Implementation of a dynamic soil albedo scheme in CABLEv2.0 – Documentation

Jatin Kala (Jatin.Kala.JK@gmail.com or J.Kala@unsw.edu.au)
Kai Lu (kai.lu@unsw.edu.au)

Center of Excellence for Climate Systems Science,
University of New South Wales, Australia.

1.0 Motivation

Surface albedo (snow-free) parameterization in CABLE, as illustrated in Figure 1, is a function of the canopy and soil albedos. The background snow-free and vegetation-free soil albedo is prescribed by default and held constant in time. Depending on how the user decides to set-up soil properties, either a broad-band soil albedo or separate Visible (VIS) and Near Infra-Red (NIR) bands are used (see Srbinovsky et al. 2013 for more details).

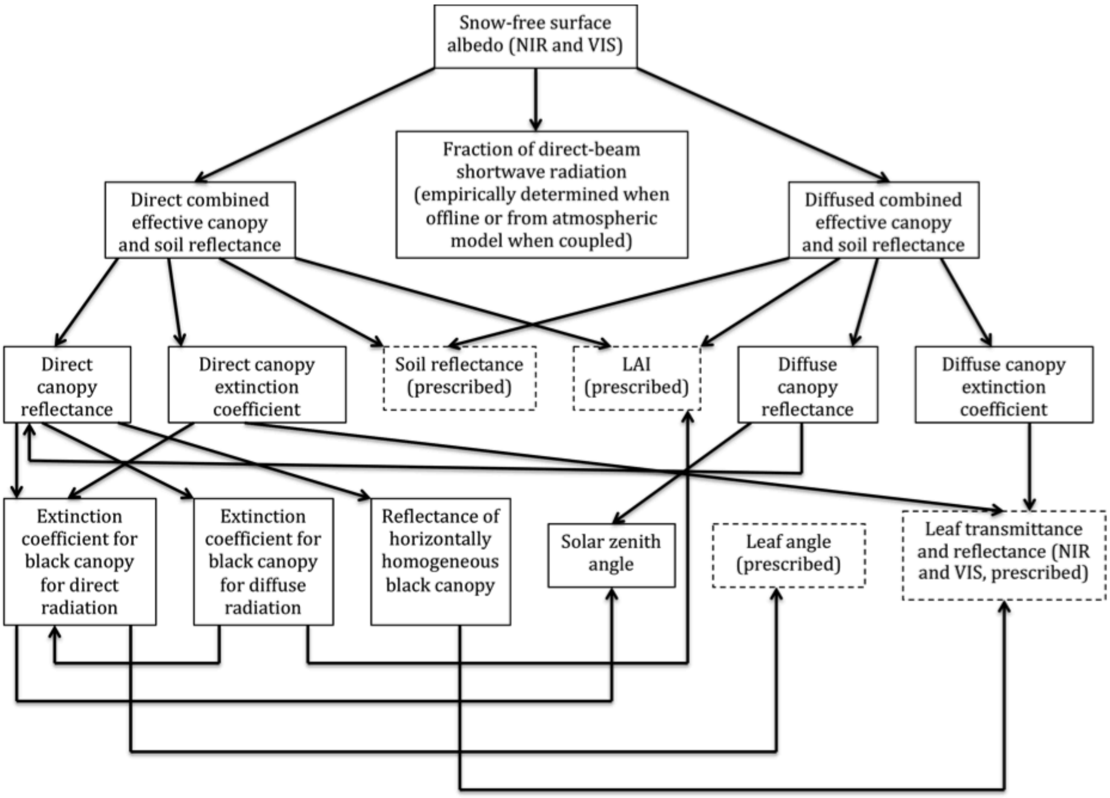

Figure 1: Schematic illustration of snow-free albedo parameterization in CABLE. Boxes with dotted lines are inputs to the albedo scheme.

