How does the WRF model capture the intrinsic features of the evening transition boundary layers?

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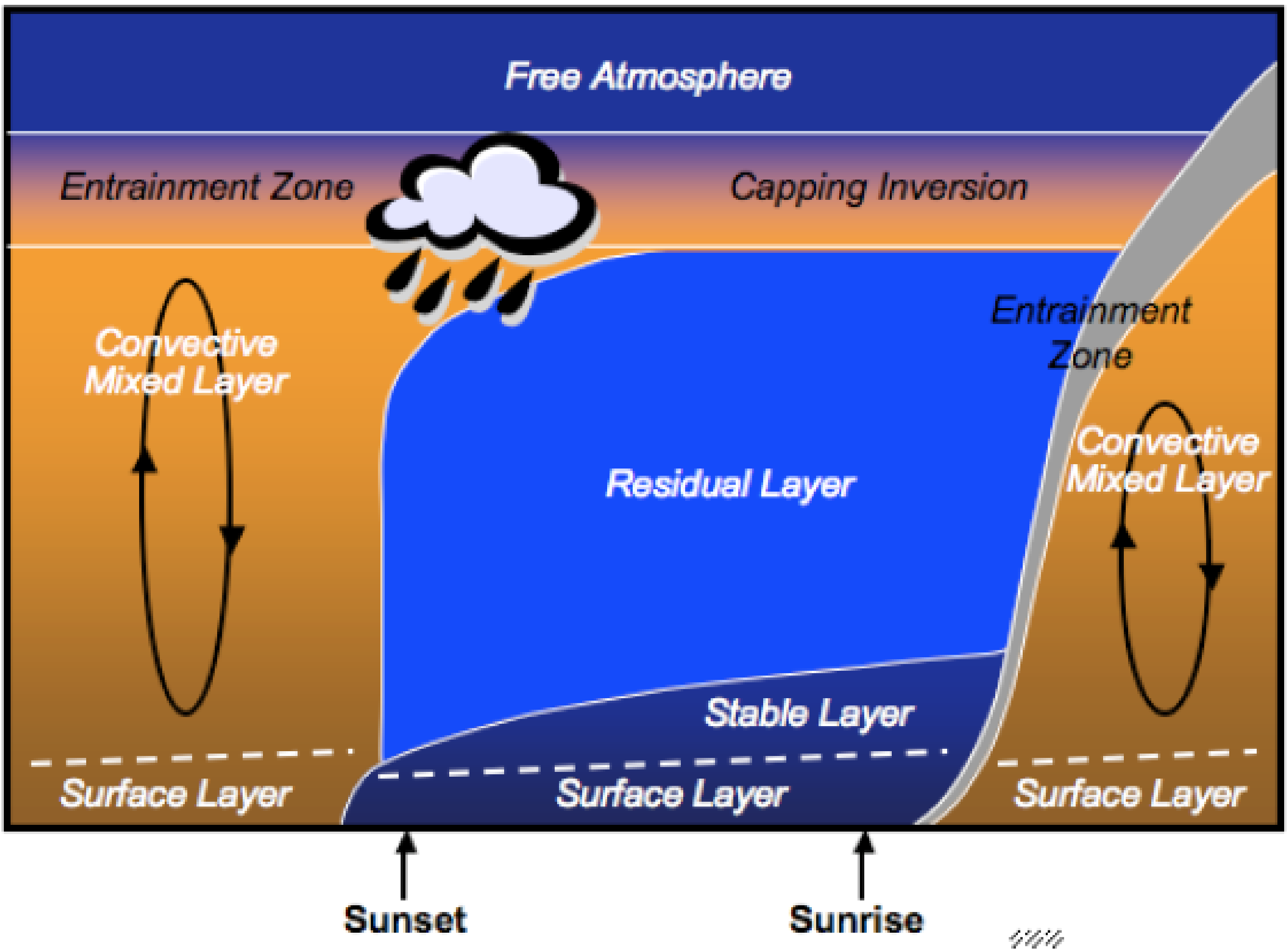
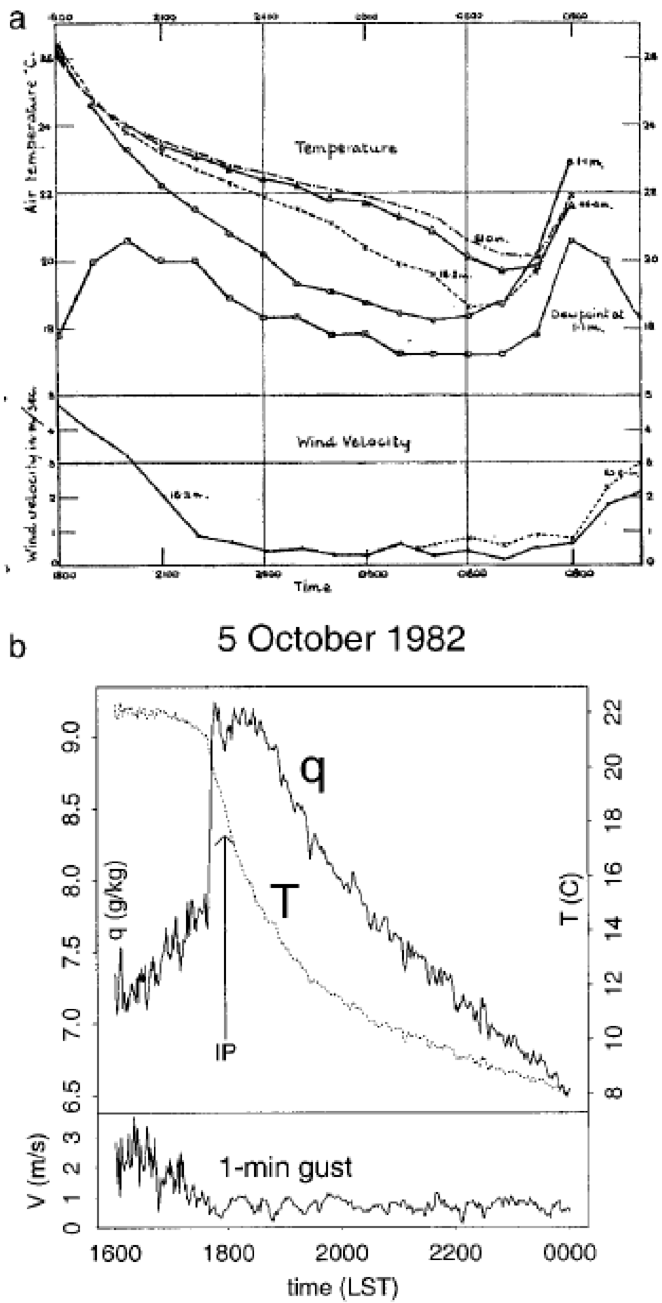
What is the evening transition?

Definition: the transition from the unstable PBL mode (CBL) to the stable mode (SBL)

Main feature: absence of steady state conditions (a transient state)

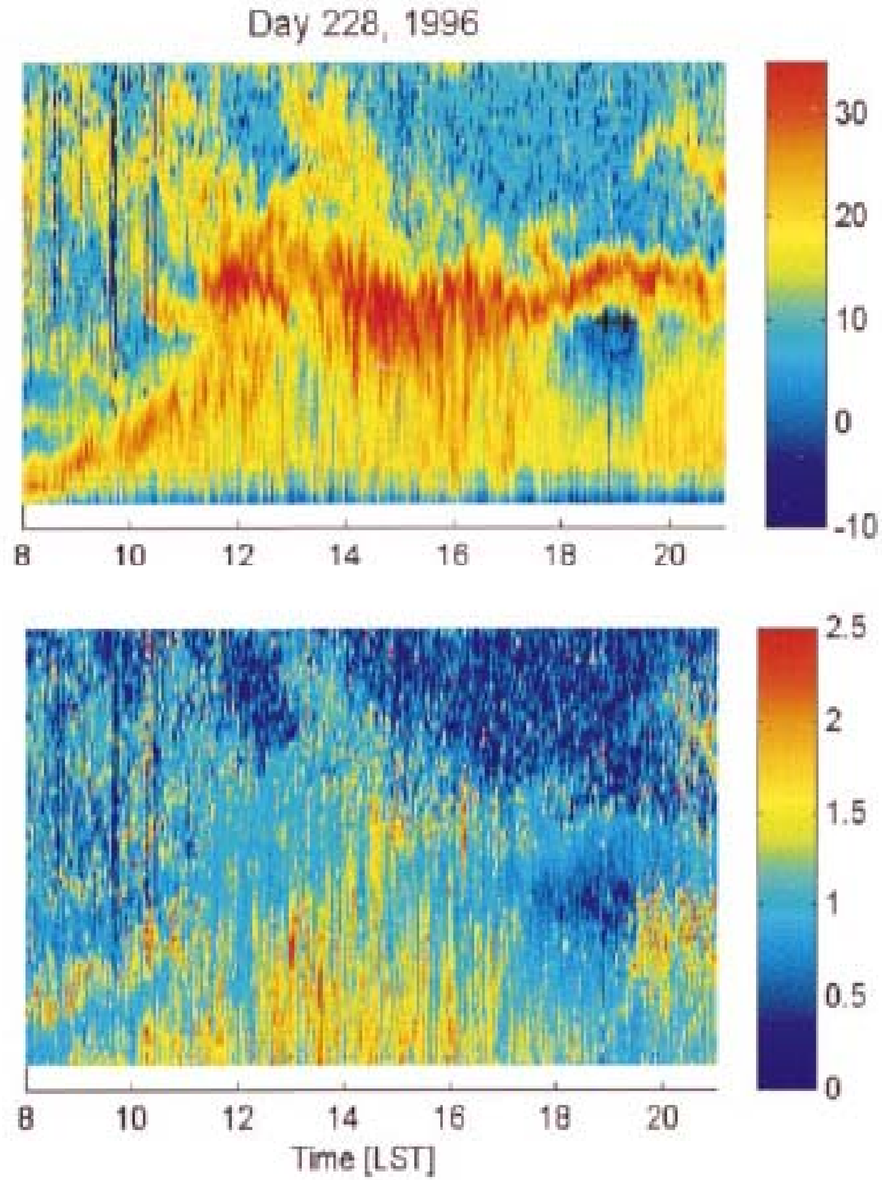
Conceptual Diagram of BL Evolution *[from Stull, 1988]*





Acevedo and Fitzjarrald, 2001

Profiler data



Grimsdell and Angevine, 2002

Radiation Measurements

Bushland Campaign 2008

Micro-meteorological Observations

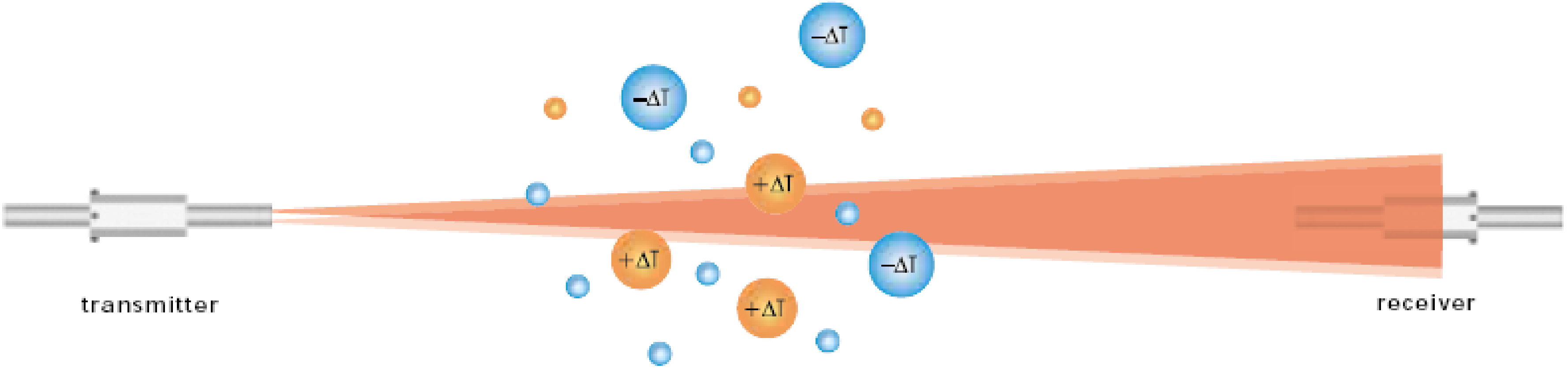
How did the WRF model perform?

