Effects of Climate Change, Atmospheric Chemistry, and Land Management on Mid-Atlantic Forests

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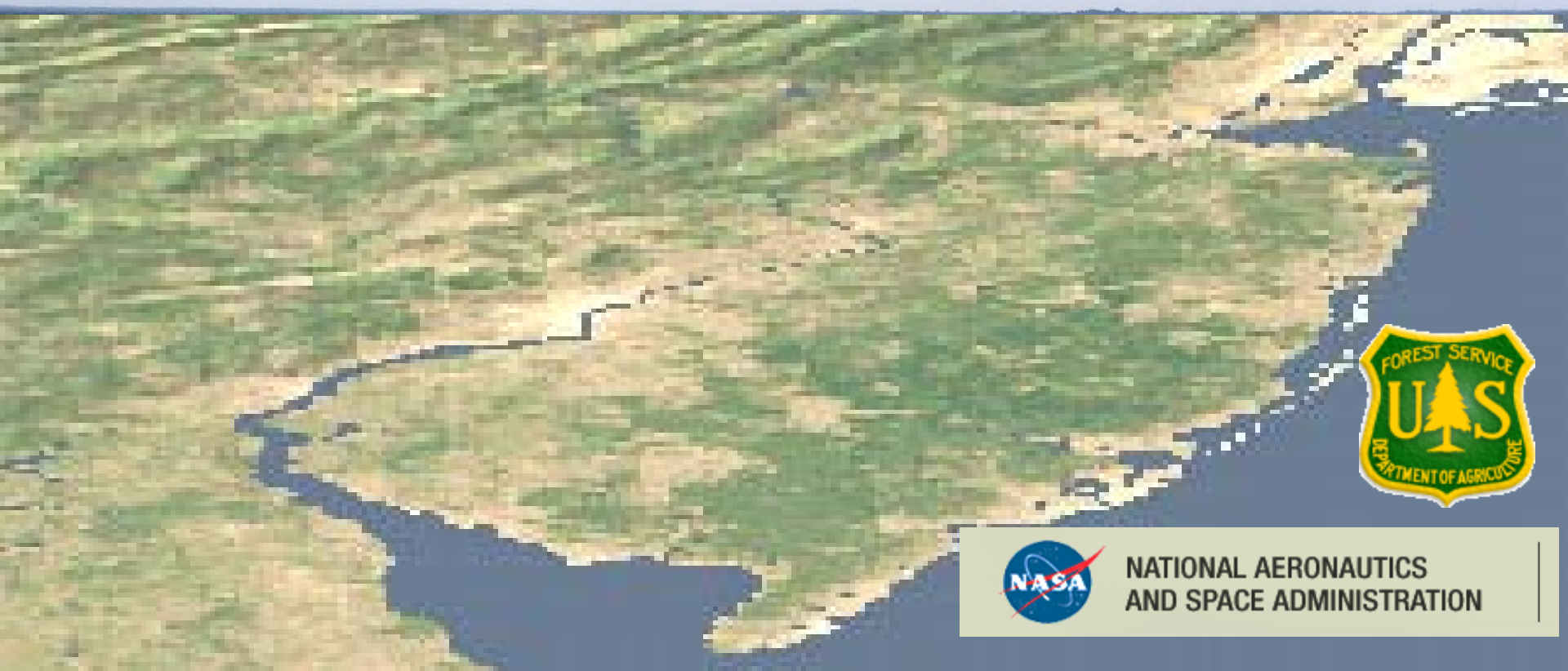
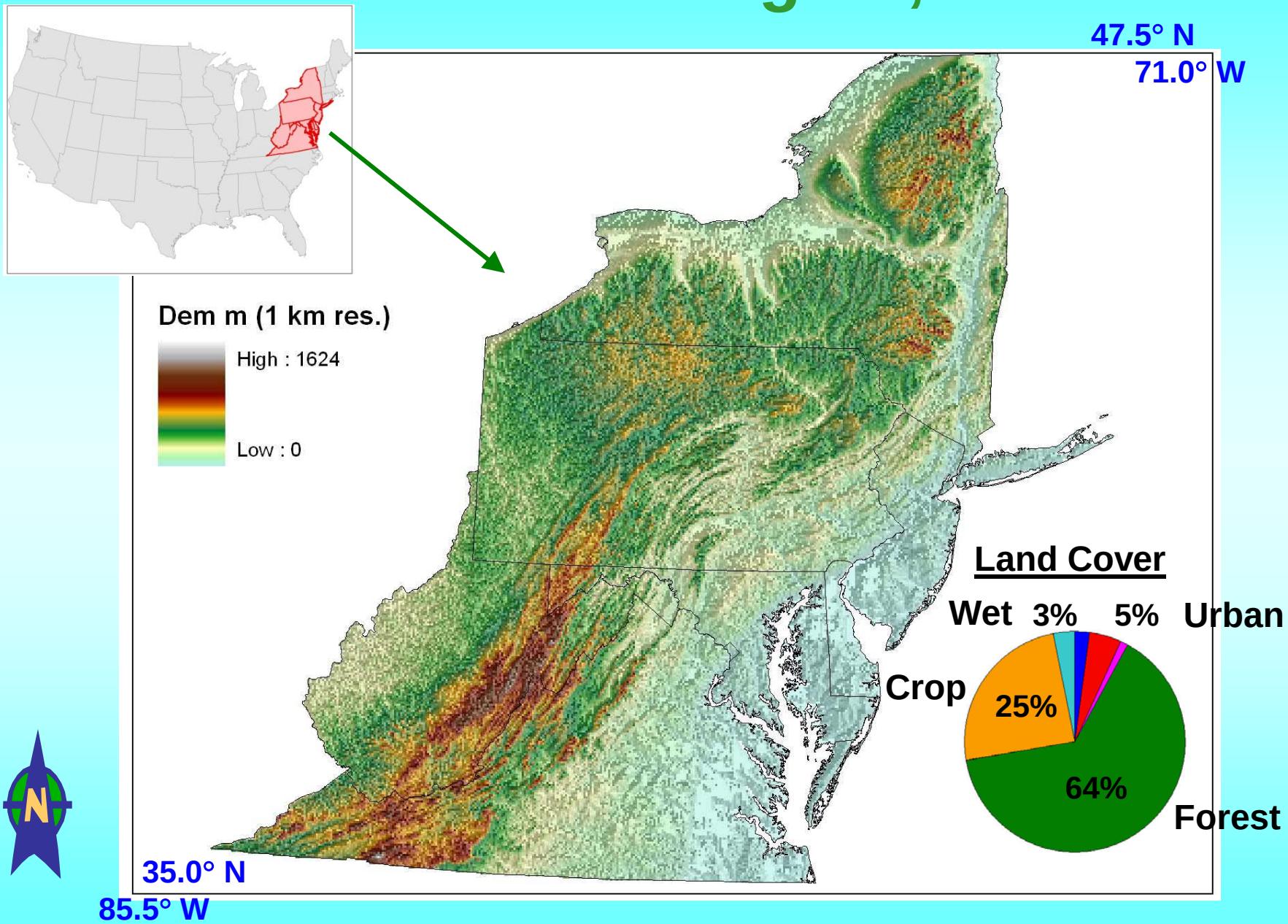


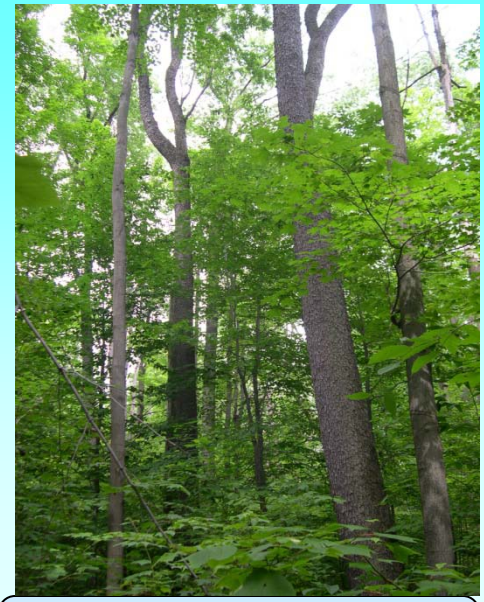
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Overview of Presentation

- Main theme: effects of climate change and interactions with other factors:
  - Increasing atmospheric CO_2
  - N deposition
  - Tropospheric ozone
  - Land management
- Separating out human-induced effects on forest productivity
- Concluding thoughts on future research and monitoring

Mid- Atlantic Region, U.S.





