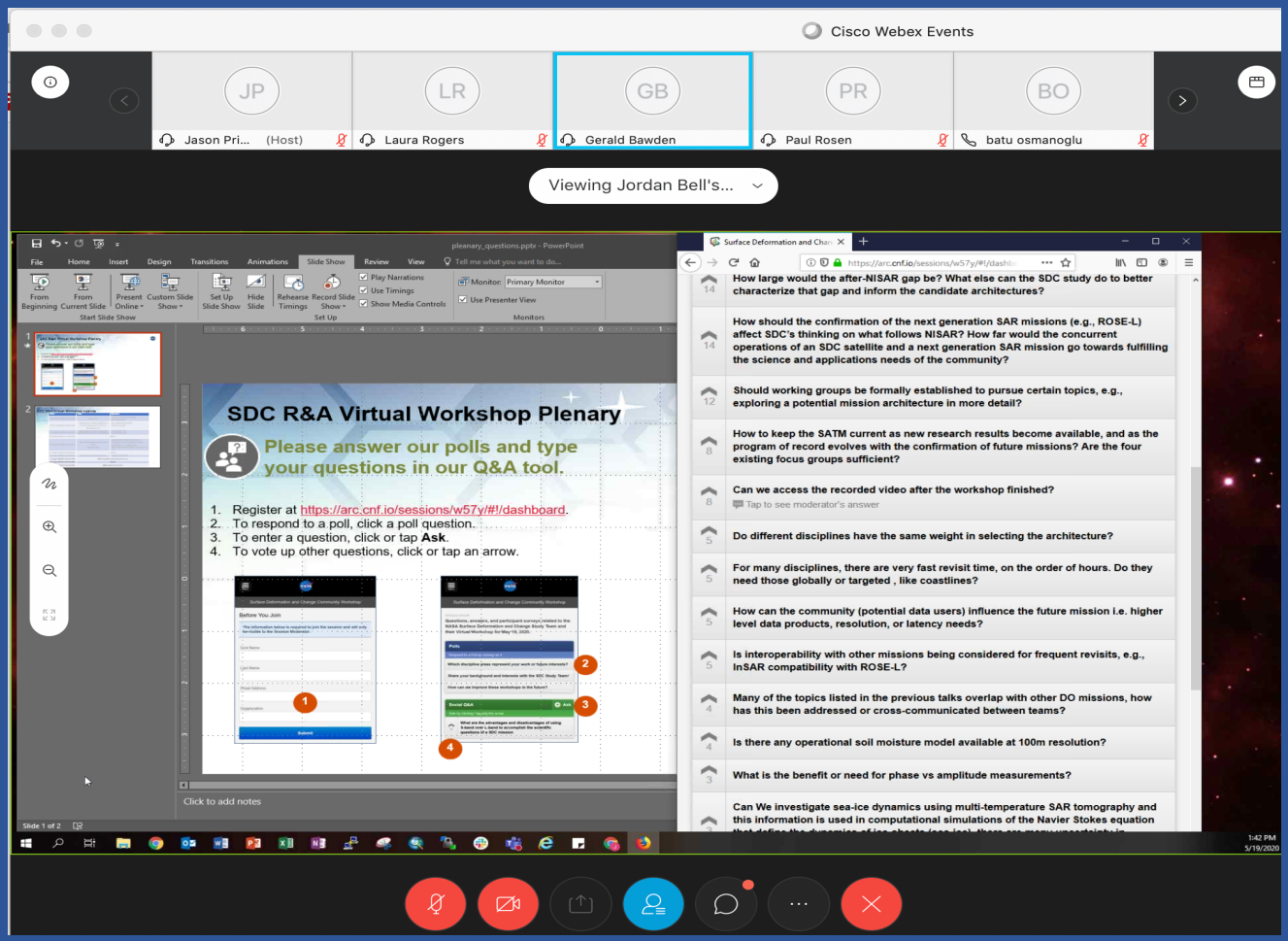
Surface Deformation and Change

Second Research & Applications *Virtual* Workshop

Tuesday, May 19, 2020

Workshop Report



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Overview

The Research and Applications Team of the Surface Deformation and Change (SDC) Study held its second workshop virtually (via WebEx Events) on the same date that an in-person event was planned at Caltech. We postponed that in-person meeting indefinitely because of pandemic-related restrictions on travel and large gatherings. Roughly 450 participants registered for the virtual event, and attendance peaked at around 250 during the workshop itself. That number is nearly three times the attendance of the First SDC Research and Applications workshop that took place between April 29 and May 1, 2019 at Caltech in Pasadena, California. That first workshop's report can be found here (link).
Our main goal of the Second Research and Applications Workshop was to present and discuss the status of the SDC Study Plan. The workshop presented inputs from SDC's four focus groups on research and applications needs and desired capabilities (see workshop agenda below). The workshop also provided an opportunity to share with the community the assessments of the Performance Tool, and preliminary SDC architectures.