The prescription of soil albedo implies a completely saturated versus dry soil would have the same albedo. Other Land Surface Models (LSMs) (e.g., CLM) instead have a simple parameterization for the background soil albedo based on soil color and surface soil moisture. Given that some studies suggest that the soil-moisture/albedo feedback can be important (e.g., Vamborg et al. 2011; Zaitchik et al. 2012), it was decided to implement and test the background soil albedo scheme used in CLMv2.0

into CABLEv2.0. This document provides the details and preliminary benchmarking results from GSWP-2 (1986-1995) forced global offline simulations.

2.0 Soil Albedo Parameterization

Background soil albedo can be parameterized as:

$$\alpha_{soil} = \alpha_{sat} + \min\{\alpha_{sat}, \max[0.11(11 - 40\theta_{sm}), \alpha_{dry}]\}$$

Where α_{sat} and α_{dry} are the VIS and NIR albedo of a saturated and dry soil respectively, dependent on the soil color, as shown in Table 1, and θ_{sm} is the surface volumetric soil moisture content.

Table1: Saturated and Dry soil albedos in the NIR and VIS wavebands, for each soil color class shown in Figure 2.

Soil Color	Saturated albedo		Dry albedo	
	VIS	NIR	VIS	NIR
1	0.25	0.50	0.36	0.61
2	0.23	0.46	0.34	0.57
3	0.21	0.42	0.32	0.53
4	0.20	0.40	0.31	0.51
5	0.19	0.38	0.30	0.49
6	0.18	0.36	0.29	0.48
7	0.17	0.34	0.28	0.45
8	0.16	0.32	0.27	0.43
9	0.15	0.30	0.26	0.41
10	0.14	0.28	0.25	0.39
11	0.13	0.26	0.24	0.37
12	0.12	0.24	0.23	0.35
13	0.11	0.22	0.22	0.33
14	0.10	0.20	0.20	0.31
15	0.09	0.18	0.18	0.29
16	0.08	0.16	0.16	0.27
17	0.07	0.14	0.14	0.25
18	0.06	0.12	0.12	0.23
19	0.05	0.10	0.10	0.21
20	0.04	0.08	0.08	0.16

This parameterization has been implemented as a namelist option:
calcsoilalbedo = .TRUE.

If set to TRUE, a soil color map has to be provided:
filename%soilcolor = 'surface_data/mksrf_soilcol_global_c090324_1x1.nc'

This soil-color map, shown in Figure 2, is the same as used in CLM, except that it has been re-gridded from it's original 0.5 by 0.5 degrees, to 1.0 by 1.0 degrees, in order to match with the default CABLE grid setup.

