Explorations of Vertical Resolution in CAM5

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History of Vertical Resolution in CAM

- CCM2 18 vertical layers, top at ~ 2mb (35-40km)
  - Circa 1992
- CCM3 26 vertical layers, same top
  - 1998 Additional layers introduced between 200 and 50mb by Dave Williamson during development of the Semi-Lagrangian Dycore.
- CAM5 30 layers, same top --- circa 2009
  - Extra layers placed above “surface layer”, and below ~2200m
- Why did we resist changing the vertical resolution?
  - Computation expense (radiation scaled as square of the vertical resolution, *and radiation was very expensive*)
  - Pathologies in interactions between boundary layer and convection parameterizations

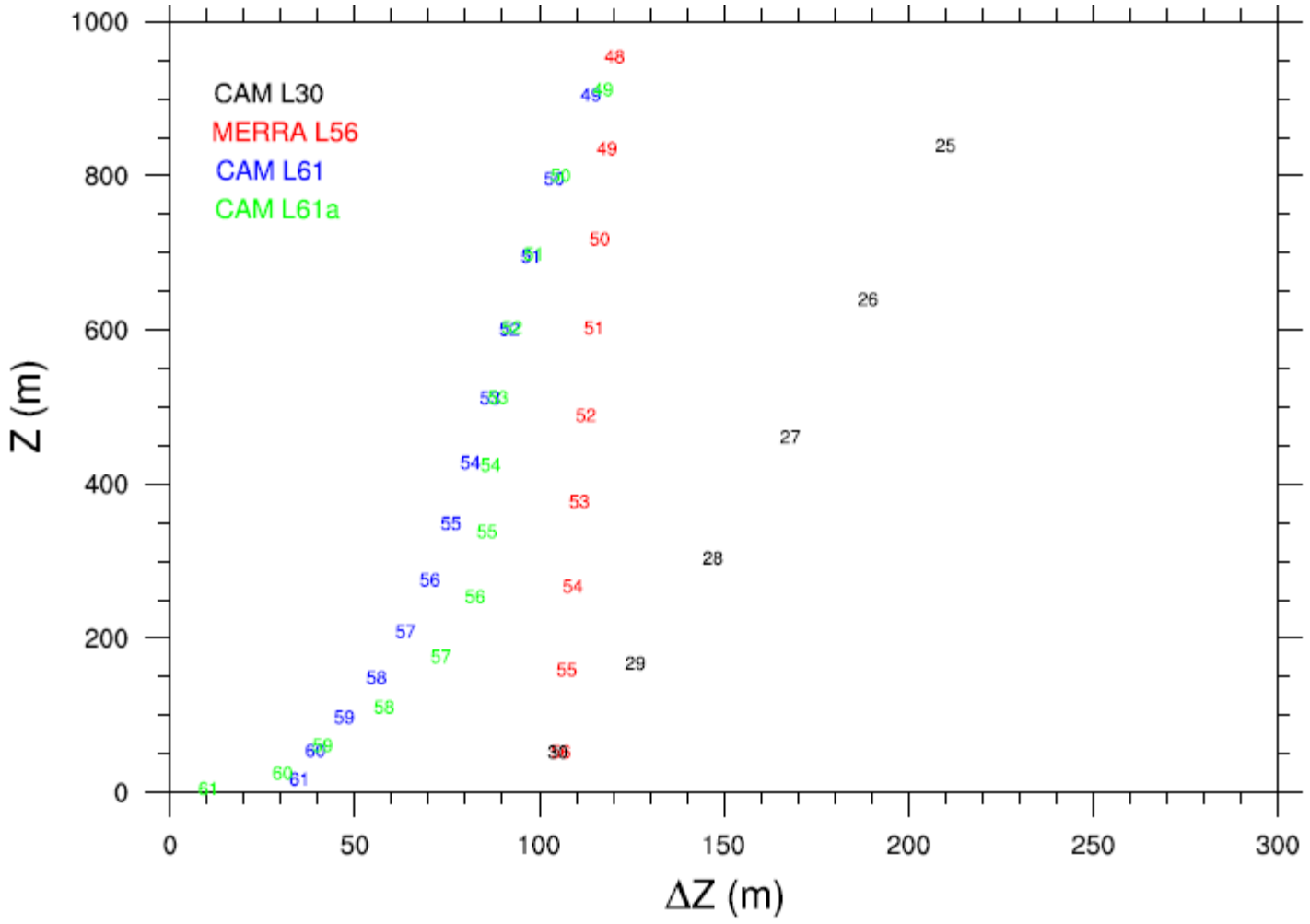
A first step in exploring resolution changes

- Desirable attributes of new layer distribution
  - Thin surface layer (order 10m)
  - Smooth variation of layer thickness to minimize numerical approximation errors
  - Thin layers in regions where stratiform clouds reside, since clouds are generally assumed to occupy full layer depths
- Thin surface layer required careful reformulation of surface exchange model and coupling between PBL and surface calculation
  - Modifications needed to provide appropriate treatment when plant canopy deeper than layer thickness
  - Changes in numerics of PBL & surface layer calculation to improve computational stability

