

1.4. Perturbation of the soil variables

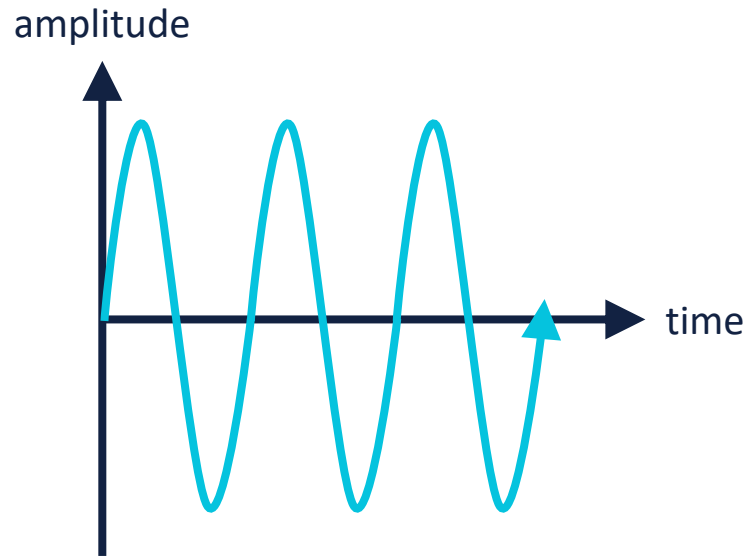
1.1. SPP in ICON: cloud microphysics parameters in single- and double-moment schemes

Grzegorz Zakrzewski, Jakub Lewandowski, Tatiana Tabalchuk, Andrzej Mazur, Andrzej Wyszogrodzki

14th September 2026, COSMO General Meeting, Rome

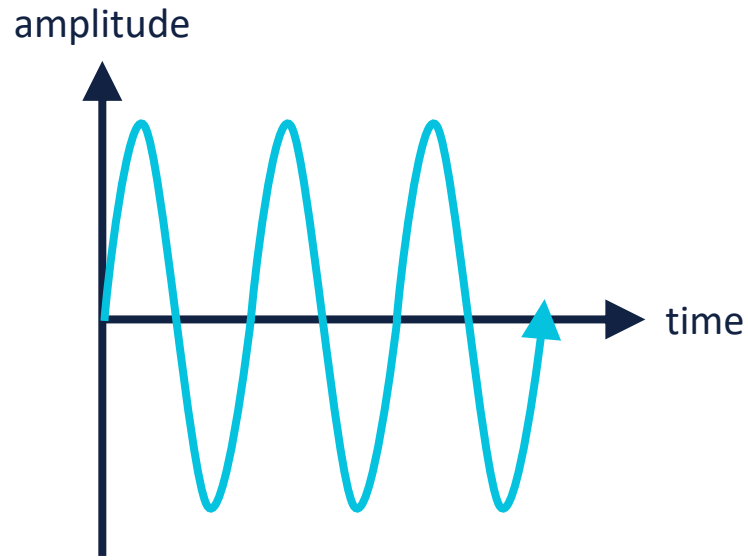


Random noise:



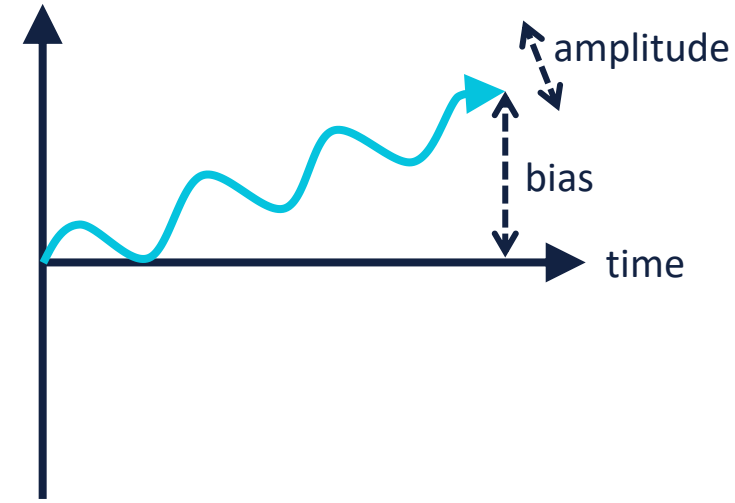
- random noise perturbations are added at each model step, up to a specific **time**
- the sum of added perturbations cannot exceed a specific **amplitude**

Random noise:

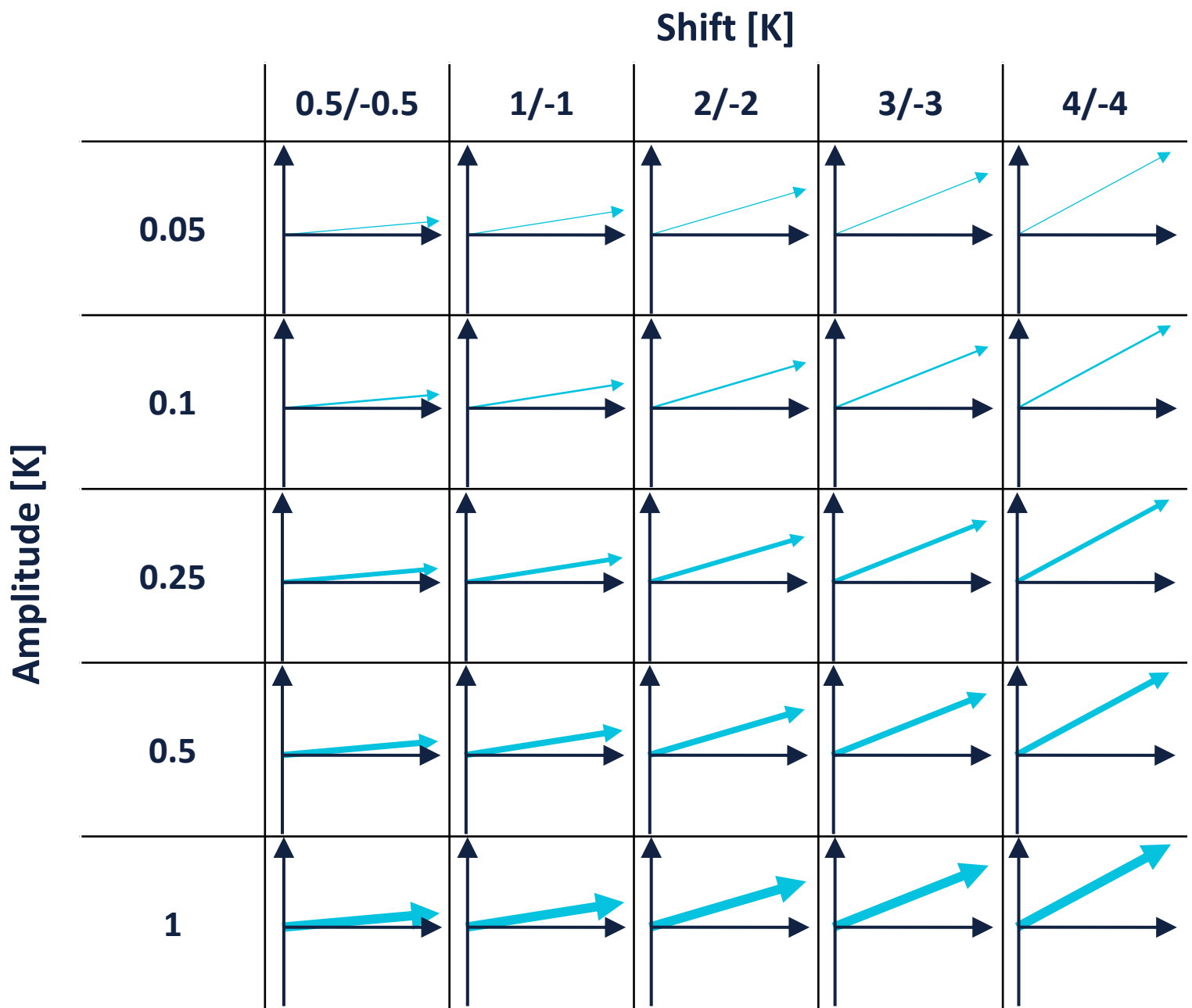


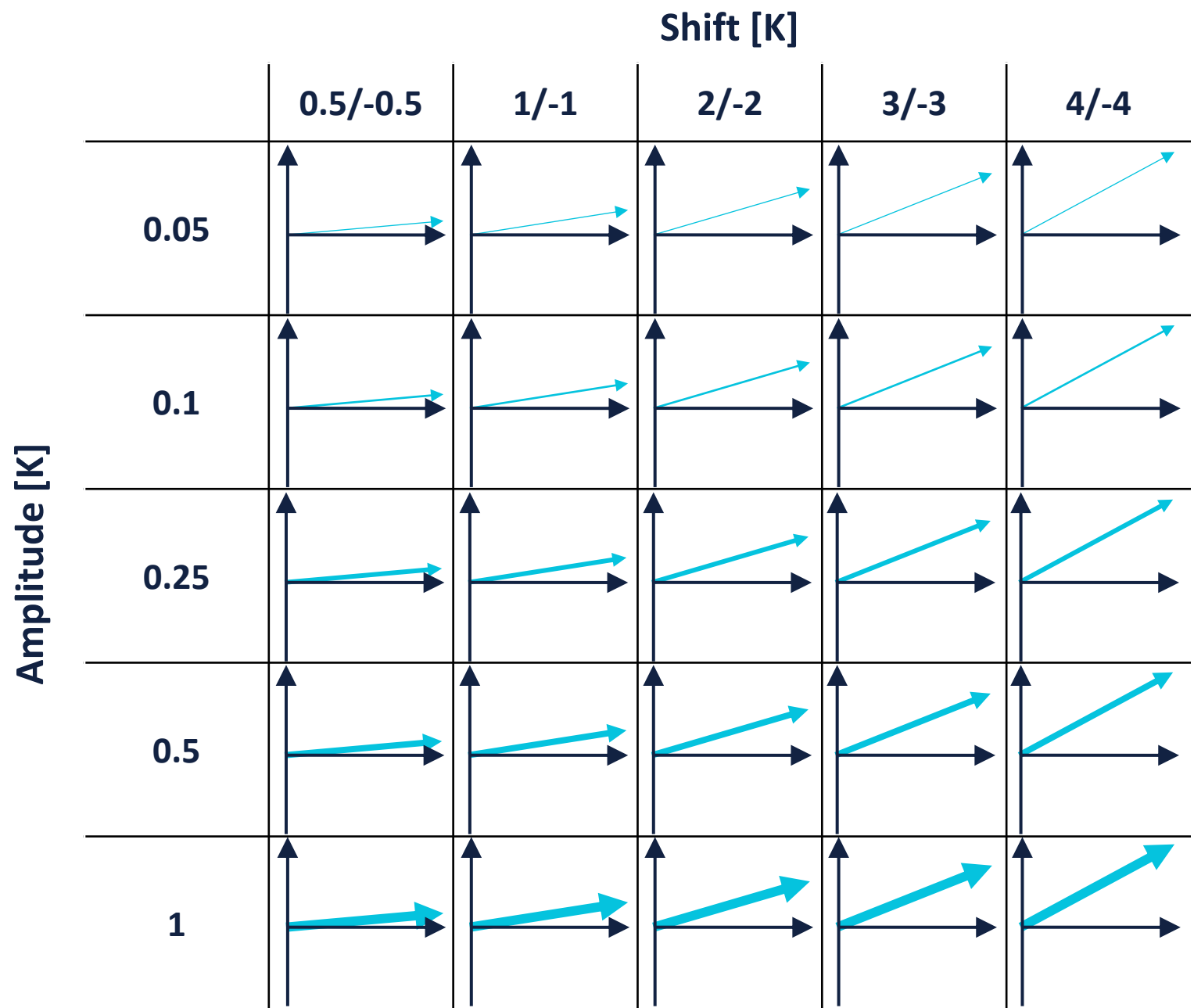
- random noise perturbations are added at each model step, up to a specific **time**
- the sum of added perturbations cannot exceed a specific **amplitude**

Bias + noise:



- a specific positive/negative **bias** is applied, distributed over a period of **time**
- random noise perturbations of a specific **amplitude** are added at each step





