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What: The Resources and Tools for Decision Scaling Climate Risk Analysis

CWEMF 2025

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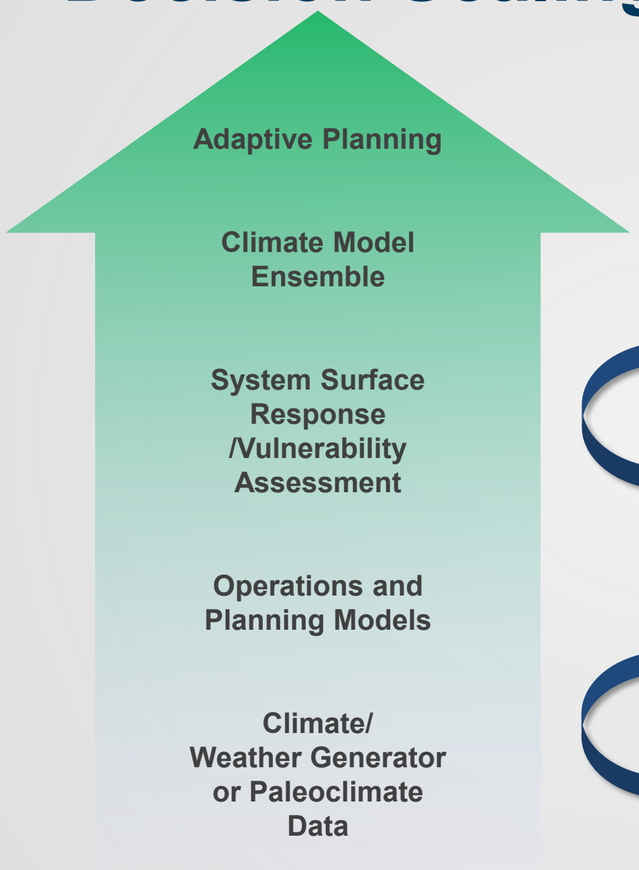
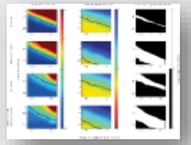
Climate Change Group

Outline

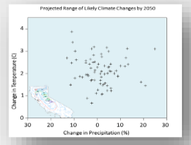
- Model, Metrics, Adaptation Strategies
- Baseline Datasets
- Stress Test Perturbation Space Dataset
- Future Projection Dataset
- Risk Analysis
- Analysis Pathways

“Bottom Up” or **Decision Scaling** Approach

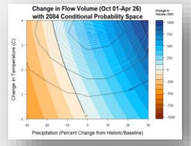




Source:
Poff et al. (2016)



Source:
DWR VA



Source:
SEI WEAP

Systematic Climate Perturbations

Other images source: Wikimedia Commons
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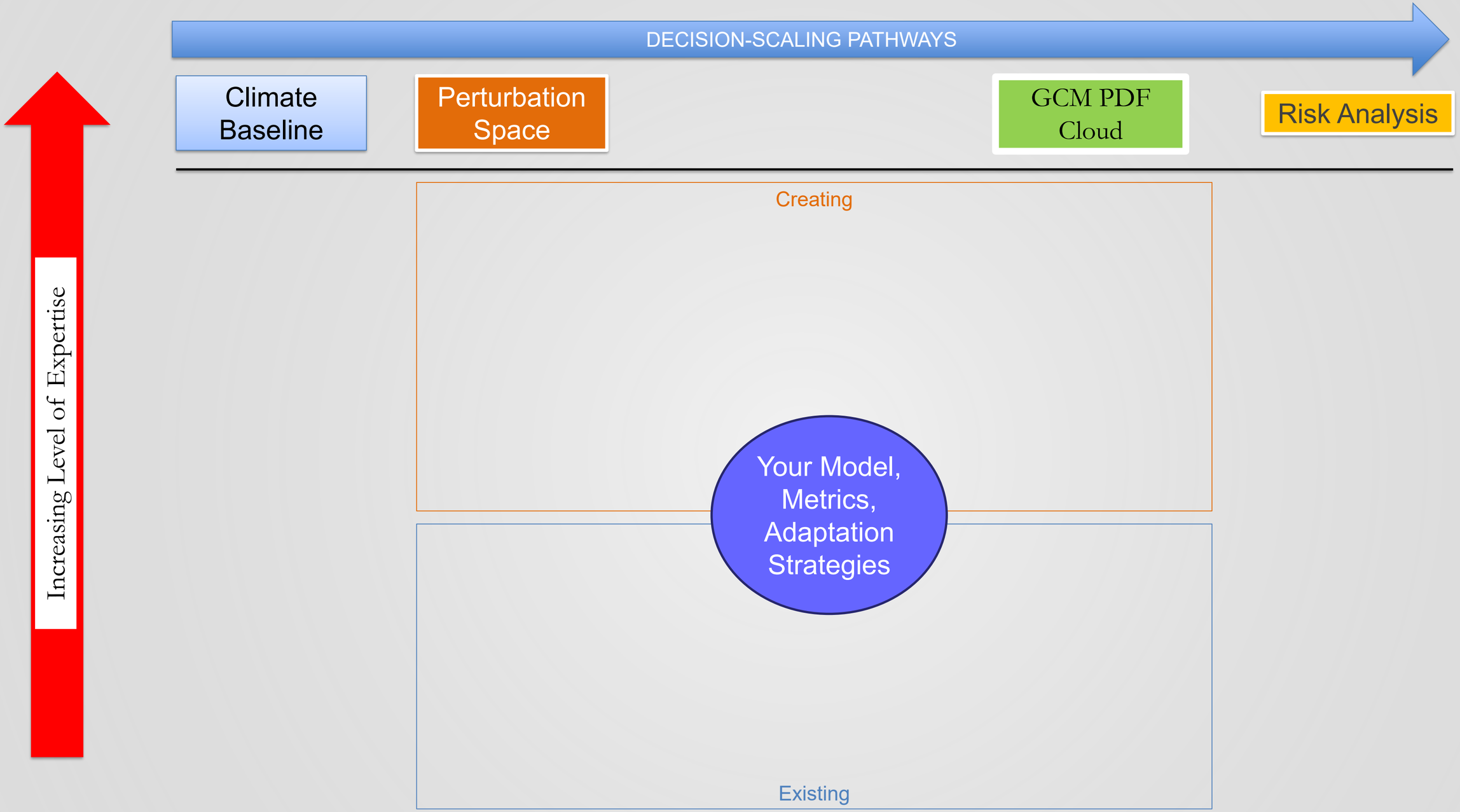

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What

MODEL, METRICS, ADAPTATION STRATEGIES

Key Components

- System Model:
  - A simulation model that captures system behavior (e.g., reservoir operations, water supply-demand, etc).
  - Hydrologic model is common: climate inputs → streamflow, soil moisture, etc.
    - Input to operations model
  - Can also be financial or economic if water-related decisions are cost-driven.
- What Input Dataset?
  - Climate in the form of Gridded or Gauge data?
  - Hydrological input?

Key Components

- Performance Metrics
  - Quantifiable criteria that define success or failure.
  - Examples:
    - Water reliability (% of demand met)
    - Flood frequency or volume
    - Hydropower generation
    - Economic losses or ROI
    - Ecosystem thresholds
- Stress Test Input Space
  - Create a wide range of climate stressors (temperature, precipitation scenarios).
  - Translate to hydrologic inputs via models.
  - Explore system behavior across uncertainty space, not just historic or GCM projections.

Existing DCR LOC Analysis

- Can you utilize the Level of Concern Scenarios from DCR 2023
  - Water Supply in Central Valley
  - Dataset is product of Decision scaling
  - Not for Flood risk
- Later – CVFPP 2027
  - LOCs for Flood (not yet available)

Eight River Index April to July		
Level of Concern (PCTL)	Change in Temperature (°C)	Change in Precipitation (%)
50th	1.5 °C	+1.5%
65th	1.6 °C	+0.8%
70th	1.6 °C	+0.3%
75th	1.7 °C	+0.1%
80th	1.7 °C	-0.1%
95th	1.8 °C	-1.8%

DECISION-SCALING PATHWAYS

Climate Baseline

Perturbation Space

GCM PDF Cloud

Risk Analysis

Increasing Level of Expertise

Creating

Eight River Index April to July

Level of Concern (PCTL)	Change in Temperature (°C)	Change in Precipitation (%)
50th	1.5 °C	+1.5%
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75th	1.7 °C	+0.1%
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95th	1.8 °C	-1.8%

Your Model, Metrics, Adaptation Strategies

Existing LOC Scenarios (Water Supply- Central Valley)

Existing LOC Scenarios (Water Supply – Central Valley)

Existing

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What

BASELINE DATASETS

Baseline Datasets (Single Time Series)

With long enough history (e.g. 50 years)

- **DWR-WGEN – HUC8 Watershed Average Baseline .csv's**
  - **Daily - Precipitation, Max/Min Temperature**
  - Could be used to for statistical analysis,
    - e.g. Return events
  - Per HUC8 for easy delineation
  - Easier Data Transfer
  - https://cadwr.box.com/s/g7myvnk4izcgdg6wdcudobuc8583jv05
- **Local Station Gauge Data**
  - Could be used to for statistical analysis,
    - e.g. Return events
  - Could be used with Local Hydrologic model
  - Per HUC8 for easy delineation
  - CDEC: https://cdec.water.ca.gov/reportapp/javareports?name=DLYPCP

