Arctic cloud type and phase determination in NSA observations for ModelE evaluation and development:

A testbed for ice nucleation

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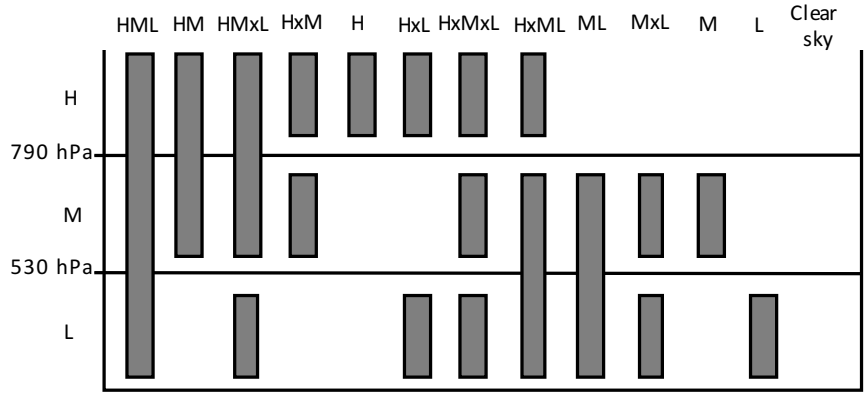
Using observations for GCM evaluation

This study is constructed around the concept of Cloud Vertical Structure (CVS) which originates from satellite-derived Global Weather States (*Tselioudis et al.* [2013])

In the current study ground-based CVS types are resampled for GCM evaluation ***and*** model diagnostics closest to observables are generated to perform a "general" but "effective" model evaluation of Arctic cloud occurrence and phase.

Schematic of 13 Arctic cloud vertical structure types



[Lamer et al. 2017, in preparation]

Datasets

Ground-based observations

ARM North Slope of Alaska 2011-2016, vertically pointing sensors

Including radar, lidar and radiometer

General Circulation Model (GCM)

Preliminary 2 year run of ModelE3

ModelE3 recent upgrades (CMIP6 development version):

- two-moment stratiform cloud microphysics following Gettelman and Morrison (2015) with prognostic precipitation, using
  - o aerosol freezing with prescribed number (100/L) and critical RHI of Karcher and Lohmann (2002)
  - o convective detrainment glaciates at 0 ℃ (with particle sizes far larger than intended because of logic error)
  - o only heterogeneous ice formation modes are inefficient: immersion (Bigg 1953) and contact (Young 1974)
- moist turbulence scheme following Bretherton and Park (2009)
- stratiform cloud cover from Smith (1990) for liquid, Wilson and Ballard (1999) for ice

