APEC Climate Center (APCC) Climate Prediction and Information Activities: New Developments

Submitted by: APEC Climate Center (APCC)
The talk covers the new operational efforts and developmental projects in APCC since the beginning of 2008. The APCC has been issuing the rolling monthly 3-month forecast since 2008, with due verification. It has also been supporting KMA by providing downscaled forecasts for 60 Korean stations. The APCC has also initiated experimental 1-tier 6-month MME prediction, slated on seasonal basis, and so far developed two forecasts. The SNU, SINTEX-F (FRCGC), UH data (all three datasets provided by CliPAS), NCEP, and POAMA datasets are used in this efforts. To boost this effort, APCC has also started to develop an in-house coupled prediction model based on the CCSM3. To do this, APCC has developed a coupled SST nudging scheme.

The presentation will briefly touch about other ongoing development projects such as a probabilistic downscaling system, a drought monitoring system etc.

The presentation will also introduce issues such as the need for longer hindcast data, need for more 1-tier forecast datasets etc. The climate conditions of since 2007 spring will also be briefly presented, along with the performance of the APCC MME system for some of the seasons. The presentation will also seek guidelines on future activities of APCC.
The APCC climate prediction activities: New Developments

APEC Climate Center (APCC)
for Climate Information Services to Society,
Busan, Republic of Korea

2008 projects

Operations

- Operationalization of monthly 3-month forecast since January, with upgraded hindcast verification.
-Downscaled forecast provision at 60 Korean stations to KMA with due hindcast verification
- New monitoring products

Development

- 6-month MME seasonal prediction
- In-house development of coupled prediction system
- Probabilistic downscaling
Enhancement of MME forecast for APCC economies ➔ 12 times/yr

Operation schedule

<table>
<thead>
<tr>
<th>10 ~ 15</th>
<th>16 ~ 18</th>
<th>19 ~ 23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data acquisition &amp; analysis</td>
<td>production of MME forecast</td>
<td>MME forecast outlook &amp; climate highlights services</td>
</tr>
</tbody>
</table>

Multi-institutional cooperation and sharing of high-cost data
**High Performance Computing System**

<table>
<thead>
<tr>
<th>Korea Meteorological Administration (Cray X1E)</th>
<th>Korea Institution of Science &amp; Technology Information (IBM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>IBM System p5 595 server</strong></td>
<td><strong>- Storage System : IBM 366 TB DS4700</strong></td>
</tr>
<tr>
<td><strong>- Shared storage : 460 TB</strong></td>
<td><strong>- Memory : 1024 GB memory per 1 node</strong></td>
</tr>
<tr>
<td><strong>- Speed : 37 TF</strong></td>
<td></td>
</tr>
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</table>

**Korea Meteorological Administration (Cray X1E)**

<table>
<thead>
<tr>
<th>Scale</th>
<th>Total number of cabinets</th>
<th>Number of nodes</th>
<th>Processor</th>
<th>Memory capacity</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>188 Mips</td>
<td>294</td>
<td>5.84 Terabytes</td>
</tr>
</tbody>
</table>

**Korea Institution of Science & Technology Information (IBM)**

- IBM System p5 595 server
- Storage System : IBM 366 TB DS4700
- Shared storage : 460 TB
- Memory : 1024 GB memory per 1 node

**APCC Dynamical Climate Forecast System (Tier2)**

**POAMA (Australia)**
**MSC (Canada)**
**NCC (China)**
**JAP (China)**
**CMIB (Chinese Taipei)**
**JMA (Japan)**
**GDAPS (Korea)**
**GCPPS (Korea)**
**METRI (Korea)**
**MIO (Russia)**
**MME (Russia)**
**COLA (USA)**
**IMPA (USA)**
**GEPR (USA)**

**PERSISTED GLOBAL SST ANOMALY**

**FORECAST SST**
- TROP. PACIFIC
  - (multi-model, dynamical and statistical)
- TROP. ATL. INDIAN
  - (statistical)
- EXTRATROPICAL
  - (damped persistence)

