CLIMATE CHANGE PROJECTIONS FOR MALAYSIA

Ir. Hj. AHMAD JAMALLUDDIN SHAABAN
Director General
National Hydraulic Research Institute of Malaysia
Ministry of Natural Resources & Environment

14 DEC 2010
UKM BANGI

OUTLINE

- INTRODUCTION
- OBSERVED AND PROJECTED CLIMATE CHANGE
- VULNERABILITY AND IMPACT ASSESSMENT ON WATER INFRASTRUCTURE
- WAY FORWARD

OUTLINE

- INTRODUCTION
- OBSERVED AND PROJECTED CLIMATE CHANGE
- VULNERABILITY AND IMPACT ASSESSMENT ON WATER INFRASTRUCTURE
- WAY FORWARD

INTRODUCTION

NAHRIM – AN OVERVIEW

The National Hydraulic Research Institute of Malaysia (NAHRIM) was established in 1995

OBJECTIVES:

i) To build a pool of experts and provide research service that need in planning, designing, building and implementing research related to development of water resources in particular and environment in general;

ii) To set up as a National Focal Point that coordinate research on hydraulic engineering in Malaysia.

VISION

To be a world premier research centre for water and environment by year 2030

MISSION

Providing excellent services as an expert centre on water and environment management for sustainable growth and improving the quality of life and well being

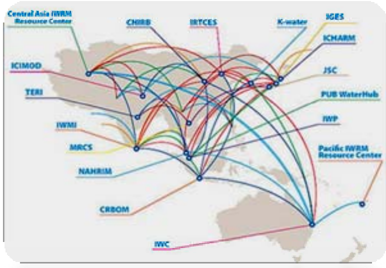
5

Why NAHRIM embark on research related to impact of climate change on Malaysian hydrology and water resources ?

- ❑ **National Water Resources Study (Peninsular Malaysia) Mac 2000.**
- ❑ **Master Plan for the Development of Water Resources in Peninsular Malaysia 2000-2050.**
- ❑ **Did not take into account potential change of hydrologic regime and water resources due to climate change.**
- ❑ **Initial National Communication (2000) recommend the need for a Regional Model for finer resolution of global climate simulations.**

NAHRIM AS ASIA PACIFIC WATER FORUM (APWF) REGIONAL WATER KNOWLEDGE HUB FOR CLIMATE CHANGE ADAPTATION (WKHCCA)

- Announced as the Regional Water Knowledge Hub for Water and Climate Change Adaptation in Southeast Asia on 26 June 2008 in Singapore International Water Week;
- Officially launched on 1 December 2008 by the Minister of Natural resources and Environment, Malaysia
- Established as one of 17 APWF Water Knowledge Hubs



7

HUB SERVICES

1. Communications Strategy & Partnership Development
2. Capacity Building
3. Regional and River Basin Hydroclimate Projections
4. Impact Assessment & Adaptation Strategies

http://www.apwf-knowledgehubs.net/

http://www.nahrim.gov.my/wkh/

http://www.wkhcca.my/





8

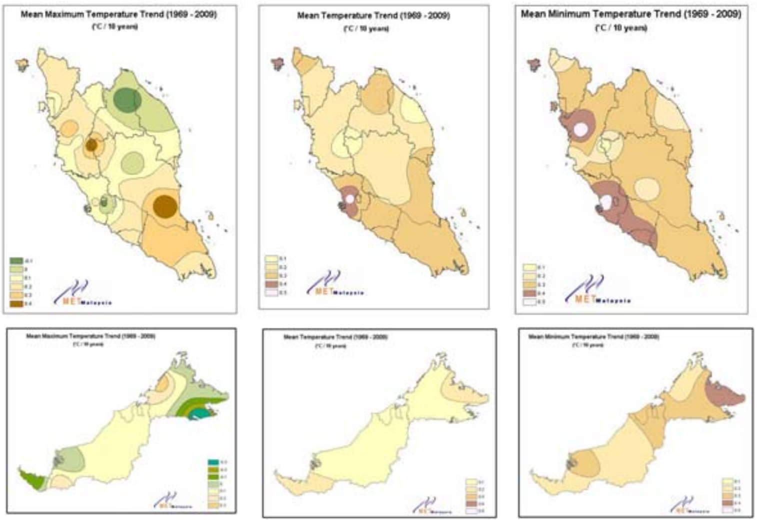
OUTLINE

- INTRODUCTION
- OBSERVED AND PROJECTED CLIMATE CHANGE
- VULNERABILITY AND IMPACT ASSESSMENT ON WATER INFRASTRUCTURE
- WAY FORWARD

Observed Climate Change

	GLOBAL*		MALAYSIA
	1906-2005		**1968-2002**
Surface temperature (ºC)	0.74		0.6 – 1.2
	1961-2003	1993-2003	1986-2006
Sea level rise (mm/yr)	1.8	3.1	1.3 **

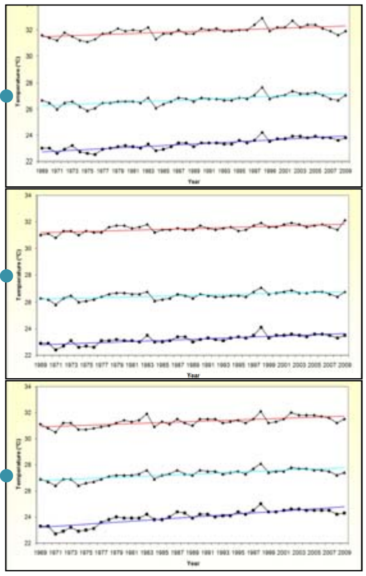
* IPCC 4TH ASESSMENT REPORT (AR4), 2007
** NATIONAL COASTAL VULNERABILITY INDEX STUDY,DID, 2007



Increased in Surface Temperature
Source: Malaysian Meteorological Department (MMD)

Local Observed Data

- **Rate of warming (temperature): 1969-2009**
  - **1.1ºC/50-yr - Semenanjung Malaysia;**
  - **0.6ºC/50-yr - Sarawak;**
  - **1.2ºC/50-yr - Sabah;**
- **Sea level change** – 1.25mm/yr, Tanjung Piai, Johor (1986-2006)
- Annual maximum **rainfall Intensity** – Period of 2000-2007 greater than 1970s (1971-80);
- 1-hr & 3-hr rainfall intensity in 2000-2007) increased 17% & 29% respectively compared to 1970s



Source: Malaysian Meteorological Department (MMD)

ANNUAL MAXIMUM RAINFALL INTENSITY

Duration	1970 – 1980	2000 - 2007	% Increased
1 -hr	96 mm/hr	112 mm/hr	+ 17 %
3 -hrs	111 mm/hr	133 mm/hr	+ 29 %
6 -hrs	111 mm/hr	145 mm/hr	+ 31 %

SOURCE : JPS AMPANG RAINFALL STATION

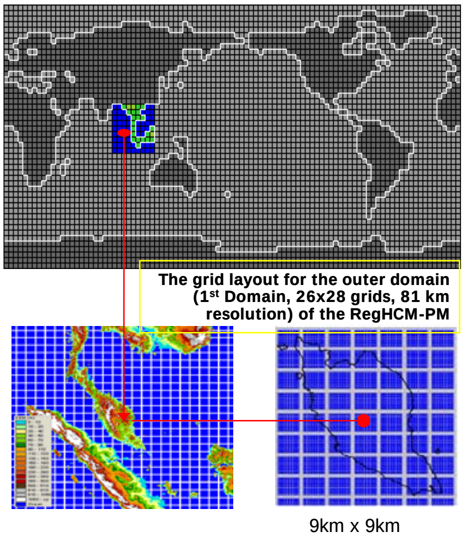
13

NAHRIM PROJECTS ON THE CLIMATE CHANGE PROJECTION FOR MALAYSIA

- RegHCM FOR PENINSULAR MALAYSIA
- RegHCM FOR SABAH & SARAWAK
- CLIMATE PROJECTION DOWNSCALING FOR PENINSULAR MALAYSIA AND SABAH-SARAWAK USING UK HADLEY CENTRE PRECIS MODEL
- SEA LEVEL RISE STUDY

NAHRIM's Regional Hydro-climate Model (RegHCM-PM)

- **2006:** A regional hydrologic-atmospheric model of Peninsular Malaysia called as '**Regional Hydro-climate Model of Peninsular Malaysia (RegHCM-PM)** was developed
- Downscaling global climate change simulation data (Canadian GCM1 current and future climate data) that are at very coarse resolution (~ 410km), to Peninsular Malaysia at fine spatial resolution (~9km) – for future period of 2025 to 2050 (2025-2034 & 2041-2050)
- Able to quantify the impact of the complex topographical and land surface features of Peninsular Malaysia on its climate conditions



What is RegHCM?

RegHCM

=

the atmospheric component of

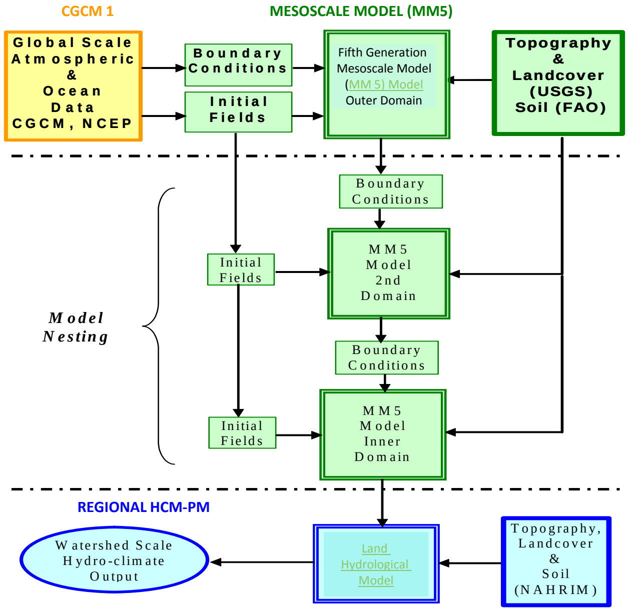
MM5 (Fifth Generation Mesoscale Model)

+

the land surface process module of IRSHAM (Integrated Regional Scale Hydrologic/Atmospheric Model).