Considerations when comparing GCM simulations and ground-based observations

Resampling to a similar spatio-temporal resolution

CVS approach
dz = 3 regions: 790 hPa, 530 hPa
dt = 30-min samples

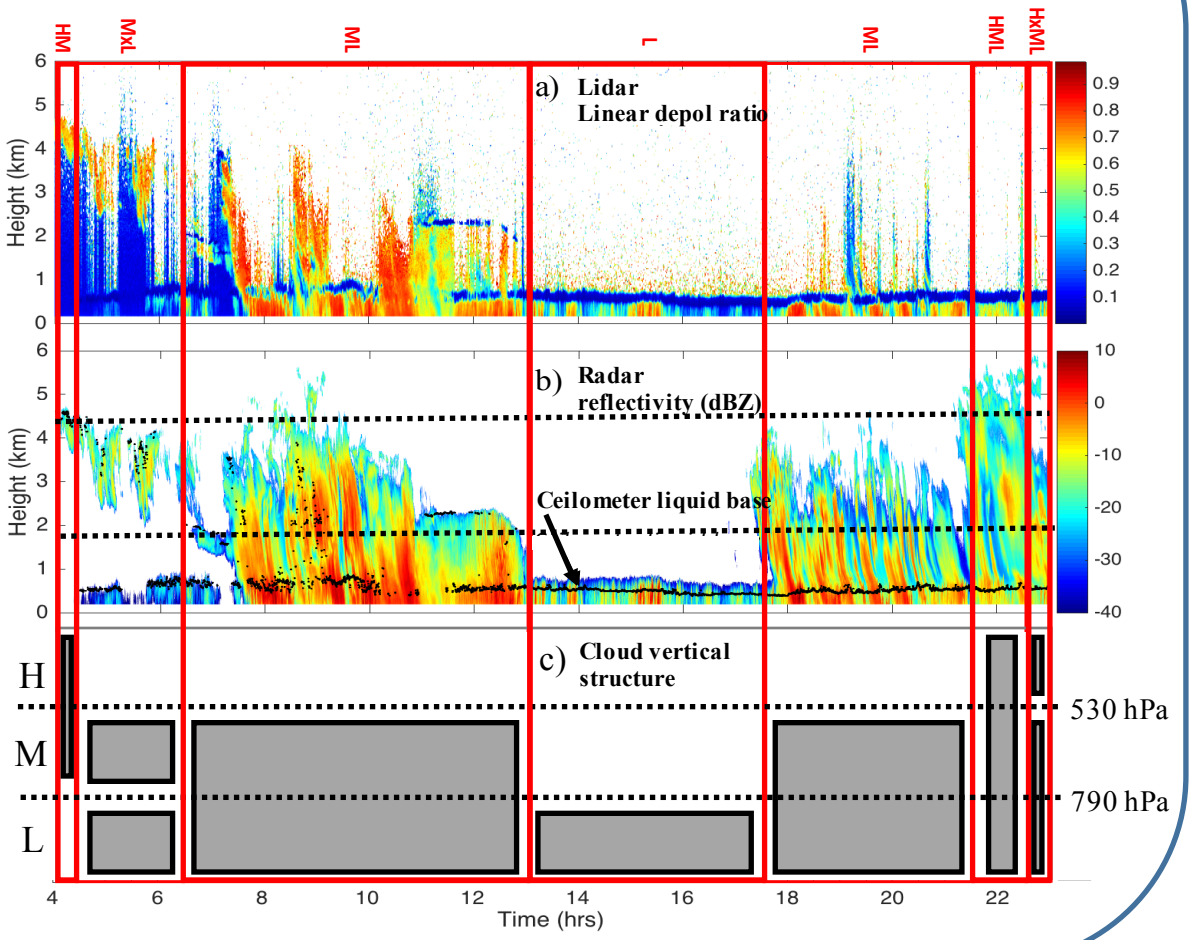
Creating a "rough" phase assignment

Using radar-lidar and,
a hydrometeor layer approach

Using a consistent hydrometeor definition

Using a radar-lidar instrument simulator on
modelled cloud and precipitation mixing ratios

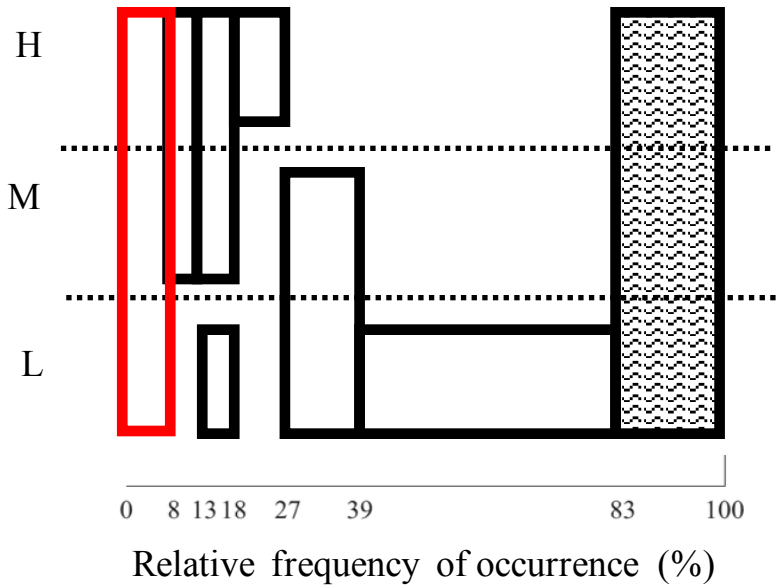
Paying special attention to the definition of clear sky



NSA cloud vertical structure relative occurrence

OBSERVATIONS

Spring



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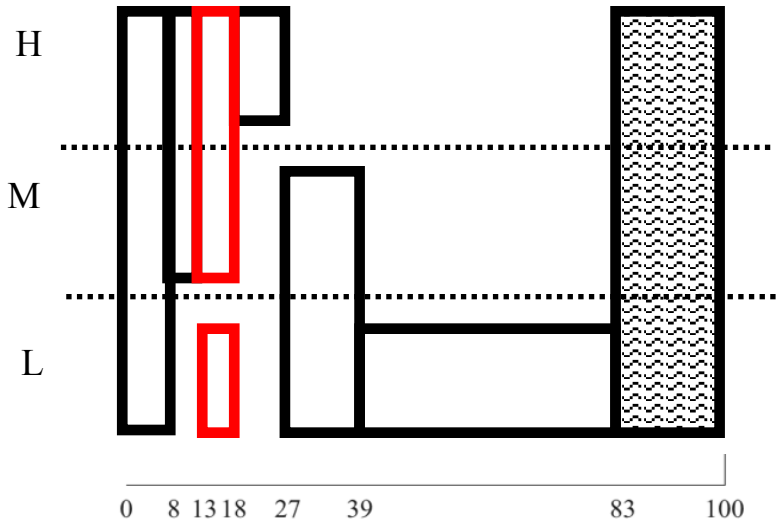