**STATISTICAL BIAS CORRECTION**

**MULTI-MODEL ENSEMBLE**

**Training Phase**

**Forecast Phase**

\[ S = \bar{S} + \sum_{i=1}^{n} (F_i - \bar{F}) \]

\[ G = \sum_{i=1}^{n} (S_i - O_i)^2 \]

The weights are computed at each grid point by minimizing the function:

**MME Real-time Prediction**
Procedure of MME Seasonal Prediction System

- Collection: 17 Models
- Quality Check
- Composite: Deterministic Forecast (4 kinds of schemes) Probabilistic Forecast
  - Graphic
  - Verification: Previous prediction, Hindcast
  - Application: Index forecast, Statistical downscaling
- Outlook: Interpretation and Description of Global/Regional Prediction
- Dissemination: Web information, Backup of the Data and Doc.

Deterministic MME Schemes

- **SCM**
  - Simple Composite Method: Simple composite of individual forecast with equal weighting
  - \[ P = \frac{1}{M} \sum F_i \]

- **SPPM**
  - Stepwise Pattern Projection Method: Simple composite of individual forecasts, after correction by SPPM (improved version of CPPM)
  - \[ P = \frac{1}{M} \sum \hat{F}_i \]

- **MRG**
  - Multiple Regression Method: Optimally weighted composite of individual forecasts.
  - The weighting coefficient is obtained by SVD based regression
  - \[ P = \sum a_i F_i \]

- **SSE**
  - Synthetic Multi-Model Super Ensemble Method: Weighted combination of statistically corrected multi model output
  - \[ P = \frac{1}{M} \sum a_i \hat{F}_i \]
**Couple Pattern Projection Method**

- **Forecast procedure – Pointwise regression method**
  \[ Y(t) = \alpha X_p(t) + \beta \]

- **Predictor field**
  \[ X(i, j, t) \] (model forecast)

- **Predictand**
  \[ Y(t) \] (observation)

- **Coupled pattern projection coefficient**
  \[ COR(i,j) = \frac{1}{\sigma_y} \sum_{i,j} \frac{(Y(t) - Y_{m})}{\sigma_y} (X(i,j,t) - X_{m}(i,j)) \]

- Calculate regression coefficient \( \alpha, \beta \) in training period, forecast a regional climate from projection coefficient of the coupled pattern onto forecast field.

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**Implemented MME-S in APCC**

- SPPM and MME-S was tested on prediction of 850 hPa temperature precipitation using APCC hindcast data for the period 1983-2003 and operational forecast data for 2006 and 2007.
- SPPM code was transferred to APCC and is now part of the Automated Forecast System.

**MME-S Procedure**

1. **STEP 1:** Applying statistical correction using SPPM to individual models
2. **STEP 2:** Simple multi-model composite using available predictions

**Advantage to using SPPM2**

1. **Computational Estimates**
   - (per 1 model, 1 variable, 22 years)
   - CPPM- OLD version : 72 hours
   - CPPM – New version : 12-15 hours
   - SPPM v2 : 5 hours
     (suggestion: If you use 8 cpu simultaneously, it takes 10 hours for all models’ hindcast and forecast and two variables)
2. **Improved skill, especially for precipitation**
Probabilistic MME Scheme

Normal fitting method

- For the middle/upper tercile boundary:
  \[ \mu + 0.43 \sigma \]
  where \( \mu \) is the mean and \( \sigma \) is the standard deviation.

- For the lower/middle tercile boundary:
  \[ \mu - 0.43 \sigma \]

Defining terciles

- Probability of Above-normal
- Probability of Near-normal
- Probability of Below-normal

Forecast probability

Monthly 3-Month Forecasts Operationalized

- 4-deterministic and one probabilistic MME forecasts carried out each month. Best deterministic forecast for that month selected on hindcast verification.
- Forecast outlooks sent out by 25th of each month to 21 NMHSs and to larger climate prediction community.
- Review of outlook by Working Group and SAC members prior to public release.