GCM datasets :
the increasing GHG and changes in sulfate aerosol (A) loading (GHG+A) of IPCC IS92a Scenario Run, simulated by CGCM1 of the Canadian Center for Climate Modeling and Analysis

NAHRIM Regional Scale Model Configuration

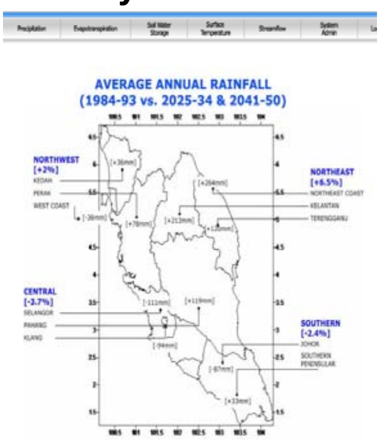


NAHRIM's Future Hydroclimate Change Projection Database

http://www.futurehydroclimate.nahrim.gov.my

5 main modules/para-meters:

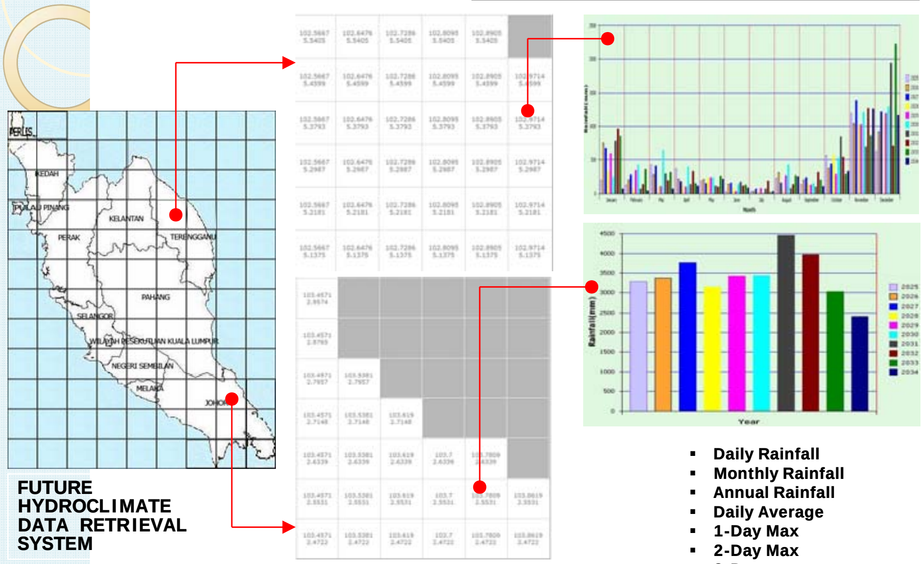
- **Precipitation**
- **Evapotrans-piration**
- **Soil Water Storage**
- **Surface Temperature**
- **Streamflow**



2 types of data sets for each module/para meter:

- **Simulated Past Data (1984 to 1993)**
- **Simulated Future Data (2025 to 2034 and 2040 to 2050)**

Future Hydroclimate Data Retrieval System for extreme events (9km x 9km)



FUTURE HYDROCLIMATE DATA RETRIEVAL SYSTEM

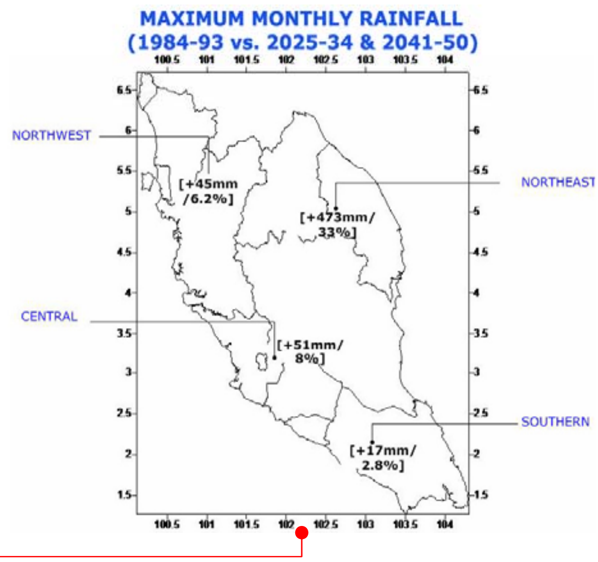
9km x 9km grid size

- **Daily Rainfall**
- **Monthly Rainfall**
- **Annual Rainfall**
- **Daily Average**
- **1-Day Max**
- **2-Day Max**
- **3-Day max**
- **5-Day Max**

19

NAHRIM's RegHCM-PM - **Simulated Future Annual & Monthly Rainfall**

Average Annual RAIN	**Max. Monthly RAIN**
Max: +264mm N/EAST COAST	Max: +473mm NORTH EAST
Min: +110mm SELANGOR	Min: +17mm SOUTHERN

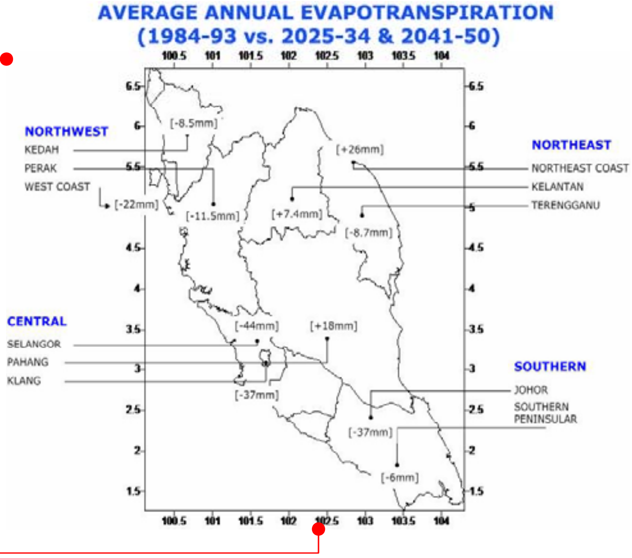


20

NAHRIM's RegHCM-PM -
Simulated Future Temperature & Evapotranspiration

Average Annual TEMP
- Max: +1.4ºC KLANG
- Min: +1.21ºC N/EAST COAST

Average Annual EVAP
- Max: +26mm N/EAST COAST
- Min: -44mm SEL



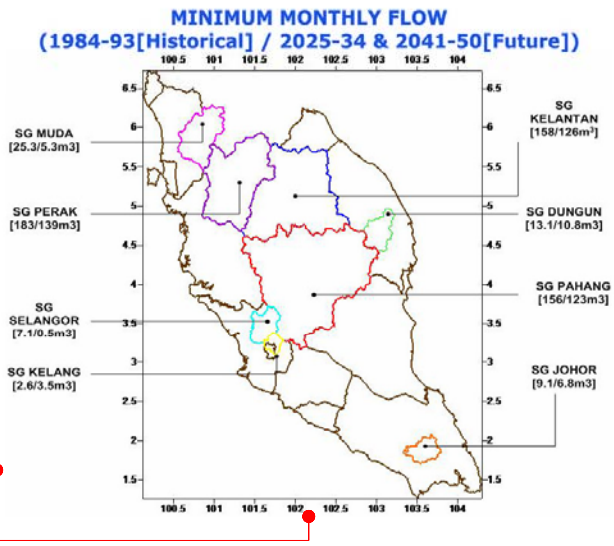
21

NAHRIM's RegHCM-PM -
Simulated Future River Flow

Mean Monthly Flow
- Max: +12% [KEL]
- Min: - 8% KLANG

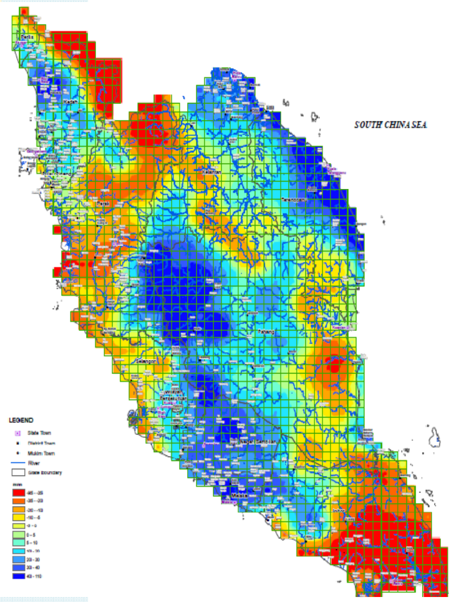
Max Monthly Flow
- Max: +47% KLANG
- Min: +0.6% [SEL]

