COLUMBIA CLIMATE SCHOOL
LAMONT-DOHERTY EARTH OBSERVATORY

Observation proxies for high-resolution simulations and satellite observations

Robert Pincus

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Observation proxies for kilometer-scale models and/or EarthCARE informed by COSP

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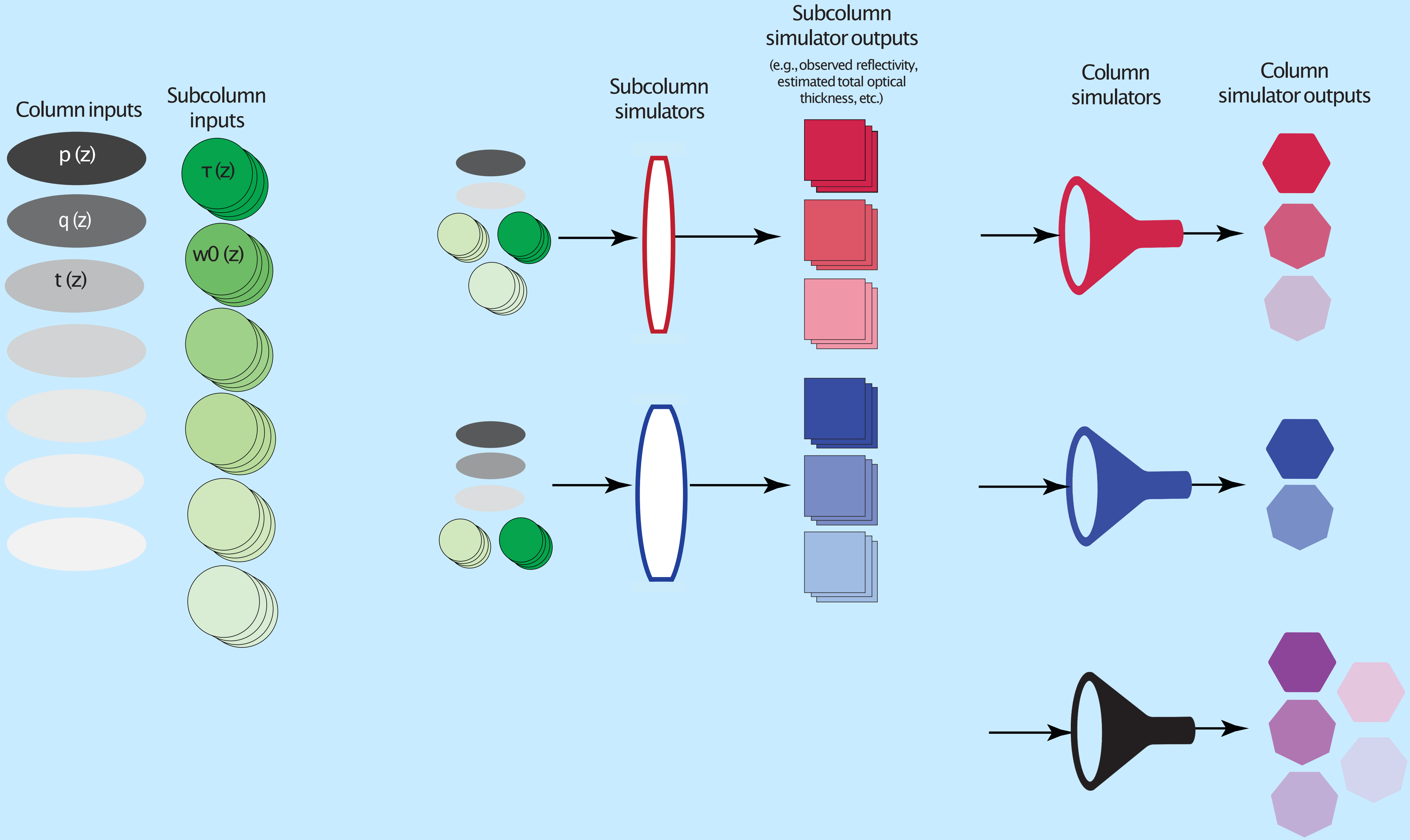
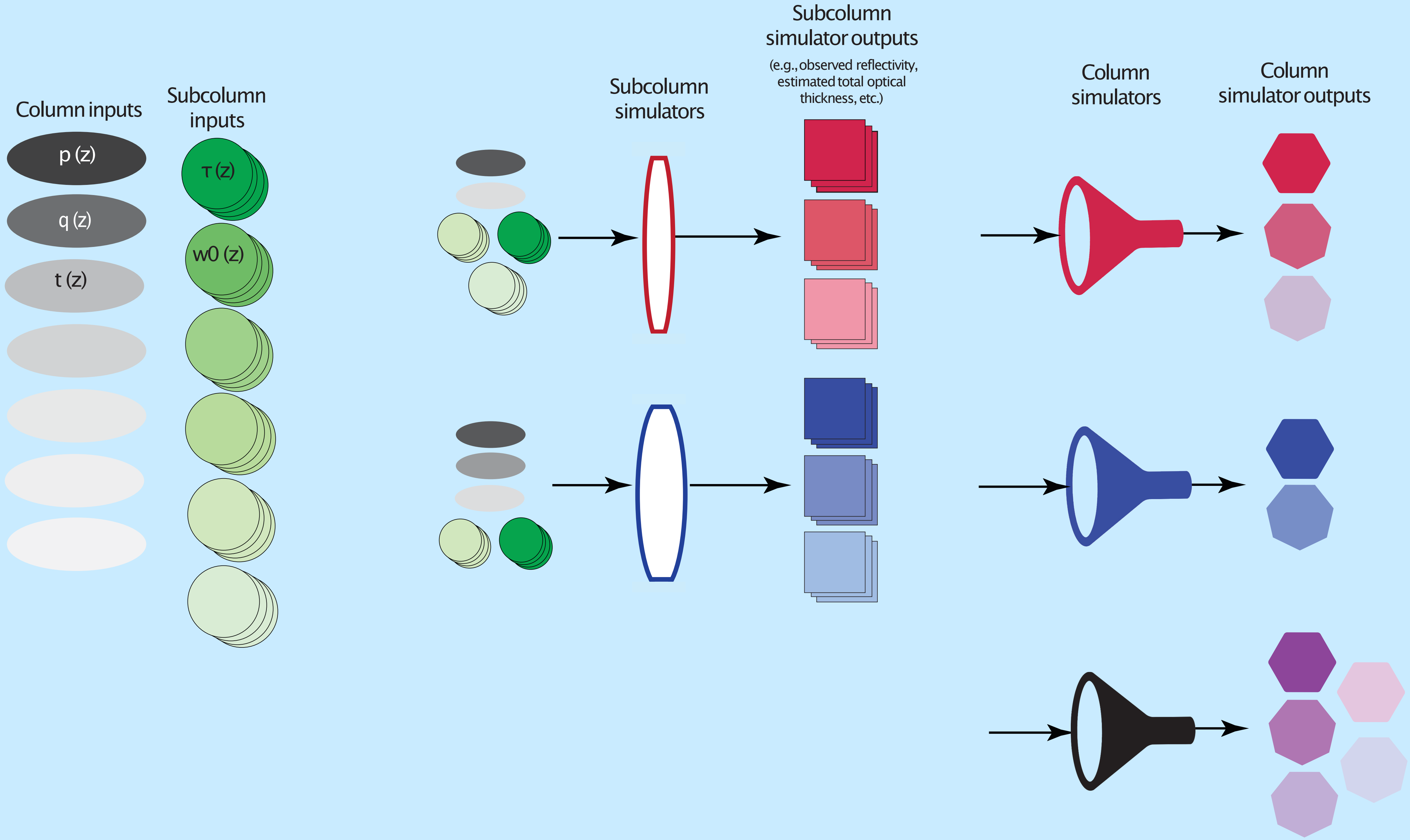
COSP: proxies for (coarse-resolution) model assessment