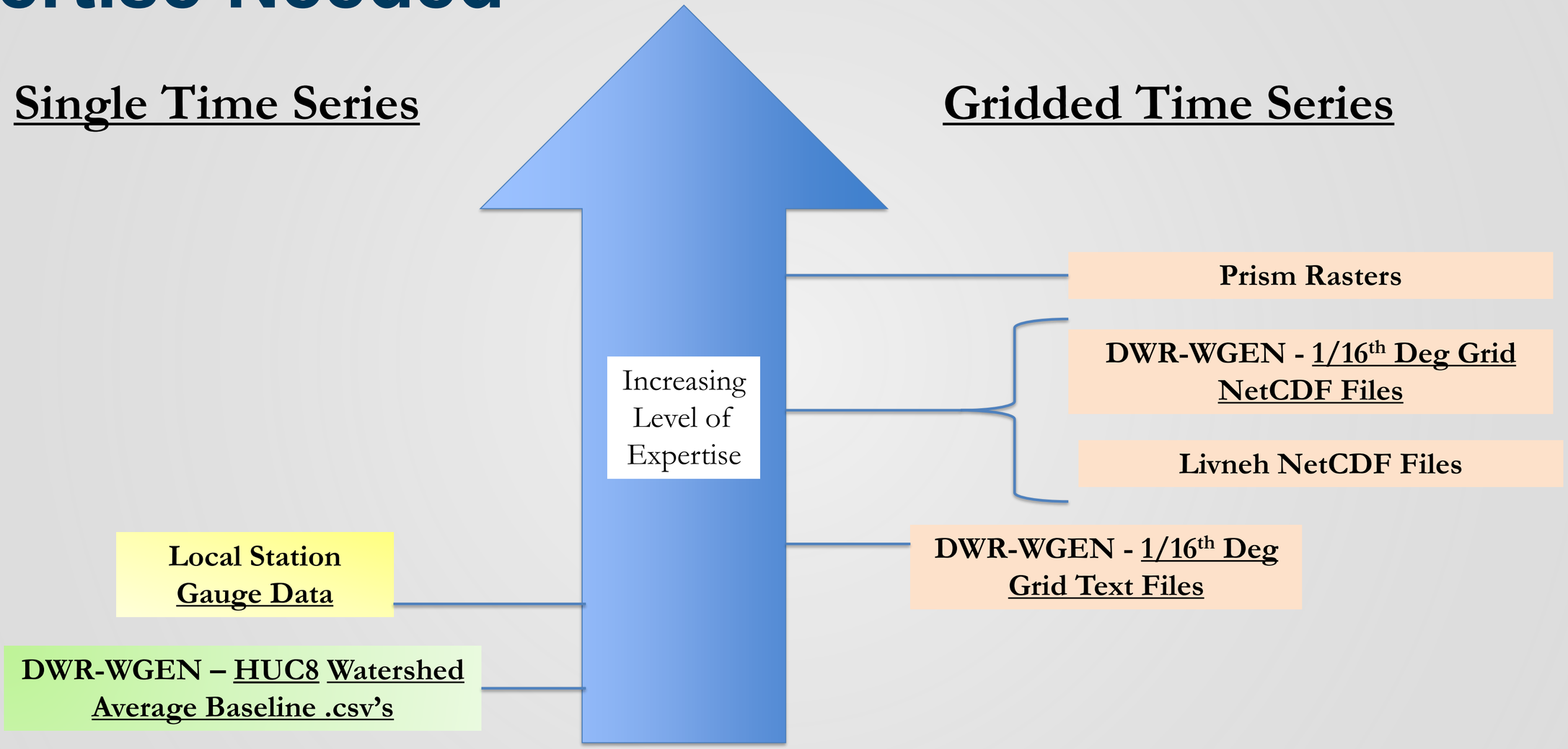
Baseline Datasets (Gridded Time Series)

With long enough history (e.g. 50 years)

- **DWR-WGEN - 1/16th Deg Grid Text Files**
  - **Daily – Precipitation (PR), Max/Min Temperature (TMAX,TMIN)**
  - Used as VIC and SAC-SMA Input
  - Greater Spatial Distribution resolution
  - Per HUC8 for easy delineation
  - 100yr observed https://cadwr.box.com/s/7x8543ivr656x8duhq9l9rpixdfr10pp
  - 1000yr stochastic https://cadwr.box.com/s/q65mgenj8hhx59cronkqq91k6o14l3rv
- **DWR-WGEN - 1/16th Deg Gridded NetCDF Files**
  - **Daily - Precipitation, Max/Min Temperature**
  - Full CA State
  - 100yr observed
    - https://cadwr.box.com/s/ettbry41ob8x4d4xsed89owojmj0nd5m
- **DWR- CWP Paleo Dataset - 1/16th Deg Gridded Text Files 1000 years**
  - **Daily - Precipitation, Max/Min Temperature**

- Others:
  - Livneh 1915-2015 (pr, tmax, tmin),
    - NetCDF
  - Livneh 1950-2013 (pr, tmax, tmin),
    - NetCDF
  - Livneh Unsplit 1915-2018 (pr)
    - NetCDF
  - PRISM (pr, tmax, tmin)
    - Raster
  - Paleo Bootstrapped (e.g. SWP-VA 2019, CWP 2023)

Baseline Datasets Expertise Needed



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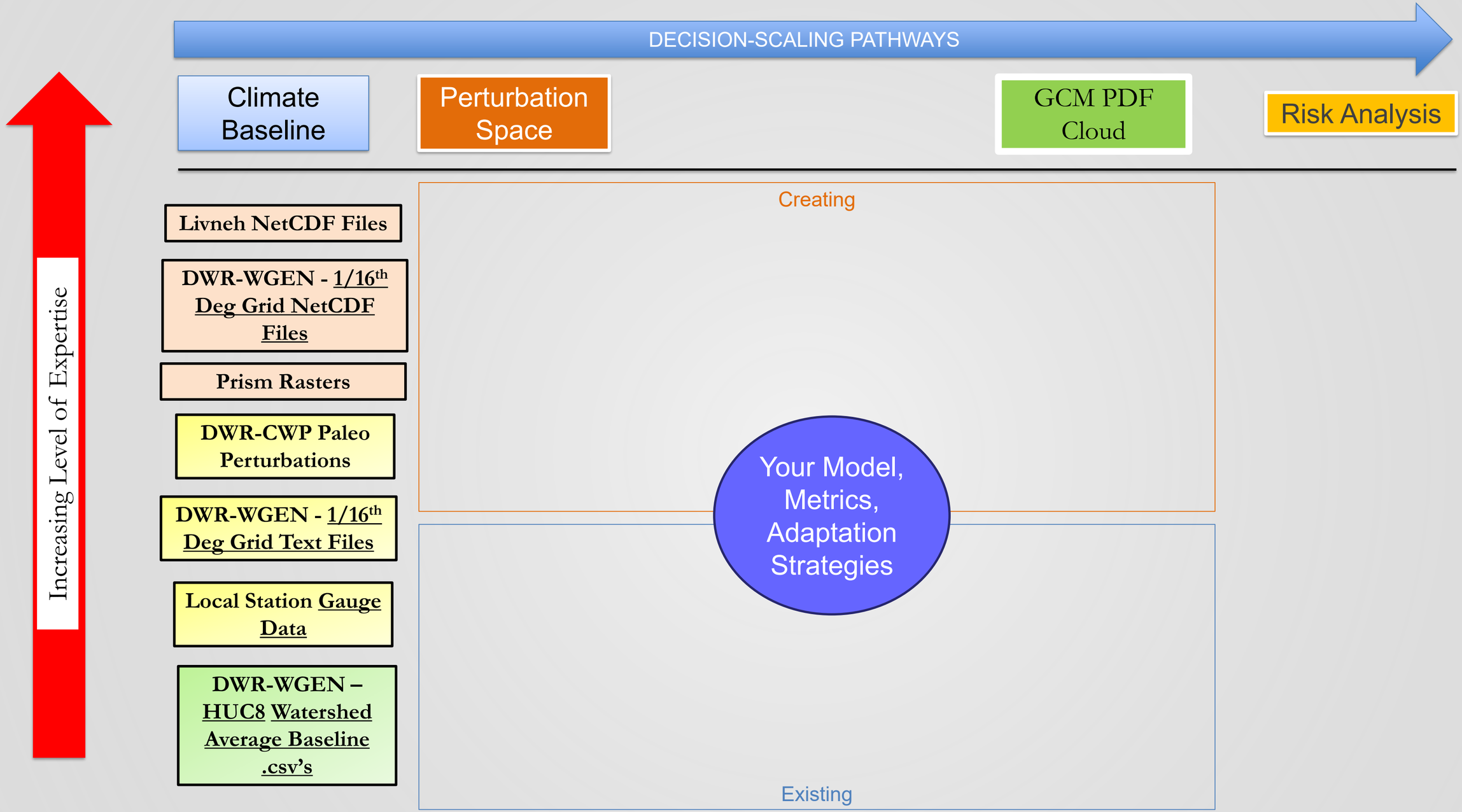