Workshop Recording and Presentations

A complete recording of the workshop (with closed captions) can be found here (link). The meeting agenda, included at the end of this report, gives the details of the three workshop session recordings posted at this link.

We can provide the slides of the individual presentations upon request. To make a request, please use the contact details given at the recordings link above.

Next Steps

- Further refine, enhance and nuance current drafts for scientific discipline focus areas comprising the SDC Science and Applications Traceability Matrix (SATM), particularly, the geophysical observables. The focus areas are Solid Earth/Geohazards, Cryosphere, Hydrology and Ecosystems. Obtain assessment and review from SDC senior management and the broader community.
  Rationale: For each geophysical observable we provide the desired measurement parameters (e.g., spatial resolution; accuracy) such that SDC Architecture Team can evaluate how well given SDC architectures can meet those measurement parameters. More generally, the SATM distills the scientific and application desires and needs of the community. It clearly presents the flow from Science Goals to the Science and Application Objectives needed to realize those goals, and then to the Geophysical Observable needed to achieve those objectives.

- Identify 5-6 thematic application areas related to the potential geophysical observables and assemble preliminary information about the applications community to support the required Community Assessment Report.

Rationale: We are seeking a fresh look and outside input to identify new end users. SDC will uniquely provide new capabilities that could open pathways for new applications, hence the need to explore those potential applications and their intended end users. We therefore plan to expand beyond the previous applications identified by the NISAR team with a focus on applications that take advantage of the InSAR observations as well as new SDC technological developments. An independent contractor selected by NASA is working with the SDC team.

- Work with Performance Tool (PT) team to identify missing science assessment tools. Identify sub-teams to produce the needed input science models.
  Rationale: We need a broader range of tools to evaluate the expanded potential architecture and the science and applications that would be made possible by them. SDC's PT helps in assessing the feasibility of a given observable, hence quantifying the efficiency of each candidate architecture in realizing the desired capabilities described in the SATM. The PT is a simulation package that takes as inputs the target (points on the ground corresponding to global or targeted coverage), the architecture (viewing geometry, data acquisition repeat time, beam parameters, orbits), and a model (noise parameters related to EM wave propagation delays; data correlation; target surface conditions such as snow and vegetation cover). PT's output is seasonally-dependent coverage and measurement uncertainty over a set of ground targets.

- Establish coordination between the SDC study and the UAVSAR Program.
  Rationale: UAVSAR may serve as an airborne platform with capabilities complementary to a future SDC mission. This complementarity would be similar to how the high-resolution L-band SAR observations that UAVSAR has been providing served as a forerunner to the NISAR mission. The workshop was held in coordination with the "2020 NextGen Airborne SAR" workshop, of which the details can be found here (link). UAVSAR, a reconfigurable, polarimetric L-band synthetic aperture radar (SAR), is specifically designed to acquire airborne repeat-track SAR data for differential interferometric measurements. Since 2018, UAVSAR facility instrument suite has been enhanced with two additional bands: P-band (AirMOSS) and Ka-band (GLISTIN-A).

- Solicit input and feedback from the Satellite Needs Working Group (SNWG) during their current 2020 input cycle. The SDC R&A team contributed to a one-day SNWG discussion focused on SDC in early July, 2020. We will assess the SNWG's community needs and consider including some of their recommendations into SDC's assessments.
  Rationale: SDC is interested in finding how its SATM aligns with SNWG's anticipated needs, either explicitly or implicitly. New or amended SATM entries from SNWG community members can influence the range of mission architectures and their overall value to the science and applications community. The SNWG conducts a biennial survey to formally document and communicate satellite Earth-observing needs to NASA and other space-based Earth observation providers regarding the data each agency needs to accomplish its objectives. The agency survey is conducted to identify potential data gaps in the current NASA program of record and/or data sets that meet agency needs.

