



*Know the Earth... Show the Way*

# **THE GENERATION AND DISSEMINATION OF “FINISHED” SRTM DATA PRODUCTS BY NGA**

**James A. Slater**

**National Geospatial-Intelligence Agency**

**SRTM Workshop  
Reston, Virginia**

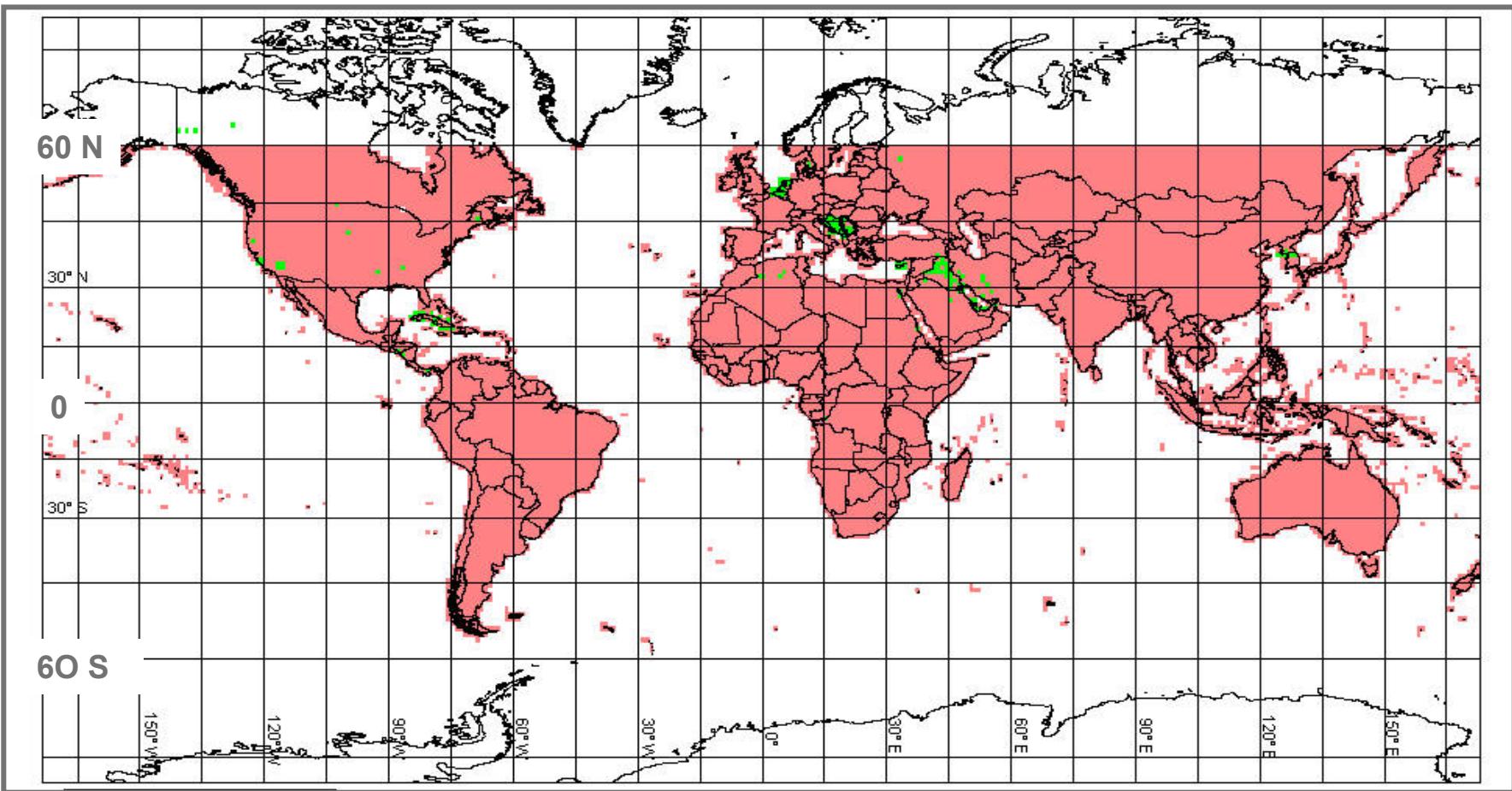
**14 June 2005**



# ► Goal

- Satisfy a global requirement for terrain elevation data
  - Mapping
  - Navigation
  - Orthorectification of imagery
  - Mission planning and simulation
  - Humanitarian and disaster relief
- Generate a single, homogeneous, complete reference surface for the Earth's topography based on the WGS 84 ellipsoid and geoid
- Provide a uniform, self-consistent depiction of the Earth, common to all users and applications

# ► DTED® Level 2 Coverage Prior to Mission and Actual SRTM Collection Area



Available DTED® 2 (non-SRTM)



SRTM Collection Area



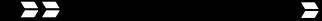
# ► Basic Requirement

## SRTM Digital Terrain Elevation Data Level 2 (DTED® 2)

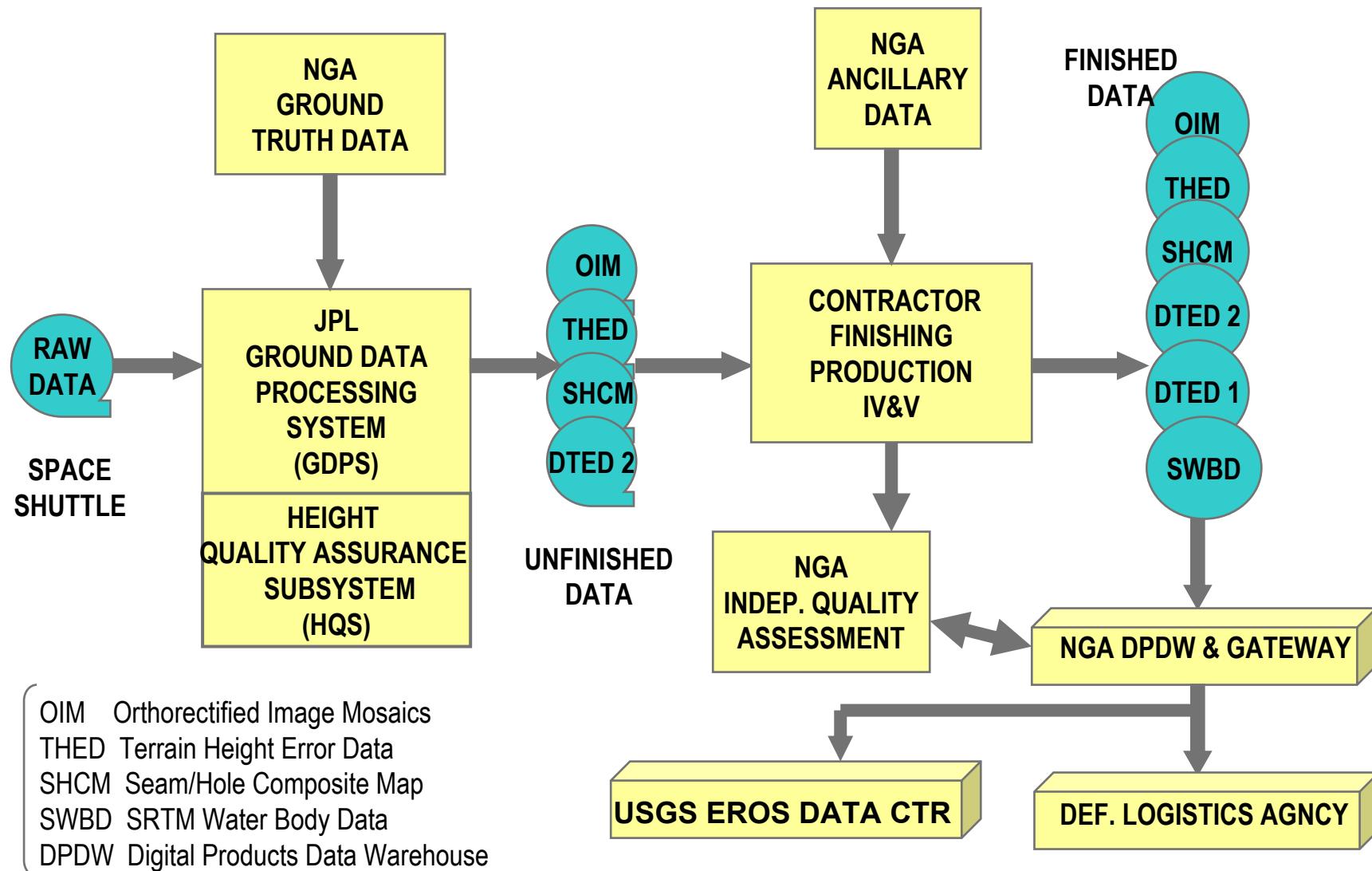
- 1 arcsec (~30 m) post spacing between 50° N and 50° S latitudes
- 1 arcsec post spacing in latitude and 2 arcsec post spacing in longitude between 50° and 60° (N and S)
- Absolute vertical accuracy: 16 m (90% L.E.)
- Absolute horizontal accuracy: 20 m (90% Circular Error)
- Relative vertical accuracy: 10 m over 225 km<sup>2</sup> area (90% L.E.)
- WGS 84 reference frame
- Elevations wrt Mean Sea Level (defined by EGM96 geoid)



- Data processing strategy set up to meet the objectives...

