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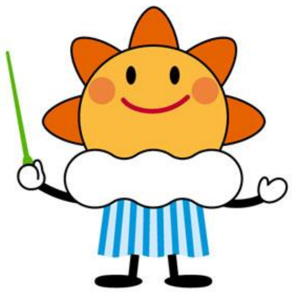
Production of Global Warming Projection Information

Assessment of Future Climate Change
Introduction to the Exercises

WAKAMATSU Shunya



Schedule of this seminar

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1st Day (9 November 2022)

- Lecture on climate change
- Lecture on IPCC AR6

2nd Day (10 November 2022)

- Lecture on Climate Change Monitoring and Future Projections
- Lecture on assessment of future climate change and introduction to your exercise <- We are here

3rd Day – 4th Day (11 and 14 November)

- (self-study format) Exercise on Observed Trends and Global Warming Projection for your country

5th Day (15 November)

- Your presentation (6 minutes per person)

Goal of this seminar (Your presentation)

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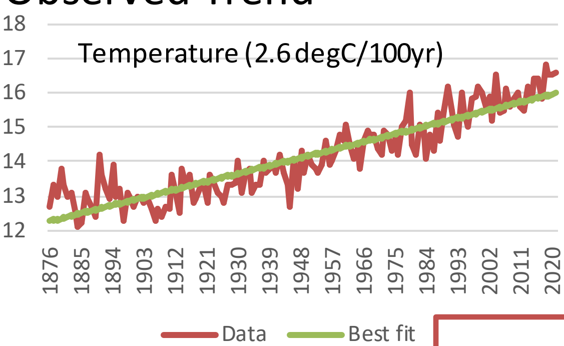
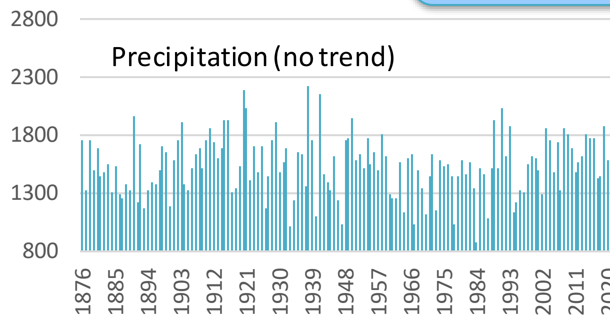
e.g., case of Tokyo (Japan)

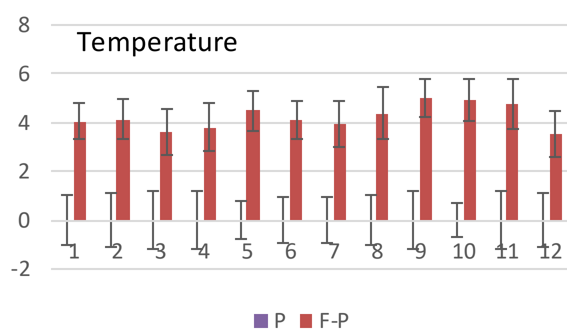
Global warming projection information for your country/region

Observed Trend

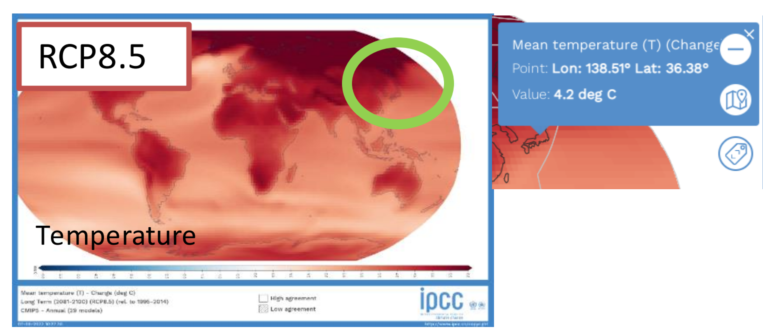




Future Change



Uncertainty (Reliability)



This lecture shows you how to make these.

Example structure of your presentation

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1. Introduction (1 page)
   1. Introduce yourself and your NHMS
   2. Introduce climatology of your country/region
   3. Show recent extreme events related to climate change in your country/region
2. Observation (1 page)
   1. Show long-term trends in temperature
   2. Show long-term trends in heavy precipitation
3. Projected future changes (1 page)
   1. Show bias-corrected temperature/precipitation changes
   2. Also check reliability of the projection
4. Summary and Discussion (1 page)
   1. Summarize your findings
   2. Estimate its impact on your society
   3. Explain desired activities you think against climate change in your country/region

Table of Contents

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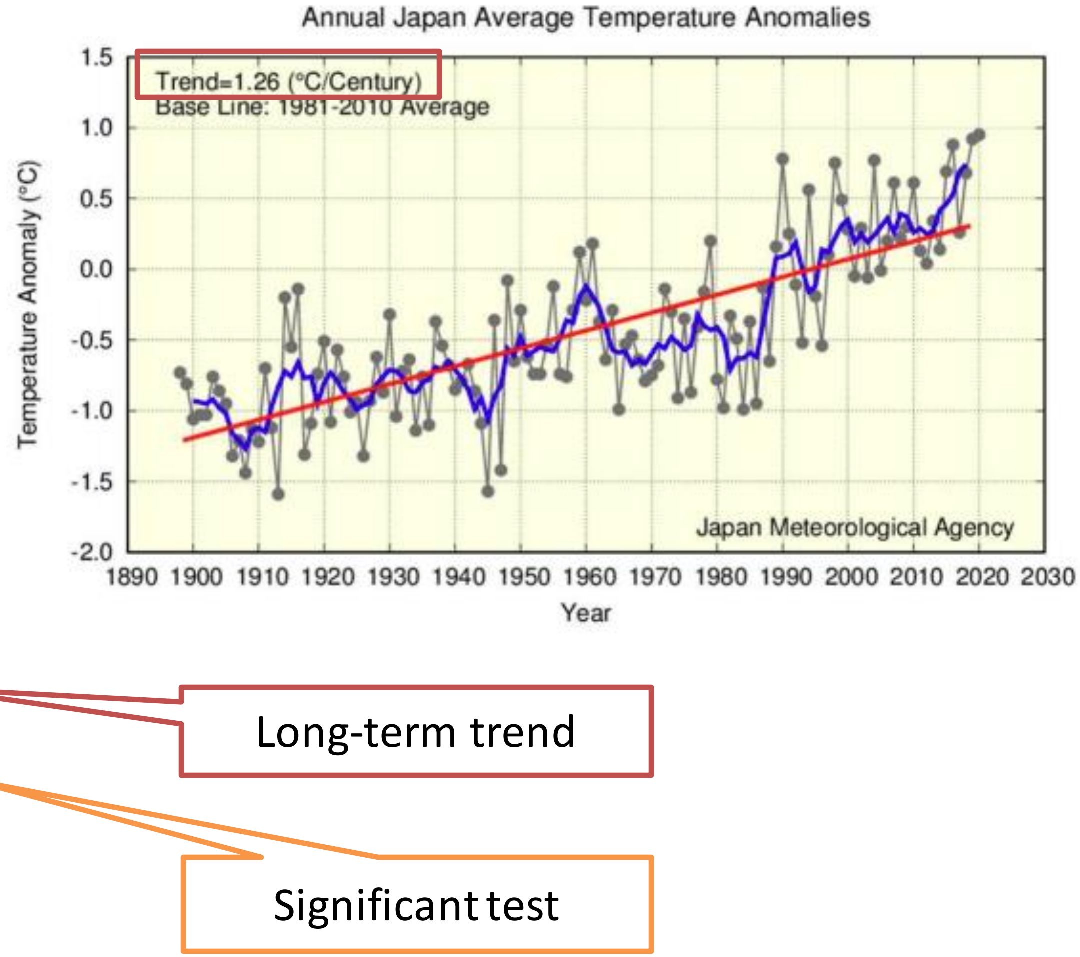
Description of a long-term trend

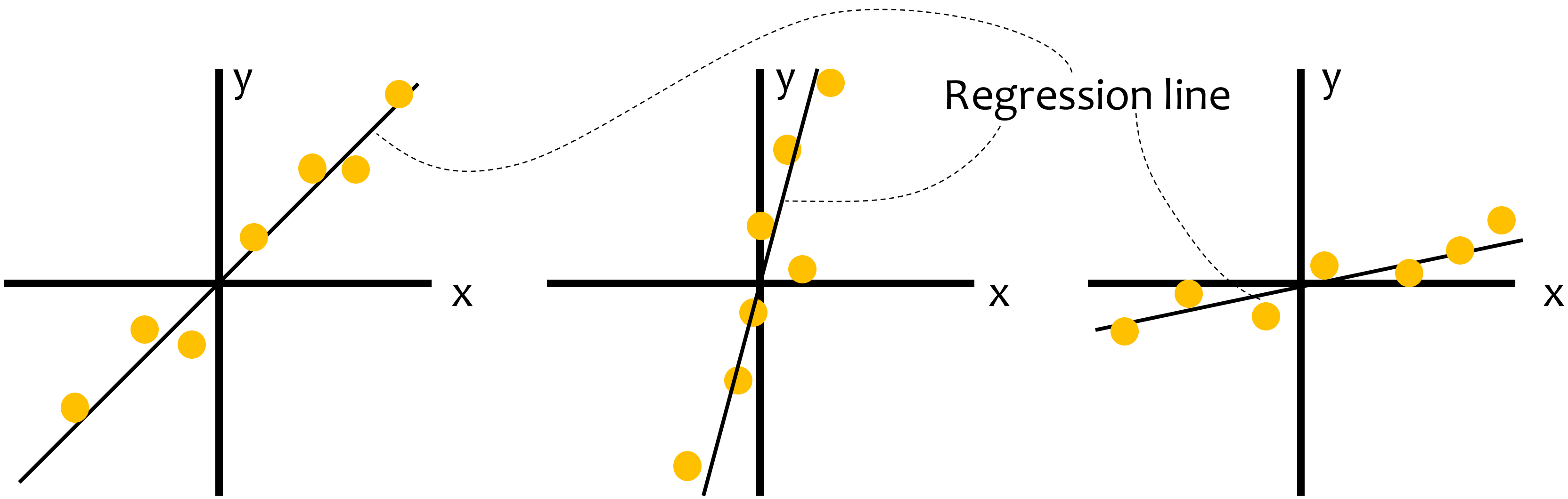
- JMA Climate Change Monitoring Report 2020
  - On a longer time scale, it is virtually certain that the annual mean surface temperature over Japan has risen at a rate of 1.26ºC per century (statistically significant at a confidence level of 99%).



https://www.jma.go.jp/jma/en/NMHS/ccmr/5_Chapter2.pdf

Linear regression analysis

- When data has a linear relationship, a linear regression coefficient (a slope of a regression line) is data's trend.
- Since the slope is given by $\Delta y/\Delta x$, regression coefficients mean how much the variable y changes when the variable x changes.

