Sea-ice Shortwave Albedo Retrieval Using NPP/VIIRS Data

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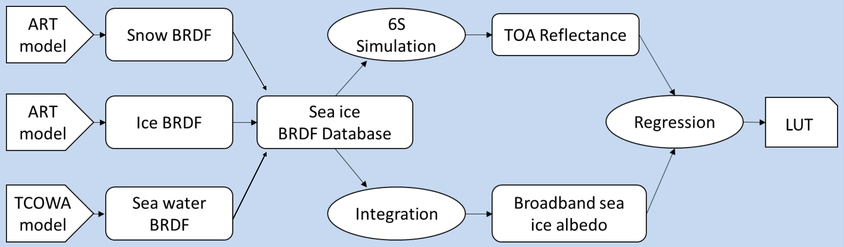
Introduction

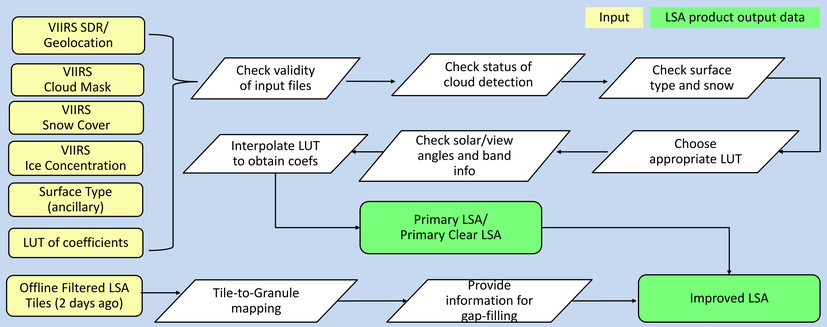
- The formation and distribution of sea ice affect the global climate dramatically since it has a much higher albedo than surrounding ocean and land surface.
- The melting of sea ice would expose lower-albedo surfaces at moderate temperature changes. This transformation results in more absorption of solar heat and thereby accelerate the sea ice melting and global warming.
- Global year-round record on sea ice albedo is important with respect to the global energy exchange in general circulation models (GCMs)
- Due to the high cloud coverage in Arctic region and the preference of MODIS atmospheric correction algorithm on dense vegetation coverage, the MODIS albedo product left the sea ice pixels blank.
- As the successor of MODIS, VIIRS started its observation from October of 2011. We deployed a direct estimation method to retrieve VIIRS sea-ice albedo (VSIA).
- The instantaneous inversion of albedo from single-date/angular observations is capable of grasping the dynamic variation of surface BRDF change.

Algorithm

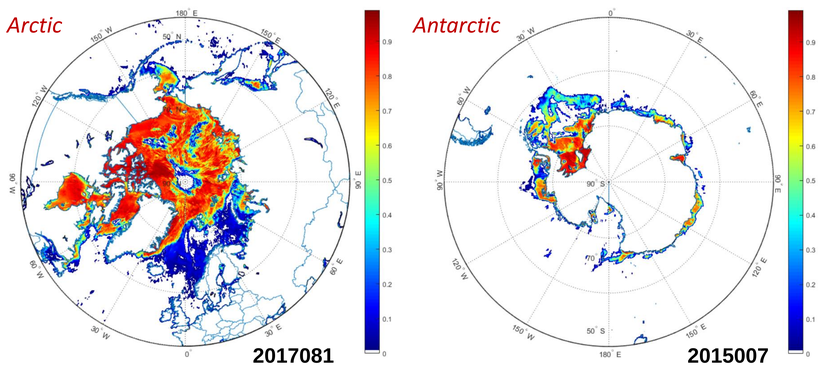
The generation of original sea ice albedo LUT



The albedo flowchart in NDE system



Test Output



Method

The LUT generation

- The regression relationship is built with the sensor spectral response convolved.
- The LUT can be further transferred between sensors through a band conversion.
- The sea ice LUT was firstly built for MODIS spectral characteristics and then converted to VIIRS instrument.
- This process avoided incur further uncertainty sources into the VIIRS LUT and causes inconsistency between instantaneous albedo from MODIS and VIIRS, extended the data source of albedo inversion for further application.

$$\alpha_s = c_0 + \sum_j c_{vj} r_{vj}, \quad j = 1,2,3,4,5,7,8,10,11$$

$$c_{vj} = \sum_i c_{mi} b_{ij}, \quad i = 1,2,3,4,5,6,7$$

The α_s represents the instantaneous broadband black-sky or white-sky albedo . r are the TOA reflectance. c means the direct retrieval coefficients from TOA reflectance to surface albedo, b denotes the band conversion coefficients. The subscript i and j are channel indexes for MODIS and VIIRS respectively. m and v denotes MODIS and VIIRS respectively.

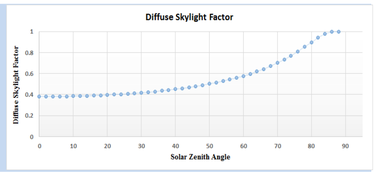
Band Conversion

- USGS spectra library provided spectral samples to derive band transfer coefficients.
- 6S was the tool to transfer the surface reflectance spectra to TOA spectra.
- The band conversion was conducted between TOA reflectances of VIIRS and MODIS
- RMSE between simulated MODIS reflectance and VIIRS predicted value < 10%.

Clear-sky albedo

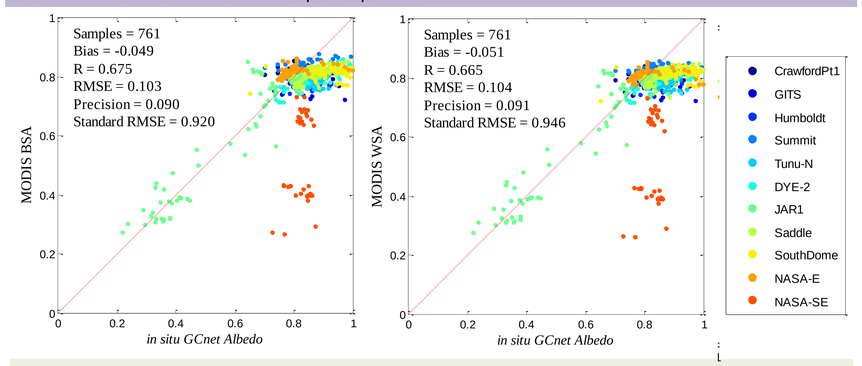
$$\alpha_{VIIRS} = (1-\beta)\,\alpha_{Black-sky} + \beta\,\alpha_{White-sky}$$

- the diffuse skylight factor β incorporated into the LUT for the convenience of users
- β varies with Solar Zenith Angle



Cross Validation

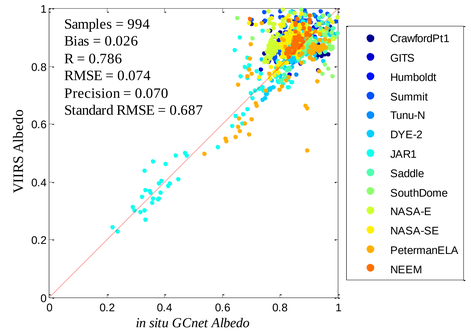
MCD43A3 and GC-NET Match-up Comparison



- MCD43A3 shows an overall underestimation of 0.05.
- MCD43A3 clusters at most sites, can not effectively in grasp dynamical change.
- MCD43A3 shows abnormal value at *NASA-SE*, invalid at *PetermanELA*, *NEEM* sites.
- MCD43A3 generally show lower R and higher RMSE than VSIA predicted albedo.
- MCD43A3 has 500-m spatial resolution, suffers less from spatial heterogeneity.

in situ Validation

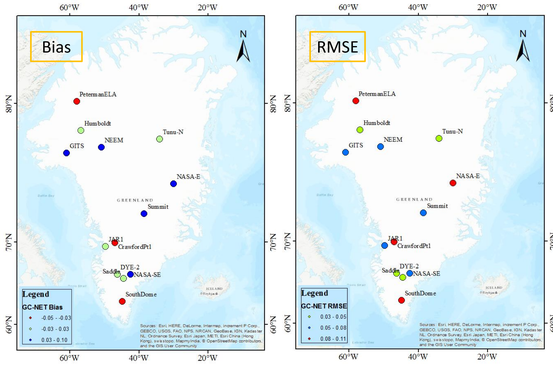
VIIRS and GC-NET Match-up Comparison



- 13 sites from GC-NET network data.
- Substitutes for sea-ice measurements.
- Collected over 2012-2017
- At local noon from 11:30 am to 12:30 pm
- Clear-sky measurements used
- *In situ albedo*: the ratio of upwelling to downwelling shortwave radiation
- Direct comparison between simultaneous albedos.

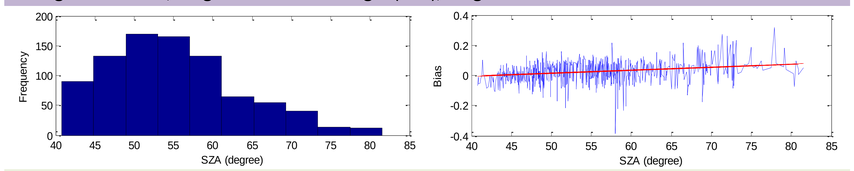
1. The overall accuracy is 0.026 with a precision of 0.07.
2. The overall Root Mean Square Error is 0.074 (the spread of the predicted albedo).
3. The standard RMSE is 0.687, showing the significance of the model.
4. The correlation coefficient is 0.786, high ability of VIIRS albedo to grasp dynamical change.
5. The result indicates that the sea-ice LUT is efficient to retrieve the albedo of ice/snow surface.
6. The three outliers are from PetermanELA on neighboring days due to surface heterogeneity.

Site by Site Evaluation



- Red sites: VSIA underestimates albedo, higher non-systematic error.
- Green sites: VSIA has accurate estimation and lowest non-systematic error.
- Blue sites: VSIA overestimates ground albedo, show moderate non-systematic error.
- *t*-test on bias: red sites have local bias.
- χ^2-test on variance: VSIA shows significant different precision PetermanELA and SouthDome .

Higher Latitude, Larger Solar Zenith Angle (SZA), Larger Bias



- SZA of the match-ups are distributed from 40˚ to 82˚ peaked at around 50˚~55˚.
- Bias show a slight increasing trend with SZA .

Summary

- New VIIRS sea ice albedo (VSIA) with high temporal (daily) and spatial (750 m) resolution could support the global climate change researches very well.
- VSIA has good quality comparing with GC-NET site measurements of snow albedo.
- VSIA shows higher accuracy and robustness than MCD43A3 snow albedo.

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