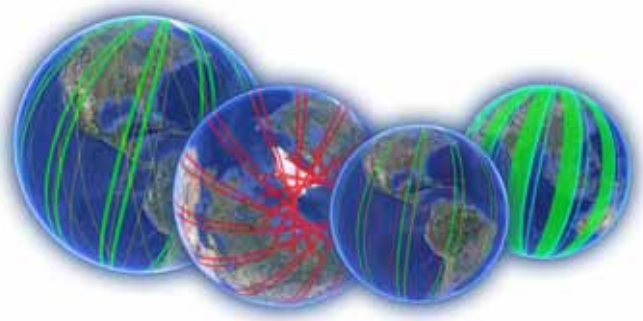
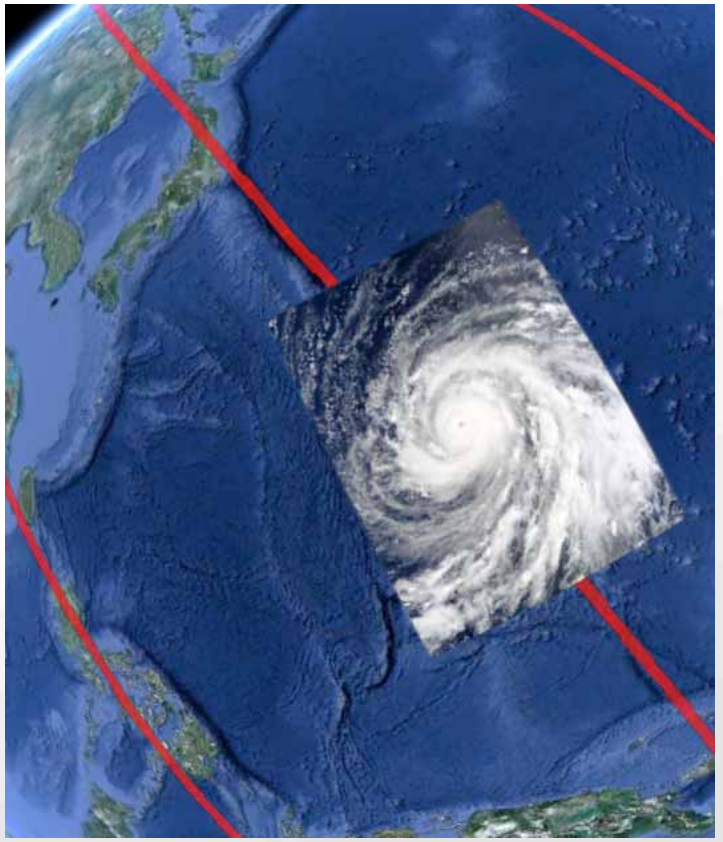
# Systems Engineering Tools and Analyses to support Space Data Acquisition Planning

**SDCG-1 Meeting**
**March 7, 2012**
**Brian Killough, NASA, CEOS SEO**



# Agenda

- What is COVE?
- How can COVE support **near-term** data acquisition planning?
- How can COVE support **long-term** data acquisition planning including systems analyses and optimization of resources?

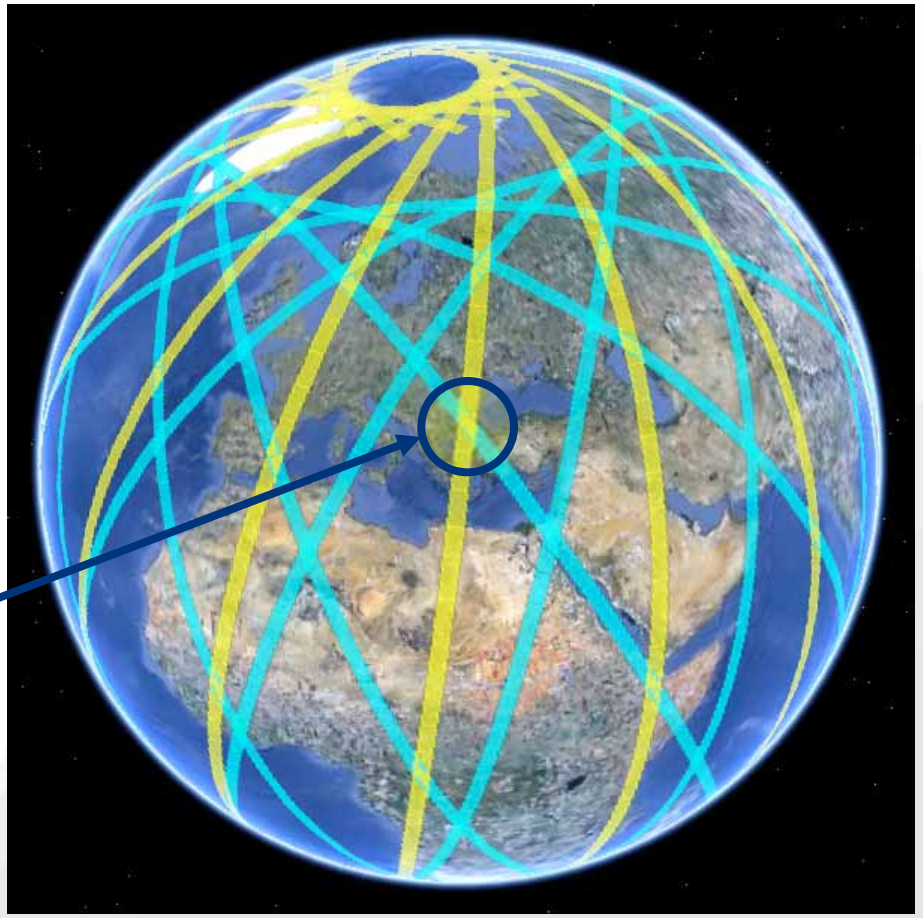


**COVE Example:** CALIPSO track over the eye of Typhoon Choi-wan on September 15, 2009

# What is COVE?

## CEOS Visualization Environment (COVE)

- **Enables** identification and visualization of satellite instrument coverage swaths over the globe
- **Reduces** the time and cost to identify and acquire international space data
- **Enhances** calibration and validation by calculating multi-satellite coincidences
- **Improves** public education of Earth science using a common Google-Earth platform



