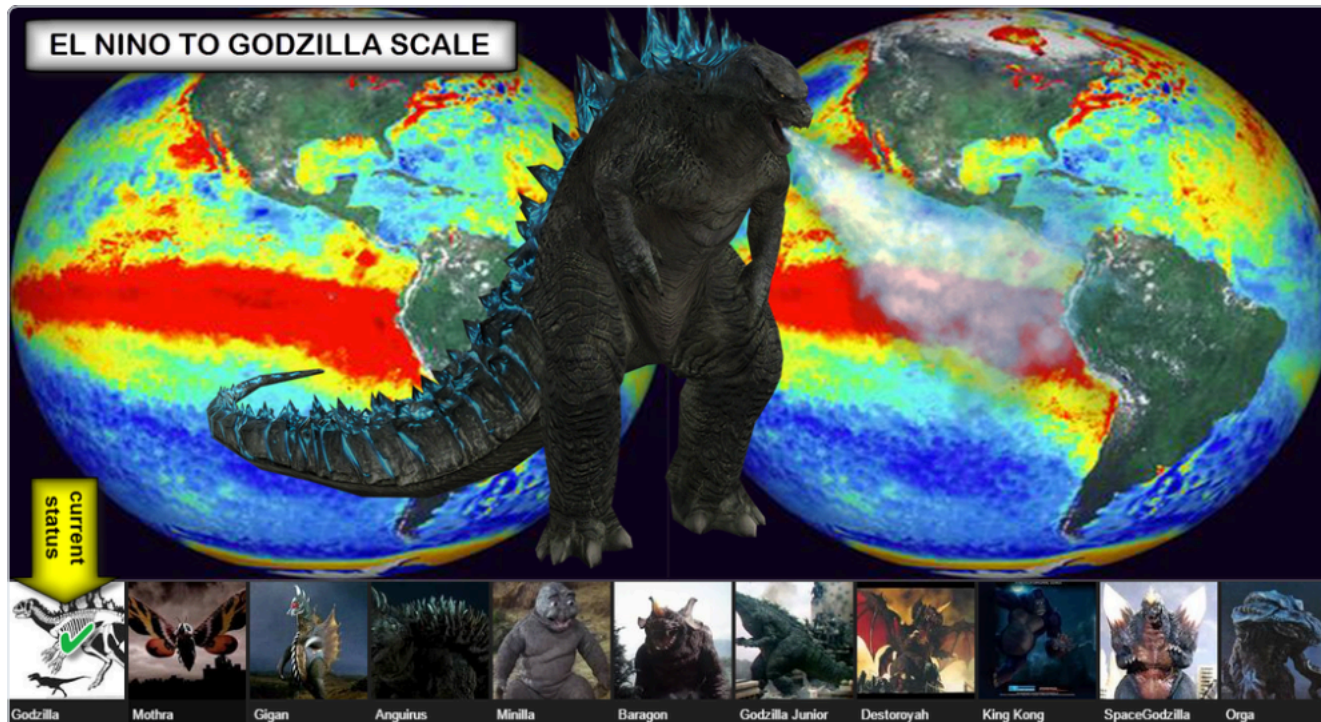


CLIK hands-on (PART I):
introduction and structure
(<http://clik.apcc21.org>)

Yun-Young Lee
1 June 2016

“Super” El Nino (15/16)

- ✓ Why ENSO is important?
- ✓ What happened in the world during 2015/16 El Nino season?

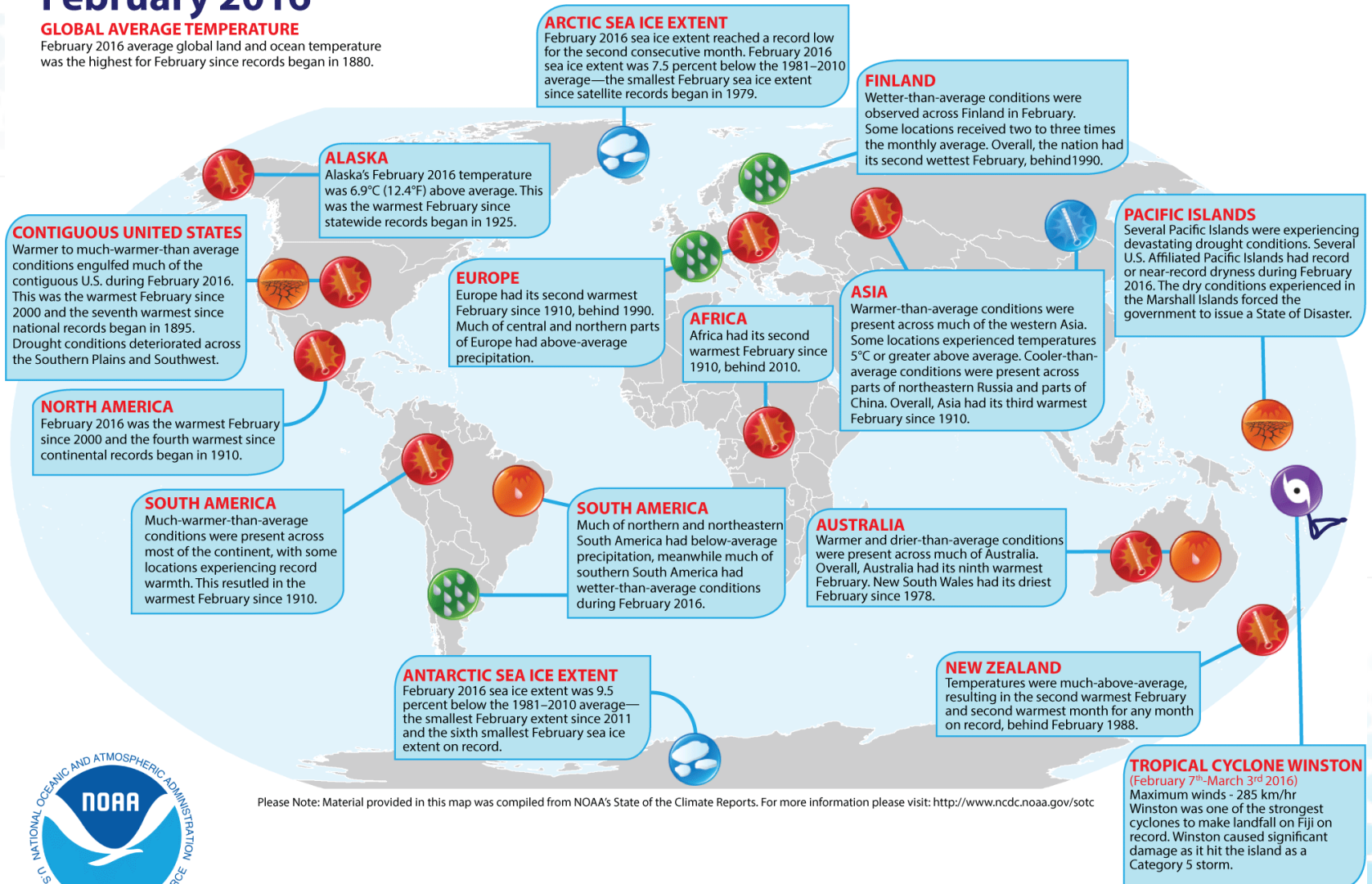


Feb 2016

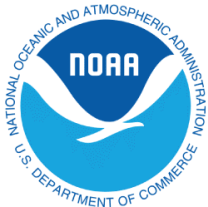
Selected Significant Climate Anomalies and Events February 2016

GLOBAL AVERAGE TEMPERATURE

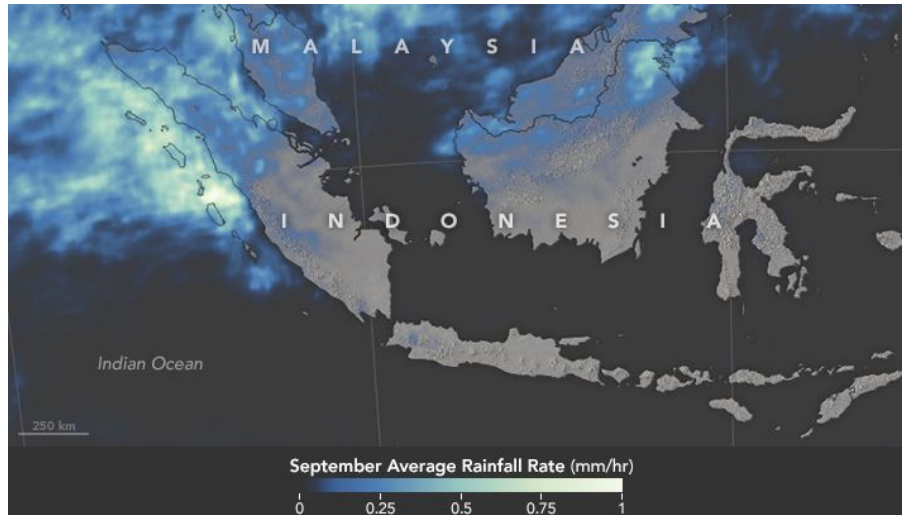
February 2016 average global land and ocean temperature was the highest for February since records began in 1880.



