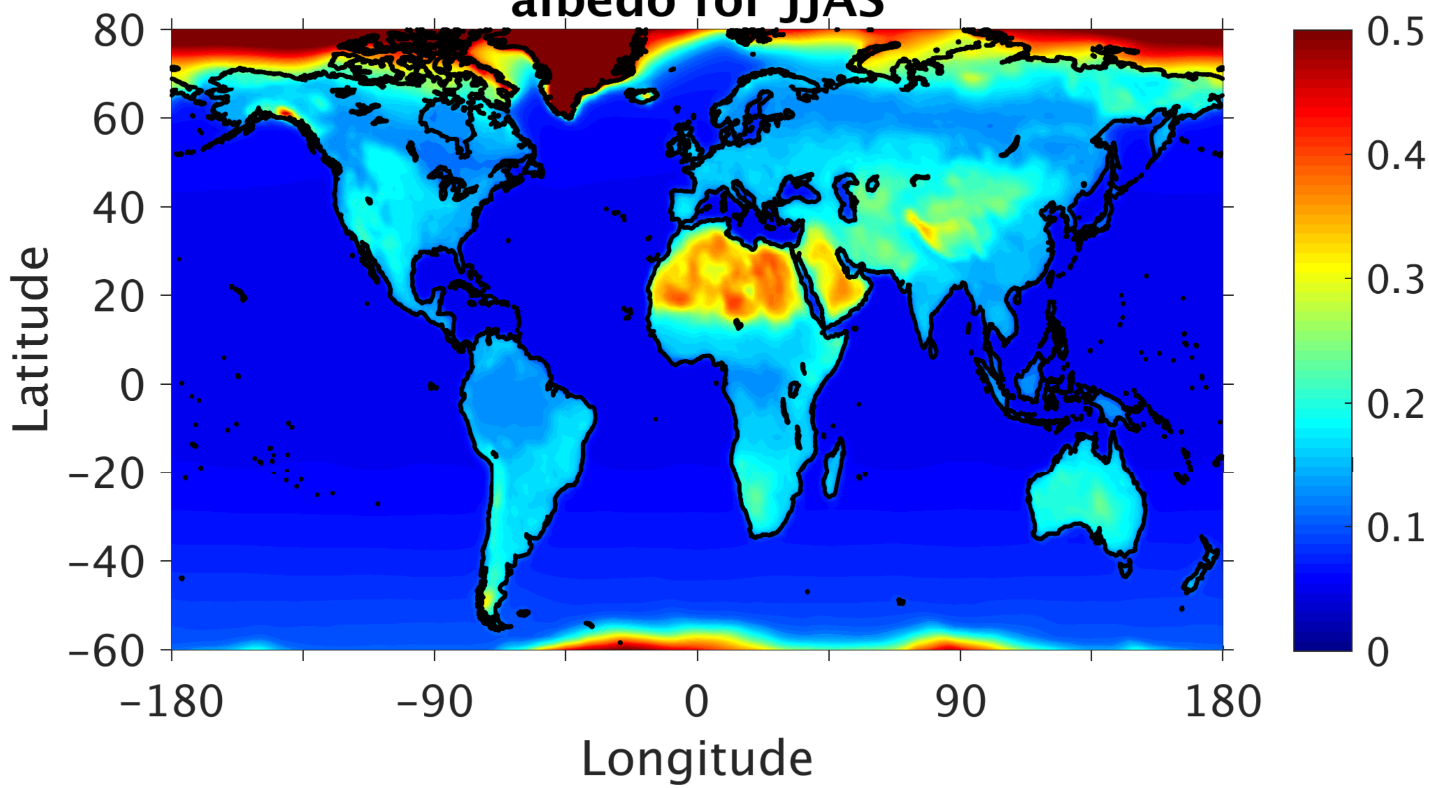
Land surface albedo and its interaction with tropical rainfall in CMIP5 simulations

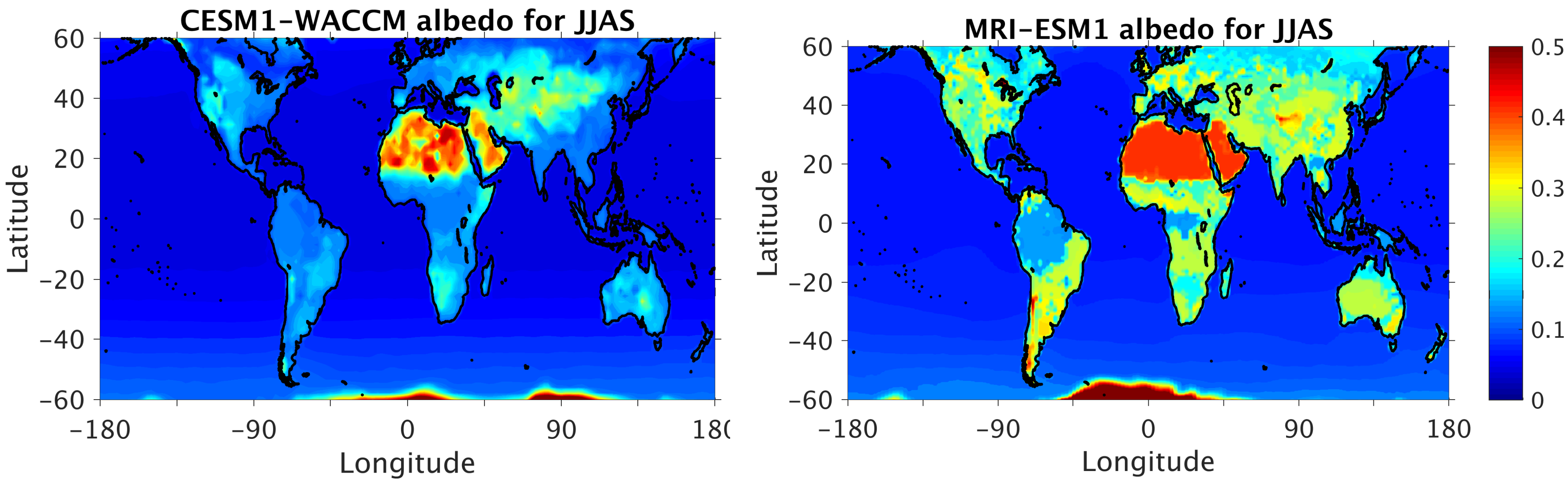
Xavier J. Levine with William R. Boos

June 17, 2016

Yale



Surface albedo can differ substantially among GCMs in CMIP5 archive



broadband shortwave albedo is defined as:

$$\alpha = \frac{SW^{\uparrow}}{SW^{\downarrow}}$$

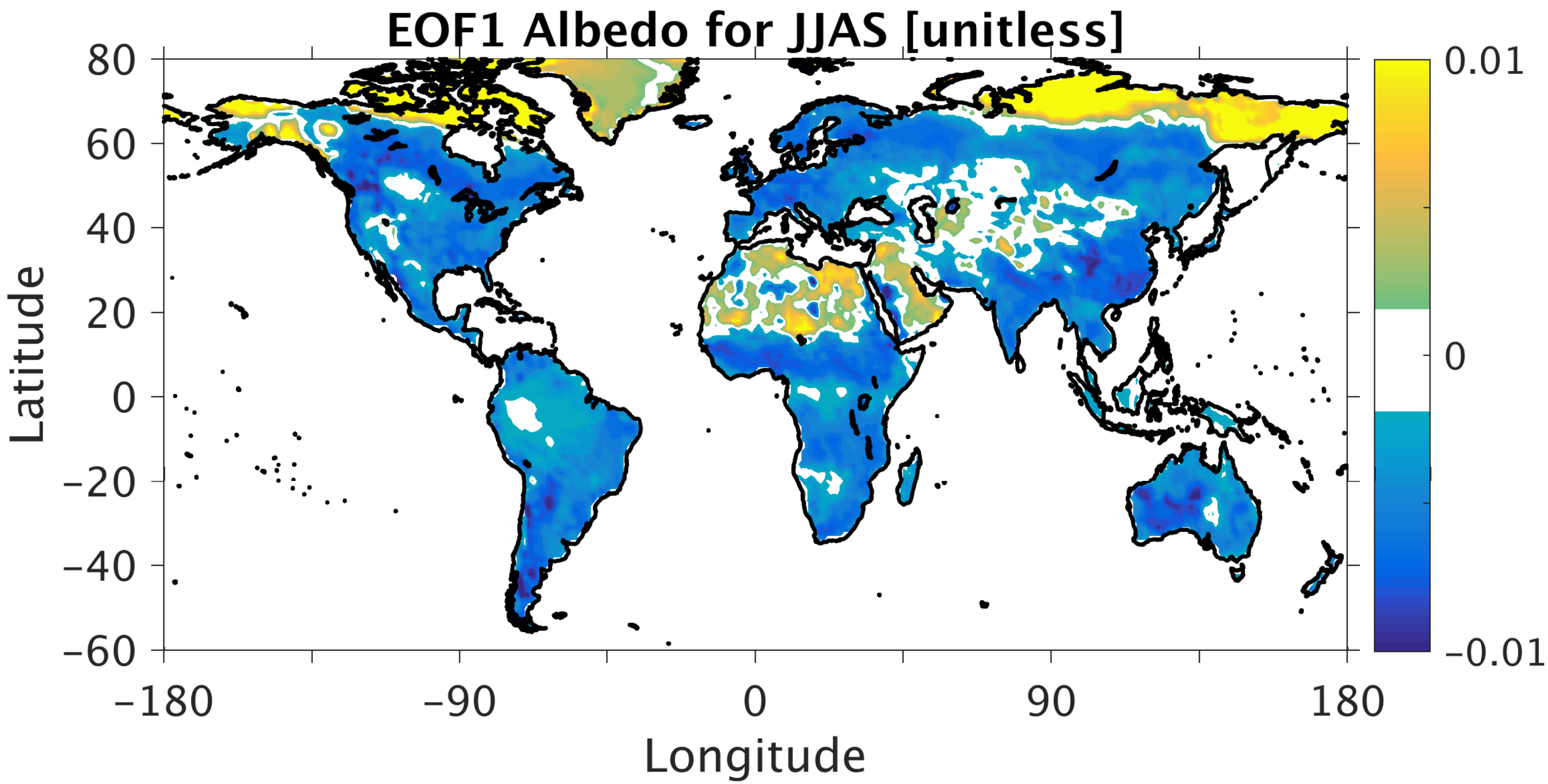
Goals

- **We analyze broadband shortwave albedo in 46 GCM simulations in CMIP5 archive. Simulations cover historical period 01/01/1984-12/31/2004**

- **We compare intermodel (IM) and interannual (IA) albedo variability during boreal summer (JJAS) to that of rainfall.**

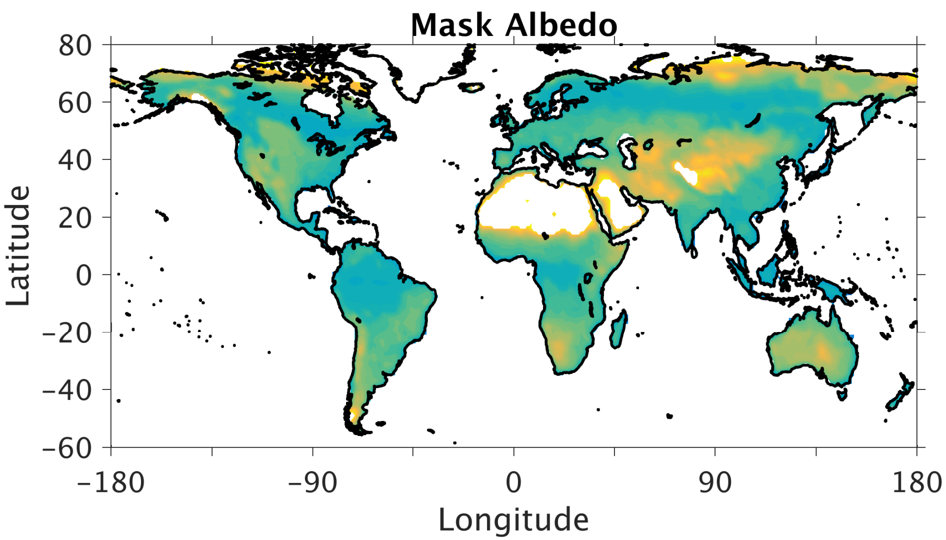
Name	Resl
GPCP Precipitation	2.5000° × 2.5000°
SRB Albedo	1.0000° × 1.0000°
ACCESS1-0	1.8750° × 1.2500°
ACCESS1-3	1.8750° × 1.2500°
BCC-CSM1-1	2.8125° × 2.7906°
BCC-CSM1-1-m	1.1250° × 1.1215°
BNU-ESM	2.8125° × 2.7906°
CanCM4	2.8125° × 3.1476°
CanESM2	2.8125° × 3.1476°
CCSM4	1.2500° × 0.9424°
CESM1-BGC	1.2500° × 0.9424°
CESM1-CAM5	1.2500° × 0.9424°
CESM1-FASTCHEM	1.2500° × 0.9424°
CESM1-WACCM	2.5000° × 1.8947°
CMCC-CESM	3.7500° × 4.1746°
CMCC-CM	0.7500° × 0.8371°
CMCC-CMS	1.8750° × 2.1037°
CNRM-CM5	1.4062° × 1.5800°
CNRM-CM5-2	1.4062° × 1.5800°
CSIRO-Mk3-6-0	1.8750° × 2.1039°
FGOALS-g2	2.8125° × 4.8855°
FIO-ESM	2.8125° × 2.7906°
GFDL-CM2p1	2.5000° × 2.0225°
GFDL-CM3	2.5000° × 2.0000°
GFDL-ESM2G	2.5000° × 2.0225°
GFDL-ESM2M	2.5000° × 2.0225°
GISS-E2-H	2.5000° × 2.0000°
GISS-E2-H-CC	2.5000° × 2.0000°
GISS-E2-R	2.5000° × 2.0000°
GISS-E2-R-CC	2.5000° × 2.0000°
HadCM3	3.7500° × 2.5000°
HadGEM2-AO	1.8750° × 1.2500°
HadGEM2-CC	1.8750° × 1.2500°
HadGEM2-ES	1.8750° × 1.2500°
inmcm4	2.0000° × 1.5000°
IPSL-CM5A-LR	3.7500° × 1.8947°
IPSL-CM5A-MR	2.5000° × 1.2676°
IPSL-CM5B-LR	3.7500° × 1.8947°
MIROC4h	0.5625° × 0.6282°
MIROC5	1.4062° × 1.5668°
MIROC-ESM-CHEM	2.8125° × 3.1215°
MIROC-ESM	2.8125° × 3.1215°
MPI-ESM-MR	1.8750° × 2.1039°
MPI-ESM-P	1.8750° × 2.1039°
MPI-ESM-LR	1.8750° × 2.1039°
MRI-CGCM3	1.1250° × 1.2649°
MRI-ESM1	1.1250° × 1.2649°
NorESM1-ME	2.5000° × 1.8947°
NorESM1-M	2.5000° × 1.8947°

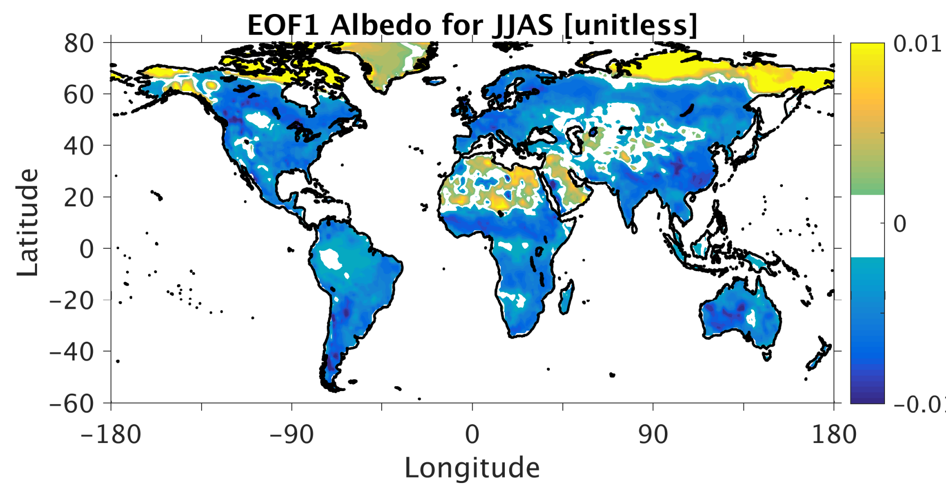
EOF analysis suggests spatially coherent variability for albedo over subtropics and midlatitudes



EOF1 explains 25% of global variability, EOF2 only 17%.

