

Pelatihan CAP – Day 1

Basis Ilmiah Perubahan Iklim Tingkat Kota

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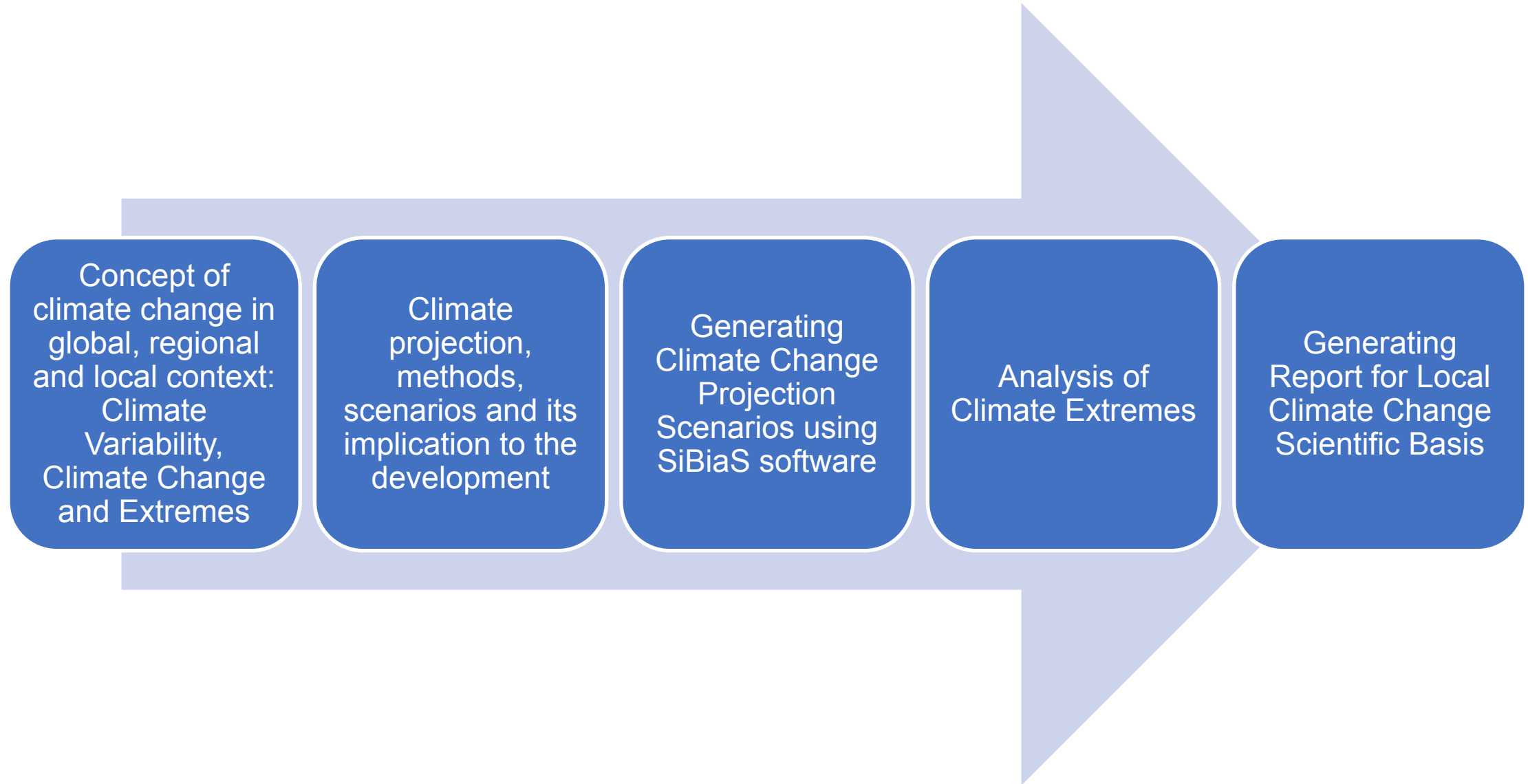
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Materi Pelatihan



Modul Pelatihan

TRAINING MODULE FOR STATISTICAL DOWNSCALING (IN BAHASA)

Proyeksi Iklim menggunakan Luaran GCM CMIP5:
Statistical Bias Correction for Climate Scenarios
(SiBiaS) versi 1.2 [Panduan Pengguna]

Departemen Geofisika dan Meteorologi
Fakultas Matematika dan Ilmu Pengetahuan Alam
Institut Pertanian Bogor
2021



MODUL

Variabilitas dan Perubahan Iklim serta
Pemodelan Iklim menggunakan *Statistical
Downscaling*
2021

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TRAINING MODULE Analisis Iklim Ekstrem dan Peluang Climate-Related Hazard

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2021

2021

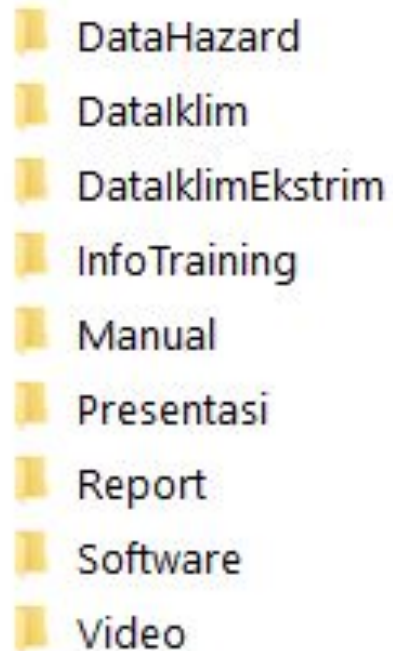
Template Penulisan

Laporan Basis Saintifik
Perubahan Iklim di Wilayah Perkotaan

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Dukungan Data dan Software



- Software SiBiaS >> proyeksi curah hujan dan suhu bulanan
- Google Collab >> proyeksi indeks ekstrim

Konsep Perubahan Iklim dalam Konteks Global, Regional dan Lokal

Variabilitas Iklim, Perubahan
Iklim dan Ekstrem

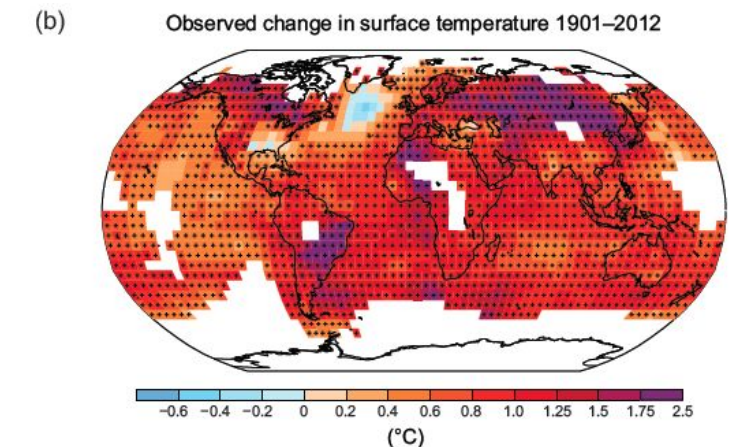
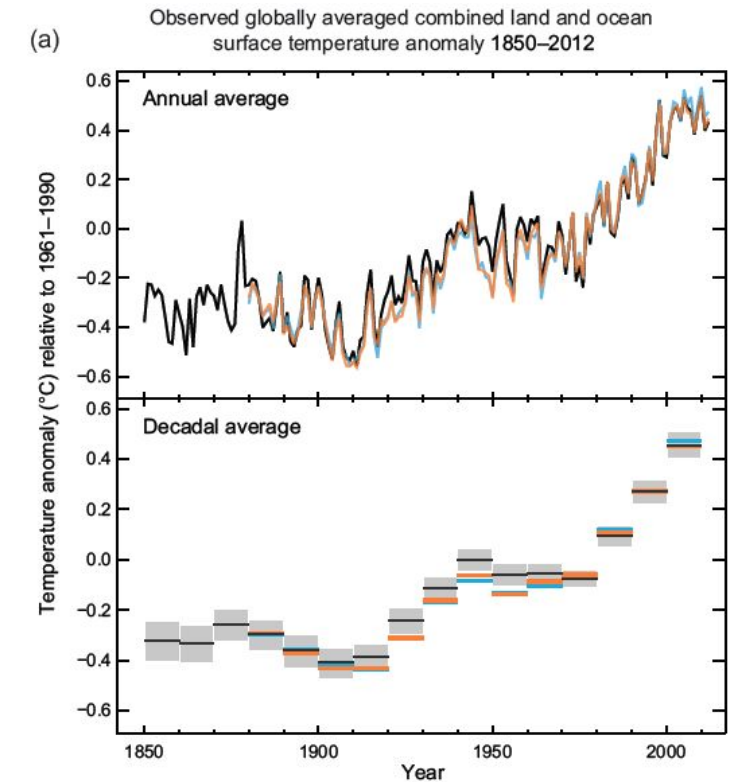
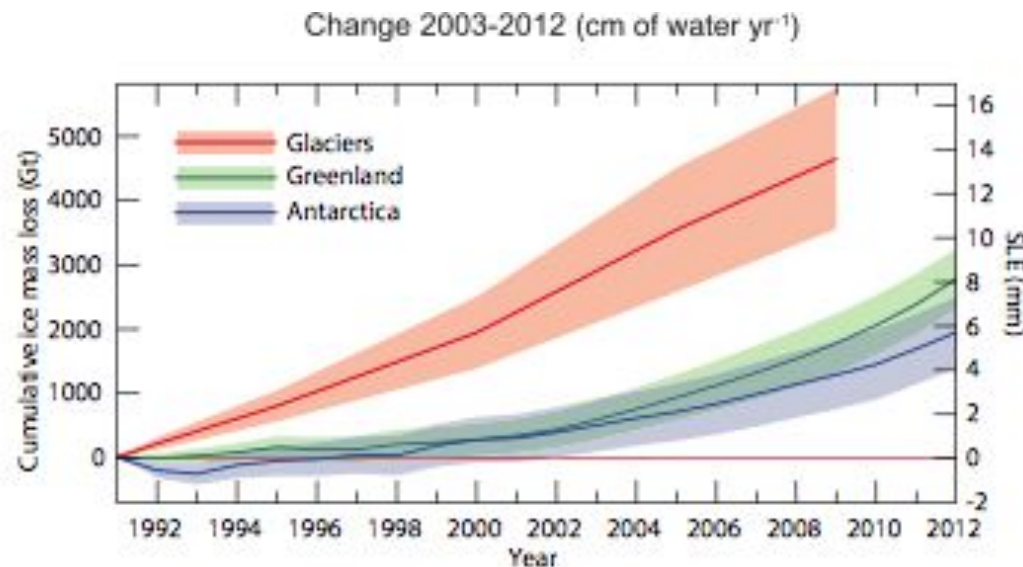


MENGAPA PERLU KAJIAN IKLIM DI INDONESIA?

1. Perubahan Sistem Iklim Global: Bukti Pemanasan Global dan Perubahan Iklim Akibat Faktor Alami dan Antropogenik

“Pemanasan pada sistem iklim tidak diragukan lagi, dan sejak 1950-an, banyak perubahan yang diamati belum pernah terjadi sebelumnya selama beberapa dekade hingga ribuan tahun. Atmosfer dan lautan telah menghangat, jumlah salju dan es telah berkurang, permukaan laut telah meningkat, dan konsentrasi gas rumah kaca telah meningkat”

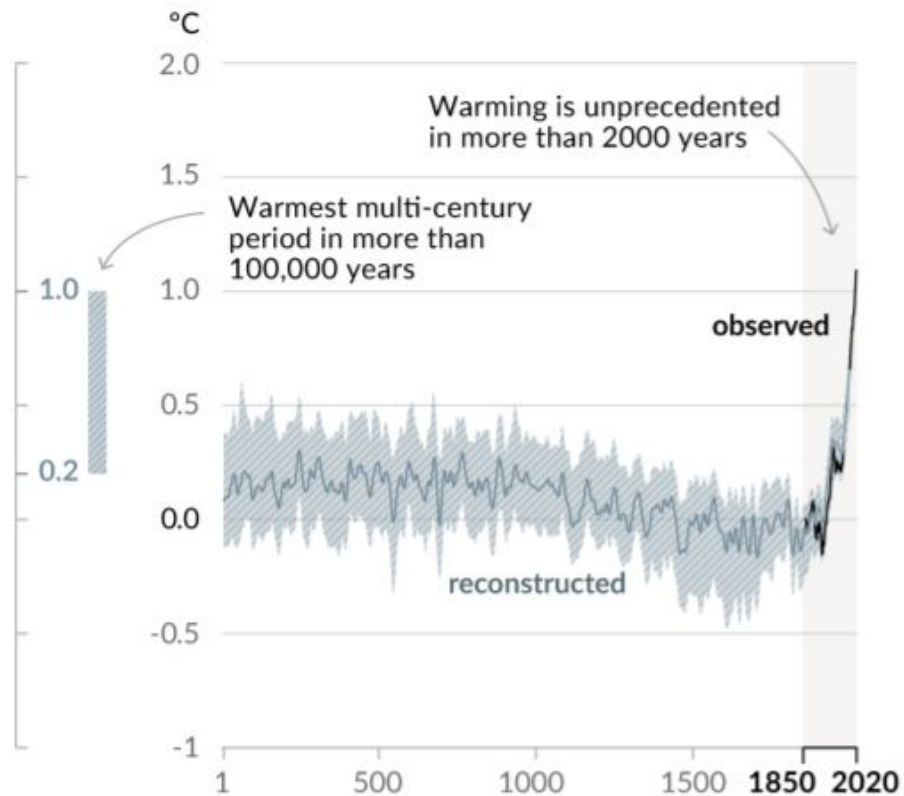
IPCC (2013)



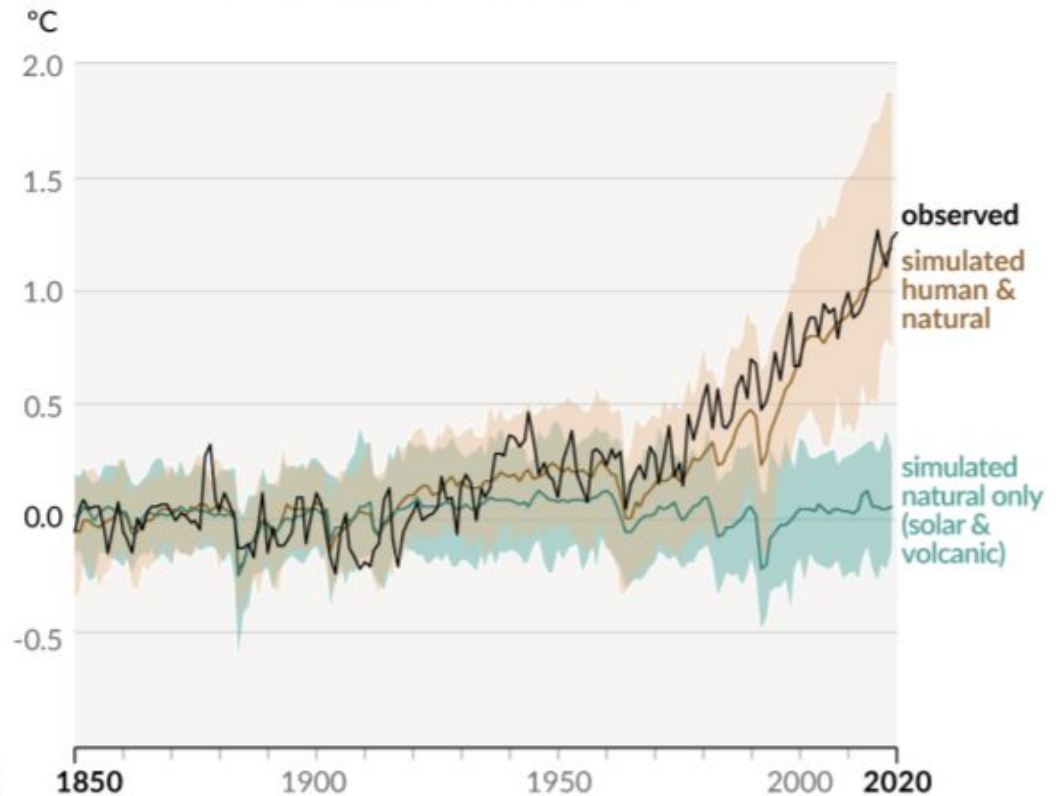
Pengaruh manusia telah menghangatkan iklim pada tingkat yang belum pernah terjadi sebelumnya setidaknya dalam 2000 tahun terakhir

Changes in global surface temperature relative to 1850-1900

a) Change in global surface temperature (decadal average) as **reconstructed** (1-2000) and **observed** (1850-2020)



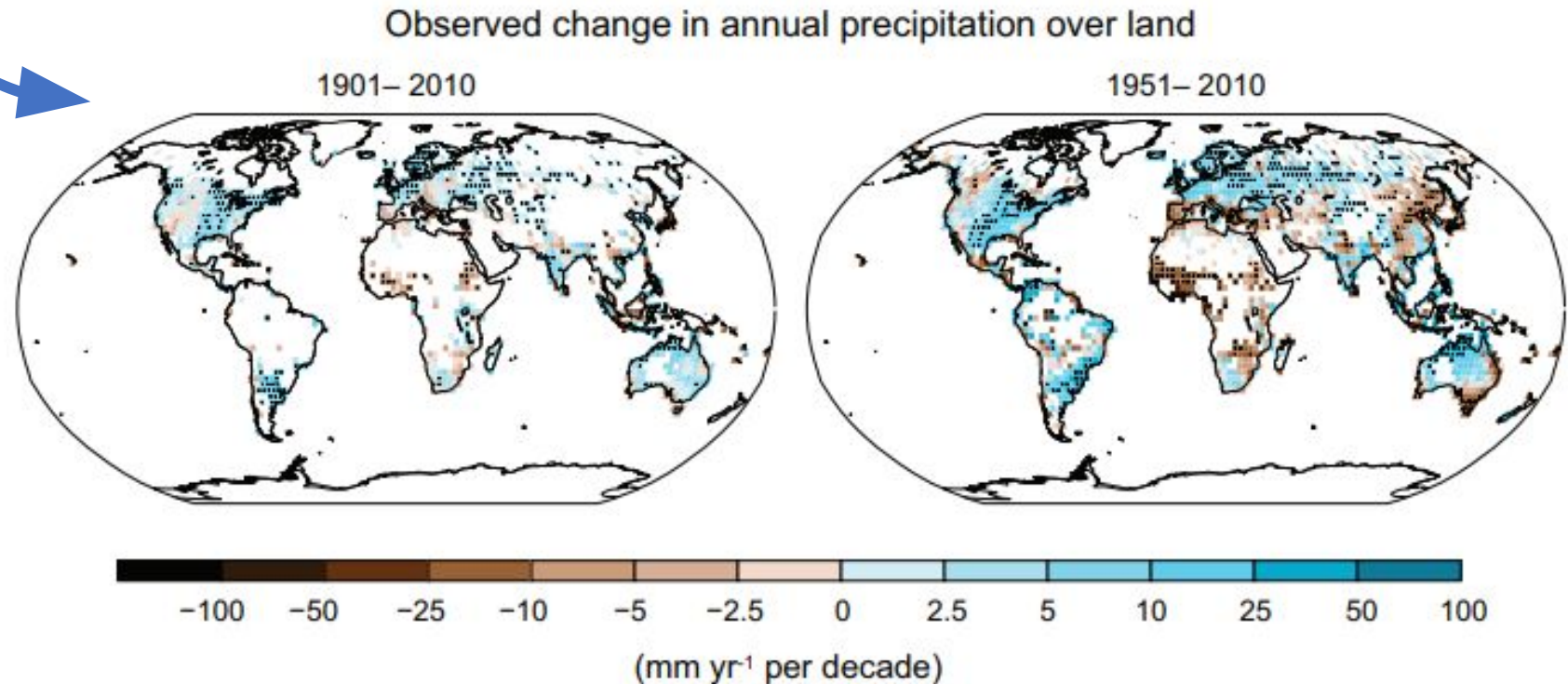
b) Change in global surface temperature (annual average) as **observed** and simulated using **human & natural** and **only natural** factors (both 1850-2020)



MENGAPA PERLU KAJIAN IKLIM DI INDONESIA?

2. Respon Perubahan Iklim yang Berbeda antar Ruang dan Waktu

“Tingkat keyakinan (confidence level) dalam perubahan curah hujan rata-rata di atas lahan global sejak 1901 rendah sebelum 1951 dan menengah sesudahnya. Dirata-ratakan di atas area daratan dengan garis lintang tengah di Belahan Bumi Utara, curah hujan telah meningkat sejak tahun 1901 (keyakinan sedang sebelum dan kepercayaan tinggi setelah tahun 1951). Untuk wilayah lintang lainnya, tren positif atau negatif jangka panjang rata-rata memiliki **kepercayaan yang rendah (low confidence)**”



Diperlukan kajian iklim dalam skala regional dan lokal dengan data yang lebih representatif dan lebih detail.

MENGAPA PERLU KAJIAN IKLIM DI INDONESIA?

3. Perubahan Cuaca dan Iklim Ekstrem yang Spesifik Wilayah

*“Ada bukti dari pengamatan yang dikumpulkan sejak 1950 tentang perubahan di beberapa ekstrem. Keyakinan pada perubahan ekstrem yang teramati bergantung pada kualitas dan kuantitas data dan ketersediaan studi yang menganalisis data ini, yang **bervariasi antar wilayah dan untuk berbagai ekstrem**. Menetapkan 'kepercayaan rendah' dalam perubahan yang diamati dalam ekstrem tertentu pada skala regional atau global tidak menyiratkan atau mengecualikan kemungkinan perubahan ekstrem ini”.*

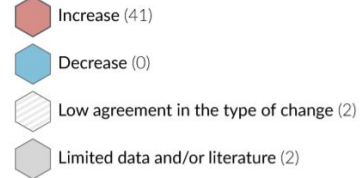
IPCC (2012)

“Perubahan iklim dapat menyebabkan terjadinya perubahan frekuensi, luasan wilayah, durasi dan waktu terjadinya kejadian cuaca dan iklim ekstrem, dan dapat menyebabkan terjadinya kejadian cuaca dan iklim ekstrem yang belum pernah terjadi sebelumnya”.

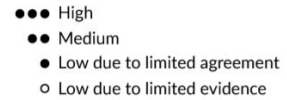
IPCC (2012)



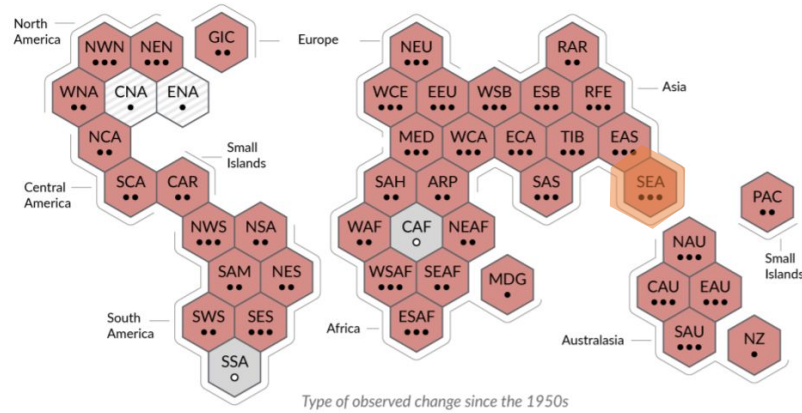
**Type of observed change
in hot extremes**



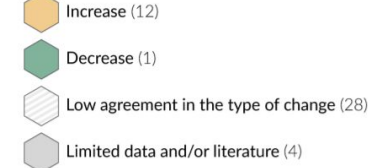
**Confidence in human contribution
to the observed change**



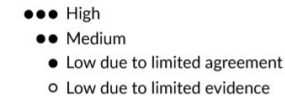
a) Synthesis of assessment of observed change in **hot extremes** and confidence in human contribution to the observed changes in the world's regions



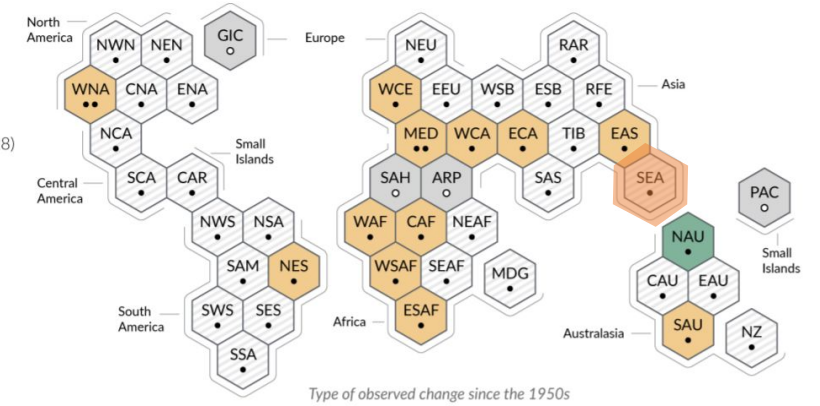
**Type of observed change
in agricultural and ecological drought**



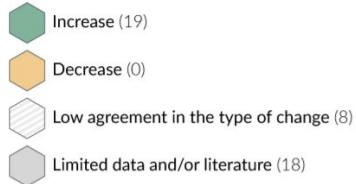
**Confidence in human contribution
to the observed change**



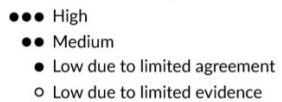
c) Synthesis of assessment of observed change in **agricultural and ecological drought** and confidence in human contribution to the observed changes in the world's regions



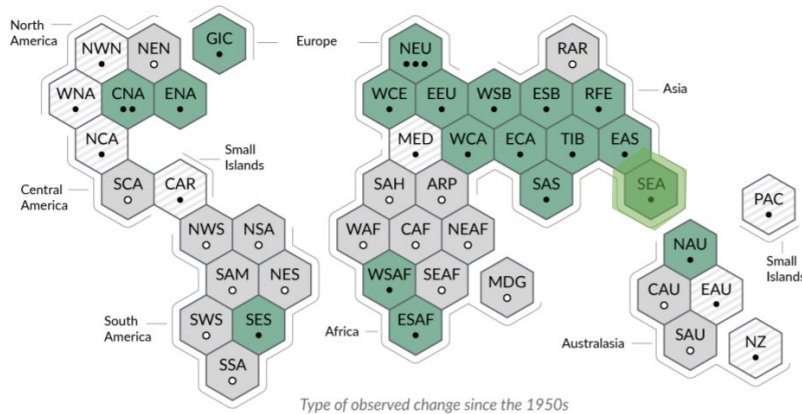
**Type of observed change
in heavy precipitation**



**Confidence in human contribution
to the observed change**



b) Synthesis of assessment of observed change in **heavy precipitation** and confidence in human contribution to the observed changes in the world's regions



Perubahan iklim telah mempengaruhi setiap wilayah berpenghuni di seluruh dunia, dengan pengaruh manusia berkontribusi pada banyak perubahan yang diamati dalam cuaca dan iklim ekstrem

Kondisi Wilayah

Sebagai negara kepulauan, Indonesia memiliki 514 kabupaten/kota yang menghadapi ancaman bencana hidrometeorologi akibat perubahan iklim seperti **banjir dan kekeringan**



Potensi Kerugian

Bukan hanya kerugian fisik, **mata pencaharian masyarakat Indonesia juga berpotensi terganggu** karena adanya perubahan iklim.



Gambar 2. Kondisi Wilayah Indonesia dan Grafik Kejadian Bencana Iklim 2010-2019 (BNPB, 2019)



Box 14.1, Table 1 | Regional climate impacts of fundamental modes of variability.

Mode	Regional Climate Impacts
ENSO	Global impact on interannual variability in global mean temperature. Influences severe weather and tropical cyclone activity worldwide. The diverse El Niño flavours present different teleconnection patterns that induce large impacts in numerous regions from polar to tropical latitudes (Section 14.4).
PDO	Influences surface air temperature and precipitation over the entire North American continent and extratropical North Pacific. Modulates ENSO rainfall teleconnections, e.g., Australian climate (Section 14.7.3).
IPO	Modulates decadal variability in Australian rainfall, and ENSO teleconnections to rainfall, surface temperature, river flow and flood risk over Australia, New Zealand and the SPCZ (Section 14.7.3).
NAO	Influences the N. Atlantic jet stream, storm tracks and blocking and thereby affects winter climate in over the N. Atlantic and surrounding landmasses. The summer NAO (SNAO) influences Western Europe and Mediterranean basin climates in the season (Section 14.5.1).
NAM	Modulates the intensity of mid-latitude storms throughout the Northern Hemisphere and thereby influences North America and Eurasia climates as well as sea ice distribution across the Arctic sea (Section 14.5.1).
NPO	Influences winter air temperature and precipitation over much of western North America as well as Arctic sea ice in the Pacific sector (Section 14.5.1).
SAM	Influences temperature over Antarctica, Australia, Argentina, Tasmania and the south of New Zealand and precipitation over southern South America, New Zealand, Tasmania, Australia and South Africa (Section 14.5.2).
PNA	Influences the jet stream and storm tracks over the Pacific and North American sectors, exerting notable influences on the temperature and precipitation in these regions on intraseasonal and interannual time scales (Section 14.7.2).
PSA	Influences atmospheric circulation over South America and thereby has impacts on precipitation over the continent (Section 14.7.1).
AMO	Influences air temperatures and rainfall over much of the Northern Hemisphere, in particular, North America and Europe. It is associated with multidecadal variations in Indian, East Asian and West African monsoons, the North African Sahel and northeast Brazil rainfall, the frequency of North American droughts and Atlantic hurricanes (Section 14.7.6).
AMM	Influences seasonal hurricane activity in the tropical Atlantic on both decadal and interannual time scales. Its variability is influenced by other modes, particularly ENSO and NAO (Section 14.3.4).
AN	Affects the West African Monsoon, the oceanic forcing of Sahel rainfall on both decadal and interannual time-scales and the spatial extension of drought in South Africa (Section 14.3.4).
IOB	Associated with the intensity of Northwest Pacific monsoon, the tropical cyclone activity over the Northwest Pacific and anomalous rainfall over East Asia (Section 14.3.3).
IOD	Associated with droughts in Indonesia, reduced rainfall over Australia, intensified Indian summer monsoon, floods in East Africa, hot summers over Japan, and anomalous climate in the extratropical Southern Hemisphere (Section 14.3.3).
TBO	Modulates the strength of the Indian and West Pacific monsoons. Affects droughts and floods over large areas of south Asia and Australia (Section 14.7.4).
MJO	Modulates the intensity of monsoon systems around the globe and tropical cyclone activity in the Indian, Pacific and Atlantic Oceans. Associated with enhanced rainfall in Western North America, northeast Brazil, Southeast Africa and Indonesia during boreal winter and Central America/Mexico and Southeast Asia during boreal summer (Section 14.3.2).
QBO	Strongly affects the strength of the northern stratospheric polar vortex as well as the extratropical troposphere circulation, occurring preferentially in boreal winter (Section 14.7.5).
BLC	Associated with cold air outbreaks, heat-waves, floods and droughts in middle and high latitudes of both hemispheres (Box 14.2).

Notes:

AMM: Atlantic Meridional Mode
AMO: Atlantic Multi-decadal Oscillation
AN: Atlantic Niño pattern
BLC: Blocking events
ENSO: El Niño-Southern Oscillation

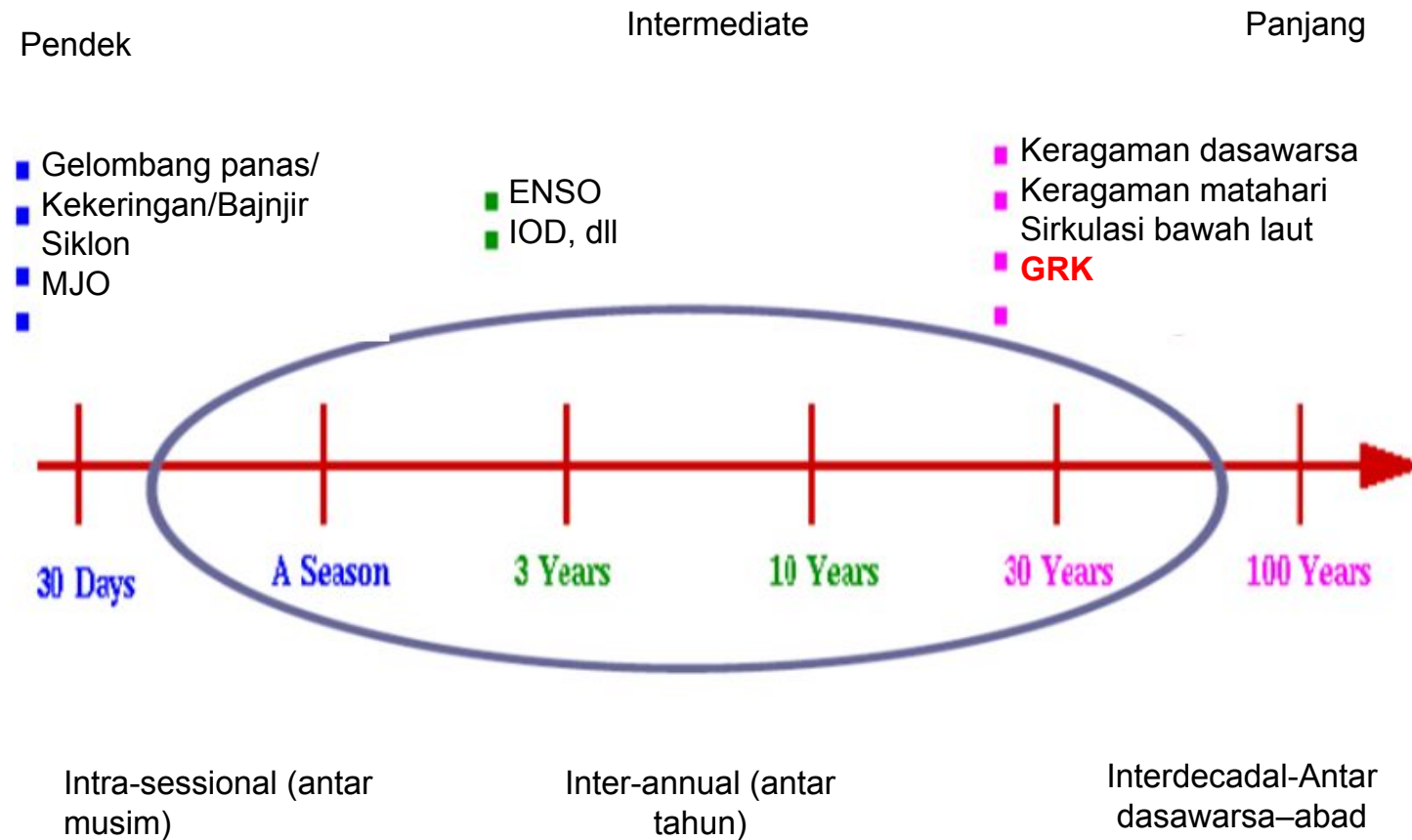
IOB: Indian Ocean Basin pattern
IOD: Indian Ocean Dipole pattern
IPO: Interdecadal Pacific Oscillation
MJO: Madden-Julian Oscillation
NAM: Northern Annular Mode

NAO: North Atlantic Oscillation
NPO: North Pacific Oscillation
PDO: Pacific Decadal Oscillation
PNA: Pacific North America pattern
PSA: Pacific South America pattern

QBO: Quasi-Biennial Oscillation
SAM: Southern Annular Mode
TBO: Tropospheric Biennial Oscillation

Keragaman dan Perubahan Iklim

Sumber : Hales et al., tanpa tahun

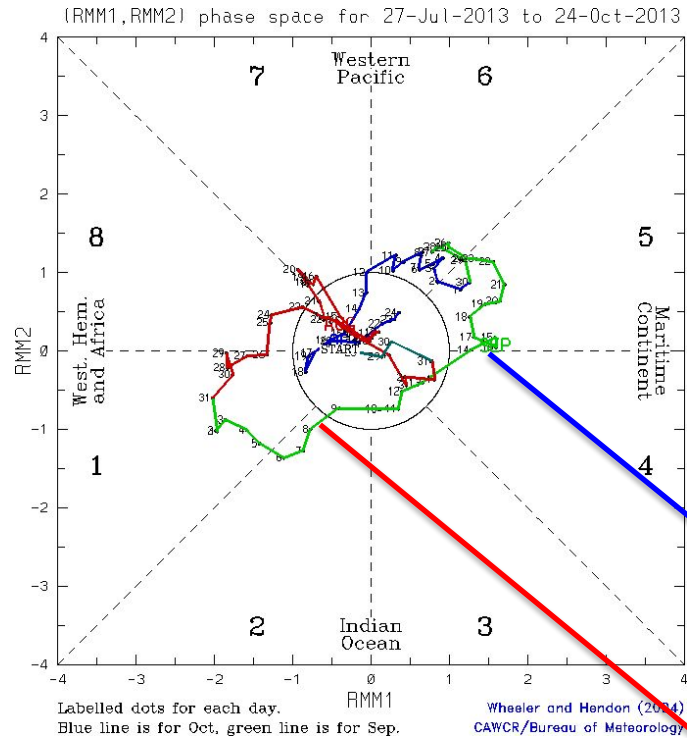


FAKTOR PENGENDALI VARIABILITAS IKLIM

Faktor pengendali iklim mulai dari skala intra-musiman (intraseasonal), antar tahun (interannual), dasawarsa dan antar dasawarsa (decadal to interdecadal)

