Progress in 3D Tomographic Cloud Reconstruction, Part 2*: Efficient determination of outer shapes of convective clouds from MISR data using radiosity

Anthony B. Davis, JPL / Caltech, Pasadena, Ca, USA
Guillaume Bal, University of Chicago, Chicago, Il, USA
Céline Cornet, Laboratoire d'Optique Atmosphérique, Lille, France

*** Part 1 is Linda Forster's oral presentation on Wednesday PM.**

Objective & Results

Tomographic reconstruction of 3D convective clouds is a large and challenging inverse problem that can benefit from a reasonably good initial guess. In this study, we use synthetic and real MISR data to demonstrate a robust and highly efficient determination of the effective outer shape of a 3D cloud, one slice at a time. Although time will tell, we believe this will constitute a viable initial guess for the full 3D cloud tomography.

In our methodology, the outer boundary of a 2D slice from a 3D cloud along any convenient direction (say N-S) is represented as an irregular n-sided off-grid polygon with the lowest facet (i.e., cloud base) being constrained to remain horizontal. Radiance emerging from each facet (except the base) is modeled with a radiosity-type angular distribution inspired by asymptotic radiative transfer theory; this function has at most two free parameters. In total, $2n$-1+2(n-1) = 4n-3 parameters need to be determined by fit to the MISR data. We found that n = 8 is a reasonable balance for a wide range of cloud sizes, in view of the coarse nature of the cloud boundary model. Thus, a nonlinear minimization problem is solved to estimate the 29 parameters per 2D slice, 15 of which will be used in the subsequent full 3D cloud tomographic reconstruction to construct an initial guess. This preliminary fitting problem also calls for an initial guess that we distill out of cloud masks for the nadir and most oblique views.

Two-parameter (a_i,t_i) **radiosity model:**

$I(\boldsymbol{\Omega}_0, \boldsymbol{\Omega}_v, \boldsymbol{n}_i; a_i, t_i) = a_i \times (\boldsymbol{\Omega}_v\cdot\boldsymbol{n}_i) \times \max(-\boldsymbol{\Omega}_0\cdot\boldsymbol{n}_i, t_i)$

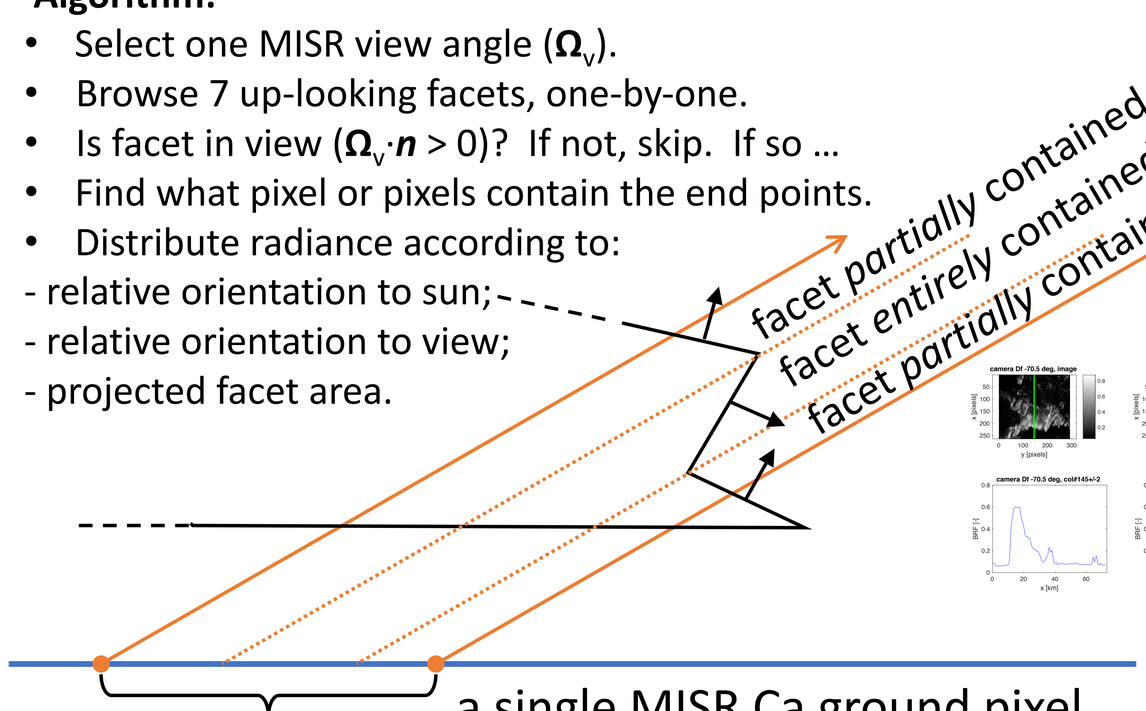
where: $\boldsymbol{\Omega}_0$ is solar incidence direction;
$\boldsymbol{\Omega}_v$ is viewing direction;
$\boldsymbol{n}_i$ is the outward normal of the i^{th} facet;
$a_i > 0$ is an albedo-like parameter;
$t_i > 0$ is a diffuse Lambertian background.

