# Report on the ECMWF 2012 annual seminar on "Seasonal prediction"

This conference took place at ECMWF, in Reading, England from September, 3rd to 7$^{th}$. As mentioned by Erland Källén in his opening talk, its main objective were to address the basic problems in seasonal prediction, span the development areas and provide outlooks for future. The list of talks that were organized is the following:

Dave Anderson: History of seasonal prediction

Namias first formulated a potential link between ocean and atmosphere in the 70s, giving hope that understanding the ocean would allow forecasting the atmosphere. Davis, following a robust statistical approach, showed that Sea Surface Temperatures (SST) could indeed be forecasted but not the Sea Level Pressure (SLP) which was rather driving the SST. Those results were criticized by Namias for using annual mean values. Davis then showed a predictability of autumn (winter) SLP from January (October) SST and developed the first statistical seasonal prediction model. The ocean integrates the atmospheric white noise which explains its red spectrum, though some resonance or coupled mechanisms have been highlighted since then. In the 80s, Walker identified the Southern Oscillation from regressions to predict the Indian monsoon. Trenberth then observed SLP teleconnections with Darwin. Bjerknes suggested a coupling between the Southern Oscillation and the already known El Nino in the Peru and Ecuador coastal areas. The El Niño Southern Oscillation (ENSO) was later described by Rasmussen and Carpenter as westward propagating warm anomalies. Climate scientists then failed to predict the 1982/83 El Nino. Gil and Rasmussen noticed that an eastward propagation had rather occurred during this event. The TOGA observation program was launched in the hope of predicting El Nino. The main following El Nino and La Nina events could be predicted thanks the ocean heat content memory. There has been steady progress in predicting the NINO3.4 index in the last two decades thanks to model development, better data coverage and data use.

Hyemi Kim: ENSO & ENSO teleconnections

Westerly wind bursts, often associated with the Madden-Julian Oscillation (MJO), might trigger El Niño. ENSO impacts the North American climate, through shifts in the mid-latitude jet, but also Europe through upper atmosphere waves and cyclonic activity in various basins. It is highly predictable up to 6 months ahead (with higher skill for stronger El Niño), though the existence of the 'spring predictability barrier'. The ENSO teleconnections are captured by CFSv2 and S4 though better over North America than Europe (the induced temperature anomalies over Europe are underestimated). The Central Pacific=Modoki El Nino associated with cool European anomalies was dominating in the last decade over the classical Eastern Pacific El Nino associated with warm European anomalies. The MJO can be predicted up to 3-4 weeks ahead though with too weak amplitude and a predictability limited by the 'Maritime Continent Barrier'.

Arnaud Czaja: Ocean-atmosphere coupling in mid-latitudes

The smoother the SST field or the lower the temporal SST forcing frequency, the more intense the storm track. On the one hand, SST front tend to anchor the storm track via an enhancement of the low level Eady growth while the storm track tends to reinforce the SST gradients, which lead to a self-sustaining storm-track/SST front system. On the other hand, the ocean heat absorption tends to damp the extra-tropical waves. A SST gradient perpendicular to the wind is more efficient to strengthen it.

Franco Molteni: Understanding teleconnections with the Indo-Pacific region during the northern winter

The early Niño phase tends to coincide with a positive Indian Ocean Dipole (IOD) phase (with the accompanying precipitation anomalies), the late phase with an Indian Ocean warming. The IOD tends to counteract the Nino-generated extratropical waves. The SST tropical trend favors an increase in tropical precipitation, an anticyclonic trend in the North Pacific and the recent NAO trend. Opposite tripolar SST and precipitation teleconnections are observed in relation to the Western and Eastern Indian Ocean. The Indian SST and precipitation are fairly well predicted by S4. The impact of the third MJO and winter Indian Ocean rain on the North Pole atmospheric circulation share similarities with the long-term trend in this atmospheric circulation.

Simon Mason: Do statistical models trade resolution for reliability?

