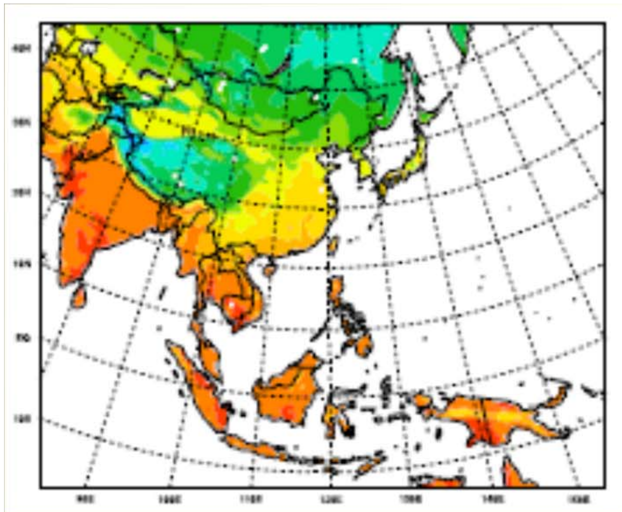

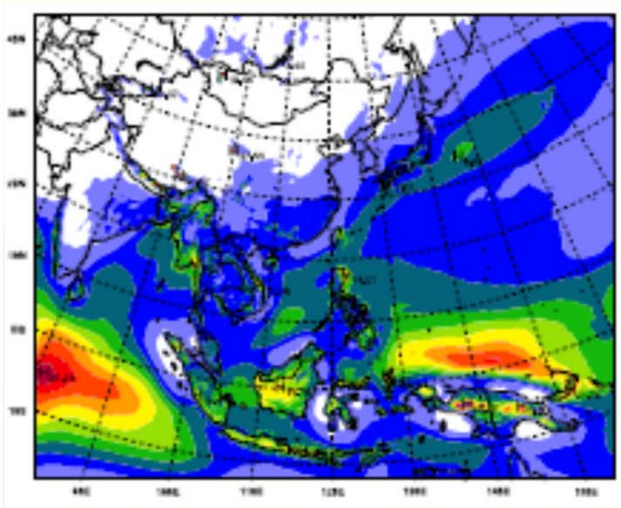

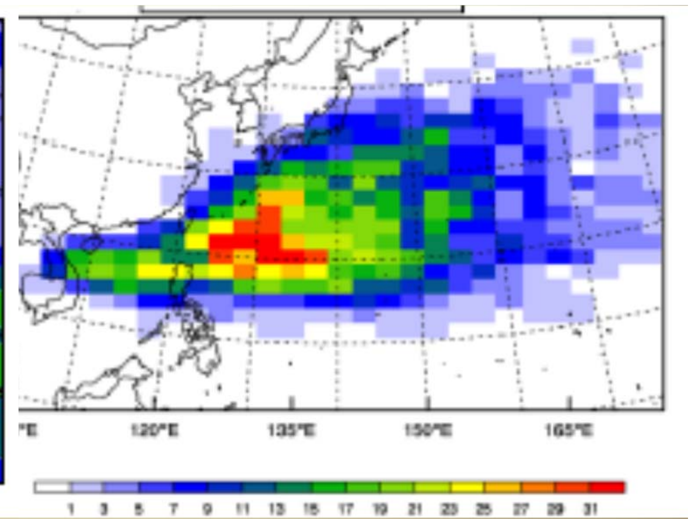

Climate Risk Assessment: Use of Evidence including Historical Data, Climate Change Projections and Sectoral Impact Models

Charles Rodgers, Senior Advisor, Climate Change Adaptation
Asian Development Bank (ADB) and Asia Pacific Adaptation Network (APAN)
Workshop on Climate Risk Management in Planning and Investment Projects
Asian Development Bank, Manila 9 February 2015

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Assessing Adaptation Needs and Options

ACTIVITIES

1. Project Screening, Scoping
2. Impact Assessment
3. Vulnerability Assessment
4. Adaptation Assessment
5. Implementation Arrangements

STEPS

(2. Impact Assessment)

Step 7: Construct climate change scenarios

Step 8: Estimate future biophysical impacts

Step 9: Assign probabilities to identified impacts

(3. Vulnerability Assessment)

Step 10: Identify vulnerabilities

Step 11: Identify biophysical drivers of vulnerabilities

Step 12: Identify socioeconomic drivers of vulnerabilities

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Overview of the Presentation

1. The Use of Climate Projections and Scenarios: Two Paradigms
2. Determining Climate Data Needs
3. Constructing Climate Change Scenarios
4. Uncertainty and Likelihood of Projections
5. Estimating Future Biophysical Impacts

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Project Cycle	Key Activities	Documents	Climate Risk Management
Identification:	• Project Identification • Establish Project Team	Project Concept Paper/PPTA Paper	Preliminary Risk Screening
PPTA Fact Finding	• Fact-Finding Missions • Interdepartmental Review • PPTA Approval		Adaptation Assessment Scoping
PPTA Inception	• PPTA Inception Mission		Impact, Vulnerability Assessments
Design: PPTA Midterm Evaluation	• In-Depth Project Analysis • Mid-Term Workshop • Detailed Project Costing, Design, Evaluation	Draft Project Design Report	Adaptation Assessment, Strategy Development
PPTA Final	• Final Tripartate Workshop	Draft Final Report Draft RPP	Implementation Arrangements
Appraisal (final design):	• Fact-Finding • Management Review Mtg • Appraisal Mission • Staff review Committee • Interdepartmental Review • Loan Negotiations • Board Consideration	RRP, PAM	
Project Implementation			Monitoring & Evaluation Arrangements

1. Climate Data and Climate Risk Management

Exposure

Sensitivity

CLIMATE SIGNAL

$$R = H \ x \ \frac{E \ x \ S}{AC}$$

VULNERABILITY CONTEXT

Risk

Hazard

Adaptive Capacity

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Source: Y. Biot et al., 2014

Climate Risk Management: Two Paradigms

Paradigm 1: "Predict-then-Act": figure out best-guess future and design the best policy you can for that future

- ***Conceptual framework:*** maximize expected net benefits
- ***Guiding question:*** "what is most likely to happen?"

Paradigm 2: "Seek Robust Solutions": identify greatest vulnerabilities across full range of futures and identify the suite of interventions that perform reasonably well across this range

- ***Conceptual framework:*** minimize regret
- ***Guiding questions:*** "how does my system work and when might my policies fail?"

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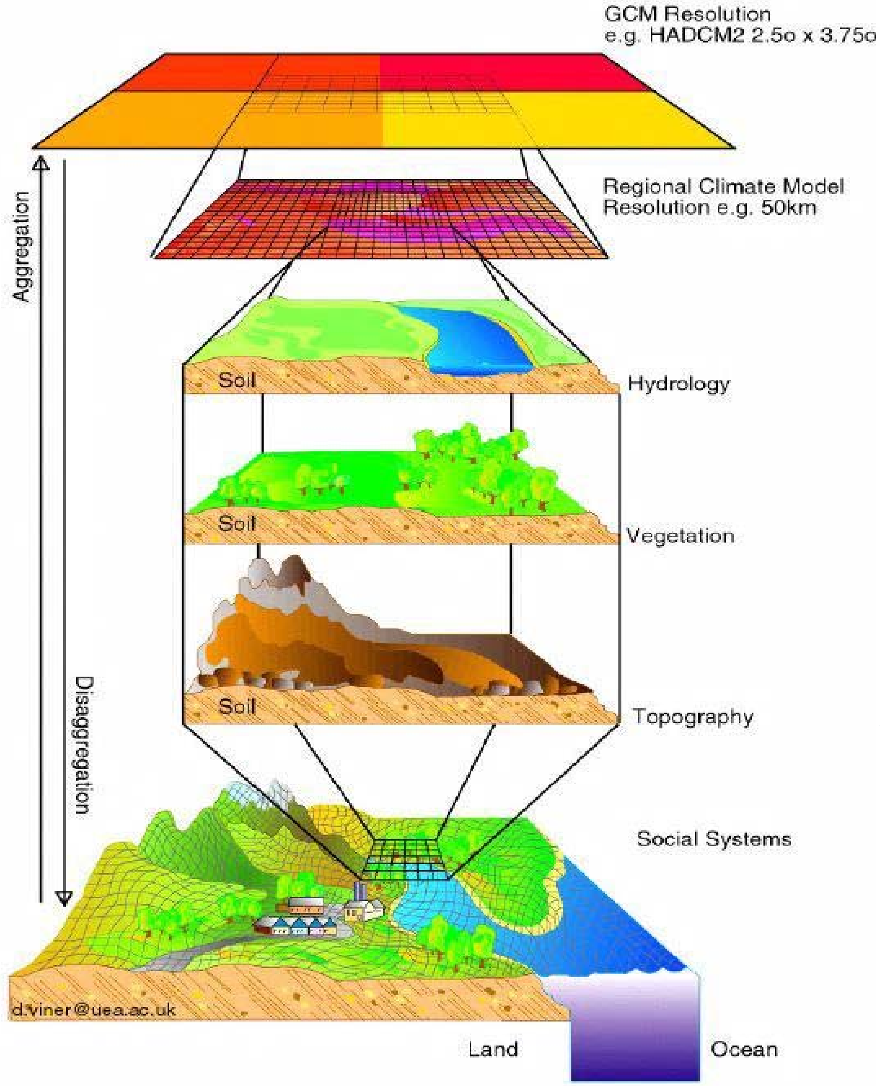
C. Weaver et al. (2013): *Improving the Value of Climate Model Information to Decision-Making: the Value and Demands of Robust Decision Frameworks*. WIREs Climate Change

Use of Climate Data in Climate Risk Management



Paradigm 1: Scenario Driven

1. Climate, socio-economic scenarios
2. GCM outputs
3. Regional down-scaling
4. Projected impacts
5. Identify vulnerabilities
6. Develop adaptation options
7. Assess alternatives

Paradigm 2: Vulnerability (System) Driven

6. Assess alternatives
5. Assess likelihoods
4. Assemble regional scenarios
3. Identify critical thresholds
2. Identify change drivers
1. Identify key parameters

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Image courtesy U.K. Met Office

Summary, Discussion Points

- **Climate risk management is not all about climate – it is also necessary to understand the vulnerability of our projects**
- **Adaptation practice is moving from impact-driven ("top-down") toward risk management approaches**
- **Climate risk management at project level should be fully integrated within the project cycle**
- **Assessments of impact, vulnerability and adaptation options should be completed prior to final design so that recommendations can be incorporated**

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2. Determining Climate Data Needs

In managing climate risks at project level it is important to determine what types of data and evidence are actually needed to support relevant decisions.

Detailed climate impact assessment involving custom down-scaling of Global Climate Models (GCM) can be expensive ($100,000 or more); and assessments involving sectoral impact models even more so.

