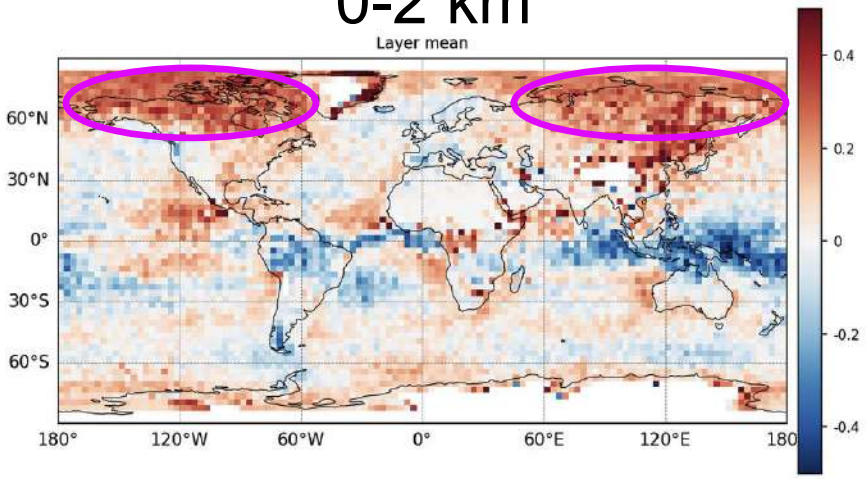
-1.2% +1.2%

EarthCARE can reveal systematic IFS cloud biases, that likely limit assimilation impact

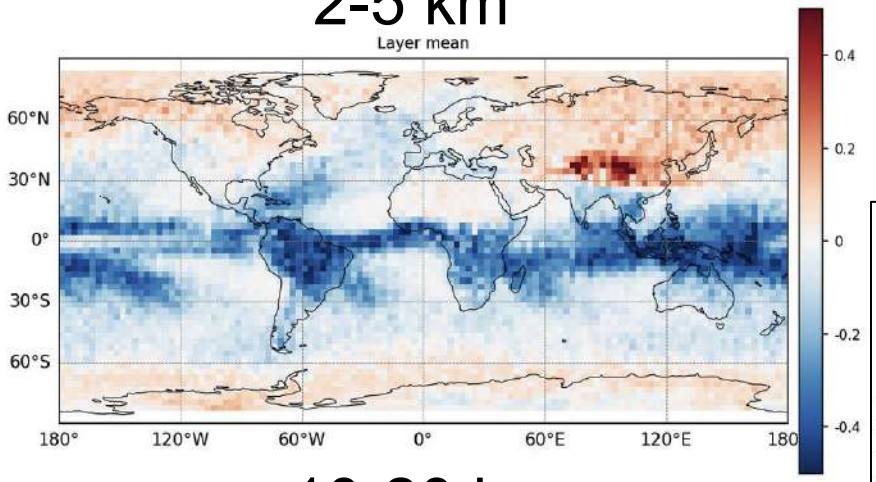
ATLID suggests some systematic errors in cloud occurrence in IFS model (*preliminary*)

Mean((ATLID cloud mask) *minus* (IFS cloud mask)): Feb-Apr 2026

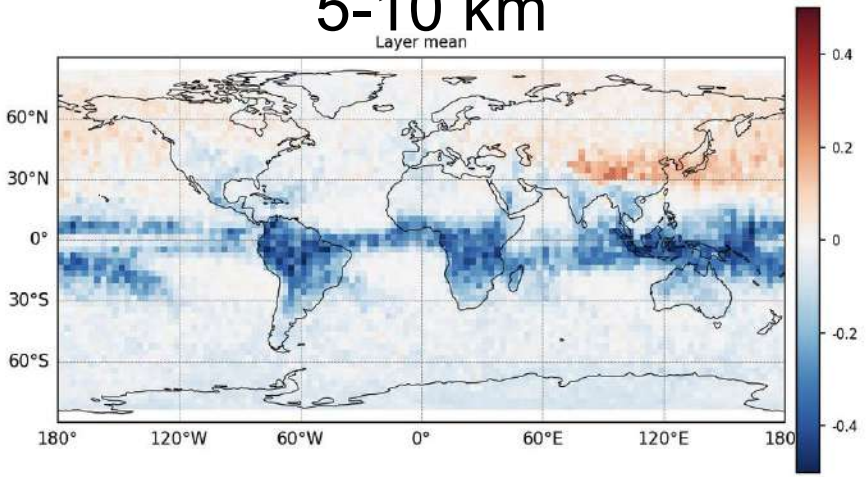
0-2 km



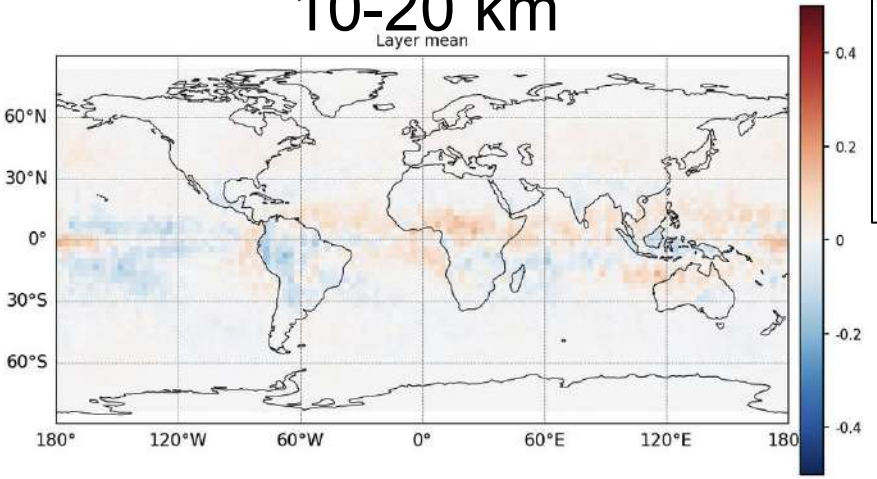
2-5 km

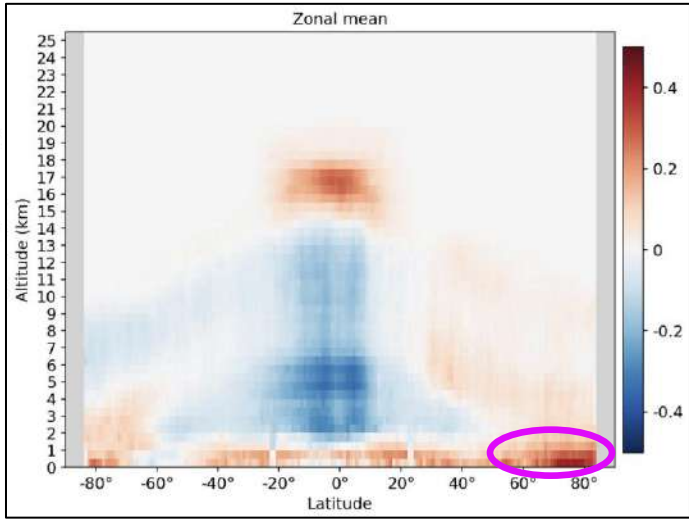


5-10 km



10-20 km

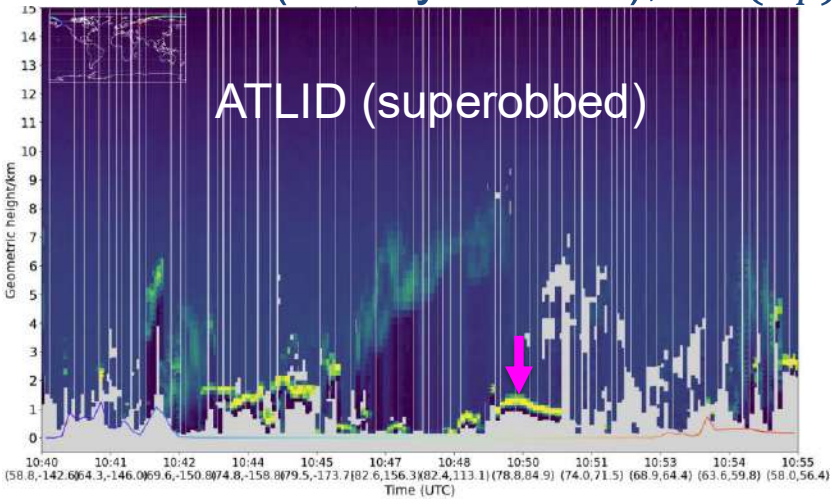


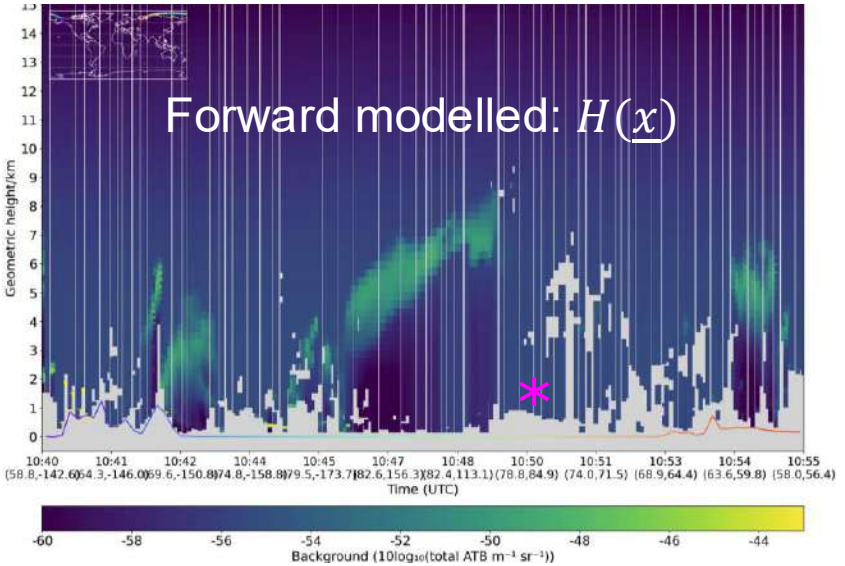


- IFS lacks low level clouds in Siberia and northern Canada
- IFS has too much cloud in ITCZ and tropical land

