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The MYNN Turbulence Parameterization: New Developments, Current Capabilities, and Best Practices

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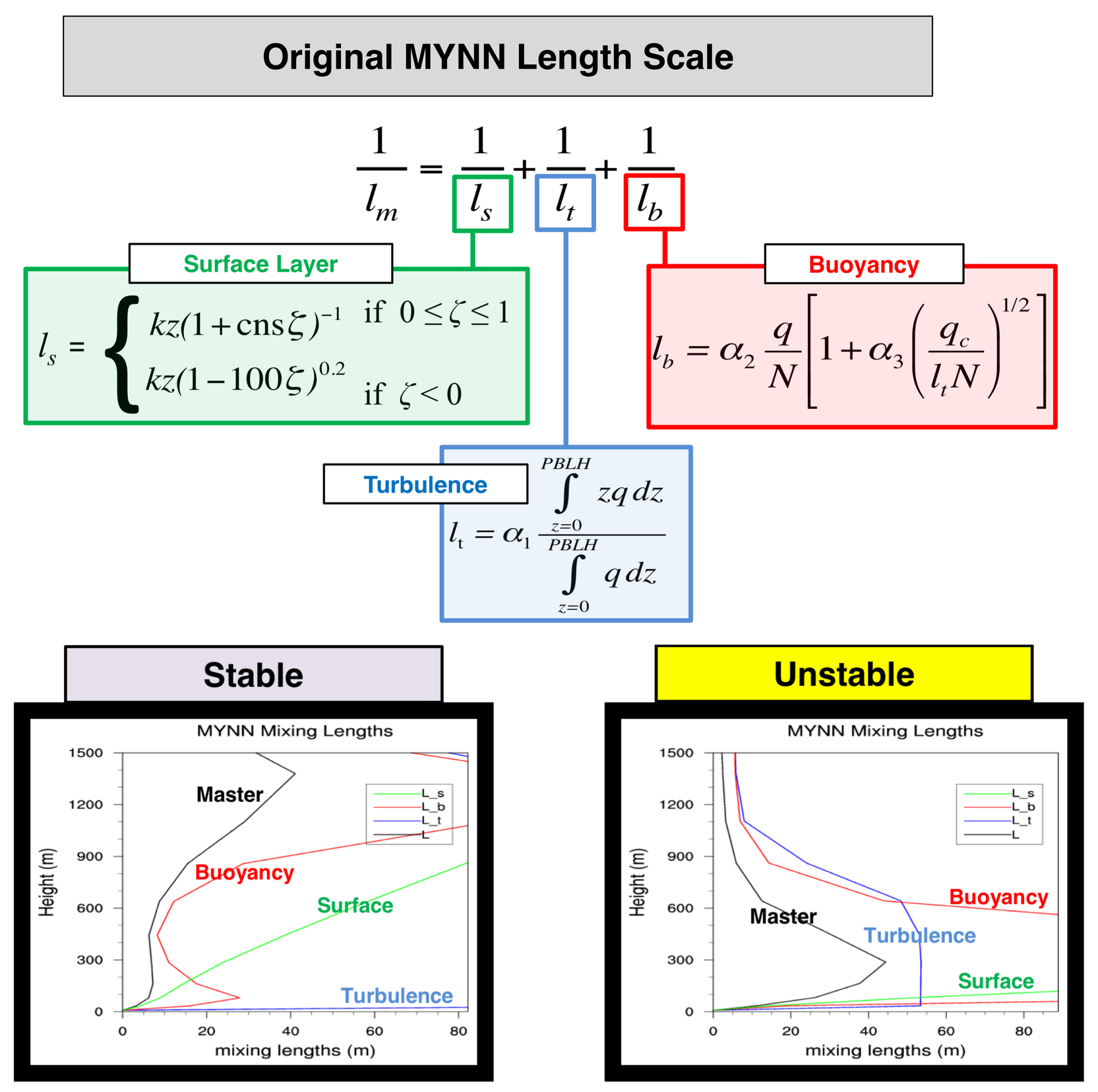
Motivation

