Documents

Day 2 - Session 3

19 May 2020

WCRP Task Team on Modeling (development and applications) and Computing Infrastructure

Input to the Implementation Plan - Report to JSC

2 December 2019

Modelling is a core activity for WCRP, throughout the Programme. The WCRP Modelling Advisory Council (WMAC) coordinates high-level aspects of modelling across WCRP, ensuring cooperation with key partners, such as the World Weather Research Programme (WWRP), and acting as a single entry point for all WCRP modelling activities. The purpose of this Task Team was to develop **recommendations on mechanisms and structures** needed so that the WCRP can achieve **integrated modelling activities** across the Programme in the future.

1) Lessons learned from WCRP modelling activities in the past

- The development, application and evaluation of models are done entirely by modelling centres and the broader research community. The role of the WCRP and its various panels and working groups is to coordinate these activities and foster collaboration. One important lesson is that organizing scientifically compelling activities needs engaging the broad modelling and analysis community, mobilizing a very large voluntary international capability.
- Do not separate the science and delivery of predictions and projections (e.g. CMIP, climate prediction) from the science of model development. There have been huge benefits from the close relationship between the working groups covering these activities.
- Lessons from coordinated modelling activities:
    - These activities, such as S2S and decadal forecasts, that offers public access to delayed forecasts, have accelerated contributions of many forecasting systems to national and WMO operations.
    - Associated databases have expanded access to data beyond the community of climate science and forecasting. Societal applications research using climate data across time scales from S2S to climate projection have started to develop real time applications based on the S2S, DCPP and the Coupled Model Intercomparison Project (CMIP) databases.
    - These modelling databases can help elucidate systematic errors, but have not thus far provided a direct pathway for coordinated model improvement efforts across the Programme. This probably needs to come from existing modelling groups like WGNE, GEWEX GASS, and CLIVAR OMDP.
- Compliance with data standards and support for them have been key factors in making CMIP such a success (everyone using CF-compliant NetCDF with CMOR extensions, having a supported Earth System Grid Federation, etc.). These have now followed through into obs4MIPS and ana4MIPs. However, the system has many weak points when trying to serve large and heterogeneous communities that need continuous access to the datasets.

- Some of the most successful activities occurred when the working groups have been allowed to develop their own efforts within the overall strategy set by WCRP. The work is typically done by people in individual institutions having interest and making the time, with the working groups providing coordination. WCRP provides the infrastructure and mechanisms that allow these projects to evolve and grow intrinsically from the researchers working on these problems.
- Many systematic errors seen in Earth System Models often have their origin in the representation of core processes and the interaction between Earth system components. Significant effort is needed to understand and model these core processes and interactions within an ESM framework.

2) Strengths, weaknesses, gaps, duplications of the existing modelling structures

Strengths:

- CMIP, now in its 6th phase, has been extremely successful, with 21 international modelling centres now engaged with more than 40 models. CMIP provides an extraordinarily valuable multi-model ensemble of historical climate simulations and future projections, along with a growing suite of targeted process-oriented experiments that feed directly into policy-relevant international activities like the IPCC, as well as national assessments and climate services in many countries. Having the timing of CMIP aligned with the IPCC contributes to its high profile, serves as additional incentive for modelling centres, and insures immediate and very visible uptake of model outputs.
- Strong interaction and the development of joint activities between different modelling groups allows for achievement of common goals and are an essential component of model improvement. The Aerosol II project developed by WCRP, WWRP, and GAW is one of many examples of how communication/coordination across programmes builds strong and effective projects.
- Having WGNE as the model development group and S2S/WGCM/WGSIP coordinating the research on prediction/projection and process evaluation relevant for the respective timescales seems to work well (although communication could be strengthened). More details on the respective roles of the modelling groups can be found in the modelling position paper

Weaknesses, gaps and duplications

- Coordination:
    - The main challenge for modelling groups (especially those going across timescales) has been a lack of coordination and common ambition between the research programmes (WCRP, WWRP and GAW). The programmes should work more closely and in a united way and identify common issues to be tackled jointly
    - Core Projects are not taking full advantage of experimental designs and data infrastructures developed in modeling groups: their domain expertise could add tremendous value under such framework
    - Coordination between WGSIP and S2S is getting better but could still be improved. Also, coordinated efforts on process understanding and model development from S2S to decadal timescales should be enhanced.

