Libera's Split-shortwave Measurements and Their Application in Climate Research

LASP

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Libera, NASA's first *Earth Venture* ***Continuity*** Mission

Overarching Science Goals

OG1: Provide seamless continuity of the Clouds and the Earth's Radiant Energy System (CERES) ERB Climate data record (CDR).

- Measurement of TOT, SW and LW with same characteristics as CERES to prevent gap in ERB Climate data record.

OG2: Advance the development of a self-contained, innovative & affordable observing system.

- Wide field-of-view camera for Scene ID and split-SW ADM development.

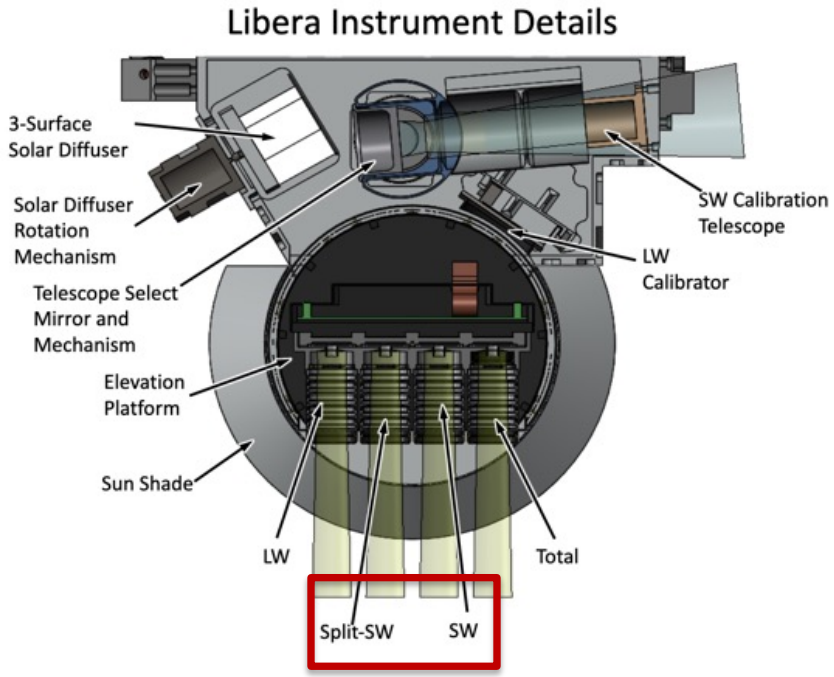
OG3: Provide new and enhanced capabilities that support extending ERB science goals.

- **Additional split-SW channel to derive shortwave near-IR and visible irradiance.**

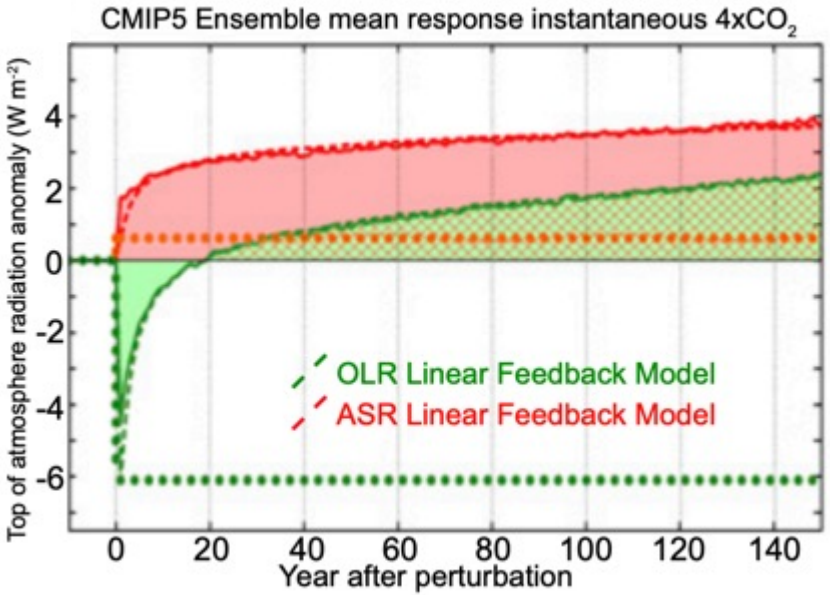
Libera's shortwave sub-band measurement

OG3: Provide new and enhanced capabilities that support extending ERB science goals.

