The WCRP strategic plan is organized by first, Overarching Scientific Objectives, then Scientific Emphases and finally, Imperatives. The distinction between these items is not always clear and evident, categories. Objectives and infrastructure. The proposed edits have been included in the text when possible.

The writing in the Scientific Emphases section could be sharpened considerably, and made less vague. Specific examples include: Paragraph 10, line 9: “It requires us...” - Don’t understand what is intended by this final sentence of this paragraph. Perhaps the writing could be changed to: “In order to advance support of climate services, improved downscaling tools are required to better represent regional and extreme phenomena.” Paragraph 14 and 15: Somewhere in these two paragraphs, it is important to mention data assimilation, as a vital tool for combining models and observations, and initializing predictions. Paragraph 16, final sentence: I am not clear what is intended by this sentence. Paragraph 17, line 3: “These can be thought of...” - I very much like the list of Imperatives, and in particular the concord way they are written.

We acknowledge that the WCRP Strategic Plan already covers a wide range of social climate research. We would support the inclusion of further details on measurement and society engagement. Based on my recent work with the EU SWITCH-Asia programme, I observe a general lack of understanding of climate change and its impacts on societies’ day-to-day lives – not only in developing countries but also in the advanced ones. This would call for research on how to engage communities more strategically to bring hopefully a leap in understanding, since we could not afford delays in, for example, correcting our unsustainable consumption and production patterns.

We hope that the new Strategic Plan will improve the usability and use of climate services in urban areas, in the regions, and globally – provides fertile ground for collaboration with a wide range of international research communities and stakeholders. In the context of a changing climate, collaboration, adaptation, and resilience are all crucial elements to consider. We support the emphasis on “Engaging with Society” in this new plan. This section on imperatives has an explicit emphasis on “Engaging with Society” addresses this suggestion.

We welcome the acknowledgement that the WCRP Strategic Plan is ready to highlight at the beginning of the document as a key strategic requirement. The section on imperatives has been re-structured as well, with a number of elements moved elsewhere in the document. We thank you for your work and response to this WCRP Strategic Plan. We high emphasis on social sciences, which is currently being strengthened within WCRP. How this work is practiced will be outlined in the WCRP Implementation Plan. Regarding capacity building, we have purposely restructured the Strategic Plan to place training, education, capacity building, we have purposely restructured the Strategic Plan to place training, education, and engagement, enabling capacities, communication, citizen sciences, and all these aspects that are so important at the beginning of the plan, as the core of everything we do. We stand for this. We hope the Plan emphasizes the critical need for sustained observational capacity, for and enhanced engagement in “Spreading climate science and society” and its explicit emphasis on “Engaging with Society” addresses this suggestion.

In summary, our responses were compiled through consultations with members of the MRI Science Leadership Council (SLC), including specific and appreciated contributions from MRI SLC’s Prof Ricardo Grau (Argentina) and Prof Pierfrancesco Ugliano (Italy). I also acknowledge the contributions and feedback from Dr Anu Kulkarni (MRI Scientific Officer), and Dr Jörg Baugere, MRI (Co-Chief). Please note the acknowledge and complement these comments, has been sent onto the WCRP Joint Scientific Committee, so any further comments are no longer necessary.

We resonate with the WCRP’s strategic plan to promote a good balance between basic science and societal relevant. This statement is particularly apt, and we appreciate the emphasis that social science is a key input. Improving the availability and use of climate services in urban areas, in the regions, and globally – provides fertile ground for collaboration with a wide range of international research communities and stakeholders.

We acknowledge the role that the WCRP Strategic Plan already covers social dimensions more generally. The Plan includes a specific emphasis on extremes, and strong references to actionable climate information and capacity building. The Implementation Plan will go into details, and may include key areas such as high-mountains.

Thank you. We have changed the title of the Strategic Plan so that there are only two boxes, we hope that this will make the document more clear, objective and structured. The proposed edits have been included in the text when possible.

The plan is to advance support of climate services. Improved downscaling tools are required to better represent regional and extreme phenomena. This is turn enables capacities to respond and manage associated risks and reduce losses of what is valued for ecosystems and communities in mountain areas. — Footnote: 1. Mountain Research Initiative EED Working Group (2013). Elevation-dependent warming in mountain regions of the world. Nature Climate Change, 3:444–450. doi:10.1038/nclimate2063.
World Climate Research Programme Strategic Plan 2019-2028 - Public Consultation Comments and Responses (online form)

Responses from WCRP Joint Scientific Committee

Thank you. We hope that Objective 4 explores the basics on actionable climate information, lay it out in a way that it... Dolphins can tell us about climate change, but is not clear from the Strategic Plan how the goal is to be achieved.

There are many open questions / suggestions to consider, and not tied to specific line numbers:

- WCRP also "advances understanding" through foundational research in addition to "coordinate" and "guide". In other words WCRP convenes the research community (i.e. coordinates) and guides (i.e. conducts) the research (i.e. advances knowledge).


- How do we get people to understand that the interventions we make now to reduce cc will benefit them?
- What are the threshold and surprise signals we can provide the public?

The Strategic Plan reads very well and tackles the main challenges in climate science. I have just two minor comments:

- The new section on "Our Decadal Ambition" now better articulates the past achievements and new societal challenges ahead. Our emphasis on "Engaging with society" which refers to "actionable climate information" addresses those concerns.

Thank you. We hope that the action plan is clear on how to use the "deeper understanding" to inform action and decision making.

The new Strategic Plan is really a new plan that addresses the past and the challenges ahead.

That is the most important message for the WCRP. I believe it is clear and concise in the Strategic Plan.

Thank you. We hope that the action plan is clear on how to use the "deeper understanding" to inform action and decision making.

The new Strategic Plan is really a new plan that addresses the past and the challenges ahead.

That is the most important message for the WCRP. I believe it is clear and concise in the Strategic Plan.

Thank you. We hope that Objective 4 explores the basics on actionable climate information, lay it out in a way that it is understandable for all stakeholders.
Responses from WCRP Joint Scientific Committee

Thank you. Thank you. The set of all strategic partners mentioned in the Draft of course (not exhaustive). We shall note that the Plan includes an explicit focus on the water cycle and hydrology.

Yes, we agree. The Sustainable Development Goals are very important to us, as is sustainable development, which are also essential to understand how extreme events can impact climate, ecosystems and humans. Past-environment research is a key aspect of IPCC’s influential reports.

I am surprised that GAW and GOOS are quoted but not GCOS. Most of the relevant parts of both are included in GCOS, together with other important objectives not included in either. Para 7 line 1: I would be useful to be clear about which partnerships here, either among the associated skill metrics and the need to understand the intrinsic predictability of the system. The figure has been completely revised. We mention the word “prediction” to be able to be achieved with the data obtained from the Infrastructure section on the broadened ‘knowledge’ area, which covers also biosphere-climate-prosys data records.

Thank you. Thank you. We have had some comments regarding the structure and in response we have modified the Strategic Plan so that there are only two, we hope self-evident, categories. Objectives and infrastructure. The next broad category is six, and in multi-scale (time and space) and multiplayer, to capture this fundamental requirement for our research.

Thank you. Yes, we agree. The Sustainable Development Goals are very important to us, as is sustainable development, which are also essential to understand how extreme events can impact climate, ecosystems and humans. Past-environment research is a key aspect of IPCC’s influential reports.

Thank you. Yes, we agree. The Sustainable Development Goals are very important to us, as is sustainable development, which are also essential to understand how extreme events can impact climate, ecosystems and humans. Past-environment research is a key aspect of IPCC’s influential reports.

Thank you. Yes, we agree. The Sustainable Development Goals are very important to us, as is sustainable development, which are also essential to understand how extreme events can impact climate, ecosystems and humans. Past-environment research is a key aspect of IPCC’s influential reports.

Thank you. Yes, we agree. The Sustainable Development Goals are very important to us, as is sustainable development, which are also essential to understand how extreme events can impact climate, ecosystems and humans. Past-environment research is a key aspect of IPCC’s influential reports.

Thank you. Yes, we agree. The Sustainable Development Goals are very important to us, as is sustainable development, which are also essential to understand how extreme events can impact climate, ecosystems and humans. Past-environment research is a key aspect of IPCC’s influential reports.

Thank you. Yes, we agree. The Sustainable Development Goals are very important to us, as is sustainable development, which are also essential to understand how extreme events can impact climate, ecosystems and humans. Past-environment research is a key aspect of IPCC’s influential reports.

Thank you. Yes, we agree. The Sustainable Development Goals are very important to us, as is sustainable development, which are also essential to understand how extreme events can impact climate, ecosystems and humans. Past-environment research is a key aspect of IPCC’s influential reports.
No. Comments
3 Thank you. We have now modified the title of Objective 2 into “Prediction of the near-term evolution of the climate system, which we believe adequately spans both aspects.”

9 Thank you. We have adjusted the wording in Objectives 2 and 3 to address these suggestions. We have included the Strategic Plan and extreme events is now linked under Objective 2, with an emphasis on Predicting Extreme Events.

13 The Plan articulates the need to connect natural and socio-economic aspects. However, WCRP is not concerned with advocacy in any way. Our ambition is to deliver the best science for fundamental understanding of the Earth system and to inform and support policy and services.

14 Thank you. Objectives have been refined to emphasize more clearly what breakthrough is aimed for. Model implementation but I wonder if we can be a bit more ambitious? This could be interpreted as a 10-year strategy for “more of the same”. What breakthroughs are we looking to facilitate in this order of the imperatives, and there is none in the infrastructures.

