문서번호 APCC-출장-18-0581(2018-06-21)

결재	선임연구원	팀장	부서장	원장직무대행
	06/18 오지현	06/20 문자연	06/21 유진호	06/21 유진호
협조				

TRAVEL REPORT FORM
출장보고서

I. Travel Overview 출장개요

1. Traveler(s) 출장자

Department 소속	Position 직위(직급)	Name 성명	Note 비고
기후사업본부 예측기술팀	선임연구원	오지현	

2. Travel Period 출장기간

- 5/28(월) - 6/3(일)

3. Occasion and destination 행사 및 출장지

- Second WMO Workshop on Operational Climate Prediction at Barcelona, Spain

- 워크샵 홈페이지: http://www.wmo.int/pages/prog/wcp/wcasp/ocp-barcelona2018.php
(agenda 및 초청발표파일 업로드 되어 있음)

II. Major Activities 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

- 2015년 인도에서 열린 제 1회 워크샵에 이어 개최된 제 2회 워크샵으로서, WMO의 공식초청을 받아 APCC의 다중모델 예측시스템에 대해 발표하였음.

- Break-out Group discussion 참여 (Sub-seasonal forecasting)

2. Relevance to APEC Climate Center's Activities 결론 및 소감

- 세션 별 주요 노트:

o Session 1: Setting the scene

본 워크샵은 현업과 연구, 전지구기후예측과 지역(국가)기후예측, 그리고 계절내예측과 계절예측간의 간극을 줄이기 위하여 현상태를 점검하고 앞으로 나아갈 방향을 토의하기 위해 개최되었음. 이를 위해 크게, 기후 예측 현업 운영 현황, 현업과 연구의 연계성, 시간규모에 따른 예측성, 기후예측정보 전달, 역량강화의 분야에 대해 다각적인 의견을 교환하는 것을 주요 쟁점으로 하며, 본 워크샵의 토의내용은 현업과 연구의 연계성을 위해 다가오는 9월 미국에서 열리는 S2D 워크숍에 공유될 것임.

o Session 2: Technical aspects and current practices of operational climate prediction across different time and spatial scales

보다 객관적인 GPC output 사용 방안 마련이 필요함. 예를 들어, 선도센터에서 수행한 설문조사

결과, 대부분의 사용자의 경우 전지구 map 사용비율이 가장 높은 것으로 나타났음. 이는 정량적인 기후예측 정보의 활용이 이루어지고 있지 않음을 반증. 또한 확률예보의 활용이 저조함. 20-40%에서 좋은 예측성을 보임에도 불구하고 삼분위 확률 중 30%의 값을 나타내는 범주의 확률 사용빈도는 저조함. 신뢰도있는 기후자료를 구축하기 위해 일관성 (homogeneity)를 보존하는 것이 중요함.

계절내 예측의 경우 WMO S2S project 자료 구축에는 성공하였으나, 자료 생산을 위한 protocol이 부재함. 이는 기후값 구성에 어려움을 초래하여hindcast MME구성이 이루어질 수 없음.
이에 대한 대처방안으로 SubX: Real-time forecast와 Hindcast의 시스템이 같음. 공통된Hindcast 기간을 가지고 있음 (1999-2010). 그러나 올해로 프로젝트 종료 예정.

S2S Phase 2(2018-2023)가 제안되었으며, forecast calibration, MME, verification, forecast format (probability of threshold exceedance) 등이 주요하게 개발될 것임. 또한 Real-time forecast와 Hindcast의 시스템을 동일하게 하는 작업도 수행될 계획임.

계절내 Forecast format의 경우, IRI에서 제공하고 있는 user-oriented flexible forecast도 한 예시가 될 수 있음 (사용자가 확률의 quantile을 자유롭게 설정)

계절예측의 경우에도 Real-time forecast와 Hindcast의 일관성을 유지하게 하는 것이 중요함

계절예측의 확률예측 방법으로서: tercile categories, all range, exceeding thresholds등이 채택될 수 있음.

지역기후예측을 위해: 해당 지역에 특히 성능이 좋은 모델을 선별하거나, 다중모델앙상블 방법을 최적화하거나, 지역관측자료를 이용한 통계적인 방법으로 보정할 필요가 있음.

보다 정확한 예측을 위해 앙상블 멤버가 많은 것은 필수적이나, 앙상블 bias를 처리하는 것은 더욱 중요함

예측정보의 품질을 평가하기 위해서는 다양한 평가방법을 동시에 적용해야 함 (ACC, ratio of standard deviation, bias)

계절내 예측에 대한 평가방법이 개발되어야 함

Tokyo Climate Center는 최근 1-개월 예측 시스템을 업그레이드함 (55km->40km, 60 vertical levels->100 levels, improved physical processes) : 각 계절별,1-2주 예측성능의 향상이 보이나 3주예측향상의 경우 가을철에 오히려 줄어듦.

APCC 현업 예측과 관련하여서는 deterministic MME 각 방법을 평가하는데 있어 관측자료의 불확실성을 고려해봤는지, 최근 예측 스킬 향상에 대한 원인, 예측스킬이 떨어지는 모델을 제외하고 다중모델 앙상블을 할 경우 스킬이 더 나아지는지에 대한 질문이 있었음.

o Session 3: Research-Operations Linkages: good practices and achievements

계절예측 연구와 관련한 질문들: Burst vs lagged ensemble : which one is better? Ensemble number, spatial resolution, hindcast length: which one is the most important? 예측성능 향상은 어떻게 검증하는가?

기후예측과 관련하여 많은 연구 주제들이 존재하나 이것이 진짜 필요에 의한 것인가에 대한 의문이 제기됨.

지역기후포럼에서 제기된 문제들이 실제로 해결되어 지역기후 예측 향상에 도움이 되었는가에 대한 질문.

o Session 4: Global and regional aspects: understanding sources of predictability

Predicatability 자체를 향상시킬수 없지만, 이에대한 지식은 향상시킬수 있음.

Blocking, cyclone, MJO, NA의 계절내 예측에 걸맞는 시간 평균이 필요함. (대부분 주별 평균을 사용하기 시작)

S2S project phase2 연구주제: MJO prediction, teleconnection, land initialization & configuration, ocean& sea ice initialization, stratosphere, atmospheric composition

Decadal prediction의 경우, 지구온난화, 화산폭발, 태양활동에 의해 예측성이 결정됨.

원격상관에 대한 모델 검증이 필요: indices & one-point correlation 둘다 평가해야함

원격상관의 비선형성에 대한 평가: NAO-MJO relationship

ENSO predictability barrier 시기 = 인도 몬순 시기
엘니뇨 타입, 중태평양의 해수면 온도 편차, 눈덮임/토양수분, 2월 초기장등의 요소가 모델에 잘 녹아들면 예측성 향상에 도움이 됨.

극지역의 경우 성층권 돌연승온후 예측스킬이 좋아지는 경향이 있음

계절예측 현업의 고정된 스케줄 때문에 predictability source를 놓칠수 있음 -> 계절내예측정보가 대안이 될수 있음

지역 별 predictability source를 규명하기 위해 어떠한 metric을 적용해야하는가?

o Session 5: Major projects outcomes

해상도에 대한 민감도 실험 결과, 모델 해상도를 고해상도로 변화시키는 것보다 관측자료로 무엇을 사용하는가에 따른 결과의 차이가 더 큼 -> 관측의 불확실성을 고려해야하는 이유

Session 6: Break-out Groups Discussions
계절내예측의 경우, 시간규모에 대한 명확한 정의가 필요로 함-> 2주 예측도 계쩔내 시간 규모에 포함되어야 함

현재 계절예측정보가 지역기후센터에 확산된 것과 같은 맥락으로 계절내 예측의 사용도 확장되어야 함

weather-subseasonal-seasonal의 이음새없는 예측이 행해져야 함

계절내 시간규모에 걸맞는 지수나 분석방법이 개발되어야 함

계절내 예측의 경우 지역성에 기반한 현업운영이 필수적임: 주별 기후값 구성을 위한 가이던스 마련이 필요함

다중모델앙상블에 대한 당위성이 밝혀져야 함

o Session 7: Good practices at global, regional and national scales

GPC 정보의 지역기후 예측 활용 여부는 정보제공 날짜에 달려 있음. GHACOF의 경우, 매달 초에 개최됨. NMME 활용에 한계가 있음.

전문가의 지식을 객관적으로 반영한 지역기후 예측정보 생산 방법을 마련할 필요가 있음.