    - Currently there are no cross-timescale modelling nor process study groups for several of the Earth system components (e.g. ocean, cryosphere), which means some of the seamless benefits we see for the atmosphere through WGNE are not being replicated for other Earth system components.
    - It appears there are a lot of common science issues (ensemble generation, data assimilation, verification, model validation, shocks and drifts, etc) on different timescales and for different earth system components, so better coordination on these topics with links to both WWRP and WCRP could be considered.
    - There is a lack of a consolidated regional framework across all time scales (e.g CORDEX, RCCs, RHPs, etc), preventing a more coordinated and seamless strategy on climate information for regions
- WGCM and CORDEX/WGRC have identified a gap between global and regional modelling activities on the added value question. There has been some initial work e.g. on comparison of global and regional modelling (e.g. CMIP+HighResMIP and CORDEX), but more work is needed in this area of the science of generating climate information for regional scales.
- Lack of common data standards/protocols/policies/infrastructures to interface observations/reanalysis/simulations and support a full science-service value cycle impedes progress (*cf also the recommendations from the Task Team on Seamless Data and Data Management).*
- A critical research gap exists on fully exploiting multi-model data sets and turning them into robust/distilled information with uncertainty measures, either in objective probabilistic form or using narratives. An improved and more ambitious data management and dissemination plan could help solving this limitation, although methodologies to generate climate information at all time and spatial scales need to be discussed and assessed.
- There is no group currently that addresses infrastructure-related problems like scalability, portability to new architectures (e.g. GPUs), efficient model output handling, etc. across the board (except WGNE for a number of aspects) and attention to this topic should be expanded.

Opportunities

- The seamless prediction approach will help identify/address common problems across timescales (including climate, weather, and environmental research community) and better engage with a large number of users.
- The application of new technologies to methods like machine learning using of the very rich datasets currently available offer tremendous opportunities to speed up numerical code, to develop ESM emulators to compensate for lack of process understanding, to post-process model simulations and to distil multi-model climate information.
- There is a clear need to explore data assimilation strategies for different Earth system components, as well as for coupled data assimilation and for initializing forecast models on weather to decadal timescales. An example could include OSSEs focused on specific observing systems (in situ, satellite products) as well specific ocean or air-sea interface variables (e.g. SSS, sea ice, RH).

- Initialized predictions provide a basis for improved understanding of the origin and development of model biases that affect simulations at all time scales, although challenges remain and the application of innovative analysis methods that establish pathways of causality could facilitate progress.

3) Recommendations for future modelling and simulations in WCRP (including resource availability/requirements)

- A mechanism to coordinate modelling activities across the programme and across research programmes (WCRP/WWRP/GAW) should be put in place. A readily available on-line map of all modelling activities across programmes would be very beneficial for situational awareness and promotion of cross-group activities.
- The WCRP modelling activities that are relied upon as service-oriented products need financial and structural support within WCRP (e.g. CMIP for IPCC). For CMIP and CORDEX to successfully move forward WCRP needs to find a way to continue to engage modelling centres in the cutting-edge research activities (e.g. through science questions raised by the GC and MIPS) whilst enabling infrastructure (e.g. data dissemination, timely delivery of forcings) support for a more service-oriented element that underpins international programmes such as IPCC, GFCS, Global Stocktake, etc.
- Large, coordinated efforts like CMIP rely on an essential but largely invisible data infrastructure that includes a carefully developed naming and formatting convention for output, and an interoperable system of disseminating model output from many modelling centres in a seamless and user-friendly way. An essential lesson is that success of such coordinated modelling activities requires this data infrastructure and therefore WCRP must pay particular attention to the maintenance and ongoing development and support of this shared capability.
- Analysis tools should be better coordinated across the WMO research programmes with the goal of sharing code (e.g. the PCMDI metrics package, ESMValTool, JWGFVR) perhaps through python with GIT revision control, with code development guidance and a set of curators. WGCM is already discussing these matters and how best to make use of these capabilities.
- Continue encouraging MIPs at all time-scales aimed at understanding and process studies (e.g. as run by WGNE, GASS, CFMIP, etc.) but avoiding the explosion of MIPs that could collapse the data and coordination infrastructure. CMIP/AMIP-type simulations with service-oriented S2S and S2D forecast system would help identify sources of model error and the impact of initialization on forecast skill. S2S and WGSIP could also help identify high-impact case studies and neglected phenomena (e.g. MJO teleconnections in the SH) as well as understanding the pathways followed by the processes responsible of the systematic errors. A critical component of these efforts should be aimed at process studies for better understanding.
- Adapting codes for exascale computing architectures is a major challenge for all modelling efforts. Optimizing code is important for enabling the experimentation needed given limited resources, for adapting to the new generation of heterogeneous computers, and to decrease electricity consumption in HPCs. WGNE is taking a leading role in sharing best practices but a more comprehensive view that illustrates the risks the community is facing in a very complex computer infrastructure scene

(with new computer architectures, large data volumes that require analysis capability next to the data, etc.) is needed.

