

# Overview of data processing to Level 1B

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Based on work by the HICO team, especially:

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# Overview of Processing

- Level 1B data signifies data that has been radiometrically calibrated and contains information that will allow geometric correction
  - ASCII text HDR file also prepared, contains a lot of metadata
- Data from ISS to NRL daily during the weekdays.
  - Occasionally there are dropped data packets (a raw HICO image is divided into data packets) in the process. When this happens we request another download, and usually we only ever need two downloads to fully reconstruct an image.
- Initial processing
  - Calibrated HICO data file
  - Ancillary files
    - NDVI, Flag, “Rough geometry”, RGB, JPG
    - Each file (except JPG) has an ASCII text header file associated with it
- Secondary process of geometric correction

# Calibrated HICO data

- Overall, the radiometric calibration follows the steps specified in Lucke, *et al.* (HICO calibration v 1.6)
  - Dark subtraction per Lucke, *et al.* (uses both pre- & post-image darks)
    - Next reprocessing will do images missing either pre- or post-image dark
  - Frame shift smear correction as specified in Lucke, *et al.*
  - 2<sup>nd</sup> order correction is performed per formula of Li, Gao, & Lucke
  - Smoothing to deal with the etalon effects: 20 nm FWHM for wavelengths > 745 nm, 10 nm smoothing otherwise (Gao & Corson, results, use Gao's values)
  - Adjust the calibration coefficients for the HICO-ISS wavelength calibration (see Gao presentation)
  - Multiply lab calibration coefficients by 13.0/13.75 to account for differing integration times in lab and on ISS
  - Multiply a line (frame) of raw data by the calibration coefficients
    - Units are  $W m^{-2} sr^{-1} \mu m^{-1}$

# Calibrated HICO data

- If any dropped packets affect this pixel, then set the entire pixel to 0
  - Missing data for smear and/or 2<sup>nd</sup> order correction
- If any bands for this pixel are saturated, set entire pixel to 0
  - Missing data for smear and/or 2<sup>nd</sup> order correction
  - So far only over bright clouds
- Multiply entire frame (all bands, all cross-track pixels) by Gao scale factor (currently 1.32)
- Multiply by Gao's spectrally dependent scale factor
- For signed two-byte integer output (the default): multiply data by 50, round, convert to signed two-byte integer
  - When using this scaled integer data, dividing the scaled integers by 50 will yield data with the units of  $W m^{-2} sr^{-1} \mu m^{-1}$

# Calibrated HICO data

- Edge pixels are set to 0 (cross track pixels 509 – 512) due to poor calibration
- For data in +XVV orientation, the data is flipped L<->R in order to be able to rotated onto a map of the world and have everything in the correct spatial orientation
  - Data obtained in the –XVV orientation is NOT flipped L<->R
  - Temporal order is preserved (first line in file is first line obtained)
- Additionally, the first three lines of data are set to 0 (see Lucke, *et al.* paper)
- At this stage, data is 512 pixels, 128 bands, 2000 lines
  - Associated ASCII text header file written, too
- Distributed (to NRL-Stennis & OSU) calibrated HICO data from NRL-DC is:
  - 512 cross-track pixels (i.e., samples)
  - 128 bands
  - 2000 lines

# Ancillary data files:

- “Rough geometry” (\*\_rad\_geom\* ) file
  - Latitude, longitude, zenith and azimuth for both solar and view angles
  - Uses value of ISS attitude and position at nearest second to start and end of first frame (**not** at actual times)
  - Includes HICO pointing angle
  - Includes ISS orientation (+XVV, -XVV: from quaternions)
  - Does **not** include bore sight offsets
  - Calculates ground position of north, center, south of first and last frame (line) and interpolates to fill in rest
  - Position to within ~10 km
  - Calculations can be performed immediately, at same time as radiometric calibration (all information is in Level 0 data)
  - Does not account for elevated surfaces; assumes WGS-84 ellipsoid
  - Calculates solar zenith and azimuth at calculated pixel positions and known date & time (from point on ground to sun)
  - Calculates view zenith and azimuth from point on ground to ISS

