Global km-scale model simulations almost look like satellite images – but not quite. We need to **understand their imperfections** to **better represent clouds**. A **statistical evaluation** of cloud structures can help.

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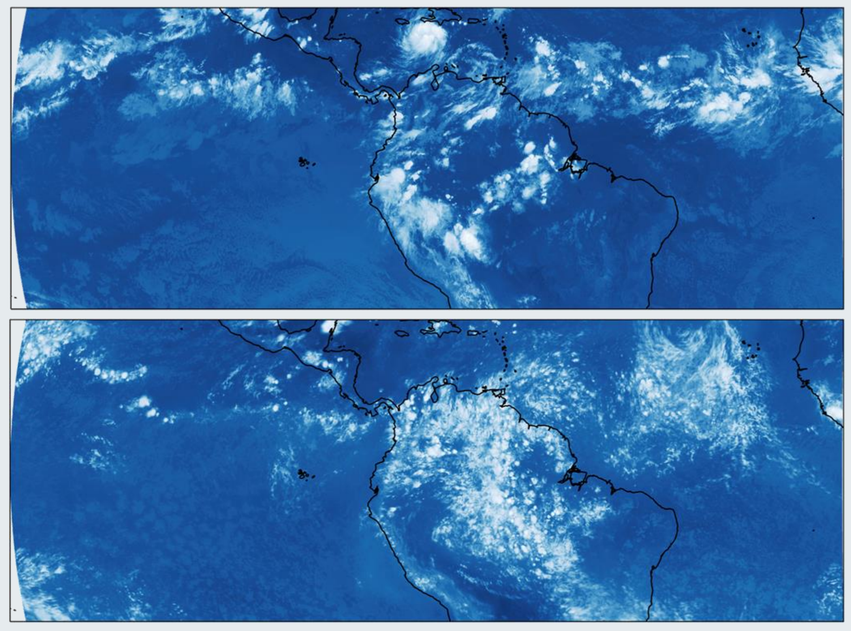
Which one is the satellite image?



Multifractal analysis for evaluating the representation of clouds in global km-scale models

Why do we need new metrics for clouds in km-scale models?

Traditional, aggregated metrics ignore the fine details contained in km-scale simulations.

Observed[2] and simulated[3] clouds show fractal behaviour.

What can we learn by comparing cloud fractals in models and observations?

Approach

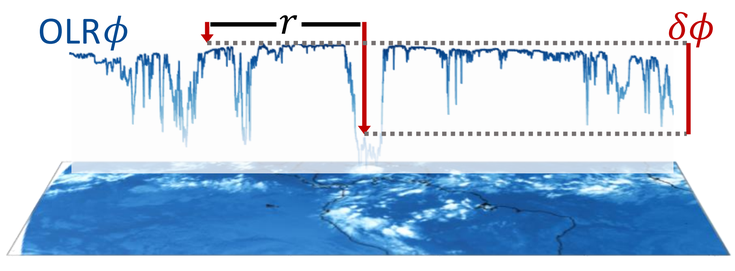
Extract snapshots of outgoing longwave radiation from simulations and observations.

Compute multifractal parameters of deep convective clouds for evaluation.

Multifractal scaling parameters

We compute structure functions $S_q(r)$ which describe average variability of outgoing longwave radiation (OLR) ϕ:

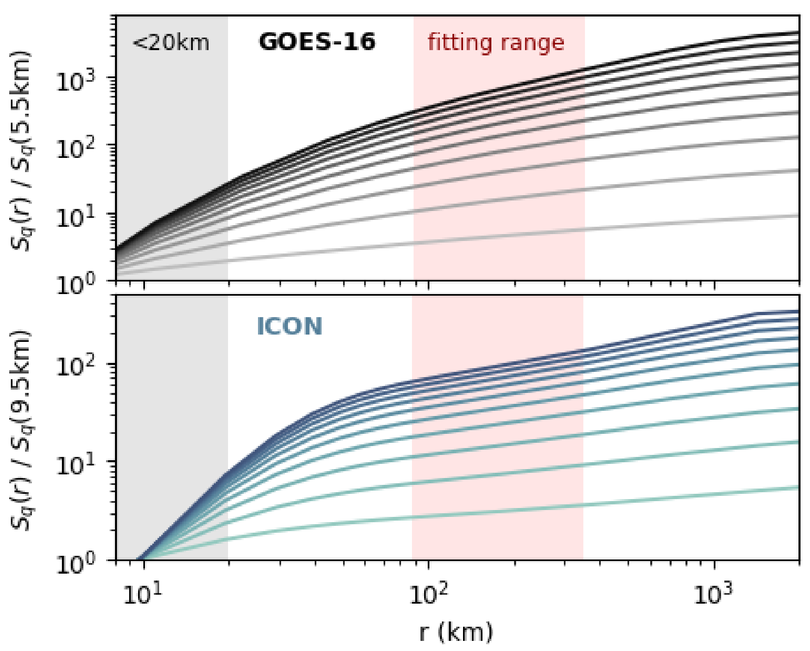
$$S_q(r) = \langle |\phi(x+r) - \phi(x)|^q \rangle \propto r^{\zeta_q}$$



