

# Variability of Surface Solar Irradiance over the U.S. from 1996 to 2019
















## Has Brightening Ceased?

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# Brightening and dimming trends of solar radiation at the surface are global and multi-decadal in nature

Trends in  $Wm^{-2}/decade$

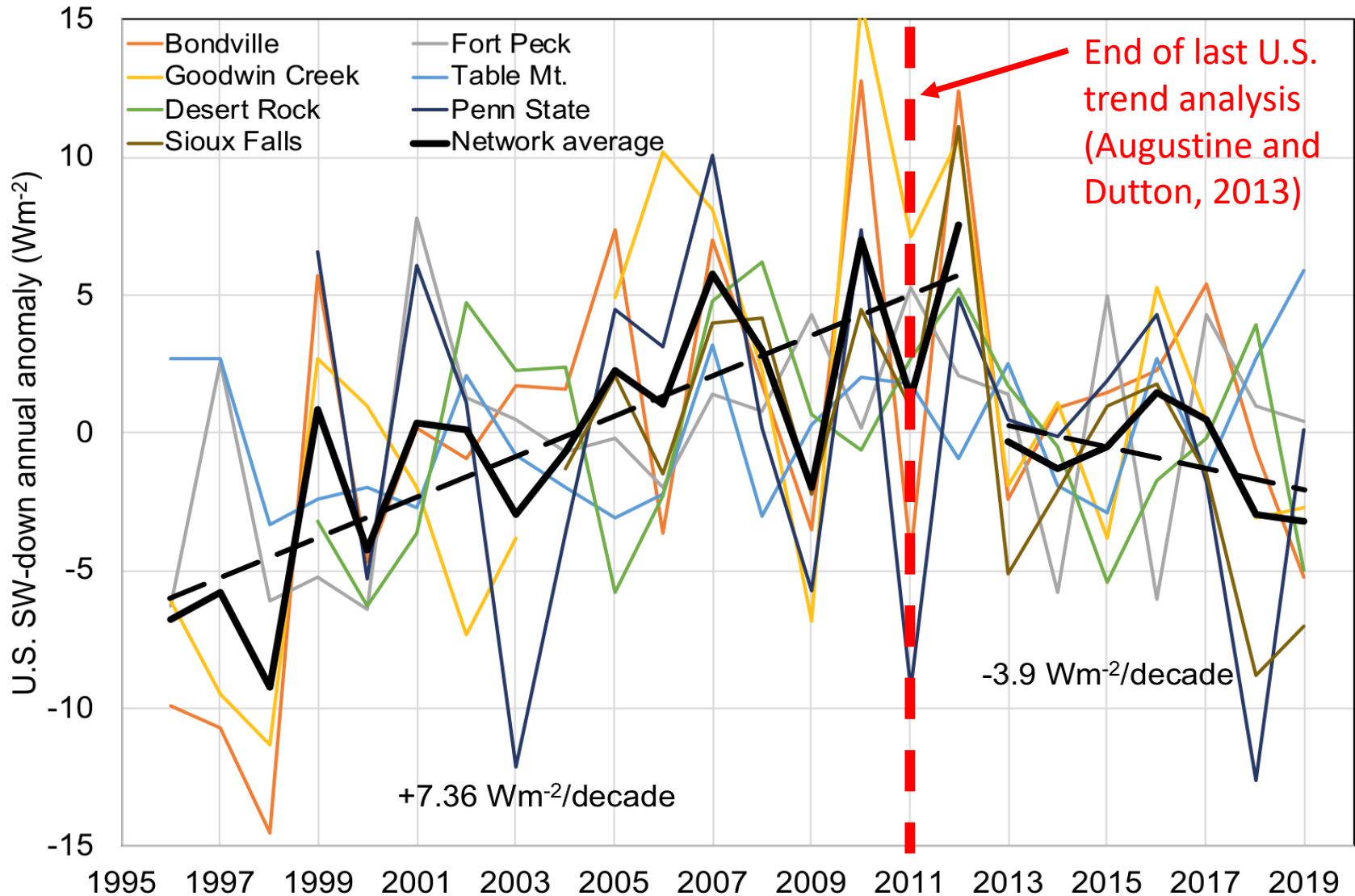
	1950s-1980s	1980s-2000	after 2000
<b>USA</b>	-6 	5 	8 
<b>Europe</b>	-3 	2 	3 
<b>China/Mongolia</b>	-7 	3 	-4 
<b>Japan</b>	-5 	8 	0 
<b>India</b>	-3 	-8 	-10 

Source: Wild (2012) BAMS review of brightening and dimming

Since 1996 SURFRAD data have been used to document surface radiation trends over the U.S.



