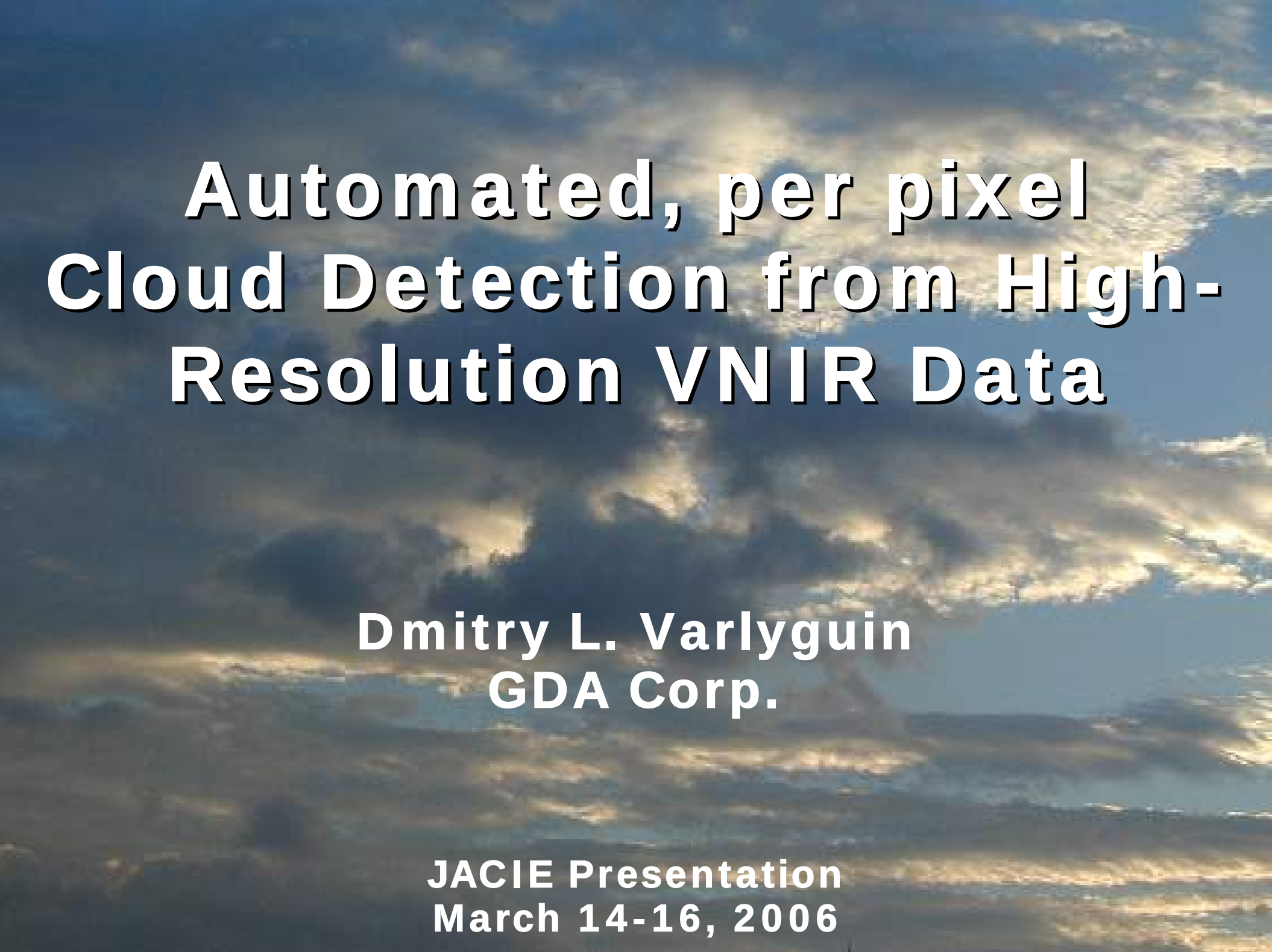

Automated, per pixel Cloud Detection from High-Resolution VNIR Data

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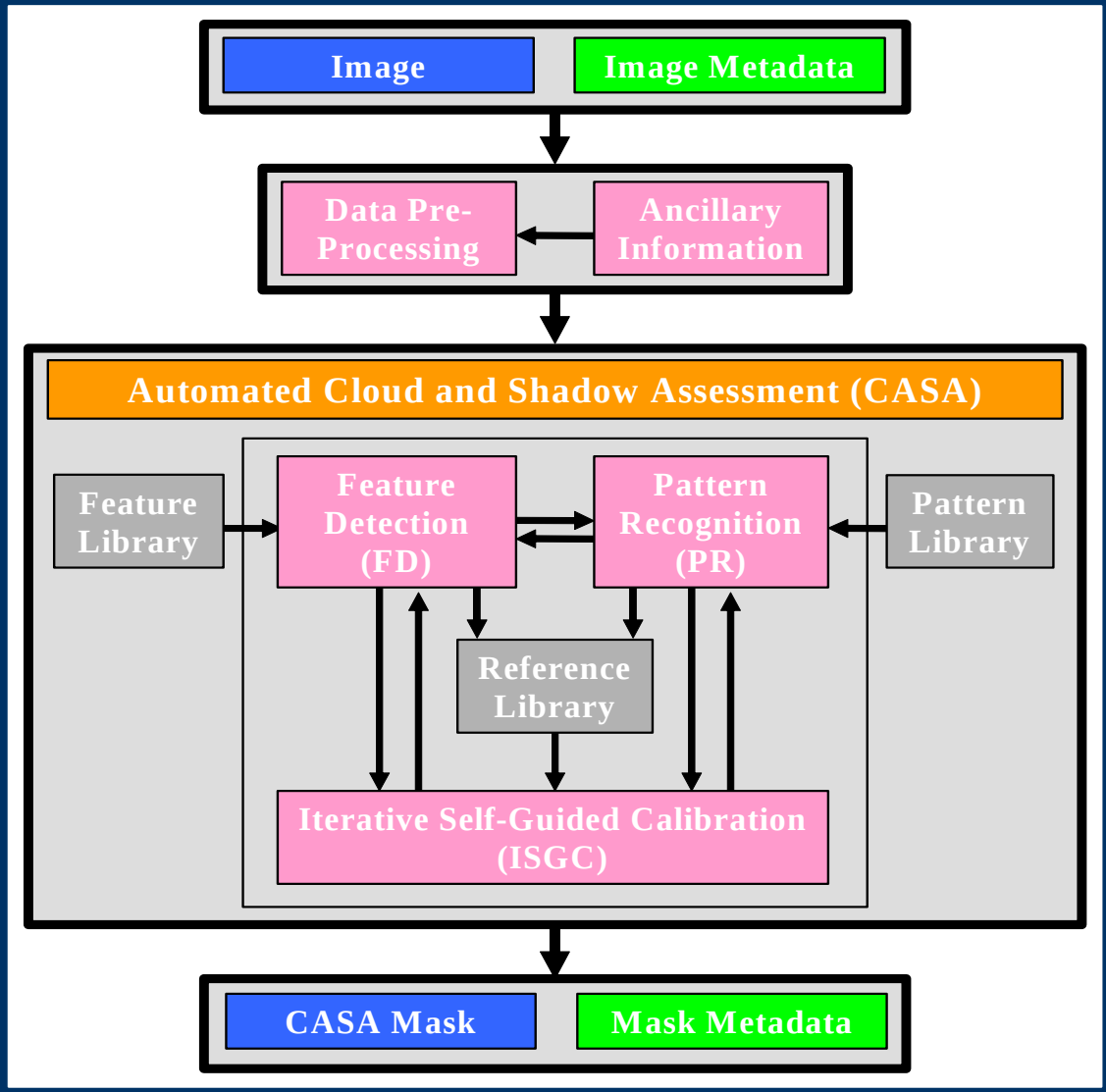
Cloud And Shadow Assessment (CASA)

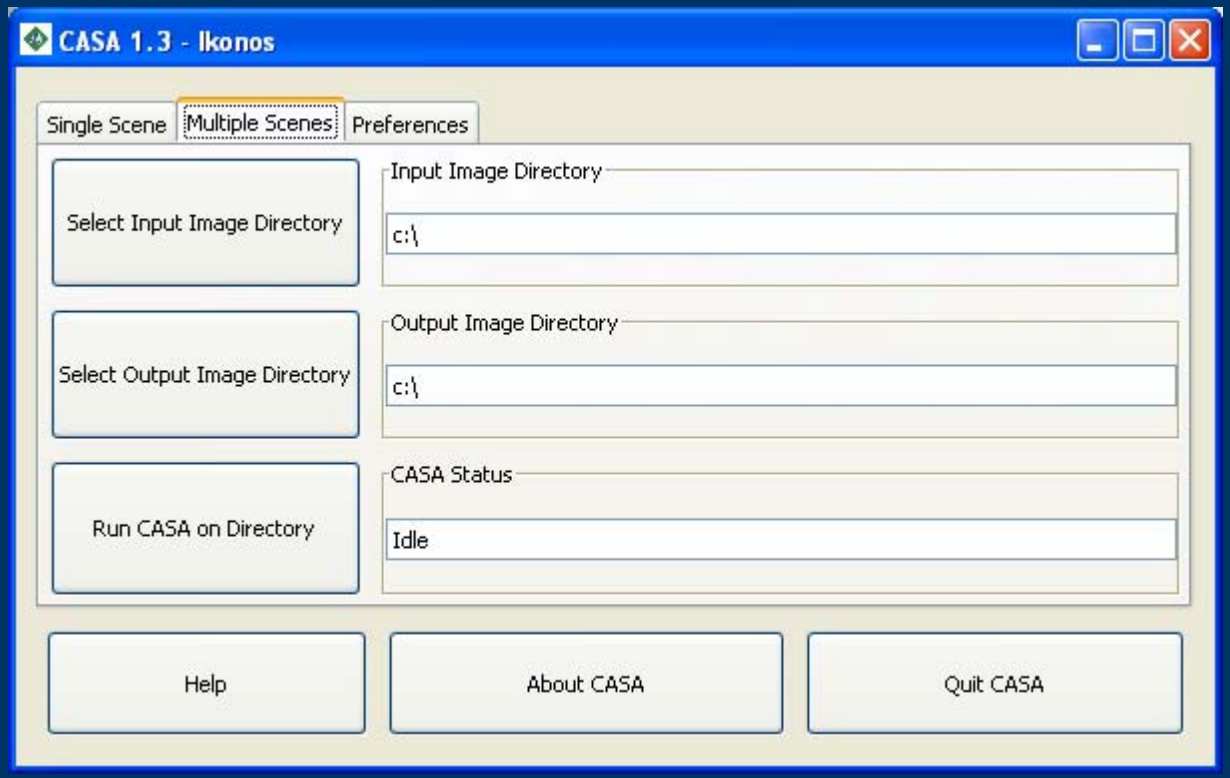
CASA is a fully automated software program for the per-pixel detection of clouds and cloud shadows from medium- (*e.g.*, Landsat, SPOT, AWiFS) and high- (*e.g.*, Ikonos, QuickBird, OrbView) resolution imagery without the use of thermal data.

CASA is an object-based feature extraction program which utilizes a complex combination of spectral, spatial, and contextual information available in the imagery and a hierarchical self-learning logic for accurate detection of clouds and their shadows.



CASA Specifications

CASA is a stand-alone, platform-independent program that can be run on Windows, Linux, and UNIX.



