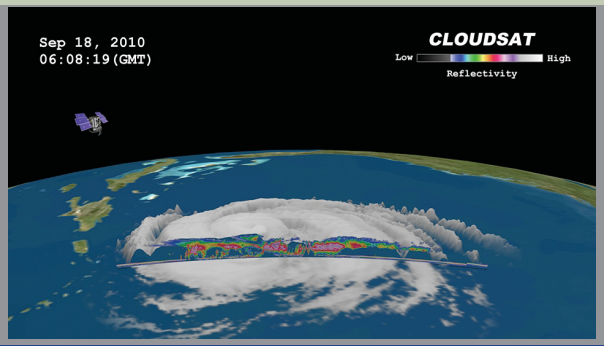


ISRSE 2011

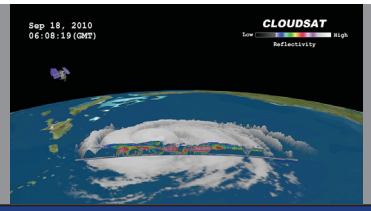
CloudSat Reflectivity Data Visualization Inside Hurricanes

Shigeru Suzuki, John R. Wright, Pedro C. Falcon

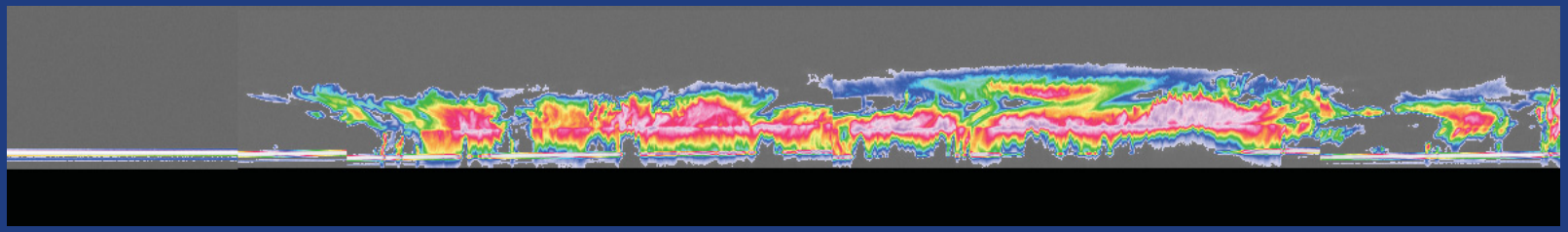
Jet Propulsion Laboratory

California Institute of Technology

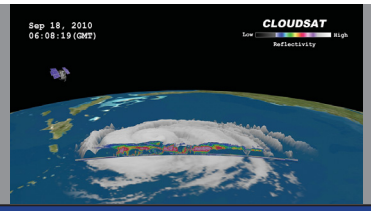
CloudSat Instrument



- Part of the A-Train and launched in 2006
- Satellite-based millimeter-wavelength cloud radar
- Detects much smaller particles of water and ice than centimeter-wavelength radars
- Sweeps a vertical profile along its orbital track capturing a profile of the water particle density in the atmosphere

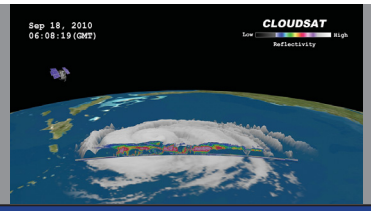


CloudSat Visualization Products



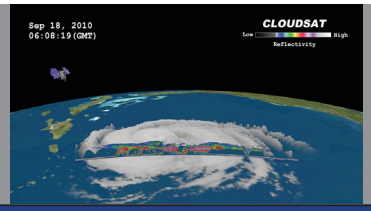
- Two basic products
  - Google Earth .kmz files for browsing
  - HD animation files for media release
- Related/similar processing
- Combine CloudSat QuickLook products with GOES imagery IR-4 band
- Based on satellite tracking data and NOAA hurricane tracking data

CloudSat Browse Products



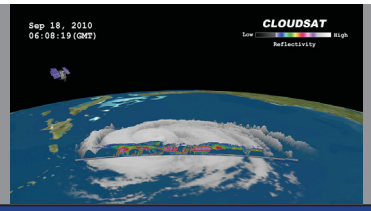
- Google Earth .kmz files
- Zipped file containing:
  - Google Earth .kml file
  - Orbital track line
  - Storm center marker
  - GOES image overlay for globe
  - Vertical image strips for CloudSat profile
    - Image file
    - Collada/DAE file

CloudSat Animation Products



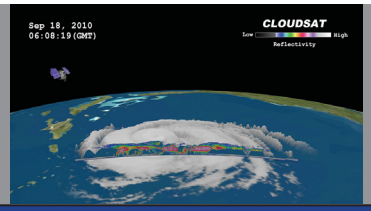
- Autogenerated from search area and time
- Primary product is HD rendered animation
- Automatic notification of results to users
- Notification email includes:
  - Key frames
  - Reduced resolution animation

CloudSat Product Comparison



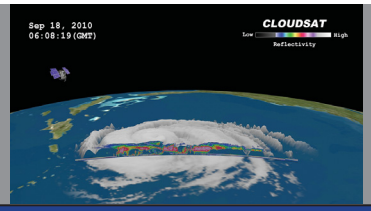
- Browse Product
  - Based on storm data
  - Specify lat/long location and time
  - Find nearest pass to storm center
  - Locate appropriate data granules
  - Generate a product
- Animation Product
  - Based on search area
  - Specify lat/long and time ranges
  - Find all passes in the search area
  - Locate granules with interesting data
  - Generate a product for each