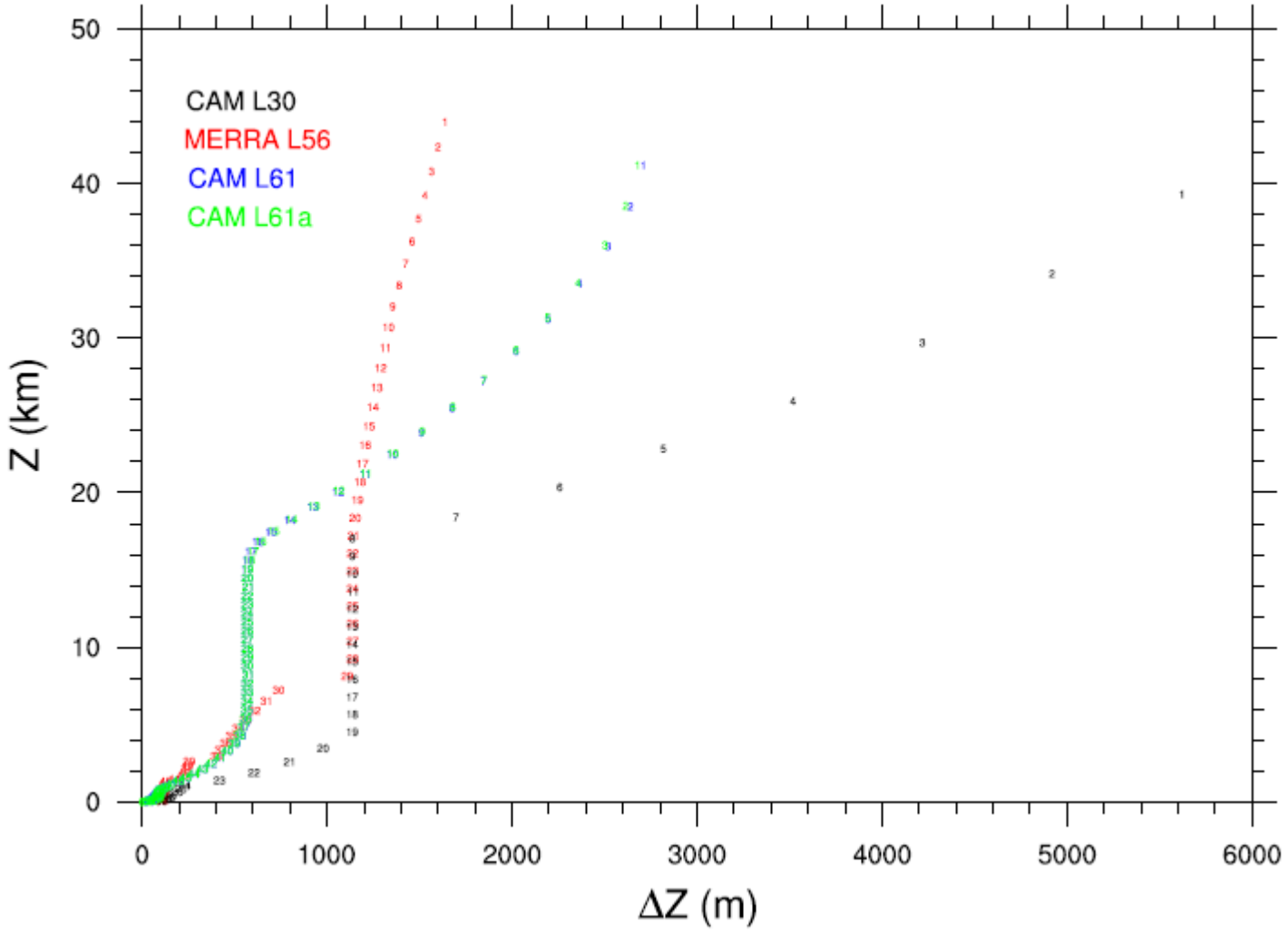
Strategy for constructing new distributions

- Case 30L – Standard CAM5 layer distribution
- Case 56L – GEOS5 layer structure → 56L + different top!
- Case 61L(30m) – start with 30L structure
  - Divide each layer in half
  - At surface add an extra layer & “redistribute interfaces” slightly to produce smoother layer structure
  - → produces a 61L model structure with surface layer about 30m thick
- Case 61L(10m) – constrain surface layer to be 10m thick

Candidate layer distributions – Near surface



Over Whole Model vertical Domain



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Simulations Stability:

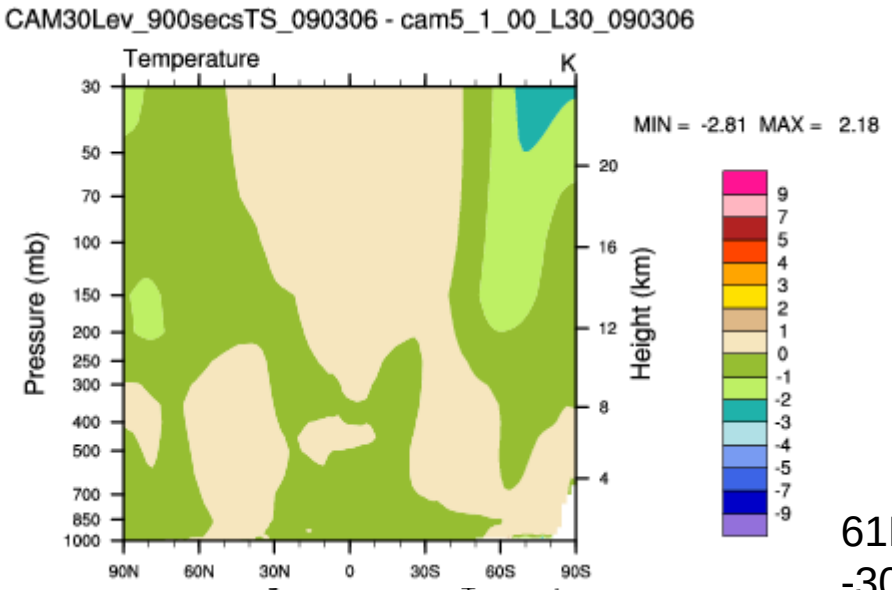
- 30L, 56L & 61L(30m) are stable with 30 minutes physics timesteps
- 61L(10m) case is not stable with 30 minute timesteps, so we decreased the physics timestep to 15 minutes
- To avoid uncertainty about timestep dependence we ran an additional 30L case with 15 minutes timesteps
  → CASE 30L(15minute)

Global Average States

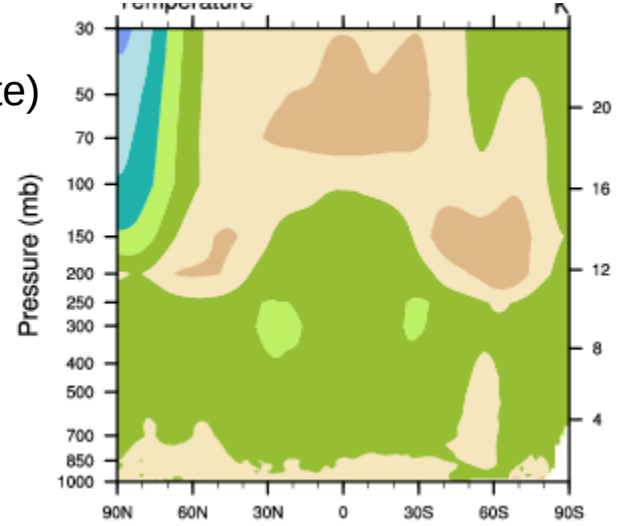
Field	30L	30L(15min)	56L	61L(30m)	61L(10m)
RESTOM	2.2	0.98		5.0	2.8
SWCF	-52.1	-54.1		-48.6	54.2
LWCF	24.1	24.9.		23.6	19.9
TGCLDLWP	44.7	48.7		37.8	43.5
TGCLDIWP	17.7	20.5		20.7	23.2

