Thoughts on the Application of TSIS/SORCE SSI in the IPCC CMIP Modeling Efforts

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2020 Sun-Climate Symposium
Tucson, January 30, 2020

Acknowledgements: NCAR Supercomputing Facilities

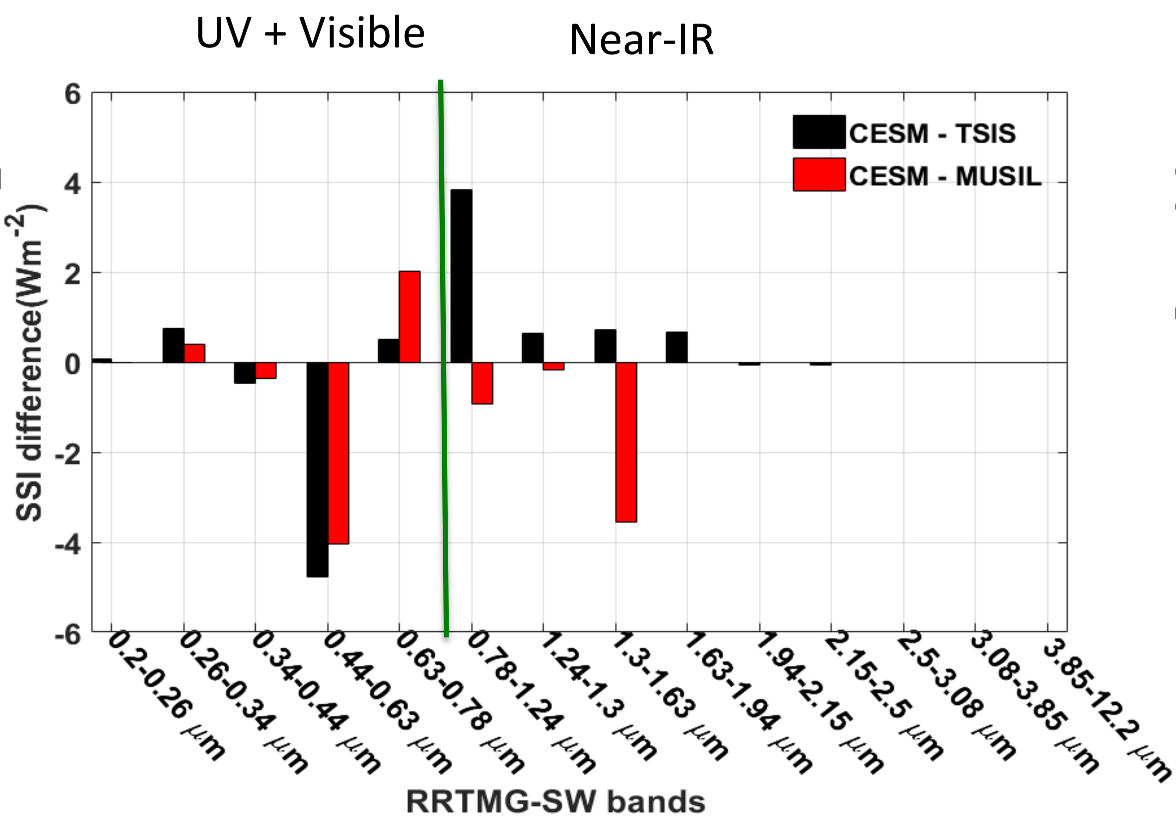
- This talk is about
  - How to use SSI observations (not TSI) in the climate model simulation
  - Compare SORCE/TSIS SSI observations with what have been used in the climate model simulation
    - What are the major differences?
  - What do such differences imply
      - Take-home message: coupled model is needed
      - Uncertainty in visible vs. Near-IR in SSI directly affects simulated high-latitude surface energy budget/climate
  - Preliminary model simulation results
  - I will focus on the troposphere-surface system: most relevant to our climate
    - I will use CESM v2, the flagship climate model from NCAR

Set-up the stage (I): climate model

- Climate models can be run with different configurations
  - Prescribed SST/sea ice runs (AMIP): only atmosphere and land can change
  - Coupled run: ocean can respond
    - Slab-ocean model run (SOM): only thermodynamic response
    - Fully-coupled run: dynamic and thermodynamic responses
  - Very different running cost
  - *Most studies about sun-climate connection employed AMIP-type run*

Set-up the stage (II): shortwave treatment in the climate model

- In atmospheric model
  - Use ~10 bands to cover UV+ Vis+ Near-IR
  - E.g. RRTMG_SW in the CESM: 14 bands (9 in Near-IR)

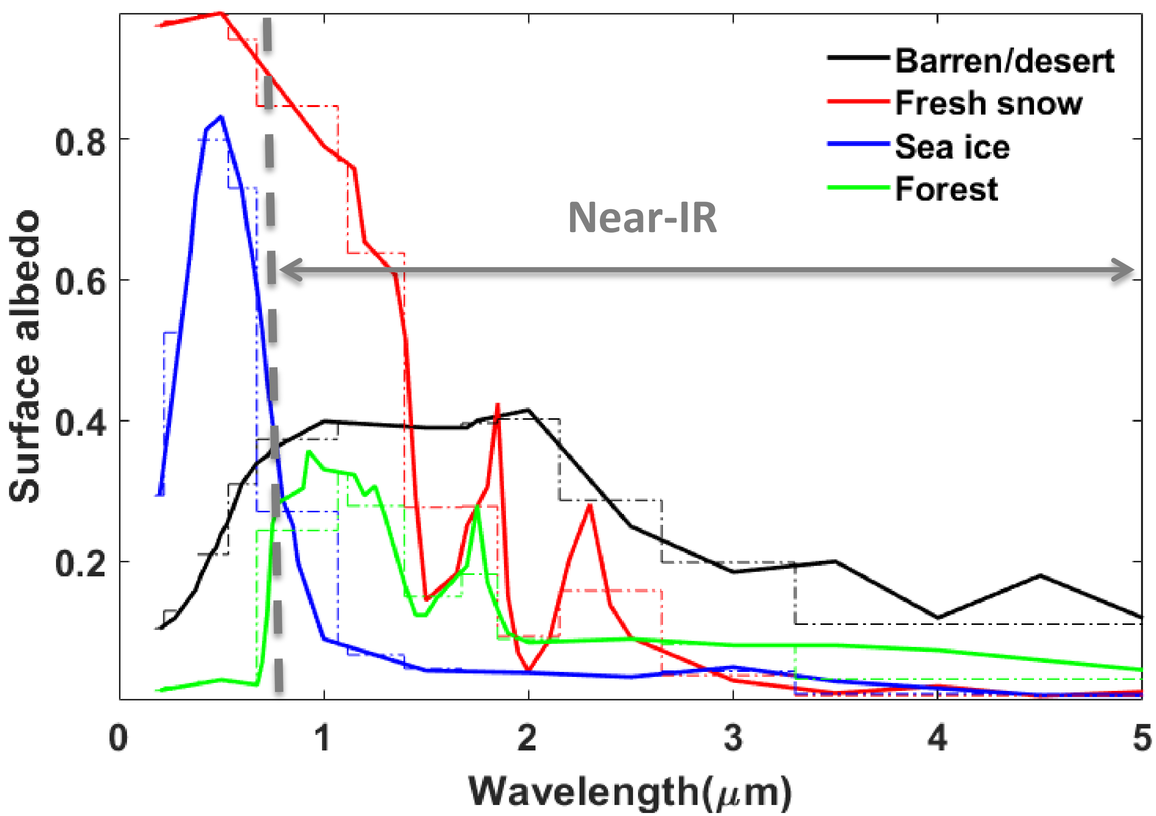


ɔ of surface

ʌo bands: Visible vs.