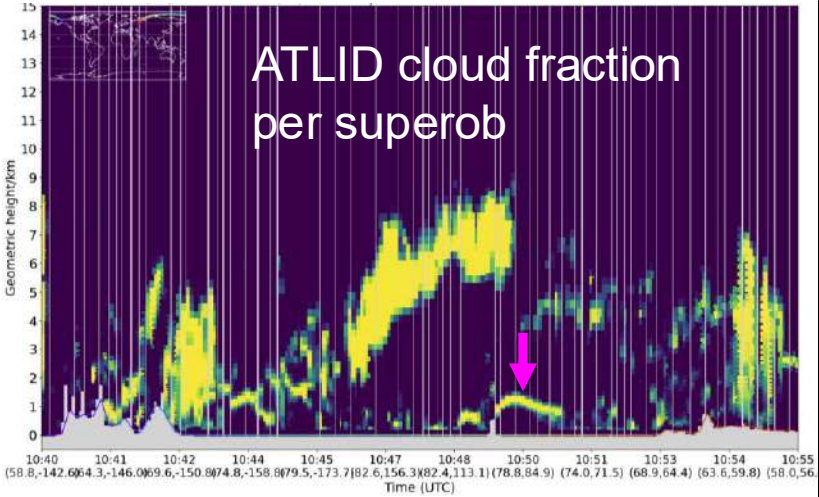
Specific case: IFS lacks supercooled liquid clouds in **Arctic**

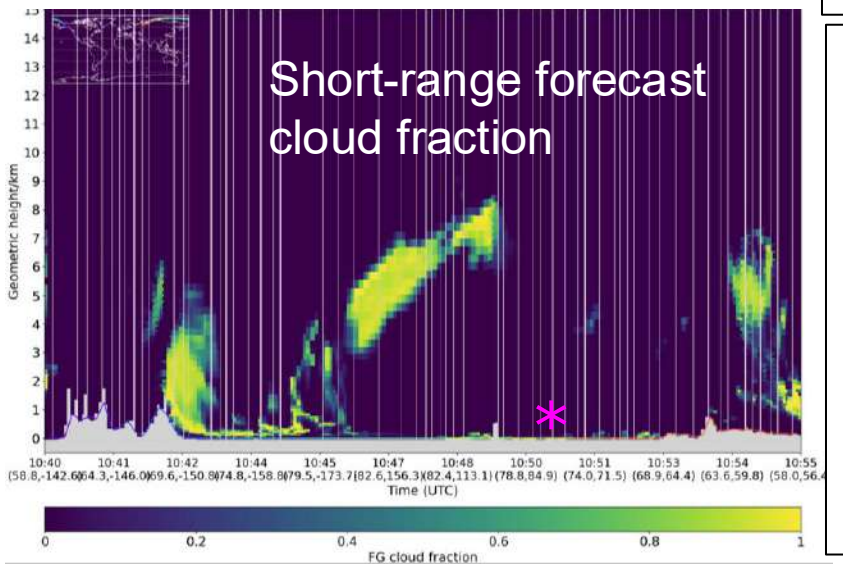
Total ATB (cloudy + ***clear***), $dB(b_T)$



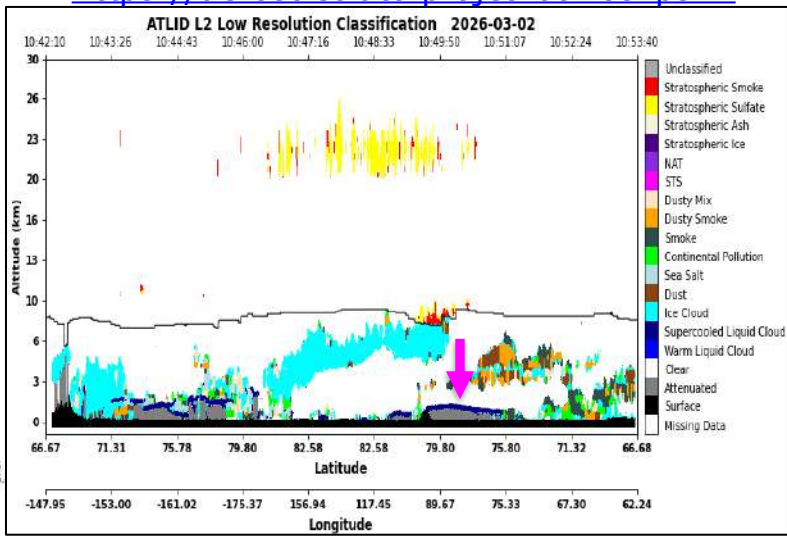


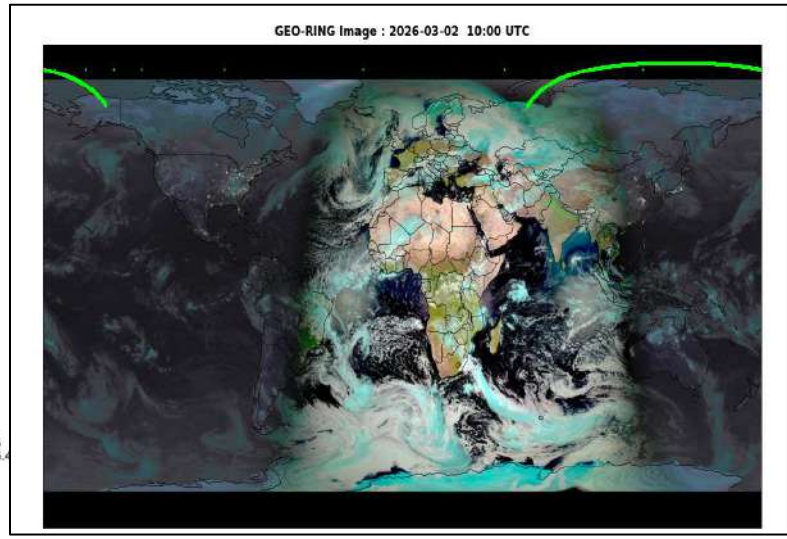
Cloud fraction





https://aerosolstrato.projet.latmos.ipsl.fr





Liquid-containing cloud occurrence is underestimated in winter and overestimated in summer in Arctic
e.g. L. Schulte et al. (2026)

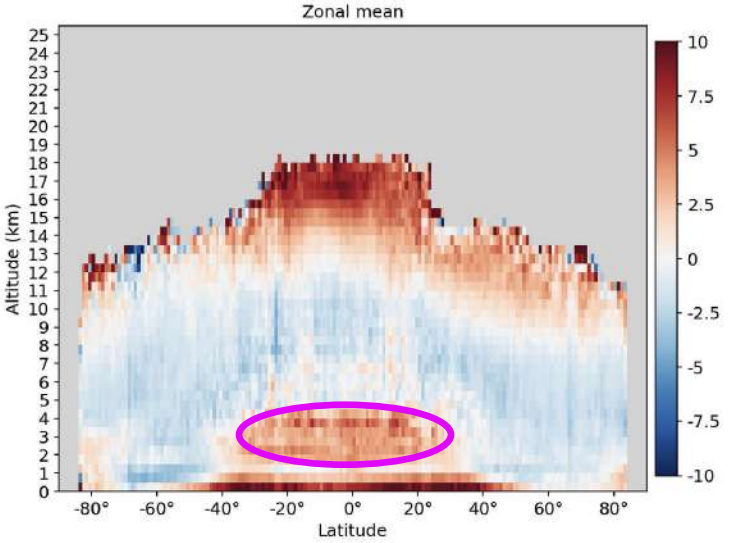
Large bias differences between day and night orbital passes

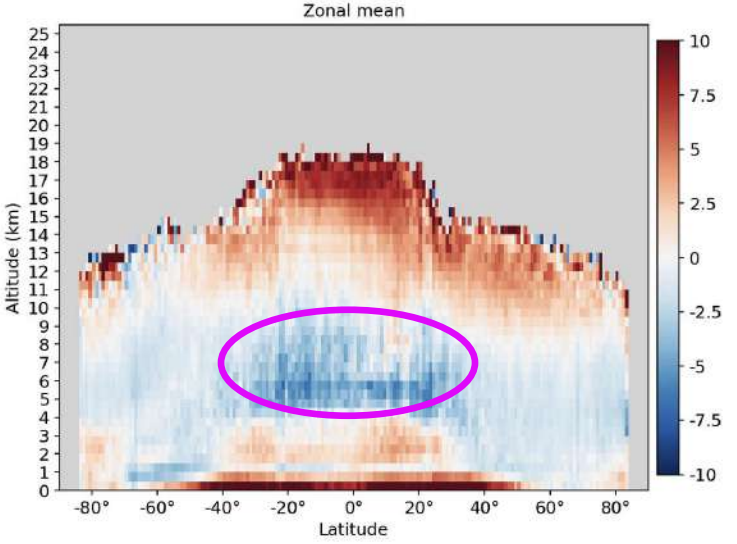
Feb –Apr 2026

Ascending, LST 2 AM (night)