CAROGEN (CARICOF Outlook Generator): CPT를 기반으로 한 지역맞춤형 계절예측정보 생산 (http://carogen.cimh.edu.bb/)

o Session 8: Delivery and communication of operational climate prediction products

www.seasonalhurricanepredictions.org : 바르셀로나 슈퍼컴퓨터센터와 미국 콜로라도 주립대학이 함께 제작한 사용자 친화적인 시각환경을 우선시한 허리케인 계절 예측 정보 홈페이지

o Session 10: Conclusions and recommendations on way forward
현재의 현업과 연구에 대한 요약을 Nature/Science 급 저널에 투고할지, WMO 문서에 출판할지 논의

3. Suggestions and Remarks 건의사항

- WMO 중심 워크샵인 만큼 장기예보 선도센터에 대한 관심이 많은 만큼 기술적인 질문들이 다수 있었음. 장기예보 선도센터 운영을 맡아준 KMA에 대한 감사가 깊어 보임. 또한 참석자 대부분이 APCC가 기상청과 함께 선도센터를 운여하고 있는 것을 알고 있는만큼, 추후 직접 선도센터 현업운영하는 APCC 관계자의 동석이 기상청의 WMO 대응에 실직적인 도움이 될 것으로 판단됨.

III. References (Presented and Collected Materials) 주요 수집자료

(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

- 발표 자료 및 outline of Guidance document on operational climate prediction practices (2018년 연말에 완

성예정) 첨부

Current Status of the Operational Multi-Model Ensemble Prediction System of APEC Climate Center

(May 30, 2018)

Ji-Hyun Oh, Young-Mi Min, Sun-Hee Shin,
Daeun Jeong, Chang-Mook Lim, and A-Young Lim
APEC Climate Center

2nd WMO Workshop on Operational Climate Prediction, Barcelona, Spain

Overview of the APEC Climate Center

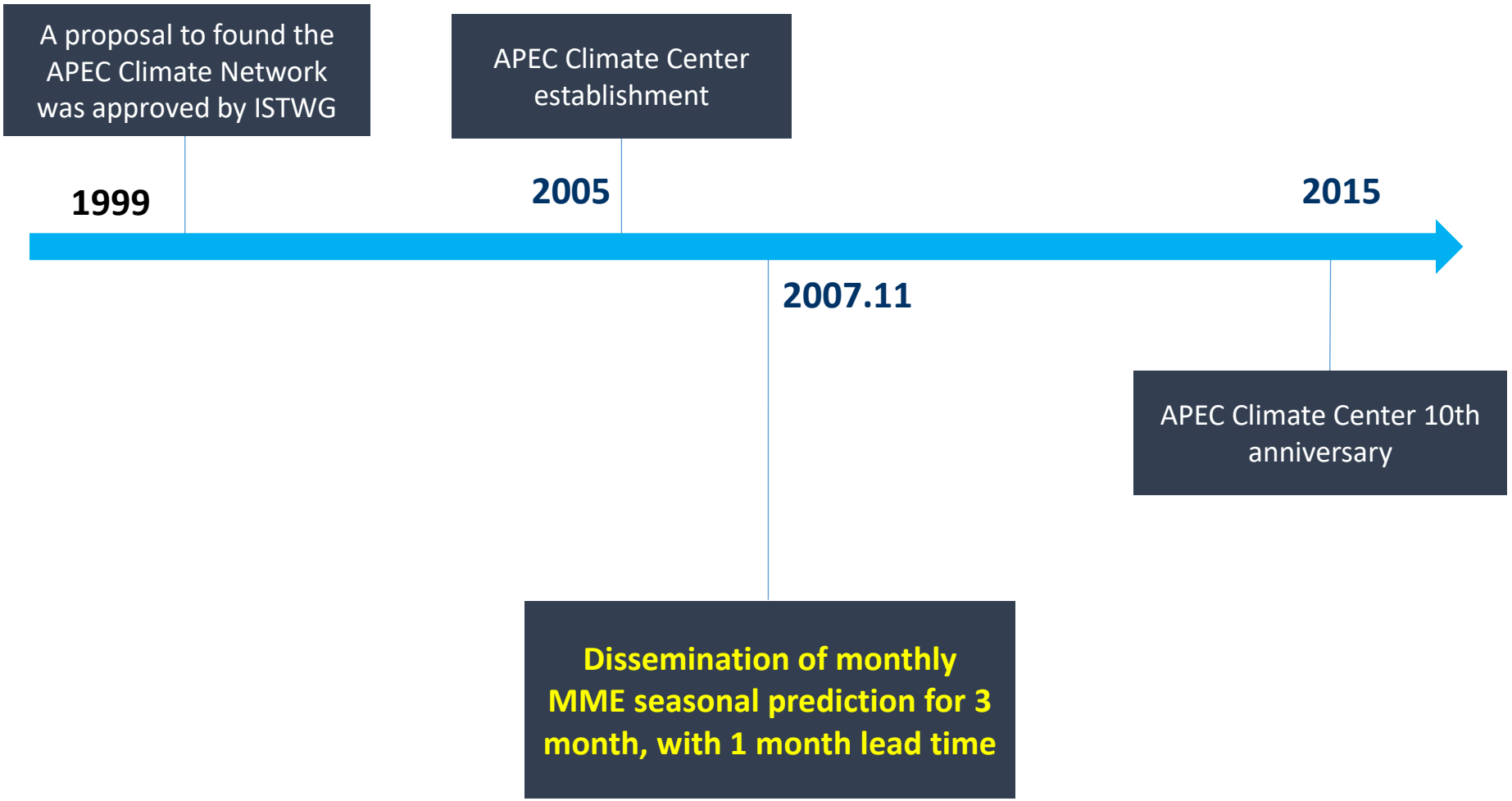
Asia-Pacific Economic Cooperation (APEC) Climate Center (APCC) is a leading climate information service provider in the Asia-Pacific region. We provide seasonal climate forecasts and other climate information products and services, conduct research and development activities, and organize capacity building initiatives for scientists from developing economies.

APEC Climate Center
12 Centum 7-ro, Haeundae-gu, Busan, Rep. Korea

Climate Prediction & Information Service

✓ ***http://www.apcc21.org***

History of the APEC Climate Center



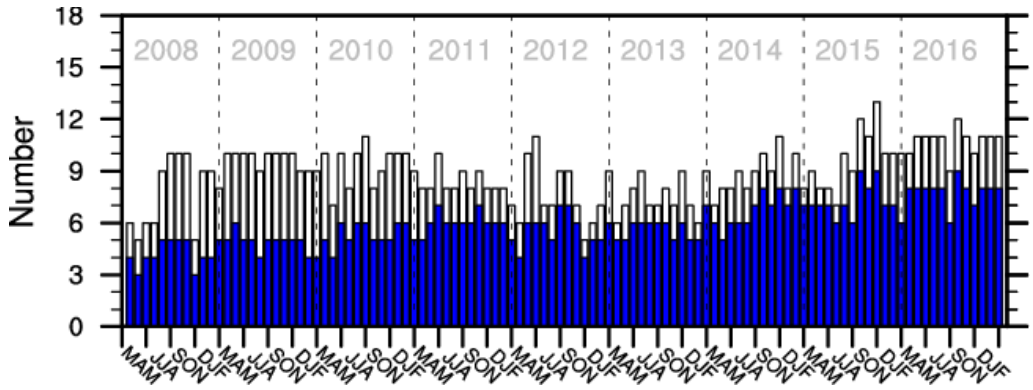
Multi-Model Ensemble seasonal prediction

- **Producing skillful real-time climate predictions and developing a value-added reliable climate prediction system based on a Multi-Model Ensemble (MME) technique.**