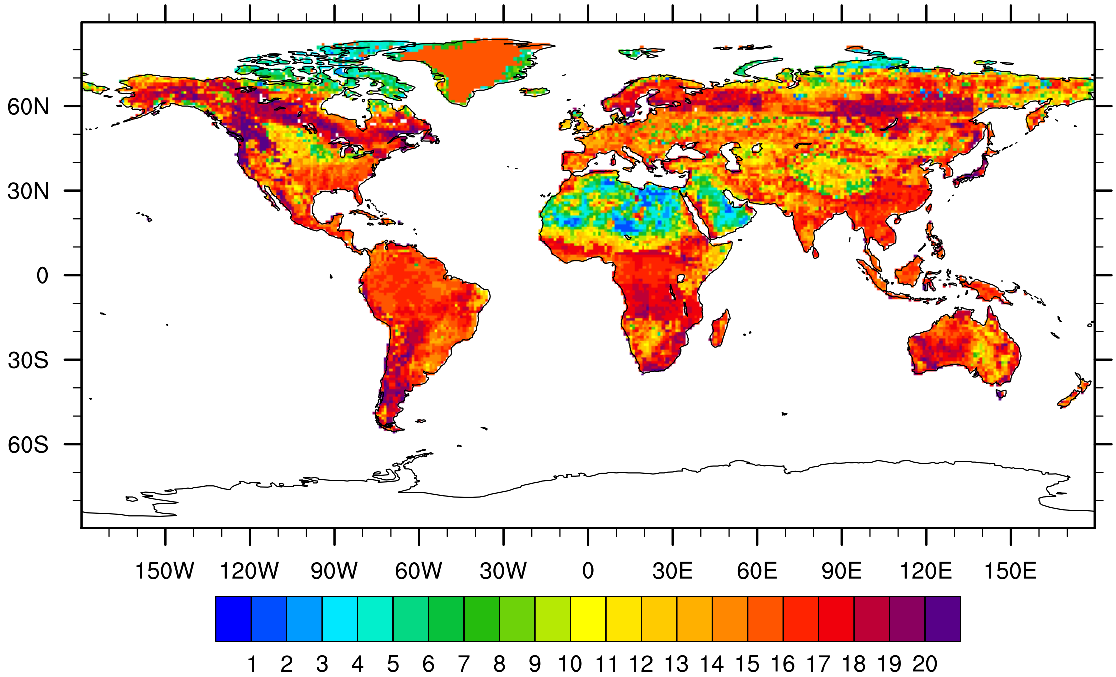

Figure 2: One by one degree re-gridded soil color map from CLM.

3.0 Benchmarking

Two simulations were carried, with GSWP-2 forcing:

1. A control simulation (CNTL) by prescribing the background soil albedo (broadband), as shown in Figure 3.
2. An experiment (SALB) identical to the control except with the background soil albedo parameterized by soil moisture and color, as described in section 2.0.

Both simulations were evaluated against the latest global snow-free MODIS VIS and NIR albedo products produced by Crystal Schaaf's group at Boston University (ftp://casfse.bu.edu/data20/sqs/average/). It is based on the V005 30-arc seconds Climate Modeling Grid product MODIS albedo product (MCD43D). The accuracy level is 0.02, and VIS and NIR white (completely diffuse) and black (direct or completely clear) sky albedos are available. Albedo values between 80N-90N in this product have known quality issues (Schaaf, 2013) and additionally, due to the large amount of missing data from 60N, only data below 60N is used for comparison.

To enable comparison with the simulations, the MODIS albedo products were interpolated to the 1 by 1 degree grid domain used. The MODIS black-sky albedo is equivalent to the CABLE albedo at local solar-noon, whilst the MODIS white-sky albedo represents the integration of the black-sky albedo at all solar zenith angles, and hence, it is comparable against the combined (direct and diffuse) VIS and NIR albedos from CABLE. Since outputs were only kept as monthly means, we only compared the CABLE VIS and NIR albedos against the MODIS white-sky VIS and NIR albedos, consistent with previous studies (Wang et al. 2004).