15 The emphasis on “Simulation capabilities” are now made very explicit in Objective 2 and 3 (and similar conditions as above). Similarly, para 13 mentions only simulation and neglects the need for interactive, validation, and verification of climate predictions. Same problem in paras 19 and para 22 (e.g. access to prediction info). The neglect of prediction and the stress on simulation sounds very GEWEX influenced and I do not believe this is the most important objective for improved understanding in climate science. In fact, many important chemical species such as CO2 are only poorly understood, and thus predicted, in models. I also feel the general lack of focus on compound extremes and links between extremes and impacts would be good to explicitly refer to.

16 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

17 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

18 Thank you. The Plan now mentions how climate “prediction” as such remains underrepresented in the Strategic Plan compared to climate “simulation”. Virtually all aspects of WCRP should have, a prediction component or at least a mention of it and very area of climate research and one which is not well captured in the Plan. Model implementation has been consolidated at the beginning of the document. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability.

19 The emphasis on “Simulation capabilities” are now made very explicit in Objective 2 and 3 (and similar conditions as above). Similarly, para 13 mentions only simulation and neglects the need for interactive, validation, and verification of climate predictions. Same problem in paras 19 and para 22 (e.g. access to prediction info). The neglect of prediction and the stress on simulation sounds very GEWEX influenced and I do not believe this is the most important objective for improved understanding in climate science. In fact, many important chemical species such as CO2 are only poorly understood, and thus predicted, in models. I also feel the general lack of focus on compound extremes and links between extremes and impacts would be good to explicitly refer to.

20 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

21 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

22 Thank you. The Plan now mentions how climate “prediction” as such remains underrepresented in the Strategic Plan compared to climate “simulation”. Virtually all aspects of WCRP should have, a prediction component or at least a mention of it and very area of climate research and one which is not well captured in the Plan. Model implementation has been consolidated at the beginning of the document. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability.

23 Thank you. The Plan now mentions how climate “prediction” as such remains underrepresented in the Strategic Plan compared to climate “simulation”. Virtually all aspects of WCRP should have, a prediction component or at least a mention of it and very area of climate research and one which is not well captured in the Plan. Model implementation has been consolidated at the beginning of the document. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability.

24 Thank you. The Plan now mentions how climate “prediction” as such remains underrepresented in the Strategic Plan compared to climate “simulation”. Virtually all aspects of WCRP should have, a prediction component or at least a mention of it and very area of climate research and one which is not well captured in the Plan. Model implementation has been consolidated at the beginning of the document. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability.

25 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

26 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

27 Thank you. The Plan now mentions how climate “prediction” as such remains underrepresented in the Strategic Plan compared to climate “simulation”. Virtually all aspects of WCRP should have, a prediction component or at least a mention of it and very area of climate research and one which is not well captured in the Plan. Model implementation has been consolidated at the beginning of the document. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability. The emphasis on extreme events now refers to climate change and variability.

28 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

29 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

30 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

31 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

32 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

33 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

34 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

35 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

36 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

37 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

38 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

39 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

40 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

41 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

42 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

43 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

44 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

45 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

46 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

47 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

48 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.

49 The emphasis on ensemble prediction systems so maybe the first sentence could be altered to say: “We require a diversity of models and prediction systems spanning a range of complexity, a range of representations of processes, and a range of spatial detail…” Items 3 and 4 on page 8 could perhaps be combined?

50 Thank you. Everybody should do more to emphasize climate extremes. I think this is one of the most important and relevant aspects of climate science and one which is not well captured in the Plan.
Thank you. Waves is meant to be surface gravity waves mainly. Ice-sheet are covered under Objective 3. The Implementation plan will develop the details on possible autonomous sensing and methods to refine observing systems.

3. Para 17, line 4: consider explicitly stating “Seven imperatives ...” as was done for the “six ... emphases” in para 10, line 2. (same as E12) The WCRP strategic plan is well-developed and structured. It skillfully and appropriately avoids addressing the challenging discussion of WCRP structure by instead focusing on Data assimilation is now mentioned under Objective 2. We will collaborate with partner programs to advance the former and the more projection oriented focus of the latter. Finally the last objective connects the information gained from the first three objectives to society through services and policy-coupled data assimilation systems for the earth system. This is notionally contained in the last sentence of paragraph 15, page 7: “Improvement ... requests that models be confronted with observations ...”

3. The strategic plan identifies the required investments and commitments to realize the objectives in the Imperatives section. Again, investments in coupled earth system state (data assimilation) should be emphasized in requirement 3 concerning observations for process understanding. Data assimilation context for (new) observations and enhances their value in fully comprehending processes. Additionally, requirement 8 concerning institutional partnerships should explicitly recognize the global community of earth system scholars in the academic community/universities (perhaps in bullet 6) that consider capacity building organizations.

3. it is a very good idea to make a detailed Plan of WCRP's activities for the next 10 years as the world increasingly looks to the global climate science community to provide guidance and cope with an ever-changing climate and its weather manifestations. We would also reassure the world that the climate science community is very interested in not just academic research in the changing climate, but also equally interested in helping in finding adaptation and mitigation options to cope with dry and wet events, including droughts of various intensities and duration, heavy rains, and extreme events, and devastating heat waves – and rising sea levels. This draft Plan, unfortunately, tells far more of the short paths and does not reflect the state of knowledge in the second decade of the 21st century. It can even be said that, with few modifications in language, this draft Plan can pass for having been written within 30 years. I have the following suggestions to revise the draft Plan to better reflect the current state of knowledge and societal needs. 1. From the beginning, this draft Plan biases climate science towards anthropogenic climate change, and neglects decadal variability. The importance of natural and anthropogenic climate variability, especially that of natural decadal-mooscale climate variability, is mentioned almost as an afterthought. The most recent assessment report on Global Change (IPCC, 2013) specifically mentions “Natural interdecadal variability will continue to be a major influence on climate, particularly in the near-term and at the regional scale. By the mid-21st century the magnitudes of the projected changes are substantially affected by the choice of emissions scenarios.” Thus, at least in the next 30 to 45 years, natural climate variability will continue to be as important as anthropogenic climate change. Considering that this WCRP draft Plan is for the next decade, a major emphasis on natural climate variability, especially on decadal-mooscale variability, must be placed on activities planned and supported by WCRP. 2. For non-staple crops in climate science and for general public, climate is an ambiguous word and is generally equated with anthropogenic climate change. For societal impacts, climate now encompasses droughts, floods, heat and cold waves, major storms and floods, and extratropical storms, heat waves, unusual rainfall, and other phenomena. These phenomena make different impacts on societies with different levels of affluence, infrastructure, and coping mechanisms. These phenomena also make different impacts even on the same society depending on the timeframe, e.g., for seasonal drought a multiyear drought may be very different. For some societies, such as LeastDeveloped Countries, a moderate existing seasonal drought event, such as the droughts of 1982-83 or 1991-96, is a matter of life and death, while in some other parts of the world it is a matter of inconvenience and aggravation. Furthermore, there are many organized, worldwide programs to bring climate scientists and other stakeholders to bring forth this dichotomy to guide the changing climate. However, there are very few organized, worldwide programs to bring climate scientists and other stakeholders to bring forth this dichotomy to guide the changing climate. Therefore, there is a very important and useful opportunity to develop multi-sectoral programs of interactions with food-fiber producers, water resources planners and managers, government officials at various levels, transportation systems, public health organizations, energy producers, social service organizations, civil society organizations, and others. The goals of such programs should be to learn what stakeholder needs are, guide climate scientists to answer those questions, and produce sound science based data and information to help stakeholders in each sector. Based on my personal experience of working with stakeholders in theMississippi River Basin for the last 12 years and in the Mediterranean Sea for the last 3 years, I am fully aware of the enormous difficulties of such activities, but therein lies the challenge for WCRP to make its mark on the global community of earth system scholars in the academic community/universities (perhaps in bullet 6) that consider capacity building organizations.

