

Robust Methodologies for Simulating Potential Impacts of Climate Change

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Peace



The Nobel Peace Prize 2007

"for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change"



Intergovernmental Panel on Climate Change (IPCC)



Photo: Ken Opprann

Albert Arnold (Al) Gore Jr.

-  Printer Friendly
-  Comments & Questions
-  Tell a Friend

The 2007 Prize in:
 
 Prev. year

The Nobel Peace Prize 2007

- Prize Announcement
- Press Release
- Presentation Speech

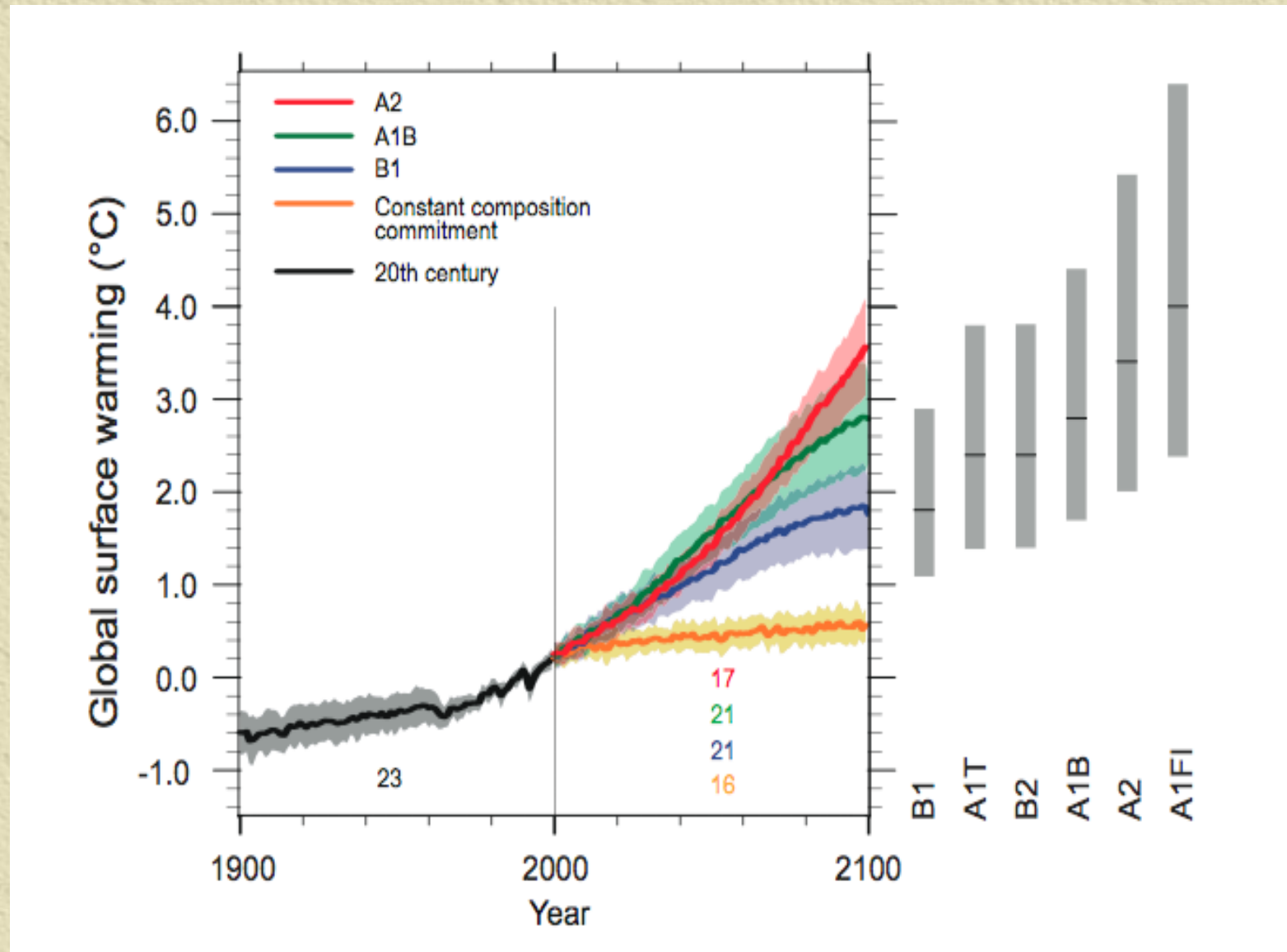
Intergovernmental Panel on Climate Change

- Nobel Lecture
- Interview
- Documentary
- Nobel Diploma
- Photo Gallery
- Other Resources

Al Gore

- Nobel Lecture
- Documentary
- Nobel Diploma

Projected Changes in Temperature (IPCC, 2007)



How does system simulation fit into IPCC activities?

✦ THE IPCC FOURTH ASSESSMENT REPORT (2007)

- Working Group II: Impacts, adaptation and vulnerability

- www.ipcc-wg2.org

✦ 2006 IPCC Guidelines for National Greenhouse Gas Inventories

- Vol. 4 “Agriculture, Forestry and Other Land Use”

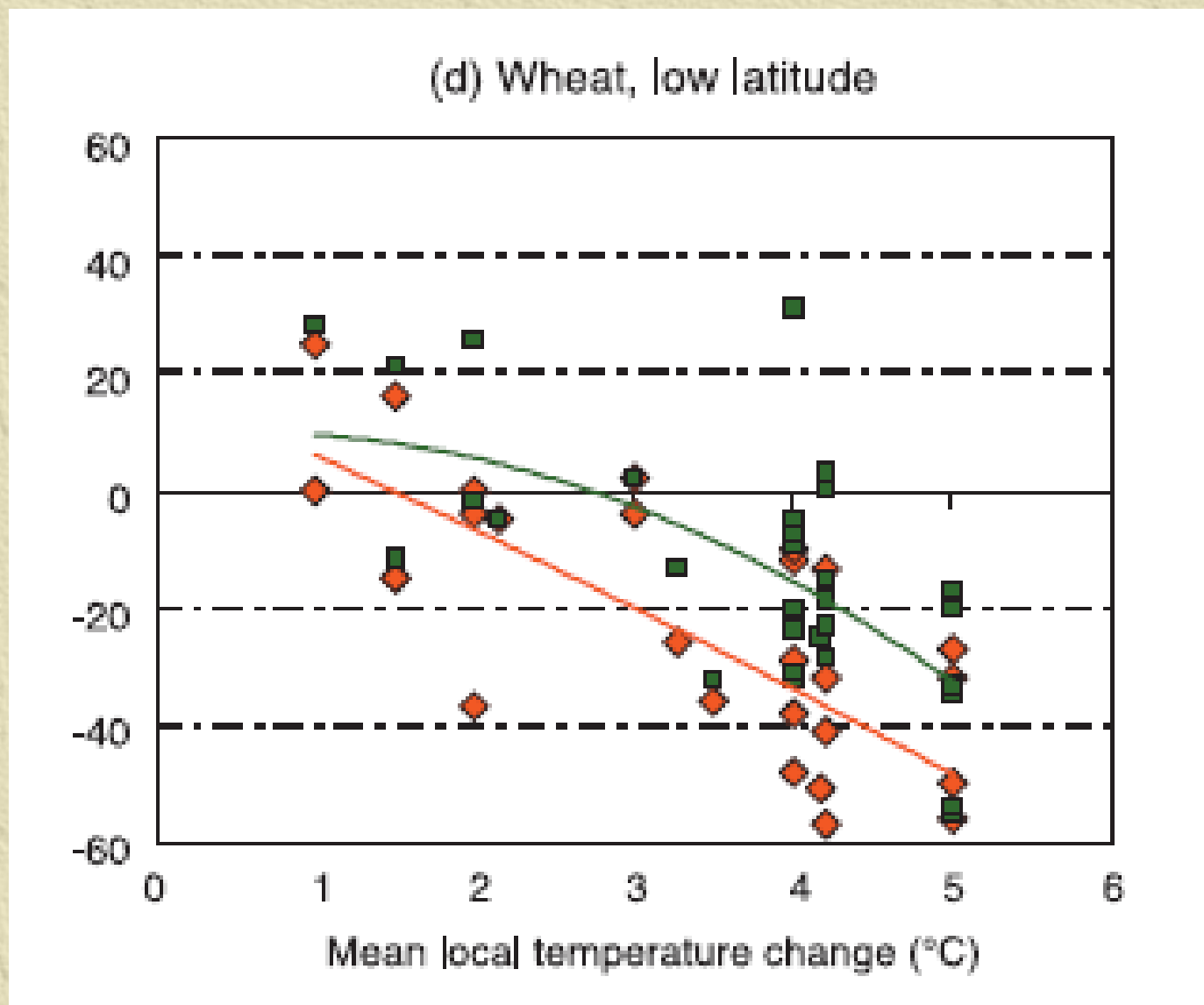
IPCC AR4, Food, fibre and forest products

Simulations of unstressed plant growth and yield response to elevated CO₂ in the main crop-simulation models, including AFRC-Wheat, APSIM, CERES, CROPGRO, CropSyst, LINTULC and SIRIUS, have been shown to be in line with recent experimental data, projecting crop yield increases of about 5-20% at 550 ppm CO₂ (Tubiello et al., 2007b)...