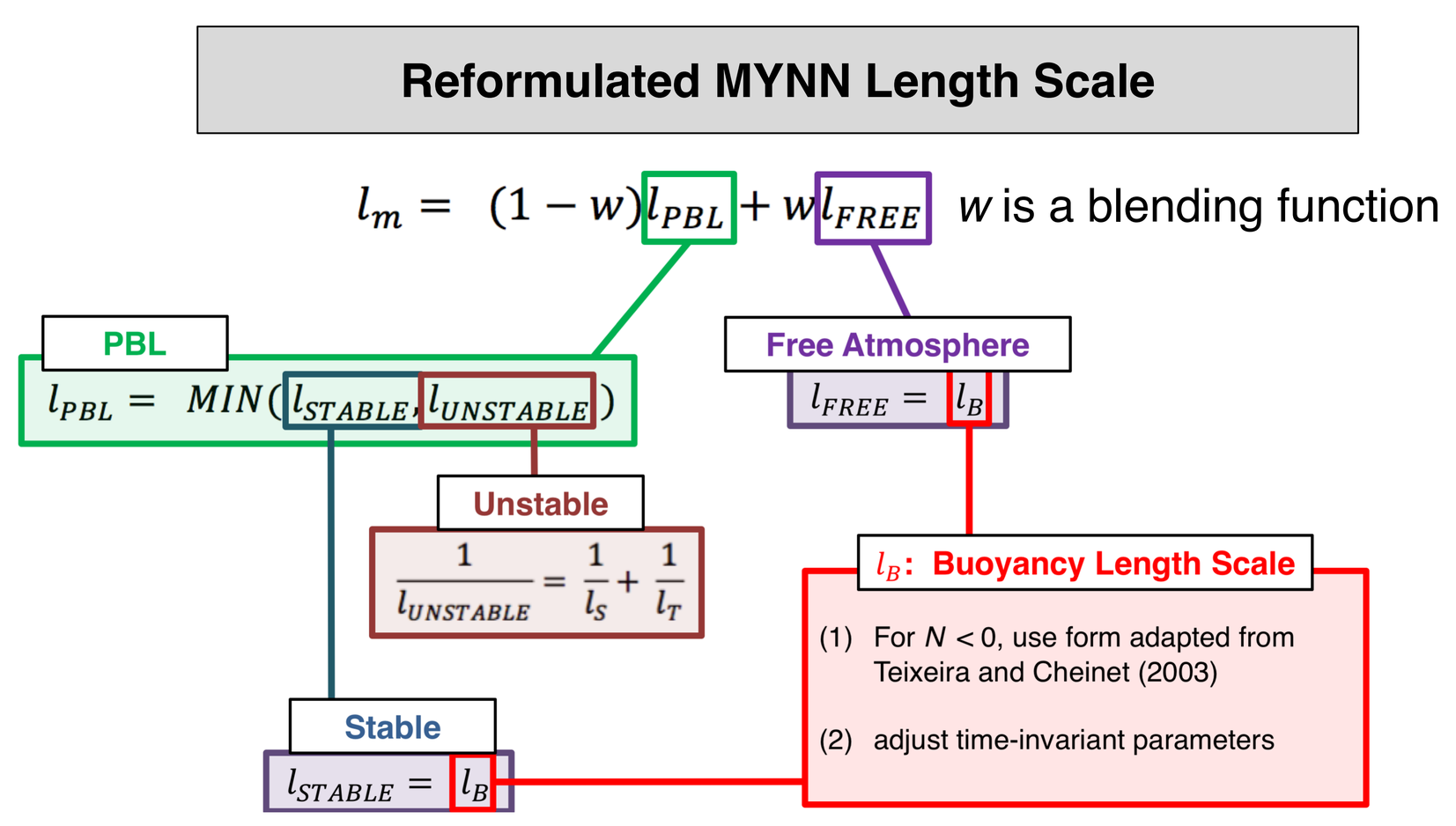
- The Mellor–Yamada–Nakanishi–Niino (MYNN) PBL parameterization, used in NOAA's RAP and HRRR models and available in WRF–ARW, has been under focused development since 2014.
- We summarize the new features and capabilities of the MYNN scheme and offer best practices, based on model development for 13-km RAP, 3-km HRRR, and 750-m nest applications.

