Earth Sciences Sector

Surface albedo and radiation budget datasets over Canada from remote sensing observations and modeling for climate change impact studies

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Reducing Canada's vulnerability to climate change

Introduction

Atmospheric and surface radiation budget are important drivers of Earth's climate system. Surface albedo links atmospheric and surface radiation together. The International Panel on Climate Change (IPCC) assessments reports identified radiation and albedo among critical factors influencing climate variations and climate change. These parameters are necessary inputs for assessment of climate change impact on ecosystems

We describe three sources of information about radiation budgets and albedo available for Climate Change program: satellite data, global and regional reanalysis results, point ground data from station observations.

Data sources

Satellite data for broadband shortwave (SW), longwave (LW) fluxes and broadband albedo are available from radiation missions, such as Earth Radiation Budget Experiment (ERBE) (1984-1990), Scanner for Radiation Budget (ScaRaB-1&2) (1994-95, 1998-99) and Clouds and Earth's Radiant Energy System (CERES). Surrogate data radiation and albedo data are available from International Satellite Cloud Climatology Project (ISCCP) as FD-type data sets (1983-2000). Above data are available as monthly mean values at resolution 2.5°x2.5° or equal area grid boxes ~ 250x250km². For use in CC Program research we produced data subsets over Canada in Lambert Conformal Conical (LCC) projection at 10x10km² spatial resolution (570 x 480 pixels). Surface reflectance/albedo at 1-km spatial resolution as well as IR emissivities are available from AVHRR, VGT and MODIS observations.

The second type of data is NCAR/NCEP Reanalysis data. There are 2 types of data available: Reanalysis and Reanalysis-2. We use Reanalysis-2 data since it is considered as an improved version. Both above datasets are of global coverage. More detailed modeling filed has become recently available for limited period as Regional North American Reanalysis product. We are working to produce these data in the similar format (LCC –570x 480 pixels).

Third type of data is the ground observations of radiation components from MSC stations.

MODIS Albedo/ Bidirectional Reflectance Distribution Function (since 2000)

The MODIS dataset employs the RossThick-LiSparse reciprocal BRDF model. This is a linear kernel-driven model expressing the BRDF as a sum of several theoretically constructed kernel functions $f_i(\theta_s,\theta_v,\phi)$; where θ_s, θ_v and ϕ are, respectively, Solar Zenith Angle (SZA), Viewing Zenith Angle (VZA) and relative azimuth angle (RAA) between the Sun and viewer planes. The reciprocal model of RossThick-LiSparse (Wanner, Li, & Strahlar, 1995) is such a kind of model with 3 kernels

$$\rho_\lambda(\theta_s,\theta_v,\phi) = a_0 + a_1 f_1(\theta_s,\theta_v,\phi) + a_2 f_2(\theta_s,\theta_v,\phi)$$

f_1 is called RossThick kernel representing scattering from a dense leaf canopy based on a single-scattering approximation of radiative transfer theory (Ross, 1981; Roujean, Leroy, & Deschamps, 1992). f_2 is LiSparse kernel which is derived assuming a sparse ensemble of surface objects and the geometric-optical mutual shadowing model (Li and Strahler, 1992). Parameters a_0, a_1 and a_2 are coefficients of the kernels and represent isotropic, volumetric and geometric reflectance, respectively. The kernels are given by the following expressions

$$f_1 = [(\pi/2-\xi)\cos\xi + \sin\xi]/[\cos\theta_s + \cos\theta_v] - \pi/4$$

where $\cos\xi = \cos\theta_s \cos\theta_v + \sin\theta_s \sin\theta_v \cos\phi$

$$f_2 = O(\theta_s,\theta_v,\phi) - \sec\theta_s' - \sec\theta_v' + \frac{1}{2}(1+\cos\xi')\sec\theta_s' \sec\theta_v'$$

where

$$O = \frac{1}{\pi}(t - \sin t \cos t)(\sec\theta_s' + \sec\theta_v')$$

$$\cos t = \frac{h}{b}\frac{\sqrt{D^2 + (\tan\theta_s' \tan\theta_v' \sin\phi)^2}}{\sec\theta_s' + \sec\theta_v'}$$

$$D = \sqrt{\tan^2\theta_s' + \tan^2\theta_v' - 2\tan\theta_s' \tan\theta_v' \cos\phi}$$

$$\cos\xi' = \cos\theta_s' \cos\theta_v' + \sin\theta_s' \sin\theta_v' \cos\phi$$

$$\theta_v' = \tan^{-1}\left(\frac{b}{r}\tan\theta_v\right); \qquad \theta_s' = \tan^{-1}\left(\frac{b}{r}\tan\theta_s\right)$$

where the two ratios, *h/b* and *b/r*, describe relative height and shape of the BRDF's crown and should be preselected. The MODIS products assume *h/b=2, b/r=1*, i.e. the spherical crowns are separated from the ground by a half of their diameter (Lucht, Schaaf, & Strahler, 2000).
More details can be found in the Algorithm Theoretical Basis Document at:
http://modis.gsfc.nasa.gov/data/atbd/atbd_mod09.pdf