Zonal, Annual Averaged Temperature differences

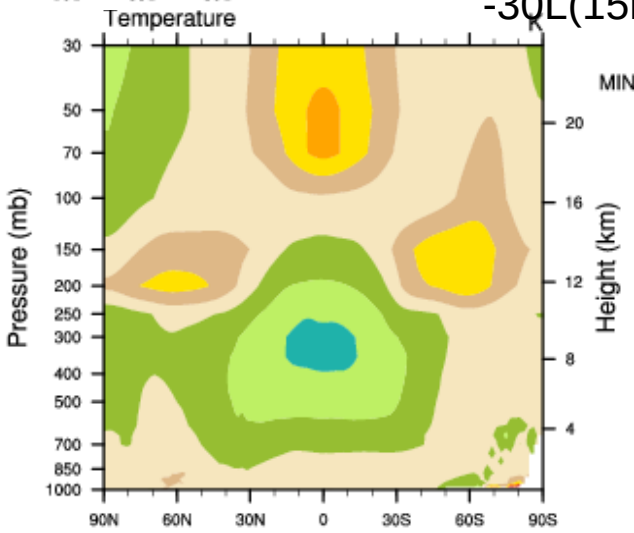
30L(30minute)
-30L(15minute)



61L(30m)
-30L(30minute)

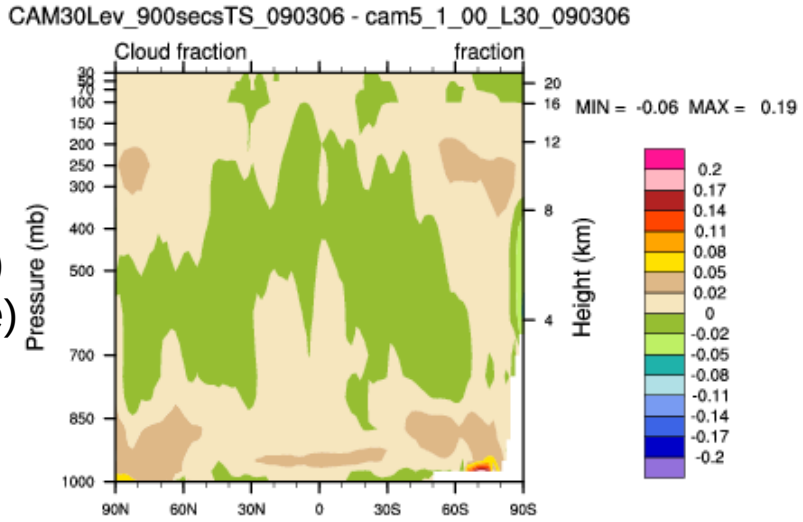


61L(10m)
-30L(15minute)

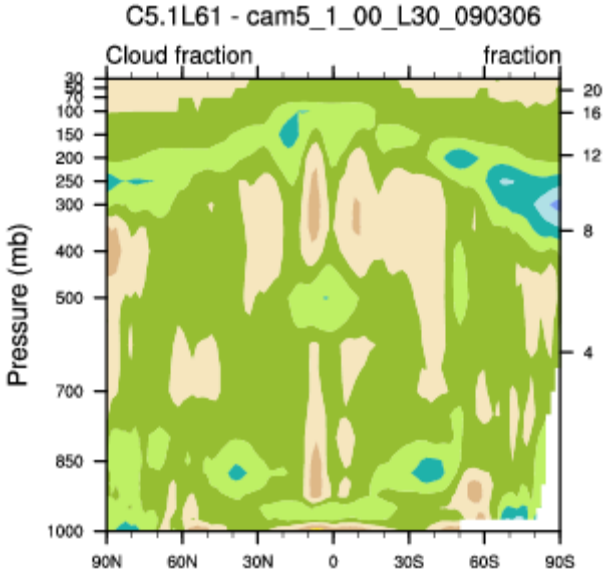


Clouds

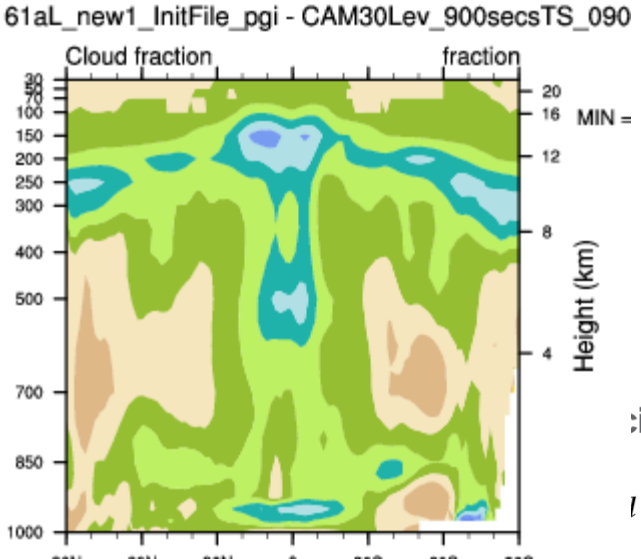
30L(30minute)
-30L(15minute)



61L(30m)
-30L(30minute)