Scintillometry

DBSAS:

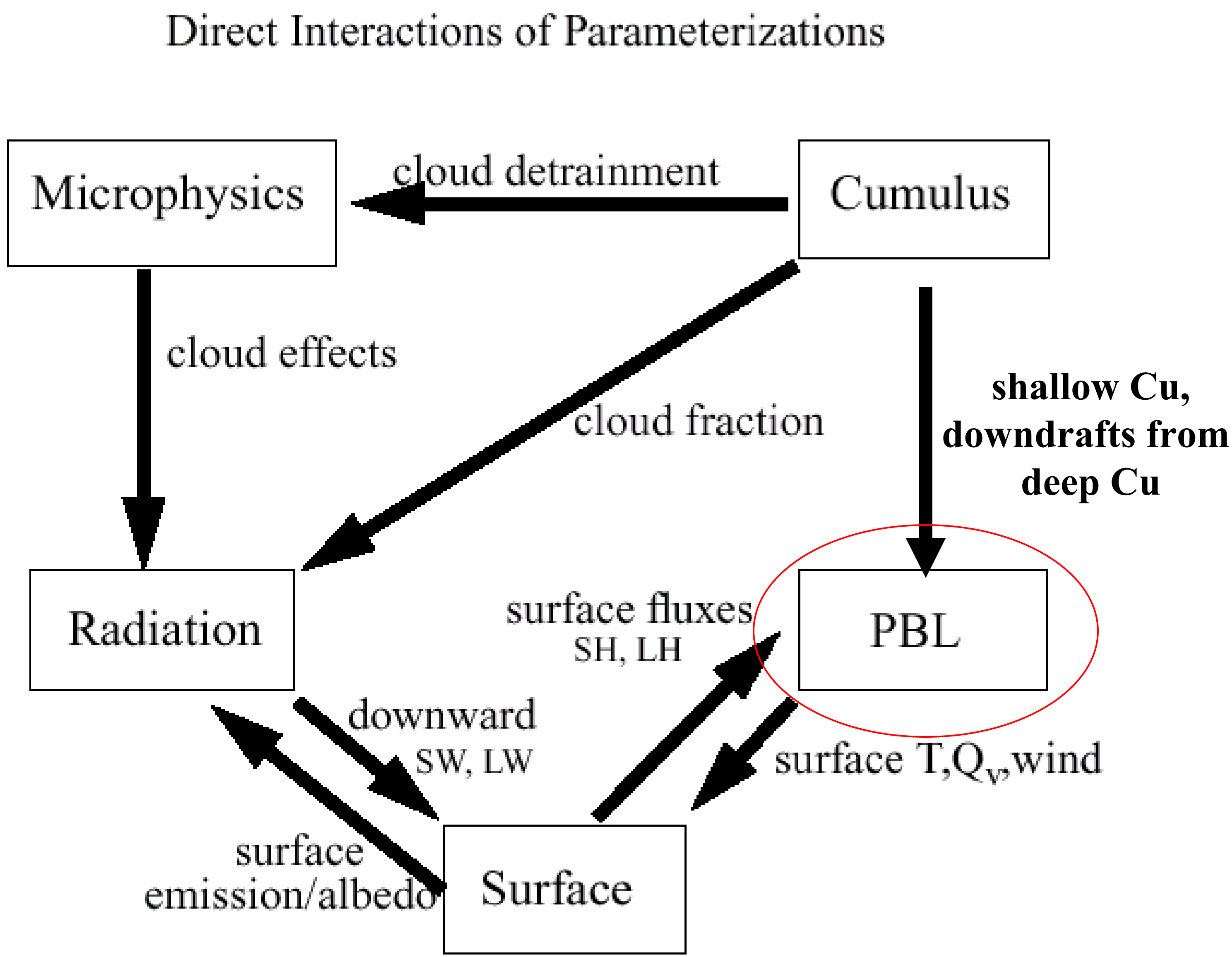
$$C_n^2 \longrightarrow C_T^2$$

$$L_0 \longrightarrow \varepsilon$$



Optical measurement of turbulence with Surface Layer Scintillometer

Courtesy: Scintec



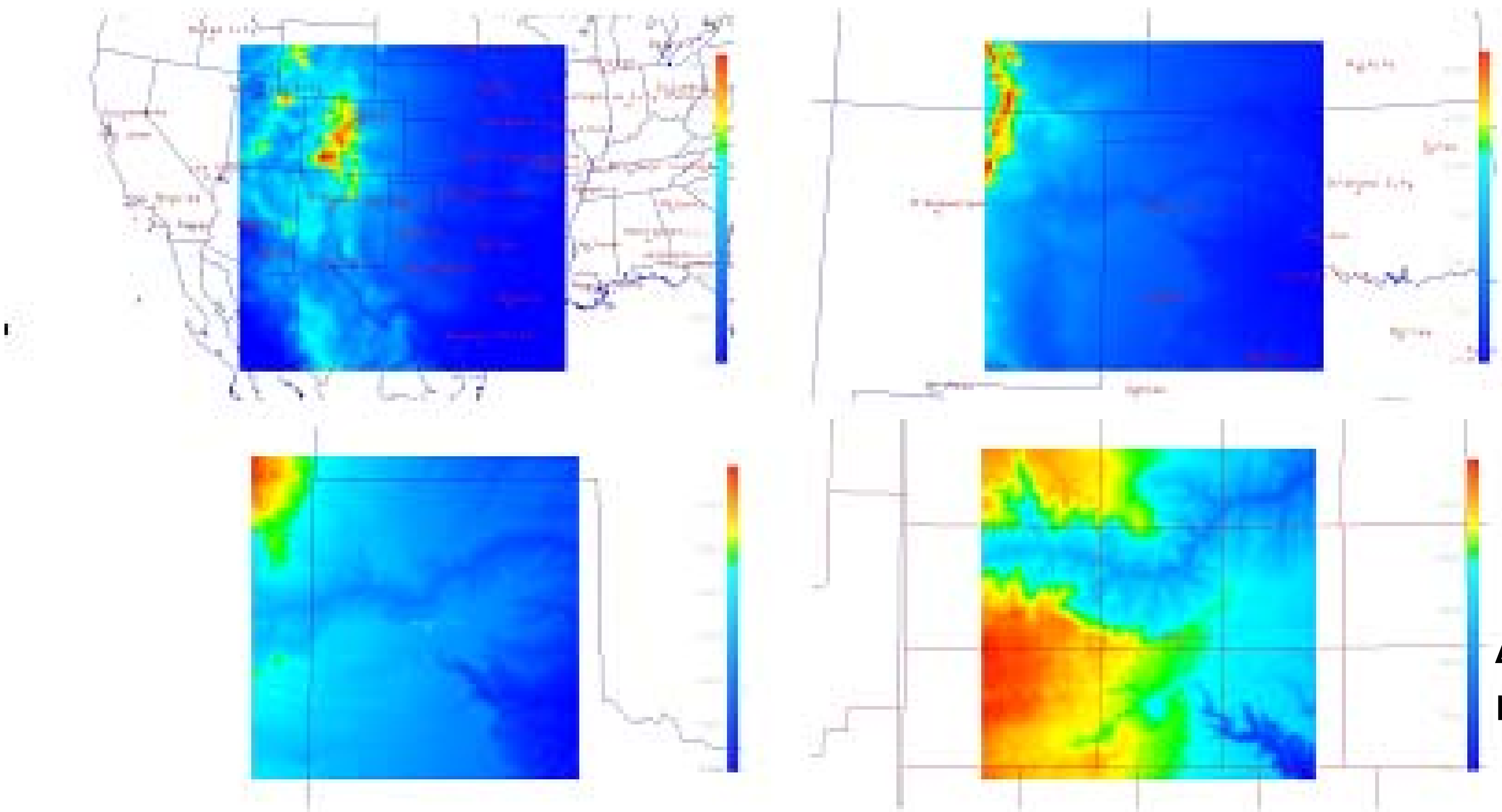
Courtesy: J. Dudhia

WRFs

- **A WRF3.1 multi-scale nesting approach was used to explicitly obtain the ET characterization on July 24th 2008**
  (Case Study, Bushland Observational Campaign)
- **Two initializations at 00:00 UTC July 24th 2008:**

NAM (North American Mesoscale), NCEP Eta 212 grid (40 km)

NARR (North American Regional Reanalysis), NCEP Eta 221 grid (32km)



Δ =1 km
n= 100

WRFs (cont…)

- **Six ABL parameterizations: YSU, MYJ, ACM2, QNSE, MYNN2, MYNN3**
- **6 ABL parameterizations x 2 data initializations**

  = 12 high resolution simulations

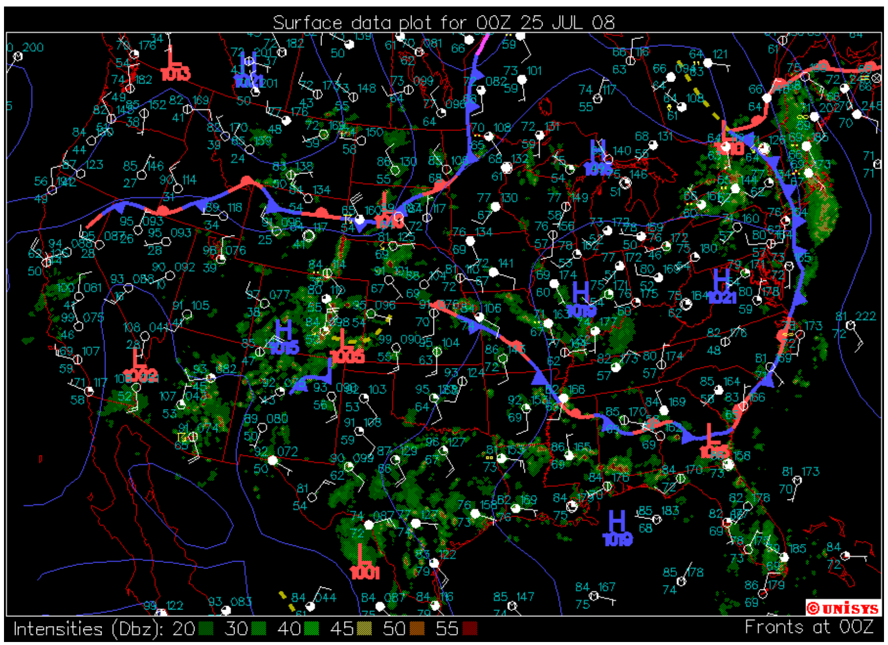
Parameterization	Mixing Scheme	Entrainment Treatment	PBL Top
YSU	K profile	Explicit	From critical bulk Ri = 0
MYJ	K from TKE	Part of the mixing scheme	From TKE
ACM2*	up: transilient down: local K	Part of the mixing scheme	From thermal profile
QNSE	scale elimination		No single Ri
MYNN2	They are modifications of MYJ		
MYNN3			