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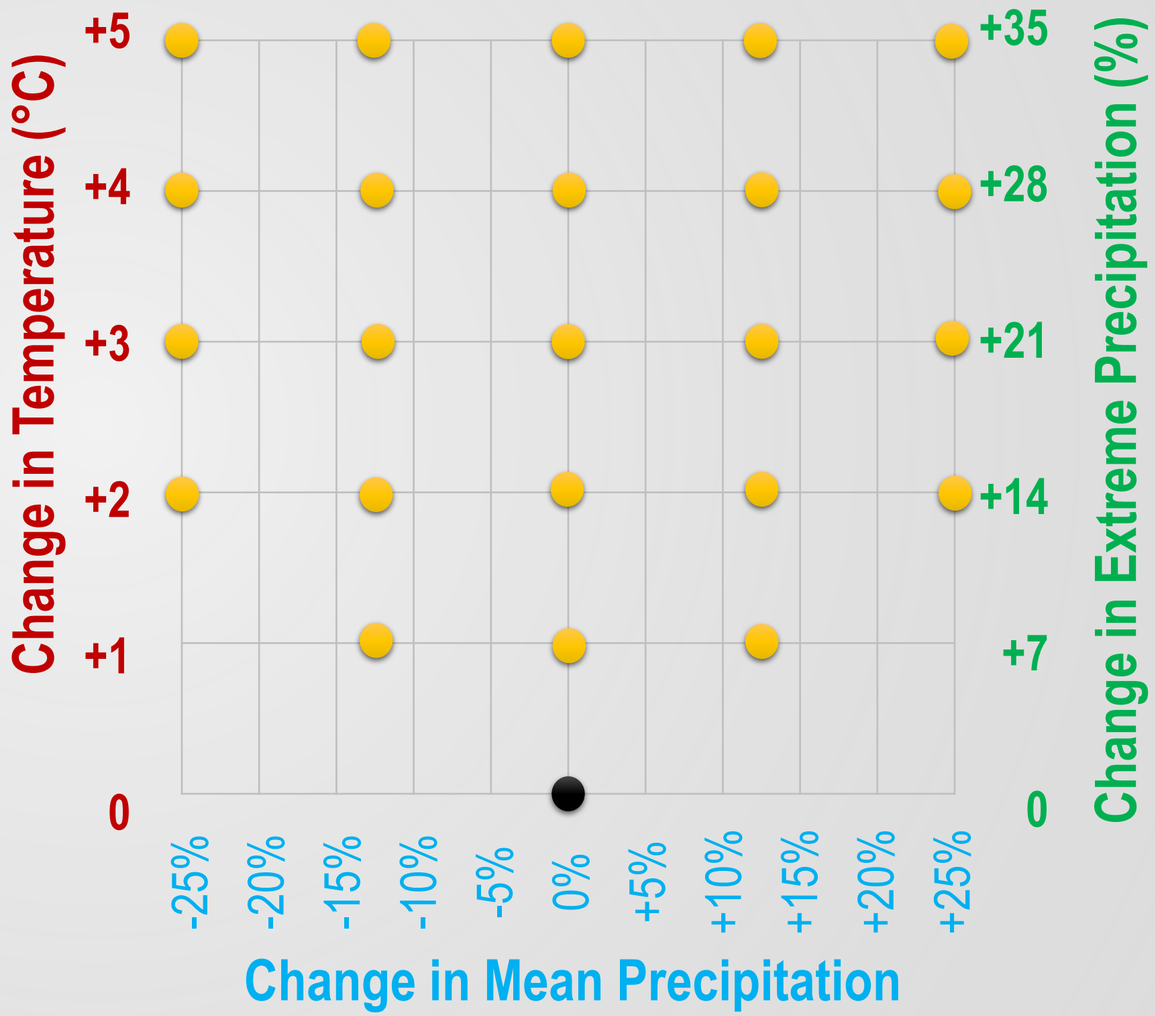
What

STRESS TEST PERTURBATION SPACE DATASET

Stress Test Perturbation Space

- **What plausible future conditions might we expect?**
- **Or want to test against?**
  - Dependent on GCM Future Projection Dataset
  - Dependent on Time horizon of interest
  - The perturbation space shown here covers enough range to cover CMIP5 and CMIP6 for CA Central Valley.
  - May not need book ends of precipitation as seen with SJV Studies using LOCA2



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Computation Time per perturbation

Stress Test Perturbation Space

Existing Datasets:

- **DWR-WGEN – HUC8 Watershed Average .csv's**
  - **Daily - Precipitation, Max/Min Temperature**
  - Single Time Series per perturbation
  - 100-year or 1000-year daily time series
  - https://cadwr.box.com/s/g7myvnk4izcgdg6wdcudobuc8583jv05
- **DWR-WGEN - 1/16th Deg Grid Text Files**
  - **Daily – Precipitation (PR), Max/Min Temperature (TMAX,TMIN)**
  - Used as VIC and SAC-SMA Input
  - Greater Spatial Distribution resolution
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  - 1000yr stochastichttps://cadwr.box.com/s/q65mgenj8hhx59cronkqq91k6o14l3rv

Stress Test Perturbation Space

Existing Datasets:

- **DWR-WGEN - 1/16th Deg Gridded NetCDF Files**
  - **Daily - Precipitation, Max/Min Temperature**
  - Full CA State
  - 100yr observed
  - https://cadwr.box.com/s/ettbry41ob8x4d4xsed89owojmj0nd5m
- **DWR- CWP Paleo Dataset - 1/16th Deg Gridded**

  Text Files 1000 years
  - **Daily - Precipitation, Max/Min Temperature**

Stress Test Perturbation Space

Creating your own Dataset via WGEN MODEL: https://github.com/nassernajibi/WGEN-v2.0/tree/main

- **Model Language – R**
- **Offers Flexibility in**
  - stress test data type,
  - stochastic time length,
  - variables to run, e.g. solar radiation, humidity etc
  - Resolution
- **Input**
  - Gridded Text files or Gauge Data Text Files
  - Defined Perturbation Space (Precip and Temp change values)
  - Thermodynamic Scaling Value

Stress Test Perturbation Space

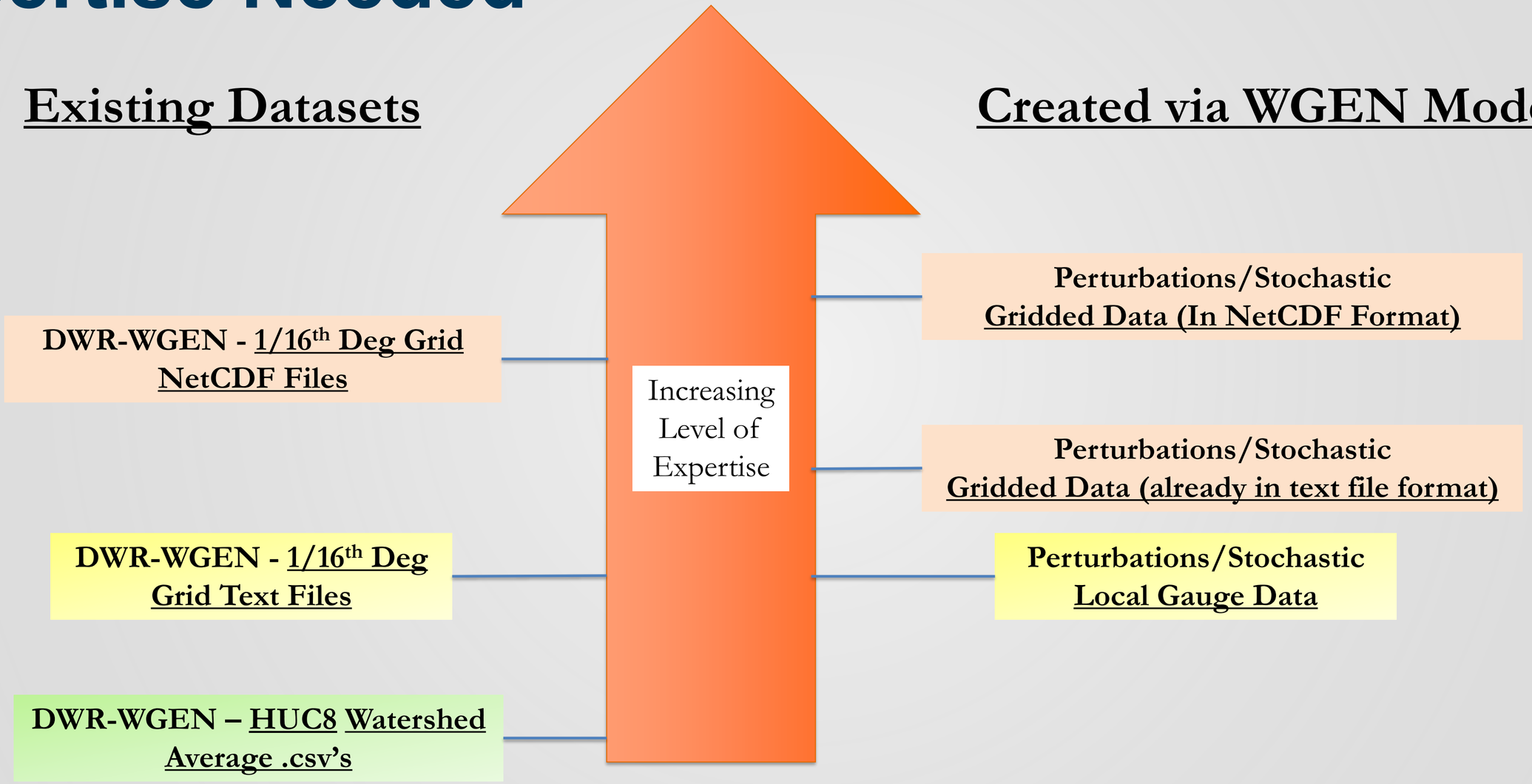
Creating your own Dataset via WGEN MODEL: https://github.com/nassernajibi/WGEN-v2.0/tree/main

- **Running Program Options**
  - Scaling/perturbing only
  - Stochastic option
    - Can play with weather regime transition probability.
  - Must be Daily Values
  - Output matches input datatype and locations

- **Dynamic parameters to adjust**
  - Weather regime transition probability
  - Thermodynamic scaling

See WGEN Workshop for more in-depth breakdown of running WGEN Model Weather Generator Technical Public Seminar - 12/12/23

