CENTER UPDATE FOR NCAR (“CMIP centric”)

Peter Hjort Lauritzen

Presentation at the joint WGNE/JWGFVR meeting (WGNE-38)
November 27, 2023

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CESM3/CAM7

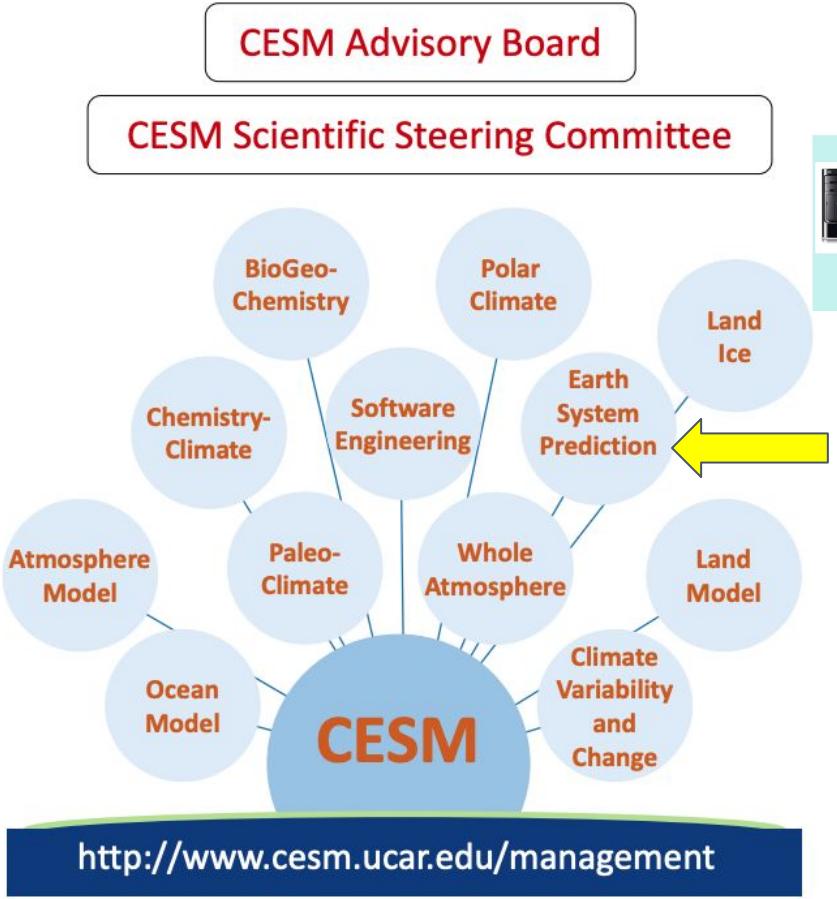
(CESM = NCARS's Community Earth System Model, CAM = Community Atmosphere Model)

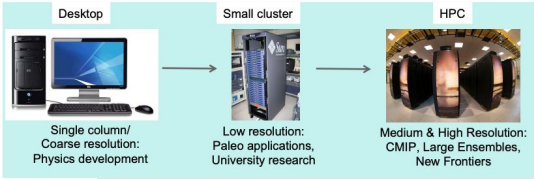
CESM Project

25+ years of model development and applications

Annual CESM Workshops are held in summers.

Most working groups have winter/spring meetings.