www.ceos-cove.org

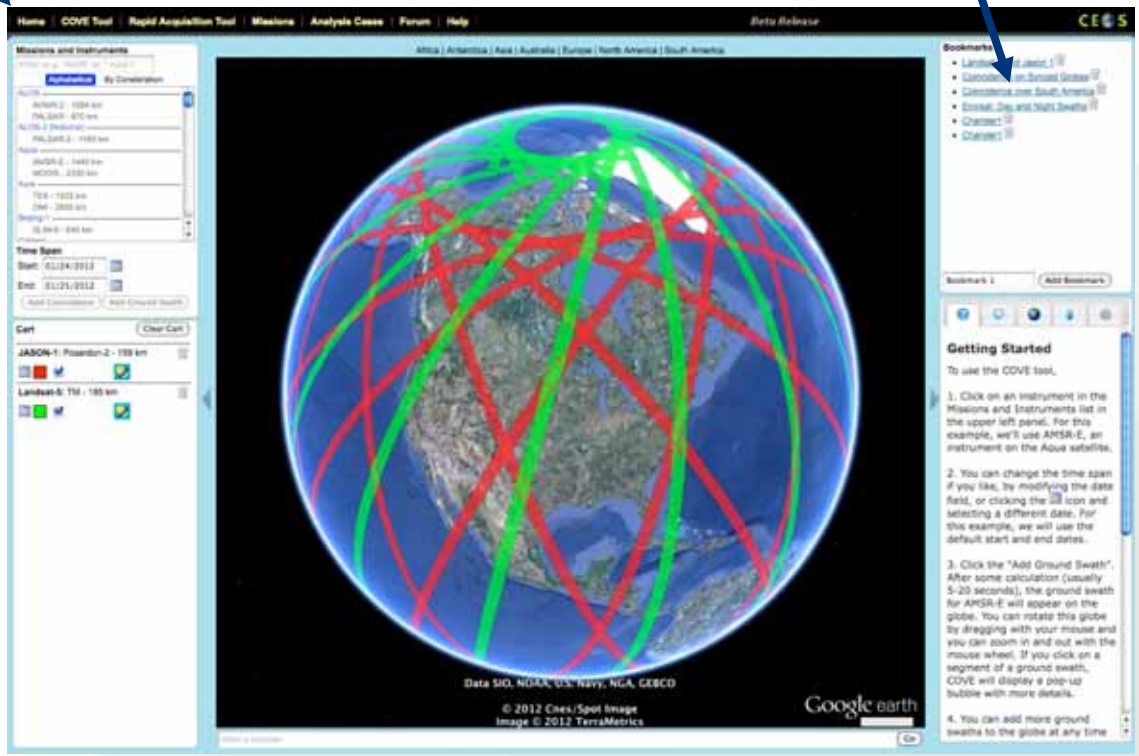
# COVE Features

- Flexible Joomla web design
- Automated daily satellite position data from Analytical Graphics Inc. (AGI) **CelesTrak** database
- Saved bookmarks and states, Keyhole Markup Language (KML) and Shapefile compatibility, collaborative sessions
- **Output**: position, UTC time, viewing angles, solar angles, day/night, and EXCEL tables
- Large mission database: **75** missions

