UNIVERSITAS NASIONAL AND RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY

CERTIFICATE OF APPRECIATION

Awarded to

Prof. Dr. Ernawati Sinaga, M.S., Apt.

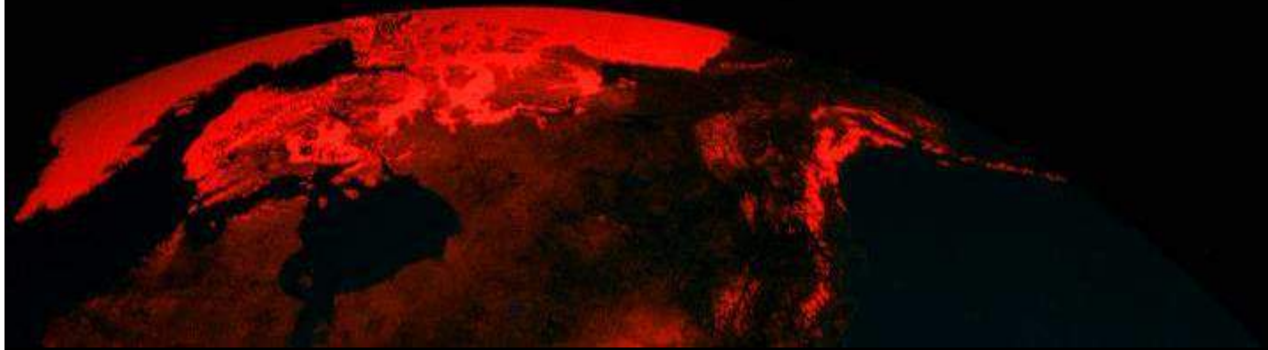
in recognition of the participation and contributions as an invited speaker:

International Symposium on Climate Change and Extinction Risk

Jakarta, 11 June 2014

Dr. Erin R. Vogel
Co-Director Tuanan Orangutan Project,
Assistant Professor Department of Anthropology and Center for Human Evolutionary Studies - Graduate Program in Ecology and Evolution
Rutgers, The State University of New Jersey

Drs. Imran S.L. Tobing, MSi
Dean of Faculty of Biology
Universitas Nasional

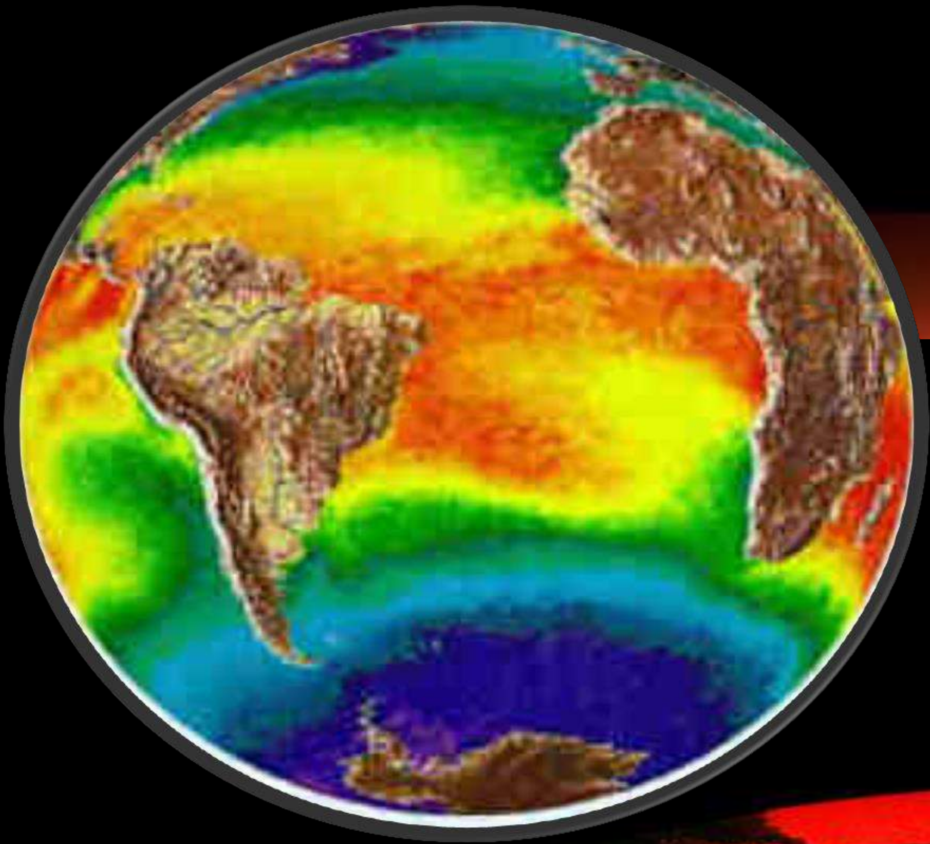


Threats of Climate Change on Medicinal Plants

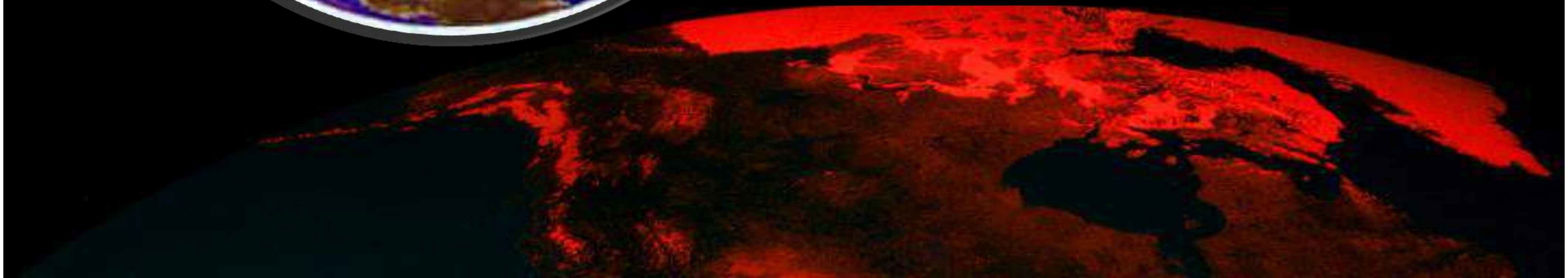
Ernawati Sinaga
Center for Medicinal Plants Research
Universitas Nasional

Symposium on Climate Change and Biodiversity
Jakarta, 11th. June 2014

CLIMATE CHANGE



GLOBAL THREAT

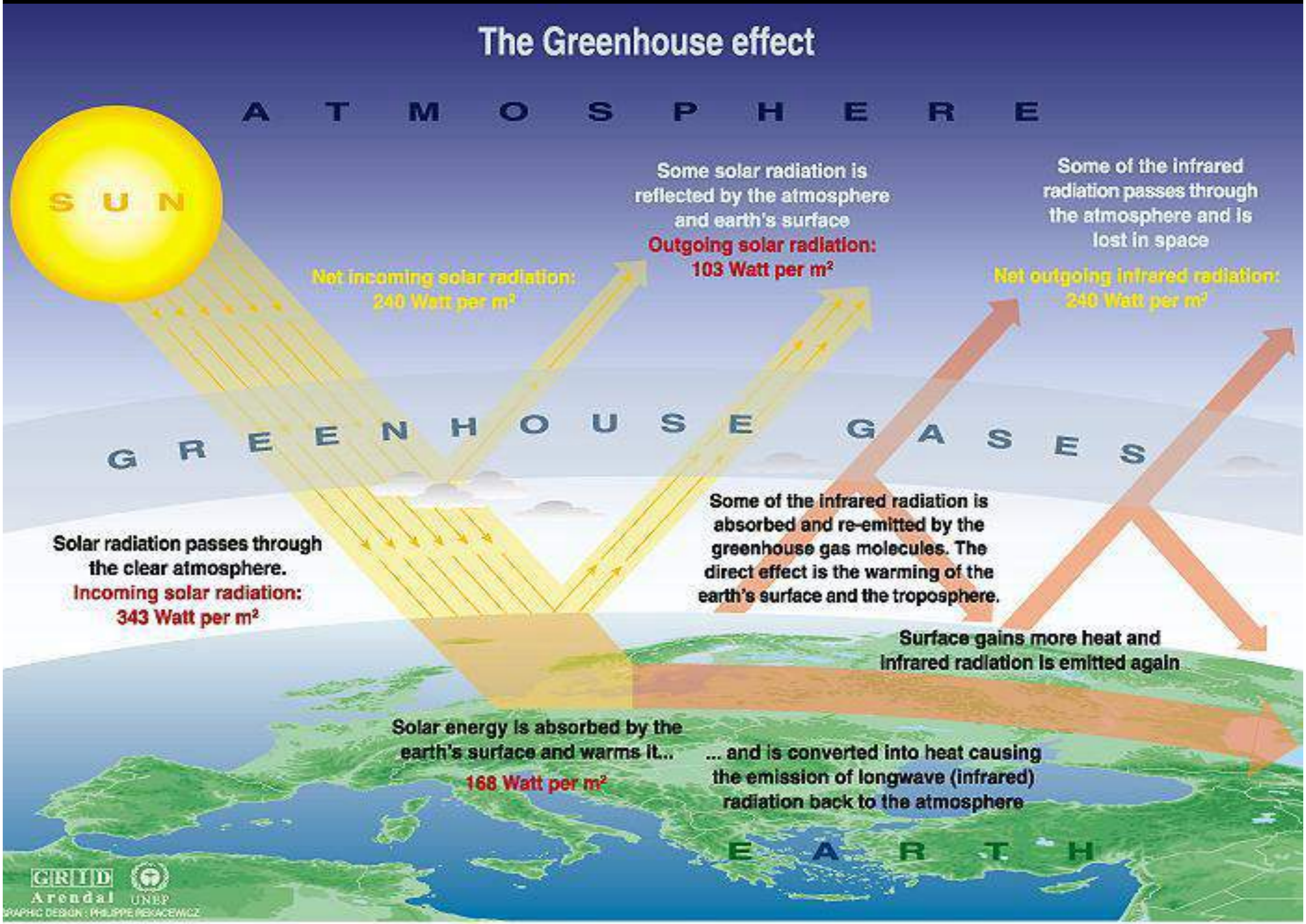



CLIMATE CHANGE
Disaster.....
Hunger......
Diseases.....