Added Option: Alternative Mixing-Length Formulation

namelist (physics): **bl_mynn_mixlength = 2**

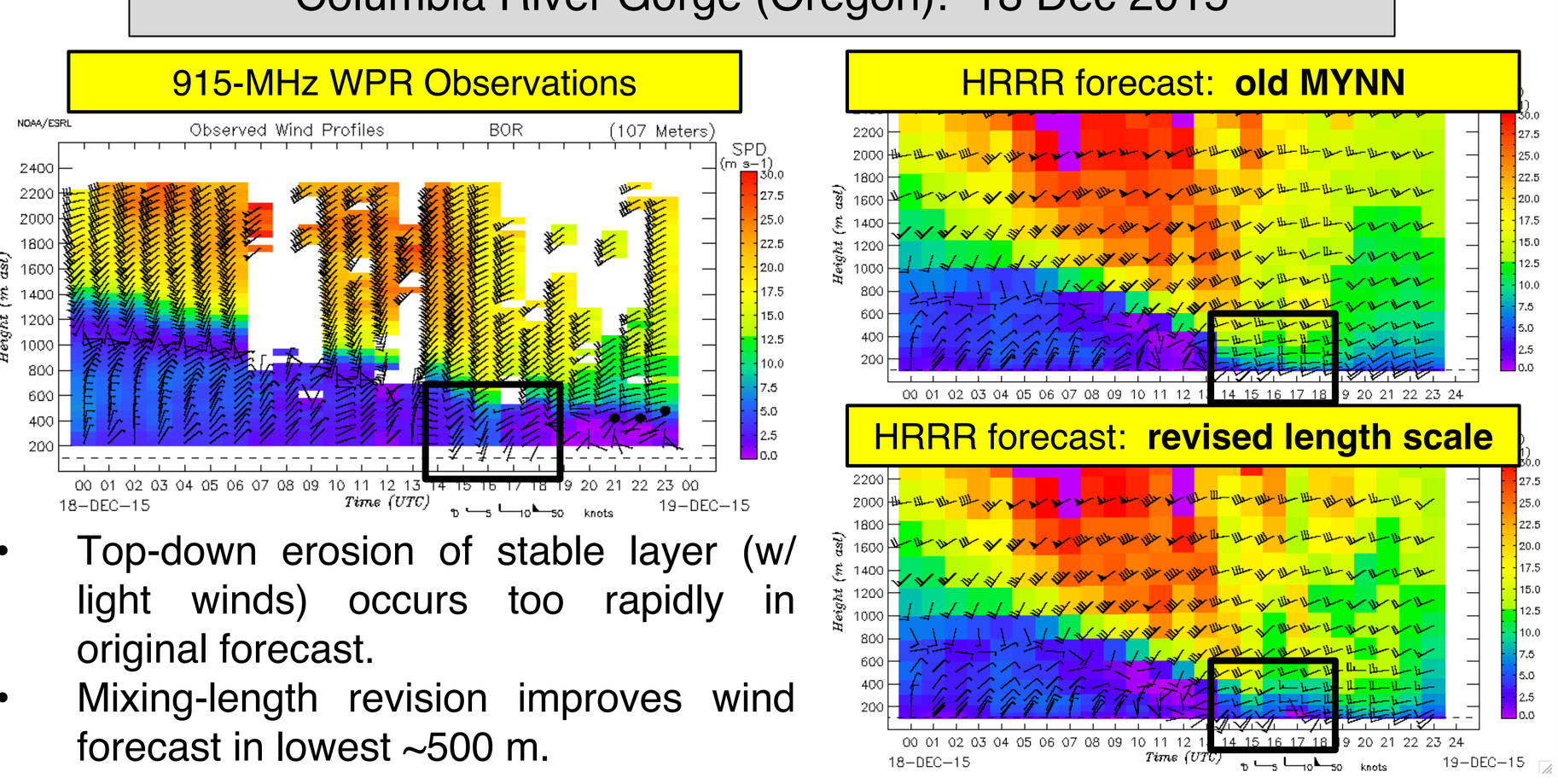


- A three-way harmonic average: master length scale is always shorter than each component scale. Length-scale specification is difficult.
- Surface-layer scale, a function of *z*, influences master length scale everywhere.



- Retains the three component length scales, but limits use of averaging. An appropriate master length-scale is more easily specified, and largely independent of *z*.
- Buoyancy length scale is more restrictive than in original formulation.

Example: Erosion of Low-Level Stable Layer
Columbia River Gorge (Oregon): 18 Dec 2015



- Top-down erosion of stable layer (w/ light winds) occurs too rapidly in original forecast.
- Mixing-length revision improves wind forecast in lowest ~500 m.

Added Option: Eddy-Diffusion / Mass-Flux (EDMF) Formulation

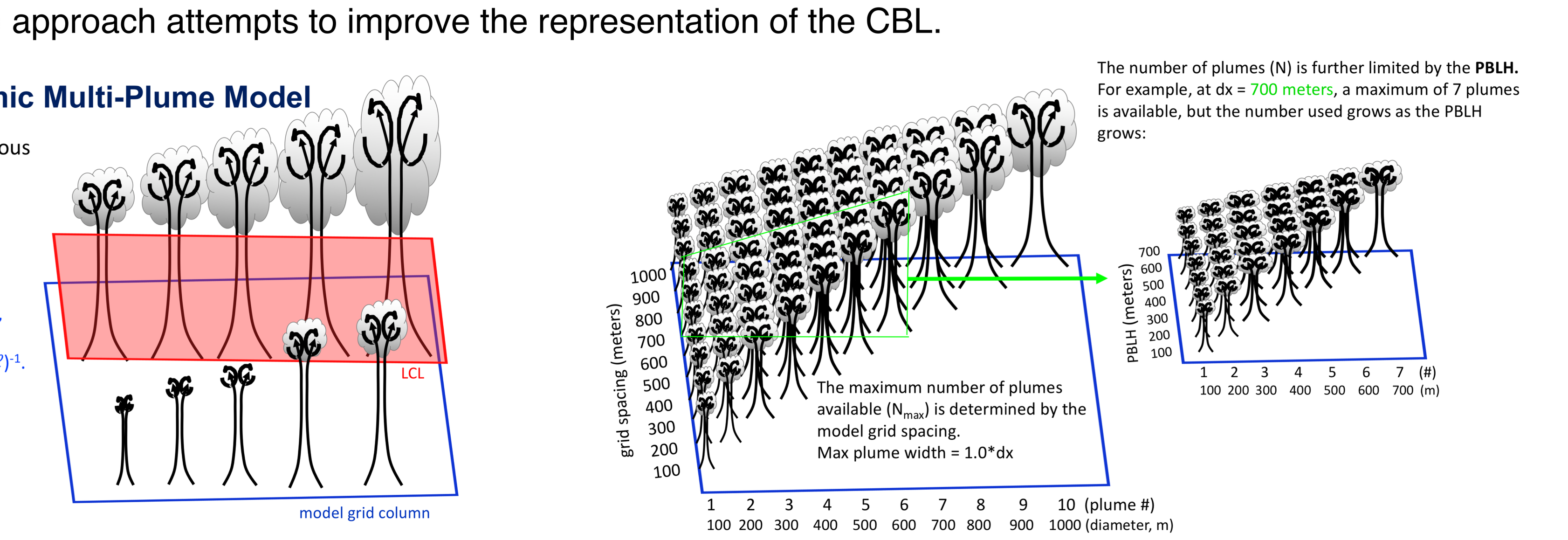
namelist (physics): **bl_mynn_edmf = 1**

Eddy-diffusion schemes typically have shortcomings in representing the convective boundary layer (CBL), since turbulent fluxes are parameterized using local gradients. In reality, energetic convective plumes accomplish strongly *nonlocal* transport. The eddy-diffusion / mass-flux (EDMF) approach attempts to improve the representation of the CBL.