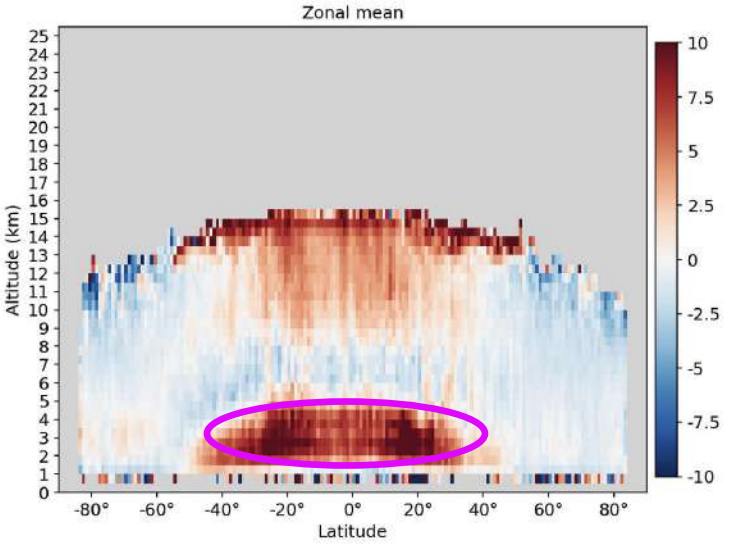
Descending, LST 2 PM (day)

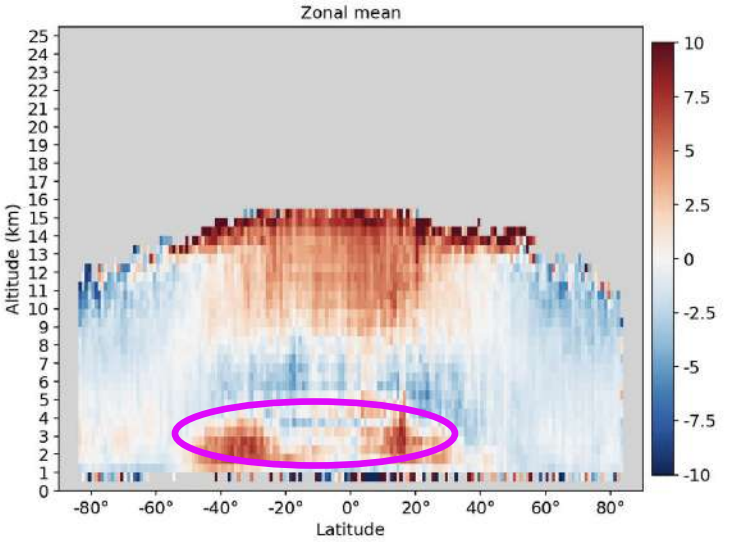
ATLID **cloud extinction** mean(O-B)





CPR **reflectivity** mean(O-B)





O=observations

B=background (short-range forecast)

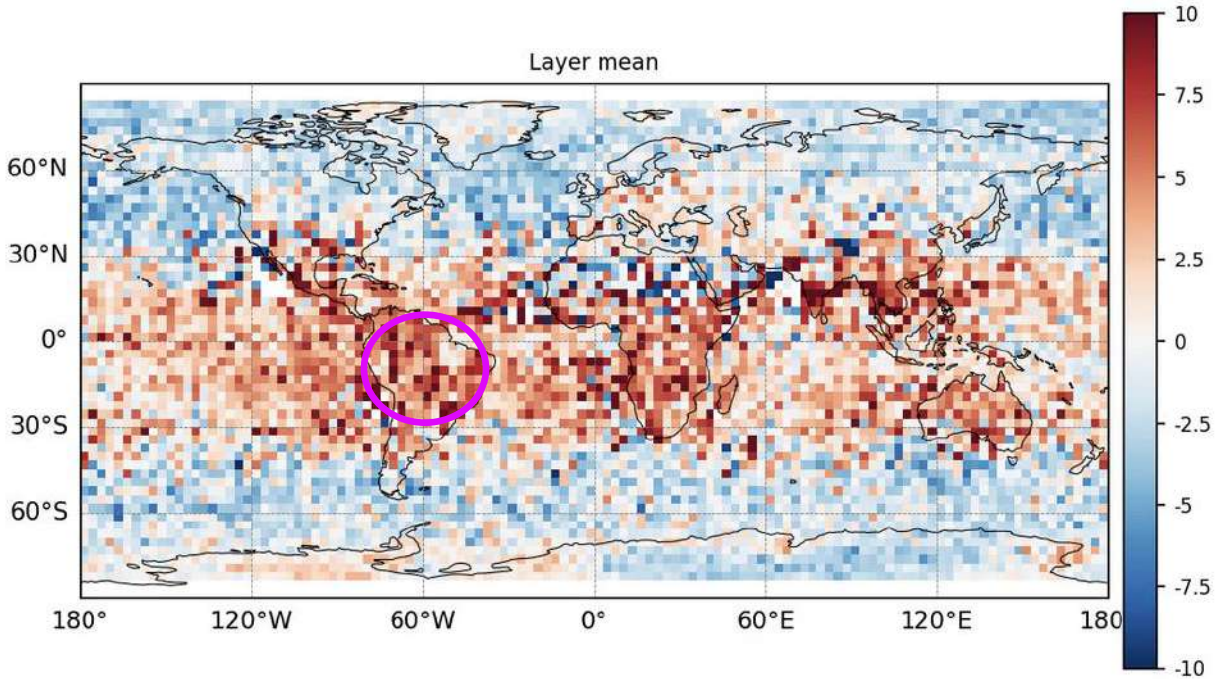
Some similarities for CPR and ATLID bias structures – *suggesting ECMWF cloud is source*

Tropical land areas stand out – convection related

ATLID cloud extinction mean(O-B) at 2-5 km

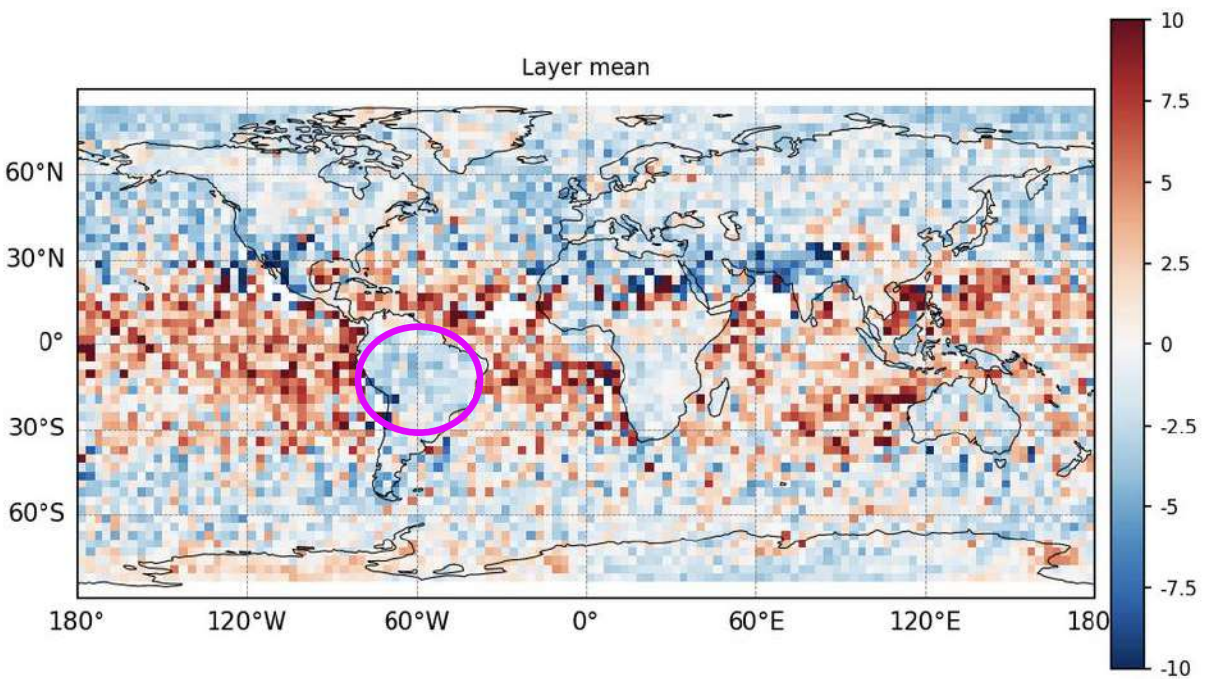
Ascending, LST 2 AM (night)

Deep convection has generally decayed



Descending, LST 2 PM (day)

