The Meridional Structure of the Effects of Global Warming on Atmospheric Radiative Cooling and Precipitation

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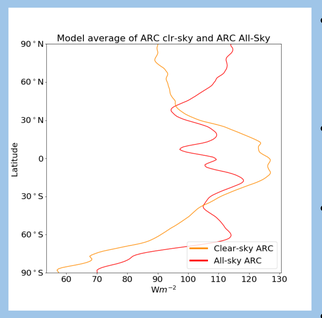
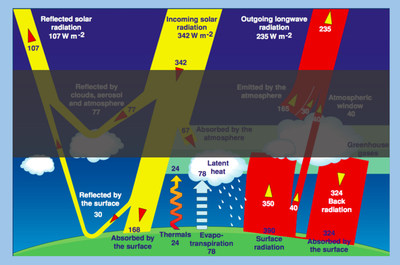
Background



- Atmospheric Radiative Cooling (ARC) is the net radiation loss from atmosphere
- ARC is positive when there is cooling
- The magnitude of ARC depends on various components of the global energy budget
- Cloud heights can influence ARC



- ARC is balanced by latent heat, which is proportional to precipitation
- All-sky conditions include all conditions
- Clear-sky conditions include everything except clouds

Data

- Climate Model Intercomparison Project 5
- Variables used:
  - Radiative components for clear sky and all sky
  - Precipitation
  - Surface Temperature

Radiative components:
Longwave downwelling
Longwave downwelling clear sky
Longwave up from surface
Longwave up at top of atmosphere
Longwave up at top of atmosphere clear sky
Shortwave down at surface
Shortwave down at surface clear sky
Shortwave down at top of atmosphere
Shortwave up at surface
Shortwave up at top of atmosphere
Shortwave up at top of atmosphere clear sky

Models
CCSM4
Hadgem
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
GISS-E2-R
ACCESS1.0
CanESM2
CNRM-CM5
INM-CM4
ISLP-CM5A-LR
ISLP-CM5A-MR
ISLP-CM5B-LR
MIROC-ESM
MIROC5
MRI-CGCM3
MPI-EMS-MR
MPI-EMS-P

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Methodology

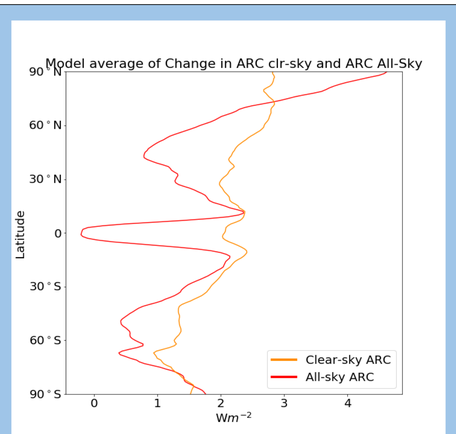
- Average across years 0-10 and 60-70 for each variable
- Calculate Atmospheric Radiative Cooling for all-sky and clear sky from the atmospheric radiative variables for each of the 18 models

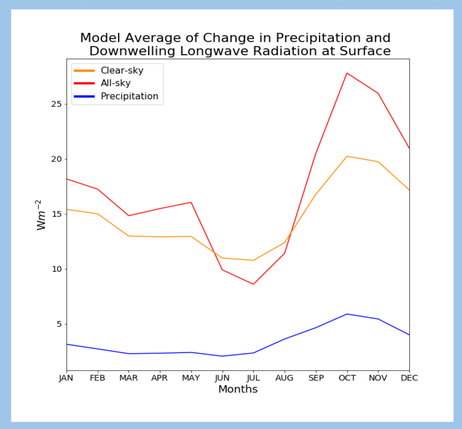
$$ARC = (LW_{TOA} - LW_{SFC}) - (SW_{TOA} - SW_{SFC})$$