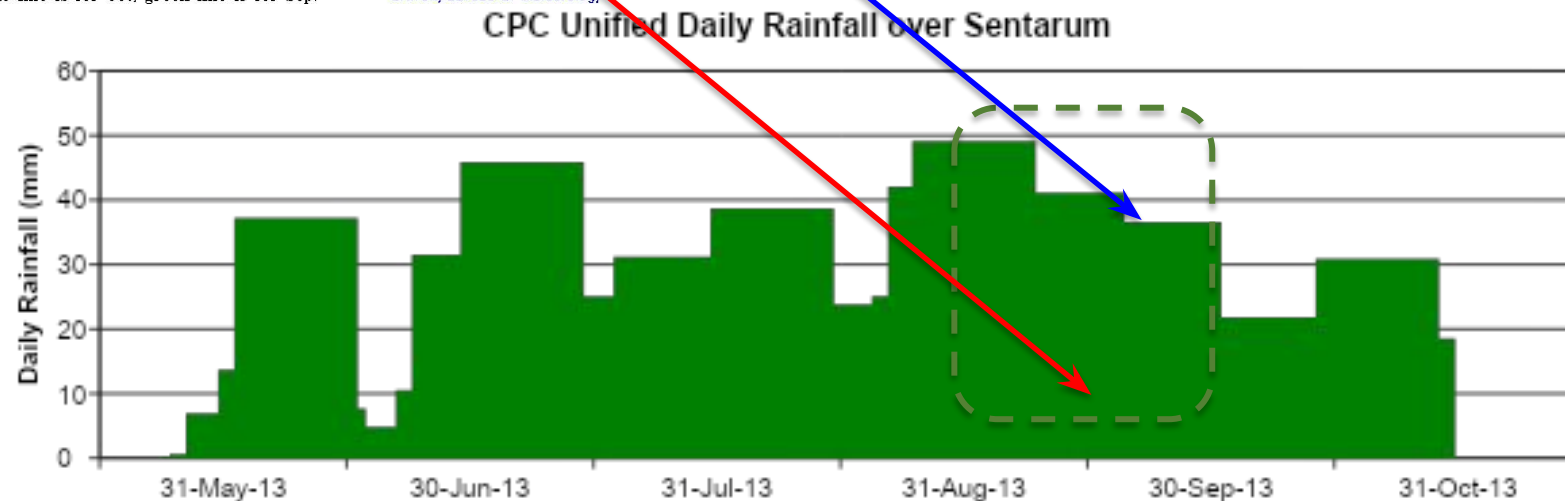
- Intraseasonal, contoh: Madden-Julian Oscillation (MJO)
□ osilasi 30-60 harian
- Interannual, contoh: El Nino Southern Oscillation (ENSO) dan Indian Ocean Dipole (IOD) □ osilasi 2-7 tahun
- Decadal to Interdecadal, contoh: Pacific Decadal Oscillation (PDO) dan Interdecadal Pacific Oscillation (IPO) □ osilasi sekitar 10 tahunan atau lebih



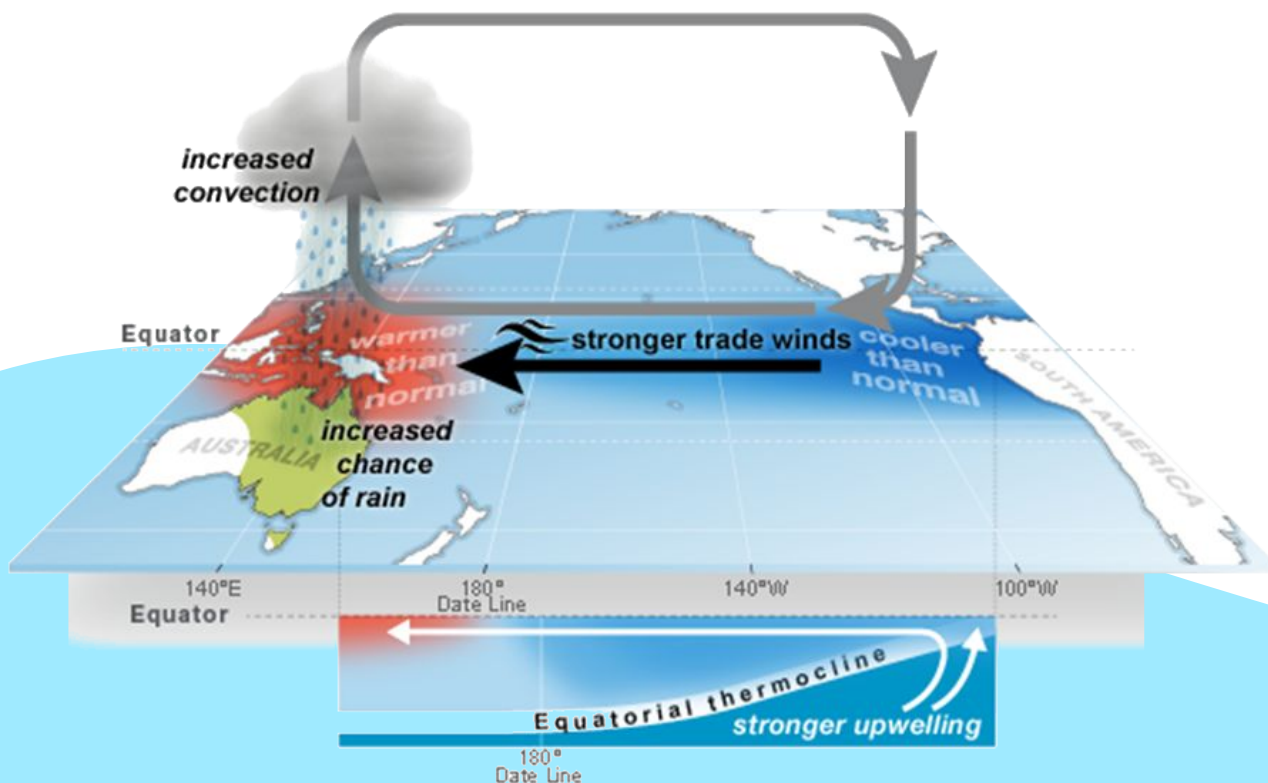


Contoh: Curah Hujan Sentarum

- Akhir Agustus hingga pertengahan September terjadi deret hari hujan selama 23 hari yang menyebabkan peningkatan tinggi muka air danau (pasang).
- Pada akhir September hingga Oktober hujan tetap turun, tetapi deret hari hujan relatif pendek.
- Hujan pada akhir Agustus hingga pertengahan September kemungkinan disebabkan oleh adanya pengaruh faktor iklim intra-musiman, seperti fenomena MJO yang memasuki fase 1 hingga fase 4



El Nino Southern Oscillation (ENSO)



El Niño–Southern Oscillation (ENSO): **La Niña**

- El Nino – Southern Oscillation (ENSO) merupakan fenomena interaksi lautan-atmosfer yang mempengaruhi variabilitas iklim di seluruh dunia.
- Fase Hangat ENSO □ El Nino
- Fase Dingin ENSO □ La Nina
- La Niña meningkatkan aktivitas konvektif terutama di bagian timur Samudera Hindia dan Benua Maritim Indonesia, dan sebaliknya mengurangi aktivitas konvektif di seluruh Pasifik ekuator
- La Niña dikaitkan dengan angin pasat yang lebih kuat dari biasanya dan SST di Samudera Pasifik Tropis yang lebih dingin dari normalnya.
- La Niña adalah fenomena anomali yang tidak terlalu ekstrim jika dibandingkan El Niño, tetapi cenderung bertahan lebih lama, rata-rata satu sampai tiga tahun.
- Transisi El Niño ke La Niña biasanya terjadi jauh lebih cepat daripada transisi La Niña ke El Niño; hampir semua transisi El Niño ke La Niña terjadi dalam satu tahun (Larkin & Harrison 2002)

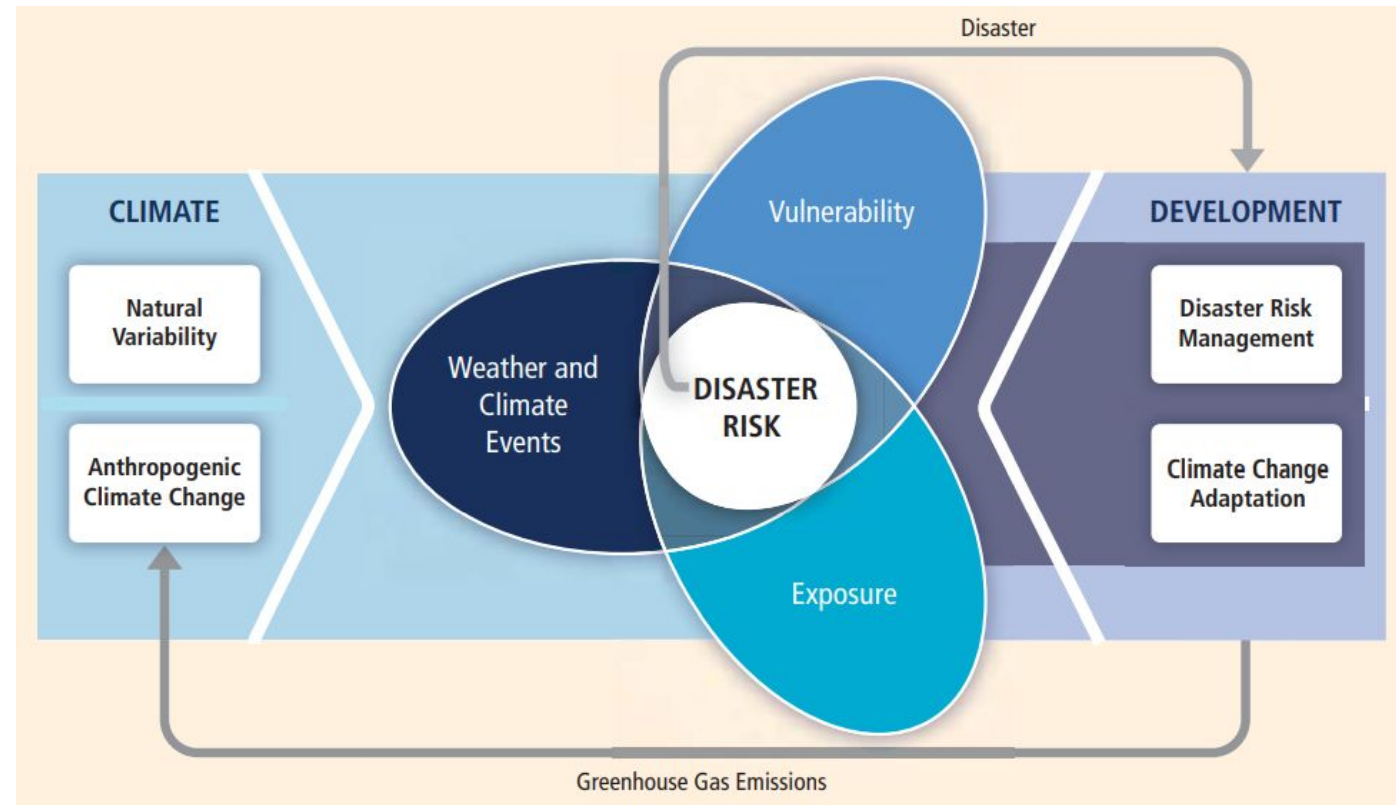
MENGAPA PERLU KAJIAN IKLIM DI INDONESIA?

4. Sebagai Basis Strategi Adaptasi dan Mitigasi Perubahan Iklim Di Indonesia

Basis saintifik terutama dalam skala regional maupun lokal diperlukan untuk kajian risiko bencana iklim terutama terkait dengan kejadian cuaca dan iklim ekstrem.

Manajemen risiko bencana khususnya dalam kaitan dengan perubahan iklim diperlukan dalam pengembangan strategi adaptasi untuk pengurangan risiko bencana dan manajemen bencana.

Basis saintifik juga diperlukan sebagai basis dalam melakukan mitigasi perubahan iklim



MENGAPA PERLU KAJIAN IKLIM DI INDONESIA?

		Observed Changes (since 1950)	Attribution of Observed Changes	Projected Changes (up to 2100) with Respect to Late 20th Century
Weather and Climate Variables	Temperature (Section 3.3.1)	<i>Very likely</i> decrease in number of unusually cold days and nights at the global scale. <i>Very likely</i> increase in number of unusually warm days and nights at the global scale. <i>Medium confidence</i> in increase in length or number of warm spells or heat waves in many (but not all) regions. <i>Low or medium confidence</i> in trends in temperature extremes in some subregions due either to lack of observations or varying signal within subregions. [Regional details in Table 3-2]	<i>Likely</i> anthropogenic influence on trends in warm/cold days/nights at the global scale. No attribution of trends at a regional scale with a few exceptions.	<i>Virtually certain</i> decrease in frequency and magnitude of unusually cold days and nights at the global scale. <i>Virtually certain</i> increase in frequency and magnitude of unusually warm days and nights at the global scale. <i>Very likely</i> increase in length, frequency, and/or intensity of warm spells or heat waves over most land areas. [Regional details in Table 3-3]
	Precipitation (Section 3.3.2)	<i>Likely</i> statistically significant increases in the number of heavy precipitation events (e.g., 95th percentile) in more regions than those with statistically significant decreases, but strong regional and subregional variations in the trends. [Regional details in Table 3-2]	<i>Medium confidence</i> that anthropogenic influences have contributed to intensification of extreme precipitation at the global scale.	<i>Likely</i> increase in frequency of heavy precipitation events or increase in proportion of total rainfall from heavy falls over many areas of the globe, in particular in the high latitudes and tropical regions, and in winter in the northern mid-latitudes. [Regional details in Table 3-3]
	Winds (Section 3.3.3)	<i>Low confidence</i> in trends due to insufficient evidence.	<i>Low confidence</i> in the causes of trends due to insufficient evidence.	<i>Low confidence</i> in projections of extreme winds (with the exception of wind extremes associated with tropical cyclones).
Phenomena Related to Weather and Climate Extremes	Monsoons (Section 3.4.1)	<i>Low confidence</i> in trends because of insufficient evidence.	<i>Low confidence</i> due to insufficient evidence.	<i>Low confidence</i> in projected changes in monsoons, because of insufficient agreement between climate models.
	El Niño and other Modes of Variability (Sections 3.4.2 and 3.4.3)	<i>Medium confidence</i> in past trends toward more frequent central equatorial Pacific El Niño-Southern Oscillation (ENSO) events. Insufficient evidence for more specific statements on ENSO trends. <i>Likely</i> trends in Southern Annular Mode (SAM).	<i>Likely</i> anthropogenic influence on identified trends in SAM. ¹ Anthropogenic influence on trends in North Atlantic Oscillation (NAO) are <i>about as likely as not</i> . No attribution of changes in ENSO.	<i>Low confidence</i> in projections of changes in behavior of ENSO and other modes of variability because of insufficient agreement of model projections.

MENGAPA PERLU KAJIAN IKLIM DI INDONESIA?

		Observed Changes (since 1950)	Attribution of Observed Changes	Projected Changes (up to 2100) with Respect to Late 20th Century
Impacts on Physical Environment	Droughts (Section 3.5.1)	<i>Medium confidence</i> that some regions of the world have experienced more intense and longer droughts, in particular in southern Europe and West Africa, but opposite trends also exist. [Regional details in Table 3-2]	<i>Medium confidence</i> that anthropogenic influence has contributed to some observed changes in drought patterns. <i>Low confidence</i> in attribution of changes in drought at the level of single regions due to inconsistent or insufficient evidence.	<i>Medium confidence</i> in projected increase in duration and intensity of droughts in some regions of the world, including southern Europe and the Mediterranean region, central Europe, central North America, Central America and Mexico, northeast Brazil, and southern Africa. Overall <i>low confidence</i> elsewhere because of insufficient agreement of projections. [Regional details in Table 3-3]
	Floods (Section 3.5.2)	Limited to medium evidence available to assess climate-driven observed changes in the magnitude and frequency of floods at regional scale. Furthermore, there is low agreement in this evidence, and thus overall <i>low confidence</i> at the global scale regarding even the sign of these changes. <i>High confidence</i> in trend toward earlier occurrence of spring peak river flows in snowmelt- and glacier-fed rivers.	<i>Low confidence</i> that anthropogenic warming has affected the magnitude or frequency of floods at a global scale. <i>Medium confidence to high confidence</i> in anthropogenic influence on changes in some components of the water cycle (precipitation, snowmelt) affecting floods.	<i>Low confidence</i> in global projections of changes in flood magnitude and frequency because of insufficient evidence. <i>Medium confidence</i> (based on physical reasoning) that projected increases in heavy precipitation would contribute to rain-generated local flooding in some catchments or regions. <i>Very likely</i> earlier spring peak flows in snowmelt- and glacier-fed rivers.
Impacts on Physical Environment (Continued)	Extreme Sea Level and Coastal Impacts (Sections 3.5.3, 3.5.4, and 3.5.5)	<i>Likely</i> increase in extreme coastal high water worldwide related to increases in mean sea level in the late 20th century.	<i>Likely</i> anthropogenic influence via mean sea level contributions.	<i>Very likely</i> that mean sea level rise will contribute to upward trends in extreme coastal high water levels. <i>High confidence</i> that locations currently experiencing coastal erosion and inundation will continue to do so due to increasing sea level, in the absence of changes in other contributing factors.
	Other Physical Impacts (Sections 3.5.6, 3.5.7, and 3.5.8)	<i>Low confidence</i> in global trends in large landslides in some regions. <i>Likely</i> increased thawing of permafrost with <i>likely</i> resultant physical impacts.	<i>Likely</i> anthropogenic influence on thawing of permafrost. <i>Low confidence</i> of other anthropogenic influences because of insufficient evidence for trends in other physical impacts in cold regions.	<i>High confidence</i> that changes in heat waves, glacial retreat, and/or permafrost degradation will affect high mountain phenomena such as slope instabilities, mass movements, and glacial lake outburst floods. <i>High confidence</i> that changes in heavy precipitation will affect landslides in some regions. <i>Low confidence</i> in projected future changes in dust activity.

Dokumen Proyeksi dan Skenario Iklim untuk Indonesia

- Indonesian Climate Change Sectoral Roadmap (ICCSR)
 - Proyeksi: temperature udara permukaan, presipitasi, suhu permukaan laut, tinggi muka air laut dan kejadian iklim ekstrem khususnya di lautan
 - IPCC AR4 □ SRES Scenario
 - Post-IPCC AR4 analysis (bukan scenario RCP)
- Rencana Aksi Nasional – Adaptasi Perubahan Iklim (RAN-API)
 - Analisis iklim □ high frequency to low frequency climate variability
 - Sebagian besar literature review dari kajian yang sudah ada
 - IPCC AR4 □ SRES Scenario
- Indonesia's National Communications
 - First National Communications (INC) □ Tidak ada scenario iklim
 - Second National Communications (SNC) □ Data: IPCC AR4 CMIP3 models (14 GCMs); Periods: 2025, 2050 and 2080
 - Third National Communications (TNC) □ Sudah cukup lengkap: Statistical Downscaling (MME) + Dynamical Downscaling (1 Model)
- Kaji Ulang RAN-API
 - Statistical Downscaling (MME) + Dynamical Downscaling (MME)
 - Prediksi Dasawarsa (MME, Probabilistic Approach)

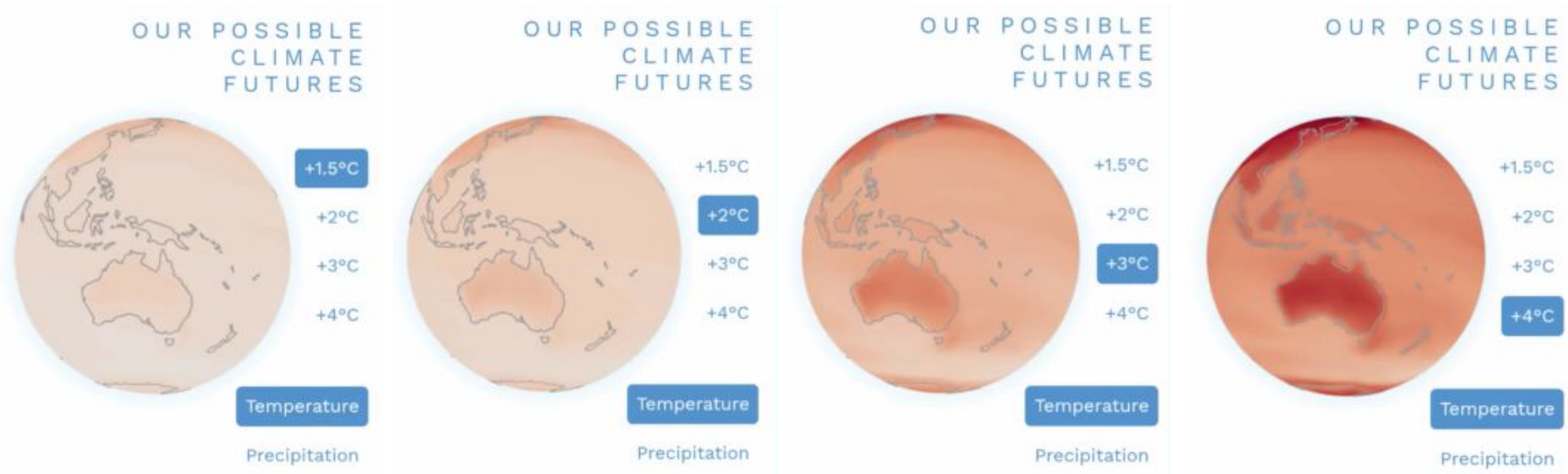


Proyeksi Iklim

Metode dan Skenario

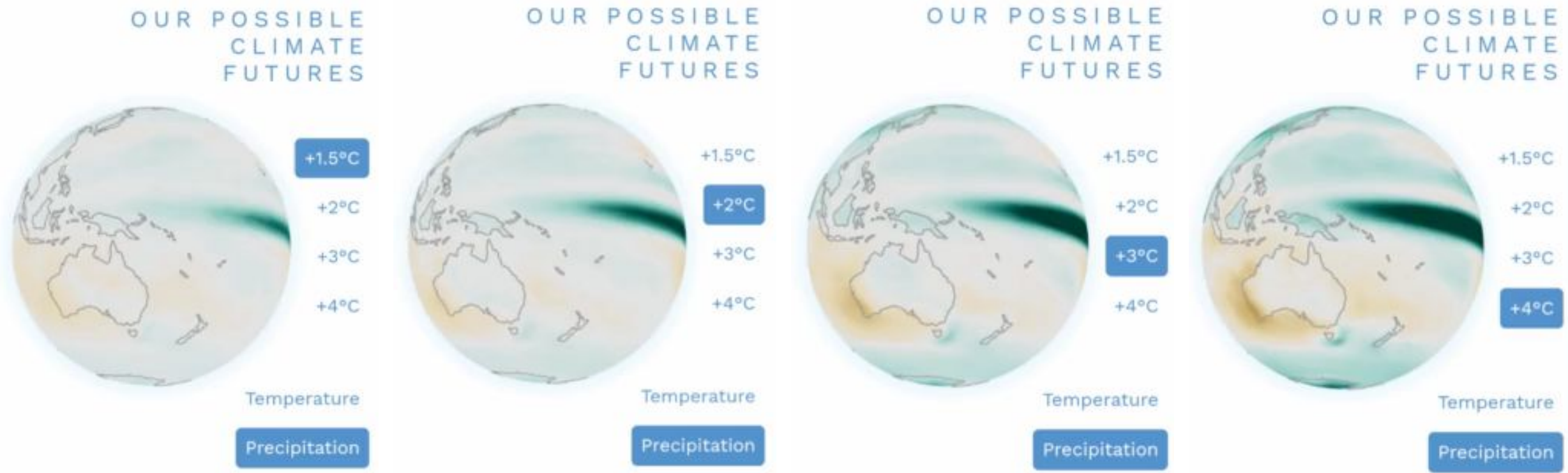


Kemungkinan Temperatur Bumi di Masa Depan



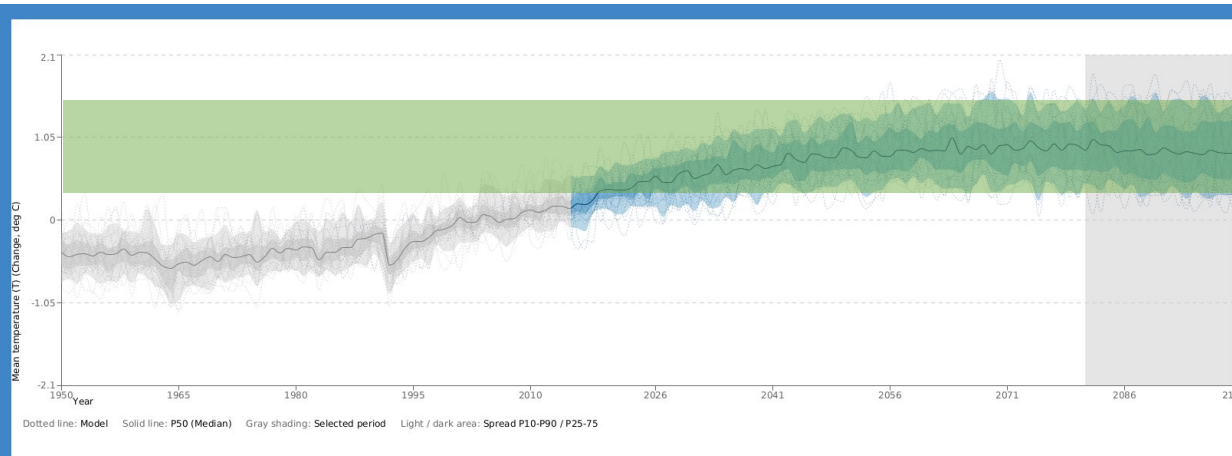
Proyeksi perubahan suhu rata-rata tahunan (°C) pada tingkat pemanasan global 1,5°C, 2°C, 3°C, dan 4°C relatif terhadap 1850-1900. Perubahan simulasi sesuai dengan rata-rata multi-model CMIP6 pada tingkat pemanasan global yang terkait.

Kemungkinan Presipitasi Bumi di Masa Depan

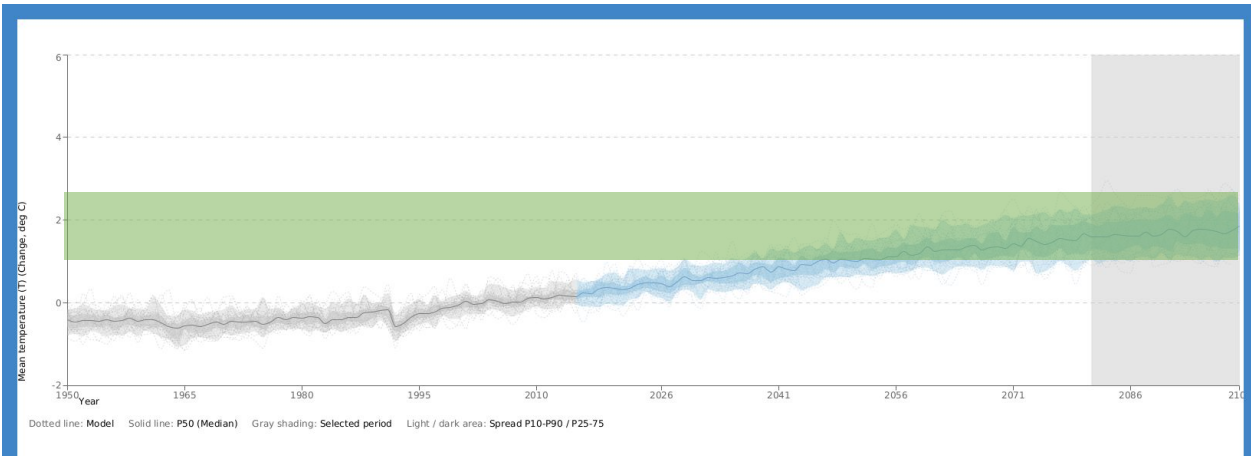


Proyeksi perubahan presipitasi rata-rata tahunan (°C) pada tingkat pemanasan global 1,5°C, 2°C, 3°C, dan 4°C relatif terhadap 1850-1900. Perubahan simulasi sesuai dengan rata-rata multi-model CMIP6 pada tingkat pemanasan global yang terkait.

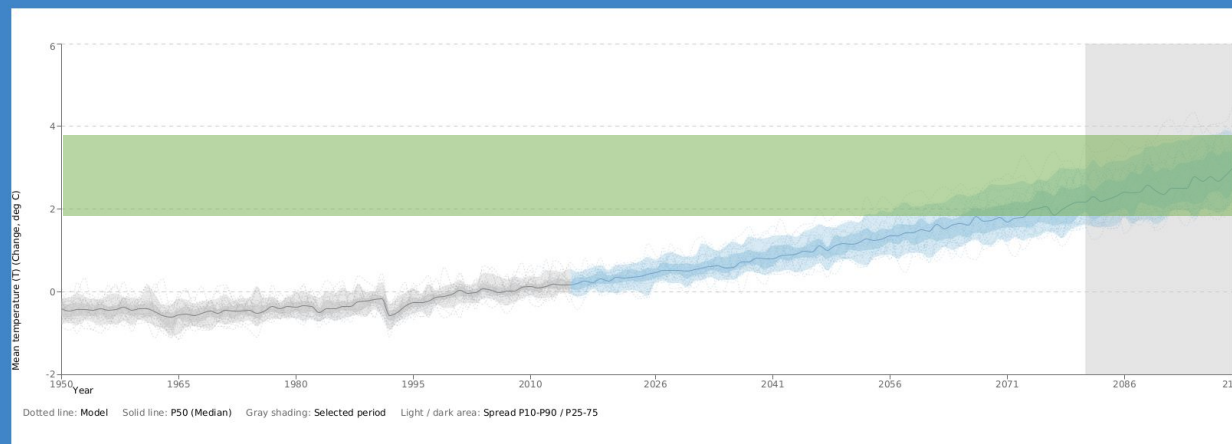
Proyeksi Tren Peningkatan Temperatur Rata-rata di Asia Tenggara



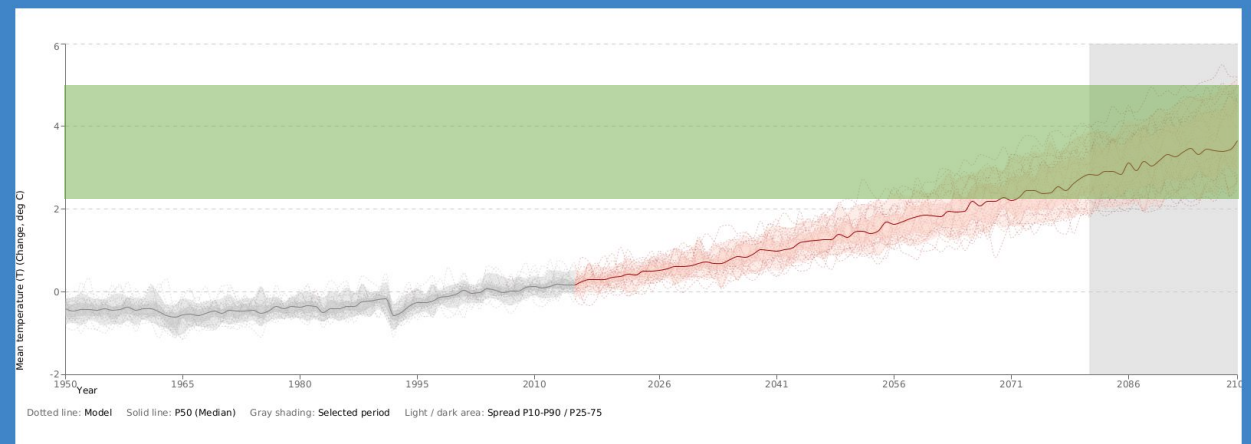
Mean temperature (T) - Change (deg C)
Long Term (2081-2100) (SSP1 2.6) (rel. to 1995-2014)
CMIP6 - Annual (32 models)-S.E.Asia



Mean temperature (T) - Change (deg C)
Long Term (2081-2100) (SSP2 4.5) (rel. to 1995-2014)
CMIP6 - Annual (34 models)-S.E.Asia



Mean temperature (T) - Change (deg C)
Long Term (2081-2100) (SSP3 7) (rel. to 1995-2014)
CMIP6 - Annual (30 models)-S.E.Asia



Mean temperature (T) - Change (deg C)
Long Term (2081-2100) (SSP5 8.5) (rel. to 1995-2014)
CMIP6 - Annual (34 models)-S.E.Asia

GLOBAL CLIMATE MODEL (GCM)

- GCM = 'Global Climate Model' or 'General Circulation Models'
- The most 'complete' models of the climate system constructed by discretizing and then solving equations which represent the basic laws that govern the behaviour of the atmosphere, ocean and land surface.
- Full, three dimensional models are typically termed 'coupled climate system model'.

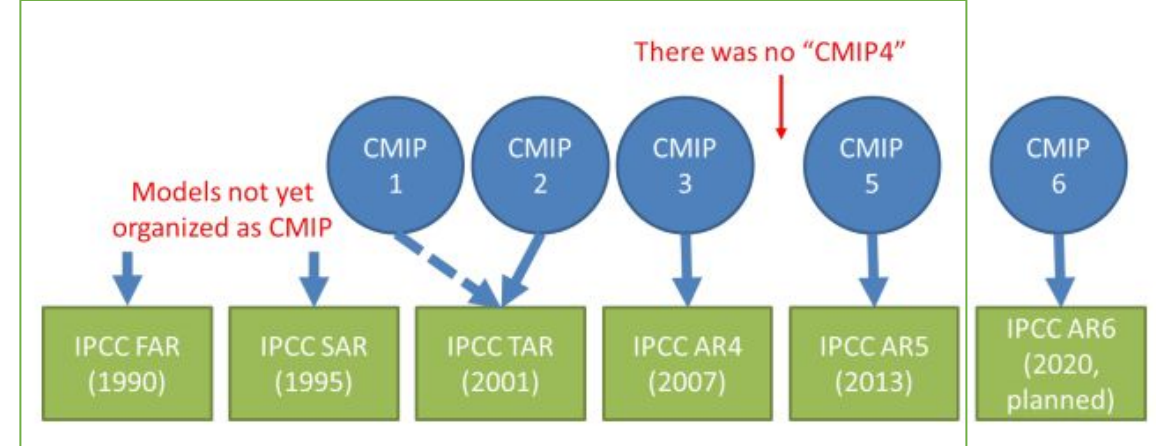
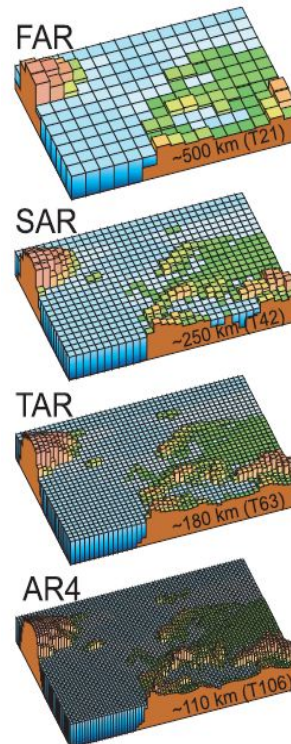
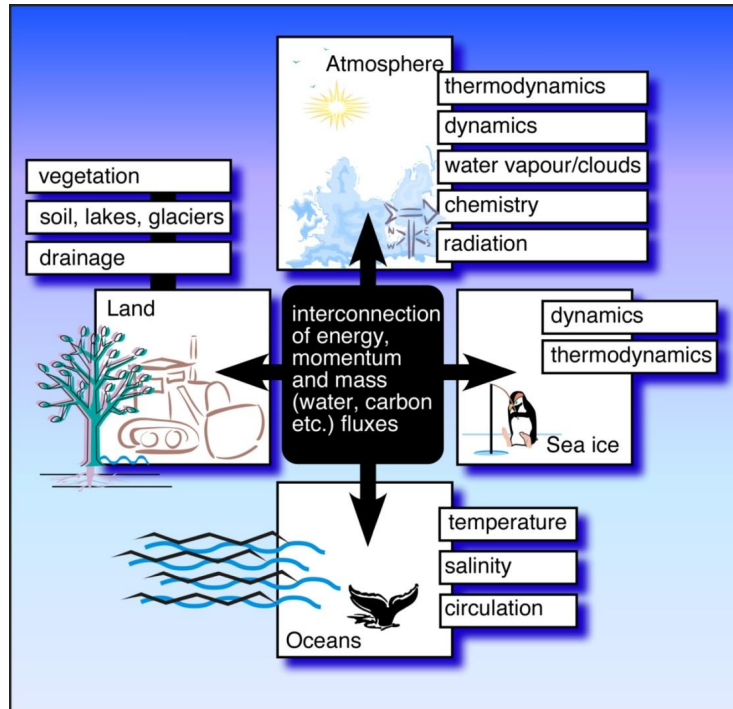
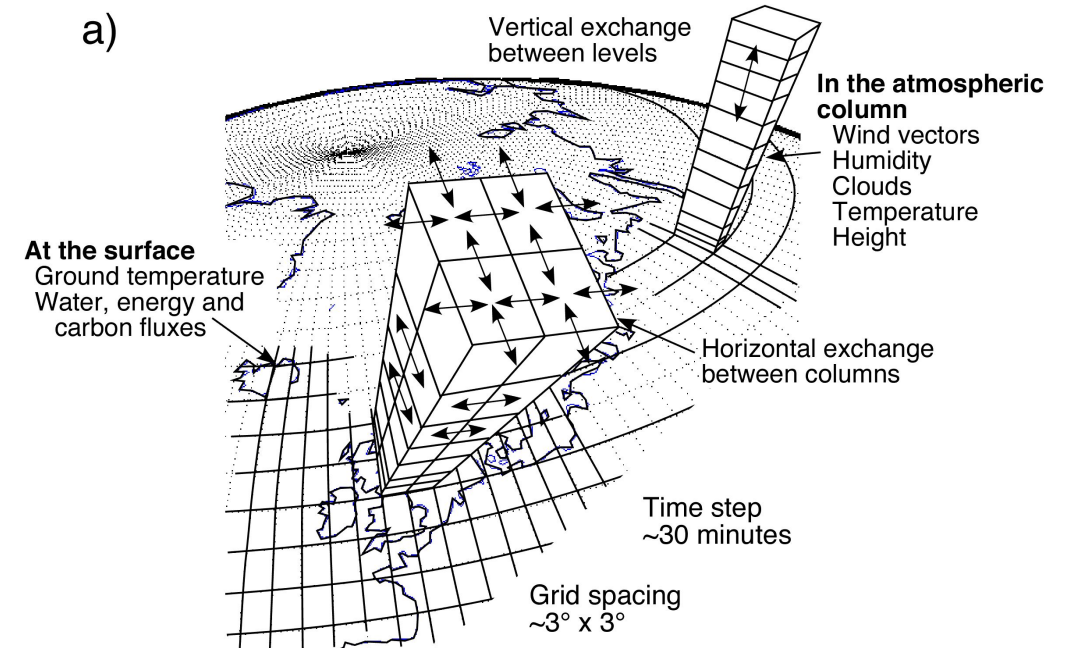
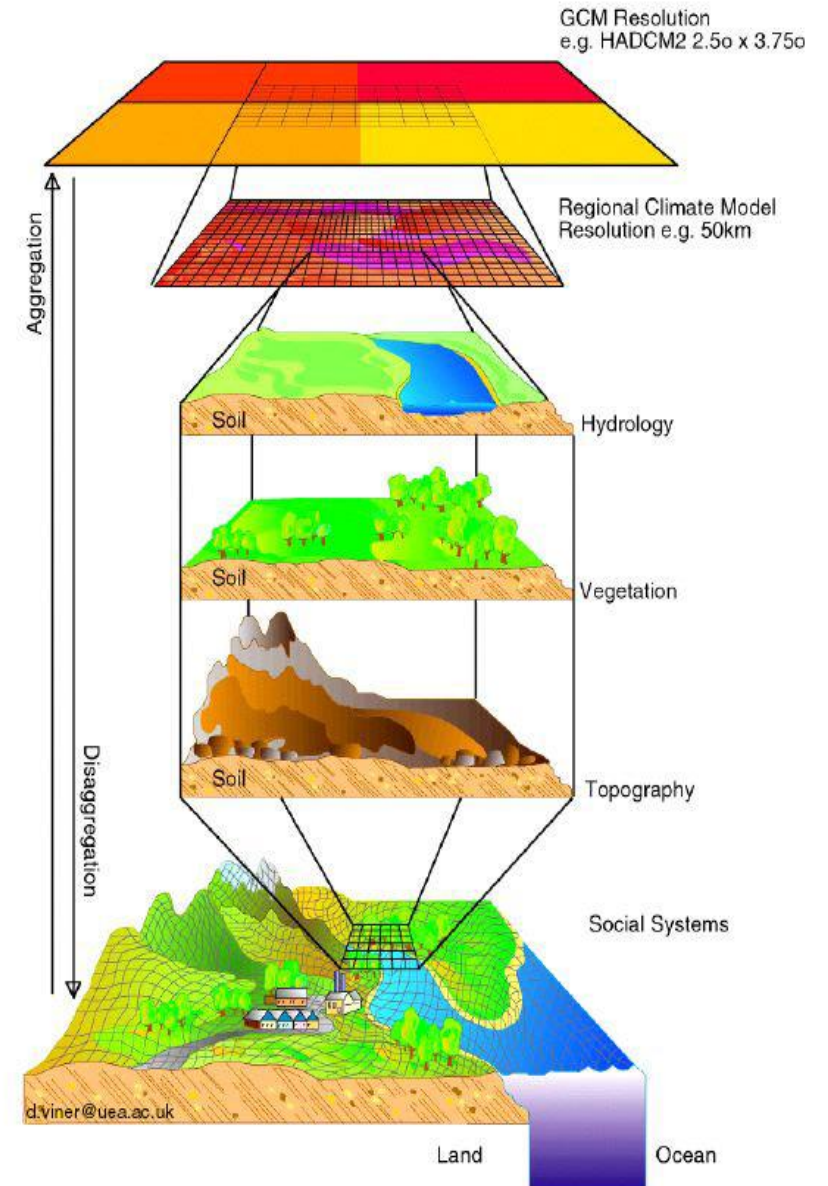


Figure 1. History of CMIPs and their contributions to IPCC Assessment Reports (ARs). Note that there was no CMIP4. As an initial attempt, CMIP1 only contains "control" (constant external conditions) simulations and contributed to the Third Assessment Report (TAR) through model evaluation together with CMIP2. The year given is the publication year of the Working Group I contribution to each Assessment Report.