Swales et al. 2018, 10.5194/gmd-11-77-2018

COSP: proxies for (coarse-resolution) model assessment

Observing system characterization



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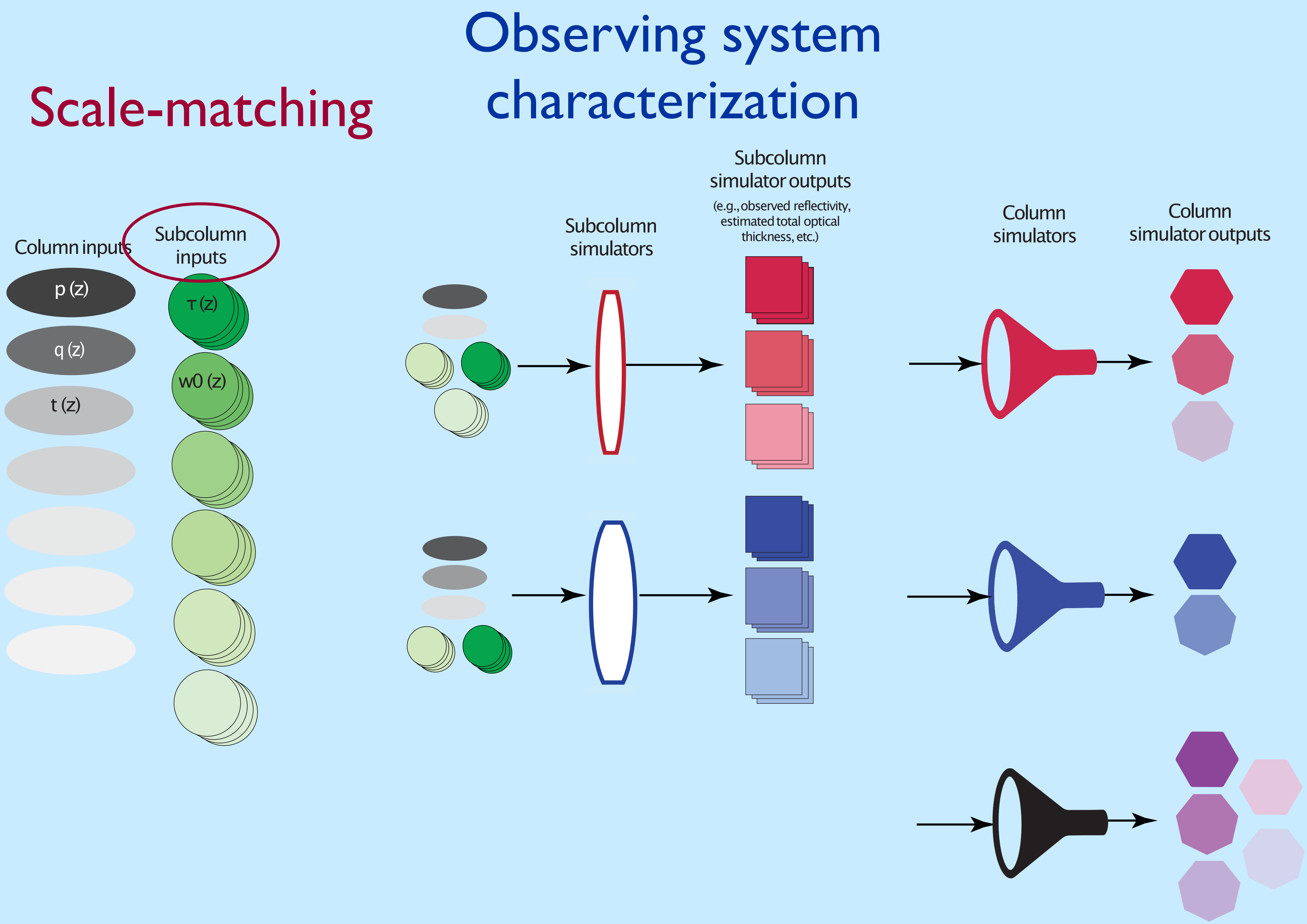

