Report of the survey organized in July 2014 on " Lessons learnt from IPCC AR5 for climate change research and WCRP "

Report outline

Acronyms used in this report

AR4/5:	Fourth/Fifth Assessment Report
CMIP:	Couple Model Intercomparison Project
ENSO:	El Niño Southern Oscillation
GCM:	General Circulation Model
IPCC:	Intergovernmental Panel of Climate Change
ISSI:	International Space Science Institute
SREX:	Special Report on Extreme Events
WCRP:	World Climate Research Program
WGI/II:	Working Group I/II

Link to the survey results

A survey was launched by World Climate Research Program (WCRP) from 27 May until 7 July to the WCRP community and Intergovernmental Panel of Climate Change (IPCC) Working Group I (WGI) and II authors. 46 responses have been collected, the major part from scientists involved in the workshop organized on 8-10 September by WCRP with IPCC co-sponsorship and hosted by International Space Science Institute (ISSI). Survey results have been interpreted by Scientific Steering Committee members (Sandrine Bony, Guy Brasseur, Anny Cazenave, Katharine Mach, Kasper Plattner, Vladimir Kattsov, James Renwick) and edited by Gilles Sommeria (WCRP consultant) & Nicolas Champollion (ISSI post doc).

A link to detailed survey results is available at:
https://www.dropbox.com/sh/nky1ycy0ww0rj3q/AAC3eI_2RmF0doTqrzAUf6b8a?dl=0

I. Purpose of the survey

WCRP is one of the main contributors to climate research assessed by "Working Group I - The Physical Science Basis" of IPCC and for certain aspects by "Working Group II - Impacts, Adaptation and vulnerability". It is therefore essential for WCRP to take stock of key scientific issues identified in the course of the IPCC's Fifth Assessment Report (AR5) and to review WCRP's future research plans in this context.

The WCRP jointly with IPCC is organising a workshop entitled "IPCC AR5: Lessons Learnt for Climate Change Research and WCRP" in order to learn from the relevant authors of the IPCC AR5 and its findings to help guide future strategies for effective and exciting climate change research. The workshop takes place from 8-10 September 2014 at ISSI, Bern, Switzerland.

WCRP & ISSI conducted the survey in preparation for the above workshop. Its purpose was to review how IPCC assessment reports impact on the climate science community in general and WCRP in particular. The survey focused on research gaps, knowledge gaps, and uncertainties, on potential ways forward to make progress (in terms of observing systems, modeling, etc.), and on how all those components are covered in the current existing WCRP programme, including the WCRP Core Projects and Grand Challenges. It also included some questions related to the way IPCC assessments are reflected in WCRP activities.

II. Structure of the survey

The starting point for the survey was the review of outstanding scientific issues identified by IPCC AR5 in WGI report (referred to as "key uncertainties" in Technical Summary, see Annex I) and "research and data gaps" in WGII report, complemented as needed by material from IPCC Special Report on Extreme Events (SREX). Respondents were also invited to mention other outstanding research issues highlighted within the reports. In order to facilitate interpretation of responses, a classification of research and observation issues was proposed (see Annex II). Views were solicited on how these issues have evolved between AR4 and AR5, how they have been taken up in new studies since AR5 cut-off dates, and how they are dealt with in WCRP plans (through the Core Projects or the Grand Challenges). In addition suggestions on future IPCC/WCRP interface issues were welcome as well as on any other aspect of climate research which participants wished to highlight.

The survey results are available to WCRP as a resource when refining WCRP work plans and to IPCC in order to inform the on-going reflection on future IPCC assessments. Comments received as part of the survey are not attributed, but we acknowledge with thanks all respondents (see the list of respondents in Annex III). The questions of the survey are presented in Annex IV.

III. Overview of the survey

The survey was sent to around 500 persons (IPCC WGI & II authors and WCRP community). We received 46 responses, e.g. around 10%. The short delay to answer, in addition to a relatively long and detailed survey, partly explains the low rate of responses. The 46 responses mostly originate from participants to the coming IPCC/WCRP workshop (where 80 persons will participate). Some of the responses are fairly exhaustive and many contain constructive proposals.

The following figures provide overall statistics on responses. A large majority of respondents (about 75%) are IPCC authors (see Fig. 1), with a ratio of about two to one for WGI versus WGII representation. A little more than a quarter of respondents are part of WCRP coordination bodies (see Fig. 2), another quarter being in the category "user of results from WCRP process". We also noticed that half of respondents are not formally related to WCRP.

With respect to geographic distribution, United States of America (USA) and Europe represent most of the responses (see Fig. 3), with, in Europe, a good participation of people from United Kingdom (UK) and Switzerland. This matches the workshop participation but indeed does not represent a balanced geographic distribution. However, 15 countries around the world and the 6 continents (see Fig. 4) are represented although Europe and USA dominate.

The areas of expertise of the respondents cover all broad climate domains of IPCC WGI and some key areas of IPCC WGII, even if the percent of responses is low. The main themes of the respondents are atmospheric and ocean circulation & interaction, water and carbon cycle, sea level, cryosphere, paleoclimate, hydrology, climate modeling & observation as well as climate prediction, remote sensing of the Earth, land cover, climate variability in space & time and sensibility, extreme events, climate attribution & adaptation, human dimensions of climate change & public policy, economics of climate change, …

Finally, the representativeness of the survey is somewhat weakened by the low rate of responses. However, because of the large cover of expertise areas of the respondents, as well as the detailed responses, survey results may still be considered as useful for WCRP & IPCC communities.

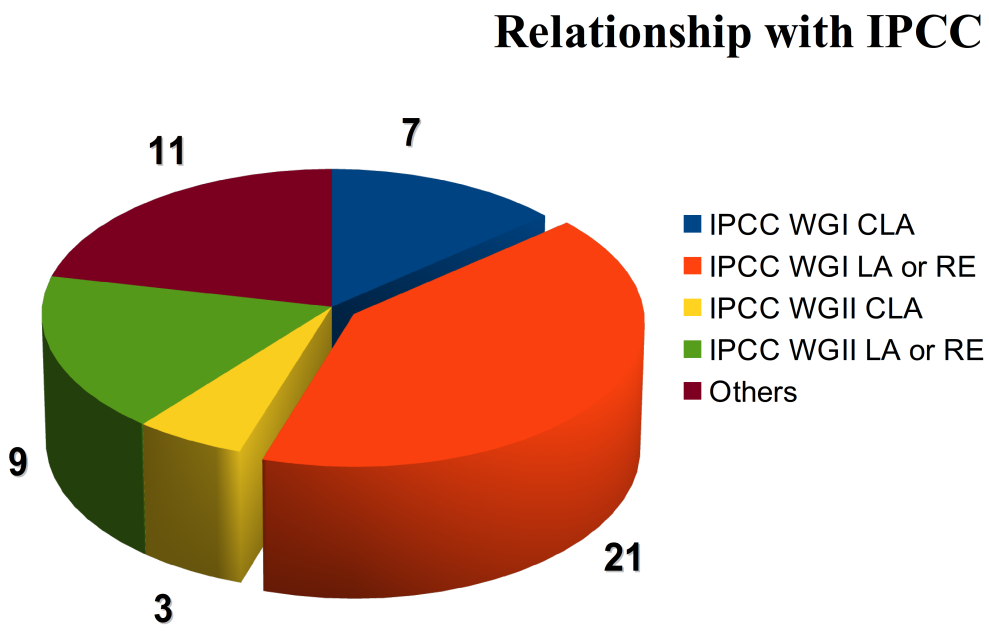


Fig. 1: Relationship with IPCC of the survey respondents. The total number of the graph respondents is higher than the number of survey respondents due to multiple relationships. (CLA: Coordinating Lead Authors – RE: Review Editors– LA: Lead Authors)

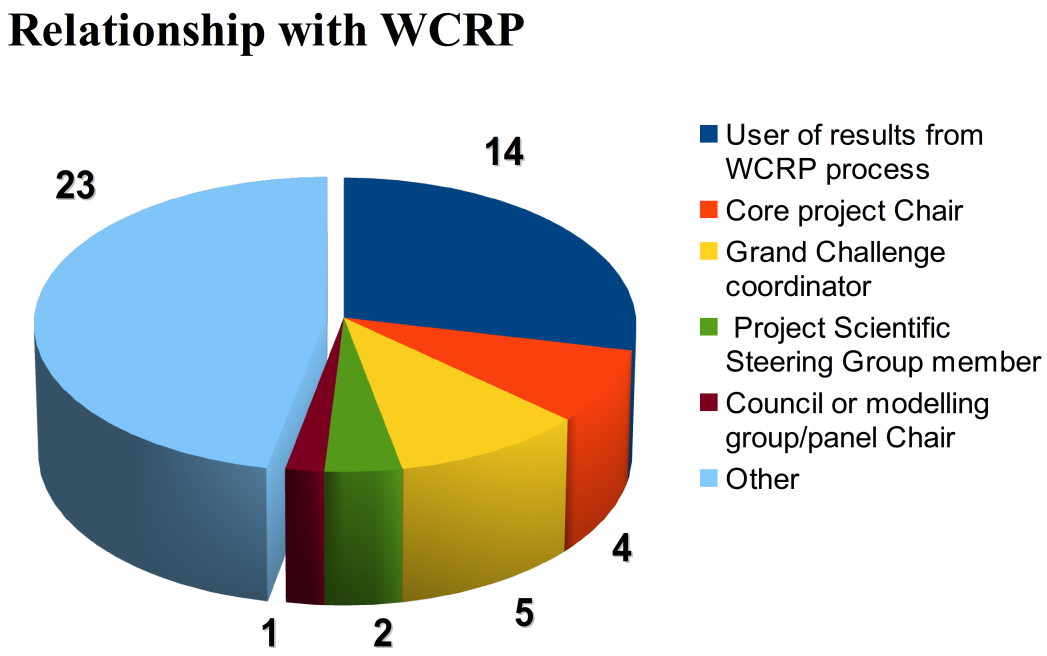


Fig. 2: Relationship with WCRP of the survey respondents, The total number of the graph respondents is higher than the number of survey respondents due to multiple relationships.

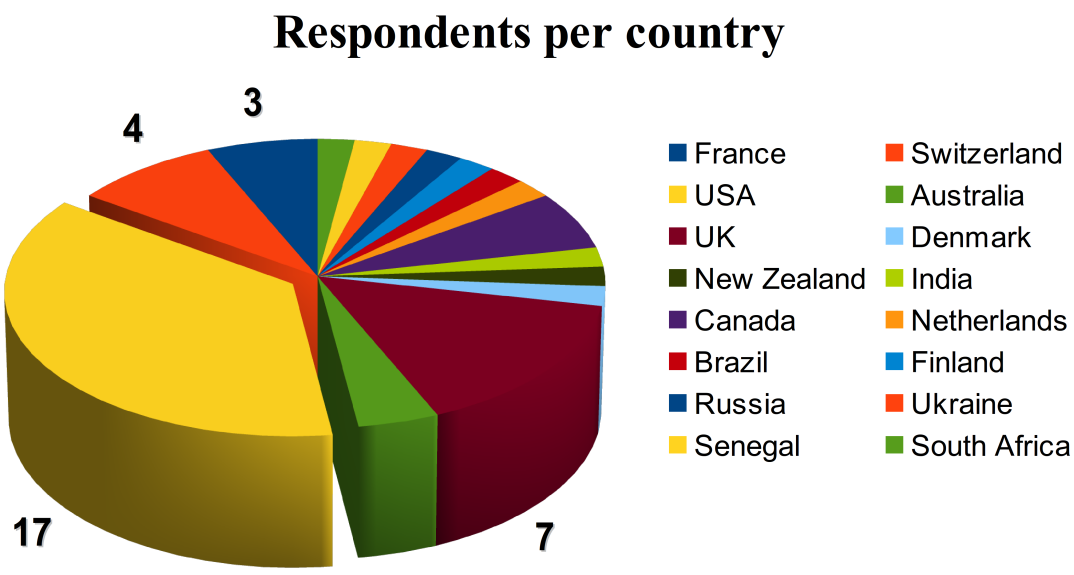


Fig. 3: Origin per country of the survey respondents (46 persons).