Group A

1 step

Instantaneous data-
access failure



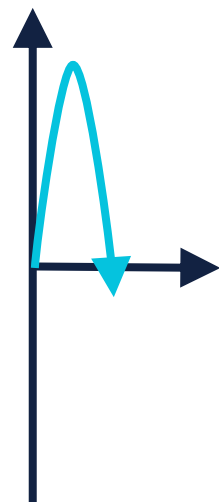
Group A
1 step

Instantaneous data-
access failure



Group B
2 steps

Instantaneous data-
access failure



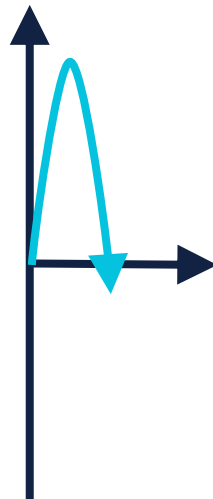
Group A 1 step

Instantaneous data-
access failure



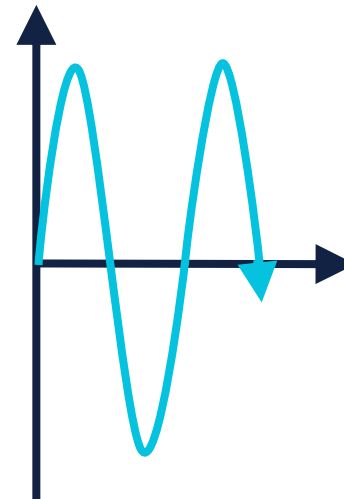
Group B 2 steps

Instantaneous data-
access failure



Group D 10 minutes

Short-term boundary-
layer variability



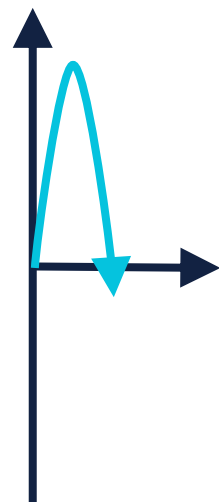
Group A
1 step

Instantaneous data-
access failure



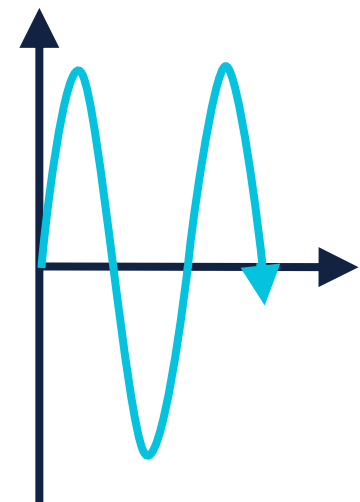
Group B
2 steps

Instantaneous data-
access failure



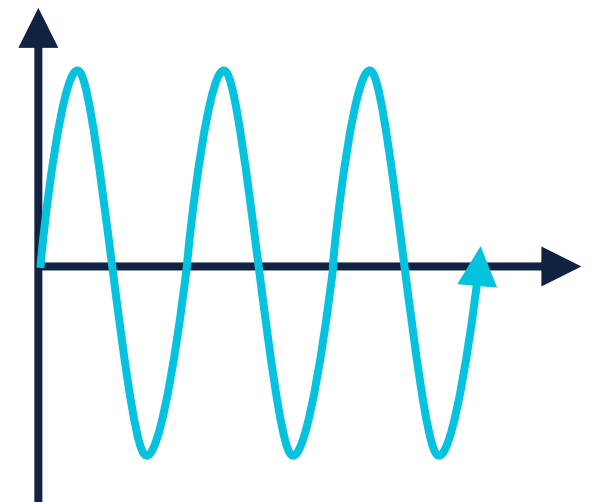
Group D
10 minutes

Short-term boundary-
layer variability



Group C
1 hour

Long-term synoptic-scale
forcing



Bias + noise perturbations:

- groups A/B/C/D
- 50 members each, 200 members in total

Bias + noise perturbations:

- groups A/B/C/D
- 50 members each, 200 members in total

Reference:

- only random noise perturbations
- noise amplitude = 2 K
- 10 members per each time horizon
(1 step, 2 steps, 10 minutes, 1 hour)
- 40 members in total

The soil temperature perturbation scheme: experiment setup



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Bias + noise perturbations:

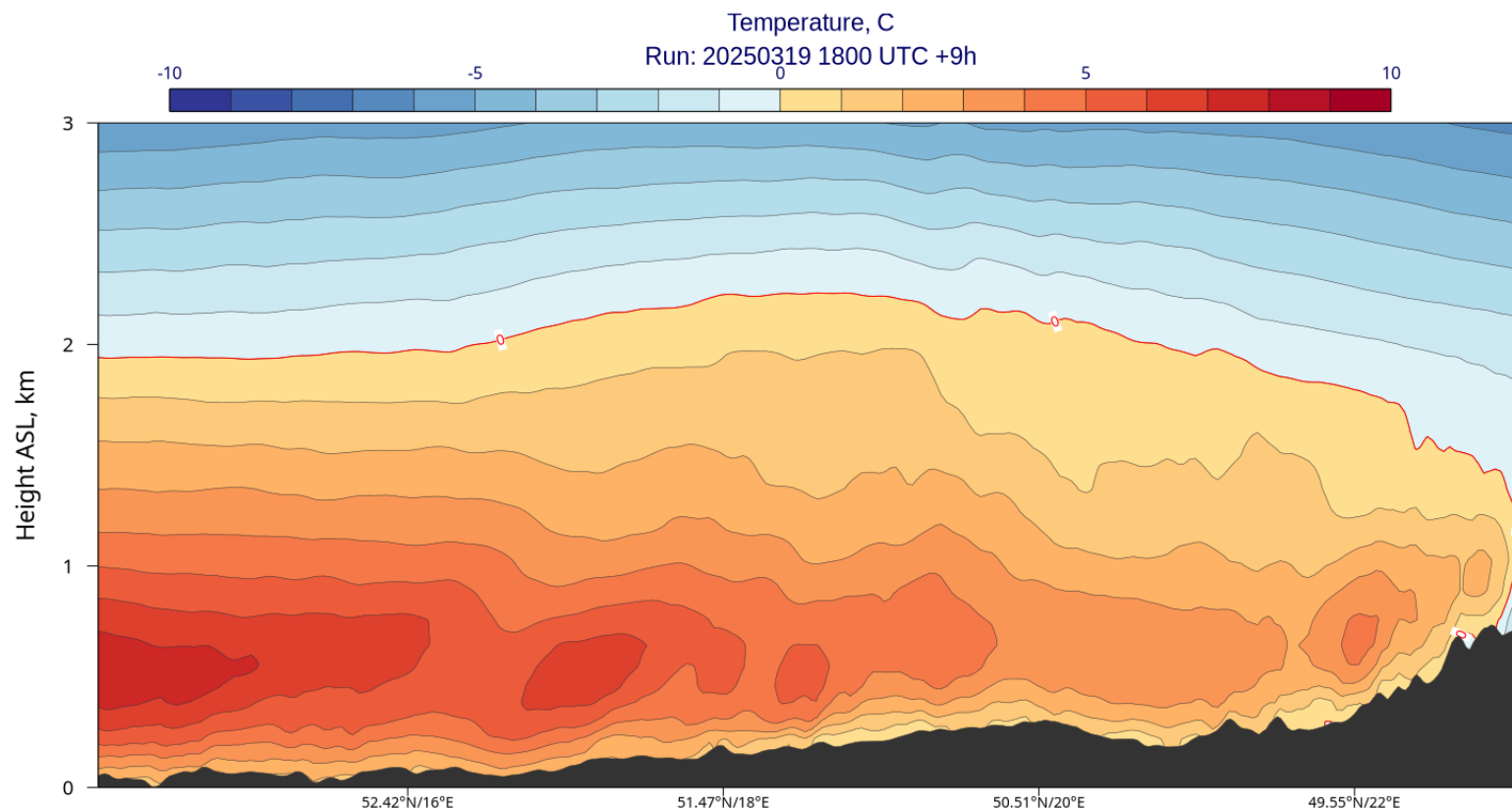
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Reference:

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Test cases – inversion favorable conditions:

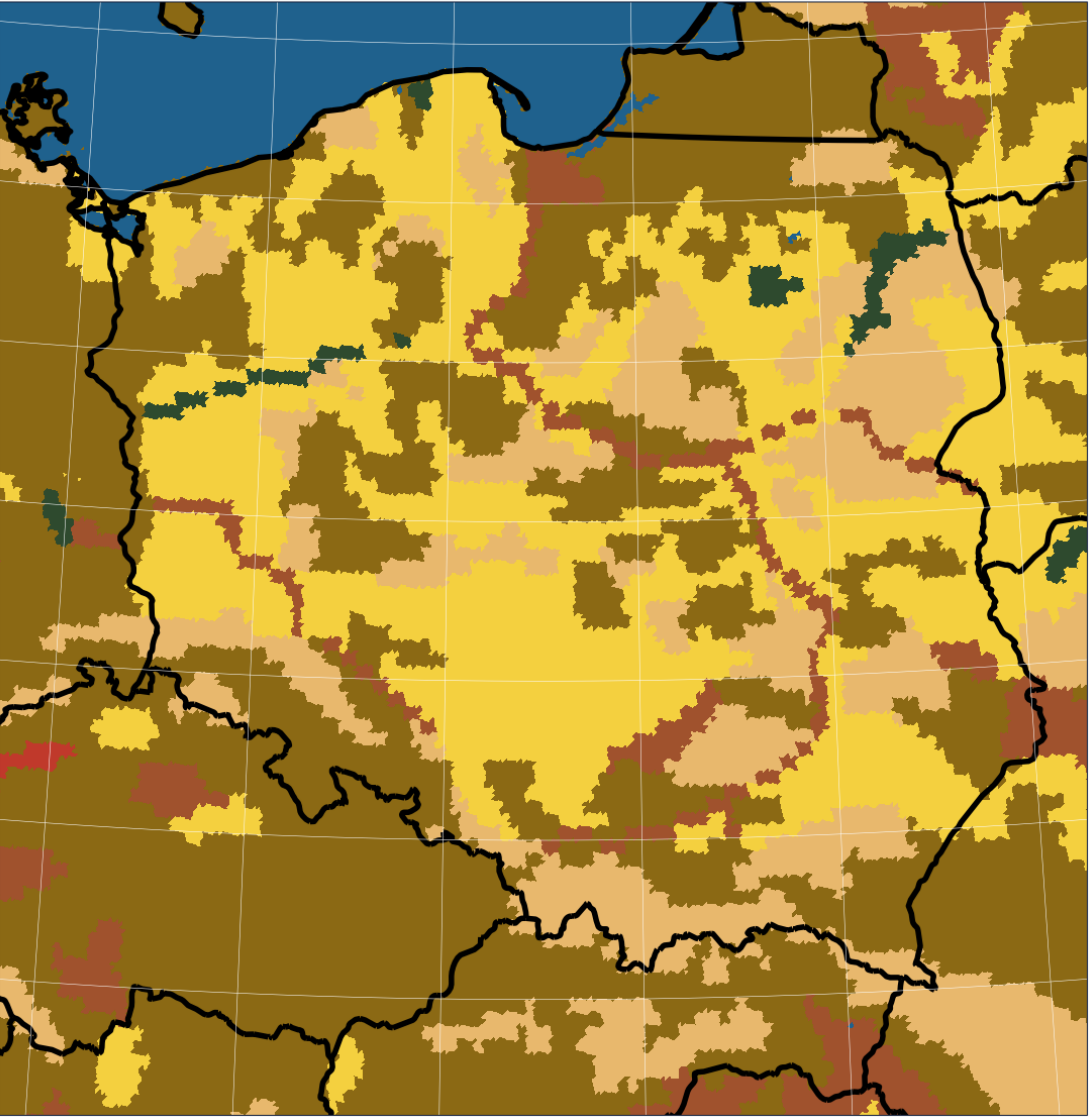
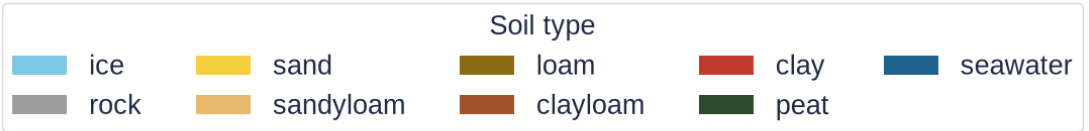
- sunset before 18:00 UTC (forecast initialization time)
- average cloud cover below 0.5 oct.
- wind speed below 3 m/s
- 23 test cases from years 2018-2025
- ICON-LAM PL 2.5 km resolution
ICs and LBCs from ICON GLOBAL



