

# **Landsat's Long-Term Acquisition Plan**

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# Science Goals

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- **Vegetation phenology and condition**
- **Land use and land cover change**
  - **Natural succession**
  - **Anthropologic change: Infrastructure, urbanization, agriculture,...**
- **Fire**
- **Water**
- **Snow/ice**

# Phenological goals

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- **Vegetation peaks capture long-term trends of vegetation condition**
- **Slopes capture transitions for the discrimination/classification of land cover types and events**
- **Seasonal curves capture annual vegetation condition and succession**

# Information available to guide acquisitions

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- **Seasonality files segment the year to guide when acquisitions are needed based on phenology and thematic niches**
- **Cloud predictions are used to avoid acquisitions of “relatively” cloudy data**
- **Cloud climatology provides a baseline to quantify “relatively” cloudy data**
- **Automatic Cloud Cover Assessments of acquisitions provide feedback to establish successful acquisitions (less than 10% cloud cover)**
- **Track most recent successful acquisitions - missed opportunity boost**
- **Campaigns and Special Requests including calibration and emergency night requests**

# The next generation LTAP

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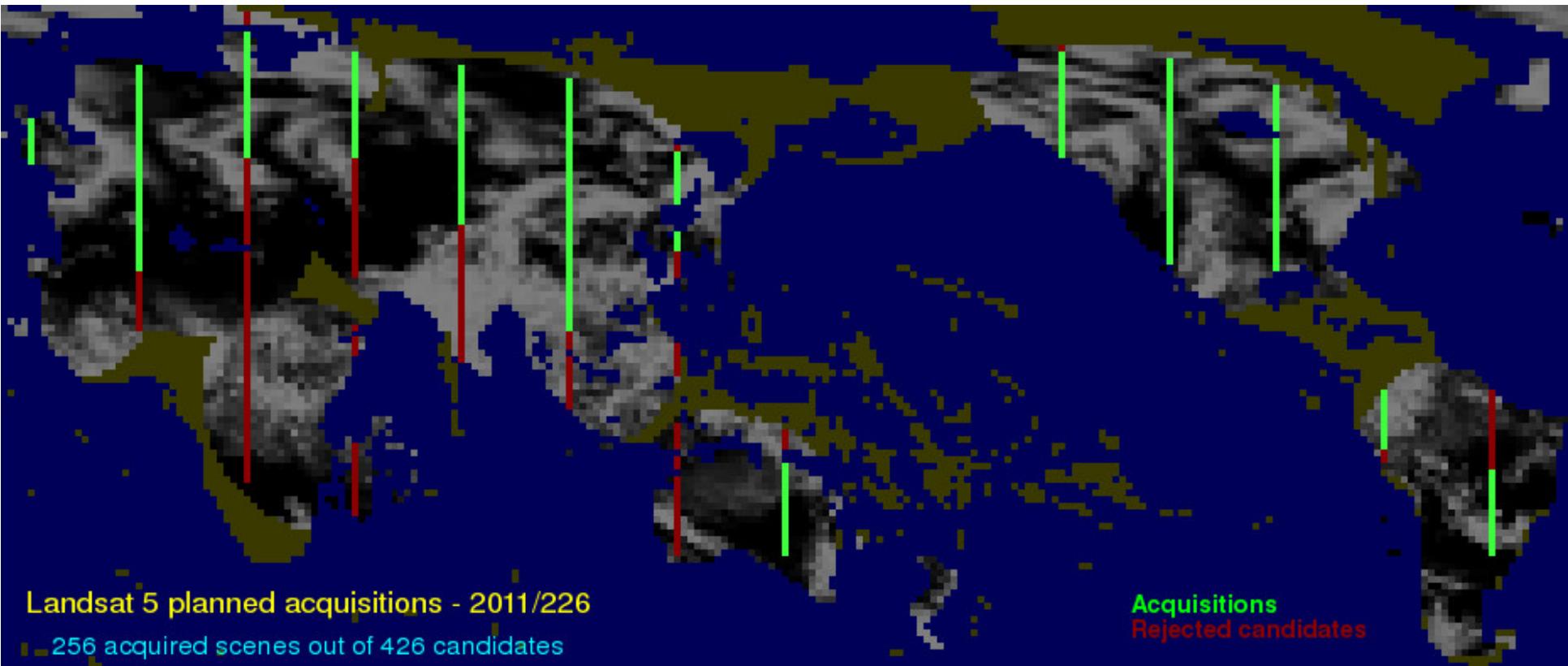
- **Why are we changing the LTAP?**
  - ◆ No direct measurement of phenology – The seasonality file is discrete and intertwines phenology and standing campaigns
  - ◆ MODIS cloud fraction data are available for derivation of cloud climatology, cloud prediction confidence, and as a universal estimate of ACCA for modeling
  - ◆ Work with LTAP science team to evaluate strategy
- **Why are we pursuing an LTAP-5 as opposed to LTAP-7?**
  - ◆ Initial implementation primarily driven by satellite constraints and cloud avoidance
  - ◆ ACCA scores are available through LGAC for many stations
  - ◆ Opportunity to leverage research conducted for Landsat 7 to improve scheduling for Landsat 5
  - ◆ Provides convenient test bed for new strategy for future implementation for Landsat 7

# Landsat 5 scheduler constraints

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- **Acquire 280/day northern summer**
- **Direct reception: seasonal stations**
- **Data download transmitter (TWTA)**
- **Power management**
- **Interval-based models: over-sample middle and under-sample end of paths**
- **Acquire on every path: the TWTA likes steady work**
- **Interval length: avoid long intervals**
- **Some dual-intervals orbits can be supported**
- **Sun angle**
- **Calibration sites**

# Landsat 5 – one 16-day cycle



Day of year 210-225

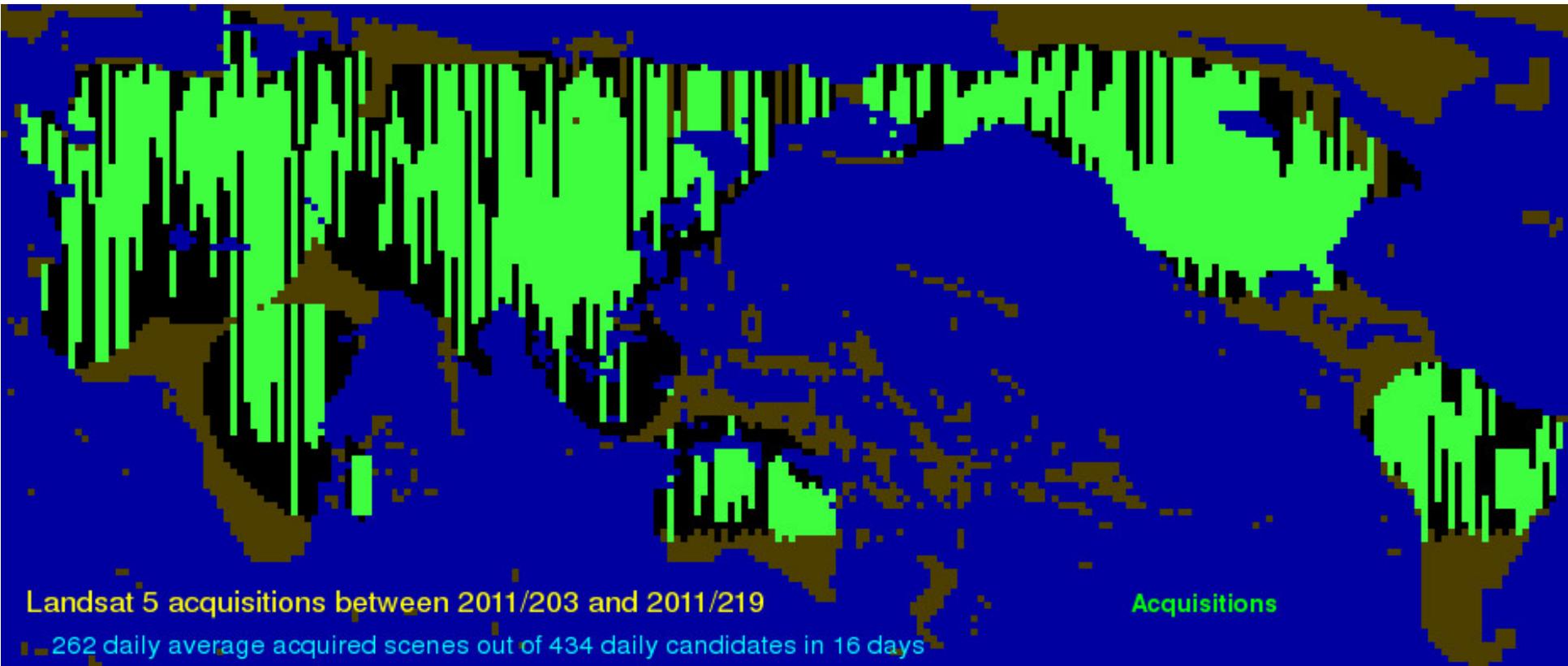
Cloud prediction data clipped to active station masks

Southern sun elevation constraint

Number of scenes scheduled scenes listed

# Landsat 5 - 16-day cycles

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Active station masks  
Sun angle cutoff

# Current Landsat 5 Scheduler evolution

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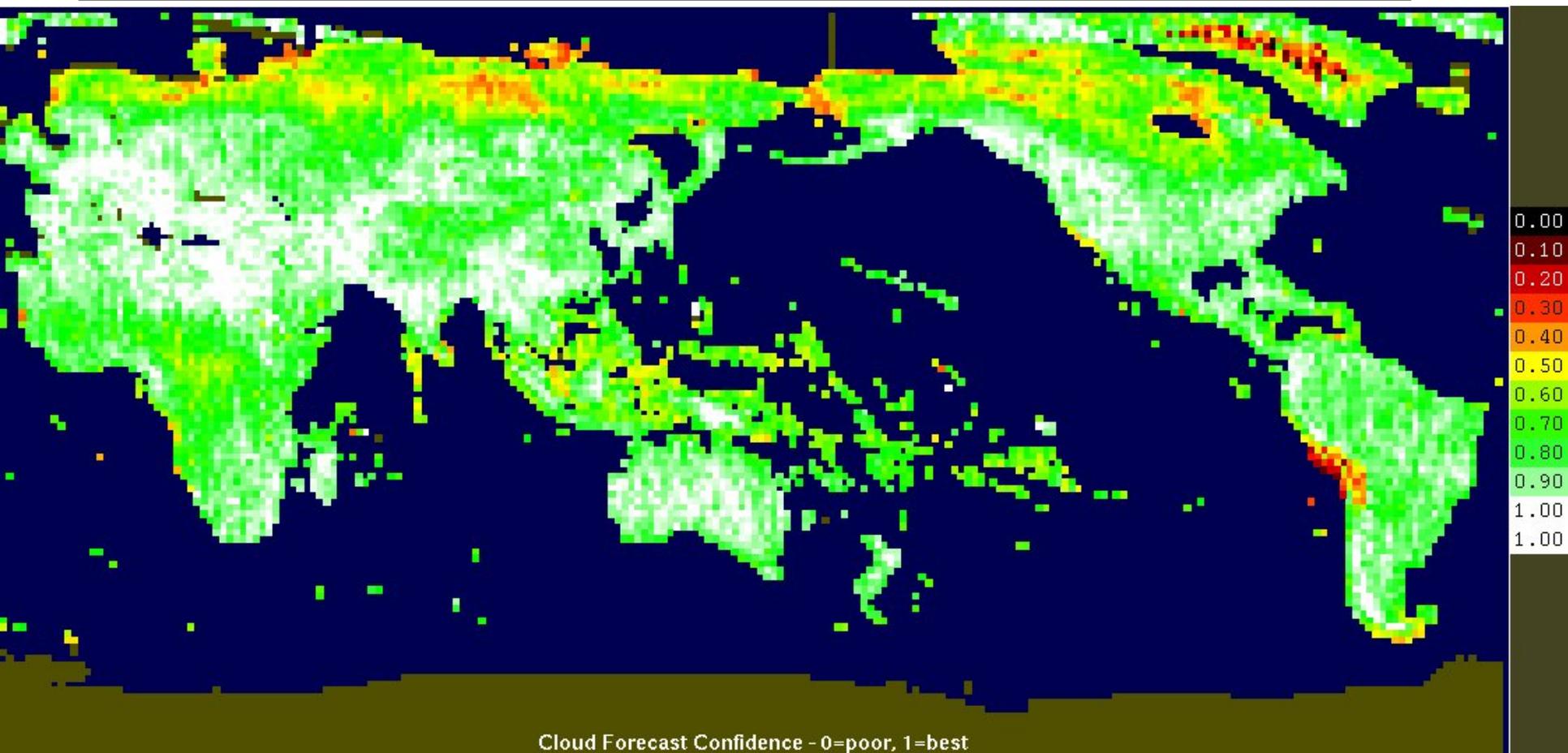
- **Explore potential advantages of adding the following environmental factors to the scene selection strategy**
  - ◆ NDVI – a direct measurement of phenology to effectively replace the phenology information currently provided for Landsat 7 in the seasonality file
  - ◆ ACCA Feedback – not currently available for Landsat 5. The LGAC project and closer partnerships and better connectivity with ICS provide new opportunity
  - ◆ NCEP cloud forecast confidence – new tool that provides an opportunity to control the influence of predictions on acquisitions.
- **New campaign manager**
  - ◆ Implement thematic niches currently in seasonality file using campaigns
  - ◆ Continue to support user campaigns and special requests

# Enhancing Cloud Avoidance

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- **Use daily NCEP cloud forecast (existing capability)**
  - ◆ NCEP GFS 0600z data set
- **Consider *confidence* of NCEP forecast**
  - ◆ Assessment of historical NCEP cloud forecast correlation with *cloud truth*
    - Reasonable facsimile of *cloud truth* derived from Terra/MODIS Cloud Fraction data
  - ◆ Formulate a static lookup table of cloud forecast confidence
    - indexed spatially, by WRS scene
- **Consider *regional bias***
  - ◆ Difference between NCEP forecasts and climatology
  - ◆ Formulate a static lookup table of cloud forecast regional bias
    - indexed spatially, by WRS scene
- **Factor in *confidence* and *regional bias correction* into the cloud avoidance priority expression**

# Map of Cloud Forecast Confidence



Temperate regions yield the best cloud forecast confidence, where the NCEP cloud forecast is historically most reliable. Confidence trails off on the Tropic and Boreal regions.