Multi-institutional Cooperation

17 organizations from 10 countries

Number of Models and Countries



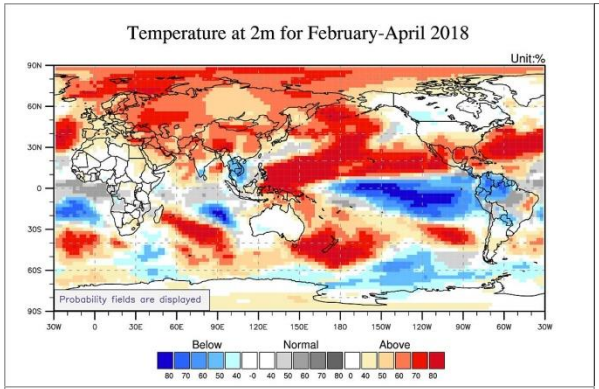
Number of participating models in MME

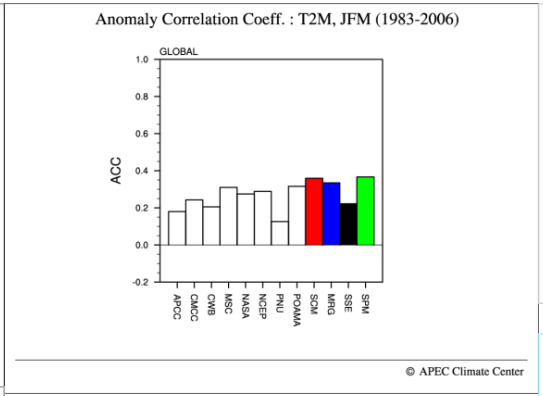
Number of countries

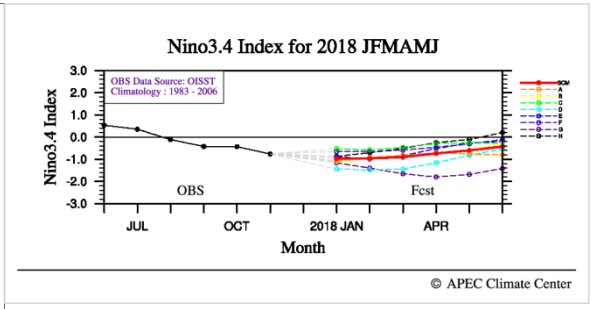
✓ ***http://www.apcc21.org***

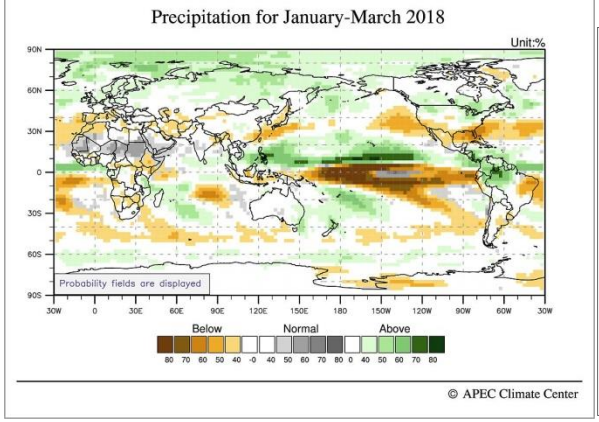
Seasonal Forecast Products

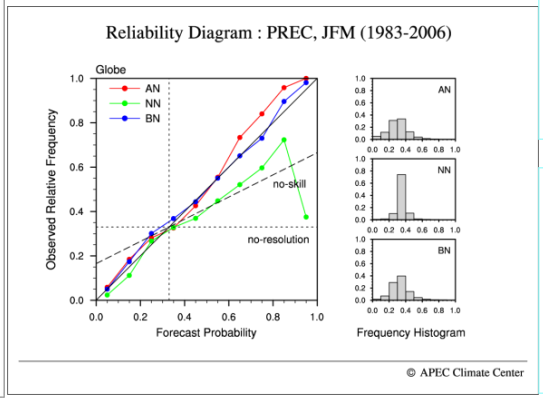
- Monthly & Seasonal mean forecast of Tsfc, Prec, T850, Z500, SLP, SST, UV (deterministic & probabilistic)
- Verification results (hindcast, realtime forecast)
- ENSO Outlook