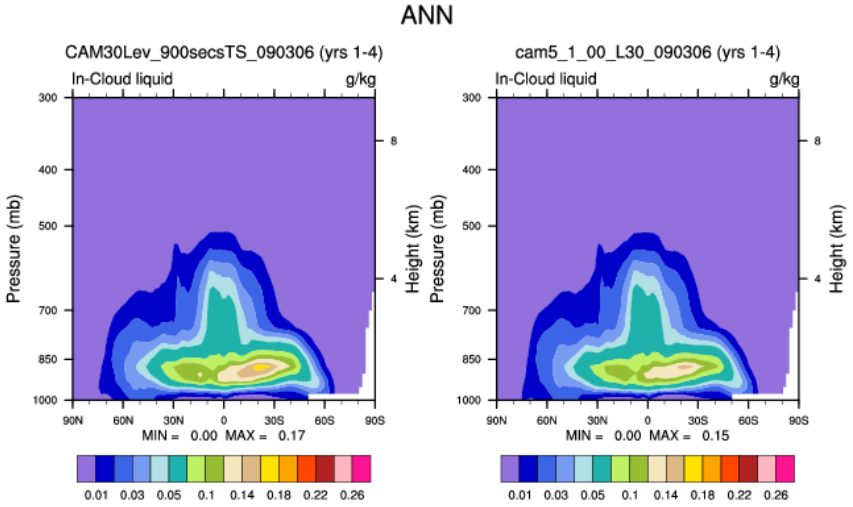


61L(10m)
-30L(15minute)

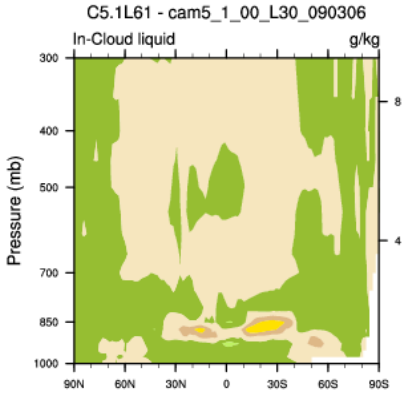


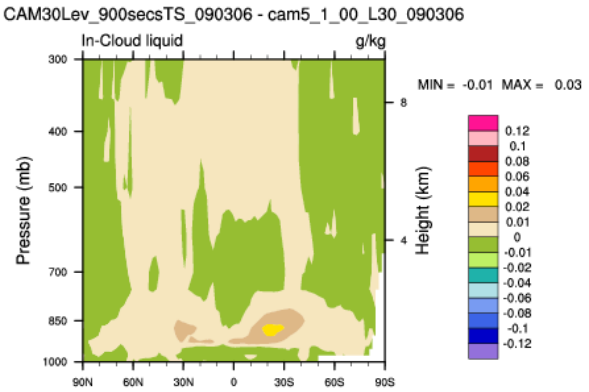
In-Cloud Liquid water mixing ratio

30L(30minute)
-30L(15minute)

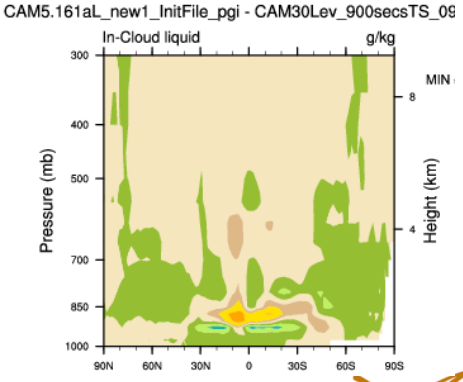


61L(30m)
-30L(30minute)



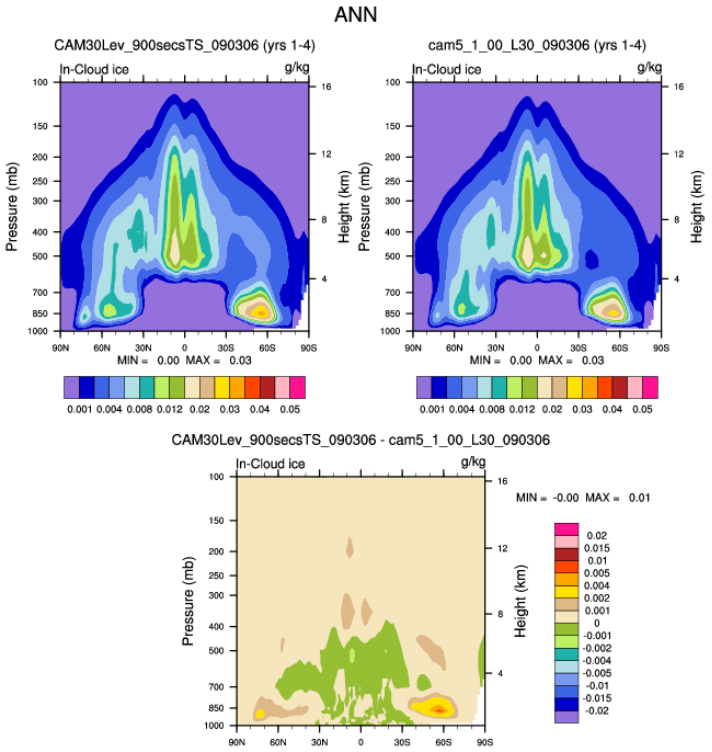


61L(10m)
-30L(15minute)



In-Cloud Ice water mixing ratio

30L(30minute)
-30L(15minute)



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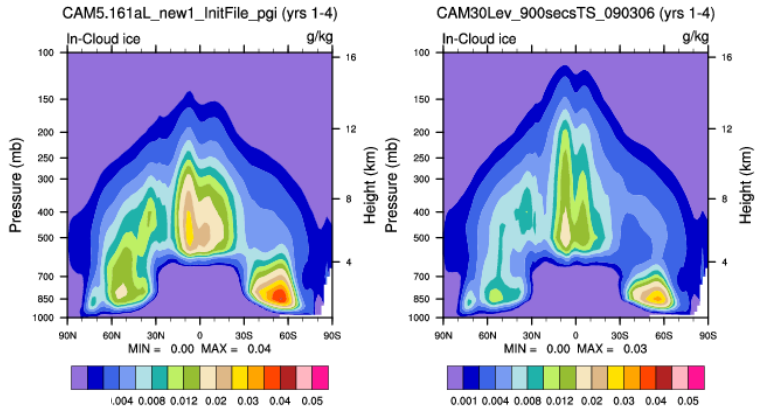
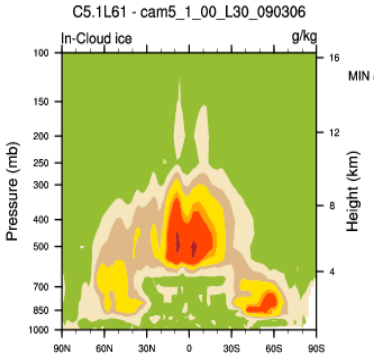
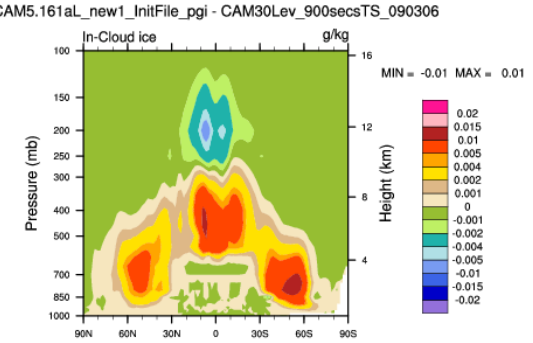