Before resources are committed to the construction of climate change scenarios, we should consider:

- **What type and extent of climate data is required?**
- **Which assessment approach is most appropriate and cost-effective?**

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Key Questions in Determining Climate Impact Assessment Approach

- **Which aspects or components of our project are sensitive to climate or changes in climatic conditions? How sensitive?**
- **What are the important climate and climate-related variables?**
- **What type of decision are we making?**
- **Are explicit projections or assumptions on future climate needed to support this type of decision? Why?**
- **What is the spatial scale of our project?**
- **What is the project time frame (for example, what is the design lifetime of the project)?**
- **What resources do we have available to conduct climate impact assessment?**
- **Are there existing studies, data sets or related resources that we can make use of?**

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Continuum from Development to Adaptation

Addressing Drivers of Vulnerability

Enabling human development: actions that reduce poverty and vulnerability; increase capability and coping capacity:

- Livelihood diversification
- Literacy and education
- Women's rights
- Community health
- Food security
- Water supply, sanitation

Building Response Capacity

Robust systems for problem solving: actions that build institutional, technical and planning capacity:

- Natural resources management
- Weather data collection, forecasting
- Disaster early warning systems
- Communications systems

Managing Climate Risks

Climate risk management: actions that incorporate climate information into decision-making to reduce risks:

- Climate proofing projects
- Disaster response planning
- Drought-resistant crops; cropping systems
- Robust, adaptive technologies

Confronting Climate Change

Addressing climate change impacts: actions that target specific, anticipated impacts outside of historical experience:

- Relocation due to sea level rise (SLR)
- Coastal defenses from SLR
- Managing Glacial Lake Outburst Floods (GLOF)
- Extra storage to capture glacial melt

Historical data (variability and extremes) >>>>>> Future Projections

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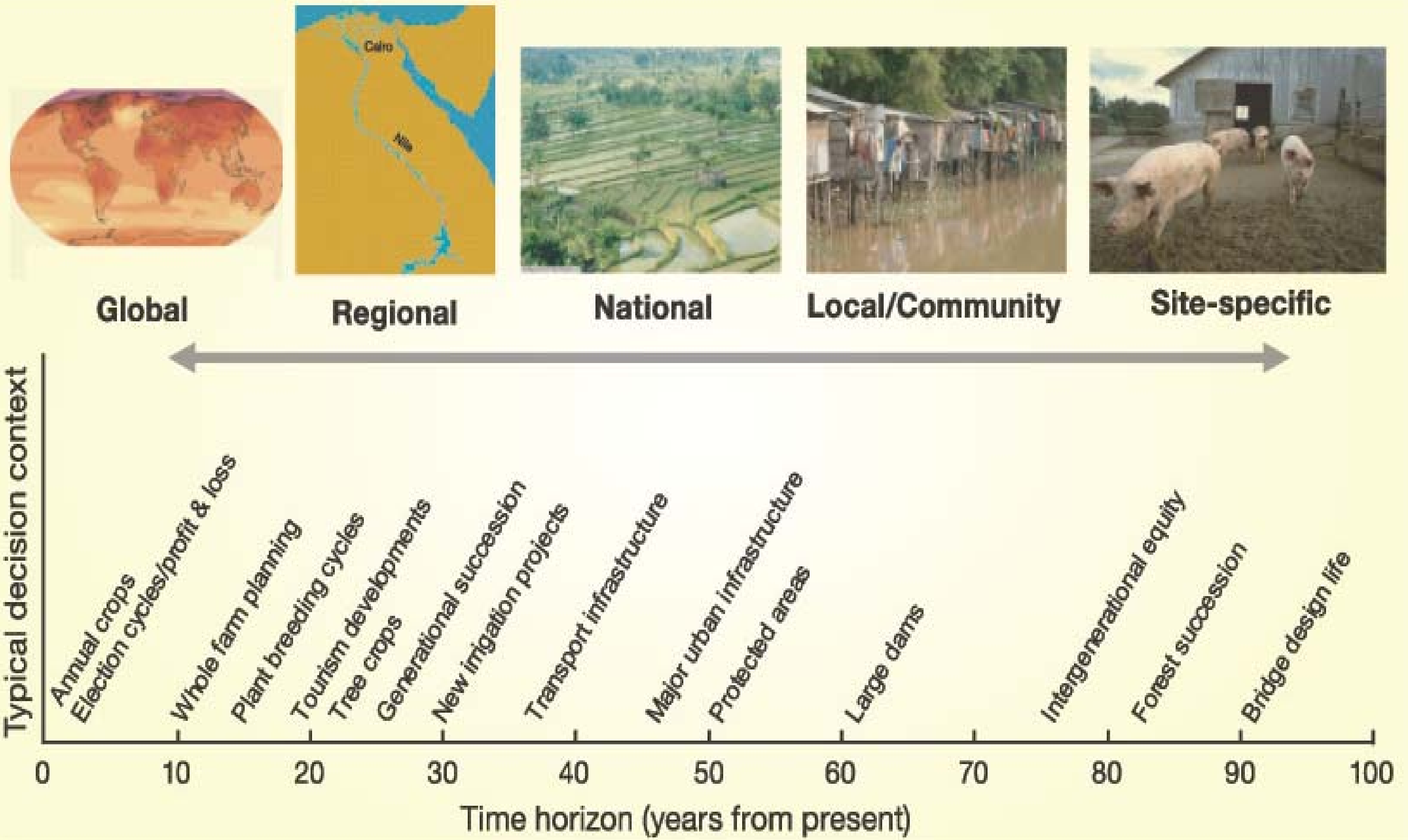
From McGray et al. (2007) *Weathering the Storm*

Examples: Adaptation Activities Requiring Climate Risk Information (Wilby et al 2009)

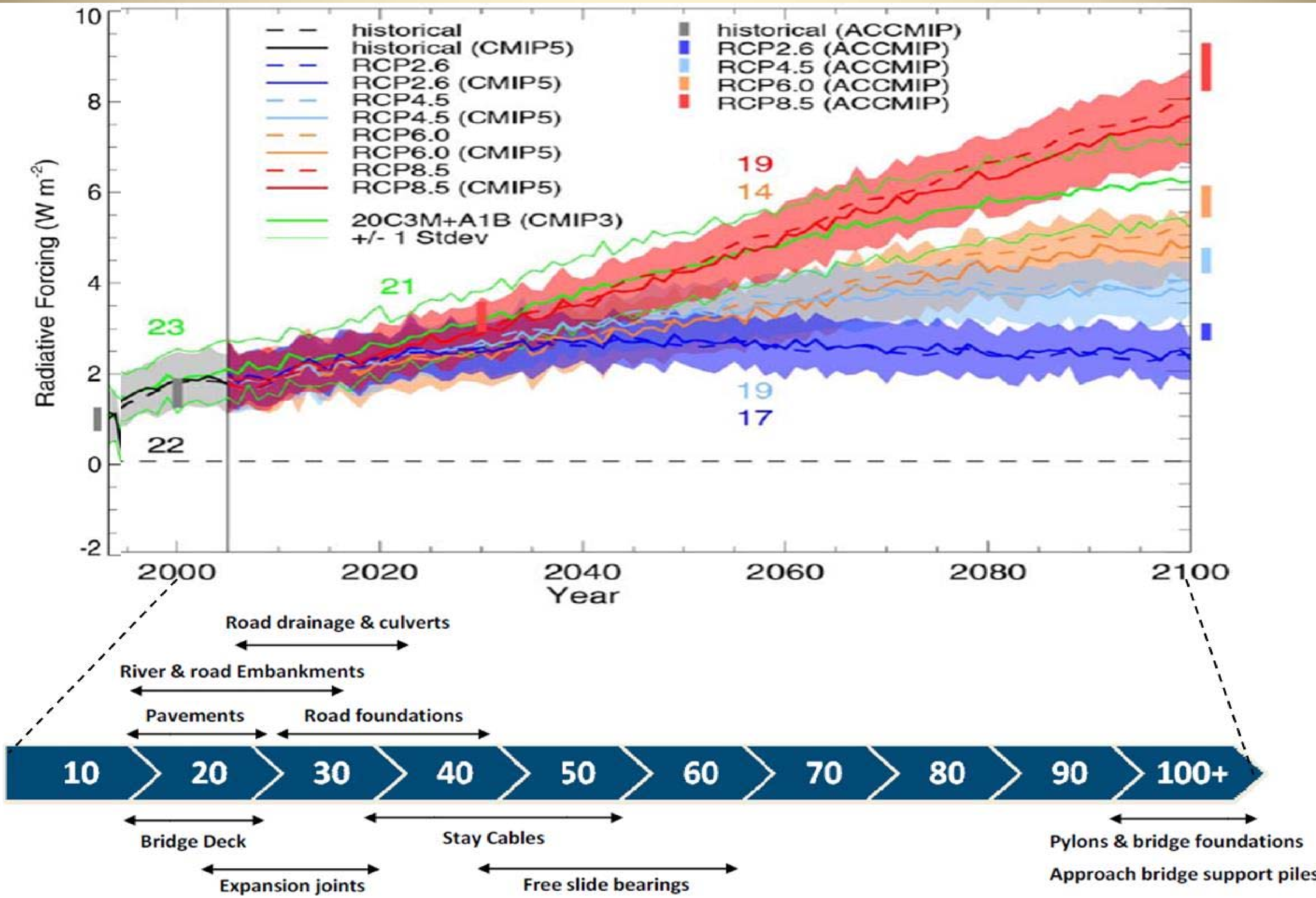
Adaptation	Activities Requiring Climate Information
New Infrastructure	Cost-benefit analysis Infrastructure performance and design
Retrofit	Scoping assessments to identify risks and reduce exposure to extreme events
Resource Management	Assessment of natural resource availability, status and allocation
Behavioural (Operations)	Measures that optimize scheduling or performance of existing infrastructure
Institutional	Regulation, monitoring and reporting
Sectoral	Economic planning, sector restructuring, guidance and standards
Communication	Communicating risks to stakeholders High-level advocacy and planning
Financial	Services to transfer risk; incentives and insurance

Spatial and Temporal Scales

Impact assessment must reflect project spatial, temporal scales



Timing of Adaptation Interventions



Relevant Meteorological Data in Hydrology

Field of Application	Hydrological Element	Meteorological Element Needed	Type of Meteorological Input Data	
			Time Scale	Spatial Scale
Quality Control	Runoff	Precipitation	Day, month	Point, area
Water Balance	Runoff Evaporation Soil Moisture Groundwater	Precipitation Radiation Sunshine duration Air temperature Air humidity Windspeed	Y, M, D D, M D, M D, M D, M D, M	Area Pt, grid Pt, grid Pt, grid Pt, grid Pt, grid
Simulation of Time Series	Runoff Groundwater Water temp. Dissolved matter	Precipitation Radiation Air temperature Air humidity	Y, M, D D, M H, D, M H, D, M	Area Pt, grid Pt, grid Pt, grid
Extreme Values (floods, low flows)	Runoff Water level	Precipitation	Y, M Min, max	Pt
Forecasting (real-time)	Runoff Water level Soil moisture, …	Precipitation Radiation Air temperature	H, D H, D H, D	Pt, area Pt Pt

Relevant Meteorological Data, Other Sectors

Field of Application	Hydrological Element	Meteorological Element
Agriculture	Soil Moisture Evapotranspiration	Precipitation (quantity, timing) Radiation Sunshine duration Air temperature (T_{MAX}, T_{MIN}) Air humidity Windspeed
Water Resources	Runoff Groundwater	Precipitation (quantity, intensity) Air temperature
Disaster Risk Management	Runoff (flood) Soil Moisture (drought)	Precipitation (quantity, intensity) Radiation Air temperature Air humidity
Transportation	Runoff Water level	Precipitation (quantity, intensity) Air temperature (T_{MAX}, T_{MIN})
Health	Runoff Water temperature Wet bulb temperature	Precipitation Air temperature (T_{MAX}, T_{MIN})

Summary, Discussion Points

- **Climate impact assessment is not "one size fits all" – it reflects a thought process linking aspects of project vulnerability with aspects of climate change and variability**
- **The assessment approach should reflect the type of project (e.g., "addressing drivers of vulnerability" vs "managing climate risks"), project sector, location, spatial- and time scales, among other factors**
- **The cost and complexity of the climate impact assessment should reflect the cost and/or complexity of the project and the available resources**
- **Not all adaptation projects require a detailed assessment of future climatic conditions within the project area (e.g., female literacy program) since outcomes may not be sensitive to specific climate parameters**

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3. Constructing Climate Change Scenarios

3.0 Some Definitions

3.1: The Climate Baseline and Adapting to Contemporary Climate

3.2: Approaches to Scenario Development Using Limited Resources

3.3: Approaches of Intermediate Complexity

3.4: General Circulation Models (GCM) and GCM-generated Projections

3.0 Some Definitions

Projection:

- **A description of the future and the pathway leading to it**
- **A model-derived estimate of future climate**

Forecast (Prediction): **A projection that is designated as *most likely to occur***

Scenario: **A coherent, internally consistent and plausible description of a possible future state of the world (IPCC 1994)**

- **a scenario is *not a forecast!***
- **one alternative image of how the future can unfold**
- **based on projections, but more comprehensive**
- **probabilities typically not assigned to scenarios**

Baseline: **Reference conditions against which change is measured**

- **present conditions**
- **future conditions without climate change**

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Source: IPCC TGICA (2007) p. 3

3.1 Climate Baseline and Use of Historical Data

Although climate is changing, the value of historical climate data (measured, estimated or reconstructed) is actually increasing:

- **To establish climatic baseline against which changes are evaluated; biases in model projections estimated**
- **To understand climate variability and extremes (not well simulated by current climate models)**
- **To support trend-based analysis and scenarios useful for the next 20 to 30 years**
- **To calibrate and validate a range of scenario development tools, including stochastic weather generators, pattern scaling and statistical downscaling methods, change factors, others**
- **To calibrate and validate sectoral impact models**
- **To identify critical thresholds**

