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Item 2

Cross-Cutting Topic: Decadal Prediction

1. Introduction

i. Natural and Anthropogenically-Forced Decadal Variations

There are many examples of extreme climate variations on decadal timescales, many of which are associated with human death and misery. Perhaps the most striking in recent decades is the decadal timescale drought in the Sahel (leading, for example, to the remarkable Band-Aid Concerts). Other decadal-timescale droughts, such as the "dust-bowl" drought in the Southern US in the 1930s, are infamous in history (inspiring classics of literature such "The Grapes of Wrath").

More generally, decadal-timescale variability can be seen in most climate records. For example, in Africa there is a bi-decadal signal in precipitation over many parts of southern Africa and parts of East Africa have a strong decadal signal in the "short rains" season (CLIVAR VACS, 2007). Changes in the Atlantic Multidecadal Oscillation (AMO) are linked with decadal Atlantic hurricane variability and have impacts in the Sahel, India, Brazil, Central America and the Arctic. Changes in AMO are dynamically linked with the variations in the Meridional Overturning Circulation (MOC) of the Atlantic, in turn linked with the thermohaline circulation (THC). In the paleoclimate record, "abrupt" climate changes are believed to be linked directly with decadal variations in the MOC/THC. In the Pacific/Indian Ocean basins, there are strong signals of decadal variability associated with the Pacific Decadal Oscillation (PDO) with statistical links to the climate of surrounding regions. For example, during the 20th century, El Niño-like phases of the PDO coincided with decades in which ENSOs impact on Australia was weak, whereas La Niña-like phases of the PDO coincided with decades in which ENSOs impact on Australia was strong (Power et al, 1999).

In addition to natural climate variability, anthropogenic emissions of greenhouse gases (GHGs) will change the statistics of weather patterns in the coming decades. Hence the decadal climate prediction problem must take into account, not only the potential role of initial conditions (especially ocean, land and sea-ice) , but also future concentrations of GHGs (including other forcings such as aerosols). A prediction which depends entirely on forecast initial conditions is often referred to as a "prediction of the first kind" (following nomenclature introduced by Lorenz). A prediction which depends entirely on some specified forcing (eg specified SST anomalies, or a specified concentration of GHGs) is referred to as "a prediction of the second kind." Decadal prediction is both of the first and second kind. Indeed, this combination of prediction type poses interesting scientific questions: for example, does the impact of GHG forcing on decadal timescales depend on initial conditions; conversely, do estimates of initial-condition predictability depend on GHG forcing?

ii The scientific basis for decadal prediction

Many of the decadal variations mentioned above, are associated with remote sea surface temperature anomalies. For example, Folland et al (1986) showed that the persistent drought in the Sahel in the second half of the 20^{th} Century was affected by decadal timescale anomalies in SSTs associated with the MOC, further exacerbated by local land surface interactions. Similarly, Schubert et al (2004) showed that the US "Dust Bowl" drought was dynamically associated with anomalously cold SSTs in the tropical Pacific and warmer than normal SSTs in the tropical Atlantic. There is evidence that decadal rainfall signals in East Africa are linked with the PDO (CLIVAR VACS 2007).

Whilst there are no clear spectral peaks in SSTs on decadal timescales eg associated with the MOC and PDO, it is nevertheless possible that these spatially-coherent patterns of variability may have some predictability on decadal timescales, ie there is some potential for predicting these climate anomalies, given sufficiently accurate knowledge of initial conditions of land and ocean. However, the existence of such predictability needs to be proven - the null hypothesis is that decadal fluctuations arise from low-pass filtering of unpredictable atmospheric noise by the slow components of the climate system such as the oceans.

There is evidence for the existence of decadal predictability. For example, PREDICATE, an EU-funded project on the mechanisms and predictability of decadal fluctuations in Atlantic-European climate, concluded that potential decadal predictability exists for both the tropical and extratropical parts of the North Atlantic European region - up to 60% of the variance is potentially predictable. The project showed that the ocean exerts an important influence on multi-decadal timescales. For example, multidecadal variations in Atlantic SST associated with the MOC/THC modulates European climate.