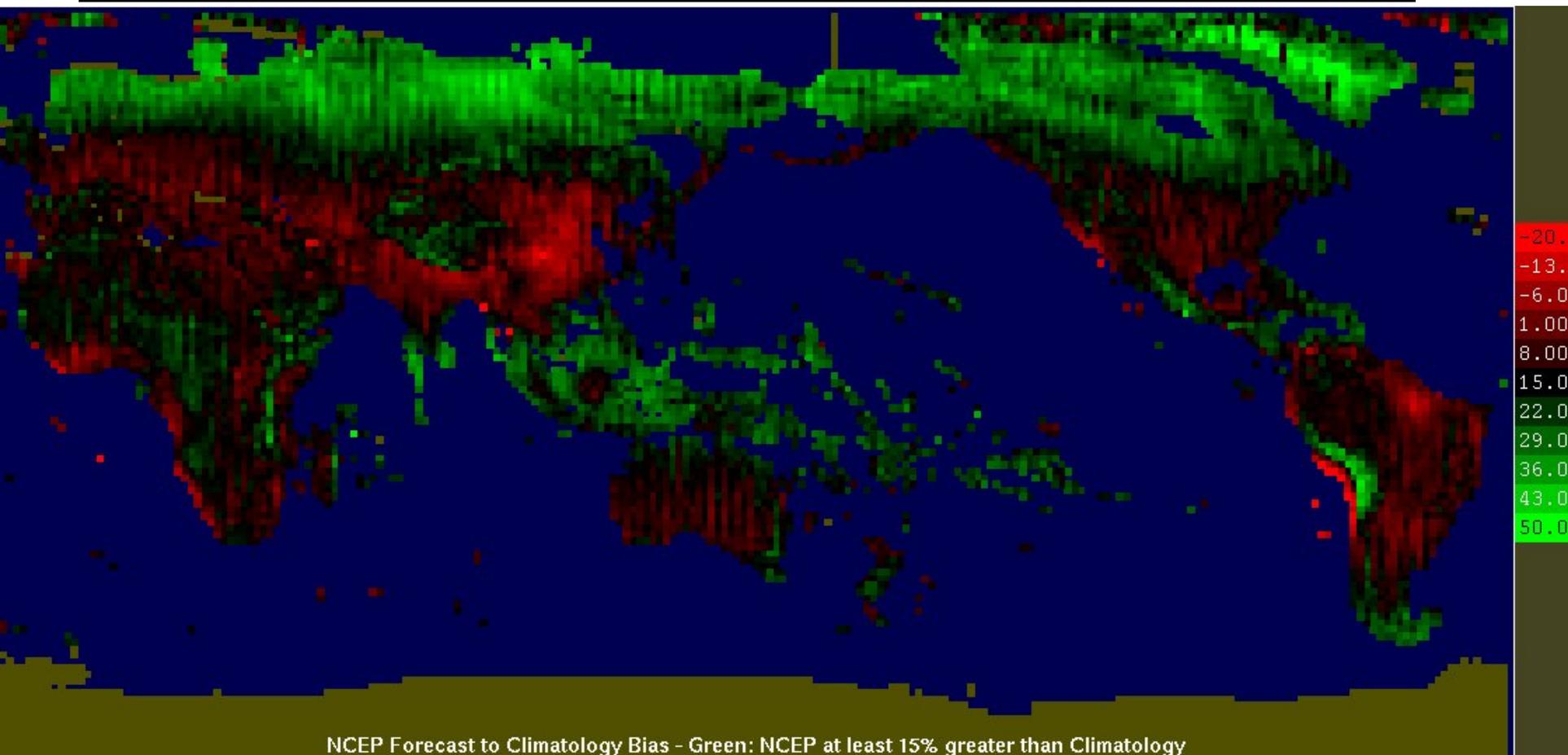
# Cloud Forecast Climatology

## Regional Bias

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- The existing cloud avoidance priority factor is based on the daily NCEP cloud forecast versus the climatology (seasonal nominal cloud cover).
- In general, NCEP cloud forecasts tend to be 15% greater than the MODIS derived climatology.
- Bias has regional variability, as shown in the map that follows.
- Implementation plan
  - ◆ Capture regional bias into a lookup table indexed by WRS scene.
  - ◆ Factor regional bias into cloud avoidance strategy.

# Normalized Cloud Forecast Climatology Regional Bias



Average global NCEP cloud forecasts tend to be 15% greater than the climatology data. This map reveals the regions and degree of disagreement between forecasts and climatology

# Factoring in ACCA feedback

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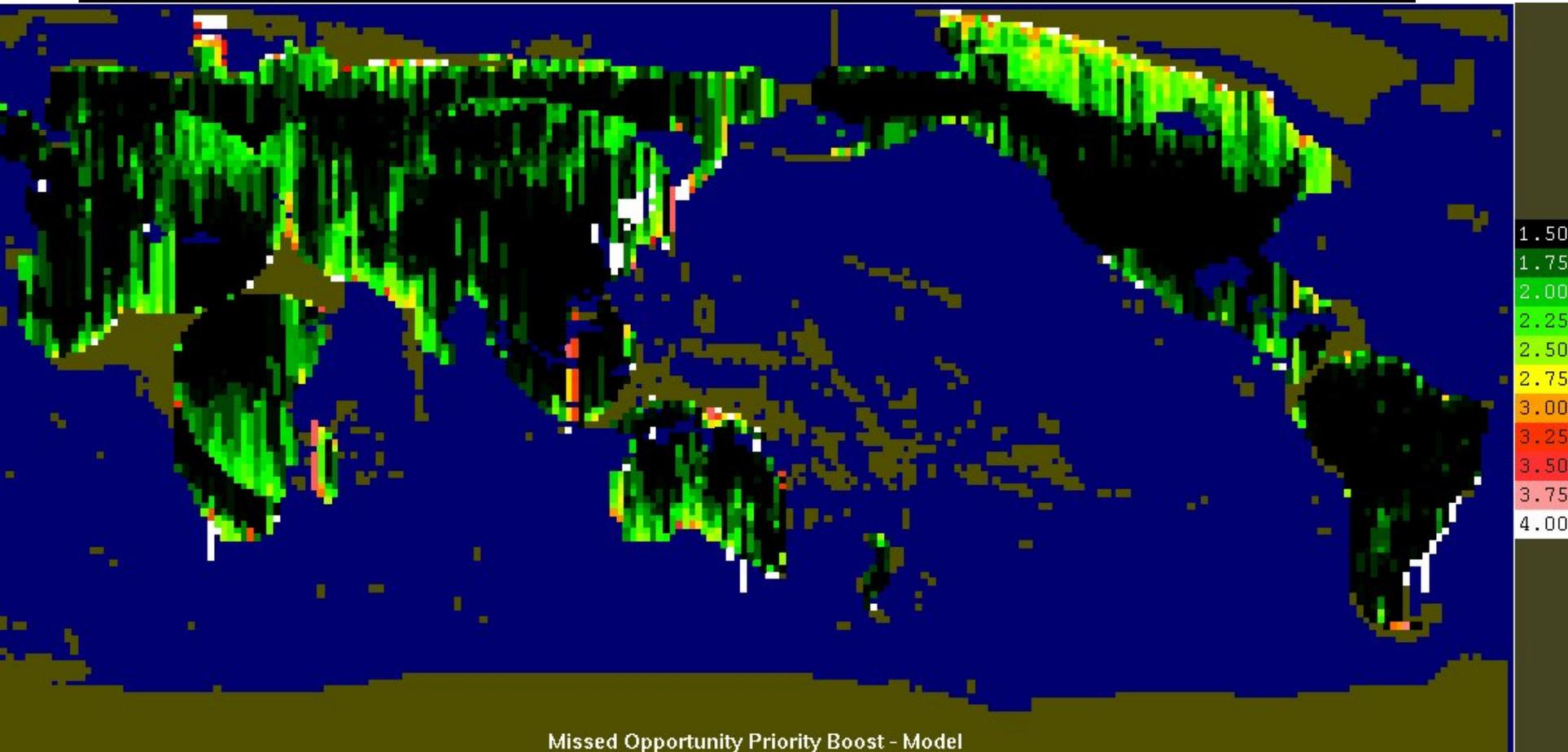
- ACCA feedback will be factored into *Missed Opportunities* priority expression for scene selection.
- Different algorithm than Landsat 7
  - ◆ ACCA available only for scenes delivered by ICs to EROS.
  - ◆ Not all ICS provide data to EROS quickly.
  - ◆ Absence of past ACCA to be interpreted as *success*.

# Missed Opportunity Priority Boost

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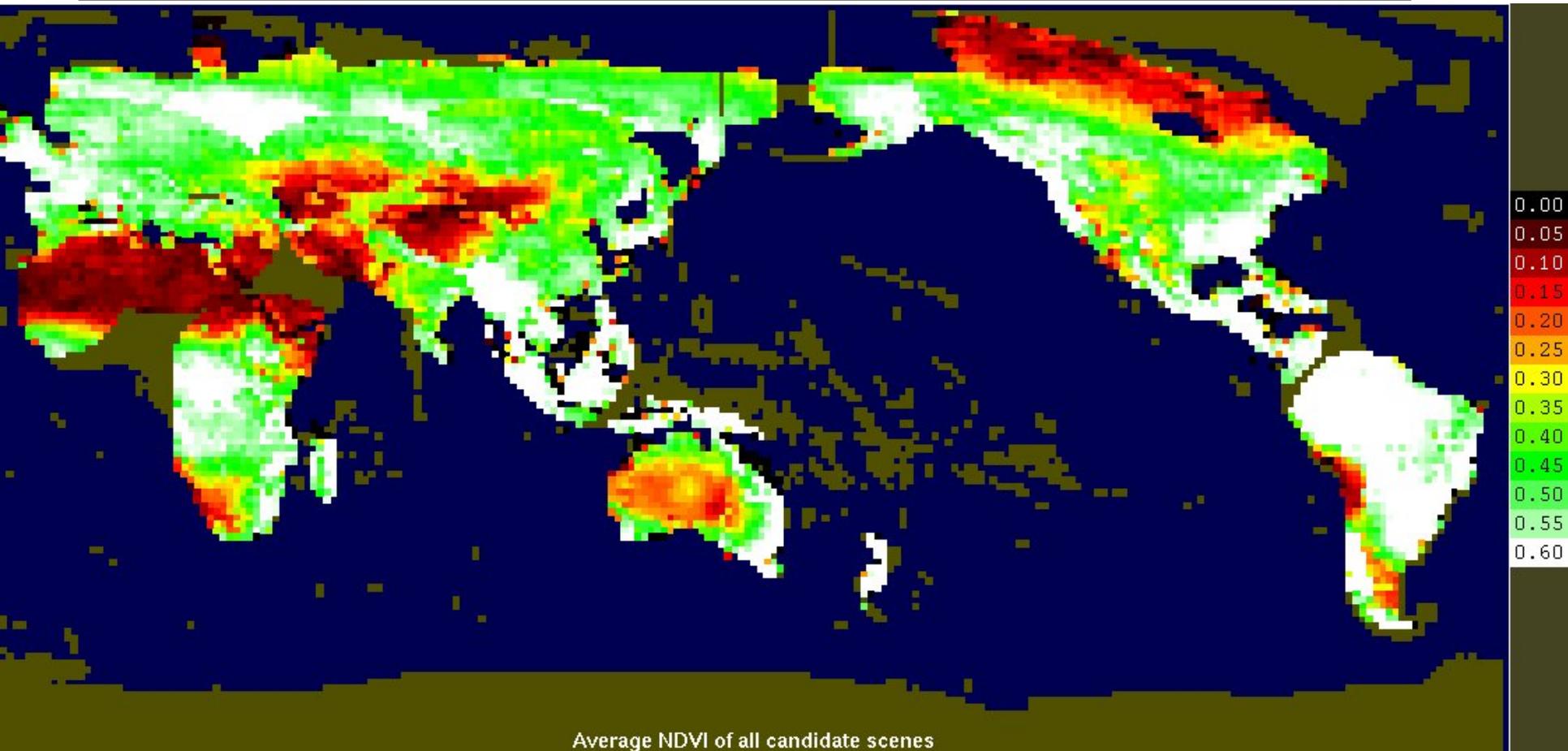
- **Effective number of cycles since last successful acquisition of a specific WRS scene.**
  - ◆ Successful acquisition resets *MissedOpportunities* to 1.
    - Success: when no ACCA available for most recent acquisition
    - Success: when most recent acquisition has  $ACCA \leq 10$
  - ◆ Partially successful acquisition rules
    - Most recent acquisition has ACCA between *SuccessThreshold* (10) and *FailureThreshold* (60)
    - *MissedOpportunities* set as a linear function of ACCA  
MissedOpportunities :=  
$$\frac{\text{DaysBetween}(\text{date}_{\text{current}}, \text{date}_{\text{last\_acquisition}}) / 16 * (\text{ACCA}_{\text{last\_acquisition}} - \text{SuccessThreshold})}{(\text{FailureThreshold} - \text{SuccessThreshold})}$$
  - ◆ MissedOpportunities domain clamped to range [1 .. 4]

# Missed Opportunity Priority Boost - Model



*Missed Opportunities* is number of cycles since last acquisition of a clear scene. Value is limited to no more than 4. Values between 1 and 2.5 are considered healthy. This is not applicable to *Baseline* scenario because this is a new feature. Yellow, Red and White scenes are those in consistent distress.