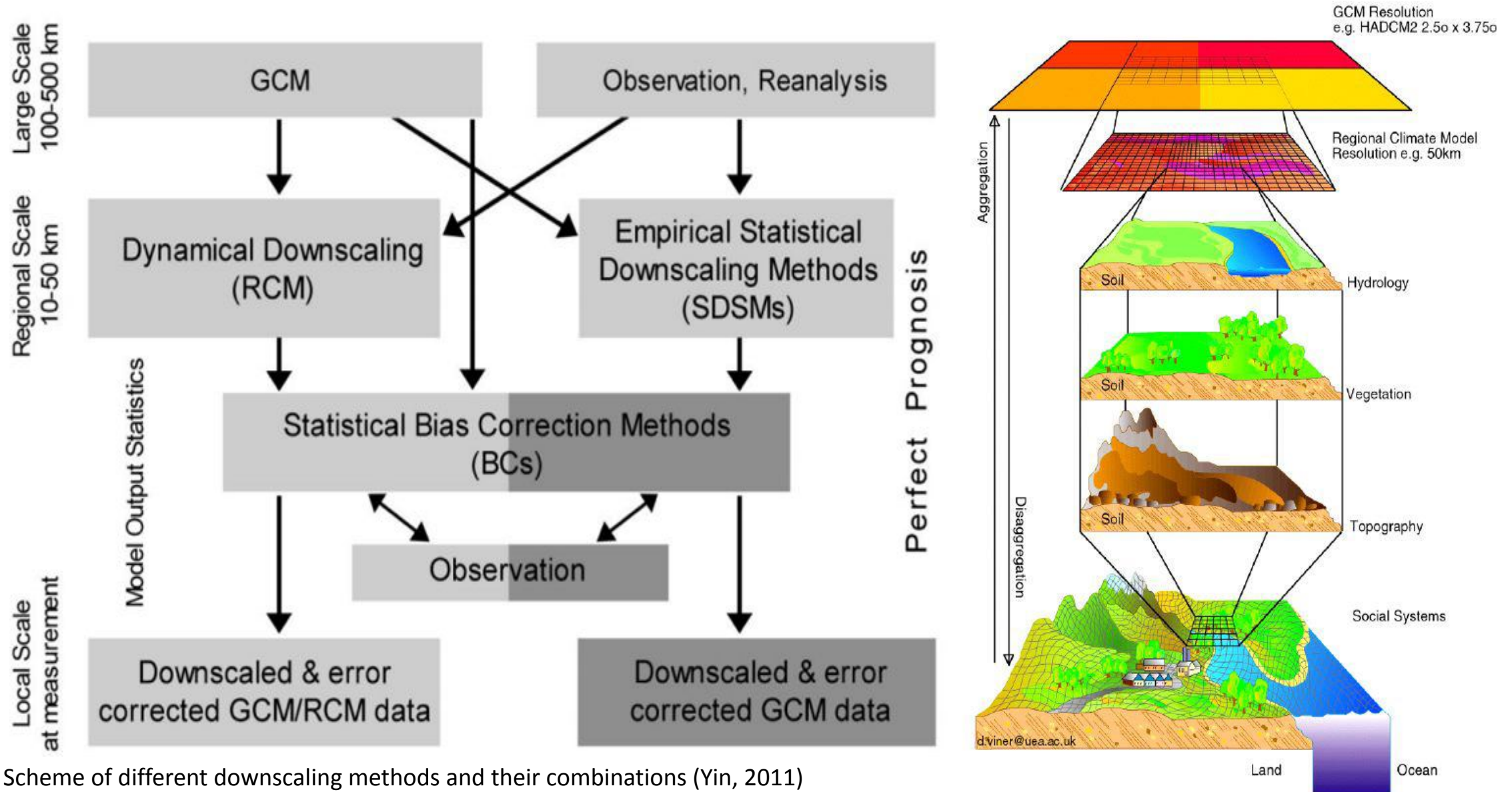


REGIONALISASI DOWNSCALING

- Model Iklim Global (GCM) memiliki resolusi yang relatif rendah sehingga tidak mampu untuk merepresentasikan kondisi iklim dalam skala lokal
- Untuk mengatasi kekurangan tersebut, diperlukan regionalisasi data melalui proses downscaling



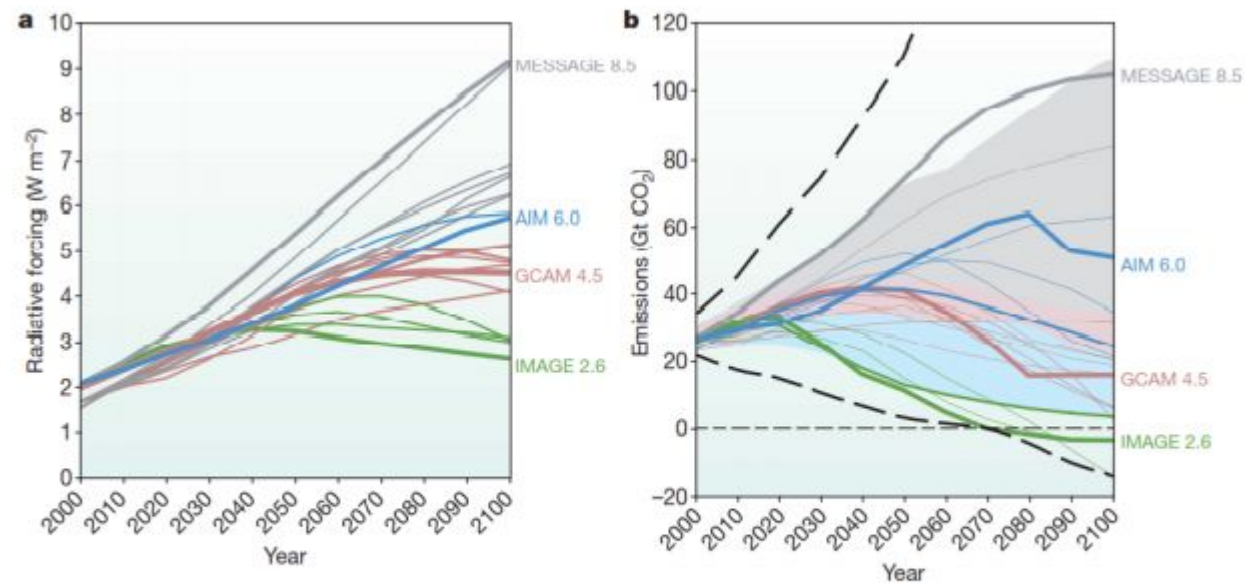
REGIONALISASI DOWNSCALING



Scheme of different downscaling methods and their combinations (Yin, 2011)

Tabel 1. Empat skenario RCP dan karakteristik alur perubahannya di masa yang akan datang (sumber: [Moss et al. 2010](#))

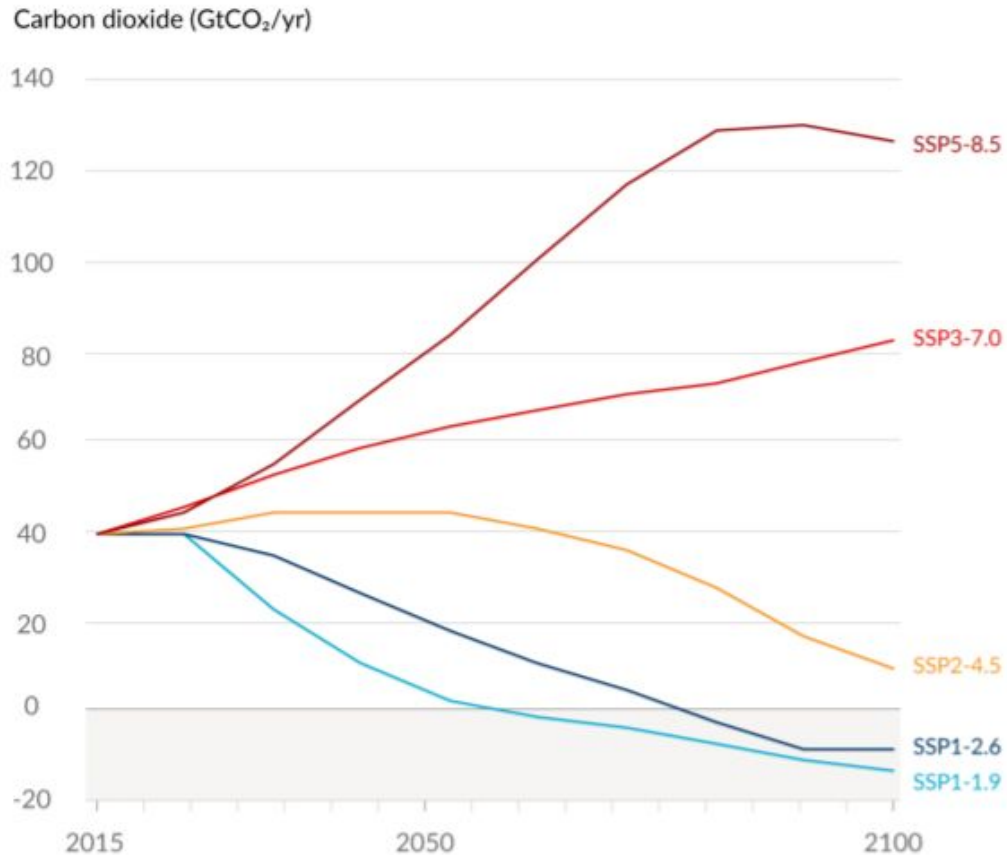
Skenario	Radiative Forcing	Konsentrasi (ppm)	Alur
RCP8.5	$>8,5 \text{ Wm}^{-2}$ pada tahun 2100	$>1.370 \text{ CO}_2\text{-ekiv.}$ pada 2100	Meningkat
RCP6.0	$\sim 6 \text{ Wm}^{-2}$ pada stabilisasi setelah 2100	$\sim 850 \text{ CO}_2\text{-ekiv.}$ (stabilisasi setelah 2100)	Stabilisasi tanpa melampaui batas
RCP4.5	$\sim 4,5 \text{ Wm}^{-2}$ pada stabilisasi setelah 2100	$\sim 650 \text{ CO}_2\text{-ekiv.}$ (stabilisasi setelah 2100)	Stabilisasi tanpa melampaui batas
RCP2.6	Naik $\sim 3 \text{ Wm}^{-2}$ sebelum 2100 dan kemudian turun	Naik $\sim 490 \text{ CO}_2\text{-ekiv.}$ sebelum 2100 dan kemudian turun	Naik dan turun



Gambar 12. Nilai radiative forcing (a) dan emisi CO_2 (b) dalam skenario RCP. GCAM 4.5 merupakan acuan dalam skenario RCP-4.5 (Moss et al. 2010).

Emisi masa depan menyebabkan pemanasan tambahan di masa depan, dengan pemanasan total didominasi oleh emisi CO₂ masa lalu dan masa depan

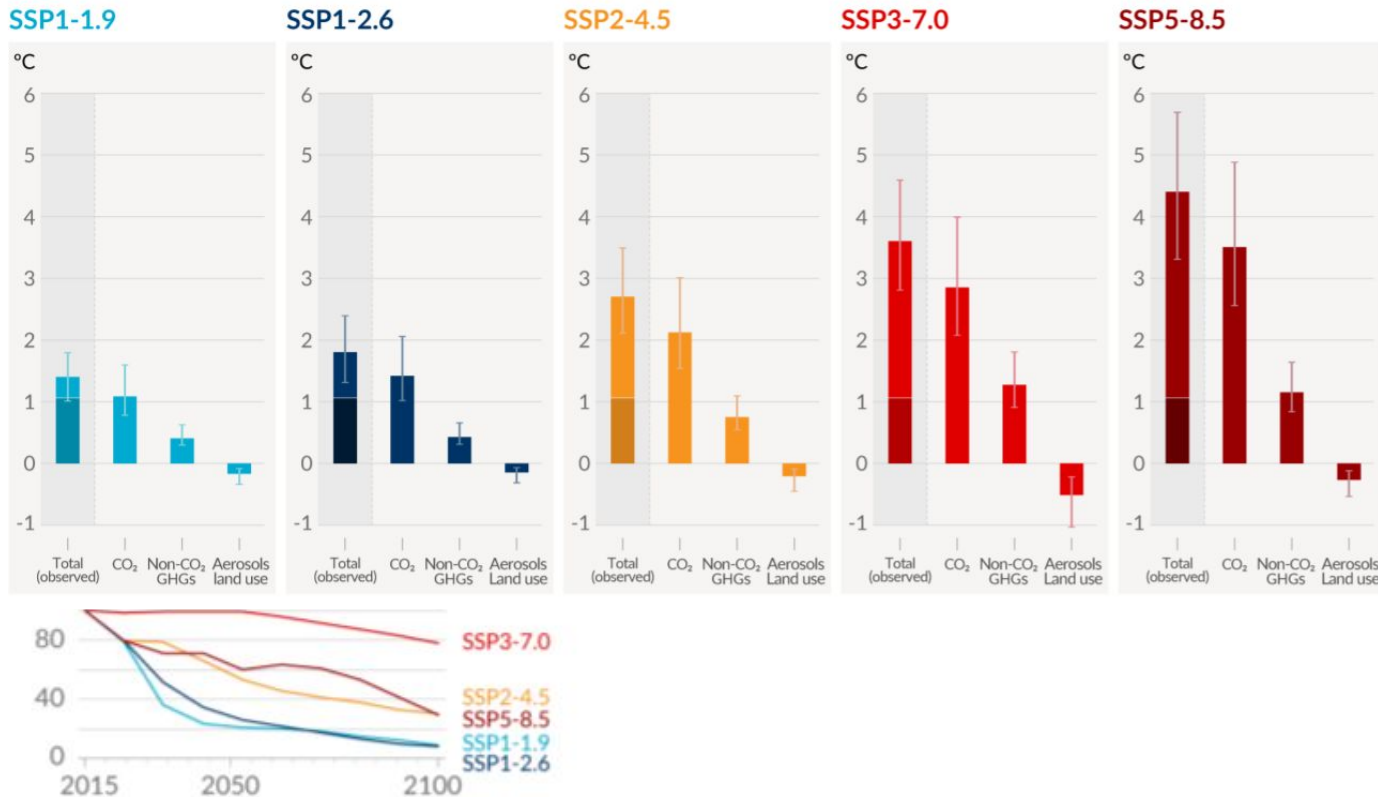
a) Future annual emissions of CO₂ (left) and of a subset of key non-CO₂ drivers (right), across five illustrative scenarios



Selected contributors to non-CO₂ GHGs

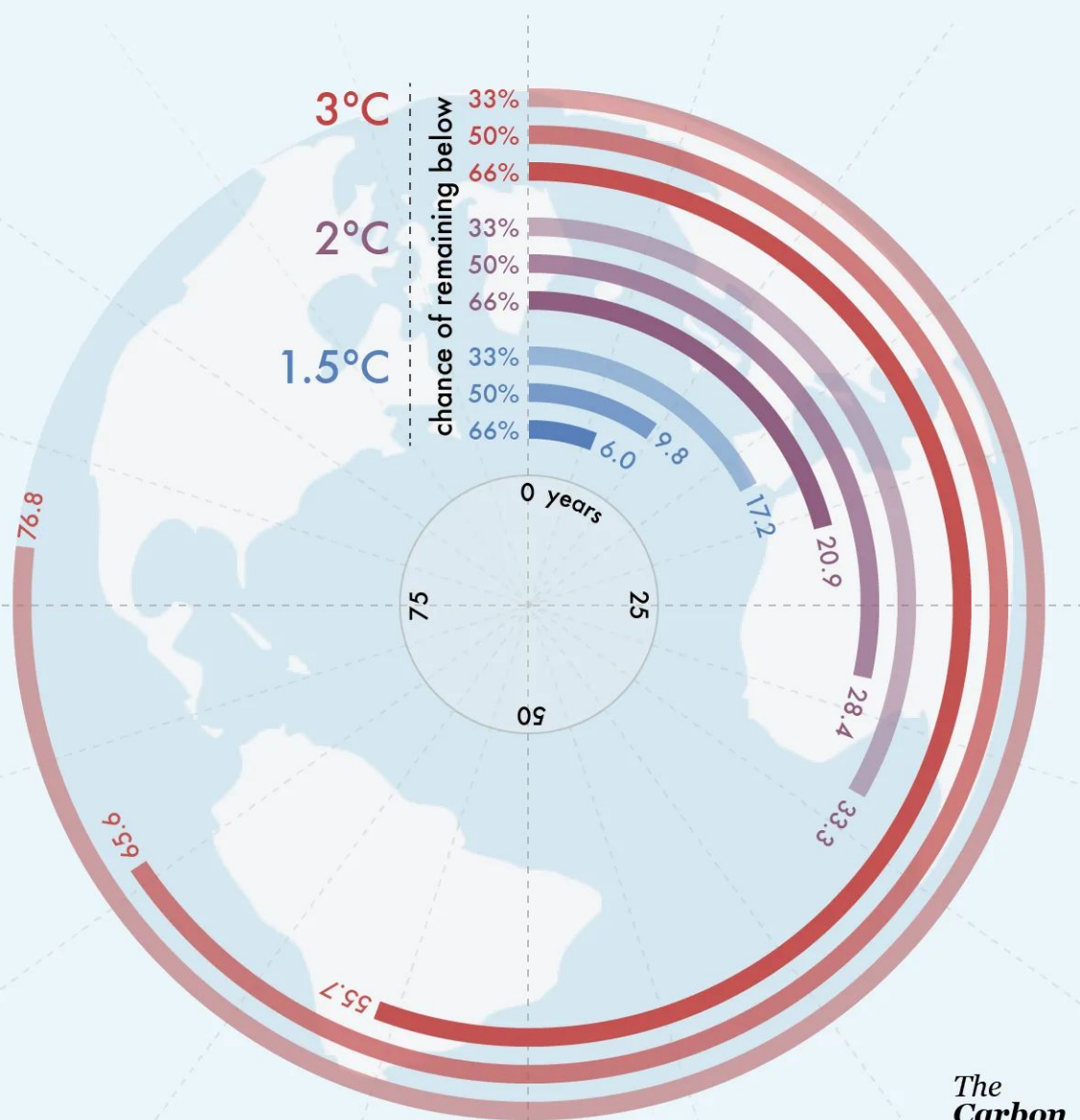
Methane (MtCH₄/yr)

Change in global surface temperature in 2081-2100 relative to 1850-1900 (°C)



Carbon Countdown

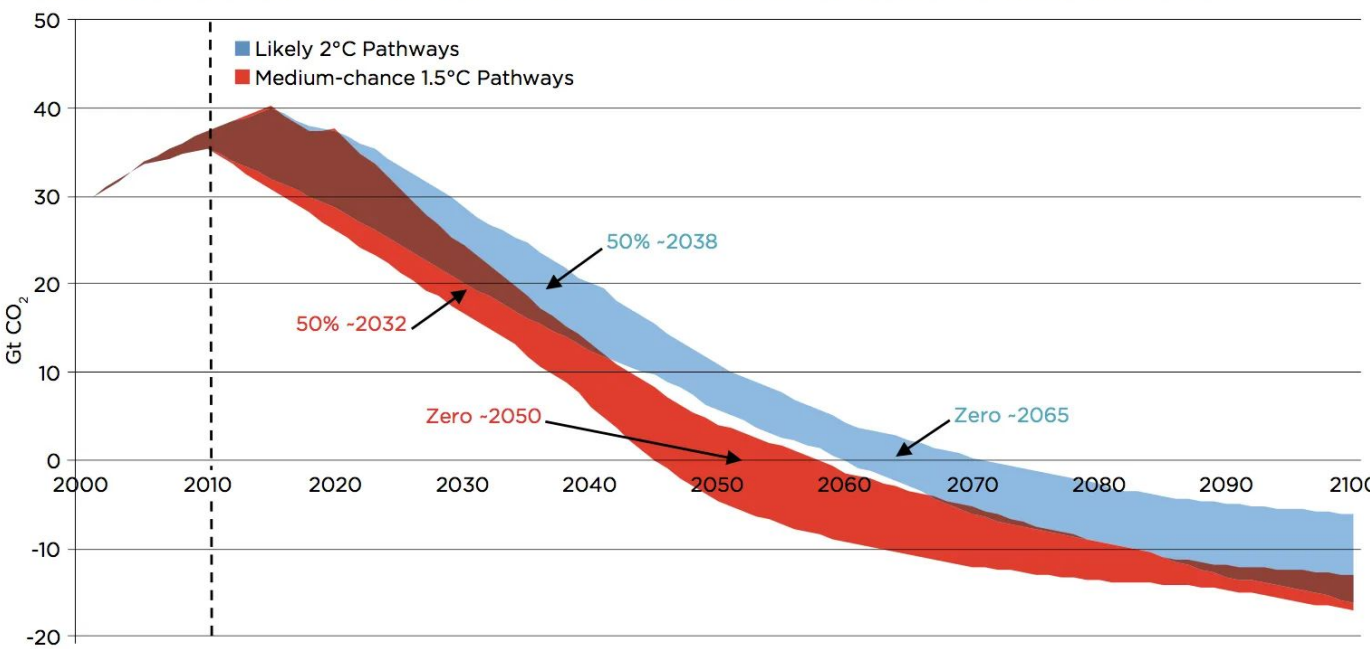
How many years of current emissions would use up the IPCC's carbon budgets for different levels of warming?



<http://bit.ly/carboncountdown>

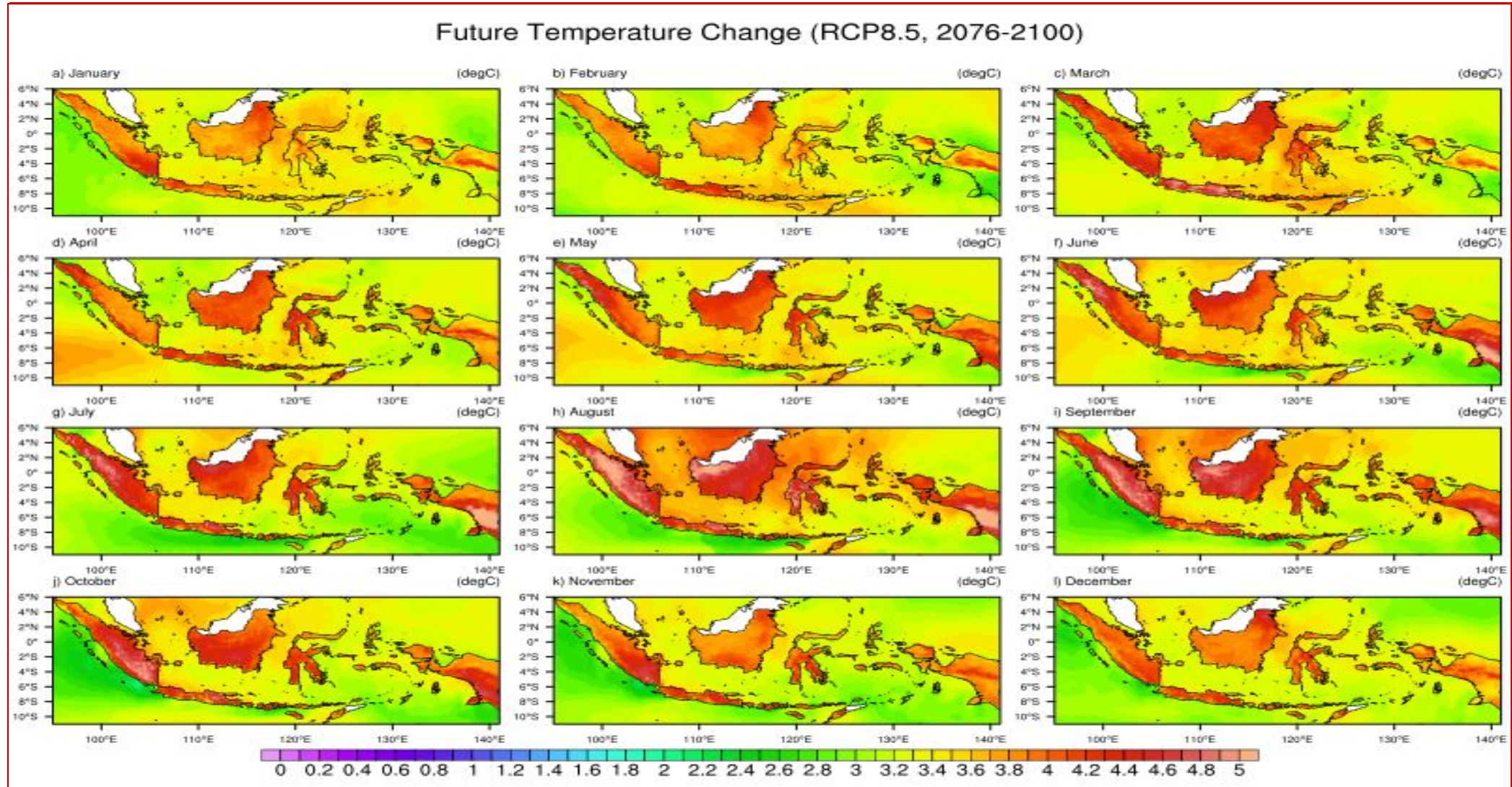
The
Carbon
Brief

Figure 1: Range of Global Emissions Pathways in Scenarios Consistent with Likely Chance of 2°C or Medium Chance of 1.5°C¹⁸



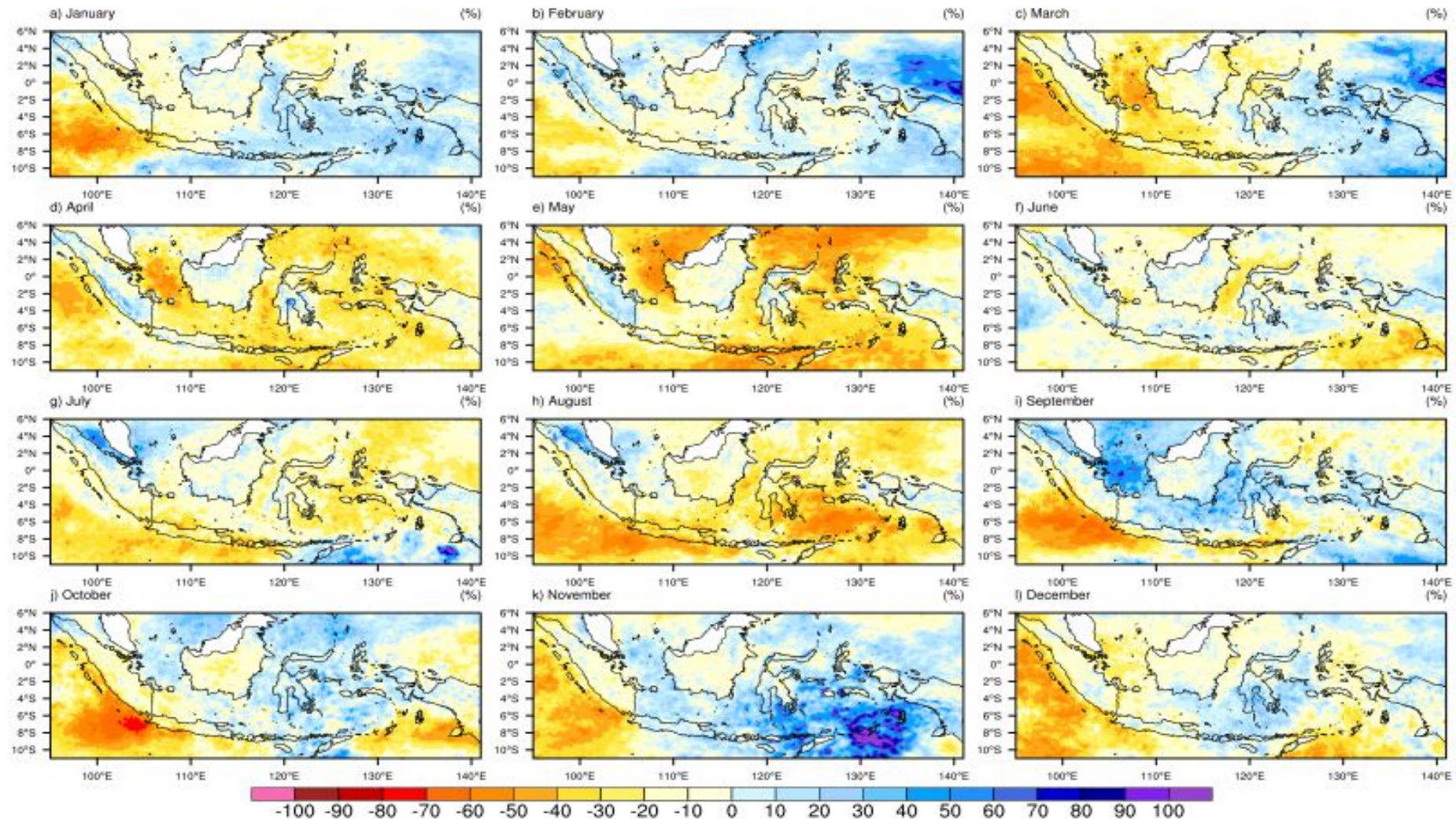
Sources: Joeri Rogelj et al

Luaran model dinamik: Temperatur permukaan



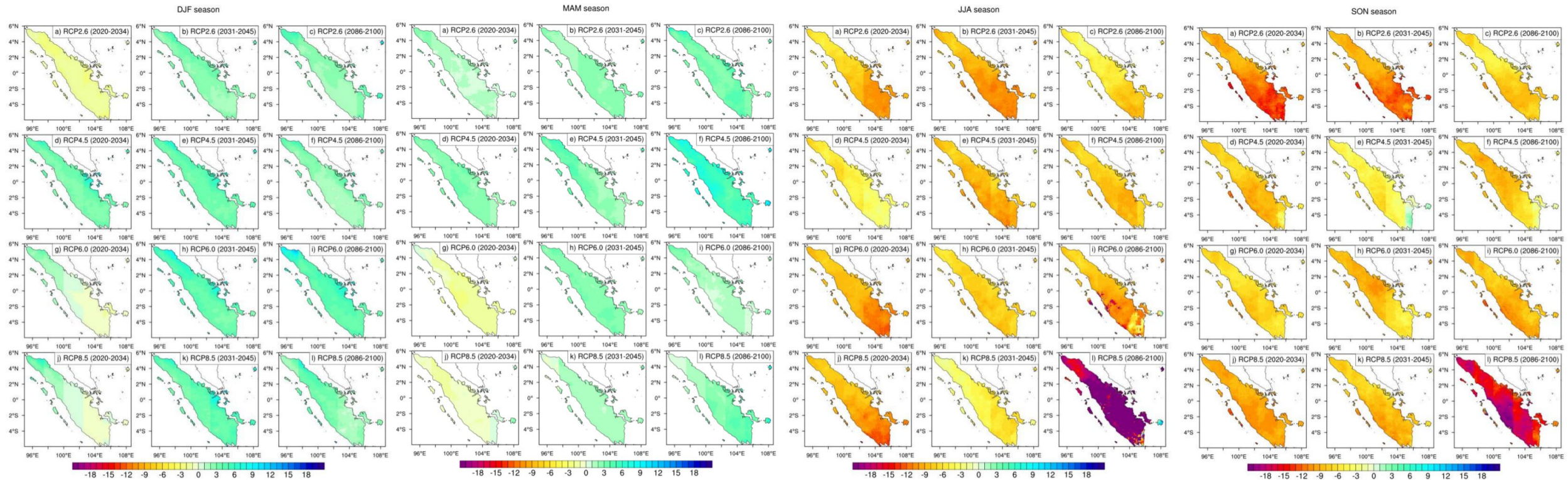
Luaran model dinamik: Curah Hujan

Future Rainfall Change (RCP4.5, 2051-2075)