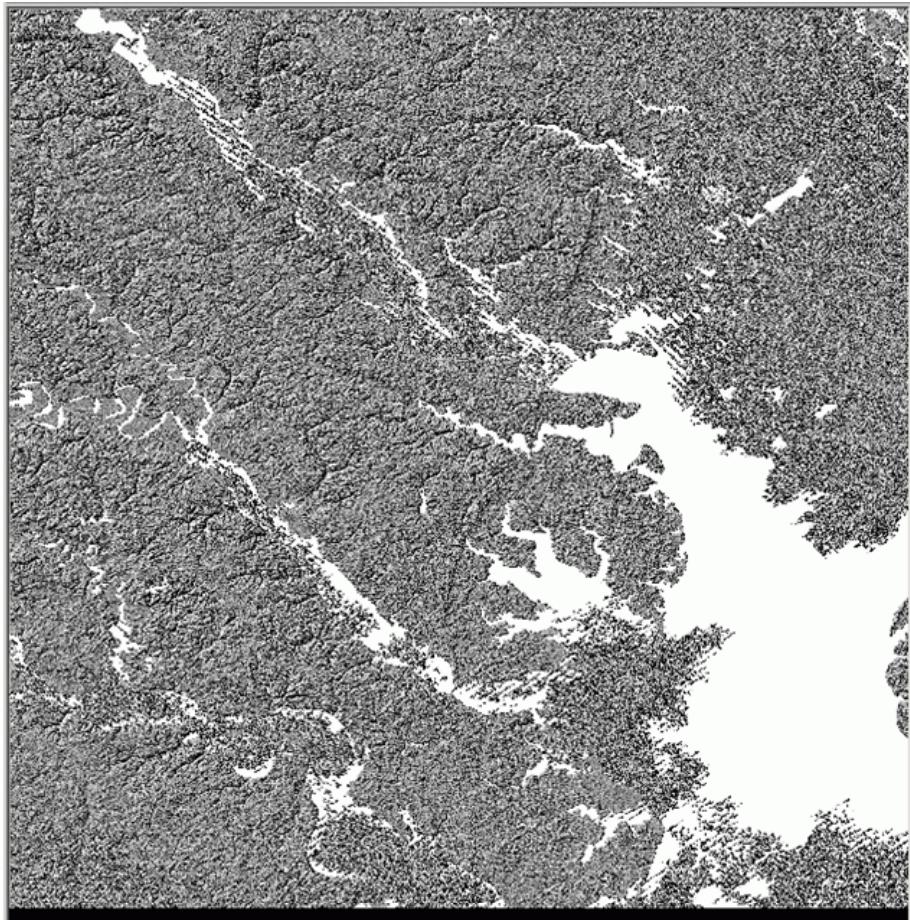


# ► SRTM Data Processing Scheme

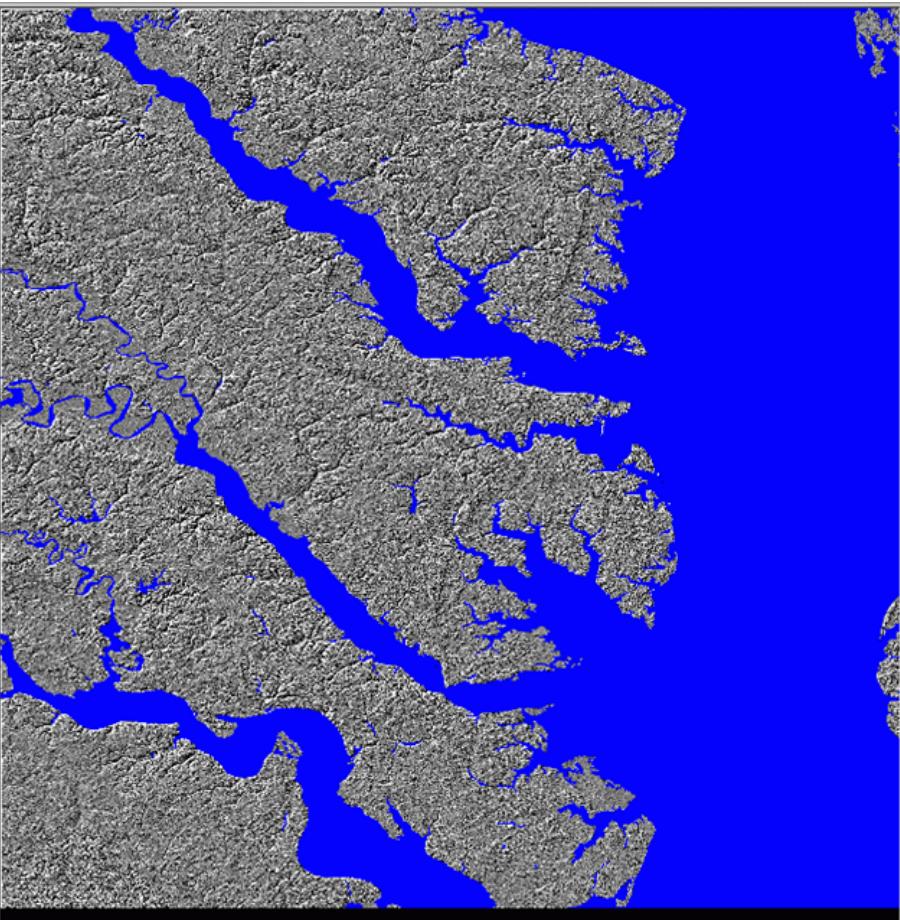


# ► The SRTM DTED® Finishing Process – W077 N37

Unfinished

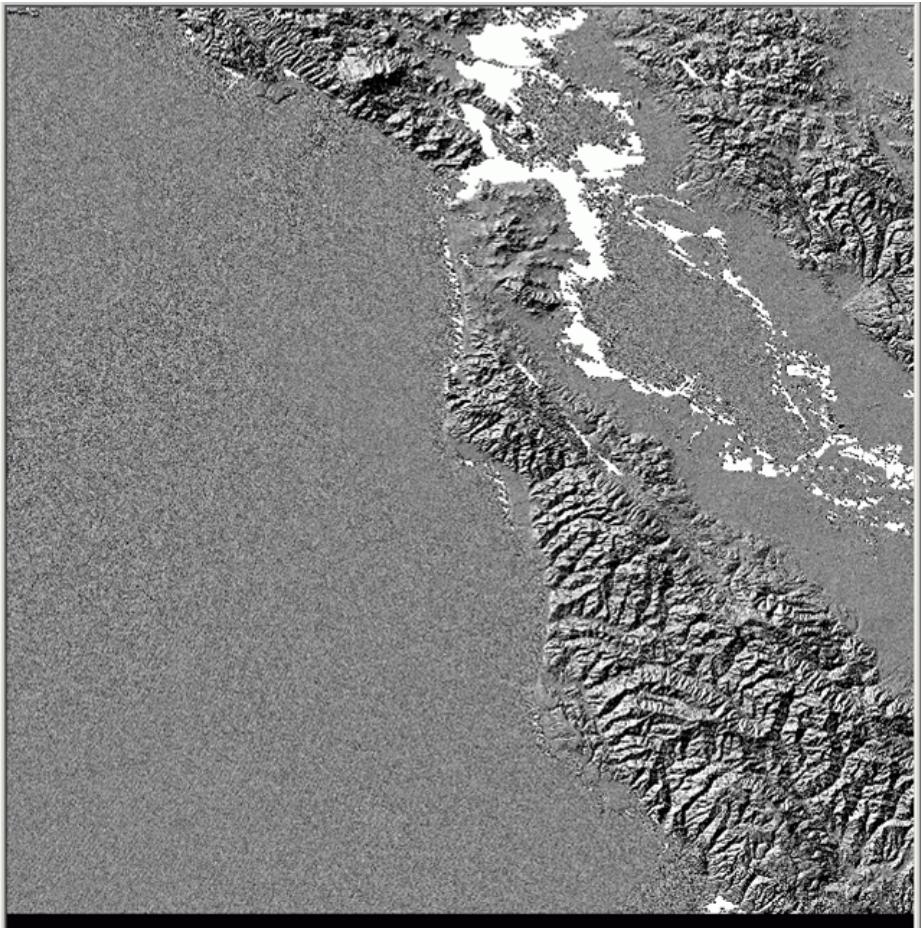


Finished

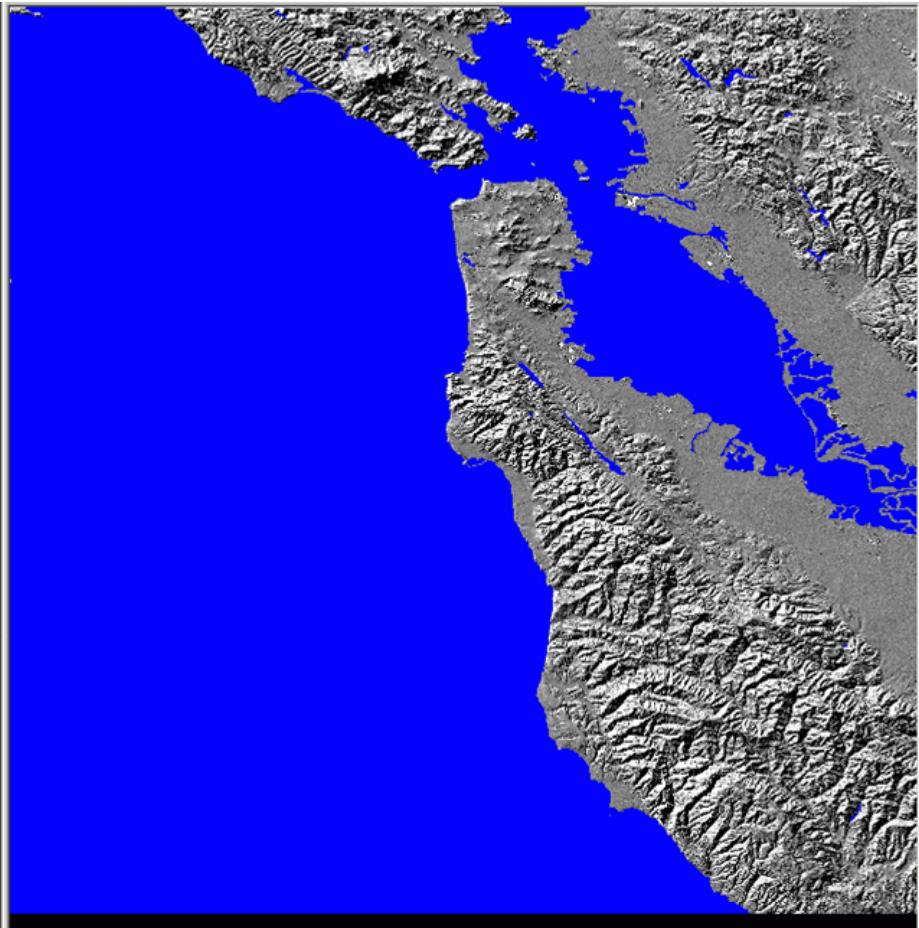


# ► The SRTM DTED® Finishing Process – W123 N37

Unfinished

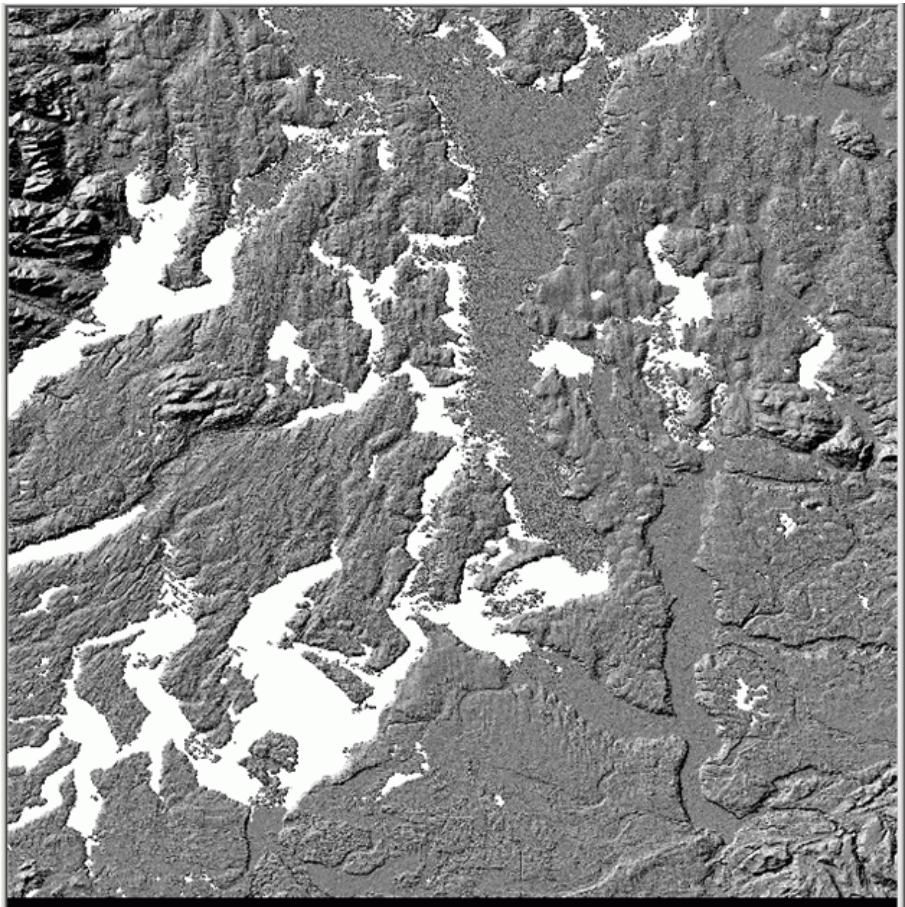


Finished

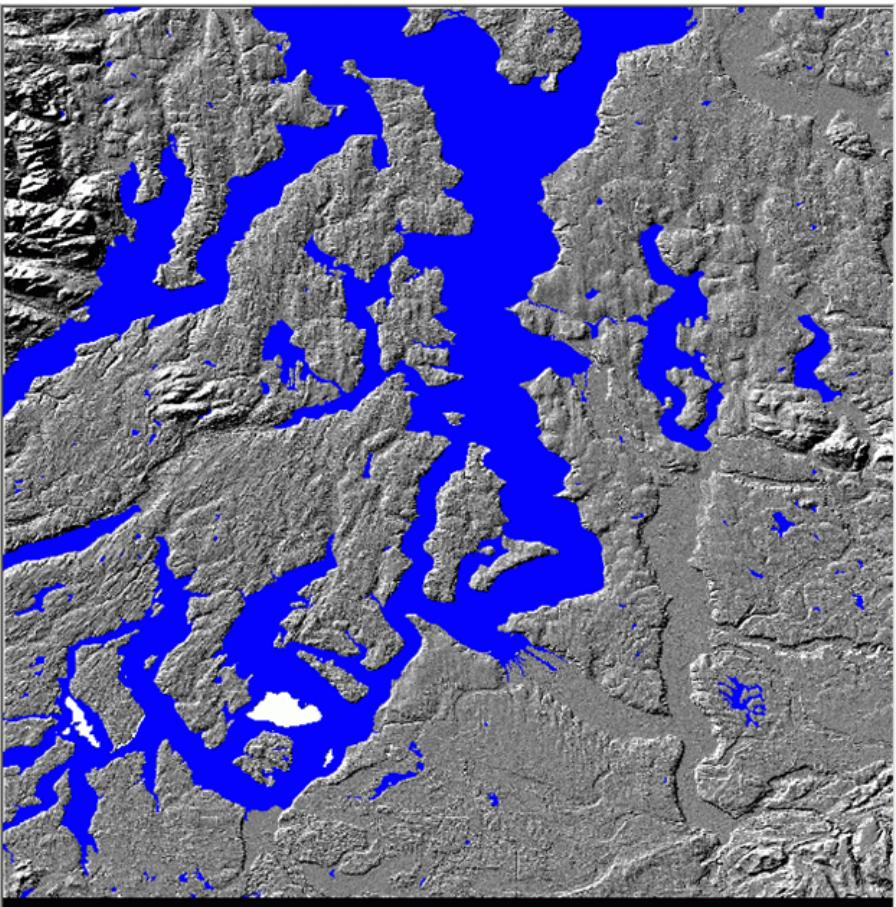


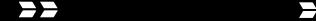
# ► The SRTM DTED® Finishing Process – W123 N47

Unfinished



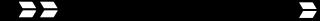
Finished





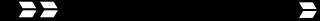
# ► SRTM Data Products Generated from JPL Deliveries

DTED 2	1 arcsec interval	DTED® 2 Format	Edited
Terrain Height Error Data (THED)	Random error for each DTED® value (90% confid.)	NITFS 2.1	Updated
Orthorectified Image Mosaics	30 m ground sample distance 1 ascending / 1 descending	NITFS 2.1	No editing
Seam/Hole Composite Map	Color-coded raster map of strip seam boundaries & voids (unfilled and filled)	NITFS 2.1	Updated
DTED® 1	Derived by thinning DTED® 2 at 3 arcsec interval	DTED® 1 Format	Created
SRTM Water Body Data	3-D vector file of water body shorelines	Shape File	Created



# ► Ancillary Reference Data Used for Finishing

- Ground Control Points
  - Photogrammetrically-derived (Accuracy: 5-10 m)
  - GPS (Accuracy:  $\leq 1$  m)
- Reference DTED® 2 (Accuracy: 10 m)
- Compressed ARC Digitized Raster Graphics (CADRG)
  - Maps and charts with scales of 1:50,000 to 1:250,000
- Landcover water mask for most cells
  - Late 1980s-1993 Landsat Thematic Mapper imagery
  - Nominal horizontal accuracy: 50 m RMSE
  - Actual accuracy: ~ 19-25 m RMSE
  - 28 m pixel resolution
  - Included rivers, lakes, reservoirs, ponds, bays, estuaries
  - Did not include ice/snow, agricultural standing water, wetlands

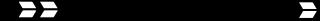