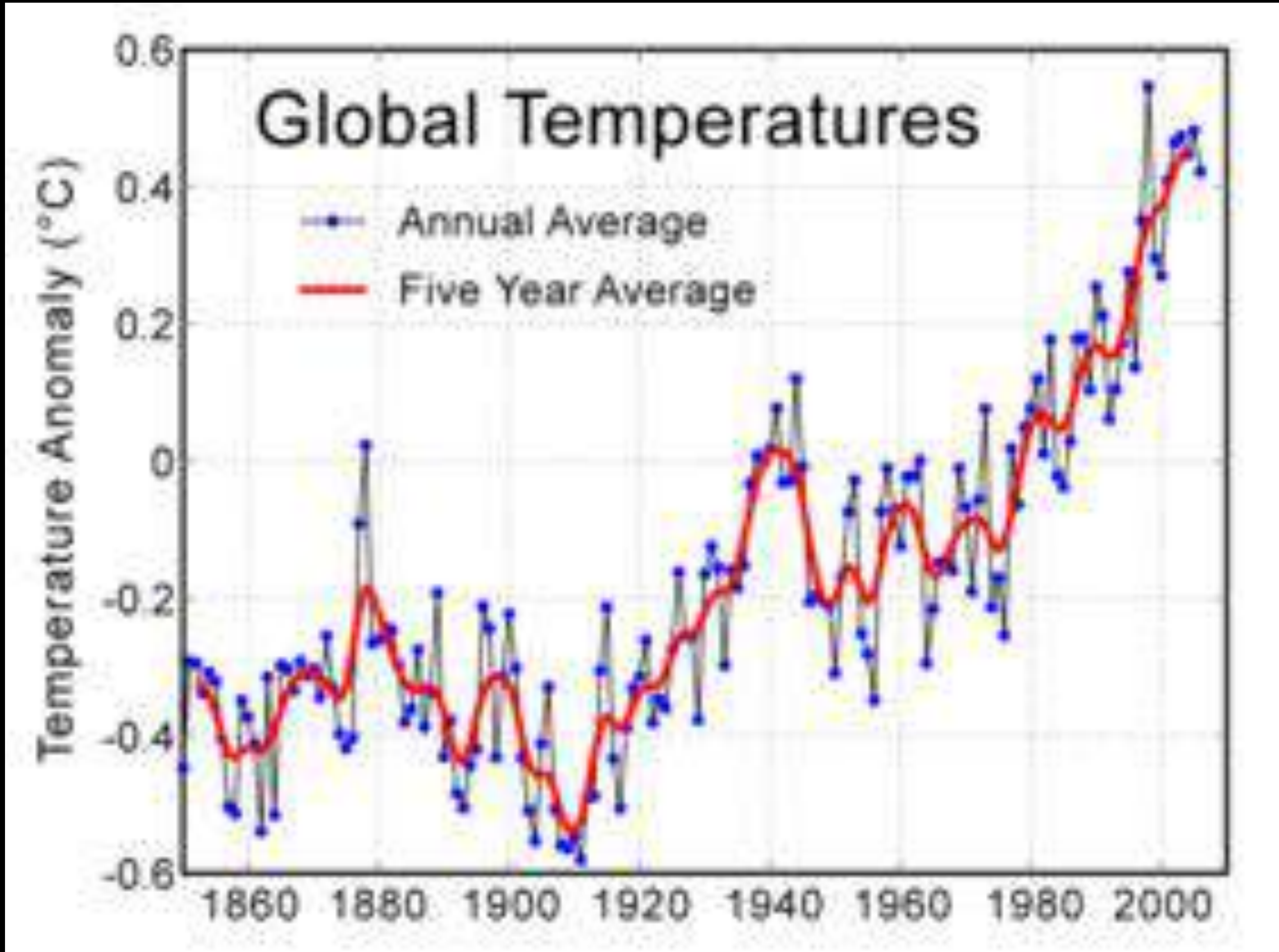
Climate Change

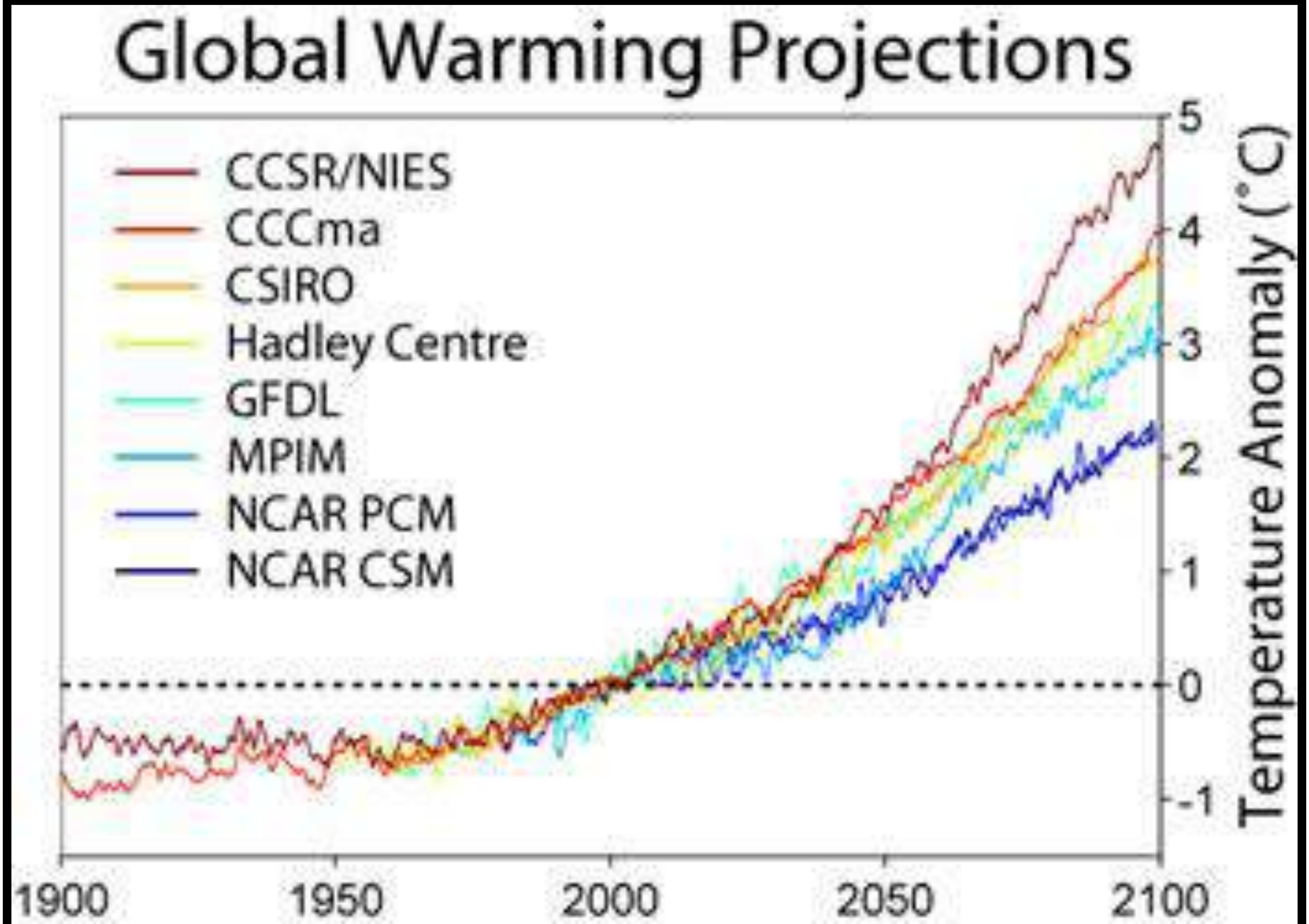
- Warming is decreasing frost, snow and ice cover.
- Rain may increase in some areas, particularly high latitudes, but decrease in others
- More frequent wildfires
- Longer periods of drought in some regions
- Floods in other regions
- Increase in the number, duration and intensity of tropical storms


CLIMATE CHANGE
GLOBAL WARMING
THE GREATEST GLOBAL THREAT



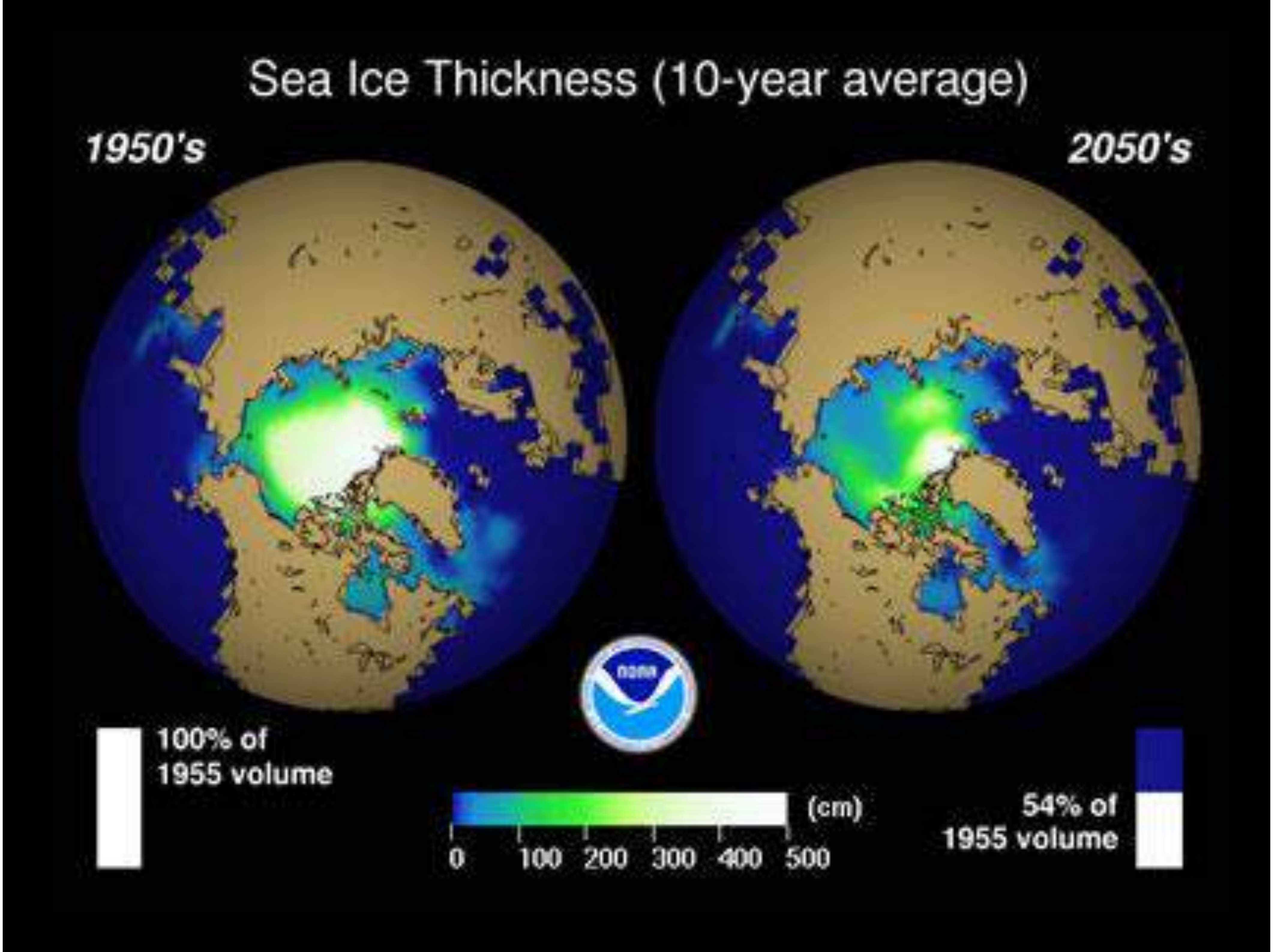
Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.