- Use of data science and machine learning should be comprehensively explored (e.g. emulation of parametrizations of more expensive schemes). WCRP needs to consider how this can be done within a climate change context. WGNE plans to continue evaluating this issue but many other possible efforts need to be identified and coordinated across the programme.
- Storage and exchange of data are already a challenge and this will likely worsen in the future. Volumes requested in coordinated experiments are too large for wide dissemination and computing next to the data (for data analysis and compression) is often not available. For big experiments, we probably need to store and process data where it is produced (as is done in many cases for CMIP), but it also remains a challenge for smaller experiments. It is a challenge to pull together what is needed for scientific processing, which suggests that a holistic approach across all WCRP initiatives is needed. (*cf also recommendations from the Task Team on Seamless Data and Data Management).*
- Create a clear path between research and operations, contributing to the definition of what operations means in the provision of climate change data and information. Need to acknowledge roles of and contributions from both research/academia and service-oriented actors.
- Source adequately (e.g. with a dedicated support such as a project office on top of what the JPS already provides) the coordination of all modelling activities in the programme and in sister programmes in a similar way as the current core project offices do. Proper internal two-way communication (with e.g. core projects) to leverage fundamental process understanding and/or disciplinary work has become indispensable.
- WGNE, together with other modelling groups have developed a positional paper for the WCRP implementation plan describing the unique and complementary rolls of the modelling groups as we navigate the evolving nature of the science and work to address future challenges.

WCRP Task Team on Seamless Data and Data Management

Input to the Implementation Plan - Report to JSC

2 December 2019

Climate observations and climate models are producing significant amounts of data and information and represent an intrinsic and critical part of WCRP activities. The purpose of this Task Team was to develop **recommendations on mechanisms and structures** needed so that the WCRP can achieve **integrated data production and management** across the Programme.

We understand seamless climate data to be all data required for understanding, predicting and projecting the climate system across all Earth-System components and scales. We understand seamless data management to be the coordination of continuous and interconnected production, acquisition, processing, archiving, transmission and dissemination of climate data across all disciplines, activities and scales.

1) Current status of Seamless Data and Data Management within WCRP

Data panels within WCRP core projects (e.g., GDAP in GEWEX, GSOP in CLIVAR) carrying out fundamental work for developing, assessing and updating a number of reference data sets

Data infrastructures being developed as part of several initiatives (S2S, CHFP, ESGF, etc), but not necessarily interfaced or using seamless formats and best practices

WCRP Data Advisory Council (WDAC) as single entry point for all WCRP data, information, and observation activities

- WDAC: Coordination across WCRP
    - Promotion of open data policies, protocols and standards
    - Recommend best practices for ECV (Essential Climate Variable) data set development and assessments
    - Coordination of reanalysis inter-comparison efforts and review of flux efforts
    - Promotion of observational and reanalysis data to support climate modelling (e.g., obs4MIPS, ana4MIPs, CREATE-IP)
    - Regular briefings on OSSE, data assimilation
- WDAC: Coordination with main partners (GCOS, GOOS, WWRP, GAW, Future Earth)
    - Linkages to GCOS: currently mainly via the joint AOPC, TOPC and OOPC panels
    - Link to satellite agencies via WG Climate

2) Lessons learned and open questions

Within WCRP there is a clear **need for an integrated management** of

- Observations for process understanding: beyond typical availability of ‘operational’ systems (dedicated field experiments)
- Observational climate data records
- Reanalyses and data generated by climate models (need to define ‘data’ in general)
- Data assimilation

- Data availability via open data infrastructures (e.g. ESGF, World Data Centres): need gap analysis
- Strategy on capturing observational uncertainties/covariances
- Synthesis on data stability and quality control (need for guidelines within WCRP)
- Data science and data mining/machine learning (need for information and knowledge exchange)

Part of this is covered by WDAC (e.g., reanalyses, obs4MIPS etc.), but some aspects need a stronger focus (e.g., observations for process understanding, uncertainties and quality control).

Topics missing and open questions

- New sensors and data products (e.g., micro-satellites, citizen science)
- Research-operations synergies (data management infrastructures, observational campaign vs operational networks) – e.g. WMO GDPFS
- Training and education
- Where should fluxes go (which cover all observations, modelling and data assimilation and are a key element of the Earth system approach)?

Potential action items

- Create room for stronger synergies between data assimilation, (re)analysis work and WIGOS
- Data infrastructure such as ESGF are not fully exploited across the programme. Interfacing with other systems, including operational ones (WIS/WIGOS, CDS/C3S) should be pursued.
- Reanalyses are currently largely uncoupled and need a stronger Earth system approach.
- Create guidelines on data quality control (avoid overlap with GCOS guidelines for ECVs). Advocate publication of quality control standards which would also provide recognition for effort spent, e.g. in Earth System Science Data.
- Encourage efforts for data synthesis, data integration and quality control, including for the provision of long-term, accurate (= stable/comparable) time series of climate relevant data.
- Check strength of the archival of both contemporary and historic research data. Including ‘stability’ of data centres / data storage sites.