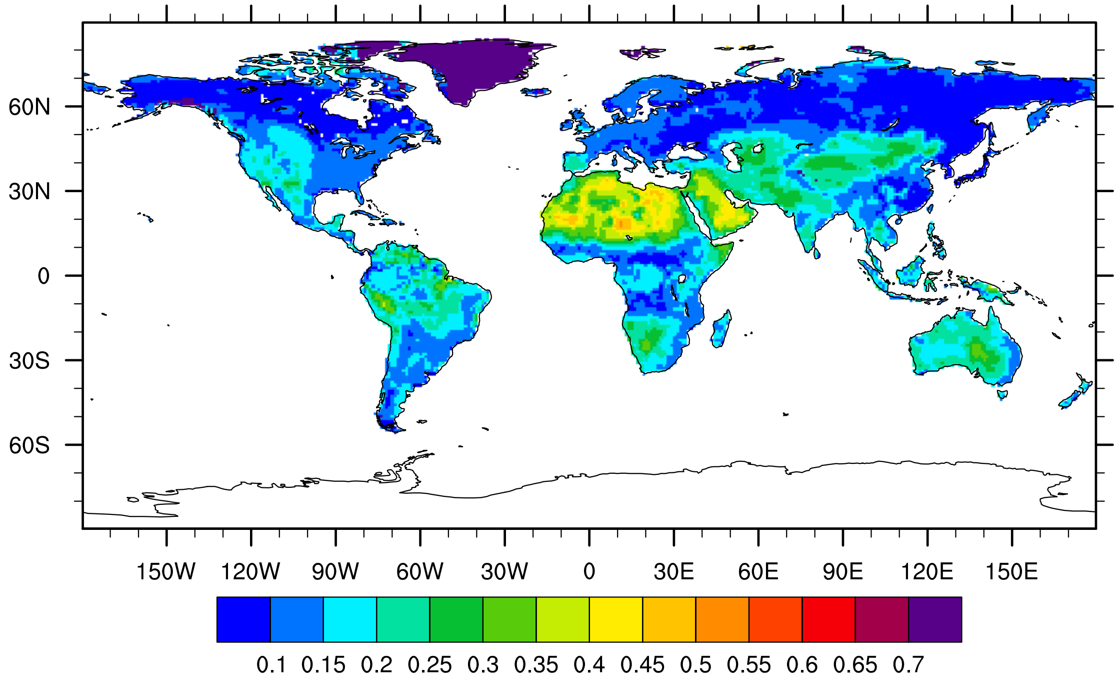

Figure 3: Background soil albedo (broad-band) used in the Control simulation.

Figures 4 and 5 show comparisons between the MODIS and CNTL and SALB experiments for the NIR and VIS bands respectively. Both the CNTL and SALB experiments do not capture the large VIS albedo (Figure 4) in the Sahara desert and surrounding areas, and the SALB experiment performs poorly as compared to CNTL. The better performance of the CNTL experiment as compared to SALB should not be un-expected, as the prescribed soil albedo in CNTL, is itself derived from MODIS (Houldcroft et al. 2009). The results are similar for the NIR albedo (Figure 5), except that the magnitude of the differences is smaller.

Comparisons between CLM and MODIS albedo have highlighted similar issues with regards to the simple parameterization of the soil albedo based on soil moisture and color alone, and more sophisticated schemes have been developed for CLM, including the dependence of soil albedo on solar zenith angle (Liang et al. 2005). Hence, the results shown here are only a preliminary attempt to include a more physically based parameterization of soil albedo in CABLE. A lot more is possible, like for example, introducing the albedo scheme of Liang et al. (2005) into CABLE.

The seasonal differences in overall Albedo between CNTL and SALB, and net radiation and sensible and latent heat fluxes are shown in Figure 6. As expected, regions where there is an increase (decrease) in albedo result in a decrease (increase) in net radiation, and most of the latter is in the form of sensible, rather than latent heat flux. The change in sensible heat between the two simulations corresponds to a change in surface radiative temperature of up to 2.5 K, as shown in Figure 6. Based on these differences, it is advisable that the new scheme only be used when for example, investigating soil-moisture albedo feedbacks. For other applications, prescribing the soil albedo would be more appropriate, until the soil albedo parameterization is further improved.