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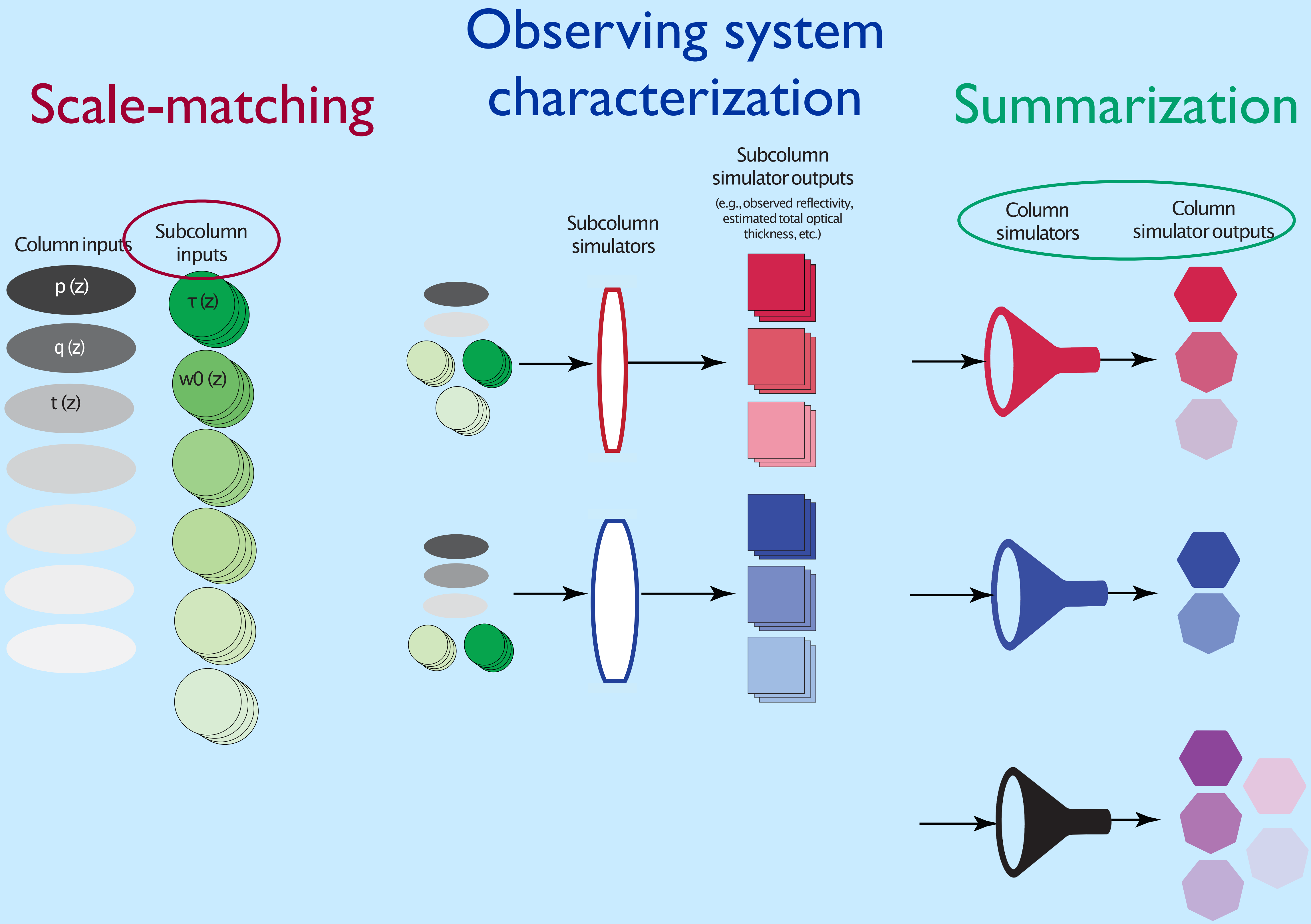

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Observing system proxies map model state to observables

I.e. for clouds:

From cloud state $q^{l,i,\cdots}(z), r_e^{l,i,\cdots}(z)$

to (potentially multi-variate) observable $f(\tau, r_e, Z, \ldots; \Delta x, \Delta y, \Delta t)$

via radiative properties $\sigma^\lambda(z), \omega_0^\lambda(z), \beta^\lambda(z), \ldots$

Mapping seeks to account for conditional biases e.g. masking, sensitivity, …

Proxies and simulators

See also:

simulators for sensor design (e.g. ECSIM) or mission design (OSSEs)