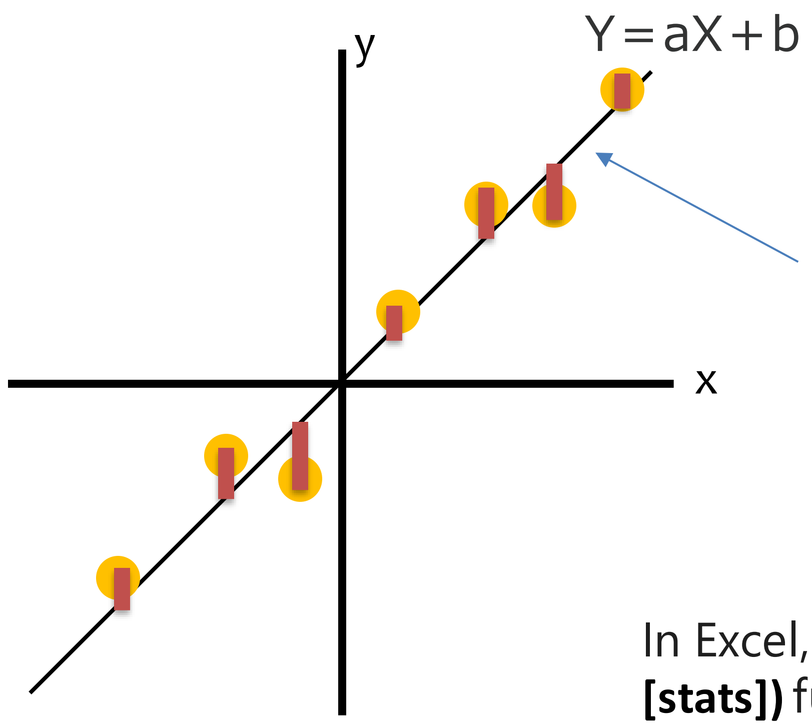


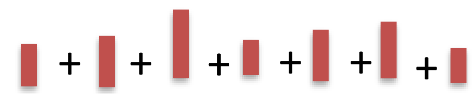
Regression coeff. ~ +1 Regression coeff. ~ +0.5 Regression coeff. ~ +3

Least-squares method

Least-squares method

- a standard approach in linear regression analysis, by minimizing the sum of the squares of the residuals between observed values and the fitted values.



Residuals = 

Find the optimal linear model that minimizes the residuals (the error of estimation)

$$m = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sum (x-\bar{x})^2}$$

$$b = \bar{y} - m\bar{x}$$

In Excel, the **LINEST(known_y's, [known_x's], [const], [stats])** function returns the m-coefficients and the constant b.

Correlation analysis

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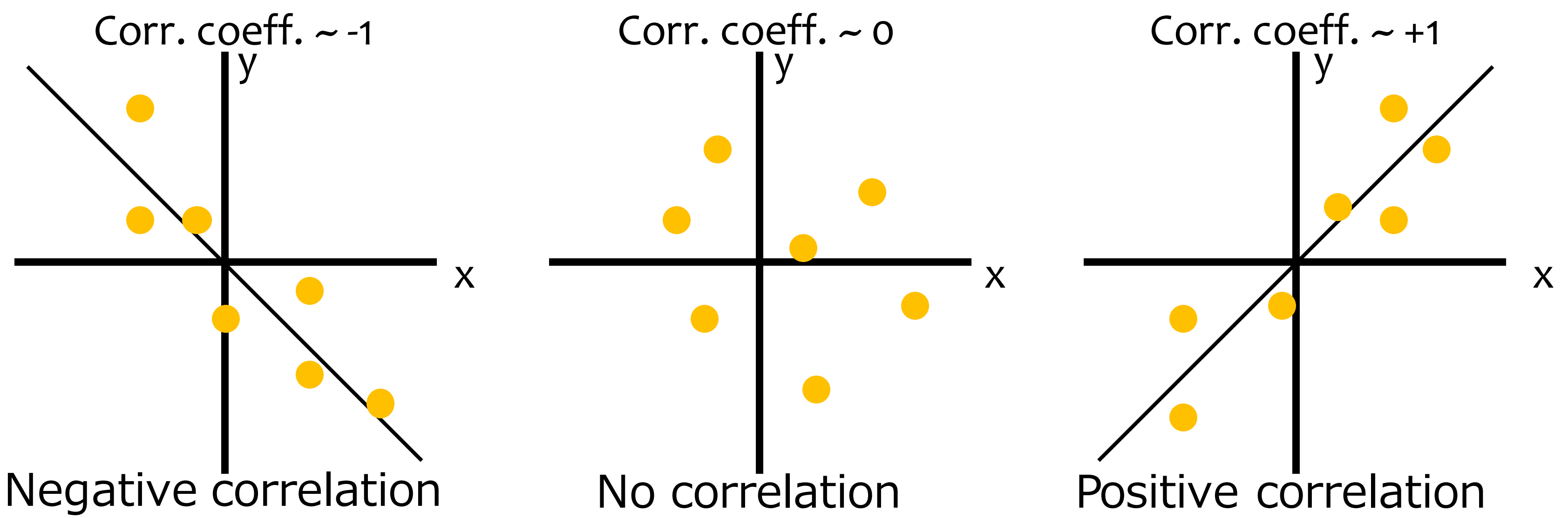
- Correlation coefficient: How close they have a linear relationship
  - Correlation coefficient values are between -1 and +1.
  - The value close to +1 (or -1) means there is a clear positive (negative) linear relationship between the targeted data pair, and the value around zero means there is little (or weak) relation between them.



Pearson correlation coefficient

Pearson correlation coefficient

- The ratio between the covariance of two variables and the product of their standard deviations (normalizing the covariance to a value between -1 and 1)

$$\frac{\text{Covariance of x and y}}{\text{(Standard deviation of x) x (Standard deviation of y)}} = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_i-\bar{y})^2}}$$

$$= \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}}$$

xi, yi: single value of dependent variable
X, Y: mean of all values of independent variable
n: population count

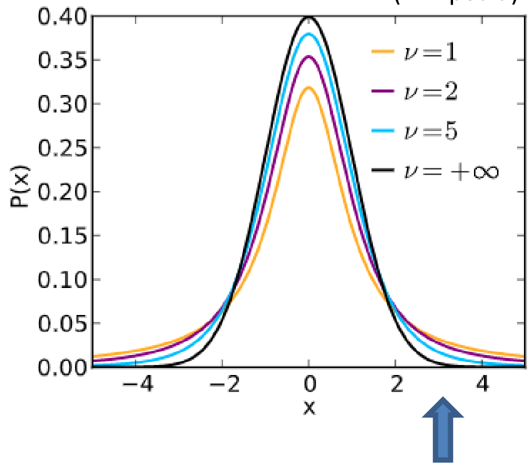
In Excel, the **CORREL(array1, array2)** function returns the correlation coefficient of two cell ranges.

Statistical test (Student's *t*-test)

- Does the long-term trend (=correlation) exist?
  - Null hypothesis: "the true correlation coefficient is equal to 0 (no correlation)."
  - Check whether the sample data are inconsistent with the null hypothesis or not
  - if they are inconsistent, then reject the null hypothesis (no correlation) and conclude that "the true correlation coefficient is not 0 (correlation exists)".
  - If the underlying variables have a bivariate normal distribution, Since the sampling distribution of the specific correlation coefficient **T** (Pearson's correlation coefficient divided by the standard error) follows Student's t-distribution with degrees of freedom n-2, if t is significantly (e.g., 99%) unlikely to have occurred in the Student's t-distribution, the null hypothesis is rejected.

$$T = \frac{|r|\sqrt{n-2}}{\sqrt{1-r^2}}$$

(Wikipedia)



Null hypothesis will be rejected when T is around here (but it depends on sample size!)

How to calculate the slope and its significance

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1. Input the yearly data

2. Trend ~ 0.0256

Mean Temperature in Tokyo (lat: 35.69, lon: 139.75)

Year	Data	Best fit
1876	12.7	12.2876153
1877	13.3	12.3131995
1878	13	12.3387836
1879	13.8	12.3643678
1880	13.3	12.3899519
1881	13	12.415536
1882	13.1	12.4411202
1883	12.5	12.4667043
1884	12.1	12.4922885
1885	12.2	12.5178726
1886	13.1	12.5434568
1887	12.9	12.5690409
1888	12.7	12.594625
1889	12.4	12.6202092
1890	14.2	12.6457933
1891	13.6	12.6713775
1892	13.2	12.6969616
1893	12.9	12.7225458
1894	13.9	12.7481299
1895	13	12.7737141
1896	13.2	12.7992982
1897	12.3	12.8248823
1898	13.1	12.8504665
1899	13	12.8760506
1900	12.7	12.9016348
1901	13	12.9272189
1902	12.9	12.9528031
1903	12.8	12.9783872

"Least squares" method

slope 0.025584144

y-intercept -35.70823865

$$y = ax + b$$

$$a = \frac{n\sum_{k=1}^{n} x_k y_k - \sum_{k=1}^{n} x_k \sum_{k=1}^{n} y_k}{n\sum_{k=1}^{n} x_k^2 - \left(\sum_{k=1}^{n} x_k\right)^2} \qquad b = \frac{\sum_{k=1}^{n} x_k^2 \sum_{k=1}^{n} y_k - \sum_{k=1}^{n} x_k y_k \sum_{k=1}^{n} x_k}{n\sum_{k=1}^{n} x_k^2 - \left(\sum_{k=1}^{n} x_k\right)^2}$$