3) Recommendations for data activities, mechanism and structures in WCRP (including resource availability/requirements)

- Need to coordinate observations, reanalyses, data science and data management issues across the programme and across WMO (with WWRP and GAW in particular)
- Information on (and access to) datasets via inventory for all WCRP key research? Important step towards seamless approach. Can provide direct input for gap analyses. However, this would need to be adequately resourced in terms of staff time.
- Better transfer of knowledge/experiences of/in data management across WCRP entities
- Establish a strong link to space agency bodies to exchange WCRP needs and space agency plans (involve GCOS and others to communicate requirements to space agencies)

- Data management strategies should include observations, reanalyses and model simulations seamlessly (close collaboration with modelling group)
- Strengthen coordination of reanalyses, in particular around Earth system reanalysis (TIRA white paper)
- Promote a broader Earth System approach to observations with GCOS
- Include data assimilation (OSEs/OSSEs in coordination with WWRP/DAOS/PDEF and WGNE)
- Include data science and data mining as we face huge and steadily growing amount of data (connect with AI/IT communities more closely)
- Interfacing/integrating (research) data infrastructure with their operational equivalent (WIS, C3S/CDS) is a necessary condition to the R-O goal

The future of seamless data and data management within WCRP requires a coordinating body. This could be a combination of 1) WDAC (with strong involvement of the existing/new core projects) and 2) a broader data group across WMO. Moving the role to the JSC or to a project office is not advisable. A number of current WDAC activities could fall under a broader umbrella within the Research Board (e.g., coupled data assimilation, Earth System reanalysis) and form a similar group to WGNE.

4) Current/future linkages with GCOS/GOOS, WWRP, GAW and Future Earth

- Interfacing between WCRP/WDAC and GCOS is crucial and should be further promoted (e.g. currently via joint panels)
- Champion ‘sustained observations’ for ECVs (e.g., only 20-25% of ocean observing system is sustained): WCRP needs to play a stronger advocacy role for observations
- Delineation of WDAC/WCRP vs GCOS responsibility should be clarified to avoid possible overlap and mission creep
- Rolling Reviews of Requirement for observations specific to climate science application area are hard to consolidate given the wealth of research needs and activities
- NB: The future of GCOS is still to be defined/confirmed as part of the WMO Reform
- Need to ensure that space-based observations will fit in the new WMO infrastructure
- Some linkages to Future Earth (e.g. SOLAS, AIMES, IGAC) in various forms
- Broader ambition with WWRP and GAW on data matters should be established

WCRP Task Team on Regional Activities
Input to the WCRP Implementation Plan

December 2, 2019

CORDEX, Working Group on Regional Climate, Grand Challenge on Weather and Climate Extremes, and CORA with representatives from JSC and JPS

1. Introduction

The mandate of the Task Team (TT) on Regional Activities is to propose implementing structures for activities on *climate knowledge and information for regions* and develop a concrete work plan for the next two years how they will intersect with each other and with WCRP core activities while each pursuing its unique role.
To date, three TT teleconferences have been held, with additional discussion by email and Skype.

The TT agreed to work on the following principles:

- The TT should work within the context of all four objectives of the WCRP Strategic Plan but with a strong emphasis on Objective 4 “Bridging climate science and society”.
- The TT should take as a starting point previous discussions and their outcomes on these issues - with respect to both WCRP and service partners. In particular, the TT has drawn on Recommendations on a Framework for WCRP Regional Activities (JSC-38/Doc. 11), though recognising that these need to be reframed in the context of the four WCRP Strategic Plan objectives rather than the three legs in the recommendation document.
- The TT agreed to postpone the start of this task to after the AGU fall meeting, as the TT must first have the results from the consultations and then figure out the structure and elements to be recommended to the JSC. The work plan will be prepared in the period Jan-April 2020 and presented at the JSC-41 in May 2020.

2. Consultation with Service Partners (Appendix A)

The TT decided to launch a consultation to the climate services (CS) community, to gather views and recommendations on how to build strategic partnerships with the WCRP for the co-production of climate research and information for regions. Given the desire to have some information to include in this initial report to the JSC by

December 2019, the decision was to target two high-level individuals within the WMO and GFCS: Celeste Saulo, WMO´s first vice president, and Felipe Lucio, ex-director of GFCS respectively. Unfortunately, to date F. Lucio has not responded to the request. In addition, a member from the Climate Services Partnership has been addressed (more will follow).

The TT will discuss some of the specific recommendations from this consultation over the coming months focusing on those relating to enhanced collaboration with the WMO. The TT recommended that CORA furthermore carries out a review of existing GFCS documents and reports based on previously undertaken regional and sectoral consultations.

3. Preliminary Recommendations for Elements and Structures

3.1 Elements

The TT has identified a first set of elements for inclusion in a two-year work plan. These elements will be further developed more specifically towards the final report in May 2020. Additional elements that are likely to be added:

- Frontiers of Climate Information (FoCI): The concept of FoCI has been updated as a potential way forward for regional activities as it expands current WCRP climate research towards objective 4 of the strategic plan, by including translational science as a vehicle for operation with stakeholders, social scientists, etc. The revised document is presented in Appendix B.

- It is proposed to explore the potential to turn the topics raised by the Core Projects initiative, i.e. Himalayas (Third Pole Experiment), ANDEX Programme, and Arctic/Greenland Sheet into FoCIs in order to link the two regional activities together.

