TELECONNECTIONS IN THE ATMOSPHERE AND OCEANS

BY FRED KUCHARSKI, IN-SIK KANG, DAVID STRAUS, AND MARTIN P. KING

Atmospheric and oceanic teleconnections govern the variability in our climate system on a broad range of time and spatial scales, in both the tropics and extratropics. On interannual time scales, the connection between El Niño–Southern Oscillation and the Asian monsoon system influences rain amounts in regions particularly sensitive to floods/droughts. On interannual and decadal time scales, rainfall variability in the Sahel region of West Africa appears to be governed to a large extent by teleconnection patterns related to the Pacific Ocean, the Indian Ocean, and the Atlantic Ocean. The decadal behavior of the North Atlantic Oscillation (NAO), influencing climate in Europe, Asia, and northern Africa, is also likely to be connected to both tropical and extratropical sea surface temperatures in the Indo-Pacific and Atlantic regions.

The subject of teleconnections in the atmosphere and oceans has motivated a great deal of vigorous research in the last 30 years or so. The main research areas have been coupled ocean–atmosphere processes that lead to better predictions of the ENSO phenomenon. The circumglobal waveguide and its use as a modeling agent for large-scale hemispheric wave patterns near the core of the subtropical jet is seen as another example of an important outcome of teleconnection research. As a consequence, enormous progress has been made in seasonal forecasting, which allows the estimation of climate anomalies for several months ahead and may have important implications for agriculture and economies. However, progress in seasonal forecasting is far from saturated and further improvements may be expected from better predictions of sea surface temperatures outside of the ENSO region.

Decadal predictions, as an emerging research field, are beginning to bridge the gap between seasonal forecasts and climate change predictions. Such predictions aim at estimating climate anomalies for the next few decades and may therefore be of more immediate relevance than climate change predictions that aim for a time horizon of several generations ahead. The separation of human-induced climate change and natural climate variations are one of the most critical challenges in this timeframe. Very complex Earth system models are necessary for this purpose.

CONFERENCE ON TELECONNECTIONS IN THE ATMOSPHERE AND OCEANS

WHAT: Nine invited lecturers and about 150 participants from developed and developing countries met to review our current understanding of atmospheric and oceanic teleconnections and to provide perspectives for future research.
WHEN: 17–20 November 2008
WHERE: Trieste, Italy

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Teleconnection research may provide crucial understanding for progress in this field. Indeed, progress in the understanding of low-frequency coupled modes as presented in the conference is one example where this research can improve decadal predictions. Teleconnection research will therefore continue to attract young researchers for some time. This conference provided an overview of what has been achieved and the outstanding issues that remain

CONFERENCE SNAPSHOT. The presentations at the 4-day conference were a mix of invited review lectures by distinguished scientists and contributions from papers on recent research submitted to the conference. The Abdus Salam International Centre for Theoretical Physics (ICTP) in Trieste, Italy, whose main mission is to foster research in developing countries, enabled the organizers to efficiently involve many researchers from developing countries and to give them the opportunity to meet some of the well-known scientists in climate research. The invited lecturers were as follows: Grant Branstator (National Center for Atmospheric Research), Isaac Held (Princeton University), Brian Hoskins (University of Reading), Gabriel Lau (Geophysical Fluid Dynamics Laboratory and Princeton University), Franco Molteni (European Centre for Medium-Range Weather Forecasts), Jagadish Shukla (George Mason University), Anastasios Tsonis (University of Wisconsin—Milwaukee), Mike Wallace (University of Washington), and Bin Wang (University of Hawaii at Manoa). Two poster sessions completed the program.

Topics included the following:

1) general aspects of the theory of teleconnections in the atmosphere,
2) methods for identifying atmospheric teleconnection patterns,
3) ENSO-related teleconnections,
4) teleconnections involving the circumglobal waveguide,
5) eddy feedback mechanisms on teleconnection patterns,
6) mechanisms that are responsible for the existence of some teleconnection patterns,
7) stratosphere–tropospheric coupling,
8) tropical teleconnections and tropical–extratropical teleconnections,
9) tropical Atlantic influences on the Indian monsoon and ENSO,
10) teleconnections on decadal time scales, including teleconnections involving coupled ocean–atmosphere modes, and
11) influences of sea ice changes on the NAO.

(See the conference Web page http://agenda.ictp.it/smr.php?1968 for a complete list of lectures as well as presentation slides and lecture notes.)

Two 90-min discussion panels near the end of the second day and on the final day became the primary focus of the meeting. Each panel consisted of outstanding scientists in the field of atmospheric and oceanic teleconnections who discussed the current knowledge and future perspectives on teleconnection research, addressing questions and issues posed by participants.

OUR CURRENT UNDERSTANDING OF TELECONNECTIONS. The first panel discussion focused on general issues related to teleconnections and mechanisms connecting tropical and extratropical regions. The panel consisted of Branstator, Held, Molteni, and Wallace. Wallace was also a panelist in the second discussion session.

One of the main questions raised during this discussion was whether teleconnections are useful for climate predictions. The panel agreed that teleconnections can be used as a predictive tool and to aid the understanding and improvement of predictive skill in seasonal forecasts. However, the predictive skill in the extratropics may be limited to 1 or 2 weeks. The main source of seasonal predictability is ENSO. Predictability could be increased by improving tropical SST forecasts outside the ENSO region, for example, in the Indian Ocean, western Pacific, and tropical Atlantic. It was also suggested that long-range predictive skill might be provided by troposphere–stratosphere teleconnections, improvements in the treatment of the land surface and snow cover, and better initializations in general circulation models. In addition, questions were raised regarding which teleconnections should be chosen to assess model performance. It was suggested that one-point correlation maps could be a good way to investigate whether models are able to reproduce the observed teleconnections. Analysis of the seasonal cycle, which is still a main cause of model errors, would be useful as well.

The panel also considered the problem of determining the best diagnostic tools to identify teleconnections, for example, linear versus nonlinear techniques. Pure linear methods, such as EOF analysis, may not reveal the important effects of nonlinearities. For instance, positive and negative phases of a teleconnection can have quite different effects (other than being of opposite sign) on regional climate. Scientists

are encouraged to consider the possible different polarities of a teleconnection.

The reproduction of realistic tropical convective heating, one of the main drivers of teleconnections, remains deficient in models. The only way forward seems to be a new generation of convection-resolving general circulation models, because the current parameterizations of convection in climate models are not able to reproduce some of the observed climate variations, such as intraseasonal variability and the Madden–Julian oscillation.

Challenges for future research, pointed out by the expert panel, include the assessment of internal and external variabilities in warming climate scenarios, and connecting progress in understanding climate change and climate variability with the problems of how teleconnections may modify or be modified by climate change.

In concluding remarks, it was mentioned that models, and in particular coupled models, should be used to study nonlinearities in teleconnections because the observed records are too short to assess such behaviors with a high statistical significance.

LONG-TERM TELECONNECTIONS. In addition to Wallace, the panelists for the second discussion session were Yochanan Kushnir (Columbia University), Lau, and Wang. The discussion was largely devoted to teleconnections on decadal to multidecadal time scales, as well as to teleconnections within tropical regions.

The first topic raised was the potential for decadal predictability. The ability to test models for skill on decadal time scales is limited. This may be because the reanalysis record is not long enough. Newly available reanalysis products for the European sector for the entire twentieth century may help in achieving better assessments of the potential in decadal predictability. Ocean initialization also will play a crucial part in achieving progress in decadal predictions. The Argo floats and other ocean observations may help to improve these initializations.

Because warm ocean–monsoon connections are not well modeled, and poor simulations of land–atmosphere interactions seem to limit present forecasts, the question remains whether there is still an ingredient missing in the current seasonal forecasts using numerical models. Examples of such missing ingredients could include complex chemical processes and ocean mixed layer processes that may need high vertical model resolution. Research in these directions is ongoing. The second panelists also discussed how Indian Ocean SSTs affect the East African monsoon. The Indian Ocean dipole (IOD) appears to play an important role in forcing the observed East African rainfall, but it is currently poorly modeled. Furthermore, the whole theory of the IOD itself as an independent mode of variability is still considered by some scientists to be controversial. The ENSO SST teleconnection pattern in the Indian Ocean resembles that of the IOD; therefore, the IOD's independence may not be easy to demonstrate.

Subsequent discussion turned to the role of aerosols in climate change and variability, which is a very complex issue. There currently is not a consensus about the detailed role of aerosols in climate variability. In particular, the causes and effects of changes related to aerosols are difficult to distinguish. Aerosol research in relation to climate change and variability was therefore suggested by the panel to be a fertile field for young scientists to pursue.

Problems identifying predictive skill using persistence of teleconnection patterns are ongoing. Unfortunately, the intrinsic persistence of pure atmospheric teleconnection patterns is limited to about 10 days, in turn limiting its useful predictability. The most predictable atmospheric teleconnection patterns are the Pacific–North American (PNA) pattern and its relative, the tropical–Northern Hemisphere (TNH) pattern, perhaps because of their linkages with ENSO. These patterns may be the cause of months-long drought as well as flood conditions in North America.

Finally, a suggestion was made to the attending scientists to make better use of paleoclimate data in research on decadal predictability through teleconnection patterns. High-resolution global coupled modeling was also noted as a solution to the problematic simulations of tropical convective heating presently apparent in many numerical models.

UPDATING THE LITERATURE. In closing remarks, the proposal to produce a book with contributions by select teleconnections authors was positively viewed. It was generally agreed that the time is ripe for the climate teleconnection community to produce such a book since the publication of Hoskins and Pearce (1983) occurred a quarter-century ago. A timeframe of 2–3 yr to produce a final draft was advised as being realistic

REFERENCES

Hoskins, B., and R. P. Pearce, Eds., 1983: *Large-Scale Dynamical Processes in the Atmosphere.* Academic Press, 397 pp.