CASA has a simple GUI and Open Source Viewer for non-GIS/non-programming experts, or can be called via a batch program within any IP software program in order to seamlessly integrate it into a standard pre-processing / production sequence

Average run-times for medium-resolution scenes are between 3 to 10 minutes on a standard development laptop (2 GHz)

CASA Specifications

Input	Output
CASA works with images in their native data type (*e.g.*, 8-bit data for Landsat 5 and 7, 11-bit data for Ikonos and Quickbird, *etc*.) No thermal or Panchromatic data is required.	Raster mask presenting per pixel cloud and cloud shadow contamination of the scene. Different IDs are assigned to dense clouds, light clouds / haze, and cloud shadows. Text file with scene total and per quad % cloud and cloud shadow contamination and an accuracy measure of cloud detection.

CASA supports GeoTIFF and ERDAS Imagine's HFA .img I/O formats. Other formats are to be incorporated (*e.g.*, NITF)

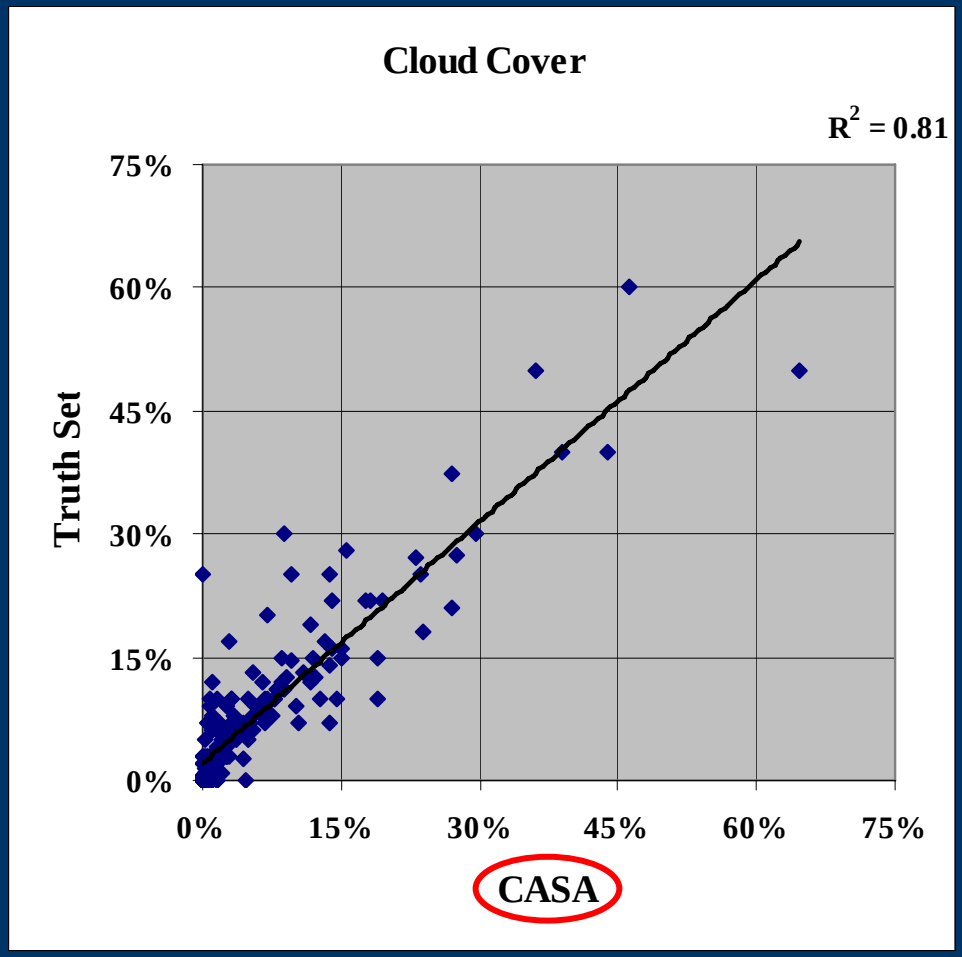
CASA Validation

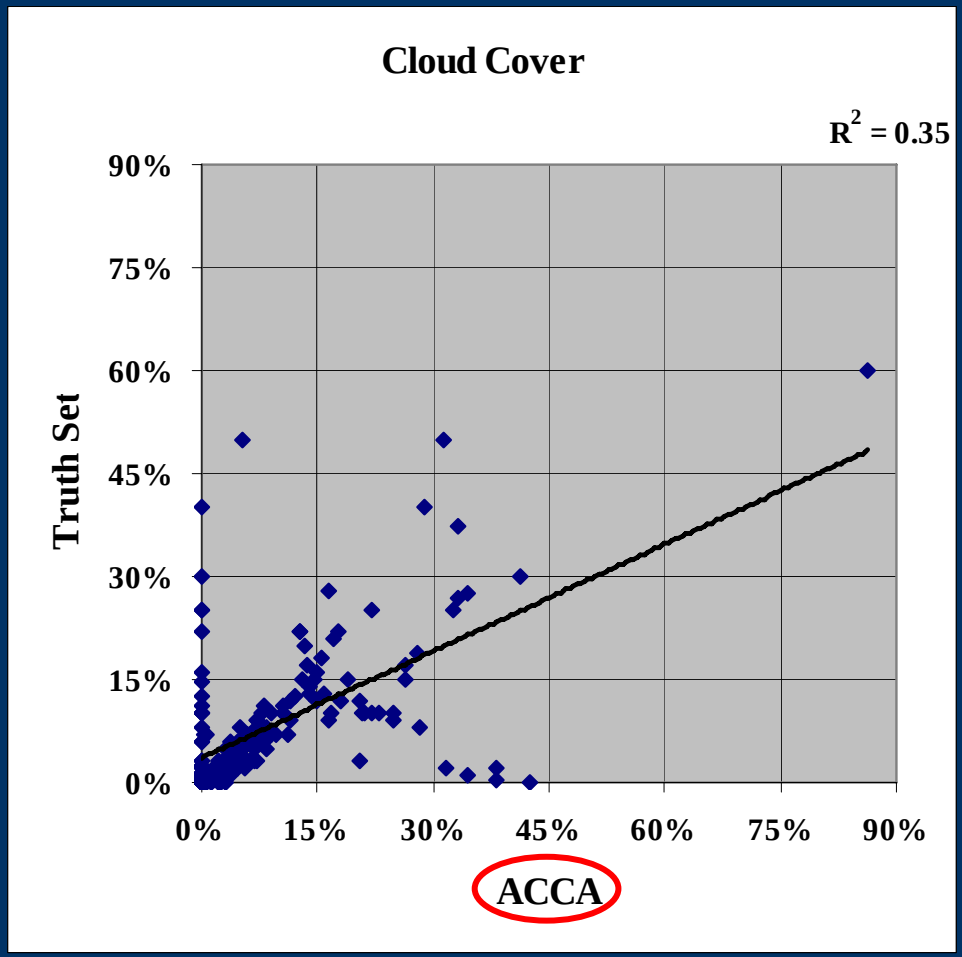
Imagery	No. of Scenes	Notes
Landsat 7 ETM+	194	dataset comprises scenes from 4 regions (tropical, polar, Western U.S., & Eastern U.S.) ~50 scenes/region. Bands 1-2-3-4-5-7.
Ikonos 2	216	11-bit, 4 MS bands (B-G-R-NIR)
QuickBird	44	11-bit, 4 MS bands (B-G-R-NIR)
AWiFS		planned
OrbView		planned
SPOT		planned

