Energy Budget in Reanalyses Version Zero

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Some general comments

- Colors: Let me propose to use the S-RIP color assignment at https://s-rip.ees.hokudai.ac.jp/mediawiki/index.php/Notes_for_Authors [This covers all the global atmospheric reanalyses – reanalysis center colleagues also participated in the decision. Note that we have to define a color for MERRA-2AMIP – or, if we don't look at MERRA, we may use the color for MERRA.]
- There are some data gaps in the middle of the period, e.g., in JRA-55, CFSR, etc. What are they?
- JRA-55C, JRA-55AMIP, CERA-20C, and ERA5 should also be included. Perhaps, MERRA as well? R-1 and R-2 as well??
- The analysis should be extended to the period before 1979 (back to 1958, back to 1948, back to 1900, back to 1850, etc.); and then, the impacts from obs system differences be investigated.
- Possible regional analysis strategies beyond the global mean:
  - Land vs. ocean
  - Latitudinal bands – 90N-60N, 60N-30N, 30N-30S, 30S-60S, and 60S-90S
  - Seven (?) continents and seven (?) oceans
  - . . . [Perhaps, the first two would be enough? Further investigations will be led by Jan?]
- (One question: If we are to calculate the budget from these components, we need to start from 6 hourly data, calculate the budget, and then take monthly means? Or, non-linearity is not so strong, and the monthly mean budget can be calculated directly from these monthly means of the components?)

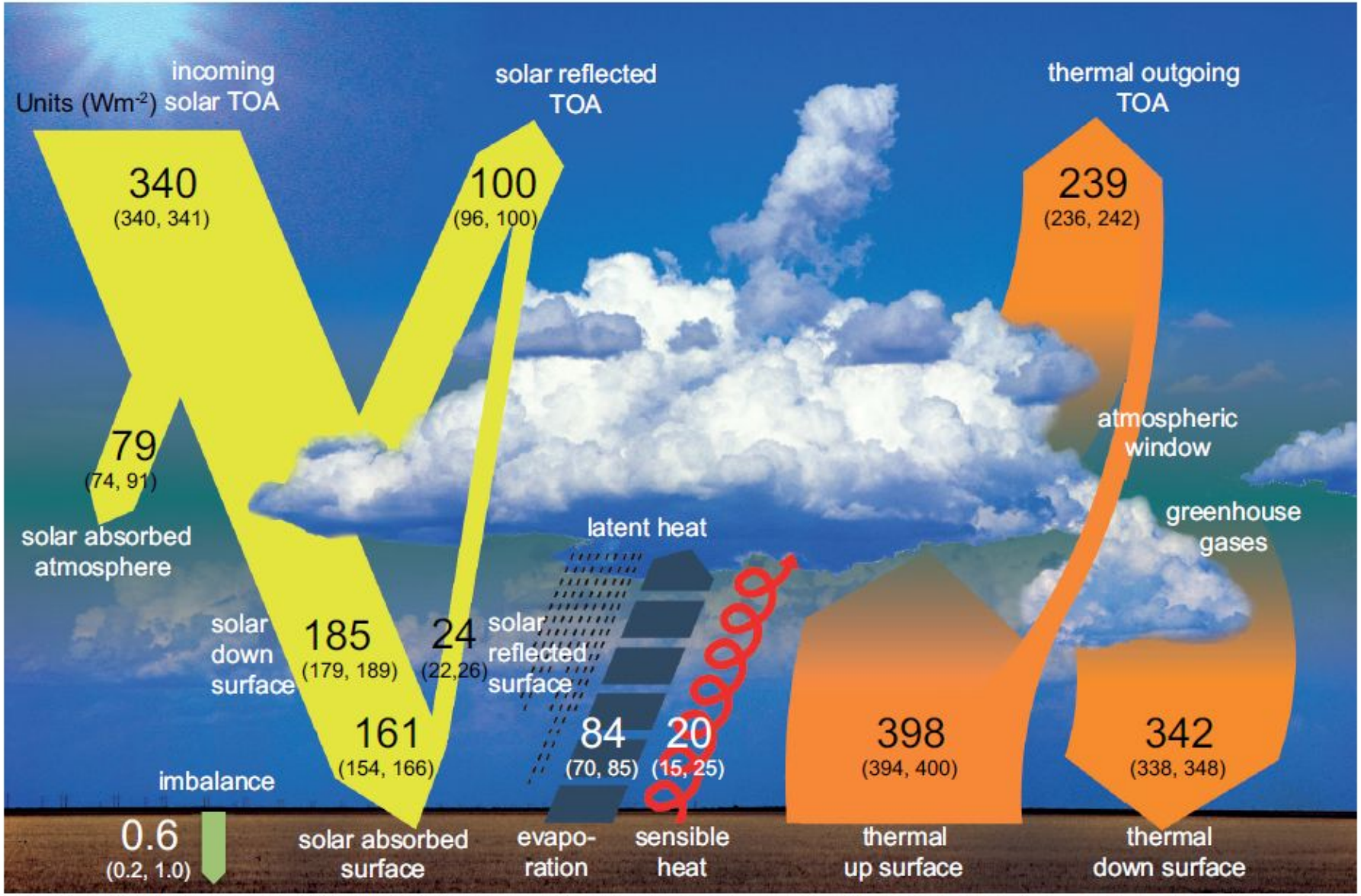
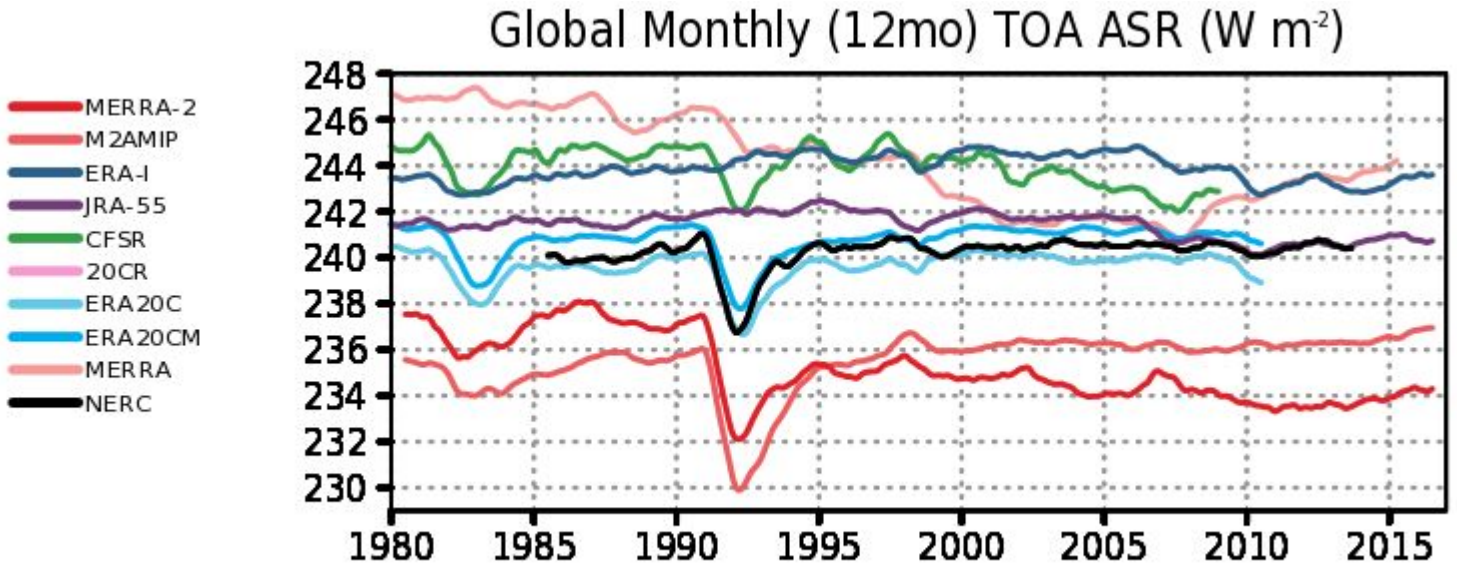


