

# 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

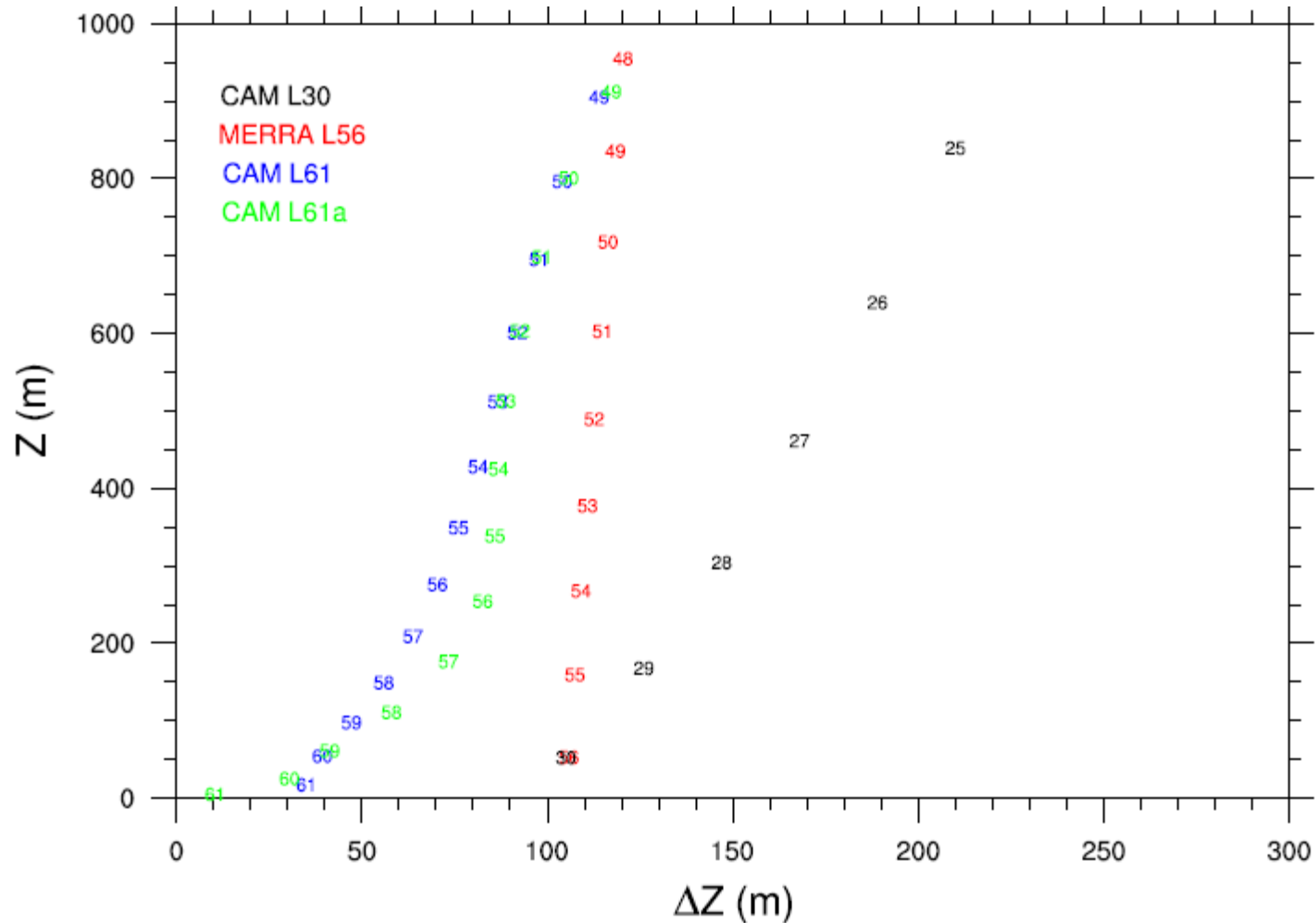


# Strategy for constructing new distributions

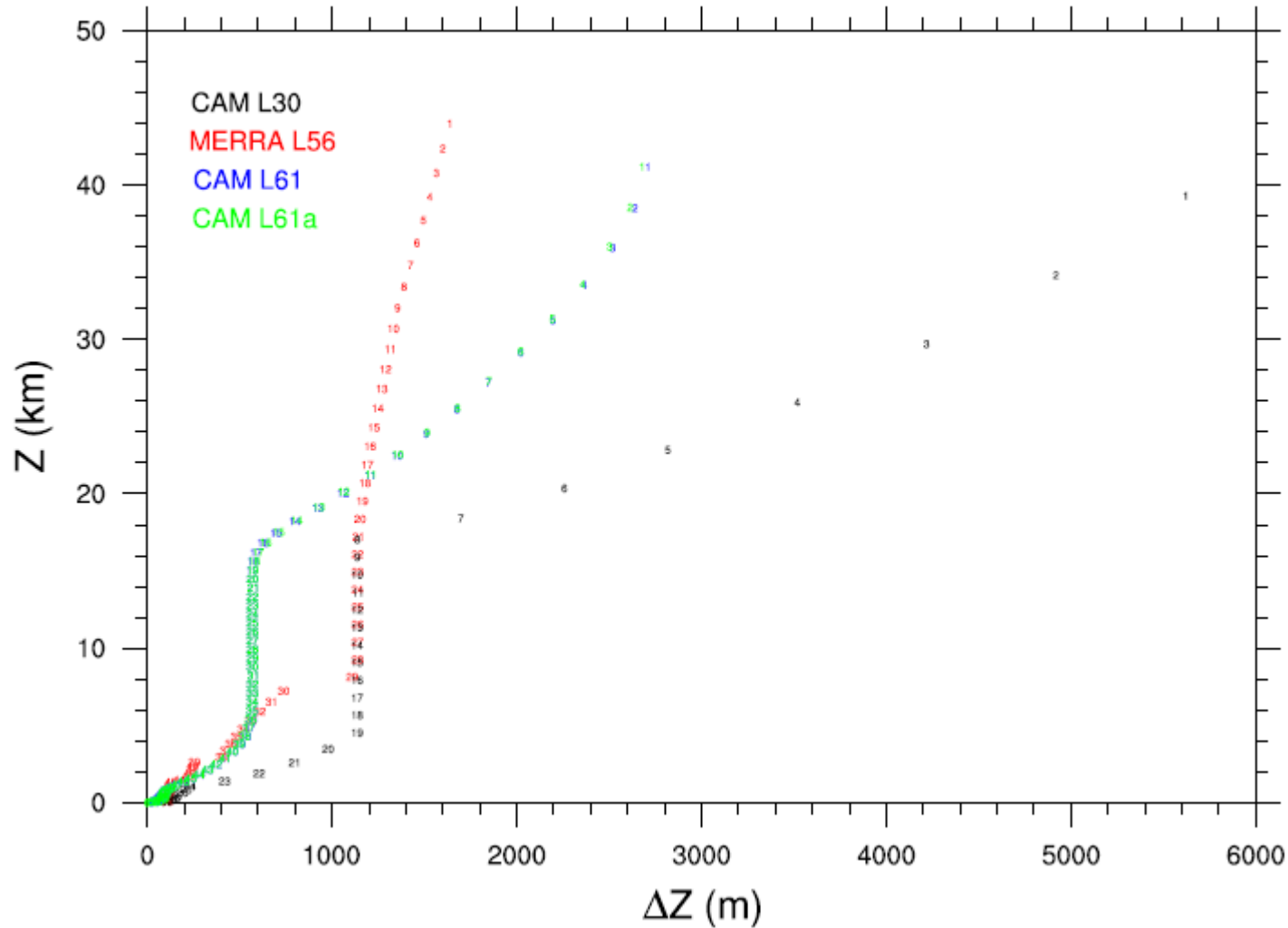
- ▶ Case 30L – Standard CAM5 layer distribution
- ▶ Case 56L – GEOS5 layer structure → 56L + different top!
- ▶ Case 61L(30m) – start with 30L structure
  - Divide each layer in half
  - At surface add an extra layer & “redistribute interfaces” slightly to produce smoother layer structure
  - → produces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