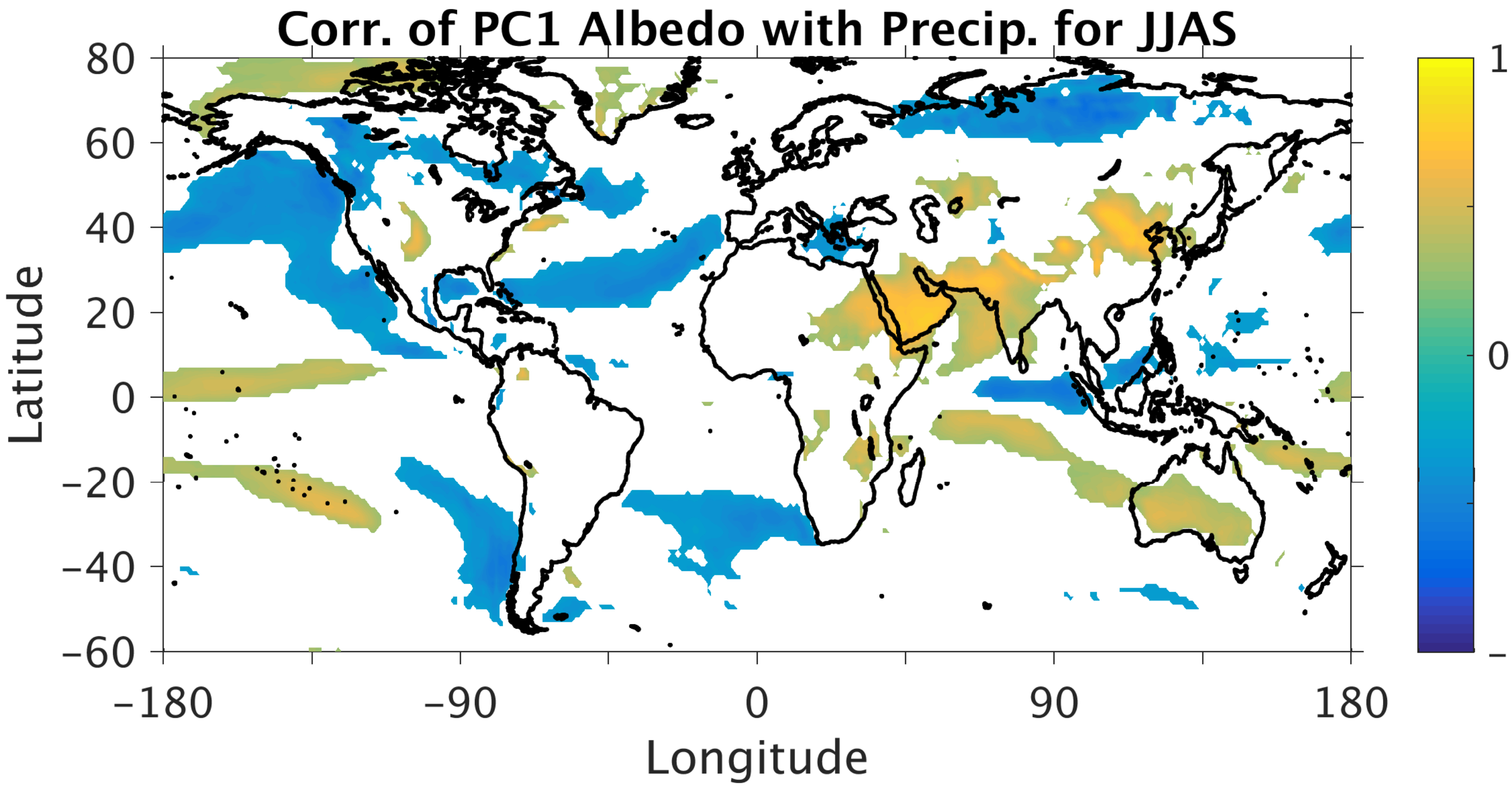
Spatial pattern of EOF1 corresponds to vegetated (dark) regions in tropics





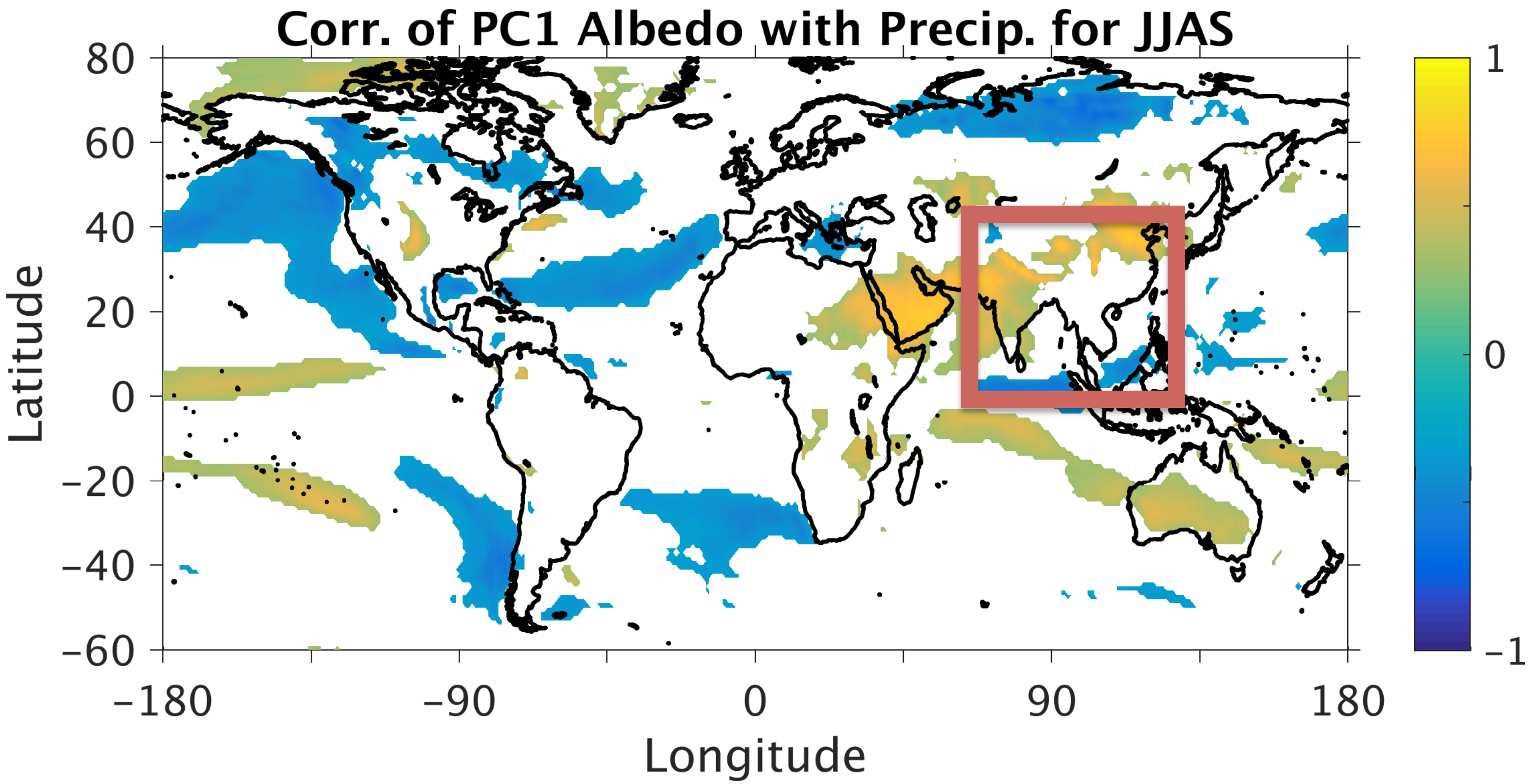
Mask albedo = albedo over regions where it is lower than 0.3