Please Note: Material provided in this map was compiled from NOAA's State of the Climate Reports. For more information please visit: <http://www.ncdc.noaa.gov/sotc>



Wildfire (Sep 2015)



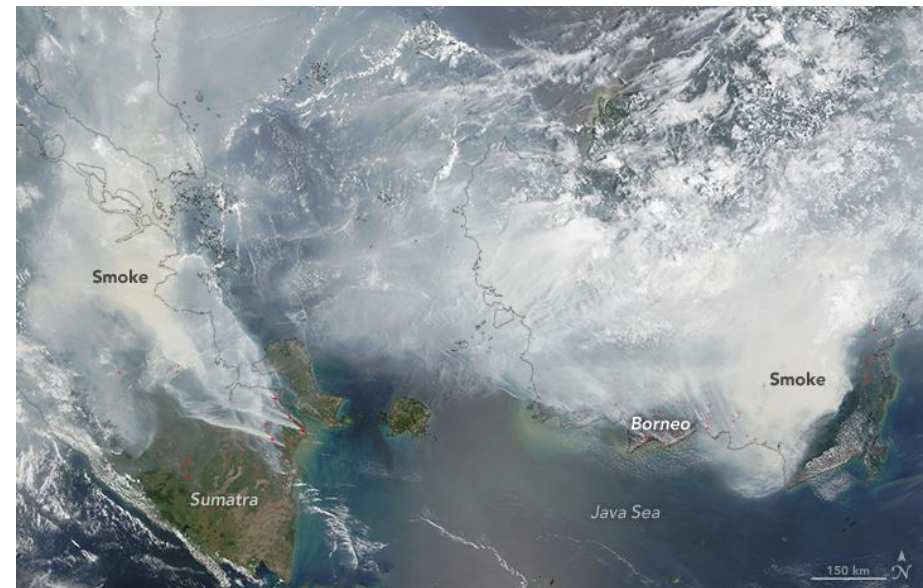
acquired September 1 - 30, 2015

Drought

Wildfire!

El Niño Brought Drought and Fire to Indonesia
(<http://www.nasa.gov/feature/goddard/2016/el-nino-brought-drought-and-fire-to-indonesia>)

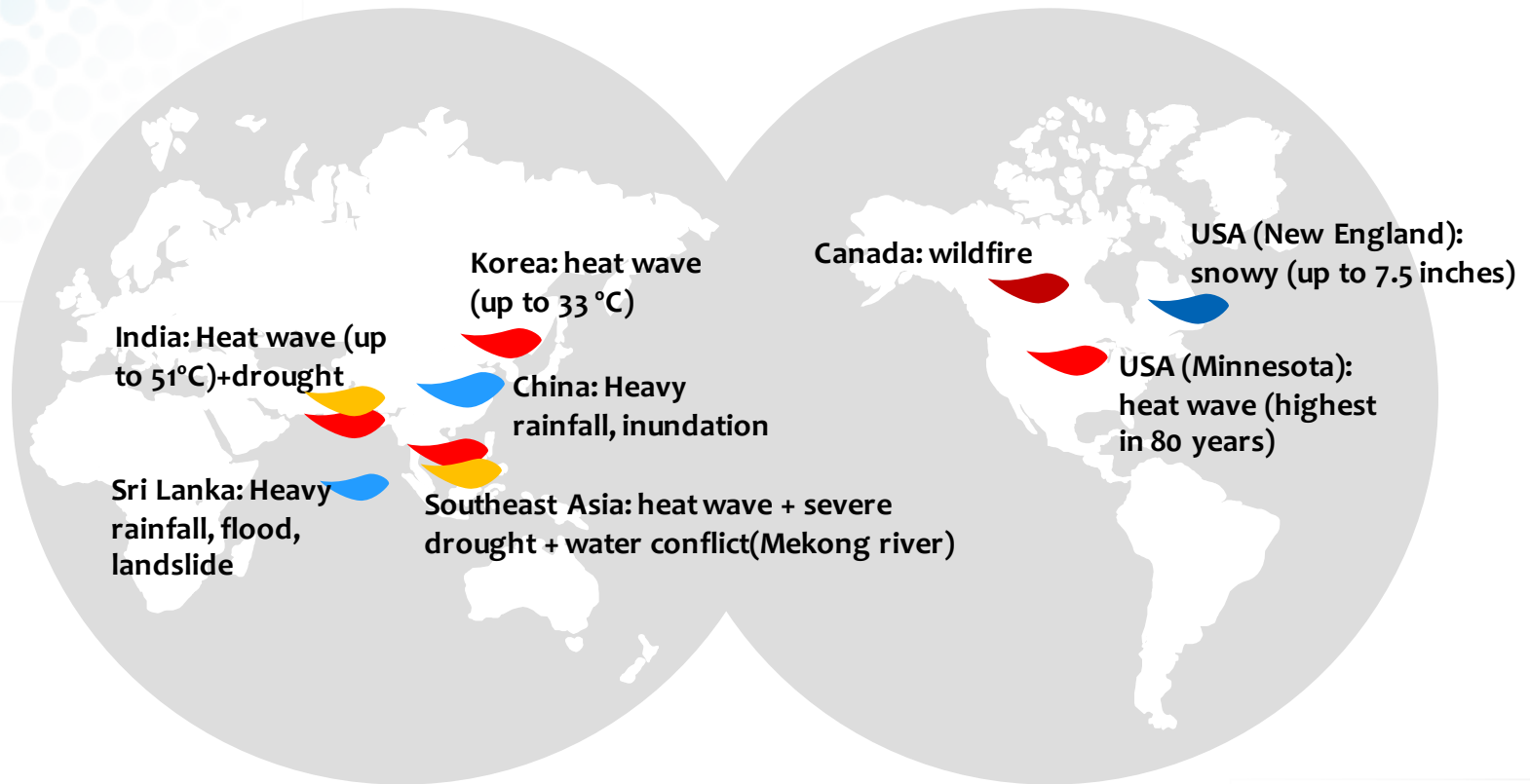
Q. Recovering from drought?



download large image (6 MB, JPEG, 7200x4800)

acquired September 24, 2015

Extreme events (May 2016)



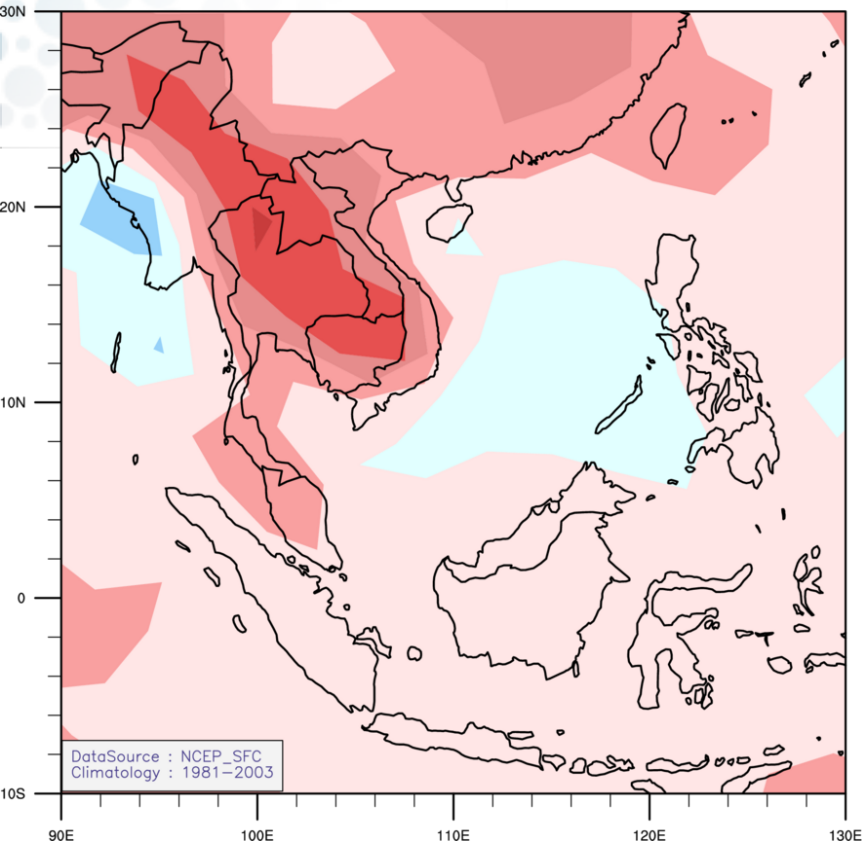
- | | |
|--|--------------------------------------|
|  Heat wave | • South Korea, Thailand, India, USA |
|  Heavy rainfall | • Sri Lanka, China |
|  Drought | • India, Cambodia, Vietnam, Malaysia |
|  Wildfire | • Canada |
|  Snowstorm | • USA |

Southeast Asia: Temp. & Prec. (2016Apr)