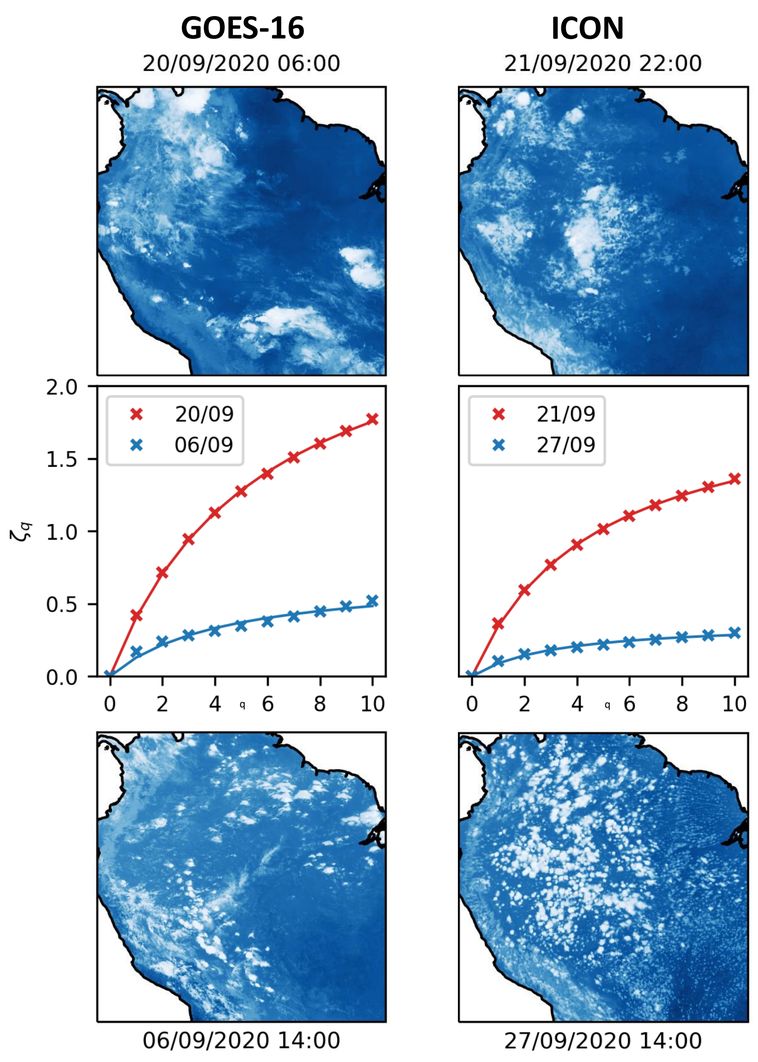
The two-parameter fit[2] to the scaling exponents $\zeta_q = aq/(1 + aq/\zeta_\infty)$ captures smoothness a and multifractality ζ_∞.

Multifractal evaluation of clouds in nextGEMS models

Structure functions $S_q(r)$ show that simulated clouds exhibit multifractal scaling between 50 and 1000km.

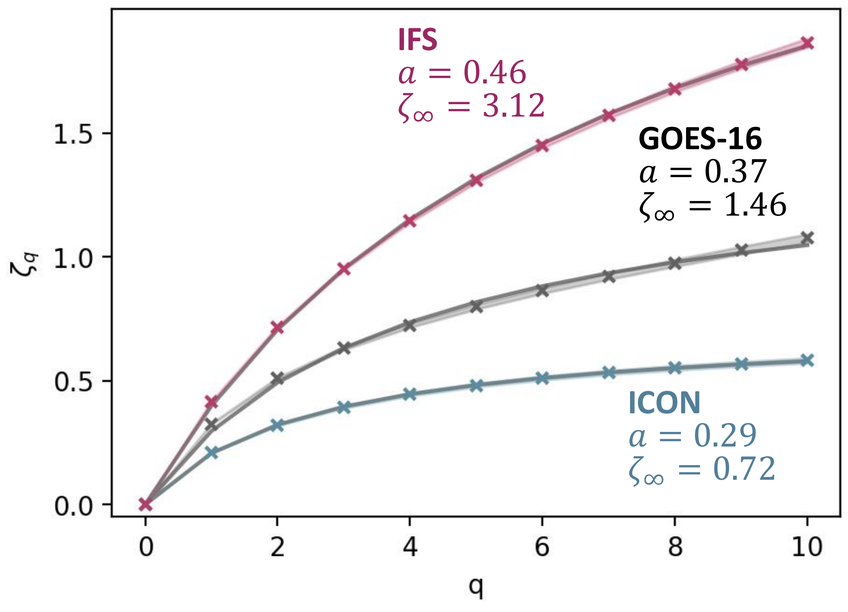


Larger fractal parameters correspond to more organised cloud fields.