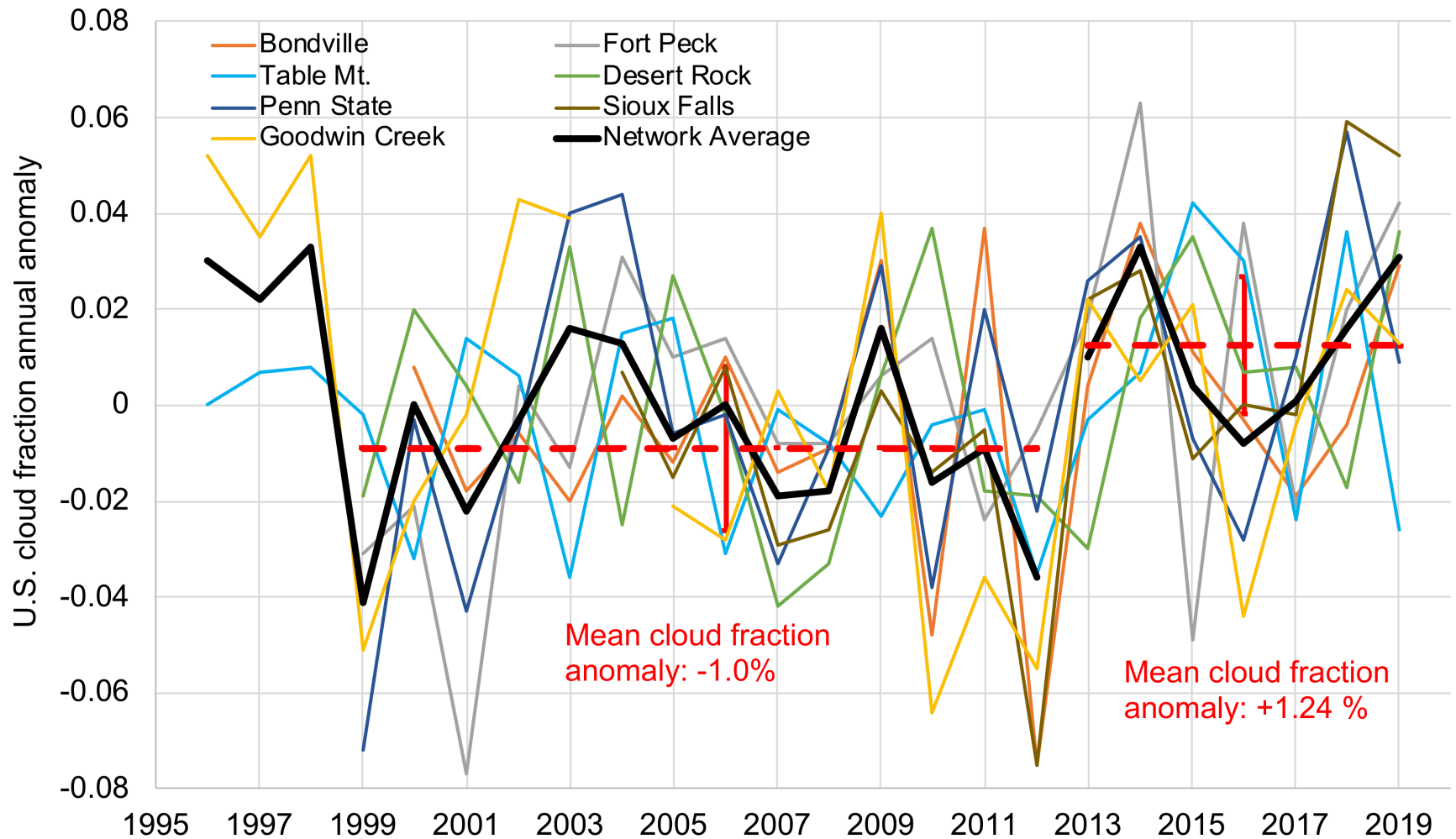
# Updated U.S. surface solar radiation anomalies through 2019



