

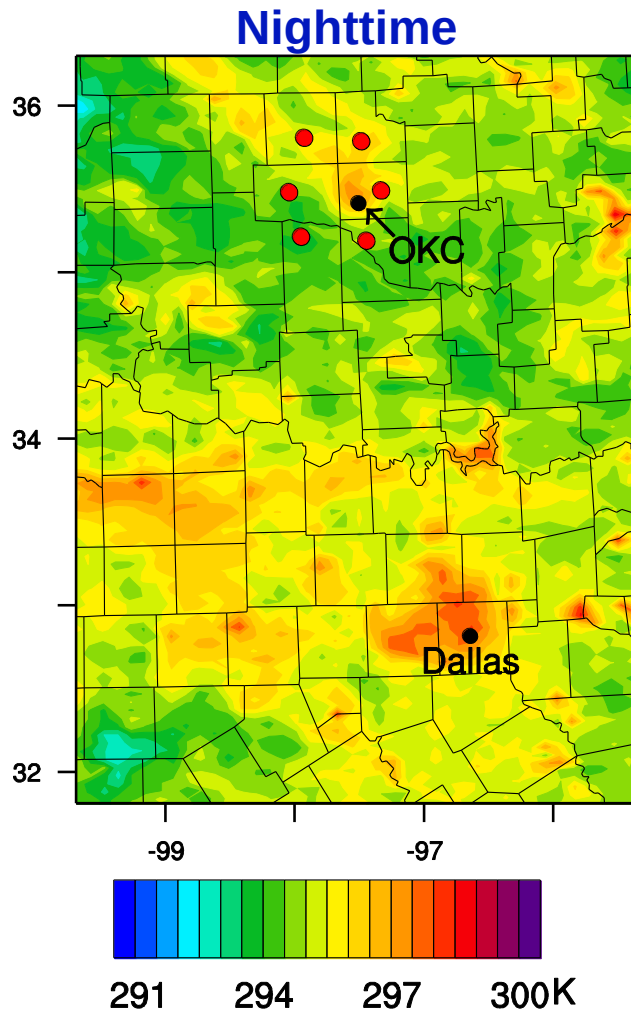
Impact of Sea Breeze Fronts on Urban Heat Island & Air Quality in Texas

Xiao-Ming Hu

Center for Analysis and Prediction of Storms, School of Meteorology
University of Oklahoma

July 7, 2015
at Central South Univ.

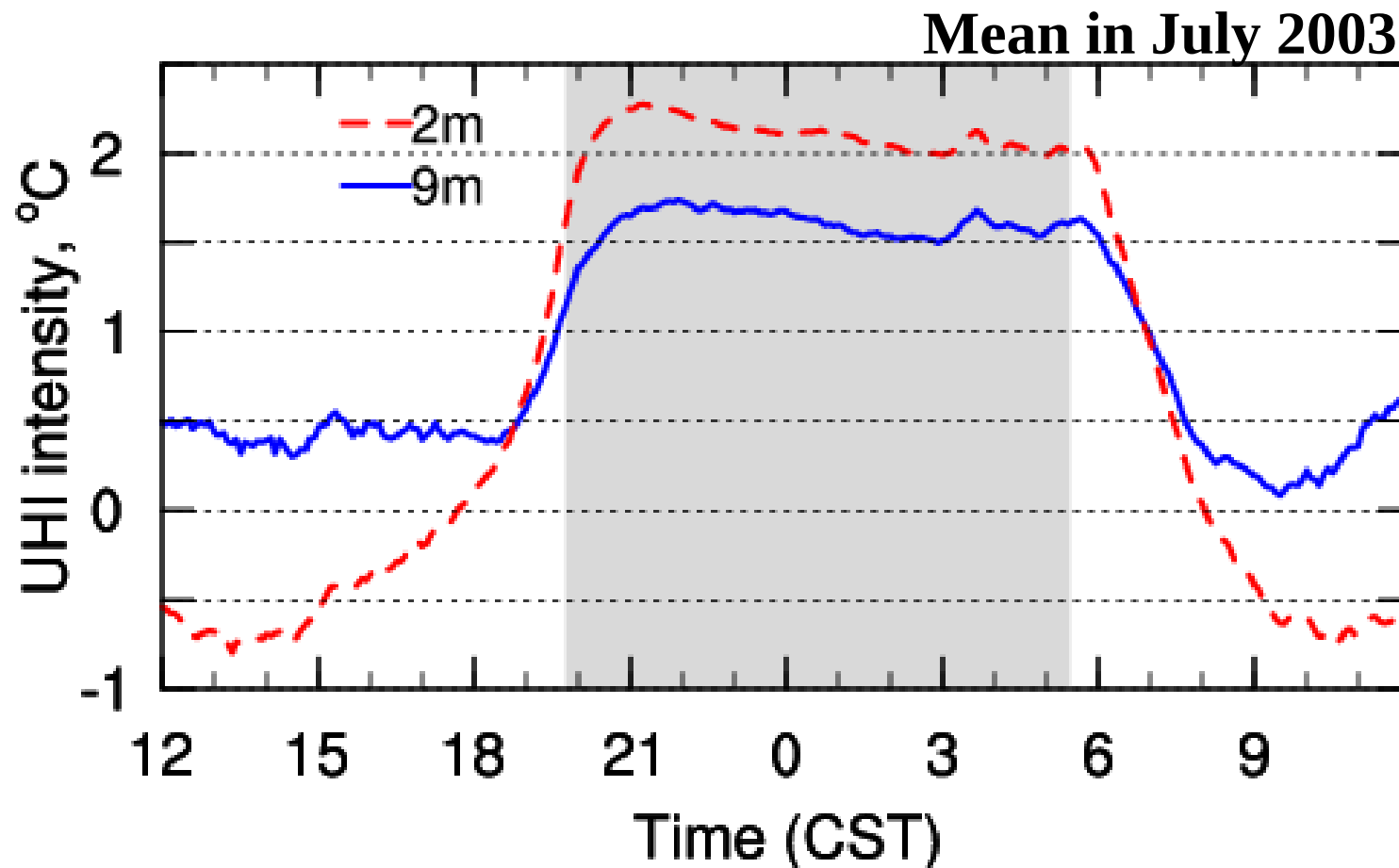
MODIS-derived land surface temperature



UHI is prominent during nighttime

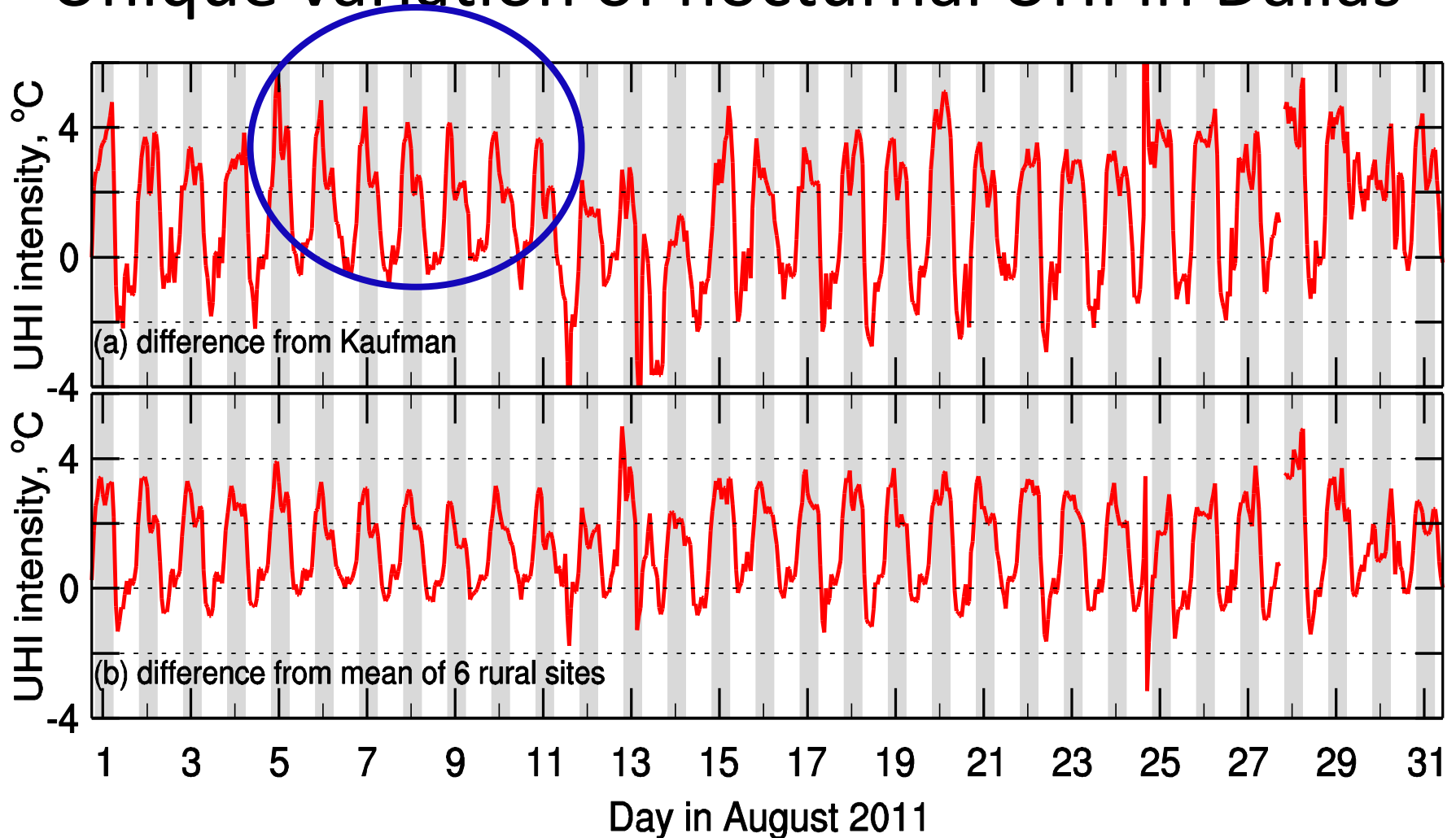
UHI intensity = T at urban location – T at rural sites

Diurnal variation of UHI intensity in OKC



UHI intensity normally increases around sunset quickly and then stays at a roughly constant level throughout the night.

Unique variation of nocturnal UHI in Dallas



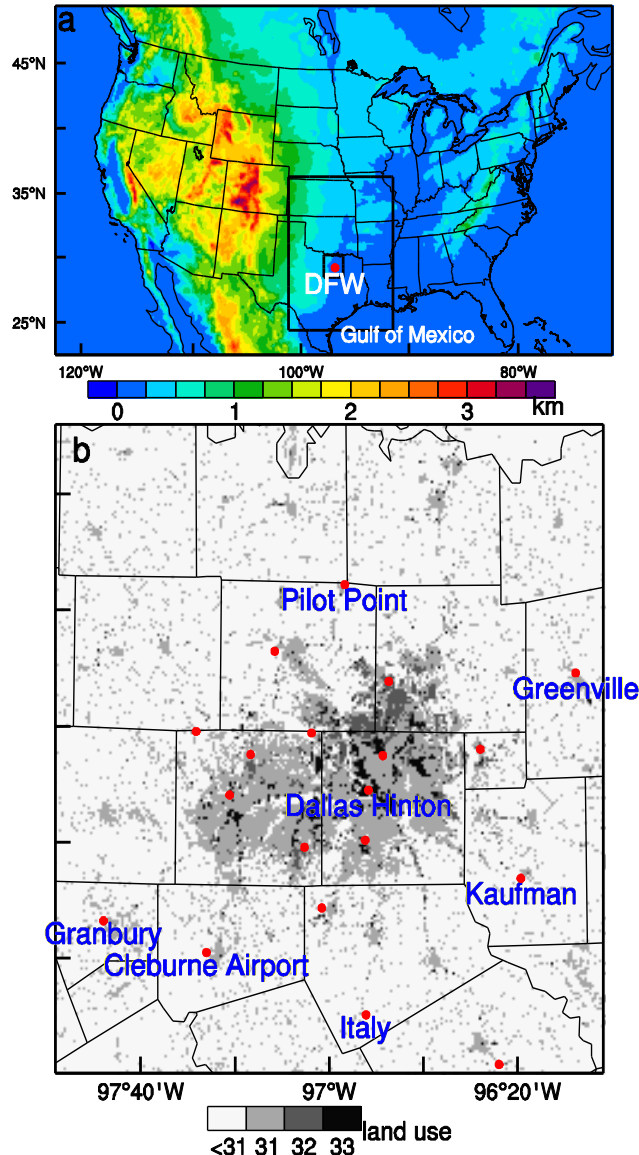
Sharp decrease (“collapse”) of the nocturnal UHI intensity

Motivations/objectives of this study

Hu and Xue (2015, MWR, conditionally accepted)

- Understand such a unique temporal variation of the nocturnal UHI intensity in Dallas
 - Mountain-Plain solenoid
 - Sea breeze
 - Nocturnal warming events
- Investigate WRF model capability to reproduce UHI
- Impact on air quality

Model domains and configurations

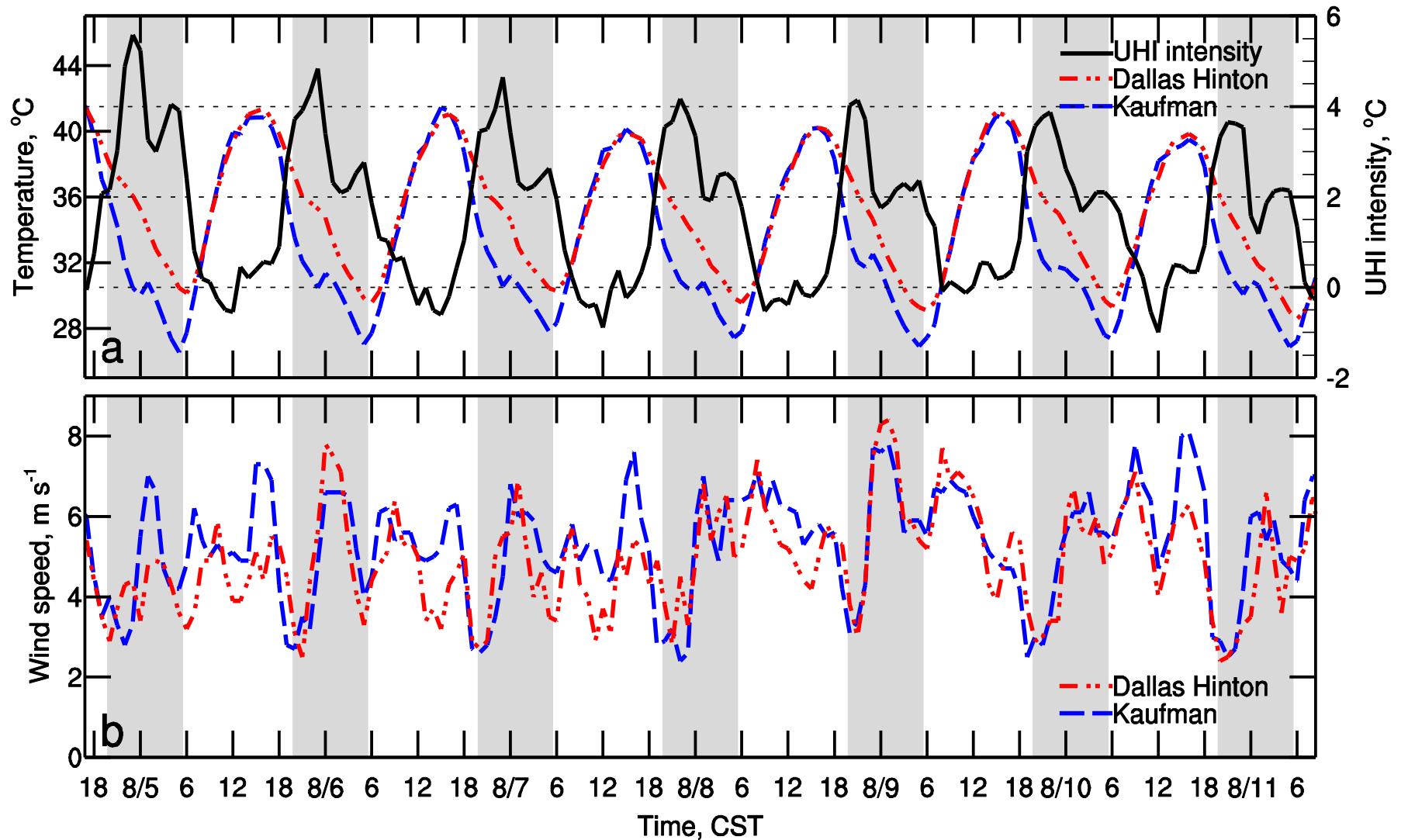


- WRF3.6.1
- 12-→4-→0.8km
- NOAH+Urban canopy model
- Boundary layer scheme: YSU
- Simulation period: August 7-8 2011

UHI intensity = T at Dallas Hinton – T at Kaufman
to be consistent with Winguth (2013, JAMC)