Global Temperatures
Annual Average
Five Year Average
Temperature Anomaly (°C)
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
1860
1880
1900
1920
1940
1960
1980
2000


Global Warming Projections
CCSR/NIES
CCCma
CSIRO
Hadley Centre
GFDL
MPIM
NCAR PCM
NCAR CSM
Temperature Anomaly (°C)
5
4
3
2
1
0
-1
1900
1950
2000
2050
2100

Climate Change

- Increasing of global temperature:
  - Now ca. 0.6°C greater than pre-industrially
  - est. 2100: 1.4^{0} C to 5.8^{0} C greater
  - 4.2°C greater towards the end of the 21st century


Sea Ice Thickness (10-year average)
1950's
2050's
100% of
1955 volume
(cm)
0
100
200
300
400
500
54% of
1955 volume

Arctic Sea Ice

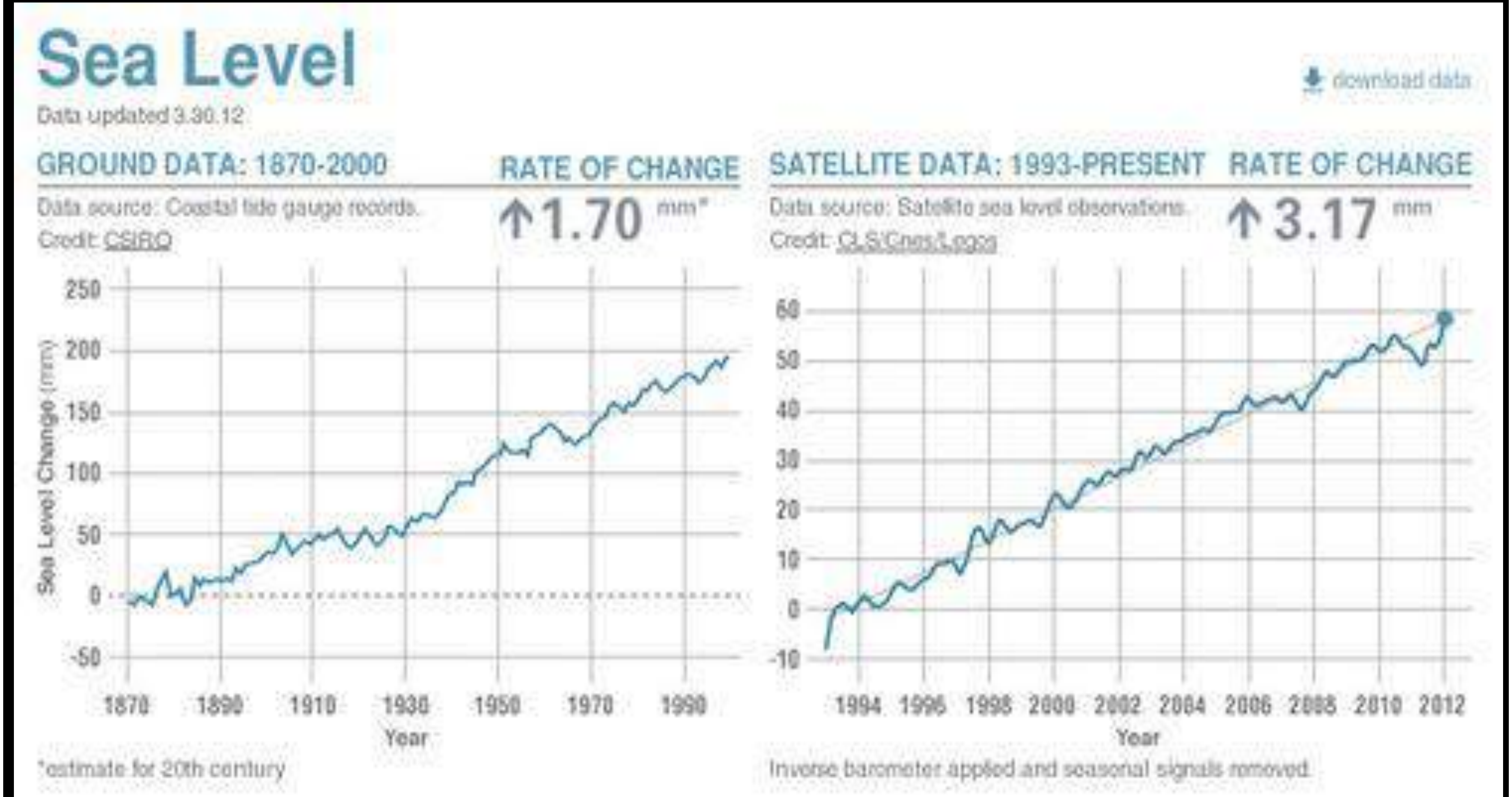
Data updated 10.10.11

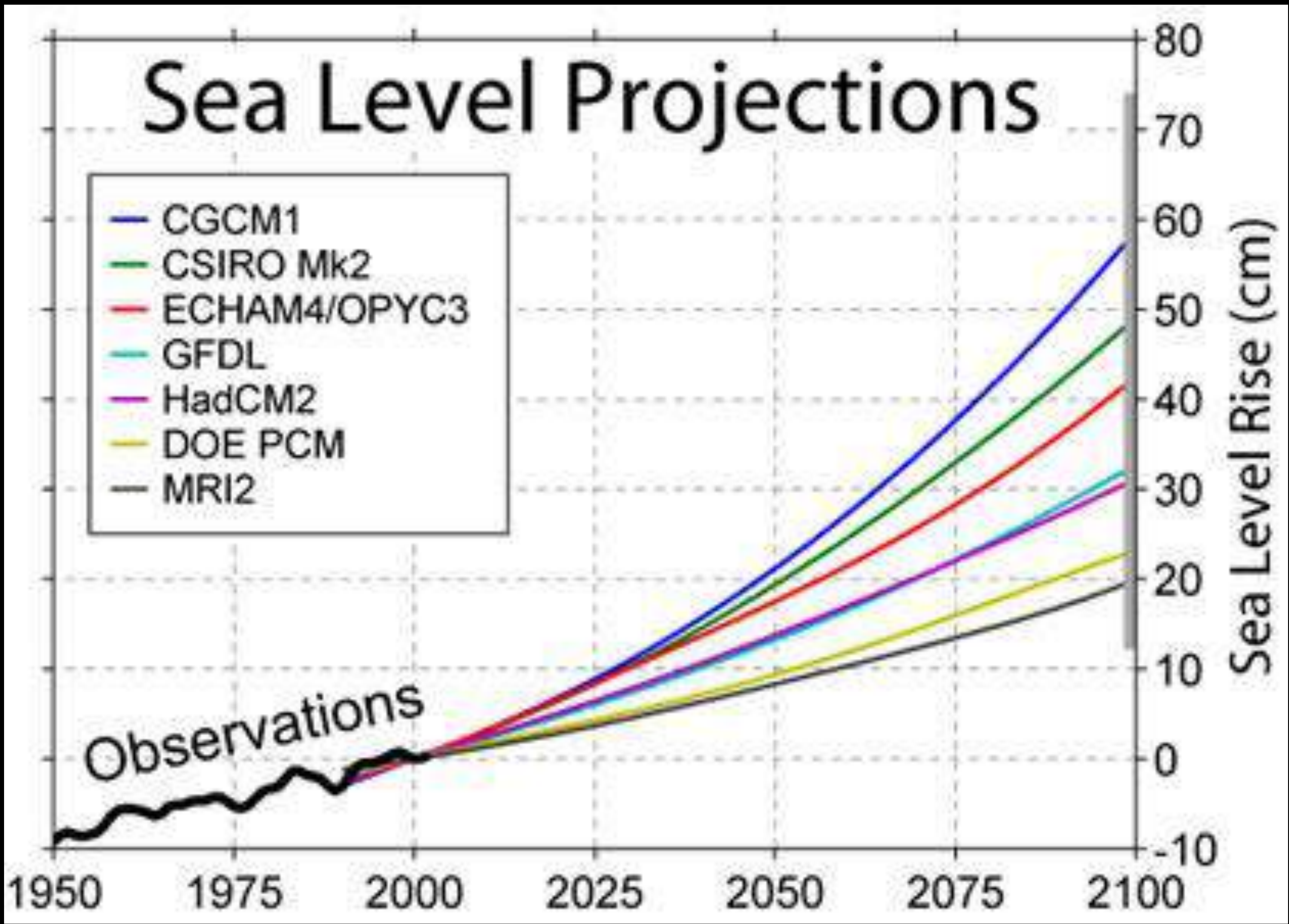
download data

AVERAGE SEPTEMBER EXTENT

Data source: Satellite observations.

Credit: NSIDC

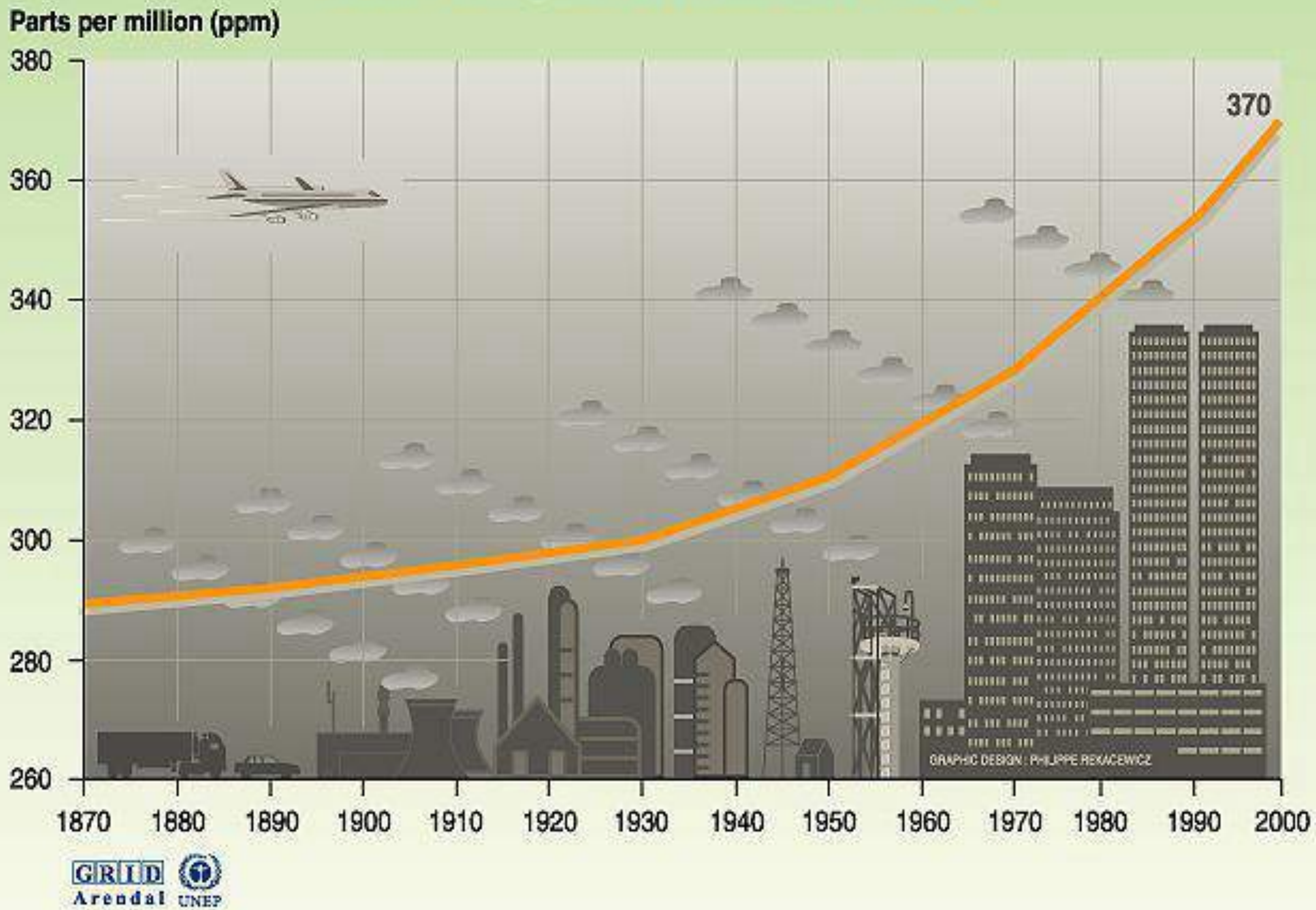

Sea Level
download data
Data updated 3.30.12
GROUND DATA: 1870-2000
RATE OF CHANGE
Data source: Coastal tide gauge records.
Credit: CSIRO
↑1.70 mm*
Sea Level Change (mm)
250
200
150
100
50
0
-50
1870
1890
1910
1930
1950
1970
1990
Year
*estimate for 20th century
SATELLITE DATA: 1993-PRESENT
RATE OF CHANGE
Data source: Satellite sea level observations.
Credit: CLS/Cnes/Legos
↑3.17 mm
60
50
40
30
20
10
0
-10
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
Year
Inverse barometer applied and seasonal signals removed.