Perturbation Space Datasets - Expertise Needed



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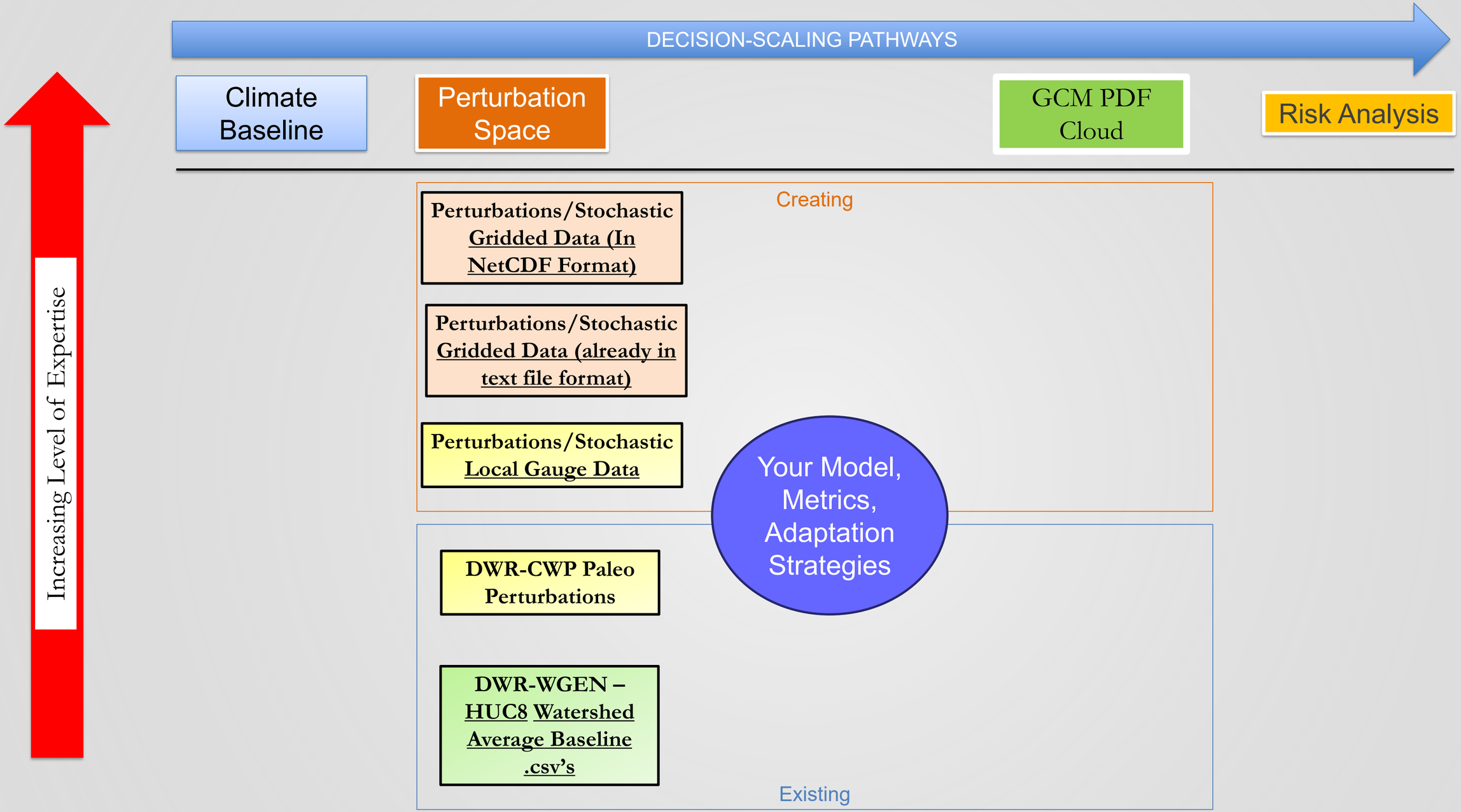

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What

FUTURE PROJECTION DATASET

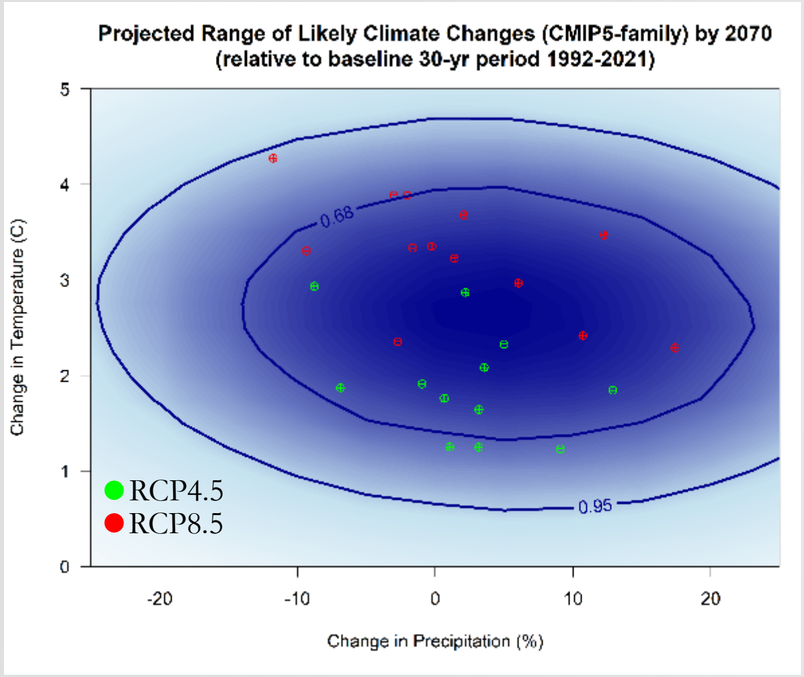
GCM Future Projections

Considerations

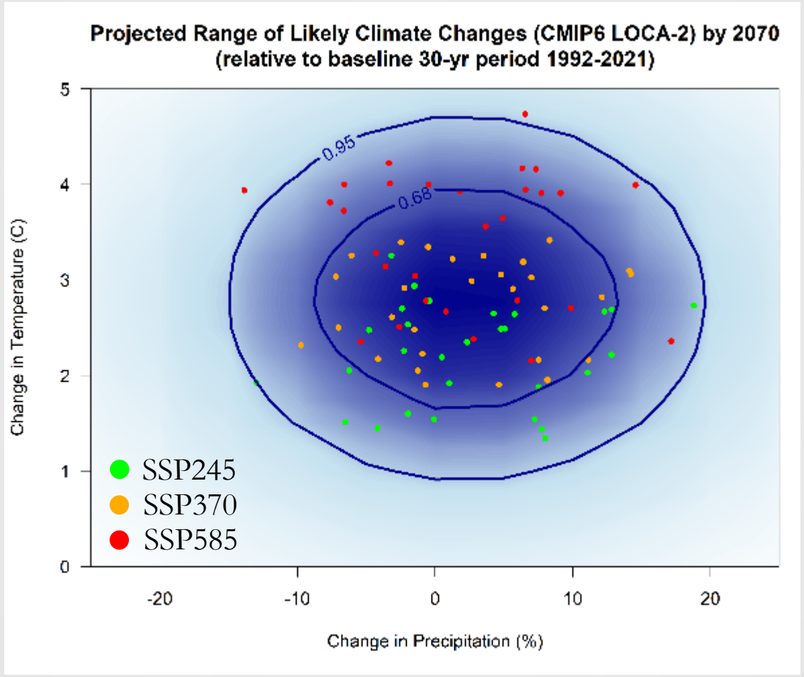
- **Generation**
  - CMIP5 vs CMIP6
- **Grid Resolution**
  - Native Scale (e.g. 100km x 100km)
  - Downscaled (e.g. 4km x 4km)
    - Better fit for microclimates
- **Models to include**
  - RCP
  - SSP
  - Variant (initial condition) Averaging
- **Time Horizon**
  - Just 1? (e.g. 2045,2070)
  - Or All
- **Climate Window**
  - 30 years?

2070 Projection in the Central Valley

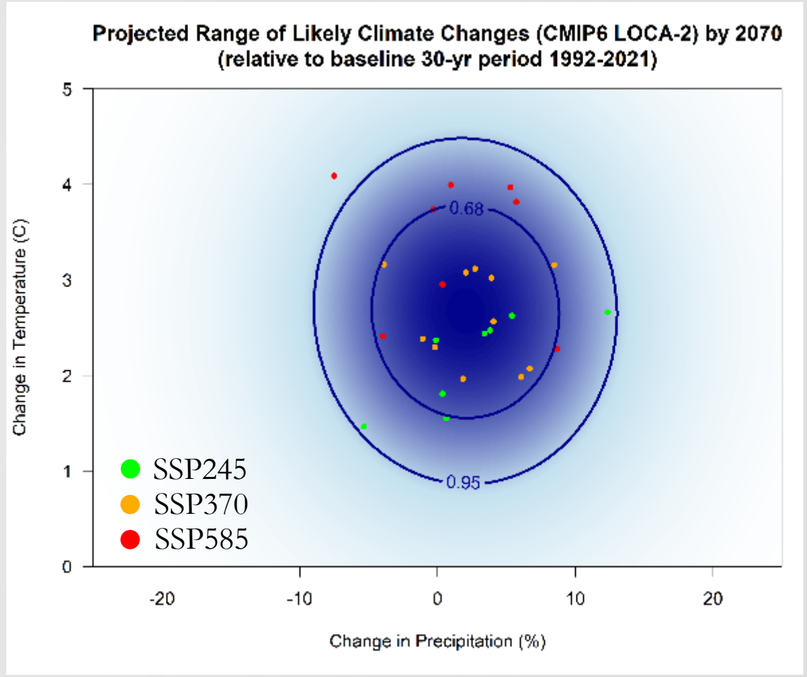
CMIP5 MODEL-FAMILY BASED



CMIP6/LOCA-2 MODEL-VARIANT-SSP BASED



CMIP6/LOCA-2 MODEL-SSP BASED (variant-averaging)



Temperature increase

- Consistent between CMIP iterations
- Lead to more rain on snow and shifts in the hydrological cycle

Annual Precipitation:

- The importance of differentiating California's climatic variability vs. climate change signal
- Tendency toward a slightly «wetter» climate

GCM Future Projections

Using EXISTING DWR's PDF Cloud Parameter Dataset for Central Valley (DCR2023, SJV Studies etc)

Provided in CSV Format

LOCA 2 Means		
period	**DT**	**DP**
2074	2.901921	2.701997
2075	2.949057	2.741732
2076	3.002219	2.781467
2077	3.051996	2.821203
2078	3.105066	2.860938
2079	3.161344	2.900673
2080	3.21522	2.940408
2081	3.260675	2.980144
2082	3.310479	3.019879
2083	3.352825	3.059614
2084	3.402911	3.099349
2085	3.450318	3.139085