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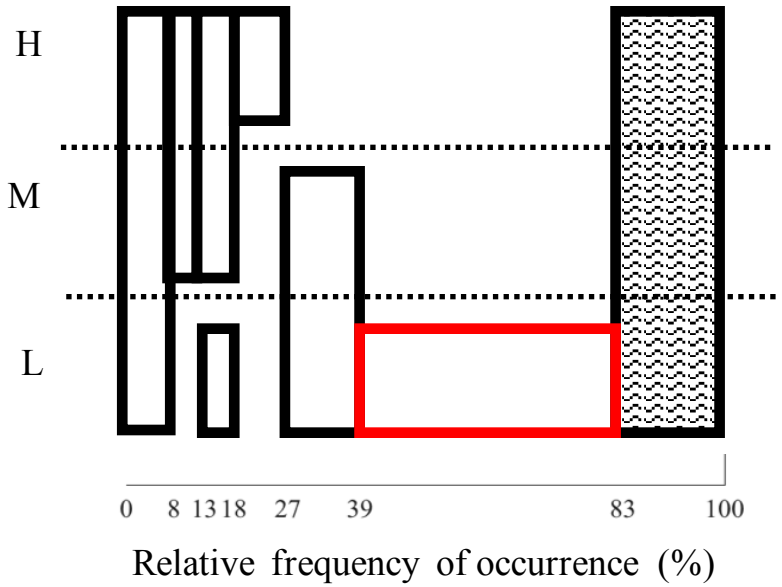

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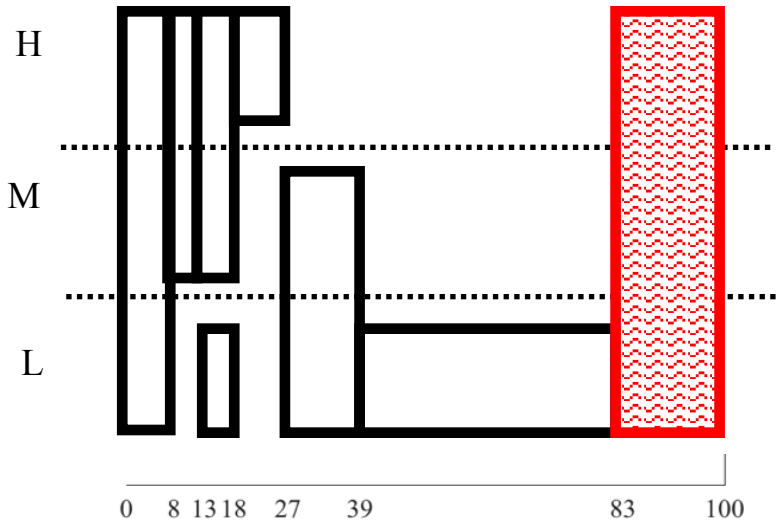