Sea Level Projections
CGCM1
CSIRO Mk2
ECHAM4/OPYC3
GFDL
HadCM2
DOE PCM
MRI2
Observations
Sea Level Rise (cm)
-10
0
10
20
30
40
50
60
70
80
1950
1975
2000
2025
2050
2075
2100

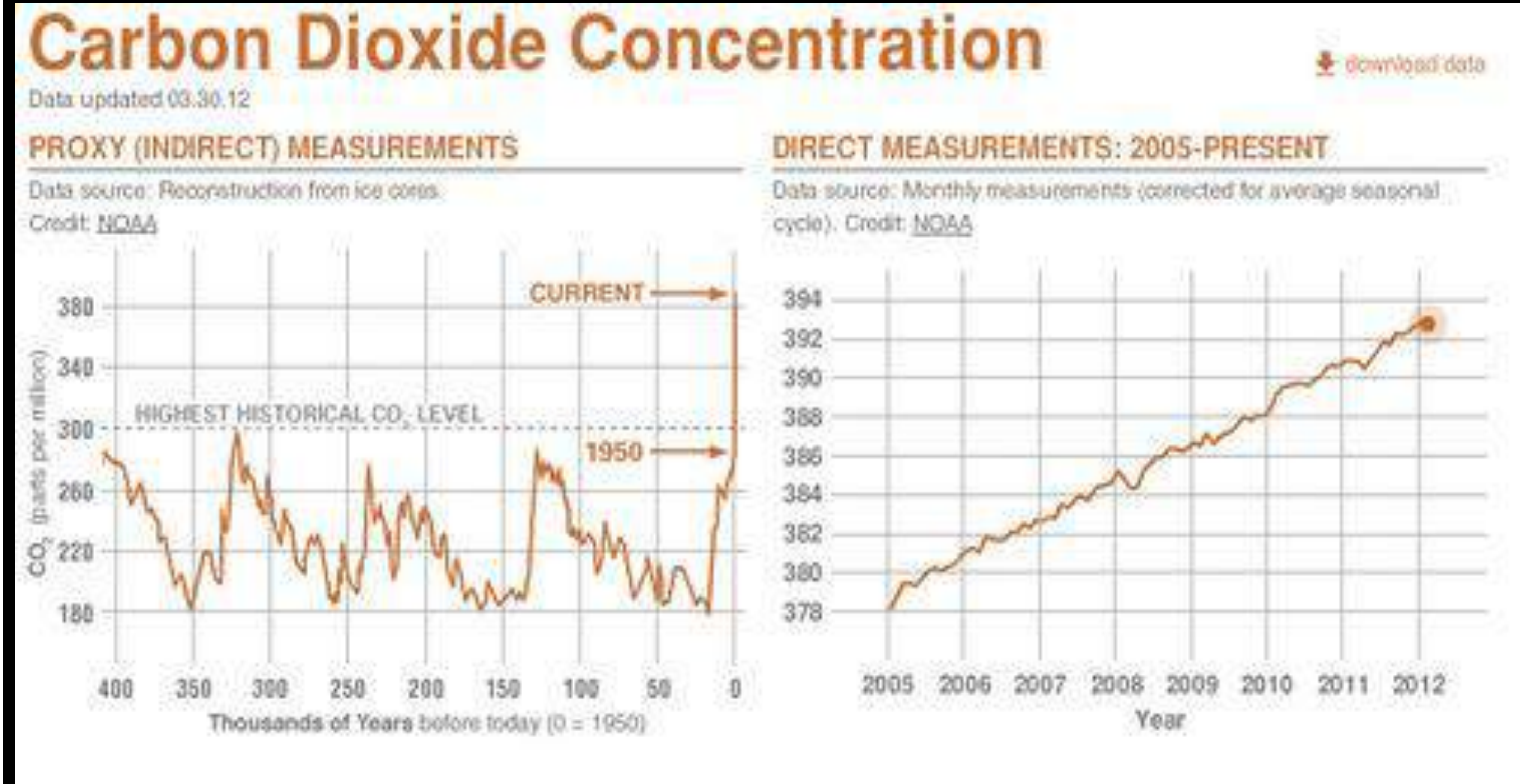
Climate Change

- Increasing of CO_2 level in the atmosfer
  - CO_2 pre-industrial was ca. 280 $\mu l\ l^{-1}$
  - Now 376 $\mu l\ l^{-1}$
  - Est. 21--: 700 $\mu l\ l^{-1}$

Global atmospheric concentration of CO_2

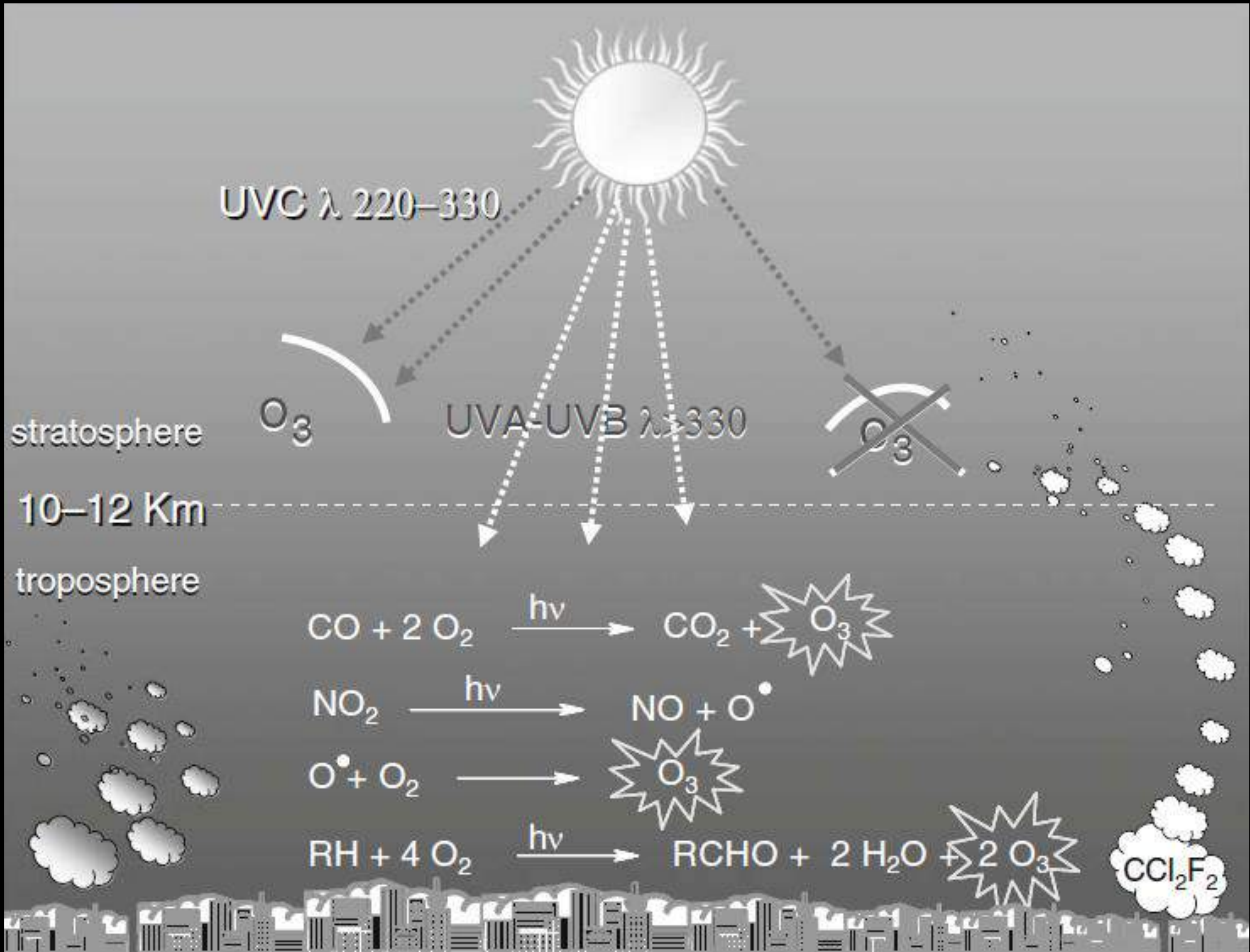


Sources: TP Whorf Scripps, Mauna Loa Observatory, Hawaii, institution of oceanography (SIO), university of California La Jolla, California, United States, 1999


Carbon Dioxide Concentration
download data
Data updated 03.30.12
PROXY (INDIRECT) MEASUREMENTS
Data source: Reconstruction from ice cores.
Credit: NOAA
CO2 (parts per million)
380
340
300
260
220
180
HIGHEST HISTORICAL CO2 LEVEL
CURRENT
1950
400
350
300
250
200
150
100
50
0
Thousands of Years before today (0 = 1950)
DIRECT MEASUREMENTS: 2005-PRESENT
Data source: Monthly measurements (corrected for average seasonal cycle). Credit: NOAA
394
392
390
388
386
384
382
380
378
2005
2006
2007
2008
2009
2010
2011
2012
Year

Climate Change

- Tropospheric (lower-atmosphere) concentrations of O_3 have increased by 20 – 50% (average, 38%) since the pre-industrial era (Denman et al., 2007)


UVC λ 220–330
O_3
UVA-UVB λ>330
O_3
stratosphere
10–12 Km
troposphere
$CO + 2\ O_2 \xrightarrow{h\nu} CO_2 + O_3$
$NO_2 \xrightarrow{h\nu} NO + O^{\bullet}$
$O^{\bullet} + O_2 \longrightarrow O_3$
$RH + 4\ O_2 \xrightarrow{h\nu} RCHO + 2\ H_2O + 2\ O_3$
CCl_2F_2