- It is proposed to draw on the experience and expertise of IPCC AR6, in particular the three new ‘regional’ chapters at the end of the Working Group I report. This material will help to identify gaps and research questions relevant for WCRP’s regional agenda.

3.2 Structures

In proposing any new structure or additional body, existing regional activities and the presence of the newly established CORA need to be acknowledged. The particular scope of each new element should be clearly specified and distinctive. Any proposals made with respect to new WCRP structures needs to be contingent on wider WCRP discussion and should not add to the complexity.

Thus at this stage, the TT does not want to add a new layer of bureaucracy, but rather focus its discussion on finding new mechanisms to identify areas where WCRP members can work together across the horizontal activities regarding regional research. As a first step, the TT has begun to identify the organisations and communities who should be involved in such partnerships:

- GFCS
- Future Earth
- WMO/CCI, including Regional Associations and Regional Climate Centers
- Social science community (e.g., WWRP's SERA)
- Climate Services Partnership and the International Conference on Climate Services
- IPCC
- Early Career Scientists (e.g., YHS, APECS, YESS)
- Disaster Risk Reduction Community
- Other UN entities e.g. UNESCO, UNDP, UNEP
- Private foundations, e.g., Bill and Melinda Gates Foundation, MacArthur Foundation, etc.
- World Bank, Green Climate Fund, etc.

In terms of linkages across and within the WCRP, CORA has started with a stocktake of WCRP links to stakeholders which will be elaborated in the future and used for identifying specific activities and areas for cross-cutting interaction. CORA has also undertaken a survey among WCRP bodies on already existing regional activities, which provides relevant material and will be assessed by the TT over the coming months.

Appendix A

Consultation with Service Partners

Status: November 28, 2019

The TT launched a consultation to the climate services (CS) community, to gather views and recommendations on how to build strategic partnerships with the WCRP for the co-production of climate research and information for regions.

The consultation was based on the following questions:

1. *What is needed to make strong and sustainable connections with WCRP for the provision of climate information for regions targeted to climate services and policy makers?*
2. *How can WCRP climate science be responsive to the climate services community?*
3. *Which on-going activities would you envision the WCRP community providing input to?*
4. *Whom should we contact to discuss the climate science?*

For a timely outcome, the survey concentrated on those parties that are either in the immediate vicinity of WCRP or easy to access. Besides conducting interviews, information was extracted from a number of relevant documents.

1. Information from Interviews

Respondent: WMO 1st vice-president, Dr Celeste Saulo

Saulo pointed out the WCRP should develop links to WMO´s Global Framework for Climate Services (GFCS), Regional Associations and Regional Climate Centres (RCCs).

Because of WMO´s reorganisation, the GFCS will be overseen and implemented by a new body: the Climate Coordination Panel (CCP; adopted by Resolution 4 (EC-71) replacing the Intergovernmental Board on Climate Services (IBCS; dissolved by Resolution 21 (Cg-18). The governance structure of GFCS includes the Partner Advisory Committee (PAC; the stakeholder engagement mechanisms of GFCS) and the Climate Services Information Systems (CSIS, the operational part of GFCS). The composition of the CCP is being defined, and will be operational in early 2020 (find ToRs here).

Below is a summary of Saulo´s comments and recommendations:

- WCRP and WMO to set up a Regional Climate Science Agenda

- WCRP to establish a sustainable partnership with the Global Framework for Climate Services (GFCS) for the co-production of actionable knowledge. This partnership will feedback to the WCRP community on the climate science needed by defining key scientific questions
- WCRP scientists to participate in the bi-annual events of WMO´s Regional Associations to be informed of the requirements, needs and priorities of stakeholders and users
- WCRP could provide quality checks and verification of the quality of climate science behind CS products and applications. By assisting in the verification process, it enhances the credibility of CS products and services
- WCRP should get involved in programmes on disaster risk reduction and climate change adaptation to provide advice and climate information
- WCRP to organize knowledge sharing events with WMO´s Global, Regional and National Frameworks for Climate Services
- WCRP to enhance its presence in the regional academic community by engaging ECR (e.g. Young Earth System Scientists -YESS) in WCRP activities and to facilitate their connection with local & regional Climate Services

Respondent: Climate Services Partnership Secretariat (Dr María Manez)

Manez pointed out that the biggest opportunity to actually establish connections to the service partners is to be present at events that are relevant for this community (e.g., Adaptation Futures, International Conference on Climate Services, COP, etc.). Most members from this community don't even know the WCRP. When asked to which bodies service partners usually turn to for scientific input, it became clear that this is usually some entity on the regional or national level (e.g., universities, meteorological services, NOAA, NCAR, COPERNICUS, etc.) and not international organizations like WCRP.

