Cooling Summer Daytime Temperatures in Coastal California During 1948-2005: Observations, Modeling, and Implications

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Outline

- Introduction to research
  - team
  - topic
- Our Coastal cooling: observations
- Our CA modeling studies for
  - mesoscale meteorology
  - urban heat islands (UHIs)
  - regional air quality
  - climate change
- Needed future efforts
  - determination of coastal-cooling impacts
  - use of mesoscale met modeling

Research Team's Expertise

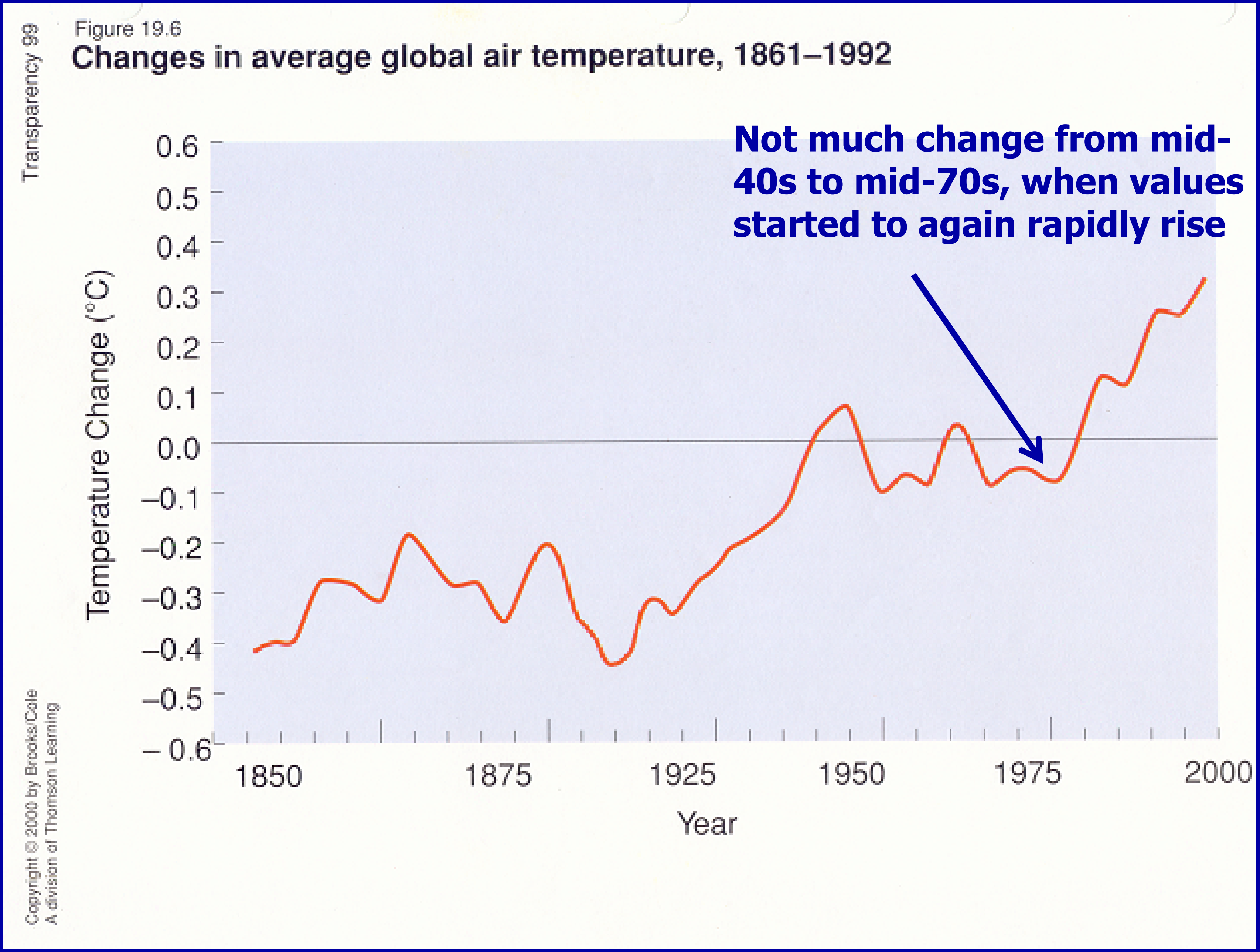
- San Jose State U.: meso-met observations and modeling
- Santa Clara U.: sustainable development; GIS; and climate change downscaling & analysis
- Altostratus Inc.: linked mesoscale modeling for urban heat island (UHI) & regional ozone
- Stanford U.: statistical evaluation of environmental data
- LBNL: energy-usage trend-analysis

The research-problem

- What are the impacts of global climate change on CA
  - climate, e.g., seasonal and daily temperature trends
  - weather, e.g., precipitation and water supply
  - air quality, e.g., ozone and PM
  - energy planning, e.g., for peak usage
  - human health, e.g., UHI and thermal stress levels
  - agriculture, e.g., winery operations
- How can mesoscale modeling best be used in CA to:
  - reproduce past changes
  - estimate future trends

Background

- Global scale observations generally show past asymmetric (more for T_{min} than for T_{max}) warming accelerated since mid-1970s on
  - global scale (1.0-2.5 deg resolution) (see graph)
  - regional scales
- Global-model results
  - match the observations
  - predict accelerated further warming
- CA downscaled global-model results (see graph)
  - have been done (at SCU & elsewhere) onto 10-km grids
  - show summer warming that decreases towards coast


Transparency 99
Figure 19.6
Changes in average global air temperature, 1861–1992
Temperature Change (°C)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
–0.1
–0.2
–0.3
–0.4
–0.5
– 0.6
1850
1875
1925
1950
1975
2000
Year
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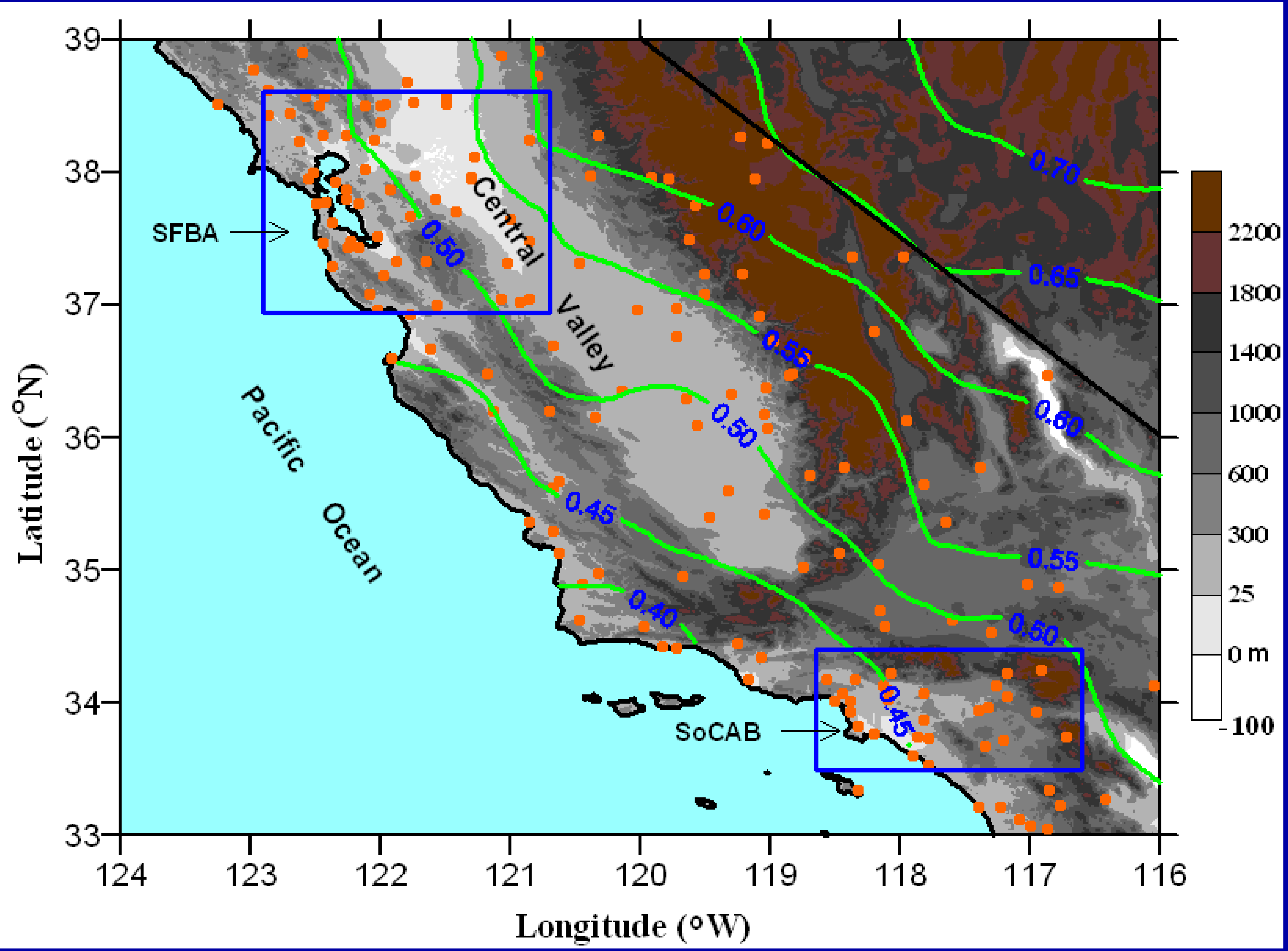
Not much change from mid-40s to mid-70s, when values started to again rapidly rise

Statistically down-scaled (Prof. Maurer, SCU) 1950-2000 modeled annual summer (JJA) temps (^{O}C) show warming rates that decrease towards coast



Earlier climate-change (* = for CA) studies have discussed climate-change impacts in terms of increased:

- SSTs & urbanization (*Goodridge '91, Karl et al. '93)
- Cloud cover (*Nemani et al. 2001)
- Coastal upwelling (*Bakum 1990; Snyder et al. 2003; McGregor et al. 2007)
- Land-cover conversions (Chase et al. 2000; Mintz 1984; Zhang 1997)
- Irrigation (*Christy et al. '06; Kueppers et al. '07, Bonfils & Duffy '07, *Lobell & Bonfils et al. '08)
- Solar absorption (Stenchikov & Robock 1995)

The Current Hypothesis

- Increased GHG-induced inland temps→
- Increased (Coast To Inland) pressure & temp gradients→
- Increased sea breeze freq, intensity, penetration, &/or duration →
- Coastal areas should show cooling summer daytime max temps (i.e., a reverse reaction)

Note:

Not a totally original idea →

A4 ★★★★ San Francisco Chronicle

How S.F. Could Get Even Foggier

'Greenhouse Effect' Could Backfire

By Charles Petit
Chronicle Science Writer

Notions that global warming from the "greenhouse effect" might bring balmy summers to San Francisco beaches got a dash of cold water this week.

A government oceanographer says a warmer Earth will make it even colder and foggier along Northern California's coast and that the trend may already have started here and in similar coastal regions in Spain, Morocco and Peru.

Hotter weather in the Central Valley might mean higher winds along the coast. The wind would stimulate upwelling of the cold water and onshore breezes that make the region's famous fogs, reports Andrew Bakun in today's issue of the journal Science.

Bakun is a physical oceanographer and chief of the Pacific Fisheries Environmental Group, a 12-person research laboratory operated by the National Oceanic and Atmospheric Administration in Monterey.

In an interview, Bakun emphasized that his projection cannot calculate just how much foggier it may get. He also said he could easily turn out to be wrong — just as widely accepted predictions that the Earth on average will warm by 3 to 9 degrees Fahrenheit in the next century may also turn out wrong.

But, he said, the main point is that even if the greenhouse scenario is correct for the planet on average, "it is a mistake to think that means it will warm up everywhere. There are very good reasons to think it will be colder here, at least in summer."

He also suspects that the summer fog season would start earlier in the season and end later.

Summer fog streams regularly across California's coast, most intensely between Point Conception northward into Oregon, because of several factors.

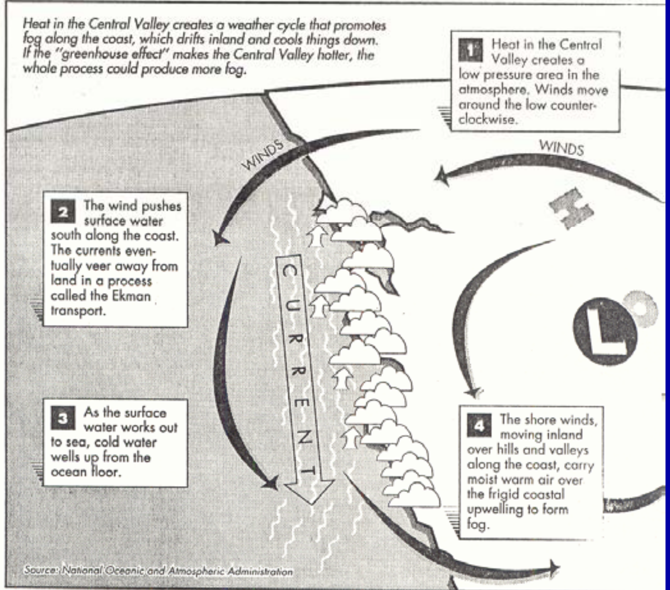
The chief ones are upwellings of deep, cold ocean water to the surface along the shore and breezes that draw relatively warm, humid air inland. The combination of chilling from the upwelling water, and land that forces the air upward, causes fog to condense from the air.

Although measurements are not precise, data suggest that winds have already started picking up along California's coast. Studies of wind stress — the amount that winds push surface currents — show a roughly upward trend since about 1945. This is during a time that some climatologists believe they have detected a slight warming of the Earth. Similar trends appear under way off the coasts of Peru, Spain and Morocco where local fog conditions resemble those of Northern California.

Upwelling causes both the frigid swimming conditions along Northern California's beaches, as well as the good fishing. The deep waters carry nutrients that support much of the shallow marine life of California.

A fisheries specialists, Ba[illegible] not sure that more intense u[illegible]ing would improve fishing. "[illegible] would be more nutrients, bu[illegible] will also have more rapid exp[illegible] these nutrients offshore, and [illegible] wind means more turbulence.

WHY 'GREENHOUSE EFFECT' MAY MEAN MORE COASTAL FOG

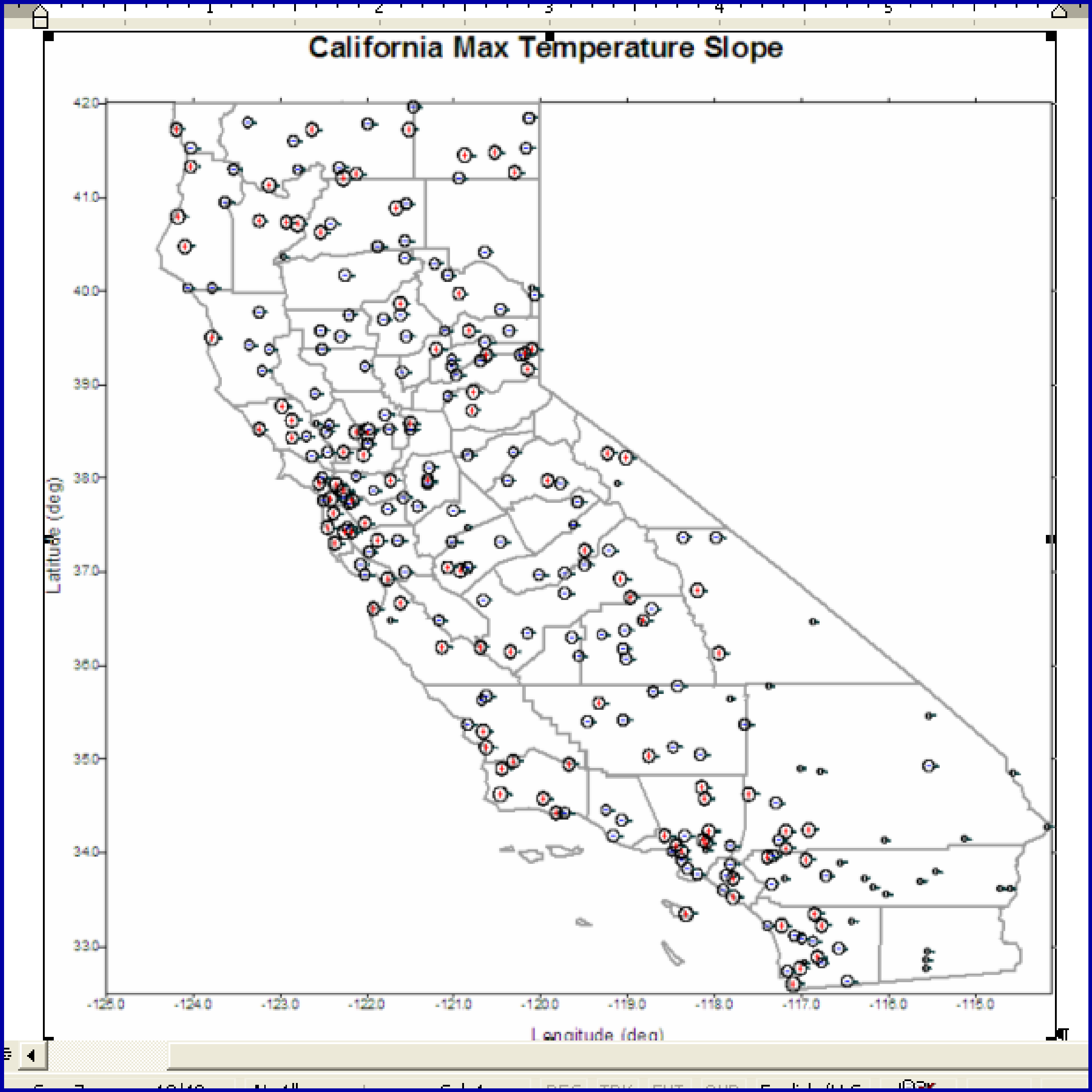


CHRONICLE

CURRENT DATA

- NCDC Daily Max & Min 2-meter Temps
  - From about 300 CA NWS COOP Sites (see map)
  - For 1948-2005
  - Have been used in many other CA climate-change studies
- NCDC Mean Monthly Gridded Sea Surface Temps (SSTs)
  - From International Comprehensive 0cean-Atm Data Set (ICOADS)
  - At 2-deg horizontal resolution
  - For 1880-2004
- NWS 1600-LST Dew-point Temps
  - From two NWS airport sites: Coastal-SFO & Inland-SAC
  - For 1970-2005
- ERA40 1.4 Deg Reanalysis 1000-LST Summer T-85
  - Sea-level pressure changes
  - For 1970-2005

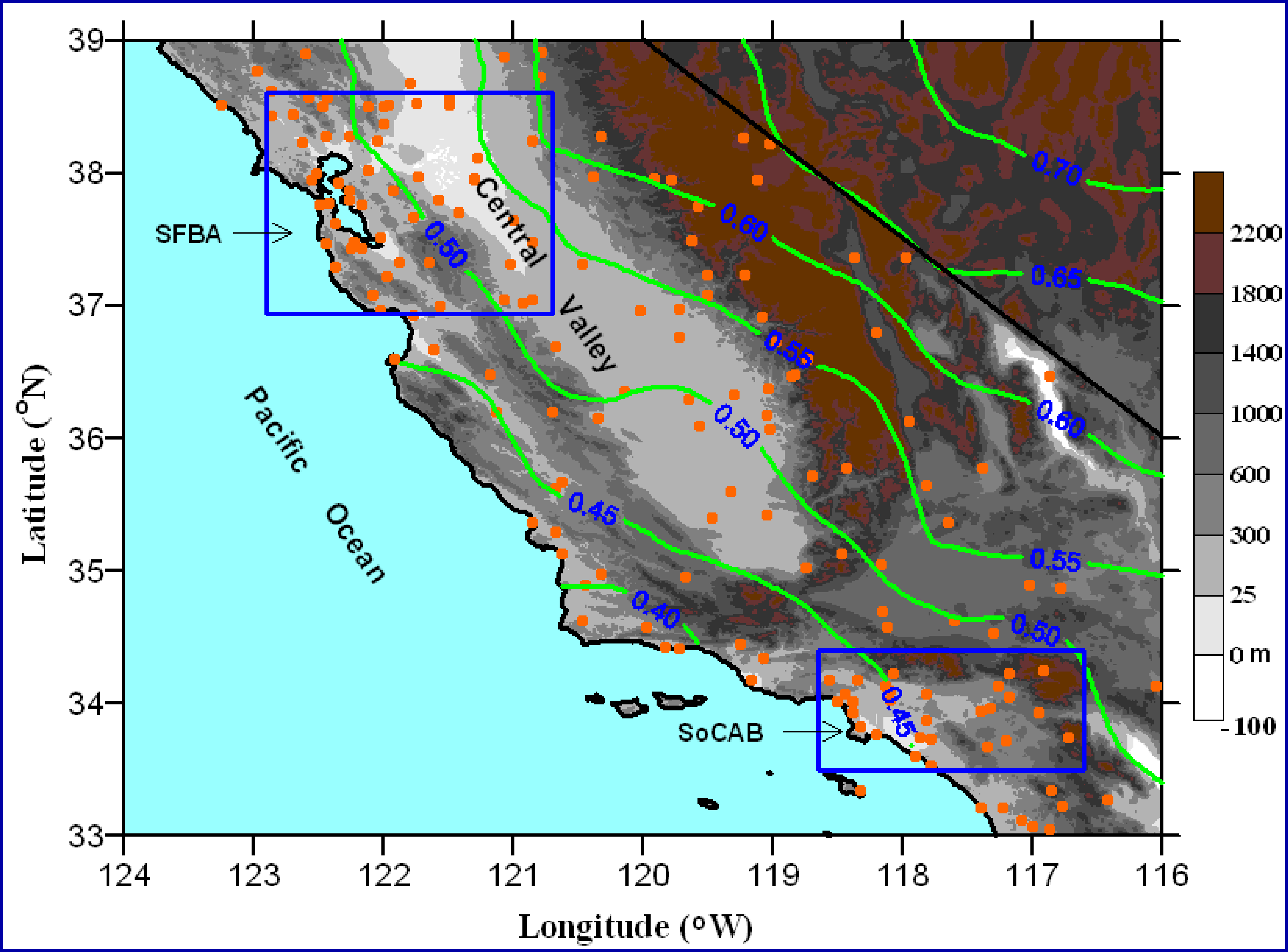
NWS COOP Sites Used In Current Study



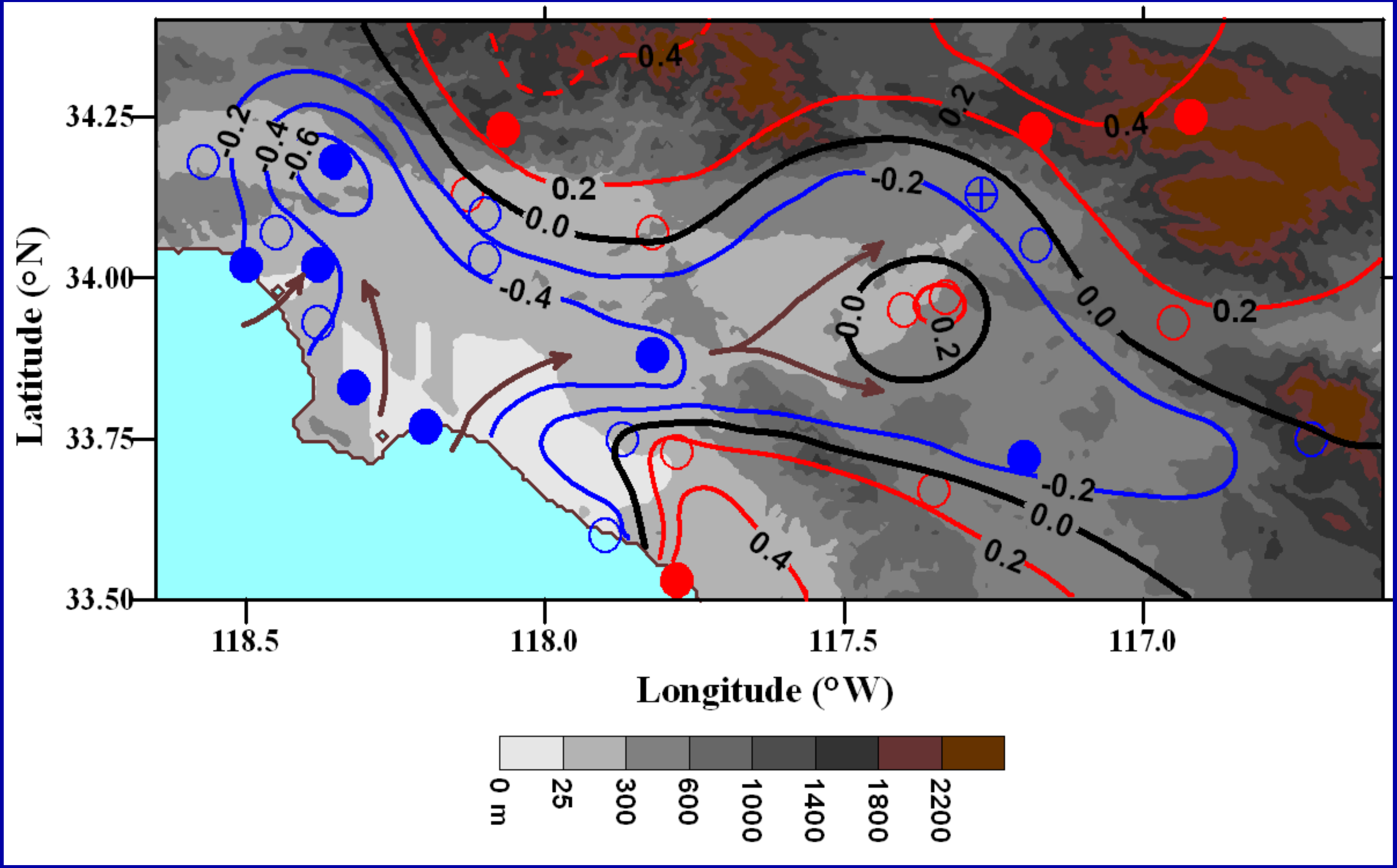
Summer-Data Analyses

- Emphasis: on data from 1970-2005
- All-CA warming/cooling trends calculated (^{O}C/decade) for: SST, T_{max}, T_{min}, T_{ave}, & daily temp range (DTR = T_{max} -T_{min})
- Spatial-distributions of T_{max} trends: plotted for the (see chart)
  - South Coast Air Basin (SoCAB)
  - SFBA (includes northern Central Valley)
- Tests of statistical significance
- Temporal-trends calculated for
  - Land-sea pressure-gradients
  - Dew-point temperatures
  - SSTs

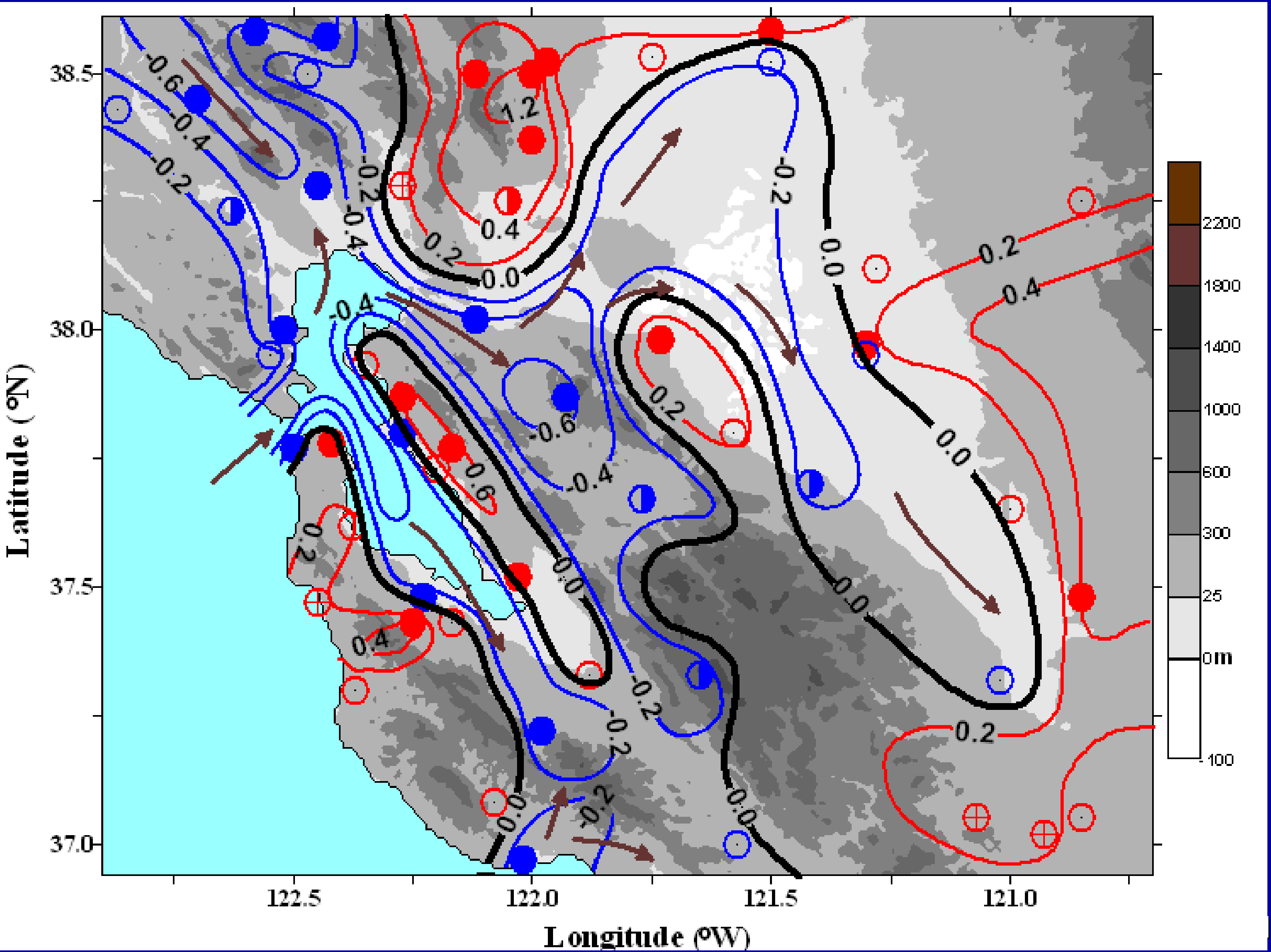
SFBA and SoCAB sub-domains (boxes)
(red dots show COOP sites)



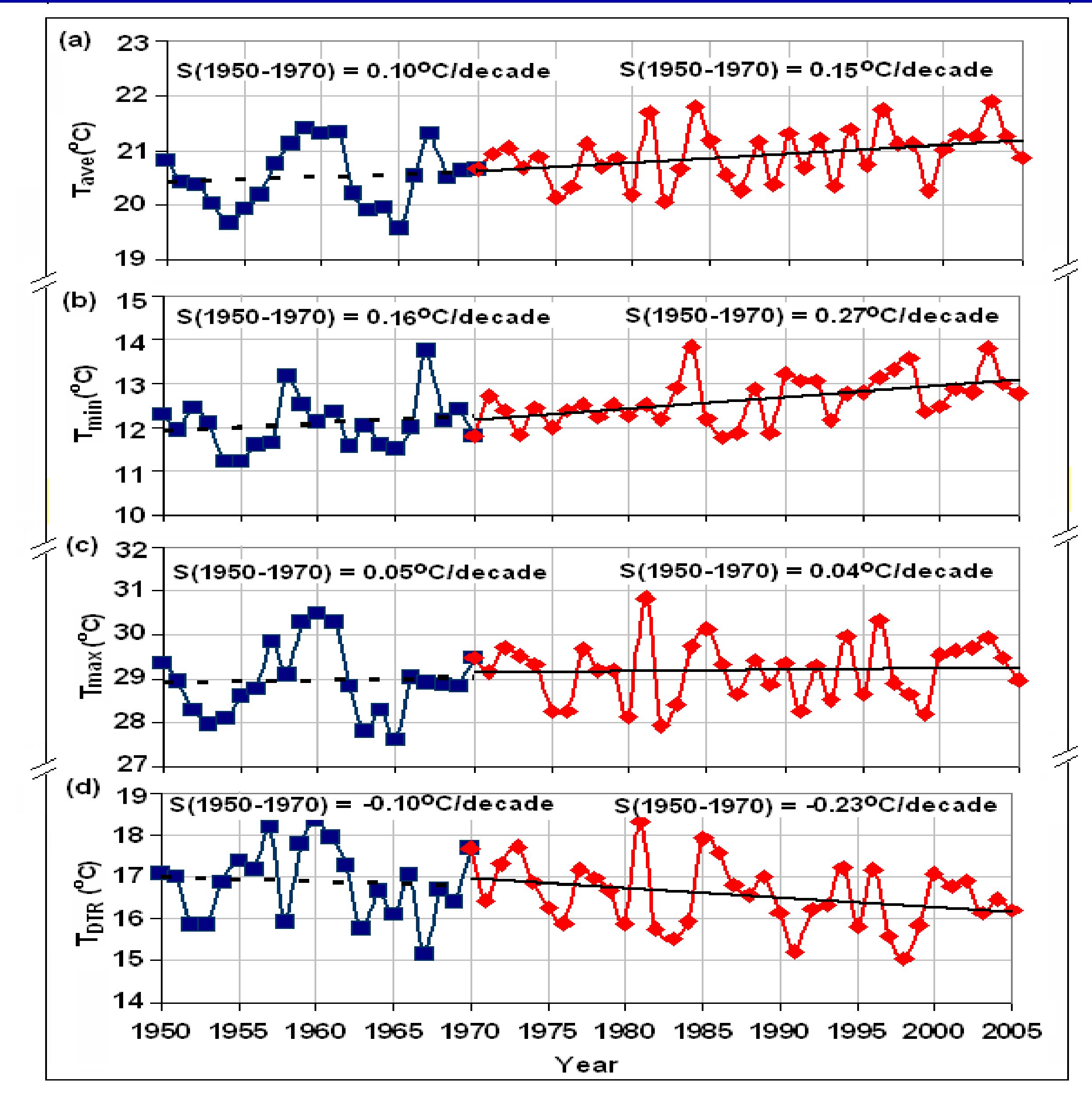
Obs. Results 1: SoCAB 1970-2005 summer T_{max} warming/ cooling trends (^{O}C/decade); solid, crossed, & open circles show stat p-values > 0.01, 0.05, & not significant, respectively)



Obs. Results 2: SFBA & CV 1970-2005 summer T_{max} warming/cooling trends (^{O}C/decade), as in previous figure

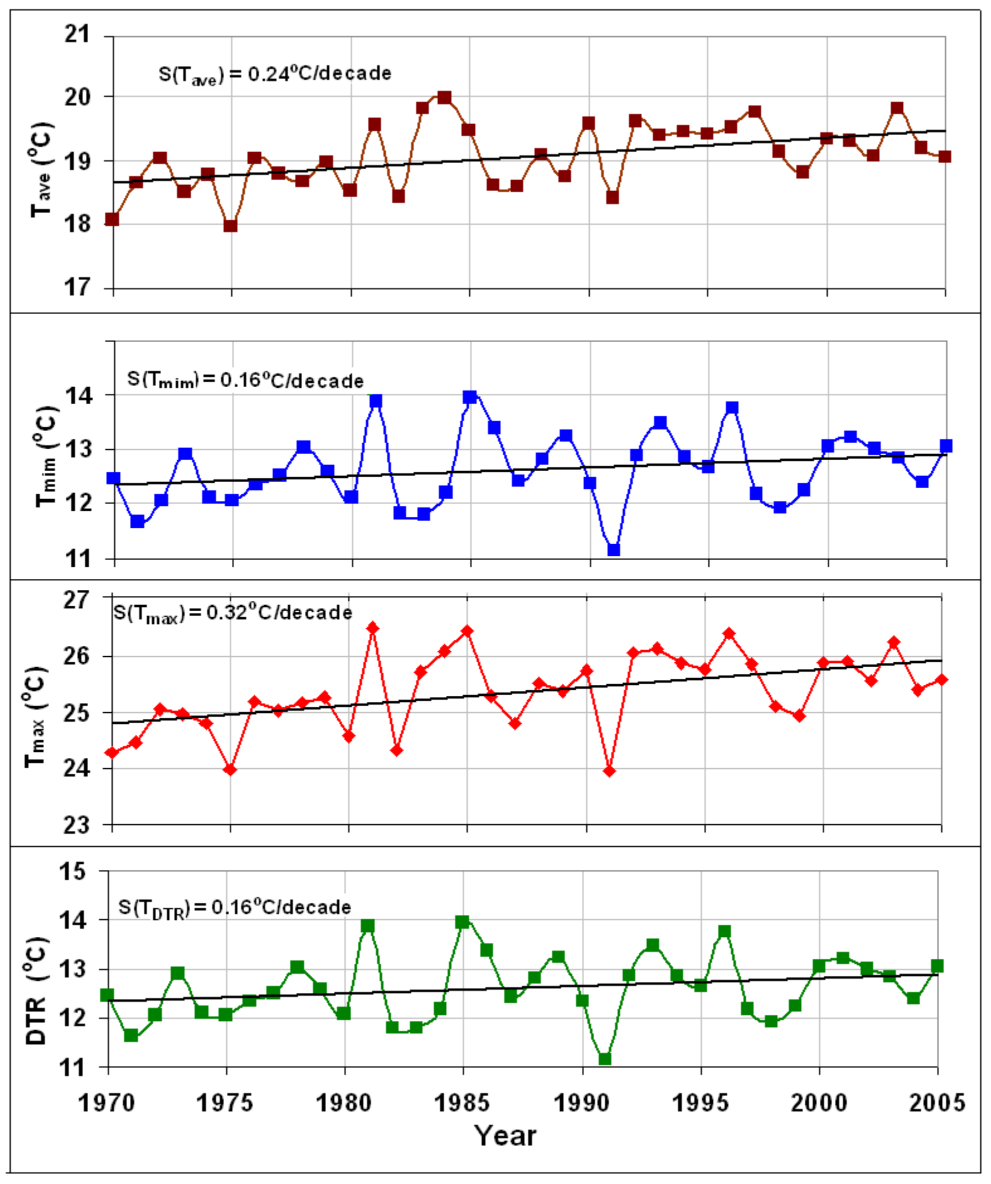


Obs Results 3: Summer temp trends; all CA-sites



- Lower trends from 1950- 70 (except For T_{max})
- Curve B: T_{min} had fastest rise (as expected)
- Curve C: T_{MAX} had slowest rise; will show it as small Δ B/T A big pos value & a big neg value
- Curve A: T_{ave} thus rose at medium rate
- Curve D: DTR thus decreased (as T_{max} falls & T_{min} rises)

T_{ave}, T_{min}, T_{max}, & DTR Trends for Inland-Warming Sites In SoCAB & SFBA



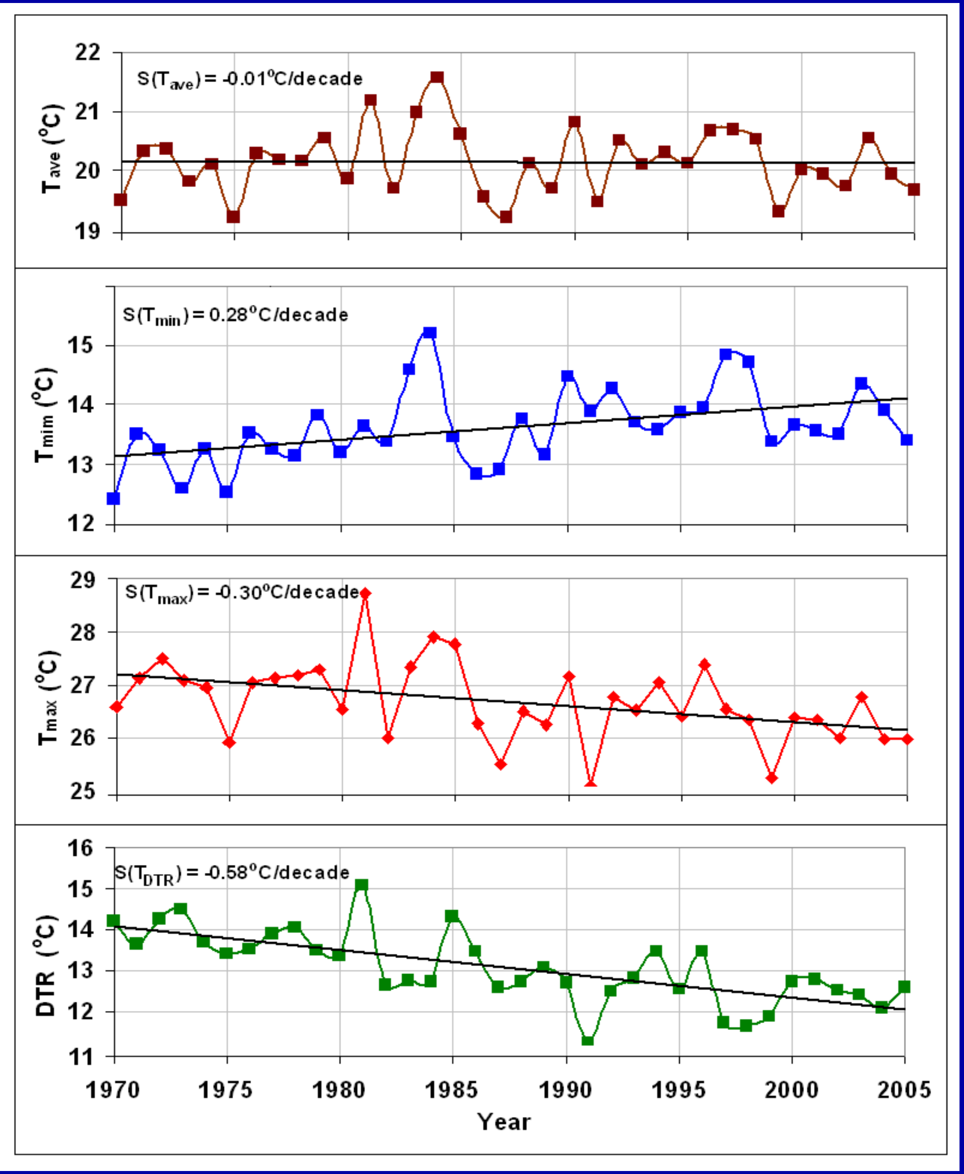
Curve A: T_{ave} Thus rose at medium rate

Curve B: T_{min} increased (expected)

Curve C: T_{max} had faster rise; (unexpected) but could be due to increased UHIs

Curve D: DTR thus increased (as T_{max} rose faster than T_{min} rose

T_{ave}, T_{min}, T_{max}, & DTR Trends for Coastal-Cooling Sites in SoCAB & SFBA



Curve A: T_{ave} showed almost no change, as found in lit.), as rising T_{min} change & falling T_{max} change almost cancelled out

Curve B: T_{min} had rise (expected)

Curve C: T_{max} had cooling (unexpected major result of study)

Curve D: DTR thus decreased, as T_{min} rose & T_{max} fell

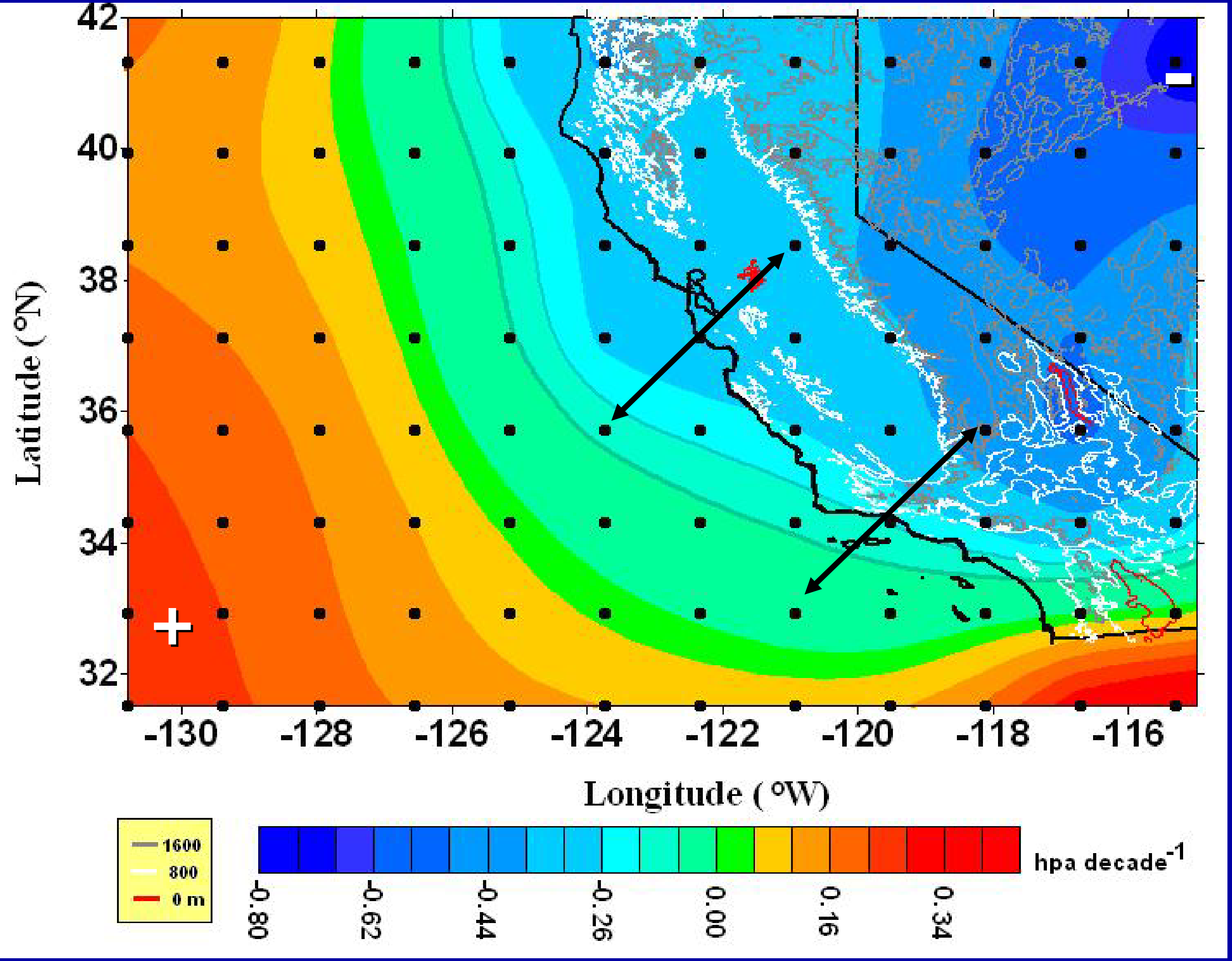
Obs 1970-2005 summer-average warming/cooling trends for all-CA COOP sites & for combined SoCAB+SFBA coastal-cooling & inland-warming sub-areas; p-values of ≥ 0.01, ≥ 0.05, ≥ 0.1 and < 0.1 indicated, respectively, by 3, 2, 1, & no (*)

Parameter	Trend (^{O}C/decade)		
	All California	SoCAB+SFBA sub-areas:	
		Inland warming	Coastal cooling
T_{ave}	0.15**	0.24	-0.01
T_{min}	0.27***	0.16	0.28
T_{max}	0.04	0.32	-0.30
DTR	-0.23*	0.16	-0.58

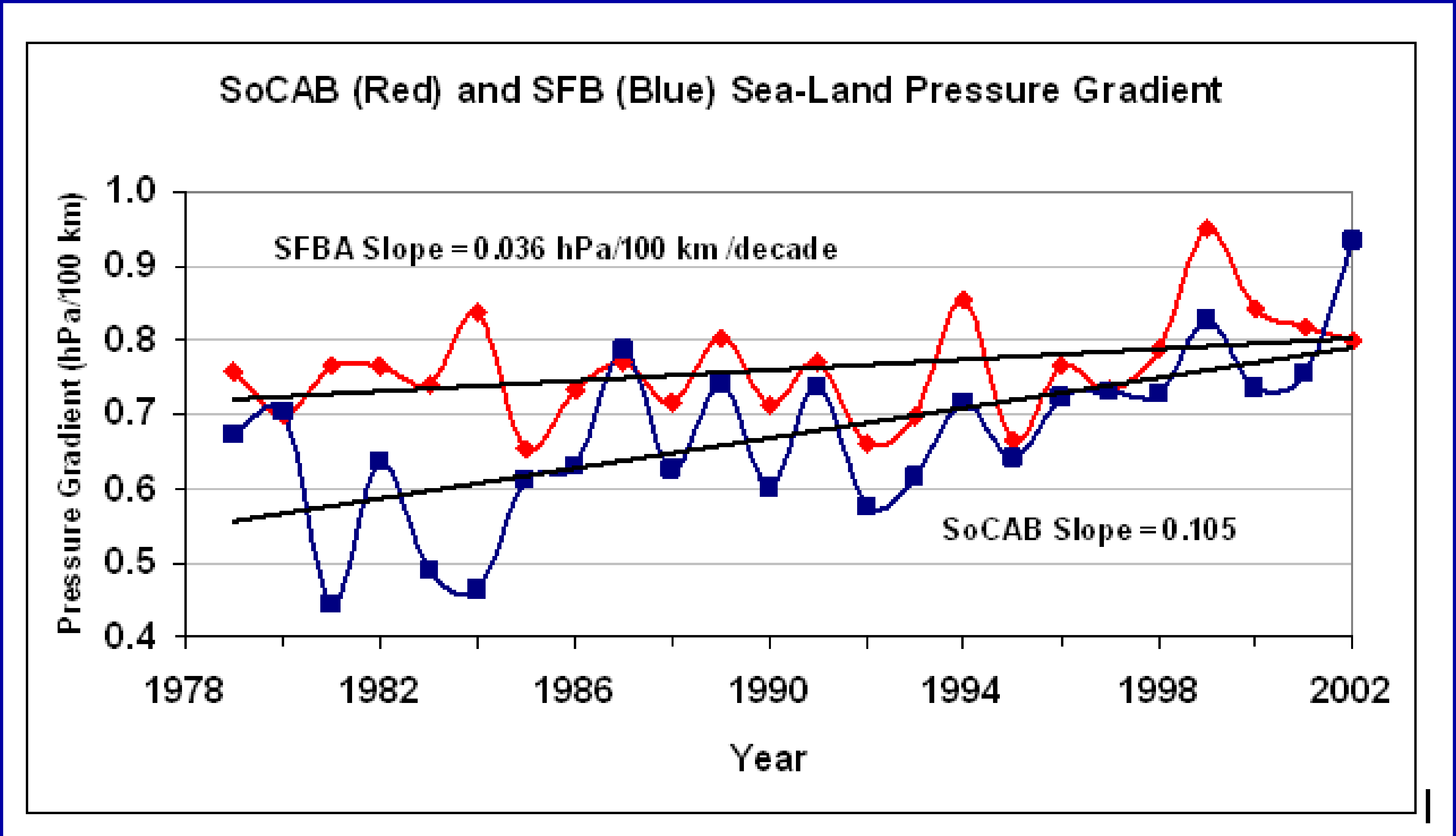
p-values notes:

- Cannot be given for sub-areas, as their a priori boundaries unfairly yield low values
- Min p-value for T_{min} is due to expected GHG warming
- Non-significant p-value for T_{max} due to its small mag, from cancellation of "+" inland & "-" coastal rates
- Mid-range p-value for T_{ave} due to averaging of T_{max} & T_{min} rates

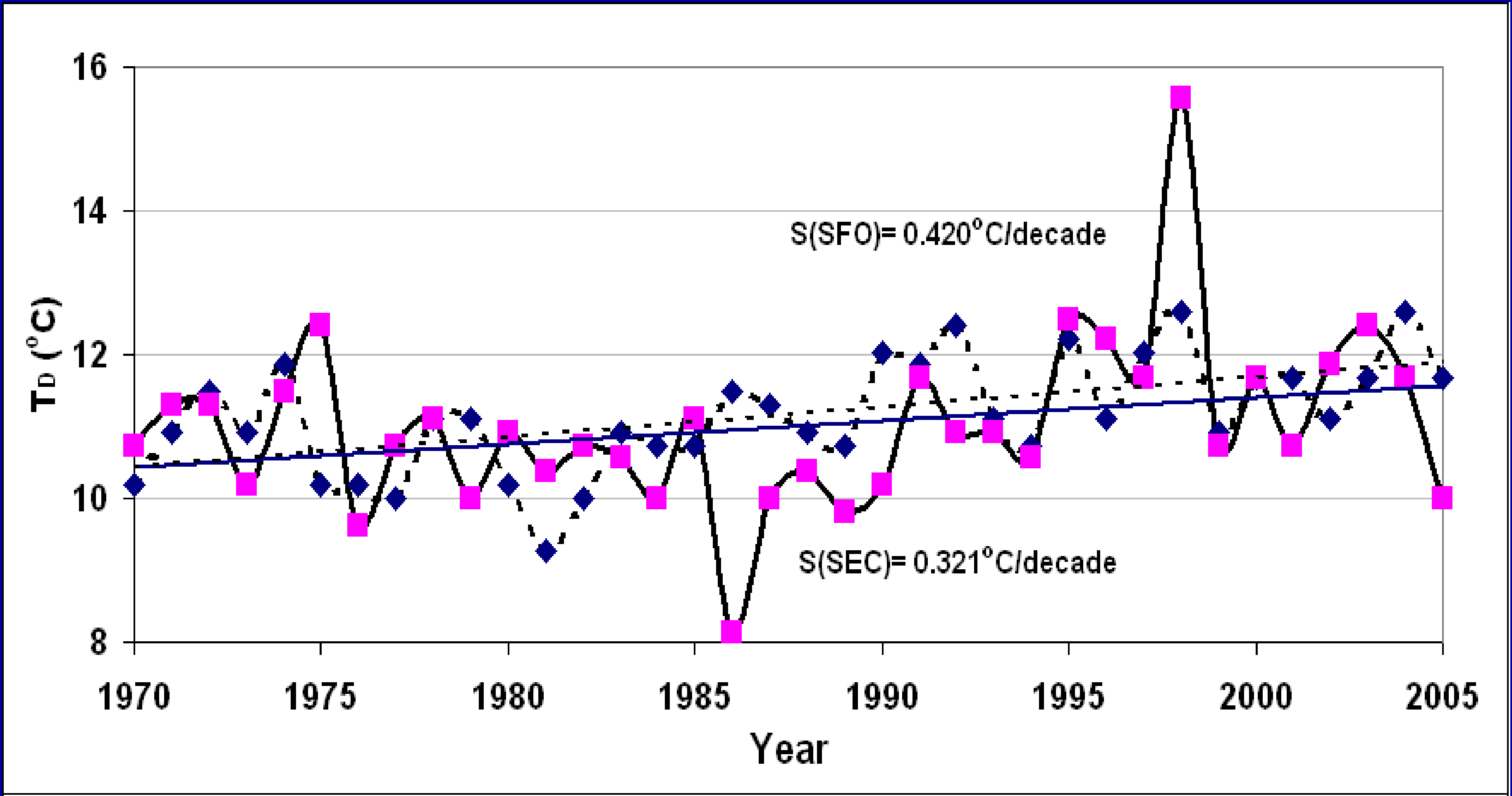
Result 4: Average 1970-2005 summer ERA40 1.4 deg model-reanalysis (dots show grid points) 1000-LT sea-level p-charges: up to +0.34 hPa/decade in oceanic Pacific-H & up to -0.8 hPa/decade in CA-NV Thermal-L; arrows represent coastal p-gradient calculation-points (next slide)



Result 5: Trend in ocean-to-land summer sea-level p-gradient (hPa/100-km/decade) at 1000 LST (between arrow-ends in previous slide)



Obs. Results 6: Summer 1600 LST dew-point temp-trends (^{O}C/decade) for 1970-2005 at two NWS airport sites: larger trend (i.e., faster increase of moisture) at coastal SFO than at inland SAC)



Current results are unique because this study is first to:

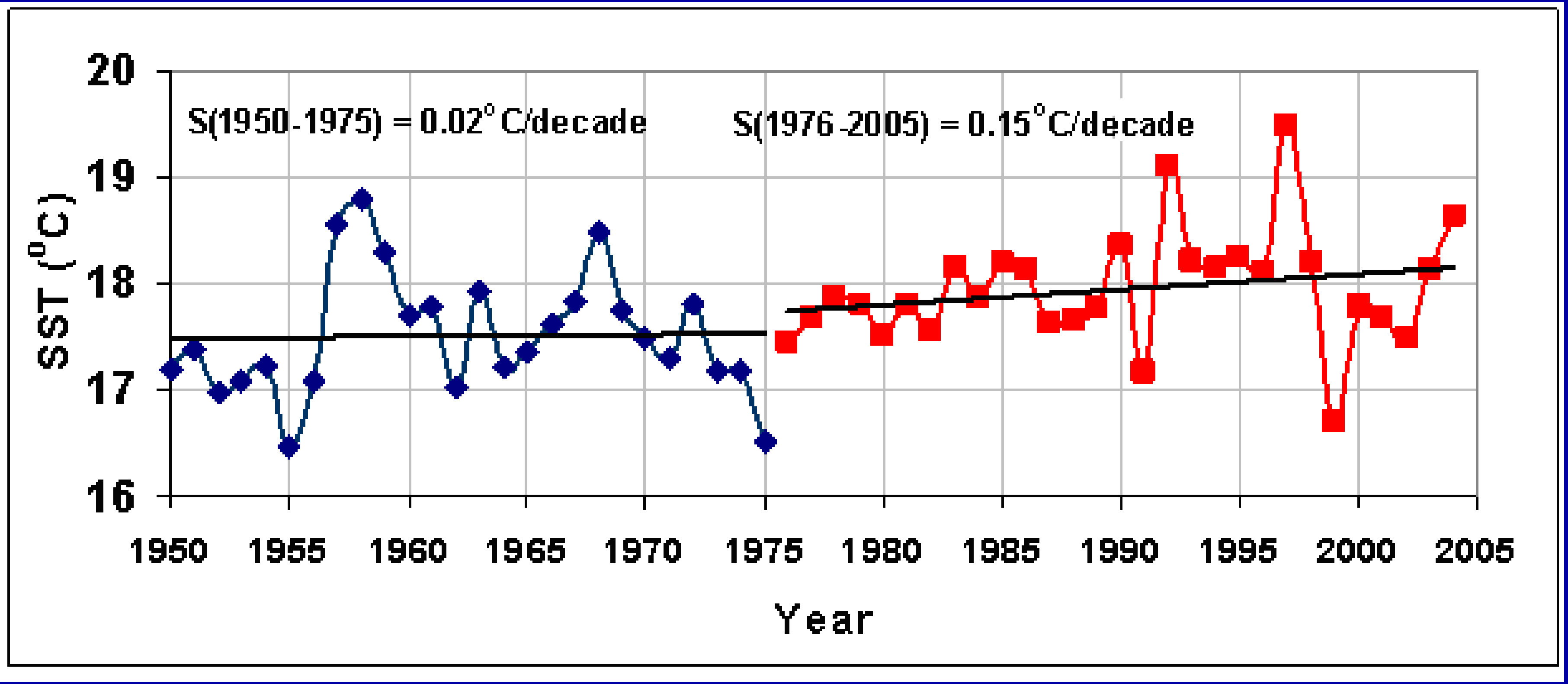
- divide obs. in all the following ways
  – summer-values only
  – T_{max} & T_{min}, as well as T_{ave}-values
  – coastal vs. inland sites
- consider sea-breeze enhancement as a causal mechanism, instead of just: GHGs, irrigation, SST, UHI, PDO, &/or aerosols (next slide)
- carry out both data analyses & urbanized meso-met modeling (next section)

Other explanations of coastal cooling

- GHG warming: a primary effect, but it can trigger secondary “reverse reaction” local effects
- UHI development: would warm (& not cool) temps
- SST changes: GHG warming off Calif.-coast seems stronger than increased upwelling (as SSTs are increasing, next slide), but a finer data resolution might show upwelling dominant near the coast
- PDO effects: were found (not shown) uncorre-lated to max-temps
- Increased (rural or urban) irrigation: can cool daytime temps; most important in Central Valley

SST-Trends

1976-2005 average JJA SSTs for ocean area of Slide 7. Trends are 0.02 and 0.15 °C/decade, respectively.



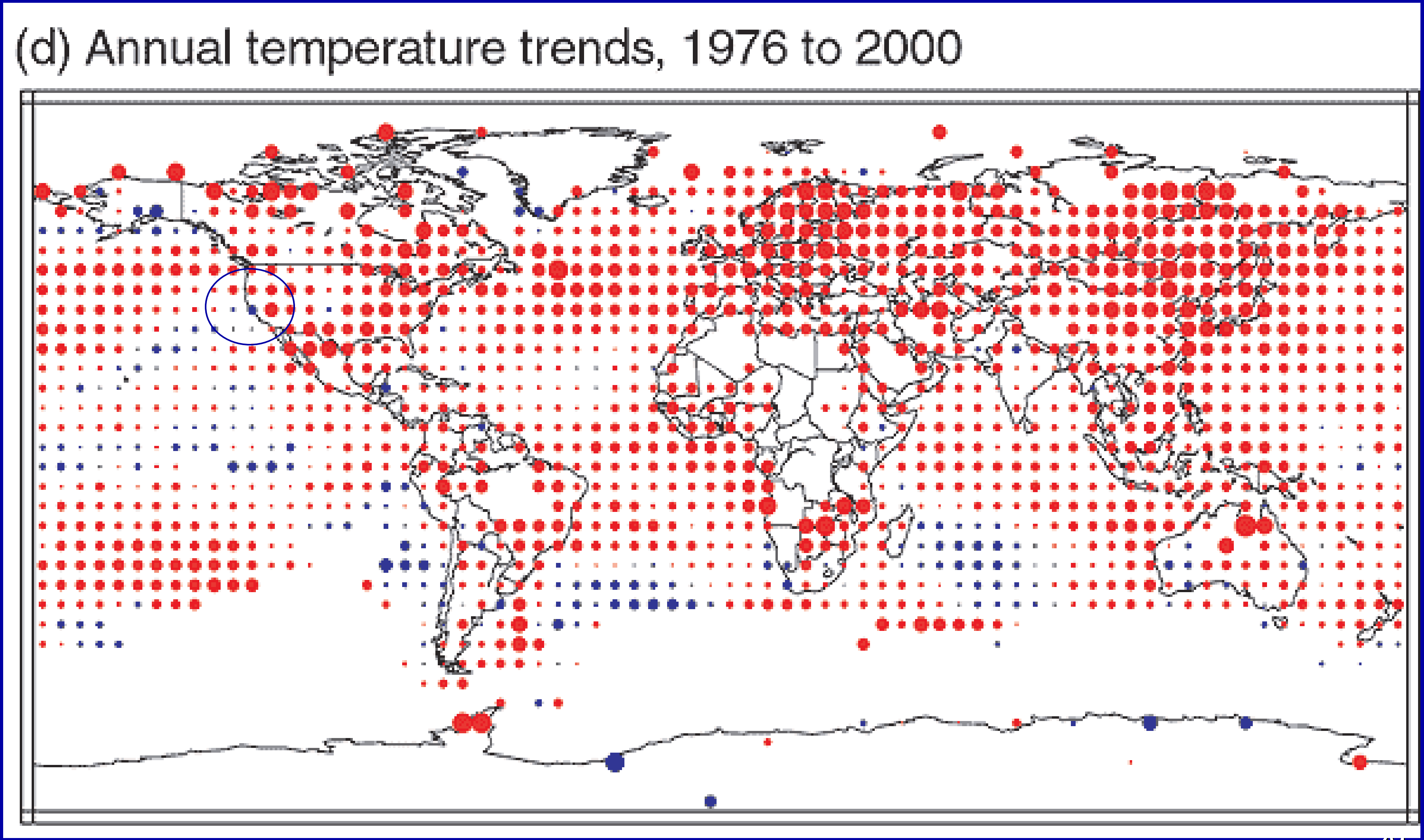
Summary Of Current CA Obs

- Summer Min-temps in CA have been warming faster than Max-temps
- Summer Daytime Max-temps have been cooling, but only in low-elevation Coastal air basins
- The following areas are Cooling in Central California:
  - >Marine lowlands   > Monterey
  - > Santa Clara & Livermore Valleys
  - > Western Sacramento Valley
- Current obs are, however, consistent with CA-COOP lit-results (next 2 slides) & IPCC (3rd next slide), but are more detailed & focused

Publication	Parameter Studied	Finding
Goodridge (1991)	80 years of annual-average daily T_{ave} at 112 site	Warming in both coastal (attributed to warming SSTs) & inland urban (attributed to UHI effects) areas; cooling in inland rural areas was unexplained
Nemani et al. (2001)	Sites in Napa & Sonoma Valleys during 1951-97 for T_{min} & T_{max}	T_{min} increased & T_{max} slightly decreased, both attributed to measured increased cloud cover. Increased annual coastal T_D related to increased SSTs
Duffy et al. (2006)	Interpolated (to grid) monthly-average T_{ave} from 1950-99	Warming in all seasons, attributed to increased UHIs or GHGs
Christy et al. (2006)	18 Central Valley sites from 1910-2003 for T_{ave} T_{max}, & T_{min}	Increased T_{ave} & T_{min} in all seasons, greater in summer & fall. Summer cooling T_{max} & warming T_D values attributed to increased summer irrigation

Bonfils & Duffy (2007)	Christy et al. (2006) T_{min}	Warming T_{min} not due to irrigation, which could only overcome GHG-warming for T_{max}
Bonfils & Lobell (2007) and Lobell & Bonfils (2008)	Gridded T_{max} & T_{min}	Expanded irrigation cooled summer T_{max}, while producing negligible effects on T_{min}
LaDochy et al. (2007)	331 sites during 1950-2000 for T_{ave}, T_{min}, & T_{max}	Annual T_{ave} warming at most sites. Almost all increases due to changes in T_{min} (max in summer), as T_{max} showed no change or cooling. Max T_{ave} warming in southern CA, but NE Interior Basin showed cooling
Abatzoglou et al. (2008)	Coastal sites during 1970-2000 for T_{max}	Significant coastal cooling in late summer & early fall

Note: note IPCC 2001 cooling over SFBA!!



Our Group's Meso-modeling Experience

- SJSU (MM5 & uMM5)
  - Lozej (1999) MS: SFBA winter wave cyclone
  - Craig (2002) MS: Atlanta UHI-initiated thunderstorm (NASA)
  - Lebassi (2005) MS: Monterey sea breeze (LBNL)
  - Ghidey (2005) MS: SFBA/CV CCOS episode (LBNL)
  - Boucouvula (2006a,b) Ph.D.: SCOS96 episode (CARB)
  - Balmori (2006) MS: Tx2000 Houston UHI (TECQ)
  - Weinroth (2009) PostDoc: NYC-ER UDS urban-barrier effects (DHS)
- SCU (uRAMS)
  - Lebassi (2005): Sacramento UHI (SCU)
  - Lebassi (2009) Ph.D.: SFBA & SoCAB coastal-cooling (SCU)
  - Comarazamy (2009) Ph.D.: San Juan climate-change & UHI (NASA)
- Altostratus (uMM5 & CAMx)
  - SoCAB (1996, 2008): UHI & ozone (CEC)
  - Houston (2008): UHI & ozone (TECQ)
  - Central CA (2008): UHI & ozone (CEC)
  - Portland (current): UHI & ozone (NSF)
  - Sacramento (current): UHI & ozone (SMAQMD)
- 2009 = submitted for presentation at AMS national conference

SJSU Ideas On Good Meso-Met Modeling

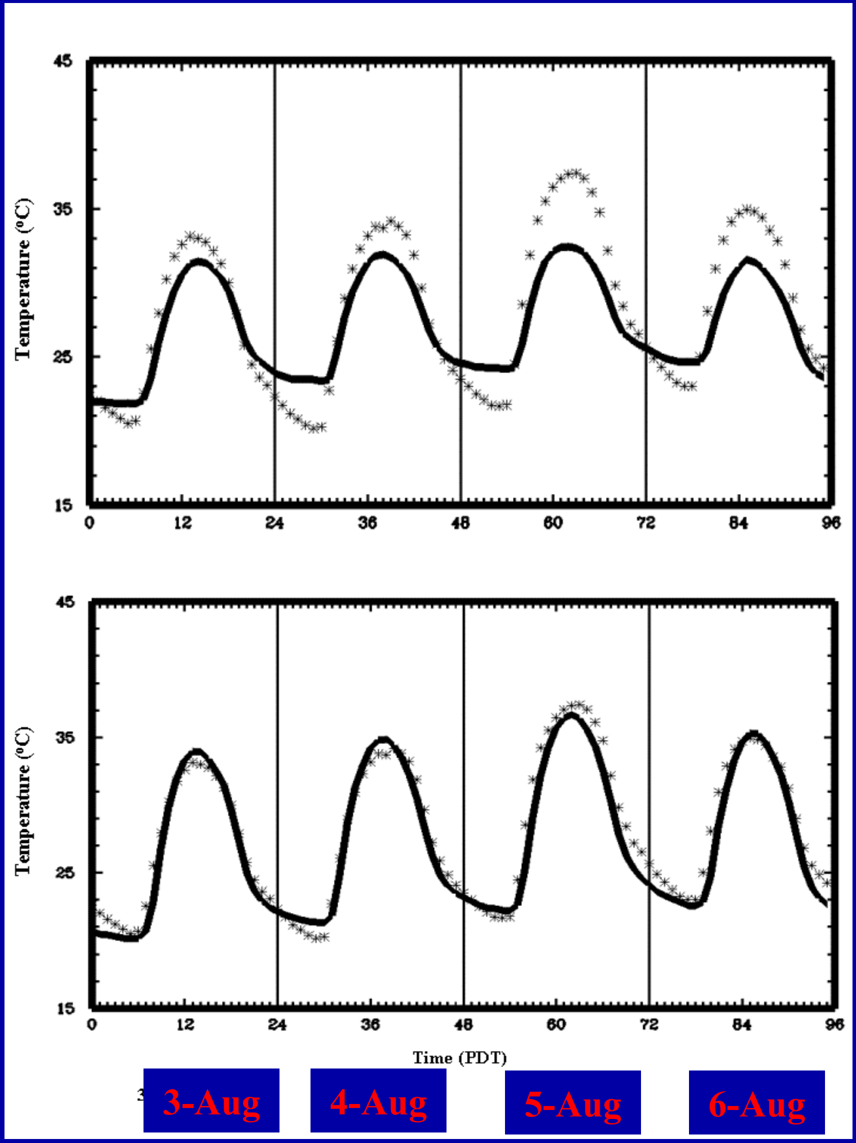
MUST CORRECTLY REPRODUCE:

- UPPER-LEVEL Synoptic/GC FORCING FIRST:
  - pressure (“the” GC/Synoptic driver) → Synoptic/GC winds
- TOPOGRAPHY NEXT:
  - min horizontal grid-spacing → flow-channeling
- MESO SFC-CONDITIONS LAST:
  - temp (“the” meso-driver) & roughness → meso-winds

Case 1: SoCAB SCOS97 O_3 episode (Boucouvula PhD)

RUN 1: has
- ➢No GC warming trend
- ➢Wrong max and min T

RUN 5: corrected, as it used
- > Analysis nudging
- > Reduced deep-soil T



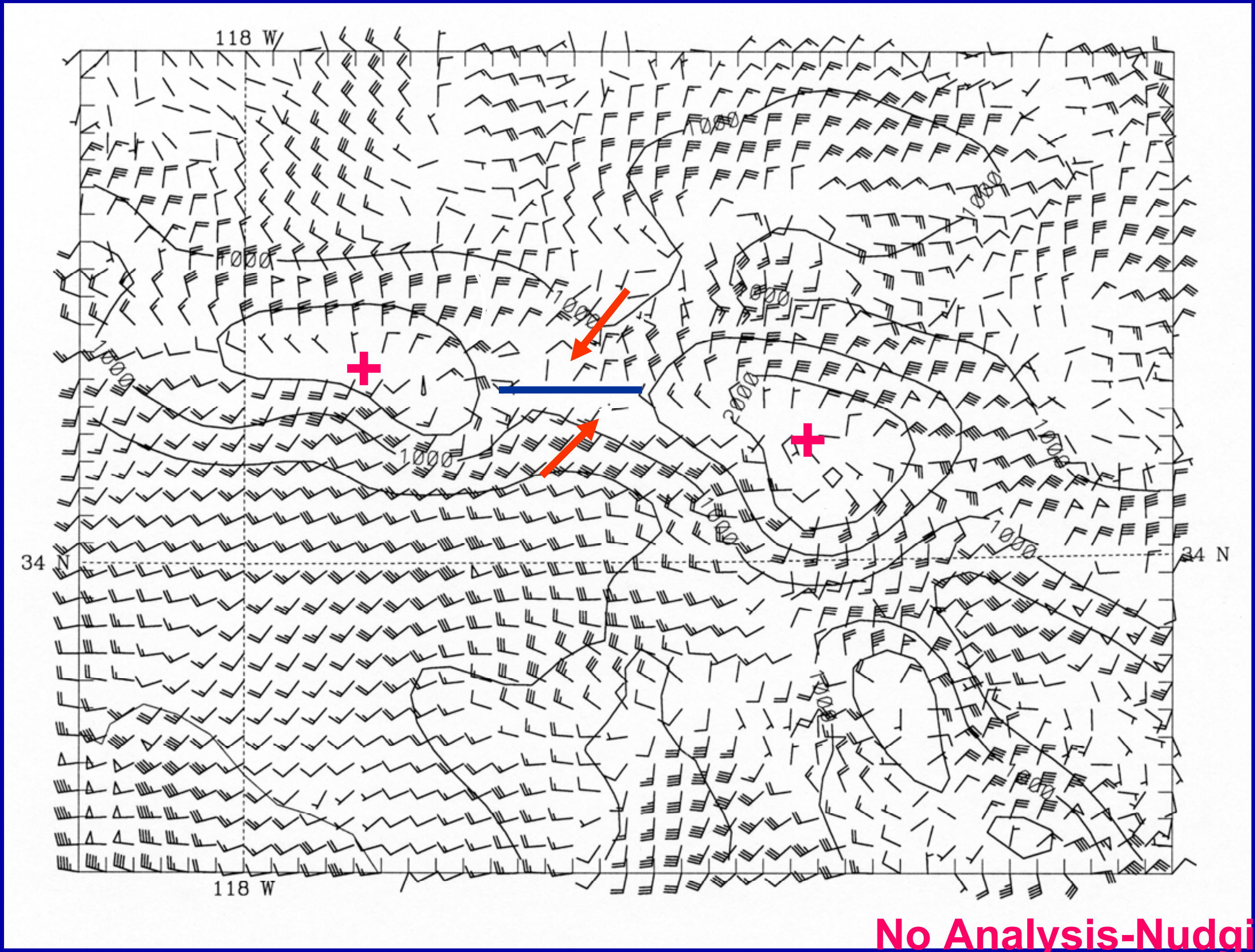


Fig. 8a

No Analysis-Nudging: MM5 sfc-V, 1-hour b/f O_3-max (weak oppos-ing sfc-flow)

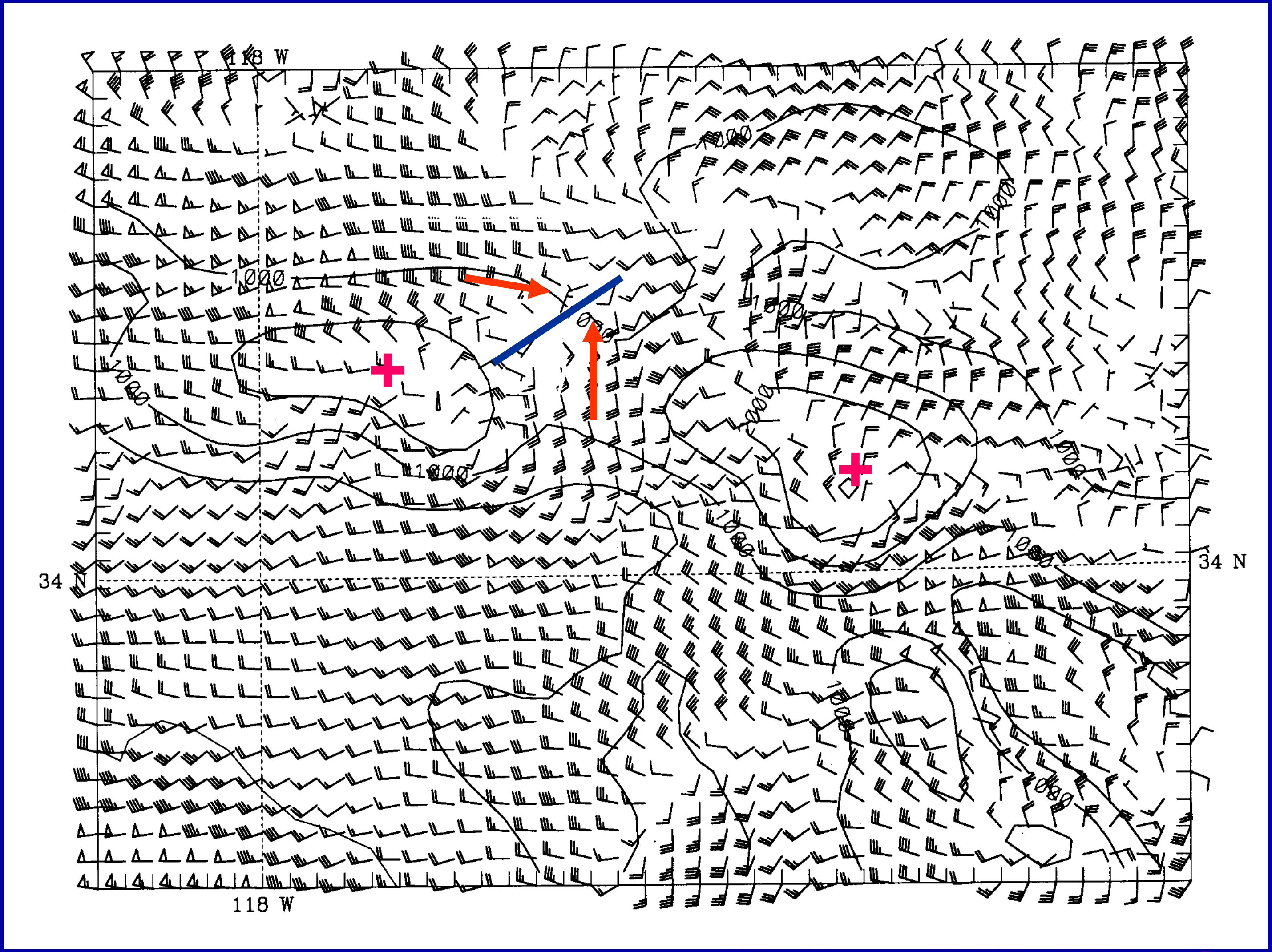


Fig. 8b

No Analysis-Nudging →
Weak opposing sfc-flow →
O_3 leaves valley → No episode

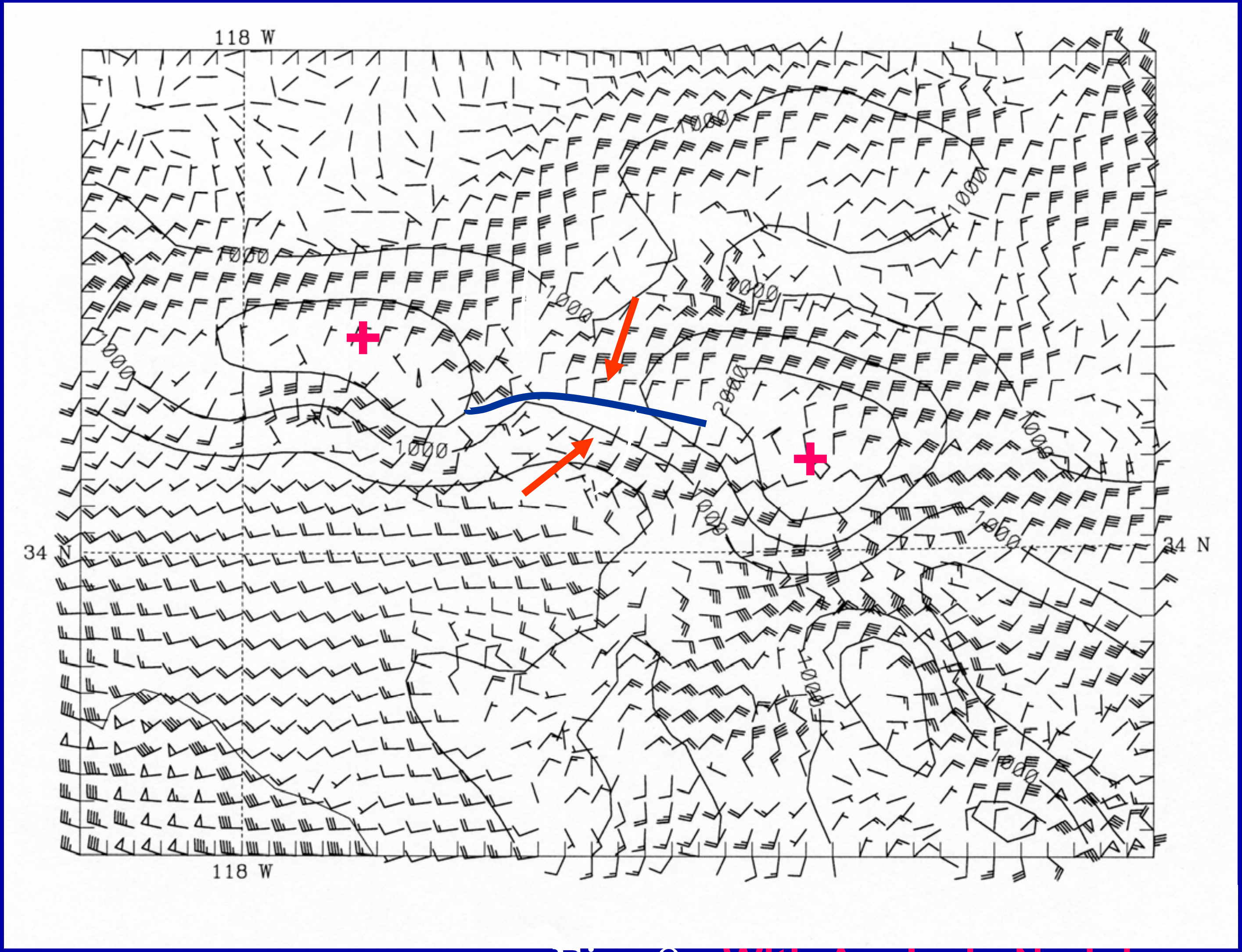


Fig. 8c **With Analysis-Nudging: MM5 sfc-V, 1-hour b/f O_3-max (stronger opposing sfc-flow)**

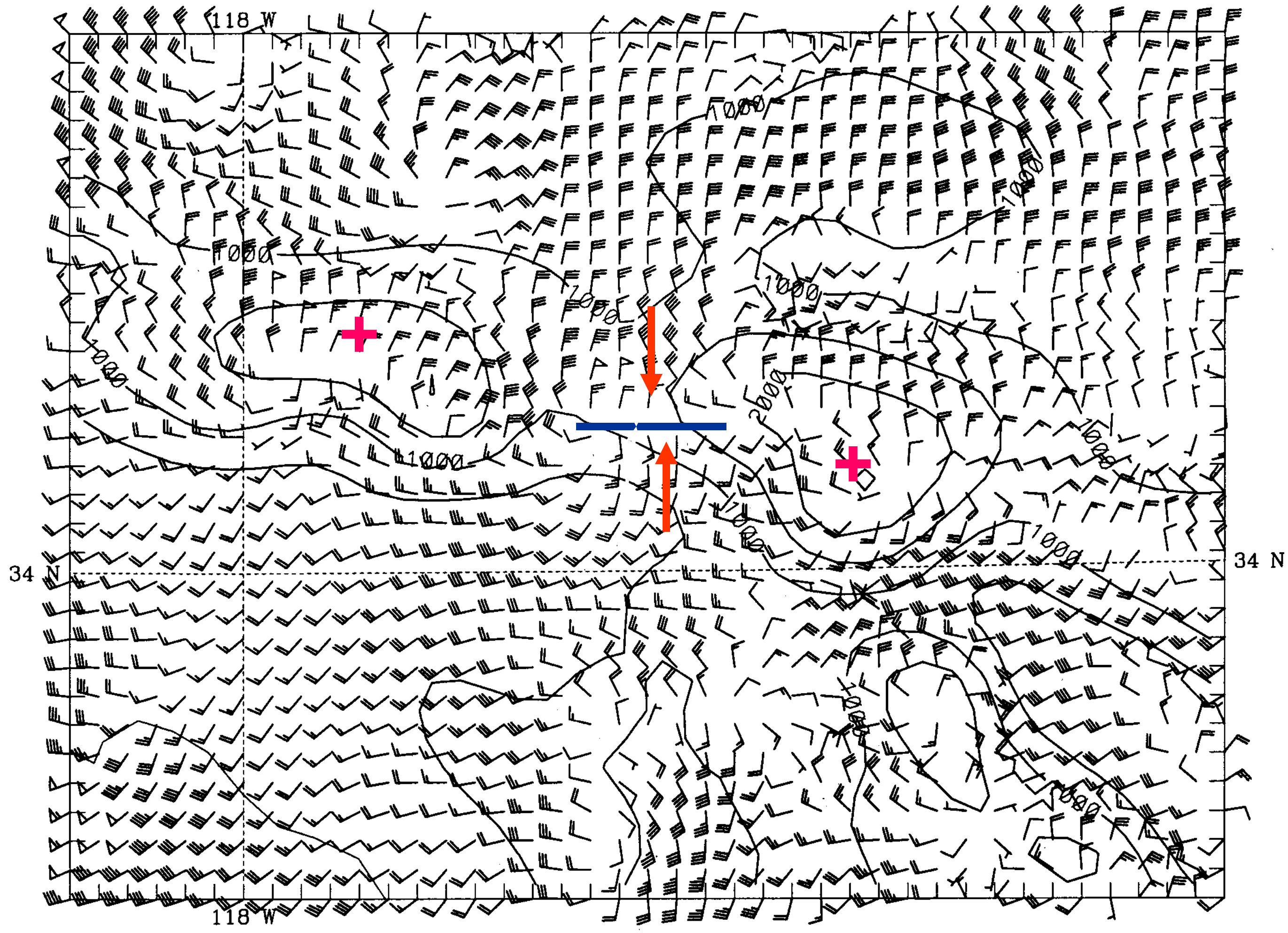


Fig. 8d

With Analysis-Nudging →
Strong opposing sfc-flow →
O_3 remains in valley→ episode

Case 2: SFBA Summer CCOS O_3-episode (Ghidey MS)

- Obs: daily max- O_3 sequentially moved from Livermore to Sacramento to SJV
- Large scale IC/BC:

  shifting meso-700 hPa high →

  shifting meso-sfc low →

  changing sfc-flow →

  max-O_3 changed location
- MM5 (next 2 slides):

  good analysis-nudging → good sfc-wind

Livermore episode afternoon (1400 PDT): W flow thru GGG & weak con into Eastern Liv

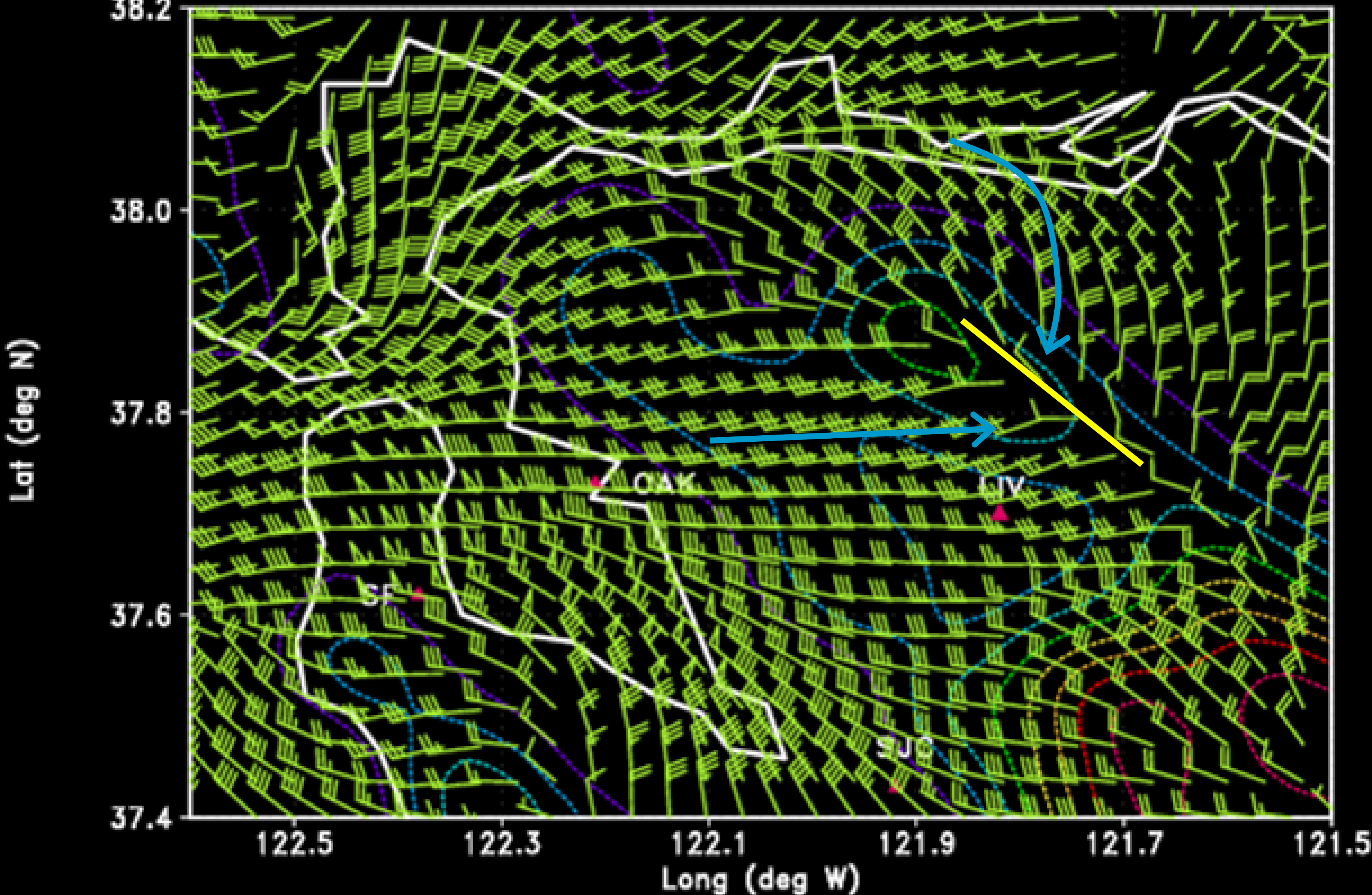


Fig. 17. Run 4 Domain 3, V (flag 5 m/s) at ~10 m for every 2nd value at 2100 UTC on 30 July, with topographic heights (dashed lines, at 100 m interval).

SAC episode day: D-1 700 hPa Syn H moved to Utah with coastal "bulge" & L in S-Cal→ correct SW flow from SFBA to Sac

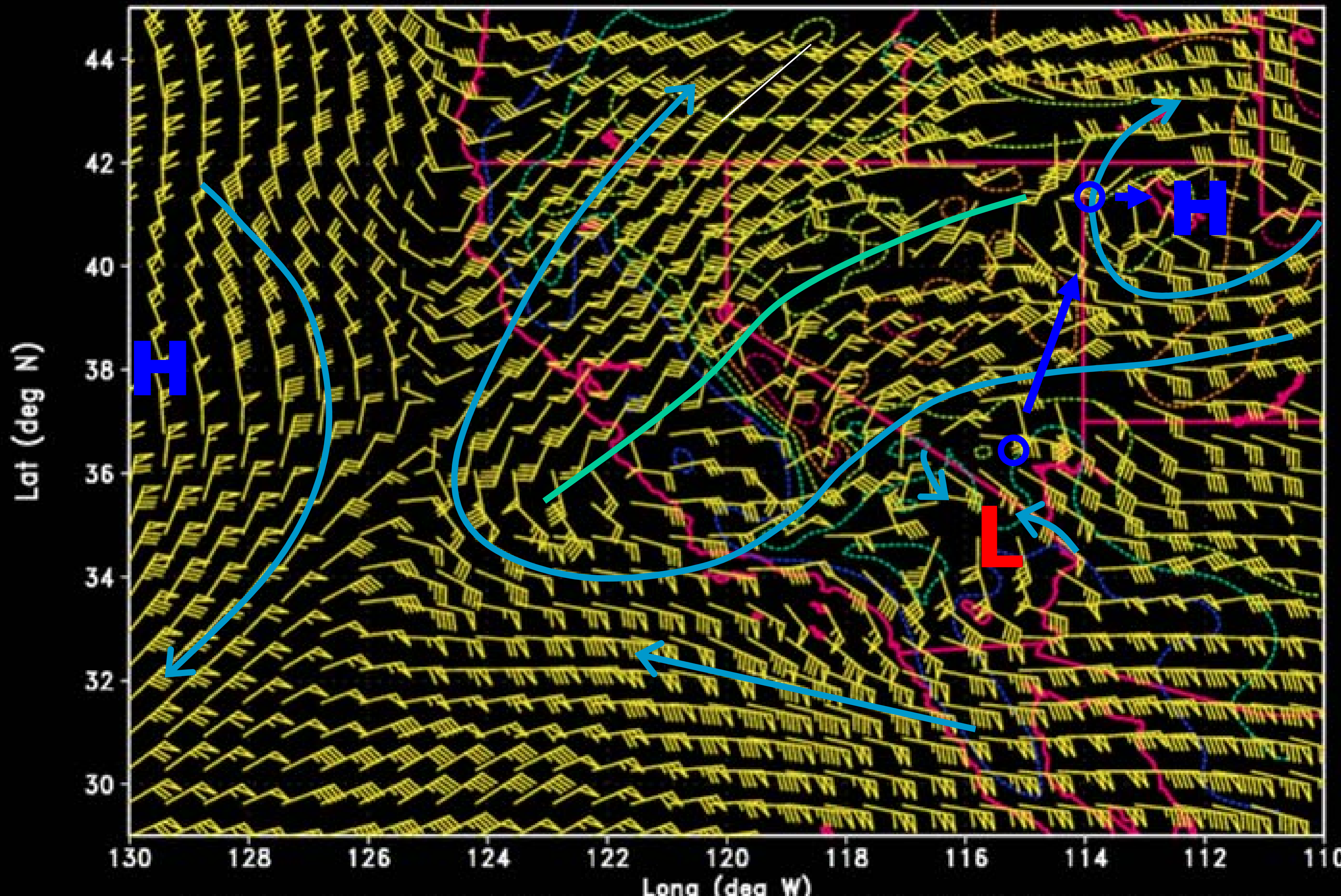


Fig. 7. Run 4 Domain 1, V (flag 5 m/s) at σ = 0.6555 (~700 hPa) for every 4th value at 1200 UTC 01 Aug, with topographic heights (dashed lines, at 500 m interval).

SJV episode day: D-3 700 hPa Fresno eddy moved N & H moves inland→ flow around eddy blocks SFBA flow to SAC, but forces it S into SJV

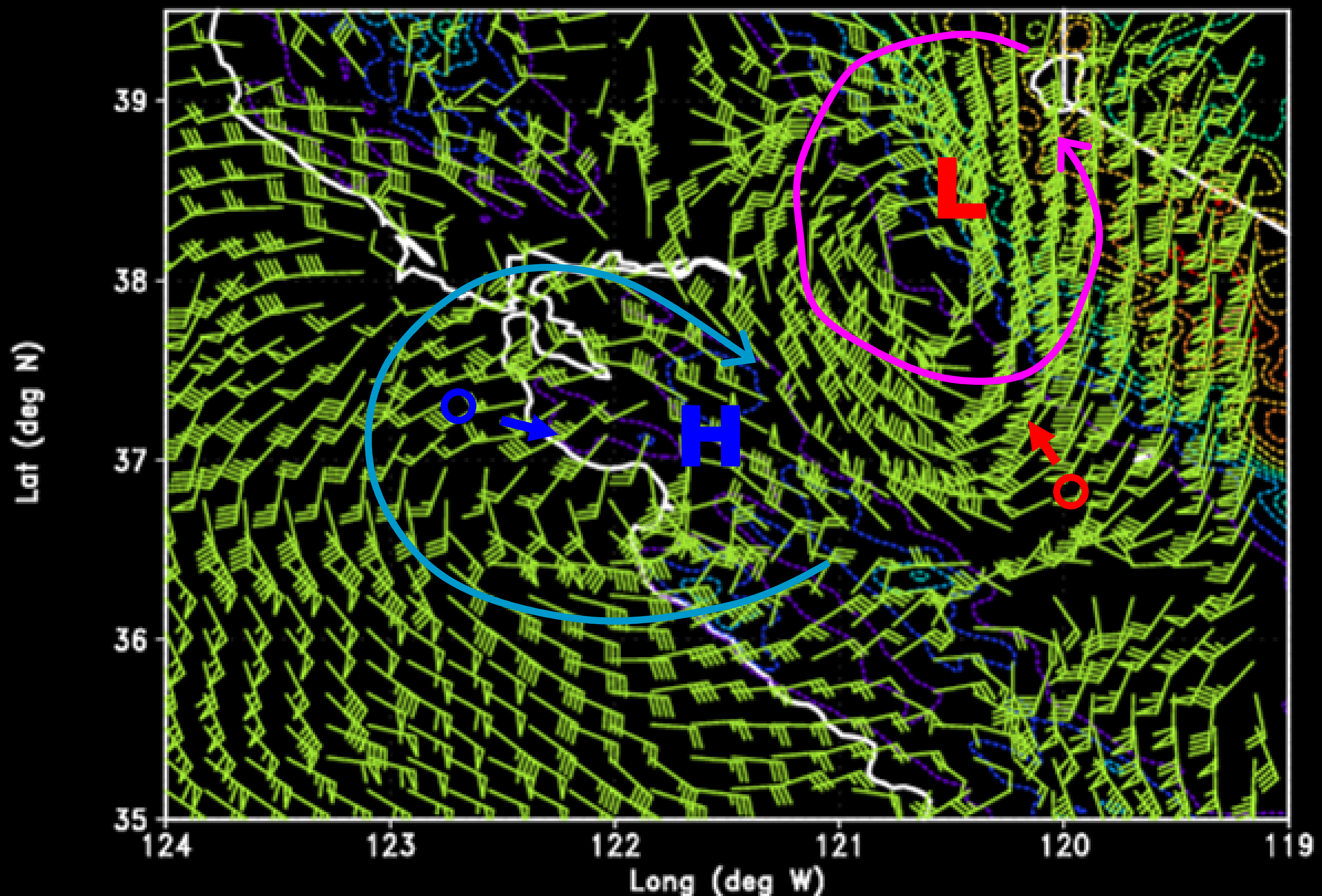


Fig. 17. Run 4 Domain 3, V (flag 5 m/s) at σ= 0.6555 (~700 hPa) for every 10th value at 2100 UTC on 02 Aug, with topographic heights (dashed lines, at 300 m interval).

Recent Meso-Met Model Urbanization

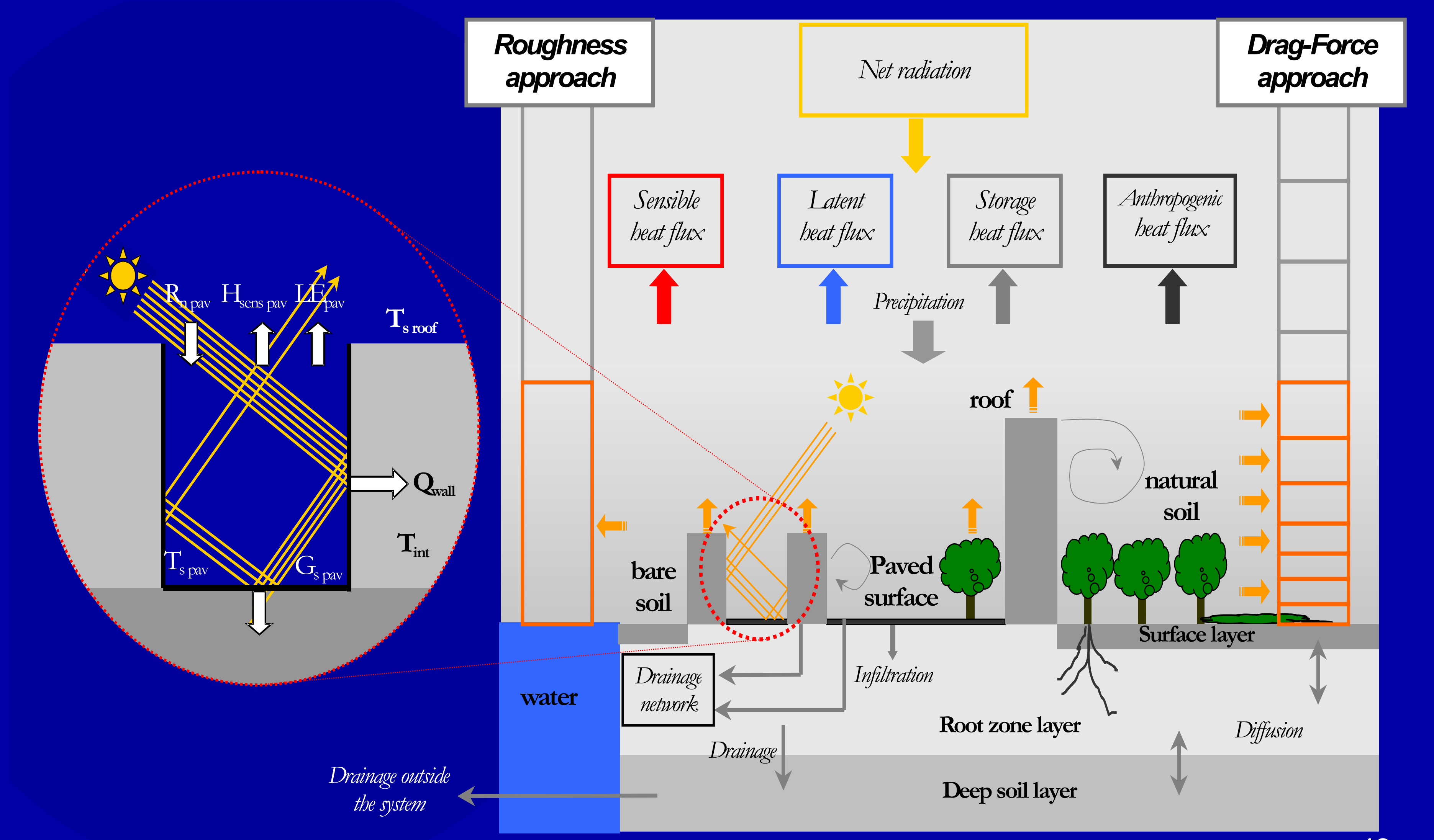
- Need to urbanize momentum, thermo , & TKE
  - surface & SfcBL diagnostic-eqs.
  - PBL prognostic-eqs.
- Start: *veg*-canopy model (Yamada 1982)
- Veg-param *replaced* with GIS/RS urban-param/data
  - Brown and Williams (1998)
  - Masson (2000)
  - Martilli et al. (2001) in TVM/URBMET
  - Dupont, Ching, et al. (2003) in EPA/MM5
  - Taha et al. (‘05, ‘08a,b,c) [& Balmori et al. (‘06)]: his uMM5 uses improved urban dynamics, physics, parameterizations, & inputs

From EPA uMM5:

Mason + Martilli (by Dupont)

Within Gayno-Seaman

PBL/TKE scheme



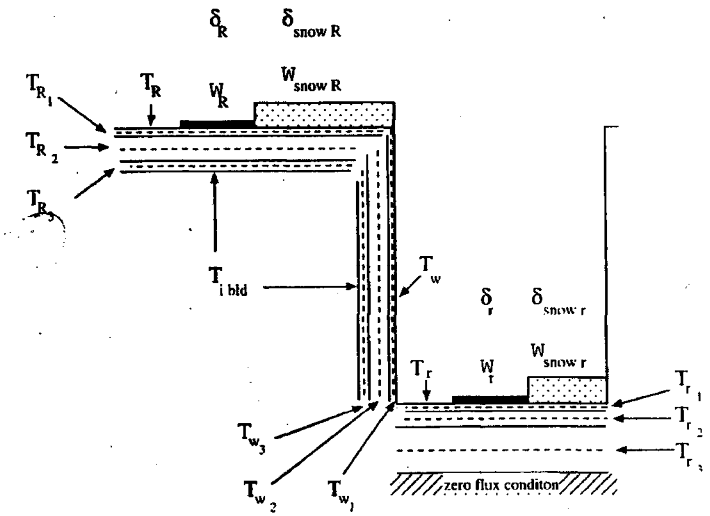


Figure 1. Discretization of the surfaces (roof, wall, road) and prognostic variables: layer temperatures T_{*k} ($* = R, w, r$; here three layers are displayed for each surface, so $k = 1, 2, 3$), surface water content W_* ($* = R, r$), surface snow content W_{snow*} ($* = R, r$). The layer temperatures are representative of the middle of each layer (dotted lines). The surface temperatures are assumed to be equal to the surface-layer temperature: $T_* = T_{*1}$. The internal building temperature $T_{i\,bld}$ is prescribed. Fractions of water or snow (δ_* and δ_{snow*}, respectively) are computed from the water and snow contents (see text). Snow density, albedo and temperature are computed independently for roof and road by a snow mantel scheme (in this paper, a one-layer scheme was chosen).

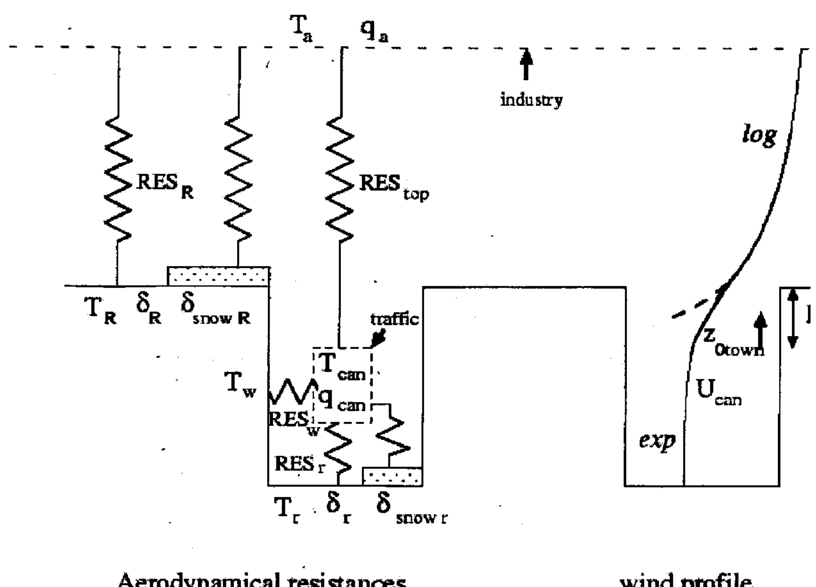


Figure 15.3: Energy fluxes between the artificial surfaces and the atmosphere.

Urban Parameterization for Mesoscale Models:

Martilli et al. (2000)

Momentum

Three terms are added to the horizontal momentum equations to account for *walls*, *roofs*, and *streets*.

Street

$$M_{S_i} = -\rho u_{*S}^2 \frac{U_i}{\sqrt{u^2+v^2}}\left[\frac{S_S}{V-V_b}\right]$$

Roof

$$M_{R_i} = -\rho u_{*R}^2 \frac{U_i}{\sqrt{u^2+v^2}}\left[\frac{S_R}{V}\right]$$

3 new terms in each prog. equation

Wall

$$M_{W_i} = -\rho C_{drag} U_{ort} U_i \left[\frac{S_W}{V-V_b}\right]$$

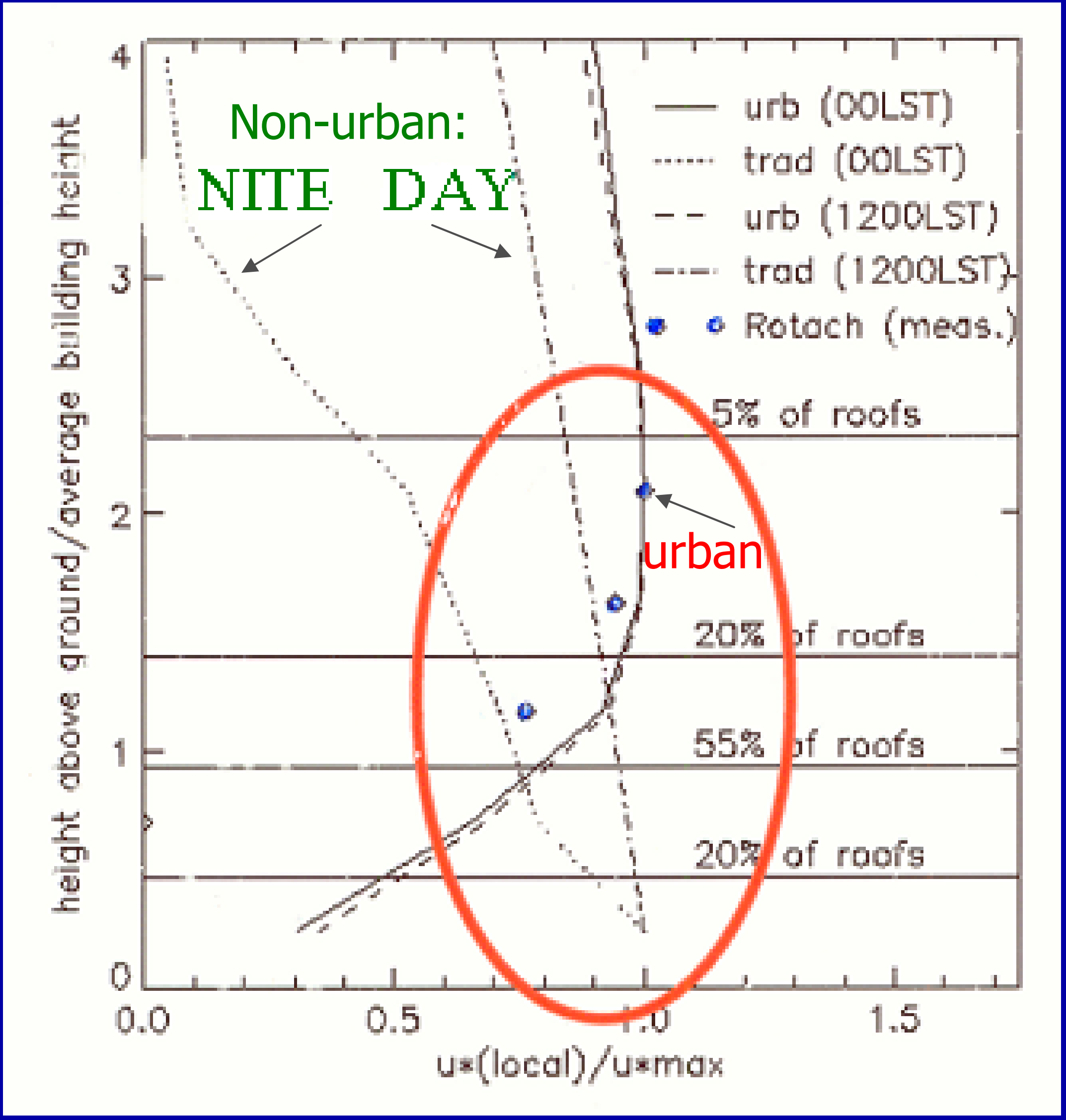
Where S = sfc area
V = vol

← Advanced urbanization scheme from Masson (2000)

But, uMM5 needs extra GIS/RS inputs as f (x, y, z, t)

- land use (38 categories)
- roughness elements
- anthropogenic heat as f (t)
- vegetation and building heights
- paved-surface fractions
- drag-force coefficients for buildings & vegetation
- building H to W, wall-plan, & impervious-area ratios
- building frontal, plan, & rooftop area densities
- wall and roof: ε, $c\rho$, α, etc.
- vegetation: canopies, root zones, stomatal resistances

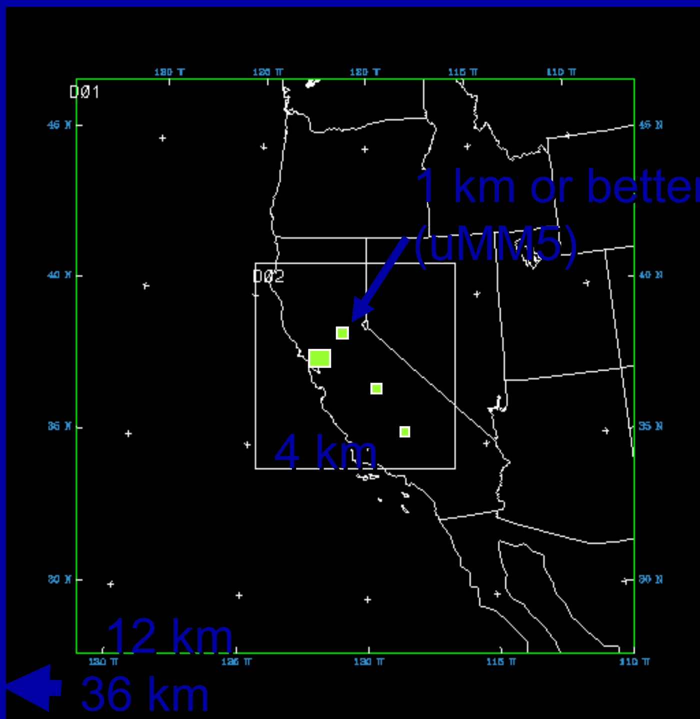
Is extra work worth it?
Below are Martilli uMM5 turbulence results

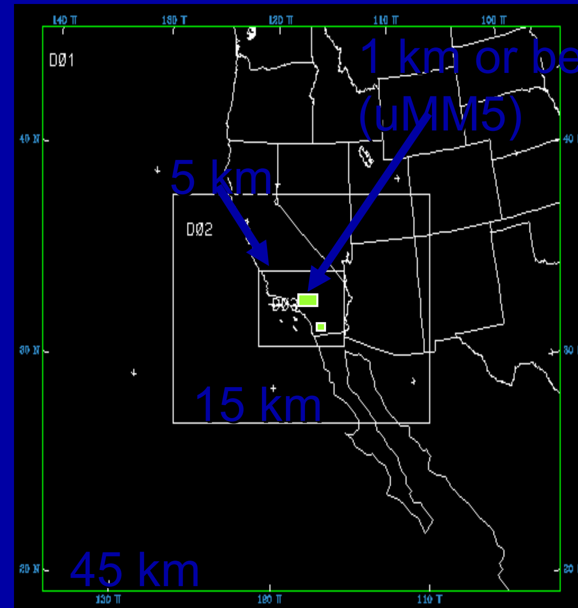


uMM5 results:

- **Day & nite values are on same line → small stability effects**
- **Rooftop max matches obs**

uMM5 work of Taha
Next 6 slides

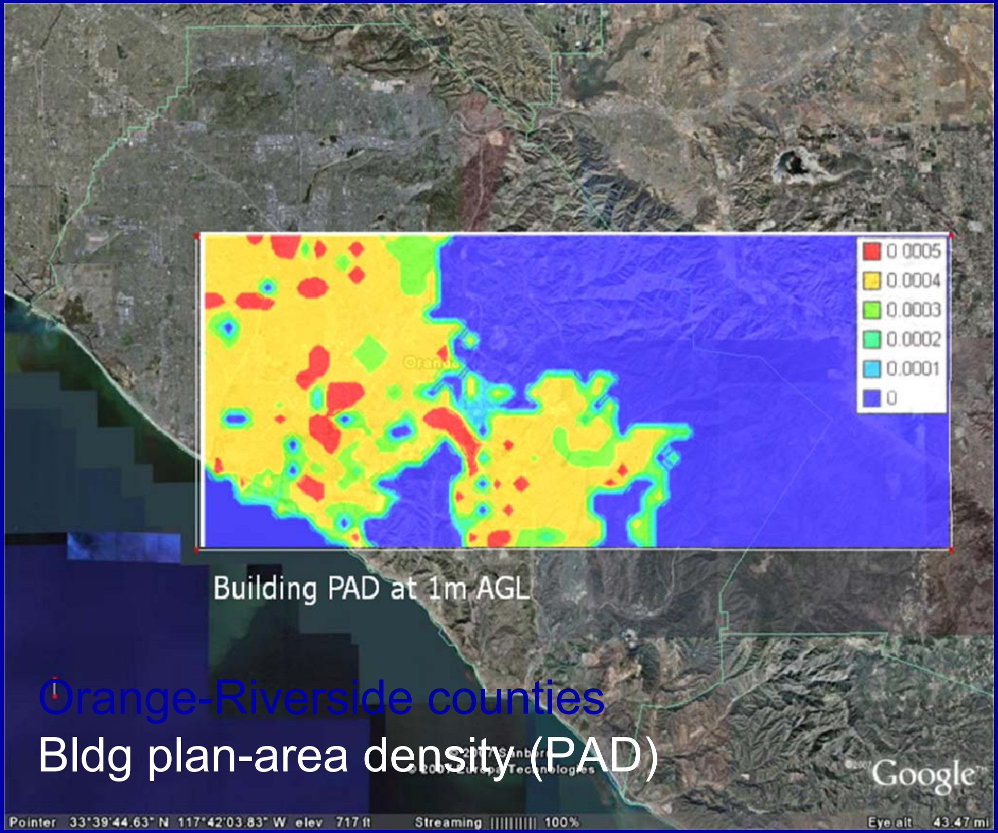


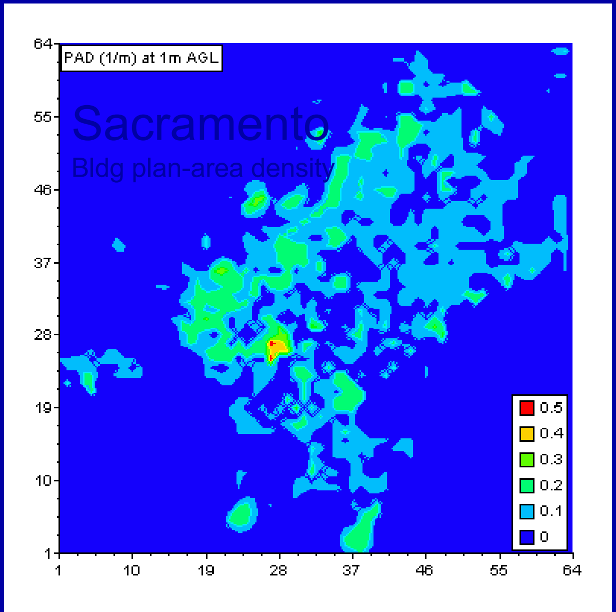


Mesoscale & meso-urban modeling domains for: central Calif., southern California, & eastern Texas

Taha, H. 2008a,b,c, *BLM & Atmos Environment*

Improved urban-region surface & morphological characterization





Development of complete fine-resolution 3-D urban canopy characterizations for input into meso-urban models, in vertical at 1 m & in horizontal at 200 m

Taha, H. 2007c, *Final Report, CEC*

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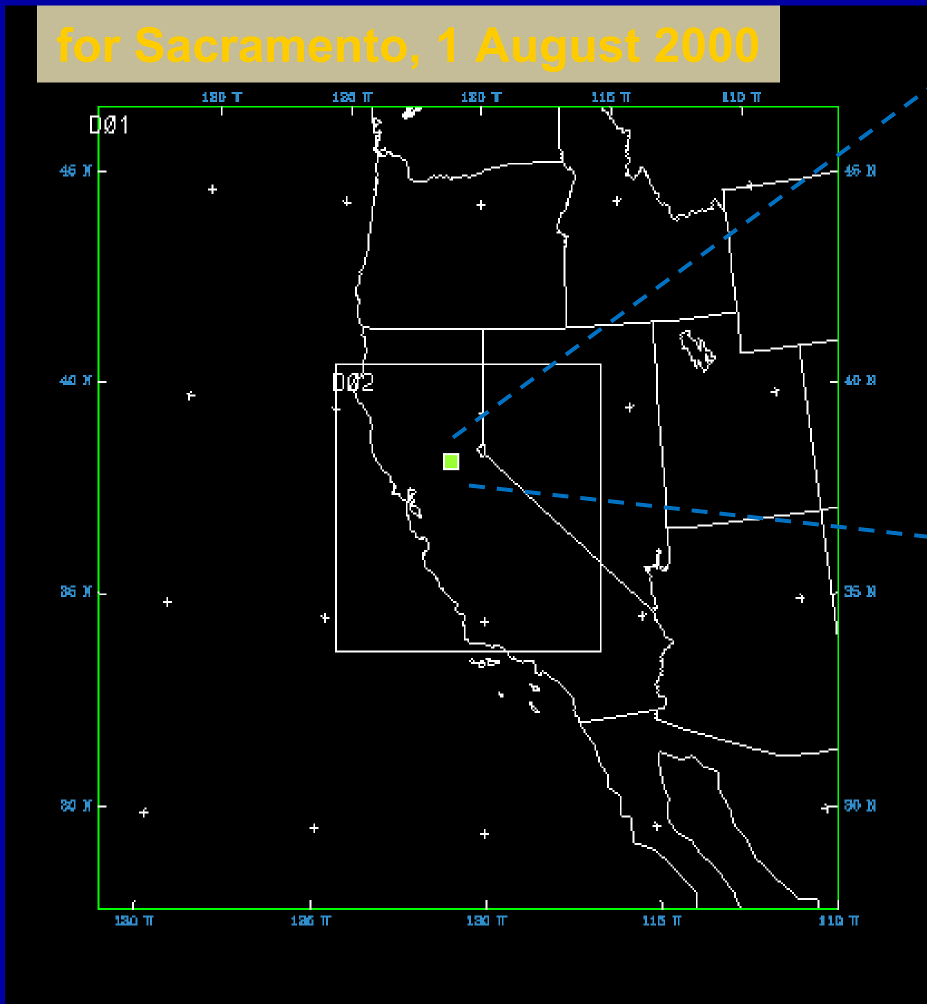
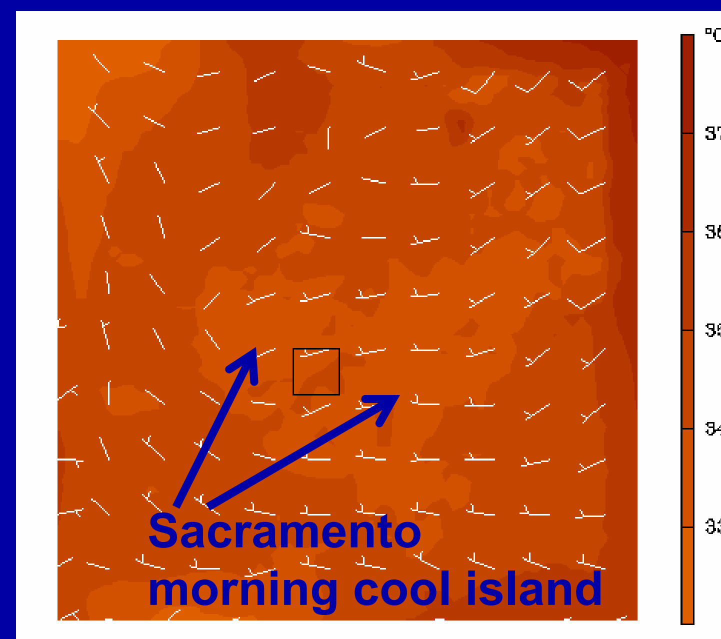


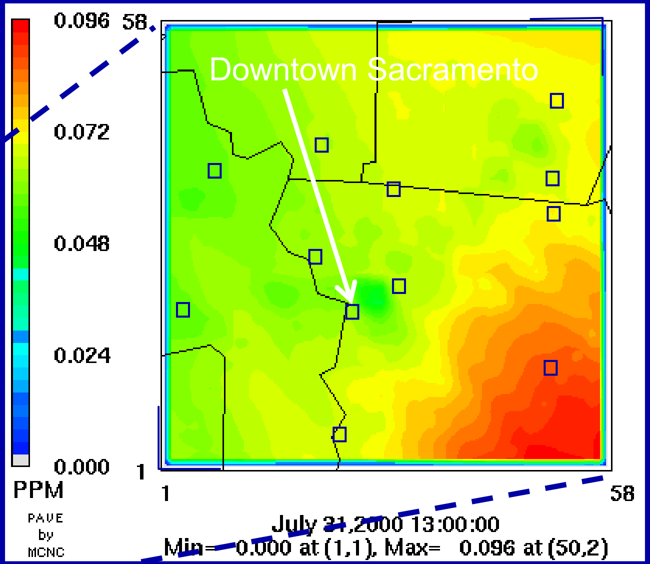


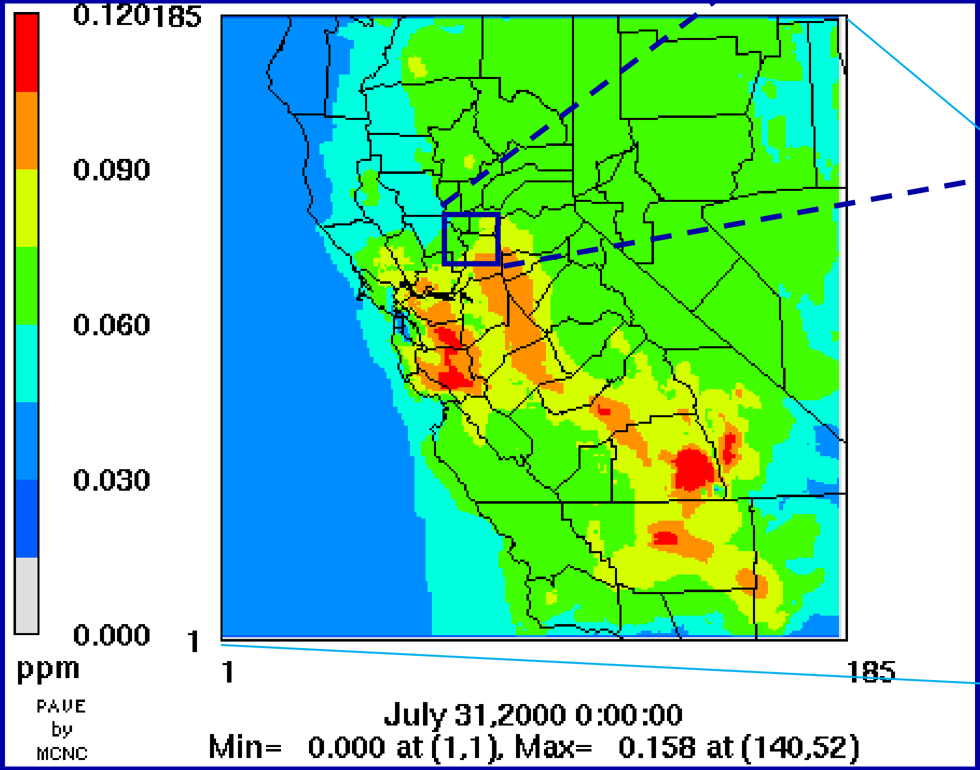
Meso-urban modeling of fine-resolution UHI features Taha, H. 2008c, *Atmos Environ*

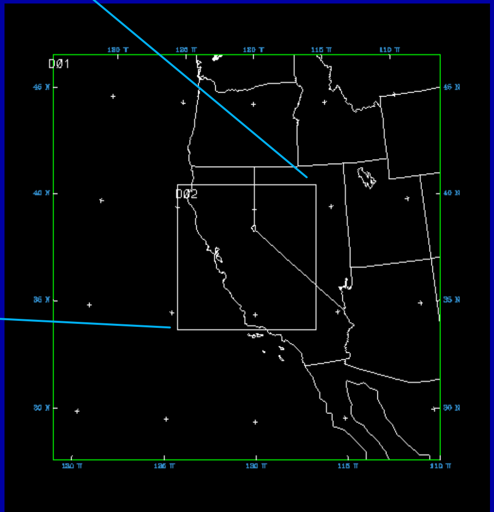
ALTOSTRATUS

Fine-resolution photochemical simulations

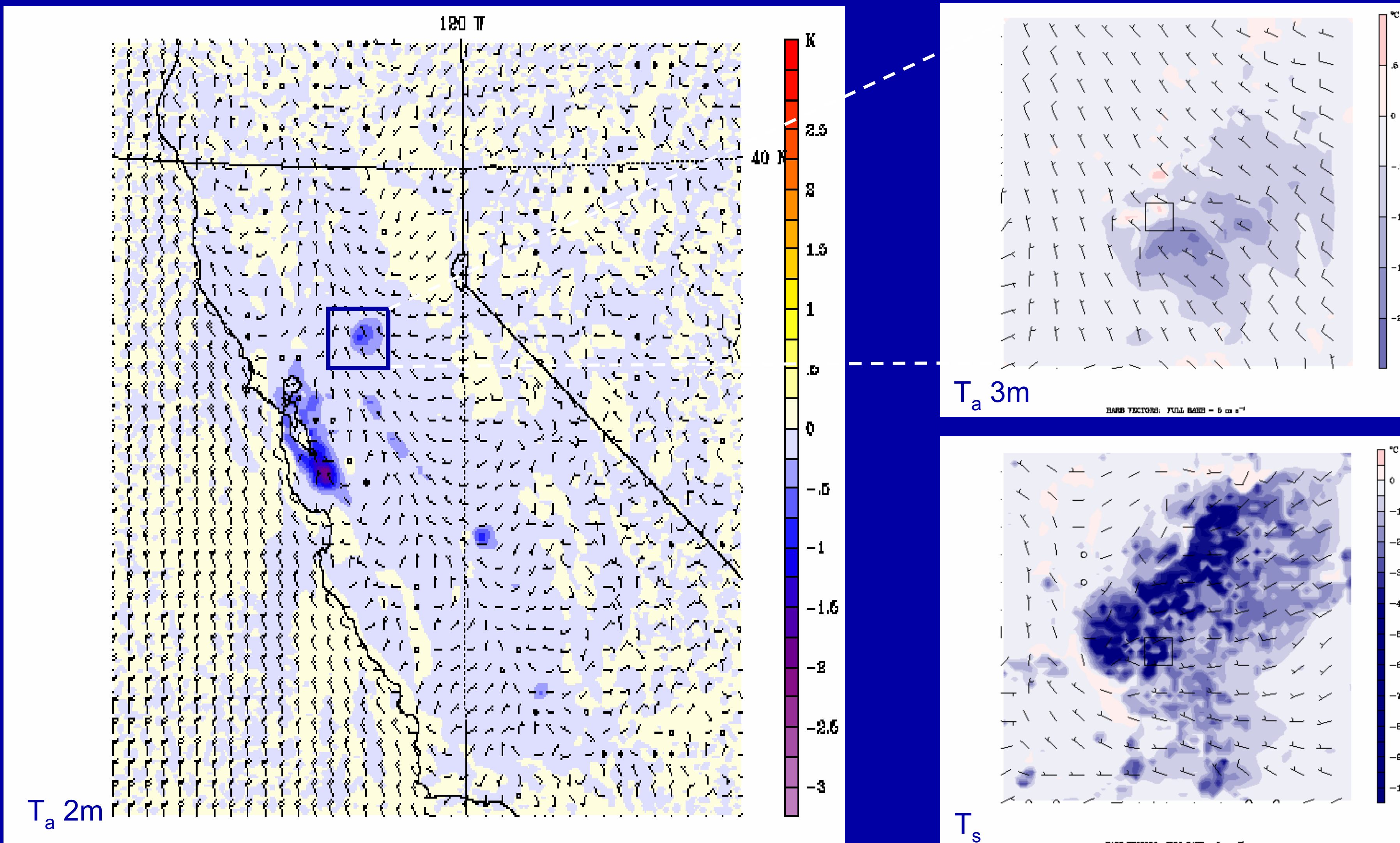
Taha, H. 2008c, *Atmospheric Environment*





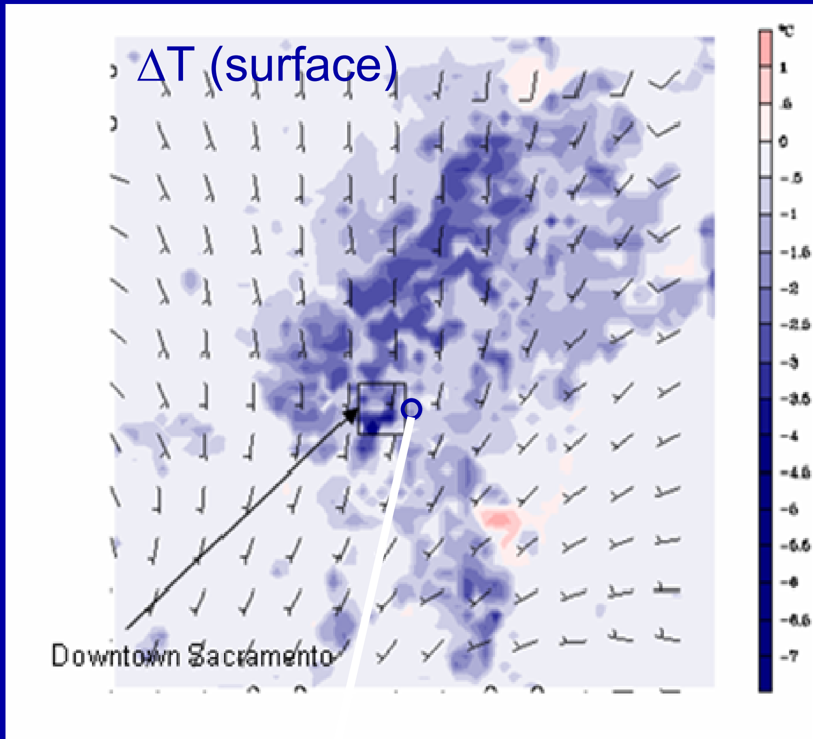


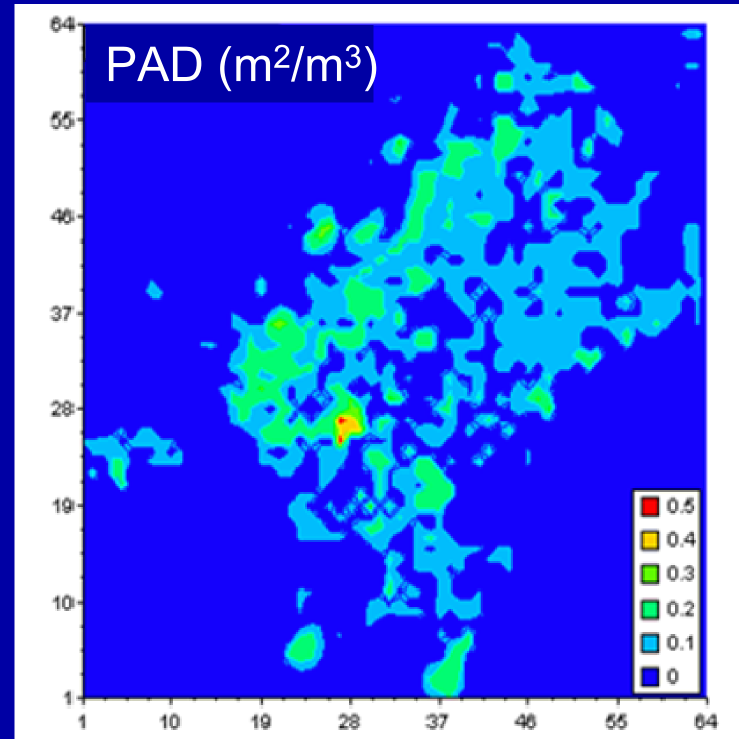
Example of impacts from UHI mitigation: Sacramento

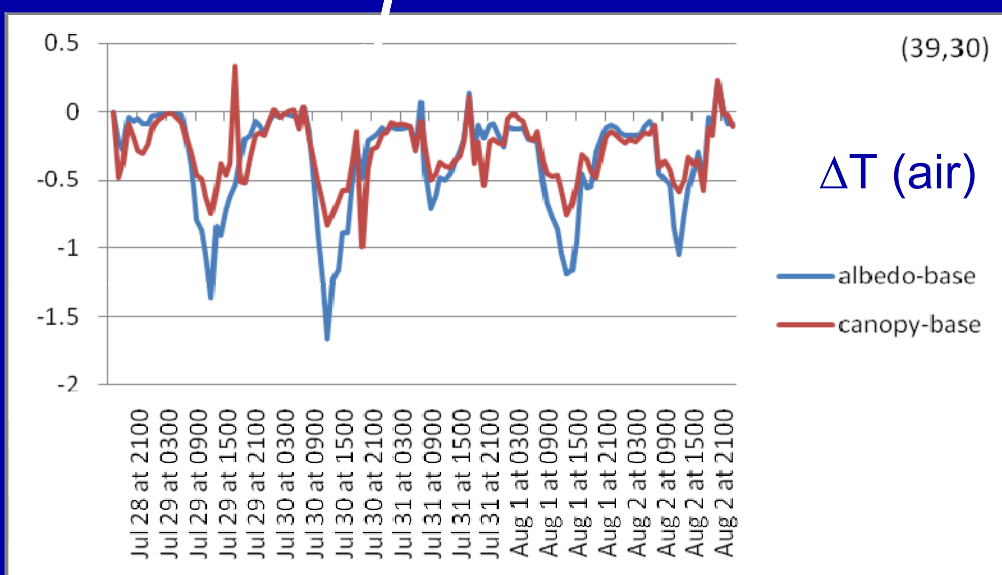


Mesoscale model

Meso-urban model







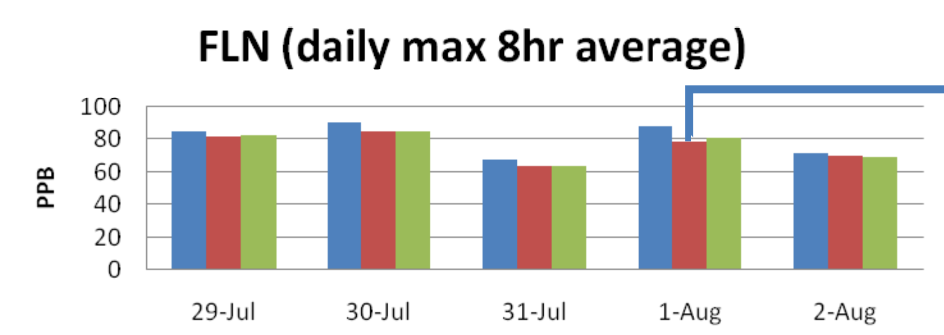
UHI mitigation: Sac Domain 5

Change in sfc temp (top left) from increased urban surface albedo, compared to building PAD function at 1m AGL (top right). Air temp change at a randomly selected location (bottom left).

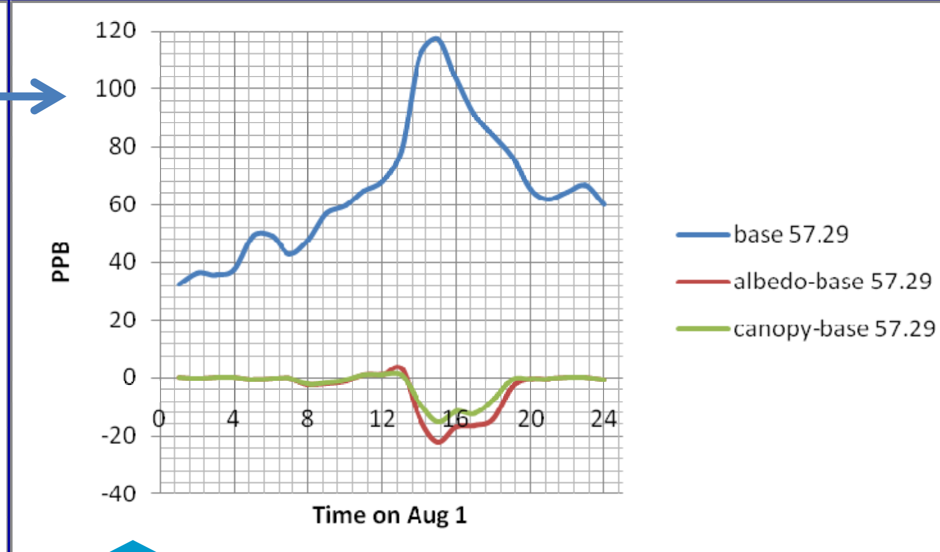
ALTOSTRATUS

Potential air-quality improvements from UHI control

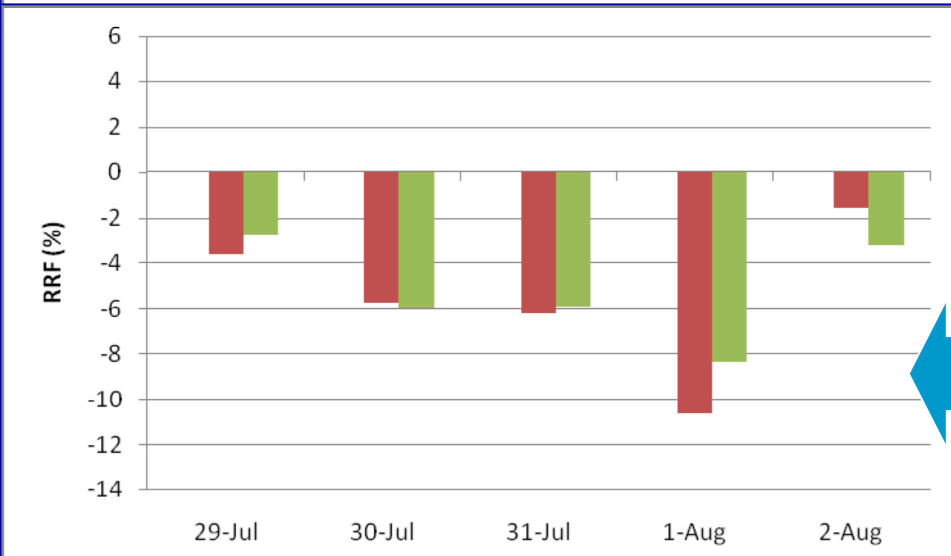
Taha, H. 2008c, *Atmospheric Environment*



	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug
base	85.3	90.3	67.9	88.5	71.3
albedo	82.2	85.1	63.7	79.1	70.2
canopy	82.9	84.9	63.9	81.1	69



August 1st, simulated ozone at location in Sacramento (top of graph) & changes resulting from UHI control (bottom of graph)



Top: Simulated daily max 8-hour average ozone in Sacramento (at Folsom Natoma monitor, FLN).
Bottom: reduction (%) in daily max as RRF from UHI control

Lebassi Ph.D. Scientific Questions

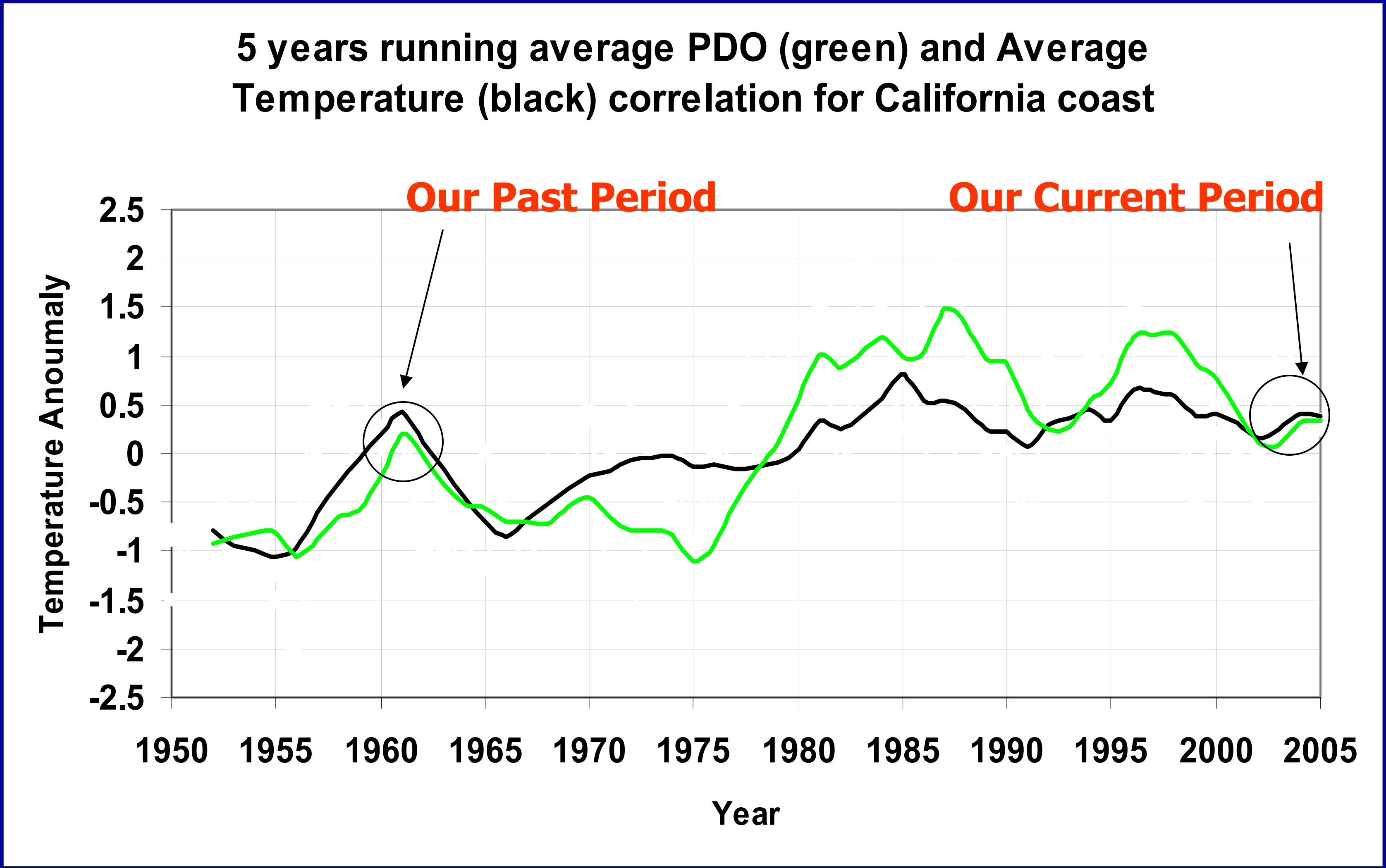
- What regional climate changes will occur in coastal environments due to global warming?
- Are sea breeze intensity, frequency, penetration, & duration climatologically increased due to global warming?
- What changed sea breeze parameters are important: air temp, stratus, etc.?
- If such coastal changes are found, which coastal areas would show such changes and which would not?
- What are the implications of such changes on energy consumption, O_3 levels, etc.?

His Planned RAMS SoCAB Simulations

- Four planned summer (JJA) simulations (next table)
- Simulated years must have
  - available LU/LC data
  - same PDO characteristics (next 2 slides)
- Three-year periods selected
  - Past: summers of 1960-1962
  - Current: summers of 2002-2004
- Results: will be shown as differences (as averages &/or CFDs) for entire simulation period

Why climate-variability indices are important for simulation-period selection

- Two characteristics distinguish Pacific Decadal Oscillation (PDOs) from El Niño/Southern Oscillations (ENSOs):
  - PDOs persist for 20-30 years, while ENSOs persist for 6-18 months
  - PDO climate "fingerprints"
    - most visible in N. Pacific & N. America, with secondary signatures in tropics
    - opposite is true for ENSO
- With past, current, &/or future climate-change simulations
  - comparison-periods must have same PDO-temp correlations
  - so differences are due to climate-change effects only (next slide)


5 years running average PDO (green) and Average Temperature (black) correlation for California coast
Our Past Period
Our Current Period
Temperature Anoumaly
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Year

RAMS Simulations

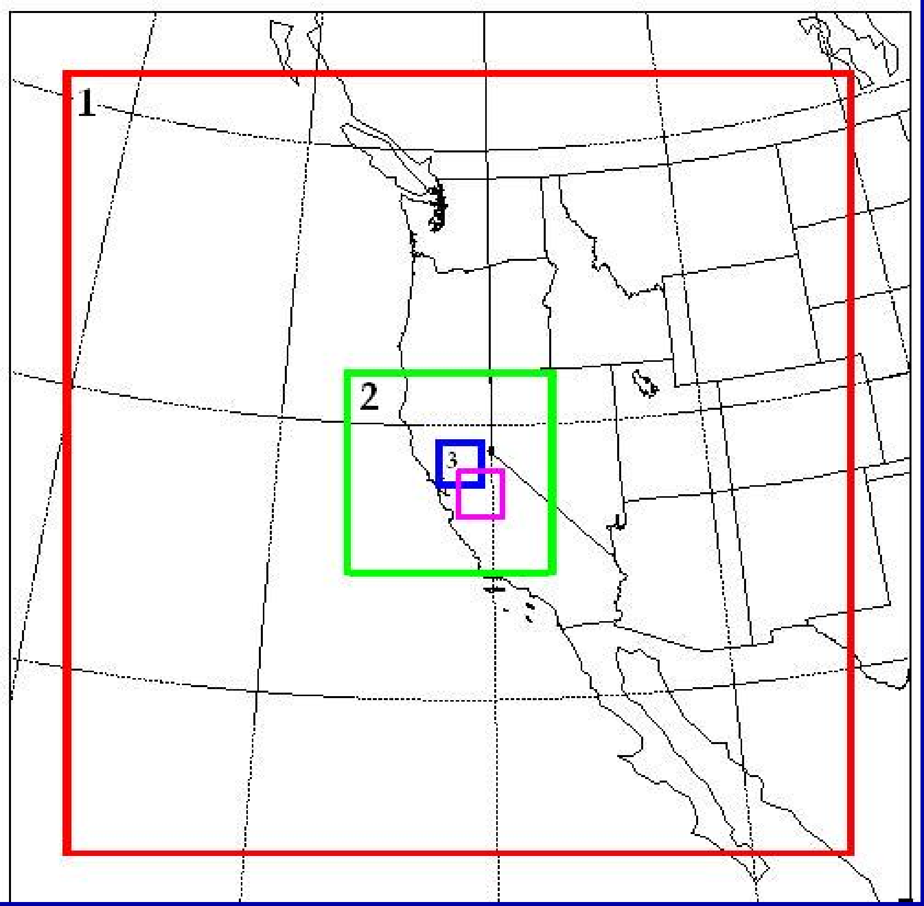
Run No.	Global CO_2 levels	Coastal SST values	LU/LC (Agriculture & Urban)	Notes on Conditions simulated
1	√	√	√	Total Current
2	√	√	o	Only Past-Global
3	o	o	√	Only Past-LU/LC
4	o	o	o	Total Past

where: o = past conditions, √ = current conditions

SIMULATION DETAILS

- Model initialized: at 0000 UTC, 1 July 2006
- 12 h allowed for spin up
- 27-day long simulations
- Large scale BCs: every 12 h, from gridded output from US NCEP global model
- Four dimensional data assimilation (4DDA): Newtonian relaxation (nudging)
- Grids 1 and 2: nudged with time scale of 6 h

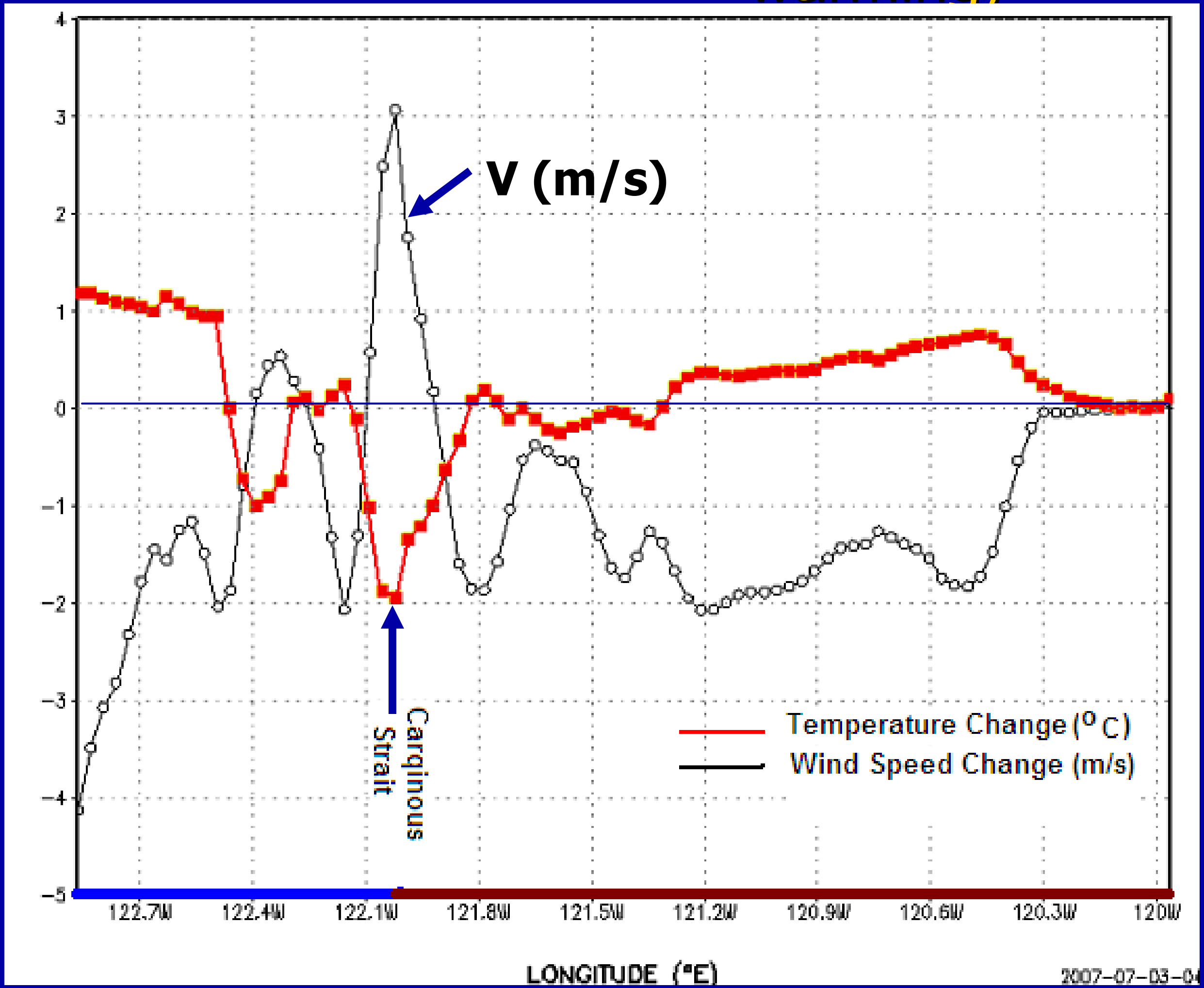
RAMS Grid Configuration



- Horizontal Grid
    - Arakawa type C staggered grid
    - Three nested grids

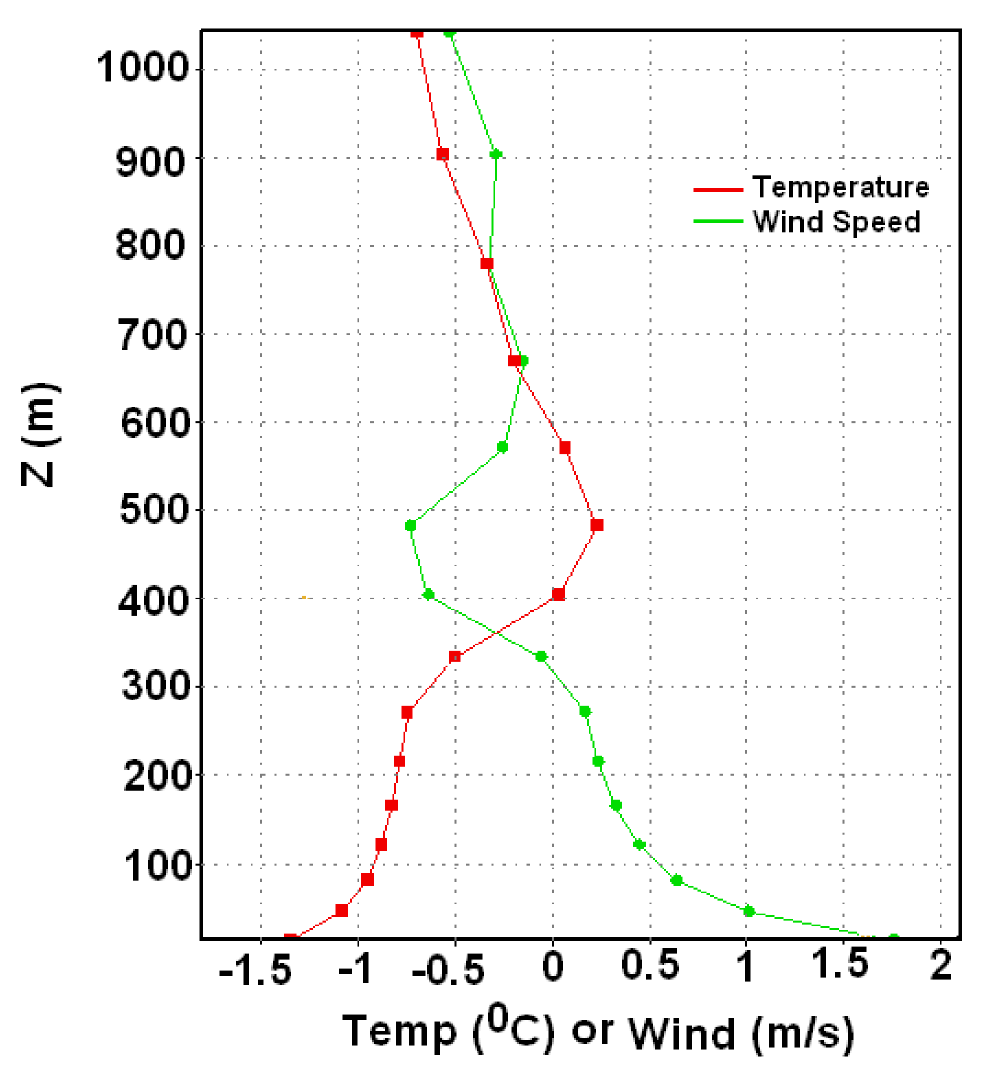
Grid	x	y	z	Δx ,Δy	Δz	Δt
1	80	80	50	60 Km	10m	10s
2	82	82	50	15 km	10m	5s
3	70	70	50	3.75 km	10m	2.5s

Preliminary RAMS SFBA Modeling Results 1: Average July 2006, 4 PM changes in 2-m T (°C) & V (m/s) in W-E Z- plane thru Carquinez Strait, when Central V. land-cover was changed back to pre-European conditions (but with no GHG warming)



Results show in-creased flow of cool sea-breeze air thru the Strait

RAMS Results 2: Vertical profile of T (^{0}C) & V (m/s) changes at 4 PM at a point with peak speed in Carquinez Strait (in previous slide)



Results show that the increased sea-breeze air thru the Strait (seen in the previous slide) decreases with altitude & is capped by a return flow aloft (at a z = 400-600 m)

Overall Modeling Lessons

- > Models can’t assumed to be
  - perfect
  - black boxes
- > Need good large-scale forcing model-fields
- > If obs are not available, OK to make reasonable educated estimates, e.g., for rural
  - deep-soil temp
  - soil moisture
- > Need data to compare with simulated-fields
- > Need good urban
  - morphological data
  - urbanization schemes

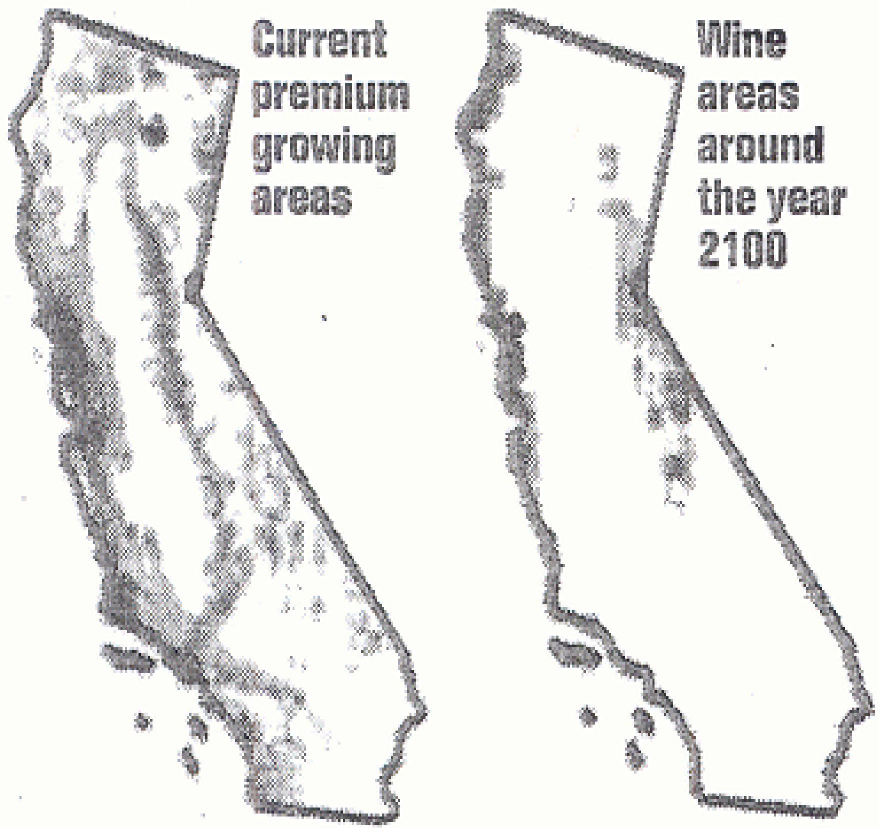
BENEFICIAL IMPLICATIONS OF COASTAL COOLING

- Napa Wine Areas May Not Go Extinct (Really Good News!) (see map)
- Energy For Cooling May Not Increase As Rapidly As Population (next 4 slides)
- Lower Human Heat-stress Rates
- Ozone Concentrations Might Continue To Decrease, As Lower Max-temps Mean Reduced
  - Anthropogenic Emissions
  - Biogenic Emissions
  - Photolysis Rates

Napa Wine Areas May Not Go Extinct Due To Alleged Rising T_{max} Values, As Predicted In NAS Study

Warming wine regions

A new study out today suggests that global warming could drastically change which areas of the United States can grow premium wine grapes. By the end of the 21st century, the country could have lost 81 percent of its best and most reliable wine regions, including Napa and Sonoma.

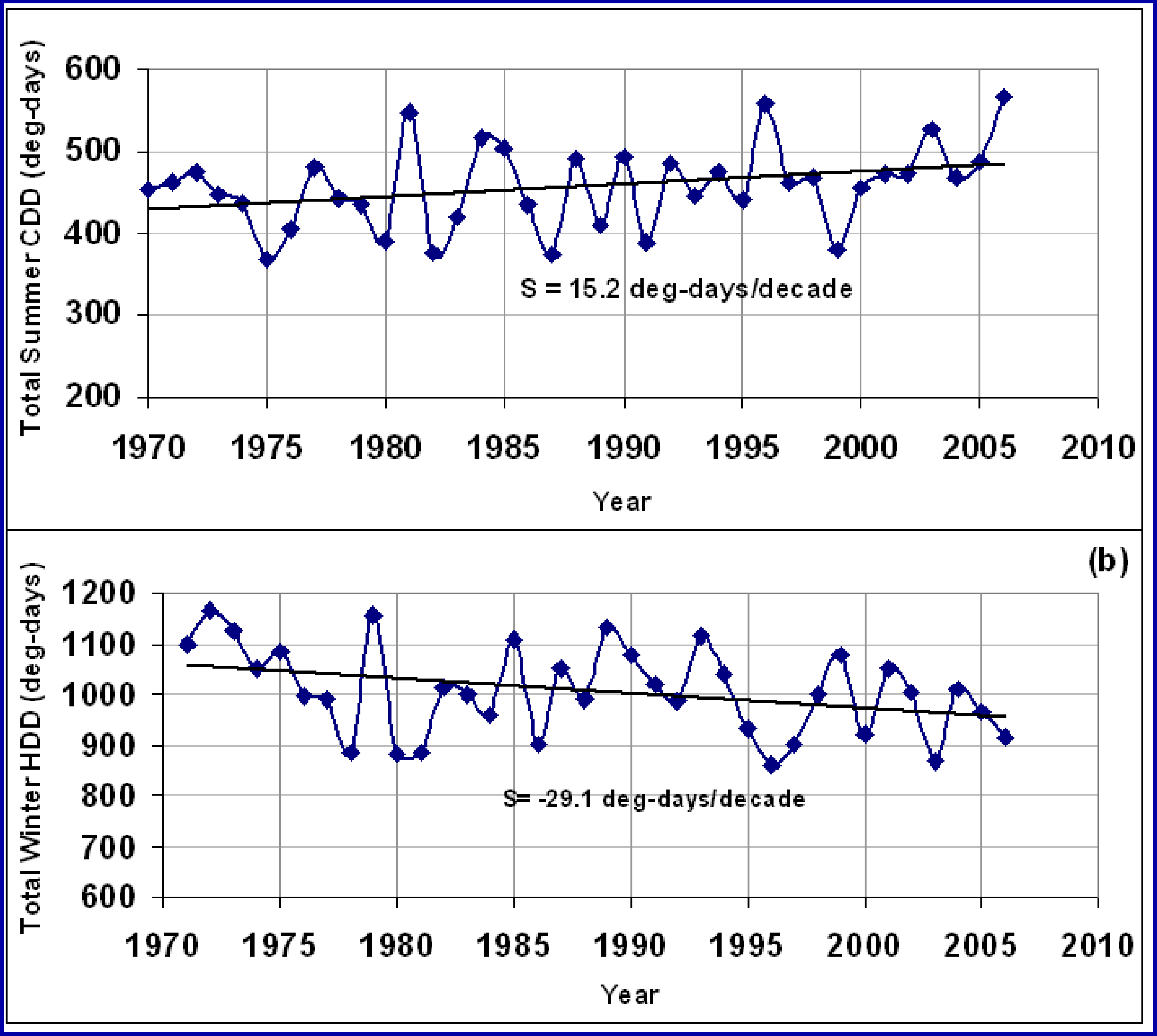


Source: Proceedings of the National Academy of Sciences — *The Chronicle*

GOOD IMPLICATIONS FOR O_3

- Past & Projected SFBA & SoCAB Oone Decreases may in part be due to daytime max-temp cooling-trends & not only to reduced anthropogenic emissions
- Recent CARB AQSMs have not reproduced the full rate of observed O_3-decrease, maybe (in part) due to this un-modeled cooling trend
- SJSU & SCU have (unsuccessfully to date) proposed to CARB to use linked down-scaled (to 1-3 Km grids) MESOMET & CAMx modeling for the SoCAB & Central Valley

Implications for ALL-CA Energy Results 1: Heating Degree Days (HDDs) & Cooling Degree Days (CDDs)



CDDs

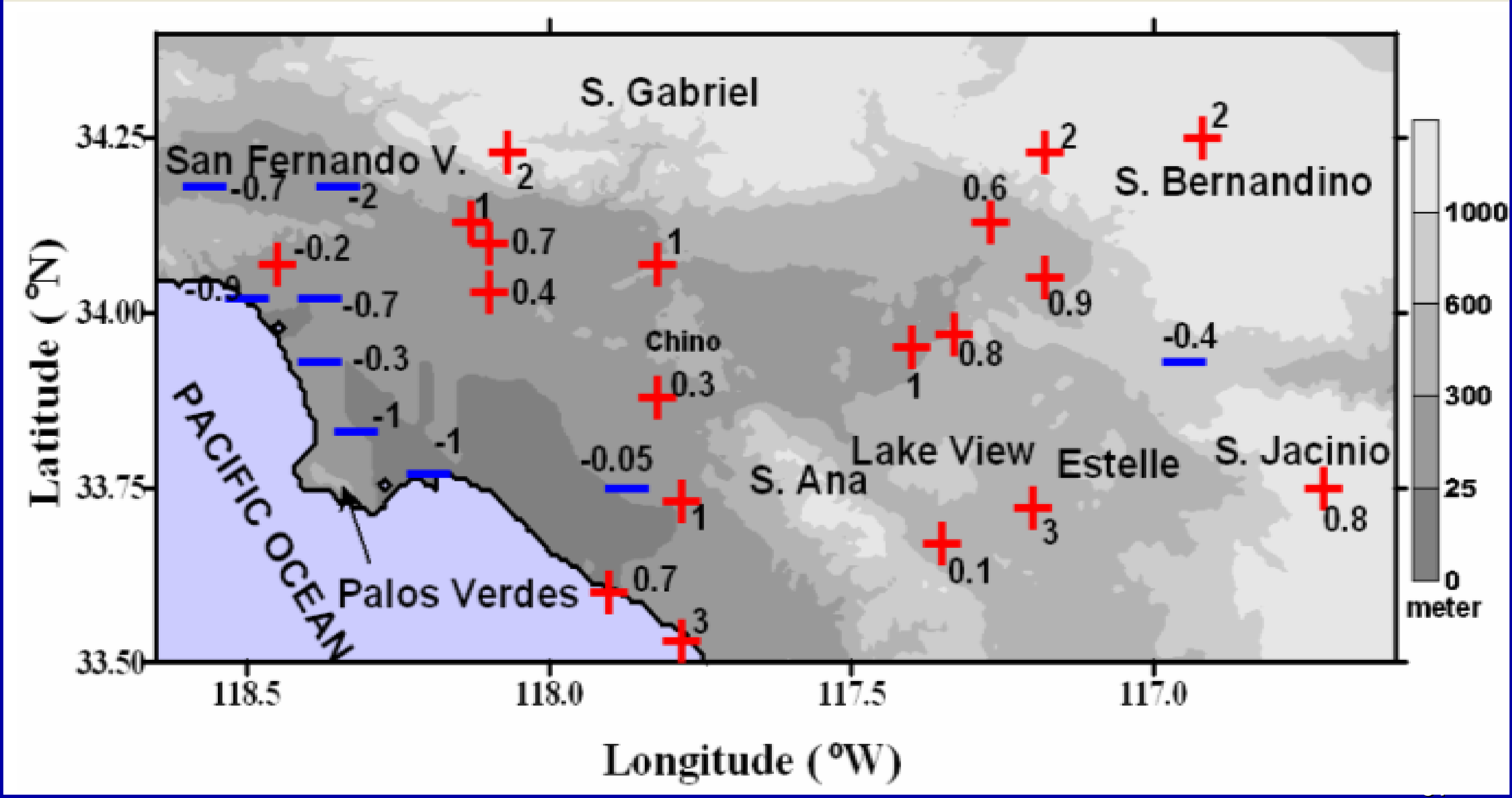
- Increased at a lower rate as summer max-T increased at a lower rate
- Need to redo this for the coastal cooling areas

HDDs

- Decreased at faster rate (we did not study winter min-T)

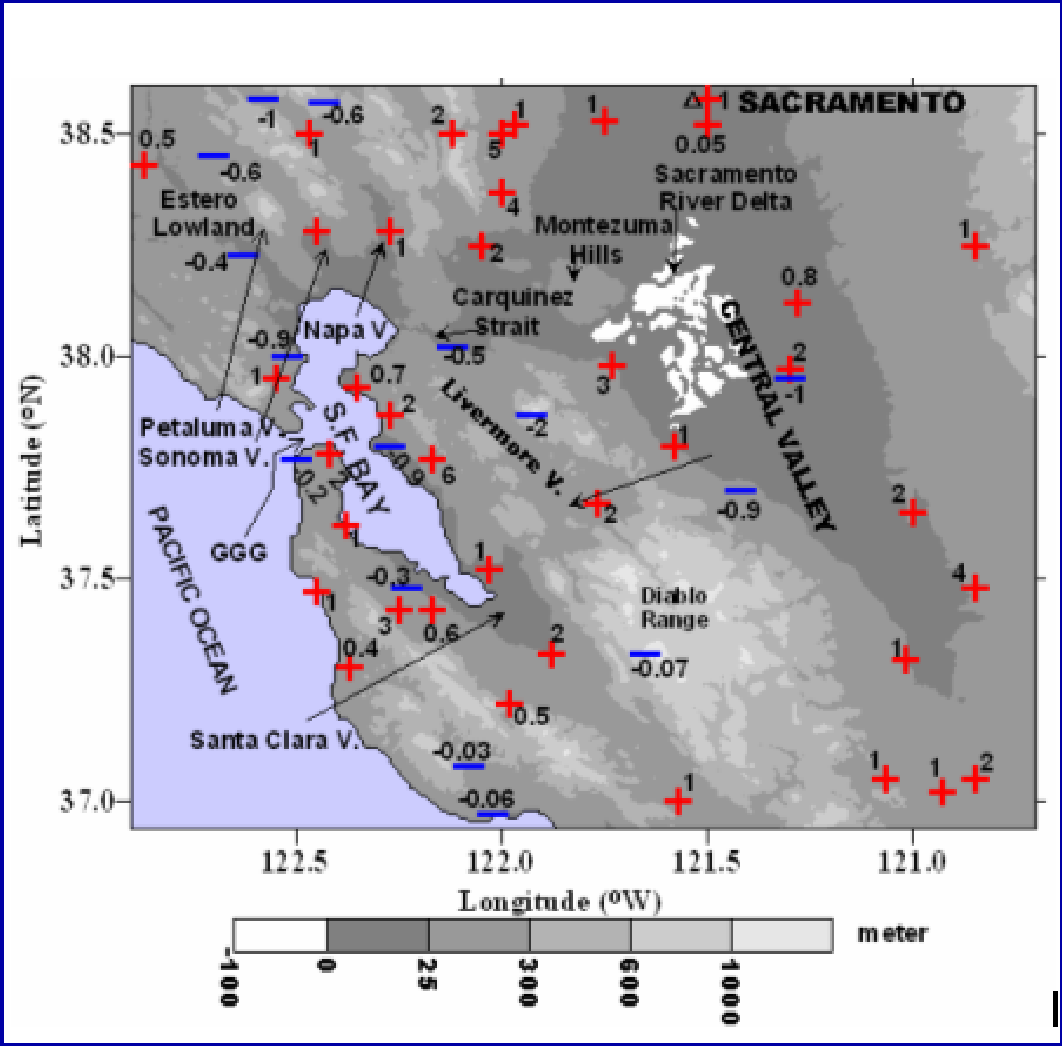
Results 2: SoCAB 1970-2005 summer CDD trends (degree-days/summer):

generally small decreased values in cooling coastal areas & small increased values in warming inland areas

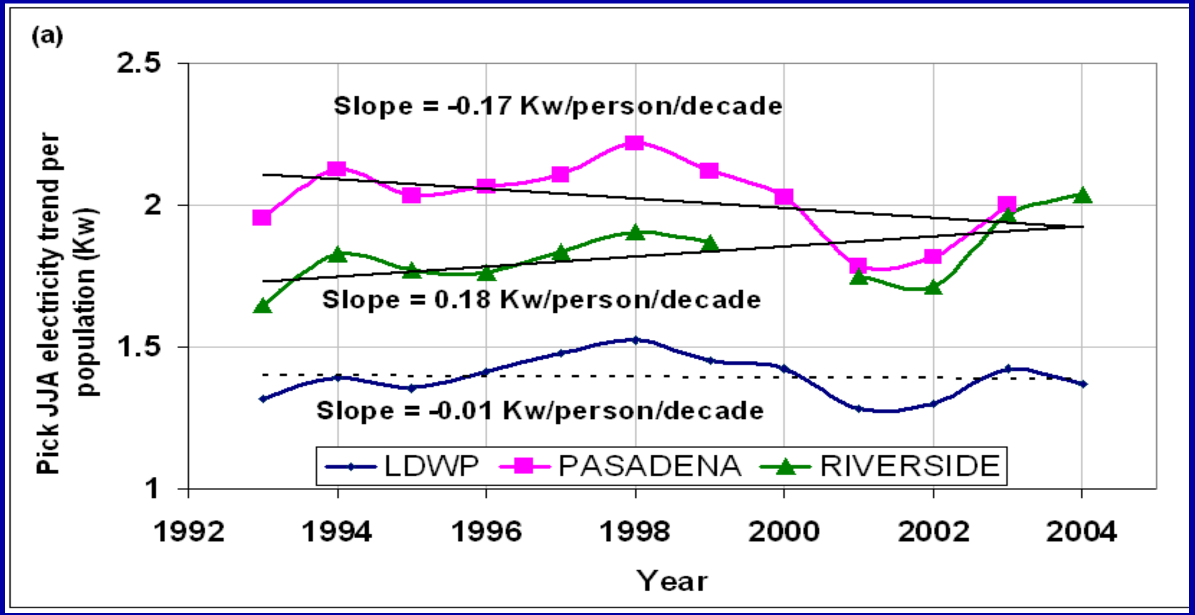


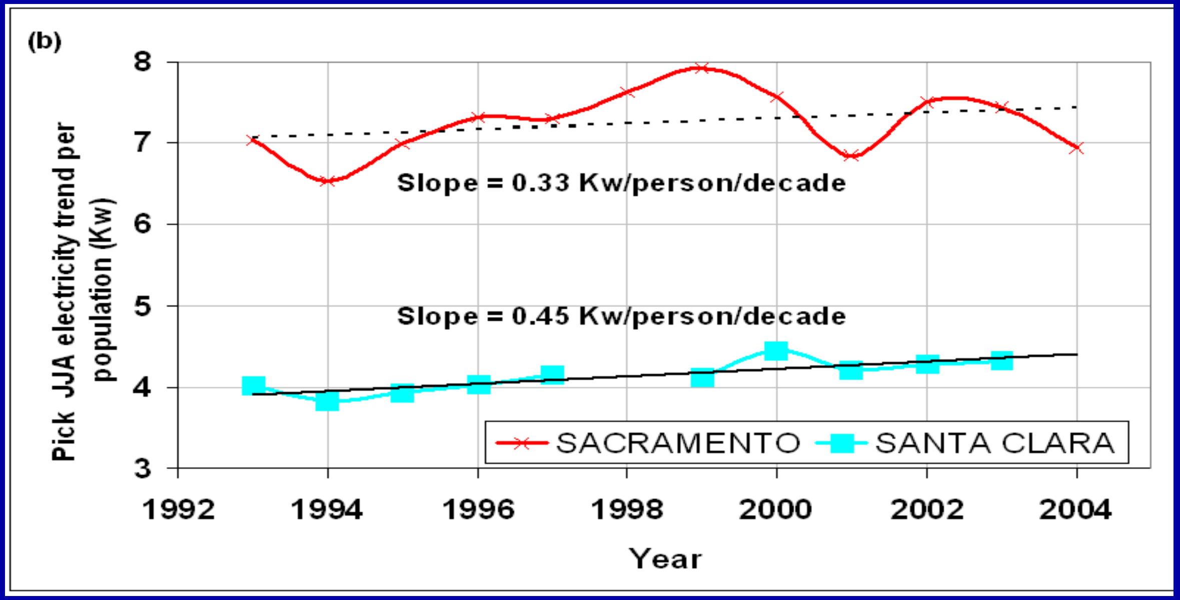
Results 3: Same for SFBA:

generally small decreased values in cooling low-elevation coastal areas & small increased values in warming inland areas



Result 4: Peak-Summer Per-capita Electricity-Trends





Down-trend at cooling coastal LA & Pasadena and up-trend at warming inland Riverside

Up-trend at warming Sac & Santa Clara

Possible Future Efforts (Part 1 Of 2)

- Expanded (to all of CA)
  - Analysis of observations (in-situ & GIS)
  - Meso-met (uMM5, uRAMS, uWRF) modeling
- Separate-out Influences of changing:
  - Land-Use Patterns Re:
    - Agricultural irrigation
    - Urbanization & UHI-magnitude
  - Sea Breeze:

    Intensity, freq, duration, &/or penetration
- Determine Possible "Saturation" of Sea-Breeze Effects from
    - Flow-velocity & cold-air transport
    - Stratus cloud-cover effects on long- & short-wave radiation

Possible Future Efforts (Part 2 Of 2)

Determine Cumulative Freq Distributions of Max-temp Values, as

- Even if average max-values decrease,
- Extreme max-values may still increase, in intensity and/or frequency

- Determine Changes in Large-scale Flow
  - How does global climate-change affect position & strength of: Pacific High & Thermal Low
  - This is the ultimate cause of climate-change

Conclusion

- Coastal-cooling of California summer day-time max-temps needs to be considered in future ozone-reduction planning
- The SJSU/SCU/Altostratus group
  - has deep experience in analysis & simulation of meso-scale met & air quality processes in California
  - can provide support to ongoing internal & external CARB efforts in climate downscaling & O_3 trend analyses
  - can downscale GCM-output down to grids of 1-5 km, so as to resolve CA coastal-topographic-urban influences
  - has existing CA efforts that could be leveraged by new CARB support

Thanks for listening!

Time for additional questions and discussion?