# Ancillary Data Files

- 3 band RGB (\*\_rad\_rgb\*) and associated JPG (\*.jpg)
  - Bands nearest to 638.1 nm, 552.2, and 460.5 nm
  - Scaled radiance file and header written
  - JPG (i.e., quicklook) also made from this image
- NDVI (\*\_rad\_ndvi\*)
  - Based on planetary reflectance (NOT atmospherically corrected)
  - Uses date to get solar distance, uses solar irradiance appropriate for bandwidth, and solar zenith angle
  - Band 89 (869 nm) for NIR, band 56 (668 nm) for red
- Flag (\*\_rad\_flag\* ; bits set for some rough data quality flags)
  - Bit 1 = 1 if  $\rho_{\text{NIR}} > 0.02$  (i.e., Land (possibly glint or even clouds))
  - Bit 2 = 1 if Latitude or Longitude is out of bounds
  - Bit 3 = 1 if navigation is rough (currently always set to 1)
  - Bit 4 = 1 if satellite view zenith angle  $> 60^\circ$
  - Bit 5 = 1 if solar zenith angle at estimated position is  $> 75^\circ$
  - Bit 6 = 1 if pixel has  $\geq 1$  bands that is (are) saturated
  - Bit 7 = 1 if pixel has  $\geq 1$  bands that are from a dropped packet
  - Bit 8 = 1 if ( $\rho_{\text{NIR}} > 0.5$  and  $\rho_{\text{RED}} > 0.5$ ) or ( $0.8 < \rho_{\text{NIR}} / \rho_{\text{RED}} < 1.1$ ) as a rough cloud mask

# “Better” Geometry file

- Full geometric processing involves the 1 Hz attitude and position data from the ISS – downloaded separately
  - GPS clock and ISS “Broadcast Ancillary Data” time are not the same
  - We now have the NASA known offsets between the clocks
- Process
  - Using known time offset, determine ISS attitude and position for each line (frame) of HICO data (done in B2)
  - Transfer files over to POC in B209 to use MatLAB/STK to obtain pointing (latitude, longitude, view zenith, view azimuth) on earth for a subset grid of pixels
    - Process unpredictably ceases – sometimes runs for 20+ hours, sometimes runs for < 1 hour
    - Note that the same process is done when determining bore sight parameters
  - Transfer files back to B2 to interpolate to entire grid and also populate the solar zenith and solar azimuth bands
  - \*\_LonLatView\*



# Bore Sight Parameters

- Currently using ISS quaternions
  - Offsets between the ISS Quaternions and HREP Star Tracker (HST) quaternions indicate  $\sim 1$  mrad offset and  $\sim 1$  mrad orbital variation
  - Additionally,  $\sim 1.6$  sec uncertainty in the time of the HST measurement – trying to track that down
- Determine bore sight offsets for image 1689 by selecting  $\sim 20$  ground control points (Thanks Jasmine!) in image and identical locations in GoogleEarth
  - For each trial bore sight offset (roll, pitch, yaw) create an IGM file (i.e., coordinates for each HICO pixel) using STK/MatLab; do this for a grid of trial bore sight parameters. Use IDL/ENVI to map each scene and determine the set of parameters that yields the smallest average distance between the calculated coordinates and the true coordinates
  - $\Delta\theta_x \sim 0.9^\circ \pm 0.1^\circ$  ( $\sim$ roll)
  - $\Delta\theta_y \sim 0.1^\circ \pm 0.1^\circ$  ( $\sim$ pitch)
  - $\Delta\theta_z \sim -0.2^\circ \pm 0.1^\circ$  ( $\sim$ yaw)
  - Mean Distance error (mapped coordinates – true)  $\sim 96$  m