LOCA2 Standard Deviation		
	DTsig	**D_pr_lm**
DTsig.74	0.964551	-0.09918
D_pr_lm.74	-0.09918	35.96051
DTsig.75	1.023081	-0.14388
D_pr_lm.75	-0.14388	36.92585
DTsig.76	1.073891	-0.1765
D_pr_lm.76	-0.1765	37.90397
DTsig.77	1.13511	-0.19405
D_pr_lm.77	-0.19405	38.89489
DTsig.78	1.180253	-0.19524
D_pr_lm.78	-0.19524	39.89858

GCM Future Projections

Using EXISTING DWR's PDF Cloud Parameter Dataset for Central Valley (DCR2023, SJV Studies etc)

- Recall Normal Distribution PDF
  - Parameters
    - σ = Standard Deviation
    - μ = Mean

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

Case 1: If X and Y are independent

Then the joint probability density function $f(x, y)$ is given by:

$$f(x, y) = f(x).f(y)$$

$$f(x, y) = \frac{1}{\sqrt{2\pi}\sigma_1} e^{-\frac{1}{2}\left(\frac{x-\mu_1}{\sigma_1}\right)^2} . \frac{1}{\sqrt{2\pi}\sigma_2} e^{-\frac{1}{2}\left(\frac{y-\mu_2}{\sigma_2}\right)^2}$$

$$f(x, y) = \frac{1}{2\pi\sigma_1\sigma_2} e^{-\frac{1}{2}\left[\left(\frac{x-\mu_1}{\sigma_1}\right)^2 + \left(\frac{y-\mu_2}{\sigma_2}\right)^2\right]}$$

https://youtu.be/Ehm0mclZs54?si=Z9R5r35jPGytYVA1

GCM Future Projections

Creating your own Distribution unique to System Domain

- **Native Scale:**
  - **CMIP 5:**
    - Request CMIP5 data sets | Computational and Information Systems Lab
    - https://aims2.llnl.gov/search/
  - **CMIP 6:**
    - Request CMIP6 data sets | Computational and Information Systems Lab
    - https://aims2.llnl.gov/search/cmip6/
    - Google Cloud CMIP6 Public Data: Basic Python Example — Pangeo Gallery documentation (for python intake-esm library)

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CMIP	NOAA-GFDL	GFDL-ESM4	historical	r2i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-CM4	ssp245	r1i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-CM4	ssp585	r1i1p1f1	Amon	pr	gr1
CMIP	NOAA-GFDL	GFDL-CM4	historical	r1i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-ESM4	ssp245	r2i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-ESM4	ssp245	r3i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-ESM4	ssp370	r1i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-ESM4	ssp245	r1i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-ESM4	ssp126	r1i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-ESM4	ssp585	r1i1p1f1	Amon	pr	gr1
CMIP	IPSL	IPSL-CM6A-LR	historical	r8i1p1f1	Amon	pr	gr
CMIP	IPSL	IPSL-CM6A-LR	historical	r2i1p1f1	Amon	pr	gr
CMIP	IPSL	IPSL-CM6A-LR	historical	r31i1p1f1	Amon	pr	gr
CMIP	IPSL	IPSL-CM6A-LR	historical	r3i1p1f1	Amon	pr	gr
CMIP	IPSL	IPSL-CM6A-LR	historical	r6i1p1f1	Amon	pr	gr

GCM Future Projections

Creating your own Distribution unique to System Domain

- **Downscaled:**
  - **CMIP 3/5:**
    - BCSD
    - LOCA
  - https://gdo-dcp.llnl.gov/downscaled_cmip_projections/dcpInterface.html
    - Even has hydrology for CMIP5-LOCA
  - **CMIP 6:**
    - LOCA2
    - CEC - https://analytics.cal-adapt.org/
      - cadcat.s3.amazonaws.com/cae-collection.json (for python intake-esm library)

activity_id	institution_id	source_id	experiment_id	member_id	table_id	variable_id	grid_label
CMIP	NOAA-GFDL	GFDL-ESM4	historical	r3i1p1f1	Amon	pr	gr1
CMIP	NOAA-GFDL	GFDL-ESM4	historical	r2i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-CM4	ssp245	r1i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-CM4	ssp585	r1i1p1f1	Amon	pr	gr1
CMIP	NOAA-GFDL	GFDL-CM4	historical	r1i1p1f1	Amon	pr	gr1
ScenarioMIP	NOAA-GFDL	GFDL-ESM4	ssp245	r2i1p1f1	Amon	pr	gr1
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CMIP	IPSL	IPSL-CM6A-LR	historical	r31i1p1f1	Amon	pr	gr
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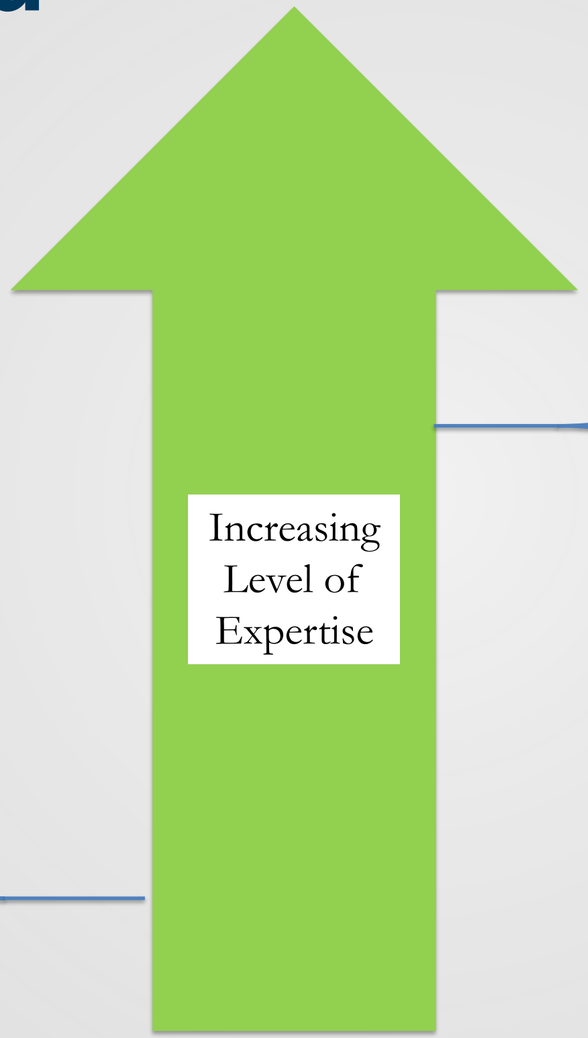
CMIP	IPSL	IPSL-CM6A-LR	historical	r6i1p1f1	Amon	pr	gr

GCM Future Projections PDF- Expertise Needed

Existing Datasets

Creating your own



CMIP 6 Native

CMIP 5 Native

CMIP 6 LOCA2 NetCDF

DWR Central Valley PDF CMIP6/LOCA2 Parameters .csv's

DWR Central Valley PDF CMIP5 Parameters .csv's

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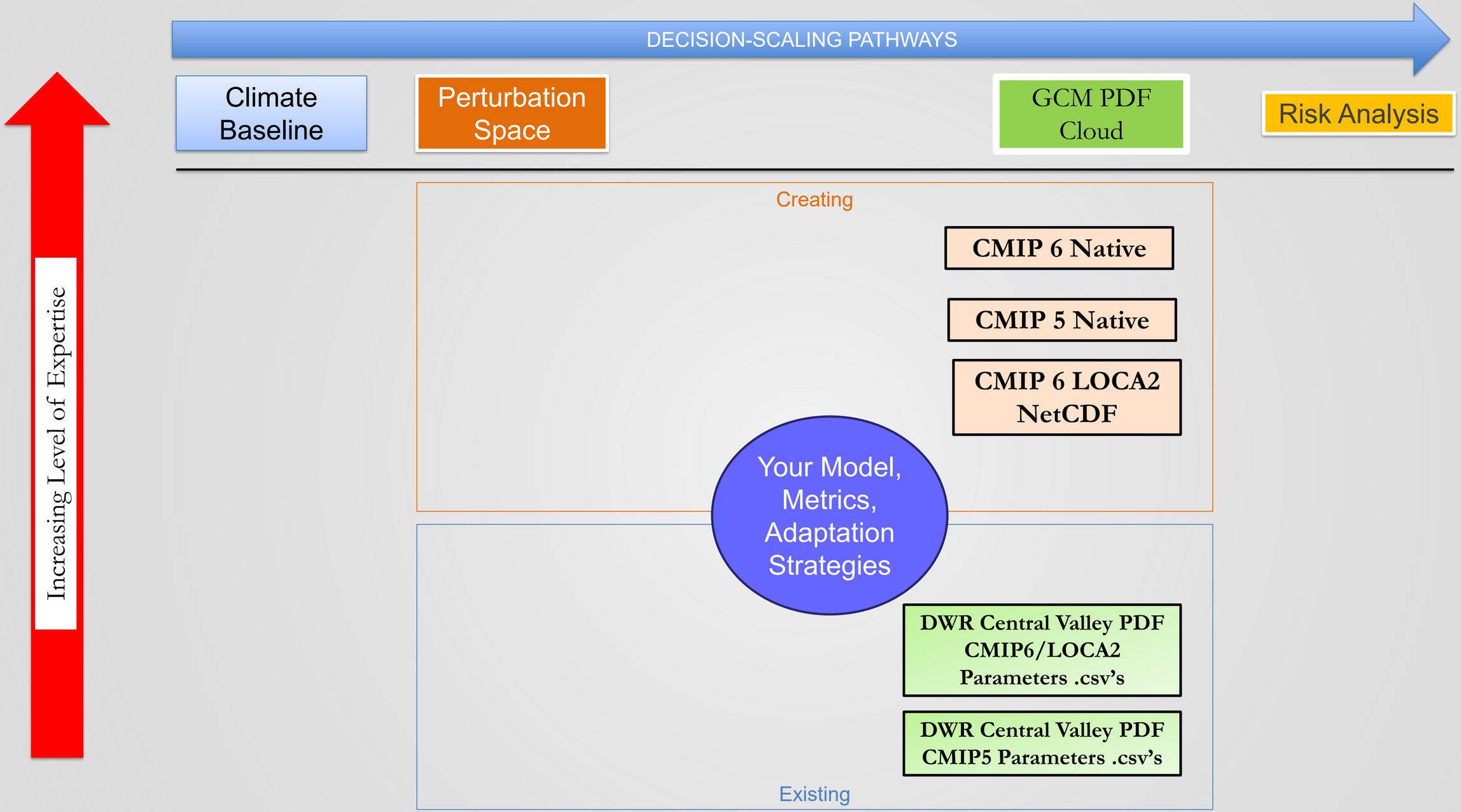