The reliability is defined as the ability to simulate the following: 'the outcome occurs as frequently as indicated', the resolution as the ability of having 'different outcomes for different forecasts', the discrimination as the ability of having 'different forecasts for different outcomes', and the sharpness as the ability of having some 'unusual forecasts'. The reliability and ROC diagrams were described. Under the hypothesis of bivariate normality, bias-correcting should improve the discrimination. On practical examples, this might not be true since the hypothesis is not valid. The variance in forecast probabilities gives a measure of the resolution. Uncertainties in the estimation of parameters (climatological probability, skill) can lead to resolution loss. Multi-variate or non-linear statistical recalibration can compensate for this type of errors. Discrimination and resolution can only be improved by recalibration for categorical forecasts.

Laura Ferranti: Calibration and validation of seasonal forecasts

The model and season dependent biases make it necessary to calibrate the forecasts which are thus issued as anomalies with re-scaled amplitude. The calibration is statistical adjustment of the probability distribution based on past performance to produce probabilistic forecasts which are sharper and more reliable, but it requires long sets of stationary training data. The multi-model approach stands as an effective alternative to create calibrated probabilistic forecasts. The combination of several independent models widens the ensemble spread by sampling model errors. Re-forecasts are an integral part of a seasonal forecast system by allowing assessing systematic errors, skill and calibrate forecasts. The improvement with calibration for S4 and the better scores for S4 than S3 were illustrated for NINO3. ROC and ACC maps for near surface temperatures were shown. A lower sharpness over Europe than over the tropical band is obtained. The robustness of the forecast skill assessment is limited by the sample-size, effect of long-term trend and the ensemble size. 40 (20) years would be needed over the mid-latitudes (Tropics) to estimate deterministic skill scores. The ENSO variability strongly depends on the period considered. The use of de-biased BSS and ranked probability skill score are advised to avoid the dependency on the ensemble-size.

Caio Coelho: The use of seasonal climate predictions in South America

Both empirical statistical models and dynamical models have been used to forecast South American seasonal precipitation since the mid-90s. Though statistical methods are based on climate observations, simple to build and cheap, they strongly depends on the quality and length of the observational dataset and they do not fully account for climate change, Though dynamical models use well-established laws of physics and can produce forecast under new climate conditions, they are expensive and their physical laws must be abbreviated. EUROBRISA proposed a combination of statistical and dynamical models. The empirical model uses Maximum Covariance analysis to relate SST and precipitation. The ECMWF S3, the UKMO, the Meteo-France and the CPTEC models are used as dynamical models. The combination and calibration procedure makes uses of data assimilation and forecast assimilation. The 2008 La Nina was well captured by the EUROBRISA system in terms of onset, amplitude and long duration. Good probabilistic scores in precipitation over South America up to 1-year leadtime were obtained during the last years. Downscaling methods improve further the precipitation skill. This project contributed substantially to the seasonal forecasting capability for South America.

Oscar Alves: Applications of seasonal prediction in Australia

The POAMA forecast system has been developed since 2000. The forecasts are now initialized from the PEODAS 1960-present 11-member reanalysis using a multi-variate pseudo-ensemble Kalman filter, incorporating temperature and salinity profiles. Coupled assimilation is planned using bred vectors. In the last decade, the skill in Nino 3.4 and IOD has improved thanks to increased supercomputing resources, forecast system development (model, physics, initialization strategy), new observing systems. The precipitation related to the 2012 La Nina was successfully captured. Despite the good performance of the forecast system, the risk-averse behavior of farmers reduces the benefits they actually make from it. A farmer would however be 80% sure of making more money after 3 years of using POAMA forecast.

Sulochana Gadgil: Seasonal prediction of the Indian Summer Monsoon

The Indian Summer Monsoon Rainfall (ISMR) has a substantial impact on GDP, in particular extreme events, with a stronger impact of drought than floods. Its interannual variability is related with ENSO (negative correlation) and the Equatorial Indian Ocean Oscillation (EQUINOO). Its poor skill might be due to the poor representation of the SST-precipitation relationship or the poor representation of the monsoon-EQUINOO relationship. A positive EQUINOO phase is characterized by positive (negative) deep convection anomalies in the western (eastern) Indian Ocean, associated with easterly anomalous equatorial winds. Using both NINO3 and EQUINOO indexes, it is possible to explain all the observed extreme ISMR events up to now. Some facets of those two oscillations are however, not well enough reproduced to capture all ISMR extremes.