Thank you. We believe the plan, which builds on extensive community consultation, includes a fair balance between internal forcings/variability and imposed forcing. We argue that an important science question at hand is to determine their mutual contributions and also global and regional effects. We agree that there is a clear distinction between climate and anthropogenic climate change. The emphasis on Decadal variability and changes is a rapidly growing field of research and WCRP intends to play a major role in coordinating this key effort, for example in support of the Intergovernmental Panel on Climate Change. Stakeholders recognize that climate science is a global enterprise and that there are limits to predictability, some of which are inherent to the system. Therefore, we believe that the WCRP Strategic Plan identifies the need for bringing climate and societal impacts research to bear on society's food, water, energy, and public health needs. To facilitate such team work, I might be able to influence people with broad background and experience in climate science and climate impacts and connect them to advisors, planners, and executors in WCRP and other WMO programs, and other U.N. organizations. IPCC, 2013: Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 104 pp. IPCC, 2017: Natural Decadal Climate Variability: Impacts. Mehta, V.M., 2017: Natural Decadal Climate Variability: Impacts. Mehta, V.M., 2017: Natural Decadal Climate Variability: Impacts. Mehta, V.M., 2017: Natural Decadal Climate Variability: Impacts. Mehta, V.M., 2017: Natural Decadal Climate Variability: Impacts. Mehta, V.M., 2017: Natural Decadal Climate Variability: Impacts. We have kept "observations" to keep it more general, as it may or may not reside in a large network or system. In this draft, "observations" are not the definitive word. We require the co-design of new observations and indicators, as well as the development of climate system observation records, and the continuous improvement and timely availability of temporarily available datasets such as "reanalysis".
<table>
<thead>
<tr>
<th>No.</th>
<th>Comments</th>
<th>Responses from WCRP Joint Scientific Committee</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>Para 4: 1) new urgency - suggest that this is a good point to highlight the emerging importance of feedbacks and palindromic amplification of climate risk as a new challenge to both science and policy for the coming decade. 2) Para 4 Ln 2: effort... to coordinated effort... 3) Para 4: replace exciting observational... with observing systems based on innovative technologies... 4) Para 4 Ln 4: Two issues do not come across very clearly: 1) the science challenge in the coming decade will be to understand, constrain and model feedbacks, abrupt change and tipping points. 2) the links to the core programmes and the Grand Challenges...</td>
<td>Thank you. We added your suggestion to highlight the emerging importance of feedbacks and potential amplification of climate risk as a new challenge to both science and policy. While important, we felt that this is too detailed for this introductory part of the plan. We cover feedback, etc. in the Objectives. We have changed the wording effort to ‘coordinated effort’. The introduction now includes the following wording: “There are also clear opportunities, to develop new partnerships for research and operations, to promote exciting observational and computational technologies, and to develop scientific capacities across the globe.”</td>
</tr>
<tr>
<td>40</td>
<td>Thank you for the opportunity to comment on the Plan. The Swedish government-funded Strategic Research Area MERGE (<a href="http://www.merge.lu.se">www.merge.lu.se</a>), based at Lund University, Sweden, has as its focus the improvement of the representation of the biosphere and land-atmosphere interactions in global and regional climate models. To that end, we propose the following minor additions to the document: Paragraph 6: Please change “... the influences of atmospheric, oceanic and cryospheric dynamics...” to “... the influences of atmospheric, oceanic, ecosystem and cryospheric dynamics...” Paragraph 10: Please change “... between and within the atmosphere, ocean, land and cryosphere...” to “... between and within the atmosphere, ocean, land, biosphere and cryosphere...” or “... between and within the atmosphere, ocean, land cover and cryosphere...” Paragraph 14: Please change “... waves, sea ice dynamics...” to “... waves, biosphere and sea ice dynamics...” or “... waves, ecosystem and sea ice dynamics...” Paragraph 20: Please change “... hydrological and cryospheric data...” to “... hydrological, biospheric and cryospheric data...” Regards, Paul Miller, MERGE Co-ordinator, on behalf of the MERGE Board.</td>
<td>Thank you. We have included the biosphere in several places in the Plan.</td>
</tr>
<tr>
<td>41</td>
<td>Paragraph 6, lines 11: perhaps replace “... the influences of atmospheric, oceanic and cryospheric dynamics...” with “... the influences of atmospheric, oceanic, ecosystem and cryospheric dynamics...” Paragraph 10: Please change “... between and within the atmosphere, ocean, land and cryosphere...” to “... between and within the atmosphere, ocean, land, biosphere and cryosphere...” or “... between and within the atmosphere, ocean, land cover and cryosphere...” Paragraph 14: Please change “... waves, sea ice dynamics...” to “... waves, biosphere and sea ice dynamics...” or “... waves, ecosystem and sea ice dynamics...” Paragraph 20: Please change “... hydrological and cryospheric data...” to “... hydrological, biospheric and cryospheric data...” Regards, Paul Miller, MERGE Co-ordinator, on behalf of the MERGE Board.</td>
<td>Thank you. Thank you for mentioning explicitly dynamical and statistical downscaling. We shall also note that there is an explicit emphasis on exascale computing in the ‘Infrastructure’ section.</td>
</tr>
<tr>
<td>42</td>
<td>In paragraph 18, a goal/imperative of a diverse research community is stated, but no metrics or methods for achieving such a goal, or integration into other parts of the plan. Paragraph 5 mentions “better connecting the natural sciences to the social sciences.” This is really important to my organization, but it is not followed up further in the plan how this will align with other goals in the plan.</td>
<td>Thank you. The methods and metrics will be part of the implementation plan. The connection to nature and social sciences can be seen as the end and beginning of the value cycle, under Objective 4, and hence feeds back to fundamental science and Earth System analysis (Objective 1) and builds on climate predictions (Objective 2) and projections (Objective 3).</td>
</tr>
<tr>
<td>43</td>
<td>The WCRP Strategic Plan is sound; its contents relevant, timely and presented in a salient manner. Overarching Strategic Objectives 2 and 3 should be combined as they reflect different dimensions of the same issue. There should be reference to specific issue areas as examples of how the Strategic Plan will be operationalized; in particular, polar regions and oceans.</td>
<td>The WCRP Strategic Plan is sound; its contents relevant, timely and presented in a salient manner. Overarching Strategic Objectives 2 and 3 should be combined as they reflect different dimensions of the same issue. There should be reference to specific issue areas as examples of how the Strategic Plan will be operationalized; in particular, polar regions and oceans.</td>
</tr>
</tbody>
</table>

The WCRP Strategic Plan is sound; its contents relevant, timely and presented in a salient manner. Overarching Strategic Objectives 2 and 3 should be combined as they reflect different dimensions of the same issue. There should be reference to specific issue areas as examples of how the Strategic Plan will be operationalized; in particular, polar regions and oceans.
1. WCRP should be commended for placing 1) Fundamental Understanding of the Climate System, followed by 2) Advancing Predictive Skill on Timescales up to a Decade as the leading two overarching scientific objectives of the entire program. Using the word “predictive” is a major step forward for the WCRP (they like to use predictability). Improved predictions are surely the most valuable thing that the WCRP can provide to society. But, this appears to be only lip service, because the language around this refers to “predictability”. Nothing that follows targets improving predictions. It could be that the improvements in predictive models, in assimilation, in ensembles, in forecast products, etc. will be done through their Institutional Partnerships. But, there is ample scope to include improved predictions in the Scientific Emphases. There is an emphasis on improved modeling capability but there is no mention or relevance to improving predictions. If WCRP is not going to tackle and coordinate improving predictions (at least for the timescales of relevance to the WCRP), then why is it?

Thank you. We have now clarified and strengthened the emphasis on improvements on predictability Objective 2. Predictability is part of this effort but the shift in this new Plan is clearly on improved predictions.

2. The plan has correctly recognized that “climate science is called upon to support the knowledge required for wise mitigation and adaptation choices in a changing world. Society’s expectations of climate science are higher, with scientists being asked to deliver predictions and scenarios at finer spatial resolutions and on a wider range of time scales.” However, the plan does not identify what are the key obstacles and how to overcome them. I can understand that a 25-page plan cannot say everything, but the section on “Advancing Predictive Skill on Timescales up to a Decade” seems to give the impression that the “partnership” and coordination among programs is going to advance predictive skill. The plan should recognize that the most serious challenge in advancing predictive skill on timescales from decades to decades is the fidelity of climate models. It is now well established, and therefore universally recognized (with the exception of a small minority of skeptics whose motives are not always based on science), that climate models are sufficiently realistic in “reaching the conclusions that human activities are responsible for the majority of observed climate change.” However, WCRP should recognize that in order to make accurate and reliable regional climate predictions from decades to decades, the fidelity of the climate models must be improved. WCRP should not hesitate in recognizing that the current generation of climate models are unable to realistically simulate some of the largest modes of climate variability, for example, the annual cycle. Recognition of model limitations by WCRP, and encouragement by WCRP to improve the models will help the global modeling communities in enhancing their efforts to improve the fidelity of climate models. There is a clear impression, not without justification, that global modeling communities spend large fractions of their time and effort to produce future projections of climate as expected by WCRP and IPCC. I am suggesting that the WCRP Strategic Plan clearly reflects the WCRP’s ambition that the improvements in the fidelity of the climate models is one of the major objectives of climate research.

Thank you. We have now clarified the focus of this effort with two scientific emphases, namely the progress on simulations capabilities (data assimilation, ensemble generation, initialization, etc) and the prediction of extremes, where the regional dimension is critical. We also hope that the plan balances focus between predictions and projections, each one having its simulation challenge requiring dedicated progress in modeling capabilities (see infrastructure section).

3. Note that ozone and stratosphere are not mentioned, neither is air quality, nor geoenengineering.

Thank you. For simplicity, we have lumped all atmospheric constituents under “climate-relevant compounds.” The stratosphere is by definition included in the atmosphere. Our focus on climate dynamics in Objective 1 also offers a clear opportunity for contributions from the atmospheric composition and stratospheric research community.

4. EXTENSION OF ONLINE COMMENTS: The new WCRP plan is very comprehensive in its scope and ambition, and we welcome the emphasis on efforts to steer scientific efforts that also account for and coordinate usable and actionable climate science and information with and for society. In this context, we wish to reiterate the importance of in-situ observation data for the developments of human-assisted and automated in this plan, particularly in fostering and improving networked observation capacities in remote areas like mountains. Better infrastructures and basic observation processes that link climate and socio-ecological monitoring efforts are needed to provide data that improves understanding of complex and interlinked environmental processes, feedbacks and their impacts in remote areas. This turn enables capacities to respond and manage associated risks and reduce losses of what is valued for ecocultures and ecosystems in mountain areas.

Thank you. We fully agree on the critical need for observations, and hope that our section on infrastructure clearly articulates that.