CloudSat Browse Product Process



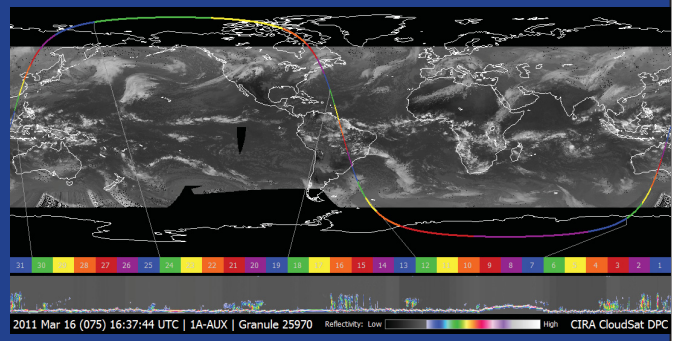
- Specify lat/long location and time
- Find closest spacecraft orbital pass to location within +/- one day
- Select CloudSat granules to cover +/- 1min
- Divide granules into 24 vertical strips
- Select GOES image and extract overlay
- Build kml file referencing everything
- Zip it all up into a kmz file

CloudSat Browse Product Process

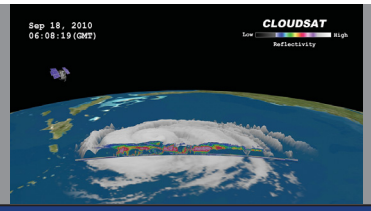


Find closest spacecraft orbital pass to location within +/- one day

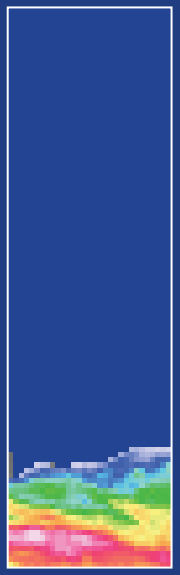
- Download TLE files for three days
- Create an associated Spice kernel
- Create lists of spacecraft position at 60 and 5 second intervals
- Scan for closest approach
- Utilize from 60 seconds before to 60 seconds after



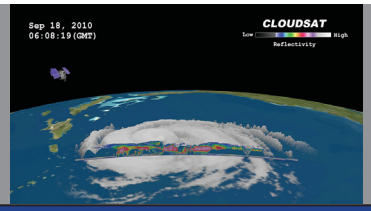
CloudSat Browse Product Process



- Select CloudSat granules to cover +/- 1min
- Divide granules into 24 vertical strips
  - Concatenate two granules together
  - Start at column associated with start time
  - Extract 24 subimages about 31 pixels wide
    - Clip off ground effect
    - Create transparency layer
    - Create associated Collada file
    - Compute strip position and orientation
    - Write to kml file



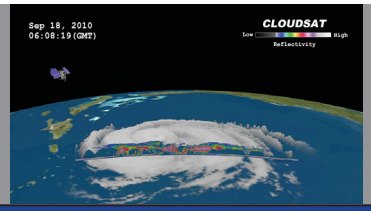
CloudSat Browse Product Process



Select GOES image and extract overlay

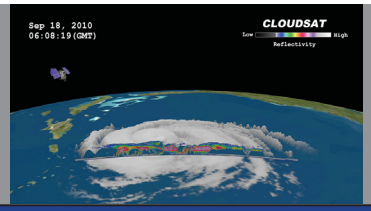
- Search prebuilt array for “best” image
  - List of images covering each lat/long
  - Distance to edge or max coverage
- Download identified GOES image
- Extract neighborhood pixels
- Use brightness temp for transparency
- Add to kml file

CloudSat Browse Products



- Demo in Google Earth

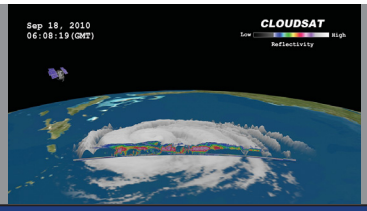
CloudSat Animation Production Process

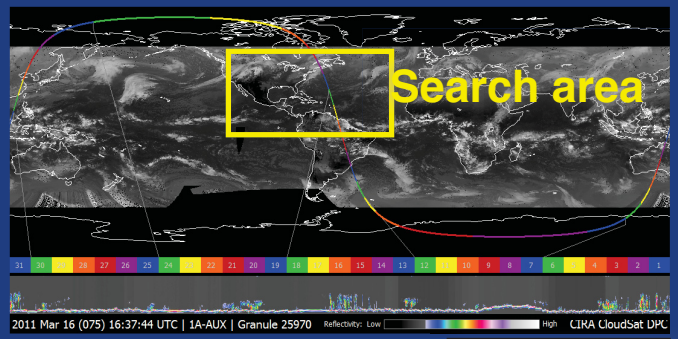


- Find all spacecraft passes through a specified search area within a specified time range
- Identify passes with “interesting” data
- Identify associated GOES imagery
- Create the 3D models of cloud shape and texture maps of CloudSat data for visualization
- Render frames using COTS tools
- Composite animation frames with time stamp and legend
- Notify users

CloudSat Animation Production Workflow

- CloudSat coverage of the storm search area





http://www.cloudsat.cira.colostate.edu/data_dist/TLEs/

CloudSat orbit in Two Line Element (TLE) format

Generate SPK spice kernel file

SPK kernel file

Start and stop date / time

Create a list of lat/lon every second

Search area (min and max lat / lon)

Date, time, lat, lon list in a text file

Check the CloudSat coverage of search area

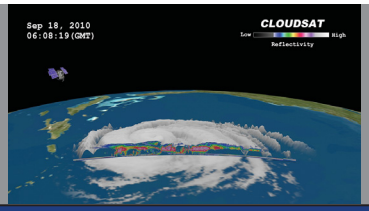
A list of start and stop time of orbit segment within the search area