Pearson correlation coefficient & test

Step 1 Determine the Pearson correlation coefficient

r 0.905342192

$$r = \frac{\frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

Step 2 Determine the number of pairs

n 146

Step 3 Determine the t-value

t 25.58169356

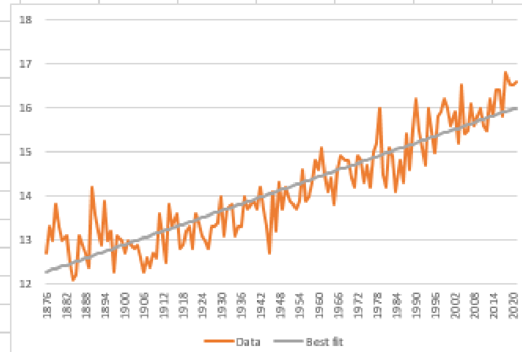
$$t_0 = \frac{|r|\sqrt{n-2}}{\sqrt{1-r^2}}$$

Step 4 Determine the degrees of freedom (n-2)

df 144

Step 5 Determine the significance in the t distribution of the freedom n-2

p = sig. = 2.02236E-55



3. Confidence level = (1 - 2.0x10^{-55}) ~ 99%

The annual mean surface temperature in Tokyo has risen at a rate of 2.56ºC per century (statistically significant at a confidence level of 99%).

Type I and type II errors

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- Even if the null hypothesis is rejected at a confidence level of 95%, this does not means the decision is 100% correct.
- Type I error (false positive)
  - Rejecting the null hypothesis which is actually true in reality.
- Type II error (false negative)
  - Not rejecting the null hypothesis which is actually not true in reality.
- Neyman-Pearson lemma
  - Retaining a prespecified level of type I error, subsequently minimize type II error.
- Use the test with the most power at a prespecified confidence level
  - Usually, Student's *t*-test is the good choice.

		Decision about null hypothesis	
		reject	Don’t reject
Null hypothesis is	Actually false	○	Type II error (false negative)
	Actually true	Type I error (false positive)	○

Type III error

- Type III error (Another definitions also exist)
  - Choosing the test falsely to suit the significance of the sample.
- The assumptions underlying a *t*-test are:
  - Normality (Samples from Normal Distribution)
  - Independent samples (No autocorrelation. Past values does not affect future one)
  - Homogeneity of variance (from past to future)
- In general, precipitation data does not have normality.
  - If you choose t-test for precipitation, type III error occurs.
  - You have to choose one of the nonparametric statistics, which does not require the assumptions of normality.
    - E.g., Kendall rank correlation coefficient

Kendall rank correlation coefficient

- Kendall rank correlation coefficient measure the <u>ordinal association</u> between two measured quantities.

(Example)

x	2001	2002	2003	2004	2005
y	1300	1350	1200	1250	1400

2001 -> 2003
2001 -> 2004
2002 -> 2003
2002 -> 2004

(number of concordant pairs) = P = 6

(number of discordant pairs) = Q = 4

(number ways to choose) = $_nC_2 = \frac{n(n-1)}{2}$ The binomial coefficient

The Kendall τ coefficient is defined as: $\tau = \frac{P-Q}{\frac{n(n-1)}{2}} = \frac{6-4}{10} = 0.2$

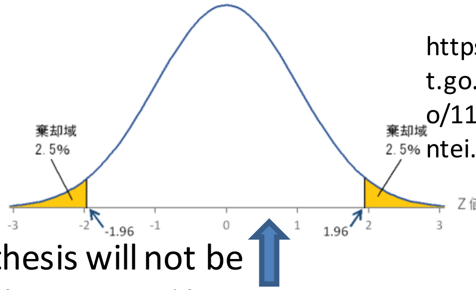
When there are ties, the formula becomes more complicated! I recommend you use R software.

With the independence and <u>larger samples</u> of X and Y, it is common to use an approximation to the normal distribution, with mean zero and variance $\frac{2(2n+5)}{9n(n-1)}$

Therefore, we can conduct statistical test with a standard normal distribution with the modified τ.

$$\frac{\tau}{\sqrt{\frac{2(2n+5)}{9n(n-1)}}} \sim 0.49$$

To be precise, this value is incorrect because of its small sample size. You can calculate the exact value by using R software.

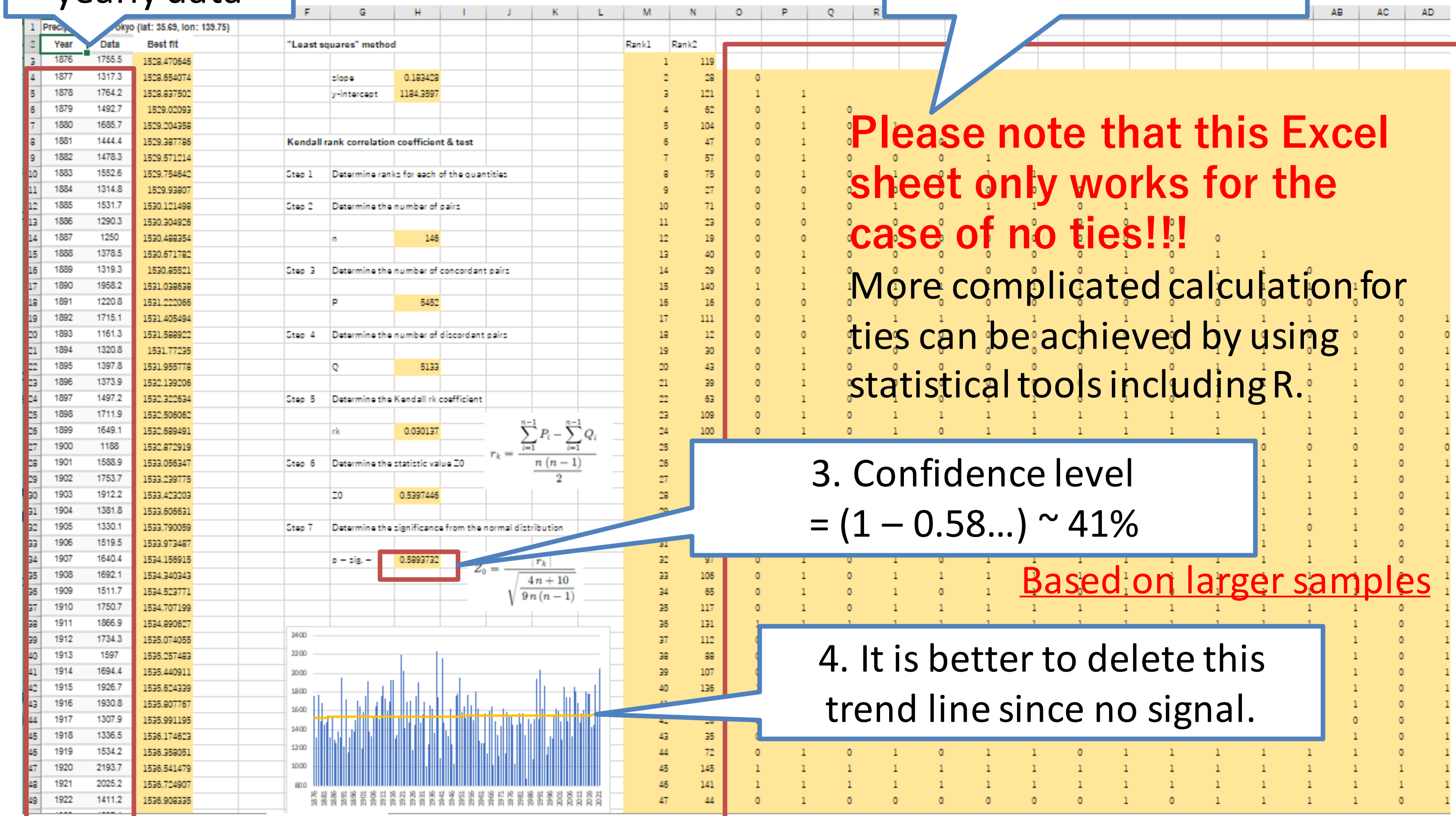


https://www.stat.go.jp/naruhodo/11_tokusei/kentei.html

Null hypothesis will not be rejected when around here

How to calculate the Kendall rank correlation coefficient

1. Input the yearly data



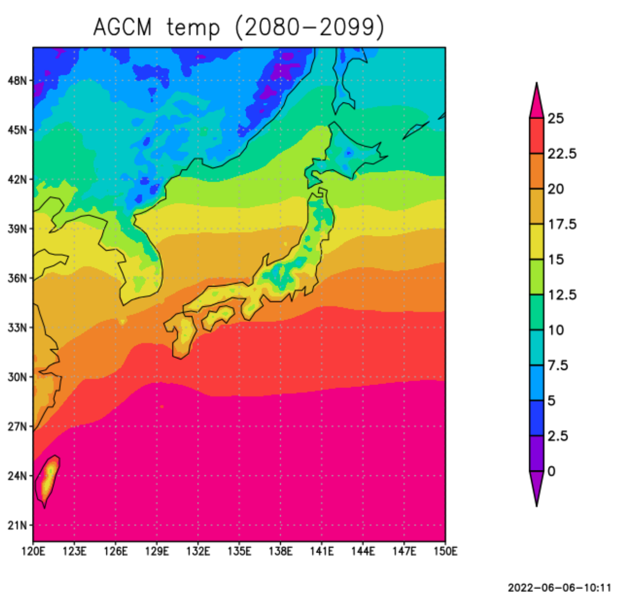
There has been no discernible trend in the annual mean precipitation in Tokyo.

