Deep convective cloud characterization and regression algorithm for inter-comparison

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- Introduction
- Statistical characterization of DCC reflectance using cumulative probability density function (CPDF)
- CPDF matching algorithm
- CPDF regression algorithm and partial CPDF regression
- Application for NOAA 18 gain degradation
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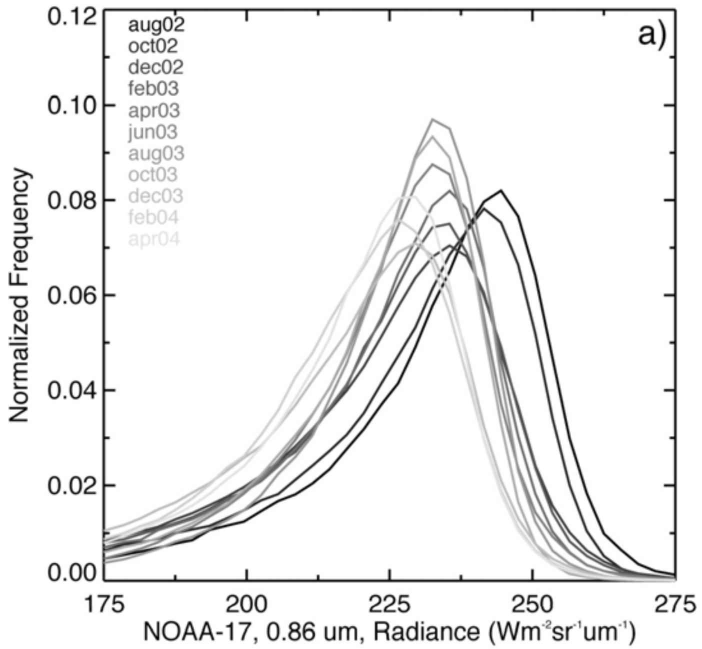
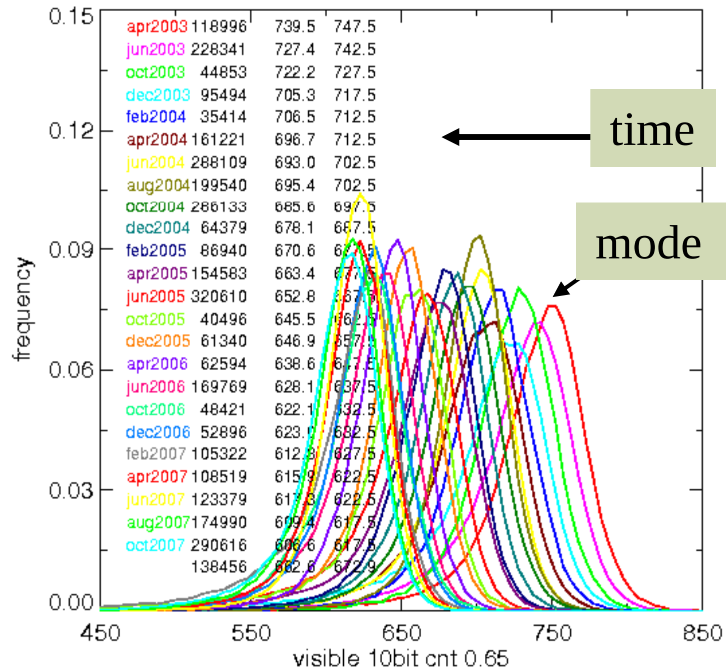
Introduction



Monthly probability density functions (PDF) of deep convective cloud NOAA-17 0.86 µm radiances from August 2002 -April 2004

D. R. Doelling, etc, "On the use of deep convective clouds to calibrate AVHRR data", Proc. SPIE 49th Ann. Mtg., Earth Observing Systems IX Conf., Denver, CO, August 2-6.(2004)



2003-2007 GOES-12 DCC monthly PDF counts

D. Doelling, etc, "On the use of Deep Convective Clouds (DCC) to calibrate visible sensors", GSICS/GWRG Session Daejon, Korea, March 29-April 1, 2011