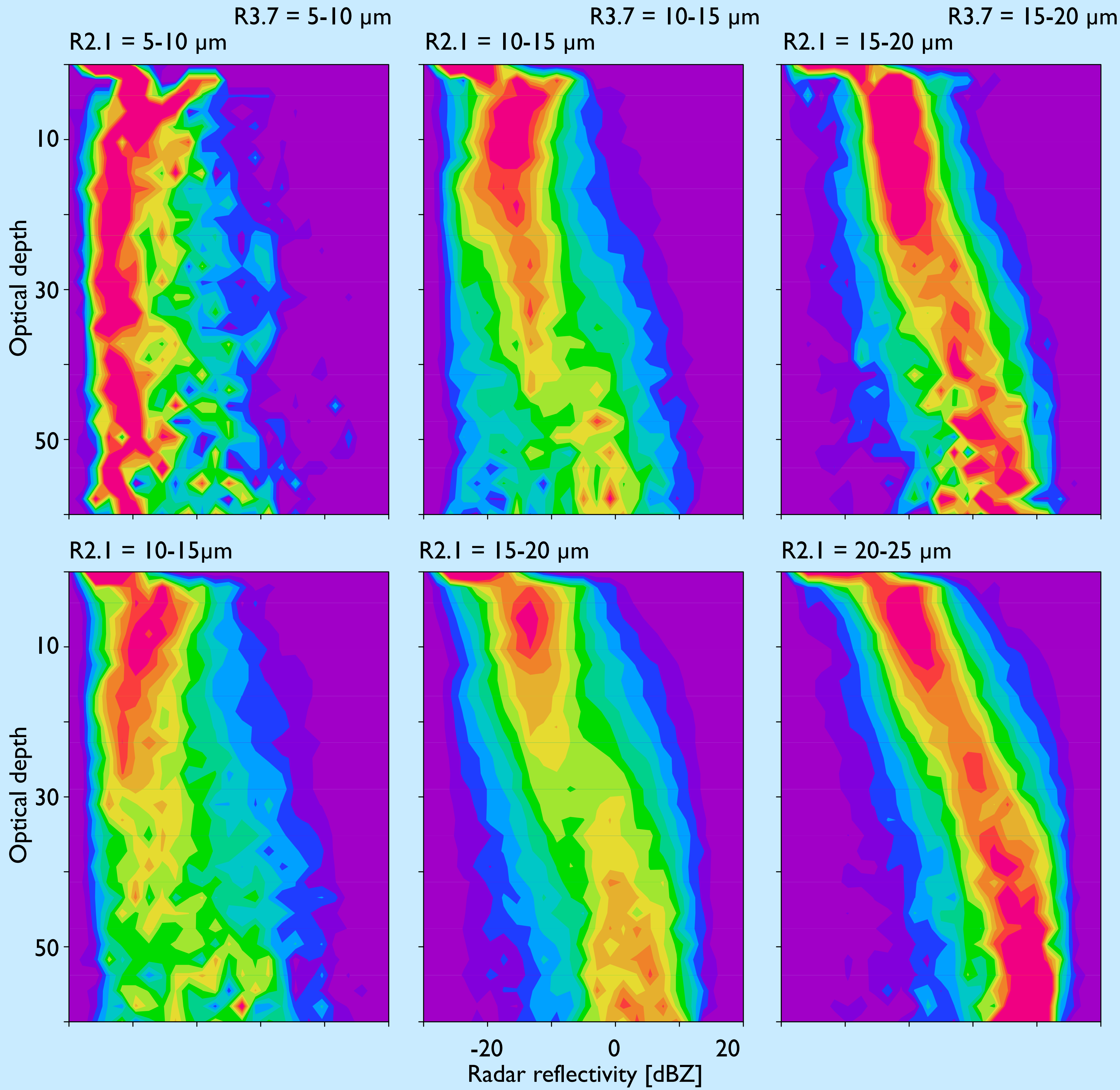
forward operators in data assimilation

Notes:

Some observables (e.g. radiative fluxes) don't use proxies

Comparisons to active sensors tend to be closer to instrument signals

Summaries may be multi-faceted (definitional, multi-variate, …)



after Suzuki et al. 2010, 10.1175/2010JAS3463.1

Proxy precision and underlying uncertainty

Some quantities are well-measured*:

$$\tau = \int_{\text{TOA}}^{0} \sigma(z) dz$$

Some observational estimate are hard to/not worth replicating in detail

$$P = \int_{\text{TOA}}^{\tau=1} P(z)\sigma(z) dz$$

Some biases are hard to anticipate

$$r_e = F^{-1}(F(r_e(z), P(z)))$$

Some comparisons are most easily made in observation space

$$Z_l^a = Z_l e^{-2\tau_l} \frac{1 - e^{-2\Delta h_l \alpha_l}}{2\Delta h_l \alpha_l}$$