Surface Air Temperature Anomaly

Apr 2016

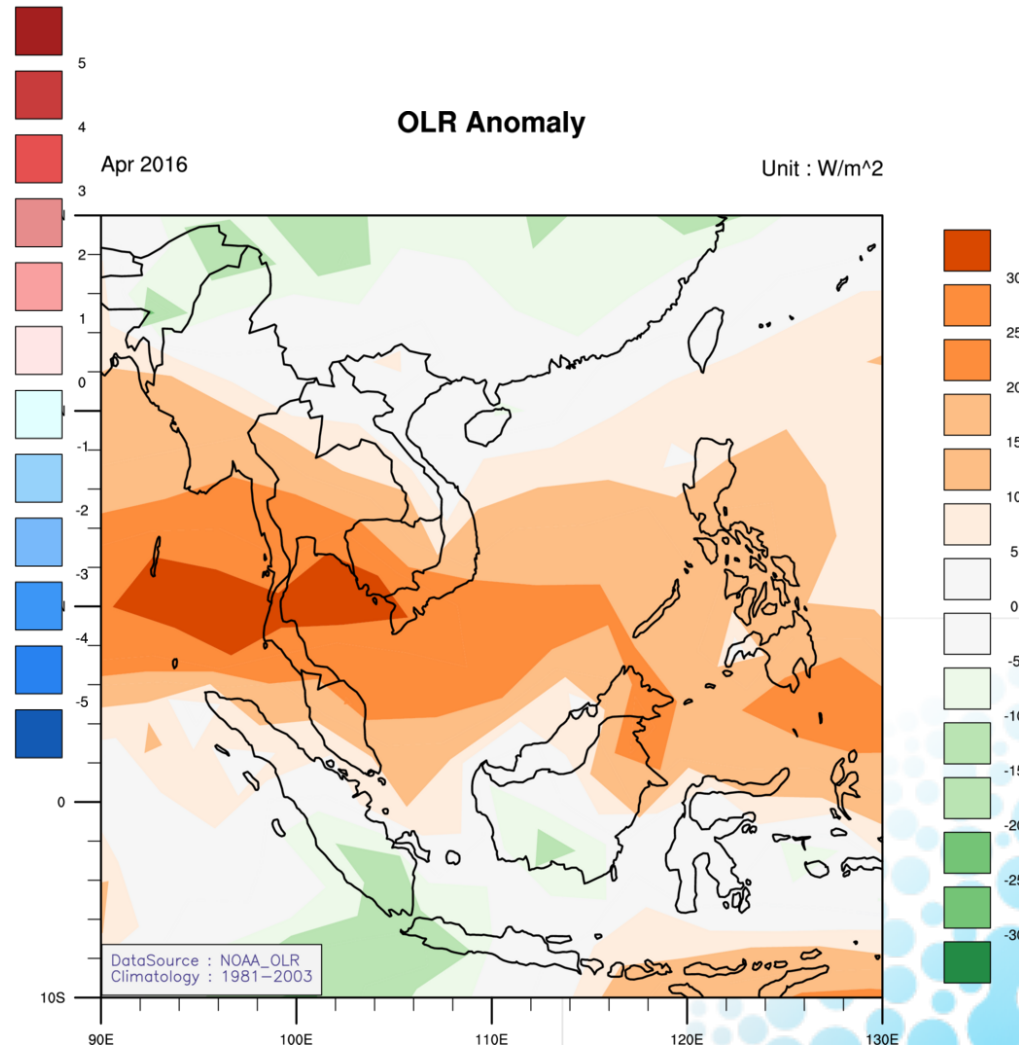
Unit : °C



OLR Anomaly

Apr 2016

Unit : W/m²



2016 Drought in Southeast Asia

Cambodia faces severe and prolonged drought

POSTED ON: March 23, 2016 | CAMBODIA - CURRENT AFFAIRS - FEATURED | By: Daniel Besant

Experts say that this year's drought will be worse than in 2015, with soaring temperatures and a delayed monsoon season likely

Cambodia is officially in a drought, and the conditions could last longer and be more severe than last year, when monsoon rains did not fall until July.



On the banks of the Mekong River in Cambodia's Kandal Province. Photo: EPA/Mak Remissa

"Based on our monitoring, drought is expected to last through the end of the year in Cambodia," said the Mekong River Commission's Secretary General. "The current drought in Cambodia is likely to be getting worse in coming months."

Last year, according to the MRC, the monsoon season was delayed until July. A similar delay is expected this year.

Schools face water shortages and government says entire nation is affected as rainy season is forecast to be delayed by months



7 photos: Children are among hardest hit by El Nino-related drought in Cambodia

2016 Drought in Southeast Asia

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On the banks of the Mekong River in Cambodia's Kandal Province. Photo: EPA/Mak Remissa

"Based on our monitoring of Cambodia," said the Mekong River Commission Secretariat. "The current drought conditions in March 2016 could be at least as severe as last year, and likely be getting worse in the coming months."

Last year, according to the Mekong River Commission, the monsoon was delayed until July. A similar delay is due in May, until as late as August this year.

Killer heatwave wreaks havoc in Southeast Asia

Nathan A. Thompson, for CNN

Updated 0405 GMT (1205 HKT) May 12, 2016

(CNN) — Drought, severe heat and water shortages are disrupting schools, killing animals and ravaging rice crops in Southeast Asia.

Thailand, Laos and Cambodia have recorded temperatures up to 44.6°C (112.4°F), beating all-time national highs, according to data from the Weather Underground, a commercial weather service. Singapore too, has seen abnormally high temperatures, while in Cambodia, rice crop output has withered.

Mekong River Crisis: Water Conflicts

China and the Mekong Delta: Water Savior or Water Tyrant?

Don't be fooled by reports about China discharging water to alleviate drought along the Mekong.

By Margaret Zhou

March 23, 2016



1.0k Shares

The Mekong Delta is facing its worst drought in recent history, causing food and water shortages for over half a million people. The Chinese government headlines amidst the disaster for its release of water from upstream dams within a briefing that China "hopes it can b



Image Credit: Hau Giang, Vietnam Image via Thoai / Shutterstock.com

Government welcomes drought relief measures by China

17 Mar 2016 , The Cambodia Daily

Government officials on Wednesday applauded China's decision to take emergency measures to counter the impact of a regional drought by releasing water into the Mekong River from the Jinghong Hydropower Station in China's southwestern Yunnan province. ...

Khy Sovuthy

<https://www.cambodiadaily.com/news/government-welcomes-drought-relief-measures-by-china-110018/>

Categories: Disasters and disaster management, Drought, Environmental & Natural Resources Management

Tag: Jinghong Hydropower Station

Weather driven disaster

5. Jan. 13 — Flooding in the capital



Flood



Strong wind



Indonesia landslide: 20 dead and dozens still missing

14 December 2014 | Asia

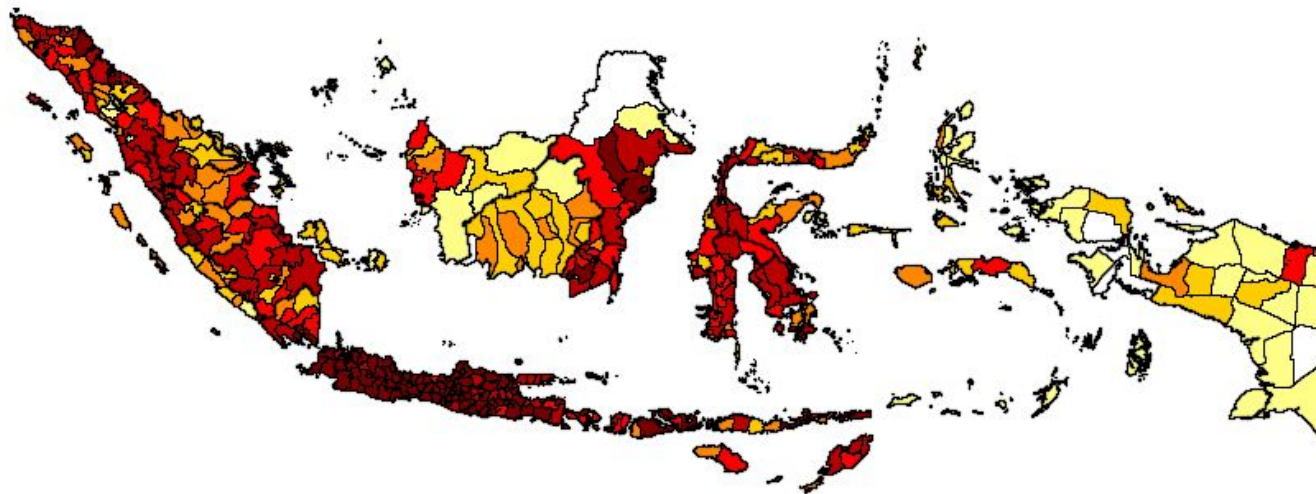
Landslide



Rescuers, including local residents, are still hoping to find survivors

Disasters

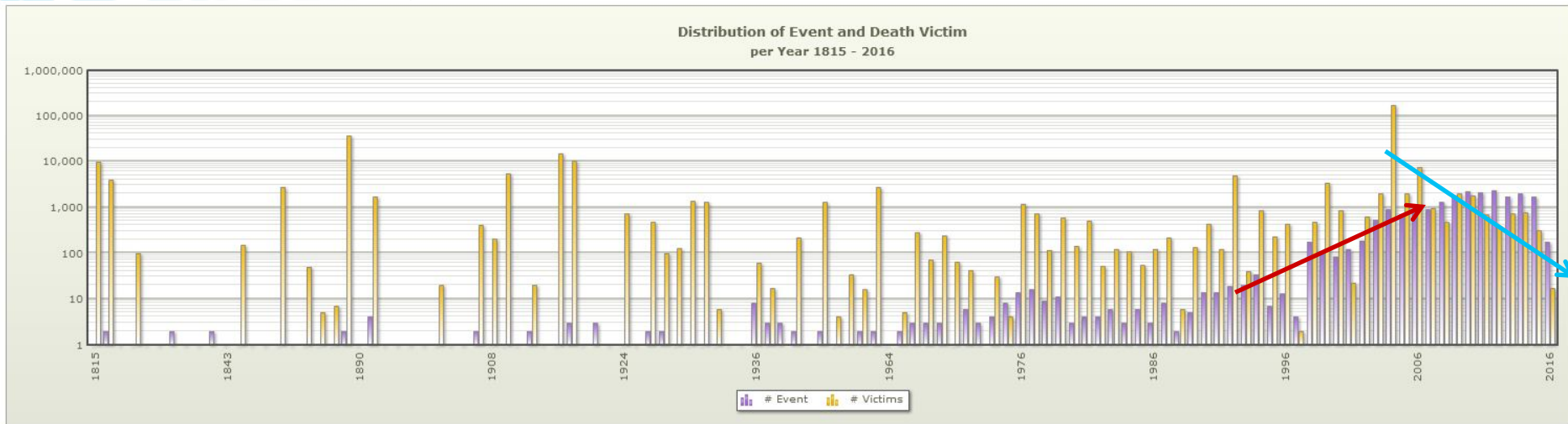
Distribution of Disaster Event per District
1815 s/d 2016



All out of four maximum event disasters are **weather driven or weather-related**.