Min Monthly Flow
- Max: -93% [SEL]
- Min: -35% KLANG

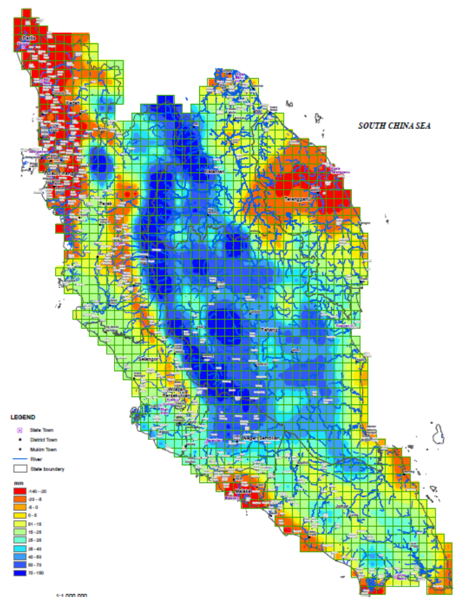


22

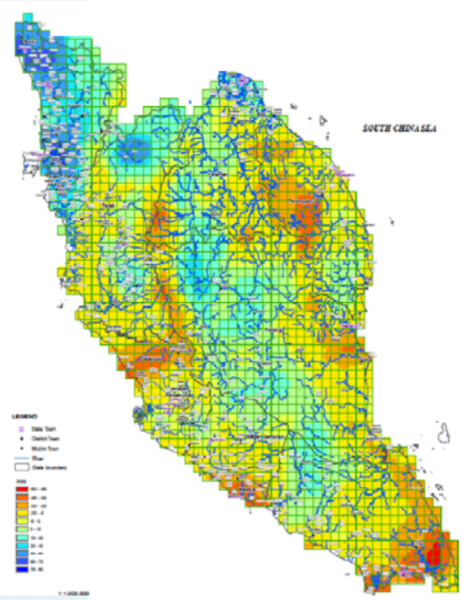
Monthly Rainfall Anomaly (April)



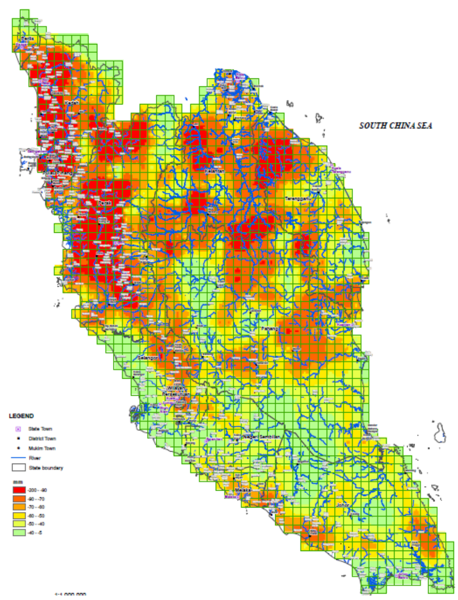
Monthly Rainfall Anomaly (May)



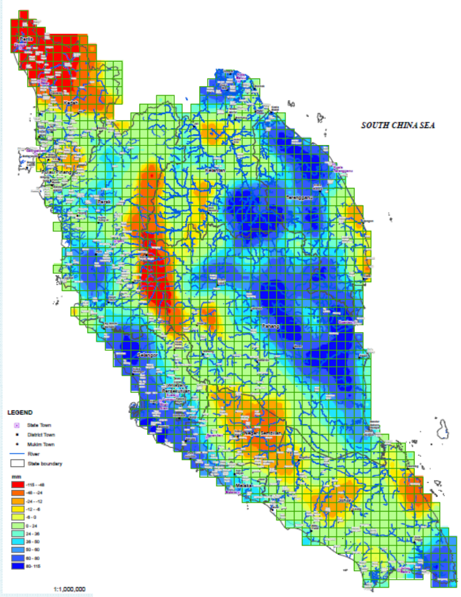
Monthly Rainfall Anomaly (June)



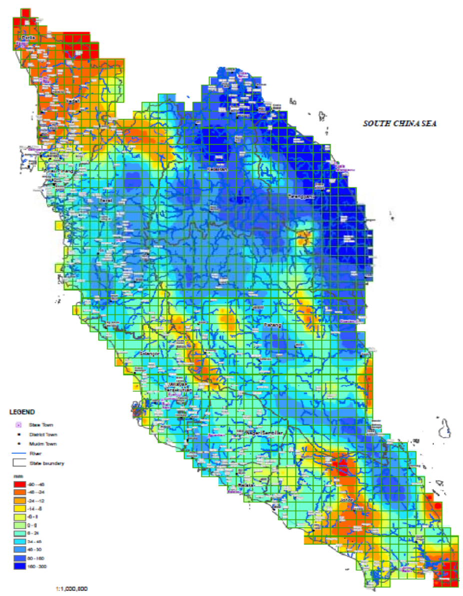
Monthly Rainfall Anomaly (August)



Monthly Rainfall Anomaly (November)



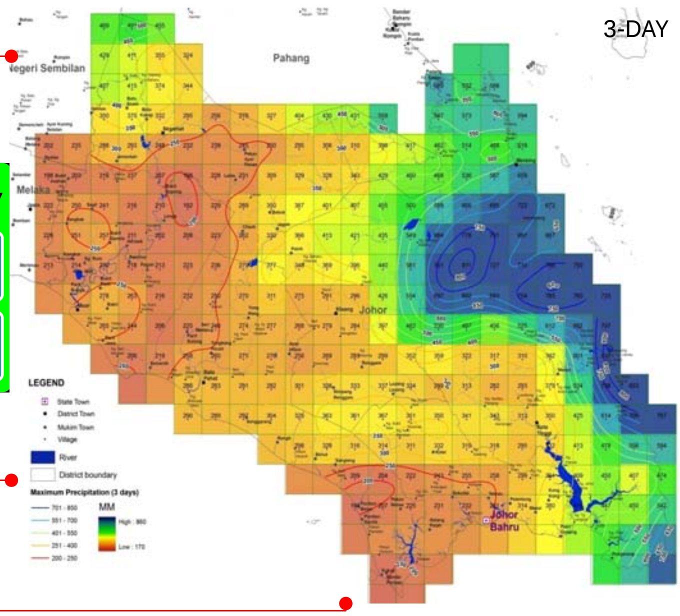
Monthly Rainfall Anomaly (December)



25

1-3 Day Annual Maxima Rainfall

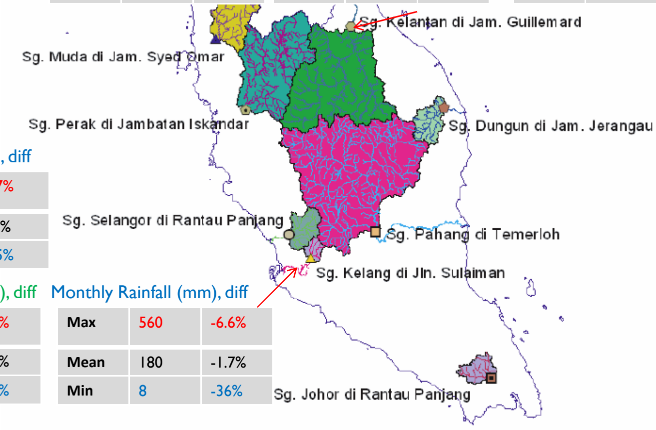
1-Day	2-Day	3-Day
Max: 720mm	Max: 785mm	Max: - 810mm
Min: 150mm	Min: 200mm	Min: 200mm



Monthly Flows (cms), diff		
Max	1950	27.0%
Mean	601	12%
Min	125	-21%

Monthly Rainfall (mm), diff		
Max	1130	21.0%
Mean	240	7.9%
Min	11	-30%

Monthly Temperature (c), diff		
Max	30	5.7%
Mean	27	4.7%
Min	22	6.7%



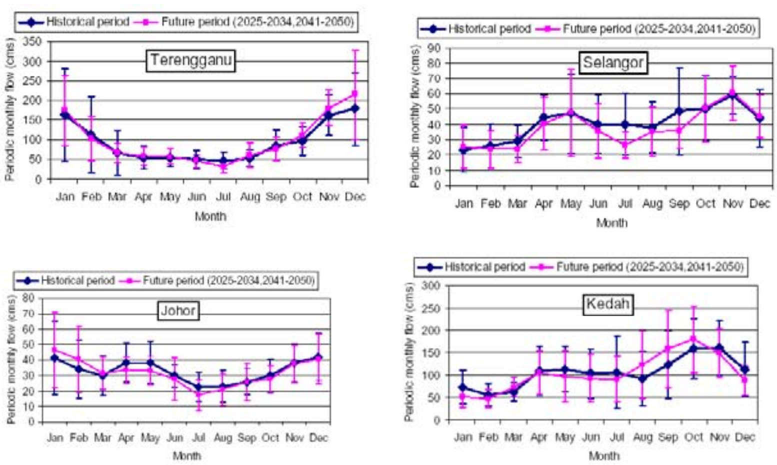
Monthly Flows (cms), diff		
Max	46	47%
Mean	13	-1%
Min	3.5	35%

Monthly Temperature (c), diff		
Max	31	6.2%
Mean	29	4.7%
Min	26	5.2%

Monthly Rainfall (mm), diff		
Max	560	-6.6%
Mean	180	-1.7%
Min	8	-36%

Average Projected Monthly Temperature, River Flows and Rainfall : 1984-1993 vs 2025-2034 , 2041-2050

Simulated Monthly River Flow Periodic Means and Standard Deviations



NAHRIM CLIMATE CHANGE PROJECTION FOR MALAYSIA

- RegHCM FOR PENINSULAR MALAYSIA
- RegHCM FOR SABAH & SARAWAK
- CLIMATE PROJECTION DOWNSCALING FOR PENINSULAR MALAYSIA AND SABAH-SARAWAK USING UK HADLEY CENTRE PRECIS MODEL
- SEA LEVEL RISE