***ACM2 has its own land surface scheme**

Case Study

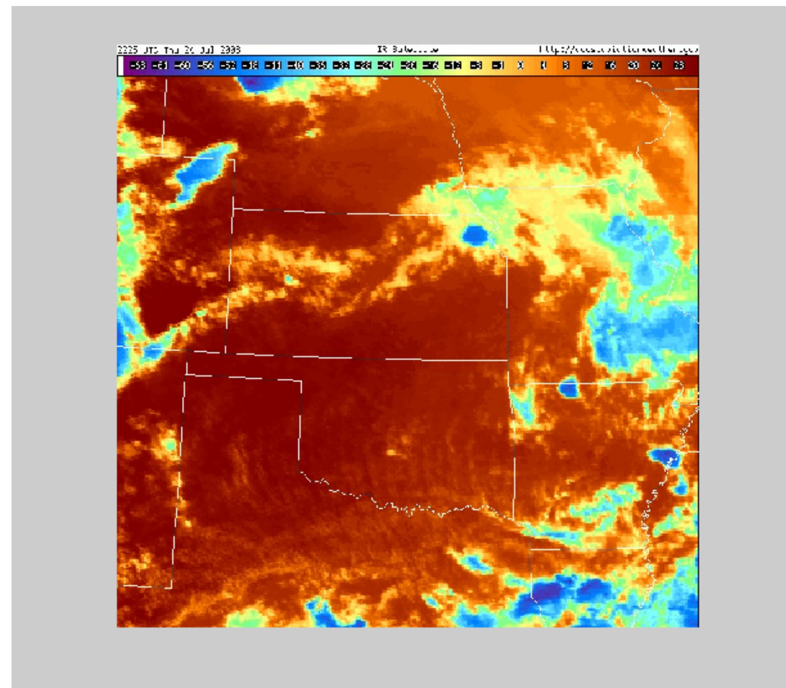
Evening 2008 07 24

Synoptic Conditions

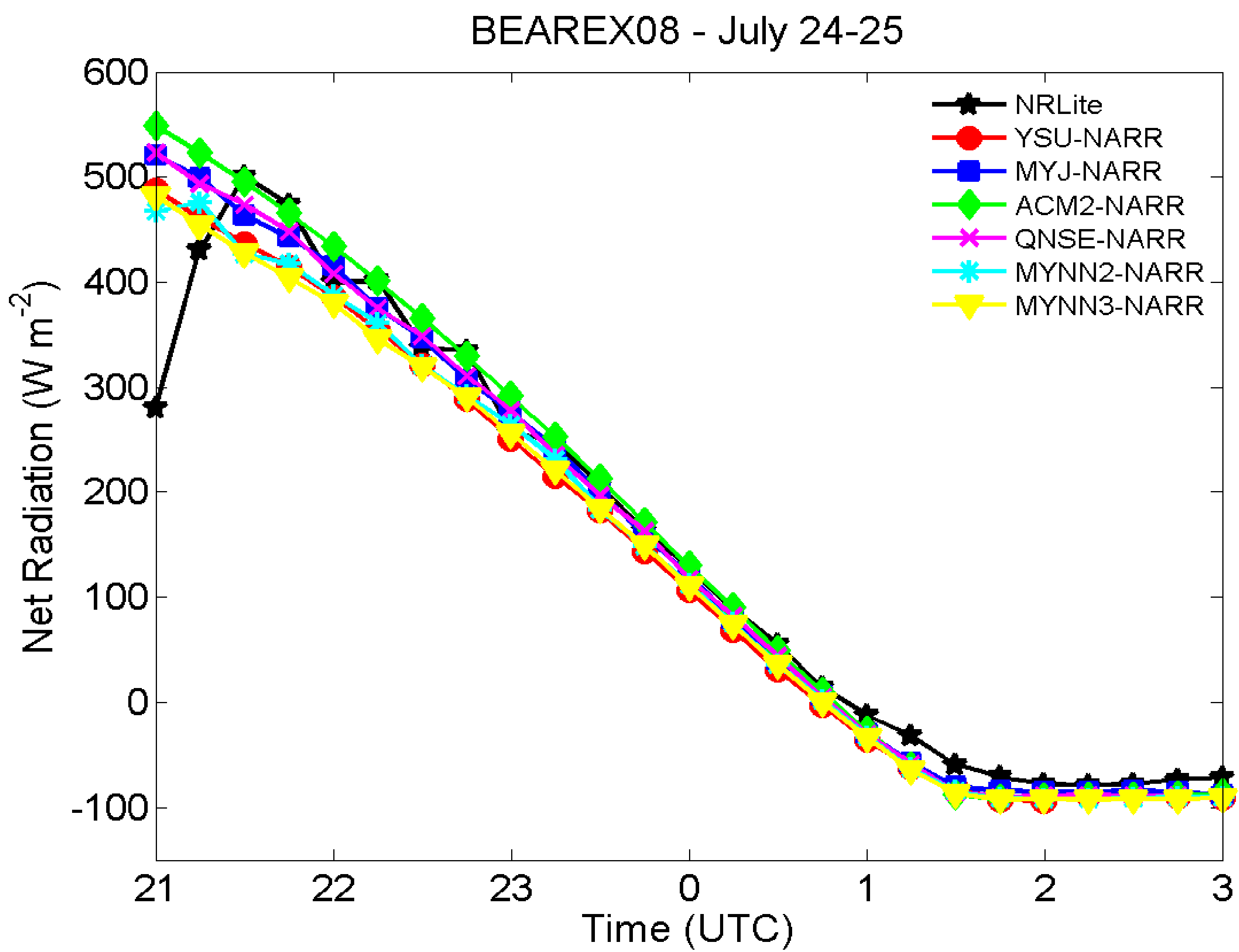


Low pressure center over Southeastern Colorado, frontal boundary over New Mexico

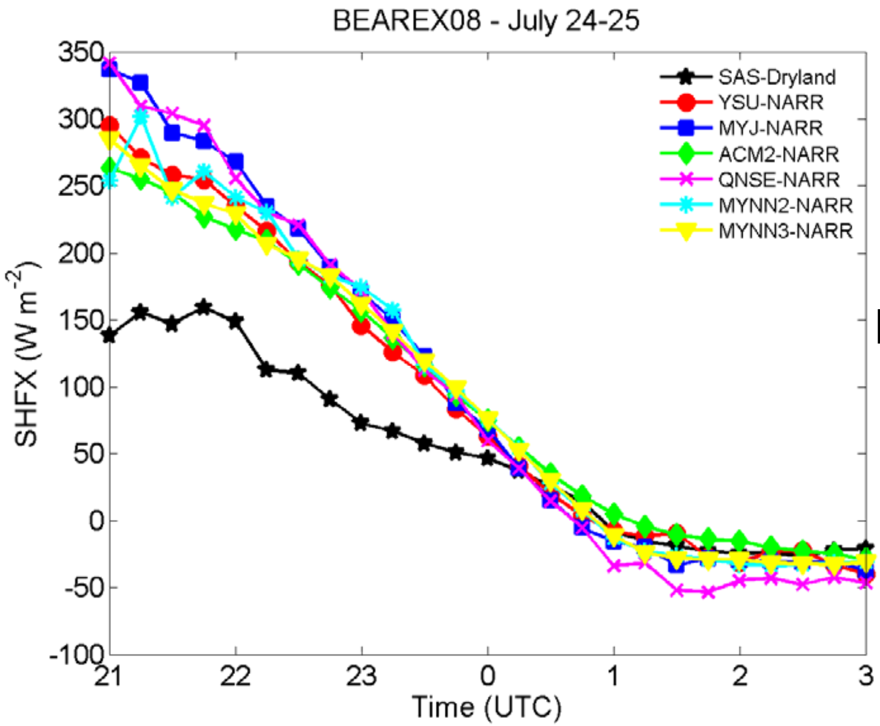
IR Satellite Picture Loop



Fair weather cumulus over the Texas Panhandle



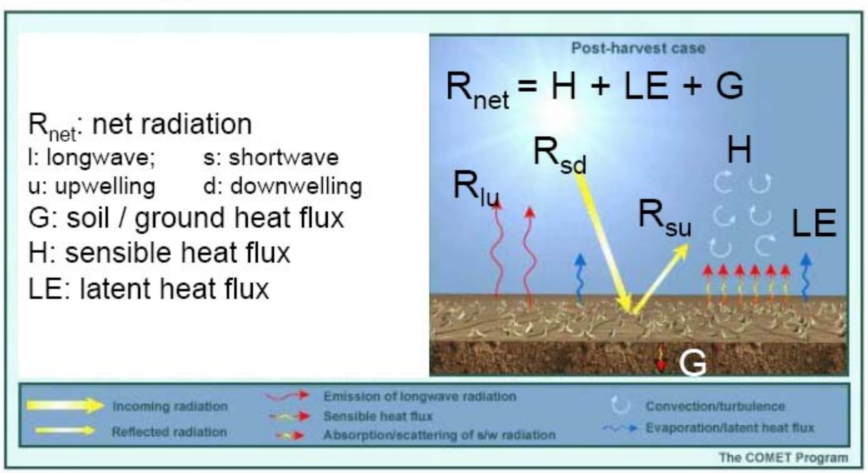
NARR: The ensemble mostly embedded the observation



As expected the heat flux followed the net radiation lead!

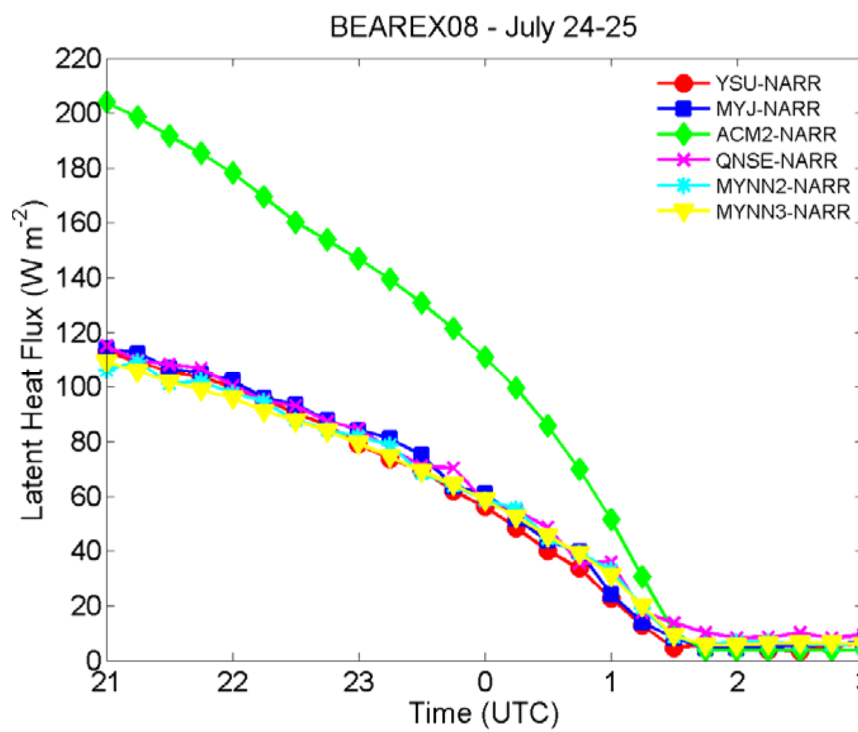
NARR: The ensemble failed to embed the obs. between 21:00 and 00:00

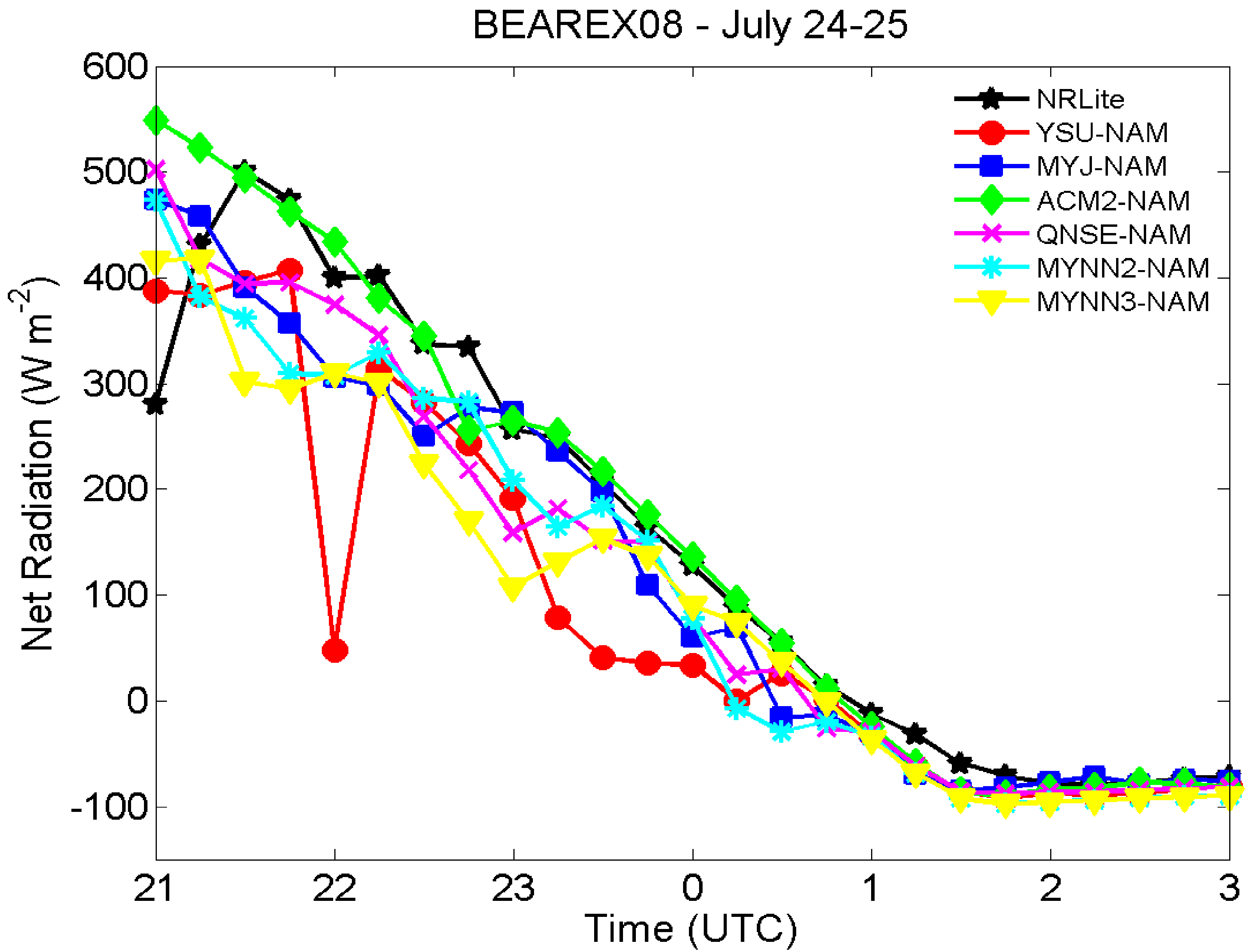
Energy Balance at the Earth's surface



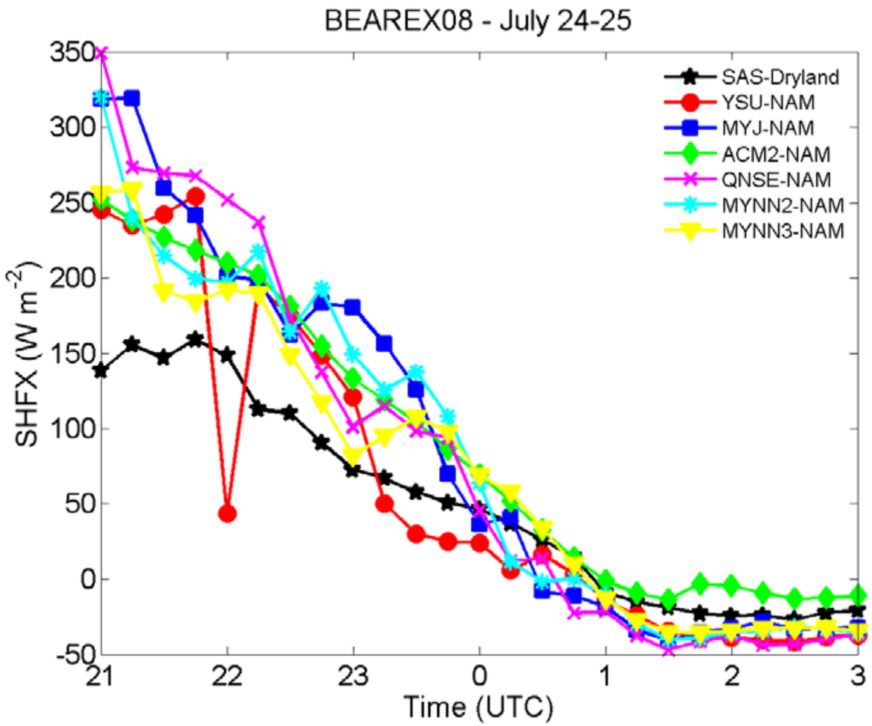
Energy balance can be used to estimate LE:

$$LE = R_{net} - G - H$$

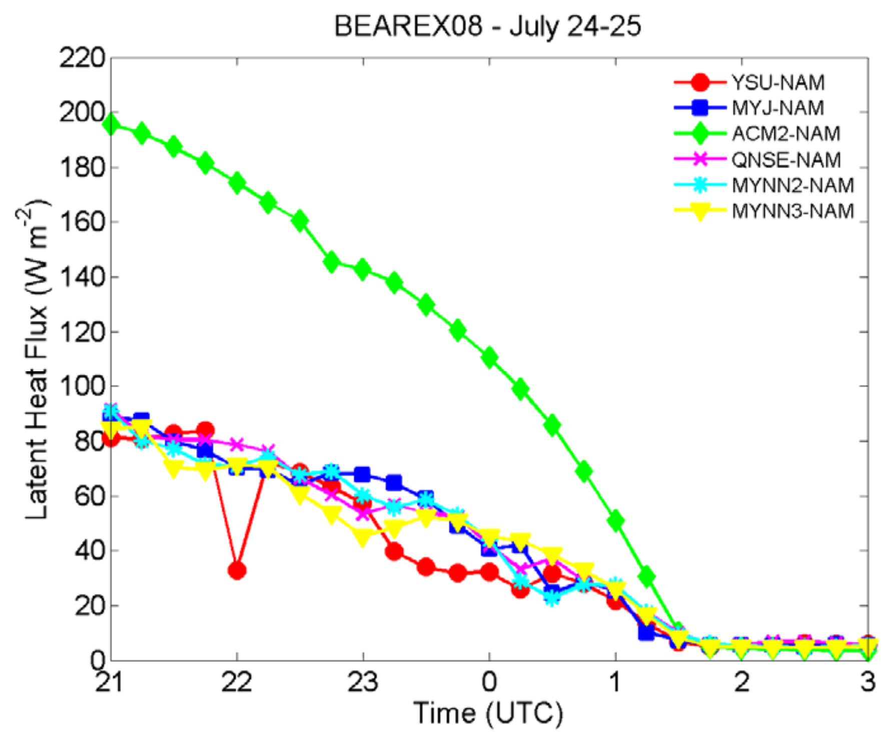




NAM: YSU indicated a strong peak at 22:00; the ensemble mostly embedded the obs.



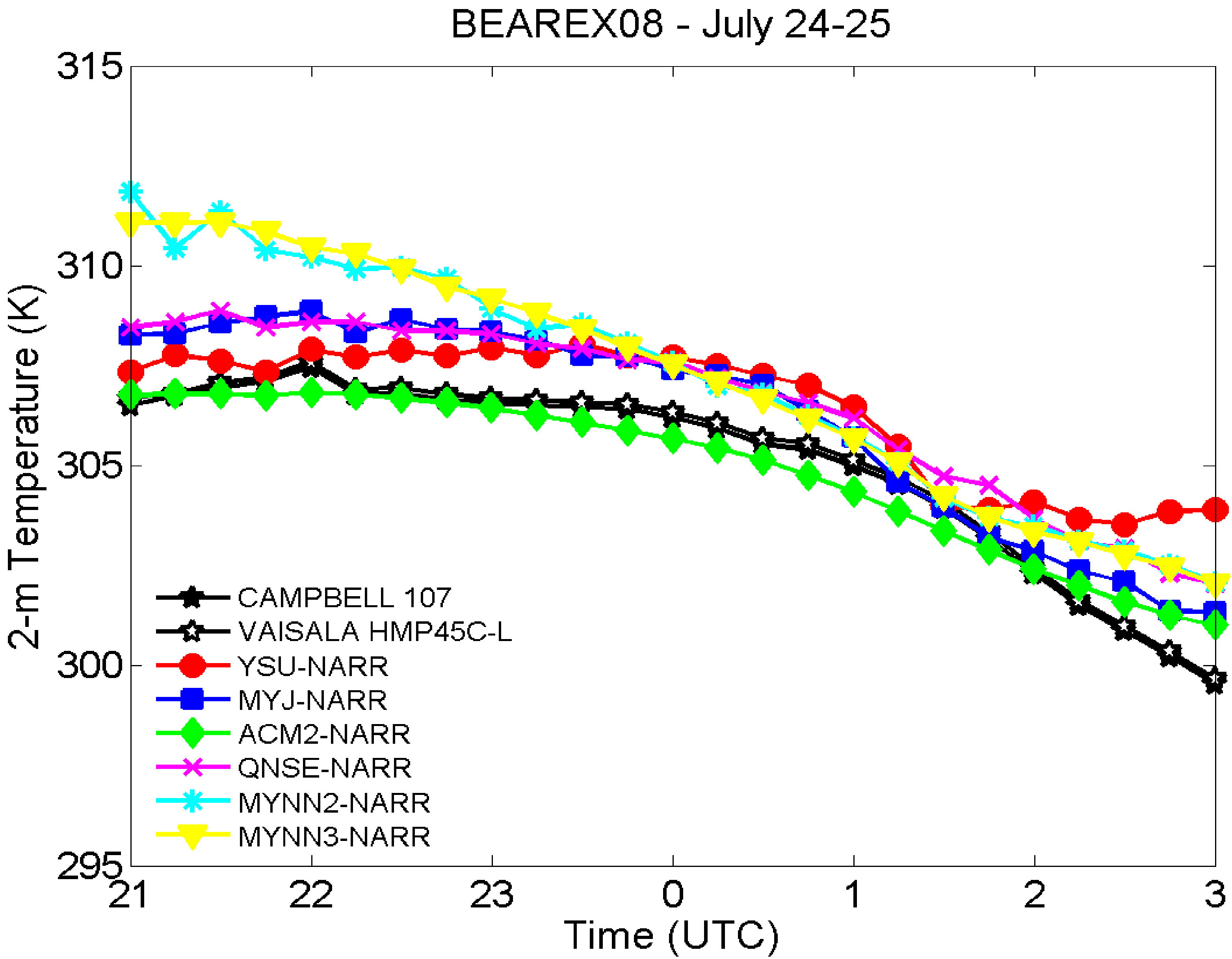
As expected the heat flux followed the net radiation lead!



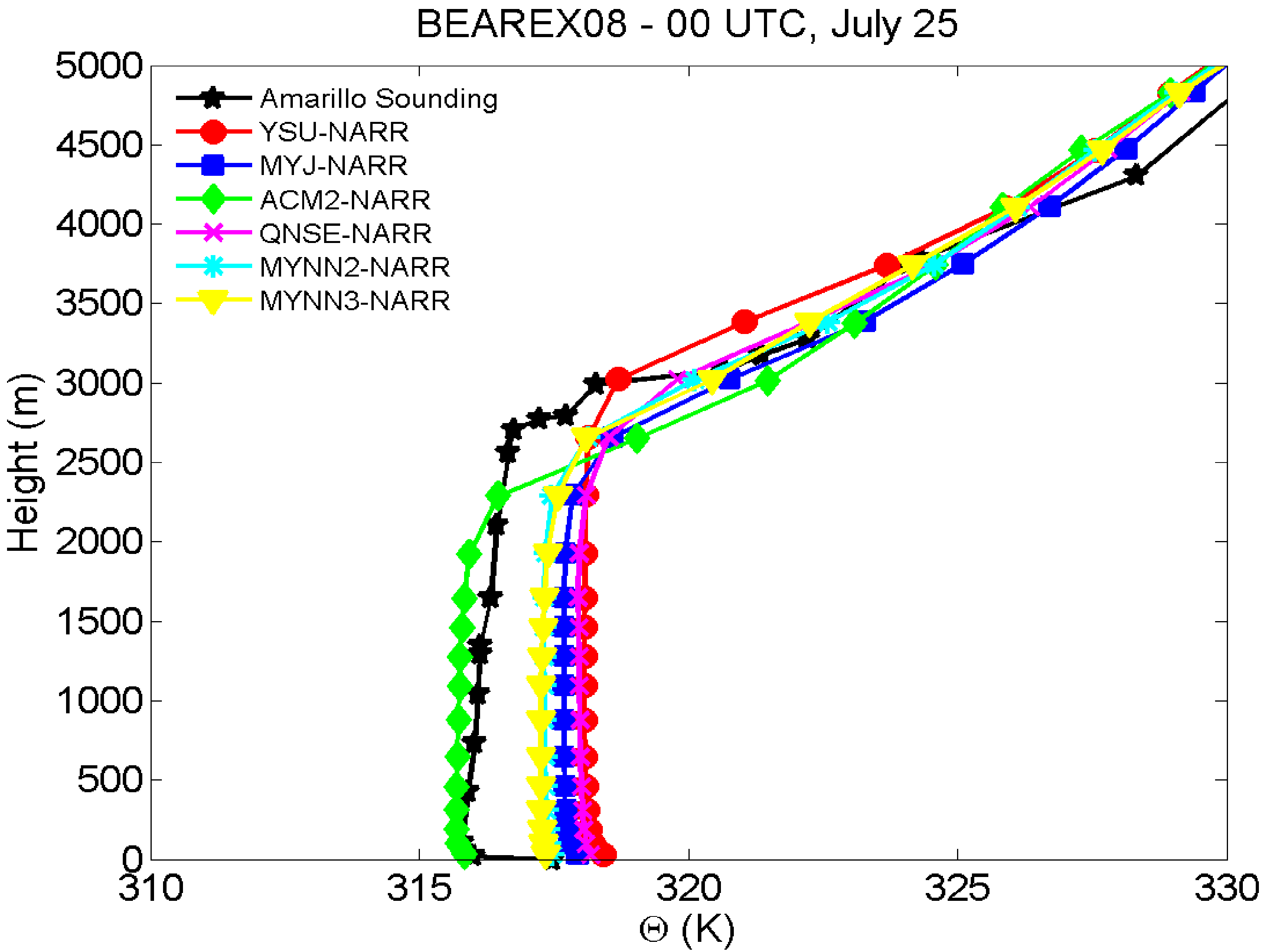
ACM2 being moister seemed to overestimate the latent heat flux

net R = H + LH + G

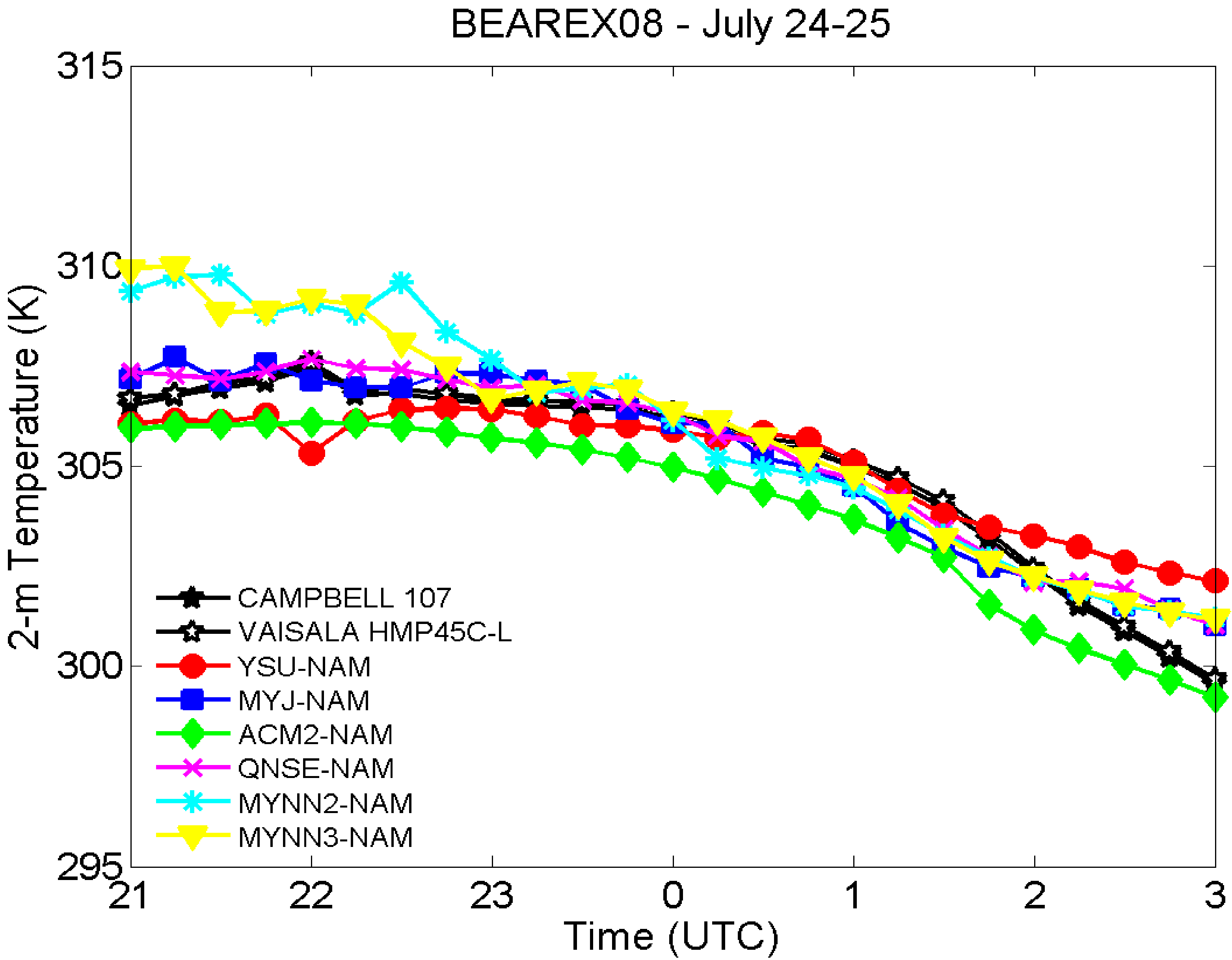
(?)