Importance of “Accurate” prediction



Recently, Events ↑, Victims ↓

National Disaster Management Authority (BNPB)

ACCURATE climate prediction optimized to specific region (your village) combining with early warning and well-trained evacuation system will reduce economic and human losses in Indonesia.

<http://dibi.bnpb.go.id/data-bencana/lihat-data>

Indonesia Version Webmail

Search...

HOME NEWS PROFILE DISASTER KNOWLEDGE - REGULATIONS PUBLICATION - PARTNERSHIP

After Haze Disaster, Flood and Landslide Preparedness in Riau

DISASTER GEOSPATIAL
We provide updated-spatial disaster data. More than 2,000 maps are ready

DATA AND INFORMATION OF INDOONESIAN DISASTER
An application that provides data and information of disaster in Indonesia from 1825 until now.

DISASTER MONITORING
Interactive maps on incidents or disasters in Indonesia within the last month.

APCC mission

- **Facilitating the share of high-cost climate data and information to minimize economic and human losses due to natural disasters**
- **Capacity building in climate prediction and sustainable social and economic applications of climate information**

CLIK (CLimate Information ToolKit) : online prediction tool

- For those **who wants to play with model data**
 - To allow **user manipulation of multi model prediction** in producing his/her own forecast
 - To provide **statistical downscaling** capability using multi model prediction
- Prediction : Diff. combinations
 - Downscaling : model to station matching

→ Facilitate the cooperation in the exchange of information and services so that users are able to **cope with climate related disasters**

Development

2008

- The CLimate Information ToolKit(CLIK) version 1.0 was developed.
 - Deterministic Multi-Model Ensemble (DMME) prediction

2009-2010

- CLIK version 2.0
 - Probabilistic Multi-Model Ensemble (PMME)
 - Statistical Downscaling

2011-2013

- Clustering Computation
Enhancing Internal Algorithm

2014

- CLIK v3.0 with New Web Framework (New CLIK)
 - Enhancement of User Interface & Performance
 - Database optimization, Lightweight Map, etc.

CLIK

CLIK 3.0: Internals

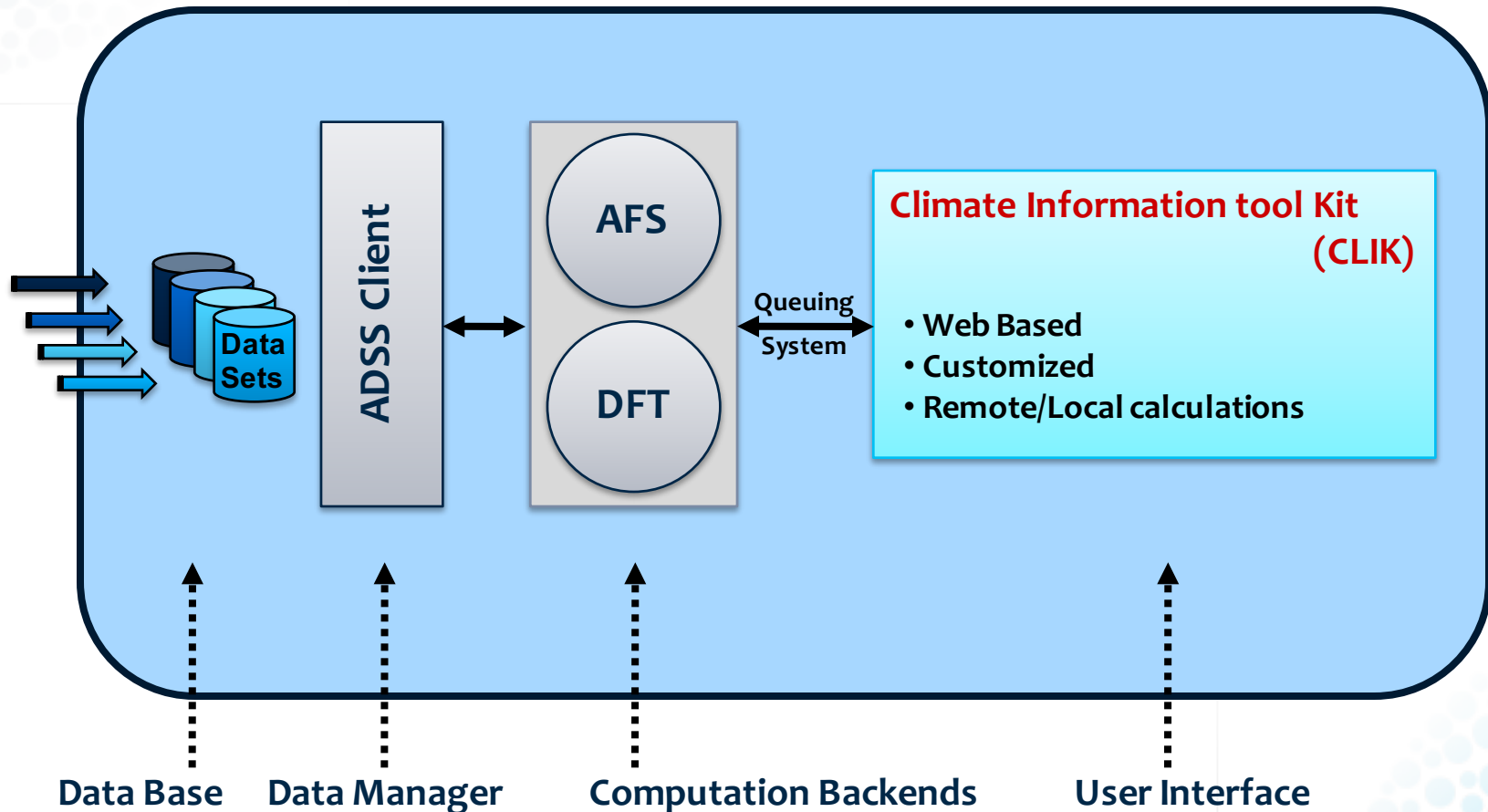
- **The Customized Climate Information Service**
- **Be able to produce and utilize the climate information data by CLIK with **only a computer and an internet connection.****
- **Based on Java and HTML with NCAR Command Language (NCL)**
- **Existing NCL, Fortran Code can be reused with Java Container**
- **Standard Web technology (HTML/JSP)**
- **CLIK 3.0 leverages on the robust functionality of previous product releases but at around 10 times the performance**

<http://clik.apcc21.org>

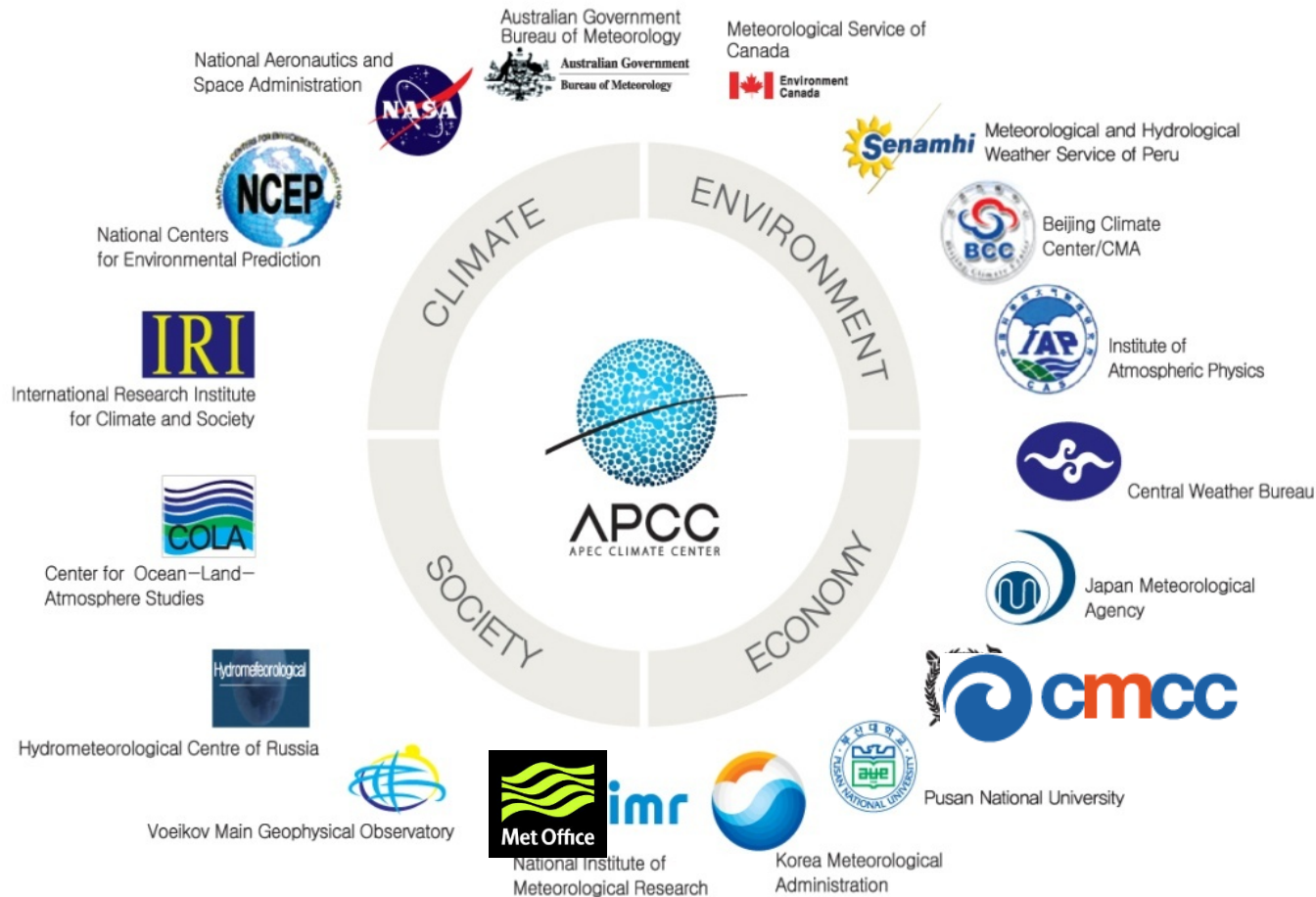
<https://www.youtube.com/watch?v=5CNPoX1f1XY>