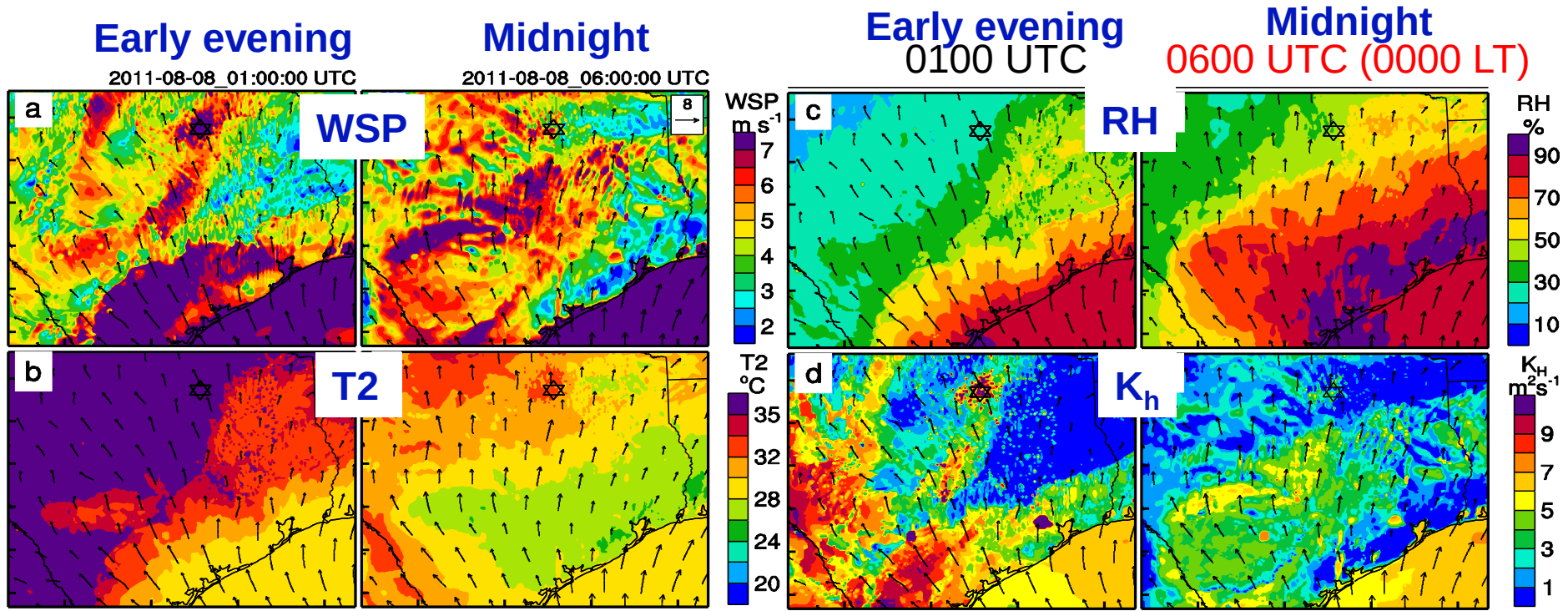
WRF/Chem for air quality impact

Observed variation of UHI, T, wind speed



Collapses of UHI coincided with wind maximum and rural nocturnal warming events

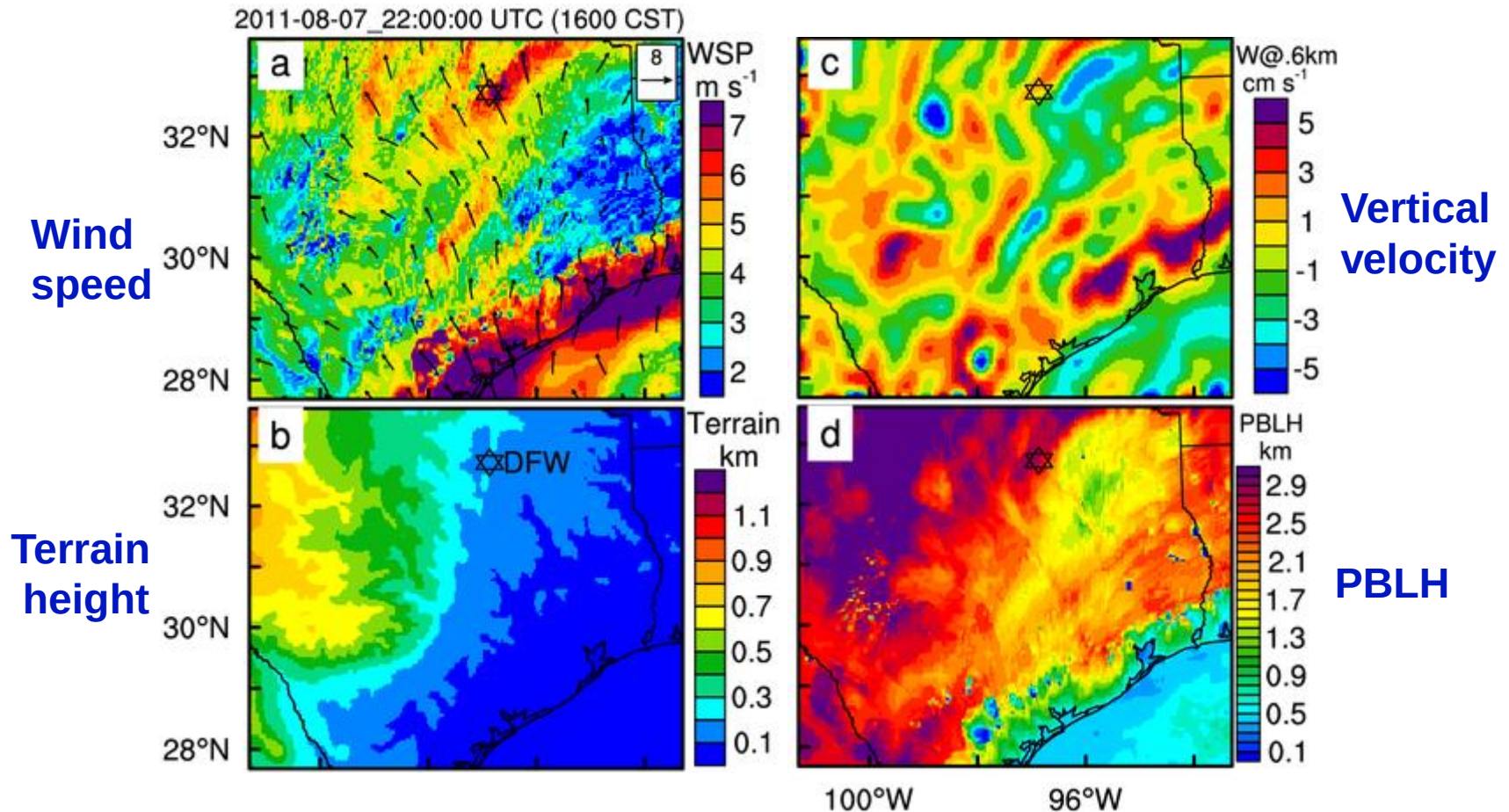
Map of wind, T2, RH, K_h at 00 and 06 UTC



Indications of a sea breeze front:

Cooler and moister air behind the front with stronger momentum and vertical mixing

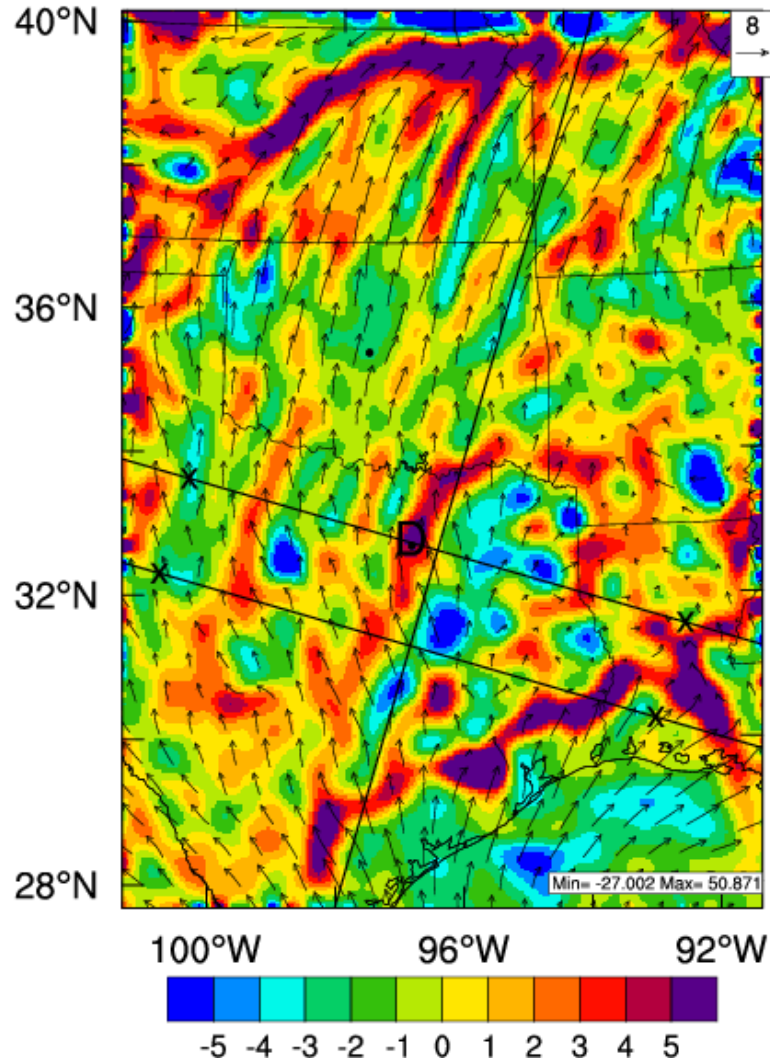
Mountain-Plain Solenoid induced wind maximum band



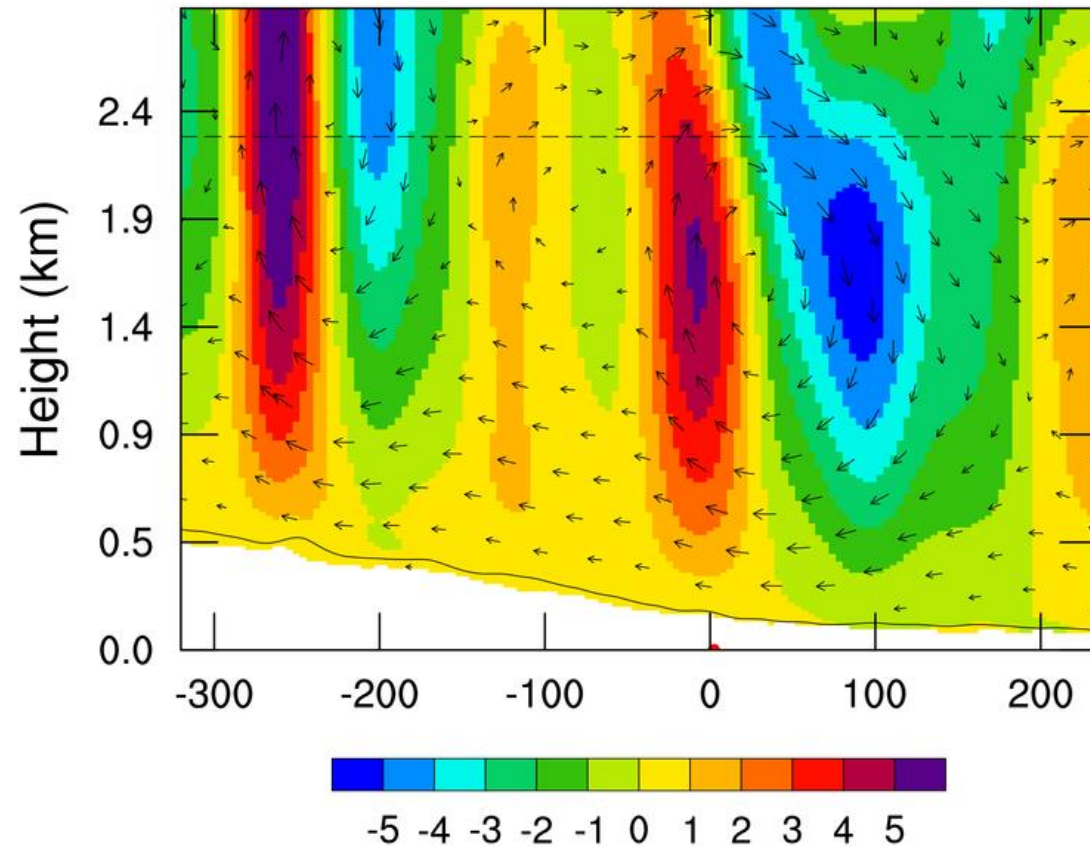
Mountain-Plain Solenoid was prominent in Aug. 2011

W layer 11@2011-08-03_00:00:00

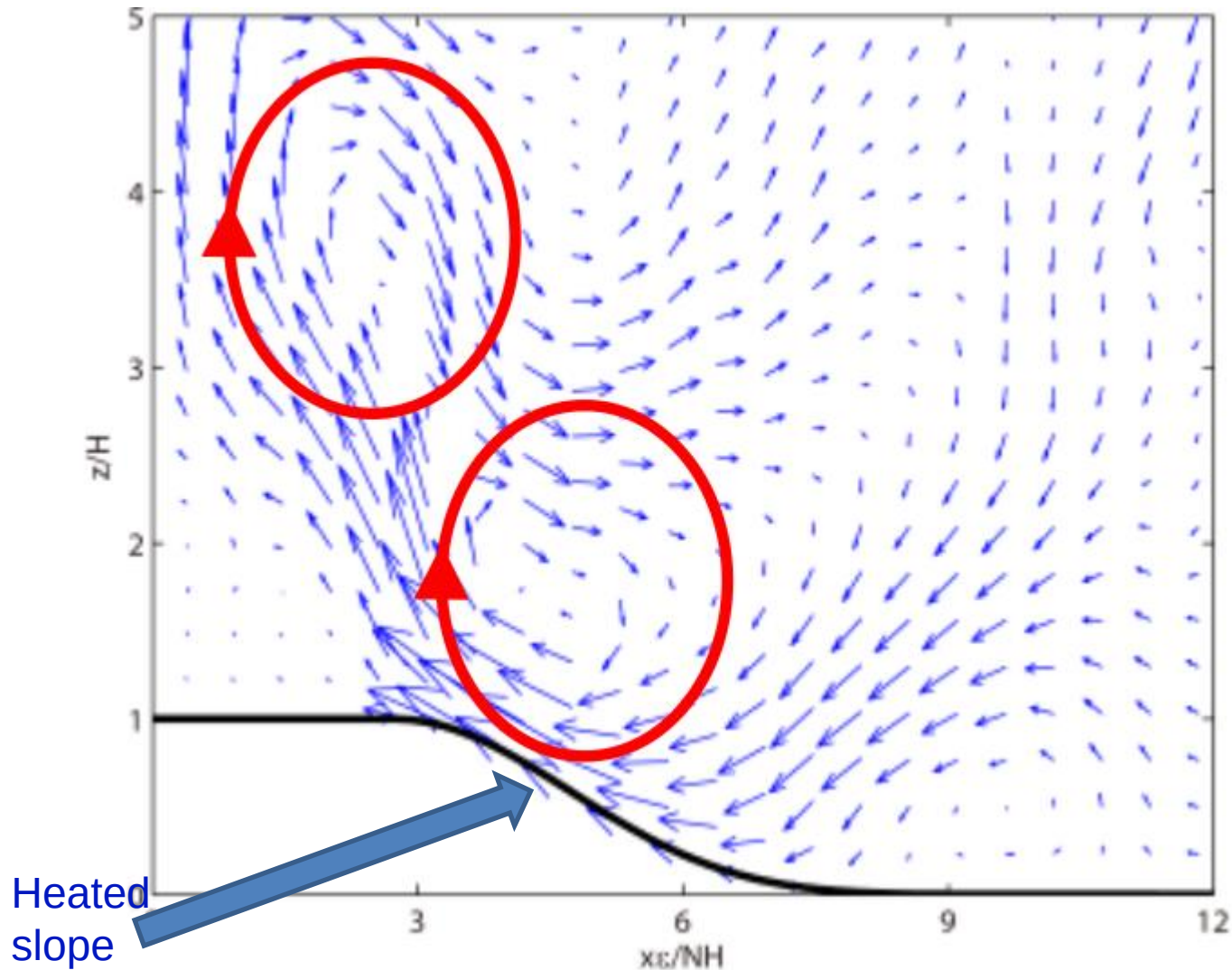
NARR3dWSM6_CONUS_UCM_YSU_JulAugMean_noMic



angle=103 2011-08-03_00:00:00 UTC



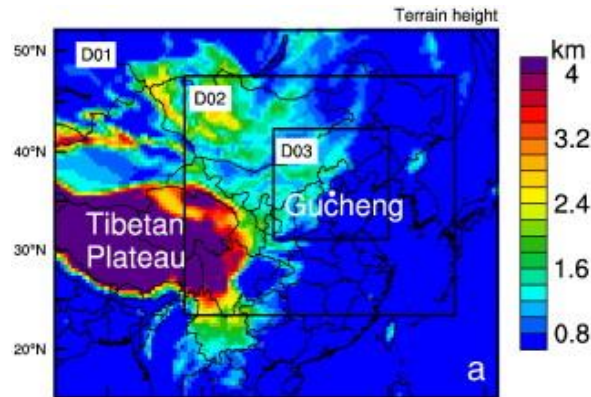
Confirmed by 2D idealized simulations



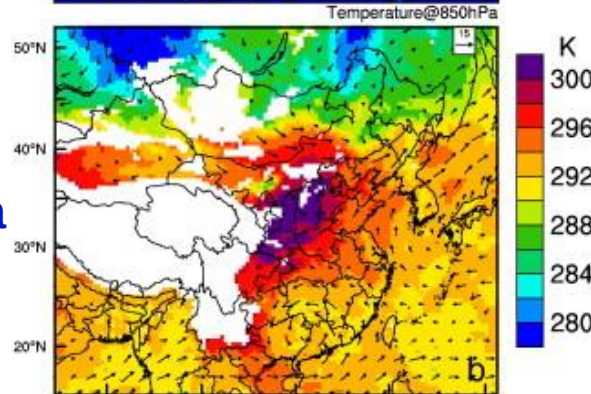
Two circulation cells along a heated slope
simulated using a 2D model from Qian et al. (2012, JAS)

Similar as North China Plain?