Introduction

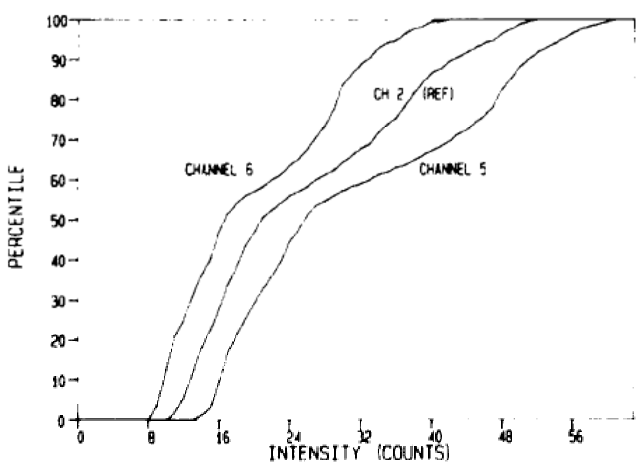
REMOTE SENS. ENVIRON. 29:185–195 (1989)

Destriping GOES Images by Matching Empirical Distribution Functions

M. P. Weinreb, R. Xie, J. H. Lienesch, and D. S. Crosby*[†]

National Oceanic and Atmospheric Administration, National Environmental Satellite, Data, and Information Service, Washington, DC

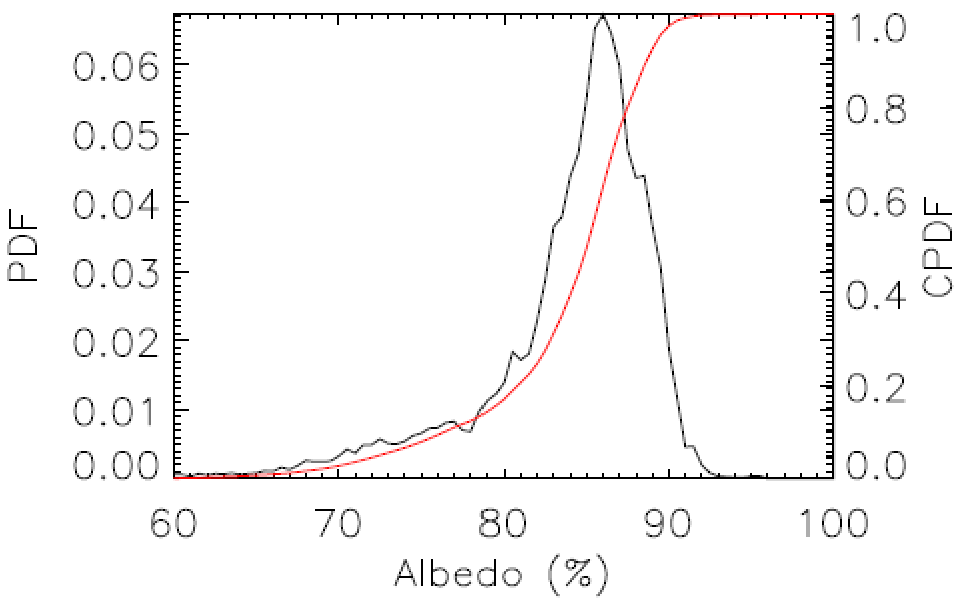
Figure 9. Empirical distribution functions for unnormalized GOES-7 image data, 1 June 1988.



Statistical characterization of DCC reflectance using cumulative probability density function