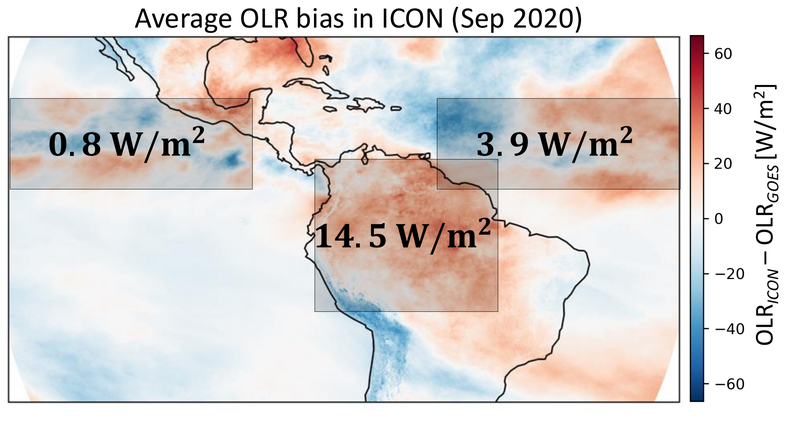


Scaling parameters ζ of deep convection in the km-scale models ICON and IFS[4] do not match GOES-16 observations[5].

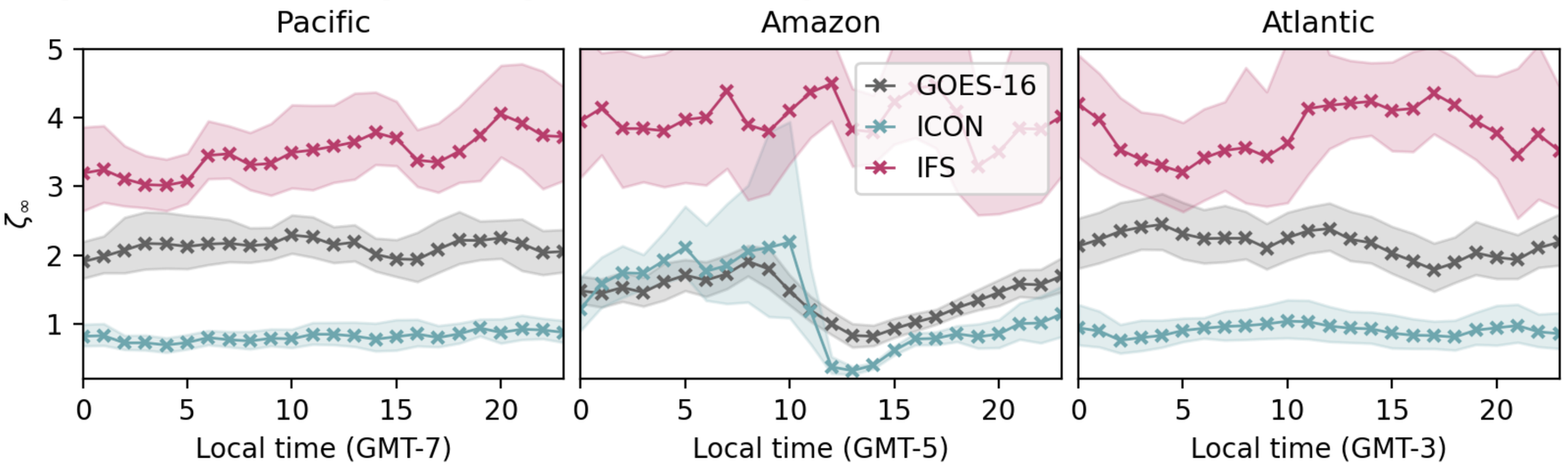
Anvils are too organised in the IFS (high ζ_∞) and not organised enough in ICON (low ζ_∞).



Fractal analysis and averaged metrics disagree on which regions are modelled better.



Regional studies can give insights into the origin of the identified biases



ICON's bias towards lower scaling parameters originates from clouds simulated over the ocean.

The IFS does not represent the diurnal cycle of convection correctly, both over land and over ocean.

References

[1] Freischem, L. J. et al. (2024). Multifractal Analysis for Evaluating the Representation of Clouds in Global Kilometre-Scale Models. *Manuscript submitted for publication.* (preprint: 10.22541/au.171813202.26984086/v1)

[2] Pierrehumbert, R. T. (1996). Anomalous scaling of high cloud variability in the tropical pacific. *Geophysical Research Letters, 23*, 1095-1098.

[3] Christensen, H. M. & Driver, O. G. A. (2021). The Fractal Nature of Clouds in Global Storm-Resolving Models. *Geophysical Research Letters, 48*(23).

[4] Koldunov, N. et al. (2023). nextGEMS: output of the model development cycle 3 simulations for ICON and IFS. *World Data Center for Climate (WDCC) at DKRZ*.

[5] GOES-R Calibration Working Group & GOES-R Series Program (2017). NOAA GOES-R Series Advanced Baseline Imager (ABI) Level 1b Radiances.

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