Uncertainty Analysis in Integrated Assessment Models

Major Steps Over the Last Year

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Major Progress Since Snowmass 2012

- Fall 2012
  - Further analyzed Snowmass 2012 “feasibility” results
  - Developed decomposition methodology
- February 2013 meeting
  - Reviewed first round results
  - Decided to simplify to 3 variables
  - Agreed to “two-track” methodology
  - Discussed approaches to determining PDFs
- Spring/Summer 2013
  - Developed Snowmass 2013 protocol
  - Participating models completed protocol

First Round: Snowmass 2012 Feasibility Exercise

7 models performed a "feasibility" exercise

1. Each model began with a baseline (no policy) run
2. Six sensitivity runs are were then performed
   - Reduce output by a one-time decline of 5% of world GDP in 2020
   - Increase world GDP growth rate by 0.5 % per year 2020-2100
   - Change equilibrium climate sensitivity by +1 °C
   - Increase population growth by 1 % per year from 2020 to 2050
   - CO_2 tax from $13 in 2010 to $427 in 2100 (from AMPERE AM3ND1)
   - Add an emissions pulse of 10 Gt of CO_2 in 2020

Which Scenarios Are Feasible?

- Reduce output by a one-time decline of 5% of world GDP in 2020
  - Feasible: EPPA, GCAM, MERGE, PHOENIX, RICE, WITCH
  - Not feasible: PAGE
- Increase world GDP growth rate by 0.5 % per year 2020-2100
  - Feasible: All models
- Change equilibrium climate sensitivity by +1 °C
  - Feasible: EPPA, GCAM , MERGE, PAGE, RICE, WITCH
  - Not feasible: PHOENIX

Which Scenarios Are Feasible? (cont.)

- Increase population growth by 1 % per year from 2020 to 2050
  - Feasible: All models
- CO_2 tax from \$13 in 2010 to \$427 in 2100 (from AMPERE AM3ND1)
  - Feasible: EPPA, GCAM , MERGE, PHOENIX, RICE, WITCH
  - Not feasible: PAGE
- Add an emissions pulse of 10 Gt of CO_2 in 2020
  - Feasible: EPPA, GCAM, MERGE, PAGE, RICE, WITCH
  - Not feasible: PHOENIX

These Results Led to Decision: Start with Three Uncertain Parameters

We chose three uncertain parameters based on importance and ability to easily perturb across (nearly all) models:

1. Population growth
2. Productivity growth
3. Temperature sensitivity

Next Decisions

- Where to get the distributions of the uncertain input parameters $f(\alpha)$?

- How to take these input distributions to the models?
  - Have each model run full Monte Carlo simulations?
  - Two-track approach?

PDFs from Where?

Where to get the distributions of the uncertain input parameters $f(\alpha)$?

- Decision: Literature when possible, expert elicitations when not possible.

- Will discuss this more this afternoon

Taking Input Distributions to the Models

How to take these input distributions to the models?

- Decision: Two-track approach

"Decomposition Procedure"

1. On one front we push forward on expert elicitations
2. On the second front we begin model runs:
   - Determine the support of $f(\alpha)$
   - Divide the domain of each element of α into *S* intervals
   - Include the endpoints of each interval
   - Populate a grid (or matrix) of α
   - Run the models for each point in the entire grid

We will discuss the integration of the two this afternoon

Decomposition Approach

- This approach has advantages
  - If we have a limited number of input parameters, then the approach is simple, easy to implement, and would not require thousands of runs
  - Provides insight into the correlation structure
  - *Does not requires knowing the PDFs of the input variables first*
- Has some disadvantages
  - May not easily extend to multiple correlated parameters
  - We need to predetermine the support of $f(\alpha)$

How To Determine the Support of $f(\alpha)$?

This determines the computational complexity of the approach

- Need to decide on the size of the intervals
- Need to know the plausible range of the parameters
  - What is the plausible range of the temperature sensitivity parameter?

This is an important discussion…

how far out to sample in the tails of $f(\alpha)$?