## ► Organizational Aspects of NGA Production

- 14,000+ cells to process
- Customized software, methodology and automated procedures required for data no one had ever seen
- Contractors performed all production work
- Target time (manual labor) to finish each cell: 20 hrs.

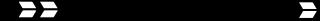
To accomplish this, NGA employed:

- 2 contractor teams
  - BAE Systems/Vexcel Corp.
  - Boeing Autometric/Intermap Technologies/PixSell
- 3 production sites
- 80-90 operators (at peak)
- 2 shifts
  - 800 finished cells/month (at peak)
  - 5 edited or new products (DTED 2, DTED 1, THED, SHCM, SWBD)



# ► Quality Assurance Strategy

- Attempted to minimize and control differences between contractors, sites, shifts and operators
- Automated production processes
- Performed extensive prototype and pilot testing and evaluation
- Standardized computational methodology
- Standardized editing procedures
- Provided extensive guidance from NGA – editing rules, reviews of work, reference data
- Multiple points of quality control:
  - Quality review of all cells delivered by JPL
  - Internal review of all editing by contractor
  - IV&V by contractor of *all* cells prior to delivery to NGA
  - Detailed review of 10% random sample of finished cells at NGA

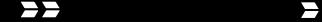


## ► SRTM DTED® 2 “Finishing” Requirements

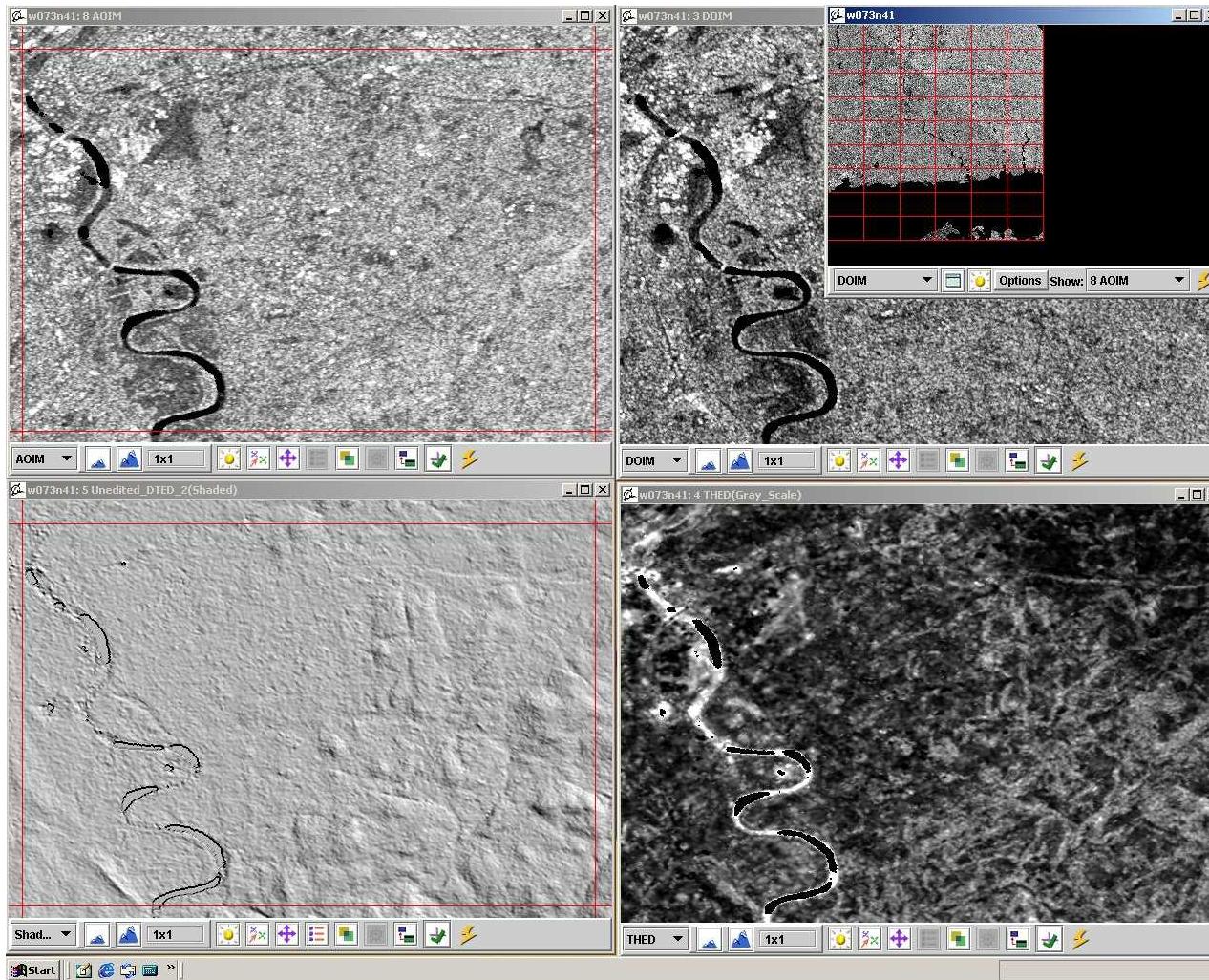
- Remove and void out spikes/wells > 100 m wrt neighboring posts
- Fill voids of 16 or less contiguous posts by interpolation
- Leave larger voids in the data
- Identify and delineate water bodies
  - Ocean coastlines
  - Lakes (> 600 m length)
  - Rivers (> 183 m width)
  - Islands (> 300 m length or  $\geq 10\%$  of elevations are over 15 m above surrounding water)
- Set water body elevations
  - Oceans: set to 0 m elevation
  - Lakes: set to constant elevation
  - Rivers: step down monotonically
- Match cell edges for continuity