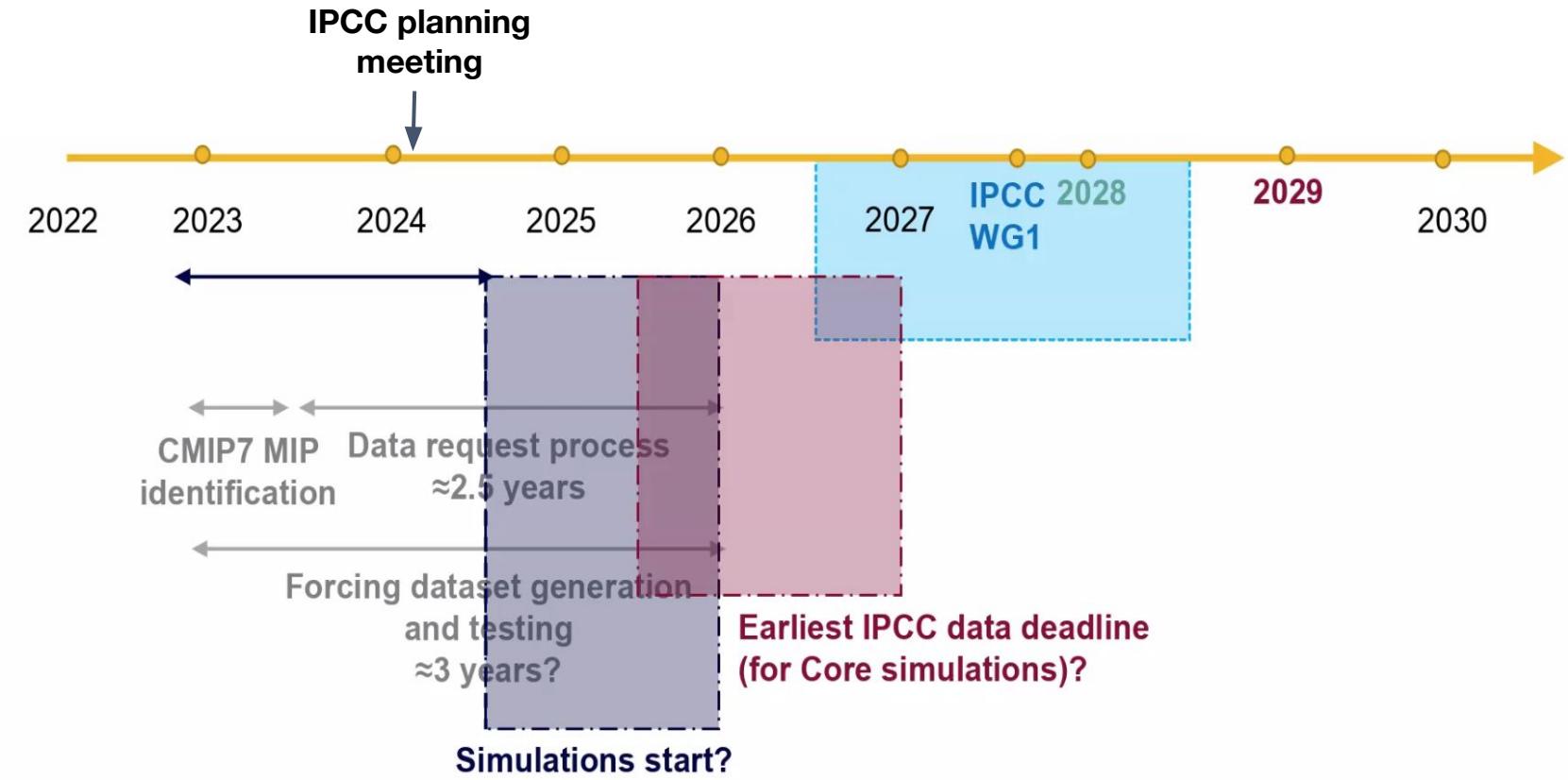




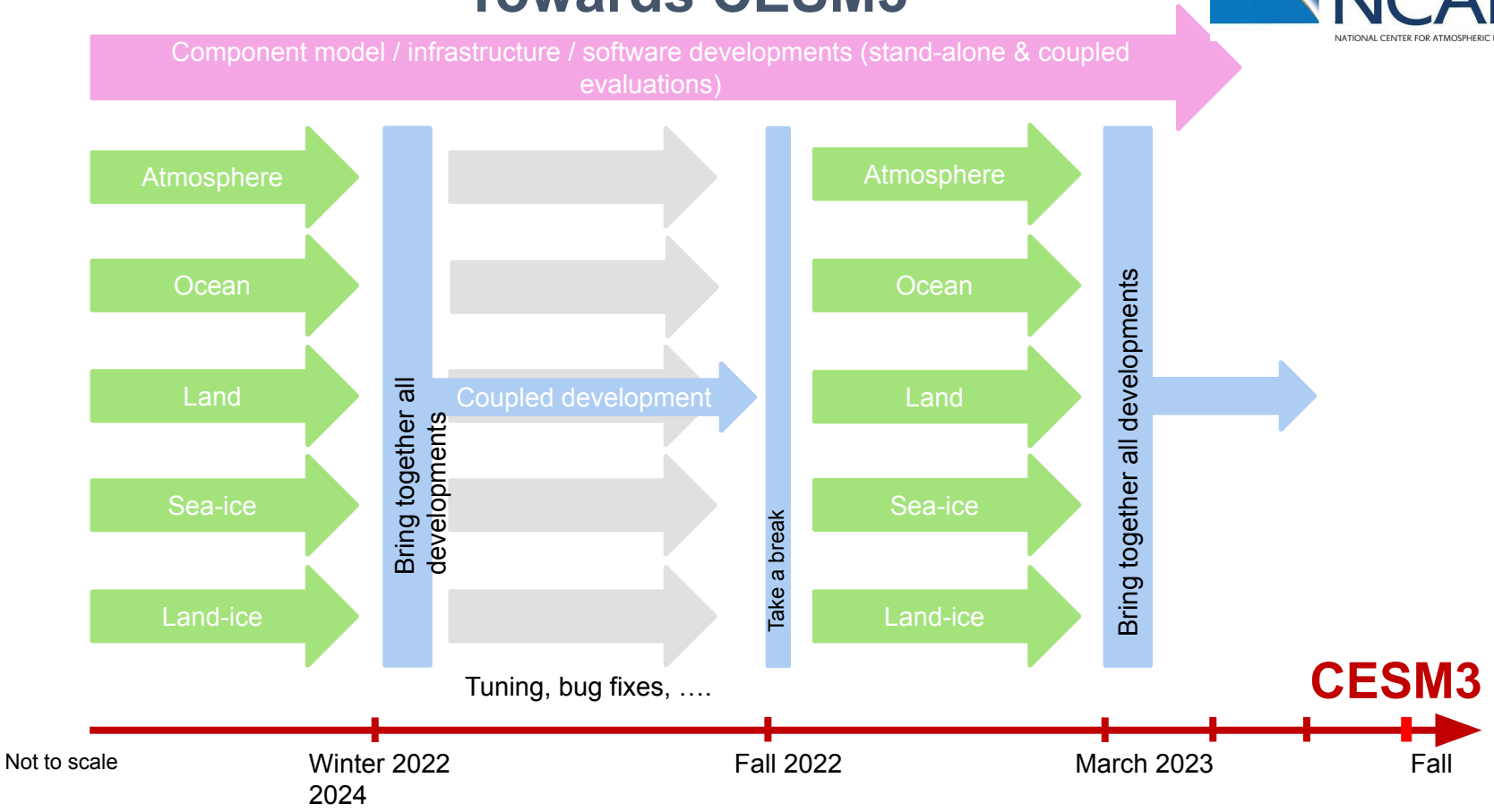
CESM also runs in the Amazon cloud using containers (used for CESM tutorials that take place all over the world - latest at WCRP Open Science Conference)