NAHRIM's Regional Hydro-climate Model (RegHCM-SS)

- **2010:** A regional hydrologic-atmospheric model of Peninsular Malaysia called as '**Regional Hydro-climate Model of Sabah and Sarawak (RegHCM-SS)** was developed
- **Downscaling** global climate change simulation data (ECHAM5 GCM and MRI GCM2.3.2 at control run simulation and future climate simulation data) that are at very **coarse resolution** (~410km), to Peninsular Malaysia at **fine spatial resolution** (~9km) – for future period of 2010 to 2100

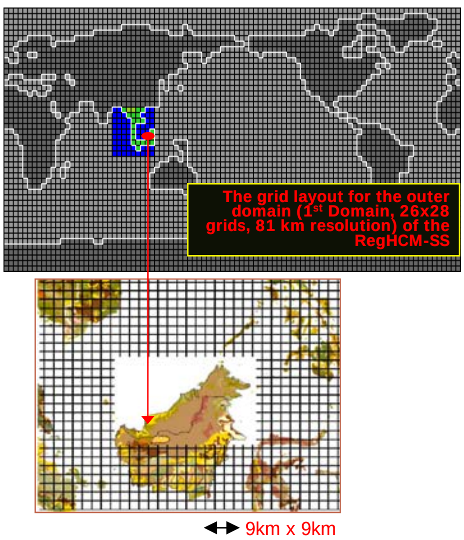
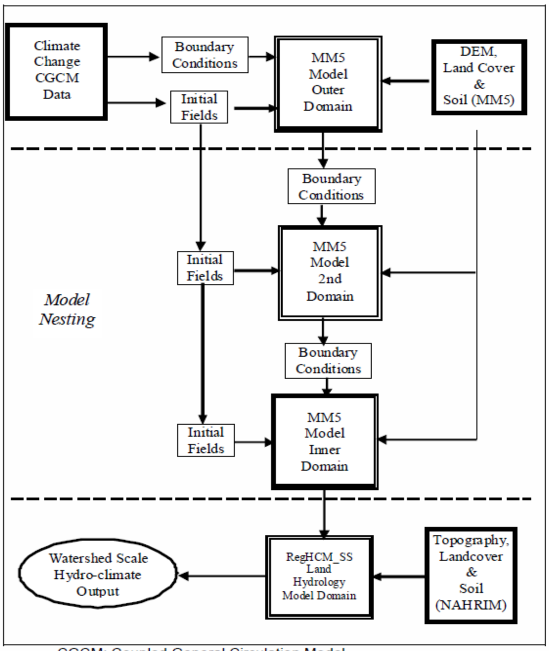


Table 1 - Global Climate Change Simulations Downscaled Over Sabah and Sarawak

Model Name	Run ID	Period	Description
MRI-CGCM2.3.2	20C	1970-2000	20th century reconstruction (20C3M) with anthropogenic forcing (greenhouse gases, sulfate)
MRI-CGCM2.3.2	SRES A1B	2010-2100	One projection under SRES A1B scenario for the 21st century
ECHAM5/MPIOM	20C_1	1970-2000	20th century reconstruction (20C3M) with anthropogenic forcing (greenhouse gases, sulfate) initialized in the year 2190 of the CTL. (EH5-T63L31_OM-GR1.5L40_20C_1)
ECHAM5/MPIOM	SRES A1B_1	2010-2100	A 21st century projection under SRES A1B scenario initialized in the year 2000 of the 20C_1. (EH5-T63L31_OM-GR1.5L40_A1B_1)
ECHAM5/MPIOM	SRES A1B_2	2010-2100	A 21st century projection under SRES A1B scenario initialized in the year 2000 of the 20C_2. (EH5-T63L31_OM-GR1.5L40_A1B_2)
ECHAM5/MPIOM	SRES A1B_3	2010-2100	A 21st century projection under SRES A1B scenario initialized in the year 2000 of the 20C_3. (EH5-T63L31_OM-GR1.5L40_A1B_3)



CGCM: Coupled General Circulation Model
NAHRIM: National Hydraulics Research Institute of Malaysia

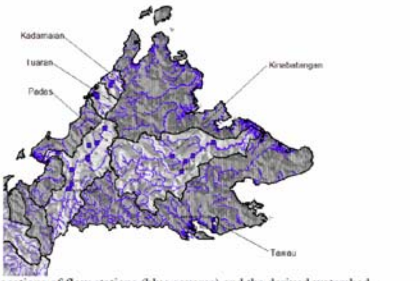


Figure 26 - Locations of flow stations (blue squares) and the derived watershed delineations of Kadamaian, Tuaran, Padas, Kinabatangan, and Tawau river basins in Sabah, Malaysia

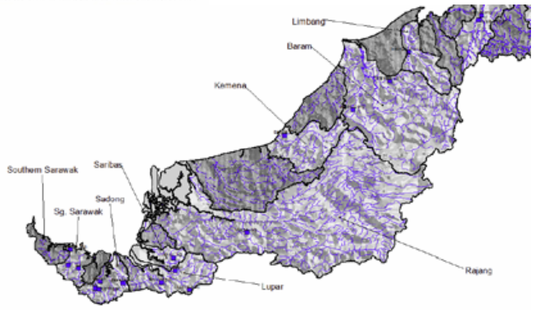


Figure 27 - Locations of flow stations (blue squares) and the derived watershed delineations of Limbang, Baram, Rajang, Kemena, Saribas, Lupar, Sadong, and Sarawak river basins in Sarawak, Malaysia

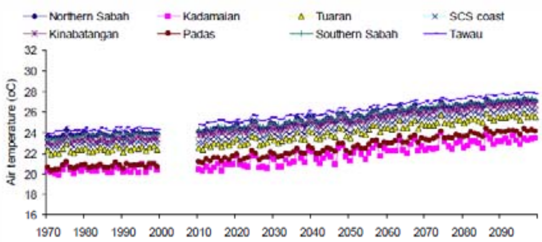


Figure 19 - Simulated sub-regional mean air temperatures in Sabah state of Malaysia

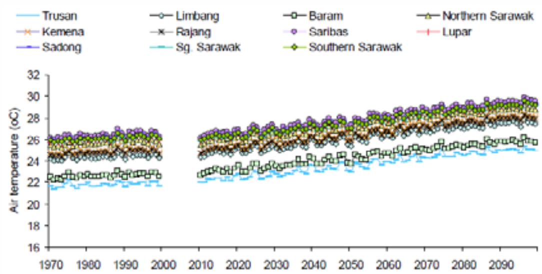


Figure 20 - Simulated sub-regional mean air temperatures in Sarawak state of Malaysia

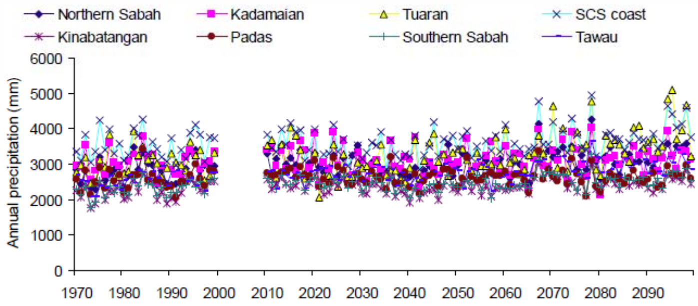


Figure 21 - Simulated sub-regional mean precipitation in Sabah state of Malaysia

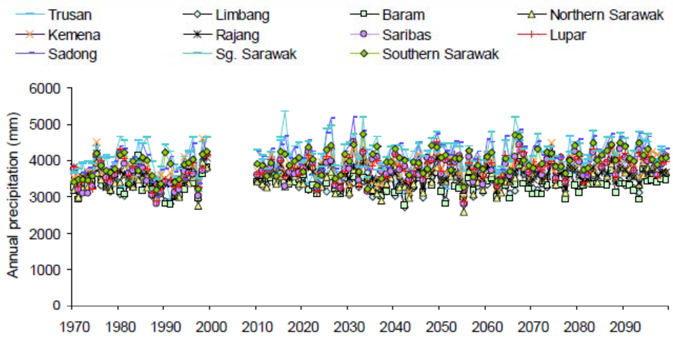


Figure 22 - Simulated sub-regional mean precipitation in Sarawak state of Malaysia

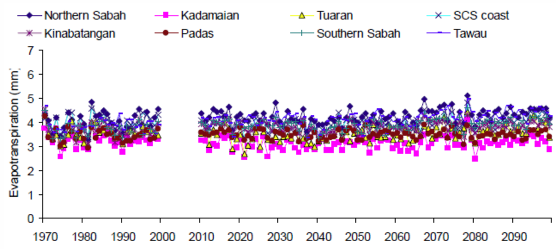


Figure 23 - Simulated sub-regional mean evapotranspiration rates in Sabah state of Malaysia

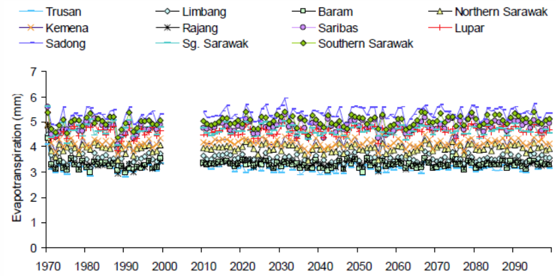


Figure 24 - Simulated sub-regional mean evapotranspiration rates in Sarawak state of Malaysia