# ► The Finishing Process...

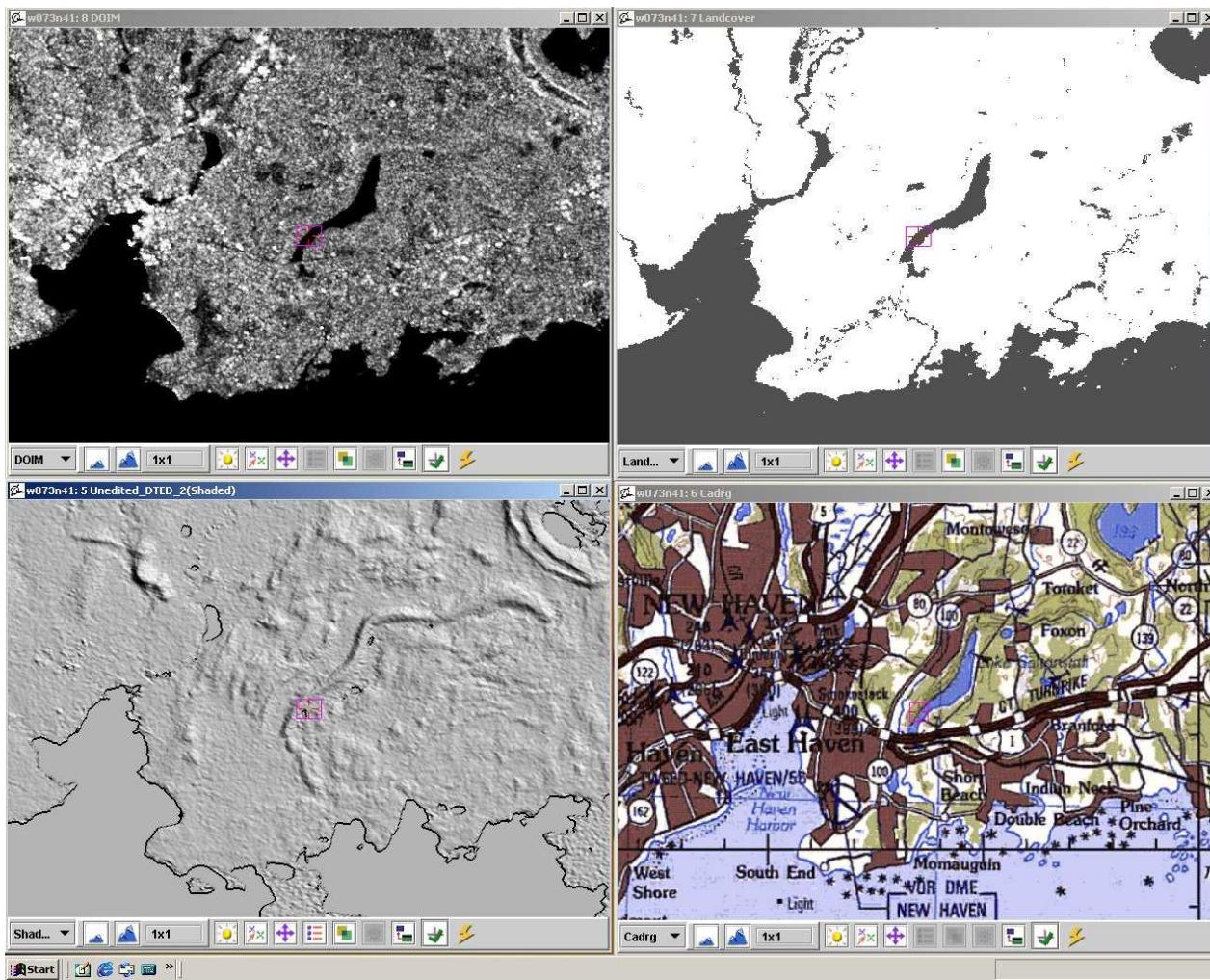


# ► Display of AOIM, DOIM, Unedited DTED® 2 Shaded Relief and THED for Finishing

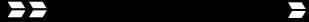


(Boeing)

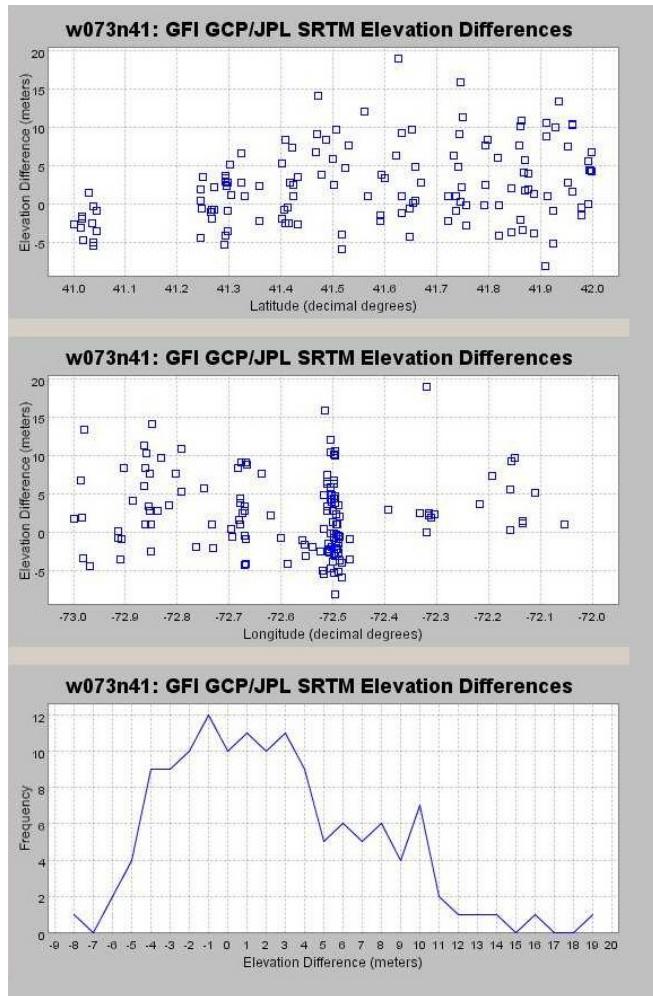
# ► Landcover Water Mask and Reference Map Source With DOIM and Associated Unedited DTED® 2 Shaded Relief



(Boeing)



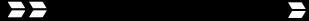
## ► Comparison of SRTM Elevations with Photogrammetric GCPs for Quality Control – Checking for Outliers and Systematic Biases



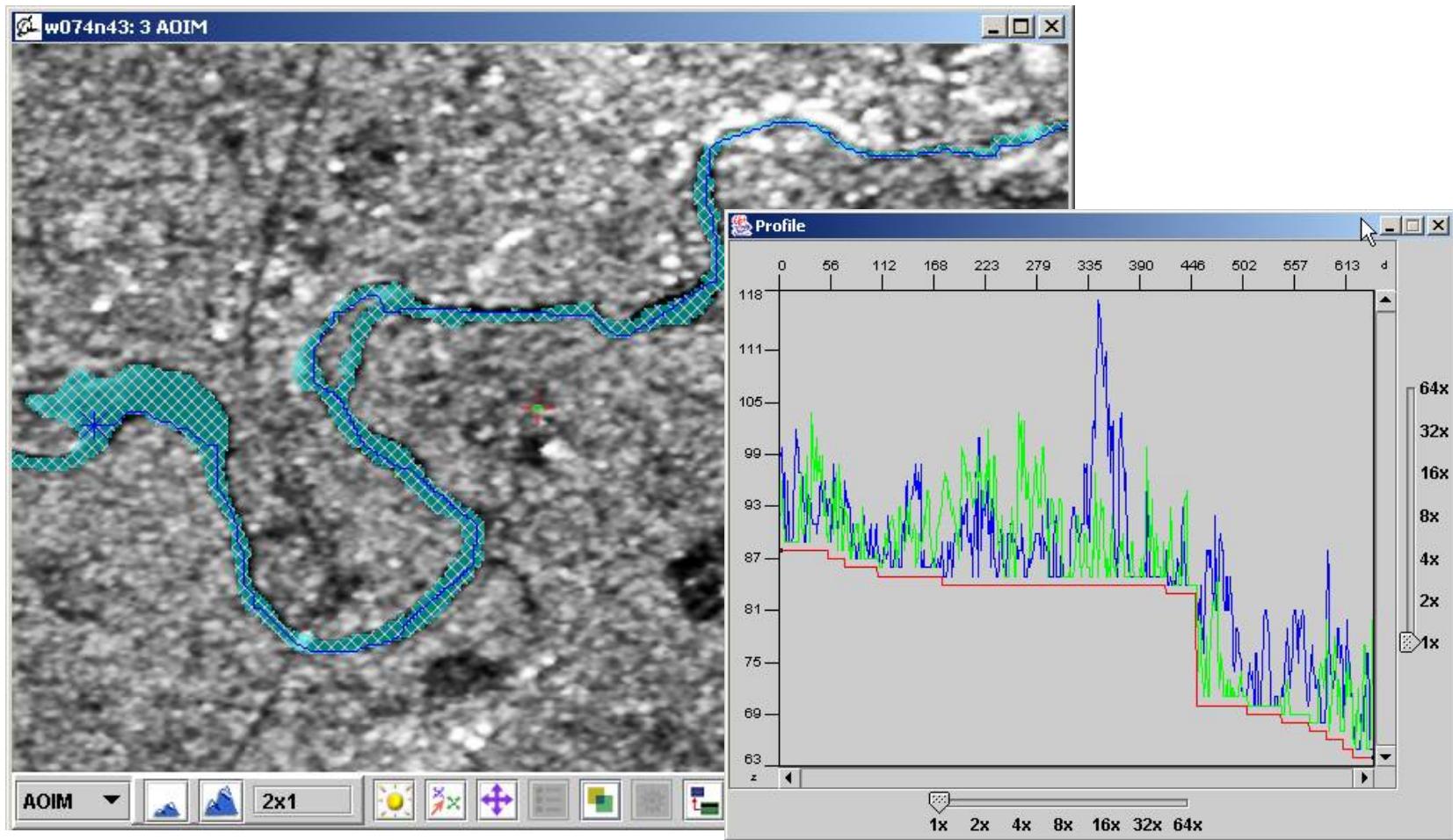
(Boeing)



## ► Water Body Editing...



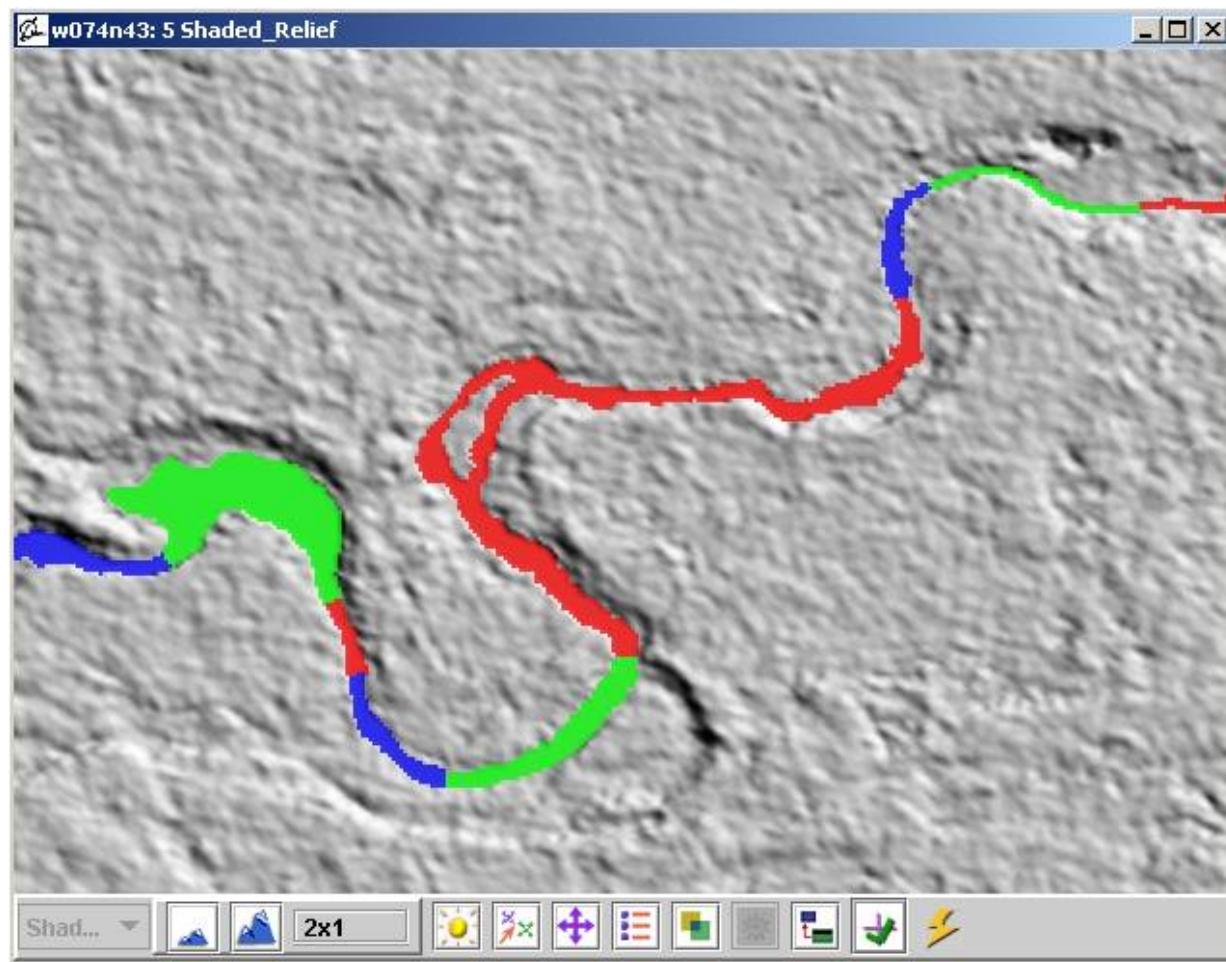
# ► Stepping Down Rivers Monotonically – Raw Elevations from Each Shoreline and Adjusted Water Elevations