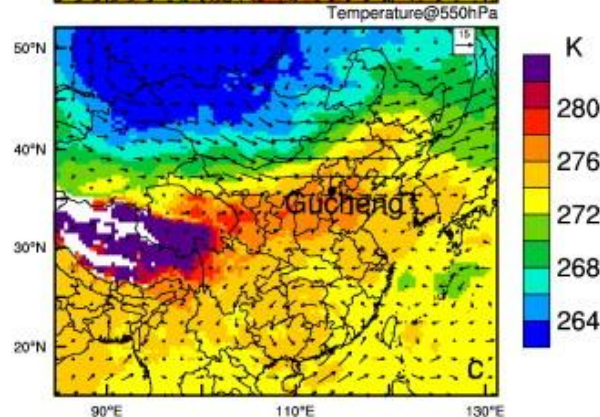
Terrain
height



T@850hPa

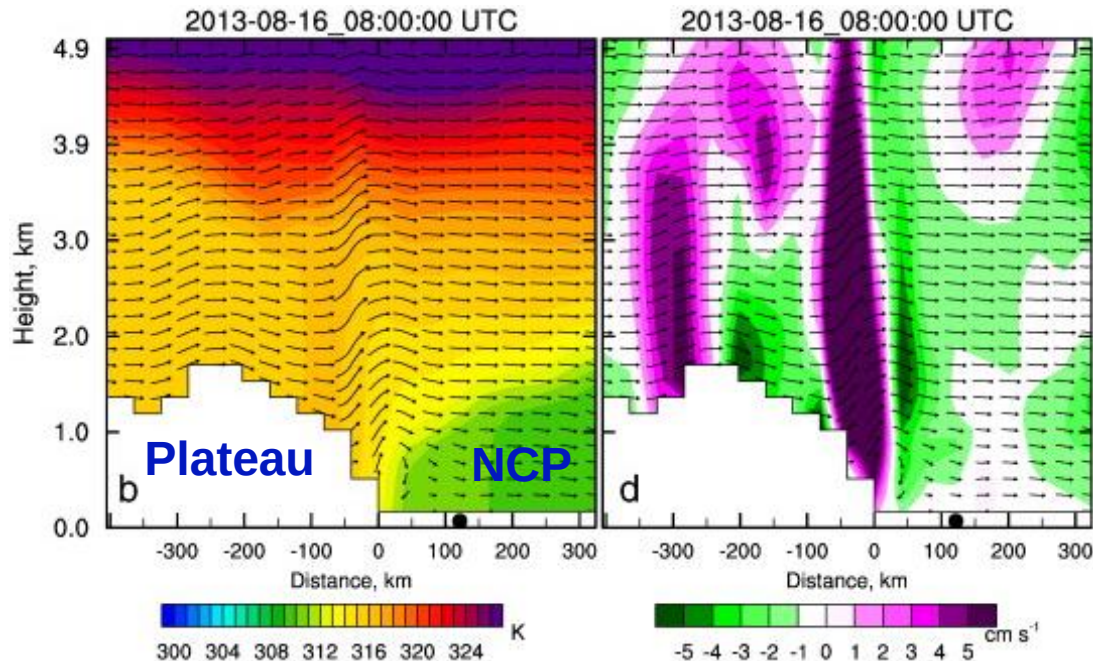


T@550hPa

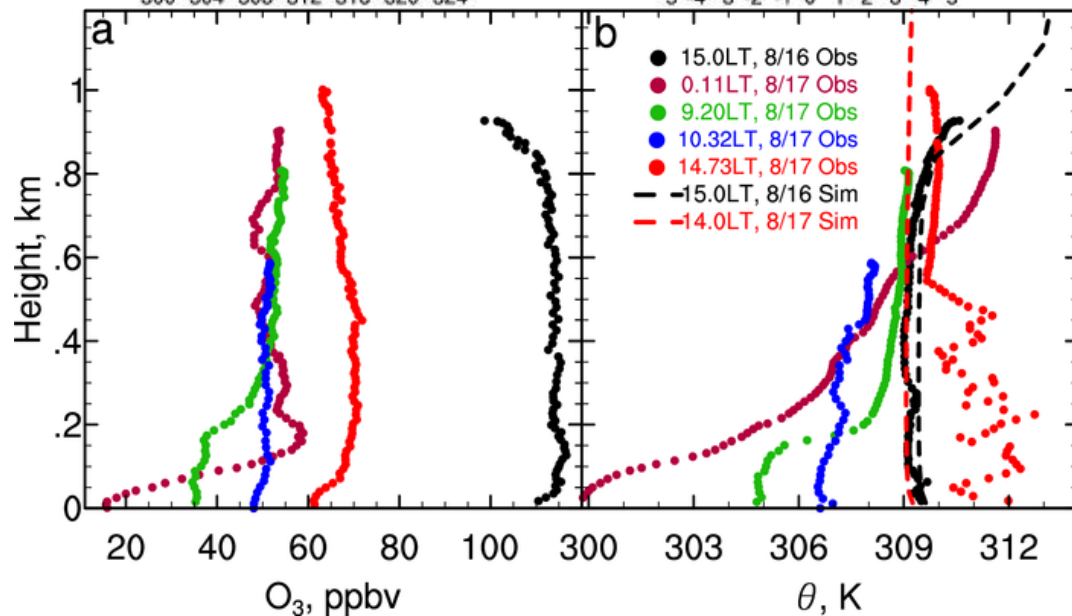


The Plateau acts as a heated source
in Summer (Hu et al., 2014, STE)

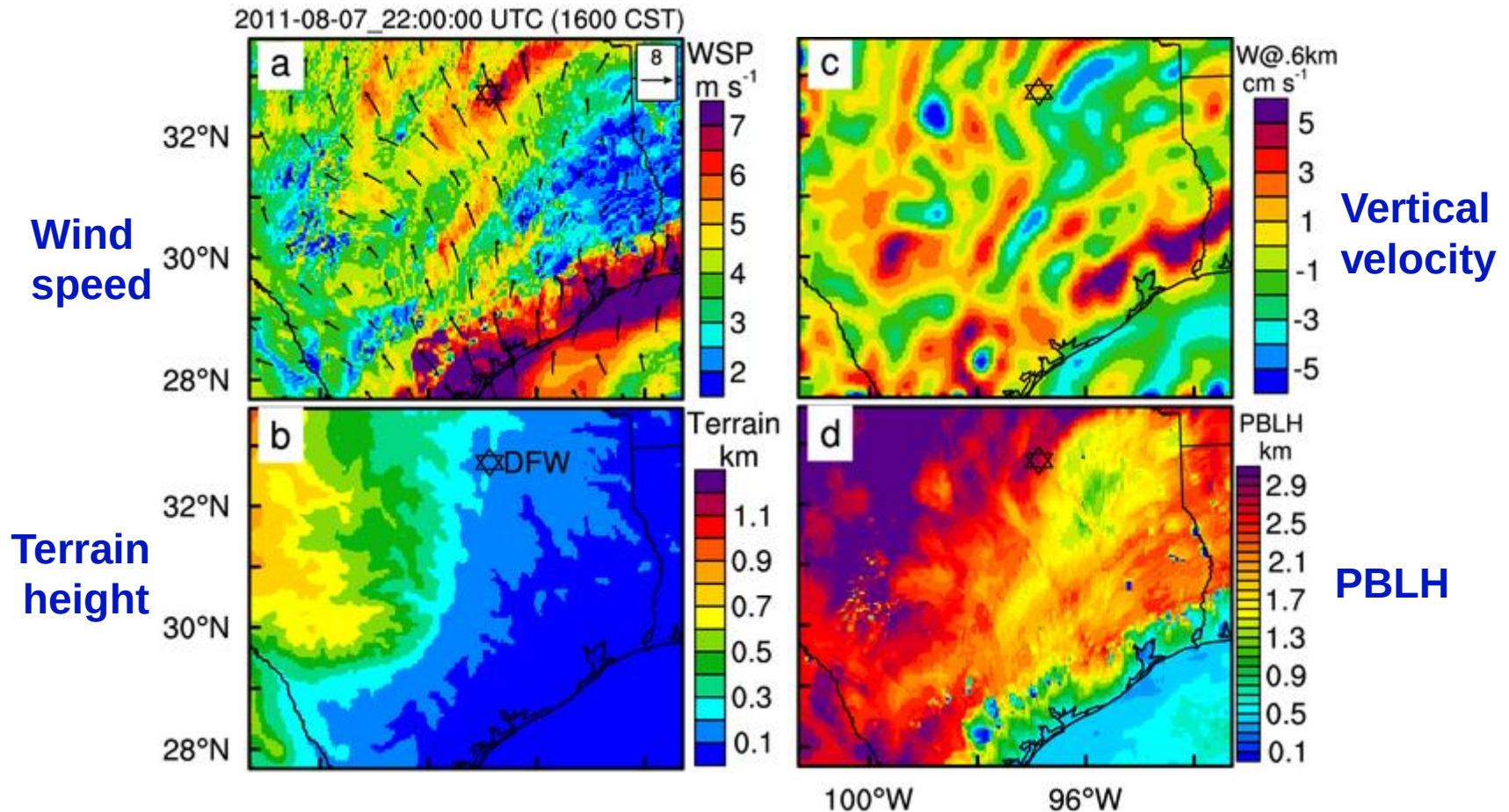
Impact of Mountain-Plain solenoid on boundary layer



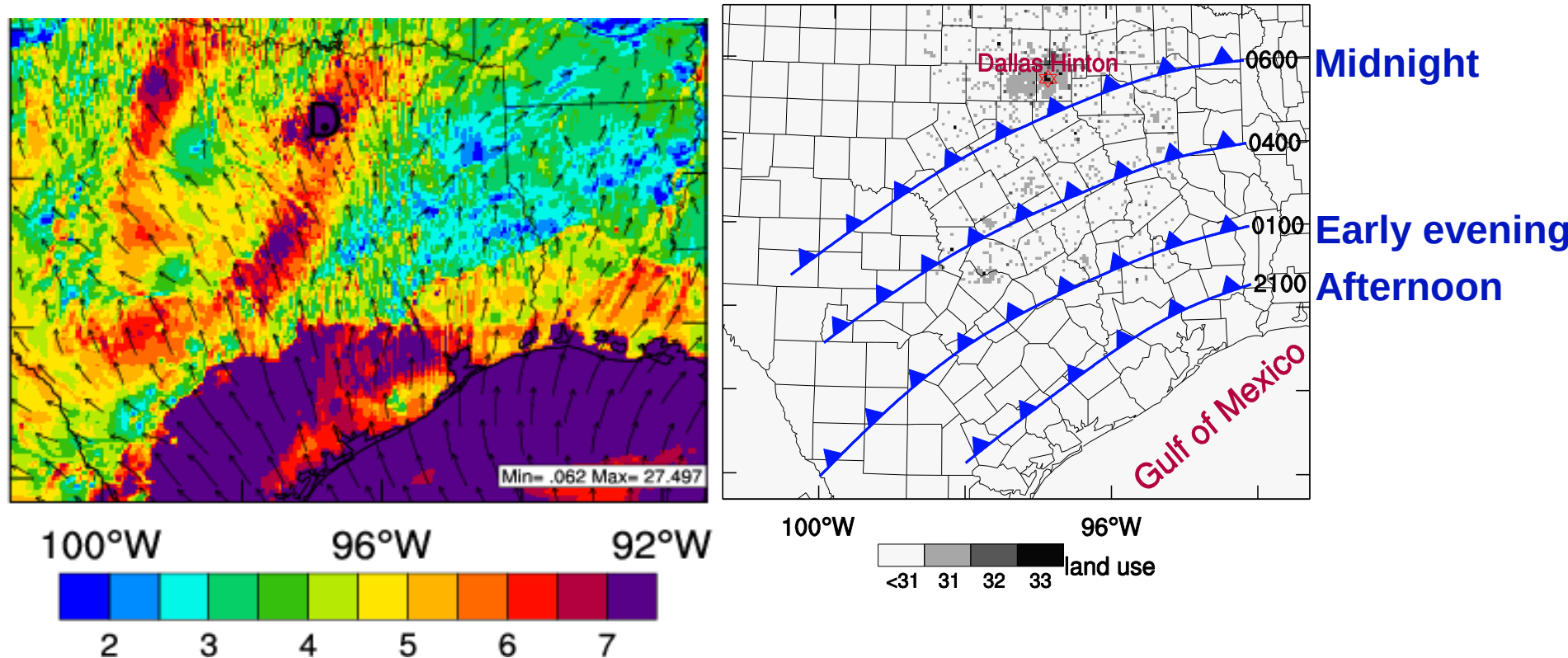
Mountain-Plain solenoid suppress boundary layer development and enhance air pollution (Hu et al., 2014, STE)



Mountain-Plain Solenoid induced wind maximum band



Inland penetration of the sea breeze front



The sea breeze front approached Dallas around midnight (0600 UTC)

