Climate Change Adaptation Planning:

Integrating Global Climate Model Projections into Stormwater Planning in Philadelphia

Philadelphia AWRA, March 14th, 2018

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Sebastian Malter, Climate Change Adaptation Program Engineer

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Overview

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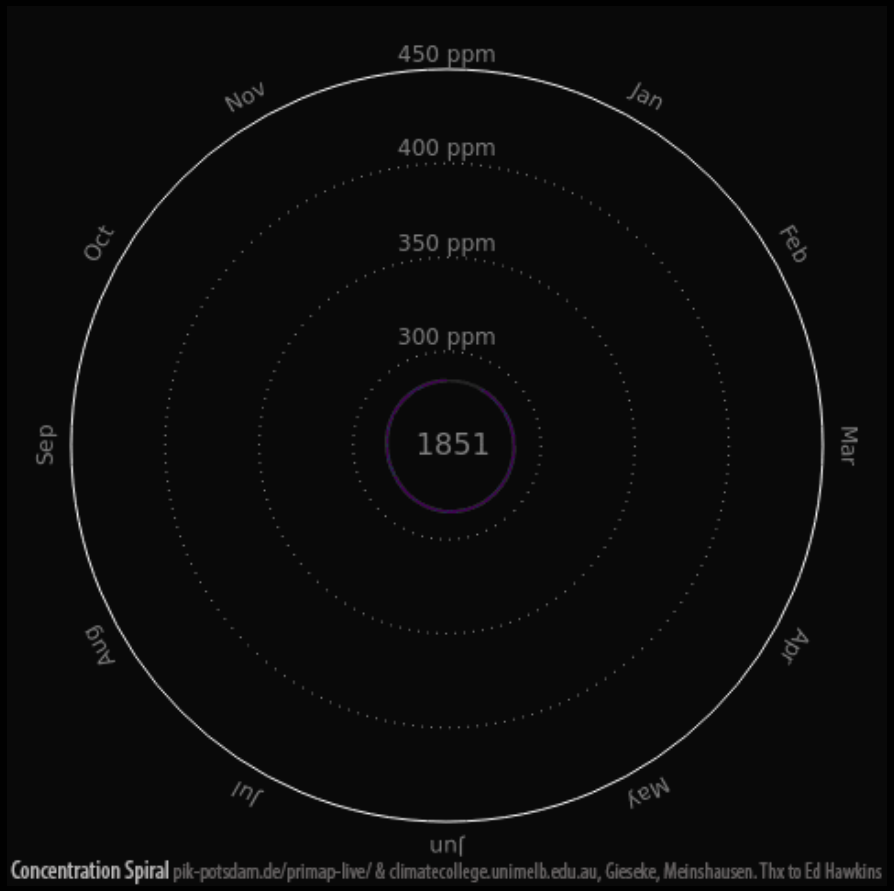
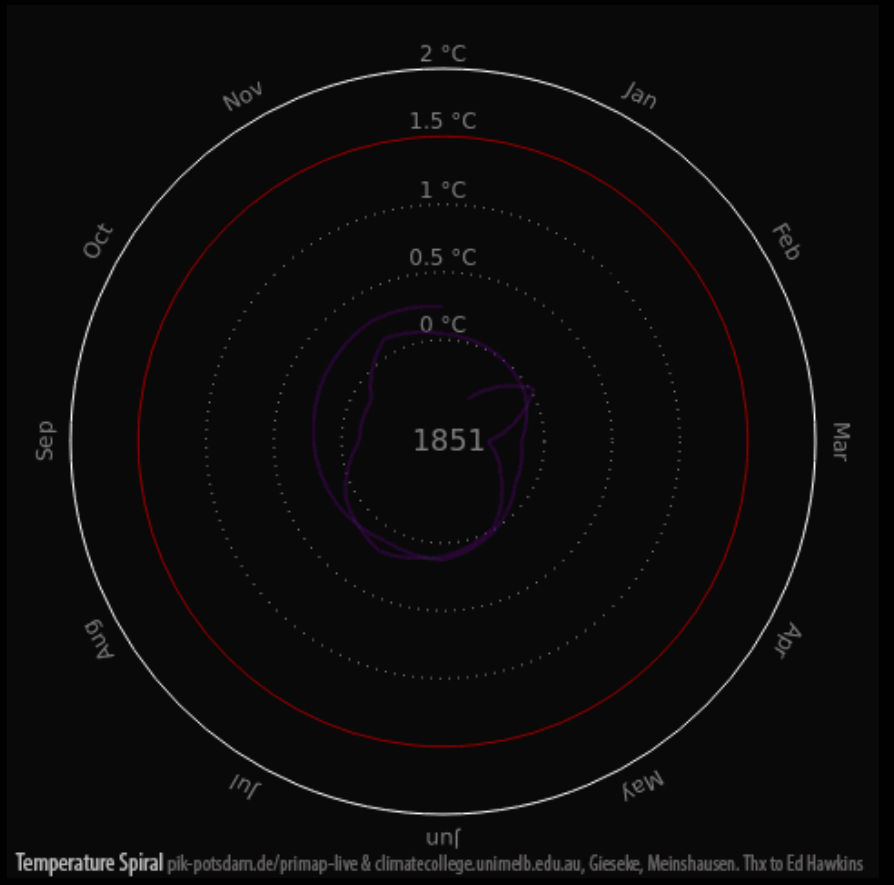
   - Creating Actionable Science
   - Best Practices



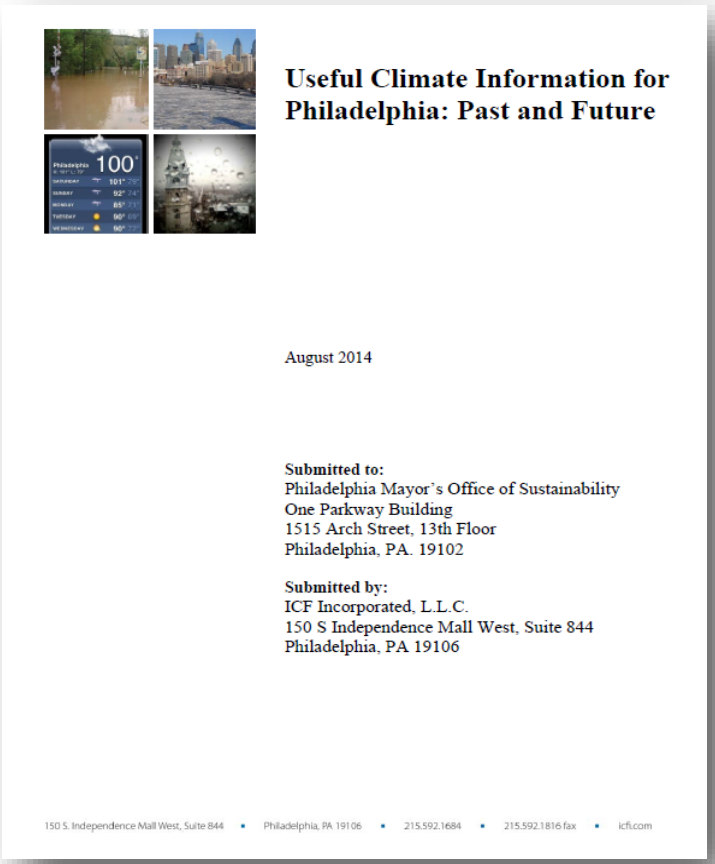


Source: Ed Hawkins and Potsdam Institute for Climate Impact Research : http://openclimatedata.net/climate-spirals/from-emissions-to-global-warming-line-chart/

Climate Change in Context

- Populations, ecosystems and natural resources will be impacted on a global scale
- The type and severity of impacts will vary on regional and local scales
- Cities around the country recognize the need to plan for and adapt to the impacts from climate change

Office of Sustainability Climate Reports



Useful Climate Information for Philadelphia: Past and Future

August 2014

Submitted to:
Philadelphia Mayor's Office of Sustainability
One Parkway Building
1515 Arch Street, 13th Floor
Philadelphia, PA. 19102

Submitted by:
ICF Incorporated, L.L.C.
150 S Independence Mall West, Suite 844
Philadelphia, PA 19106

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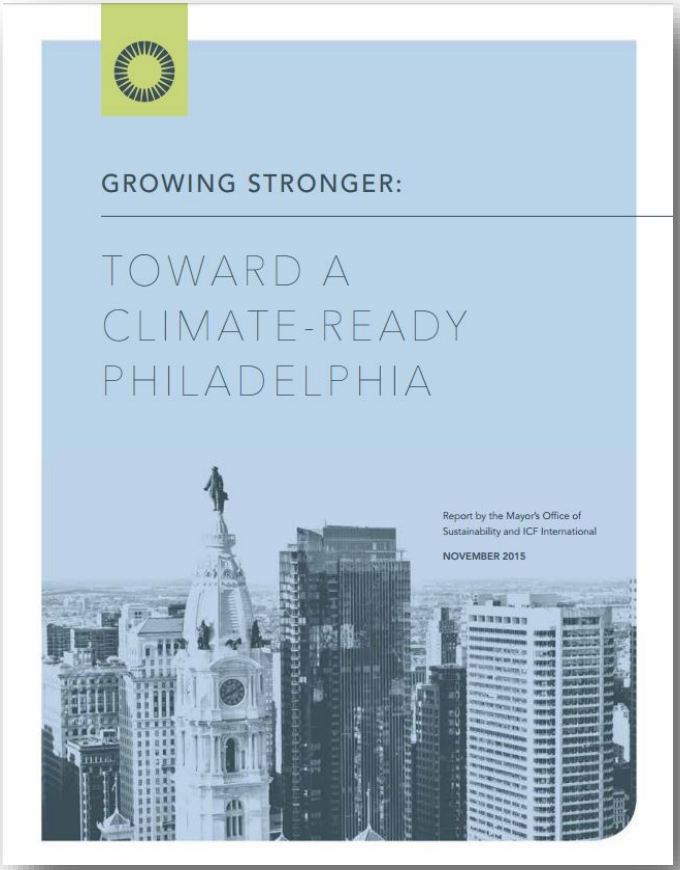

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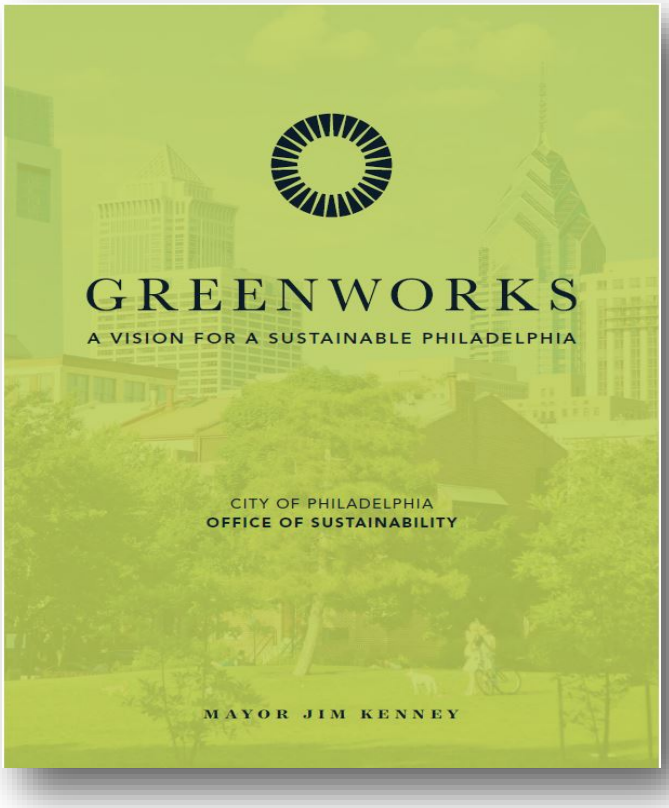
Greenworks: A Vision for a Sustainable Philadelphia



1. Accessible Food and Drinking water
2. Healthy Outdoor and Indoor Air
3. Clean and Efficient Energy
4. **Climate Prepared and Carbon Neutral Communities**
5. Quality Natural Resources
6. Accessible, Affordable, and Safe Transportation
7. Zero Waste
8. Engaged Students, Stewards, and Workers

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Philadelphia Water Department
Integrated One Water Utility