Validation Strategy: Correlation of CASA results to independent visual estimates of cloud cover. Landsat 7 ETM+ results were also compared to ACCA (Automated Cloud Cover Assessment), NASA's operational cloud assessment system which requires thermal data.

Each scene was visually inspected to assess, separately, percent dense cloud cover, percent light, transparent cloud and haze cover, and percent of total cloud and light cloud / haze cover. For each scene, two independent assessments of cloud cover were made. Then results were compared and cases of significant disagreement were resolved by scene re-evaluation simultaneously by both operators.

CASA-Landsat Validation

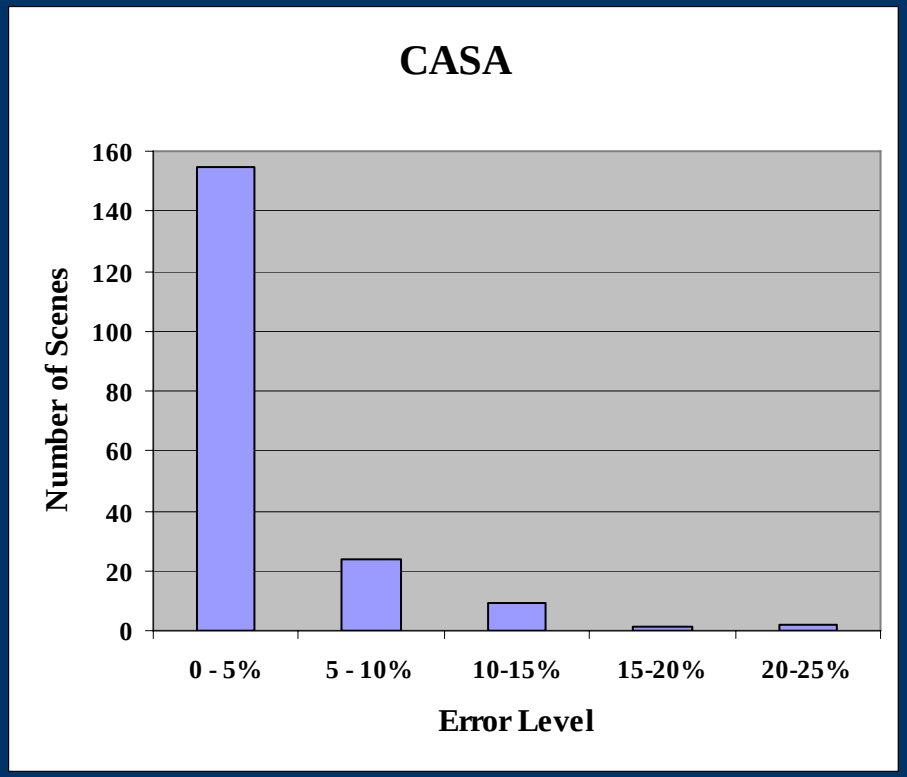




CASA-Landsat Validation

Error Level	Number of Scenes	Percent of Scenes
0 to 5%	155	81%
0 to 10%	179	94%
0 to 15%	188	98%
0 to 20%	189	99%
0 to 25%	191	100%
Max Error		25%