Plenary Discussion Notes

(From discussions during Session 3 of the workshop. Notes have been edited for clarity)

Question: *What are the advantages of using S-band over L-band?*

Paul Siqueira, University of Massachusetts Amherst and SDC Ecosystems Focus Area Lead: From the ecosystems point of view, an S-band mission would offer the potential of making multi-frequency observations (complementing the program of record, since NISAR, ALOS-4, and potentially ROSE-L are going to be L-band). Dual frequency measurements have interesting applications. However, in general, longer wavelengths are better for the measurements relevant to ecosystems. S-band alone has not really been explored.

Paul Rosen, JPL and SDC Study Team Lead: The wavelength of S-band that we are allowed to use is about 9 cm. C-band is 6 cm, and L-band is about 24 cm. So, S-band and C-band are pretty close together - we don't know how different S-band measurements actually are from C-band. There might be a "knee in the curve", which would make S-band observations optimal, but so far there is no evidence of that. One could argue that S-band data would be similar to C-band data that already exists, whereas L-band would make a big difference. L-band data from the SDC mission would be more available than it is now, from currently-operating missions.

In general, L-band has the advantage of remaining correlated over longer times. S-band would be better than L-band for ionosphere. We will see clearly the differences when NISAR is in orbit acquiring L-band and S-band data simultaneously. From a hardware perspective, S-band is easier because antenna can be made smaller. However, from a cost perspective, given that many of the systems that are launched tend to be unique, it's not clear how much of a differentiator that will be. Steve Horst can comment on that.

Stephen Horst, JPL, and SDC Technology Lead: Moving from L-band to S-band is notionally cheaper, but not significantly.

Question: *How far do existing missions go towards fulfilling the needs of the community?*

Paul Rosen: For many applications, where C-band remains coherent, you can think of NISAR + Sentinel as two missions where one doubles the coverage and observation frequency of the other. There are specific observations where even higher repeat times would be preferable - some people are advocating for sub-daily repeat and global coverage. Those two systems go a long way toward that goal, but not all the way. Also, NISAR will not continue forever, so we are looking for post-NISAR instruments that will provide continuity with Sentinel.

Susan Owen, JPL, and SDC Solid Earth Focus Area Lead: This was a question that I was asking myself when putting together the slides: what do we really need to advance science beyond NISAR and Sentinel?

John (JT) Reager, JPL and SDC Hydrology Focus Area Lead: From the hydrology side, sub-daily repeat times could open up much more exciting science. For many applications, however, continuity is most important. There is science that can benefit from either improved measurements or just improved continuity.

Paul Siqueira: The idea of formation flying and something like a Tandem-L mission would have a major advantage for ecosystems.

Alex Gardner, JPL and SDC Cryosphere Focus Area Lead: Our highest priority is continuity - it is necessary to continue the science that we've been doing. But innovation in both resolution and accuracy can allow us to tap into new questions. There are large benefits to increasing capabilities.

Gerald Bawden, NASA Headquarters and SDC Program Scientist: Sentinel is a right-looking mission, NISAR is a left-looking mission. This has an impact on coverage: with the two missions combined, we get coverage at the poles. In addition, this means we can have more diversity in look directions – this will allow us to resolve 3-D deformation better with the two combined missions than with each one of them alone.

How should the confirmation of the next generation SAR missions (e.g., ROSE-L) affect SDC's thinking on what follows NISAR? How far would the concurrent operations of an SDC satellite and a next generation SAR mission go towards fulfilling the science and applications needs of the community?

Paul Rosen: ROSE-L as it's conceived is an extremely capable mission, which has a lot of functionality for both radiometric and deformation measurements. It is similar to the Sentinel-1 C-band mission. Duty cycle is still being decided, but it will probably be similar to NISAR, covering all land and ice surfaces. They will probably have it achieve maximum repeat in Europe, and fewer observations in the rest of the world, but maybe that can be changed if we negotiate with ESA. Essentially, ROSE-L is like two NISARs. From a continuity perspective, if ROSE-L launches when NISAR is completing its mission, you can argue that we will have continuity out to the end of the Copernicus era, which is a program with a multi-decade commitment. It is not clear yet whether ROSE-L will be realized, and whether it will have the full capabilities that have been discussed, but it is a very promising mission.