Correlation of PC1 albedo with local rainfall suggests strong interaction over South Asian Continent



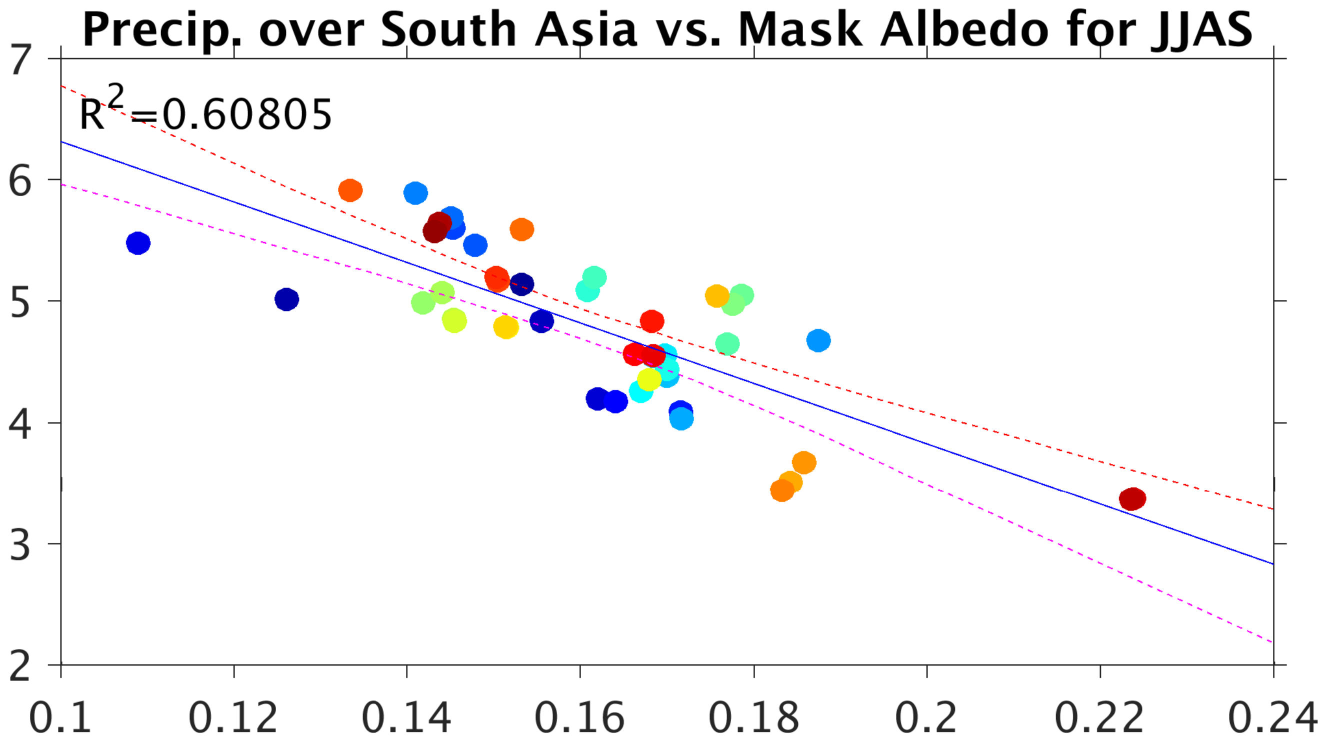
Yellow color: regions where positive rainfall bias scales with negative albedo bias

Correlation of vegetated albedo with local rainfall suggests strong interaction over South Asian Continent



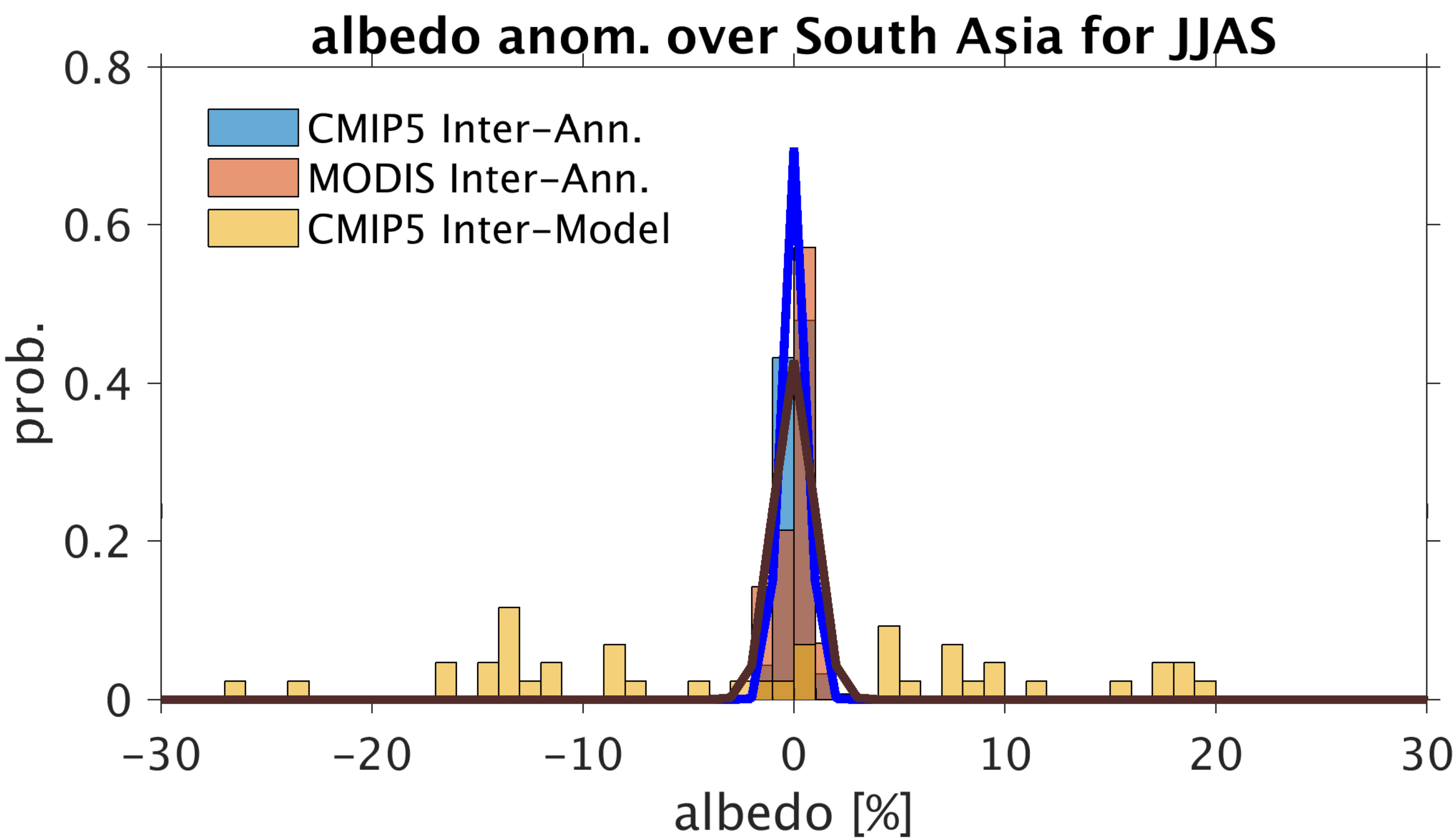
Let's focus on rainfall over South Asia continent

Dark-land albedo correlates well with rainfall averaged over continental South Asia