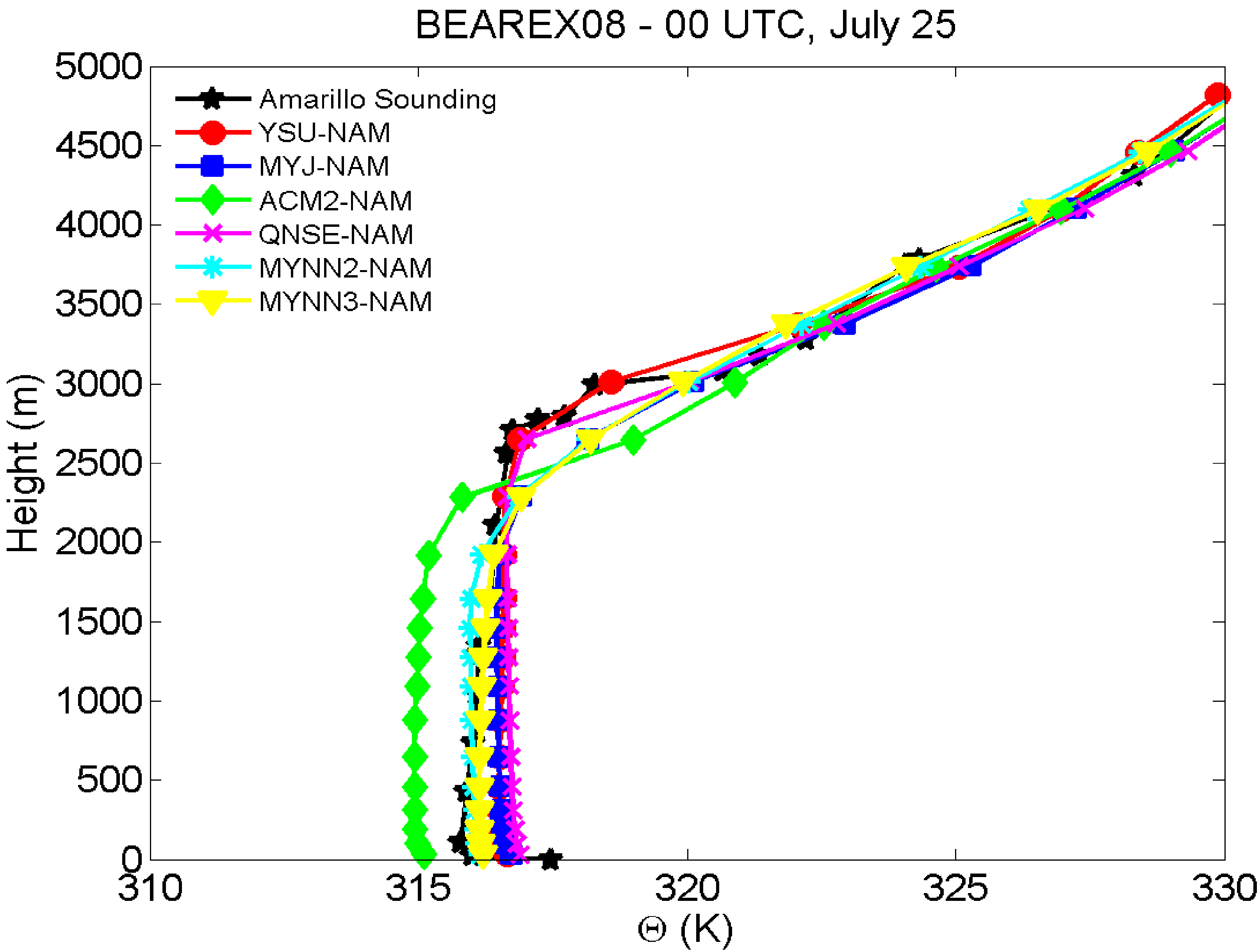
NARR: The ensemble mostly embedded the observations;
warm bias during the late evening (all the parameterizations)



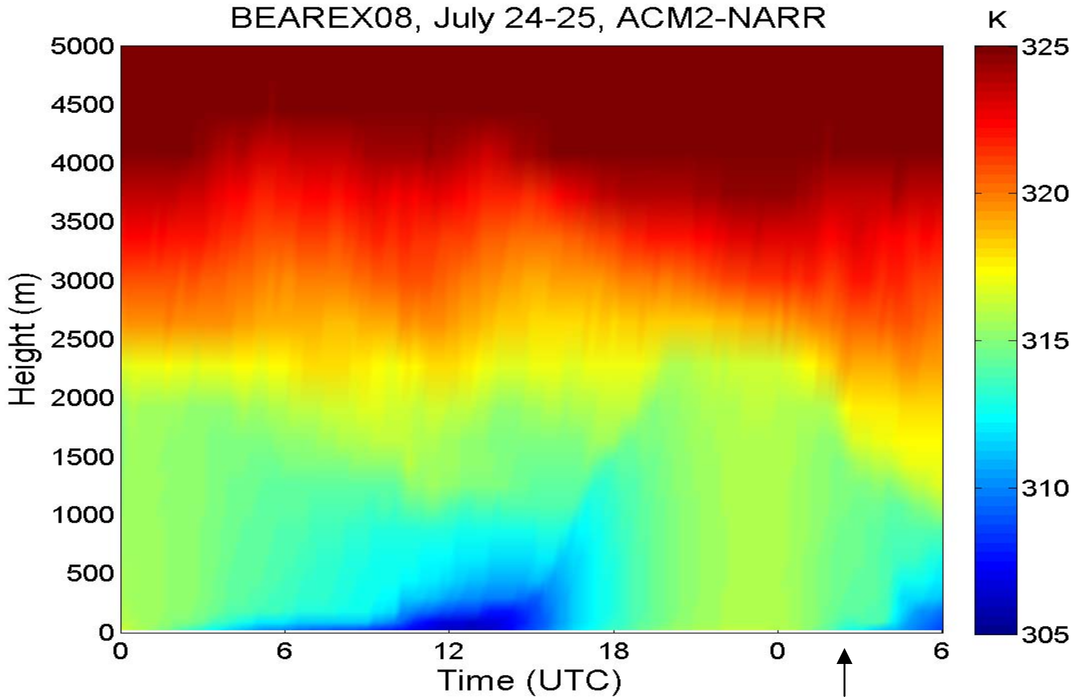
Here the ensemble failed to embed the observations between about 2300-3000 m; AMC2 inversion lower than the others



NAM: The ensemble embedded the observations better (than with NARR);
AMC2 is the coldest