Set-up the stage (III): surface spectral reflectance Visible vs. Near-IR

Actual measurement



Values in the CESM

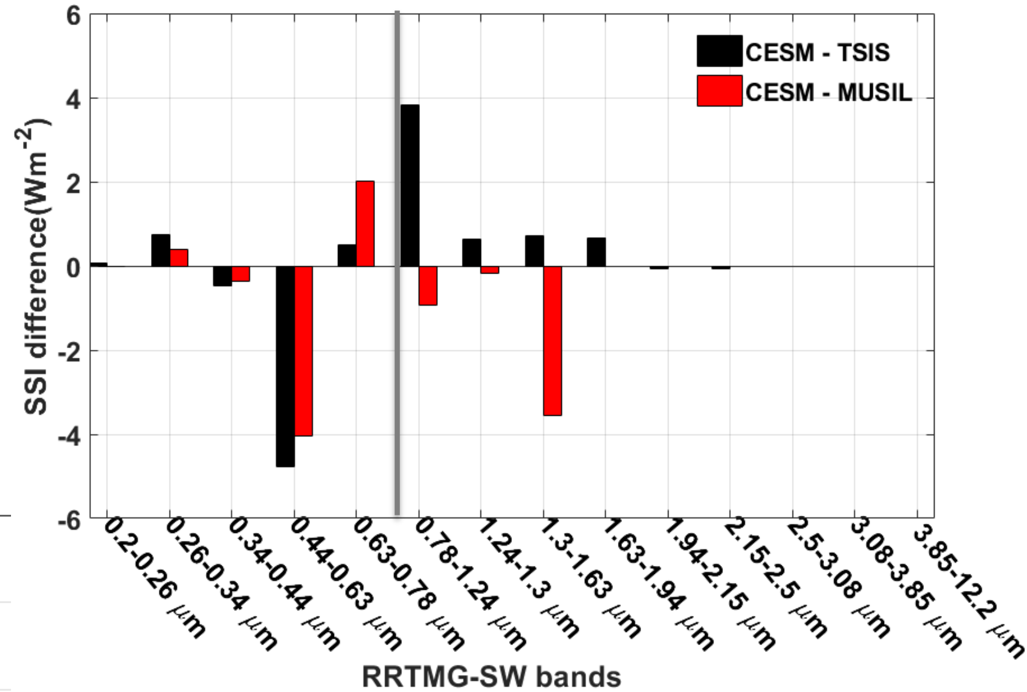
Surface	VIS	NIR
Dry Snow	0.98	0.70
Wet Snow	0.88 min	0.55 min
Bare Ice	0.78	0.36
Melting Ice	0.71 min	0.29 min
Open water	NA	NA

Bottom Line: Snow and ice surfaces have sharp VIS-vs-NIR reflectance difference

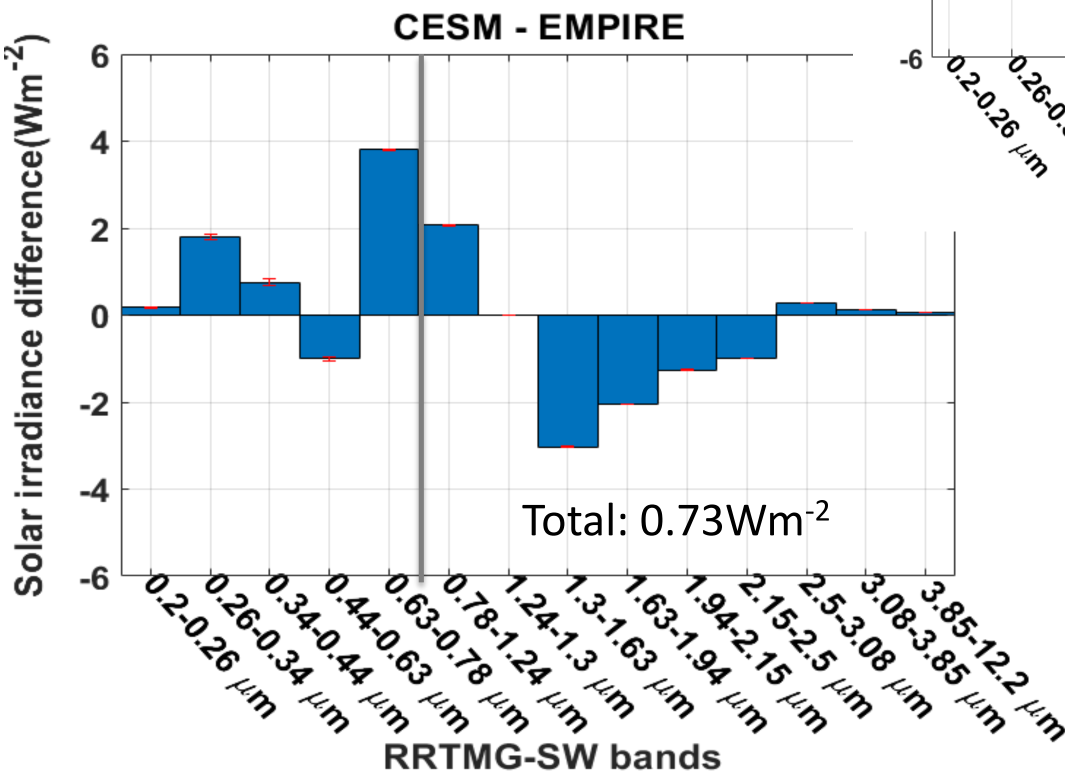
- Questions to be addressed
  - Do we have the right VIS-vs-NIR specifications for the SSI used by the climate modeler?
  - If not, how much can it affect the simulation
    - A model with allowable sea ice change is needed
    - Suface needs to respond here. Prescribed SST/sea ice won't do the work
  - Both can be investigated using SORCE/TSIS SSI measurements

	From	Download site	Time period and WV range	References
EMPirical Irradiance REconstruction (**EMPIRE**)		http://lasp.colorado.edu/lisird/data/empire_ssi/	Feb.14,1947-May13,2017; 0.115 – 160 μm	A robust empirical reconstruction of solar irradiance variability Yeo et al. 2017, JGR doi:10.1002/2016JA023733
Multiple Same-Irradiance-Level (**MuSIL**)	SORCE	http://lasp.colorado.edu/lisird/data/musil_sim/	Apr.14,2003-Aug.29, 2017; 0.24 -1.6 μm	Total solar irradiance (TSI) record has an estimated relative uncertainty of about 5% of the measured solar cycle variability. Woods, et al, Decoupling Solar Variability and Instrument Trends using the Multiple Same-Irradiance-Level (MuSIL) Analysis Technique, Solar Phys., 293, A76, 2018.
TSIS	Spectral Irradiance Monitor (SIM)	https://disc.gsfc.nasa.gov/datasets?keywords=TSIS&page=1	Mar.14,2018-Aug.13, 2019; 0.2 -2.4 μm	Absolute accuracy is about 2% in the visible (about 10% in the infrared) https://acdisc.gesdisc.eosdis.nasa.gov/data/TSIS_Level3/TSIS_TSI_L3_24HR.02/doc/README.TSIS.pdf.
CESM (used for virtually all CMIP6 models)	spectral_irradiance_Lean_1978-2014_daily_GOME-	https://svn-ccsm-inputdata.cgd.ucar.edu/trunk/inputdata/atm/cam/solar/	1978-2014; 0.121-100 μm	Modeled using GOME Mg index Lean et al., JGR, 116, A01102, doi:10.1029/2010JA015901, 2011; Adjusted using 0.9965, Wang, Lean & Sheeley, Astrophys J (2005) vol.