(Boeing)

20

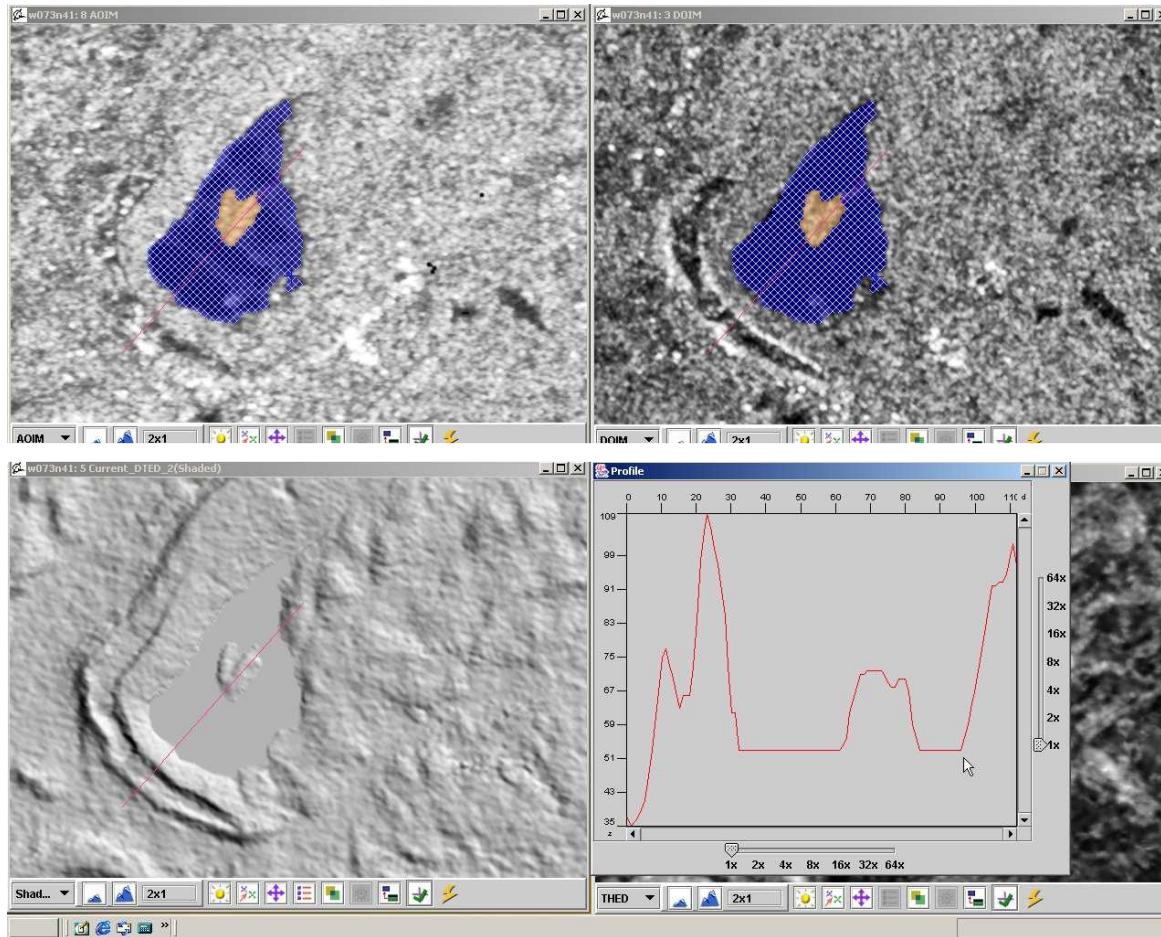
# ► Checking for River Monotonicity With Color-Coded Steps



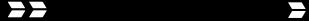
(Boeing)



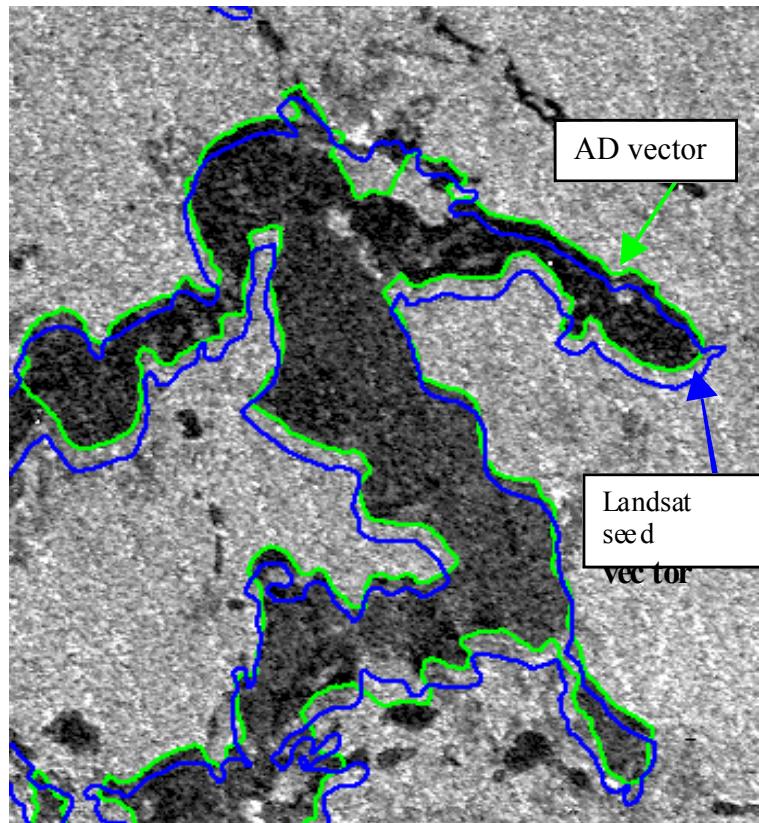
# ► Profile of Lake and Island After Finishing – AOIM and DOIM (top), Shaded Relief (bottom)



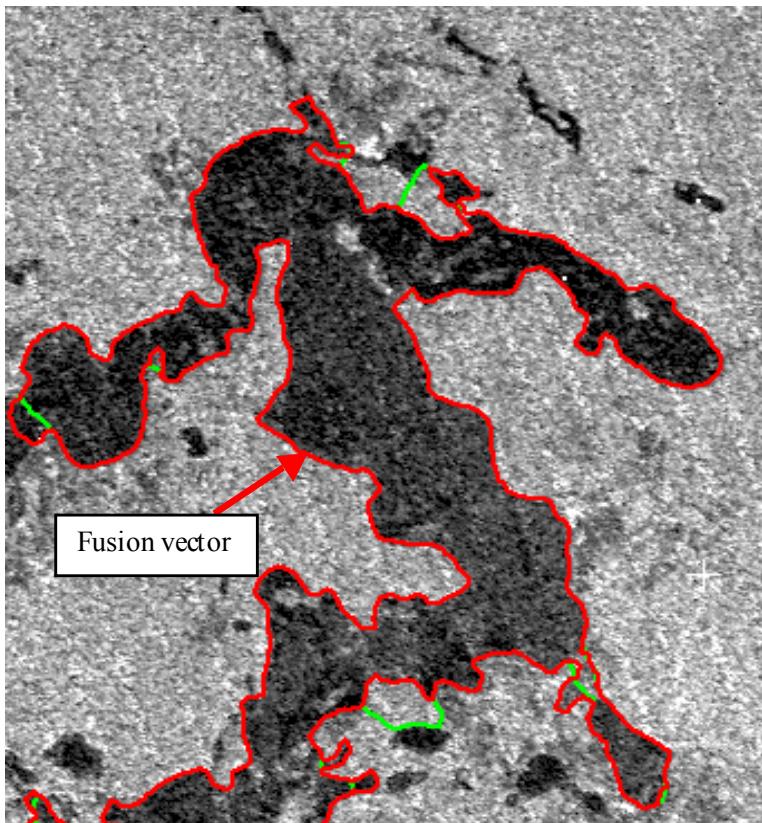
(Boeing)



## ► Autodelineation of Lake (Green) and Resultant Improvement (Red) from Algorithm Using Landsat Seed (Blue)



(a) Seed vector from Landsat in blue and vector with AD in green.



(b) Improved water body vector with fusion in red.

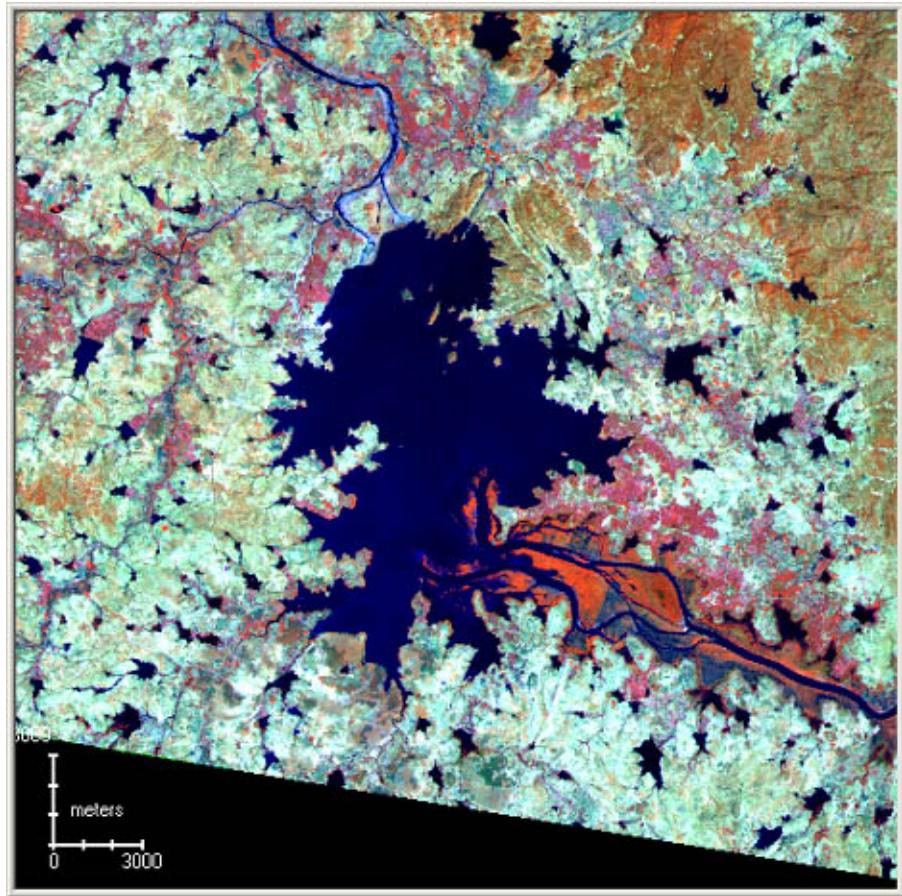
(BAE)