Question: *How large would the after-NISAR gap be? What else can the SDC study do to better characterize that gap and inform the candidate architectures?*

Paul Rosen: The plan at NASA is to start with 3 years of NISAR observations, and then to extend that should the system be healthy and the science is still compelling. ISRO's plan is to operate it for 5 years - this probably means that we will operate it minimally for 5 years. That said, the resources on board the spacecraft should be sufficient to be able to continue the deformation time series and surface change time series well past ten years. Taking into account the end of life capabilities for solar arrays and batteries, a ten-year mission should be possible. I don't expect that there will be a gap between the SDC mission and NISAR - of course, if ROSE-L is there, then there definitely won't be a gap. One thing we can do in our study is to consider some architectures that are agile toward a launch sooner than later - perhaps those would be emphasizing new

capabilities that could work with ALOS-4 or Sentinel-1, but could add a new dimension toward observations, while we wait for a new mission to be developed. But we are not currently planning for a gap.

Gerald Bawden: Second slide in my presentation showed the NASA fleet. Almost all of them are in extended operation - all of them are still functioning past their 5-year plan. If we have to do a lot of maneuvers with NISAR, that will use up some of its resources, but NASA and ISRO are planning to keep the satellite in operation as long as possible.

Question: *Should working groups be formally established to pursue certain topics, e.g., exploring a potential mission architecture in more detail?*

Stephen Horst: We have been having some preliminary meetings for architecture discussions, and would like to engage the scientific focus groups more. Laura Rogers has set up a first meeting for that in another week.

Paul Rosen: We have a multi-NASA-center team, headed by Stephen. You can already think of that as a working group for evaluating architectures. Adding other participants would be possible, but in terms of the architectures we are in pretty good shape. We have enough working groups that are satisfying our needs at the moment.

Stephen Horst: We are looking for feedback from the science community (from existing focus groups) for what metrics we should be considering for performance evaluation.

Paul Rosen: To summarize: not sure we need more focus groups, but we are open to suggestions.

Question: *How to keep the SATM current as new research results become available, and as the program of record evolves with the confirmation of future missions? Are the four existing focus groups sufficient?*

Paul Rosen: It is already going to be difficult to meet the needs of the existing four focus groups in a balanced way with just one mission, and adding more focus groups will make it even more difficult. If we can leave it at four, that would be best - maybe subdividing them into smaller topics could be useful, but this is for the focus group leads to decide. In terms of keeping the SATM current - Ala and his team will comment.

Andrew Molthan, MSFC, and SDC R&A Team Co-Lead: We've got inputs from focus groups, and we will consolidate them into an updated SATM. We might be able to have additional follow-ups with different disciplines. We plan to have an AGU town hall in 2020 to update the community. We are working on engaging the private sector to assess Applications needs.

Question: *Do different disciplines have the same weight in selecting the architecture?*

Stephen Horst: Yes - at the moment, there is no favorite discipline in terms of the focus groups. We need to come up with a value framework for our down-selection process, which will start around this time next year.

Paul Rosen: It is difficult for different disciplines to agree on the relative importance of their science. We will likely end up relying on NASA to look at their entire portfolio, and come up with some kind of evaluation based on political, financial, and other considerations. One possible weighting you can consider is cost - for some disciplines the volume and complexity of the data is much higher than for others, and if that volume and complexity kicks the measurement out of the cost bracket, we will need to weight that down, simply because we cannot do it. With ROSE-L in the mix, that can change the game entirely in terms of our architectural decisions. Cost is the bigger weighting factor than science.

Gerald Bawden: With each of the different DO studies, NASA has asked us to come up with a range of architectures that would address the science goals in the Decadal Survey. We were also asked to come up with additional questions that have not been defined in the DS. From a large trade-space, we will come up with a handful of architectures that address these science questions. NASA will be trying to gain as much science as possible for their investment. The agency will be looking for other partners who would be able to contribute to the mission. Maybe we can take advantage of what other agencies have planned, maybe there can be co-flying missions, maybe there can be complementary measurements, like tropospheric vapor. We also have to take a look at the politics of the time. There will be other considerations beyond science.