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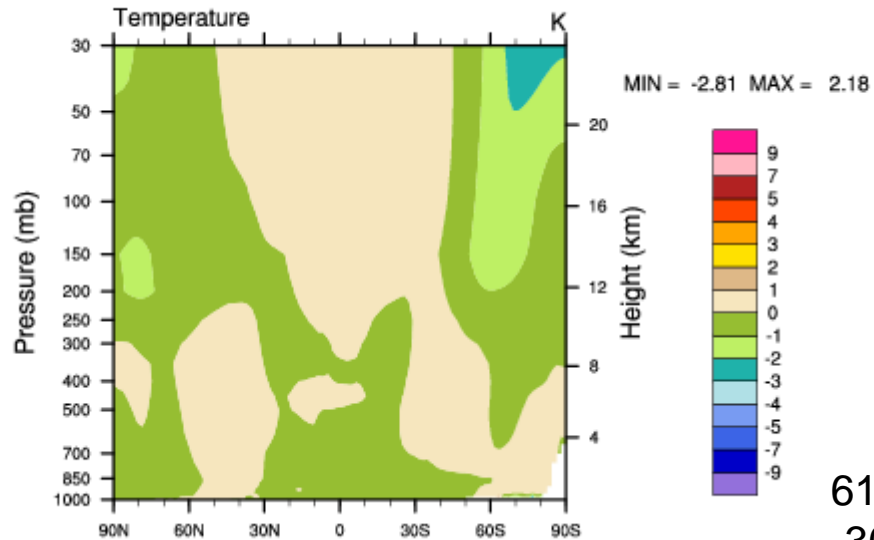
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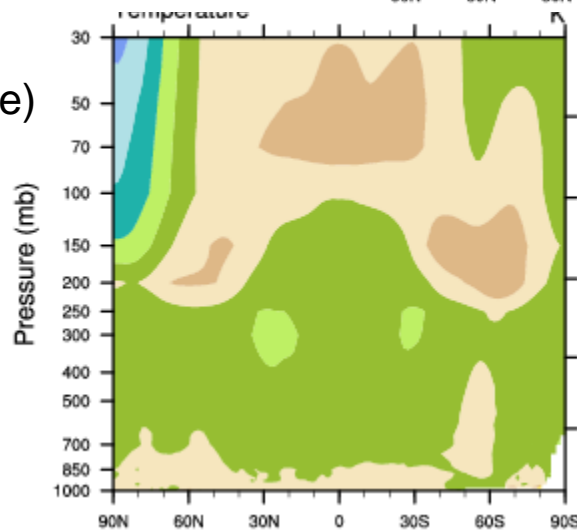
# Zonal, Annual Averaged Temperature differences

CAM30Lev\_900secsTS\_090306 - cam5\_1\_00\_L30\_090306

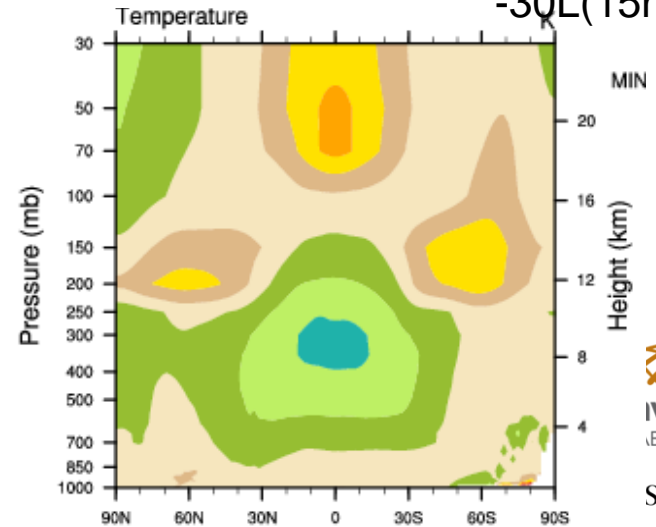
30L(30minute)  
-30L(15minute)



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

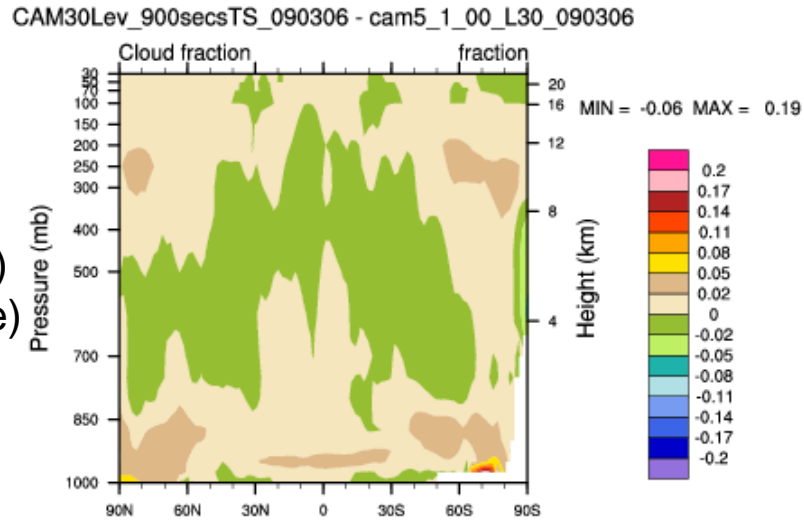


61L(10m)  
-30L(15minute)