Figure 2.11: | Global mean energy budget under present-day climate conditions. Numbers state magnitudes of the individual energy fluxes in W m^{-2}, adjusted within their uncertainty ranges to close the energy budgets. Numbers in parentheses attached to the energy fluxes cover the range of values in line with observational constraints. (Adapted from Wild et al., 2013.)

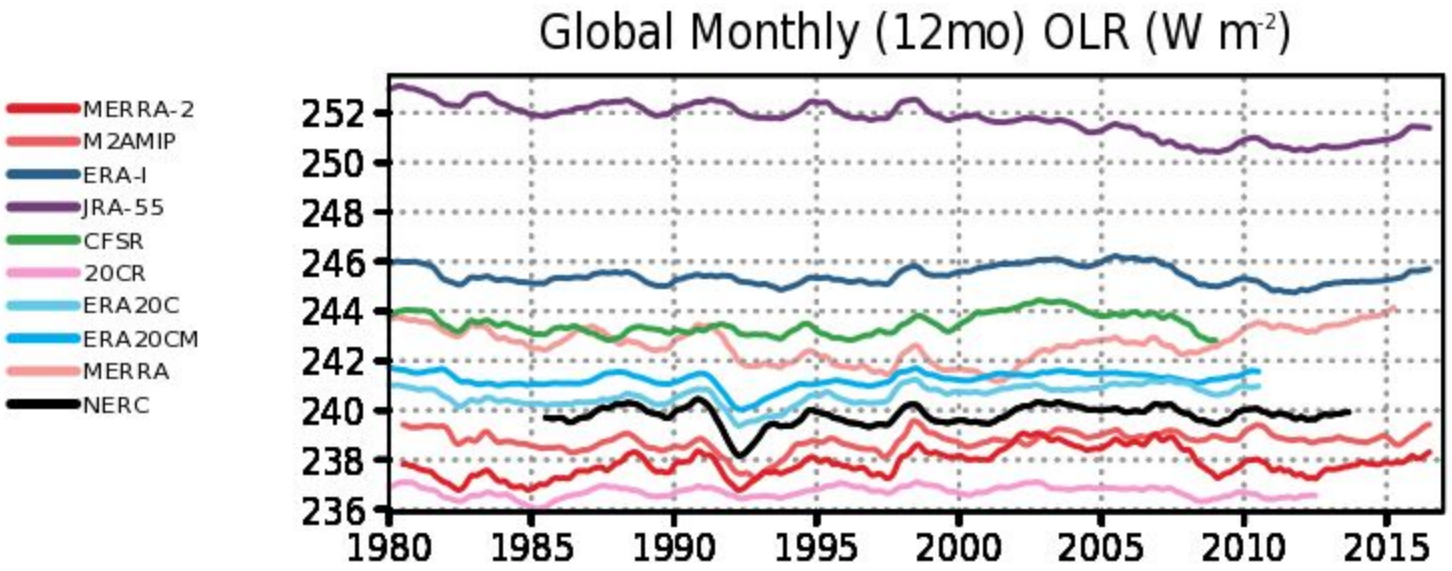
[IPCC Fifth Assessment Report (AR5), Climate Change 2013, Working Group I Report "The Physical Science Basis"]



Top of Atmosphere Absorbed Solar Radiation

- NERC- Allan DEEP-C extension of CERES intercalibrated data into the past
- CFSR (or “CDAS-T382”) can be extended to the end of December 2010 – and can be further continued using CFSv2 (or “CDAS-T574”).
- MERRA-2 and M2AMIP have a too strong response to Mt. Pinatubo eruption, and MERRA-2 clouds increase over time, reflecting more SW.

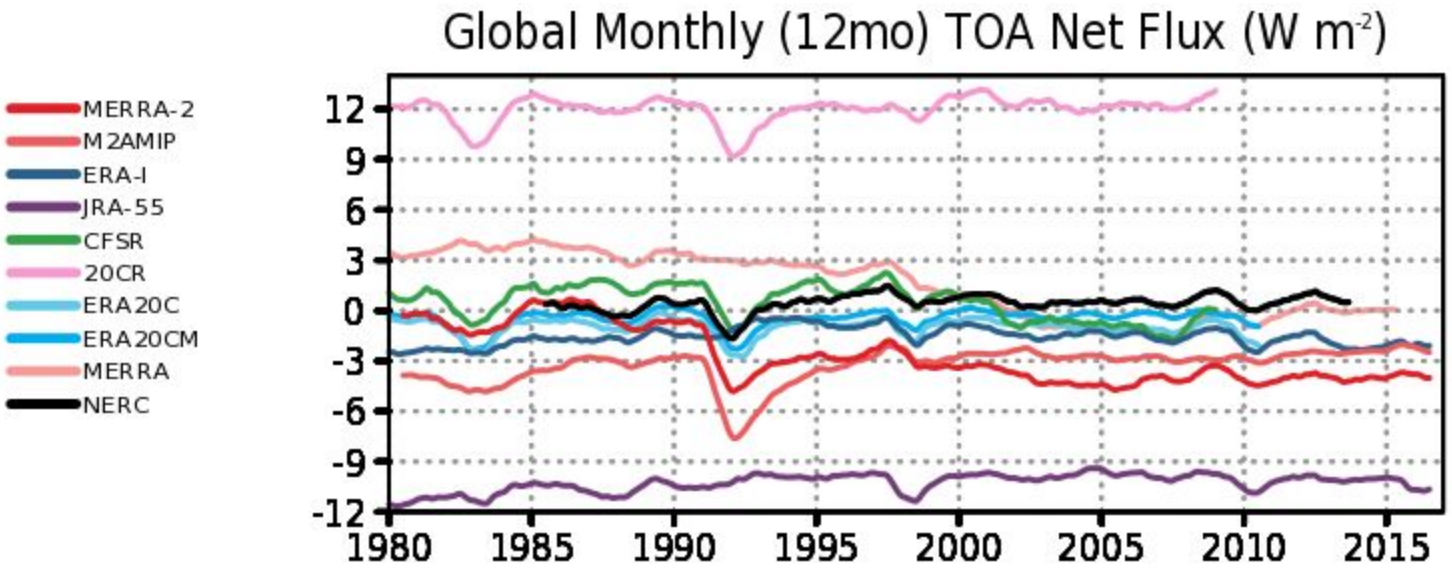
- Can we specify the reason for the bias of each reanalysis? Ask inputs from each reanalysis center?
- It looks the signals of El Chichon eruption (April 1982) and Mount Pinatubo eruption (June 1991) can be clearly seen in the reanalyses that have volcanic aerosols (i.e., MERRA-2, CFSR, ERA-20C (and 20CR)). ASR is negative because scattering to the space was enhanced.