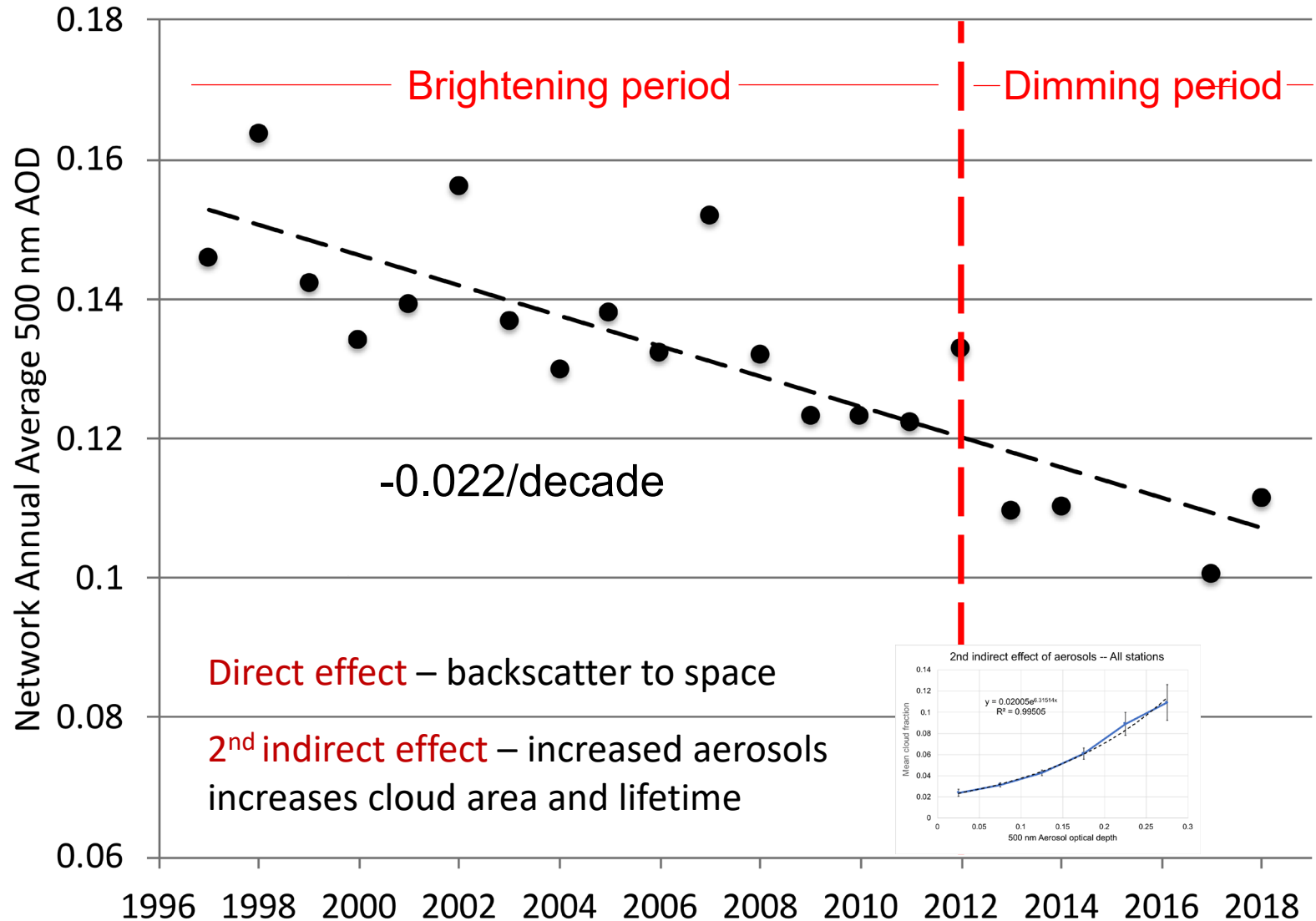
# What causes decadal trends in solar radiation at the surface?

- No consensus in the literature, except that the source of variability is not at TOA
- Studies have attributed surface solar trends to aerosols alone, clouds alone, or a combination of both
- Alternately, decadal variations in circulation patterns could systematically affect cloud cover
- So, is it clouds or aerosols for the U.S.?