CLIK: process diagram

APCC Climate Application System



APCC: data collection



- Collection of Dynamic ensemble seasonal prediction data from NMHS and research institutes (16 operations/institutions from 10 countries)

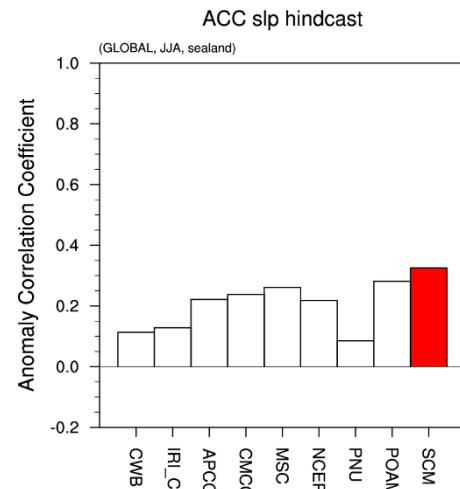
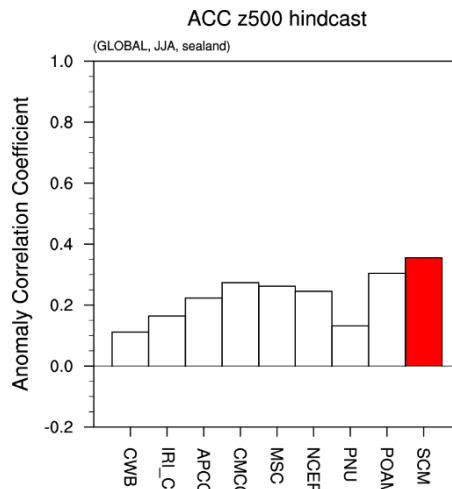
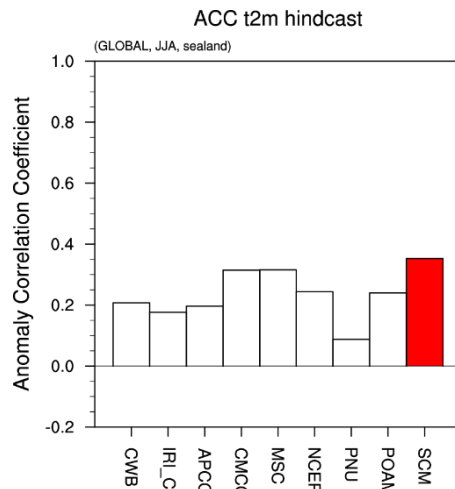
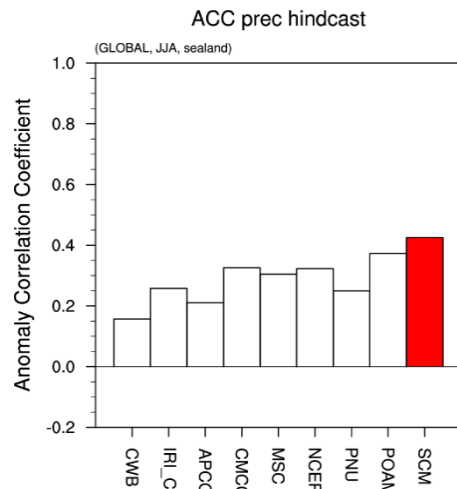
List of available models

DATA SOURCES

Nation	Organization	Acronym
Australia	Bureau of Meteorology	BoM
Canada	Meteorological Service of Canada	MSC
China	National Climate Center, CMA	NCC
	Institute of Atmospheric Physics	IAP
Chinese Taipei	Central Weather Bureau	CWB
Italy	Centro Euro-Mediterraneo sui Cambiamenti Climatici	CMCC
Japan	Japan Meteorological Agency	JMA
Korea	Korea Meteorological Administration	KMA
	Pusan National University	PNU
	National Institute of Meteorological Research	NIMR
Peru	Servicio Nacional de Meteorología e Hidrología	SENAMHI
Russia	Hydrometeorological Research Centre of Russian Federation	HMC
	Voeikov Main Geophysical Observatory	MGO
UK	Met Office	Met Office
USA	International Research Institute for Climate & Society	IRI
	Center for Ocean-Land-Atmosphere Studies	COLA
	National Centers for Environmental Prediction, NOAA	NCEP
	National Aeronautics and Space Administration	NASA

Why MME?

- Climate predictions has **uncertainty** coming from two major sources,
 - Initial conditions uncertainty (errors in obs. system or estimates)
 - Model formulation uncertainty (errors due to discrete representation of temporally and spatially continuous real world)
- ➔ multi-institutional multi-model ensemble approach **to minimize the uncertainty**
- ➔ multi-model ensemble (MME) approach yields **superior forecasts** compared to any single model.



PREDICTION_methodology

Deterministic

Multi-Model
Ensemble
(MME)

Probabilistic

SCM

GAUS

Simple Composite Method:

Average of individual forecast with equal weighting

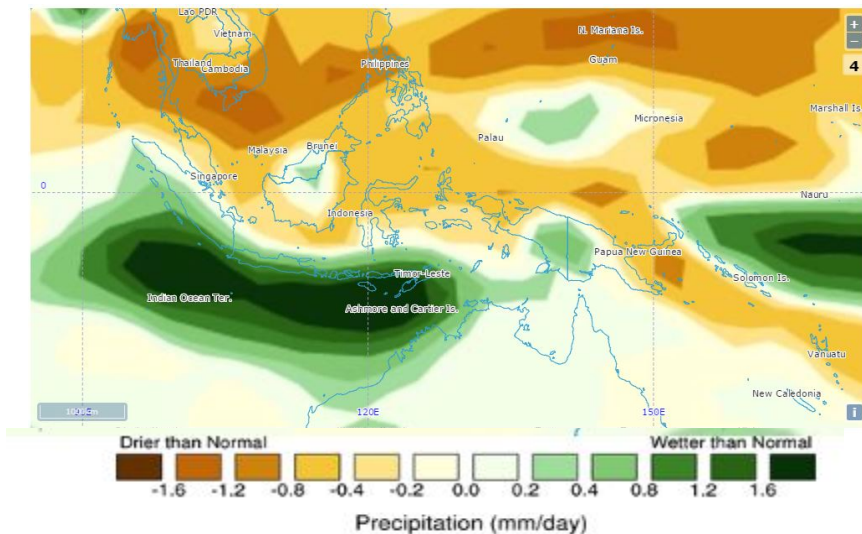
$$P = \frac{1}{M} \sum_i F_i'$$

A parametric **Gaussian fitting method** for the estimation of tercile-based categorical probabilities; forecast probability of each category is estimated as a portion of the forecast PDF (Probability Density Function) with respect to the historical one.