- Libera's fourth channel measures VIS at the same accuracy as the total SW radiance (0.17%)
- Retrieval of VIS, NIR, SW irradiance at TOA and surface:
  - NIR at 0.7-5 µm
  - SW at 0.3-5 µm
  - Conversion of SW-NIR to VIS irradiance
  - NIR = SW - VIS
- **Goals:**
  - **NIR & VIS signatures of processes that control the absorption of solar radiation & SW climate feedbacks.**
  - **Better understand the hemispheric symmetry of planetary albedo.**
  - **Quasi-spectral model evaluation to reveal process-related biases.**



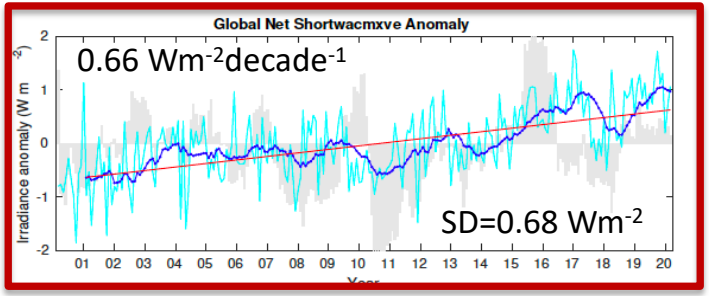
Motivation: Absorption of solar radiation sustains global warming



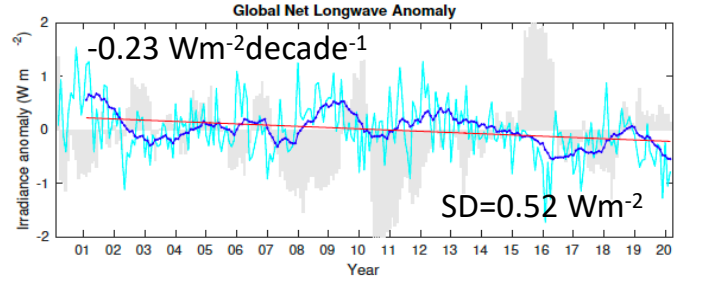
(Donohoe et al., 2014).

Climate model simulations under different future scenarios suggest global warming on decadal to centennial time scales is largely sustained by shortwave absorption (positive climate feedbacks).