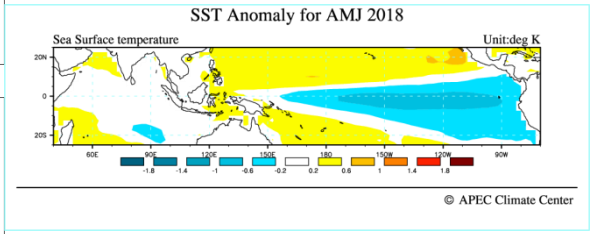


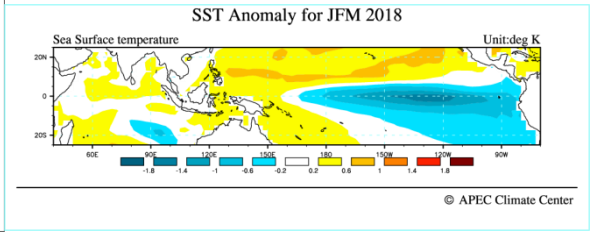




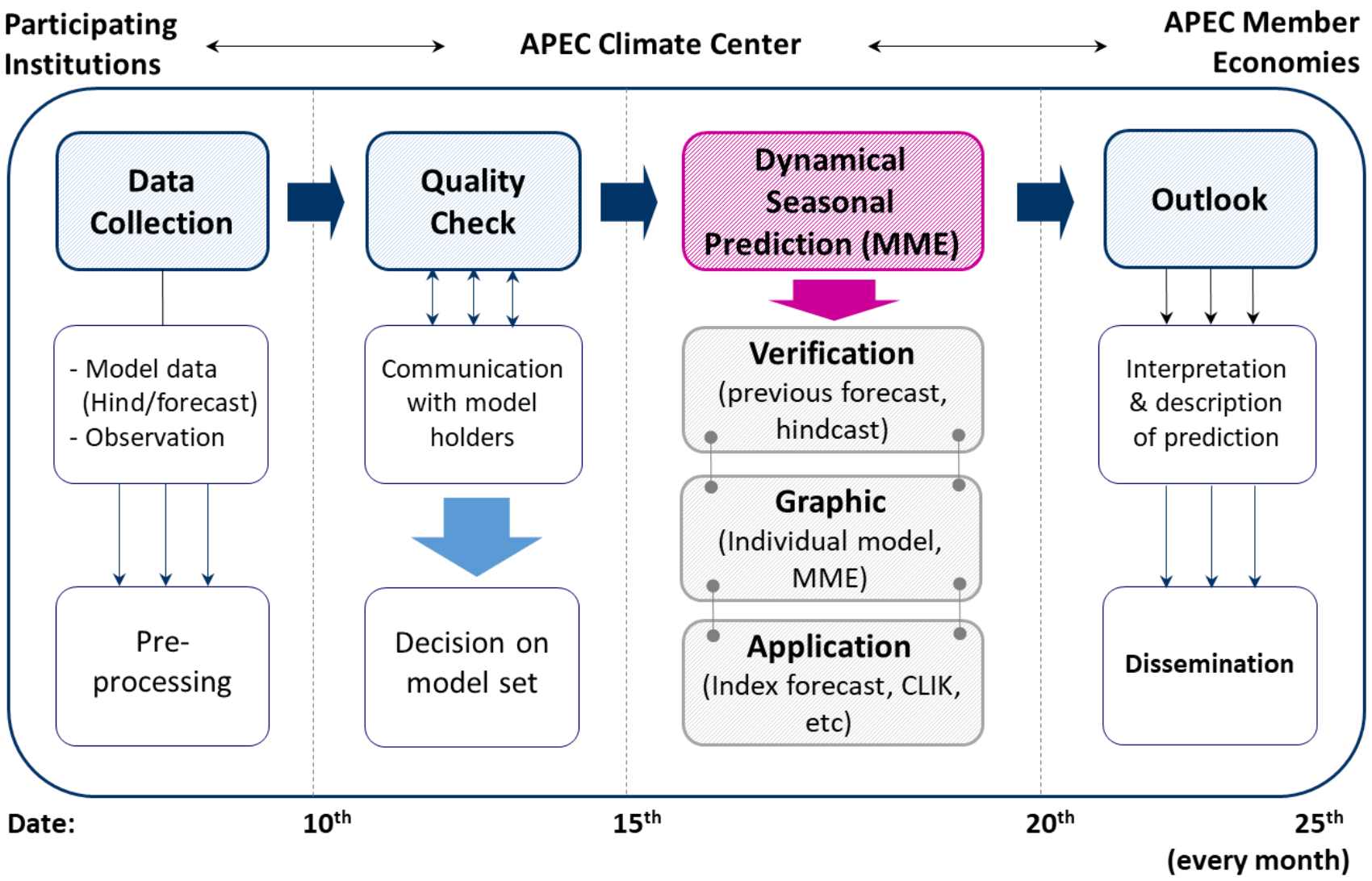






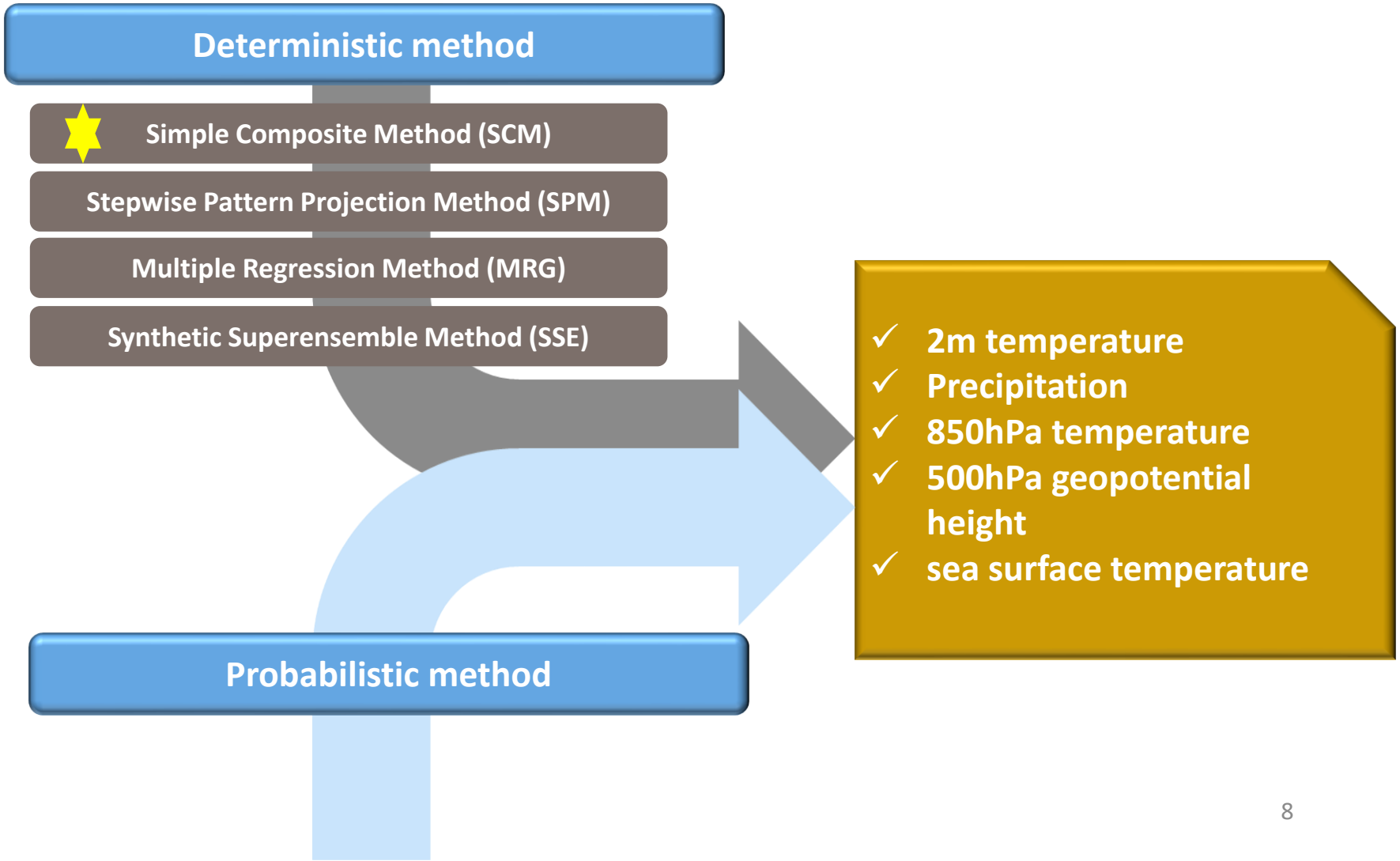


Operation Schedule



Seasonal forecast: Multi-model ensemble

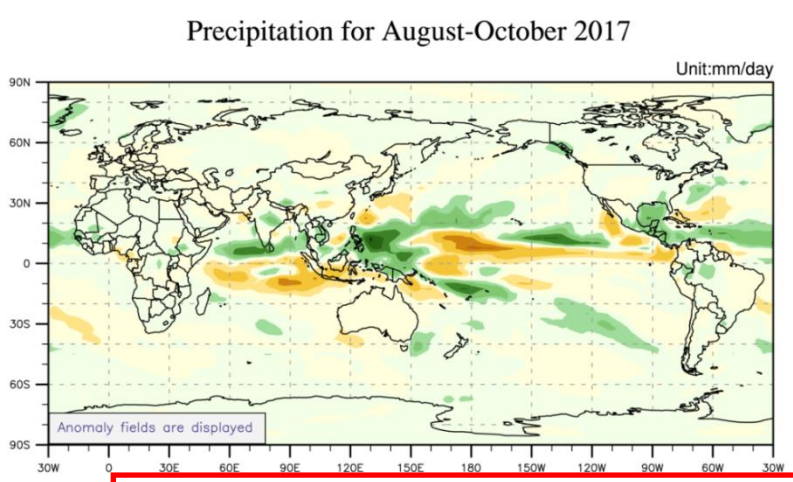
- **Methodology of the APCC MME Prediction System (Min et al. 2014)**