An important workshop on Atlantic Decadal Predictability was held at GFDL in June 2006. A working hypothesis of the workshop was that if the state of the Atlantic MOC can be determined from data assimilative ocean models, then, when coupled to atmospheric models, the state of the MOC and perhaps the AMO can be projected into the future. Results from the workshop showed evidence from coupled GCM experimentation that the MOC was partially predictable on timescales of a decade or two.

In any case, even if initial-value predictability is limited, there is little doubt that the statistics of modes such as the MOC, AMO, PDO and so on will be affected by ACC.

2. A Cross-Cutting Proposal to Advance the Science of Decadal Prediction

The last decade has seen substantial developments in the development of coupled ocean-atmosphere models in global data assimilation systems for the ocean and the atmosphere, and in ocean observing systems. With these data assimilation systems, retrospective global analyses of the ocean and atmosphere state have been made over the past 40 years. In addition, impact and application models eg for health, agronomy and hydrological applications, have been developed and coupled to climate models. These developments suggest that the time is ripe to assess decadal predictability using state-of-the-art coupled model, initialised using realistic ocean-atmosphere analyses, and to assess the utility of these assessments on practical applications.

Some studies of decadal predictability using observed estimates of atmosphere-ocean initial conditions are already underway (eg Smith et al, 2007; ENSEMBLES, 2007). However, given the importance of this problem, it is timely to propose these types of study to the international community. The organisation of internationally-coordinated multi-model experimentation has been one of WCRP's strengths, and below is a proposal for a first step to explore decadal predictability from realistic ocean-atmosphere initial states, at coordinated international level. It is important at this stage not to propose too extensive a set of integrations. Firstly, institutes may not have sufficient resources to undertake an extensive programme of experimentation. Secondly, this preliminary study will raise as many issues, scientific and technical, as it will solve. Hence this study should be seen as a precursor to a second, more definitive study in a few years time.

The proposal would be to take two suggested initial dates from distinct decades, here suggested 1965 and 1994 (cf ENSEMBLES, 2007; Troccoli and Palmer, 2007). ECMWF can provide atmospheric and oceanic initial conditions from their atmosphere and ocean reanalysis effort. Modelling groups would then be asked to run four 20-year 3-member ensembles:

A 1965 initial conditions, observed GHGs (including aerosols) from 1965
B 1994 initial conditions, observed GHGs from 1994
C 1965 initial conditions, observed GHGs from 1994
D 1994 initial conditions, observed GHGs from 1965

By comparing A with B we can gauge the overall level of predictability arising from both having different initial conditions and different GHG forcings. By comparing A with D, and B with C, we have two estimates of decadal predictability (arising from having different initial conditions and the same GHG forcing). By comparing A with C, and B with D, we have two estimates of the impact of GHG forcings (since initial conditions would be the same).

These experiments allow yet more subtle types of analysis to investigate the dependence of initial conditions on GHG impact, and GHG impact on initial-condition predictability. Hence by comparing (A-C) with (B-D) we can study how the impact of the greenhouse forcing depends on the initial condition. Similarly, by comparing (A-D) with (B-C) we can study how the influence of initial conditions depends on the underlying GHG forcing.

There are technical issue which need to be discussed before finalising this proposal. For example, what is the best way to initialise the ocean from a set of analyses. For example, adding analysed anomalies (analysis - climatology) to some pre-existing state spun-up with climatological (eg Levitus) forcing might be best to try to reduce initial imbalances.

This type of experimentation is reminiscent of that proposed under the TOGA Monsoon Numerical Experimentation Group (MONEG 1992). There, seasonal AGCM integrations were made from initial conditions on 1 June 1987 and 1 June 1988 and run with observed SSTs from 1987 and 1988 (cf A and B). With additional hybrid experiments (cf C and D) running 1 June 1987 atmosphere/land initial conditions and 1988 SSTs (and vice versa) the impact of the atmosphere/land surface initial conditions could be distinguished from the impact of the SSTs.