Active convective intensification phase

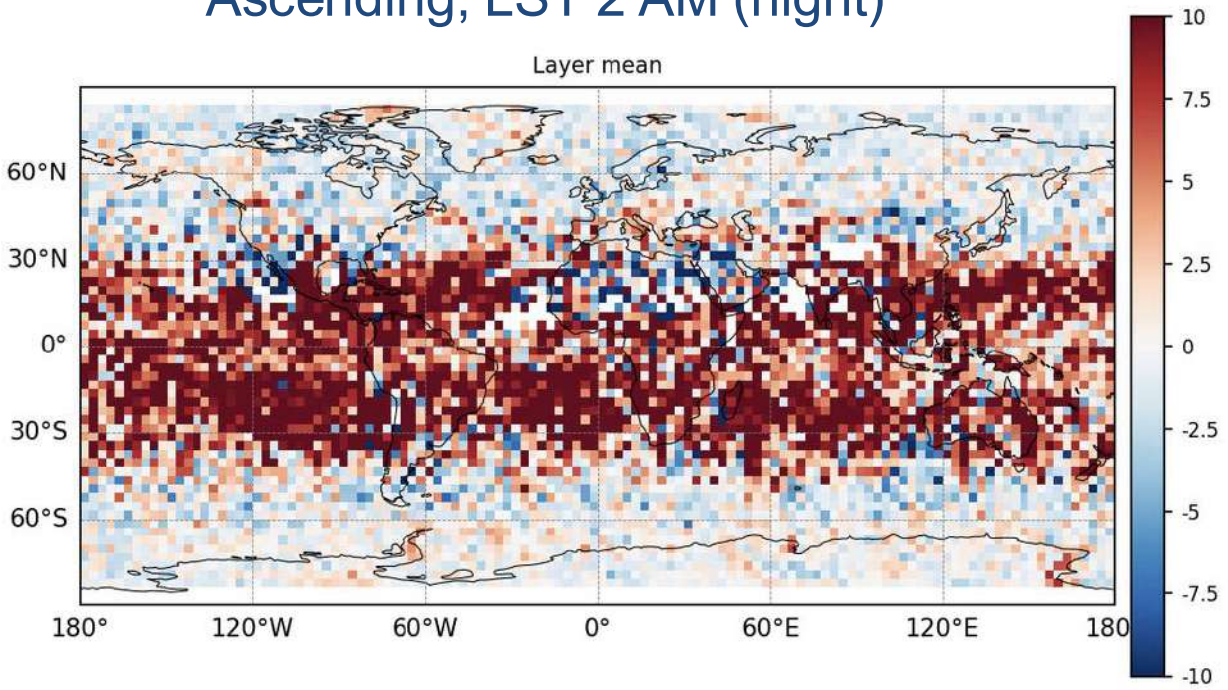


ECMWF

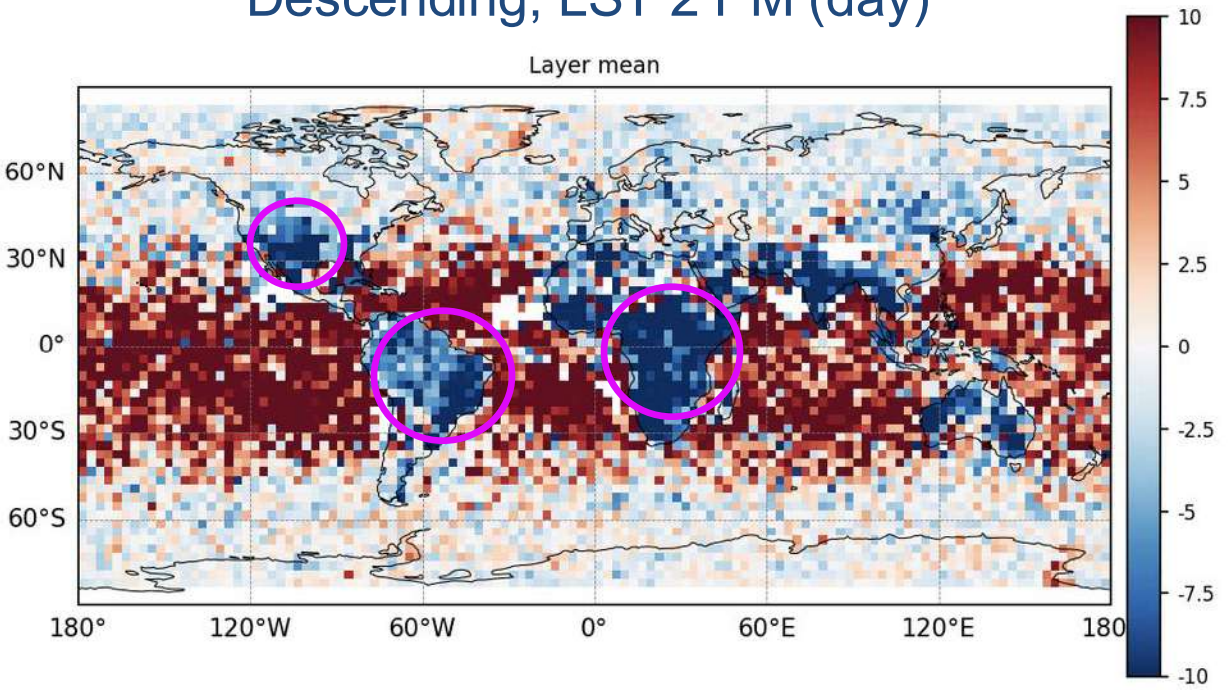
CPR Z biases show a marked contrast between land and sea in day

CPR reflectivity mean(O-B) at 2-5 km

Ascending, LST 2 AM (night)



Descending, LST 2 PM (day)



ECMWF

Tropical land convective region focus: very different day/night biases

Amazon region

Tropical Africa

Night

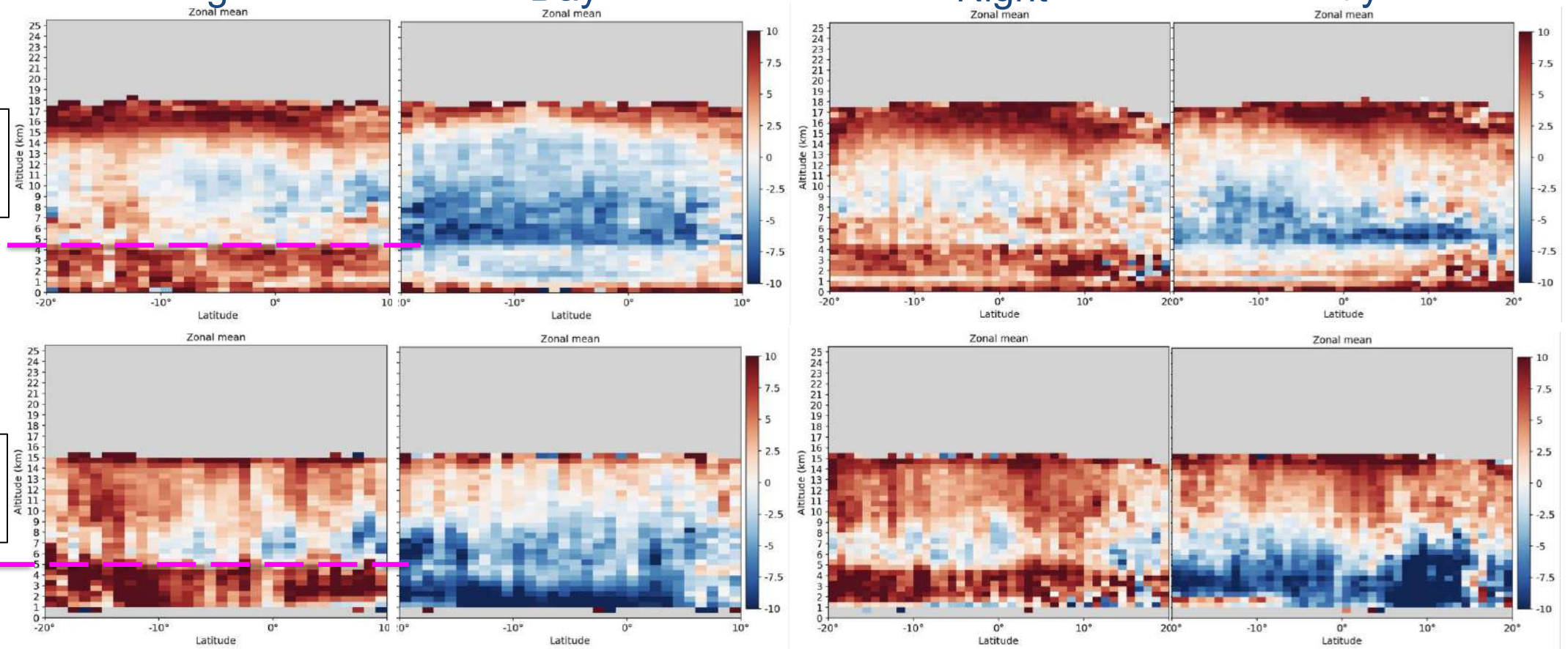
Day

Night

Day

ATLID α mean(O-B)