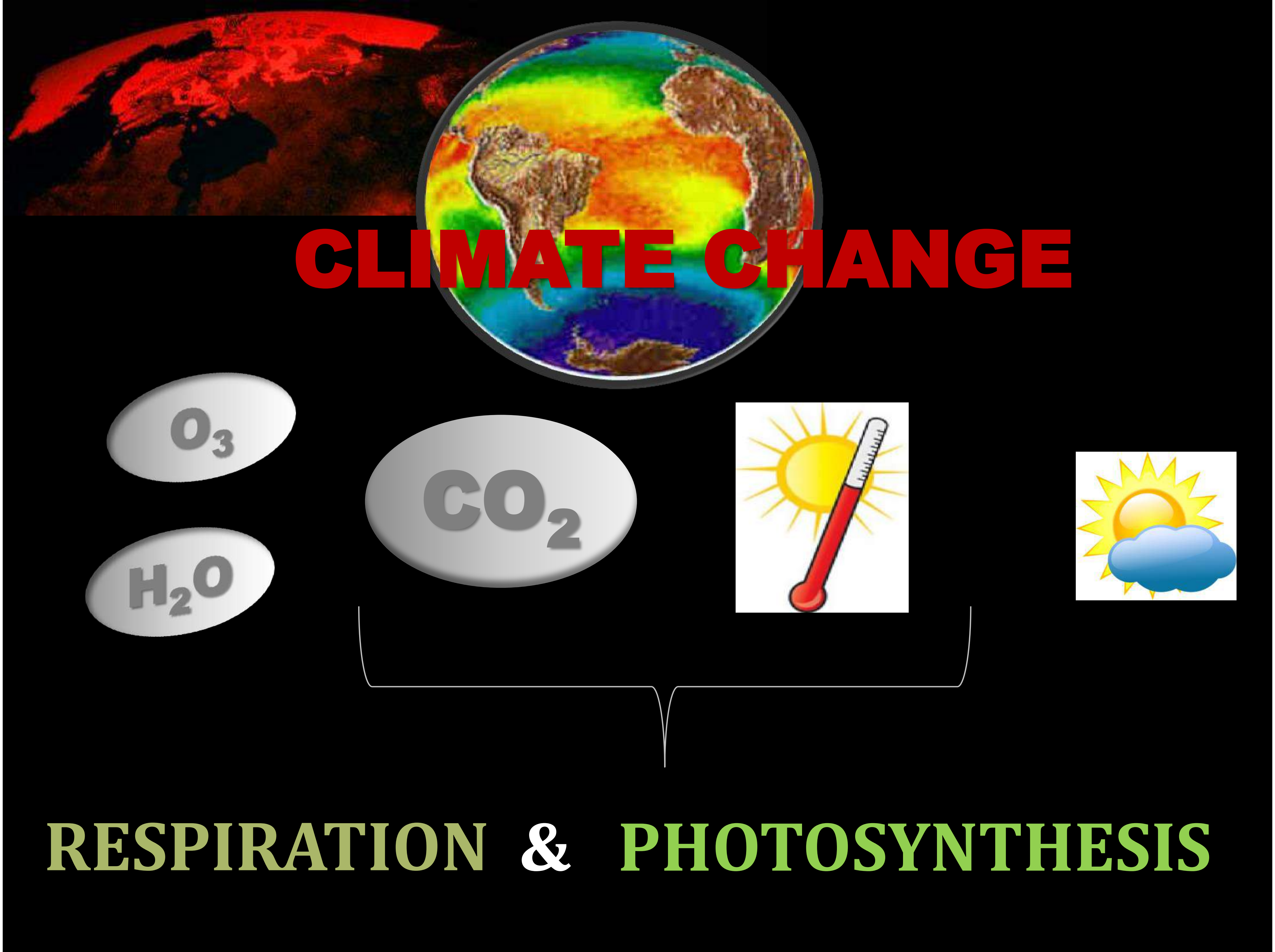
A globally coherent fingerprint of climate change impacts across natural systems

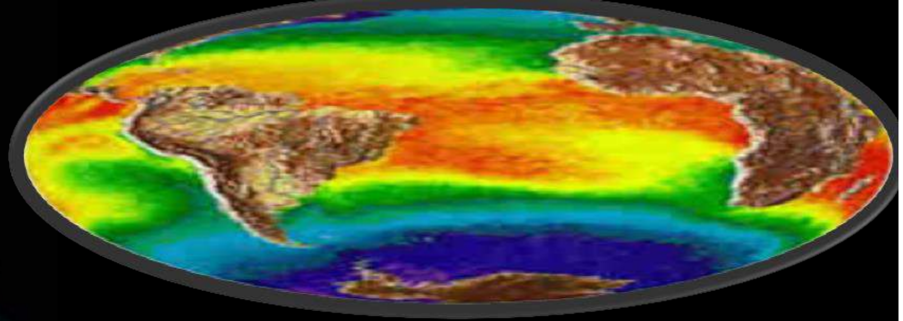
Camille Parmesan* & Gary Yohe (Nature 421, 2003)

- Meta analysis on diverse species: more than 1,700 species
- Phenological (timing) shifts, range boundary shifts, and community studies on species abundances

‘very high confidence conclusion’

climate change
is already affecting living systems


CLIMATE CHANGE
O_3
H_2O
CO_2
RESPIRATION & PHOTOSYNTHESIS



PHOTOSYNTHESIS

Health/ Sturdiness

Reproduction

Primary Metabolism

Secondary Metabolism

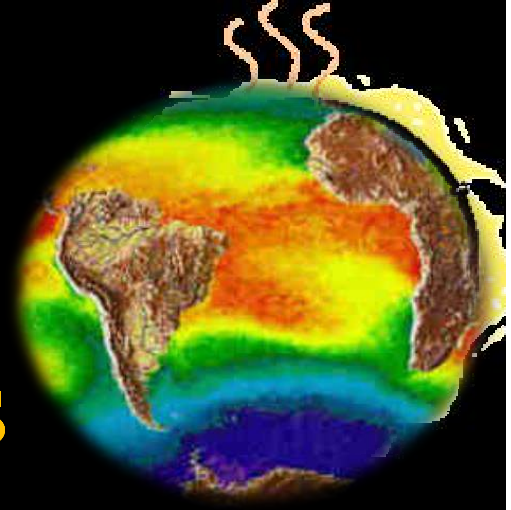
Plant's response to climate change

Migration

Adaption

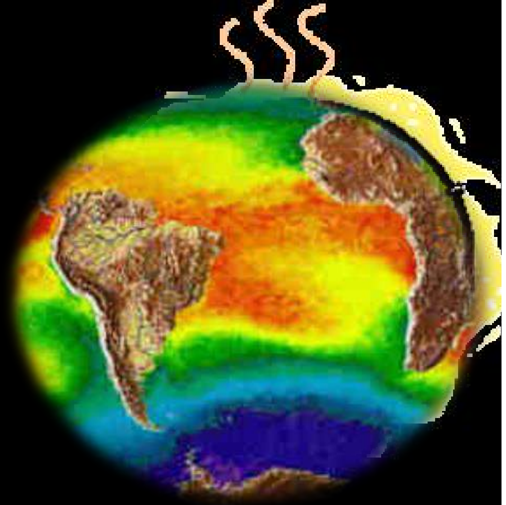
Extinct

Climate change reduce biodiversity of medicinal plants



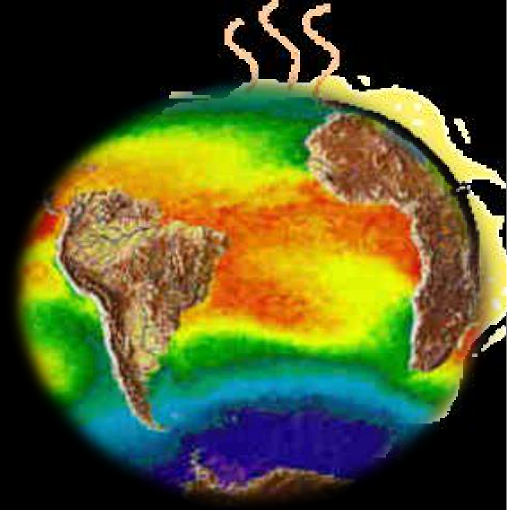
- Species with **long life cycles** and/or **slow dispersal** are particularly vulnerable
- **Isolated** or **disjunct** species are particularly vulnerable, as they may have '**nowhere to go**‘ → **Arctic and alpine species**, and **Island endemics**

Climate change reduce biodiversity of medicinal plants



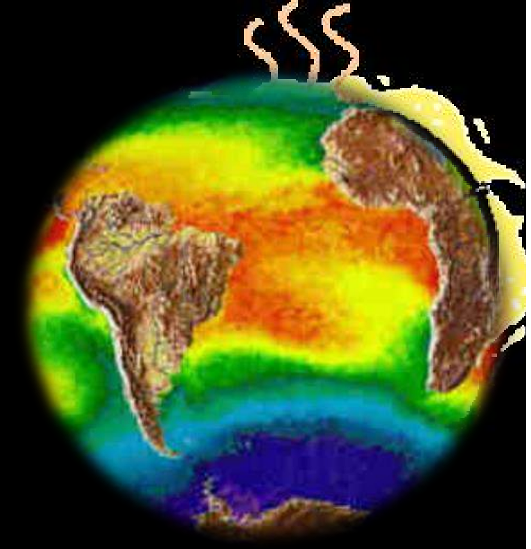
- Some **plant communities** or species associations may be lost as species move and adapt at different rates.
- Many plant communities act as 'sinks' (store carbon), which helps to offset carbon emissions. However, over the next 70 years, the effects of climate change on plants mean many terrestrial **sinks may become sources**

Climate change reduce biodiversity of medicinal plants



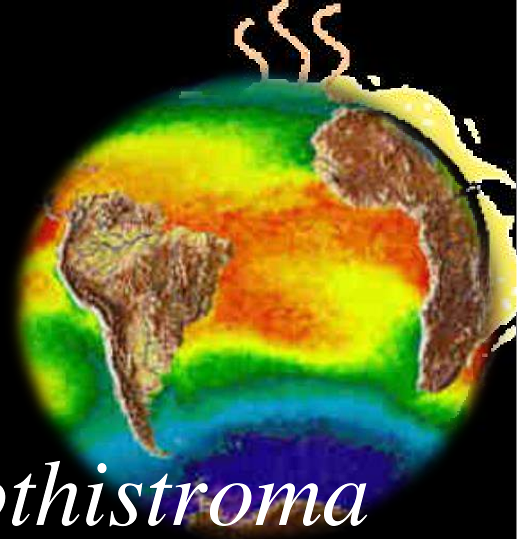
- **Increased invasions** by alien species may occur, as conditions become more suitable for exotic species whilst native species become less well suited to their environment (for example, *Bromus* is more invasive in wet years (Smith et al, 2000)).