Example:

Start Time	End Time
2011-03-20T04:26:39.682	2011-03-20T04:42:14.682
2011-03-20T06:04:29.682	2011-03-20T06:21:09.682
2011-03-20T07:43:19.682	2011-03-20T07:59:59.682

CloudSat Animation Production Workflow

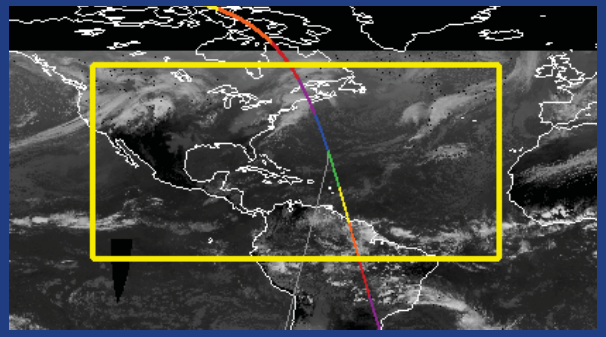
- Storm detection from CloudSat reflectivity granules



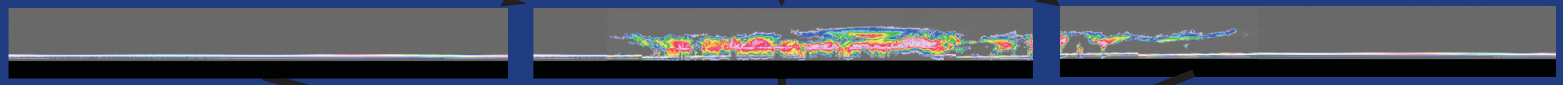
http://www.cloudsat.cira.colostate.edu/dpcstatusQL.php

Quicklook granule image files

Start and end time of an orbit segment within the search area



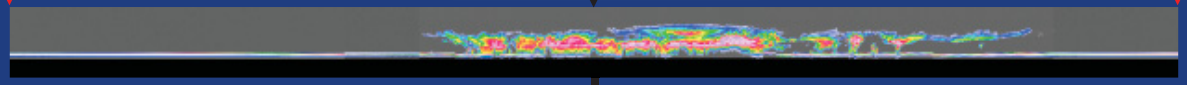
Download all granules to cover the time period



Merge them in one granule and crop from start to end of the coverage

End of the search area

Start of the search area



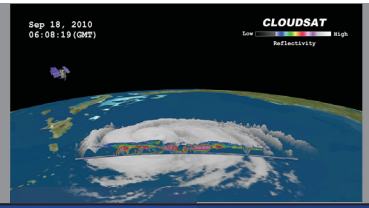
Detect a storm cloud and set start time and end time of the storm

End of storm clouds

Mid point of storm clouds

Start of storm clouds

CloudSat Animation Production Workflow



- Generate Cloud model from GOES Image

Mid point date and time of the detected storm clouds

SPK kernel of the CloudSat spacecraft

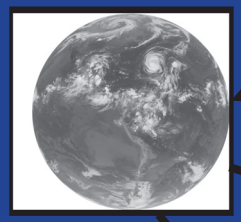
http://goes.gsfc.nasa.gov/goes{east,west}-lzw/

GOES East/West IR-4 images

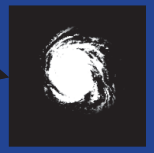
Calculate lat/lon of the mid-point of the detected storm

GOES image index table for each lat/lon

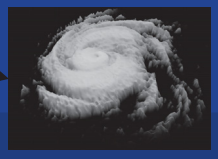
Download the GOES image observed closest to the pass, after determining which GOES image to use for the highest resolution



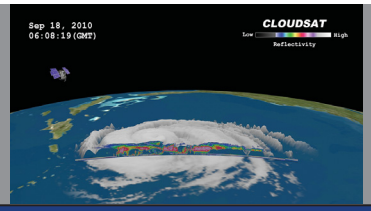
Make a mask of the storm cloud



Create 3D cloud shape model



CloudSat Animation Production Workflow



- National Hurricane Center Tropical Cyclone Advisory

http://www.nhc.noaa.gov/archive/2010/

Date, location, status of each storm in text files

Parse text files to extract date, location, and status.
Update the database.

Storm database (MySQL)

Date / time

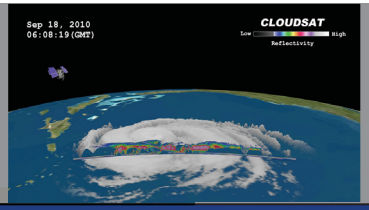
Query to the storm database

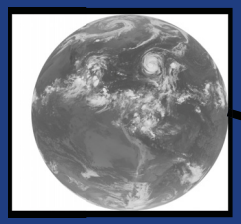
List of storms at the specified date and time. Example:

lat 29.125 lon -74.625 name Hurricane EARL
lat 22.5 lon -65.2375 name Tropical Storm FIONA
lat 13.4875 lon -38.1375 name Tropical Storm GASTON

CloudSat Animation Production Workflow

- Putting it all together





Apply texture map

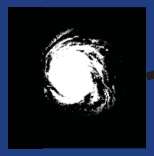
Import CloudSat spacecraft position for every frame

COTS Visualization Software

Camera motion control

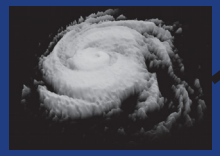
Add red dots if any storms are visible

Query to storm database (MySQL)