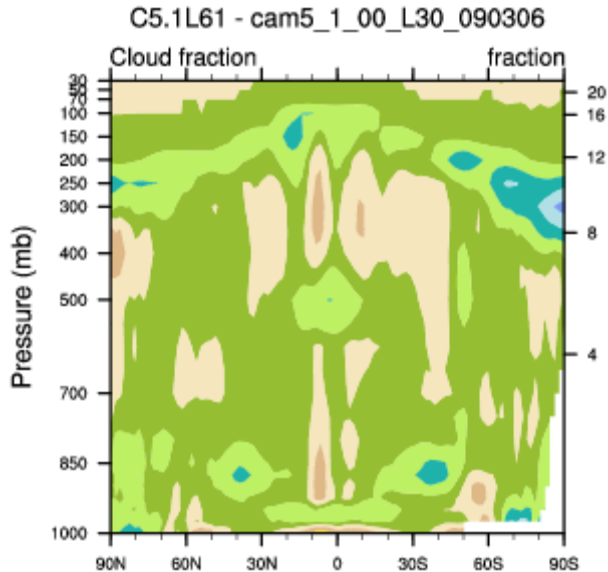


# Clouds

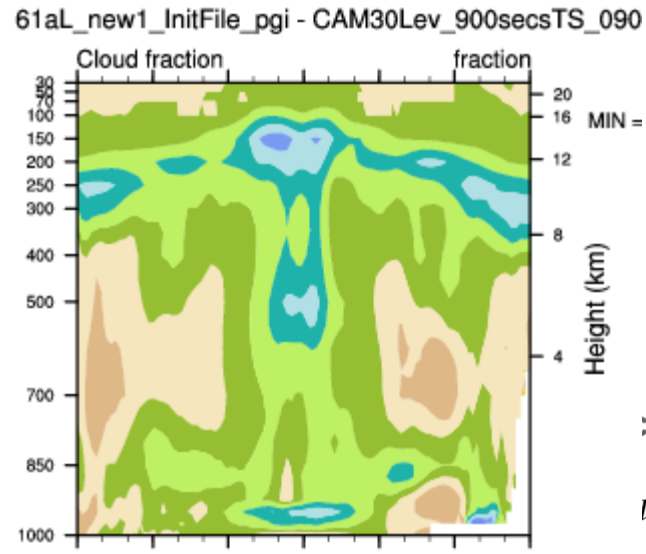
30L(30minute)  
-30L(15minute)



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



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

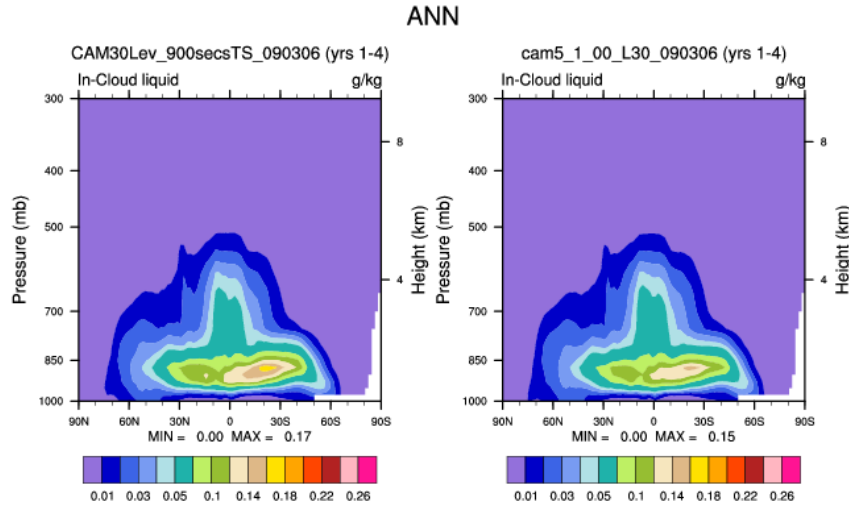


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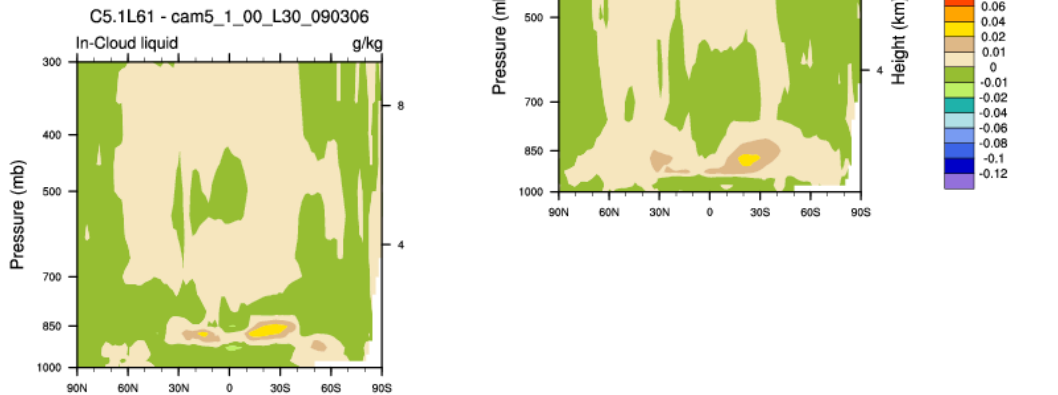
*Part of Battelle Since 1965*

# In-Cloud Liquid water mixing ratio

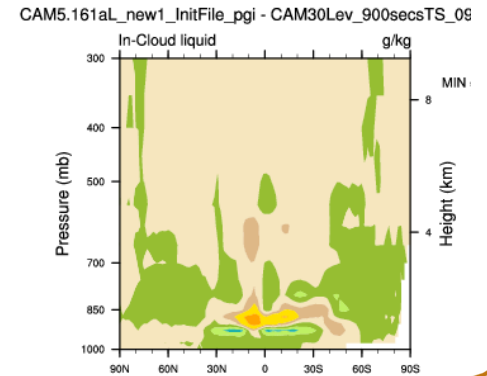
30L(30minute)  
-30L(15minute)



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

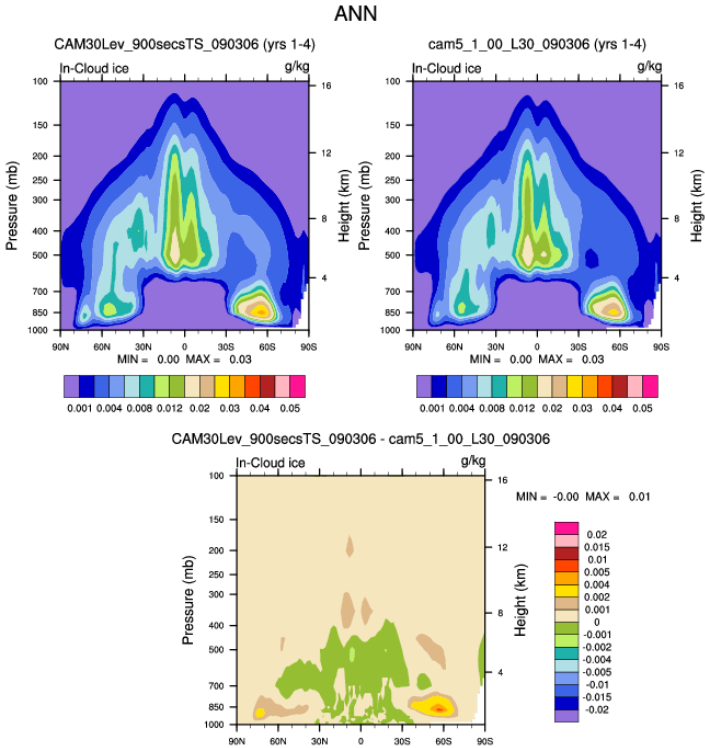


61L(10m)  
-30L(15minute)

