Integration of theta-l dycore into EAM

Hydrostatic (H) and non-hydrostatic (NH) formulations for theta-l:

$$\mathbf{u}_t + (\nabla_s \times \mathbf{u} + 2\Omega) \times \mathbf{u} + \frac{1}{2}\nabla_s \mathbf{u}^2 + \dot{s}\mathbf{u}_s + \frac{1}{\kappa}\theta_v \nabla_s \Pi + \mu \nabla_s \phi = 0,$$ hor. momentum (H/NH)

$$w_t + \mathbf{u} \cdot \nabla_s w + \dot{s} w_s + g(1-\mu) = 0,$$ vertical momentum (NH)

$$\phi_t + \mathbf{u} \cdot \nabla_s \phi + \dot{s}\phi_s - gw = 0,$$ geopotential eqn (NH)

$$\Theta_t + \nabla_s \cdot (\mathbf{u}\Theta) + (\dot{s}\Theta)_s = 0,$$ theta eqn (H/NH)

$$(\pi_s)_t + \nabla_s \cdot (\mathbf{u}\pi_s) + (\dot{s}\pi_s)_s = 0,$$ continuity eqn (H/NH)

$$\pi - \text{hydrostatic pressure}, p - \text{nonhydrostatic pressure},$$

$$\Theta = \pi_s \theta_v, \ \mu = \frac{p_s}{\pi_s}$$

$$EOS : \phi_s = -\Theta \frac{\Pi}{p}$$ eqn. of state (NH)

Integration of hydrostatic model

For hydrostatic model most of effort was spent on infrastructure and conversion of temperature tendencies.

Theta model uses this particular definition of potential temperature:

Potential temperature definition in homme, allows decoupling of vapor in dycore

$$\theta_v := \frac{R^* T}{R\Pi}, \quad \Theta_v := \pi_s \theta_v$$

theta variable in code for conservation form

There are a few options to convert temperature tendencies into theta tendencies:

1. $$\frac{D\theta_v}{Dt} = \frac{(R^*)^n}{R\Pi^n}\frac{DT}{Dt}$$

2. $$\frac{D\theta_v}{Dt} = \theta_v^{n+1} - \theta_v^n, \quad \theta_v^{n+1} = \frac{(R^*)^{n+1} T^{n+1}}{R\Pi^{n+1}}$$

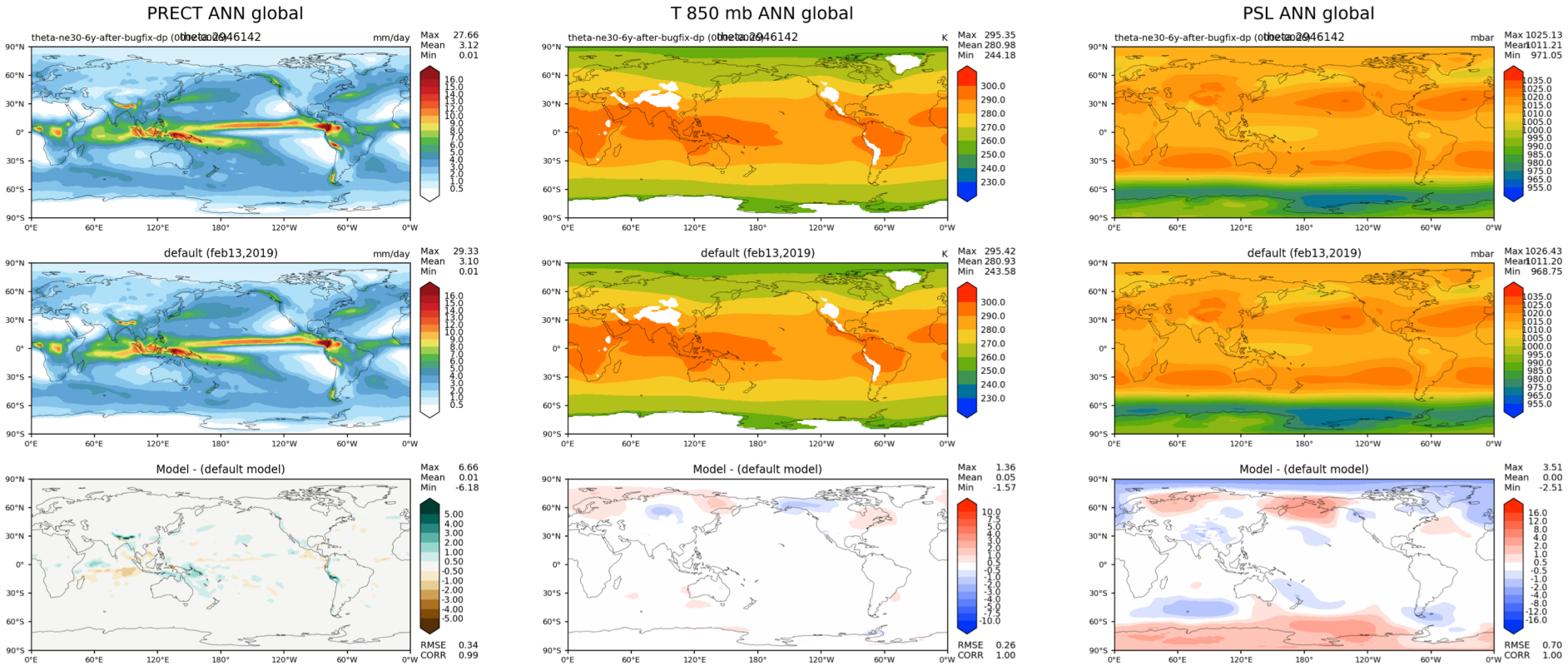
Implemented because it keeps theta definition consistent

Integration of nonhydrostatic model

Integration is done, some conceptual questions are work in progress.

Theta hydro, F case, 5 years climo (very preliminary)

Theta model vs default model comparison:



Tests and consistency

As we introduce more features into the dycore, including coupling options (ftypes) and dycore models, we get more tests into E3SM, too.

Thanks to Jim Foucar now there is an option to reuse the same executable in tests to save build time (only namelists change).

Potentially, there could be inconsistencies in definitions of potential temperature, Exner pressure, geopotential, energy, etc. To monitor for and to resolve these inconsistencies are on our list.