FUND model

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Questions

1. **How can the characterization of damages used to estimate the SCC be improved over the next 1-3 years through incorporation of existing evidence or changes to modeling approaches?**
2. What improvements can be made with respect to representation of market and non-market damages for particular sectors, catastrophic impacts, adaptation, changes in vulnerability/resiliency, and interactions among these aspects of climate damages?
3. What are the technical merits and challenges of using a damage function that aggregates across multiple damage categories relative to explicitly modeling individual damage categories (e.g., sectoral or regional)?
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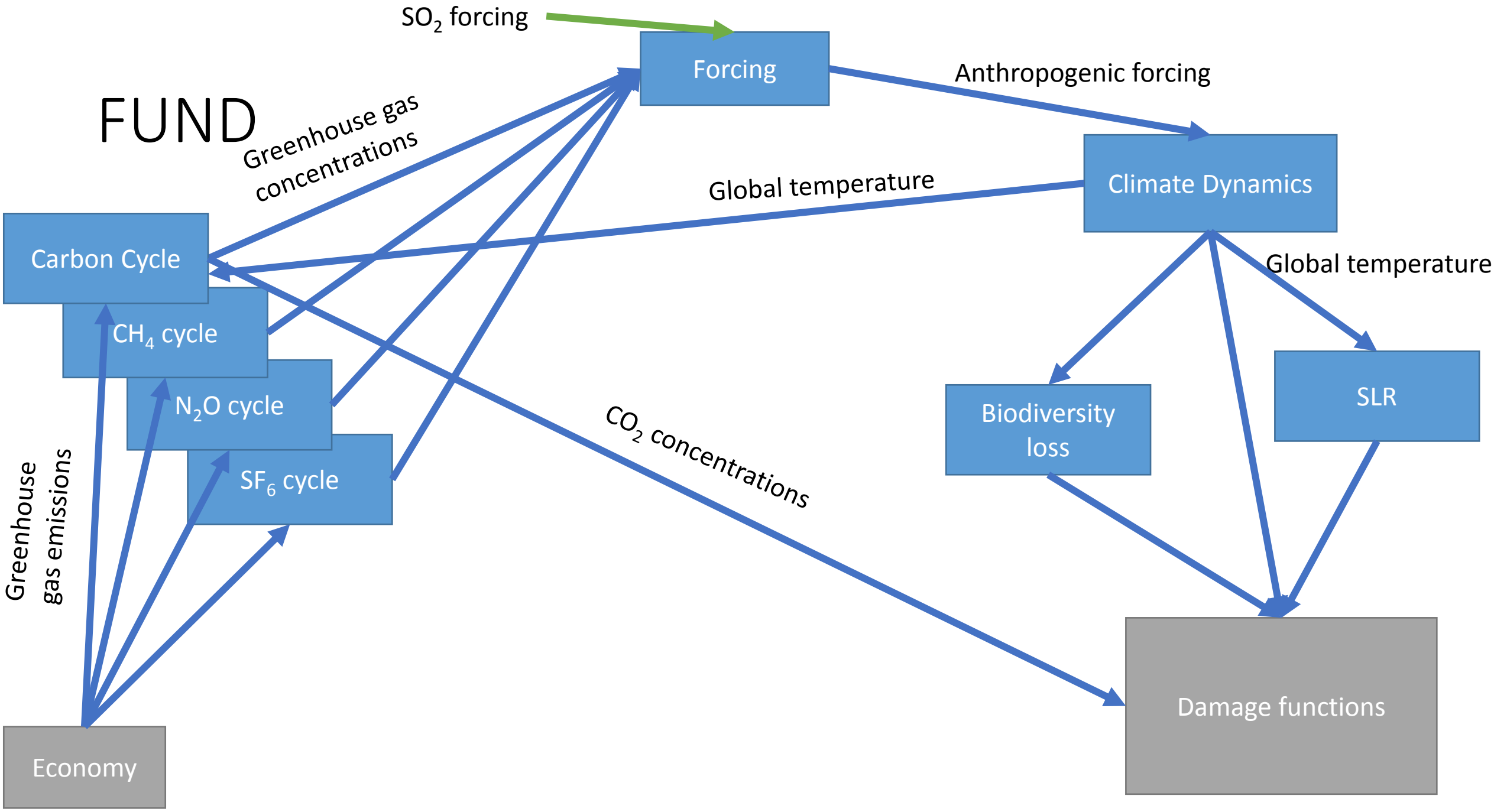
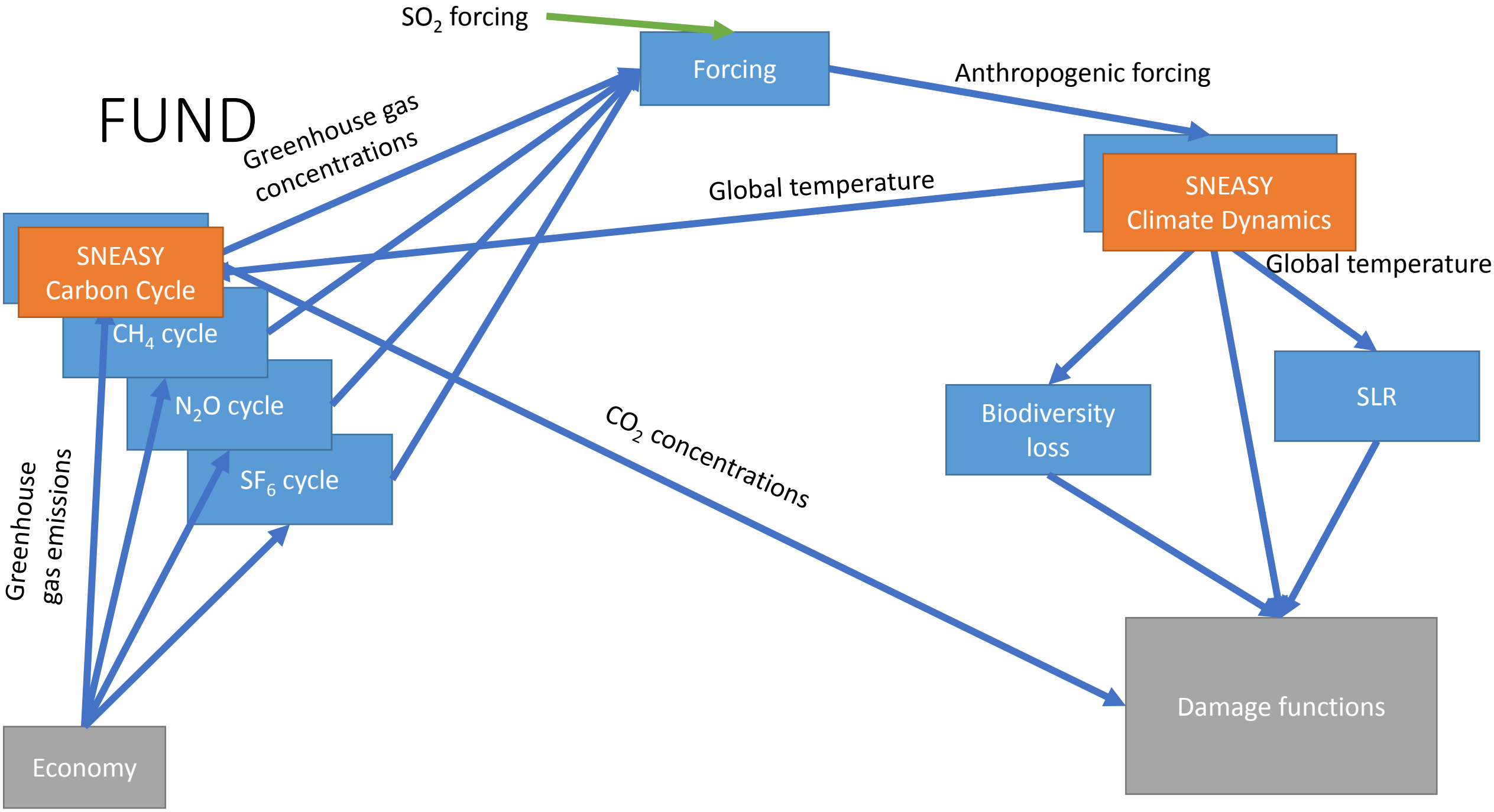
How can the characterization of damages used to estimate the SCC be improved over the next 1-3 years through incorporation of existing evidence or changes to modeling approaches?