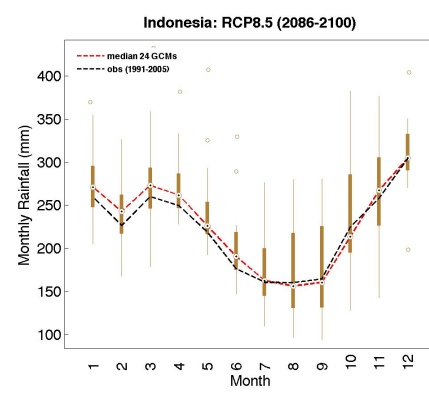
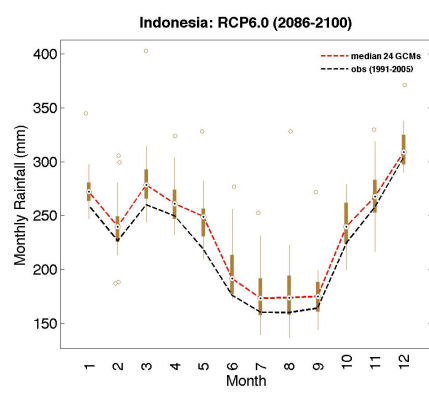
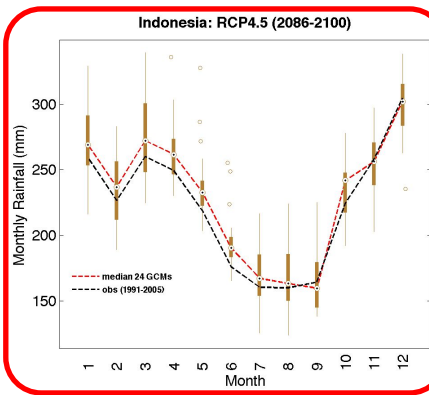
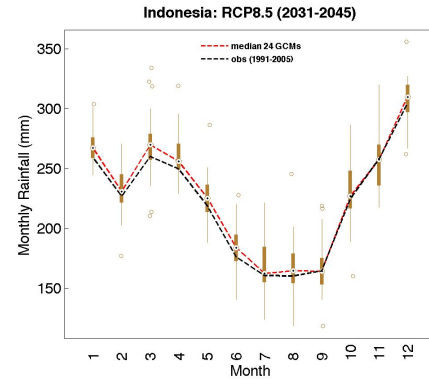
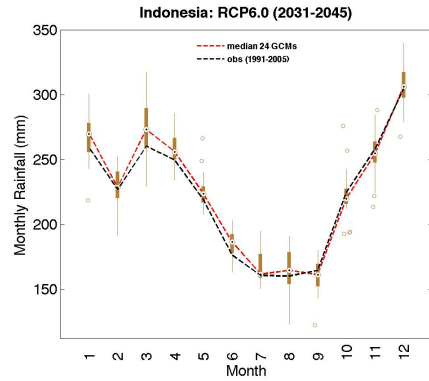
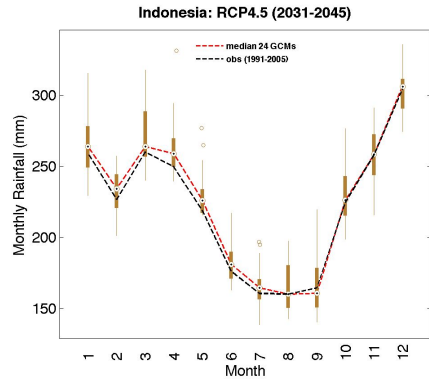
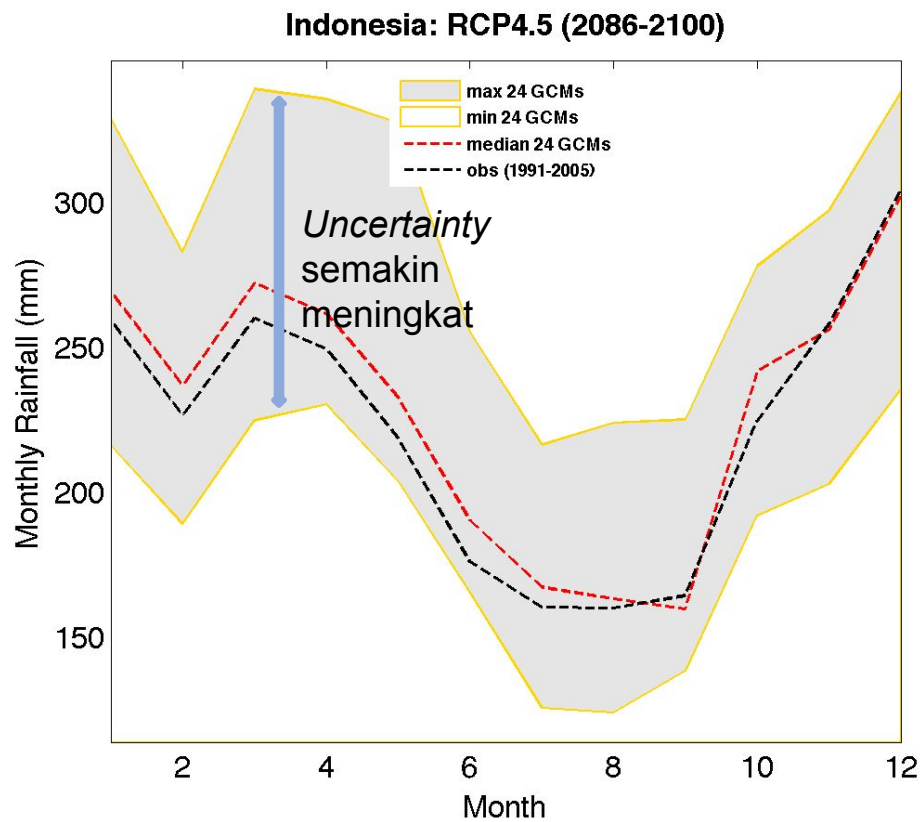
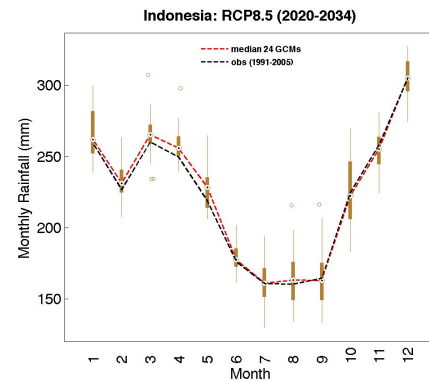
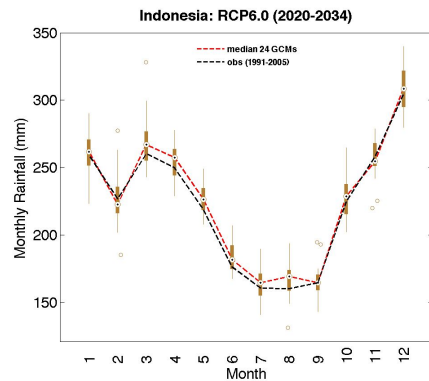
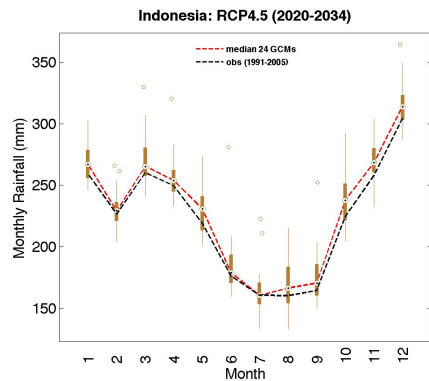
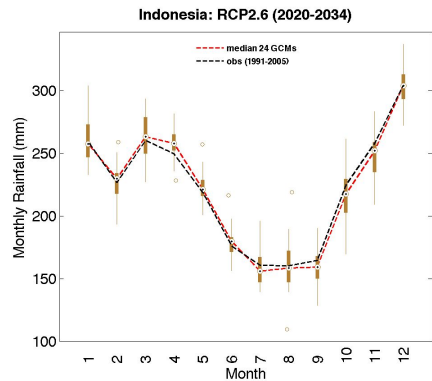


Skenario perubahan curah hujan musiman (Spasial)

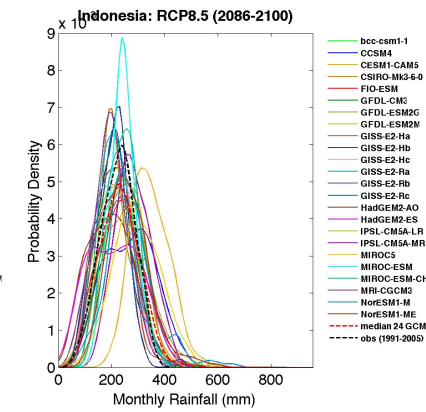
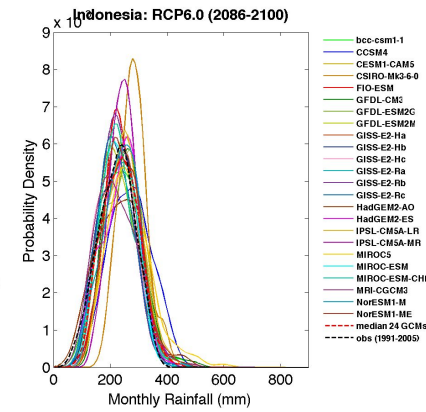
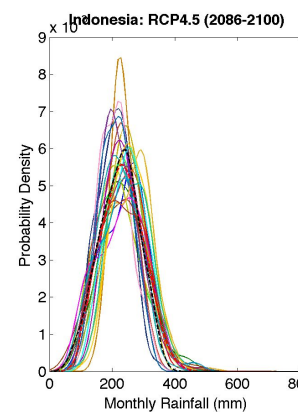
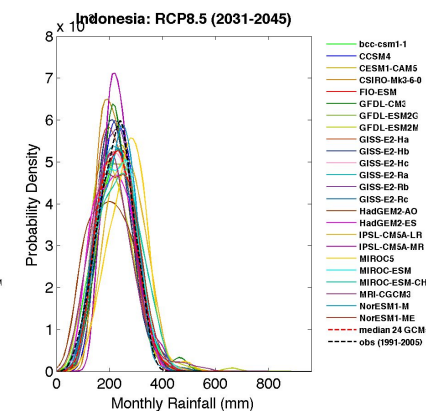
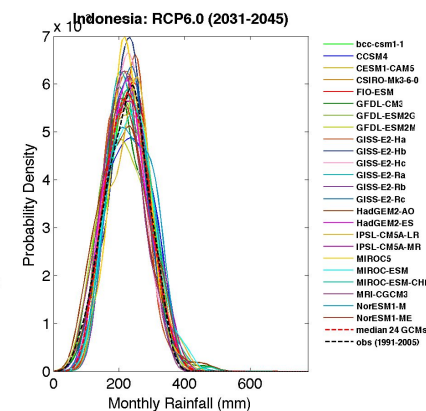
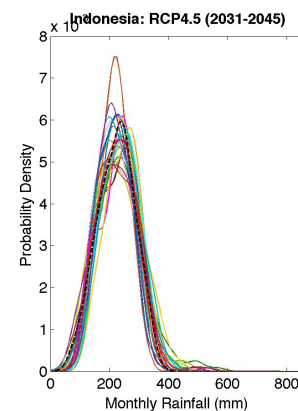
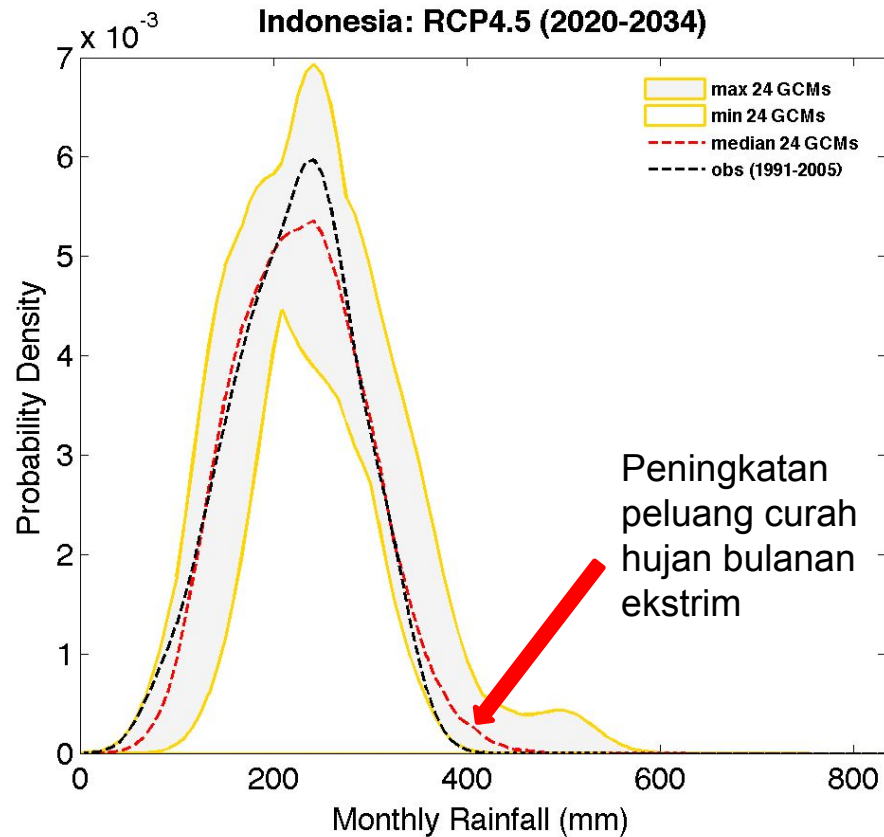
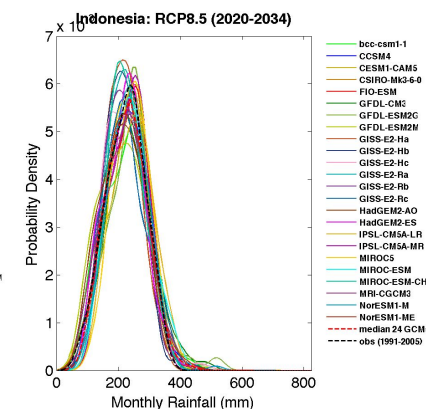
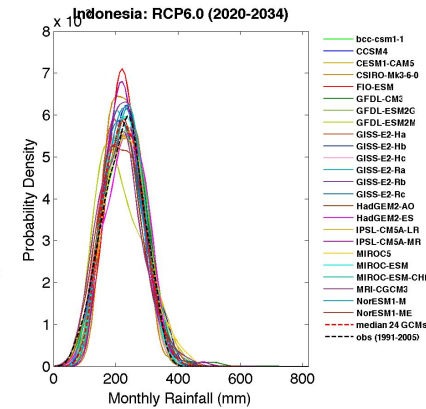
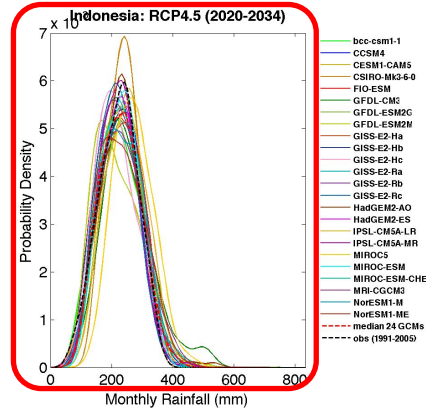
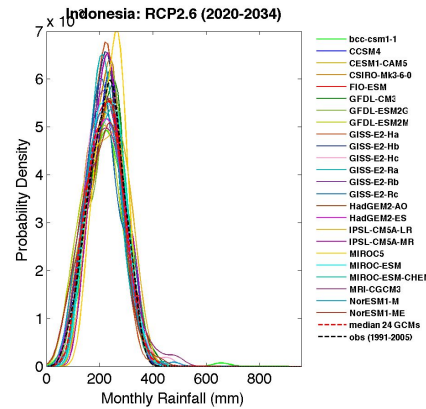
Sumatera



Skenario perubahan Curah Hujan

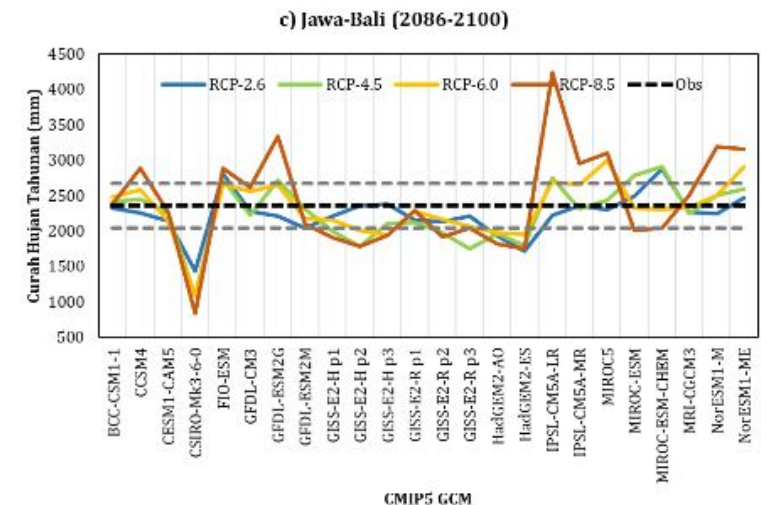
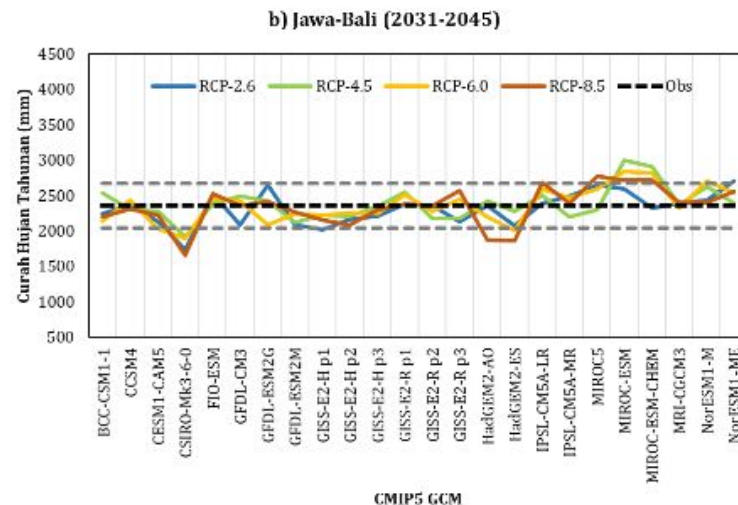
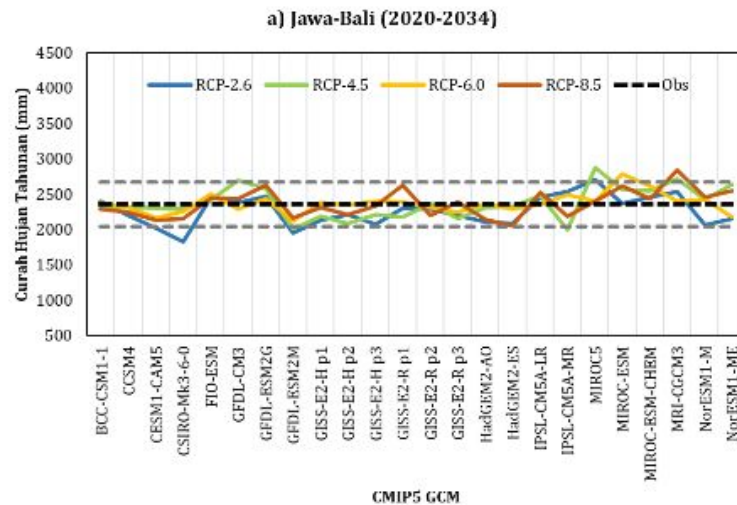
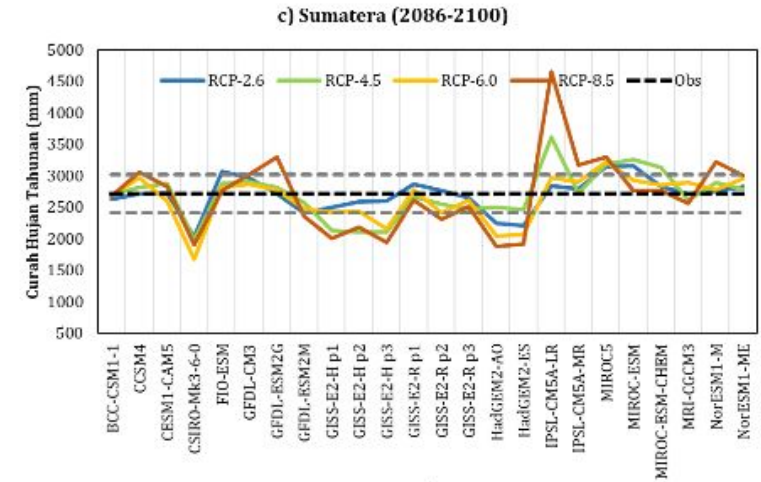
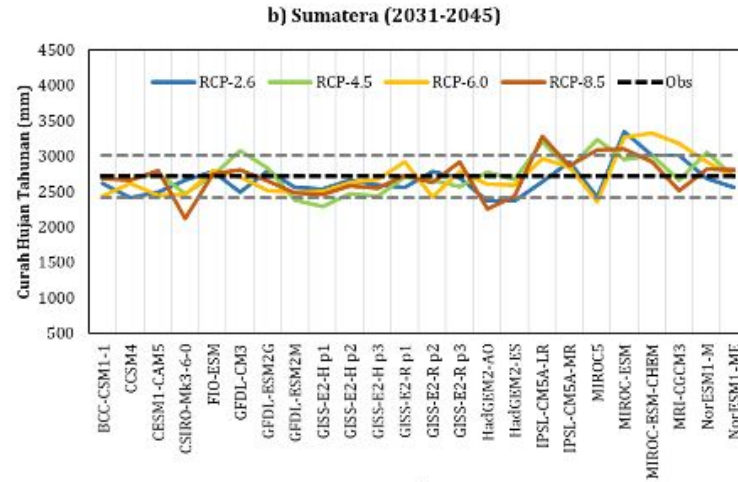
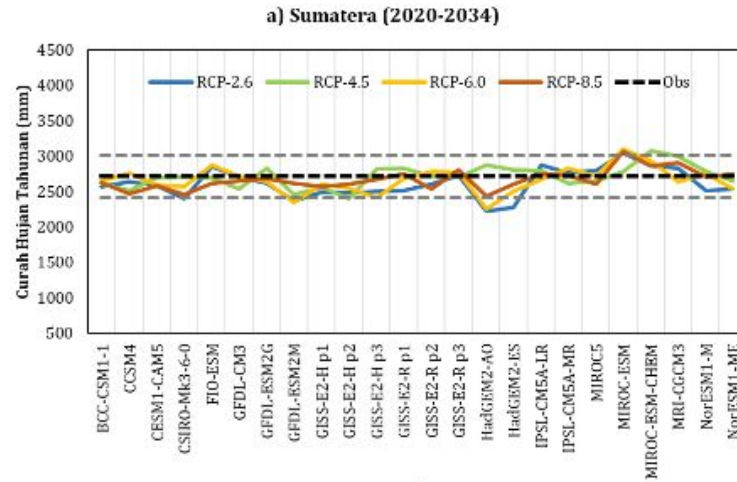


PDF Curah hujan Bulanan Di Indonesia



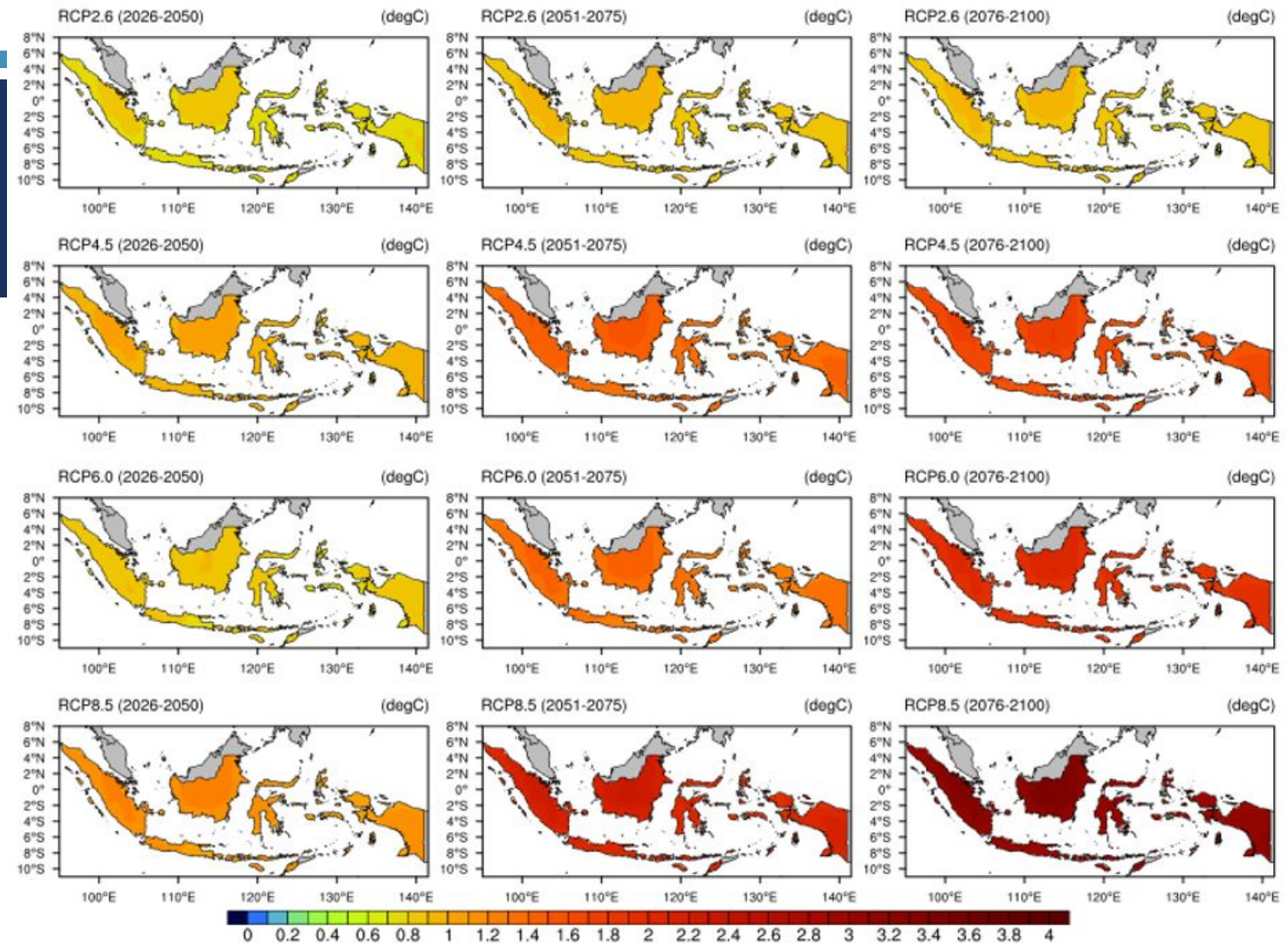
Perbandingan Skenario antar model GCM

- Klimatologi Curah Hujan Tahunan



PROYEKSI SUHU

- Berdasarkan median dari 24 GCMS dengan skenario RCP2.6, rata-rata suhu tahunan diproyeksikan meningkat sekitar 0,67 °C di 2026-2050, serta 0,75 °C di 2051-2075 dan 2076-2100.
- Untuk RCP4.5, perubahan suhu diperkirakan meningkat sebesar 0,87 °C di 2026-2050, dan 1,22 °C di 2051-2075 dan 1,41 °C di 2076-2100.
- Kenaikan serupa ditunjukkan pada RCP6.0 yang diproyeksikan mendekati 0,1 °C di bawah RCP4.5 hampir di semua periode, kecuali periode 2076-2100 yang justru menunjukkan sebaliknya, yaitu menjadi 0,2 °C lebih tinggi dari RCP4.5 pada periode yang sama.
- Berdasarkan skenario ekstrim (RCP8.5) dari nilai median 24 GCM, suhu diproyeksikan akan meningkat 1 °C di 2026-2050, 1,8 °C di 2051-2075 dan 2,7 °C di 2076-2100.



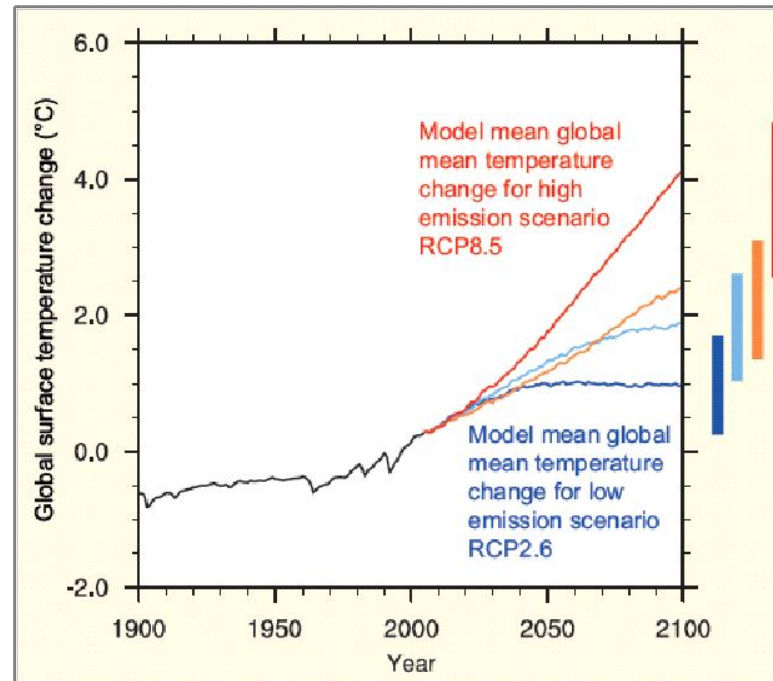
Faqih et al. (2016)

Perbedaan suhu rata-rata tahunan di Indonesia dari MME 24 GCM CMIP5 untuk semua skenario RCP dan masing-masing untuk 3 periode (2026-2050, 2051-2075 dan 2076-2100), relatif terhadap data observasi (1981-2005).

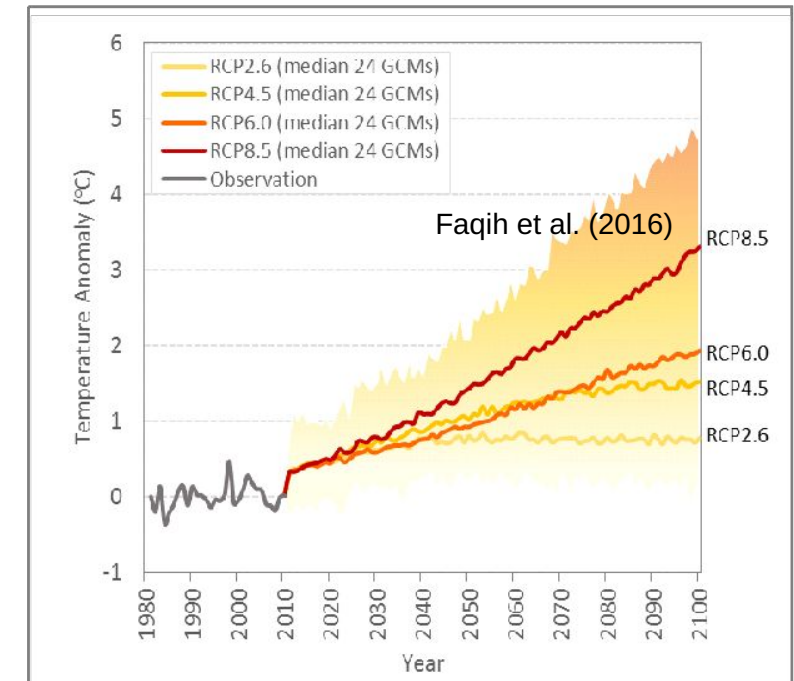
Proyeksi Suhu

- Perbandingan antara hasil proyeksi suhu global dengan proyeksi suhu regional untuk Indonesia menunjukkan bahwa tren suhu di Indonesia lebih rendah dari global di semua skenario RCP.
- Peningkatan suhu di Indonesia pada RCP2.6 diproyeksikan kurang dari 1 °C pada tahun 2100, sedangkan nilai global bisa mencapai 1 °C.
- Perbedaan kenaikan suhu pada tahun 2100 seperti yang ditunjukkan oleh RCP4.5 hampir 0,5 °C lebih rendah untuk Indonesia, yaitu sekitar 1,5 °C di Indonesia dan hampir 2 °C di global.
- Penyebaran model iklim mengandung ketidakpastian (*uncertainty*), kenaikan tertinggi suhu rata-rata proyeksi di Indonesia berpotensi mencapai nilai yang sama seperti pada rentang temperatur global pada tahun 2100, yaitu lebih dari 4 °C.

a) Global [71]

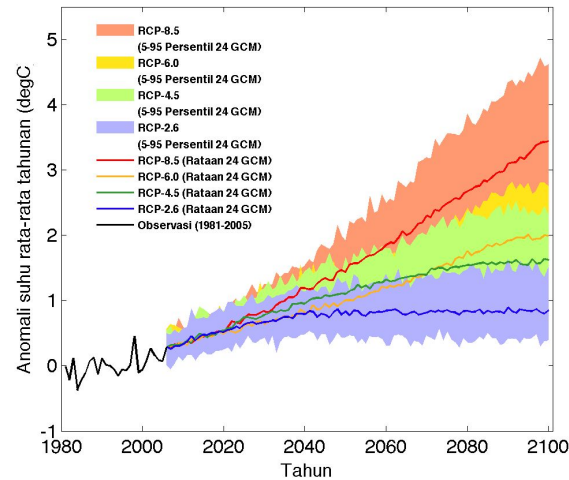


b) Indonesia

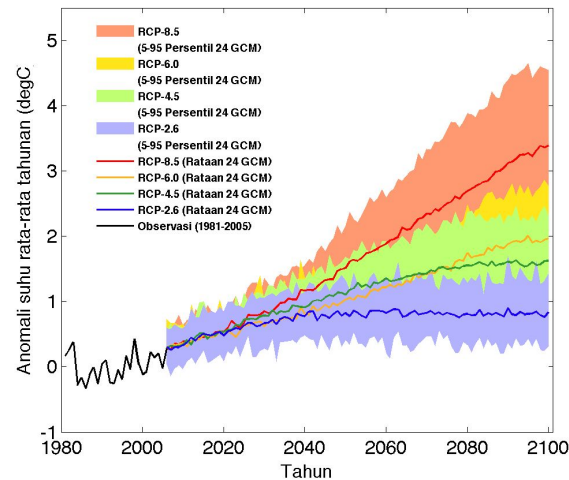


PROYEKSI SUHU UDARA RATA-RATA

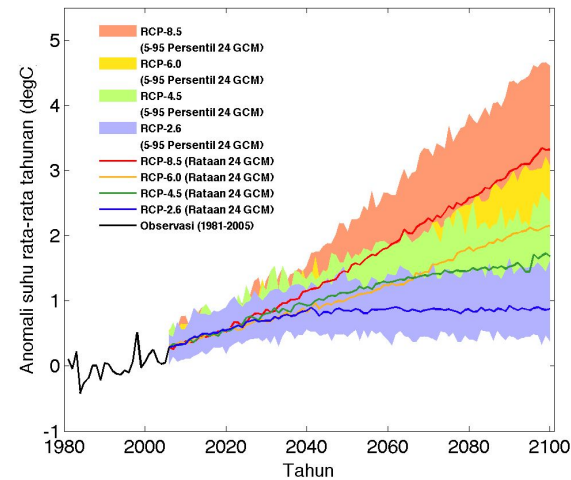
Indonesia



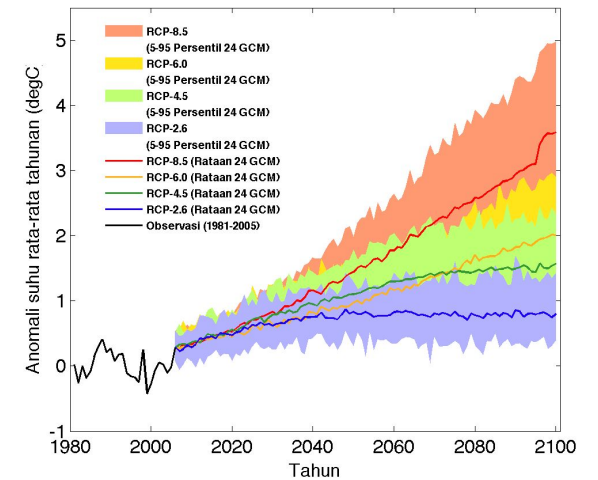
Jawa - Bali



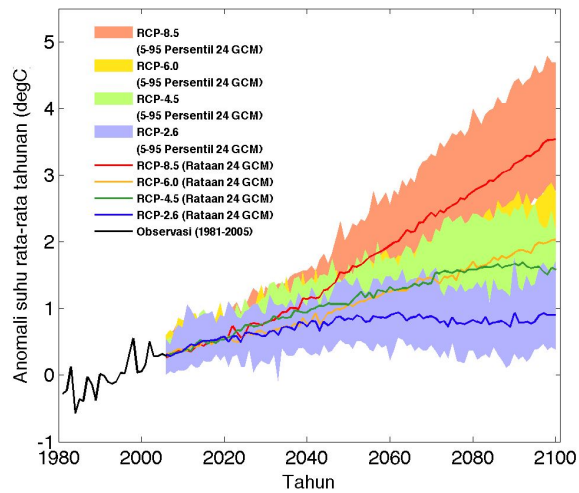
Kalimantan



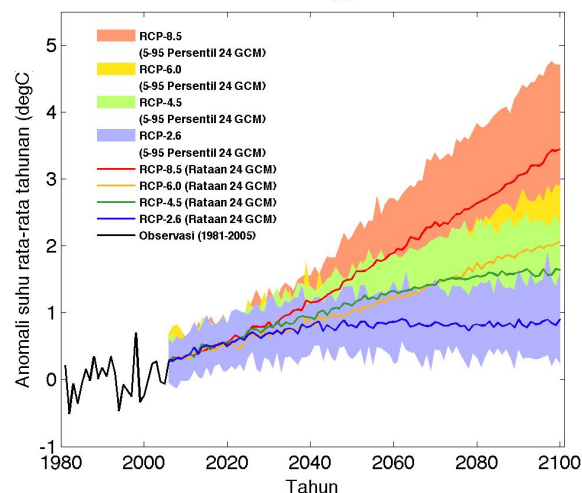
Maluku



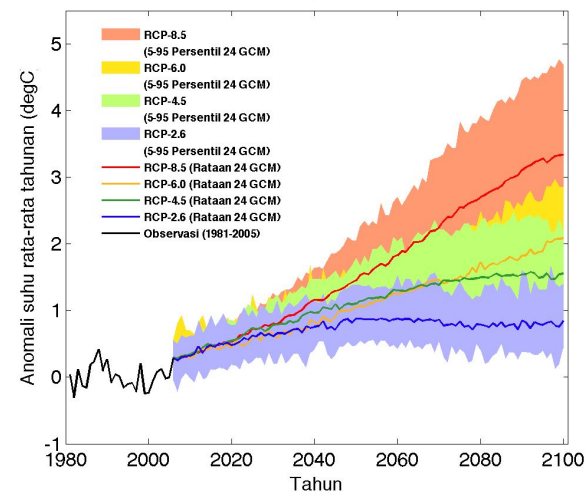
Sumatera



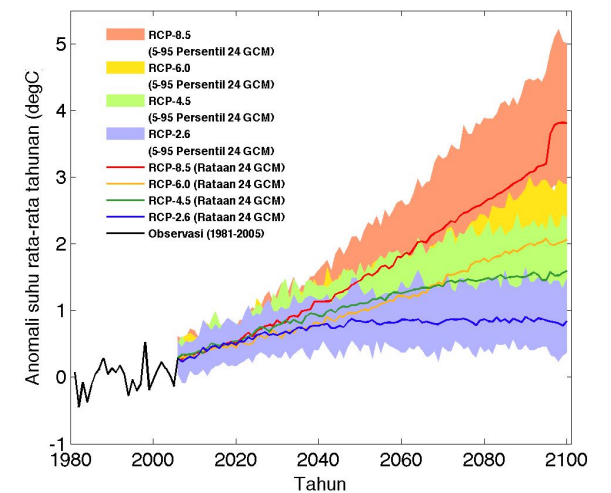
Nusa Tenggara



Papua

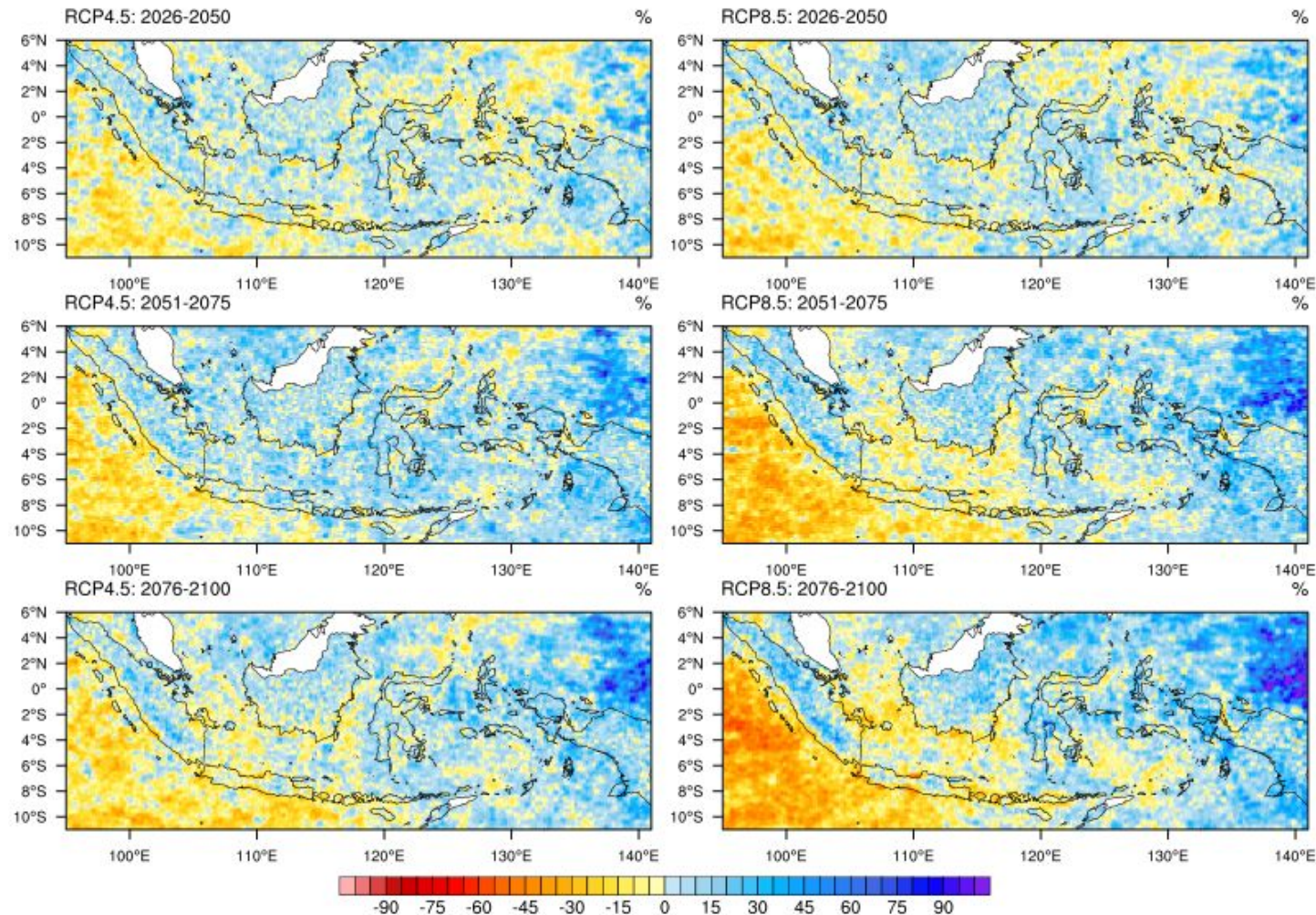


Sulawesi

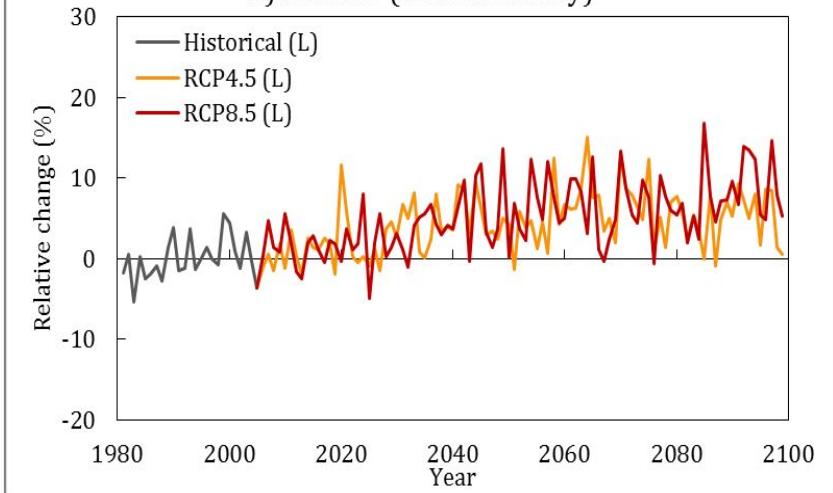


Analisis Luaran model dinamik: Indeks Ekstrim

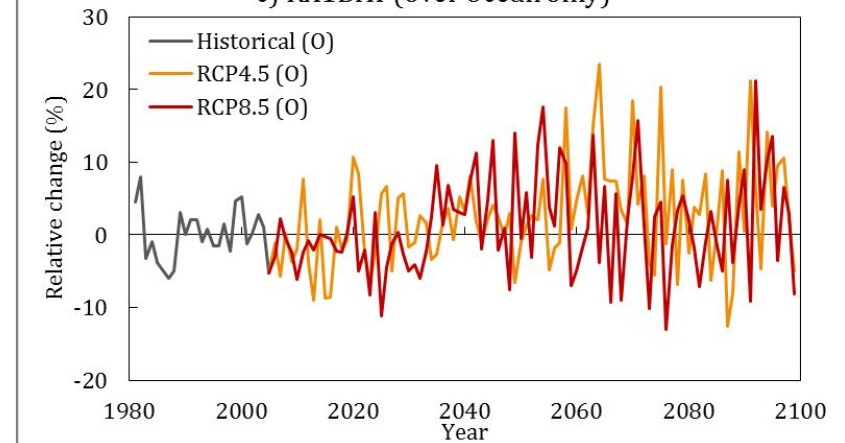
Percent Change of RX1DAY



b) RX1DAY (over Land only)



c) RX1DAY (over Ocean only)