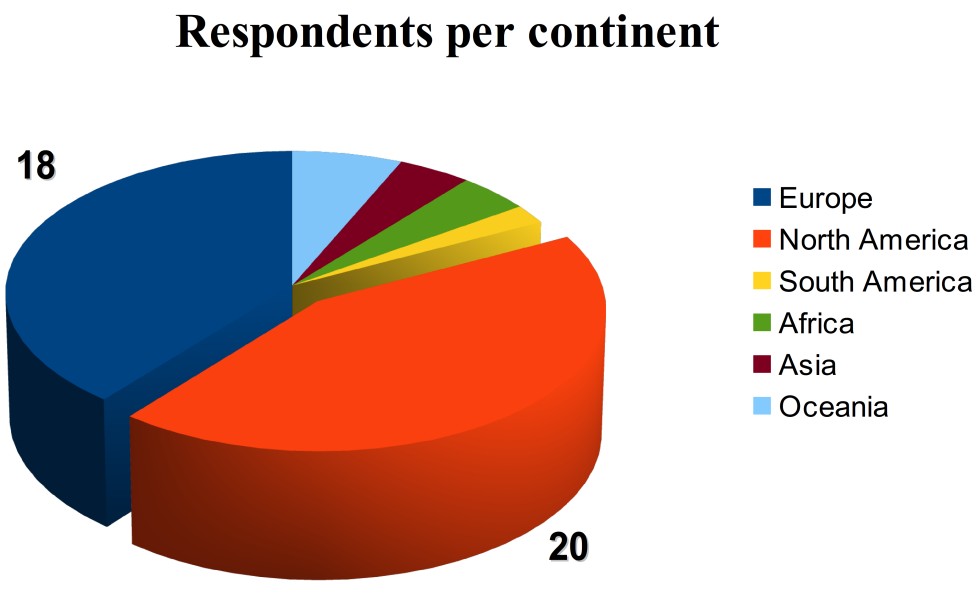


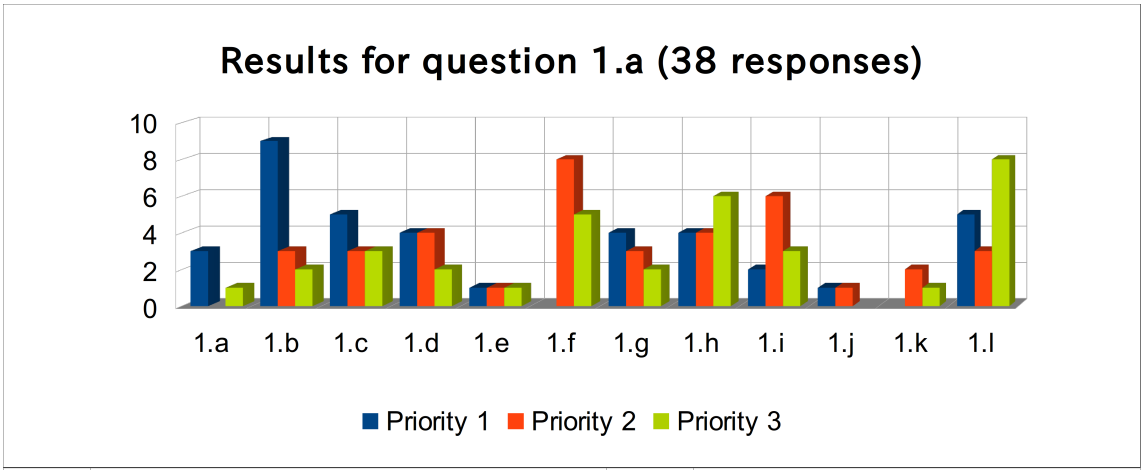
Fig. 4: Origin per continent of the survey respondents (46 persons).

IV. Detailed analysis of the survey results

Issues covered by WGI: the physical science basis

1. Key gaps in observations of changes in the climate system

1.1. Priority issues identified by IPCC: the first question is on prioritizing the key issues by listing the top 3 among the 12 "gaps" identified in IPCC AR5 by WGI. The statistics of the 38 responses is summarized in Fig. 5 below.



1.a	Troposheric & stratospheric warming	1.g	Sub-surface ocean temperature
1.b	Global precipitation change over land	1.h	Annual & global deep ocean temperature
1.c	Observation of global cloud variability	1.i	Observation of ocean deeper than 2000 m
1.d	Observation of global dryness	1.j	Observation of ocean circulation features
1.e	Long-term change in tropical cyclones	1.k	Sea ice change in Antarctica
1.f	Long-term change in large-scale atmospheric circulation	1.l	Antarctica mass loss

Fig. 5:The top 3 main issues among the 12 "gaps" identified in IPCC AR5 by WGI (see Annex I).

Fig. 5 shows that the top priority is about improving precipitation data (key variable to understand the global water cycle; high societal impacts). The next two issues are about ice sheet dynamics & ice-ocean interactions, especially Antarctica mass loss (key for future sea level rise), and observation of clouds variability & change (largest uncertainty in climate modeling). The following issues are about ocean temperature measurements, including the deep ocean, and observation of global dryness. If issues g, h and i are grouped together (all about 3-D ocean temperatures), then better observations of the ocean heat content (critical to understand energy uptake in the climate system and close the Earth's energy budget) becomes the top priority (10 responses), followed by precipitations and ice sheet dynamics.

The top 2nd choice is about the atmospheric circulation and variability of large scale atmospheric patterns. It is followed by the issue about deep ocean heat content (2nd choice for those who did not rank it first).

The top issue of the 3rd choice is ice sheet dynamics & ice-ocean interactions. It is followed by ocean temperatures and ocean heat content. The 2nd and 3rd choices are coherent with the top priority list. While responses are in general agreement with the key uncertainties identified by IPCC WGI in AR5, they highlight 4 key issues: (i) ocean heat content, (ii) precipitation, (iii) ice sheet dynamics and (iv) large-scale circulation patterns for which improved observations are critically needed.

1.2. Important issues in addition to the identified list by IPCC: on the important issues to highlight in addition to the identified list, there are two categories of responses: observations of additional climate variables & processes, and improvements in data processing.

Observations of additional climate variables & processes:

- all components of the Earth's energy budget not listed in the survey annex: radiation at the top-of-atmosphere and surface, land fluxes, sea fluxes
- extremes
- soil moisture, evapotranspiration, runoff
- aerosols-clouds interactions
- coastal processes
- land carbon budget and permafrost

Improvements in data processing:

- data rescue (especially on extremes and coastal processes)
- systematic estimate of observational uncertainties
- validation and intercomparison of gridded data sets (develop a Climate Model Intercomparison Project (CMIP) -type program for observations and gridded data sets)
- analyses in synergy of several climate variables

Others: more research is needed on adaptation planning and on closing the gap between model results and coastal management

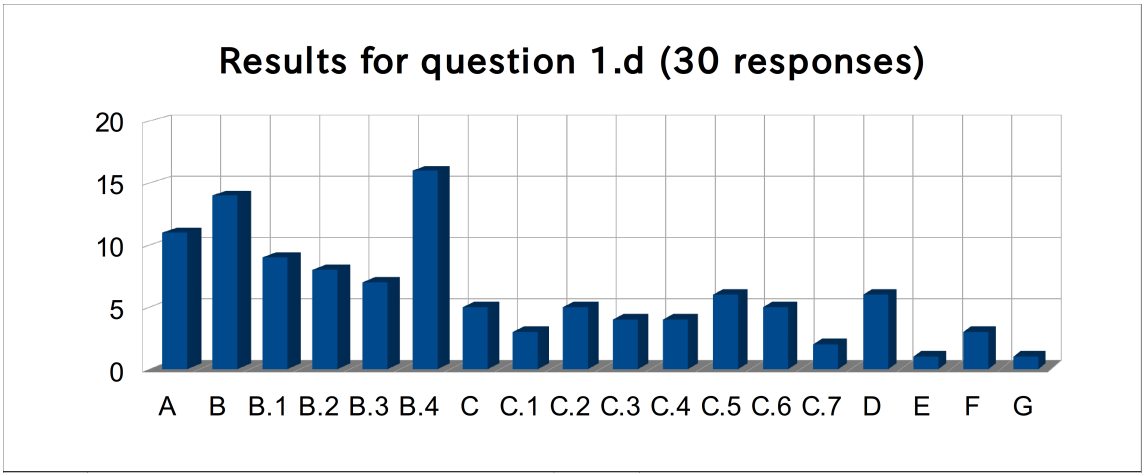
1.3. Proposals for making progress: on proposals for making progress, responses are numerous and broad range (see Fig. 6). Observation & data, followed by fundamental processes, are highlighted by comparison of modeling. Especially, making progress in temporal and spatial coverage of observations is essential for the majority of respondents.

The main recommendations about observations are:

- insure continuity of the various observing systems (space-based and in situ)
- provide traceable reference quality measurements from in situ networks and satellite missions in order to build long, well calibrated climate records
- insure regular upgrades of satellite observations and reprocessing of climate records
- develop an intercomparison project for gridded data sets
- improve atmospheric and ocean reanalysis
- develop (expand) a deep Argo program
- expand in situ networks for soil moisture and evapotranspiration
- make freely available in situ data on precipitation and runoff
- improve data access and metadata information; more generally provide users with some guidance about the most suitable data sets to be used at regional scale

A few recommendations deal with climate modeling:

- need for more research on downscaling (for adaptation planning)
- improve sub-grid processes parameterization
- develop model evaluation at the scale and variables relevant for socio-economic needs



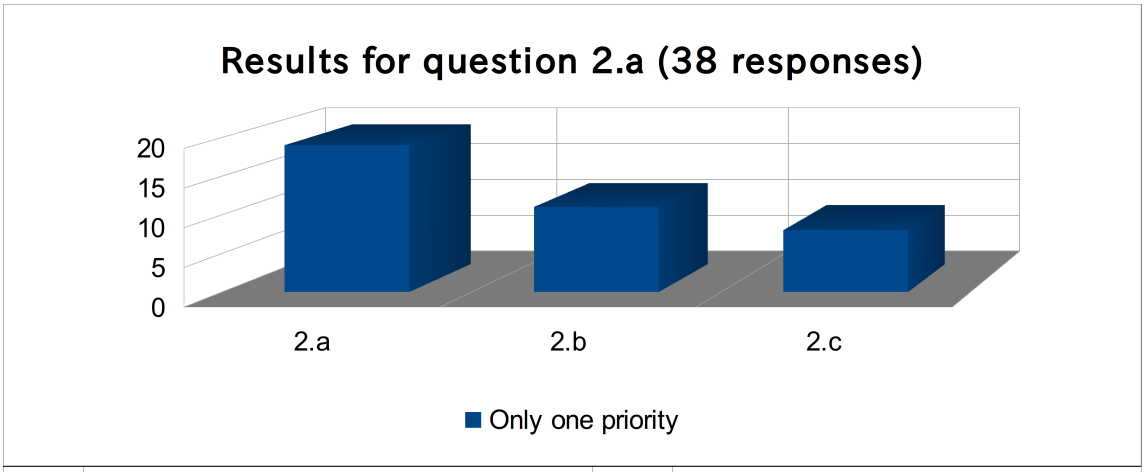
A.	Fundamental processes	C.3.	Data assimilation
B.	Observations & data	C.4.	Validation
B.1.	Observing technology	C.5.	Reanalysis capabilities
B.2.	Data & metadata quality	C.6.	GCM issues
B.3.	Data access & stewardship	C.7.	Downscaling issues
B.4.	Temporal and/or spatial coverage of observations	D.	Application of climate analyses to societal needs
C.	Modeling	E.	Present and future emission scenarios
C.1.	Grid size/resolution; Computing power	F.	Linkage of climate applications to socio-economic data
C.2.	Processes parametrization	G.	Other

Fig. 6: Proposals for making progress in the top 3 issues selected in the 12 "gaps" identified in IPCC AR5 by WGI using Annex II. Multiple choice for the respondents was available.