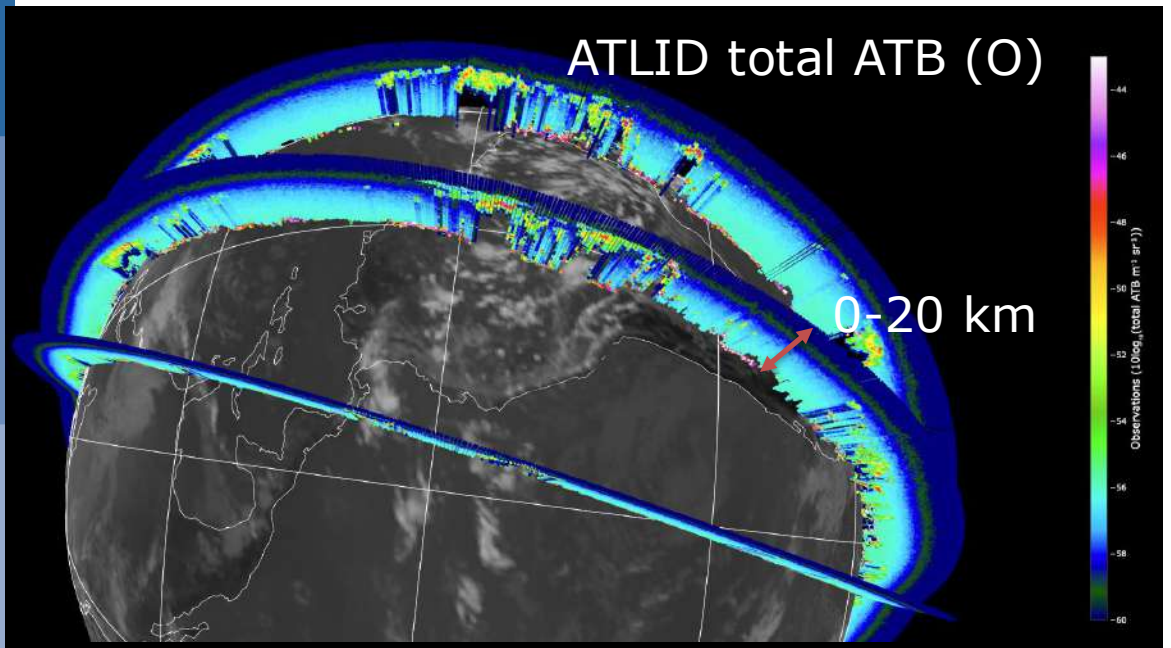
CPR Z mean(O-B)

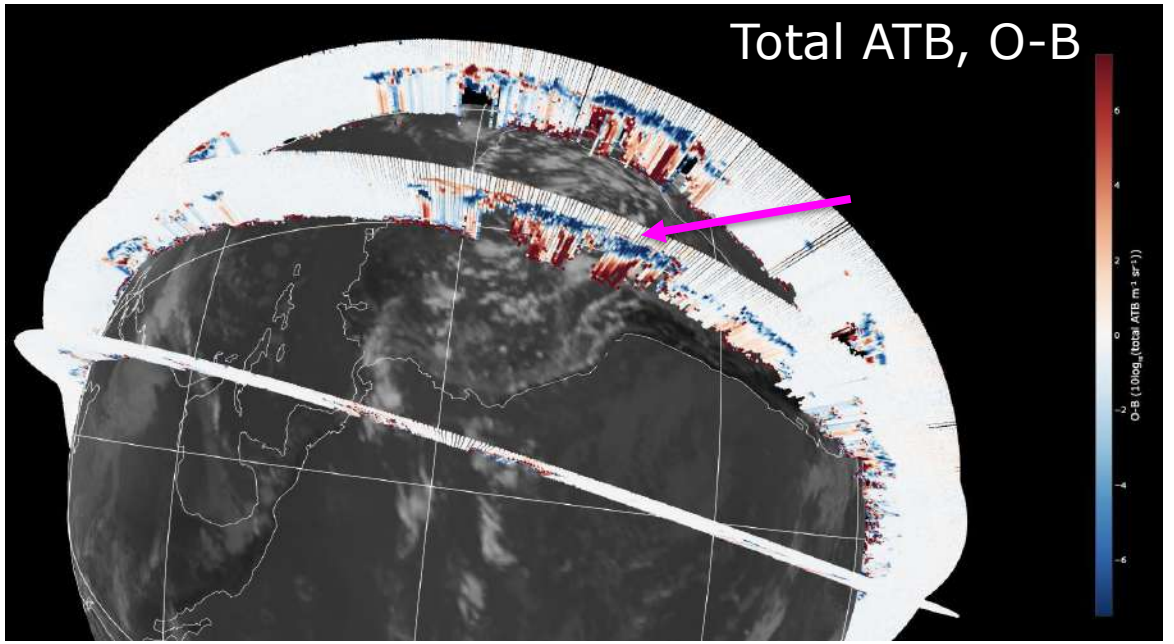


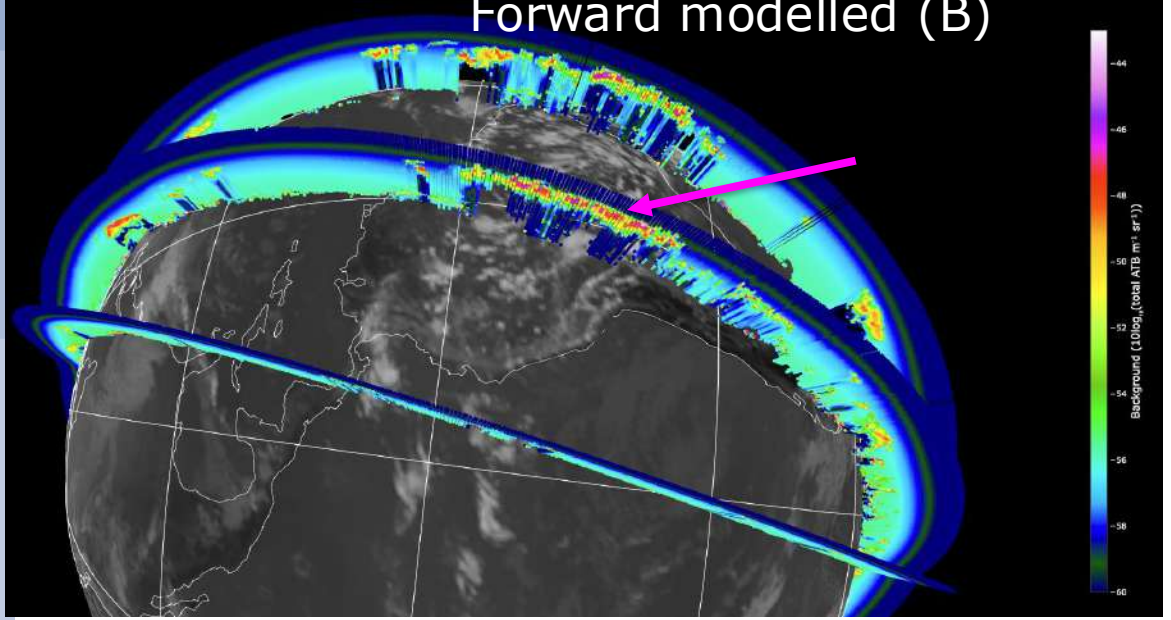
- Similarities in CPR and ATLID bias structures *suggest ECMWF cloud is source* – but *complex* picture!
- Biases seem to change around melting layer

IFS convective cloud too extensive in upper troposphere in day

Amazon daytime case (22 Feb ’26)