The APEC CLIMATE CENTER
Climate Outlook for August-October, 2008

BUSAN, 23 July 2008 - Synthesis of the latest computer model forecasts for August to October, 2008 at the APEC Climate Center (APCC), located in Busan, Korea, predicts warmer than normal temperatures in Western Europe, Mediterranean, parts of middle East, Mongolia and the East Asian region covering China, Kore and Japanese archipelagos. Many parts of Asia may experience near normal to drier-than normal conditions. The current conditions in the tropical Indian Ocean are indicative of a positive IOD event.

Current Climate Conditions

During the past May-to-July period (based on data up to July 18, 2008), it has been drier than normal in the southeastern as well as western part of US, while a larger region covering northeastern Brazil and the equatorial Atlantic has seen surplus rainfall. It has been warm and dry in the Middle East, midlatitude Central Asia and northeast Asia. Most part of the continental Australia also experienced deficiency in rainfall in the past three months or longer. On the other hand, it has been warmer than normal in the Philippines, the southern Pacific Islands and also northern part of India. Current cooler than normal Sea Surface Temperature over equatorial eastern Indian Ocean and alongshore surface wind easterly anomalies off Sumatra persisted, indicative of a positive Indian Ocean Dipole (IOD) event.

Forecast

The APCC forecasts for ASO, 2008 indicate that a broad region covering from north Australia, through most of the Maritime Continent and Indochina, to India is expected to see anomalously cool conditions. On the other hand, southwest Australian continent to New Zealand may experience slightly warmer and dry than normal conditions. The expected rainfall conditions are in agreement with the positive IOD-like conditions that currently prevail, indicating a possibility of continuation of the event.
Upgrading of the SVS

- APCC pursues the WMO-prescribed SVS measures.
- We are upgrading our efforts of verification. We have upgraded our verification almost to level 3 suggested by WMO.

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Parameters</th>
<th>Verification Regions</th>
<th>Deterministic Forecasts</th>
<th>Probabilistic Forecasts</th>
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<tbody>
<tr>
<td></td>
<td>T2m anomaly, Precipitation anomaly</td>
<td>Tropics, Northern Extra-Tropics, Southern Extra-Tropics</td>
<td>MSSS (bulk number)</td>
<td>ROC curves, ROC areas, Reliability diagrams, Frequency histograms</td>
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<tr>
<td></td>
<td>Nino3.4 Index</td>
<td>N/A</td>
<td>MSSS (bulk number)</td>
<td>ROC curves, ROC areas, Reliability diagrams, Frequency histograms</td>
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<table>
<thead>
<tr>
<th>Level 2</th>
<th>Parameters</th>
<th>Verification Regions</th>
<th>Deterministic Forecasts</th>
<th>Probabilistic Forecasts</th>
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<tr>
<td></td>
<td>T2m anomaly, SST anomaly, Precipitation anomaly</td>
<td>Grid point verification on a 2.5° by 2.5° grid</td>
<td>MSSS and its three term decomposition at each grid point</td>
<td>ROC areas at each grid point</td>
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</table>

<table>
<thead>
<tr>
<th>Level 3</th>
<th>Parameters</th>
<th>Verification Regions</th>
<th>Deterministic Forecasts</th>
<th>Probabilistic Forecasts</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>T2m anomaly, SST anomaly, Precipitation anomaly</td>
<td>Grid point verification on a 2.5° by 2.5° grid</td>
<td>3 by 3 contingency tables at each grid point</td>
<td>ROC reliability tables at each grid point</td>
</tr>
</tbody>
</table>

- Fig.: One of the level 3 scores, based on 3X3 deterministic contingency tables
- A new extreme event index has also been designed based on Gerrity Score.
Some verification statistics

ACC prec hindcast
(GLOBAL, JJA, sealand)

ACC

ACC prec hindcast
(EAST ASIA, JJA, sealand)

ACC
Some verification statistics

ACC t850 hindcast
(GLOBAL, JJA, sea/land)

ACC t850 hindcast
(EAST ASIA, JJA, sea/land)

Some verification statistics


Some verification statistics


Downscaled forecast provision

GCM Output

Statistical Downscaling

Multi-Model Ensemble Prediction for Local Precipitation/Temperature

Agriculture, Hydrology, Energy, Electric Power, Insurance ...
Earlier, downscaling products successfully developed for Thailand and the Philippines. Collaborative development also going on for Malaysia.