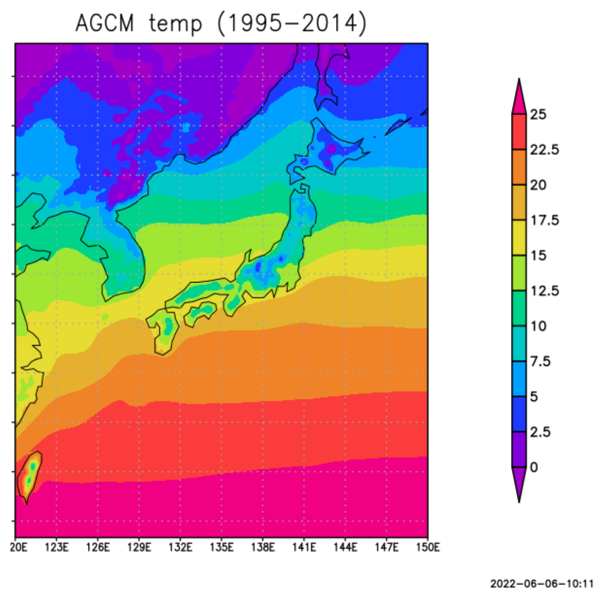
(Note for further study) Extreme precipitation events (e.g., annual number of days with precipitation ≥ 100 mm, annual maximum precipitation amounts) are known to have significant historical changes. (this is out of the scope of this training. You can check by obtaining additional observation data on your own).

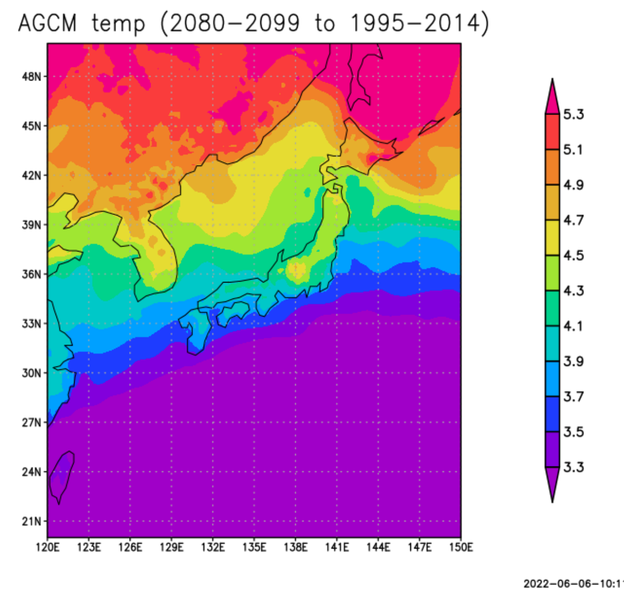
Description of future change

- In general, future changes of climate are described as the difference of climate model outputs between present and future.
  - In this training seminar, we use MRI-AGCM3.2 as the model.

Future (Climate model) − Present (Climate model) = Future change (F–P)



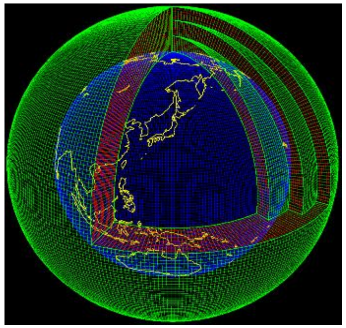




Projection by MRI-AGCM3.2S based on RCP8.5

About MRI-AGCM projection data

- MRI-AGCM3.2S, the model joining in the CMIP6 (HighResMIP).



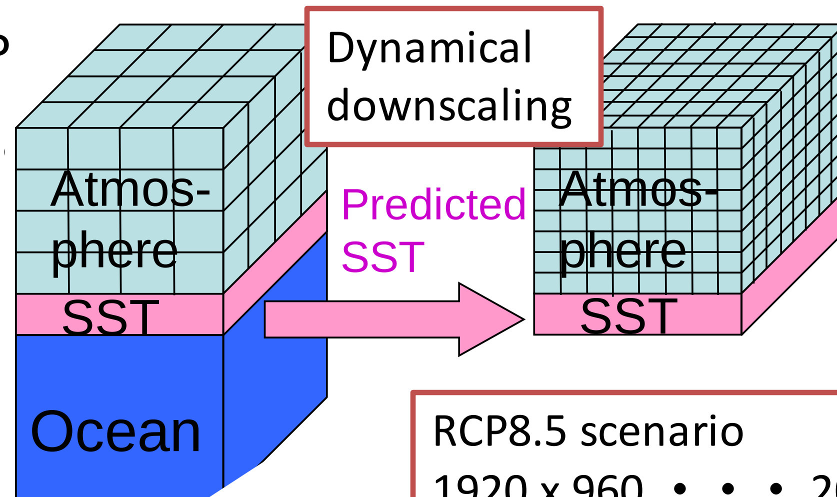
MRI-AGCM projection Data

Atmosphere-Ocean Couple Model
RCP8.5 Scenario

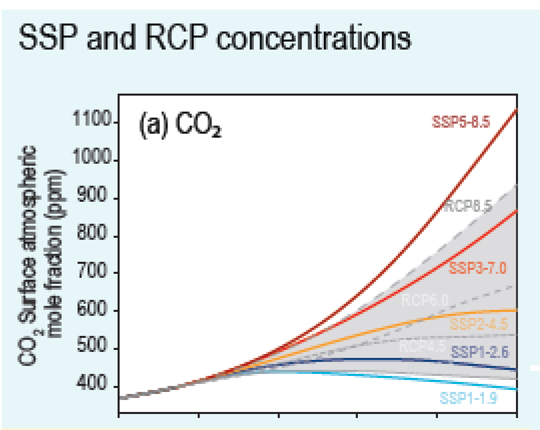
⇨

High resolution Atmosphere model experiment

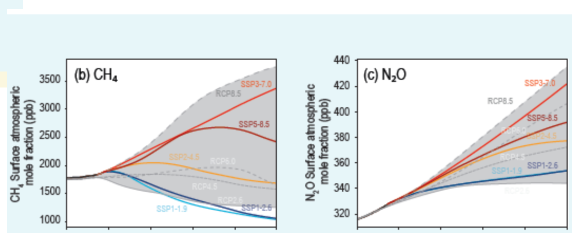
WCRP
CMIP5



RCP8.5 scenario
1920 x 960 ・・・ 20km mesh !!



AR6 WG1 Cross-Chapter Box 1.4, Figure 2



How to obtain MRI-AGCM projection data

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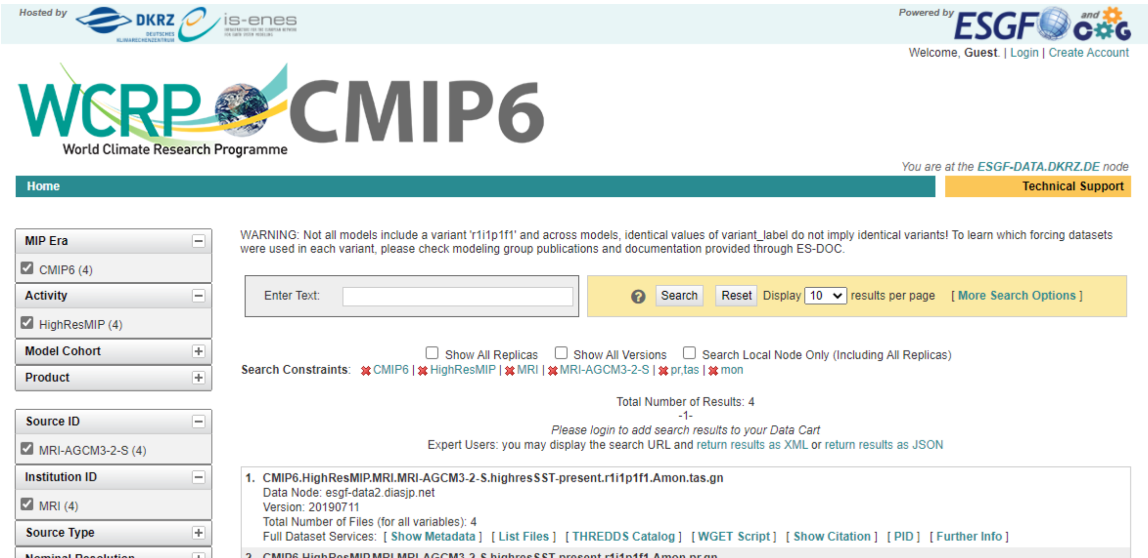
Data can be obtained from the WCRP website.



https://esgf-data.dkrz.de/search/cmip6-dkrz/

File Name	Content
tas_Amon_MRI-AGCM3-2-S_highresSST-future_r1i1p1f1_gn_207101-209012.nc tas_Amon_MRI-AGCM3-2-S_highresSST-future_r1i1p1f1_gn_209101-209912.nc	AGCM temperature (monthly, future) [K]
tas_Amon_MRI-AGCM3-2-S_highresSST-present_r1i1p1f1_gn_199001-200912.nc tas_Amon_MRI-AGCM3-2-S_highresSST-present_r1i1p1f1_gn_201001-201412.nc	AGCM temperature (monthly, present) [K]

File Name	Content
pr_Amon_MRI-AGCM3-2-S_highresSST-future_r1i1p1f1_gn_207101-209012.nc pr_Amon_MRI-AGCM3-2-S_highresSST-future_r1i1p1f1_gn_209101-209912.nc	AGCM precipitation (monthly, future) [kg m-2 s-1]
pr_Amon_MRI-AGCM3-2-S_highresSST-present_r1i1p1f1_gn_199001-200912.nc pr_Amon_MRI-AGCM3-2-S_highresSST-present_r1i1p1f1_gn_201001-201412.nc	AGCM precipitation (monthly, present) [kg m-2 s-1]

How to obtain MRI-AGCM projection data

- By using GrADS or OpenGrADS, time series of output values can be obtained easily.
  - However, the operation of GrADS or OpenGrADS is beyond the scope of this training seminar.
  - In this training seminar, simplified csv data prepared by lecturer will be provided for time saving.