Drinking Water

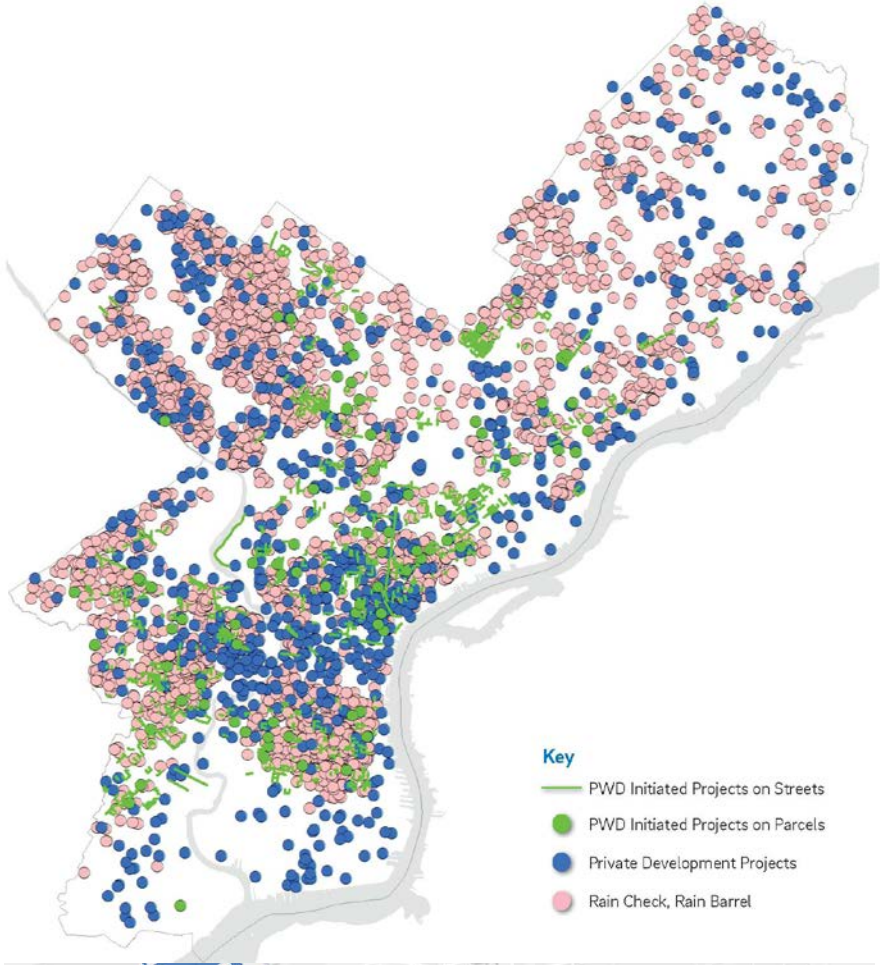
- Source: Delaware and Schuylkill Rivers
- 1.7 million drinking water customers
- Three Water Treatment Facilities
- Over 300 million gallons treated per day
- 3,000 miles of water mains, 25+ pumping stations

Wastewater

- 2.2 million wastewater customers
- 3 Water Pollution Control Plants
- Over 522 million gallons treated per day
- 3,716 miles of sewers, 19 pumping stations
- Biosolids handling facility

Stormwater

- Roughly 60% Combined Sewer, 40% Separate Sewer
- Green City, Clean Water - Large-scale green stormwater infrastructure program
- To date, the program has reduced CSOs by more thar 1.5 billion gallons annually with over 440 GSI sites



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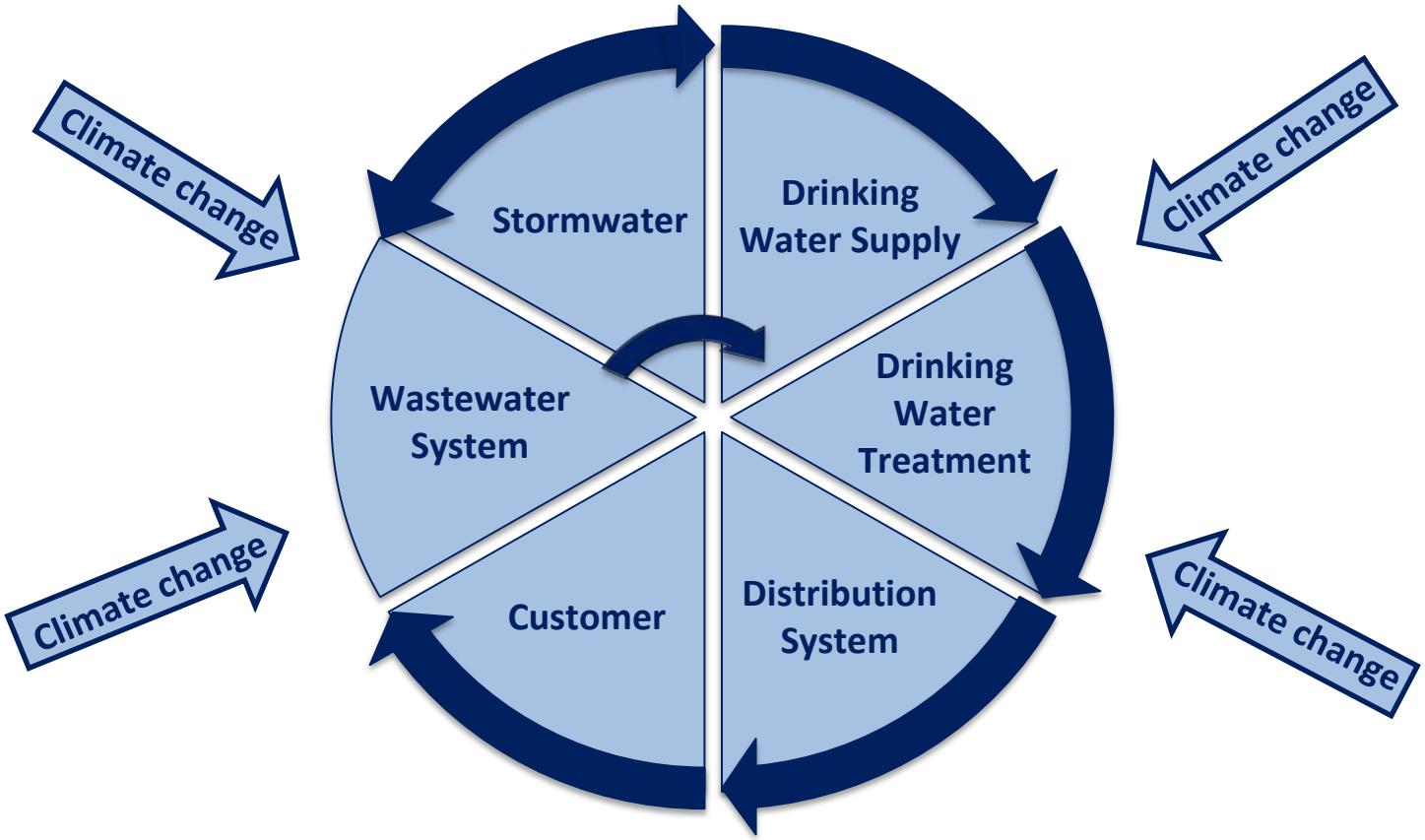
Integrated One Water Management



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Climate Change Adaptation Program (CCAP)

Program Goal

Reduce the risks and associated expenses PWD will face from the impacts of climate change by identifying and implementing effective and feasible adaptation strategies

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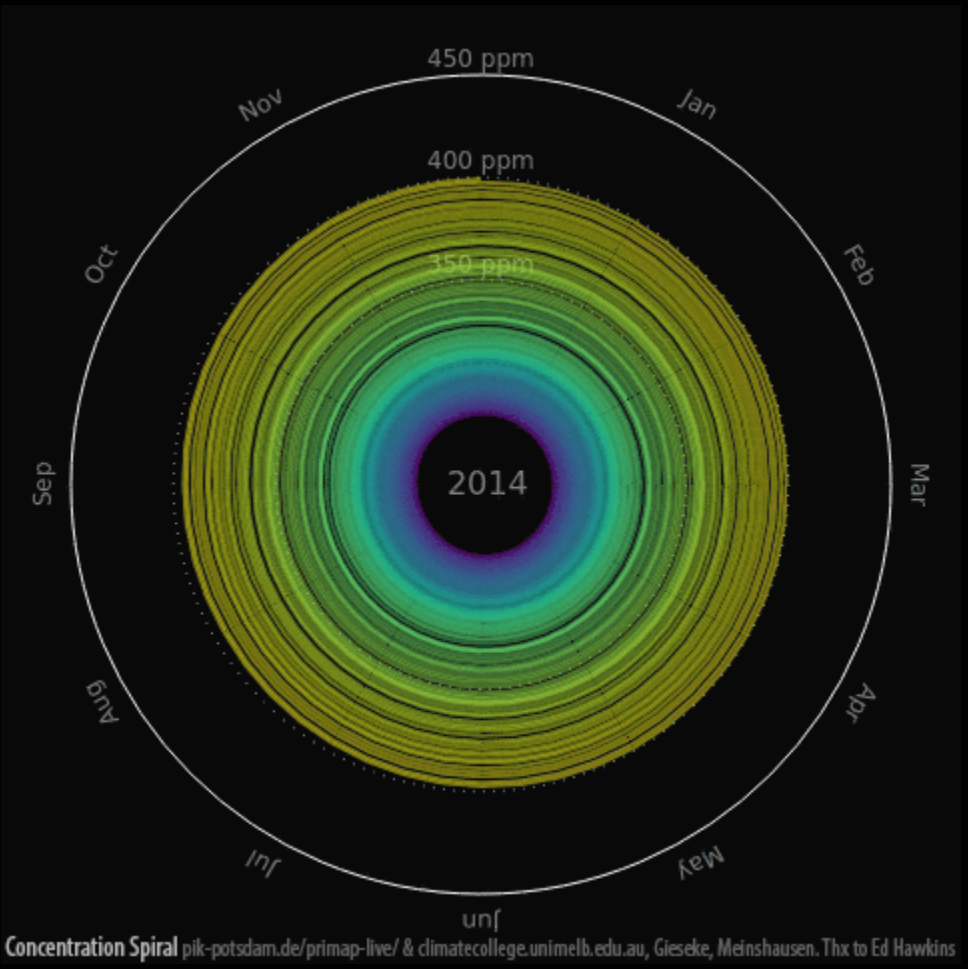

