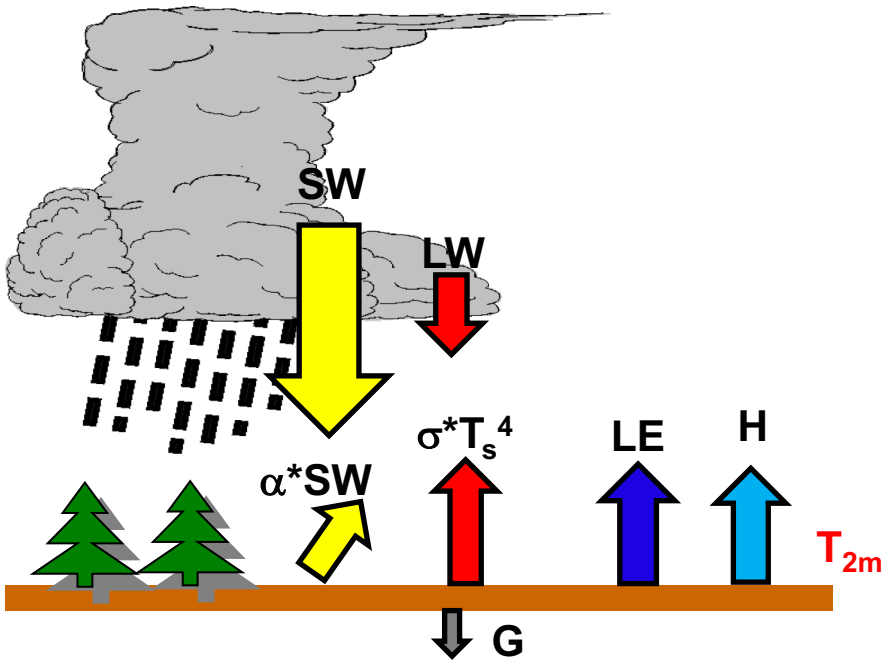
Theoretical interpretation of warm bias

Two reasons for the warm-bias are:

- Excess absorbed radiation directly heats the surface causing a warm bias.
- If evaporation is suppressed, radiative heating (even if unbiased) will be used to heat the surface instead of evaporating water causing a warm bias.

Knowing which factor contributes more helps with knowing what direction one needs to go in to reduce the warm bias

Surface energy budget



Forcing Variables

- SWAbs (+ LWDN)
- Evaporative Fraction:

  $EF \equiv LH / (LH+SH)$

Forcing variables drive the surface temperature error

Response Variables

- LWUP
- SH

Response variables are assumed proportional to the surface temperature

Theoretical interpretation of warm bias

$$SW + LW = SH + LH, \quad (1)$$

()’ = error

$$SW' + LW' = SH' + LH', \quad (2)$$

$$SW' + LW' = (\gamma SH)', \qquad \gamma = 1 / (1 - EF) \quad (3)$$

$$(SW' + LWDN') - SH_{mod}\gamma' = LWUP' + \gamma_{obs}\, SH', \quad (4)$$

$$(SW' + LWDN') - SH_{mod}\gamma' = \left(\frac{\partial LWUP}{\partial T_{2m}} + \gamma_{obs}\frac{\partial SH}{\partial T_{2m}}\right) T'_{2m}, \quad (5)$$

$$(SW' + LWDN') - EF'\,\gamma_{obs}(SH_{mod} + LH_{mod}) = \left(\frac{\partial LWUP}{\partial T_{2m}} + \gamma_{obs}\frac{\partial SH}{\partial T_{2m}}\right) T'_{2m}, \quad (6)$$

$$T'_{2m} = \frac{(SW'+LWDN')}{\frac{\partial LWUP}{\partial T_{2m}} + \gamma_{obs}\frac{\partial SH}{\partial T_{2m}}} - \frac{EF'\,\gamma_{obs}(SH_{mod}+LH_{mod})}{\frac{\partial LWUP}{\partial T_{2m}} + \gamma_{obs}\frac{\partial SH}{\partial T_{2m}}}, \quad (7)$$