Outgoing Longwave Radiation (at TOA)

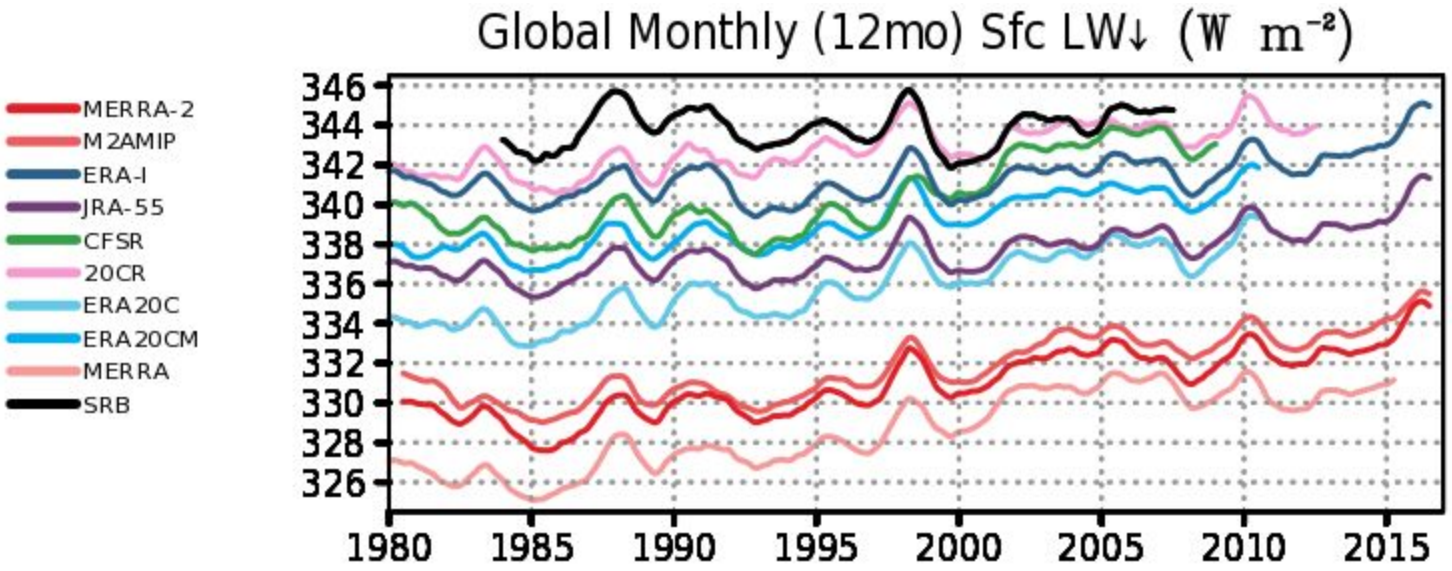
- What is “NERC”? Satellite observations? Can we extend it to present?
- JRA-55 has a gap around 1993/94.
- CFSR (or “CDAS-T382”) can be extended to the end of December 2010 – and can be further continued using CFSv2 (or “CDAS-T574”).
- Now we see 20CR.

- Can we specify the reason for the bias of each reanalysis? Ask inputs from each reanalysis center?
- It looks the signals of Mount Pinatubo eruption (June 1991) can be seen in MERRA-2 and ERA-20C but maybe not in CFSR and 20CR. The reason for the former may be due to less ASR, with a closed (thus better) budget?
- There might be the El Chichon signals for all reanalyses? Why?



Top of Atmosphere Net Flux

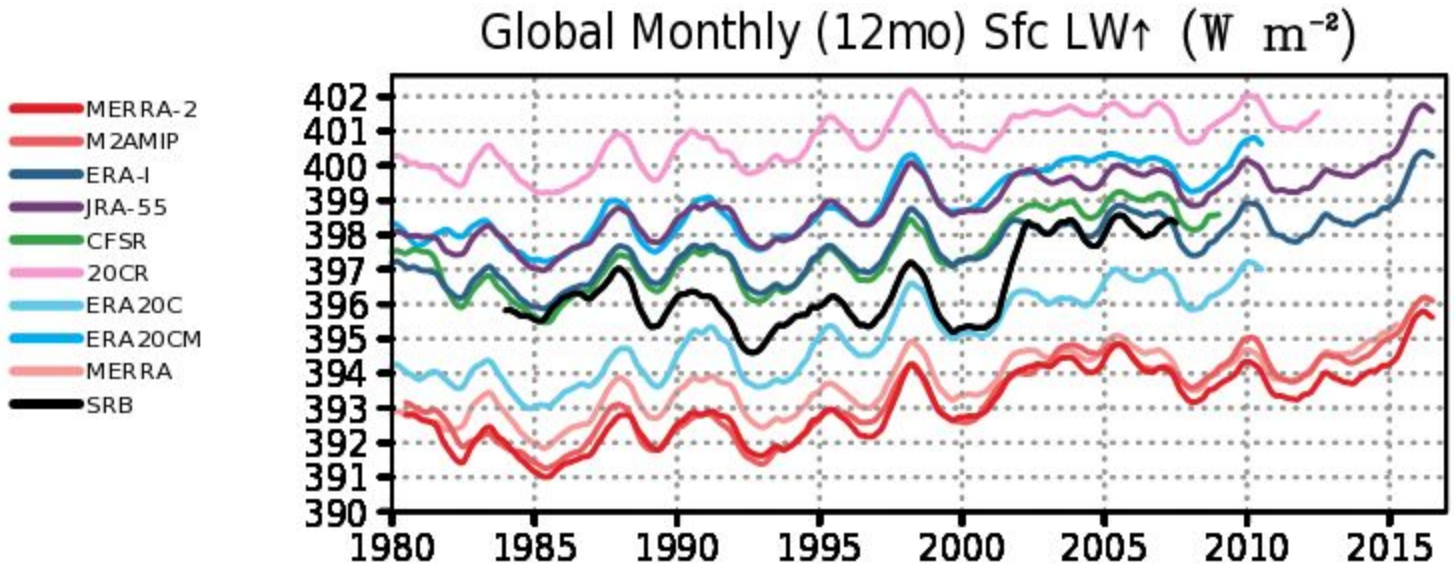
- JRA-55 and 20CR are outliers. JRA-55 should have issues in the OLR.
- MERRA-2 seems to have difference between pre-Pinatubo and post-Pinatubo (but MERRA-2AMIP does not have such a difference)? Or, downward trends? Also, if “NERC” is observation, MERRA-2’s Pinatubo aerosols are too strong?
    - The thinking is that MERRA-2 clouds are sensitive to observations. There is a shift in SSMI instruments that coincide with Pinatubo. Computing MERRA-2 aerosol radiative effect shows reasonable time series.