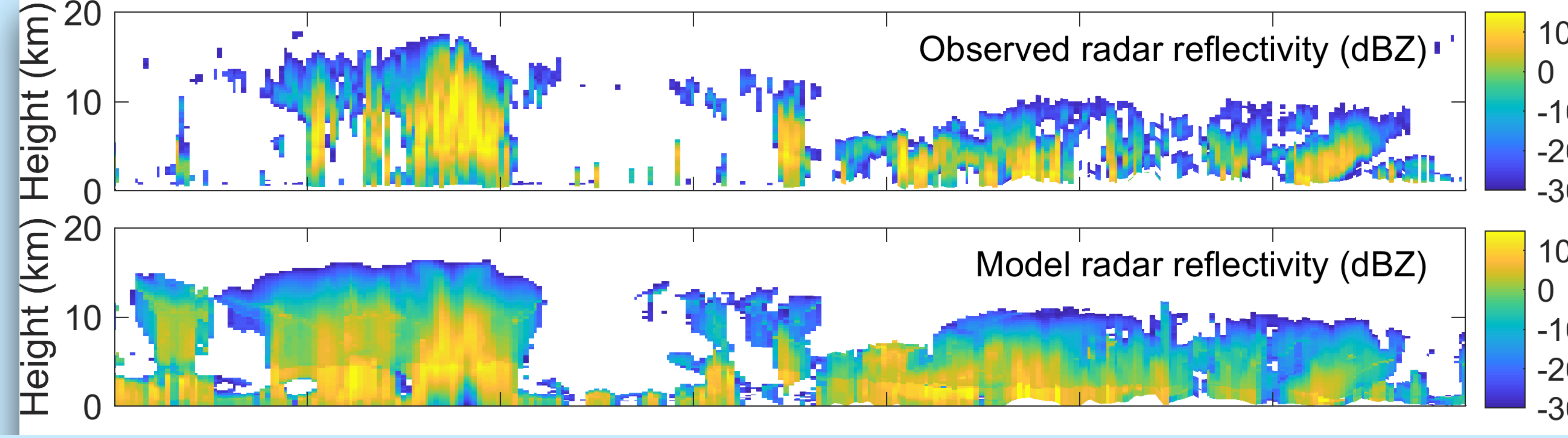
Data assimilation for understanding uncertainty budgets

Data assimilation is effective when observations are unbiased* and conditional uncertainties are known

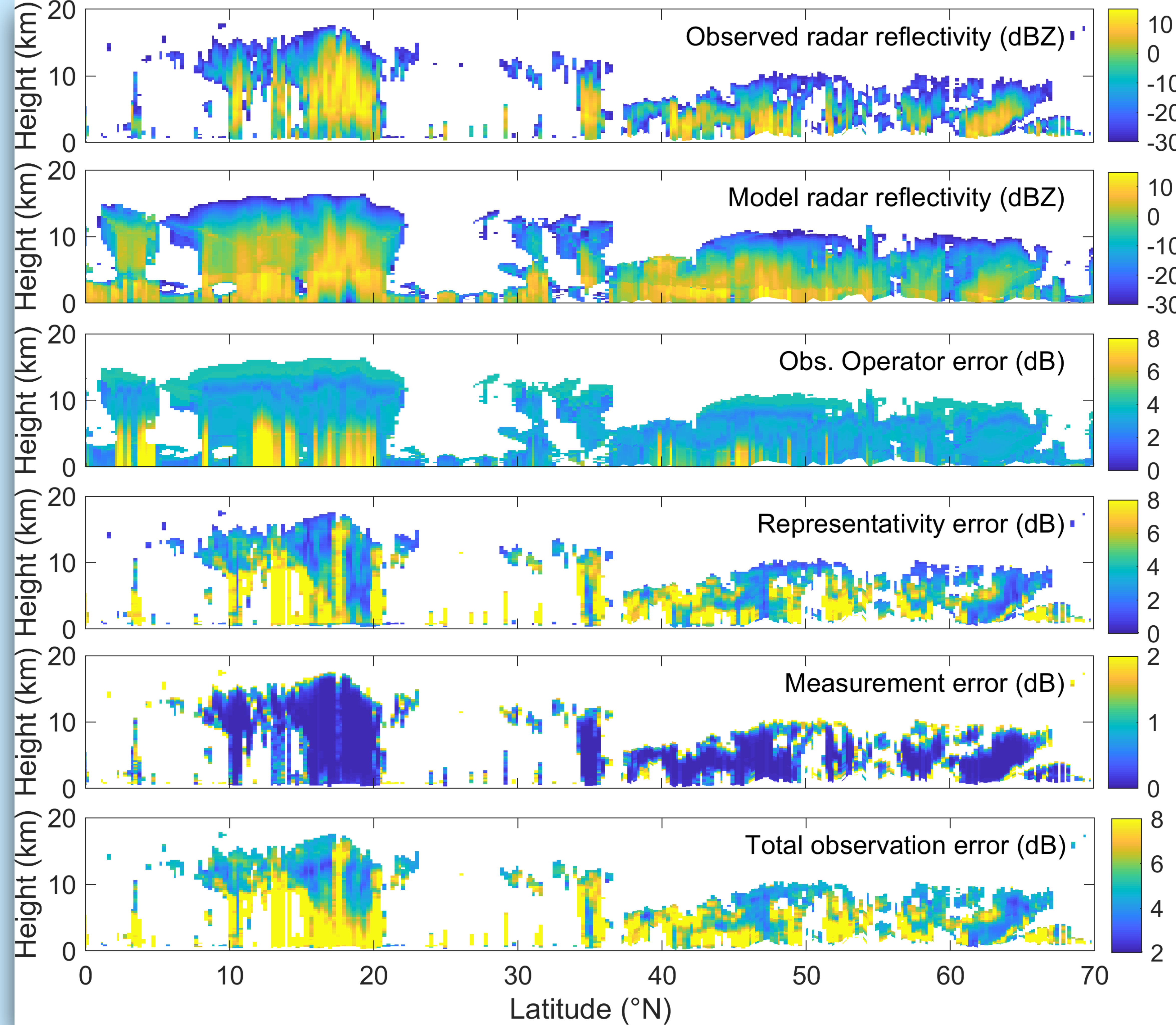
$$\mathcal{J}(\delta \mathbf{x}_0) = \frac{1}{2}(\delta \mathbf{x}_0)^T \mathbf{B}^{-1}(\delta \mathbf{x}_0) + \frac{1}{2}\sum_i (H_i' \delta \mathbf{x}_i - \mathbf{d}_i)^T R_i^{-1} (H_i' \delta \mathbf{x}_i - \mathbf{d}_i)$$