It can be envisaged that, following successful execution of this initial phase, a full scale decadal-prediction study, organised under the auspices of WCRP, could be devised.

3. Relevance to WCRP

i Scientific impact, balance and relevance of WCRP overall

The two overarching objectives of WCRP are:

1. to determine the predictability of climate, and:
2. to determine the effect of human activities on climate

A study of decadal prediction addresses both of WCRP's objectives - the intrinsic predictability of climate, ie the role of initial conditions, and the anthropogenic forcing of climate.

The WCRP strategic framework (WCRP, 2005) aims to facilitate analysis and prediction of Earth System variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society. Clearly an expansion of work in the area of decadal prediction fits well this aim. More specifically, however, a key focus of the WCRP strategic framework is towards seamless prediction, and there are many theoretical and practical reasons for the weather and climate community to adopt a seamless prediction methodology (Hurrell et al, 2007). Decadal prediction is a "meeting ground" for the weather and climate modelling communities. The climate-change community is typically focussed on the problem of estimating anthropogenically-induced climate change on centennial timescales. For this community, the provision of accurate initial conditions is not a major concern, since the level of predictability of the first kind is believed to be small on century timecales. By contrast, the numerical weather prediction and seasonal forecast community have well-developed data assimilation schemes to determine initial conditions, however the models do not incorporate many of the cryospheric and biogeochemical processes believed to be important on timescales of centuries. A focus on decadal prediction by the two groups may help expedite the development of data assimilation schemes in Earth-System models, and the use of Earth-System Models for shorter-range, eg seasonal prediction. For example, as has been discussed elsewhere (Palmer et al 2007), seasonal predictions can be used to calibrate probabilistic climate-change projections, in a seamless prediction system. Hence there is common ground over which to base a cooperation of the two communities in order to develop seamless prediction systems.

ii Policy relevance for WCRP

The proposal in Section 2 is extremely policy-relevant for WCRP. Firstly, reliable decadal predictions have application in many sectors: health, agriculture, water management, tourism, forestry, fisheries, hurricane predictions, arctic navigation, permafrost and methane gas emission, electrical power generation, shipping and offshore construction (Crawford et al, 2006) to name a few.

These applications would all be relevant without the additional complication of anthropogenic climate change (ACC). However, in the light of ACC, many public and private sectors are now facing the problem of assessing what infrastructure investment is needed to adapt to climate change. Whilst mitigation policy is relevant for controlling carbon concentrations a hundred or more years ahead, infrastructure investment decisions in climate-sensitive areas are most relevant on the decadal timescale. Hence developing a reliable decadal prediction system will be a key contribution WCRP can make to the problem of climate adaptation.

Because of the importance of short-range climate prediction for climate adaptation decisions, it is conceivable that multi-decadal climate prediction from observed initial states will play a prominent role in the next IPCC assessment report.

iii Organisation and governance of WCRP

This paper proposes activities which will draw on the expertise of scientists across the whole range of WCRP and build on overarching issues which lie under the scope of both WMP and WOAP. In particular it requires attention to both state of the art analysis and assimilation systems for initialization of coupled models and carefully designed numerical experimentation. Both of these are key issues for CLIVAR which can bring considerable wider expertise to this activity (decadal variability is a cross-cutting science topic within CLIVAR which also has the lead within WCRP on the role of the oceans in climate. Further, GEWEX can supply important expertise on the role of land surface processes and in particular experimentation on how initialization of the land surface may influence decadal predictions. In addition, expertise on the the role of ice for decadal prediction through involvement of CliC scientists and of the potential influence of stratospheric processes on decadal prediction via SPARC will also be crucial.