Getting ready for CMIP7: CESM3/CAM7

(CESM = NCARS's Community Earth System Model, CAM = Community Atmosphere Model)



Towards CESM3



Getting ready for CMIP7: CESM3/CAM7

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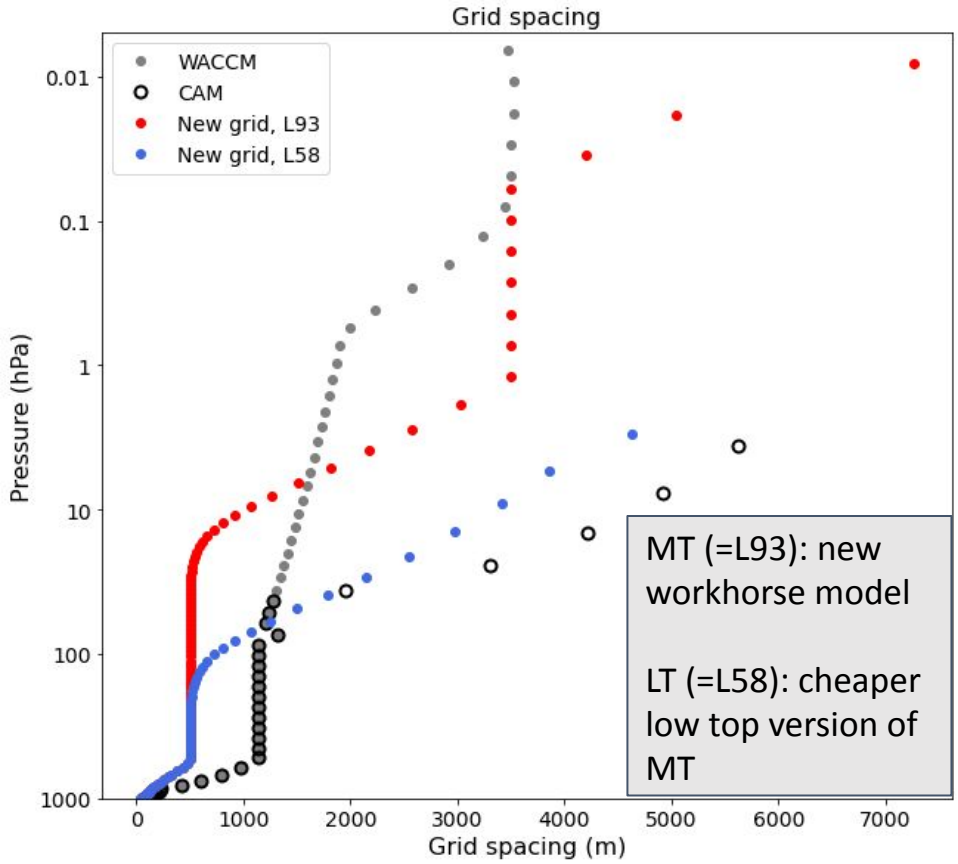