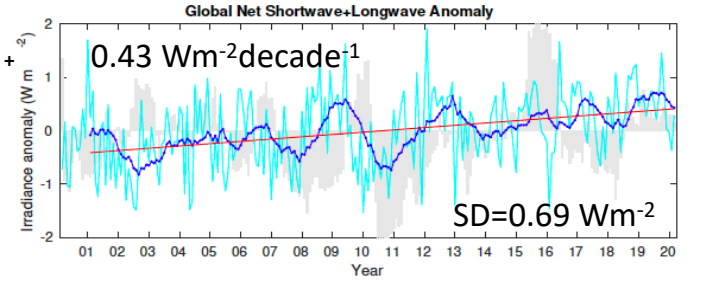
Absorbed shortwave



Absorbed longwave

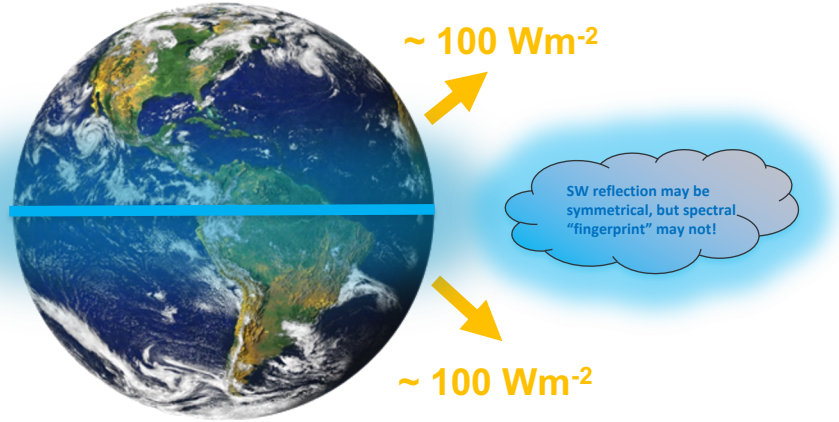


Absorbed shortwave + longwave

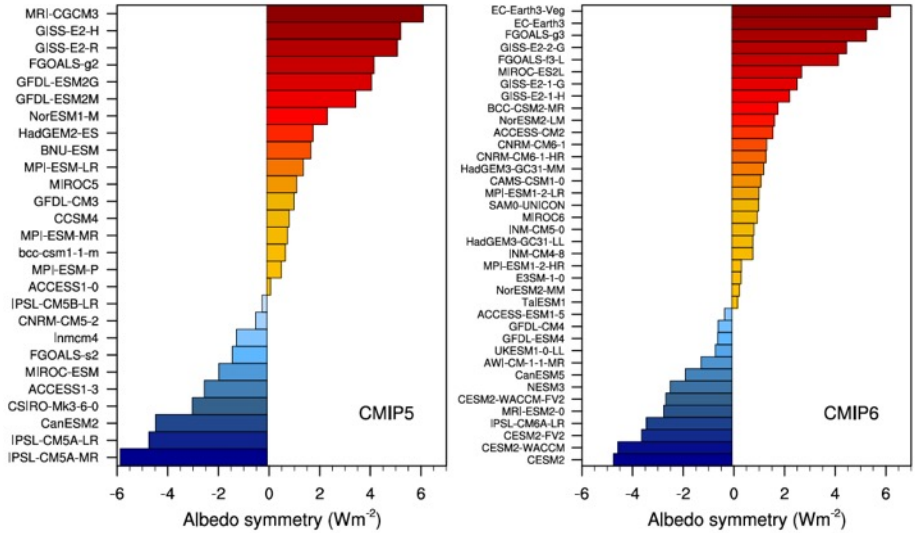


Stephens et al., accepted

Motivation: Hemispheric albedo symmetry



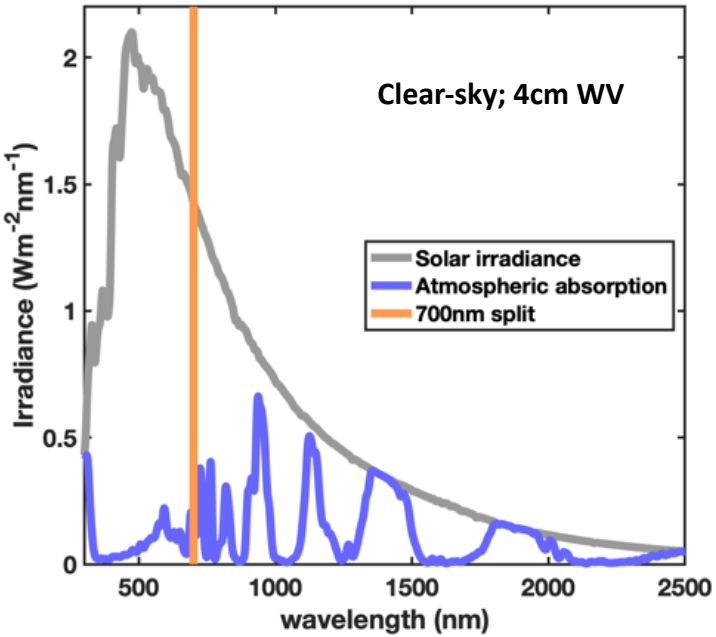
Rugenstein & Hakuba, in prep

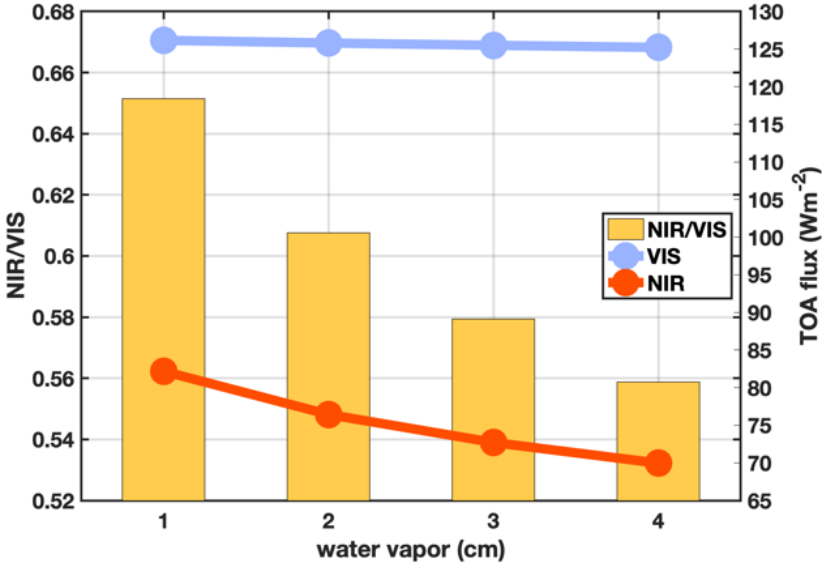


- Average and decreasing all-sky trends in albedo are symmetric across hemispheres
- Surface albedo asymmetry compensated by cloud asymmetry over extra-tropics, SH storm-tracks are 10% cloudier
- **Models and clear-sky observations show evolution to asymmetry!**

- 30% of models are symmetric within $\pm$ 1 Wm^{-2}
- 70 (80)% of models are symmetric within $\pm$ 4 Wm^{-2}.
  (An asymmetry of 4 Wm^{-2} in the hemispheric energy budget would imply 3 times more heat transport across equator!)