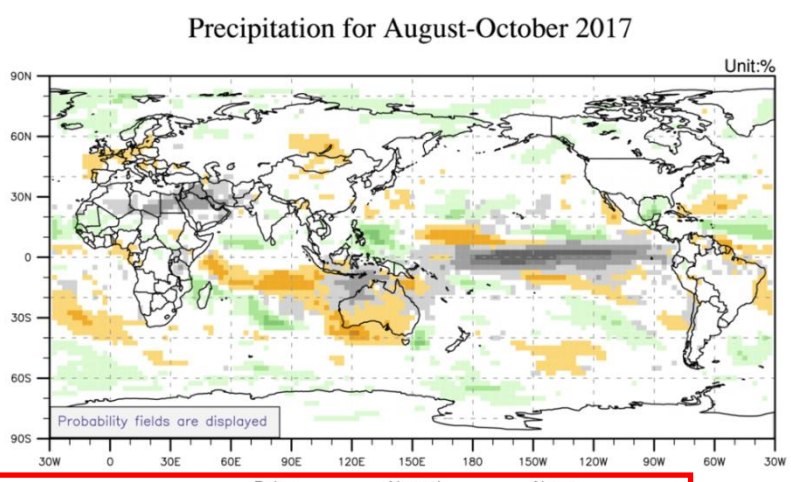


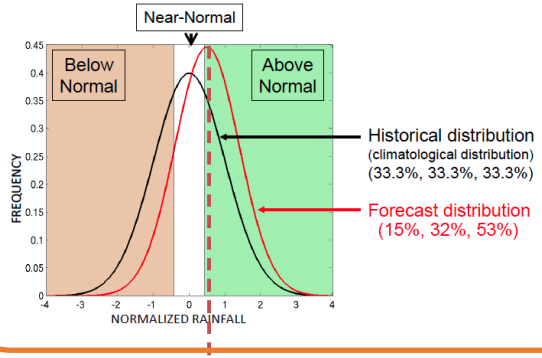
Seasonal forecast: Multi-model ensemble

Deterministic

Probabilistic



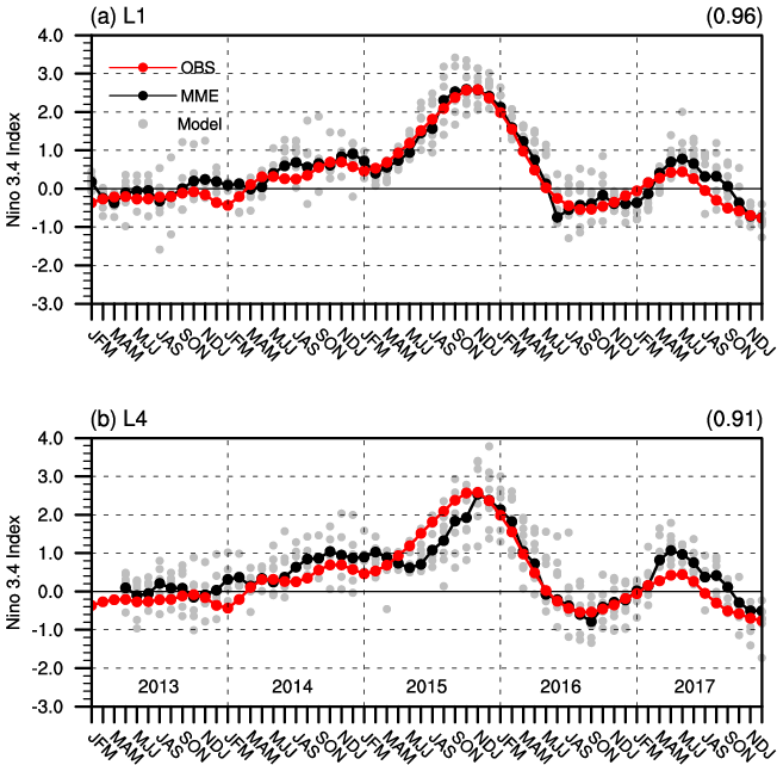




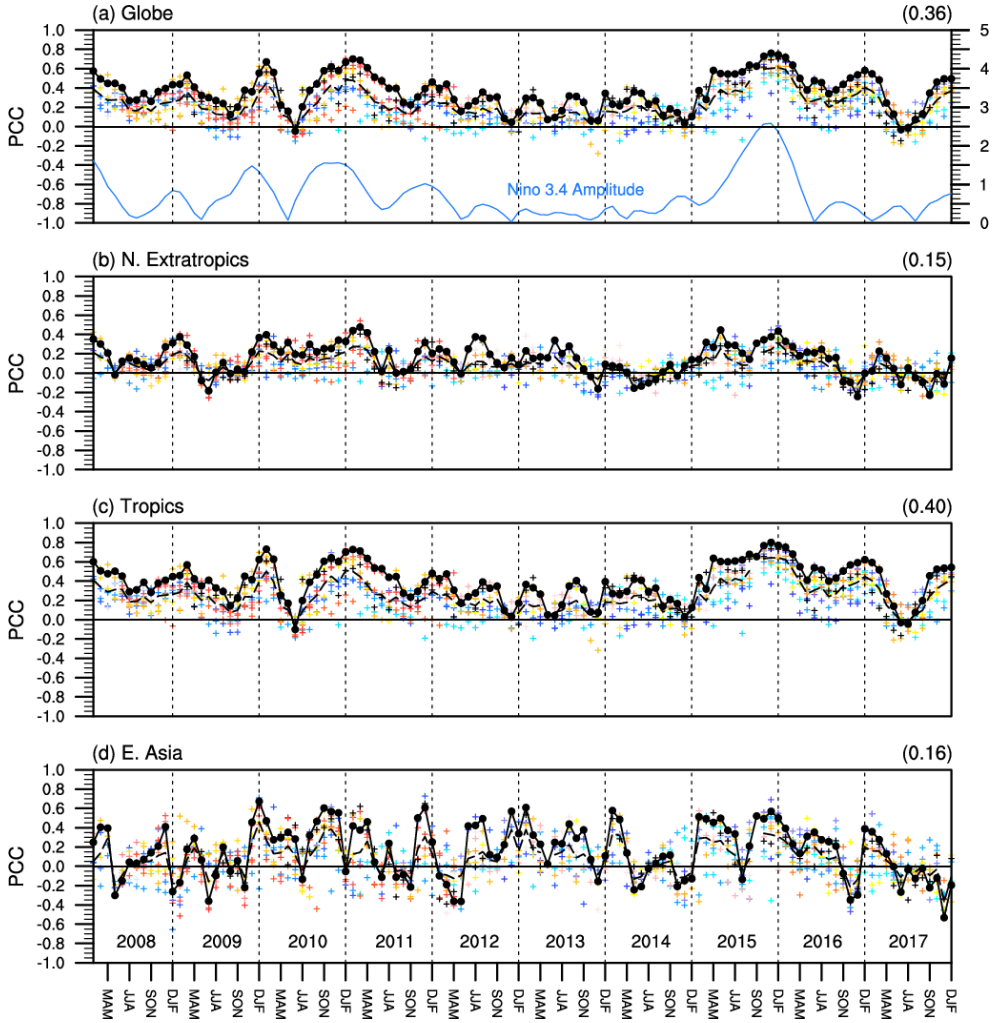
Map showing probility of rainfall falling in one of three categories (with respect to climatology) : BN vs NN vs AN

