Cloud-top Relief Spatial Displacement Adjustments of GOES-R Images

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NOAA-Collaborators: Andrew Heidinger and Robert Kuligowski, NESDIS-STAR,

Objectives:

- Estimate Cloud-Top Height (CTH) using 3-D principals;
- Enhance quality of high resolution GOES-R images by adjusting cloud-top relief Spatial Displacements (SD).

Introduction:

Cloud images can posses Spatial Displacements (SD) because of satellite-cloud view angle and the variation of Cloud-Top Height (CTH). As an example: for a cloud cell at 10km height and 45 degrees view angle, SD ≈ 10km.

CTH and its associated SD are determined utilizing stereo-graphical procedure for corresponding and simultaneous cloud Infra Red (IR) images from GOES-E and -W.

Satellite-cloud view angle, zenith sun-angle, and earth curvature uncertainties are also considered to improve estimation of cloud-top relief SD.

Proposed 3-D based technique will be incorporated in the GOES-R Algorithm Theoretical Basis Document (ATBD) to examine if the combined methods can improve CTH output. CTH estimates by proposed and ATBD models will evaluate against CALIPSO CTH product.

Project Description & Methodology:

Using stereoscopic principal to estimate CTH and adjust its associated relief spatial displacement for each cloud cell. The proposed tasks are:

1. Derive the geometric relationship between cloud-top height and pixel-based spatial displacement;
2. Derive the relationship between CTH, X-parallax of spatial displacement, and IR cloud-top brightness temperature, by applying stereoscopic principals from scan-synchronous GOES-E and -W Images;
3. Estimate the best values for parameters of the fitted piecewise line using the SCE (Shuffled Complex Evolution) calibration Model;
4. Evaluate the CTH estimates from the proposed method and the GOES-R ATBD algorithm by comparing with the CALIPSO CTH product;
5. Examine improvement of CTH estimates by incorporating the proposed technique into ATBD model by evaluating the new CTH product and comparing with CTH outputs of both models.
6. Imply the optimized parameters of the modified height-T_b profile to estimate and adjust X- and Y-components of spatial displacements of GOES-R images;
7. Update/Modify the optimized model parameters based on seasonal, geography, topography, land type, and storm type variability.

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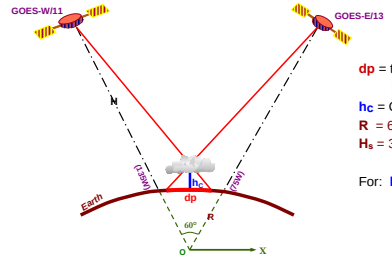
Introduction:

Improving quality and accuracy of high resolution GOES-R IR observations by adjusting cloud-top relief spatial error is the objective of the proposed study. Because of satellite-cloud view angle and the variation of Cloud-Top Height (CTH), cloud images posses Spatial Displacements (SD). CTH and its associated SD are determined utilizing stereo-graphical procedure for simultaneous and corresponding cloud Infra Red (IR) images from GOES-E and -W. Satellite-cloud view angle, zenith sun-angle, and the earth curvature uncertainties are also considered to improve estimation of cloud-top relief SD. Proposed 3-D based technique might be incorporated with the GOES-R Algorithm Theoretical Basis Document (ATBD) after evaluation of their CTH outputs against CALIPSO CTH product. Cloud-top Tb from GOES-11 and -13 imager will be used as a proxy for the GOES-R east and west data because both sensors have two similar channels at 11 and 12 μm wavelengths.

ATBD-CTH Weaknesses:

ATBD-CTH model have problems with non-rainy cirrus clouds, multi-layer clouds, low accuracy of estimates (lower than 0.5 km), and requirement of knowledge of atmospheric physics because it is a physical-based algorithm.