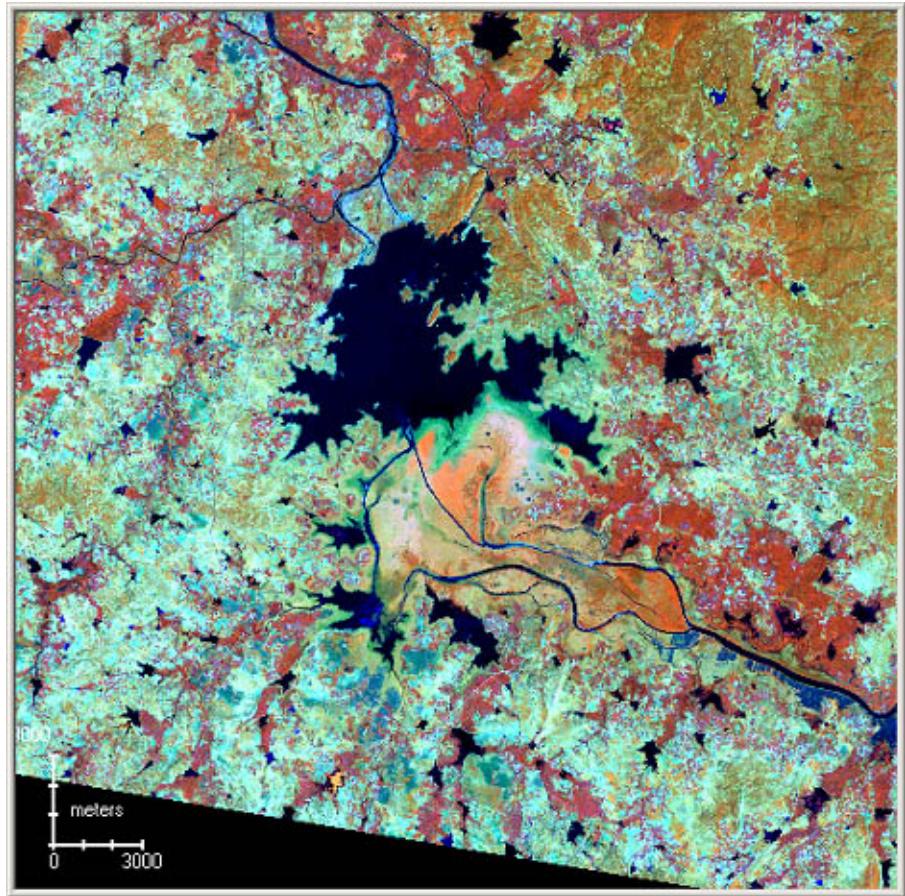
## ► Issues Regarding SRTM Water Body Identification and Delineation...

# ► Decadal Differences In Water Features

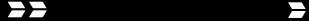
## Example: India Landsat P144 R047 (4,5,3 in R,G, B)



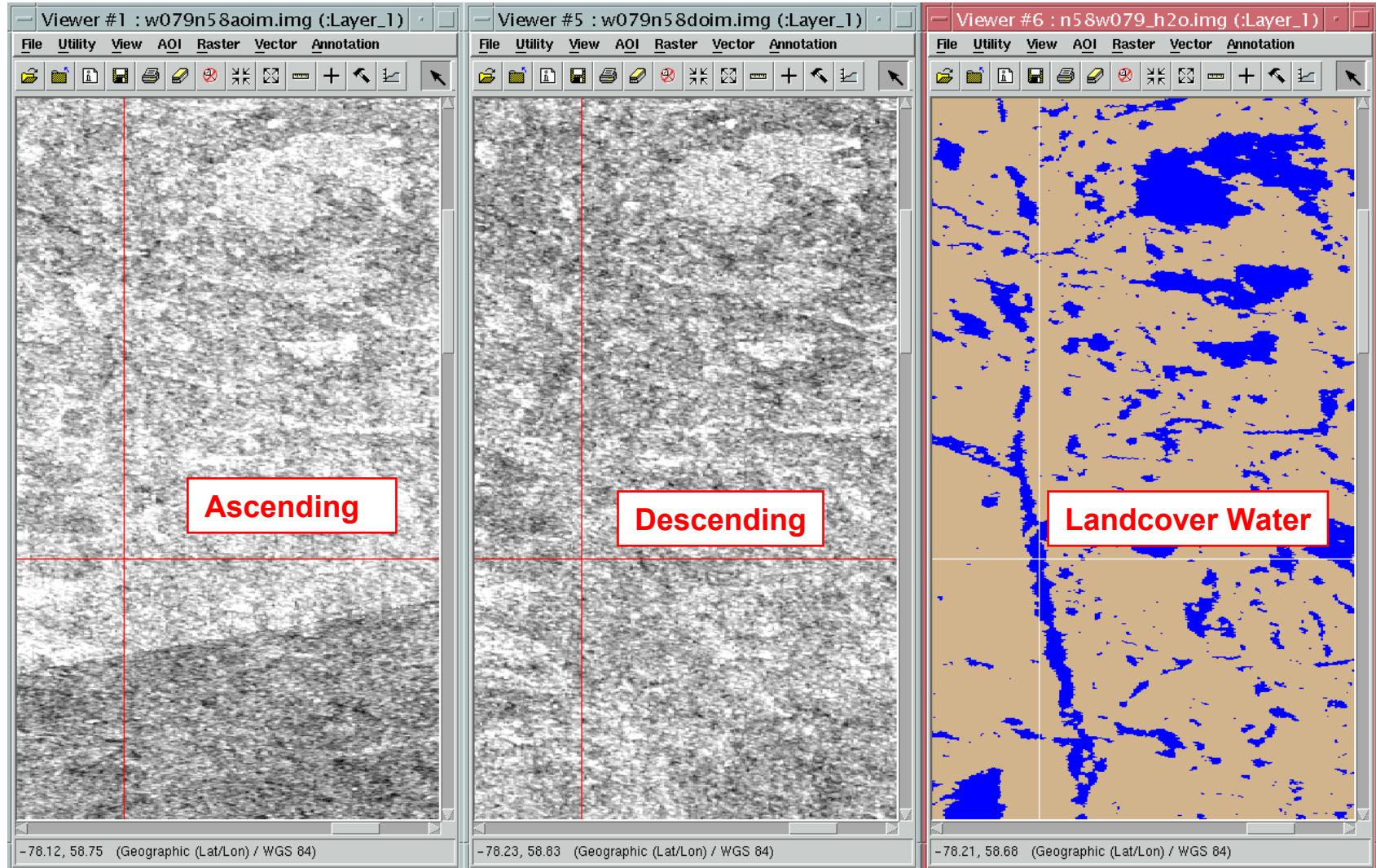
Water mask: 21 Nov 1989



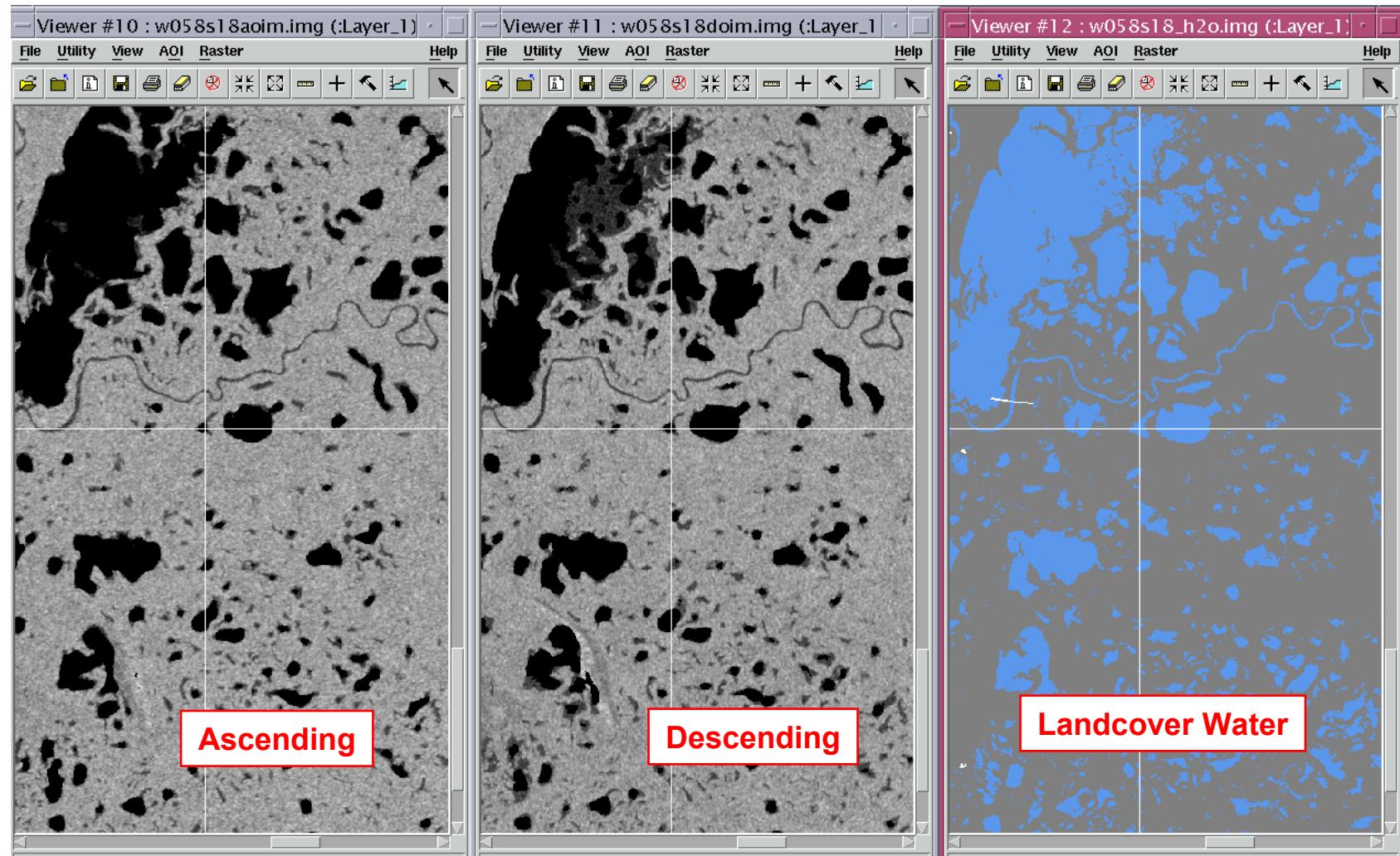
Landsat 7 Image: 29 Oct 2001

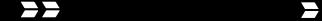


# ► Problems with Identifying and Delineating Water Bodies in DTED® - Frozen Water Bodies (W079N58)



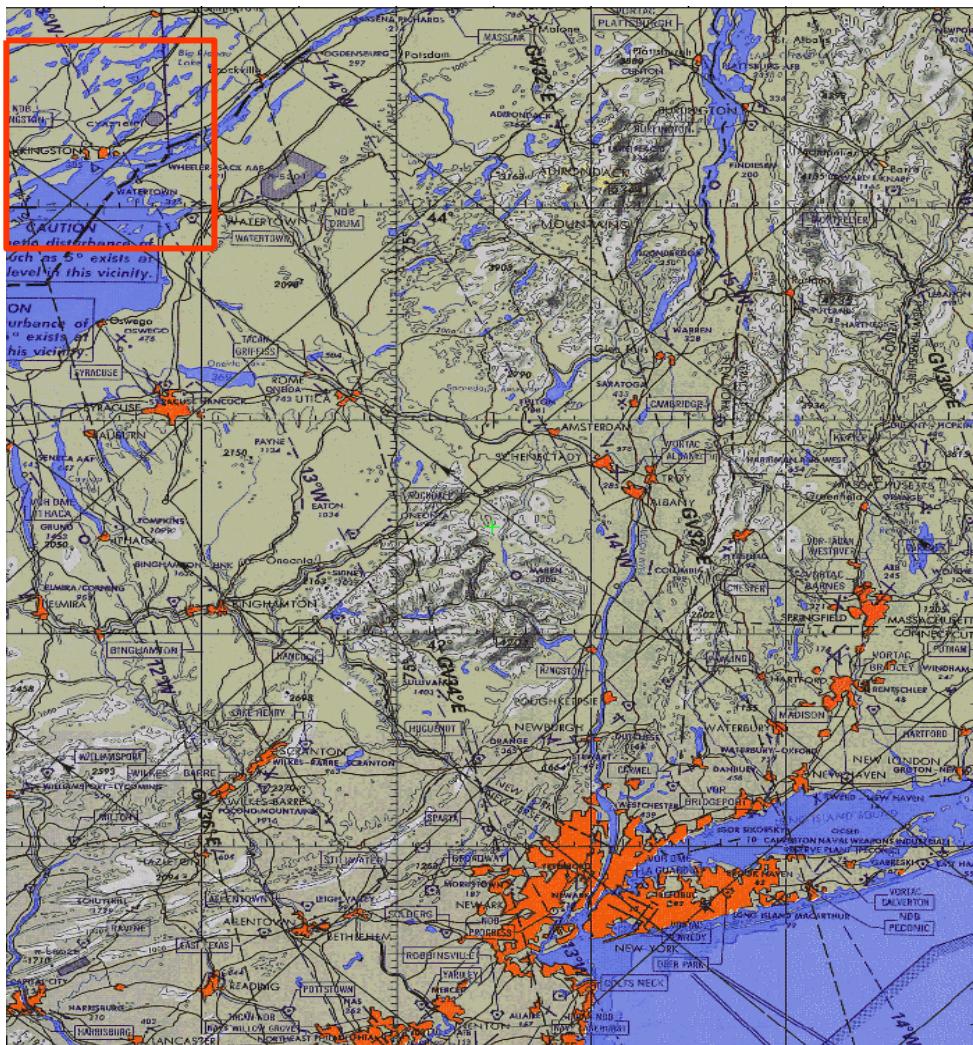
# ► Problems with Identifying and Delineating Water Bodies in DTED® - Complexity Issues with Good Data