Annual-mean difference on the RRTMG_SW bandwidth



2000-2014, CESM - EMPIRE



- Compared to EMPIRE:
- The offset between VIS and Near-IR.
- Diff in one band can be much larger than that of TSI

Make solar spectral irradiance for CESM simulation

Control run dataset (Solar_avg_CESM_control.nc)
(1) do multi-year average from daily solar spectral irradiance of CESM
(2) scale it using TSIS total solar irradiance

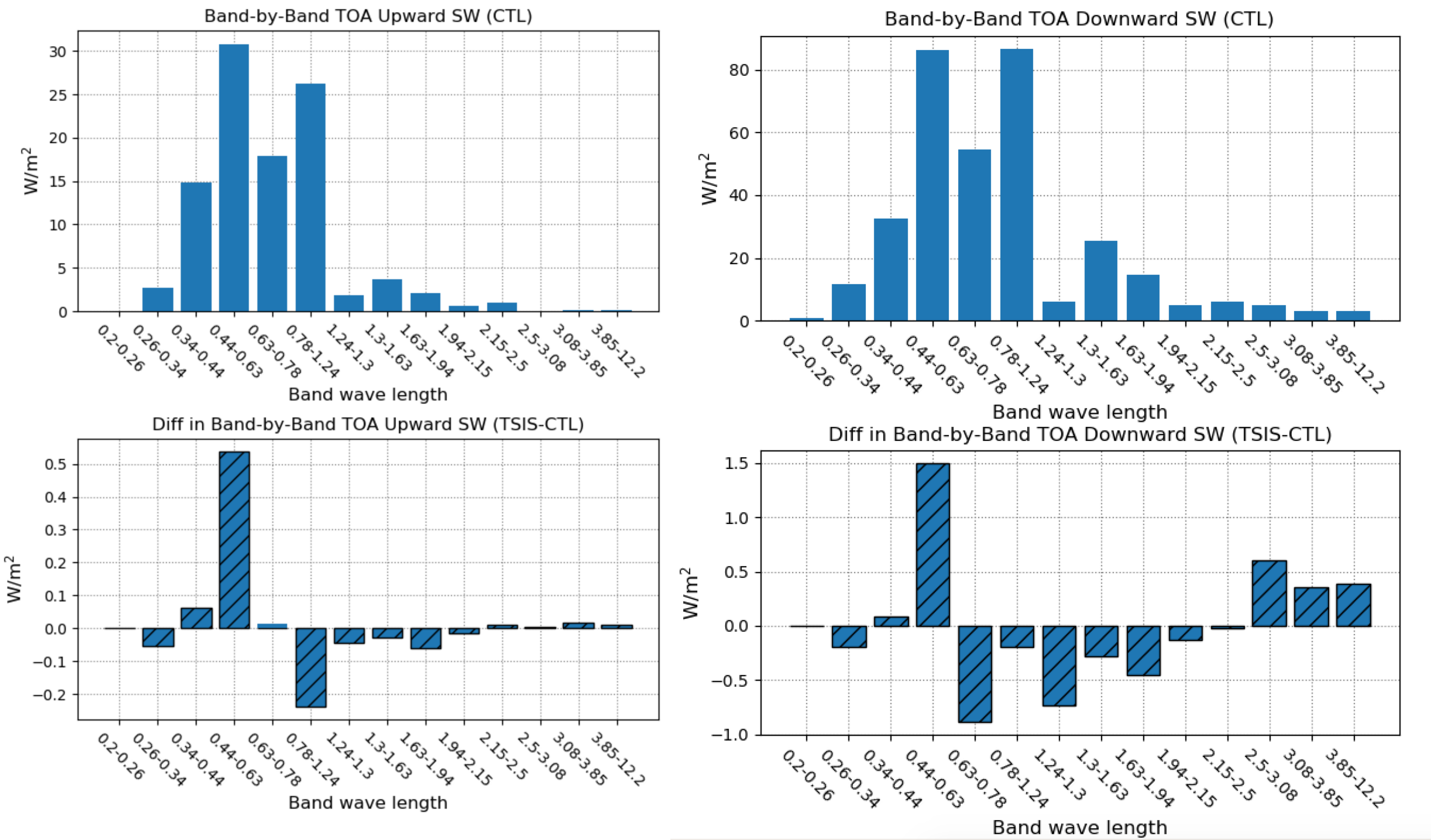
TSIS run dataset(Solar_avg_CESM_TSIS.nc)
(1)Use **TSIS** measurements from 0.2-2.4 micron
(2) for <0.2 micron and >2.4 micron, the spectral shape is same as the control run dataset, but scaled to have the TSI identical to the control run dataset

Same TSI, but different SSI specification. Repeating every year.

Simulation Set-up

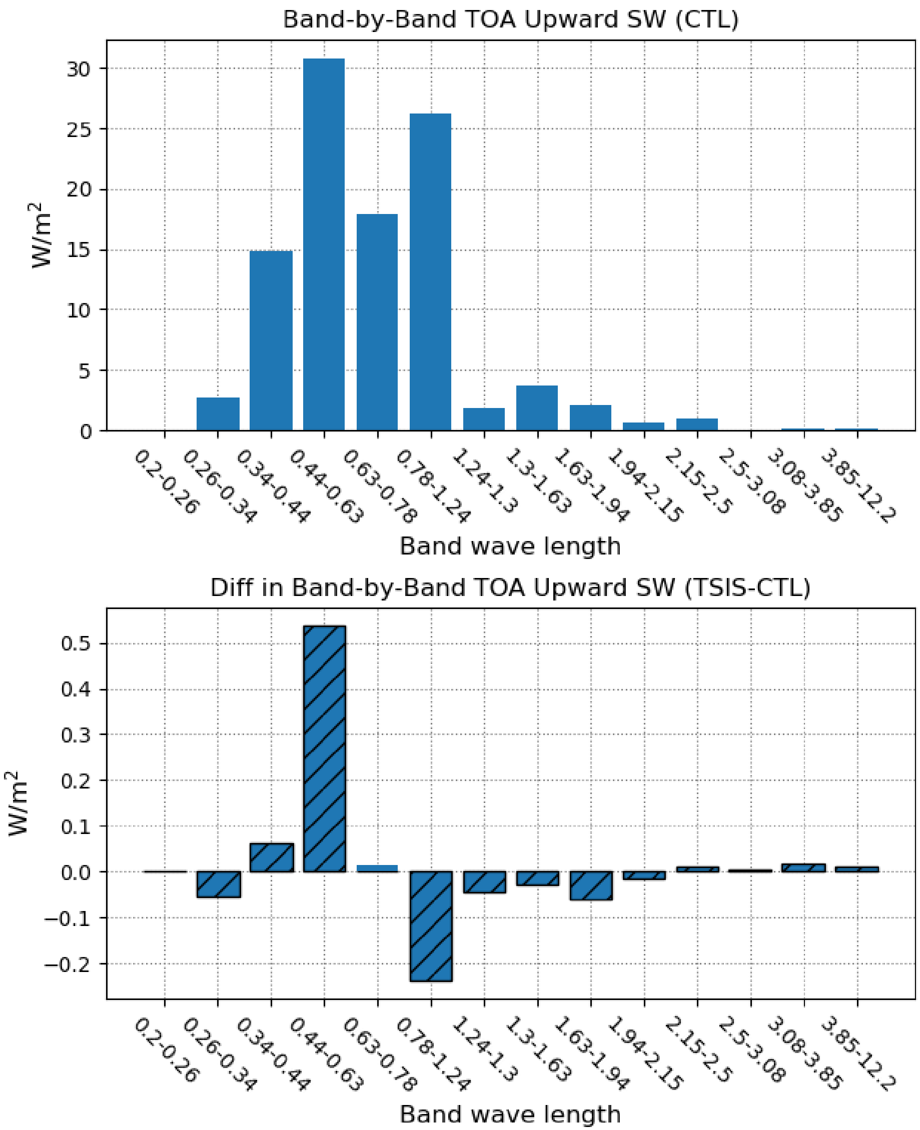
- Model version:
  - CESM 2.1.1
- Model components (compset=ETEST):
  - CAM6 physics; Sea ICE (cice) model version 5; DOCN **slab ocean model**; MOSART River runoff; Stub glacier (land ice) component (SGLC); Stub wave component (SWAV).
- Gases:
  - O3, OH, NO3, and HO2 are prescribed as the 3-D (lon-lat-lev) climatology for 2000 (averaged between 1995-2005), with a temporal resolution of 5 days.
  - Surface emissions for CO2, CH4, N2O, CFC11eq, CFC12 are the 2000 climatology (averaged between 1995-2005) with a temporal resolution of 1 month.
- Aerosol and precursor emissions: fixed at the 2000 level.
- Four-member ensemble runs
- Simulation period:
  - 2000-2019. Ensemble mean of the last 10 years (2010-2019) are used for the analyses.