Performance of APCC MME

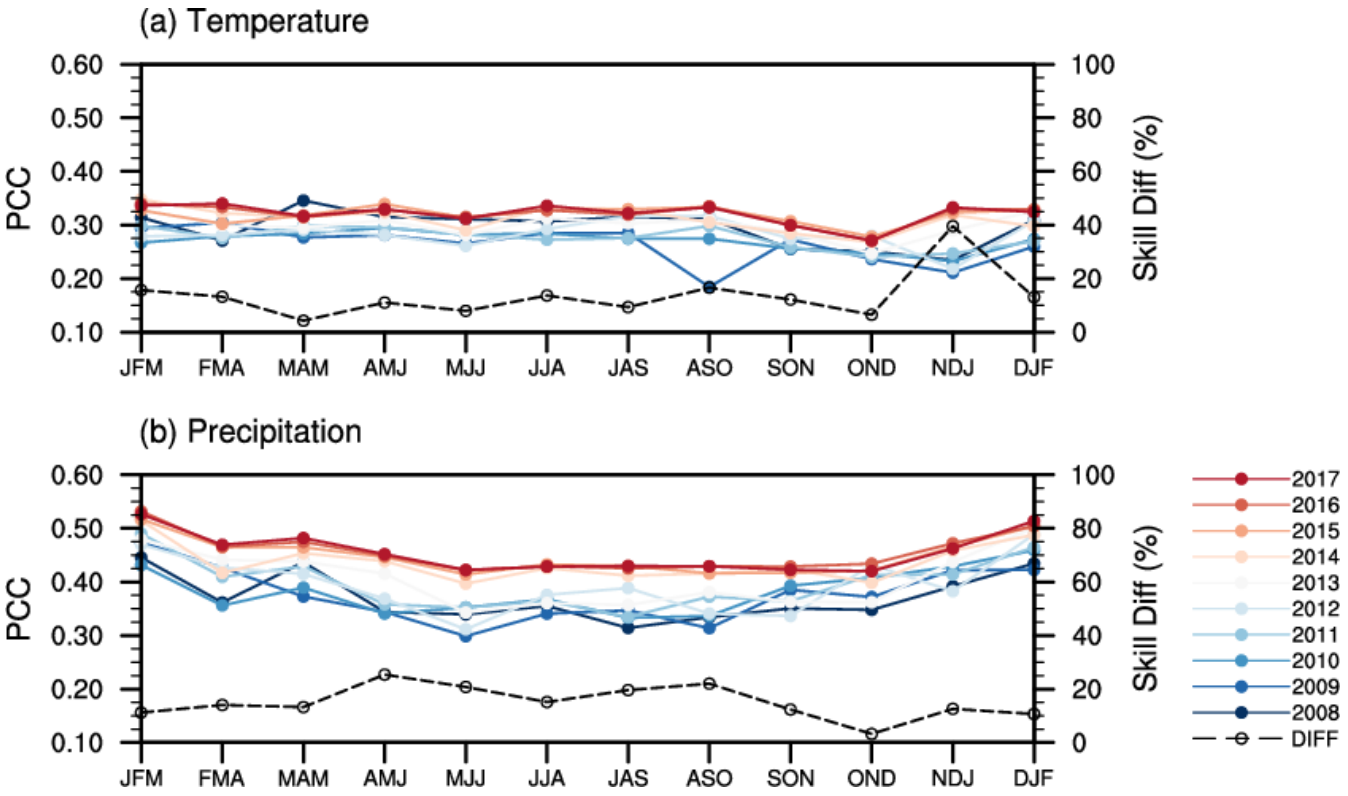
Time Series: Nino 3.4 Index



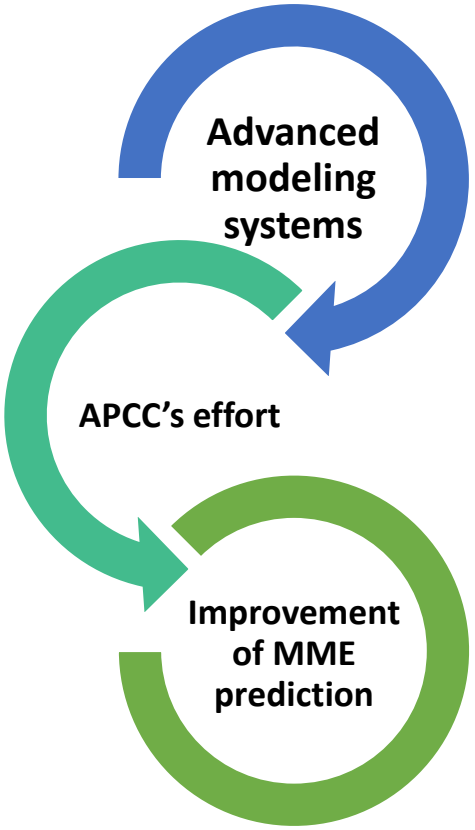
RT Forecast Skill: PREC, ACC



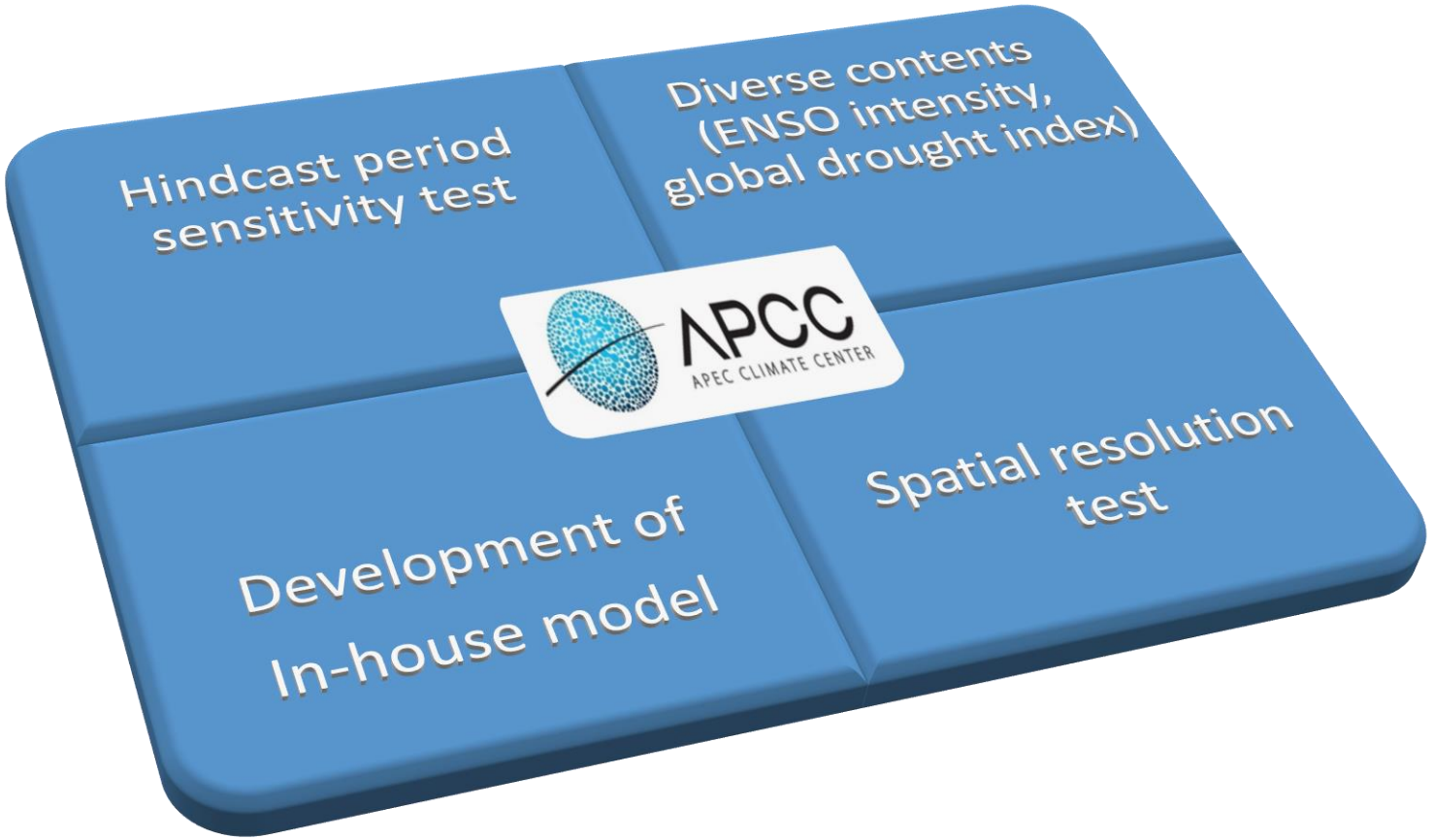
Continuous improvement of MME prediction



(1983-2005)



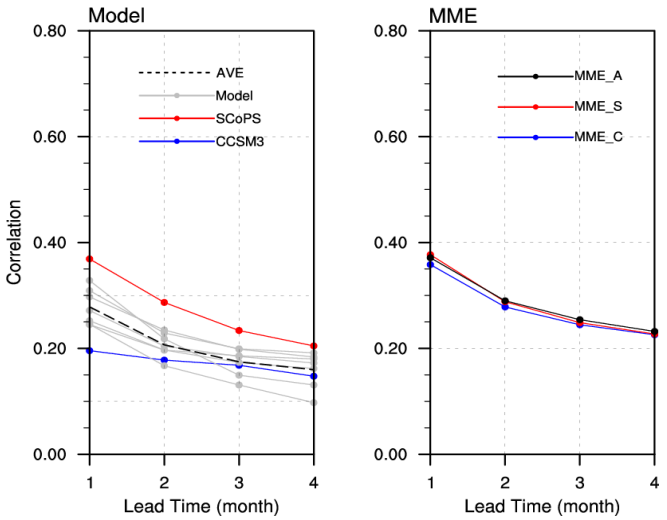
APCC's on-going effort



Upgrading APCC's forecast system

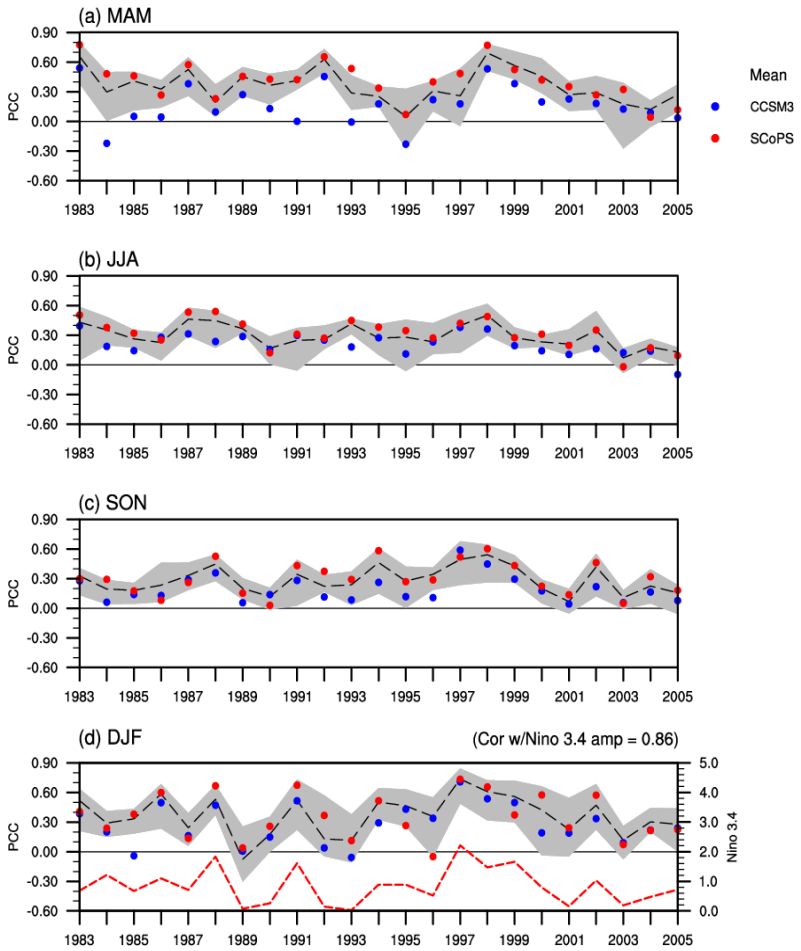
		SCoPS	CCSM3
Model Description	Atmos.	ECHAM v5.3	CAM3
	Ocean	POP v2.0.1	POP v1.4.3
	Sea ice	CICE v4.1	CSIM4
Resolution	Atmos.	T159 // 31 levels	T85 // 26 levels
	Ocean	1° X 0.5 // 40 levels	
Initial condition	Atmos.	3D nudging from CFSR	–
	Ocean	EAKF from CFSR SST and profile data (WOD)	3D nudging from GODAS
Hindcast period		1982~2013	1983~2013
Ensemble configuration		Time lagged with perturbation on Gaussian noise	Time lagged
Ensemble		10	

SST Skill: Averaged TCC over GL



2014FMA-16DJF

Interanuual Variation: GL, PREC



THANK YOU

(http://www.apcc21.org)