IPCC, Food, fibre and forest products

Modelling results for a range of sites find that, in mid- to high latitude regions, moderate to medium local increases in temperature (1-3°C), along with associated carbon dioxide (CO₂) increase and rainfall changes, can have small beneficial impacts on crop yields. In low-latitude regions, even moderate temperature increases (1-2°C) are likely to have negative yield impacts for major cereals.

Simulations of crop response to global warming and elevated CO₂. From Fig. 5.2 of IPCC report



How are assessments conducted? Can we make them more “robust”?

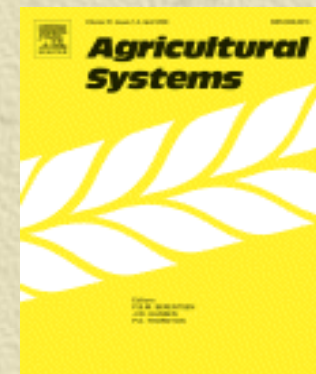
✦ “robust” – replicable, reliable, relevant

✦ Survey journal publications

➤ Query CABI bibliographic database:

(*wheat* and *model**) and

((*climate change*) or (*global change*)
or (*global warming*)) and (*impact*
or *assess**)



Results of queries for 1997-present

✳ Wheat	: 107 (+ 42 before 1997)
✳ Rice	: 52 (+ 22 before 1997)
✳ Maize	: 94
✳ Barley	: 16
✳ Sorghum	: 8
✳ Soybean	: 37
✳ Potato	: 17
✳ Alfalfa	: 5

... but approximately 50% inapplicable or unavailable through Internet sources, so supplementing with citations, IPCC references, etc.

Our Criteria

- ✦ Type of paper – methods, impact, adaptation
- ✦ Justification of crop, region
- ✦ Model:
 - Response to [CO₂]:
 - Direct effect on water use/transpiration
 - Canopy temperature
- ✦ Evaluation of model
 - Field data
 - [CO₂] and temperature responses
- ✦ Global change scenarios
 - GHG scenarios
 - Climate change effect (circulation model)
- ✦ Sampling framework:
 - Temporal
 - Spatial – single, points, polygons, gridded
 - Soil profiles

Our Criteria – Adaptation & impacts

✦ Adaptation

- Planting date
- Fertilizer
- Irrigation
- Cultivar/genotype
- System/rotations

✦ Impacts

- Economic yield, biomass, quality, water use, etc.
- Soil health
- Economic indicators
- Production risk

Strategies for Assessing Crop Response to Global Change: Surveysheet_V9.Doc Reviewer _____

Paper no: _____ Name: _____

1. Paper type: IPCC-type impact _____ Methods _____ Adaptation _____ Other _____

2. Crop(s) considered: _____

3. Country or region: _____

4. Justifies selection of crop or system?
A. None
B. Simple rationale based on local/regional importance (1 sentence)
C. Moderate rationale (2 sentences to 1 paragraph)
D. Full rationale (two or more paragraphs)
E. Other: _____

5. Justifies geographic sample?
A. None
B. Simple rationale based on local/regional importance (1 sentence)
C. Moderate rationale (2 sentences to 1 paragraph)
D. Full rationale (two or more paragraphs)
E. Other: _____

6. Model type:
A. Regression\correlation
B. Econometric
C. Simulation. Name: _____
D. Other: _____

7. Justifies model(s) selection
A. No
B. General statements, minimal citations (one paragraph or less)
C. Cites truly relevant papers
D. Full rationale (two or more paragraphs)
E. Other: _____

8. Model includes CO₂ effect on water use
A. No

Preliminary results

- ✦ 29 papers
- ✦ Mainly wheat and rice
- ✦ Each person reviewed 5 to 8 papers
- ✦ Limited cross checking during data entry

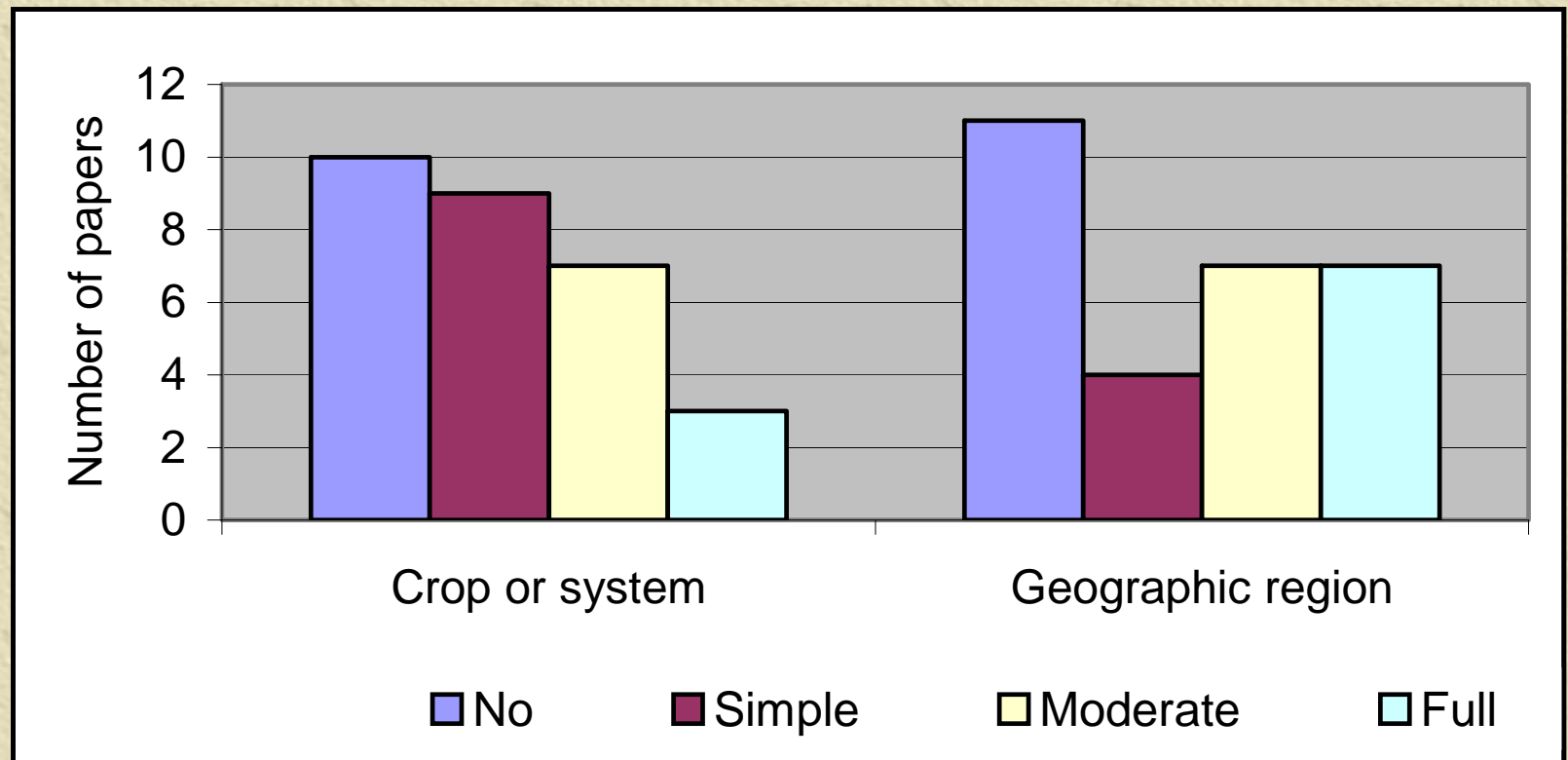


Country or region	No.
Australia	4
Austria, Czech Rep.	1
Bulgaria	1
Czech Rep	1
Europe	2
France	1
Iberian Peninsula	1
India	3
Nigeria	1
Romania	1
Switzerland	1
UK	2
UK, Spain	1
USA	9