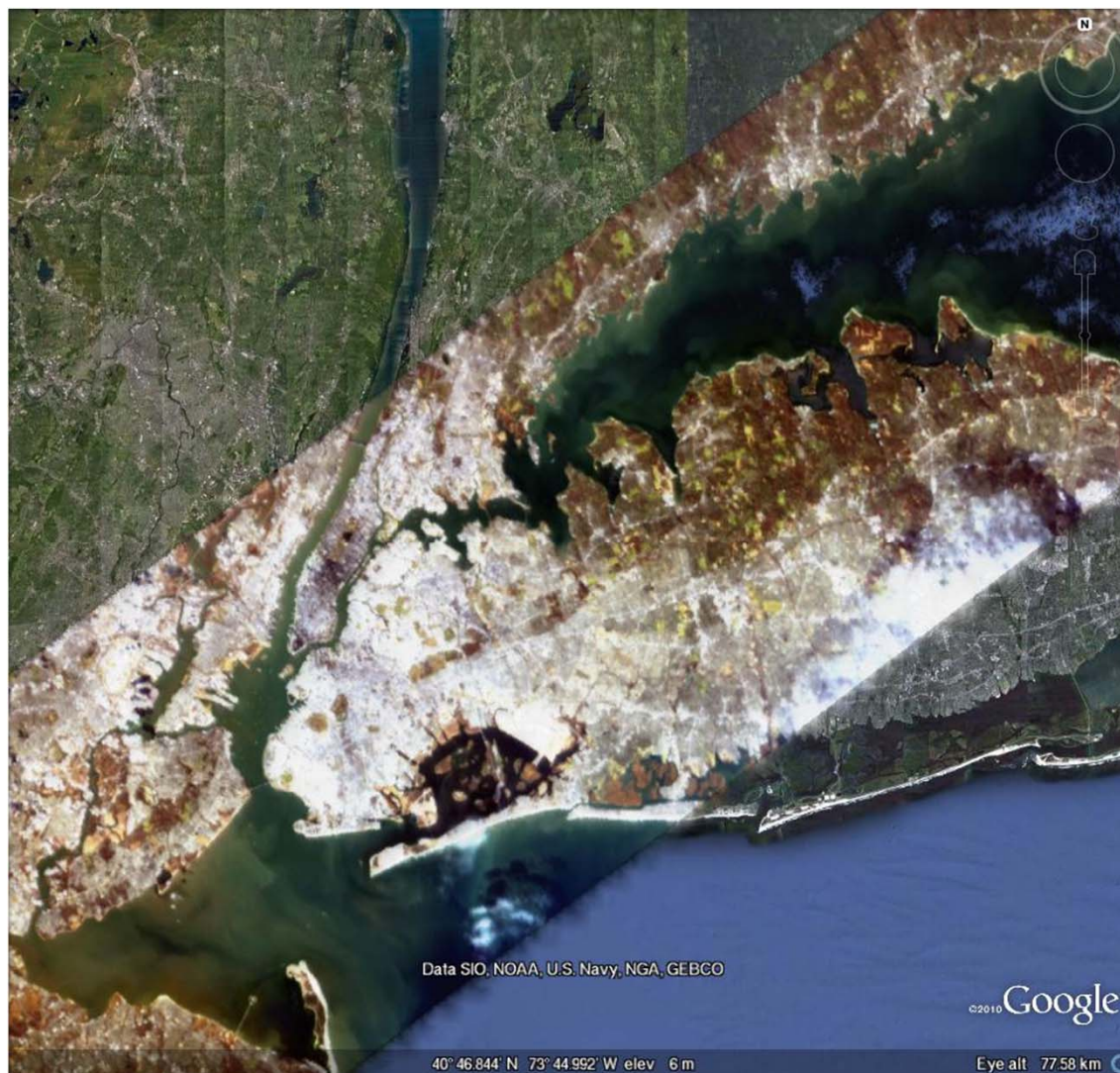
# Bore Sight Parameters

- Image 1689 RGB mapped with bore sight offsets from previous page mapped in ENVI, then overlaid onto Google Earth
- View angle from stow  $\sim 57.7^\circ$ , so  $\sim 2.3^\circ$  from nadir
- 2010 Jan 18, 18:25:03 UTC



# Bore Sight Parameters

- Same image, HICO scene 1689 overlay on top of Google Earth, zoomed in





# Bore Sight Parameters

- Locations calculated on a grid with  $0.1^\circ$  spacing (i.e.,  $\sim 7$  pixel at nadir)
- Results indicate that there is no single fixed bore sight parameter that will work at the 1 pixel level for all scenes (see first slide for possible reasons)
- Current mode: select a single value and use for all scenes; user will need to refine by hand using, for example, ENVI's RST transformation (rotate, scale, translate)