Laurent Dubus: Monthly and seasonal forecasts in the French power sector

EDF is highly interested in optimizing its production (which for hydropower electricity strongly depends on precipitation) in order to fit users needs which depend on the temperature. 1% misfit represents a loss of several million euros. Probabilistic forecasts are required and used to forecast power demand and energy prices on the market and to compute financial risk indicators and determine hedging strategies. ECMWF monthly forecasts (Z700 & Z1000) are used after a statistical downscaling of temperature and precipitation performed by Meteo-France which provides skill up to 3-4 weeks on local scale. Hydrological models provide streamflow probabilistic forecasts. This approach is successful in the Petit Saut hydropower plant which provides 70% of French Guinea energy. The most crucial EDF need is for monthly forecast of extremes.

Magdalena Balmaseda: Initialization techniques in seasonal forecasting

ENSO prediction has experienced a steady progress of 1 month/decade, half thanks to model improvement, and half to ocean initialization. Initialization of subsurface ocean is crucial to reproduce Rossby and Kelvin waves. A crucial ingredient of an ocean reanalysis are the surface fluxes. Changing observing systems is a challenge for consistent reanalysis. Spurious bias introduced by such changes has been tackled in the past by developing bias correction method. The ORAS4 reanalysis is presented and showed to bring a consistent improvement in seasonal forecasts in every basin. Initializing with a reanalysis can lead to a drift such as propagating Kelwin waves. Initialization shocks can be larger than the model bias. While in the medium range, initializing close to the observed state is perceived as beneficial since the model retains this initial information, for longer timescales, new methods are developed to initialize close to the model attractor (anomaly initialization either from an ocean reanalysis=2-tier of from ocean observations=1-tier). Another possibility to avoid the initial drift is the online flux correction in which the wind correction is essential to improve the skill. Initial shocks could also be avoided by coupled data assimilation.

Peter Bechtold: Convection and the Tropics

Most of the energy generation and conversion occurs in the upper-tropical troposphere. The convective heating must occur in the right phase of the large-scale wave, and as temperature variations are small it must show the right sensitivity to mid-tropospheric moisture. The main forecast errors concern the spindown of Hadley cell, and a too strong south-eastern Asian Monsoon. The largest low-level wind model errors appear in the East tropical Pacific where the reanalysis uncertainty is also relatively large for 950-700 hPa winds.

Adam Scaife: Stratosphere-troposphere interaction and long-range prediction

On seasonal to decadal timescales, the mid-latitudinal jet strength largely influences the European temperature and frosts. Unfortunately, the NAO/AO prediction skill is currently very low. On monthly timescales, wind anomalies have been shown to propagate from the upper stratosphere to the troposphere, for example before the cold 2009 event. The 2005/2005 cold event can be simulated by imposing stratospheric anomalies. The intraseasonal prediction of European cold spells is significantly improved when using a high-top (80km) rather than a low-top (40km) model. On seasonal timescales, some predictability can be brought by the Quasi-Biennial Oscillation which has a period of 2-3 years and is predictable 1-2 cycles. El Nino has been shown to favor a negative NAO through a Rossby wave reaching the stratosphere. On multi-annual timescales, the solar cycle induces NAO-like surface temperature anomalies through descending winter wind anomalies following an equatorial stratopause temperature anomaly. Under climate change, an increase in meridional winds and a strengthening of the Brewer-Dobson circulations are to be expected. The response of the mid-latitudinal jet to climate change is day and night between low-top and high-top models.

Sonia I. Seneviratne: Role of land-surface processes for seasonal prediction

A strong coupling between soil moisture and precipitation during the hottest months is observed in transitional areas, i.e. in between dry and wet areas. In southeastern Europe, the correlation between the percentage of hot days and the soil moisture is higher and higher when the quantile defining the hot days is increased. The soil moisture affects the evapotranspiration in transitional climate regions which impacts temperature and precipitation. GLACE-2 international project aimed at quantifying the impact of soil moisture initialization on prediction skill at 1-2 month leadtimes. A perfect model study showed a weak contribution to precipitation skill in South Africa and northern America and a much larger contribution to the temperature skill in every continent. The skill is however very low in real forecasting exercises. The skill is higher for extreme initial soil moisture. The soil moisture persistence, though highly dependent on the soil type, would allow early warming for the runoff which can be forecasted with a simple water balance model. A drying of many continents is to be expected with climate change; transitional climate areas will move.