In summary, she gave the following comments and recommendations:

- WCRP should consider involving at least to some degree social scientist in some of its activities.
- For some activities it might be necessary that people from a different discipline (social science, communication science) are employed.
- While WCRP addresses current science topics, it does not address all topics that are relevant for the effects of climate change on society. Topics like high-resolution modelling of small islands and coasts are currently not at all addressed or neglected. This holds for both modelling and observations.
- The process of connecting to service partners will take time, as the two communities are very different. Thus, to really engage with this community, WCRP needs to plan for a long time span (full lifetime of the strategic plan).
- WCRP needs to approach the respective communities to make itself known.

- WCRP should actively seek opportunities to get together with service partners and listen to their concerns and needs. This would allow for finding the "gaps" in current research activities.

2. Information extracted from relevant documents

2.1 Report from WMO international workshop on "Climate Services Information System Operations and Coordination" (2017) to WCRP JSC-38

The workshop discussions identified a number of areas where research input from, and collaboration with WCRP would bring mutual benefits, such as: Strengthening of linkages between the research and operational (particularly Regional Climate Centres -RRCs -and NMHS) communities and thus enhanced direct societal relevance of WCRP activities; more effective and targeted incorporation of regional and national expertise in specific WCRP research activities; added authority of national climate information products; enhanced capacity building at the regional and national level through RCCs and NMHSs; and, efficient and open data and knowledge exchange.

The following WCRP research areas were identified as the most pressing priorities by workshop participants:

1. Optimised approaches for the use of multi-model ensembles across all forecasting/prediction timescales, from subseasonal to decadal, and including climate projection timescales for which no standard methods currently exist
2. Improved access to CMIP5/6 and CORDEX outputs and evaluation of these outputs at the regional and national level
3. Improved methods for, and appropriate use of, downscaling and bias adjustment - across all forecasting/prediction/projection timescales
4. Improved and advanced methods for the construction and analysis of national observational climatologies, including extreme events and the effective use of multiple data sources
5. Enhanced understanding of the linkages between local/national weather and climate (including extreme events) and regional/large-scale climate dynamics and circulation – both to improve understanding of current trends and variability (which is important for climate resilience and adaptation decision making), and for improved forecasting/prediction/projection
6. More robust and objective approaches to the interpretation and distillation of observations and model outputs into climate information (as outlined in the proposed WCRP Frontiers of Climate Information (FoCI) project concept)
7. Improved predictability of extreme rainfall (including drought) on subseasonal to decadal scales

8. Improved understanding and forecasting ability of processes with regional impacts, such as the variability in the Niño 1+2 region
9. There is an evident demand from in-country users for information on decadal prediction timescales, and thus interest in a number of NMHSs in this developing research area

These research topics cut across a number of WCRP activities, but the following (in alphabetical order) are considered particularly relevant:

- CORDEX
- CMIP (including from CMIP6: DCPP, ENSOMIP, HighResMIP, ScenarioMIP)
- Grand Challenge on Near-term Climate Prediction
- Grand Challenge on Understanding and Predicting Weather and Climate Extremes
- Grand Challenge on Water for the Food Baskets of the World
- WGRC/WGIR (Information for Regions)
- WGSIP (working with WWRP in the case of subseasonal timescales)

Note: this report does not seem to have been tabled at the JSC-38.

2.2 Regional Climate Projections: WCRP input to the WMO´s Inter-Programme Expert Team on Regional Climate Activities (IPET-RCA)

Summary of recommendations

1. The IPET- RCA should contribute to the development and review of guidance on the use and interpretation of climate change projections, even though lead responsibility for developing this guidance lies elsewhere.
2. There is a clear and pressing need for RCCs to assist users in accessing CMIP5, CMIP6 and CORDEX data.
3. Regional Climate Centres (RCCs) are well placed to provide advice and guidance on climate model selection, particularly based on expertise in relevant regional phenomena.
4. Further discussion is needed as to the scope of guidance that RCCs should be expected to provide on the post-processing and tailoring of information for vulnerability, impact and adaptation assessments.
5. IPET-RCA and RCCs should develop stronger linkages with the research community (including the WCRP) in order to effectively address these issues.

2.3 GFCS and (WCRP) research needs, gaps and priorities

The following information was extracted from a presentation from Filipe Lucio to the WCRP Grand Challenge Near-Time Climate Prediction group on 4 September 2018[2]:

Climate information needs for decision making	**Time scales**	**Climate Research Frontier Knowledge gaps**
Strategic ahead of season planning	1-12 months	Improved seasonal prediction, Remote and local drivers
Risk monitoring and management droughts/wet spells	7-40 days	Sub-seasonal prediction: Improved understanding of sources of variability
Long-term strategic planning/policy development	1-10 years	Decadal prediction: Drivers AMO, PDO/ Role of aerosols
Climate change adaptation policy development	Next 50 years	Climate Change scenarios ESM, attribution methodology, uncertainty

<u>Gaps in Research, Modelling and Prediction</u>

- Communication between communities of scientists and practitioners
- Last mile between science products and service-oriented climate information
- Lack of seamless suite of climate products for contiguous time scales from weather to centennial climate projections
- Limited or unknown predictability for a range of key time-space scales
- Dealing with uncertainty

Priorities

- Improve the availability of regularly updated standardized climate diagnostic and prognostic information.
- Climate research to deliver sustained improvement of climate information identified as feasible and most needed in the five priority areas of GFCS implementation.
- Support applied climate research for developing practical applications for the four near-term GFCS priorities through pilot and demonstration projects that bring together all five elements of the GFCS with a primary focus on integration and delivery of best climate information to users and decision makers.