MT (=L93): new workhorse model

LT (=L58): cheaper low top version of MT

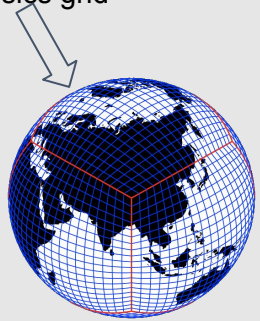
MT (~80km top) and LT (~40km top) unification:

- same simplified chemistry in low top (LT) and mid-top (MT) configurations (prognostic greenhouse gasses, e.g., CO2 is advected & radiatively active)

- unified treatment of gravity waves: using frontal and convective GW in LT as well as MT - and to the extent possible using the same settings

Switched to SE-CSLAM (SE=spectral-elements; CSLAM = Conservative Semi-LAgrangian Multi-tracer scheme) dynamical core using a separate physics grid

- dry-mass vertical coordinate
- variable latent heats formulation



Boundary layer scheme: CLUBB

Microphysics: PUMAS

Radiation: RRTMG-P

PPE (Perturbed Parameter Ensemble): systematic tuning approach that we are exploring that may supplement and guide conventional tuning.

Talk more about this in tomorrow's "energy" presentation …

Working on the implementation of explicit passing of enthalpy fluxes between atmosphere and ocean (variable latent heats in atmosphere to match MOM6)

AGU ADVANCING EARTH AND SPACE SCIENCE
Journal of Advances in Modeling Earth Systems
10.1029/2022MS003117

Modified CAM total energy equation incl. missing flux terms

$$\frac{\partial}{\partial t}\int \overline{\rho}^{(d)}\left\{\left(1+\overline{m}^{(H_2O)}\right)\left[\overline{K}+\overline{\Phi}_s+c_p^{(d)}\left(\overline{T}-T_{00}\right)\right]+\overline{m}^{(wv)}L_{s,00}+\overline{m}^{(liq)}L_{f,00}\right\}dz$$

$$-\Delta\widehat{\mathcal{I}}_{\partial m^{(H_2O)}/\partial t}-\Delta\mathcal{I}_{m_{tn}^{(H_2O)}}=\overline{F}_{net}^{(H_2O)}\left[c_p^{(d)}\left(\widetilde{\overline{T}}_s-T_{00}\right)+\widetilde{\overline{K}}_s+\overline{\Phi}_s\right]+\overline{F}_{net}^{(wv)}L_{s,00}+\overline{F}_{net}^{(liq)}L_{f,00}+\overline{F}_{net}^{(turb,rad)}$$

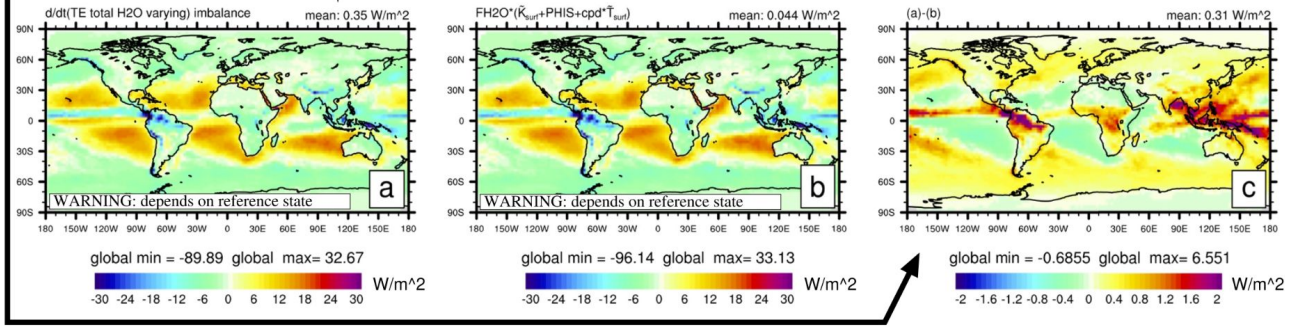


Figure 6. Modified (consistent) CAM total energy equation terms in W/m^2: (a) Imbalance introduced by "dry-mass adjustment" using all forms of water in the kinetic, geopotential and enthalpy terms, (b) missing flux terms, and (c) is the difference between (a and b). Note that the imbalance is locally much reduced when using the modified total energy equation. Also, the imbalance does not depend on the reference state (as should always be the case).