TOA Annual Global Mean

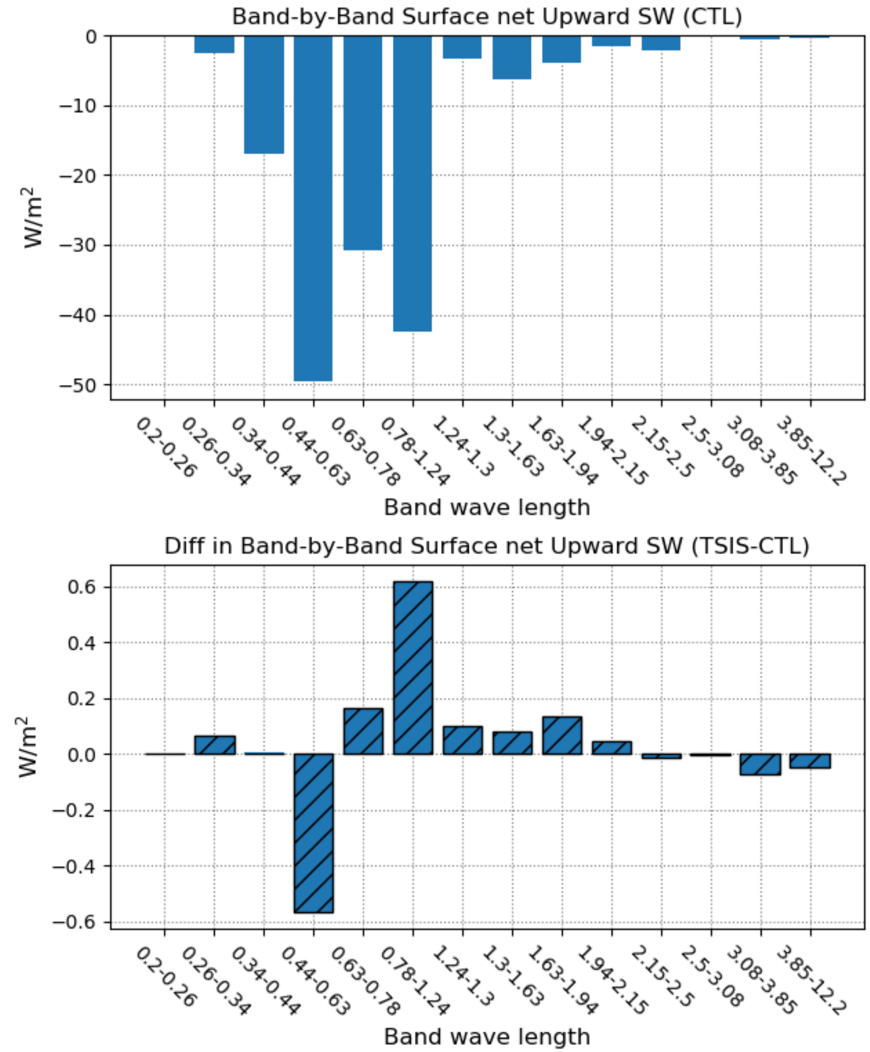


Total difference = 0.005Wm^{-2}

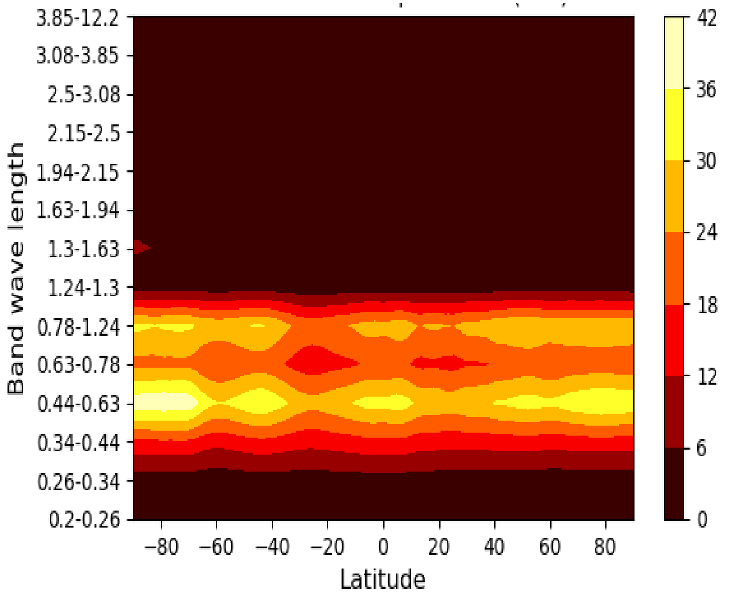
TOA Annual Global Mean



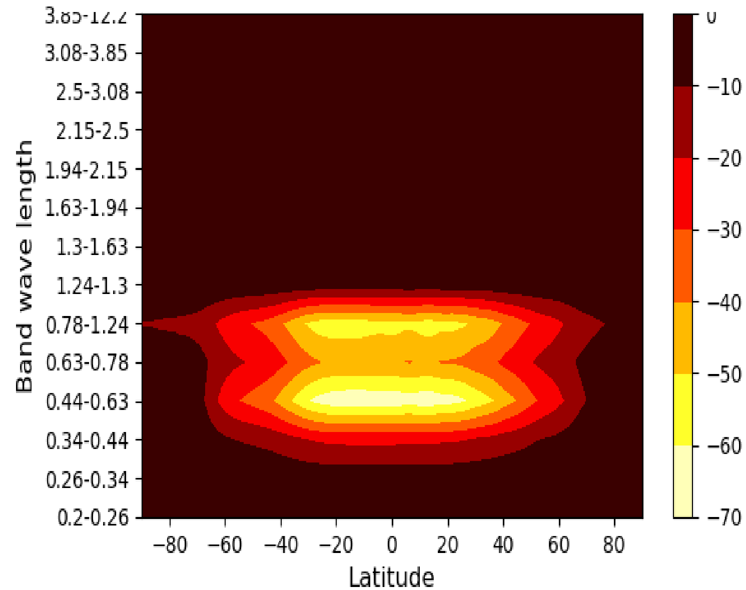
Surface Annual Global Mean