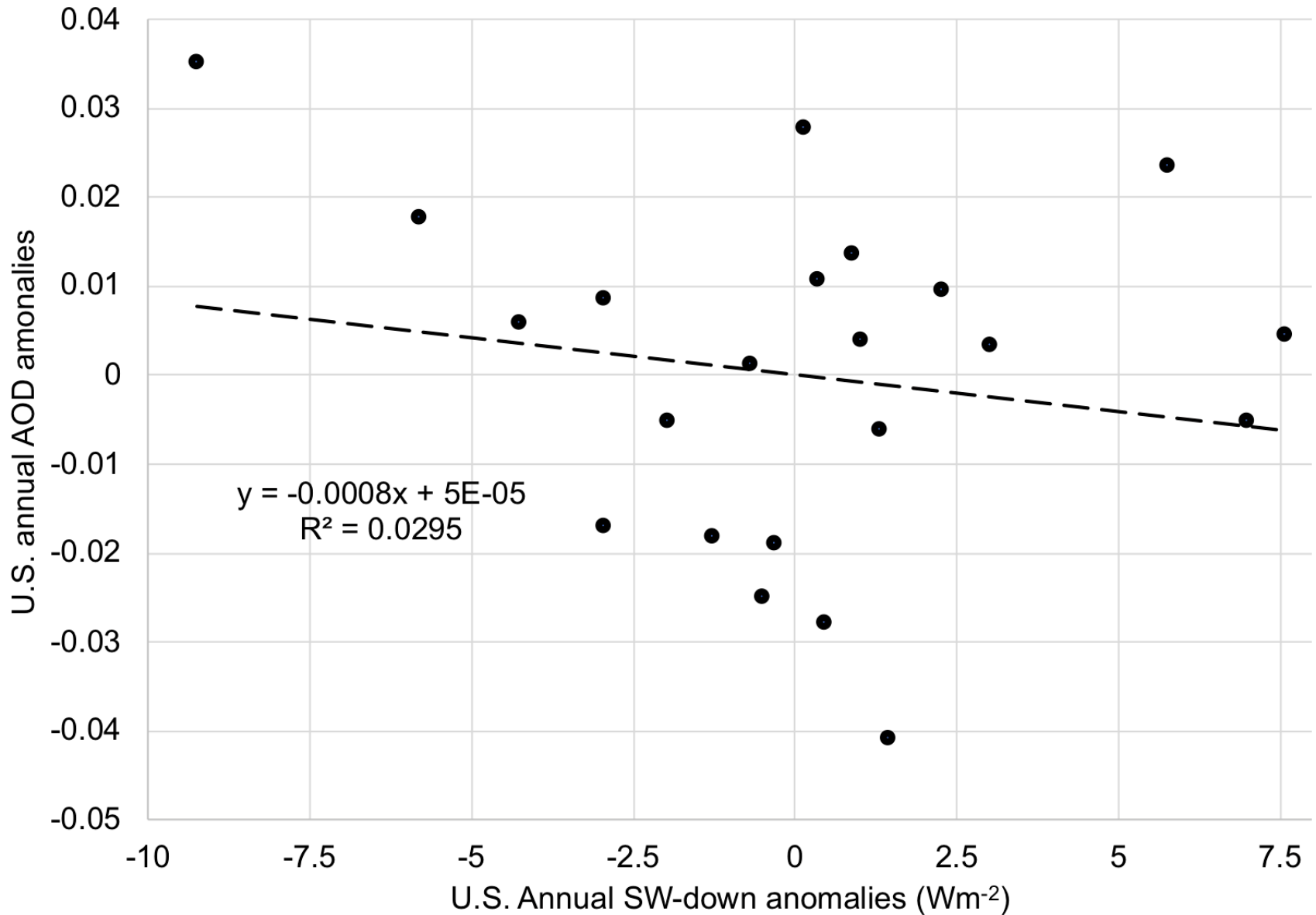
# Cloud fraction annual anomalies for the U.S.