# ► Inter-Comparison of Contractors' Water Body Editing - Test and Evaluation Cells

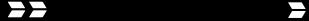
45N



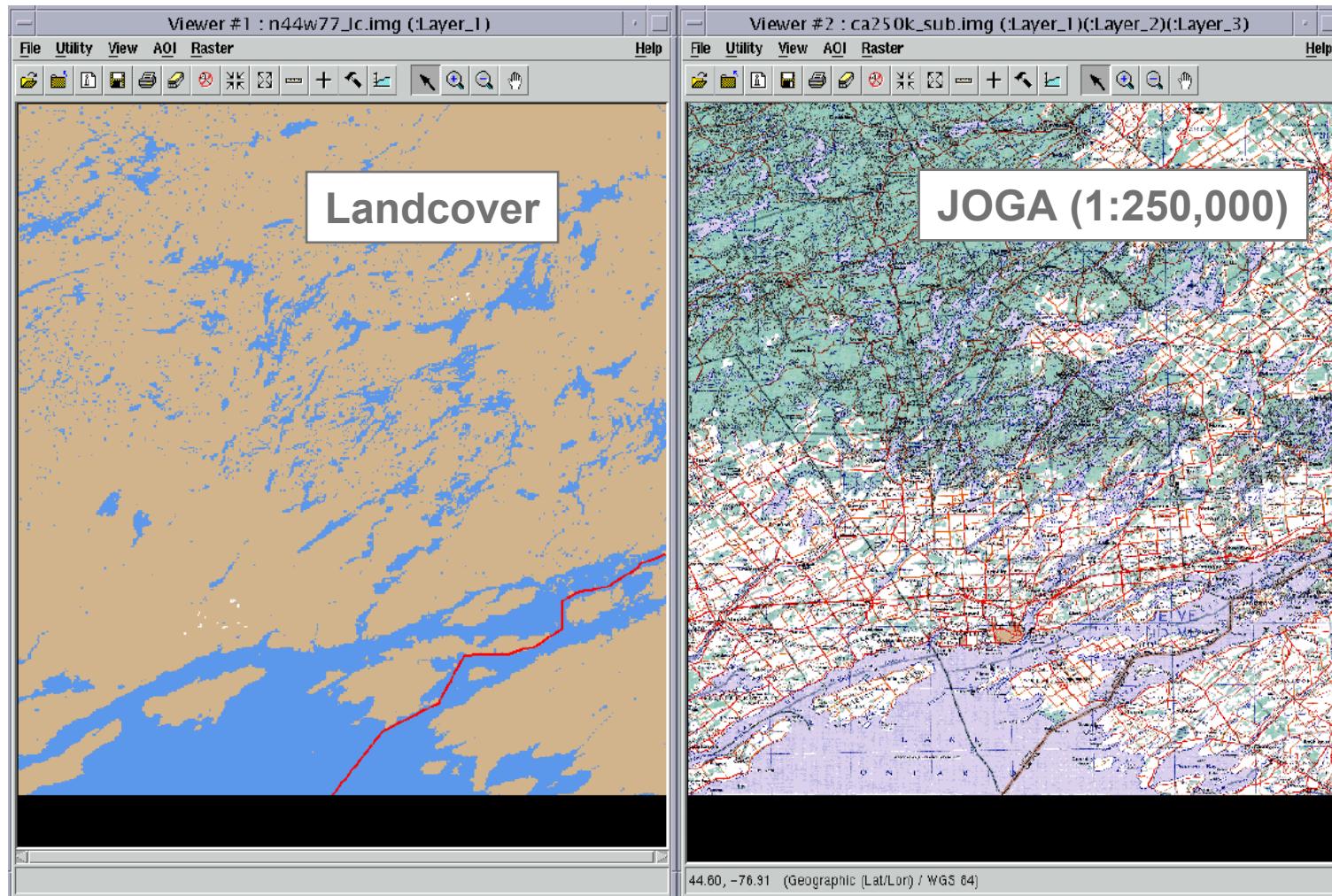
40N

77W

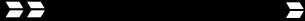
- 25 common cells processed by both contractors
- Northeastern U.S. and Canada
- Diverse terrain and hydrology
- Boeing/Autometric completed test cells early in production, while BAE completed them later – introduced differences in maturity of software and operators



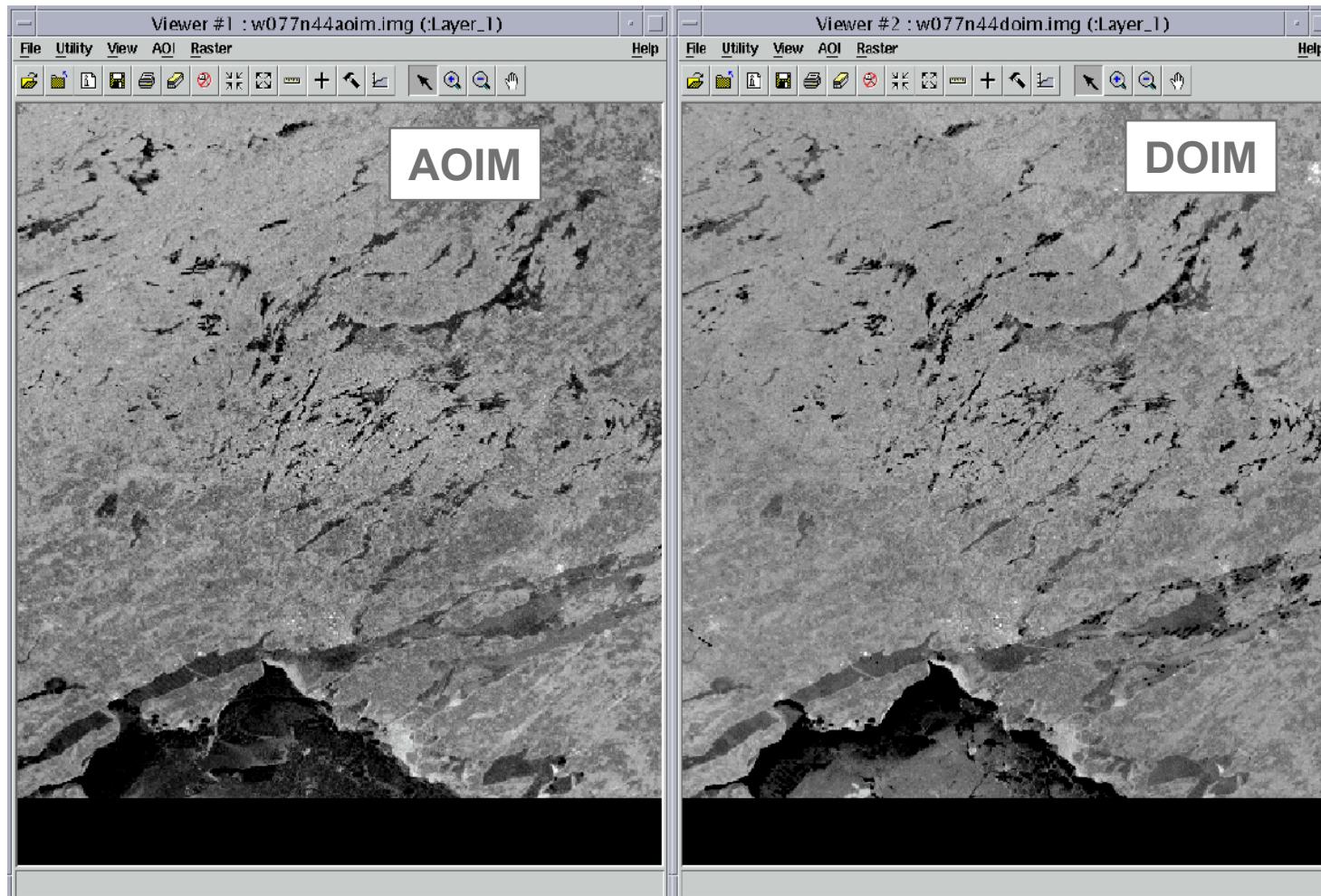
# ► Test and Evaluation Cell W077N44



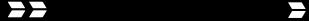
Note: No Landcover provided over Canadian territory (area to the left of red line).



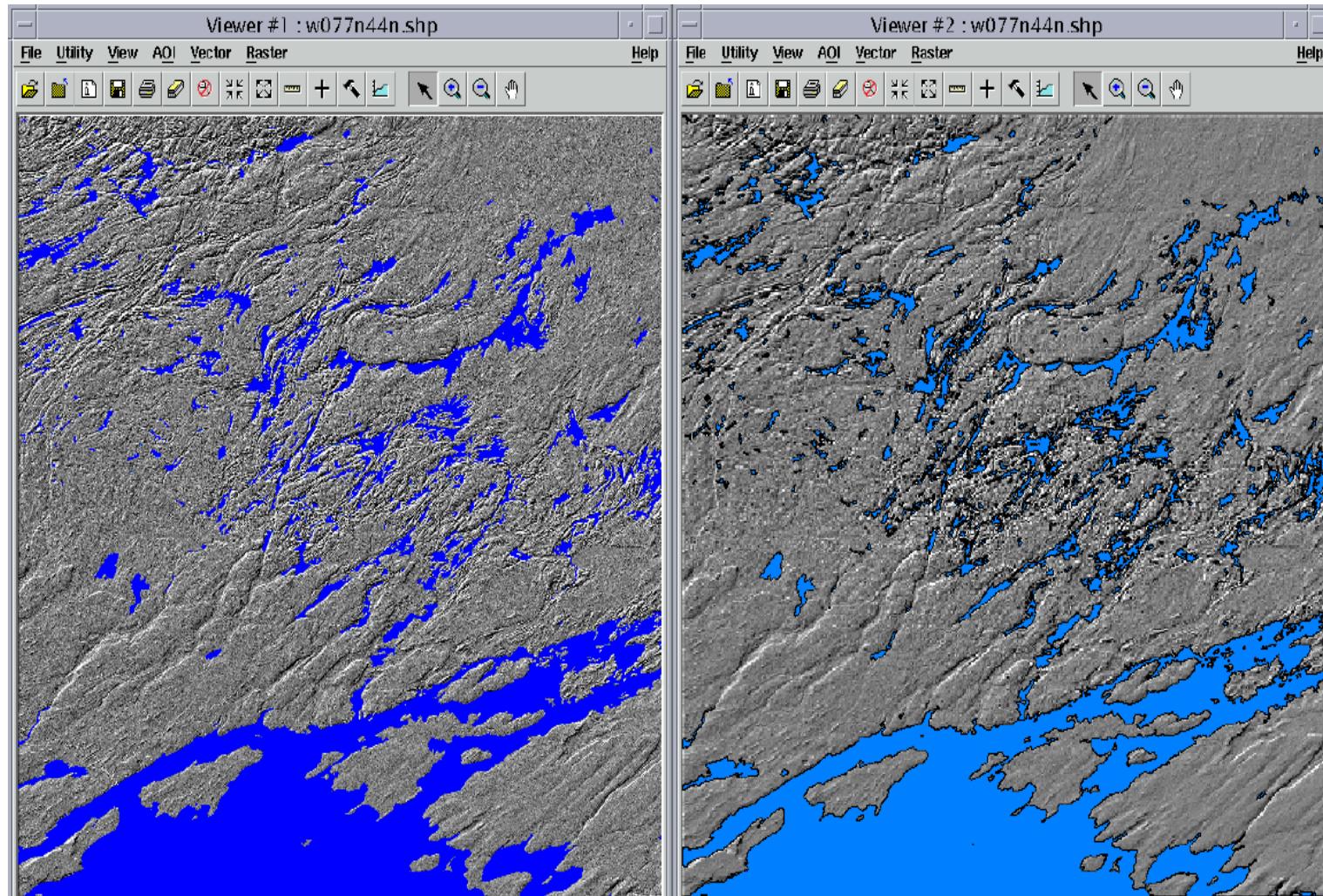
# ► Test and Evaluation Cell W077N44 Orthorectified Image Mosaics