Rapid Acquisition Planning Tool for EXCEL output

User Discussion Forums

Bookmarks and Help Support



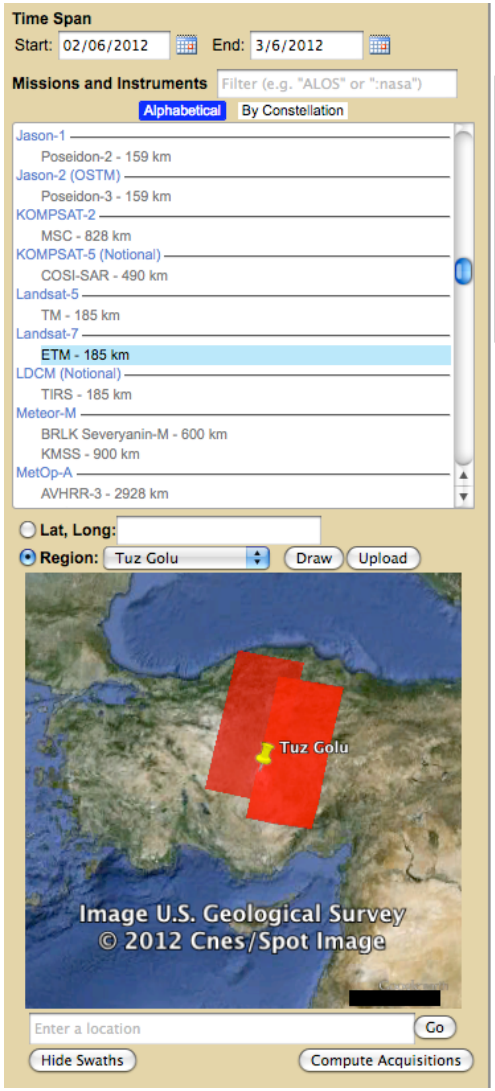

**Did you know ....**

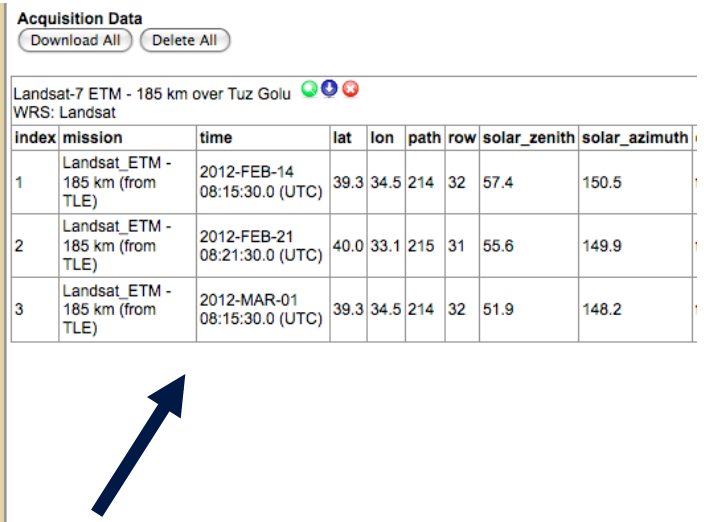
There are **958** Earth orbiting missions

There are **109** CEOS missions

# Rapid Acquisition Tool

- Efficient tool for large time periods to produce tabular output of acquisitions or coincidences.
- Avoids plotting all groundtracks on the globe.
- Output data can be previewed on the globe or output as EXCEL.




| index | mission | time | lat | lon | path | row | solar_zenith | solar_azimuth |
|---|---|---|---|---|---|---|---|---|
| 1 | Landsat_ETM - 185 km (from TLE) | 2012-FEB-14 08:15:30.0 (UTC) | 39.3 | 34.5 | 214 | 32 | 57.4 | 150.5 |
| 2 | Landsat_ETM - 185 km (from TLE) | 2012-FEB-21 08:21:30.0 (UTC) | 40.0 | 33.1 | 215 | 31 | 55.6 | 149.9 |
| 3 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-01 08:15:30.0 (UTC) | 39.3 | 34.5 | 214 | 32 | 51.9 | 148.2 |

**Output table includes ...**
UTC time, Lat, Long, Path, Row, solar angles, viewing angles, day/night, TLE date.

65 current missions
10 future missions

# COVE Mission-Instrument List

- **ALOS**
- Aqua
- Aura
- Beijing-1
- CALIPSO
- **CBERS-2**
- Cloudsat
- **COSMO SkyMed (1 to 4)**
- CryoSat-2
- **Deimos-1**
- **UK-DMC (1 and 2)**
- **Envisat**
- NMP-EO1
- ERS-2
- FengYun-3A (FY-3A)
- GeoEye-1 (commercial)
- GOSAT
- HAIYANG (HY-1B)
- HJ (1A and 1B)
- Ikonos-2 (commercial)
- Jason (1 and 2=OSTM)
- KOMPSAT-2
- **Landsat (5 and 7)**
- Meteor-M N1
- MetOp-A
- Monitor-E
- NigeriaSat-1
- NOAA 15,16,17,18,19
- OceanSat-2
- Proba
- QuickBird-2 – MS (commercial)
- **Radarsat (1 and 2)**
- **RapidEye (5 satellites)**
- **ResourceSat-1 = IRS-P6**
- **ResourceSat-2**
- Resurs-DK-1
- RISAT-2
- SAC-C
- **SAOCOM (1A and 1B)**
- SMOS
- SPOT (4 and 5)
- **TanDEM-X**
- Terra
- **TerraSAR-X**
- THEOS
- Worldview (1 and 2 - commercial)

**Future (Notional)**

- **ALOS-2**
- **CBERS-3**
- HJ-1C
- KOMPSAT-5
- **LDCM (Landsat-8)**
- RISAT-1
- **Sentinel (1A, 2A, 2B)**
- TRUTHS

# Calibration and Validation

- The efforts of the CEOS Working Group on **Calibration and Validation** (Cal-Val) were the initial focus of the COVE tool.
- COVE currently supports two CEOS annual international cal-val campaigns in Turkey and Antarctica
- The need for annual individual satellite forecasts is eliminated and scientists and engineers utilize more satellites and focus on the research.
- **Tuz Golu, Turkey**
  - Dry salt lake with a homogeneous surface
  - Forecasts for 13 missions
- **DOME-C Antarctica**
  - Uniform permanent snow surface
  - Forecasts for 6 missions

# Near-Term Data Acquisition Planning

- COVE is a single tool capable of forecasting near-term past and future data acquisitions for numerous CEOS missions.
- CEOS is utilizing COVE to support multiple GEO projects for Data Acquisition Planning
  - Joint Experiment for Crop Assessment and Monitoring (JECAM) and GEO Global Agriculture Monitoring (GEO-GLAM)
  - Forest Carbon Tracking (FCT) and **Global Forest Observation Initiative (GFOI)**
  - Geohazard Supersites (Earthquakes and Volcanos)
- COVE is definitely relevant to the new Satellite Data Coordination Group (SDCG) and GFOI.
- COVE currently includes ALL data core and desired data sets mentioned in the GFOI Strategy document.