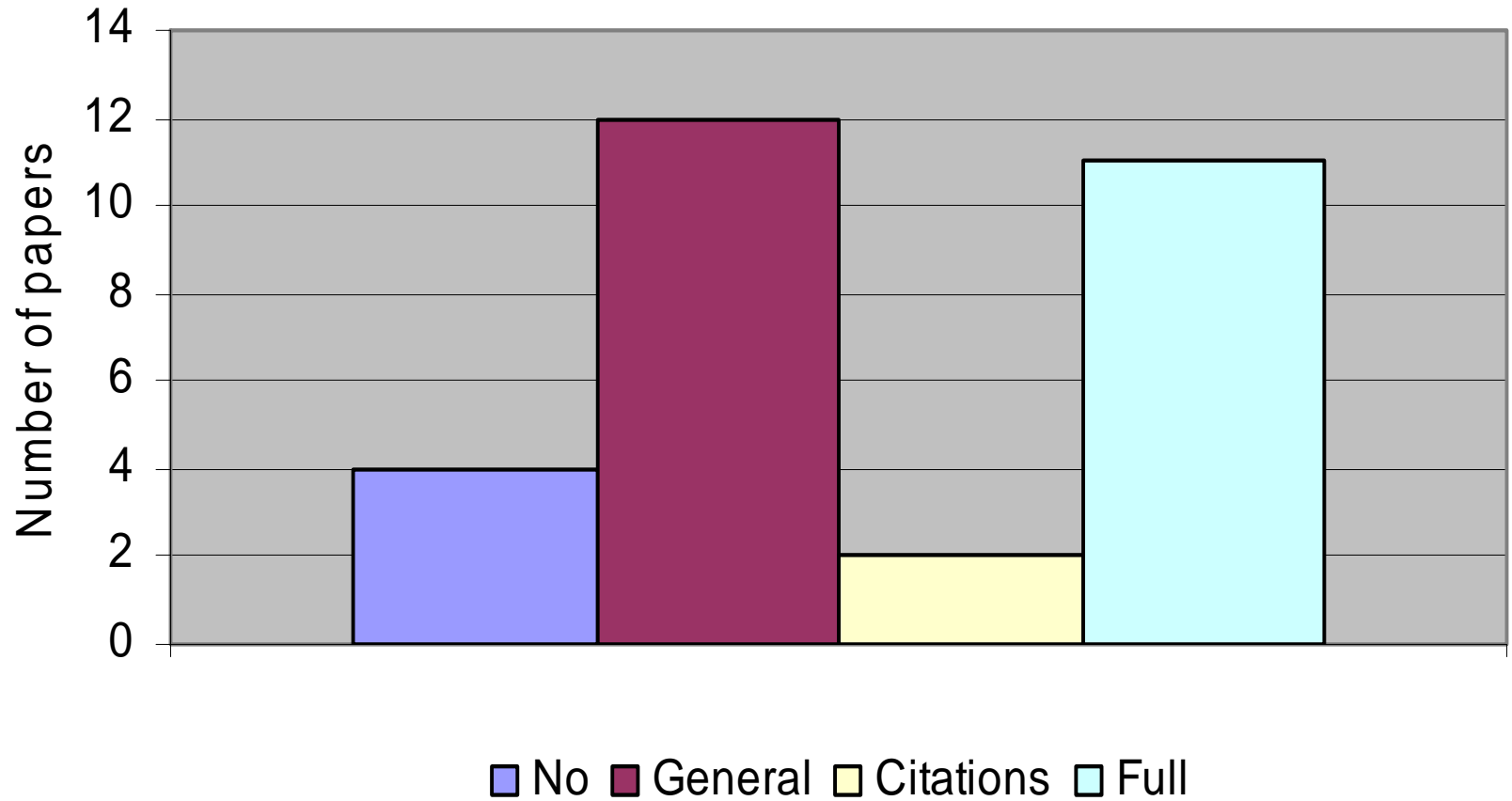
Papers that justified selection of:

Crop

Geographic region



Model assessed for application?



Model validation

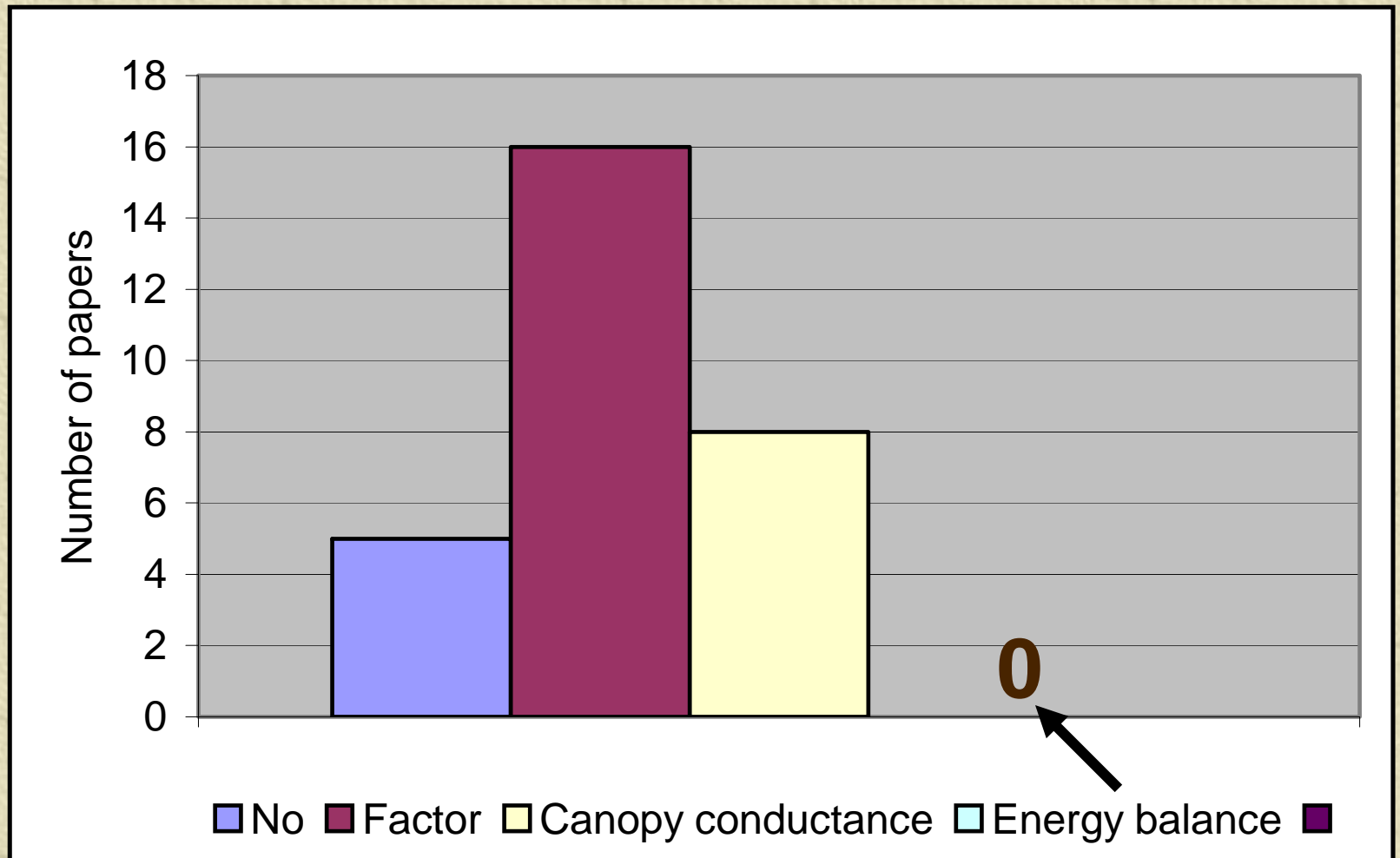
Lists other papers	3
Minimal	2
Same location/region	11
None	12



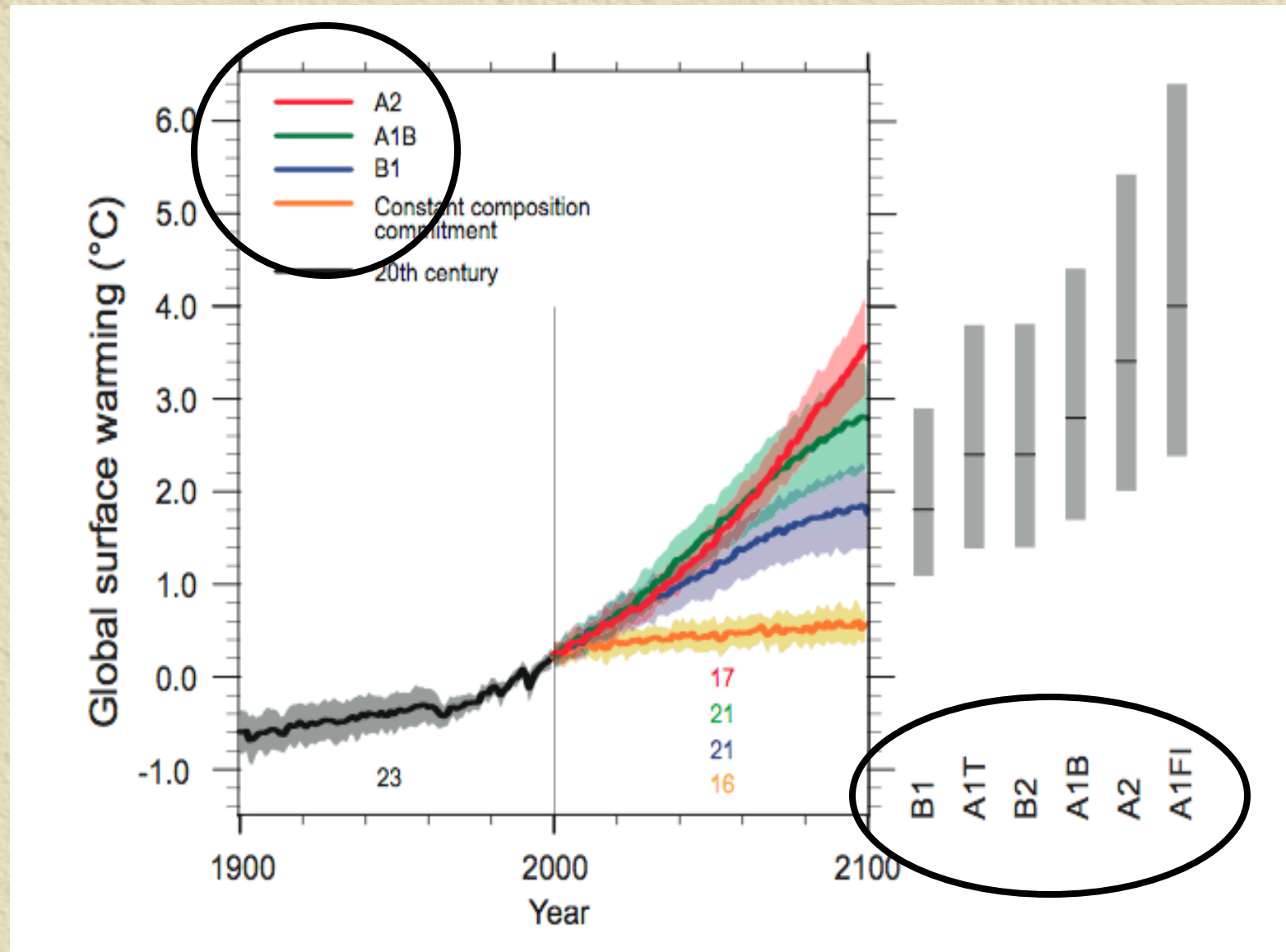
Models

AFRCWHEAT2	1
APSIM N-Wheat	2
APSIM-Wheat	1
APSIM I-Wheat	1
CERES	12
CERES, ORYZA1N	1
CH-Farm, PaSim, CropSyst	1
EPIC	3
EuroWheat	1
InfoCrop	1
SIRIUS Wheat, AFRCWheat2	1
SIRIUS	1
Soygro	1
WEPP	1
YIELD	1

Simulates CO₂ effect on water use?



Greenhouse gas emission scenarios and projected changes in temperature (IPCC, 2007)



Greenhouse gas scenarios

✦ IPCC Special Report on Emission Scenarios

- Approved March 2000
- Four story lines: A1B, A2, B1, and B2
- A1: very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies.
- A1FI: similar but fossil intensive
- Etc.

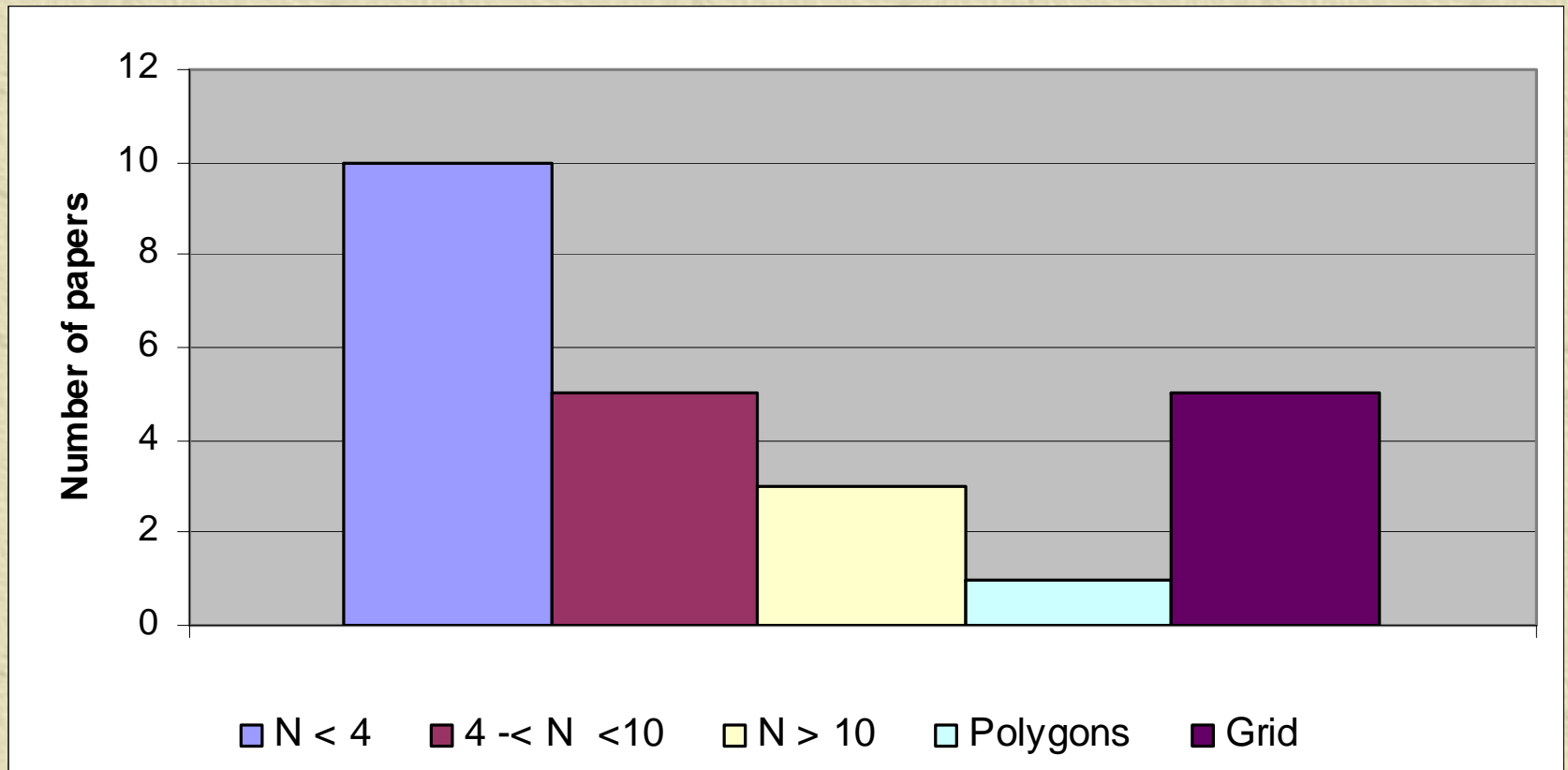
GHG scenario	No.
IS92E,IS92f, A1FI, A2	1
2080H1	1
A2, B2	1
B1, B2, A1B, A2, A1F, A1T	1
GCa1 (IS92a; IS95a)	1
GHG+A1, GSa1	1
IS92a	2
IS92a, IS92d	1
ISN2a	1
Generic	16

Circulation models	No.
9 GCMs	1
CCCM, GISS	1
CGCM1, HadCM2	1
CSIRO GCM, NCAR RCM	1
ECHA4, HadCM2, NCAR DOE	1
ECHAM, HadCM2, NCAR DOE	1
ECHAM4, HadCM2, CGCM1, CSIRO-Mk2b	1
GISS, GFDL	1
GISS, UKTR, BMRC	1
HADAM3H,ECHAM	1
HadCM2	3
HadCM2-GHG, HadCM2-SUL	1
HadCM3	1
NCAR RCM2 CSIRO	1
RegCM	1
UKCIP02	1
UKCIP98	1
UKTR	1
(None)	8