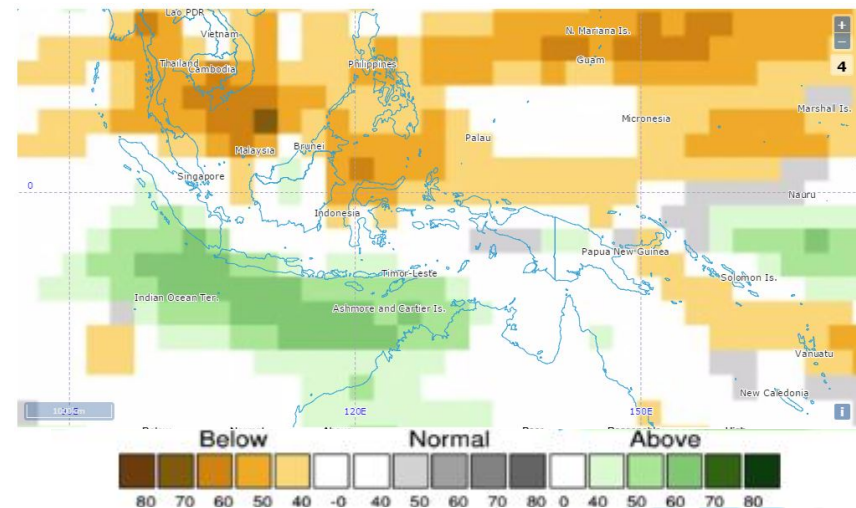
PREDICTION_product

Lead Month <input checked="" type="radio"/> 3Month	When Year <input type="text" value="2016"/> Season <input checked="" type="text" value="MJJ"/>
Variables <input checked="" type="radio"/> PREC <input type="radio"/> T850	Model <input checked="" type="checkbox"/> ALL <input checked="" type="checkbox"/> APCC <input checked="" type="checkbox"/> COLA <input checked="" type="checkbox"/> CWB <input checked="" type="checkbox"/> IRIF <input checked="" type="checkbox"/> IRI_CA <input checked="" type="checkbox"/> MGO <input checked="" type="checkbox"/> MSC <input checked="" type="checkbox"/> NASA <input checked="" type="checkbox"/> NCEP <input checked="" type="checkbox"/> POAMA

DMME (SCM)



PMME (GAUS)

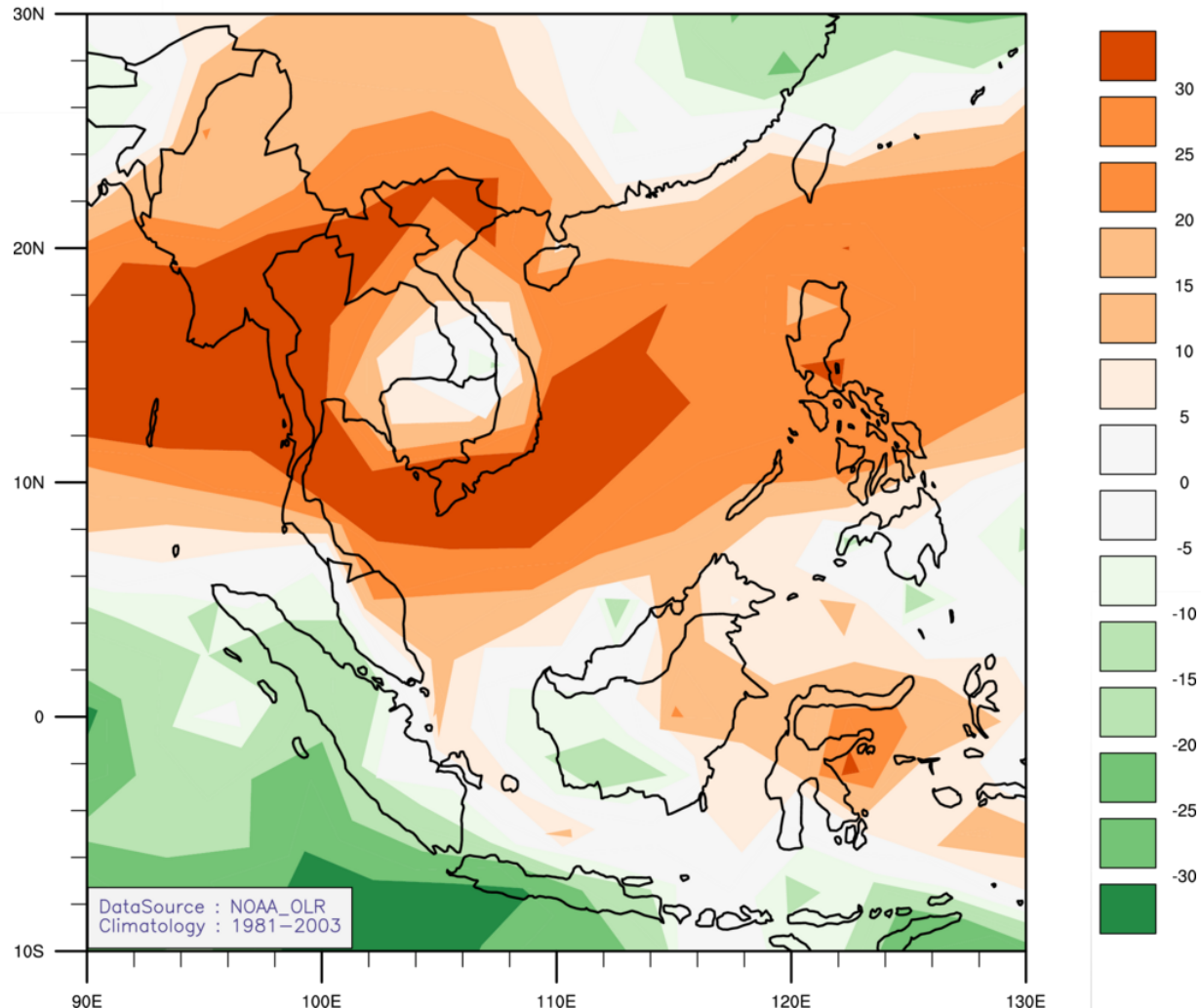


Early May!

OLR Anomaly

May 1 2016 - May 10 2016

Unit : W/m²



PREDICTION_skill_score

Success Rate

the fraction or percentage of success among a number of attempts. CLIK provides a simple success rate as the hindcast skill score

F \ O	AN	NN	BN
AN	1	4	9
NN	2	3	4
BN	2	6	3

$$= 7/34 \sim 0.20$$

~0.33 : Poor skill region

0.33~0.66 : Reasonable skill region

0.66~ : High skill region

Heidke Skill Score (HSS)

measuring the fractional improvement of the forecast over the standard forecast

F \ O	Yes	No
Yes	Hit (H)	False Alarm (F)
No	Miss (M)	Correct Rejection (C)

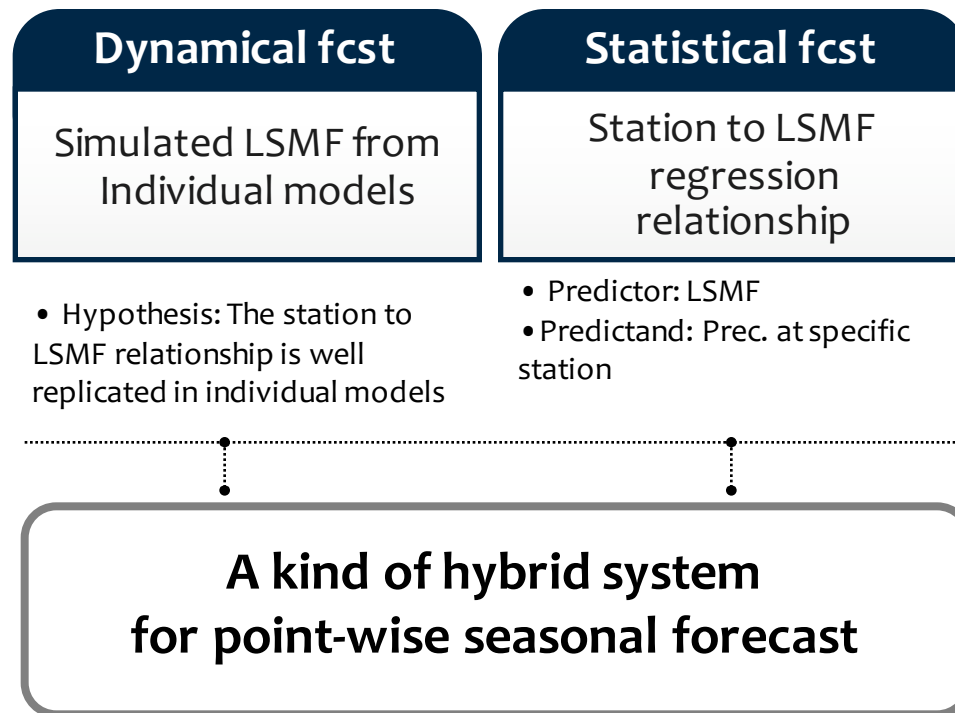
$$HSS = \frac{(score - score\ by\ chance)}{(perfect\ score - score\ by\ chance)}$$

$$\frac{\{(h+c)/n - [(h+f)(h+m) + (f+c)(m+c)]/n^2\}}{\{1 - [(h+f)(h+m) + (f+c)(m+c)]/n^2\}}$$

CLIK downscaling

➡ A way to localize existing coarse climate information

CLIK downscaling is mainly based on station to Large Scale Meteorological Field (LSMF) relationship. ($Y = a \cdot X + b$) By utilizing the simulated LSMF (X, predictor), CLIK estimates seasonal mean precipitation/temperature (Y, predictand) at specific station.



CLIK

CLimate Information ToolKit

<http://clik.apcc21.org>



CLIK - main page



Prediction Downscale My Page

Register Login

Background

The CLimate Information ToolKit version 1.0 (CLIK1.0) was developed in line with APCC's mission of empowering users to maximize the use of climate information and forecasts. The CLIK system provides customized multi-model ensemble (MME) prediction with verification. It also has a statistical downscaling tool which conducts predictor variable pre-screening, basic diagnostic testing, and graphing of climate data from January 2008 onwards. More than 1,200 registered users enjoy the service and about 7,500 predictions have been generated based on the users' request since 2008. Building on the success of CLIK 1.0, new features such as inclusion of other MME methods, improving the downscaling function, enhancing performance, and supporting multiplatform use have been added in the updated version CLIK 2.0 based on user feedback. The product is continuously being improved as APCC responds to the climate information needs of APEC member economies and users worldwide.