# Near-Term Data Acquisition Planning
## JECAM-Argentina Example

Argentina desired 3 acquisitions per month (Fine QUAD-Pol, 25-km swath, 8-m resolution) to support land-use mapping studies in Feb-2012. The COVE table forecasted 15 potential acquisitions. The 4 shaded cells are the ONLY acquisitions taken by Radarsat-2 during this period.

| Minimum Data Acquisitions Needed per Each Month Listed | | COVE Acquisitions Reported | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Time | Lat | Lon | Path | Row | Solar Zenith | Solar Azimuth | Daytime | Max Viewing Zenith | Min Viewing Zenith | Max Viewing Azimuth | Min Viewing Azimuth | TLE Date |
| 3 | Feb 2012 | 2012-FEB-01 09:05:30.0 (UTC) | -34.40 | -51.90 | 37 | 84 | 87.50 | 109.20 | TRUE | 48.10 | 44.00 | 103.50 | 102.90 | 2012-FEB-01 05:09:22 (UTC) |
| | | 2012-FEB-04 09:18:30.0 (UTC) | -35.80 | -55.50 | 39 | 85 | 87.80 | 108.70 | TRUE | 33.80 | 28.20 | 100.90 | 99.90 | 2012-FEB-04 02:00:17 (UTC) |
| | | 2012-FEB-05 22:45:30.0 (UTC) | -35.40 | -64.90 | 45 | 159 | 83.20 | 255.30 | TRUE | 38.10 | 32.90 | 259.40 | 258.30 | 2012-FEB-05 19:30:48 (UTC) |
| | | 2012-FEB-08 22:57:30.0 (UTC) | -37.50 | -67.40 | 47 | 157 | 83.60 | 256.10 | TRUE | 50.80 | 47.40 | 256.40 | 255.80 | 2012-FEB-09 02:54:08 (UTC) |
| | | 2012-FEB-11 09:13:30.0 (UTC) | -33.00 | -53.60 | 38 | 83 | 89.50 | 106.60 | TRUE | 36.10 | 35.10 | 101.30 | 101.10 | 2012-FEB-11 05:09:26 (UTC) |
| | | 2012-FEB-12 22:41:30.0 (UTC) | -34.70 | -64.00 | 45 | 159 | 84.50 | 257.20 | TRUE | 32.70 | 27.00 | 260.60 | 259.50 | 2012-FEB-12 19:58:05 (UTC) |
| | | 2012-FEB-14 09:26:30.0 (UTC) | -34.50 | -57.20 | 40 | 84 | 89.90 | 106.00 | TRUE | 21.50 | 14.90 | 98.20 | 95.30 | 2012-FEB-14 05:20:24 (UTC) |
| | | 2012-FEB-15 22:53:30.0 (UTC) | -36.80 | -66.60 | 46 | 158 | 85.00 | 258.00 | TRUE | 47.30 | 43.10 | 257.20 | 256.60 | 2012-FEB-16 02:49:52 (UTC) |
| | | 2012-FEB-18 09:09:30.0 (UTC) | -33.80 | -52.80 | 37 | 84 | 90.80 | 104.70 | FALSE | 43.90 | 39.40 | 102.70 | 102.00 | 2012-FEB-18 05:39:25 (UTC) |
| | | 2012-FEB-19 22:37:30.0 (UTC) | -34.00 | -63.20 | 44 | 160 | 85.90 | 259.20 | TRUE | 26.70 | 20.50 | 262.30 | 260.80 | 2012-FEB-19 19:53:24 (UTC) |
| | | 2012-FEB-21 09:22:30.0 (UTC) | -35.20 | -56.30 | 40 | 85 | 91.20 | 104.00 | FALSE | 27.90 | 21.80 | 99.70 | 98.40 | 2012-FEB-21 03:44:54 (UTC) |
| | | 2012-FEB-22 22:49:30.0 (UTC) | -36.10 | -65.70 | 46 | 158 | 86.60 | 259.90 | TRUE | 43.00 | 38.30 | 258.10 | 257.40 | 2012-FEB-22 05:07:51 (UTC) |
| | | 2012-FEB-25 09:05:30.0 (UTC) | -34.40 | -51.90 | 37 | 84 | 92.00 | 102.60 | FALSE | 48.10 | 44.00 | 103.50 | 102.90 | 2012-FEB-22 05:07:51 (UTC) |
| | | 2012-FEB-28 09:18:30.0 (UTC) | -35.80 | -55.50 | 39 | 85 | 92.50 | 101.90 | FALSE | 33.80 | 28.20 | 100.90 | 99.90 | 2012-FEB-22 05:07:51 (UTC) |
| | | 2012-FEB-29 22:45:30.0 (UTC) | -35.40 | -64.90 | 45 | 159 | 88.30 | 261.90 | TRUE | 38.20 | 33.00 | 259.40 | 258.30 | 2012-FEB-22 05:07:51 (UTC) |

Data Acquired

Fortunately, these 4 acquisitions were taken with Fine QUAD-Pol mode. This sparse sampling is very typical of SAR missions ... they do not take data for the entire orbit.

