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COORDINATION OF PLANETARY COORDINATE SYSTEM RECOMMENDATIONS BY THE IAU WORKING GROUP ON CARTOGRAPHIC COORDINATES AND ROTATIONAL ELEMENTS—2020 STATUS AND FUTURE

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ABSTRACT:

Our goal is to request input from the lunar and planetary community regarding issues of planetary coordinate systems and cartography standards. We begin with an overview of the work of the International Astronomical Union Working Group on Cartographic Coordinates and Rotational Elements. We briefly describe the operations and membership of the Working Group, some of the various uses of the recommendations it makes, our most recent (2018) published report and the recommendations therein, and the outlook for our next such report. We then consider several issues and questions regarding the future of the Working Group and regarding planetary cartography and planetary data spatial infrastructure in general. This includes possible near-term projects, how we and others might collect and consider community input and includes some ideas regarding possible outcomes or future work that will need to be addressed by the Working Group or other organizations.

1. OVERVIEW

Approximately every 3 years since 1979, the Working Group on Cartographic Coordinates and Rotational Elements (hereafter the WGCCRE) a functional WG of the International Astronomical Union (IAU) has issued a report following most IAU General Assembly (GA) meetings. The report includes recommendations on coordinate systems and related parameters (body orientation and shape) that can be used for making cartographic products (maps) of Solar System bodies. These recommendations, which are open to further modification when indicated by community consensus, are intended to facilitate the use and comparison of multiple datasets by promoting the use of a standardized set of mapping parameters for all Solar System bodies.

This paper includes first a summary of the WGCCRE's works in 2018-2020, including a description of our report published in 2018 (Archinal et al., 2018) and a 2019 correction (Archinal et al., 2019c). Next, we look to the future of the WGCCRE and that of related organizations focusing on recommendations and standards for planetary mapping. This includes discussion of how

we and others might collect community input as we consider these questions and issues and outlines ideas on possible outcomes or future work that will to be need addressed by the Working Group or other organizations. We end with our usual request for new membership and input on new results to the Working Group.

Additional information on the WGCCRE can be found on our website (<http://astrogeology.usgs.gov/groups/IAU-WGCCRE>).

2. OPERATION OF THE WORKING GROUP

The Working Group consists of 16 volunteers, including C. Acton, B. Archinal (Chair), A. Conrad (Vice Chair), T. Duxbury, D. Hestroffer, J. Hilton, L. Jorda, R. Kirk, S. Klioner, J.L. Margot, J. Oberst, F. Paganelli, J. Ping, K. Seidelmann, D. Tholen, and I. Williams. We are always looking for volunteers to join the WGCCRE to help with each new report. The WGCCRE looks at new determinations of coordinate systems (e.g., body sizes and orientations) that have been published in refereed

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papers and makes recommendations as to which to use based on consensus decisions to the extent possible.

As a volunteer organization, the WGCCRE has no resources to verify results or conduct its own research, so it relies only on published results and community input. For this reason, recommending one set of results over another is sometimes not possible. The WGCCRE cannot verify or endorse any results. The WGCCRE has no enforcement powers, but tries, in reflecting the long-term planetary community consensus, to make persuasive recommendations.

The WGCCRE does not deal with issues related to the formats of mapping products; such issues have largely been left to individual map developers, archiving organizations such as the NASA Planetary Data System (PDS), the International Planetary Data Alliance, or the NASA Mars Geodesy and Cartography and Lunar Geodesy and Cartography Working Groups [MGCWG (Duxbury et al., 2002), LGCWG (Archinal, 2009)] and individual missions. We are communicating with two newer related organizations, IAU Commission A3 on Fundamental Standards, and the NASA Mapping And Planetary Spatial Infrastructure Team (MAPSIT) (Radebaugh et al., 2019; <https://www.lpi.usra.edu/mapsit/>). Input from such organizations is welcome by the WGCCRE and the frequency of interaction highlights the strong need for such organizations at mission, space agency, and international programmatic levels. As pointed out at the 2012 IAU General Assembly (Meech et al., 2012), a substantial body of IAU recommendations exist that have been developed over many decades of input by IAU members, national space agencies, and other institutions. We strongly urge those who work with planetary data to follow such recommendations or to present well-reasoned arguments why they should be changed. The IAU and its Working Groups stand ready to help authors, journal editors, instrument teams, and missions to understand and follow IAU recommendations.

