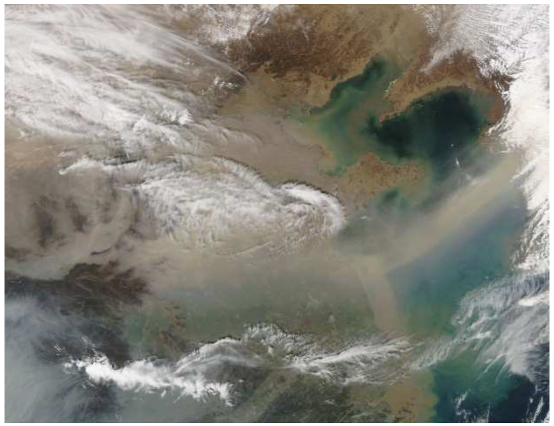
Yale-NUIST Workshop 2014Jan03

Air quality modeling in the Yangtze River Delta

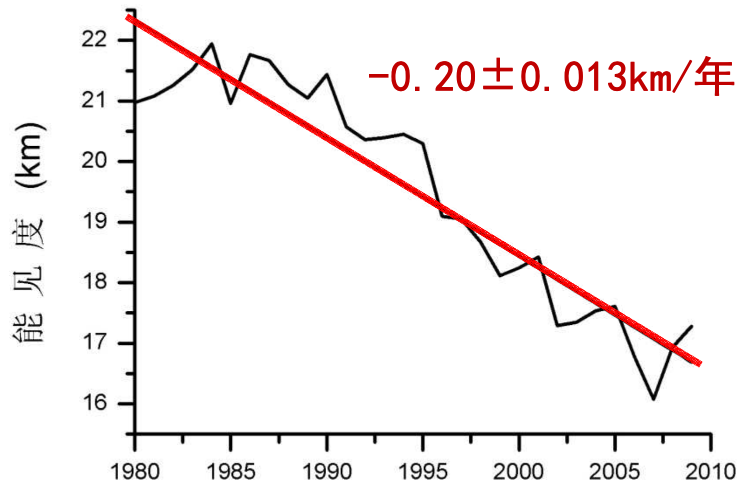
Zhu Bin’s group NUIST



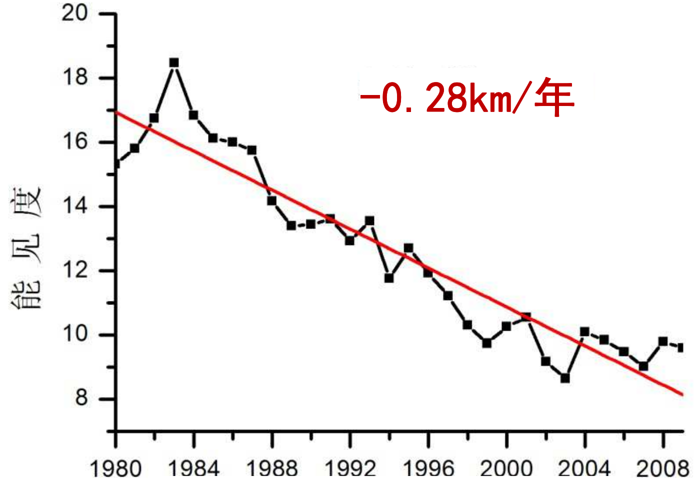
Contents

- Introduction of air quality in YRD
- Models: Global – regional – city cluster
- Modeling of Urban Heat Islands
- Modeling of air pollution events
  (ozone; Biomass burning; aerosol)

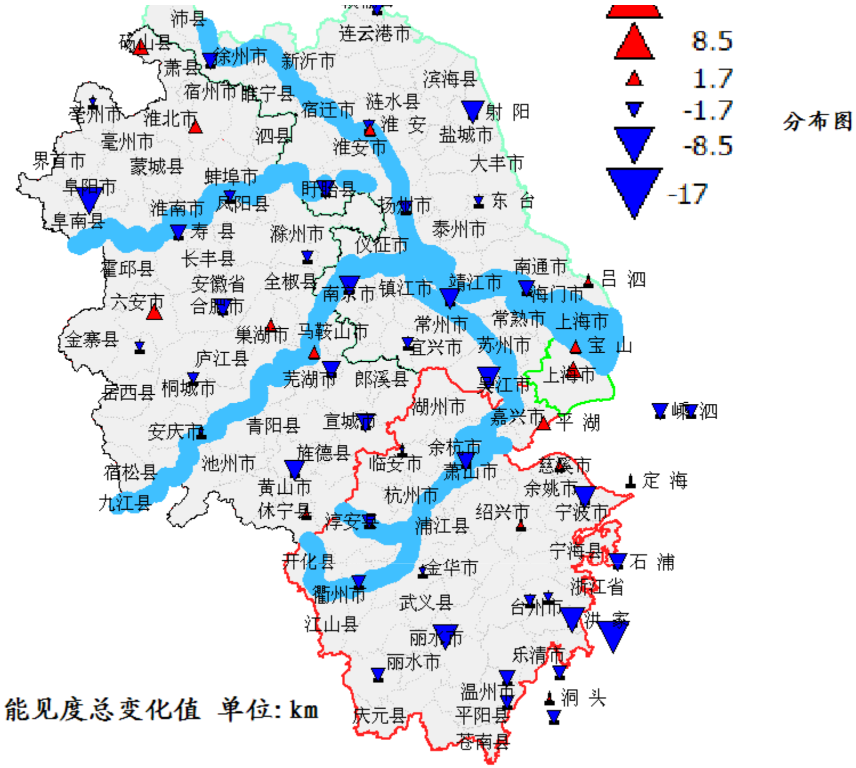
1、Background

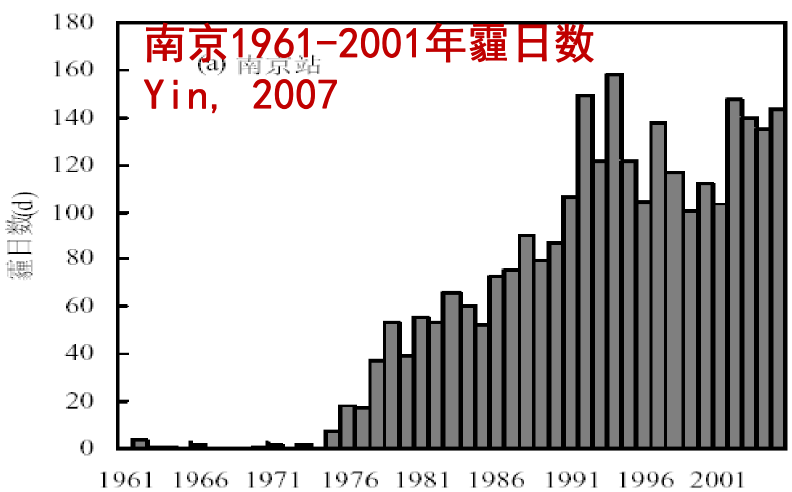


30年长三角年均能见度变化

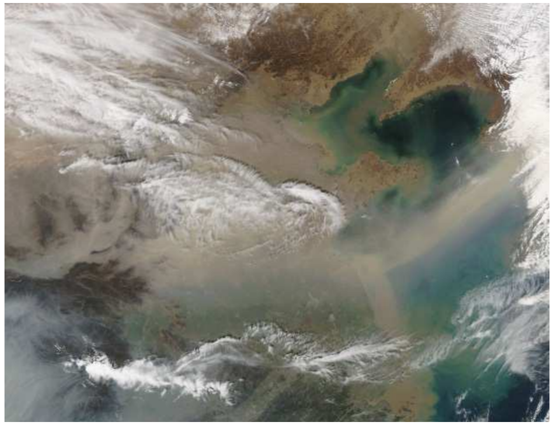


30年南京年均能见度变化





Classification of Haze 霾污染的三种类型

- 通过强化观测和资料分析，南京地区空气污染类型可分为三类：

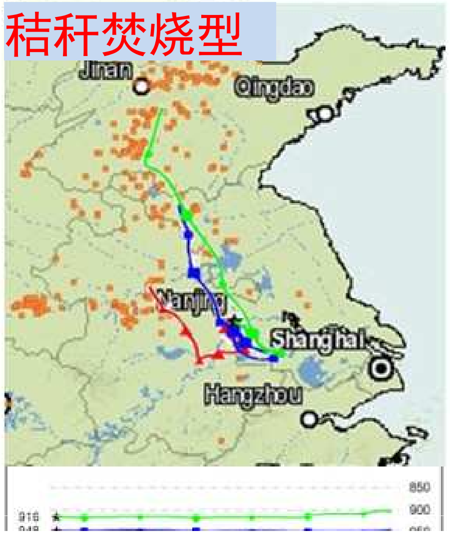
  a）局地和长三角区域人为源污染，包括工业、汽车尾气和城市建筑排放的一次气溶胶以及光化学反应形成的二次气溶胶。该类型污染一般是南京城市灰霾日数的主要成因；

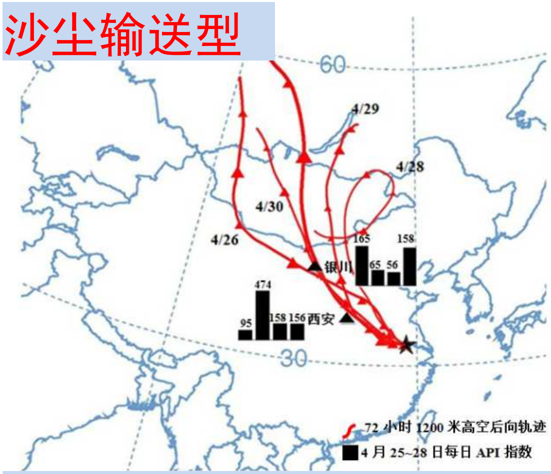
  b）季节性的局地污染和区域输送。每年春末和秋季，长三角地区作物收获期间农田秸秆焚烧，由污染物长距离输送导致城市空气质量严重污染，污染事件往往十分严重；

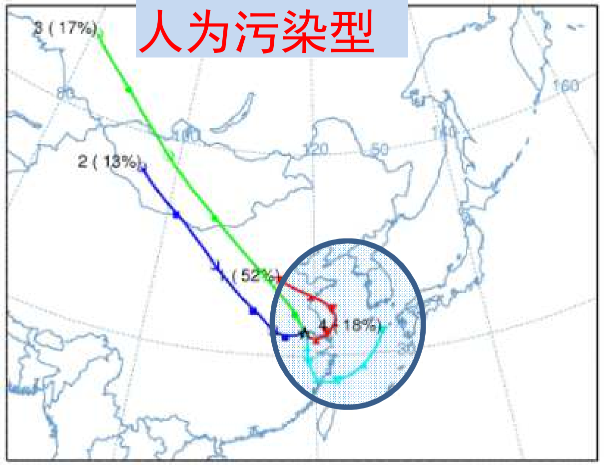
  c）污染物长距离输送。每年初春，北方沙尘气溶胶经长距离输送时有导致下风地区，包括南京的空气污染。