APCC Deterministic MME

- **SCM (Simple Composite Method):** simple averaged MME with equal weight

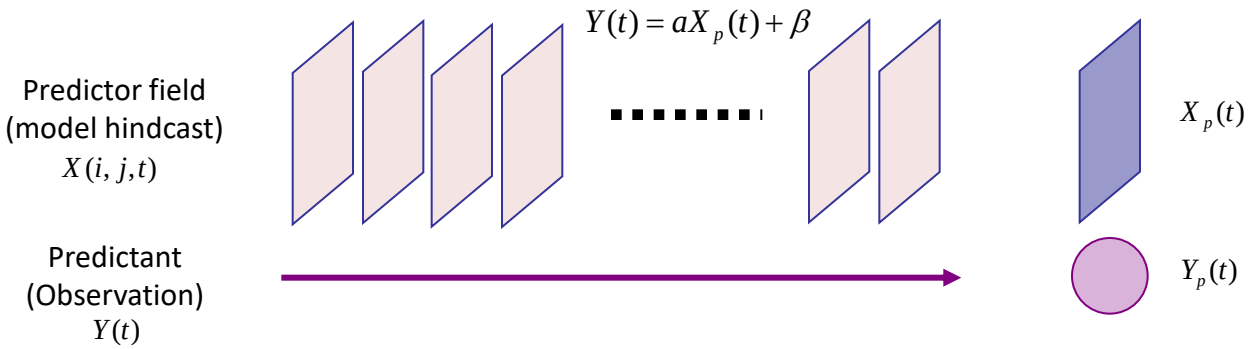
$$P = \frac{1}{M}\sum_{i=1}^{M} F_i$$

M: number of forecast models
F_i: forecast of i^{th} model

- **SPM (Stepwise Pattern Projection Method) :** simple composite of individual model forecasts, after statistical correction (downscaling) by **pattern projection method** (Kug et al. 2008)

$$P = \frac{1}{M}\sum_{i=1}^{M} \hat{F}_i$$

$\hat{F}_i$: corrected forecast of i^{th} model

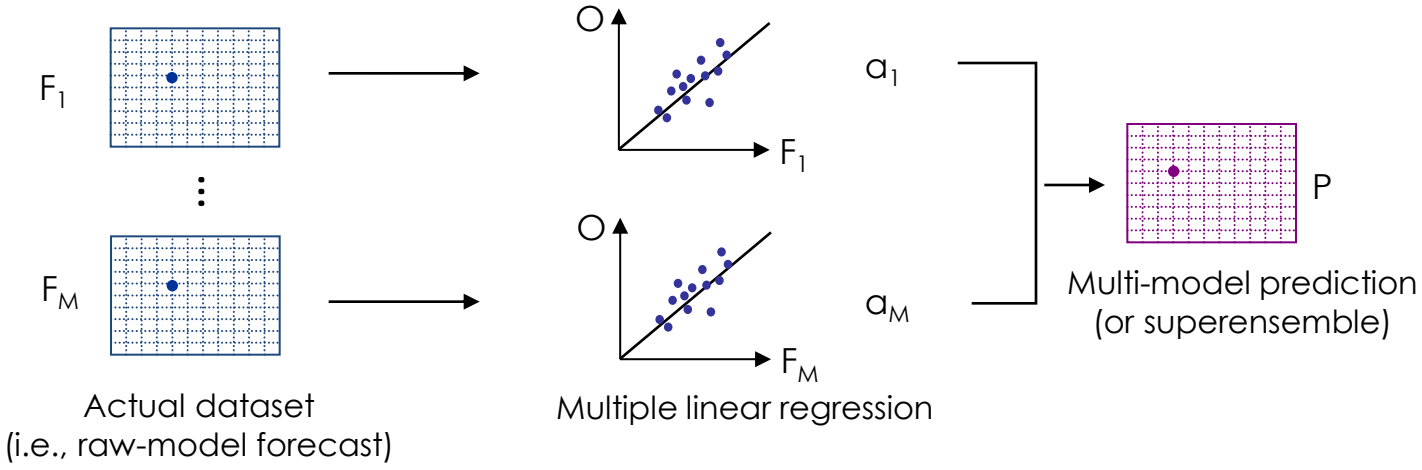


APCC Deterministic MME

- **MRG (Multiple Regression Method) : empirically weighted MME** with **regression coefficients** (Yun et al. 2003)

$$P = \sum_{i=1}^{M} a_i F_i$$

M: number of forecast models
F_i: forecast of i^{th} model
a_i: regression coefficients during the training period

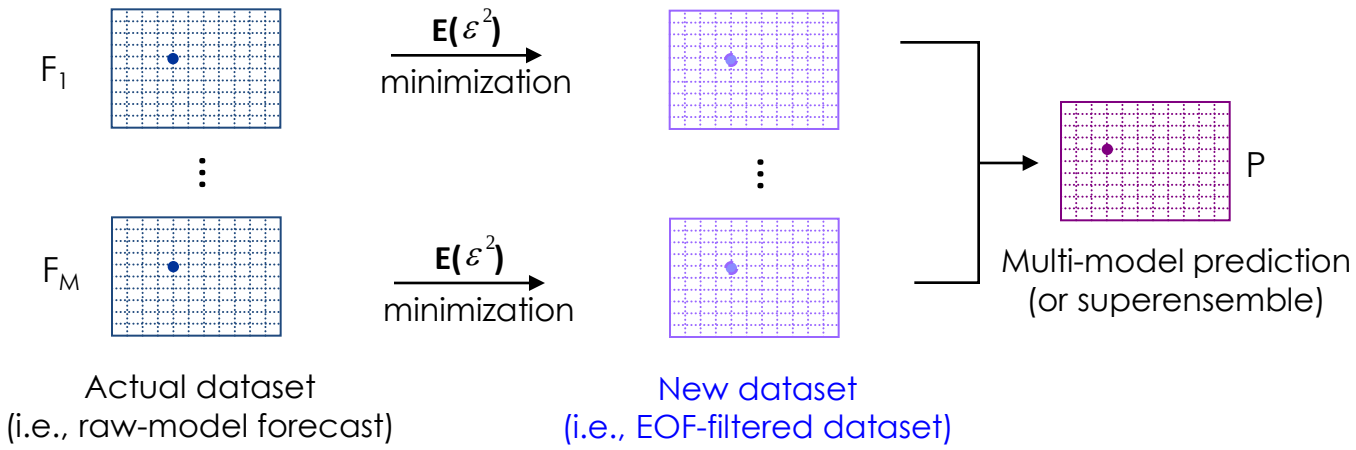


APCC Deterministic MME

- **SSE (Synthetic Superensemble Method): empirically weighted MME** with **EOF-filtering of the actual dataset** by finding a consistent spatial pattern between the observed and individual model forecast (Yun et al. 2005)

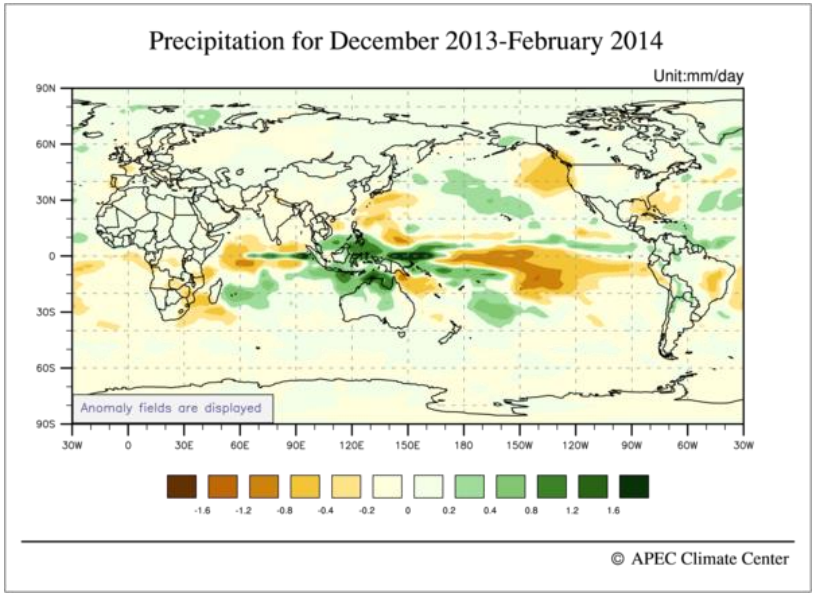
$$P = \sum_{i=1}^{M} a_i \hat{F}_i$$

M: number of forecast models
$\hat{F}_i$: corrected forecast of i^{th} model
a_i: regression coefficients during the training period