MYNN-EDMF: Dynamic Multi-Plume Model

An attempt to explicitly model plumes of various sizes that are likely to exist in a given environment state, following **Neggers (2015, JAMES)** and **Suselj et al. (2013, JAS)**.

- Total maximum number of plumes possible in a single column: 10.
- Diameters (ℓ): 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 m.
- Lateral entrainment varies for each plume ∝ $(w\ell)^{-1}$.
- Plumes condense only if they surpass the lifting condensation level (LCL).



Mapping the Contribution of Each Plume to the Total Fractional Area

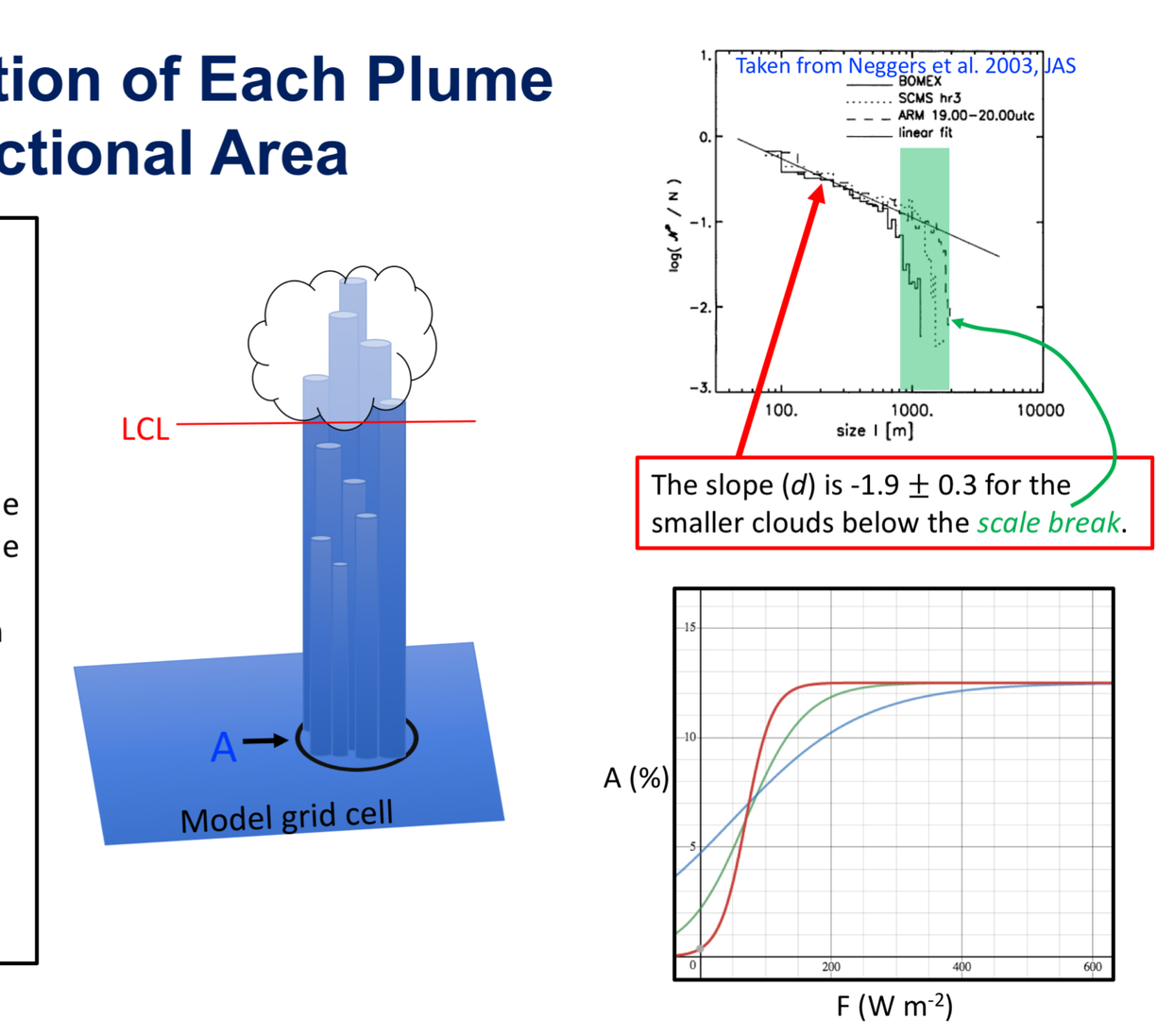
The number density, N, of each plume that contributes to the total plume mixing is represented by a power law:

$$N(\ell) = C\ell^{d}$$

where C is a constant of proportionality, ℓ is the diameter of the plume, and *d* is the slope of the power-law relationship. N effectively weights the contribution of given plume to the fraction area, A (%), which is set to be proportional to the surface buoyancy flux (F, W m^{-2}):

A = 10.0(Stanh((F - 70)/90) + .5),

So A varies between ~10% for F > 300 W m^{-2} and can be as small as ~2% for F near 0 W m^{-2}.