N. Hardwood forest

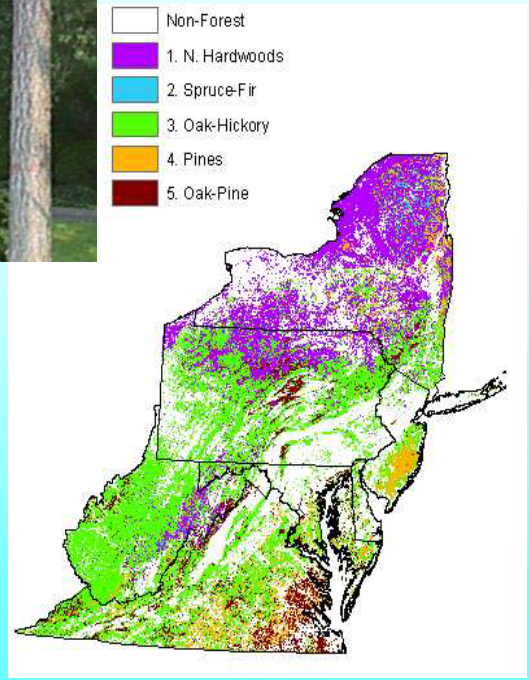
N. conifers

Spruce-fir forests

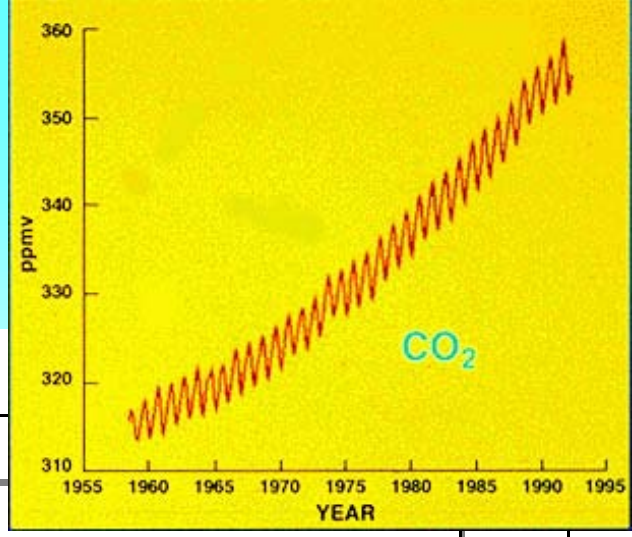
Loblolly pine

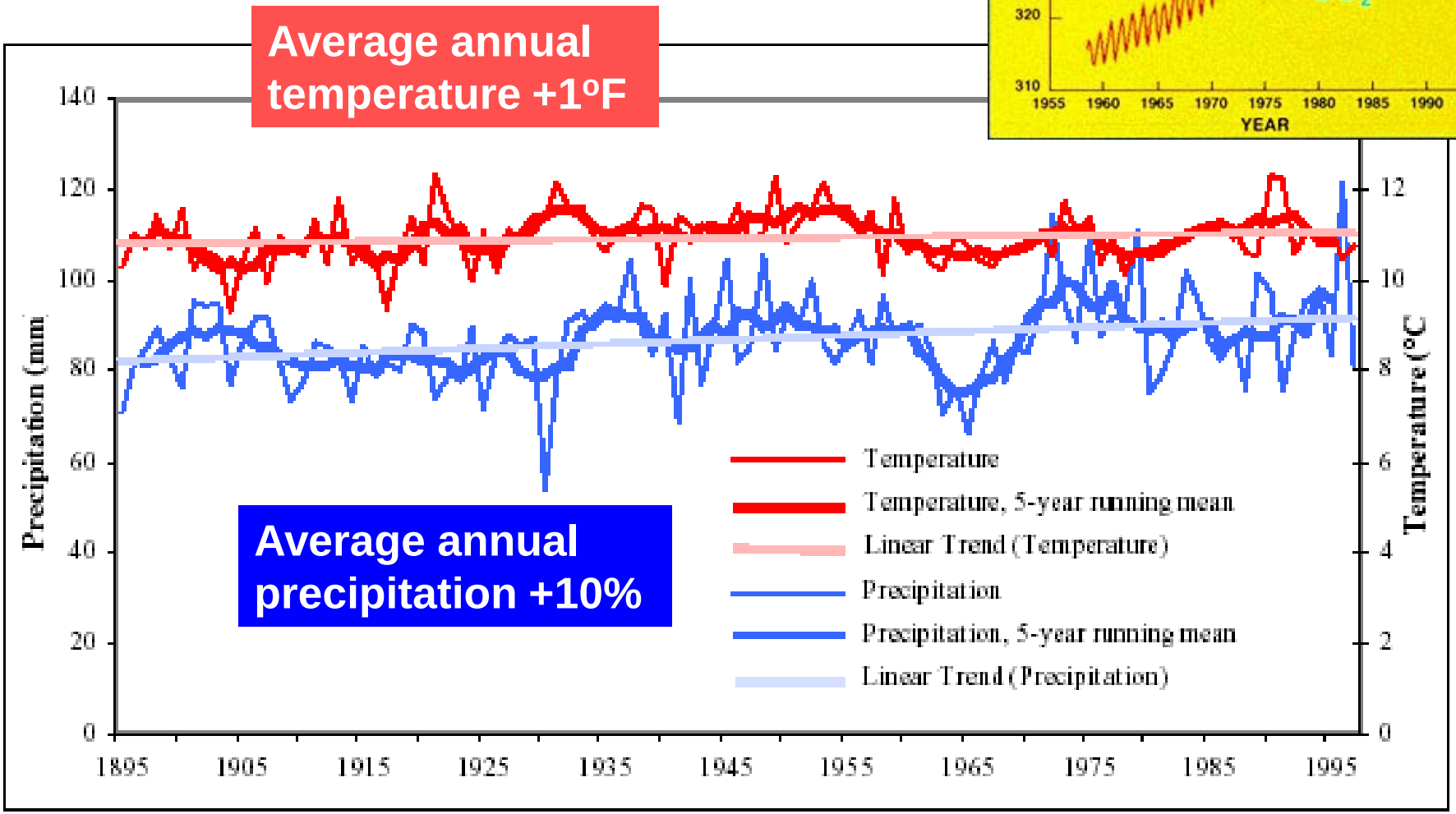
Oak-hickory forest

Oak-pine



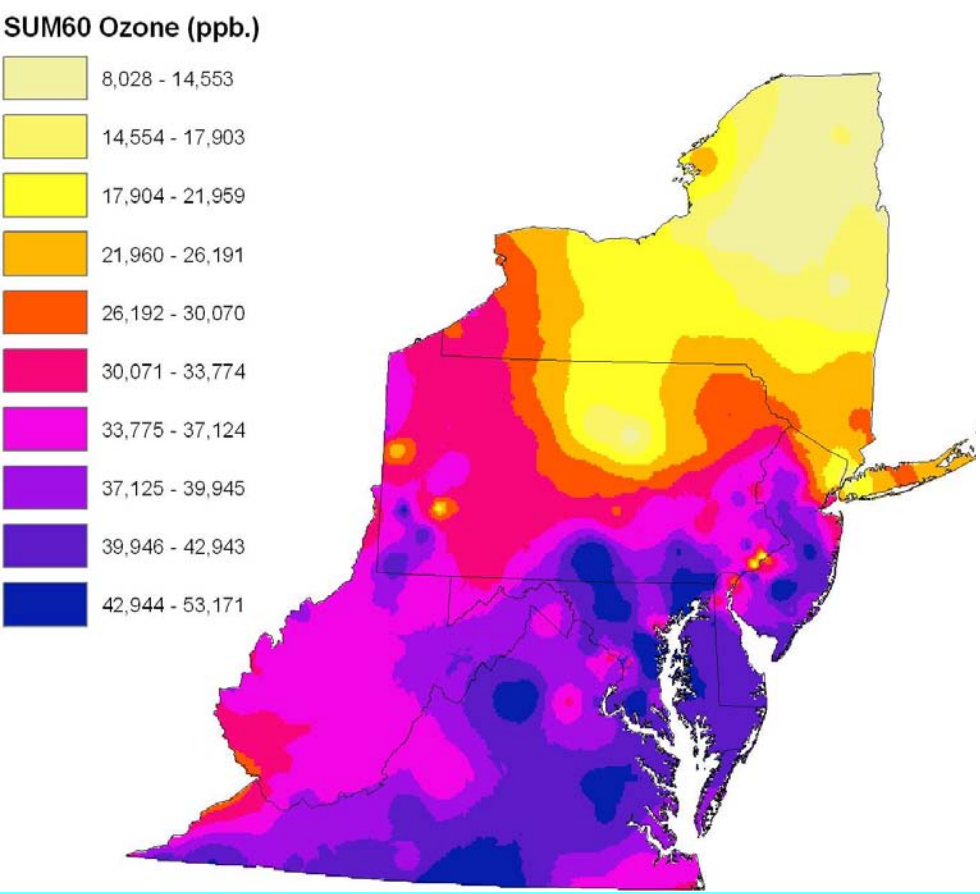
Climate and CO_2 Trends in the Mid-Atlantic Region