# Contribution of NDVI toward Priority



Visualization of NDVI of *all candidate scenes*.



# Acquisition criteria: Rules of thumb

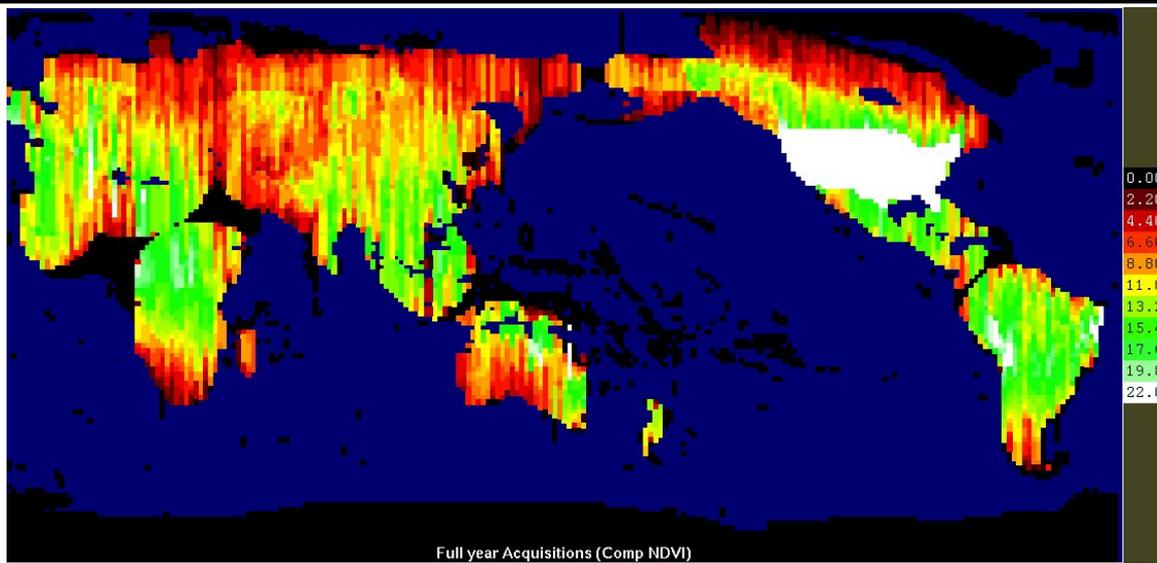
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- **Sample areas of consistently high NDVI to capture vegetation variability and change**
  - ◆ 8-10 clear to moderate (<60% ACCA) scenes evenly distributed
- **Sample areas of consistently low (desert/tundra) NDVI**
  - ◆ 2-3 clear scenes evenly distributed
- **Sample areas with well-defined seasonal curves**
  - ◆ 5-10 clear to moderate scenes in proportion to NDVI

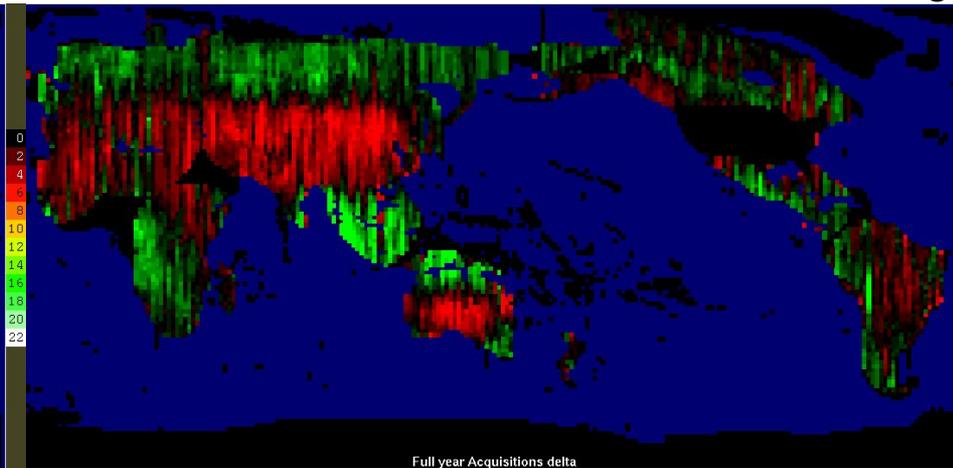
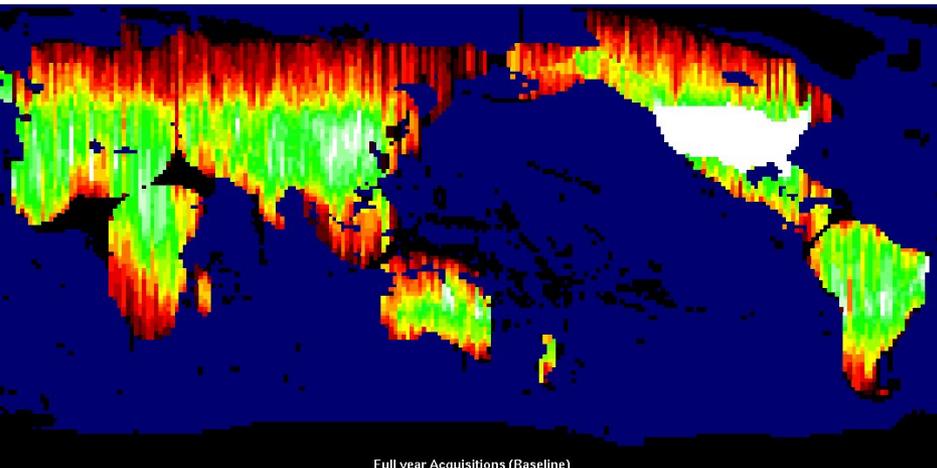
# Annual Acquisitions

Global coverage density of acquisitions over the course of the one-year model scenario. White scenes are those acquired every opportunity.