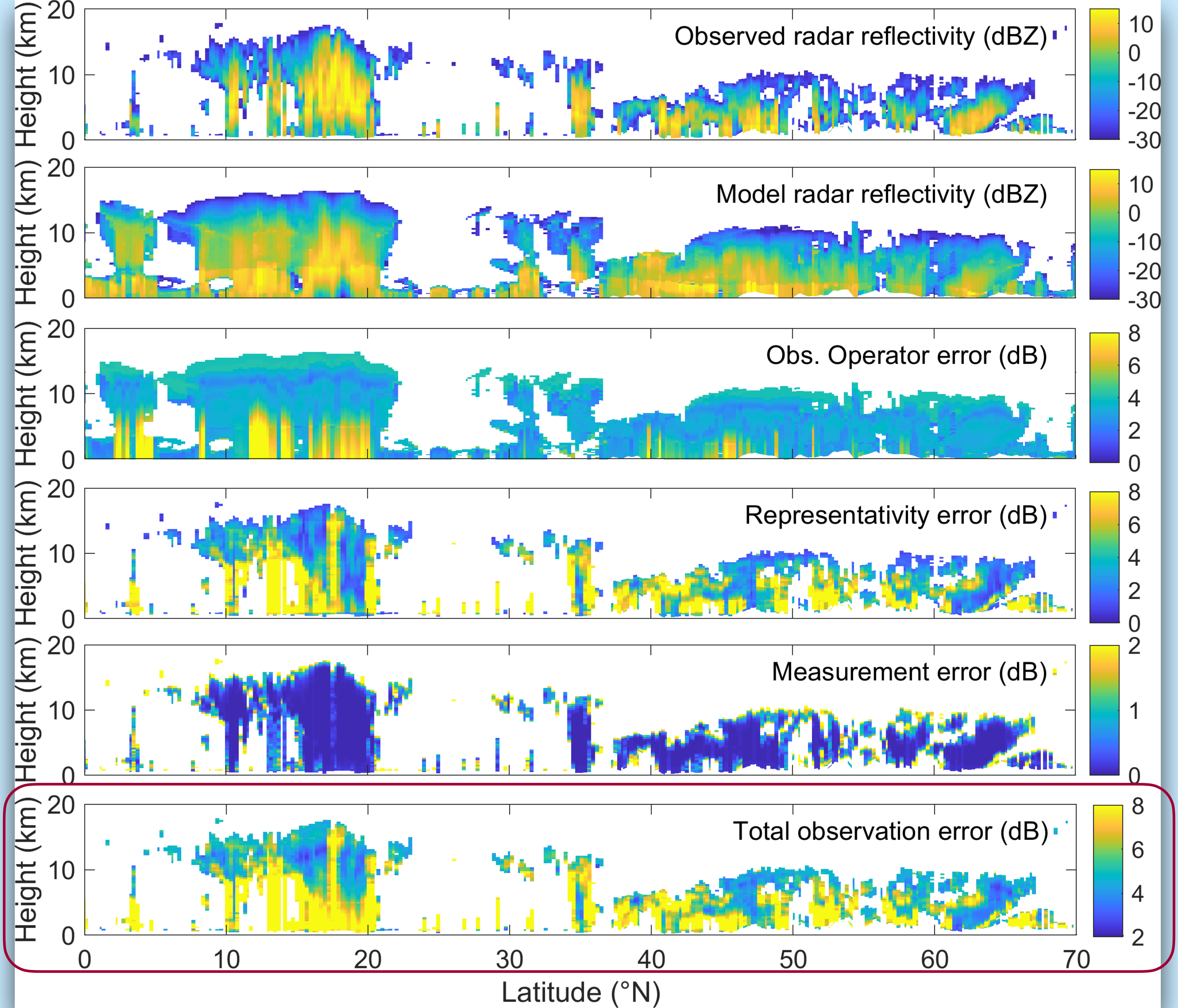
with $\mathbf{d}_i = \mathbf{y}_i^o - \mathbf{H}_i(\mathbf{x}_i^b)$

Efforts to quantify uncertainty for data assimilation might inform proxies/operators for other contexts



after Fielding and Janisková 2020, 10.1002/qj.3878


Observed radar reflectivity (dBZ)
Model radar reflectivity (dBZ)
Obs. Operator error (dB)
Representativity error (dB)
Measurement error (dB)
Total observation error (dB)
Height (km)
Latitude (°N)
0
10
20
30
40
50
60
70
10
0
-10
-20
-30
8
6
4
2
1



