



During fall 2015, the Federation of Earth Science Information Partners (ESIP) performed technology evaluations of three projects funded through NASA's [Advanced Information Systems and Technology \(AIST\)](#) program. This work was part of a Cooperative Agreement between NASA and the Foundation for Earth Science to expand evaluation capabilities within the ESIP Testbed, a space where prototype standards, services, protocols and best practices can be incubated and matured. The Testbed also serves as an environment for innovative collaborations across all sectors of ESIP to improve access to, and awareness of, member products and services. This post outlines the motivation, process, outcomes and future technology evaluation activities related to ESIP and AIST.

Background

The NASA [Earth Science Technology Office \(ESTO\)](#) manages technology and application development for a broad range of Earth science measurements and missions. Information technology (IT) plays a critical role in the advancement of ESTO projects, particularly surrounding the collection, management and analysis of data. Within ESTO, NASA's AIST program is charged with developing IT projects that enable new observations and information products; increase the accessibility and utility of science data; and reduce the risk, cost, size and development time for Earth science space based and ground-based information systems.

The AIST program uses Technology Readiness Level (TRL) to assess the maturity of its funded projects. The TRL scale (ranging from one to nine) is a common metric of technology readiness used throughout NASA and other agencies. While AIST funds projects at various stages of technology readiness, it predominantly accepts mid-TRL projects. Projects enter AIST through a typical NASA solicitation process, during which the PI declares the project's entry-TRL and desired exit-TRL, i.e. the TRL level they would like to reach at the end of their award. However, AIST has identified several shortcomings with the process of projects self-assessing TRL.

AIST concluded that independent assessment of TRL within the ESIP Testbed could mitigate several issues with their current technology development process. First, an independent TRL assessment could identify shortcomings before the project's funding is closed out. Second, independent assessment could resolve issues missed when a project's team is approaching the problem from the same point of view. Lastly, independent testing could resolve issues related to systems requirements, permissions, firewalls, etc. that may be missed while working on a project only within a home institution. Independent assessment also exposes AIST projects to a broader audience, which has the potential to increase infusion opportunities. If a project gains such exposure while it still had funding, the project could implement desired end-user changes, further increasing adoption potential.

ESIP is well-situated to perform independent technology evaluations. During the last eighteen years ESIP has developed collaboration methods and infrastructure that provide a scalable, neutral platform to support Earth science research, data and technical communities. ESIP's partner organizations and community participants lead the advancement of Earth science information best practices in an open and transparent fashion. By partnering with ESIP, AIST is able to leverage the expertise within the ESIP community and expose AIST projects to a broad audience of Earth science practitioners.

Key Objectives

The key objectives of ESIP's evaluation of AIST projects were:

- Independent TRL verification.
 - Ensure that technology is usable by someone other than developer.
 - Identify components which need maturation in order to be usable by others.
- Showcase technologies to potential adopters.
 - Identify more technology infusion opportunities.
 - Get more people thinking about who else (individuals, agencies, missions) might use it.
 - Encourage projects to examine technologies for possible use.
 - Examine it without making an investment.

Evaluation Outline

The first round of ESIP technology evaluations took place between August and December 2015. The ESIP evaluation process was structured as follows

- 1) AIST selects projects
 - a) Three projects were selected ranging from TRL 3-5.
 - i) Two projects were at NASA JPL. One project was at the Marshall Space Flight Center/University of Alabama at Huntsville.
- 2) ESIP initiated communications with the PI
 - a) ESIP organized a telecon to discuss the evaluation objectives and process.
- 3) ESIP selects evaluators
 - a) ESIP selected evaluators from the ESIP community as well as individuals suggested by the project PIs, predominantly domain experts familiar with their respective AIST project.
 - b) Four evaluators were from academic institutions, two from the federal government, one from a non-profit and one from the private sector.
- 4) Evaluators work with AIST PIs to create test plans.
- 5) Evaluators carry out testing.
- 6) Evaluators submit final report content to ESIP.
- 7) ESIP edits and submits reports to AIST.