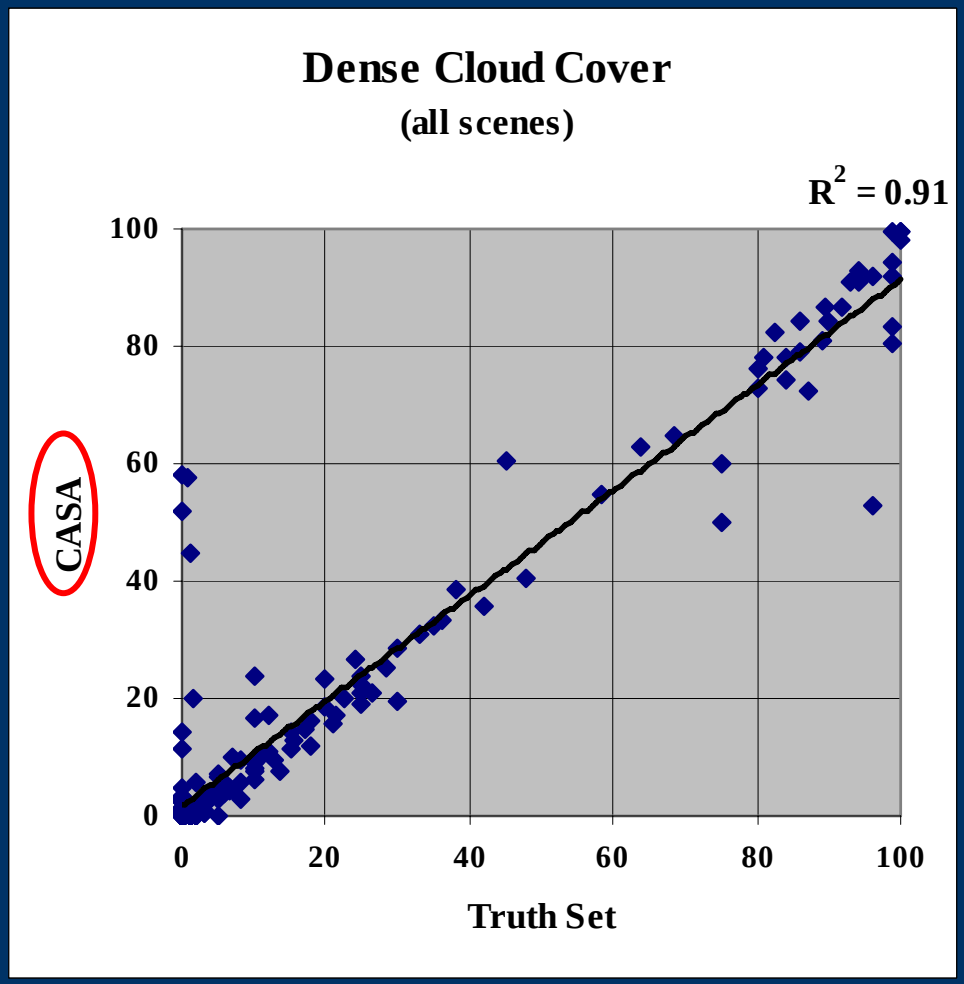
CASA is within 10% of the visual estimate for more than 90% of all images (n=194) tested

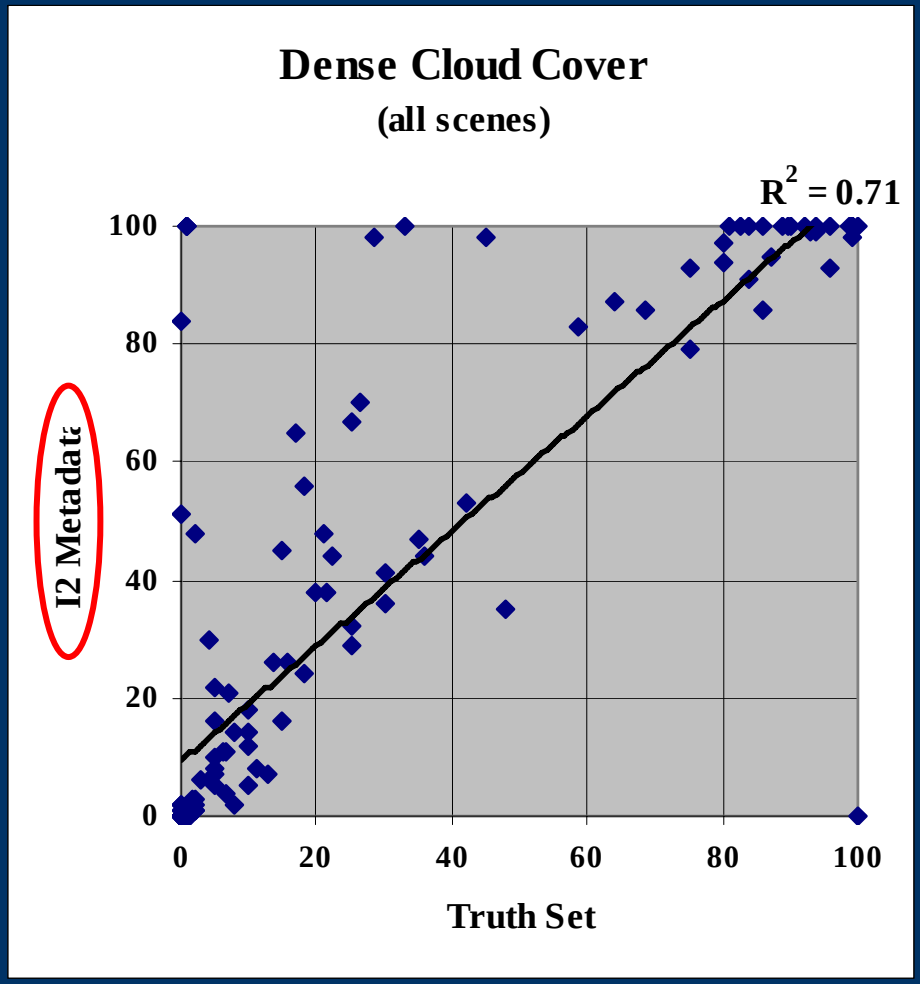


Summary of statistical results – correlation coefficients :

	Overall	Atlantic	Pacific	Tropical	Polar	Leaf On	Leaf Off
CASA vs. Visual	90%	92%	79%	89%	91%	83%	94%
ACCA vs. Visual	59%	70%	57%	51%	39%	63%	59%
CASA vs. ACCA	46%	61%	42%	44%	30%	46%	50%