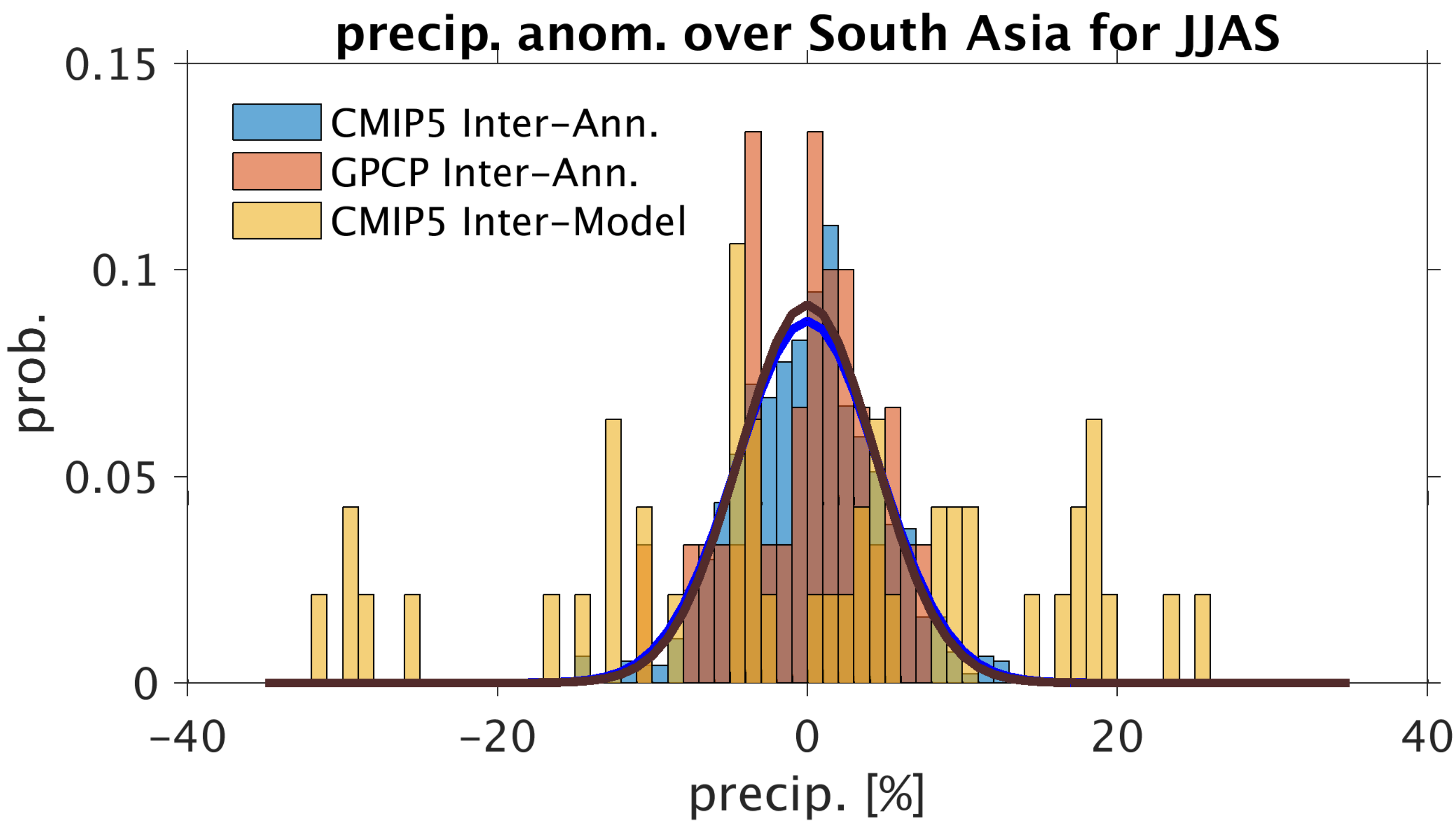
Dark-land albedo is defined as albedo averaged over regions where CMIP5 ensemble-mean albedo is lower than 0.3

Interannual (IA) variability in albedo is small compared to its intermodel (IM) spread



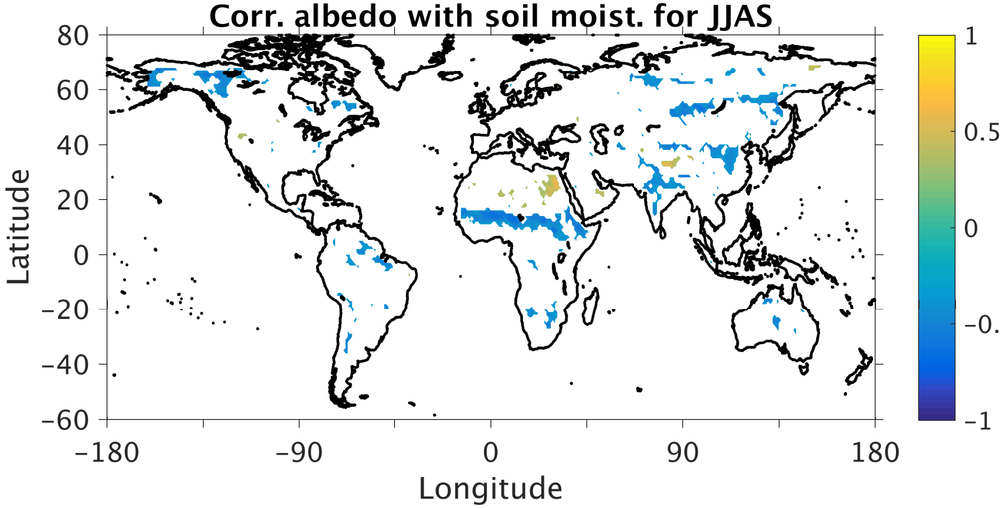
Albedo appears to be insensitive to interannual climate variability

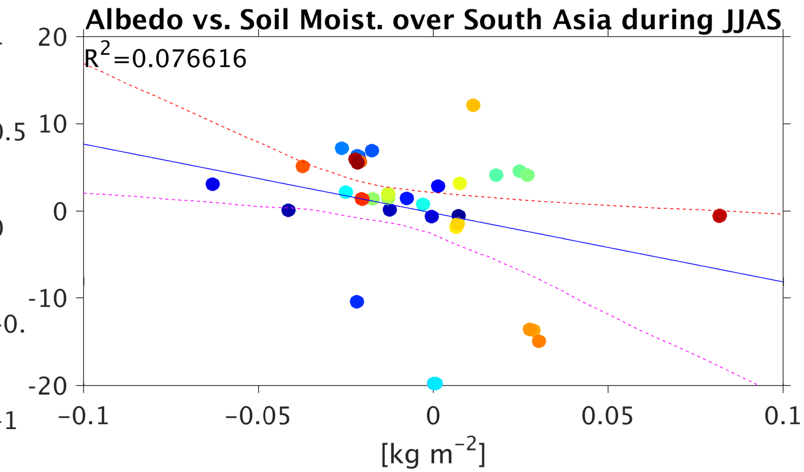
…. while rainfall has large IM and IA variability



➔ **Albedo seems insensitive to rainfall variability on IA timescales, which suggests albedo IM variability is not driven directly by rainfall**