MODIS Surface Emissivity and Temperature (since 2000)

This product provides surface emissivity (Figure 2) values and is based on the Land Processes Distributed Active Archive Center's MODIS/Terra Land Surface Temperature/Emissivity 8-Day L3 Global 1km SIN Grid (MOD11A2V004) (LST/E) product. Emissivities are estimates derived from applying algorithm output to land cover database information. The LST/E algorithms use MODIS data as input, including geolocation, radiance, cloud masking, atmospheric temperature, water vapor, snow, and land cover.

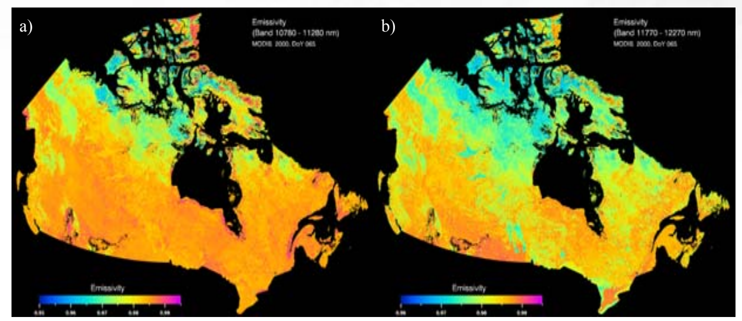


Figure 1: Canada-wide Emissivity 8-Day 1km (March 07, 2000)

a) MODIS Channel 31; b) MODIS Channel 32

Spec. Range			Spatial / Vertical Position: at the Surface	in the Atmosphere	at Top of the Atmosphere
	SW	Upwelling Flux	All Flux Variables	-	All Flux Variables
	SW	Downwelling Flux	All Flux Variables	-	XX
	SW	Net Flux	All Flux Variables	All Flux Variables	All Flux Variables
	LW	Upwelling Flux	All Flux Variables	-	All Flux Variables
	LW	Downwelling Flux	All Flux Variables	-	-
	LW	Net Flux	All Flux Variables	All Flux Variables	All Flux Variables
		Total Flux	All Flux Variables	All Flux Variables	All Flux Variables

Note: All Flux Variables = Full Sky, Cloudy Sky, Clear Sky, Cloud Effect; XX = flux variable is irrelevant

Table 1: Canada-wide Radiative Flux Data Product Parameter List

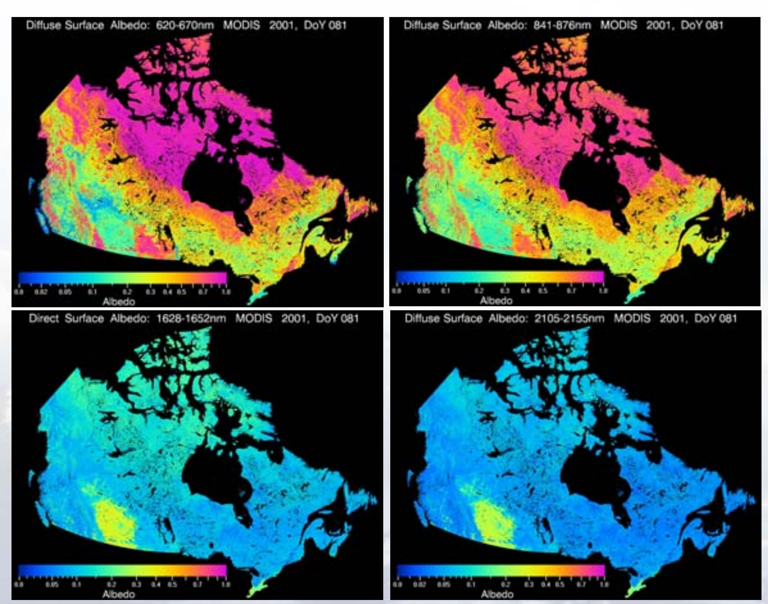


Figure 2: Examples of Canada-wide albedo from MODIS
a) 620 – 670 nm Band; b 841-870nm; c) 1628-1652 nm; d) 2105-2155 nm