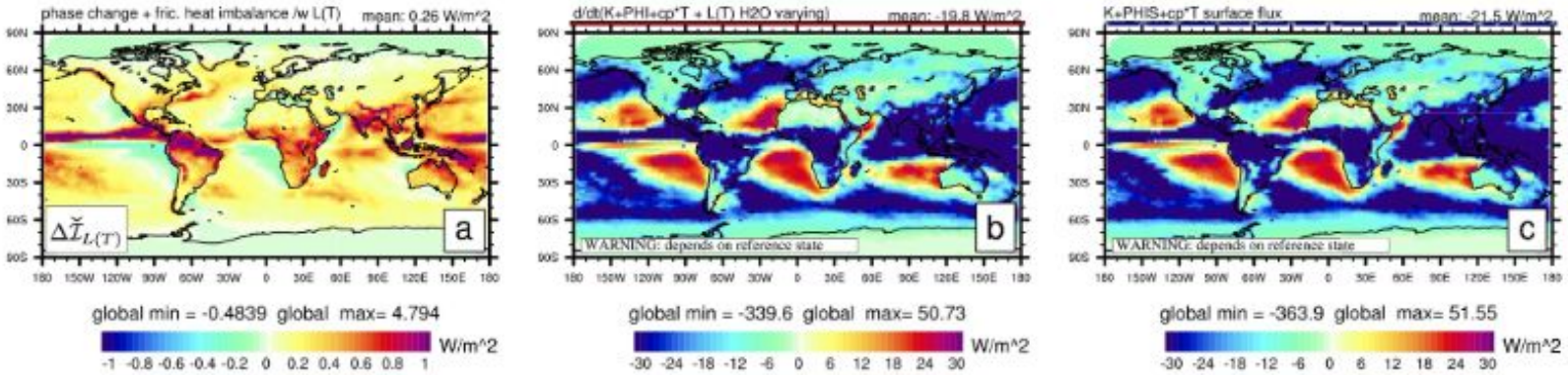
Talk more about this in tomorrow's "energy" presentation …

Working on the implementation of explicit passing of enthalpy fluxes between atmosphere and ocean (variable latent heats in atmosphere to match MOM6)

Modified (consistent) total energy equation assuming variable latent heats

$$\frac{\partial}{\partial t}\int \overline{\rho}^{(d)}\left\{\left(1+\overline{m}^{(H_2O)}\right)\left(\overline{K}+\overline{\Phi}_s\right)+c_p^{(d)}T+\sum_{\ell\in\mathcal{L}_{H_2O}}\overline{m}^{(\ell)}c_p^{(\ell)}\left(\overline{T}-T_{00}\right)+\overline{m}^{(wv)}L_{s,00}+\overline{m}^{(liq)}L_{f,00}\right\}dz$$

$$-\Delta\breve{\mathcal{I}}_{L(T)}-\Delta\hat{\mathcal{I}}_{L(T)}=-\sum_{\ell\in\mathcal{L}_{H_2O}}\overline{F}_{net}^{(\ell)}\left[c_p^{(\ell)}\left(\widetilde{\overline{T}}_s-T_{00}\right)+\widetilde{\overline{K}}_s\right]+\overline{F}_{net}^{(wv)}L_{s,00}+\overline{F}_{net}^{(liq)}L_{f,00}+\overline{F}_{net}^{(turb,rad)}$$