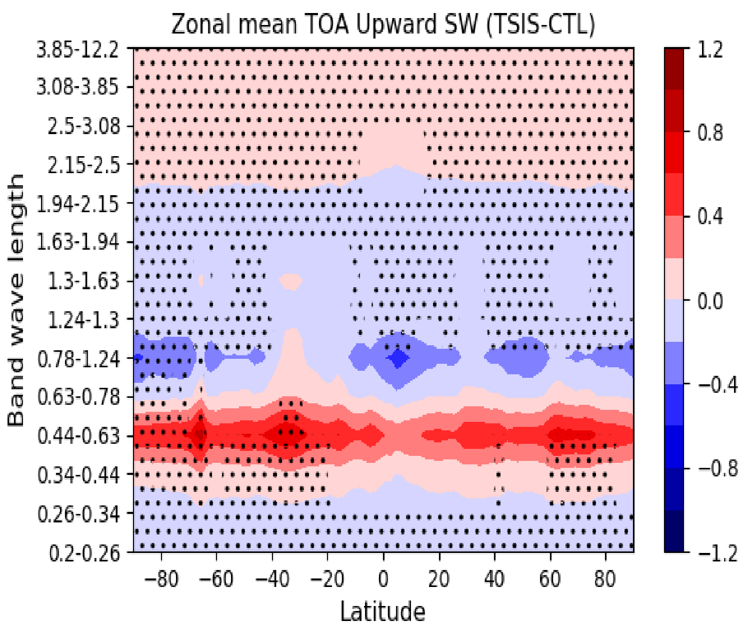


Annual-mean TOA Upward Flux

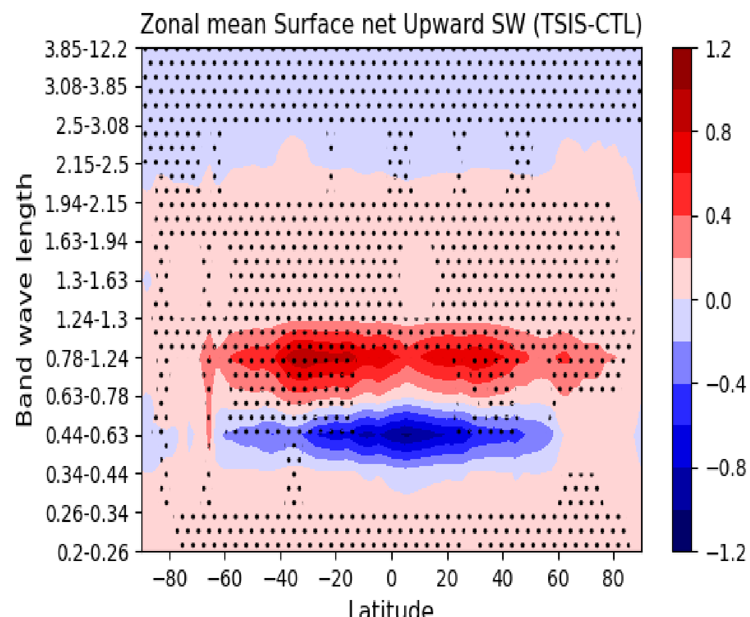


Annual-mean Surface Upward Flux





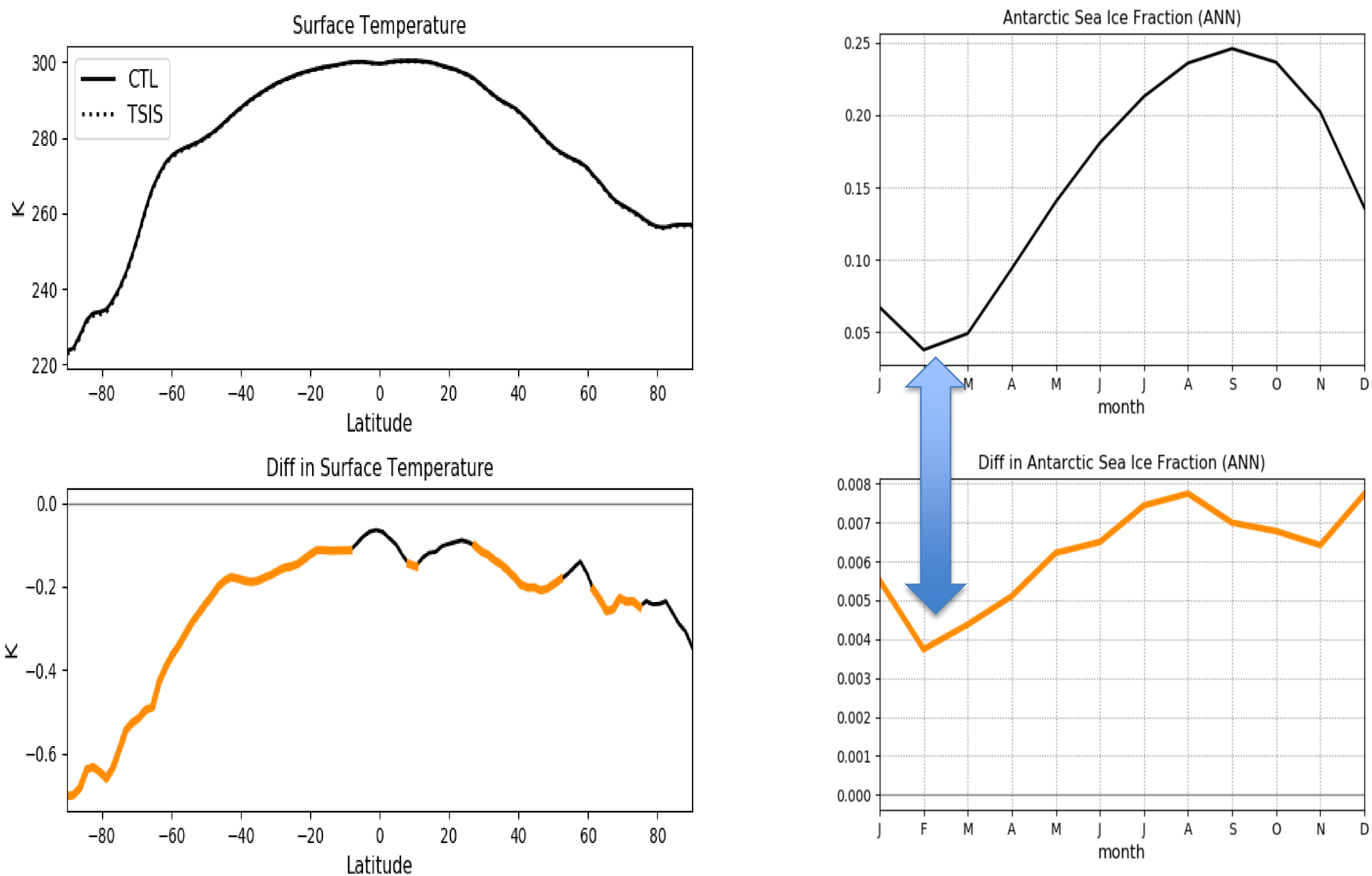
Positive upward.



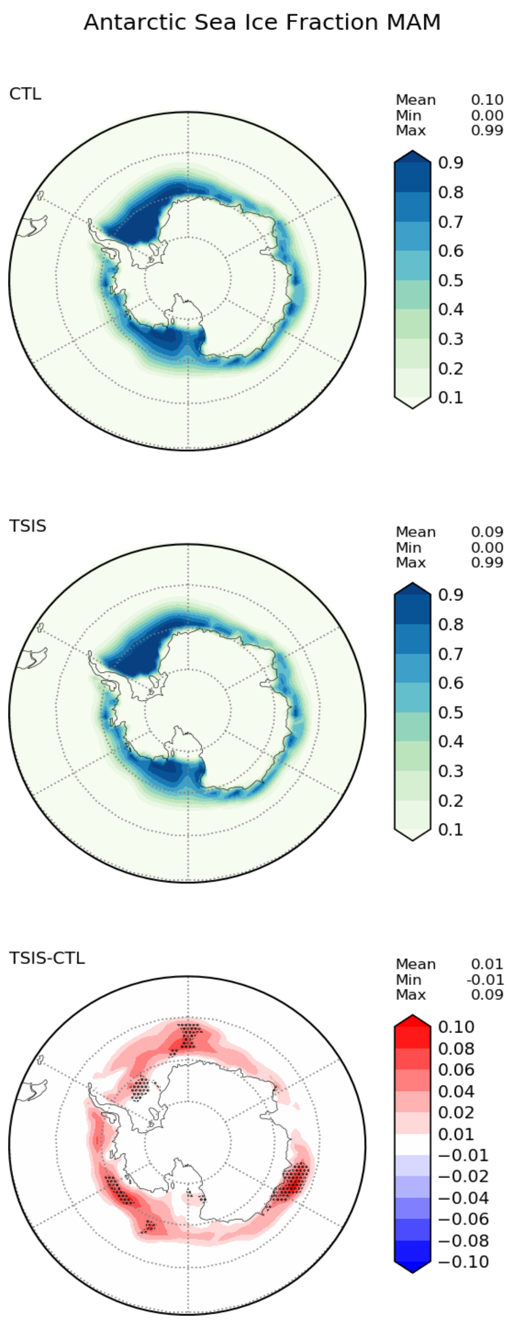
Positive upward.