Evaluation Components

To satisfy the evaluation goals outlined by AIST, ESIP required the following three components be addressed by the evaluation teams:

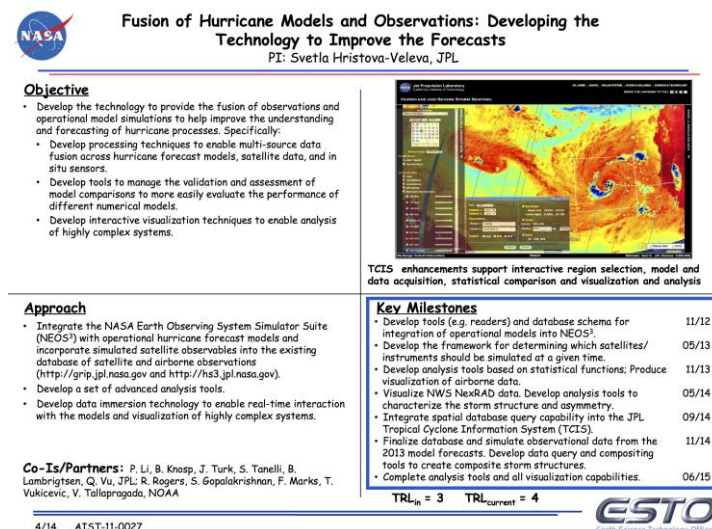


Figure 1: Example AIST Quad Chart.

- 1) Milestone Completion Review: Review "Key Milestones" in the project's Quad Chart and determine a level of completion.
- 2) TRL Objective Completion Review: Determine a level of completion for each of the project's [TRL objectives](#). For example, TRL 5 objectives are:
 - a) Thorough testing of prototyping in representative environment;
 - b) Basic technology elements integrated with reasonably realistic supporting elements; and
 - c) Prototyping implementations conform to target environment and interfaces.
- 3) Assess the project using the [TRL Evaluation Structure](#), a template for software Levels. TRL Evaluation Structure features

include category summaries; binary, normalized (0.0 to 1.0), or positive value (>0.0) ratings; TRL-based line item weightings; page and category averages; line item and page-wide comments; and instant re-calculation for different TRL levels. The template includes source references and some user documentation.

Technology Evaluation Framework

To organize the evaluation process, ESIP developed the Technology Evaluation Framework (TEF), a web portal built using the [Open Science Framework](#), which provided a space for AIST project PIs and project evaluators to find information about:

- AIST Project Abstracts
- AIST Project Quad Charts
- AIST Project Access Instructions
- ESIP Code of Conduct
- ESIP Evaluation Timeline
- ESIP Reporting Requirements
- ESIP TRL Evaluation Structure
- PI and Evaluator Contacts
- Funding and Supporting Organizations

The TEF was also a collaborative space for sharing notes and communications about the evaluation process between evaluators and project PIs. The TEF was developed such that it could be used in a broad range of technology evaluations.



Figure 2: Home page of the Technology Evaluation Framework web portal.

Outcomes

While the first set of ESIP evaluations of AIST projects was billed as preliminary, they were largely successful. Each evaluation team spoke to all required evaluation components. ESIP submitted final reports from each evaluation team to AIST on time. See an example final report in Appendix A. ESIP gave presentations about the AIST evaluation process at the 2015 American Geophysical Union [Fall Meeting](#) and ESIP [Winter Meeting](#).

Next Steps

We will continue to refine the evaluation process, including better documentation within the Technology Evaluation Framework for reporting requirements, privacy and time commitments. This spring (2016), the ESIP [Products and Services](#) (P&S) committee will continue to improve the specific software evaluation guidelines used during the evaluation process. The P&S committee has scheduled a codesprint (spring 2016) and [workshop](#) to develop the ESIP Software Evaluation Guidelines. The workshop will be held at the 2016 ESIP Summer Meeting and focus on the feedback/revisions gathered during the spring's software evaluation codesprint. The workshop will end by considering the draft guidelines as a whole in preparation for presenting them at International Data Week in September 2016.

