How well do we know forest carbon balance in China?

Baozhang Chen
(Chinese Academy Sciences)

Shilong Piao
(Beijing University)

Lingxi Zhou
(China Meteorological Administration)

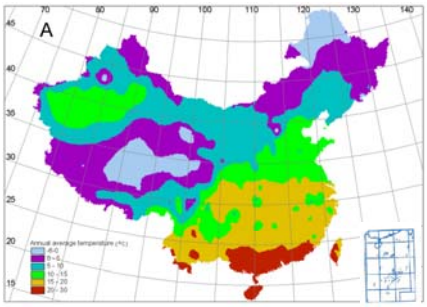
IPCC Expert Meeting, Yokohama, Japan, Feb. 23-25

Outline

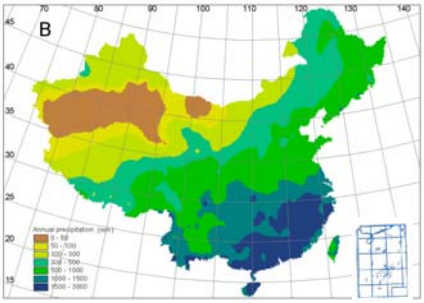
1. Basic characteristics of climate and forests in China
2. China's forest C stock?
3. Uncertainties, Scaling and Future Work
4. Conclusions

Spatial distribution climae

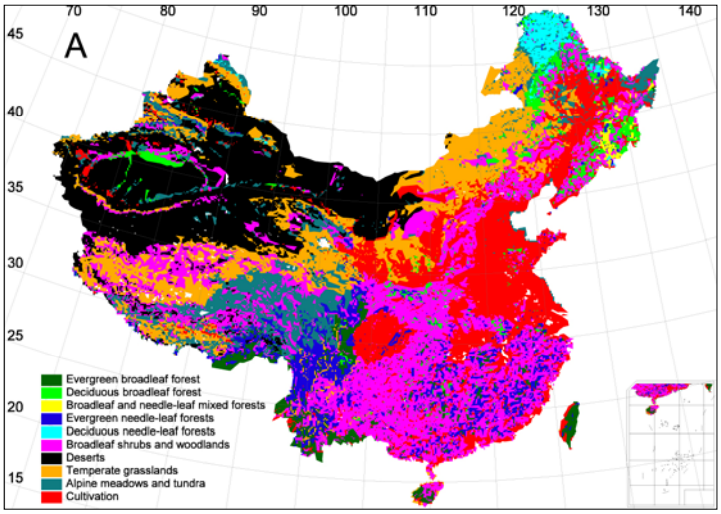
Mean annual temperature



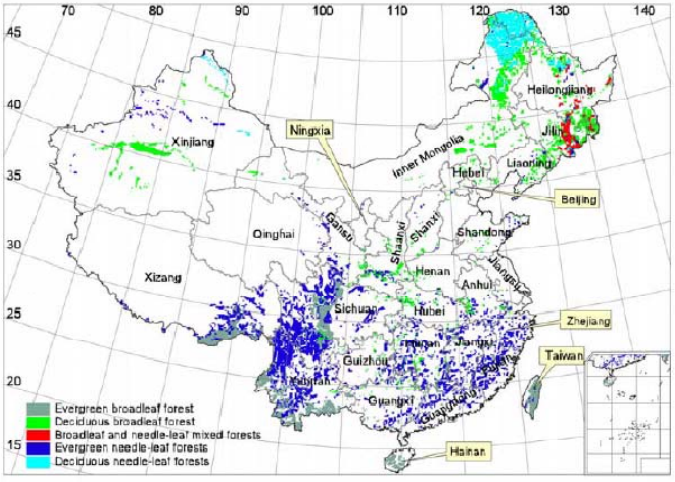
Annual Precipitaion



Distribution of vegetation types in China

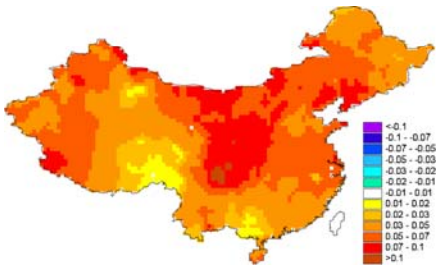


Forest distribution in China

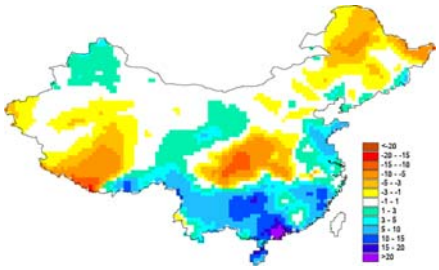


Significant climate change

Temperature change



Precipitation change

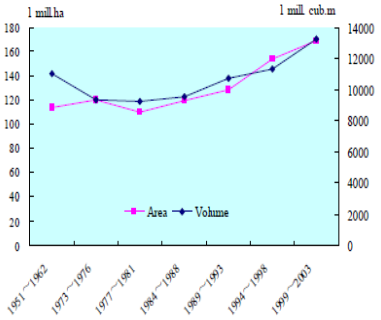


- During the past two decades, mean annual temperature over China increased by more than 0.5 ºC/decade.
- Warmer-dryer in the *North* and warmer-wetter in the *South* where most productive ecosystems are distributed.