No significant correlation exists between albedo and soil moisture



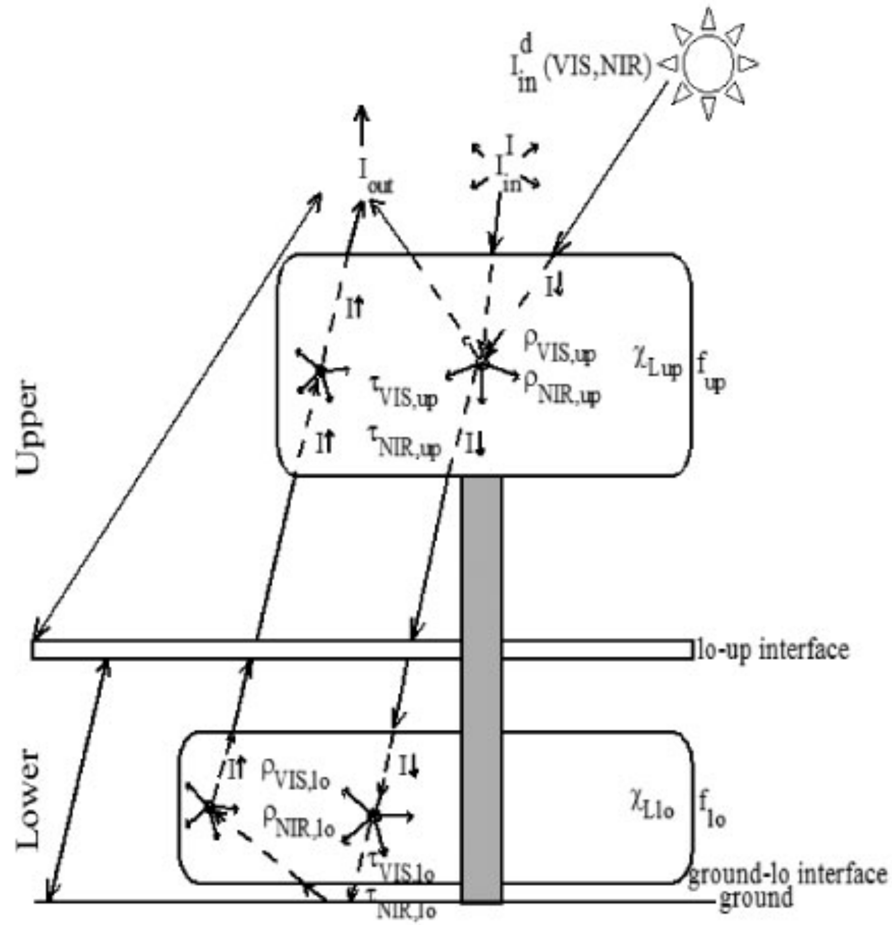


Summary

- Albedo intermodel variability is large in CMIP5.
- Variability is coherent across subtropics and midlatitudes.
- Rainfall intermodel variability over South Asia continent correlates well with global albedo variability.
- Mechanism for albedo influence on rainfall remains unclear, but direct influence of rainfall on albedo seems unlikely.

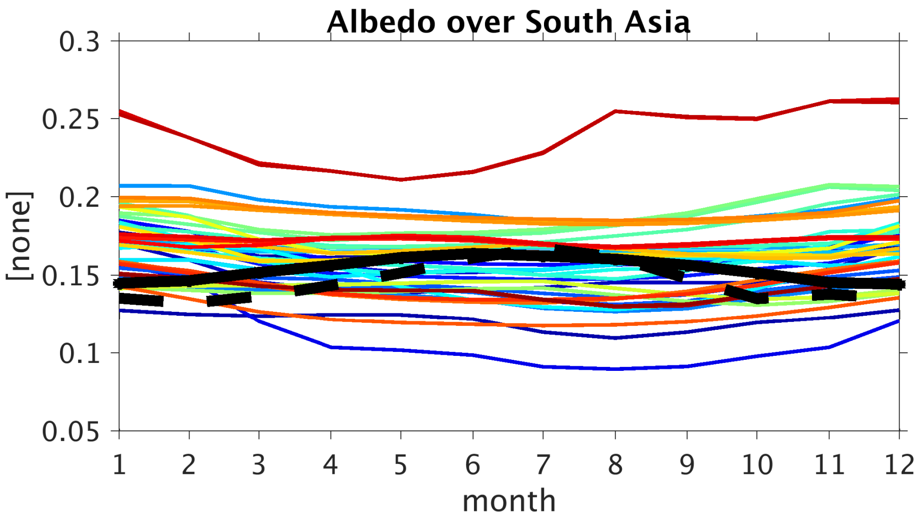
Thank You!

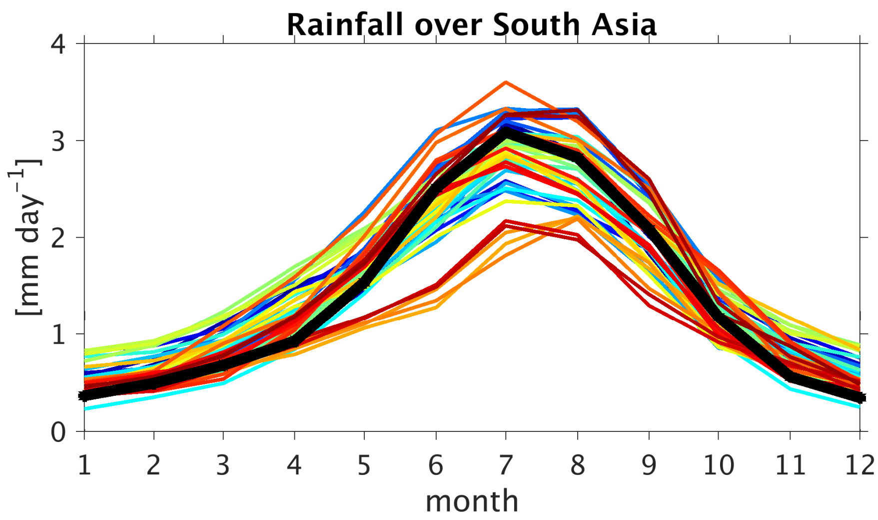
Incoming shortwave flux bias cannot explain the large variability in albedo



Removing all clouds or all water vapor from troposphere, broadband albedo can be lowered by 10 to 20% at most.

