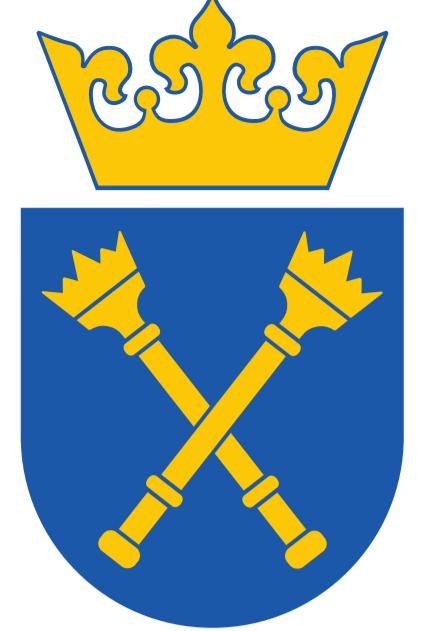


# On Probabilistic Particle-Based Modeling of Immersion Freezing

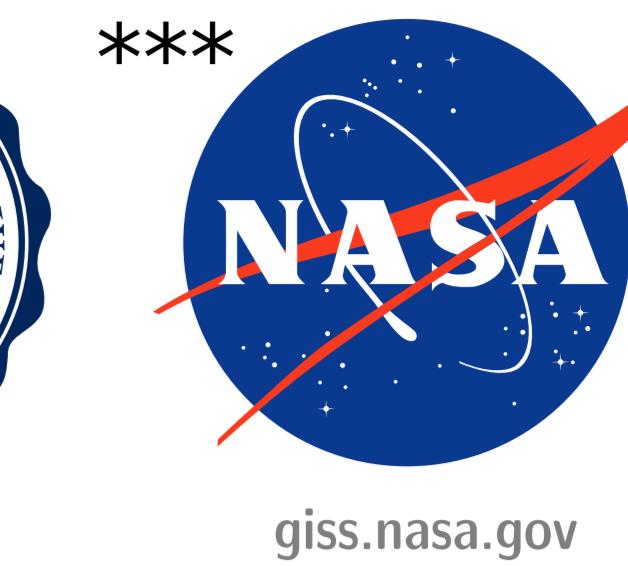