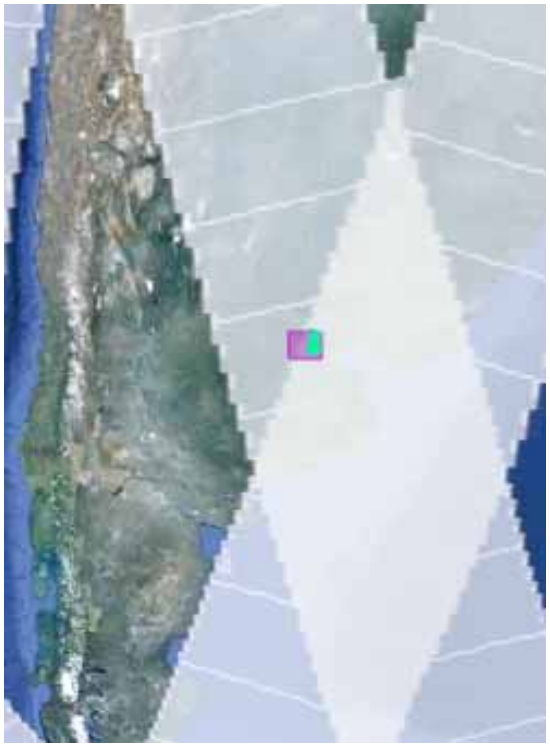
The COVE forecasts were very accurate and within seconds of the actual R-2 acquisitions.

# More JECAM-Argentina …

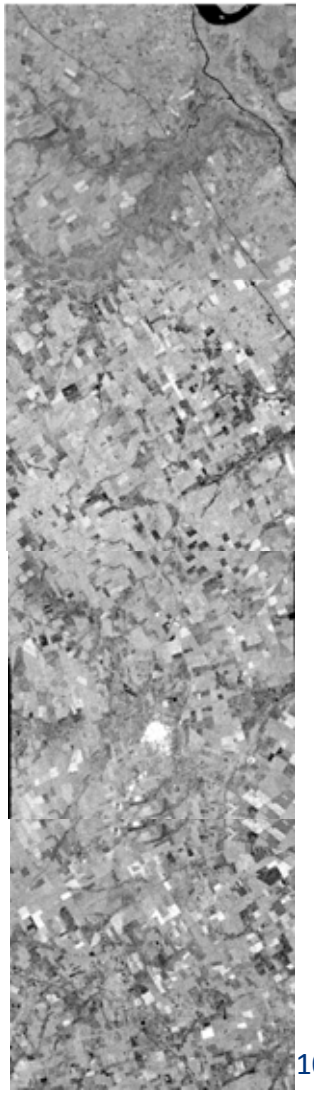
**February 5, 2012, COVE Forecasts and Radarsat-2 Data Acquisitions**

Argentina region shown in PURPLE. Radarsat-2 acquisitions shown in GREEN (25-km, Fine QUAD-POL)

COVE forecasted Radarsat-2 full-swath coverage in WHITE.