61L(30m)
-30L(30minute)



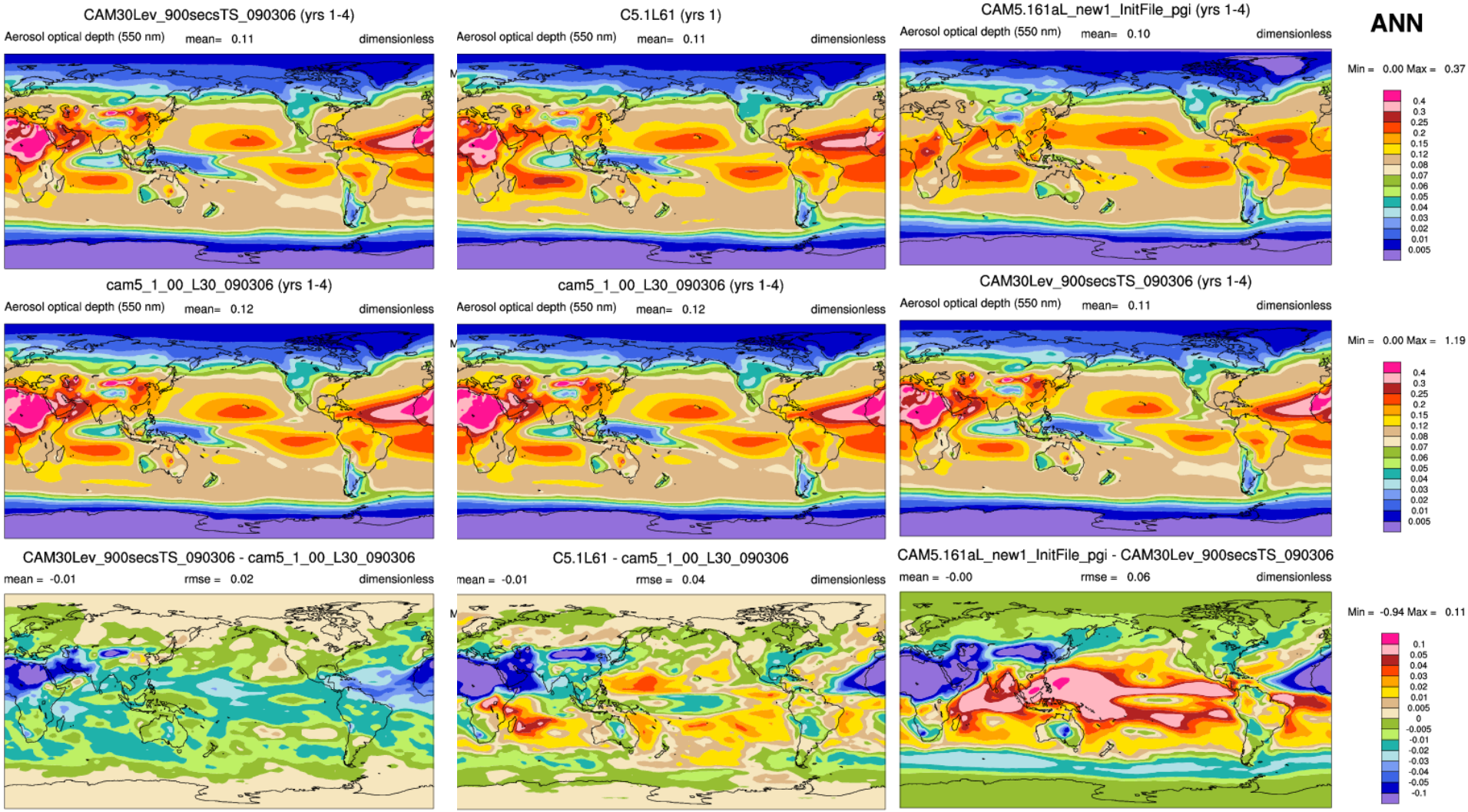
61L(10m)
-30L(15minute)

Aerosol Optical Depth

30L(30minute)
-30L(15minute)

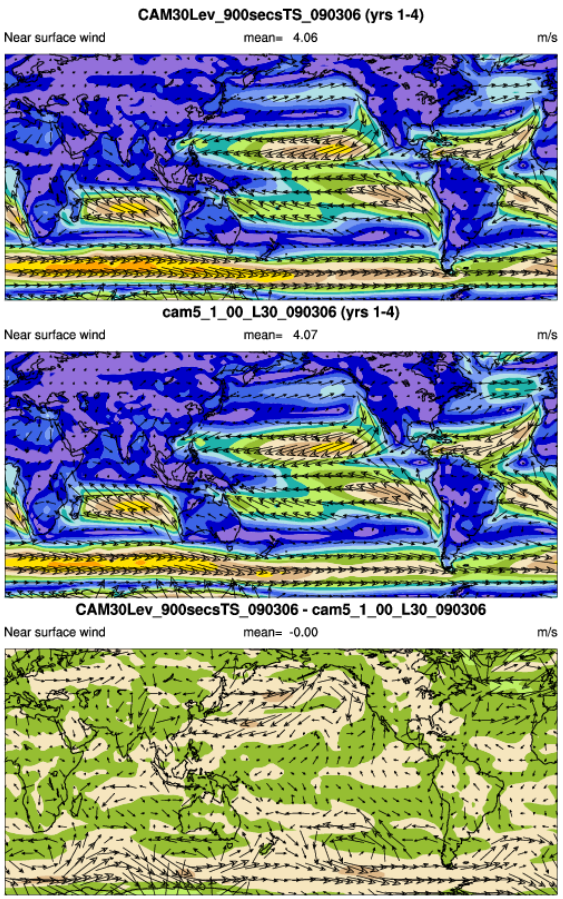
61L(30m)
-30L(30minute)

