The handshake between IAMs and ESMs: IPCC AR5 as a catalyst

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Nebojša Nakićenović (IIASA-WGCM)
Steven Rose (EPRI)
Jean-Francois Lamarque (NCAR/NOAA)
Detlef van Vuuren (PBL)
Jae Edmonds, Tony Janetos, Allison Thomson, Steve Smith (PNNL)
George Hurtt/Steve Frolking/Louise Chini (UNH)
And MANY MANY others

New scenarios development process: parallel vs. sequential approach

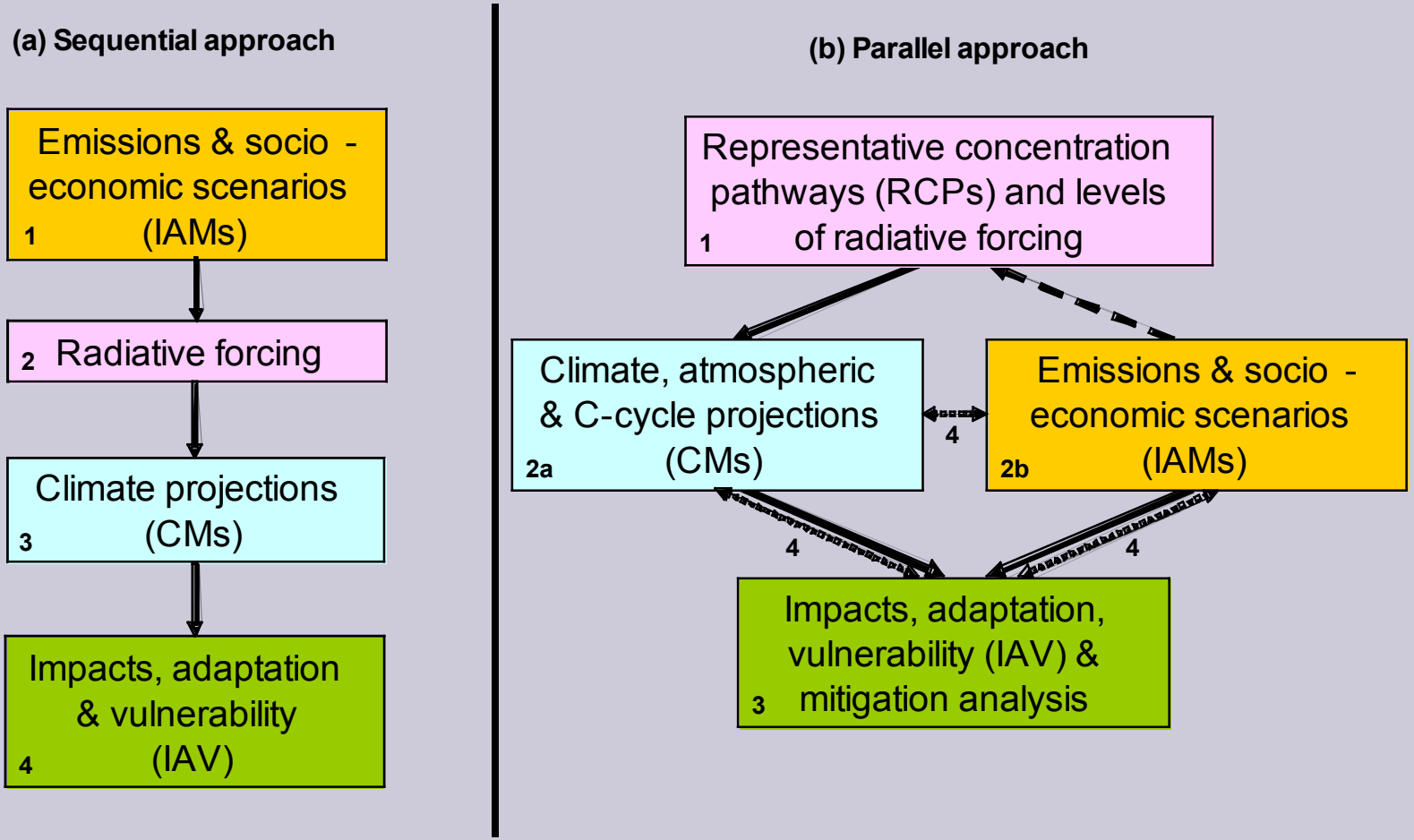


Figure from Moss et al., 2008, 2009

New scenarios development process: Critical path of scenario development

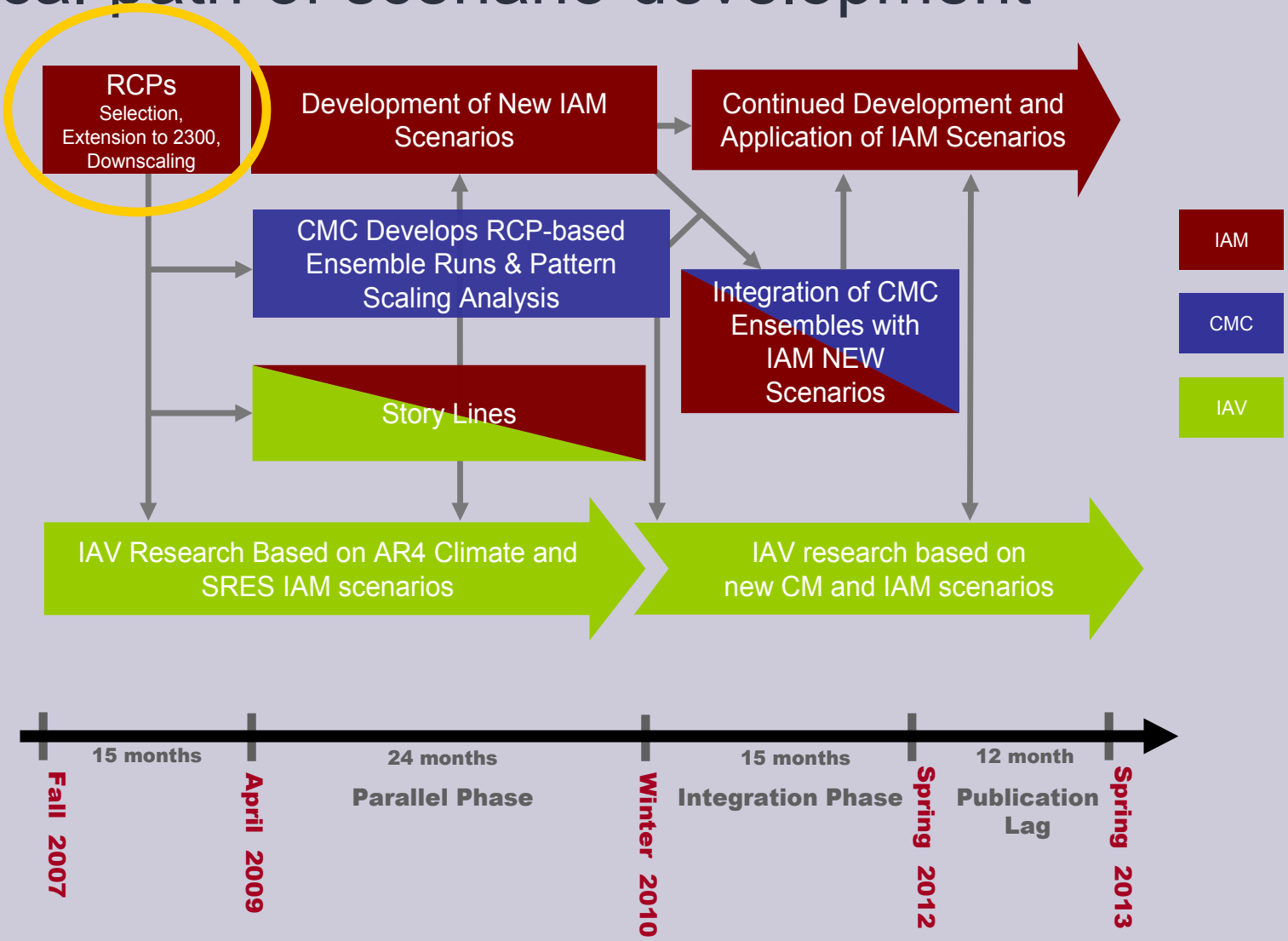
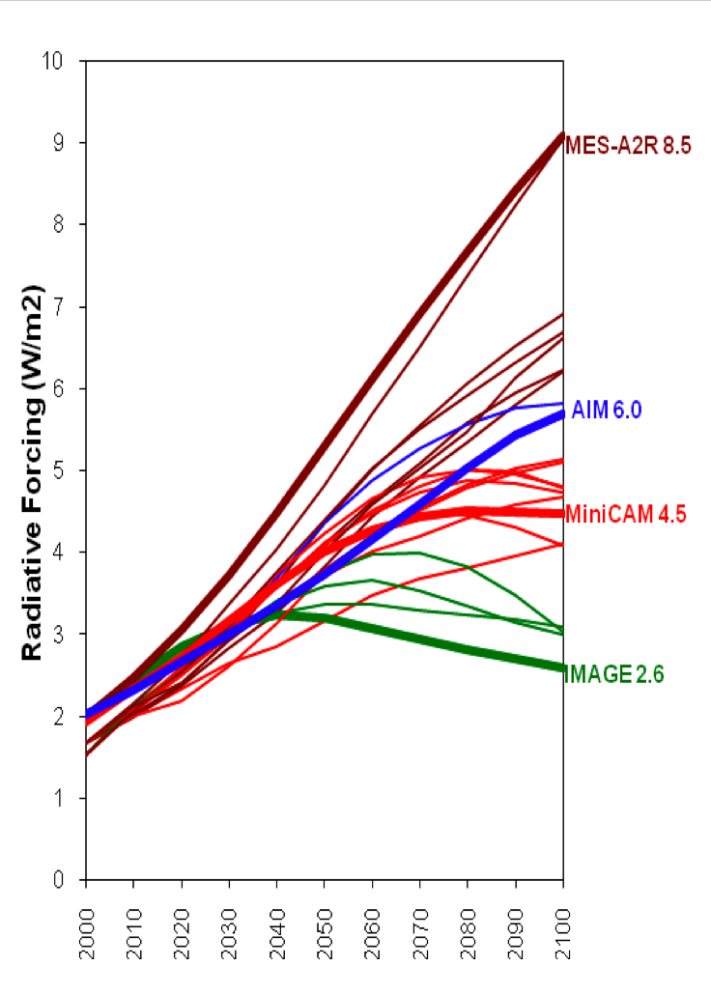


Figure adapted from Moss et al., 2008, 2009

Scenarios selected to span climate space.
(and new scenario development process with scientific communities as responsible party, e.g., NOT IPCC)

Representative Concentration Pathways

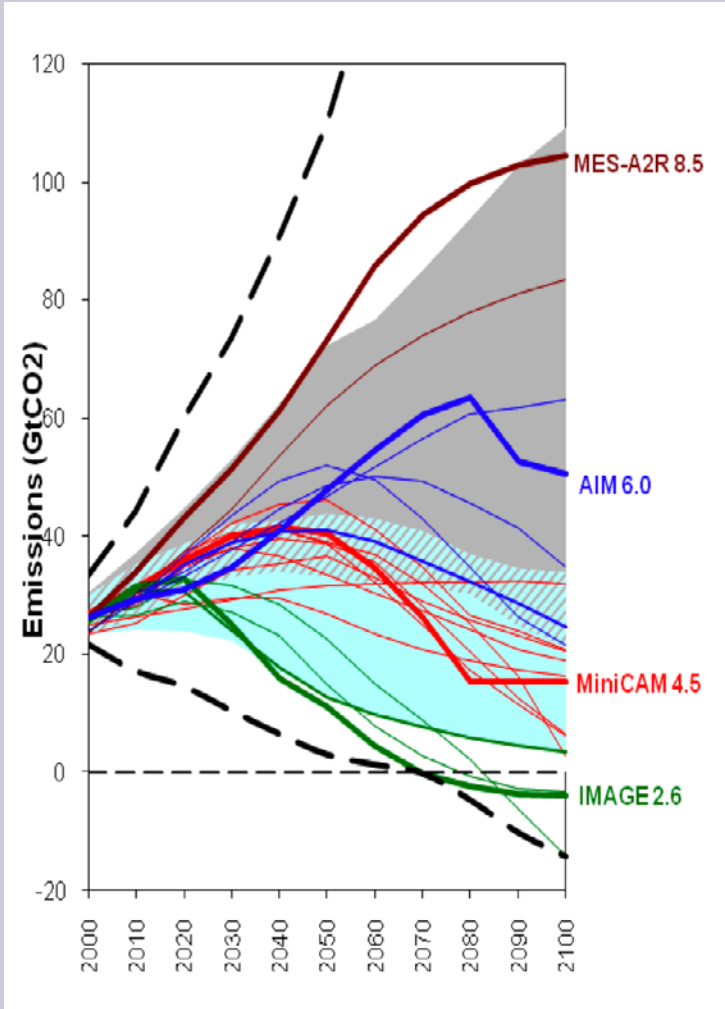


(956 ppmv)

(~671 ppmv)

(526 ppmv)

(410 ppmv)



(CO_2 concentration in 2100)

Figure adapted from Moss et al., 2008, 2009

Identified desirable characteristics for RCPs

- *Range:*
  - Set "should be compatible with the full range of stabilization, mitigation, and baseline emissions scenarios available in the current scientific literature."
- *Number:*
  - Four RCPs – even number avoids the natural inclination to select the intermediate case as the "best estimate"
- *Separation and Shape:*
  - To be statistically distinguishable, radiative forcing pathways should be well separated by the end of the 21st century and/or have distinctive shapes
- *Robustness:*
  - Given the substantial resource requirements associated with running CMs, the RCPs and the scenarios on which they are based should be robust. A key criterion is whether several models can produce similar radiative forcing outcomes with plausible and technically sound scenarios.
- *Comprehensiveness:*
  - For internally consistent data, models need to model all radiative forcing factors (full suite of GHGs, aerosols, chemically active gases, and land use/land cover)
- *Near-term resolution:*
  - Produce data at higher resolution for the first 30 years (to 2035) for experimental climate change and atmospheric chemistry projections

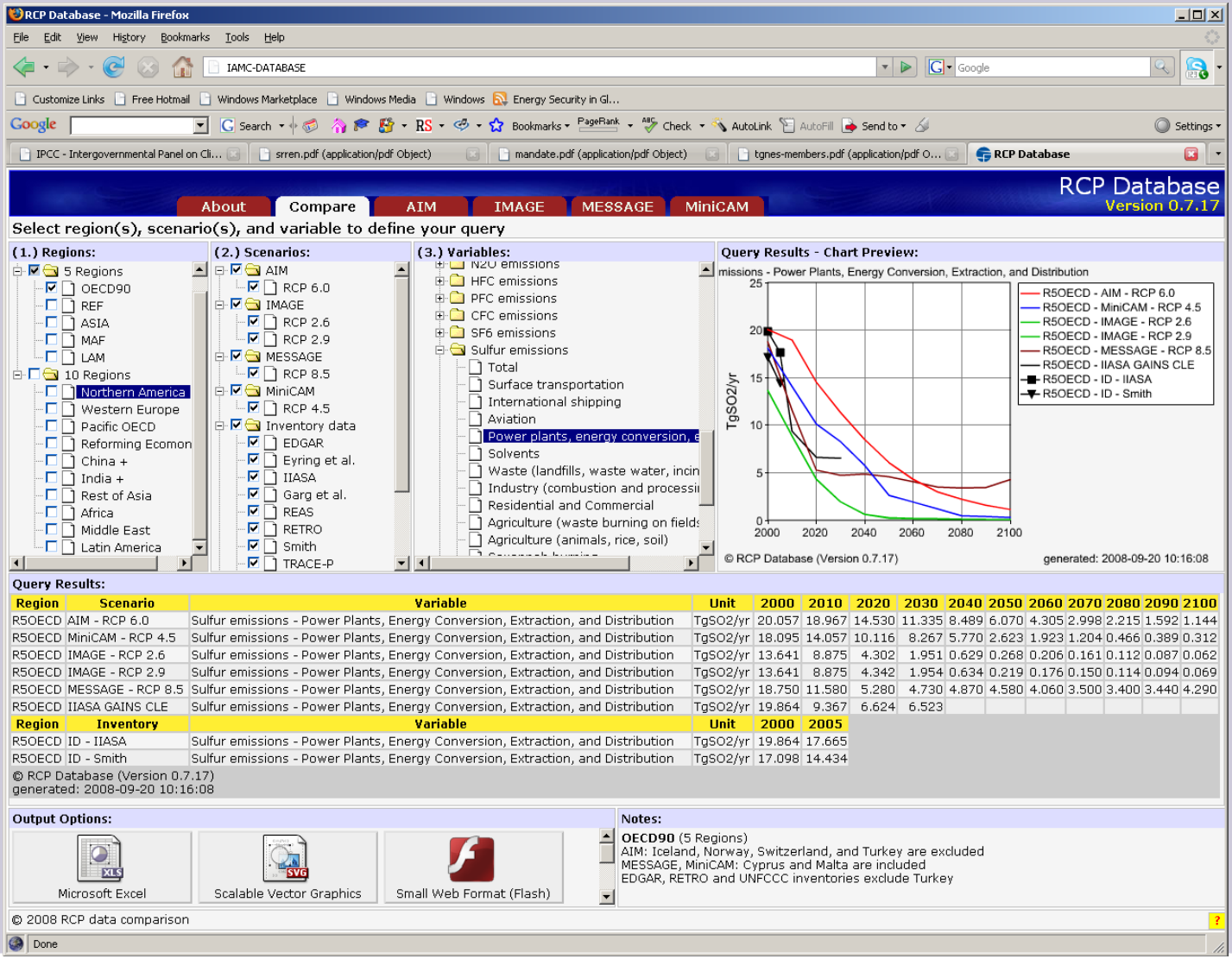
User guidance: Intended uses and limits of RCPs

- **Intended uses**
  - **Input to climate models to jump-start scenario development across research communities**
  - **To facilitate pattern scaling of climate model outcomes**
  - **To explore ranges of socioeconomic conditions consistent with different forcing pathways**
  - **To explore climate implications of spatial forcing patterns**
  - **To provide a consistent analytical thread through the literature**

- **Limits**
  - **Not forecasts or absolute bounds**
  - **Not policy prescriptive**
  - **Socioeconomics underlying each RCP are not unique; and, across RCPs, are not a set or representative of the range of assumptions**
  - **Uncertainties in the translation of emissions profiles to concentrations and radiative forcing**

Central IAM Data Repository

IAM working environment & data dissemination



Database open for scientific review: http://www.iiasa.ac.at/web-apps/tnt/RcpDb/

RCP status

- Significant coordination within and outside RCP teams over two years
- Completed IMAGE 2.6 review for lowest RCP (Weyant et al., 2009)
- Developed RCP database: web-based central repository with standardized set of reporting variables
- Developed emissions and land-use standardization data: spatially explicit base year and historic data for standardizing the RCP base years and projections
- Completed detailed internal review (data to 2100)
- Outside technical review underway (for 3 of the RCPs to 2100) – IAM, climate, and atmospheric chemistry communities, as well as others
- Completing internal review of 4th RCP
- Atmospheric chemistry runs beginning/offline and spinup CM runs beginning
- Forthcoming: Land-use transition standardization, recent request for historic concentrations, RCP 2300 extensions

Early 1980s | Early 1990s | Late 1990s | Present Day

Energy-climate multigas+landuse models

Energy-climate multigas models

Energy-climate CO_2 models

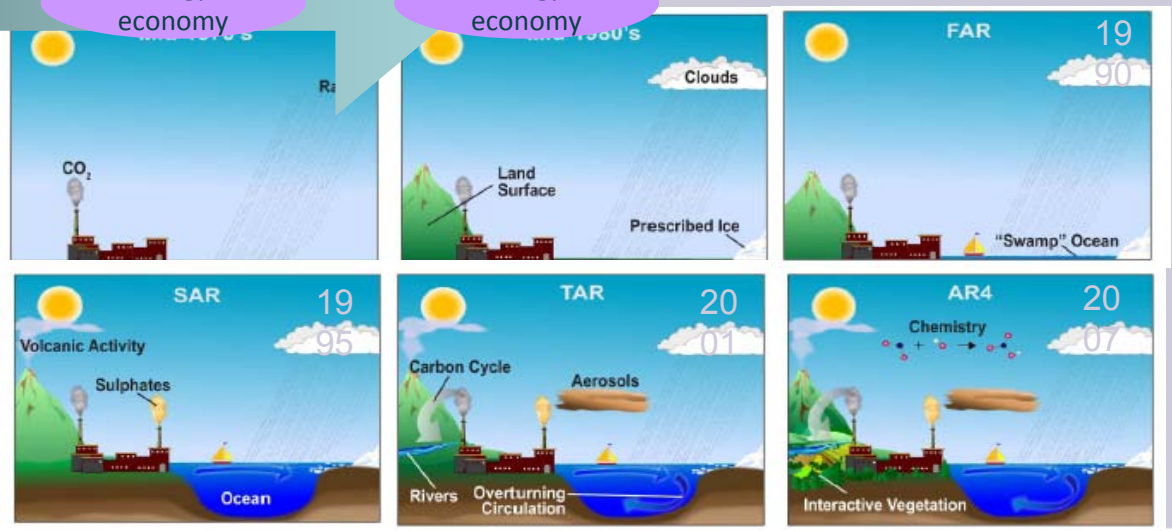
Energy CO_2 models

Energy-economy

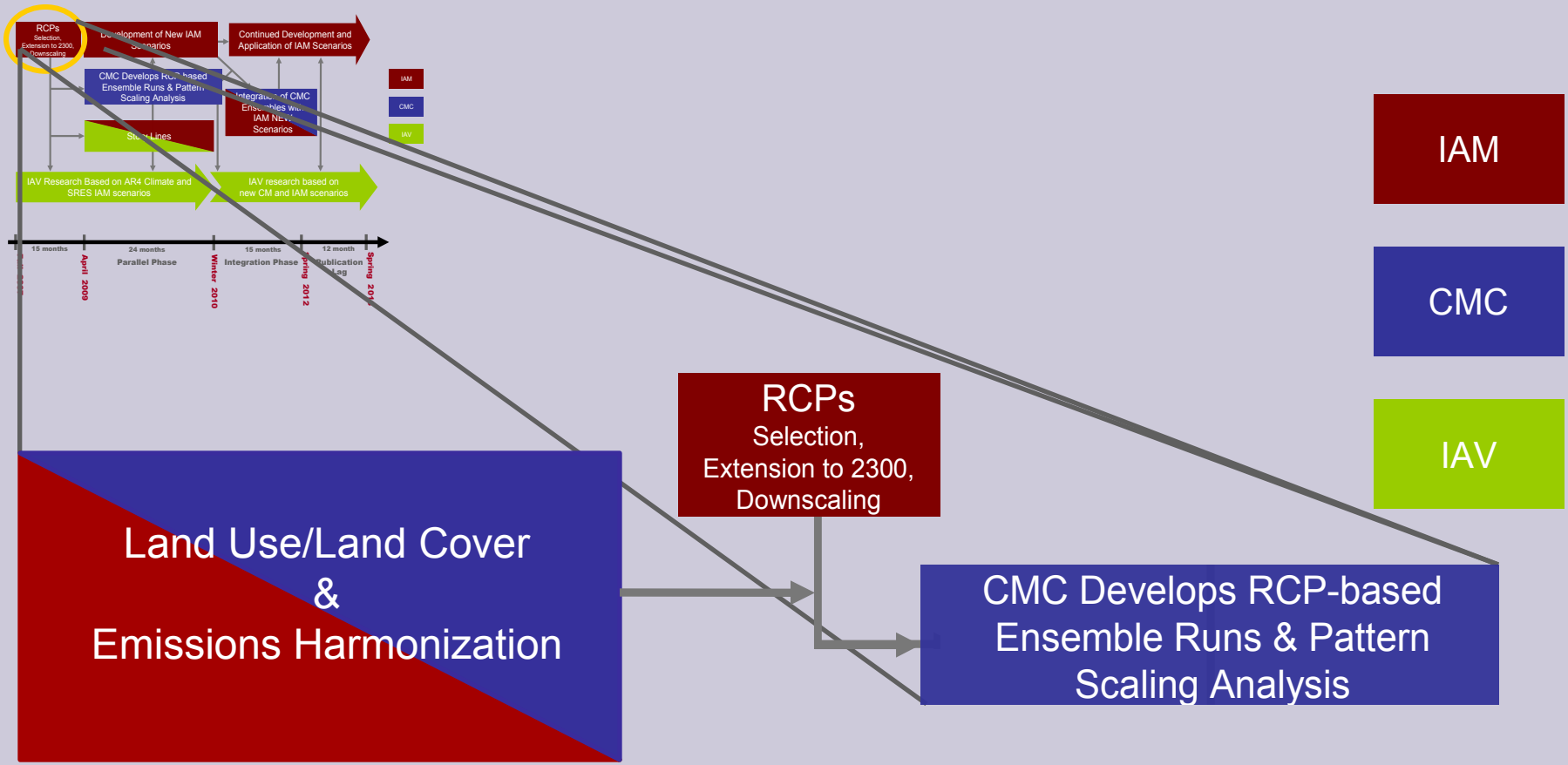
Atmos. Chem.
Climate model
Ocean carbon cycle
Energy-economy

Sulfur aerosol
Energy technology
Atmos. Chem.
Climate model
Ocean carbon cycle
Energy-economy

Ag-land-use
Terr. carbon cycle
Non-sulfur aerosol
Sulfur aerosol
Energy technology
Atmos. Chem.
Climate model
Ocean carbon cycle
Energy-economy



IAM and CM: growing overlap in domains



As RCP development commenced, it became increasingly clear that consistency between IAM and CMs would be necessary

A strategy, or handshake between the modeling communities for harmonized land use/land cover and emissions was proposed at EMF Snowmass 2007

RCP data hand-shake: An IAM-ESM-inventory-chemistry-land cover collaboration

- Consistency and coordination between the communities required and essential to increase comparability and provide a smooth transition from historic to future periods
- Coordination events:
  - Joint Meeting, February 2008, Washington, DC
  - Emissions meeting, May 2008, Paris
  - Joint Meeting, Summer 2008, Snowmass, CO
  - IAMC meeting, September 2008, Vienna
  - CM/IAM LU/LC and Wetland May 2009, Hamburg
  - And MANY additional informal meetings, conference calls

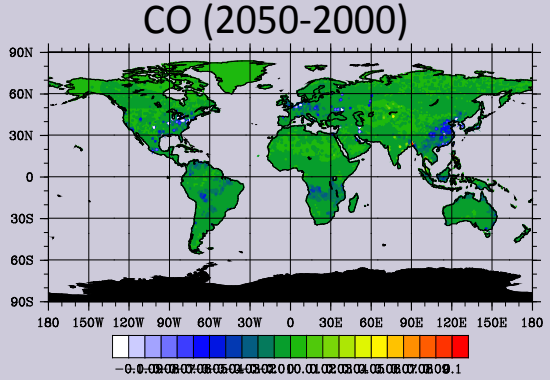
RCP Emissions Sectoral Detail

ftp://ftp-ipcc.fz-juelich.de/pub/emissions/gridded_netcdf

The RCP emissions data will be provided in greater sectoral detail than for previous scenario exercises:

- Ground Transportation
- International Shipping
- Aviation
- Power Plants, Energy Conversion, Extraction, and Distribution
- Solvents
- Waste (landfills, wastewater, non-energy incineration)
- Industry (combustion & processing)
- Residential and Commercial

- Ag waste burning on Fields
- Agriculture (e.g. Animals, Rice, & Soil)
- Savannah Burning
- Land-Use Change (Deforestation)



Aim to have data at regional, national and grid scale

Emissions data:

Variable	Units	Spatial scale	
		Concentrations	Emissions
Greenhouse gases			
CO_2 (fossil fuel, industrial, land use change)	ppm and Pg/yr	Global average	Sum
CH_4	ppb and Tg/yr	Global average	Grid[1]
N_2O	ppb and Tg/yr	Global average	Sum
HFCs[2]	ppb and Tg/yr	Global average	Sum
PFCs[2]	ppb and Tg/yr	Global average	Sum
CFCs[2]	ppb and Tg/yr	Global average	Sum
SF_6	ppb and Tg/yr	Global average	Sum
Aerosols[2]			
Sulfur (SO_2)	Tg/yr	Generated by CM community[3]	Grid
Black Carbon (BC)	Tg/yr	Generated by CM community[3]	Grid
Organic Carbon (OC)	Tg/yr	Generated by CM community[3]	Grid
Chemically active gases			
CO	Tg/yr	Generated by CM community[3]	Grid
NO_x	Tg/yr	Generated by CM community[3]	Grid
VOCs[2]	Tg/yr	Generated by CM community[3]	Grid
NH_3	Tg/yr	Generated by CM community[3]	Grid
Land use & land cover			
CO_2 flux (land use change)	Tg/yr	n/a	$\leq 1° \times 1°$

Inventory communities provide global averages

[3]J-F Lamarque and others to provide

Emissions Data Status

- All emissions 1850-2000 available for download:

  ftp://ftp-ipcc.fz-juelich.de/pub/emissions/gridded_netcdf

- Processing (addition of seasonal cycle and vertical distribution where appropriate) of RCP8.5 done and emissions are being evaluated by a small group of collaborators
- RCP2.6 and RCP4.5 next
- Still some issues with RCP6.0

- With regard to fossil fuel data: Patricia Cadule from IPSL contacted Bob Andres, who provided fossil fuel data. A continuous file from 1751 to 2006, monthly data, netcdf format is now available (as of Tuesday morning!).

RCP LU/LC Harmonization from the IAMS:

ftp://tarot.sr.unh.edu

Land-use/land-use change data on a gridded (0.5^{o} lat x 0.5^{o} lon) format:

- Cropland
- Harvested forest area (secondary forests)
- Deforested area (primary forests)
- Pasture and grazing land
- Urban land

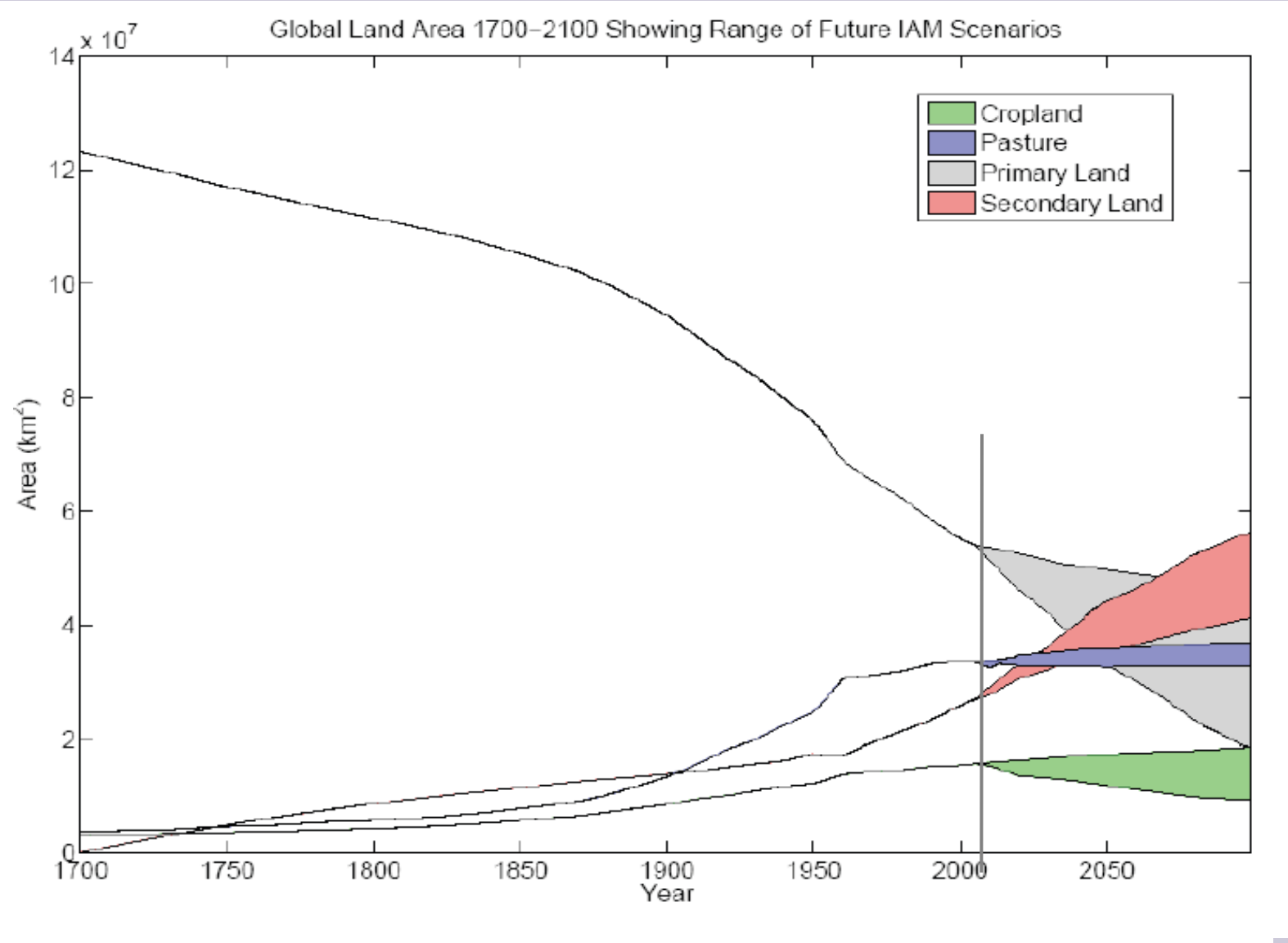
Supplementary data that has also been requested includes:

- Irrigated area
- Timber and wood harvest amounts (and disposition)
- Standard of living indicator
- Fertilizer use

RCP Standardization: Land Cover/Land Use Change

1. All scenarios will use an identical 2005 land cover as a starting point
2. All pathways share the same historical trajectory to 2005. After 2005 they diverge following their own representative pathway.
3. For each RCP, minimal information related to land cover change is provided as changes in four basic land units:
   - Primary Vegetation (V)
   - Secondary Vegetation (S)
   - Cropping (C)
   - Pasture (P)
4. Historical harvesting of biomass is also prescribed for both primary and secondary vegetation land units (Hurtt, 2006)
5. The University of New Hampshire (UNH) group is standardizing each scenario and the historical trajectory for harvest and land cover information
6. Each ESM group will have to construct land cover datasets by blending their own natural land cover with the prescribed human activities

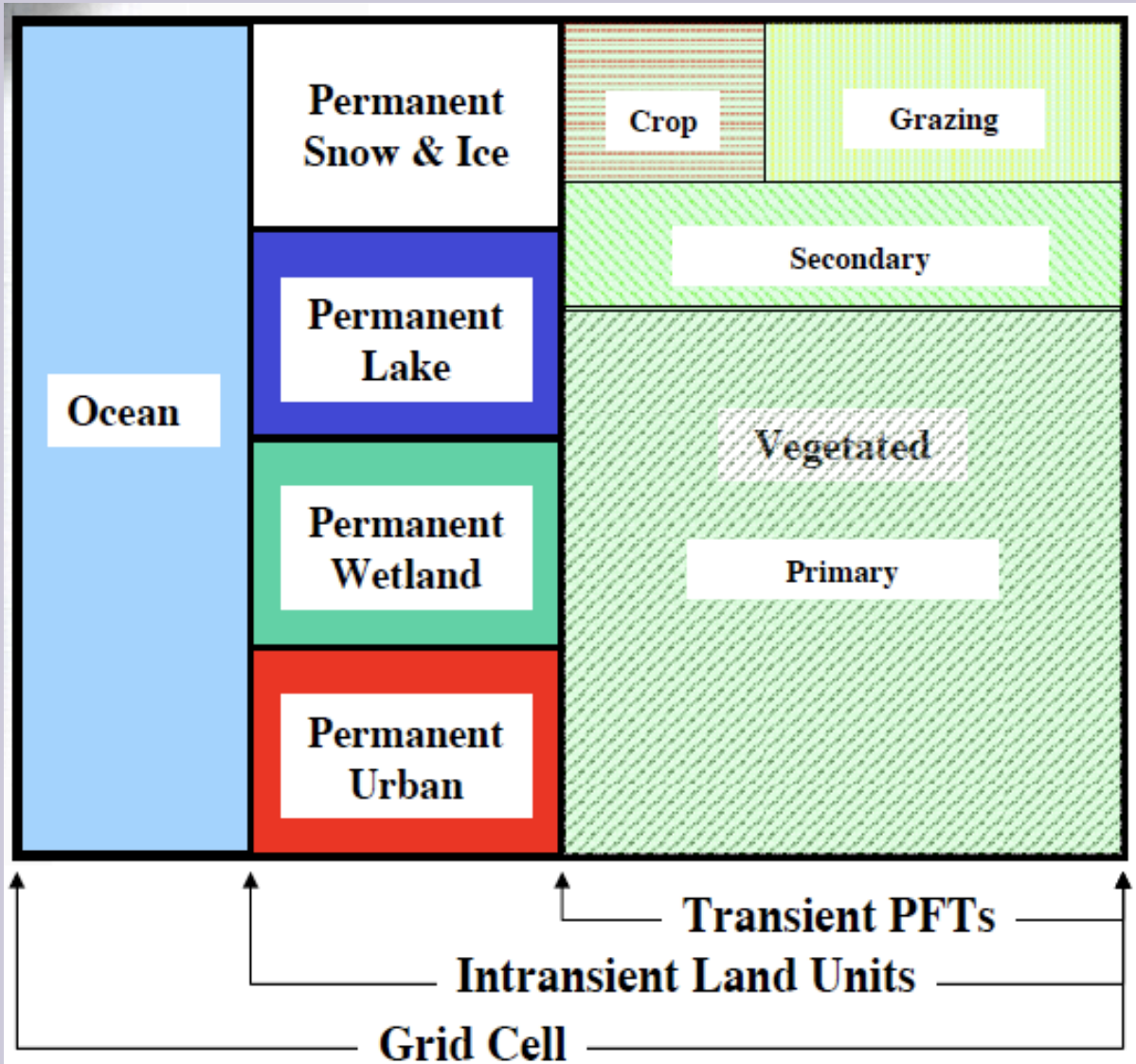
LULC Harmonization Strategy (UNH)



Implementation: Issues of definitions

e.g. What is Pasture/Grazing

Translating from harmonized to Earth system model: the CLM 4.0 Land Cover Representation



19 Plant Functional Types

Needleleaf evergreen tree
- temperate
- boreal

Needleleaf deciduous tree

Broadleaf evergreen tree
- tropical
- temperate

Broadleaf deciduous tree
- tropical
- temperate
- boreal

Shrub
- broadleaf evergreen, temperate
- broadleaf deciduous, temperate
- broadleaf deciduous, boreal

Grass
- C_3, arctic
- C_3
- C_4

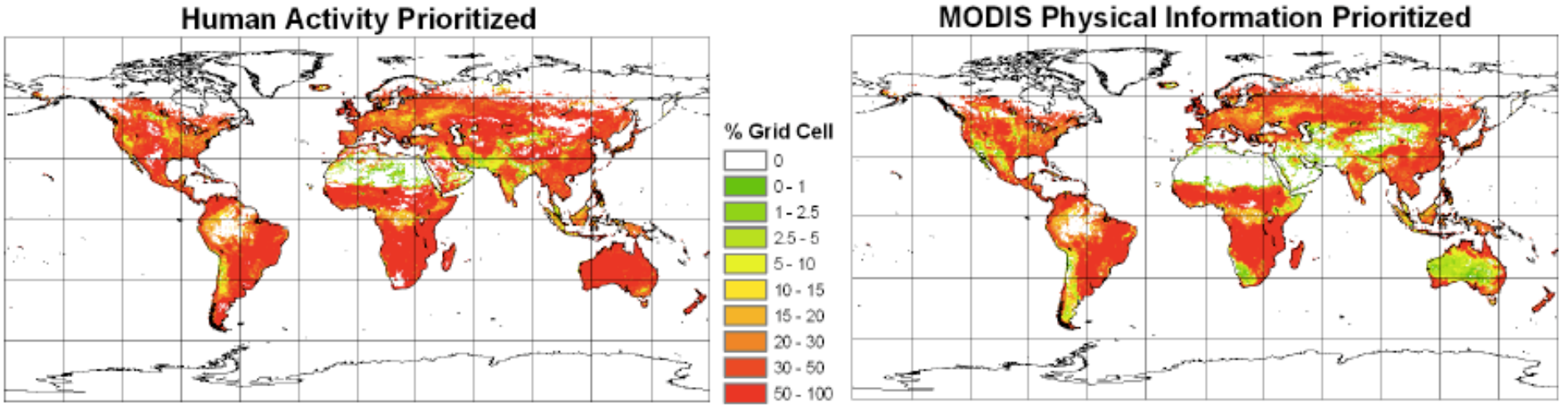
Crop
- Wheat
- Winter wheat
- Maize
- Soy

+ Bare Ground

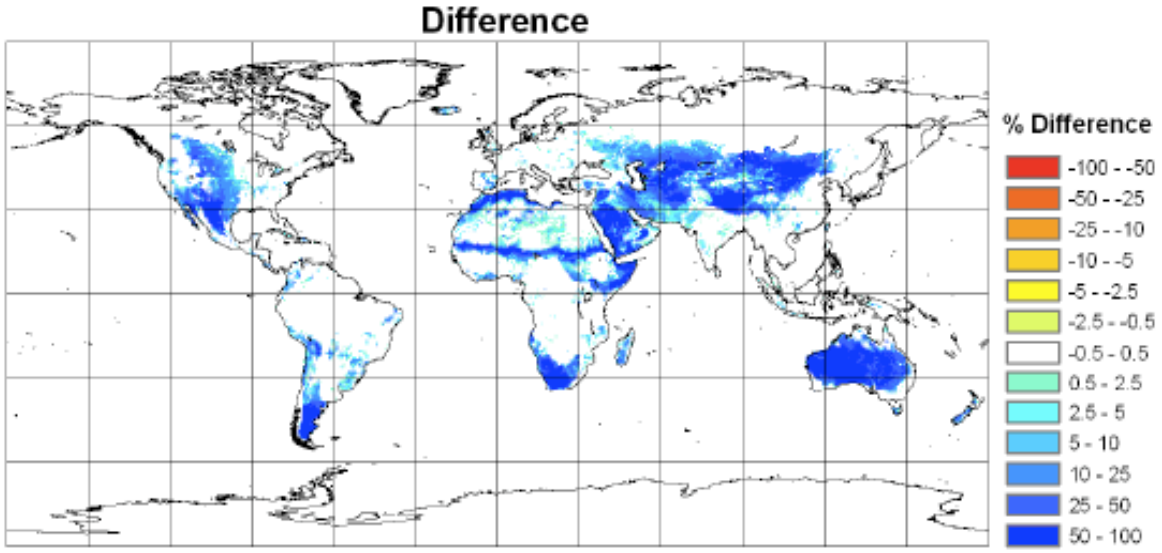
The National Center for Atmospheric Research NCAR managed by UCAR to serve the community

OAK RIDGE NATIONAL LABORATORY Managed by UT-Battelle for the Department of Energy

Creating datasets order of entry: grasslands



Order of entry
Urban
Agriculture
Pasture/Grazing
Bare ground
Forest
Shrub
Grass



Order of entry
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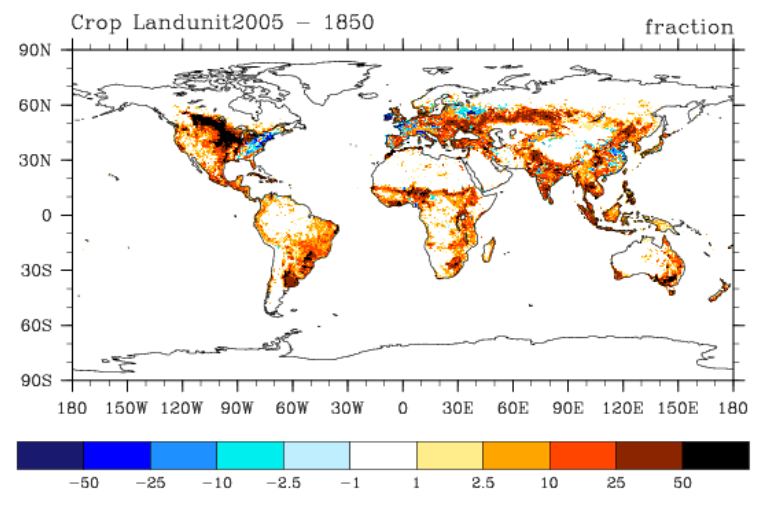
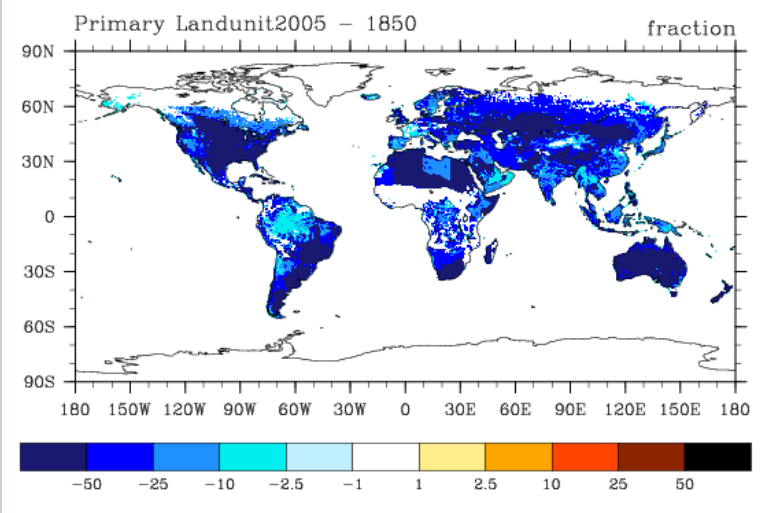
Historical (UNH Hurtt): Land cover change 2005-18[illegible]

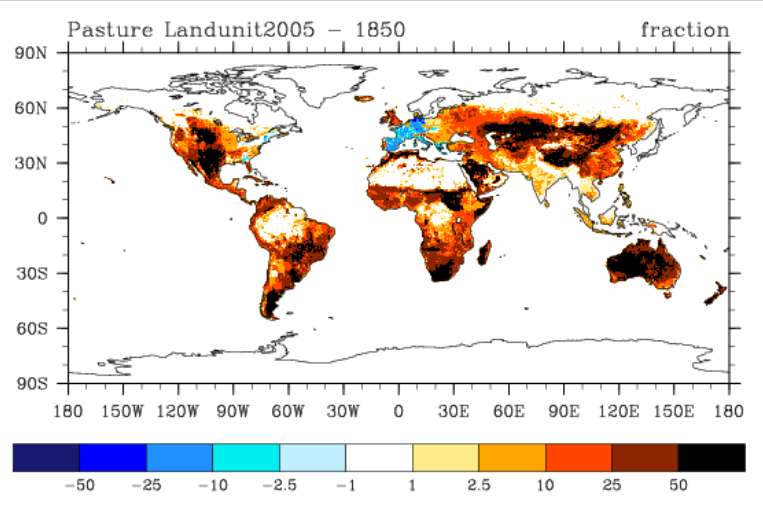
Crop



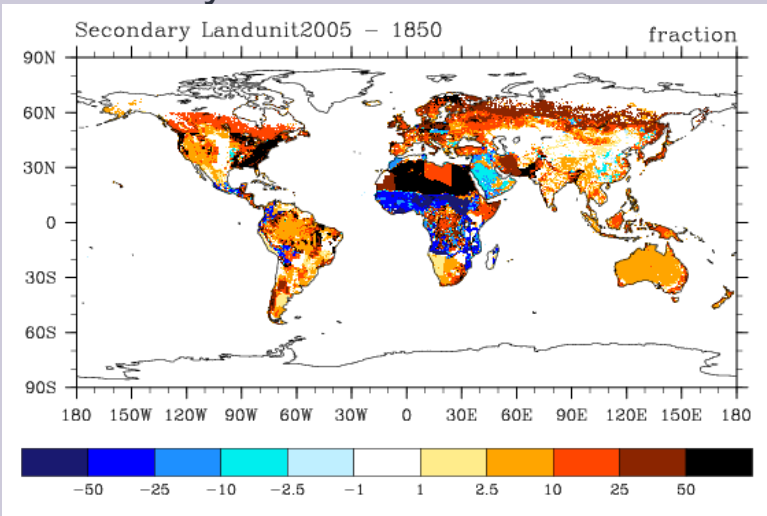
Primary



Pasture

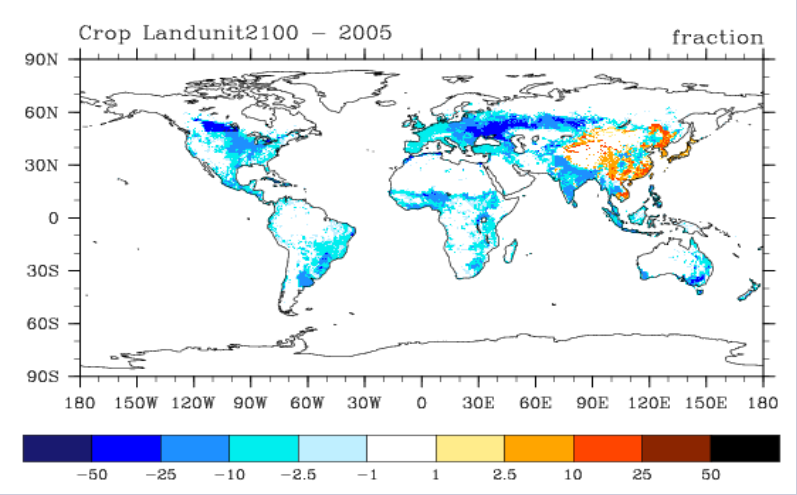


Secondary

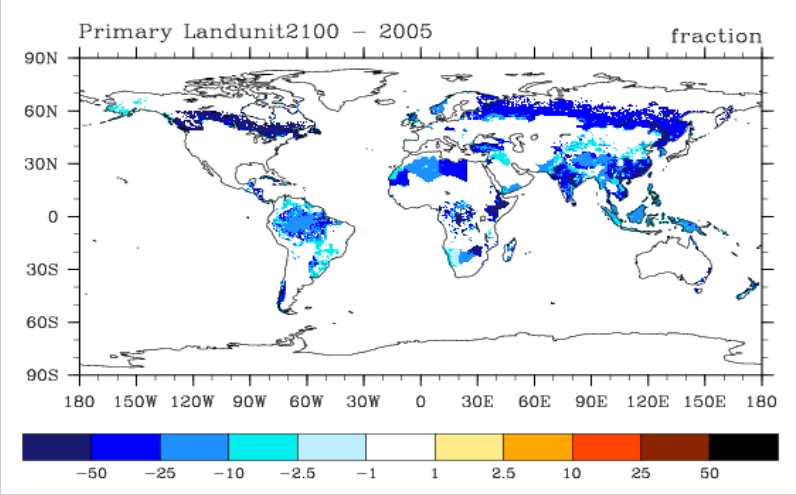


Mini-Cam (RCP 4.5 Wm^{-2}): Land cover change 2100-2005

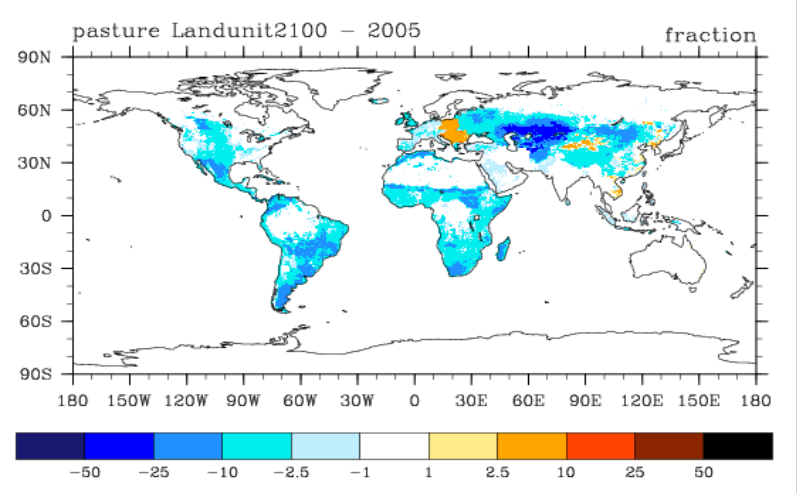
Crop



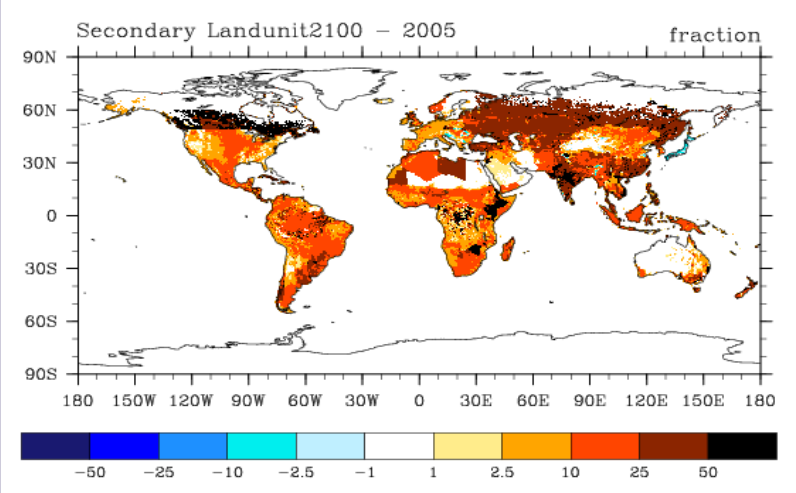
Primary



Pasture

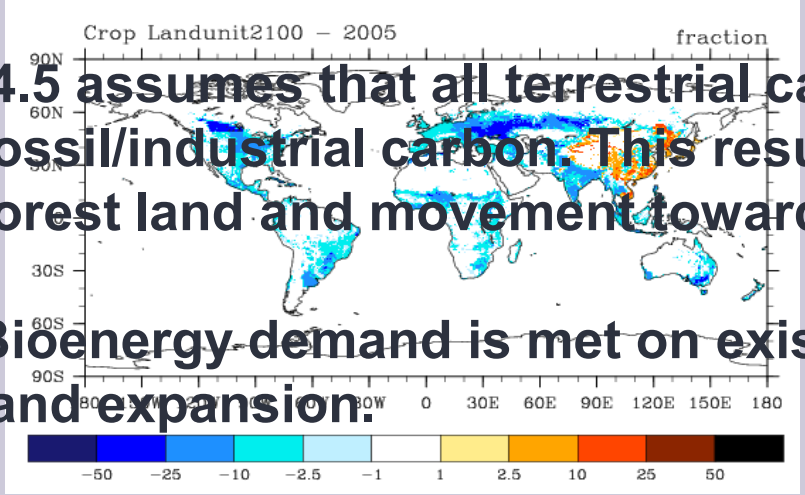


Secondary

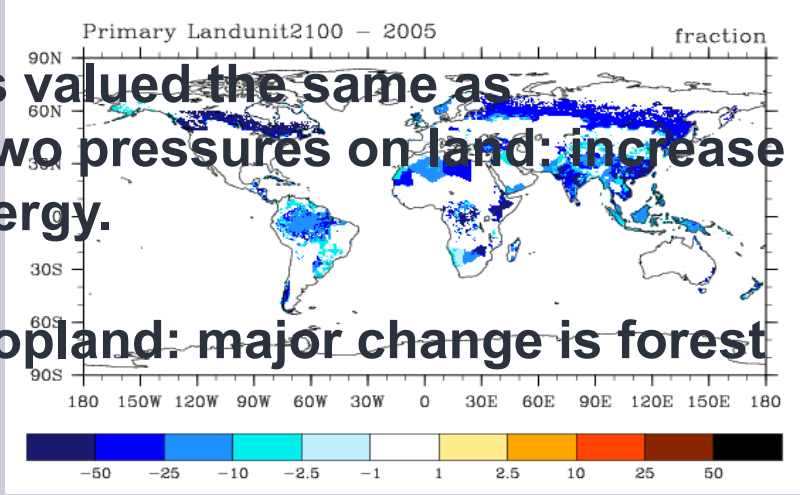


Mini-Cam (RCP 4.5 Wm^{-2}): Land cover change 2100-2005

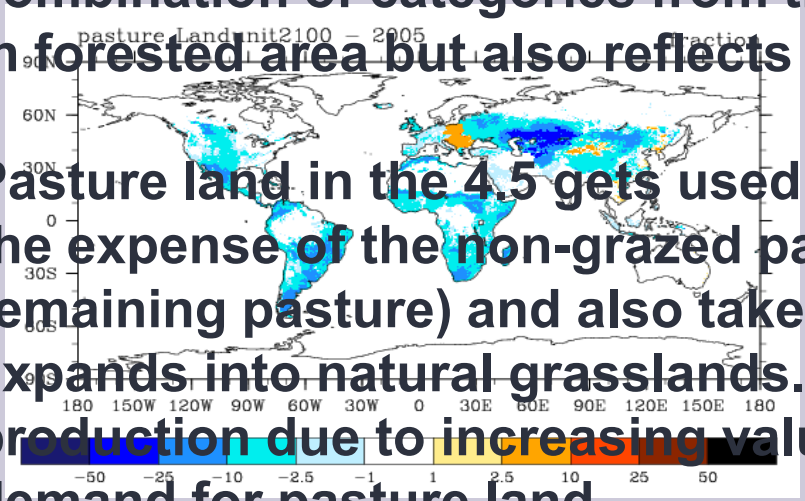
Crop



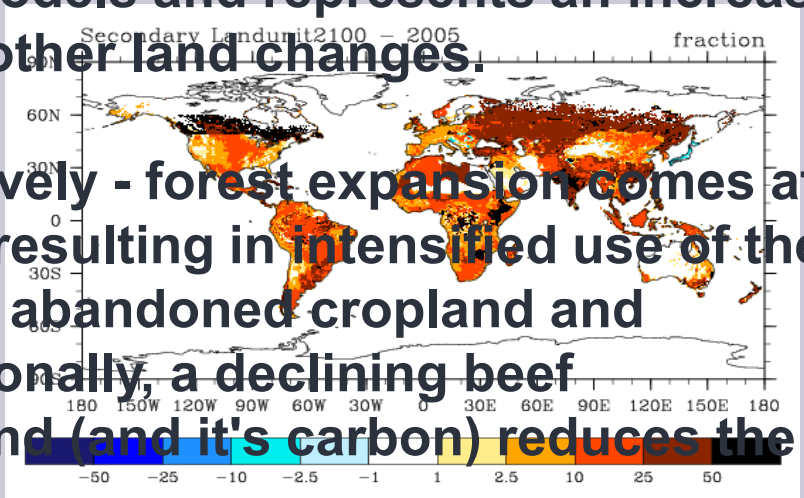
Primary



Pasture



Secondary



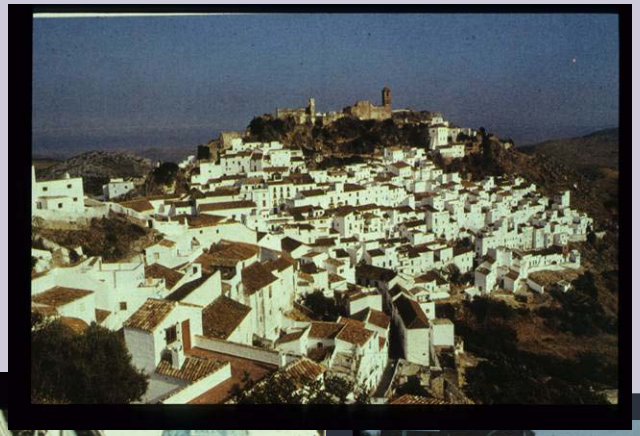
4.5 assumes that all terrestrial carbon is valued the same as fossil/industrial carbon. This results in two pressures on land: increase in forest land and movement toward bioenergy.

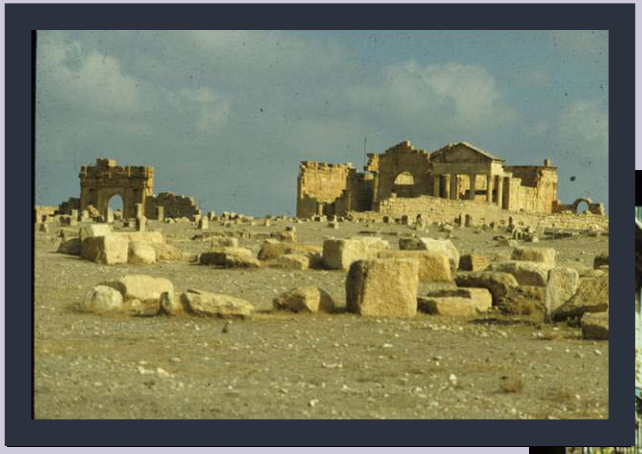
Bioenergy demand is met on existing cropland: major change is forest land expansion.

The "secondary land" category from the harmonization represents a combination of categories from the IA models and represents an increase in forested area but also reflects all the other land changes.

Pasture land in the 4.5 gets used intensively - forest expansion comes at the expense of the non-grazed pasture (resulting in intensified use of the remaining pasture) and also takes some abandoned cropland and expands into natural grasslands. Additionally, a declining beef production due to increasing value of land (and it's carbon) reduces the demand for pasture land.

Defining Classes: What is Urban?



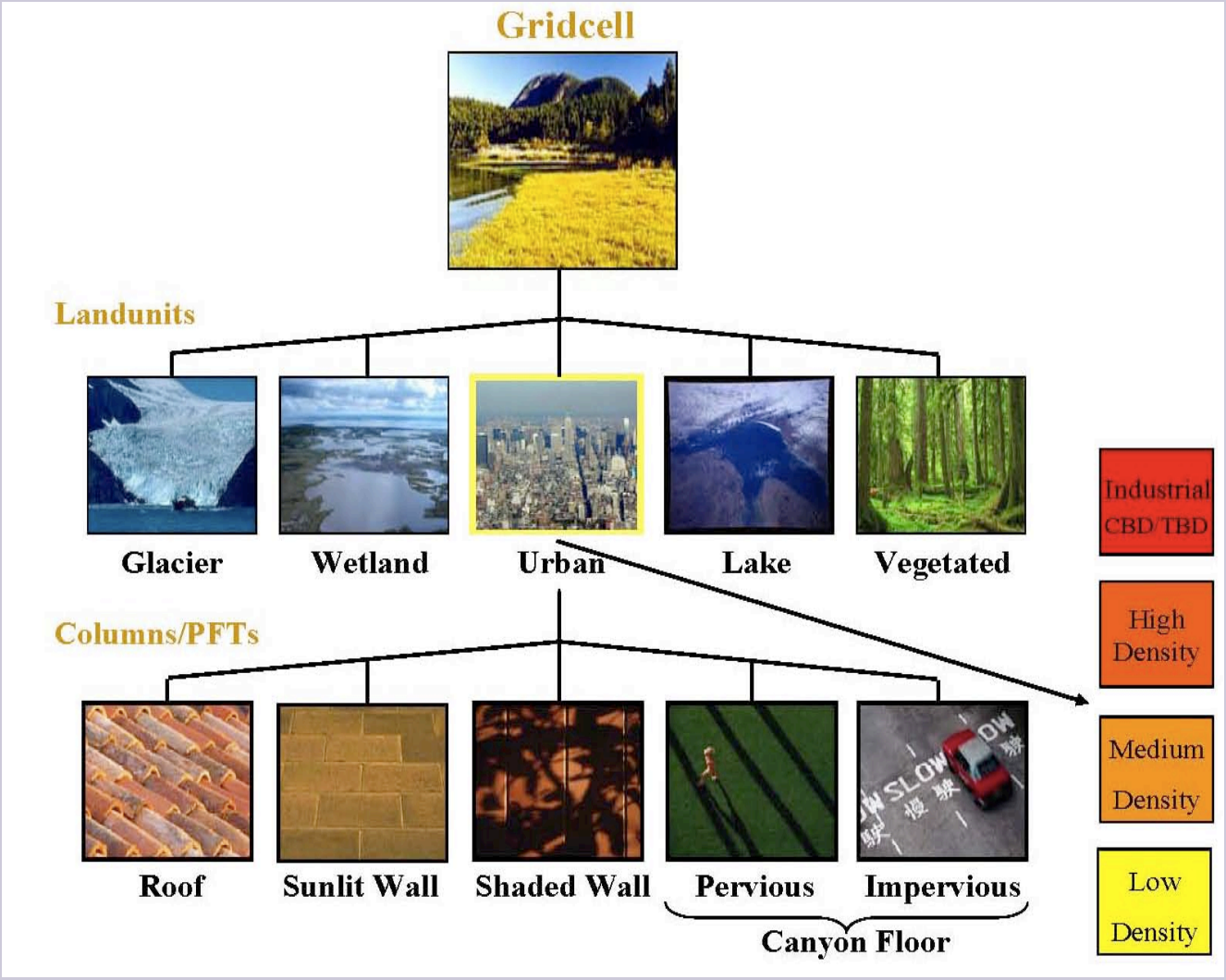


Defining urban classes (CBD/HD)

Urban characteristics: Nairobi (Kibara slum)

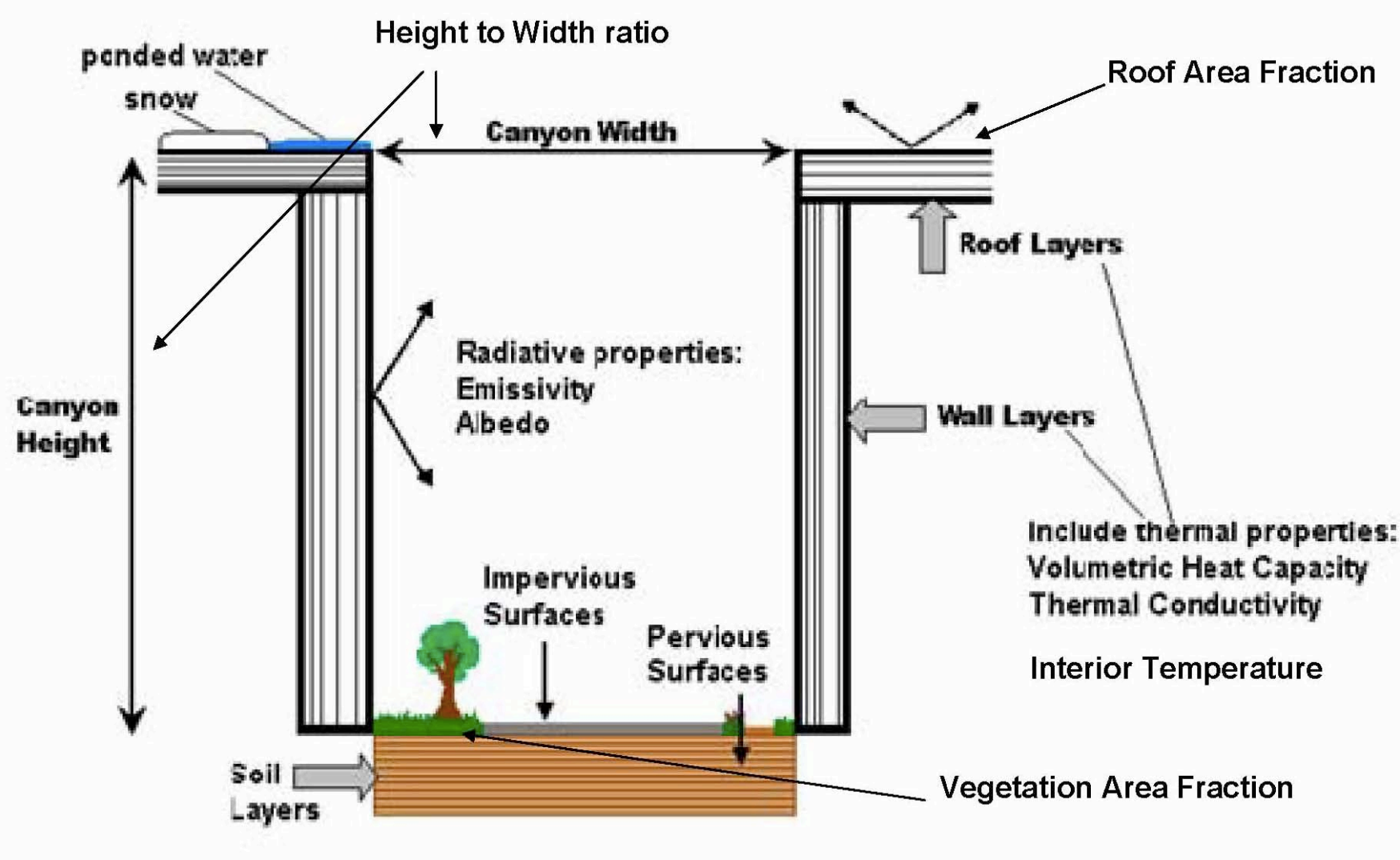
Defining urban classes (LD/HD???)

CLM 4.0 Urban Subgrid Structure: a 'permanent' land cover type: e.g., no transient or development



From Feddema et al., 2009 *in press tp AAG*

Required parameters in CLM

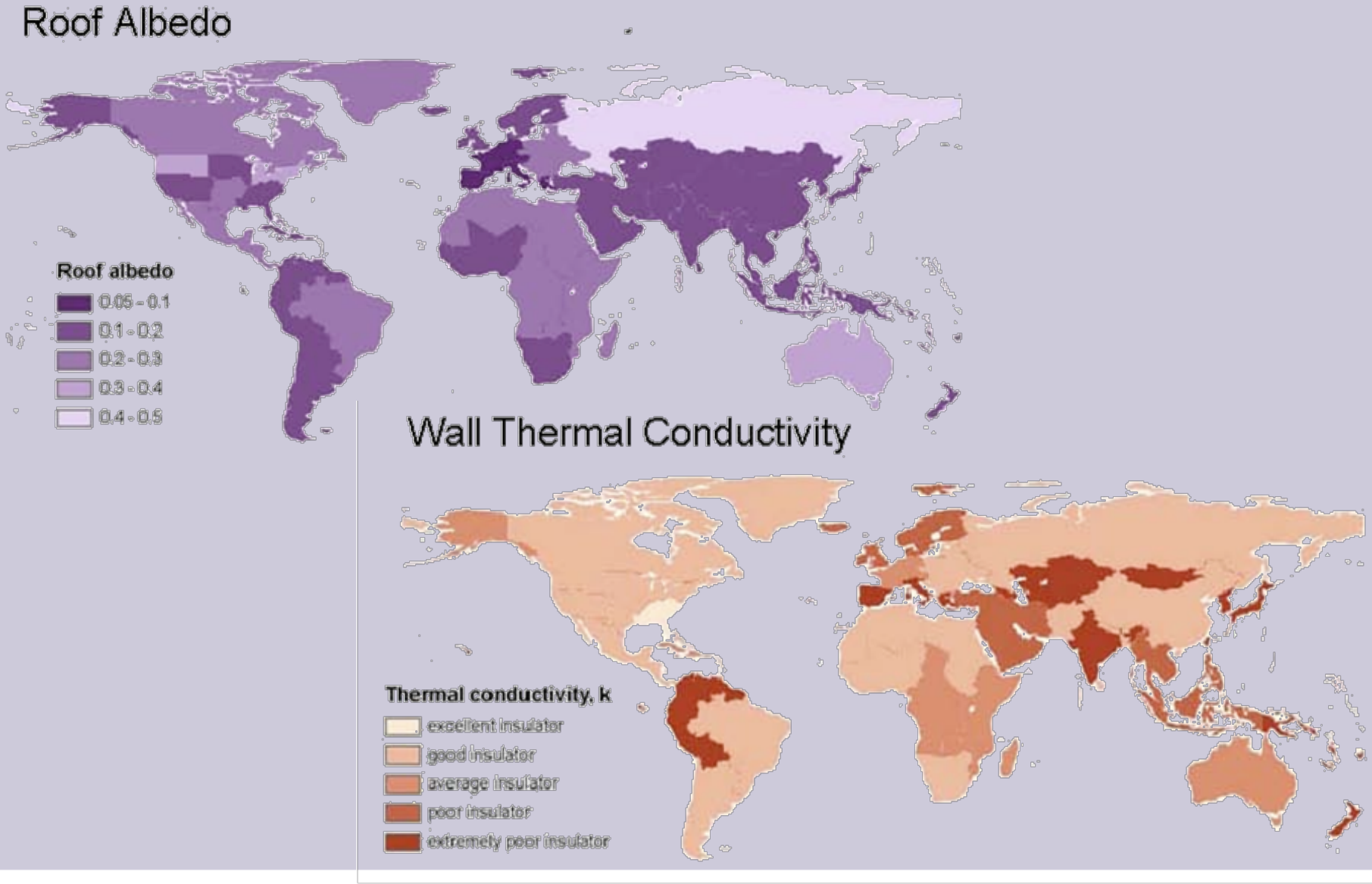


From Feddema et al., 2009 *in press to AAG*

Urban parameterizations

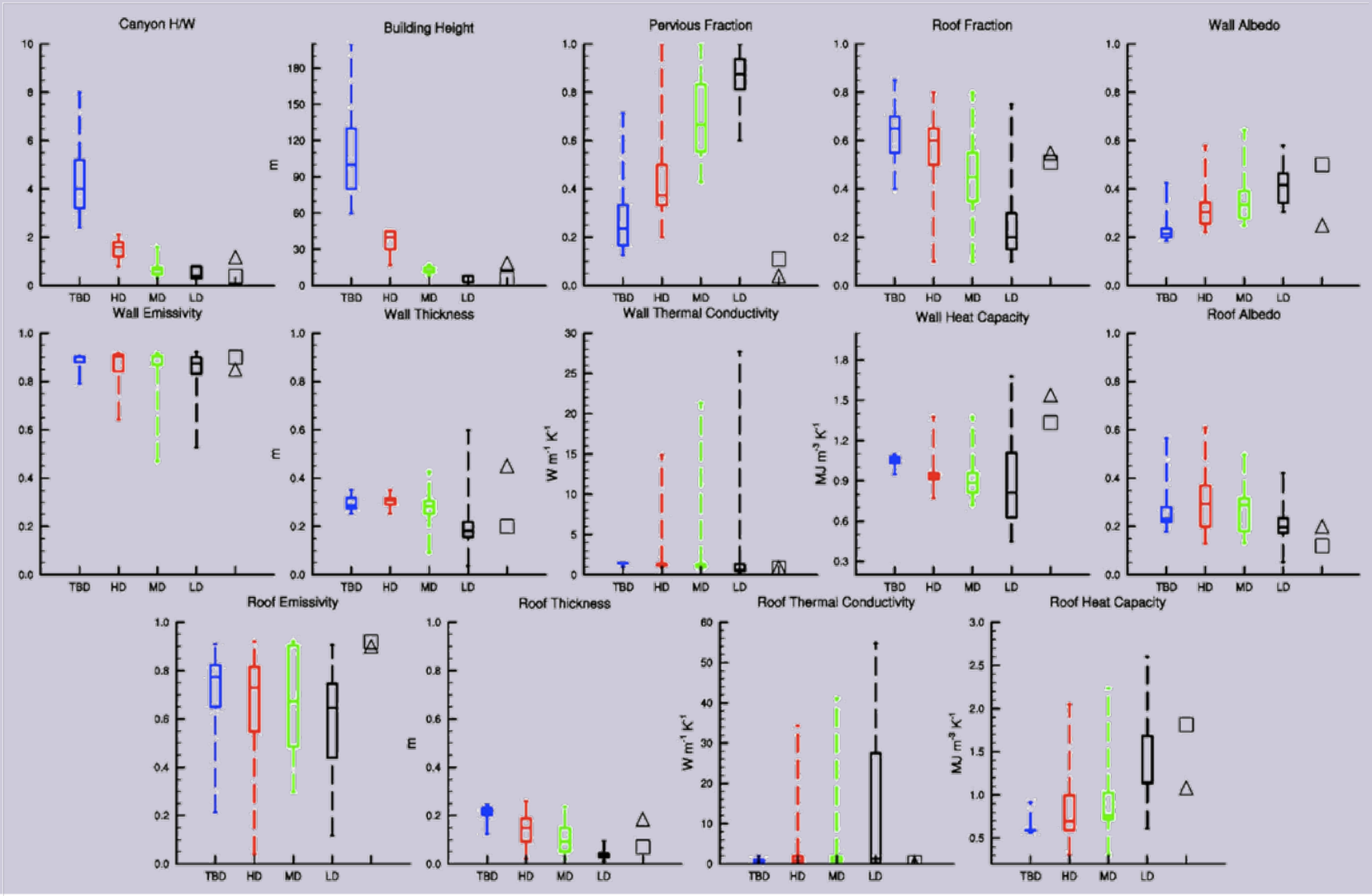
- Wall types: concrete, brick, stone, plaster, etc.
- Roof types: PVC, BUR/concrete deck, ceramic tiles, etc.
- Exterior wall materials and properties
- Interior wall materials and properties
- Wall type construction from 10 types of materials
- Roof type construction from 10 layers of materials
- Road types and properties (asphalt, concrete, unpaved, etc.)
- Bridging factors applied across various wall types

Example results



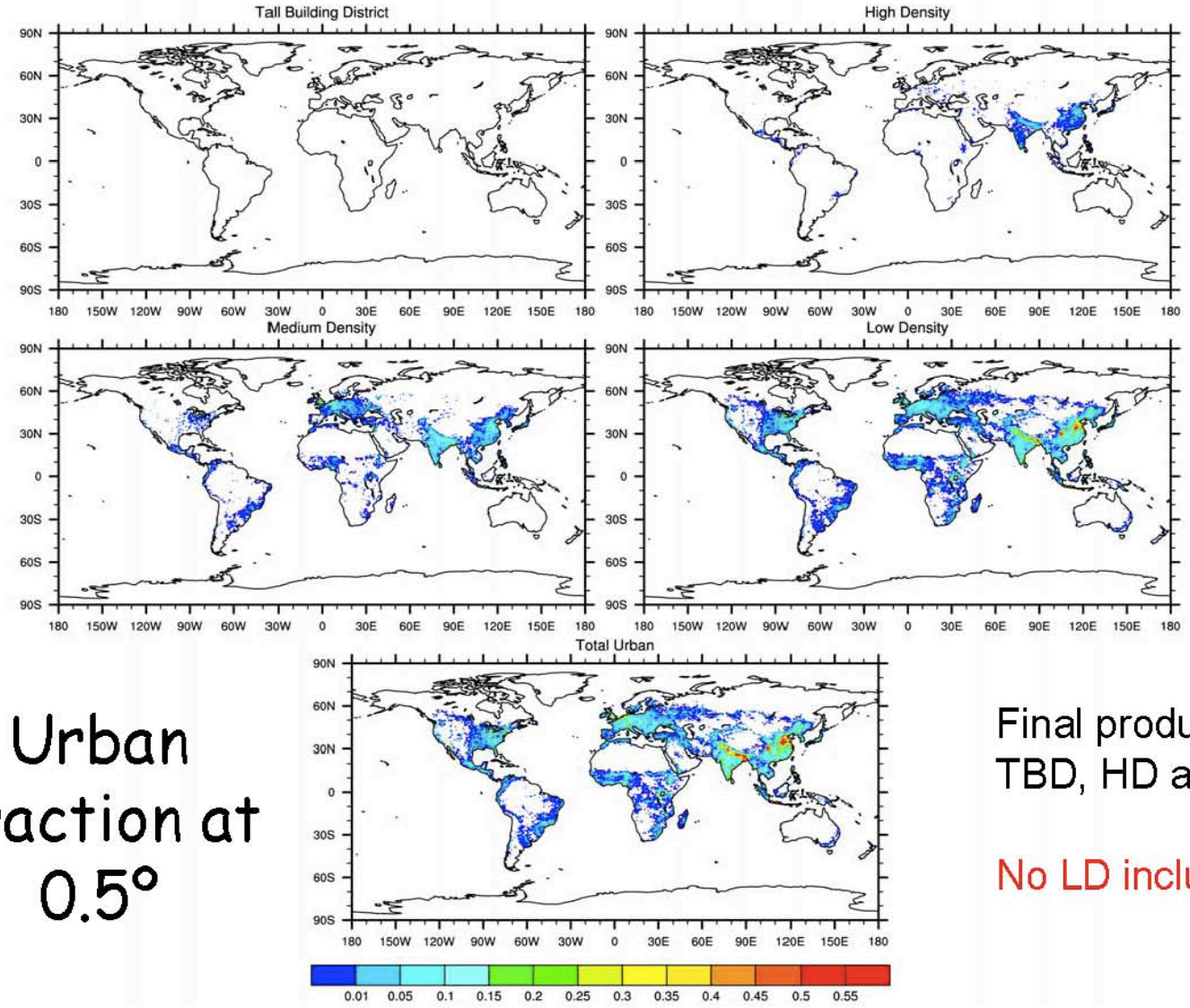
From Feddema et al., 2009 *in press to AAG*

Global urban properties



From Feddema et al., 2009 *in press to AAG*

Example: Urban input data



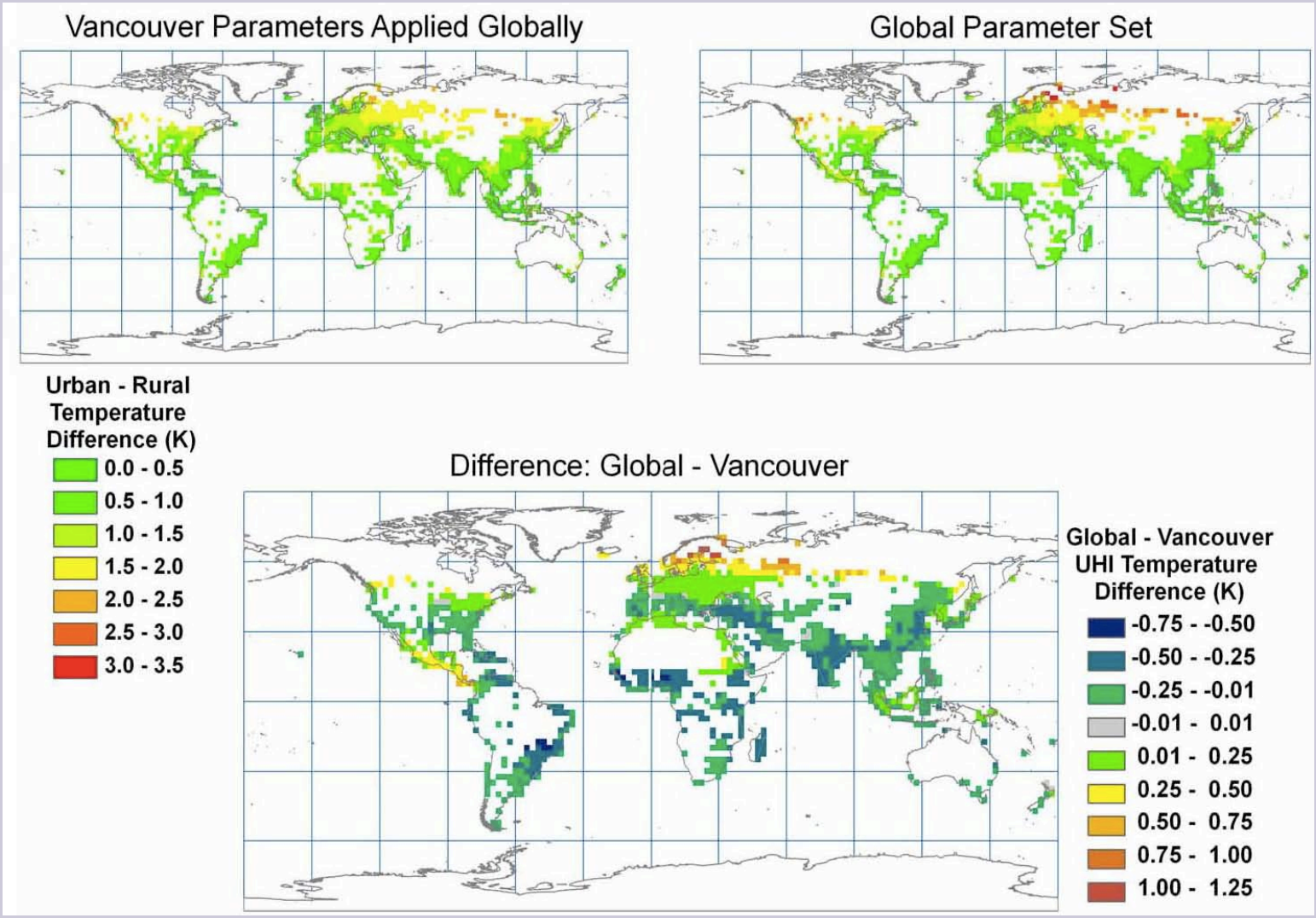
Urban Fraction at 0.5°

Final product aggregates TBD, HD and MD areas

No LD included

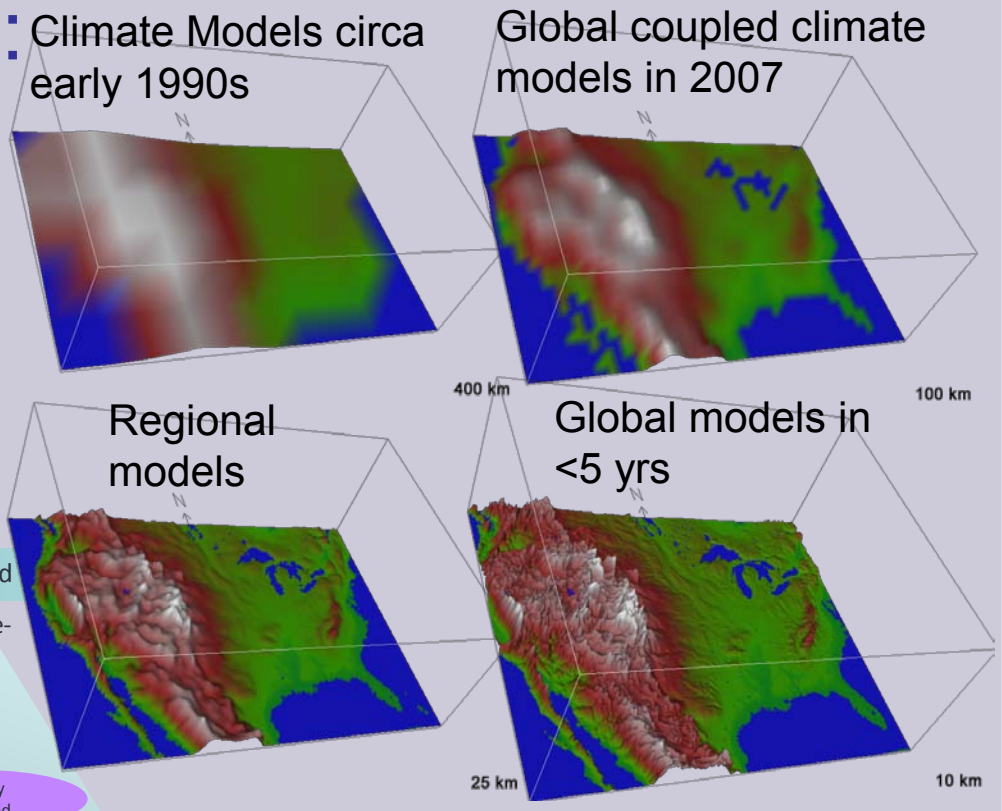
From Feddema et al., 2009 *in press to AAG*

Urban heat island comparison: Parameterization sensitivity



From Feddema et al., 2009 *in press to AAG*

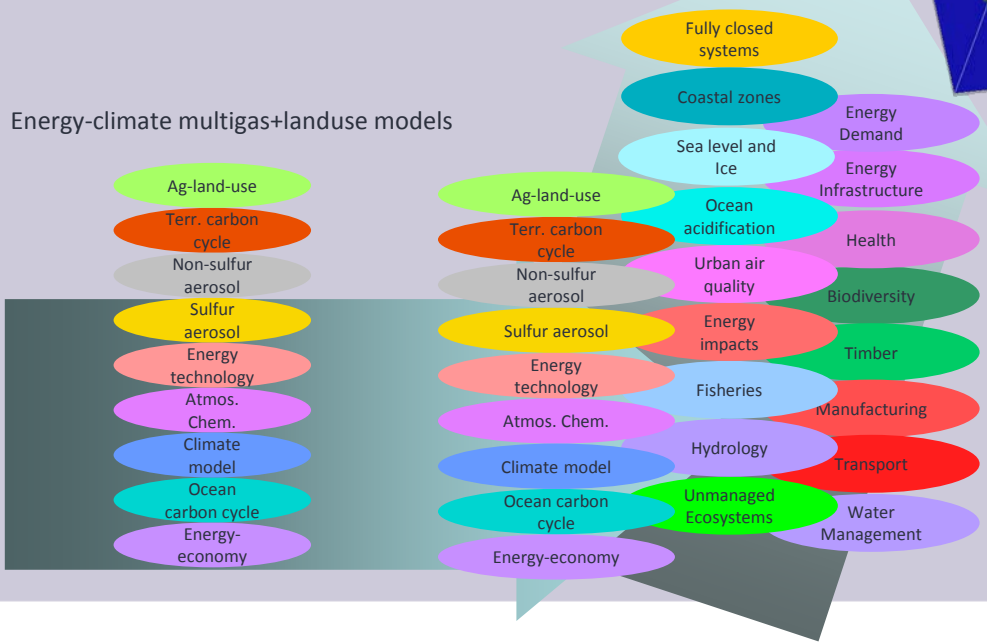
Complexity & resolution: ALL groups



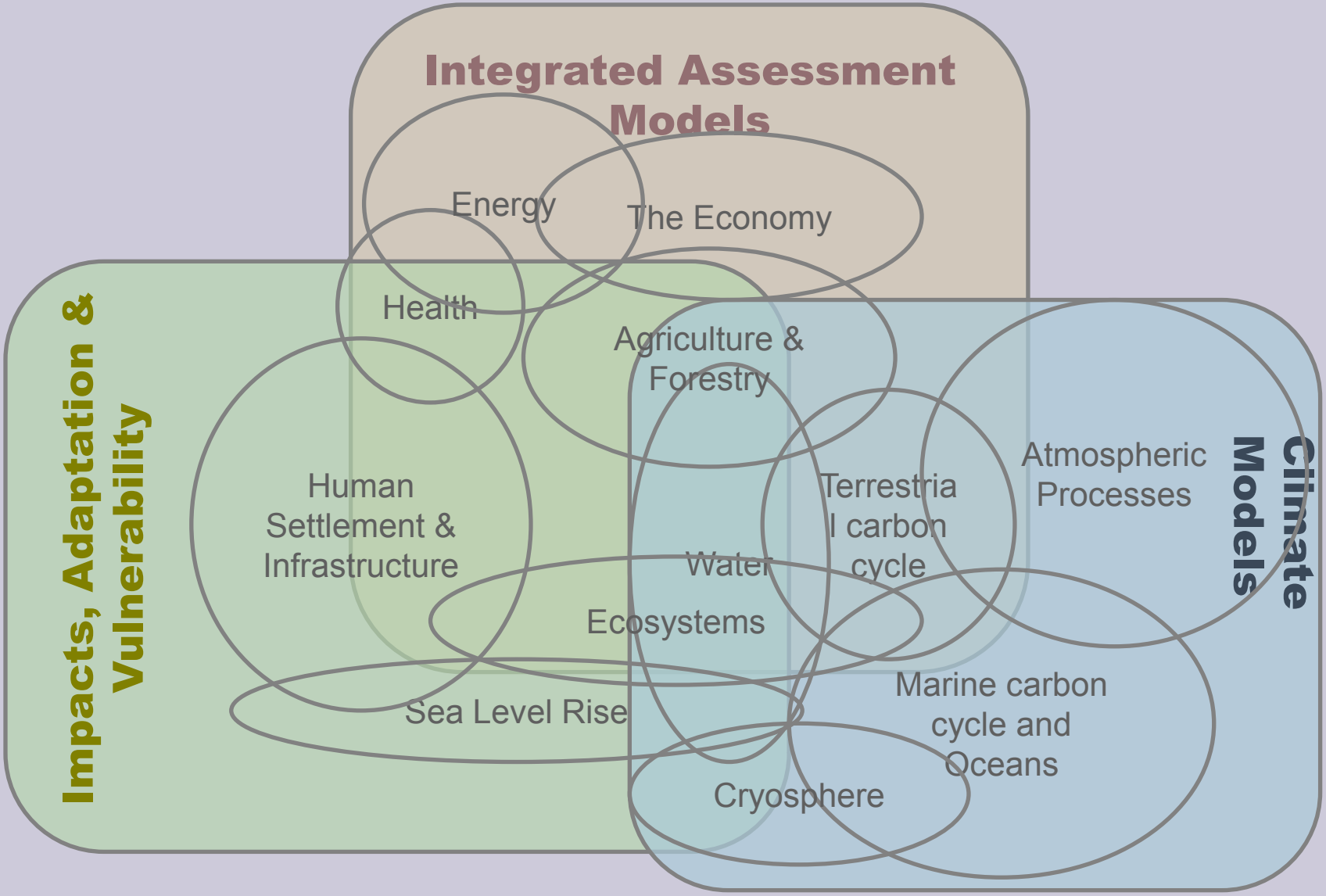
Present Day — In the Decade Ahead

Fully integrated (emissions, climate, impacts and adaptation), science-based, decision support tools

Energy-climate multigas+landuse models



Growing Overlap in Domains



From Janetos et al.,BER workshop on IA assessment, 2009

Beyond the Handshake: next steps and priorities

New Scenarios development charged with an integrative and collaborative approach. At least two approaches possible:

1. Use existing RCPs to develop new storylines
2. Use new, multiple concentration pathways to develop new storylines.

The handshake activity is extremely new – there will certainly be pitfalls and difficulties with implementation and assumptions by both IA and CM groups, the least of which are development of alternative historic reconstructions for both land cover/land use and emissions.

As the models evolve, both with regard to increased spatial and process information, it will be important to recognize what is important for global vs. regional, vs local analyses: e.g., there is no one size fits all!

Introduction of observations (e.g., satellite and regional studies) as well as evolving observatories (e.g., NEON, Europe and Asian counterparts) for model evaluation and forecasting, data assimilation skill as building towards future.

Beyond the Handshake: new models, **new collaborations**

Despite the ongoing model development with regards to embedding existing structures, new models and ideas; still missing hooks to even basic and simple models of human behaviour, links to states, institutions and governance structures.

There are fundamental differences between the social and biophysical sciences; not just in modeling paradigms, but in culture (e.g., reward systems, perceptions of 'success').

There are opportunities to develop a networked suite or system of models through collaborations, integrative research that can provide insight into the coupled human-environmental system that is meaningful for resource managers, decision makers and policy communities, BUT, the hooks to the socio-ecological, economic and policy as well as climate modeling communities must be present.

THANKS!