Scene ID	$\Delta\theta_x$ (degrees)	$\Delta\theta_y$ (degrees)	$\Delta\theta_z$ (degrees)	rms dist (m)
1689	$0.9 \pm 0.1$	$0.1 \pm 0.1$	$-0.2 \pm 0.1$	96
2141	$1.1 \pm 0.1$	$0.1 \pm 0.1$	$-0.2 \pm 0.1$	226
3797	$1.0 \pm 0.1$	$0.1 \pm 0.1$	$-0.1 \pm 0.1$	252
3044	$1.0 \pm 0.1$	$0.1 \pm 0.1$	$0.0 \pm 0.1$	257

- Files are put into an HDF archive
  - If a “better” geometry file, then it is put into the HDF file; otherwise a \*\_rad\_geom\* file is used
  - No matter which geometry file is used, users will need to do a correction
  - Usually a simple affine transformation (rotate, scale, translate) will be all that is necessary
  - Some instructions are at HICO web site:  
<http://hico.coas.oregonstate.edu/index.shtml>
- Files sent to NRL-Stennis and OSU
  - At OSU, before distribution each calibrated radiance file is trimmed spectrally to 400 nm – 900 nm: 87 bands
  - At OSU, all files are trimmed spatially: 10 left most and 2 rightmost pixels trimmed (+XVV): 500 cross-track
  - 2000 lines
- Questions?

# Questions?



```
description = { Scaled calibrated HICO radiance, see history for more info. }
samples = 512
lines = 1997
bands = 128
header offset = 0
interleave = bil
data type = 2
byte order = 0
file type = ENVI Standard
sensor type = HICO
version = 1
scene_id = 2645
x start = 1
y start = 4
z plot titles = {wavelength (micrometer), 50.00* radiance (W/m^2/micrometer/sr)}
image_unscaled_units = {W/m^2/micrometer/sr}
wavelength units = micrometers
image_center_date = {2010, 5, 1}
image_center_time = {13, 25, 8.777}
image_center_lat = { 34.07976, 0.,0.}
image_center_lat_hem = S
image_center_long = { 18.13748, 0.,0.}
image_center_long_hem = E
image_center_zenith_ang = { 9.90000, 0.,0.}
image_center_azimuth_ang = { 318.27025, 0.,0.}
sensor_altitude = 355.0
```