# Aerosol optical depth declined through the brightening and dimming periods

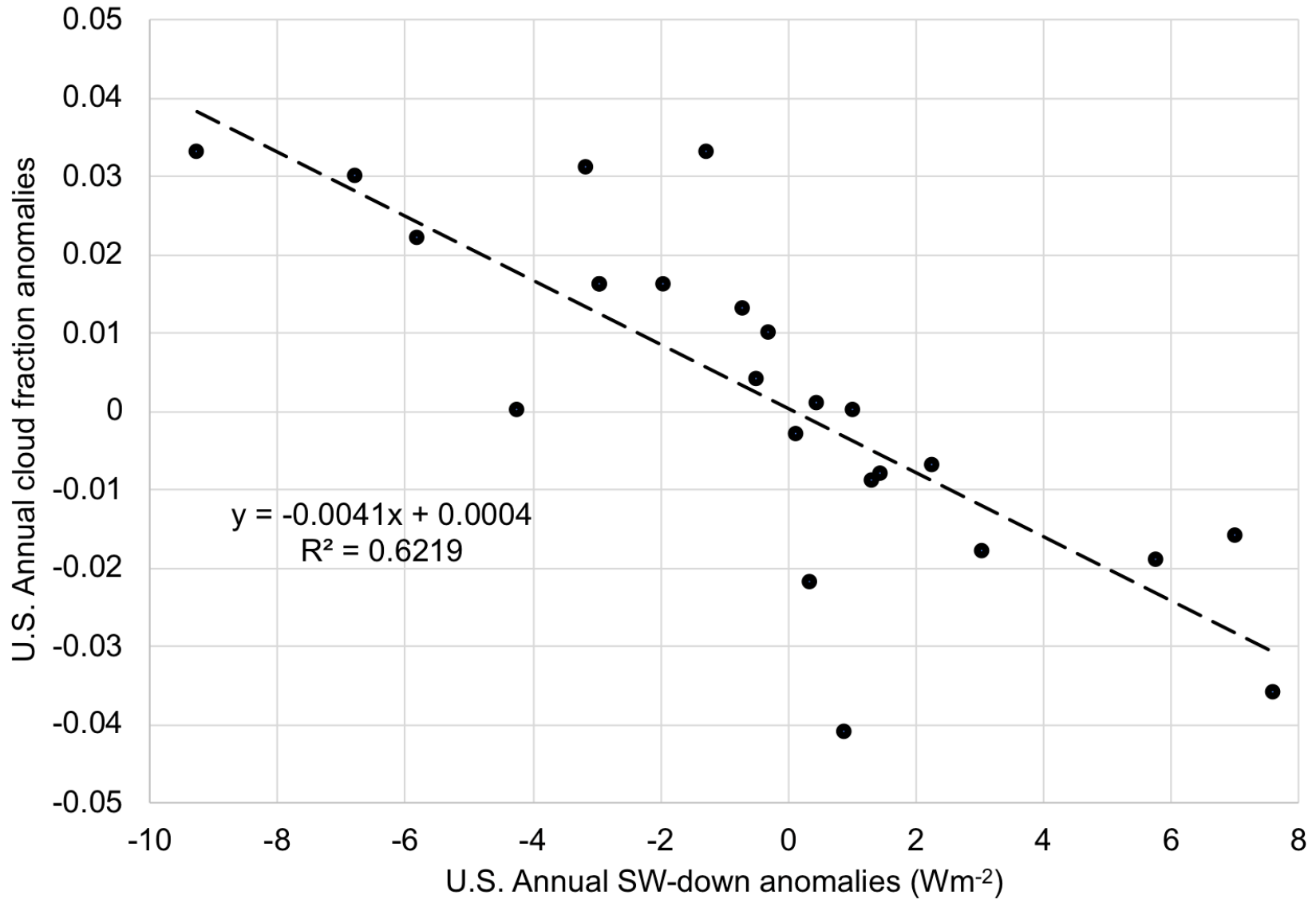


# AOD accounts for 3% of surface solar variability





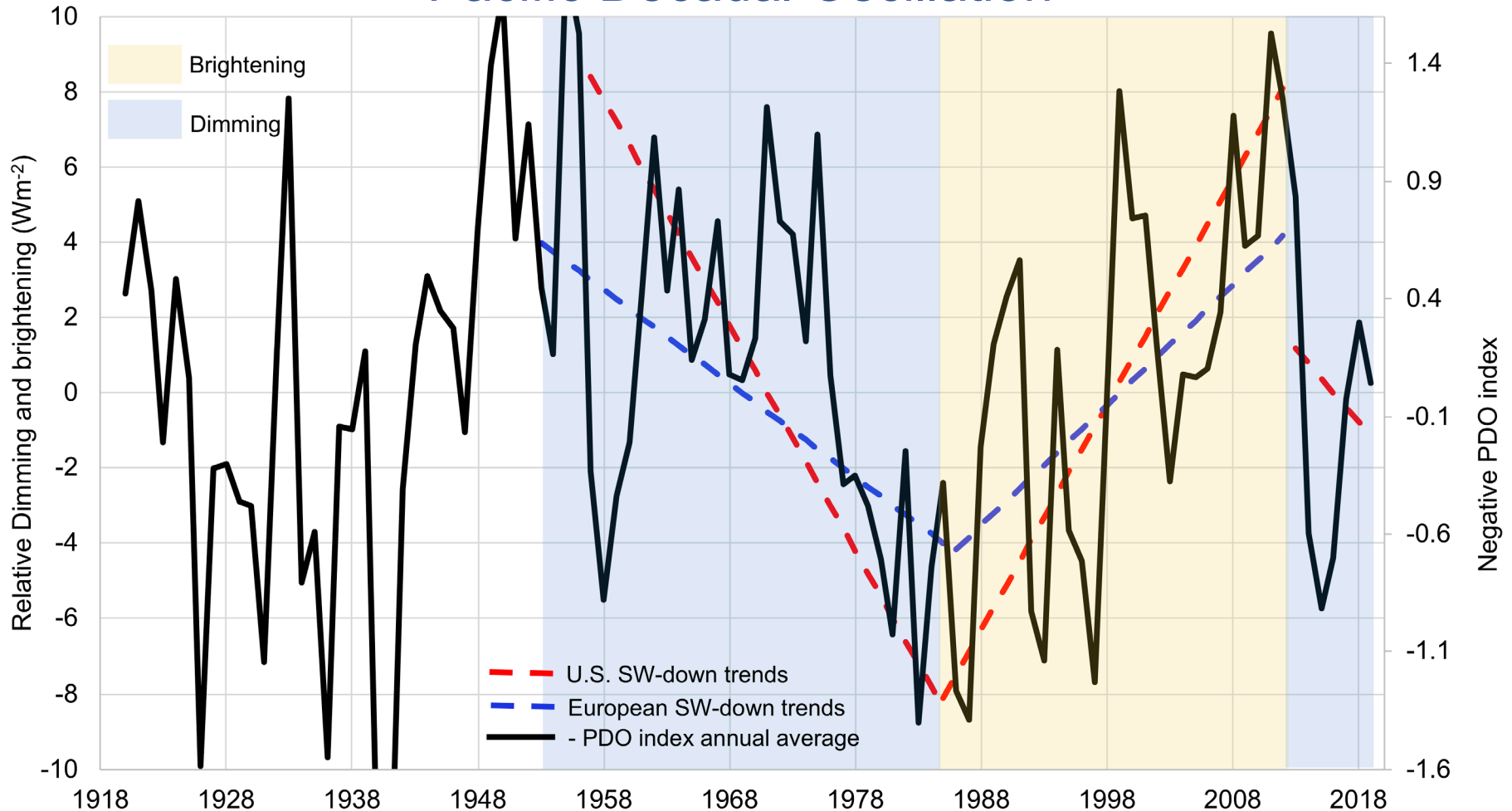
# Cloud fraction accounts for 62% of surface solar variability