Getting ready for CMIP7: CESM3/CAM7

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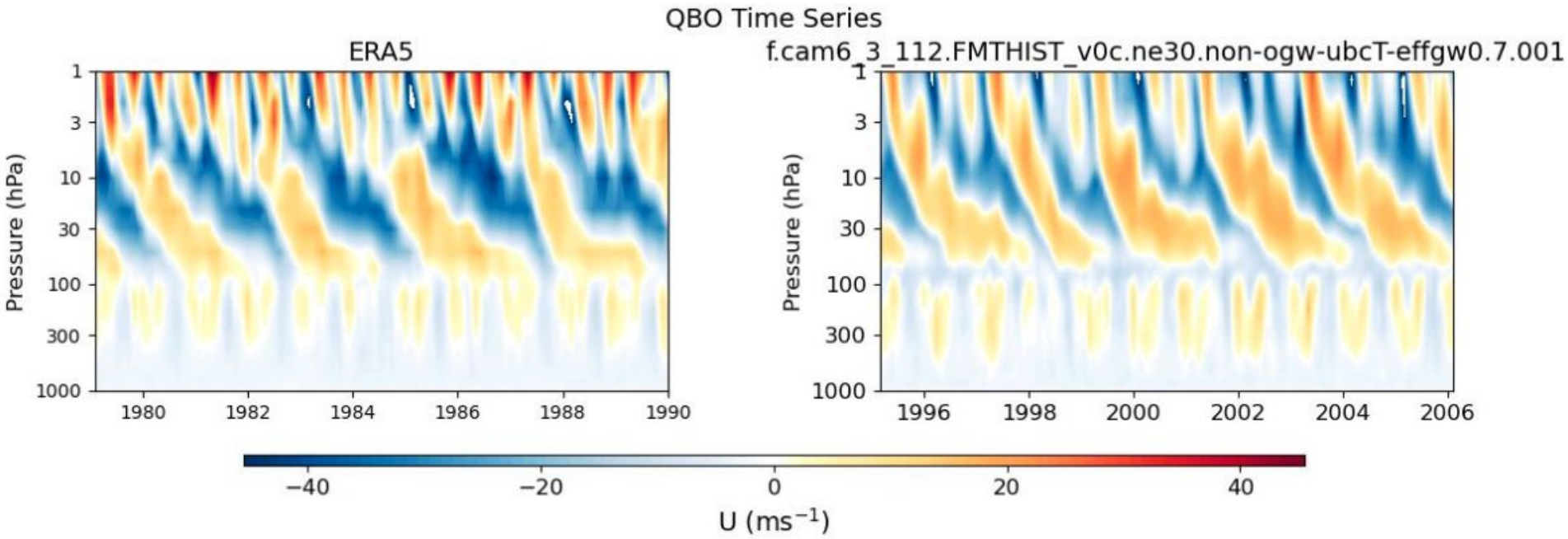
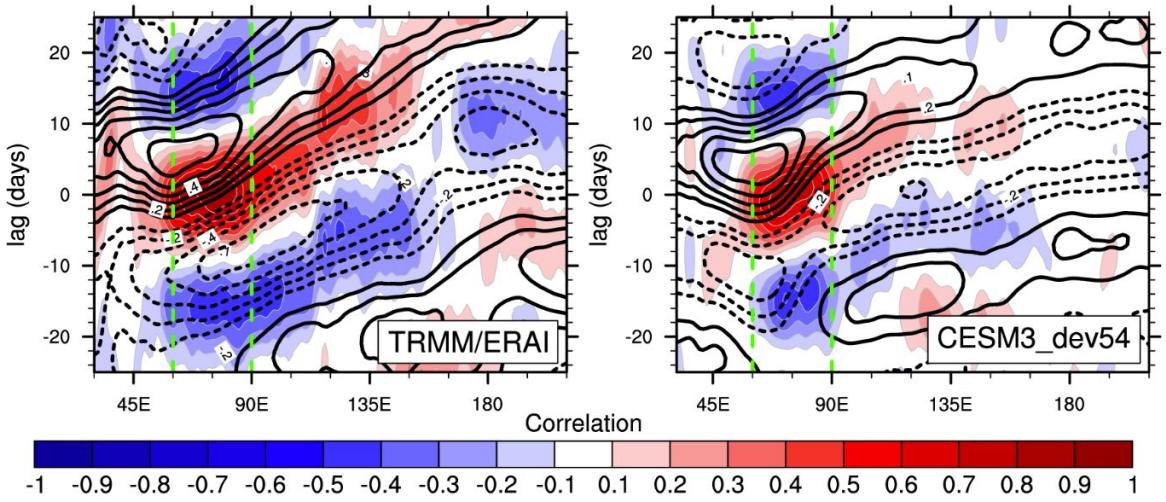
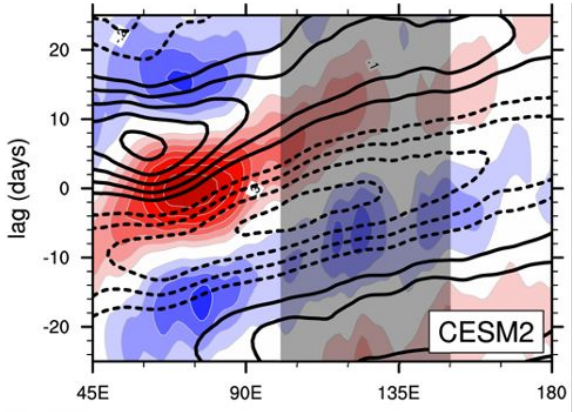
Our workhorse model (MT) now has a "good" QBO



MJO diagnostics



30-90 day filtered time lag correlation of PRECT (colors)
And U850 (contours) - centered in the Indian Ocean (5N-10S).