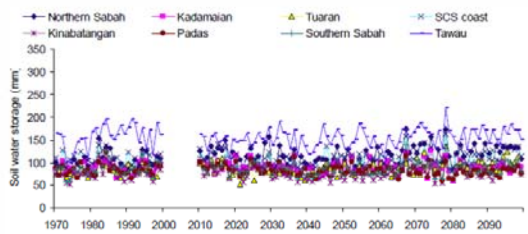


Figure 25 - Simulated sub-regional mean soil water storage in Sabah state of Malaysia

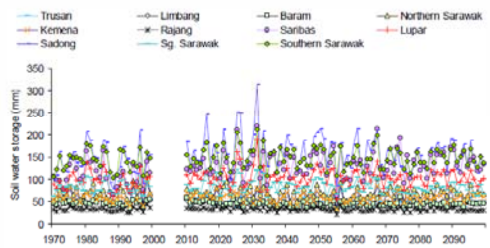
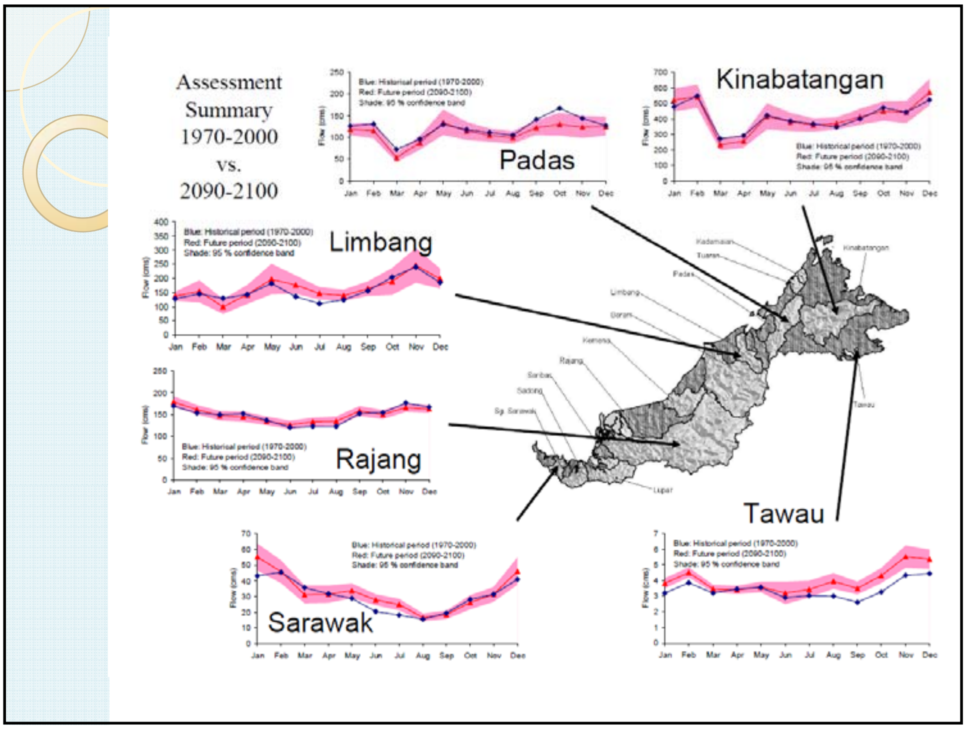


Figure 26 - Simulated sub-regional mean soil water storage in Sarawak state of Malaysia



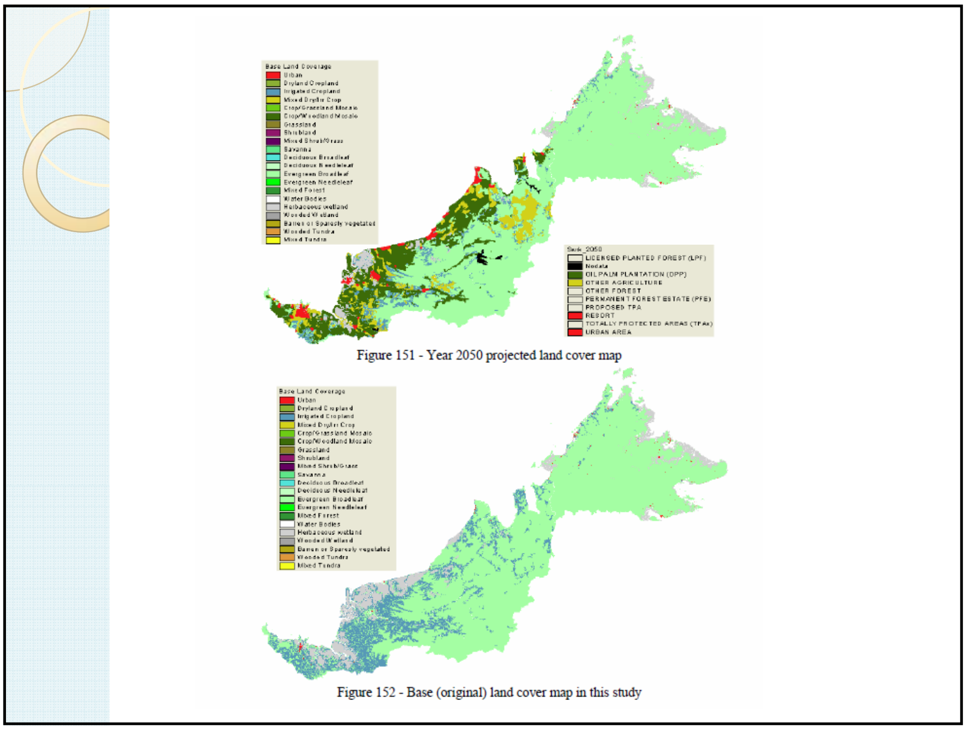


Figure 151 - Year 2050 projected land cover map

Figure 152 - Base (original) land cover map in this study

MALAYSIA CLIMATE CHANGE PROJECTION

- RegHCM FOR PENINSULAR MALAYSIA
- RegHCM FOR SABAH & SARAWAK
- CLIMATE PROJECTION DOWNSCALING FOR PENINSULAR MALAYSIA AND SABAH-SARAWAK USING UK HADLEY CENTRE PRECIS MODEL

PRECIS

"Providing REgional Climates for Impact Studies"
Regional Climate Model (RCM) or PRECIS

PRECIS EXPERIMENTS

- Evaluates the performance of three GCMs including HadAM3P, HadCM3 and ECHAM5,
- Downscaled to 25 km x 25 km resolution using PRECIS Regional Climate Model,
- Simulating the past and present climate over Malaysia and provides future climate projection

- **Domain: ~25x25km, 19 vertical hybrid coordinates.**

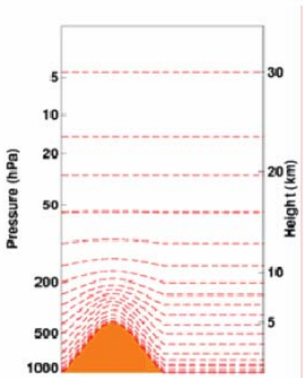


Figure 2: PRECIS hybrid vertical coordinate system (after Cox et al. 1999)

NAHRIM PRECIS Ver 1.9.2 Lab.

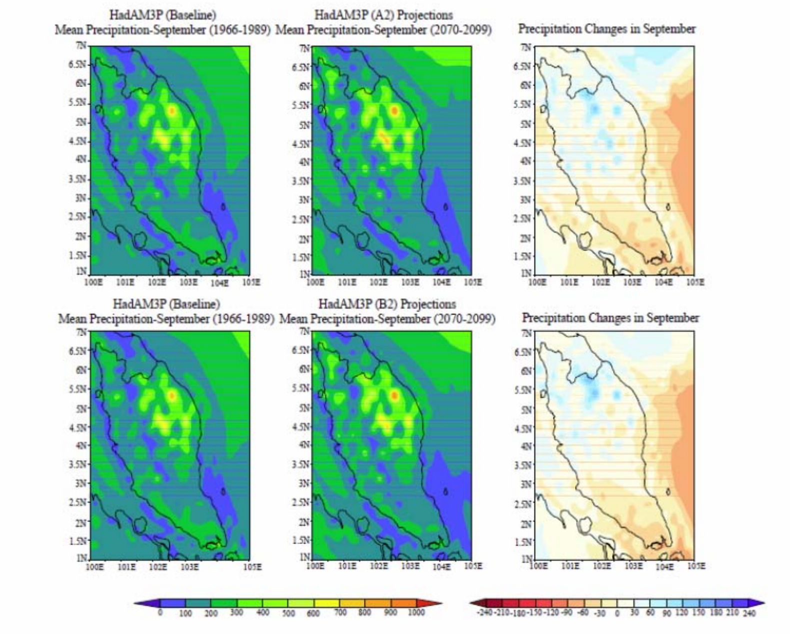
Larger Domain to incorporate:-
-cyclogenesis ,
-IOD,
-MJO ,
-Monsoon surge
-Near equatorial trough

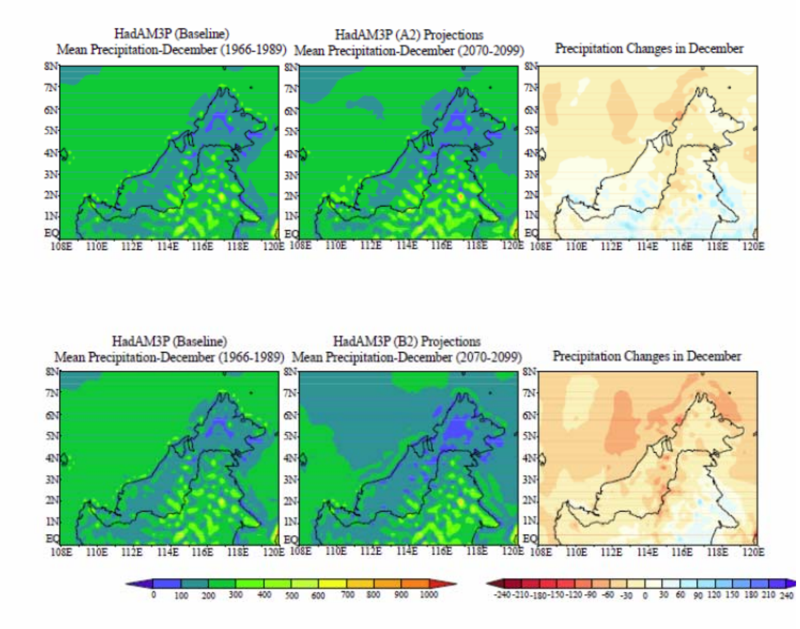
Version 1.9.2 allows the user to choose between the MOSES1 and MOSES2 land surface schemes. MOSES 2.2 is an improved version of the original MOSES 1 land-surface scheme which includes a tiled representation of subgrid heterogeneity and includes improved higher-resolution descriptions of land-surface characteristics including a representation of the annual cycle of vegetation.