Grid Analysis and Display System (GrADS)

OpenGrADS "Opening GrADS to a World of Extensions"

http://cola.gmu.edu/grads/
http://opengrads.org/

```
ga-> sdfopen temp/tas_Amon_MRI-AGCM3-2-S_highresSST-present_r1i1p1f1_gn_199001-200912.nc
ga-> set lon 139.75
ga-> set lat 35.69
ga-> set gxout print
ga-> set prnopts %7.3f 1 1
ga-> set time jan1995 dec2009
ga-> d tas
```

- Open a file (sdfopen)
- Longitude and Latitude Setting (set lon / set lat)
- Print format (set prnopts)
- Set time range and Draw (set time / d tas)

```
ga-> sdfopen temp/pr_Amon_MRI-AGCM3-2-S_highresSST-present_r1i1p1f1_gn_199001-200912.nc
ga-> set lon 139.75
ga-> set lat 35.69
ga-> set gxout print
ga-> set prnopts %10.3e 1 1
ga-> set time jan1995 dec2009
ga-> d pr
```

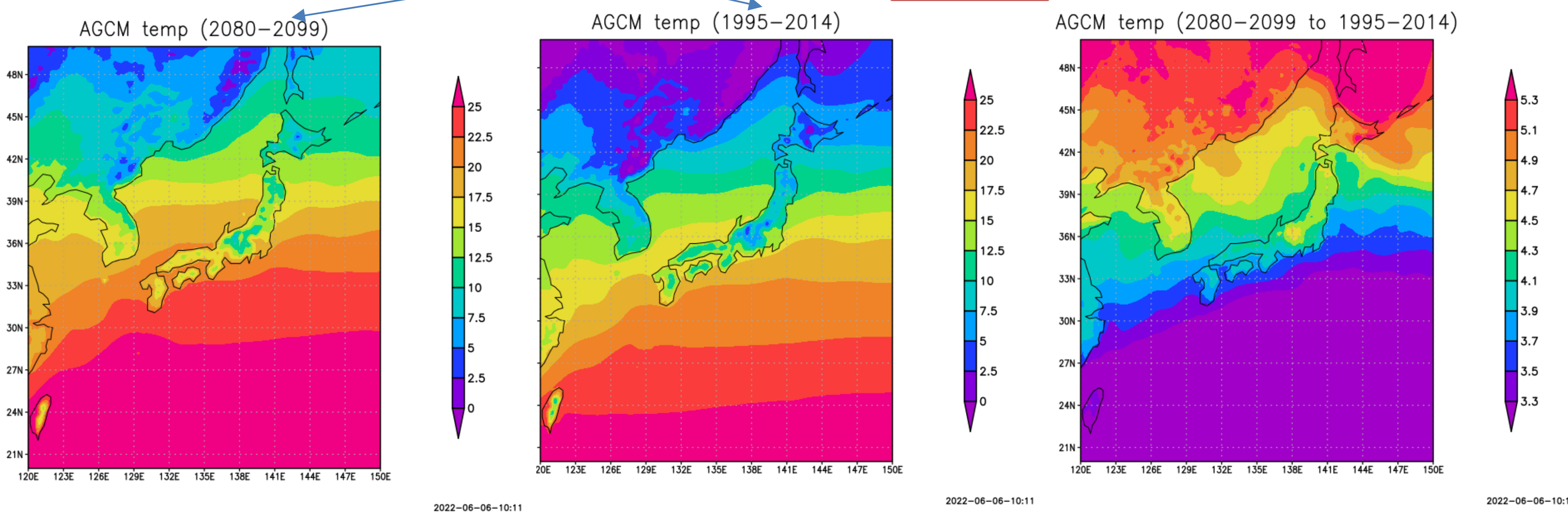
Concerns when describing the future change

- In general, future changes of climate are described as the difference of climate model outputs between present and future.
  - There are several points to be included into consideration.

Future (Climate model) − Present (Climate model) = Future change (F–P)

Mean climate state?

Realistic?



Projection by MRI-AGCM3.2S based on RCP8.5

Reliable?

Uncertainties in global warming projection

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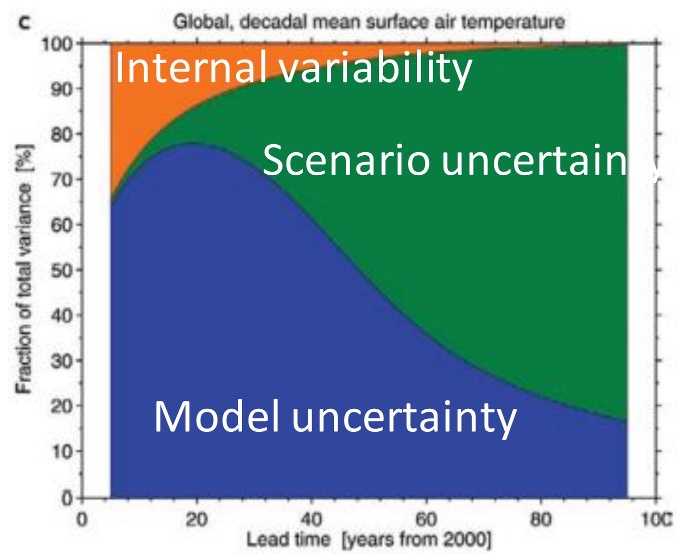
- Global warming projection contains many uncertainties. Therefore, we cannot say the results are correct projections without considering the uncertainties.
- Types of uncertainty
  - Natural climate variability
  - Regional scale
  - Incompleteness of climate model
  - Short period for calculation



(Hawkins and Sutton 2009)

Remarks on interpretation of key uncertainties

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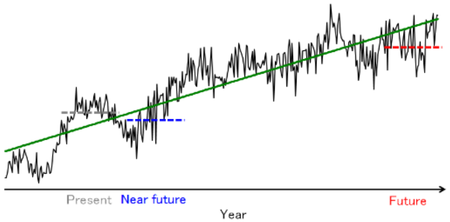
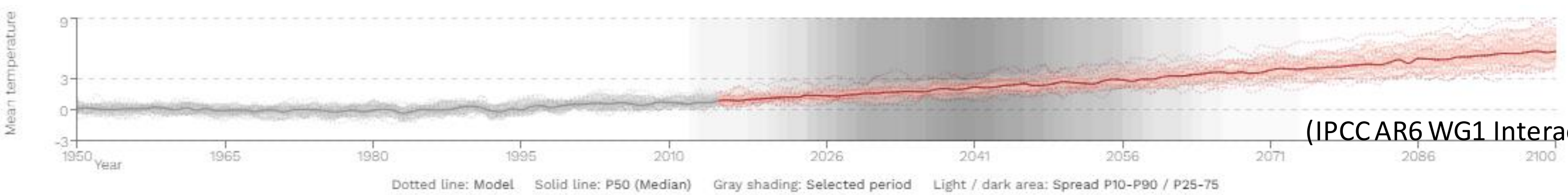
- The aim is to project climate change signals rather than natural climate variability.
  - Even state-of-the-art climate models cannot predict natural variability.
  - The 20-year average of results from the climate model are used for global warming projection.
- Uncertainties in regional-scale climate projections are greater than those in global-scale climate projections.
  - It is necessary to examine whether projected regional-scale climate change is consistent with broader-scale climate change.
- Uncertainties in near-future climate projections are larger than those in future climate projections.
  - As the level of greenhouse gas concentration in near-future projections is expected to be lower than that in future projections, less pronounced climate change signals may be dominated by natural variability.



http://ds.data.jma.go.jp/tcc/tcc/products/gwp/gwp8/html/section1_3.html

Remarks on interpretation of key uncertainties

- Uncertainties exist even in long-term trends.
  - Future climate projection uncertainties can be estimated via multi-model or multi-parameter experiments.
- The ability of models to project future climate conditions is limited.
  - Large-scale patterns averaged over a broader area provide a more meaningful picture than changes on a single-grid scale.
- Uncertainties in future projections depend on the variables used.
  - Detecting climatological trends for precipitation is more difficult than that for temperature because extreme rainfall events are rare by definition and occur on relatively limited spatial and temporal scales.
- Future projections depend on the greenhouse gas emissions scenario used.



(IPCC AR6 WG1 Interactive Atlas)

http://ds.data.jma.go.jp/tcc/tcc/products/gwp/gwp8/html/section1_3.html

Tackle the uncertainty (example)

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- Natural climate variability
  - Choose longer mean period than natural variability
    - In this training seminar, we choose 20-years mean
- Regional scale
  - Check the regional response as a part of the wider area
    - In this training seminar, we check the wider response by IPCC reports.
- Incompleteness of climate model (Model bias)
  - Check the reproducibility of the model
    - Take some bias correction method to correct the response
      - In this training seminar, we take a simple bias correction method.
- Short period for calculation
  - See the long-term climate change in the model
    - In this training seminar, we see the response at the end of 21st century.

Further explanation is in the following slide.

Comparing the regional response with the wider response: How to get the value from IPCC WG1 Interactive Atlas

