Urban Surface Modifications: Ozone air quality impacts in California

US EPA
Urban Heat Island Conference Call
January 31, 2006

Haider Taha
Altostratus Inc.
haider@altostratus.com
www.altostratus.com
(925) 228-1573

Ongoing relevant urban meteorology/air quality projects at Altostratus

For:

- California Energy Commission
- San Jose State University Foundation / Department of Homeland Security
- NASA / Goddard Space Flight Center
- National Science Foundation (NSF)

Meteorological and air-quality modeling of surface modifications: Impacts in California

- Currently in **Phase-2** of study (through mid 2007)
- **CEC's** objectives; interest in "approval" by **ARB** and **EPA Region 9**
- Interest and support by cities, as well as California APCDs and AQMDs: **SIP modeling**
- Study based on **new generation** met/AQ modeling

[Previous presentation/update: October 5, 2004]

Goals of CEC / PIEREA UHI study Phase 2

- Update and use an urbanized (UCP) meteorological model (uMM5); link with emissions and photochemical models
- Develop fine-resolution, region-specific input database and morphology characterization; Also use as a basis for developing control scenarios
- Test modeling system and evaluate performance
- Apply models to California with regional focus; Evaluate potential meteorological/air quality impacts; Estimate emission reduction equivalents

Some considerations

- Increased urban albedo vs. UV albedo
- Increased vegetation cover vs. biogenic emissions
- High levels of modifications vs. inadvertent meteorology (e.g., mixing height, wind speed)
- Model performance: noise/signal
- FDDA and strength of nudging – 3-D variation in coefficients – FDDA-free “bubble”
- Input improvements, data resolution, overriding met-model LULC input

Heat Islands Control (surface modifications) And Ozone

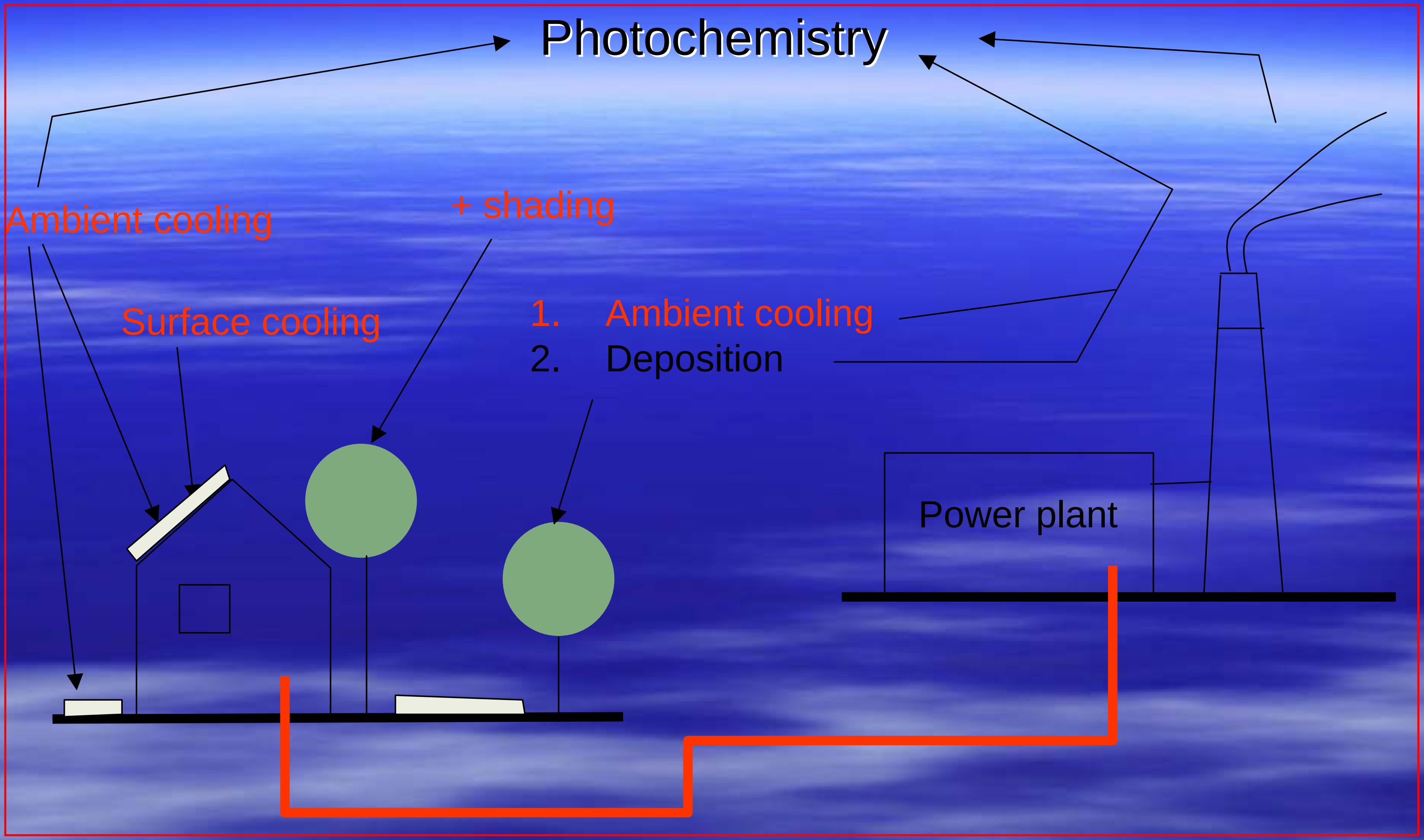
Direct effect

Indirect effect

Proposed (via $\Delta\alpha$, $\Delta\eta$, etc)

$$\mathbf{ROG\ (\ldots, T) + NOx\ (\ldots, T) + h\nu \xrightarrow{T} O3 + \ldots\ldots}$$

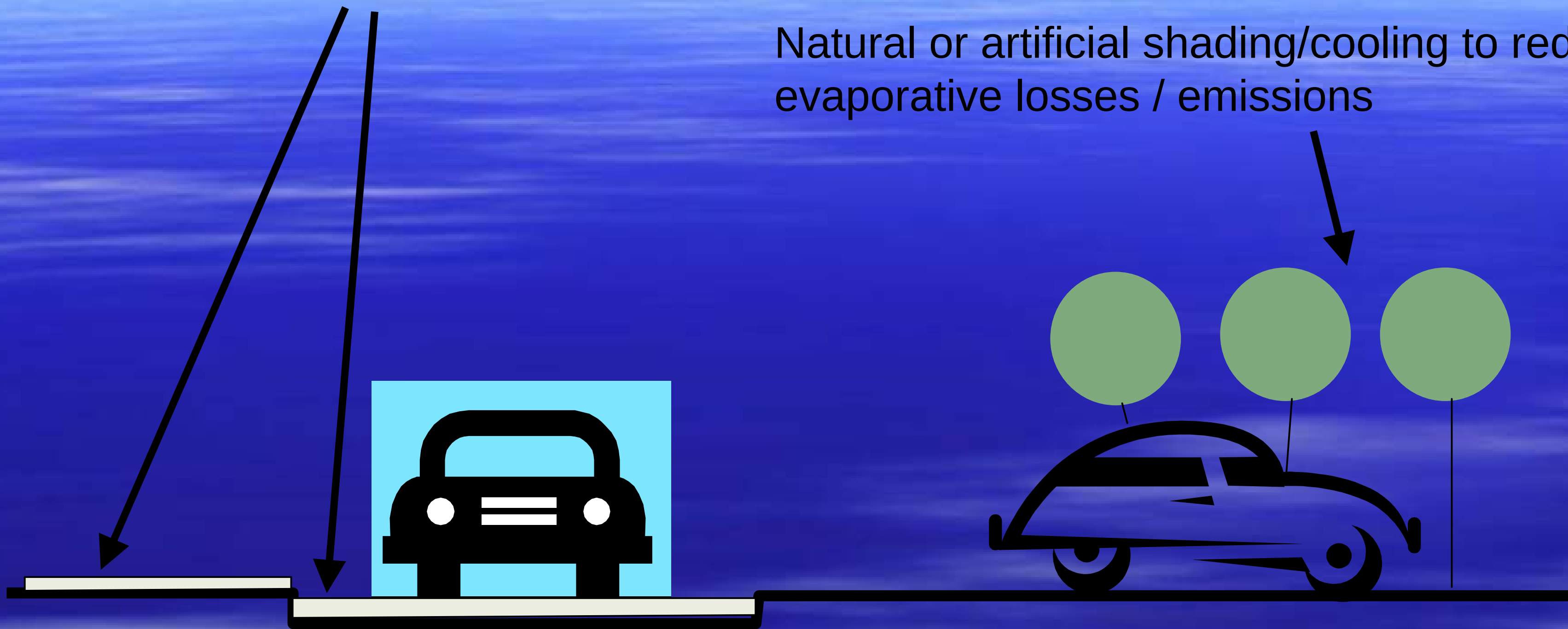
“conventional” (e.g., emission reduction)