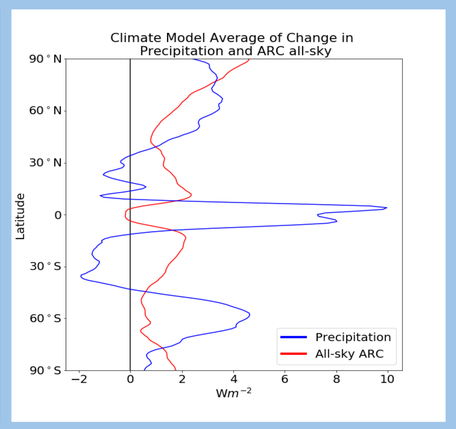
- Take the difference between years 0-10 from 70-60 to return the change in ARC and precipitation
- Take zonal mean
- Average across models for the multi-model mean

Results and Conclusions

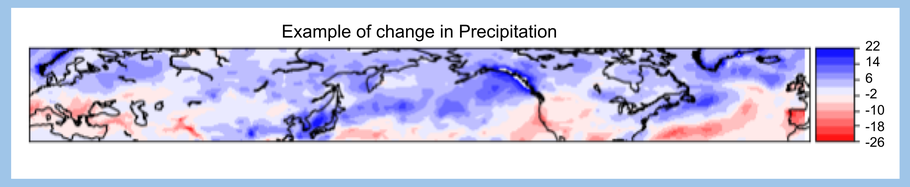
- Change in ARC clear-sky is larger than change in ARC all-sky (right)
- The tropics have no change in ARC all-sky (right)
- ARC has a inverse relation to precipitation (lower right)
- Wet gets wetter and dry gets drier (lower right)
- In the Arctic the change in ARC depends on the season with the largest increase in the fall (lower left)

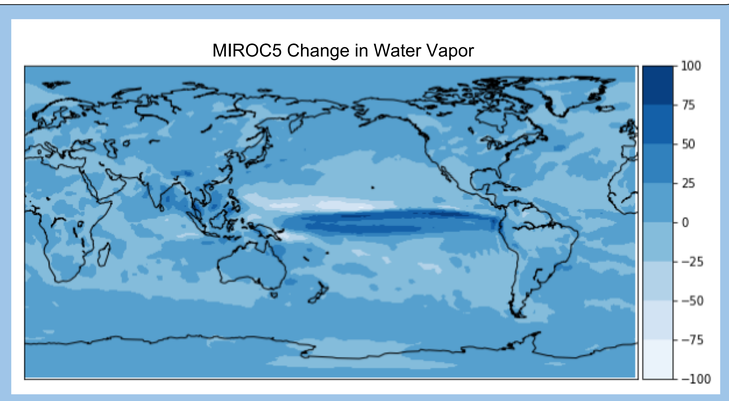
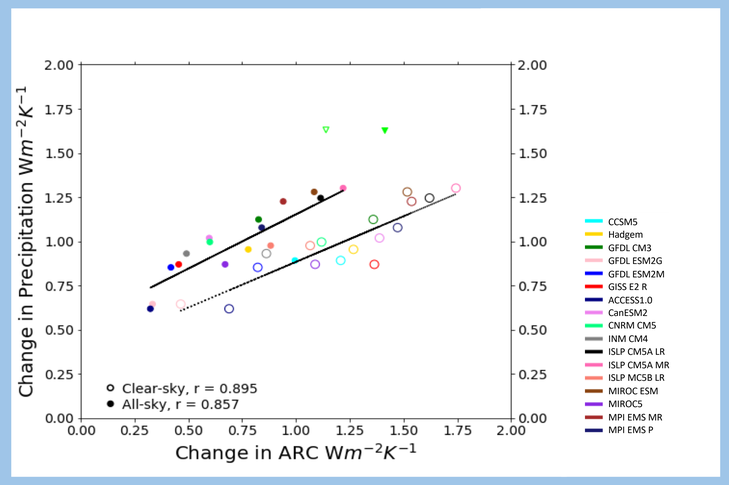






- The change in precipitation shows the poleward shift of the storm track (below)





- The greatest increases in water vapor and precipitation occur in the Tropics, despite the near-zero change in the ARC there (top)
- Correlations between the normalized global mean change in precipition and both all-sky and clear-sky ARC are very similar (below)