SiBiaS

Metode dan Skenario



REGIONALISASI DOWNSCALING

Sarana komputasi untuk simulasi *regional climate model* TNC:

- 1 Web Server HP Proliant DL 380 G9
 - Processor Xeon E5-2609v3, 8GB (1 x 8 GB) RDIMM DDR3-2133
 - OS Red Hat Enterprise Linux Server with smart management include 1 year standard subscription. Fiber Channel HBA minimum 2 port
 - SAS 250Gb x 2 (RAID1)
 - OS (Linux RHE) installed
- 2 Server HP Proliant DL 580 G9
 - Processor, 4x Intel Xeon E7-8880L V3 2.0 GHz, 45 cache, 9.6GT/s QPI, Turbo, HT, 18C/36T (115W), max mem 1867 MHz.
 - Memory DDR4 LRDIMM 256 GB, Memory configuration type Performance Optimized;
 - HDD SAS 2TB 72K x 24 (RAID 5 (1 Failure+1Hotspare))
 - OS Red Hat Enterprise Linux Server with Smart Management
 - MPI-Open MPI
 - HPC Clustering



**Model
Dinamik
(RCM)**

+

**Model
Statistik**



TNC_SiBias_v1p1_Win_CHIRPS

3rd National Communication [TNC]

Statistical Bias Correction for Climate Scenarios **SiBias** version 1.1

Climate Data Downscaling & Projections – CMIP5 GCMs RCP Scenarios

Select Variable:
☒ Rainfall ☐ Temperature

Select Observed Data:
☒ Grid Global lowres (0.25) ☐ Stations
Input Monthly Data Browse

Define Periods:
Observation Periods:
Start Year : 1981
End Year : 2010
Future Periods:
Start Year : 2011
End Year : 2040

Selections for CMIP5 GCM Datasets:
Select Scenario:
☐ RCP2.6 ☐ RCP6.0
☒ RCP4.5 ☐ RCP8.5
Select GCM(s):
GCMs Selected:
bcc-csm1-1
CCSM4
CESM1-CAM5
CSIRO-Mk3-6-0
FIO-ESM
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
GISS-E2-H (r1i1p1)
GISS-E2-H (r1i1p2)
GISS-E2-H (r1i1p3)
GISS-E2-R (r1i1p1)
GISS-E2-R (r1i1p2)
GISS-E2-R (r1i1p3)

Input Domain:
Latitude : -8.9 S -5.65 N
Longitude : 105.0 E 114.7 E
Region : Jawa

Select Method:
☒ Delta ☐ CDF-based

START CALCULATIONS

Figures:
***** MAPS & PLOTS *****

Info

Department of Geophysics and Meteorology, Bogor Agricultural University (IPB) - 2016

Model Statistik

*“**S**tatistical **B**ias Correction for Climate **S**cenarios” - **SiBiaS** -*

- SiBias is built to process baseline and projection data from the CMIP5 GCMs outputs into downscaled climate change scenarios for various locations in Indonesia.
- It is specially designed to facilitate the use of CMIP5 GCM outputs and process their statistical bias corrections relative to the reference data from observations.
- The program consists of rainfall and surface temperature data outputs from 24 CMIP5 GCMs under 4 Representative Concentration Pathways (RCP) scenarios [[2](#)].

Reference Datasets used in SiBiaS

The main data used as reference are taken from the gridded observation of rainfall and surface temperatures data:

1. The Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) version 2.0 [3, 4] is used as the observed reference file of rainfall data in the system. The data has two selections of spatial grid resolutions, i.e. 0.25° (low) and 0.05° (high).
2. For temperature data, the Climate Research Unit (CRU) TS3.22 [5] data is used for reference file. This data has 0.5° grid resolution.
3. In addition, users can also add their own datasets through the 'browse' file menu. This user-defined data has to be prepared by following the file format as shown in the user manual [6].

Table 2.1 List of available CMIP5 GCMs used for future climate change projections. Green-shaded cells indicate 24 models that are available at all RCP scenarios

No	RCP2.6	RCP4.5	RCP6.0	RCP8.5	Reference
1	-	ACCESS1-0	-	ACCESS1-0	
2	-	ACCESS1-3	-	ACCESS1-3	
3	bcc-csm1-1	bcc-csm1-1	bcc-csm1-1	bcc-csm1-1	[4-6]
4	bcc-csm1-1-m	bcc-csm1-1-m	bcc-csm1-1-m	-	
5	BNU-ESM	BNU-ESM	-	BNU-ESM	
6	CanESM2	CanESM2	-	CanESM2	
7	CCSM4	CCSM4	CCSM4	CCSM4	[7]
8	-	CESM1-BGC	-	CESM1-BGC	
9	CESM1-CAM5	CESM1-CAM5	CESM1-CAM5	CESM1-CAM5	[8]
10	-	CMCC-CM	-	CMCC-CM	
11	-	CMCC-CMS	-	CMCC-CMS	
12	CNRM-CM5	CNRM-CM5	-	CNRM-CM5	
13	CSIRO-Mk3-6-0	CSIRO-Mk3-6-0	CSIRO-Mk3-6-0	CSIRO-Mk3-6-0	[9]
14	EC-EARTH	EC-EARTH	-	EC-EARTH	
15	FGOALS_g2	FGOALS_g2	-	FGOALS_g2	
16	FIO-ESM	FIO-ESM	FIO-ESM	FIO-ESM	[10]
17	GFDL-CM3	GFDL-CM3	GFDL-CM3	GFDL-CM3	[11, 12]
18	GFDL-ESM2G	GFDL-ESM2G	GFDL-ESM2G	GFDL-ESM2G	[13, 14]
19	GFDL-ESM2M	GFDL-ESM2M	GFDL-ESM2M	GFDL-ESM2M	[13, 14]
20	GISS-E2-H*	GISS-E2-H*	GISS-E2-H*	GISS-E2-H*	[15]
21	GISS-E2-H**	GISS-E2-H**	GISS-E2-H**	GISS-E2-H**	[15]
22	GISS-E2-H***	GISS-E2-H***	GISS-E2-H***	GISS-E2-H***	[15]
23	-	GISS-E2-H-CC	-	-	
24	GISS-E2-R*	GISS-E2-R*	GISS-E2-R*	GISS-E2-R*	[15]
25	GISS-E2-R**	GISS-E2-R**	GISS-E2-R**	GISS-E2-R**	[15]
26	GISS-E2-R***	GISS-E2-R***	GISS-E2-R***	GISS-E2-R***	[15]
27	-	GISS-E2-R-CC	-	-	
28	HadGEM2-AO	HadGEM2-AO	HadGEM2-AO	HadGEM2-AO	[16, 17]
29	-	HadGEM2-CC	-	HadGEM2-CC	
30	HadGEM2-ES	HadGEM2-ES	HadGEM2-ES	HadGEM2-ES	[16, 17]
31	-	inmem4	-	inmem4	
32	IPSL-CM5A-LR	IPSL-CM5A-LR	IPSL-CM5A-LR	IPSL-CM5A-LR	[18]
33	IPSL-CM5A-MR	IPSL-CM5A-MR	IPSL-CM5A-MR	IPSL-CM5A-MR	[18]
34	-	IPSL-CM5B-LR	-	IPSL-CM5B-LR	
35	MIROC5	MIROC5	MIROC5	MIROC5	[19]
36	MIROC-ESM	MIROC-ESM	MIROC-ESM	MIROC-ESM	[19]
37	MIROC-ESM-CHEM	MIROC-ESM-CHEM	MIROC-ESM-CHEM	MIROC-ESM-CHEM	[19]
38	MPI-ESM-LR	MPI-ESM-LR	-	MPI-ESM-LR	
39	MPI-ESM-MR	MPI-ESM-MR	-	MPI-ESM-MR	
40	MRI-CGCM3	MRI-CGCM3	MRI-CGCM3	MRI-CGCM3	[20, 21]
41	NorESM1-M	NorESM1-M	NorESM1-M	NorESM1-M	[22]
42	NorESM1-ME	NorESM1-ME	NorESM1-ME	NorESM1-ME	[23]

CMIP5 GCMs

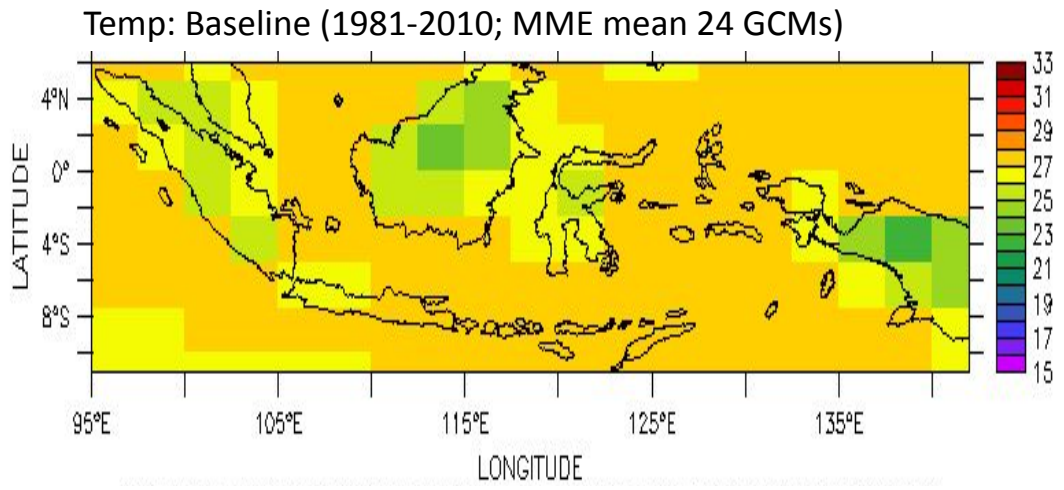
There are 42 GCMs in CMIP5 database, but only RCP45 that has representation from all models.

Green shaded cells in the table show the model that represents all scenarios

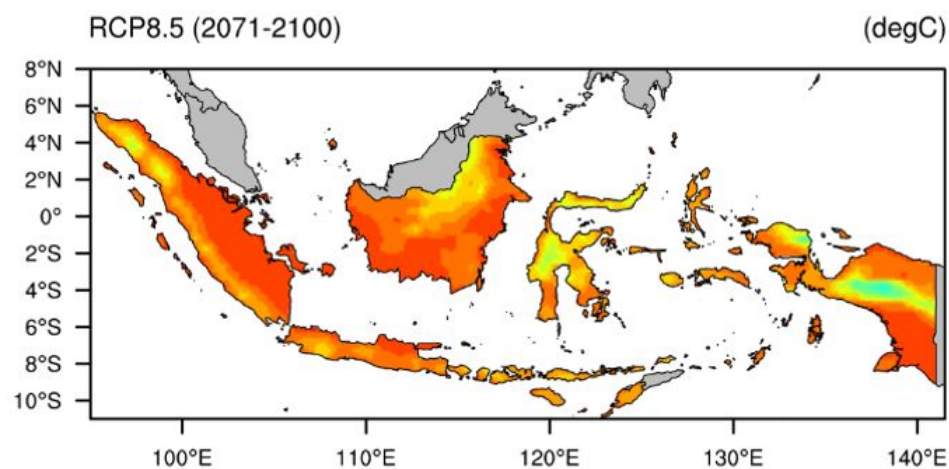
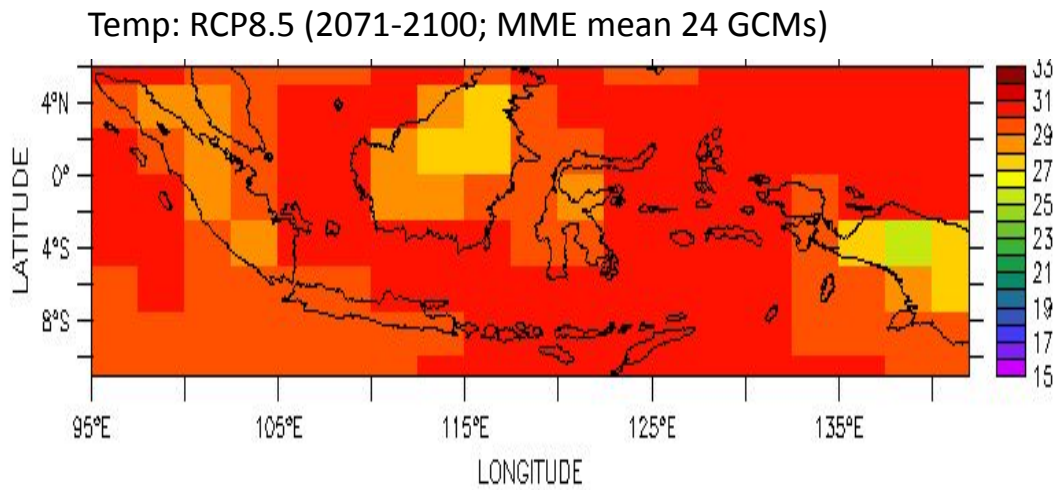
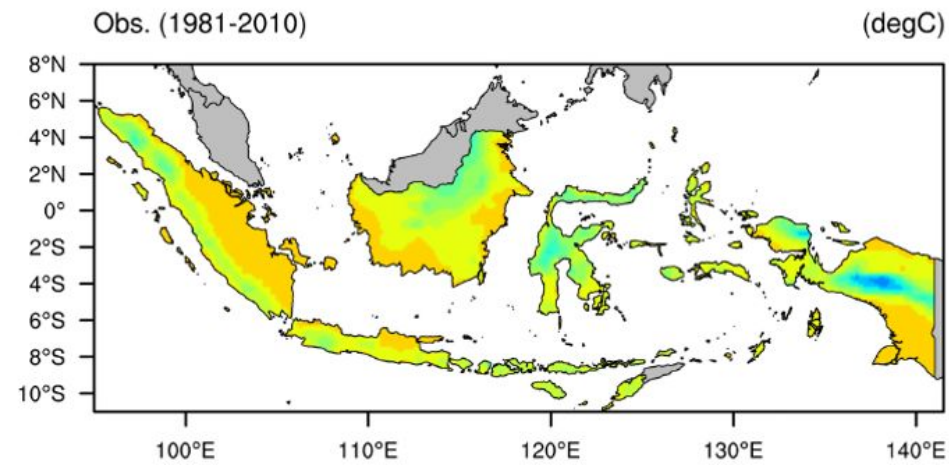
Outputs from 24 models are selected for SiBiaS v1.1 datasets

Example: using simple approaches by adding climate changes from GCMs to observed data fields

GCMs



Adding changes to observed data



Simple approaches such as spatial interpolation or adding climate changes from GCMs to observed data fields increase the spatial resolution

Metode downscaling statistik yang digunakan dalam kegiatan TNC Indonesia dan diadopsi dalam software SiBiaS versi 1.1

A. Downscaling Sederhana (Pendekatan Delta)

Metode delta [e.g. 40] adalah metode downscaling sederhana yang banyak digunakan untuk mempersiapkan skenario perubahan iklim di tingkat lokal. Penggunaannya dapat melalui penambahan atau perkalian delta ($\Delta\mu$) dengan data periode baseline. Pendekatan Perubahan delta didasarkan pada penggunaan faktor perubahan, rasio antara nilai rata-rata dalam waktu historis dan masa depan. Faktor ini kemudian diterapkan pada data observasi time series untuk mengubah set data ini kedalam data time series yang mewakili iklim di masa depan [40]. Namun demikian, untuk menjaga variabilitas model ketika menghitung time series dari curah hujan atau suhu di masa depan, $\Delta\mu$ dihitung dari perbedaan atau dari rasio antara nilai rata-rata observasi (μ_{ob}) dan model baseline (μ_{mb}). Secara umum, metode Delta digunakan dalam penelitian ini mengikuti persamaan di bawah ini:

$$x_{cor,i} = x_{mp,i} + \mu_{ob} - \mu_{mb} \quad (1)$$

$$x_{cor,i} = x_{mp,i} \times \frac{\mu_{ob}}{\mu_{mb}} \quad (2)$$

Metode delta dengan rumus penambahan umumnya digunakan untuk data suhu (Persamaan 1), sementara perkalian digunakan untuk data curah hujan (Persamaan 2).

Metode downscaling statistik yang digunakan dalam kegiatan TNC Indonesia dan diadopsi dalam software SiBiaS versi 1.1

B. Distribusi Intensitas Statistik

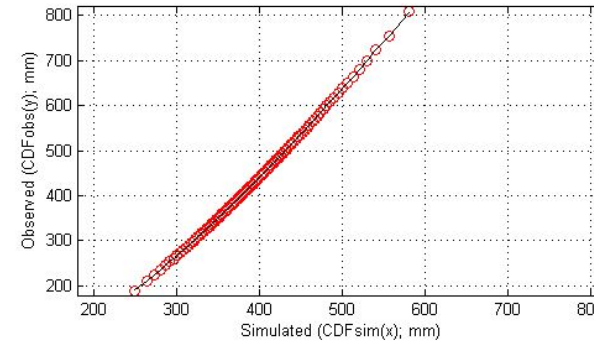
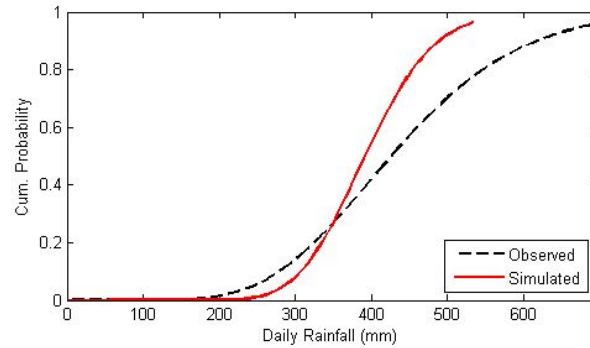
Metode distribusi intensitas statistik didasarkan pada koreksi dari distribusi data model iklim, yang diubah agar sesuai dengan distribusi data observasi [41]. Dalam proses koreksi, data observasi dan simulasi diasumsikan memiliki pola distribusi tertentu, di mana untuk data curah hujan umumnya memiliki distribusi Gamma [41]. Persamaan PDF Gamma mengikuti Persamaan 3 di bawah ini:

$$pdf(x) = \frac{e^{(-\frac{x}{\theta})} x^{(k-1)}}{\Gamma(k)\theta^k} \quad (3)$$

Di mana x adalah data curah hujan dan k adalah parameter bentuk dan θ adalah parameter skala. Secara umum, proses koreksi dilakukan dengan menghitung nilai kurva kebalikan Cumulative Distribution Function (CDF) untuk data observasi (y) dan model (x). Data dari kebalikan CDF kemudian digunakan untuk mengembangkan persamaan regresi dimana $y = f(x)$. Persamaan yang diperoleh dari regresi dianggap sebagai faktor koreksi yang dapat digunakan untuk memperbaiki model baseline dan data proyeksi masa depan. Kami telah mencoba beberapa pendekatan regresi untuk menemukan model regresi yang paling cocok. Ditemukan bahwa regresi polinomial orde ketiga dengan memaksakan garis ke titik asalnya (0, 0), memberikan hasil yang lebih baik untuk faktor koreksi data curah hujan. Berbeda dengan fungsi distribusi data curah hujan yang mengikuti distribusi Gamma, kami memodifikasi distribusi untuk data suhu. Pola distribusi suhu umumnya berbentuk Gaussian – berbeda dengan data curah hujan – sehingga cenderung mengikuti pola distribusi normal. Pendekatan delta sederhana dan pendekatan distribusi intensitas statistik merupakan metode downscaling yang berkaitan dengan pendekatan bias-koreksi. Perbandingan dari berbagai metode koreksi bias untuk suhu bulanan dan curah hujan disimulasikan dengan beberapa model iklim telah dibahas dan dibandingkan dalam studi terbaru [42].

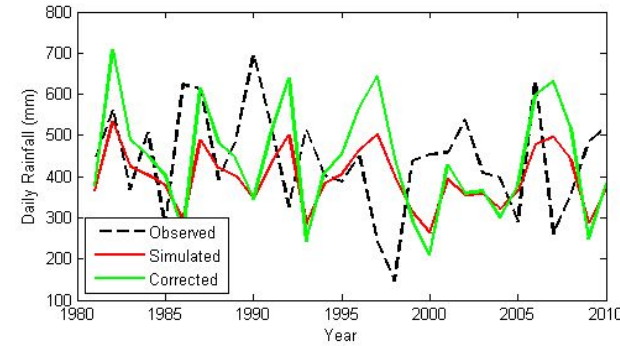
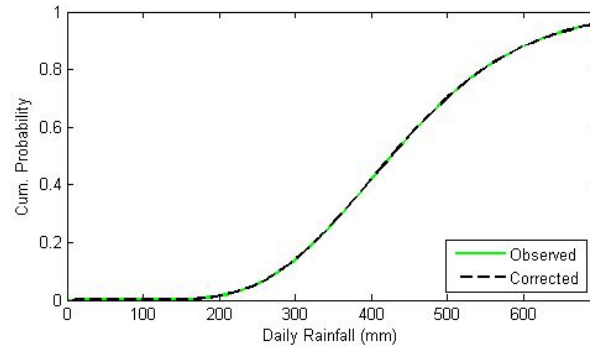
Steps for Bias correction in SiBiaS

1. Create CDF from observation and model baseline
2. Calculate invers CDFs from both CDFs



3. Create scatter plot from the invers CDF
4. Calculate regression model used as correction factor

5. Use the baseline data from the model into the regression model in order to get the corrected baseline data
6. Create CDF from the corrected baseline and compare it with the CDF from observation



7. Plot time series comparing the corrected data with observation
8. Repeat stap 5-7 by using projection data from the model in order to get future sceanrio data

MODEL STATISTIK

TNC_SiBiaS_v1p1_Win_CHIRPS

3rd National Communication [TNC]

Statistical Bias Correction for Climate Scenarios *SiBiaS* version 1.1

Climate Data Downscaling & Projections – CMIP5 GCMs RCP Scenarios

Select Variable
☒ Rainfall ☐ Temperature

Select Observed Data
☒ Grid Global lowres (0.25) ☐ Stations
Input Monthly Data Browse

Define Periods
Observation Periods
Start Year : 1981
End Year : 2010
Future Periods
Start Year : 2011
End Year : 2040

Selections for CMIP5 GCM Datasets
Select Scenario
☐ RCP2.6 ☐ RCP6.0
☒ RCP4.5 ☐ RCP8.5
Select GCM(s)
GCMs Selected
bcc-csm1-1
CCSM4
CESM1-CAM5
CSIRO-Mk3-6-0
FIO-ESM
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
GISS-E2-H (r1i1p1)
GISS-E2-H (r1i1p2)
GISS-E2-H (r1i1p3)
GISS-E2-R (r1i1p1)
GISS-E2-R (r1i1p2)
GISS-E2-R (r1i1p3)

Input Domain
Latitude : -8.9 S - -5.65 N
Longitude : 105.0 E - 114.7 E
Region : Jawa

Select Method
☒ Delta ☐ CDF-based

START CALCULATIONS

Figures
***** MAPS & PLOTS *****

Info

Department of Geophysics and Meteorology, Bogor Agricultural University (IPB) - 2016

Two climate variables:
Rainfall & Surface Temperatures

Two resolutions
(for rainfall): 0.25 deg (25 km x 25 km) and
0.05 deg (~5 km x ~5 km)

User defined dataset:
From stations or other data

Define baseline and observation
periods

Define periods of future
scenarios

MODEL STATISTIK

Select RCP scenario:
RCP2.6, RCP4.5, RCP6.0 & RCP8.5

Select one or more of 24 available
CMIP5 GCM outputs

TNC_SiBiaS_v1p1_Win_CHIRPS

3rd National Communication [TNC]

Statistical
Bias Correction
for Climate Scenarios

SiBiaS version 1.1

Climate Data Downscaling & Projections – CMIP5 GCMs RCP Scenarios

Select Variable:
☒ Rainfall ☐ Temperature

Select Observed Data:
☒ Grid Global lowres (0.25) ☐ Stations
Input Monthly Data Browse

Define Periods

Observation Periods
Start Year : 1981
End Year : 2010

Future Periods
Start Year : 2011
End Year : 2040

Selections for CMIP5 GCM Datasets

Select Scenario:
☐ RCP2.6 ☒ RCP4.5 ☐ RCP6.0 ☐ RCP8.5

Select GCM(s):
GCMs Selected
bcc-csm1-1
CCSM4
CESM1-CAM5
CSIRO-Mk3-6-0
FIO-ESM
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
GISS-E2-H (r1i1p1)
GISS-E2-H (r1i1p2)
GISS-E2-H (r1i1p3)
GISS-E2-R (r1i1p1)
GISS-E2-R (r1i1p2)
GISS-E2-R (r1i1p3)

Input Domain
Latitude : -8.9 S - -5.65 N
Longitude : 105.0 E - 114.7 E
Region : Jawa

Select Method:
☒ Delta ☐ CDF-based

START CALCULATIONS

Figures
***** MAPS & PLOTS *****

Info

Department of Geophysics and Meteorology, Bogor Agricultural University (IPB) - 2016

3rd National Communication [TNC]

Statistical Bias Correction for Climate Scenarios *SiBiaS* version 1.1

Climate Data Downscaling & Projections -- CMIP5 GCMs RCP Scenarios

Select Variable

☒ Rainfall ☐ Temperature

Select Observed Data

☒ Grid Global ☐ Stations

lowres (0.25) ▼

Input Monthly Data Browse

Define Periods

Observation Periods

Start Year : 1981

End Year : 2010

Future Periods

Start Year : 2011

End Year : 2040

Selections for CMIP5 GCM Datasets

Select Scenario

☐ RCP2.6 ☐ RCP6.0

☒ RCP4.5 ☐ RCP8.5

Select GCM(s)

GCMs Selected

bcc-csm1-1

CCSM4

CESM1-CAM5

CSIRO-Mk3-6-0

FIO-ESM

GFDL-CM3

GFDL-ESM2G

GFDL-ESM2M

GISS-E2-H (r1i1p1)

GISS-E2-H (r1i1p2)

GISS-E2-H (r1i1p3)

GISS-E2-R (r1i1p1)

GISS-E2-R (r1i1p2)

GISS-E2-R (r1i1p3)

Input Domain

Latitude : -8.9 S - -5.65 N

Longitude : 105.0 E - 114.7 E

Region : Jawa

Select Method

☒ Delta ☐ CDF-based

START CALCULATIONS

Figures

***** MAPS & PLOTS ***** ▼

Info

Department of Geophysics and Meteorology, Bogor Agricultural University (IPB) - 2016

User defined domain location within Indonesia

Select one of two available statistical downscaling methods

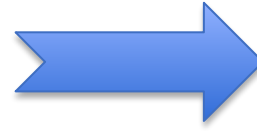
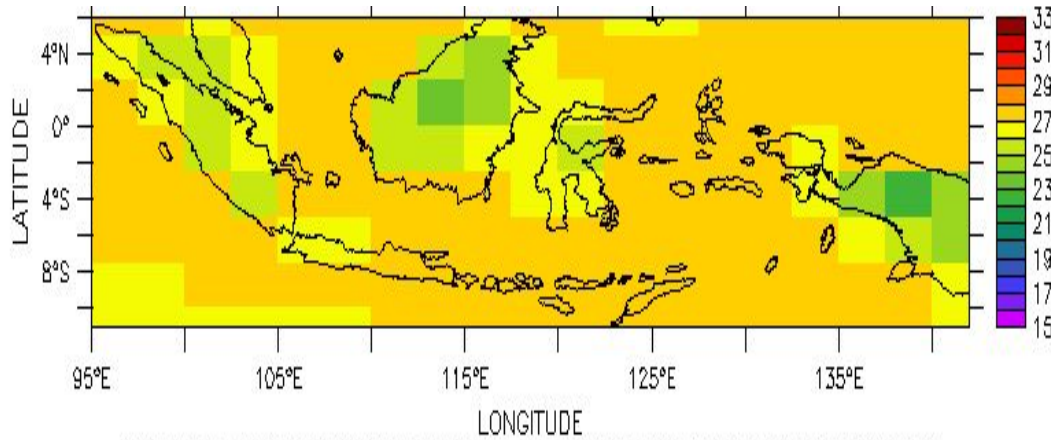
Start processing

Display Map & Graphics

Example: using simple approaches by adding climate changes from GCMs to observed data fields

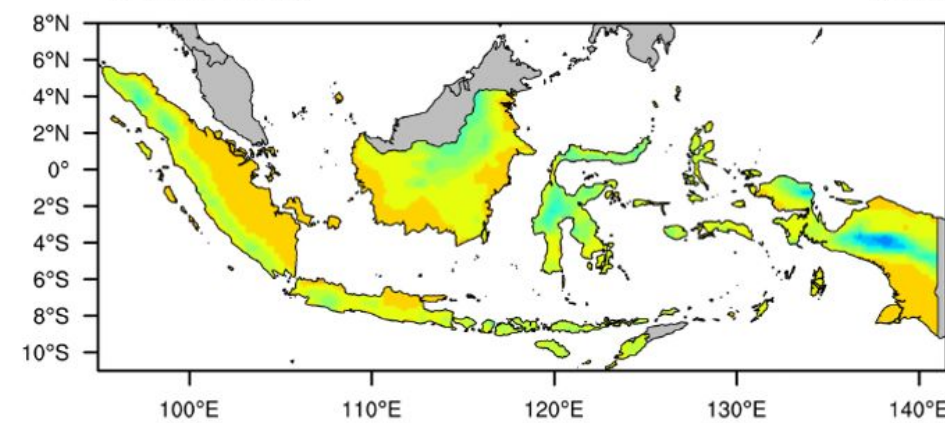
GCM

Temp: Baseline (1981-2010; MME mean 24)

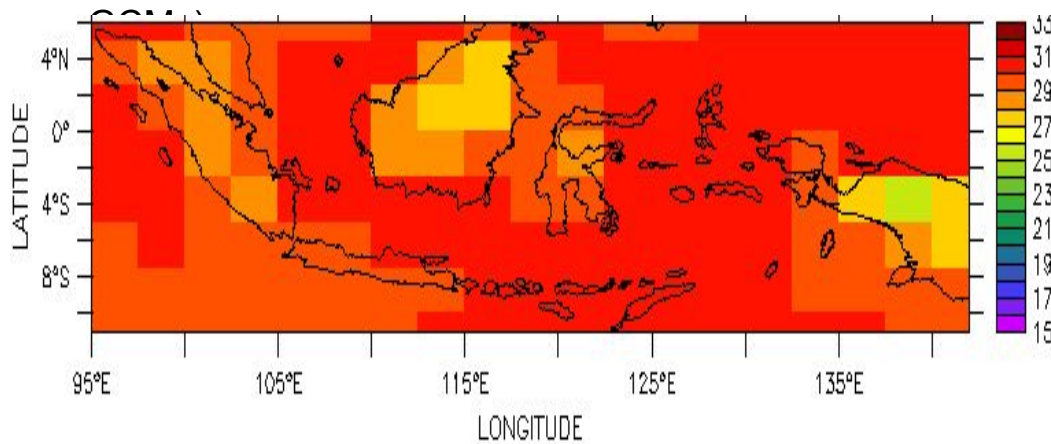


Adding changes to observed data

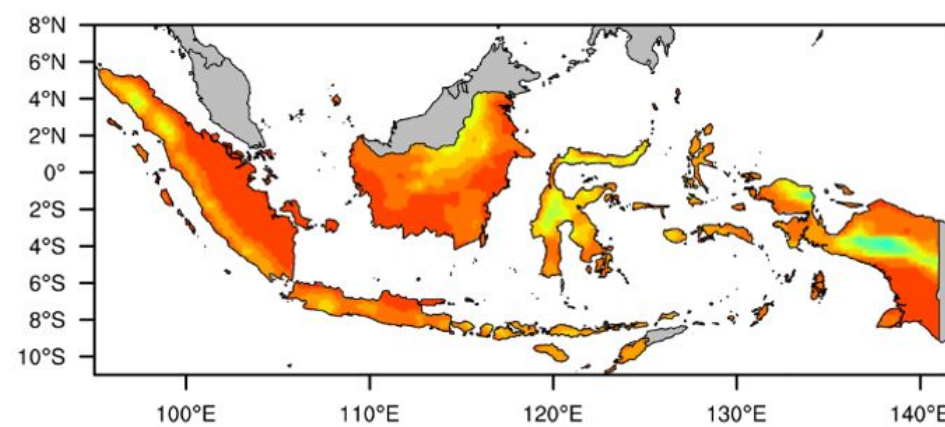
Obs. (1981-2010)



Temp: RCP8.5 (2071-2100; MME mean 24)



RCP8.5 (2071-2100)

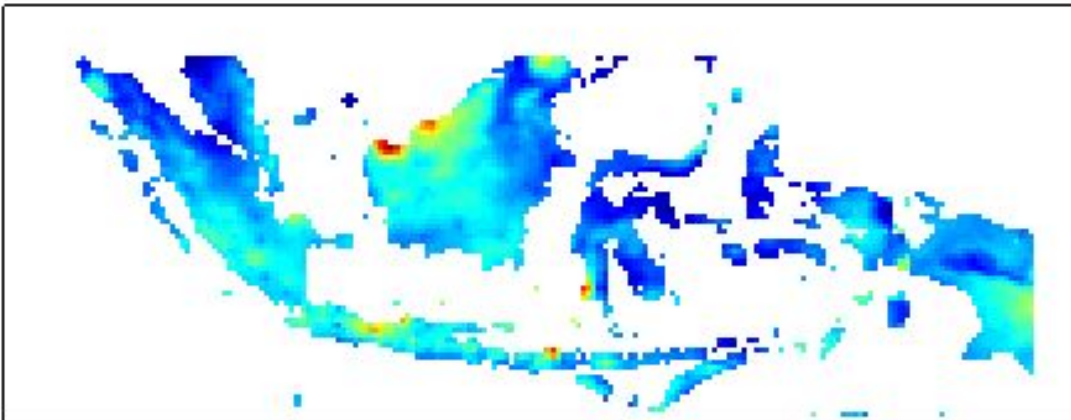


Simple approaches such as spatial interpolation or adding climate changes from GCMs to observed data fields increase the spatial resolution

SiBiaS v1.1 outputs

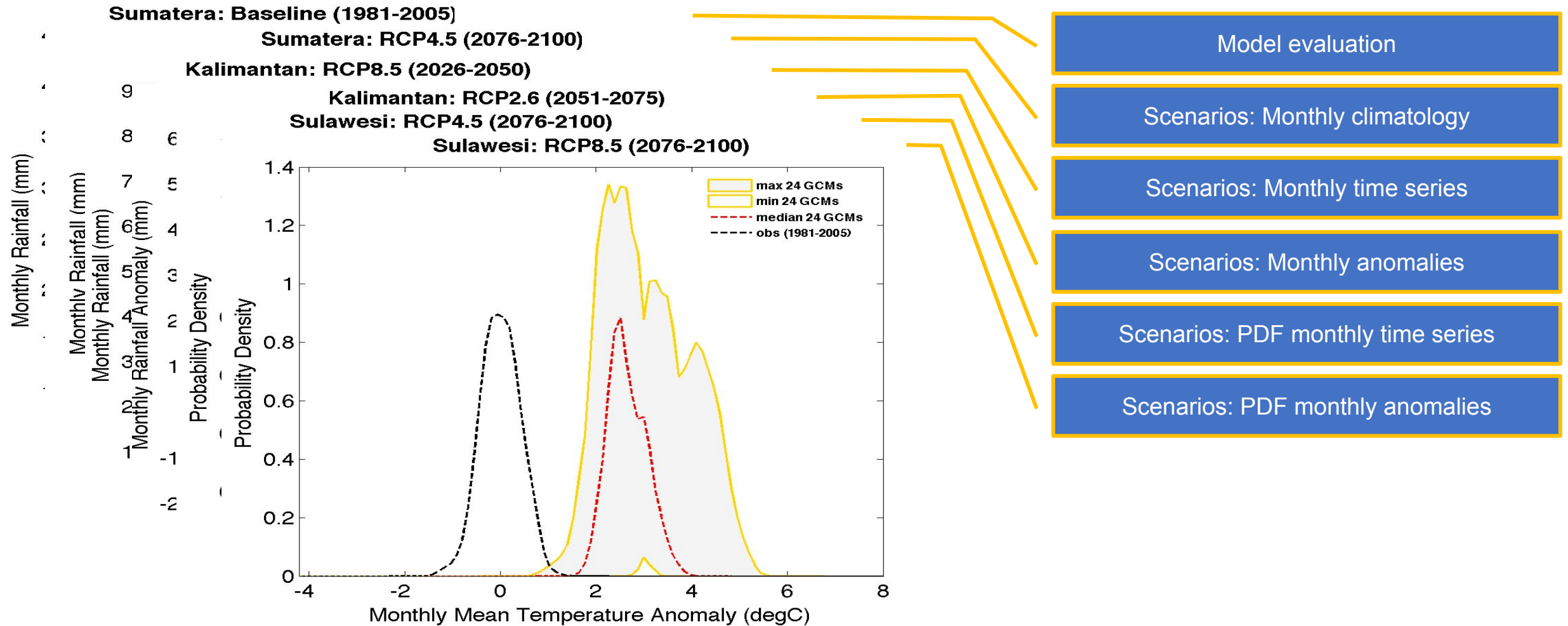
SiBiaS v1.1 delivers two types of outputs:

1. downscaled data in simple ASCII format, and
2. graphic plots from the results of the area-averaged monthly climatology, monthly time series, anomalies of monthly time series and probability density function (PDF).