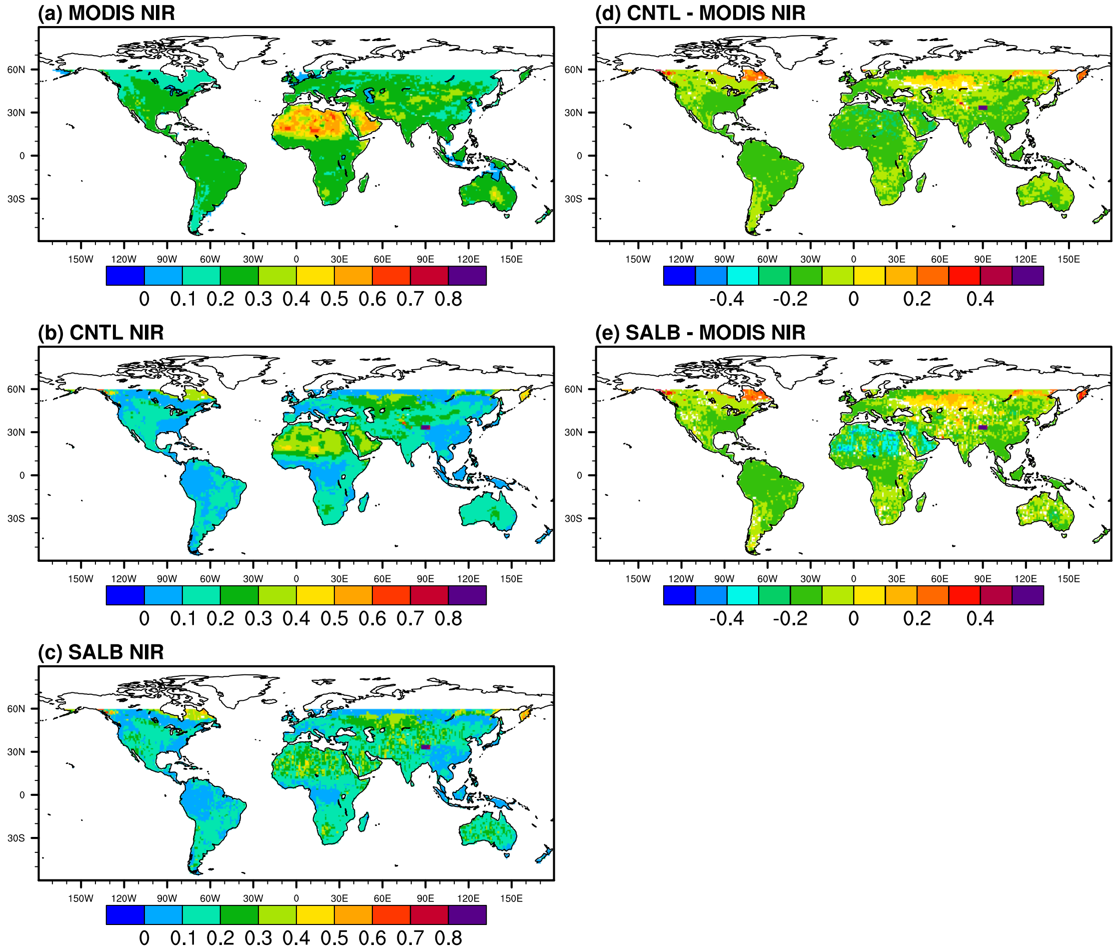

Figure 4: (a) MODIS yearly mean white-sky NIR albedo, (b) CNTL yearly mean white-sky NIR albedo, (c) SALB yearly mean white-sky NIR albedo, (d) CNTL minus MODIS yearly mean white-sky NIR albedo, (d) SALB minus MODIS yearly mean white-sky NIR albedo. Differences less than 0.02 have been masked in panels (d) and (e).

Some Caveats are that the empirical relationships between soil moisture and color and soil albedo, was originally based on the BATS LMS and incorporated into CLM. It is possible that CLM surface soil moisture, and CABLE soil moisture are sufficiently different, to warrant a “recalibration” of the scheme for CABLE. Comparisons between CLM and CABLE surface soil moisture is currently under-way. Additionally, the scheme depends on surface soil moisture, which will largely be influenced by the input precipitation data from GSWP2. The quality of the input precipitation forcing could hence influence the results.

