Spectral and Broadband Albedos of Sea Ice in the East Antarctic Sea Ice Zone Maria Zatko and Stephen Warren University of Washington, Department of Atmospheric Sciences, Seattle, WA, USA

Introduction

The solar energy budget of the Antarctic Ocean is largely determined by the areal extent and albedo of sea ice, the latter of which is highly variable depending on the surface type. The albedos of open water, nilas, nilas with frost flowers, slush, and firstyear ice with both thin and thick snow cover were measured in the East Antarctic sea ice zone during the Sea Ice Physics and Ecosystems Experiment II (SIPEX II) field campaign from September to November 2012, near 65 S, 120 E. Spectral albedos were measured from λ =350-2500 nm using an ASD portable scanning spectroradiometer (see Figure 2).



Figure 1. Track of the Aurora Australis Icebreaker from September 16 to November 16, 2012 during SIPEX II. Courtesy of Australian Antarctic Division.



Figure 2. 5-8 mm thick nilas in a narrow lead (left), 1 cm thick frost flowers on 6 cm nilas (center), 18 cm thick slush (right)

Spectral Albedos Measured During SIPEX II Frost Flowers on Nilas -10/23/2012: 18 cm - 10/04/2012: dense coverage 9/28/2012: sparse coverage - 10/20/2012: 10 cm - 10/14/2012: 3 cm over 50 cm ice 10/09/2012: 5 cm Figure 3. Frost flowers Figure 4. Slush Snow–covered Slush on Thin Ice 11/02/2012: 2 cm snow;3 cm slush;12 cm ice Brandt et al. [2005]: 5 cm 11/02/2012: 5 mm snow;10 cm slush;16 cm ice 10/13/2012: 3-6 cm - Brandt et al. [2005]: 2.2–3 cm∏ - Brandt et al. [2005]: 2.2 cm - 10/24/2012: Open Water







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Figure 5. Nilas



Figure 7. Snow on ice

Figure 6. Mixed ice types

Figures 3-7: Dashed lines indicate where spectral noise was smoothed. Noise resulted over $\lambda = 1800-2100$ nm and λ =2350-2500 nm when surface albedos were measured under cloudy skies.

- -Sea ice albedos are highest in the UV and visible wavelengths and lowest in near-infrared wavelengths.
- -Sea ice albedos increase with increasing ice thickness.
- -The addition of frost flowers on nilas increases albedo by 0.2.
- -Underlying ice surfaces are influential when snow cover is less than 2 cm thick
- -Snow covered first-year ice is the most common sea ice type in the East Antarctic sea ice zone
- -Light absorbing impurities in snow on first-year sea ice have mixing ratios similar to values in continental Antarctica (blackcarbon equivalent 0.1-0.5 ng g^{-1})

Broadband Albedo (α)

Spectral albedos and clear and cloudy sky solar spectra are integrated over λ to obtain broadband albedos



 $\frac{\int \alpha_{\lambda} F_{\lambda} d\lambda}{\int F_{\lambda} d\lambda}$ where, α_{λ} is measured spectral albedo and $F_{\lambda} d\lambda$ is downward solar spectral irradiance at λ .

Ісе Туре	Date	350-2500 nm		350-700 nm		700-2500 nm	
		Clear	Cloudy	Clear	Cloudy	Clear	Cloudy
Open water	10/14	0.06	0.06	0.07	0.07	0.06	0.06
Nilas							
5-8 mm	10/6	0.13	0.14	0.15	0.15	0.12	0.13
3-6 cm	10/13	0.13	0.14	0.15	0.15	0.12	0.12
Frost Flowers							
sparse	9/28	0.26	0.29	0.33	0.33	0.21	0.23
dense	10/4	0.42	0.45	0.50	0.50	0.35	0.39
Slush							
5 cm	10/9	0.30	0.35	0.46	0.47	0.16	0.19
10 cm	10/14	0.41	0.46	0.59	0.59	0.25	0.29
10 cm	10/20	0.39	0.45	0.60	0.61	0.20	0.24
18 cm	10/23	0.51	0.59	0.78	0.78	0.28	0.33
Snow							
2-4 cm	10/14	0.69	0.74	0.80	0.80	0.25	0.29
No crust	10/8	0.80	0.87	0.98	0.98	0.65	0.73
Crust	10/8	0.80	0.86	0.98	0.98	0.62	0.70
Snow on Slush							
2 cm snow,	11/2	0.75	0.80	0.87	0.87	0.65	0.72
3 cm slush,							
12 cm ice							
5 mm snow,	11/2	0.59	0.63	0.68	0.68	0.51	0.56
10 cm slush,							
16 cm ice							

Summary

-Broadband albedos from 0.07-0.87 were measured in the East Antarctic sea ice zone during SIPEX II.