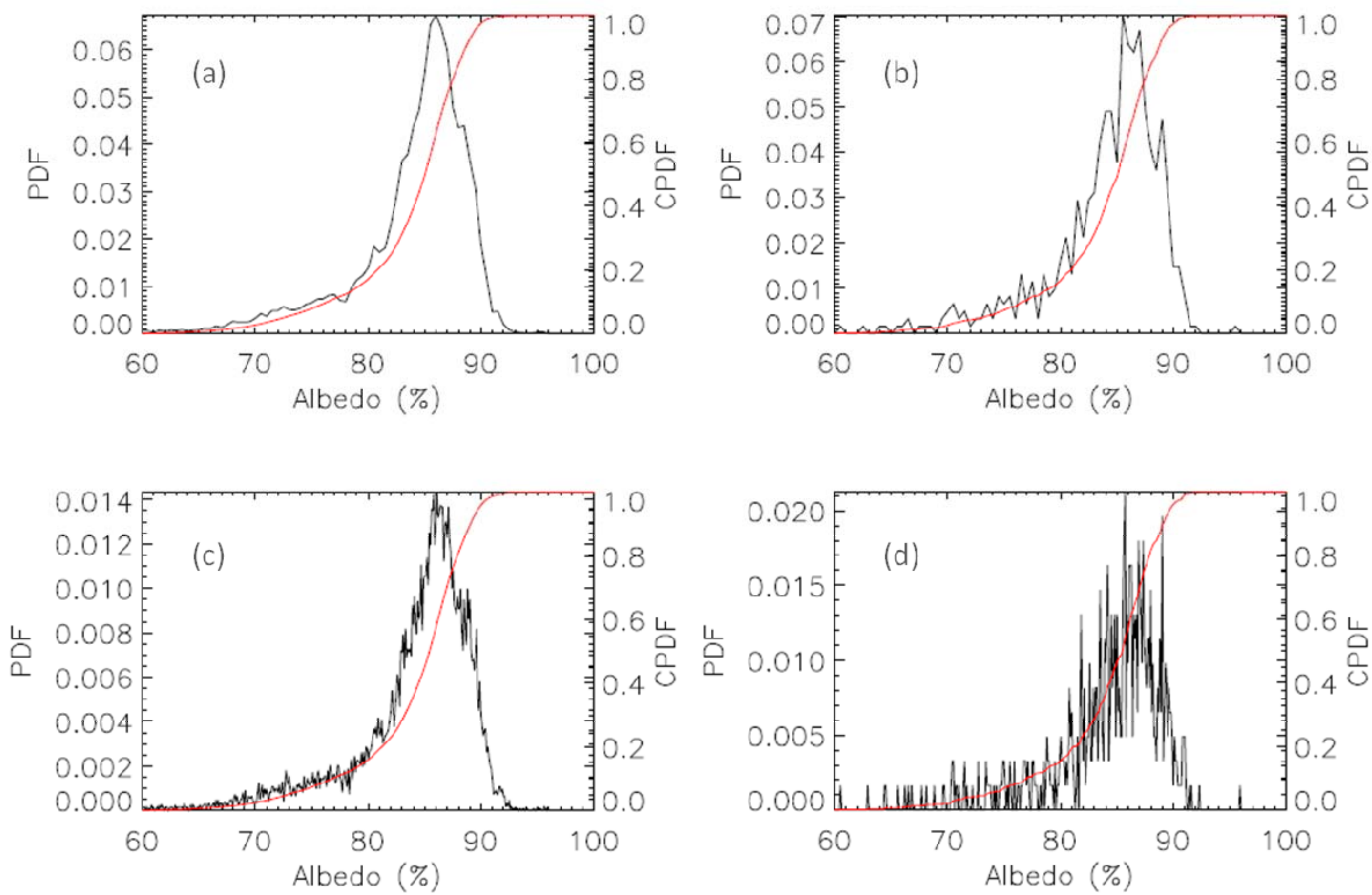
Cumulative probability density function (CPDF), also known as "Cumulative distribution function" or "Empirical distribution function", can be used to characterize statistically DCC reflectance measurement.