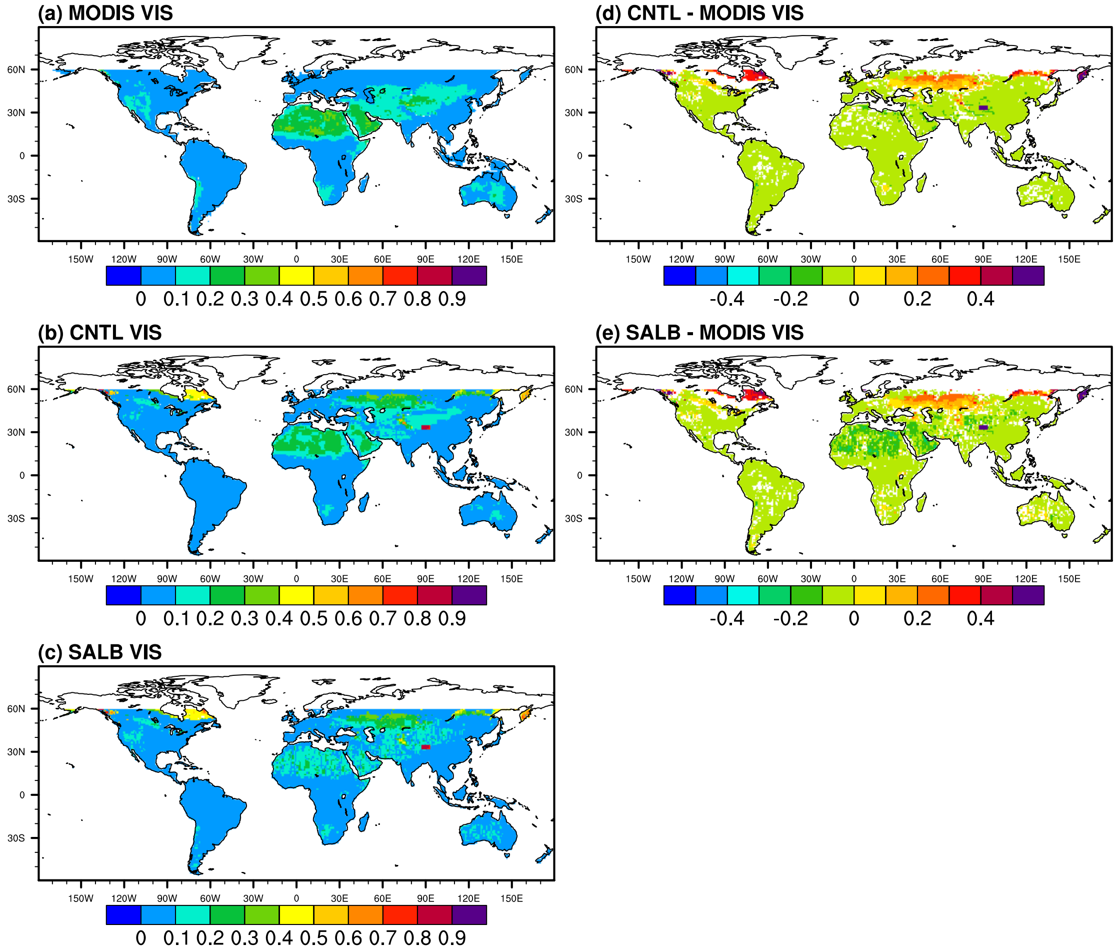

Figure 5: (a) MODIS yearly mean white-sky VIS albedo, (b) CNTL yearly mean white-sky VIS albedo, (c) SALB yearly mean white-sky VIS albedo, (d) CNTL minus MODIS yearly mean white-sky VIS albedo, (d) SALB minus MODIS yearly mean white-sky VIS albedo. Differences less than 0.02 have been masked in panels (d) and (e).

4.0 Conclusions

- We have introduced a simple parameterization of background soil albedo in CABLEv2.0, based on CLMv2.0.
- The new scheme performs poorly as compared to the default (prescribed soil albedo), especially in desert regions like the Sahara. This is however not un-expected as the prescribed albedo is derived from remotely sensed estimates.
- This option should hence be used when the aim is for example, to investigate soil-moisture albedo feedbacks. For other applications, it would be more advisable to use the default set-up, which is to prescribe the soil albedo, until more improvements are made to the parameterization.