Due to ESIP's broad expertise around Earth sciences data and software lifecycles, the evaluation process will continue to evolve as new recommended practices are established.

Appendix A: Example Final Report

Title: Fusion of Hurricane Models and Observations: Developing the technology to improve the forecasts

Project PI: Svetla Hristova-Velva, NASA Jet Propulsion Laboratory

Evaluation Team:

Member 1; Florida International University

Member 2; NOAA

Member 3; NOAA

TRL Level 6: TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space): Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.

Conflicts of Interest with PI or Project

The following potential conflicts of interest have been identified for the individual Evaluation Team Members:

None.

Project Overview

The Tropical Cyclone Information System (TCIS) developed at NASA JPL is a valuable tool for the tropical cyclone community. The available TCIS products are generally recognized as important for describing a tropical cyclone (TC) structure and its surrounding environment. The analysis tools the TCIS team has developed, such as ARCHER and the Wave Number Analysis, are appropriate for popular research topics in the TC community. The TCIS and the incorporated analysis tools are generally easy to use, though the ARCHER and Aggregation tools were less successful.

Overall, the capabilities currently available in the TCIS for synthesizing satellite observations with similarly simulated model observables are progress towards achieving goal of better understanding and forecasting hurricane processes.

Assessment of Completion: Key Milestones from Quad Chart

Descriptions of the assessment levels are: 0 -> dropped (evaluation is not applicable) 1 -> initiated, only very minor progress made 2 -> some elements complete, but most are initiated or less 3 -> moderately complete, significant work remaining on many elements 4 -> nearly complete; some elements need minor work 5 -> complete, all elements functional and no further work required

5 – Develop tools (e.g. readers) and database schema for integration of operational models into NEOS3 (November 2012)

The goal of this milestone, as well as subsequent ones, is to incorporate simulated satellite observables from both high-resolution model forecasts (so far, HWRF) and lower resolution global models (ECMWF and GFS) into the TCIS framework, which would allow a user to produce a statistical comparison that quantifies the similarity between the observed TC structure and the structure depicted in a model forecast.

The team assesses this milestone at a five; however, the model and satellite products have inconsistent time coding which makes it difficult to navigate between the two. *Model* is indexed by initial time and forecast time, whereas *satellite* is just indexed by hour. The initial times for *model* fields are not as clearly listed as they are for the satellite times. This could confuse inter-comparisons, as model time may not synch.

5 – Develop the framework for determining which satellites/instruments should be simulated at a given time (May 2013)

System is able to display various satellite observations from polar orbiting and geostationary satellites, satellite retrieved fields (e.g., rain indicator) and simulated retrievals from model output that can be compared to the satellite observed fields. TCIS makes the horizontal and vertical polarized brightness temperatures at 19, 37 and 85 GHz, as well as the Rain Indicator, from passive microwave sensors available as simulated observables from the model forecasts. The passive microwave sensors included are SSMI, SSMIS, TMI, AMSRE and GMI. While the function

(overlaying simulated model fields) does appear to be available within TCIS, the capability appears to be available only for model forecasts initialized at 0000 UTC.

For these reasons, this milestone is considered complete, but we offer an additional suggestion: Model forecasts initialized for 1200 UTC should probably be made available within the portal, with six hour intervals, particularly if the portal is to be used in an operational environment.

4 – Develop analysis tools based on statistical functions; produce visualization of airborne data (November 2013)

The following analysis tools have been included in the portal: an ARCHER center tool, one for computing a joint PDF of two brightness temperatures, another for producing a vertical cross section (“slicer”), as well as one to produce a wave number analysis (85 GHz only) of the precipitation and wind fields. The user can easily manipulate analysis regions. Documentation that describes these analysis tools was provided to evaluators, but is not yet available on the portal. The documentation provided offers example usages of the analysis tools, and their interpretations, but little instruction on how to use the tool. Attention should be paid to providing a user the necessary documentation and instructions on the use of the tools. The visualization of airborne data is available for limited cases.