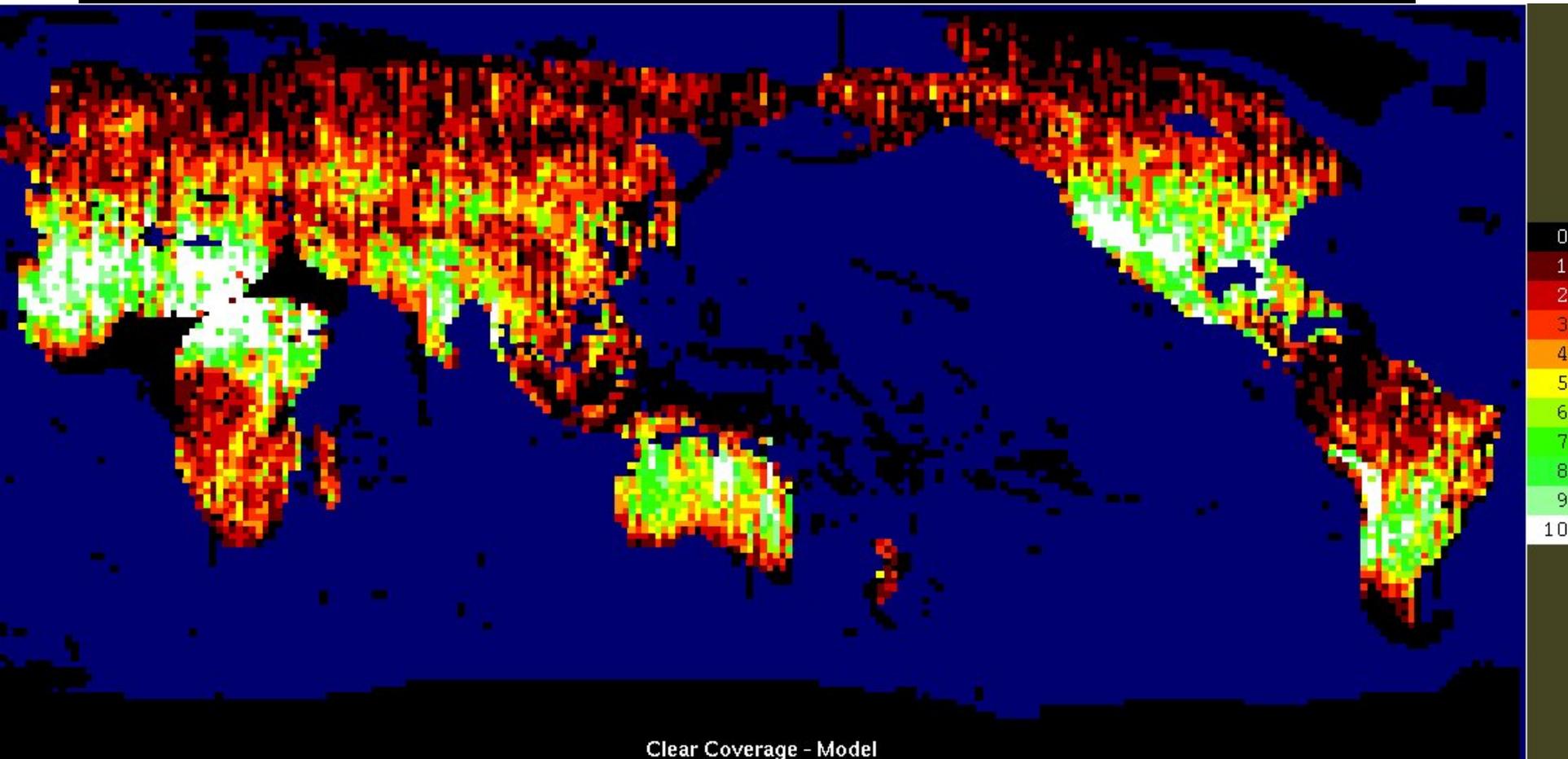
Baseline Scenario



Difference image

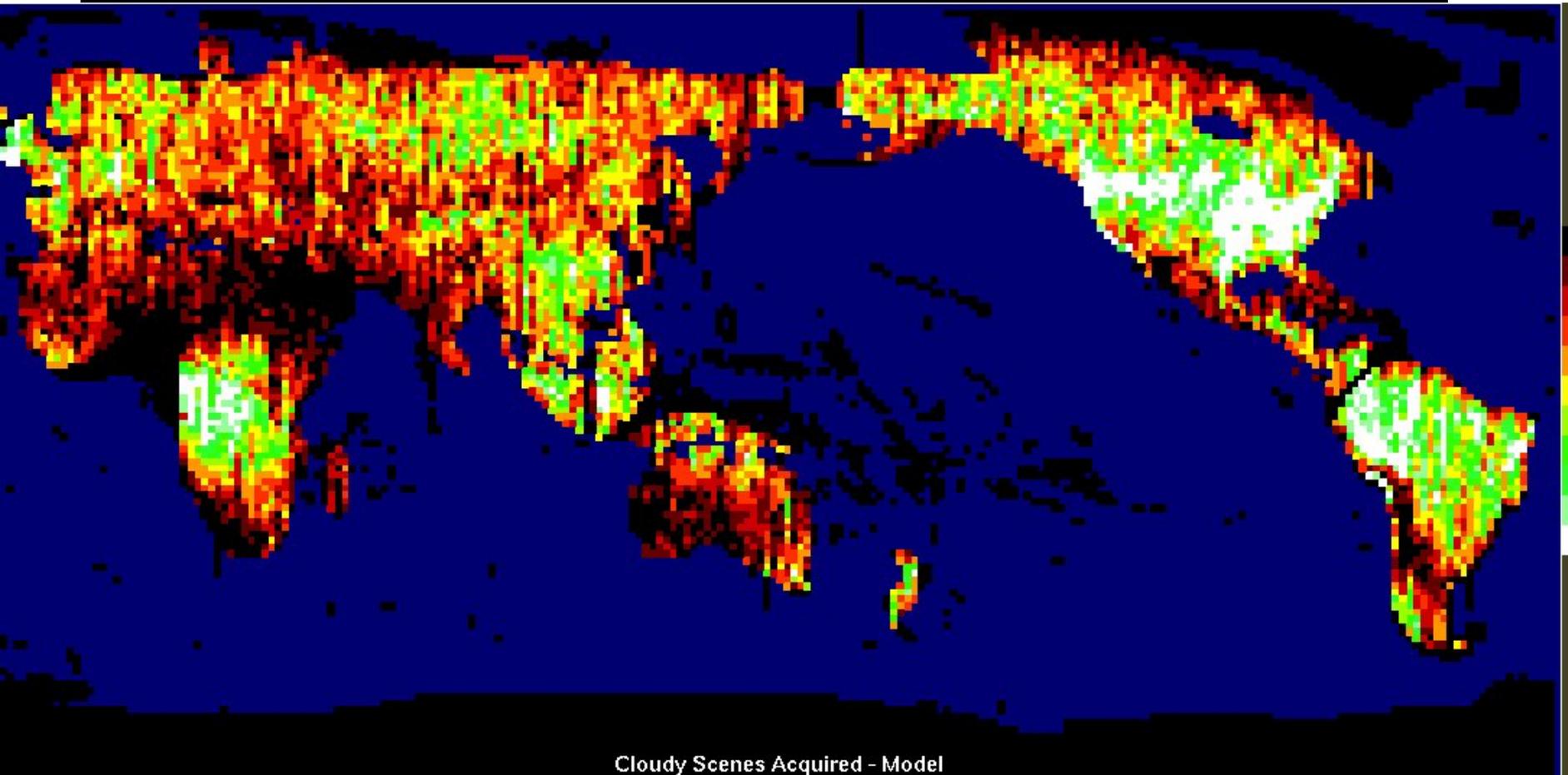


# Density of Clear Acquisitions - Model



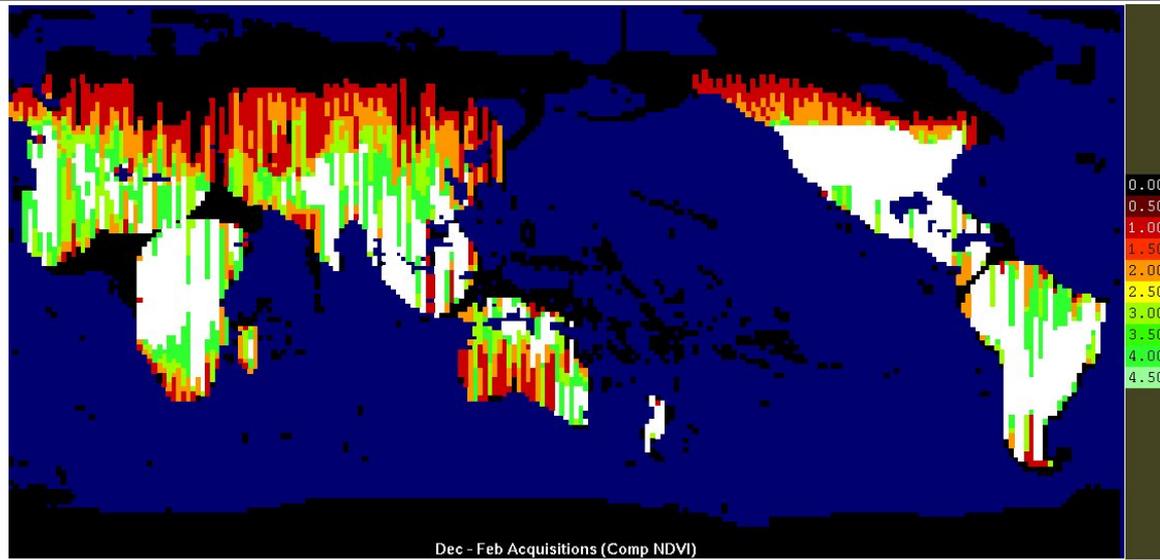
This is a success-metric of the performance of the new scene selection strategy. White scenes are those where 10 or more images with simulated ACCA  $\leq 10$ .

# Acquired Scenes that were Cloudy - Model



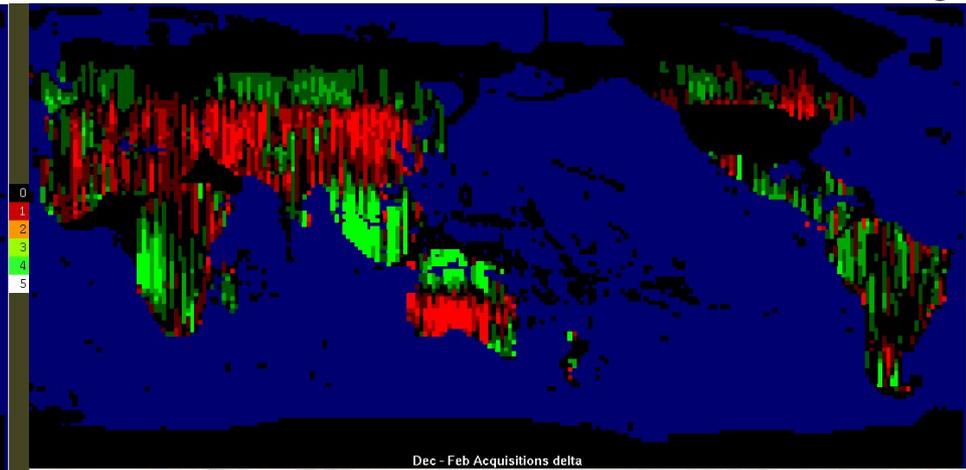
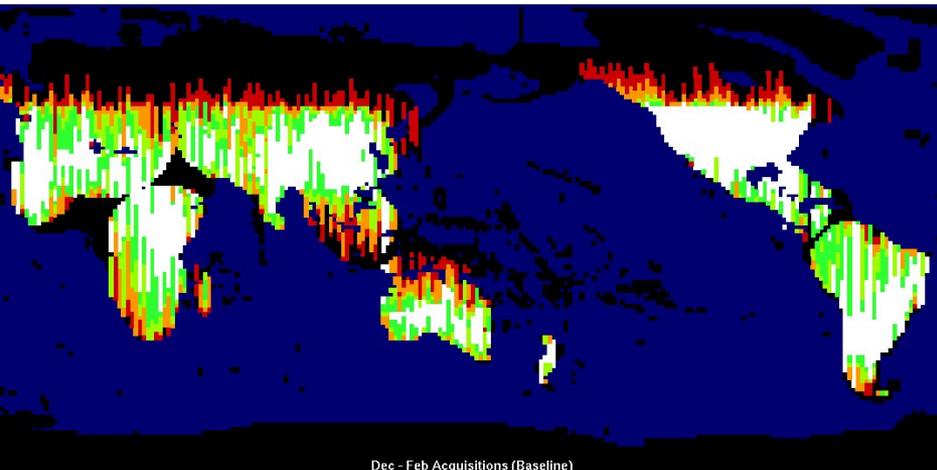
Scenes acquired by the model that were cloudy (ACCA > 60)  
White = 10 or more cloudy scenes acquired over the year.

# Dec-Feb Acquisitions

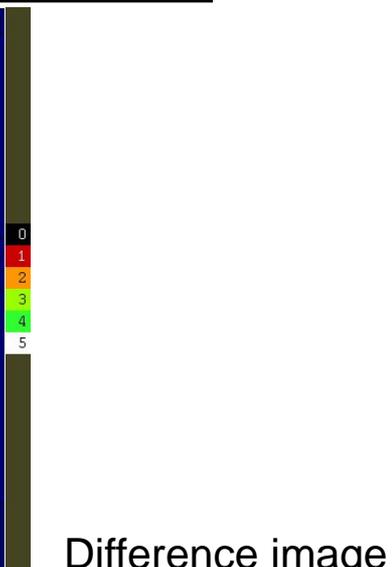
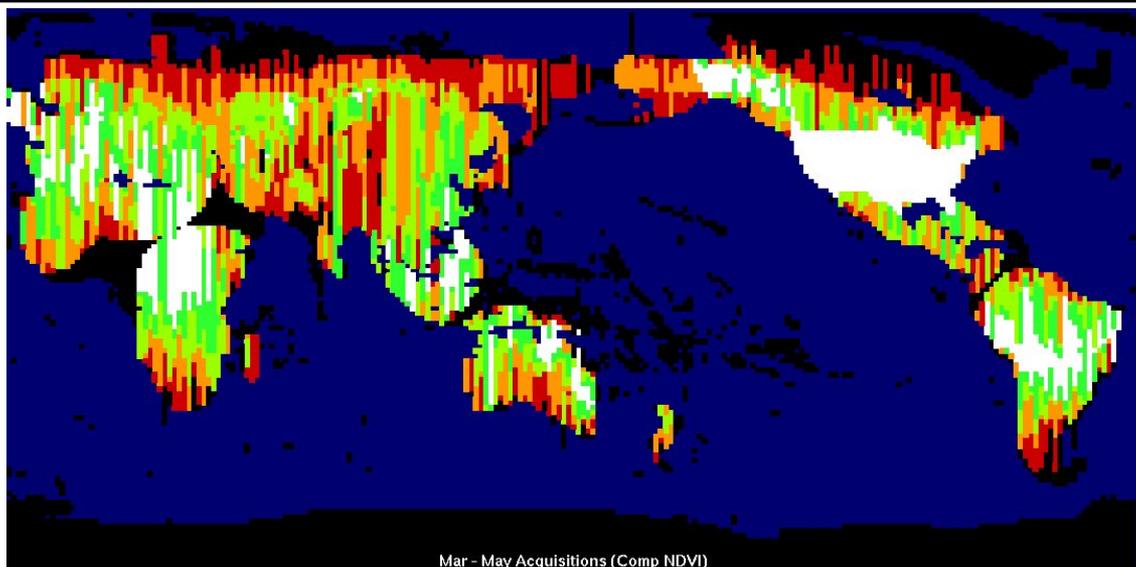


Difference image

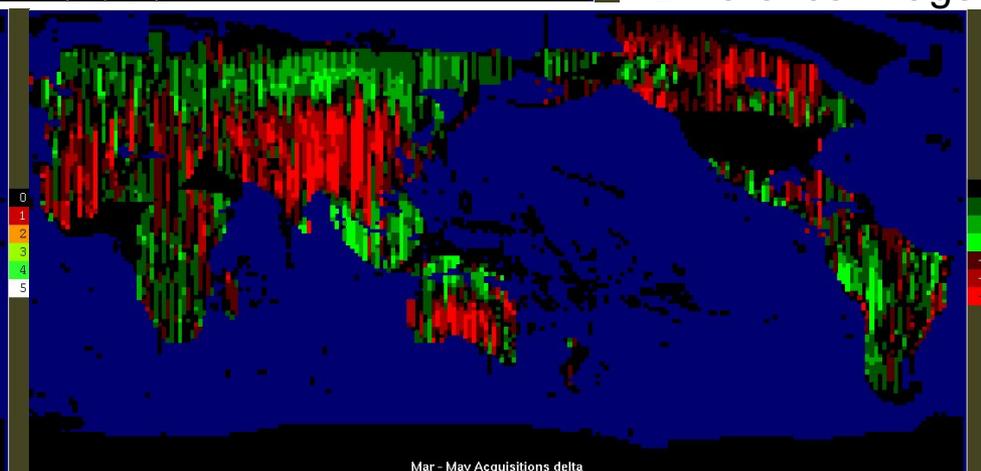
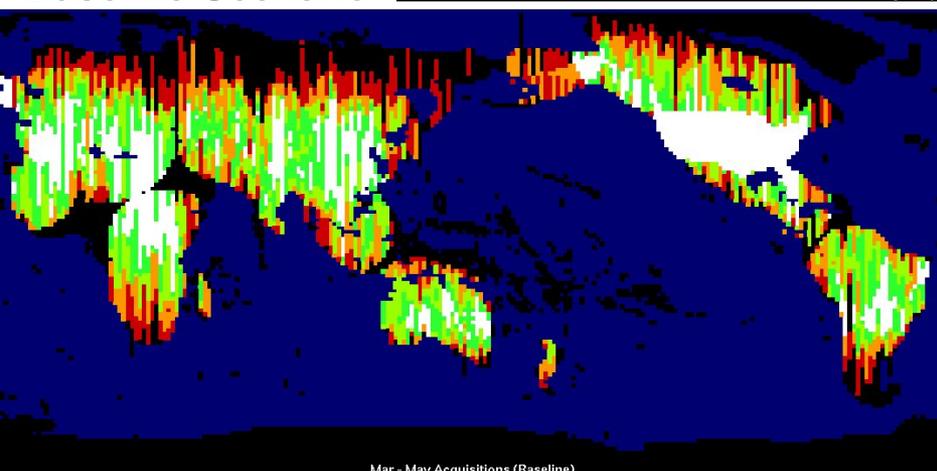
Baseline Scenario