Question: *For many disciplines, there are very fast revisit times, on the order of hours. Do they need those globally or targeted, like coastlines?*

Alex Gardner: For the Cryosphere, continuity is the most important. The places where we want to have faster repeats - those acquisitions are targeted to areas where the ice sheet interacts with the ocean. They are not necessarily needed for the entire ice sheet. So, we do consider that when thinking about resolution and revisit.

Susan Owen: For Solid Earth and Geohazards, in theory much of the interest in fast repeats would be over a particular area at a particular time. For example, an erupting volcano, or capturing post-seismic deformation after an earthquake. It's tough, however, without global coverage prior to the event, to make those observations meaningful. It would be ideal if there can be an architecture that would provide global coverage but also have a quick-response mode. For some applications, like volcanoes and landslides, we want capabilities for identifying future potential activity, and that starts to look very global.

Batuhan (Batu) Osmanoglu, GSFC, and SDC Study Phase 1 Co-Lead: With the advance of smart tasking and having many satellites instead of one, we might be able to direct acquisitions to certain areas just in time, but that will not address the points addressed earlier about having the precursory information.

Paul Rosen: Even if we are looking for observations in targeted areas, such as coastlines - coastlines are highly irregular and don't follow orbits, so everything needs to be designed for global accessibility, in any case. That tends to drive the overall cost of the system.

Gerald Bawden: This is an opportunity for some of the commercial-based SAR - we can try working with commercial vendors for higher, possibly sub-daily sampling, while using the SDC mission to have a global view.

Question: *Is interoperability with other missions being considered for frequent revisits, e.g., InSAR compatibility with ROSE-L?*

Stephen Horst: Yes, it is very much being considered. However, getting international agreements can be complicated. ROSE-L has indicated that any cooperation that we would have with them would not be allowed interfere with their timelines, goals, or objectives.

Paul Rosen: There is a strong desire for multiple L-band missions to coordinate with each other, because of interference between them. We already see that interference with C-band missions. China is launching a Tandem-L type mission, and JAXA has their L-band missions. All of them have the potential of interfering with each other. Restrictions on use of L-band are getting greater, the FAA are concerned with having multiple L-band satellites, and are lowering our power levels. This consideration should be part of the trade space.

Question: *Many of the topics listed in the previous talks overlap with other DO missions, how has this been addressed or cross-communicated between teams?*

Paul Rosen: NASA has encouraged each of the DO teams to communicate with each other in order to find synergies in technology or observation strategies, to achieve their optimal science, reduce the cost of the science, or augment the science. We have identified liaisons - many of the people on our team participate in several teams, and have firsthand knowledge of what is going on in those other teams. From a practical perspective - some of the other DO missions will be launching much sooner than SDC. Because of the peculiarities of their own partnership scenarios, and instrumentation on board, it is challenging to synergize observations. Since we have a longer time horizon, our approach is to look at what other studies are doing, and factor that into our architectural decisions. For example, if there were a way for one of these missions to provide better weather models or water vapor data, to provide a way for us to correct tropospheric noise, that might influence our decision for how many satellites we need, or how frequent our sampling should be.

Gerald Bawden: If we look at the overall DO portfolio, the synergy sweet spot for all four missions is somewhere mid-decade. It is otherwise really hard to have direct synergies with these other missions.

Question: *What is the benefit or need for phase vs amplitude measurements? Since phase information is key to so many SDC observables, what were barriers to prior missions incorporating tropospheric delay measurement into their architectures?*

Paul Rosen: Answering first part of the question: phase is mostly used for geodetic imaging, e.g., surface deformation, whereas amplitude measurements are typically used for characterizing other geometric or dielectric changes on the surface of the Earth.

There is, obviously, overlap where phase and amplitude measurements can be used across disciplines.

Stephen Horst: Answering the second part of the question: The concept for removing those errors is taking different paths through the atmosphere simultaneously. Almost all current candidate missions would not have had that capability.

Paul Rosen: Prior missions like NISAR were science-driven, and the observation strategy was designed for fast sampling to improve the accuracy of the measurement in light of tropospheric variability. A large portion of the data is acquired in order to mitigate this tropospheric delay. You can say that this is an architectural decision for NISAR, employed in order to take into account tropospheric measurements. Other SAR missions have not been driven by science requirements the way NISAR and SDC have been - they are either operational or capability driven, so the need to incorporate water vapor measurements has not been a priority for them.