Climate change affect the plant’s pests & diseases

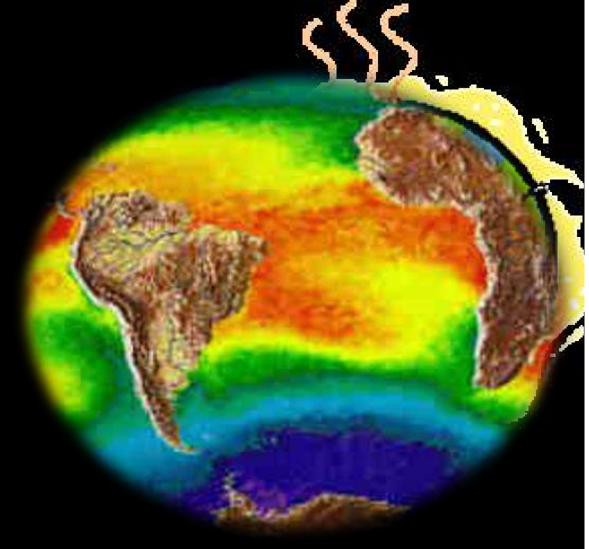


- Elevated concentration of CO_2 altered the expression of three soybean diseases, namely downy mildew (*Peronospora manshurica)*, brown spots (*Septoria glycines) and sudden* death syndrome *(Fusarium virguliforme)*
- Increased resistance to powdery mildew (*Blumeria graminis)* in barley

Climate change affect the plant’s pests & diseases

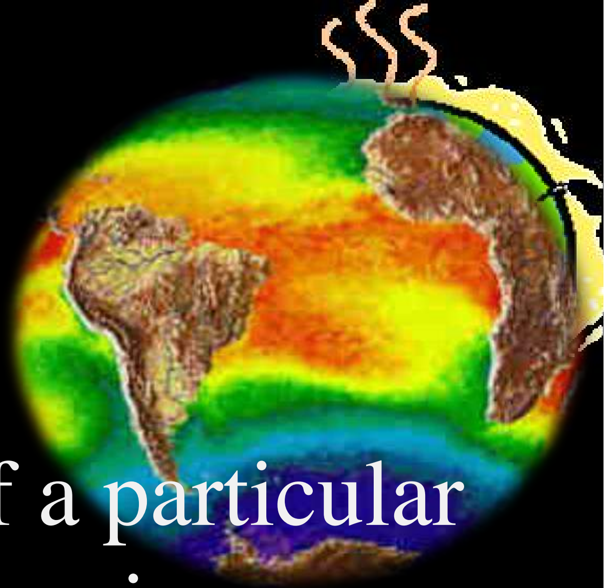


- In North America, needle blight (*Dothistroma septosporum) is reported to be spreading northwards with* increasing temperature and precipitation
- Higher threat of late blight (*Phytophthora infestans*) and sheath blight (*Rhizoctonia solani*) disease on potato
- Higher risk of blast (*Pyricularia oryzae*) disease in rice



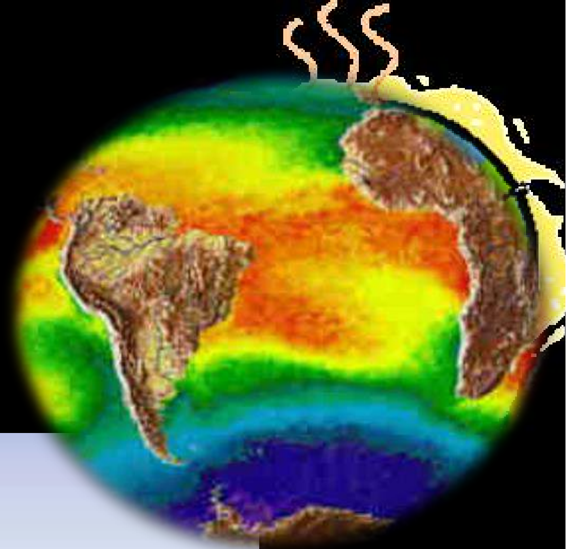
Climate change may change plant genetic → as adaptive response

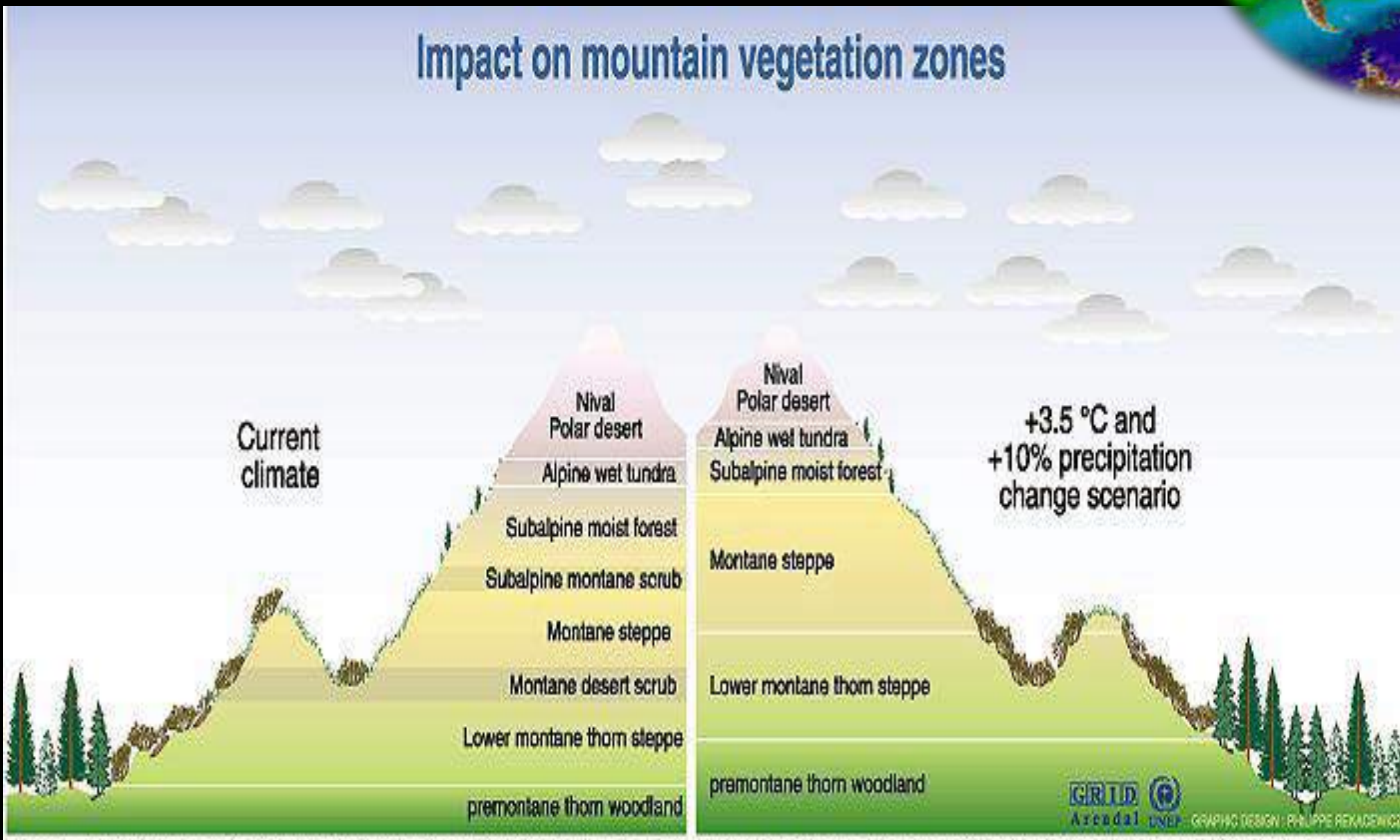
Attunement to climate change



- Phenotypic plasticity: the capacity of a particular genotype to produce varied phenotypes in response to different environments
- Dispersal of seed & pollen: dispersal processes can create a shift in gene frequencies and introduce novel genotypes from different populations
- Genetic change: creating novel genes by mutatio

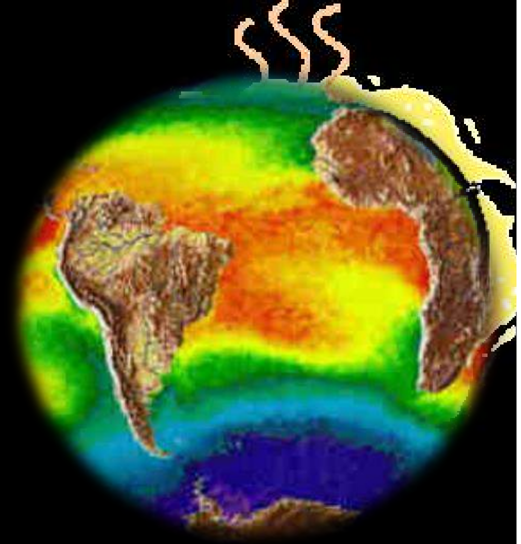
Climate change influences the shift in species distribution

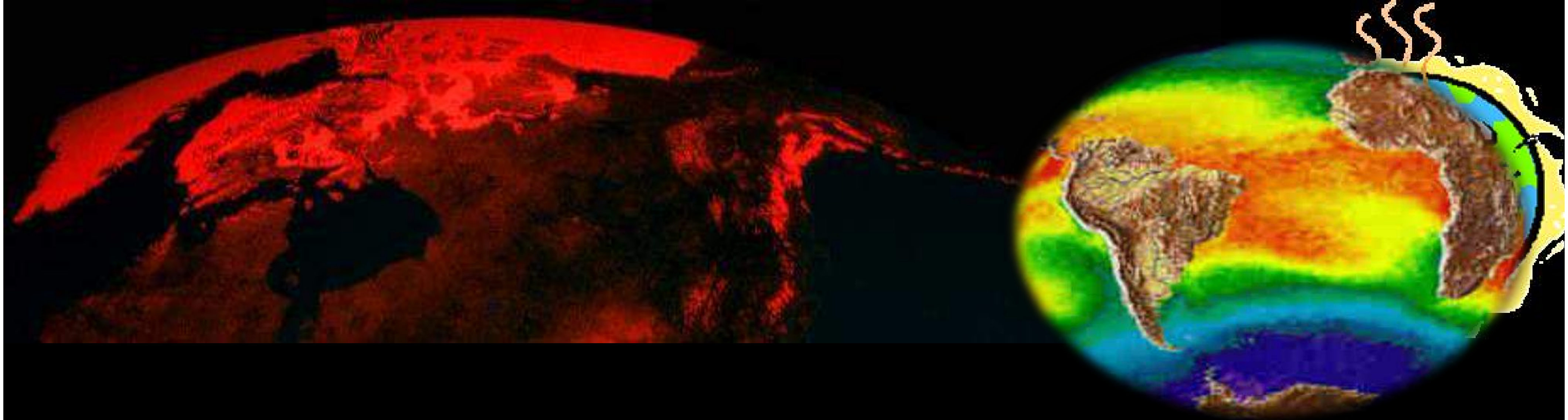




Sources: Martin Beniston, Mountain environments in changing climates, Routledge, London, 1994; Climate change 1995, Impacts, adaptations and migration of climate change, contribution of working group 2 to the second assessment report of the Intergovernmental panel on climate change (IPCC), UNEP and WMO, Cambridge press university, 1996.