Some work on the tools is still required for them to be considered successfully implemented. One significant issue is that lack of time stamping on the flight track (data), which limits the users’ ability to compare it to the model fields. While some capability of plotting airborne remote sensor data is available, this is limited in its usefulness as there are only aircraft remotes sensed data available from the HS3 and GRIP NASA field campaigns. This limits its usefulness for working with NOAA or USAF flights into hurricanes. For example, flight-level data would be helpful, as would a larger set of aircraft. Also dropsonde data would be useful to have, even from the NASA field campaigns.

4 – Visualize NWS NexRAD data. Develop analysis tools to characterize the storm structure and asymmetry (May 2014)

An analysis tool was developed (the “Wave Number Analysis”) to evaluate the storm structure; in particular, the symmetry of the precipitation and wind field. The ability to analyze the degree of wavenumber-0 and -1 symmetry, as well as the ability to compare the radial peak of the precipitation distribution to the wind distribution, is very relevant to the TC community.

However, visualization of NWS NEXRAD data does not seem to be possible in the current configuration of the TCIS portal (either the Google Earth-based HS3 or the Cesium NAHW), although the evaluators do not believe this to necessarily be an important component to add to the portal. There is an asymmetry tool that allows for the assessment of the degree of symmetry for the TC rain index, but it did not seem to work, except with the 85 GHz satellite fields. It would be good to have the ability to perform a similar symmetry analysis for some of the retrievals from the satellites, e.g., 19, 37, 85 GHz imagery. Also, no NWS NexRAD data appeared to be available on the website for the cases checked (U.S. landfalls, in particular Arthur 2014 and Isaac 2012).

4 – Integrate spatial database query capability into the JPL Tropical Cyclone Information System (TCIS) (September 2014)

The user has the ability to query the tool based on storm and date. A specific type of spatial database query has been integrated into the analysis tools, which allows the user to manipulate the size and location of area in which a tool will analyze data.

However when changing storms, the fields (satellite or model) originally displayed do not disappear unless they are turned off prior to changing the storm.

3 – Finalize database and simulate observational data from 2013 model forecasts. Develop data query and compositing tools to create composite storm structures (November 2014)

A query-type tool, called an “Aggregation Query,” to composite storm structures is available. This tool allows the user to download images (via email) that aggregate data for precipitation and wind speed structure for a user-defined range of storm intensities, basin location and time. The evaluators attempted to retrieve aggregated data through this tool, but did not receive an email. Model forecasts that also simulate observational data are available within the tool for 2013 and in near real-time as well.

While the composite storm structure utility is very valuable in concept, upon submitting a request for this information, the requested plot fails to appear. Also, the default TCI websites use the Google Earth API that is being phased out. One could use the new Cesium open source API, but only for the NAWW version. A Firefox browser would not allow the Google Earth API to run for the other two versions, displaying a message that Google Earth was not compatible.

3 – Complete analysis tools and all visualization capabilities (June 2015)

There are numerous instances where the analyses and visualization capabilities are incomplete. The evaluators see the potential of this product but feel it needs more work to become a reliable and valuable tool for research and operational uses.

Assessment of Completion: TRL objectives

Descriptions of the completion levels are: 0 -> dropped (evaluation is not applicable) 1 -> initiated, only very minor progress made 2 -> some elements complete, but most are initiated or less 3 -> moderately complete, significant work remaining on many elements 4 -> nearly complete; some elements need minor work 5 -> complete, all elements functional and no further work required

4 – Prototyping Implementations on Full-Scale Realistic Problems

Example TCIS use cases were provided to evaluators and outlined in an “Introduction/Overview” document provided to the evaluators. These examples have shown the utility of the portal and its incorporated analysis tools in meeting the project’s goal (model evaluation using satellite observations for better understanding/forecasting tropical cyclones).

While most aspects of the product are functional, there are a few elements that do not work. For example, when changing storms, the fields (satellite or model) originally displayed do not disappear unless they are turned off prior to changing the storm. There were also issues with the API used for the geo-referenced data with the Firefox browser, and some of the tools worked only on specific fields and not others.

4 – Basic Technology Elements Partially Integrated with Existing Systems

All aspects of the product appear to be integrated with necessary systems, including querying the various databases. It would be nice to add some of the other aircraft observations, even those from NASA missions such as dropsondes, and flight tracks.

4 – Limited Documentation Available

The “Introduction/Overview” document provided to the evaluators was very helpful and should be provided with the portal on the webpage. However, even if placed on the website, it seems burdensome to expect users to wade through the entire document.

It would be *more* useful to have a streamlined set of instructions easily accessible that would facilitate database queries and access of information. Also, and this is an important point, *it would be very helpful to have a brief description or way to quickly get information on each product displayed on the website*. In some cases there are acronyms (e.g., OW, Pouch, CAPE, LI, etc.) that users may not be familiar with, so a simple “What’s this?” kind of tool would be helpful.

5 – Engineering Feasibility Fully Demonstrated in Actual System Application

The current configuration of the portal demonstrates an appropriate level of sophistication when used to analyze TC events in real-time, or in archives, which is an “actual system application.”

Summary of Technology Infusion Opportunities

Technology Infusion Opportunities/Reuse Applications

The TCIS has the potential to be a valuable product for the assessment of tropical cyclone structure as indicated by satellite imagery, in particular, passive microwave imagery. TCIS assessments could be valuable in real-time, for use by researchers as well as forecasters. Each assessment could be useful for map discussions and mission planning for field experiments. Additionally, the ability to view model output in a similar framework as the satellite imagery is a powerful way to evaluate the ability of the model to depict the environmental and vortex-scale structures.

Some of the TCIS utilities also have great research potential. For example, the slicer could be a method of examining the vertical structure from both satellite observations and model output, however it is currently limited to plots of satellite observations along the cross-section line, only providing a vertical cross-section of relative humidity and temperature retrievals. The wavenumber analysis is also a nice capability, though there are some questions about the assignment of a storm center, which is crucial to obtaining a reliable Fourier decomposition. Some of the storm center issues can be solved using the ARCHER utility, but it would be helpful to have the working best track as a first guess or alternative to the ARCHER center. Finally, the aggregation tool has great potential for performing composites of TC structure from satellite imagery in a variety of frameworks. If this could be applied in a storm motion-relative and shear-relative framework, it would be even more valuable. The ability to perform such a composite from model output would also provide the capability of performing reliable comparisons between model and observations in a statistically robust fashion.

Specific infusion opportunities are listed below, with potential roadblocks provided when applicable.

1. *As a platform for more informed and organized tropical weather discussions.*

Many of the observation and model fields provided in the TCIS are commonly used in this discussion. However, some additions would further help facilitate its use in this format. Most of the improved capabilities should focus on the modeling component. For example, more operational model tracks need to be provided. One commonly used diagram is the spaghetti plot showing the five plus day tracks from various models/ensembles. The time interval needs to be reduced to six-hourly, and 1200 UTC model runs should also be included. Without more extensive model forecast information, the presenters of the discussion may not feel the need to use the portal when much of the observational information is available from other sources, such as the NRL TC page.

2. *As a platform to facilitate 1) post-mortem discussions on cases, particularly those that involved aircraft missions and 2) mission-planning decisions before, and during, an aircraft mission.*

The two points above mostly pertain to the observations available on the portal. Satellite observations, in particular, provide critical information that is used during mission planning, hazardous weather avoidance and post-mortem analysis for the context of events that were encountered during the flight. Although bandwidth is a significant liability, a “lightweight” version of the portal could possibly be used on an aircraft for coordination/flight planning purposes. Most of the satellite observations needed for this format are already available; however, the addition of a user-defined looping tool may be required.