Product Description

CLIK aids users in retrieving and using climate prediction data and information available from APCC data servers in a user-friendly manner. Climate forecasters, disaster managers, water resource managers, researchers, and other users anywhere in the world can use this service to generate customized climate predictions on seasonal to inter-annual timescales for their region of interest. The tool has an immense potential to contribute to early warning and management of climate-related disasters and resource management, particularly in developing countries.

The data processing engines powering CLIK at the backend are built on the NCAR Command Language (NCL), a powerful suite of libraries for climate data manipulation and visualization. The web interface of CLIK 1.0 and CLIK 2.0 was built on the web framework Ruby on Rails (RoR). RoR provided simplicity and productivity to the developers but resulted in heavy use of computing resources and raised software incompatibility problems. To resolve these performance and incompatibility issues, we have designed and developed a faster, lighter CLIK 3.0 based on Java and pure HTML with NCL. The main motivation for the new developments is to make the product more useful to developing countries.

CLIK 3.0 leverages on the robust fun

User Interface:

- Modern layout and more use
- Higher resolution maps with
- Side-by-side viewing of pred
- Simultaneous panning of pre
- Layered prediction and verifi

Performance:

- Cleaner user interface that re
- Web display is up to five time
- Climate information processi
- Database access is up to 13
- Reduction of downscaling st

Future product development plans in

User Manual

PDF

Contact Information

If you have any questions or feedback regarding APCC CLIK, please contact the Climate Informatics and Application Team (clik@apcc21.org)

Data Sources

Please refer to [\[DATA SOURCES\]](#)

Terms of Data Use

Please refer to [\[TERMS OF DATA USE\]](#)

✓ User can see the information about the **CLIK background, product description, user manual** and so forth.

CLIK - "Prediction"



Prediction Downscale My Page

Logout Edit

Predict

Lead Month

3Month

When

Year Season

Methods

SCM GAUS

Variables

PREC T850

Model

ALL APCC COLA CWB IRIF
 IRI_CA MGO MSC
 NASA NCEP POAMA

✓ User can produce the **customized MME climate forecast**, then view the result figure map and download corresponding data.

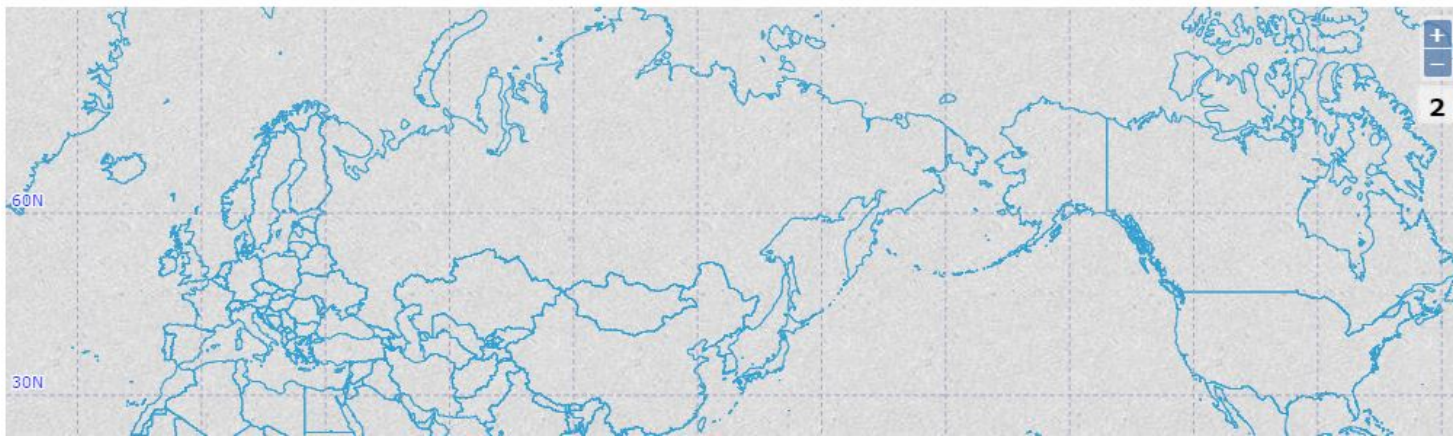
Predict & Verify

Result

SingleMap BindingMap

Move Center

Download



CLIK - “Downscale”



Prediction **Downscale** My Page

Logout Edit

Select Dataset / Station

Datasets

Dataset Name	Countries	Total Stations	Period(prec)	Period(temp)	Public
MCDW(Monthly Climatic Data for th...	The World	6463	1998 ~ 2014	1998 ~ 2014	PUBLIC
Imsi		0	N/A	N/A	dolkong400
GHCN	GHCN	3707	1950 ~ 2009	N/A	PUBLIC
Aphrodite data interploated to Mons...	Afghanistan, Bangladesh, Brunei D...	4918	1961 ~ 2004	N/A	PUBLIC
Korea 60 Stations	Korea, Republic of	60	1973 ~ 2008	1973 ~ 2006	PUBLIC
NewCLIK dataset		0	N/A	N/A	dolkong400

Create Edit Remove



✓ User can upload their own regional station data and make a **downscaled forecast**

CLIK - "My Page"



Prediction Downscale **My Page**

Logout Edit

My Page

Jobs			System Status		
JOB ID	TYPE	STATE	RESULT DATA	CREATED	UPDATED
3864	Prediction	success	download	2016-05-13 15:40:26	2016-05-13 15:41:08
3851	Prediction	fail		2016-05-13 11:16:03	2016-05-13 11:16:07
3850	Prediction	fail		2016-05-13 10:39:59	2016-05-13 10:40:30
3822	Prediction	fail		2016-04-01 16:56:12	2016-04-01 16:56:21
3821	Prediction	fail		2016-04-01 16:52:45	2016-04-01 16:52:58
3776	Downscale	success	download	2015-12-02 17:49:46	2015-12-02 17:52:29
3775	Downscale	fail		2015-12-02 17:47:18	2015-12-02 17:47:34
3774	Downscale	success	download	2015-12-02 14:57:44	2015-12-02 15:54:35
3773	Downscale	success	download	2015-12-02 14:56:14	2015-12-02 14:57:00
3772	Downscale	fail		2015-12-02 14:54:55	2015-12-02 14:54:59
3771	Downscale	fail		2015-11-30 09:14:31	2015-11-30 09:14:37
3769	Downscale	success	download	2015-11-27 14:56:09	2015-11-27 15:01:06
3765	Downscale	success	download	2015-11-24 19:42:23	2015-11-24 19:47:43
3757	Downscale	fail		2015-11-10 16:16:24	2015-11-10 16:16:27

Processing 0 Queued 0 Image Processor 14 CPU Usage 16.5 %

- ✓ Users can find the **list of jobs requested**, identify the status of jobs, and download result data of successful jobs.

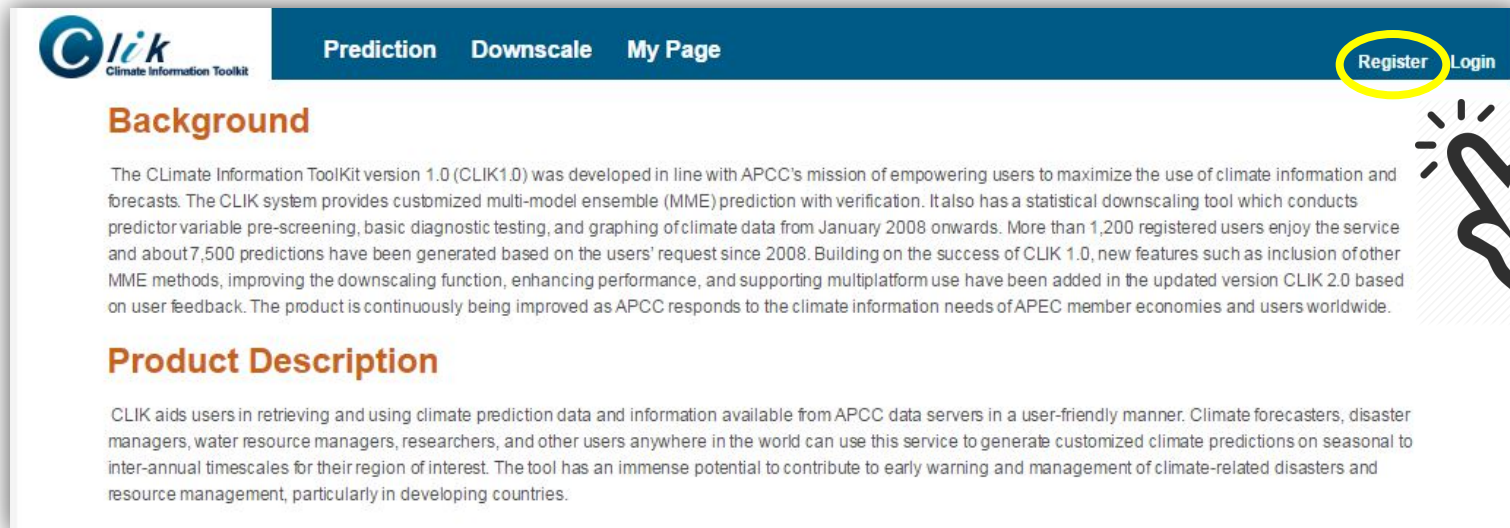
CLIK

<http://clik.apcc21.org>



CLIK - Getting Started

- **Creating your account**



The screenshot shows the CLIK website interface. The top navigation bar is dark blue with the CLIK logo on the left and the text "Prediction Downscale My Page" in the center. On the right side of the navigation bar, the words "Register" and "Login" are displayed, with "Register" circled in yellow. Below the navigation bar, the main content area has a white background. The section "Background" is highlighted in orange. The text under "Background" describes the development and features of CLIK 1.0 and 2.0. The section "Product Description" is also highlighted in orange. The text under "Product Description" explains how CLIK aids users in retrieving and using climate prediction data. To the right of the screenshot, there is a hand icon pointing to the word "CLIK" in red text.