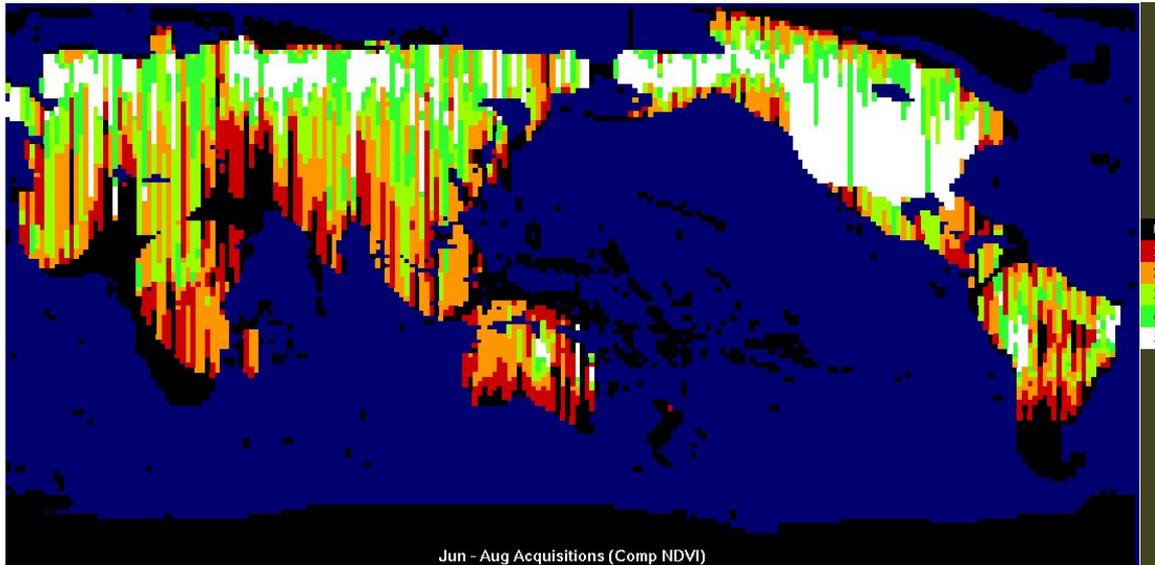
# Mar-May Acquisitions



Baseline Scenario

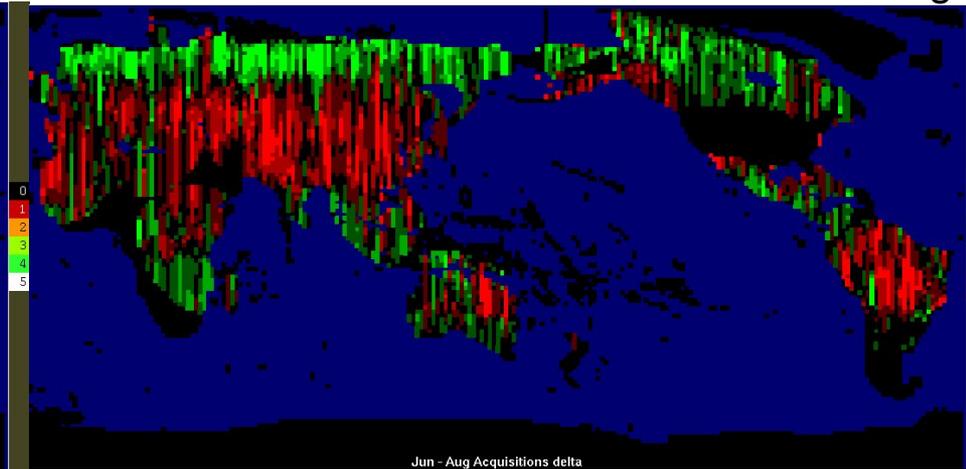
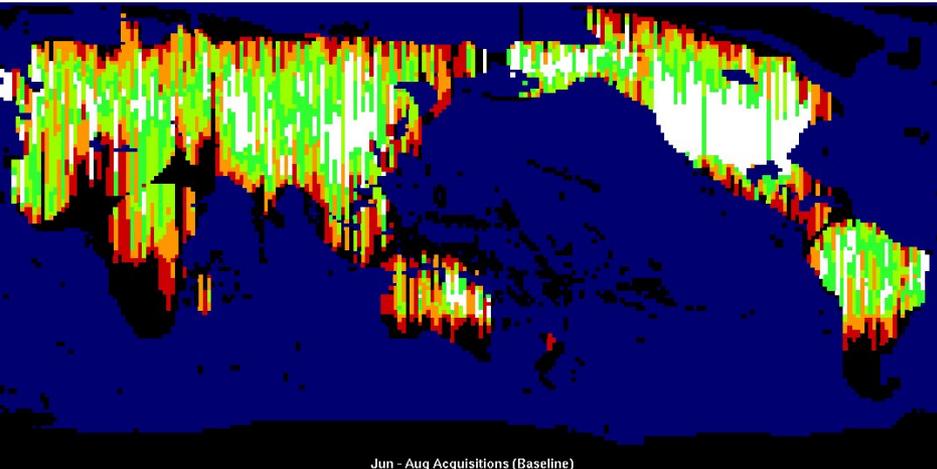


# Jun-Aug Acquisitions

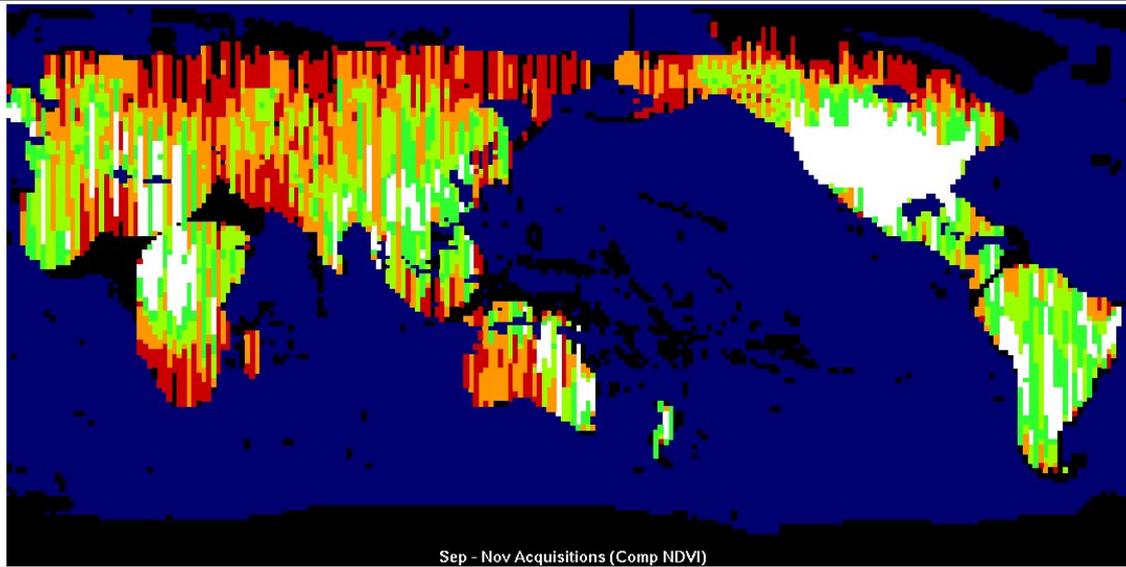


Difference image

Baseline Scenario

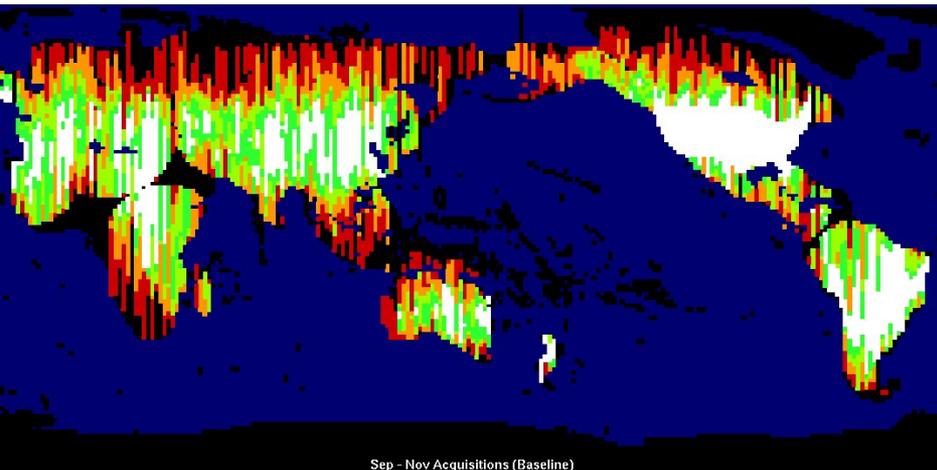


# Sep-Nov Acquisitions

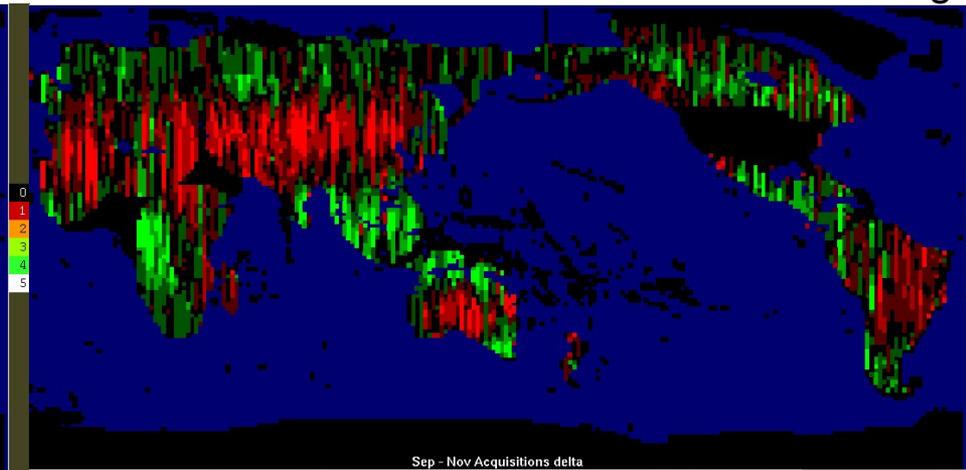


Difference image

Baseline Scenario



Sep - Nov Acquisitions (Baseline)



Sep - Nov Acquisitions delta

# Landsat 5 evolution summary

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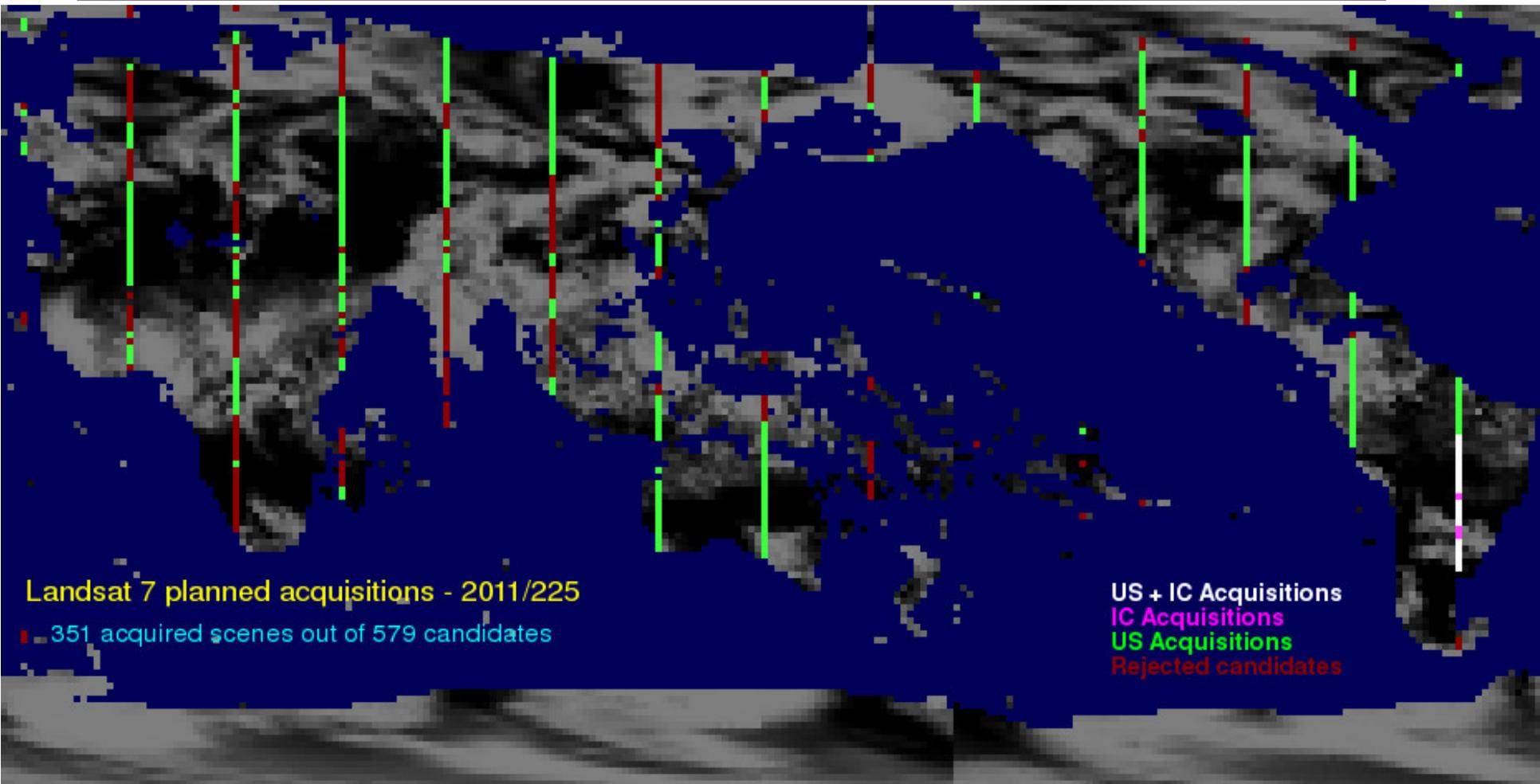
- NDVI provides explicit measurement of phenology
- Cloud confidence provides objectivity in the implementation of cloud prediction
- ACCA scores provide critical feedback
- **Nonetheless – spacecraft constraints drive model:** interval-based scheduling, every path scheduling, and power management
- Long term benefits of new model will be realized with Landsat 7 and LDCM