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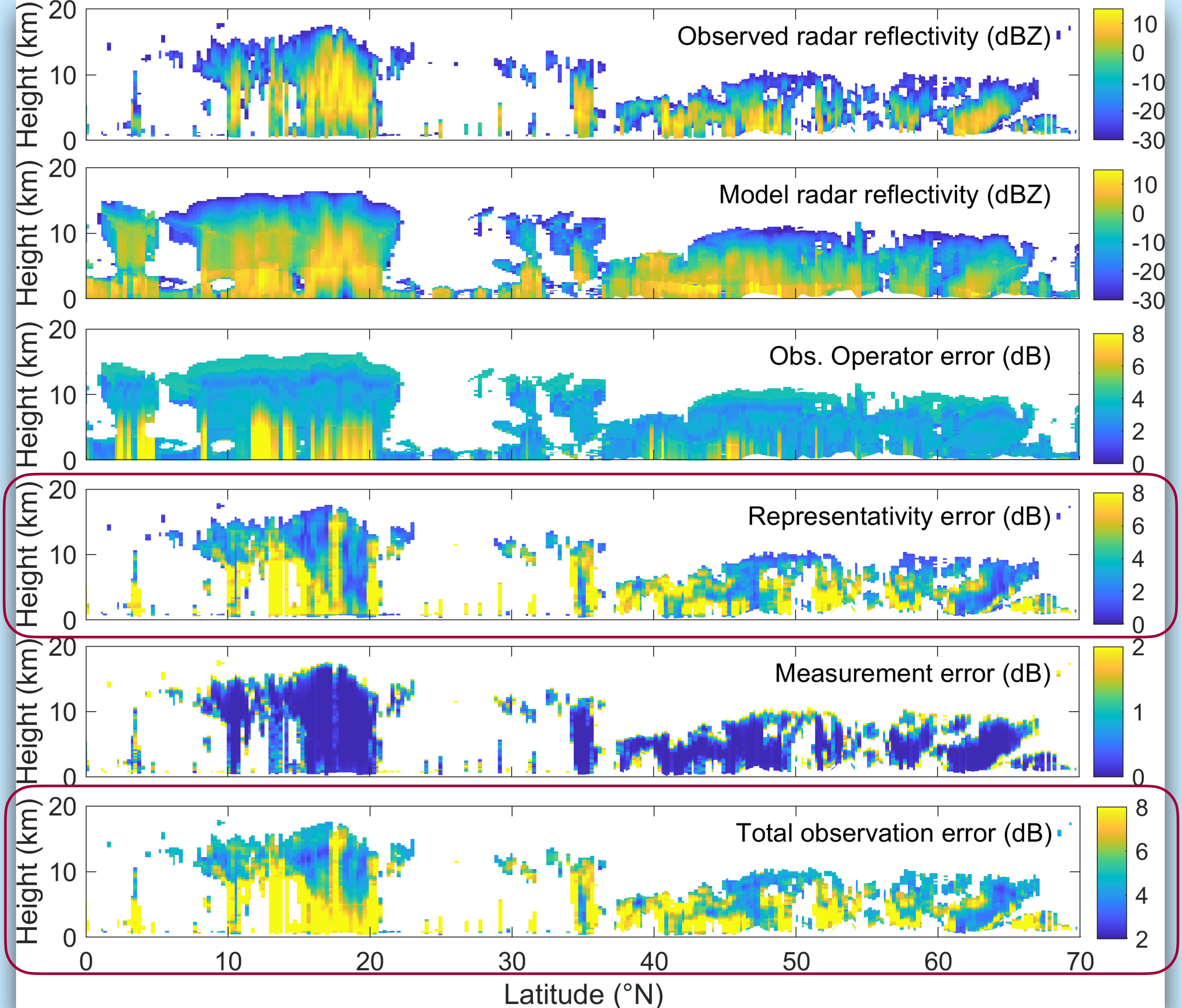