- Current empirical basis for damages in IAMs thin and old
- I believe more subject area experts should contribute to the development of IAMs
- Decentralized model
  - Mimi
  - DMAS (http://dmas.berkeley.edu/)

Mimi.jl

- Component framework for IAMs (“Lego for IAMs”)
- Written in julia (open source language for technical computing)
- All open source
- Easy to use (!)
- My vision is simply that different groups can work on different parts of an IAM, without each having to build a full IAM
  - Build alternative physics components that can be plugged in
  - Add new damage functions
  - Replace existing damage functions
  - Etc.


FUND
SO_2 forcing
Forcing
Anthropogenic forcing
Greenhouse gas concentrations
Global temperature
Climate Dynamics
Carbon Cycle
Global temperature
CH_4 cycle
N_2O cycle
SF_6 cycle
Biodiversity loss
SLR
CO_2 concentrations
Greenhouse gas emissions
Damage functions
Economy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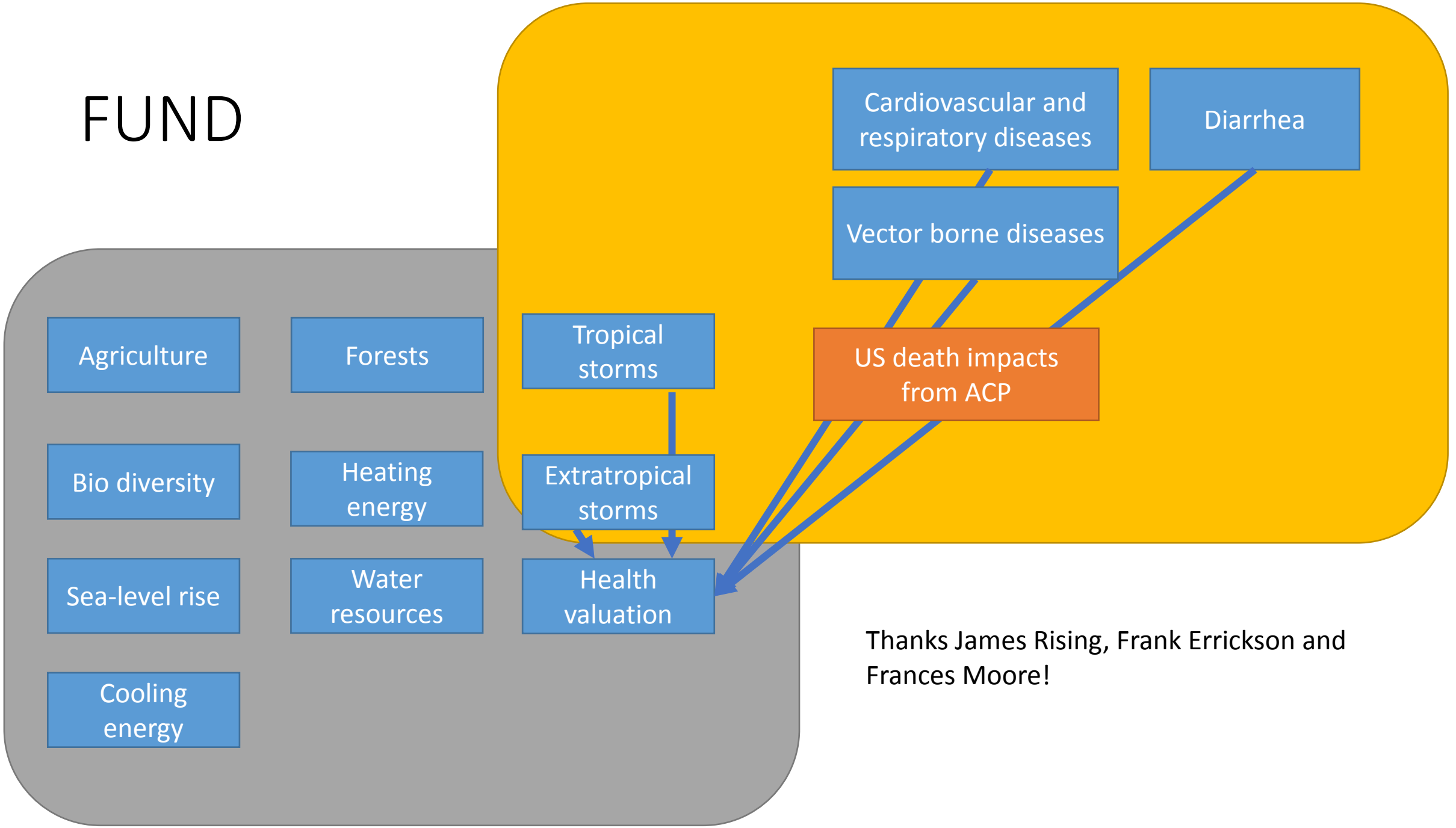

Thanks James Rising, Frank Errickson and Frances Moore!

Mimi momentum

Existing things

- FUND (default platform going forward)
- Mimi-DICE
- Mimi-RICE
- Mimi-SNEASY (Keller)

Planned, but not committed

- Sea-level rise (Diaz)
- Updated ag impacts (Diaz, Hertel and Moore)

Potential (relatively easy)

- Biodiversity impacts (Brooks and Newbold, 2014)
- Tourism impacts (Hamburg model)
- Non-constant income elasticity for VSL
- Diarrhea impacts (Downs, Hanemann and others)

Potential (but more work)

- Global Climate Prospectus (Hsiang et al.)
- Health (Cromar and Howard at NYU)
- Link Mimi with DMAS (Rising, Hsiang and me at UC Berkeley)

Other options

- Hopefully many other groups that I've talked to over the last couple of years

Mimi momentum

Existing things

- FUND (defau
- Mimi-DICE
- Mimi-RICE
- Mimi-SNEAS

Planned, but n

- Sea-level rise
- Updated ag i

With the current funding situation, hardly any of this will happen on our end.

ooks and Newbold, 2014)
rg model)
sticity for VSL
s, Hanemann and others)

us (Hsiang et al.)
ard at NYU)
sing, Hsiang and me at UC

groups that I've talked to
of years

Issues

- If this works, we might end up with models that share X% of their structure
- This doesn’t solve the issue of quality control
- This is not a systematic approach, it is opportunistic

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What improvements can be made with respect to representation of market and non-market damages for particular sectors, catastrophic impacts, adaptation, changes in vulnerability/resiliency, and interactions among these aspects of climate damages?

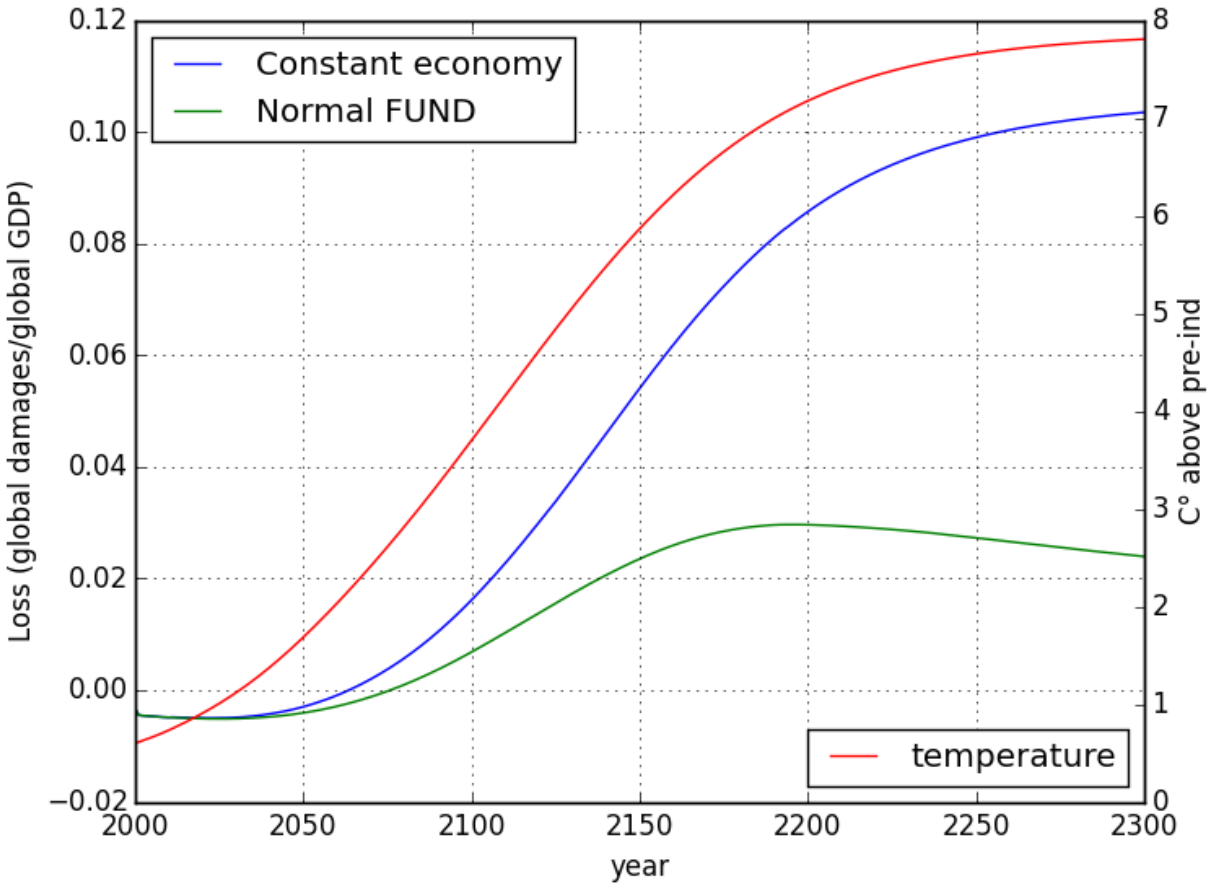
- More studies that use data from around the world
- Estimate income elasticities

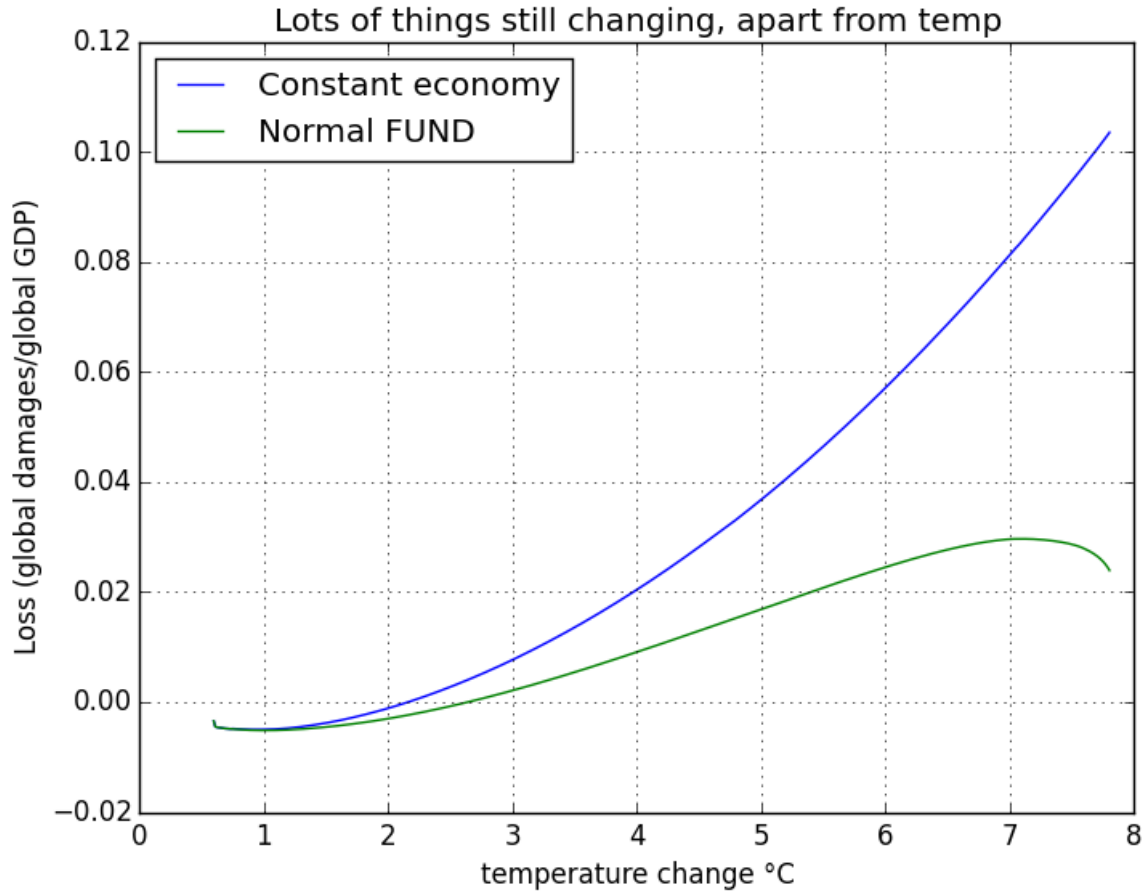
Dynamic vulnerability – Malaria

$$D_{t,r}^{v} = D_{1990,r}^{v}\alpha_{r}^{v}\left(T_{t} - T_{1990}\right)^{\beta}\left(\frac{y_{t,r}}{y_{1990,r}}\right)^{\gamma} \qquad \gamma = -2.65$$

Damage function	SCC ($/tCO2) for 2010
Standard impacts	13
All income elasticities = 1	32

Source: Anthoff et al. (2011); FUND 3.5, prtp=1%, in 2015 USD


Constant economy
Normal FUND
temperature
Loss (global damages/global GDP)
C° above pre-ind
year
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
8
7
6
5
4
3
2
1
0
2000
2050
2100
2150
2200
2250
2300


Lots of things still changing, apart from temp
Constant economy
Normal FUND
Loss (global damages/global GDP)
temperature change °C
0.12
0.10
0.08
0.06
0.04
0.02
0.00
−0.02
0
1
2
3
4
5
6
7
8

What improvements can be made with respect to representation of market and non-market damages for particular sectors, catastrophic impacts, adaptation, changes in vulnerability/resiliency, and interactions among these aspects of climate damages?

- More studies that use data from around the world
- Estimate income elasticities
- Adaptation: no need for explicitly modeling it in an IAM, but don't assume it away
- Catastrophic impacts: some great papers on optimal decision making with tipping points etc. (Traeger, Judd and others), but very, very thin empirical basis
- Interactions between sectors: there have been some CGE studies, but I would first focus on getting better coverage of primary impacts, more regional cover etc.

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Three different approaches with respects to sectors

- Enumerative data sources, aggregate damage function in IAM (DICE, PAGE)
- Enumerative data sources, disaggregated damage functions in IAM (FUND)
- Aggregate data sources (no IAM?) Nordhaus (2006), Dell et al. (2012), Burke et al. (2015)

Sectoral aggregation vs disaggregation in damage functions

- Scientific complexity
  - Dynamic behavior of the model
  - Optimization, e.g. recent stochastic work by Traeger, Judd and others
- Code complexity
  - Potential for bugs (but what about bugs upstream?)
- Decentralized workflow
  - Add new damage type
  - Replace one type of damage
- Transparency of damage estimates
  - Where do these numbers come from?
  - What type of impacts drives results?
- Other drivers than temperature
  - Sea-level rise
  - CO2 concentrations
  - Socio-economic

Aggregate impact estimates (Nordhaus 2006, Dell et al. 2012, Burke et al. 2015)

- Includes types of impacts that we have “forgotten” in enumerative approach
- Misses all non-market impacts
- Misses anything we haven’t observed in the past (problem of all empirical approaches)
- Captures interactions between sectors
- Wrong “unit”: we really want willingness-to-pay estimates, not GDP impact (capital destruction, adaptation expenditures incorrectly accounted)
- Not clear how things like trade effects are handled

What are the technical merits and challenges of using a damage function that aggregates across multiple damage categories relative to explicitly modeling individual damage categories (e.g., sectoral or regional)?

- Regional disaggregation
  - FUND currently 16 regions, we are working on a national version
  - We will keep both versions maintained
  - One major driver in FUND are region specific non-climate drivers (income, mainly)
  - I expect we will use the finer regional disaggregation for impact assessment, and keep using the regional version for e.g. finding optimal policies etc.
    - I have long hoped to build a global, simple FUND (like the DICE/RICE distinction) that is consistent with the more disaggregated version.
- **Overall: I don't think there needs to be harmonization on any of these issues, let the models differ in their approach**

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- Really difficult question!
- Hindcasting, why it essentially doesn't work for damage estimates:
  - WTP is not easily observed
  - We might be able to identify real non-sense results, but I doubt this is much of a problem
  - Problem of conditional forecasts: FUND doesn't forecast GDP, that is an input, it forecasts damages, so doesn't make sense to see how well it does on GDP prediction
- Checklist for studies:
  - Is it peer-reviewed?
  - Is it methodological sound?
  - Does it estimate the right thing?
  - Does it handle things like weather-climate distinction?
  - Does it account for adaptation?
  - Does it take into account non-climate drivers?

  → Don't be too dogmatic about methodological approaches!

What criteria can be used to assess the reliability of potential improvements to damage functions used for SCC estimation, with respect to both modeling approach and specific evidence?

- EMF style model comparison study on damages specifically
  - Sector by sector
  - Understand why there are differences in estimates in existing IAMs
  - Review new literature, identify research needs
  - There has been remarkable little model comparison on the damage side of the cost-benefit IAMs.
    - Gillingham, Nordhaus et al. shows how valuable that can be (see also EPRI work)

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How do we get CBA IAM modelers, empirical economists and the creators of the larger IAMs to work on this together?

- Ideal world
  - Damage function pipeline (copy paste from journal article vs fully integrated pipeline)
  - How do we make sure people estimate the things we need in IAMs? (weather vs climate, WTP vs other metrics etc.)
  - How can non-IAM modelers play with IAMs, contribute etc. without investing too much time (software and scientific complexity)
- Concrete steps
  - I don't think we need more meetings/workshops (we had many, they were great, but at some point talking about the problem has diminishing returns)
  - We need to get the incentives right
    - No one wants to work for a year on a new damage estimate, and then have his/her work become part of FUND and be forgotten → I think the Mimi framework might work here, people can stay in control over their work, get credit, and IAMs are collections of sub-models
    - There is a lot (REALLY a lot) of not very exciting ground work involved. Great opportunity for early grad students, but that needs funding
  - I think this should be organized along specific sectors (ag, cooling energy, health etc.), and small groups (that include an IAM person and subject matter experts) should try to make headway

What research areas are of the highest priority to improve the characterization of damages over time?

- There seem to be VERY many people that want to estimate impacts that inform the SCC.
  - How can we make sure that enthusiasm results in work that can be used in IAMs, and then *is* used in IAMs?
- Centralized, systematic major effort vs spontaneous, bottom up, chaotic, opportunistic approach

Concluding remarks

- I’m optimistic about a more decentralized approach
- Model development needs to be funded
- I would like to see more models in the mix (not good to have only four people as gatekeepers)
- We shouldn’t fool ourselves that we might “solve” the issue of damage functions anytime soon, this will remain a highly uncertain area of research

Thank you!

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