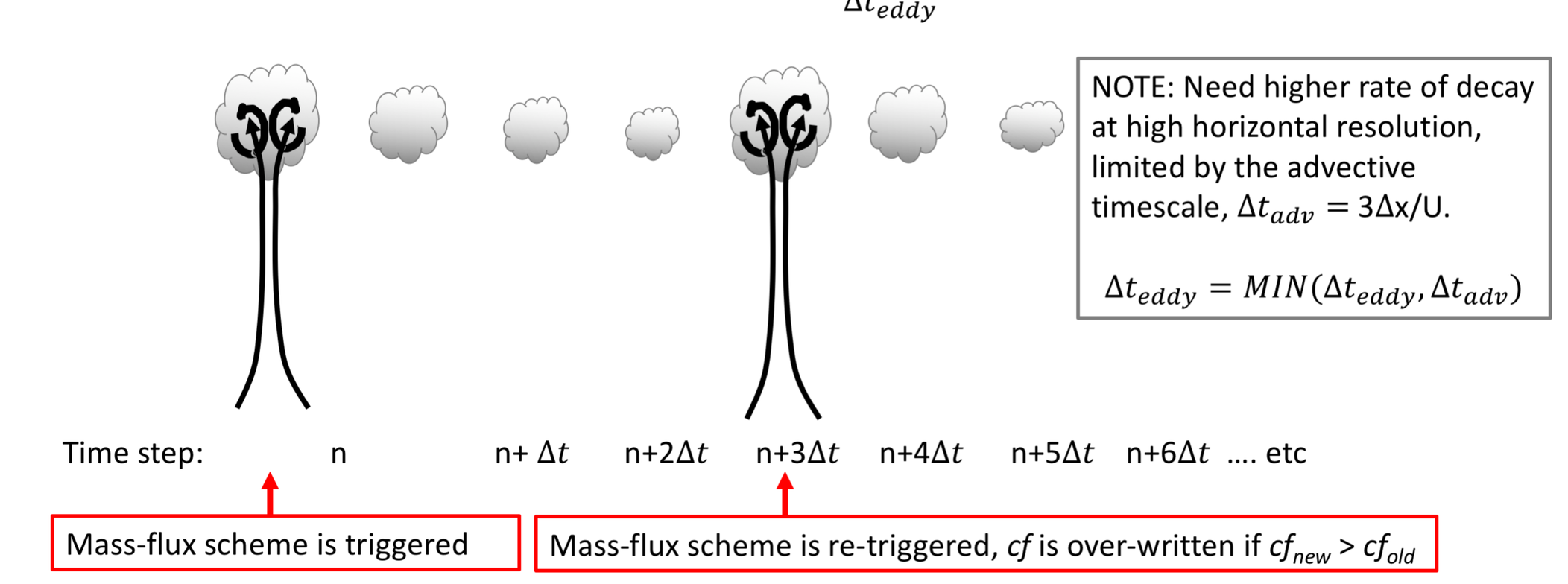
Diagnostic-Decay for Subgrid Clouds

To retain subgrid cloud fraction (*cf*) produced by the mass-flux scheme at later time steps, a diagnostic-decay approach has been implemented:

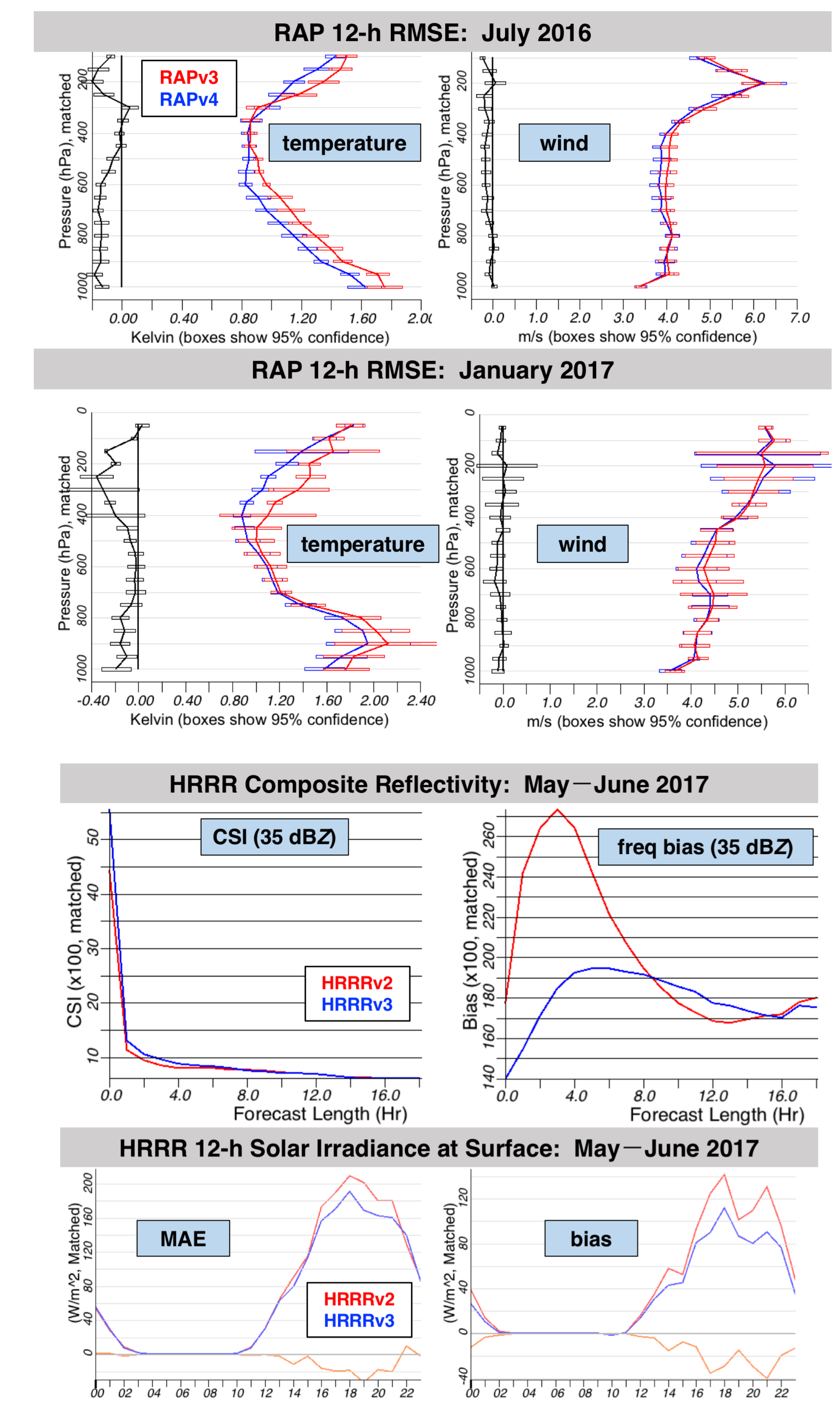
$$cf = cf - cf_m \frac{\Delta t}{\Delta t_{eddy}}$$, where cf_m = 0.25 and Δt_{eddy} = 1800 s.

NOTE: Need higher rate of decay at high horizontal resolution, limited by the advective timescale, $\Delta t_{adv} = 3\Delta x/U$.

$$\Delta t_{eddy} = MIN(\Delta t_{eddy}, \Delta t_{adv})$$



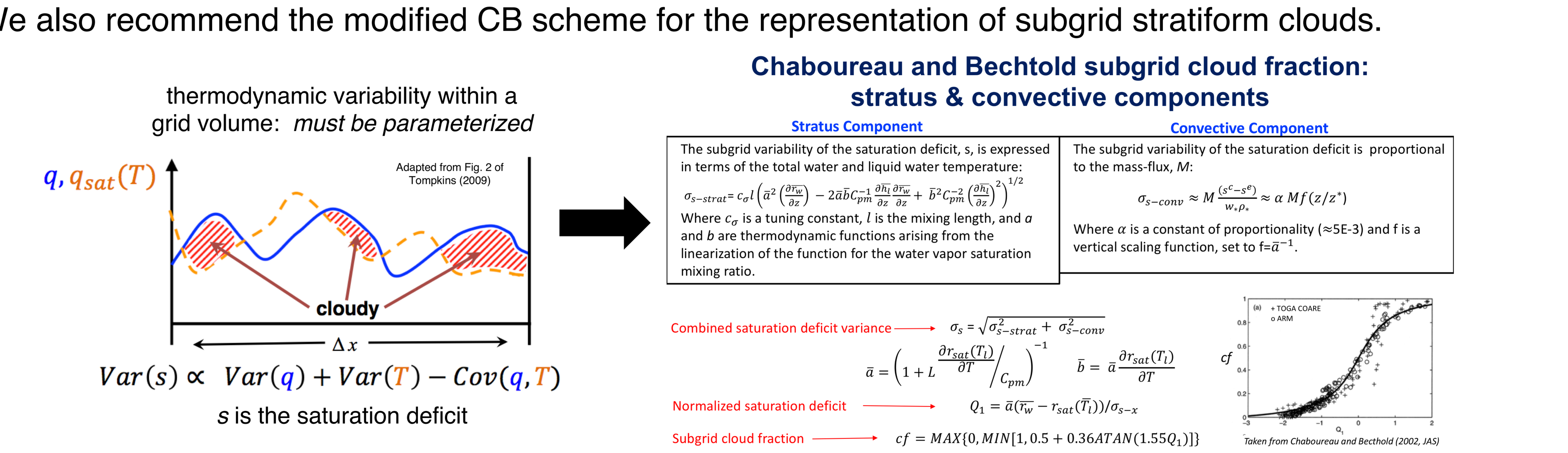
Preview of Operational RAP and HRRR Upgrade with Latest MYNN