**Korea Station Skills**

**MME: Area-averaged JJA rainfall anomaly for Korea**

- COR = 0.75
- COR = 0.21
MME: Verification skills for Korea

Precipitation

Real Time Downscaling Forecast for Korea

PREC T2m
**Forecast Verification**

Precipitation anomaly for AMJ 2008

- Stational observation
- MME prediction
- Downscaling prediction

**Spatial Distribution of Skills (DJF) over Malaysia**

- Downscaled APCC-MME
- Downscaled CCA-MME
- RAW MME
- CCA-SST (pure statistical model)
**Forecast Verification for Korea**

- **Area-averaged anomaly**
  - Observation
  - Raw MME
  - Downscaling

- **2008 Month**
  - Mar
  - Apr
  - May
  - Jun

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**APCC Climate Monitoring Products**

- Provided since summer 2008
- Weekly / monthly / seasonal SST, temperature, OLR, rainfall, geopotential height at 500hPa, surface wind anomalies
- Current (monthly) indices for tropical Indo-Pacific monitoring
Experimental Global Drought Monitoring

- Experimental drought monitoring system set up using Standardized Precipitation Index (SPI; McKee et al. 1993)
- SPI is calculated for multiple time scales: 1, 3, 6, 12 months
- Summary maps of rainfall deficiency on the short term (1 to 3 months) and intermediate term (6 to 12 months) are also provided.
- Datasets: Japanese 25-year ReAnalysis and Japan Meteorological Agency Climate Data Assimilation System

Standardized Precipitation Index (SPI)

- Precipitation is quantified by transforming its distribution (usually fitted to a Gamma) into a standardized normal distribution on a equal a probability basis

\[
G(x) = \frac{1}{\Gamma(\alpha)} \int_0^x t^{\alpha-1} e^{-t} dt
\]

\[
H(x) = q + \frac{1}{1 - q} G(x)
\]

\[
Z = \pm \left[ t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3} \right]
\]

- Climatological Gamma Distribution
- Standard Normal Distribution

P(SPI<1) = .1587
P(SPI>1) = .1587
Quality Check of JRA-25/JCDAS

- Result is encouraging, especially for the Asia Pacific region.

Pattern correlation (Land only) of SPI

<table>
<thead>
<tr>
<th>Region</th>
<th>Global (50S-90N)</th>
<th>East Asia (50N-30N, 150E-100E)</th>
<th>Tropics (30S-30N)</th>
<th>Extratropics (30N-90N)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>![Bar Chart]</td>
<td>![Bar Chart]</td>
<td>![Bar Chart]</td>
<td>![Bar Chart]</td>
</tr>
</tbody>
</table>

Temporal Correlation of Precipitation

<table>
<thead>
<tr>
<th>Month</th>
<th>JRA-GPCP</th>
<th>SPI</th>
<th>JRA-CMAP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>![Map]</td>
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<tr>
<td></td>
<td>![Map]</td>
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</tr>
</tbody>
</table>

APEC Climate Center
**Development of drought prediction system**

Drought prediction system

- Observation (JRA or NCEP/NCAR)
- MME prediction (SCM)

**MME prediction**: variance corrected forecast

- Continuous precipitation data
- Standardized precipitation index
- Drought prediction

(*MME variance is smaller than observation*)

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**Performance in 3-Month MME Forecast**

SON 2007  
"Weak La Niña-like tropical Pacific conditions"

[Maps and diagrams showing precipitation and temperature anomalies]
Performance in 3-Month MME Forecast