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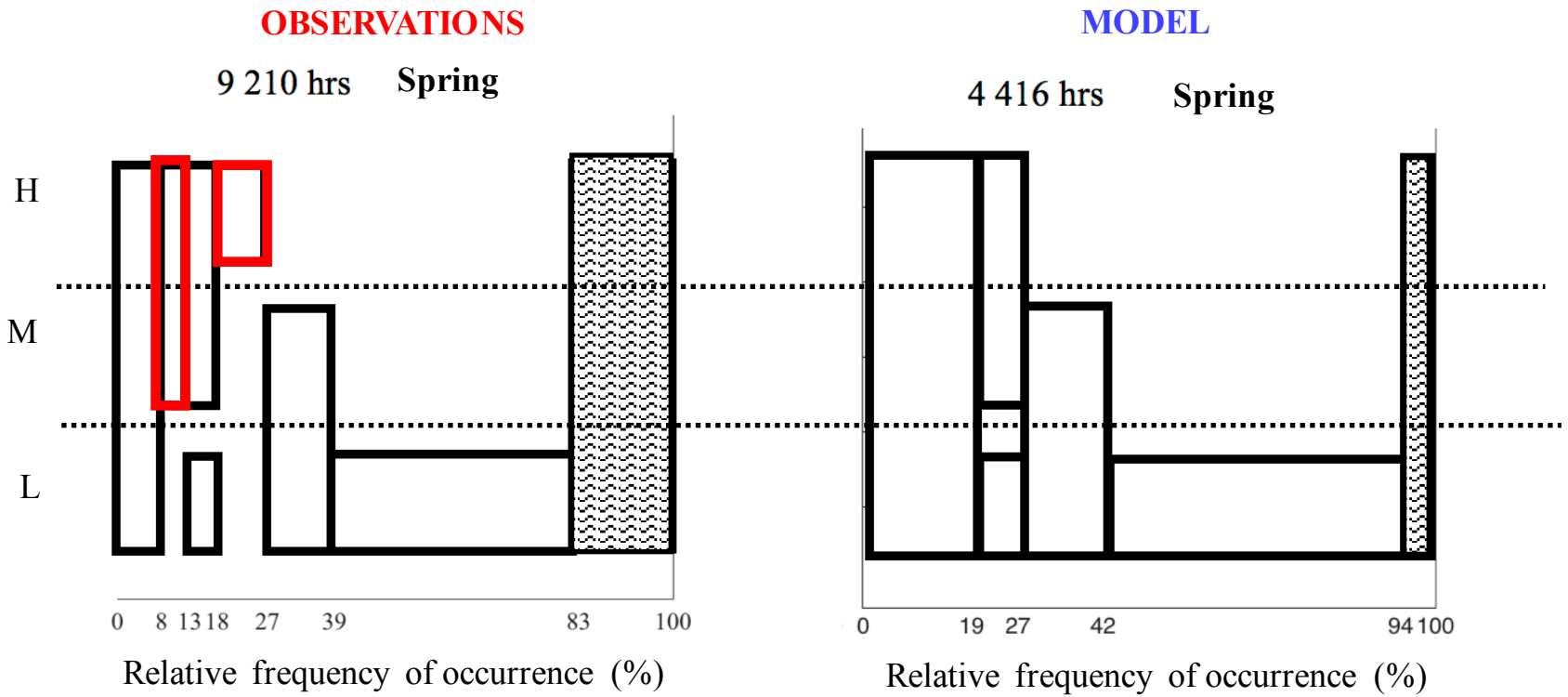
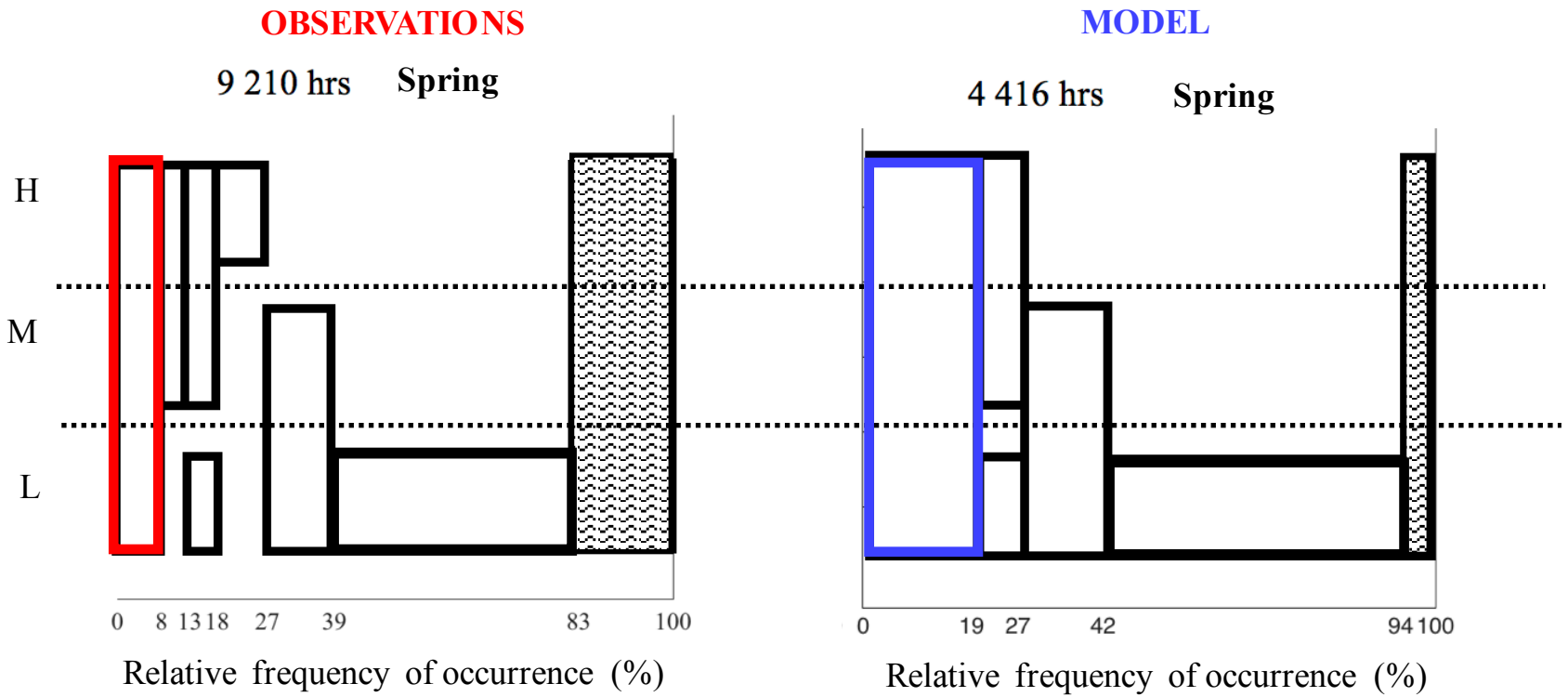