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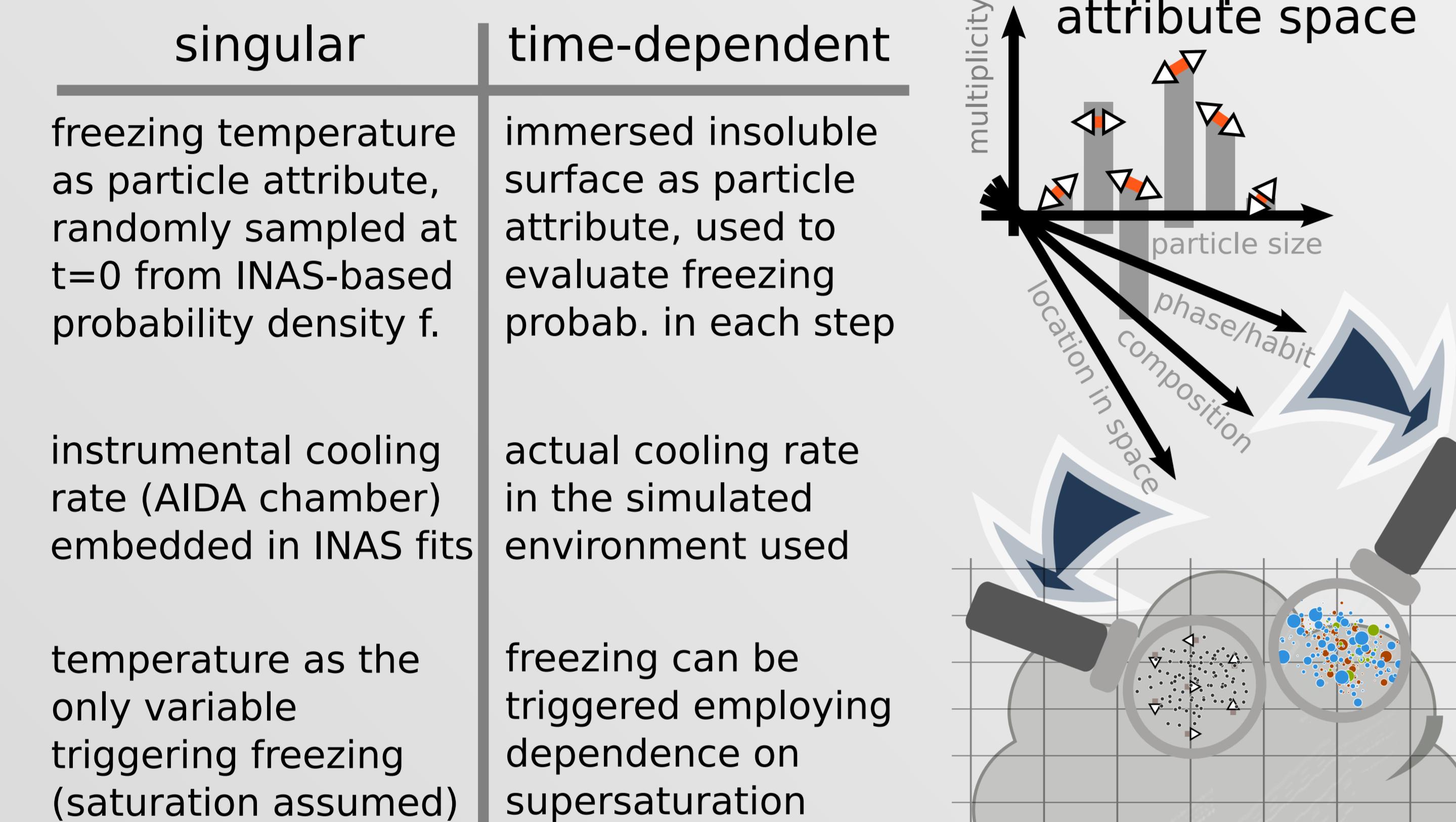