Resources – Historical Meteorological Data

Resource	URL	Uses	Products
Climatic Research Unit (CRU) – Global historical climatography (U. East Anglia UK)	www.cru.uea.ac.uk/cru/data/hrg/	Long-term historical analysis, trends, frequency estimation	Monthly values of pre, tmp, tmx, tmn, dtr, vap, cld, wet, frs, pet 0.5^o grid for 1901-2013
WorldClim - Global Climate Data (CIAT and partners)	www.worldclim.org	Climatic baseline	Monthly gridded historical climate 1950-2000: T_{min} T_{max} T_{avg} Prec; resolution down to 1 km
Tropical Rainfall Measurement Mission (TRMM) NASA and partners	http://trmm.gsfc.nasa.gov/data_dir/data.html	Augment ground instrument records; support assessment of high-intensity events	Gridded (0.25^o) precipitation from RS. 3-hour to monthly, time series 1998-present
APHRODITE (Asian Precipitation Highly Resolved Observational Data)	http://www.chikyu.ac.jp/precip/	Hydrologic design, analysis of trends	High resolution gridded (0.25^o) daily precipitation from observations for Asia 1950-2007

3.2 Scenarios Requiring Limited Resources

Method	Advantages	Disadvantages
Sensitivity Analysis Uses: resource management; sectoral assessment	• Easy to apply • Requires no climate change info. • Shows most important variables/system thresholds • Allows comparison between studies	• Provides no insight into likelihood of associated impacts • Impact model uncertainty seldom reported or unknown
Change Factors Uses: Most adaptation	• Easy to apply • Can handle probabilistic climate model output	• Perturbs only baseline mean and variance • Limited availability of scenarios
Climate Analogues Uses: most adaptation activities	• Easy to apply • Requires no future climate change information • Reveals multi-sector impacts, vulnerability to past climate conditions or extreme events	• Assumes similar socio-economic, environmental responses recur under similar climate conditions • Requires data on confounding factors such as population growth, technological advance
Trend extrapolation Uses: New Infrastructure (e.g., coastal) **Source: Wilby et al. 2009)**	• Easy to apply • Reflects local conditions • Uses recent patterns of climate variability and change • Observed series can be extended through environmental reconstruction • Tools freely available	• Typically assumes linear change • Trends are sensitive to choice/ length of record • Assumes underlying regional climatology is unchanged • Needs high quality time series • Confounding factors can cause false trends

Illustration of Sensitivity Analysis: Irrigation

Sutami Dam, Brantas Basin, East Java. Photo: Perum Jasa Tirta I

The Brantas Basin:

- **Area: 12,000 Km^2**
- **Population: 15 Million**
- **Rainfall: 2,000 mm/yr**
- **Runoff: 10 - 12 BCM**
- **Runoff Ratio: 48% - 52%**

Sutami-Lahor Dam:

- **200 MCM total storage**
- **175 MCM live storage**
- **200 M kWH Hydropower**
- **85,000 Ha Irrigation**
- **Dry season flushing Q**

Total storage is a small percentage of average annual discharge, so that operation is sensitive to climate and hydrology

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Sensitivity Analysis - Climatic Water Balance

Climate Change Scenarios: Incremental (sensitivity analysis):

- **Hypothetical temperature changes of +1, +2, +3, +4 ºC**
- **Hypothetical rainfall changes of 0%, -5% (annual)**

Changes in runoff estimated using climatic water balance

Aridity Index:

$$\phi = \frac{ET_0}{P}$$

ratio of potential annual evapo-transpiration to annual precipitation

Turc-Pike equation:

$$\frac{E}{P} = F(\phi) = \frac{1}{\sqrt{1 + \left(\frac{1}{\phi}\right)^2}}$$

describes actual evapo-transpiration as a function of the AI

Annual runoff:

$$Q = P - E$$

runoff is annual precipitation less annual actual evapo-transpiration

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Results of Sensitivity Analysis

	Changes in:			Reliability of Irrigation by Season		
Temperature	Rainfall	Runoff	Ir. Demand	Season 1	Season 2	Season 3
Baseline				96.3%	100.0%	89.0%
+1 Deg. C	0.0%	-1.8%	2.6%	96.3%	100.0%	81.7%
+2 Deg. C	0.0%	-3.6%	5.1%	95.4%	100.0%	75.2%
+3 Deg. C	0.0%	-5.5%	7.5%	88.1%	99.1%	74.3%
+4 Deg. C	0.0%	-7.4%	10.0%	86.2%	99.1%	67.0%
+1 Deg. C	-5.0%	-10.7%	6.0%	83.5%	99.1%	67.9%
+2 Deg. C	-5.0%	-12.5%	8.4%	84.4%	96.3%	59.6%
+3 Deg. C	-5.0%	-14.4%	10.9%	74.3%	95.4%	51.4%
+4 Deg. C	-5.0%	-16.2%	13.5%	73.4%	91.7%	39.4%

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Data to inform sensitivity analysis: IPCC AR5 WG I Appendix A – Atlas of Global and Regional Climate Projections

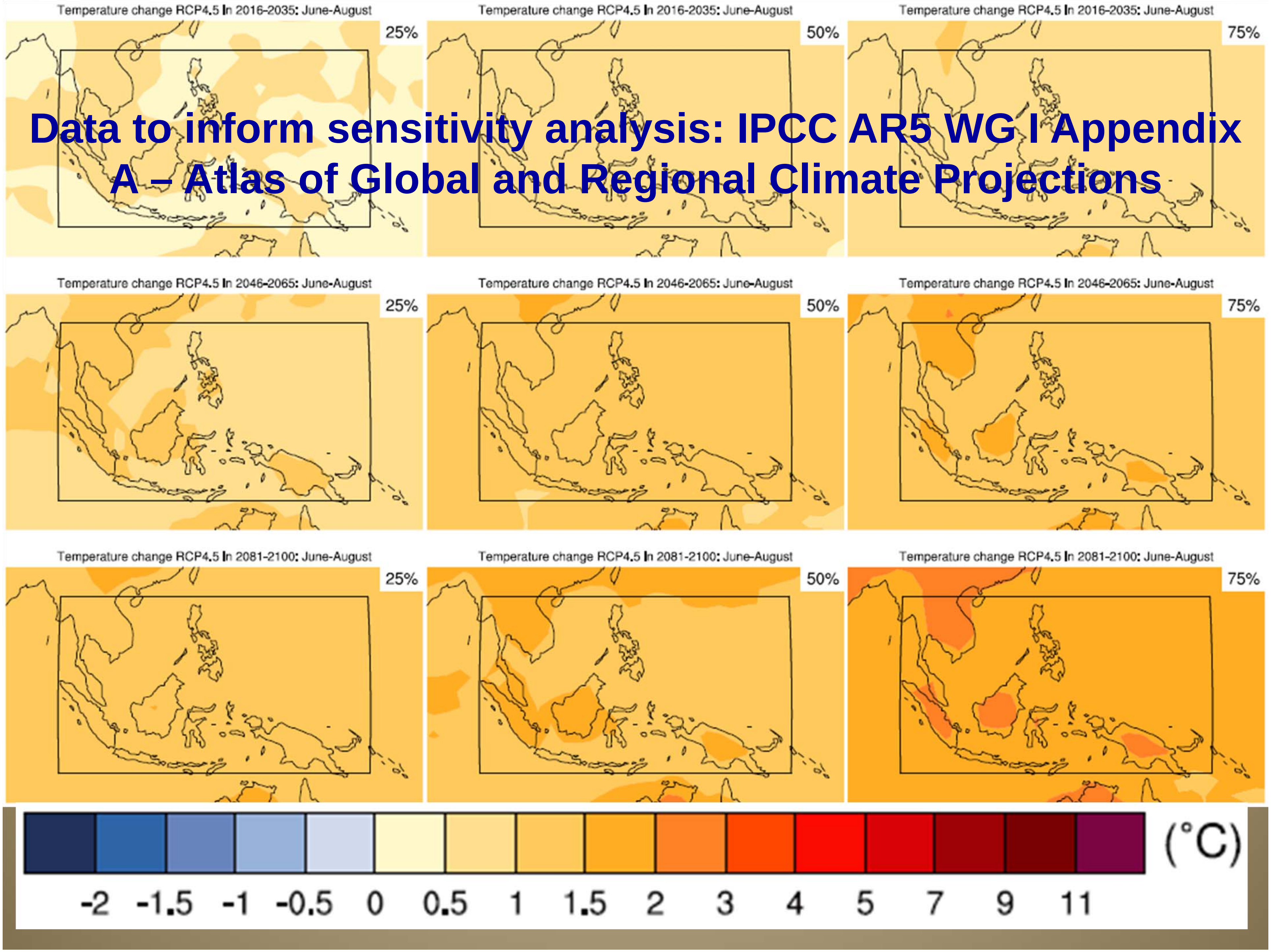
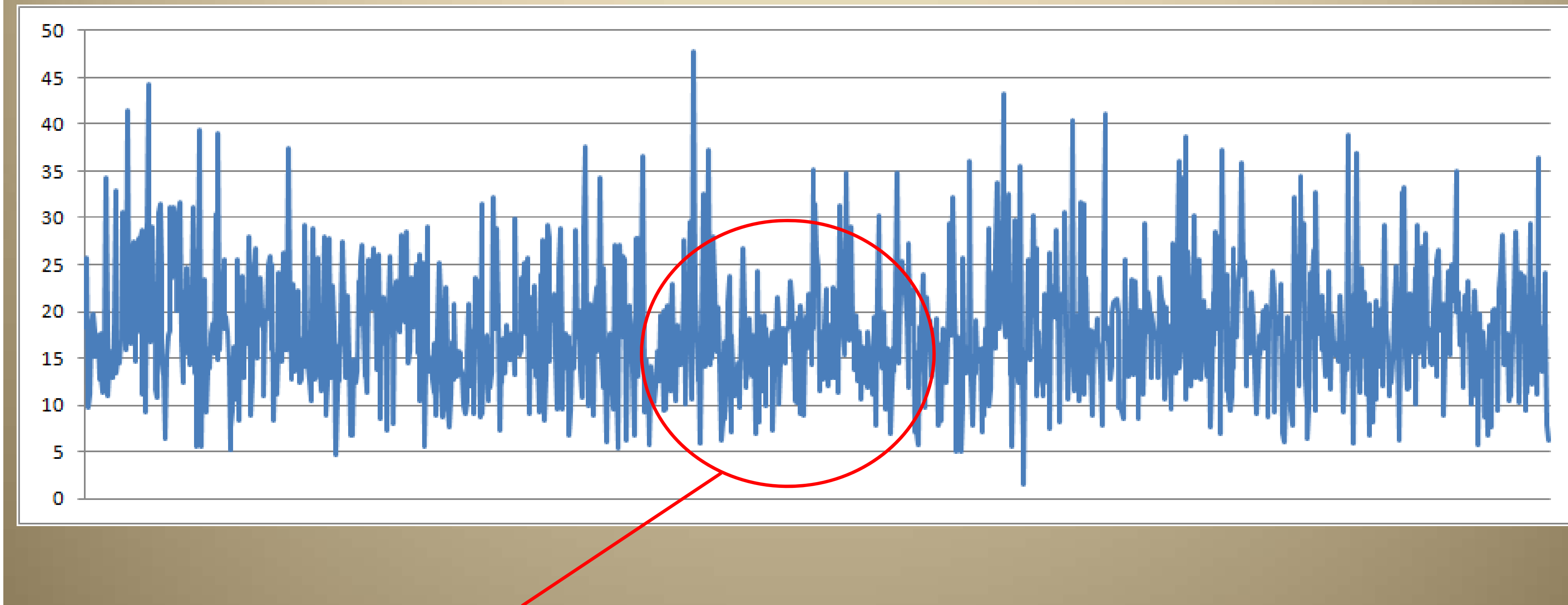


Illustration of Climate Analogues: Water Res.