ModelE3 preliminary simulation apparent cloud type biases

Single-layer upper-level systems: ~ 10 % deficit

NSA cloud vertical structure relative occurrence



ModelE3 preliminary simulation apparent cloud type biases

Deep systems: ~ 10 % excess

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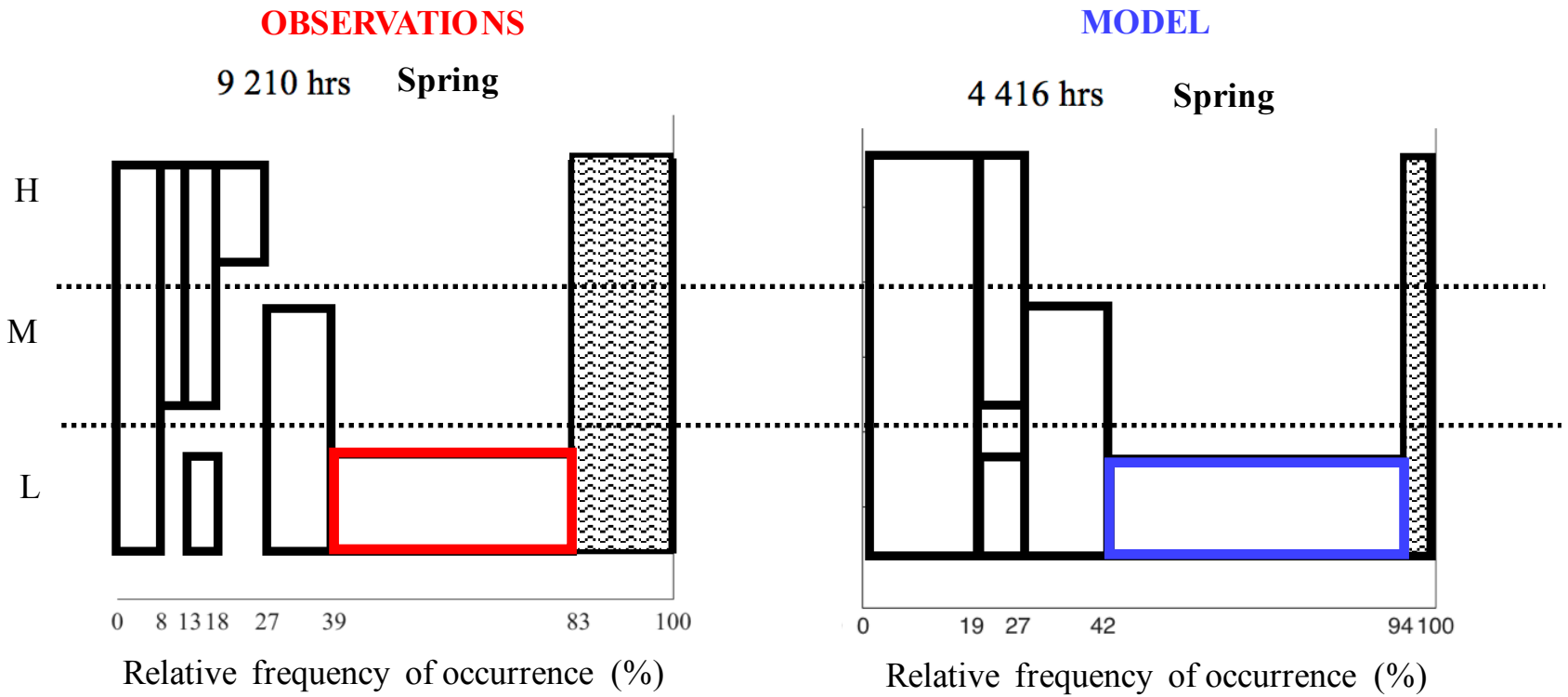
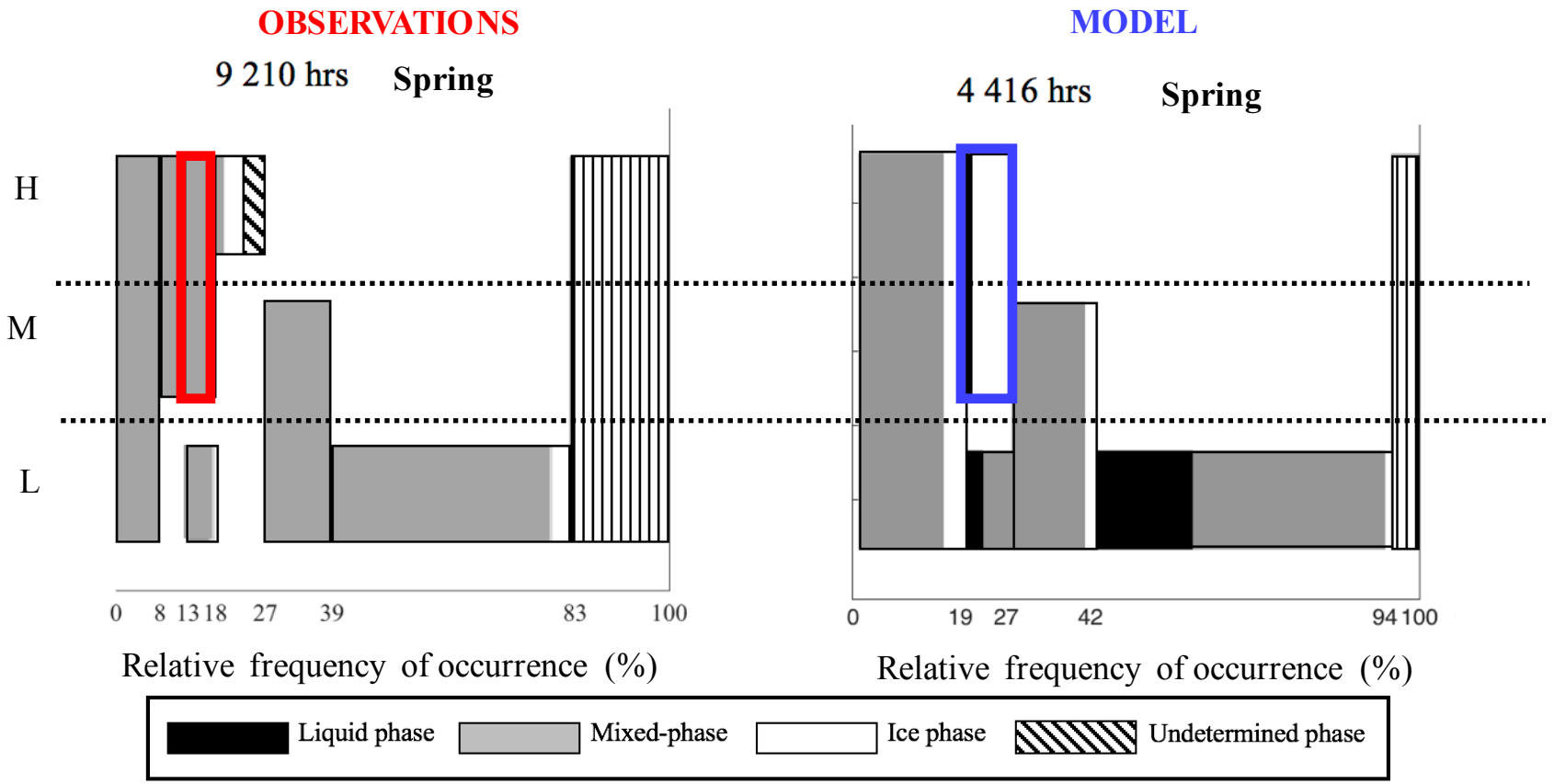