Apply transparency map

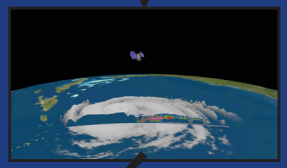
Import cloud shape model



Render frames

Render Date / Time layer

Import reflectivity granule as a texture map



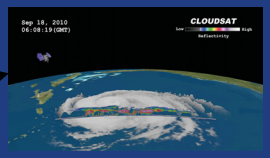
Mar 20, 2011
18:39:54(GMT)

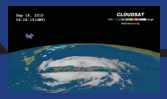
1920x1080 full HD movie

Mobile devices

COTS Composite Software

Overlay date/time, legend
Create full HD movie
Create small movie file

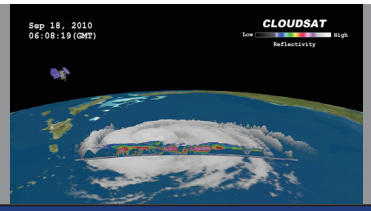


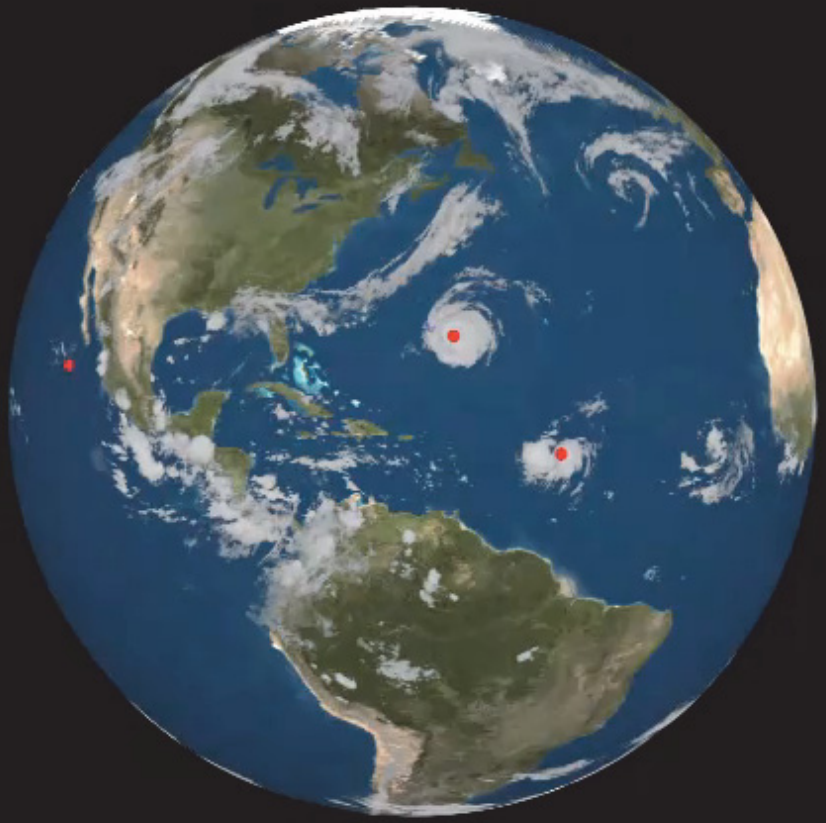


Half resolution movie

Send notification to the subscribers with a movie and images attached