Experiments (Boundary conditions)

- ERA 40 (1969-2000)
- HadAM3P baseline (1965-1990)
- HadAM3P A2 (2070-2100)
- HadAM3P B2 (2070-2010)
- HadCM3 A1B (1969-2100)
- ECHAM5 A1B (1969-2100)

- Output resolutions: Daily.





PRECIS Results and Findings

- Overall all models --- HadCM3, HadAM3P and ECHAM5 performed equally in simulating Tmean
- Projected Tmean is between 3-4°C.
- Simulated Tmax and Tmin do not match well to that of the CRU and this may also associated with the inadequacy of the CRU dataset
- Both PRECIS/HadCM3 and PRECIS/HadAM3P performed equally with large correlation with PRECIS/EAR40.
- The outputs of PRECIS/ECHAM5 do not correlate well with PRECIS/EAR40 especially during northeast monsoon, and also southwest monsoon.
- Both PRECIS/HadCM3 and PRECIS/HadAM3P projected minimal changes of mean precipitation based area averaged precipitation. However, spatially significant changes indicated in some areas i.e. reduction of precipitation during northeast monsoon and increase in southwest monsoon.

THE STUDY OF THE IMPACT OF CLIMATE CHANGE ON SEA LEVEL RISE AT PENINSULAR MALAYSIA AND SABAH&SARAWAK

The main objective of this project may be stated as:

To carry out a study on the projection of the sea level changes along the Peninsular Malaysia (PM) and Sabah and Sarawak (SS) coastlines for the 21st century in order to determine the potential inundation of the coastal areas of PM and SS due to the expected climate change during the 21st century.

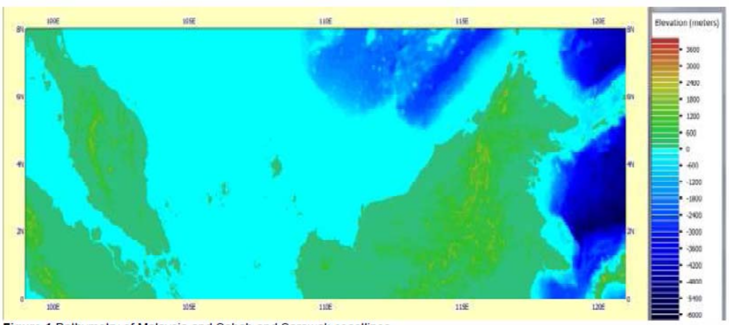


Figure 1 Bathymetry of Malaysia and Sabah and Sarawak coastlines

1 arc-minute bathymetry data of PM and SS coastlines

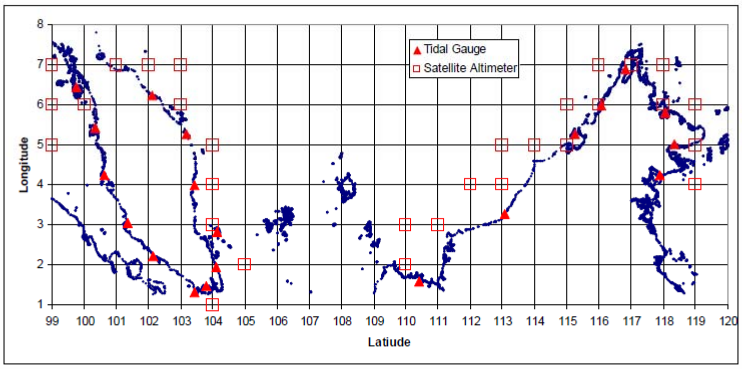


Figure 2 Locations of the tidal gauge stations and the centers of the satellite altimeter data grids that were considered for the linear trend analyses

Table 1 Sea level rise rates calculated by linear regression analyses of tidal gauge data around PM and SS coastlines

Location			Period of analysis		Slope (cm/yr)	
Name	Latitude	Longitude	Start	End	by daily averages	by daily maximums
P. Langakawi	06 25 51	99 45 51	12/1/1985	8/25/2009	0.19	0.20
P. Pinang	05 25 18	100 20 48	12/1/1984	8/25/2009	0.23	0.17
Lumut	04 14 24	100 36 48	1/1/1985	1/12/2009	0.21	0.22
P. Klang	03 03 00	101 21 30	1/1/1984	12/2/2007	0.13	0.23
Tg. Keling	02 12 54	102 09 12	12/1/1984	8/18/2009	0.13	0.13
Kukup	01 19 31	103 26 34	1/1/1996	12/31/2008	0.30	1.22
J. Bahru	01 27 42	103 47 30	1/1/1984	1/17/2009	0.23	0.14
Tg. Sedili	01 55 54	104 06 54	11/1/1986	8/18/2009	0.12	0.16
P. Tioman	02 48 26	104 08 24	12/3/1985	8/17/2009	0.18	0.29
Tg. Gelang	03 58 30	103 25 48	1/1/1984	8/17/2009	0.26	0.33
Chendering	05 15 54	103 11 12	11/1/1984	12/11/2008	0.22	0.27
Geting	06 13 35	102 06 24	11/1/1986	8/18/2009	0.13	0.31
Sejingkat	01 34 58	110 25 20	4/1/1996	12/31/2008	-0.58	-1.15
Bintulu	03 15 44	113 03 50	4/30/1992	11/29/2009	0.02	0.47
K. Kinabalu	05 59 00	116 04 00	7/1/1987	1/1/2005	0.44	0.18
Kudat	06 52 46	116 50 37	1/1/1996	1/1/2009	0.30	1.20
Sandakan	05 48 36	118 04 02	8/20/1993	1/16/2009	0.41	1.17
Lahad Datu	05 01 08	118 20 46	1/1/1996	1/17/2009	0.36	0.58
Tawau	04 14 00	117 53 00	7/1/1987	1/18/2009	0.35	0.35
Labuan	05 16 22	115 15 00	1/1/1996	3/13/2008	0.07	1.11

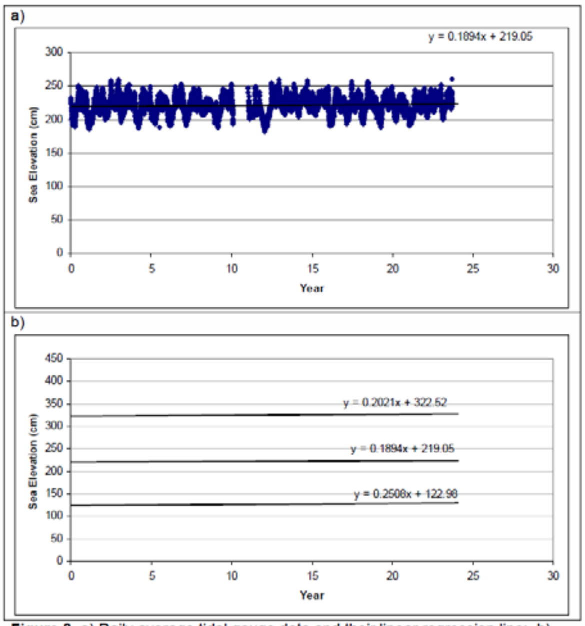


Figure 3 a) Daily average tidal gauge data and their linear regression line; b) Linear regression lines for sea levels using daily maximum, daily average and daily minimum tidal gauge data at P. Langakawi.

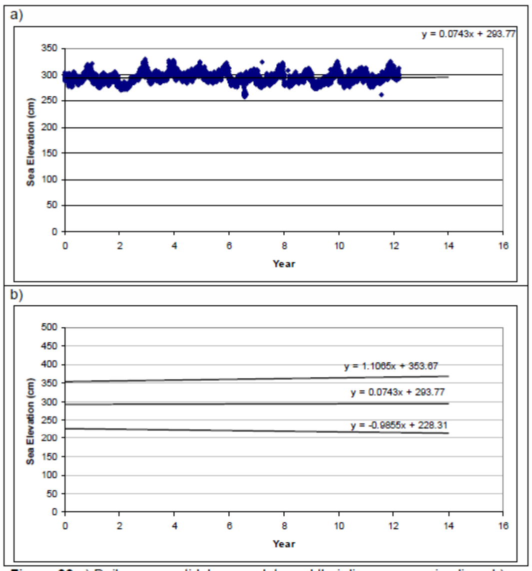


Figure 22 a) Daily average tidal gauge data and their linear regression line; b) Linear regression lines for sea levels using daily maximum, daily average and daily minimum tidal gauge data at Labuan

Preliminary results:

The general trend in sea level rise along PM and SS coastlines in the last 5 years is significantly higher than the general trend corresponding to the previous 20 years.