  d）烟花爆竹

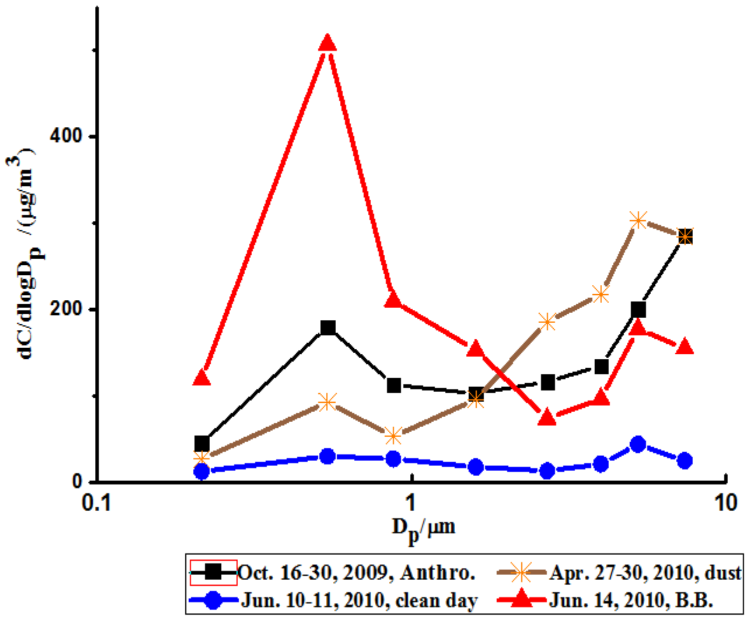
霾污染类型差异







三种污染类型的后向轨迹分析



三种污染类型质量谱差别明显

➢左图质量浓度谱表明：秸秆焚烧在细粒子段(0.43~0.65μm)；最高；沙尘在粗粒子段最高；人为污染在粗细粒子段都有峰值

$PM_{2.5}/PM_{10}$: Clean day> B.B. > Anthrop. > Dust

2、 Air quality simulations from Global – regional - urban

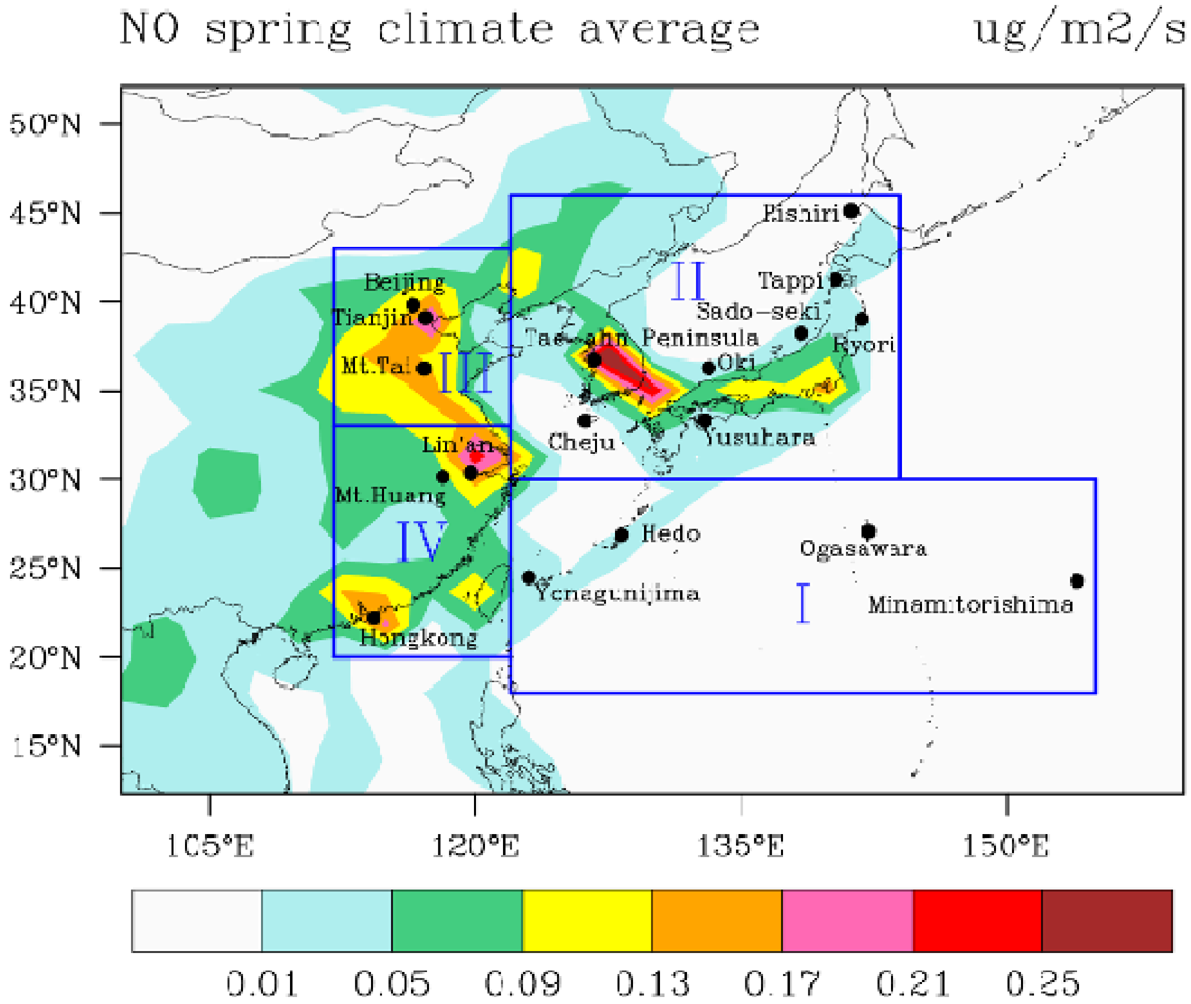
MOZART-4： The Model of Ozone and Related chemical Tracers, version 4.The source code and standard input files are available for download from the NCAR Community Data Portal (http://cdp.ucar.edu).

Resolution: 2.8° ×2.8° , with 28 hybrid levels in vertical from the surface to approximately 2 hPa

Standard simulation: 2000-2007 year, the first year is for spin-up

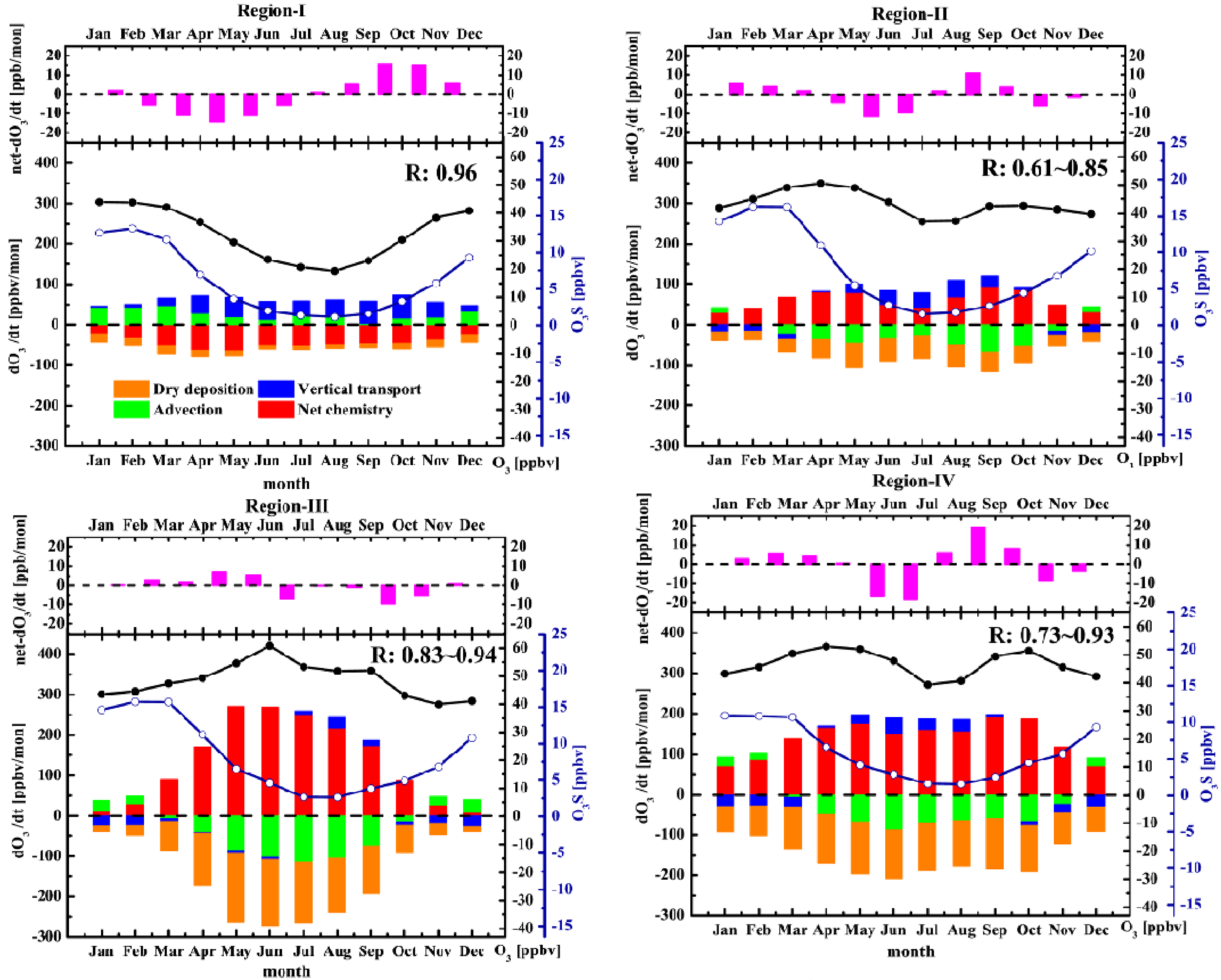
More details were listed in Emmons et al. [2010].

Seasonal cycle and budget of BL O_3



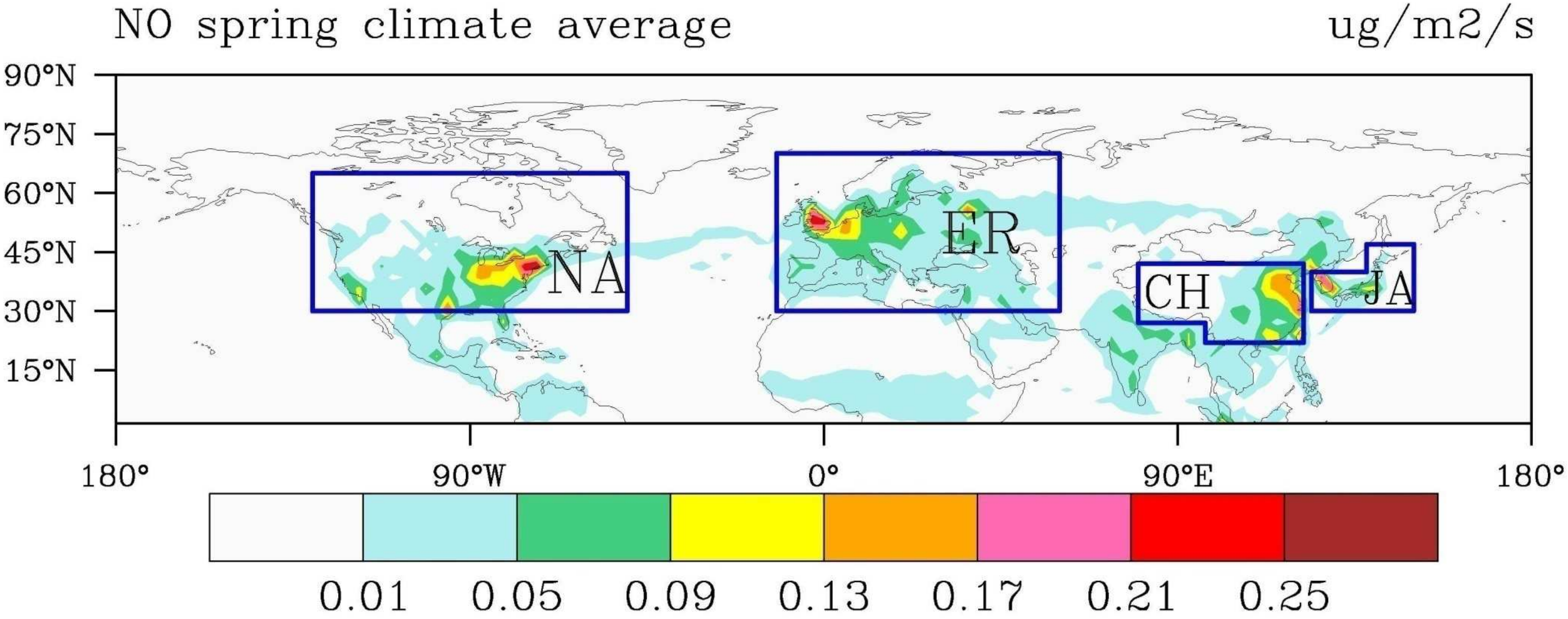
R: 0.61 ~ 0.96

The distribution of climatological NO emission rate ($\mu g/m^2/s$) on surface in spring