3. *As a convenient educational tool for teachers to provide informative discussions in a classroom setting, and to enable students to write reports on recent or past events. Examples of case studies (like those shown in the “Introduction/Overview” document) can help facilitate this.*

The portal can be a quick and useful tool for students to report on events, since it does not require downloading/manipulating data. Under this pursuit, however, the documentation needs to be simplified, shorthand notation explained and instructions clearly provided within it. Example case studies can be made available on the webpage to guide students toward an effective use of the portal.

4. *Offer information on the webpage for a pathway for potential collaborators to communicate their interest in integrating their products onto the TCIS.*

Users should be considered a source for potential new product/analysis tools for infusion to TCIS. They could provide them directly, or recommend additions. Either way, an email form should be clearly available on the webpage to allow users to offer this advice and feedback.

5. *Consider working more closely with other groups that provide similar data, in particular, the group that operates the Naval Research Laboratory’s (NRL) Tropical Cyclone Page.*

The NRL TC webpage is arguably one of the most widely used sources of satellite information available within the community. While it is the most comprehensive source of satellite data, the visualization capabilities are limited to static images. The archive/visualization capabilities and analysis tools provided within TCIS are a logical compliment to the wealth of data provided by NRL TC.

Summary of Technology Infusion Roadblocks

The following table is a list of comments, questions and suggestions to improve TCIS utility.

Action Items
1 Labels for the images, including a clear display of the dates and times of the images.
2 Link the selection of the model or satellite observations times together so that when you choose one the other selects the closest comparable data from the other. For example if you select a storm at a certain data and time from the satellite observations, it would be helpful to have the appropriate model run automatically displayed. Right now, the user selects one and then has to go and adjust the data and time on the other to match.
3 Display model output initial conditions. The models run at least twice per day, yet there is only one set of model output per day.
4 Better descriptions of the products listed to be displayed, while avoiding acronyms that may not be familiar to all users. Addition of some type of “what’s this?” kind of utility would also

help.
5 Color tables for most variables displayed are too small, and hidden at the top left or top of the images (and for the model variable they cover the time at the top of the display).
6 When changing storms the previous selected satellite or model products should be cleared out.
7 There should be a way to overlay things like lat/lon, or at least to get that information when you pass the mouse over specific locations.
8 Provide the option to compare model and observations in a storm-relative framework, and provide the ability to do difference calculations.
9 For model-derived shear plots, it would be good to see the shear vectors (or streamlines) in addition to the shear magnitude.
10 Is it possible to calculate CFADs using a tool similar to the joint PDF one? After all, a CFAD is similar to a joint PDF, it's just that one of the variables is altitude.
11 For the wavenumber analysis, is there a way to automatically center the grid to a user-specified storm using the best track or ARCHER centers?
12 The aggregation query is nice, but it would be better if it could aggregate in a storm-relative framework, e.g., motion-relative or shear-relative.
13 The specific time of the observational data is not clear, as the tool simply lists the "Ending Hour" of the data. What period of time is being shown for the data and when does it get updated? The product would probably also benefit from having the overpass time of the TC shown. That way a user can more readily compare another dataset to that overpass time. Without knowledge of the precise time of data in a certain region, the user may not be comparing datasets correctly. For instance, if a comparison with model data is required, how will the user know which lead time to select that is most close in time to the satellite data? Time of the flight track is also not displayed, which means a user cannot relate other data available in the product to what they see in the instrument data (e.g., from HAMSRS). This is really the most critical issue with the current configuration of the portal: the lack of precision in the timing of observations does not facilitate a proper comparison with model fields, which has been defined by the developers as one of the main goals of the project.
14 The evaluator was not able to work the ARCHER tool. The "dataset" prompt always said, "N/A", despite having the Rain Indicator selected in the tool bar, which is what the bubble that appears when selecting the ARCHER tool instructs. It also not clear how the ARCHER center ties in with the other analysis tools. In other words, does the center fix selected by the ARCHER algorithm feed into the other analysis tools (i.e., the wavenumber analysis)? If not, then wouldn't this be a useful capability? Also, can the ARCHER centers be provided for 37 GHz? It looks like only the 85 GHz is provided. The liquid emission signal would likely be a better center estimate (lower in the troposphere) than the one from the 85 GHz ice scattering (preference for higher in the troposphere).
15 It would be helpful if the wavenumber symmetry analysis could be done using individual frequencies instead of just the rain indicator for all frequencies. As currently quantified, it appears to be biased towards the scattering channels and heavier rain. Recent research has demonstrated the importance of symmetry in the shallow/moderate precipitation (convection) distribution as important to TC intensification. The implication of this result is that data from the emission channels (19, 37 GHz) may also be relevant. Regardless, quantifying the symmetry for wavenumber-0 and -1 for each individual frequency (19, 37, 85-91 GHz and also PCT, perhaps) could be explored.
16 Evaluator did not receive an email of results when using the "Aggregation Query" tool, and thus was not able to evaluate this tool.