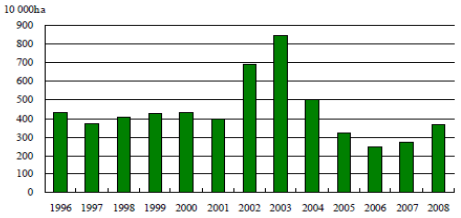
Based on CRU climate data (Mitchell et al., 2003)

Forest ressource change

Forest ressource change by area and volume in China, 1951-2003

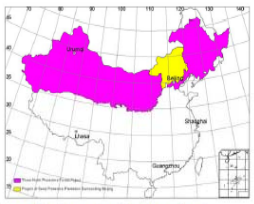


Annual afforestation in China, 1996-2008

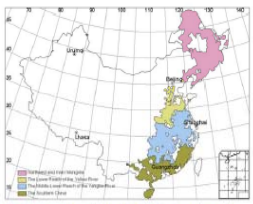


Dai et al., 2009

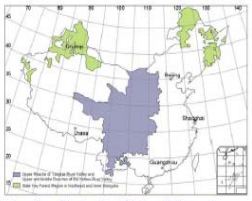
Afforestation/reforestation projects



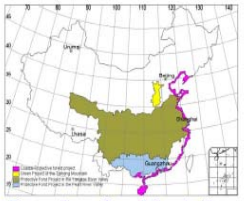
Three-North protective forest and sand-control plantation surrounding Beijing



Fast-growing high yield timber forest bases project of key regions



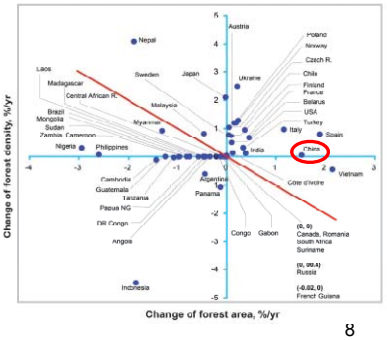
Protective Project of Natural Forests



River valley and coastal protective project

-China contributed about one quarter of the global plantation area.

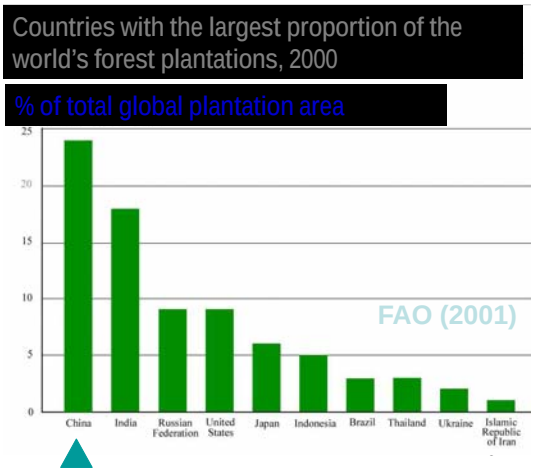
-Forest plantation benefit net carbon uptake



Kauppi et al., (2006)

Reforestation and afforestation

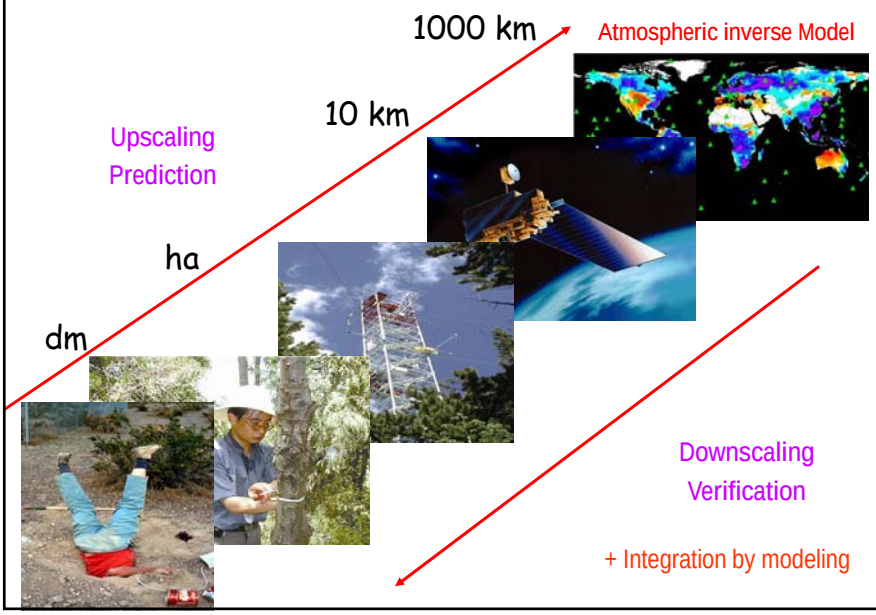
China is the largest country with planted forests, about 1/4 of total global plantations (FAO, 2001)



