Introduction

Earth scientists not only characterize existing conditions but must also identify physical changes that are taking place, and sometimes even need to predict potential future change. This role is increasingly important as the effects of climate change begin to have a significant effect on the landscape. Change evaluation can be challenging because there may be multiple transformations that are occurring at the same time and place, albeit at different temporal and spatial scales. To further complicate matters, the abundance of available information has skyrocketed, making it challenging to manage and interpret pertinent data in an efficient manner. Therefore, a key challenge for many projects is how to sort through multiple types of changes and data sources to focus in on the specific change of interest.

The integration of aerial or satellite image data with other observations or sensors is a well-documented component in geologic change evaluation. Li et al.’s (2011) outline on shoreline change assessment techniques includes interpretation of optical, SAR, and LiDAR data among other approaches. Young and Norby (2009) included integration of airborne and satellite imagery with field-derived data in their comprehensive manual on field monitoring methods for geologic changes in a variety of geomorphic settings. While these and other sources typically called for analyzing several repeat images, in recent years advances in cloud computing have increased the efficacy of analyzing large areas with dozens or thousands of images.

Maxar has decades of experience acquiring, integrating, and interpreting stacks of optical and radar imagery and other sensor data for practical applications. Therefore, in this presentation, we provide examples of data analytical strategies we use to improve the potential for actionable change detection using multisource, multiscale and multitemporal data.

Analytical Approaches

One of the first steps in selecting an analytical approach is to consider what type of change needs to be detected (Table 1). The required change category must then be balanced against factors that could be of concern, such as the necessary spatial scale, the temporal requirements for new data acquisition, the certainty of getting data, and the timing needed to receive the results of the assessment.

<table>
<thead>
<tr>
<th>Type of Change</th>
<th>Description</th>
<th>Geologic Examples</th>
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<tbody>
<tr>
<td>Persistent/Permanent Change</td>
<td>A stable condition converts to a different stable condition (e.g., a forest becomes a parking lot).</td>
<td>Movement along a fault, erosion, or man-made effects on land cover</td>
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<tr>
<td>Emerging Persistent/Permanent Change</td>
<td>A stable condition begins to change (e.g., a forest is cleared in preparation to become a parking lot).</td>
<td>InSAR-detected minor deformation before a landslide</td>
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<tr>
<td>Gradual Change</td>
<td>Slow, ongoing, naturally occurring change often resulting from a change in intensity of cyclical events (e.g., a parking lot gradually erodes).</td>
<td>Glacier retreat, change in wetlands, or land subsidence</td>
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<tr>
<td>Transient Change or ‘Activity’</td>
<td>Short term activity or variation in conditions that do not affect the underlying setting in general (e.g., cars enter, park and then leave a parking lot).</td>
<td>Rapidly shifting sedimentation, ice floe movement, or business-related operations</td>
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<tr>
<td>Clutter</td>
<td>Real change that is not of interest to the user (e.g., a change in shadow location).</td>
<td>Non-geologic change, animal herds, shadows</td>
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Figure 1 is a schematic showing how prioritization of these individual factors is used to determine the optimal analytical approach. For example, during an emergency response frequency or timing of new
results becomes the critical factor, so Algorithm A, B or C would be preferred, whereas the permanency of a change is more important when assessing building encroachment, so in that case Algorithms G, H or I would be preferred.

![Image of Schematic](image)

**Figure 1 – Schematic showing the assessment used to select the preferred method of nine potential analytical approaches.**

Under many circumstances, data acquisition logistics may require that a combination of data sources and analytical approaches be used. For example, persistent change, emerging persistent change and gradual change all require the use of stacks of imagery. For wide areas or regions that need frequent monitoring, acquiring stacks of high-resolution imagery may not be logistically (or financially) feasible. On the other hand, high resolution images may be needed to identify certain issues of potential concern, such as erosional changes at pipeline river crossings. Therefore, a “tipping and cueing” approach is used whereby medium-resolution data that may be open-source, more frequently acquired, or penetrate cloud cover is used to initially screen for the presence of a change. Then high-resolution imagery is acquired only in the areas where the screening has indicated that it may be needed.

**Examples of Results**

Figure 2 provides an example of this type of tipping and cueing during wide-area monitoring in Eastern Europe. Dozens of Landsat images were automatically cloud-cleaned and analyzed for persistent change. This algorithm was effective at capturing development related to expansion of a natural gas facility without including clutter such as seasonal greening-up or daily water fluctuations. A high-resolution image was acquired later to determine the nature of the change. This same approach is used to evaluate other business activity such as well pad development, but also shows changes in geologic features such as dune movement, landslides, or channel migration.

Figure 3 shows an approach to quickly complete a wide-area assessment of a geologic change by combining machine processing with a vetted crowd of interpreters (GeoHive). After a rapid assessment is performed to identify likely areas of potential change or concern, high-resolution “before and after” image chips with embedded imagery slider bars and specific instructions are provided to the crowd members without any identifying locational information. The crowd members are told what to look for and provide an interpretation of whether that condition is present within the area of each chip. In this example, a rapid assessment was needed to assess regional landslide damage
in Southern Honshu Japan in 2018. Each image chip was evaluated three times by members of a 12-person GeoHive team to look for damaged infrastructure or roads. This highly-accurate detailed assessment was completed in 2 hours and 46 minutes.

Figure 2 – Persistent Change Monitoring results near a natural gas facility in Eastern Europe. The year when change was first detected is shown in the legend at right. A portion of a high-resolution image acquired to confirm the nature of the change is provided at left.

Detecting gradual change in fluctuating systems requires consideration of the phenomenon’s properties as well as the project objectives. For example, well pad revegetation in Alberta was assessed by Rochdi by using a change in vegetation from two images acquired eight years apart. Dacre
et al. (2017) needed an understanding of the trajectory of well pad revegetation, so annual change was assessed from machine-learning-derived landcover from a seven-year series of images. Figure 4 shows a different approach that was taken to assess Lake Razaza in Iraq – a water body subject to seasonal variation in extent, but that appears to be drying over time. Hundreds of Landsat images between the late 1980s to the late 2010s were automatically processed to indicate presence or absence of standing water, allowing a statistical evaluation by various time periods and confirming gradual drying.

Figure 4. Statistical evaluation of the frequency of standing water in Lake Razaza in Iraq

Conclusions

Due to cloud computing and other innovations, there are new options available for detecting specific types of change within our evolving world. In selecting the analytical approach, the type of change required, the strengths and weaknesses of the available algorithms, and data availability must be considered. The current change analytical tools are being used for a wide variety of geologic-related needs, ranging from business intelligence to sustainable development to tracking natural processes.

References