Spectral nature of shortwave radiation (MODTRAN calculations)

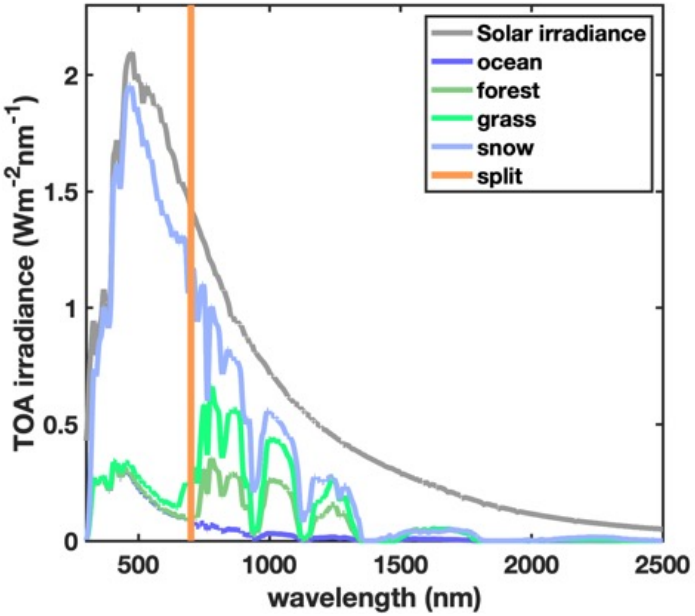


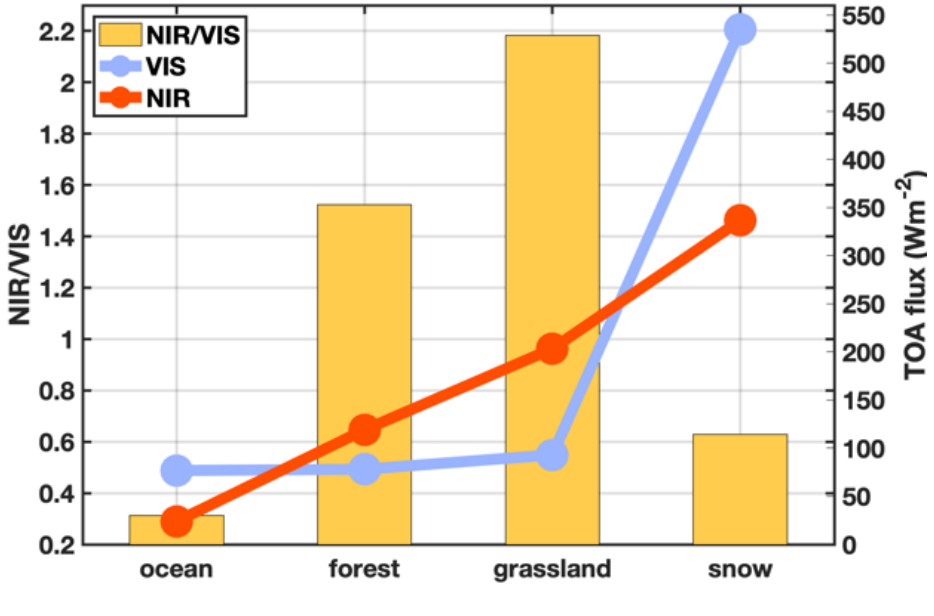


Water vapor absorption acts mostly in the NIR; ~5 Wm^{-2}/cm NIR absorption

C-C 7%/K ~ 0.2cm/K ⟶ ~ 1 Wm^{-2} NIR absorption/K in arid regions

Spectral nature of shortwave radiation



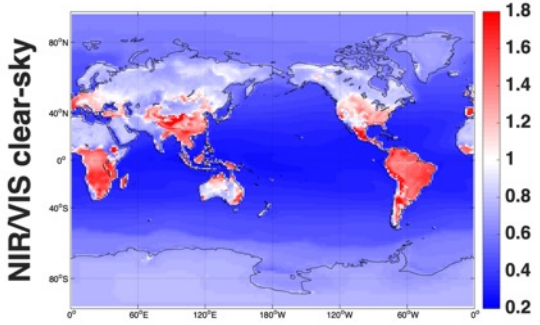


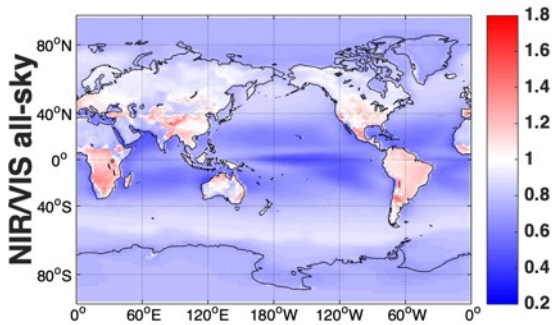
Different surface types associated with very different NIR/VIS ratios (~NDVI); Libera's NIR/VIS may help track land cover change and impact on ERB