$$CPDF(R_i) = \sum_{j=0}^{i} PDF(R_j)$$



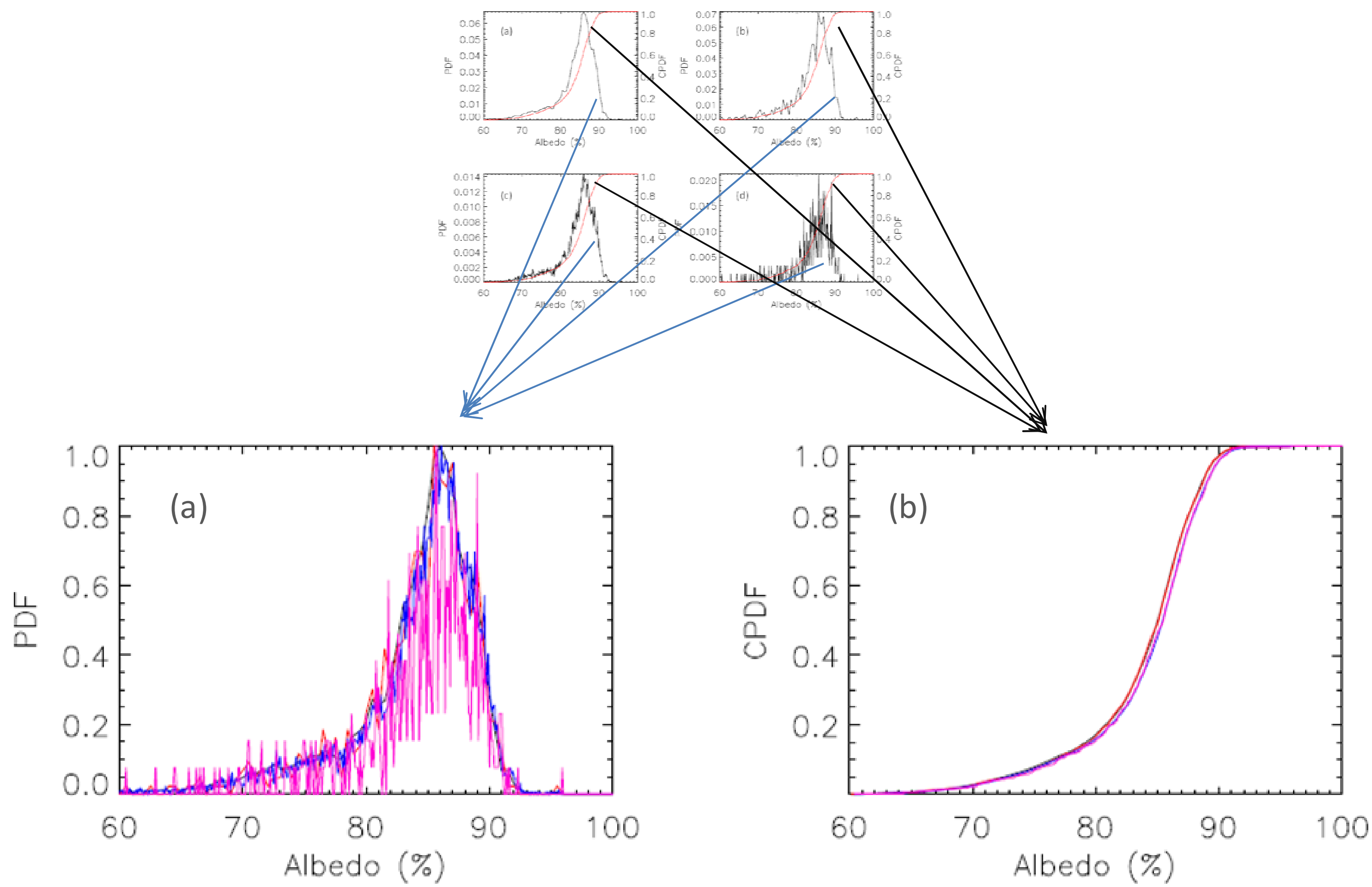
The DCC pixel selection follows GSICS DCC ATBD with fixed temperature limit.

Statistical characterization of DCC reflectance using cumulative probability density function