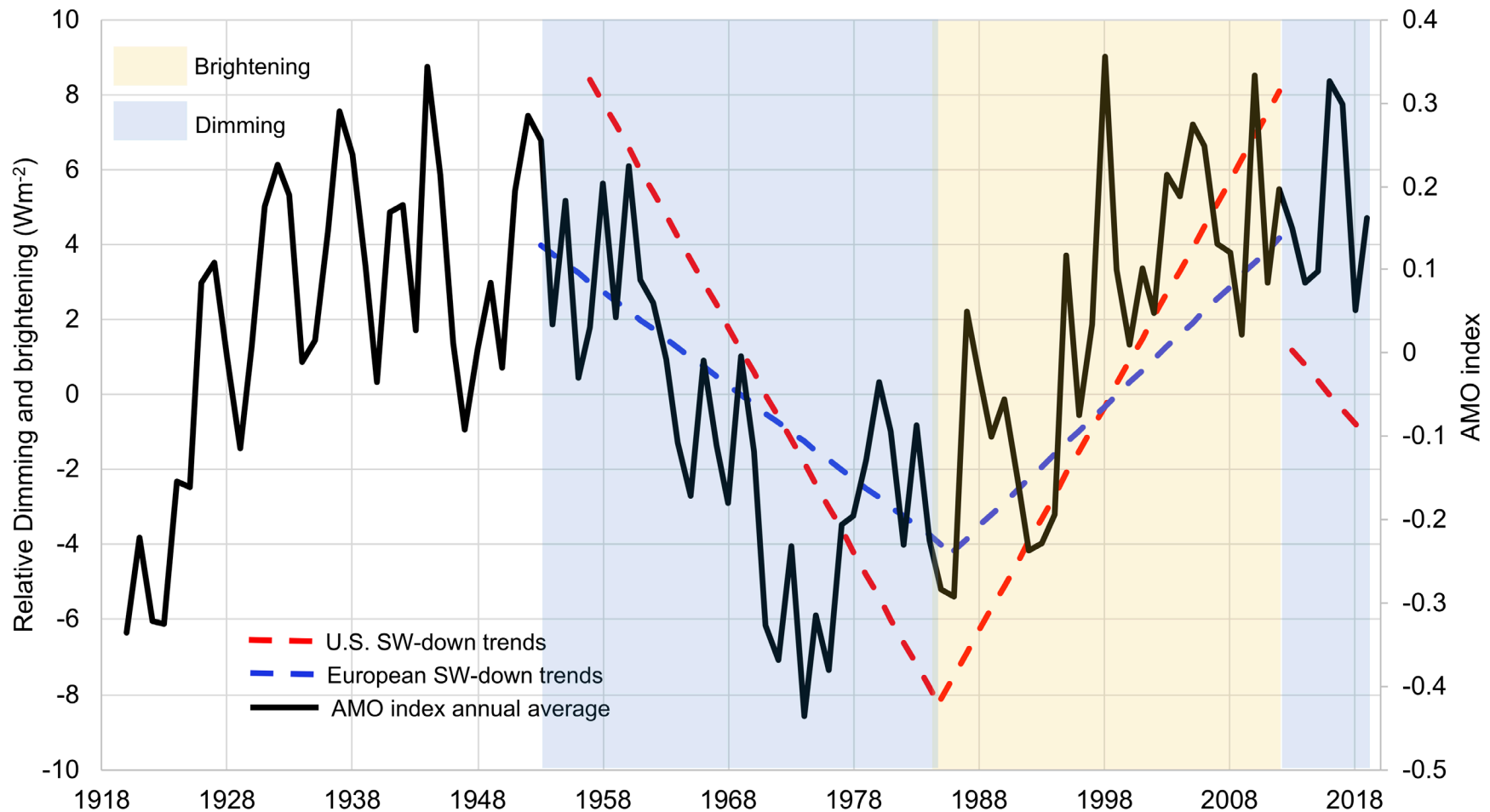
# What forces decadal changes in cloud cover?