Hatched are significant at 5% level. Cancellation between green and N-IR bands

50-90°S sea-ice fraction



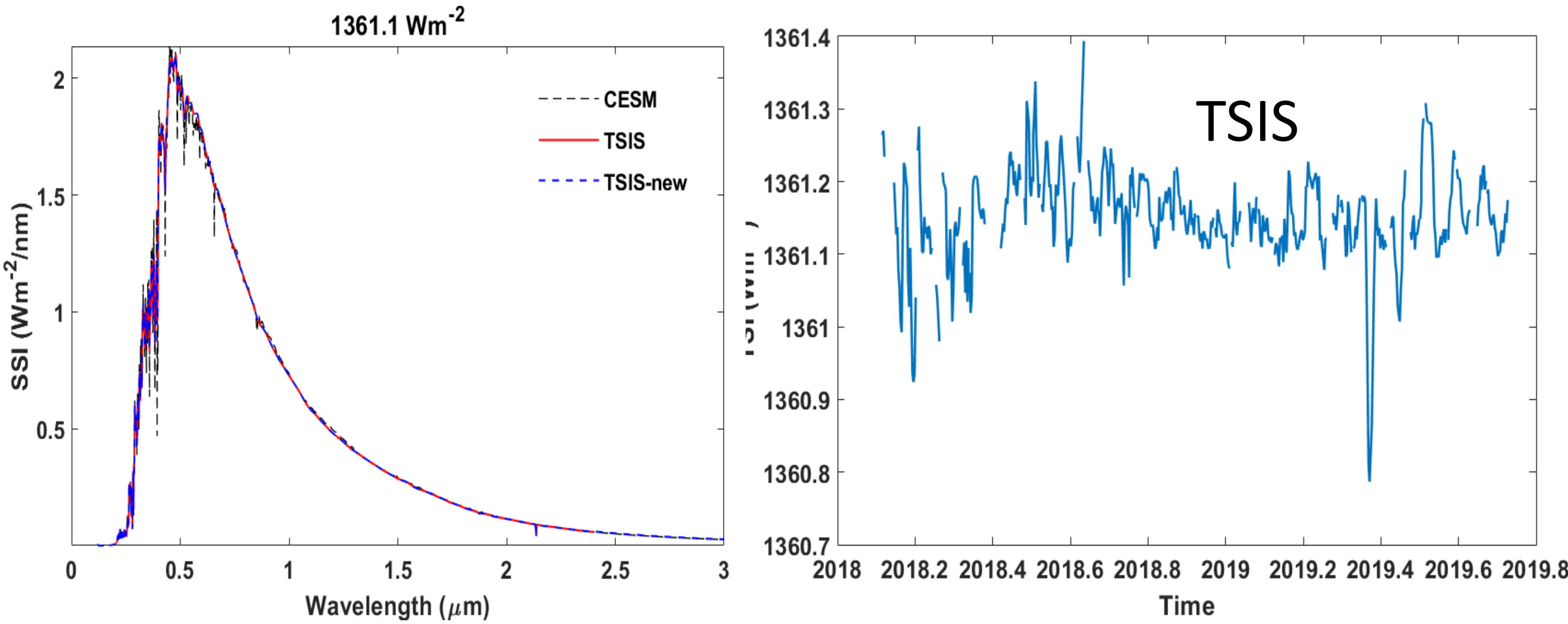
Orange parts are significant at 5% level.


Antarctic Sea Ice Fraction MAM
CTL
Mean 0.10
Min 0.00
Max 0.99
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
TSIS
Mean 0.09
Min 0.00
Max 0.99
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
TSIS-CTL
Mean 0.01
Min -0.01
Max 0.09
0.10
0.08
0.06
0.04
0.02
0.01
−0.01
−0.02
−0.04
−0.06
−0.08
−0.10

Conclusions and Outlooks

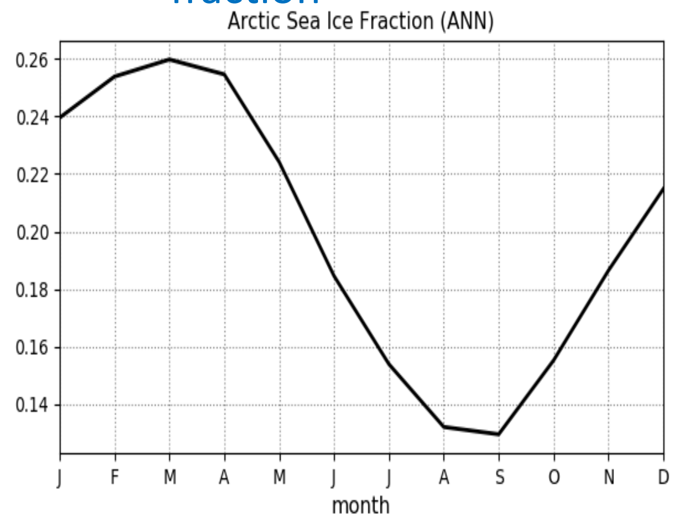
- Visible-vs-NIR SSI is directly relevant to surface energy budget, more so at the high latitudes
- Their impact can only be correctly assessed with coupled models, not a prescribed SST/sea ice run
- A proof-of-concept simulation shows statistically significant changes in SH sea ice and $T_{surface}$
- SORCE/TSIS are where we can get observation-based constrains from
  - A new SSI dataset for climate modeling community?
- Future works:
  - Fully coupled runs
  - Time-dependent SSI variations

THANK YOU!

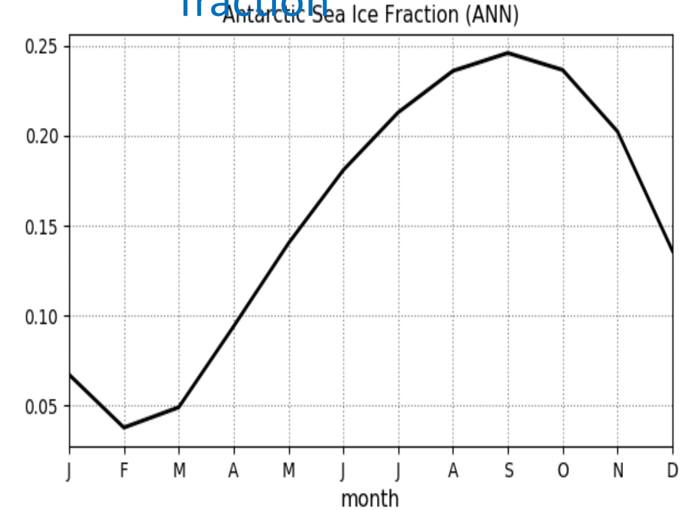


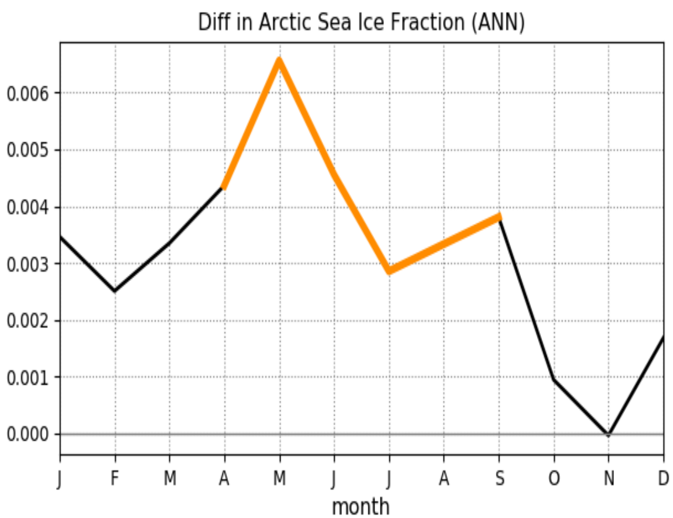
CESM spectral interval: 1, 3, 5, 7, 10, 30, 50 nm
TSIS spectral interval: 0.04~9 nm