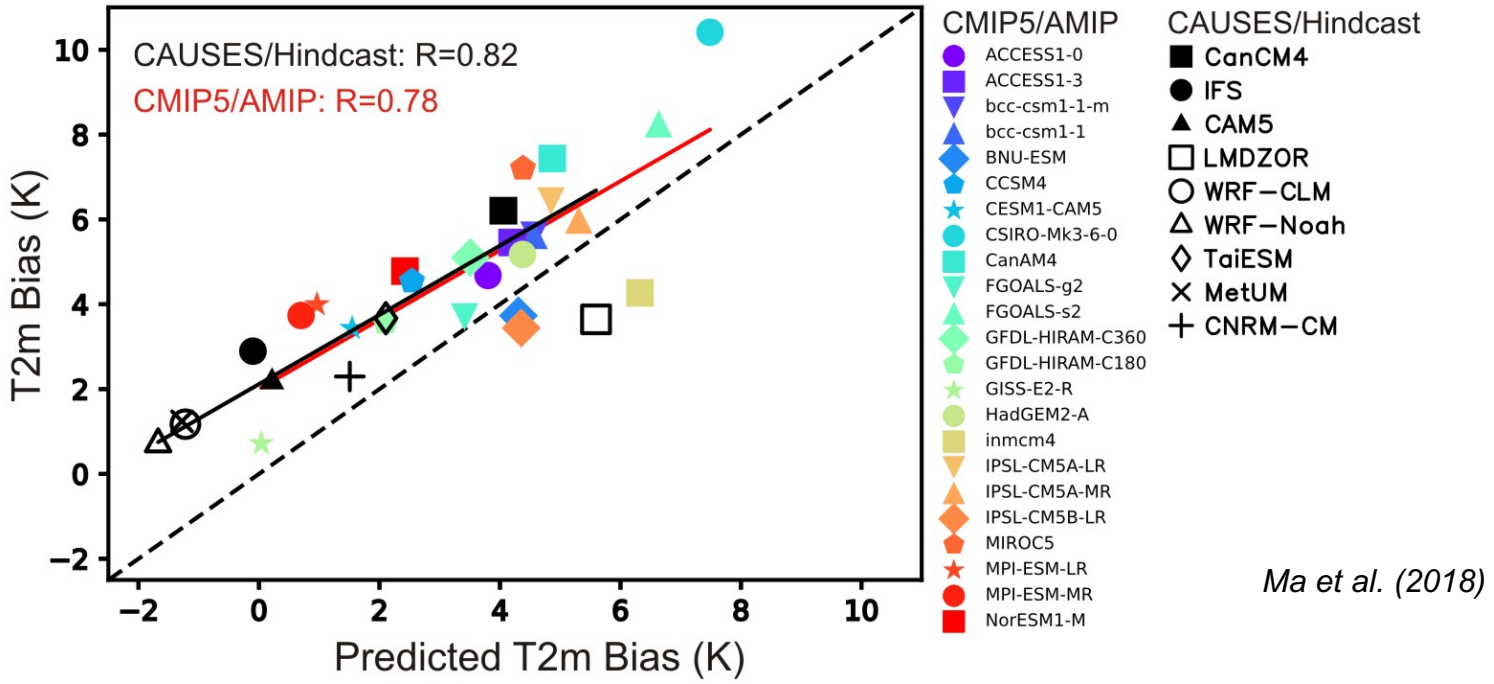
Given $\frac{\partial LWUP}{\partial T_{2m}} = 7$, $\frac{\partial SH}{\partial T_{2m}} = 9$, γ_{obs}=2.5 from model values and observations,

Ma et al. (2018)

$$T'_{2m} = \frac{(SW' + LWDN')}{30\ W\ m^{-2}K^{-1}} - \frac{2.5\ EF'(SH_{mod} + LH_{mod})}{30\ W\ m^{-2}K^{-1}}. \quad (8)$$