Actual Radarsat-2 SAR Imagery from the CCRS Data Tool

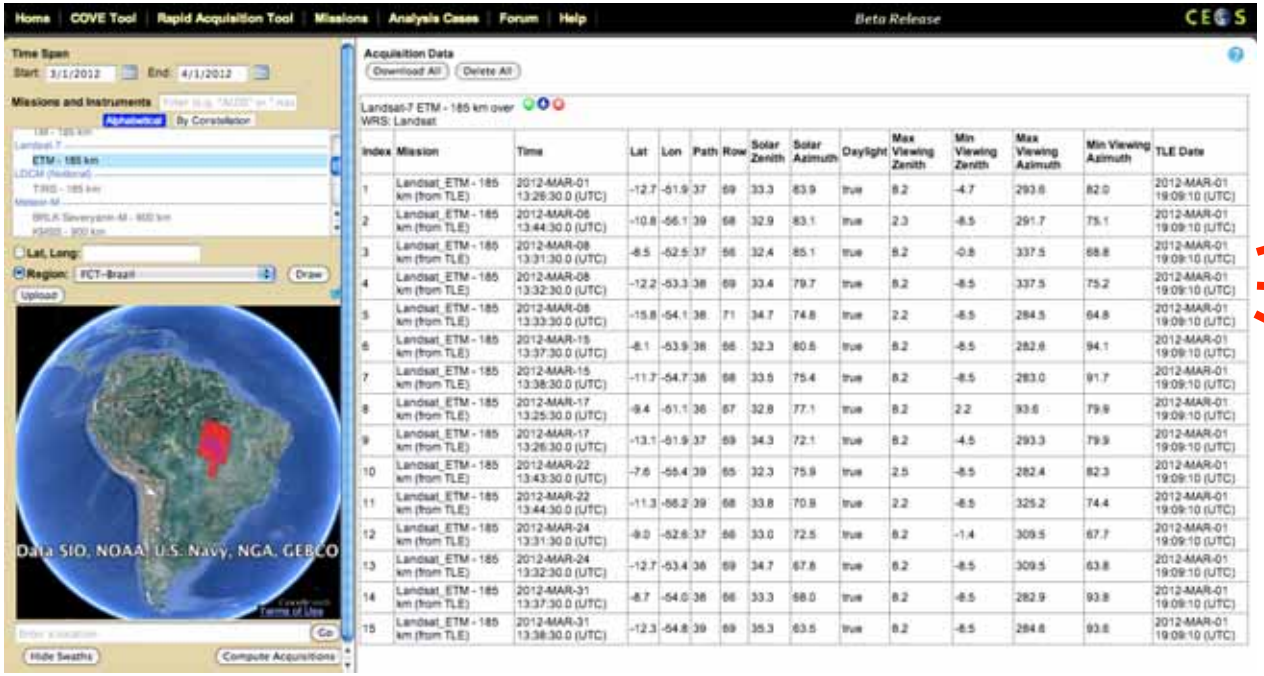


# Long-Term Data Acquisition Planning
## FCT-Brazil Example

**Example**: FCT-Brazil Region, March 2012, Landsat-7 ETM+, Optical Measurements

**Question**: How many cloud-free acquisitions can we expect from Landsat over this region per month?

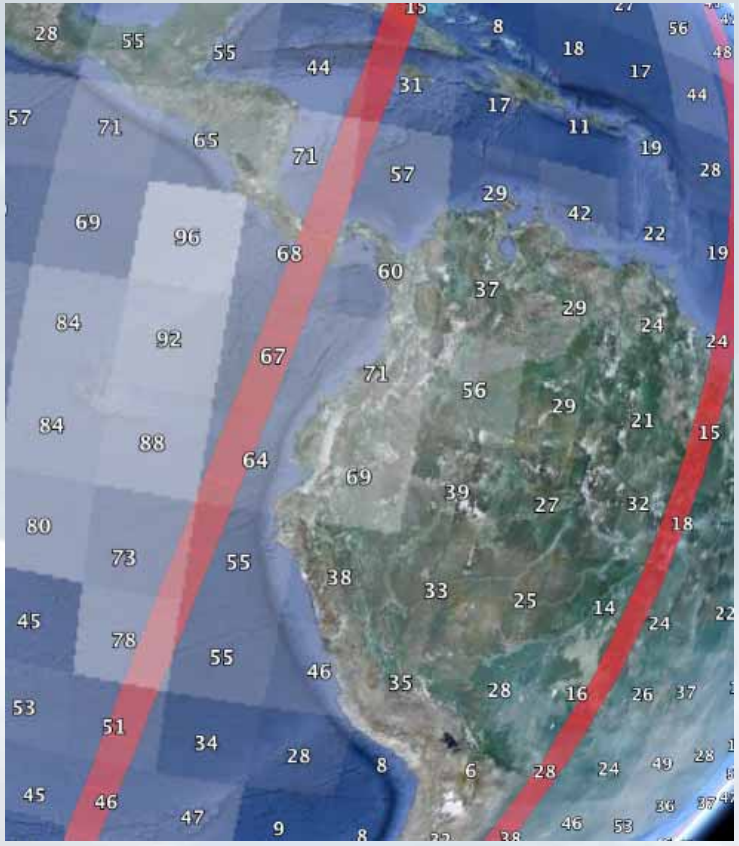
**Solution**: Use the Rapid Acquisition Tool to forecast potential acquisitions. Select the Date Range, Mission-Instrument, FCT-Brazil Region. The results show 15 potential acquisitions, but careful review in the main COVE tool suggests many are "duplicates". There are actually 8 acquisitions per month that cover the entire FCT region. Landsat has 16-day repeat cycle, so future monthly returns will be similar.




| Index | Mission | Time | Lat | Lon | Path | Row | Solar Zenith | Solar Azimuth | Daylight | Max Viewing Zenith | Min Viewing Zenith | Max Viewing Azimuth | Min Viewing Azimuth | TLE Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-01 13:26:30.0 (UTC) | -12.7 | -61.9 | 37 | 69 | 33.3 | 83.9 | true | 8.2 | -4.7 | 293.6 | 82.0 | 2012-MAR-01 19:09:10 (UTC) |
| 2 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-08 13:44:30.0 (UTC) | -10.8 | -56.1 | 39 | 68 | 32.9 | 83.1 | true | 2.3 | -8.5 | 291.7 | 75.1 | 2012-MAR-01 19:09:10 (UTC) |
| 3 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-08 13:31:30.0 (UTC) | -8.5 | -52.5 | 37 | 66 | 32.4 | 85.1 | true | 8.2 | -0.8 | 337.5 | 68.8 | 2012-MAR-01 19:09:10 (UTC) |
| 4 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-08 13:32:30.0 (UTC) | -12.2 | -53.3 | 38 | 69 | 33.4 | 79.7 | true | 8.2 | -8.5 | 337.5 | 75.2 | 2012-MAR-01 19:09:10 (UTC) |
| 5 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-08 13:33:30.0 (UTC) | -15.8 | -54.1 | 38 | 71 | 34.7 | 74.8 | true | 2.2 | -8.5 | 284.5 | 64.8 | 2012-MAR-01 19:09:10 (UTC) |
| 6 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-15 13:37:30.0 (UTC) | -8.1 | -53.9 | 38 | 66 | 32.3 | 80.6 | true | 8.2 | -8.5 | 282.6 | 94.1 | 2012-MAR-01 19:09:10 (UTC) |
| 7 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-15 13:38:30.0 (UTC) | -11.7 | -54.7 | 38 | 68 | 33.5 | 75.4 | true | 8.2 | -8.5 | 283.0 | 91.7 | 2012-MAR-01 19:09:10 (UTC) |
| 8 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-17 13:25:30.0 (UTC) | -9.4 | -51.1 | 36 | 67 | 32.8 | 77.1 | true | 8.2 | 2.2 | 93.6 | 79.9 | 2012-MAR-01 19:09:10 (UTC) |
| 9 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-17 13:26:30.0 (UTC) | -13.1 | -51.9 | 37 | 69 | 34.3 | 72.1 | true | 8.2 | -4.5 | 293.3 | 79.9 | 2012-MAR-01 19:09:10 (UTC) |
| 10 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-22 13:43:30.0 (UTC) | -7.6 | -55.4 | 39 | 65 | 32.3 | 75.8 | true | 2.5 | -8.5 | 282.4 | 82.3 | 2012-MAR-01 19:09:10 (UTC) |
| 11 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-22 13:44:30.0 (UTC) | -11.3 | -56.2 | 39 | 68 | 33.8 | 70.8 | true | 2.2 | -8.5 | 325.2 | 74.4 | 2012-MAR-01 19:09:10 (UTC) |
| 12 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-24 13:31:30.0 (UTC) | -9.0 | -52.6 | 37 | 66 | 33.0 | 72.5 | true | 8.2 | -1.4 | 309.5 | 67.7 | 2012-MAR-01 19:09:10 (UTC) |
| 13 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-24 13:32:30.0 (UTC) | -12.7 | -53.4 | 38 | 69 | 34.7 | 67.8 | true | 8.2 | -8.5 | 309.5 | 63.8 | 2012-MAR-01 19:09:10 (UTC) |
| 14 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-31 13:37:30.0 (UTC) | -8.7 | -54.0 | 38 | 66 | 33.3 | 68.0 | true | 8.2 | -8.5 | 282.9 | 93.8 | 2012-MAR-01 19:09:10 (UTC) |
| 15 | Landsat_ETM - 185 km (from TLE) | 2012-MAR-31 13:38:30.0 (UTC) | -12.3 | -54.8 | 39 | 69 | 35.3 | 63.5 | true | 8.2 | -8.5 | 284.8 | 93.8 | 2012-MAR-01 19:09:10 (UTC) |