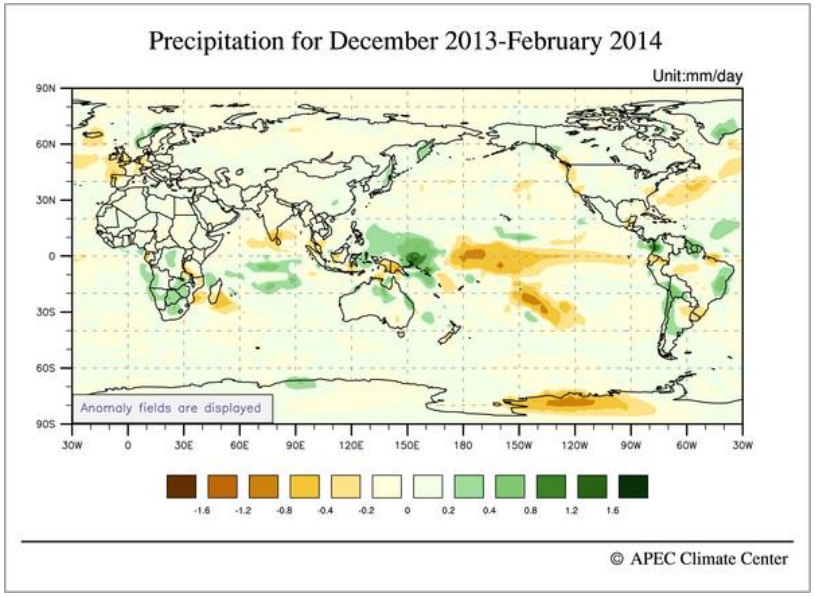


Example of DMME Prediction

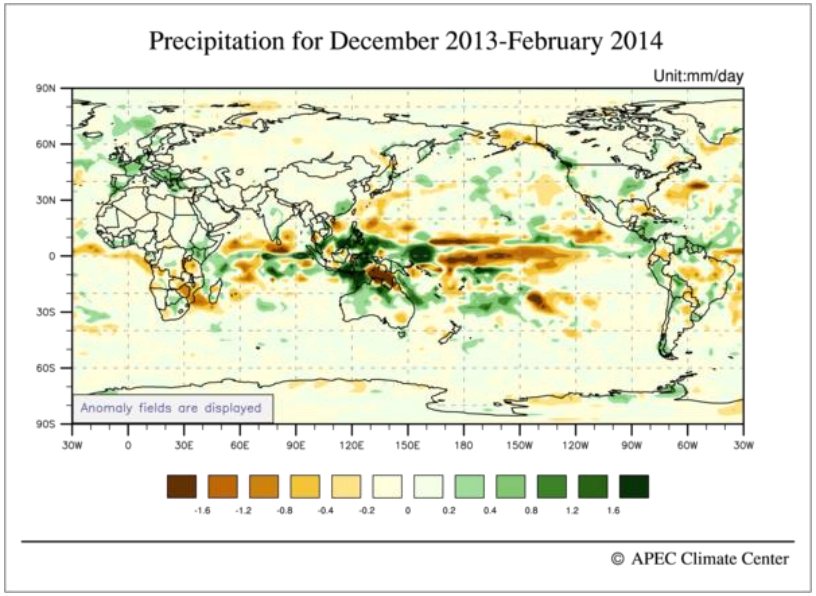
SCM



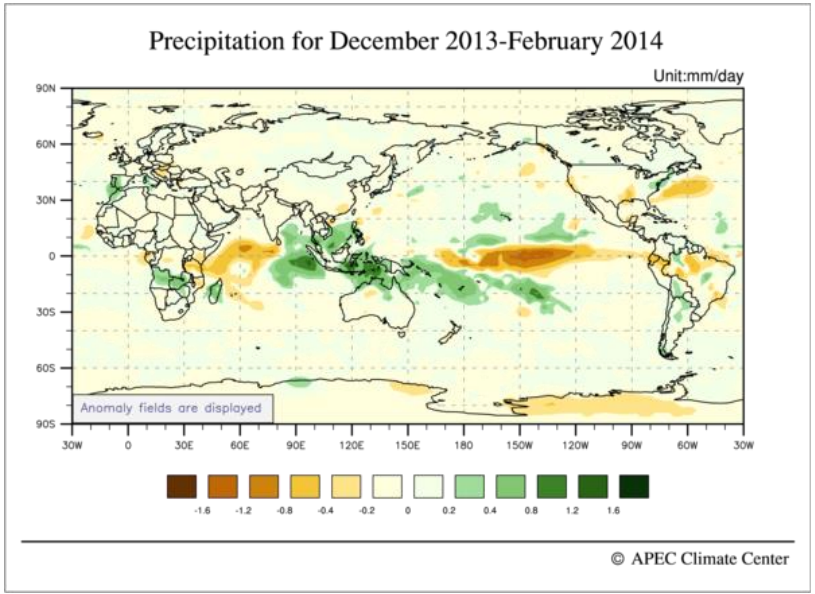
SPM



MRG



SSE



Guidance on Operational Practices for Seasonal Climate Forecasting

08 December 2017
Revised: 19 April 2018

- Seasonal predictions – Some background
    - Introduction
        - Societal context
        - Historical overview
        - Elements of interannual climate variability
    - Scientific basis for seasonal forecasting
        - Role of slowly varying boundary conditions in modulating seasonal atmospheric variability – SSTs (ENSO), land surface (soil moisture), …
        - Teleconnections and key drivers of seasonal to interannual variability of climate (global/regional/national/local)
        - Role of low-frequency trends (e.g., warming trends) in seasonal forecasts.
    - Predictability issues, including the associated space-time aspects; predictability limits and its spatial dependence
    - Probabilistic nature of seasonal predictions – why seasonal predictions need to be probabilistic? Discussion of forecast lead-time and growth of forecast uncertainty (cone of uncertainty diagram).
    - Seasonal prediction methods (including a discussion of their pros and cons)
        - Empirical seasonal prediction methods.
        - Dynamical seasonal prediction methods.
            - Some basic aspects of climate models
        - Combining seasonal forecasts from multiple seasonal prediction tools.
        - Target variables and their space-time aggregation.
- Expression of seasonal prediction
    - Reference period and prediction of seasonal anomalies.
    - Deterministic seasonal outlooks.
    - Probabilistic seasonal outlooks.
    - Seasonal outlooks and dividing/slicing the PDF of seasonal mean variability into forecast categories, e.g., terciles (pros and cons).
    - Predicting PDF of seasonal mean outcomes and probability of exceedance approach (pros and cons).
    - Interpreting probabilistic seasonal outlooks, e.g., if probabilistic seasonal outlooks are reliable then they will fail [the probabilities for seasonal outlooks also carry the information about the chance how often seasonal outlooks will fail (in the context of categorical forecasts)].

    - Attributes for building credibility as the seasonal forecast provider (use of objective methods; transparency of forecast process; provide the track record…).
- Components of a seasonal prediction system
    - Real-time forecasts.
    - Hindcasts – purpose
        - establishing skill of seasonal prediction system.
        - bias correction and calibration.
        - Observed climate data requirements (quality, density, length, etc.)
    - Optimizing multimodel ensemble approaches for geographic domains of interest
        - Selection of most appropriate model(s)
    - Bias correction and calibration of real-time prediction.
        - Tools
        - Tailoring
    - Blending forecasts from different prediction tools.
    - Statistical downscaling; issues with dynamical downscaling
    - Outlook verification
    - Forecast reliability and its implications for seasonal outlooks.
- Guidance on operational practices for developing seasonal climate forecasts
    - Catalog and document regional drivers of climate variability
        - Seasonal climatology (e.g., onset/withdrawal dates of rainy season; variability of NAO).
        - Spread in the “drivers of climate variability” from year-to-year - based on observational data, i.e., document what is the expected range for seasonal mean outcomes?
        - Document recent trends (if any).
    - Establish a publicly available schedule for seasonal outlooks.
    - Provide a postmortem of the most recent verifying seasonal outlook and its performance.
    - Provide a discussion of the current state of climate to set the context for the outlook for the coming season(s).
    - Follow probabilistic guidance for seasonal outlooks.
    - Provide a text discussion for a possible physical basis for the forecast/Reasons for shift in probabilities.
    - Establish feedback mechanisms from the users (web; periodic face-to-face meetings/workshops).
    - Start from an objective guess for seasonal outlook (e.g., from LC-LRFMME), and if altered, then as part of the text discussion provide reasons for altering the first guess objective forecast.
    - Keep an archive for objective seasonal outlook guidance and the final seasonal outlooks to document the improvements.

    - Guidance on communicating forecasts
        - Provide information about past skill (based on hindcasts and/or if a long history of track record of real-time forecasts exists).
        - Provide guidance on the interpretation of forecast probabilities (could be the same statement each time and refer to the probabilistic aspect of the seasonal outlook).
        - User engagement
    - Guidance on establishing credibility
        - Keep the forecast process (methodology) transparent.
        - Keep a track record.
        - Keep documentation of the evolution of forecast practices.
        - Keep/highlight regional relevancy in seasonal outlooks (by referring to regional drivers of climate variability and their climatology).
- Use of WMO infrastructure (and resources) for seasonal prediction
    - GPCs for LRF
    - LC-LRFMME
    - GSCU
    - RCCs
    - RCOFs
- Other potential sources of seasonal prediction products
    - NMME
    - C3S
    - APCC
    - Others ?
- Other aspects of seasonal predictions and variability
    - Connection between attribution (forecast postmortem) and predictability.
    - Connections with research
    - Exploring historical data (data mining to extend historical data record).

Second WMO Workshop on Operational Climate Prediction
30 May - 1 June 2018
&
Meeting of the Expert Team on Operational Predictions from Sub-Seasonal to Long Time-Scales (IPET-OPSLS)
2 – 6 June 2018

Barcelona, Spain

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