1.4. Evolution since AR4: on the evolution between AR4 and AR5, responses are rather contrasted. A few indicate minimal evolution. Other refer to some specific publications to highlight some progress (e.g., on ice sheet dynamics and cloud feedback). Most responses acknowledge improvement in data monitoring over the recent years but also stress the need for better data coverage in some regions and complain about still too short and inhomogeneous climate records. A few responses mention progress in process understanding.

2. Key gaps in drivers of climate change

2.1. Priority issues identified by IPCC: only three sources of uncertainty were listed in the IPCC AR5 by WGI regarding drivers of climate change. People who responded to question 2 prioritized them, but many respondents noticed that (i) items 2a and 2b were not independent from each other, and (ii) other important uncertainties were not listed (see Fig. 7). Fig. 7 also shows that uncertainty in cloud-aerosol interactions and the associated radiative forcing is considered 47% of times the most important, following by uncertainty in cloud feedbacks, e.g. 31%, and at last uncertainty in carbon-climate feedbacks, e.g. 22%.



2.a	Radiative forcing associated to aerosol-cloud interactions	2.c	Positive feedback between climate & carbon cycle
2.b	Quantification of positive cloud feedback		

Fig. 7:The main issue among the 3 "gaps" identified in IPCC AR5 by WGI (see Annex I).

Cloud-aerosol interactions are considered as a priority uncertainty because:

- they prevent reliable estimates of the past radiative forcing, and therefore hinder the interpretation of recent climate trends, and the estimate of the observed response to greenhouse gas forcing
- uncertainties in past radiative forcing is key for many areas of climate science (e.g. D&A, estimates of climate sensitivity, interpretation of past regional responses, climate modeling)
- aerosols and clouds impact circulation through their effect on heating profiles, and then affect teleconnections

Cloud feedbacks are considered as a priority uncertainty because:

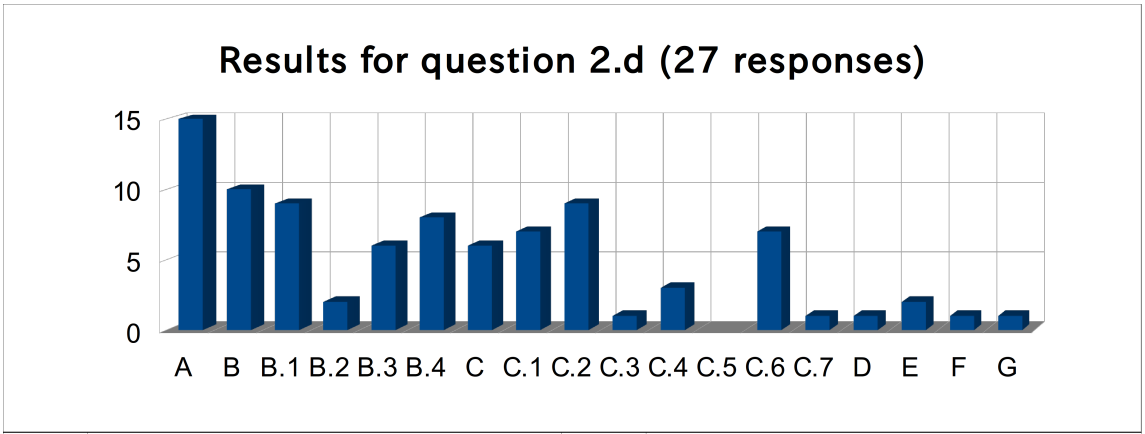
- they impact climate on all timescales (while aerosols impact climate mostly on short timescale and carbon cycle feedbacks on long timescales)
- they are key for the long-standing uncertainty in climate sensitivity
- uncertainty in cloud feedbacks impacts all areas of climate change science

Carbon-climate feedbacks are considered as a priority uncertainty because:

- they can be pervasive and abrupt
- they constitute a major challenge for understanding and simulating paleo-climatic changes
- they are critical for understanding the effectiveness of land-use changes in mitigation policies

2.2. Important issues in addition to the identified list by IPCC:

- projections of future drivers, particularly emissions of CH4 and N2O
- deforestation, land-use and terrestrial carbon feedbacks (e.g. vegetation feedbacks associated with droughts)
- volcanic aerosol forcing (small volcanoes entirely missing, big eruptions too idealized)
- solar forcing (e.g. its amplitude for last millennium and last glacial maximum)
- ocean heat uptake
- ozone interaction with climate



A.	Fundamental processes	C.3.	Data assimilation
B.	Observations & data	C.4.	Validation
B.1.	Observing technology	C.5.	Reanalysis capabilities
B.2.	Data & metadata quality	C.6.	GCM issues
B.3.	Data access & stewardship	C.7.	Downscaling issues
B.4.	Temporal and/or spatial coverage of observations	D.	Application of climate analyses to societal needs
C.	Modeling	E.	Present and future emission scenarios
C.1.	Grid size/resolution; Computing power	F.	Linkage of climate applications to socio-economic data
C.2.	Processes parametrization	G.	Other

Fig. 8: Proposals for making progress in the main issue selected in the 3 "gaps" identified in IPCC AR5 by WGI using Annex II. Multiple choice for the respondents was available.

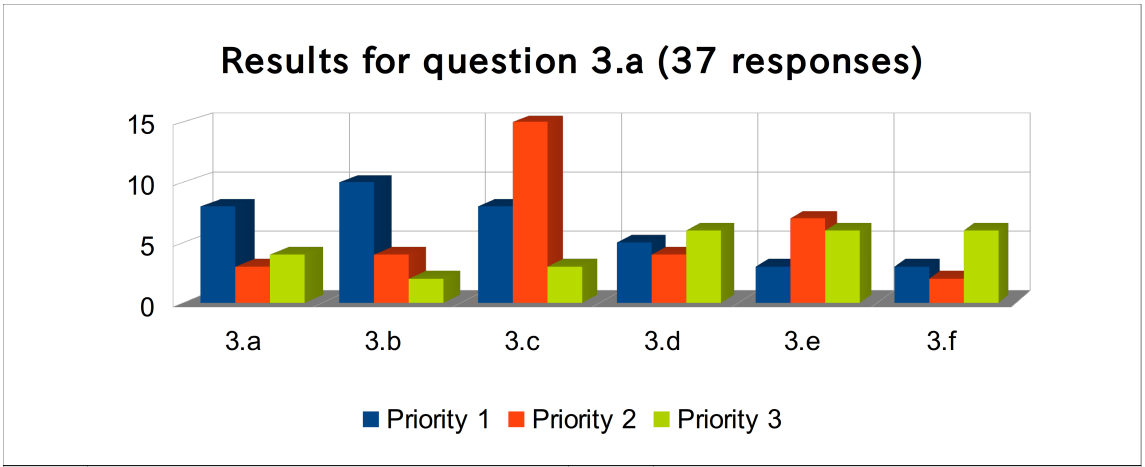
2.3. Proposals for making progress: most important proposal for making progress is about fundamental processes (see Fig. 8), following by observation & data, especially observing technology and spatial and temporal coverage of observations. Modeling is not on the top priority for making progress on drivers of climate change, however computer processing is an important issue as grid resolution, computer power, processes parameterization and Global Circulation Model (GCM) issues. Proposals for making progress include:

- the provision of annually updated historical forcing
- putting more emphasis on the validation of past drivers
- organize coordinated assessments of regional drivers
- paying more attention to the relative roles of natural variability vs forced climate changes

2.4. Evolution since AR4: progress in taking into account bio-geochemical feedbacks between AR4 and AR5 is noted. Significant progress has taken place on radiative forcing and cloud feedback, with an improved definition of radiative forcing, a better understanding of cloud feedback, and the identification of the role of convection in controlling low cloud layers. The prioritization of this topic within the WCRP Grand Challenge on clouds, circulation and climate sensitivity should help support future progress.

3. Key gaps in understanding the climate system and its recent changes

3.1. Priority issues identified by IPCC:



3.a	Simulation of clouds	3.d	Regional scale & uncertainties due to model resolution
3.b	Observational uncertainties for climate variables	3.e	Simulation of extreme events
3.c	Modeling the changes in the water cycle	3.f	Human influence on drought, tropical cyclone & Antarctic warming, sea ice and mass balance

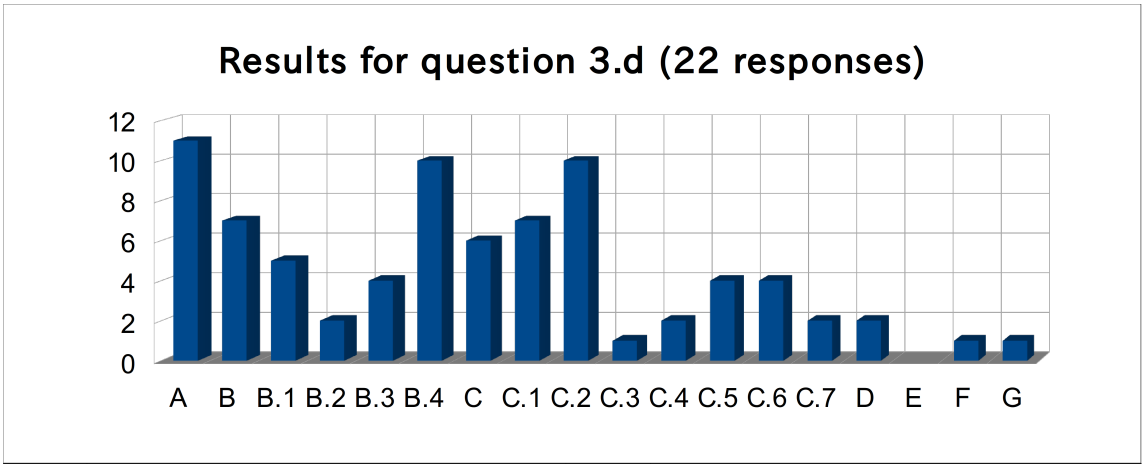
Fig. 9:The top 3 main issues among the 6 "gaps" identified in IPCC AR5 by WGI (see Annex I).

Of the key uncertainties in understanding the climate system and its recent changes – observational uncertainties (3b), clouds (3a), and water cycle (3c) are leading as the 1st priority. Changes in the water cycle (3c) is the absolute leader as a second priority, which makes it also the total champion in the "all-three-priorities list". In the latter list, the other two "prize-winners" are extremes (3e) and observations (3b), but with significantly lower scores.