CLIK Climate Information Toolkit

Prediction Downscale My Page

Register Login

Background

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CLIK - Getting Started

- **Creating your account**

The screenshot shows the APCC Single Sign On System registration page. It features the APCC logo (APEC Climate Center) and the title 'APCC Single Sign On System'. The page contains two agreement sections and a registration form. Red annotations highlight key steps: 1. A red circle with the number '1' is next to a checked checkbox 'I read the contents and I Agree' under the 'Agreement of Getting Personal Information' section. 2. A red circle with the number '2' is next to a checked checkbox 'I read the contents and I Agree' under the 'Agreement of Registering for APCC Website / CLIK / ADSS' section. 3. A red circle with the number '3' is next to a red-bordered box around the 'First Name', 'Last Name', and 'E-mail' input fields. 4. A red circle with the number '4' is next to a hand icon pointing to the 'apply' button. The 'apply' button itself is also circled in red.

APCC
APEC CLIMATE CENTER

APCC Single Sign On System

Agreement of Getting Personal Information

Agreement to collecting personal information
(APEC Climate Center)

Purposes for collecting personal information
We collect and use the information that you provide for the following purposes:
To provide customized information;
To manage website usership, such as maintaining a membership database, member identification, and transmitting announcements; and
To gauge and improve the effectiveness of the website and services

1 I read the contents and I Agree

Agreement of Registering for APCC Website / CLIK / ADSS

PRIVACY POLICY
(APEC Climate Center)

Purposes for collecting and using personal information
We collect and use information that you provide
To provide customized information;
To manage website usership, such as maintaining a membership database, member identification, and transmitting announcements; and
To gauge and improve the effectiveness of the website and services
To improve your interaction with the site or service

2 I read the contents and I Agree

- Check your name and E-mail for uniqueness property

3	First Name	<input type="text"/>
	Last Name	<input type="text"/>
	E-mail	<input type="text"/>

4

CLIK

CLIK - Getting Started

- **Creating your account**

APCC
APEC CLIMATE CENTER

APCC Single Sign On System

You have already registered one of our site, but we integrate our site (APCC website / CLIK / ADSS) recently.
Please check our new Single Sing On Service and Re-register our new Service. There are your old registered information below :

Your Registered Information

Site	E-mail	ID
APCC WebSite	Not Registered	
CLIK	Not Registered	
ADSS	Not Registered	

By checking the button, then you can re-register our sites NOW

APCC CLIK ADSS

apply



CLIK - Getting Started

- **Creating your account**

✓ Please fill in the blanks!

Register info

*ID	<input type="text"/>	<input type="button" value="ID Check"/>
*First Name	<input type="text" value="Alex"/>	
*First Name	<input type="text" value="Lee"/>	
*E-mail	<input type="text" value="yyalexlee@gmail.com"/>	
*Country	<input type="text" value="select"/>	
Institution	<input type="text"/>	
Department	<input type="text"/>	
Position	<input type="text"/>	
Tag	<input type="text"/>	
*Password	<input type="text"/>	
*Re-Password	<input type="text"/>	
* Do you want to receive mail?	<input checked="" type="radio"/> YES <input type="radio"/> NO	
Register Site	APCC <input checked="" type="checkbox"/> CLIK <input checked="" type="checkbox"/> ADSS <input checked="" type="checkbox"/>	

Other info

CLIK

Time Zone	<input type="text"/>
purpose	<input type="text"/>
Sub email	<input checked="" type="radio"/> YES <input type="radio"/> NO

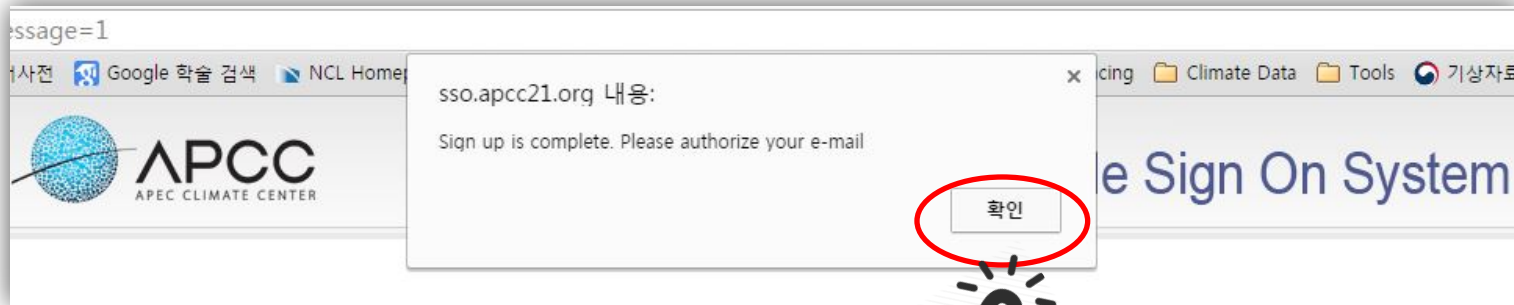
ADSS

purpose	<input type="text"/>
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CLIK - Getting Started

- **Creating your account**



CLIK - Getting Started


- **Creating your account**



✓ Please **activate your account** by clicking the LINK in the e-mail sent you.

CLIK - Getting Started

- **Creating your account**



The screenshot shows the APCC Single Sign On System login page. At the top left is the APCC logo (APEC Climate Center). At the top right is the text "APCC Single Sign On System". The main content area features a large APCC logo on the left and a login form on the right. The login form has two input fields: "ID" and "Password". The "ID" field is empty, and the "Password" field contains several dots. To the right of the "Password" field is a blue "login" button. Below the login form are three buttons: "Get Password", "Get ID", and "Registration". At the bottom of the page, there are three small icons with labels: "APCC", "APCC ADSS", and "APCC CLIK".

- ✓ Please **log in** with your ID and password.
- ✓ Finally, you guys are **READY** to use the CLIK system!



Thank you.

CLIK:

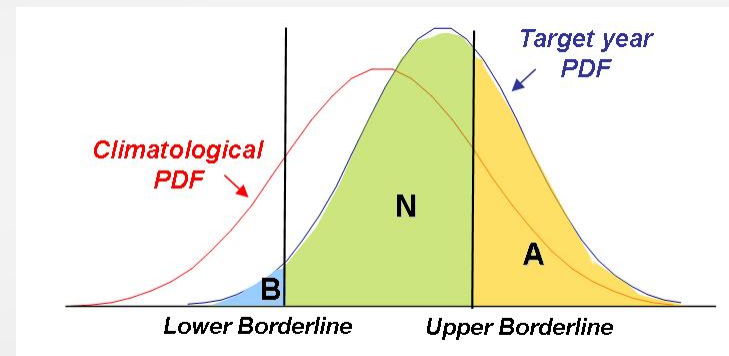
- Aids users in retrieving and utilizing climate prediction data and information available from APCC data servers **in a user friendly manner** through **web-based format**
- Provides **the customized multi-model ensemble (MME) prediction** and **the statistical downscaling tool** which performs ancillary tasks of predictor variable prescreening, basic diagnostic testing, and graphing of climate data

Probabilistic MME Scheme(GAUS)

A parametric **Gaussian fitting method** for the estimation of tercile-based categorical probabilities; forecast probability of each category is estimated as a portion of the forecast PDF(Probability Density Function) with respect to the historical one.

Forecast probability

- A** Probability of Above-normal
- N** Probability of Near-normal
- B** Probability of Below-normal



Skill Scores: Success Rate (SCM)

Success Rate

is the fraction or percentage of success among a number of number of attempts. CLIK provides a simple success rate as the hindcast skill score.

- ~ 0.33 : Poor skill region
- $0.33 \sim 0.66$: Reasonable skill region
- $0.66 \sim$: High skill region

Skill Scores: Success Rate (SCM)

The verification metric is success rate.

Divided the prediction into 3 categories normal, above normal and below normal. The observations are also similarly divided.

If model and observations are in the same category then the forecast is counted a success. Otherwise it is a failure. For example,

- Model predicted **above normal** and observations was **normal** – failure
- Model predicted **above normal** and observations was **below normal** – failure
- Model predicted **above normal** and observations was **above normal** – success

Because the forecast is divided into 3 equal category, and there is equal chance to be in each category then there is 33.3% chance that a forecast can be any of normal, above or below normal. That is why the forecast has some skill if the success rate is above 33.3%(0.33).

Skill Scores: Heidke Skill Score (GAUS)

- HSS (Heidke Skill Score)

	F	O	Yes	No
Yes			Hit (H)	False Alarm (F)
No			Miss (M)	Correct Rejection (C)

- $HSS = (score - score\ by\ chance) / (perfect\ score - score\ by\ chance)$

$$\frac{\{(h+c)/n - [(h+f)(h+m) + (f+c)(m+c)]/n^2\}}{\{1 - [(h+f)(h+m) + (f+c)(m+c)]/n^2\}}$$