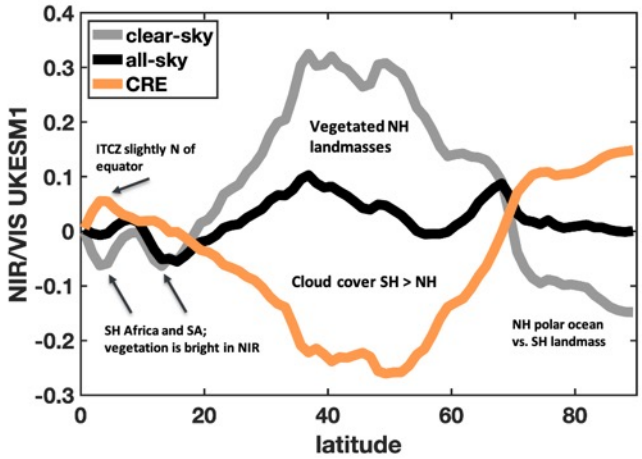
Improved knowledge of SW absorption processes can help understand bigger picture mysteries… or unveil more mystery…

UKESM1: albedo and NIR/VIS are symmetric (20y pi-control)

All-sky	Glo	NH	SH
TOT SW	99.3	**99.1**	**99.6**
NIR	44.0	44.2	43.7
VIS	55.0	55.8	55.4
NIR/VIS	0.79	**0.80**	**0.78**
Clear-sky	**Glo**	**NH**	**SH**
TOT SW	54.4	57.4	51.4
NIR	20.2	22.3	18.2
VIS	34.2	35.1	33.2
NIR/VIS	0.59	**0.63**	**0.55**

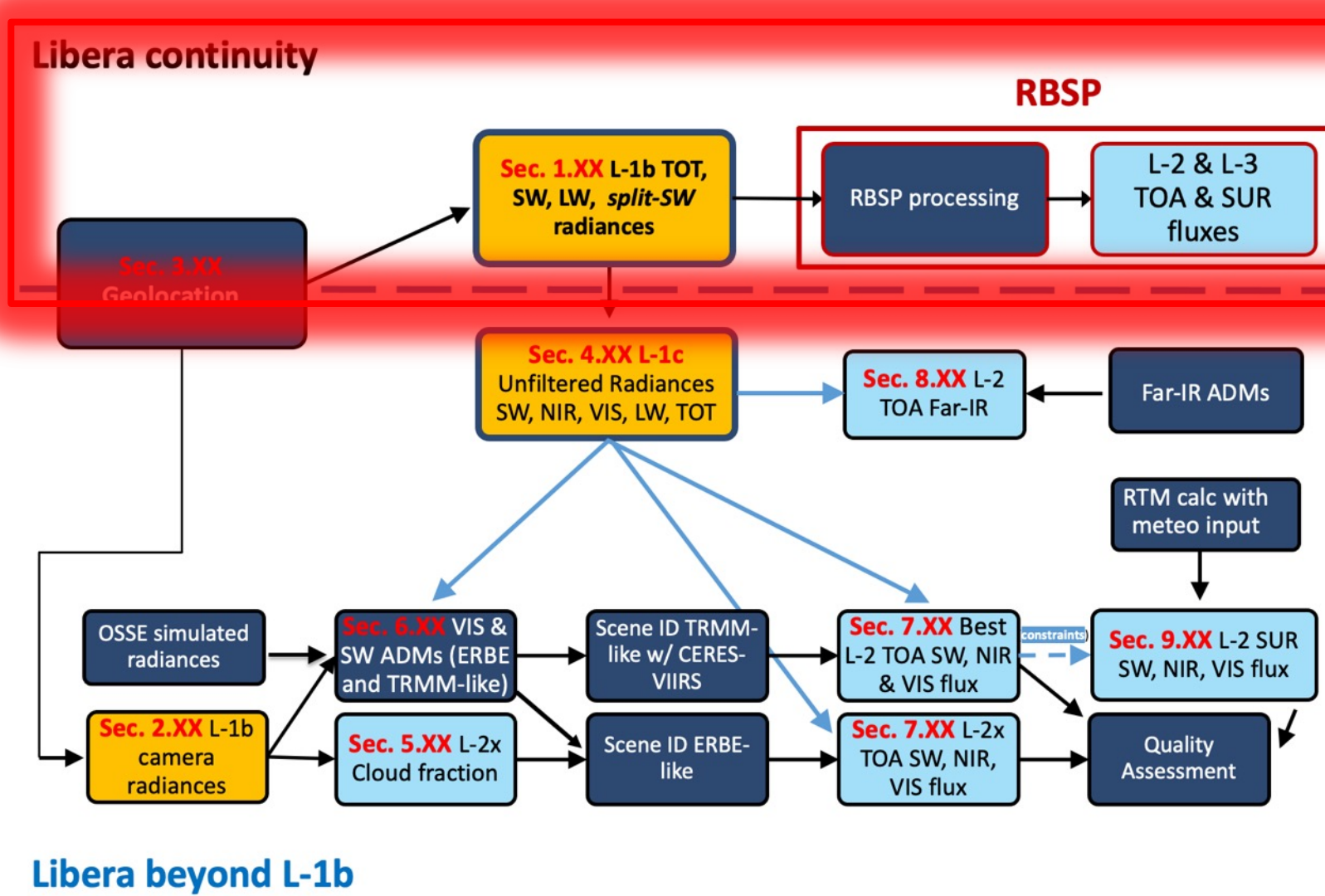






- Clear-sky hemispheric “land-sea contrast” in NIR/VIS
- CRE diffuse spatial pattern in NIR/VIS
- CRE increase NIR/VIS over ocean
- **Clouds not only balance mean albedo and trend across hemispheres but also NIR/VIS ratio**

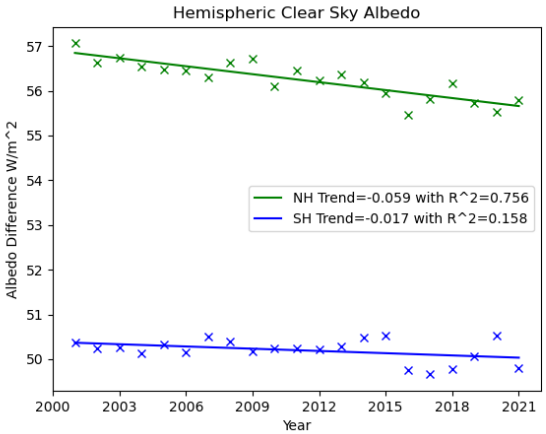
Thank you!

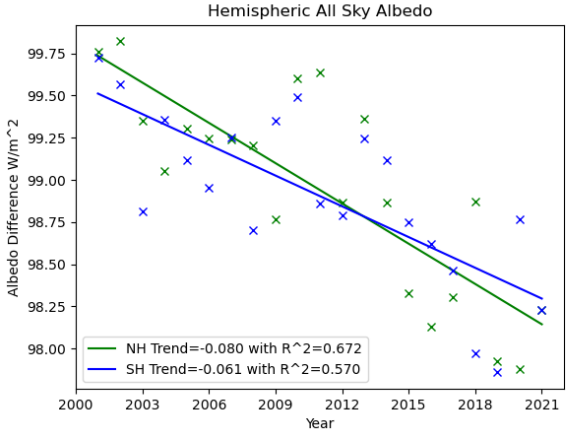


Libera beyond L-1b

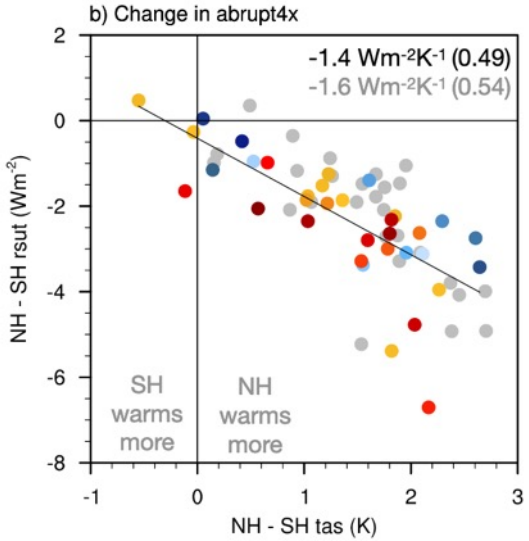
Evolution of hemispheric albedo symmetry

- CMIP models suggest hemispheric albedo is evolving to a-symmetry in response to asymmetric surface warming
- Observations indicate a positive trend in NH-SH clear-sky albedo of -0.4 Wm^{-2} /decade





Matt Watwood



Rugenstein & Hakuba, in prep

UKESM1 SW, NIR, and VIS fluxes

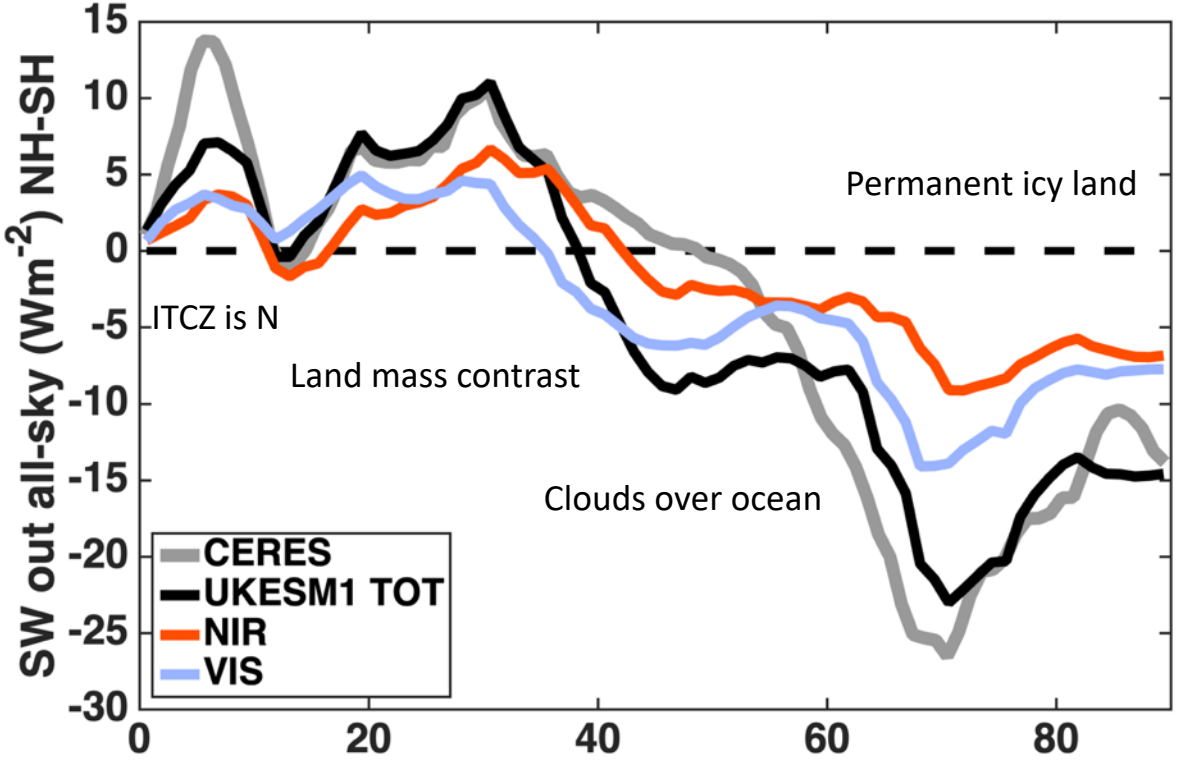
- UK Earth system modeling project
- Successor to HadGEM2-ES
- “The complexity of coupling between the ocean, land, and atmosphere physical climate and biogeochemical cycles in UKESM1 is unprecedented for an Earth system model.” (Sellar et al., 2019)
- Limits of spectral intervals (wavelengths in m.)

Band	Lower limit	Upper limit
1	2.000000000E-07	3.200000000E-07
2	3.200000000E-07	5.050000000E-07
3	5.050000000E-07	6.900000000E-07
4	6.900000000E-07	1.190000000E-06
5	1.190000000E-06	2.380000000E-06
6	2.380000000E-06	1.000000000E-05

- Integrate bands 2-3 for visible, and bands 4-5 for near-IR

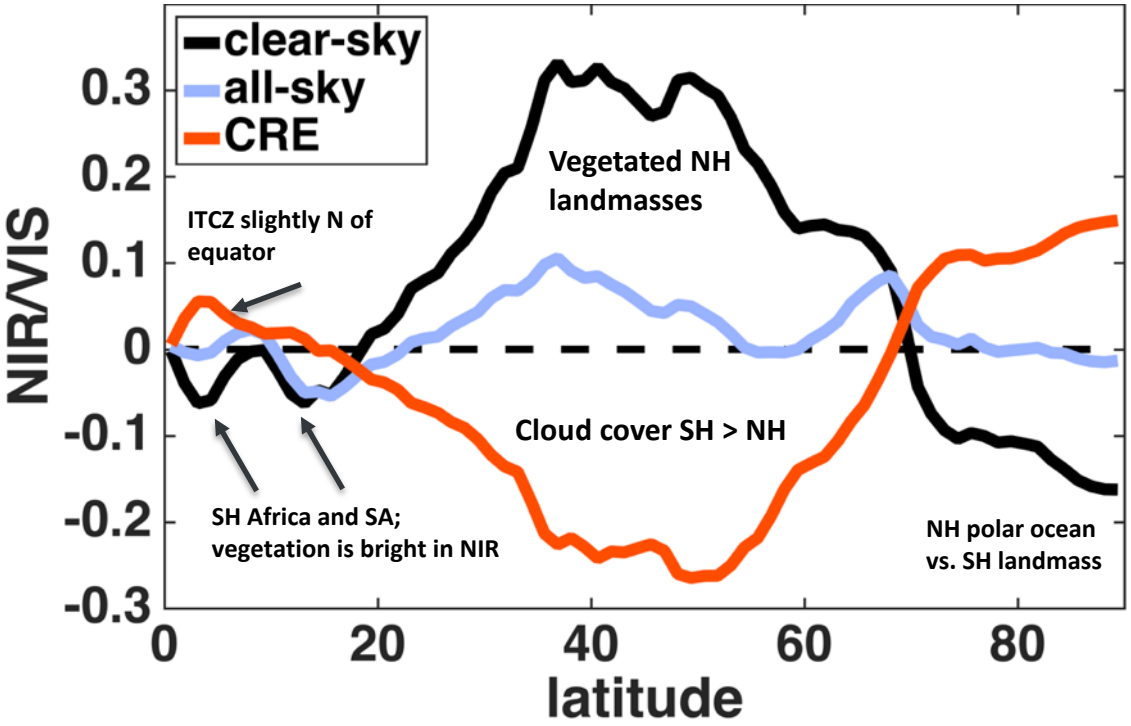
Model simulation:
Alejandro Bodas-Salcedo

NH-SH differences per latitude



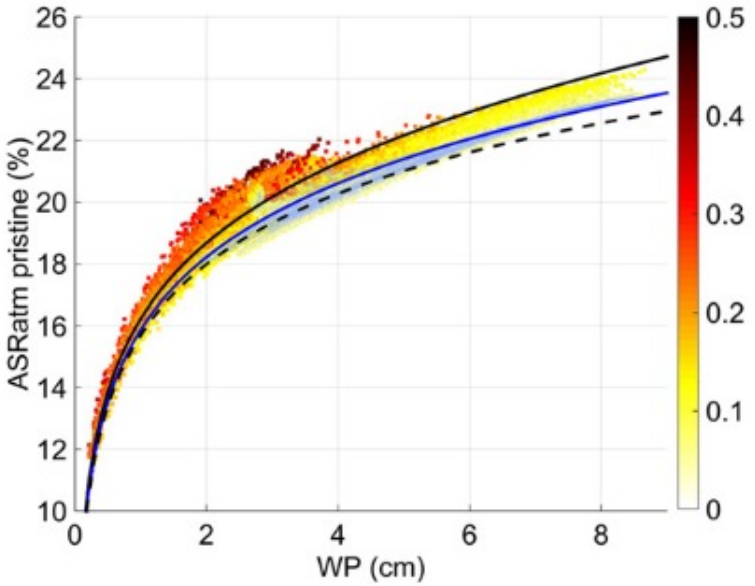
- NH is mostly brighter over 0-40 degree, but darker poleward
- Model agrees OK with CERES
- NIR & VIS zonal variability looks similar to total SW

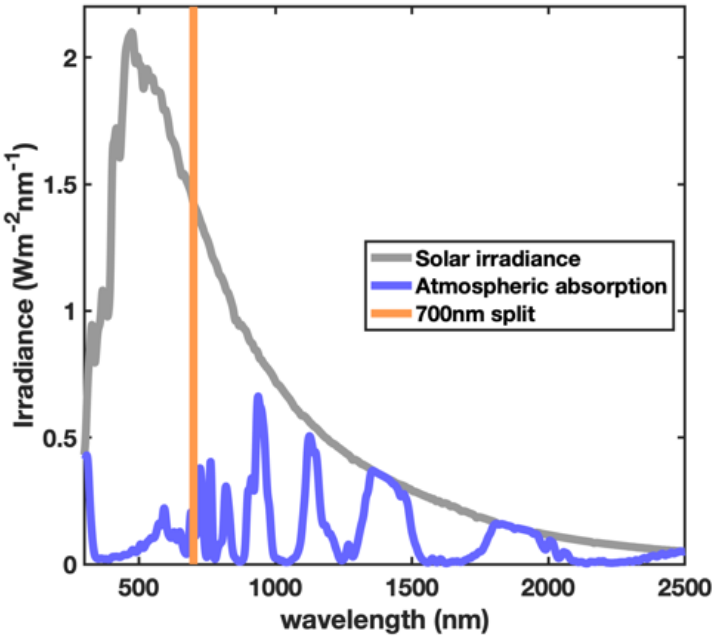
NH-SH differences NIR/VIS ratio per latitude



- Positive values: NIR/VIS ratio is larger on NH than on SH; especially true under clear-sky between 20-70 deg. (note: locally, SH Africa and SA have largest NIR/VIS)
- CRE balance the hemispheric NIR/VIS ratio zonally & mirror the Clear-sky effects.
- But NIR/VIS ratio remains slightly larger on NH under all-sky conditions.

Spectral nature of shortwave radiation





- Water vapor saturation yields non-linear increase
- Underlying surface impacts relationship by several Wm^{-2}