3.2. Important issues in addition to the identified list by IPCC and further suggestions for making progress: according to respondents, additional issues missed in the suggested list of uncertainties include: monsoons, El Niño Southern Oscillation (ENSO), circulation and precipitation together, circulation alone, vegetation productivity and ocean carbon cycle, Earth energy imbalance, small-scale disasters, wind speed, long scale variability in the ocean in mid to deep levels, Arctic and mountains. But there is no agreement at all between respondents on the missed issues.

Identify solutions for making progress in understanding the climate system and its recent changes are in first priority to better understand fundamental processes and with significantly lower scores to improve observation & data and modeling (see Fig. 10). However, two more specific points are highlighted: temporal and spatial coverage of observations (B.4) and processes parameterization (C.2). Noteworthy comments from respondents are as follows:

"This list is mixing issues related to process understanding and climate change attribution. For example the points listed under 3.f are important in a wider context than just climate change attribution. Similarly as for point 3.a, the uncertainties are related to fundamental issues with process understanding, in addition to issues with data availability (quality of observations, number of considered events, etc.)."



A.	Fundamental processes	C.3.	Data assimilation
B.	Observations & data	C.4.	Validation
B.1.	Observing technology	C.5.	Reanalysis capabilities
B.2.	Data & metadata quality	C.6.	GCM issues
B.3.	Data access & stewardship	C.7.	Downscaling issues
B.4.	Temporal and/or spatial coverage of observations	D.	Application of climate analyses to societal needs
C.	Modeling	E.	Present and future emission scenarios
C.1.	Grid size/resolution; Computing power	F.	Linkage of climate applications to socio-economic data
C.2.	Processes parametrization	G.	Other

Fig. 10: Proposals for making progress in the top 3 issues selected in the 6 "gaps" identified in IPCC AR5 by WGI using Annex II. Multiple choice for the respondents was available.

"These issues (and issues raised on previous pages of this survey) are all identified in the WCRP Grand Challenges (Sea Level, Cryosphere, Clouds and Climate Sensitivity, etc.), and well identified also by the different core projects of WCRP."

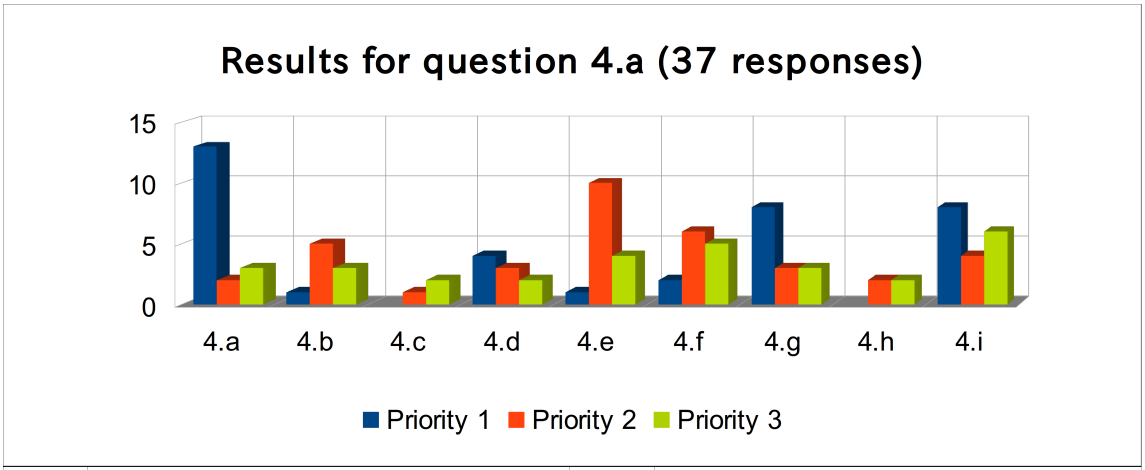
"This section reflects the end-to-end problem of observing, modeling and understanding the climate system. All aspects are important and there seems no clear path to making progress in a systematic way. Pouring additional long-term resources into 3 major climate centers (North America, Europe, Asia), say, could provide focus but seems unlikely to happen. Otherwise, it is business as usual with funding agencies, international agencies, and researchers focusing on parts of the problem on a short term basis."

4. Projections of global and regional climate change

4.1. Priority issues identified by IPCC:

Issue 4.a, limited skill for short-term projections and for precipitation projections, is clearly the biggest issue for most respondents. Comments suggest that advances on decadal scales will lead to improvements in longer-term projections, and public uptake of climate change information would increase if credible short-term predictions can be provided.

Issue 4.e, low confidence about abrupt changes, doesn't rate as the most important isnce, when the frequency of selection is summed across all three choices, issues 4.i and 4.a are the two most commonly selected. Issue 4.g, ice-sheet contributions to sea level rise, also came in as relatively important overall. The least important issues overall were deemed to be 4.c, tropical cyclones, and 4.h, semi-empirical models of sea level rise.



4.a	Yearly to decadal averages of temperature prediction	4.f	Carbon losses from thawing permafrost
4.b	Changes in Northern storm position and strength	4.g	Ice sheet dynamics contribution to sea level rise
4.c	Basin-scale tropical cyclone frequency and intensity	4.h	Semi-empirical model for sea level rise projections
4.d	Changes in soil moisture and surface run off	4.i	Regional climate changes
4.e	Abrupt or nonlinear changes		

Fig. 11: The top 3 main issues among the 9 "gaps" identified in IPCC AR5 by WGI (see Annex I).

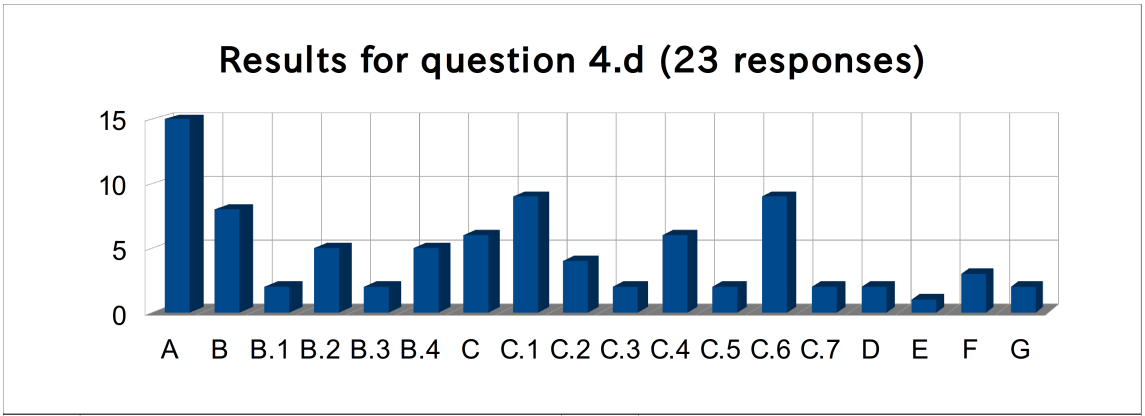
Issue 4.e, low confidence about abrupt changes, doesn't rate as the most important isnce, when the frequency of selection is summed across all three choices, issues 4.i and 4.a are the two most commonly selected. Issue 4.g, ice-sheet contributions to sea level rise, also came in as relatively important overall. The least important issues overall were deemed to be 4.c, tropical cyclones, and 4.h, semi-empirical models of sea level rise.

4.2. Important issues in addition to the identified list by IPCC: issues considered to be missing were quite an eclectic mix, including changes to ENSO, teleconnections, regional precipitation projections and uncertainties, regional extremes, parameterisations, ocean model initialisation. Most of these come back to better regional and better decadal-scale climate change projections/predictions.

4.3. Proposals for making progress: suggested ways forward include improved observing systems and process studies, smarter use of GCM output (taking account of model error), and improved GCMs-higher resolution, better ice sheet modelling, improved air-sea coupling etc (see Fig. 12). The first proposal for making progress in global and regional climate change still stays to impove observation and data with specific improvement needed in modeling as ust expained above.

4.4. Evolution since AR4: several respondents felt there had been little progress between AR4 and AR5. It was noted that we now have a clearer picture of changes in tropical cyclones, and larger ensembles of model output. Regional uncertainty is more explicitly recognised in at least some papers now.

4.5. Specific proposals for CMIP: regarding CMIP, several respondents expressed concern that the CMIP5 archive has not been fully exploited and that we need more data-model intercomparison work, rather than just more model runs. "*Less model runs but more thought and coordination*". Better representation of ice sheets (and other cryosphere components), to improve sea level projections, and "better" handling of extremes were also identified.



A.	Fundamental processes	C.3.	Data assimilation
B.	Observations & data	C.4.	Validation
B.1.	Observing technology	C.5.	Reanalysis capabilities
B.2.	Data & metadata quality	C.6.	GCM issues
B.3.	Data access & stewardship	C.7.	Downscaling issues
B.4.	Temporal and/or spatial coverage of observations	D.	Application of climate analyses to societal needs
C.	Modeling	E.	Present and future emission scenarios
C.1.	Grid size/resolution; Computing power	F.	Linkage of climate applications to socio-economic data
C.2.	Processes parametrization	G.	Other

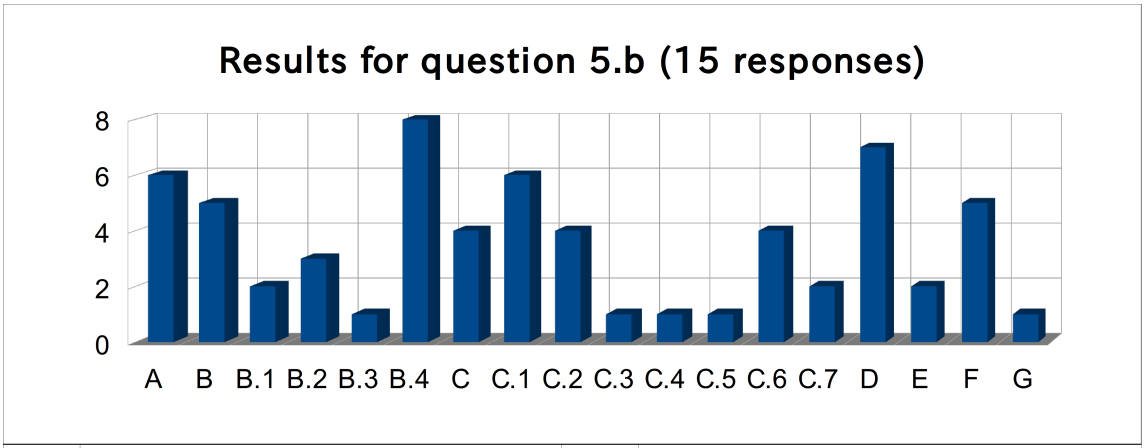
Fig. 12: Proposals for making progress in the top 3 issues selected in the 9 "gaps" identified in IPCC AR5 by WGI using Annex II. Multiple choice for the respondents was available.

Issues covered by WG II: impacts, adaptation and vulnerability

5. Impacts

Across responses, the following impact categories were identified as especially relevant to future WCRP work: extreme events, sea level rise and ice sheets, water availability and resources, consequences of high-magnitude warming, and food security. While attribution of impacts to climate change creates important understanding of the sensitivity of human and natural systems, challenges in attributing impacts to anthropogenic climate change were noted, especially for human systems.

Using only Annex II to identify key issues, the temporal and spatial coverage of observations is the first issue identified as a gap in impact, following by application of climate analyses to societal needs, grid resolution & computing power and fundamental processes (see Fig. 13).