Downward Longwave Radiation at the Surface

- JRA-55 has a gap around 1993/94. CFSR (or "CDAS-T382") can be extended to the end of December 2010 – and can be further continued using CFSv2 (or "CDAS-T574").
- MERRA, MERRA-2 and M2AMIP use Chou Suarez radiation parameterization. This underestimates cloud effects, so the LW down is biased low. This is being addressed for future reanalyses.
- GEWEX Surface Radiation Budget - a new version is coming "soon"

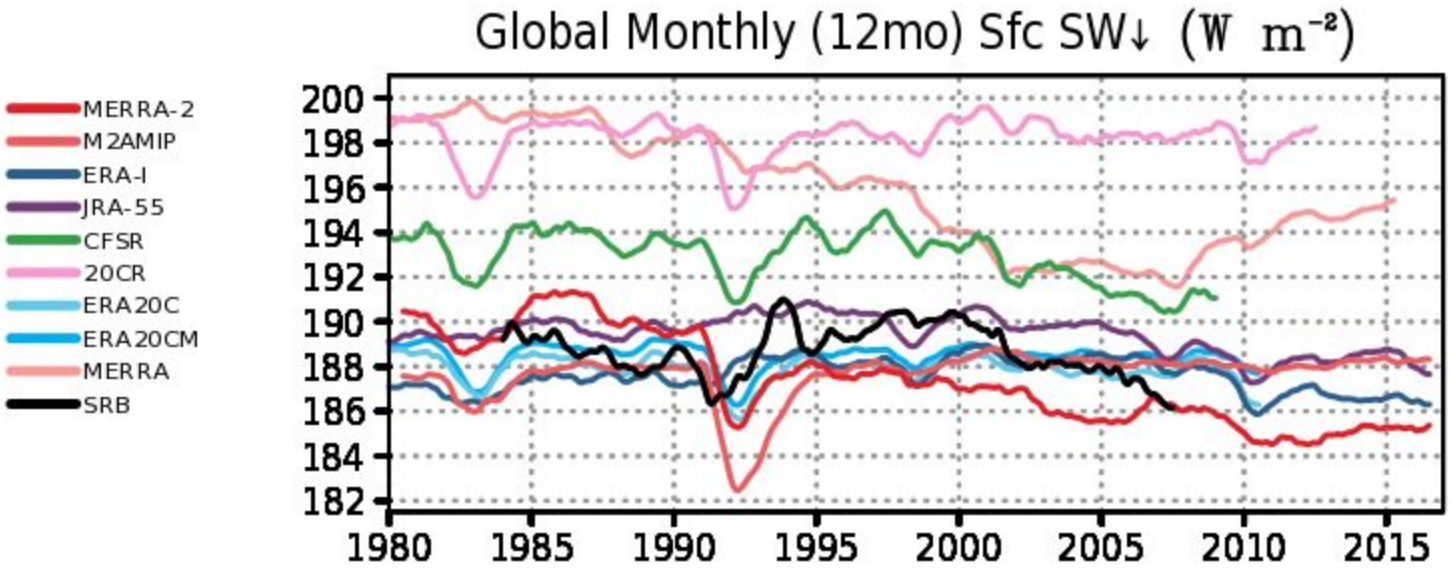
- This is largely determined by the atmospheric temperature (i.e., ENSO related), plus by the increasing CO2 level?
- Can we specify the reason for the bias of each reanalysis? (All are too low (compared to "SRB")?) Ask inputs from each reanalysis center?
- It looks this is strongly linked to ENSO. The 1982, 1987, 1997, 2010, and 2015 El Nino events can be seen.



Upward Longwave Radiation at the Surface

- JRA-55 has a gap around 1993/94. CFSR (or "CDAS-T382") can be extended to the end of December 2010 – and can be further continued using CFSv2 (or "CDAS-T574").
- Is there a jump around 2001 in SRB? Seems like it, possibly related to some reanalysis input from GEOS4 (P. Stackhouse personal communication)