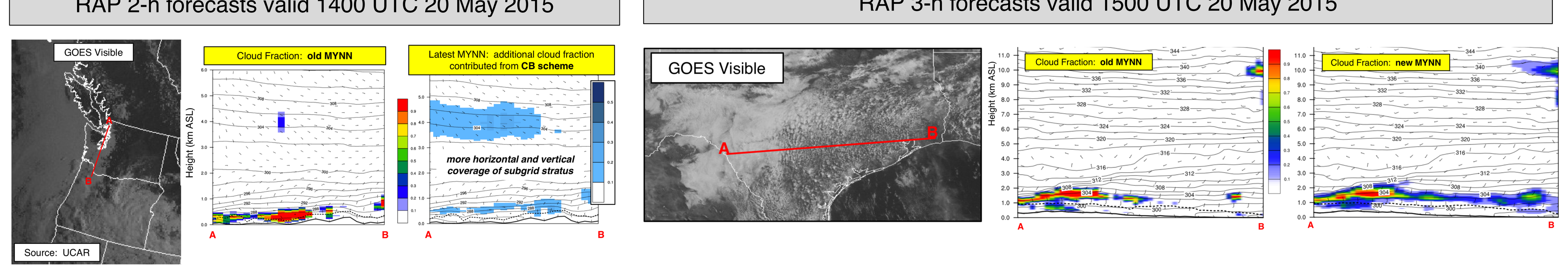


Added Option: Alternative Statistical Cloud Parameterization

namelist (physics): **bl_mynn_cloudpdf = 2**

A statistical cloud scheme, adapted from Chaboreau and Bechtold (2002, JAS, hereafter "CB"), is used within the mass-flux scheme for calculating buoyancy flux and stability functions in shallow-cumulus layers. We also recommend the modified CB scheme for the representation of subgrid stratiform clouds.