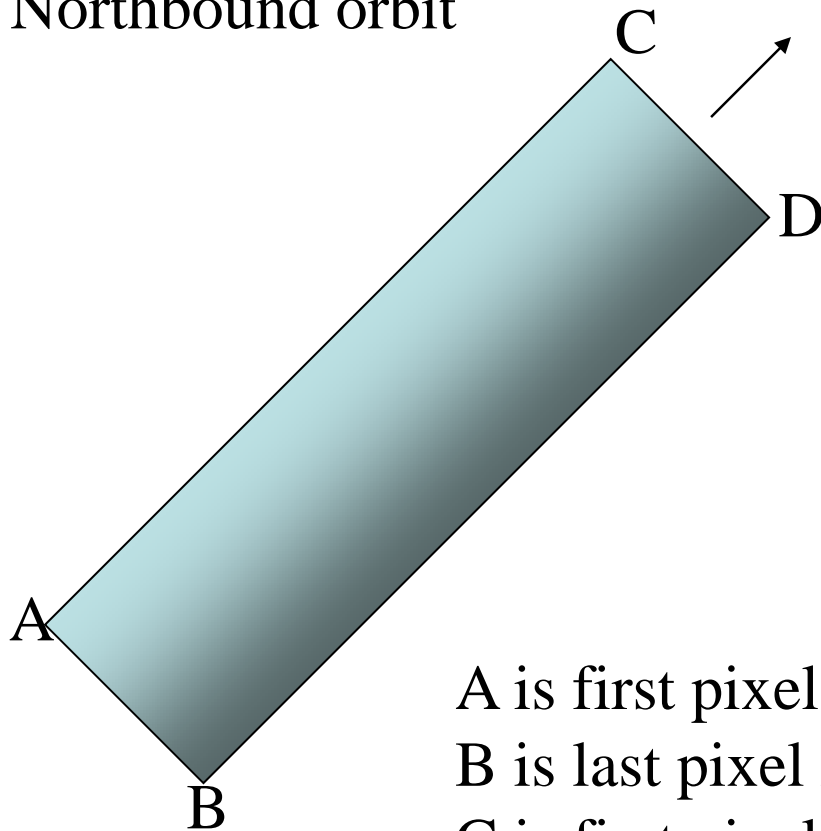




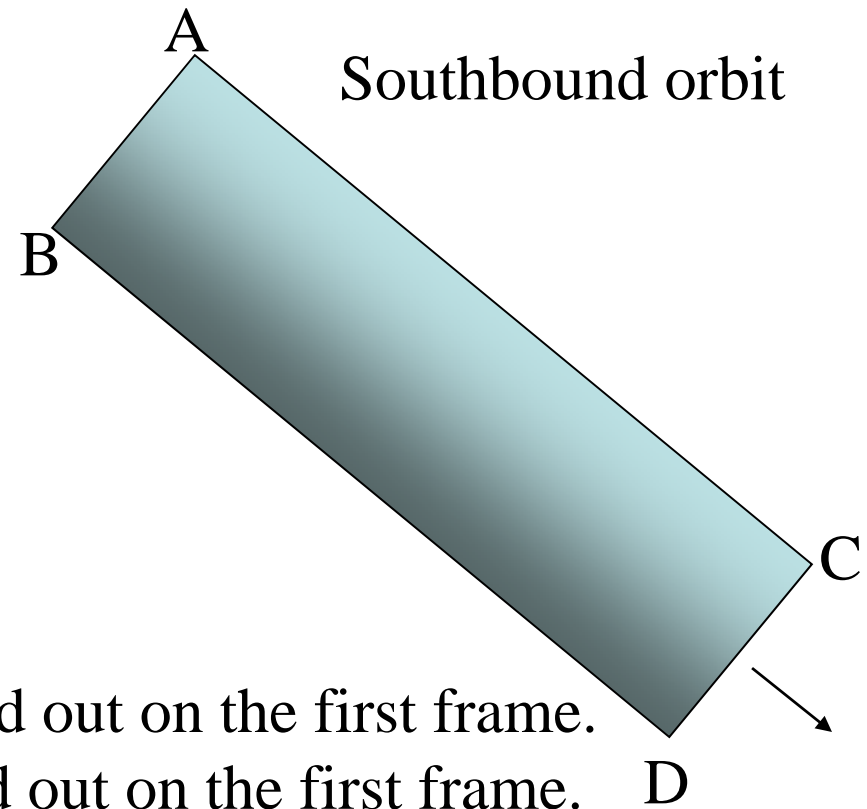
```
hico_derived_FirstFrame_LatLonHkm = { -34.27778, 16.92921,355.365}
hico_derived_LastFrame_LatLonHkm = { -33.04843, 18.45074,355.043}
hico_derived_FirstFrameOrbitVelMag_kmpersec = 7.399
hico_derived_LastFrameOrbitVelMag_kmpersec = 7.399
hico_estimated_angle_degrees_to_rotate_envi_image_to_map = -133.812
hico_iss_orientation = +XVV
hico_estimated_LatLon_NorthEndFirstFrame = { -34.54733, 17.22012}
hico_estimated_LatLon_CenterFirstFrame = { -34.69456, 17.38015}
hico_estimated_LatLon_SouthEndFirstFrame = { -34.84500, 17.54448}
hico_estimated_LatLon_NorthEndLastFrame = { -33.31780, 18.73724}
hico_estimated_LatLon_CenterLastFrame = { -33.46496, 18.89480}
hico_estimated_LatLon_SouthEndLastFrame = { -33.61532, 19.05658}
hico_estimated_image_center_latitude = { -34.07976, 0.,0.}
hico_estimated_image_center_longitude = { 18.13748, 0.,0.}
hico_estimated_view_zenith_angle = { 9.90000, 0.,0.}
hico_estimated_view_azimuth_angle = { 318.27025, 0.,0.}
hico_estimated_solar_zenith_angle = { 62.07398, 0.,0.}
hico_estimated_solar_azimuth_angle = { 315.09974, 0.,0.}
hico_cal_code_processing_start_time_utc = Wed May 12 20:16:02 2010
hico_number_of_lines_with_saturated_bands = 0
hico_number_of_lines_affected_by_dropped_packets = 0
hico_number_of_pixels_with_saturated_bands = 0
hico_number_of_pixels_with_dropped_packets = 0
hico_cal_code_processing_finish_time_utc = Wed May 12 20:16:22 2010
target_scene_id = 2645
target_name = Cape_Town_SAfrica
target_angle = 69.90
target_type = image
target_aos = Sat May 1 13:24:40 2010
```

## HICO Orientation (initial, +XVV)

Northbound orbit



Southbound orbit



A is first pixel read out on the first frame.