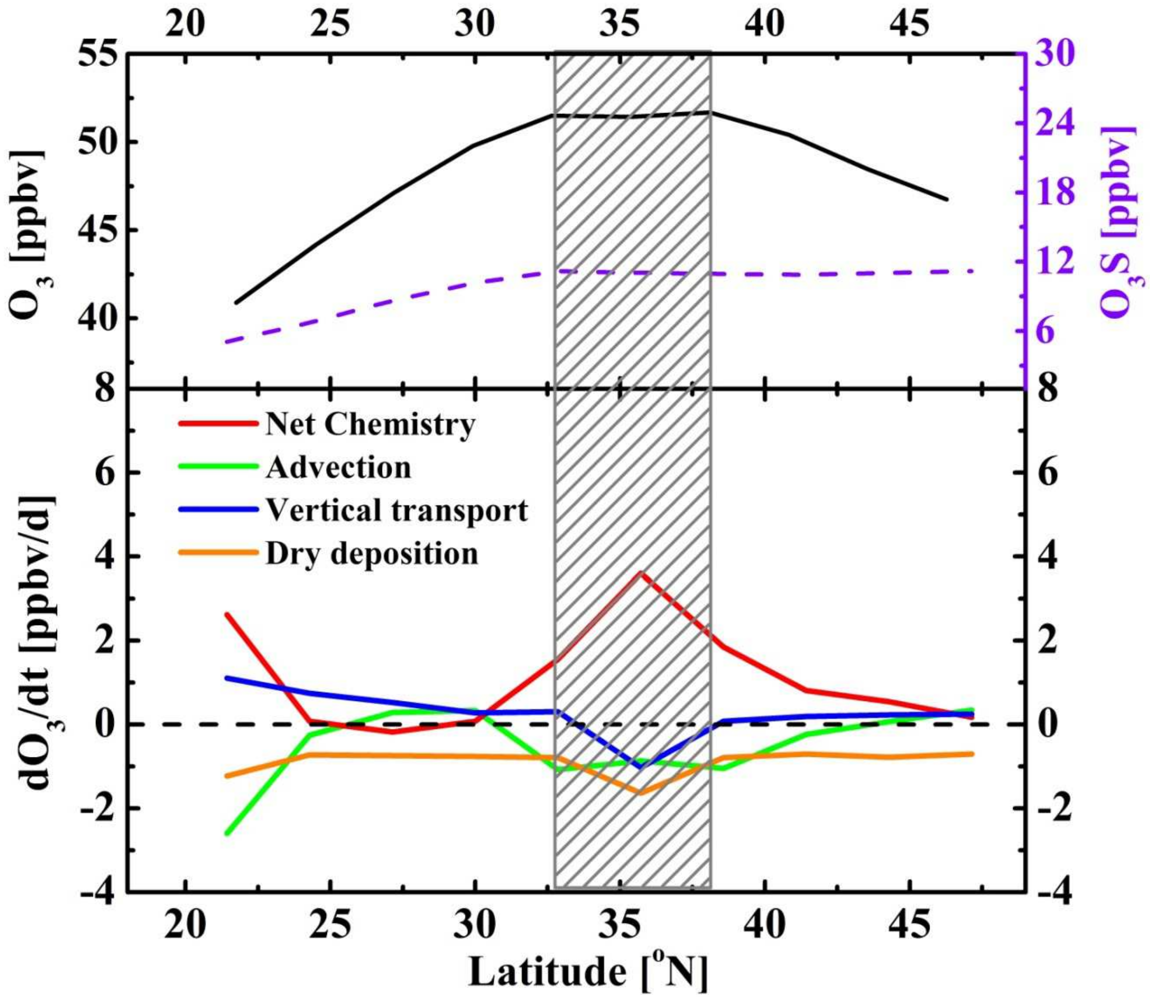


各分区边界层（2km内）O_3及其各分项气候平均（2001-2006年）季节变化

The additional sets of sensitivity experiments



Experiments	Year	Description	Purpose
ER-FT		FT: Europe	
Strato		Stratosphere	
REST		The rest region	
Tagged NO experiment	2002	Tagging ozone produced from NO sources in China	Emmons et al., 2012, Geosci. Model Dev.

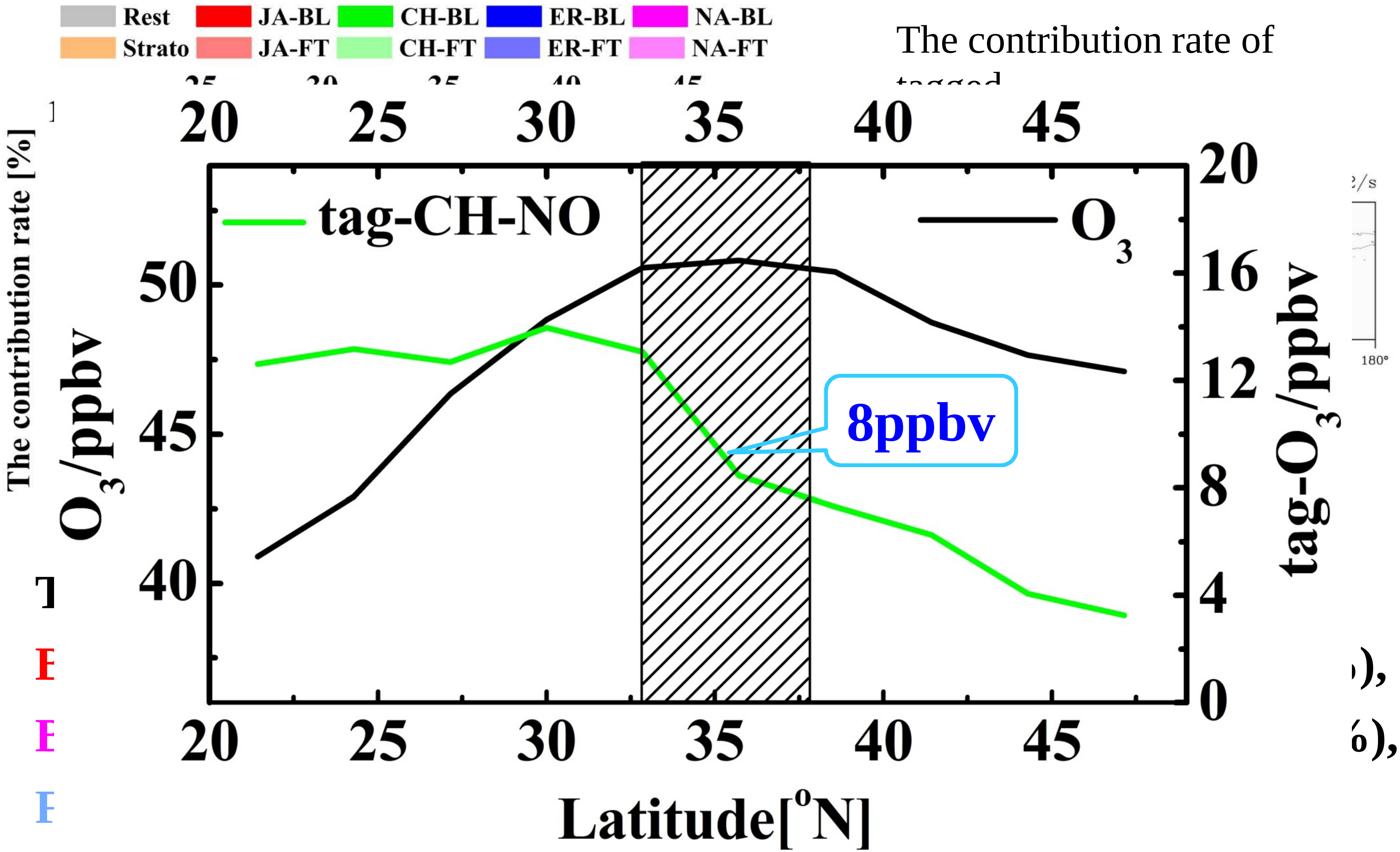


Maxima (about 51.5ppbv) of spring BL O_3 at 35° N.

advection, vertical transport -> outflow

springtime high O_3 in mid-latitude -> chemistry

The latitude variation of BL O_3 (a) and daily rates of change in BL O_3 (b). The shaded region covers high O_3.

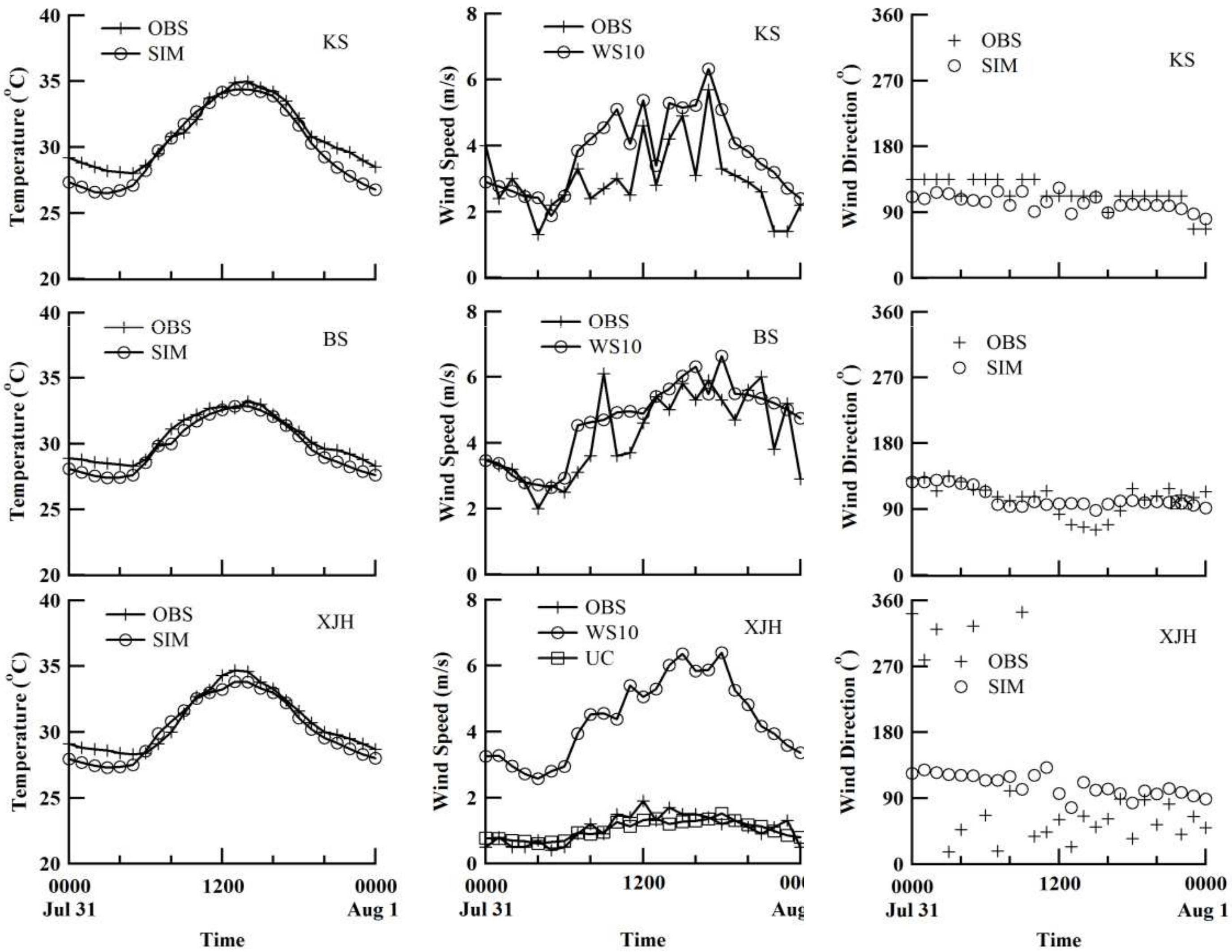


Mid-latitude high ozone in spring mostly due to regional photochemical production.

区域-城市空气质量模拟

WRF-CMAQ
WRF-Chem

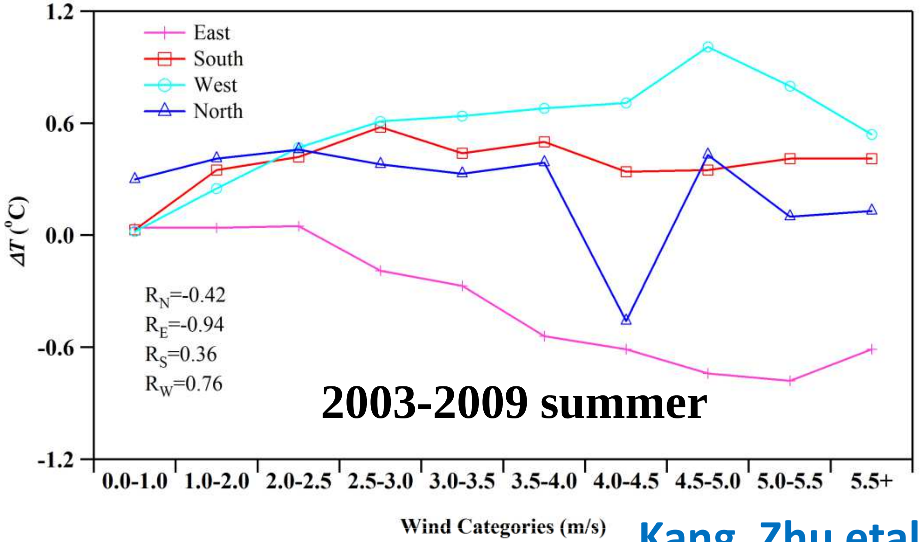
WRF模拟气象场验证



冠层风（**UC**）能较好的反映市区建筑物对风场的影响，以后将采用多层**UCM**。

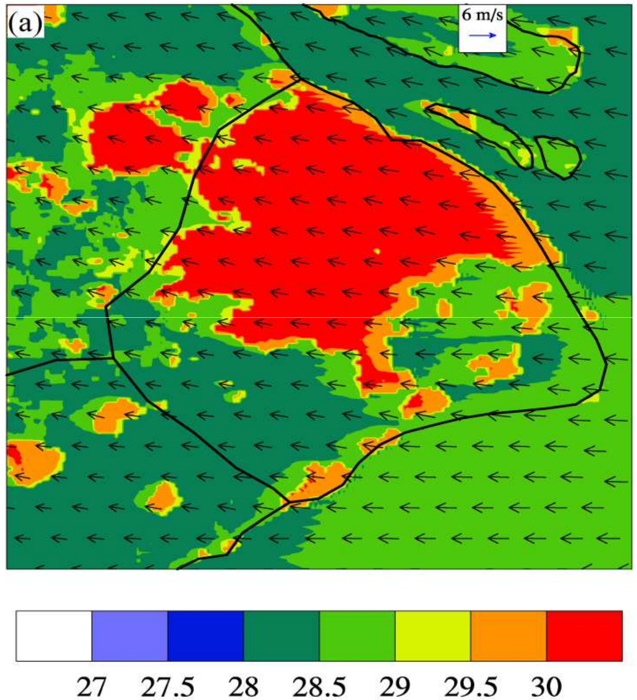
城市串热岛 Urban Cluster HI study by WRF

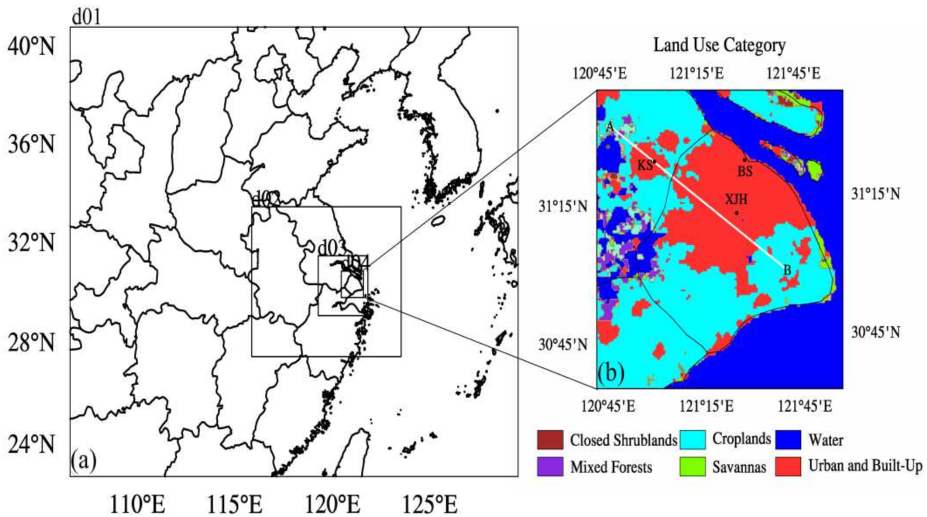
Impact of Shanghai urbanization on the UHI effects over Kunshan