# Landsat 7 LTAP constraints

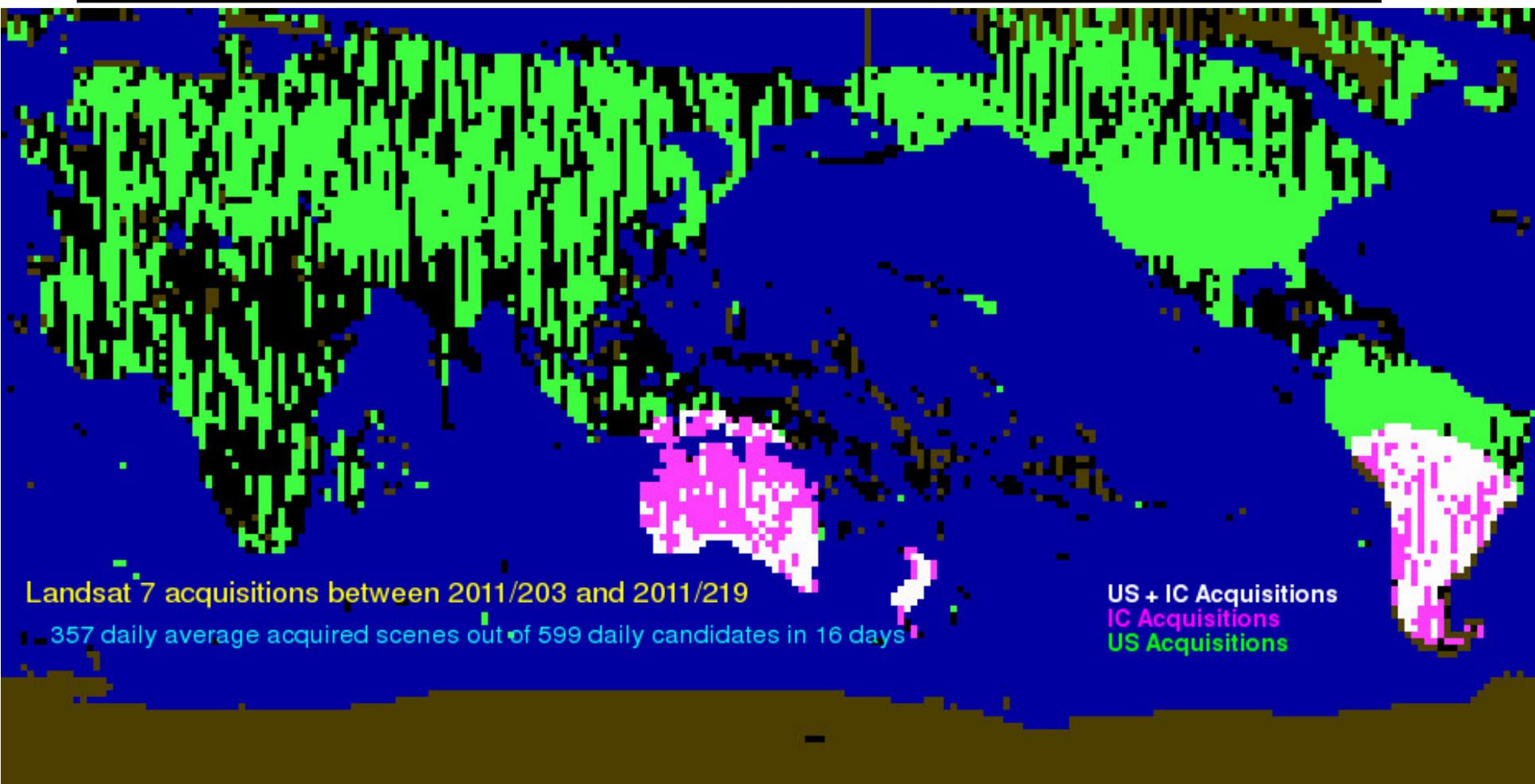
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- **Acquire 350/day with continued cooperation with ICs to increase acquisitions**
- **ETM+ duty cycle**
- **Number of download opportunities and solid state recorder management**
- **SLC-off: image pair**

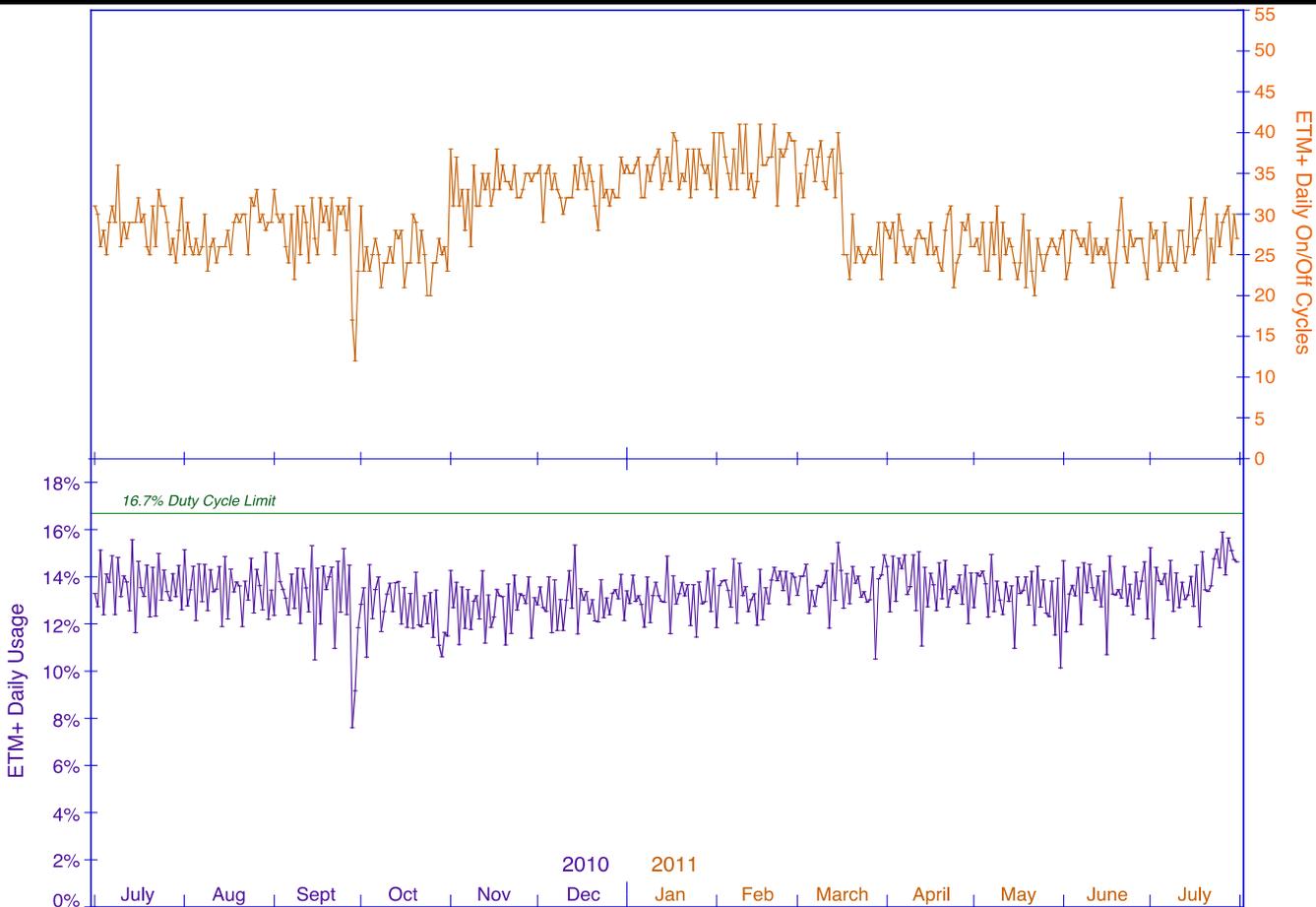
# Landsat 7 16-day cycle



# Landsat 7 16-day cycles



# ETM+ Utilization : 13 month trend



We are now averaging 15.1% duty cycle and collecting 385 scenes/day, up from 13.5% when we were constrained to 300 scenes/day.

# LDCM LTAP

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- **Acquire 400/day**
- **LTAP is frozen at Landsat 7 LTAP circa September 2008**
- **Modeling is required to ensure the effective distribution of images using the LDCM LTAP**
- **We can improve the LDCM scheduler with new inputs**
  - ◆ New seasonality file
  - ◆ New cloud climatology file
  - ◆ New NCEP cloud prediction has already been integrated
- **Plan for post-launch integration of evolving Landsat 5 & 7 functionality**

# LTAP summary

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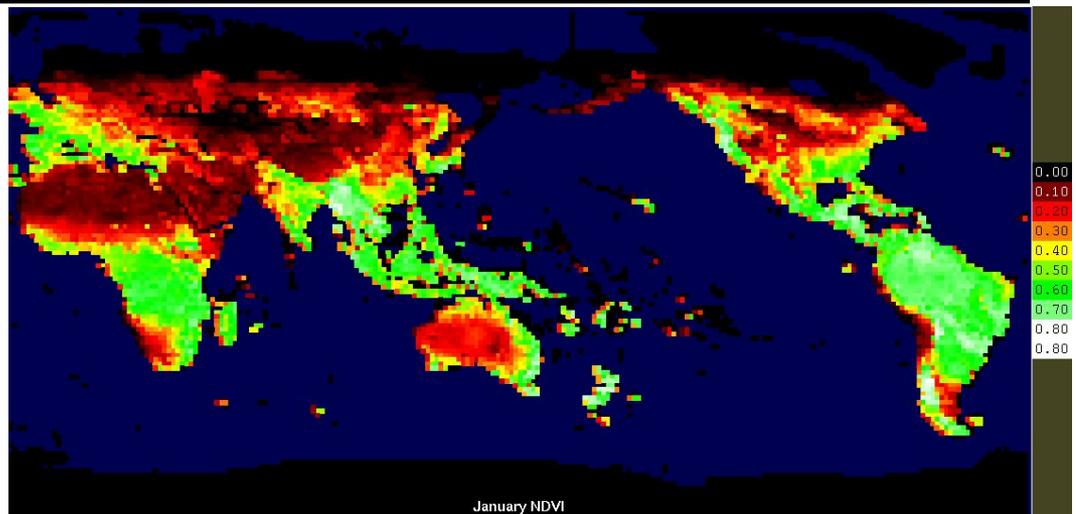
- **Landsat 5 - New functionality currently being implemented**
  - ◆ NDVI
  - ◆ Cloud prediction confidence
  - ◆ Terra/MODIS derived cloud climatology
  - ◆ Modeling of parameters continues, but satellite constraints will limit how much the scheduler can be tuned
  - ◆ Release planned for this fall for the new Landsat 5 scheduler
- **Landsat 7**
  - ◆ Migration of new Landsat 5 functionality to Landsat 7 scheduler has begun
  - ◆ The full potential of the changes will be realized in the Landsat 7 scheduler
- **LDCM**
  - ◆ Migration to LDCM is not expected until after launch
- **Future**
  - ◆ Confidence of NDVI
  - ◆ Land ACCA scores
  - ◆ Further tuning of parameters
  - ◆ Thematic campaigns
  - ◆ QA/QC: How can we quantify the ability to meet the acquisition criteria?
  - ◆ Need to reconvene and reconstitute LTAP team to dig into the details