Urban heat islands – NOx, VOC, O3

High albedo roadways and pavements to reduce exhaust emissions, e.g., **A/C** and engine

Natural or artificial shading/cooling to reduce evaporative losses / emissions



indirect

direct

Urban heat islands – NOx, VOC, O3

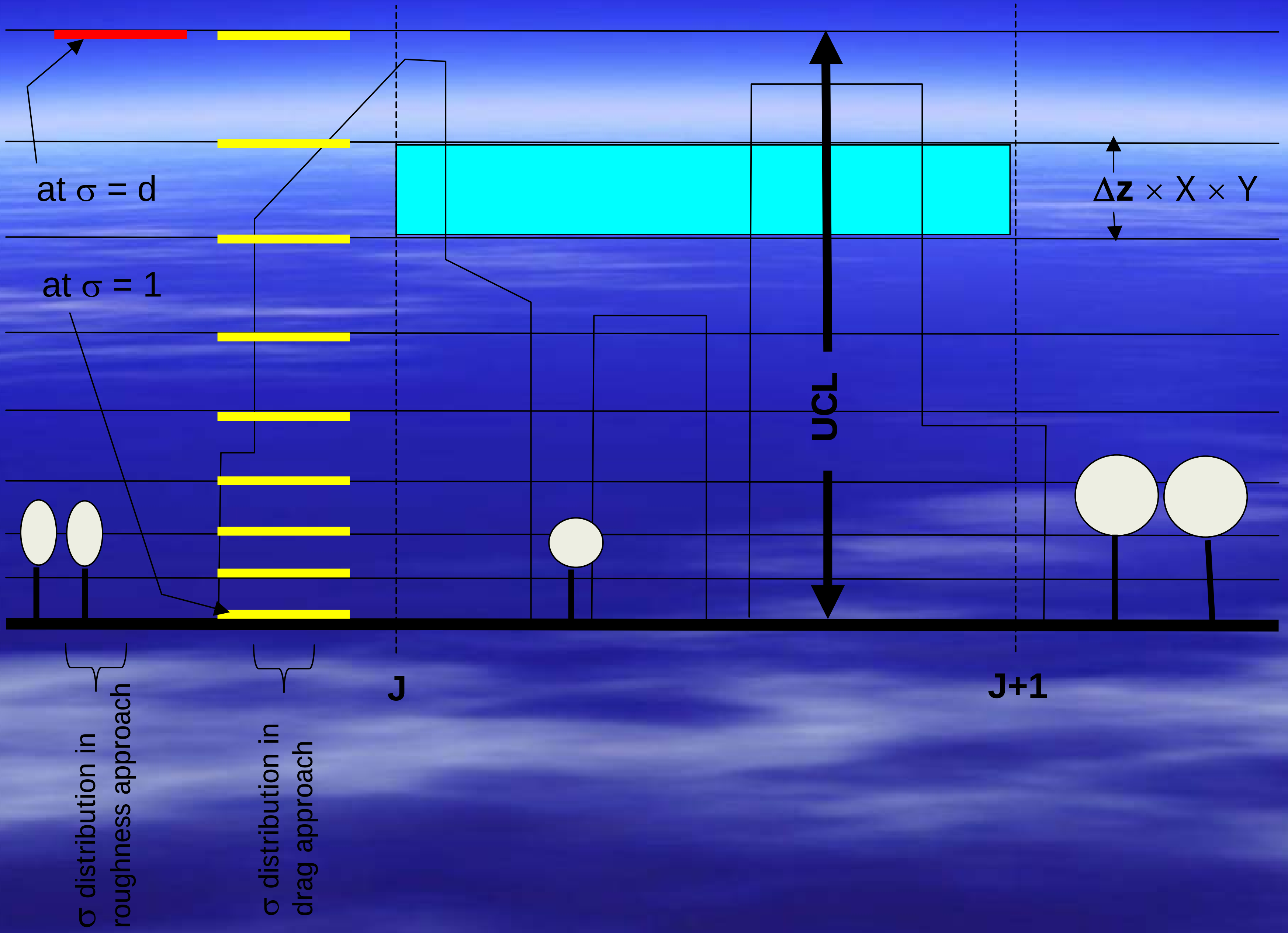
Modeling environment

Current study:

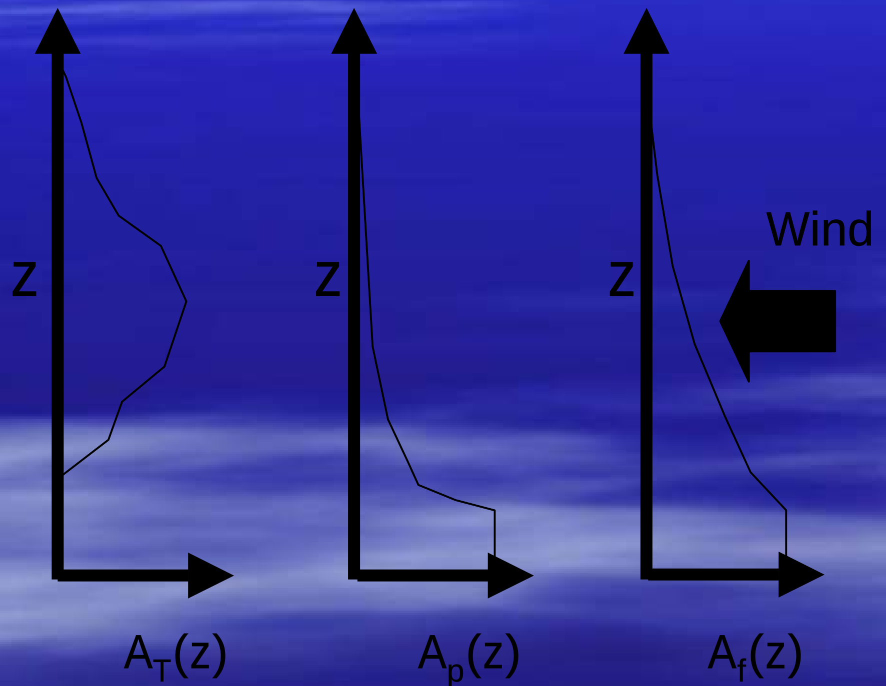
- **MET: Urbanized MM5 (uMM5) v. 3.5-3.7,**
  (UCP implementation in WRF)
- **AQ: CAMx 4.03 - 4.20 / CMAQ v4.4**
  (SAPRC99 mechanism)
- **Emissions update models**