DJF 2007/08

“Cold winter in the northern portion of North America”

Jan 2008

Severe snow storms hit the Middle East, central and eastern China
Performance in 3-Month MME Forecast

Jan 2008 Severe snow storms hit the Middle East, central and eastern China

Anomaly Pattern Correlation for DJF 2007/08 T850 Forecast

DJF 2007/08  Jan 2008  MMEs

Global

East Asia
(80-180E, 10-60N)
Experimental 6-Month 1-Tier MME Prediction

**Objective**
- To provide a longer and more reliable forecast

**Status**
- **First forecast for MAMJJA**
  - Three models were available (FRCGC, UH and NCEP)
  - Development of the relevant additional software unique 6-month prediction (especially deterministic)
- **Second forecast for JJASON**
  - Five models were available (FRCGC, UH, NCEP, SNU and POAMA)
  - Development of probabilistic prediction system for 6-month
  - Development of hindcast verification for deterministic and probabilistic

→ Started, Hindcast packages completed in August

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**Experimental 6-Month 1-Tier MME Prediction**

**Participating Models**
- FRCGC/Japan, SNU/Korea, UH/USA, NCEP/USA, and BMRC/Australia

<table>
<thead>
<tr>
<th>Institute</th>
<th>AGCM</th>
<th>Resolution</th>
<th>OGCM</th>
<th>Resolution</th>
<th>Ensemble Member</th>
<th>Reference</th>
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</thead>
<tbody>
<tr>
<td>FRCGC</td>
<td>ECHAM4</td>
<td>T106 L19</td>
<td>OPA 8.2</td>
<td>2^6 cos(lat)x2^6 lon L31</td>
<td>9</td>
<td>Luo et al. (2005)</td>
</tr>
<tr>
<td>SNU</td>
<td>SNU</td>
<td>T42 L21</td>
<td>MOM2.2</td>
<td>1/3° lat x 1° lon L32</td>
<td>6</td>
<td>Kug et al. (2005)</td>
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<tr>
<td>UH</td>
<td>ECHAM4</td>
<td>T31 L19</td>
<td>UH Ocean</td>
<td>1° lat x 2° lon L2</td>
<td>10</td>
<td>Fu and Wang (2001)</td>
</tr>
<tr>
<td>NCEP</td>
<td>GFS</td>
<td>T62 L64</td>
<td>MOM3</td>
<td>1/3° lat x 1° lon L40</td>
<td>15</td>
<td>Saha et al. (2005)</td>
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<tr>
<td>BMRC</td>
<td>The Bureau of Meteorology unified climate/NWP model (BAM) version 3.0d</td>
<td>T47 L17</td>
<td>ACOM2 Ocean Model based on GFDL MOM2</td>
<td>72 x 144 grid points for the physics grid</td>
<td>Daily Ensemble Generation</td>
<td>Colman et al. (2002)</td>
</tr>
</tbody>
</table>

FRCGC, SNU, and UH: 10 Variables (tsfc, prcp, mslp, ts2m, t850, z500, u200, v200, u850, v850)
NCEP, BMRC: 11 variables (olr, prec, slp,sst, t2m, t850, u850, v200, u200, v850, z500)
Recent Forecasts: 2008JJASON

T850

2008JJA

2008SON

PREC

SST

Predictions for MAM

(left) from 6 month 1-tier MME

(right) APCC operational MME
Verification: Deterministic Hindcast Forecast

T850, 1983-2003

APEC Climate Center

Verification: Deterministic Hindcast Forecast

APEC Climate Center
Verification: Probabilistic Hindcast Forecast

- APCC Operational MME (JJA)
- 6-Month 1-Tier MME (SON)

Development of an in-house coupled prediction system

- To develop an in-house coupled climate prediction system suitable for 12-month climate prediction by 2010

2008 Plans

Phase 1
- Porting the CCSM3 (T85L26) to KMA/KISTI computer.
- Development of an initialization package by APCC.
- Simple coupled SST nudging.
- NCEP/CDC OISST (Reynolds, 1992).