In general, during its 44-year history, the WGCCRE has not been directly involved in holding broad scientific meetings. However, in 2019 the WGCCRE, with other components of the IAU, including Division A Commissions, submitted a proposal to the IAU to hold a symposium in 2021 at the IAU General Assembly in Busan, South Korea. The proposed title is “Reference systems and their ties with the rotation of the Earth and other Solar System bodies.” This would be the first such meeting to our knowledge to broadly discuss the theory and practical aspects of both terrestrial and planetary reference systems, frames, and body rotation.

3. RECOMMENDATIONS AND THEIR USES

The recommendations included in the report are intended primarily to serve as the basis of mapping of all Solar System bodies other than the Earth. Hence, the “cartographic coordinates” is part of the WGCCRE’s name. The goal is to allow data concerning a given body, as obtained from different missions and instruments from different space agencies and nations, to be registered together to allow comparison and joint use of the various datasets. Such mapping products are critical not only for scientific use and comparison of datasets, but also for critical operational uses such as navigation to, near, and on the variety of Solar System bodies and planning observations. The use of these standards recommendations, themselves a component of planetary data spatial infrastructure (PSDI, see Laura et al., 2017 and further discussion below), allows for the creation of PSDI foundational and framework data products, i.e., essential mapping products for any planetary body. A description

of such products and a brief listing of such products for large Solar System bodies is given by Laura et al. (2018a).

The WGCCRE also provides general guidelines about planetary coordinate systems including information on how to set up specific coordinate systems and frames for bodies based on availability of initial datasets, and how to update them as new data become available. Numerical recommendations are made as to the best consensus values which describe a body’s orientation and shape. Such values can then be used with existing and new data when processing of the latter data is not expected to improve on those values, or where, at least initially, early registration of new data is desired with existing data products created following the recommendations. When new data are used to derive better values for a reference frame definition, the recommended values still have use as a reference to see what the magnitude of the changes (and often uncertainties) are, and to help estimate the magnitude of likely discrepancies in positional information of existing cartographic products.

An important point to consider in this process is that some recommendations and recommended values or constants are based on physical attributes of a given body. These include spin pole position (for latitude determination), spin rate, size, and shape. Other values, such as the origin for measuring longitude, must be based on arbitrary definitions, which emphasizes a strong need for the international coordination role that the WGCCRE provides.

The WGCCRE reports also provide important definitions and terminology that must be coordinated internationally among the spacefaring nations. Such coordination avoids confusion and expensive and time-consuming re-projecting and conversion of datasets and formats.

Of course, recommendations in the WGCCRE reports have served many other important purposes not necessarily directly related to mapping. These include making observation geometry calculations of Solar System bodies, and the general comparison of properties of various Solar System bodies relative to each other and even to exoplanets, regarding rotation velocity, length of day, pole position, object size, shape, density, and other related properties.

One practical way to implement the use of WGCCRE recommended quantities is through the use of “SPICE” routines and data (“kernel”) files from the NASA Navigation and Ancillary Information Facility (NAIF; <https://naif.jpl.nasa.gov/naif/>, Acton, 1996). Other organizations and companies that have developed commercial software for mapping also often provide methods to use recommended values—particularly for body shape—following WGCCRE recommendations.

4. THE 2018 REPORT AND CORRECTIONS

Our current report (Archinal et al., 2018, 2019c) is available on our website (<http://astrogeology.usgs.gov/groups/IAU-WGCCRE>) and the *Celestial Mechanics and Dynamical Astronomy* publication website (<https://link.springer.com/article/10.1007/s10569-017-9805-5>). Here, we note several general changes. First, the WGCCRE has reworded and clarified its recommendations regarding updating longitude systems. Second, mission and community input indicate a need for the WGCCRE to differentiate between planetary body shapes and sizes for image projection and scientific modeling versus reference surfaces used for elevation

and map projection and scaling. Long-accepted values for the latter are documented for the Moon and are now recommended for Titan. Third, after considerable input from the community, including from New Horizons team members, the discussion of terminology for the poles (and hemispheres) of small bodies has been modified. We now make it clear that cardinal directions can be used informally or as shorthand for directions on small bodies. For example, though such bodies formally have positive and negative poles, the direction toward the positive pole can be called “north” and the direction of rotation “east.” Fourth, updates to the orientation models of Jupiter and Saturn are not recommended at this time, as we await community consensus on a model for Jupiter and results from the Cassini mission regarding Saturn.