It is proposed that scoping of the proposed activity be carried out by a short period pan-WCRP Task Force led by CLIVAR and involving experts from CliC, GEWEX and SPARC, reporting on progress to the WMP and WOAP and aiming of the development of a comprehensive plan for the initial experiment in time for JSC XXIX. Such a plan would build on, and benefit from the planning for the upcoming TFSP Seasonal Prediction experiment. The activity would therefore be built on existing WCRP governance structures and forms of working set out in the WCRP Stategic Framework 2005-2015.

iv Visibility and communication by WCRP

Development of the basis for decadal timescale prediction will be a key activity with potential for high visibility for WCRP, in particular providing a legacy similar to that which emerged from TOGA and ongoing efforts under CLIVAR for seasonal prediction. WCRP will need to communicate our understanding of and the potential for decadal prediction to its stakeholders at an early stage and to then build on this as key science achievements and capabilities emerge. The role of decadal prediction as a meeting ground for the weather and climate modelling communities and a vehicle for seamless prediction will also need to be widely communicated to ensure the buy-in from a wide range of the community and from a broad spectrum of agencies world-wide. It will also be essential to involve and communicate with those involved with the potential applications of decadal prediction both through publicity, but more importantly through their involvement in activities to assess the utility of the predictions themselves and advertisement of emerging capability.

v. Interaction with other bodies

There are potentially considerable opportunities to develop interactions with other bodies, including e.g. the WMO World Climate and Applications Services Programme (and in particular its Climate Information and Prediction Services (CLIPS) project) as well as a wide range of potential user communities, especially agencies seeking predictions for long-term planning. Decadal timescale predictions will also provide an interface with a range of other programmes and in particular with IGBP in terms of the impact of variability on biogeochemical systems, with IHDP in terms of impacts on society and its ability to plan and input to any future IPCC assessments (eg on short-range projections for climate adaptation), providing the perspective of the influence of long timescale climate variability.

vi. Capacity building in/by WCRP

As a cross cutting topic of WCRP, decadal prediction will provide a focus for development of capacity in terms of seamless prediction and to help direct the activities and requirements (e.g. for observations and assimilation and prediction systems within WCRP overall as well as more widely. Decadal prediction has potential for a wide range of prediction services, building capacilty for planning across both the developed and developing world. It will also impact on capacity building at intraseasonal-seasonal-interannual prediction timescales through increased understanding of the role of decadal timescale variability on seasonal predictions themselves

References

CLIVAR VACS, 2007: Decadal variability issues in Africa.

Crawford, W., Martinez, R. and Suga, T., 2006: List of possible applications for decadal prediction. CLIVAR Pacific Panel Document.

ENSEMBLES, 2007. http://www.ensembles-eu.org/

Folland et al, 1986: Sahel rainfall and worldwide sea temperatures 1901-85: Observational, modelling and simulation studies. Nature, 320, 602-607.

Hurrell, J., Bader D., Delworth, T., Kirtman, B., Meehl, J., H.L.Pan, B. Wielicki: 2007. White Paper on Seamless Prediction. In preparation for BAMS.

Leetmaa, A. and J. Marshall, 2006: Workshop report: Atlantic Decadal Predictability and Plan for Next Steps.

MONEG, 1992. Simulation of interannual and intraseasonal monsoon variability. WMO/TD-No 470, 185pp

Palmer et al, 2007: Calibration of probabilistic climate-change projections of precipitation using seasonal reforecasts. Nature. Submitted.

Power, S., Folland, C., Colman, A. and V. Mehta, 1999: Inter-decadal modulation of the impact of ENSO on Australia. Climate Dynamics, 15, 319-324.

PREDICATE, 2006: http://ugamp.nerc.ac.uk/predicate/

Schubert et al, 2004: On the cause of the 1930s dust bowl. Science, 303(5665), 1855-1859.

Smith et al, Improved surface temperature prediction for the coming decade from a global climate model. 2007. Science. Submitted.

Troccoli A. and Palmer, T.N., 2007: Climate prediction as an initial-value problem. Phil. Trans. Roy. Soc., submitted.

WCRP, 2005: http://wcrp.wmo.int/About_Strategy.html