# NDVI refinements - backups

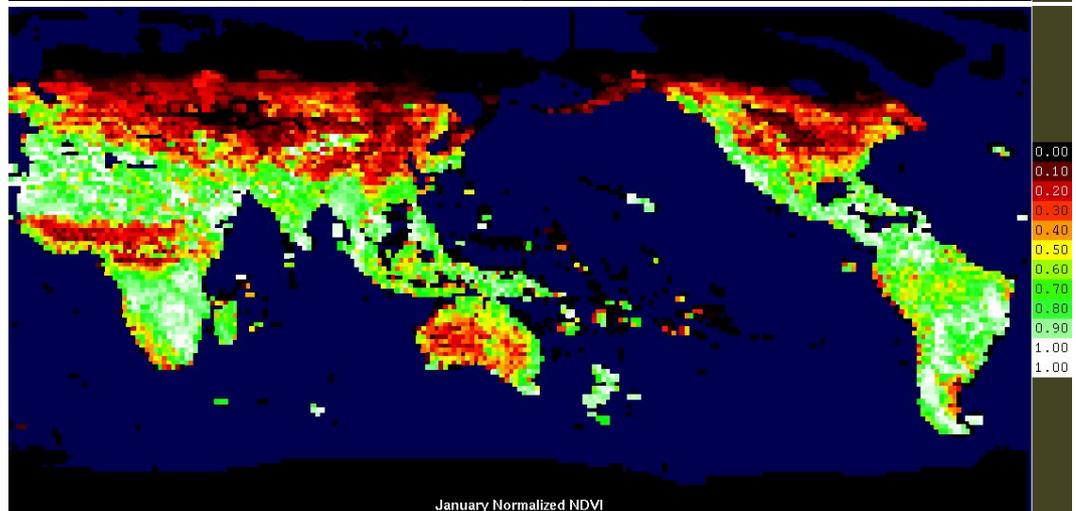
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# Normalizing monthly NDVI - Examples

January  
NDVI



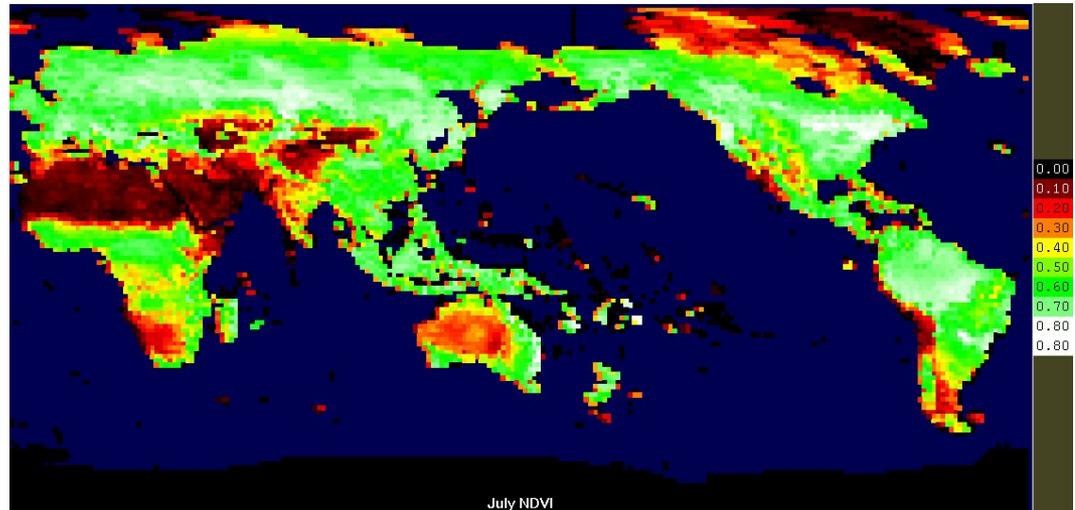
January  
Normalized  
NDVI



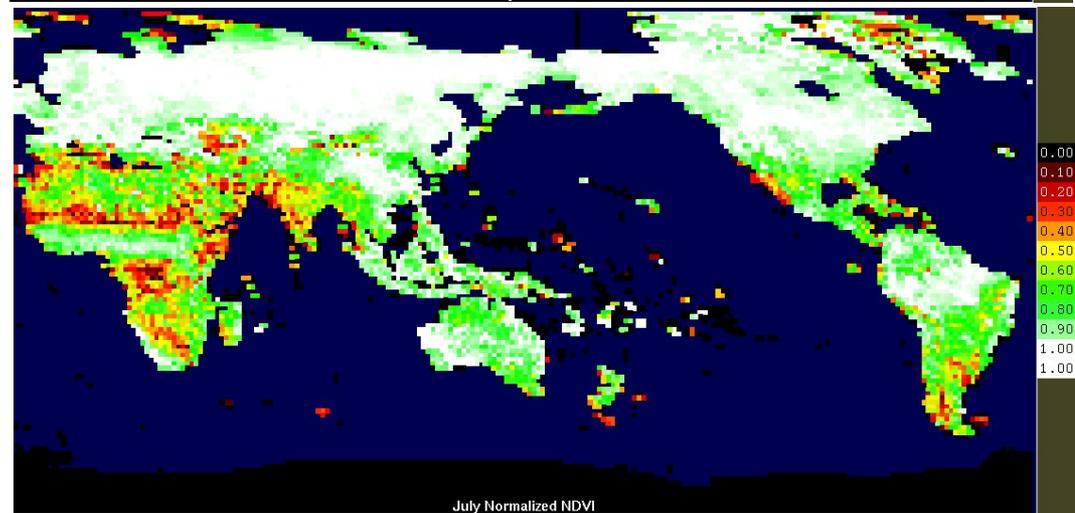
Northern Hemisphere coverage  
discouraged, as well as Australia.

# Normalizing monthly NDVI - Examples

July  
NDVI

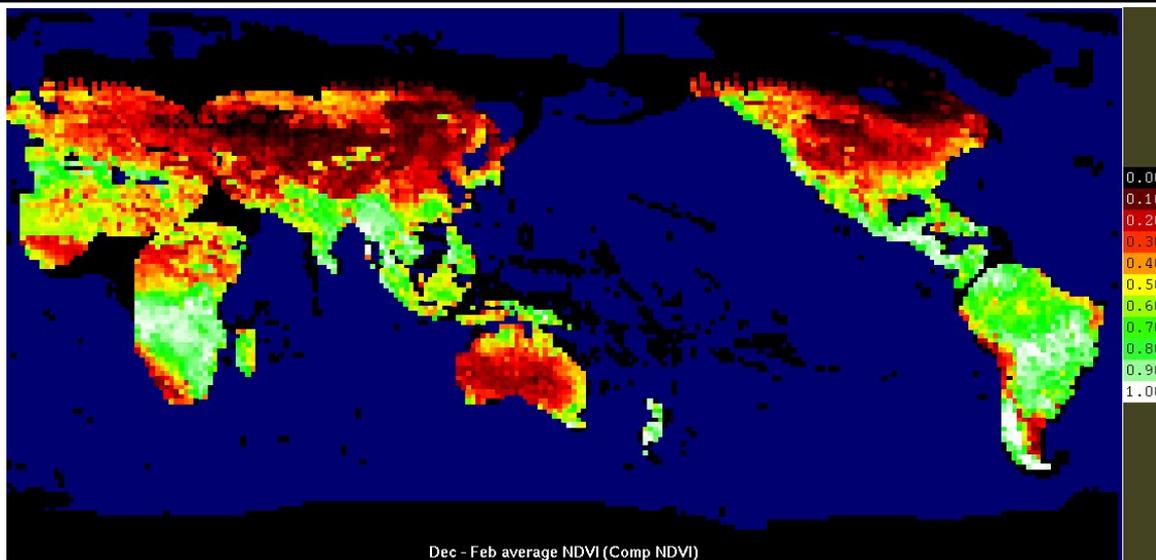


July  
Normalized  
NDVI



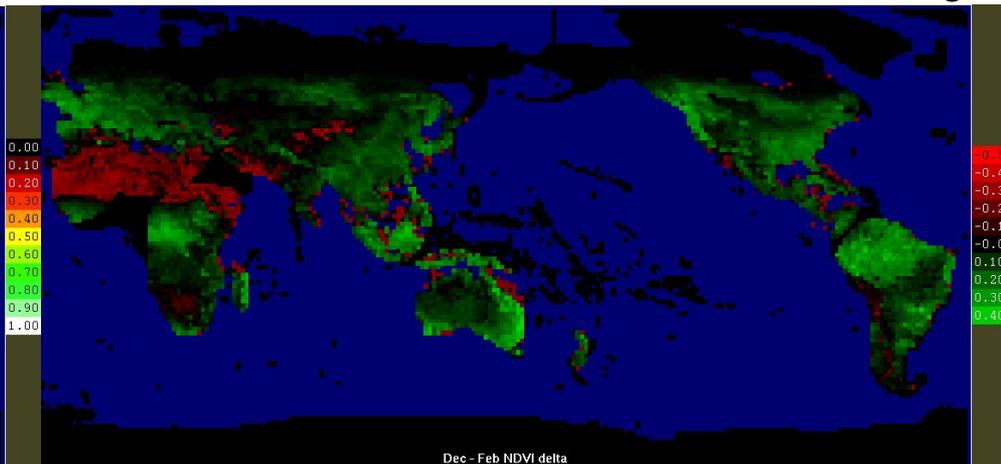
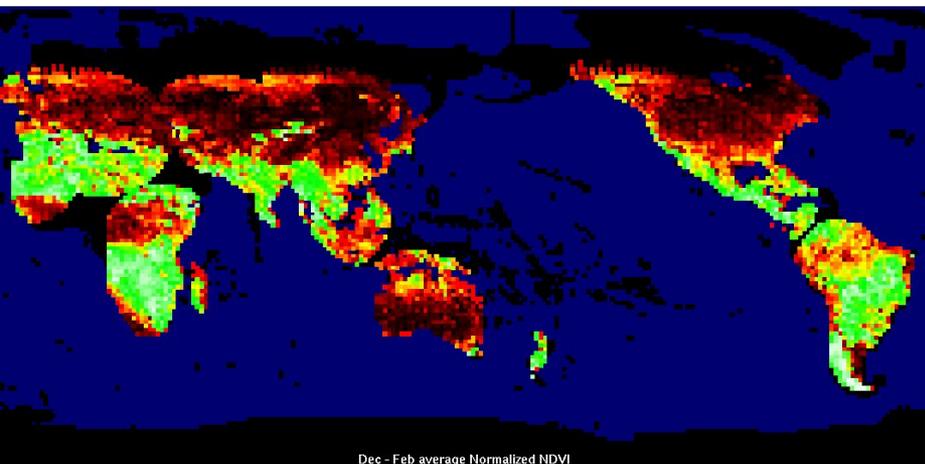
Shift of attraction toward Northern Hemisphere, Australia, northern S.America, and tropical band of Africa.