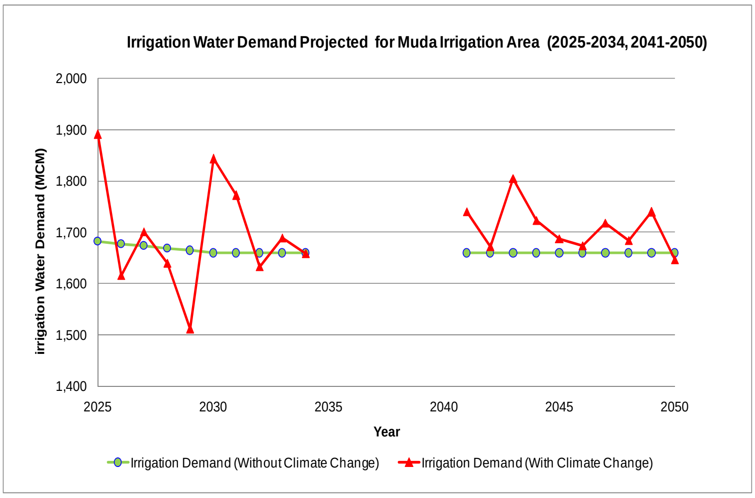
Meanwhile, the linear trends that are calculated from 17 years of satellite altimeter data give much more weight to the last 5 years of sea level observations than about 25 years of tidal gauge data that are generally available around PM and SS coastlines.

From an analysis of the Figures 3 – 22 it can be inferred that the linear trend regression lines for the daily sea level maxima along the PM and SS coastlines are significantly above the corresponding linear trends for the daily sea level averages.

OUTLINE

- INTRODUCTION
- OBSERVED AND PROJECTED CLIMATE CHANGE
- VULNERABILITY AND IMPACT ASSESSMENT ON WATER INFRASTRUCTURE
- WAY FORWARD

IMPACT ON WATER RESOURCES



Demand increases under CC due to higher Evapotranspiration in Main Season

Water Surplus/Deficit for Muda Irrigation Scheme under Climate Change Scenario (Projected Condition with Initial Full Dam Supply)-MCM

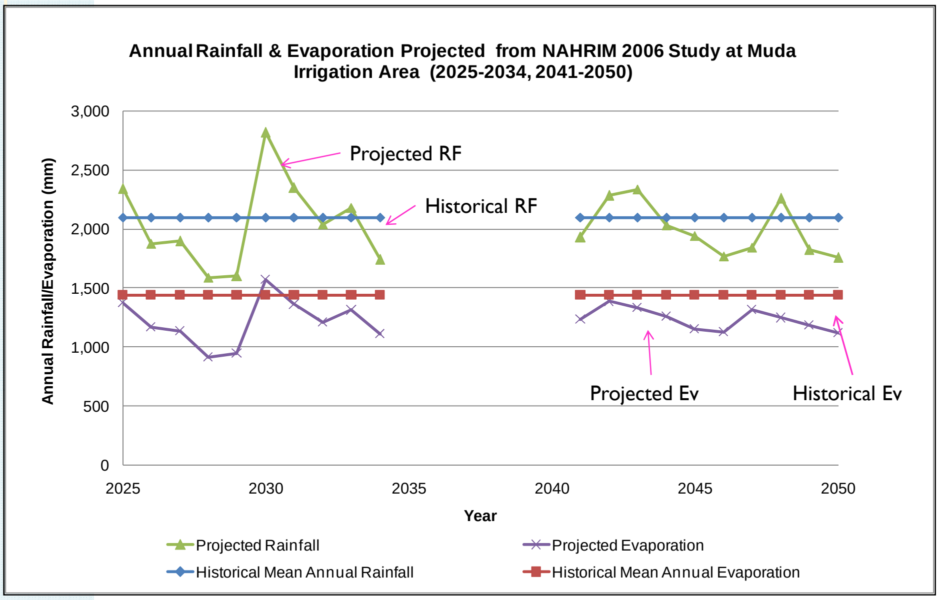
Month/ Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2025	1447	1445	1225	1017	832	817	737	750	782	1021	1021	1001
2026	1000	1021	862	773	594	582	521	545	343	189	-37	46
2027	-4	6	-163	-189	-134	-13	-16	43	303	286	430	442
2028	436	464	311	138	-4	-56	-34	2	-161	97	174	129
2029	132	162	13	-140	-136	-67	-2	-5	-173	163	-14	-49
2030	78	171	44	54	86	127	183	425	364	523	572	552
2031	547	569	514	698	599	941	956	1003	867	898	859	799
2032	766	776	624	513	490	553	757	931	992	1019	1053	1030
2033	1003	1040	833	643	548	672	670	836	718	874	885	929
2034	937	962	813	663	594	576	549	584	430	194	117	66
Average 2025-2034	634	662	508	417	347	413	432	511	447	526	506	495
2041	1456	1453	1335	1280	1216	1368	1375	1509	1509	1509	1425	1427
2042	1399	1410	1214	1060	1028	1036	1051	1250	1094	1085	900	870
2043	781	804	607	470	408	427	401	453	523	471	584	701
2044	740	787	627	437	755	943	1019	1097	983	1020	827	770
2045	717	715	561	361	184	149	177	210	120	268	224	197
2046	181	195	53	-142	-166	-46	-51	2	68	555	589	604
2047	610	636	470	398	298	330	370	384	189	47	-106	-61
2048	-70	-15	-194	-210	-63	-82	-25	80	-64	173	-23	-156
2049	19	50	-115	-152	-8	-26	-7	11	-88	51	55	18
2050	-12	17	-140	-197	-105	-29	242	342	344	535	459	425
Average 2041-2050	582	605	442	330	355	407	455	534	468	572	493	480

Assume full dam storage at Jan 2025 and Jan 2041:= 1509 MCM.

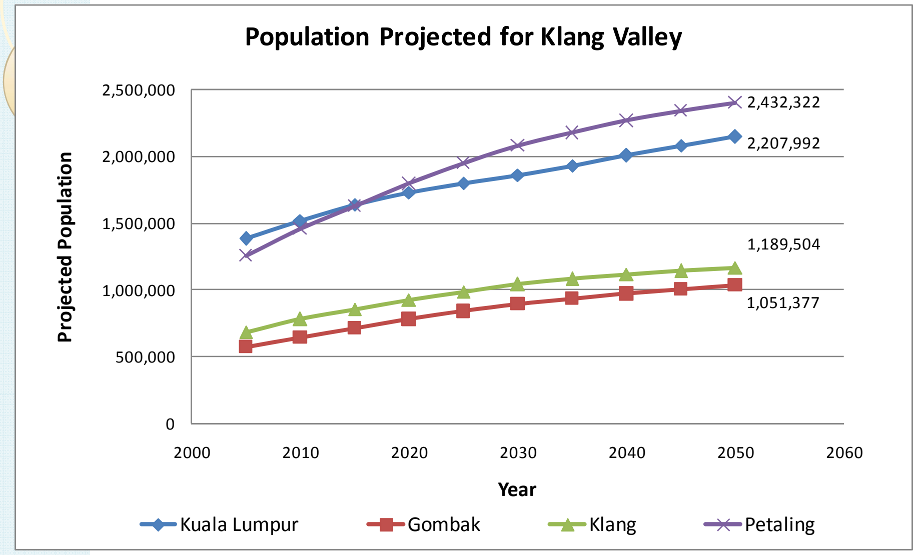
Water Demand-Availability for Muda Irrigation Scheme with Dam Storage

- For water demand-availability assessment, it shows that 46 months of water deficit (19%) and 194 months of water surplus (81%) over the 240 months projection period.
- Deficit mainly occurs in Mar to July in 2027-2029 and 2048-2050
- 4 out of 20 planting seasons facing water deficits for the first 10-years, and 4 out of 20 for the second 10-year periods, most off-season crops
- Water deficit is mainly due to:
  - lower RF esp during 1st 10-year period.
  - Large variability in the monthly RF distribution
  - High Monsoonal evapotranspiration

Projected Annual Rainfall and Evapotranspiration at Muda Irrigation Scheme (2025-2034 & 2042-2050) versus Simulated Historical Mean (mm)



Climate Change Impact on Water Supply Demand for Klang Valley.