# What about Cloud Cover?

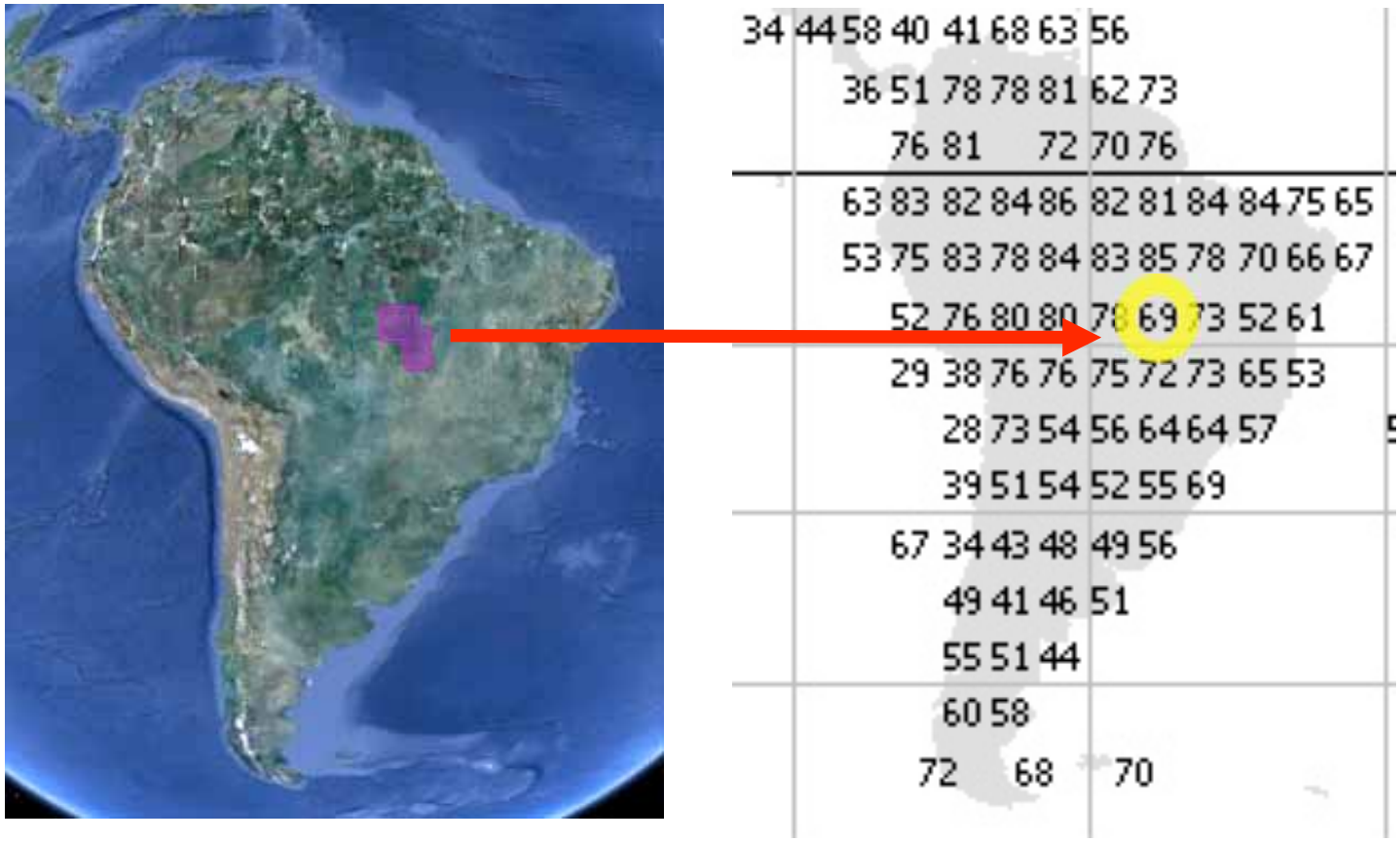
- Clouds have a significant impact on data acquisition planning for optical instrumentation.
- The COVE team plans to add cloud data to the tool for improved planning.
- Two datasets are under consideration ...
  **University of Washington** (25 yrs, 550-km spacing, 2x per day, ground-based) and the International Satellite Cloud Climatology Program (**ISCCP**):
  30 yrs, 280-km spacing, 8x per day, satellite-based.
- COVE would have a dedicated link for cloud overlays to assess the average cloud coverage at a given location and time. EXAMPLE on the right.