# Dec-Feb Compromise NDVI

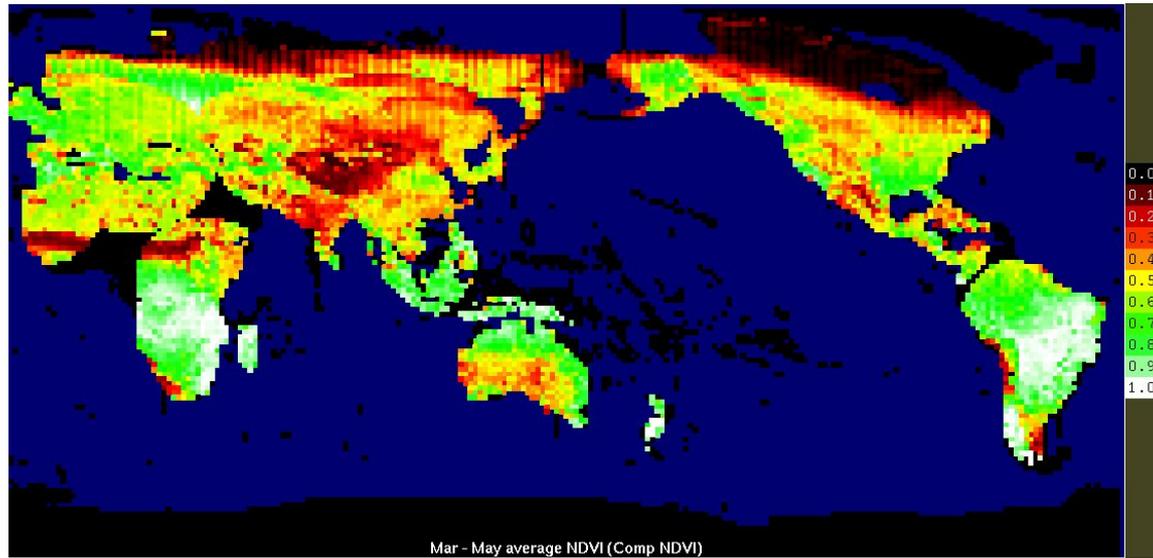


Normalized NDVI

Difference image

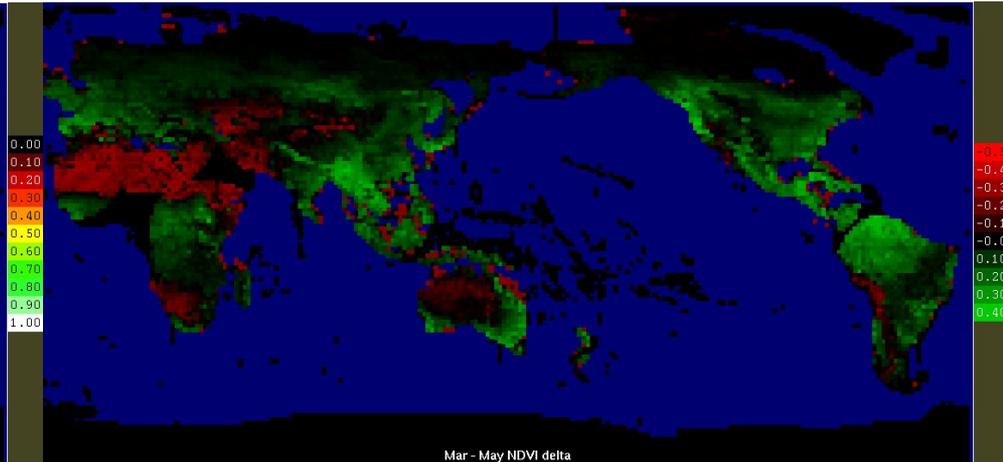
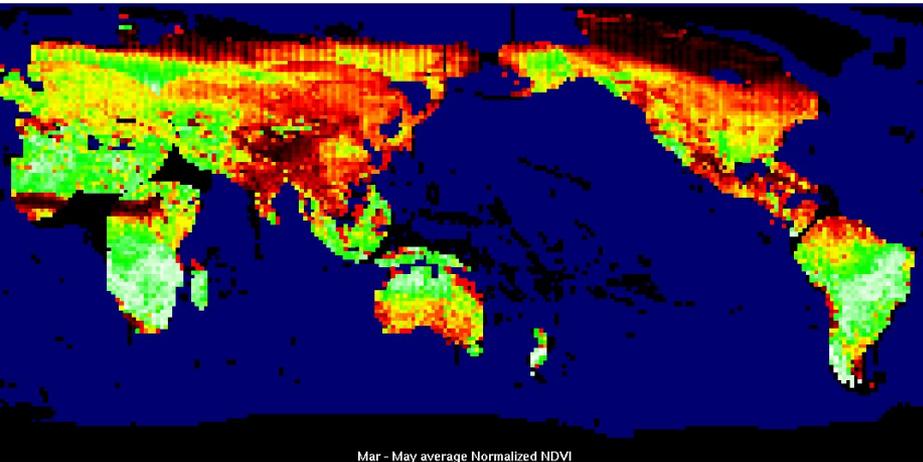


# Mar-May Compromise NDVI

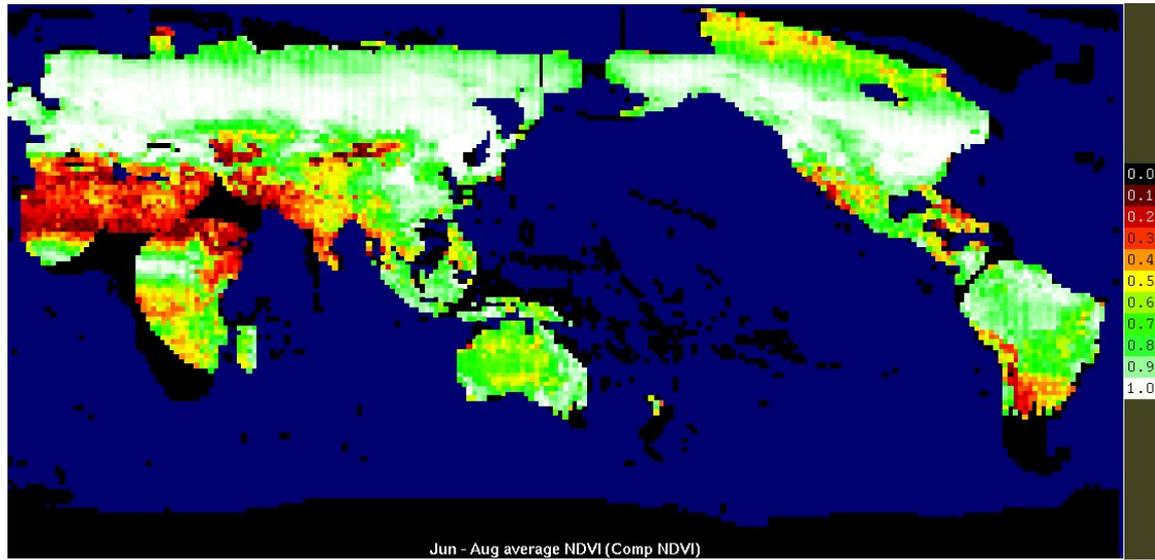


Normalized NDVI

Difference image

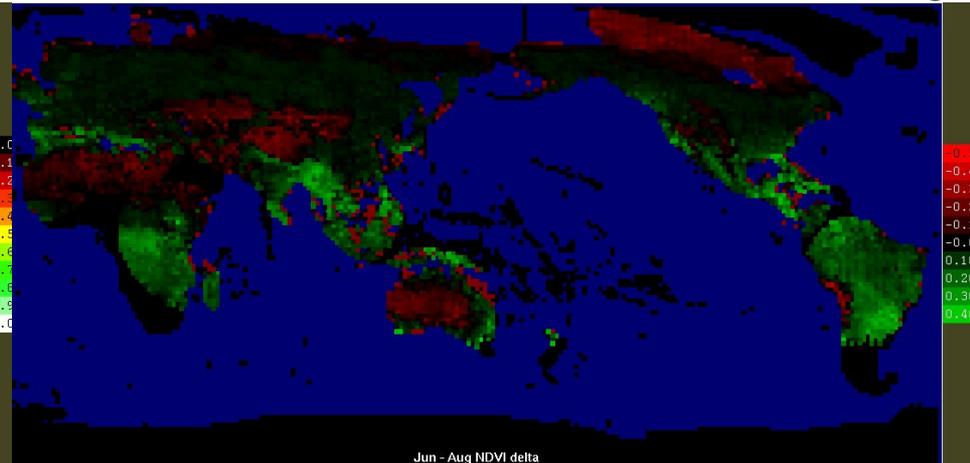
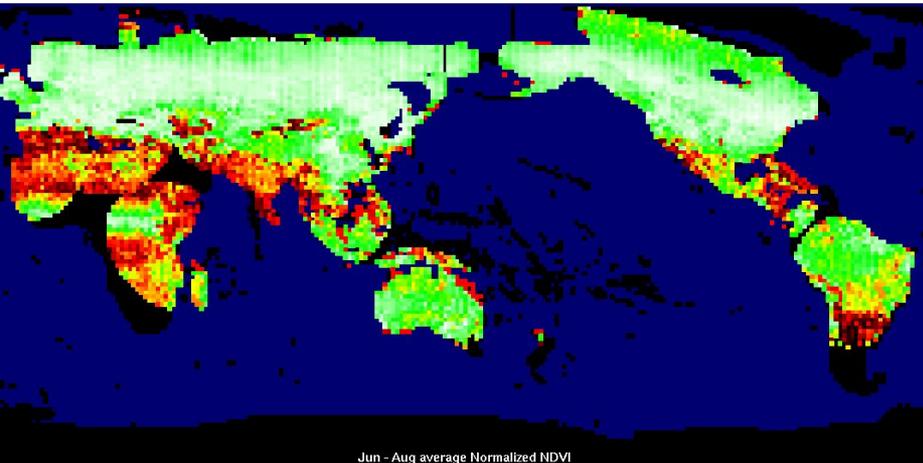


# Jun-Aug Compromise NDVI

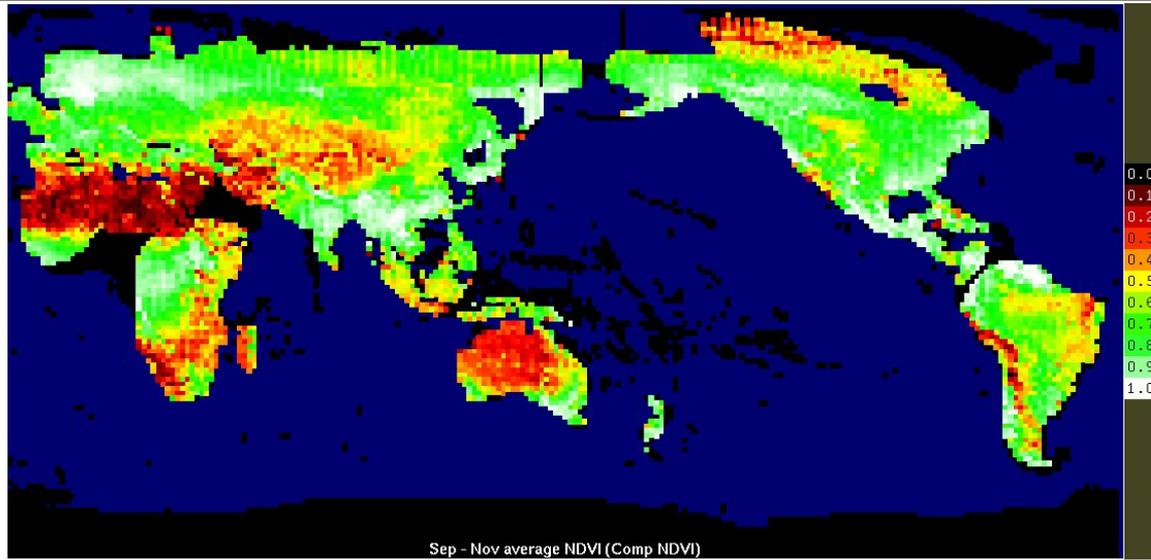


Normalized NDVI

Difference image

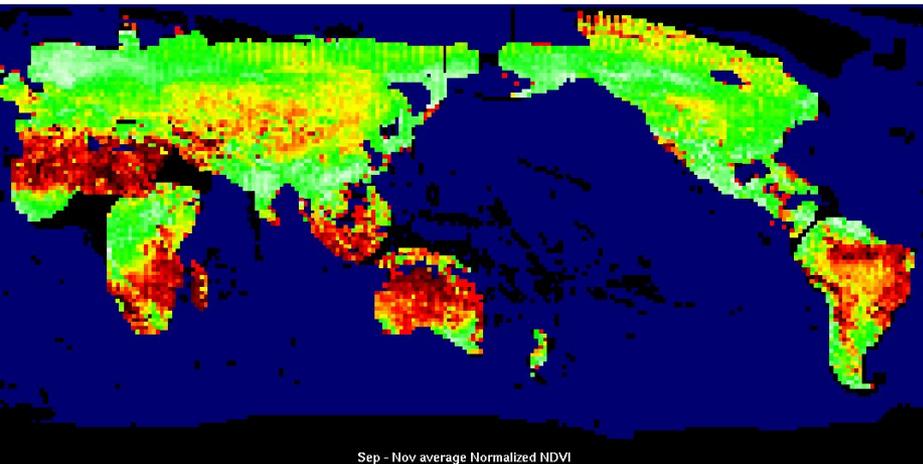


# Sep-Nov Compromise NDVI

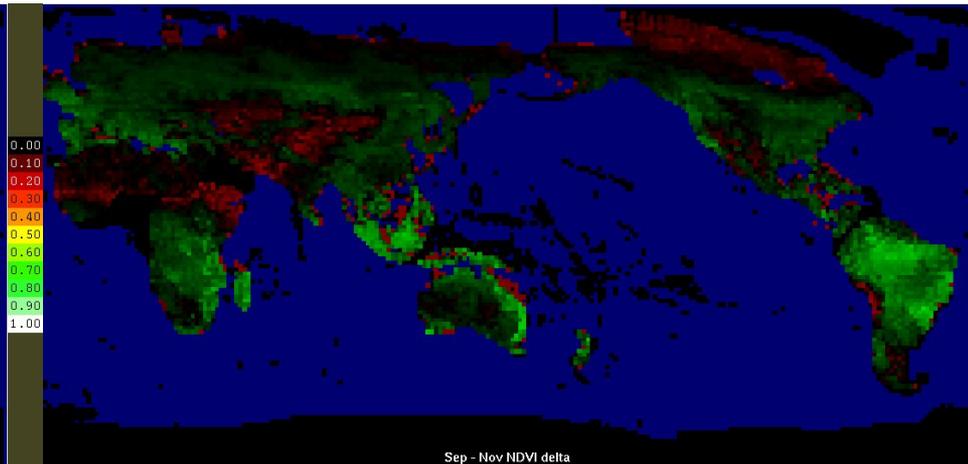


Normalized NDVI

Difference image



Sep - Nov average Normalized NDVI



Sep - Nov NDVI delta

# Seasonality plots with adjusted means

Path 199 Row 56

Means  
 Green NDVI  
 Cyan normalized NDVI  
 Magenta equally weighted