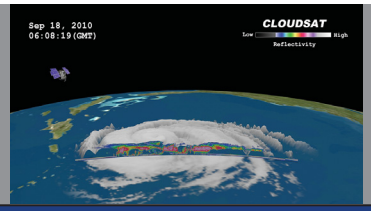
CloudSat Visualization Products

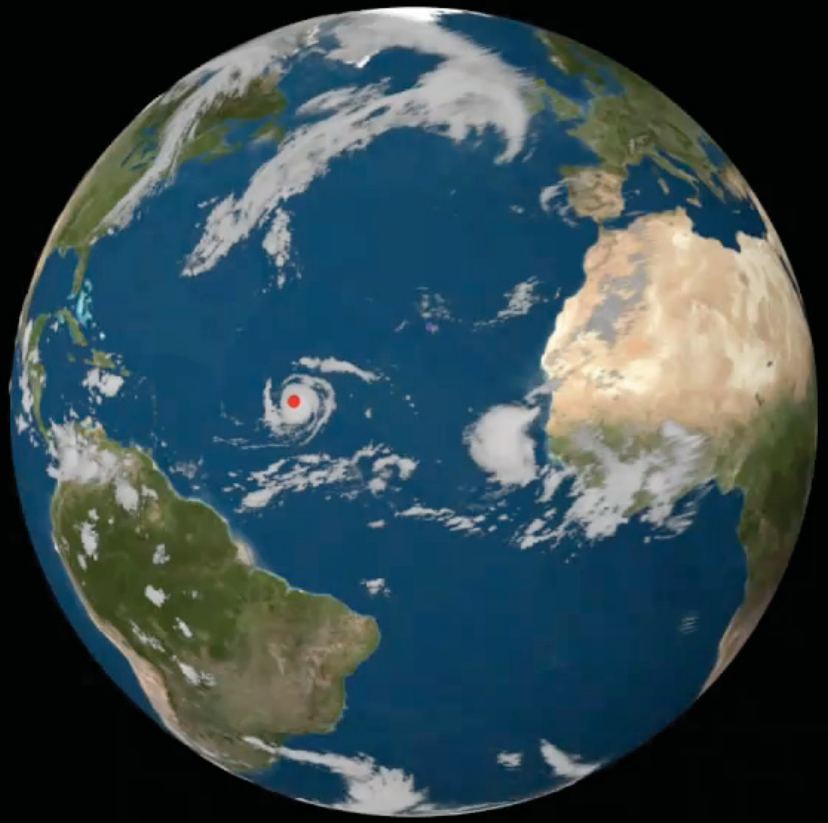




Hurricane Earl 31 Aug, 2010

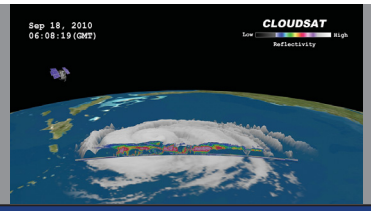
CloudSat Visualization Products





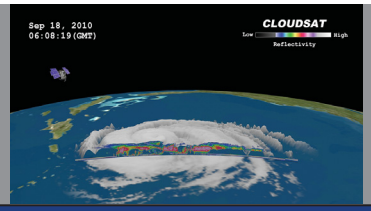
Hurricane Julia 15 Sep, 2010

CloudSat Visualization Products



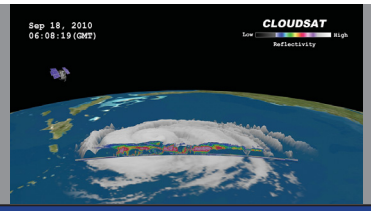
Hurricane Igor 16 Sep, 2010

CloudSat Visualization Products



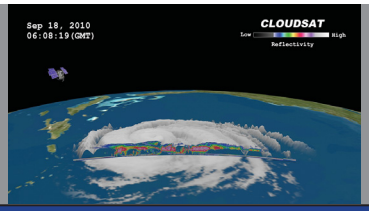
Hurricane Igor 18 Sep, 2010

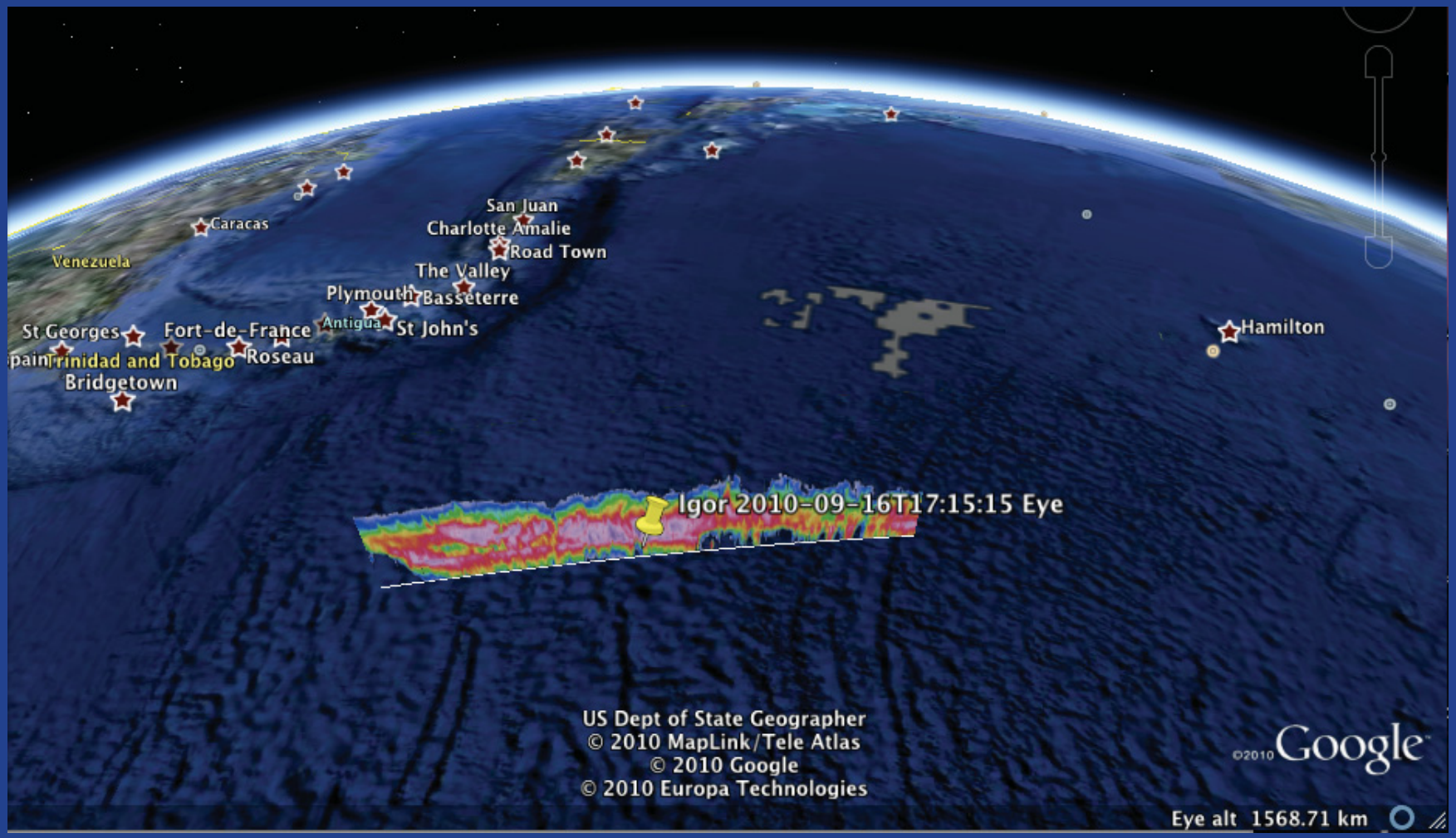
CloudSat Visualization Products