uMM5/fine-resolution modeling: some highlights

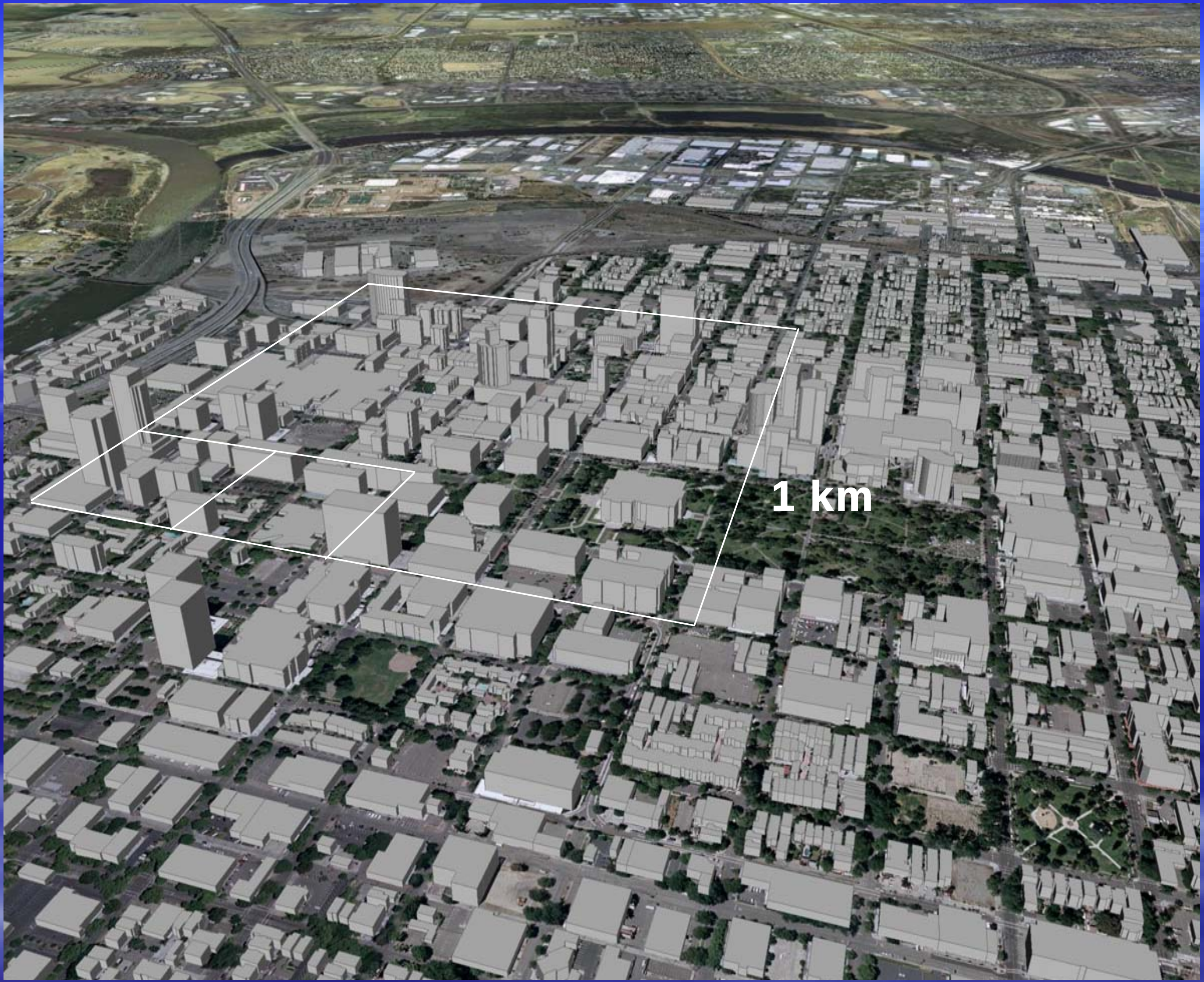
- Fine-resolution meteorological modeling -- non-LULC
- Morphology and 3-D surface characterization
- Effective albedo / Urban geometry and radiation
- Modified dynamics, thermodynamics, LSM, physics
- Canopy/vegetation model, more realistic walls and roofs: not parameterizations
- Capability to more accurately model green roofs
- Capability of modeling multi-level heat sources and sinks


at σ = d
at σ = 1
Δz × X × Y
UCL
J
J+1
σ distribution in roughness approach
σ distribution in drag approach

Typical UCP scaling parameters

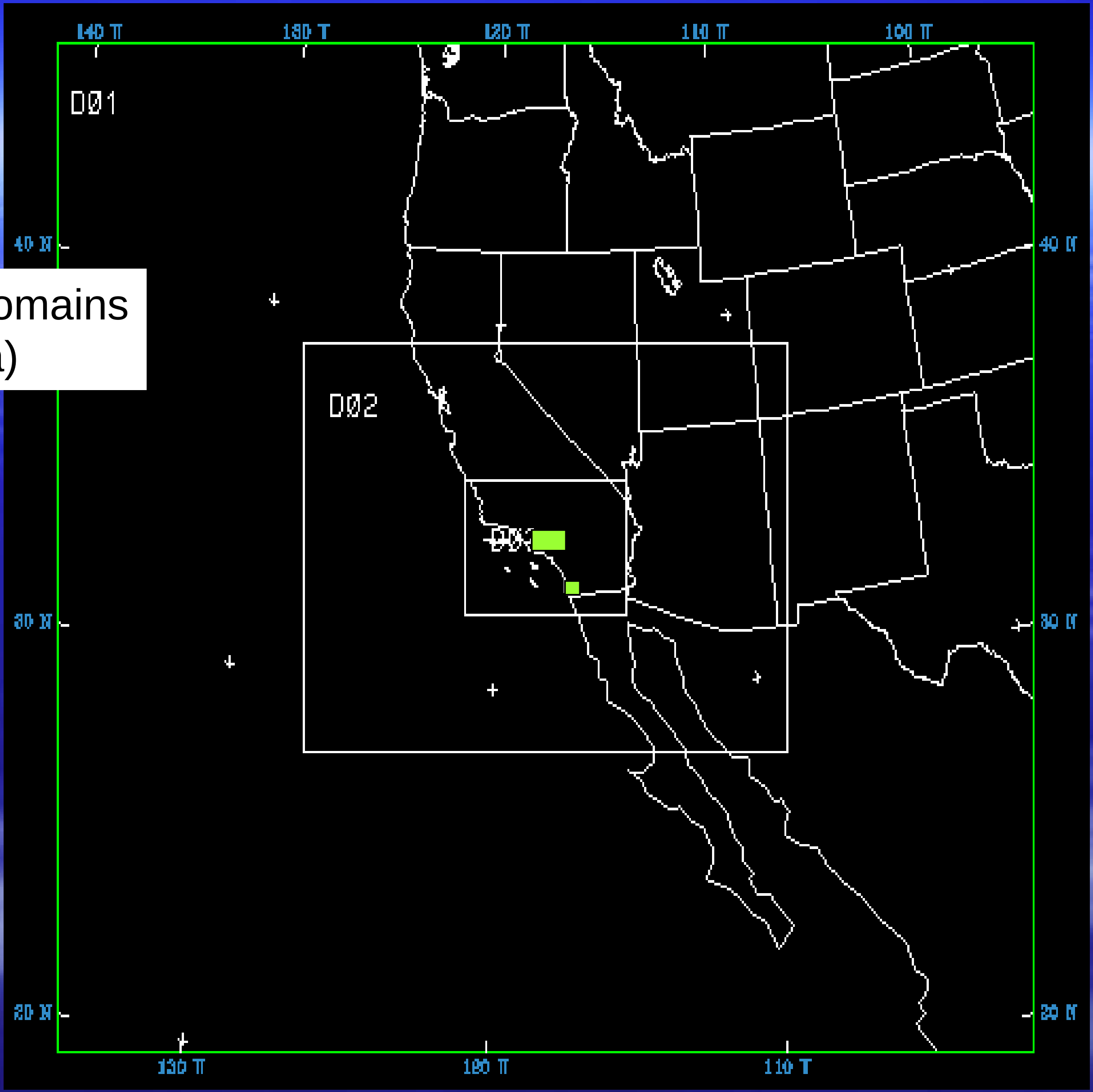


1. Land-use fraction
2. Land-cover fraction (paved)
3. Land-cover fraction (roof)
4. Land-cover fraction (vegetation)
5. Land-cover fraction (water)
6. Building height-to-width ratio
7. Building wall-to-plan ratio
8. Connected impervious area
9. Mean orientation of streets
10. Mean building height
11. Standard deviation of building height
12. Vegetation mean height
13. Canopy mean height
14. Zo and Zd (multi-directional)
15. Building frontal area density (multi-directional)
16. Building top (roof) area density
17. Building plan area density
18. Vegetation frontal area density
19. Vegetation plan area density
20. Vegetation top area density
21.Plan-area weighted mean building height
22. SVF