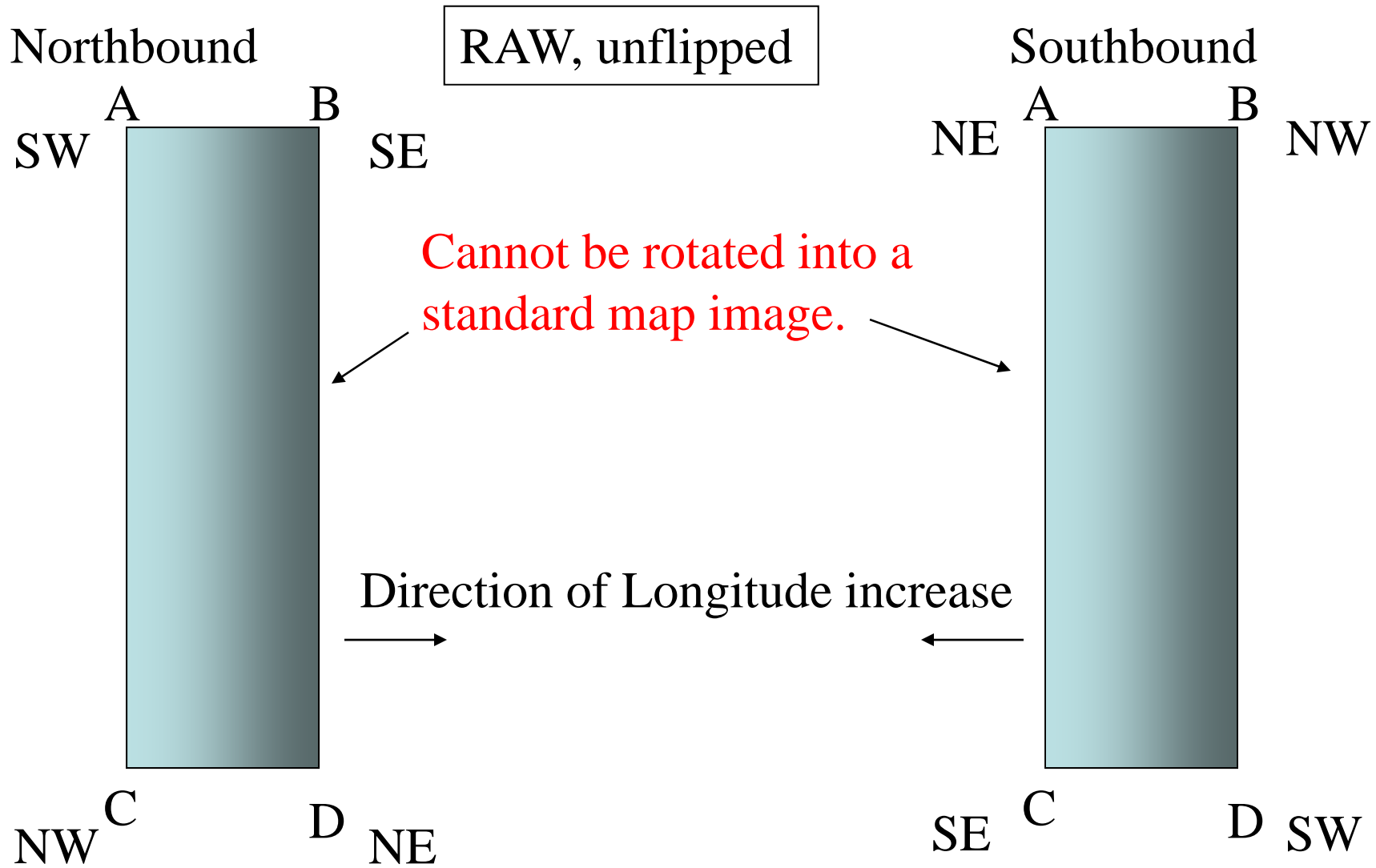
B is last pixel read out on the first frame. D

C is first pixel read out on the last frame.