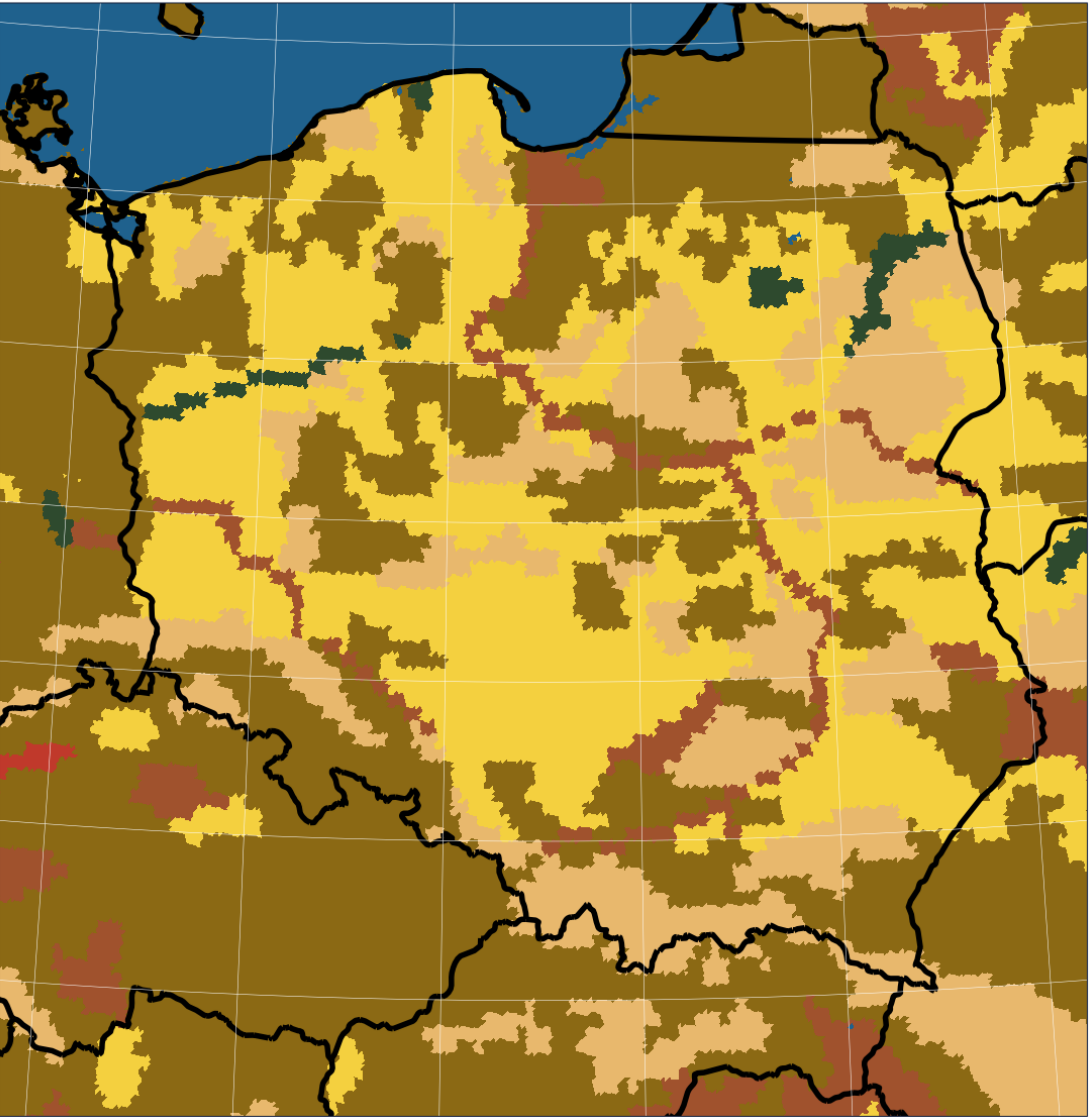
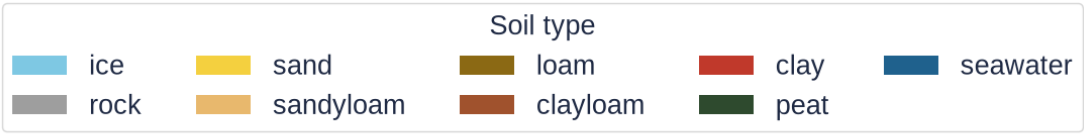
The soil temperature perturbation scheme: soil type and depth dependence



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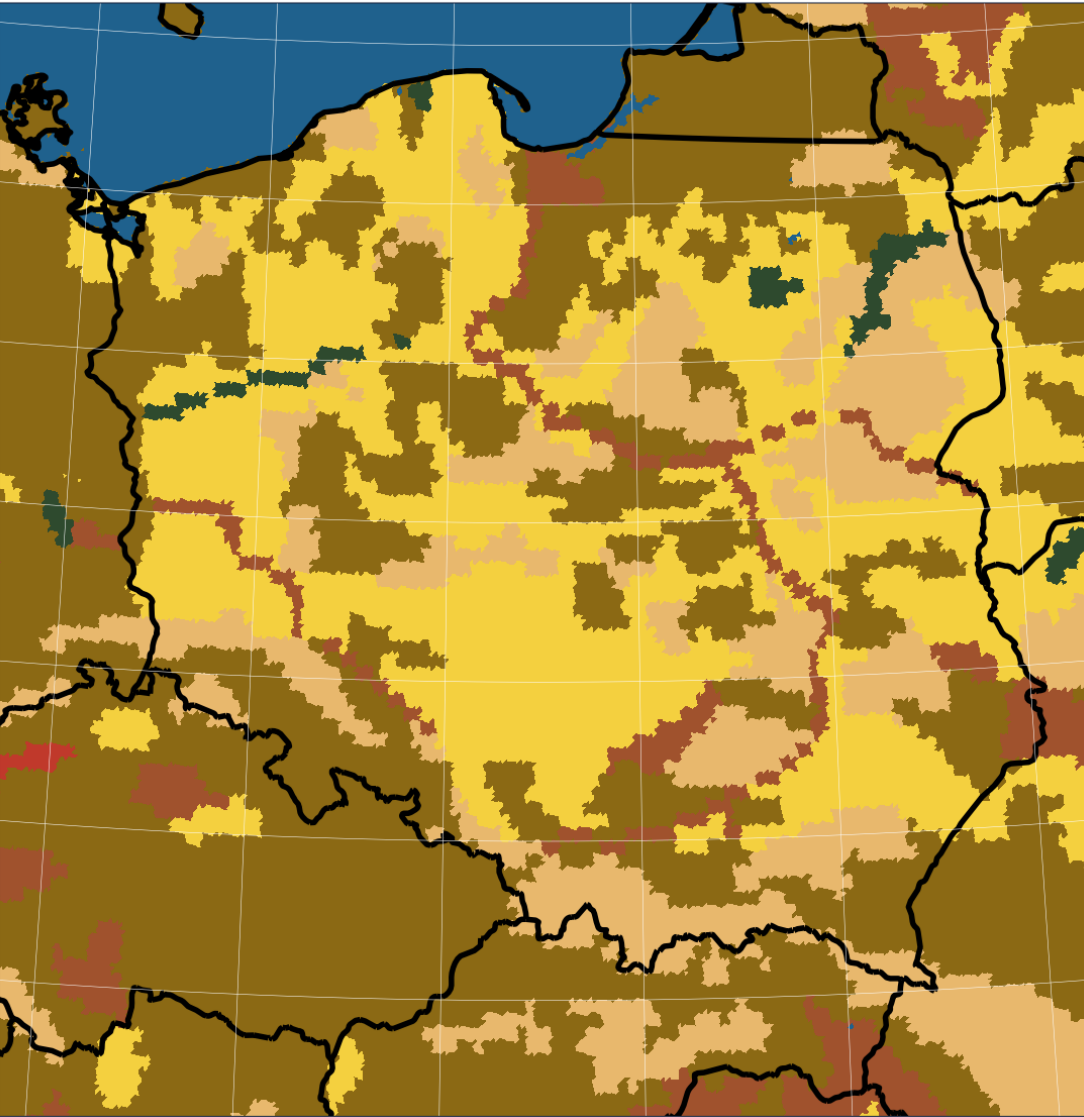
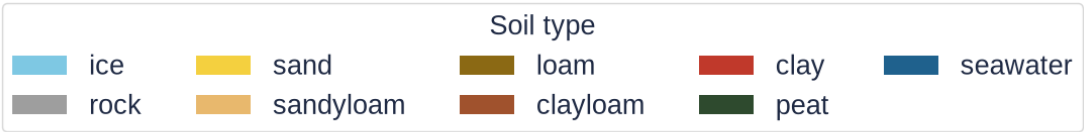
The soil temperature perturbation scheme: soil type and depth dependence



Coefficients for specific soil types

ice	0.0	sandy loam	0.9	clay	0.6
rock	0.0	loam	0.8	peat	0.5
sand	1.0	clay loam	0.7	sea water	0.5

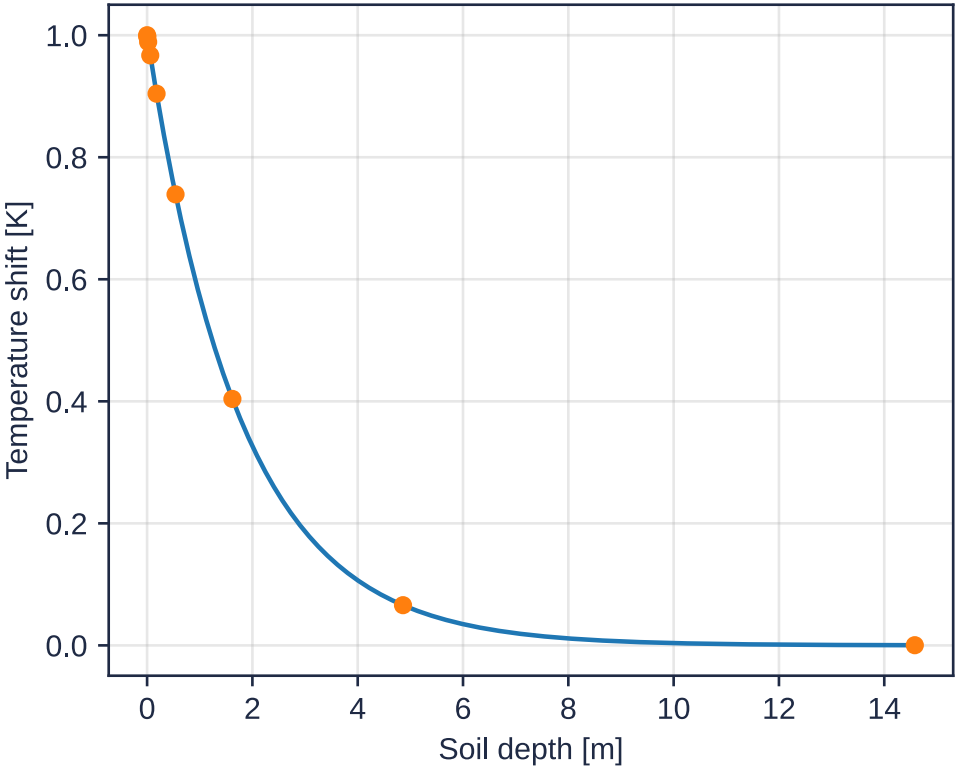
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Temperature shift as a function of soil depth -- original temperature shift 1 K



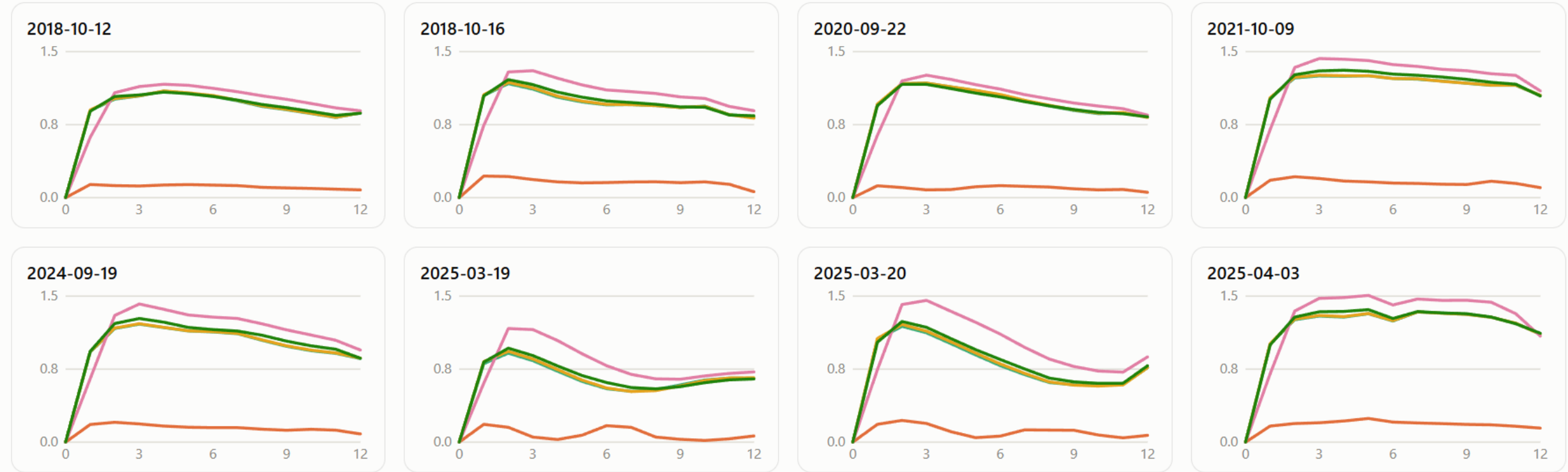
The soil temperature perturbation scheme: results



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Siedlce (12385) — 8 of 23 runs, metric: spread, tsurf

● det (000) ● noise (reference) ● A ● B ● C ● D



- the groups A/B/C/D show much larger spread than the reference run
- for this station, we can observe that spread in group C (perturbations over 1 hour) raises more slowly, but to higher levels than for other groups