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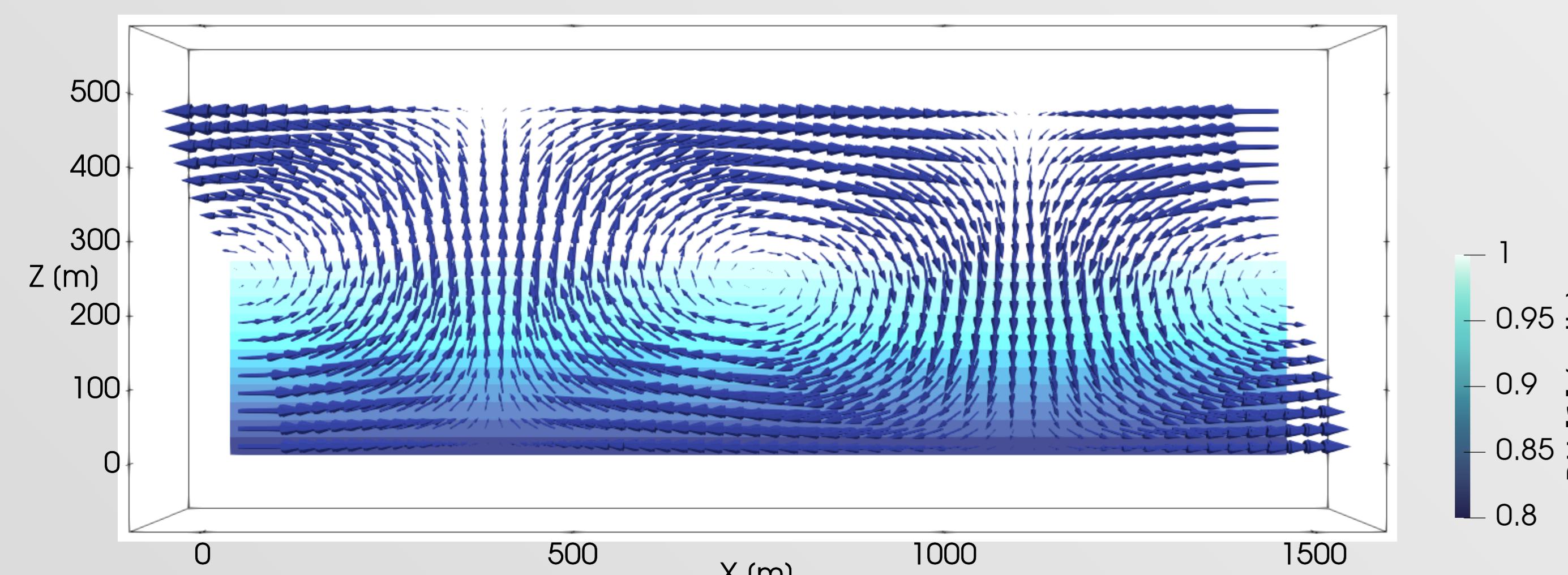
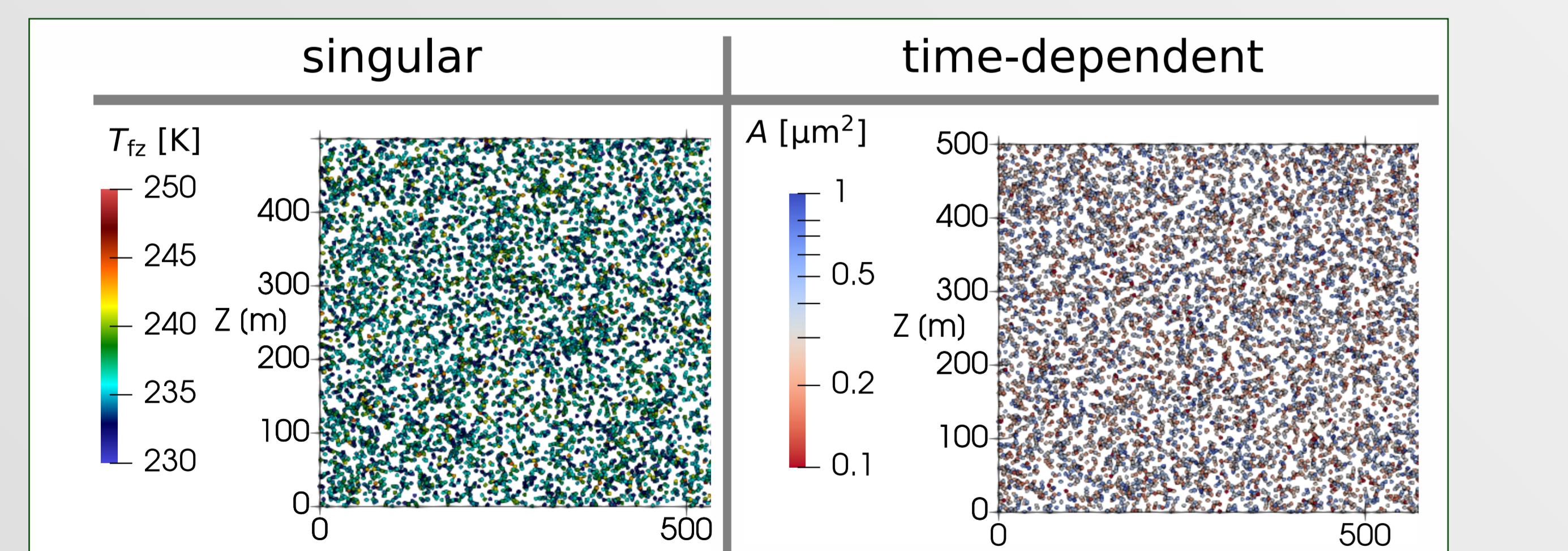
## Key concepts