Appendix B

Implementation Framework
for
WCRP Frontiers of Climate Information (FoCI) Projects

(Status December 2019)

Background

In 2015, the 36th session of the WCRP Joint Steering Committee (JSC-36) concluded that climate information for regions is a key issue across all deliverables of WCRP projects and activities and therefore called for a more inclusive and harmonized effort in support of the WCRP's Key Deliverable on Regional Climate.

As a way to develop mechanisms to advance the research on developing climate information for regions, the JSC requested the Working Group on Regional Climate (WGRC) to take responsibility as an implementing agent of FoCI[1] Projects with a city/regional focus. In this role the WGRC would facilitate and support relevant scientific efforts across the WCRP as well as initiate activities within the WGRC terms of reference. This would also include developing guidance and catalyzing linkages with external partners for climate services.

In 2016, the 37th session of the WCRP Joint Steering Committee (JSC-37) asked an ad-hoc group to organize a workshop to discuss the status of and issues regarding WCRP regional activities and design a concept to explain climate information for regions in the WCRP context. This activity resulted in the report Scoping a framework for WCRP regional activities. One of the recommendations was to launch an international call to establish a coordinator office for WCRP regional activities (CORA). The office is jointly hosted by GERICS in Germany and the BCCR in Norway, and become fully operational in June 2019.

In 2019, and regarding WCRP Strategic Plan 2019-2028, the JSC assigned a number of short-lived Task Teams to address specific questions relevant towards the Implementation Plan over the next two years about the new structure of the WCRP. A Task Team on Regional Activities (TT) was then appointed with members from CORDEX, WGRC, GC Extremes and CORA and representatives from the JSC and JPS representatives. The TT was to make recommendations to the JSC about future structures dealing with climate information for regions and how they will intersect with each other and within WCRP core activities while each pursuing its unique role.

It is in this context that the TT recommends the implementation of FoCI projects, in revised form as shown in this document, as an element in the future structure of the WCRP. The FoCI is meant to address the challenge of the rapidly expanding availability of different climate data sets from a multiplicity of global and regional models and other downscaling techniques. This is matched by an increasing pressure from a wide range of stakeholders and organizations for scale-relevant information to support regional decision-scale needs.

[1] At the time of JSC-36, these projects were referred to as 'frontier projects' – the WGRC-3 meeting subsequently established the FoCI title.

These data, along with new observational datasets that are themselves not fully congruent, convey mixed and contrary messages about climate change and variability. This presents a clear challenge to the scientific community and there exists a fundamental and critical research frontier on how to move from the expanding production of data to the construction of defensible and scale-relevant information. The FoCI project notably targets objective 4 of WCRP's Strategic Plan, *Bridging science and society*, in that it will be a primary vehicle to engage in collaborative research with boundary organizations[2] in order to support the generation and delivery of decision-relevant information and knowledge about the evolving Earth System.

Concept

A FoCI project adopts a specific phrasing of "information for regions" – as distinct from "regional information". While the latter implies a focus on resolution and location specific data, especially via downscaling, the concept of "information for regions" infers a broader scope to consider scales of processes ranging from local to global in-so-far as these inform our understanding of the regional climate dynamics and the local response to climate forcings. FoCI projects would approach this through a lens whereby the needs for robust, scale-relevant information for regional decision making expressly help steer and prioritize foundational research on the relevant climate processes that operate and interact across all scales.

Explicitly a FoCI project seeks to engage with the research challenge of *data distillation*. The term "distillation" refers here to the conflicting information from across the range of observational, Earth System Models (ESMs), Global Climate Models (GCMs), Regional Climate Models (RCMs), and empirical-statistical downscaled (ESD) data. These data represent a conflated mix of natural variability, deterministic responses to anthropogenic forcing, and multiple sources of bias and error. The response to the distillation challenge is to develop new approaches and analysis techniques to contribute to building physical understanding of robust scale-relevant information for decision needs.

The objectives for FoCI projects are to:

- Comply with all WCRP´s Strategic Plan objectives regarding regional climate science and climate information.
- Work on the appropriate spatial and temporal scales for decision-relevant issues
- Distillate climate system information from varied sources.
- Integrate and link climate information in the context of risk management of the Earth and societal systems.
- Develop and support research capacity, especially in developing nations.
- Co-produce cross-cutting, trans-disciplinary and translational science with boundary organisations.