Illustration of paleoclimate analogue used in water resources planning: 1,000 years of reconstructed flow on the Sacramento River, California USA



Use the historical low flow decades to test robustness of water resources system to prolonged drought

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3.3 Scenario Methods Intermediate Complexity

Method	Advantages	Disadvantages
Pattern Scaling Uses: institutional, sectoral	• Modest computational demand • Allows analysis of GCM and emissions uncertainty • Shows regional and transient patterns of climate change • Tools freely available	• Assumes climate change pattern for 21st Century maps to earlier periods • Assumes linear relationship with global mean temperature • Coarse spatial resolution
Weather generators Uses: resource management, retrofitting, behavioural	• Modest computational demand • Provides daily or sub-daily meteorological variables • Preserves relationships between weather variables • In widespread use for simulating present climate • Tools freely available	• Needs high quality observational data for calibration, validation • Assumes a constant relationship between large-scale circulation patterns and local weather • Scenarios sensitive to choice of predictors; quality of GCM output • Provides time-slices (not transient)
Empirical down-scaling Uses: new infrastructure, resource management, behavioural **Source: Wilby et al. 2009)**	• Modest computational demand • Provides transient daily variables • Reflects local conditions • Can provide variables for exotic variables • Tools freely available	• Requires high quality data for calibration, validation • Assumes constant relationship between large-scale circulation patterns and local weather • Scenarios are sensitive to choice of forcing factors and host GCM • Choice of host GCM constrained

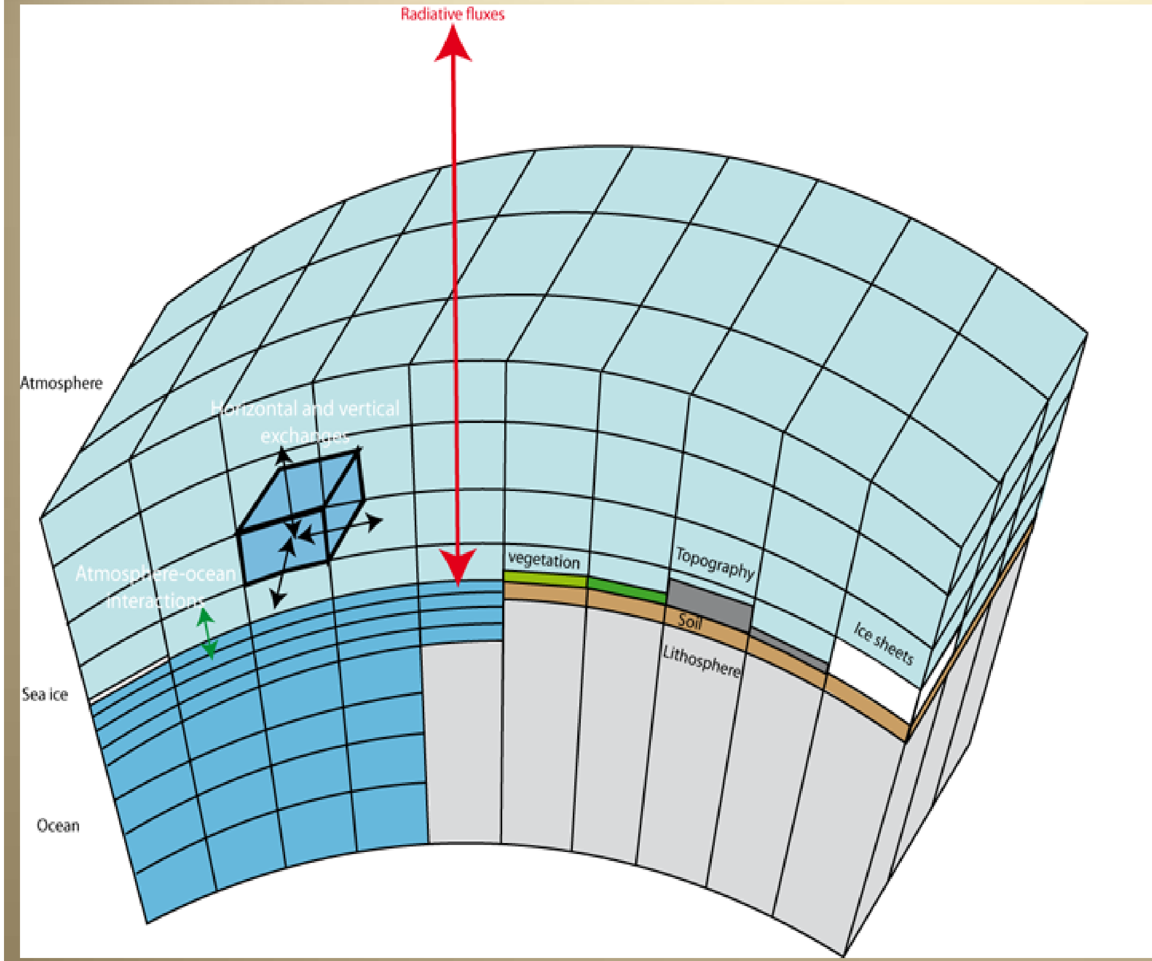
3.4 General Circulation Models (GCM) and Projections

Global climate models are indispensible tools for anticipating and preparing for future climatic and hydrologic conditions – no alternative currently exists **(USGCRP, 2009)**

Long-term climate predictions of 20-, 50- and 100 years hence are simply unsuitable to the contemporary needs of planners, designers and water systems operators. **(Stakhiv, 2009)**

Sources: U.S. Global Change Research Program (2009), Global Climate Change Impacts in the United States; Eugene Stakhiv (2009), Adapting to climate change in water resources and water services.

General Circulation Models (GCM)



- Primary approach for climate projection
- Global in scope
- Physics-based
- Internally consistent
- Evaluated against historical data
- Spatial resolution continually improving: highest resolution now 20 km (or less) regionally

Caveat: GCMs are research tools designed to improve our understanding of the coupled earth-ocean-atmosphere systems and were never intended to support adaptation decisions.

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Image: Universite Catholique de Louvain: stratus.astr.ucl.ac.be/…/chapter3_node8.html

What GCMs Can and Cannot Do

Dimension	Simulate Well	Simulate Less Well	Simulate Poorly
Spatial	Global 50 – 500 km[1]	Regional 20 - 50 km	Local < 20 km
Temporal	Mean Annual, Seasonal	Mean Monthly	Daily Hourly
Vertical	500 hPa	800 hPa	Earth Surface
Working Variables	Temperature Pressure Wind	Cloudiness Precipitation Humidity	Evaporation Transpiration Runoff Soil Moisture

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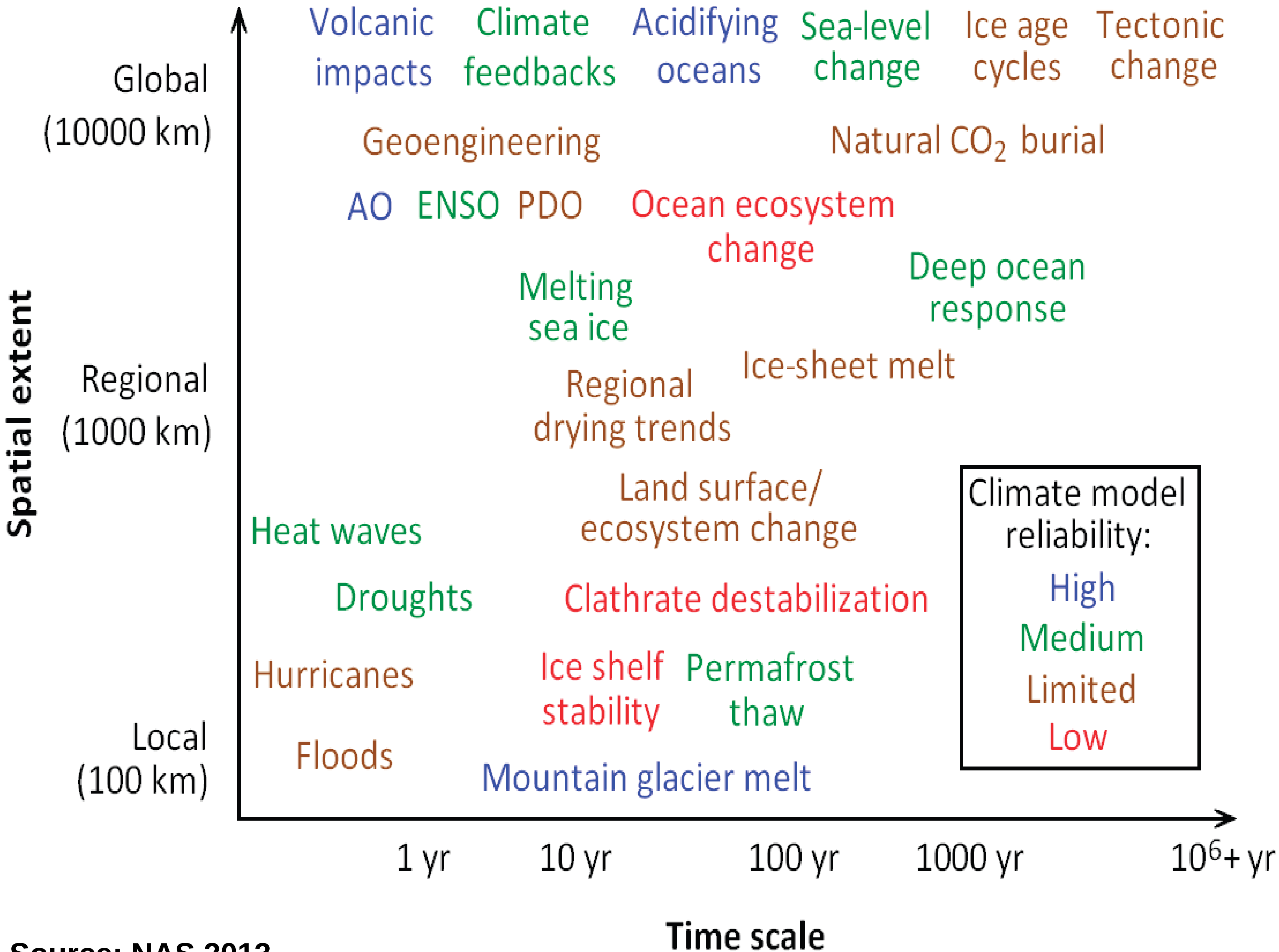
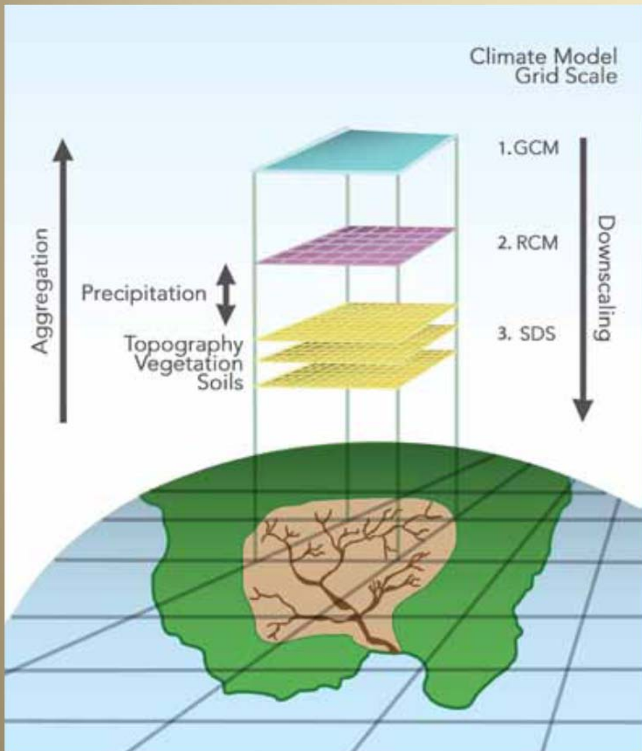


Source: NAS 2013

Downscaling GCM outputs to Project Level



- **GCM resolution often too coarse for regional (river basin), project use**
- **Statistical downscaling:**

- estimate statistical relationships between local climate variables and larger-scale atmospheric variables

- predict local variables from GCM outputs

- **Dynamic downscaling:**

- Embed regional climate-hydrology model within GCM

- Use GCM outputs as initial and boundary conditions for RCM

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Downscaling GCM outputs to Project Level

	Statistical Downscaling	Dynamic Downscaling
Strengths	• Relatively inexpensive • Computationally efficient • Can provide point estimates from GCM-scale outputs • Observations incorporated directly into method	• Results based on physically consistent processes • Can resolve atmospheric processes that GCMs cannot (orographic, rain shadow effects)
Limitations	• Does not account for non-stationarity in relationships • Climate system feedbacks not represented • Dependent on GCM forcings (GCM biases enter estimates) • Dependent on statistical model structure: different methods can lead to different results	• Computationally intensive • Limited number of ensembles available • Dependent on GCM forcings (GCM biases enter estimates) • Dependent on RCM parameterizations: different specifications can lead to different results