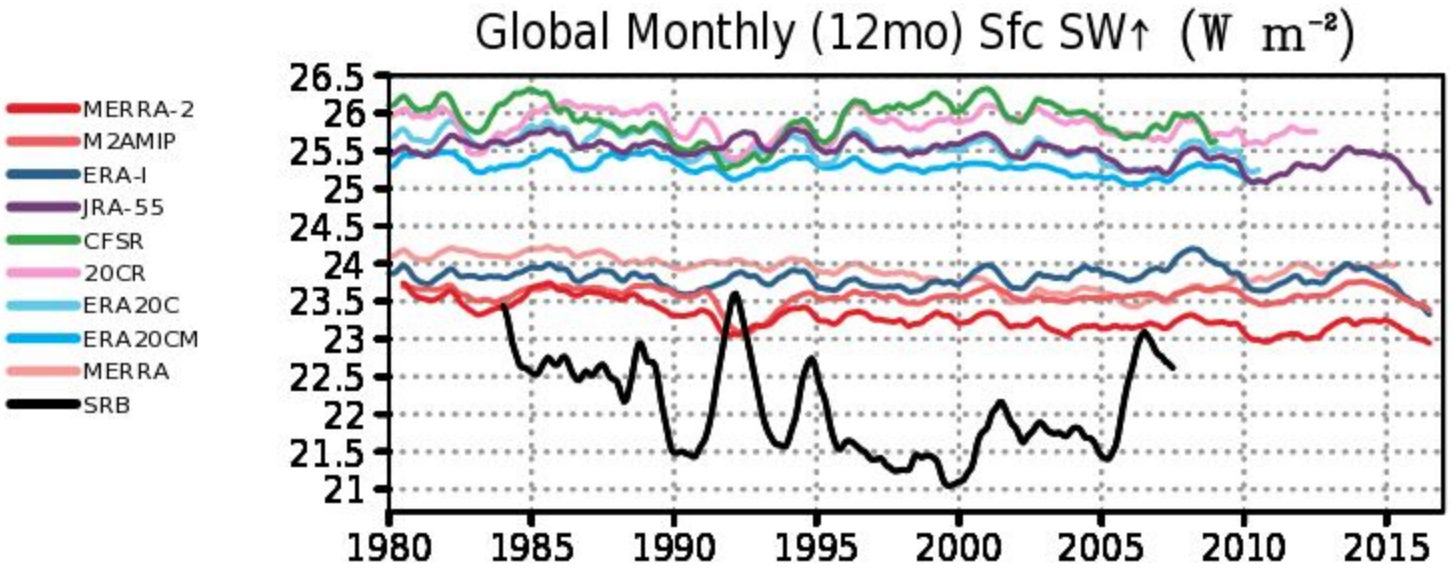
- This is largely determined by the surface temperature (including the effects of ENSO and CO2)?
- Can we specify the reason for the bias of each reanalysis? (Now, "SRB" is in the middle) Ask inputs from each reanalysis center?
- Again, it looks this is strongly linked to ENSO.



Downward Shortwave Radiation at the Surface

- CFSR (or "CDAS-T382") can be extended to the end of December 2010 – and can be further continued using CFSv2 (or "CDAS-T574").

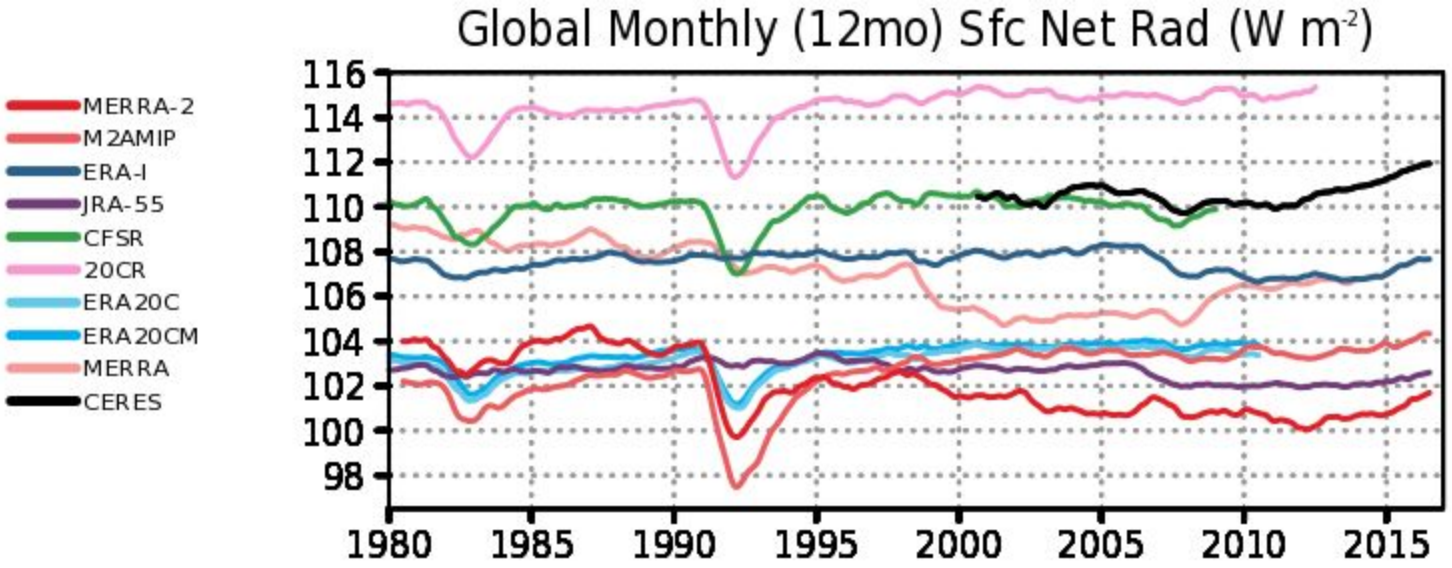
- This is largely determined by the cloudiness, plus by the aerosol loading (in particular, volcanic)?
- Can we specify the reason for the bias of each reanalysis? (20CR and CFSR might be biased high?) Ask inputs from each reanalysis center? Best would be checking in on the developing center.
- The effects of El Chchion and Mount Pinatubo eruptions can be seen in the reanalyses that have volcanic aerosols included.
- CFSR, MERRA-2, and "SRB" show downward trends after 2000. What are the possible causes? Real? Could be a regional signal, fairly weak in global average



Upward Shortwave Radiation at the Surface

- CFSR (or “CDAS-T382”) can be extended to the end of December 2010 – and can be further continued using CFSv2 (or “CDAS-T574”).
- SRB has uncertainty at the poles (polar night) and not a comparable baseline. Albedo would be a better value to look at, and perhaps net SW at surface. Intercomparing reanalyses albedos is probably a good thing anyway.

- This is largely determined by the surface albedo.
- There are two groups: Upper group includes CFSR, 20CR, ERA-20C, JRA-55; lower group includes ERA-I, MERRA-2s. Why? Related to the specified ocean surface albedo, for example?
- We may see some Pinatubo influence? That is just due to the reduced downward shortwave radiation?