17	The lat/long grid does not overlay on top of the data, even when the opacity is set to zero.
18	IR, VIS, WV images should include a specific time somewhere. This is particularly important for the "IR 2 Day Animation."
19	The cyclone track should probably be available for overlay at all times. There were instances where data is overlaid on top of the track, and thus not visible
20	"RI_MULTI" under the Wave Number Analysis dataset should probably spell out, "Rain Indicator", as this shorthand notation is not used elsewhere.
21	It would be helpful if the two calendars (observations and models) were synced
22	The error messages need to be simplified and more informative for the user. Recommendations could also be provided to the user in the message, which would offer advice on how to make the request work properly, at least for the obvious mistakes a user may make.
23	The user should be able to define the period for IR and TPW loops, rather than the pre-defined two-day period already available.
24	The navigation list on the "Model and Simulation Data" bar disappears when resizing the window. The user has to minimize the navigation bar and open it again to make it work with a resized window.

Test Plan

The test plan agreed upon by the evaluators and PI simply involved manipulating the portal (Cesium-based NAHW) and the analysis tools for some recent hurricane cases. The main webpage, as well as the "Introduction/Overview" documentation provided to the evaluators, was also considered in the evaluation. Each evaluator performed an individual assessment of the evaluation components; the team then met to review each assessment and discuss the overall evaluation of the TCIS.

Evaluation Summary and Conclusions

The evaluation has determined that the TRL level 6 is appropriate for the current state of the TCIS technology. The evaluation team was generally successful in testing the TCIS components. The TCIS developers should continue to build on the available models in the framework, as well as other model simulated satellite observations to allow for more comparison opportunities. Additionally, the documentation provided, while comprehensive, should be better organized with sections more clearly separated and succinct instructions provided for basic use of the portal and associated tools. A detailed list of recommendations for fixes and additions are provided in section five.

The main concern, however, is increasing the number of users of TCIS in the future. The developers should accumulate user metrics, perhaps through a registration process, in order to understand their current users and identify areas for improvement. Infusion opportunities are listed in the evaluation, but one possible, simple route for increasing usage is to identify a pathway for users interested in collaborating (offering to adapt their product or analysis tool into TCIS), to communicate their interest to the developers (e.g., a link or form on the webpage).

TRL Evaluation Structure

To support a structured review of this project, ESIP provided the evaluation team with detailed evaluation criteria and TRL-dependent criteria weights that are documented in the [TRL Evaluation](#)

[Worksheet](#). The evaluation criteria included question groups related to the (1) Usability, (2) Sustainability and Maintainability and (3) Fitness of the project. A total of 237 individual evaluation questions were addressed.

Complete TRL Evaluation Worksheet

Each member of the evaluation team completed and annotated a TRL Evaluation Worksheet. Each evaluator's worksheet is available here:

- [TRL Evaluation Worksheet 1](#)
- [TRL Evaluation Worksheet 2](#)
- [TRL Evaluation Worksheet 3](#)