Notional Data

# Cloud Cover over FCT-Brazil

Using the “coarse” University of Washington Cloud Cover dataset, the average daytime cloud cover over the FCT-Brazil region is **69%**. This is quite high and will significantly impact the probability of acquiring cloud-free optical imagery.

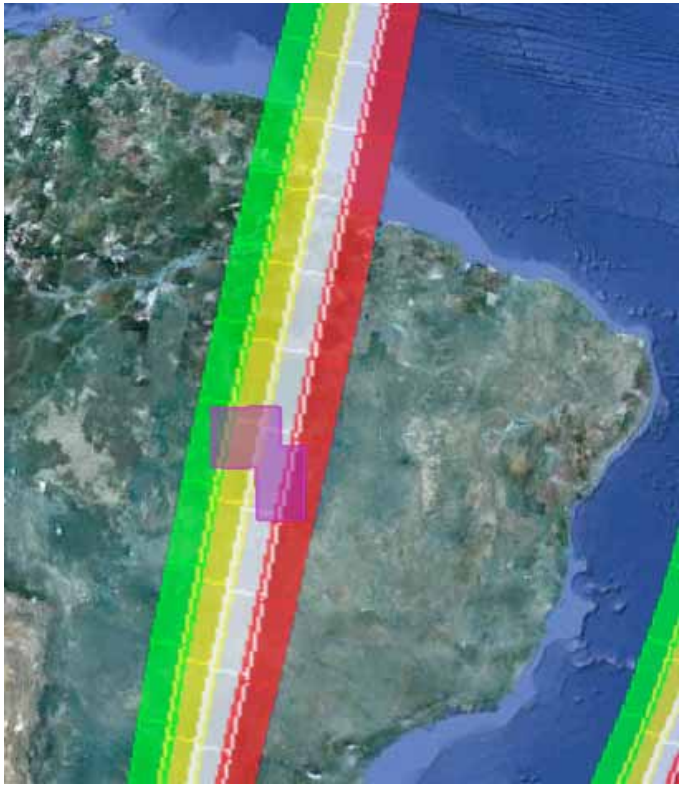


| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 34 | 44 | 58 | 40 | 41 | 68 | 63 | 56 | | | | |
| | | 36 | 51 | 78 | 78 | 81 | 62 | 73 | | | |
| | | | 76 | 81 | | 72 | 70 | 76 | | | |
| | | 63 | 83 | 82 | 84 | 86 | 82 | 81 | 84 | 84 | 75 | 65 |
| | | 53 | 75 | 83 | 78 | 84 | 83 | 85 | 78 | 70 | 66 | 67 |
| | | | 52 | 76 | 80 | 80 | 78 | 69 | 73 | 52 | 61 | |
| | | | 29 | 38 | 76 | 76 | 75 | 72 | 73 | 65 | 53 | |
| | | | | 28 | 73 | 54 | 56 | 64 | 64 | 57 | | |
| | | | | 39 | 51 | 54 | 52 | 55 | 69 | | | |
| | | | 67 | 34 | 43 | 48 | 49 | 56 | | | | |
| | | | | 49 | 41 | 46 | 51 | | | | | |
| | | | | 55 | 51 | 44 | | | | | | |
| | | | | 60 | 58 | | | | | | | |
| | | | 72 | | 68 | | 70 | | | | | |

# Systems Analysis

**Coverage:** It takes 4 swaths to cover the entire Brazil FCT region. COVE forecasts 8 potential acquisitions per month. So, we cover this entire region 2 times per month ... on average. This corresponds to the 16-day Landsat-7 repeat cycle.

**Clouds**: 69% average cloud cover (Univ of Washington) on previous chart. Probability of a cloud-free scene is then 31% per pass.



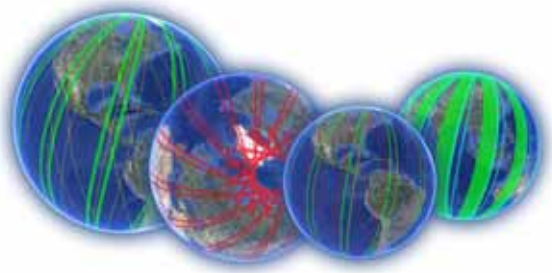
## Conclusions

**Long-term Data Assessment**: How often can we obtain coverage of the entire region including clouds? It will take an average of 3.2 repeat cycles (51 days) to obtain a full cloud-free image of the FCT-Brazil area.

If monthly coverage is desired, it will not be possible with Landsat alone. We need at least one more mission with a different orbit crossing time or repeat cycle.

# Conclusions and Thoughts

- The Space Data Coordination Group (SDCG) is very important to the long term goals of CEOS ... For example, utilization and optimization of space assets.
- COVE and its many features can definitely help the SDCG. GFOI data users will need to be trained on its use in the future to generate their own forecasts and assessments.
- There is much to consider when performing data acquisition planning in the near-term and the long-term. For example ...
  - What are the **data policy** restrictions (access and distribution)?
  - What are the specific **measurement requirements** (optical and SAR) for each GFOI region (all levels), including spatial resolution, frequency, and modes?
- The **Good News** ... A systematic data acquisition plan, meeting the GFOI requirements, and optimizing the CEOS space assets, is possible !!!



THANKS !

# COVE Demonstration: YouTube Video

**You-Tube**: Search for "**CEOS Visualization**"