Second Round: Snowmass 2013 Protocol

6 models participated in filling out the grid (125 x 2 = 250 runs)

- Perform a set of runs to fill in the 3-dimensional grid:
  - Add to baseline TSC: +3°C, +1.5°C, 0°C, -1.5°C, -3°C (equilibrium °C per CO2 doubling)
  - Add to the baseline TFP growth: +1%, +0.5%, 0%, -0.5%, -1% (annually until 2100, no change in growth rate afterwards)
  - Add to the baseline population growth: +1%, +0.5%, 0%, -0.5%, -1% (annually until 2100, no change in growth rate afterwards)
- Grid was filled in for both the modeler's baseline and a carbon tax policy
  - CO_2 tax from \$13 in 2010 to \$427 in 2100 (from AMPERE AM3ND1)

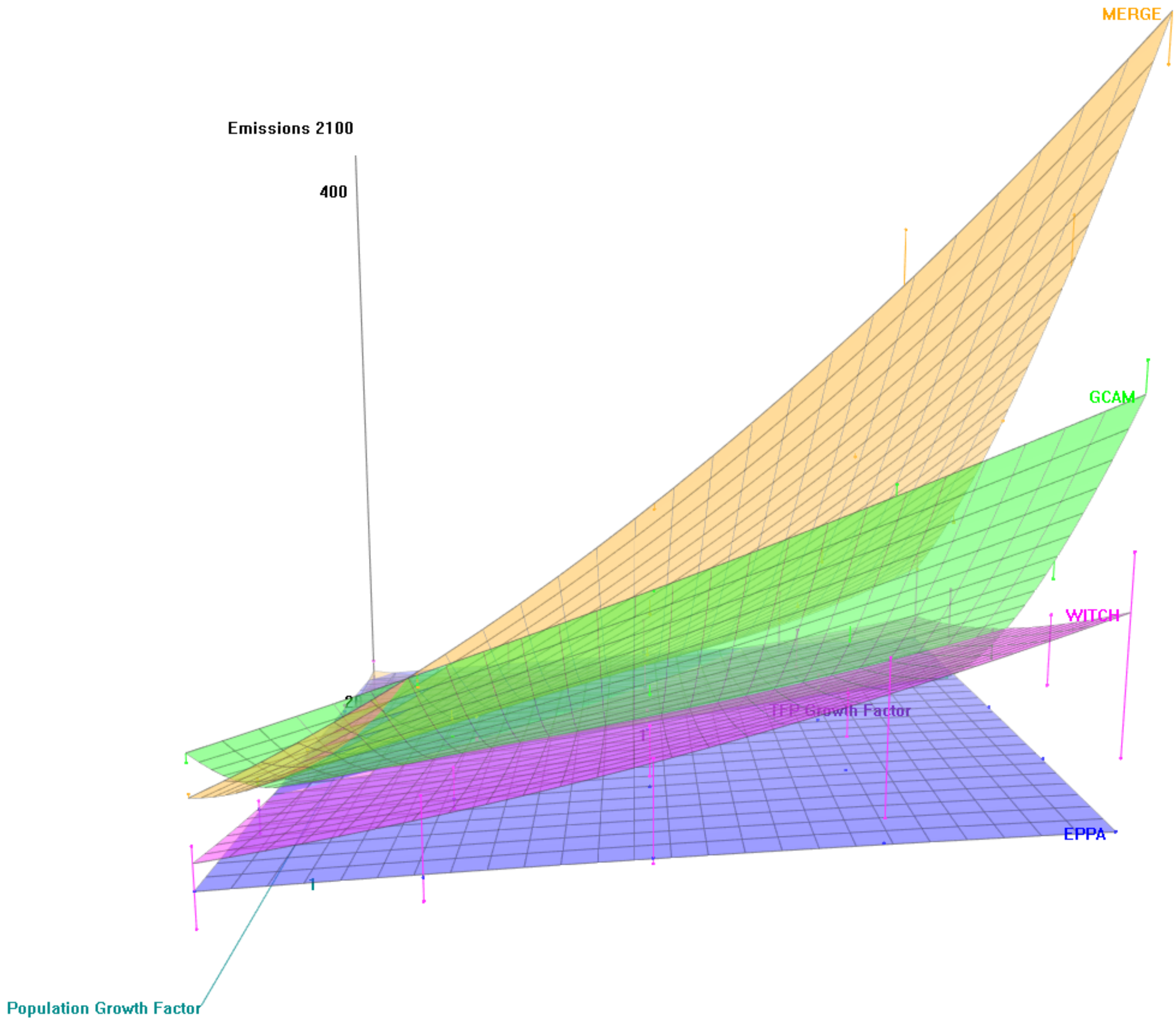
Things We Realized

- -3°C is not very useful when the baseline TSC is 3°C!
- Interestingly, in several models, the carbon tax policy hardly changed the estimate of air surface temperature, particularly in some of the high cases
  - One question is exactly what is covered under the tax
  - AMPERE covers all greenhouse gases
  - Do we want to cover sectors where taxation is largely infeasible?