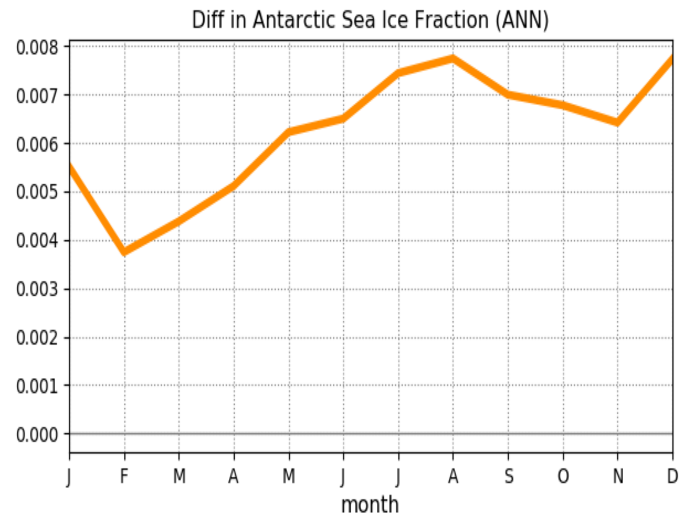
50-90N sea-ice fraction



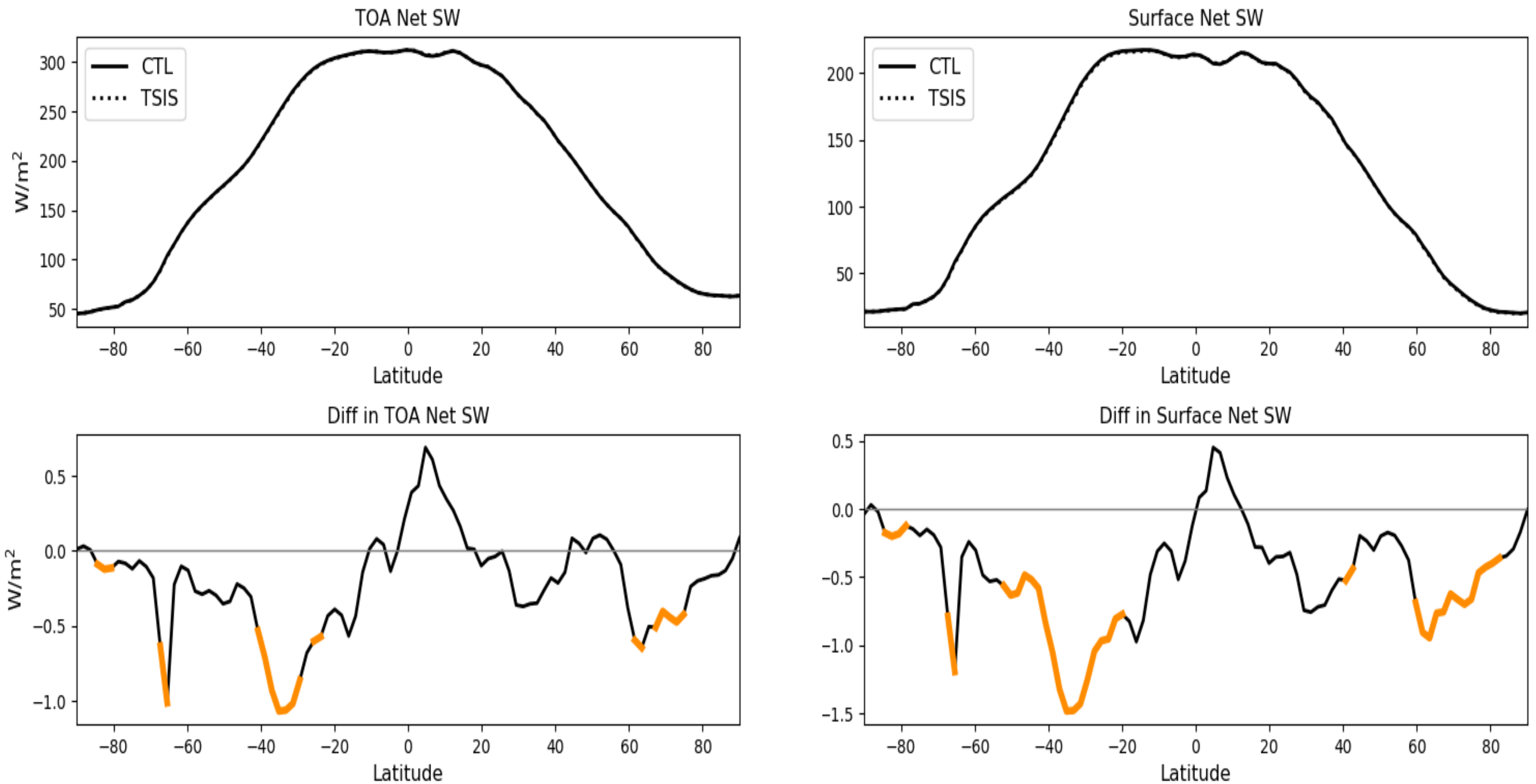
50-90S sea-ice fraction







Orange parts are significant at 0.05 level.