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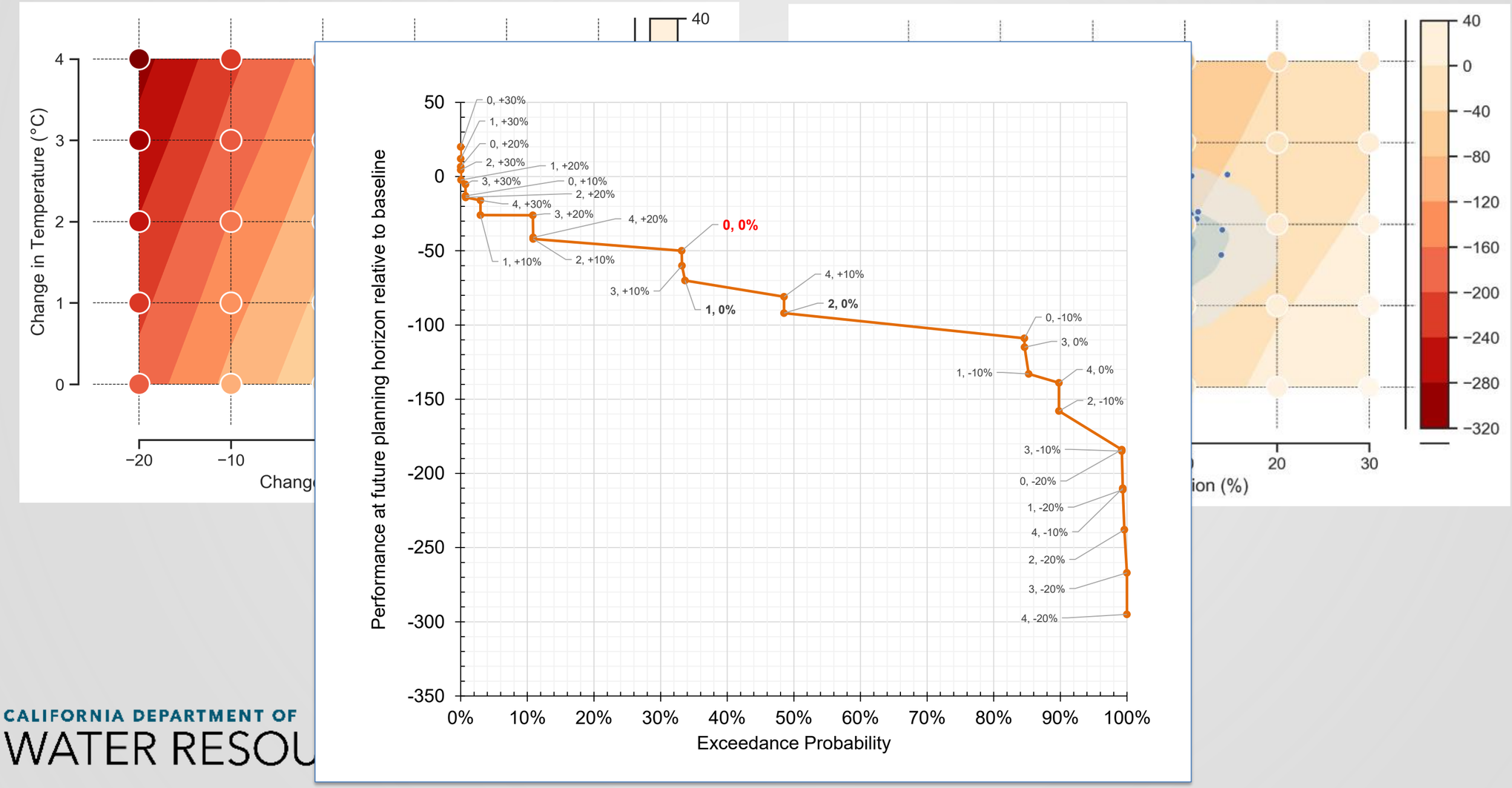
What

RISK ANALYSIS

Simplified Risk Analysis

- Looking only at Perturbation intersections



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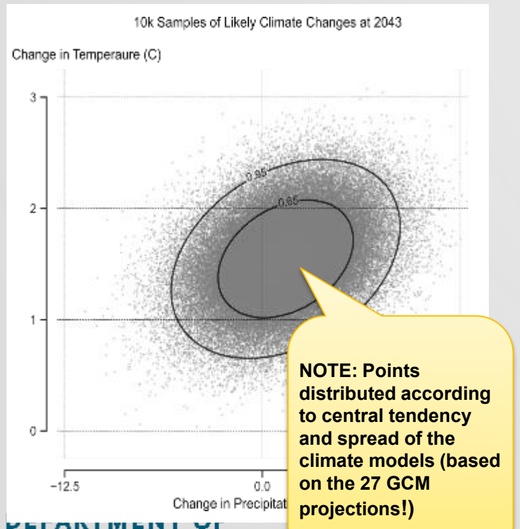
10k Sampling Risk Analysis

- Interpolating Response Surface
- Sampling GCM-PDF 10k Times
- [CADWR-Climate-Change-Program/risk-informed-scenarios]

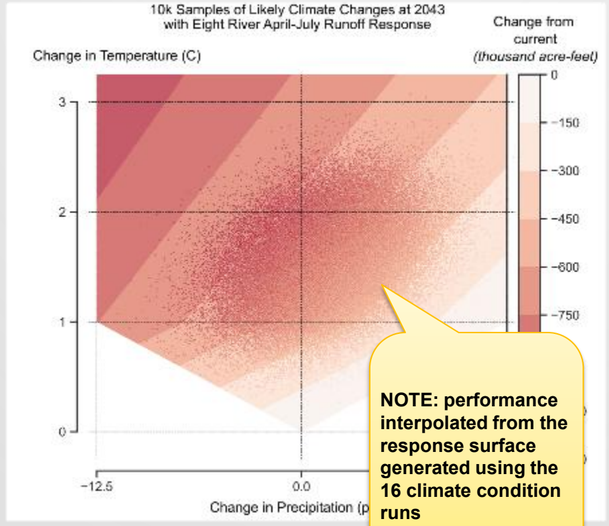
Climate PDF sampling + Response surface metric = Distribution of outcomes

Step 1: Sample the climate PDF 10k times



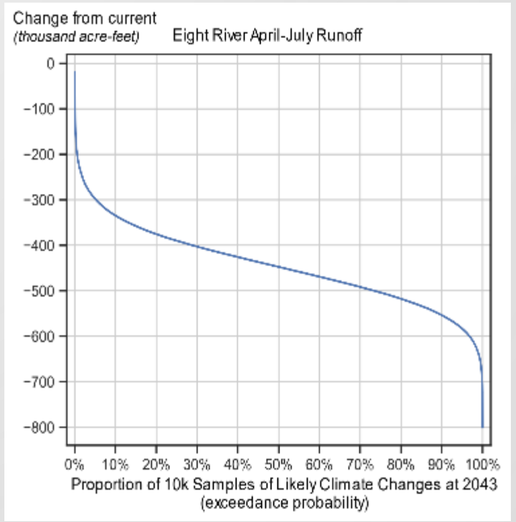
NOTE: Points distributed according to central tendency and spread of the climate models (based on the 27 GCM projections!)

Step 2: Assign a value to each 10k point using the interpolated response surface



NOTE: performance interpolated from the response surface generated using the 16 climate condition runs

Step 3: Sort those 10k values from largest to smallest to get percentiles of performance



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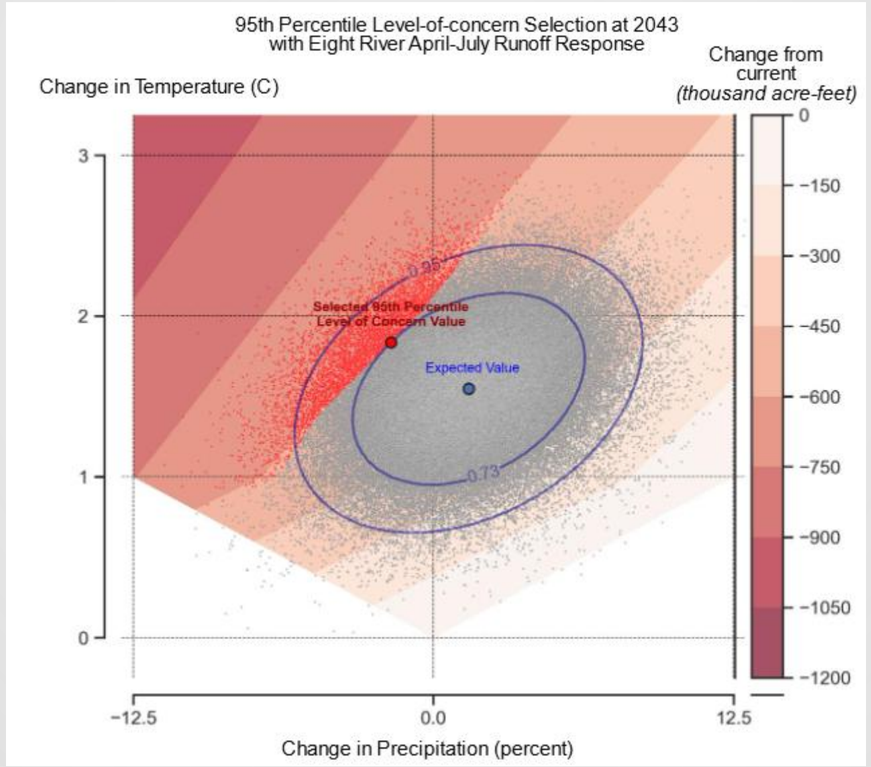
Level of Concern Risk Analysis