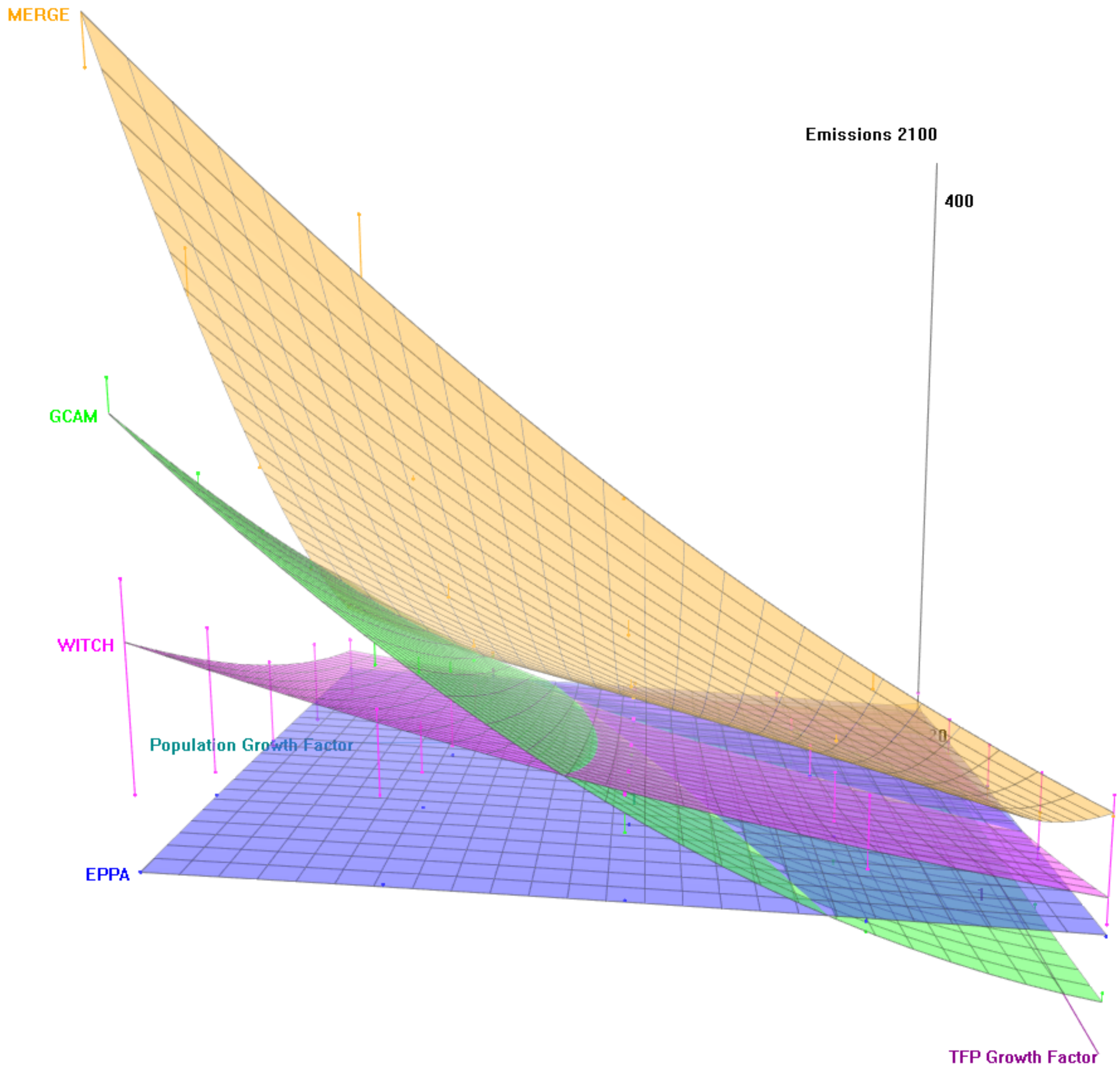
Visualizing the Results

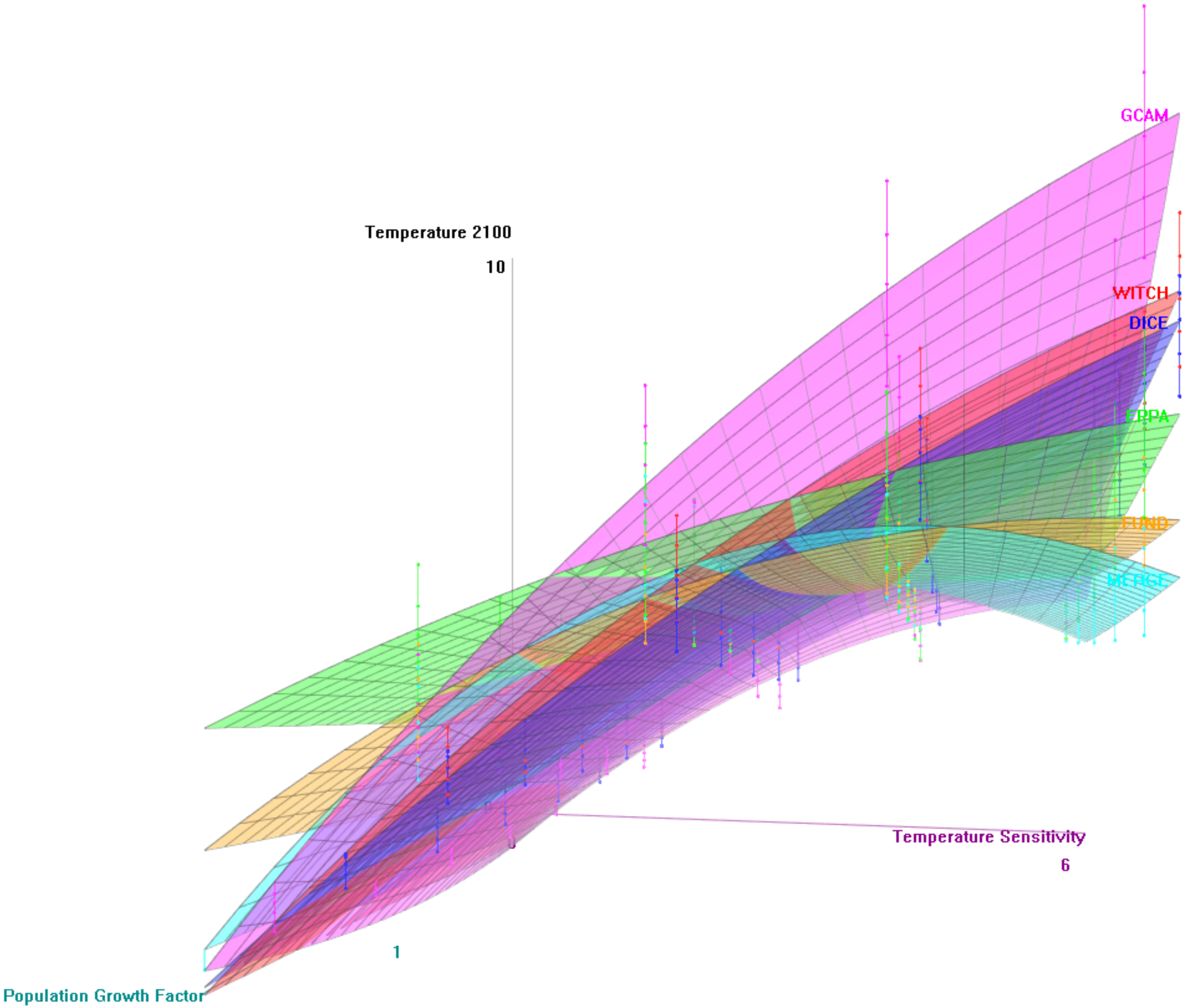
- One way to visualize the results is to plot at the surface
  - Since we can't see in 4D, we are limited to 3D graphs
  - Consider the y-axis the output variable and the two x-axes as two of the uncertain input variables
  - Can also show the range from the third input variable with additional lines