District	Total Water Demand (Mld)				
	2010	2020	2030	2040	2050
Kuala Lumpur	1,247	1,607	1,748	1,898	2,021
Gombak	538	690	768	905	957
Petaling	848	1,048	1,121	1,201	1,259
Klang	1,343	1,804	1,995	2,199	2,298
Total	**3,976**	**5,149**	**5,632**	**6,203**	**6,534**

Water Supply-Demand Scenario for Klang Valley Water-Supply under Climate Change (Projected Condition with Initial Full Dam Storage)-MCM

Month/ Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2025	284	141	16	-20	-57	-116	-135	-118	-141	-92	53	118
2026	148	112	90	120	152	88	-22	-101	-131	-117	-1	44
2027	9	-36	-27	-48	-100	-124	-144	-141	-149	-147	40	92
2028	32	-81	-128	-98	-129	-145	-154	-158	-159	-65	48	10
2029	-59	-37	-87	-56	-104	-135	-143	-127	-144	-120	23	81
2030	64	125	154	221	463	485	414	302	173	61	169	191
2031	144	35	20	70	101	88	-7	-130	-145	55	265	405
2032	448	385	282	327	261	252	192	148	62	13	98	69
2033	-16	-70	-54	-111	153	136	36	-88	-140	45	49	76
2034	30	-39	-68	-31	-14	-76	-117	-121	-137	-76	57	92
Average	108	53	20	37	73	45	-8	-53	-91	-44	80	118
2041	260	92	-77	-158	73	2	-124	-75	-135	125	267	273
2042	182	67	-73	2	-57	-125	-152	-140	-150	-168	-133	-124
2043	-159	-169	-161	-26	-29	-105	-117	-150	-12	7	-50	-2
2044	-101	-142	-154	-145	-153	-162	-179	-115	-144	-81	-69	-108
2045	-109	-155	-155	19	-22	-95	-144	-161	-167	-46	-9	-101
2046	-141	-159	-163	-110	-6	-99	-147	-166	-117	-45	0	-99
2047	-23	-112	-131	-72	-136	-157	-165	-31	-113	-112	-82	-137
2048	-167	-173	-177	-143	128	213	151	45	-89	-26	-50	-115
2049	-158	-145	-163	104	221	179	64	-91	-161	-77	6	-16
2050	13	-83	-121	-75	-95	-143	-152	-172	-177	-124	5	-89
Average	-40	-98	-137	-60	-8	-49	-96	-106	-126	-55	-12	-52

Assume full dam storage at Jan 2025 and Jan 2041:= 423 MCM.

Water Supply-Demand Scenario for Klang Valley Water-Supply under Climate Change (Projected Condition)- MCM

Month/ Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2025	-139	-144	-125	-36	-57	-116	-135	-118	-141	-92	53	65
2026	30	-35	-22	30	32	-64	-110	-101	-131	-117	-1	44
2027	-35	-44	-27	-48	-100	-124	-144	-141	-149	-147	40	52
2028	-61	-113	-128	-98	-129	-145	-154	-158	-159	-65	48	-38
2029	-69	-37	-87	-56	-104	-135	-143	-127	-144	-120	23	58
2030	-18	61	29	68	241	22	-71	-112	-129	-112	108	22
2031	-47	-109	-15	50	31	-13	-95	-130	-145	55	210	139
2032	44	-64	-103	45	-66	-9	-60	-45	-85	-50	85	-29
2033	-85	-70	-54	-111	153	-17	-100	-124	-140	45	4	27
2034	-82	-128	-147	-152	-145	-162	-162	-158	-149	-158	-1	13
Average	**-46**	**-68**	**-68**	**-31**	**-14**	**-76**	**-117**	**-121**	**-137**	**-76**	**57**	**35**
2041	-163	-168	-169	-158	73	-71	-126	-75	-135	125	142	7
2042	-91	-115	-140	2	-59	-125	-152	-140	-150	-168	-133	-124
2043	-159	-169	-161	-26	-29	-105	-117	-150	-12	7	-57	-2
2044	-101	-142	-154	-145	-153	-162	-179	-115	-144	-81	-69	-108
2045	-109	-155	-155	19	-41	-95	-144	-161	-167	-46	-9	-101
2046	-141	-159	-163	-110	-6	-99	-147	-166	-117	-45	0	-99
2047	-23	-112	-131	-72	-136	-157	-165	-31	-113	-112	-82	-137
2048	-167	-173	-177	-143	128	85	-62	-106	-134	-26	-50	-115
2049	-158	-145	-163	104	117	-42	-115	-156	-161	-77	6	-22
2050	13	-96	-121	-75	-95	-143	-152	-172	-177	-124	5	-94
Average	**-110**	**-143**	**-153**	**-61**	**-20**	**-91**	**-136**	**-127**	**-131**	**-55**	**-25**	**-80**

Water Demand-Availability for Klang Valley Water Supply

- Water deficit is projected to occur for 154 out of 240 months (64 %) under climate change scenario.

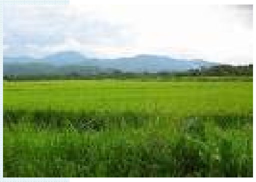
- The water deficit is mainly due to:
- Larger variability of the projected monthly rainfall.
- New water projects (eg. Inter-state transfer) are not considered – existing water sources are insufficient to meet the future water demand
- Increasing water demand with time horizon : 24 and 62 deficit months in 1st and 2nd 10-year period respectively.
  - Of the 240 months, 99 months (41%) having monthly rainfall higher than historical mean while 141 months (59%) having rainfall lower than the historical mean.

Possible Climate Change Implications

- In Klang Valley, water rationing would have to be imposed like the past droughts due to the very prolong consecutive months of the water deficit.

- The most severe drought occurs in July 2044 with a peak deficit of -179 MCM/month.

Identification of Anticipated Impacts



- **Oil palm** : a temperature of 22°C – 32°C with a mean annual rainfall of 2000 – 3500 mm in order to yield and sustain an optimum number of crops; the yield will decrease by approximately 30% if the temperature increases by 2°C above optimum levels and rainfall decrease by 10 percent;
- **Rice cultivation** : **temperature of 24°C – 34°C** and **optimum rainfall of 2000 mm per year** is ideal for rice cultivation; an increase in daily **temperature above 34°C**, it will **decrease the rice** yields. Floods and droughts early in growing season could decrease yields by as much as 80 percent;
- **Rubber production** : an optimum annual temperature of 23°C – 30°C with a mean annual rainfall of 1500-2500 mm is needed. Increase in annual temperatures above 30°C coupled with a reduction in rainfall below 1500mm will retard growth and prolong immaturity resulting in up to a 10 percent reduction in yields;

Identification of Anticipated Impacts

Bekok Dam

- Generally, **water resources** are adequate but urban areas might experience disruption of water supply during extreme drought events;
- Increase & decrease volume of rainfall : potential factor for droughts and floods;
- In turn, influence policy decision and enhance water resources management

Tanjung Piai Mangrove

NCVI study : based on the global-high (worst case) projection for sea level rise (SLR) of 10mm/year (1 meter by the end of the century), an estimated 1820 ha of coastal land at Tanjung Piai and 148 ha at Pantai Chenang, Langkawi will be inundated;

Redang Island

Increase in sea surface temperature (SST) is one of the identified stressors for aquatic life such as coral reefs which thrive at optimum temperatures of 25°C to 29°C

WAY FORWARD

- NAHRIM will continue with extension study of Hydroclimate Projection for Peninsular Malaysia using more Global Climate Models (GCM) and down to 3 km resolution for selected river basins.
- Embarking in R&D for Adaptation to Climate Change: **Impact Assessment of Changed Hydroclimate on Water Infrastructure in Malaysia**
  - Approved by the 4th National Water Resources Council (NWRC) Meeting on 20th August 2008
- Networking at Regional level (ASIA PACIFIC and SOUTHEAST ASIA)
  - NAHRIM as Water Knowledge Hub for Climate Change Adaptation (WKHCCA)
  - AguaJaring/CapNet: IWRM Capacity Building

69

THANK YOU

ahmadj@nahrim.gov.my
zubaidi@nahrim.gov.my

http:/ www.nahrim.gov.my

??

FOLLOWING PARTS ARE

NOT TO BE PRINTED

JUST EXTRA NOTE

CLIMATE PREDICTION

A climate prediction or climate forecast is the result of an attempt to produce a most likely description or estimate of the actual evolution of the climate in the future, e.g. at seasonal, inter-annual or long-term time scales.

CLIMATE PROJECTION

A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasise that climate projections depend upon the emission/concentration/ radiative forcing scenario used, which are based on assumptions, concerning, e.g., future socio-economic and technological developments, that may or may not be realised, and are therefore subject to substantial uncertainty.

http://www.ipcc.ch/ipccreports/tar/wg1/518.htm

The distinction between prediction and projection is straightforward:

A projection is a conditional statement: X will happen if Y. It is ok for X to be probabilistic, eg X = "The distribution over delta T in 2100 is 3 +- 1.5 C" and Y = "CO2 doubles".

A prediction removes the conditional, usually by substituting Y with its most likely value, eg: "CO2 will double, therefore the distribution over delta T in 2100 is 3 +- 1.5 C".
If you like, a prediction is the maximum likelihood projection.

SRES (Special Report on Emissions Scenarios) (2001)

A1

- Rapid economic growth.
- A global population that reaches 9 billion in 2050 and then gradually declines.
- The quick spread of new and efficient technologies.
- A convergent world - income and way of life converge between regions. Extensive social and cultural interactions worldwide.

There are subsets to the A1 family based on their technological emphasis:

- **A1FI** - An emphasis on fossil-fuels (fossil fuel intensive).
- **A1B** - A balanced emphasis on all energy sources (balanced).
- **A1T** - Emphasis on non-fossil energy sources (predominantly nonfossil fuel).

A2

- A world of independently operating, self-reliant nations.
- Continuously increasing population.
- Regionally oriented economic development.
- Slower and more fragmented technological changes and improvements to per capita income.

B1

- Rapid economic growth as in A1, but with rapid changes towards a service and information economy.
- Population rising to 9 billion in 2050 and then declining as in A1.
- Reductions in material intensity and the introduction of clean and resource efficient technologies.
- An emphasis on global solutions to economic, social and environmental stability.

B2

- Continuously increasing population, but at a slower rate than in A2.
- Emphasis on local rather than global solutions to economic, social and environmental stability.
- Intermediate levels of economic development.
- Less rapid and more fragmented technological change than in B1 and A1.

Identification of Anticipated Impacts on the climate

The projections based on the medium range emission scenario indicate a **1.5°C to 2.0°C** increase in surface air temperature by 2050