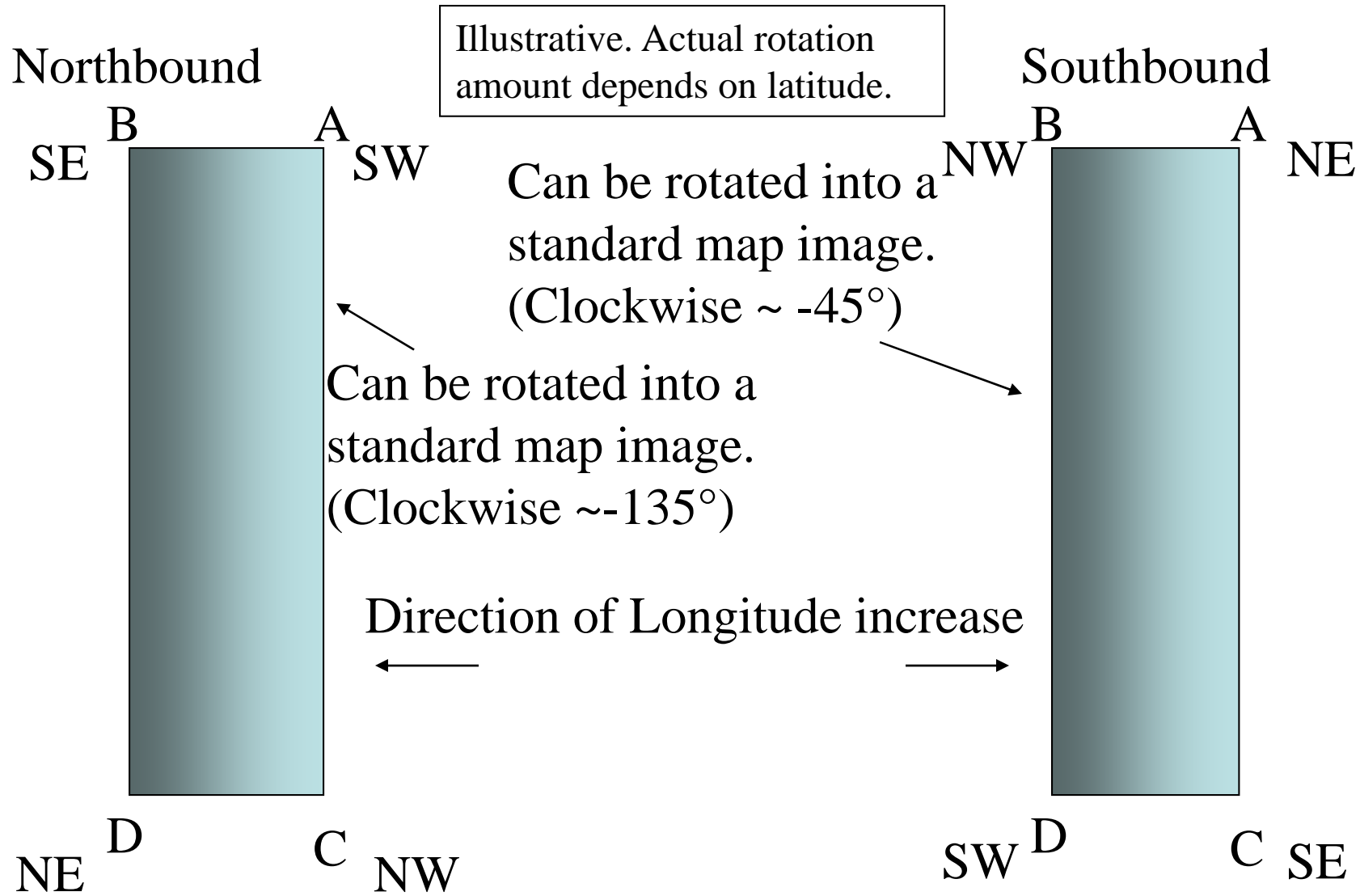
D is last pixel read out on the last frame.