Natural variability of the climate system is decadal in nature and some indexes correspond well to brightening and dimming cycles

## Pacific Decadal Oscillation



# Atlantic Multidecadal Oscillation (AMO) of North Atlantic SSTs



## How do changing SSTs relate to weather (clouds)?

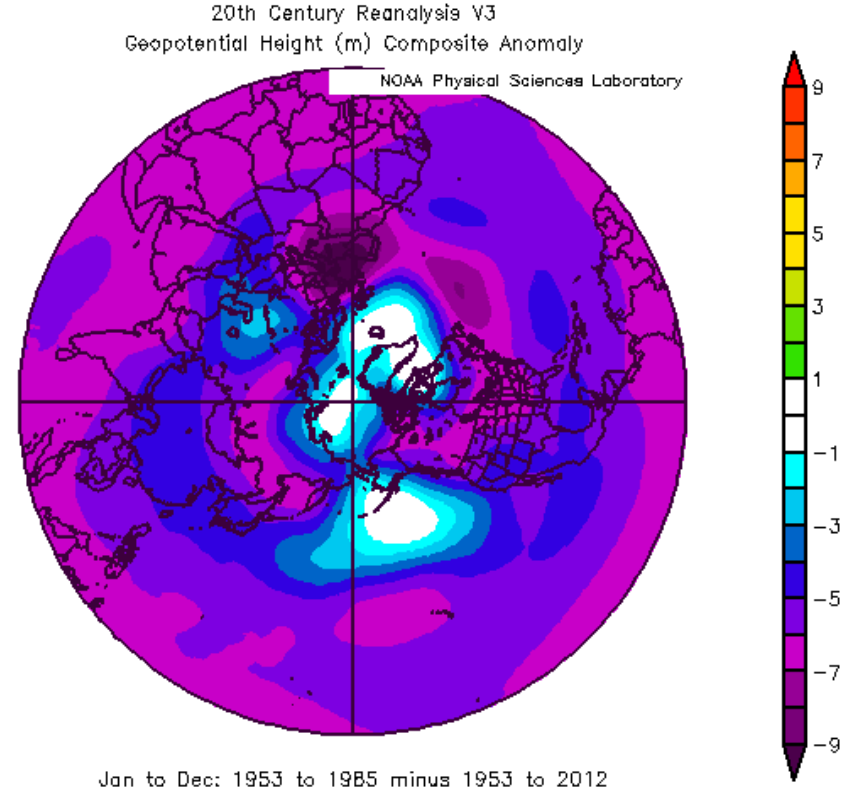
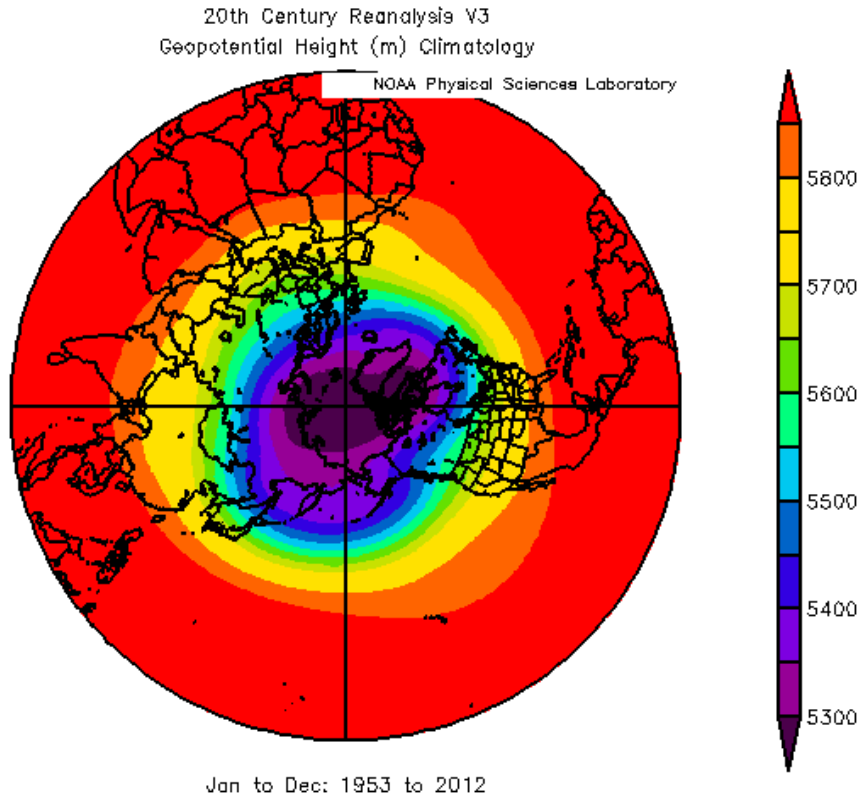
- Weather is forced by temperature and moisture fluxes at the surface
- There is a lot of evidence in the literature that shows northern ocean SSTs having a profound effect on short-term climate over adjacent continents