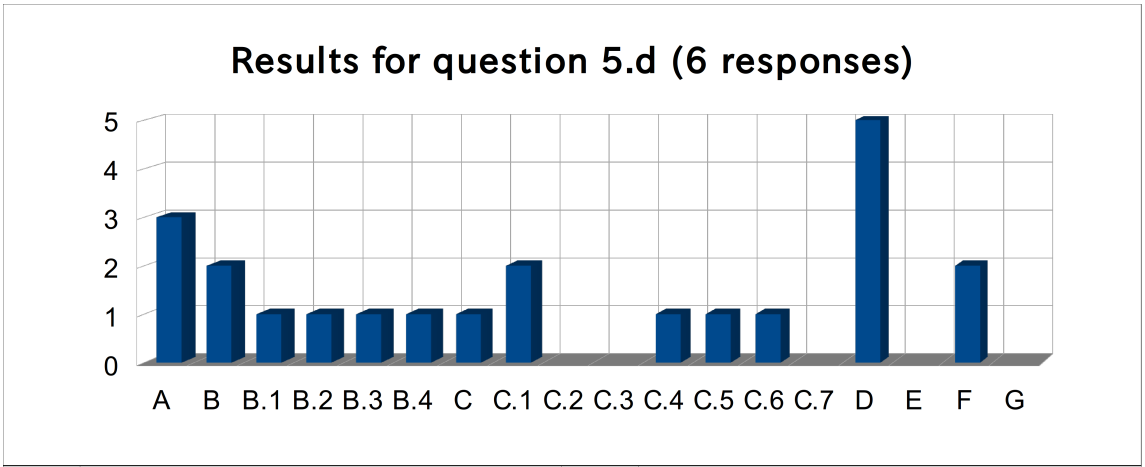


A.	Fundamental processes	C.3.	Data assimilation
B.	Observations & data	C.4.	Validation
B.1.	Observing technology	C.5.	Reanalysis capabilities
B.2.	Data & metadata quality	C.6.	GCM issues
B.3.	Data access & stewardship	C.7.	Downscaling issues
B.4.	Temporal and/or spatial coverage of observations	D.	Application of climate analyses to societal needs
C.	Modeling	E.	Present and future emission scenarios
C.1.	Grid size/resolution; Computing power	F.	Linkage of climate applications to socio-economic data
C.2.	Processes parametrization	G.	Other

Fig. 13: Key issues in impacts of climate change, selected using Annex II. Multiple choice for the respondents was available.

Key issues (from above graph and all comments) underpinning current data gaps were identified as follows: (i) limitations in available high-quality observational data (historical and present, ground-based and remote) with which to evaluate the sensitivity of human and natural systems to climate variability and calibrate and test impact models; (ii) needs for improved guidance on how to best select observations, modeling outputs, and downscaling methods in analyzing impacts; (iii) challenges in incorporating societal, economic, technological, and environmental factors that strongly affect sensitivity (as well as vulnerability and exposure) of human and natural systems to climate change; (iv) the importance of prioritizing impact model development, which has lagged behind climate model development but is central to understanding

the risks of climate change; (v) the need to expand impact modeling intercomparisons and improve them, to understand responses of human and natural systems across more impact sectors (from agriculture, water, and vegetation, to human health, biodiversity, infrastructure, and coasts).



A.	Fundamental processes	C.3.	Data assimilation
B.	Observations & data	C.4.	Validation
B.1.	Observing technology	C.5.	Reanalysis capabilities
B.2.	Data & metadata quality	C.6.	GCM issues
B.3.	Data access & stewardship	C.7.	Downscaling issues
B.4.	Temporal and/or spatial coverage of observations	D.	Application of climate analyses to societal needs
C.	Modeling	E.	Present and future emission scenarios
C.1.	Grid size/resolution; Computing power	F.	Linkage of climate applications to socio-economic data
C.2.	Processes parametrization	G.	Other

Fig. 14: Proposals for making progress in impacts of climate change, selected using Annex II. Multiple choice for the respondents was available.

Finally, proposals for making progress in gaps of impact understanding of climate change is essentially in application of climate analyses to societal needs (see Fig. 14).

6. Adaptation

Responses emphasized that adaptation is about people making decisions under uncertainty in a changing world. The tight link between impacts and adaptation was underscored, with lessons on how to effectively grapple with available information and persistent complexities starting to emerge. Responses highlighted the importance of contemplating opportunities to rethink and "co-produce" work on impacts and adaptation, with user input into problem definition, the range of options explored, and the presentation of results.

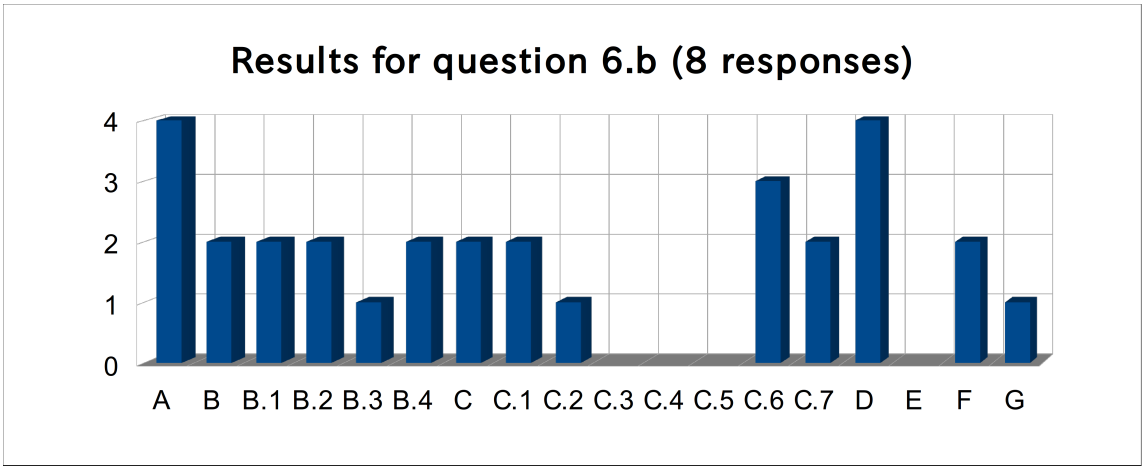
Diverse responses speaking to these themes include the following:

"*More data does not mean better adaptation. What is needed are opportunities for learning under uncertainty, to assess options… and implications of certain decisions for human and natural systems. This implies a shift from quantification and prediction to ethical decision-making.*"

"*Progress on adaptation has been slow, despite advances in climate science. This suggests the need for a more concerted effort at knowledge exchange and knowledge brokering with regional/local practitioners (engineers, foresters, water managers, urban planners, etc.). This would occur within a planning process oriented towards risk management that enables learning in an iterative manner. Climate services could be part of this effort…*"

3 priorities are highlighted: *"i) how to enhance adaptive capacities, including ways to embrace change and uncertainties; ii) understanding limits to adaptation (e.g. by considering risks at different levels of warming); iii) supporting adaptation as a process"*.

The following graphs, e.g. Fig. 15 & 16, were used in the paragraph above to analyze the comments on key issues, gaps and how to make progress in adaptation to climate change. Especially, they highlight two main issues in order to make up for the gaps in adaptation: (i) fundamental processes and (ii) application of climate analyses to societal needs. However, respondents mainly emphasize progress needed in fundamental processes.



A.	Fundamental processes	C.3.	Data assimilation
B.	Observations & data	C.4.	Validation
B.1.	Observing technology	C.5.	Reanalysis capabilities
B.2.	Data & metadata quality	C.6.	GCM issues
B.3.	Data access & stewardship	C.7.	Downscaling issues
B.4.	Temporal and/or spatial coverage of observations	D.	Application of climate analyses to societal needs
C.	Modeling	E.	Present and future emission scenarios
C.1.	Grid size/resolution; Computing power	F.	Linkage of climate applications to socio-economic data
C.2.	Processes parametrization	G.	Other

Fig. 15: Key issues in adaptation of climate change, selected using Annex II.
Multiple choice for the respondents was available.

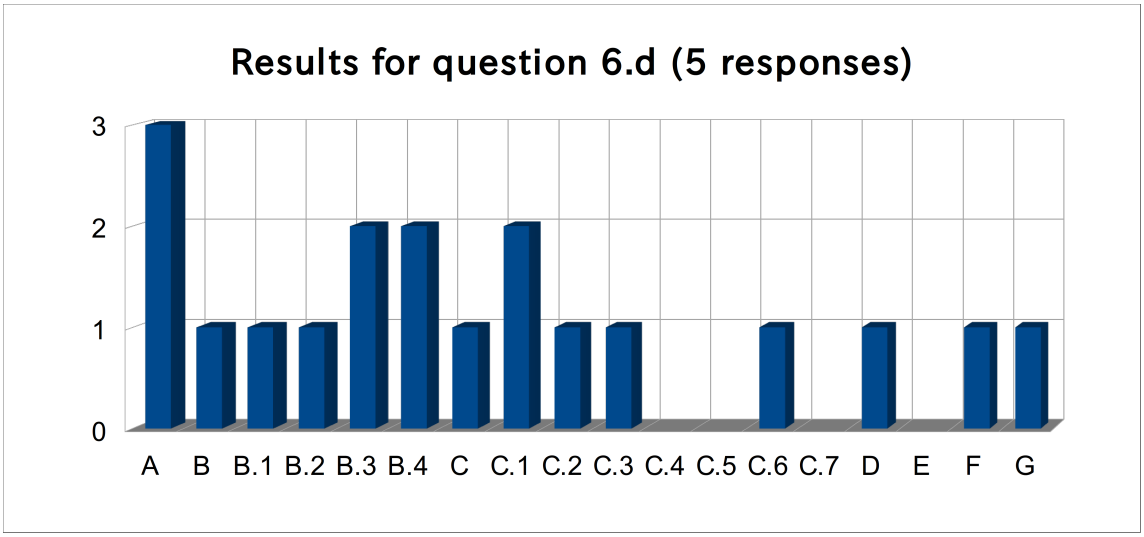


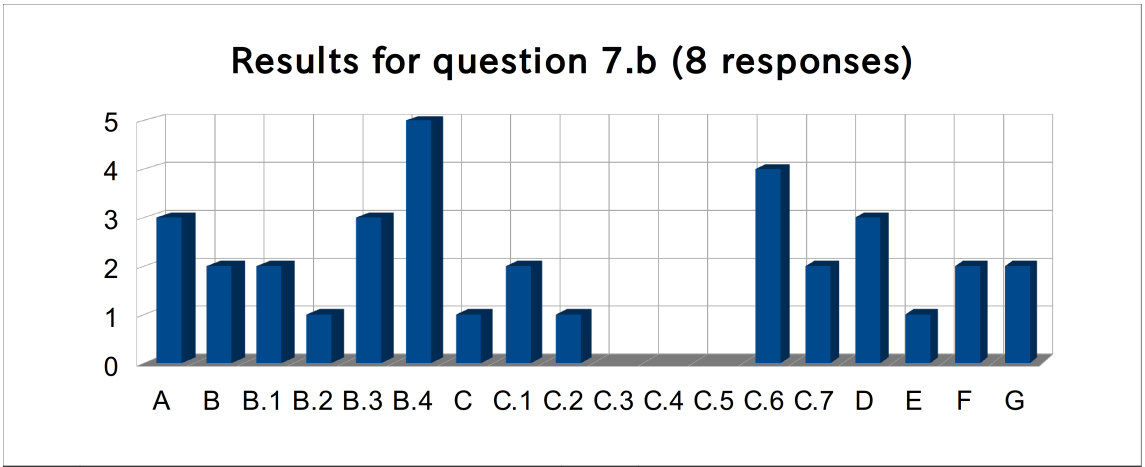
Fig. 16: Proposals for making progress in adaptation of climate change, selected using Annex II. Multiple choice for the respondents was available.