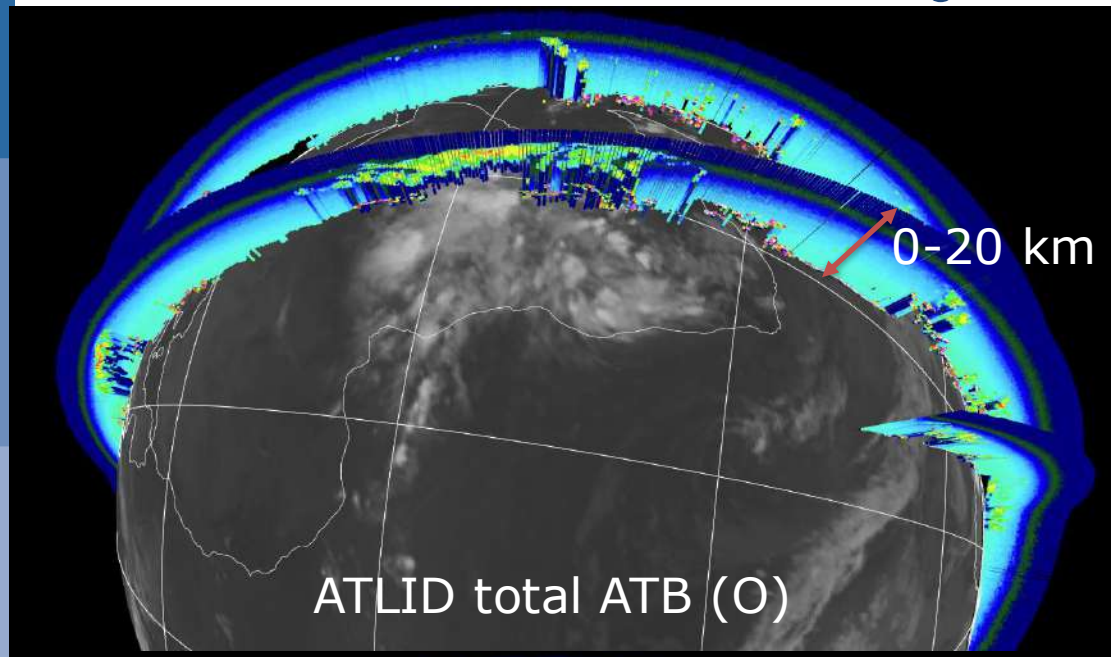


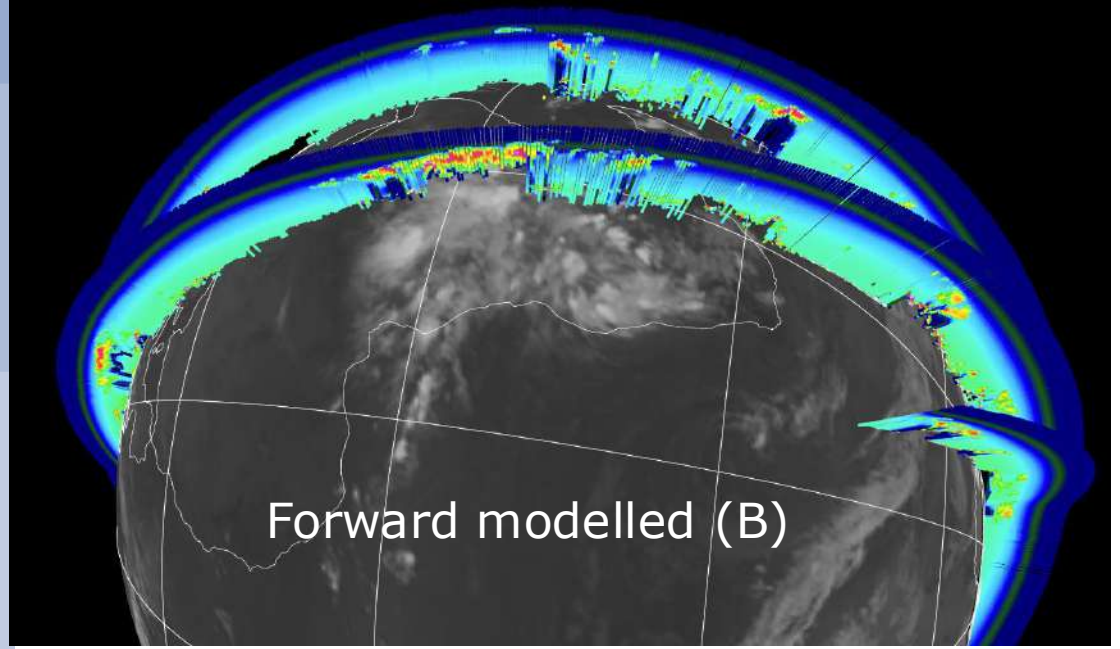


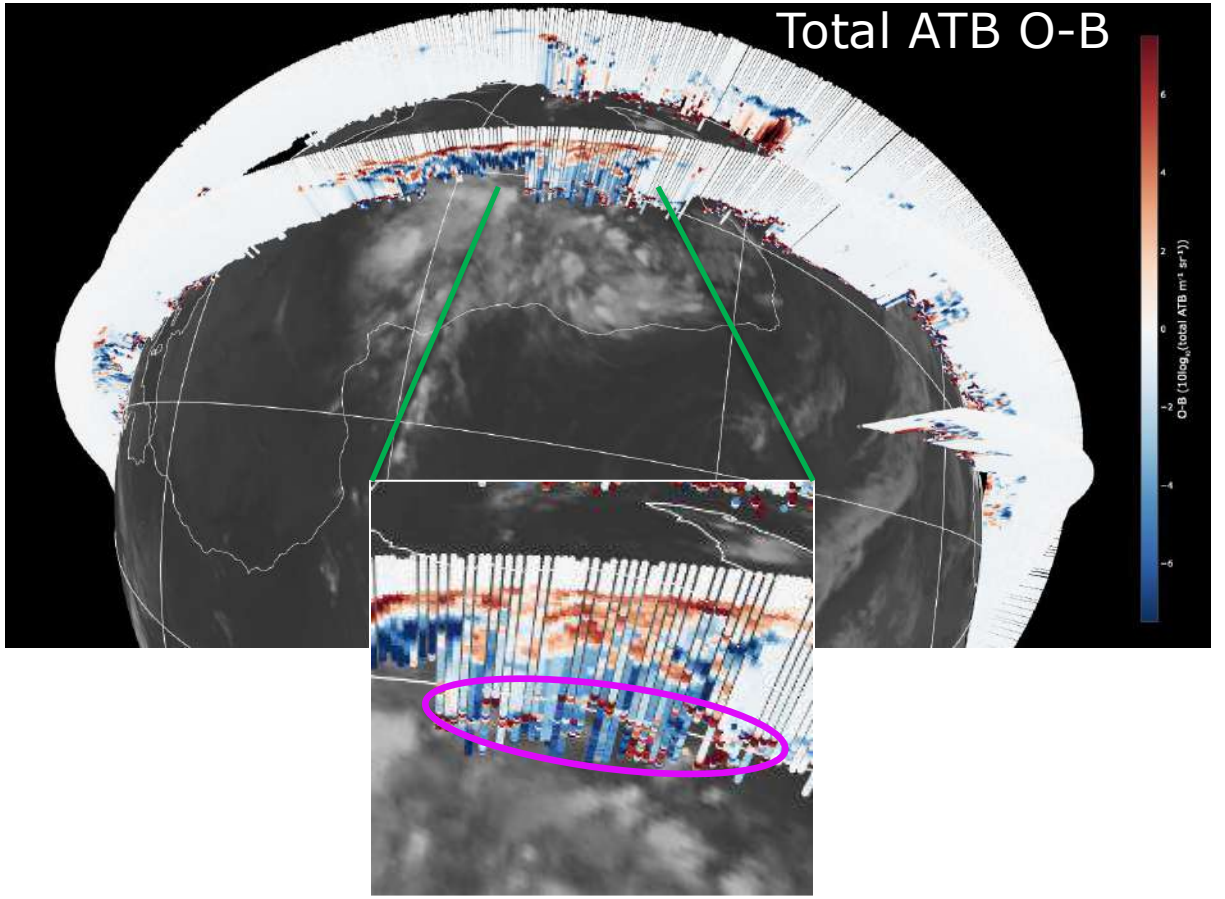


IFS lacks mid-level clouds at night

Africa nighttime case (22 Feb ’26)