Tendency: difference between current and next hours

Early evening

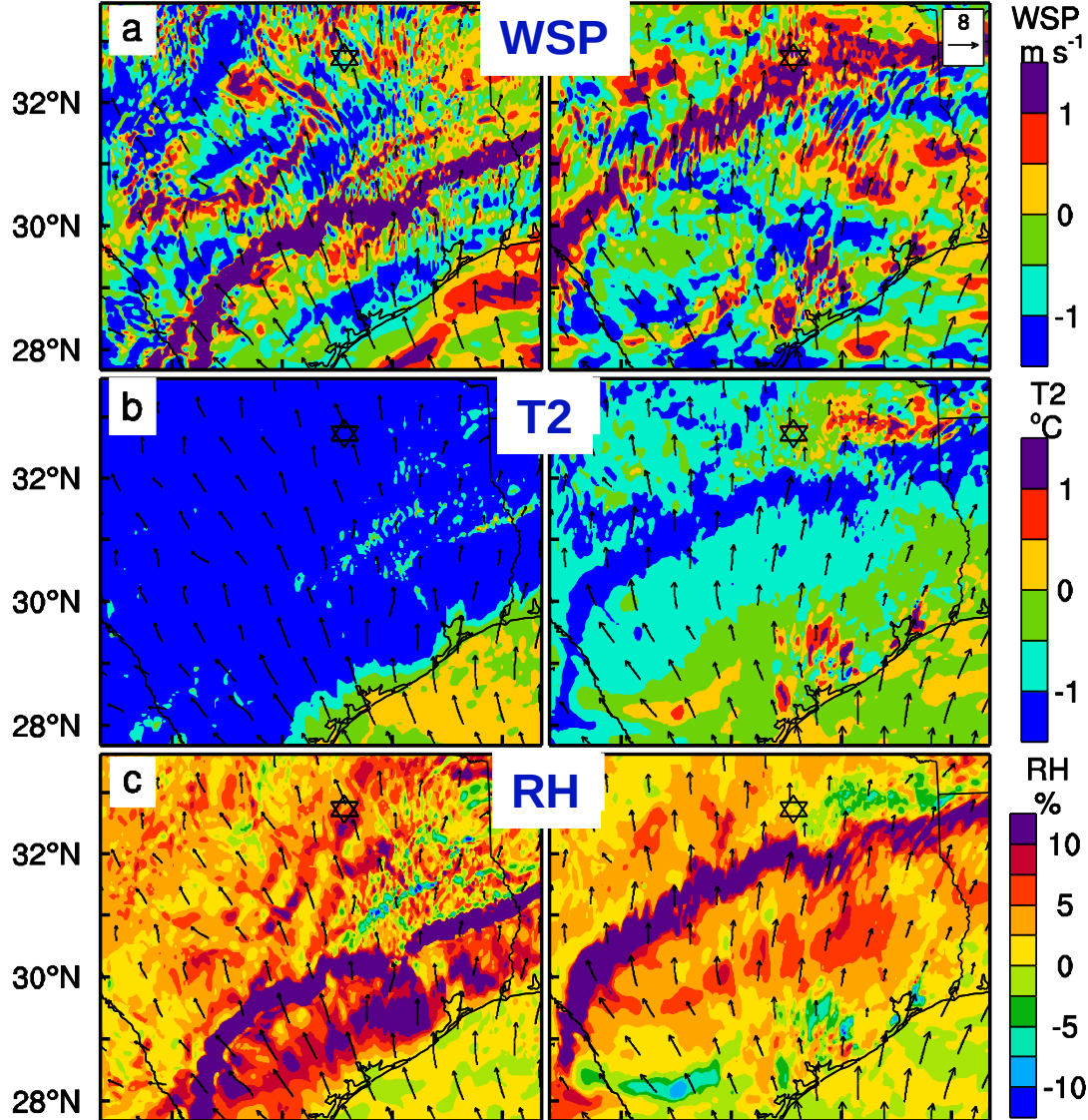
Midnight

Tendency@2011-08-08_01:00:00 UTC

Tendency@2011-08-08_06:00:00 UTC

Wind

Relative Humidity Temperature

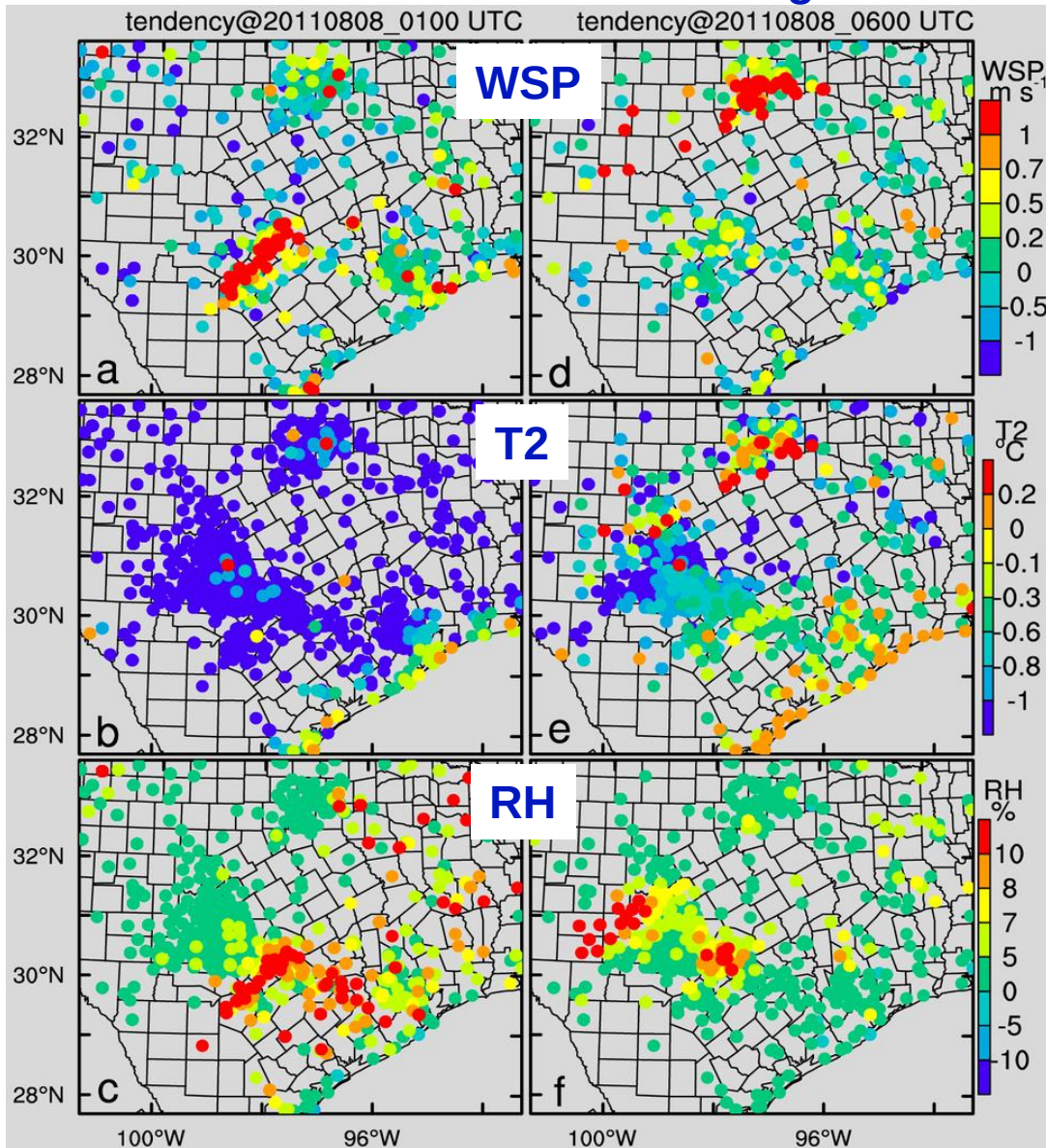


The inland penetration of sea breeze front can be clearly illustrated in the tendency of WSP, T2, RH.

Observed tendency in MADIS data

Early evening

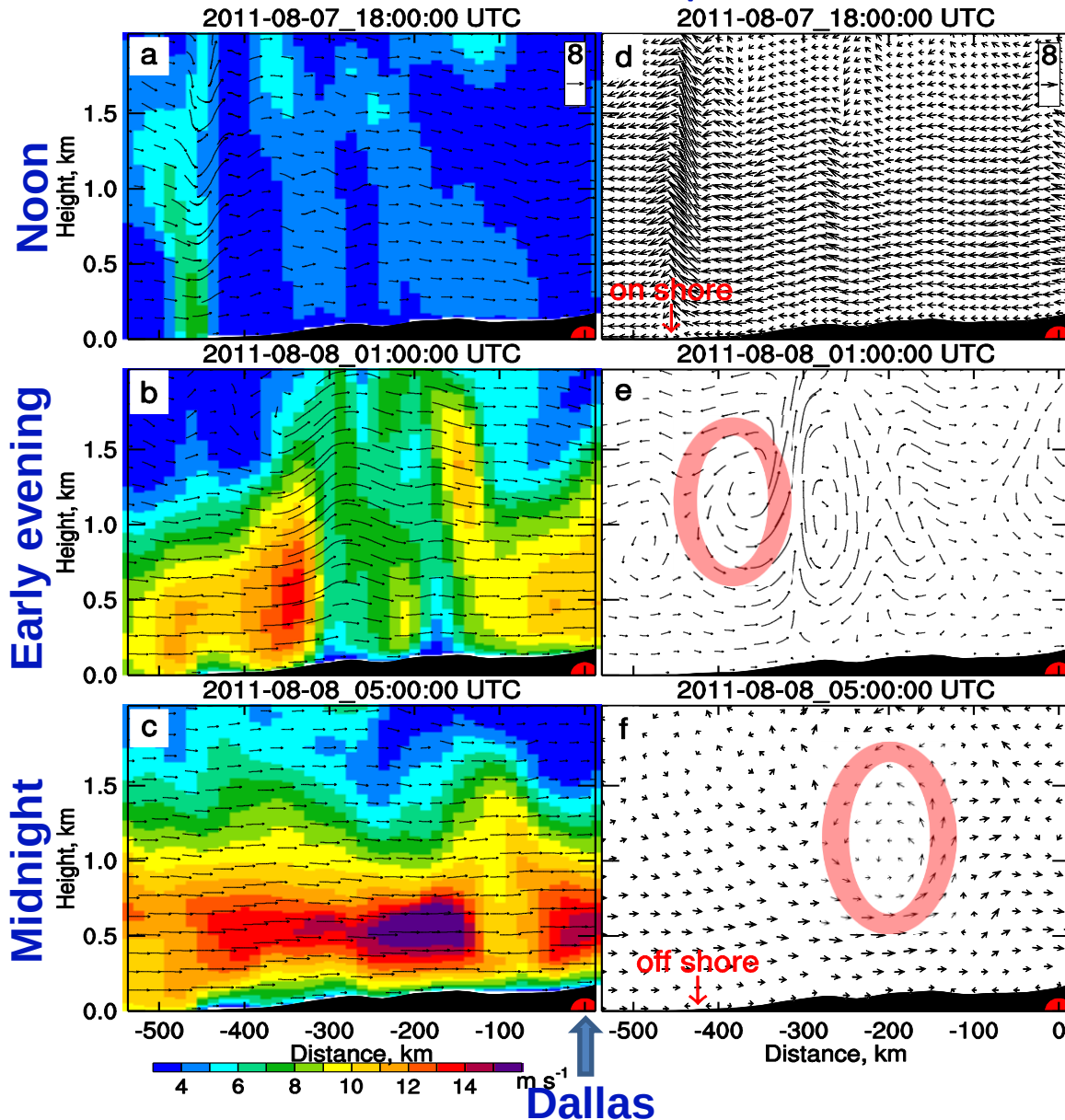
Midnight



MADIS integrated data from many providers

In the spatial distribution of tendency, the small scale local **heterogeneity** in instantaneous values is removed and only the spatial information of temporal variation is remaining.

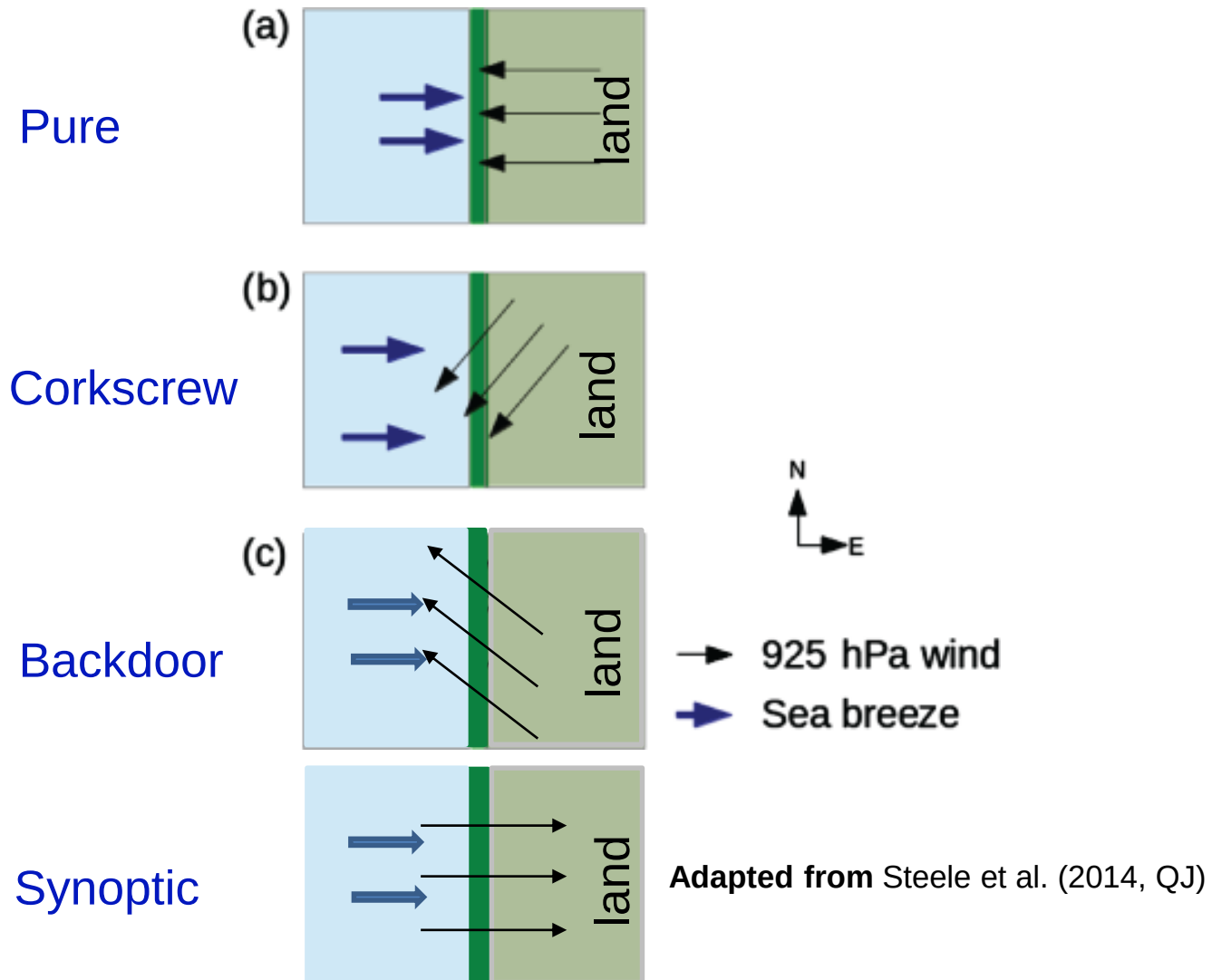
Vertical cross-section of wind and its perturbation