For a non-illuminated facet ($\boldsymbol{\Omega}_0\cdot\boldsymbol{n}_i > 0$) or a grazing sun ($-\boldsymbol{\Omega}_0\cdot\boldsymbol{n}_i < t_i$), $a_i t_i$ combines into a single free parameter.

Algorithm:

- Select one MISR view angle ($\boldsymbol{\Omega}_v$).
- Browse 7 up-looking facets, one-by-one.
- Is facet in view ($\boldsymbol{\Omega}_v\cdot\boldsymbol{n} > 0$)? If not, skip. If so …
- Find what pixel or pixels contain the end points.
- Distribute radiance according to:

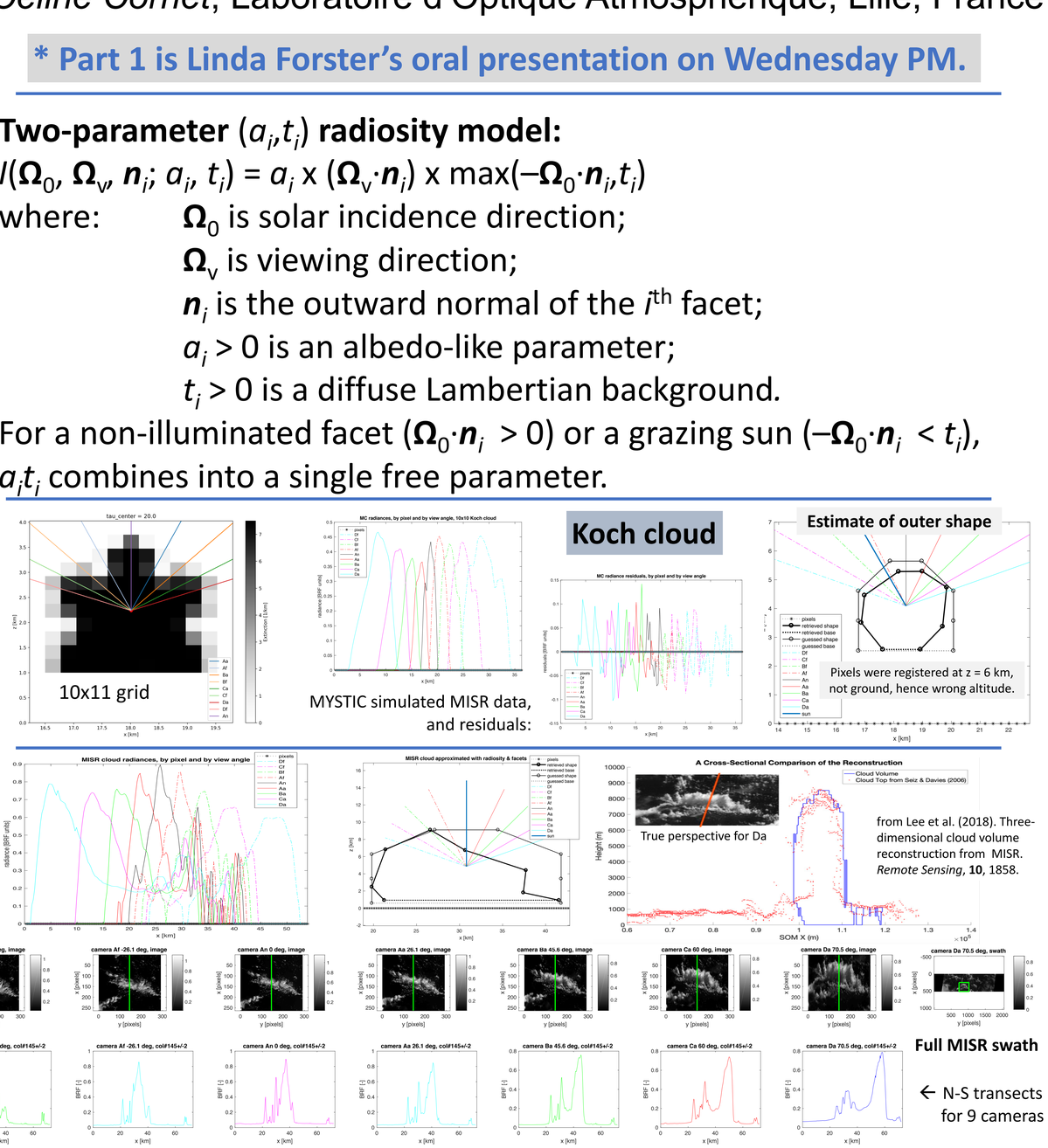
- relative orientation to sun;
- relative orientation to view;
- projected facet area.



Koch cloud

BRF<0.1 → 0

MISR cloud



from Lee et al. (2018). Three-dimensional cloud volume reconstruction from MISR. *Remote Sensing*, **10**, 1858.

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