Getting ready for CMIP7: CESM3/CAM7

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We still have a lot of work to do in terms of tuning and evaluating coupled model:

- **Coupled 20th century simulation with MOM6, etc.**
- **Aerosol indirect effect and climate sensitivity assessment**

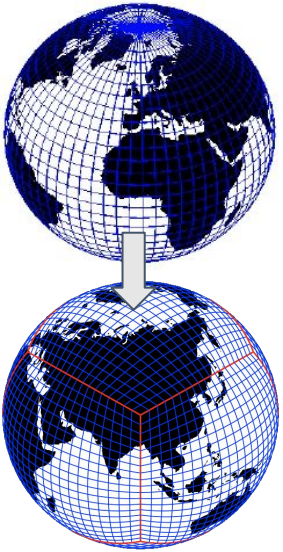
Working on the implementation of explicit passing of enthalpy fluxes between atmosphere and ocean (variable latent heats in atmosphere to match MOM6)

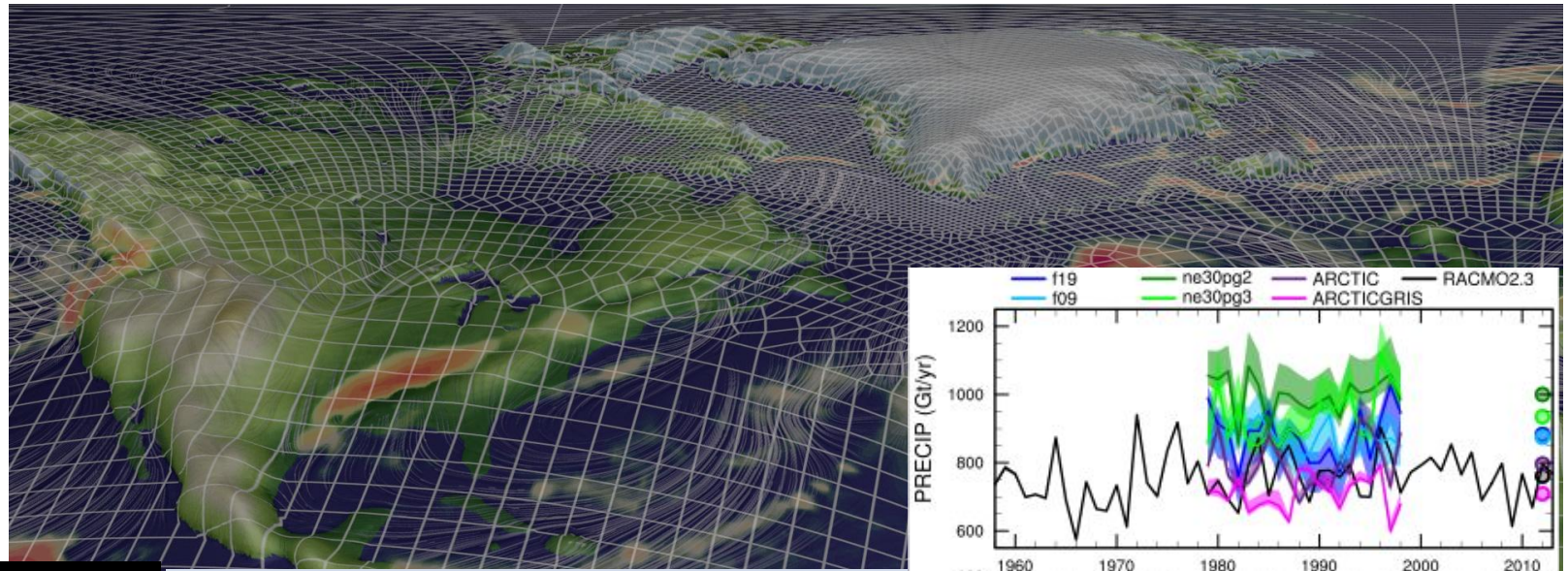
My risk assessment for timeline:

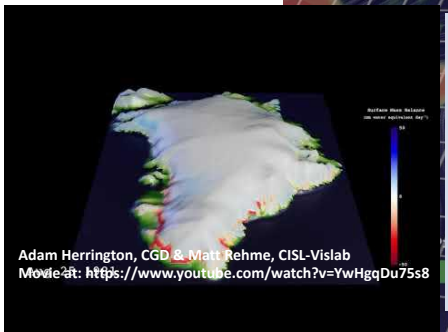
If there are issues with aerosol indirect effect, climate sensitivity or "bad" 20th century simulation our timeline is NOT realistic …

Also we are not tuning model with new forcing dataset!