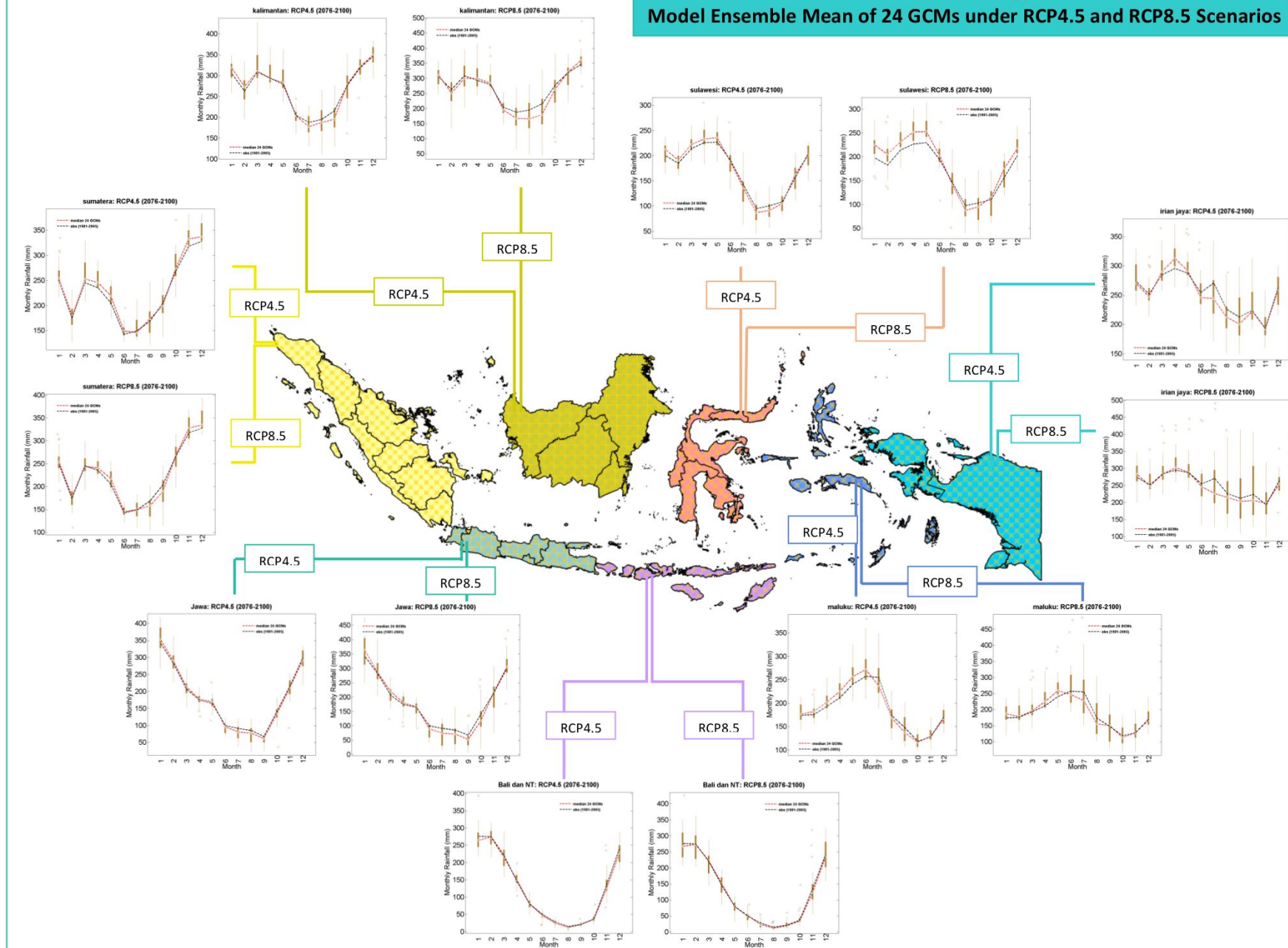


A Map of the Selected
Domain Location

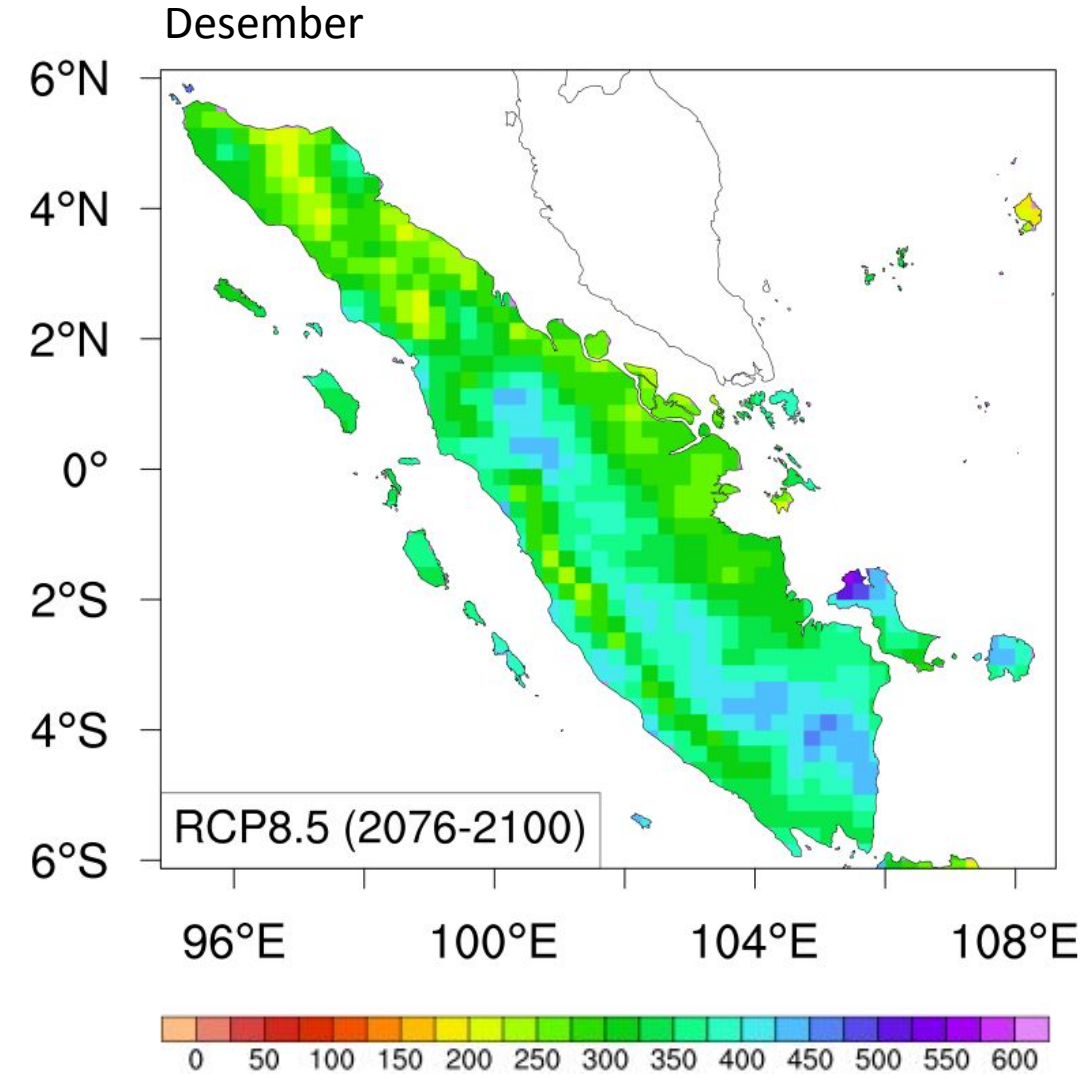
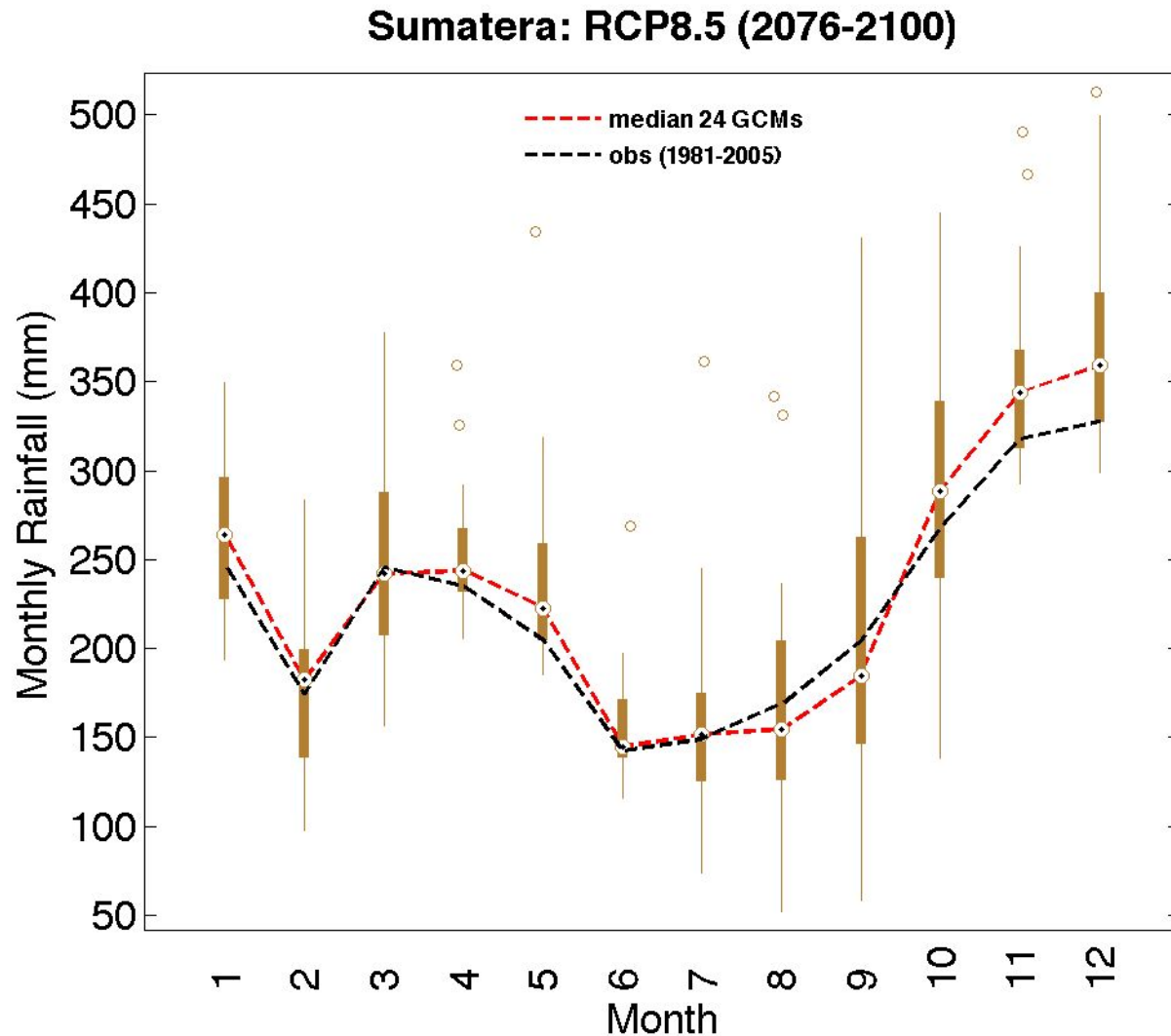
Figures resulted from SiBiaS v1.1



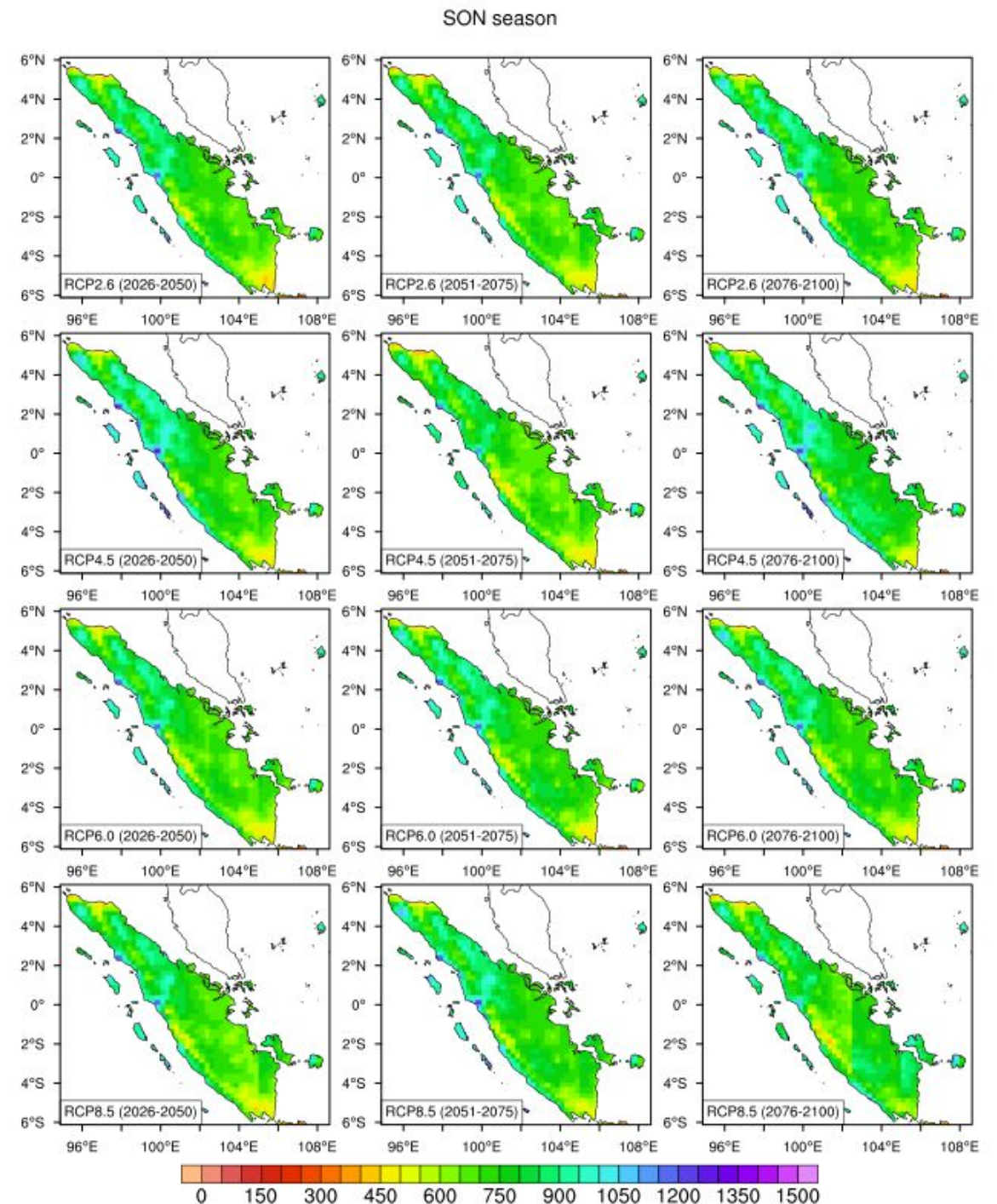
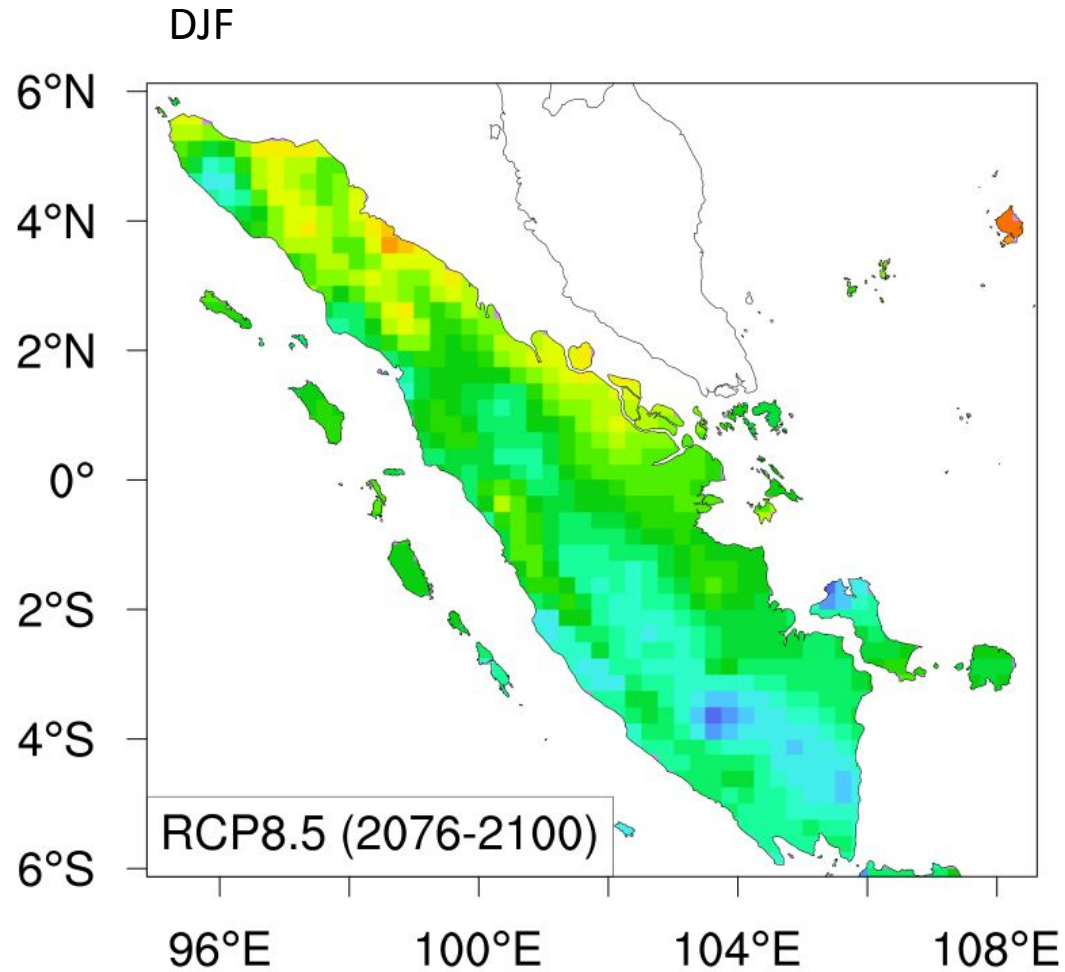
Scenarios of Future Rainfall Climatology in Indonesia from Multi-Model Ensemble Mean of 24 GCMs under RCP4.5 and RCP8.5 Scenarios



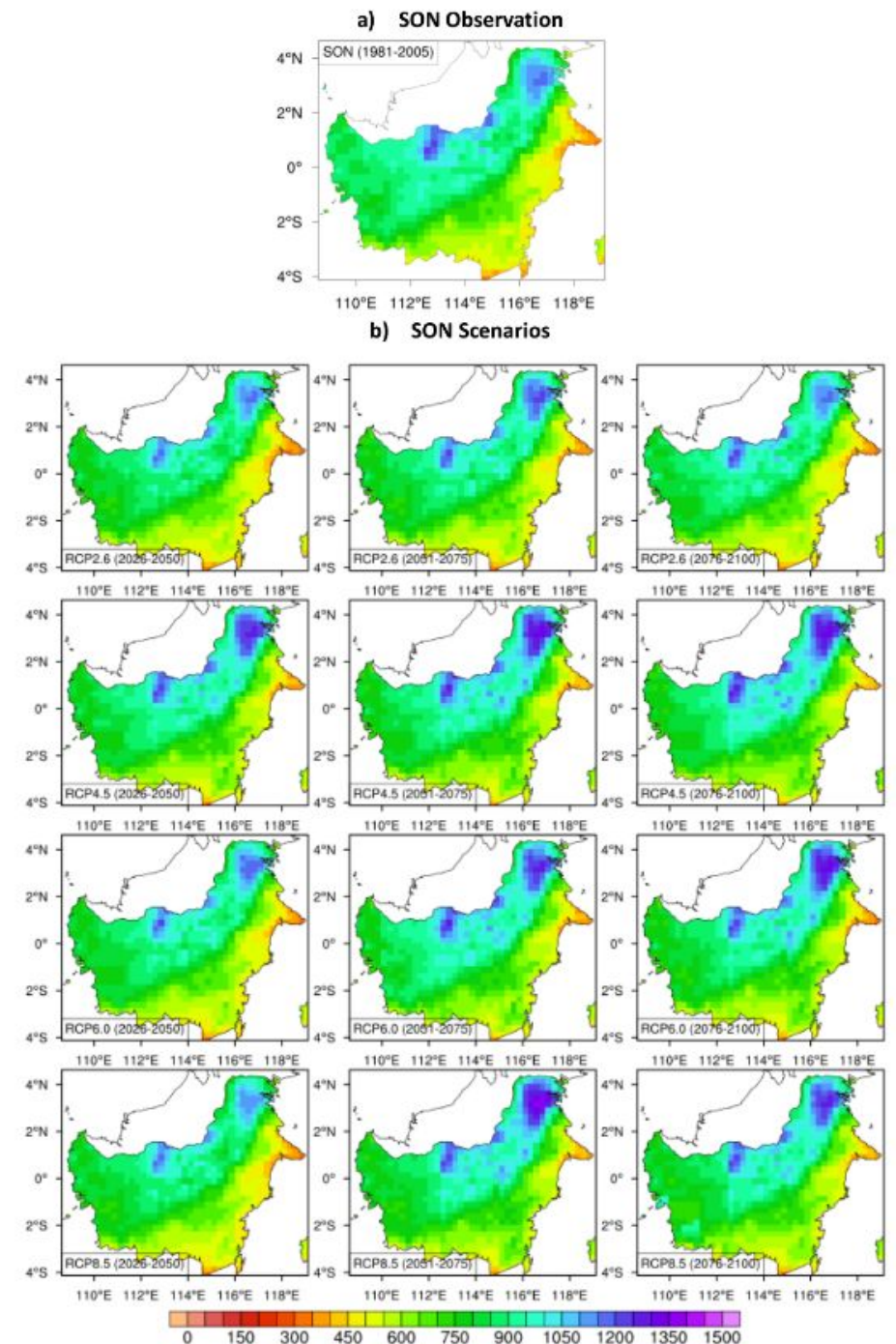
Skenario Perubahan Curah Hujan Rata-rata Bulanan



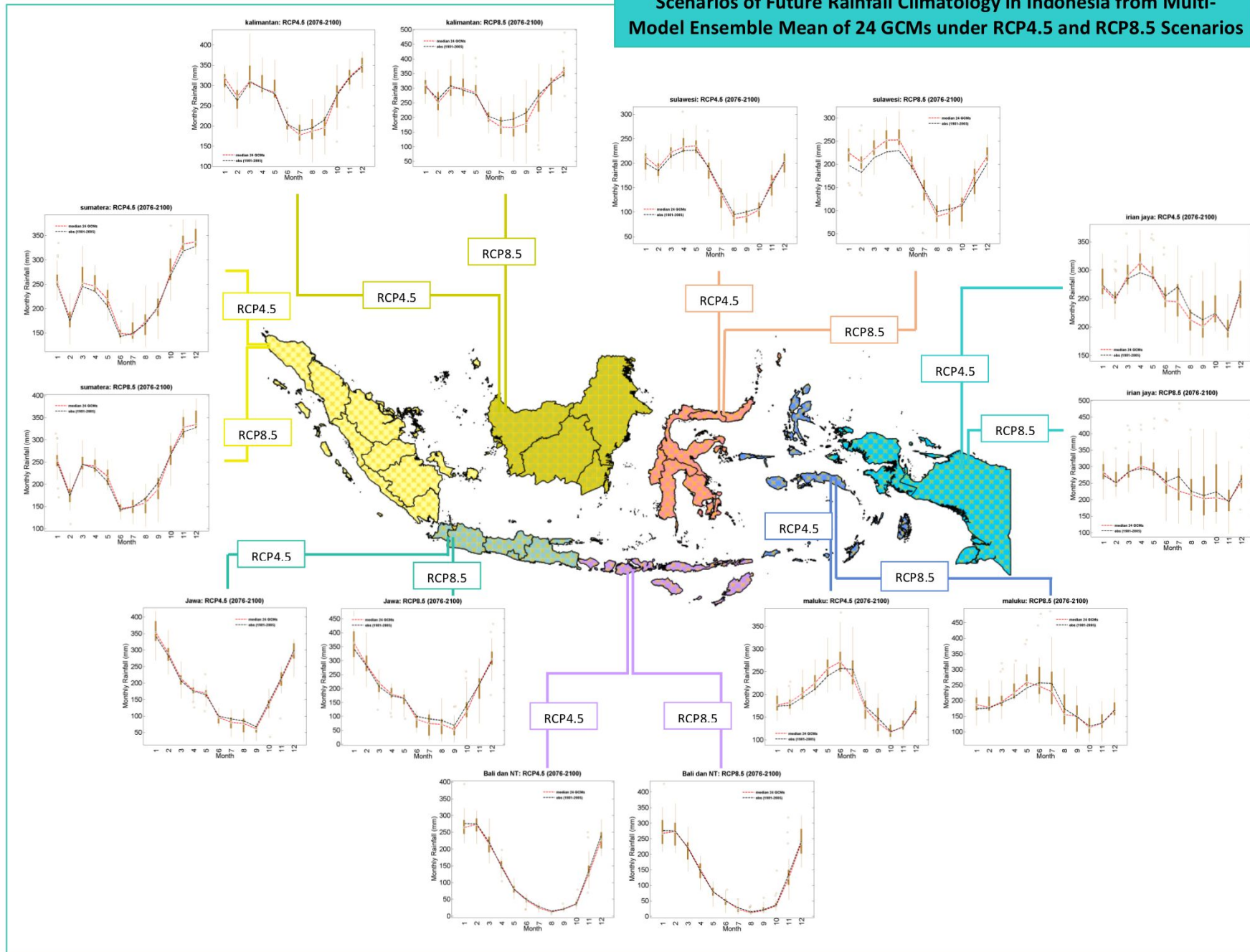
Skenario Perubahan CH musiman

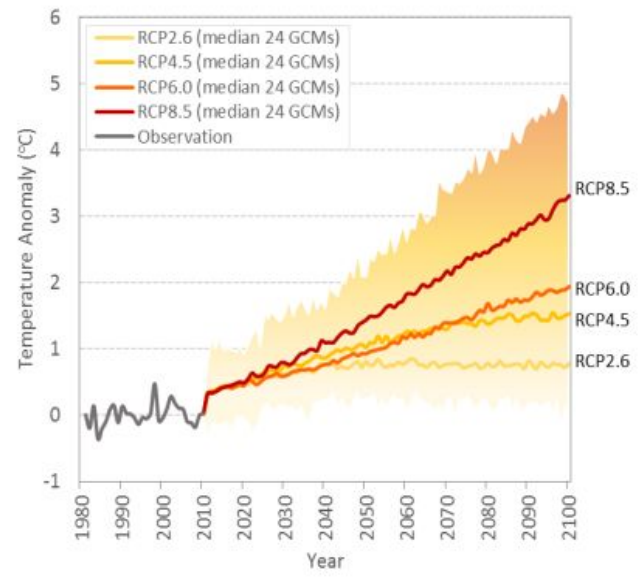
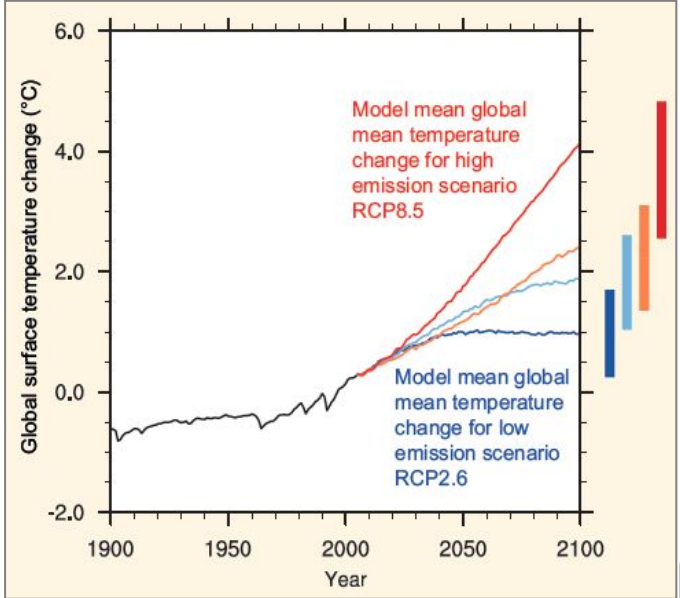


Skenario Perubahan CH musiman di Kalimantan



Scenarios of Future Rainfall Climatology in Indonesia from Multi-Model Ensemble Mean of 24 GCMs under RCP4.5 and RCP8.5 Scenarios





Gambar: Tren temperatur masa depan: a) temperatur permukaan rata-rata global seperti yang ditunjukkan di AR5 [71], b) anomali temperatur di Indonesia diproyeksikan oleh 24GCM CMIP5 dengan empat skenario RCP [Sumber: 4].

Kajian perubahan iklim masa depan mempertimbangan berbagai skenario perubahan konsentrasi emisi gas rumah kaca dan aerosol yang dapat mempengaruhi perubahan nilai *Radiative forcing* (RF) (Wm^{-2}) di atmosfer.

Skenario perubahan iklim yang digunakan adalah skenario RCP, yang didefinisikan berdasarkan pada jalur RF sampai tahun 2100 yaitu RCP2.6, RCP4.5, RCP6.0 dan RCP8.5.

Proyeksi perubahan suhu permukaan rata-rata global dari simulasi multi-model menunjukkan adanya tren peningkatan pada berbagai skenario dengan laju peningkatan yang berbeda, dimana pada skenario ekstrim terjadi peningkatan hingga lebih dari 4 °C.

Suhu rata-rata permukaan regional untuk Indonesia yang dihitung dari MME 24 GCM CMIP5, menunjukkan bahwa tren suhu di Indonesia lebih rendah dari global di semua skenario RCP. Akan tetapi uncertainty dari model menunjukkan kemungkinan nilai yang setara dengan suhu global.