7. Regional aspects

The following research issues and data gaps emerged across responses:

- given that different processes can be active at regional scales, understanding of regional climate change needs to consider regional drivers and feedbacks, especially for extremes
- major data gaps still exist in Africa, South America, and Asia in particular. These gaps limit current understanding of impacts at regional scales. The data gaps can be accompanied, in addition, by fewer available scientists to investigate climate processes in given regions
- at the same time, research on impacts for people and human systems even in high-income countries has lagged, especially in terms of the distribution of impacts
- uncertainties persist for complex topographies such as in the Himalayas, foothills, and major river basins

As often responded, the temporal and spatial coverage of observations & data is the key issue regarding the uncertainties and gaps in our understanding of regional aspects of climate change (see Fig. 17). Regarding this result, respondent proposals for making progress in regional aspects relate to fundamental processes, GCM issues and application of climate analyses to societal needs (see Fig.18).



A.	Fundamental processes	C.3.	Data assimilation
B.	Observations & data	C.4.	Validation
B.1.	Observing technology	C.5.	Reanalysis capabilities
B.2.	Data & metadata quality	C.6.	GCM issues
B.3.	Data access & stewardship	C.7.	Downscaling issues
B.4.	Temporal and/or spatial coverage of observations	D.	Application of climate analyses to societal needs
C.	Modeling	E.	Present and future emission scenarios
C.1.	Grid size/resolution; Computing power	F.	Linkage of climate applications to socio-economic data
C.2.	Processes parametrization	G.	Other

Fig. 17: Key issues in regional aspects of climate change, selected using Annex II. Multiple choice for the respondents was available.

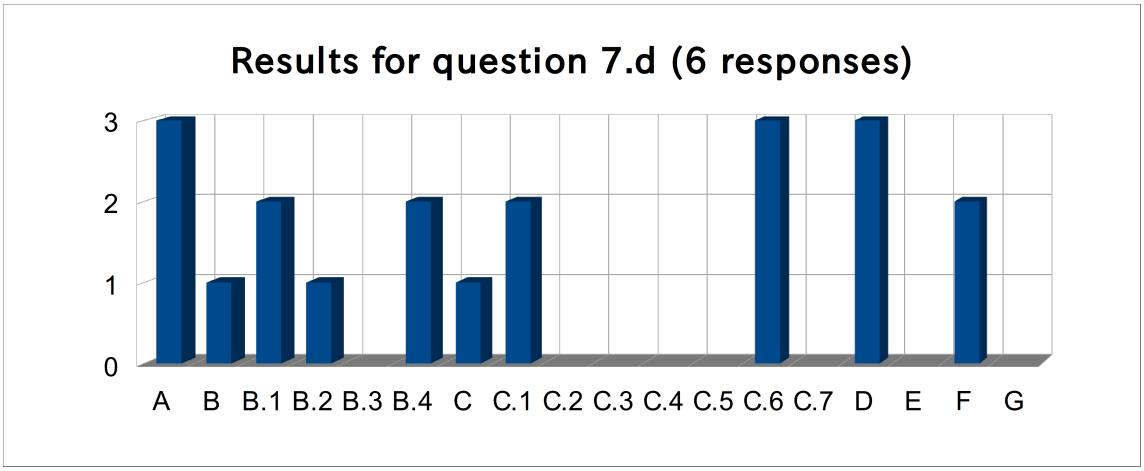


Fig. 18: Proposals for making progress in regional aspects of climate change, selected using Annex II. Multiple choice for the respondents was available.

8. Material from SREX report

There were only 14 respondents for parts (a) and (b) of question 8, and only 5 for parts (c), (d), and (e). The most commonly selected issues were: uncertainties around tropical cyclones, storm tracks and extreme precipitation (including drought). Other issues mentioned were: sea level extremes, improved modelling of extremes, Arctic and high-elevation extremes, making information more user-relevant (WGII focus), using better risk assessment frameworks, and better methods of comparing point and gridded information. There was little justification given, apart from recognising the inadequacy of existing observing networks, and the high social relevance of advancing our understanding of and ability to predict changes in extreme events.

In terms of the list of research and observation needs, the most commonly selected were:

- level of understanding of fundamental processes (e.g., aerosol-cloud interaction)
- temporal and/or spatial coverage of observations (e.g., length of time series, global/regional networks, satellites)
- grid size/resolution; computing power
- GCM issues

Regarding proposals for making progress (5 responses), similar responses were forthcoming – a need for better observing networks, especially for extremes, and better process understanding and modelling. This was reflected in the "needs" selected from Annex II (mostly observations & data). Comments on advances from AR4 to AR5 were a mixed bag, with no clear message.

Priorities for research within WCRP, implications for core projects and Grand Challenges

9. Top priorities to be considered by WCRP in order to fill the most critical gaps in possible future IPCC assessments reports

9.1. Core Projects:

- better understanding of decadal to multi-decadal variability; predictions from seasons to multi-decades
- field observations of ocean heat content, ice shelf-ocean interactions and air-sea exchanges
- critical cryospheric processes, Greenland, Antarctica, ice sheet mass
- surface tropospheric interactions with sea ice, ocean, land (including water), stratosphere
- climate variation and food security
- storm tracks, extreme events and their attribution
- better estimate of climate sensitivity
- rephrase activities in terms of society relevant questions
- bio-geochemical cycles (release of CO2,, CH4 from permafrost)
- synergy view of the hydrological cycles including aerosols and chemistry aspects

9.2. Grand Challenges:

- estimates of heat content, improved ocean-ice interactions, coupled climate-ice sheet GCMs
- simulation of the last millennium including the role of internal variability
- new grand challenge in biogeochemistry
- emphasis on extreme events and on risks associated with climate change
- more focus on sea level rise and contribution of ice sheets
- more on regional downscaling projections including clouds and extreme events
- better marry physical and process understanding with statistical and model based attribution
- more focus on aerosol effects on climate (clouds and precipitation)

9.3. Modeling Activities:

- ice sheet-climate interactions
- land-climate interactions
- extreme events
- develop an “European ReAnalysis (ERA)” international supercomputing infrastructure
- develop Earth system grid
- provide results at higher frequency
- assess what is really gained through regional modeling
- CMIP should recognize the service aspect of some coordinated experiments

9.4. Observation Coordination Activities & other suggestions:

- improve estimate of ocean heat and salinity changes
- need central storage of WCRP datasets
- better integration between observational and modeling communities
- Obs4MIP should support metadata and include observational uncertainties
- need fine resolution information to improve understanding and simulation of intense precipitation

10. Topics to be addressed by WCRP in addition to Grand Challenges

Here are some topics that are being proposed:

- ocean heat content and decadal variability
- patterns of climate change
- biogeochemistry/ecosystems: carbon and nitrogen cycles; interactions between carbon and water cycles
- improvement in climate modeling
- development of climate services: climate communication, climate research, shaping climate services, societal impacts of climate change, climate change and poverty, partnership with the Copernicus Program in Europe; partnership with the Global Framework for Climate Services (GFCS)

11. Improvement of current institutional and technical infrastructure

Here are some improvements that are being proposed:

- more sustained funding. Infrastructure should be recognized as an operational requirement
- maintain a fair number of models, but only the best ones; develop a number of well funded multi-national climate prediction centers
- develop seamlessness between climate modeling and dissemination of information, particularly on extremes; make stand against pseudo-science
- add a grand challenge on biogeochemistry
- become more interdisciplinary: climate scientists should work with other scientists, include more social scientists, link with International Geosphere-Biosphere Programme (IGBP), more cooperation between climate-related organizations
- develop training activities
- IPCC activities need to be improved (avoid duplications between chapters). IPCC effort should not relay on voluntary efforts; scientists are burned out
- support sustained, long-term observation networks. Improve links between observation and modeling

Suggestions for future IPCC assessments

12. Specific aspects of the IPCC AR5 assessment results to be better taken account in WCRP activities

19 responses have been received, 16 with substantive input. One theme highlighted by several of the respondents was the need for WCRP to consider the gaps identified and the uncertainty assessment in the IPCC AR5 in its activities. One respondent mentioned in this context the need to focus more on understanding projections, another one the poor definition of high-end scenario for sea level rise. Other topics mentioned for WCRP to focus more on include:

- extremes (e.g., tropical storms), extreme impacts, vulnerability globally
- paleo-climate
- land biosphere representation in climate models (e.g., nutrient controls)
- climate risks related to abrupt or nonlinear changes
- improve understanding of WGII-type frameworks used in IPCC (e.g. risk, transformation) in the climate science community

A few more fundamental process related comments were received, including:

- reporting on (observed) changes should be more routine work and operational, no longer be done by the IPCC; Modeling activities should then be covered independently
- may need to find alternatives to constantly improving models in order to keep advancing understanding
- links between WCRP activities and IPCC should be made clearer and more transparent
- more involvement in WCRP of scientists from countries with economies in transition; more use of references in languages other than English

13. Specific aspects of the IPCC AR5 assessment process to be better taken account in WCRP activities

15 responses have been received, 12 with substantive input. Several respondents mentioned (i) the ever-increasing burden from IPCC assessments on the science community and the need to carefully review the timing of WCRP activities with the IPCC time-line in mind, and (ii) the need for WCRP to focus on gaps and uncertainties identified and quantified in IPCC assessments.

One respondent summarized the contribution with "*maybe we need to completely decouple the Model Inter-comparison Project (MIP) and IPCC time-lines, and avoid a new MIP coming in shortly before an IPCC report is released.*" Another respondent proposed an alternative process where WCRP would prepare "a *sequence of scientific reports*". Instead, that would provide input to a possible, "*much reduced*" IPCC report. Finally, one respondent proposed to restructure the IPCC WGs to have only two WGs: (i) Physical science basis plus impacts and vulnerability to climate changes; (ii) Adaptation and mitigation of climate change.

Other topics mentioned for WCRP to focus more on include:

- more regional scale assessments needed in order to most efficiently inform decision making on decision-relevant scales
- more focus on adaptive capacity due to changes in extremes; more on hydrological extremes; hurricanes projections; variability vs forced changes

- need to better involve the WCRP members in the expert review of WGI drafts
- improve regional balance of members/contributors/authors in WCRP/IPCC

14. Specific suggestions for new climate change research activities (within or outside WCRP) that would serve future IPCC assessments

17 responses have been received, 16 with substantive input. A wide range of specific suggestions have been received. A number of respondents highlighted the need to focus more on climate change impacts and to better integrate approaches across disciplines.

A listing of research topics suggested by respondents is provided below:

- hiatus
- land climate engineering as an adaptation option
- modeling of heavy precipitation events and links to flooding and related impacts
- social, institutional, and technological innovation processes, and their role in adaptation
- regional focus: regional modeling, downscaling, regional monitoring in developing countries to improve science basis for future WGII assessments
- value transformation in solving the climate change challenge
- understanding impacts and risk in the context of intersecting inequalities
- increased focus on impacts of climate change on key resource sectors. Reduction in uncertainties in modeling impacts, costs and possible adaptation responses. Closer linking/collaboration across communities (climate, impacts, costs, etc.)
- end-to-end attribution of impacts

In terms of process and institutions, suggestions include:

- 2-3 year WCRP assessments on certain WCRP relevant topics in between successive IPCC assessment reports
- proposal for a new CLImate VARiability and predictability (CLIVAR) “Climate Dynamics Panel”
- WCRP to foster interactions with other disciplines through Future Earth project
- closer connection of research to applications

And finally, one submission calls for an end of the comprehensive IPCC assessments (in particular for WGI) and a focus on cross WG Special Reports, plus perhaps more frequent updates on the state of climate, possibly done by WCRP for WGI physical science basis topics.