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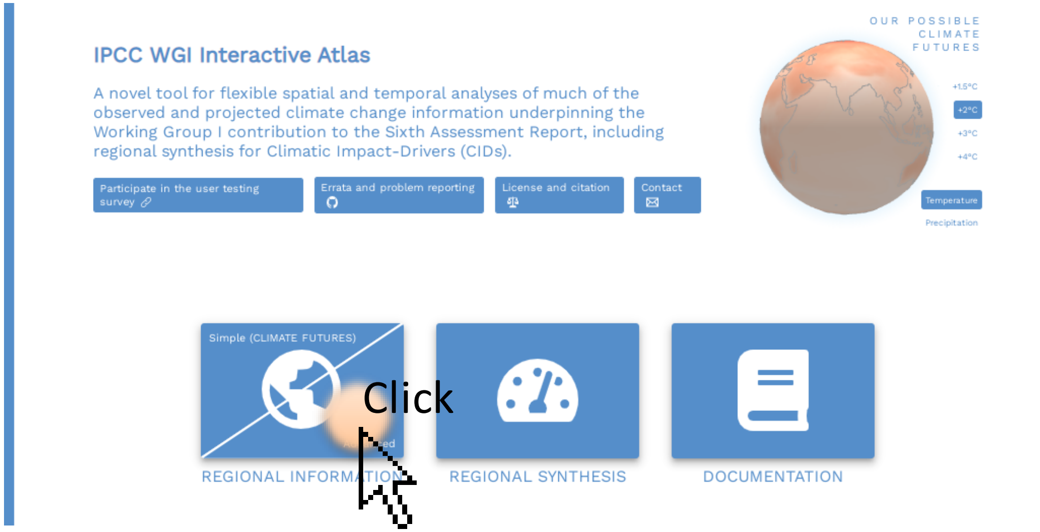
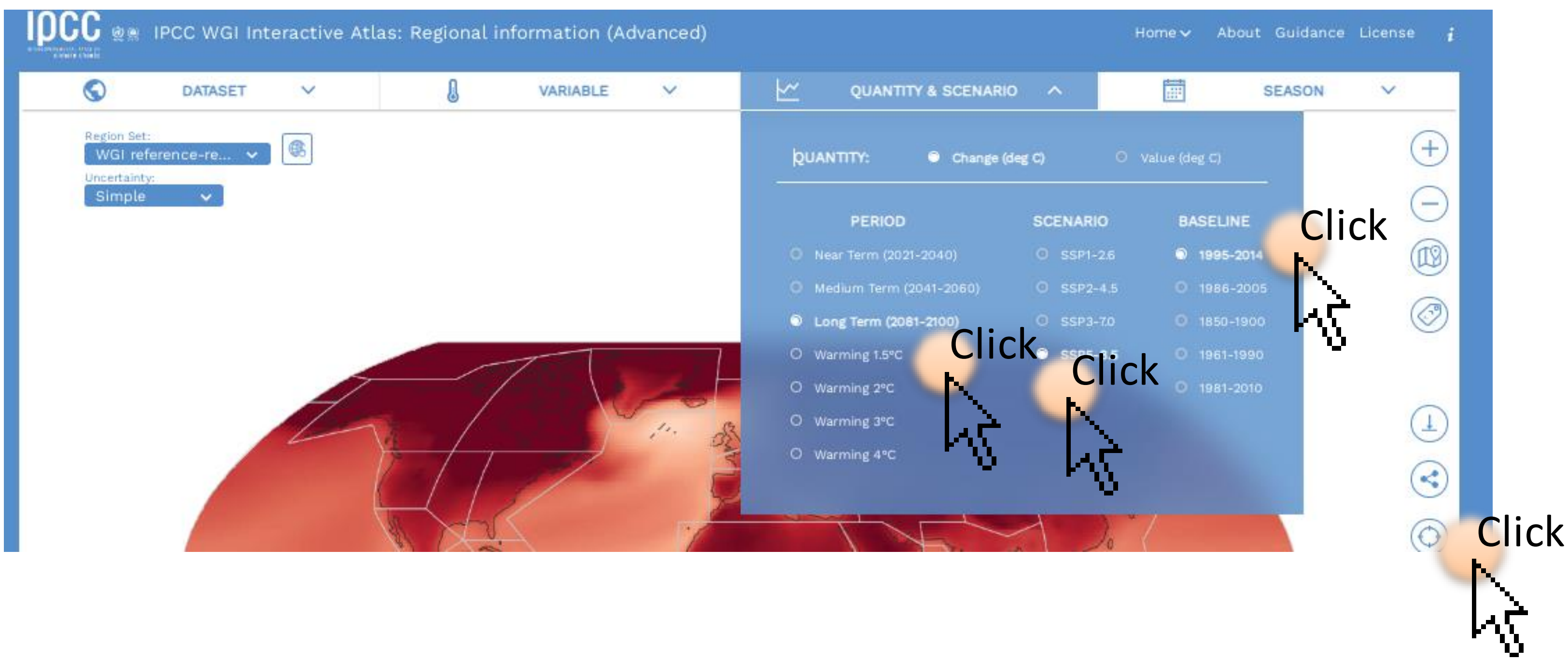


- Go to the website
  - https://interactive-atlas.ipcc.ch/
- Click “Advanced”
- Hover over “Quantity & Scenario”
- Click “Long Term (2081-2100)”
- Click “SSP8-8.5”
- Click “1995-2014”
- Click “Point Information”
- Click the point in your country/region



Checking reproducibility and correcting bias

- Bias (systematic errors) in climate models is defined as certain tendency for errors in climate models.
  - E.g., the model tends to project warmer than observation (positive bias).
- The reproducibility can be judged by calculating the bias. Bias can be defined here as Simulation minus Observation.
  - Simulation is the forecast which is conducted by climate models.
  - Observation is the values which the model tries to reproduce.
- Simulation and Observation cannot be exactly the same result. Every model has its own bias.
  - Arising from simplified physics, parameterizations, rack of resolution and so on.
- Bias correction is the way to overcome the problem, which adjusts present simulation to observation. For example, a simple way (Delta method) is:
  - (Temp.) $\mathrm{Future}_{\mathrm{Bias\ corrected}} = \mathrm{Observation} + \mathrm{Future} - \mathrm{Present}$
  - (Precip.) $\mathrm{Future}_{\mathrm{Bias\ corrected}} = \mathrm{Observation} * (\frac{\mathrm{Future}}{\mathrm{Present}})$

How to make future change of your county/region

Japan Meteorological Agency 気象庁

Temperature

Mean Temperature in Tokyo (lat: 35.69, lon: 139.75)

Raw values are taken from CMIP6 MRI-AGCM3.2S RCP8.5

1. Input the monthly observation data

Year	Month	Obs	Raw (K)	Raw (℃)
1995	1	5.4	274.514	1.364
1995	2	5.7	274.934	1.784
1995	3	8.3	279.495	6.345
1995	10	18.5	288.082	14.932
1995	11	11.5	280.917	7.767
1995	12	6.6	278.026	4.876
1996	1	5.7	275.207	2.057
1996	2	4.6	275.236	2.086
1996	3	8.6	279.54	6.39
1996	4	12.1	283.22	10.07
1996	5	17.4	289.816	16.666
1996	6	21.9	293.648	20.498
1996	7	25.5	296.582	23.432
1996	8	25.1	297.876	24.726
1996	9	21.4	294.134	20.984
1996	10	17	288.569	15.419
1996	11	12	282.032	8.882
1996	12	8.2	277.371	4.221
1997	1	5.9	275.264	2.114
1997	2	6.2	275.38	2.23
1997	3	9.9	278.423	5.273
1997	4	14.6	284.341	11.191

2. Input the model data (provided)

Bias Correction based on Delta method

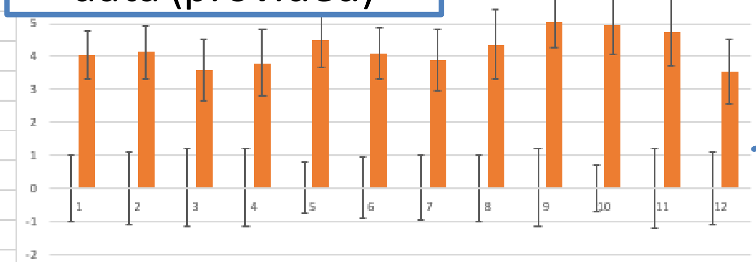
3. Future changes

Month	Obs mean	Present	Future	F-P	σP	σF	Corrected F
1	5.275	1.74665	5.801	4.05445	1.01315	0.71498	9.32945
2	5.89	2.5999	6.725	4.1254	1.10194	0.80172	10.0154
3	9.275	6.7532	10.365	3.61265	1.18281	0.92999	12.88765
4	14.22	11.9615	15.77	3.80855	1.18382	0.99861	18.02855
5	18.56	17.3392	21.825	4.48625	0.78176	0.82953	23.04625
6	21.845	21.3262	25.412	4.08595	0.93604	0.77681	25.93095
7	25.83	24.9881	28.901	3.91305	0.98133	0.93467	29.74305
8	26.855	25.5625	29.931	4.36925	1.00362	1.07522	31.22425
9	23.32	21.8494	26.886	5.03685	1.18382	0.7762	28.35685
10	18.02	16.0807	21.017	4.93665	0.69091	0.85141	22.95665
11	12.435	9.68345	14.426	4.74295	1.20278	1.03635	17.17795
[illegible]	7.51	4.942	8.4794	3.53745	1.09189	0.9662	11.04745

4. Bias-corrected Future values

Year	Month	Raw	Raw (℃)
2080	1	278.092	4.942
2080	2	279.51	6.36
2080	3	283.953	10.803
2080	4	288.476	15.326
2080	10	293.342	20.192
2080	11	286.233	13.083
2080	12	280.19	7.04
2081	1	278.631	5.481
2081	2	278.03	4.88
2081	3	282.193	9.043
2081	4	287.185	14.035
2081	5	294.295	21.145
2081	6	298.284	25.134
2081	7	300.554	27.404
2081	12	283.54	10.39
2082	1	278.288	5.138
2082	2	278.774	5.624
2082	3	283.997	10.847
2082	4	289.132	15.982