Sea breeze develops in the morning and is advected by Low-Level Jet at night

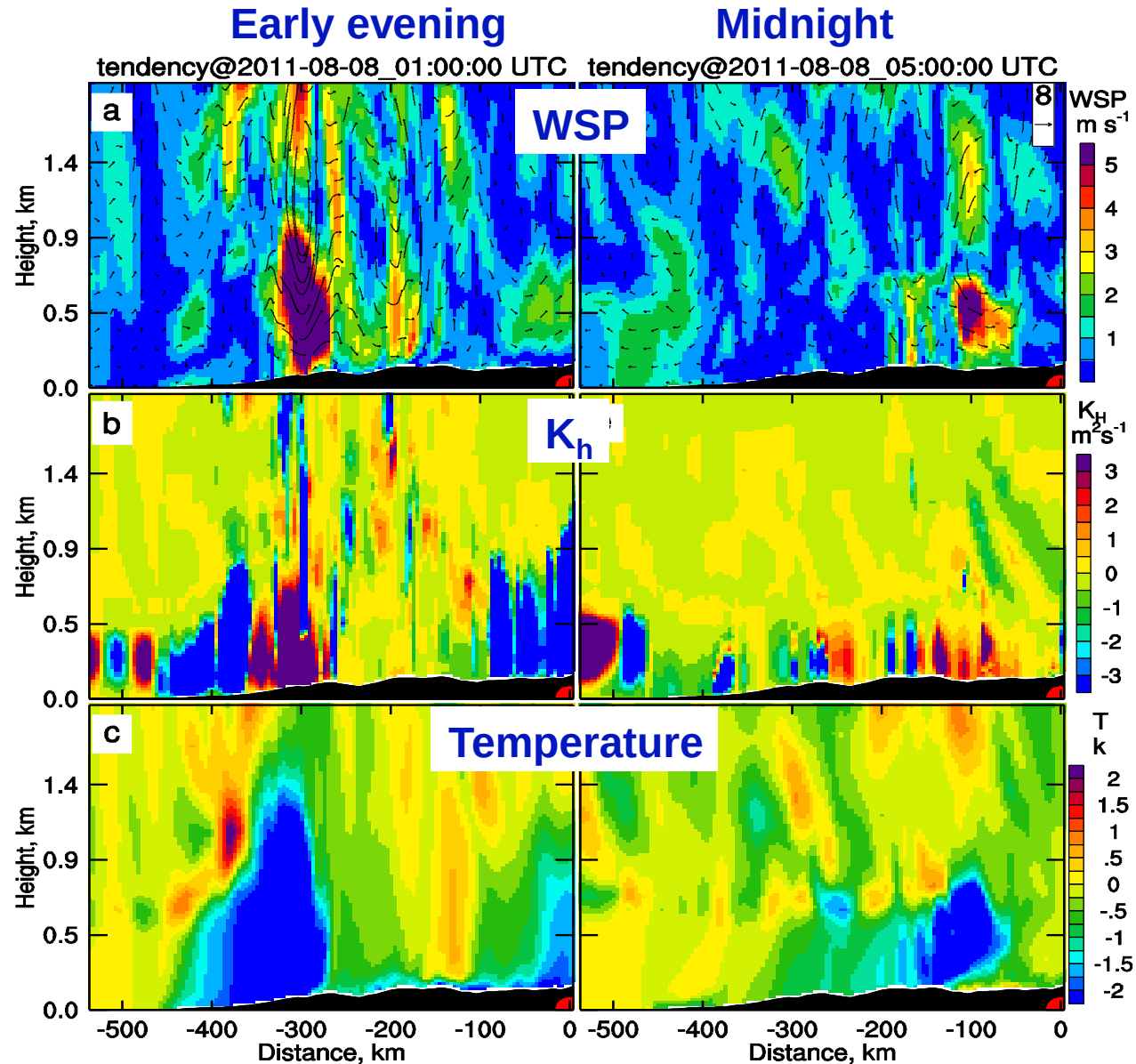
Synoptic sea breeze

Categories of Sea Breeze

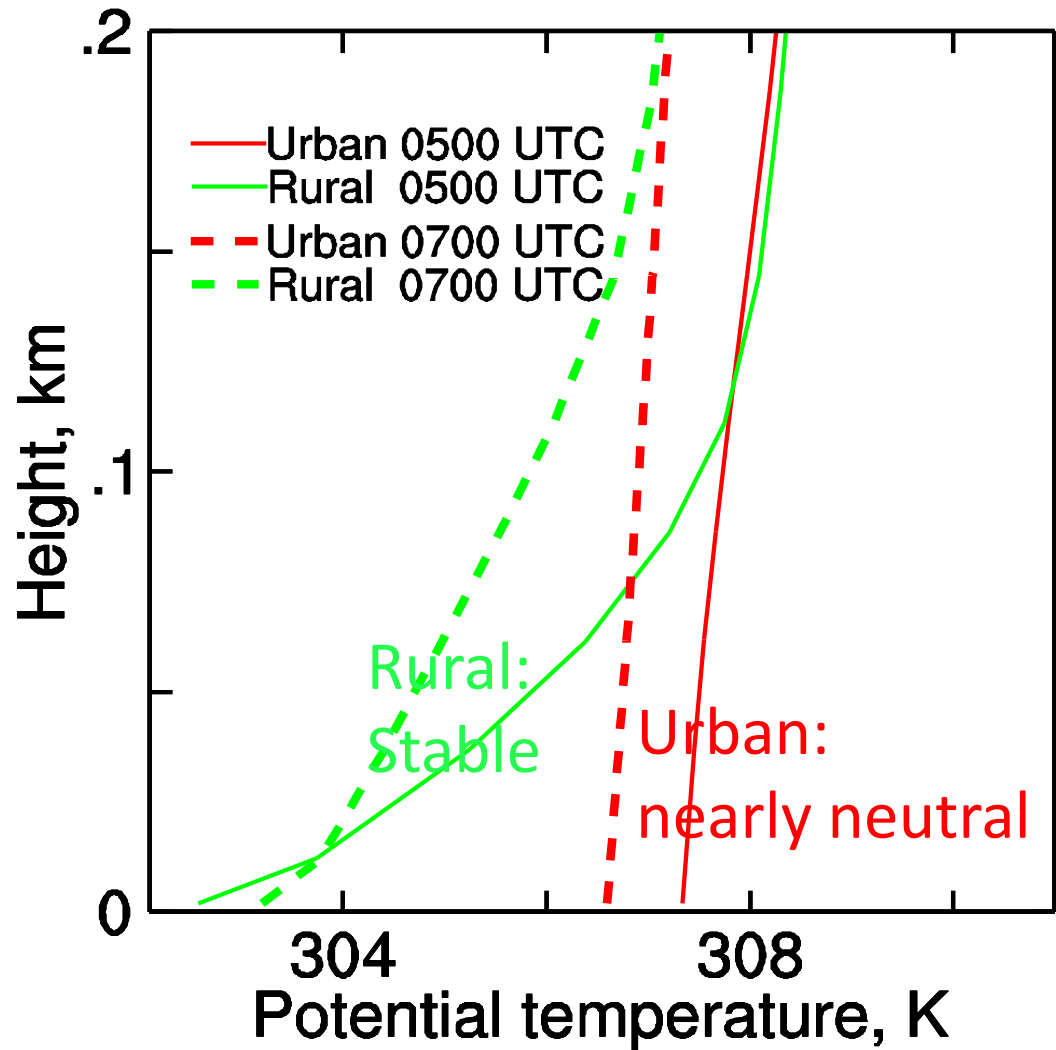
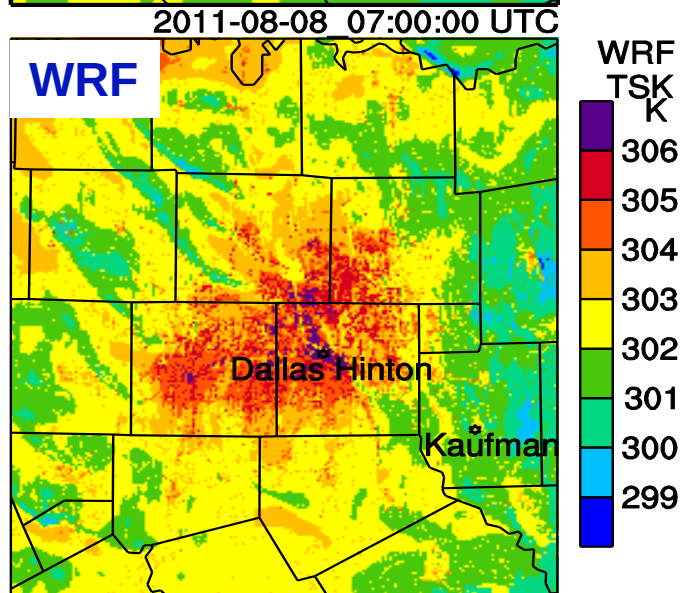
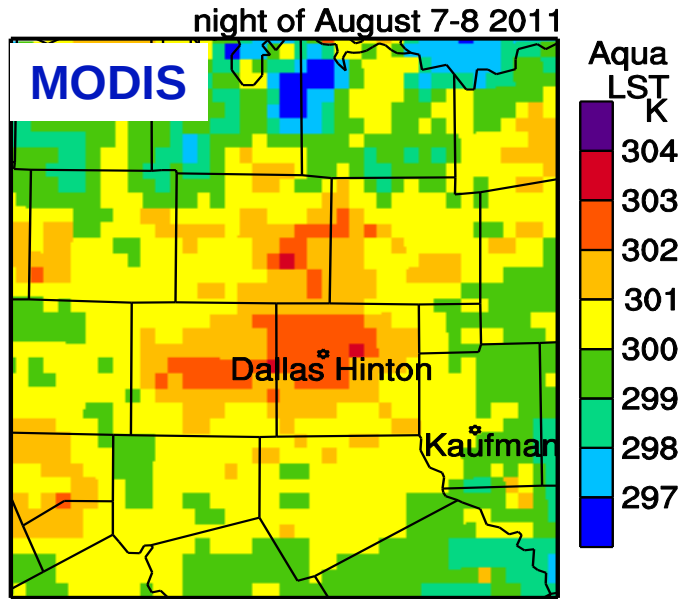


Synoptic sea breezes were less studied previously

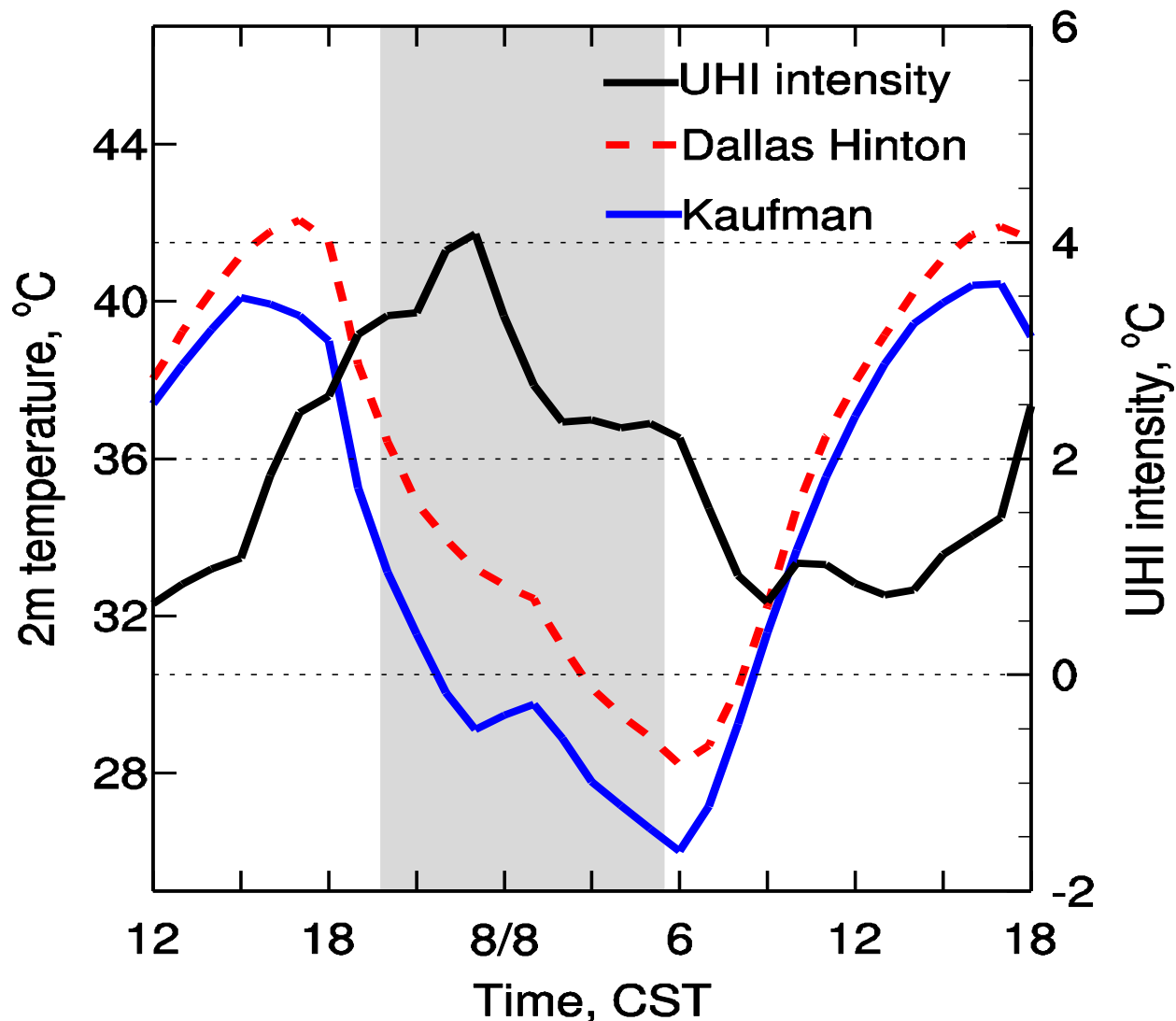
Vertical cross section of tendency of WSP, K_h , T



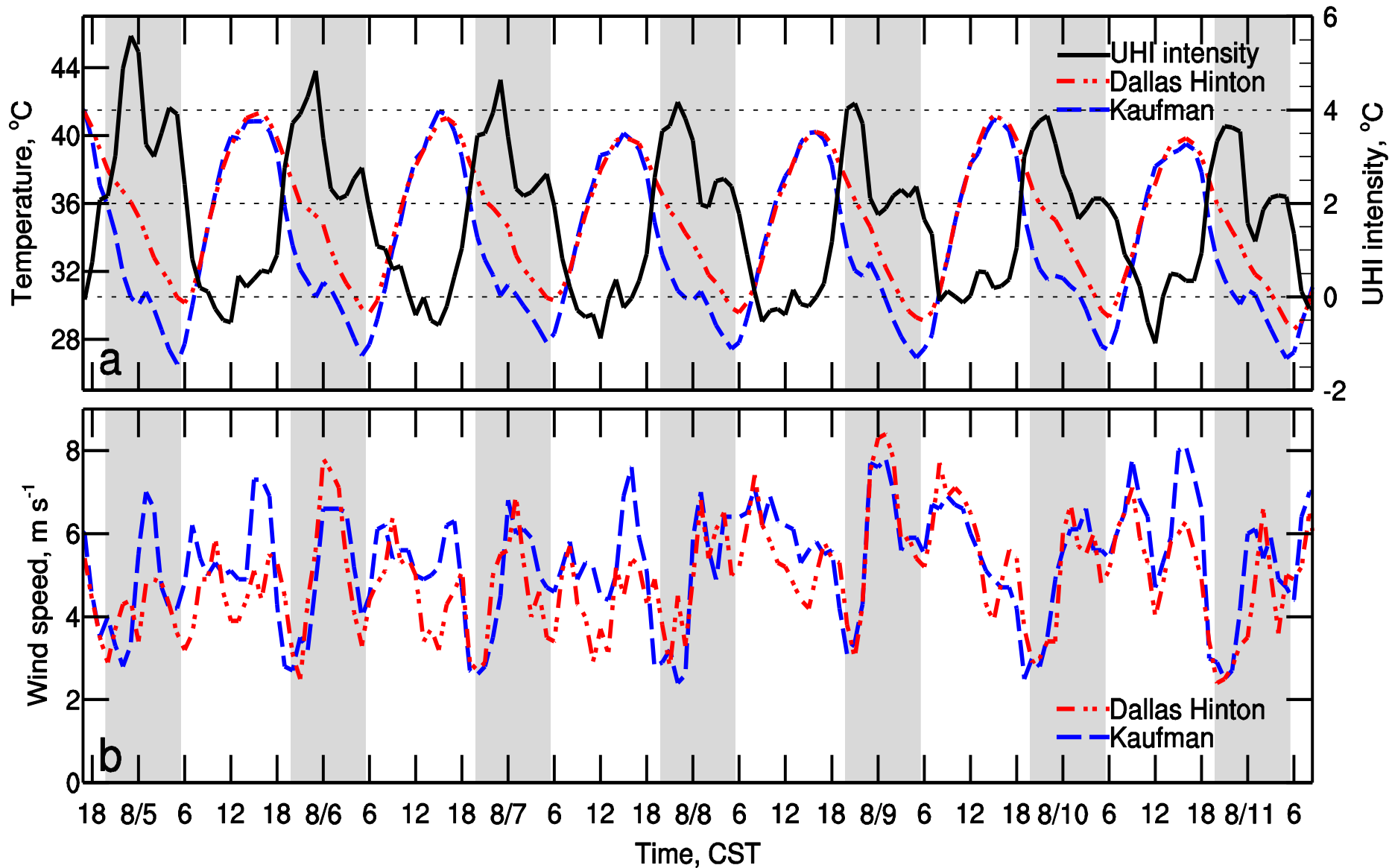
Different response to the front in rural and urban



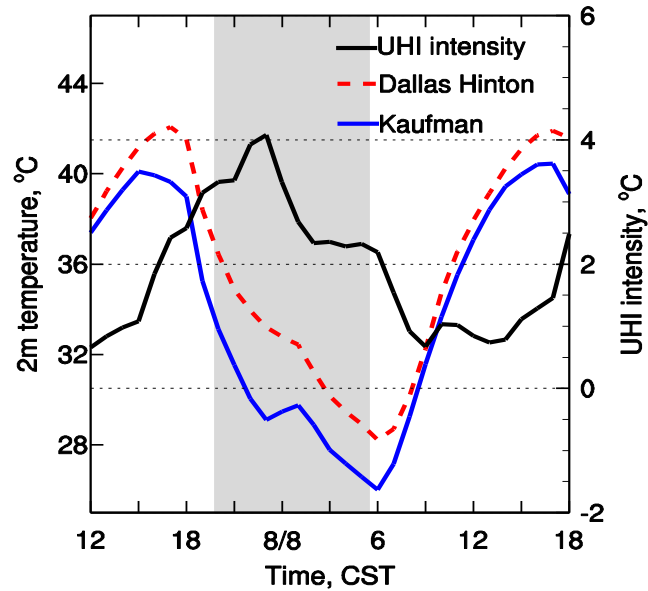
Simulated variation of T, and UHI intensity



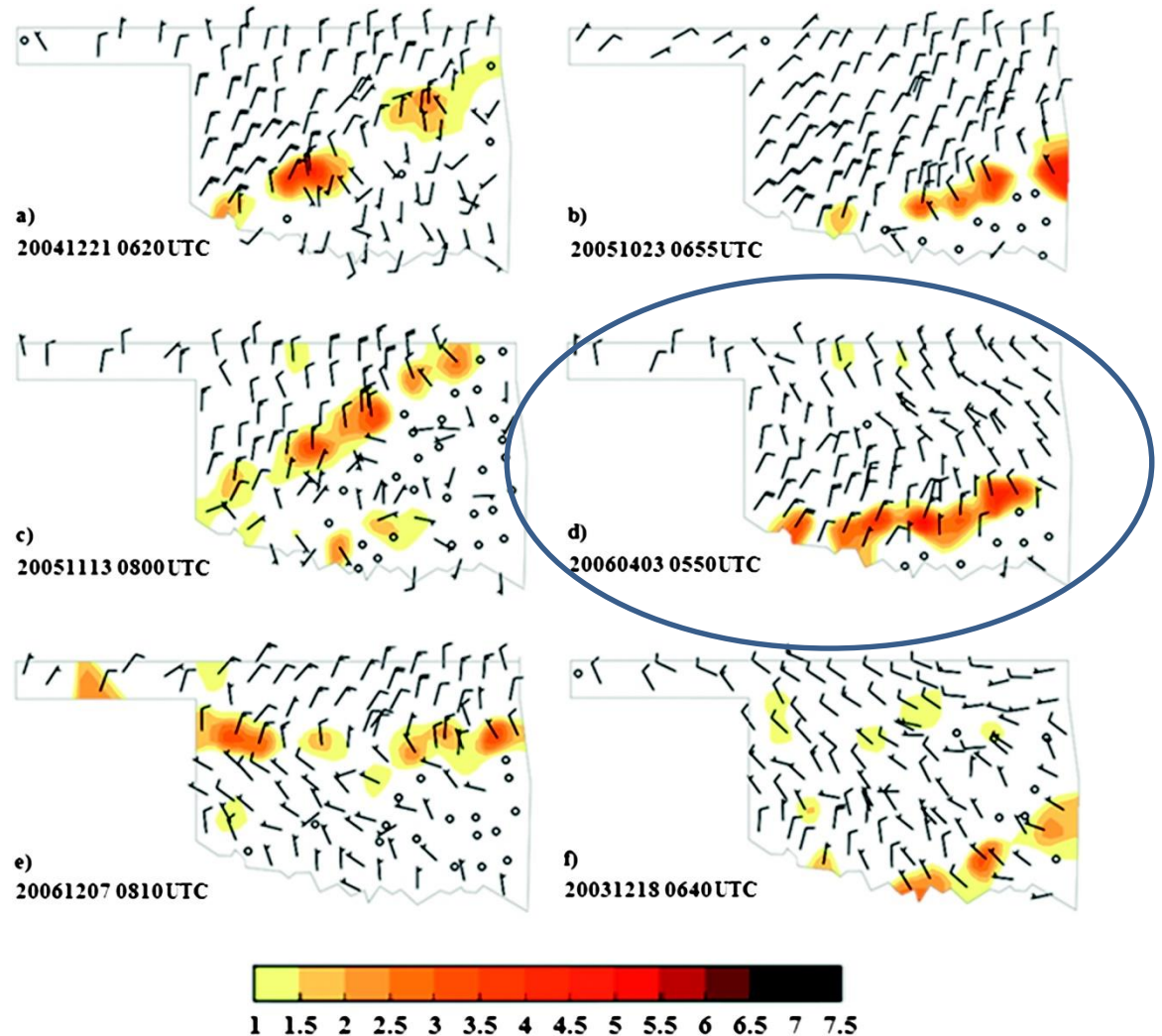
Observed variation of UHI intensity in Dallas