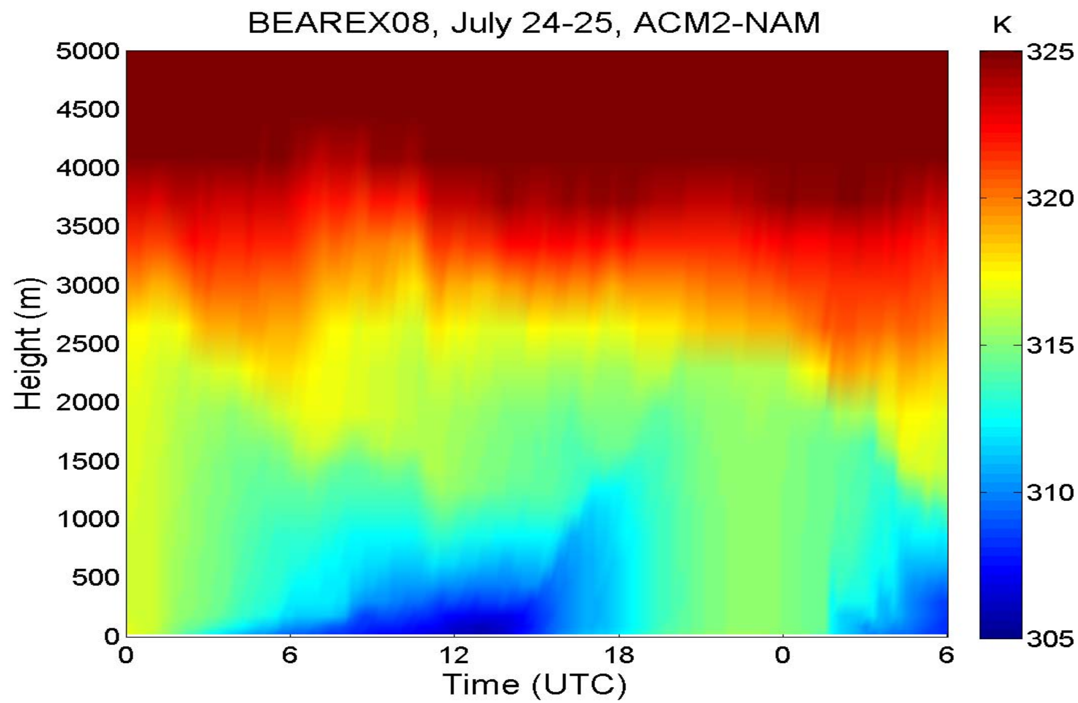


The ensemble embedded the observations

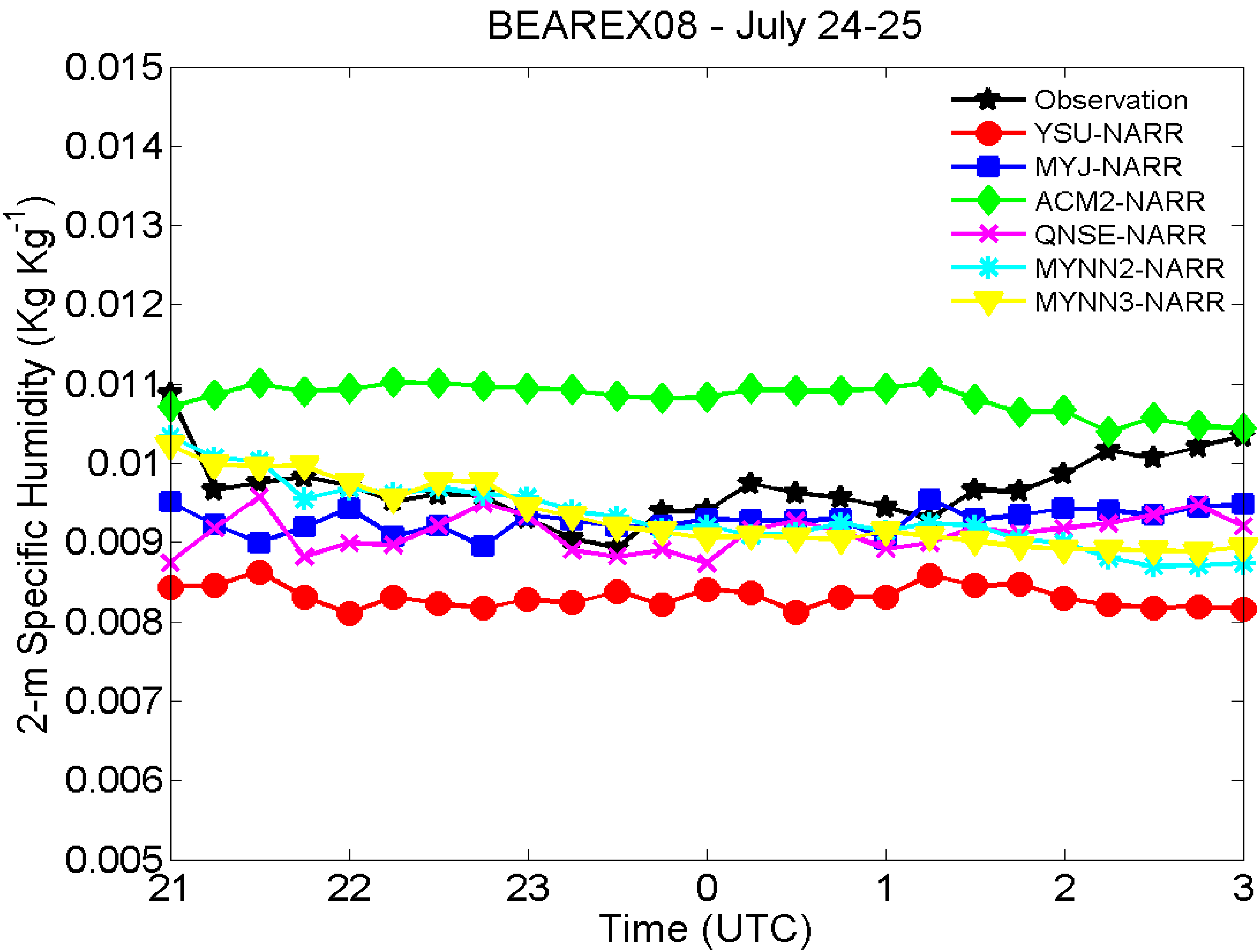


NARR

Sunset at 02:00 UTC



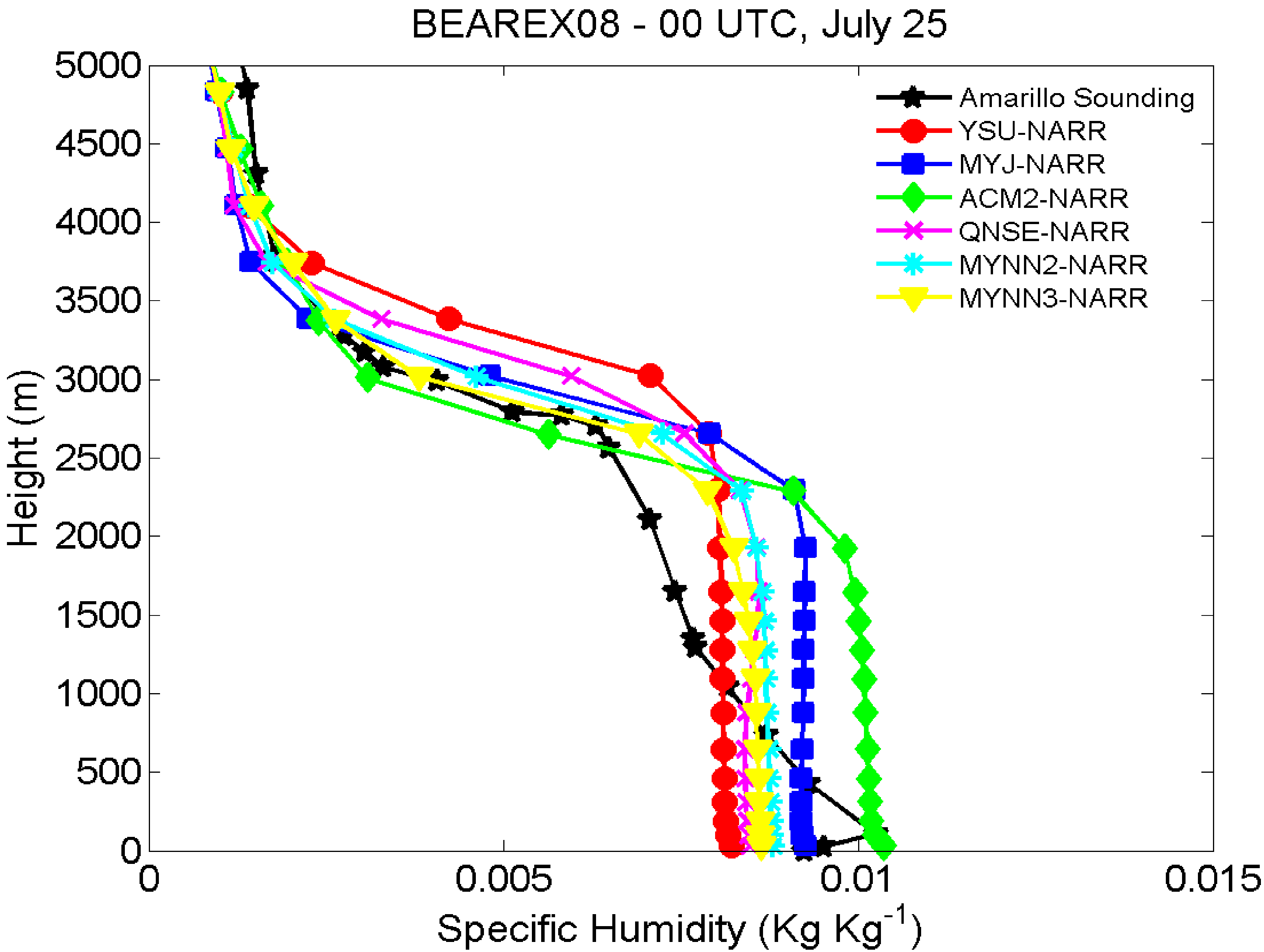
NAM



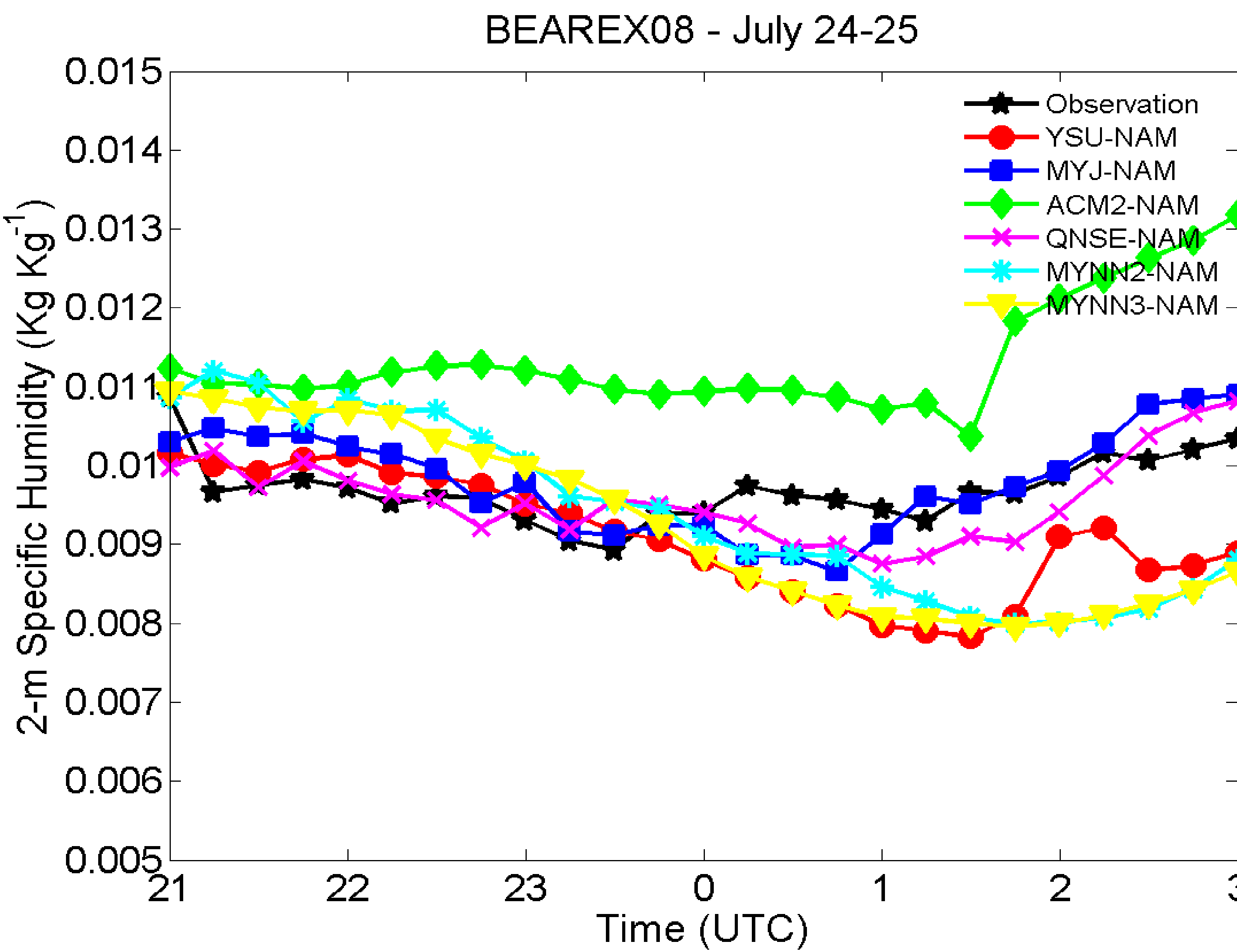
NARR: The ensemble embedded the observations

ACM2 moister than the others;

q jump?

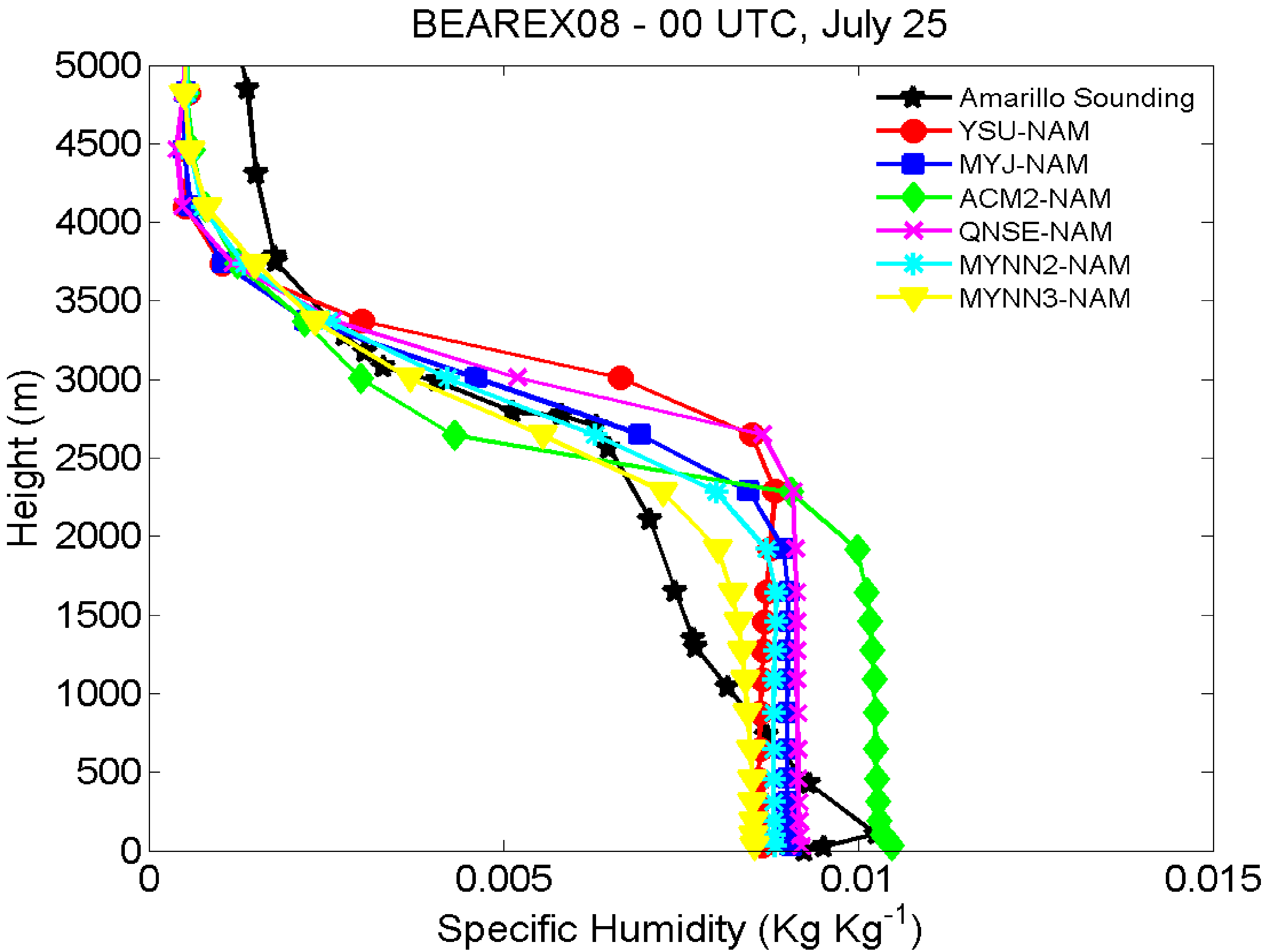


NARR: The ensemble failed to embed the observations between ~ 1200 – 2500 m
ACM2 moister than the others at the surface and within the incipient residual layer