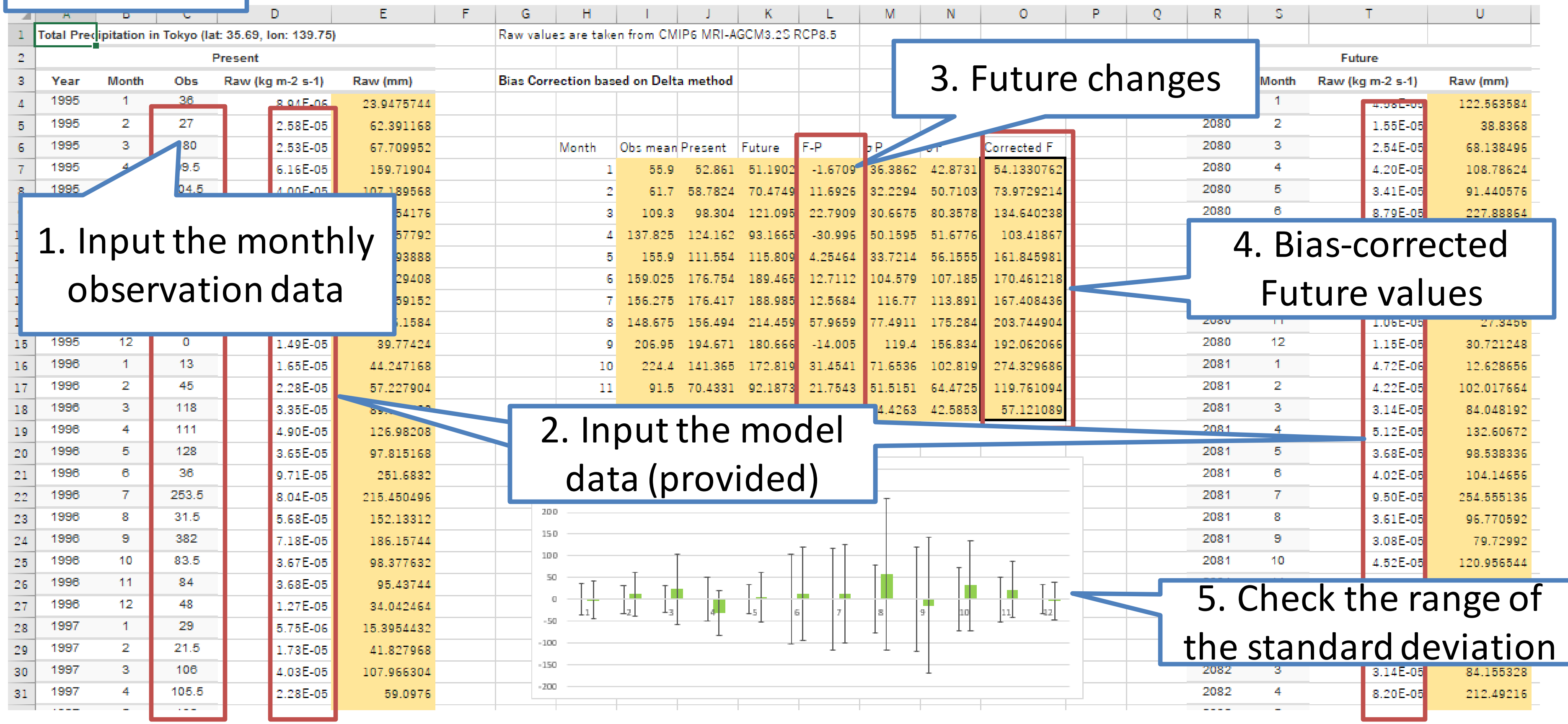
5. Check the range of the standard deviation



The projected changes in monthly mean surface temperatures in Tokyo in 2080-2099 relative to the 1995-2014 are in the range of +3.5ºC (Dec.) to +5.0ºC (Sep.). In August, the future value is 31.2ºC (Aug.).

How to make future change of your county/region

Precipitation



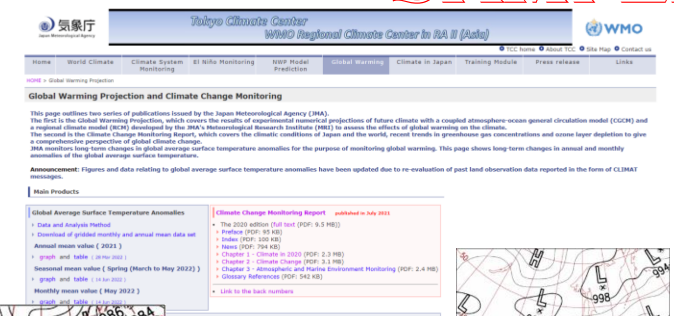
The projected changes in total precipitation in Tokyo in 2080-2099 relative to the 1995-2014 ~~are in the range of -3.9mm (Dec.) to +58.0mm (Aug.)~~ have no significant tendency.

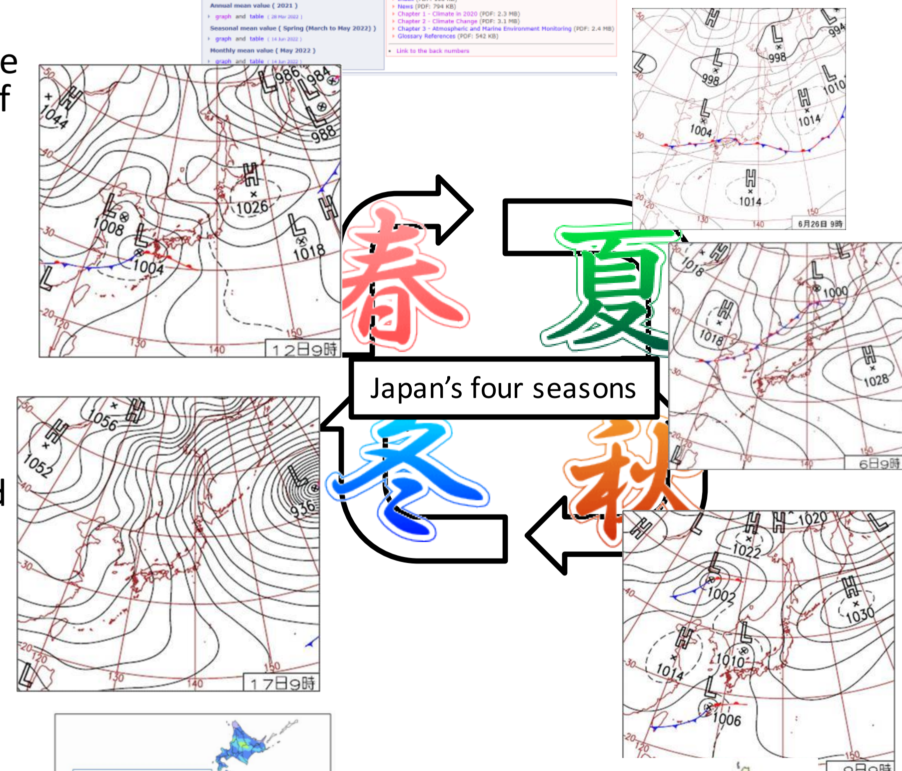
(Note for further study) Extreme precipitation events (e.g., annual number of days with precipitation ≥ 100 mm, annual maximum precipitation amounts) are known to have significant changes in projections (this is out of the scope of this training seminar. You can check by analyzing the original GPV on your own).

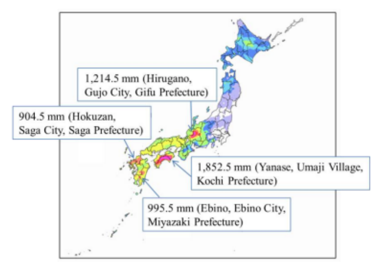
Template: Introduction

Japan Meteorological Agency

- Tokyo Climate Center / Japan Meteorological Agency
  - JMA assess the effects of global warming on the climate with the Global Warming Projection with climate models developed by the JMA's Meteorological Research Institute (MRI).
  - JMA monitors long-term changes in global average surface temperature anomalies for the purpose of monitoring global warming.
- Climatology in Japan
  - Early summer is the rainy season, known as the Baiu, caused by a stationary Baiu front.
  - In Summer, the North Pacific High extends northwestward around Japan, bringing hot and sunny conditions.
  - Monthly precipitation amounts are large in autumn due to the active autumnal rain front and tropical cyclones.
- Recent extreme events
  - The Heavy Rain Event of July 2018 from western Japan to the Tokai region and the Subsequent Heatwave from Mid-July Onward
  - Record-heavy rain In mid-August 2021 from western to eastern Japan
  - Record-heavy rain and record low sunshine durations from eastern to northeastern Japan







(28th June – 8th July)

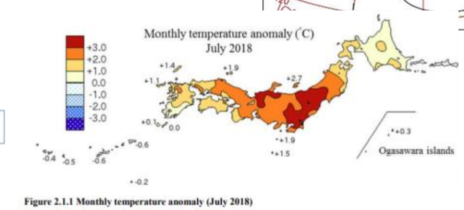


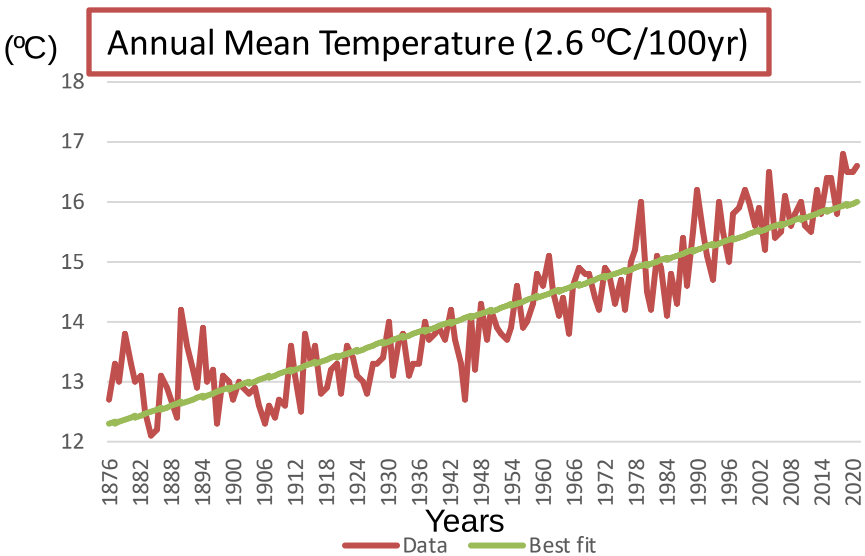
Figure 2.1.1 Monthly temperature anomaly (July 2018)