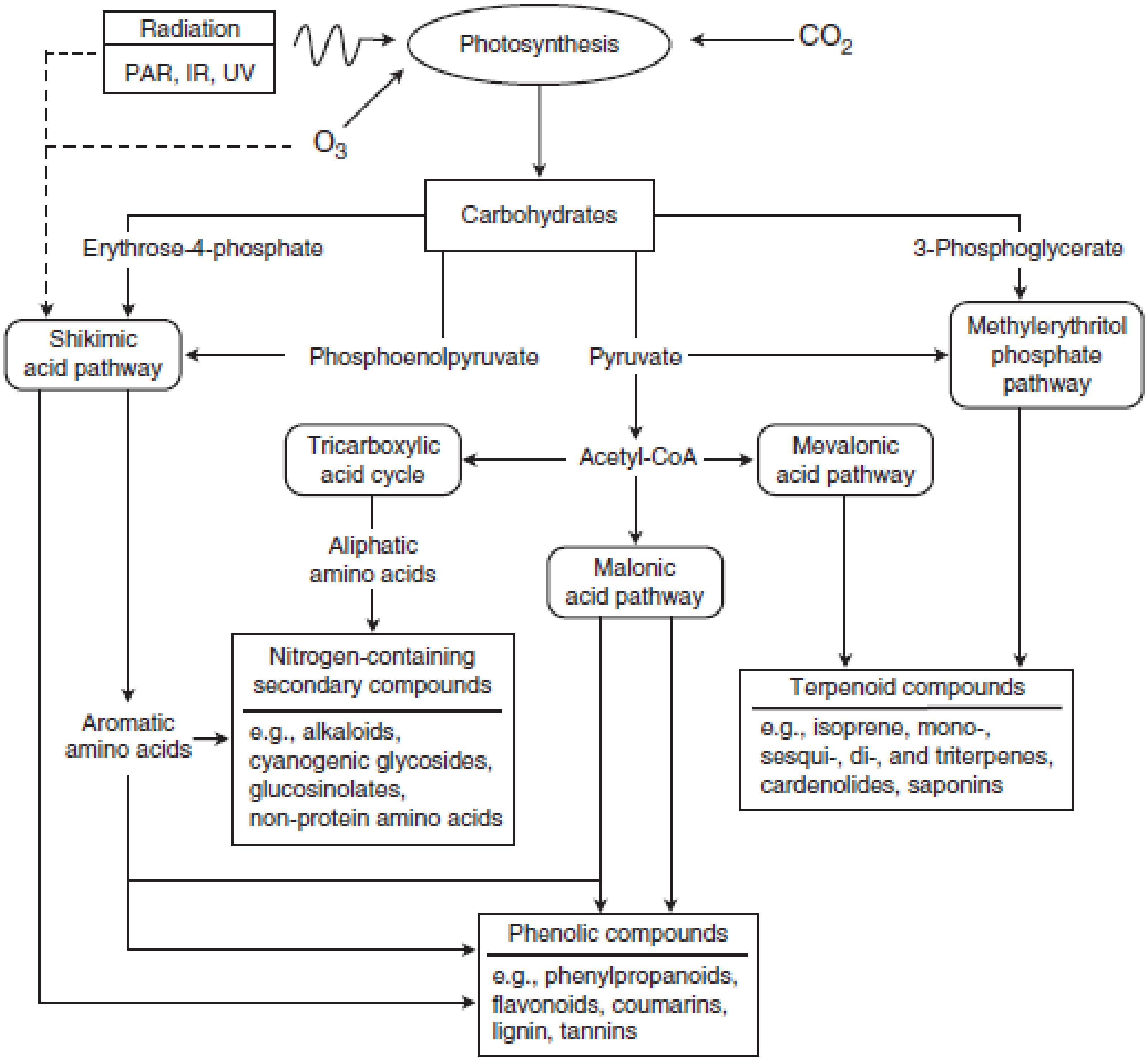
Climate change altered the plant phenology





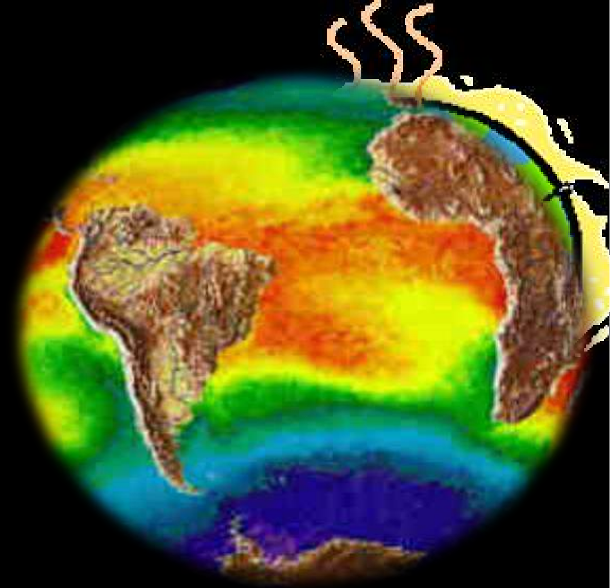
Climate change affects the production of secondary metabolites

atropine	*Atropa belladonna*
codeine	*Papaver somniferum*
cocaine	*Erythroxylon coca*
ephedrine	*Ephedra sinica*
digoxin	*Digitalis purpurea*
quinine	*Cinchona officinalis*
colchicine	*Colchicum autumnale*
scopolamine	*Datura fastuosa*
reserpine	*Rauvolfia serpentina*
capsaicin	*Capsicum frutescens*
salicylin	*Salix purpurea*
vincristine	*Catharanthus roseus*
taxol	*Taxus brevifolia*
curcumin	*Curcuma domestica*



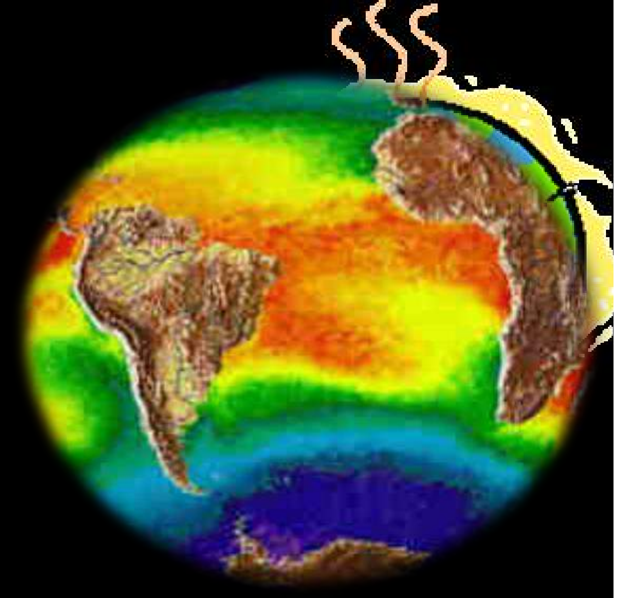
Radiation
PAR, IR, UV
Photosynthesis
CO_2
O_3
Carbohydrates
Erythrose-4-phosphate
3-Phosphoglycerate
Shikimic acid pathway
Phosphoenolpyruvate
Pyruvate
Methylerythritol phosphate pathway
Tricarboxylic acid cycle
Acetyl-CoA
Mevalonic acid pathway
Aliphatic amino acids
Malonic acid pathway
Nitrogen-containing secondary compounds
e.g., alkaloids, cyanogenic glycosides, glucosinolates, non-protein amino acids
Terpenoid compounds
e.g., isoprene, mono-, sesqui-, di-, and triterpenes, cardenolides, saponins
Aromatic amino acids
Phenolic compounds
e.g., phenylpropanoids, flavonoids, coumarins, lignin, tannins