Resources – GCM and Down-scaled Projections

Resource	URL	Uses	Products
Earth System Grid Federation (ESGF)	http://pcmdi9.llnl.gov/esgf-web-fe/	Regional projections, boundary conditions for regional climate modeling, down-scaling	CMIP5 GCM outputs, all available experiments and variables, including Hindcasts, Decadal, RCP (long term) projections
WorldClim - Global Climate Data (CIAT and partners)	www.worldclim.org	Adaptation planning	Downscaled IPCC AR3 and AR5 (spline interpolation), time slices from 2020s to 2080s, precip, Tmx Tmn Tavg, bioclimatics, 30 minute resolution
Coordinating Regional Downscaling Experiment CORDEX	http://wcrp-cordex.ipsl.jussieu.fr/ http://www.ukm.my/seaclid-cordex/	Sectoral adaptation planning	Multi-GCM Multi-RCM at 50km (25 km) by region, RCP 4.5, 8.5 2005-2100 Near term (2005-2035) (forthcoming in SEA)
World Bank Climate Change Knowledge Portal	http://sdwebx.worldbank.org/climateportal/index.cfm	Sectoral, project adaptation planning	Country map-based search for historical, projected climate (precip, temp), 30-yr means or 30-yr change, monthly climatologies)

Summary, Discussion Points

- **Global Climate Models (GCM) are our primary tool for understanding the future behavior of climate, but …**
- **GCM outputs are not "data" and cannot (should not) be used in the same way as historical data in the design process**
- **Many processes (e.g., high intensity rainfall, frequency rainy days) are not well simulated by GCMs and RCMs**
- **GCM outputs (and down-scaled products) are fundamentally uncertain**
- **Avoid over-interpretation of specific GCM projections**
- **We can't assign probabilities to specific GCM projections - there is no "most likely" projection**

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4. Uncertainty and Likelihood

Phenomenon, Direction of Trend	Likelihood of Future Trends (IPCC)	Projections at Short Time- and Length Scales
Warmer and fewer cold days, nights over most land areas	Virtually Certain ($p > 99\%$)	Uncertain
Warmer, more frequent hot days, nights over most land areas	Virtually Certain ($p > 99\%$)	Uncertain
Frequency warm spells/heat waves increases over most land areas	Very likely ($p > 90\%$)	Uncertain
Frequency heavy precipitation events increases over most areas	Very likely ($p > 90\%$)	Very uncertain
Area affected by drought increases	Likely ($p > 66\%$)	Uncertain
Intense tropical cyclone activity increases	Likely ($p > 66\%$)	Very uncertain
Increased incidence of extreme high sea level	Likely ($p > 66\%$)	Reasonably certain given global

Sources of Uncertainty

Select Projection(s): SRES Scenario, GCM, Period, Downscaling Approach, …

↓

Impact Analysis based on Projections

↓

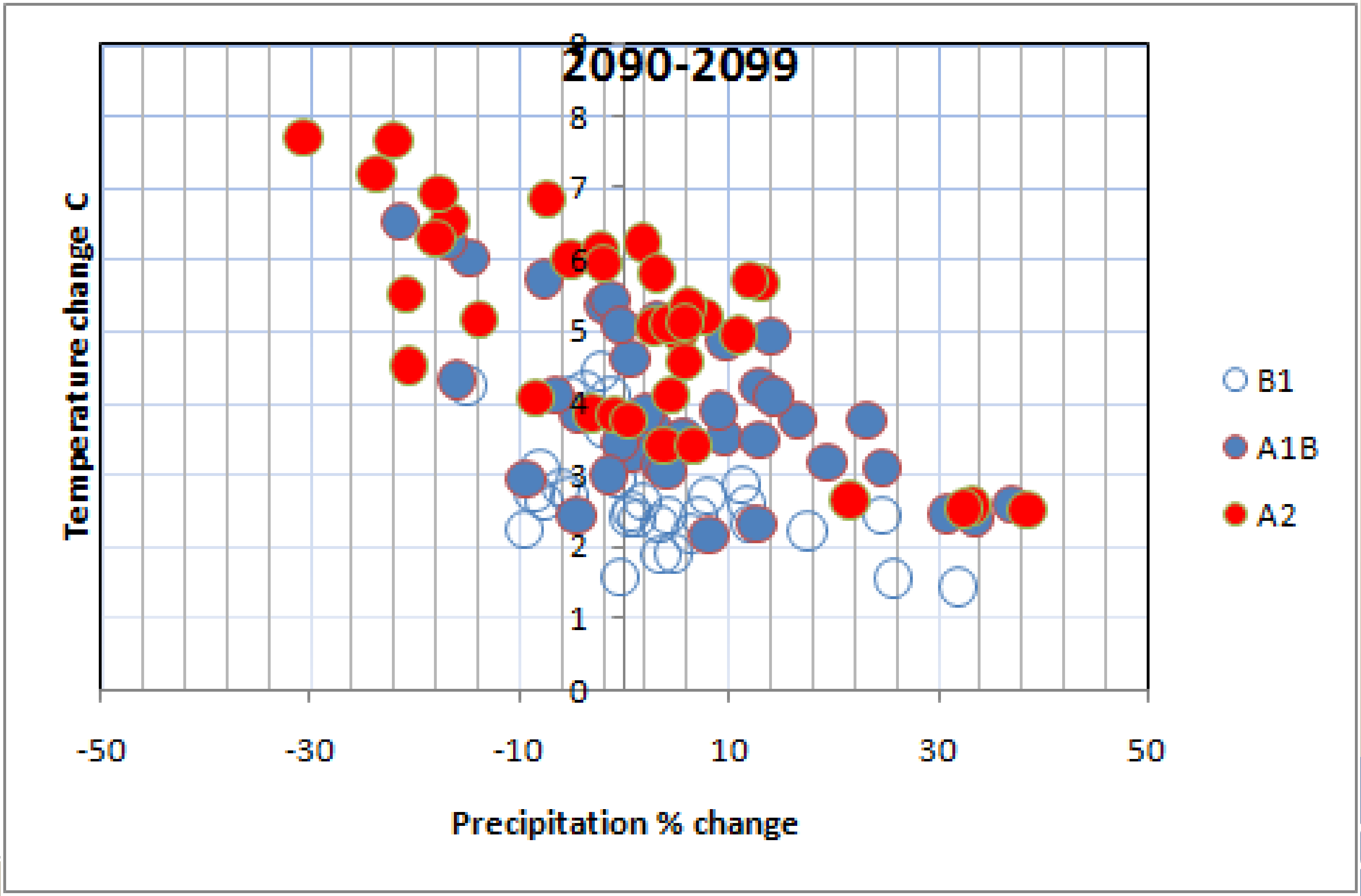
Select/Design Adaptation Measures

↓

Evaluate Effectiveness of Measures

- Forcing uncertainty
- Initial condition uncertainty
- Model identification uncertainty
- Model imperfection uncertainty
- Downscaling uncertainty
- Impact modeling uncertainty
- Uncertainty in prices, technology, other socioeconomic factors, …

Uncertainty and Projection Horizon



112 Projections, Statistically Downscaled CMIP3 for Boulder, Colorado USA

Other Sources of Uncertainty

- **Land Use/Land Cover Change**[1]
- **Global Bio-Geochemical (BGC) cycle**[2]
- **Energy use/technology**[3]
- **Demographic trends**
- **Economic trends**
- **Shocks (e.g., volcanic eruptions)**

[1] J. Foley (2009) – "The Other Inconvenient Truth" (http://e360.yale.edu/content)
[2] Foley (2009), V. Smil (2001) "Enriching the Earth", many others
[3] V. Smil (2010), "Energy Transitions: History, Requirements, Prospects"

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Strategies for Managing Uncertainty

- ***Robust Strategies:*** **identify approaches that will provide a reasonable level of adaptation over a wide range of future conditions**
- ***Adaptive Strategies:*** **identify approaches that can be modified or amended as new information (including diagnostic feedback) becomes available**
- ***Precautionary Strategies:*** **identify approaches that minimize the down-side (e.g. impacts of severe, low-probability scenarios)**
- ***Quantification of Uncertainty:*** **(ensembles)**

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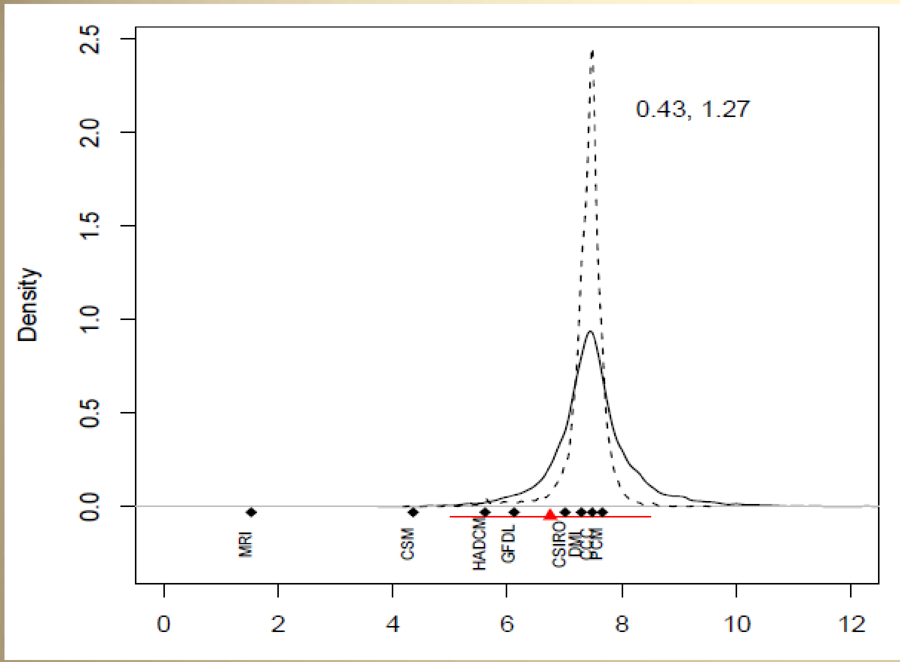
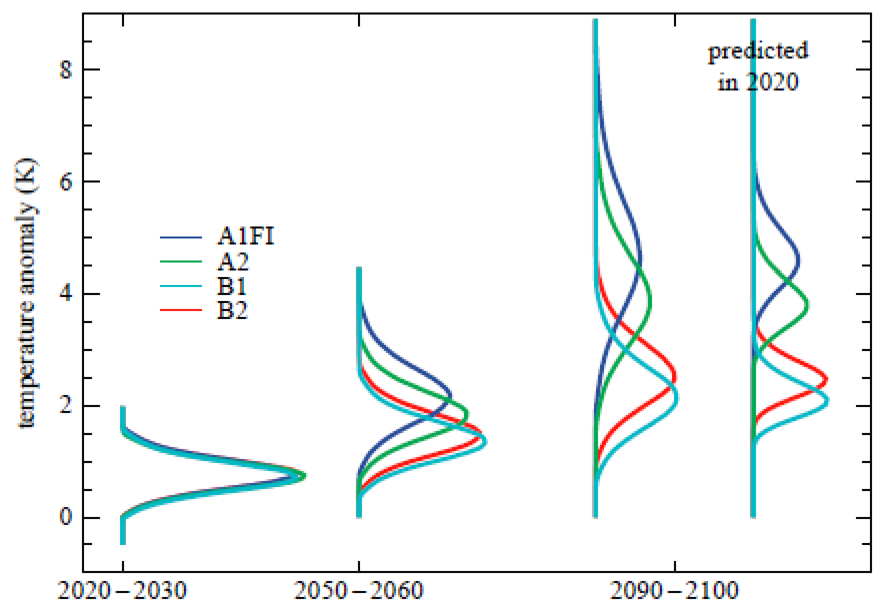


P. A. Stott and C. E. Forest



Quantification of Risk:

In general we cannot assign probabilities to GCM projections:

- **Assumptions underlying parametric distributions - independent, identically distributed values – are not true for model-generated projections**
- **Over-interpret the "mean" as most likely to occur**
- **Implied behavior of climate in the tails is seldom justified**