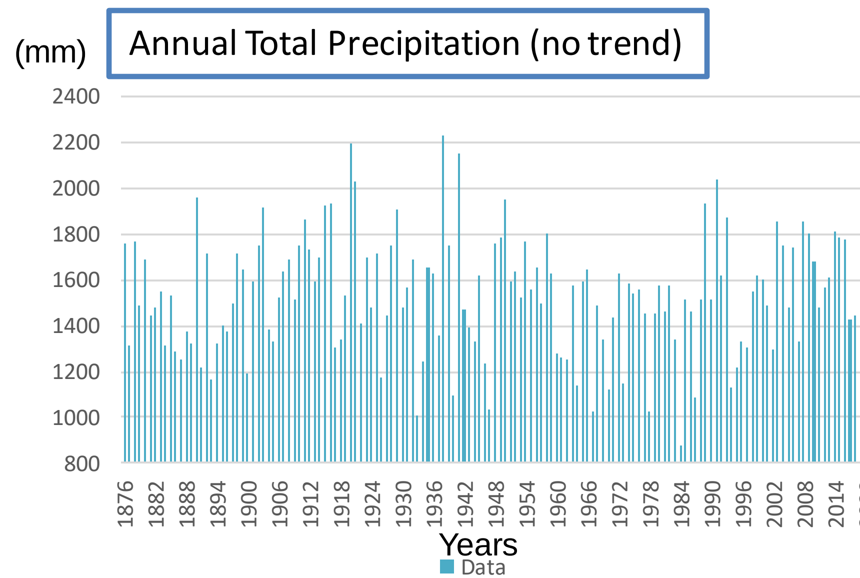
Template: Observed Trend

Japan Meteorological Agency
気象庁

SAMPLE

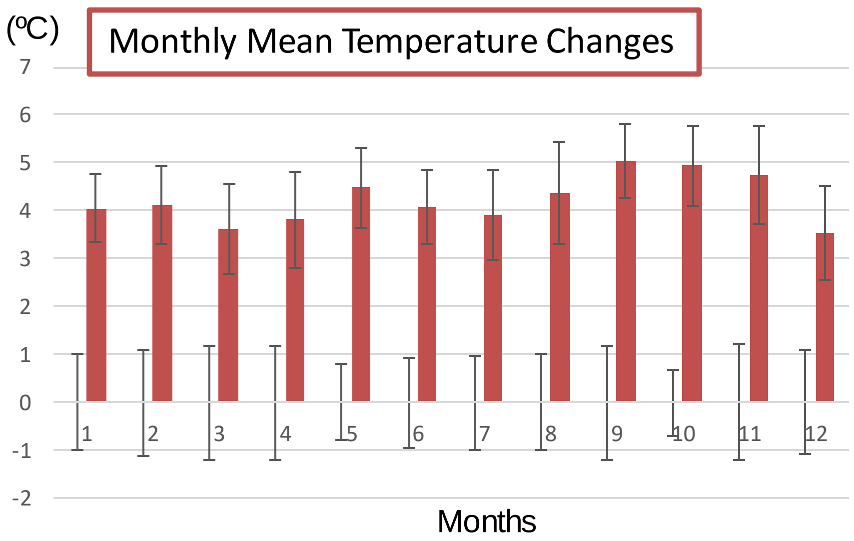
- ✓ The annual mean surface temperature in Tokyo has risen at a rate of 2.56ºC per century (statistically significant at a confidence level of 99%).
- ✓ There has been no discernible trend in the annual mean precipitation in Tokyo.

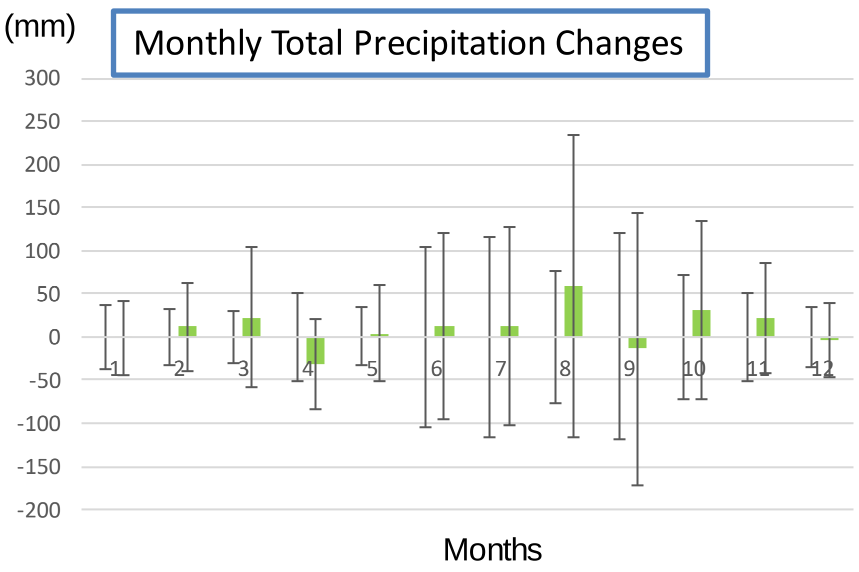




Template: Future Change

- ✓ The projected changes in monthly mean surface temperatures in Tokyo in 2080-2099 relative to the 1995-2014 are in the range of +3.5ºC (Dec.) to +5.0ºC (Sep.). In August, the future value is 31.2ºC (Aug.).
- ✓ The projected changes in total precipitation in Tokyo in 2080-2099 relative to the 1995-2014 have no significant tendency.



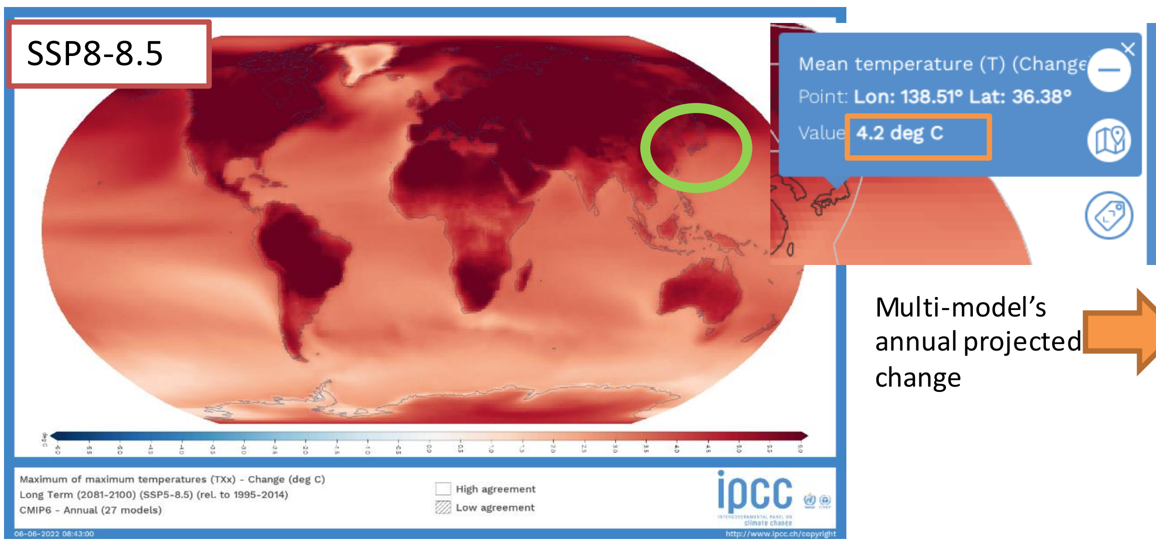


Template: Uncertainty (Reliability)

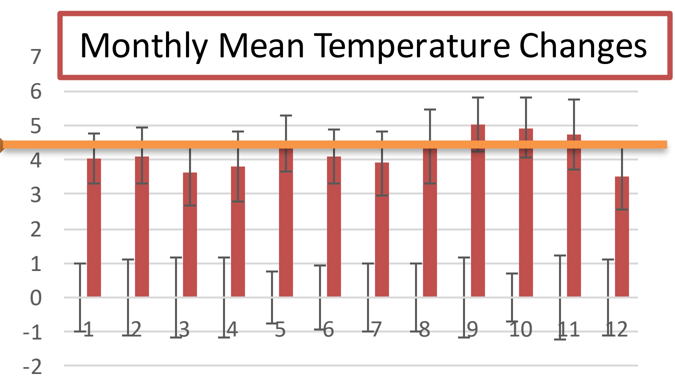
Japan Meteorological Agency 気象庁

SAMPLE

- ✓ Under RCP8.5/SSP5-8.5, it is likely that most land areas will experience further warming of at least 4ºC compared to a 1995–2014 baseline by the end of the 21st century, and in some areas significantly more. <AR6 WG1 TS.4.3.1>
- ✓ Considering emission scenario difference and the country location in the IPCC projection map, the projection with MRI-AGCM is similar with those in IPCC.



Multi-model's annual projected change



The change from 1995 – 2014 to 2081 – 2100 in annual mean temperature. <AR6 WG1 Interactive Atlas>
https://interactive-atlas.ipcc.ch/

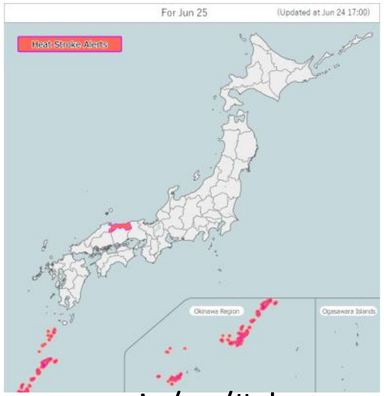
Template: Summary and Discussion

Findings

- The annual mean surface temperature in Tokyo has risen at a rate of 2.56ºC per century.
- In August, the projected value in surface temperatures in Tokyo in 2080-2099 relative to the 1995-2014 is 31.2ºC.

Estimated impact on the society

- Risk of heat stroke would be increased.

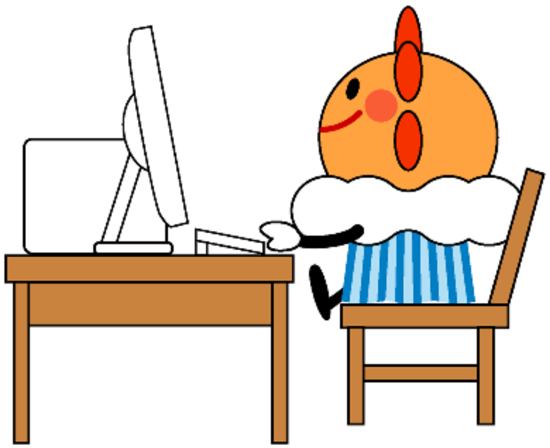


https://www.wbgt.env.go.jp/en/#alert_map

Actions to be needed I think

- Increasing people’s awareness about "Heat Stroke Alert"

Let's try these exercises!
(self-study format)



3rd Day – 4th Day (11 and 14 November)

- (self-study format) Exercise on Observed Trends and Global Warming Projection for your country

5th Day (15 November)

- Your presentation (6 minutes per person)