5. SAME COMMENTS AS ONLINE COMMENT: I have read the WCRP strategy draft, and I think it is quite good. It takes into account that the climate research field has matured a lot over the lifespan of WCRP and that many results are close to applications. The draft also mentions explicitly GAW and WWRP as important partners. The draft retains the “international climate research coordination” as the identity of WCRP. That might be necessary, on the other hand for the environmental sciences, the distinction into scales, all related through strong flux and feedback mechanisms. Still the “data” needs to be in some way to provide manageable organisation. The draft would have liked an even stronger emphasis on the role of “translational” science in the draft, which would fit into item 4 of the “Overarching Scientific Objectives:” With translational science is meant (in my view) the value cycle from discovery to translation to application, where a curiously driven science component is needed everywhere in order to make the cycle as continuous and efficient as possible. As the draft is written, there is still quite a bit of traditional reluctance to engage with the applications in an intimate way, and it is done through reference for instance to Future Earth while I think it should be a more built-in mechanism in the new WCRP. The Scientific Emphases (§10 onwards) are mainly on “enabling technologies” (better models, extreme event understanding, planetary cycles, responses to man made emissions, better observations, provide information), while I think there should be a parallel emphasis on “enabling cultures”, where the evolution of translational science is an important example. To further illustrate the value cycle discovery-translation-application, I think S-GDPS is a good example. It is a test bed for research, a translation mechanism of mature results to operations, and it has a significant user interface which feed experience back into R&D, in particular in NWP but more and more across all earth system components and issues. In a more concrete language, I see WMO as the only global technical organisation which is the “home” of the backhand of the global earth system forecasting system, while a number of international organisations feed on this backhand system for their downstream postprocessing models or needs (IOC, UNESCO-hydrology, WHO, UNEP, FAO etc).

The draft strategy emphasizes quite a bit the need for R&D in observational sciences, as we have access to observations of known quality (§13). The interoperability and balance of observation systems across earth system components and issues is gaining importance, as the initialisation, verification and postprocessing of earth system (component) prognostic calculations, or reanalysis, develop. Data policy is a critical element here. These are some thoughts. I do not know if any of you are intending to send comments on the draft through the electronic submission mechanism, or if we should submit something from CAS?

Thank you. See response on the table with online responses.

6. Thank you for sharing WCRP’s draft strategic plan for 2019-2028. We in the Global Carbon Project (GCP) are excited with the new plan, including its focus and sharp objectives, emphasis on fundamental science and reducing uncertainty, and recognition of the need to create products and services of societal relevance. Carbon and other greenhouse gas research features prominently in the Objectives and Emphases underpinning the plan. The document highlights the carbon cycle, carbon budget and carbon-climate feedbacks, the very topics the GCP was created by WCRP and others to address. We look forward to continue working with WCRP to advance these goals.

Your email also requested feedback on the draft strategic plan. One suggestion would be to broaden the first sentence of Objective #1 slightly to: “We will advance the science of both reservoirs and flows of energy, water, carbon, nitrogen and other climate-relevant compounds within and between the components of the climate system.” The reason for this suggestion is to recognize the importance of nitrous oxide (N2O) as the third most-dominant greenhouse gas under human control. Over the next six months or so, GCP will launch our first Global N2O budget to complement our annual CO2 budget (http://www.globalcarbonproject.org/carbonbudget/index.htm) and, as of 2016, biennial CH4 budget, next due out in 2019 (http://www.globalcarbonproject.org/methanebudget/index.htm).

With this email we wish to renew our formal link to WCRP through the research partnership we signed two years ago. We confirm our willingness and interest to support WCRP’s implementation plan on all carbon and other greenhouse gas related components. We also welcome the chance to become even more closely involved in the creation of joint projects with WCRP.

We remain grateful for your scientific direction, successful outreach, and support.

Thank you. Likewise WCRP looks forward to collaborating very closely with GCP and developing joint products.

We want to keep the Strategic Plan short and crisp and have lumped NITROGEN etc in other climate-relevant compounds. We will for sure consider including other GHG such as CH4 and N2O in our detailed Implementation Plan.
Comments

We believe that the wording ‘WCRP research provides the climate science that underpins the United Nations Framework Convention on Climate Change and contributes to...’

This sentence is not clear even by reading in sequence with previous lines of the paragraph. It can be written as "Thus, new urgencies and opportunities about climate science are now emerging."

The recent study “A global economic assessment of city policies to reduce climate change impacts” by Estrada et al. (2017) highlights that the importance of the UHI is enhancing the effects of global climate change. For the most populated cities (that is, the top 5%), the effects of UHI add 1.72°C, 2.08°C and 2.35°C to the temperature increase due to global climate change in 2015, 2050 and 2100, respectively. These estimates are 0.7°C, 0.84°C and 0.93°C for the maiden cities. At about 20% of these cities could experience a total warming to 7°C by the end of this century. Under these scenarios, the cities face paying twice the economic cost to fight climate change than the rest of the world (Estrada et al., 2017).

Specific:

Please find here the suggestions/corrections/addition etc for the improvement of initial draft of Strategic plan 2019-2019 of WCRP which you can accept or deny to incorporate in your final version.

«WCRP research provides the climate science that underpins the United Nations Framework Convention on Climate Change and contributes to...»

This sentence is not clear even by reading in sequence with previous lines of the paragraph. It can be written as “Thus, new urgencies and opportunities about climate science are now emerging.”


Para 8 line 6: the use of the word "functional" to describe factors due to external influence is a little confusing, or at least not specific.

Para 25 here I see the partnerships mentioned several pages ago are listed. Why here and not there? or there and not here?

Para 25 line 1: if WCRP is the only programme then it's also by definition the longest serving and every other superlative. Tautology.

Para 3 line 1: if WCRP is the only programme then it's also by definition the longest serving and every other superlative. Tautology.

Para 7 line 1: It would be useful to be clear about which partnerships here, rather than much later quote one example. A clear statement about the importance of partnerships should be useful, together with some better examples.

What is the more generic link to climate services? Is this where relevance to society will be focussed.

Para 8 line 8: I am surprised that IAWG and GCOS are quoted but not GCOS. Most of the relevant parts of both are included in GCOS, together with other important aspects not included in either.

Para 7 line 1: It would be useful to be clear about which partnerships here, rather than much later quote one example. A clear statement about the importance of partnerships should be useful, together with some better examples.

Thank you. We hope that the Plan now clearly articulates its core mission, its engagement strategy, its partnerships and decadal ambition. We apologize for the earlier omission of GCOS in the list of partners. The Plan has also been restructured and there were indeed some category errors. The simpler structure will hopefully also lead to a simpler structure of the implementation plan. The contribution to city services and SFCOS is made quite explicit upfront. We have rewritten many sections to take these useful comments into account. Thank you.

Recommendation 5: Financing

WCRP should seek to develop strategic and strong partnerships with other WMO research programmes (specifically WWRP and GAW), with GCOS, and with Future Earth.

Thus this Strategic Plan is the response to Recommendation 1. Governance issues are separate as discussed in Recommendations 2 and 4. I also do not see that the Strategic Plan has dealt with the other tasks of building adaptive capacity and decision making. There is not a sense of a 'backstop' or 'insurance' for decision making. There is a sense that the Strategic Plan needs to be more specific about the nature of the partnerships it seeks to develop. WCRP is 'on the ground' and the Strategic Plan needs to be more specific about the nature of the partnerships it seeks to develop.

Recommendation 4: Structure

Involves a simplified set of delivery mechanisms.

Thank you. Yes, we will sunset the Grand Challenges. The restructured structure of WCRP will be addressed in the new Implementation Plan. We hope that the Plan now clearly articulates the strategic objectives being undertaken by WCRP and the role of partnerships in this context. The Plan does not address governance as such, as this will be part of a process to re-catalogue the relationship between the 3 sponsors WMO, ICSU and newly formed ISC and the respective roles of the JSC, the Joint Planning Staff, etc. The plan now mentions explicitly ISC and its member groups. The Sponsors’ Review will be published together with this new Plan, which is indeed a response to the Recommendation 1 of the Review. Climate Services also deal with reanalysis, prediction and projections. We shall also note that our Infrastructure section has a dedicated section on sustained observations, archiving etc.

Recommendation 3: Science

Involves a simplified set of delivery mechanisms.

Thank you. Yes, we will sunset the Grand Challenges. The restructured structure of WCRP will be addressed in the new Implementation Plan. We hope that the Plan now clearly articulates the strategic objectives being undertaken by WCRP and the role of partnerships in this context. The Plan does not address governance as such, as this will be part of a process to re-catalogue the relationship between the 3 sponsors WMO, ICSU and newly formed ISC and the respective roles of the JSC, the Joint Planning Staff, etc. The plan now mentions explicitly ISC and its member groups. The Sponsors’ Review will be published together with this new Plan, which is indeed a response to the Recommendation 1 of the Review. Climate Services also deal with reanalysis, prediction and projections. We shall also note that our Infrastructure section has a dedicated section on sustained observations, archiving etc.

Recommendation 2: Governance

Involves a simplified set of delivery mechanisms.

Thank you. Yes, we will sunset the Grand Challenges. The restructured structure of WCRP will be addressed in the new Implementation Plan. We hope that the Plan now clearly articulates the strategic objectives being undertaken by WCRP and the role of partnerships in this context. The Plan does not address governance as such, as this will be part of a process to re-catalogue the relationship between the 3 sponsors WMO, ICSU and newly formed ISC and the respective roles of the JSC, the Joint Planning Staff, etc. The plan now mentions explicitly ISC and its member groups. The Sponsors’ Review will be published together with this new Plan, which is indeed a response to the Recommendation 1 of the Review. Climate Services also deal with reanalysis, prediction and projections. We shall also note that our Infrastructure section has a dedicated section on sustained observations, archiving etc.