CASA-Ikonos Validation: Dense Cloud Cover

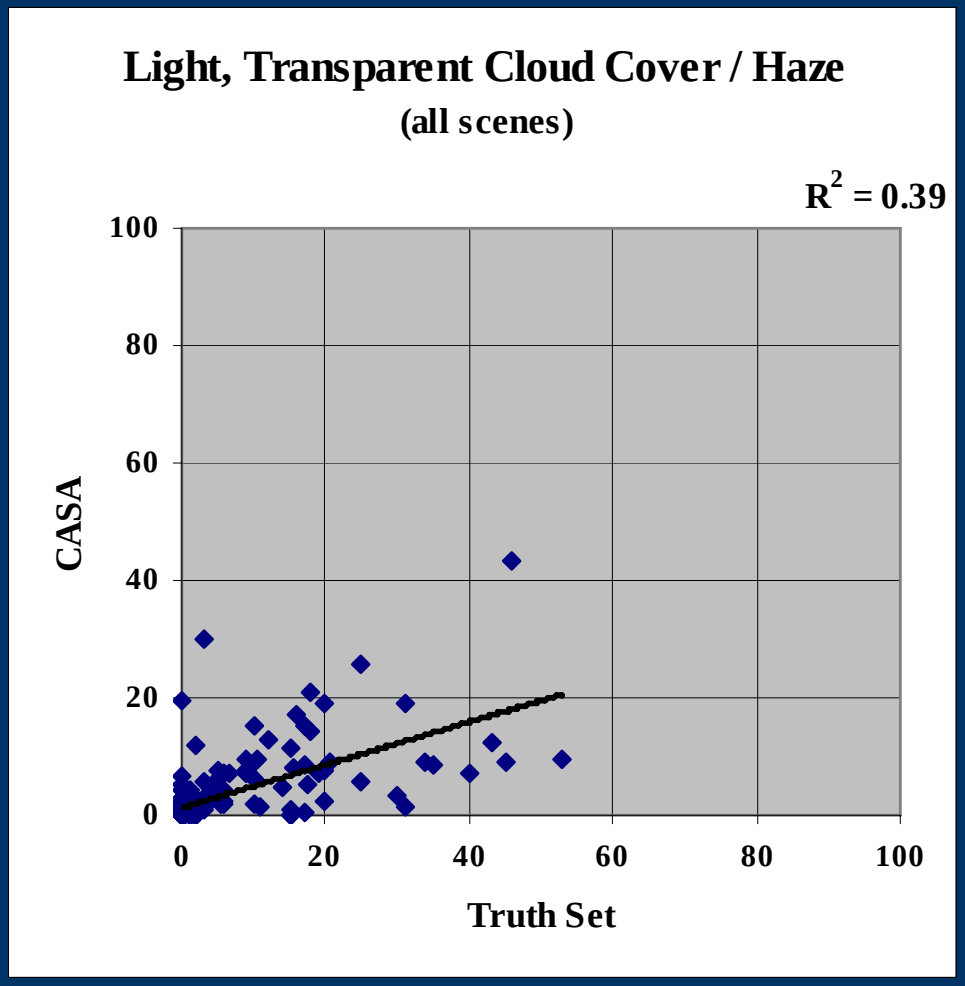


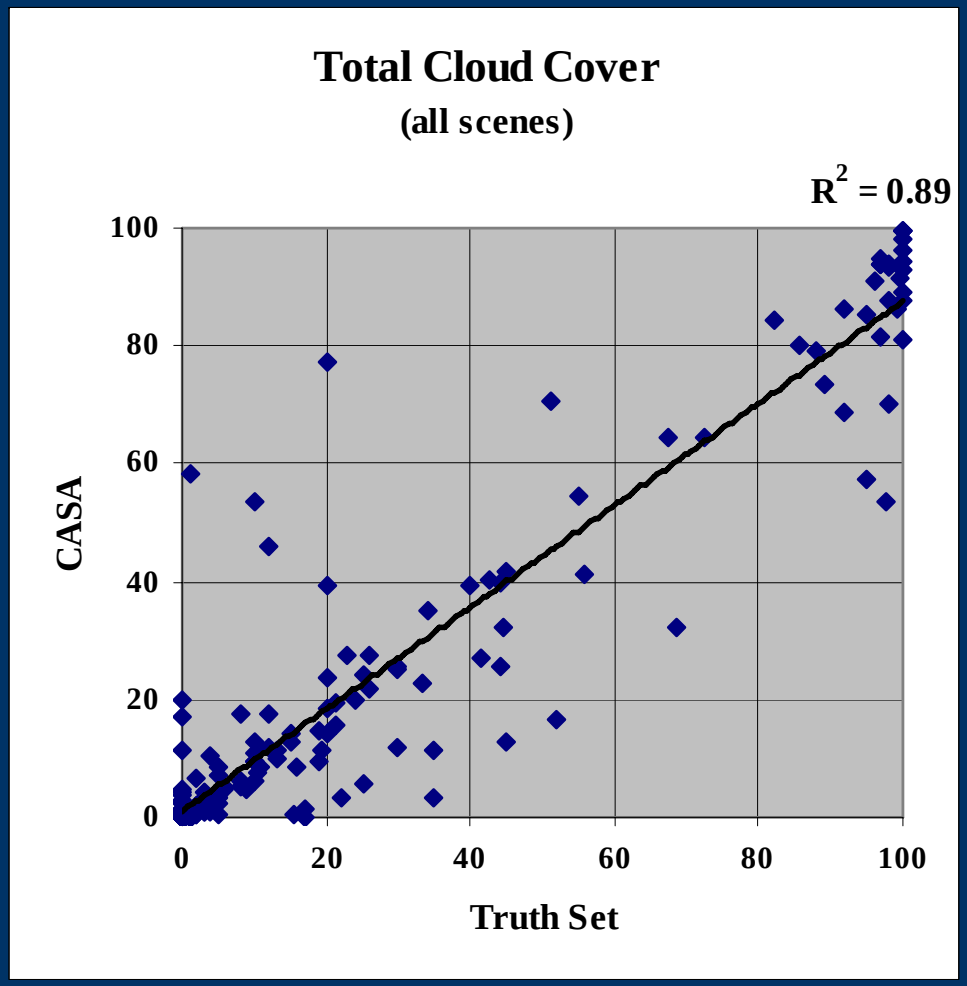


$R^2 = 0.91$

$R^2 = 0.71$

CASA-Ikonos Validation: Light CC / Haze & Total Cloud Cover