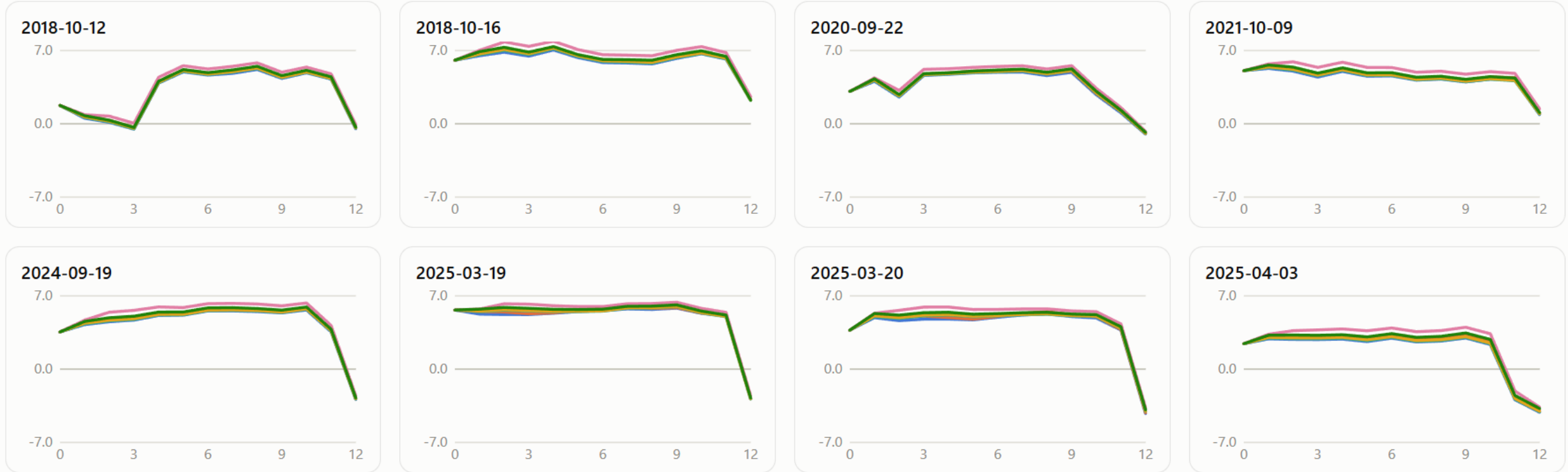
The soil temperature perturbation scheme: results



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Siedlce (12385) — 8 of 23 runs, metric: bias, tsurf

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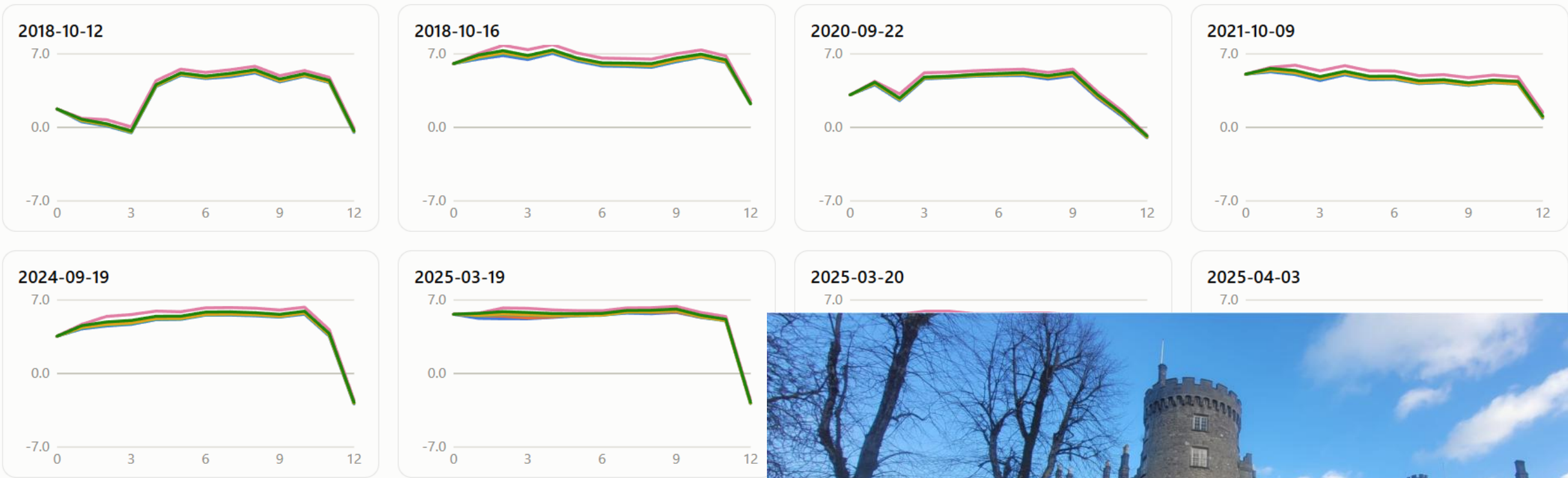
- despite having a nice spread, bias and error are quite large
- other stations also exhibit such trend

The soil temperature perturbation scheme: results



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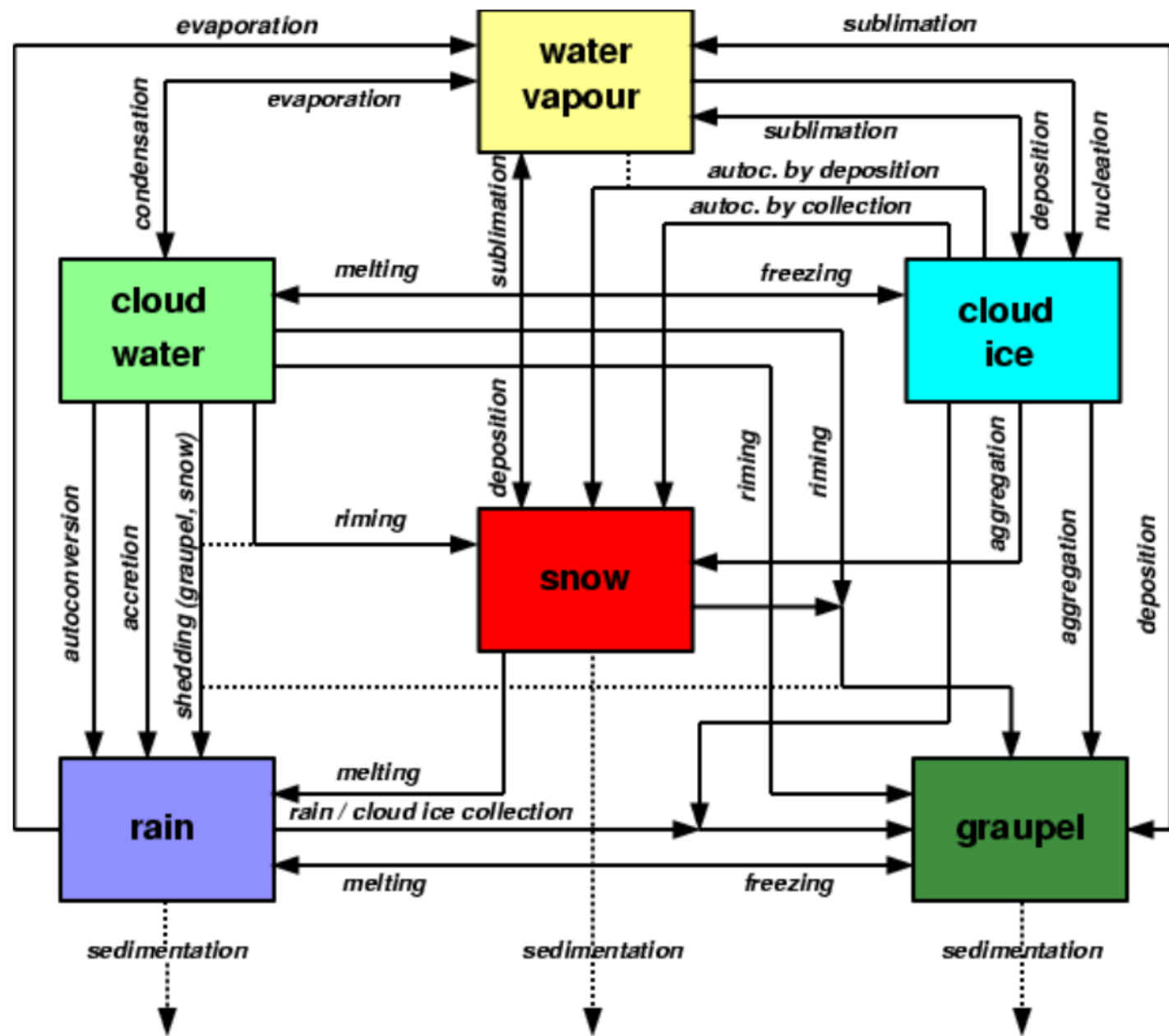


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Tatiana will present full results during EWGLAM ->



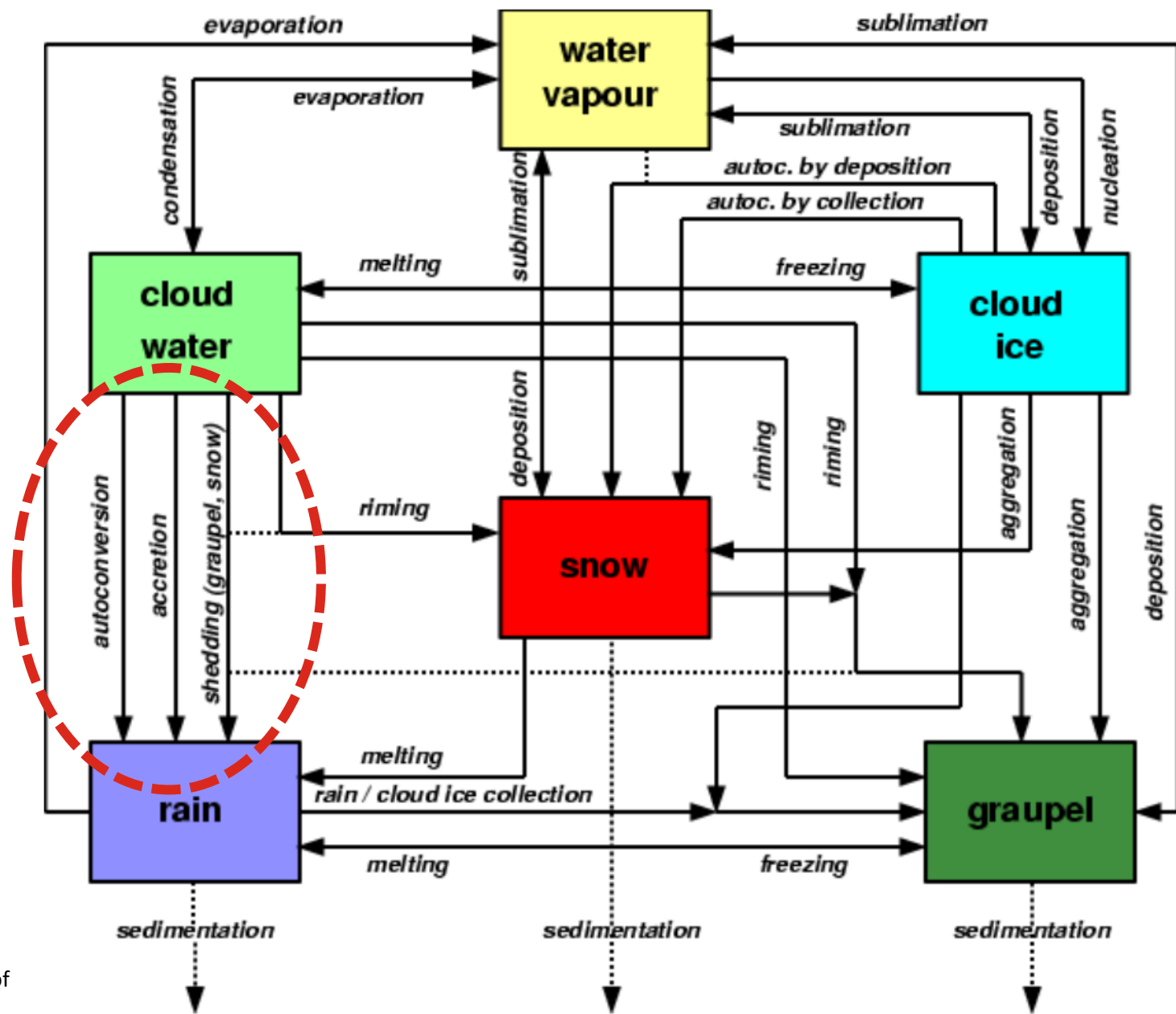
48th EWGLAM and 33rd SRNWP Workshop
Kilkenny, Ireland, September 28 – October 01 2026



Doms, G., Förstner, J., Heise, E., Herzog, H.-J., Mironov, D., Raschendorfer, M., Reinhardt, T., Ritter, B., Schrodin, R., Schulz, J.-P., Vogel, G., 2021. A Description of the Nonhydrostatic Regional COSMO-Model: Part II Physical Parametrizations.