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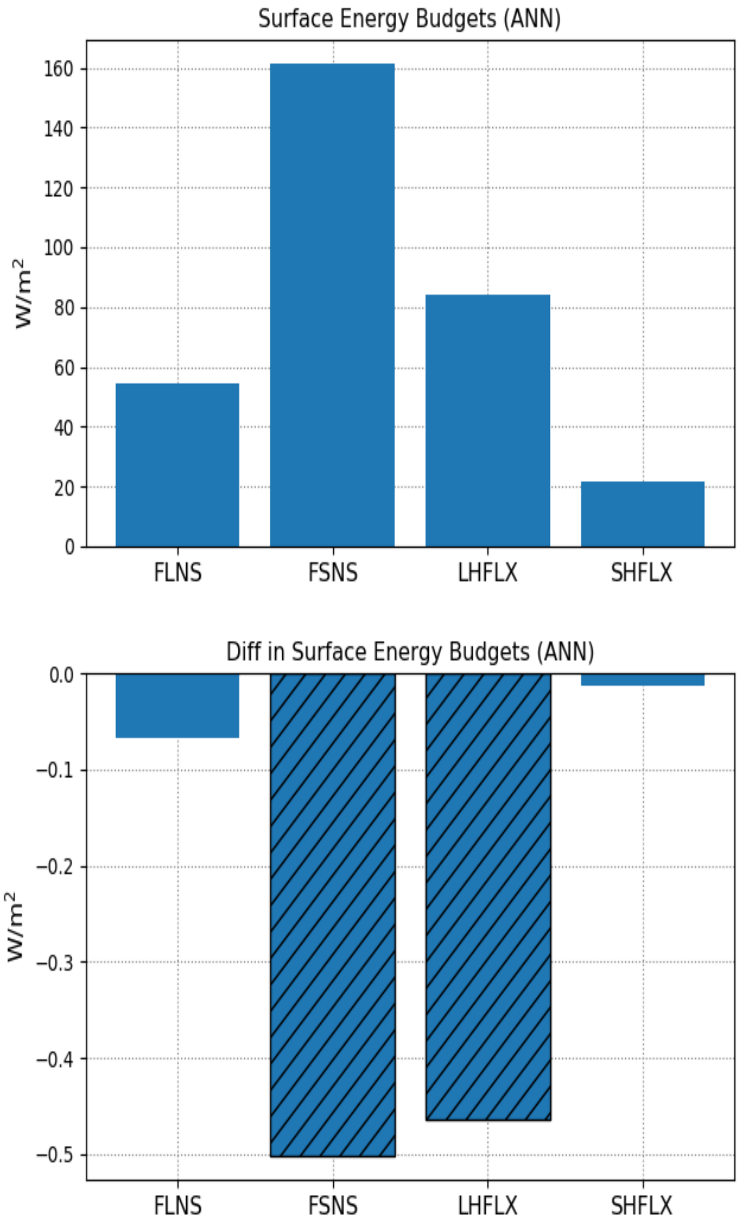
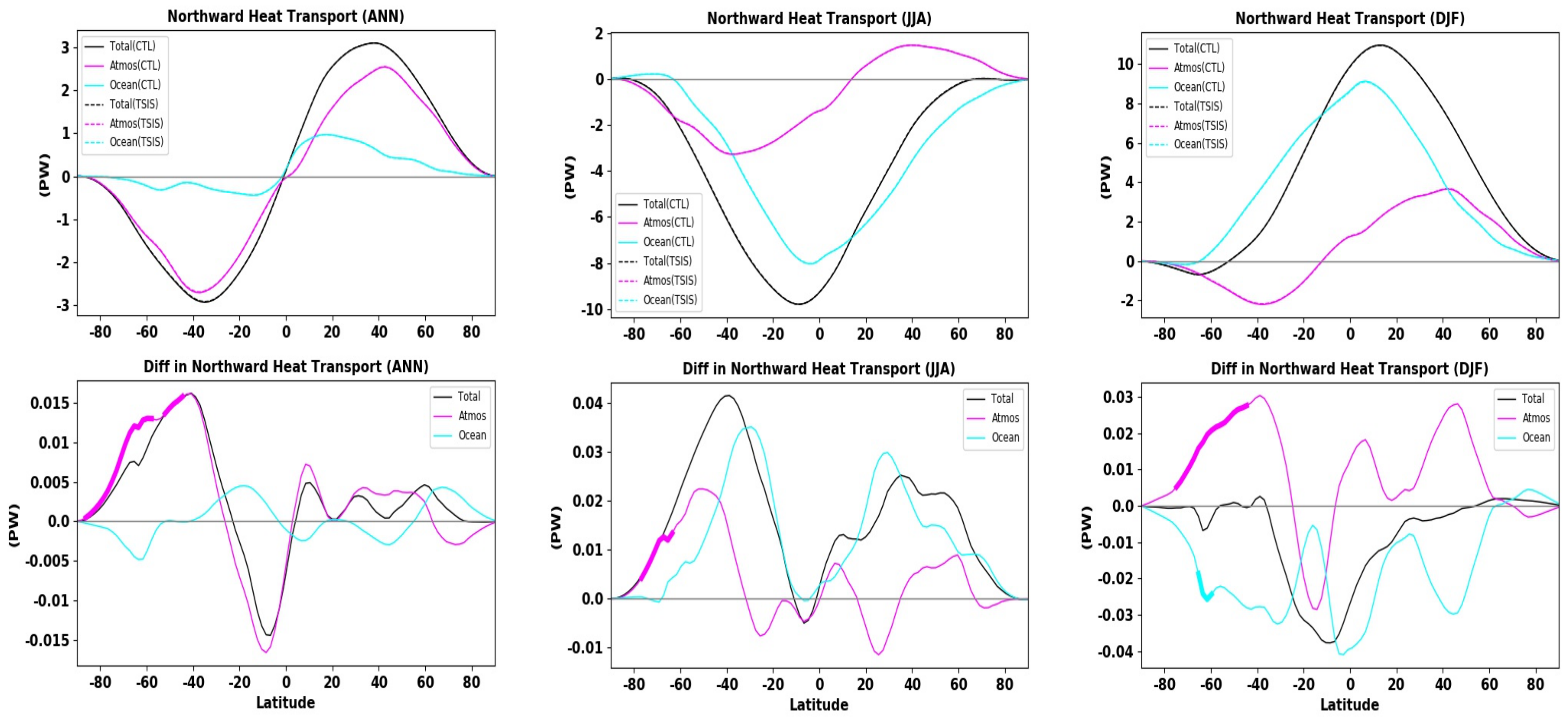
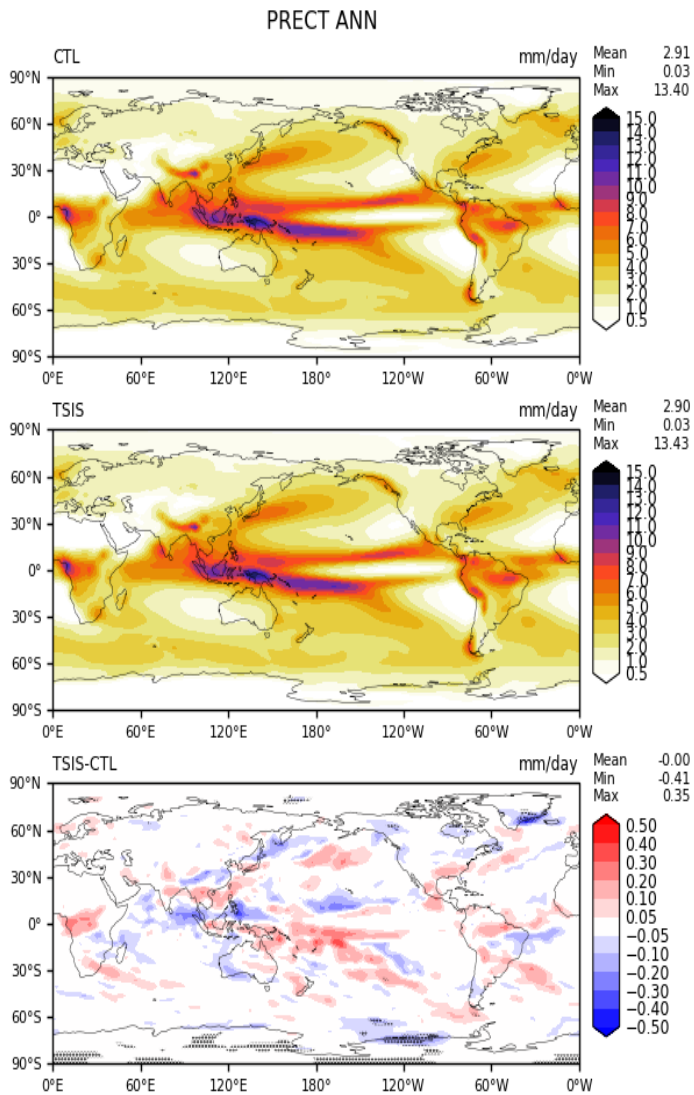


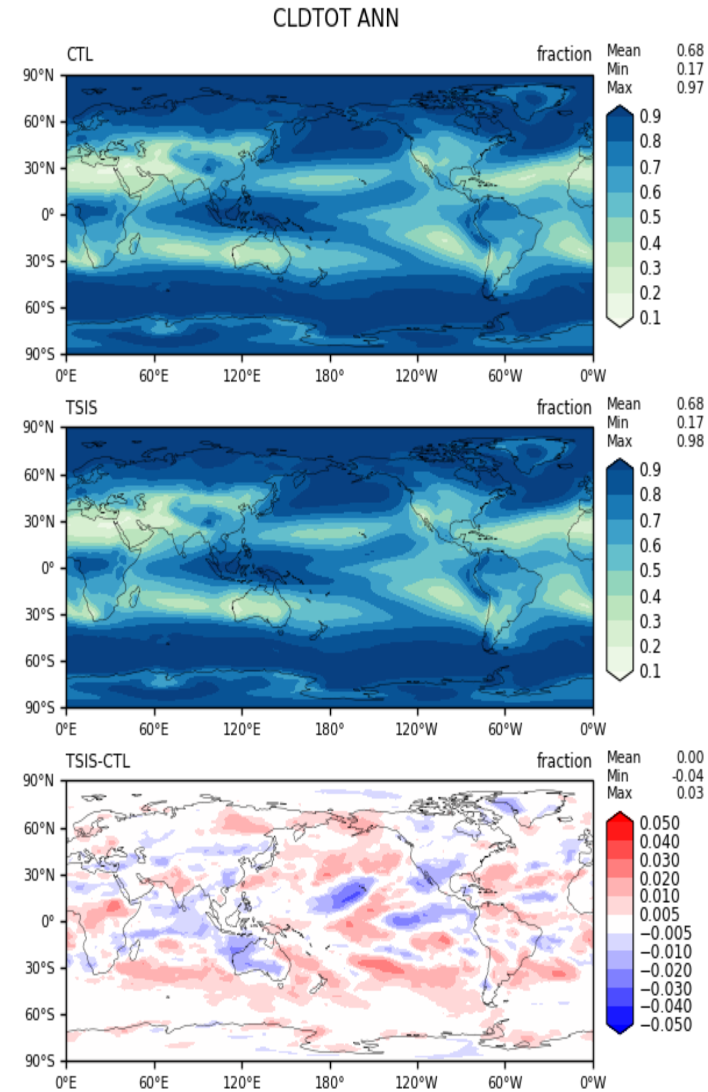
Hatched are significant at 0.05 level.

ANN, JJA, DJF energy transport



Bold parts are significant at 0.05 level.





Hatched are significant at 0.05 level.