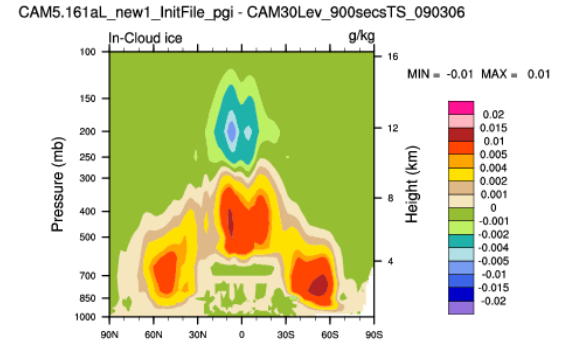
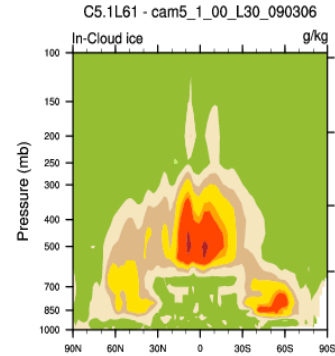
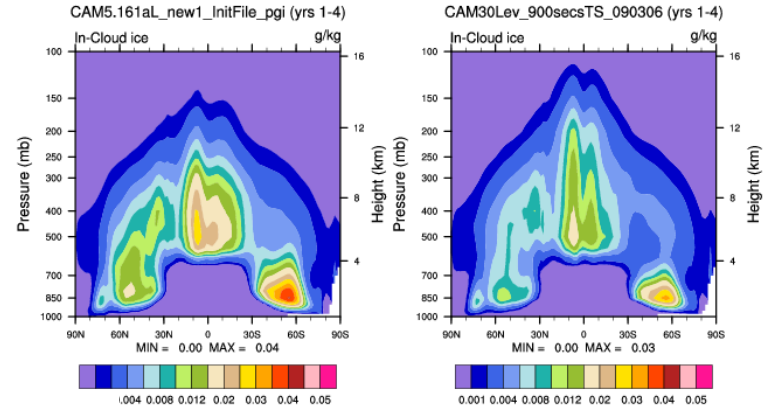


# In-Cloud Ice water mixing ratio

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



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

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



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# Aerosol Optical Depth

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

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

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

CAM30Lev\_900secsTS\_090306 (yrs 1-4)

C5.1L61 (yrs 1)

CAM5.161aL\_new1\_InitFile\_pgi (yrs 1-4)

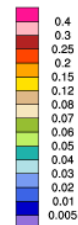
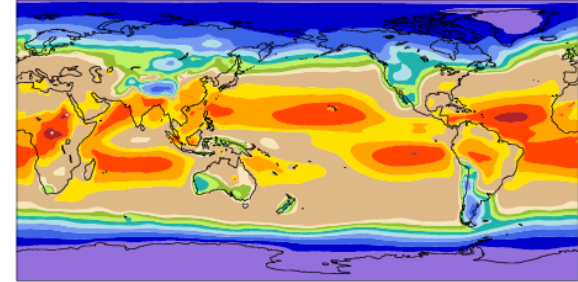
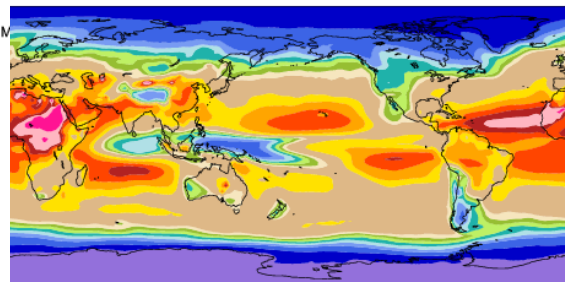
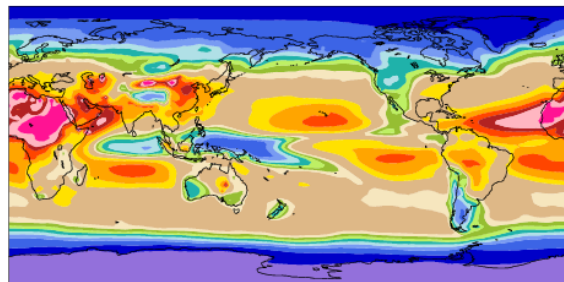
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Aerosol optical depth (550 nm) mean= 0.11 dimensionless

Aerosol optical depth (550 nm) mean= 0.11 dimensionless

Aerosol optical depth (550 nm) mean= 0.10 dimensionless

Min = 0.00 Max = 0.37



cam5\_1\_00\_L30\_090306 (yrs 1-4)

cam5\_1\_00\_L30\_090306 (yrs 1-4)

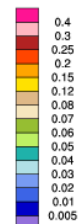
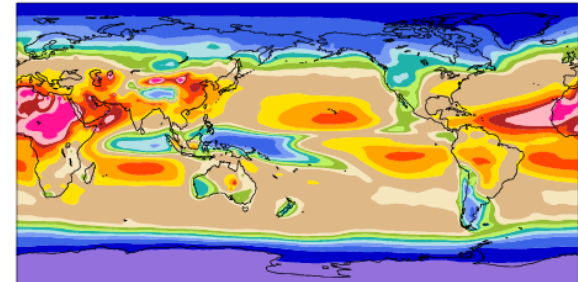
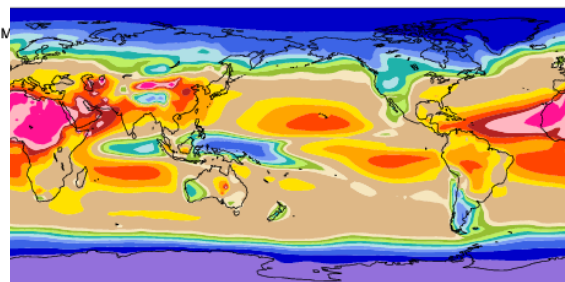
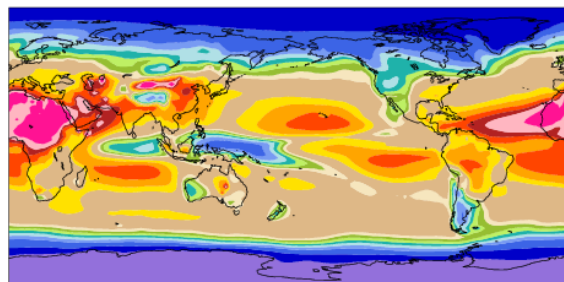
CAM30Lev\_900secsTS\_090306 (yrs 1-4)