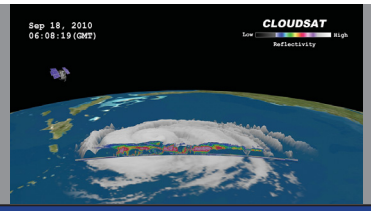
Of course, not everything goes smoothly

CloudSat Visualization Bloopers



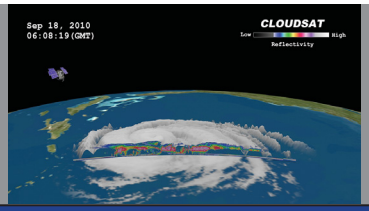


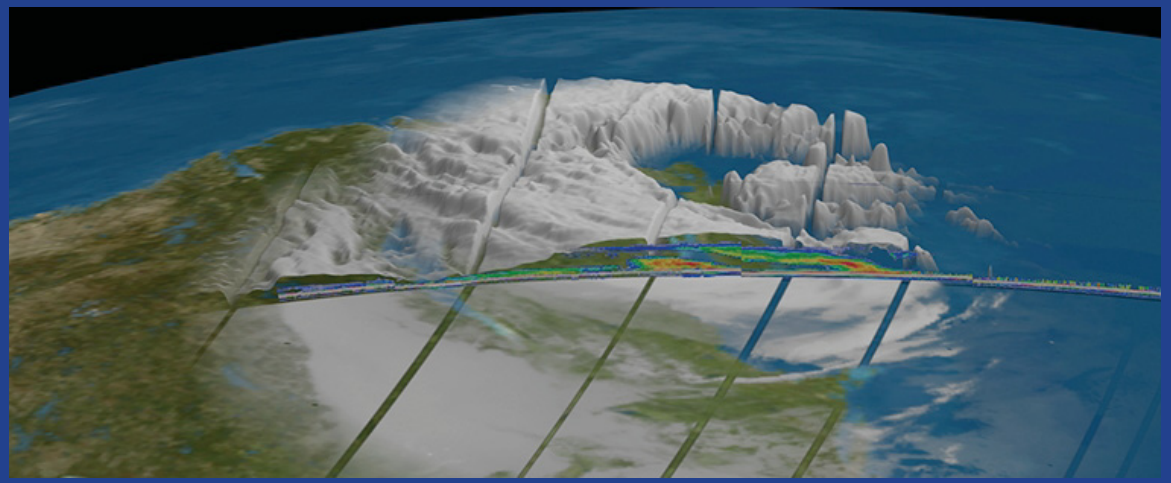
CloudSat Visualization Bloopers



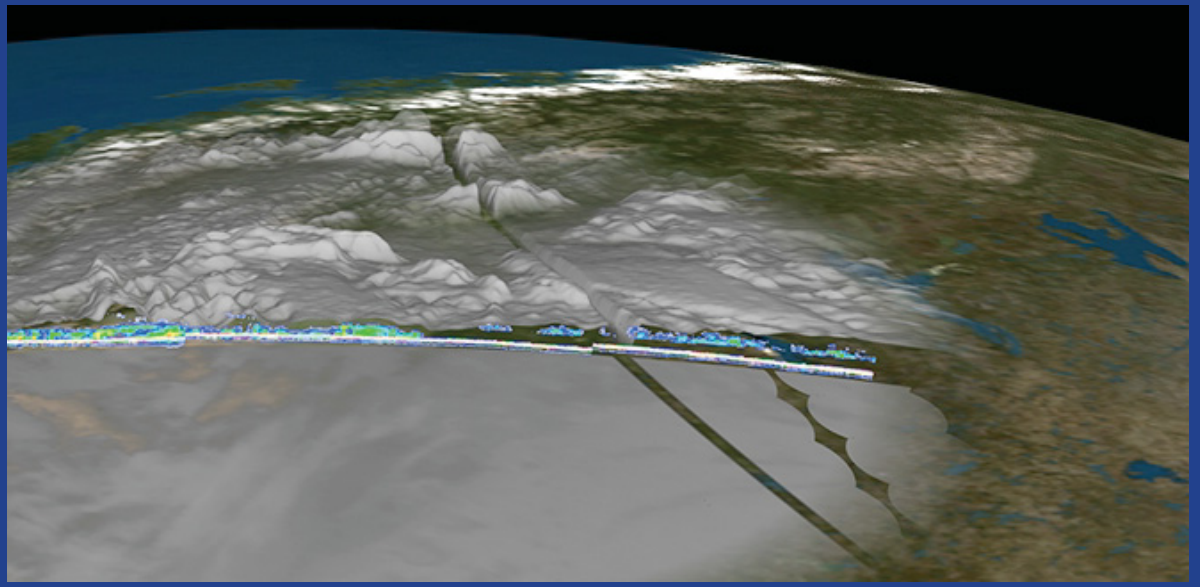
Mispointed camera

CloudSat Visualization Bloopers

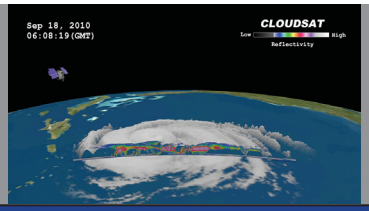


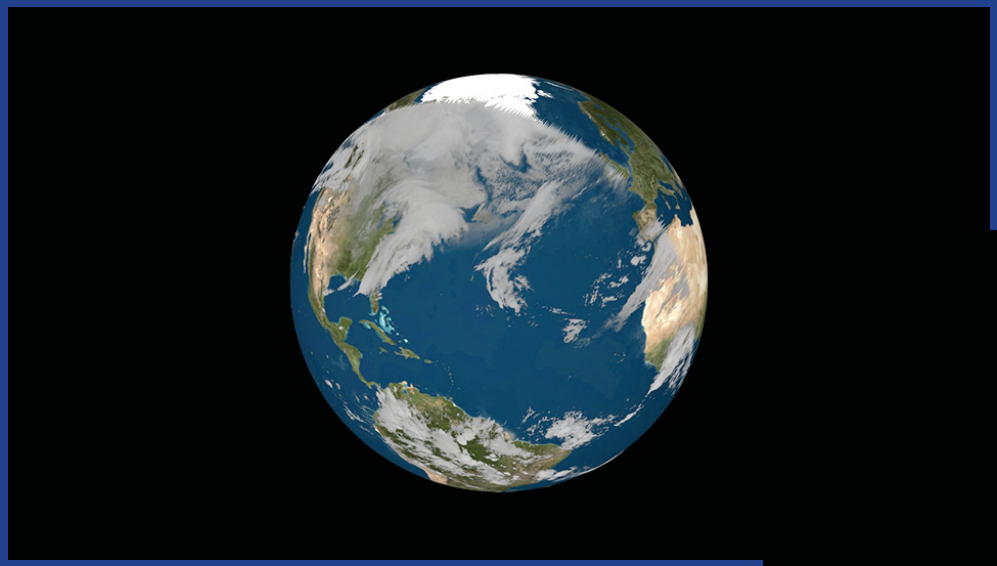


Missing data

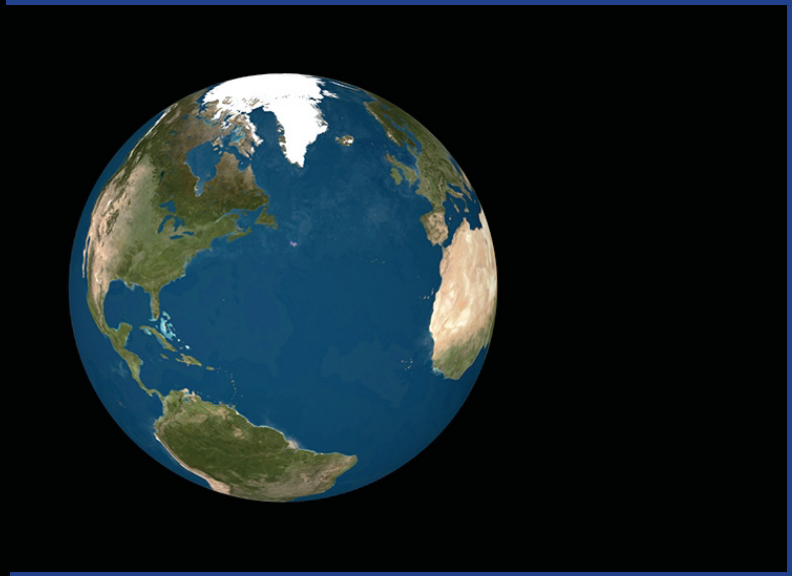


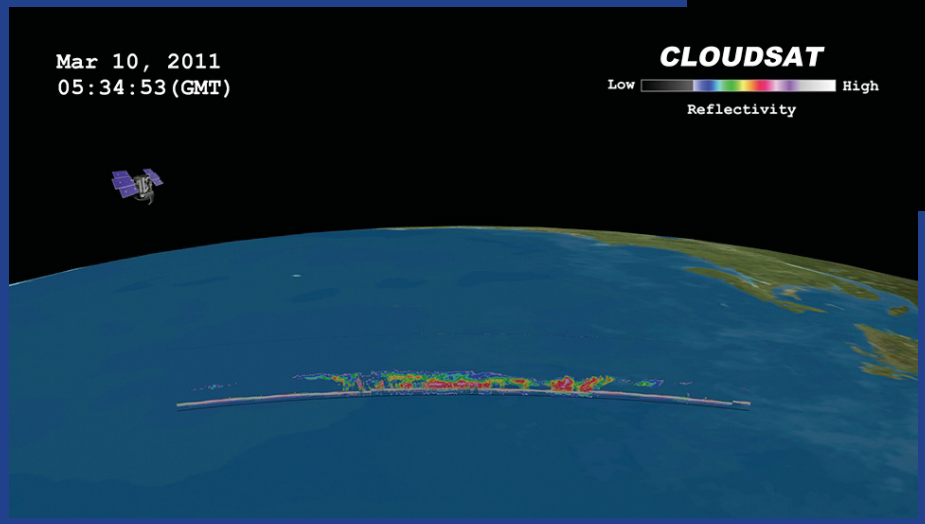
CloudSat Visualization Bloopers



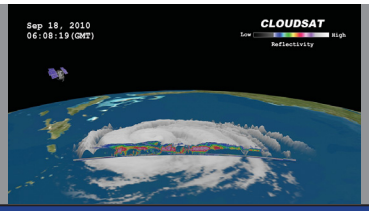


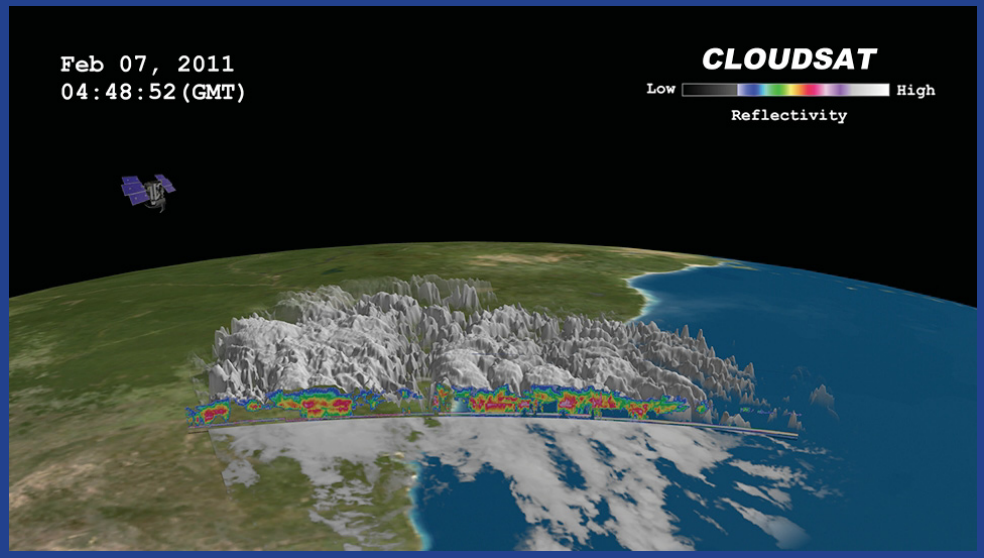