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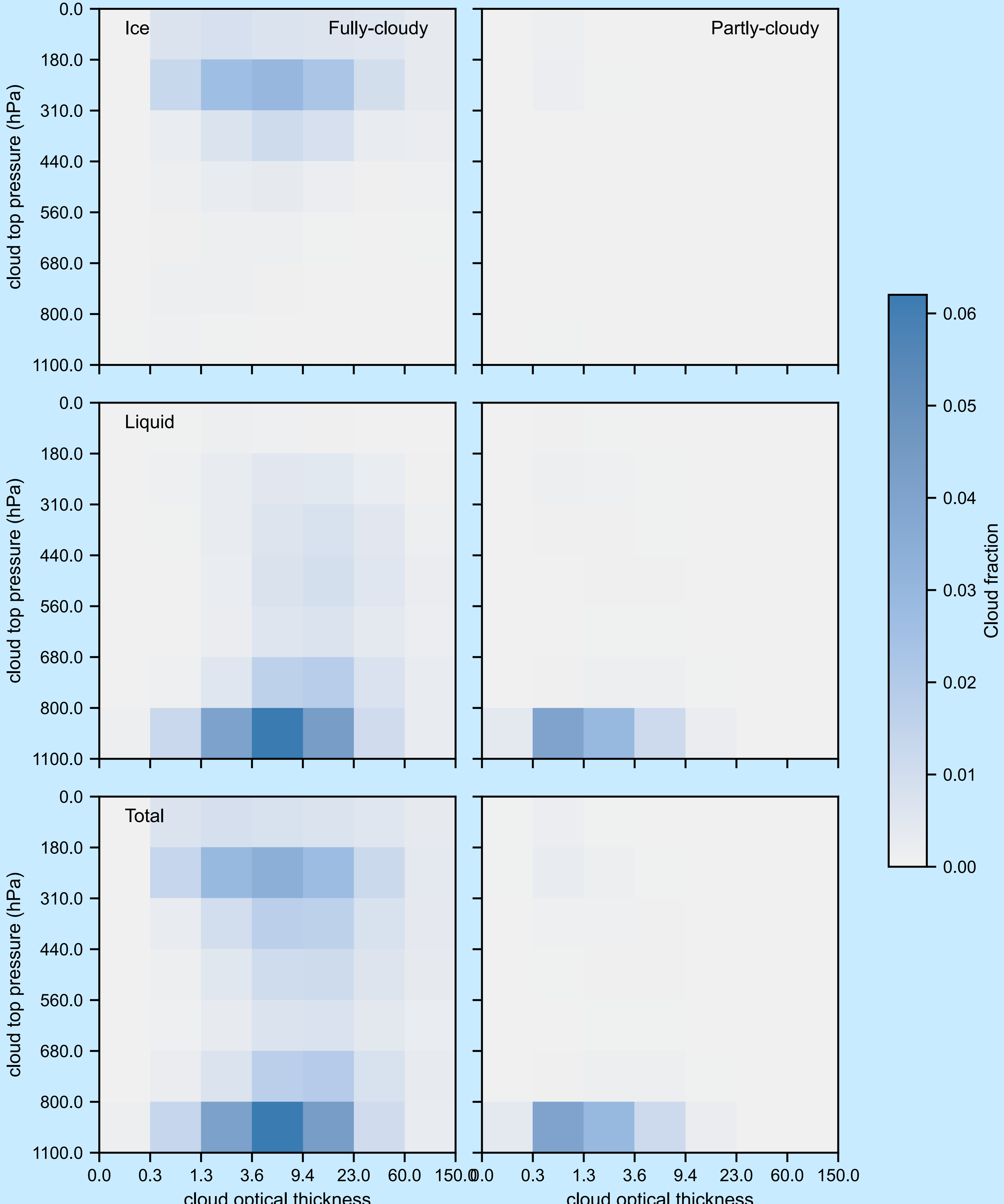
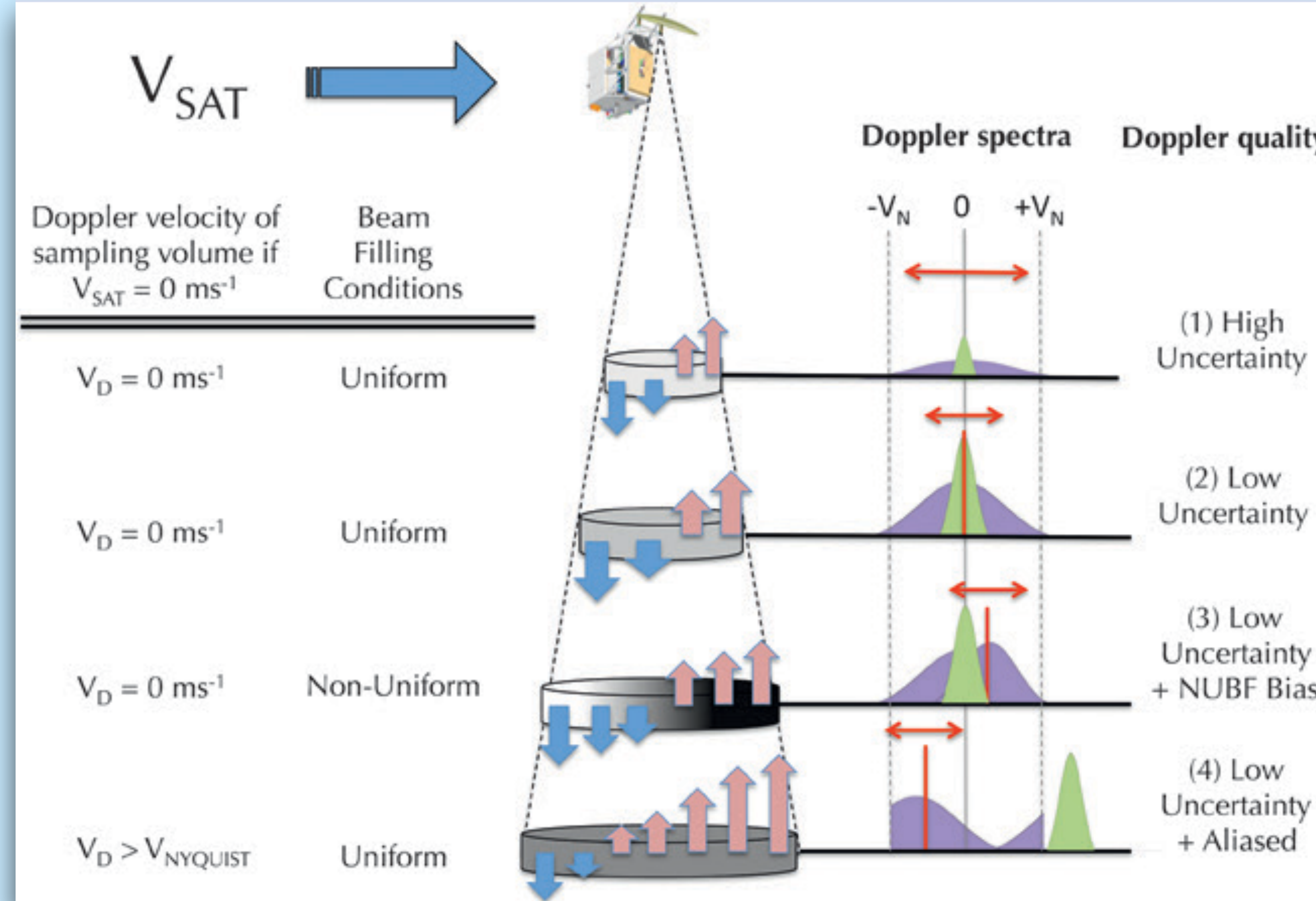


Pincus et al. 2023, 10.5194/essd-2022-282



Illingworth et al. 2015, 10.1175/BAMS-D-12-00227.1

From COSP to km-scale models

Innovation is endless - experience suggests enabling experimentation and iteration

At resolved scales:

- What is required for ergodicity to defeat limited sampling?
- To what extent can vertical motion and microphysics be unfolded?

At unresolved scales:

- Can confidence in observations and/or models be categorized?

Effort spent in mapping model to observations can be targeted (observing system proxy is not always the largest source of uncertainty)

- What lightweight proxies for km-scale models?