Aerosol optical depth (550 nm) mean= 0.12 dimensionless

Aerosol optical depth (550 nm) mean= 0.12 dimensionless

Aerosol optical depth (550 nm) mean= 0.11 dimensionless

Min = 0.00 Max = 1.19



CAM30Lev\_900secsTS\_090306 - cam5\_1\_00\_L30\_090306

C5.1L61 - cam5\_1\_00\_L30\_090306

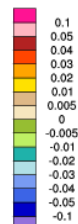
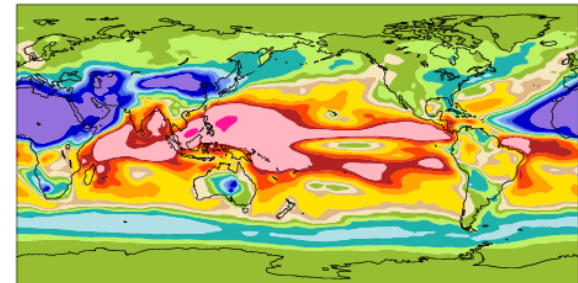
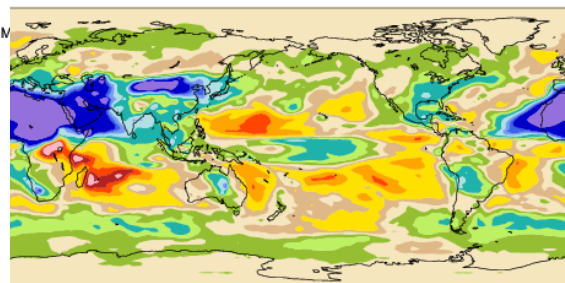
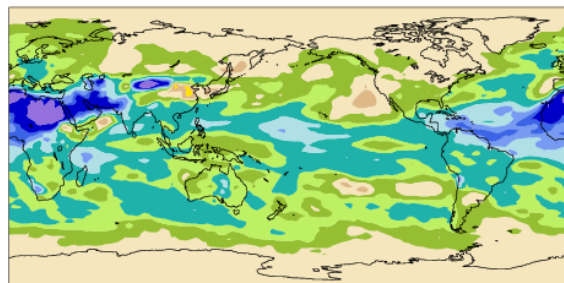
CAM5.161aL\_new1\_InitFile\_pgi - CAM30Lev\_900secsTS\_090306

mean = -0.01 rmse = 0.02 dimensionless

mean = -0.01 rmse = 0.04 dimensionless

mean = -0.00 rmse = 0.06 dimensionless

Min = -0.94 Max = 0.11





# Near Surface Wind Speed

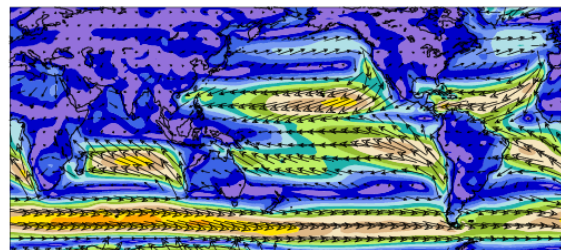
30L(30minute)  
-30L(15minute)

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

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

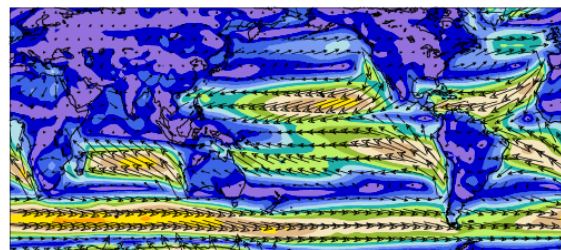
CAM30Lev\_900secsTS\_090306 (yrs 1-4)

Near surface wind mean= 4.06 m/s



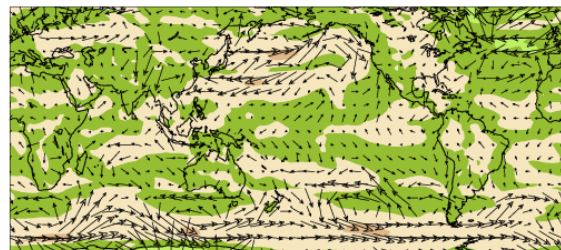
cam5\_1\_00\_L30\_090306 (yrs 1-4)

Near surface wind mean= 4.07 m/s



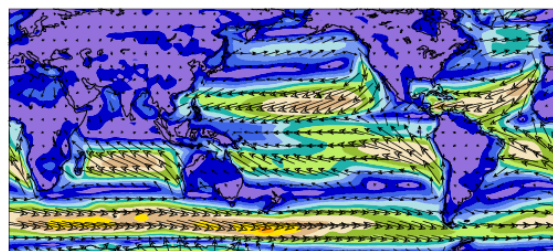
CAM30Lev\_900secsTS\_090306 - cam5\_1\_00\_L30\_090306

Near surface wind mean= -0.00 m/s



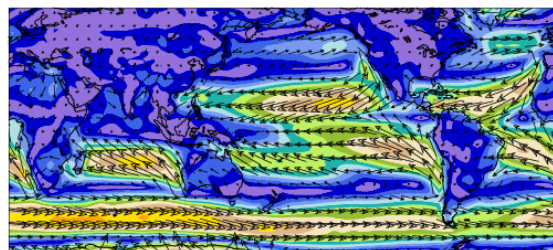
C5.1L61 (yrs 1)

Near surface wind mean= 3.69 m/s



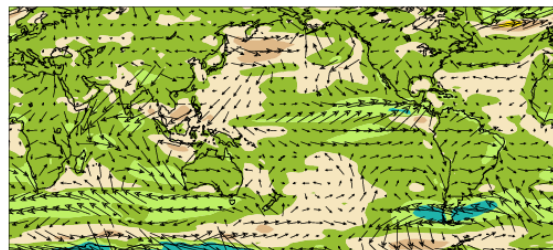
cam5\_1\_00\_L30\_090306 (yrs 1-4)