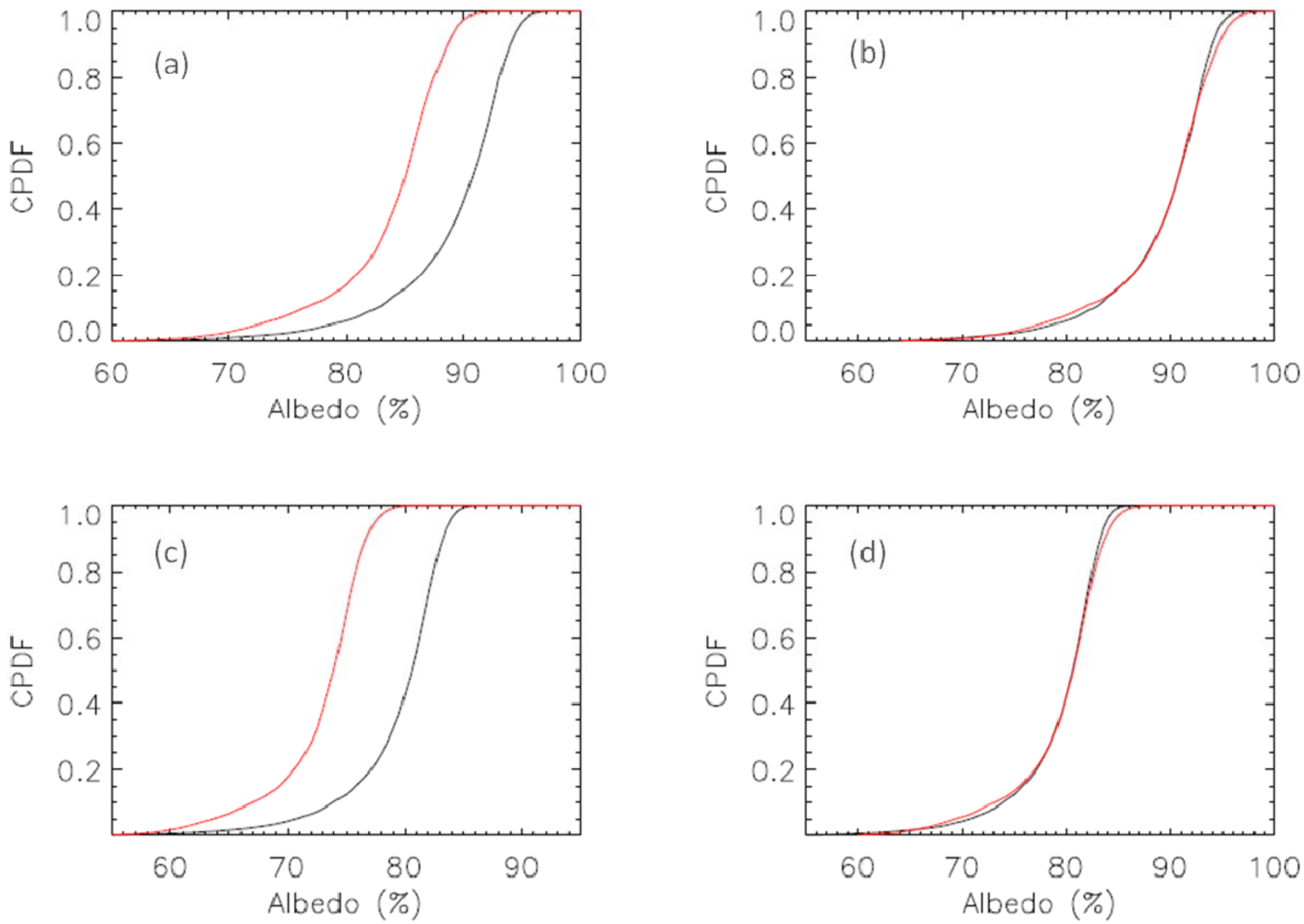
CPDF (red) and PDF (black), using all (upper row) and 5% (lower row) of NOAA-18 AVHRR channel 1 DCC measurements in January 2012, with albedo bin size of 0.5% (left column) and 0.1% (right column). The PDF scale is shown on the left side of plots as the normalized frequency, and the CPDF scale is shown on the right side of the plots. This illustrates that statistical characteristics of CPDF are less sensitive than those of PDF to sample size and bin size.

Statistical characterization of DCC reflectance using cumulative probability density function



CPDF matching algorithm

$$\min\left\{\sum_{R}\left[CPDF_1(R) - CPDF_2(aR)\right]^2\right\}$$



$$a = 1 - r*(M_2 - M_1)/12$$

By applying the least-square method, the annual gain degradation rate can be derived from the coefficient

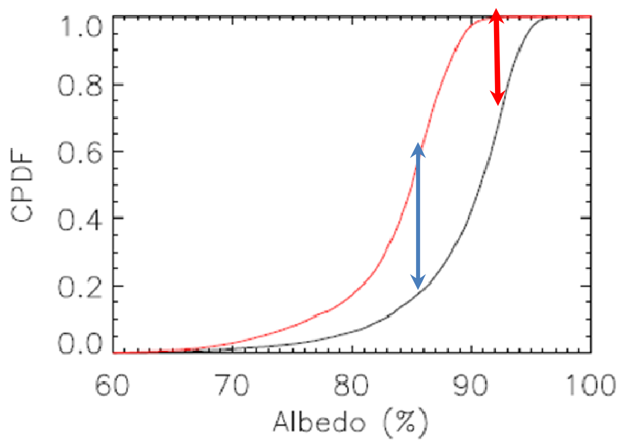
It can also be used for the inter-comparison of two sensors.

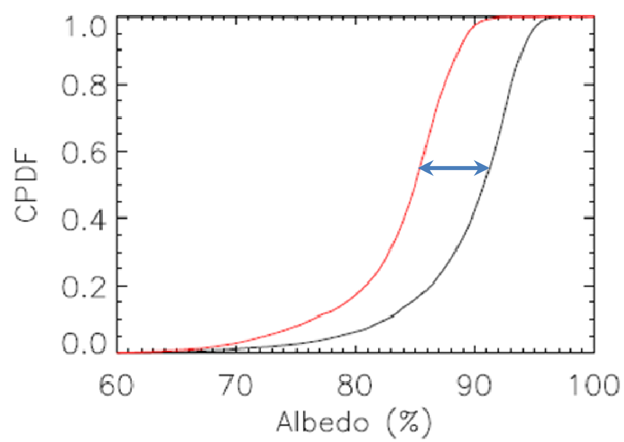
(a) CPDFs from October 2005 DCC measurements (dark) and from January 2012 (red) for NOAA18 AVHRR channel 1. (b) The results of CPDF matching by correcting the albedo with an annual degradation rate of -1.07% for January 2012 CPDF. (c) and (d) are the CPDF before and after the matching with an annual degradation rate of -1.45% for channel 2.

CPDF matching algorithm improvement

Matching algorithm improvement

$$\min\left\{\sum_R \left[CPDF_1(R) - CPDF_2(aR)\right]^2\right\} \longrightarrow \min\left\{\sum_i \left[R_1(L_i) - aR_2(L_i)\right]^2\right\}$$





This improvement solve the problem for
(1) an instrument has a large degradation over a long period of time, or
(2) the difference of two sensors is large

The benefits also include
(1) the number of points for regression can be varied
(2) good for using partial CPDF for regression

CPDF regression algorithm

Matching algorithm

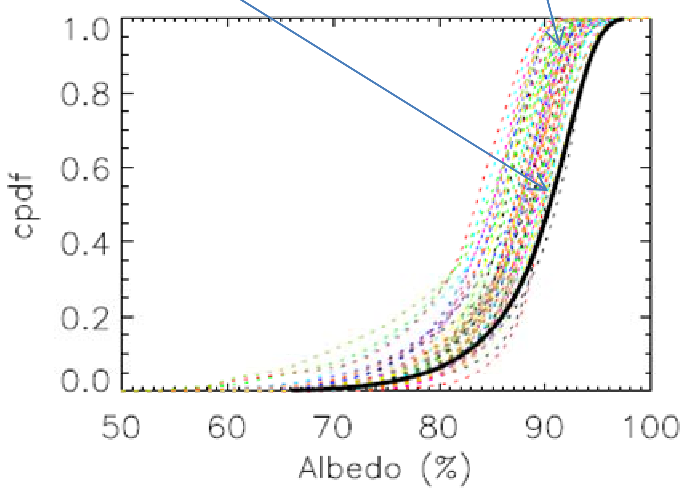
$$\min\left\{\sum_i \left[R_1(L_i) - aR_2(L_i)\right]^2\right\}$$

Regression algorithm

$$\min\left\{\sum_M \sum_i \left[R_{regression}(L_i) - a(M)R_{measurement}(M, L_i)\right]^2\right\}$$

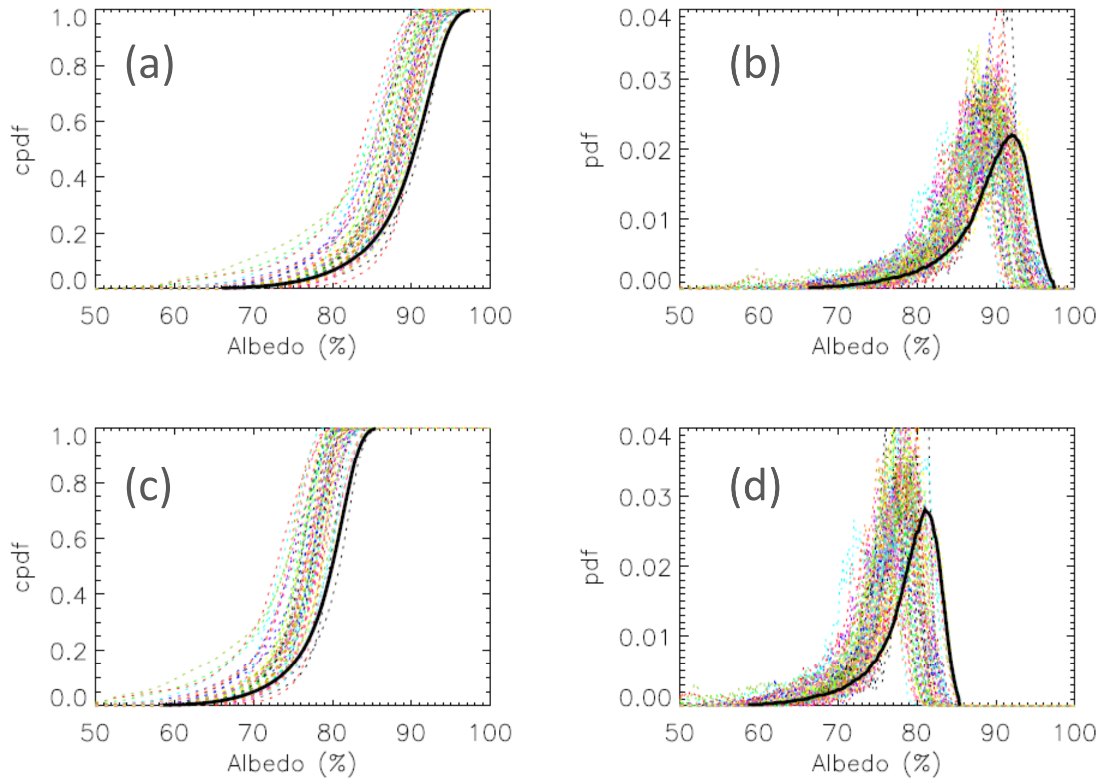
Sum over multiple measurements

Sum over CPDF level



CPDF matching algorithm improvement and regression algorithm

Regression algorithm $$\min\left\{\sum_{M}\sum_{i}\left[R_{regression}(L_i)-a(M)R_{measurement}(M,L_i)\right]^2\right\}$$



Products

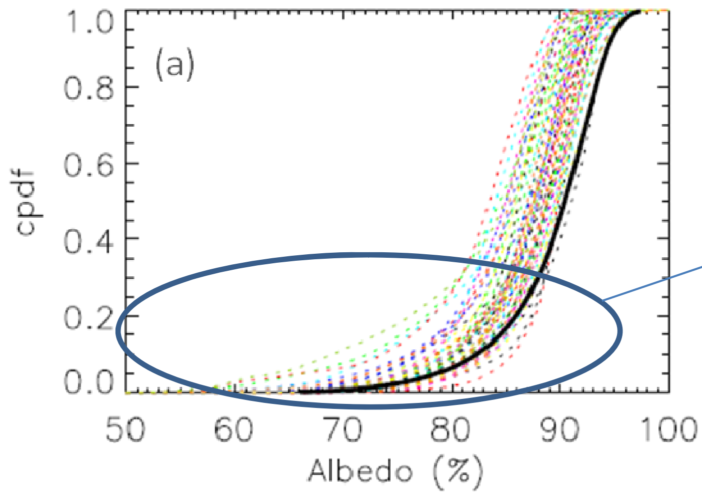
(1) Gain degradation

(2) "True" CPDF

(3) "True" PDF

NOAA-18 AVHRR channel 1 and 2 CPDF regression results using monthly DCC measurements from the first operational month (September 2005) to April 2012. The dotted color curves in (a) and (c) are CPDFs of DCC albedos in a month using pre-launch calibration coefficients. The dark curves are the regressed first day CPDF. The dotted color curves in (b) and (d) are the original monthly PDFs. The dark curves in (b) and (d) are the PDF for the first day after launch, which is recovered from the regressed first day PDFs. (a) and (b) are CPDF and PDF curves from channel 1, while (c) and (d) are from channel 2

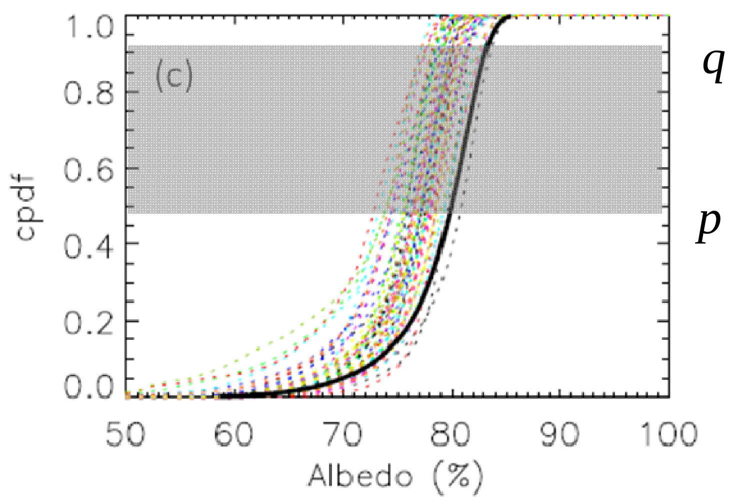
CPDF matching algorithm improvement and regression algorithm



Larger uncertainty

Regression algorithm using partial CPDF

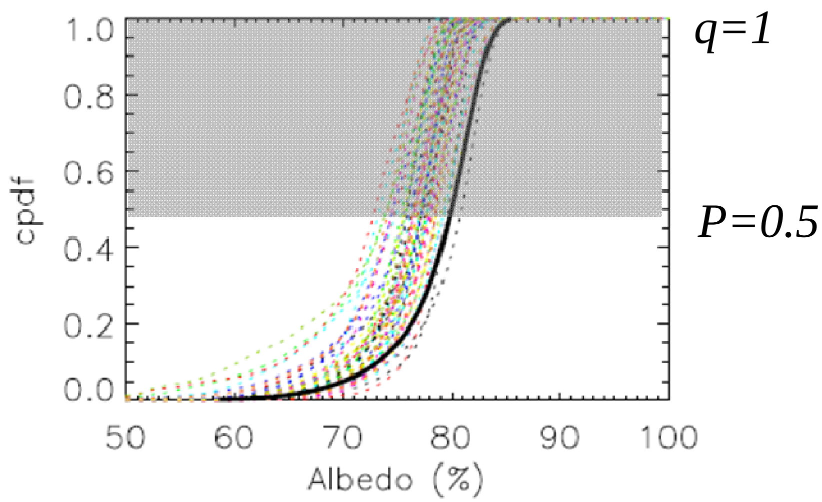
$$\min\left\{\sum_{M}\sum_{i=p}^{q}\left[R_{regression}(L_i)-a(M)R_{measurement}(M,L_i)\right]^2\right\}$$

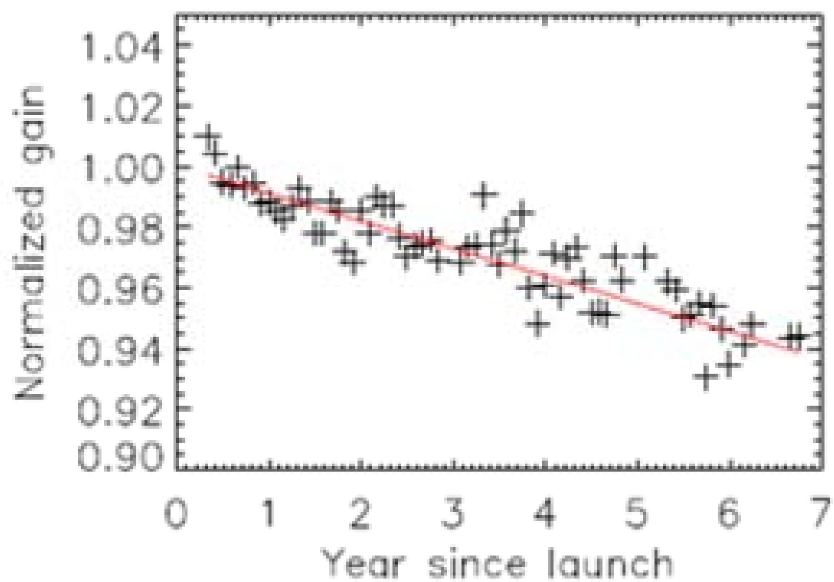


Application to NOAA 18 degradation

Regression algorithm using partial CPDF

$$\min\left\{\sum_{M}\sum_{i=p}^{q}\left[R_{regression}(L_i)-a(M)R_{measurement}(M,L_i)\right]^2\right\}$$





NOAA18 AVHRR channel 1 normalized gain changes from DCC monthly measurement using (a) the partial CPDF regression method using the data with CPDF from 0.5 to 1

Summary

❑ The CPDF matching and regression algorithms have been developed.

❑ These methods can be used for time series instrument response comparison (such degradation) and inter-instrument comparison.

❑ The in-house tools have been developed for applying these algorithm. The matrix of normal equation method is used to perform the least square for the regression.

❑ Application to NOAA 18 for the instrument response degradation, and the results are consistent with degradation from operational calibration update using Libyan Desert.

❑ Future work includes the application to inter-instrument comparison and uncertainty assessment.