Nocturnal warming events reported previously

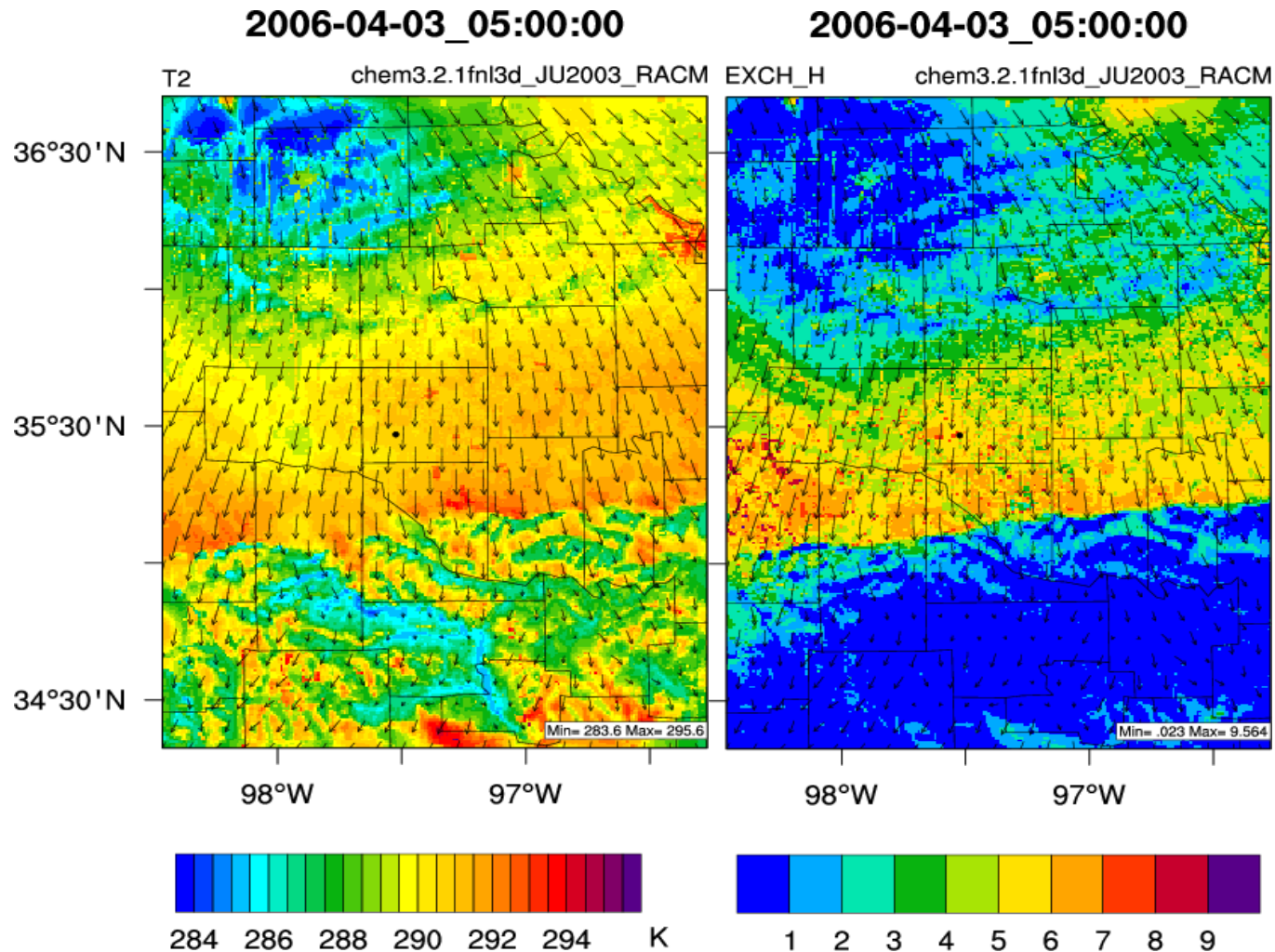


Induced by sea breeze



Induced by **synoptic cold fronts** (Nallapareddy et al., 2011)

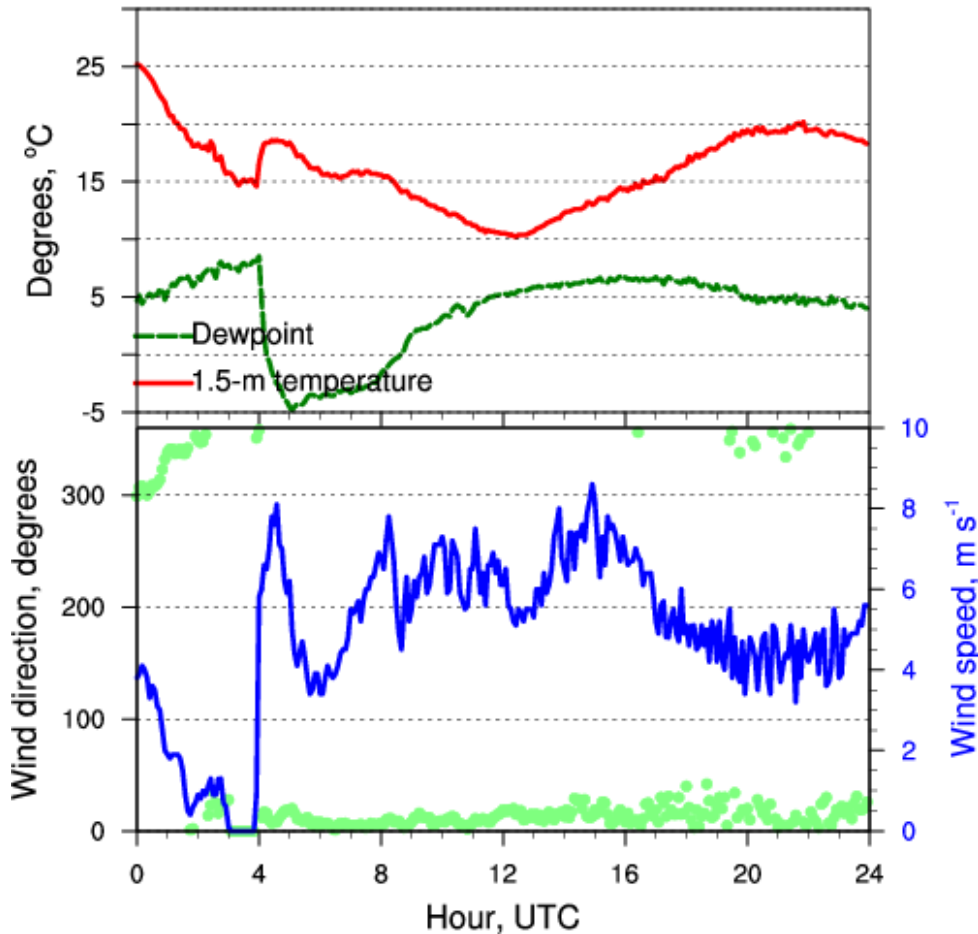
T2 and vertical mixing coefficient at the leading edge of a cold front



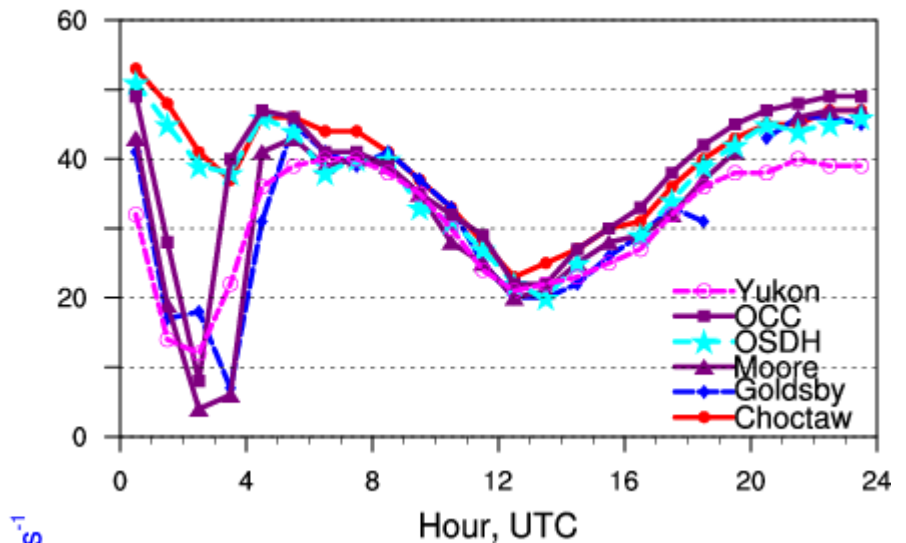
Enhanced vertical mixing associate with cold fronts led to surface warming (Hu,2013,JGR)

Nocturnal warming events and O₃ maximum induced by a cold front

20060403 Start time: 0355 @nrmn



20060403 Start time: 0355 @nrmn



O₃ increased by 40 ppb when the nocturnal warming event occurred (Hu, 2013, JGR)

Conclusions

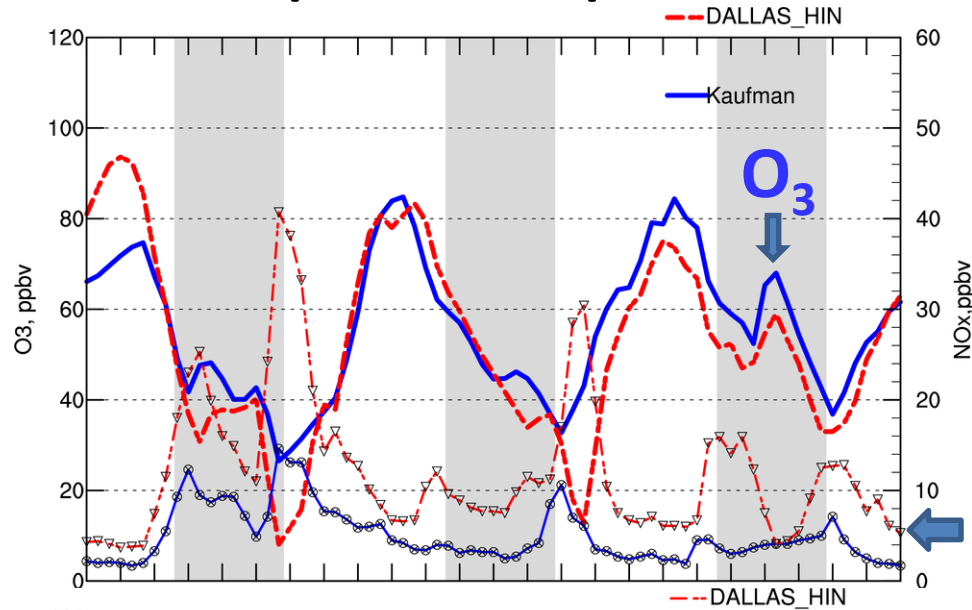
1. “collapse” of nocturnal UHI intensities occurred frequently around midnight in August 2011 in Dallas.
2. Synoptic sea breeze circulation cells can be advected to Dallas and influence its UHI, such a sea breeze category is rarely studied in the past.

Conclusions

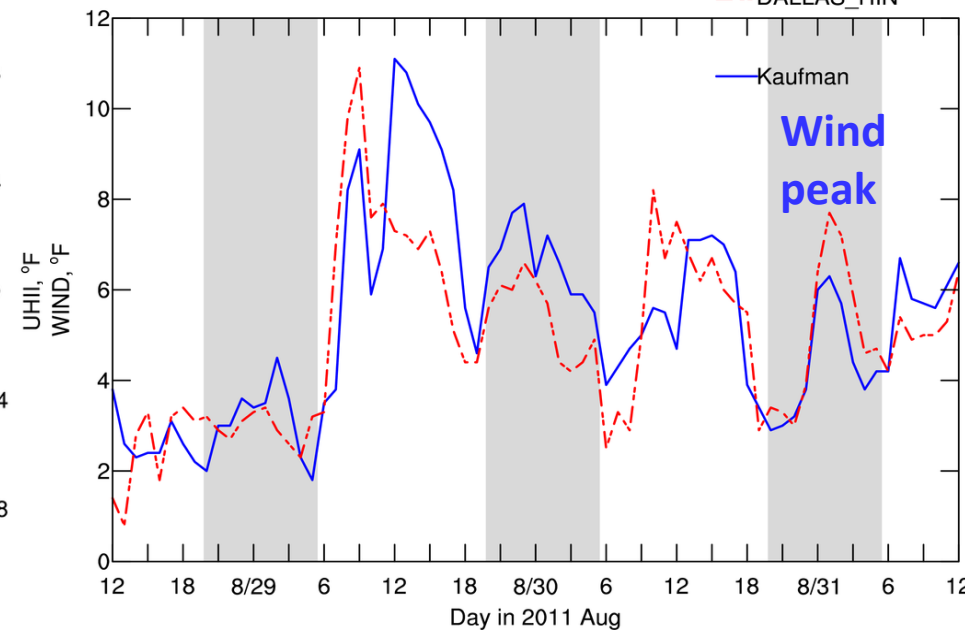
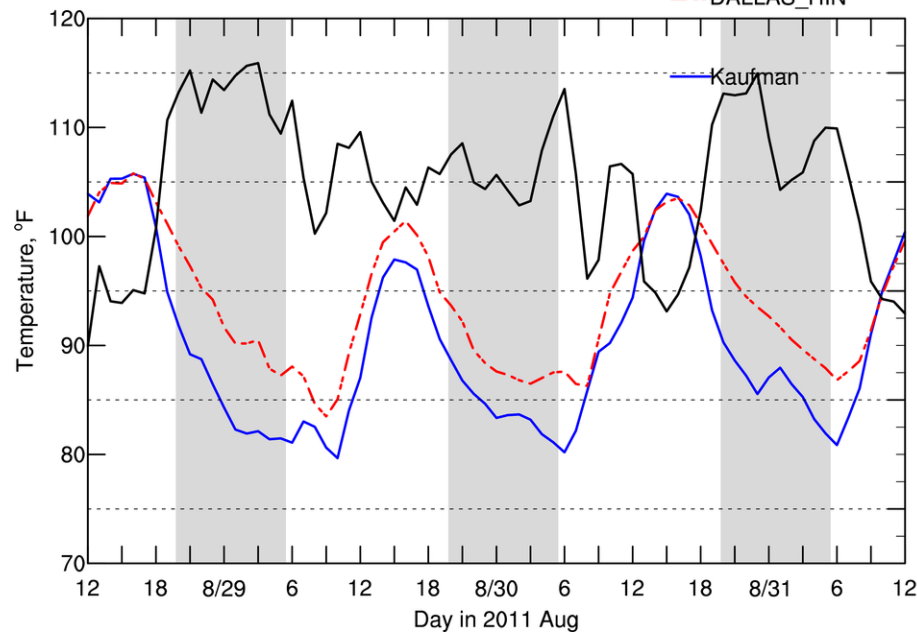
3. Sea breeze frontal passage induced nocturnal warming events in rural area, while it did not alter urban boundary layer much, leading to collapse of UHI.

Nocturnal warming events were reported before, but as a result of synoptic cold fronts. In both cases the mechanism is similar, i.e., enhanced vertical mixing associated with momentum fronts plays a dominant role.