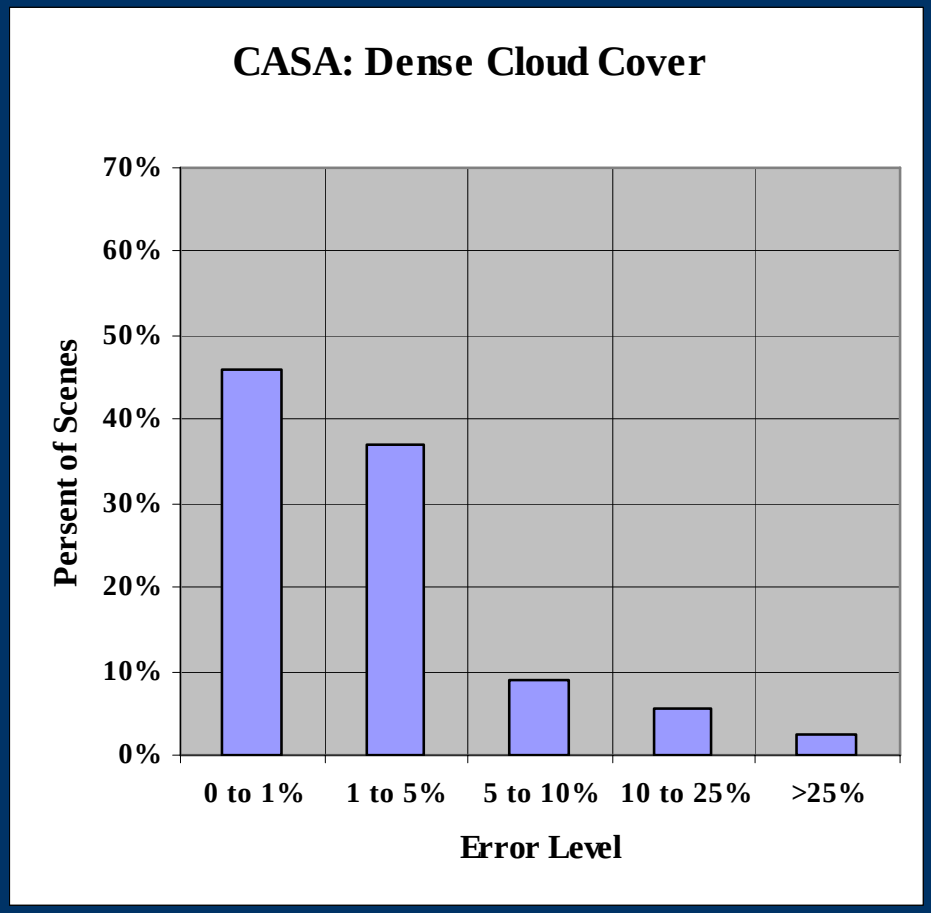




$R^2 = 0.39$

$R^2 = 0.89$

CASA-Ikonos Validation

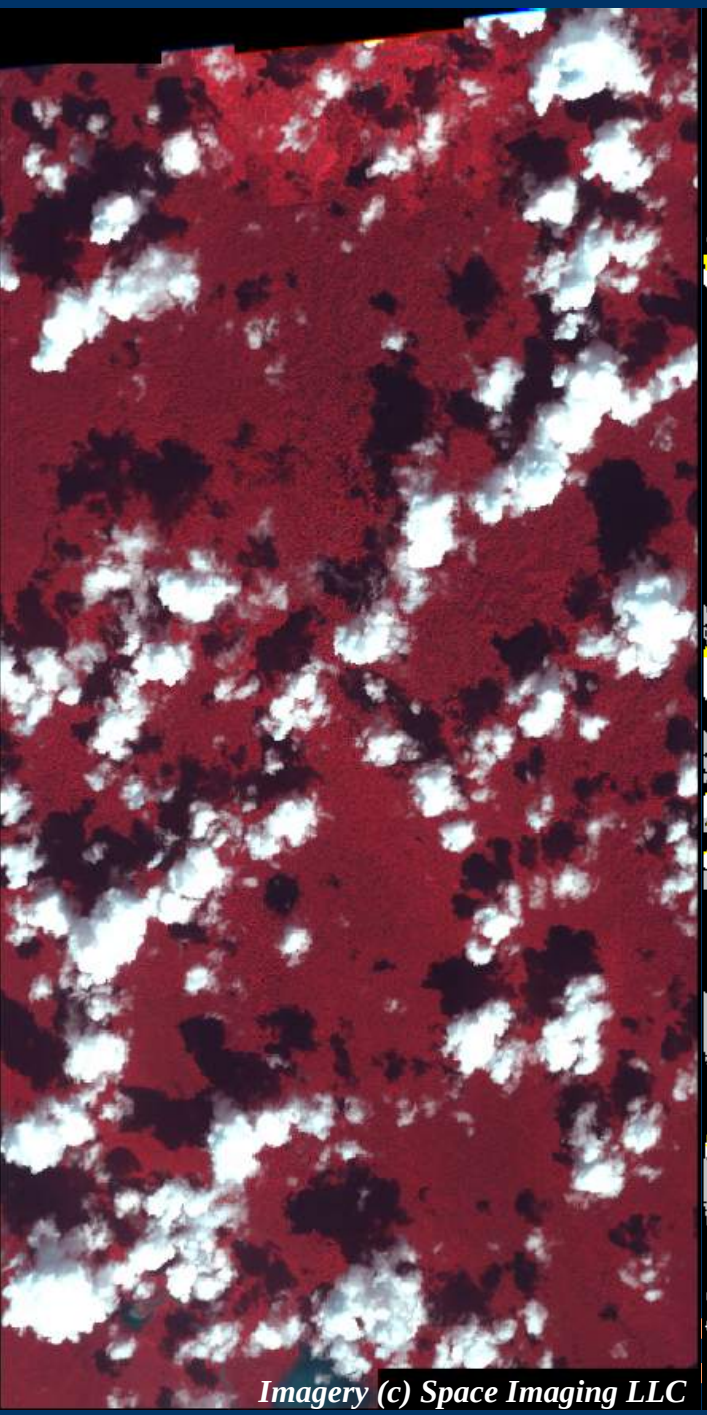


Correlation	Dense Cloud Cover	Light Cloud / Haze Cover	Total Cloud / Haze Cover
CASA *vs.* "Truth"	95.5%	62.1%	94.4%