Outline

1. Basic characteristics of climate and forests in China
2. China's forest C stock?
3. Uncertainties, Scaling and Future Work
4. Conclusions

Methods



Method 1

Forest inventory-based estimation

Data

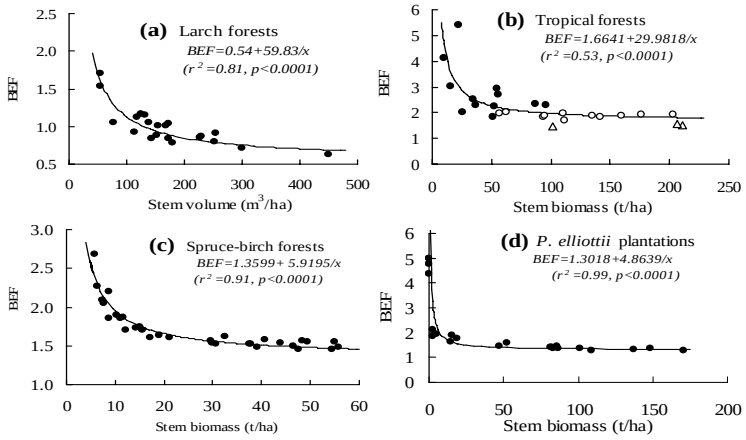
Through China's National Forest Resource Inventory project, >200,000 permanent and temporary plots were set up throughout China, particularly since the late 1970s, producing statistics about China's forest resources nearly every 5 years: 1977-81, 1984-88, 1989-93, 1994-98, 1999-2004.

Method

Because forest inventory data only provide information on timber volume, a factor to convert timber volume to total biomass (biomass expansion factor, BEF) is frequently used to estimate forest biomass

BEF = Biomass/volume

Biomass expansion factor (BEF) as a function of stem volume or stem biomass



forest biomass density was estimated from timber volume using BEF (Biomass expansion factor), the ratio of biomass to timber volume, expressed as a function of stem volume (x), *BEF = a + b/x*

Fang JY 1998

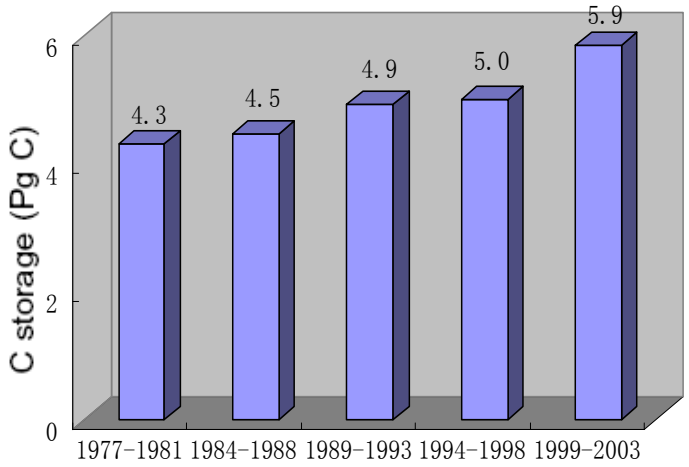
Biomass and BEF parameters for major forest types in China

Forest type	Mean biomass n	Mean (Mg/ha)	SD (Mg/ha)	Biomass/volume Mean (Mg/m³)	SD (Mg/m³)	Parameters in equation, *k=a+b/x* *a* (Mg/m³)	*b* (Mg/ha)	n	r^2
Abies, Picea	19	135.9	89.66	0.91	0.33	0.4642	47.4990	13	0.98
Cunninghamia lanceolata	74	86.3	53.03	0.54	0.15	0.3999	22.5410	6	0.95
Cypress	19	213.1	89.51	0.67	0.07	0.6129	26.1451	1	0.96
Larix	13	139.5	75.36	0.99	0.20	0.9671	5.7598	8	0.99
Pinus koraiensis	19	65.4	29.44	0.98	0.67	0.5185	18.2200	7	0.90
P. armandii	10	71.8	25.04	0.86	0.19	0.5856	18.7435	9	0.91
P. massoniana, Pyunnanensis	12	81.1	31.84	0.52	0.04	0.5101	1.0451	12	0.92
P. sylvestris var. *mongolica*	11	49.3	19.23	1.11	0.02	1.0945	2.0040	11	0.98
P. tabulaefomis	90	88.7	56.84	0.81	0.13	0.7554	5.0928	82	0.96
Other pines and conifer forest	22	120.3	98.07	1.05	0.67	0.5168	33.2378	16	0.94
Tsuga, Cryptomeria, Keteleer	2	208.9	126.15	0.57	0.14	0.4158	41.3318	21	0.89
Mixed conifer & deciduous fo	9	93.7	84.48	1.14	0.46	0.8019	12.2799	9	0.99
Betula	6	123.1	45.25	0.97	0.03	0.9644	0.8485	4	0.96
Casuarina	11	88.8	48.19	0.97	0.19	0.9505	8.5648	3	1.00
Deciduous oaks	6	89.2	76.27	1.24	0.05	1.3288	-3.8999	3	0.99
Eucalyptus	11	178.3	187.97	0.90	0.06	0.7893	6.9306	4	0.99
Lucidophyllous forests	21	163.7	81.29	1.08	0.17	1.0357	8.0591	17	0.89
Mixed deciduous & *Sassafras.*	19	313.6	80.30	0.91	0.13	0.6255	91.0013	19	0.86
Nonmerchantable woods	11	52.2	29.00	0.97	0.19	0.7564	8.3103	11	0.98
Populus	16	109.1	42.83	0.66	0.11	0.4754	30.6034	10	0.87
Tropical forests	12	324.3	147.06	0.97	0.02	0.9505	8.5648	3	0.99