Christophe Cassou: Sources of intraseasonal to interannual predictability over the North Atlantic / Europe region

The intraseasonal variability of the large-scale atmospheric circulation can be decomposed into a reduced set of four "preferred" states, named weather regimes. Those are computed from the 1957-2011 Z500 from the NCAR reanalysis, by maximizing the inter-regime variance and minimizing the intra-regime variance. The winter regimes are the NAO–, the NAO+, the Blocking, and the Atlantic Ridge. A seasonal forecast can be formulated as the percentage of occurrence of each weather regime. 8 phases constitute the MJO, each one lasting 7-8days. Phase 2/3 favors the NAO+ (+30%) and inhibits the NAO- (-50%). Phase 6 favors the Blocking (+15%). Phase 7/8 favors the NAO- (+30%) and inhibits the NAO+ (-50%). The MJO leads the weather regimes by 5 to 10days. La Nina favors the Atlantic Ridge and NAO+. El Nino favors NAO- and inhibits the Atlantic Ridge. A warm (cold) tropical Atlantic ocean favors NAO- (NAO+). The re-emergence mechanism tends to favor the persistence of a regime from one winter to another.

Tim Palmer: Stochastic Physics and reliable seasonal prediction

Precipitation forecasts are reliable for first the 10 days, they loose reliability afterwards except for some key regions such as the Amazon and the Southeast Asia. Reliability is also an issue for short-term forecast of heavy rain. Traditionally, the sub-grid scale closure schemes rely on deterministic bulk parameterizations. This is based on the strong assumption that the sub-grid scale processes are in quasi-equilibrium flow. A stochastic parameterization provides the sub-grid tendency associated with a potential realization of the sub-grid flow, not the tendency associated with an ensemble average of sub-grid processes. It can incorporate physical processes not described in conventional parameterizations. It allows accounting for the computational uncertainties. Stochastic physics is a way of increasing forecast reliability.

Annica Ekman: Aerosols and their seasonal variability

Most of the uncertainty on the Earth's energy budget comes from the aerosol contribution. Since the 80s, the $SO_2$ concentration has decreased after a steady increase for one century while the black and organic carbons still increase. The current models capture the general patterns of aerosol optical depth. Though huge progress was made in the last years, large uncertainties are still present because of the complexity of the processes. There are three different aerosol effects: a) the direct effect, .i.e. greenhouse effect, b) the 1st indirect effect (increase in reflection) and the 2nd indirect effect (increase in precipitation since aerosols are condensation nuclei). Their net impact seems to have been a weakening of the South Asian monsoon, changes in the Walker circulation, the extra-tropical wave patterns and a widening of the Northern Hemisphere tropical belt. Through changes in location and strength of the tropical precipitation, aerosols can affect the latent heat release in the troposphere and hence the Walker circulation and the propagation of extra-tropical waves. In the extra-tropics, the direct relation between shortwave changes and temperature is small.

Yuhei Takaya: High-resolution efforts

The need for a full set of re-forecasts for calibration stands as a main obstacle to the increase in resolution in seasonal prediction. One has to choose also between including new processes and increasing the resolution. The high-resolution in the ocean improves the representation of western boundary currents, fronts, tropical instability waves, meso-scale eddies, Atlantic Meridional

Overturning Circulation and ENSO and reduces the cold tongue biases. In the atmosphere, the sub-synoptic eddies, the blocking frequency, the tropical and extratropical cyclones, the precipitation and the stratosphere-troposphere interactions are better represented. Air-sea interactions are also better simulated. In the Athena project, an increase in seasonal prediction skill was found in both the Tropics and extratropics in winter when increasing the horizontal resolution. Increase in vertical atmospheric resolution must go along with appropriate treatment in model physics. About 25km resolution in the atmosphere and 10km in the ocean are advisable to resolve all the above-mentioned features.