Really missing data



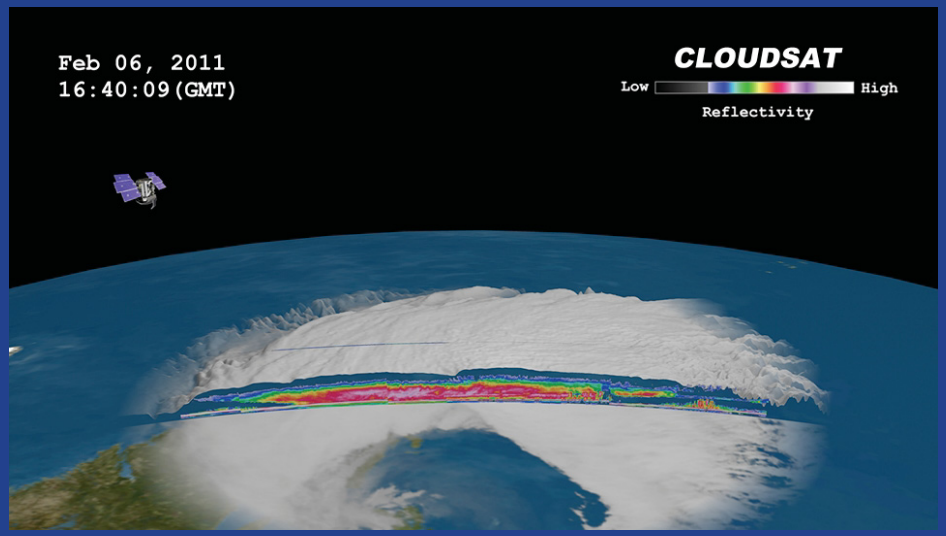


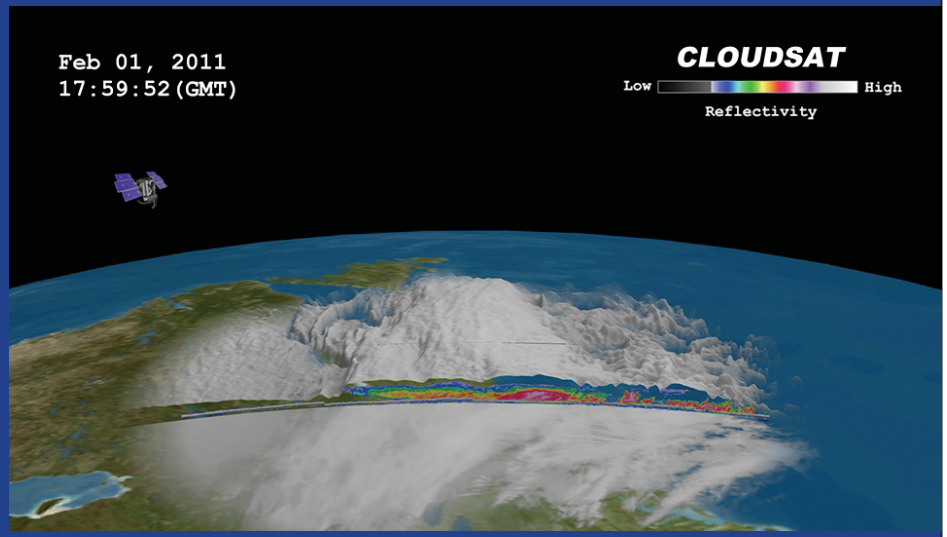
CloudSat Visualization Bloopers



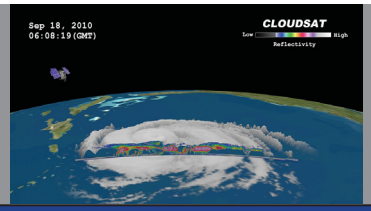


Changes in height of granule data based on latitude



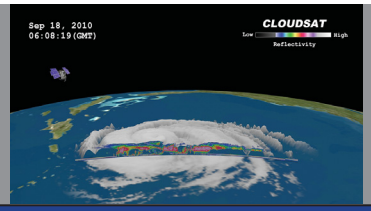


Conclusion



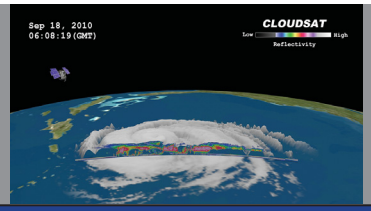
- We have presented methods to rapidly produce visualization and outreach products from CloudSat data for science and the media
- These methods combine data from several sources in the product generation process
- In general, the process can be completely automatic, producing products and notifying potential users

Future Work



- Create a searchable website for animations
- Global coverage of cloud products
  - Merge GOES East and West full disk images to fully wrap the globe
  - Use global cloud coverage data (+-60 degrees)
  - Add another data set (e.g. CALIPSO?, MeteoSat?)
- Render in stereo 3D
- Match CloudSat data height and GOES cloud automatically
- Check missing data in GOES images
- Generate iPad, iPhone version of the movies
- Convert the cloud shape and granules to KMZ

Acknowledgement



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