Net Radiation at the Surface

- The comments for each of the four components can be combined to understand this.
- This ~100 W m^-2 is balanced with the evaporation and sensible heat at the surface.
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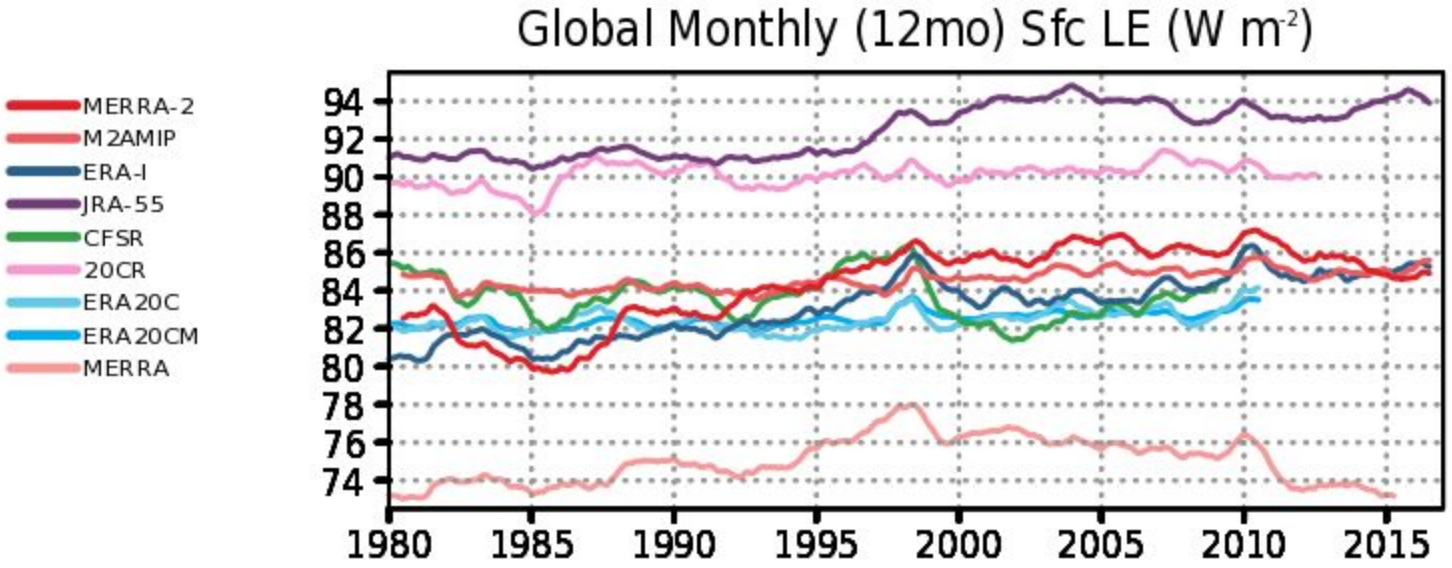
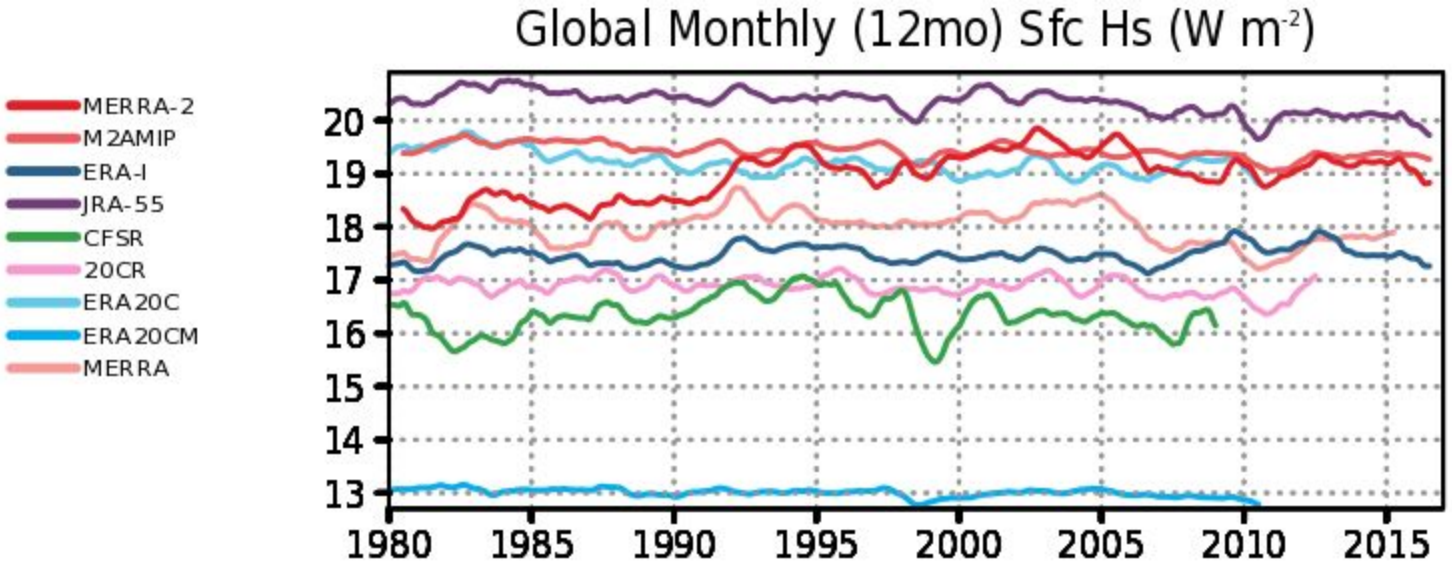
- Probably should redo with SRB for consistency, alternatively, use CERES inplace of SRB until their new version. Any other surface radiation?