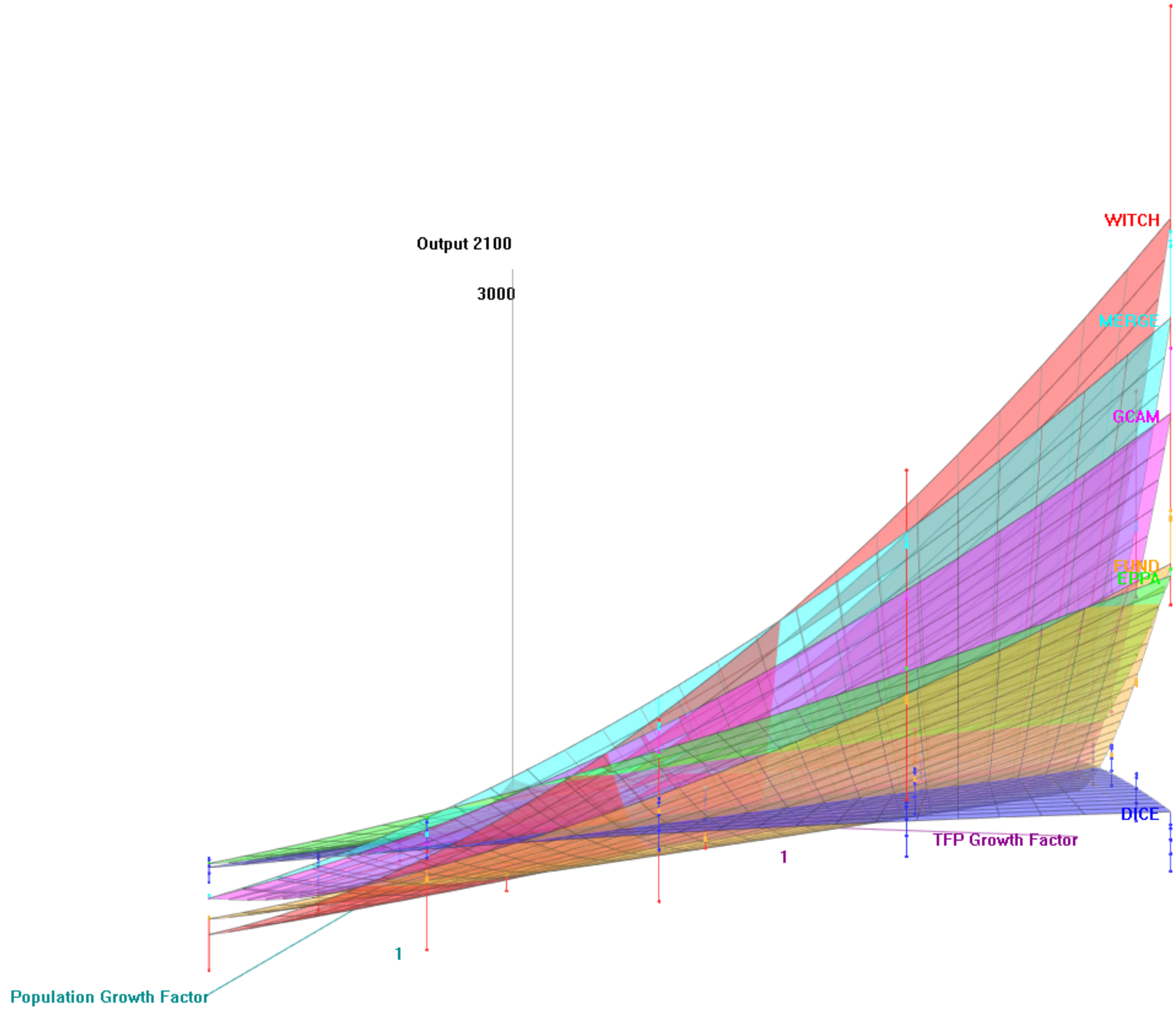
- Note some of these results just came in, so we are still going through them



MERGE
Emissions 2100
400
GCAM
WITCH
TFP Growth Factor
EPPA
Population Growth Factor


MERGE
GCAM
WITCH
EPPA
Emissions 2100
400
Population Growth Factor
TFP Growth Factor


Temperature 2100
10
GCAM
WITCH
DICE
EPPA
FUND
MERGE
Temperature Sensitivity
6
0
1
Population Growth Factor



Output 2100
3000
WITCH
MERGE
GCAM
FUND
EPPA
DICE
TFP Growth Factor
1
1
Population Growth Factor

One Take-away

- One initial take-away:
  - Models are very consistent in terms of 2100 output, but much less consistent in terms of temperature and CO_2 emissions