61L(10m)
-30L(15minute)

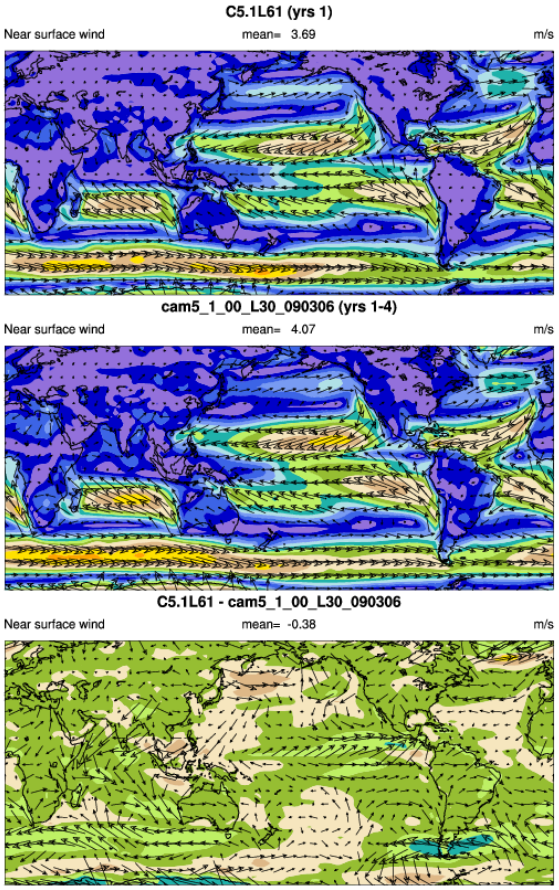


Near Surface Wind Speed

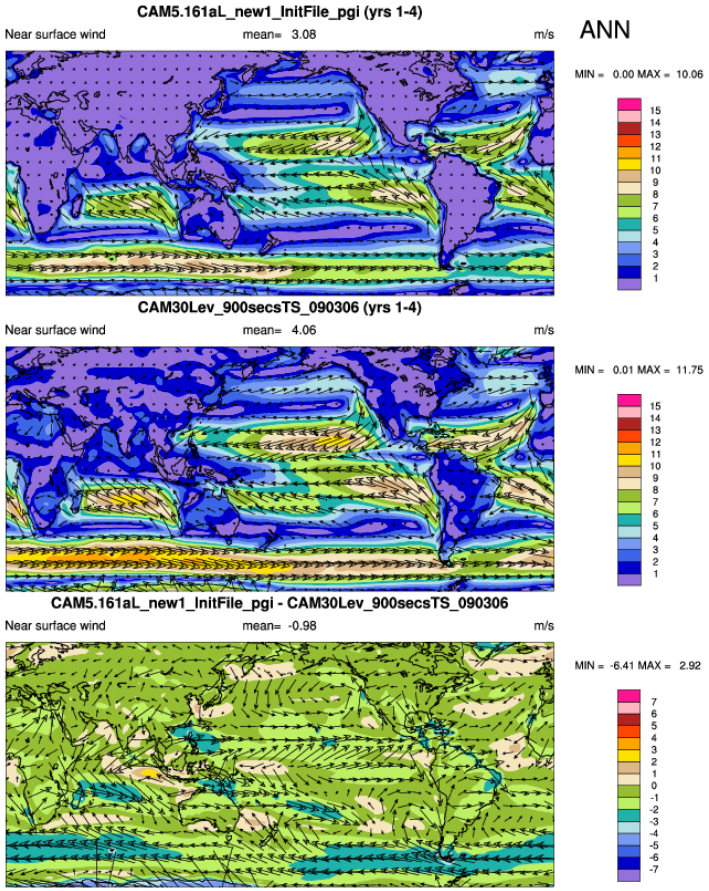
30L(30minute)
-30L(15minute)



61L(30m)
-30L(30minute)



61L(10m)
-30L(15minute)



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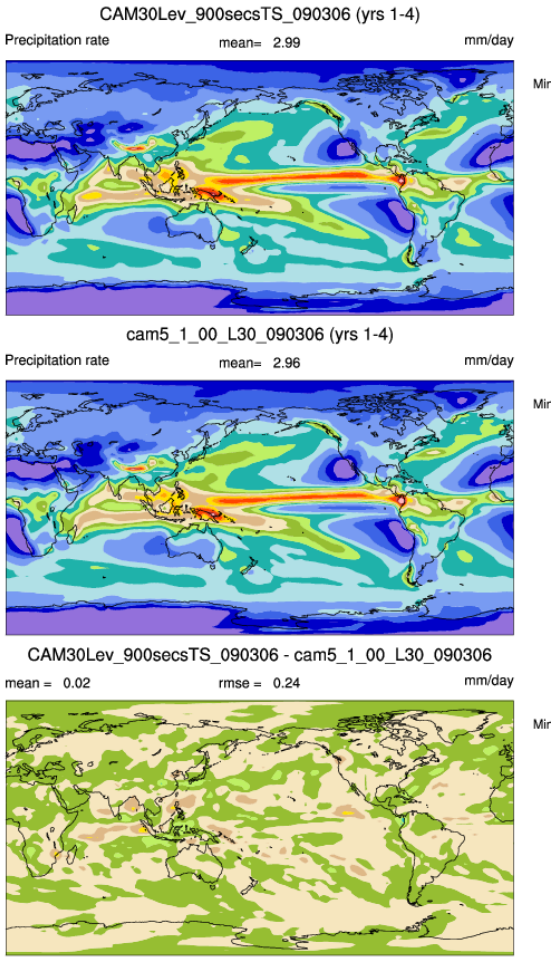
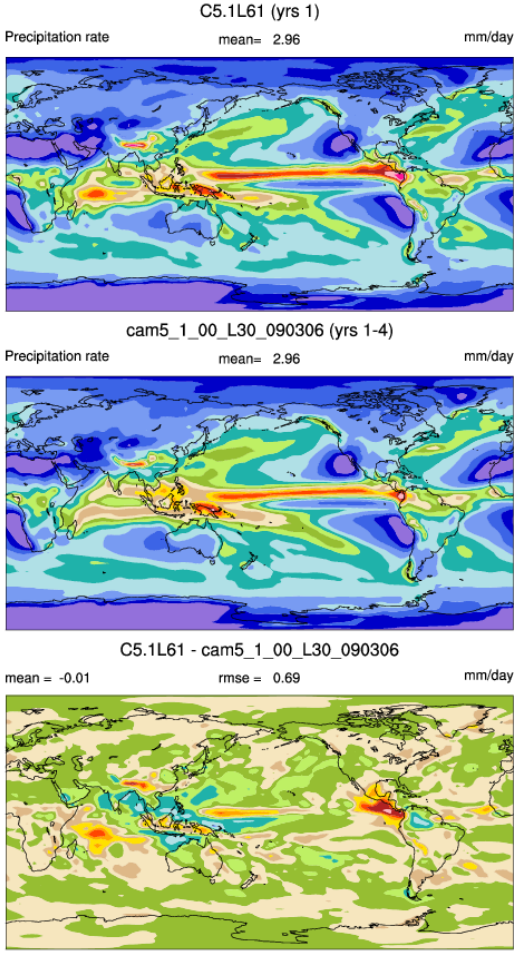
Precipitation

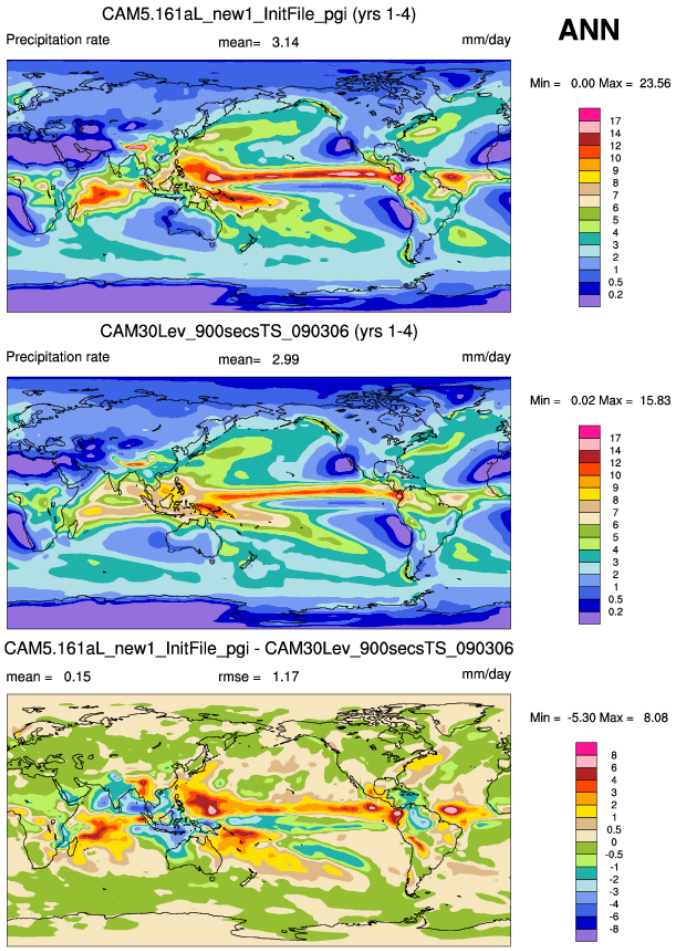
30L(30minute)
-30L(15minute)



61L(30m)
-30L(30minute)



61L(10m)
-30L(15minute)

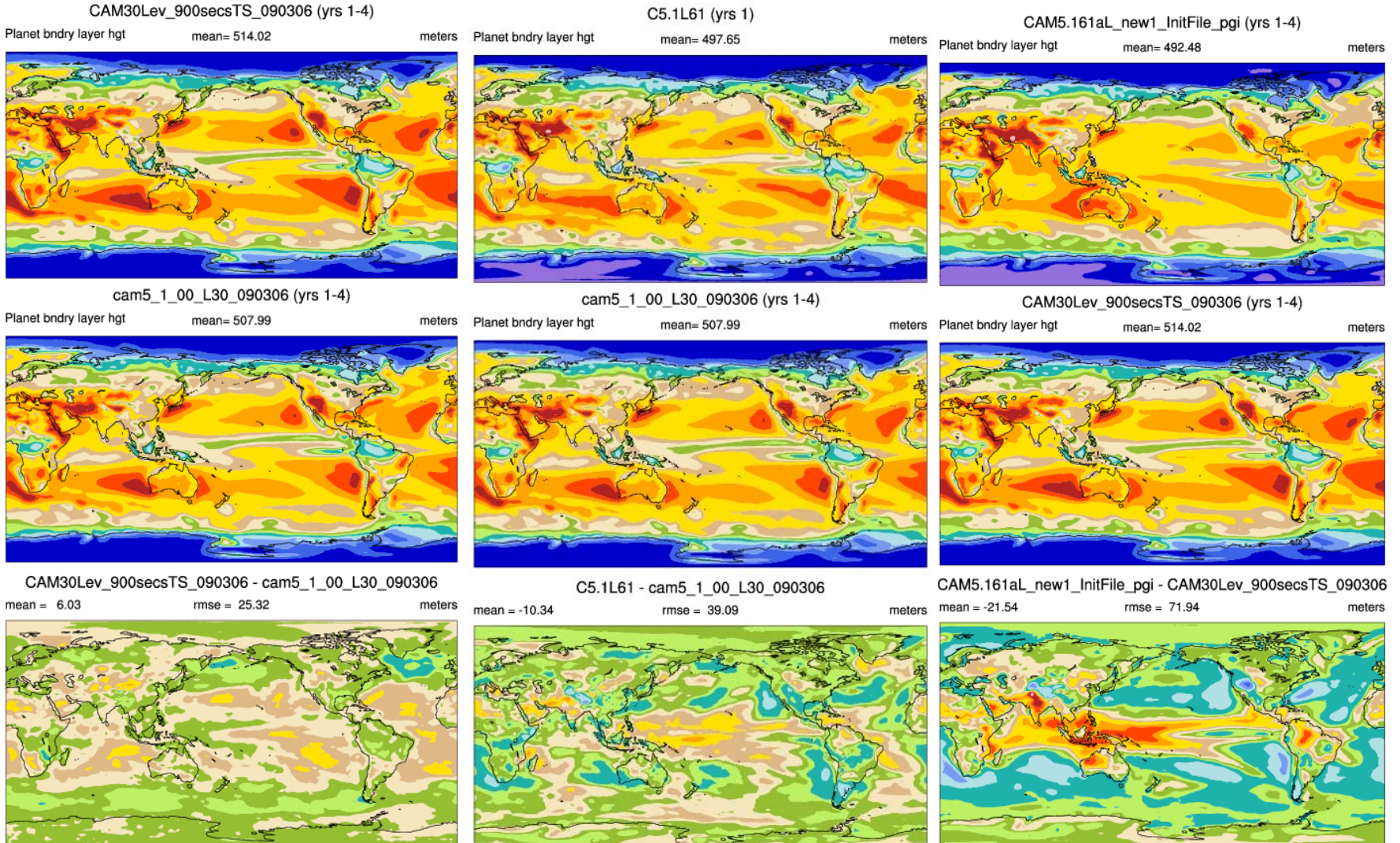


PBL Height

30L(30minute)
-30L(15minute)

61L(30m)
-30L(30minute)

61L(10m)
-30L(15minute)

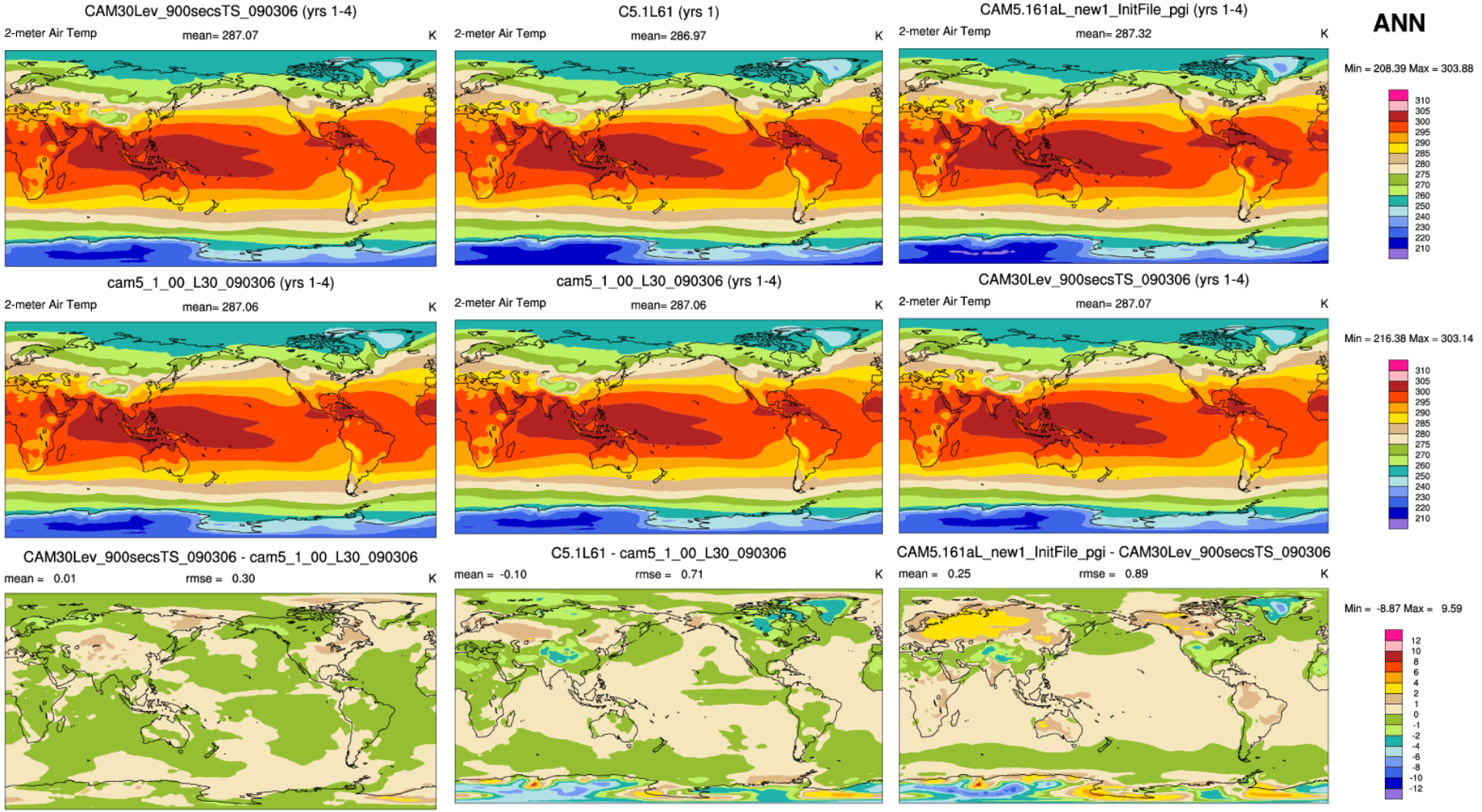


2m Reference Temperature

30L(30minute)
-30L(15minute)

61L(30m)
-30L(30minute)

61L(10m)
-30L(15minute)



Conclusions

- Some remaining timestep sensitivity
- There are robust signals in changes in condensate amount.
  - Thinner layers produce higher mixing ratios
  - Cloud fraction decreases.

  → Cloud Radiative forcing doesn't change too much
- Surface wind speed very sensitive to the surface layer thickness.
  - It has profound effect on the dust mobilization, sea-salt emissions
  - Circulation features influenced
- Hints of sensitivity in convection also
  - Launching level
  - CAPE
- Tuning will definitely be necessary