Parametrized warm-rain processes:

- accretion
- autoconversion
- selfcollection
- breakup



Doms, G., Förstner, J., Heise, E., Herzog, H.-J., Mironov, D., Raschendorfer, M., Reinhardt, T., Ritter, B., Schrodin, R., Schulz, J.-P., Vogel, G., 2021. A Description of the Nonhydrostatic Regional COSMO-Model: Part II Physical Parametrizations.

	cloud droplets	raindrops
cloud droplets	selfcollection: $c + c \rightarrow c$ (Eq. 9) autoconversion: $c + c \rightarrow r$ (Eqs. 4–6)	
raindrops	accretion: $r + c \rightarrow r$ (Eqs. 7–8)	selfcollection: $r + r \rightarrow r$ (Eqs. 10–11) breakup: $r + r \rightarrow r$ (Eqs. 13–15)

Seifert, A., Beheng, K.D., 2006. A two-moment cloud microphysics parameterization for mixed-phase clouds. Part 1: Model description. Meteorol. Atmos. Phys. 92, 45–66.

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	single-moment	double-moment
autoconversion	$k_{cc} = 9.44 \text{ m}^3\text{kg}^{-2}\text{s}^{-1}$	Onishi & Seifert (2016)
accretion	$k_{cr} = 5.25 \text{ m}^3\text{kg}^{-1}\text{s}^{-1}$	$k_{cr} = 5.78 \text{ m}^3\text{kg}^{-1}\text{s}^{-1}$
selfcollection	N/A	$k_{rr} = 4.33 \text{ m}^3\text{kg}^{-1}\text{s}^{-1}$ $D_{br} = 1.1 \text{ mm}$
breakup	N/A	$k_{br} = 1 \text{ mm}^{-1}$

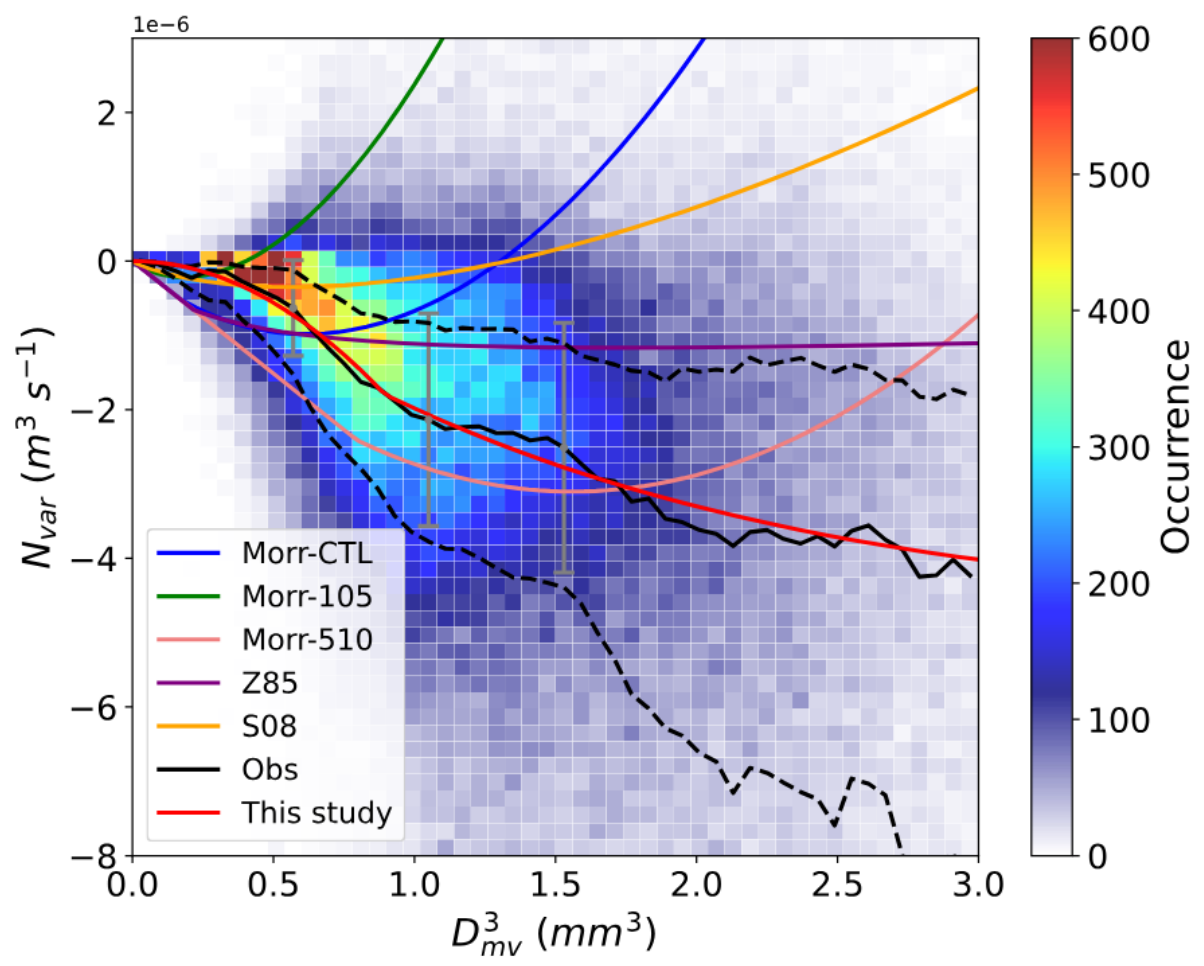


Figure 10. Probability density function of $N_{\text{var}} = (1/N_r^2)(dN_r/dt)$ as a function of D_{mv}^3 with observation points corresponding to the combination of the Finland and Oklahoma cases shown as a density plot in color.

Niquet, L., Tridon, F., Grzegorzczak, P., Causse, A., Bordet, B., Wobrock, W., Planche, C., 2024. Evaluation of the Representation of Raindrop Self-Collection and Breakup in Two-Moment Bulk Models Using a Multifrequency Radar Retrieval. Journal of Geophysical Research: Atmospheres 129, e2024JD041269.

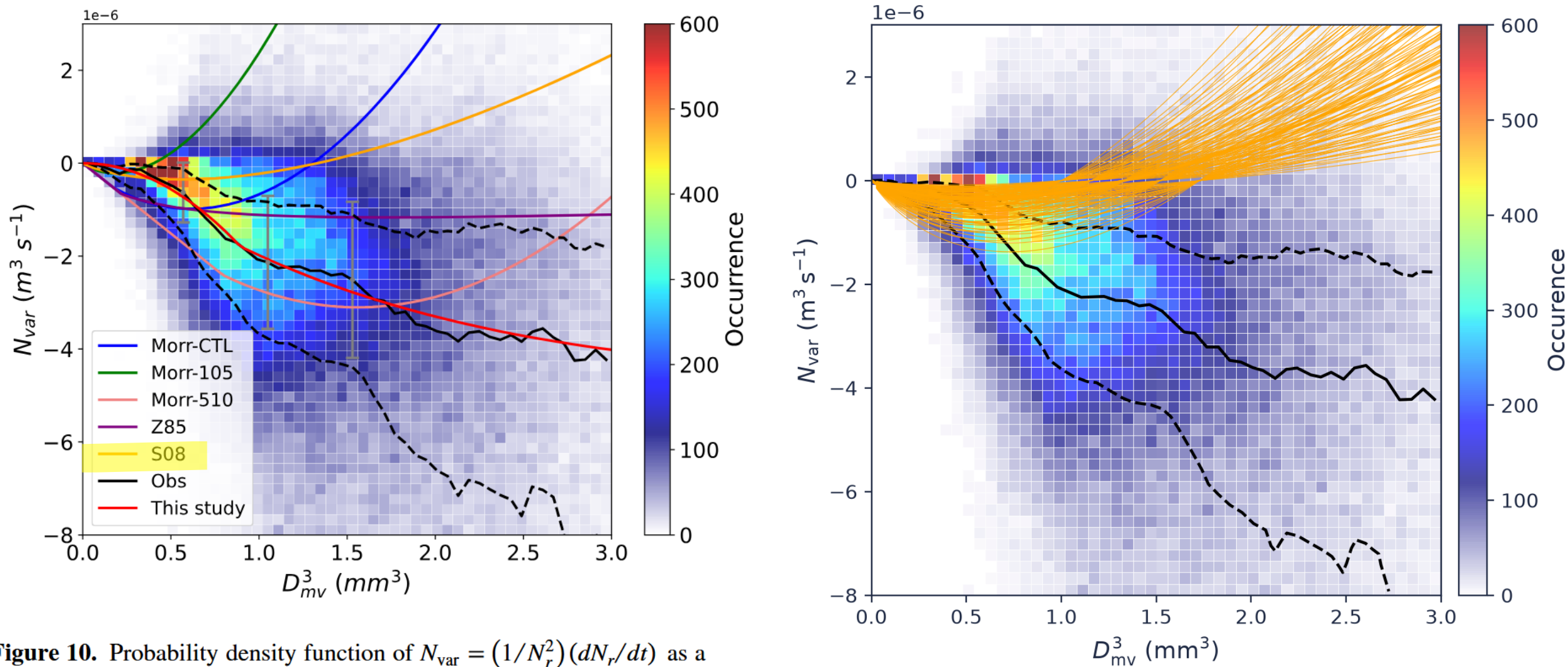


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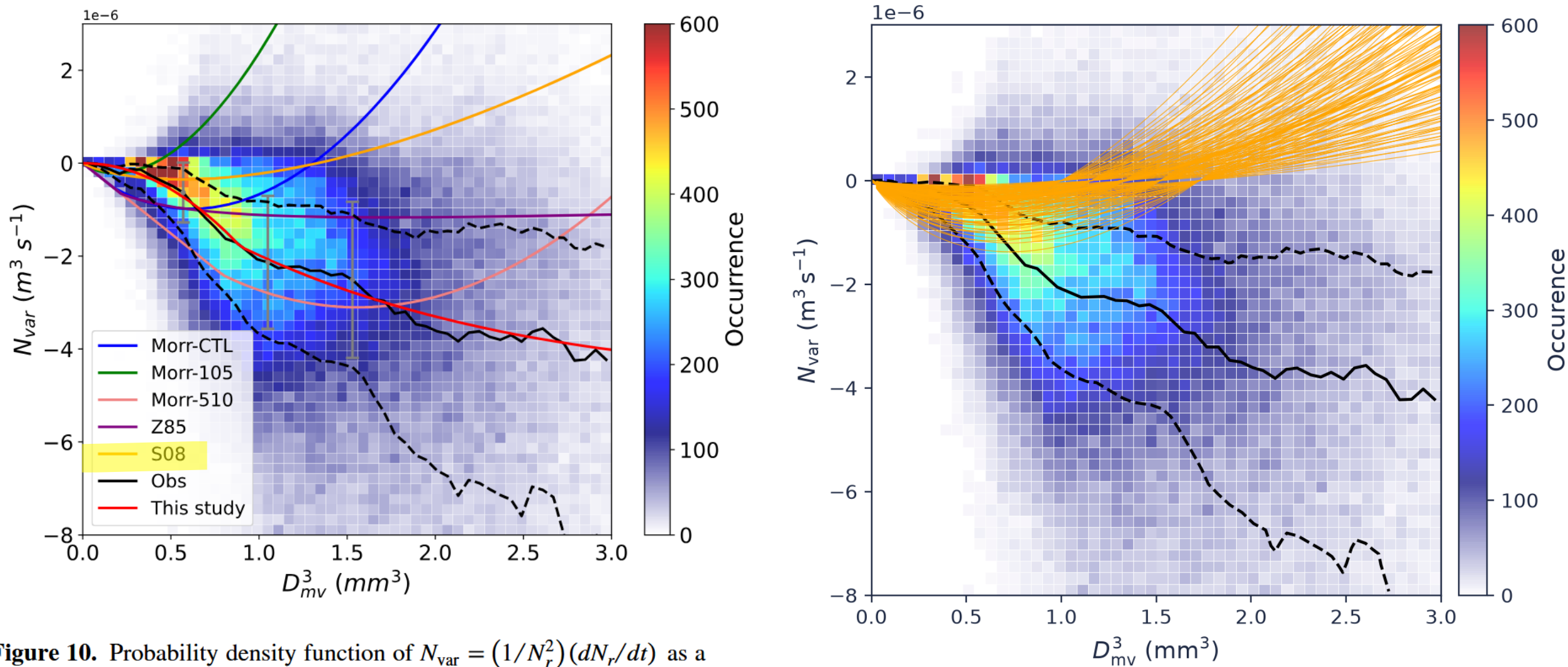


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- Selected perturbation ranges:**
- $k_{rr} \in [3.0, 6.0] \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-1}$
 - $k_{br} \in [0.5, 2.0] \text{ mm}^{-1}$
 - $D_{br} \in [1.0, 1.2] \text{ mm}$

Seifert, A., Beheng, K.D., 2006. A two-moment cloud microphysics parameterization for mixed-phase clouds. Part 1: Model description. Meteorol. Atmos. Phys. 92, 45–66.

$$k_{cr} = 5.25 \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-1}$$

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Seifert, A., Beheng, K.D., 2001. A double-moment parameterization for simulating autoconversion, accretion and selfcollection. Atmospheric Research, 13th International Conference on Clouds and Precipitation 59–60, 265–281.