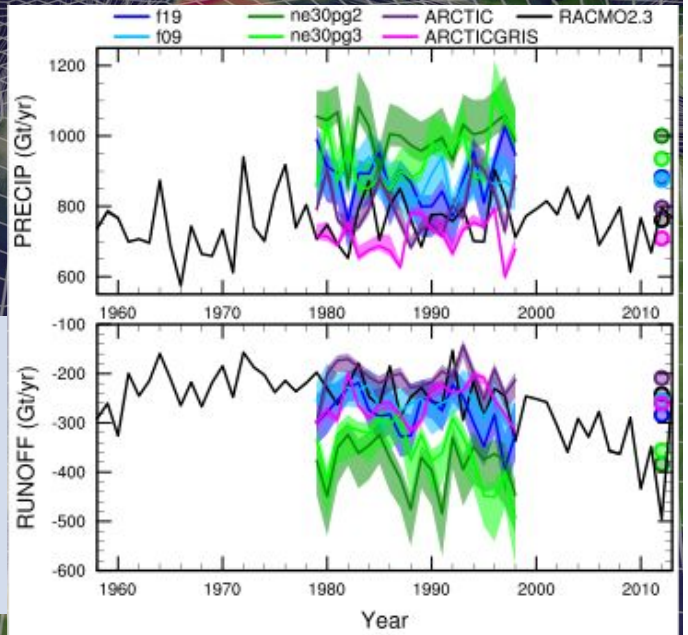
Dynamic downscaling with mesh-refinement: Coupled regional climate in global CESM





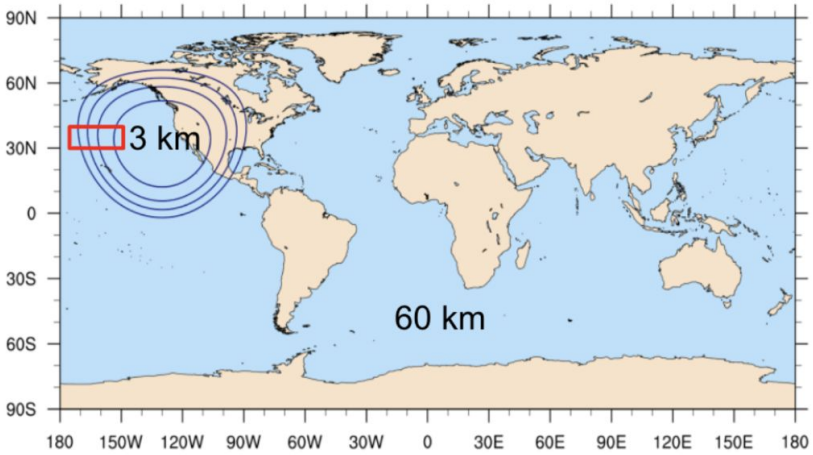


Challenges:
- Physics is time-step dependent
-Well-behaved physics across scales …

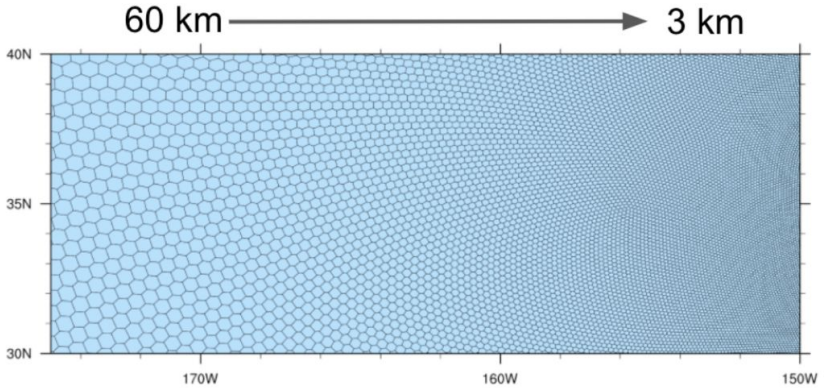


“Weather resolution” in CESM/CAM

MPAS (Model for Prediction Across Scales) non-hydrostatic dynamical core coupled with the CAM (Community Atmosphere Model) physics package (SIMA-MPAS)



A) Grid mesh configuration in 60-3km experiments



B) Unstructured spherical centroidal Voronoi mesh with a smooth transition mesh densities

Huang et al. (2022)
https://gmd.copernicus.org/preprints/gmd-2022-111/

Other NCAR projects

Also, we are working on new code base (CAM-SIMA) with CCPP compliant physics (will likely be in a later CESM release, i.e. CESM3.x where x>0)

In the future one should be able to run, e.g., WRF physics in CAM-SIMA!

SIMA = System for Integrated Modeling of the Atmosphere (mostly internal NCAR effort)
CCPP = Common Community Physics Package (CCPP)

Lots of work on ultra-high resolution CESM (Earthworks project, DYAMOND simulations, etc.), S2S configurations, deep atmosphere version of MPAS, …

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