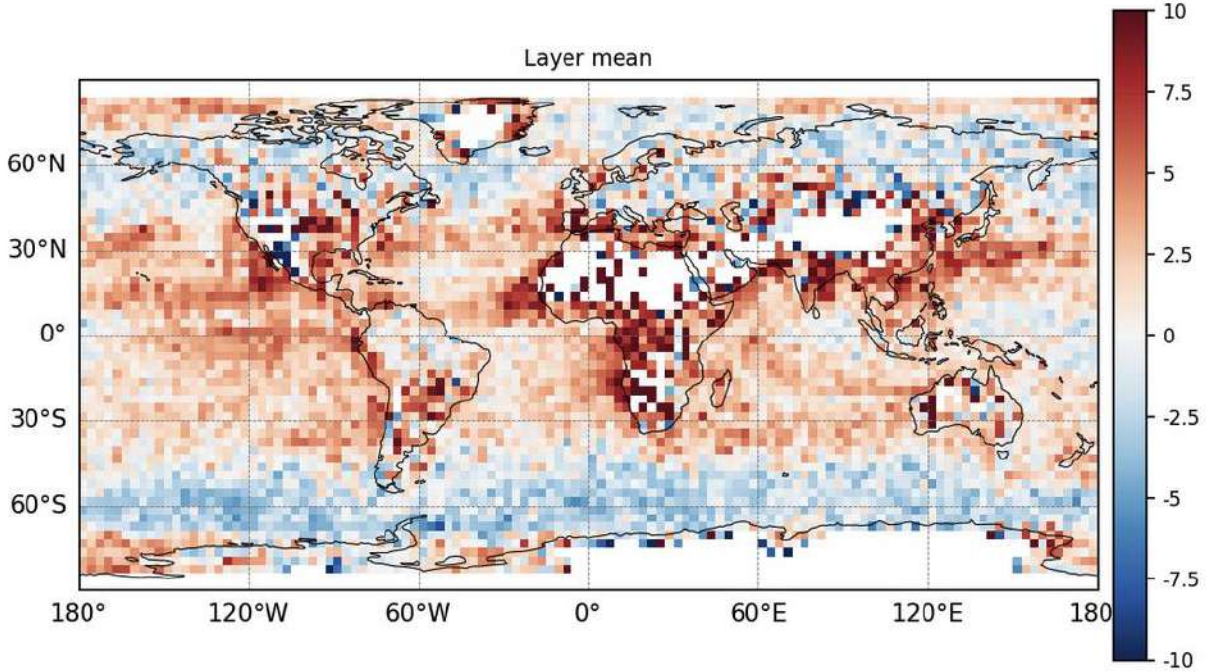




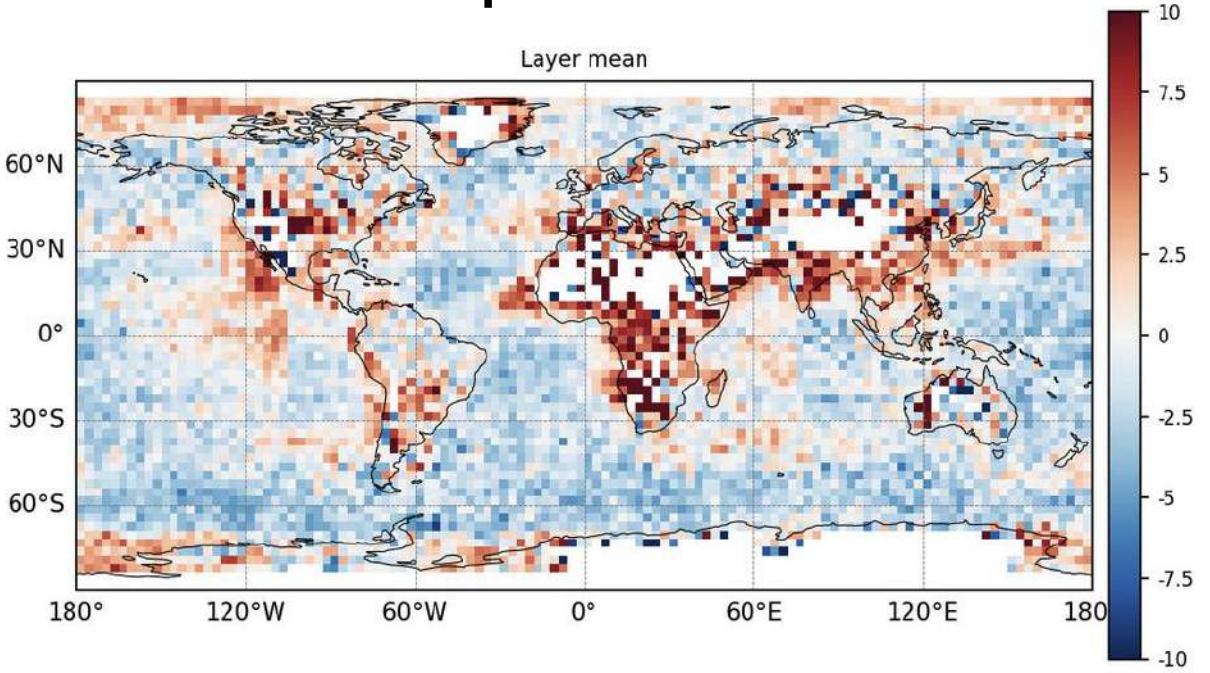
A parametrisation change being worked on looks promising (preliminary)

ATLID cloud extinction mean(O-B) at 0-2 km

Control



Experiment



Positive bias over oceans is reduced (via more cloud)

Perhaps too strong?

Mark Fielding: Allow cloud scheme to see convective detrainment in same timestep and change in cloud erosion (mixing at cloud edges)

Conclusions

- EarthCARE O-B departures reveal systematic IFS cloud biases
  - ATLID highlights missing supercooled liquid cloud in Arctic winter/spring and ATLID/CPR show large tropical land biases
- Biases are strongly regime- and time-of-day dependent
  - Tropical land: daytime cases suggest too much upper-tropospheric convective cloud; night-time cases suggest too little mid-level cloud
  - Timing of convection issues?
- These model biases likely limit EarthCARE assimilation impact
  - Reducing cloud-related systematic errors should improve the value of cloud-sensitive observations in NWP

The end

ECMWF

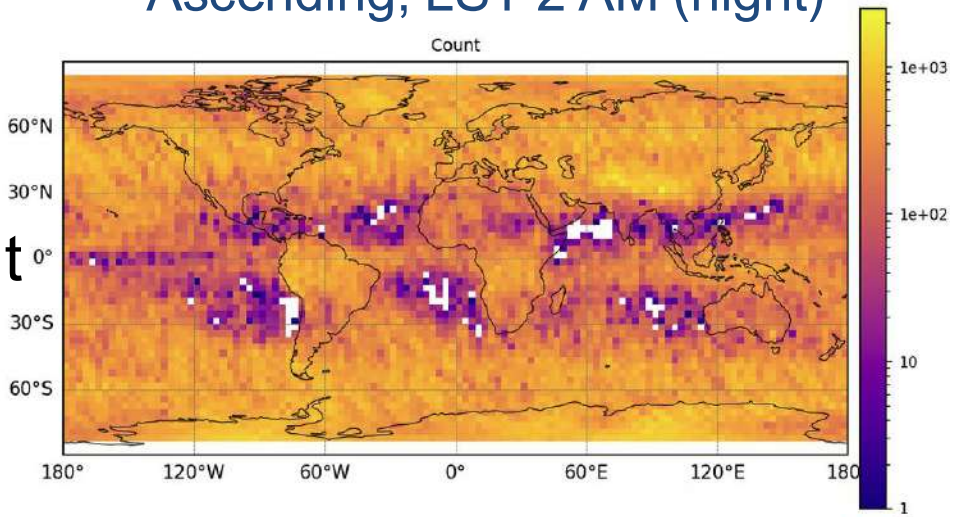
Backup slides

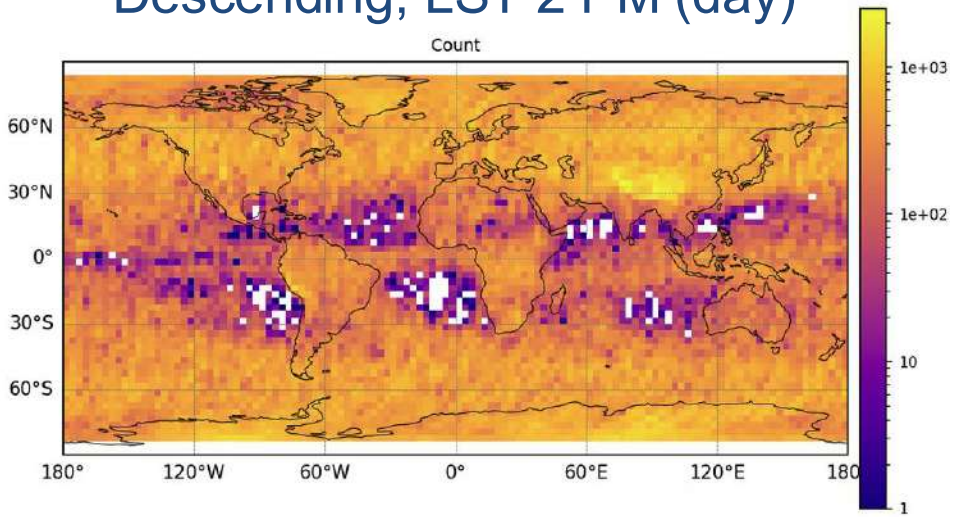
5-10 km for ATLID α

Ascending, LST 2 AM (night)

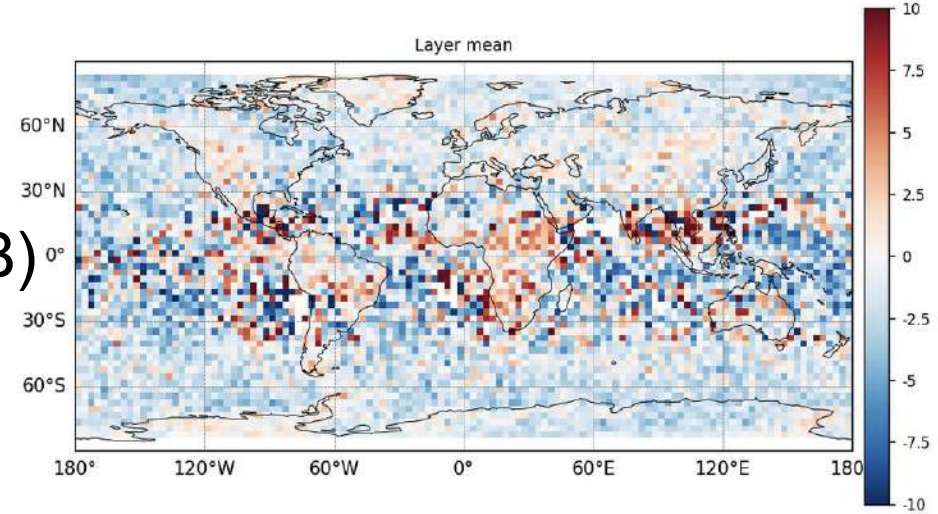
Descending, LST 2 PM (day)

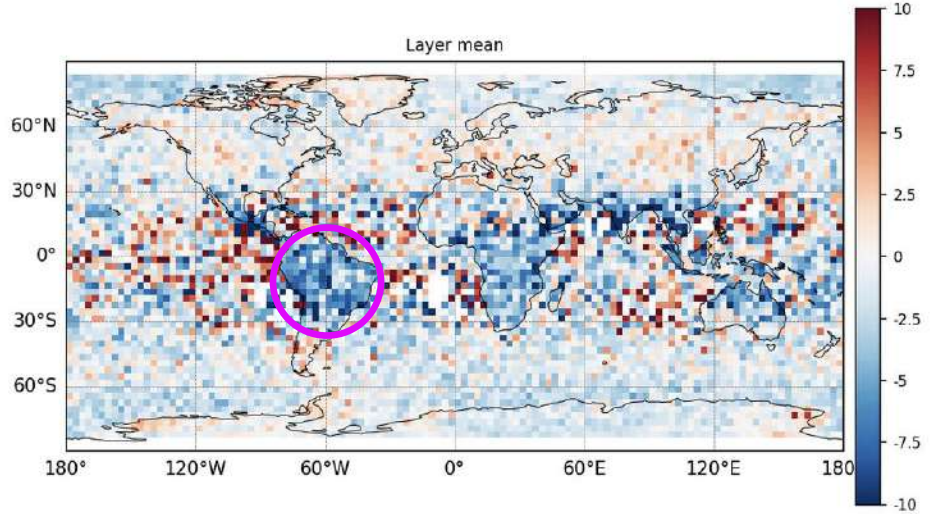
Data count





Mean(O-B)