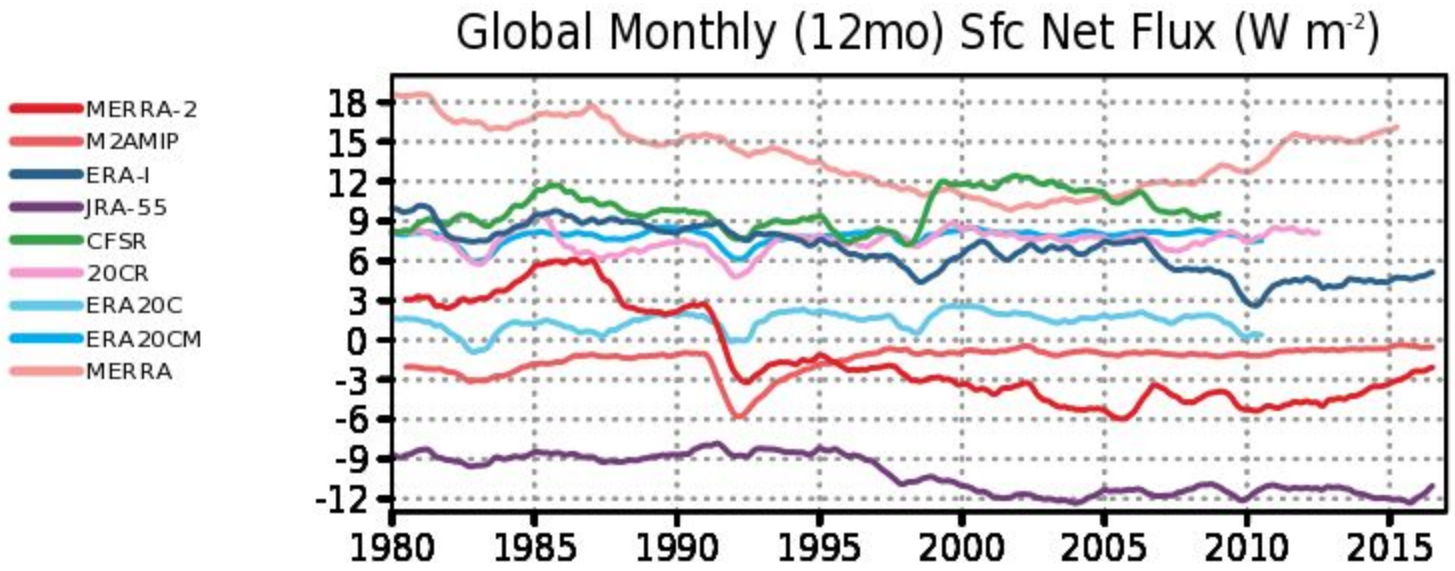
Surface Latent Heat Flux

- JRA-55 and 20CR may be outliers? Any reason?
- MERRA low evap was also a reason for its low precipitation
- No signals related to the two volcanic eruptions? (but should have those??) Are there ENSO signals?
- It looks there are general increasing trends (except for CFSR). Reasonable? Reason?



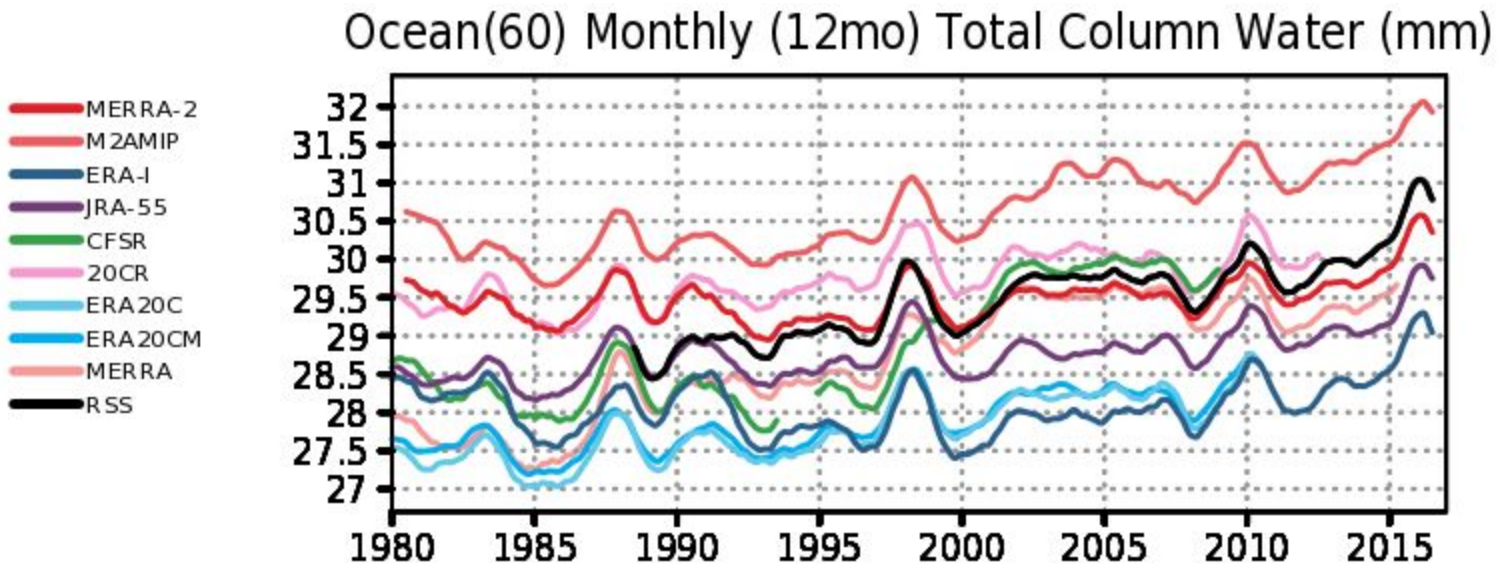
Surface Sensible Heat Flux

- What controls this variable? - surface wind, near surface temperature gradient (stability), roughness. I think wind signal apparent in M2 1992-3
- No clear characteristics? CFSR shows a large drop in 1999. La Nina?



Net Flux at the Surface

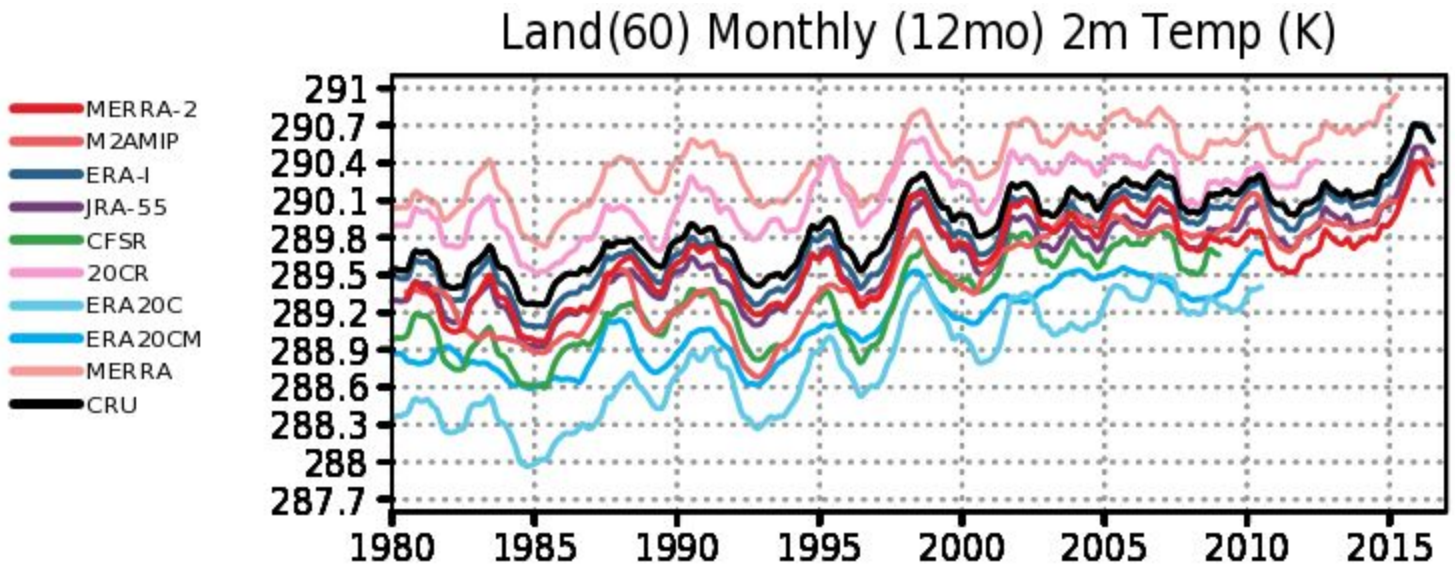
- Similar to the net radiation at the surface, with different baselines.
- MERRA-2 shows large negative trends.
- JRA-55 shows differences between pre-1995 and post-2000.
- CFSR shows a jump around 1999. One reason is sensible heat, but that is not the whole story?