V. Summary & concluding remarks

Survey results cover 46 responses, coming mostly from workshop participants and with a majority of USA and European respondents. Contributors made a remarkable effort for interesting comments and proposals. The responses, analyzed and summarized in this report, may contribute to WCRP & IPCC planning and serve the climate community. The survey is divided into 4 parts: issues covered by IPCC WGI, the physical science basis; issues covered by IPCC WGII, impacts, adaptation and vulnerability; priorities for research within WCRP, implications for Core Projects & Grand Challenges; suggestions for future IPCC assessments.

Questions covering WGI issues concern gaps in observations and understanding of climate change, "drivers" of climate change and model projections of global and regional climate change. The main gaps & uncertainties in observations concern precipitation data, changes in large-scale circulation, ice-sheet evolutions and deep ocean. According to the survey, drivers of climate change that deserve most attention are aerosol-cloud interactions followed by cloud feedbacks. The main gap in understanding processes is considered to be the modeling of changes in the water cycle. At last, main priorities highlighted for projections of climate change are related to yearly to decadal temperature predictions, abrupt non-linear changes and regional prediction. On the evolution since AR4, responses are rather contrasted but the main areas of progress concern ice-sheet dynamics and cloud feedback. Survey respondents mainly consider that improvements should be achieved on fundamental processes and observations & data. Indeed, observing technology, temporal and spatial coverage of observations are the most often mentioned. Most of respondents suggest to continue and maintain existing observation networks as well as improving data quality. Concerning climate modeling, grid size/resolution, computing power and processes parametrization are the main issues where improvements are recommended, with specific needs for better representation of ice-sheets and better handling of extremes. Further exploitation of CMIP5 data is also recommended.

Questions covering WGII issues concern gaps in impacts, adaptation and vulnerability of climate changes. Main issues identified by respondents with respect to impacts are extreme events, sea level rise, ice-sheets, water availability and resources, food security ... Respondents highlighted the importance of contemplating opportunities to rethink and "co-produce" work on impacts and adaptation. The development of risk management strategies associating the scientific community and regional/local practitioners is one important orientation for progress. Regional aspects are very important, especially for extreme events, and some respondents noticed major data gaps in observations in Africa, South America and Asia, as well as for complex topographies and major river basins. Finally, all respondents agreed on recommendations for making progress which are temporal and spatial coverage of observations (similar to questions covering WGI issues) and grid size/resolution associated with computing power, in addition to application of climate analyses to societal needs. Responses concerning SREX issues cross over responses for WGI & WGII, highlighting gaps in extreme events, sea level and ice sheets.

Questions covering WCRP research concern priorities for WCRP to fill the most critical gaps for next IPCC reports, possible additions to Grand Challenges and improvement of institution and infrastructure. A number of topics are highlighted within the present WCRP structure but the range of priorities is fairly large. Recommendations for Core Projects include decadal variability, observations of ocean heat content, critical cryospheric processes and surface-atmosphere interactions. The priorities expressed through the Grand Challenges are overall endorsed, with special attention recommended to ocean-ice interactions (in observations and models), risk associated to extreme events, contribution of ice-sheets to sea level rise, uncertainties in water cycle processes, regional downscaling and aerosol effects on clouds and climate. A number of

recommendations are related to modeling activities including better parameterizations, advanced supercomputing and data management, higher frequency outputs, better assessment of regional modeling. The benefits of coordinated observation activities are also highlighted, with the need to improve estimate of ocean parameters, fine resolution information and central availability of datasets. The need to create a new Grand Challenge in biogeochemistry is expressed by a number of respondents. Concerning coordination activities & technical aspects, the development of appropriate infrastructures for supporting research and climate services seems essential with a number of suggestions: development of long-term observational networks, better integration between observation & modeling communities, partnership with Copernicus Program (Europe) & the Global Framework for Climate Services (GFCS), development of interdisciplinarity, especially with the IGBP community and social scientists.

Questions covering future IPCC assessments concern IPCC assessment results and processes that could be taken account in WCRP activities and suggestions for new climate change research activities that would serve future assessments. Respondents expressed the importance for WCRP to focus on gaps & uncertainties identified and quantified in IPCC assessments, which is precisely the main motivation for the Bern workshop. The need to better take into account WGII approach in the climate science community is mentioned as one important issue. The ever increasing burden from IPCC assessments on the science community is mentioned as a serious concern. Specific suggestions include decoupling observed climate change assessments (to be done separately on a more frequent basis) from model assessments, more involvement of scientists from countries with economies in transition and more use of references in languages other than English, making clearer and more transparent the links between WCRP & IPCC activities. It is also recommended to carefully review the timing of WCRP activities in relation with the IPCC time-line. Other proposals include the preparation of a sequence of climate change specific reports by WCRP as input to a reduced IPCC report, and restructuring IPCC in two WGs. On the question of new research activities that would serve IPCC assessments, a number of respondents highlighted more research on impact issues, better interaction with other disciplines through Future Earth, and closer connection with applications.

Overall, the dialogue initiated with the scientific community through this survey was useful even if many of the suggestions are not necessarily innovative. The reflection on how to deal with research gaps assessed by IPCC enables to highlight specific issues and may provide additional support to some already agreed research orientations. Interaction with the impact and adaptation community and the development of services are two areas where new activities could be developed. The IPCC motivation can probably help support requests from the scientific community for improved observation, data and research infrastructures. This survey also shows that the scientific community represented by WCRP is ready to confirm its commitments to climate change assessments and actively participate in the reflection on future IPCC activities. It is unfortunate that, for a variety of reasons, the participation of respondents from developing countries or countries with economies in transition is very small, and this should be improved in any future survey.

The Science Steering Committee and the survey organizers would like to acknowledge the work of respondents and greatly thank them for their participation.

Annex I

KEY UNCERTAINTIES IDENTIFIED IN IPCC AR5, WGI REPORT

The following paragraph and list is extracted from the Technical Summary of WGI I report (TS.6 Key uncertainties). More details on specific research needs can be found in the respective chapters of the reports.

This final section of the Technical Summary provides the reader with a short overview of key uncertainties in the understanding of the climate system and the ability to project changes in response to anthropogenic influences. The overview is not comprehensive and does not describe in detail the basis of for these findings. These are found in the main body of this Technical Summary and in the underlying chapters to which each bullet points in the curly brackets.

1. Key Uncertainties in Observation of Changes in the Climate System

a/ There is only medium to low confidence in the rate of change of tropospheric warming and its vertical structure. Estimates of tropospheric warming rates encompass surface temperature warming rate estimates. There is low confidence in the rate and vertical structure of the stratospheric cooling. {2.4.4}

b/ Confidence in global precipitation change over land is low prior to 1950 and medium afterwards because of data incompleteness. {2.5.1}

c/ Substantial ambiguity and therefore low confidence remains in the observations of global-scale cloud variability and trends. {2.5.7}

d/ There is low confidence in an observed global-scale trend in drought or dryness (lack of rainfall), due to lack of direct observations, methodological uncertainties and choice and geographical inconsistencies in the trends. {2.6.2}

e/ There is low confidence that any reported long-term (centennial) changes in tropical cyclone characteristics are robust, after accounting for past changes in observing capabilities. {2.6.3}

f/ Robust conclusions on long-term changes in large-scale atmospheric circulation are presently not possible because of large variability on interannual to decadal time scales and remaining differences between data sets. {2.7}

g/ Different global estimates of sub-surface ocean temperatures have variations at different times and for different periods, suggesting that sub-decadal variability in the temperature and upper heat content (0–700 m) is still poorly characterized in the historical record. {3.2}

h/ Below ocean depths of 700 m the sampling in space and time is too sparse to produce annual global ocean temperature and heat content estimates prior to 2005. {3.2.4}

i/ Observational coverage of the ocean deeper than 2000 m is still limited and hampers more robust estimates of changes in global ocean heat content and carbon content. This also limits the quantification of the contribution of deep ocean warming to sea level rise. {3.2, 3.7, 3.8; Box 3.1}Final Draft (7 June 2013) Technical Summary IPCC WGI Fifth Assessment Report

j/ The number of continuous observational time series measuring the strength of climate relevant ocean circulation features (e.g., the meridional overturning circulation) is limited and the existing time series are still too short to assess decadal and longer trends. {3.6}.

k/ In Antarctica, available data are inadequate to assess the status of change of many characteristics of sea ice (e.g., thickness and volume). {4.2.3}

l/ On a global scale the mass loss from melting at calving fronts and iceberg calving are not yet comprehensively assessed. The largest uncertainty in estimated mass loss from glaciers comes from the Antarctic, and the observational record of ice-ocean interactions around both ice sheets remains poor.{4.3.3, 4.4}

2. Key Uncertainties in Drivers of Climate Change

a/ Uncertainties in aerosol-cloud interactions and the associated radiative forcing remain large. As a result, uncertainties in aerosol forcing remain the dominant contributor to the overall uncertainty in net anthropogenic forcing, despite a better understanding of some of the relevant atmospheric processes and the availability of global satellite monitoring. {2.2, 7.4, 7.5, 8.5}

b/ The cloud feedback is likely positive but its quantification remains difficult. {7.2}

c/ Paleoclimate reconstructions and Earth System Models indicate that there is a positive feedback between climate and the carbon cycle, but confidence remains low in the strength of this feedback, particularly for the land. {6.4}

3. Key Uncertainties in Understanding the Climate System and its Recent Changes

a/ The simulation of clouds has shown modest improvement since AR4, however it remains challenging.{7.2, 9.2.1, 9.4.1, 9.7.2}

b/ Observational uncertainties for climate variables other than temperature, uncertainties in forcings such as aerosols, and limits in process understanding continue to hamper attribution of changes in many aspects of the climate system. {10.1, 10.3, 10.7}

c/ Changes in the water cycle remain less reliably modelled in both their changes and their internal variability, limiting confidence in attribution assessments. Observational uncertainties and the large effect of internal variability on observed precipitation also precludes a more confident assessment of the causes of precipitation changes. {2.5.1, 2.5.4, 10.3.2}

d/ Modelling uncertainties related to model resolution and incorporation of relevant processes become more important at regional scales, and the effects of internal variability become more significant. Therefore, challenges persist in attributing observed change to external forcing at regional scales. {2.4.1, 10.3.1}

e/ The ability to simulate changes in frequency and intensity of extreme events is limited by the ability of models to reliably simulate mean changes in key features. {10.6.1}

f/ In some aspects of the climate system, including changes in drought, changes in tropical cyclone activity, Antarctic warming, Antarctic sea ice extent, and Antarctic mass balance confidence in attribution to human influence remains low due to modelling uncertainties and low agreement between scientific studies. {10.3.1, 10.5.2, 10.6.1}

4. Key Uncertainties in Projections of Global and Regional Climate Change

a/ Based on model results there is medium confidence in the predictability of yearly to decadal averages of temperature both for the global average and for some geographical regions. Multi-model results for precipitation indicate a generally low predictability. Short-term climate projection is also limited by the low confidence in projections of natural forcing. {11.1, 11.2.2, 11.3.1; Box 11.1}

b/ There is low confidence in projections for a poleward shift of the position and strength of Northern Hemisphere storm tracks. {11.3.2, 12.4.4}

c/ There is generally low confidence in basin-scale projections of significant trends in tropical cyclone frequency and intensity in the 21st century. {11.3.2, 14.6.1}

d/ Projected changes in soil moisture and surface run off are not robust in many regions. {11.3.2, 12.4.5}

e/ Several components or phenomena in the climate system could potentially exhibit abrupt or nonlinear changes, but for many phenomena there is low confidence and little consensus on the likelihood of such events over the 21st century. {12.5.5}

f/ There is low confidence on magnitude of carbon losses through CO2 or CH4 emissions to the atmosphere from thawing permafrost. There is limited confidence in projected future methane emissions from natural sources due to changes in wetlands and gas hydrate release from the sea floor. {6.4.3}

g/ There is medium confidence in the projected contributions to sea level rise by models of ice sheet dynamics for the 21stcentury, and low confidence in their projections beyond 2100. {13.3.3}

h/ There is low confidence in semi-empirical model projections of global mean sea level rise, and no consensus in the scientific community about their reliability. {13.5.2, 13.5.3}

i/ There is low confidence in projections of many aspects of climate phenomena that influence regional climate change, including changes in amplitude and spatial pattern of modes of climate variability.