Cecilia Bitz: The predictability of Arctic sea ice on seasonal to interannual timescales

The Artic sea ice extent reached a record low this summer which was not predicted by the sea ice outlook efforts. The sea ice growth is inversely proportional to the thickness. It occurs at the ocean-ice interface but ice can melt at top and base of the ice cover. The polar amplification occurs only in winter though the positive ice-albedo feedback occurs only in summer. Lagged correlations of pan-Arctic sea ice area show a characteristic e-folding time of 3-5 months but also a re-emergence up to 15 months later. Spring-to-fall reemergence occurs since the SST persists until the sea ice shows up again in the same area in the growing season. The persistence from one summer to another lies in the thickness, which signal is maximum from September to the next September. A substantial source of sea ice predictability is the trend, especially after 3 years. The persistence of thickness and SST and the dependence of the area on thickness in summer and on the ocean heat provide additional predictability. The pan-Arctic sea ice area is intermittently predictable for several years and the volume for 3-4 years in a perfect model approach. A barrier to sea ice predictability appears in spring because of the ice-albedo feedback. Accounting for the sea ice transport increases the predictability limit by about 50%. Sea ice concentration nudging raises problems up to now since it tends to increase unrealistically the sea ice thickness.

Richard Graham: Use of dynamical seasonal forecasts in the consensus outlooks of African Regional Climate Outlook Forums (RCOFs)

Outlooks have been developed for four different regions with four different target periods in Africa depending on the farmer's needs. Probabilistic forecasts, in terms of terciles, are issued. The outlooks are currently mainly based on statistical methods which rely on ENSO, IOD for example and which are competitive with dynamical methods. Dynamical systems bring added-value for longer leadtimes than those usually used by farmers. One of the key needs is the prediction of the onset which shows promising potential.

Tim Stockdale: The EUROSIP system

Using multi-model forecasts allow averaging out the individual model forecast errors. The spread should be more realistic also since sampling more model uncertainty. Limitations are, for example, the potential dependencies between the model forecast errors. The forecast pdf should be an appropriate interpretation of the model ensemble. A multi-model is more reliable than a single-model with the same number of members. In DEMETER, it has been shown that when using more models, the RPSS increases over the Tropics. The EUROSIP system comprises the ECMWF, MetOffice and ECMWF forecast systems. The variance is scaled to improve every individual model, make them consistent with each other, and improve the accuracy of the multi-model ensemble. To estimate a forecast pdf, normality is assumed and a t-distribution is estimated. The ensemble mean is estimated using 50% skill dependent, 50% uniform weighting. The lower-weighted models are re-centered. The error variance is estimated from past performance.

Suru Sara: NCEP climate forecast system version2 (CFSv2) in the context of the US National muli-model ensemble NMME for seasonal prediction

The use of NCEP reanalysis requires a split of the climatology between two periods: 1982-1998 and 1999- 2009 in the 30S-30N latitude band. Elsewhere, a single 1982-2009 climatology can be used. The improved skill of CFSv2 over CFSv1 is illustrated with 2-meter temperature, precipitation, SST, the MJO. The national multi-model ensemble, including NCEP-CFSv1, NCEP-CFSv2, GFDL-CM2, IRI-ECHAM-4f, IRI-ECHAM-4a, NCAR-CCSM3 and the NASA models, produce forecast every month with 9 month leadtimes. A set of accompanying re-forecasts covering the 1981-2010 is available for research purposes.

Jin Ho Yoo: Multi-model ensemble seasonal prediction of APEC climate center

The APEC aims at facilitating the sharing of high-cost climate data and information, building capacity in prediction and sustainable social and economic applications of climate information, accelerating and extending socio-economic innovation. Climate forecasts from 17 institutes are gathered. Forecast probabilities are combined with weight proportional to the square root of the ensemble size (PMME method). Results are released online through the CLIK website, with online downscaling available. The multi-model ensemble deterministic prediction combines predictions post-processed by the Step-Wise Pattern Projection Method (based on linear correlation between model and observed patterns). The failure of the 2012 forecast might be attributable to the Arctic region.

Michel Jarraud: Seasonal forecasts: needs and opportunities for international coordination

This presentation stressed the importance of attempting at providing climate information close to user's needs and decision-making requirements. The four priorities are: water resources, health, food security and disaster risk reduction. The crucial need for capacity training and international collaborative work was also stressed.

General comments:

This conference was fascinating since the sessions spanned a very comprehensive set of aspects of the seasonal predictions. The European Meteorological Society “Young Scientist Travel Award” thus gave me the opportunity to deepen and broaden my knowledge of this research field for which I am very grateful. I could also meet key scientists for my work and discuss future collaborative work.