FoCI projects will provide opportunities for engagement by all relevant activities of the future WCRP and across the Strategic Plan objectives. In particular, CORDEX´s Flagship Pilot Studies (FPS) and the Coordinated Output for Regional Evaluations (CORE) will be of

[2] The term "boundary organizations" is used broadly to include climate services and activities that engage across the science-society gap, such as WMO´s GFCS, Future Earth, etc.

relevance to FoCI Projects, while the GEWEX Regional Hydroclimate Projects (RHP) afford additional potential for the establishment of FoCI Projects as these translate fundamental knowledge into actionable information (objective 4). FoCI will also encompass process understanding of the climate system and the near-term evolution of the climate system (objectives 1 and 2).

Framework of FoCI Projects

The heart of a FoCI Project is to develop climate information for regions, framed by relevance to regional stakeholders, and approached through innovation in analysis and methods. Thus, FoCI will play a key role in fulfilling WCRP´s objective 4, *Bridging Science and Society* in that they will:

1. Relate to regional aspects of one or more **WCRP activities in their new form**, with the goal to:
    - Understand the separation of local and remote contributions to natural and forced variability and change
    - Leverage existing climate research targeting different time-scales
    - Integrate research across multiple topics; e.g. understanding of extremes with local feedbacks and inter-annual variability of global drivers.
2. **Develop new approaches to distill decision- and scale-relevant information** from different sources within the WCRP and related external programs to reconcile differences across data sources, data types, and relevant scales of time and space.
3. **Improve the quality of regional information** through innovation of methodology and analysis with **special emphasis on multi-scale climate processes.** Focus on scales of user relevance, by which is implied a domain of notable societal vulnerability to climate where there is limited understanding of the co-behavior of the multi-scale driving climate processes, and for pragmatic purposes also likely to attract a high level of funding interest from a range of agencies.
4. **Adopt data criteria of "free sharing for researcher use"** and full and free public access wherever possible.
5. **Target stakeholder relevant information about the regional climate;** recognizing that data is not necessarily information, but that information for regions is about messages backed by robust physical understanding, of scale-relevant climate attributes, tailored to the decision and risk management needs of stakeholders and defensible through understanding of multi-scale climate processes.
6. **Address the information needs of regional stakeholders.** This will imply finding a mechanism to engage with pertinent stakeholders, or to use existing opportunities for collaboration to access user information to inform the research. This is not a simple needs-driven approach, but a process to inform the research through a user-directed identification of key attributes of the climate system that have identifiable relevance to thresholds and vulnerabilities in the coupled socio-ecological regional system.
7. **Focus on relevant time scales** from sub-seasonal to multi-decadal.
8. **Includes linkages with relevant research communities** in impact modeling, vulnerability assessment, and adaptation and policy.

Criteria for selecting FoCI Projects

A FoCI project

- Identifies varied sources of climate information and steps to be followed for distillation.
- Identifies the added value of involving relevant WCRP projects/activities to be synthesized into the FoCI project.
- Identifies the engagement of participants from stakeholder/users and eventually, the need of capacity building.
- Defines relevant temporal and spatial scales (e.g., decision and climate scales, etc.).
- Contributes to well-defined policy questions.
- Assesses the effectiveness of distillation messages.

Monitoring and success metrics for FoCI Projects

- To what degree the project draws on WCRP activities and encompasses the program´s objectives
- Measure of different types of information incorporated
- Success in synthesis of different sources of information
- Distillation:
    - the formulation of scientifically, physically robust, credible and scale appropriate messages on changing climate
    - Measures of uptake of the distillation messages to the targeted audience
- Self-reflection on how well the group has engaged the varied participants (including stakeholders)
- Capacity building: activities and outcomes /sustaining elements
- Lessons learned from the interaction with the boundary organisations/ stakeholders/users
- Impact: What policy relevant outcome(s) has been produced? What policy has been affected? Is there a demonstrable link to policy?
- To what degree the project has contributed to advance/refocus the fundamental research by identifying new scientific questions

An implementation plan for FoCI Project Portfolio and potential funding

The process of identifying and implementing an initial portfolio of FoCI projects should be the task of a **new WCRP coordinating element or structure on regional activities**, to be in place in the coming two years of the WCRP implementation plan.

However, the activities proposed by the “Core Project joint initiative” at the JSC-40 (2019) are potential candidates to include in a preliminary FoCI portfolio. The initiative of CLIVAR, CliC, GEWEX, SPARC and CORDEX proposes to launch coordinated, cross-cutting and societal relevant fundamental research on selected regional topics (e.g. ANDEX, Arctic Greenland Ice Sheet and the Third Pole project). At least one of these topics could be implemented under the FoCI framework and run for 3-5 years after which the project(s) would be evaluated to assess future modalities. If successful, and with the new WCRP structure in place, open calls for new FoCI would then be issued.

An open and early dialogue with potential funders and regional scientists should be explored. This could be done by funding for a meeting between potential future funding agencies (e.g., USAID, development agencies, World Bank, DFID, SIDA) and regional scientists.