Kang, Zhu etal,2014

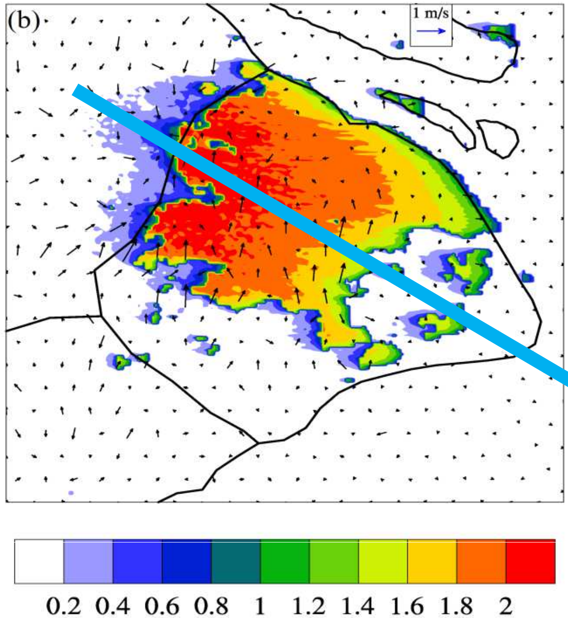
Observation: ΔT between Shanghai and Kunshan increases with wind speed under easterly and westerly wind.

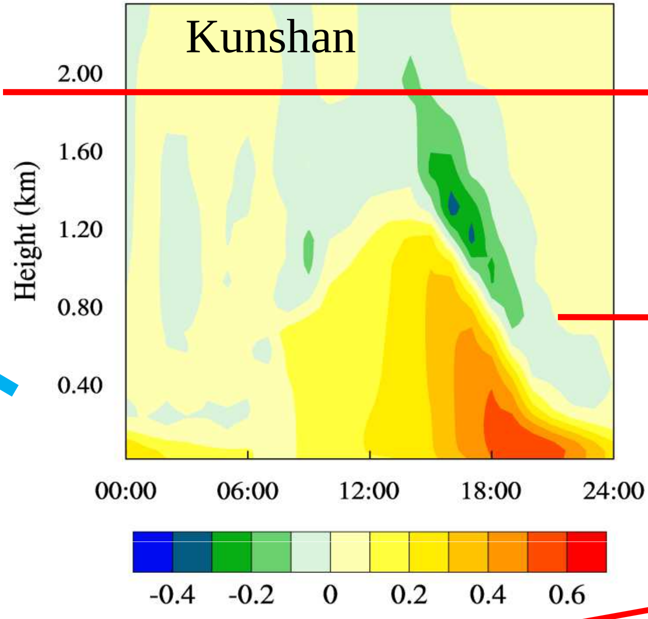




- WRF coupled single layer UCM
- Grid distance13.5、4.5、1.5、0.5 km
- 30 σ layers，20 layers below 2km
- MODIS land use data

Simulated upstream effects

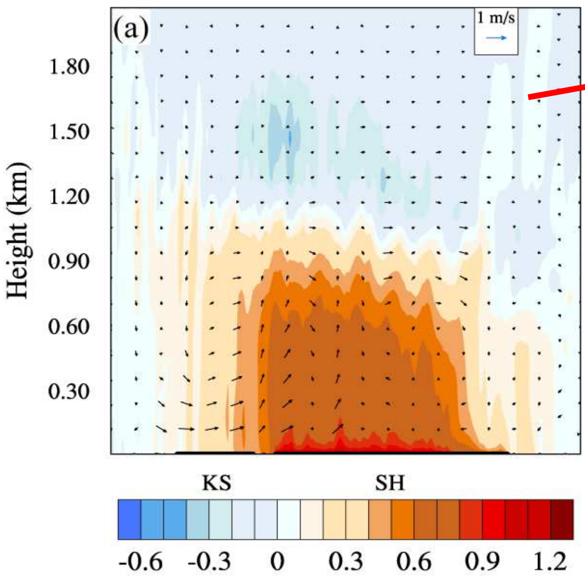


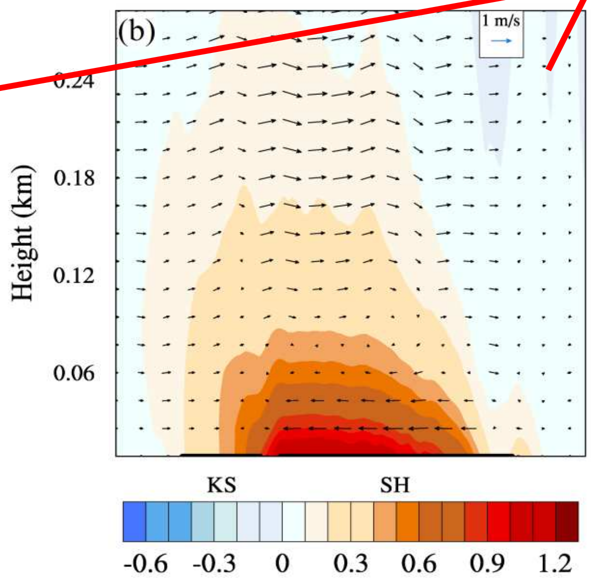


$\Delta T = T_{URB} - T_{NO\_SH}$

Surface ΔT and wind field differences.

Time series of ΔT profile over Kunshan indicating temperature advection strength from Shanghai .

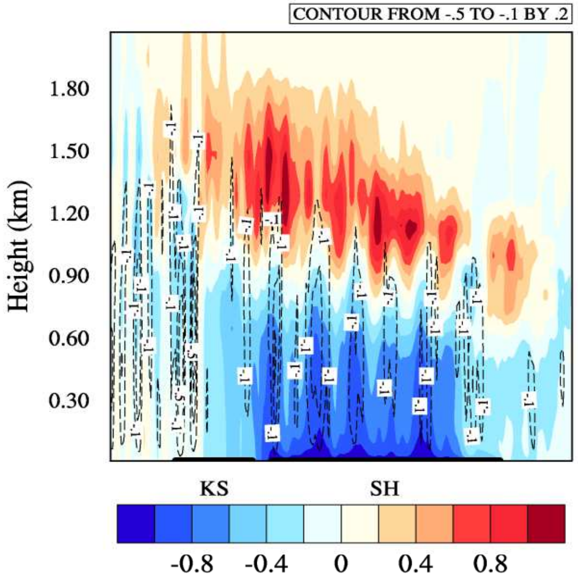




Vertical cross section of ΔT and wind fields differences along line AB, (a) daytime; (b) nighttime.

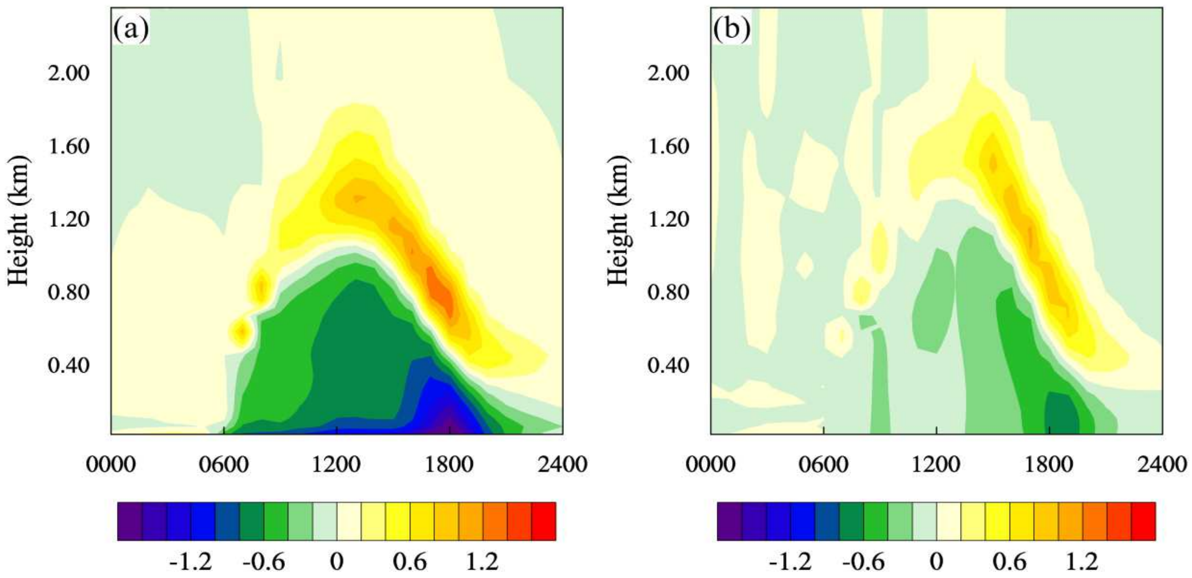
- 白天城市湍流强、垂直运动剧烈，不利于热岛平流；夜间相反，热岛平流.
- **UHI accelerate upstream sea breeze.**

Impact of Shanghai urbanization on the UHI effects over Kunshan



URB-NO_SH比湿差

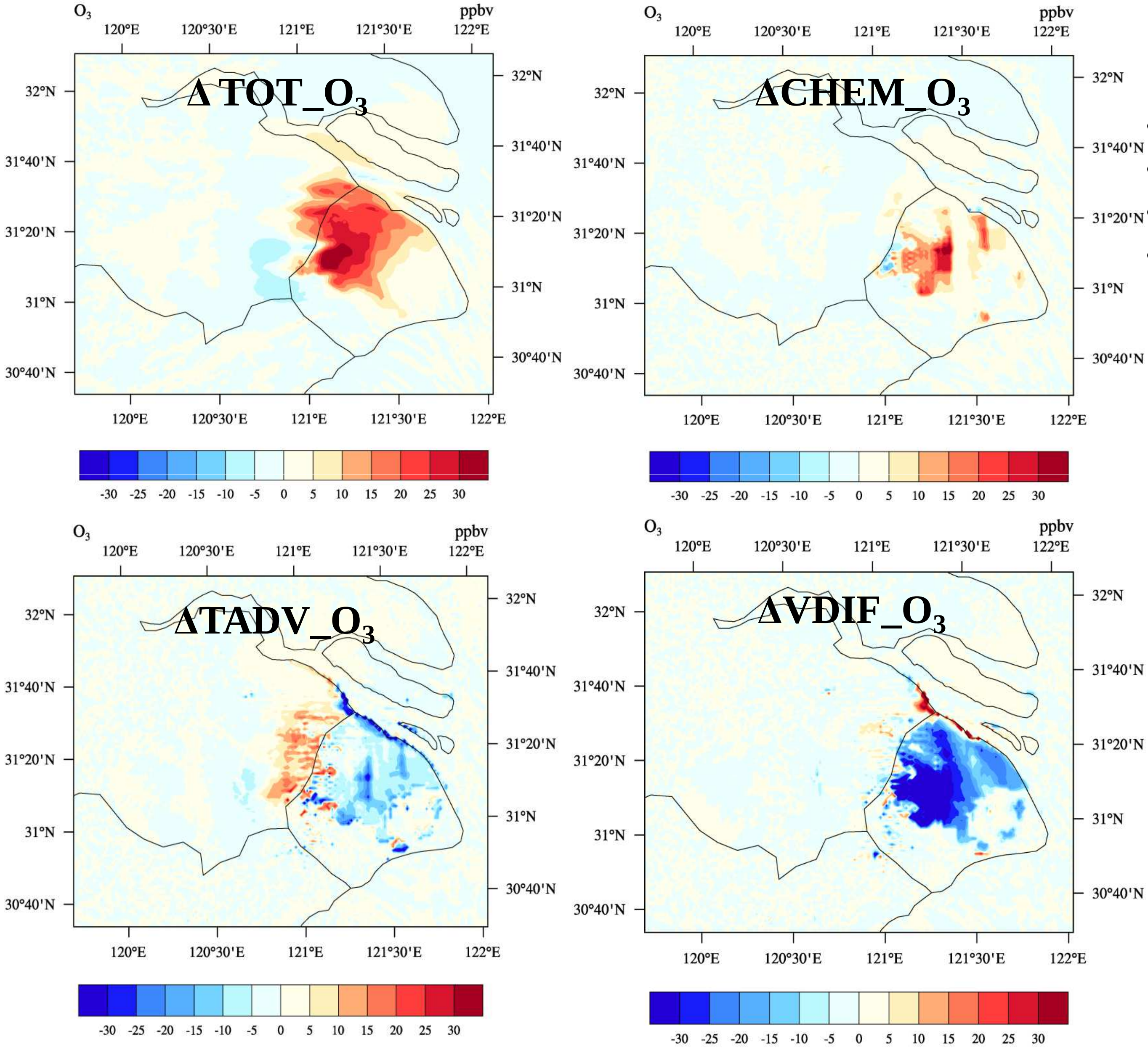
- 低层干岛，下沉气流强则干岛强
- 强热岛环流将水汽抬升至高空，形成上空湿岛



a) URB-NO_SH上海比湿差，反映上海城市干岛/湿岛强度日变化；

b) URB-NO_SH昆山比湿差，反映上海对昆山水汽平流强度的日变化。

Surface O_3 differences caused by UHI effects (URB-NO_SH)



- TOT: Total
- CHEM: Chemical production
- TADV: Total advection
- VDIF: Vertical diffusion

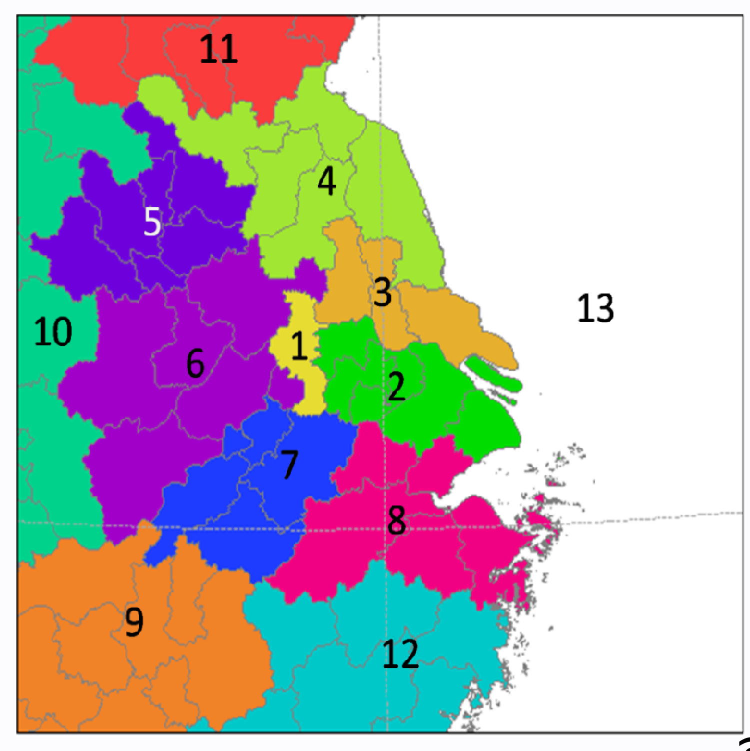
- UHI increases total O_3 concentration.
- UHI increases O_3 chemical production.
- Advection process increases downstream city O_3.
- Vertical diffusion contributions are stronger in NO_SH experiment.

空气质量源追踪新方法
WRF-Chem by Tracer-tagged method

- Implement the Tracer-tagged method into WRF-Chem.
- Taking Nanjing as the center, we mark Nanjing as the region 1. And the surrounding areas are marked from region2 to8, the remote regions and sea a set from region9 to 13. Besides these regions, we also set middle troposphere(700~400Hpa), upper troposphere(400~150Hpa), Stratosphere(150Hpa~top of model), the names of them are region14, 15 and 16.
- By using the method, we isolate the contributions from each individual source regions

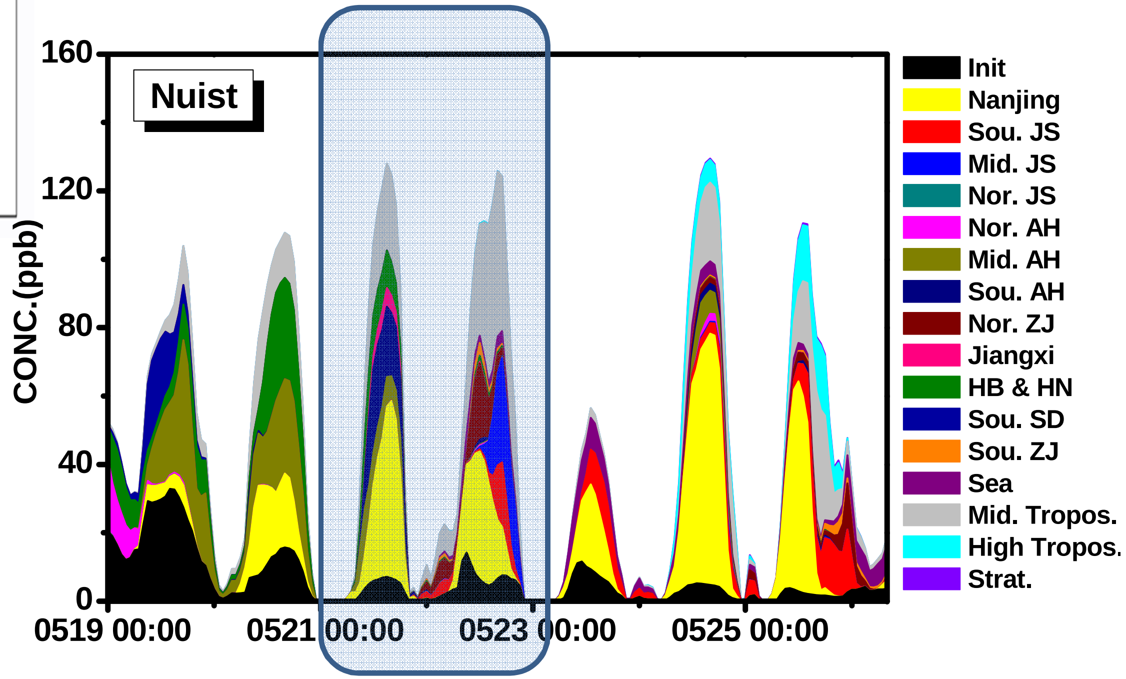
臭氧污染的区域源追踪

Gao & Zhu, in preparation

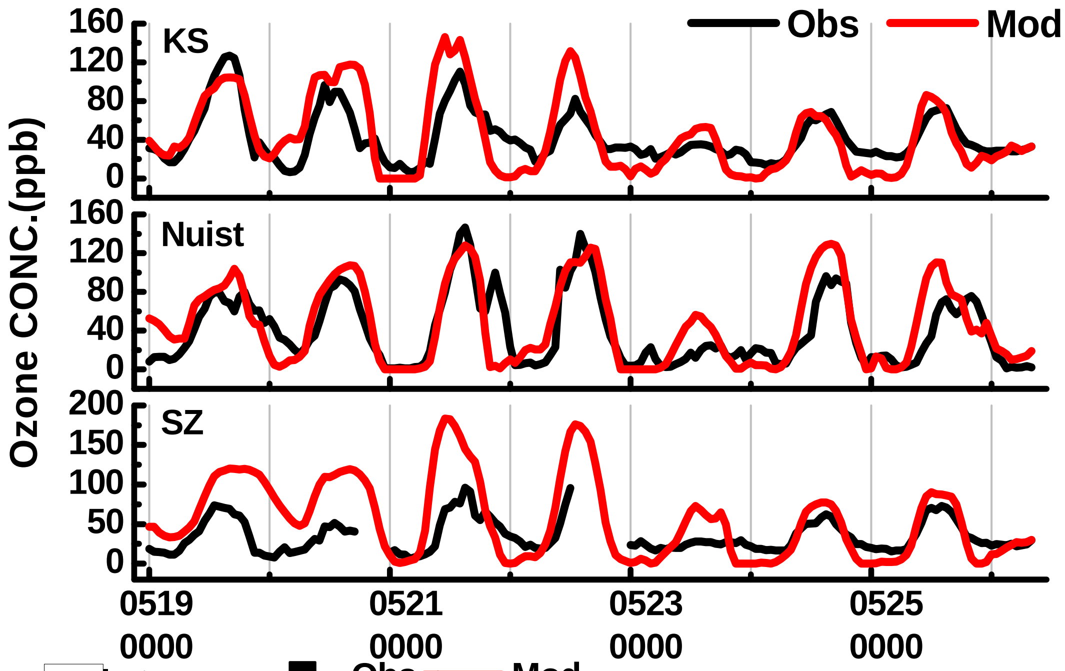


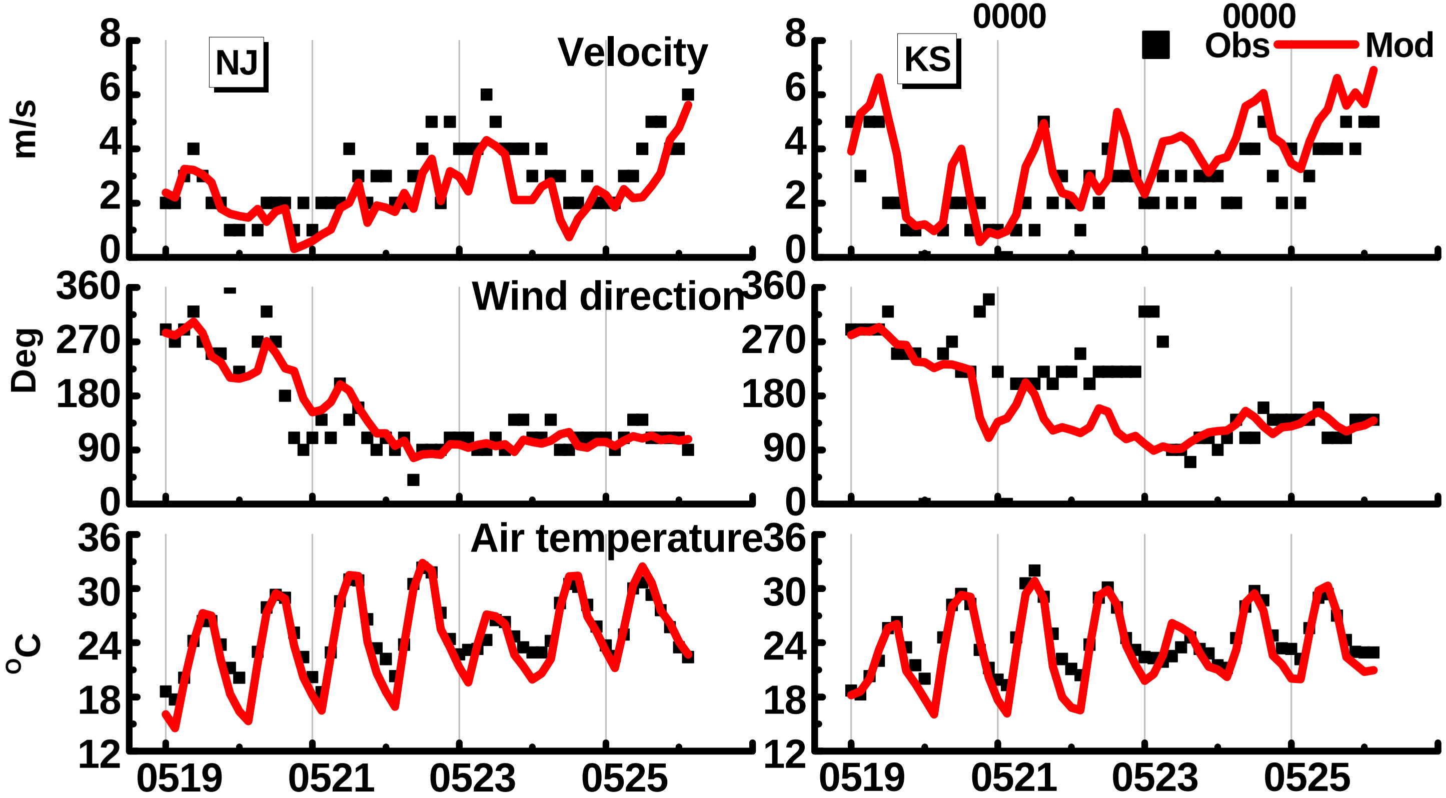
01)NanJing	02)South JS[1]
03)Middle JS	04) North JS
05)North AH[2]	06)Middle AH
07)South AH	08)North ZJ[3]
09)Jiangxi	10)HB&HN[4]
11)South SD[5]	12)South ZJ[6]
13)Sea	14)Middle Trop.[7]
15)upper Trop.	16)Stratosphere

[1] Jiangsu; [2]Anhui; [3]Zhejiang; [4]Henan & Hubei; [5]Shandong; [6]Zhejiang; [7]Troposphere

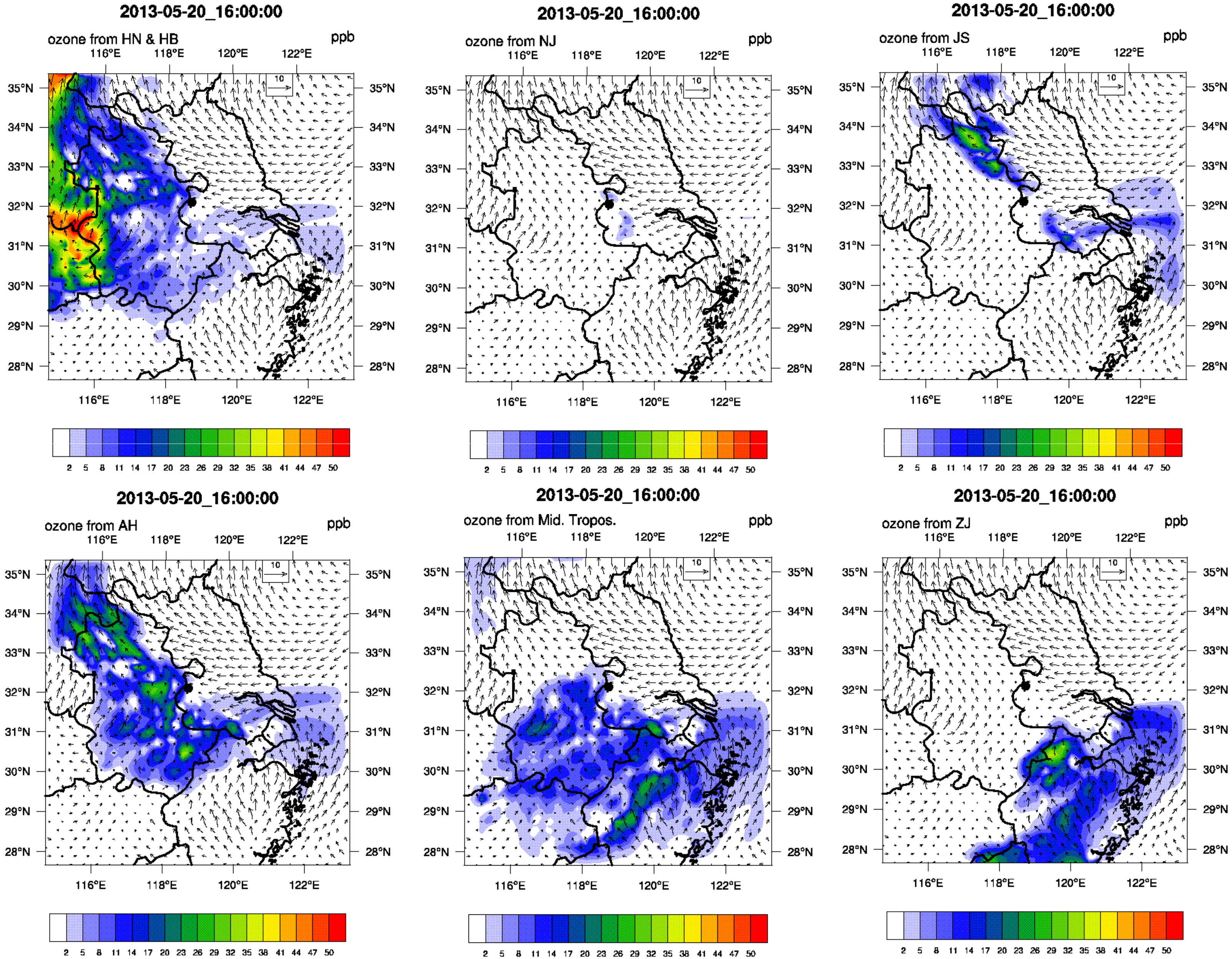


春末臭氧模拟及过程分析
—WRF-Chem
2013May19-26

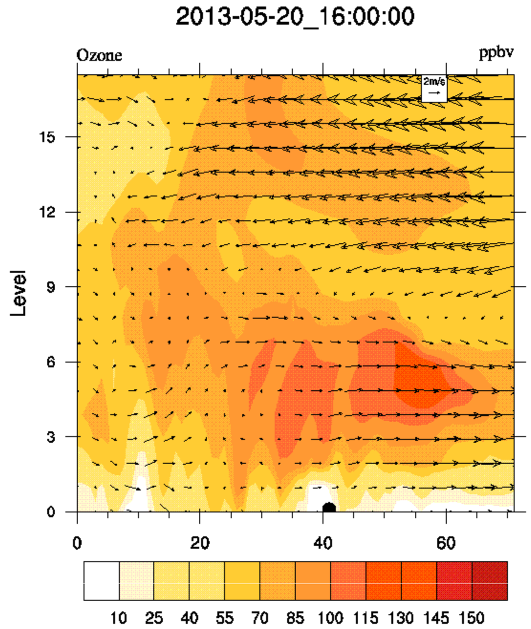




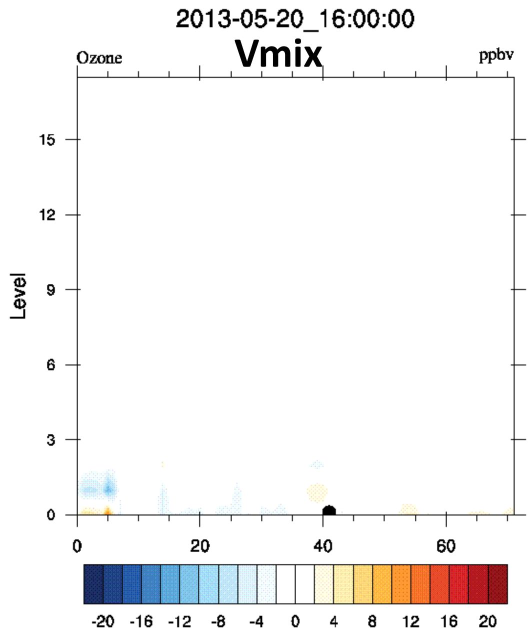
主要源区臭氧浓度分布演变

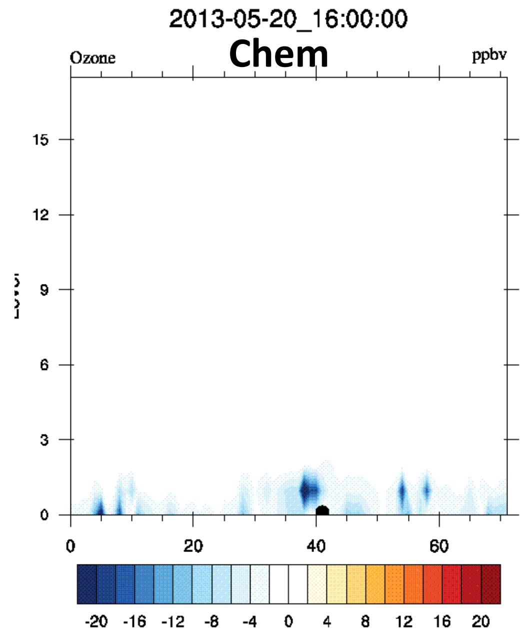


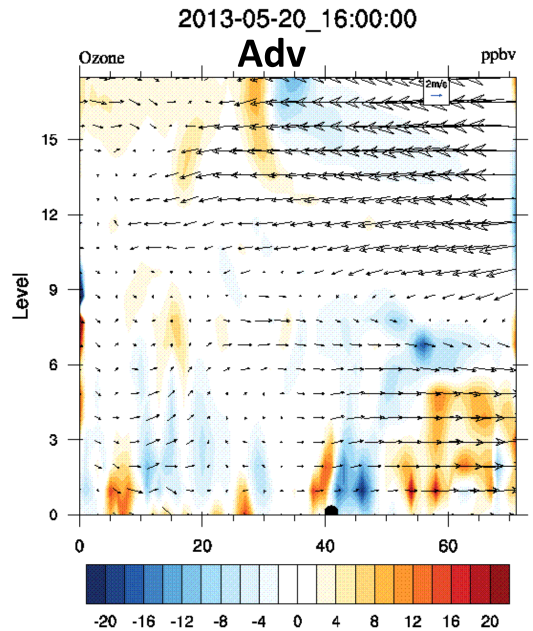
臭氧浓度垂直剖面及过程量演变



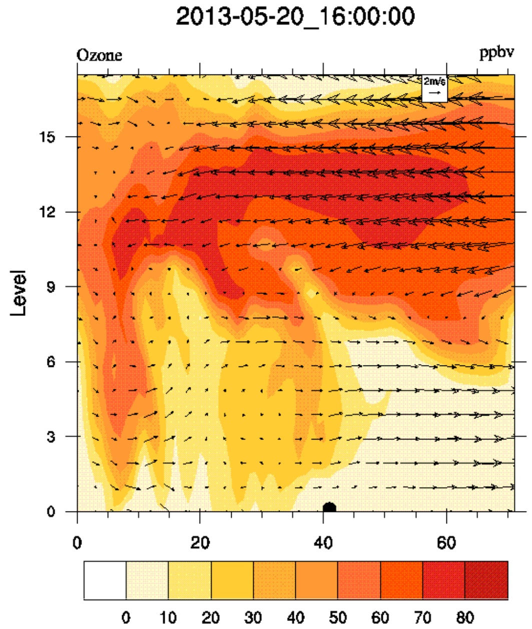
5月21日为例，以偏南风为主，沿南京南北向臭氧以及过程量的剖面图：日出到正午前，垂直混合对地面臭氧升高有正贡献且占主导，正午到午后由光化学反应的正贡献占主导，平流作用在午后有较为明显的作用，且在18时(北京时)后有高臭氧向南京上空输送的现象。



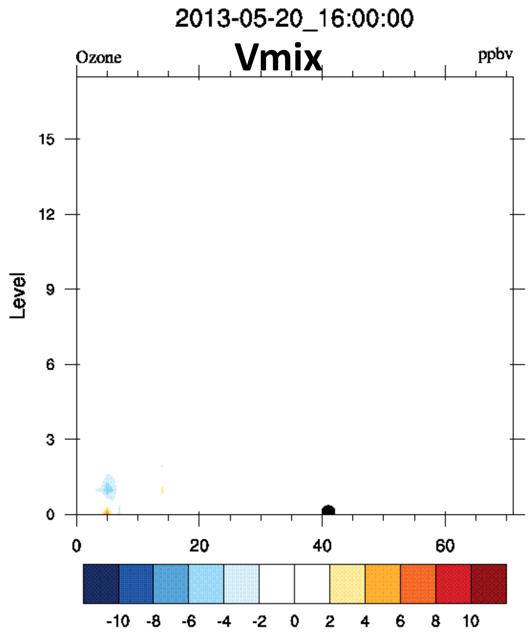


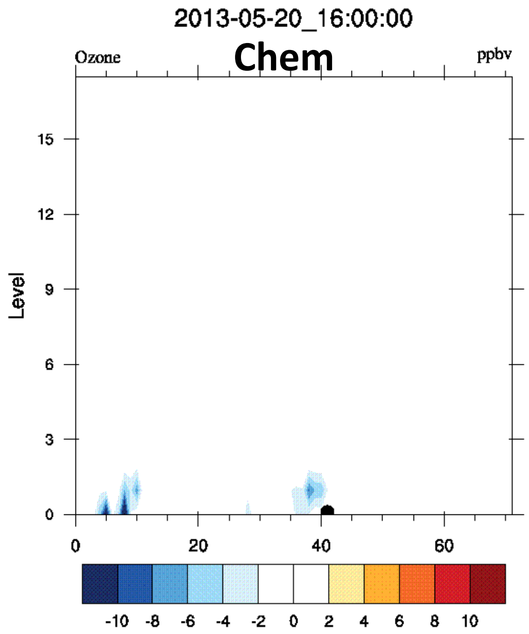


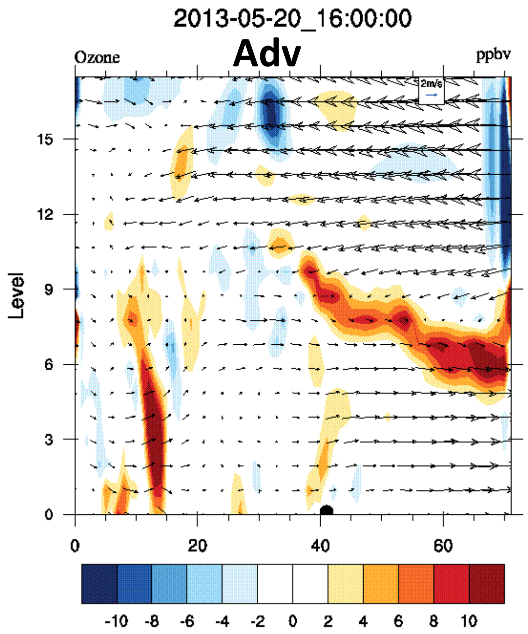
对流中层臭氧垂直剖面及过程量演变



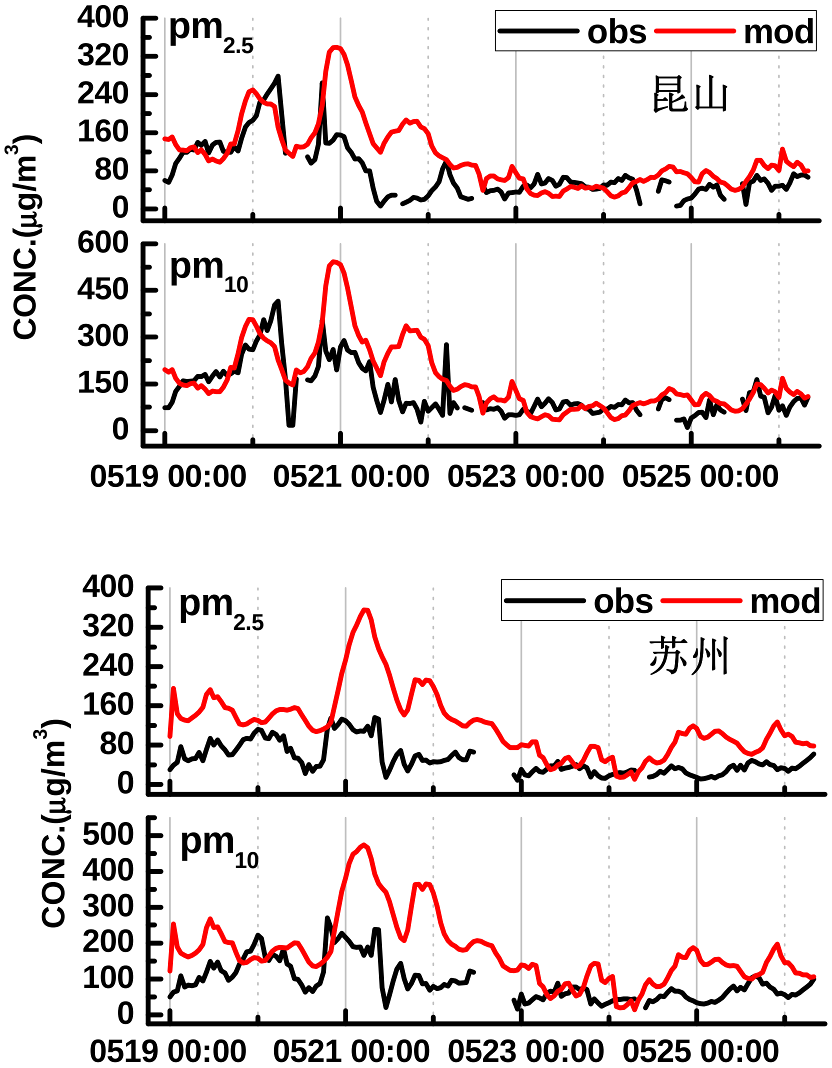
正午之前，主要通过垂直混合作用，对流中层(9~18层)臭氧对近地层有正贡献，而对流中层的臭氧在近地面主要表现为消耗。平流作用在入夜后有浓度向观测点及上空输送臭氧的现象。

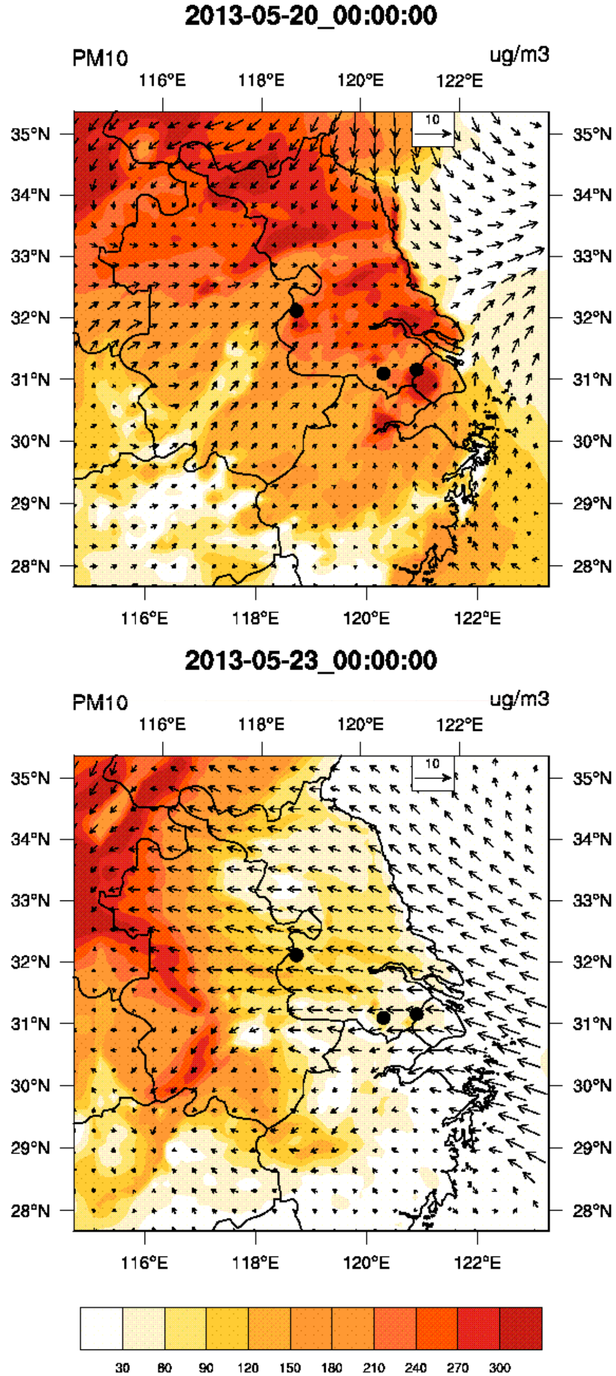






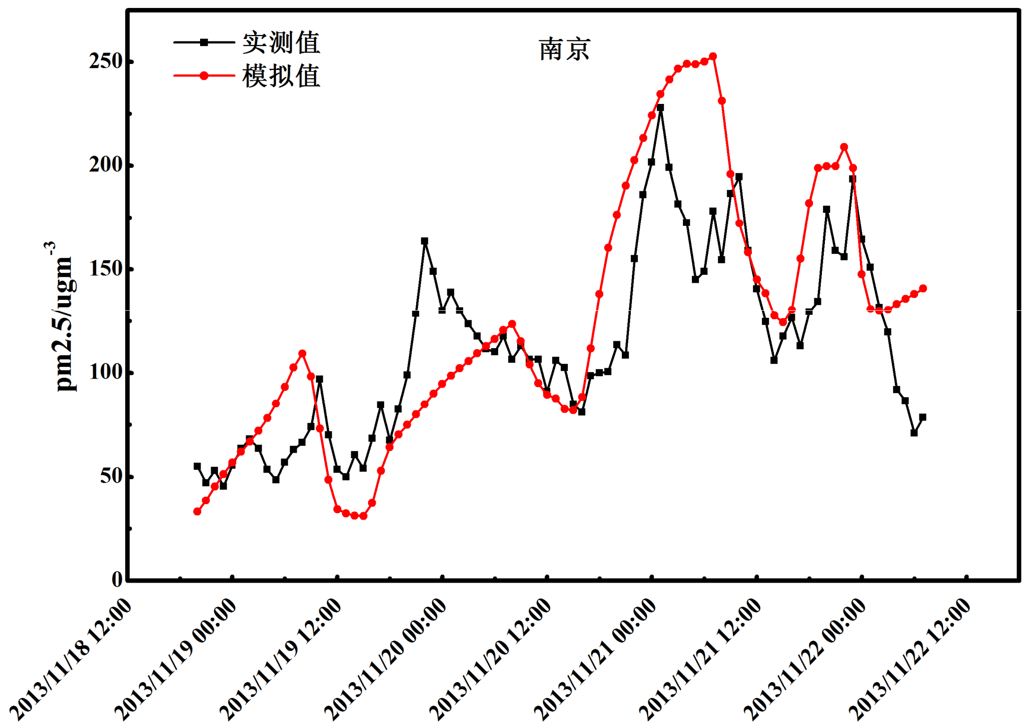
春末气溶胶模拟对比及浓度分布
—WRF-Chem

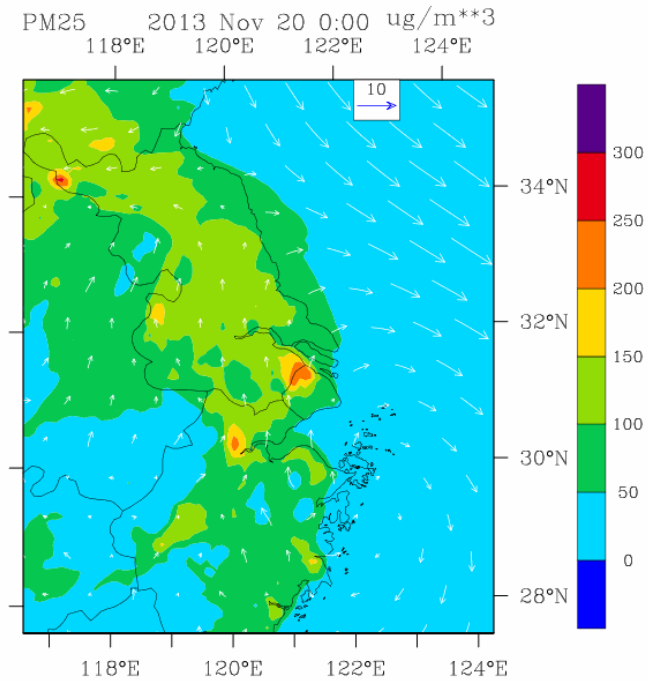




2013年11月18-22灰霾污染过程模拟

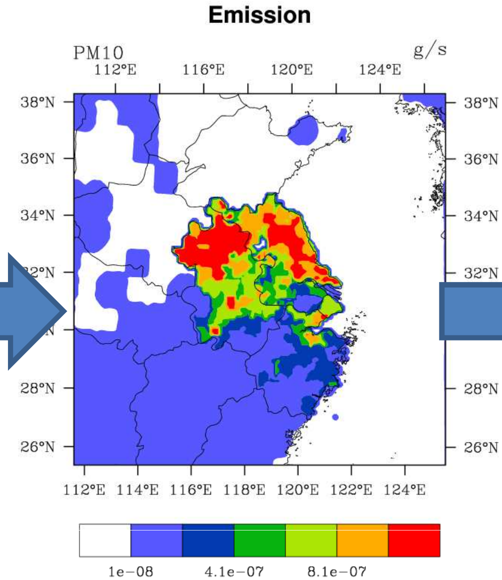
WRF-CMAQ



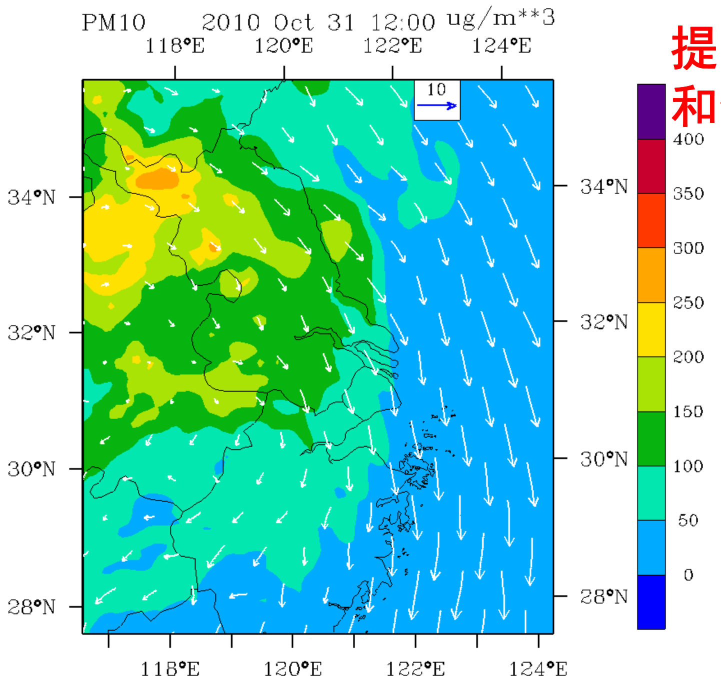


秸秆焚烧源的建立和灰霾数值模拟

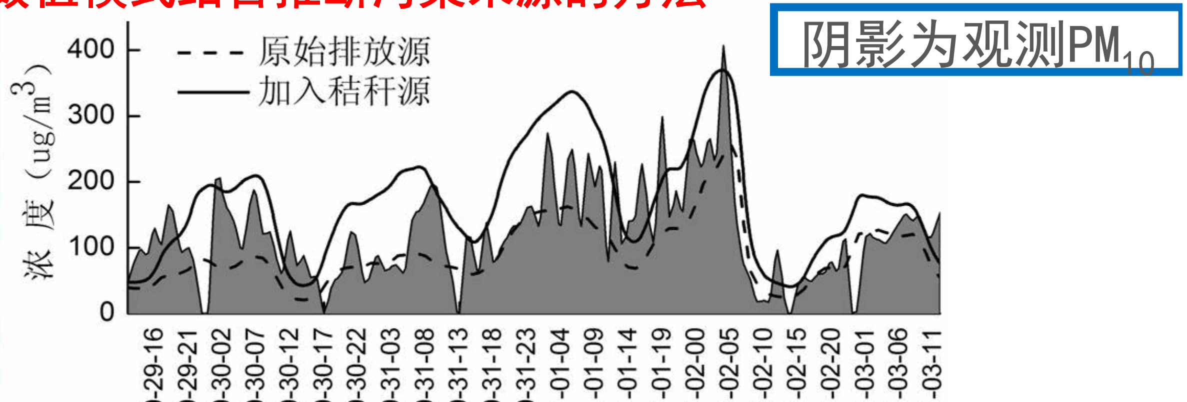
由作物产量统计年报、作物谷草比、秸秆焚烧比例和排放因子等信息建立了泛长三角地区216个县的秸秆焚烧排放源



中尺度气象模式WRF
空气质量模式CMAQ



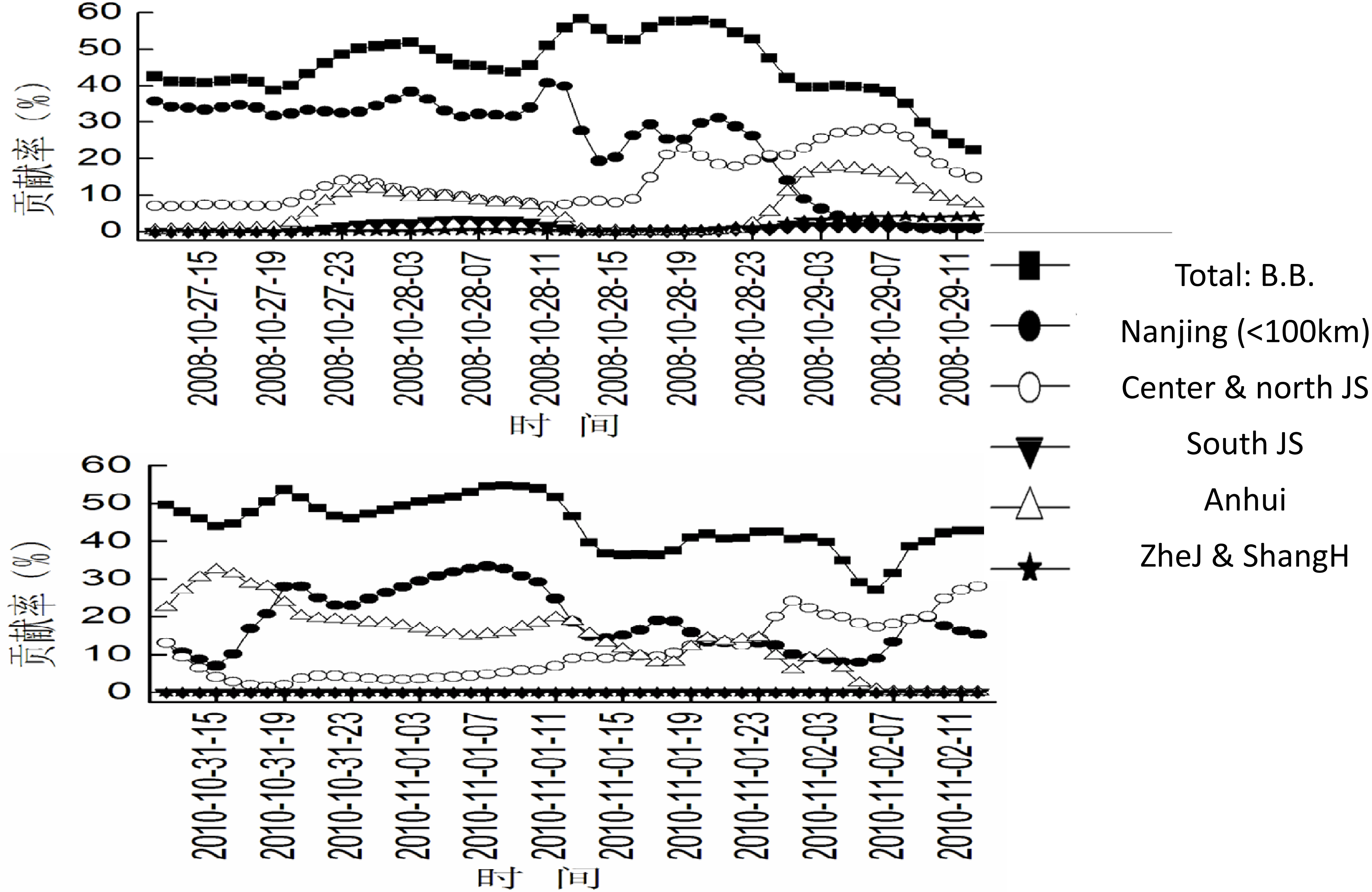
提出：结合API、能见度、卫星资料、轨迹模拟和数值模式结合推断污染来源的方法



模式能很好地反映观测结果和以及污染源和气象条件的定量贡献

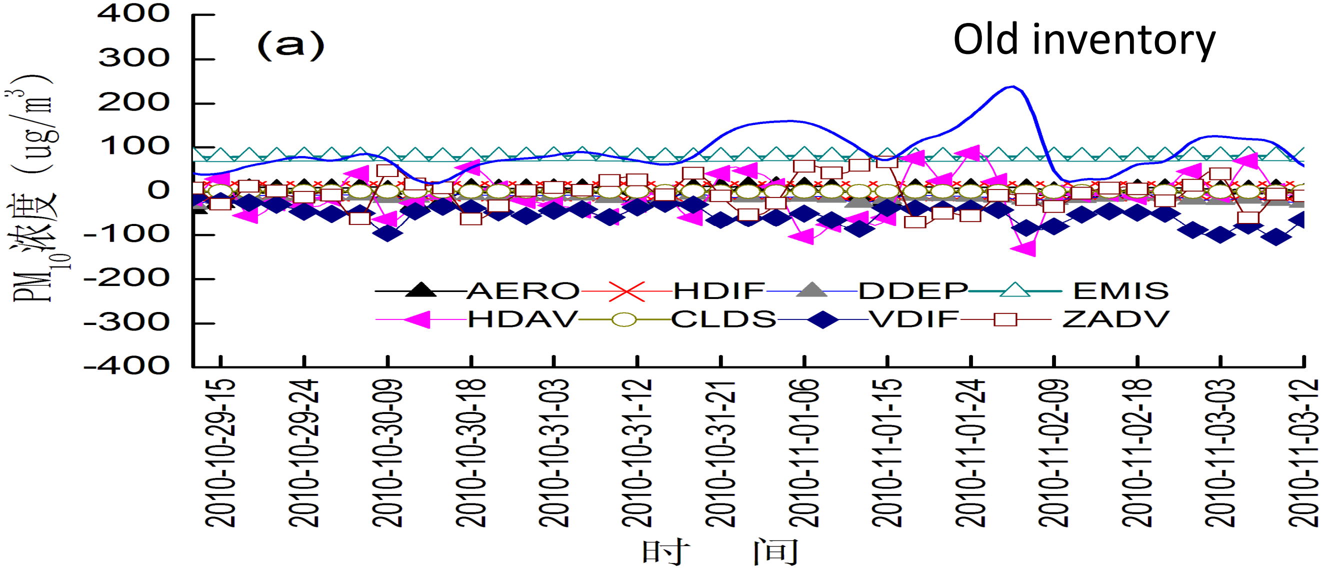
污染物来源模拟

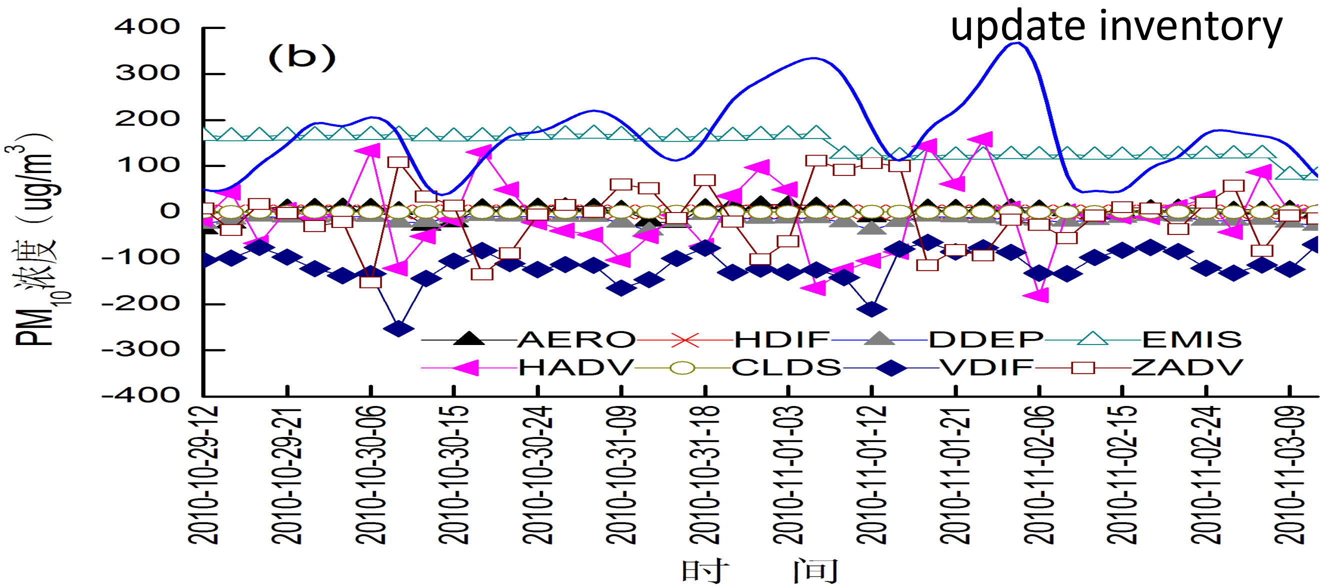
Switch on/off the BB emission sources: case1~case6



Contribution rate to PM_{10} of Nanjing by each region in the periods

污染过程分析





Solid blue: Obs PM_{10}

AEROsol processes

Horizontal DIFfusion

DryDEPosition

EMISsion

Horizontal ADVection

CLouDS processes

Vertical DIFfusion

Vertical ADVection

Process contributions to PM10 of Nanjing

气候-生态系统相互作用研究发展方向

- 耦合了大气化学模块的GCM模式与与包含臭氧损伤机制的作物生长机理模型结合的生态系统模型

GCM-大气化学-作物生长机理耦合模型示意图

GCM-化学模型：
臭氧变化和分布

作物生长机理模型

叶面积
子模型

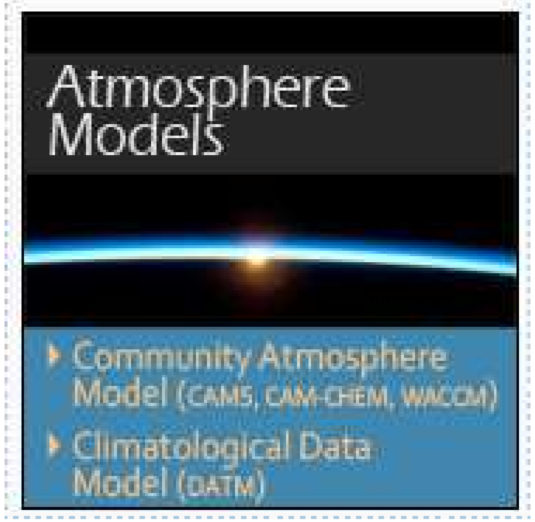
光合作用
子模型

作物自我缓解
修复功能

减少叶面积、
加速叶片老化

预测、评估局地、区域作物产量和经济损失

Climate effect of aerosol simulated by CAM5.1



Model and Data

- Version 5 of the Community Atmosphere Model (CAM) is the latest in a series of global atmosphere models developed primarily at the National Center for Atmospheric Research (NCAR).

- CAM5 is an atmosphere-chemistry coupled online model, contains a detailed process of physical and chemical parameters, can simulate the complete aerosol-cloud interactions.

- NCEP/NCAR reanalysis data

小结

- 略
- 不同尺度的嵌套：全球-区域-城市-局地
- 不同过程、圈层的耦合
- 模式新技术

Thanks for your time!