Annex II

REFERENCE TO RESEARCH AND OBSERVATION NEEDS

Whenever possible, please structure your answers using the following list of research and observation needs (A-G), in order to facilitate processing of the survey. In addition, where appropriate, please reference the WCRP Grand Challenges or Core Projects (as presented on WCRP website http://www.wcrp-climate.org/).

List of research and observation needs

A. Level of understanding of fundamental processes (e.g., aerosol-cloud interaction)

B. Observations and data
- B.1. Observing technology (e.g., instrument capability and quality)
- B.2. Data and metadata quality (e.g., homogeneity of long time series)
- B.3. Data access and stewardship
- B.4. Temporal and/or spatial coverage of observations (e.g., length of time series, global/regional networks, satellites)

C. Modelling
- C.1. Grid size/resolution; Computing power
- C.2. Parameterization of physical, chemical and biogeophysical processes
- C.3. Data assimilation
- C.4. Validation
- C.5. Reanalysis capabilities
- C.6. GCM issues
- C.6. Downscaling issues into geographical regions (e.g., in relation to risk assessments)

D. Application of climate analyses to societal needs (e.g., impacts on and feedback from biodiversity, human health, water management, agriculture)

E. Development of present and future emission scenarios

F. Linkage of climate applications to socio-economic data (e.g., for attributing economic and social value to climate analyses)

G. Other (do not fit in the above categories)

Annex III

LIST OF SURVEY RESPONDENTS

Ananicheva Maria Institute of Geography RAS
Bala Govindasamy Indian Institute of Science
Boer George CCCma
Brown Otis NC State University
Carter Timothy SYKE
Cazenave Anny LEGOS /CNES
Church John CSIRO
Cohen Stewart Environment Canada
Collins Matthew University of Exeter
Forest Chris Pennsylvania State University
Hegerl Gabi University of Edinburgh
Gille Sarah UC San Diego
Gleckler Peter PCMDI/LLNL
Gutowski William Iowa State University
Joos Fortunat University of Bern
Marengo José CCST/INPE
Joussaume Sylvie LMD/CNRS
Karl Tom NOAA
Knutti Reto ETH Zurich
Krinner Gerhard LGGE/CNRS
Nicholls Robert University of Southampton
Ly Omar INGE SAHEL SA
Otto-Bliesner Bette NCAR
Overpeck Jonathan University of Arizona
Patt Anthony ETH Zurich
Thorne Peter NERSC
Polonsky Alexander Marine Hydrophysical Institute
Porter John Uinversity of Copenhagen
Power Scott Bureau of meteorology
Ramaswamy Venkatachalam GFDL /NOAA
Renwick James Victoria University of Wellington
Rignot Eric UC Irvine
Sabine Christopher NOAA/PMEL
Scaife Adam Met Office
Seneviratne Sonia ETH Zurich
Stott Peter Met Office
Stouffer Ronald GFDL/NOAA
Sutton Rowan NCAS
Taylor Karl PCMDI
Shepherd Ted University of Reading
Tol Richard University of Sussex
Trenberth Kevin NCAR
Tschakert Petra Pennsylvania State University
Urquhart Penny Independent consultant
van de Wal Roderik IMAU
Zhang Xuebin Environment Canada

Annex IV

WCRP SURVEY: LESSONS LEARNT FROM IPCC AR5 FOR CLIMATE CHANGE RESEARCH AND WCRP

KEY GAPS, UNCERTAINTIES AND DEFICIENCIES IN CLIMATE RESEARCH

Issues covered in Working Group I: The Physical Science Basis

1. Observations of changes in the climate system (refer to the IPCC-identified key uncertainties in **Annex I**).

1.a. Prioritize issues by listing the top three ones in your views from Annex I (e.g. : 1e, 1g, 1a)
1.b. Provide reasons for those you selected
1.c. Are there any important issues you would like to highlight in addition to the identified list? Please be as specific as possible
1.d. Identify proposals for making progress (indicate where your proposals fit, using A-G categories as in Annex II)
1.e. How have the above mentioned issues evolved between AR4 and AR5, how have they been taken up in studies post the AR5 cut-off dates for published literature to be covered in the WGI report (15. March 2013)

2. Drivers of climate change (refer to the IPCC-identified key uncertainties in **Annex I**).

2.a. Prioritize issues by listing the main one in your view from Annex I (e.g. : 2c)
2.b. Provide reasons for your selection
2.c. Are there any important issues you would like to highlight in addition to the identified list? Please be as specific as possible
2.d. Identify proposals for making progress (indicate where your proposals fit, using A-G categories as in Annex II)
2.e. How have the above mentioned issues evolved between AR4 and AR5, how have they been taken up in studies post the AR5 cut-off dates for published literature to be covered in the WGI report (15 March 2013):

3. Understanding the climate system and its recent changes (refer to the IPCC-identified key uncertainties in **Annex I**).

3.a. Prioritize issues by listing the top three ones in your views from Annex I (e.g. : 3b, 3c, 3a)
3.b. Provide reasons for those you selected
3.c. Are there any important issues you would like to highlight in addition to the identified list? Please be as specific as possible
3.d. Identify proposals for making progress (indicate where your proposals fit, using A-G categories as in Annex II)
3.e. How have the above mentioned issues evolved between AR4 and AR5, how have they been taken up in studies post the AR5 cut-off dates for published literature to be covered in the WGI report (15. March 2013)

4. Projections of global and regional climate change (refer to the IPCC-identified key uncertainties in **Annex I**).

4.a. Prioritize issues by listing the top three ones in your views from Annex I (e.g. : 4a, 4b, 4d)
4.b. Provide reasons for those you selected
4.c. Are there any important issues you would like to highlight in addition to the identified list? Please be as specific as possible
4.d. Identify solutions for making progress (indicate where your proposals fit, using A-G categories as in Annex II)
4.e. How have the above mentioned issues evolved between AR4 and AR5, how have they been taken up in studies post the AR5 cut-off dates for published literature to be covered in the WGI report (15. March 2013)
4.f. Make here any specific proposal related to the Climate Model Intercomparison Project

Working Group II: Impacts, Adaptation and Vulnerability

In WGII report, research and data gaps, key uncertainties or research needs and priorities are identified at the end of most chapters in a special paragraph. You are therefore invited to focus on the chapters which correspond to your specific expertise or experience and make use of the information contained generally at the end of each chapter, restricting as much as possible your comments to domains related to WCRP activities . For convenience we have separated impact and adaptation issues.

5. Impacts

5.a. Select up to three "impact" domains where research and data gaps can be addressed by WCRP
5.b. Identify key issues and provide reasons for this (indicate where your proposals fit, using A-G categories as in Annex II)
5.c. Is there any important issue missing in your view from the report or not sufficiently highlighted ? Please be as specific as possible
5.d. Identify proposals for making progress (indicate where your proposals fit, using A-G categories as in Annex II)
5.e. How have the above mentioned issues evolved between AR4 and AR5, how have they been taken up in studies post the AR5 cut-off dates for published literature to be covered in the WGII report (31 August 2013)

6. Adaptation

6.a. Select up to 3 "impact" domains where research and data gaps can be addressed by WCRP
6.b. Identify key issues and provide reasons for this (indicate where your proposals fit, using A-G categories as in Annex II)
6.c. Is there any important issue missing in your view from the report or not sufficiently highlighted ? Please be as specific as possible
6.d. Identify proposals for making progress (indicate where your proposals fit, using A-G categories as in Annex II)
6.e. How have the above mentioned issues evolved between AR4 and AR5, how have they been taken up in studies post the AR5 cut-off dates for published literature to be covered in the WGII report (31 August 2013)

7. Regional aspects (chapters 21-30)

7.a. Select up to three major issues identified under research and data gaps, key uncertainties or research needs and priorities (valid for any region or related to specific regions)
7.b. Provide reasons for the issues you selected (indicate where your proposals fit, using A-G categories as in Annex II)
7.c. Is there any important issue missing in your view from the report or not sufficiently highlighted ? Please be as specific as possible
7.d. Identify proposals for making progress (indicate where your proposals fit, using A-G categories as in Annex II)
7.e. How have the above mentioned issues evolved between AR4 and AR5, how have they been taken up in studies post the AR5 cut-off dates for published literature to be covered in the WGII report (31 August 2013)

8. Material from SREX report

8.a. Select up to three major issues identified in SREX in the domain of competence of WCRP
8.b. Provide reasons for the issues you selected (indicate where your proposals fit, using A-G categories as in Annex II)
8.c. Identify proposals for making progress (indicate where your proposals fit, using A-G categories as in Annex II)
8.d. Is there any important issue missing in your view from the report or not sufficiently highlighted ? Please be as specific as possible
8.e. How the above issues have evolved between AR4 and AR5, how they have been taken up in new studies since AR5 publication cut-off dates?

PRIORITIES FOR RESEARCH WITHIN WCRP, IMPLICATIONS FOR CORE PROJECTS AND GRAND CHALLENGES

9. What should the top priorities be within present WCRP structure in order to fill the most critical gaps in possible future IPCC assessment reports? Please provide not more than one for each core project or activity within your domain of expertise(this may repeat some suggestions made earlier).

9.a. Recommendations related to Core Projects (CliC, CLIVAR, GEWEX , SPARC)
9.b. Recommendations related to Grand Challenges (Regional climate information, Clouds, circulation and climate sensitivity, Changes in water availability, Cryosphere in a changing climate, Sea level rise and regional impacts, Science underpinning the prediction and attribution of extreme events)
9.c. Recommendations related to modeling activities (WGCM, WGNE, WGSIP, WGRC, Model development activities under WMAC, Model-data archiving and dissemination: obs4MIPs, ana4MIPs, Earth System Grid Federation). Identify specific recommendations for CMIP.
9.d. Recommendations related to observation coordination activities (under WDAC)
9.e. Recommendations related to capacity building activities
9.f. Do you have suggestions on improving the communication of climate research results to the public and decision makers

10. Which scientific issues of relevance to climate change research you believe should be addressed by WCRP in addition to the present Grand Challenges, and how they should be addressed.

11. How can the current institutional or technical infrastructure for climate research be improved? Please select your top two improvements.

SUGGESTIONS FOR FUTURE IPCC ASSESSMENTS

12. Are they any specific aspects of the IPCC AR5 assessment results that you believe should be better taken into account in WCRP activities or that you would like to highlight in relation with WCRP activities?

13. Are they any specific aspects of the IPCC AR5 assessment process that you believe should be better taken into account in WCRP activities or that you would like to highlight in relation with WCRP activities?

14. Do you have specific suggestions for new climate change research activities (within or outside WCRP) that would serve future IPCC assessments?