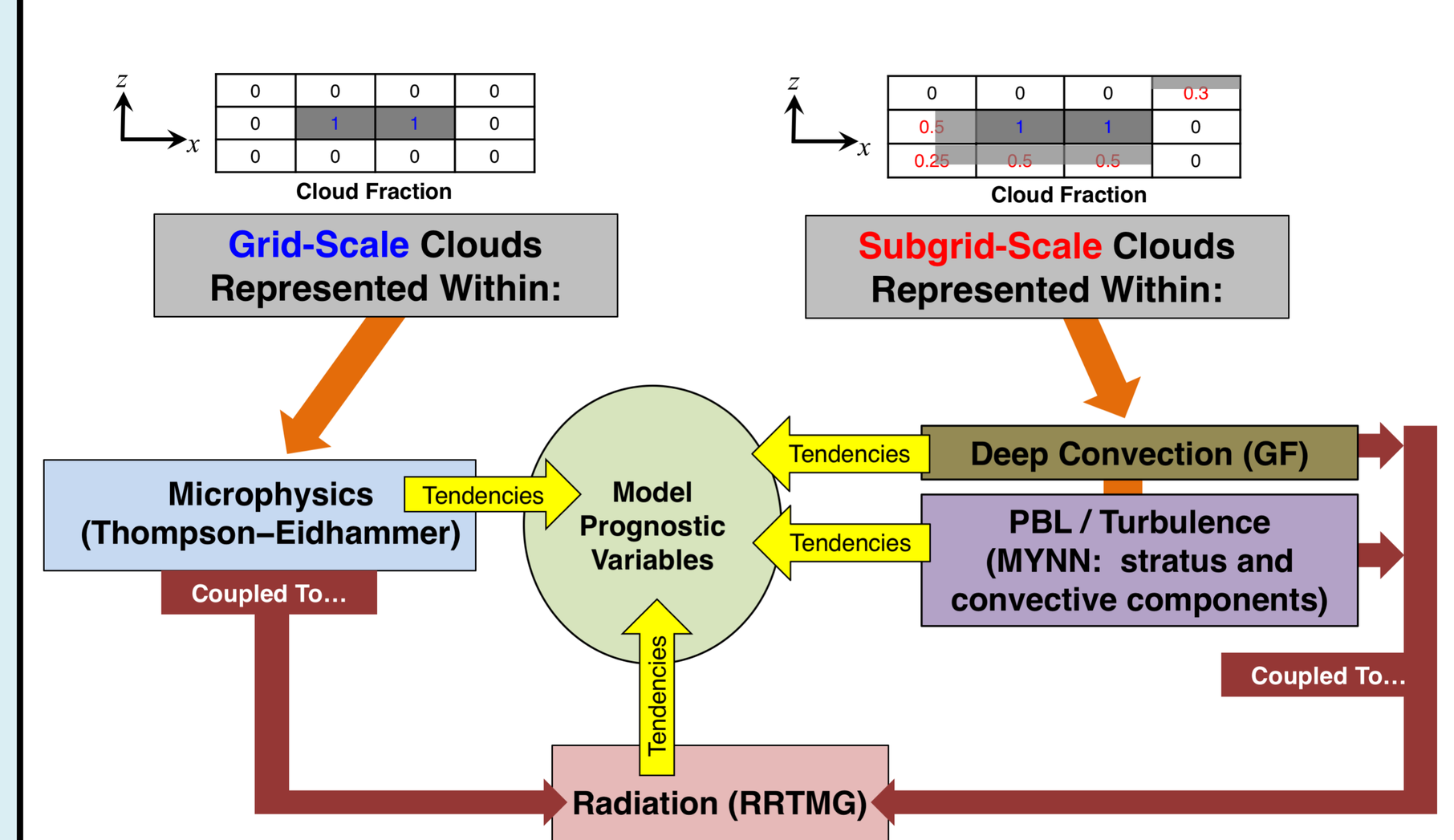


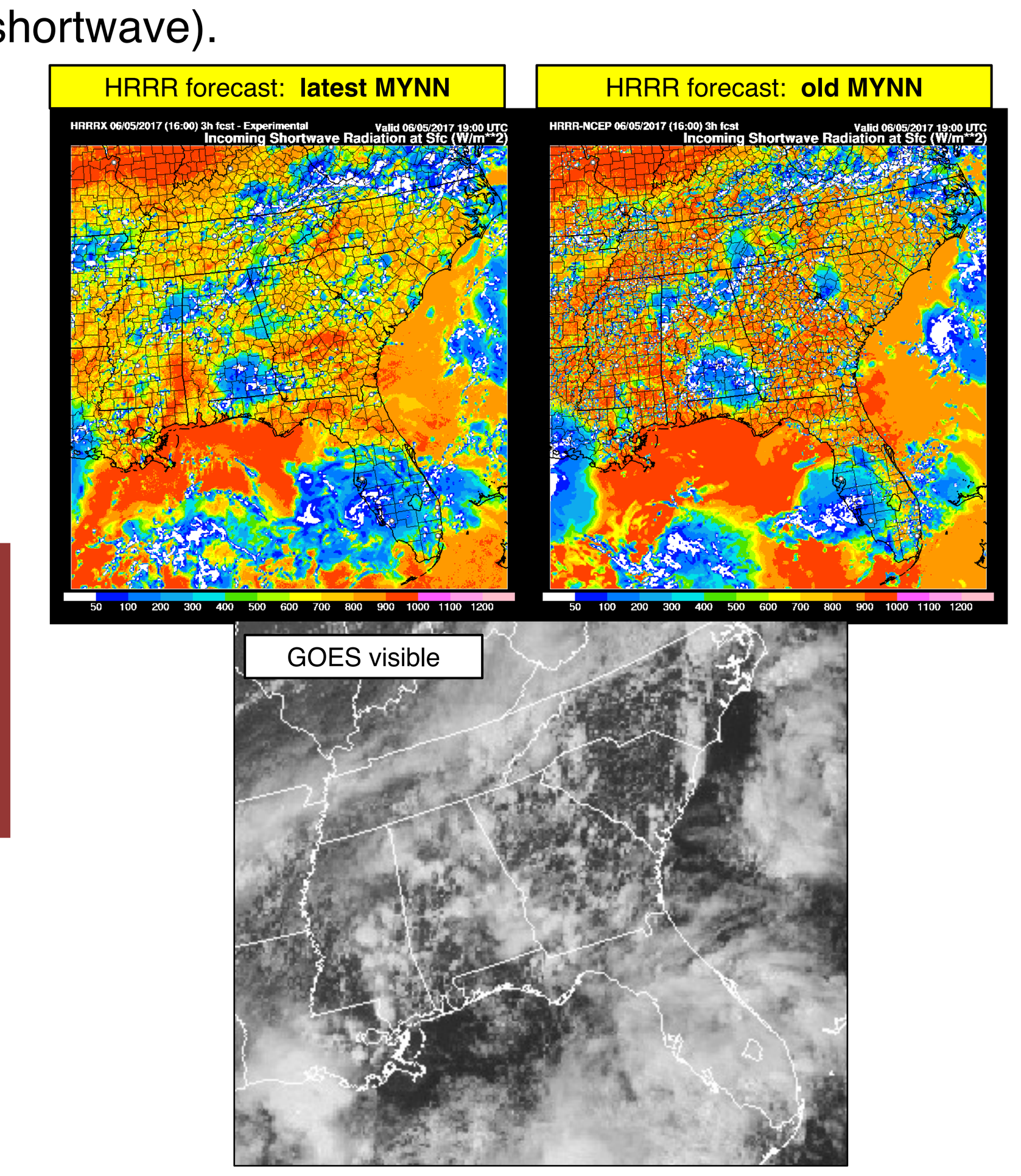


Added Option: Coupling of Subgrid-Scale Clouds to Radiation

namelist (physics): **icloud_bl = 1**

The cloud fractions and cloud mixing ratios within MYNN (with stratus and convective components) are available for radiative coupling (longwave and shortwave).





Conclusions

- MYNN has undergone considerable development, and this has contributed to improvements in RAP and HRRR forecast skill at modest (~4%) computational expense.
- Latest MYNN developments can be accessed in WRF–ARW v3.9 release via four namelist settings (as indicated). Older WRF versions only capture prototype MYNN developments. Mixing of chemical species is available in v3.9.
- "Scale-aware" aspects have been incorporated; MYNN performance is being assessed at 750 m horizontal grid spacing.