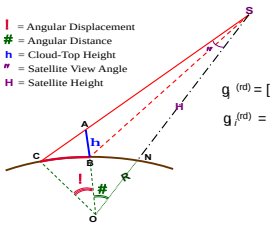
Stereoscopic Parallax Related to CTH:



dp = the X- or Stereoscopic Parallax associated with
h_C = Cloud-top Height,
R = 6370 km (Radius of Earth)
H_s = 36000 km

For: **h = 10 km** → **dp = 16.0 km**

Cloud-Top Height-Displacement Relationship:



$$g = \text{¡}(h, q, a)$$

$$g_j^{(rd)} = [h_c (H + R) \sin(dj)] / \{R [(H + R) \cos(dj) - (R + h_c)]\}$$

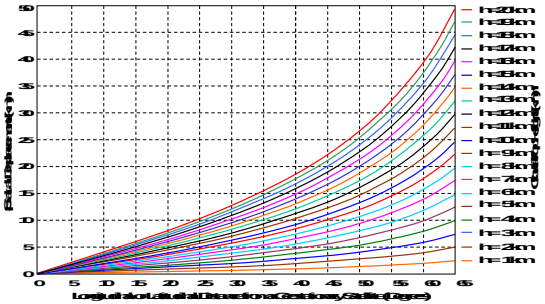
$$g_{j'}^{(rd)} = [h_c (H+R) \sin(dl_{j'})] / \{R [(H+R) \cos(dl_{j'}) - (R+ h_c)]\}$$

$$dL_x = R_i g^{(rd)} \ (km)$$

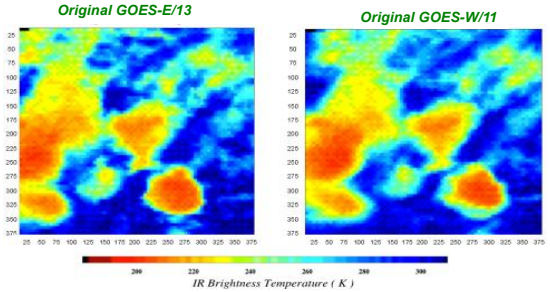
$$dL_y = R\, g_j^{(rd)} \ (km)$$

Methodology & Results:

Cloud Top Relief Spatial Displacement for GOES Images

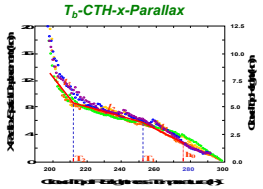


Dependency of Spatial Displacement and Height/Temperature



GOES-13 (left) and GOES-11 (right) channel-4, cloud-top brightness T_b, Southwestern U.S, 07/12/10.

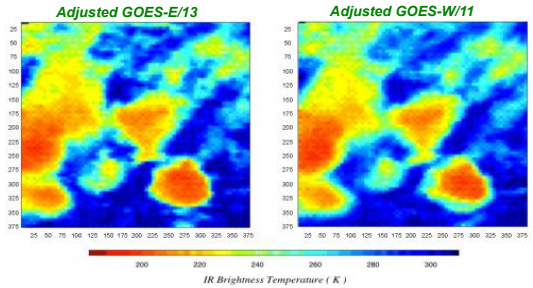
Designing Fitted Piecewise T_b-Height Relationship Lines



6 parameters of a 3-pieces Linear Profile

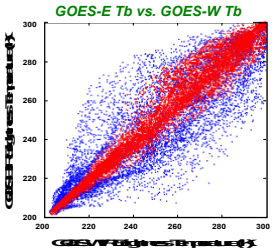
H_0	2.5 km
T_1	244 K
T_2	220 K
I_1	0.123
I_2	0.109
I_3	0.132

Designing a 3-Pieces Piecewise Line with 6 Parameters for T_b-Height/Displacement Relationship. Optimized parameters are estimated by minimizing X-Parallax between a pair of simultaneous GOES IR images using stereoscopic principle and Shuffled Complex Evolution algorithm



GOES-13 (left) and GOES-11 (right) channel-4, cloud-top brightness T_b after incorporating the optimized 6-paramters to adjust cloud-top relief spatial errors.

GOES-E/13 IR-T_b vs. GOES-W/11 IR-T_b before (blue) and after (red) adjusting pixel based cloud-top relief spatial displacements.



Future Plan:

- Improve the piecewise linear T_b-CTH using more simultaneous corresponding GOES-E and -W IR images;
- Determine the best number of pieces of lines (parameters) for the T_b-CTH relationship to enhance CTH and SD estimation;
- Evaluate CTH estimates and CTH from ATBD by comparison with CALIPSO to understand how good these methods work,
- Incorporate the proposed technique into ATBD model to examine if the CTH and associated SD can be improved.
- Apply the optimized parameters of CTH-T_b profile to estimate and adjust x- and y-components of spatial displacements of GOES-R images;
- Update/Modify the optimized model parameters based on seasonal,

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