Near surface wind mean= 4.07 m/s



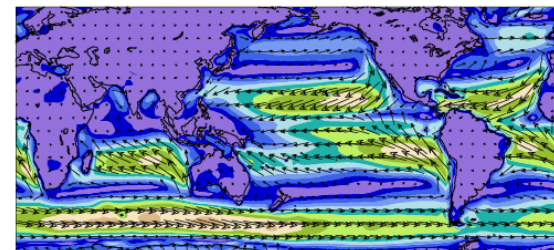
C5.1L61 - cam5\_1\_00\_L30\_090306

Near surface wind mean= -0.38 m/s



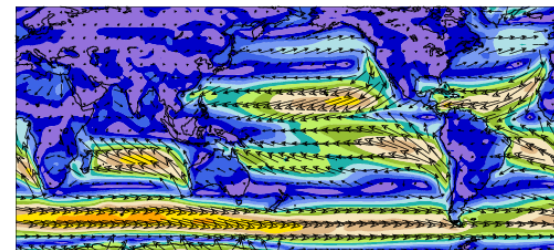
CAM5.161aL\_new1\_InitFile\_pgi (yrs 1-4)

Near surface wind mean= 3.08 m/s



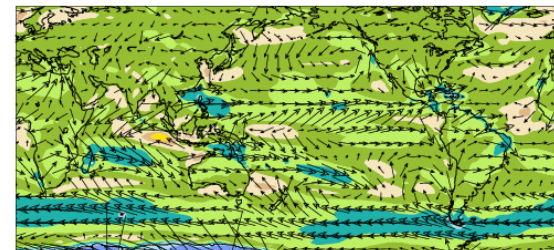
CAM30Lev\_900secsTS\_090306 (yrs 1-4)

Near surface wind mean= 4.06 m/s



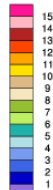
CAM5.161aL\_new1\_InitFile\_pgi - CAM30Lev\_900secsTS\_090306

Near surface wind mean= -0.98 m/s



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MIN = 0.00 MAX = 10.06



MIN = 0.01 MAX = 11.75



MIN = -6.41 MAX = 2.92

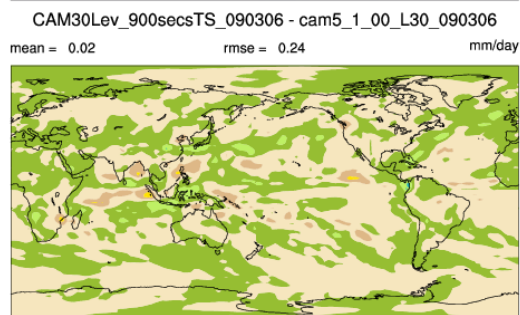
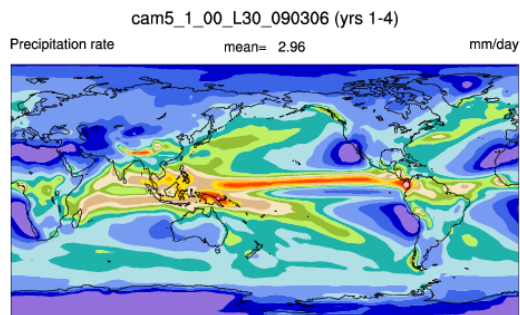
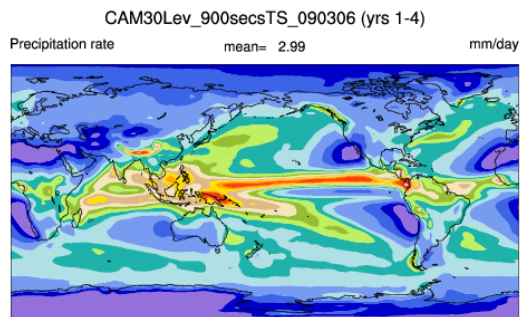


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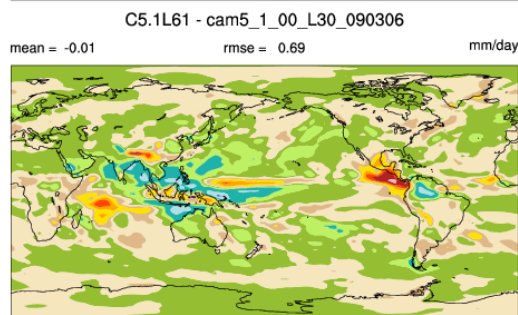
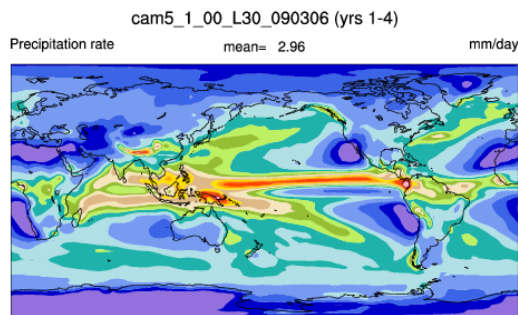
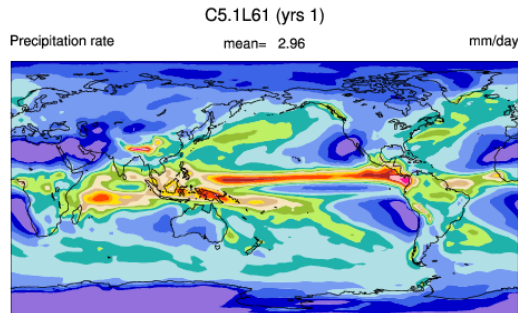
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# Precipitation

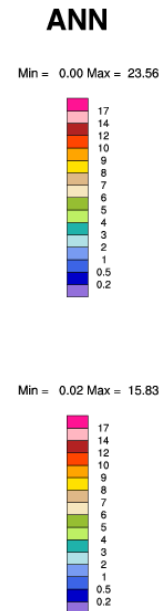
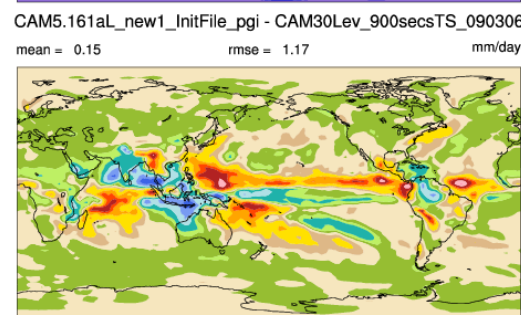
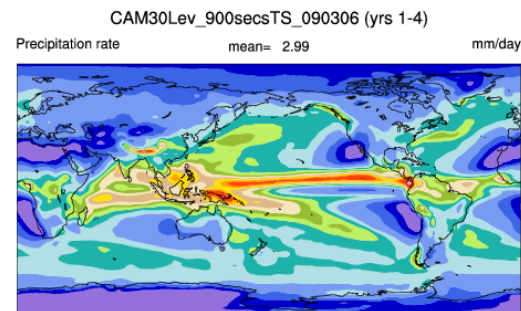
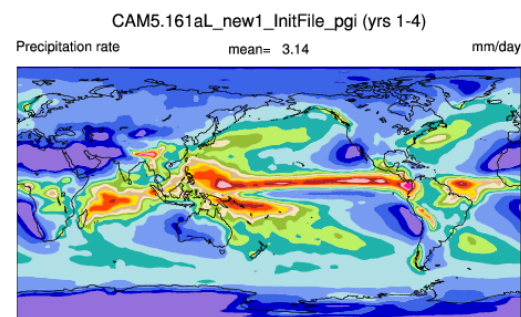
30L(30minute)  
-30L(15minute)