See the report for details of changes for other bodies, such as Mercury, Mars (Kuchynka et al., 2014), Phobos and Deimos, Neptune, Ceres, Pluto, and Charon. Changes for asteroids Psyche, Europa, Šteins, and Itokawa, as well as several comets are also included.

In 2019, we also published (Archinal, 2019c) corrections to the report, which primarily corrected the equation for the spin orientation of Phobos.

In the report, we repeated our previous recommendations that planning and efforts be made to make controlled cartographic products. We recommended that common formulations should be used for orientation and size and that historical summaries of the coordinate systems for given bodies should be developed. We pointed out that planetographic systems have generally been historically preferred over planetocentric systems for planets and satellites; in cases when planetographic coordinates have been widely used in the past, switching to the use of planetocentric coordinates has no obvious advantage. We therefore do not recommend changing from planetographic to planetocentric coordinate systems under such circumstances.

5. OUTLOOK FOR THE NEXT REPORT

We are currently compiling our next overall report, as a follow up to the 2018 IAU GA. We expect routine updates to recommended orientation and size models resulting from processing or reprocessing of various planetary datasets, with improvements possible for bodies such as Mercury, Venus, Jupiter, Saturn, Saturnian satellites, Ceres, 67P/Churyumov–Gerasimenko, Arrokoth, Toutatis, Bennu, and Ryugu.

Although lunar ephemerides currently seem to provide the orientation of the Moon with an accuracy of several meters, updates from various groups based on new lunar laser ranging (LLR) solutions continue to be made and improvements should be considered. Another issue is whether to finally base the mean Earth/polar axis (ME) lunar system directly on no-net rotation based LLR solutions for retroreflector coordinates rather than on a specific lunar ephemeris as is done currently. At the 2018 IAU GA, the X2 Cross-Division A-F Commission on Solar System Ephemerides recommended that a new WG should be set up to consider issues related to such updates (Folkner, 2018). However, such a WG has not yet been created, and updates will not be ready for our next report. The WGCCRE urges that such a WG should be formed to consider these issues of lunar orientation, either by the IAU or (like the now inactive LGCWG) by NASA.

For Mars, the recommended orientation model could be updated to that of Konopliv et al. (2016) as formulated by Jacobson et al.

(2018), since this model is based on additional data and improved over the previously recommended system (Kuchynka et al., 2014). A separate issue has been raised that the new systems (Kuchynka et al., 2014; Konopliv et al., 2016; Jacobsen et al., 2018) seem to have a ~100 m offset in longitude at the fundamental epoch of J2000.0 relative to the previous recommended system. Clarification is needed as to the cause of this offset, given the stated intent that “the definition adopted in this paper does not change the position of the prime meridian” (Kuchynka et al., 2014, p. 344). A decision may then need to be made by the MGCWG and WGCCRE, based on community input, as to whether some correction in longitude should be made to these newer models, and perhaps whether such a change should be made in advance of the next report.

A related concern is that Tom Duxbury has stepped down from his leadership of the MGCWG and no one else has agreed to coordinate this activity. The WGCCRE has relied heavily on the MGCWG in the past regarding decisions related to the coordinate systems for Mars and its satellites. We strongly recommend that the planetary community, including NASA and/or other space agencies reinvigorate the MGCWG so that it can discuss and make recommendations regarding coordinate system and other mapping issues, as it had successfully since the 1990s. The WGCCRE may attempt to address the longitude issue without such expert input but given its limited resources has not been able to do so in a timely way.

6. ADDRESSING THE FUTURE

6.1 Future Project Already Identified

The WGCCRE has received multiple requests for a summary of model recommendations made since the formulation of the WGCCRE in 1976 as a table or database. We have also received suggestions that the WGCCRE extend the recommendations in its reports about establishing and updating coordinate systems. These and perhaps other projects may be undertaken given enough volunteer effort.

6.2 Questions for the Future

The WGCCRE began in 1976 and as part of the IAU established fundamental principles regarding planetary coordinates and planetary mapping. After 44 years, some obvious questions naturally arise. Are these principles still adequate? Are changes needed? As one example, for bodies where a longitude definition has been previously defined based on ground-based observations, should that be maintained or extended for spacecraft observations, and if so, how? What are the best methods for recording the fundamental parameters defining cartographic coordinates and rotational elements for well-studied bodies? What procedures need to be further recommended for establishing and updating these reference coordinate systems and frames? The WGCCRE has recommended (Archinal et al., 2018, Section 9) that where planetographic coordinates have been widely used in the past there is no obvious advantage to switching to the use of planetocentric coordinates, as for example apparently planned by the NASA Europa Clipper mission (Phillips and Korth, 2017). This has been based on WGCCRE analysis and input received, but would additional input be useful? If significant portions of the community wish to switch the type of coordinate system, how can this sentiment be determined, and what new recommendations should we make? How could conflicting published information on planetary coordinate systems be addressed in a timely way, particularly when such issues often require substantial research?

Operational questions are also key to future WGCCRE activities. Does the lunar and planetary community understand the need and value of such recommendations and standards? How could such effort be better publicized to further such understanding? What methods could improve input from the community? Is a service, perhaps analogous to the International Earth Rotation and Reference Systems Service (IERS; <https://www.iers.org/>), needed to provide real time support for addressing issues and questions as they arise, and perhaps more quickly updating coordinate system recommendations? Should it be recommended that journals require the proper use of coordinate system definitions (just as some journals currently require proper identifications for meteorites)? How should this work be supported and funded? Presumably, the various space agencies involved would have to agree to support such infrastructure, based on the value of improvements possible for science and exploration and increased efficiency from the use of improved standards and mapping methods. How important were groups such as the now inactive NASA MGCWG and LGCWG? Do those groups need to be reestablished? How? Are separate such groups needed to address coordinate systems, data formats, and products needed for other bodies (e.g., outer planets, Mercury, small bodies)? For example, Nefian et al. (2013, pp. 23-25) point out the need for a Small Bodies Geodesy and Cartography Working Group to coordinate mapping of small bodies. How does all this fit into the recently recognized need to develop planetary spatial data infrastructure (Laura et al., 2017), whether overall or for individual bodies, with Europa as an example (Laura et al., 2018b)?

What types of coordination would be beneficial (and possible) between the existing groups that, to some degree, address the listed issues? These include the IAU itself, other international groups, and the various international space agencies. Because of its long history and number of missions, several NASA-centric groups have addressed these issues in the past and present, although most have included a significant international component (Table 1). These groups and space agencies are already connected to varying extents. Are there cases where strengthening of a formalized relationship would be useful or where new connections need to be established? How would any increased activities be staffed and funded? The benefits of such activities are well known, but likely would need to be better publicized in terms of the critical support provided for planetary science and exploration, e.g., for allowing for safe navigation, registration and comparison of datasets, and supporting landing and surface exploration, operations, and science.

| IAU Groups | |
|--|---|
| Working Group on Cartographic Coordinates and Rotational Elements (WGCCRE) | http://astrogeology.usgs.gov/groups/IAU-WGCCRE |
| Division F Planetary Systems and Astrobiology | https://www.iau.org/science/scientific_bodies/divisions/F/ |
| Division A Fundamental Astronomy | https://www.iau.org/science/scientific_bodies/divisions/A/ |
| IAU Commission A3 on Fundamental Standards | https://www.iau.org/science/scientific_bodies/commissions/A3/ |
| IAU Working Group on Planetary System Nomenclature (WGPSN) | https://www.iau.org/science/scientific_bodies/working_groups/98 |

| Other International Groups | |
|---|---|
| International Association of Geodesy (IAG) | https://www.iag-aig.org/ |
| ISPRS ICWG Commission III/II Planetary Remote Sensing and Mapping working group | http://www2.isprs.org/commissions/comm3/icwg-3-2.html |
| International Cartographic Association Commission on Planetary Cartography | https://planetcarto.wordpress.com |
| International Planetary Data Alliance (IPDA) | https://planetarydata.org |
| Regional and National Space Agencies | E.g., 12 listed at https://planetarydata.org/about |
| Committee on Space Research (COSPAR) | https://cosparhq.cnes.fr/ |
| NASA groups | |
| Mapping And Planetary Spatial Infrastructure Team (MAPSIT) | https://www.lpi.usra.edu/mapsit/ |
| Other analysis and assessment groups | https://www.lpi.usra.edu/analysis/ |
| Planetary Data System (PDS) | https://pds.nasa.gov/ |

Table 1. Groups addressing planetary coordinate system issues and mapping, past and present.

6.3 Near Term Action

To address the questions and issues, the WGCCRE will encourage the discussion of these topics at upcoming meetings. This could be done via presentations, following discussions or perhaps during a Town Hall community meeting hosted by us or others. Possible venues include the “ISPRS 2020 Virtual Event for the end of August” (ISPRS e-mail of April 24), the COSPAR Scientific Assembly on January 28 – February 4 (<https://www.cospar2020.org/>) the Lunar and Planetary Science Conference in 2021 March, the ISPRS Congress on 2021 July 4-10 (<http://www.isprs2020-nice.com/>), and the IAU General Assembly in 2021 August 16-27 (<http://www.iauga2021.org/>), which will include the next WGCCRE meeting. Circulating this paper for comment, both internal and external to the IAU, would be useful. Such groups internally could include IAU Divisions F and A, Commission A3, and the Working Group on Planetary System Nomenclature. External groups such as the NASA MAPSIT, the ISPRS Planetary Remote Sensing and Mapping working group, and the ICA Commission on Planetary Cartography could be included. The WGCCRE might also discuss either formal or informal affiliation with those groups for purposes of further planning.

Other options could be considered for collecting and assessing input but would be dependent on volunteer efforts of WGCCRE member (or others) and possible funding for paid staff work from sources such as the various space agencies or the IAU. This could include asking for input via announcements via various organizations’ news publications, such as the IAU, ISPRS, ICA, and IAG; NASA components such as MAPSIT and the other analysis/assessment groups; and planetary science newsletters such as the American Astronomical Society Division for Planetary Sciences and Division on Dynamical Astronomy newsletters, the *Planetary Exploration Newsletter*, the Lunar and Planetary Institute *Planetary News*, and the American Geophysical Union Planetary Science and Geodesy Sections’ newsletters. A survey could also be undertaken, given adequate

personnel to process the responses, summarize the results, and make recommendations.

In any case, once discussions have taken place at meetings, whether in person or virtual, and community input has been acquired via “requests for input (RFIs),” surveys, or discussions with journals and data providers, some final set of recommendations must be formulated. Part of that process would include deciding to whom the recommendations should be made, including one or more of the groups listed in Table 1, but particularly the IAU and various space agencies, perhaps via their relevant internal advisory or analysis groups.

6.4 Possible Outcomes

Until community input (from beyond the WGCCRE members and their immediate colleagues) is obtained, predicting any outcome, of course, is difficult to impossible. However, we can speculate on possible future actions that the WGCCRE and other organizations might take that would address the questions and issues discussed above. The items listed here are based on both short- and long-term discussions within the WGCCRE and related organizations. They are listed here in no particular order.

6.4.1 Coordinated recommendations effort: The WGCCRE has for many years considered working with other organizations to make sure those bodies are aware of our recommendations and to support their use by such organizations when feasible. Not much progress has been made in this direction due to a lack of resources. However, individual WGCCRE members have often helped review papers from various journals regarding WGCCRE recommendations, and the WGCCRE has informally agreed to help with NASA Planetary Data System reviews regarding coordinate system issues. It would likely be worthwhile to increase awareness of WGCCRE recommendations among journal editors, and to encourage them to promote or comply adherence by authors. Such action would have greatly reduced the resulting confusion in several recent cases when authors did not follow WGCCRE recommendations. For example, coordinate systems were set up that conflicted with existing systems or resulted in a need for users to do tedious and unnecessary conversions of either existing data into a new system or new data in the existing system in order for the data to be registered and properly compared.

6.4.2 Coordinated data providers support: Having similar discussions with data archiving facilities and other data and product providers would also be useful. The NASA PDS has long required that data providers follow the recommendations of the WGCCRE, citing—and extending in some cases, e.g., for ring system coordinates—the WGCCRE recommendations in their own standards (PDS, 2009; PDS-SBN, 2014). Such arrangements could also be discussed with the IPDA and other space agency archives.

6.4.3 Coordinated decision making: Once discussions have taken place at meetings, whether in person or virtual, and community input has been acquired, some final set of recommendations must be formulated. Part of that process would include deciding to whom to make the recommendations, including one or more of these groups, but particularly the IAU and various space agencies, perhaps via their relevant internal advisory or analysis groups.

6.4.4 Coordinated effective work practices: One way forward for this work would be as part of the evolving concept of developing a PSDI with international scope, for planetary bodies generally or PSDIs for individual bodies (Laura et al., 2017). The WGCCRE efforts are already cited as the likely foundational *standards* portion of such work (ibid., Section 3.3), but other PSDI topics are also relevant, such as *policies* (e.g., space agencies requirements and needs), *people* (workforce planning to maintain sufficiently qualified and experienced staff to do such work), *access networks* (to obtain planetary data in useful formats), and *data*, in the form (for planetary use) of *reference frame*, *elevation*, and *mosaic* foundational data products, and framework products for other data types. Such efforts would be in line with the Mapping and PSDI Roadmap recently created by the NASA MAPSIT (2019).

6.4.5 Coordinated effective implementation: The WGCCRE or other related group (see next item) could work more directly with space agencies in considering requiring missions and instrument teams to follow existing international standards recommendations for coordinate systems and products, or at least making clear and negotiating needs to change or improve such recommendations.

6.4.6 Coordinated international input by bodies: Recreating the previous “Geodesy and Cartography Working Groups” or creating new ones would be worthwhile. They could be created in a standalone form or as part of some existing group to address the outstanding issues for the Moon and Mars, while beginning to consider needs for other Solar System bodies and addressing ongoing concerns. Although NASA centric, the past versions of these groups had significant non-U.S. participation and took care to consider international input, and such input should of course be expanded on in the future. These groups could at a minimum advise relevant space agencies, missions, instrument teams, and the WGCCRE as they have done in the past but could also assist in the development of PSDIs for given bodies and make recommendations for lower level (e.g., data format) standards and data products.

6.4.7 Coordination cartographic products accuracy: The WGCCRE or related groups could work with space agencies to require that cartographic products be geodetically controlled as much as possible to known and reasonable levels of accuracy (e.g., sub-pixel level), so that datasets can properly be registered and compared for science and exploration use. Control of products has been recommended by several authors, including the WGCCRE and others (Archinal et al., 2018, Section 9; NASA Advisory Council, 2007; Committee on the Planetary Science Decadal Survey (2011, p. 5-16); International Space Development Conference, 2015; Archinal et al., 2016; Laura et al., 2017; the Mapping and Planetary Spatial Infrastructure Team, 2019, Finding I).

6.4.8 Coordinated centralization effort: Finally, consideration should be given to whether the current work of the WGCCRE and related past and present groups needs to be reorganized. Possibly, such work should be coordinated and funded differently, similar in organization but likely not yet in scale, to what has been done for the Earth. For example, the IERS largely performs the service of establishing coordinate systems and frames for the Earth and inertial space and the connection between the two (Earth rotation). The WGCCRE performs analogous work for the *rest of the bodies in the Solar System*. This is not to say the magnitude of the work of these organizations is comparable, but in some ways and for some bodies, the complexity levels are similar as are the long-term community needs served. The IERS includes a Directing Board that oversees policy and operation and the development of standards, and operational components that perform the routine work of the organization. The future function of the WGCCRE could be undertaken in a similar way, with the WGCCRE itself replaced by some sort of oversight board (perhaps an IAU Commission) of operational components that would deal with routine updating of planetary coordinate system information, answering community questions, helping with reviews, and making routine lower level recommendations regarding coordinate systems and/or planetary mapping.

7. REQUEST FOR INPUT

The WGCCRE desires continued input from the planetary community, especially regarding any updates to the systems for specific Solar System bodies, WGCCRE, our proposed question submitting process (Archinal et al., 2018, pp. 4-5), and posting of updates on the WGCCRE website. We particularly would like to receive input on the questions and issues and possible long-term outcomes raised here. We encourage those in the planetary science and particularly the planetary mapping community to contact us via the first author (at barchinal@usgs.gov) or via participation in various possible future discussions as described in Section 6.2 above.

We would like our colleagues in these communities to be aware that we regularly provide summaries (such as this one) and make meeting presentations to increase awareness of our work (Archinal et al., 2019a, 2019b, 2020a, 2020b). We encourage volunteers to become WGCCRE members and help with our efforts. Our membership is open to IAU members who are willing to indicate their area of expertise and how they plan to help with our reports. Contact the first author or other authors for additional information.

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