# Reanalysis was used to reveal weather patterns associated with systematic changes in northern ocean SSTs

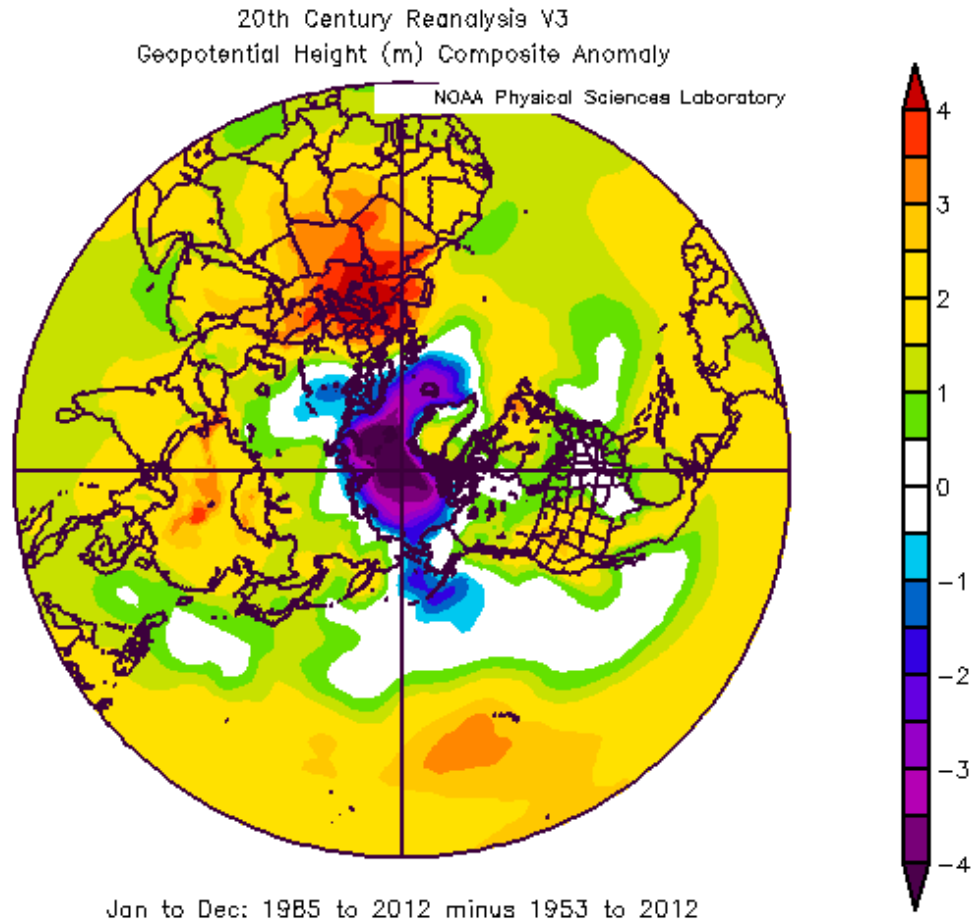
## 500 mb. geopotential heights

Mean 500 mb. height pattern for (1953 - 2012) that includes two well documented dimming and brightening periods

Anomaly pattern for the dimming period (1953 through 1985)



# 500 mb. height anomaly pattern for the brightening period period (1985 through 2012)



# Summary

- Brightening over the U.S. that began in 1980s appears to have ended in 2012
- A new dimming period may have started in 2013 and has continued through 2019
- Surface solar trends over the U.S. have been attributed primarily to systematic changes in cloud cover
- Evidence is presented that decadal-scale variability of North Atlantic and North Pacific SSTs force standing planetary waves that support brightening and dimming over the U.S. and Europe

End of presentation  
Thank you