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



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



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# PBL Height

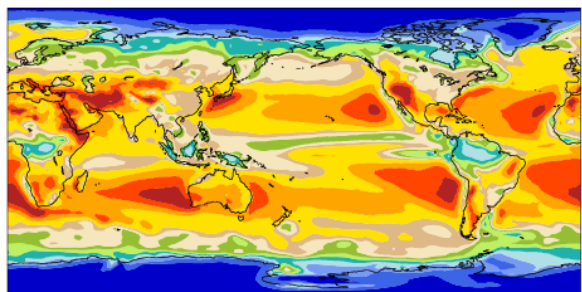
30L(30minute)  
-30L(15minute)

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

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

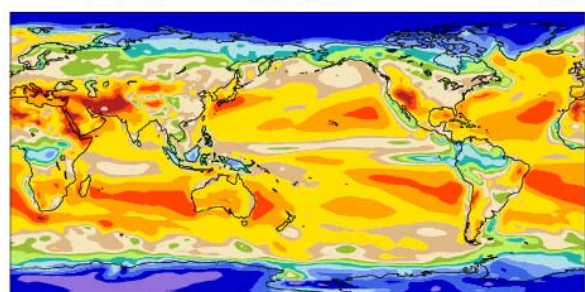
CAM30Lev\_900secsTS\_090306 (yrs 1-4)

Planet bndry layer hgt mean= 514.02 meters



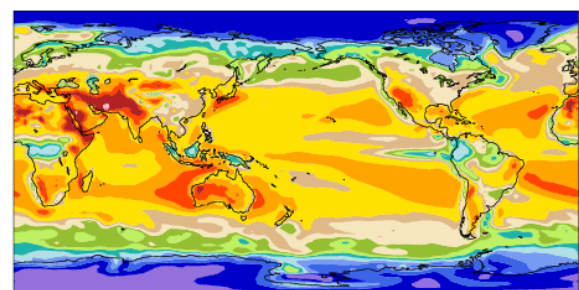
C5.1L61 (yrs 1)

Planet bndry layer hgt mean= 497.65 meters



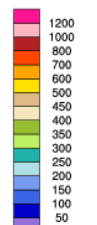
CAM5.161aL\_new1\_InitFile\_pgi (yrs 1-4)

Planet bndry layer hgt mean= 492.48 meters



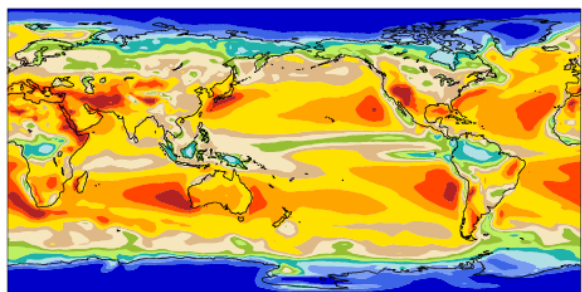
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Min = 11.55 Max = 1000



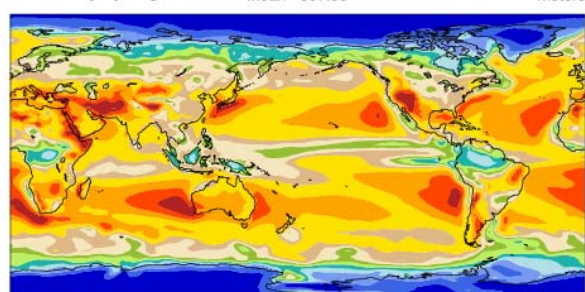
cam5\_1\_00\_L30\_090306 (yrs 1-4)

Planet bndry layer hgt mean= 507.99 meters



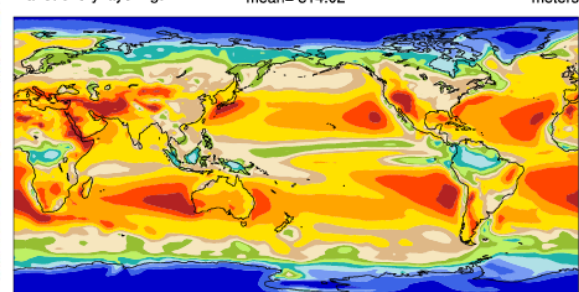
cam5\_1\_00\_L30\_090306 (yrs 1-4)

Planet bndry layer hgt mean= 507.99 meters

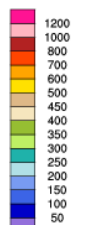


CAM30Lev\_900secsTS\_090306 (yrs 1-4)

Planet bndry layer hgt mean= 514.02 meters

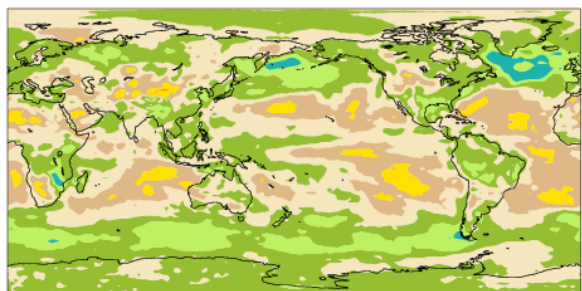


Min = 52.26 Max = 980



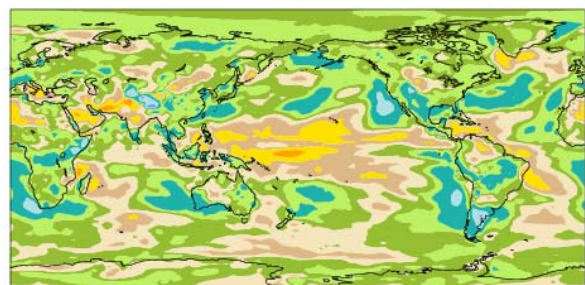
CAM30Lev\_900secsTS\_090306 - cam5\_1\_00\_L30\_090306

mean = 6.03 rmse = 25.32 meters



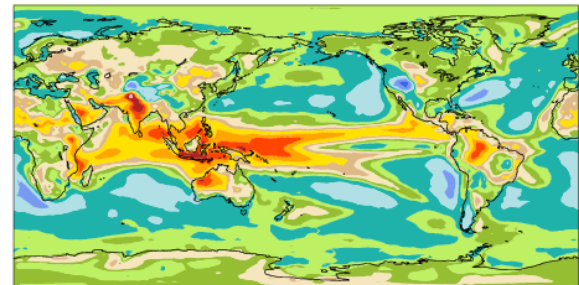
C5.1L61 - cam5\_1\_00\_L30\_090306

mean = -10.34 rmse = 39.09 meters

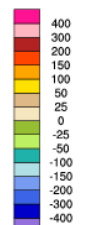


CAM5.161aL\_new1\_InitFile\_pgi - CAM30Lev\_900secsTS\_090306

mean = -21.54 rmse = 71.94 meters



Min = -240.85 Max = 300





# 2m Reference Temperature

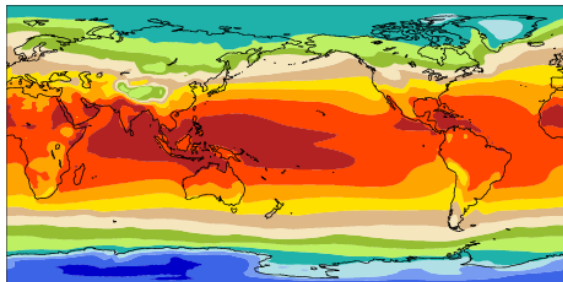
30L(30minute)  
-30L(15minute)