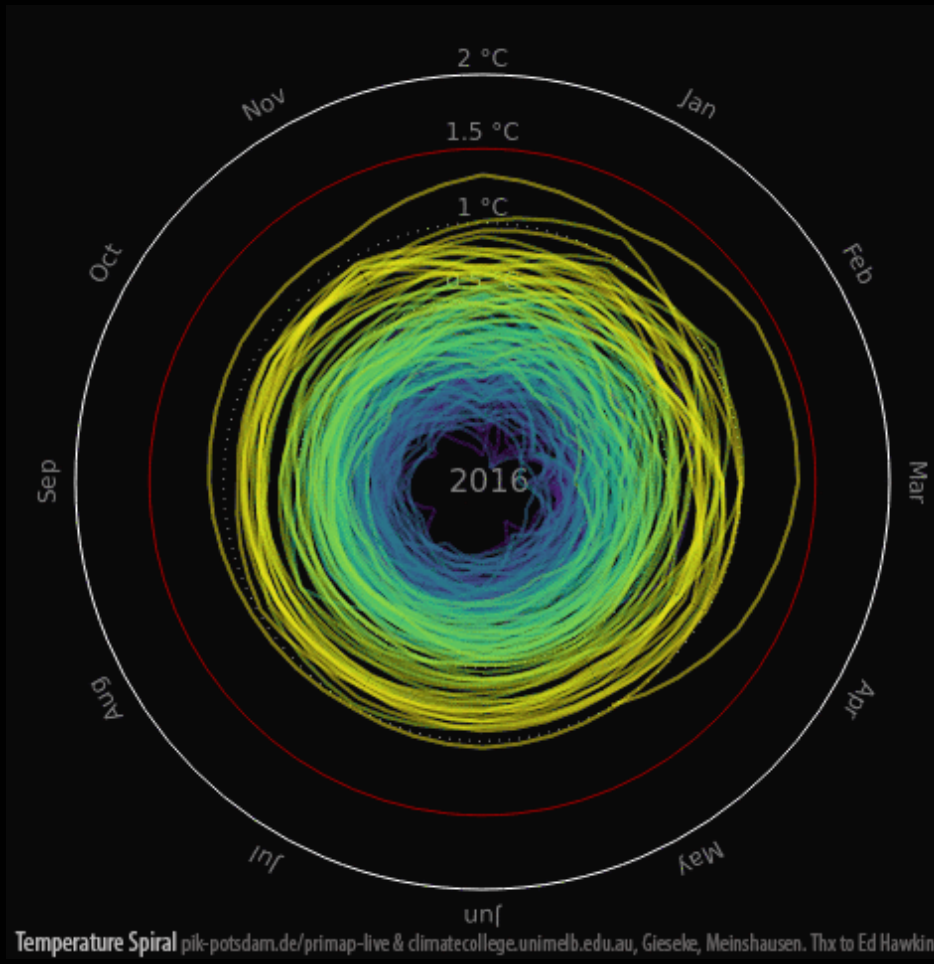

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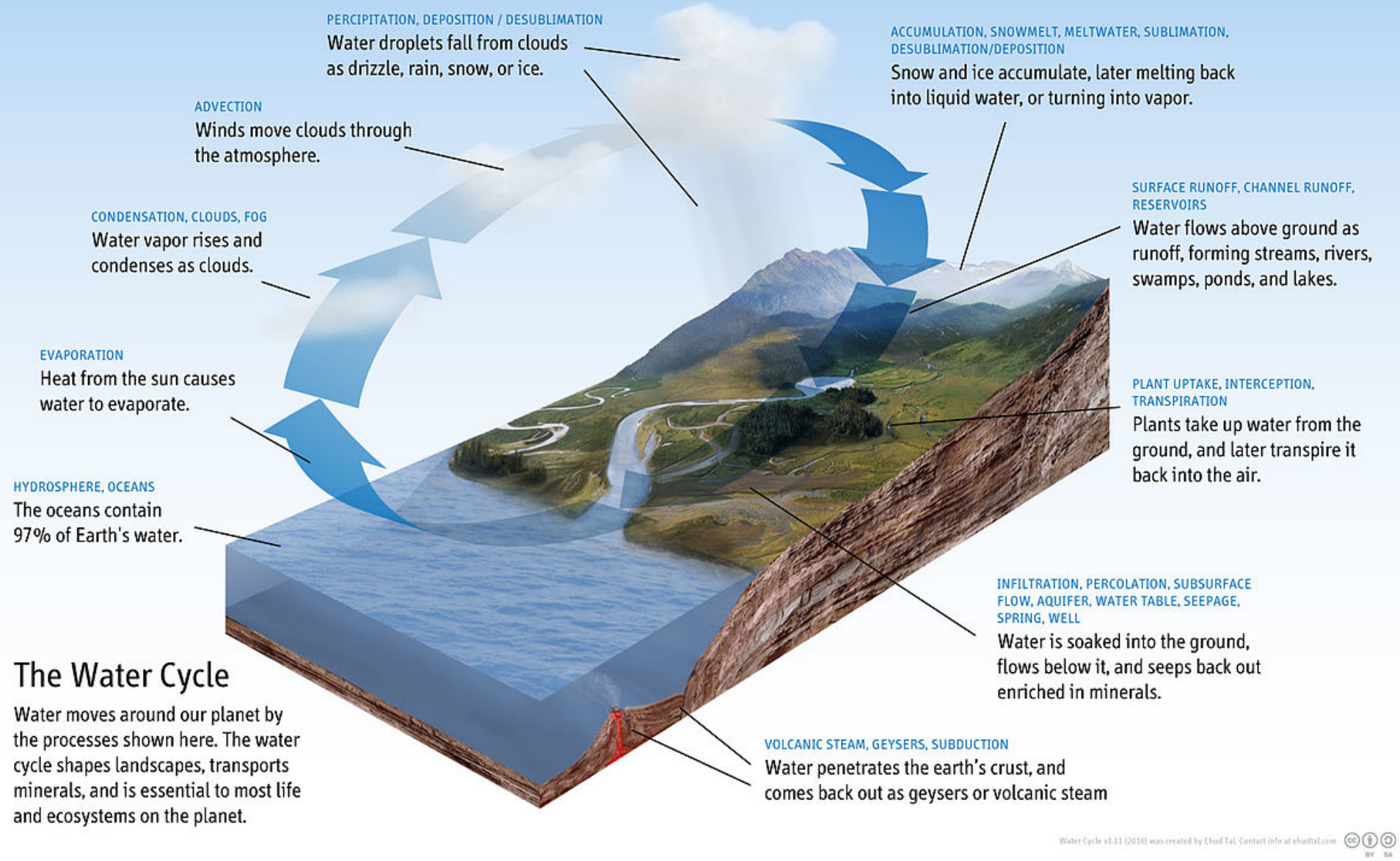


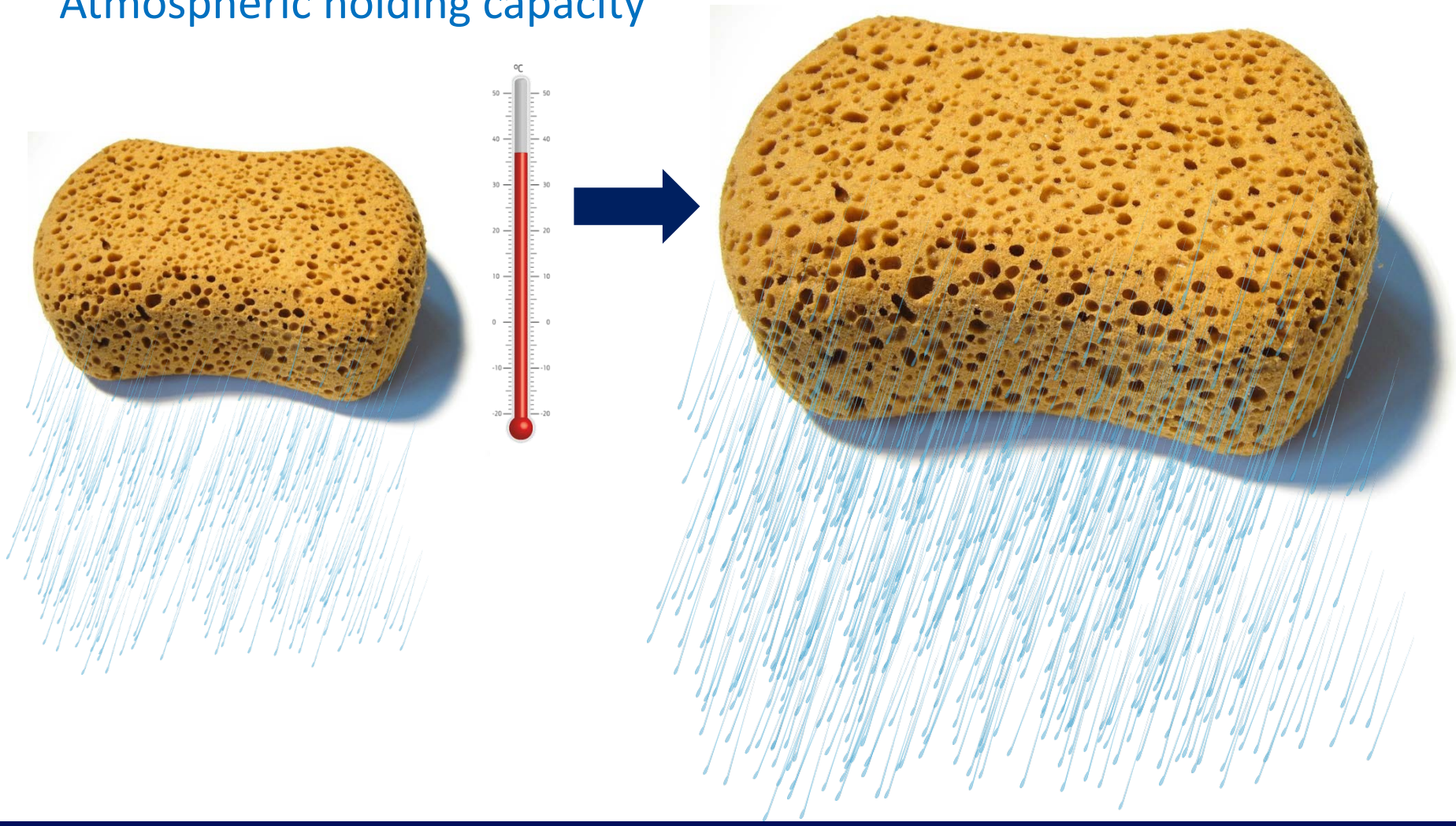
The Water Cycle

Water moves around our planet by the processes shown here. The water cycle shapes landscapes, transports minerals, and is essential to most life and ecosystems on the planet.

Water Cycle v1.11 (2016) was created by Ehud Tal. Contact info at ehudtal.com

Principle #1 – Warm air holds more moisture than cold air.

"Atmospheric holding capacity"



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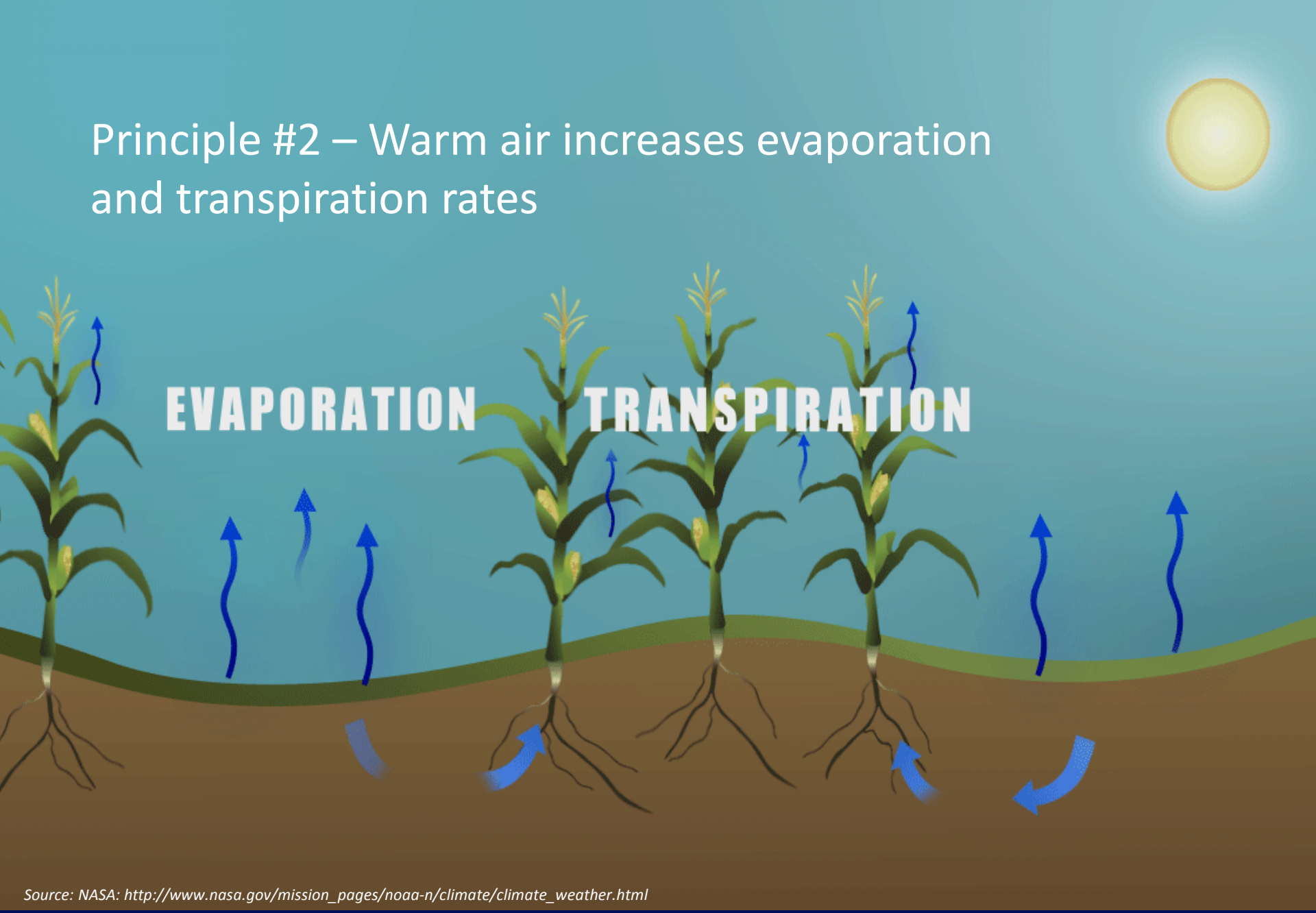
Principle #2 – Warm air increases evaporation and transpiration rates



Source: NASA: http://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html

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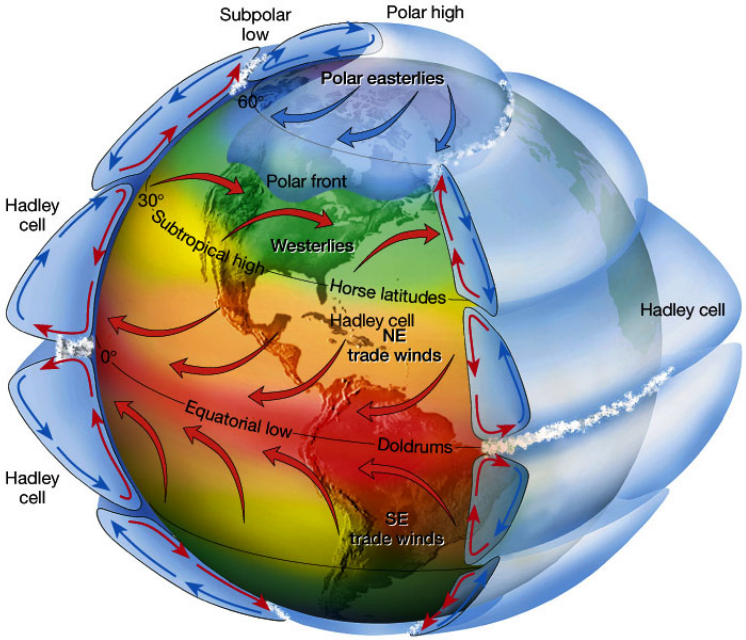
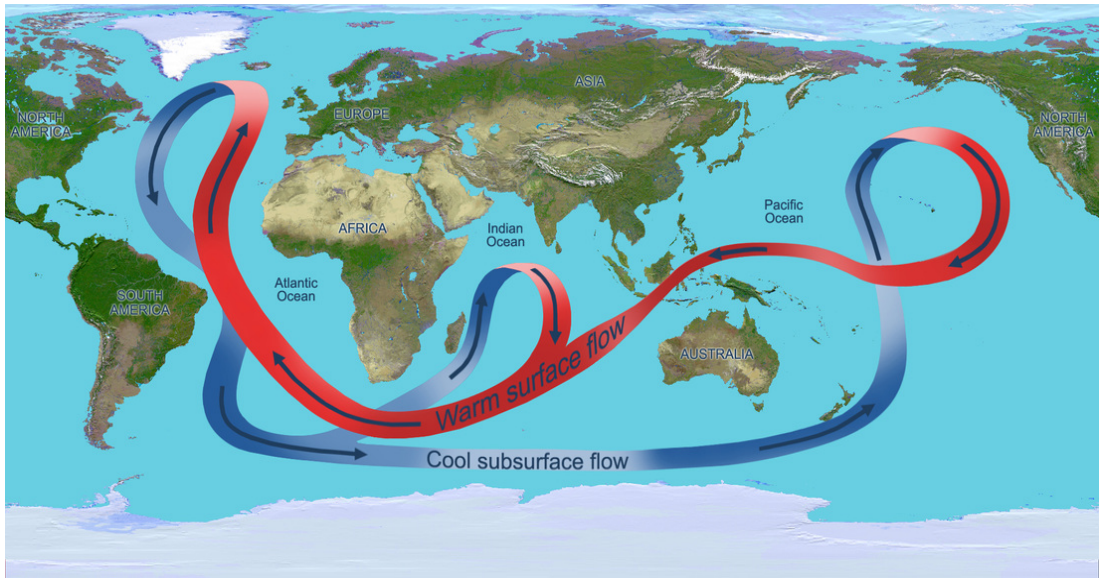
Principle #3 – Temperature changes influence global circulation patterns (atmosphere & ocean)