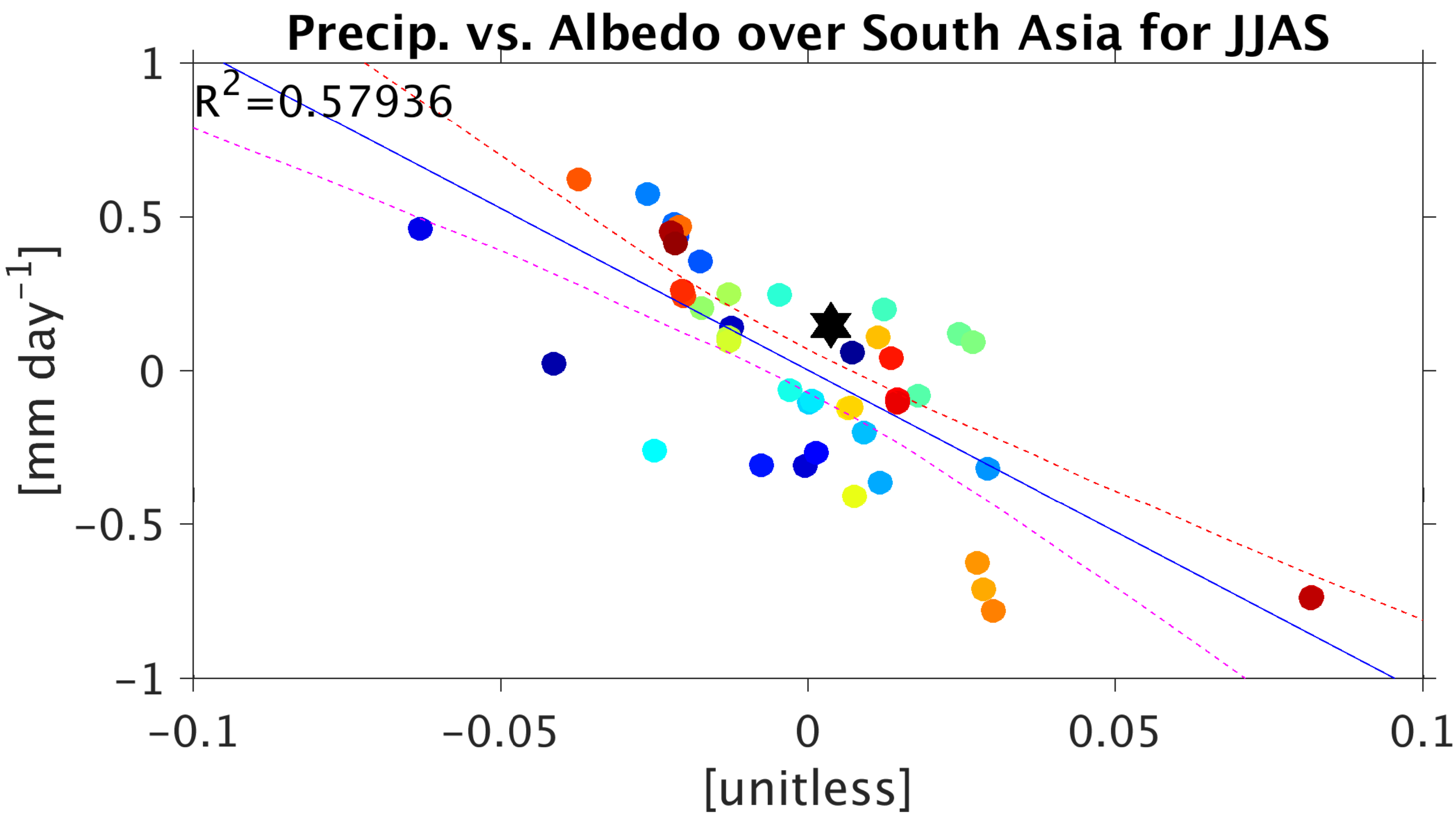
Albedo bias exists in all seasons



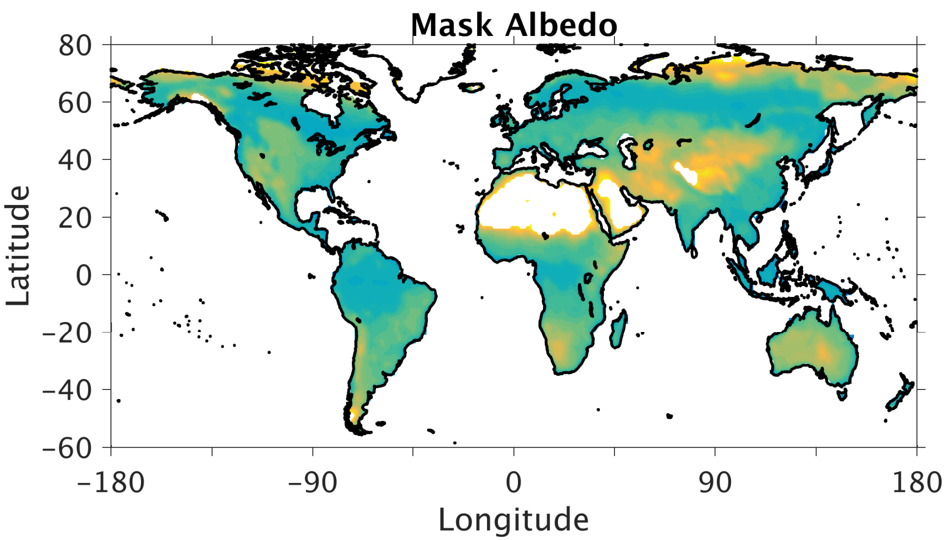


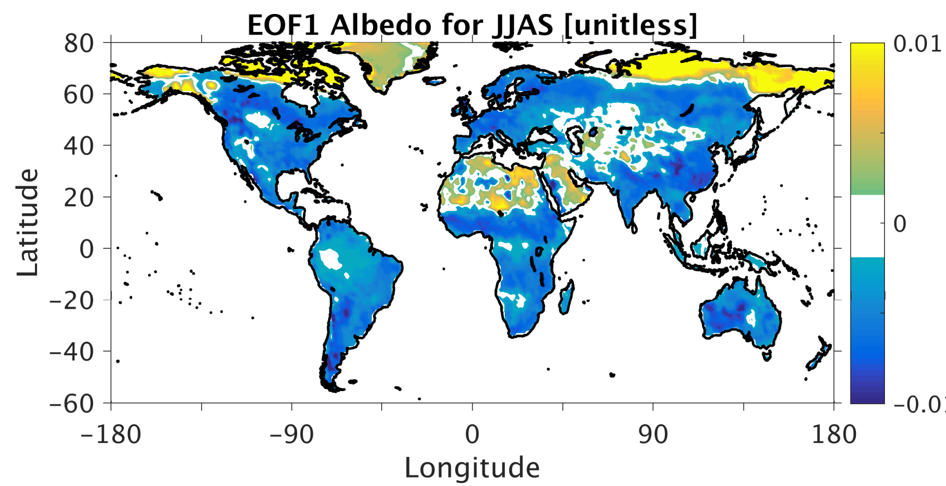
Colors: CMIP5 simulation
Black line: MODIS (albedo) or GPCP (rainfall)

To explain this correlation, we compare albedo and rainfall over South Asia continent



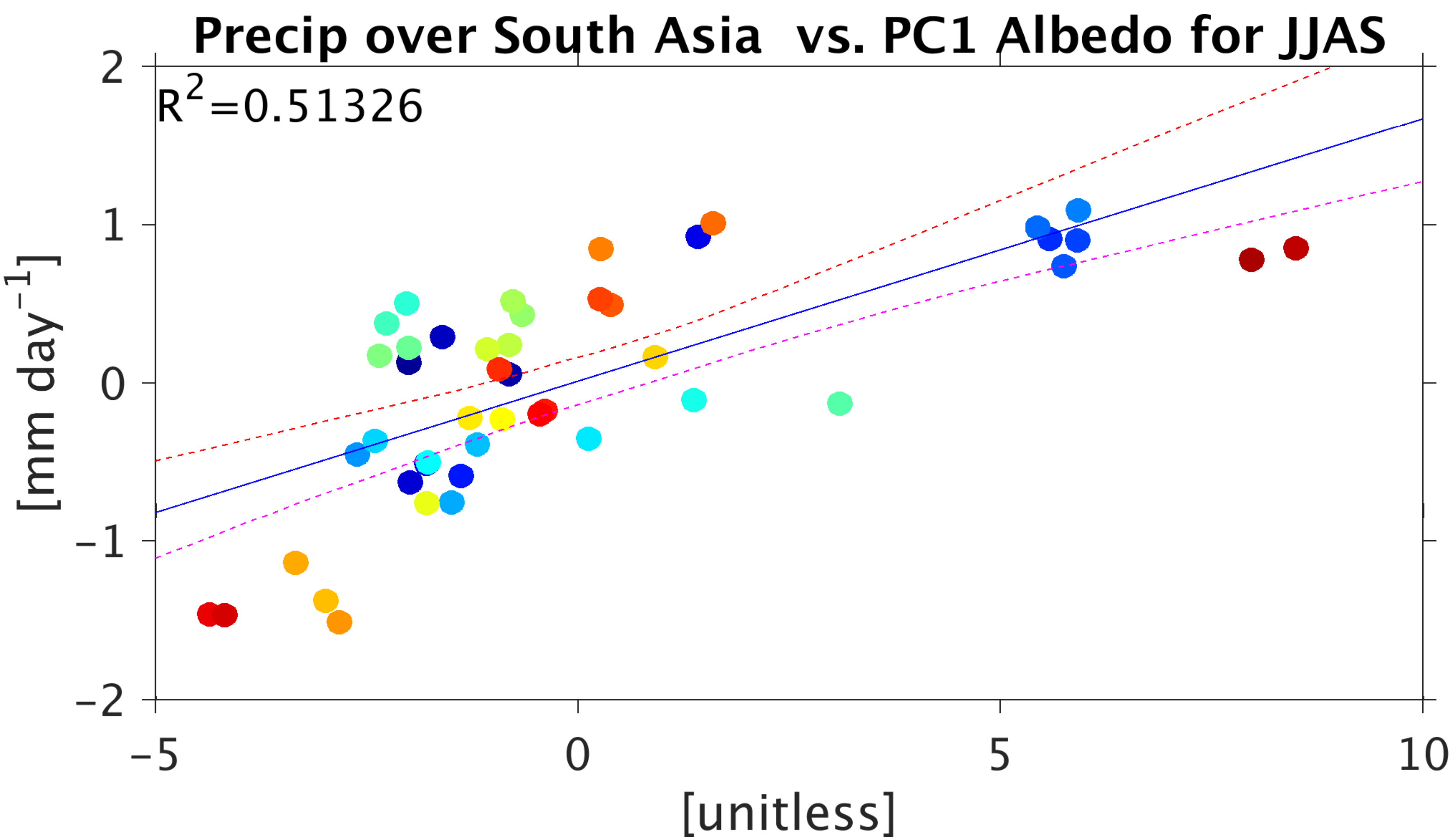
Spatial pattern of EOF1 corresponds to vegetated (dark) regions in tropics