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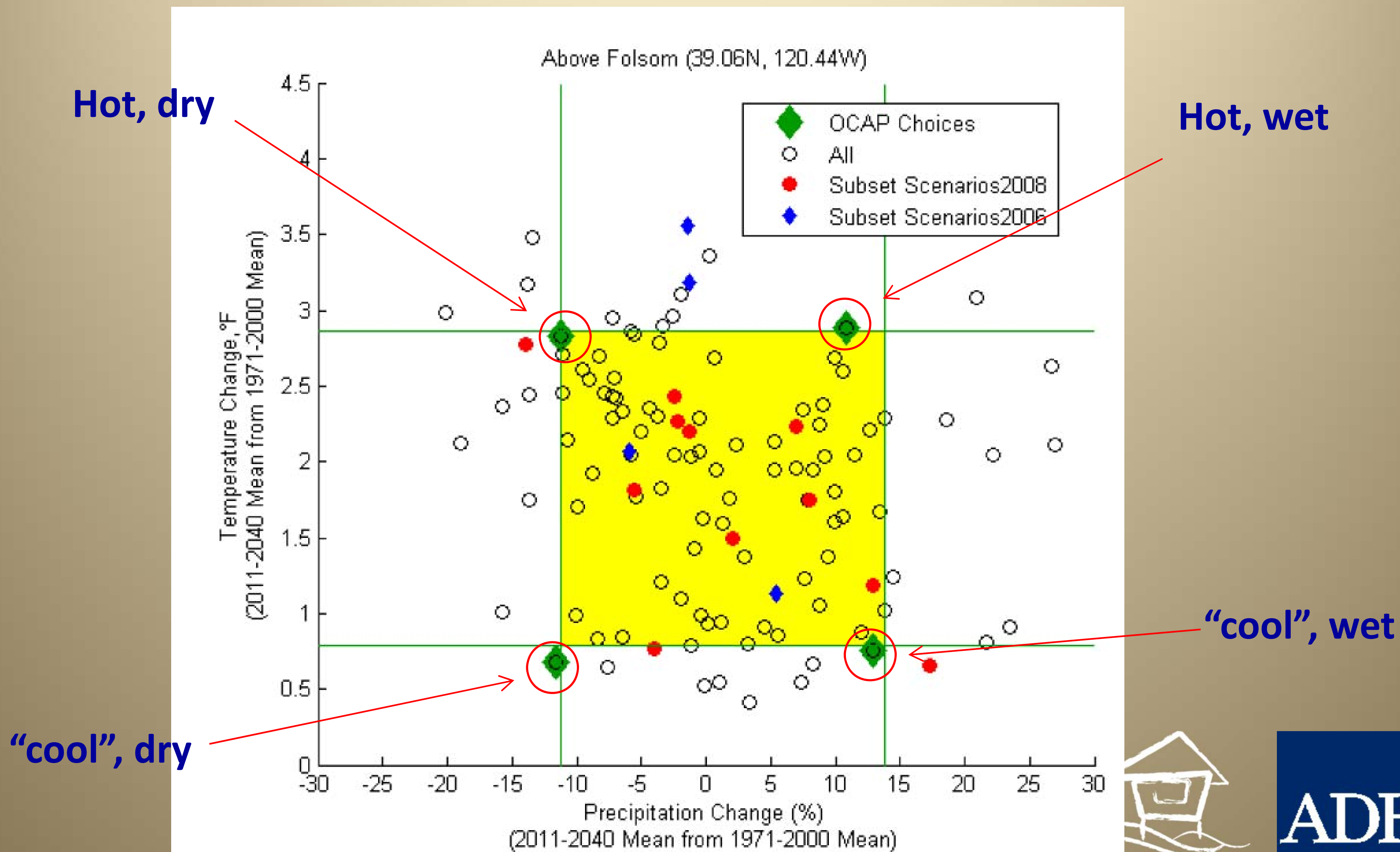
Empirical Risk Quantification

Find, examine the extreme cases (112 projections, statistically downscaled CMIP3)



Source: U.S. Bureau of Reclamation (2008), Sensitivity of Future Central Valley Project and State Water Project Operations to Potential Climate Change and Associated Sea Level Rise

Summary, Discussion Points

- Uncertainty is a fundamental characteristic of model-generated climate projections
- On-going improvements to GCMs will not eliminate this uncertainty
- Not all climatic variables are equally uncertain
- Climate uncertainty is not the only source of uncertainty that we must consider in project-level risk management
- While probabilities cannot be assigned to specific projections, the properties of ensembles (sets of multiple projections) can be useful in understanding, managing climate risks
- Several design approaches have been proposed to address uncertainty, including robust, adaptive and precautionary strategies

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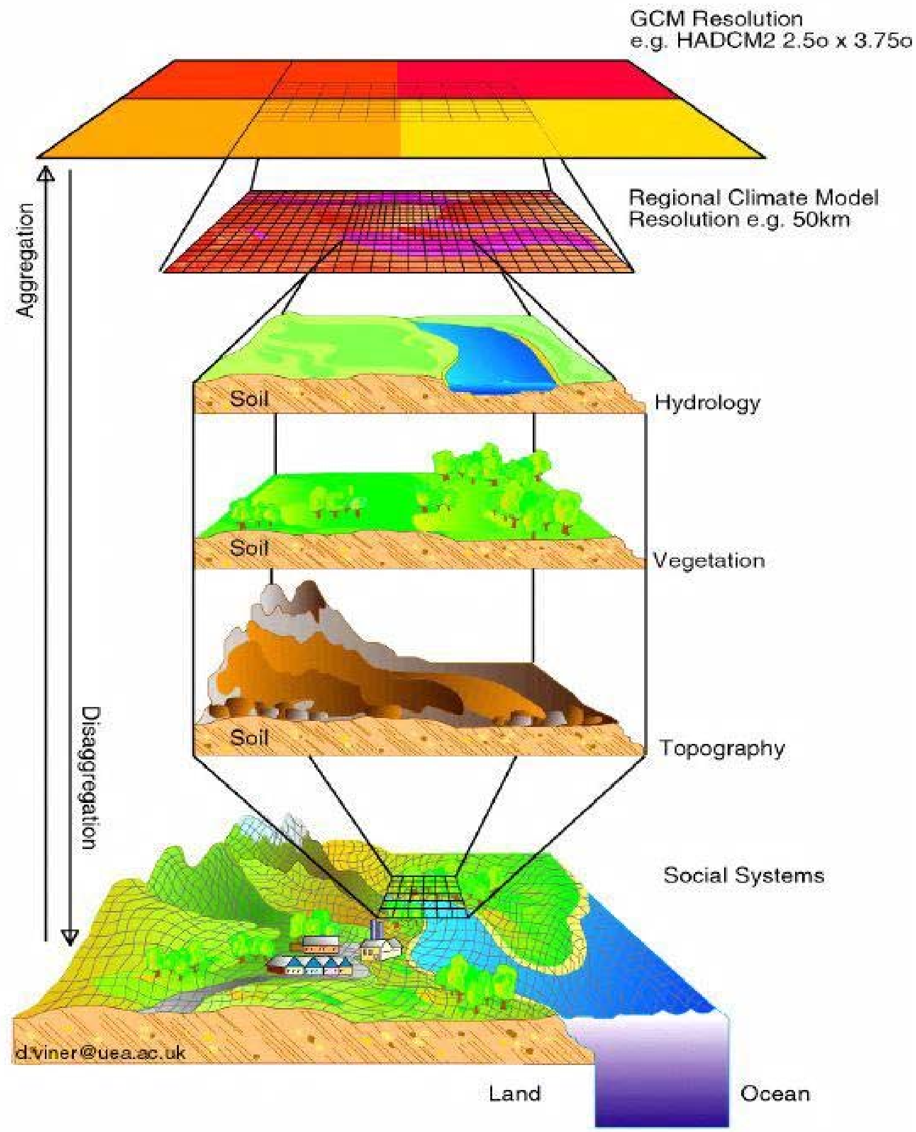
5. Estimating Future Biophysical Impacts



GCMs and down-scaled regional projections based on GCM outputs do not provide us with information on bio-physical impacts associated with GHG warming. Such impacts are significant in many areas:

- **Hydrology (runoff, groundwater)**
- **Agriculture (plant physiology)**
- **Natural Resources (forestry, …)**
- **Natural Disasters (flood, drought)**
- **Health**

Once climate change scenarios have been constructed, key relationships between changes in climate parameters and sectoral impacts must be quantified.

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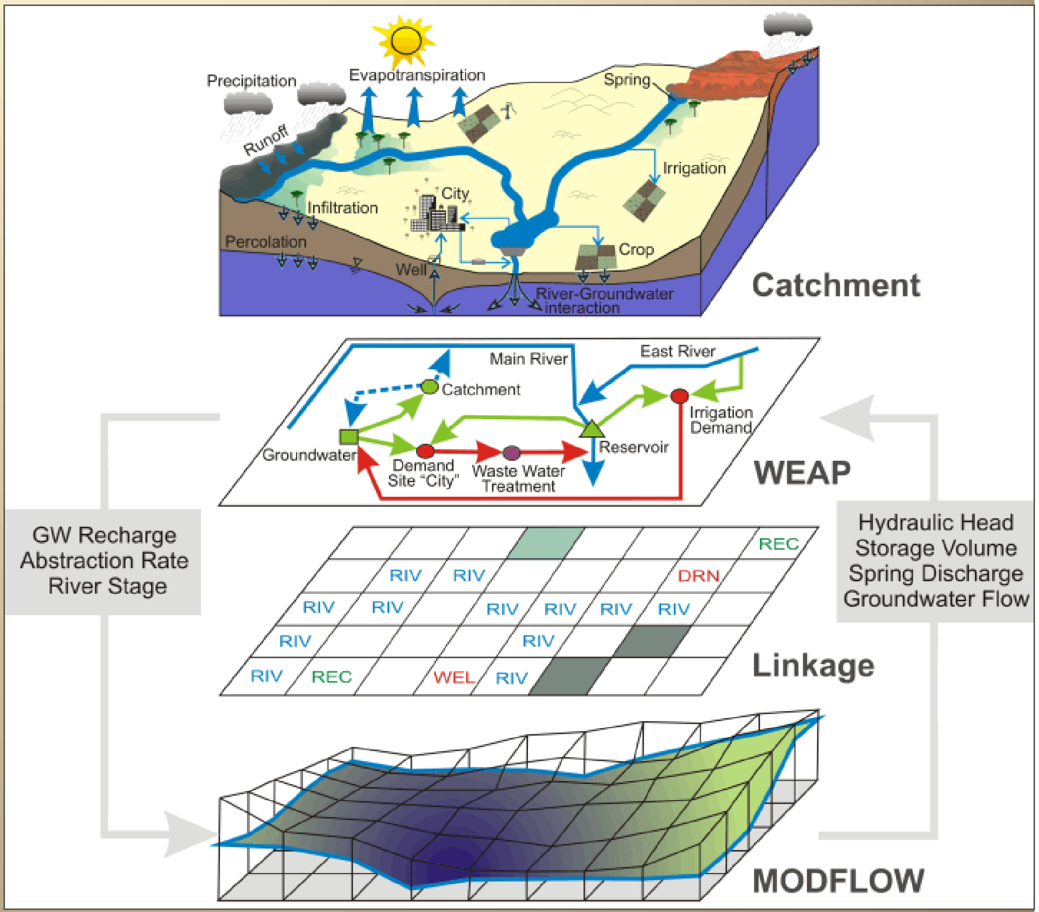
Estimating Biophysical Impacts in Agriculture

Type of Model	Description and Use	Strengths	Weaknesses
Agro-climatic indices and Geographic Information Systems (GIS)	• Based on combinations of climate variables important for crops • Used in many agricultural planning studies • Useful for general audiences	• Simple calculation • Useful for comparing • across regions or crops	• Climate-based only • Lack management • responses or consideration • of CO_2 fertilization
Statistical Models and Yield Functions	• Based on empirical relationship between observed climate and crop responses • Used in yield prediction for famine early warning and commodity markets	• Present-day crop and climatic variations are well described	• Do not explain causal mechanisms • May not capture future climate–crop relationship • May not be location specific
Process-based Crop Models	• Calculate crop responses to factors that affect growth and yield (i.e., climate, soils, nutrients, and management) • Used by agricultural scientists for research and development	• Process-based, calibrated widely, and validated • Useful for testing a broad range of adaptation options • Available for most major crops	• Require detailed weather, soil and management data as well as agronomic data and model expert(s)

Decision Support Tools for the Water Sector

Hydrological Modeling:

- River Flow
- Groundwater Flow
- Water Quality
- Flood (Hydraulic model)
- Water use
- Reservoir Management



Hydrological models should be selected on the basis of the desired space- and time resolution and evidence of skill in simulating historical patterns of hydrologic response within the region.

WEAP and MODFLOW modelling. Available at: http://www.bgr.bund.de/EN/Themen/Wasser/Projekte/abgeschlossen/TZ/Acsad_dss/dss_fb_en.html

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Flood Vulnerability: Integrated Citarum Water Resources Management Investment Program

- 15-year, $1 Bn Assistance
- Upgrade infrastructure, institutions (IWRM)
- 1,400 Mw Hydro
- 400,000 Ha irrigation
- Water supply for Jakarta, Bandung

Challenges:

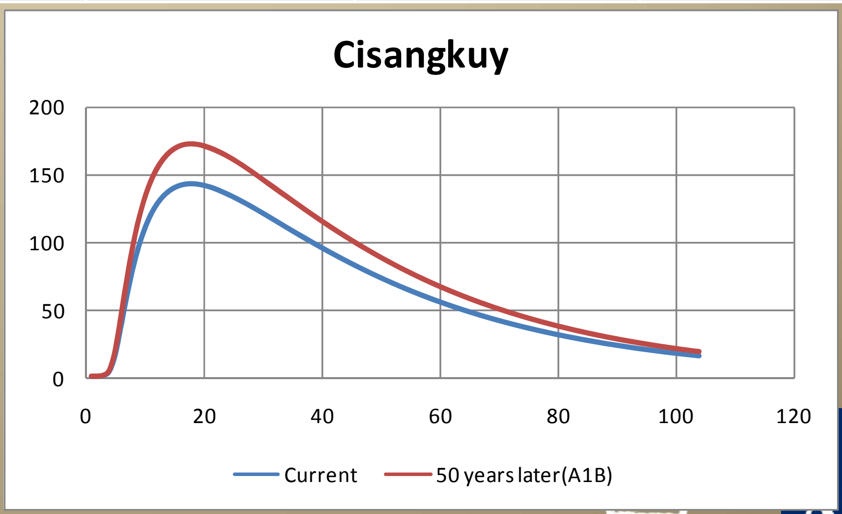
- Water security
- Groundwater depletion
- Water quality
- Flood risk in upper basin

Source: NAHRIM 02/2009

Analysis of Flooding using 17 GCM

Scenario	A1B	A1B	B1	B1
Projection Period	2046-65	2081-00	2046-65	2081-00
No. Models showing increase (17 total)	14/17 (82%)	16/17 (94%)	13/17 (76%)	9/17 (53%)
5-year Ppt. change	1.18	1.31	1.14	1.18
10-year Ppt. change	1.20	1.35	1.15	1.20
100-year Ppt. change	1.20	1.36	1.17	1.18

Change in precipitation used to model change in flood runoff



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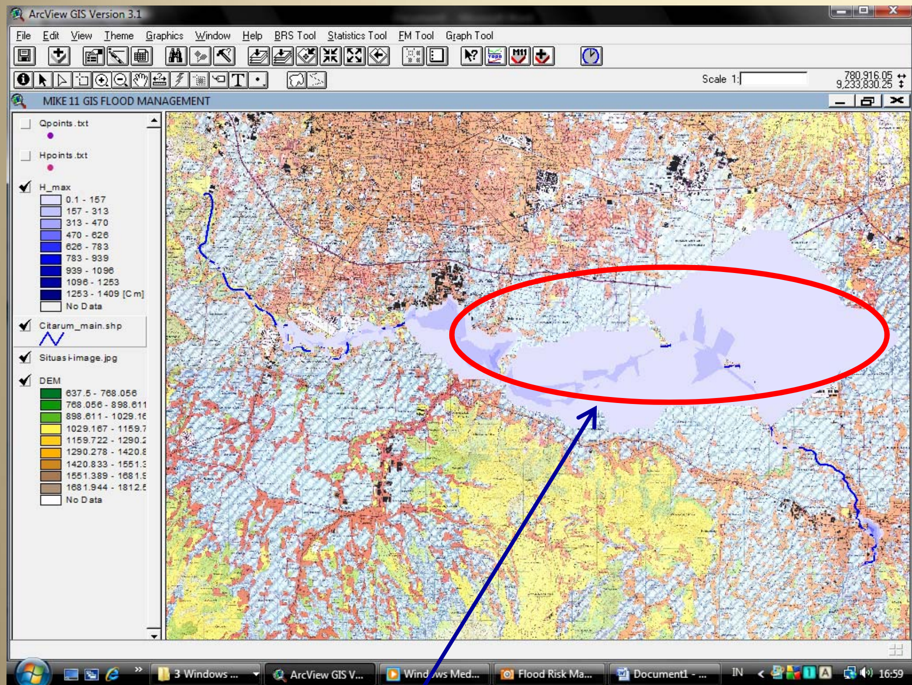
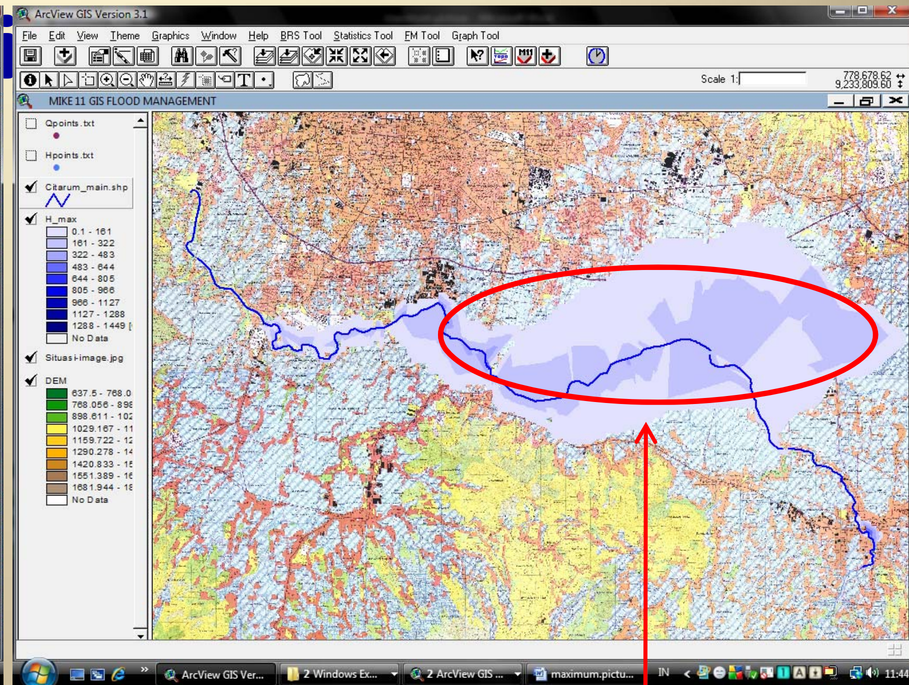
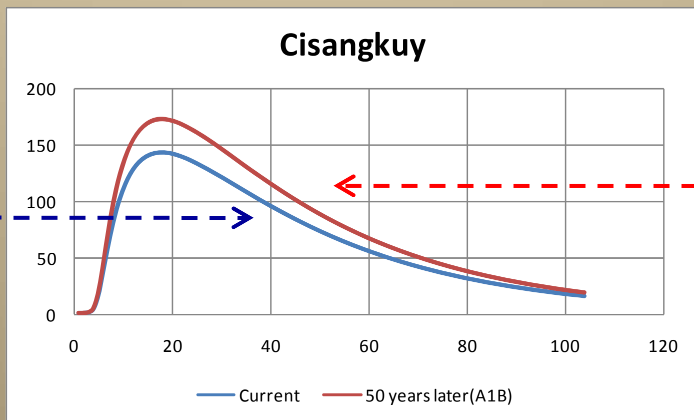
Source: NAHRIM 02/2009

Vulnerability Assessment: Increased Flooding





Current design flood



Future design flood under climate change

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Source: NAHRIM 02/2009

Resources – Sectoral Impact Models and Tools

Resource	URL	Uses	Products
ISI-MIP: Inter-sectoral Impact Model Intercomparison Project	https://www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/research/rd2-cross-cutting-activities/isi-mip/	Impact model selection, performance evaluation, documentation	Research literature on model descriptions, evaluation and performance. Primary emphasis on water sector
AGMIP: Agricultural Model Comparison, Improvement Project	http://www.agmip.org/	Agricultural simulation model selection, performance evaluation, documentation	Research literature on crop simulation model descriptions, evaluations and performance.
UNFCC Compendium on Methods and Tools	http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/5457.php	Impact Assessment, Adaptation evaluation, climate scenarios, economic analysis	Descriptions, evaluations and links to many sectoral impact assessment and related tools
QGIS: Free GIS software and products	http://www.qgis.org/en/site/	Impact assessment, adaptation planning (regional, sectoral, project)	GIS software, tools documentation and training materials

Summary, Discussion Points

- For many types of impact assessment, once climate change scenarios have been constructed, key relationships between changes in climate parameters and sectoral impacts must be quantified
- Sector-specific tools and simulation models are typically required for this purpose
- The complexity of tools, and corresponding data needs vary widely, so that the cost and complexity of the impact assessment modeling effort should reflect the cost and/or complexity of the project
- Many impact assessment models (such as hydrologic and crop simulation models) require calibration and validation for local conditions, so that the availability of the required data should be established before selecting models
- The credible and effective use of sectoral impact assessment models often requires specialized expertise

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Overall Summary Observations:

- **There is no "best way" to develop and use climate data and projections in climate risk management**
- **Many options available require the project team to find a balance between credibility, detail and feasibility (i.e., the need to work within resource constraints)**
- **The ways we use projections data in decision support determine the significance and treatment of uncertainty**
- **"Predict-then-Act" approaches can be relatively fragile in the face of uncertainty**
- **Robust decision-making approaches, by contrast, can make positive use of climate uncertainty in exploring, identifying climate-resilient plans and designs**
- **Climate isn't the only source of uncertainty and should not be treated as such**

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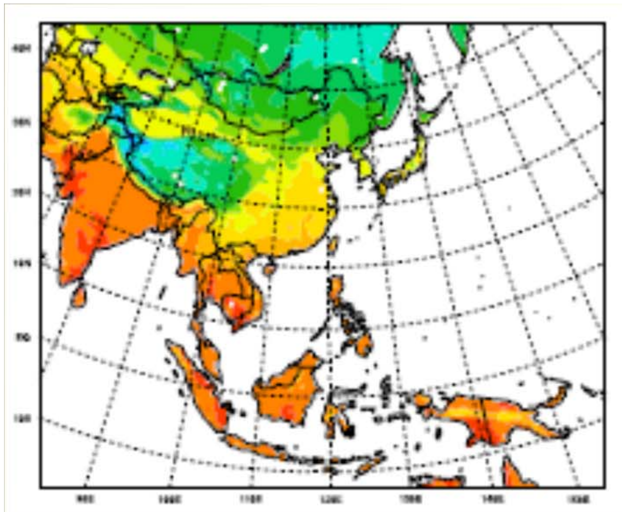

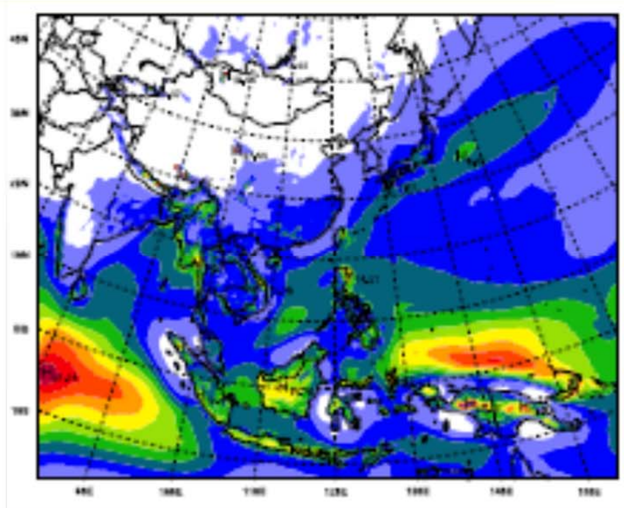

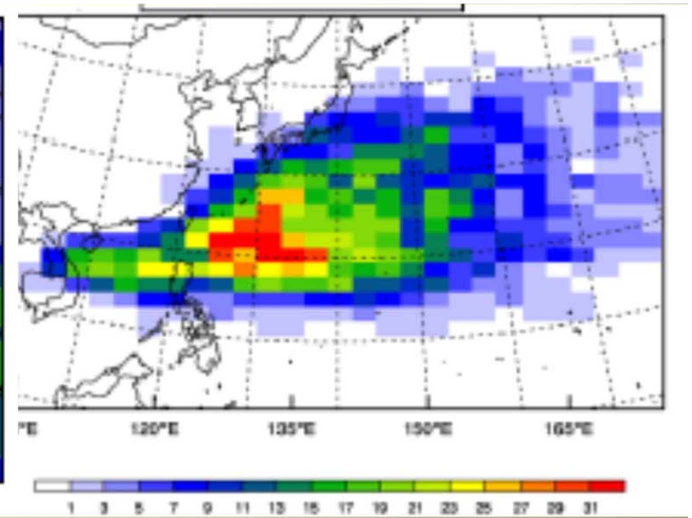

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More information and literature available at:

http://www.adb.org

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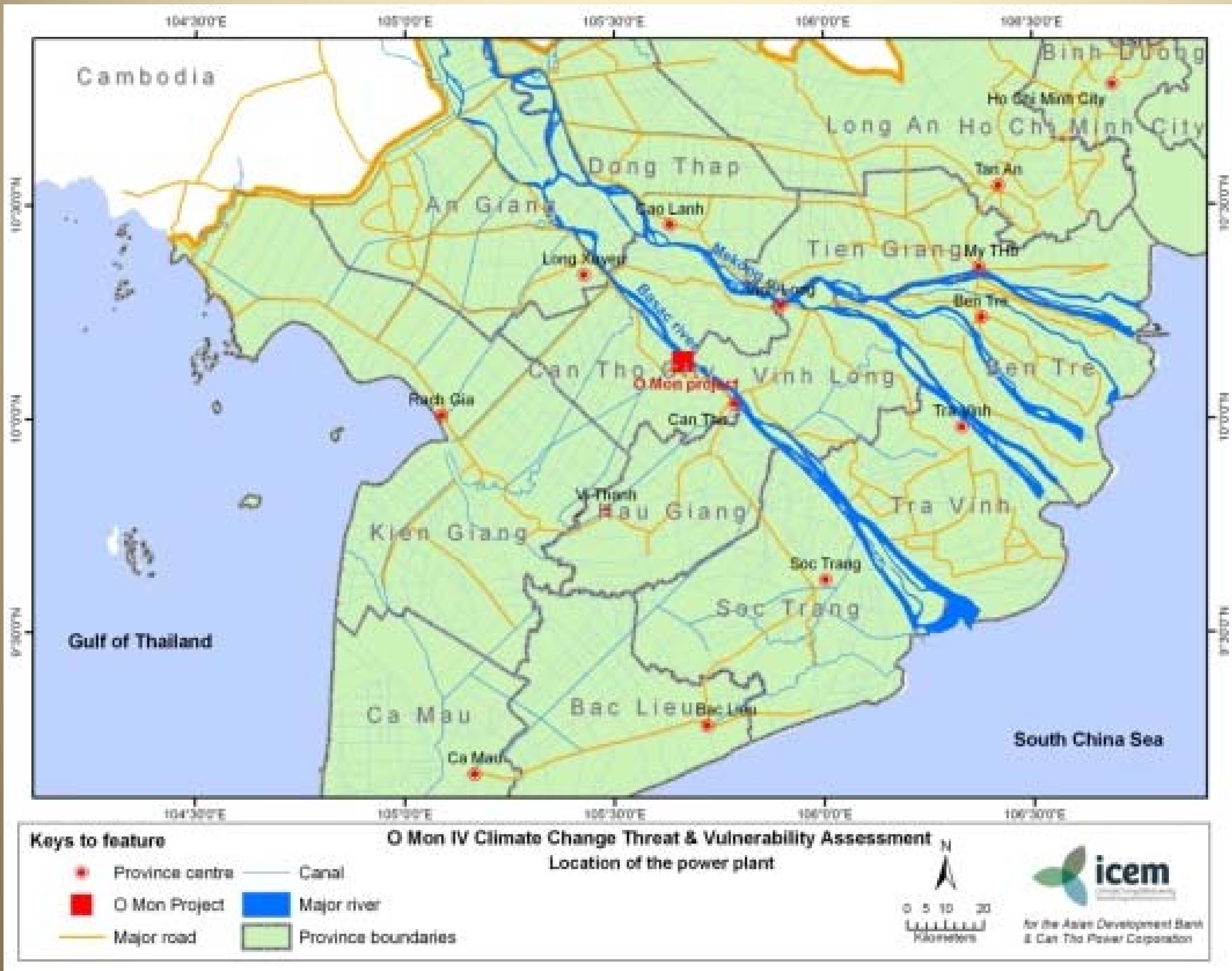
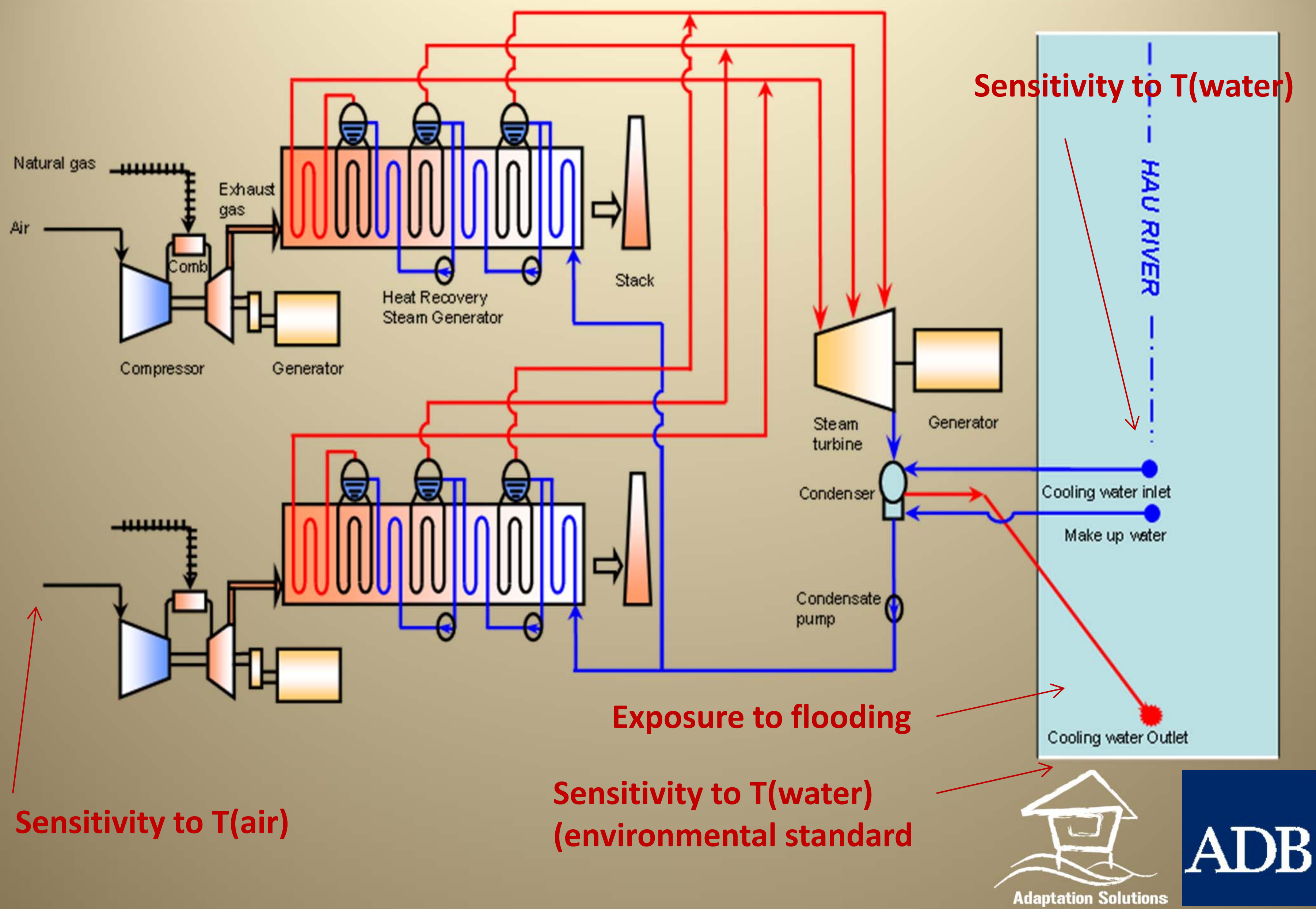
Location of O Mon IV in Mekong Delta



Schematic: O Mon IV Gas Power Plant



Case Study: O Mon IV Gas Power Plant

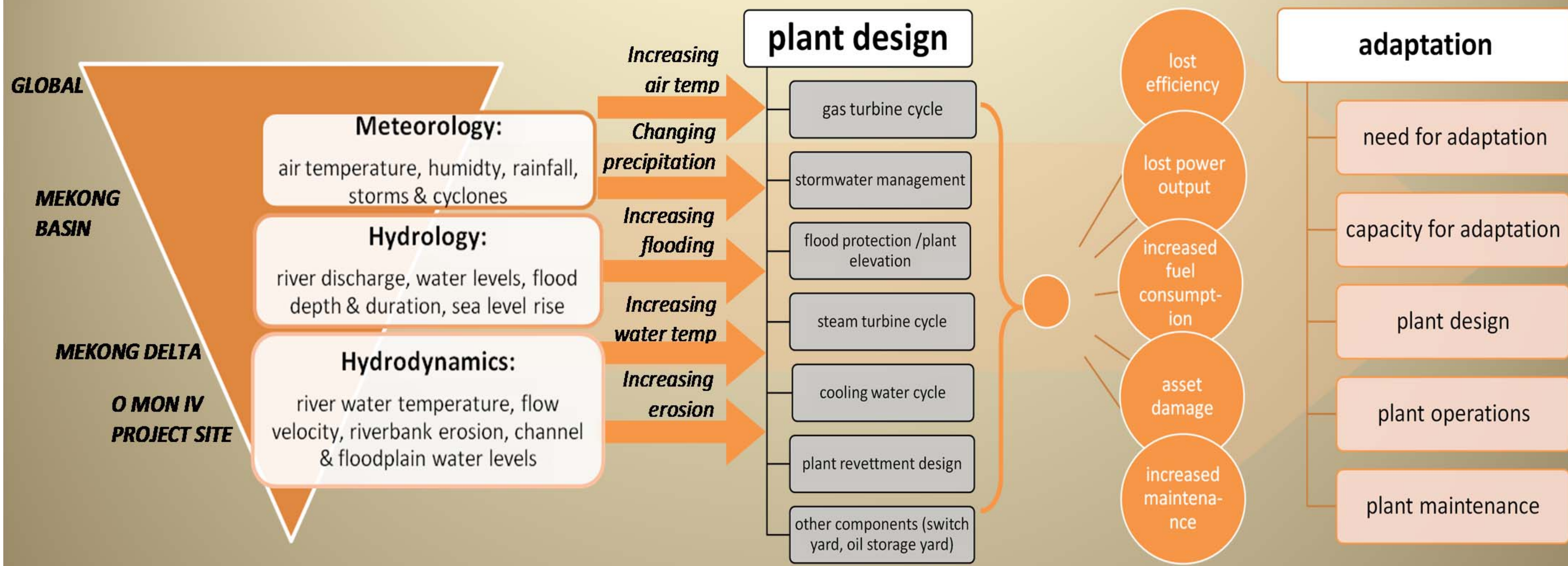


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Figure 6. Potential Threats

Direct climate threat	Potential sensitivity of a power plant
Air temperature →	Gas turbine cycle performance
River water temperature →	Steam turbine cycle + coolant water cycle performance
Direct precipitation →	Performance of gravity-driven stormwater management
Flood depth + Duration →	Asset damage + plant downtime
Erosion →	Asset damage

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