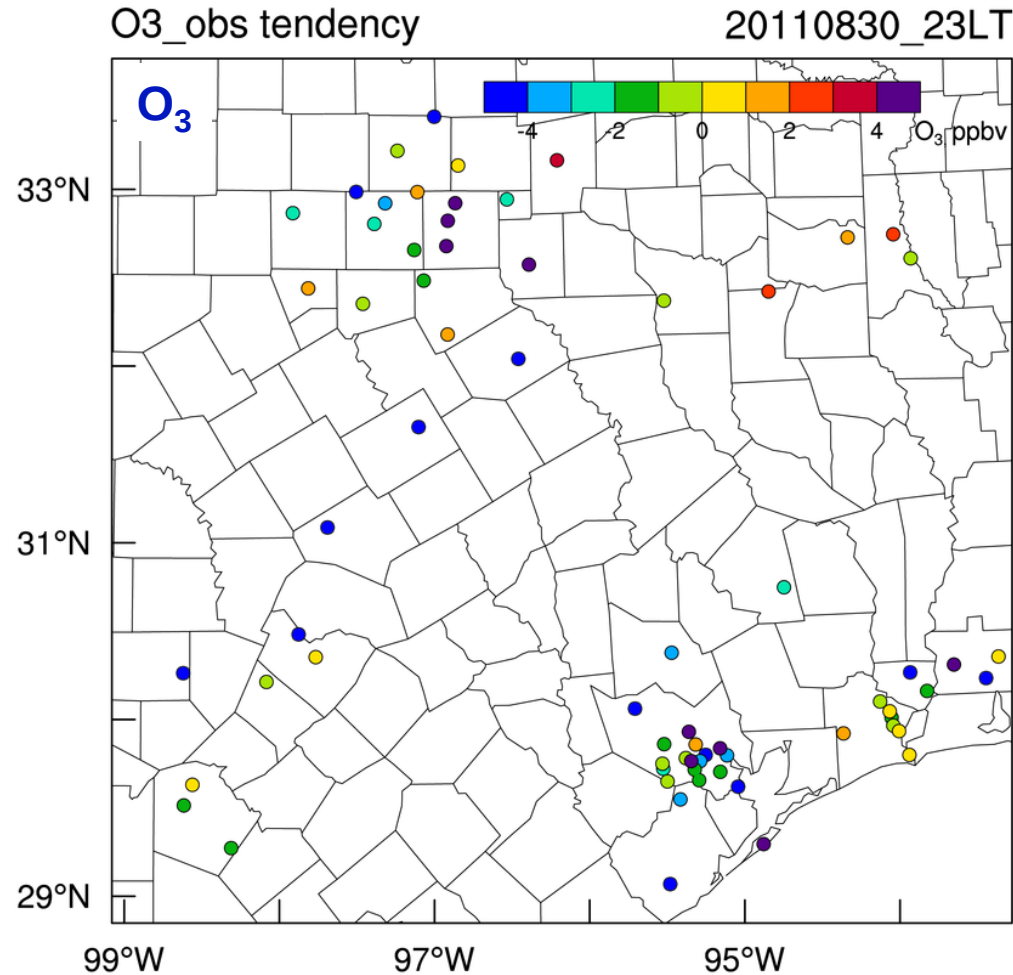
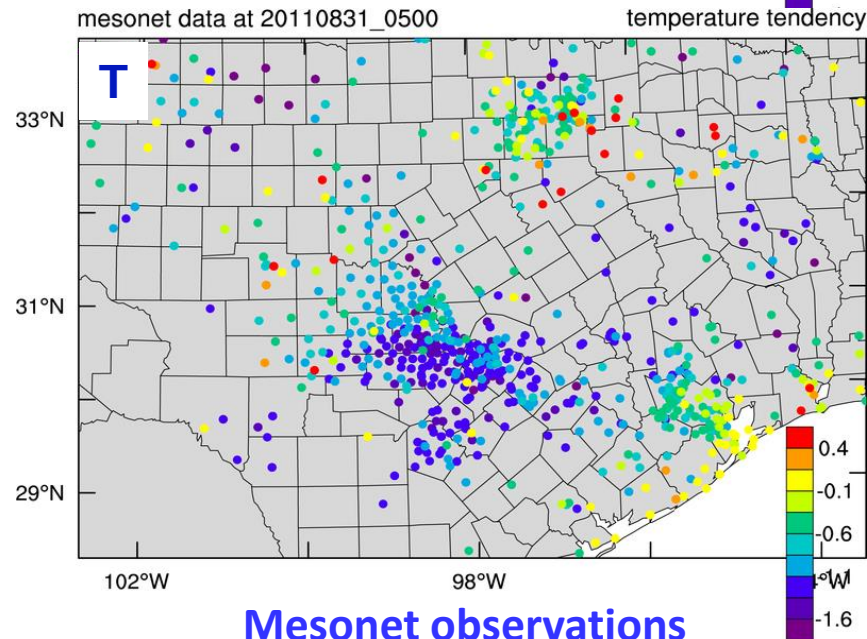
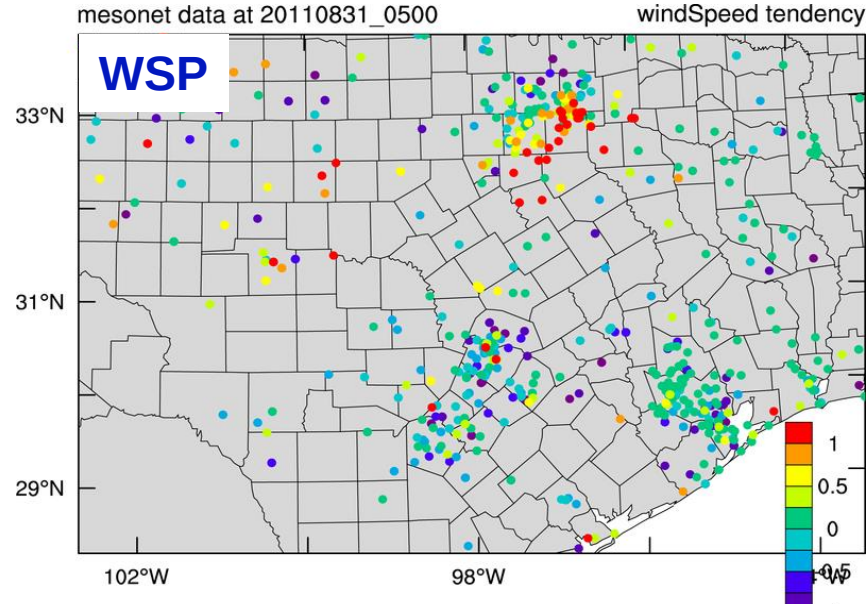
Unique temporal variation of nocturnal O_3



Nighttime O_3 maxima
associated with collapse of UHI



Induced by sea breeze frontal passage? tendencies



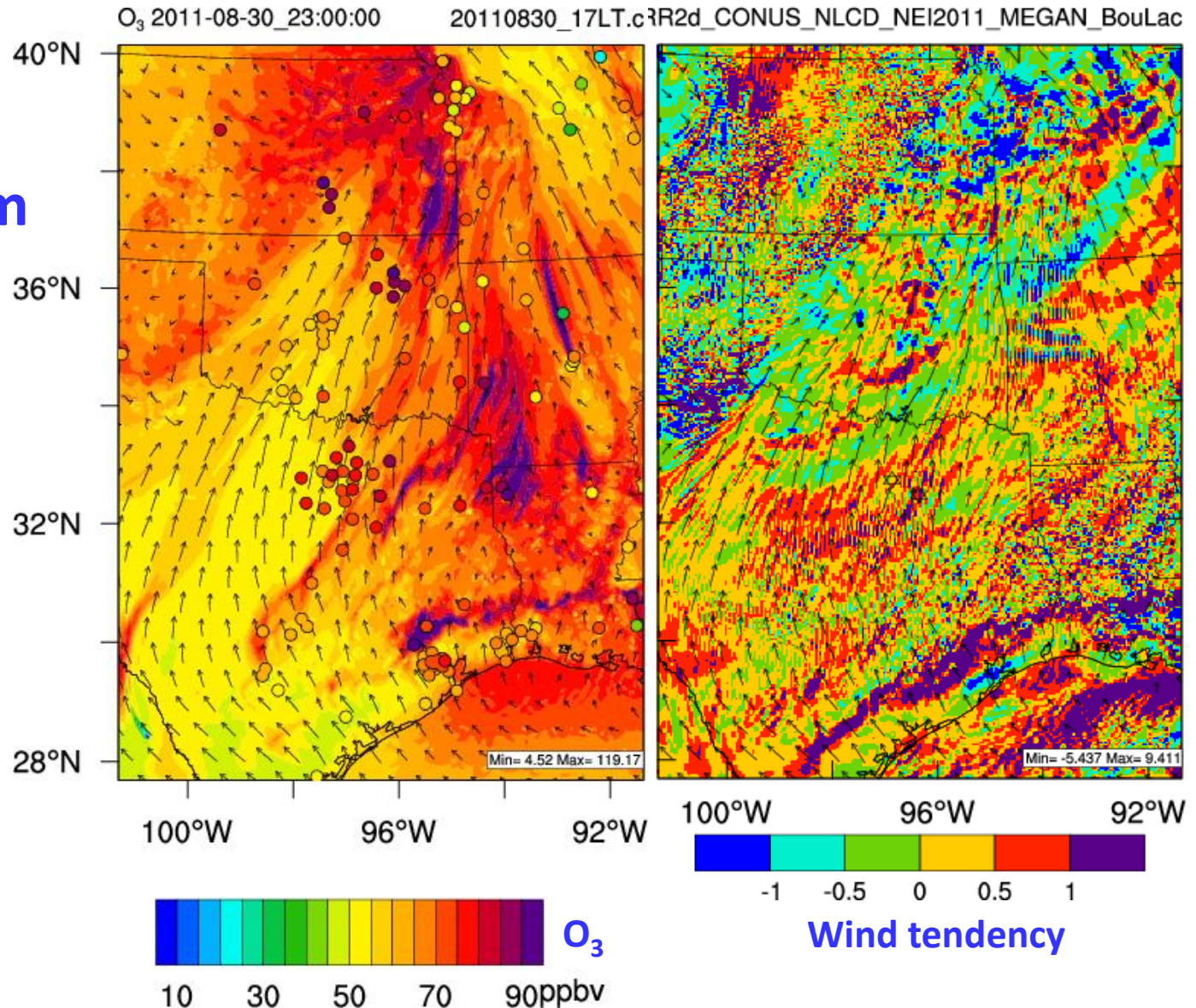
EPA AQS observations

Impact of sea breeze fronts on O₃ in the afternoon

WRF/Chem
3.7

Emission:
NEI2011
MEGAN

IC/BC:
NARR



Impact of sea breeze front on O₃ at night

T2diffPreHour@2011-08-31_05:00:00

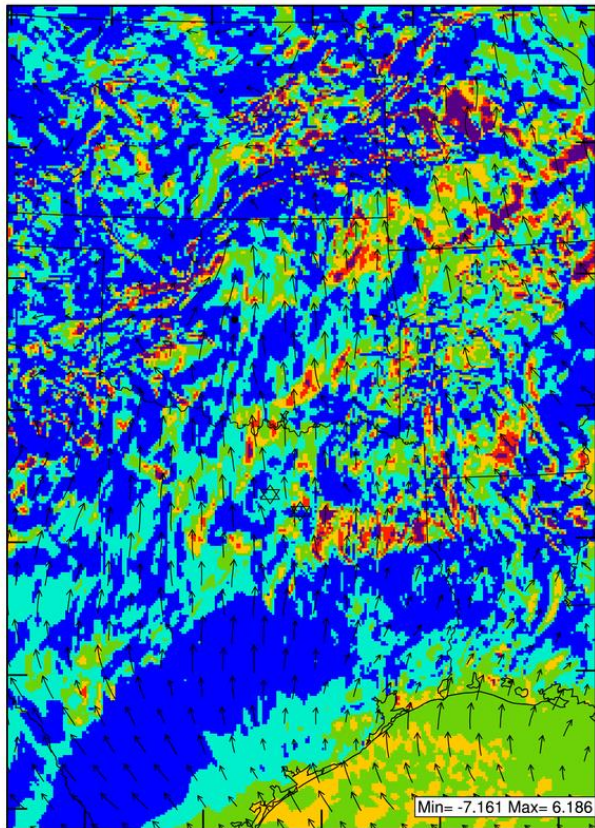
NARR3dWSM6_CONUS_UCM_YSU O₃ 2011-08-31_05:00:00