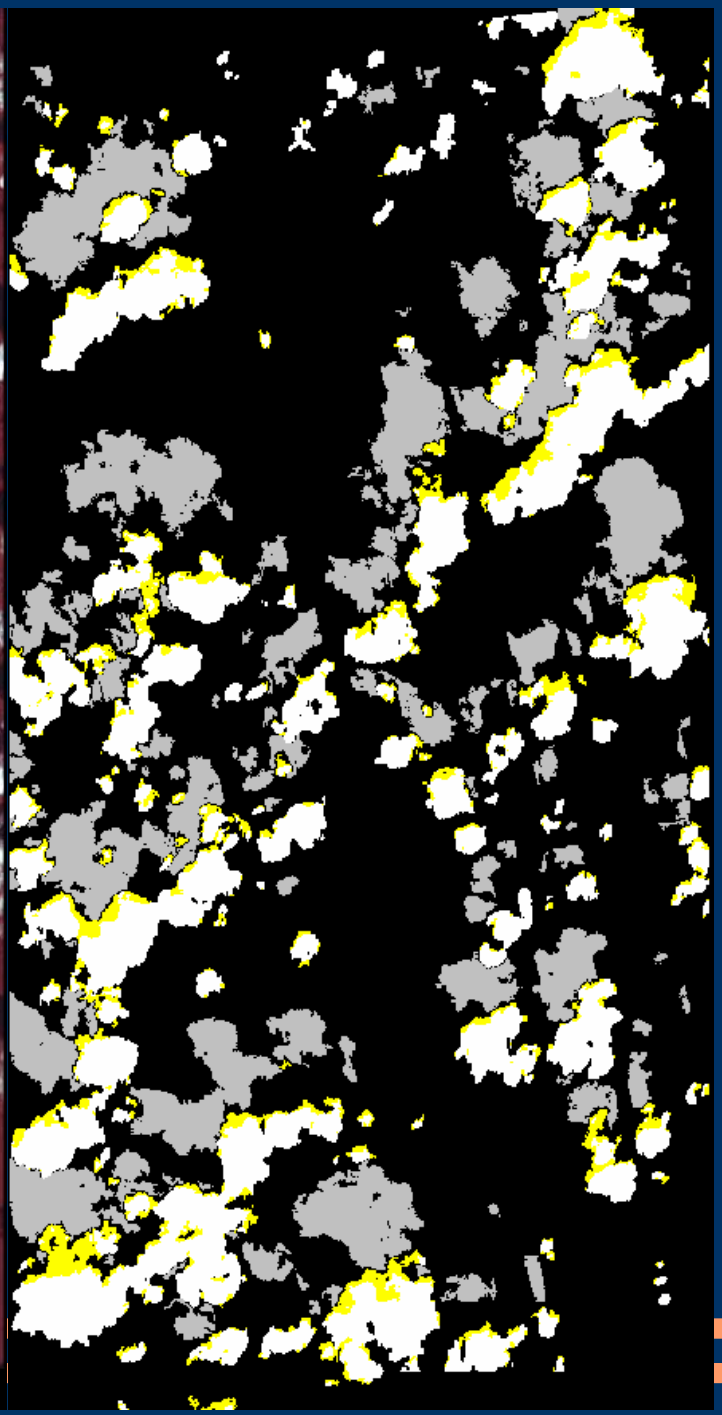
Error Level	Percent of Scenes		
	Dense Cloud Cover	Light Cloud / Haze Cover	Total Cloud / Haze Cover
0 to 1%	46%	63%	41%
0 to 2%	62%	76%	52%
0 to 5%	83%	85%	74%
0 to 10%	92%	89%	82%
0 to 15%	95%	93%	87%
0 to 25%	98%	96%	95%
Max Error	58%	43%	57%

CASA is within 10% of the visual estimate for more than 90% of all images tested

CASA: Sample Output



Imagery (c) Space Imaging LLC



Coverage report for
c:\casa\po_187902_0000000_casa_result.tif (%):

Total cloud cover: 16.12
Total haze cover: 3.36
Total shadow cover: 14.52

UL cloud cover: 14.86
UL haze cover: 3.12
UL shadow cover: 14.86
UR cloud cover: 15.39
UR haze cover: 3.03
UR shadow cover: 14.12
LL cloud cover: 19.51
LL haze cover: 4.42
LL shadow cover: 16.22
LR cloud cover: 12.77
LR haze cover: 2.32
LR shadow cover: 9.19

Size of processed image (pixels): 21658065
Total processing time: 410 seconds
Cloud cover quality estimate: Good
CASA result warnings: None

Total Cloud Cover
Total Light Cloud / Haze Cover
Total Cloud Shadow Cover

CASA Benefits / Value

- ✓ Reduce labor and operating costs for cloud identification, and QA/QC
- ✓ Operationally identify "failed" acquisitions
- ✓ Automatically generate cloud and cloud shadow pixel-level masks for each acquisition
- ✓ Automatically update the cloud cover percentage metadata tag
- ✓ Provide customers with cloud and cloud shadow masks as an additional data layer
- ✓ More easily generate value-added products such as image mosaics / composites (*e.g.*, Digital Globe's CitySphere™) through pixel-by-pixel replacement of cloud and/or cloud shadow areas

Future R&D

- **Further improvements to the automated version**
  - Accuracy
  - Speed
  - Introduction of new sensors and I/O options
- **Under-shadow area and feature enhancement**
- **Improved, Automated Gap Filling and Image Mosaicing**
- **Automated detection of other features of interest**
  - *E.g.*, buildings, roads, streams, individual trees, auto-vehicles
  - Map updates
  - Change assessment

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  - Space Imaging LLC
  - The Global Land Cover Facility (GLCF) at UMD

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