Note: Black may indicate no information.

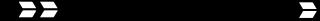


# ► Test and Evaluation Cell W077N44 Terrain Shaded Relief Overlaid With Water Features (Blue)

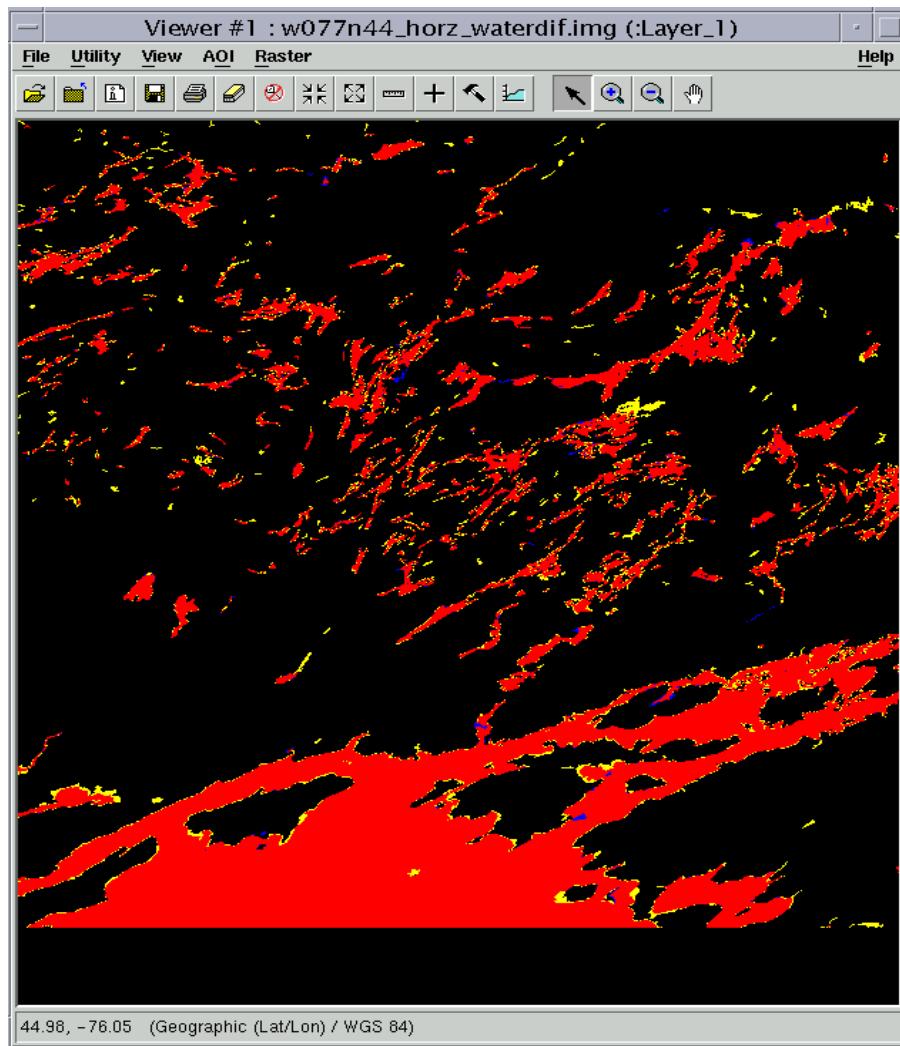


Autometric Solution

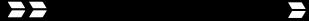
BAE Systems Solution



# ► Test and Evaluation Cell W077N44 Horizontal Water Difference



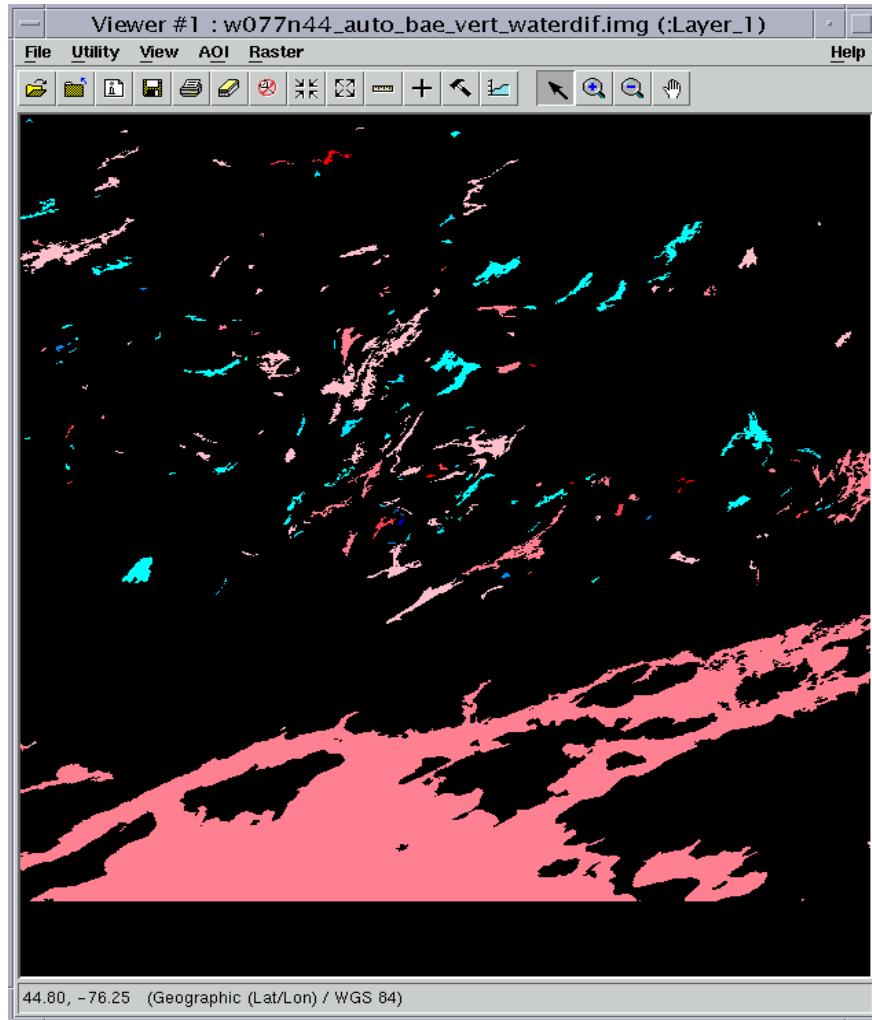
Histogram	Class_Names	Color
10334662		
268136	BAE water only	Yellow
25958	Autom. water only	Blue
2338445	common water	Red



# ► Test and Evaluation Cell W077N44

## Water Elevation Difference (m)

### (Autometric minus BAE)



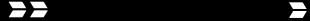
Value	Histogram	Color
-4	3621	Red
-3	6132	Light Red
-2	1741742	Pink
-1	150511	Light Pink
0	10960459	Black
1	91352	Cyan
2	10784	Light Cyan
3	2374	Blue
4	0	Light Gray
5	226	Dark Blue

Range: -4m to 5m



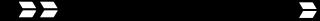
## ► Key Data Issues for Users

- SRTM is a snapshot of the Earth at one time through the eyes of a single radar sensor
- Heights represent reflective surface
- Water conditions are time-dependent and portrayed as they were in February 2000
  - Daily effects
  - Seasonal effects
  - Annual effects
- SRTM data are not perfect
  - Voids (missing data) are inevitable
    - Rugged terrain or high relief
    - Desert areas
  - Radar imaging constraints, data regridding and filtering affect heights of ridge tops and valleys
  - Phase unwrapping errors cause small localized areas of systematically incorrect heights



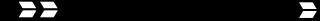
# ► SRTM Data Dissemination to Public

- All SRTM data are unclassified
- Restrictions apply to release of products
- Public data include:
  - World-wide DTED® 1 (3 arc sec or approx 90 m spacing)
  - U.S. DTED® 2 (1 arc sec or approx 30 m spacing)
  - SRTM Water Body Data (worldwide)
- USGS EROS Data Center distributes:
  - “Finished” Public SRTM DTED® 1, SRTM DTED® 2 and SRTM Water Body Data
  - “Unfinished” Public JPL SRTM Terrain Elevation Data
  - Website at <http://edc.usgs.gov/products/elevation.html>
- Other products [OIMs, THED, SHCM, DTED® 2 (non-U.S.)]
  - By request to NGA Public Affairs Office



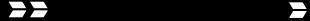
## ► **Void-Filling Finished SRTM DTED®**

- Follow-on to finishing
- Contract with Boeing/Intermap to assess feasibility of filling voids in subset of total SRTM DTED®
- Assessment performed on about half of 14,000 cells
- Alternate data sources (non-SRTM) available for most
- Current void-filling production
  - 300-400 cells per month
  - Work includes some larger area interpolation, limited data editing and some detection and removal of phase unwrapping errors
  - Updates to associated THED, SHCM and SWBD products
  - Documented in metadata to distinguish from original finished products
- Delivery Schedule
  - May 04 – May 05            ~4,000 cells
  - May 05 – Dec 05            ~3,000 cells



# ► Summary

- Single set of homogeneous, self-consistent, terrain elevation data now available for 80% of Earth's landmass, much of which had no comparable data prior to SRTM
- Production finishing completed in September 2004
  - 14,277 cells of DTED® 2, DTED® 1 and associated products including ascending and descending Orthorectified Image Mosaics (OIMs), Terrain Height Error Data (THED), Seam Hole Composite Map (SHCM) and SRTM Water Body Data (SWBD)
- Data Quality
  - Emphasis placed on consistency and standardization between and within contractors for removal of large anomalies, filling small voids and editing in water bodies.
  - After water body editing, 94-98% of all cells on a continental basis have less than 5% voids left in data



## ► Summary (cont'd)

- Public Access to finished SRTM data products
  - USGS EROS Data Center (public data only)
  - Special request to NGA (all products)
- Active program underway to fill voids in about half the SRTM cells