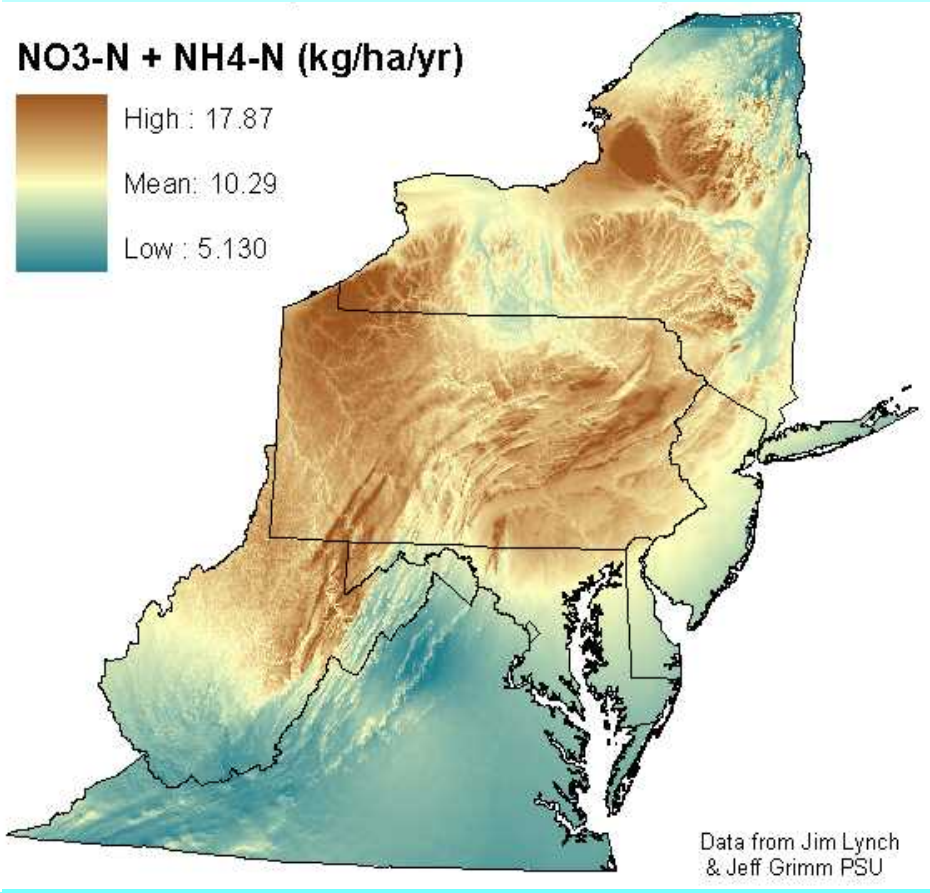




From Mid-Atlantic Regional Assessment

Patterns of Ground-level Ozone and Nitrogen Deposition for the Mid-Atlantic





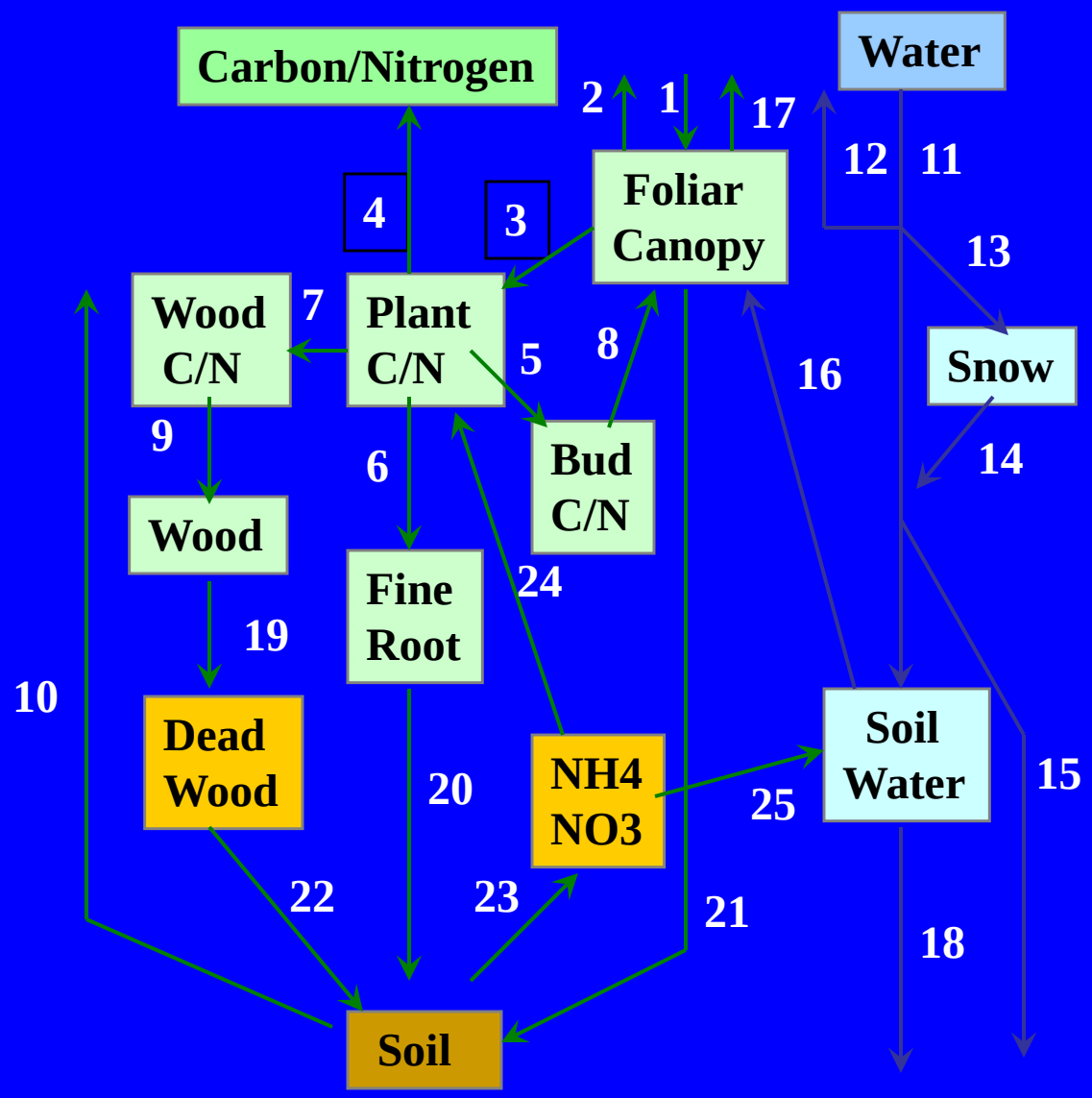
Interactions Among Factors

Elevated CO_2

Increased N deposition

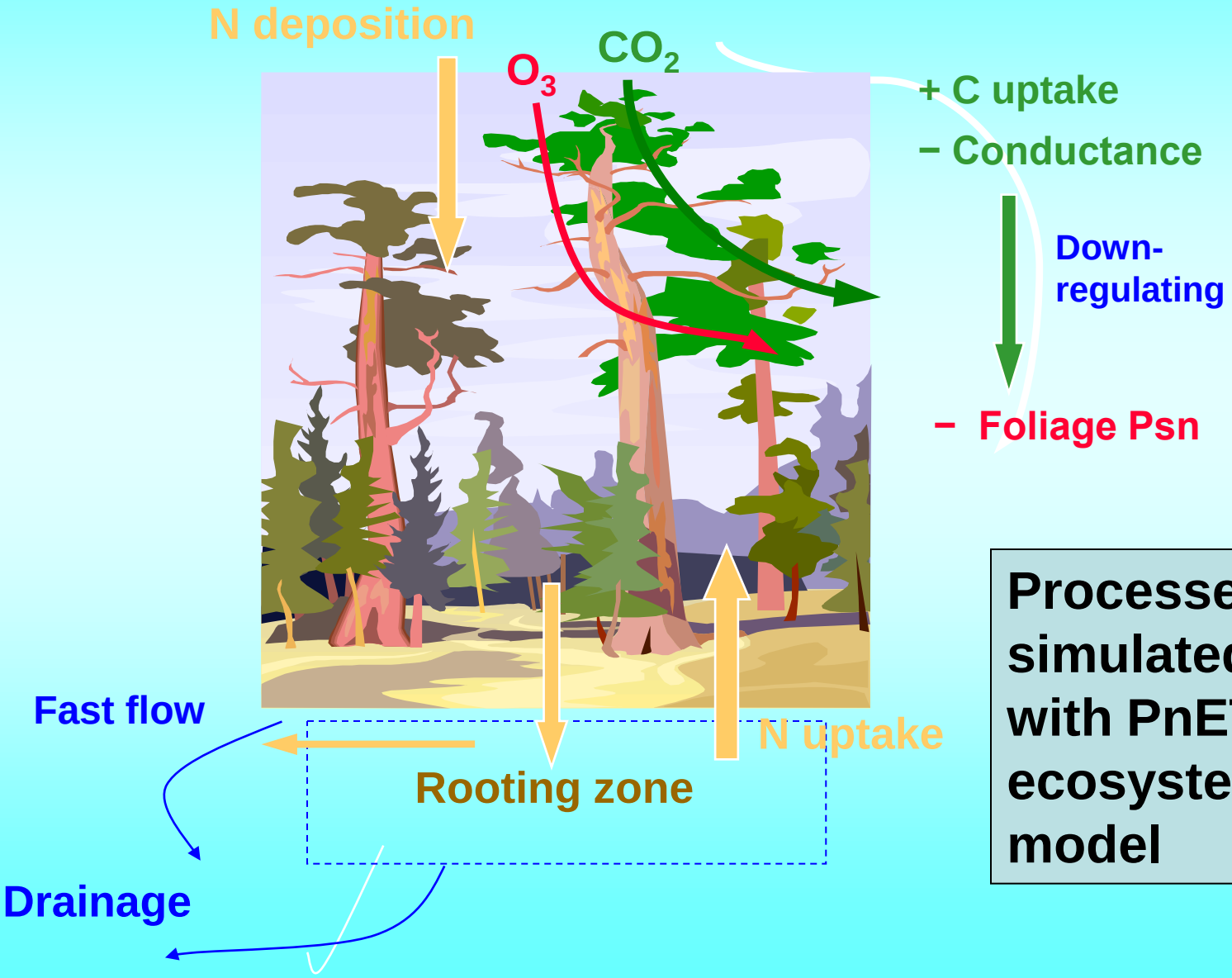
Ozone pollution

PnET-CN Model



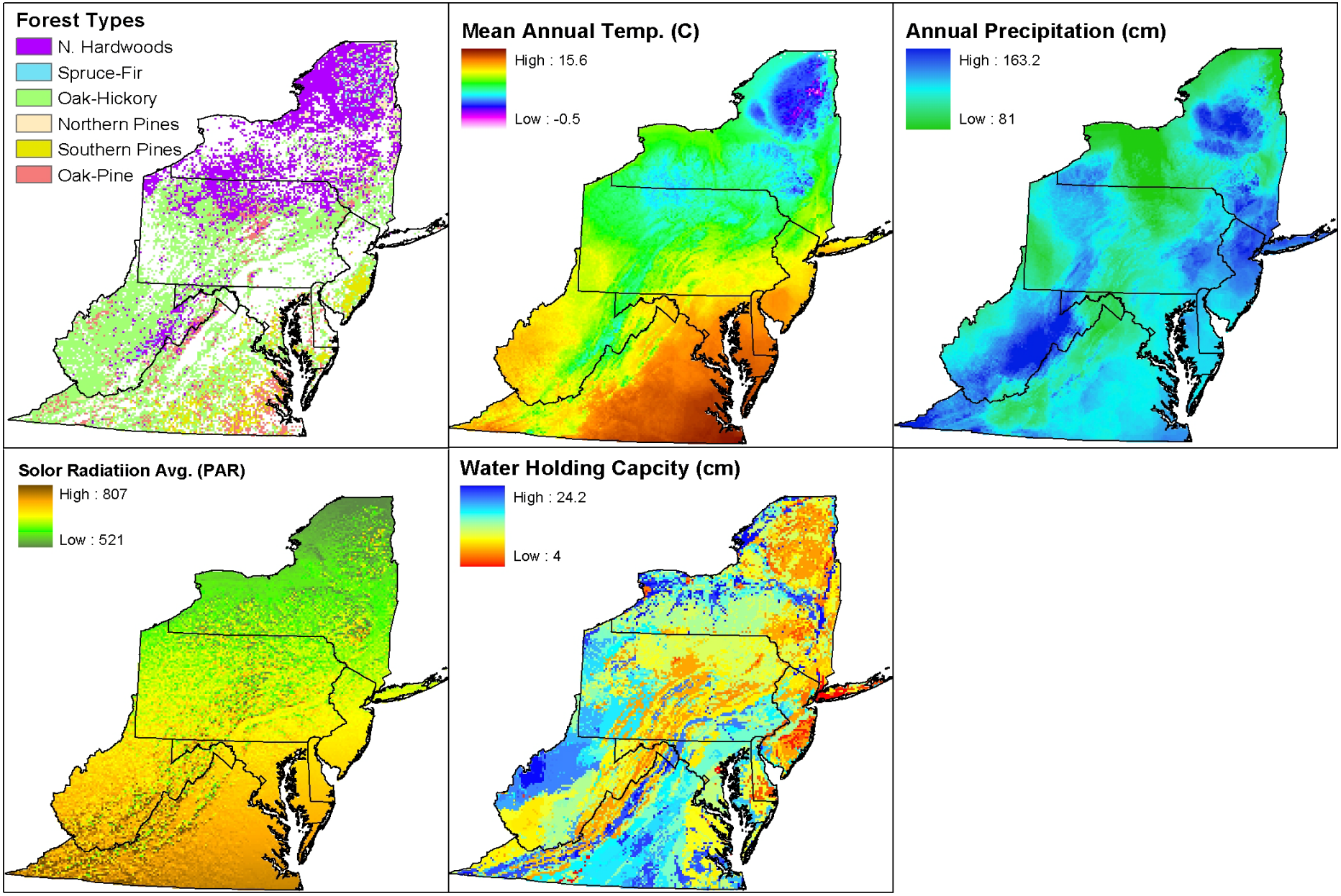
1. Gross photosynthesis
2. Foliar respiration
3. Transfer to mobile C
4. Growth and maintain resp.
5. Allocation to buds
6. Allocation to fine roots
7. Allocation to wood
8. Foliar production
9. Wood production
10. Soil respiration
11. Precipitation
12. Interception
13. Snow-rain partition
14. Snowmelt
15. Fast flow
16. Water uptake
17. Transpiration
18. Drainage
19. Wood litter
20 Root litter
21. Foliar litter
22. Wood decay
23. Mineralization
24. N uptake
25. To soil solution

Interactions and Effects of Atmospheric Chemical Components on Forest Ecosystems



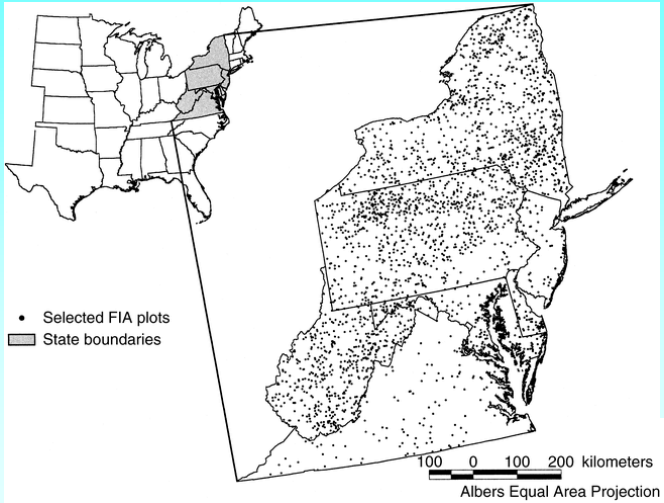
Processes simulated with PnET-CN ecosystem model

Additional Input Data Layers for the PnET-CN Model



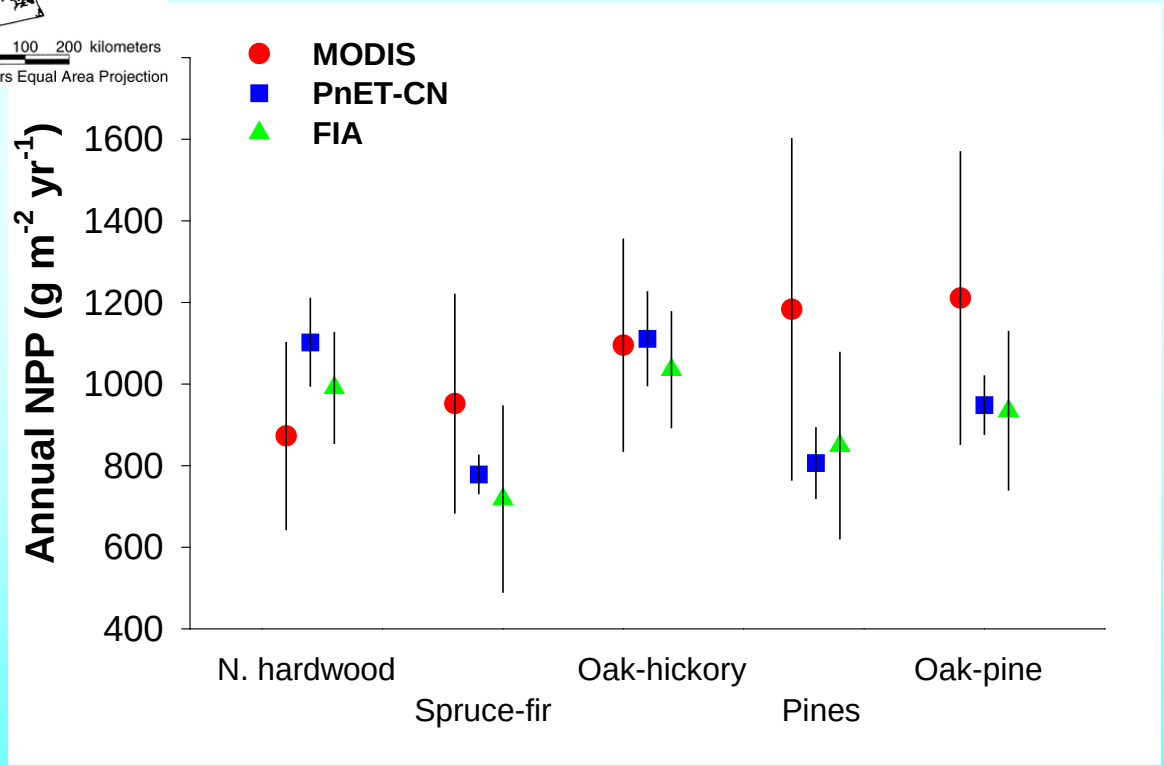
NPP Validation

Comparison among remote sensing, PnET-CN modeling, and inventory



Net Primary Production:

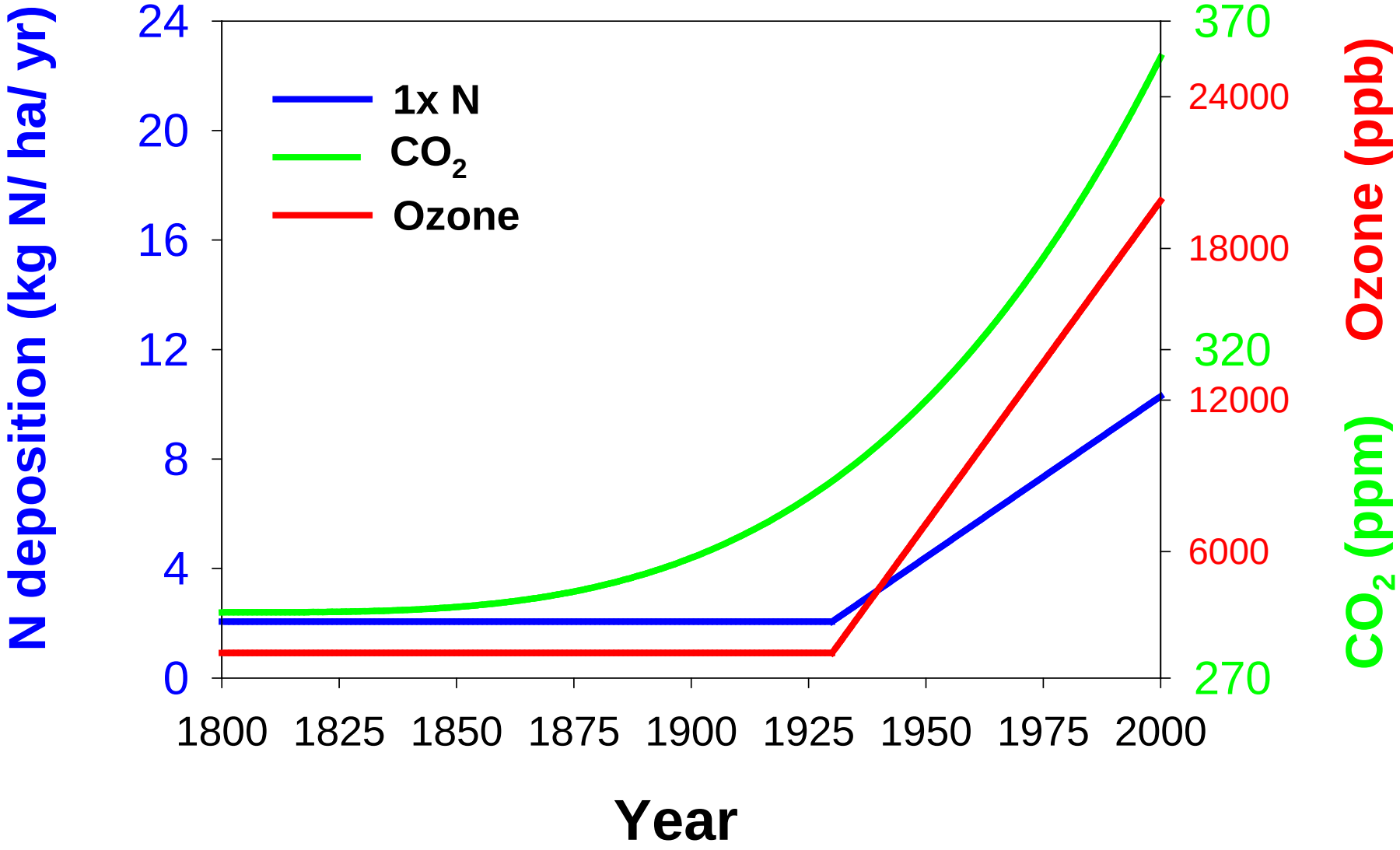
Net uptake of carbon by plants in excess of respiratory loss

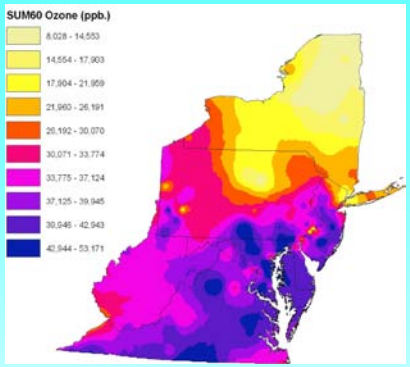


N-Cycle Validation: Comparison with field data and other models

Watershed/ pixels	Mean stream output ($kgN\ ha^{-1}yr^{-1}$)	N Deposition ($kgN\ ha^{-1}yr^{-1}$)	N Retention (%)
Rhode River, MD	1.77	11.8	85
Baldwin Ck, PA	2.19	15.5	87
Benner Run, PA	0.73	15.6	95
Rober Run, PA	0.64	15.2	96
Stone Run, PA	0.26	15.3	98
Miller Run, MD	3.51	6.52	46
Upper Big Run, MD	2.79	6.52	57
Monroe Run, MD	5.02	6.52	23
Peapatch Ridge, MD	4.70	6.52	28
Lower Big Run, MD	4.27	6.52	35
Fernow #4, WV	5.15	16.0	68
PnET-CN (HW/mix)	0.18 – 5.82	5.13 - 16.11	18 - 98
EPA (CPB)	1.39	12.91	89
SPARROW (CPB)	2.28	12.91	82
CBP model (CPB)	1.90	10.00	81
PnET-CN (forests)	1.23	10.04	88
PnET-CN (CPB)	1.46	10.04	85