Convective detrainment change

Preliminary: For April-June 2026, 50R1 MONITOR_ONLY experiments

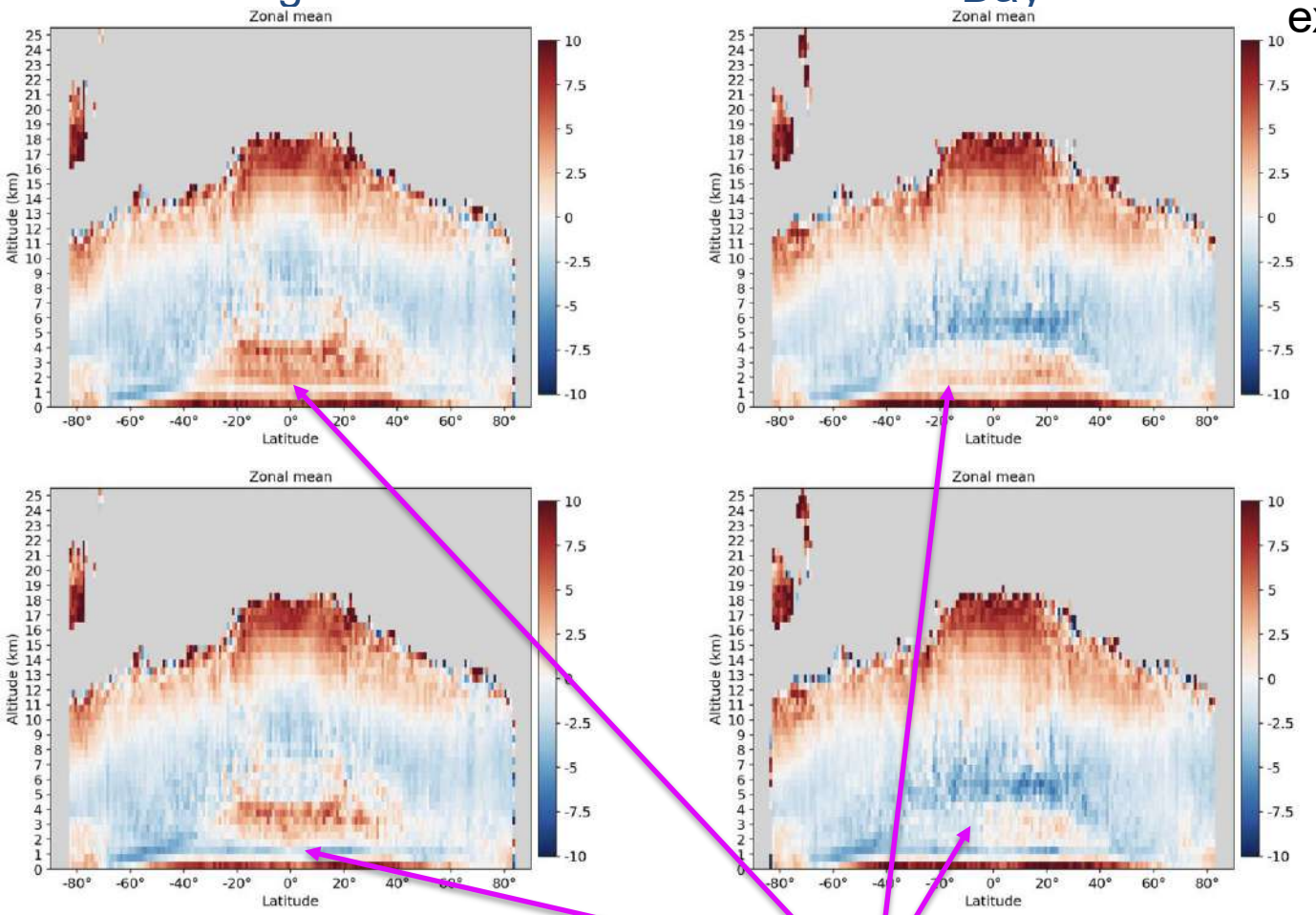
ATLID cloud α zonal mean(O-B)

Night

Day

Control

Experiment



Allow cloud scheme to see convective detrainment in same timestep (should remove cloud in 850-600 hPa layer)

- Positive bias is reduced
- Negative bias above unaffected

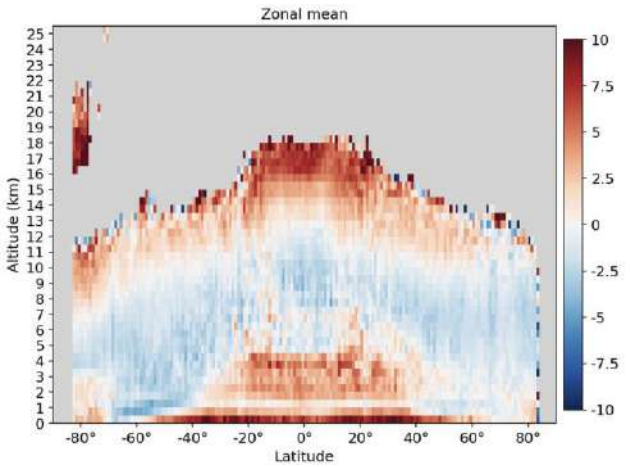
Cirrus change

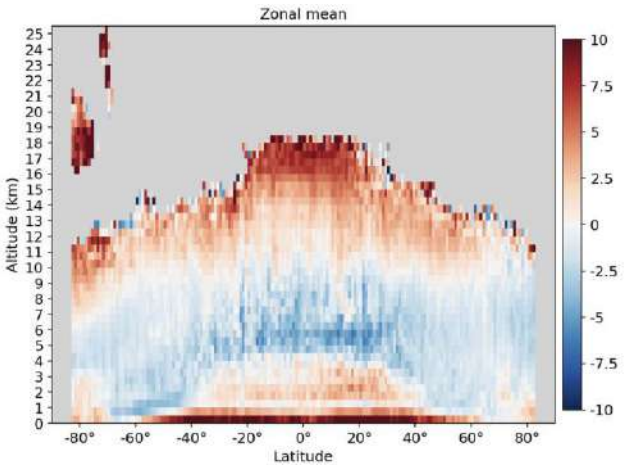
ATLID cloud α zonal mean(O-B)

Night

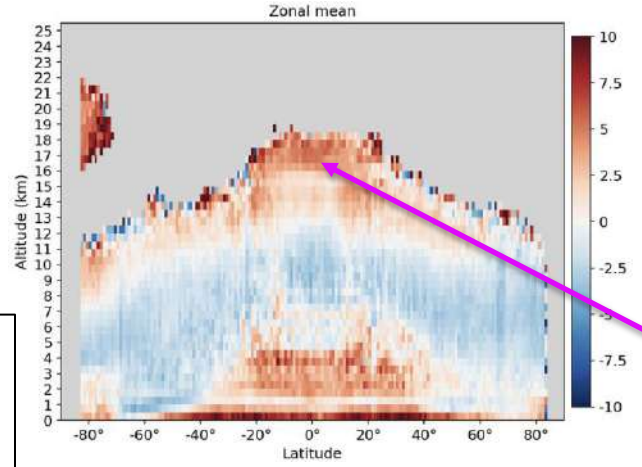
Day

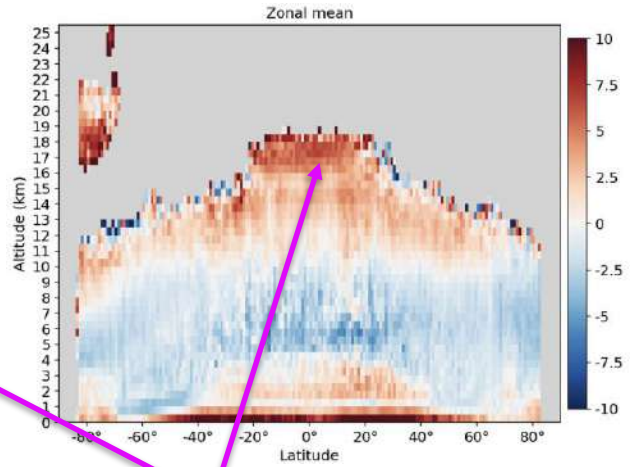
Control





Experiment:
"*cirrus changes*"

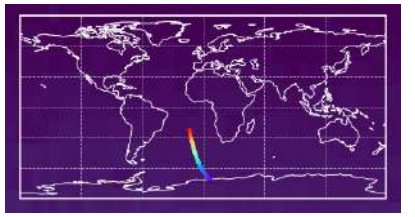




Switched on heterogeneous ice nucleation, new temperature dependent ice fall speed and ice deposition/sublimation based on grid-box mean humidity.

- Positive bias in ice cloud is reduced – but not eliminated

ATLID data averaged to ECMWF model resolution and ECMWF model equivalents



28 May 2026

Rayleigh ATB (cloudy + ***clear***), $dB(b_R)$

Total ATB (cloudy + ***clear***), $dB(b_T)$

Extinction (cloud-only), $dB(\alpha_{M,cloud})$