ModelE3 preliminary simulation apparent cloud type biases

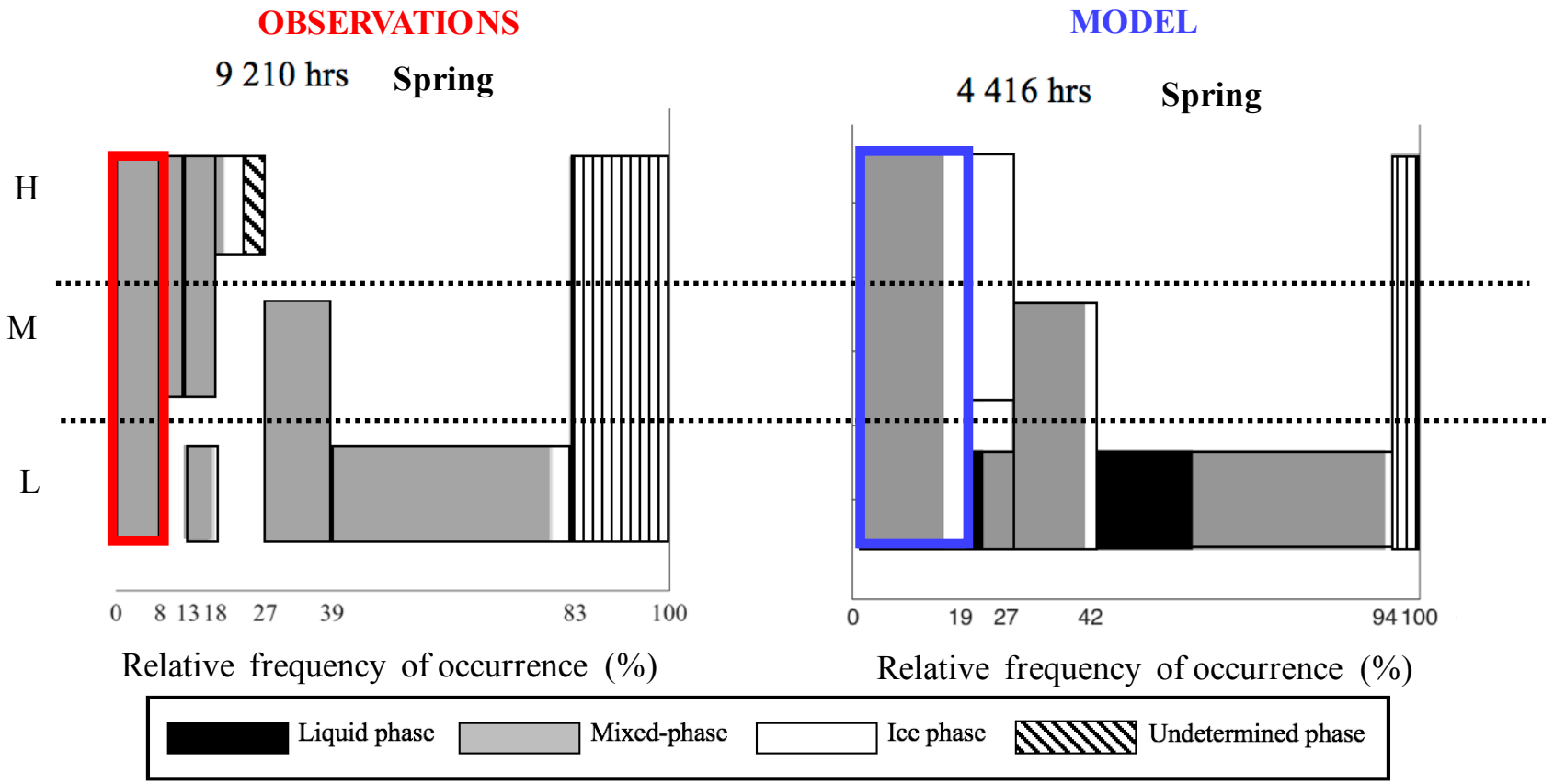
Single-layer low-level clouds: ~ 10 % excess