20110830_23LT.c

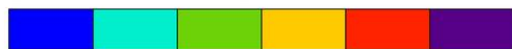
WSP10mdiffPreHour@2011-08-31_05:00:00

NARR3dWSM6_CONUS_UCM_YSU

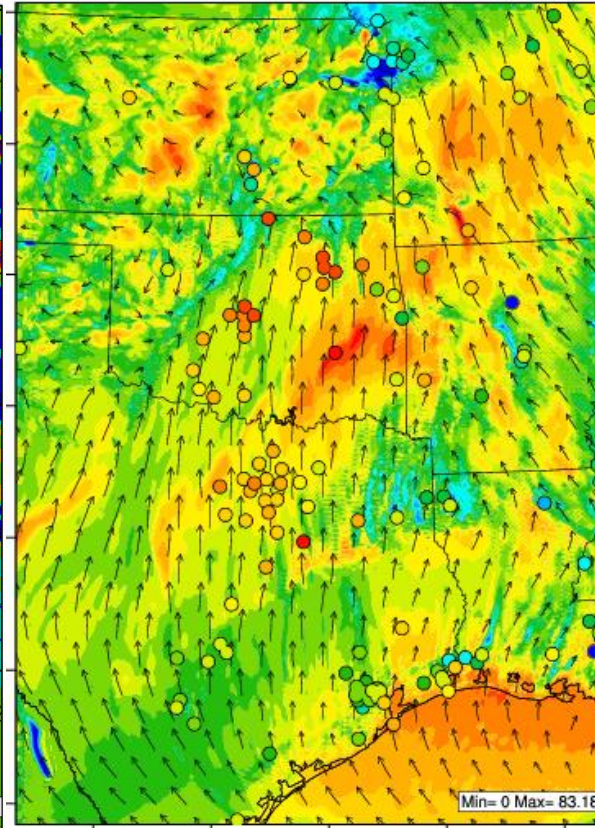
40°N
36°N
32°N
28°N



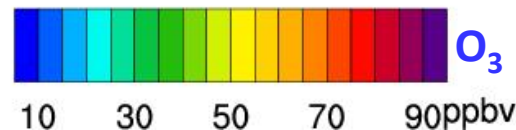
100°W 96°W 92°W



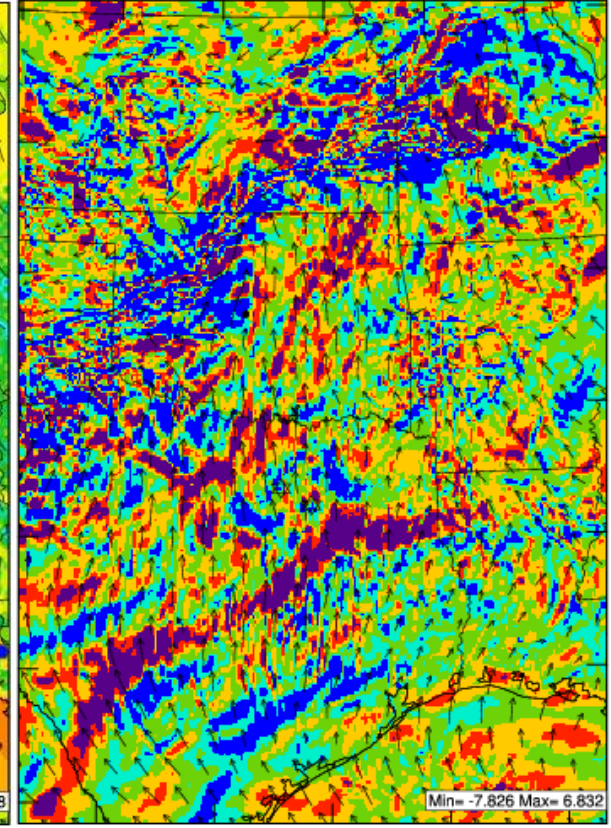
T2 tendency



100°W 96°W 92°W



O₃



100°W 96°W 92°W



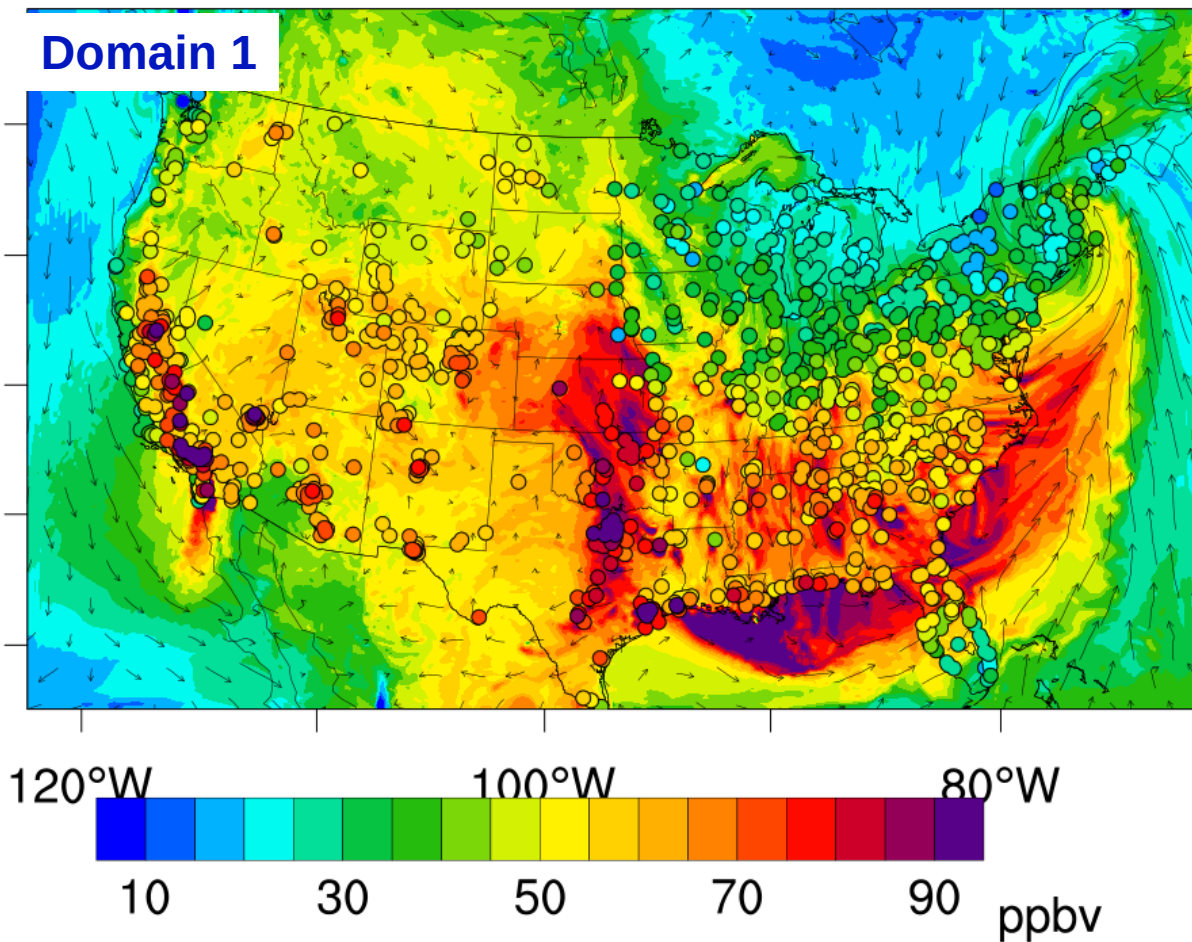
Wind tendency

Impact of Hurricane on O₃?

O₃ 2011-08-28_21:00:00

20110828_15LT c 14m 13p 16e

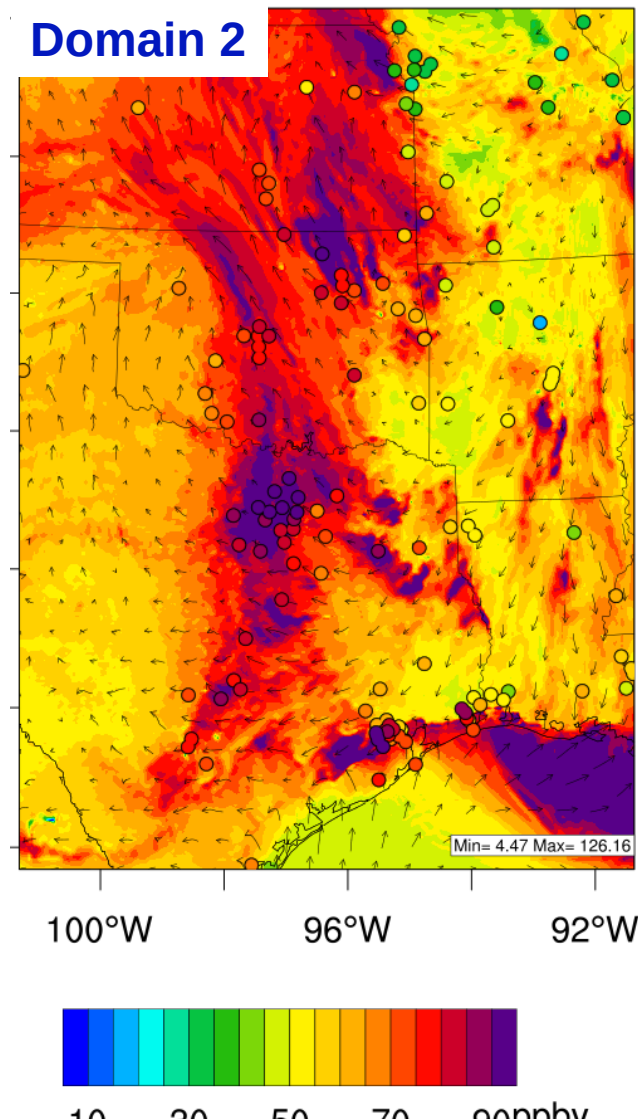
Domain 1



O₃ 2011-08-28_23:00:00

20110828_17LT.c

Domain 2

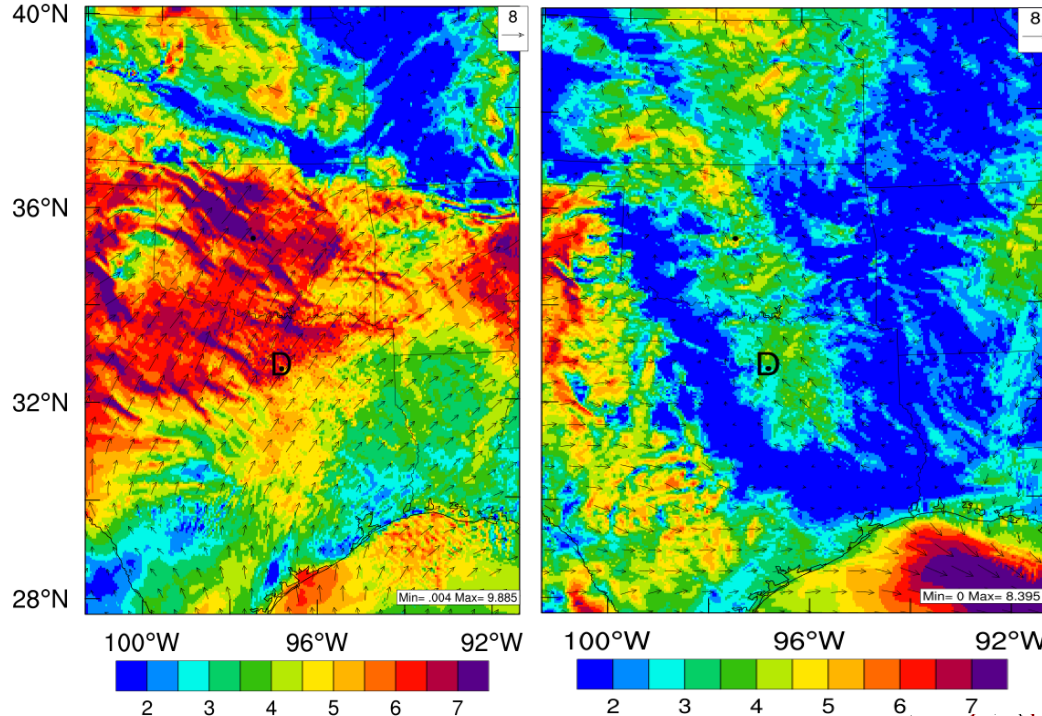


Weak wind zone around Dallas?

No Hurricane

WSP10m@2011-08-07_14:00:00

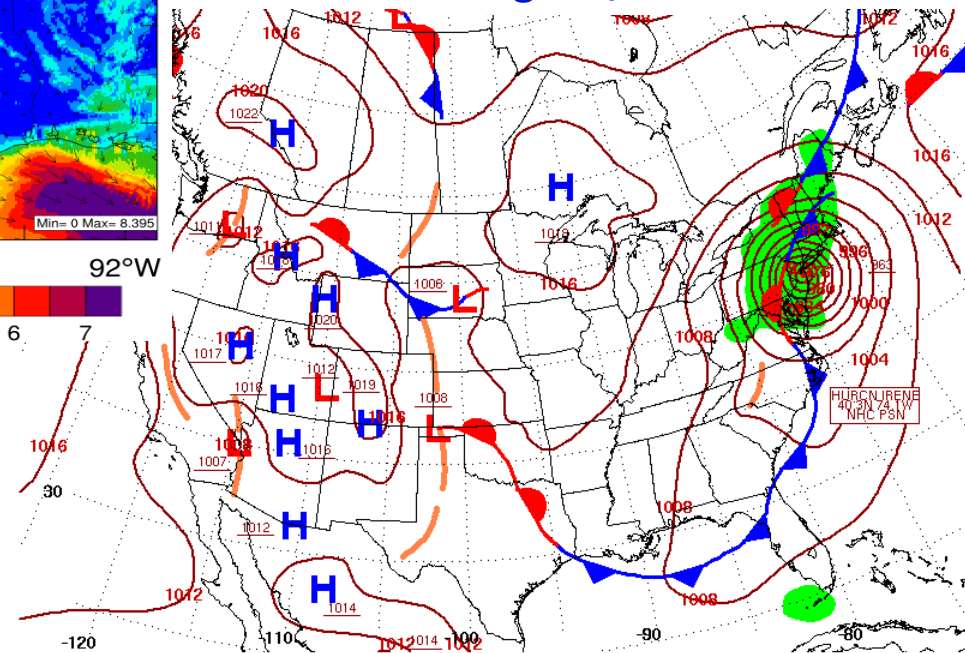
361_NARR2d_CONUS_NLCD_NEI2011_MEGAN_BouLac :R2d_CONUS_NLCD_NEI2011_MEGAN_BouLac



Hurricane

WSP10m@2011-08-28_14:00:00

Aug 28, 2010



Surface Weather Map at 7:00 A.M. E.S.T.

Aug 25-30, interesting episode

Area	Monitoring Site	POC	August 2011																														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Dallas-Fort Worth																																	
	Ft. Worth Northwest C13/AH302	2	54	65	64	55	50	45	45	36	45	41	41	39	31	69	56	47	53	52	54	61	60	54	50	56	82	81	86	87	73	66	58
	Keller C17	2	69	80	80	68	63	58	55	48	57	49	50	48	40	76	70	58	67	62	64	73	74	68	63	70	100	97	95	103	88	78	70
	Frisco C31/C680	1	86	80	92	78	65	61	54	52	62	47	42	45	43	68	77	57	68	67	71	79	65	73	70	71	91	92	78	89	83	76	72
	Midlothian OFW C52/A137	1	50	63	61	56	50	42	41	40	42	37	43	36	29	74	58	46	49	57	58	66	57	47	54	60	65	72	95	81	80	71	60
	Denton Airport South C56/A163/X157	1	73	86	86	77	66	62	59	52	54	53	45	48	44	70	74	61	70	60	67	72	74	76	63	66	102	87	81	98	90	76	71
	Arlington Municipal Airport C61	1	55	66	67	58	50	44	44	39	44	38	43	37	26	74	61	45	49	54	56	63	53	51	53	57	69	73	92	83	77	68	59
	Dallas North No.2 C63/C679	1	81	78	87	69	58	53	48	46	50	41	41	38	44	68	68	50	59	64	64	75	67	64	64	67	90	98	88	86	82	73	67
	Rockwall Heath C69	1	80	76	91	69	56	48	46	42	47	42	44	40	57	61	67	36	45	54	54	67	59	49	52	56	65	79	73	65	64	66	56
	Grapevine Fairway C70/A301/X182	1	71	83	86	73	60	NV	NA	NV	56	44	45	42	37	68	71	53	64	61	64	71	69	68	62	67	98	91	87	97	81	72	64
	Kaufman C71/A304/X071	1	58	65	65	57	60	54	44	36	40	42	41	41	47	60	60	54	50	56	60	66	65	50	58	52	62	76	81	68	73	74	64
	Granbury C73/C681	1	45	59	60	55	48	41	41	37	43	39	49	35	37	67	51	44	49	51	52	59	53	48	50	53	61	70	82	80	71	67	56
	Eagle Mountain Lake C75	1	55	70	67	59	53	49	48	37	45	47	39	38	36	74	59	49	59	52	55	62	65	59	52	56	84	75	79	85	73	63	58
	Parker County C76	1	52	67	69	63	56	50	50	41	49	47	58	39	45	70	62	55	61	58	59	67	68	59	56	61	84	78	88	93	82	72	63
	Cleburne Airport C77/C682	1	50	60	60	56	50	43	41	38	43	41	44	38	37	74	50	43	48	54	56	62	52	50	52	57	67	69	90	82	75	67	56
	Dallas Hinton St. C401/C60/AH161	3	70	75	75	61	52	48	44	41	43	35	41	33	34	68	59	45	40	52	55	67	60	55	55	58	79	88	90	84	76	66	58
	Dallas Executive Airport C402	1	60	70	69	55	48	41	40	37	42	34	41	32	30	69	58	44	47	55	59	67	58	51	56	57	71	78	96	82	82	73	63
	Greenville C1006/A198	1	70	67	80	64	52	49	46	38	44	36	41	45	38	69	74	50	54	61	65	71	64	54	58	59	73	83	77	73	66	76	66
	Pilot Point C1032	1	78	88	91	84	75	68	60	60	64	56	42	51	50	71	91	65	75	67	74	79	64	79	72	67	91	87	79	92	81	83	77
	Italy C1044/A323	1	43	54	56	52	44	38	33	37	36	35	43	33	34	58	57	47	46	55	57	66	57	49	53	59	62	NV	83	75	79	71	60
	Corsicana Airport C1051	1	54	64	61	56	58	51	40	37	39	42	43	38	27	64	61	53	57	59	61	67	58	57	59	57	63	69	84	70	76	78	66
Houston-Galveston-Brazoria																																	
	Houston East C1/G316	2	61	49	43	39	29	31	27	29	23	27	29	29	27	36	36	40	52	68	68	62	48	55	53	54	58	97	80	92	97	80	65
	Houston Aldine C8/AF108/X150	2	71	57	49	45	34	32	29	32	30	29	33	32	29	32	43	46	56	69	74	64	44	61	62	63	59	100	78	70	73	86	69
	Channelview C15/AH115	3	60	43	37	39	28	29	24	28	25	28	26	29	28	39	34	33	46	69	66	55	40	52	50	47	56	73	78	77	93	68	55
	Northwest Harris Co. C26/A110/X154	2	64	64	50	42	37	37	30	30	27	34	39	36	29	29	42	48	57	63	70	71	44	65	56	NV	NA	80	79	75	79	100	83
	Hou.DeerPrk2 C35/235/1001/AFH139FP239	1	39	33	27	29	22	23	21	23	22	24	24	24	23	33	28	32	44	54	55	54	37	44	42	42	52	80	83	82	92	79	59
	Seabrook Friendship Park C45	1	42	32	26	32	23	23	21	23	21	22	23	23	21	28	25	26	37	43	49	52	34	39	37	40	52	65	84	76	83	76	55
	Houston Bayland Park C53/A146	1	47	41	35	31	24	24	23	25	23	22	27	23	26	33	30	34	43	51	58	50	32	39	39	37	46	88	79	98	99	71	63
	Conroe Relocated C78/A321	1	63	64	56	51	48	49	33	36	34	44	45	49	34	60	63	72	62	61	60	47	66	66	56	60	71	77	64	72	78	62	
	Houston Regional Office C81	1	47	39	33	30	NV	25	23	24	20	22	25	23	22	34	30	34	45	56	59	54	40	43	44	45	45	97	80	99	96	76	65
	Manvel Croix Park C84	1	41	39	31	28	25	24	24	26	21	25	27	25	23	32	27	34	43	49	55	52	32	35	36	34	47	89	88	98	84	73	65
	Clinton C403/C304/AH113	3	44	37	30	27	21	24	22	21	18	21	23	22	21	35	26	30	41	53	55	54	41	40	42	44	42	90	78	92	90	69	59
	Houston North Wayside C405	1	61	52	44	39	29	30	27	25	26	28	29	27	36	39	39	51	66	69	62	47	54	56	57	49	99	80	74	84	80	66	
	Houston Monroe C406	1	38	31	26	25	22	21	19	22	18	21	22	20	19	27	24	28	37	47	46	47	33	31	37	38	76	75	81	76	71	55	
	Lang C408	2	60	48	41	36	29	28	27	29	26	28	32	29	27	34	40	39	50	59	63	60	41	57	48	49	50	94	77	77	72	78	62
	Houston Croquet C409	2	45	39	33	30	25	25	23	25	22	24	26	23	24	32	28	33	41	49	55	49	30	36	38	35	45	80	79	101	85	67	62
	Houston Westhollow C410	1	46	43	37	32	26	27	23	23	20	26	28	27	23	30	28	33	44	49	55	50	35	39	NV	37	46	81	75	93	92	67	60

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