Radiation Contribution

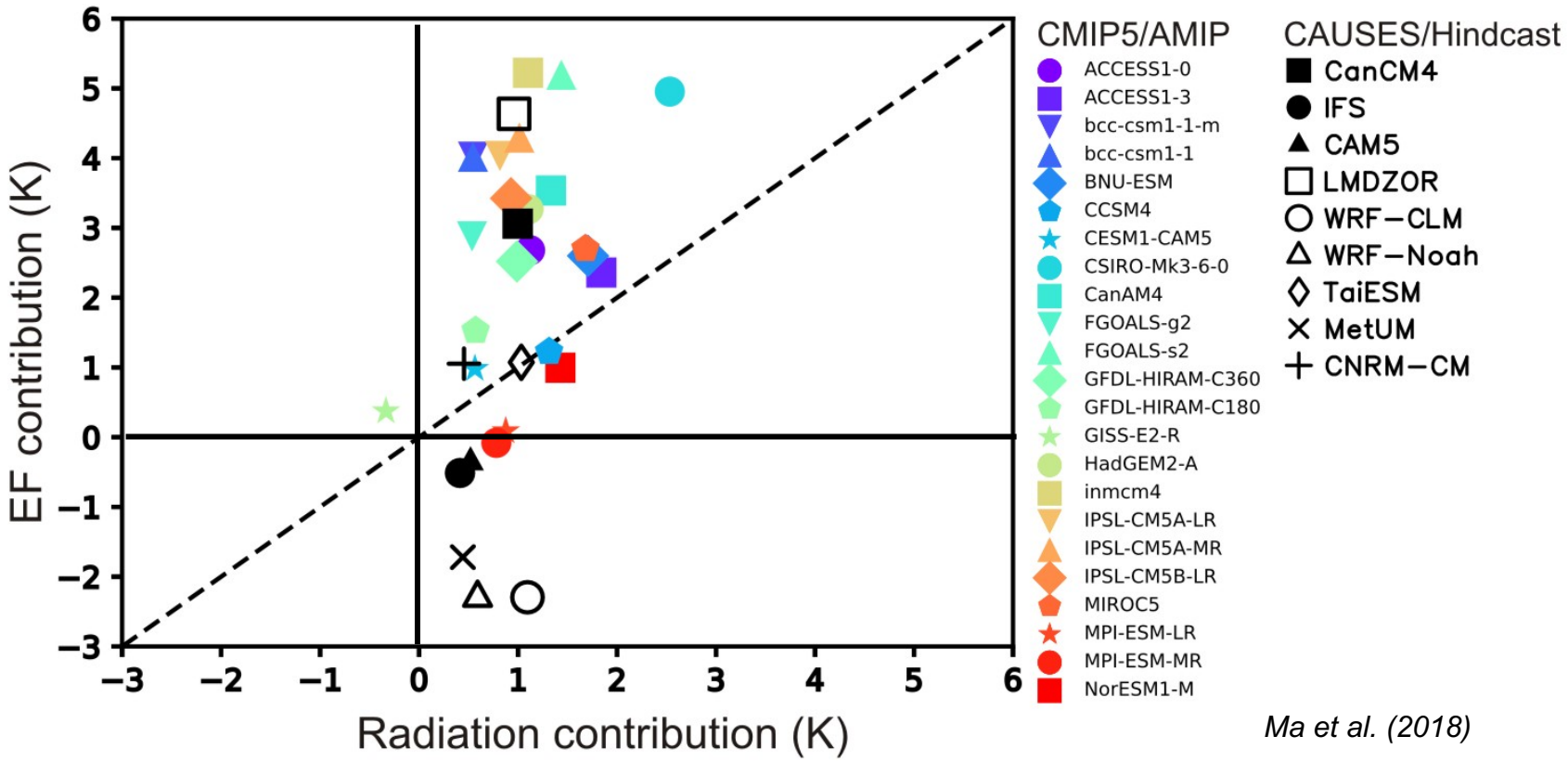
Evaporative Fraction Contribution



Ma et al. (2018)

- The approximate equation predicts the T2m bias reasonably well with the biases estimated from radiation and evaporative fraction biases.

Relative contribution of radiation and evaporative fraction biases



Ma et al. (2018)

- Contribution from surface radiation biases (shortwave absorbed and downward longwave fluxes) is ~ 0.5 – 2 K for most models while contribution from evaporative fraction bias varies from ~ -2.5 to 5.5K.
- Long-term climate simulations (CMIP5/AMIP) show larger positive evaporative fraction biases than short-term hindcasts.