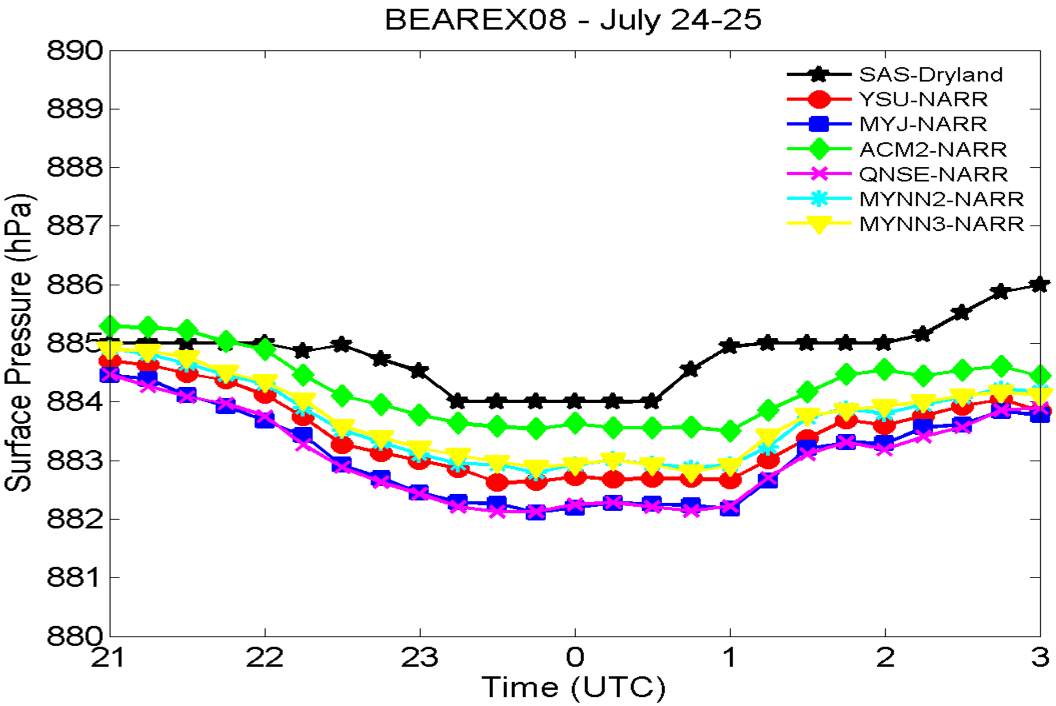


NAM: The ensemble mostly embedded the observations

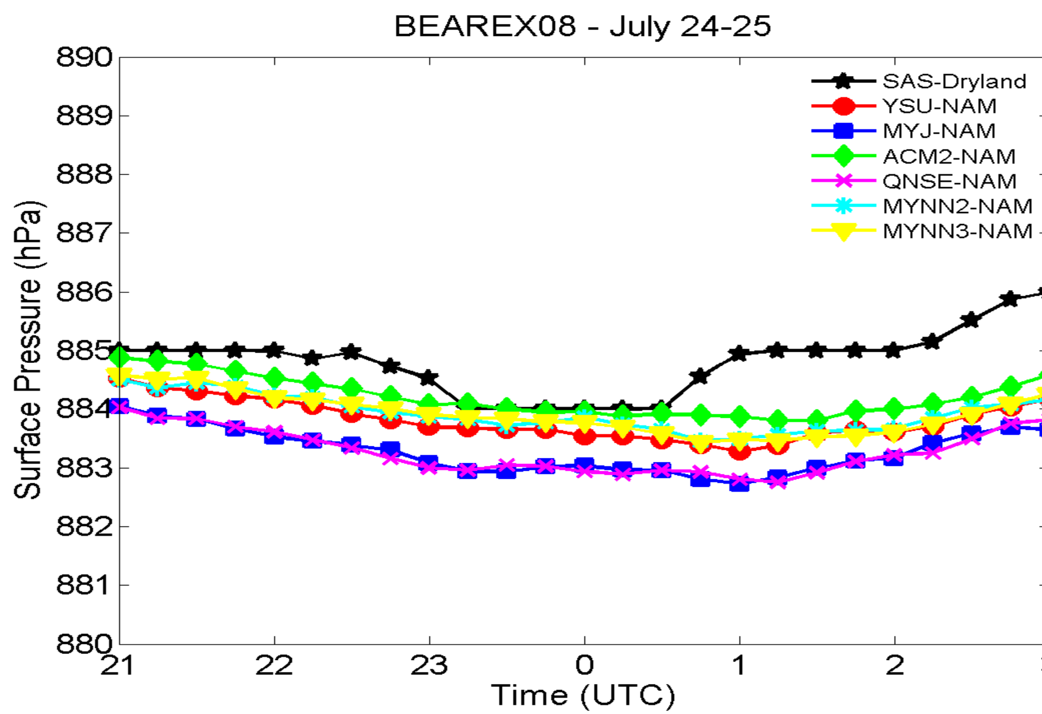
four parameterizations seemed to capture the increasing q after 01:00



NAM: The ensemble failed to embed the observations between ~ 1000 – 2500 m
ACM2 moister than the others at the surface and within the incipient residual layer


BEAREX08 - July 24-25
Surface Pressure (hPa)
Time (UTC)
SAS-Dryland
YSU-NARR
MYJ-NARR
ACM2-NARR
QNSE-NARR
MYNN2-NARR
MYNN3-NARR
890
889
888
887
886
885
884
883
882
881
880
21
22
23
0
1
2
3

NARR


BEAREX08 - July 24-25
Surface Pressure (hPa)
Time (UTC)
SAS-Dryland
YSU-NAM
MYJ-NAM
ACM2-NAM
QNSE-NAM
MYNN2-NAM
MYNN3-NAM
890
889
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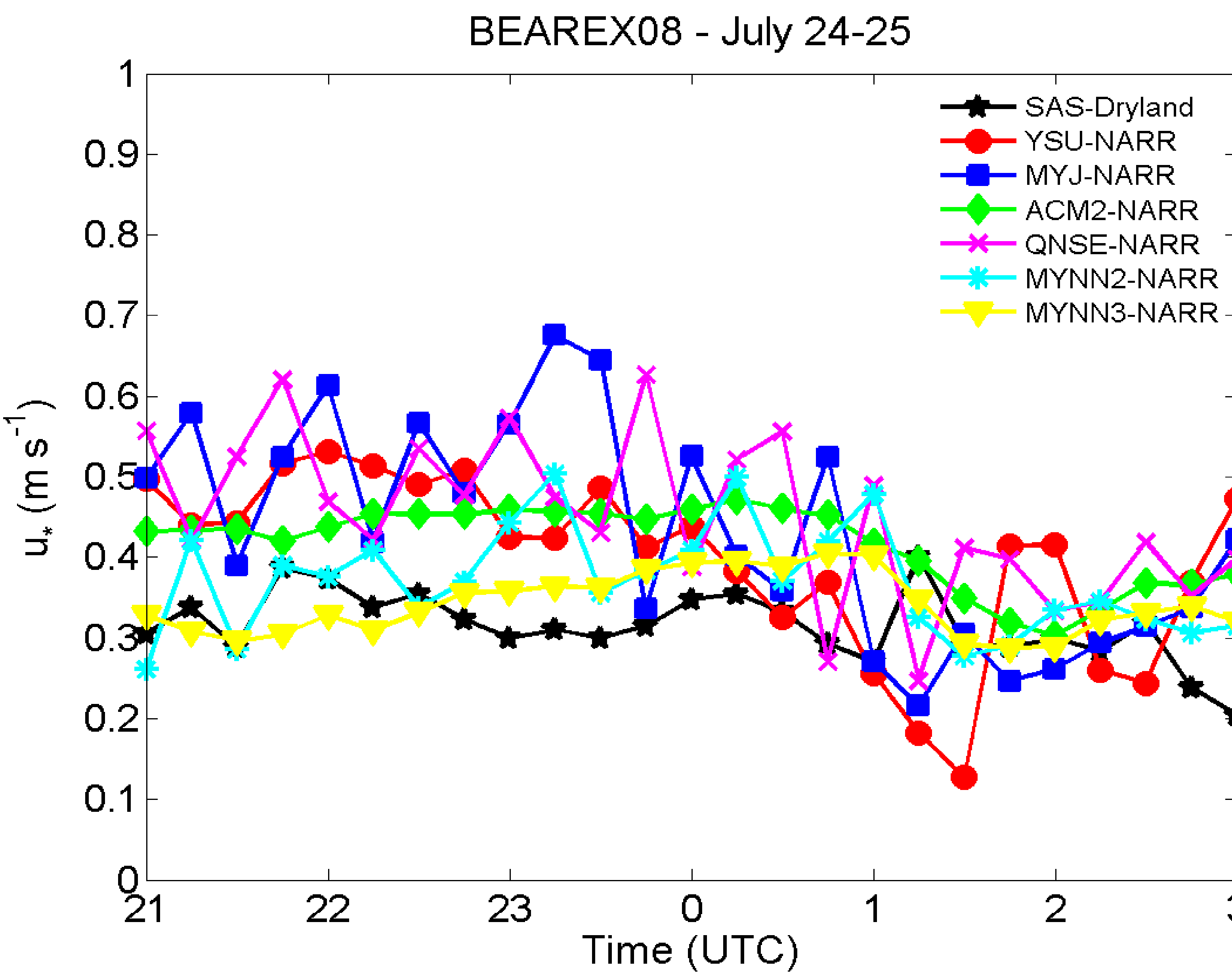
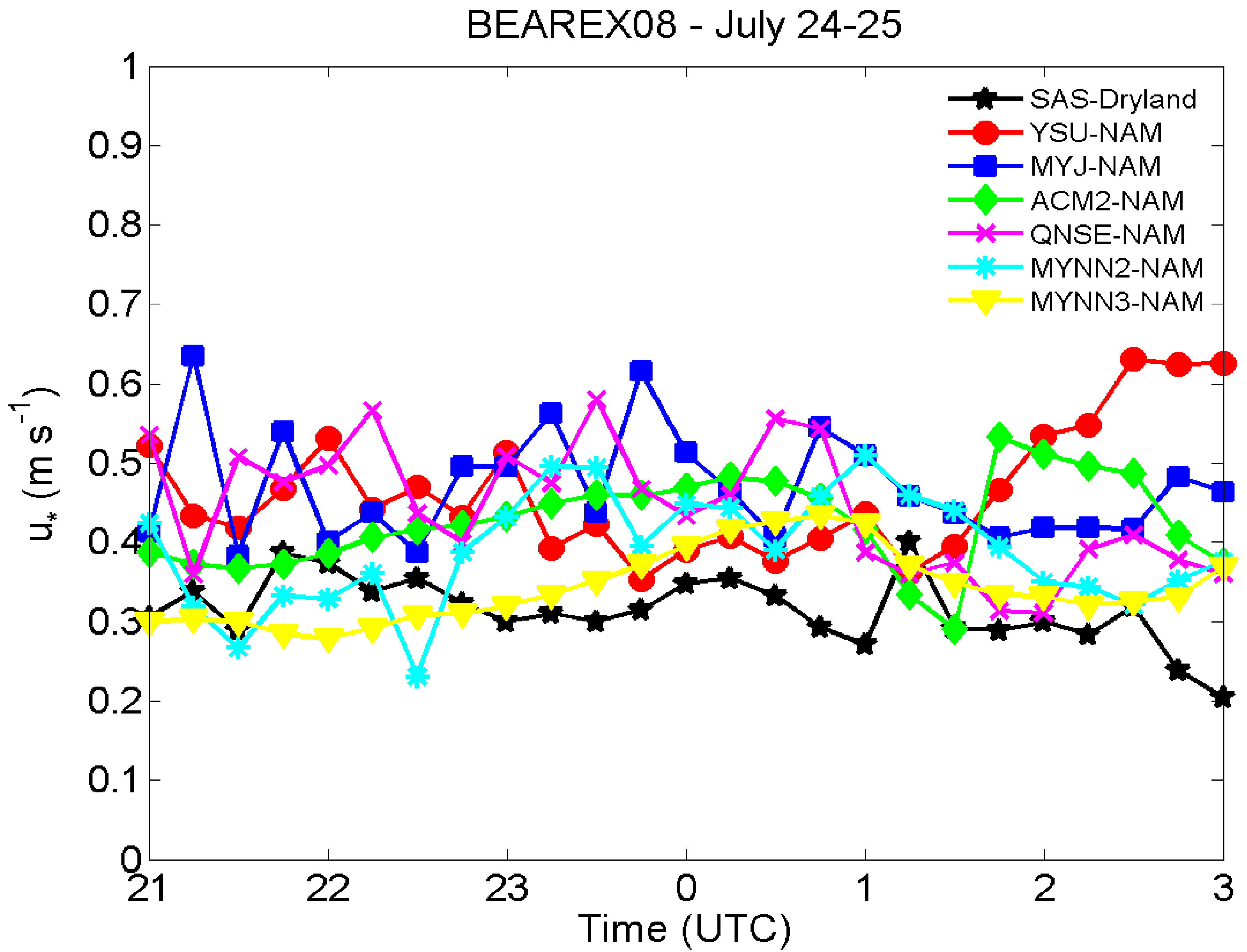
NAM