Phase 2
- Coupled climate run and validation.
- Retrospective 6-month forecast with November 1 initial conditions.
- 20 years and 10 ensembles.

Phase 3
- 6-month forecast with November, 2008 initial conditions.
- 10 ensembles.
**In-House Coupled Model (CCSM3)**

**Overview**
- Coupled model forecasts are superior to the stand-alone AGCM forecasts on seasonal scale, particularly in the monsoon region.
- It is expected that APCC operational MME prediction can be improved through using 1-tier model predictions.

**Goals/Objectives**
- To develop an in-house coupled model based on NCAR’s CCSM3 that would be capable of joining 12-month lead time climate prediction

**NCAR’s CCSM3 (T85L26, gx1v3L40)**
- Coupled global climate prediction model
- Atmos., ocean, land, and sea-ice connected by a flux coupler
- Resolution : AGCM = 256 Lon X 128 Lat X 26 Level
  - OGCM = 320 Lon X 384 Lat X 40 Level
- Simulation Time : approx. 1 year / 1 day (64 CPUs)

**In-House Coupled Model (CCSM3)**

- Import of an ocean-atmosphere CGCM & climate simulation
- Development of initialization scheme & hindcast experiment

**Porting of CGCM**
- CCSM3 (T85L26)
- Porting and testing

**Climate simulation**
- 20 year integration

**Analysis and Validation**
- Drift
- Monsoon
- ENSO

**Development of Initialization package**
- Coupled SST nudging
- NOAA/CDC SST

**Hindcast experiment and analysis**
- Retrospective 6-month forecasts with May IC
- 20 years and 5 ens.

**Recommendations for Improvements**

**Atmos. Model (CAM3)**

**Land Model (clm3)**

**Ocean Model (pop)**

**Coupler (cpl6)**

**Sea-Ice Model (cism5)**
Performance for CCSM3 Free-run

Total Precipitation (JJA)

Temperature at 850 hPa (DJF)

Development of initialization scheme for CGCM

Background

- APCC is trying to predict 6~12-month forecast using in-house CGCM
- Initialization scheme is important for the seasonal forecasting in order to provide skillful forecast
- Nudging method shows successful prediction of the ENSO events (Luo et al. 2005)

Goal

- development of initialization scheme based on nudging for CCSM3
- hindcast experiment using the initialization scheme
- sensitivity of the predictions to factors such as initial condition, boundary condition
Framework of Initialization & Forecast

Forced run (11 years) → Initialization by nudging 3~12-month → Hindcast & forecast

AGCM → OGCM

1971 → 1982 Jan → 1983 Jan

AGCM forcing(τ, Q) → Coupled nudging → Coupled run

(1) generate 2-hourly forcing (τ, Q) for OGCM using AGCM. Then, observed SST is required for AGCM.
(2) forced run of OGCM using AGCM forcing
(3) generate initial data for forecast using OBS by nudging (CGCM)
(4) run forecast from the initial data (CGCM)

Nudging Performance for CCSM3

Observed SST (1982-06) vs. Using Nudging Scheme (1982-06) vs. Without Nudging Scheme (1982-06)
APEC Climate Center

Preliminary results for Hindcast (1983 DJF)

I.C. : Nov 1st, 1983

SST

Precipitation

Observation

CCSM3

Time series of hindcast SSTA from Nov 1982 to May 1983

Climatology : 20 years mean of free run
### Plans for 2009

- Development of ISV prediction
- 6-month operational prediction since next summer
  
  Designing of the ENSO/ENSO Modoki/IOD indices for 1-tier MME system to facilitate the prediction of these events.
- Experimental 6-month downscaling
- Further development of in-house coupled model
- Drought prediction
- Other applications (?)

### Plans for 2009

- Development of extreme event prediction
- 6-month operational prediction since next summer
- 6-month downscaling
- Further development of in-house coupled model
Thanks for the attention

APCC New Building (To be completed in Dec. 2008)