Total Column Water

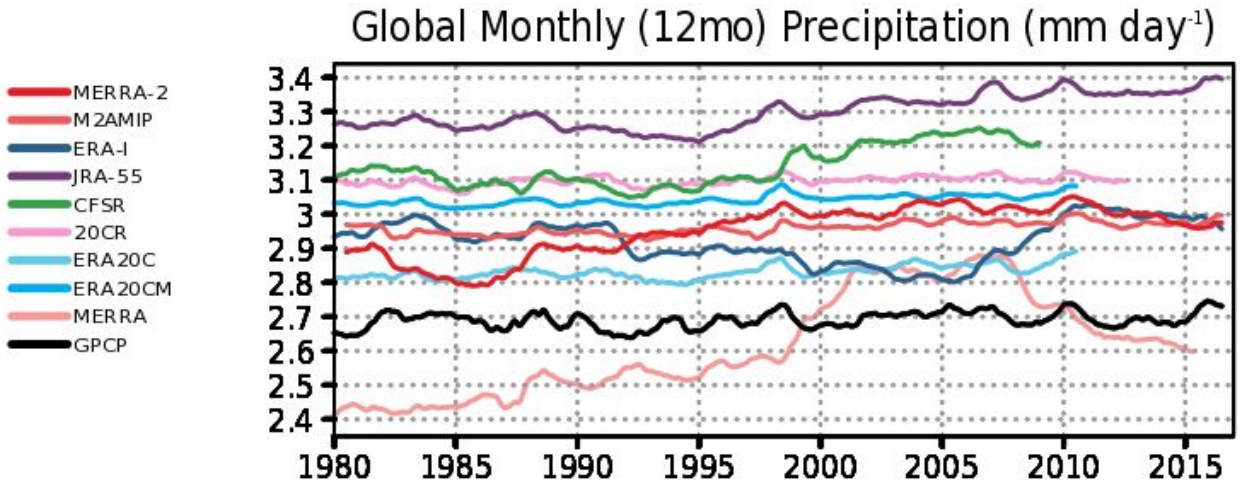
- "Ocean(60)" - Ocean Only 60S-60N
- CFSR has a gap around 1993/4.

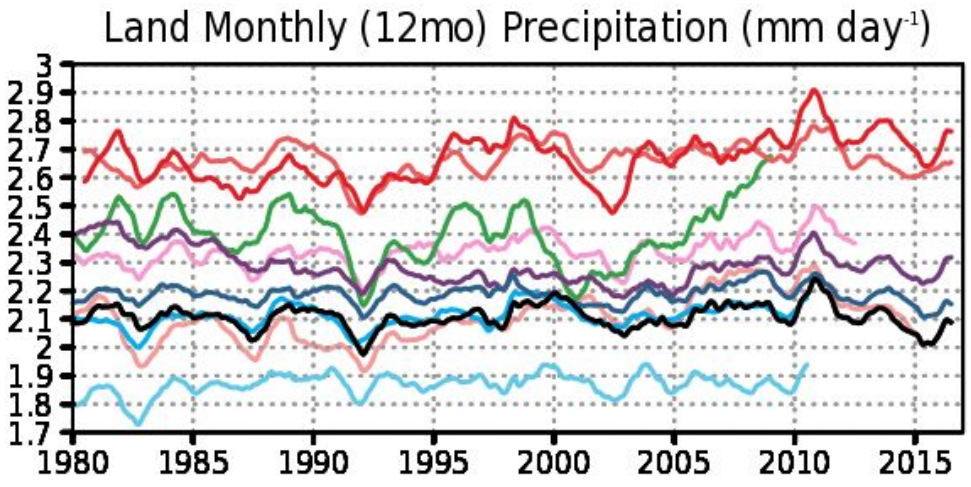
- The biases need to be explained (for each reanalysis). If assimilating radiances, then the radiative transfer model connecting radiance with water vapor is different for each system. If not assimilating water vapor, then the model has its own bias.
- Variabilities include ENSO related plus increasing trends (volcanic eruptions also?) Variability is generally good, except note that RSS has more of a trend than some (MERRA-2 especially)
- Mike B has presented results for Claussius-Clapyeron comparisons among many of these, and the satellite reanalyses produce a weak CC relationship compared with obs.

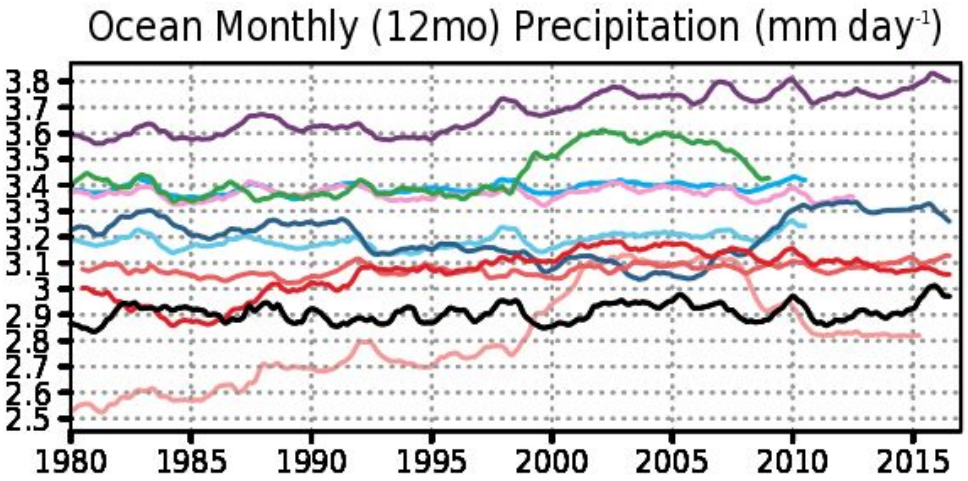


2m Surface Air Temperature

- ERAI tracks CRU well owing to their surface temperature and humidity analysis
- JRA-55 and MERRA-2 are so close that JRA-55 is covered most times
- MERRA di have a general wam bias over land







Precipitation

- MERRA interannual variability is tied to significant changes in the observing system ((AMSU, AIRS, then SSMI decommissioning)
- MERRA-2 Pr is tied to surface Evap, which is strongly dependent on wind observations; Also has a high bias over tropical topograpy
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- Obs are GPCP v2.3