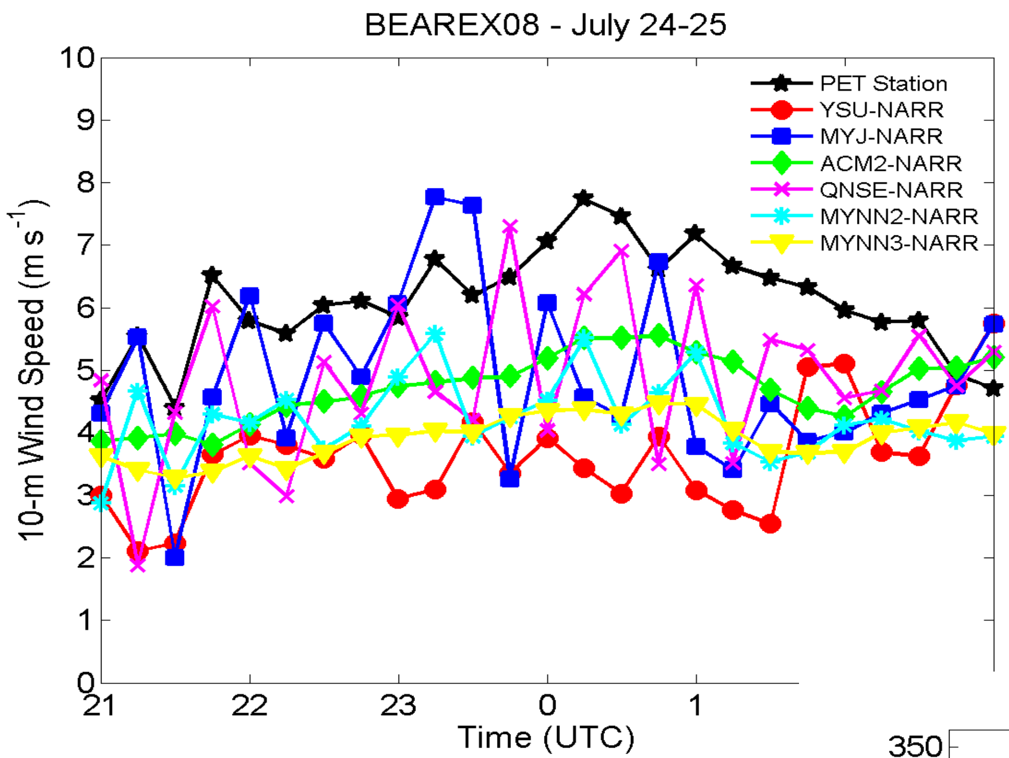


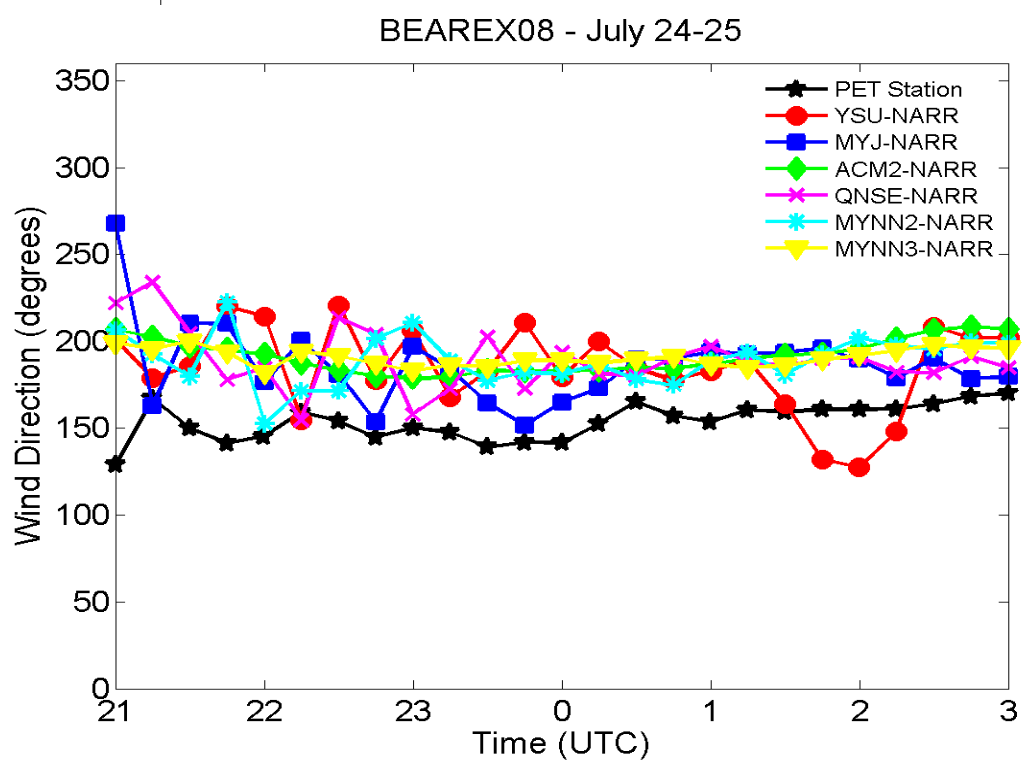
NARR: The ensemble embedded mostly the observations although with a positive bias

Remember YSU clipping value =0.1

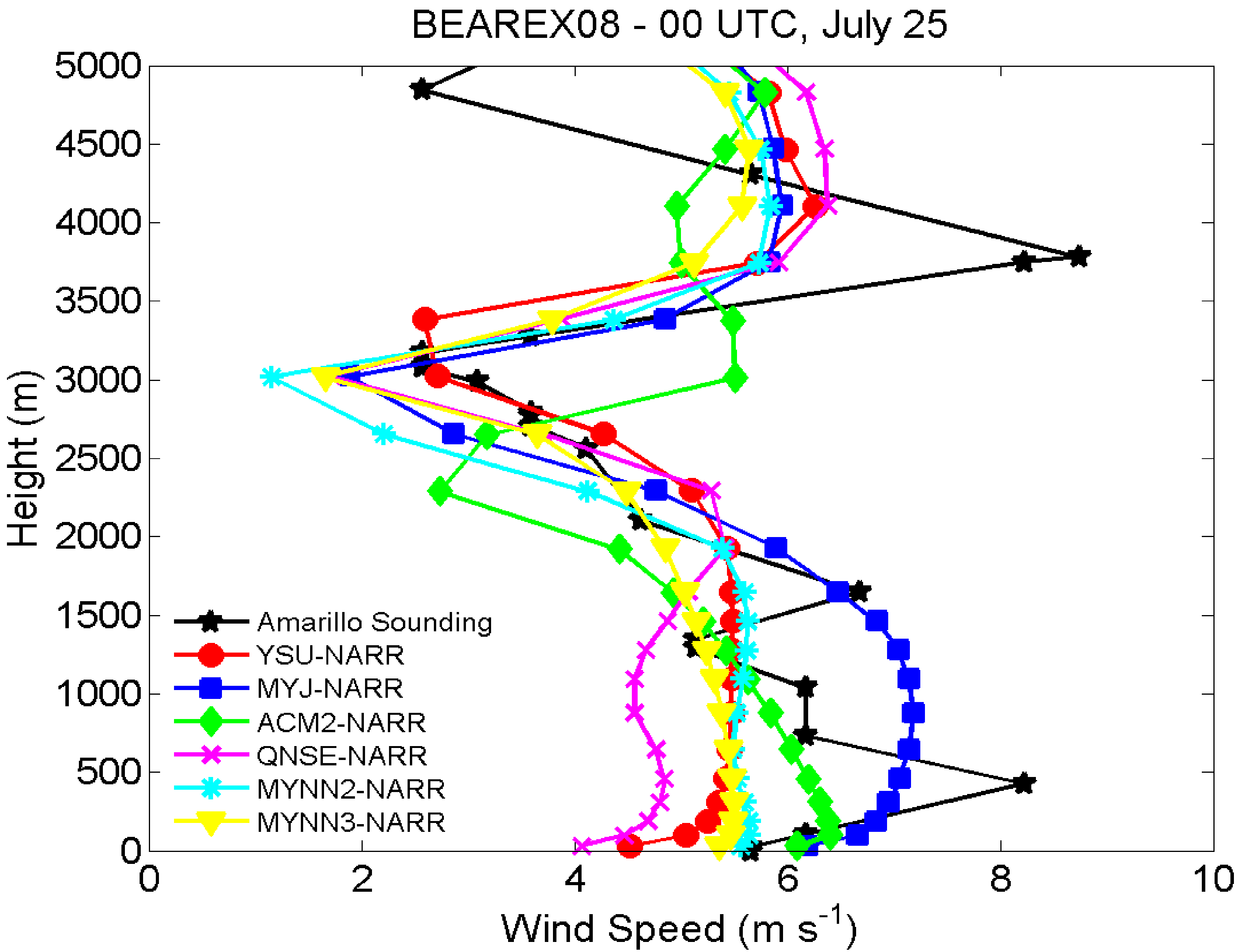


NAM: The ensemble mostly missed to embed the observations (clear positive bias)

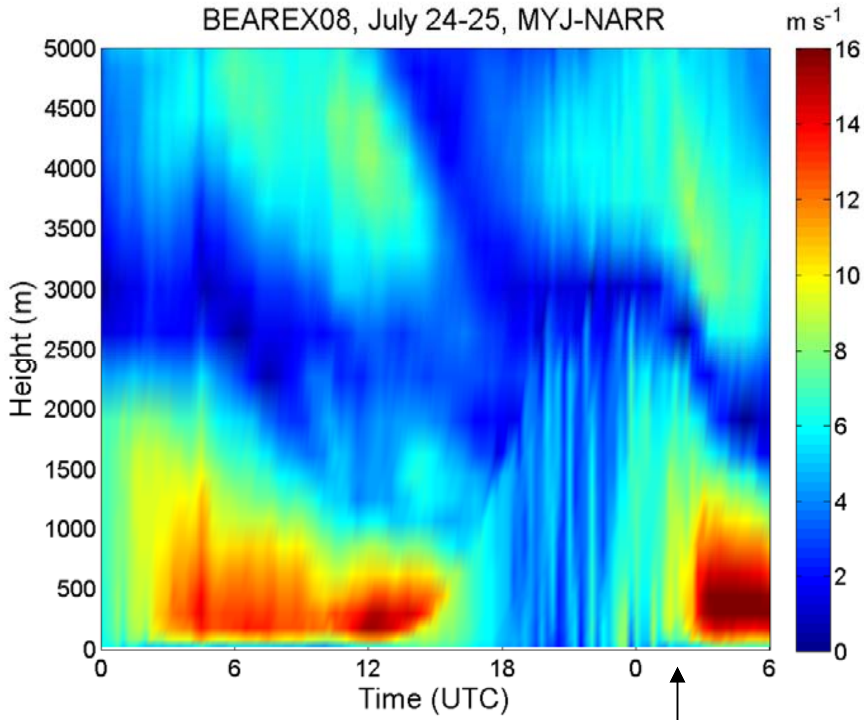




NARR: Both ensembles have problem embedding the observations



NARR: The ensemble mostly embedded the observations;
problems at **~ 400 m**, 3800 m, and 4800 m

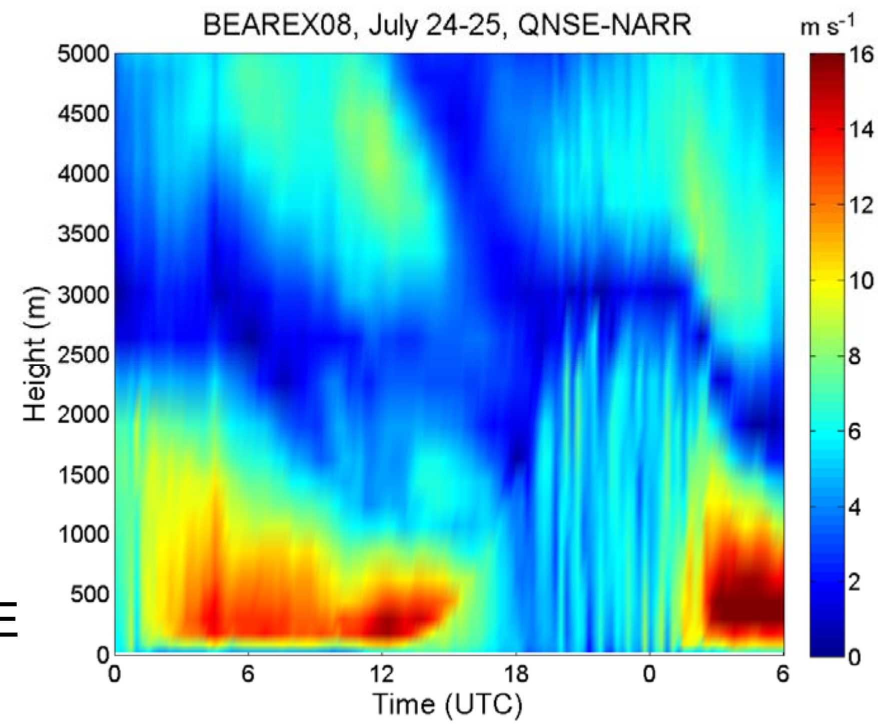


NARR - MYJ

Sunset at 02:00 UTC

Both captured the evening wind features although MYJ seemed to give stronger speed values

NARR- QNSE



Conclusions:

WRF parameterization ensembles seemed to capture the physics by embedding the observations of the mean variables and illustrating some of the correlations; biases of course were present;

However, the biases were greater when calculating the fluxes, especially heat fluxes (sensible and latent)

Particularly, evening wind features appeared to be well captured

Thanks!

Literature Review

Observation-based

- Taylor (1917):
  (turbulent decay)
- Richardson (1920):
  (TKE budget)
- Mahrt (1981): Wangara exp.
- Grant (1997): vertical profiles
- Acevedo and Fitzjarrald (2001):
  (T- inflection, q-jump)
- Grimsdell and Angevine (2002)
  (profiler max reflectivity)
- Brazel et al (2005)
  (Arizona: ET and locality)
- Edwards et al (2006)
  (England: ET-synoptic and mesoscale factors)

Modeling-based

- Nieuwstadt and Brost (1986): (LES, TKE decay, anisotropy)
- Sorbjan (1997): LES
  (better surface heat flux)
- Goulart (1998):
  (LES and Theoretical)
- Pino et al (2004): LES
  (external forcings and fluxes)
- Beare at al (2006): LES
  (external forcings)
- Sorbjan (2007): LES
  (afternoon weakening)

Laboratory-based

- Cole and Fernando (1998): (water tank, cooling and T-pulsation decay)

LES for Large-Eddy Simulation