Sources:
Principles from the Water Research Foundation Project 4381, Effective Climate Change Communication for Water Utilities
Atmospheric circulation patterns and cells from The Atmosphere *by Lutgens and Tarbuck, 2015*
Ocean conveyor belt from NASA/Jet Propulsion Laboratory http://www.nasa.gov/images/content/436189main_atlantic20100325a-full.jpg

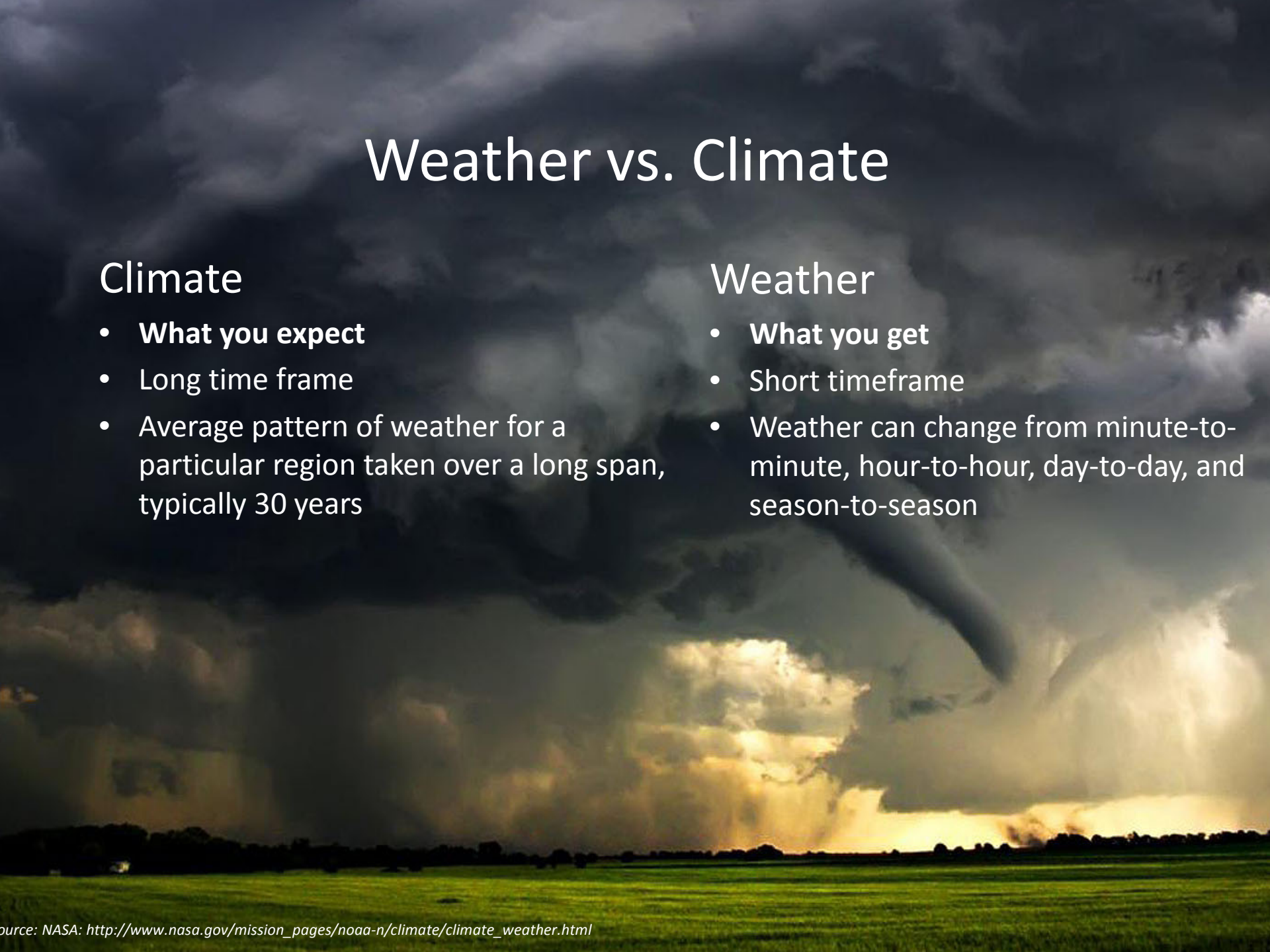
Weather vs. Climate

Climate

- **What you expect**
- Long time frame
- Average pattern of weather for a particular region taken over a long span, typically 30 years

Weather

- **What you get**
- Short timeframe
- Weather can change from minute-to-minute, hour-to-hour, day-to-day, and season-to-season



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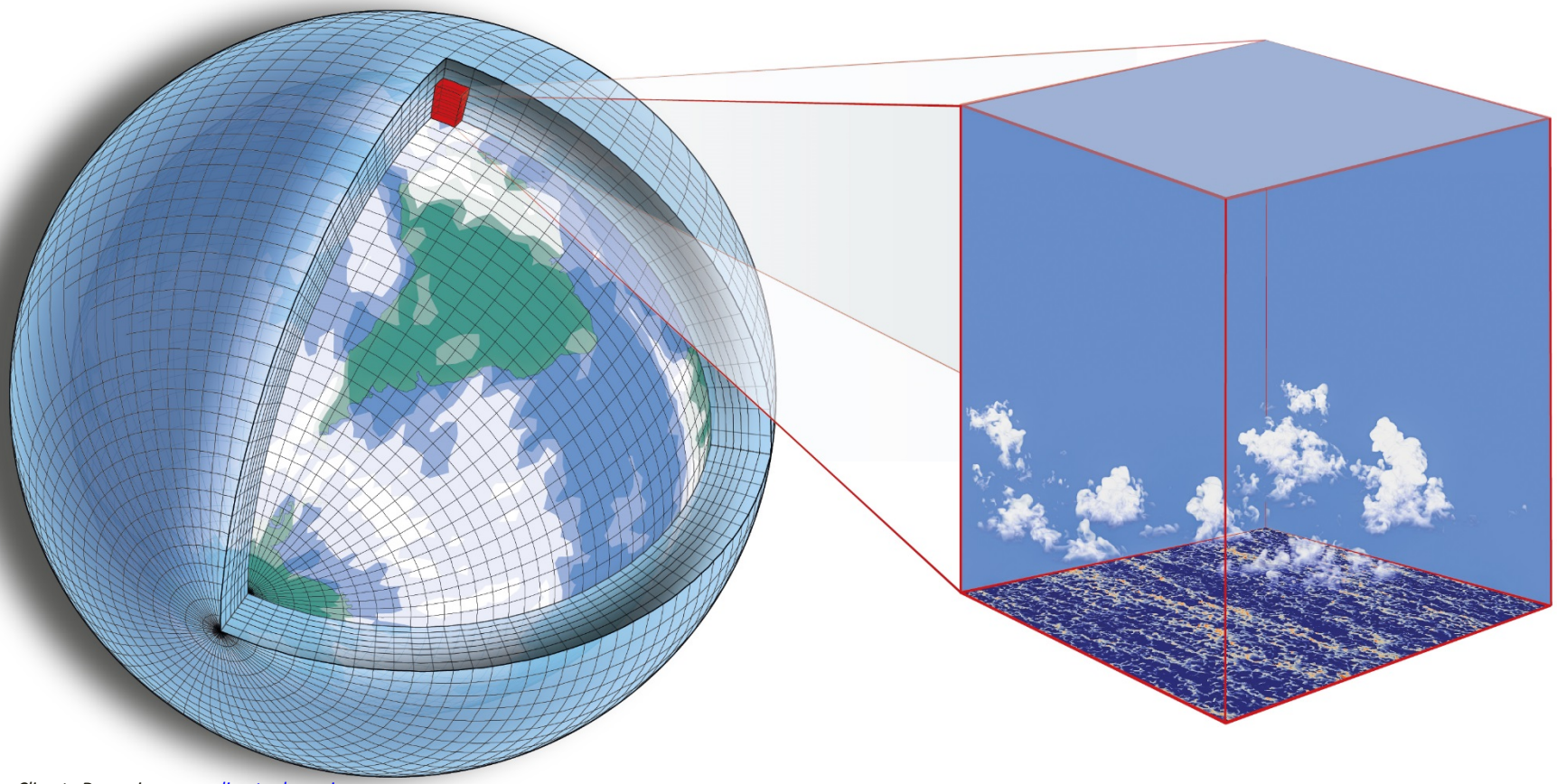
Climate Model Projections

Global Climate Models



Source: Climate Dynamics. www.climate-dynamics.org,
Environmental Science and Engineering California Institute of Technology

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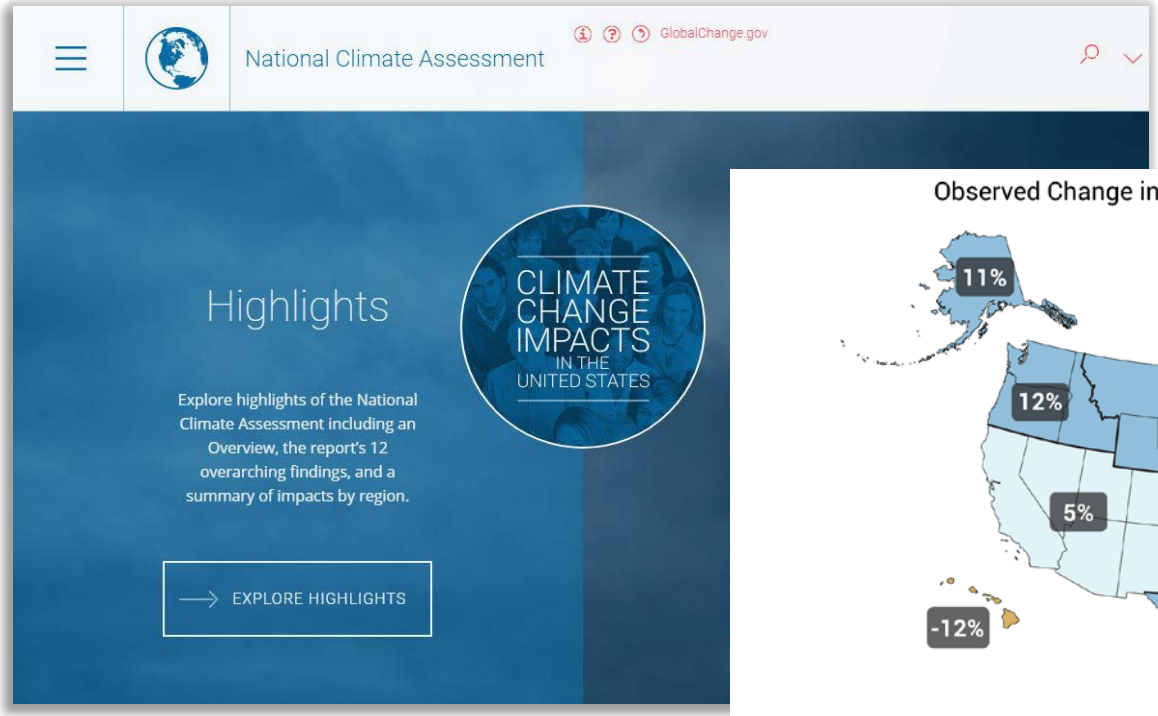
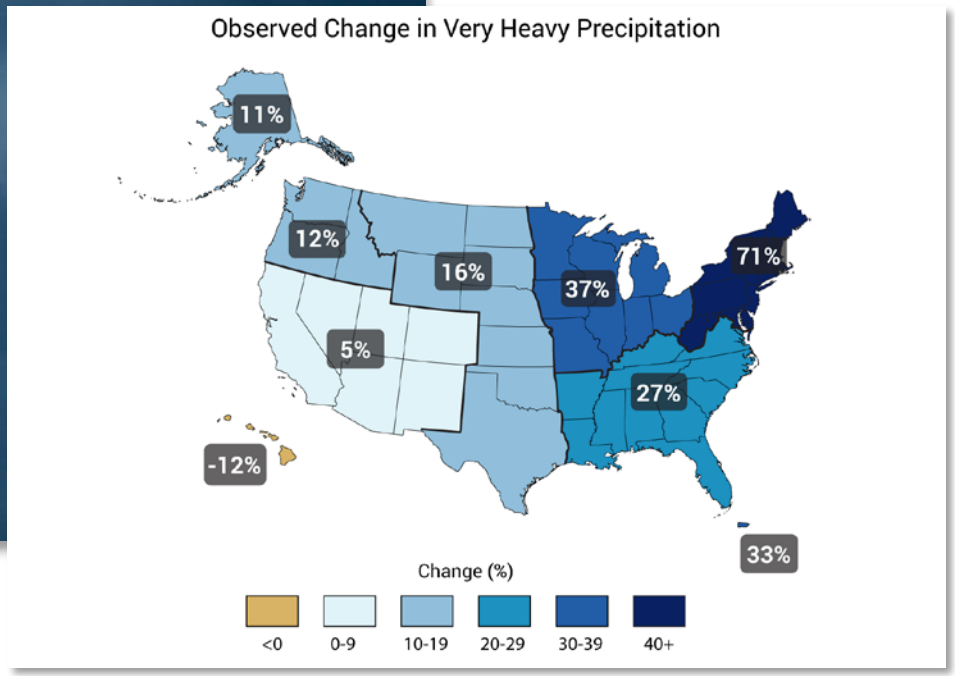
National Climate Assessment



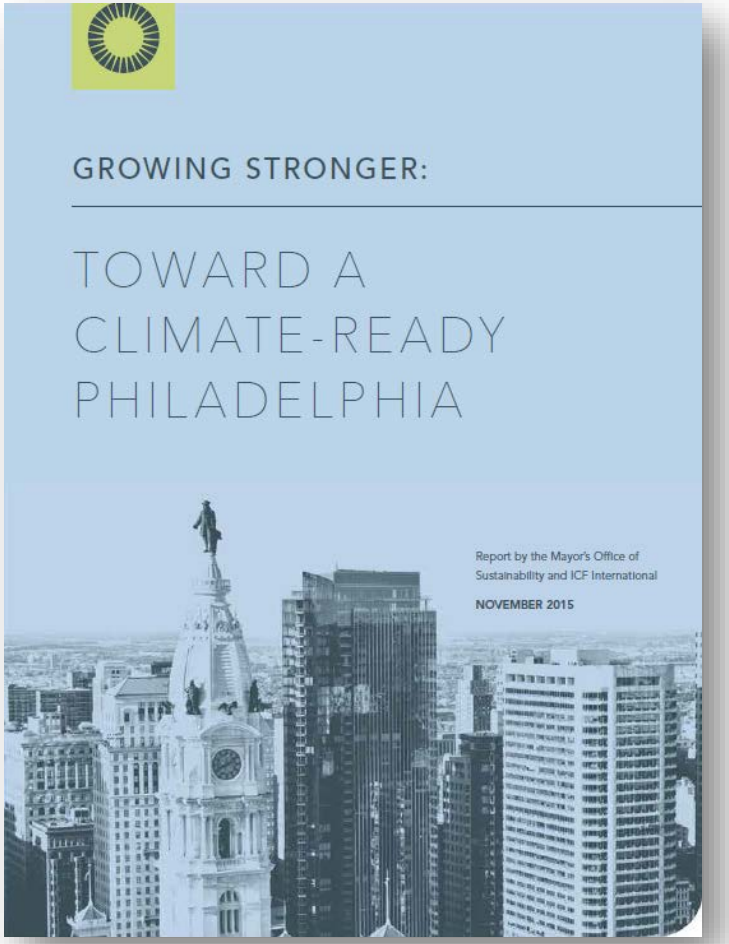


"The Northeast has experienced a greater recent increase in extreme precipitation than any other region in the U.S.; between 1958 and 2010, the Northeast saw more than a 70% increase in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events)" (NCA 2014).

Projections for Risk Assessment

- Precipitation ↑
- Sea level ↑
- Air temperature ↑
- Extreme storm events* ↑
- Drought? ↑ ↓ —

*this is referring to the **number of heavy & extremely heavy precipitation events per year** only



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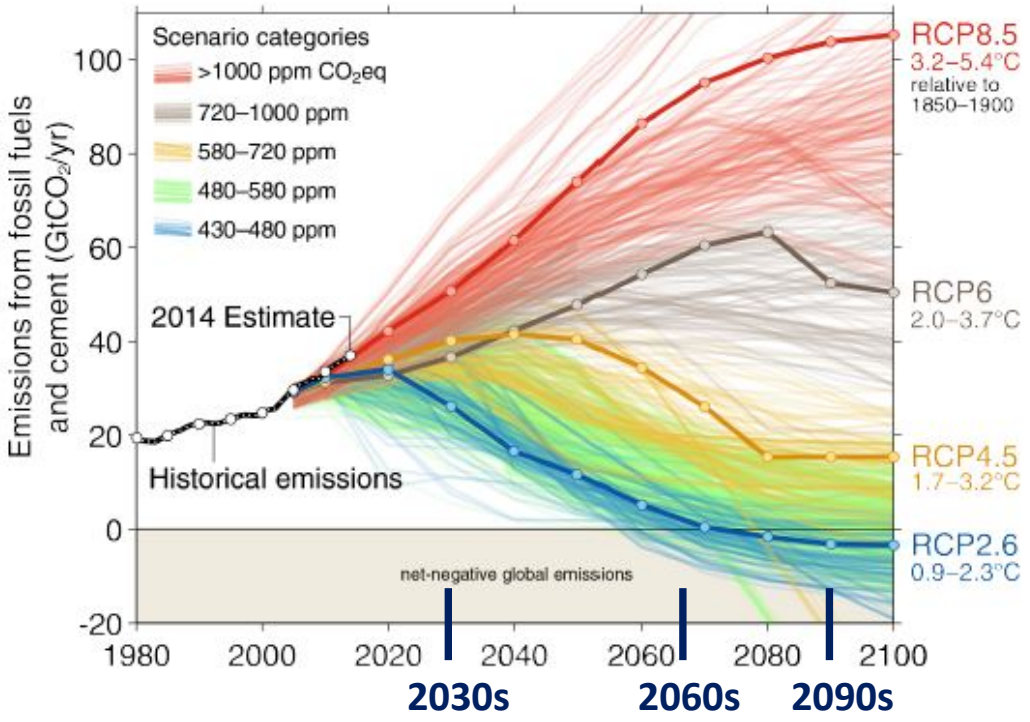
Climate Model Projections

Future emission scenarios



RCP8.5
> 1000 ppm CO_2-eq

RCP6.0
720-1000 ppm CO_2-eq

RCP4.5
580-720 ppm CO_2-eq

RCP2.6
430-480 ppm CO_2-eq
Large and sustained mitigation is required

Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014

GLOBAL CARBON PROJECT

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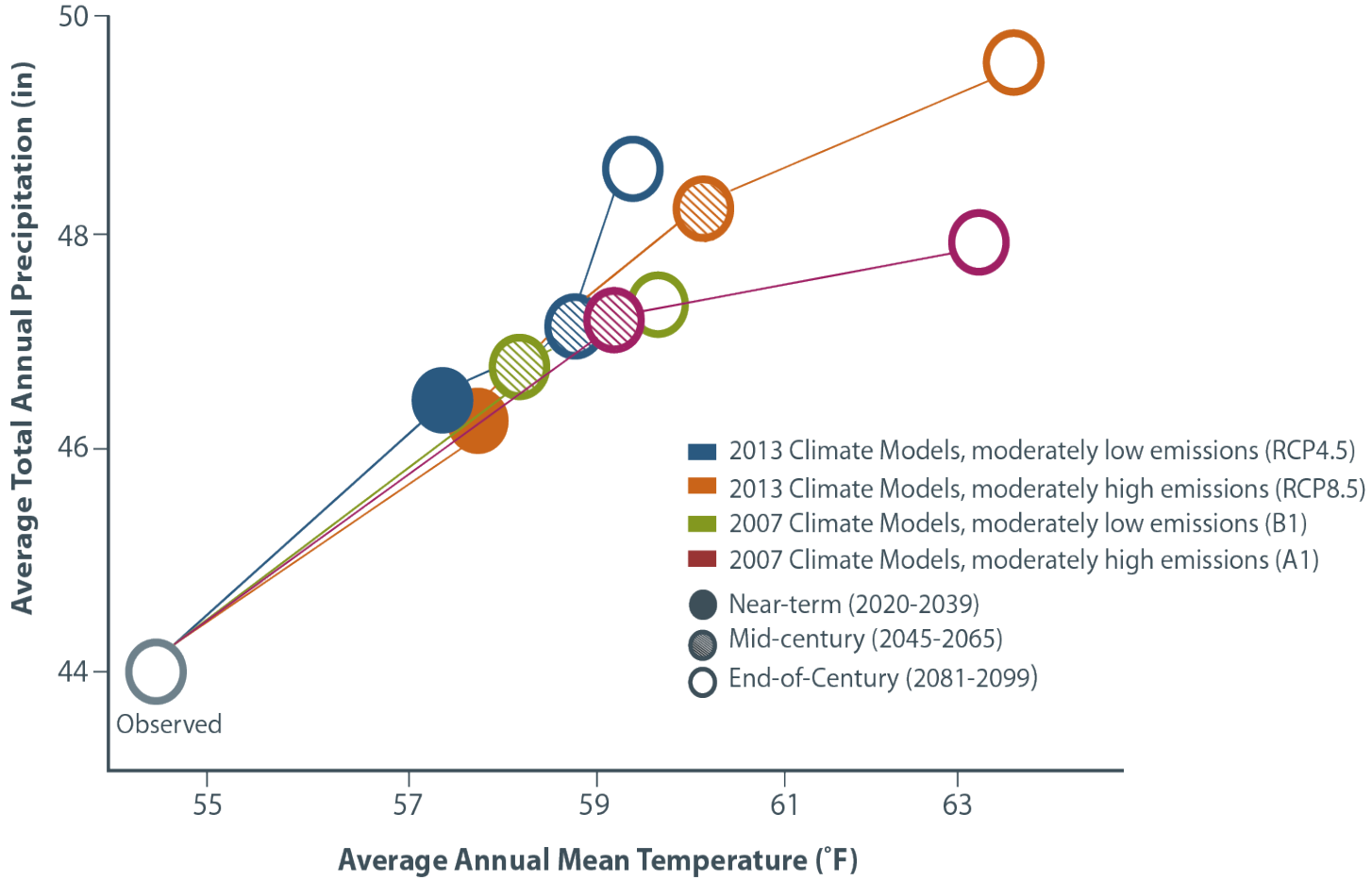
Climate Model Projections

Projected Changes in Philadelphia: Temperature & Precipitation



Source: Useful Climate Information for Philadelphia, ICF 2014

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Climate Model Projections

Projected Changes in Philadelphia: Temperature & Precipitation

Source: CCAP analysis of GCM output under RCP8.5

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Climate Change Impacts

Examples of local impacts from increasing precipitation

Sources: www.phillywatersheds.org

- Source water quality degradation
- Erosion of stream banks and channels
- Localized flooding
  - Riverine/out-of-bank
  - Surface and/or property flooding (drainage system capacity exceeded)

Sources: www.phillywatersheds.org

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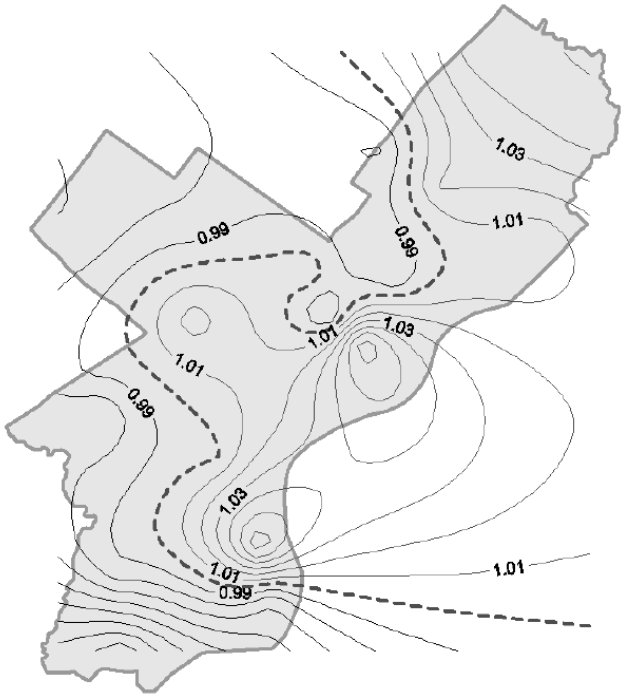
Climate Change Adaptation Planning

Use of Precipitation Information

Stormwater Conveyance System Performance

- Hydrologic & hydraulic (H&H) models use precipitation time series to simulate system performance (CSS & MS4)
- Input requirements are stringent; inaccuracies have direct consequences on modeling process and results
- High resolution precipitation time series are needed
- A long-term record is important to capture variability



LTCPU, 2009: Rainfall Distribution Map for PWD 24-raingage Network Bias Adjusted, Data for Calendar Year 2005

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Climate Change Adaptation Planning

Use of Precipitation Information

Planning, Research and Design

- Flood management planning and flood risk analyses (storm probabilities)
- System planning and sewer design (rainfall intensities and time to peak during a storm)

Green Stormwater Infrastructure

- Designed to capture current 90th percentile storm depth (~1-2 inch)

Source: www.phillywatersheds.org

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Climate Change Adaptation Planning

Use of Precipitation Information

Characterizing Extreme Rainfall

- Intensity-Duration-Frequency (IDF) curves
- Main characteristics of rainfall are:
  - Volume
  - Frequency
  - Intensity (i = volume/duration)
- For specified frequencies, IDF curves show average rainfall intensity as a function of duration

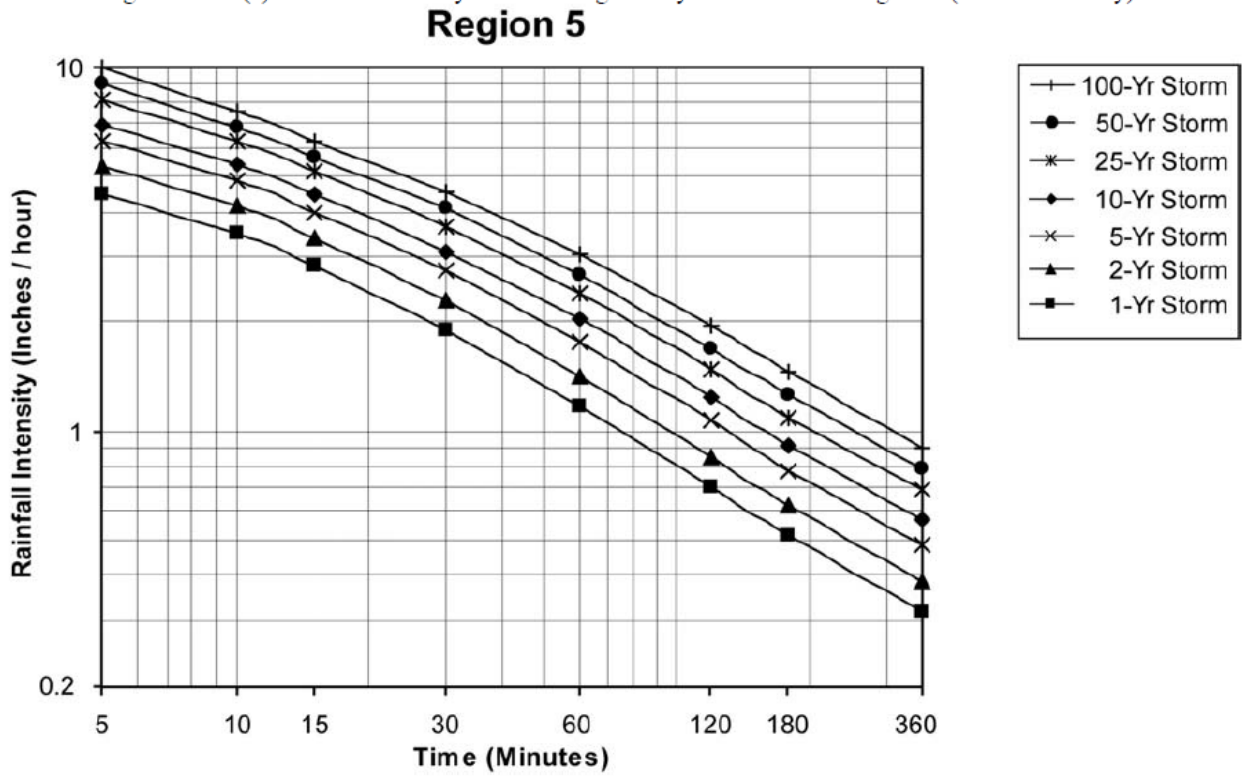
Climate Change Adaptation Planning

Use of Precipitation Information

Chapter 7, Appendix A - Field Manual for Pennsylvania Design Rainfall Intensity Charts from NOAA Atlas 14 Version 3 Data

Publication 584
2010 Edition

Figure 7A.16(a) Rainfall Intensity for 1- through 100-year Storms for Region 5 (U.S. Customary).



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Climate Change Adaptation Planning

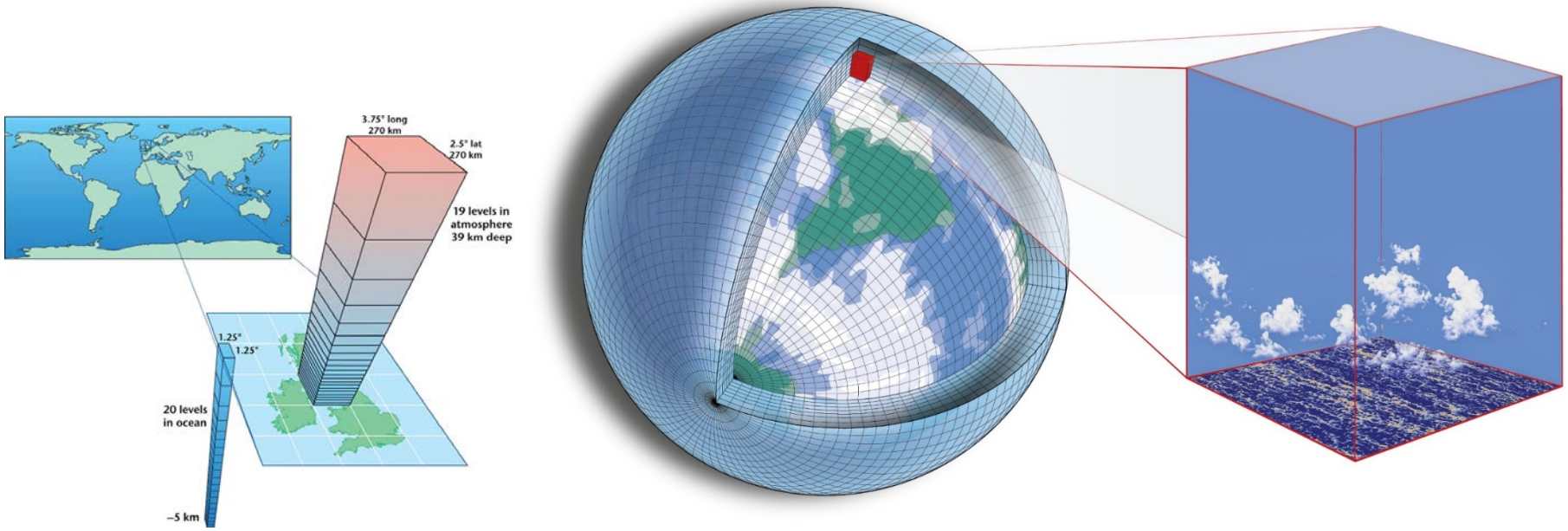
Creating Actionable Science

“Actionable science provides data, analyses, projections or tools that support planning and decision making under climate change.”

(Vogel et al, 2016)

Climate Change Adaptation Planning

Creating Actionable Science



Global Climate Model Projections

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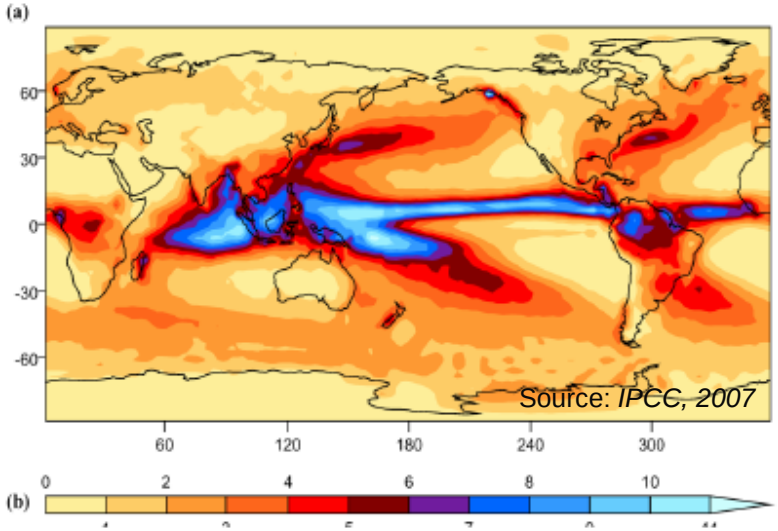
Climate Change Adaptation Planning

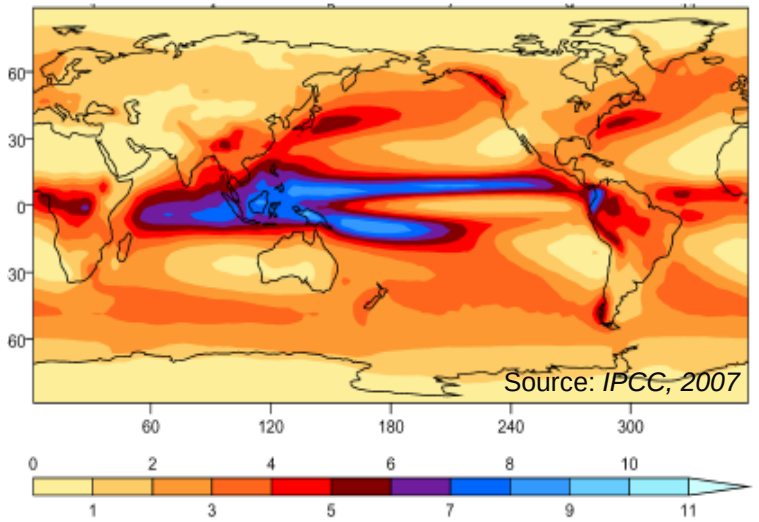
Creating Actionable Science

Global Climate Models

- Perform well at large spatial scales (regional to global) and long time scales (seasonal to multi-annual averages)



Observed Rainfall (1980-1999)



Modeled Rainfall (1980-1999)

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Climate Change Adaptation Planning

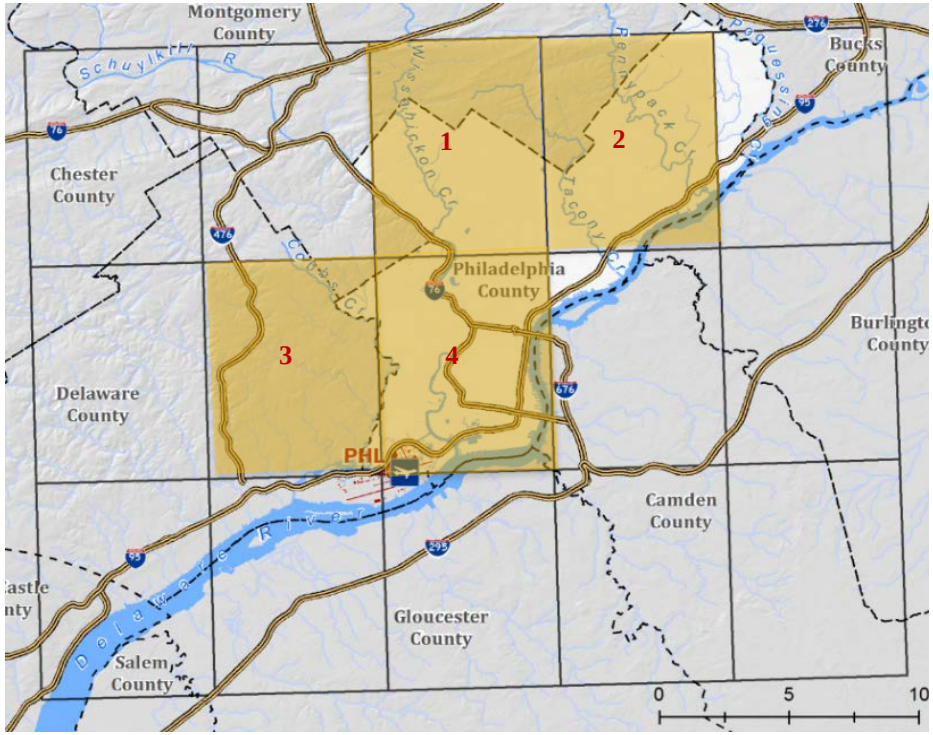
Creating Actionable Science

- Statistically downscaled data from the Bureau of Reclamation (and others) – CMIP5
- Spatial resolution: 1/8° grid cells (approx. 7.5mi x 7.5 mi) - 4 over Philadelphia
- 9 GCMs
- RCP8.5 climate scenario
- Available period: 1950-2099
- Temporal resolution: daily

RECLAMATION NCAR USGS

Santa Clara University CIRES CLIMATE CENTRAL

SCRIPPS INSTITUTION OF OCEANOGRAPHY



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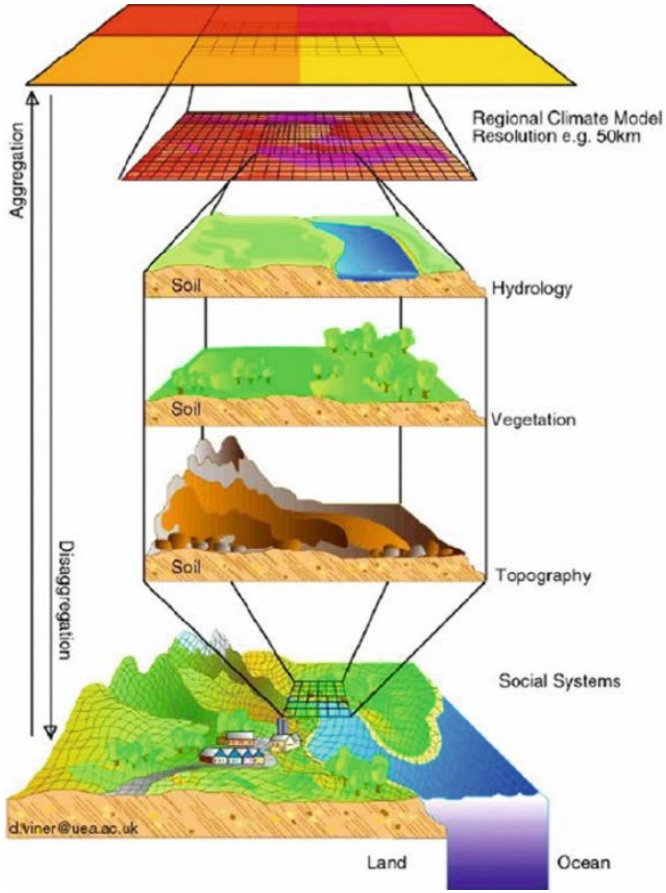
Climate Change Adaptation Planning

Creating Actionable Science

The challenge

- …but even statistically downscaled GCM output is not always sufficient for stormwater applications because high temporal resolutions are required
- Another approach must be utilized to make use of rainfall projections in stormwater system modeling and design



Source: David Viner, Climatic Research Unit, University of East Anglia, UK

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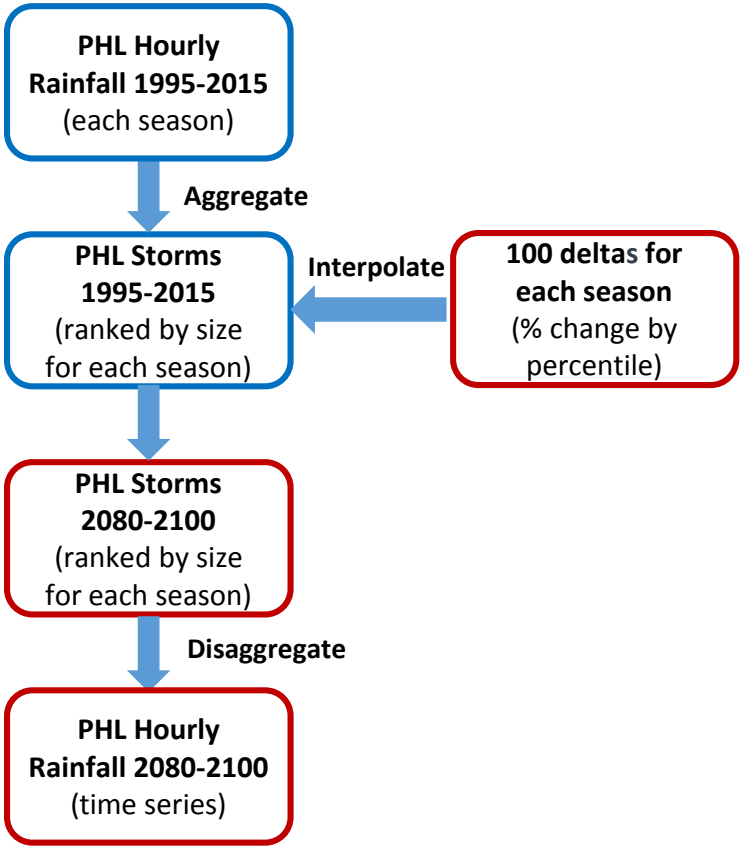
Climate Change Adaptation Planning

Creating Actionable Science

Future time series



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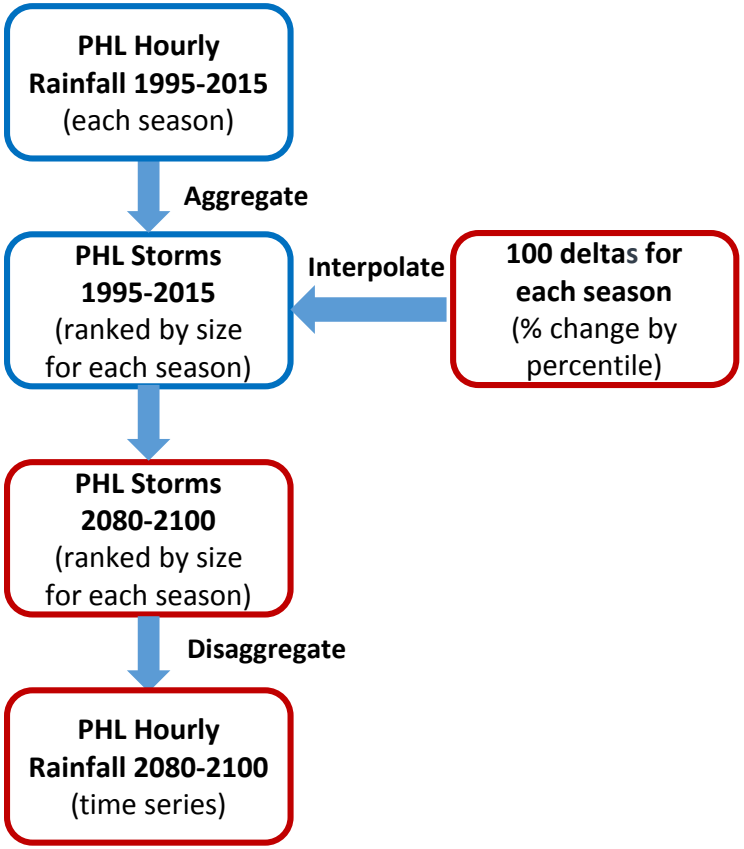
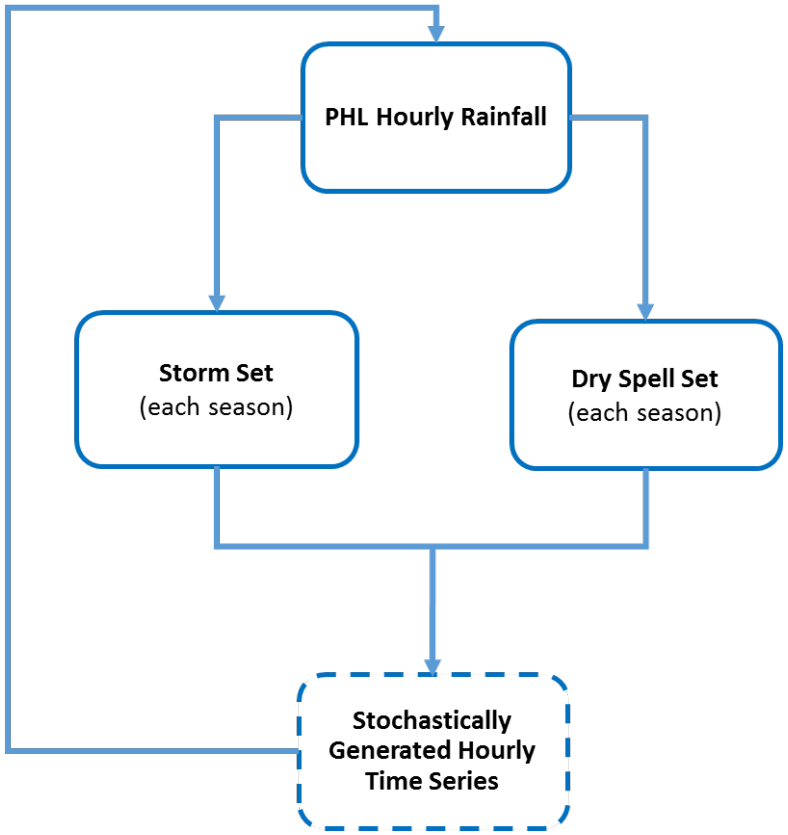
Creating Actionable Science

Future time series



Stochastically generated time series



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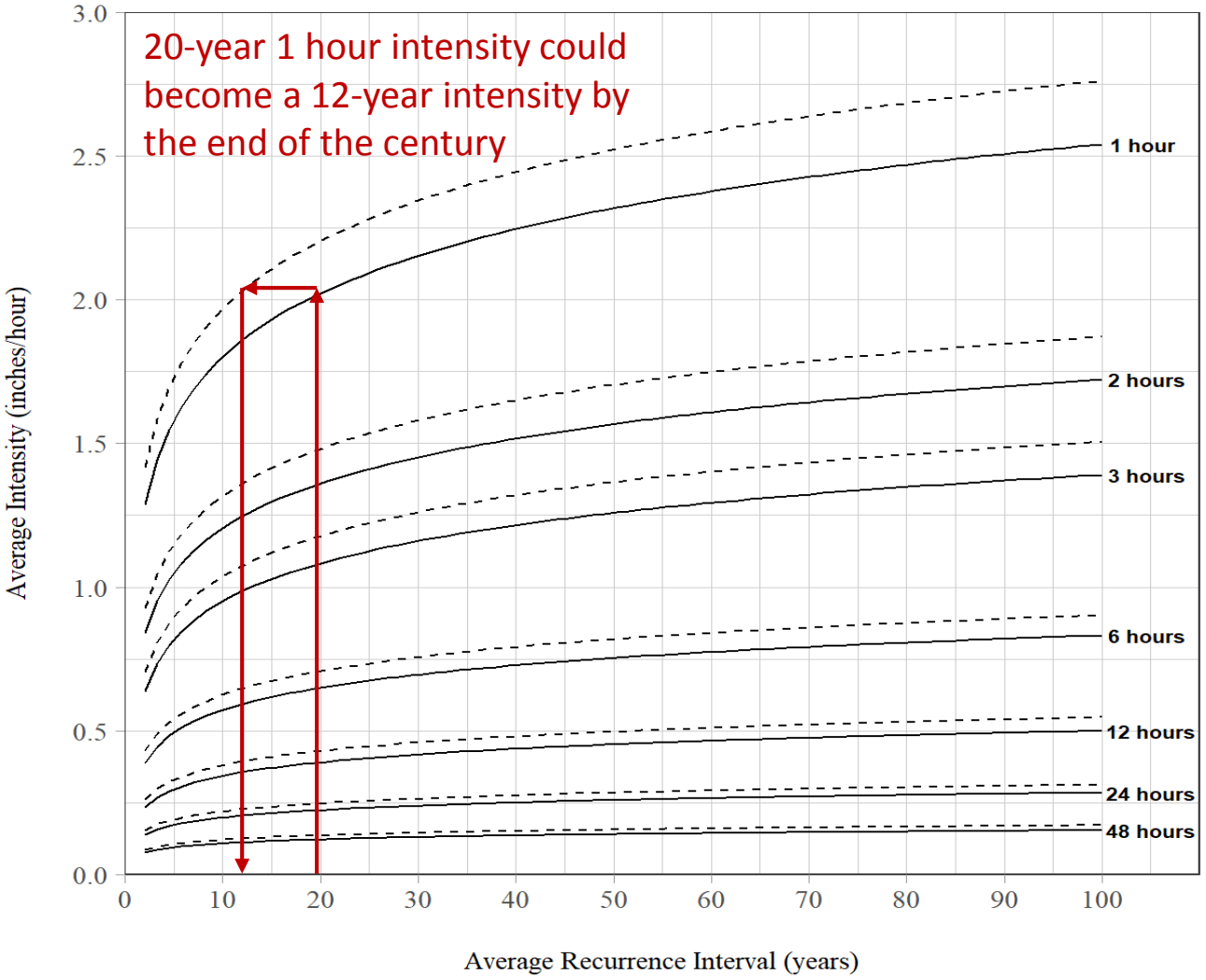
Climate Change Adaptation Planning

Creating Actionable Science

CCAP developed method to:

- Generate future (sub)hourly precipitation time series that preserve local precipitation patterns
- Evaluate extreme future storm events
- Explore variability in current and projected precipitation patterns

Climate Change Adaptation Planning



PHL Current vs. PHL Future

Created using PHL time series (1900-2016)

Created using GCM projections (2080-2100)

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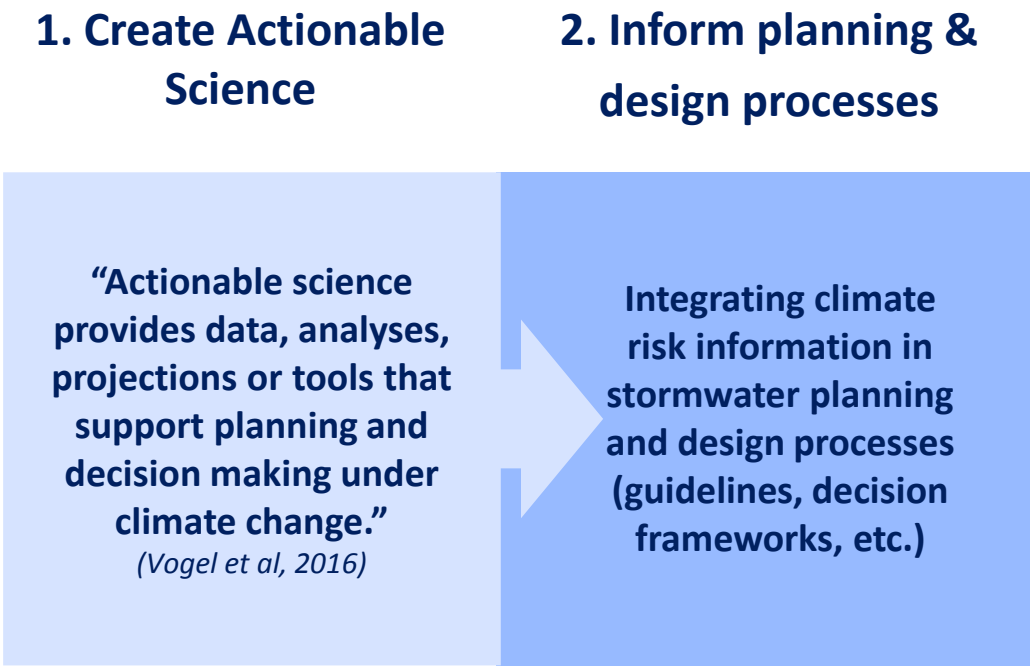
Creating Actionable Science



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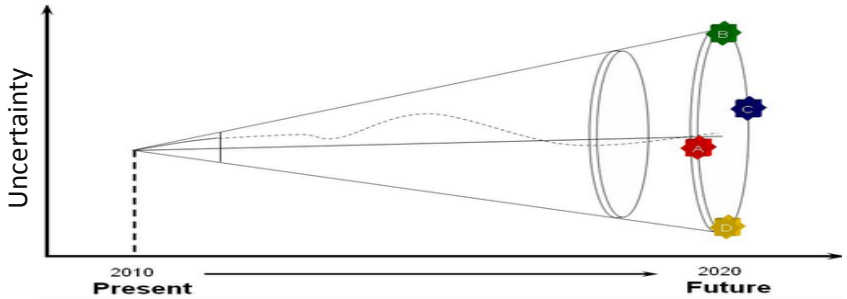
Climate Change Adaptation Planning

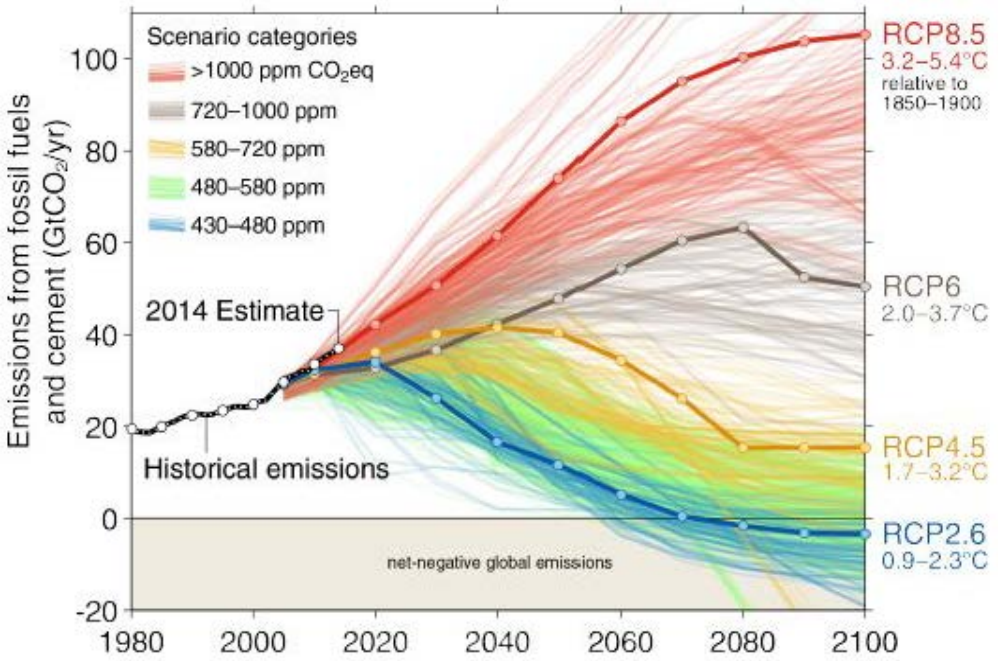
Creating Actionable Science

The Challenge: Uncertainties

- Emission scenarios
- GCMs
- Natural variability
- Downscaling



The Futures cone (Parson et al. 2013)



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Overview

1. PWD Climate Change Adaptation Planning in Context
2. Climate Change Primer
   - Climate Change & the Water Cycle
   - Global Climate Model Projections
3. Climate Change Adaptation in Practice
   - Precipitation Applications
   - Creating Actionable Science
   - Best Practices

Climate Change Adaptation Planning

Best practices

1. Evaluate current planning methodologies and design criteria using:

- Most up to date information to represent current conditions
- Best available science (most recent climate model information) to represent potential future conditions (multiple CMIP5 models)

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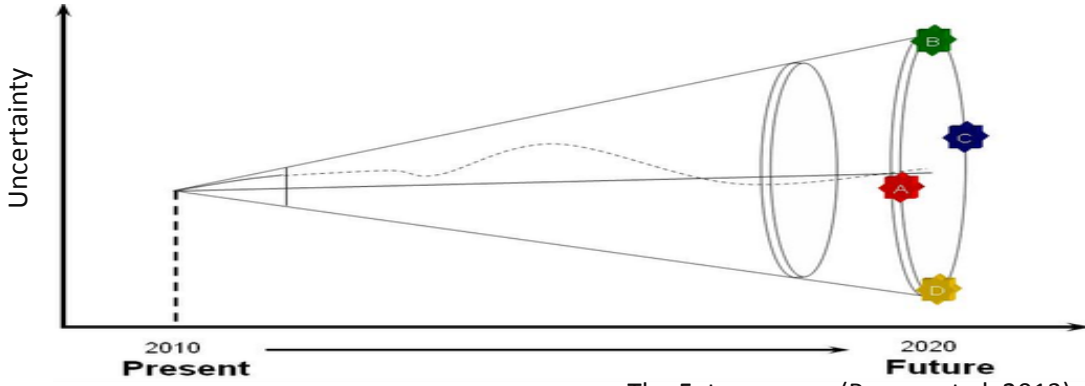
Climate Change Adaptation Planning

Best practices

2. Use climate change info. to inform planning and design criteria

- Climate change is one of many uncertain factors that can influence the future performance of engineered systems (population growth, land use changes, new or changing regulations, etc.)
- There are ways to account for uncertainty:
  - Consider the useful service life
  - Test sensitivity of system to range of climate scenarios
  - Use a safety factor in design



The Futures cone (Parson et al. 2013)

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Climate Change Adaptation Planning

Best practices

3. Consider adaptive planning and design practices

- **Phased adaptation** – plan for future upgrades or design modifications when possible (e.g. stormwater detention pond might need to be expanded in future so acquire lands now)

http://www.greenwoodvillage.com/357/Caley-Detention-Pond

PWD Subsurface Infiltration

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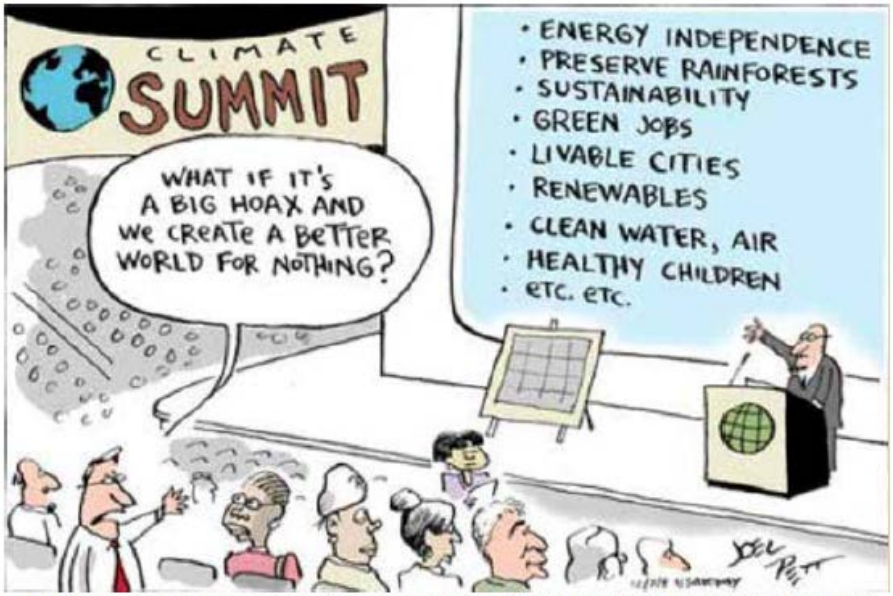
Climate Change Adaptation Planning

Best practices

3. Consider adaptive planning and design practices

- **Low regret** or **no regret** investments



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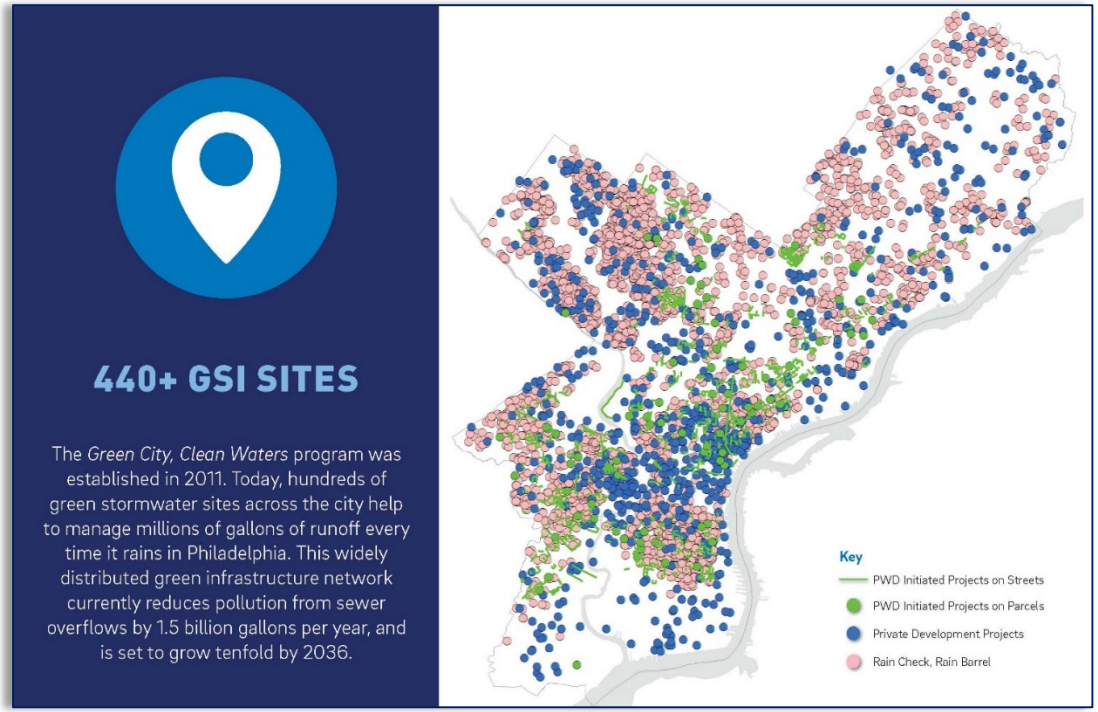
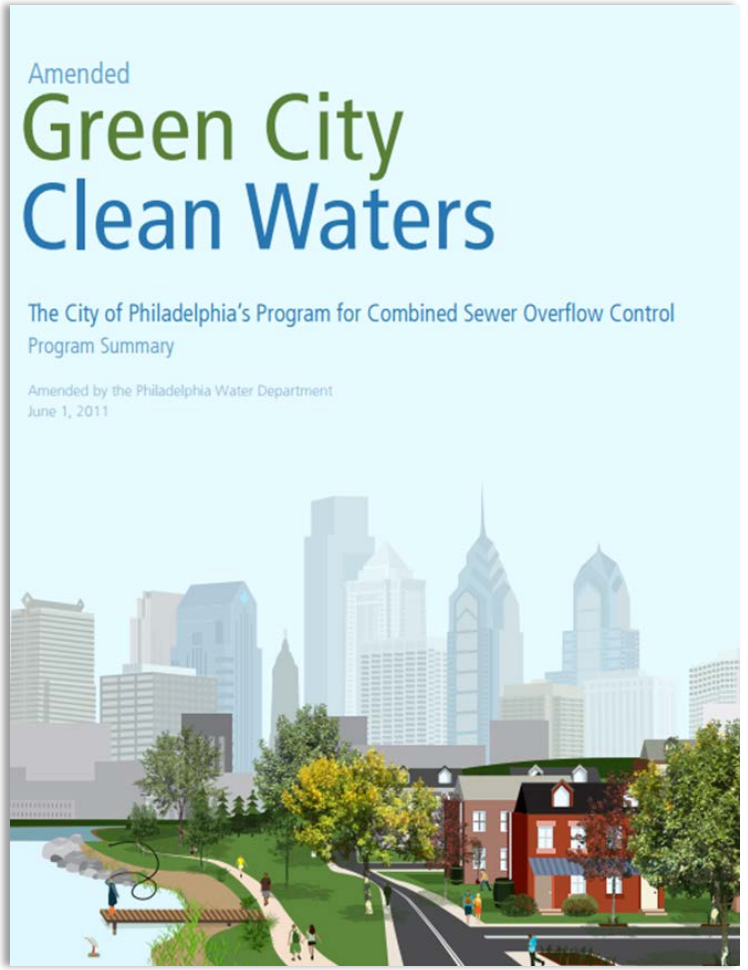
Climate Change Adaptation Planning

Adaptive Stormwater Management

Green Stormwater Infrastructure





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Climate Change Adaptation Planning

Adaptive Stormwater Management

Green Stormwater Infrastructure (GSI)

- GSI is a flexible solution for managing stormwater runoff in the context of climate change
- Provides additional benefits
  - Improved air and water quality
  - Reduced heat island effect
  - Aesthetic and recreational value

www.phillywatershedss.org

Thank you!

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Photo by Joseph Kaczmarek

Key Takeaways

- Global Climate Model (GCM) projections indicate increasing rainfall (more volume, higher intensity) for Philadelphia
- Despite uncertainty with climate projections, climate change needs to be considered as an additional planning criterion
- There is a need to create actionable science in order to bridge the gap between readily available GCM output and urban stormwater management applications
- With actionable science, planning and design standards can be evaluated against the best available climate science
- Best practices already exist when it comes to adaptive planning and design strategies