Skenario	Perubahan Temperatur Tahunan (T, °C)								
	2026-2050			2051-2075			2076-2100		
	Min	Med	Max	Min	Med	Max	Min	Med	Max
RCP2.6	0.51	0.67	1.31	0.52	0.75	1.55	0.42	0.75	1.62
RCP4.5	0.69	0.87	1.52	0.99	1.22	2.06	1.08	1.41	2.40
RCP6.0	0.54	0.76	1.33	1.00	1.15	1.90	1.45	1.63	2.79
RCP8.5	0.82	1.02	1.65	1.63	1.83	2.93	2.37	2.73	4.09

Penyusunan Laporan Basis Saintifik Perubahan Iklim

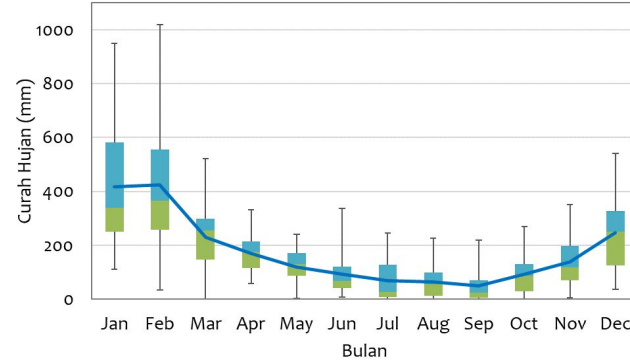
Tingkat Lokal



Analisis Kondisi Iklim Historis

a. Pola Hujan Bulanan

Pola monsunal tersebut umumnya memiliki satu puncak hujan dengan musim hujan di bulan Desember-Januari-Februari (DJF) dan transisi ke musim kemarau di bulan Maret-April-Mei (MAM)

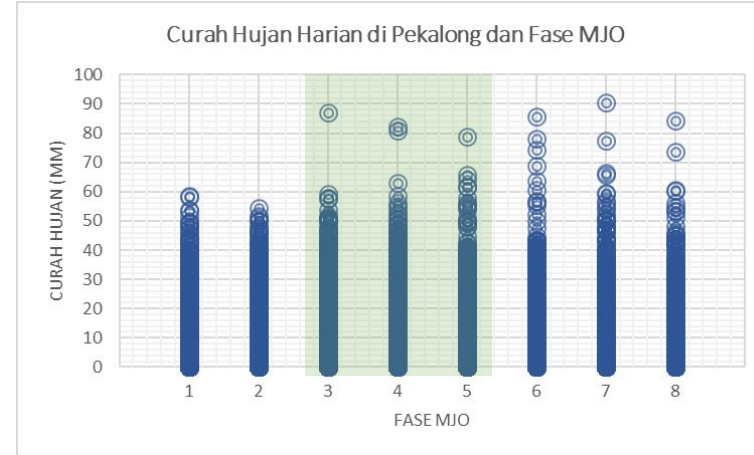


a. Variabilitas Iklim dan Faktor

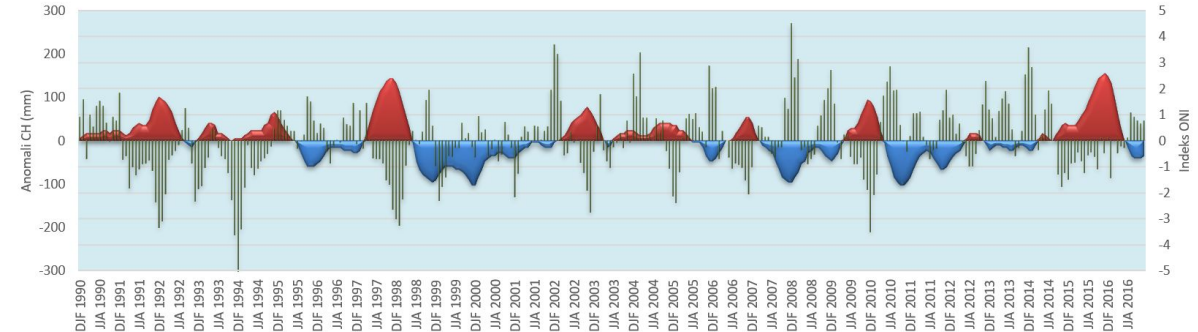
Pengendalinya

Variabilitas curah hujan di Pekalongan dipengaruhi oleh faktor pengendali variabilitas iklim dalam skala sub-musiman (*subseasonal*) dan antar-tahun (*interannual*)

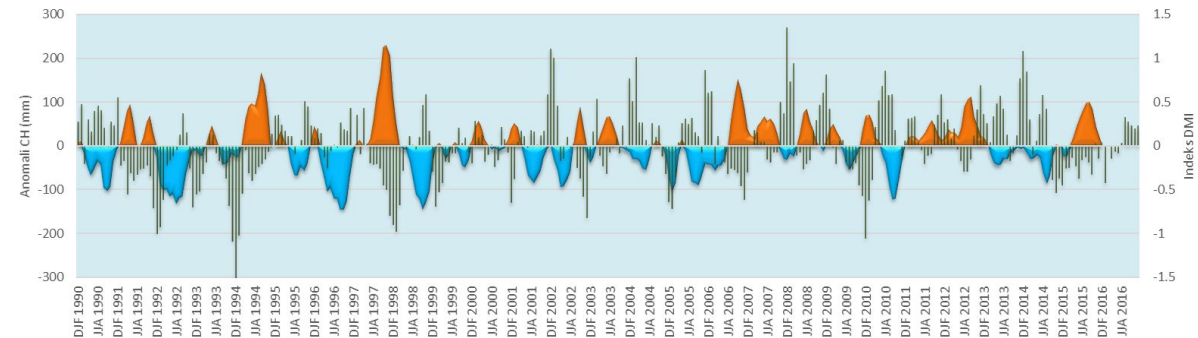
- Pengaruh Madden-Julian Oscillation (MJO) □ Curah hujan ekstrim > 60 mm lebih banyak terjadi ketika MJO memasuki khususnya Fase 3, 4 dan 5, dimana jumlah terbanyak ditemukan pada Fase 5.
- Pengaruh El Nino-Southern Oscillation (ENSO) □ Anomali curah hujan cenderung meningkat saat terjadi La Nina, seperti pada tahun 1996, 1998, 2006, 2008, 2009, 2010, 2012, dan 2016
- Pengaruh Indian Ocean Dipole (IOD) □ Peningkatan anomali curah hujan (anomali positif) terjadi pada saat DMI bernilai negatif terjadi pada tahun 1990, 1999, 2002, 2004, 2005, 2006, 2010 dan 2014



Hubungan antara berbagai fase MJO dengan nilai rata-rata wilayah curah hujan harian di Pekalongan selama periode 1 Januari 1981 hingga 31 Desember 2016

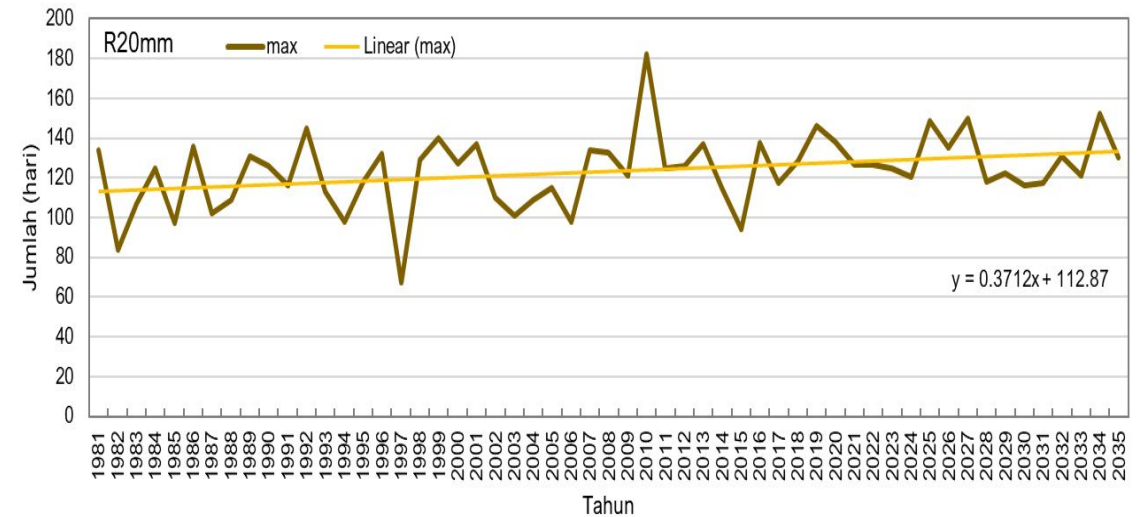
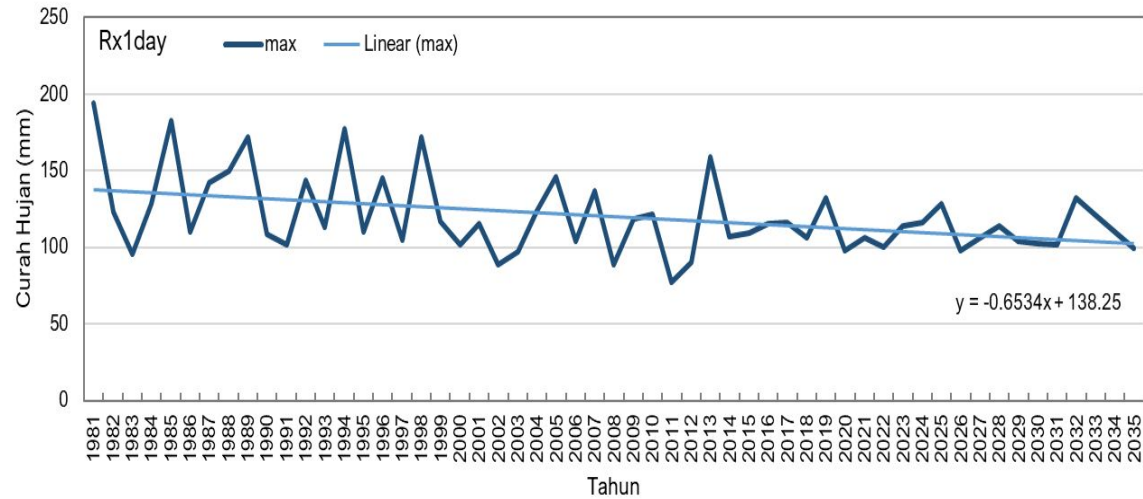


Time series perbandingan data historis anomaly curah hujan musiman (rata-rata berjalan 3-bulanan) di Pekalongan dengan data Ocean Niño Index (ONI) periode DJF 1990 - JJA 2016



Time series perbandingan data historis anomaly curah hujan musiman (rata-rata berjalan 3-bulanan) di Pekalongan dengan data Dipole Mode Index (DMI) periode DJF 1990 - JJA 2016

Tren Analisis Kondisi Iklim Historis dan Proyeksi



*Tren Historis dan Prediksi Dasawarsa Indeks Ekstrim Basah
Rx1day (atas) dan R20 mm (bawah)*

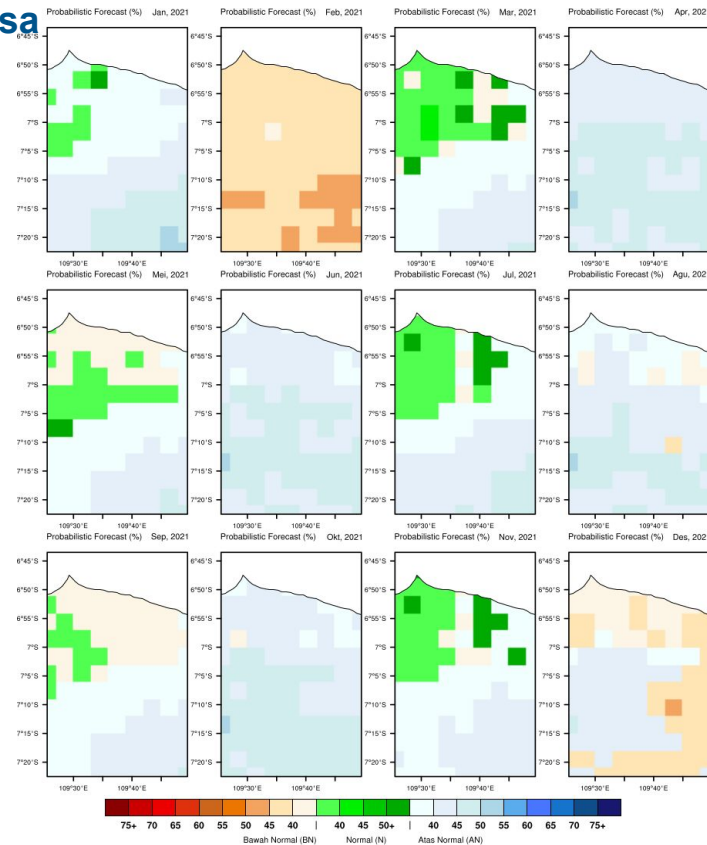
Skenario Iklim Masa Depan

a. Prediksi Iklim Dasawarsa

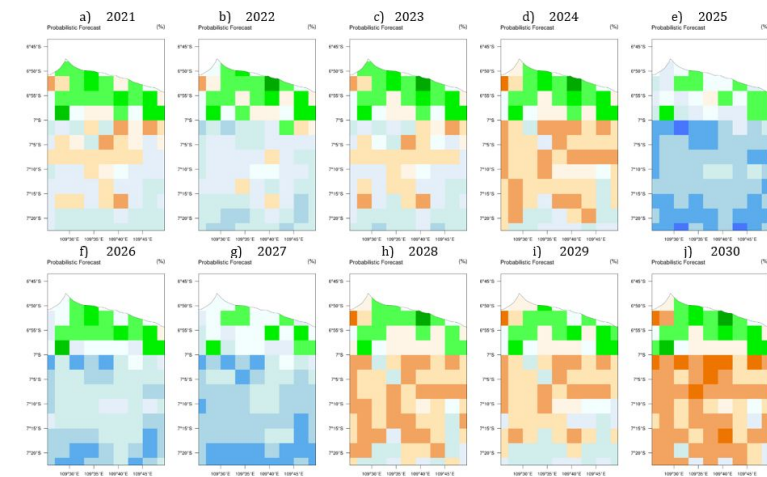
Analisa probabilitas sifat curah hujan bulanan menunjukkan kecenderungan adanya dominasi sifat hujan Atas Normal (AN).

Indeks ekstrim basah yang dianalisa di bawah prediksi iklim dasawarsa meliputi:

- 1) **Rx1day** yaitu curah hujan harian yang tertinggi dalam 1 tahun;
- 2) **Rx5day** yaitu curah hujan kumulatif 5-harian yang tertinggi dalam 1 tahun;
- 3) **R20mm** yaitu jumlah hari hujan dalam setahun dengan nilai curah hujan harian lebih dari 20 mm.



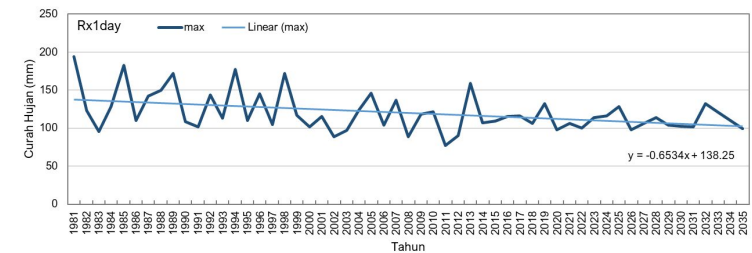
Prediksi Iklim Dasawarsa - Probabilistik Sifat Curah Hujan Bulanan Periode Januari-Desember 2021 (Tim Penyusun 2020)



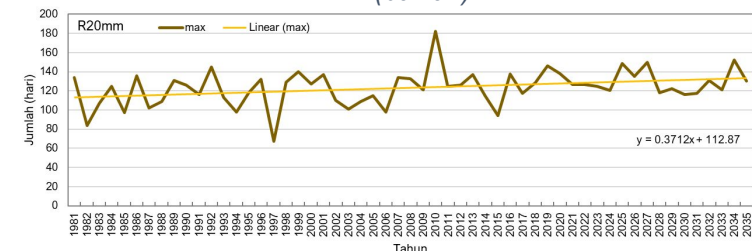
Prediksi Peluang Sifat Indeks Ekstrim Basah R20mm Untuk Tahun 2021-2030 (Tim Penyusun, 2020)

Data historis dan prediksi menunjukkan indikasi **menurunnya intensitas hujan harian maksimum tahunan**. Dari sisi probabilistik kejadian, prediksi dasawarsa menunjukkan **dominasi peluang kondisi AN untuk Rx1day**, dengan peluang kejadian lebih tinggi di hulu dibandingkan di hiir dan pesisir.

Secara umum hasil prediksi iklim dasawarsa mengindikasikan **kemungkinan terjadinya penurunan intensitas indeks ekstrim basah**, namun **dengan kondisi jumlah kejadian ekstrim basah yang semakin meningkat**.



Tren Historis dan Prediksi Dasawarsa Indeks Ekstrim Basah Rx1day (atas) dan R20 mm (bawah)



Skenario Iklim Masa Depan

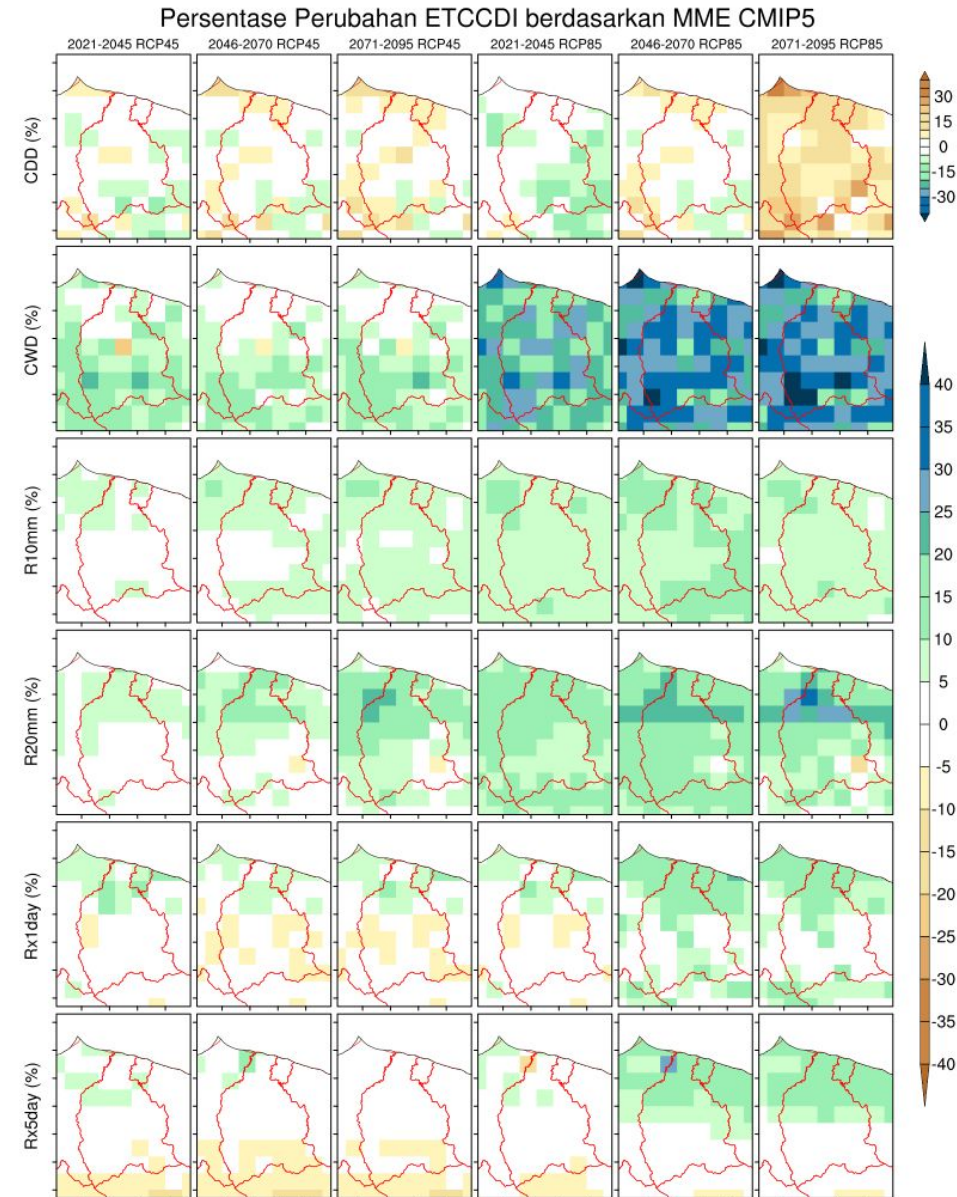
b. Proyeksi Iklim Jangka Panjang

Proyeksi iklim jangka panjang dilakukan untuk 2 skenario, yakni

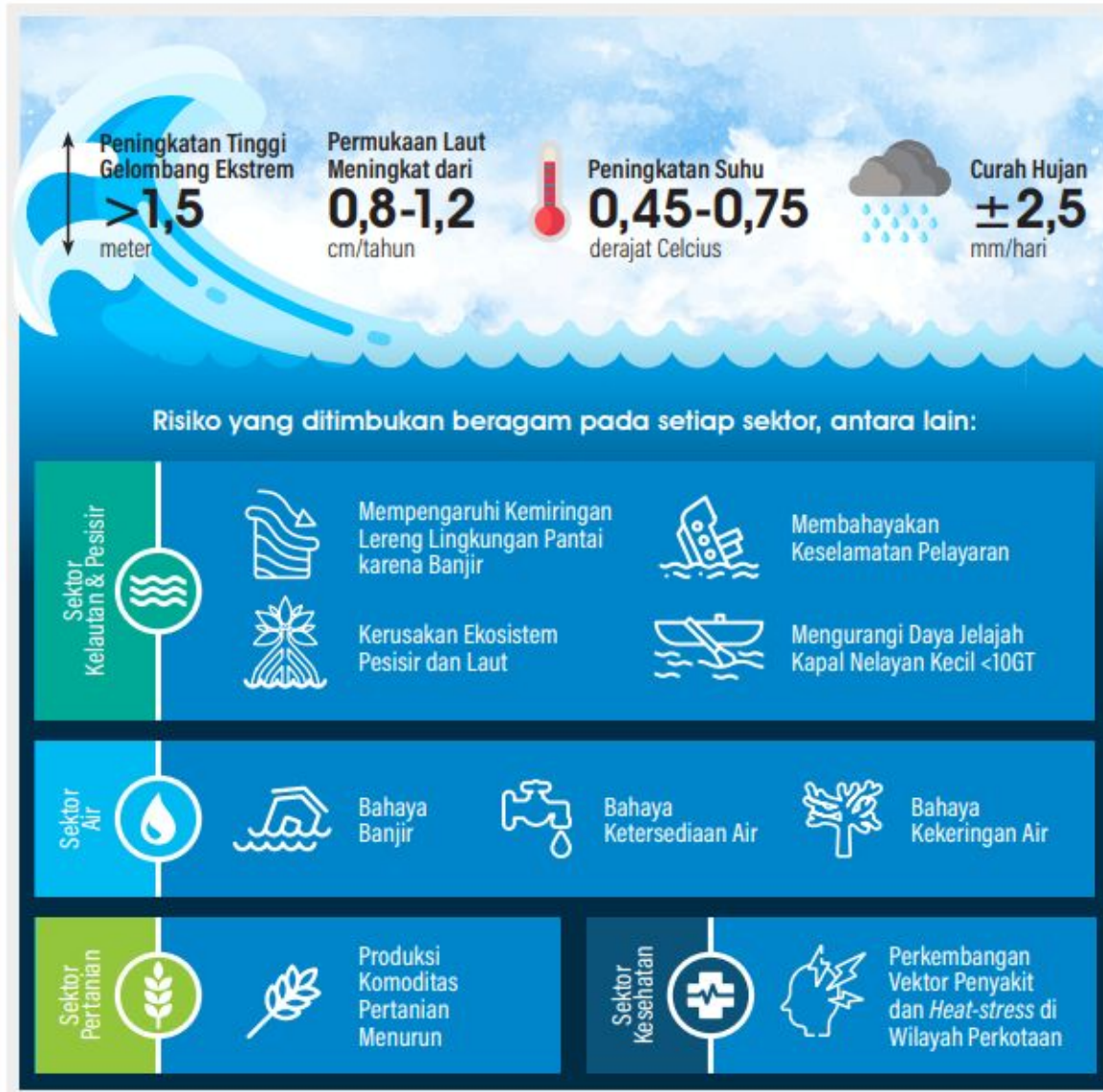
- 1) RCP 4.5 yang mewakili kondisi moderat dengan skenario upaya mitigasi menengah untuk menjaga tingkat *radiative forcing*, dan
- 2) RCP 8.5 mewakili kondisi ekstrim dengan skenario tidak ada usaha membatasi emisi gas rumah kaca. Periode yang digunakan untuk proyeksi iklim jangka panjang adalah 2021-2095.

Hasil proyeksi iklim jangka panjang mengindikasikan **wilayah kajian akan mengalami kondisi yang lebih basah**.

- Analisis spasial menunjukkan **peningkatan persentase intensitas dan frekuensi kejadian curah hujan ekstrim terutama di wilayah pesisir** seperti diindikasikan oleh peningkatan persentase perubahan indeks Rx1day, Rx5day, R10mm dan R20mm.
- Proyeksi indeks **CWD memperkuat peluang kondisi wilayah yang semakin basah dengan deret hari hujan yang semakin lama**, dimana pada skenario RCP8.5 peningkatan persentasenya diperkirakan mencapai >40%.
- Disisi lain, deret hari kering yang direpresentasikan oleh nilai **CDD menunjukkan adanya perubahan persentase yang tidak terlalu signifikan** di masa depan.

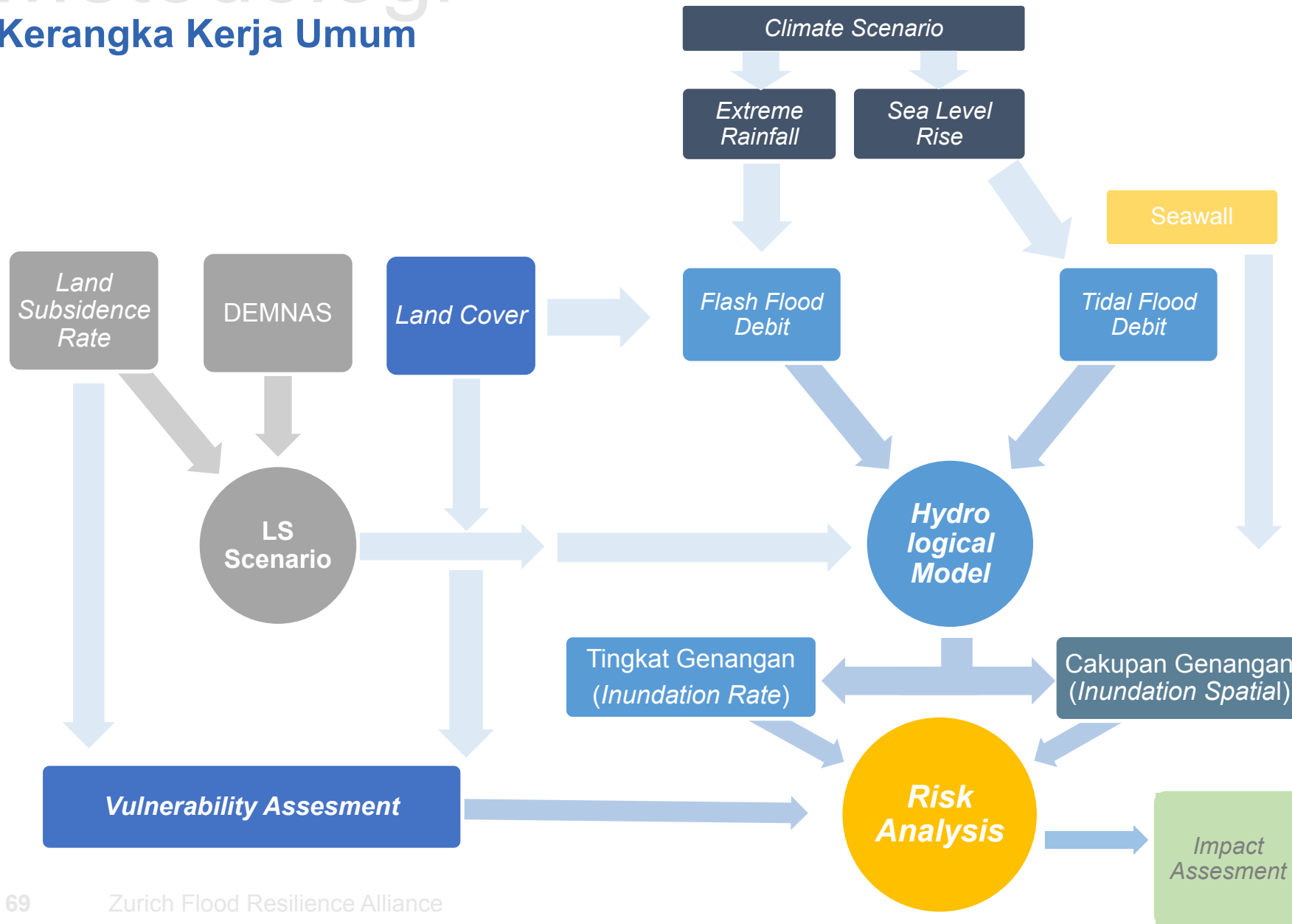


Persentase Perubahan Indeks Ekstrim Poyeksi Iklim Jangka Panjang (Tim Penyusun, 2020)



Metodologi

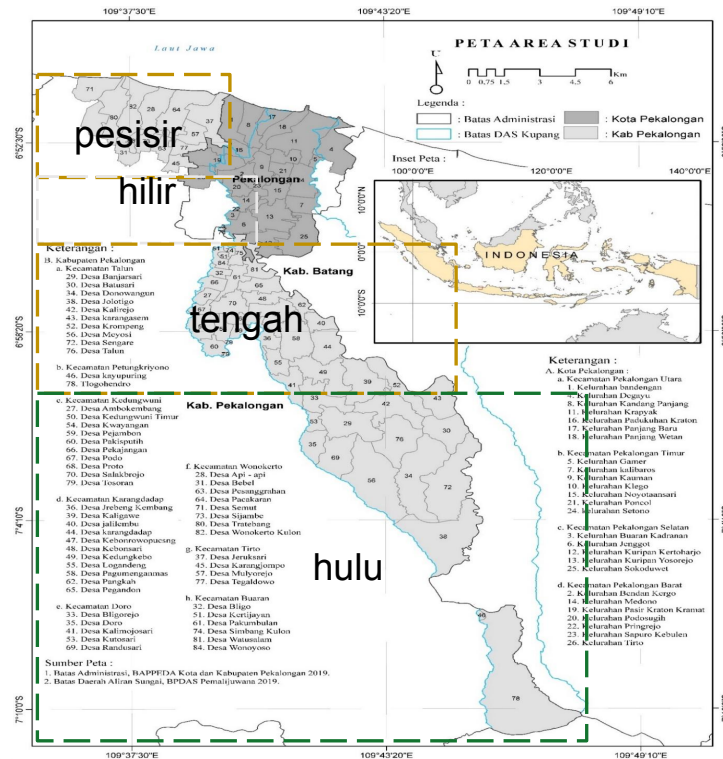
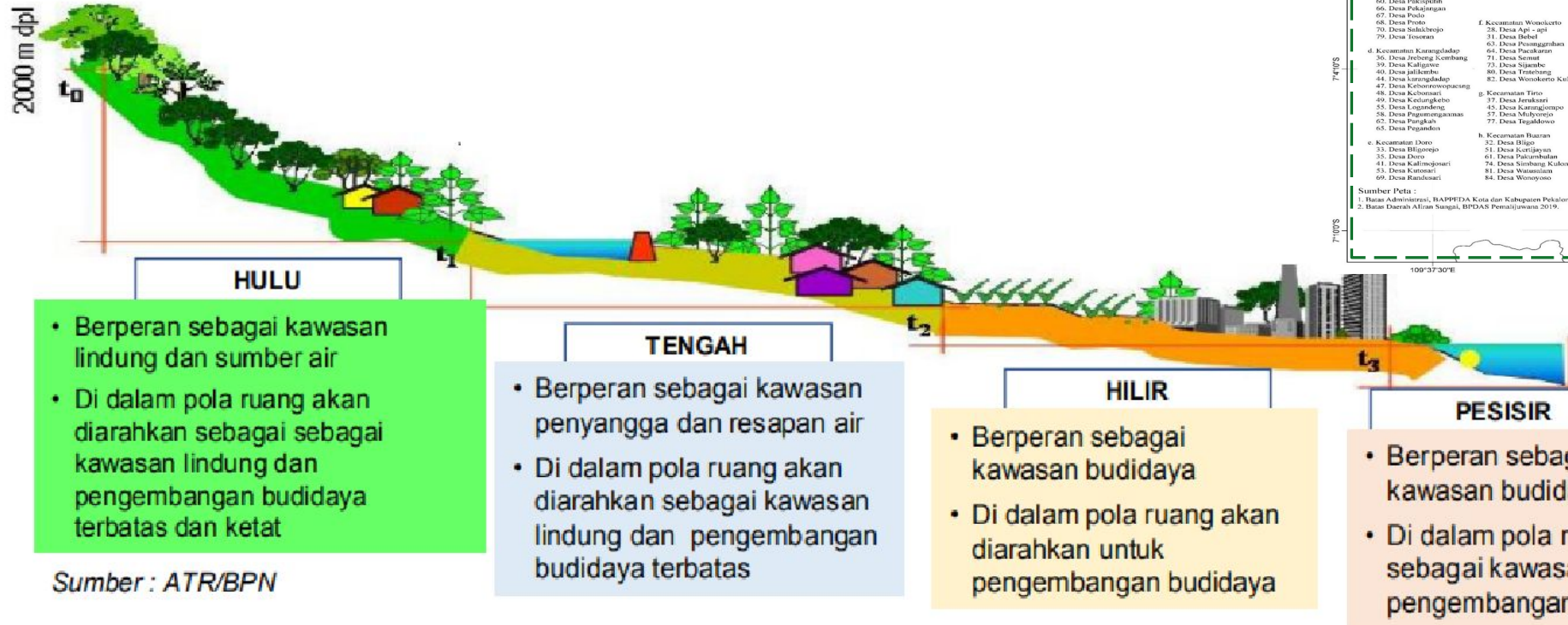
Kerangka Kerja Umum



- Kerangka umum Kajian Risiko Iklim dan Dampak ini mengacu kepada **Six Steps Approach (GIZ, 2018)** untuk memahami dampak dan risiko terkait iklim di suatu sistem kajian serta mengidentifikasi langkah-langkah pengendalian yang sesuai.

- Kajian ini terbangun dari proses **analisa bahaya, analisa kerentanan, analisa risiko serta analisa dampak ekonomi dan non-ekonomi** dari kejadian banjir limpasan dan rob.

Konteks Lansekap



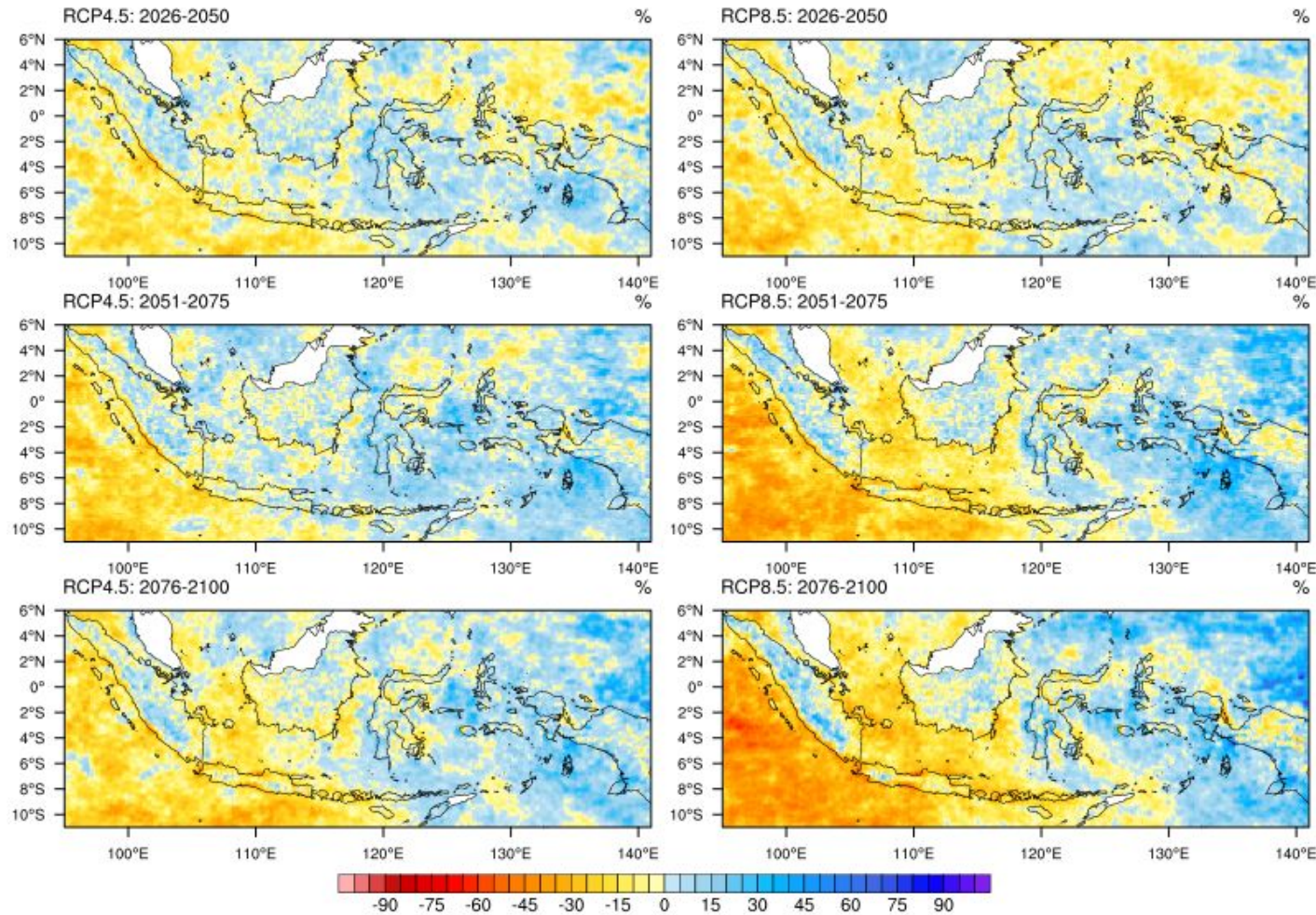
Terima Kasih

Email: akhmadfaqih@gmail.com

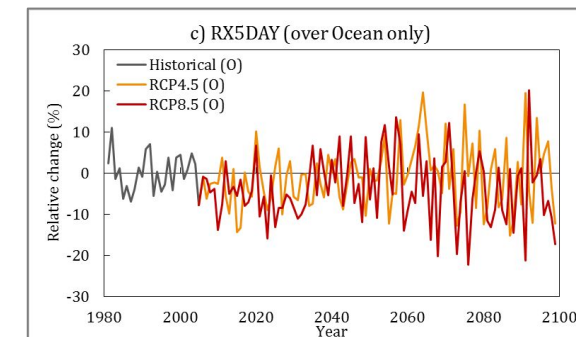
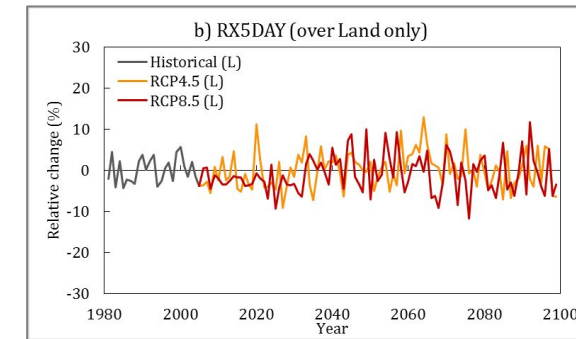
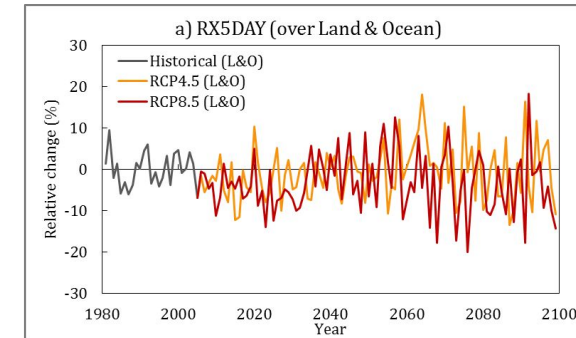


Rx5day (annual maxima of cumulative 5-days precipitation)

Percent Change of RX5DAY



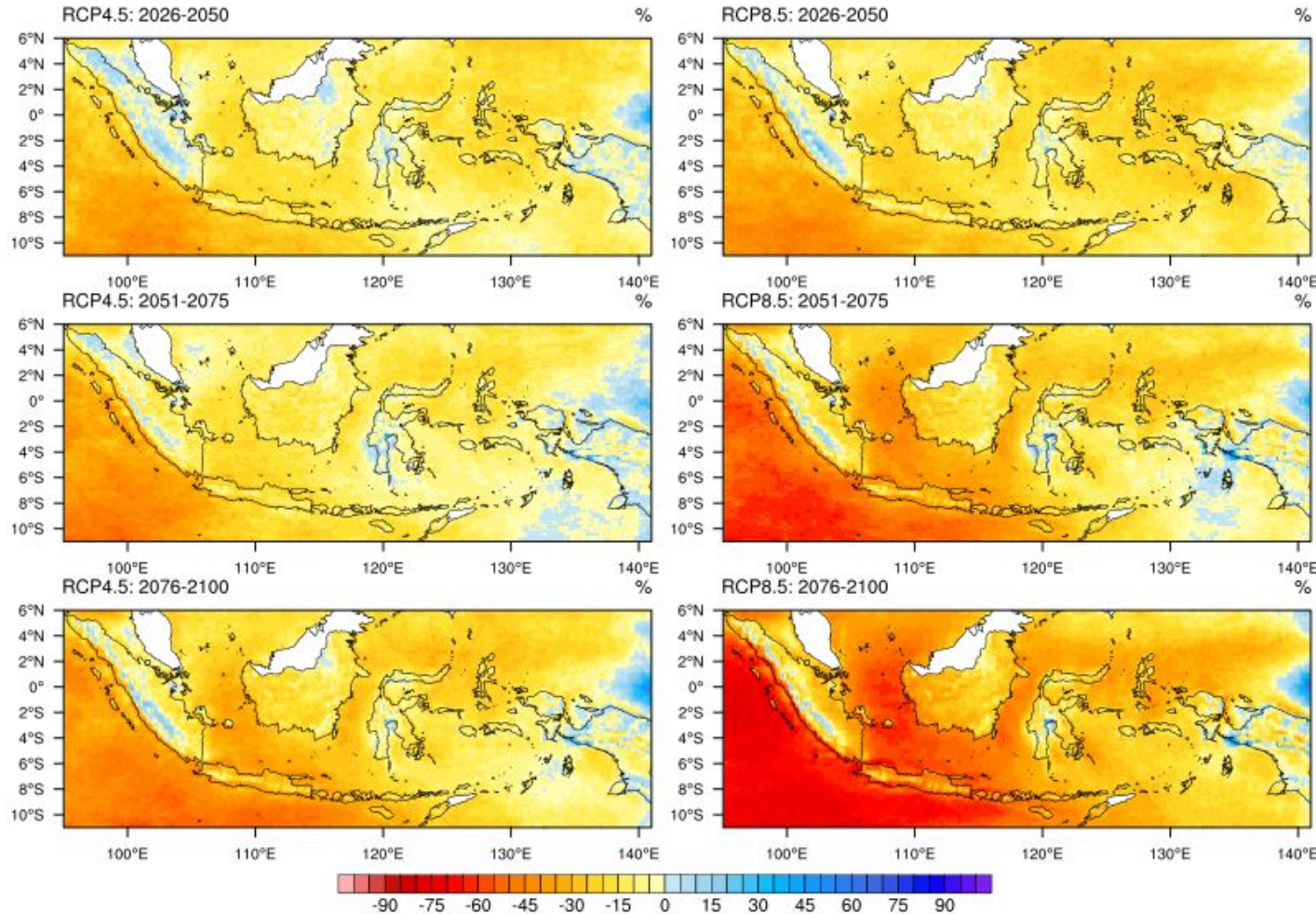
Projected percent changes (relative to the 1981–2005 reference period) in RX5day, the annual maximum five-day precipitation accumulation projected by RegCM4 regional climate model driven by HadGEM2-ES GCM outputs under RCP4.5 (left) and RCP8.5 (right).