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```
software > icon > src > granules > microphysics_1mom_schemes > gscp_data.f90 > { } gscp_data
18      MODULE gscp_data
125     | zkcac = 5.25e+00_wp, & ! kernel coeff for SB2001 accretion
```

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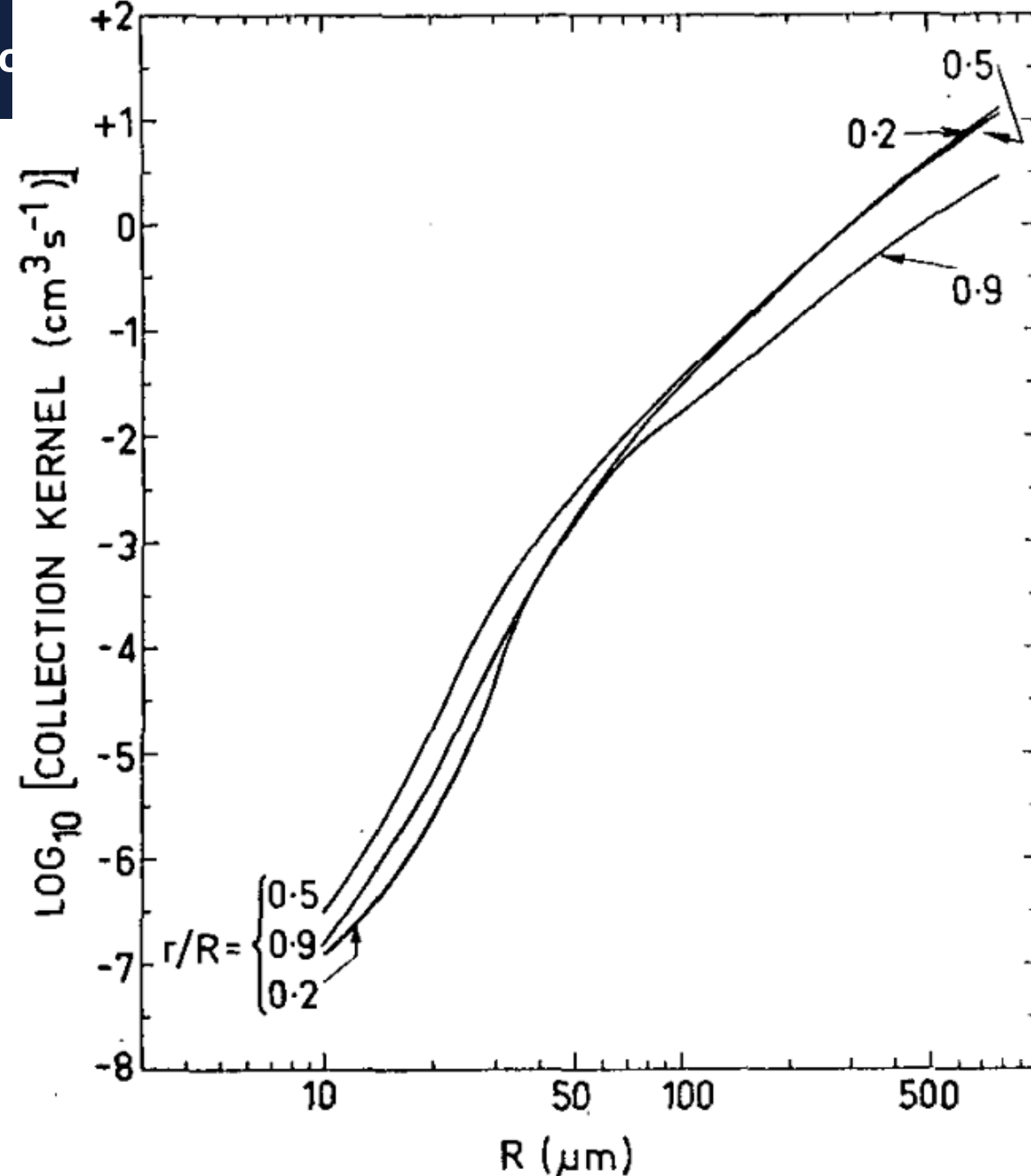
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18  MODULE gscp_data
125  zkcac = 5.25e+00_wp, & ! kernel coeff for SB2001 accretion

software > icon > src > atm_phy_schemes > mo_2mom_mcrph_processes.f90 > { } mo_2mom_mcrph_processes
21  MODULE mo_2mom_mcrph_processes
508  SUBROUTINE accretionSB(ik_slice, dt, atmo, cloud, rain)
509  ! *****
510  ! Accretion of Seifert and Beheng (2001, Atmos. Res.)
511  ! *****
524  REAL(wp), PARAMETER :: k_r = 5.78_wp ! kernel
```

Solutions to (1) have been either numerical or analytic depending upon the form of $K(x,y)$. Numerical solutions (Twomey, 1964, 1966; Berry, 1965, 1967; Warshaw, 1967, 1968b) have been based upon a gravitational collection mechanism, for which the kernel is

$$K(x,y) = \pi [R(x) + r(y)]^2 E(x,y) [V(x) - V(y)],$$
$$x \geq y, \quad (2)$$



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 $x \geq y, \quad (2)$

FIG. 1. Actual droplet-collection kernel $K(x,y)$.

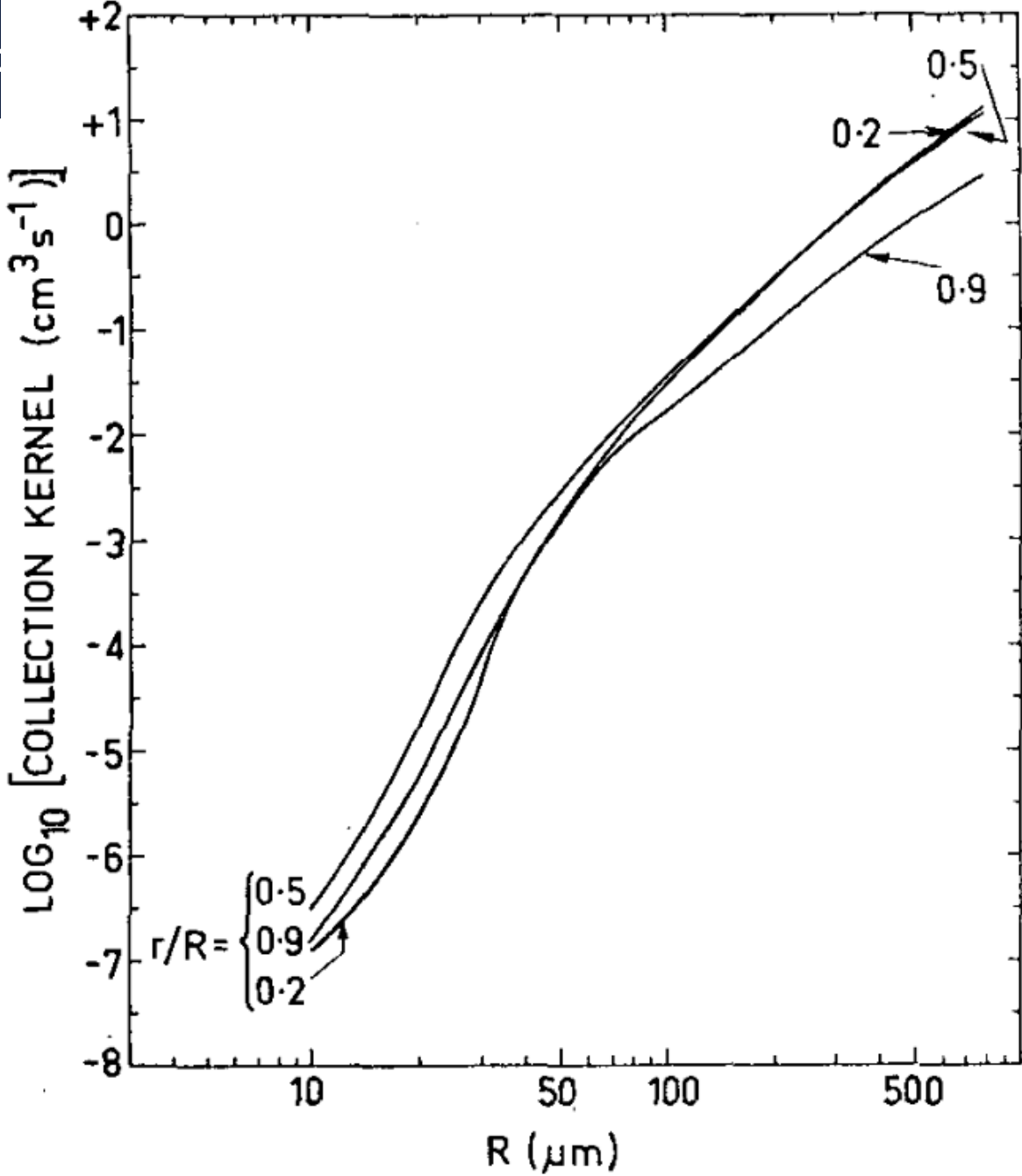


FIG. 1. Actual droplet-collection kernel $K(x,y)$.

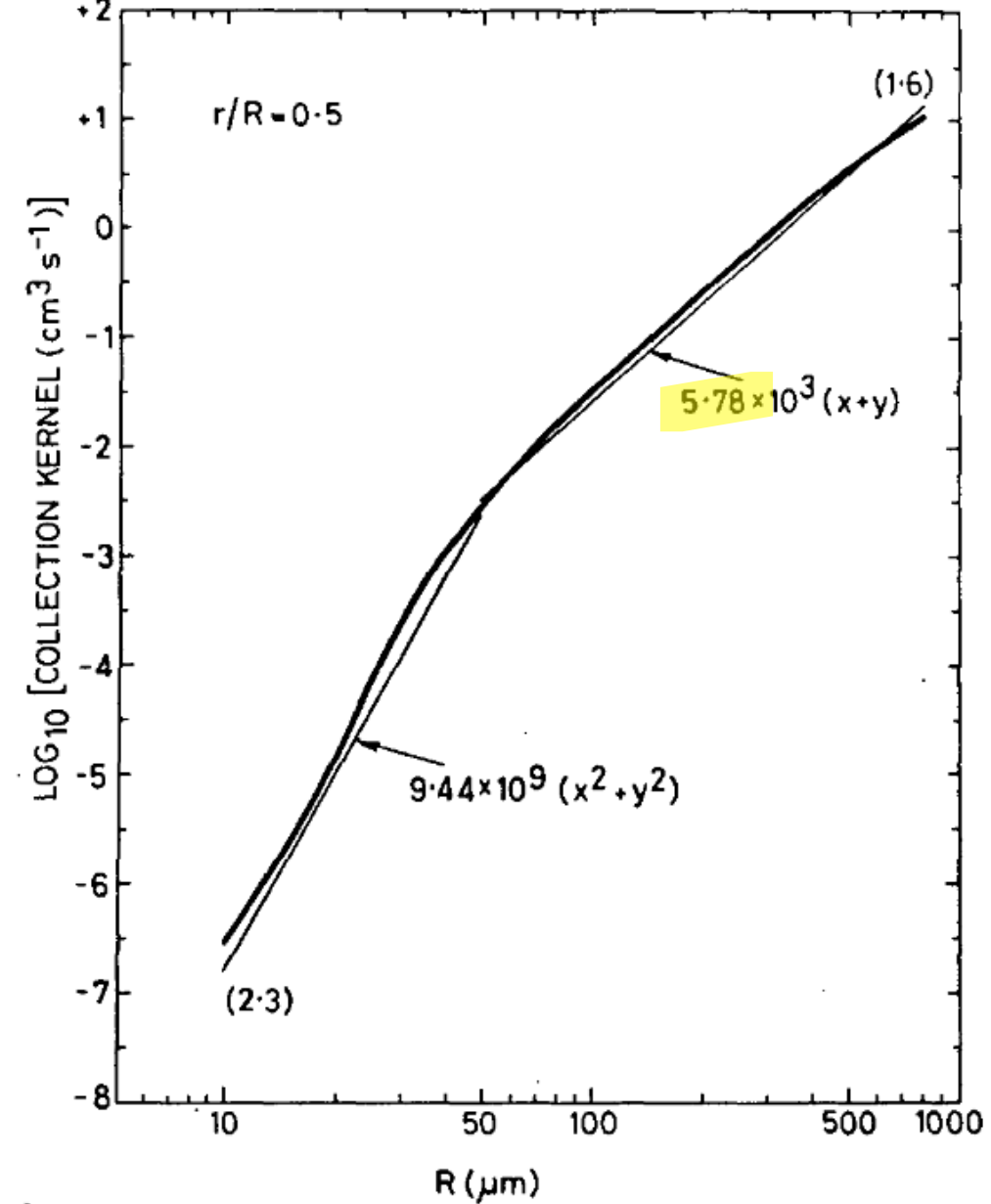


FIG. 9. Comparison of the approximating polynomial in (11) and the actual kernel. The parenthetical numbers give $\exp[D(P;K)]$ for the two parts of the polynomial, fitted over domain I and over that portion of domain V exterior to domain I.