NSA cloud phase relative occurrence



ModelE3 preliminary simulation apparent cloud phase biases Cirro-stratus systems: overly glaciated

NSA cloud phase relative occurrence



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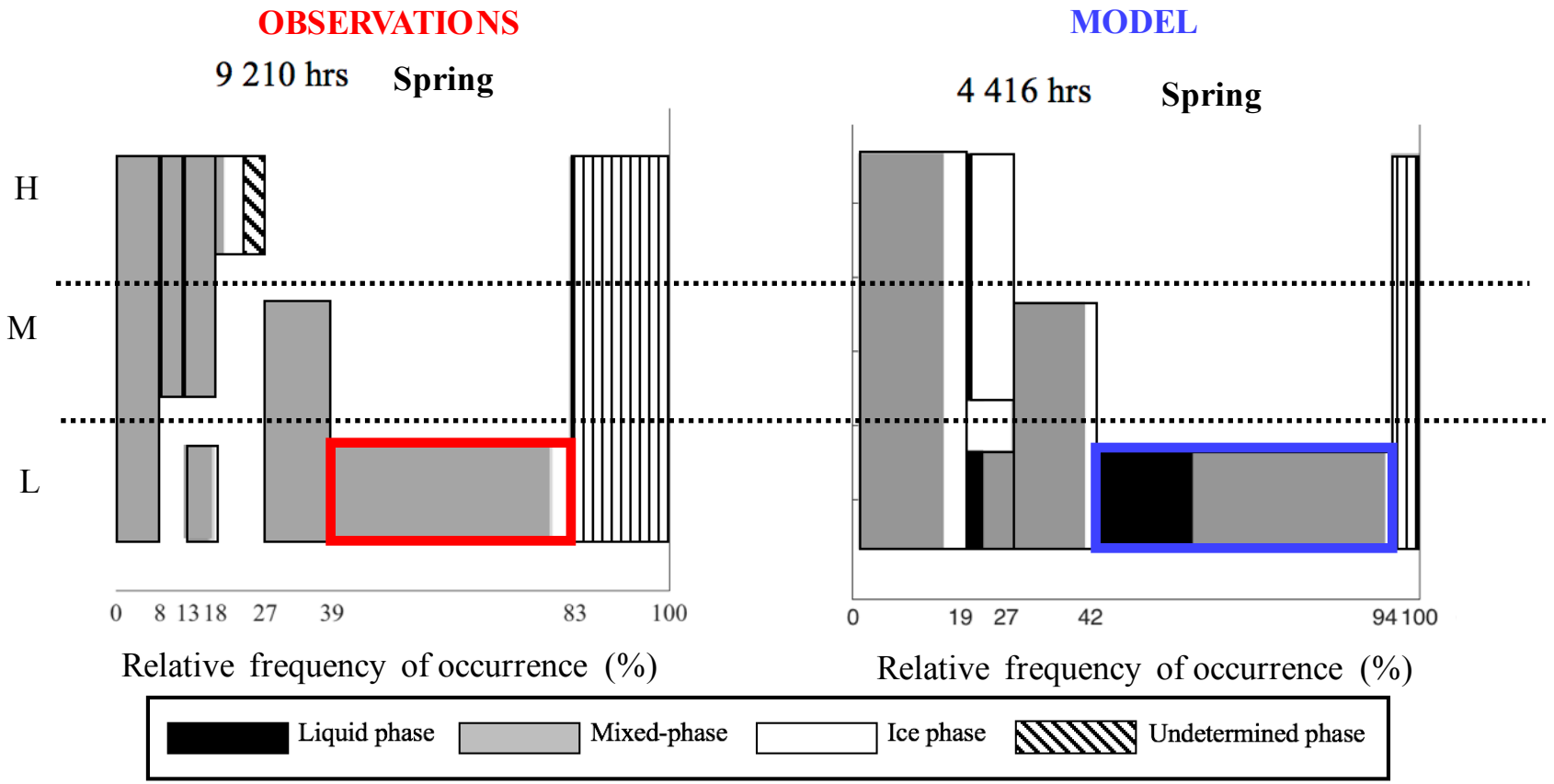
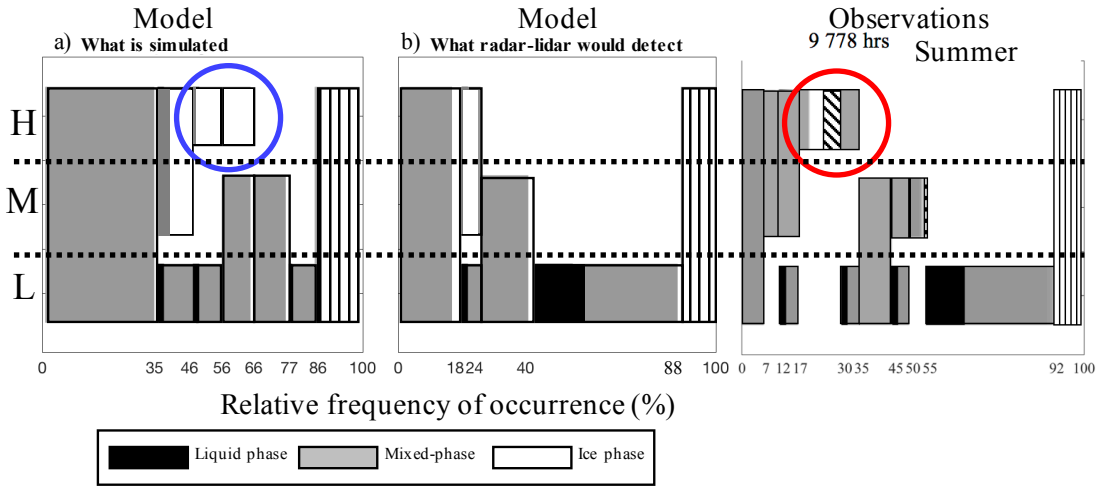