# ENVI Waterfall Display Orientation

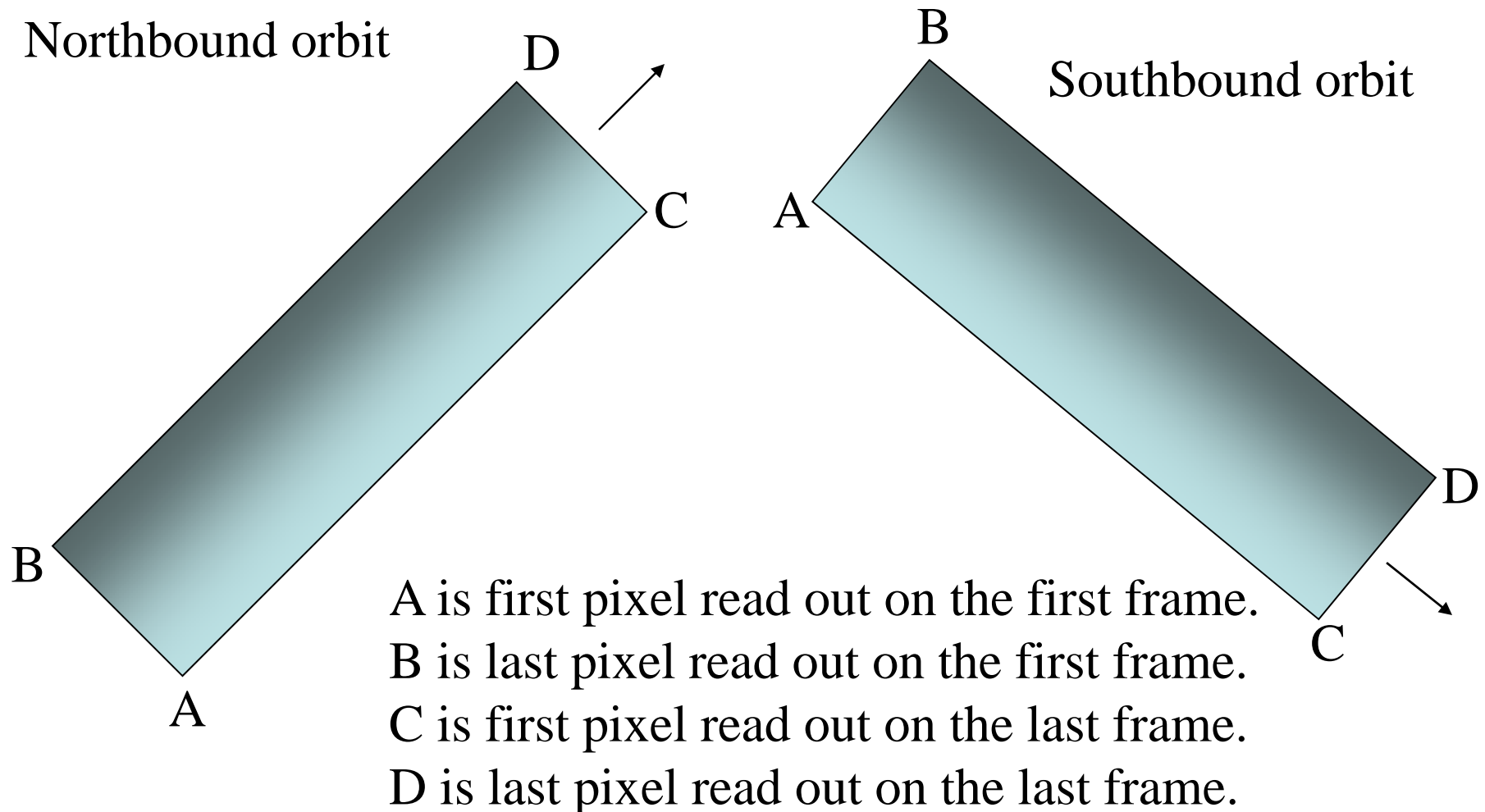
## First pixel read on upper left, +XVV



# Flip Left/Right in ENVI Display, +XVV



# HICO Orientation (-XVV)



# ENVI Waterfall Display Orientation

## First pixel read on upper left, -XVV