Canada-wide Radiative Flux Data Product

Canada-wide Radiative Flux Data Product (Figure 4 and 5) has been derived from the International Satellite Cloud Climatology Project (ISCCP) 18-year (1983-2000) global radiative flux data product (called ISCCP FD). ISCCP FD has been created by employing the NASA GISS climate GCM radiative transfer code and a collection of global datasets describing the properties of the clouds and the surface every 3 hours (ISCCP), daily atmospheric profiles of temperature and humidity (NOAA TOVS), daily ozone abundances (TOMS), a climatology of cloud vertical layer distributions from rawinsonde humidity profiles, a climatology of cloud particle sizes, a climatology of stratospheric aerosol and water vapour, a climatology of the diurnal variations of near-surface air temperature (surface weather observations and NCEP-1 re-analysis), a climatology of tropospheric aerosols (NASA GISS climate model), and the spectral dependence of land surface albedo and emissivity by land-cover type (NASA GISS climate model) (Zhang, Y-C., W.B. Rossow, 2003).

Canada-wide Radiative Flux Data Product results include the full, clear and cloudy sky upwelling and downwelling, shortwave (0.2 - 5 μm) and longwave (5 - 200 μm) radiative fluxes calculated at the top of the atmosphere, in the atmosphere, and at the surface (61 parameters, see Table 1). These results, originally reported with a resolution of 3 hours and 280 km (equal-area map equivalent to 2.5 latitude-longitude at the equator), are reprojected to a Lambert Conformal Conic projection with a resolution of 3 hour and 10 km. Along with the net and total fluxes, monthly, seasonal and annual flux averages are also reported.

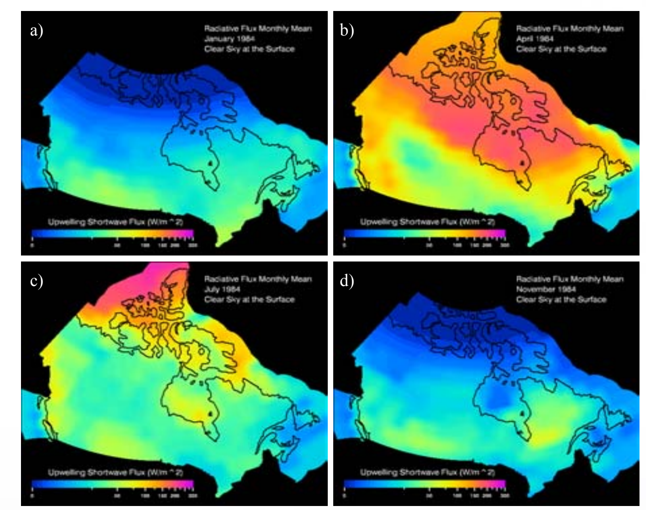


Figure 3: Upwelling Short-wave Monthly Mean Radiative Flux, Clear Sky at the Surface, 1984

a) January; b) April; c) July; d) November

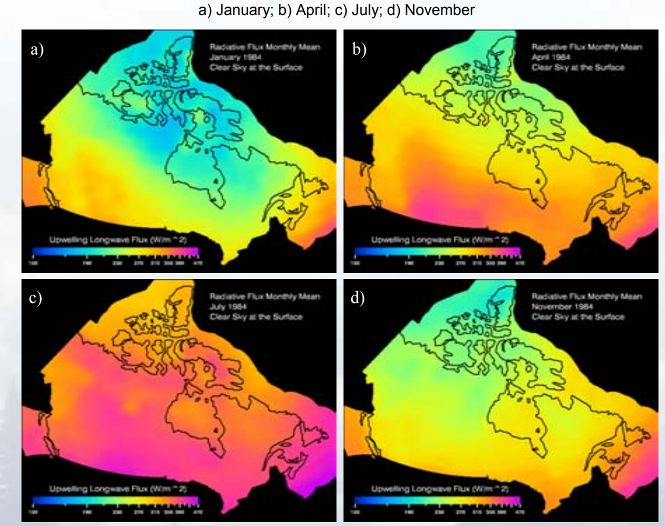


Figure 4: Upwelling Long-wave Monthly Mean Radiative Flux, Clear Sky at the Surface, 1984

a) January; b) April; c) July; d) November

Reanalysis-2 Data Set

NCEP Reanalysis 2 data was provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA (http://www.cdc.noaa.gov). Results provided by this data set will be used for comparison to and evaluation of satellite data for the climate change impact studies. Reanalysis 2 data is in NetCDF format with 1979/1/1 - 2002/12/31 (18:00:00) temporal coverage. Available parameters are listed in Table 2.