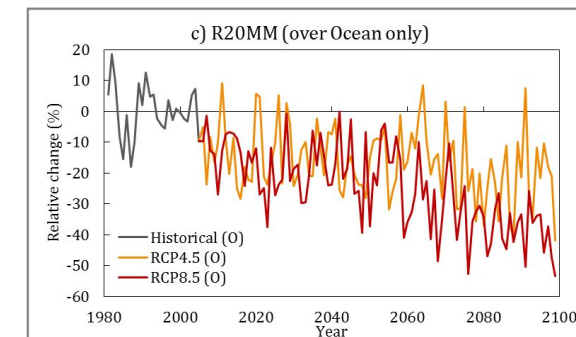
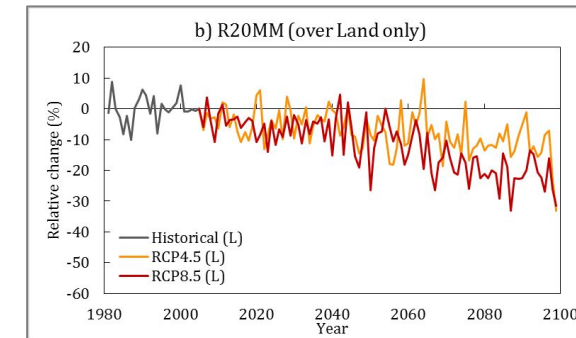
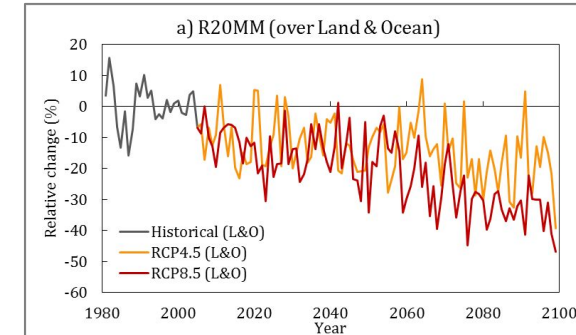
Indonesia average percent change in RX5day, the annual maximum five-day precipitation accumulation, over a) land & ocean, b) land only, and c) ocean only regions for the RCP4.5 and RCP8.5 scenarios as projected by RegCM4 regional climate model driven by HadGEM2-ES

R20mm (annual count of days when daily rainfall $\geq 20\text{mm}$)

Percent Change of R20MM



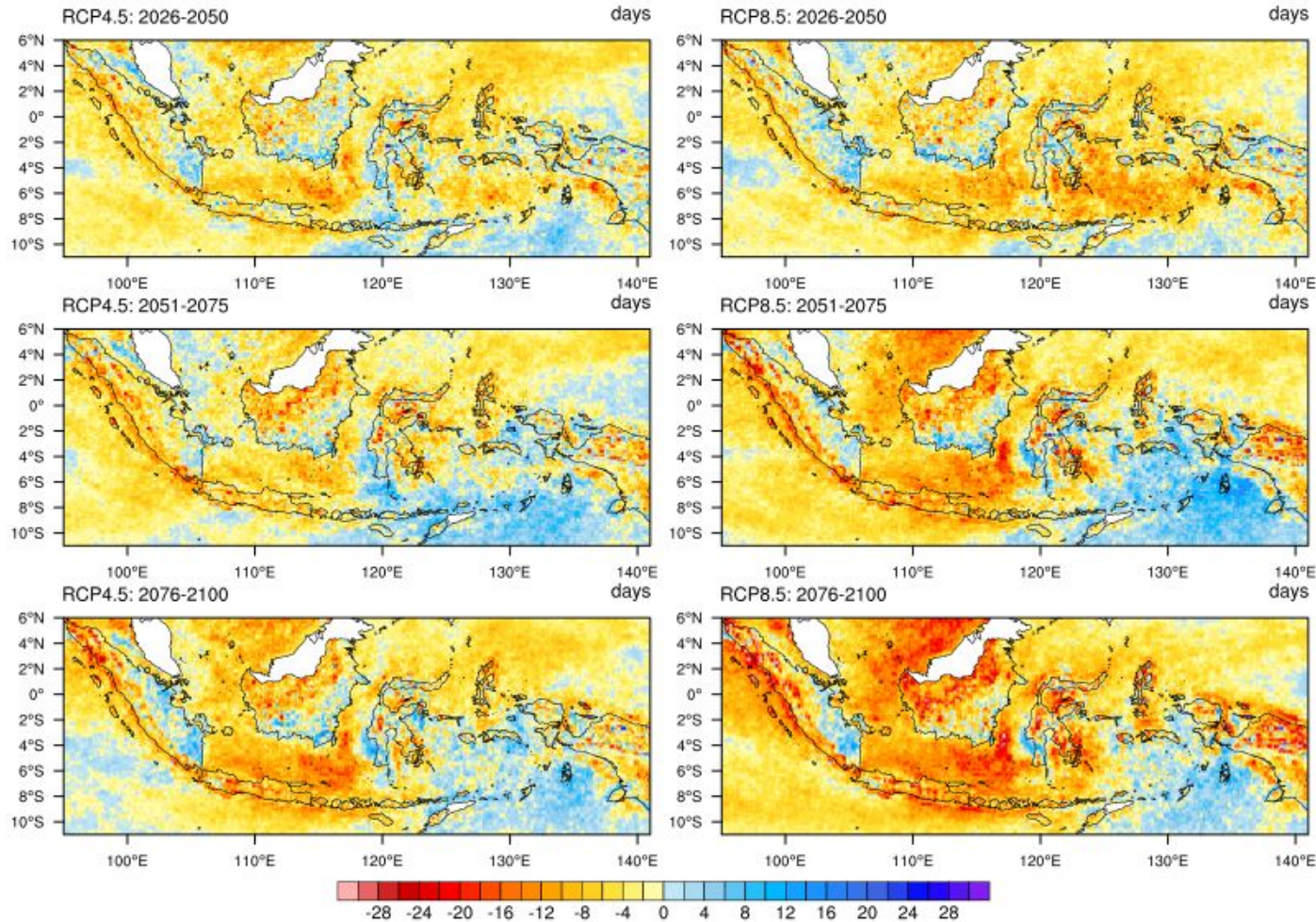
Projected percent changes (relative to the 1981–2005 reference period) in R20MM, the number of days with daily precipitation sum exceeding 20 mm, projected by RegCM4 regional climate model driven by HadGEM2-ES GCM outputs under RCP4.5 (left) and RCP8.5 (right).



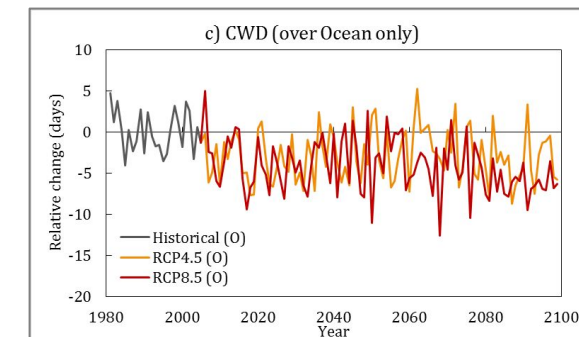
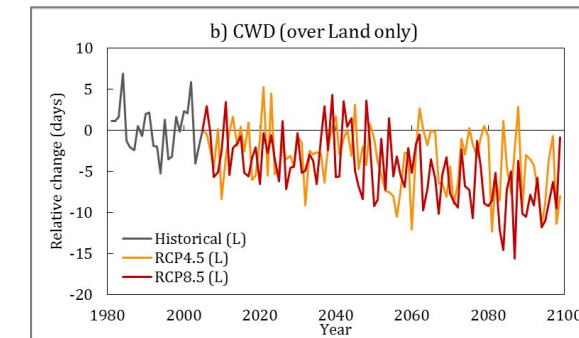
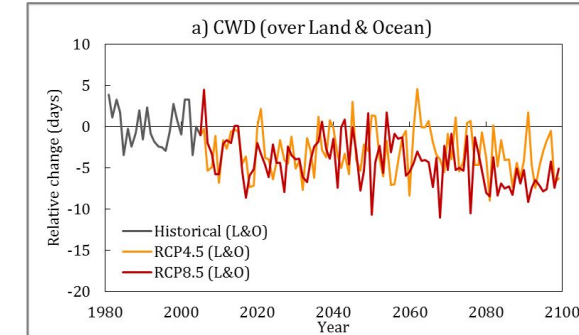
Indonesia average percent change in R20MM, the number of days with daily precipitation sum exceeding 20 mm, over a) land & ocean, b) land only, and c) ocean only regions for the RCP4.5 and RCP8.5 scenarios as projected by RegCM4 regional climate model driven by HadGEM2-ES

CWD (consecutive wet days)

Projected Change in CWD



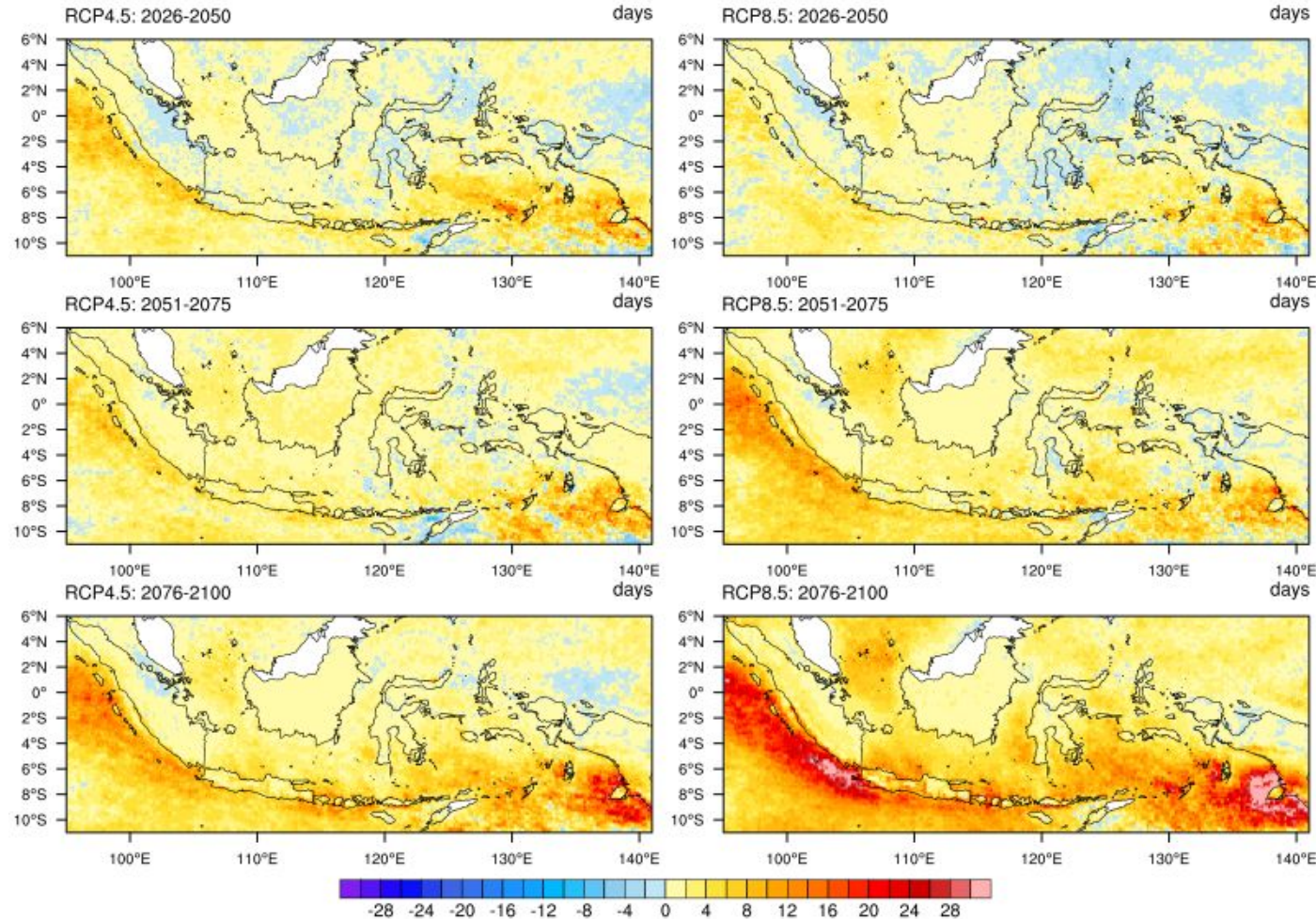
Projected changes (relative to the 1981–2005 reference period) in CWD, the maximum number of consecutive wet days when precipitation is equal or more than 1 mm, projected by RegCM4 regional climate model driven by HadGEM2-ES GCM outputs under RCP4.5 (left) and RCP8.5 (right).



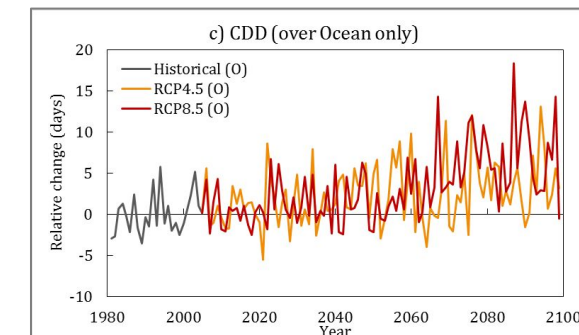
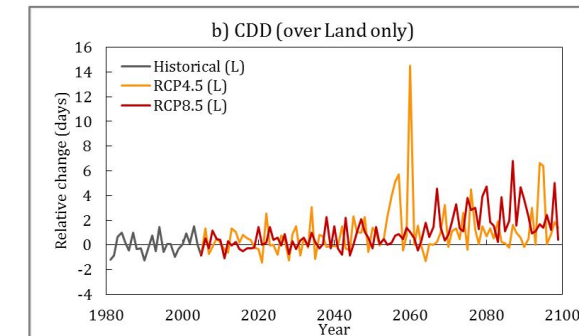
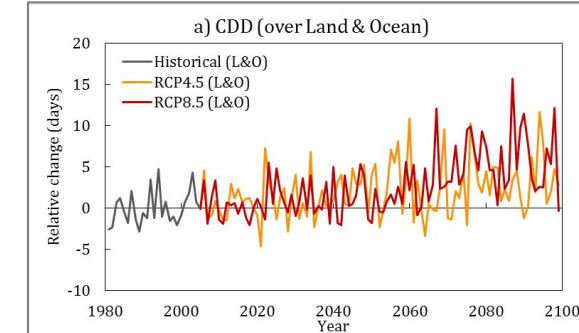
Indonesia average change in CWD, the maximum number of consecutive wet days when precipitation is equal or more than 1 mm, over a) land & ocean, b) land only, and c) ocean only regions for the RCP4.5 and RCP8.5 scenarios as projected by RegCM4 driven by HadGEM2-ES GCM outputs.

CDD (consecutive dry days)

Projected Change in CDD

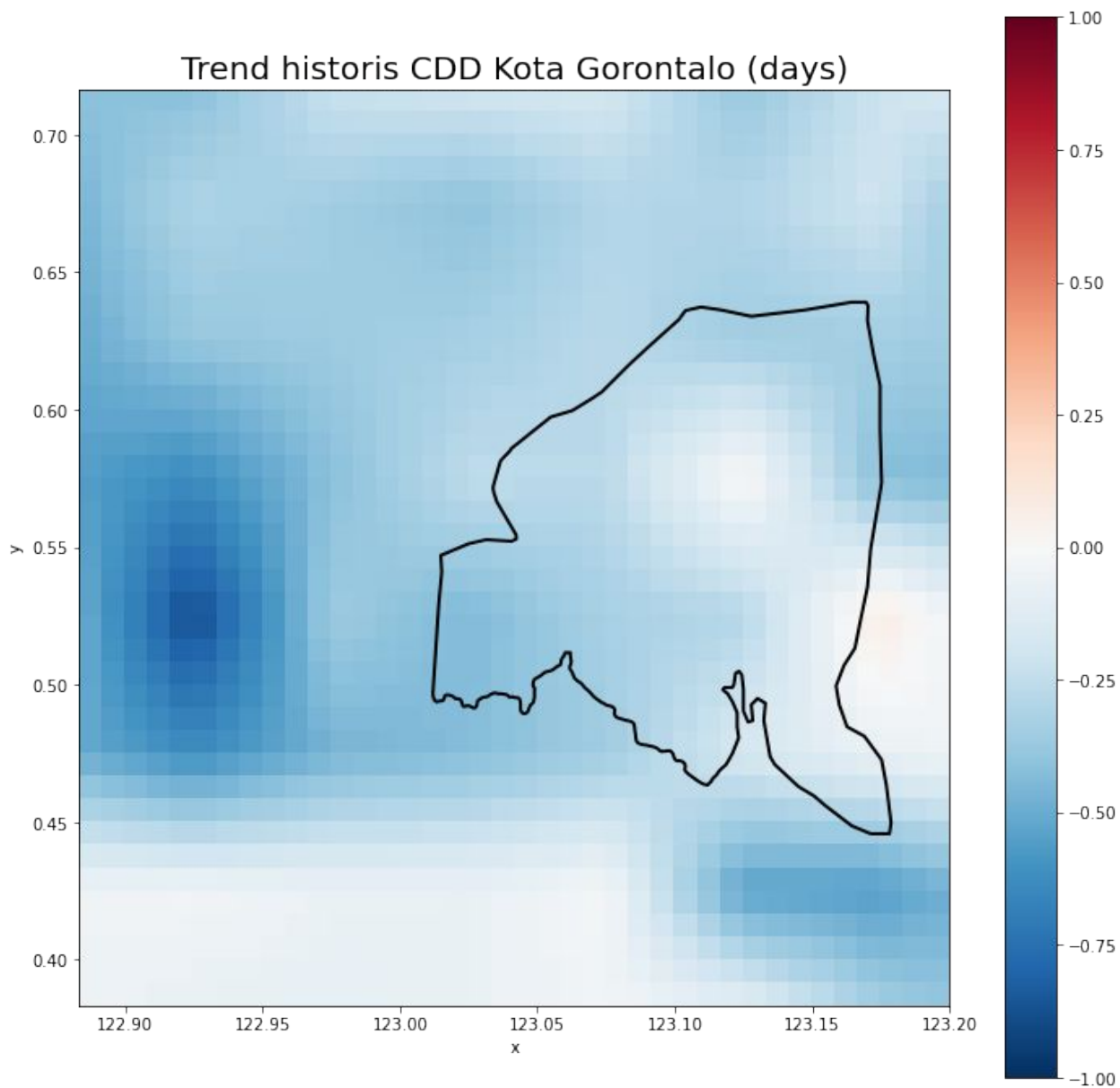


Projected changes (relative to the 1981–2005 reference period) in CDD, the maximum number of consecutive dry days when precipitation is less than 1 mm, projected by RegCM4 regional climate model driven by HadGEM2-ES GCM outputs under RCP4.5 (left) and RCP8.5 (right).

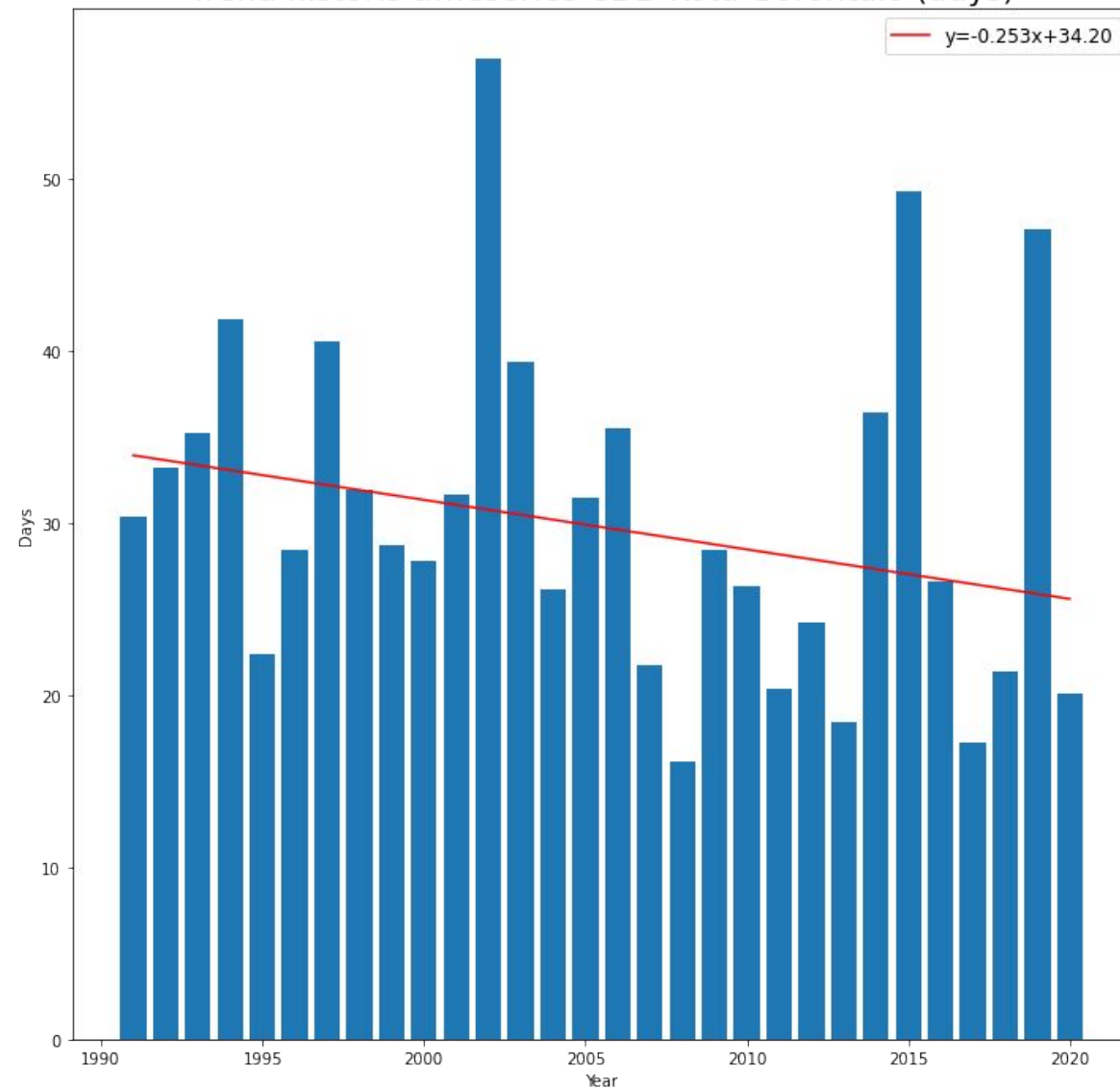


Indonesia average change in CDD, the maximum number of consecutive dry days when precipitation is less than 1 mm, over a) land & ocean, b) land only, and c) ocean only regions for the RCP4.5 and RCP8.5 scenarios as projected by RegCM4 driven by HadGEM2-ES GCM outputs.

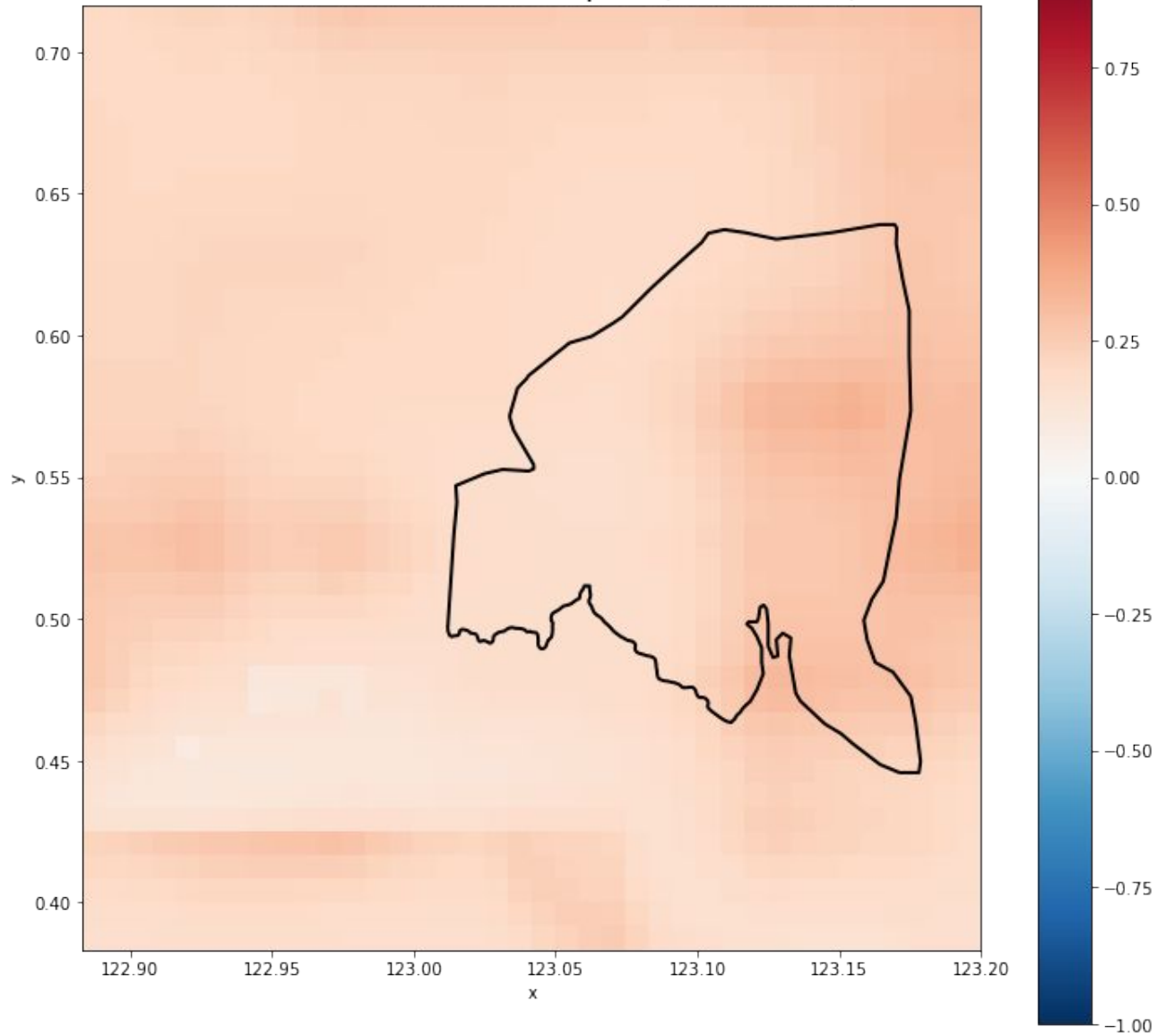
Trend historis CDD Kota Gorontalo (days)



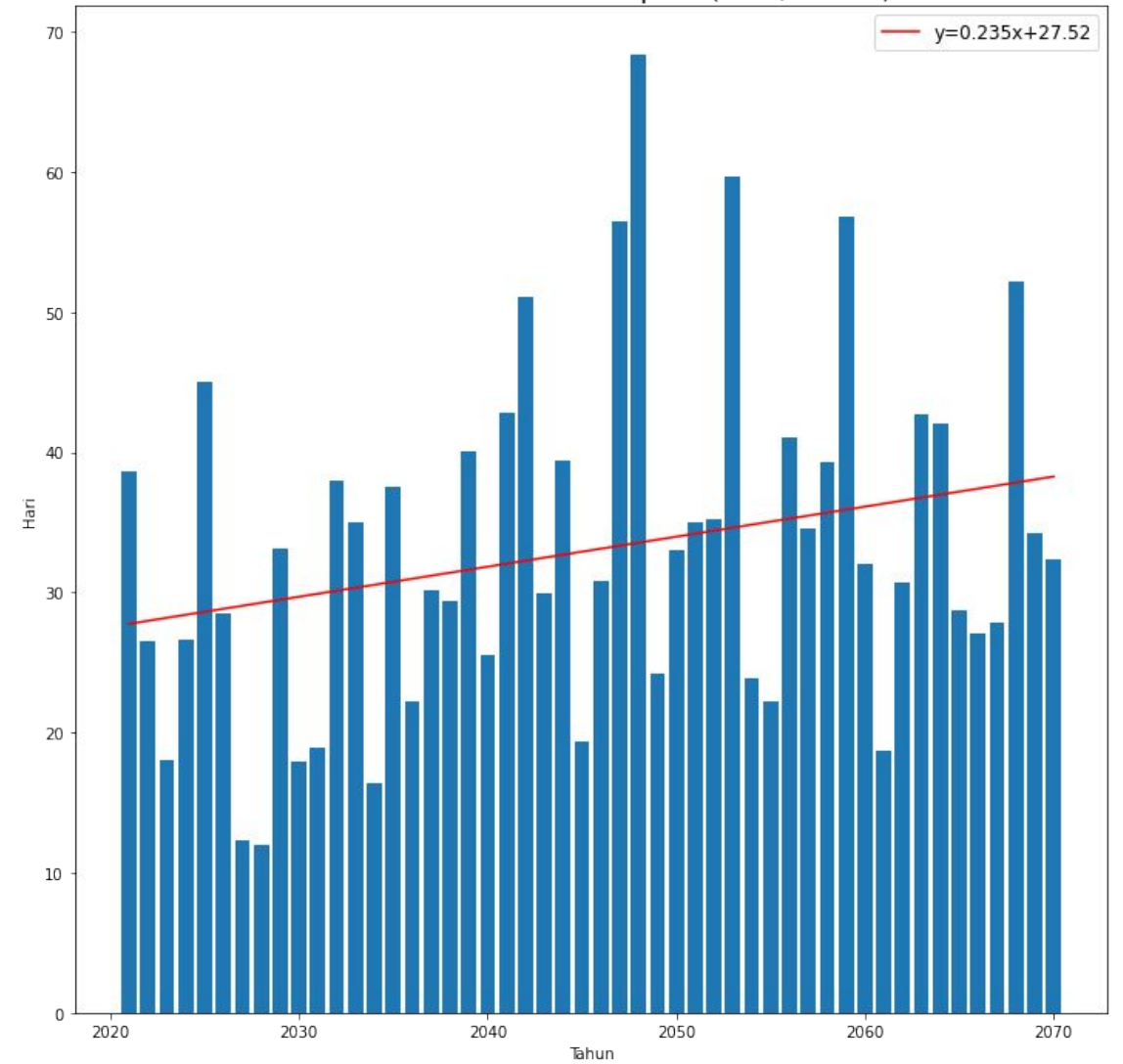
Trend historis timeseries CDD Kota Gorontalo (days)



Proyeksi trend CDD Gorontalo berdasarkan
CSIRO-Mk3-6-0 dan rcp45 (hari/tahun)

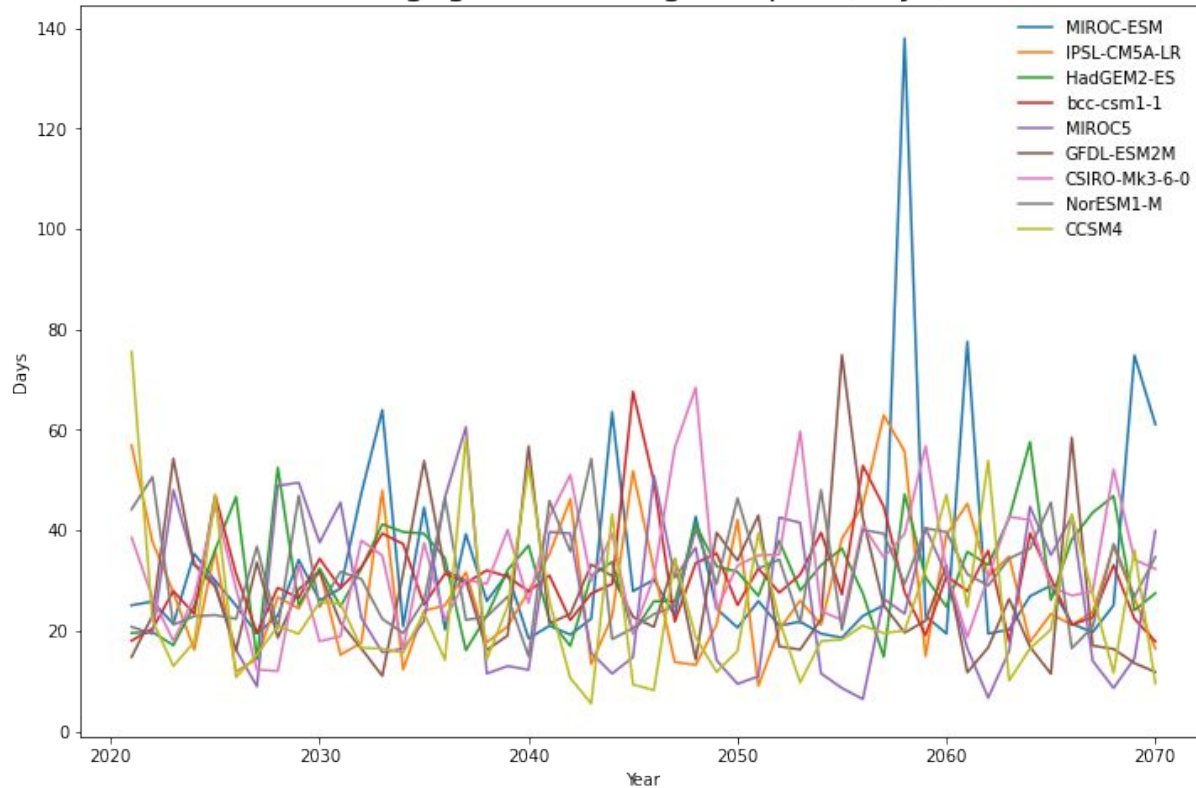


Proyeksi trend timeseries Gorontalo berdasarkan
CSIRO-Mk3-6-0 dan rcp45 (hari/tahun)

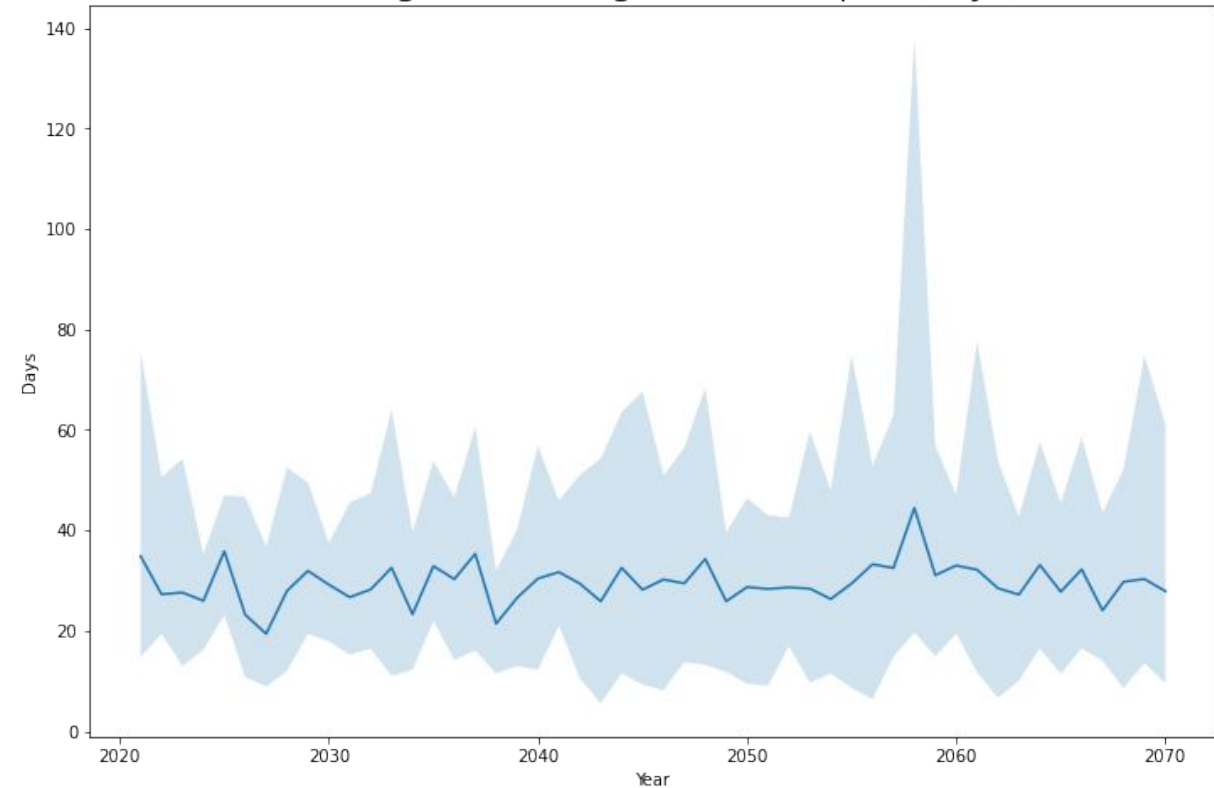


Rentang ketidakpastian (*uncertainty*) proyeksi indeks ekstrim

Proyeksi CDD Gorontalo berdasarkan
berbagai GCM dengan rcp45 (days)



Proyeksi CDD Gorontalo berdasarkan
berbagai GCM dengan skema rcp45 (days)



Trend CDD Gorontalo spasial berdasarkan
berbagai GCM dengan skema rcp45 (days)