Refined Interpolated Scenarios

- [Final State Water Project Delivery Capability Report 2023 - Risk Informed Future Climate Scenario Development for Final SWP DCR 2023 - California Natural Resources Agency Open Data]



Eight River Index April to July

Level of Concern (PCTL)	Change in Temperature (°C)	Change in Precipitation (%)
50th	1.5 °C	+1.5%
65th	1.6 °C	+0.8%
70th	1.6 °C	+0.3%
75th	1.7 °C	+0.1%
80th	1.7 °C	-0.1%
95th	1.8 °C	-1.8%

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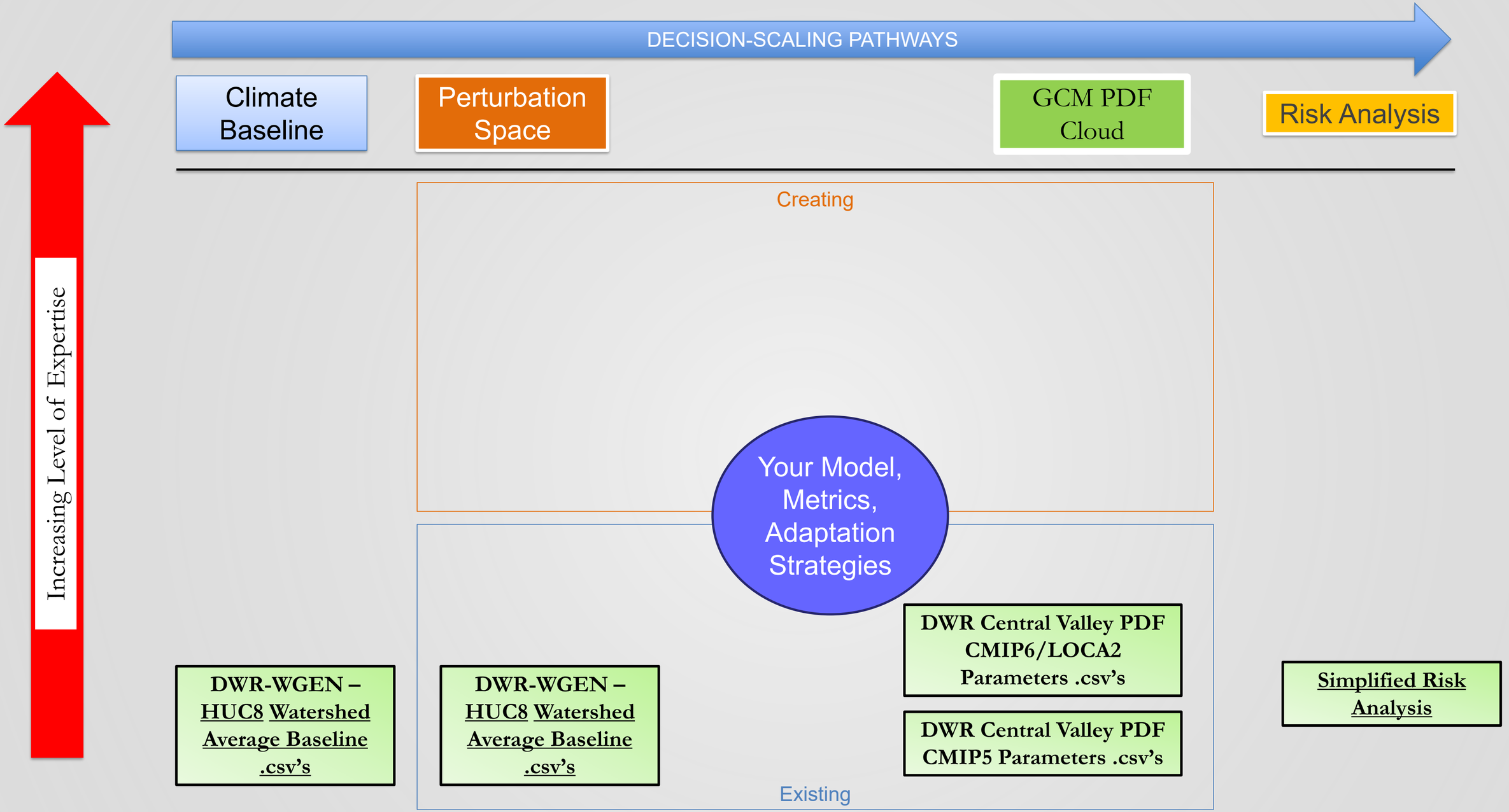
ANALYSIS PATHWAYS



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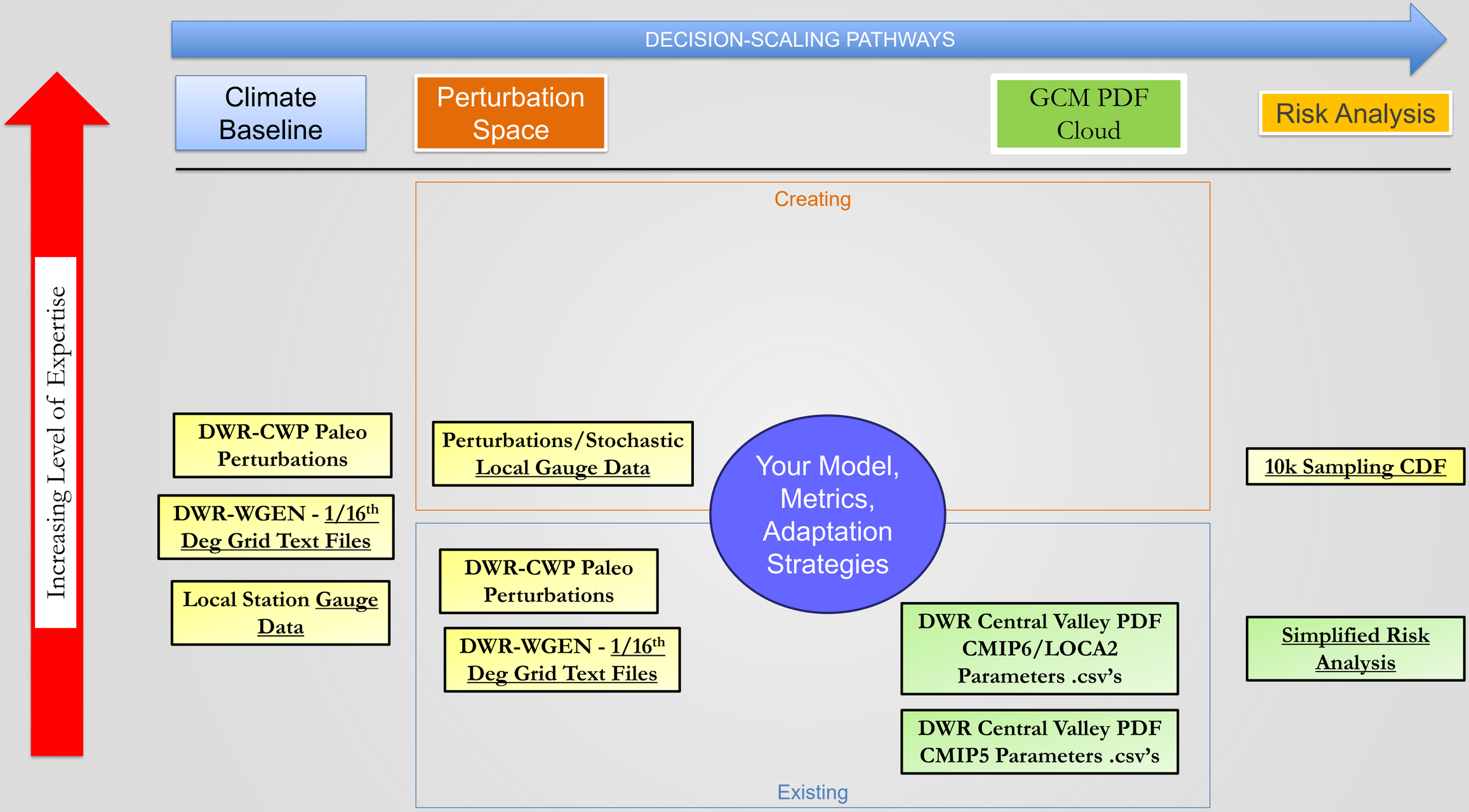