- aerosol particles, water droplets and ice crystals modelled with super-particles (each representing a large multiplicity of real-world particles)
- immersion freezing using stochastic Monte-Carlo schemes:
  - singular (INAS); as in Shima et al. 2020
  - time-dependent (ABIFM); as in Alpert & Knopf 2016



## 2D flow-coupled simulations: setup

- prescribed-flow setup (Morrison & Grabowski '07)
- stratiform cloud deck, periodic boundary conditions
- 16 inclusion-rich + 16 inclusion-free super-particles per 25 m x 25 m cell (on average, random positions at t=0)
- Niemand et al. 2012 AIDA-based dust params for INAS and ABIFM



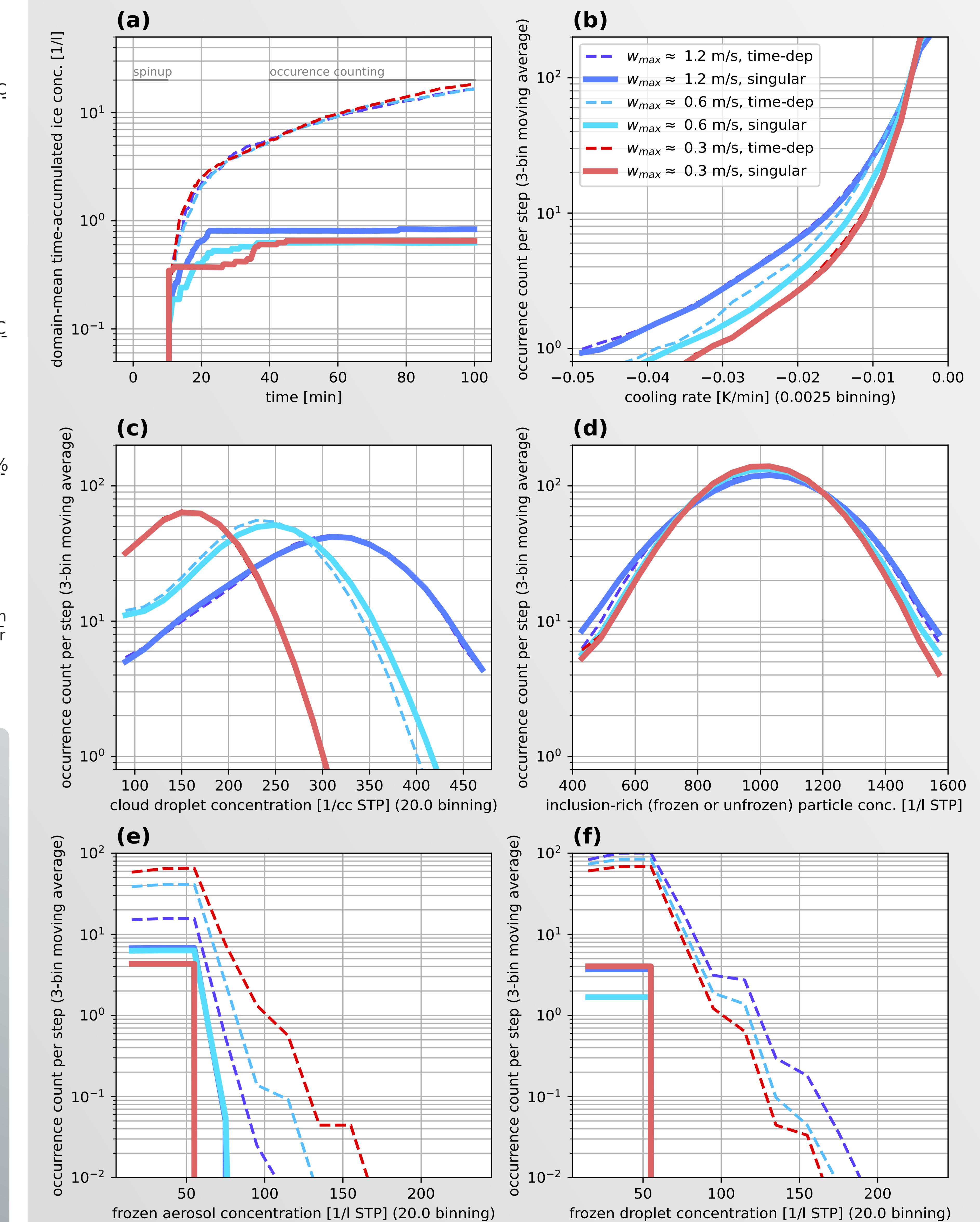
## Key takeaways:

- both singular and time-dependent immersion freezing models cast in particle-based and probabilistic simulation framework
- models tested using 2D prescribed-flow simulation setup
- ice concentrations obtained with time-dependent model are robust to flow regime, order of magnitude higher than from singular scheme, and do not feature an a priori bound
- particle-based schemes by-design resolve INP-reservoir dynamics

## References:

- probabilistic singular INAS-based scheme: **Shima et al. 2020**, doi:10.5194/gmd-13-4107-2020
- probabilistic time-dep. ABIFM-based scheme: **Alpert & Knopf 2016**, doi:10.5194/acp-16-2083-2016
- 2D kinematic modelling framework: **Morrison & Grabowski 2007**, doi:0.1175/JAS3980
- mineral dust parameters from AIDA measurements: **Niemand et al. 2012**, doi:10.1175/JAS-D-11-0249.1
- PySDM microphysics package extended & used herein: **Bartman et al. 2022**, doi:10.21105/joss.03219

## 2D flow-coupled simulations: domain-wide statistics



## Funding:

