Validation of WRF surface meteorology simulations

Robert Fovell

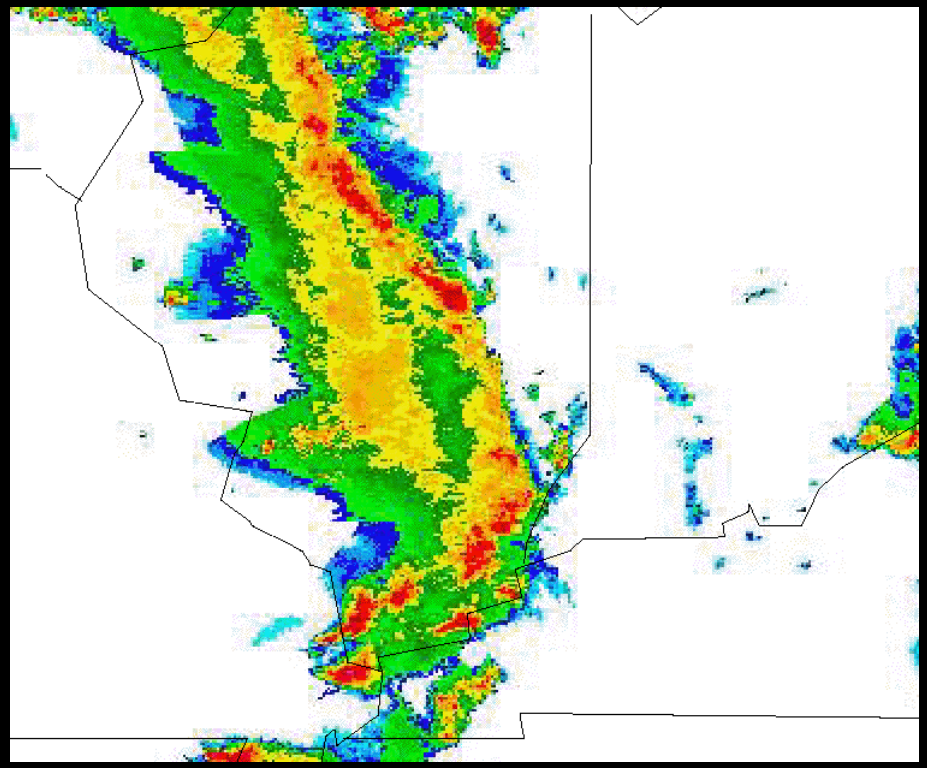
University of California, Los Angeles

rfovell@ucla.edu

Background

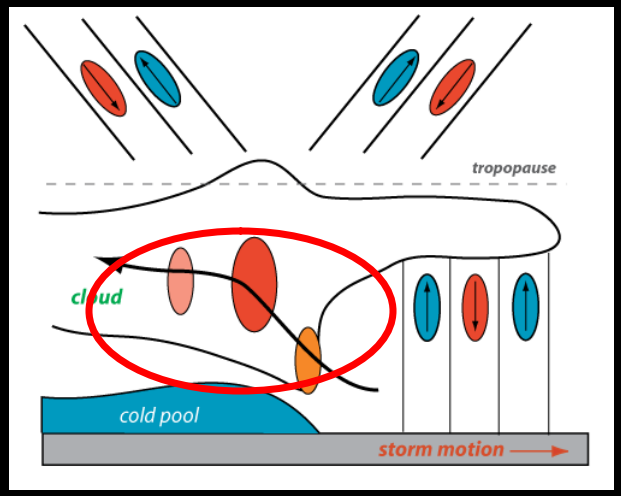
- Ph.D., 1988 - University of Illinois (Atmospheric Sciences)
- Postdoc at University of Washington (Atmospheric Sciences)
- 1991 - joined faculty at UCLA (Atmospheric & Oceanic Sciences)
- Full Professor, Vice Chair, Undergraduate Faculty Advisor
- Chair of the Faculty of the College of Letters & Science
- UCLA Distinguished Teaching Award
- Chair of Mesoscale Processes Committee (American Meteorological Society)
- Member, WRF Ensemble Working Group

Selected research on squall-lines



Fovell and Ogura (1988, 1989)
storm maintenance, viability, microphysics influence on structure

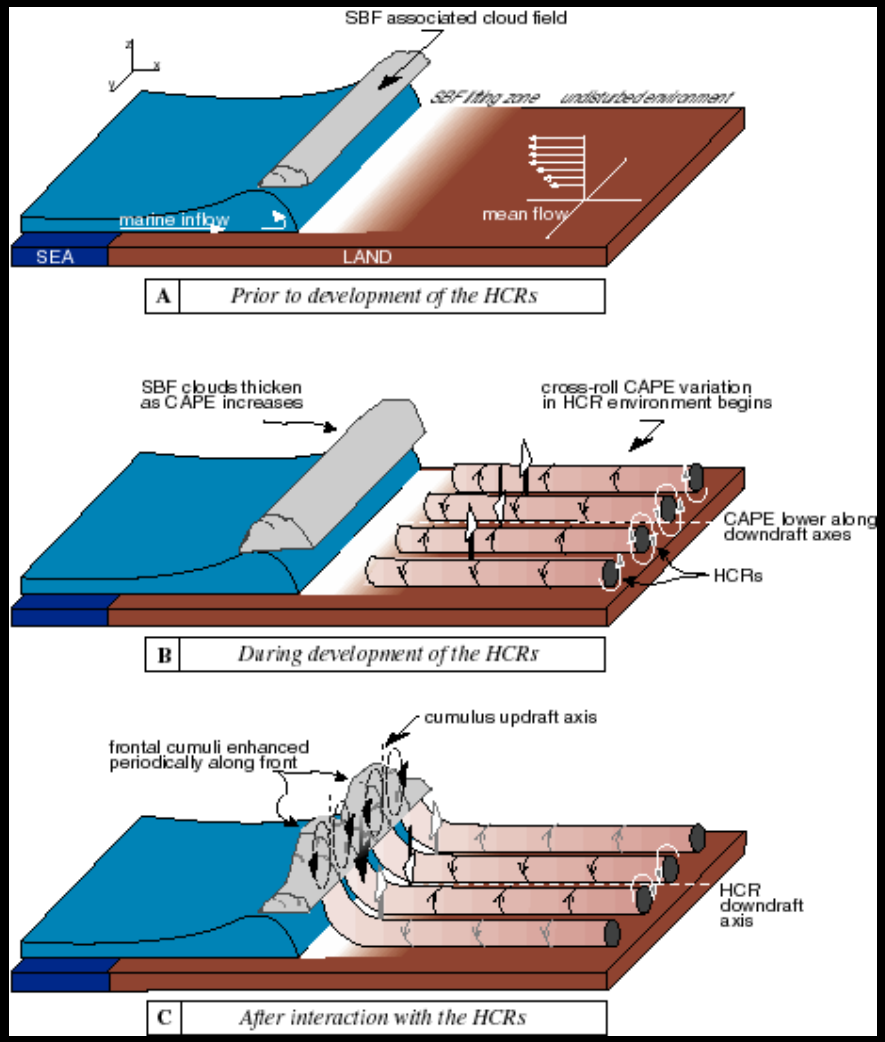
Fovell, Durran and Holton (1992)
stratospheric gravity waves



Fovell and Tan (1998, 2000)
storm unsteadiness

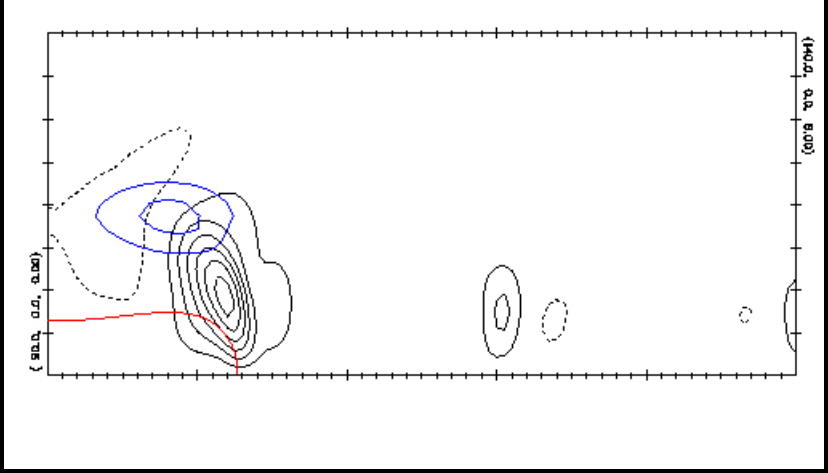
Fovell (2002)
Fovell, Mullendore and Kim (2006)
upstream influence and cell initiation

Sea-breeze and convective initiation



Dailey and Fovell (1999)
Why convective rolls modulate sea-breeze convection

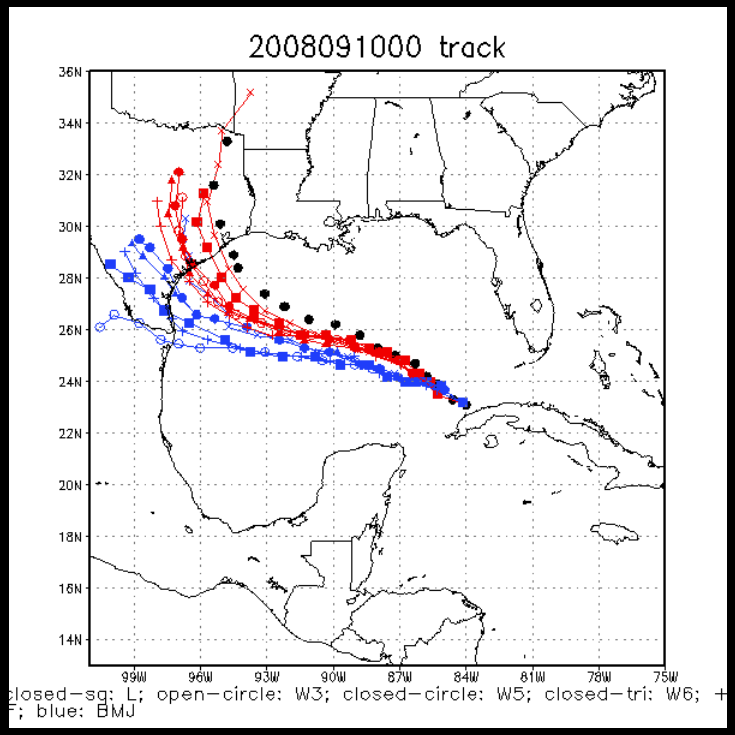
Fovell and Dailey (2001)
Fovell (2005)
Convective initiation ahead of the sea-breeze front



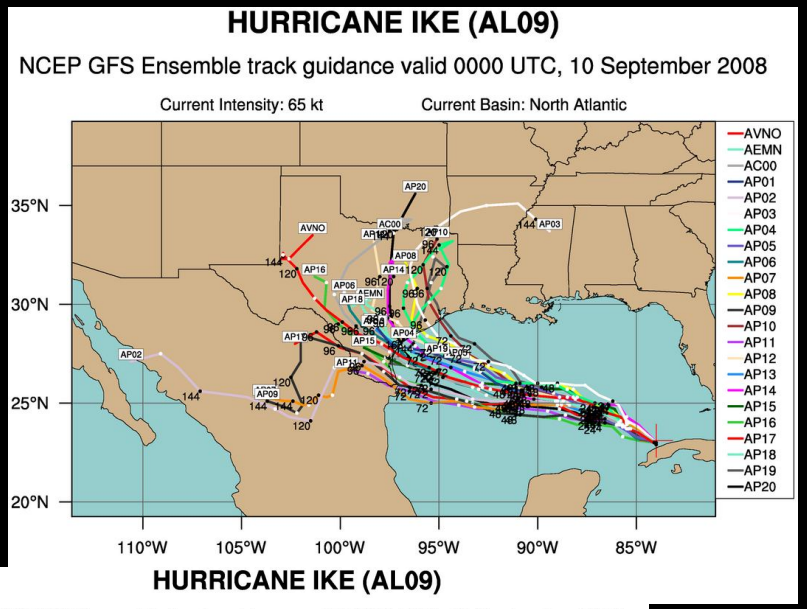
Hurricane tracks and microphysics

Fovell and Su (2007)

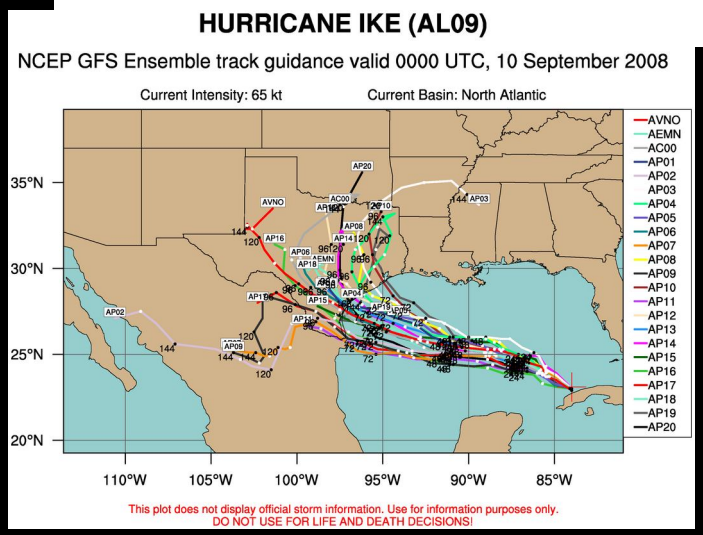
(a)



(b)

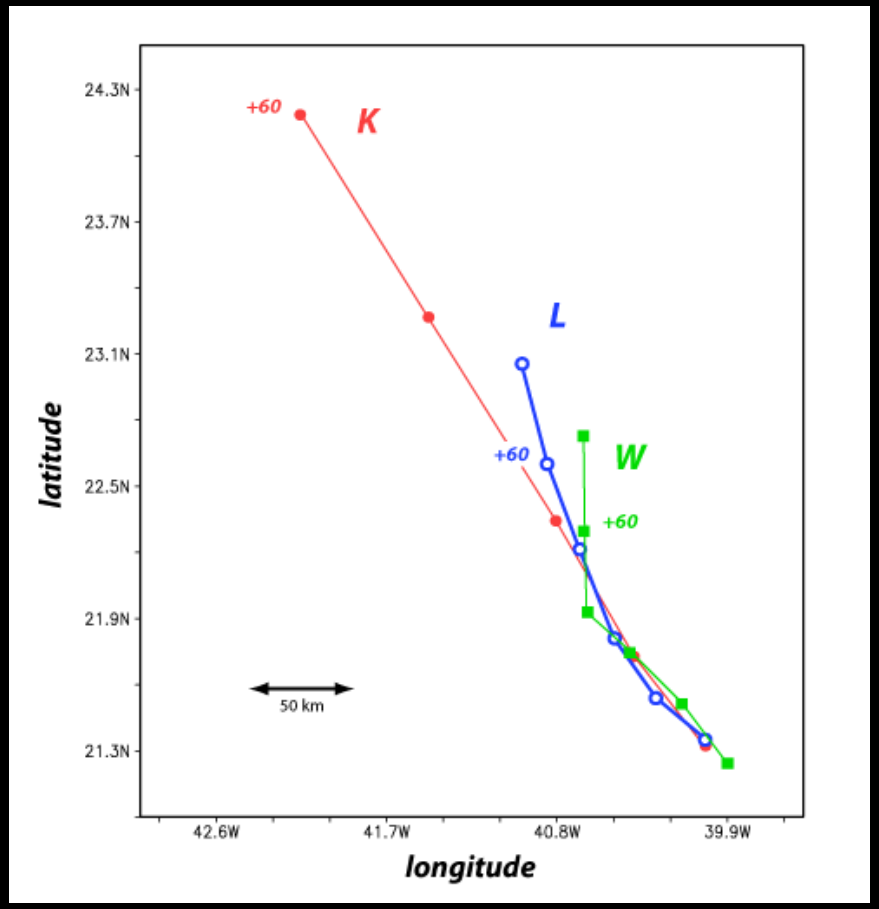


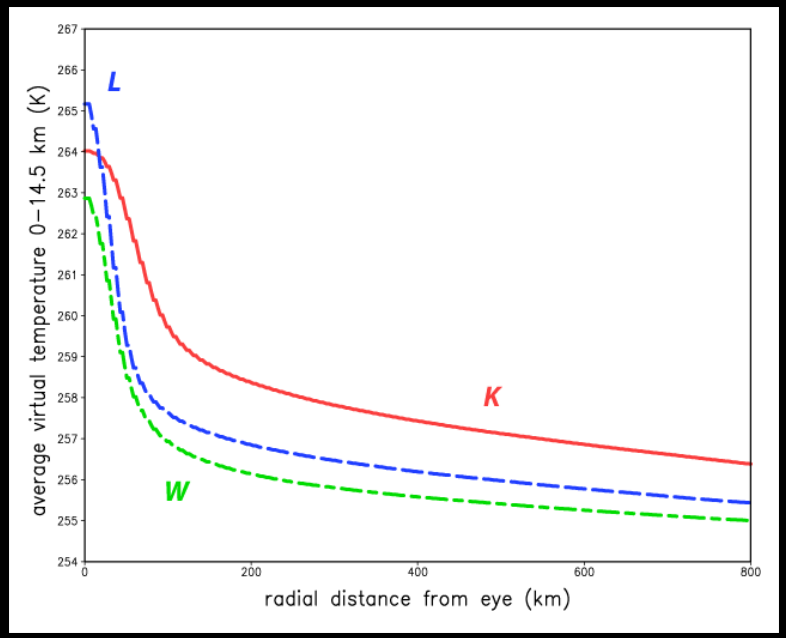
(c)



Hurricane Ike - (a) WRF convection ensemble;
(b) NHC multi-model ensemble;
(c) GFS ensemble

Hurricane tracks and microphysics





Fovell, Corbosiero and Kuo (2009)

A few other papers

- Fovell and Fovell (1993)
  - Very early application of cluster analysis to geophysical data
- Berk and Fovell (1999)
  - “willingness to pay” for climate change avoidance
- Hughes, Hall and Fovell (2006)
  - Effect of topography on diurnal cycle in Los Angeles
- Hughes, Hall and Fovell (2008)
  - Los Angeles rainfall and topographic blocking

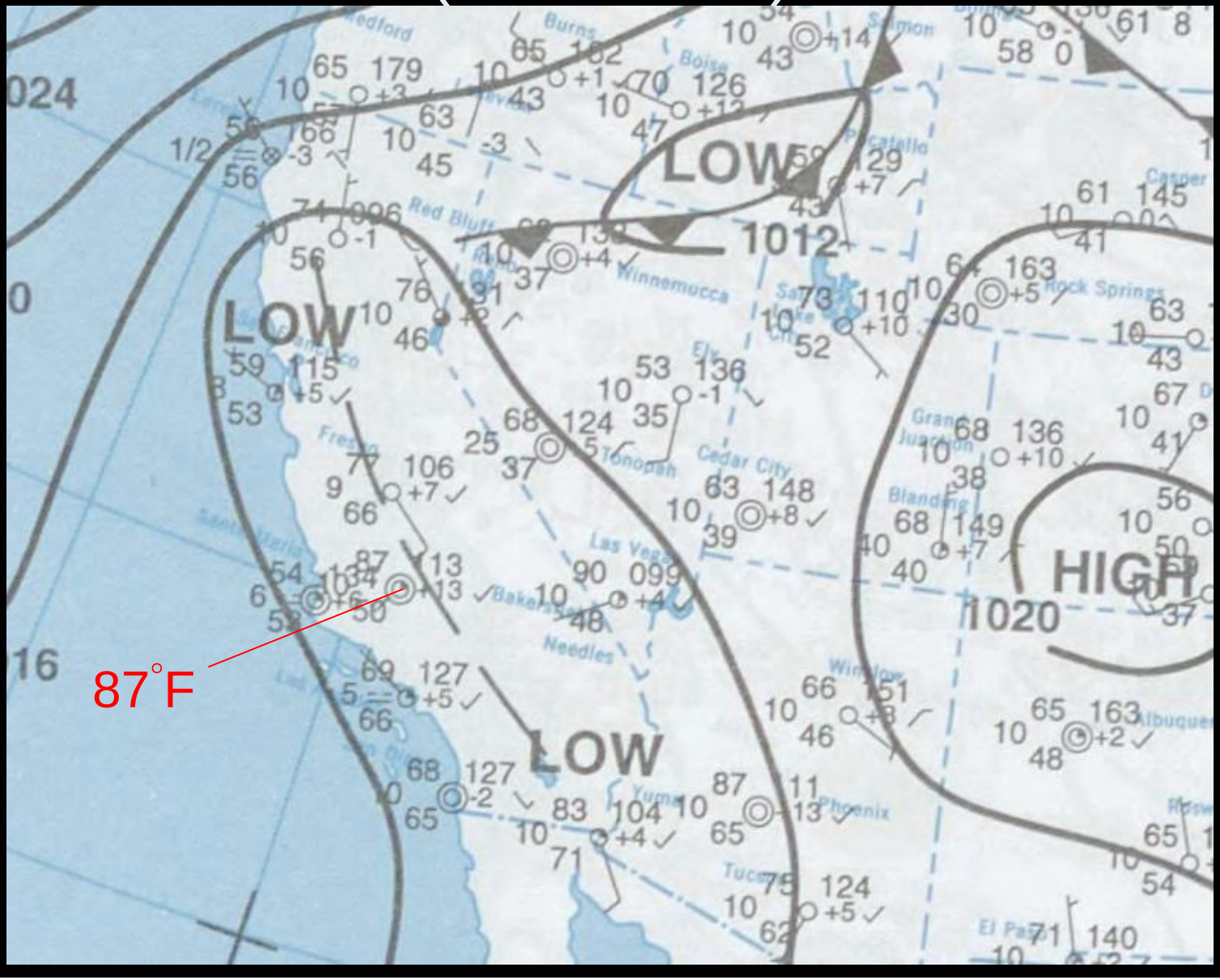
Outline

- Summer event (August 2000)
- Winter event (January 2001)

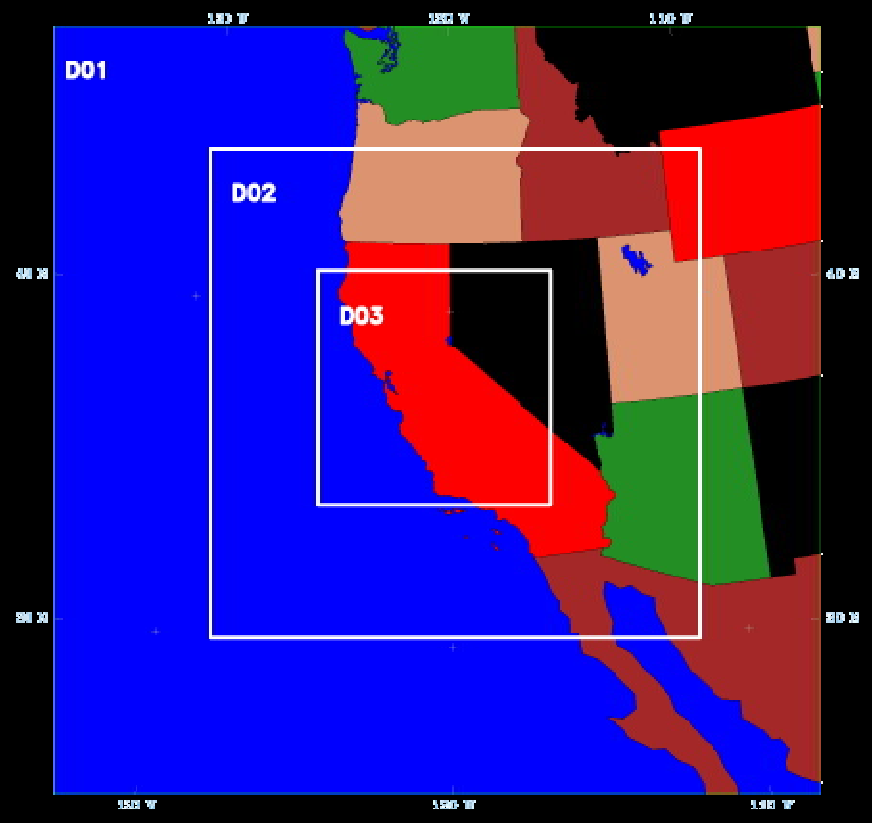
Summer event

- August, 2000 high-ozone event
  - August 1st-3rd
  - Very “asynoptic” situation
- WRF and MM5 models
  - 3 telescoping domains
  - 4 km resolution over central CA
  - Emphasize WRF owing to ARB dissatisfaction w/ MM5
- Comparison of model with available surface observations
- “Achilles heel” of regional-scale modeling

1 August 2000 @ 12Z
(5 AM PDT)



WRF/MM5 domain setup

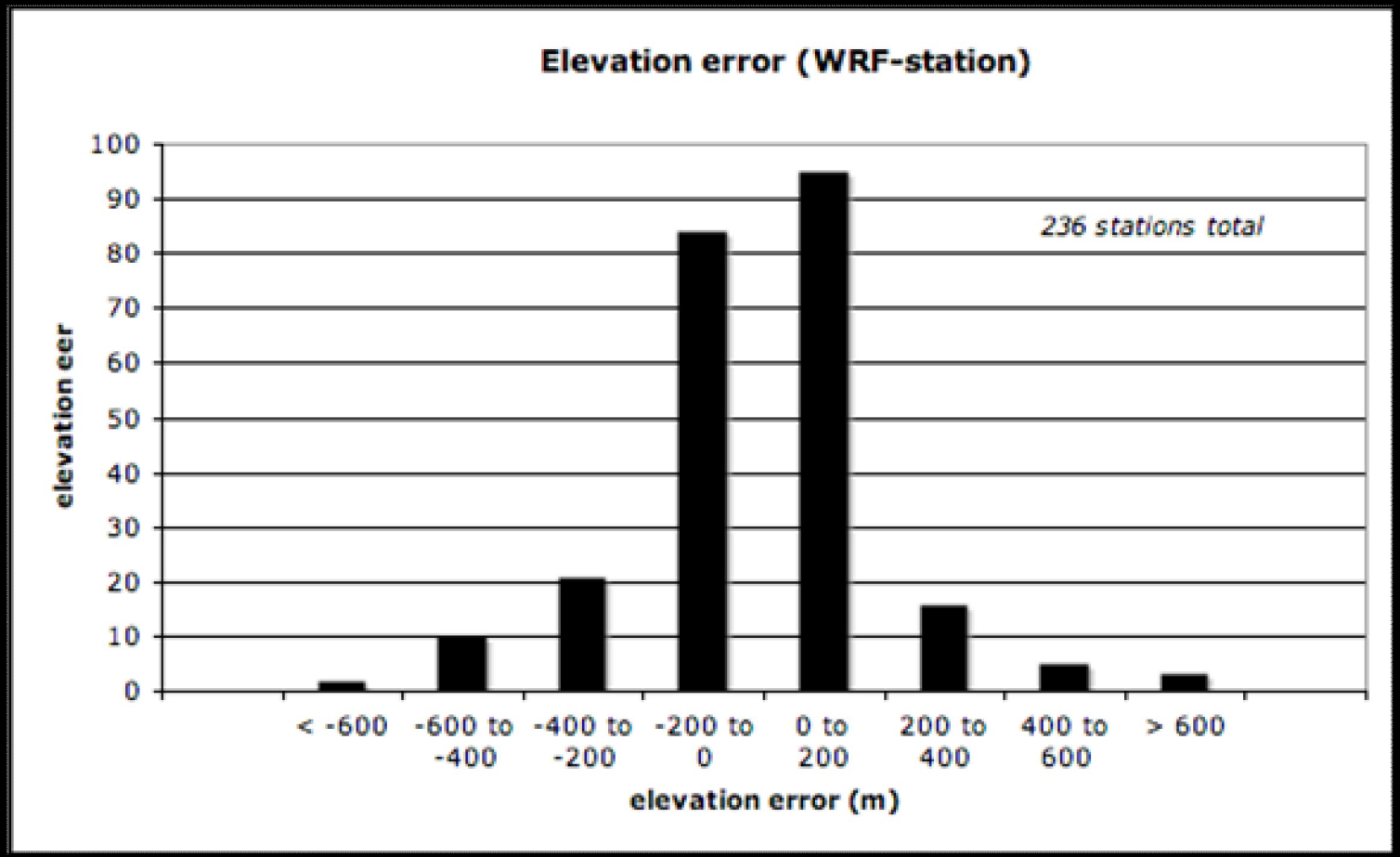


36, 12 and 4 km

Observations for comparison

- Mesowest archive (Univ. of Utah)
- California ASOS and RAWS stations
  - ASOS - mainly airports, populated areas
  - RAWS - many in remote areas, especially higher elevation
- 2 m temperature, dew point and 10 m wind speed
  - Need to get the mesoscale circulation right

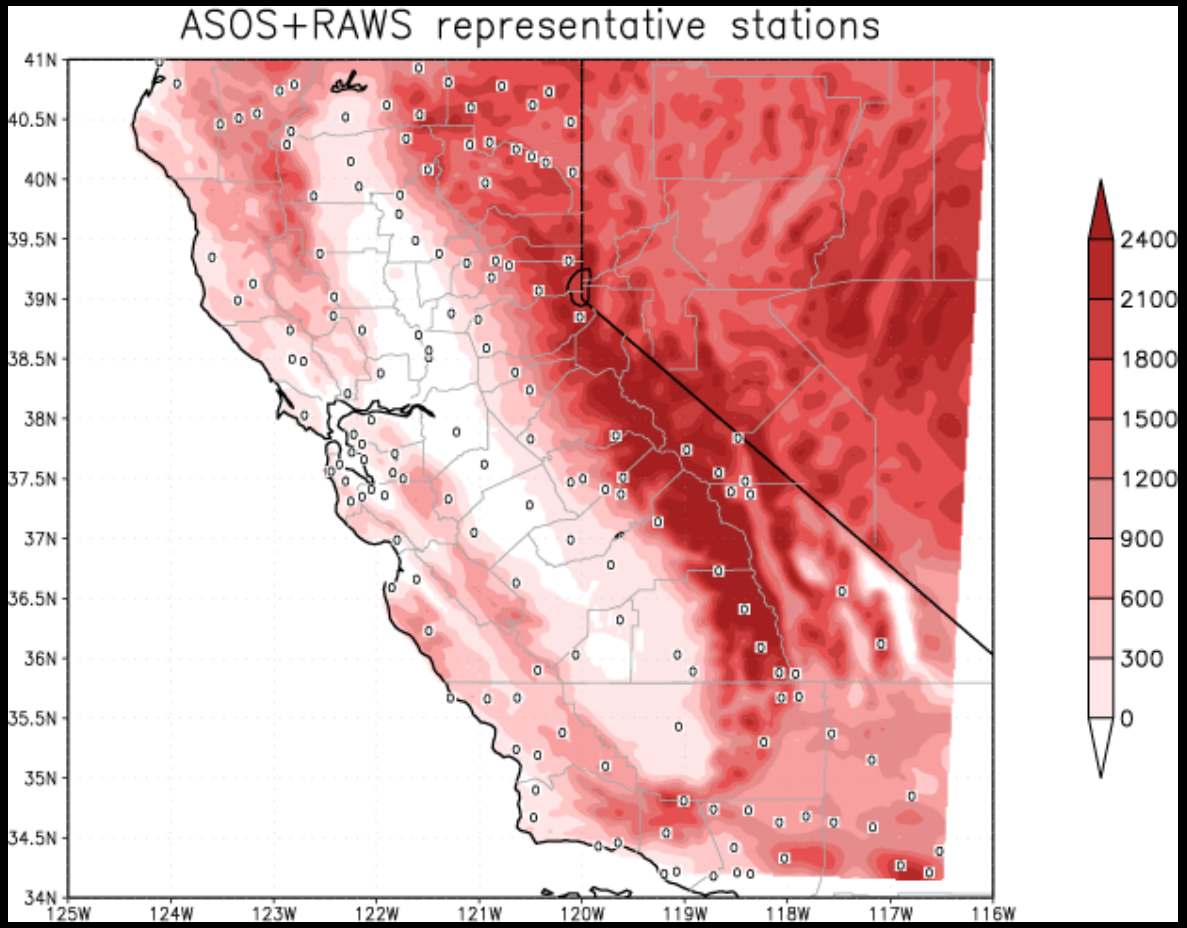
Model vs. station elevation



76% within ± 200 m

ASOS+RAWS “representative stations”

(WRF elevation error under 200 m; < 5 missing hours)

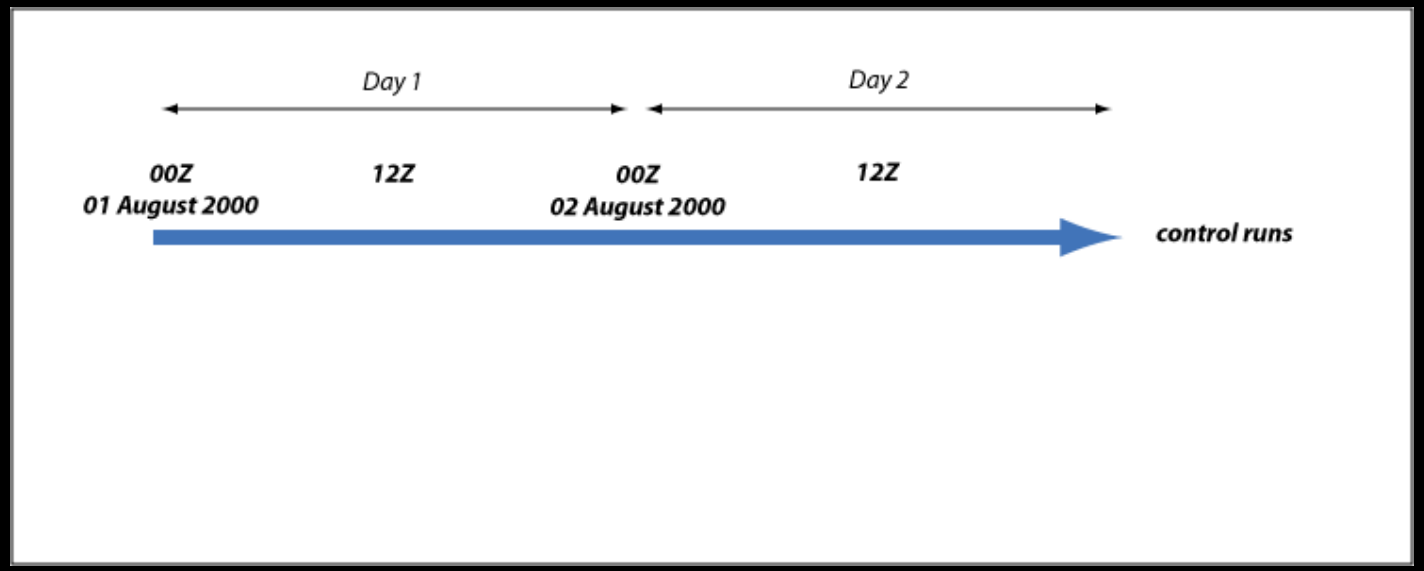


156 stations

Results using WRF version 2

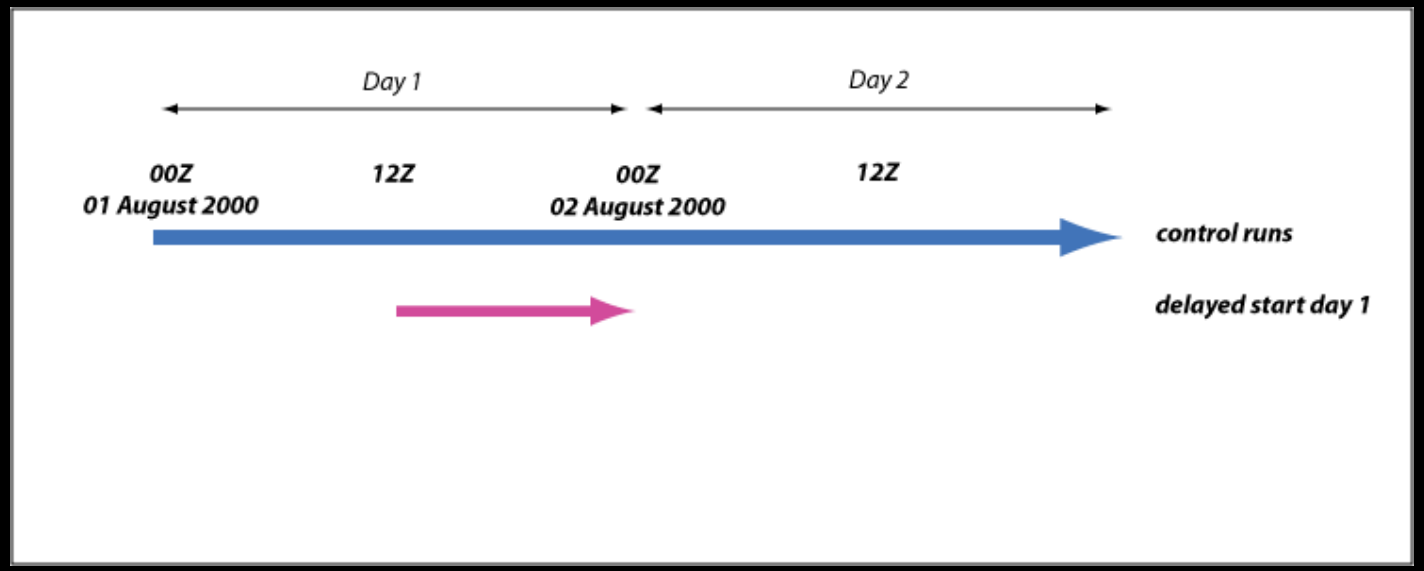
- Eta and FNL initializations
- Investigated surface physics, radiation, model start time, simulation length, nudging

Experimental design



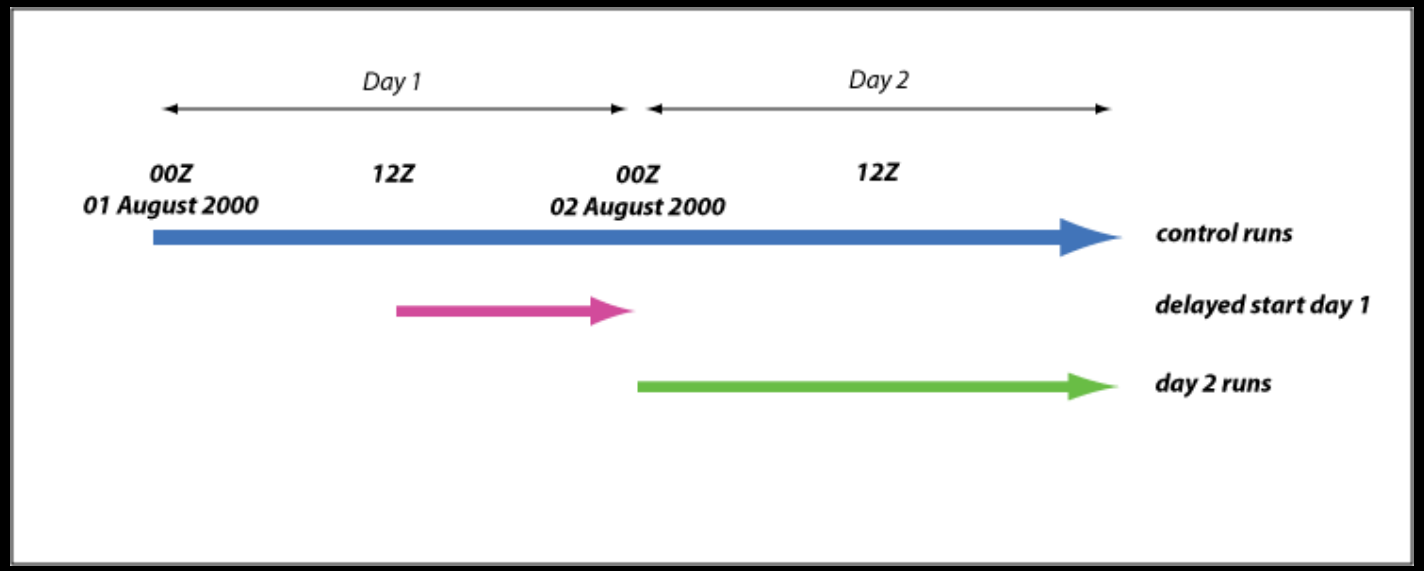
Control runs:
Simulation set with varying physics combinations
Starts at 00Z (5 PM PDT July 31)

Experimental design



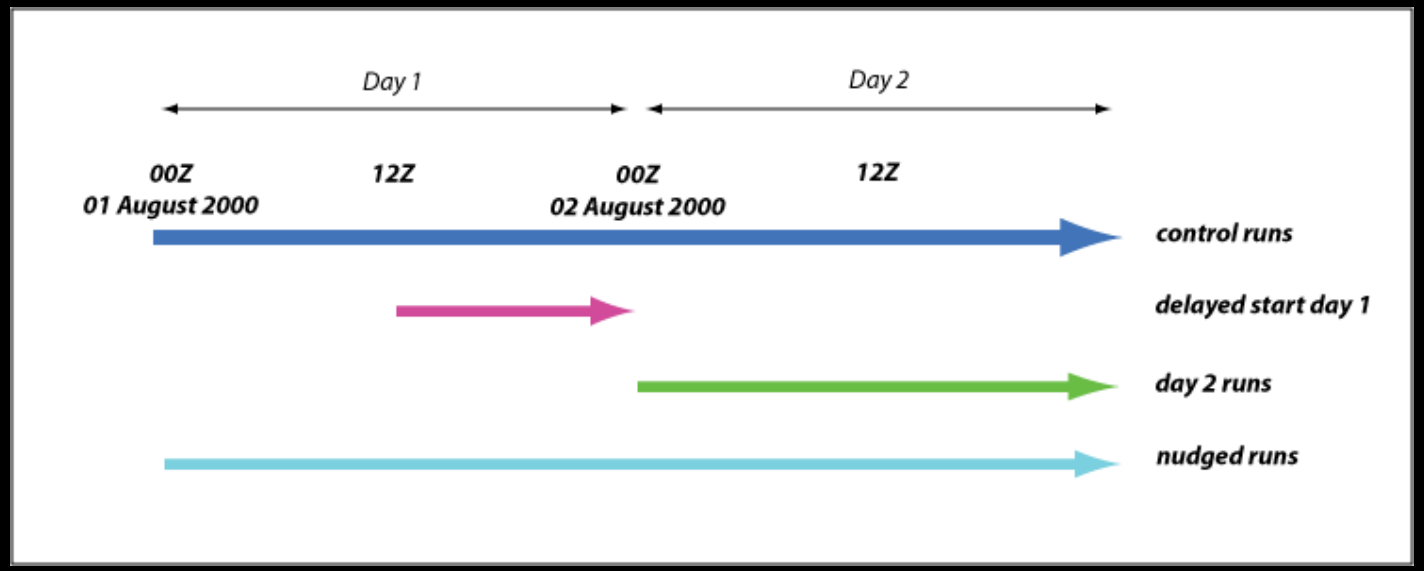
Delayed start runs:
Tests whether better to start with more stable conditions

Experimental design



Day 2 (and Day 3) runs:
Tests whether model behaves similarly on a similar (Day 2) and cooler (Day 3) day

Experimental design

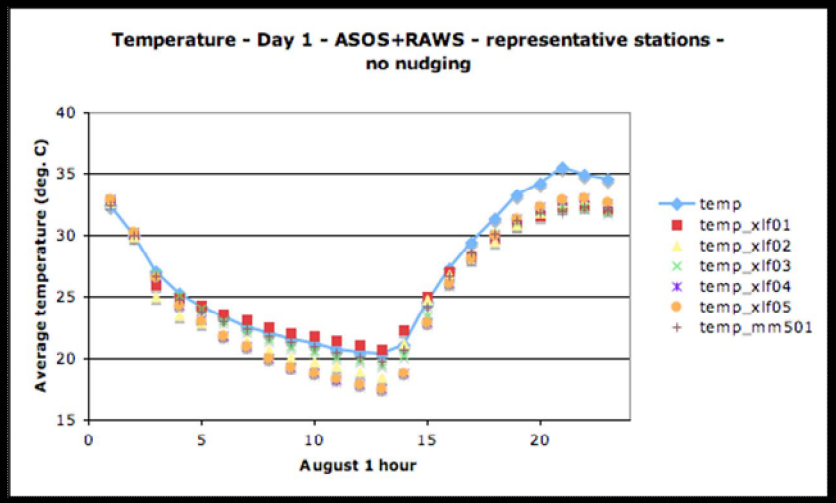


Longer runs: Does model need spin-up time?

Nudged runs:

Tests whether model performs better when prodded

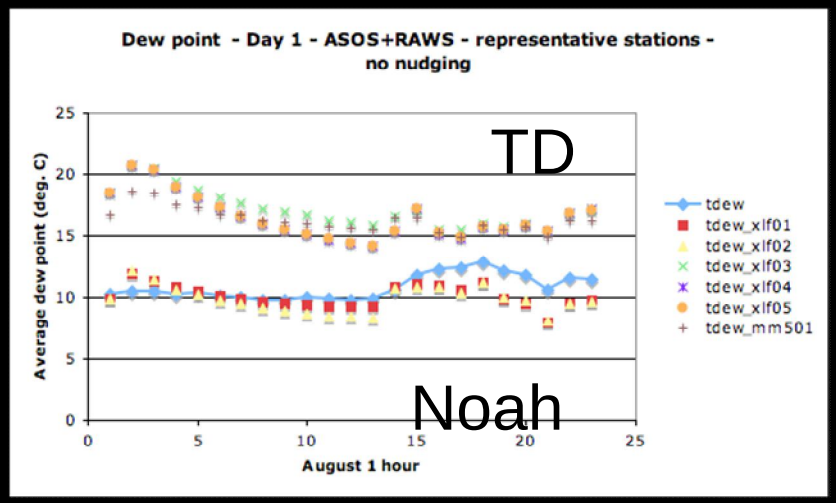
August 1 temperature (representative stations)



Simulation started
00Z 1 August 2000
Using Eta analyses

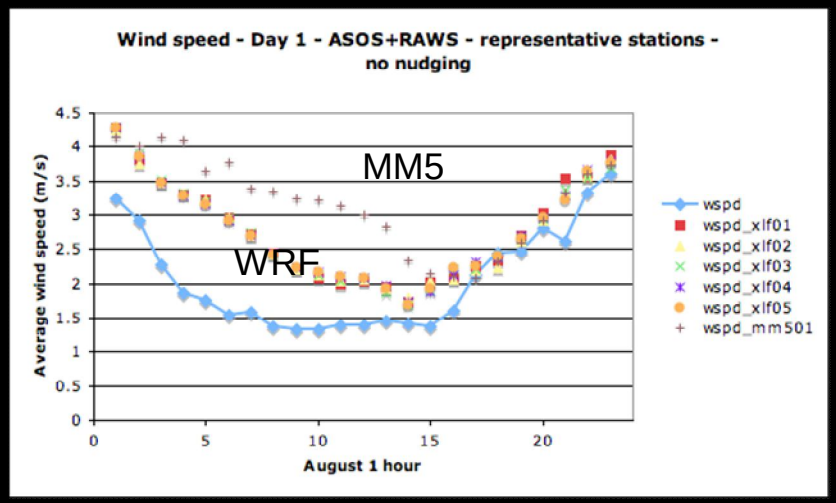
- Underpredicted 2m T in afternoon
- Did no better with
  - Starting at 12Z instead
  - Using FNL
  - August 2nd, starting 00Z on 2nd
  - August 2nd, starting 00Z on 1st
  - August 3rd, a cooler day
  - Nudging WRF
  - Using MM5

August 1 dew point (representative stations)



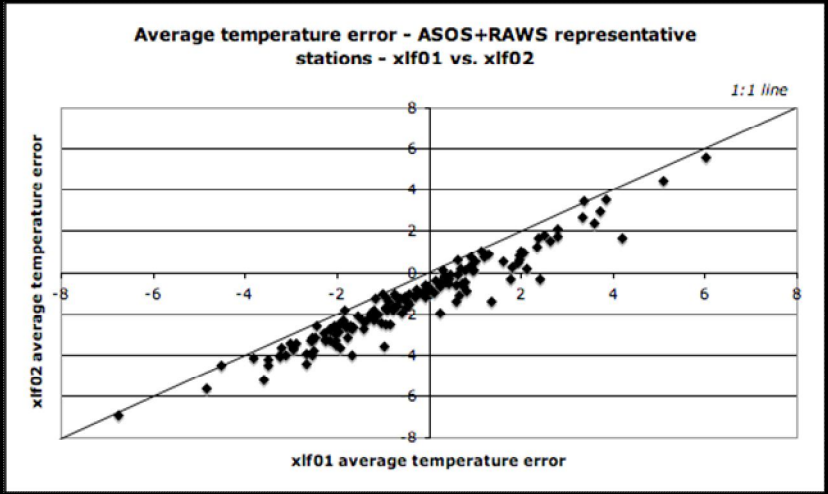
- Noah surface scheme better than TD
- Better Td predictions marginally improved T forecast skill

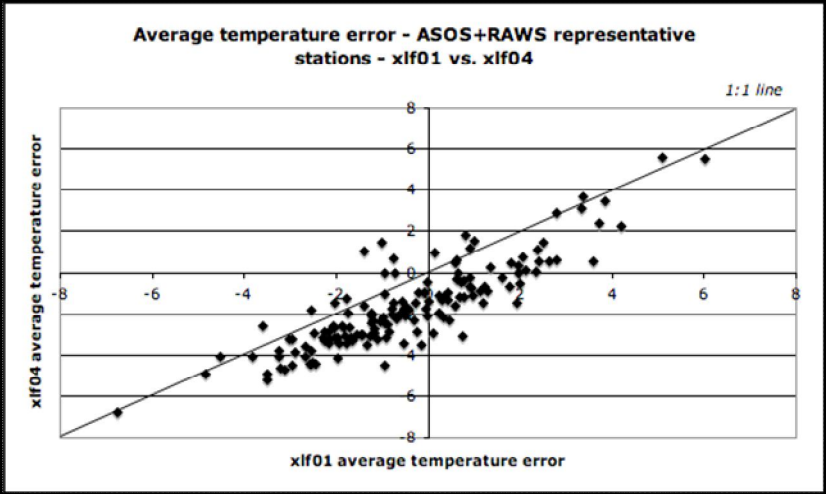
August 1 wind speed (representative stations)



- Simulations too "windy" overnight but not to blame for afternoon cold bias
- WRF superior to MM5
- Wind errors largest when overall model doing best

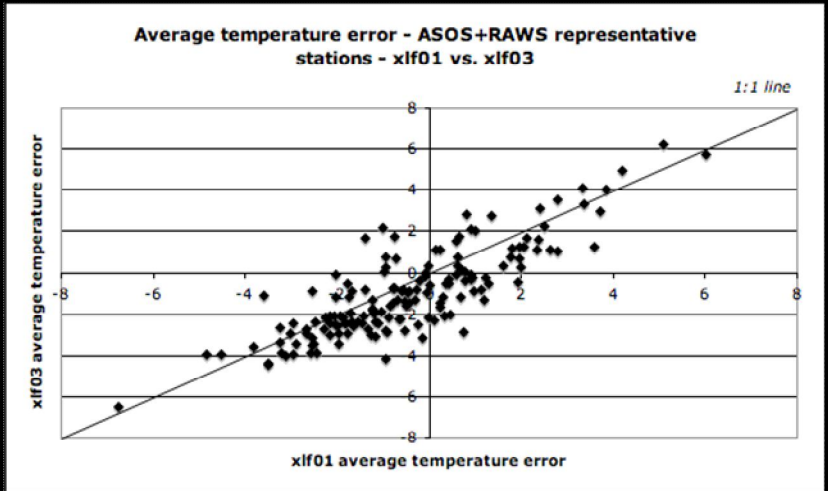
Errors among different simulations highly correlated

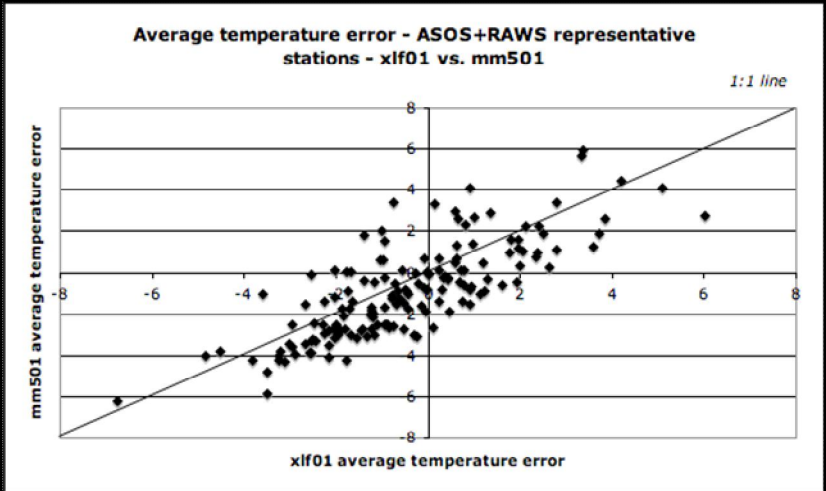




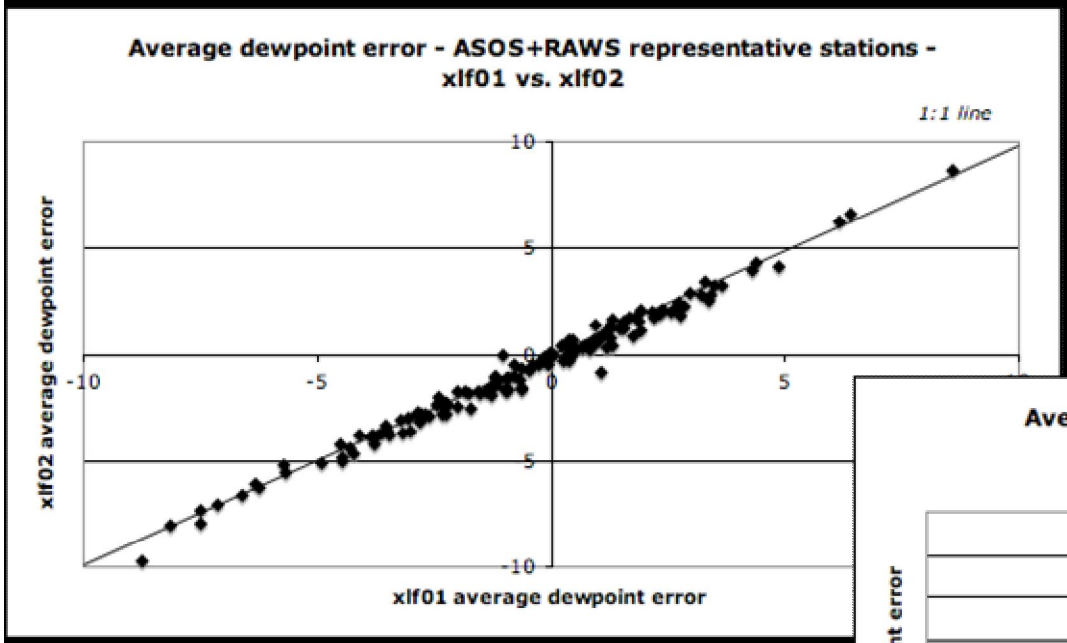
^ diff. radiation - diff surface v

^ diff. rad & sfc - diff models v

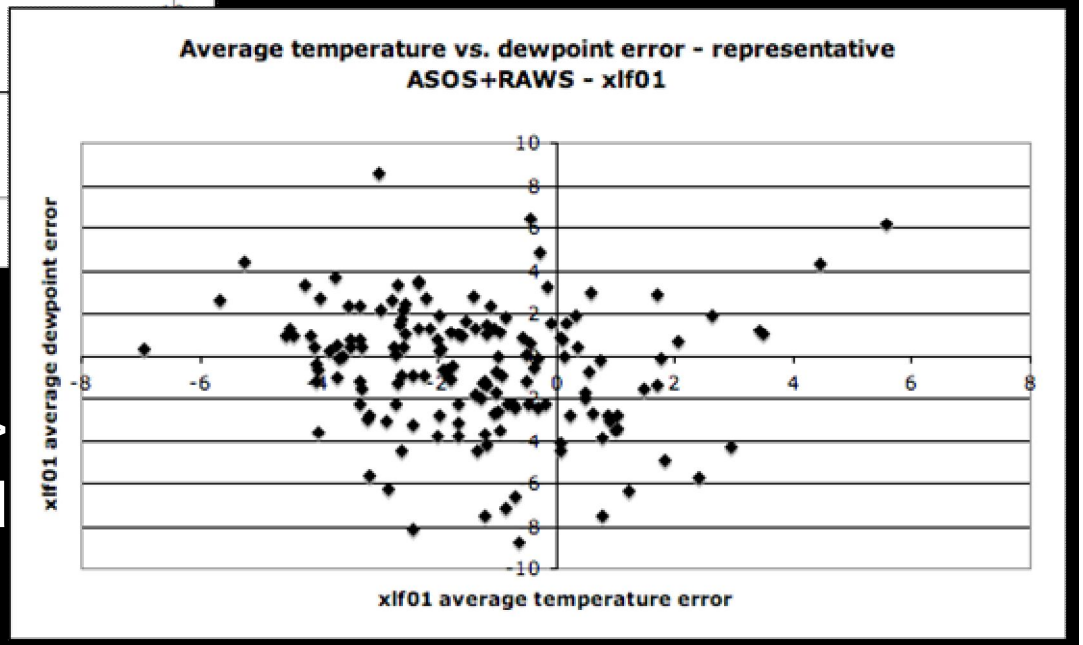




T and Td errors



< Td errors w/
different radiation scheme



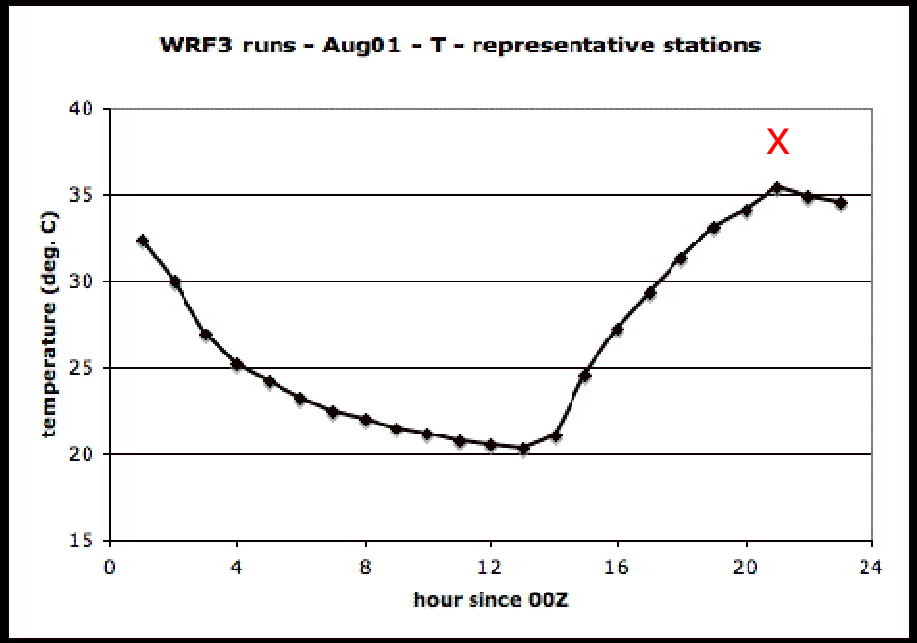
T and Td errors >
not correlated

(not correlated w/ elevation error either)

Simulations with WRF v.3

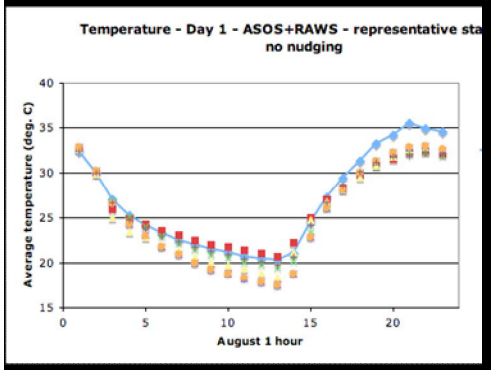
- modified TD scheme
- improved nudging
- slope radiation & topo shading
- extend study to include NARR, PBL variations, landuse contributions

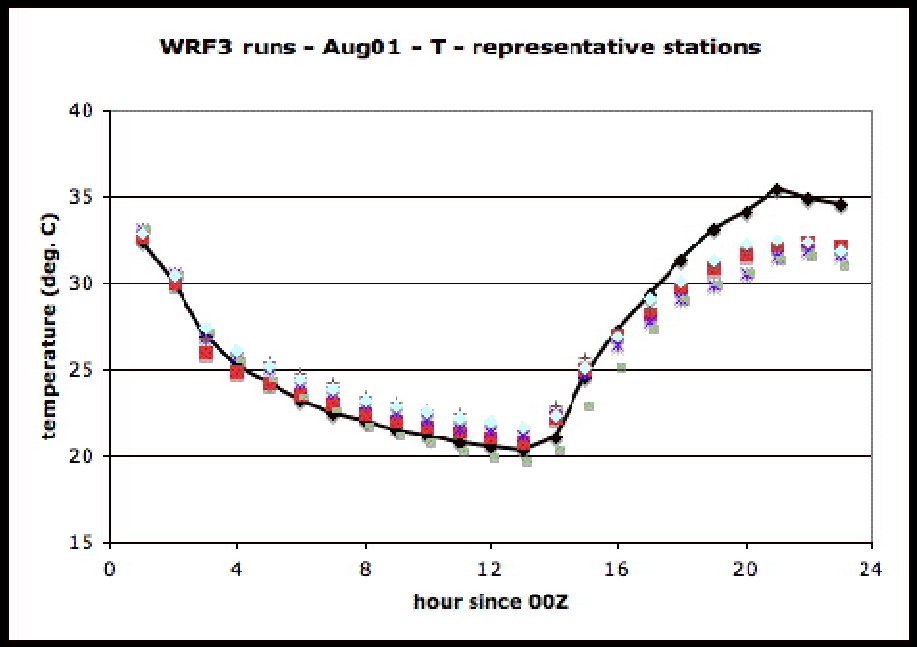
Avg. T for representative stations



X = relatively large # of data dropouts

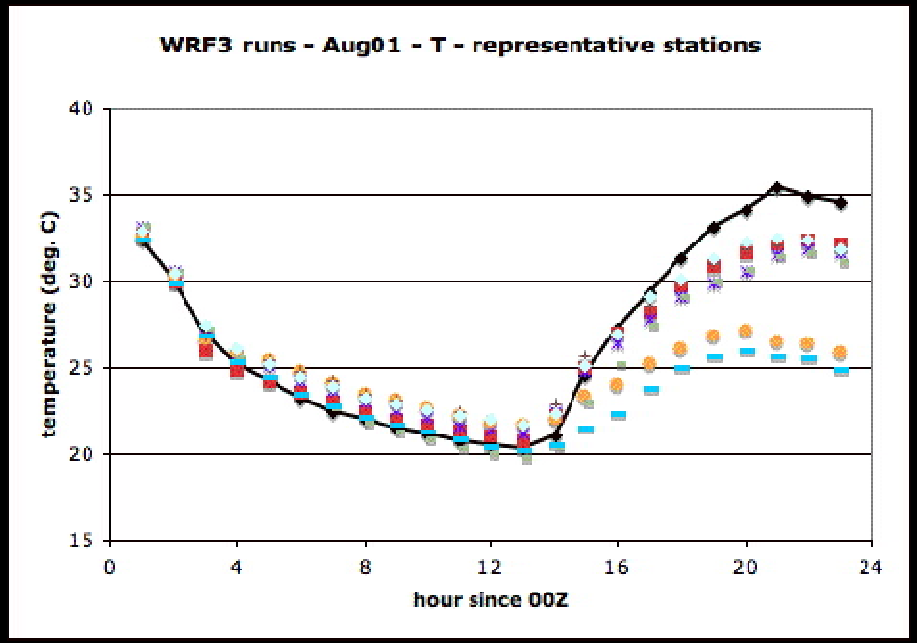
Avg. T for representative stations





Added simulations initialized with Eta and FNL, Noah and TD surface, various PBLs. Results very similar to WRF v.2.

Avg. T for representative stations

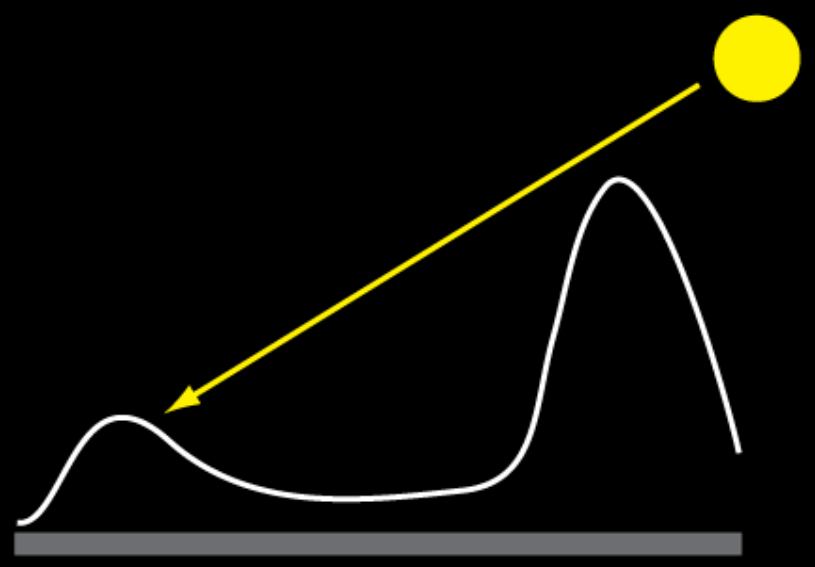


NARR runs;

2 different PBL schemes

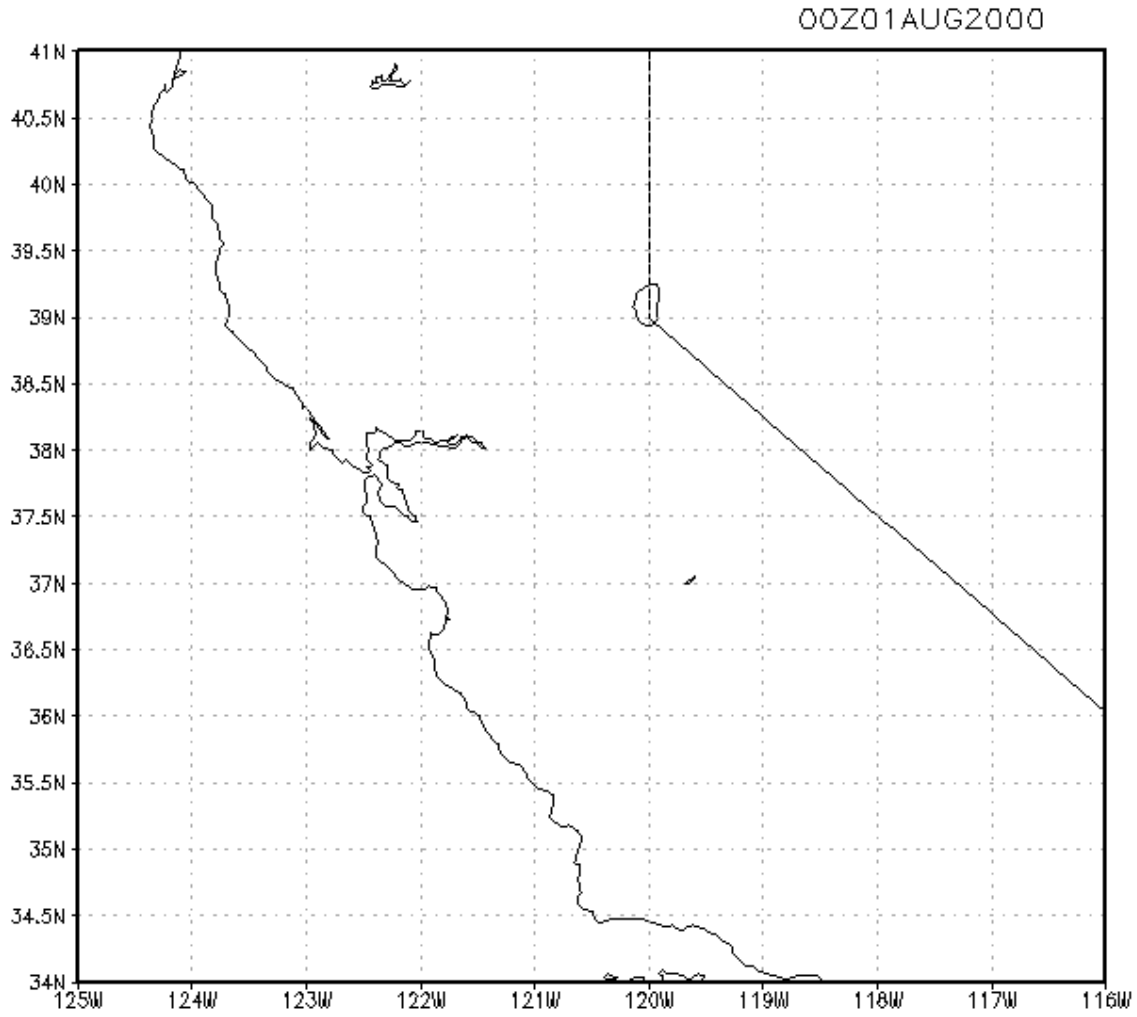
Added simulations initialized with NARR.
(NARR actually has smallest error before sunrise.)

Slope radiation and shading

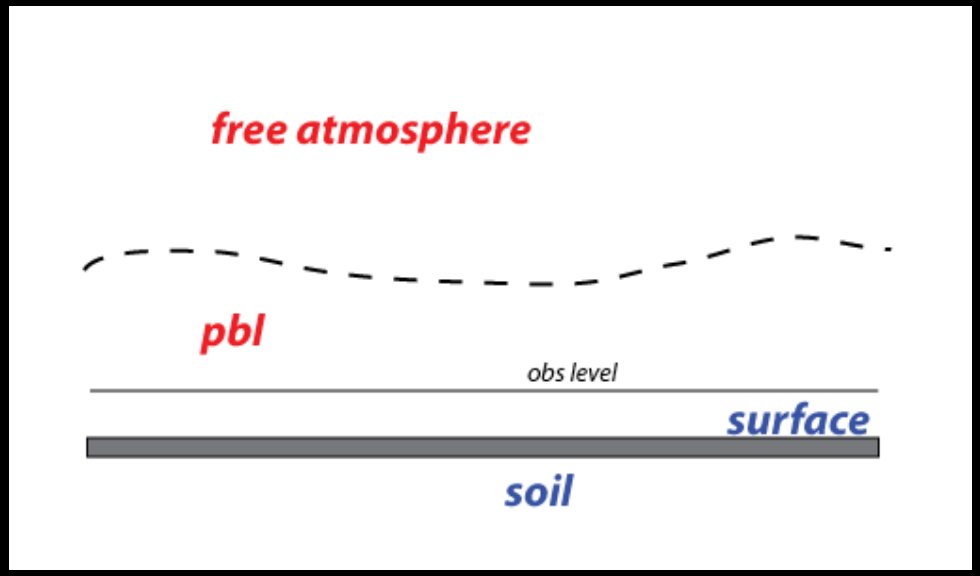


Hypothesis: sets up T gradient across Central Valley, inducing mesoscale circulation

Slope radiation and shading



Source of error: bottom-up vs. top-down?



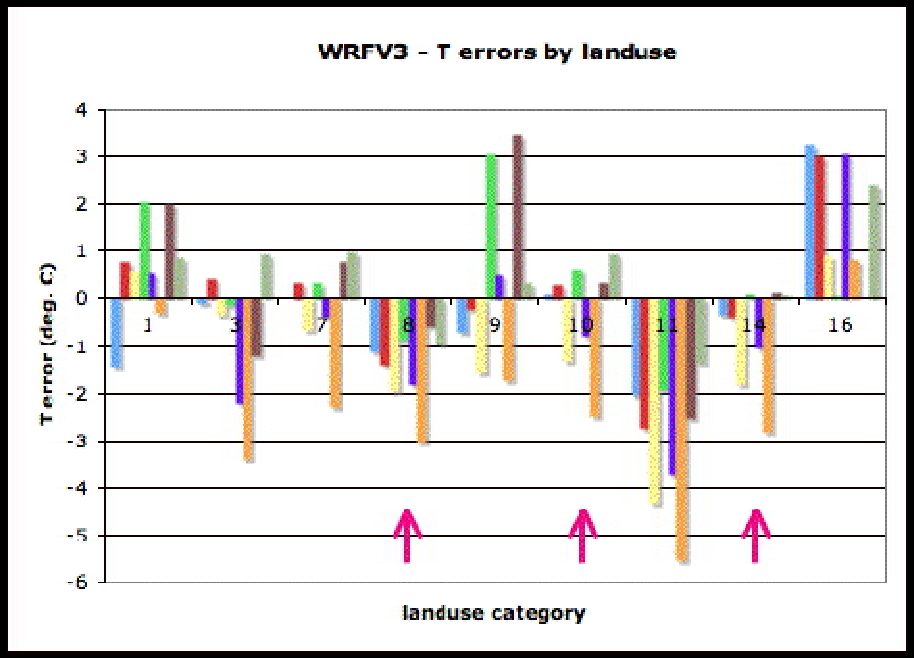
Asynoptic, low wind conditions: expect errors strongly local & <u>bottom-up</u>

Landuse type distribution among representative stations

landuse cat.	type	count
1	urban	10
3	Irrigated cropland	5
7	grassland	5
8	shrubland	32
9	shrub/grass	6
10	savanna	39
11	deciduous forest	6
14	evergreen forest	52
16	water	2

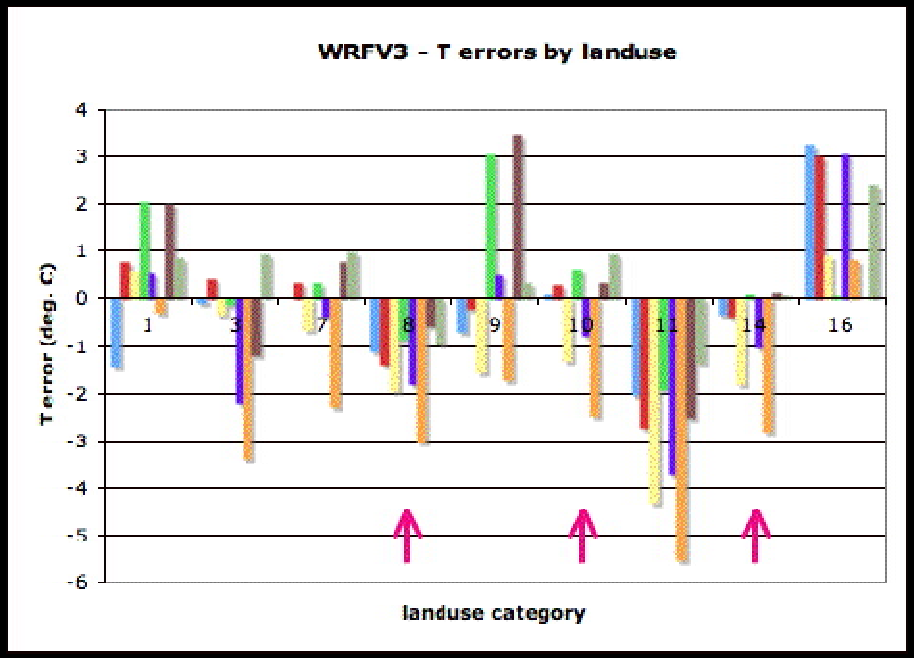
Cat. 8, 10, 14
79% of total

T errors by landuse category for representative stations



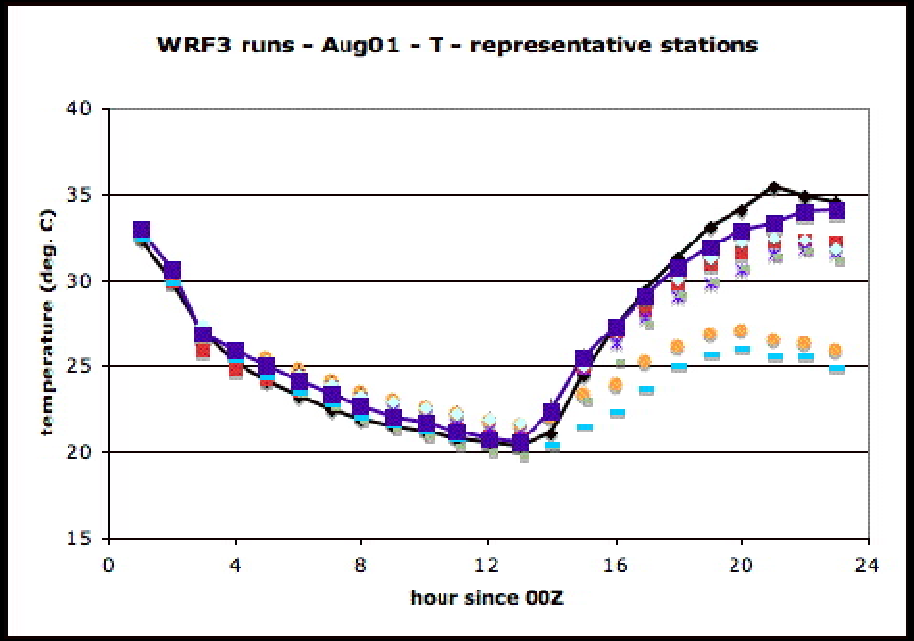
Categories 8, 10 and 14 account for 79% of stations
Categories 8 (shrub) and 14 (evergreen) reveal cold biases
[and represent 54% of all stations]

T errors by landuse category for representative stations



Experiment to manipulate surface/soil characteristics failed to resolve temperature bias

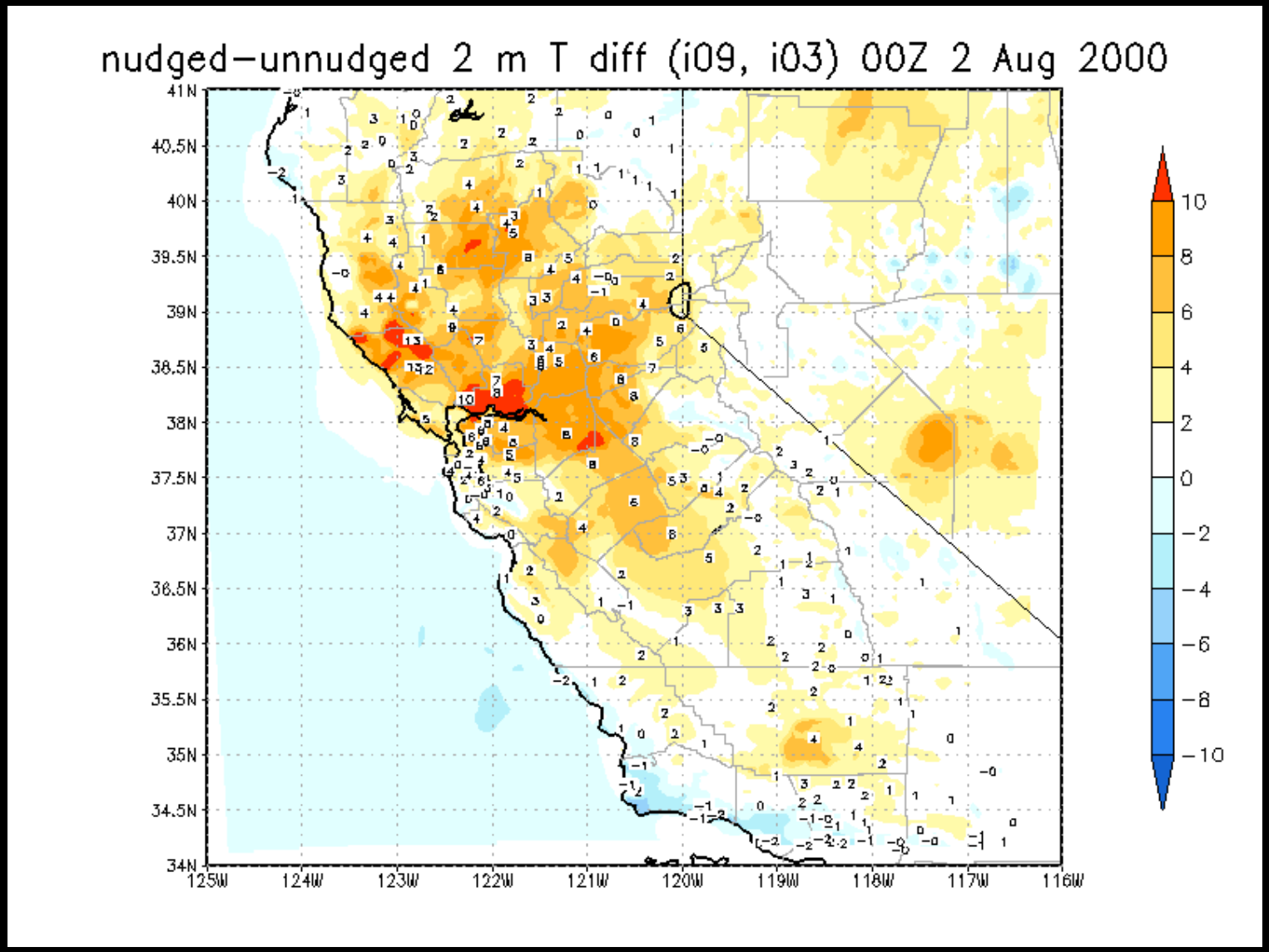
Avg. T for representative stations



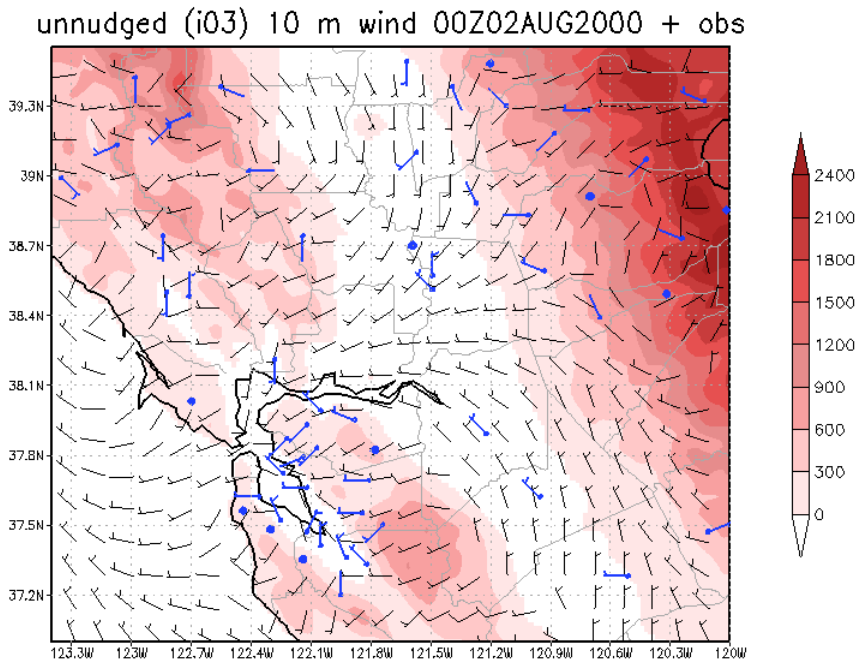
nudged run

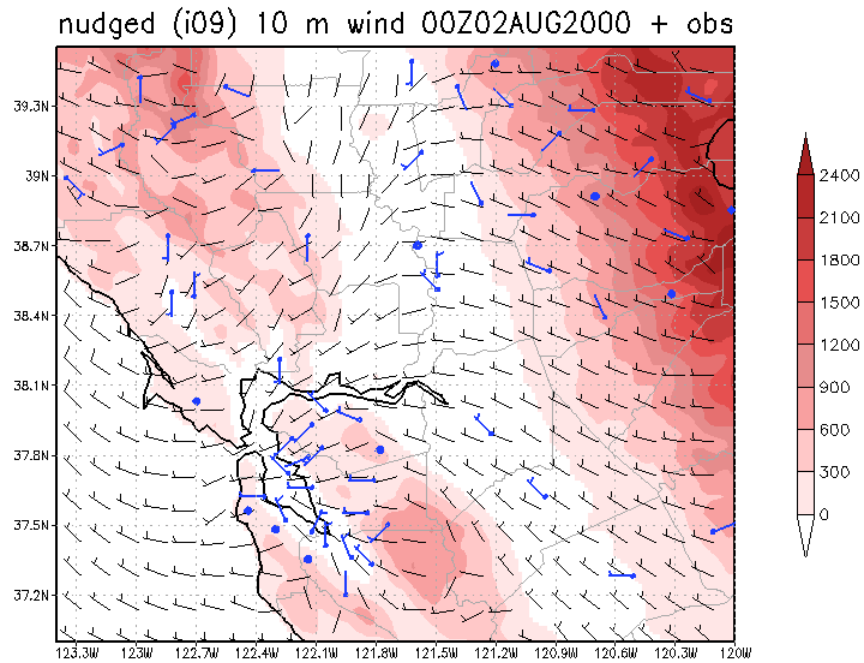
Added Eta-nudged run.

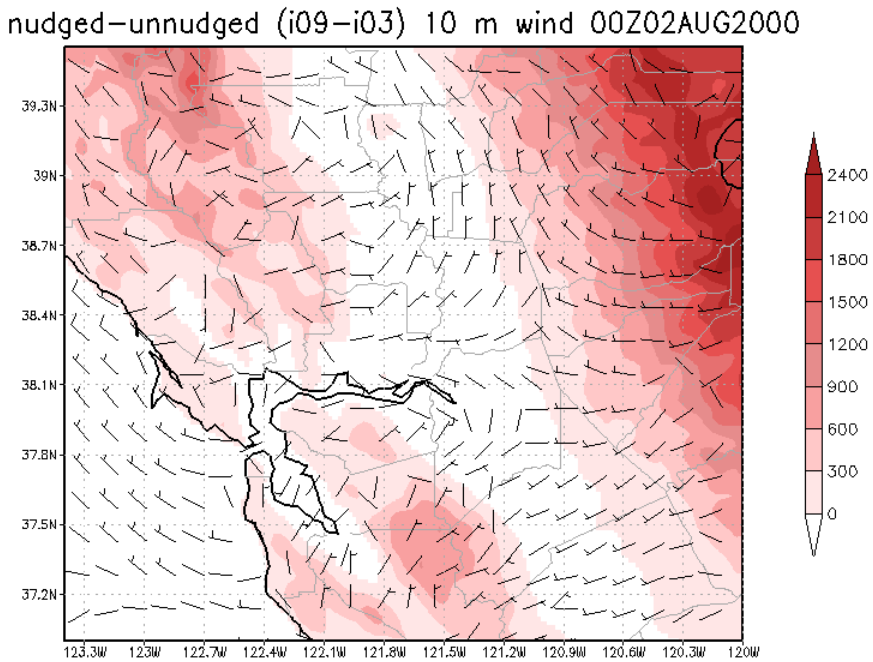
Nudged free atmosphere only. Nudging PBL also didn't help. ***Also nudged nests***.



Colors and digits: nudged-unnudged

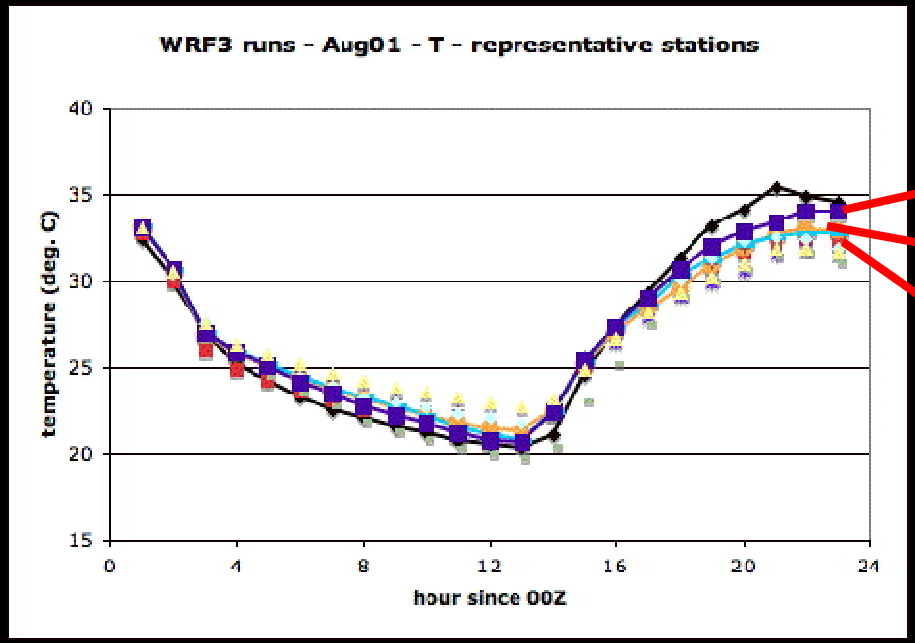






^ Delta 'sea-breeze" weaker

Avg. T for representative stations



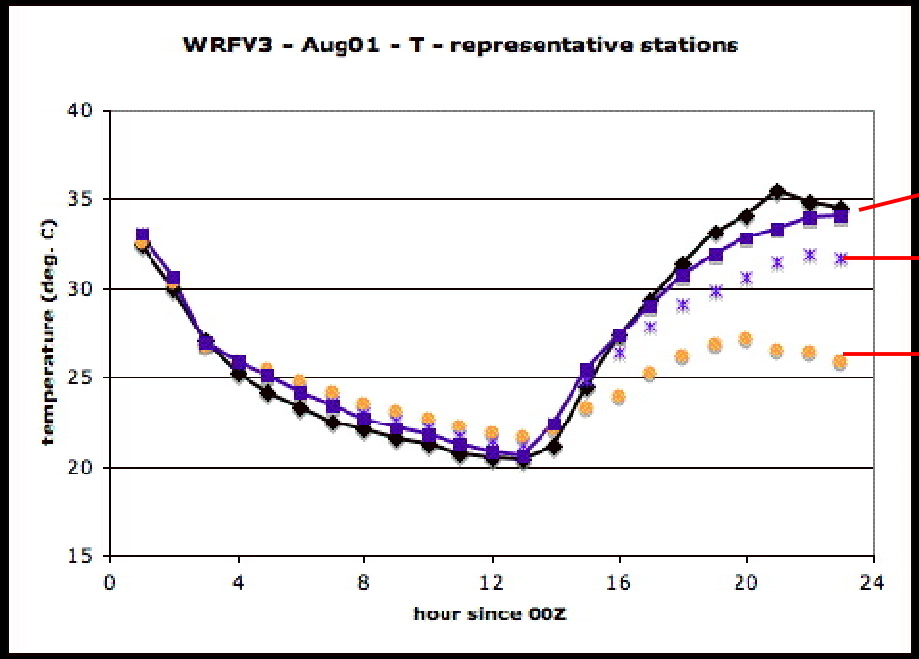
nudged all

nudged D1

nudged D1 & D2

Nudging nests experiment:
Nudging *all* best, nudging just D1 or D1&D2 nearly indistinguisable

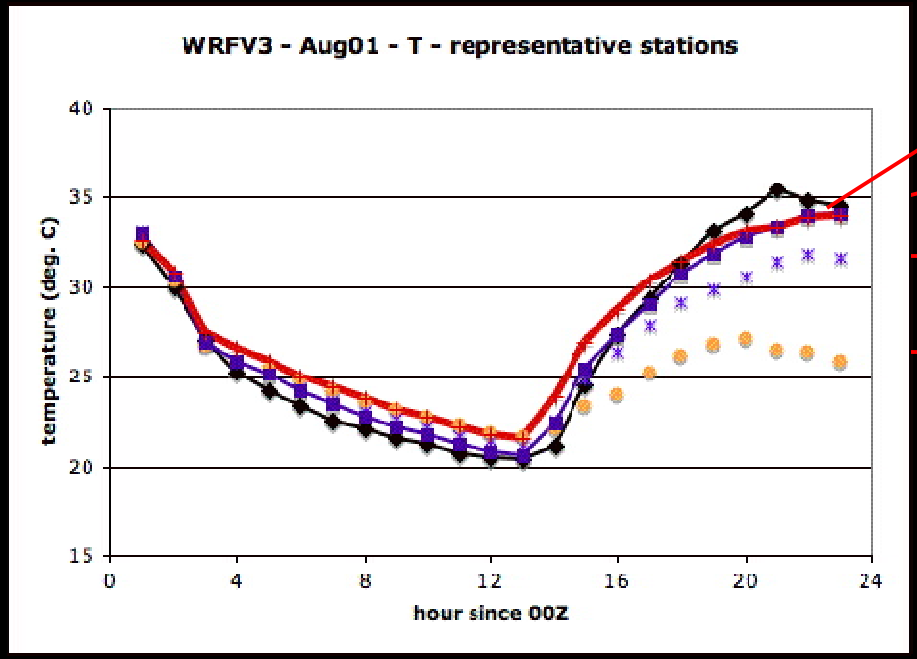
Nudging NARR?



Nudged Eta
Unnudged Eta

Unnudged NARR

Nudging NARR?



Nudged NARR

Nudged Eta

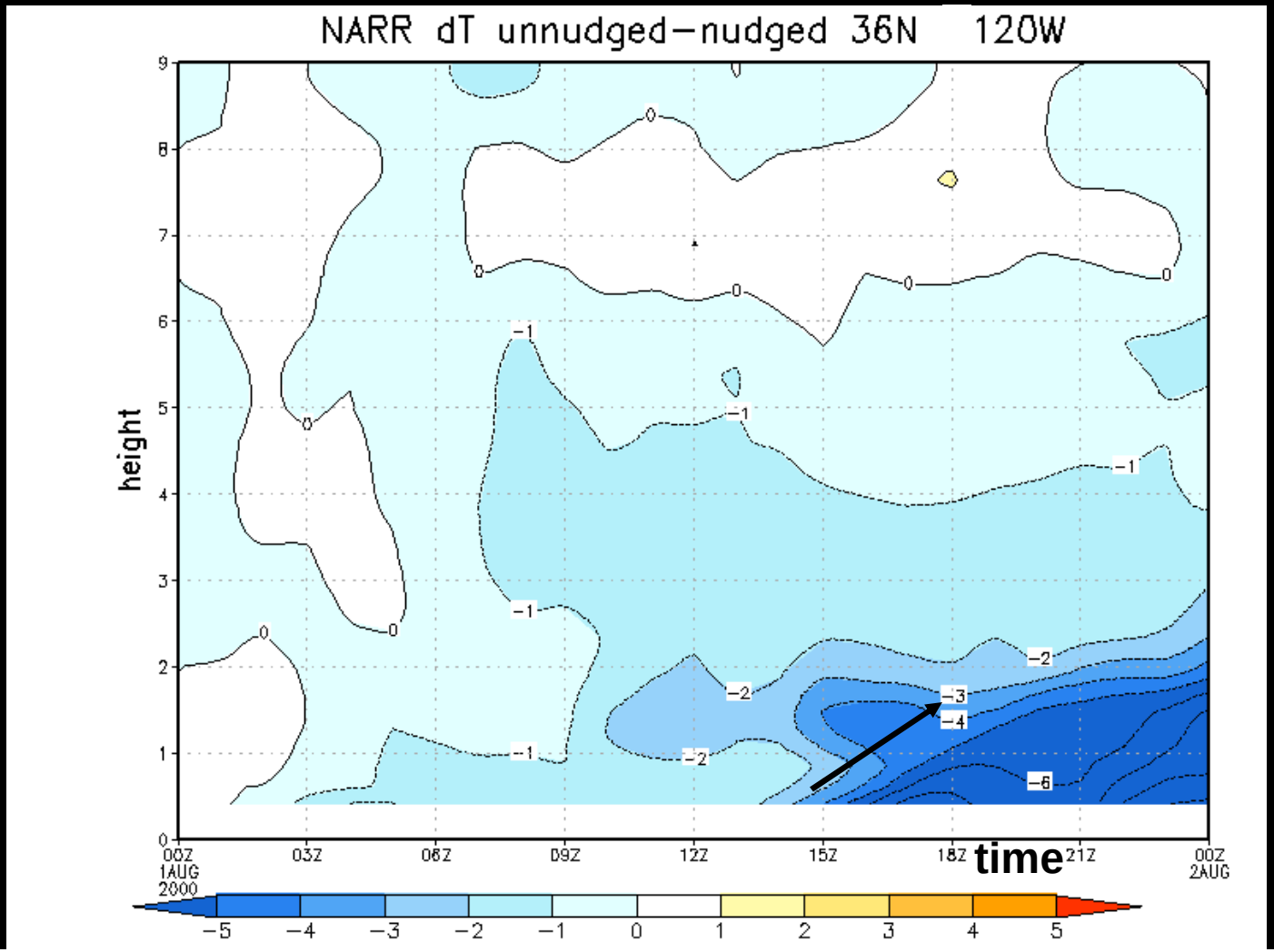
Unnudged Eta

Unnudged NARR

Difference in nudged vs. unnudged NARR starts right after sunrise. Why?

△T nudged-unnudged for NARR runs

Central Valley, near Kettleman City



NARR-Eta hybrid initialization

- Feature of WPS - combine data sources
- Tested NARR 3D information with *surface/soil initialization from Eta*
- Result: little different from unnudged NARR-only run (i.e., still very poor after sunrise)

Comments

- MM5 and WRF both have difficulty simulating an asynoptic, heat-wave situation
  - Particularly acute for NARR initialization
  - Varying PBL, other physics, landuse, fails to cure
- WRF v.3 nudging produces highest fidelity results
  - Even for NARR initialization… bugs?
  - Unnudged skill loss apparently ‘top down’ from free atmosphere
- LW radiation (in RRTM) bugfix released 10/23/08
  - Little impact on results (actually a little worse)
- Brute force (nudging) doesn’t cure/excuse bad physics (or bugs)

Generalized results

(subject to change as matrix gets filled out, more cases examined)

- Nudged runs better than unnudged
- Nudging all domains better than outer alone
- FNL better than Eta, much better than NARR
- Noah better than TD surface scheme
- YSU better than MJY PBL
- Slope/shading effects unimportant
- Local landuse variations apparently unhelpful
- RRTM radiation bug fixes don’t help

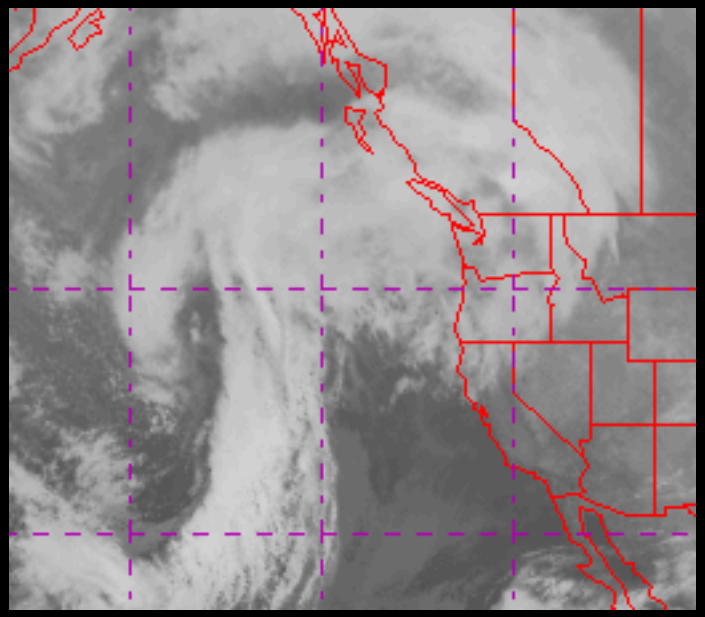
Winter case

January, 2001

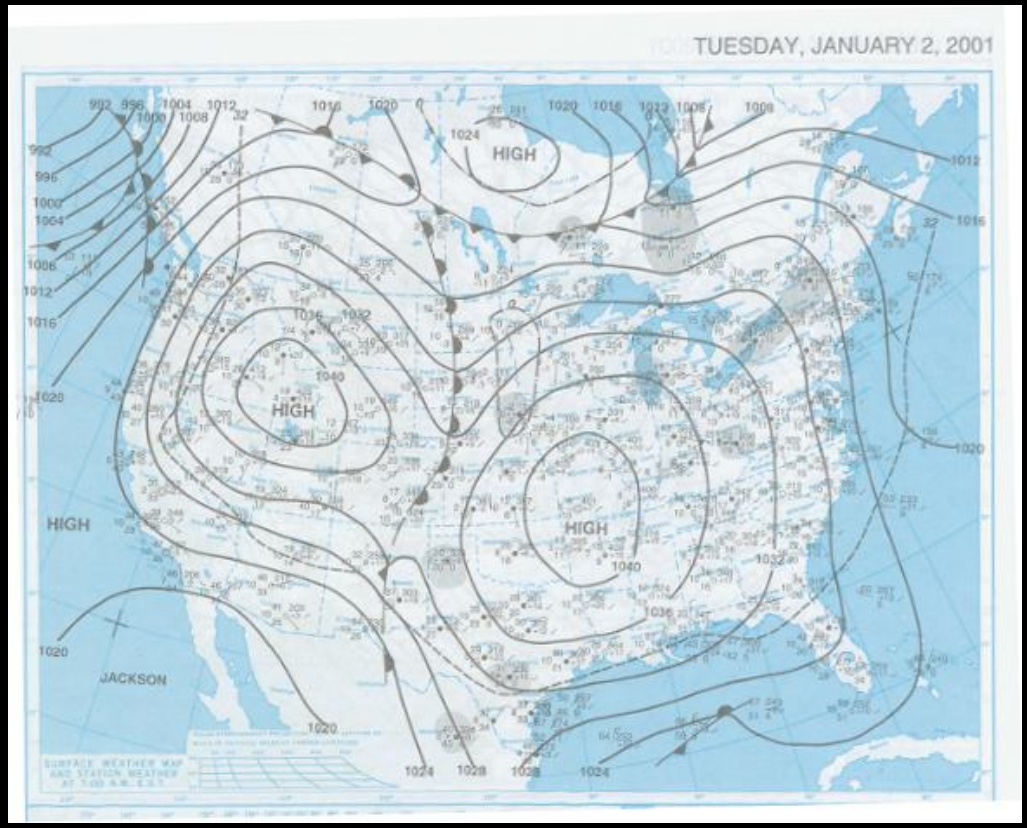
January 2 weather summary

- High pressure interior west
  - Santa Ana conditions in So. California
  - Light winds in Central Valley
- Persistent low fog in Central Valley
- Slow-moving N Pacific storm approaching

12Z January 2 observations

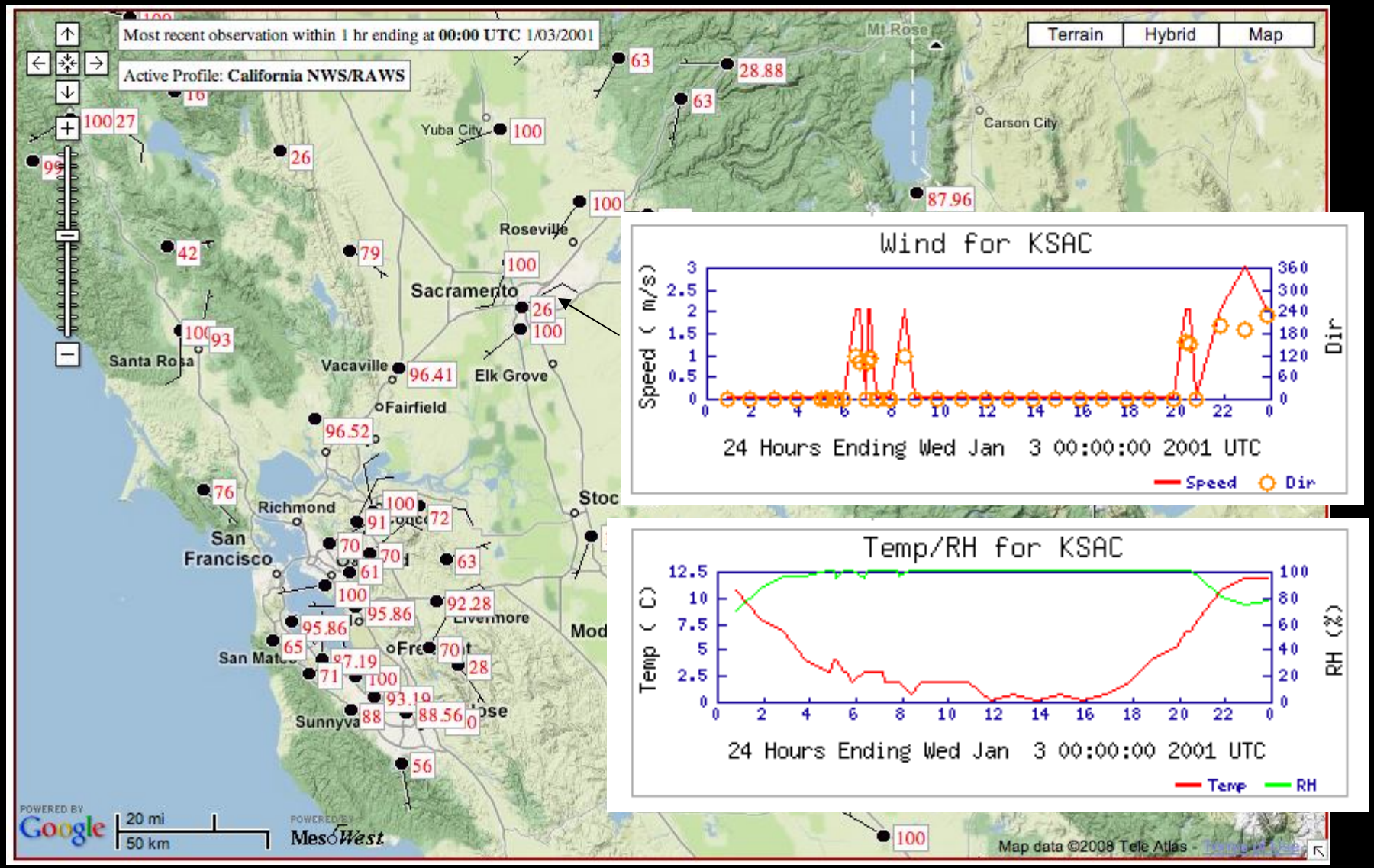


^ IR



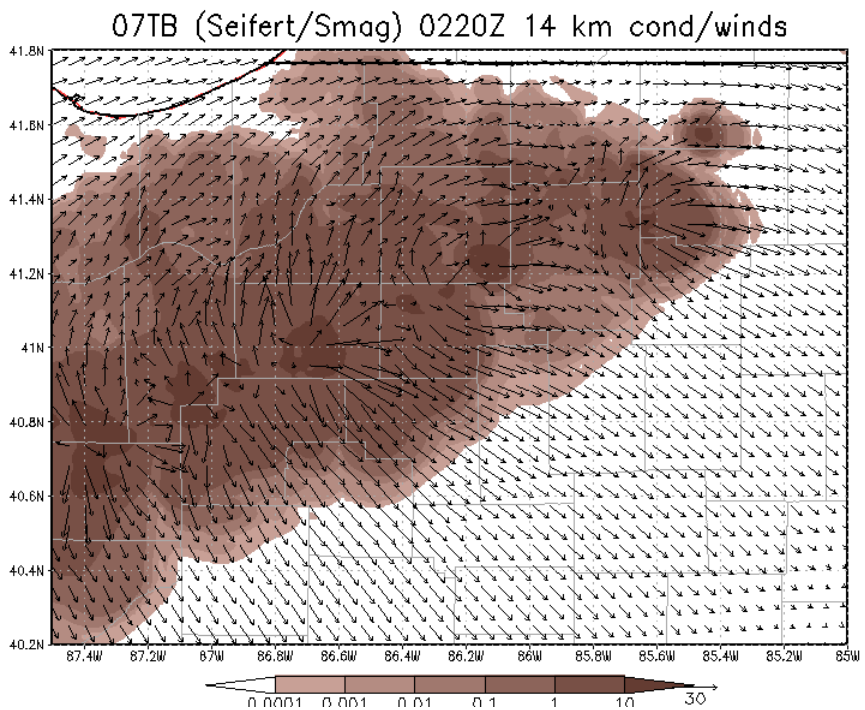
Surface map >

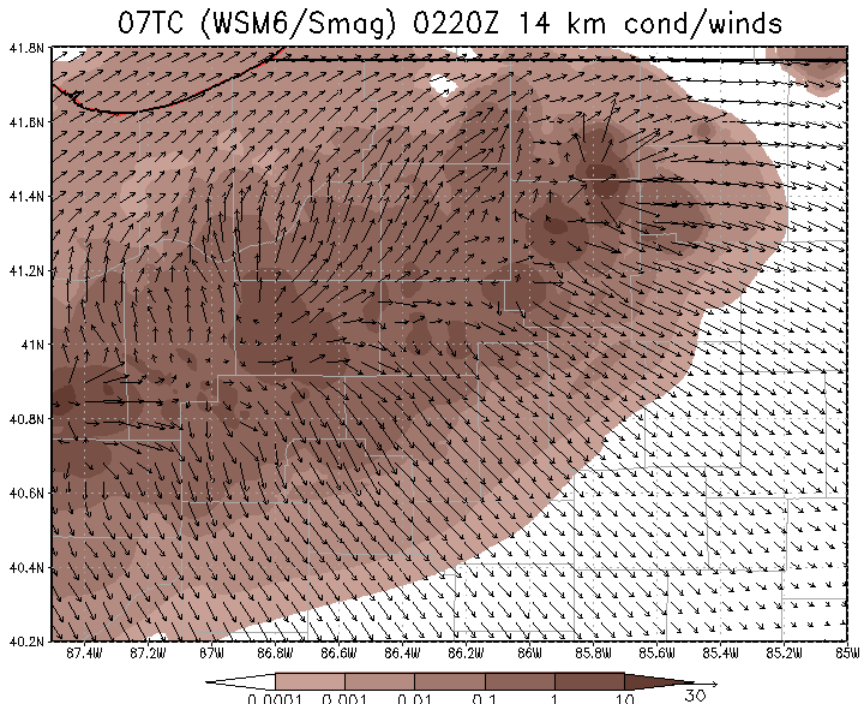
24 h max RH on January 2nd



WRF-ARW configuration

- Same three domains as August 2000 case
- FNL data input
- RRTM (pre-fix), Noah schemes
- **Microphysics** (both 6 class):
  - Seifert-Behing two-moment microphysics
  - Thompson scheme (single moment cloud)
- Kain-Fritsch cumulus parameterization in outer 2 domains
- No nudging





Clear air turbulence case

Storm anvil cloud shown

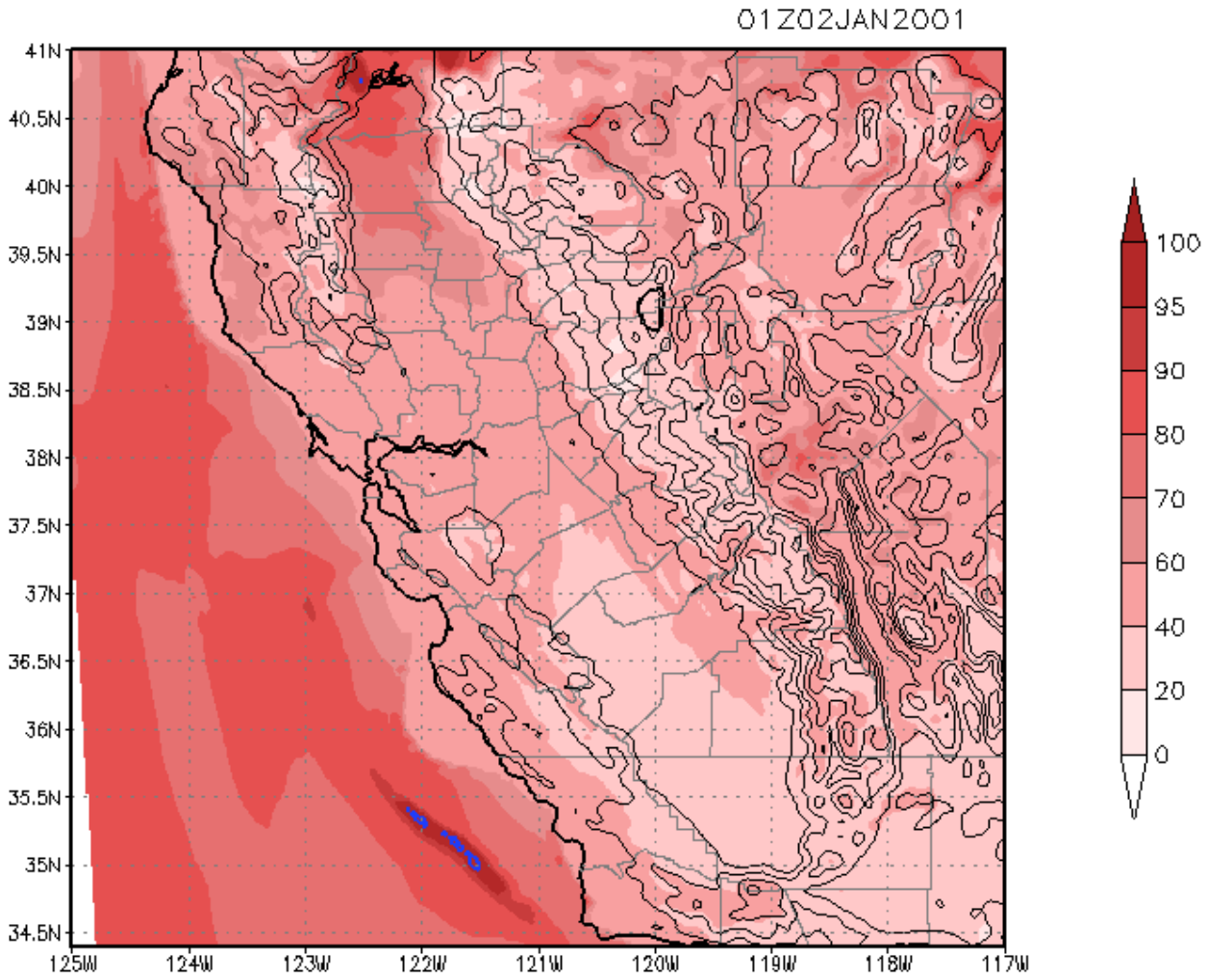
(Fovell et al. 2008)

< Seifert-Beheng microphysics

Seifert anvil more sharply defined, comparable to obs

< WRF Single Moment 6 class (WSM6) microphysics

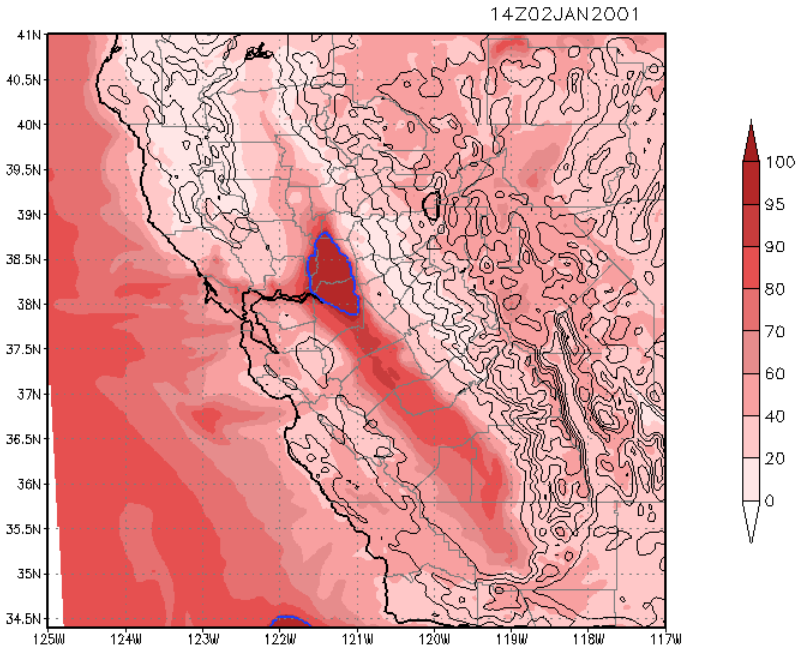
Jan 2 near-sfc RH - Seifert



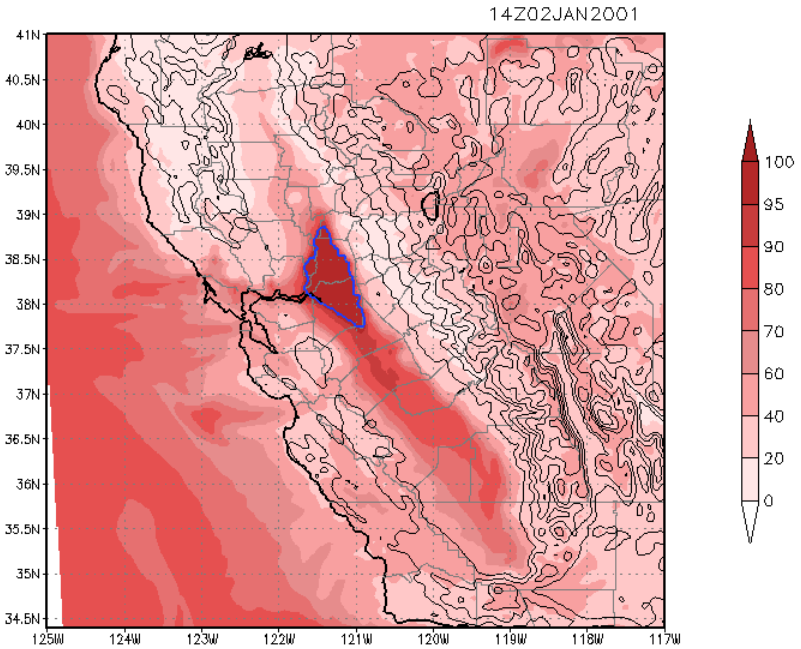
Blue = cloud water > 0.1 g/kg

14Z January 2 (14 h forecast)

Seifert



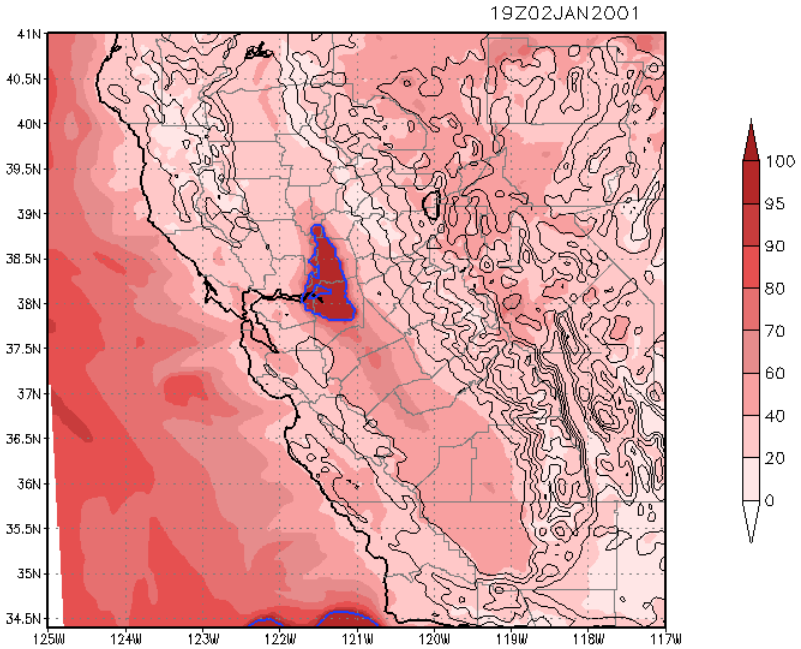
Thompson



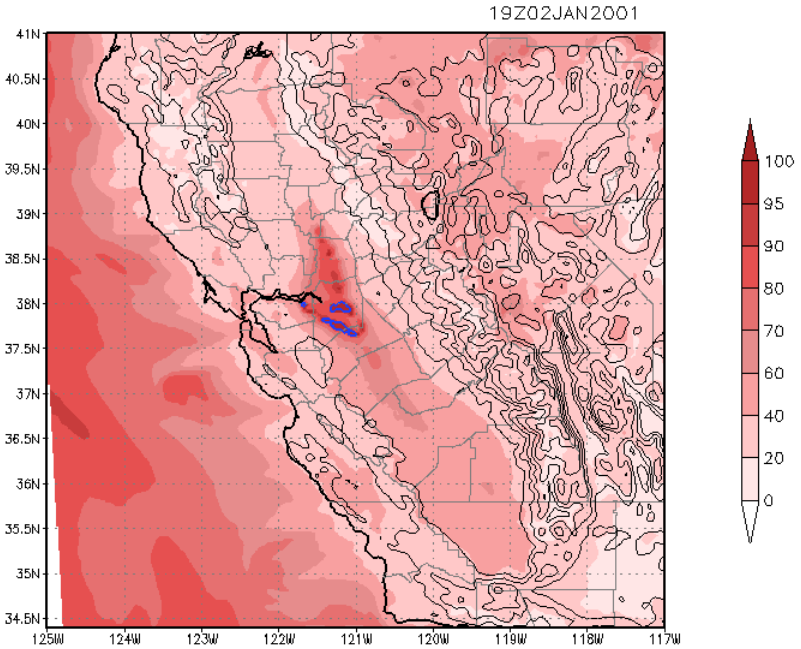
Little difference at this time

19Z January 2 (19 h forecast)

Seifert



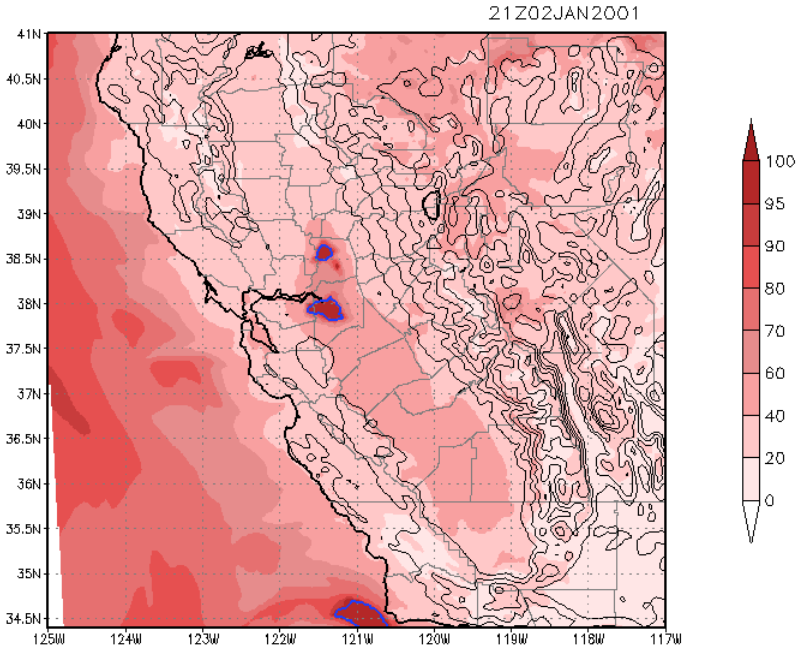
Thompson



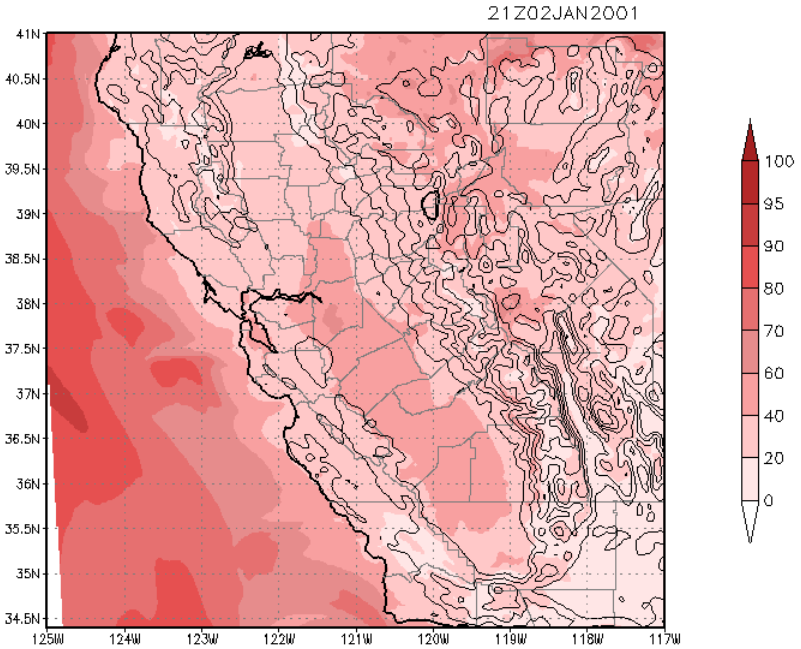
Seifert fog breaks up more slowly

21Z January 2 (21 h forecast)

Seifert

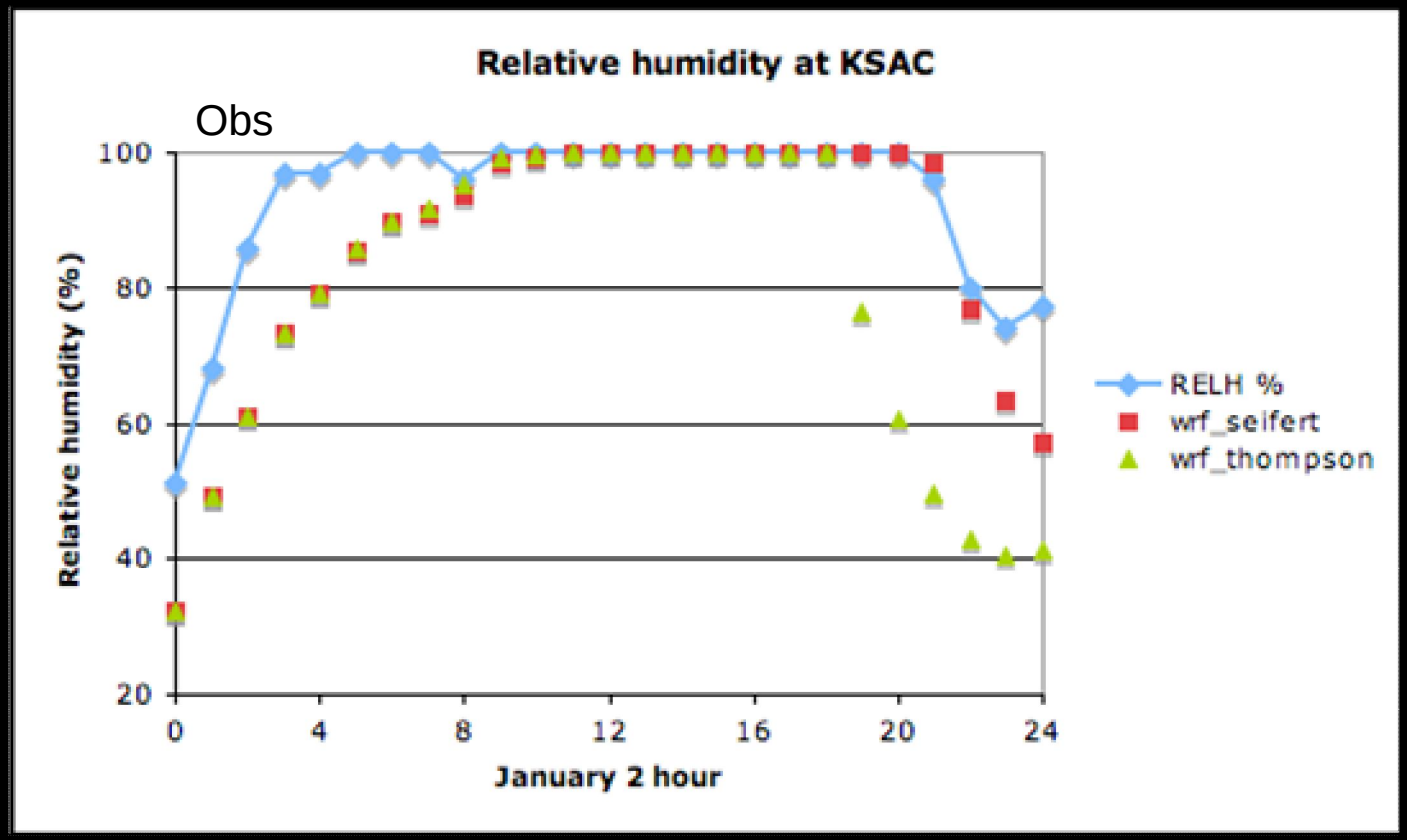


Thompson



No fog remains in Thompson simulation

Sacramento relative humidity



end