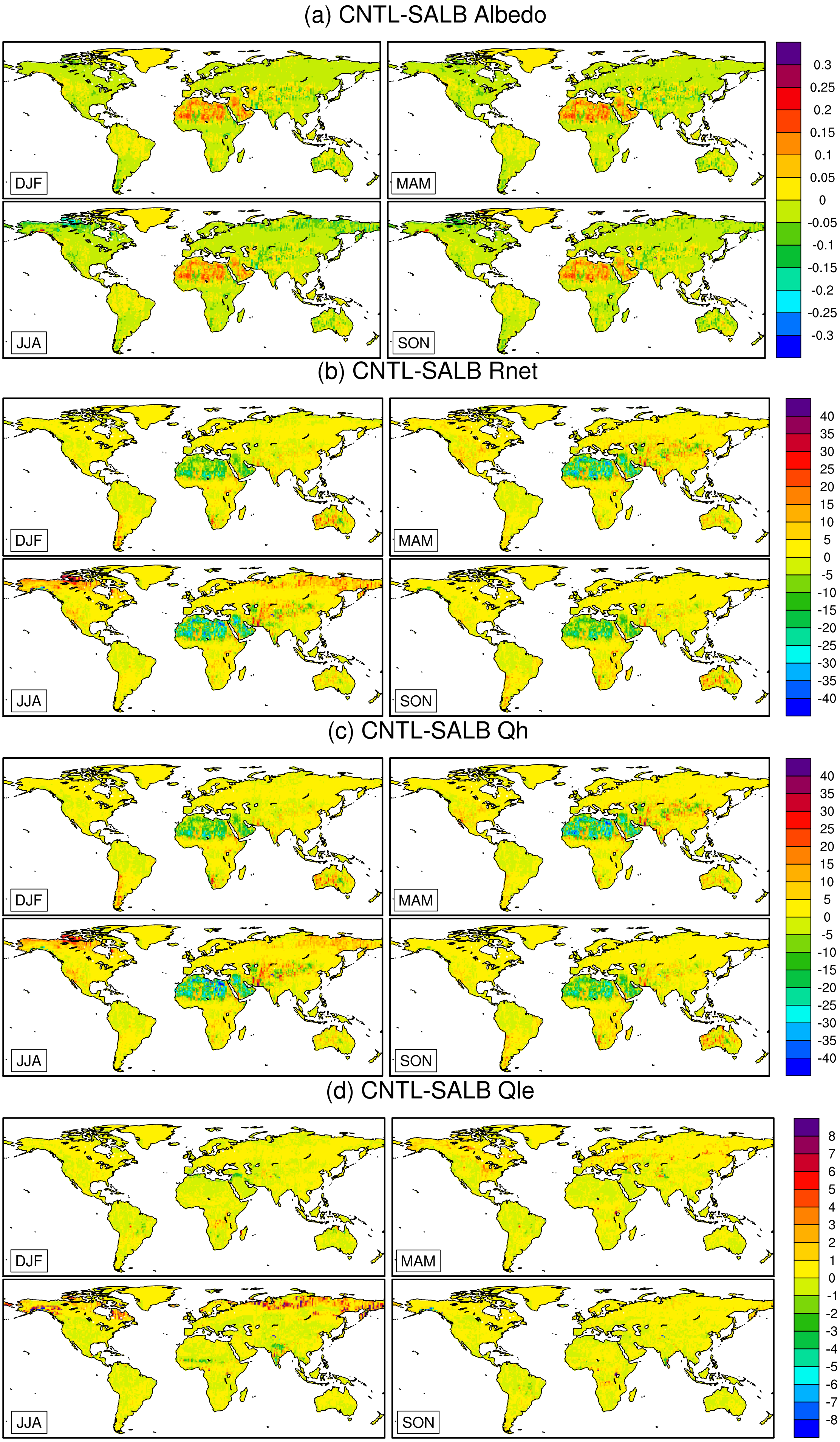

Figure 6: Seasonal differences between CNTL and SALB for (a) Albedo (broadband), (b) net radiation (Rnet, W m^{-2}), (c) sensible heat (Qh, W m^{-2}), and (d) latent heat (Qle, W m^{-2}).