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

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

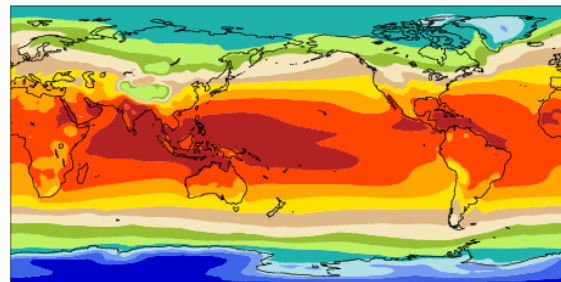
CAM30Lev\_900secsTS\_090306 (yrs 1-4)

2-meter Air Temp mean= 287.07 K



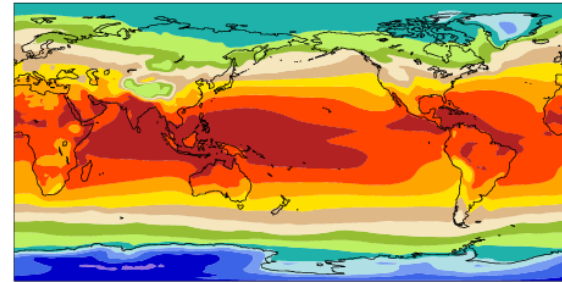
C5.1L61 (yrs 1)

2-meter Air Temp mean= 286.97 K



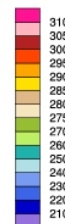
CAM5.161aL\_new1\_InitFile\_pgi (yrs 1-4)

2-meter Air Temp mean= 287.32 K



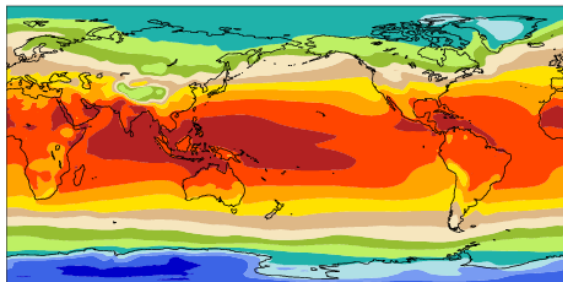
ANN

Min = 208.39 Max = 303.88



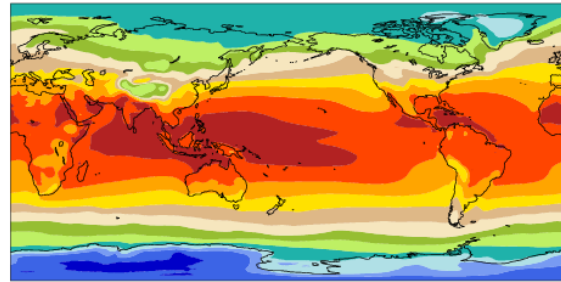
cam5\_1\_00\_L30\_090306 (yrs 1-4)

2-meter Air Temp mean= 287.06 K



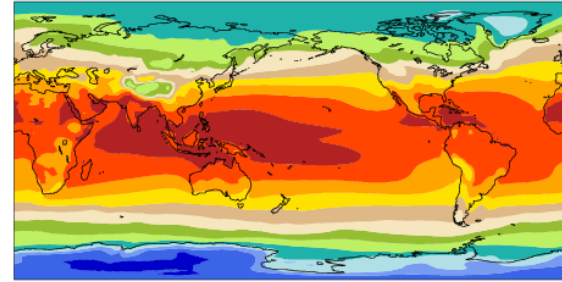
cam5\_1\_00\_L30\_090306 (yrs 1-4)

2-meter Air Temp mean= 287.06 K



CAM30Lev\_900secsTS\_090306 (yrs 1-4)

2-meter Air Temp mean= 287.07 K

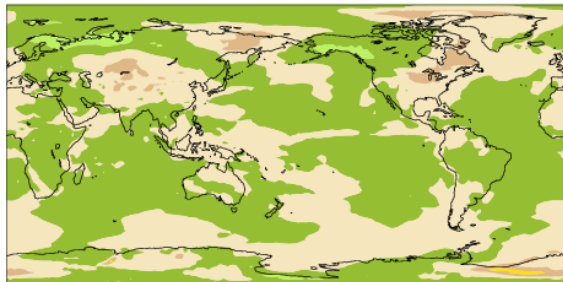


Min = 216.38 Max = 303.14



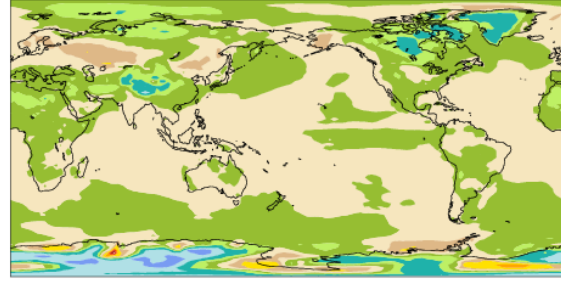
CAM30Lev\_900secsTS\_090306 - cam5\_1\_00\_L30\_090306

mean = 0.01 rmse = 0.30 K



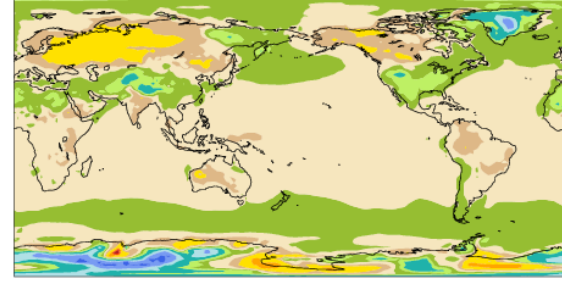
C5.1L61 - cam5\_1\_00\_L30\_090306

mean = -0.10 rmse = 0.71 K

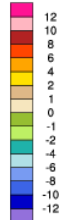


CAM5.161aL\_new1\_InitFile\_pgi - CAM30Lev\_900secsTS\_090306

mean = 0.25 rmse = 0.89 K



Min = -8.87 Max = 9.59



# 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