Effect of CO_2 level on the production of secondary metabolites

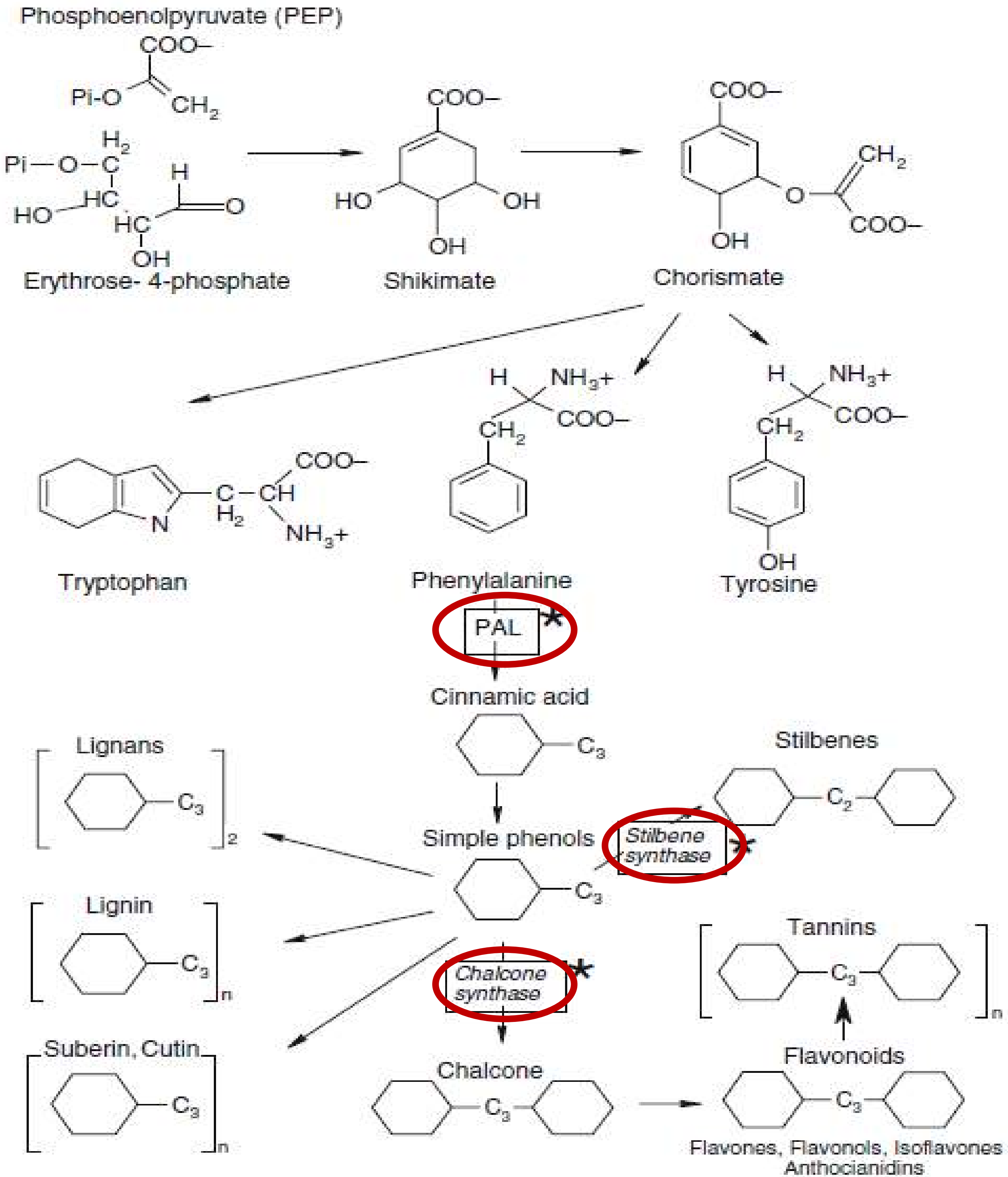


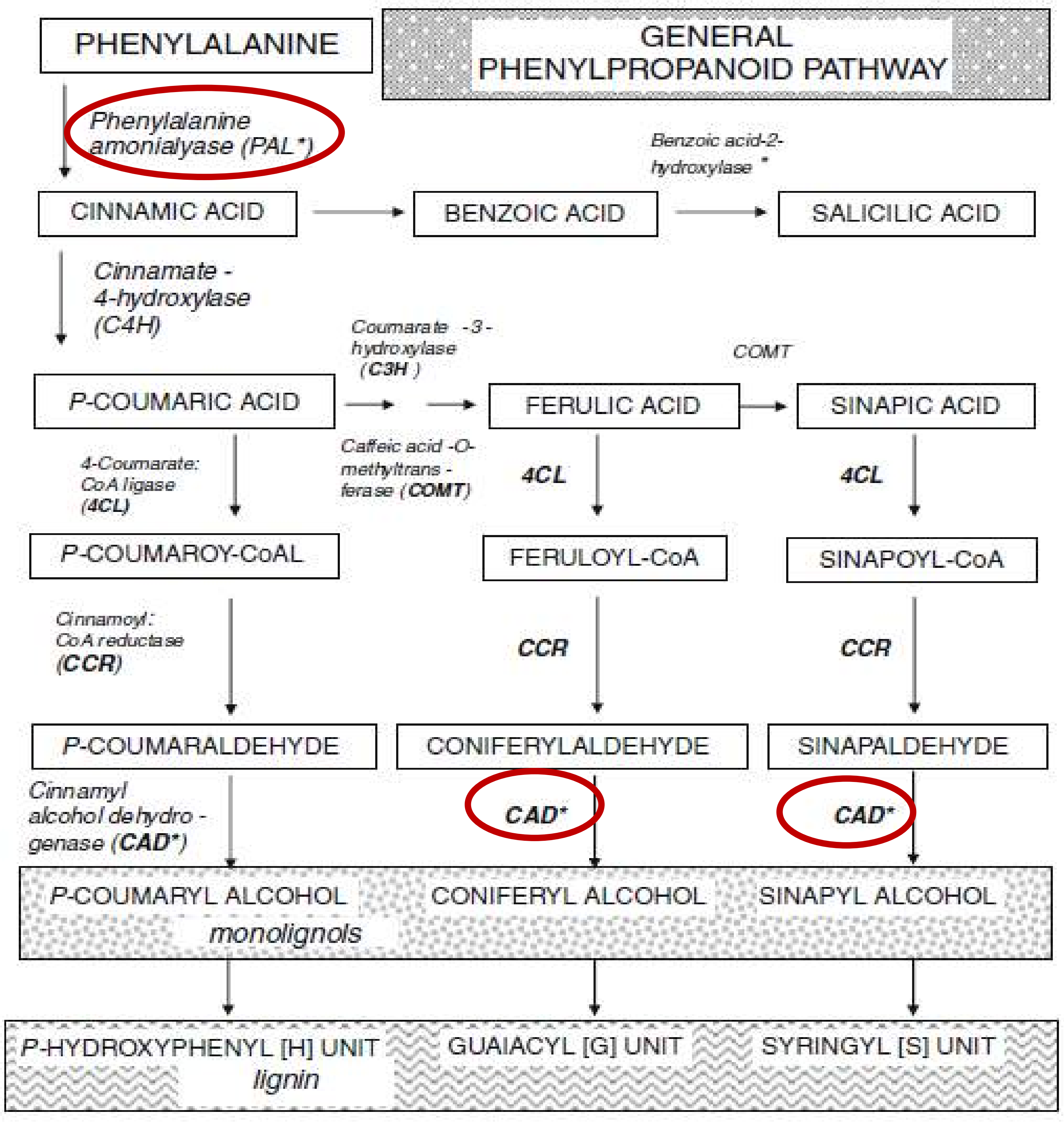
- Responses are species-specific & PSM-specific
- Responses could be physiologically &short-term) or genetically & permanently

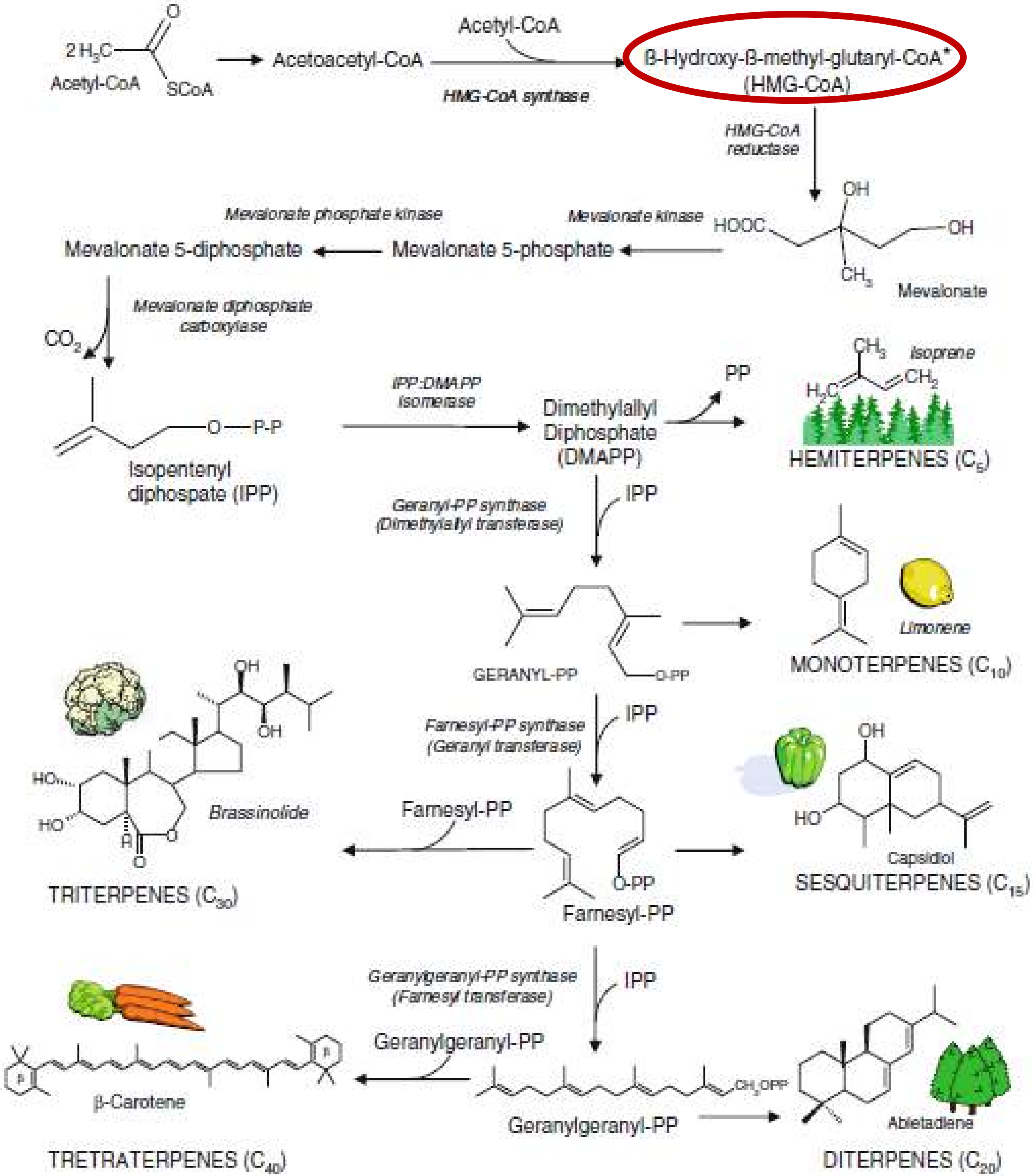
Effect of O_3 level on the production of secondary metabolites



- Ozone contributes to oxidative stress and proliferation of oxygen radicals → leads to the up-regulation of genes and enzymes associated with the shikimate-phenylpropanoid pathway


Phosphoenolpyruvate (PEP)
Erythrose- 4-phosphate
Shikimate
Chorismate
Tryptophan
Phenylalanine
Tyrosine
PAL
Cinnamic acid
Simple phenols
Lignans
Lignin
Suberin, Cutin
Stilbene synthase
Stilbenes
Chalcone synthase
Chalcone
Tannins
Flavonoids
Flavones, Flavonols, Isoflavones
Anthocianidins


PHENYLALANINE
GENERAL PHENYLPROPANOID PATHWAY
Phenylalanine amonialyase (PAL*)
Benzoic acid-2-hydroxylase *
CINNAMIC ACID
BENZOIC ACID
SALICILIC ACID
Cinnamate - 4-hydroxylase (C4H)
Coumarate -3-hydroxylase (C3H)
COMT
P-COUMARIC ACID
FERULIC ACID
SINAPIC ACID
4-Coumarate: CoA ligase (4CL)
Caffeic acid -O-methyltrans-ferase (COMT)
4CL
4CL
P-COUMAROY-CoAL
FERULOYL-CoA
SINAPOYL-CoA
Cinnamoyl: CoA reductase (CCR)
CCR
CCR
P-COUMARALDEHYDE
CONIFERYLALDEHYDE
SINAPALDEHYDE
Cinnamyl alcohol dehydro-genase (CAD*)
CAD*
CAD*
P-COUMARYL ALCOHOL
CONIFERYL ALCOHOL
SINAPYL ALCOHOL
monolignols
P-HYDROXYPHENYL [H] UNIT
GUAIACYL [G] UNIT
SYRINGYL [S] UNIT
lignin



$2 H_3C$
Acetyl-CoA
SCoA
O
Acetoacetyl-CoA
Acetyl-CoA
HMG-CoA synthase
ß-Hydroxy-ß-methyl-glutaryl-CoA*
(HMG-CoA)
HMG-CoA reductase
HOOC
OH
CH_3
Mevalonate
Mevalonate kinase
Mevalonate 5-phosphate
Mevalonate phosphate kinase
Mevalonate 5-diphosphate
Mevalonate diphosphate carboxylase
CO_2
O—P-P
Isopentenyl diphospate (IPP)
IPP:DMAPP isomerase
Dimethylallyl Diphosphate (DMAPP)
PP
CH_3
Isoprene
H_2C
CH_2
HEMITERPENES (C_5)
IPP
Geranyl-PP synthase (Dimethylallyl transferase)
GERANYL-PP
O-PP
Limonene
MONOTERPENES (C_{10})
IPP
Farnesyl-PP synthase (Geranyl transferase)
Farnesyl-PP
O-PP
Farnesyl-PP
OH
HO
Capsidiol
SESQUITERPENES (C_{15})
OH
HO
Brassinolide
TRITERPENES (C_{30})
IPP
Geranylgeranyl-PP synthase (Farnesyl transferase)
CH_2OPP
Geranylgeranyl-PP
Geranylgeranyl-PP
β-Carotene
TRETRATERPENES (C_{40})
Abietadiene
DITERPENES (C_{20})

Plant response to climate change varies with topography, interactions with neighbors, and ecotype

Pierre Liancourt et al, Univ. Pennsylvania
esa Ecology 94(2), 2013

- *Festuca lenensis*

- Three-years experiment set in the Mongolian steppe
- Manipulated temperature and water
- Controlling for topographic variation, plant–plant interactions, and ecotypic differentiation

Plant response to climate change varies with topography, interactions with neighbors, and ecotype

- Plant survival and growth responses to a warmer, drier climate varied within the landscape.
- Response to simulated increased precipitation occurred only in the absence of neighbors, demonstrating that plant–plant interactions can supersede the effects of climate change.
- Response of this species to increased precipitation was ecotype specific, with water addition benefiting only the least stress-tolerant ecotype from the lower slope origin

Plant response to climate change varies with topography, interactions with neighbors, and ecotype

- *F. lenensis* also showed evidence of local adaptation in populations that were only 300 m apart:
  - Individuals from the steep and dry upper slope showed a higher stress/drought tolerance, whereas
  - Individuals from the more productive lower slope showed a higher biomass production and a greater ability to cope with competition.

Conclusions

- Climate change threats medicinal plants in various aspects:
  - Extinction → Biodiversity reduction
  - Health & Sturdiness
    - Pests and diseases
    - Physiological conditions
  - Reduction in production of secondary metabolites
  - Genetic modification

Recommendations

- Seed conservation → Seed Bank
- Developing plants that accommodate/tolerate climate change → genetic engineering (e.g.analyzing genome of heat and drought resistant)
- Tissue culture techniques for producing secondary metabolites → biotransformation technology

Recommendations

- Study the potential and real threats of climate change on medicinal plants

Thank You
Terimakasih

ersinaga2003@yahoo.com.sg; warekppm@unas.ac.id