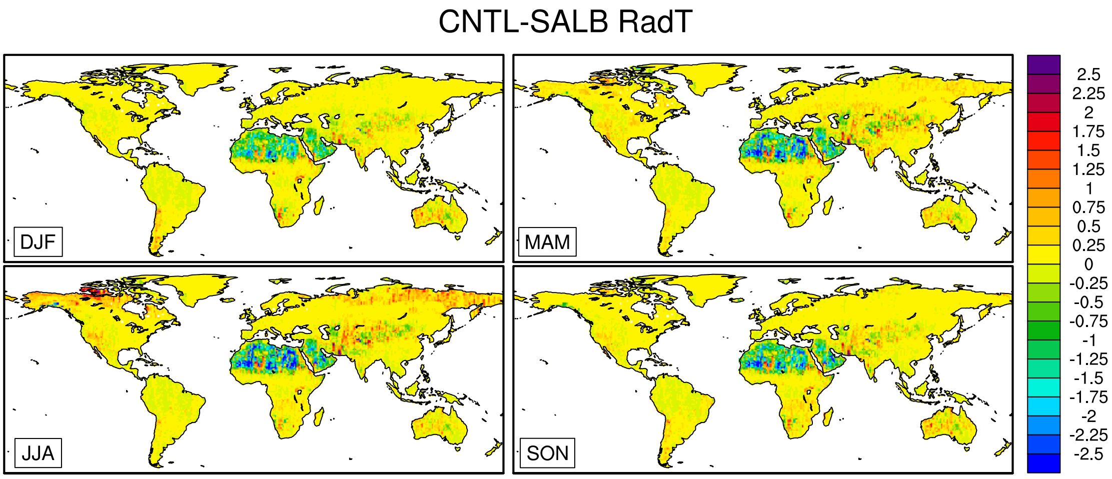

Figure 7: Seasonal differences in surface radiative temperature (K) between CNTL and SALB.

5.0 References

Houldcroft, C. J., W. M. F. Grey, M. Barnsley, C. M. Taylor, S. O. Los, and P. R. J. North, 2009: New vegetation albedo parameters and global fields of soil background albedo derived from MODIS for use in a climate model. Journal of Hydrometeorology, 10, 183-198, doi:10.1175/2008JHM1021.1.

Liang, X.-Z., et al. (2005), Development of land surface albedo parameterization based on Moderate Resolution Imaging Spectroradiometer (MODIS) data, J. Geophys. Res., 110, D11107, doi:10.1029/2004JD005579

Schaaf, C, 2013: Product Description: SZN-extended MODIS/Terra+Aqua 30 arc second Global Gap-Filled, Snow-Free BRDF Parameters Product. Online at: ftp://casfse.bu.edu/data20/sqs/average/readme.pdf

Srbinovsky, J., Law, R., and Pak, B, 2013: The Community Atmosphere Biosphere Land Exchange (CABLE) land surface model. User guide for CABLE-2.0. Available online: https://trac.nci.org.au/trac/cable/attachment/wiki/CableDocuments/CABLE_USER_GUIDE_2.0.pdf

Vamborg, F. S. E., V. Brovkin, and M. Claussen, 2011: The effect of a dynamic background albedo scheme on sahel/sahara precipitation during the mid-holocene. Climate of the Past, **7**, 117-131, doi:10.5194/cp-7-117-2011.

Wang, Z., X. Zeng, M. Barlage, R. E. Dickinson, F. Gao, and C. B. Schaaf, 2004: Using MODIS BRDF and albedo data to evaluate global model land surface albedo. Journal of Hydrometeorology, **5**, 3-14.

Zaitchik, B. F., J. A. Santanello, S. V. Kumar, and C. D. Peters-Lidard, 2012: Representation of soil moisture feedbacks during drought in NASA Unified WRF (NU-WRF). Journal of Hydrometeorology, doi:10.1175/JHM-D-12-069.1.