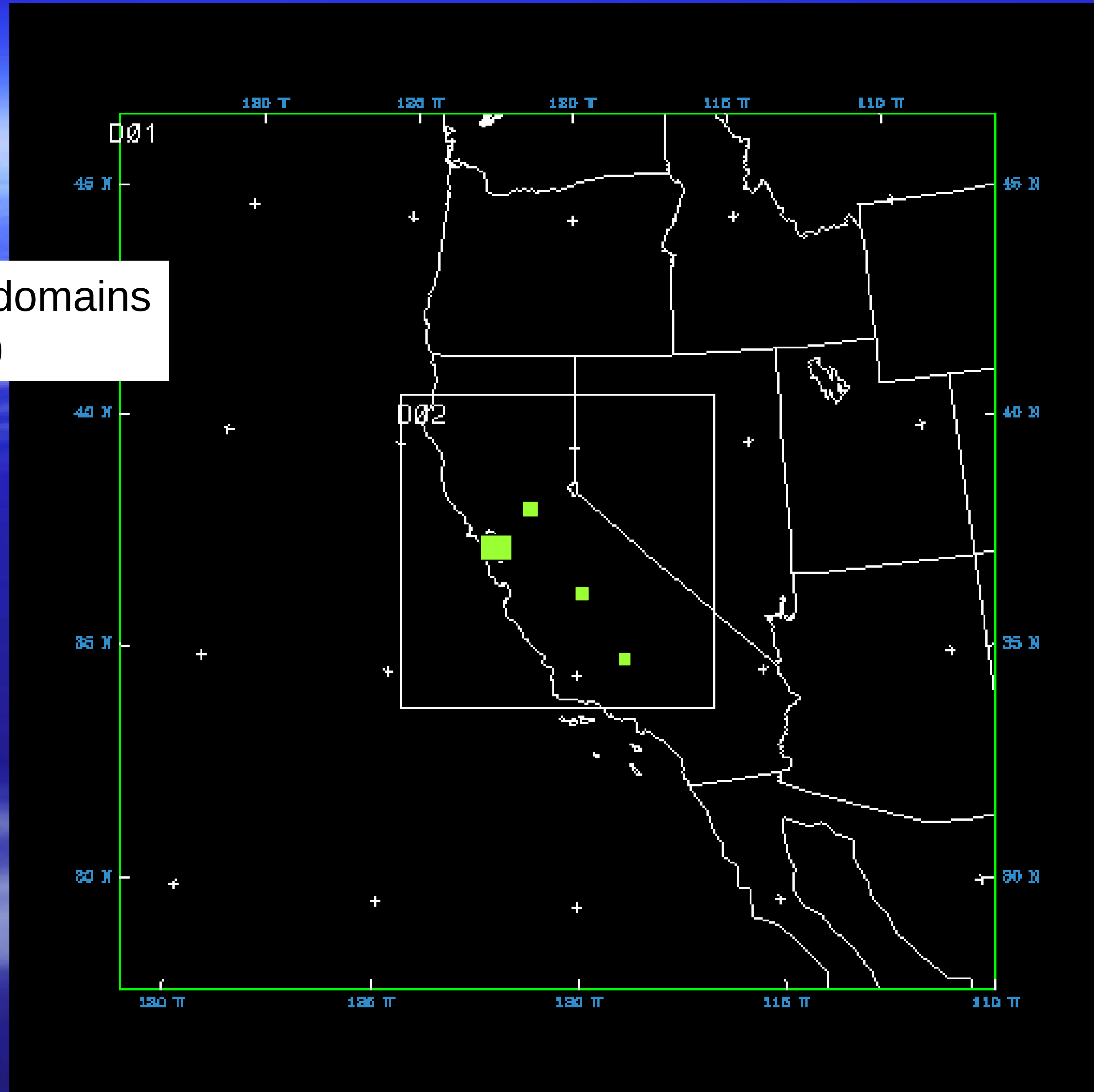


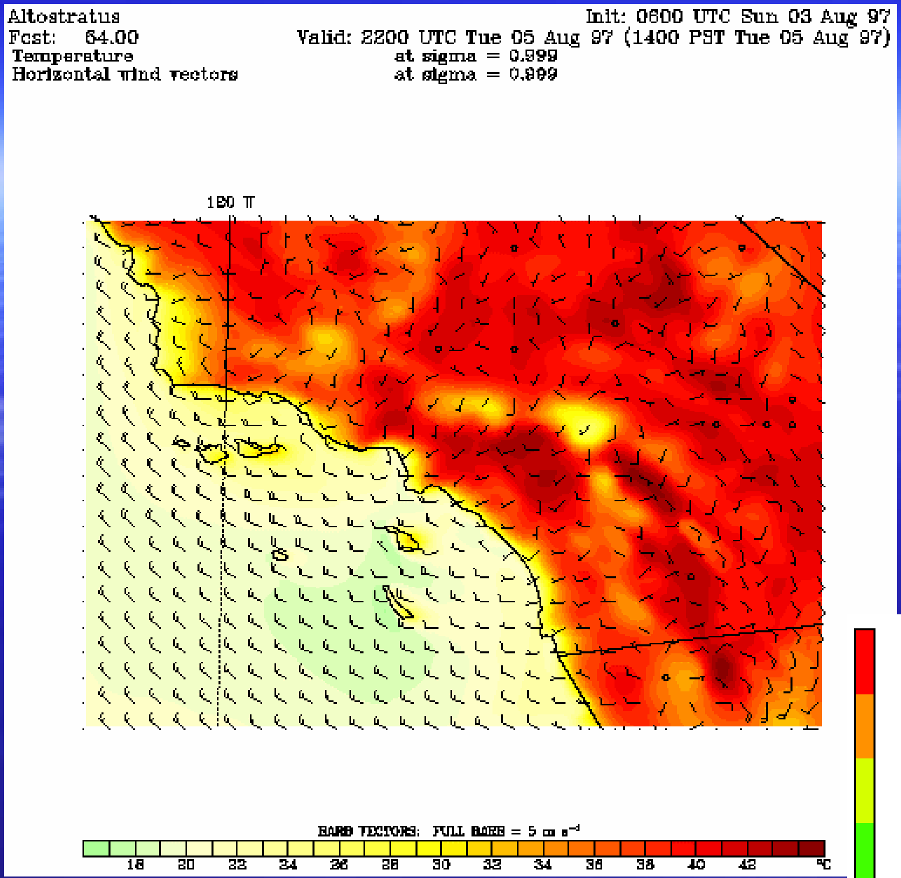
Downtown Sacramento, CA

Urbanized model domains (southern California)

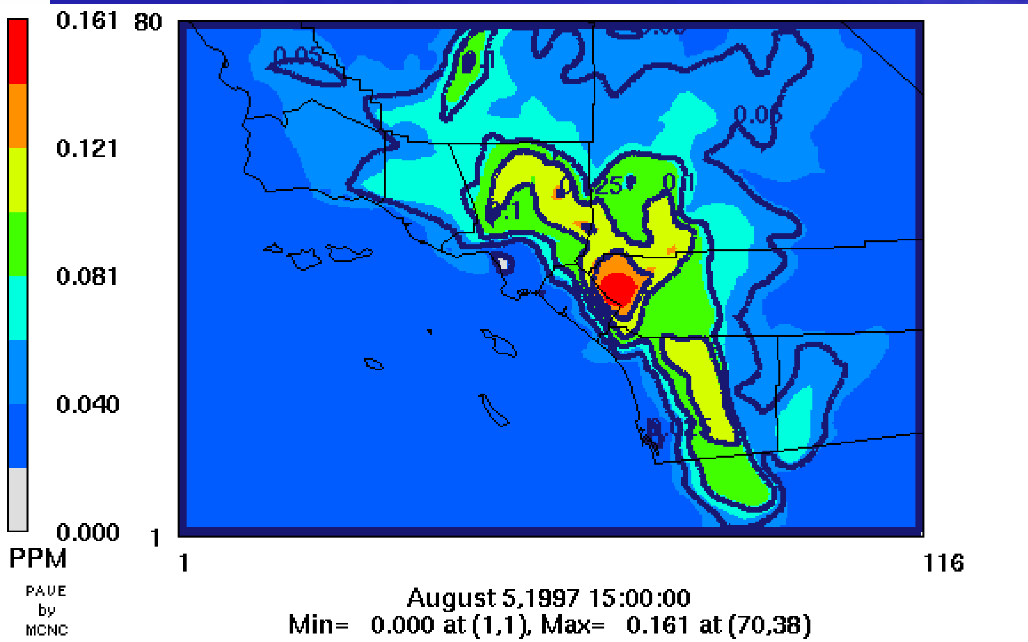


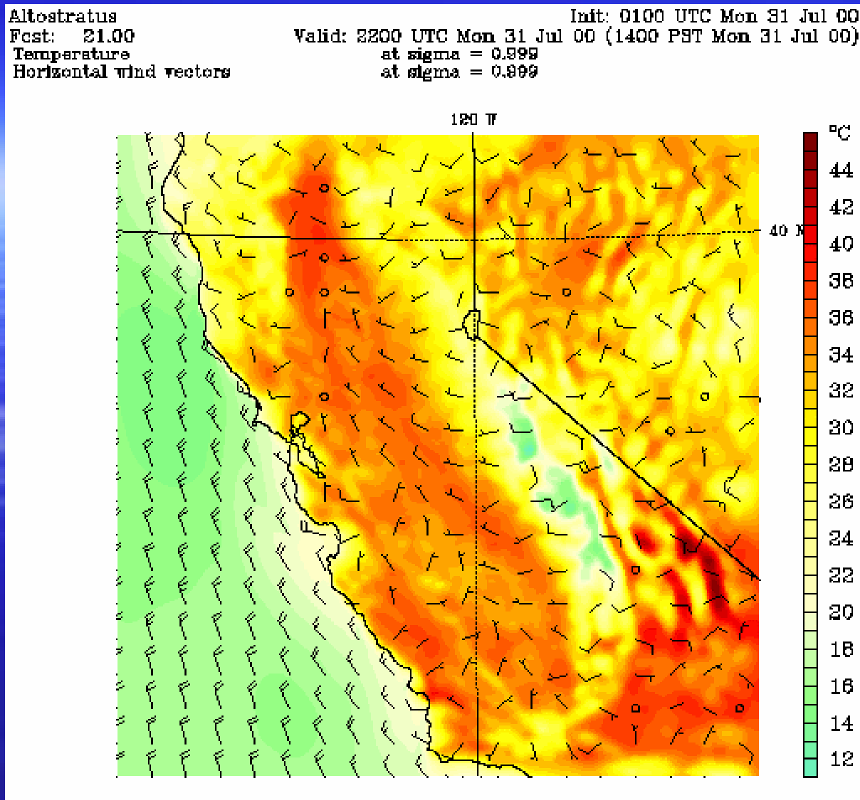
Urbanized model domains (central California)



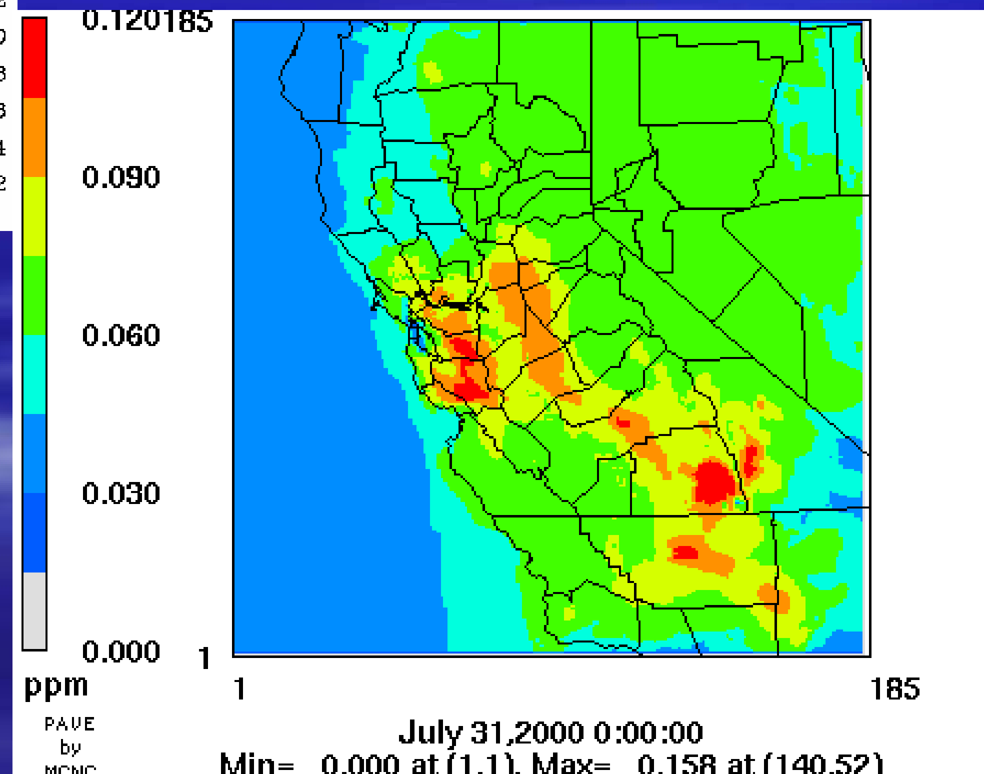


Base-case conditions example.
Southern California (August 5, 1997)

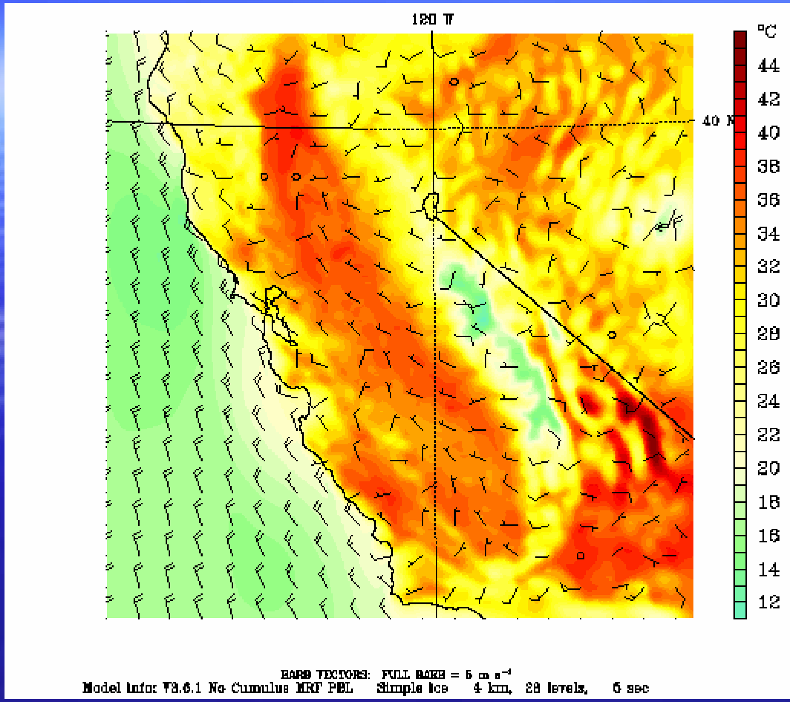


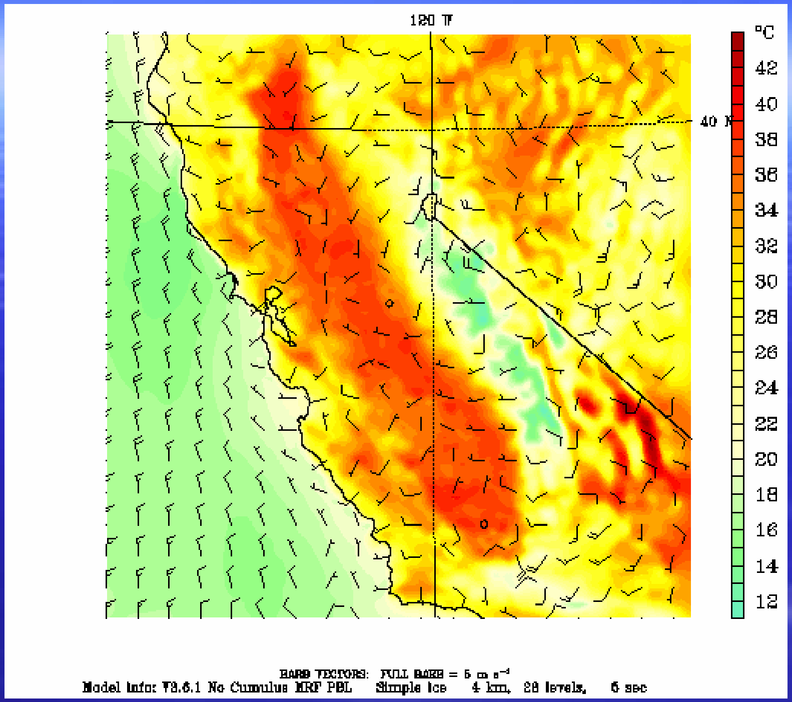


Base-case conditions example.
Central California (July 31, 2000)



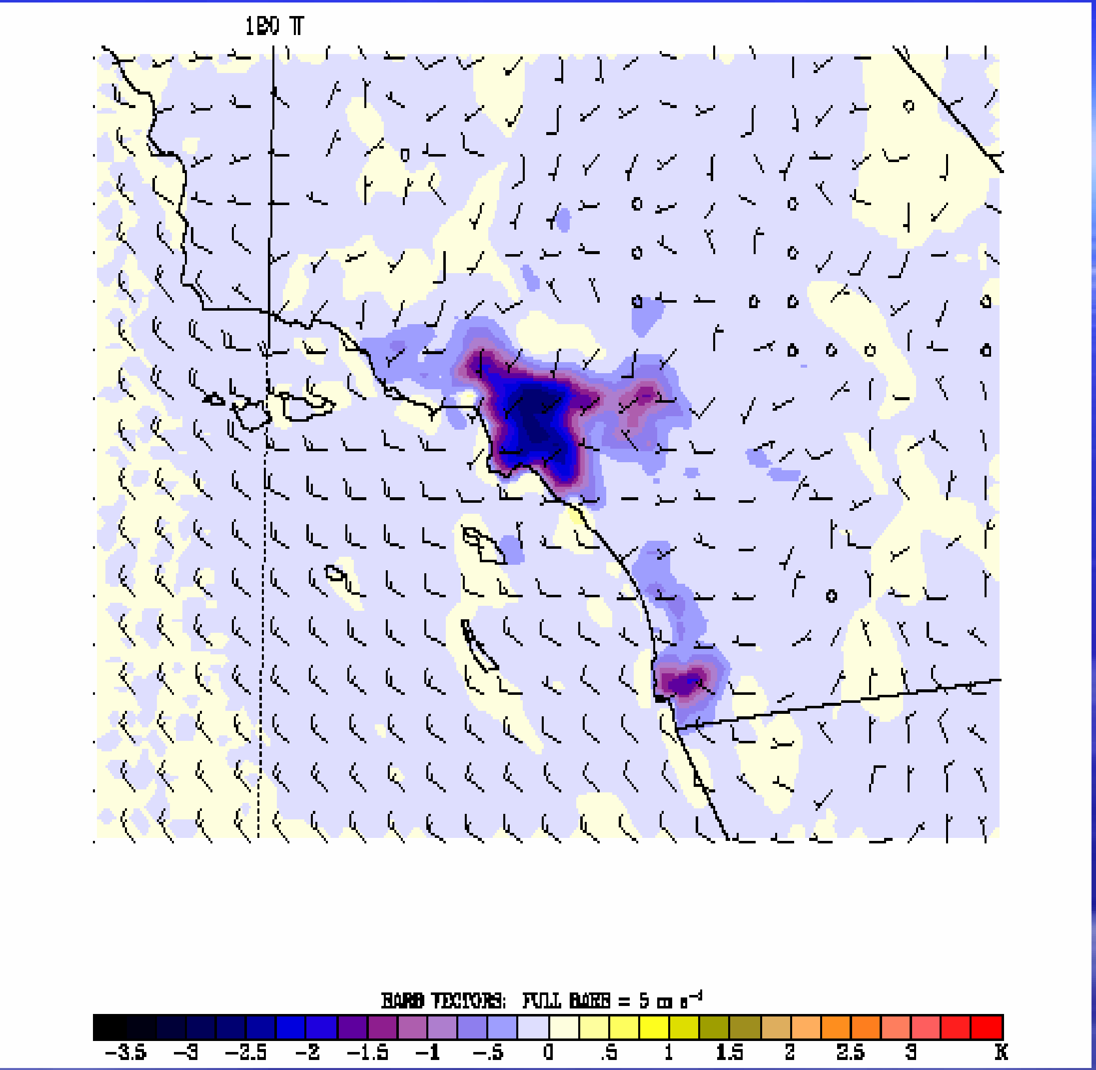
ALTOSTRATUS



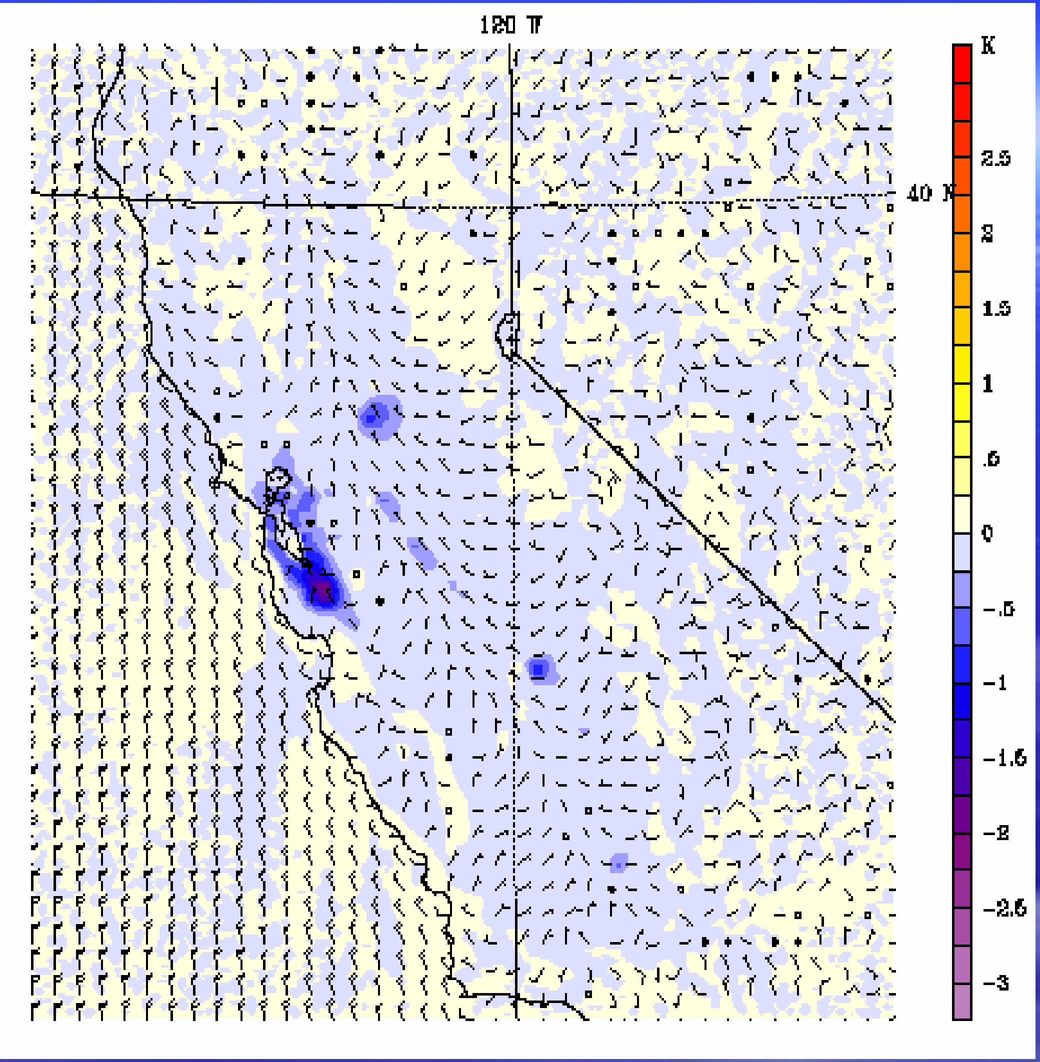


Simulated temperature and winds at 1600 PST on July 31st (left) and August 1st (right) 2000, at $\sigma = 0.999$, for Central California.

➡ **Quantitative model performance evaluation and statistics presented in October 2005 call. Also see study report.**



Example: 2-m temperature impacts – Southern California (high albedo) 1300 PDT (August 3)



Example: 2-m temperature impacts – Central California (high albedo) 1200 PDT (July 31)

Ozone air-quality impacts assessment:

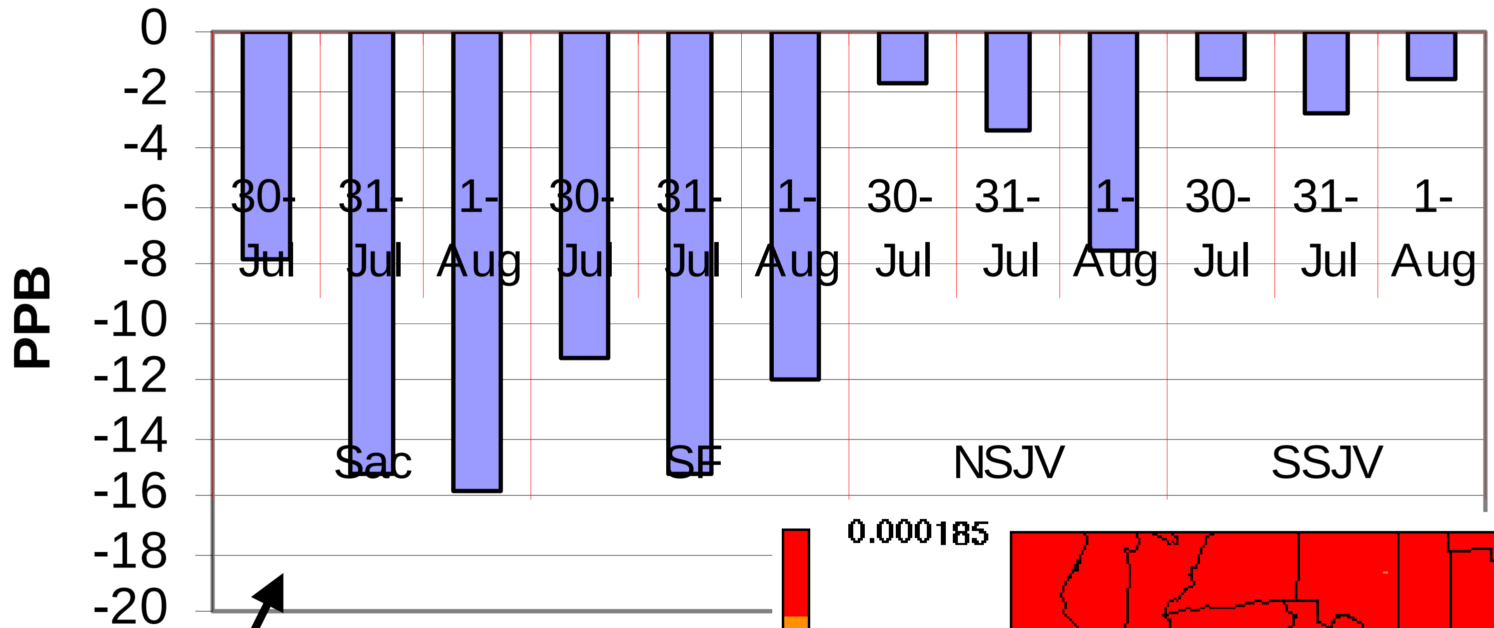
1. Photochemical impacts (atmospheric – indirect effects)
2. Emission impacts (direct effects)

INDIRECT

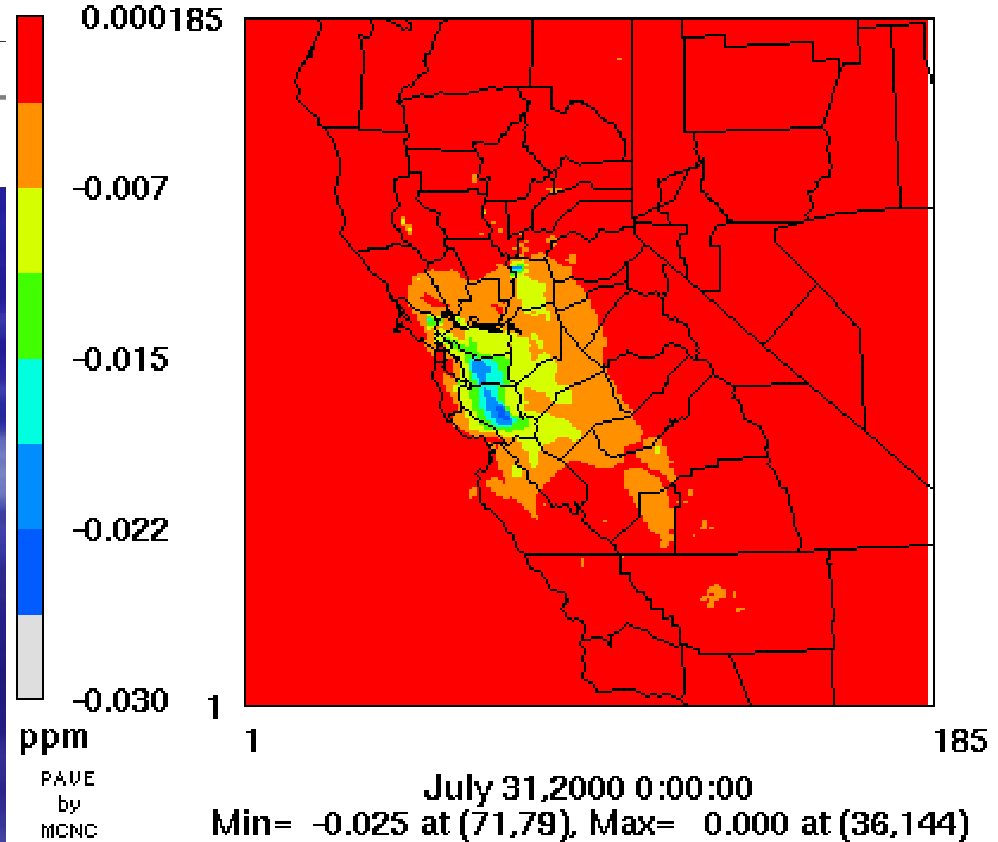
- Regional peak metrics (1 hour, 8 hour)
- RRF (8 hour)
- Area/averaged metrics
- Population-weighted exceedance exposure (e.g., >120,>90,>80 ppb)
- Sub-regional peaks
- Conversions to emission equivalents

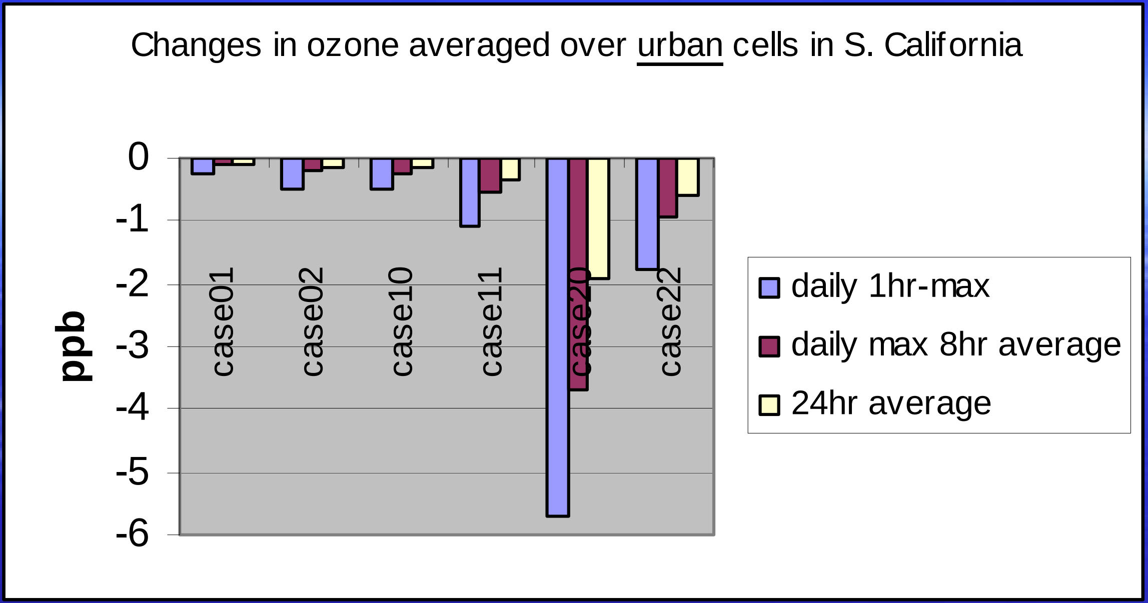
DIRECT

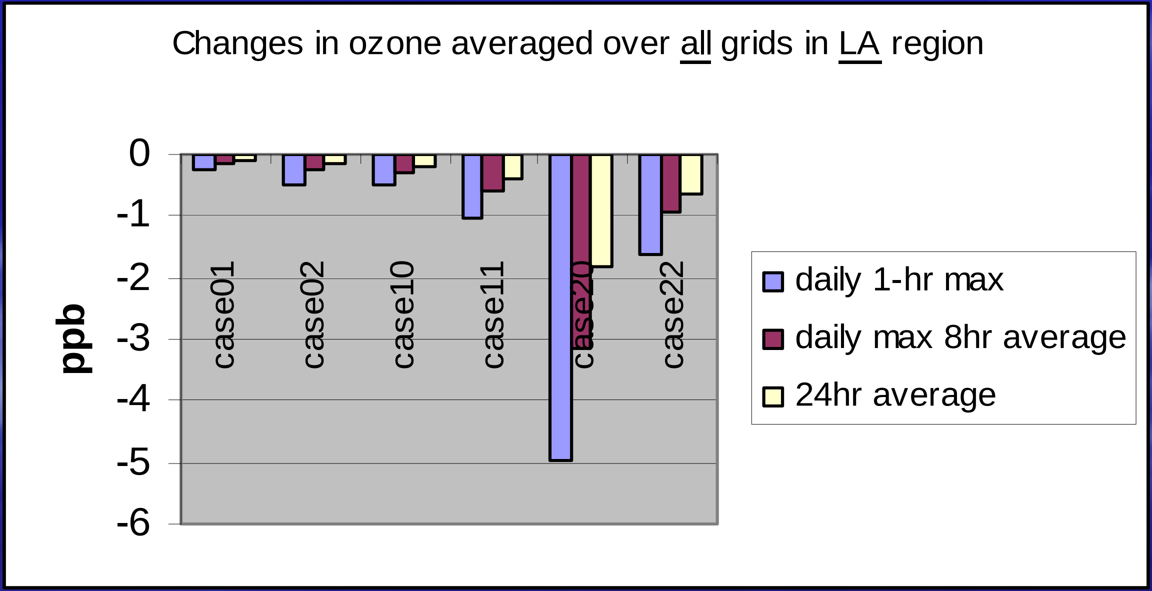
- Point source emissions / power plants
- Fugitive emissions / evaporative losses
- On/off-road mobile source emissions
- Biogenic emissions



Impacts on regional peaks (case 20): Central California




Changes in ozone averaged over urban cells in S. California
0
-1
-2
-3
-4
-5
-6
ppb
case01
case02
case10
case11
case20
case22
daily 1hr-max
daily max 8hr average
24hr average


Changes in ozone averaged over all grids in LA region
0
-1
-2
-3
-4
-5
-6
ppb
case01
case02
case10
case11
case20
case22
daily 1-hr max
daily max 8hr average
24hr average

Indications from Phase-1:

- Satisfactory meteorological and photochemical model performance
  - Regional meteorology features captured reasonably well
  - Heat islands ~2-3C in major urban areas
  - Ozone field and location/magnitudes of highs reasonable
  - Transport and coupling
  - Statistical benchmarks similar to or better than AQMD's (although uneven)

- Surface modifications: Impacts on meteorology
  - Temperature reduction (2m)
    ~up to 3.5C in large urban areas, up to 0.5C in smaller areas
  - Impacts on wind speed and vertical mixing (up to ~1 m/s, 10%)
  - Consistent/repetitive diurnal cycles

- Surface modifications: Impacts on ozone/air quality
  - Peaks reduced in central CA (2-15 ppb), smaller impacts in SoCAL (1-6 ppb) (consistent decrease in central CA but can increase in SoCAL)
  - Area-averaged metrics all decrease in central CA and SoCAL (slide 22)
  - RRF ranges from 1 to 8% in SoCAL
  - Equivalent emissions reductions: UP TO 4% of each of NOx and VOC, (i.e., ~50 TPD of each) for the high albedo case in SoCAL

Next steps

- All above results will be re-evaluated/re-visited in Phase 2

- Presentation of modeling results to CEC/ARB/AQMDs/EPA
- Approval of modeling environment and model performance
- Begin modeling of more resolved scenarios
- Initiate “implementation” type of modeling specific to cities