Recommendation 1: Mission

Involves a simplified set of delivery mechanisms.

Thank you. Yes, we will sunset the Grand Challenges. The restructured structure of WCRP will be addressed in the new Implementation Plan. We hope that the Plan now clearly articulates the strategic objectives being undertaken by WCRP and the role of partnerships in this context. The Plan does not address governance as such, as this will be part of a process to re-catalogue the relationship between the 3 sponsors WMO, ICSU and newly formed ISC and the respective roles of the JSC, the Joint Planning Staff, etc. The plan now mentions explicitly ISC and its member groups. The Sponsors’ Review will be published together with this new Plan, which is indeed a response to the Recommendation 1 of the Review. Climate Services also deal with reanalysis, prediction and projections. We shall also note that our Infrastructure section has a dedicated section on sustained observations, archiving etc.

We believe that the wording ‘WCRP research provides the climate science that underpins the United Nations Framework Convention on Climate Change’ is clear. WCRP is focussed on making sure that the research products and knowledge needed by the UNFCCC process is available. Regarding the last suggested change, the corresponding text has been completely revisited.
Thank you. Yes, we will sunset the Grand Challenges. The new/revised structure of WCRP will be addressed.

Which brings me to the biggest danger of this Strategic Plan. It has been developed in the absence of a WCRP Director so that, presumably, it will be the template used by any future WCRP Director. A new 10-year WCRP science strategy and related 5-year implementation plan must be developed as soon as possible in discussion with the sponsors and with wide consultation and community buy-in.

Recommendation 2: Governance and the MoU

Recommendation 3: Operations

Recommendation 4: Structure

The WCRP leadership, with its newly created Governing Board, should work with the community to establish a new structure for the WCRP research effort that best serves its new strategy and involves a simplified set of delivery mechanisms.

Recommendation 5: Financing

In light of the importance to society of the goals of WCRP and the precarious level of current financial support for the JPO, the co-sponsors should re-double their efforts to support WCRP financially at a higher level of enabling funding so that it can operate more effectively.

Recommendation 6: Science to services

WCRP should seek to develop strategic and strong partnerships with other WMO research programmes (specifically WWRP and GAW), with GCOS, and with Future Earth.

Thus this Strategic Plan is the response to Recommendation 1. Governance issues are separate as discussed in Recommendations 2 and 4. I also do not see that the Strategic Plan has dealt with Recommendation 6 as I would understand it. Following on the Panel Discussion on Climate Services held at the IUGG General Assembly in Prague, I interpret climate services as dealing with the advance of climate science specifically in response to this focus has been a signal achievement of the community.

Well, in that some research areas received less attention. Some of these areas are now understood as new, but they are critical for progress in climate services, understanding how extreme events interact with variability and change; the many roles of chemistry in the energy balance of the Earth system; etc.

Perhaps most critical is the aspiration to break down the barriers of time scale that have been created in the physical science (natural and social sciences of the Earth system). Attention has been paid to clarify the perspectives and understandings. Hence, this recommendation is for us the first step in a process to achieve that.

1.6. The Strategic Plan makes no comment on governance/structure. CliC, GEWEX, CLIVAR and other WCRP projects have been around for a long time and with the strong emphasis on cross-observational capability, there is an odd lack of clarity around how WCRP operationally provides leadership and/or interacts with its global partners and, therefore, how this strategic plan advances that critical element of our system science (natural and social sciences of the Earth system). As a suggestion for improving the structure, it may be helpful for the authors consider thinking about the four Overarching Scientific Objectives, all Scientific Emphases, and all Imperatives as six parts of the Strategic Plan, but not in the list.

Goal #1 Advance Fundamental Understanding of Climate System

Goal #2 Advance Predictive Skill on Timescales up to a Decade

Goal #3 Constrain Projections on Decadal to Centennial Time Scales

Goal #4 Develop Global Infrastructure Supporting Integrated Systems Approach for Climate Research

Goal #5 Tackle the Consequences of Climate Change

Goal #6 Develop Global Infrastructure Supporting Integrated Systems Approach for Climate Research

1. The Strategic Plan makes no comment on governance/structure. CliC, GEWEX, CLIVAR and other WCRP projects have been around for a long time and with the strong emphasis on cross-observational capability, there is an odd lack of clarity around how WCRP operationally provides leadership and/or interacts with its global partners and, therefore, how this strategic plan advances that critical element of our system science (natural and social sciences of the Earth system). As a suggestion for improving the structure, it may be helpful for the authors consider thinking about the four Overarching Scientific Objectives, all Scientific Emphases, and all Imperatives as six parts of the Strategic Plan, but not in the list.

2. Structure of the document

(1) Clearly stated Goals

(2) Action-orientated statements

(3) Re-organized sections

(4) Clear and strategic actions

(5) Action plans

(6) Action 1.1, Action 1.2), so they cannot be easily reframed as clear and strategic Actions. Instead, these paragraphs seemed to mix lists of actions with justifications of the objective, descriptions of processes, and approaches.

As a suggestion for improving the structure, it may be helpful for the authors consider thinking about the four Overarching Scientific Objectives, all Scientific Emphases, and all Imperatives as six parts of the Strategic Plan, but not in the list.

We thank you for your extensive feedback on the first draft of the strategic plan document. Below we articulate some responses to substantive comments received, and we also attached a table summarizing responses to recommendations received during the open comment periods. We have aimed for a short, focused and comprehensive document which can be used in various contexts and with a variety of audiences, capturing the key strategic priorities in response to the WCRP Sponsors’ Review, which has been instrumental in shaping these priorities and particularly the emphasis on collaborative effort to move forward. This plan will be operationalized by an Implementation Plan which will similarly rely on wide community consultation.

Strategic development, from past to future:

- The establishment of WCRP 40 years ago was prompted by a specific focus on the fundamental science that was required to detect, simulate and attribute climate change in the Earth System. “Earth System” as a concept was initially construed very narrowly with the tools then available and has broadened over time, of course.

- Furthermore, there were and will remain other critical climate research endeavours. But the facilitation and promotion of climate research has been viewed by many as the core business of WCRP.

- The climate research community has been successful in responding to the set of questions prompted by this focus. This is of course not to suggest that there are not significant gaps remaining in our understanding, but the advance of climate science specifically in response to this focus has been a signal achievement of the community.

- This focus had the advantage of being a narrowly articulated goal. But there have been disadvantages as well, in that some research areas received less attention. Some of these areas are now understood as required for the kinds of demands now being made on climate science, such as large scale circulation dynamics of the deep ocean, or clouds physics. These areas may seem less compelling because they are not new, but they are critical for progress in climate services, understanding how extreme events interact with variability and change; the many roles of chemistry in the energy balance of the Earth system; etc.
This is why we wish to foreground the fundamental science in this strategic plan.

1. As a result, while it would be satisfying to articulate a single new step in understanding climate change, we need to seek in this strategic plan to make space for the diversity of fundamental research that speaks to the fundamental challenges, and at the same time hewed to the understanding that there is a process of refinement and understanding to be articulated.

2. It follows that the remaining objectives seek to put this imperative into a framework of aspirations for the future.

3. Perhaps most critical is the aspiration to break down the barriers of time scale that have been created between meteorology, climate science, socio-economic systems, and the human and the broad and quite unable to be operationalized.

4. The gaps in prediction are fuzzy boundaries to be pushed through collaboration.

5. To date, projections have been developed as scenarios. New scientific insight is required that are inherently free of potential biases, or other scientific knowledge, about the way in which the system varies over a variety of timescales. This is the focus of the third objective.

Intrinsic role of society in the climate system:

1. We are acutely aware that a substantive integration of efforts, that since, the Enlightenment, have been deeply divided, is a complex and challenging task. While there are members of the ISC and the WCRP research community who possess expertise in some of the required expertise, coming to grips with this is a joint endeavor spanning many programs. We will seek to engage the community of co-sponsors in the development of approaches to move this forward as questions of implementation of Objectives 4 are considered.

2. Furthermore, we strongly support the ISC Governing Council’s recommendation to include the process going forward researchers who focus on key aspects of social sciences that present, at this stage, the most tractable opportunities for enhanced and new collaboration between climate research disciplines which can move us forward on the stated objectives. Different parts of the WCRP research community are starting from different perspectives and understandings. Hence, this recommendation is for us the first step in a process to achieve meaningful and substantive integration of epistemologies that have been separated for far too long.

Downscaling:

1. We would like to emphasize the technique among many to address the scientific question of how much data on a domain of enquiry in itself. It can and will be part of the implementation of the strategy.

Governance:

1. The co-sponsors will understand that changes to the structure of WCRP to operationalize the aspirations of this strategy is necessarily a sensitive issue for the climate research community. The WCRP JSC is aware that (i) existing research communities are collective for progress to take time to form and (ii) it is not small things that can be achieved with the current institutional frameworks and methods dependent on how the systems evolve. Hence, the implementation of the strategy is the next stage of what is, in our view, a social process for the climate research community to tackle collectively. These concerns are therefore explicitly omitted from this strategic plan.

Science to Services:

1. We did not address Recommendation 6 of the WCRP Sponsors’ Review. The role of WCRP is to provide the underpinning scientific understandings, approaches and technologies that will enable services, but that implementation of that goal is properly the domain of other entities, particularly, operational centres around the world and within national and international agreed frameworks such as the GEMS.

General comments on the scope of WCRP

1. In our usage, consistent throughout the document, “natural sciences” refer to physical, chemical and biological sciences, while being clear WCRP does not span this entire domain. Similarly, we distinguish between climate system science (largely physical, chemical and biological sciences of the climate) and Earth system science (natural and social sciences of the Earth system). Attention has been paid to clarity between the distinct partnerships where appropriate and necessary in new areas of research to further progress in climate research. Some examples of such areas are hydrology, atmospheric chemistry.

2. It is important to note that there is a clear push for more integration in climate and Earth system science. Whilst WCRP will continue its tradition and focus on observations, analysis and prediction, it will inevitably have to rethink, together with partner programmes, how the strategy will be implemented. This is unnatural territory. The challenge is huge, but so are opportunities to make a difference in the long-term.

3. It is clear that the vision is an operationalization of the climate system science and Earth system science of the IPCC and the Global Environment Facility, which focuses on policy-oriented research to address global environmental problems.

4. It is also clear that the vision is an operationalization of the climate system science and Earth system science of the IPCC and the Global Environment Facility, which focuses on policy-oriented research to address global environmental problems.
1. General comments

We thank you for your extensive feedback on the first draft of the strategic plan document. Below we articulate

1.1. The document is generally comprehensible, admirably short and easy to read. Overall, the Strategic Plan highlights the achievements of WCRP and makes a good case for its future development.

1.2. However, the document lacks bite and urgency, the sense of what’s new and what’s currently vital, in terms of scientific research, which policymakers demand, is often lacking. There is not a comprehensible document which can be used in various contexts and with a variety of audiences, capturing particularly:

(i) Fundamental understanding of the climate system – this objective led to the establishment of WCRP almost 40 years ago; what specifically does WCRP now aim to resolve in terms of better operationalized by an Implementation Plan which will similarly rely on wide community consultation.

The discovery that the multi-model ensemble has better predictive skill than any single model has enabled the predictive uncertainty to be reduced. That is a brilliant well, in that some research areas received less attention. Some of these areas are now understood as new, but they are critical for progress in climate services, understanding how extreme events interact with

1.8. It would be useful to know who this document is intended for, as content needs to be well-tailored to audience. The impression the document gives is that it is designed as a general public

1.10. There is a concern that the plan has been developed in the absence of a WCRP Director so that, presumably, it will be the template used by any future WCRP Director to guide their future


<table>
<thead>
<tr>
<th>No.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Action 1.2, so they cannot be easily retained as clear and strategic actions. Instead, these paragraphs seemed to mix lists of actions with justifications of the objective, descriptions of programs, partnership declarations, and definitions of climate research terms.</td>
</tr>
<tr>
<td>1.2</td>
<td>Following these paragraphs and beginning on Page 5, the document introduces six “Scientific Emphases” and eight “Imperatives” that, the authors note, are needed to meet the four overarching scientific objectives. This seems to imply they might be the actions needed to achieve the objective/signals. Yet this doesn’t quite make sense when looking at the Page 3 graphic. This only seems to explain the larger WCRP conceptual framework for climate research, not how Emphases and Imperatives will be action steps to achieve the objectives of the 10-year WCRP Strategic Plan.</td>
</tr>
<tr>
<td>1.3</td>
<td>As a suggestion for improving the structure, it may be helpful for the authors consider thinking about the four overarching scientific objectives, all scientific emphases, and all imperatives as six high-level strategic goals. For example:</td>
</tr>
<tr>
<td>1.4</td>
<td>Goal #1: Advance Fundamental Understanding of Climate System Goal #2: Advance Predictive Skill on Timescales up to a Decade Goal #3: Constrain Projections on Decadal to Centennial Timescales Goal #4: Connect Climate Science with Policy &amp; Services Goal #5: Utilize Systems Approach for Climate Science Emphasis Areas Goal #6: Develop Global Infrastructure Supporting Integrated Systems Approach for Climate Research</td>
</tr>
<tr>
<td>1.5</td>
<td>This may not be correct, but – whatever organizational structure the authors choose - this document’s structure be revised to more closely mirror the format of an actual strategic plan, or it should not be called a strategic plan.</td>
</tr>
<tr>
<td>1.6</td>
<td>It is recommended that at the end of this document a complementary “implementation” document is attached or to be written in near future that will indicate (1) who will be tasked with implementing the actions to meet the WCRP goals (i.e., the person, organization, or governing body with authority and resources to achieve the goal), and (2) what kind of indicators will be used by WCRP to assess its progress towards its stated strategic goals over the next ten years.</td>
</tr>
<tr>
<td>1.7</td>
<td>More specific comments</td>
</tr>
<tr>
<td>1.8</td>
<td>3.1. p. 7 “The Next Decade”. This section is too generic. It would have been appropriate at almost any time during the last 2-3 decades. It gives no guidance to the reader on “what’s new for 2019-2029”. Or is it more of the same? The next section on overarching science is much more specific, and could be substituted for the text in “the next decade”</td>
</tr>
<tr>
<td>1.9</td>
<td>1.2 If this document is actually the “10-year WCRP Science Strategy” as recommended by a WCRP Review Report; then (3) and (4) could be addressed in the “related 5-year implementation plan” that was also recommended to be developed in that report. Still, these critical strategic planning operational steps should be acknowledged somewhere in a document entitled “Strategic Plan.”</td>
</tr>
<tr>
<td>1.10</td>
<td>3.2 P. 3 Diagram. Is this intended as a logo for the next decade, or is it intended to transmit information? If it is the latter it is unclear, and at least needs a text caption.</td>
</tr>
<tr>
<td>1.11</td>
<td>3.3 p. 4. Advancing predictive skills … The mention of extreme events begs to be linked to the increasing scientific input to disaster risk reduction as set out in the Sendai framework, and as promoted through bodies such as RDR. There is also a potential link in 4. on page 5.</td>
</tr>
<tr>
<td>1.12</td>
<td>3.4 p. 5. Scientific Emphases. This appropriately stresses the centrality of a “systems approach”, but the following text is disappointing to a scientist in not going beyond a description of system analysis that could have been produced at any time during the last 3-4 decades.</td>
</tr>
<tr>
<td>1.13</td>
<td>3.5 p. 6.4. There is no doubt that the WCRP committee is well aware of the dramatic advances in computer modeling that modern data resources, advanced HPC and machine learning technologies have enabled, but it would be useful in this section to get a sense that the advance of technology permits us to undertake modeling with massively enhanced capacity and potential, and that this potential is vital to the objectives set out in the strategy.</td>
</tr>
<tr>
<td>1.14</td>
<td>3.6 p. 7.8 – 8. Impeive 1-7. This is a useful wish list, but it would, again, be helpful to indicate what specific actions and what collaboration/coordination and at one level will be required.</td>
</tr>
<tr>
<td>1.15</td>
<td>3.7 Paragraph 3. “deliver improved predictions and scenarios at finer spatial resolutions”. If the large ensembles are correct this may not be possible because of intrinsic variability within the climate system.</td>
</tr>
<tr>
<td>1.16</td>
<td>3.8. Paragraph 8. It is good to see emergent constraints highlighted as this is an important, current area of research that has a lot of promise.</td>
</tr>
<tr>
<td>1.17</td>
<td>3.9. Paragraph 11. “determine the processes responsible for the existence of regional climate hotspots”. In scientific writing, this could be made clearer. Are we talking about areas that will have more extremes? Or are we talking about areas of higher temperature?</td>
</tr>
<tr>
<td>1.18</td>
<td>3.10. Paragraph 14. “Improvements are critically required in representations of the hydrological cycle, including clouds and precipitation oceanic eddies and waves, sea ice dynamics and glacial flow”. We also need to have better simulation of the different water masses in the ocean, such as Circumpolar Deep Water, which is critically related to the melt of the Antarctic ice sheet.</td>
</tr>
<tr>
<td>1.19</td>
<td>3.11. Paragraph 17 could be better worded. It is not clear what it is that can be thought of as “essential infrastructure”. But then if the challenges are essential infrastructure, the paragraph does not make sense. Nor does it if the objectives are the essential infrastructure.</td>
</tr>
<tr>
<td>1.20</td>
<td>3.12. In the list of Acronyms, ICTP should be spelled as “The Abdus Salam International Centre for Theoretical Physics”. Also the Global Ocean Observing System (GOOS) is mentioned in the Strategic Plan, but not in the list.</td>
</tr>
</tbody>
</table>
Paragraph 3

Line 9: Please further specify ‘wise’ mitigation and adaptation, because ‘wise’ could be interpreted in different ways, please consider using more objective terminology.

Line 10: Are these just a set of ‘mitigation and adaptation choices’ or more encompassing, highly dependent, and complex strategies? Please consider more action oriented wording here than choices. Possibly change ‘choices’ into something along the lines of ‘approaches or strategies’.

Line 11: ‘higher’; please specify higher than what exactly (because the impacts of climate change are being felt new urgencies and questions emerged? and/or more freely available information arriving faster to society due to advanced technologies, posing new challenges and expectations?). Please consider to avoid ambiguity for the reader’s interpretation.

Paragraph 4

Line 7: consider adding ‘to promote and to take advantage of computational technologies’

Last 2 lines of paragraph: WCRP’s main focus would possibly not be to ‘deliver’ climate information, but merely to improve climate science underpinning climate information and to generate climate information. Please consider revising accordingly. As this is the last sentence of this section it is coming across as one of the key focus areas of WCRP described in the SP.

Paragraph 5

Paragraph 6

Line 4: ‘close’ is very ambiguous, and might slightly contradict objective 3 and the related scientific challenges. Possibly consider slight modification to ease the wording.

Paragraph 7

General remark: Consider to mention the aim for seamless predictions here, also identified as an Earth System Science Frontier by ECRs in Rausser et al. (2017) and possibly make the scales explicit (‘from minutes to centuries and from meter to global spatial scales’).

Paragraph 8

Last sentence: The idea that the reduction of uncertainties promises useful information on longer horizons overlook the improvement of the quality of information on the actual timescales under consideration. It could be rephrased to also imply this.

Paragraph 9

The title of paragraph mentions ‘services’, but the paragraph doesn’t explicitly.

Paragraph 11

Line 4: Please clarify what ‘This’ refers to.

Paragraph 13

General remark: What is WCRP’s position on climate engineering / geoengineering / climate intervention research?

Paragraph 14

General remark: possibly mention that training the next generation of modelers is fundamental to this scientific goal. Increase the number of scientists trained and with in-depth knowledge, especially in developing countries, by creating a larger network of scientists capable of modeling the climate system (this could be mentioned in connection with paragraph 18/19/22).

Paragraph 15

Paragraph 16

Citizen science and emerging technologies are mentioned explicitly in the text.

Paragraph 17

Paragraph 18

Paragraph 19

Additional remarks on the text have been taken into account where possible.
12. I found the plan to be well developed. I was curious on others thoughts. Attached are my comments. I think explicit references to academic community and data assimilation are missing elements.

Report: The WCRP strategic plan is well-developed and structured. It skillfully and appropriately avoids addressing the challenging discussion of WCRP structure by instead focusing on the scientific objectives, etc., and imperatives/requirements.

1. The vision and mission are well-articulated.
2. The scientific objectives are appropriate and relevant. Critically important, and serving as an underpinning for the entire climate science enterprise is the first objective “Fundamental understanding of the climate system.” Objectives 2 and 3 break the problem into two parts (subseasonal to decadal) and decadal to centennial – in recognition of the likely predictive capacity of the former and the more projection oriented focus of the latter. Finally the last objective connects the information gained from the first three objectives to society through services and policy-relevant information.

3. The Scientific Emphases are comprehensive in scope. Emphasis 5 (“Innovation through observation”) could be strengthened by an explicit reference to the (necessary) development of fully coupled data assimilation systems for the earth system. This is notionally contained in the last sentence of paragraph 15, page 7: “Improvement ... requires that models be confronted with observations …”

4. The strategic plan identifies the required investments and commitments to realize the objectives in the Imperatives section. Again, investments in coupled earth system state estimation (data assimilation) should be emphasized in requirement 3 concerning observations for process understanding. Data assimilation provides context for (new) observations and enhances their value in fully comprehending processes. Additionally, requirement 8 concerning institutional partnerships should explicitly recognize the global community of earth system scholars in the academic community/universities (perhaps in bullet 6 that considers capacity building organizations?)

13. Thank you. See response to the on-line comments.

14. Thank you. Under our objective 2, we have an explicit focus to “determine the processes responsible for the predictability objective and emphasis on mechanisms of extreme events is particularly relevant to today’s society. Compound events, where a double whammy or triple whammy really knocks out a region or community for a while, often have the greatest impact – it would be great to see some further study and attribution of compound events.

Partnerships and impact data are essential for understanding climate impacts, but those data are much less organized and standardized than climate and weather data. If WCRP could encourage activity to regularize impact data that would be very helpful.

15. The importance of model development to achieve the goals mentioned in the text is not emphasized enough. The basis for this is model development. This was underlined by WMO President David Grimes at the 5th WGNE workshop on systematic errors in weather and climate models in June 2017 in Montreal. The WCRP strategic plan should point this out clearly and encourage national and international funding organizations to provide resources for pure model development.

Paragraph 4: It would be helpful to give a short overview of differences between objectives, emphases and imperatives here in order to understand these different categories right from the beginning. E.g. engagement is named in all three categories.

Page 4: The green text “short summaries” next to paragraphs 6 and 8 (left side) should be changed in order so that the order of the main text is also followed in the short summaries.

Paragraph 7 (9th line): The sentence “Working with…” does not fit to this headline (“2. Advancing predictive skill …”) but should be moved to paragraph 9 (“4. Connecting climate science with policy and services”).

Thank you. The sentence in paragraph 4 has been changed to “The task is formidable, both scientifically and technically complex while deeply engaged with the structure and limitations of social institutions at every level from local to international.”

May I suggest:

“The task is formidable, both scientifically and technically complex while deeply intertwined with social and economic institutions at every level from local to international.” The references to partnerships have now been restructured into a single section at the beginning of the document.

Paragraph 13: I am not a native speaker but “… to inform policy and decisions” (3rd line) sounds odd to me. Is it rather “… to inform policy and decision makers”?

Thank you. The sentence in paragraph 4 has been changed to “The task is formidable, both scientifically and technically complex while deeply intertwined with social and economic institutions at every level from local to international.”

Remark on paragraph 15: we fully agree and have a corresponding text to that effect in the infrastructure section.

Page 2, paragraph 4, second sentence: This doesn’t really make sense.

“The task is formidable, both scientifically and technically complex while deeply engaged with the structure and limitations of social institutions at every level from local to international.”

May I suggest:

“The task is formidable, both scientifically and technically complex while requiring engagement with the structure and limitations of social institutions at every level from local to international.”
### World Climate Research Programme Strategic Plan 2019-2028 - Public Consultation Comments and Responses (by email)

<table>
<thead>
<tr>
<th>No.</th>
<th>Comments and Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Overall, the draft WCRP SP is in good shape. It provides a broad vision on priorities. The imperatives are strong. Scientific emphases are appropriate, and in areas like extremes compelling. My comments and suggestions are minor; none are mandatory. They can be addressed with small edits as needed. The comments are intended to clarify points, help build the case for WCRP’s value, and note fruitful areas for further collaborations with the WWRP.</td>
</tr>
<tr>
<td></td>
<td>1. Paragraph 3: To avoid a possible criticism, after “human activities are responsible for the majority of observed climate change” insert “since 1950” or otherwise specify a time period consistent with IPCC attribution findings.</td>
</tr>
<tr>
<td></td>
<td>2. All four science objectives start with “We will ...” as, for example, Objective 3. “We will quantify the sensitivities, uncertainties and emergent constraints ...”. If the SP is intended for a broader audience, there is a possibility for misinterpretation that the WCRP will conduct this research. To specifically emphasize WCRP’s role as articulated in the mission statement, consider starting each objective with “WCRP”, and modifying the text slightly as appropriate: e.g., Objective 2 becomes “WCRP will advance partnerships to ...”.</td>
</tr>
<tr>
<td></td>
<td>3. Objective 1. After the sentence listing sources for spurious budget imbalances that concludes “in observations”, consider inserting an additional sentence on the implications of these imbalances: “Such deficiencies limit current capabilities to predict climate variability, confidently attribute changes for recent changes, and project future changes from global to regional scales.” If this edit is made, then the text beginning “Furthermore ...” to “As a result” can be deleted.</td>
</tr>
<tr>
<td></td>
<td>4. Objective 4. The text does not call out connections to national or regional climate services, whether or not they are formally labeled as such. These are likely to be crucial to realizing and broadly disseminating benefits of research advances from WCRP-related efforts, especially on climate time scales of S2S (and potentially also S2D). In WWRP, relationships to NMHS are critical toward developing useful and usable science with broad public benefits, and there is value in identifying this sustained customer of WWRP. As climate services develop WCRP’s central role toward achieving the GCFS is also not stated in the paragraph. It may be helpful to add brief text here emphasizing potential benefits of WCRP activities to existing national and regional climate services, innovating and testing new services, and achieving the objectives of the GCFS.</td>
</tr>
<tr>
<td></td>
<td>5. Emphasis 1. The importance of extreme events will be easily appreciated by nations and other end users. The connections to WWRP are especially strong on this topic. As in WWRP, WCRP should also consider variations and changes in other high-impact events that are not necessarily extreme. This is a specific area where working together with WWRP there is great potential to develop seamless information products so that societies can better anticipate and prepare for evolving risks for such events over time scales from climate change to weather.</td>
</tr>
<tr>
<td></td>
<td>7. Emphasis 3. First sentence, change “factors” to “forcing.”</td>
</tr>
<tr>
<td></td>
<td>8. Emphasis 4. The main emphasis of the paragraph is on improvements in physical process representation. While this is certainly crucial, for improved S2S and S2D predictions, there are also strong needs for improved initializations and data assimilation methods for the coupled climate system. Developing and testing CDA can also help reveal errors in model representations of physical processes, for example, coupling and flux errors at component interfaces. There is also a need to learn how to best optimize modeling strategies to better understand, predict and project changes in high impact phenomena that manifest at small spatial scales or occur in complex orographic regions that typically require very high model resolution. Collaborations between WWRP and WCRP in this area could contribute to improved assessments for existing risks of such phenomena in a variable and changing climate.</td>
</tr>
<tr>
<td></td>
<td>9. Emphasis 5. The observational paragraph is excellent. Beyond the value of confronting the models with observations to test model fidelity, which is vital, model sensitivity experiments that incorporate special observations can help identify where deficiencies in current observing systems reduce predictive skill. This observations-model interplay can help determine new requirements for innovations in observations and observing system design. In the long run we are building the capability for ongoing Earth system analyses and reanalyses for real-time monitoring and a long-term record of global and regional changes. This will require advances in fundamental observations but also improvements in model-data integration. Developing this capability is another potential integrating activity that could involve WWRP, WCRP, and other partners.</td>
</tr>
</tbody>
</table>

|     | Thank you. |
|     | 1. We have now added: ‘since the mid 19th century’ |
|     | 2. The Plan is written by the JSC who has the lead on the strategy and its implementation. The use of the first plural voice is in the name of WCRP. |
|     | 3. The text has been significantly revised, emphasizing the focus on fundamental understanding, of which the focus on reservoirs and flows is a science emphasis. |
|     | 4. Climate services and policy are now highlighted at the very beginning of the document. |
|     | There are many aspects of predictions that will require improvement and innovation, including initializations and data assimilation methods. |
|     | Comments on the emphases have all been dealt with when possible and integrated / merged with either the relevant objective or infrastructure section. We look forward to collaborating very closely with WWRP in many areas of our Plan. |

---

### World Climate Research Programme Grand Science Challenge on Climate, Circulation and Climate Sensitivity to provide feedback on the proposed WCRP strategic plan.

There is a great deal to like about the draft strategic plan. It’s broad, relevant to society and research and reframingly addresses the major issue facing future climate science. The two tracks of Objectives and Emphases gave it an effective structure. What we found worked less effectively was how the ‘Objectives’ were articulated, particularly given the ‘Emphases’. We very much endorse the identification of ‘Climate dynamics and extreme events’ as the first point of Emphasis; but given the underlying content, it would be better titled ‘Changing circulation systems’ or ‘Drivers of atmospheric and oceanic circulation changes’ or ‘Global circulations systems’. All of these titles more saliently identify the physical imperative to better understand global circulations systems and the consequences implied by their changes.

Given the near-plausible emphasis on the cir-culation, the too singular focus on budgets in the ‘Objectives’ text became discordant with the fact that there are, and rightfully so, two points of emphasis, i.e., process controls on budgets (of water, energy, and carbon), and drivers of global circulation systems. This discord could easily be addressed by slightly rewriting the first ‘Objective’ to better explain the importance of understanding global circulation, drivers of its changes, and its consequences for things like budgets and extremes. We would be happy to provide a specific text suggestion in this regard if that would be helpful.

In this context we also wonder if splitting the different facets of the prediction problem into two components (Objective 2 and Objective 3), is really helpful. Why not simply have advancing skill in predictions and projections as a single objective? We understand the tradition of people thinking about different facets of the problem that are often articulated by shorter and longer time-scales; but given the seamless approaches, and increasing evidence that long-term bias has many of its seeds in short-term errors, this tradition has ceased to be helpful. Combining projections and predictions into a single objective would make the explanation of this objective a bit ponder, but appropriately so, and not out of balance with an expanded articulation of the first objective as advocated above. It would also bring a better balance to what would then be three objectives.

In summary we urge you to consider three specific changes:

1. Better bringing out the importance of understanding drivers of circulation changes by rewriting the paragraph explaining the first objective.
2. Replacing the first point of Emphasis to identify it with the idea that global circulations, and drivers of their changes, must be better understood. |

|     | Merging the prediction and projections objectives to have a better overall balance of the Objectives. |
|     | As indicated above, we would be happy to assist in making these changes, if you would find it helpful. |
Thanks for the opportunity to provide some additional comments from the WWRP SSC at the final stages of your Strategy revision. These are based on the draft Version 14. You have already received— and responded to — comments from WWRP SSC members.

A) Primary Objectives

We appreciate and support the very prominent role given to the partnership with WWRP for Primary Objectives 1. Fundamental understanding of the climate and 2. Predictive skills in climate. We have joint activities for both of these objectives and look forward to developing further and initiating new activities as part of the implementation of the strategy.

For objectives 3 and 4 we see the need to work in partnership to our mutual benefit also. Although other WCRP partners will be at the forefront for these objectives, we consider it important to refer to WWRP for these objectives.

For 3. Understanding future earth system trajectories:

There are strong interdependencies between the observations and observing systems needed to characterise the earth system at all time and space scales. We need to exploit synergies between research on the future development of the observing system as well as on techniques to diagnose and verify the models we use. The representation of regional and extreme phenomena in support of climate services should draw on the expertise in the weather science community. The knowledge of how such phenomena may be impacted by climate change should, through our partnership, feed into the development of prediction systems at shorter time and space scales.

For 4. Climate science connections with policy and services:

The mission statement of WWRP includes “to enhance society’s resilience to high-impact weather and the value of weather information for users”. To this end we have strong emphasis on the collaboration between natural, social and economic sciences through our working group on Societal and Economic Research applications as well as concrete activities in our three core projects: High Impact Weather, Polar Prediction Project and (our joint project) Seasonal-to-Subseasonal Prediction. Collaboration between WCRP and WWRP in this area will be important for both programmes.

B) Infrastructure

The WCRP strategy identifies key challenges with respect to infrastructure. These challenges must be addressed by considering all aspects of Earth System Prediction – across time and space scales, across compartments of the Earth System, and taking into account the manner in which weather, climate, water and environmental information must be made available. Thus a commitment to working in partnership is at least as important here as in the previous sections.

In our view, the challenge associated with extreme-scale computing and data handling is not given enough emphasis either in the WWRP Implementation Plan or in the new WCRP strategy. In the former, the challenge is addressed across a number of different Action Areas. In the latter, the challenge is referenced but more with the view to taking advantage of advances rather than addressing a fundamental bottleneck. At the recent WWRP SSC meeting we identified the need to respond to this challenge with WCRP, GA and other partners. The first draft of the rationale for undertaking this is as follows:

https://mail.google.com/mail/u/1?ik=84137fd5&view=pt&search=all&permmsgid=msg-f%3A1615052132680813269&permmsgid=msg-f%3A1615052132680813269&amtsclude=1615052132680813269

The progress in numerical weather and climate monitoring and prediction has been intimately connected with the progress in supercomputing. Over the years, more computing power has enabled us to increase the size and range of our forecasts through increasing spatial resolution, enhancing realism by adding more physical process detail, coupling with more Earth system components and inventing in ensemble techniques to characterise the uncertainty of initial conditions and forecasts. Better models and better data assimilation techniques have allowed us to exploit information on the Earth system from high-quality observations for producing initial conditions. As a computing task, data assimilation is as costly as producing forecasts and this cost grows along with model enhancements and with the increase in both volume and diversity of the assimilated observations.

As prediction systems improve, the volume and diversity of the output data grows at similar rates or even faster than the computing cost. In the past, this growth in cost was mostly compensated by a comparable growth in computing and data handling capabilities arising from the ability to engineer more transistors onto microprocessors (Moore’s law) and from higher clock-speeds, while processor prices reduced. As transistor density reaches physical limits and clock-speeds stabilise to limit electric power consumption, added growth in performance can only be expected from much enhanced parallelization and from new processor technologies that combine such parallelism with enhanced power efficiency. Much of this technology is currently derived from commodity devices such as mobile phones. In about 10 years, typical operational weather prediction and climate projection workloads with high-resolution, coupled Earth-system model ensembles will lead to at least a factor of 1000 larger computing and data handling needs compared to today. This need cannot be fulfilled by the evolution of hardware technology alone, as in the past, but needs to be complemented by fundamental developments in numerical methods and mathematics but also in programming techniques that allow to optimally map the diverse range of computing tasks of models onto the emerging processor types ranging from CPU, GPU, FPGA to highly specialized ASIC devices. This range may widen even more in the future.

A key upper limit imposed on HPC systems is the affordable electric power level. Present petascale (i.e. supercomputers allowing 1015 floating point operations per second for tasks running at peak performance) systems consume O(108) MW per year, which translates to O(106$) cost for power and cooling per year. At present, most HPC centres are built on the assumption that their overall power budget will not exceed O(200MW), which falls way short of the above factor-1000 increase.

Data communication is a central concern in this equation as moving data (on and off memory and between processes) consumes about 10 times more energy than performing the calculations themselves. Another major concern is how observational input and model output data are managed along the prediction workflow to enable efficient pre- and post-processing, again aiming to minimize data movement, reduce storage needs and ensure resilient forecast production at the same time. While the computing and data handling challenges increase drastically, the requirements for data usability and fast access by users rather tighten.

The re-emergence of artificial intelligence methods sponsored by large-scale commercial applications has created opportunities for contributing to the much-needed efficiency gains. Their use for observational data pre-processing and model output post-processing can help to better distribute the data handling workload along the workflow, to extract useful information from large data volumes more effectively, and to reduce the computational burden of selected prediction model components by replacing them with surrogate neural network models for example.

The above challenges pose a fundamental bottleneck for the future advancement of both weather and climate prediction capabilities. The awareness of this problem has led to large-scale research and development efforts in many developed countries which are supported by significant governmental and public-private funding efforts, for example by the Department of Energy in the US or the European Commission. The challenges clearly contribute to widening the capability gap between more and less developed countries further as they require a unique level of expertise, co-design and technological support.

The need and urgency of a concerted effort between weather and climate science and computational science requires a much-enhanced representation of this issue in WMO’s strategic thinking. We very much look forward to contributing to the development of the WCRP implementation Plan and to strengthening the partnerships between WWRP and WCRP.