Inventory

Forest biomass C storage change

C sink=5.9-4.3=1.6 Pg C (or 0.075 Pg C/yr)



Piao SL 2009

Inventory

Large uncertainties of C stock

Total biomass C stocks of China's forests during 1989-1993 estimated by different authors.

Method	Period	C stock (Pg C)	Source
MBM	1989–1993	6.9	Zhou et al. (2000)
Age-specific MBM	1989–1993	6.6	Pan et al. (2004)
Regional-averaged MRM	1989–1993	4.2	Wu et al. (2008)
CBM	1989–1993	4.2	Liu et al. (2000)
Age-specific CBM	1989–1993	4.0	Pan et al. (2004)
Hyperbolic function	1989–1993	3.8	Zhao and Zhou (2006)
Age-specific CBM	1989–1993	4.1	Xu et al. (2007)
CBM	1989–1993	4.5	Guo et al. (2010)

All the estimates are based on China's forest inventory data but different method

Soil C storage estimation

Soils are the largest source of uncertainty in the terrestrial carbon balance of China (as well as in other regions of the world), as data from repeated inventories are lacking.

Assume: Change in litter input can be inferred from change in biomass, and that changes in decomposition of SOCD are driven by temperature (temp) and precipitation (ppt).

Evergreen forests:

$$Ln(SOCD) = -2.80 \times 10^{-2}\, temp + 6.05 \times 10^{-5}\, ppt + 2.20 \times 10^{-4}\, biomass + 3.77 \quad (R^2 = 0.23,\ P < 0.001) \qquad (5)$$

Deciduous forests:

$$Ln(SOCD) = -7.92 \times 10^{-2}\, temp + 7.09 \times 10^{-4}\, ppt + 1.84 \times 10^{-5}\, biomass + 4.42 \quad (R^2 = 0.29,\ P < 0.001) \qquad (6)$$

Soil carbon sequestration in Chinese forests is about 0.004±0.004 PgC yr-1, resulting from counterbalancing changes in evergreen and deciduous forest soils. A large soil carbon accumulation in the evergreen forests of southern China (0.022±0.008 PgC yr-1) that is nearly offset by a net soil carbon loss in northern deciduous forests (0.018±0.004 PgC yr-1). Northern regions were exposed to a stronger warming trend and also experienced net deforestation during the 1980s and 1990s.

Again large uncertainties due to small R2.

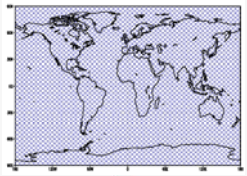
Piao SL 2009

Method 2

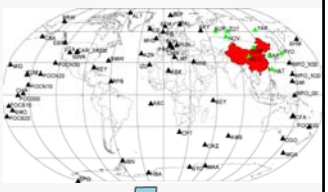
Atmospheric inversion estimation

Prior flux information

LMDZ transport model

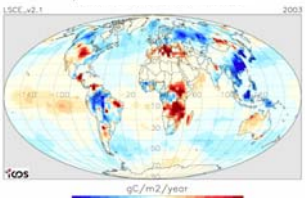


observations



Inverse Procedure

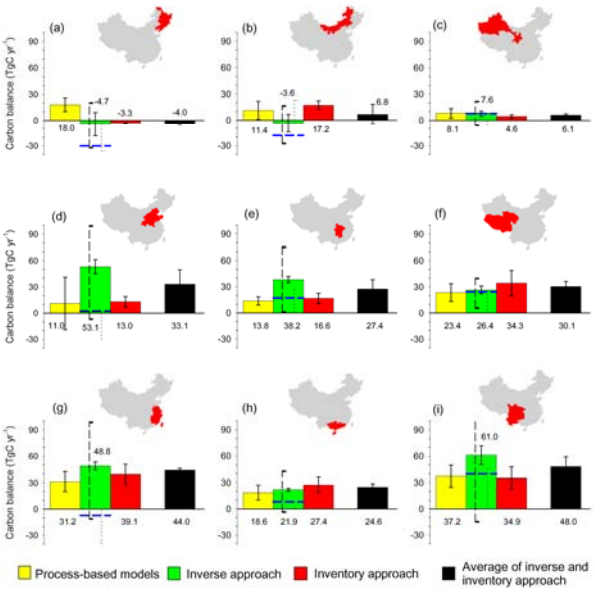
Optimized fluxes



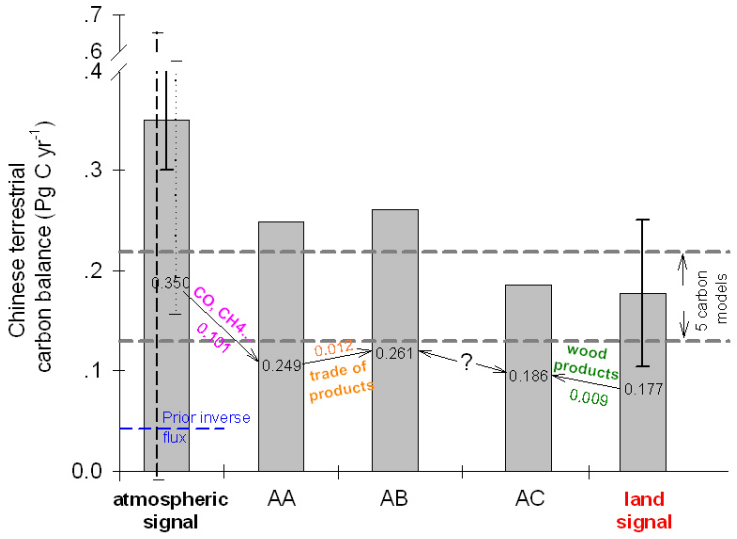
Limitations1: scarce atmospheric netwrork (only 9 sites in North Asia) and uncertainty from transport model

Limitations2: Due to low spatial resolution, we can only estimate co2 flux at regional scale, but can not separate each ecosystem

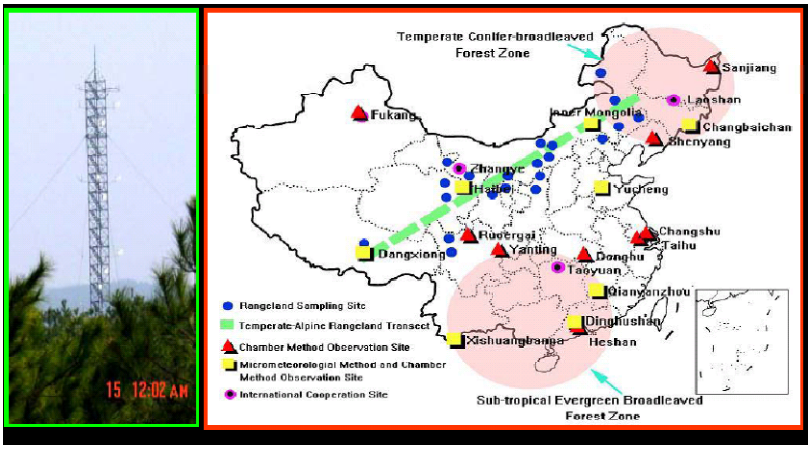
Spatial distribution of the C balance in China



Carbon balance of Chinese terrestrial ecosystems

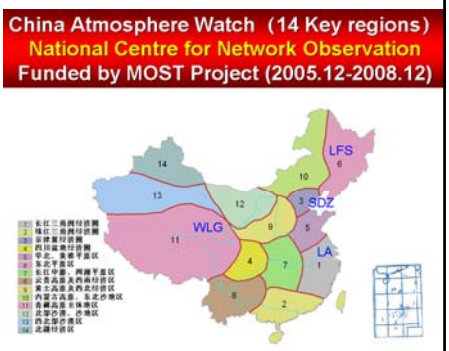


In Situ Sampling measurements



Remote sensing is applied to design sampling network

Network in-situ and sampling measurements
(ambient GHGs concentration in China)
More sites expected



Outline

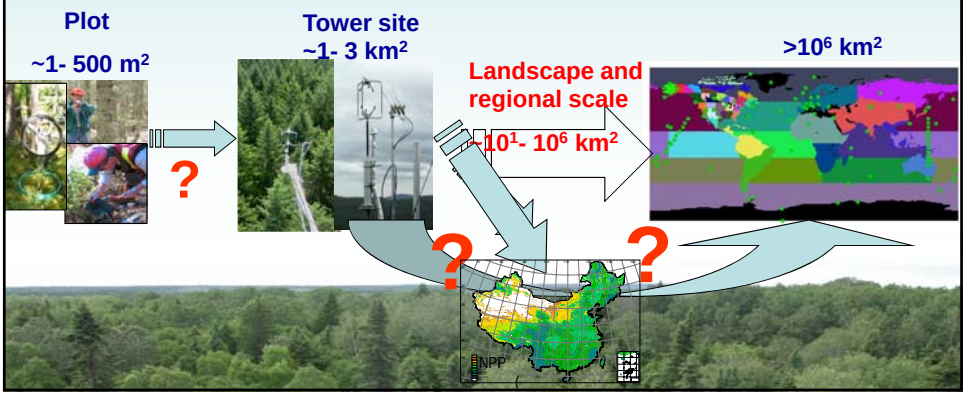
1. Basic characteristics of climate and forests in China
2. China's forest C stock?
3. Uncertainties, Scaling and Future Work
4. Conclusions

Carbon budget scales

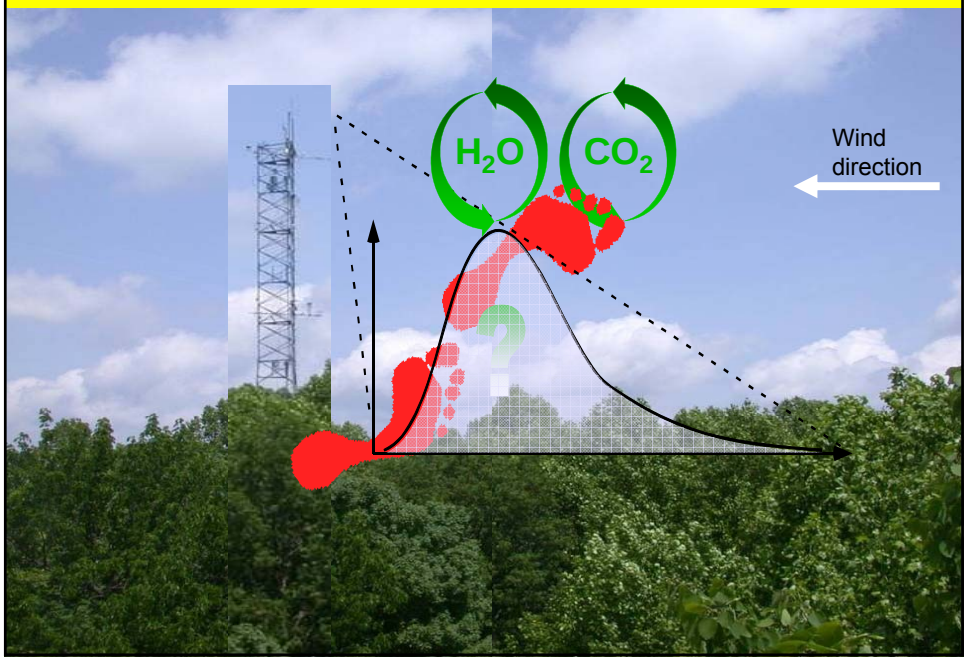
- Direct measurements of terrestrial C fluxes are being made worldwide, e.g., (1) biometric plots & chambers, (2) eddy-covariance flux towers.

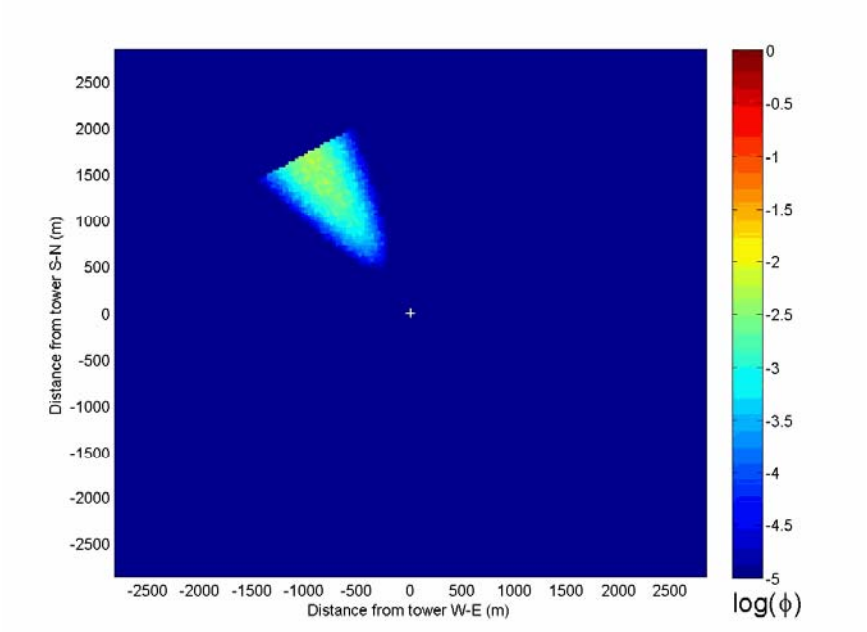
Carbon balance estimates at global and continental scales have also been much improved through atmospheric inverse modeling.

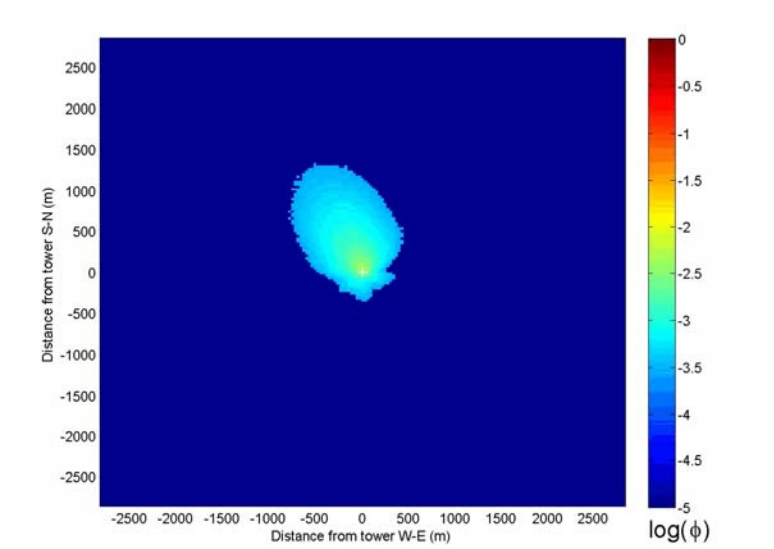
There is a large knowledge gap at landscape and regional scales.



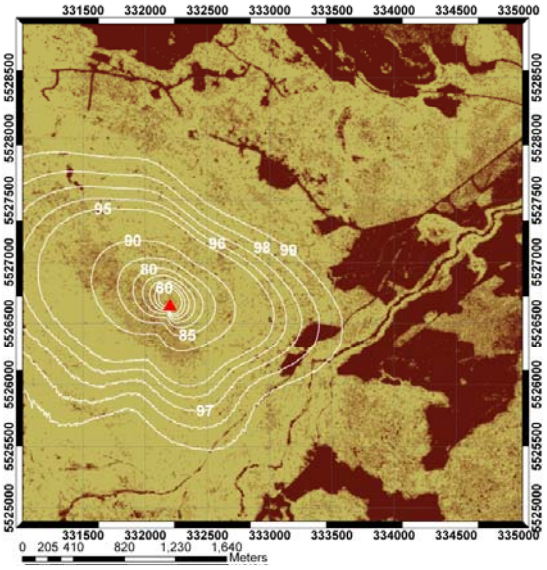
EC flux footprint and footprint climatology







Overlaying footprint climatology on remotely sensed monthly GPP field



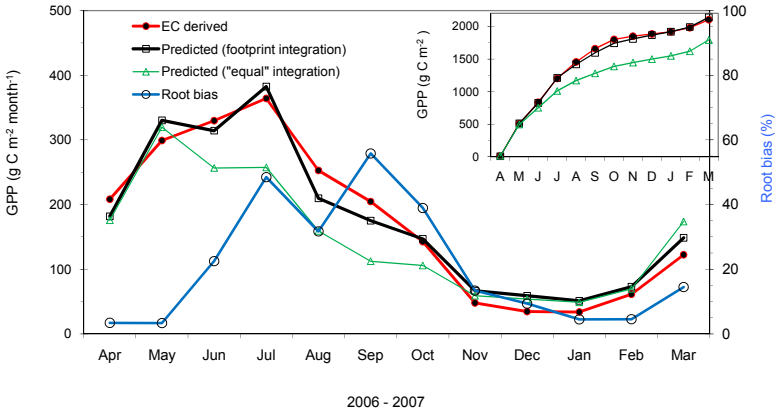
October

GPP (μmol m^{-2} s^{-1})

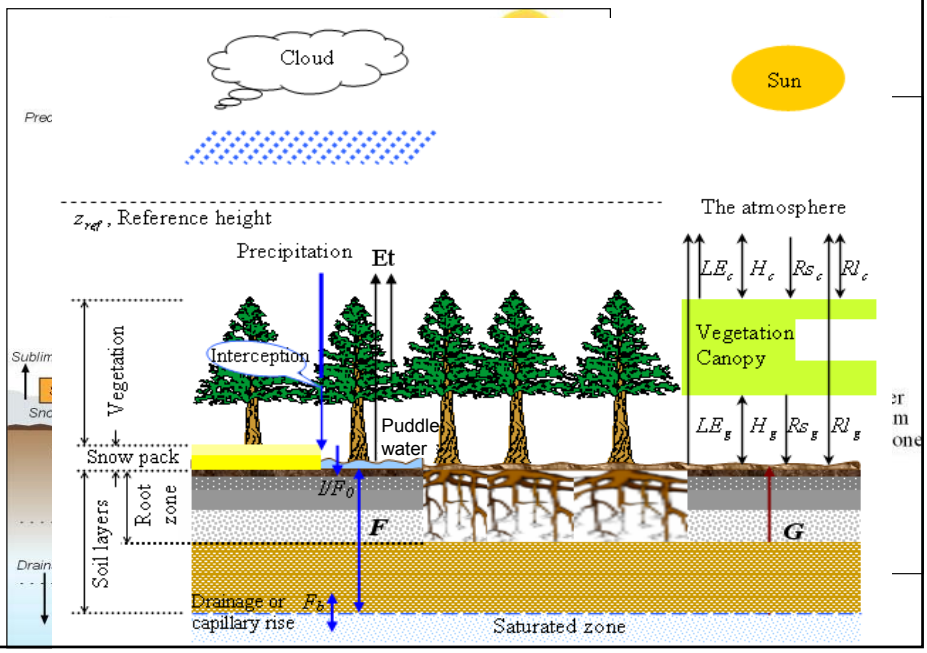
- 0 - 2.5
- 2.5 - 5
- 5 - 7.5
- 7.5 - 10
- 10 - 12.5
- 12.5 - 15
- 15 - 17.5
- 17.5 - 20
- 20 - 22.5
- 22.5 - 25
- 25 - 27.5
- 27.5 - 30

DF49,BC

Comparisons in ecosystem-scale GPP estimates between integrated from remotely sensed GPP maps and directly derived from EC measurements



Spatially-explicit ecohydrological modeling



Model parameter optimization using the Ensemble Kalman filter (EnKF) data-model fusion technique

Model parameters were optimized by minimizing the 'cost' function (Tarantola, 1987),

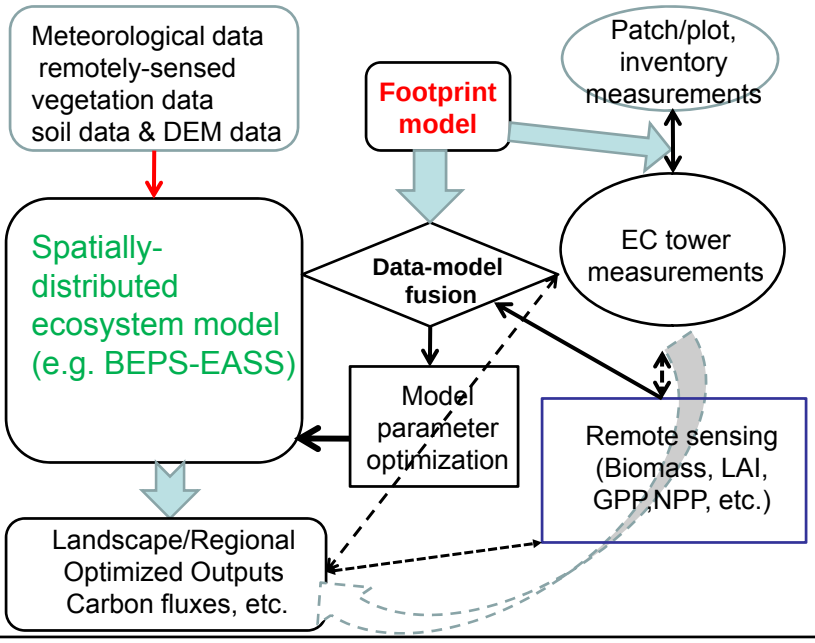
$$\mathbf{J(x)} = \frac{1}{2}\left[\left(\mathbf{O}-\mathbf{Y(x)}\right)^{\mathrm{T}}\mathbf{C_o^{-1}}\left(\mathbf{O}-\mathbf{Y(x)}\right)+\left(\mathbf{x}-\mathbf{x_b}\right)^{\mathrm{T}}\mathbf{P_b^{-1}}\left(\mathbf{x}-\mathbf{x_b}\right)\right]$$

where **x** is the vector of unknown parameters and $\mathbf{x_b}$ is a vector of *a priori* values of **x**; ***O*** is the vector of observations and **Y** is the nonlinear model results, $\mathbf{C_o}$ is the covariance matrix of observations and $\boldsymbol{P_b}$ is the covariance matrix of *a priori* parameters.

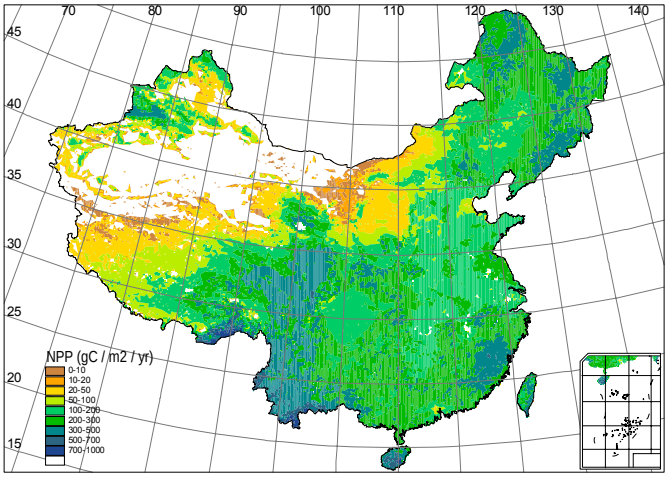
Highlight: **Y** is weighting averaged by footprint:

$\mathbf{Y} = \sum \mathbf{Y}_j f_j$

Summary: Up-scaling framework



Distribution of NPP in China



Conclusions

- **Chinese forest carbon budget:**
- **A carbon sink of 0.19 to 0.26 Pg C / yr**
  Offsets ≈ 28-37% of emissions over 1980-2000
  Offsets ≈ 16-22% of emissions over 2001-2005
- **50% forest; up to 30% in shrublands**
- **Forest biomass C sink = 0.075 Pg C/yr, averaging over last 40 years**
- **More than 65% of the sinks are distributed in southern China** owing to regional climate change, reforestation and afforestatioin programs active, and shrub land recovery.
- Reduce uncertainties in estimation…

Thank you very much
for your attention

Baozhang.chen@igsnrr.ac.ca