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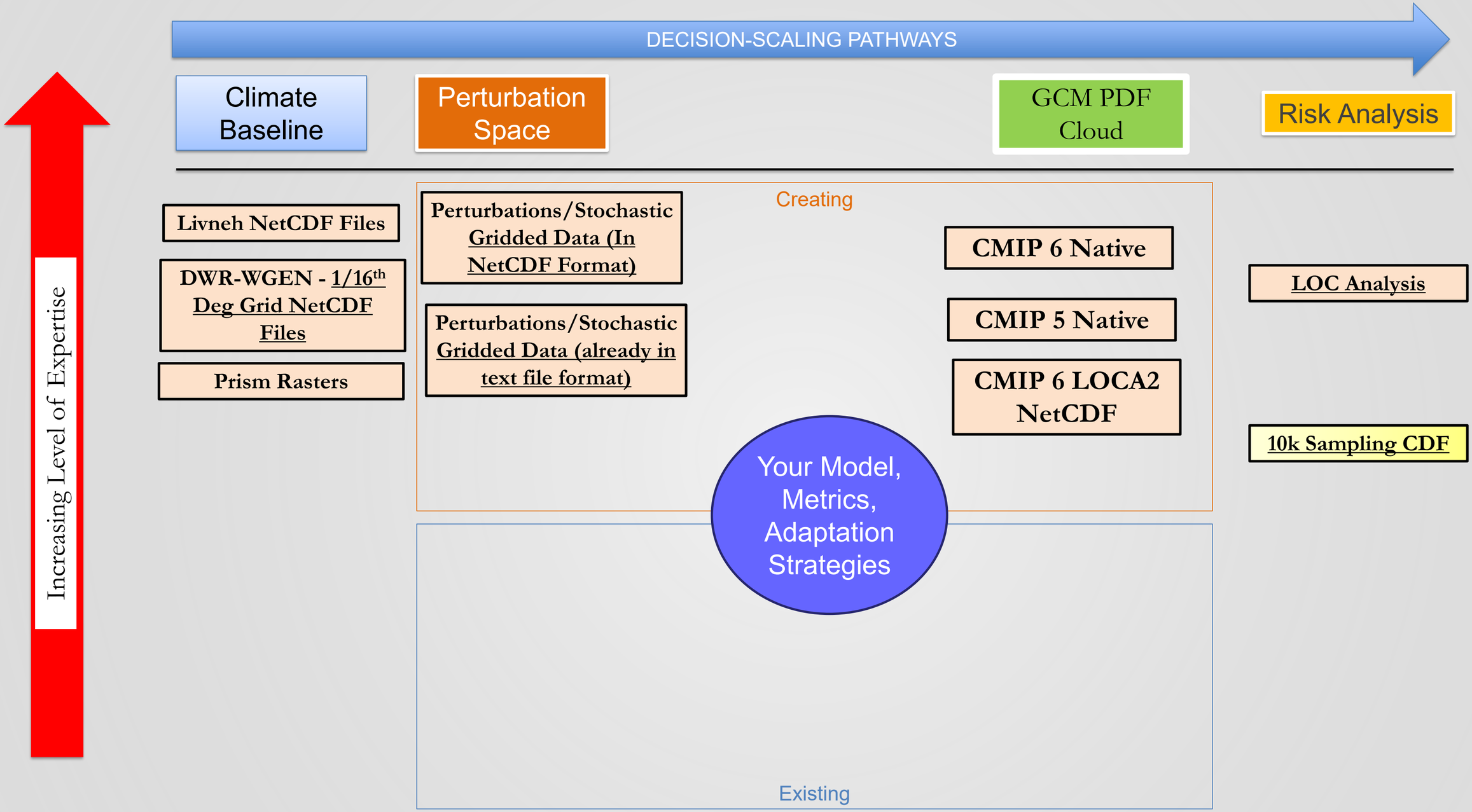

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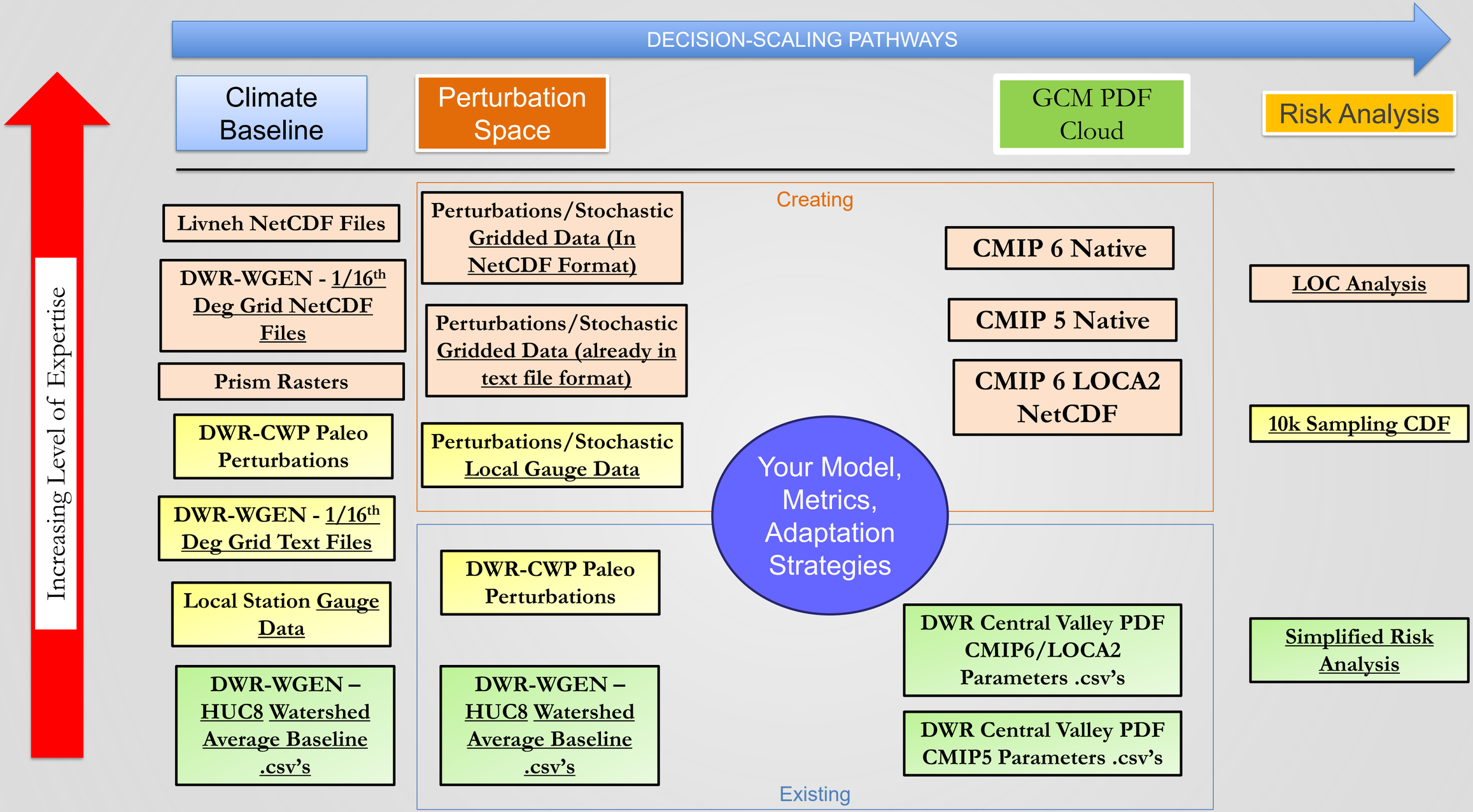

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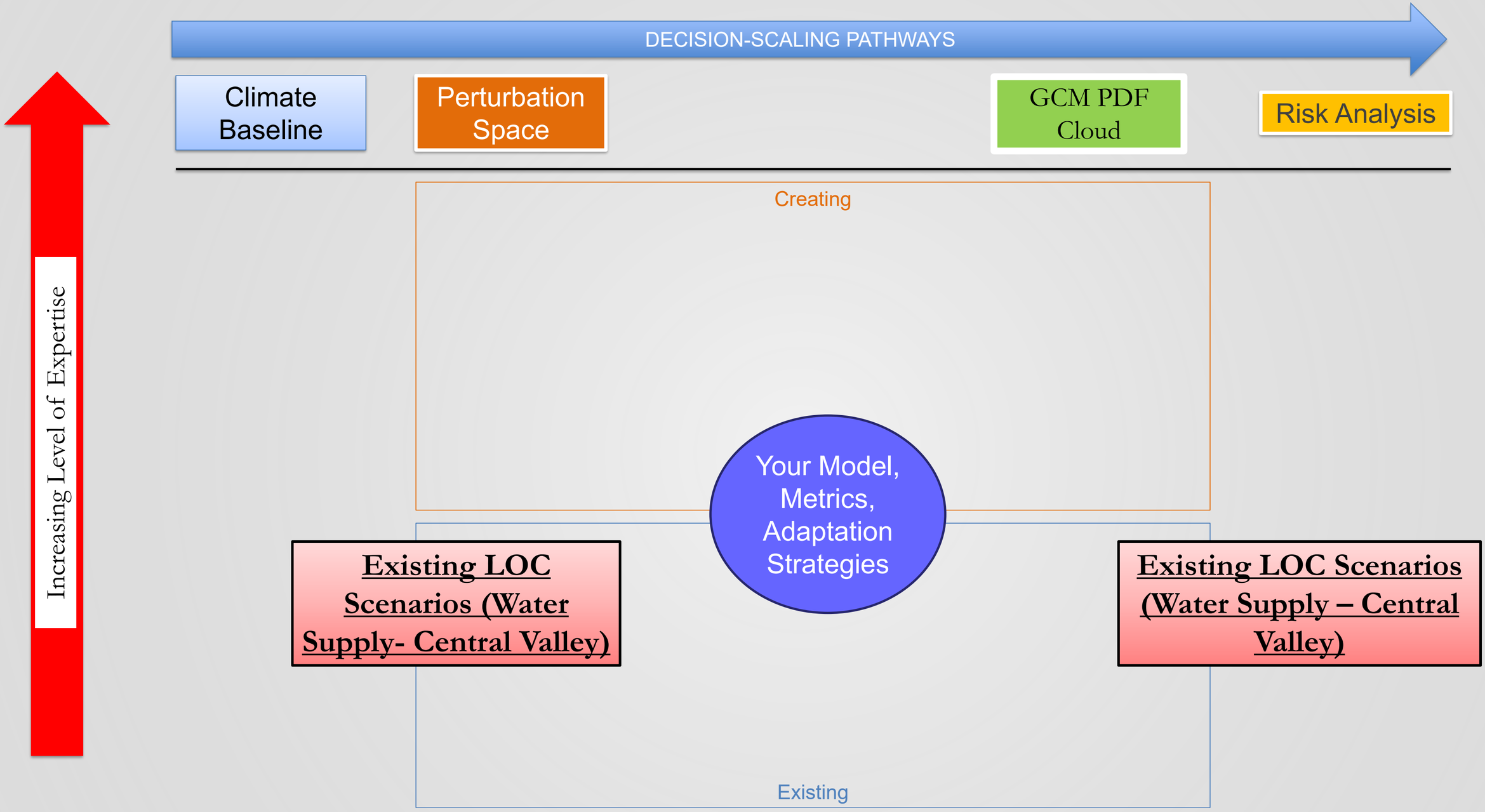

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Q&A

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