Data Set	Parameter	Statistic	Level
Gaussian Grid Data			
	Air temperature @ 2m	4 Time Daily Mean	2 m
	Downward Longwave Radiation Flux	4 Time Daily Mean	Surface
	Downward Solar Radiation Flux	4 Time Daily Mean	Surface
	Downward Solar Radiation Flux	4 Time Daily Mean	Nominal top of atmosphere
	Skin Temperature	4 Time Daily Individual Obs.	Surface
	Total cloud cover	4 Time Daily Individual Obs.	Entire Atmosphere Considered As a Single Layer
	Upward Longwave Radiation Flux	4 Time Daily Mean	Surface
	Upward Longwave Radiation Flux	4 Time Daily Mean	Nominal top of atmosphere
	Upward Solar Radiation Flux	4 Time Daily Mean	Surface
	Upward Solar Radiation Flux	4 Time Daily Mean	Nominal top of atmosphere
	Specific humidity @ 2m	4 Time Daily Individual Obs.	2 m
	U-wind @ 10 m	4 Time Daily Individual Obs.	10 m
	Precipitation rate	4 Time Daily Mean	Surface
	Maximum temperature @ 2m	4 Time Daily Individual Obs.	2 m
	Minimum temperature @ 2m	4 Time Daily Individual Obs.	2 m
	Water equiv. of snow depth	4 Time Daily Individual Obs.	Surface
	Convective precipitation rate	4 Time Daily Mean	Surface
	Ground heat flux	4 Time Daily Mean	Surface
	Latent heat net flux	4 Time Daily Mean	Surface
	Potential evaporation rate	4 Time Daily Individual Obs.	Surface
	Sensible heat net flux	4 Time Daily Mean	Surface
	Soil moisture (0-10cm)	4 Time Daily Individual Obs.	Between 0-10 cm BGL
	Soil moisture (10-200cm)	4 Time Daily Individual Obs.	Between 10-200 cm BGL
	Temperature of 0-10cm layer	4 Time Daily Individual Obs.	Between 0-10 cm BGL
	Temperature of 10-200cm layer	4 Time Daily Individual Obs.	Between 10-200 cm BGL
Pressure Level Data			
	Air temperature	4 Time Daily Individual Obs.	Pressure Levels
	Geopotential Height	4 Time Daily Individual Obs.	Pressure Levels
	Geopotential Height	4 Time Daily Individual Obs.	Surface
Surface Data			
	Precipitable Water Content	4 Time Daily Individual Obs.	Entire Atmosphere Considered As a Single Layer
	Pressure	4 Time Daily Individual Obs.	Surface
Time Invariant Data			
	Surface Height	-	Surface
	Land-sea Mask	-	Surface

Table 2: List of Reanalysis 2 Parameters

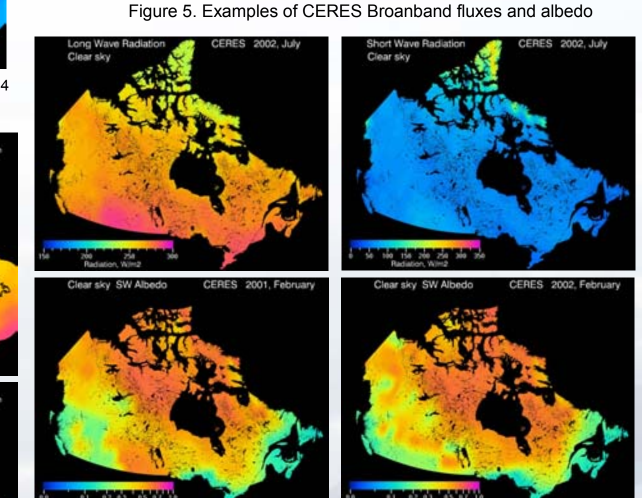
BroadBand Radiation Missions

ERBE Earth Radiation Budget Experiment (ERBE) (1984-1990)

ScaRaB Scanner for Radiation Budget (ScaRaB-1&2) (1994-95, 1998-99)

CERES Clouds and Earth's Radiant Energy System since 2000

Figure 5. Examples of CERES Broanband fluxes and albedo



CONCLUSIONS

Collected data are available for CC Program research. We are working on validation and intercalibration of data from various sources using primary observations from ground or satellite observations. Improved and validated algorithms will be applied in reprocessing satellite data to generate consistent long-term datasets for climate change and ecosystem impact studies.

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