ModelE3 preliminary simulation apparent cloud phase biases Single-layer low-level systems: overly liquid

Outlook on microphysical parameterization development

Interpreting the differences

Apparent biases indicate that model modifications are required, but determining the way forward is not always straightforward.



Model development candidates

Stratiform cloud schemes

- Microphysics (e.g., prognostic ice nucleation from MATRIX aerosol, ice properties and processes)
- Macrophysics (e.g., cloud and precipitation fractions by phase)

Convective cloud scheme

- Triggering
- Outflow phase and properties

Moist turbulence scheme (e.g., tunable parameters, layer merging criteria)

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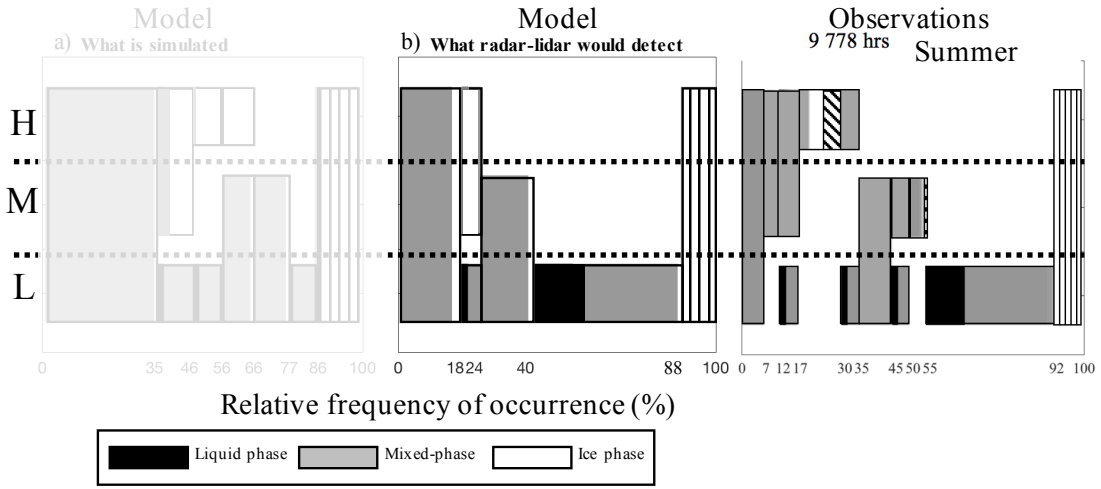

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