$$V^*(R) = 1.443646 - 3.417072 \times 10^3 R + 4.243126 \times 10^6 R^2 - 1.263519 \times 10^9 R^3 + 2.432383 \times 10^{11} R^4 - 1.917038 \times 10^{13} R^5, \quad 0.0015 \leq R \leq 0.0035 \text{ cm.} \quad (4)$$

$$V^*(R) = 3.510302 \times 10^1 + 2.865716 \times 10^3 R + 2.559450 \times 10^5 R^2 - 5.064069 \times 10^6 R^3 + 3.971905 \times 10^7 R^4 - 1.135044 \times 10^8 R^5, \quad 0.0300 \leq R \leq 0.0800 \text{ cm.} \quad (8)$$

$$V^*(R) = -[554.5/D] + 921.5 - [4 \times 10^{-3}/(R - 0.0210)], \quad 0.0800 \leq R \leq 0.2900 \text{ cm,} \quad (9)$$

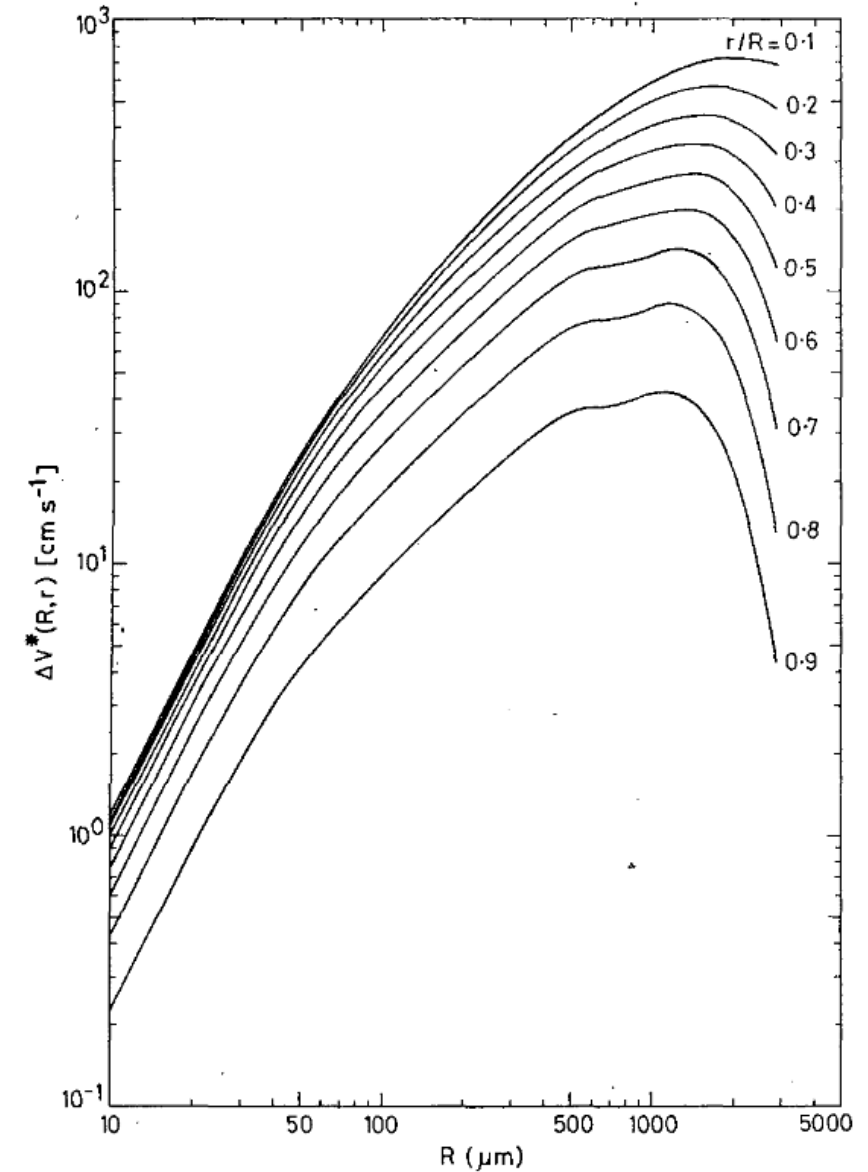


FIG. 4. The relative terminal velocity $\Delta V^*(R, r)$ computed with the improved formula described in Section 4.

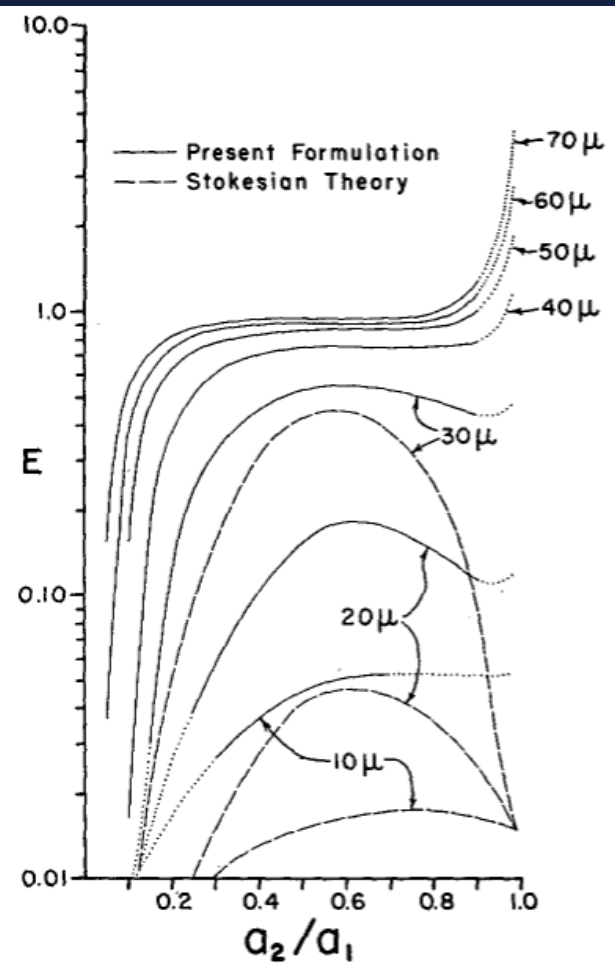


FIG. 4. Collision efficiencies according to the present method (solid and dotted lines) and the Stokesian treatment of Davis and Sartor (1967) (dashed lines). The dotted portions of the curves represent regions where the results are of doubtful accuracy, owing to the large number of integration steps required in the computations.

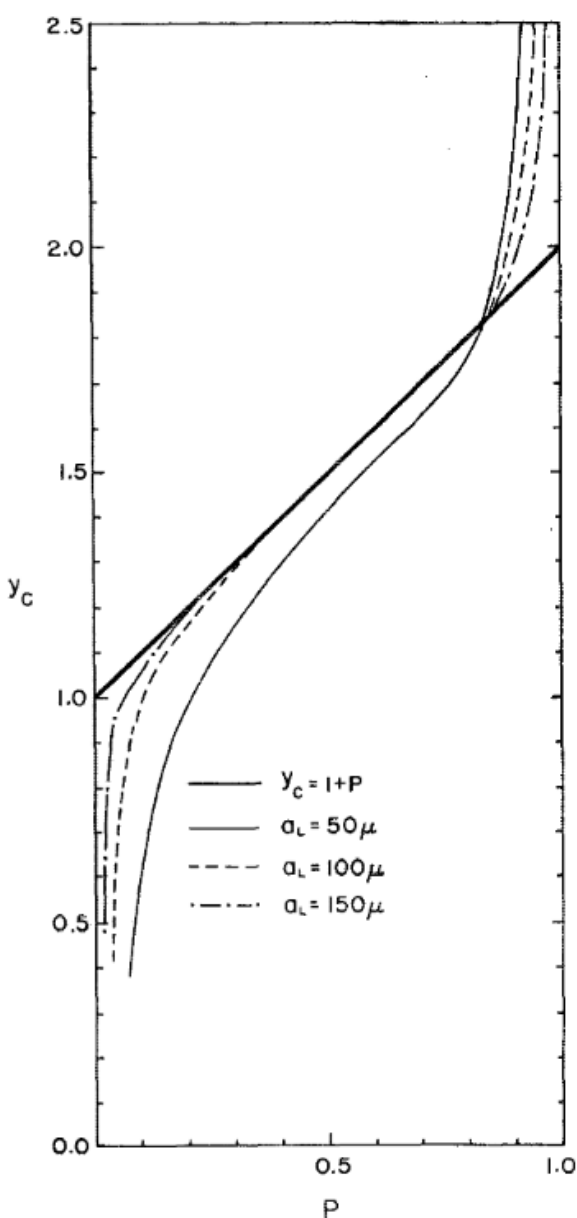


FIG. 14. Linear collision efficiencies y_c as a function of the ratio of the radii $p = a_s/a_L$, for $a_L = 50, 100$ and 150μ .

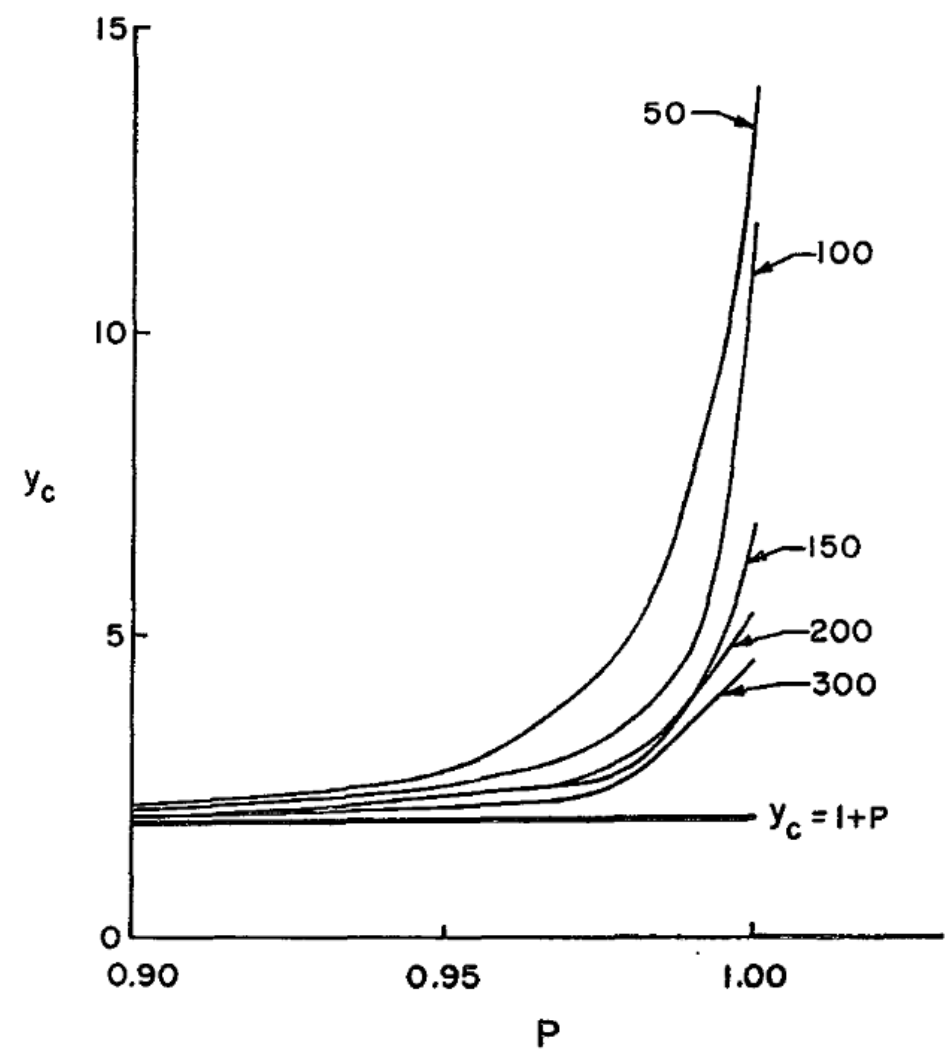


FIG. 15. Same as Fig. 14, for $0.9 \leq p \leq 1.0$ and $50\mu \leq a_L \leq 300\mu$.

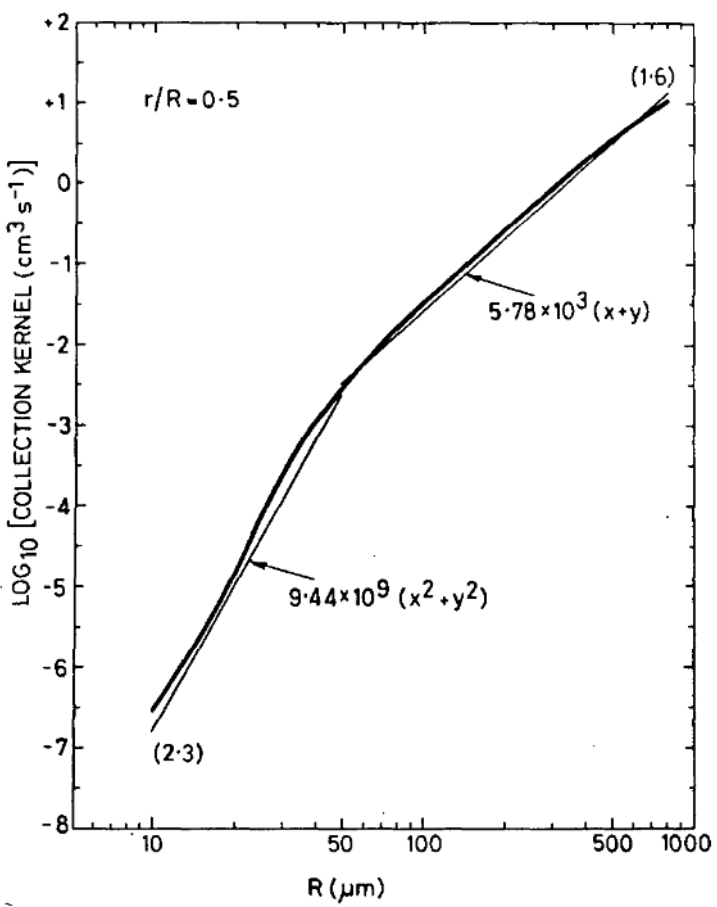


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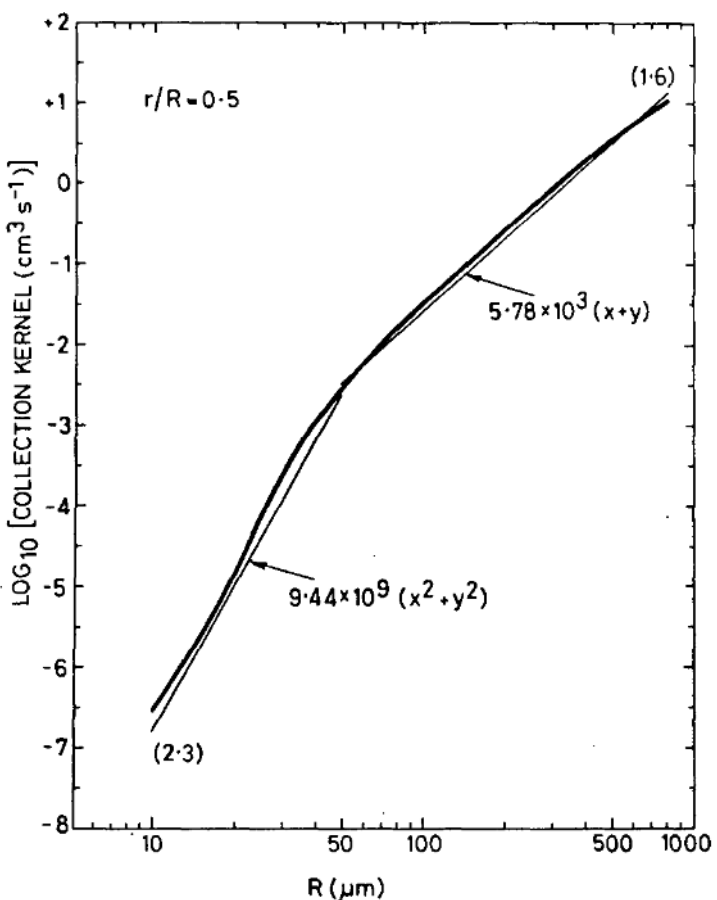
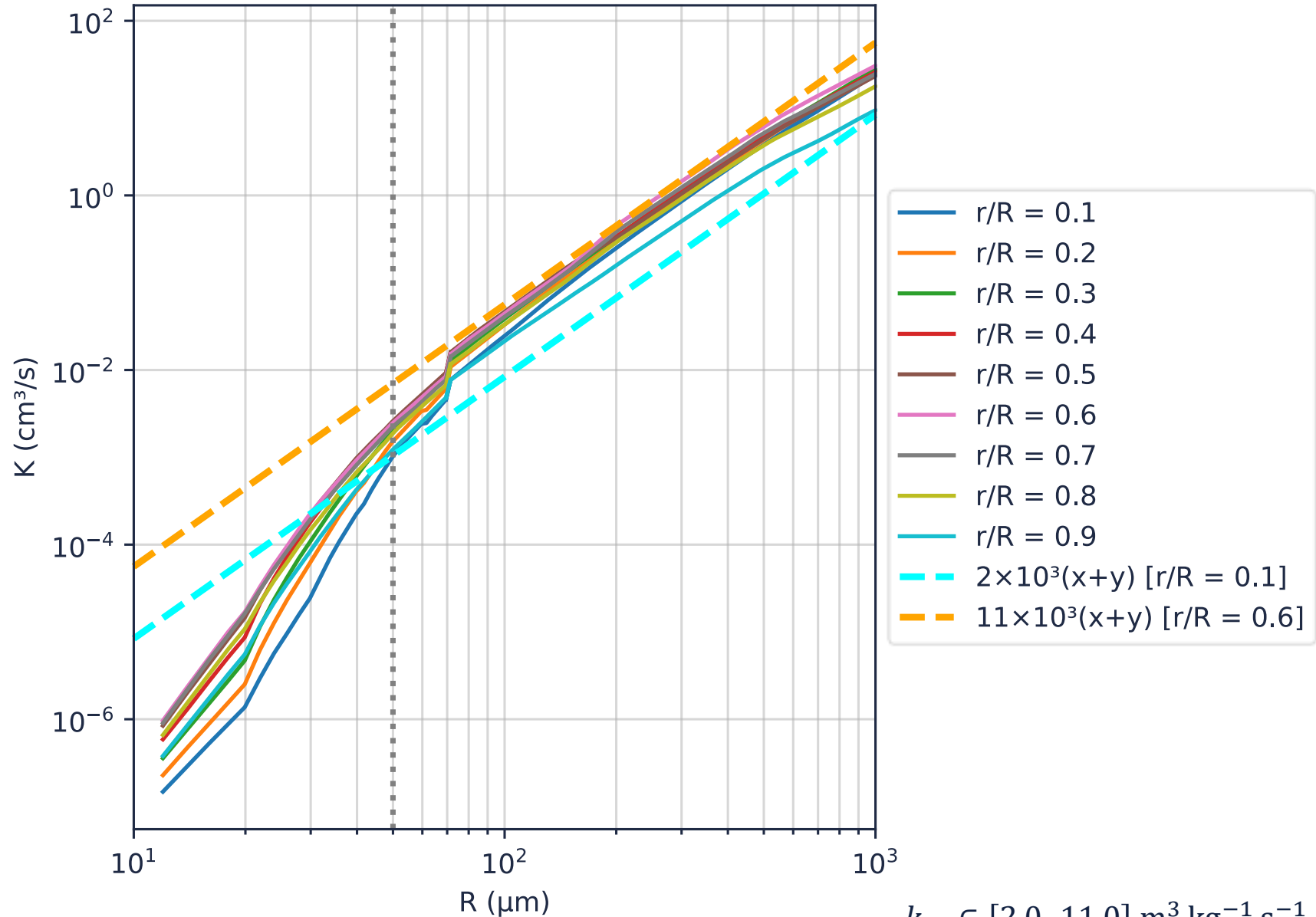


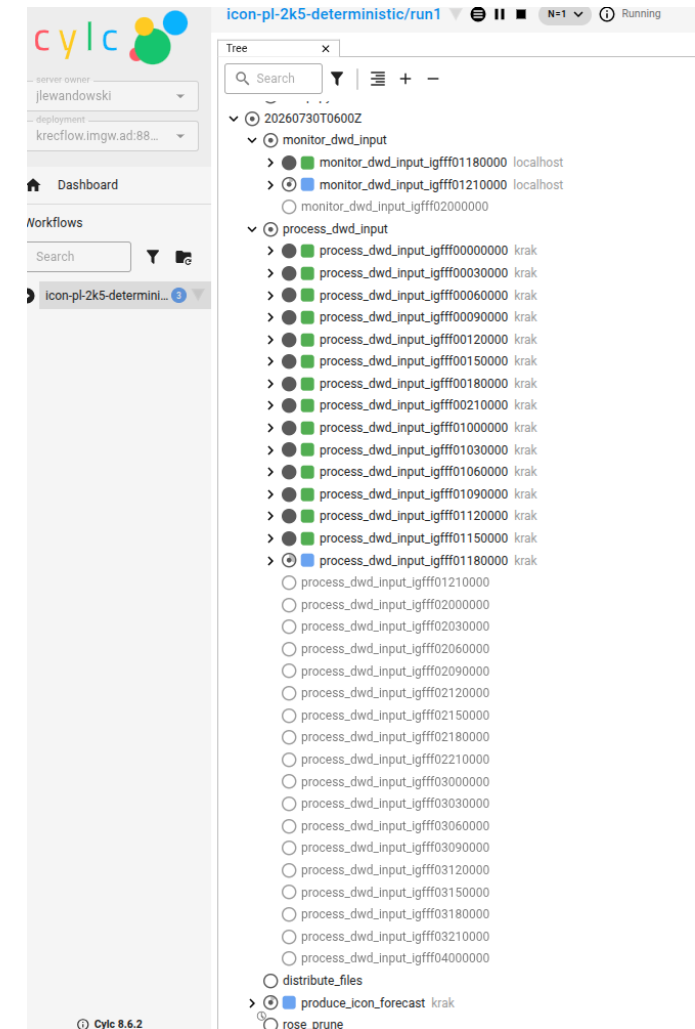
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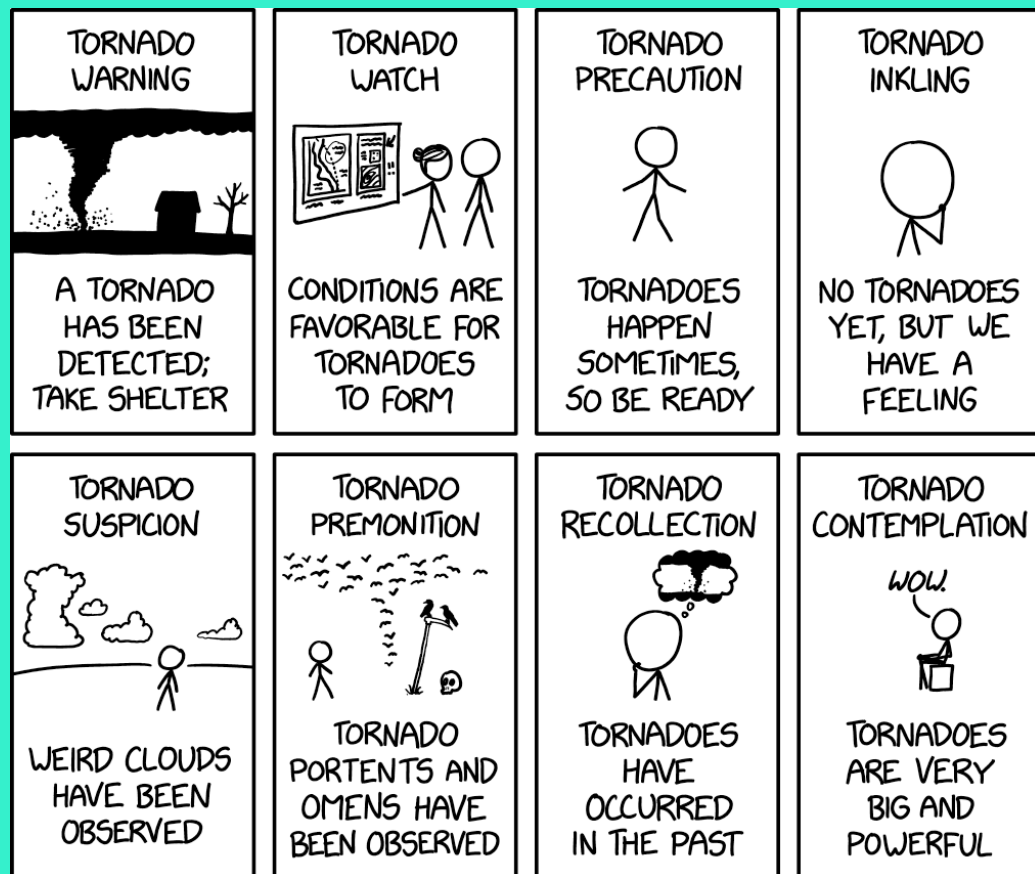
$k_{cr} \in [2.0, 11.0] \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-1}$

Lots of progress, but nothing shiny

- Deployed new scheduler - cylc
- Acquired IFS-ENS data for boundary conditions
- Created converter of in-situ observations (SYNOP, TEMP, SHIP, BUOY, AMDAR)
- Sorted out conversion of volumetric radar reflectivity data
- Updated EMVORADO metadata for the upgraded Polish radar network (merge to upstream after more testing)



Thank You!



Instytut Meteorologii i Gospodarki Wodnej – Państwowy Instytut Badawczy
Institute of Meteorology and Water Management – National Research Institute

01-673 Warszawa, ul. Podleśna 61 | tel.: +48 22 569 41 00 | fax: +48 22 834 18 01 | e-mail: imgw@imgw.pl | www.imgw.pl

Regon: 000080507 | NIP: 525-000-88-09