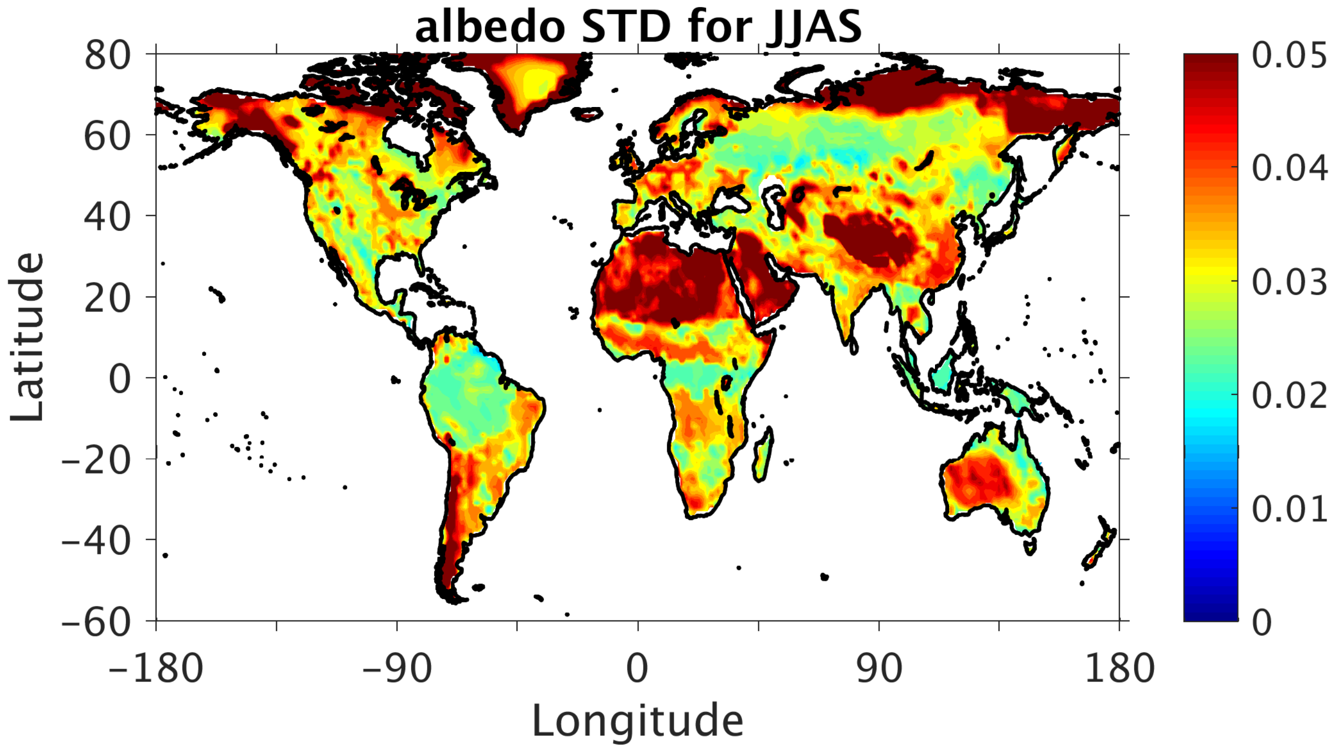


Global albedo bias over vegetated regions (defined as regions where ensemble-mean albedo is lower than 0.3) correlates well with rainfall averaged over continental South Asia

Correlation of rainfall over continental South Asia with PC1 albedo is confirmed

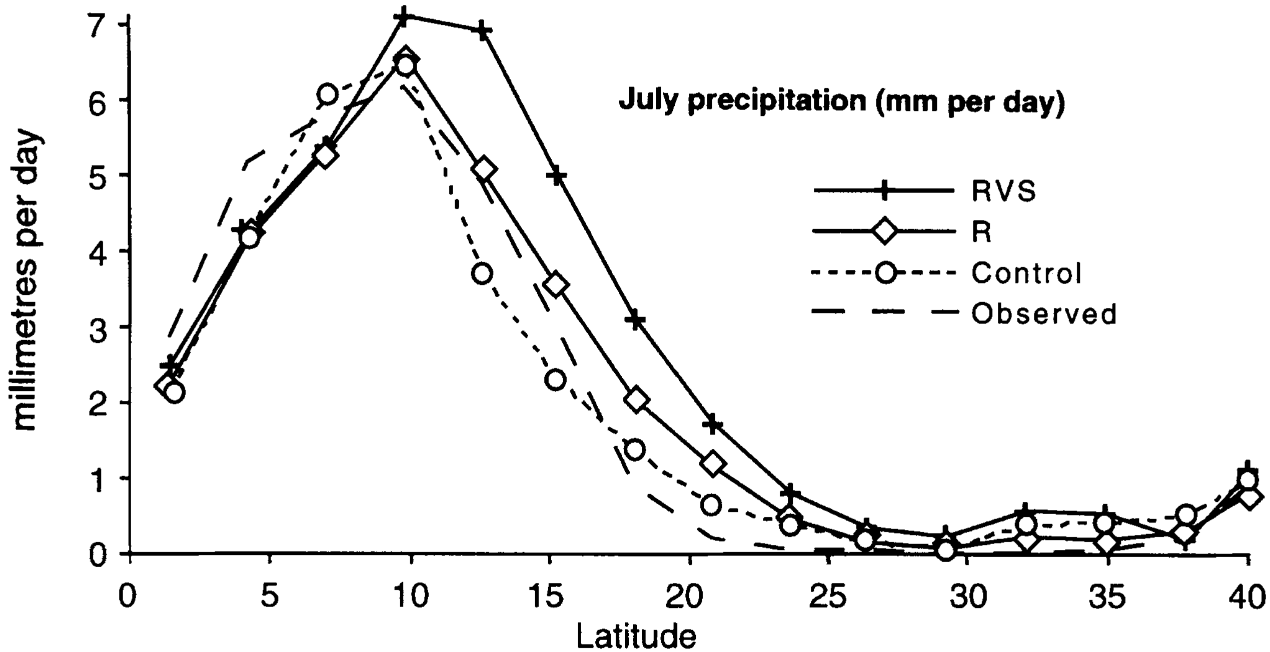


Intermodel variance in albedo



Largest absolute variance over bright regions, snow and ice-covered polar regions, and subtropical dry zones.

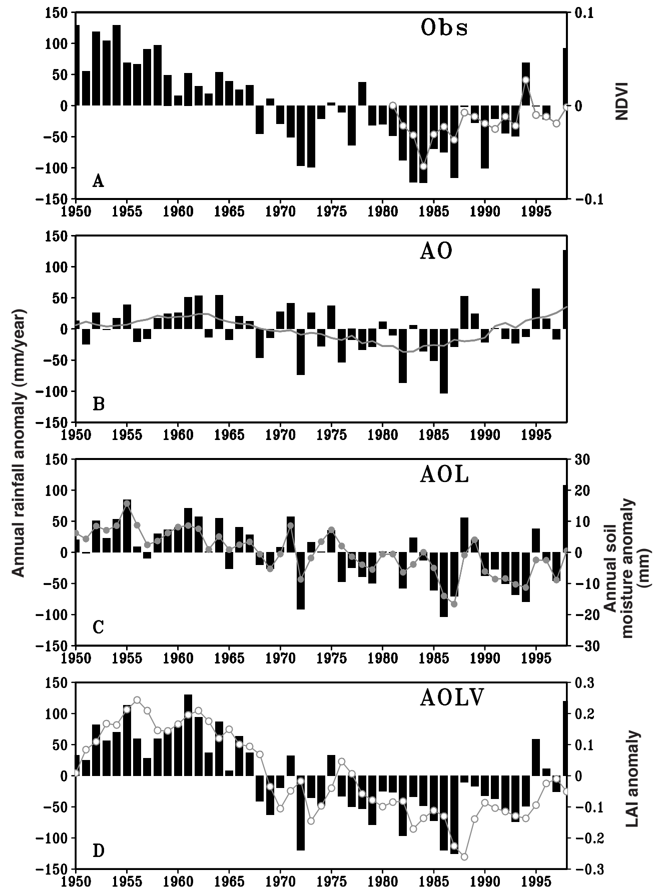
Albedo as a driver of climate change



A lower albedo over North Africa critical for boosting rainfall over Sahara during Mid-Holocene

(Kutzbach et al. 1996)

Albedo as a driver of multiyear variability



observation

SST only

SST + soil moisture

SST + soil moisture + vegetation

Albedo variability amplifies rainfall variability over Sahel

(Zeng et al. 1999)

Incoming shortwave flux bias cannot explain the large variability in albedo