Question: *When we can expect Full polarized L and S band data under NISAR mission over the Indian region?*

Paul Rosen: The full-pol capability of NISAR is currently planned over India, Alaska, and a few other areas. Those data will be available both in India and the US within about three months after NISAR launch. There will be six months of preliminary data, after which final calibrated data sets will be available. We are talking about some time in 2023.

Question: *How can the community (potential data users) influence the future mission i.e. higher-level data products, resolution, or latency needs?*

Susan Owen: For Solid Earth and geohazards, you should reach out to me or Cathleen Jones. There are ways to contact the SDC study group through the NASA webpage as well. Contacting the folks who are chairing different SATM groups to provide feedback is a good idea.

Batu Osmanoglu: The SDC study emailing list is on the NASA website. If you send an email to the team with your intent, we can forward it to the correct person if you don't know the person who is in charge of your discipline.

Batu Osmanoglu: Want to emphasize that we value community input a lot - we really want to hear about your interest. The questions and comments you make are really valuable.

Question: *How many more R&A workshops are we planning?*

Paul Rosen: Through the next 3.5 years there should be at least one per year. Even after we have begun evaluating potential architectures, we would like to keep the community involved. There could be a time in the future when we have to make pretty difficult decisions - in line with the question of weights on different disciplines. The R&A community plays an important role in how we move forward in architecture selection.

Gerald Bawden: I support Paul's perspective. As we begin to identify the missions to be presented to NASA HQ it would be nice to have community feedback on the architectures. The best way to get that is through these interactive workshops.

Question: *When do you lock the SATM for SDC?*

Paul Rosen: The goal was to lock it after this workshop, so that we can focus mostly on architectures. But locking the SATM is a soft thing - if something new comes up, we will be accommodating. Most disciplines have been pretty stable, although some disciplines were added recently. The plan was for us to be putting the finishing touches on the SATM in the next few months.

Andrew Molthan: We are putting together a full package now with the help of focus groups.

Question: *What role does new technology play for SDC?*

Stephen Horst: We are putting together a technology roadmap - if you know of any other technologies that will help address questions in your discipline, please let us know.

Question: *Are there any simulated datasets for NISAR observations?*

Paul Rosen: Yes, and they are based on UAVSAR observations. If you go to the UAVSAR website, you can search for "simulated-NISAR", and there you can find all the simulated datasets that we have produced. India has also flown (in the US, on a US platform) their simultaneous L and S band instrument. Since it is a new platform and since there has been a COVID-19-related lockdown, the release of those datasets has been delayed, but the preliminary results are very interesting and the data should be released soon, probably also through the UAVSAR website.
(A link was provided through the chat box)

Question: *Is there any plan to use W-band?*

Paul Rosen: People are looking at it for both atmospheric and land applications, where you can get through the atmosphere. However, for the kinds of things we want to do for SDC, it might not be a practical band. It is difficult to get coverage and do InSAR with this band.

Workshop Agenda
(All times in PDT)

8:30 AM (5 min) Welcome and Meeting Plan and Rules (*R&A Team: Jordan Bell*)

Session 1 *(R&A Team Moderator: Jeanne Sauber and Ala Khazendar)*

8:35 AM (15 min) Why SDC (Gerald Bawden/Paul Rosen)

8:50 AM (20 min) SAR Thus Far: SDC's Program of Record (PoR) and its Recent Developments (Batu Osmanoglu)

9:10 AM (15 min) Spreading its Wings: UAVSAR's Capabilities and Future Directions (Yunling Lou)

9:25 AM (10 min) Break

Session 2 *(R&A Team Moderator: Jordan Bell)*

9:35 AM (60 min, 4 talks, 15 minutes each): SDC's Contributions to Science and Applications
Cryosphere (Moderator: Alex Gardner)
Ecosystems (Moderator: Paul Siqueira)
Hydrology (Moderator: J. T. Reager)
Solid Earth and Geohazards (Moderator: Susan Owen)

10:35 AM (10 min) Break

Session 3 *(R&A Team Moderators: Andrew Molthan and Laura Rogers)*

10:45 AM (20 min) Tentative SDC Architectures (Steve Horst)

11:05 AM (40 min) Plenary Discussion (All previous speakers/R&A Team)

11:45 AM (5 min) Break

11:50 AM (40 min) Mic's Open with Paul Rosen: Dialogue with the SDC Study Coordinator

12:30 PM End of Meeting