Scenarios of Increasing Atmopsheric Chemistry





Factorial Model Experiments

	CO_2	O_3	N dep.	Clm
Run 1: control	○	○	○	○
Run 2: scenario	●	○	○	○
Run 3: scenario	○	○	●	○
Run 4: scenario	●	●	○	○
Run 5: scenario	●	○	●	○
Run 6: Scenario	●	●	●	○
Run 7: Scenario	●	●	●	●

Running years 1800-2000

28 Scenarios

○ Fixed 280 ppmv

● Ramped up to 366 ppmv

○ No ozone input

● Ramped up to current level

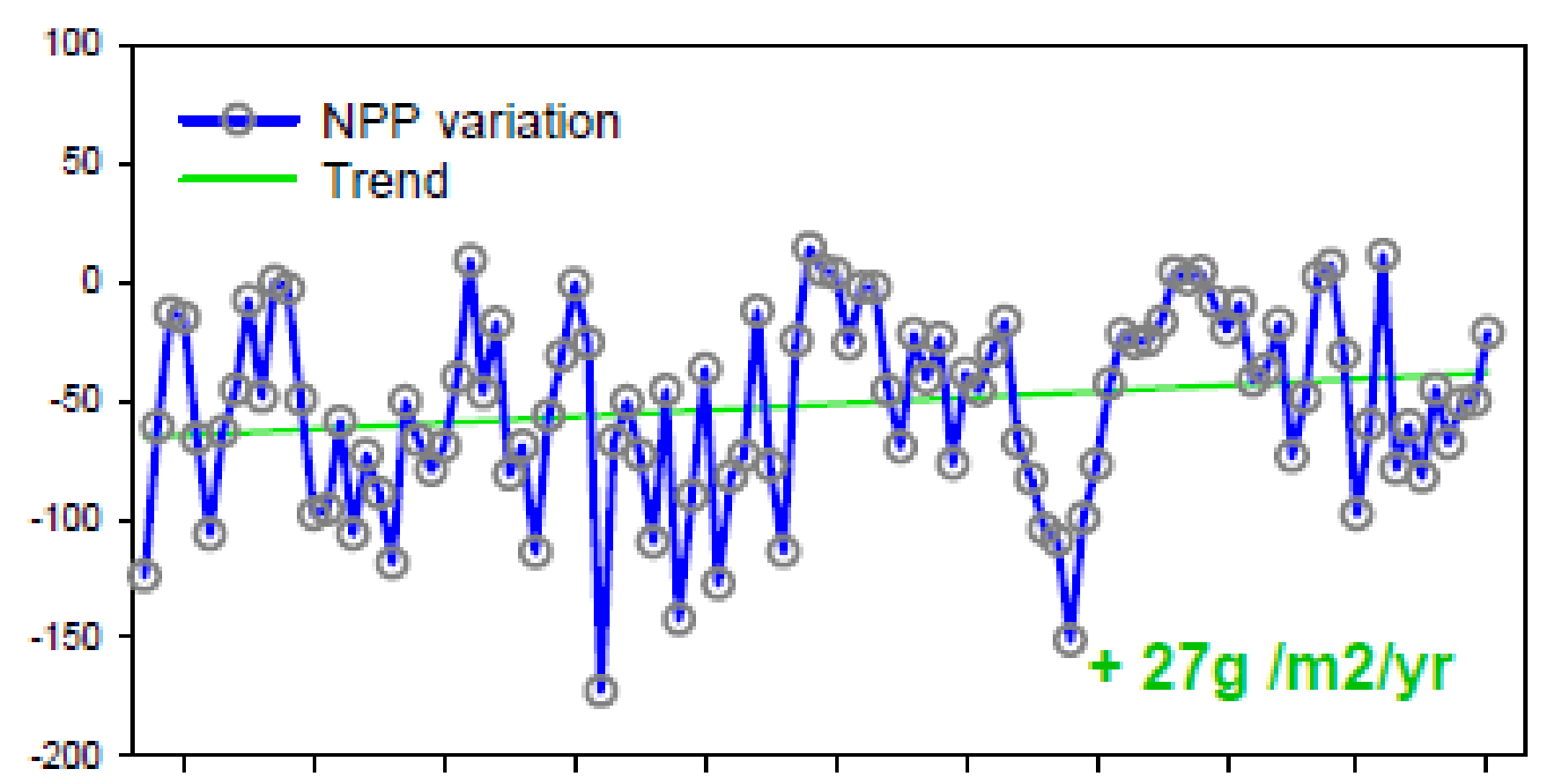
○ No N input

● Ramped up to current level

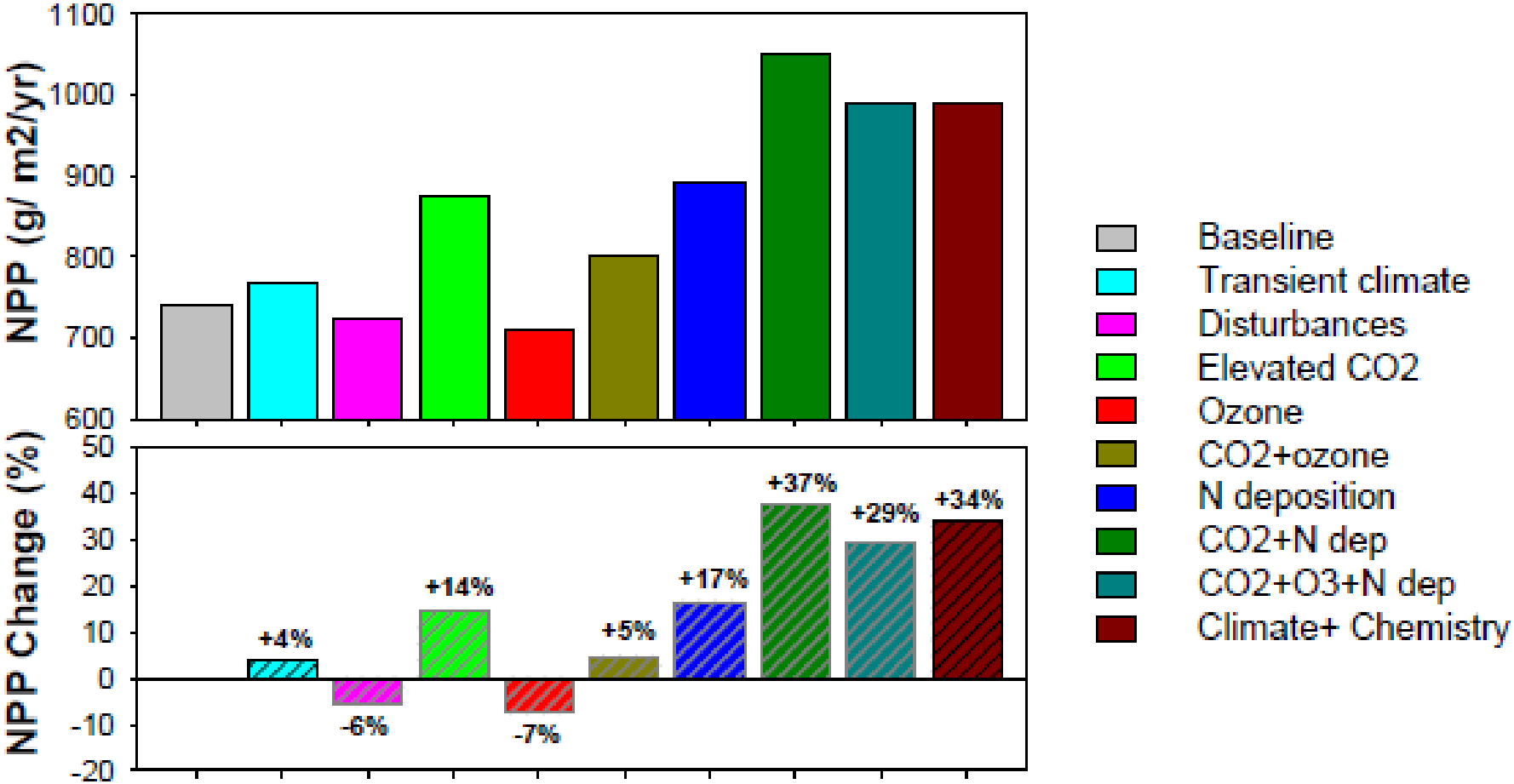
○ Mean climate

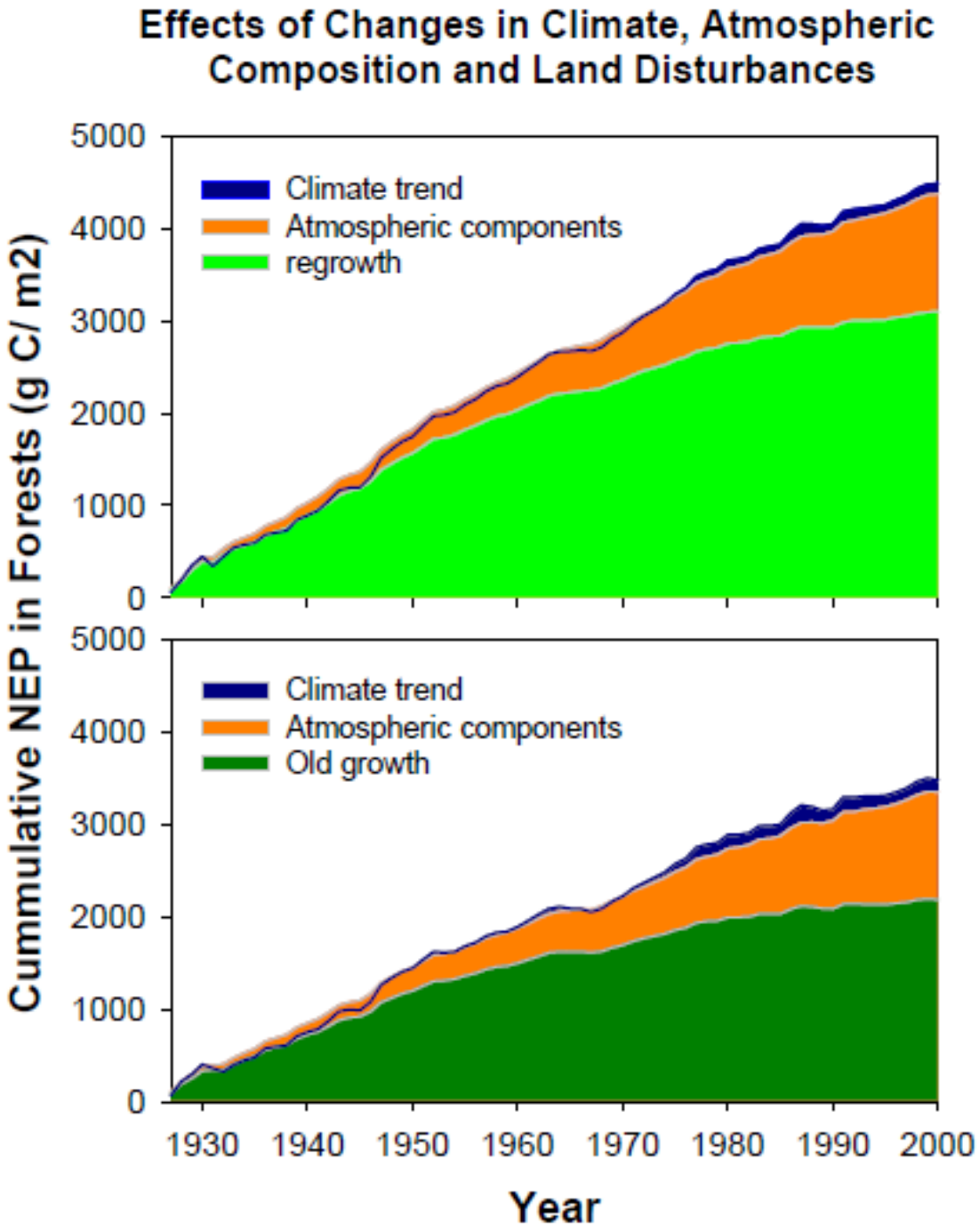
● Historical climate

NPP Response to Climate Variability (g/m^2)



NPP Responses to Multiple Environmental Changes





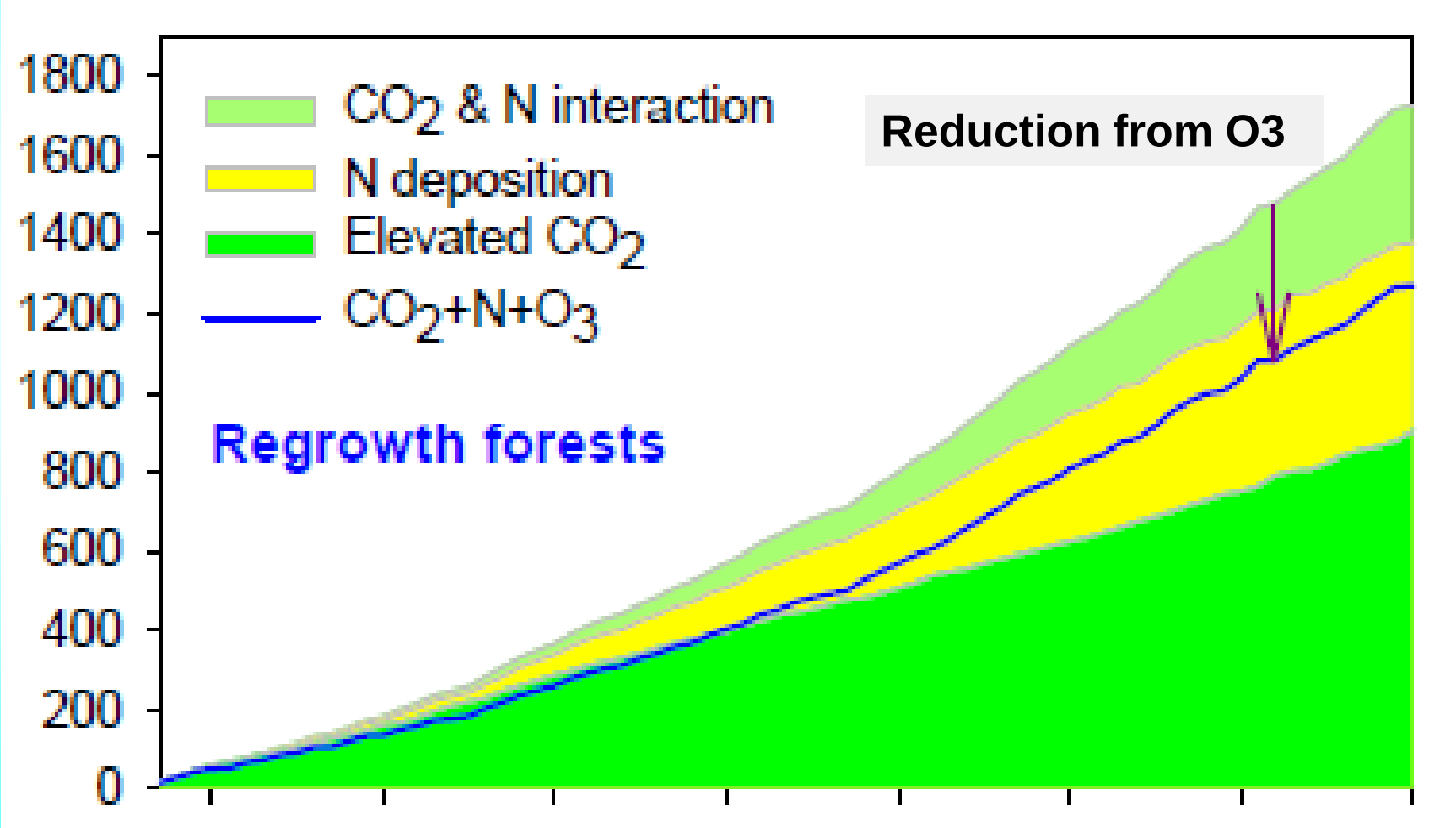
The direct effect of land management (regrowing forests) is about 70% of the total effect of all factors combined

Net Ecosystem Production:

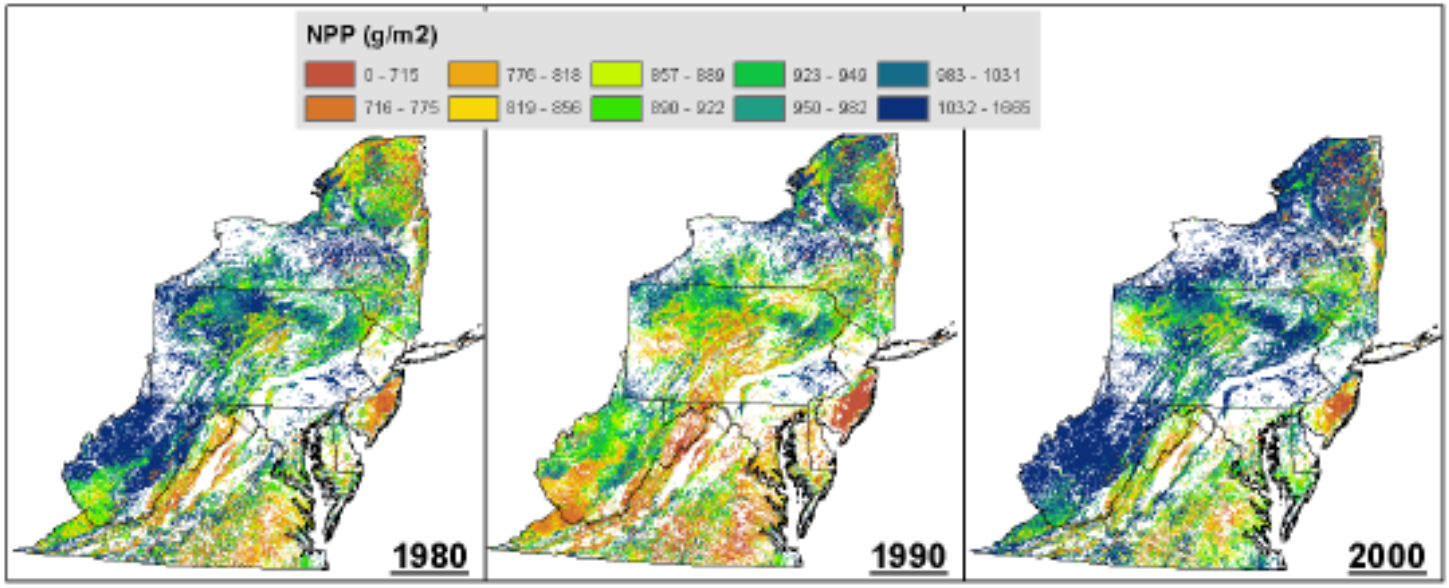
Net carbon accumulation within the ecosystem after accounting for all gains and losses

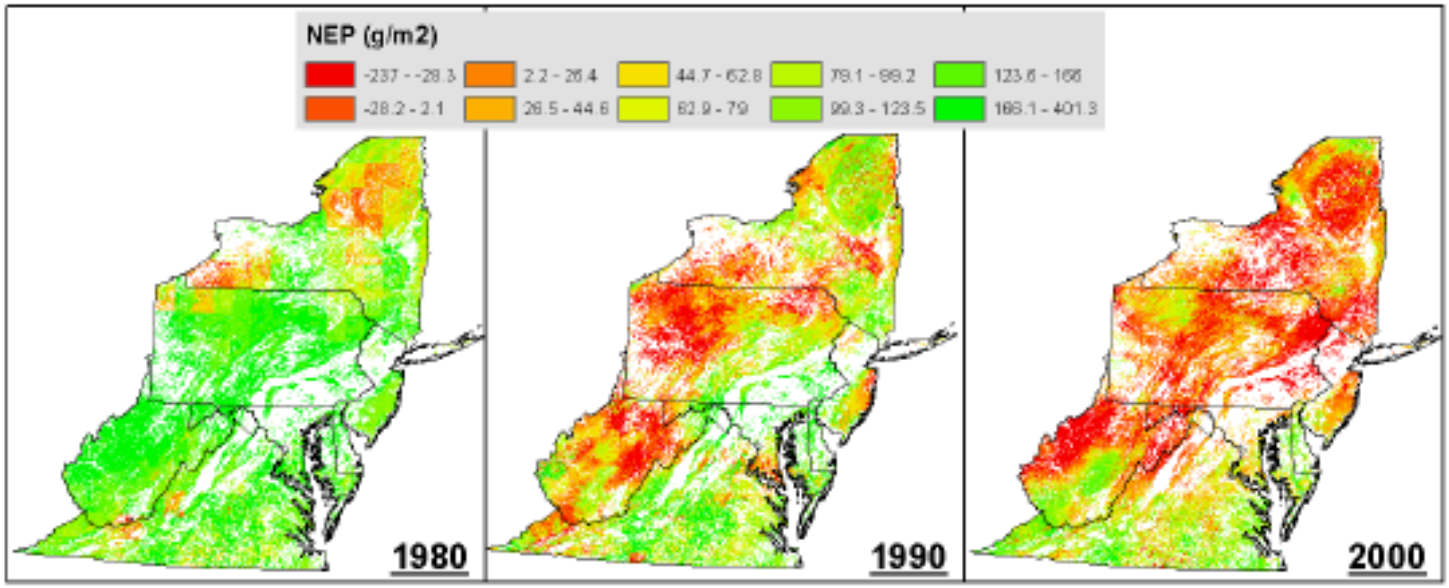
Partitioning Effects of Changes in Atmospheric Composition

(Cumulative NEP, gC/m^2)



Spatial Distribution of Recent Changes in NPP and NEP





Changes in NPP and NEP are not always consistent because of influence by different control factors

Analysis of Variance for Modeled NPP and NEP

<u>Most Significant variables</u>

NPP: CO_2, N, O_3, Climate, and CO_2 x N

NEP: CO_2, Climate

Source of variation		NPP			NEP		
	DF	SS	Contribution of variation (%)	P	SS	Contribution of variation (%)	P
CO_2	1	330162	28.04	<0.001 **	35746	16.81	<0.001 **
N deposition	1	482136	40.95	<0.001 **	4549	2.14	0.153 *
Ozone	1	74245	6.31	<0.001 **	4621	2.17	0.150 *
Climate	1	131330	11.15	<0.001 **	5540	2.60	0.057 **
CO_2 x N interaction	1	15012	1.27	0.003 **	1575	0.74	0.398
CO_2 x O_3 interaction	1	620	0.05	0.540	175	0.08	0.778
N x O_3 interaction	1	306	0.03	0.667	114	0.05	0.820
CO_2 x O_3 x N interaction	1	82	~ 0.01	0.823	5	~ 0.00	0.962
Climate x CO_2 interaction	1	44	~ 0.00	0.818	120	0.06	0.699
Climate x O_3 interaction	1	704	0.06	0.358	175	0.08	0.712
Climate x N interaction	1	27	~ 0.00	0.866	2925	1.38	0.120 *
Climate x CO_2 x O_3 interaction	1	1422	0.12	0.192 *	112	0.05	0.768
Climate x CO_2 x N interaction	1	311	0.03	0.524	110	0.05	0.761
Residual	108	141016	11.98		156904	73.78	
Total	119	1177107	100.00		212670	100.00	

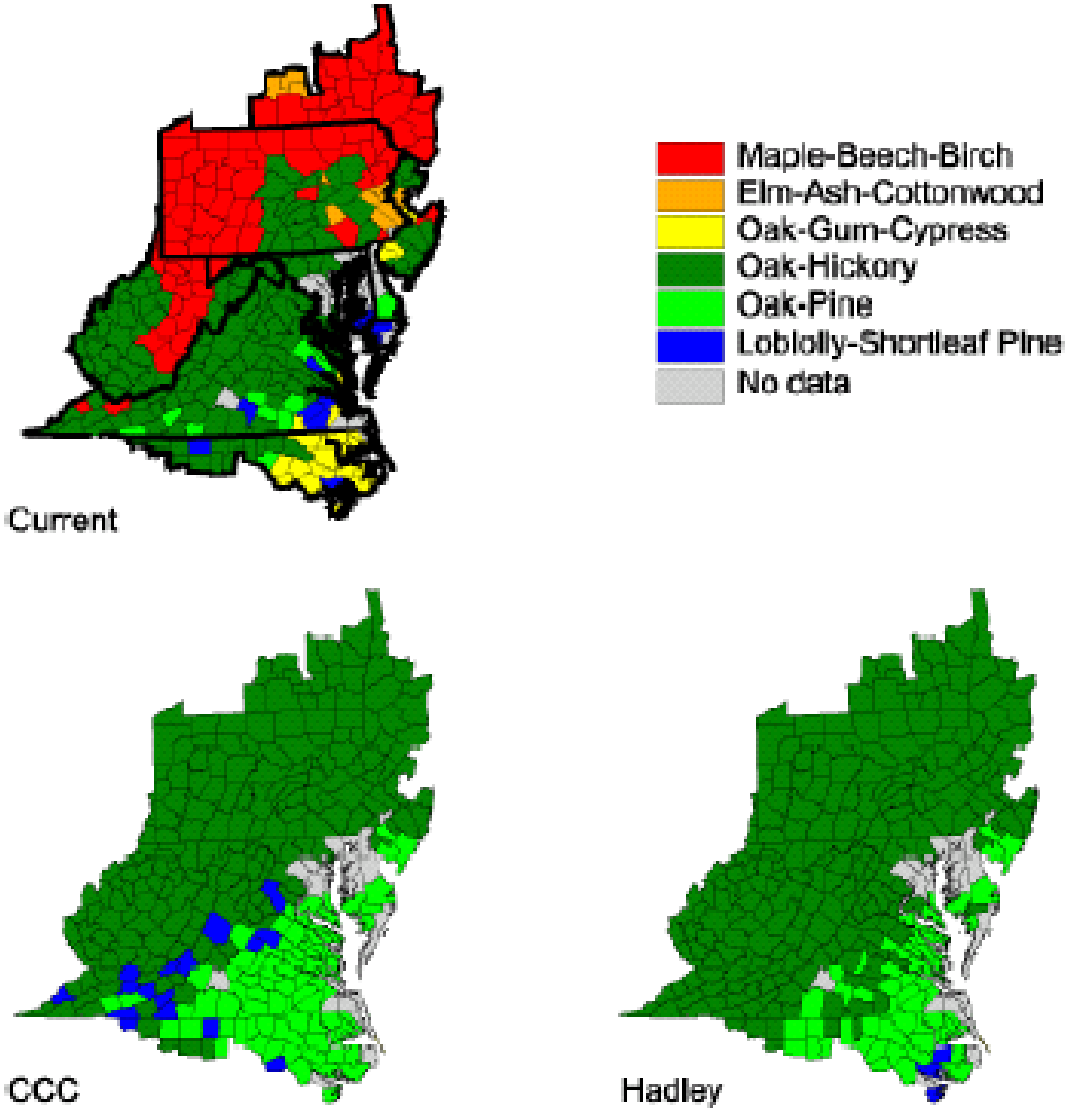
Some Related Work

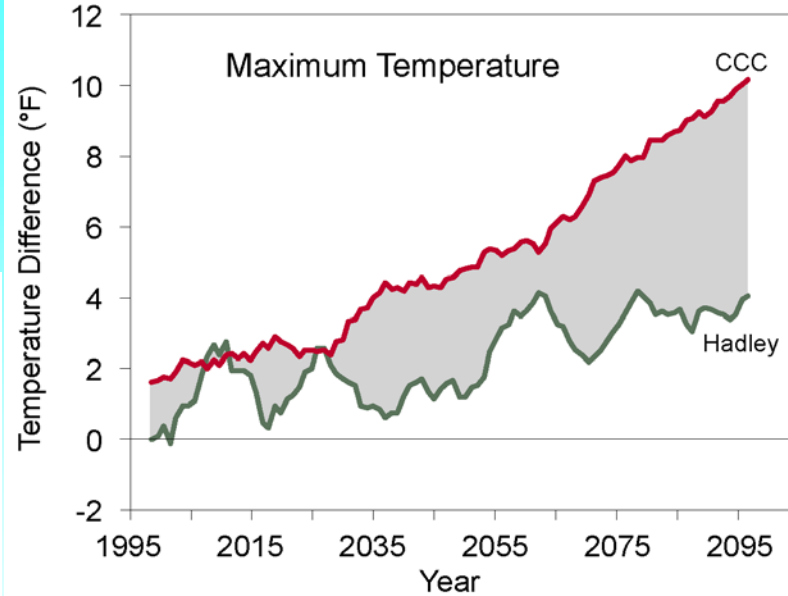
Forest N export and retention in the Chesapeake Basin watershed.

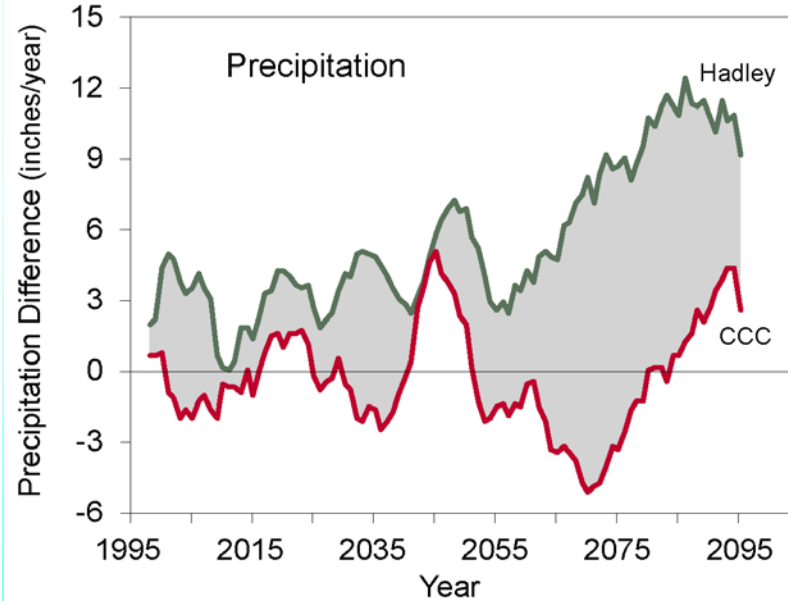
Current N Scenario (Mean N deposition = 10.04 kg N ha^{-1} yr^{-1})

Tree Groups	Area (km^2)	Total N loss (Mg N)	Min	Mean (kg N m2 yr-1)	Max	Retention (%)
N. Hardwood	20,298	3,013.88	0.313	1.4847	2.725	86
Spruce-fir	22	4.97	0.617	2.2580	4.444	78
Oak-hickory	52,065	5,326.24	0.179	1.0230	2.766	90
Pine	7,404	1,023.37	0.207	1.3822	10.590	84
Oak-pine	14,724	2,248.66	0.224	1.5272	5.817	84
Region	94,514	11,617.00	0.179	1.2291	10.590	88

More Model Experiments Needed…. Interactions with Projected Range Shifts in Vegetation







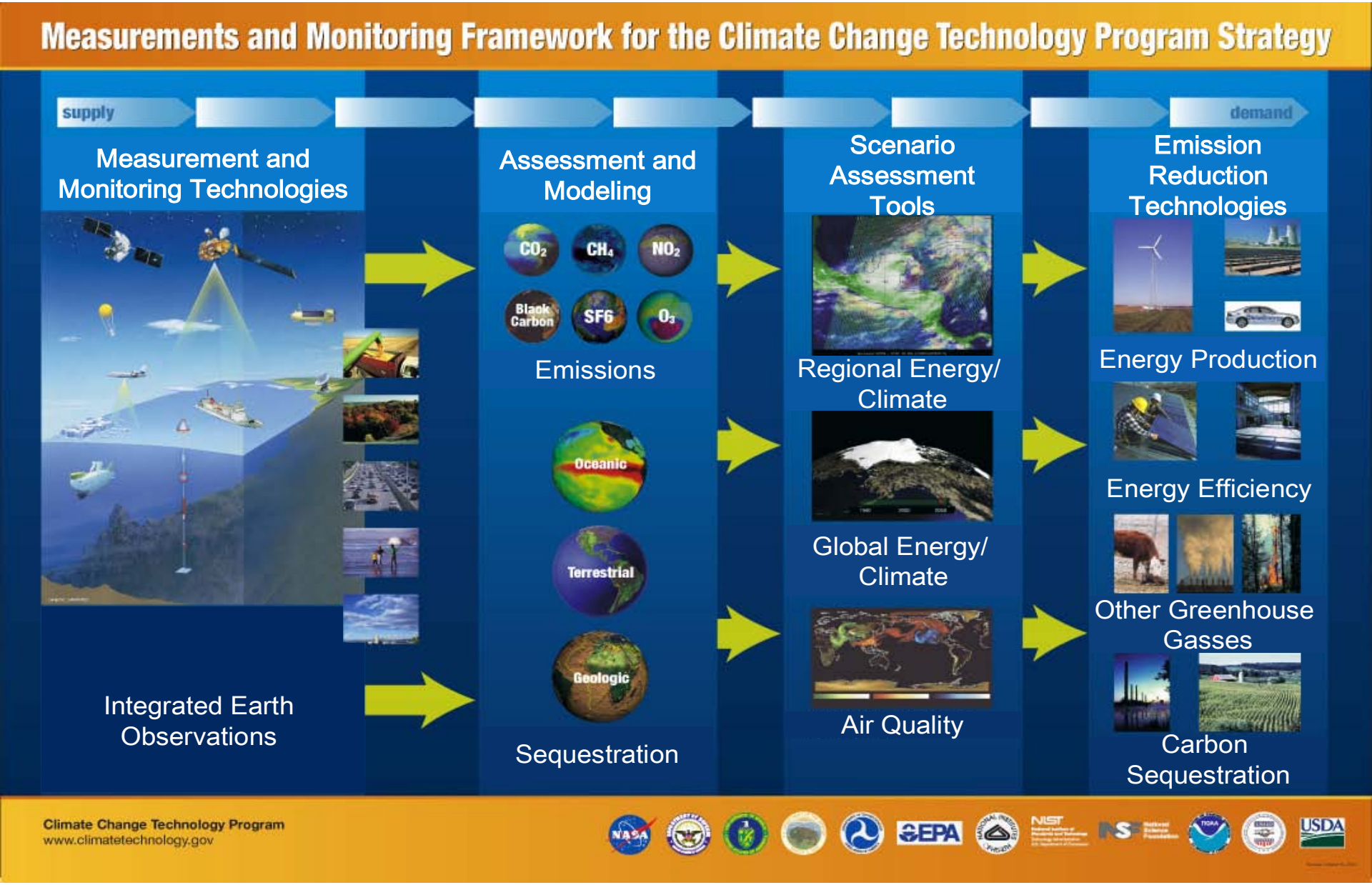
Hadley and CCC model differences from the observed 1960-1989 base period, for the MAR.

Information Needs for Climate Change Policy and Management

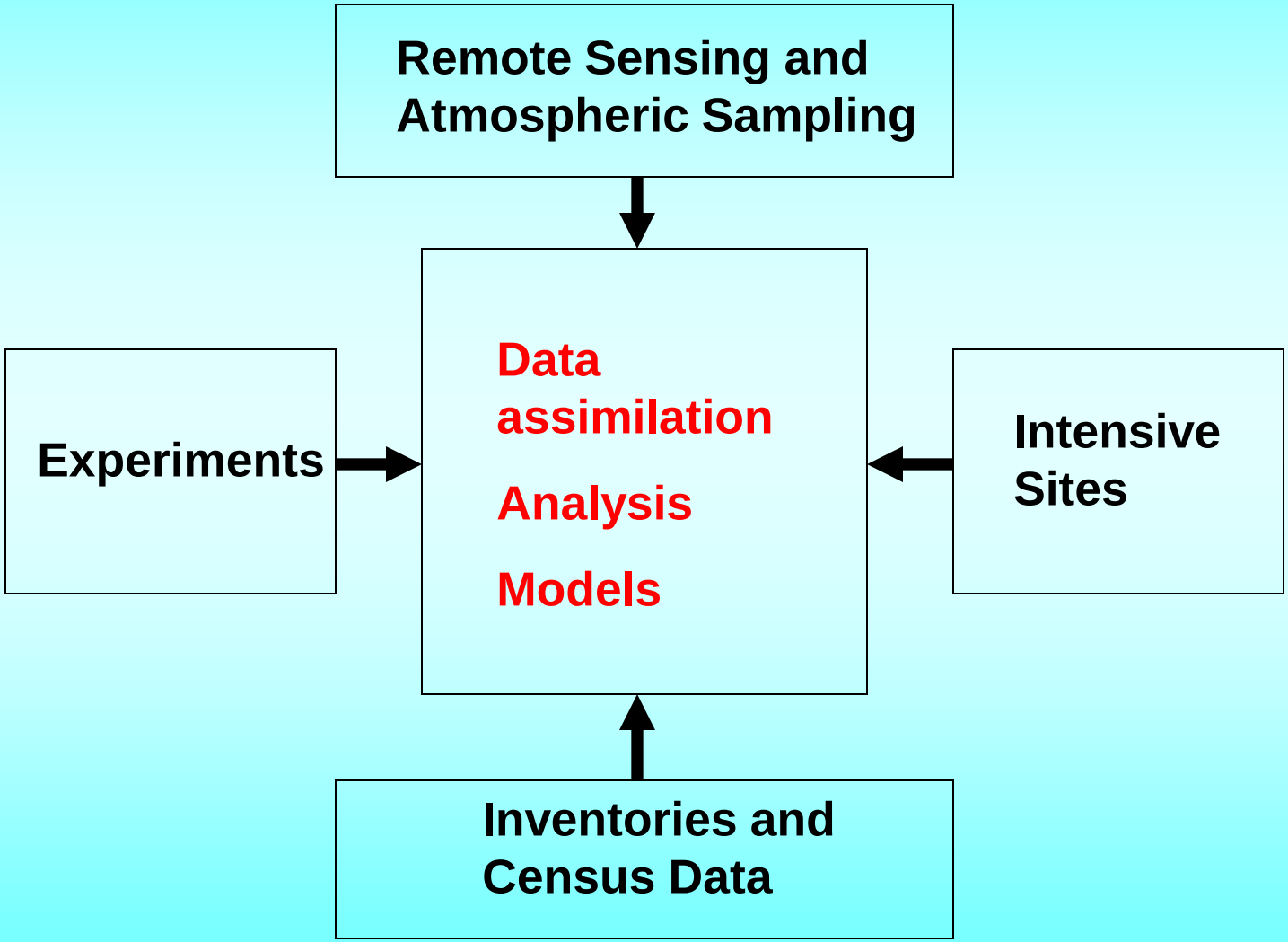
- “Good data” about past trends and current conditions (understand system status)
- Projections based on reasonable assumptions and models (guide policy)
- Monitoring system to track progress toward management goals (verification)

Observations of climate and carbon management effects may be confounded with other factors.

Linking Monitoring with Decision Support



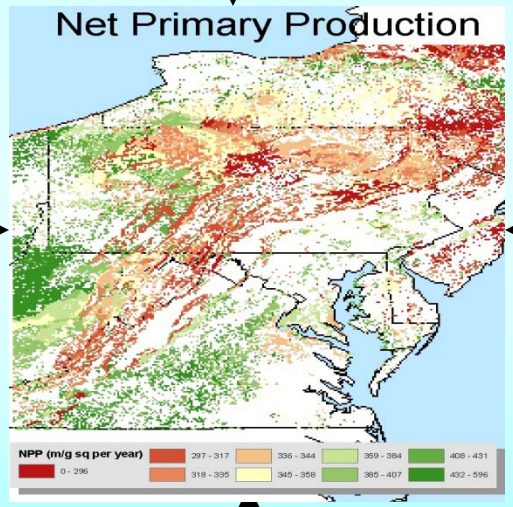
Integration of Measurements with Models to Represent Critical Ecosystem Processes



Integration of Measurements with Models to Represent Critical Ecosystem Processes

Remote Sensing and Atmospheric Sampling

Experiments



Intensive Sites

Inventories and Census Data

Conclusions

- It is important to understand and quantify the effects of multiple factors and their interactions
- The additive effects of increasing CO_2 and N deposition on NPP are significantly stronger than effects of climate variability and change
- The most significant variables are different for NPP and NEP:
  - NPP: CO_2, N, O_3, Climate, and CO_2 x N
  - NEP: CO_2, Climate
- Direct human effects on productivity account for about 70% of the Net Ecosystem Productivity over the last century
- Emerging programs for reducing greenhouse gases and adapting to climate change require a robust monitoring and analysis system capable of separating effects of multiple factors

References

- Pan, Yude, Richard Birdsey, John Hom, Kevin McCullough. 2009. Separating effects of changes in atmospheric composition, climate and land-use on carbon sequestration of U.S. Mid-Atlantic temperate forests. Forest Ecology and Management 259 (2009) 151–164
- Birdsey, Richard, and others. 2009. Carbon Cycle Observations: Gaps Threaten Climate Mitigation Policies *Eos*, Vol. 90, No. 34 p. 292.
- Pan Y, Birdsey R, Hom J, McCullough K, Clark K. 2006. Improved Estimates of Net Primary Productivity from MODIS Satellite Data at Regional and Local Scales. *Ecological Applications* 16(1):125-132
- Pan, Y, Hom J, Birdsey R, McCullough K. 2004. Impacts of rising nitrogen deposition on N exports from forests to surface waters in the Chesapeake Bay Watershed. *Environmental Management* 33 (4): s120-131

http://www.nrs.fs.fed.us/units/climate/

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  - John Hom
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