Sampling framework

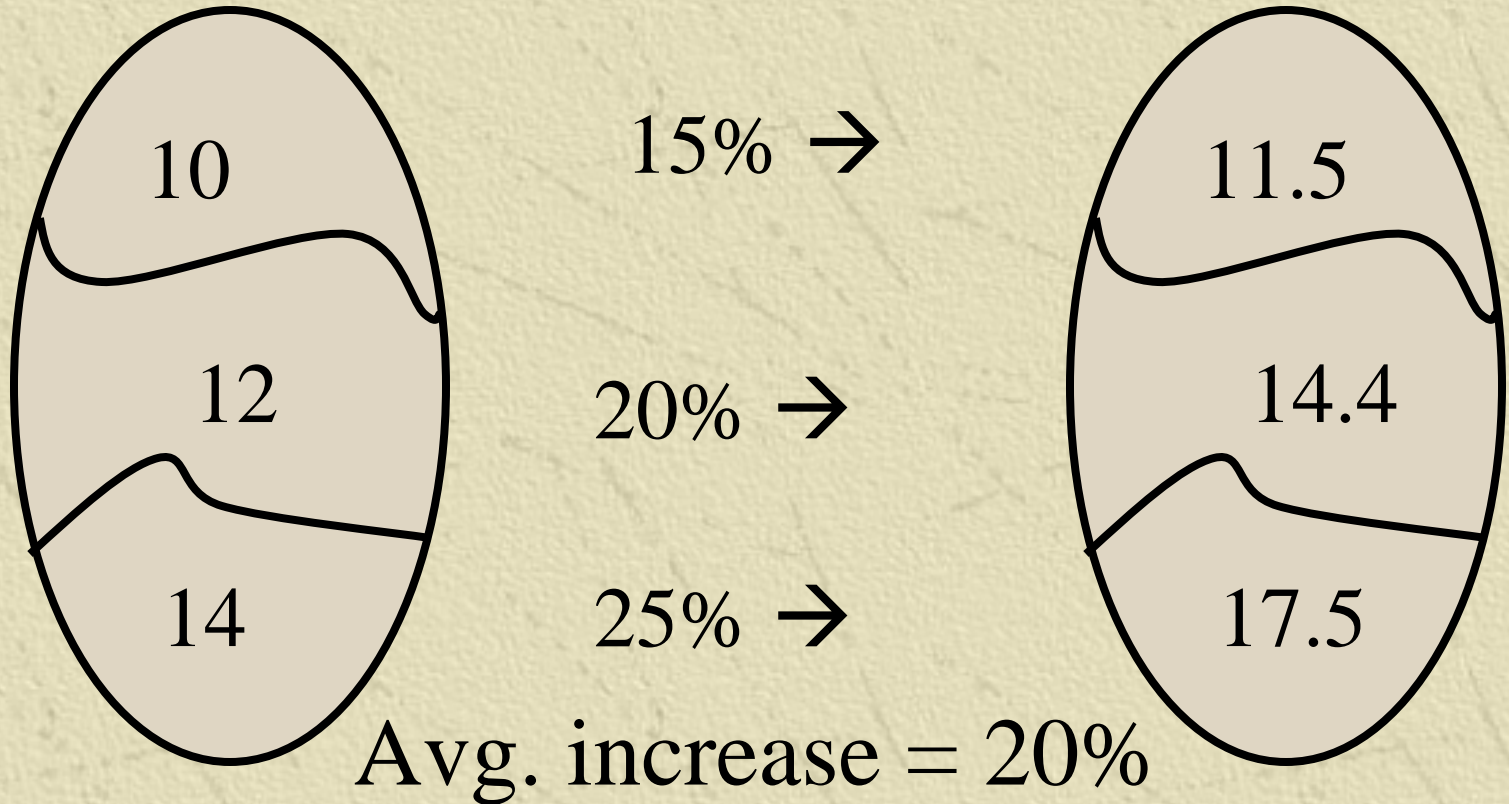


Location sampling: locations, polygons, or gridded



Number of units and locations most often justified with qualitative arguments: “selected to represent”

Rediscovering the Modifiable Areal Unit Problem - MAUP



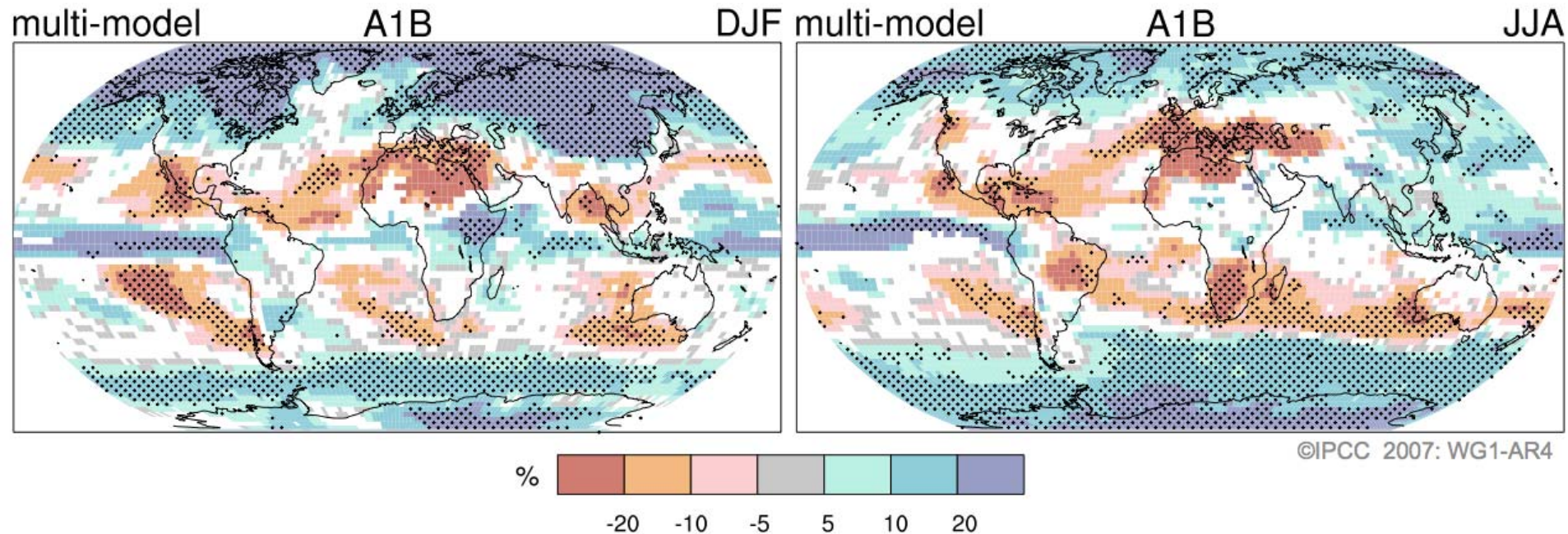
$$\bar{X} = 12.0$$

$$\bar{X} = 14.5$$

Avg. increase = 20.6%

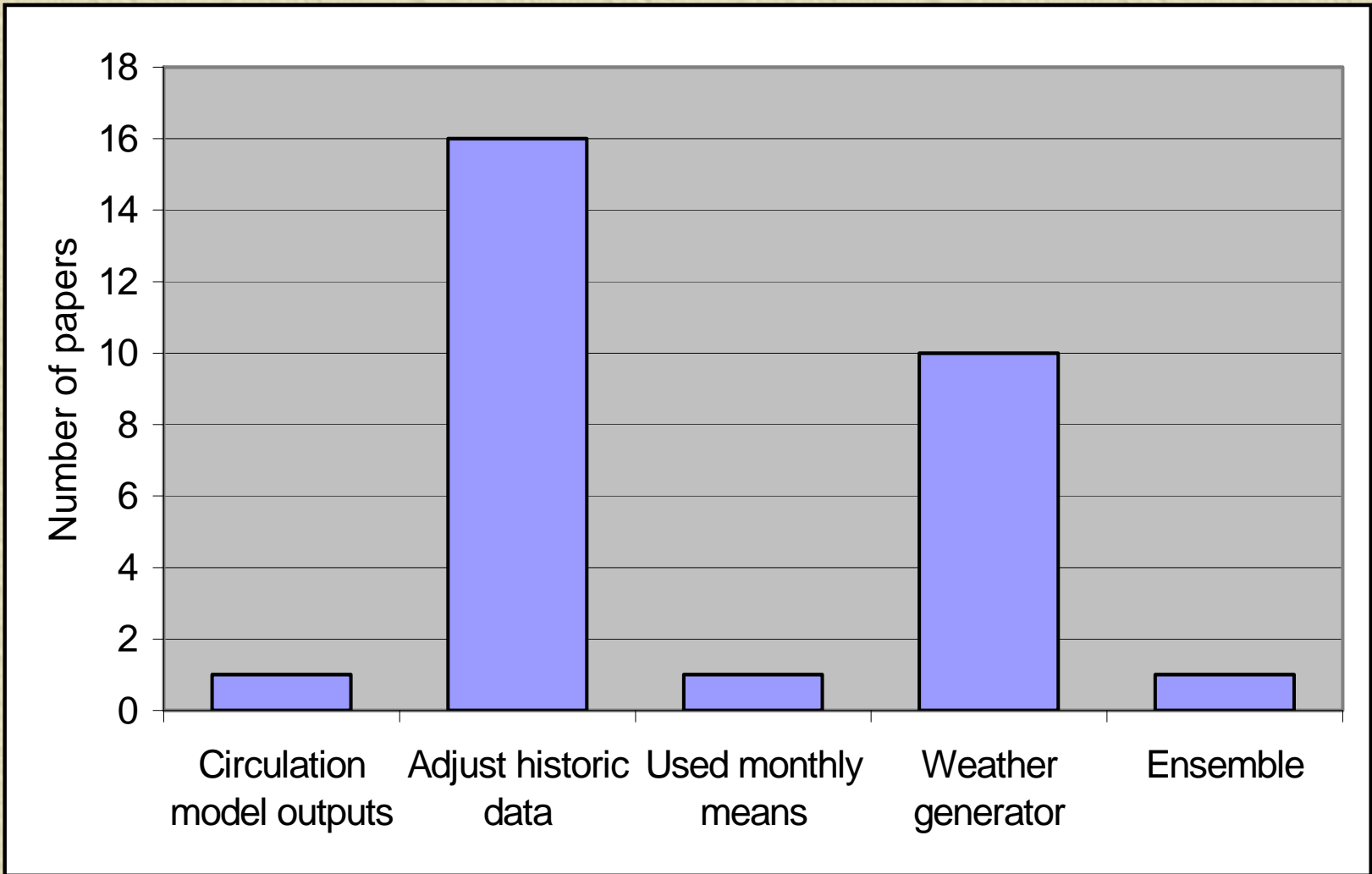
Projected Changes in Precipitation (IPCC, 2007)

Projected Patterns of Precipitation Changes

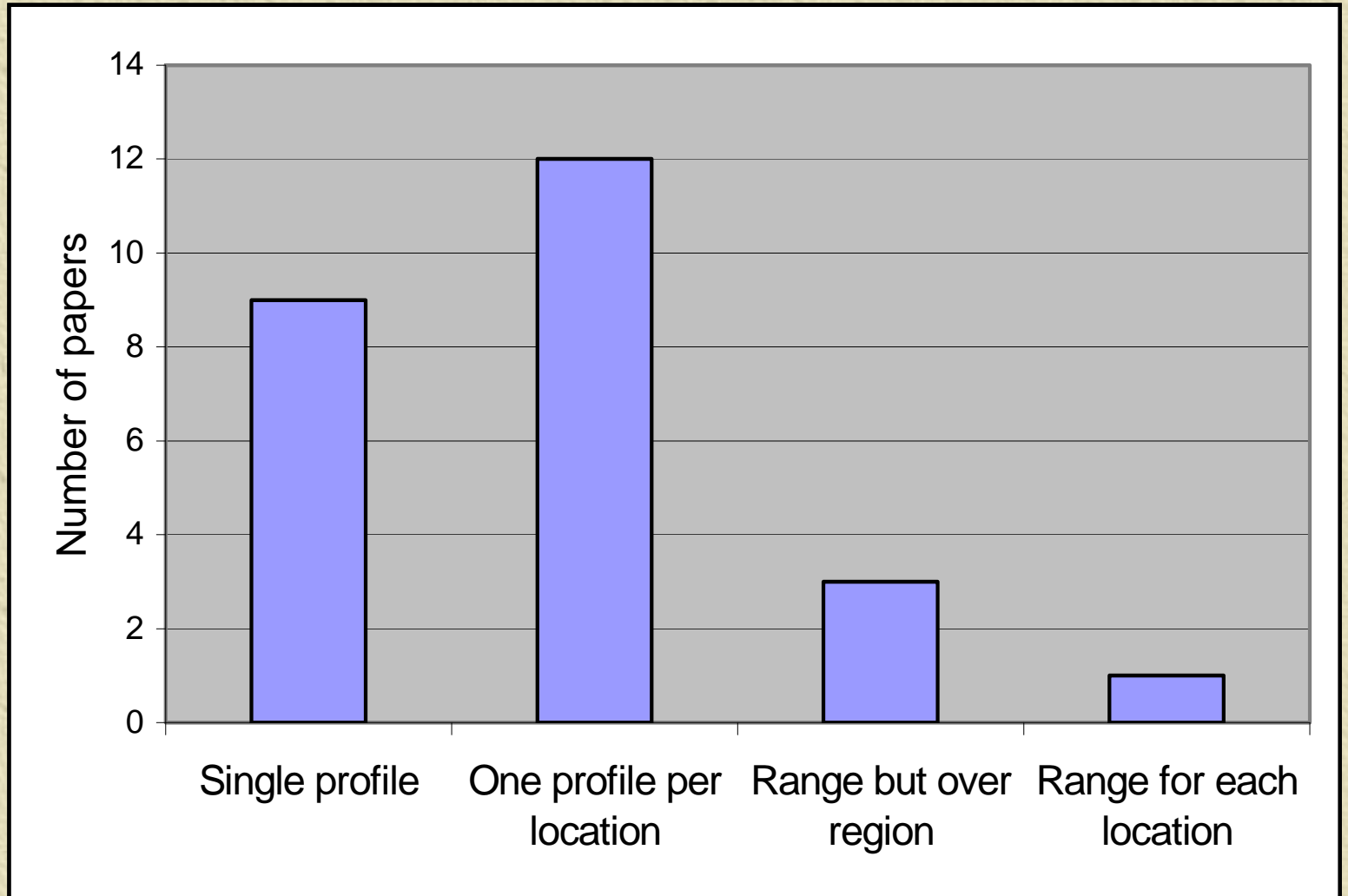


Precipitation increases *very likely* in high latitudes
Decreases *likely* in most subtropical land regions
(Stippling is where models agree. White is where models don't even agree on sign of change.)

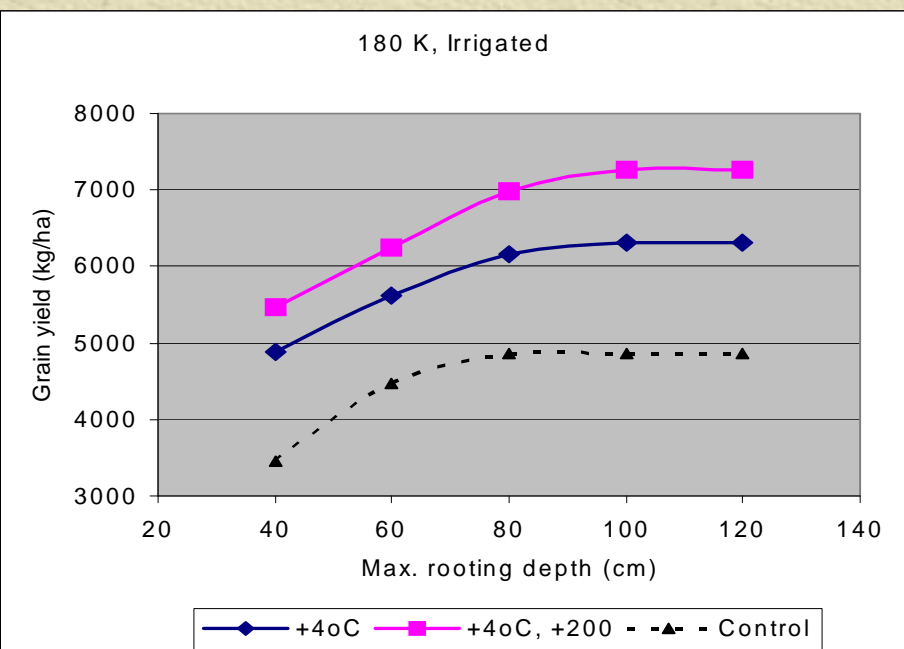
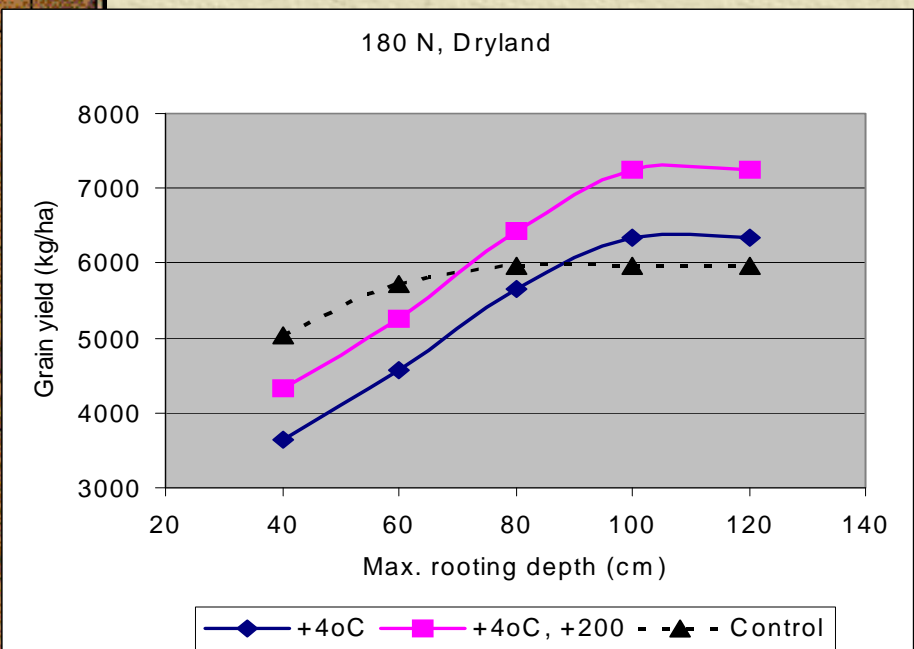
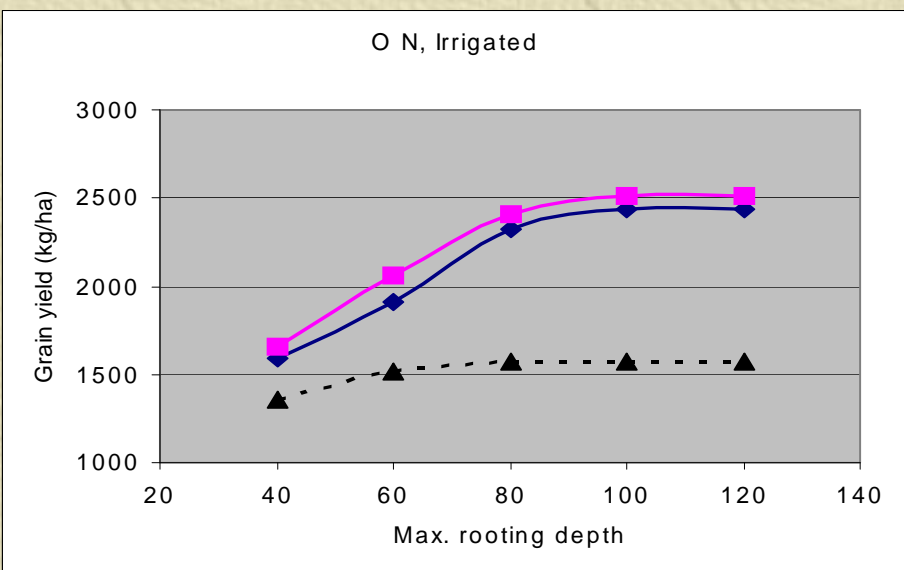
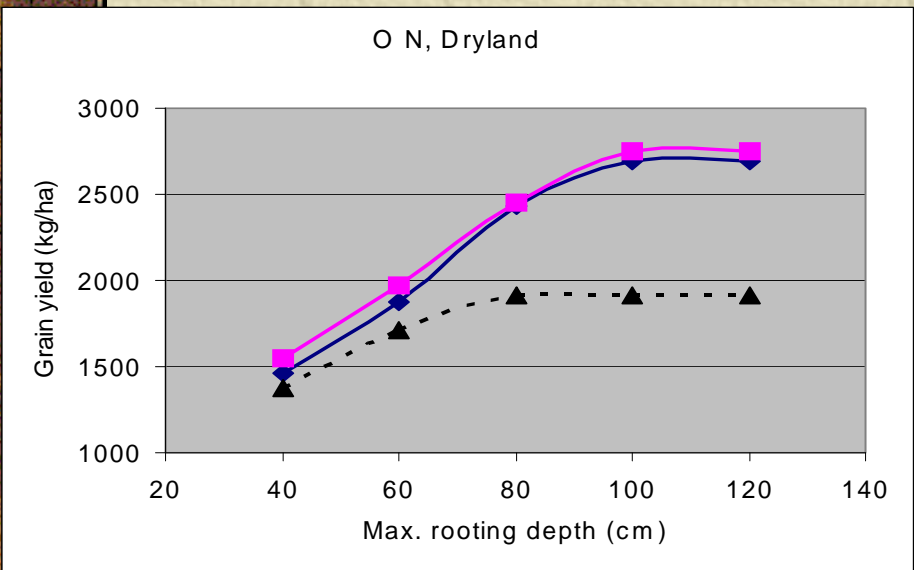
Sources of weather data that incorporate global change scenario(s)



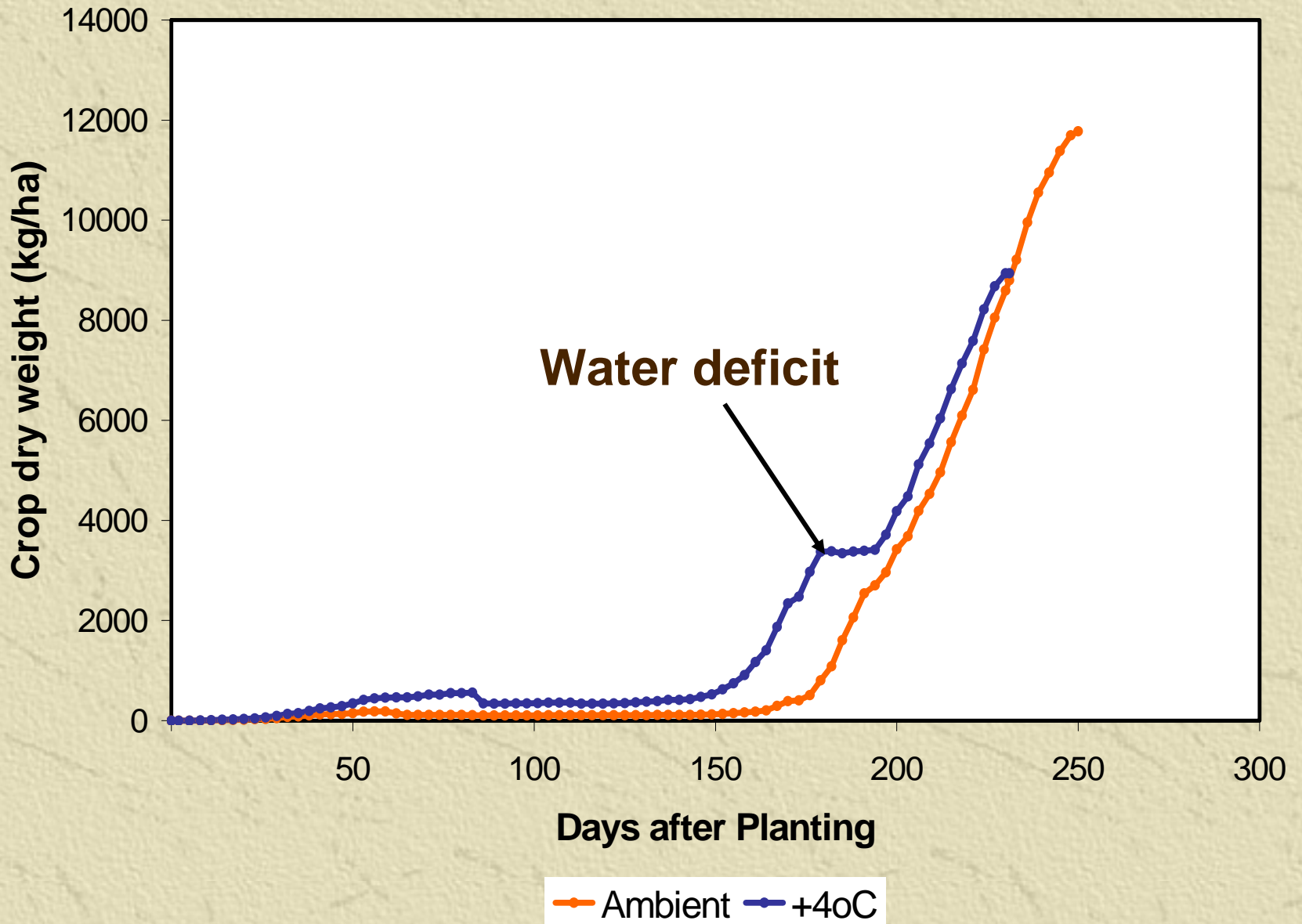
Number of soil profiles considered



Effect of maximum rooting depth for simulations of winter wheat at Manhattan, KS



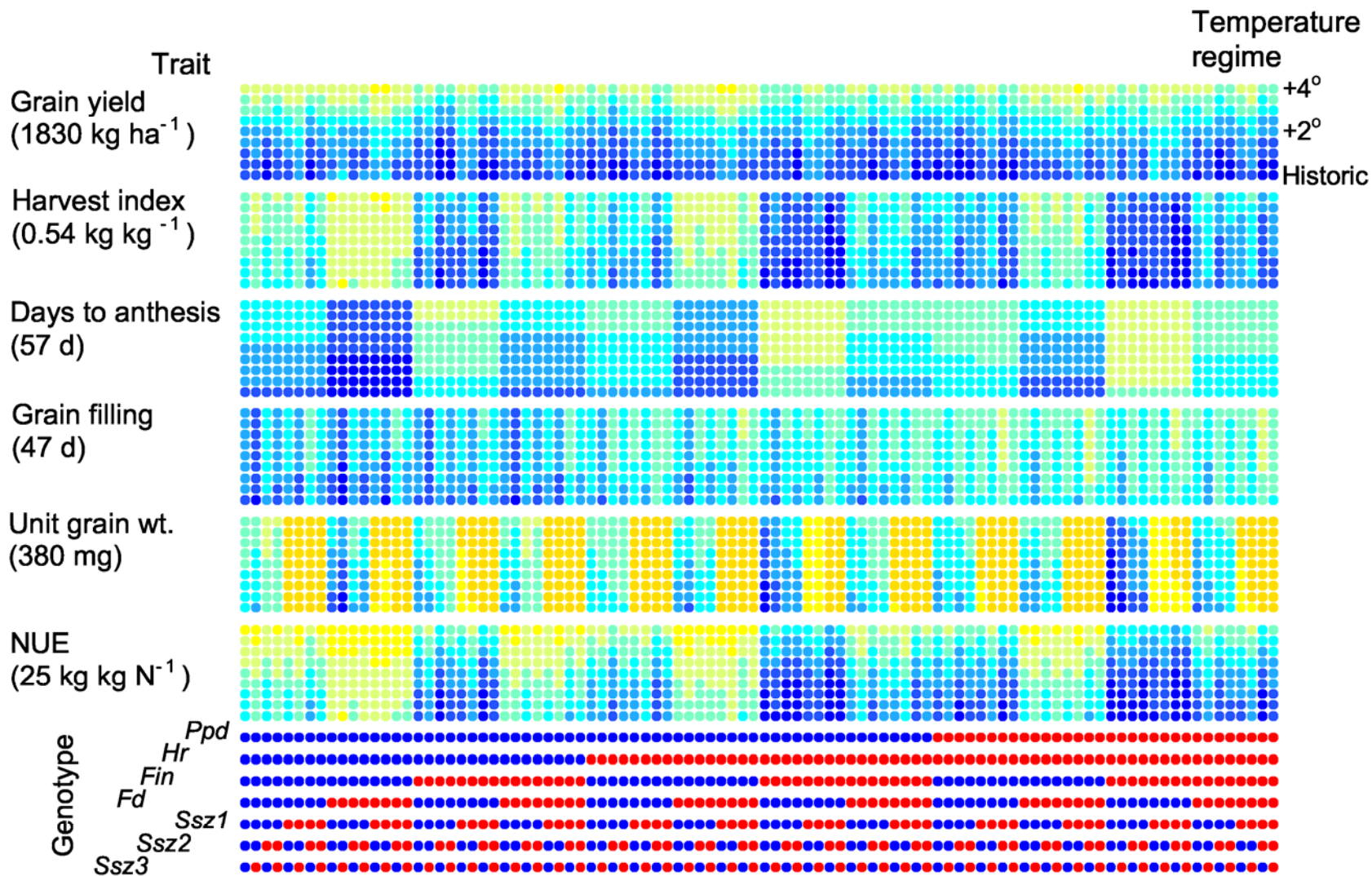
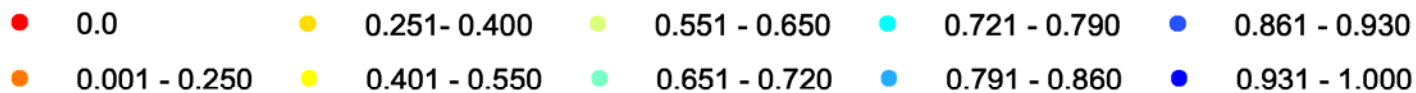
Why the cross over at 40-60 cm?



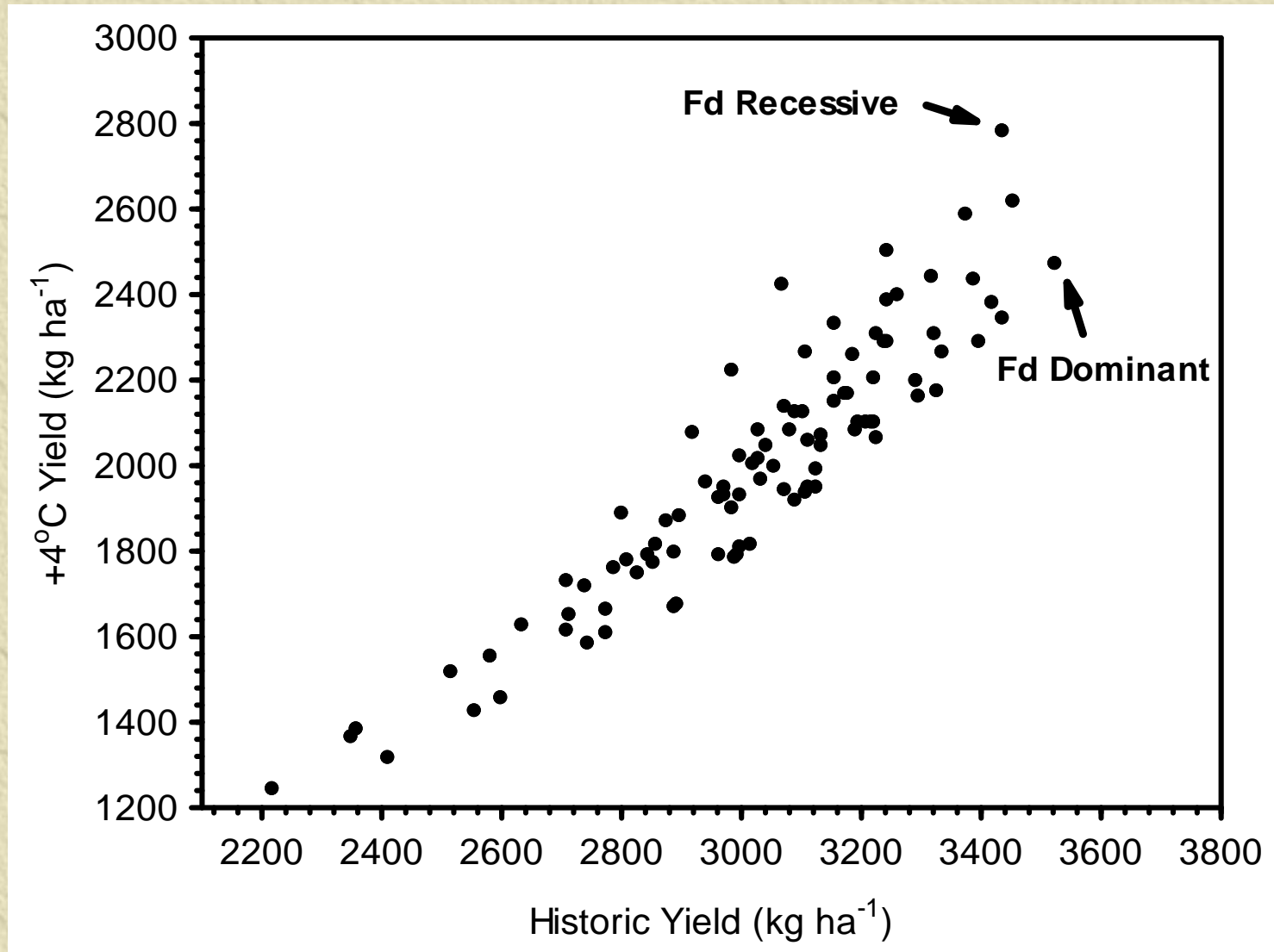
Adaptation scenarios

	None/ fixed	2 to 4	> 4	Not applicable
Planting dates	12	4	13	0
Fertilizer	25	2	2	0
Irrigation	5	3	1	20
Cultivar	13	8	8	0
Cropping system	27	1	1	0

Standardized (0 to 1) values for traits




Gene-based adaptation assessment: GeneGro V2, seven alleles. Hoogenboom et al., 2003.



Adaptation vs. history of agriculture

- ✦ 1831: McCormick reaper
- ✦ 1837: John Deere steel plow
- ✦ 1868: First steam tractor
- ✦ 1913: Synthetic ammonia
- ✦ 1913: Strampelli crossed to Akakomugi, source of semi-dwarf habit & day-neutrality
- ✦ 1926: Hi-Bred Corn Co. founded
- ✦ Late 1940s: 2,4-D
- ✦ 1966: Allis Chalmers sold first no-till planter
- ✦ 1974: Roundup
- ✦ 1998: Roundup Ready Corn is introduced

What will farming look like in 2050? 2100?



Trait assessed	No.
Economic yield	28
Yield quality	4
Phenology	4
Biomass	9
Water use	7
WUE	3
Nitrogen balance	4
Verbal	2
Greenhouse gas emis.	1
Soil carbon	1
Salinity	0
Soil erosion	1
Soil nitrogen	3
Economic return	1

Why are papers “incomplete” ?

✦ Information to be included is very large

- Results presented over multiple papers
- Results presented in reports

✦ Low confidence in results

- Ecophysiological models not reliable enough
- Scenarios/climate forecasts too confusing
- Agronomic scenarios too complex

✦ Engineering or science

- What's the hypothesis?
- Lack of hypothesis testing leads to:
 - Testing methods
 - Search for novelty or controversy

What's the solution?

✦ Society expects answers from the “best available science”

- Hiding away is not an ethical or sustainable research strategy
- Federal employees are mandated to have impact – on whom/what?

✦ More structure or standardization

- Improved reproducibility
- Parallel advances in greenhouse gas scenarios and circulation models

What are some of the opportunities?

- ✦ Better testing and justification of models used
 - Independent papers
 - CO₂ especially problematic
 - Canopy temperature effects
- ✦ More uniform approach to selecting scenarios
 - Increase-based: “+4°C, 700 ppm”
 - GCM-based: “HadCM2”
- ✦ Clearly stated sampling framework
 - Number of locations
 - Daily weather data
 - Soil profile variation
- ✦ Adaptation
 - Gene-based cultivar variation
 - Changes in system – rotations, annual to perennial
- ✦ Impact
 - System changes – GHG, soils, water
 - Net return

Benjamin Franklin (1754) says:

