The impact of Great Basin Desert on summer monsoon precipitation over Southwest North America: the role of mineral dust

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North America monsoon

- The North American Monsoon (NAM) system: an important component of the regional hydrological cycle over the southwestern US

- IPCC climate model simulations show that the southwestern US will be warmer and dryer in the 21st century. The projected drought parallels the severity of the 1930s Dust Bowl [Seager et al., 2007, *Science*].

- Understanding the interaction between NAM system and the future drought conditions is important.

Dust impact on NAM system

- Mega-droughts may lead to widespread dust storms [e.g., Woodhouse and Overpeck 1998].
- The mega-droughts driven dust may potentially change the NAM precipitation through both direct and indirect effect over the southwestern US.
- Changes in the NA monsoon circulation and hydrologic cycle may provide a feedback to strengthen/weaken the mega-drought and enhance/reduce dust emissions.

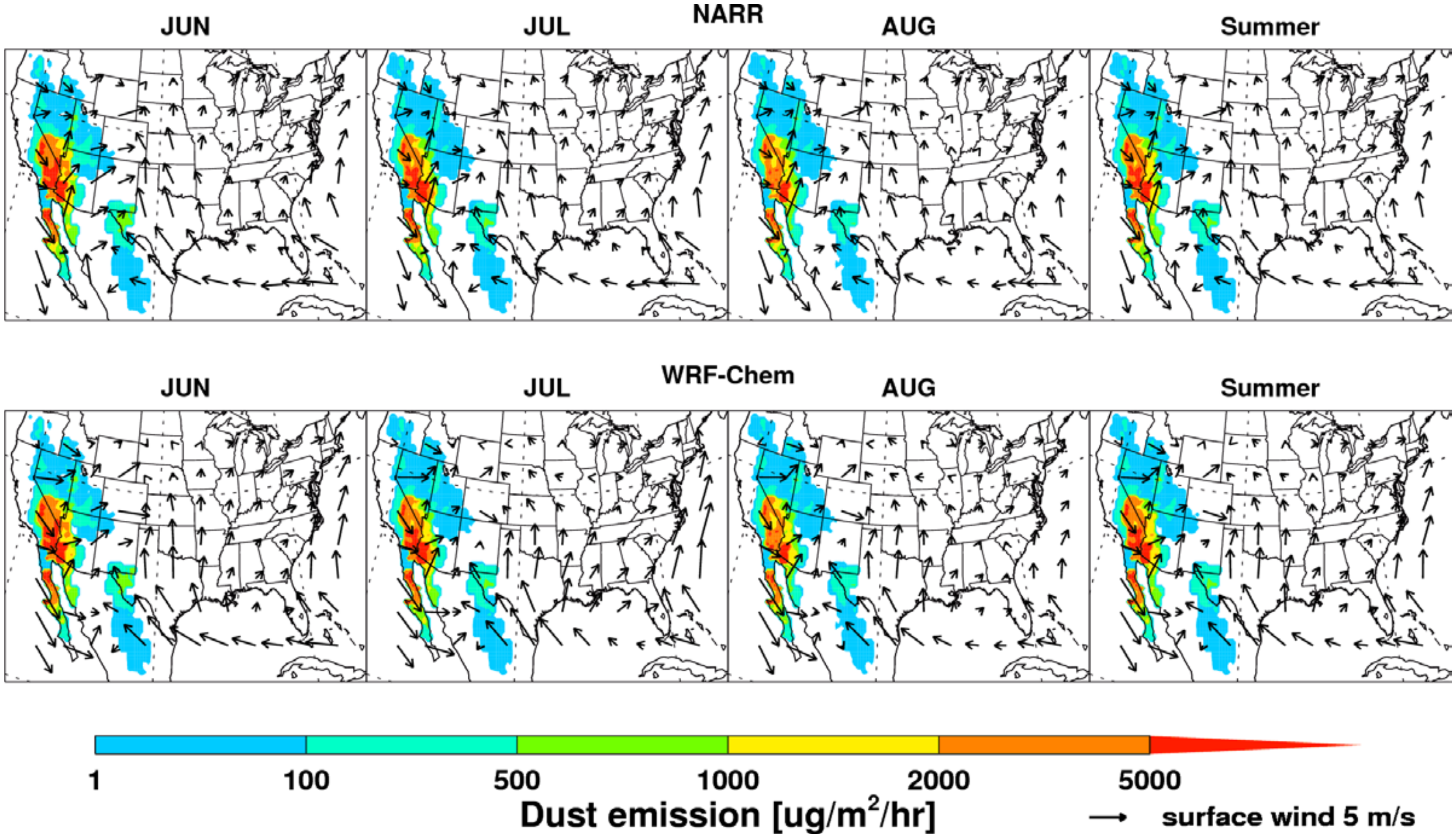
WRF-Chem

- WRF-Chem: a version of WRF that can simulate trace gases and aerosols simultaneously with the meteorological fields.

- MADE/SORGAM aerosol scheme (Modal) coupled with GOCART dust emission scheme [Ginoux et al., 2001, Zhao et al., 2010a].

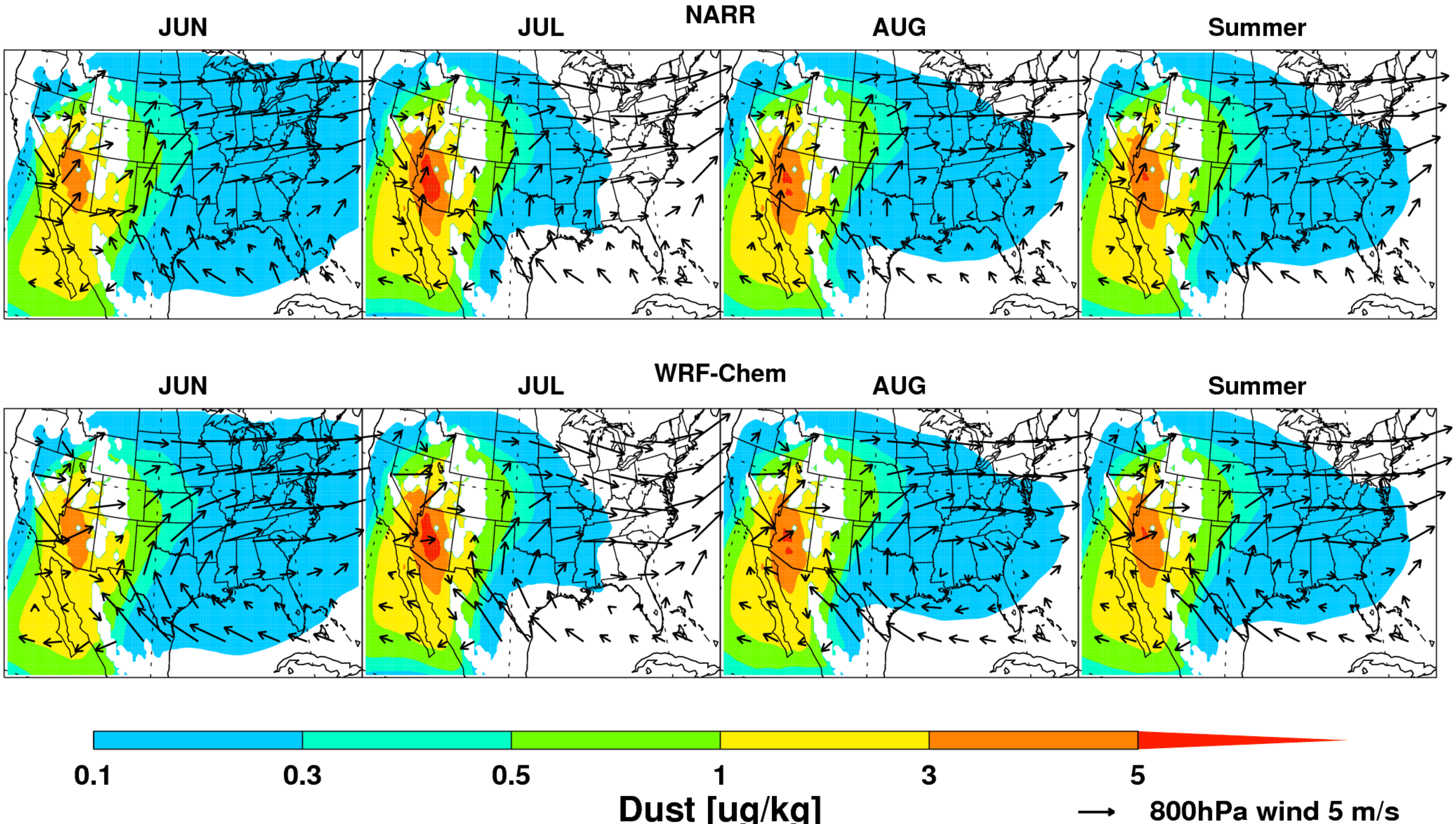
- Aerosol SW and LW direct radiative effects coupled with RRTMG radiation schemes [Zhao et al., 2010b].

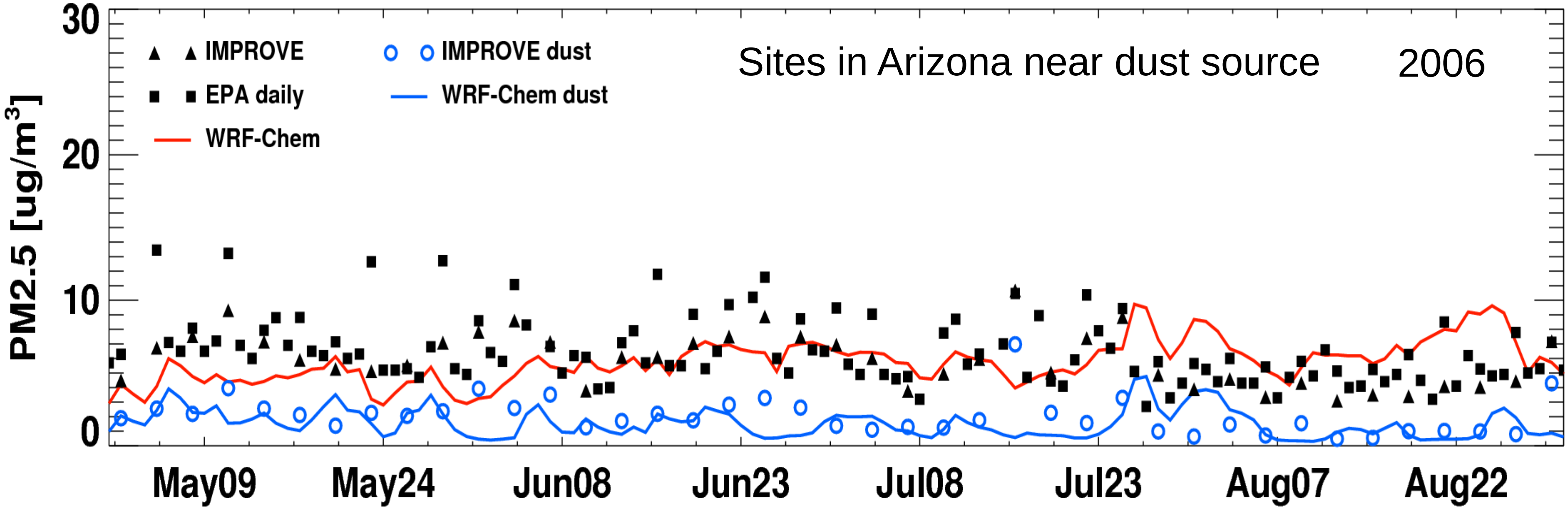
10m Wind + Dust emission

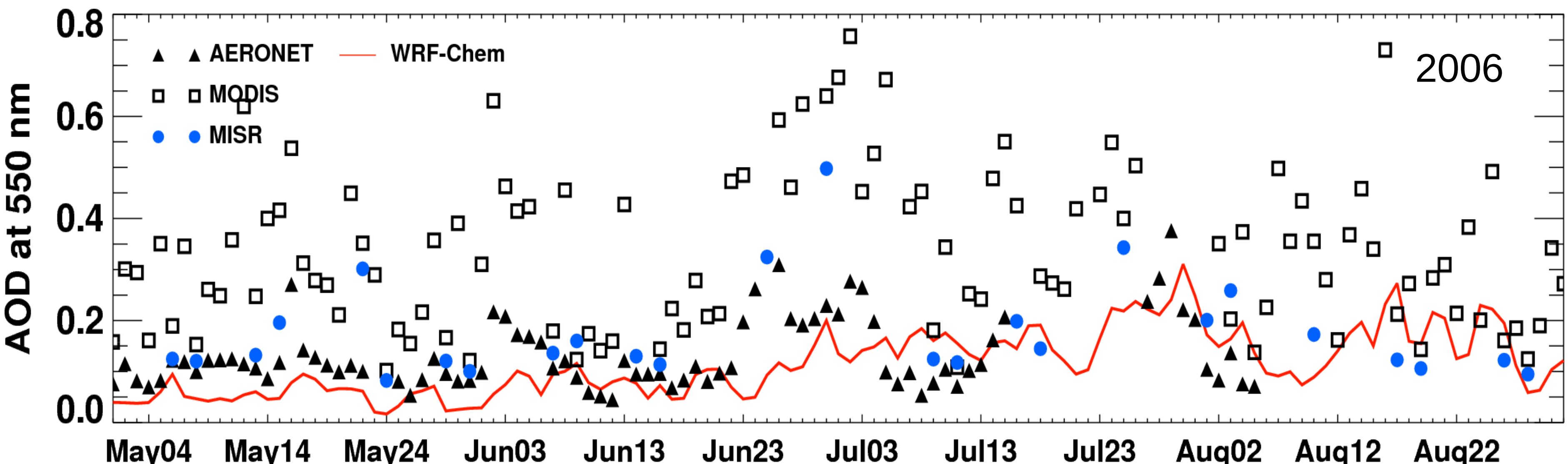


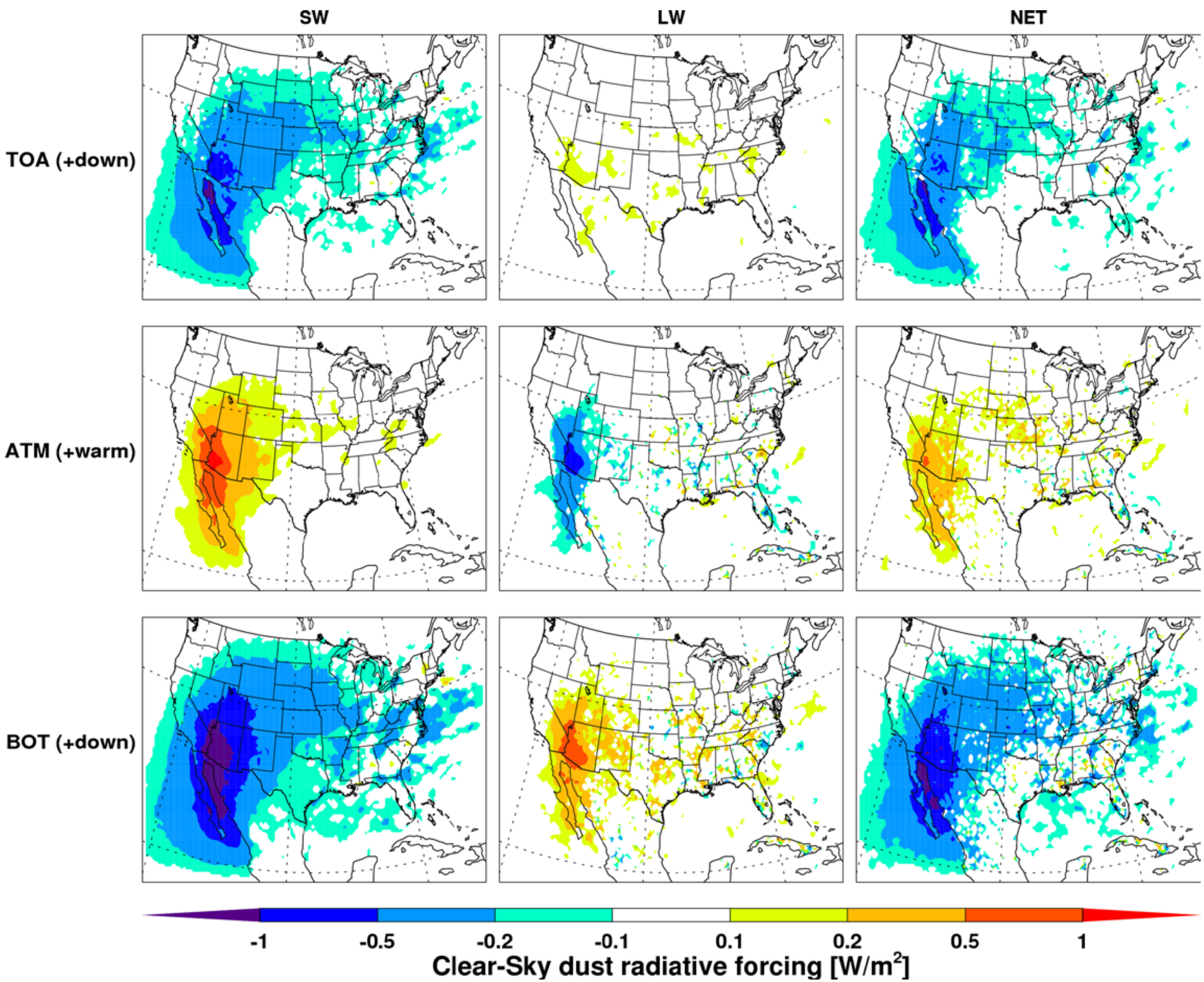
- 36km horizontal resolution; simulation for April-September, 2002-2009
- NARR Reanalysis data driven
- Morrison microphysics scheme
- Grell convective scheme

800 hPa Wind + Dust mass




Sites in Arizona near dust source
2006
IMPROVE
IMPROVE dust
EPA daily
WRF-Chem dust
WRF-Chem
PM2.5 [ug/m^3]
30
20
10
0
May09
May24
Jun08
Jun23
Jul08
Jul23
Aug07
Aug22


AERONET
WRF-Chem
MODIS
MISR
2006
AOD at 550 nm
0.8
0.6
0.4
0.2
0.0
May04
May14
May24
Jun03
Jun13
Jun23
Jul03
Jul13
Jul23
Aug02
Aug12
Aug22

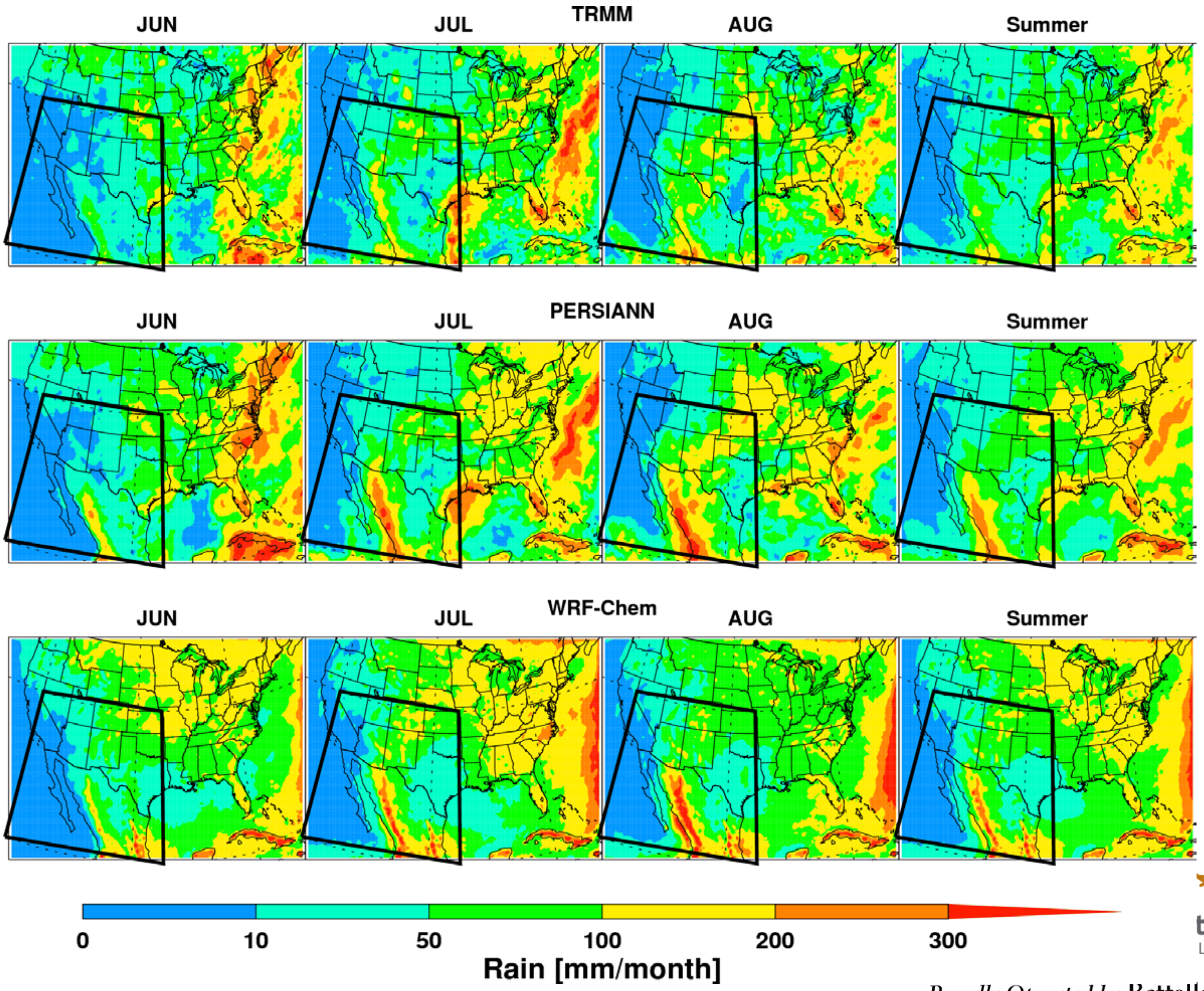


TOA: -0.50 W m^{-2}

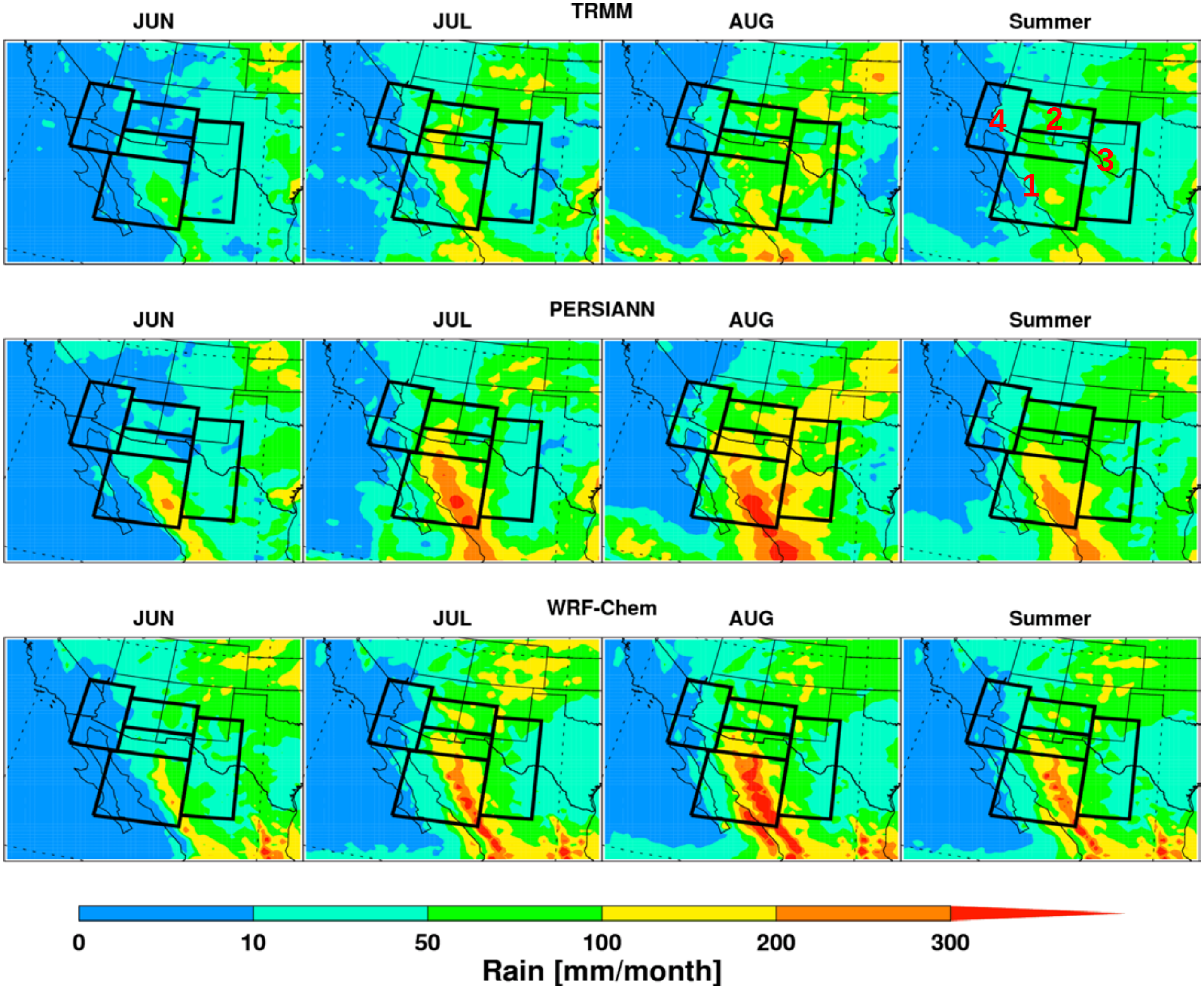
ATM: 0.40 W m^{-2}

BOT: -0.90 W m^{-2}

The black box: North America Monsoon Region (NAM)



North America Monsoon Region (NAM)



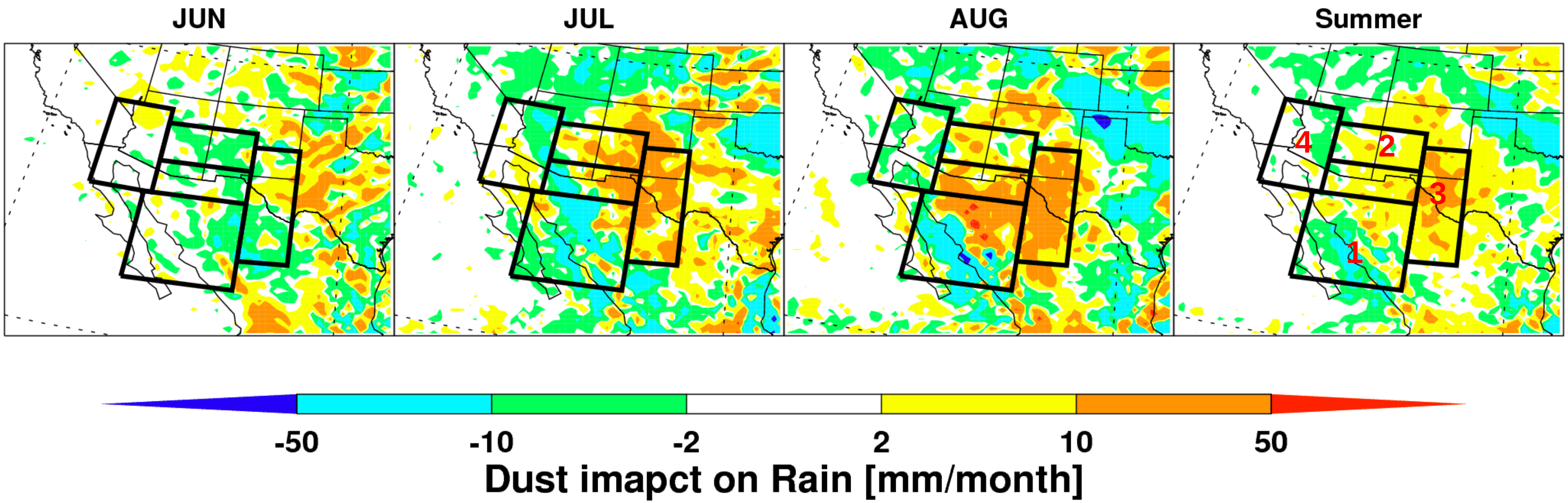
Region 1: CORE

Region 2: AZNM

Region 3: TXNM

Region 4: DESERT

Dust Impact on NAM precipitation



Region 1: CORE (24.0^{o}N-30.0^{o}N, 112.5^{o}W-106.0^{o}W)

Region 2: AZNM (32.3^{o}N-35.0^{o}N, 112.0^{o}W-106.0^{o}W)

Region 3: TXNM (26.0^{o}N-34.0^{o}N, 106.0^{o}W-103.0^{o}W)

Region 4: DESERT (30.0^{o}N-36.0^{o}N, 116.0^{o}W-112.0^{o}W)

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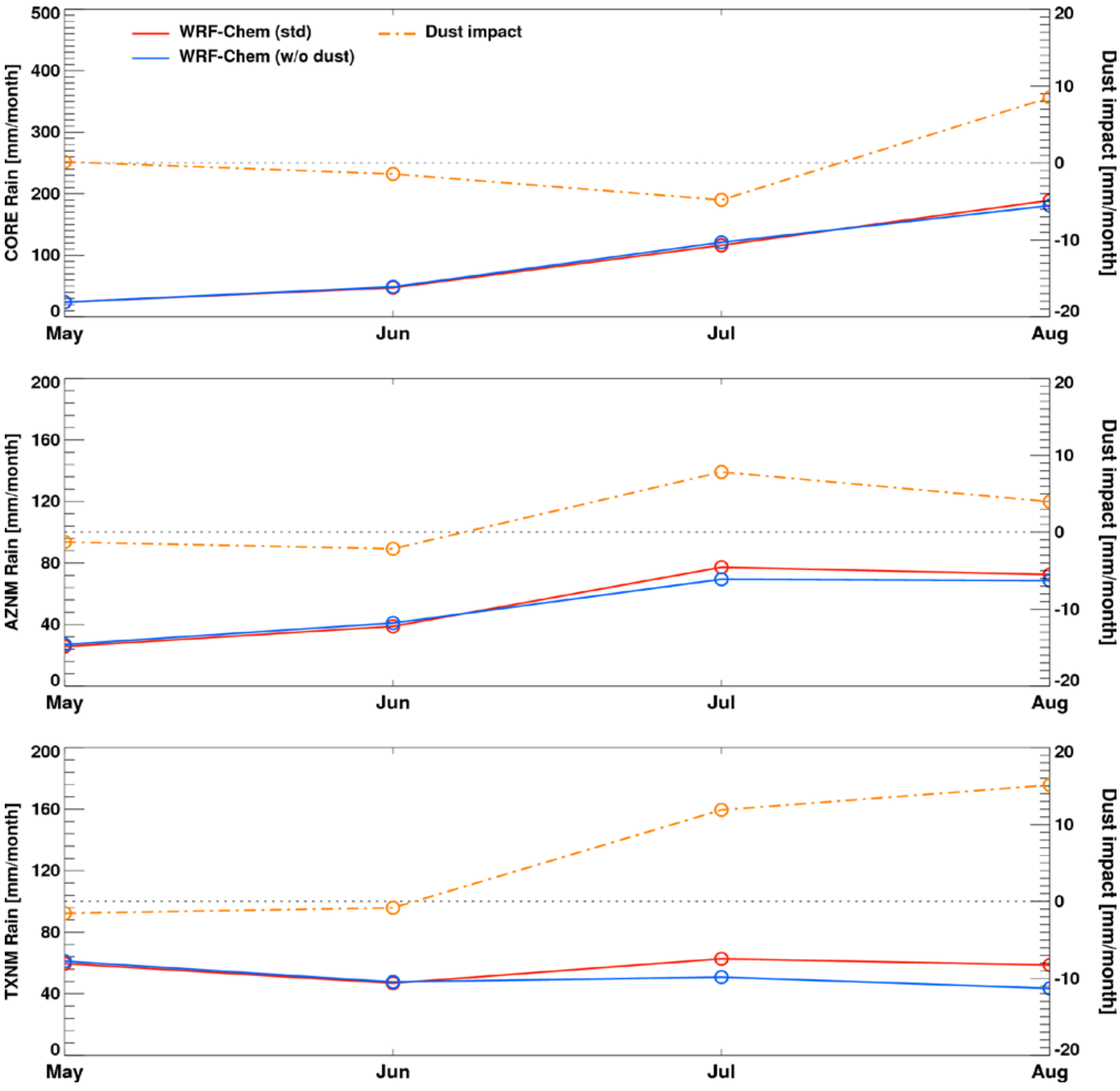
Dust Impact on NAM precipitation



CORE: Jul. -5%, Aug. 6%

AZNM: Jul. 12%, Aug. 6%

TXNM: Jul. 30%, Aug. 40%

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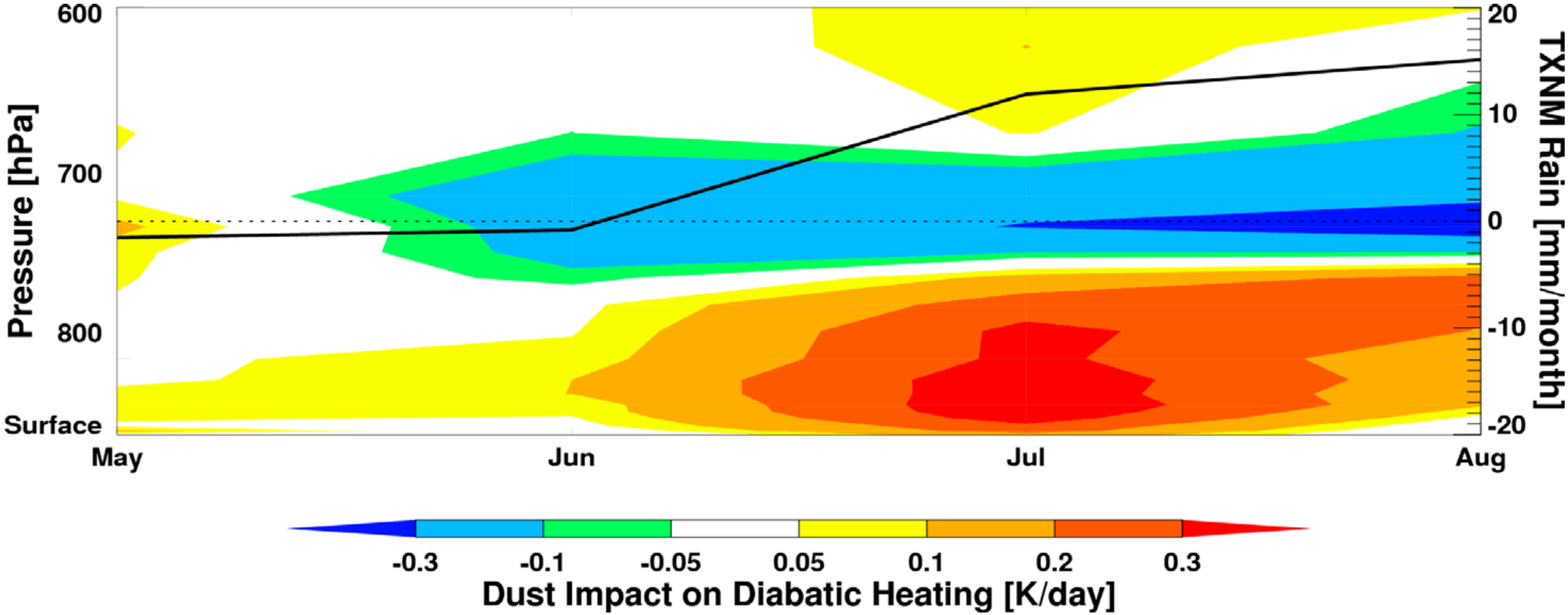
Dust-induced

DESERT diabatic heating v.s. TXNM precipitation



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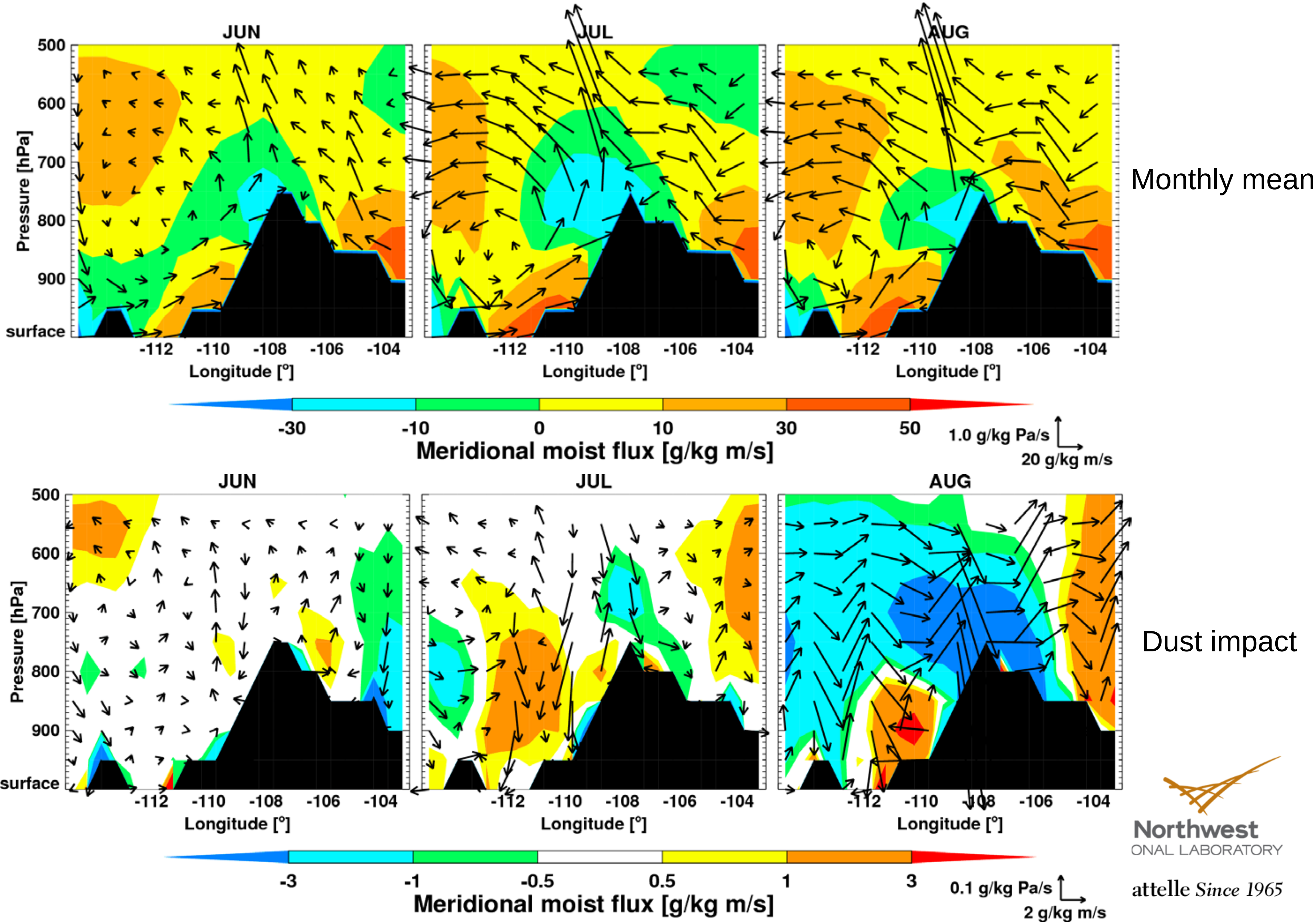
Cross-section of moisture fluxes at 29°N,115°W-103°W



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Summary

- During the NAM season, WRF-Chem simulated dust concentration and AOD over the Southeast US are well consistent with measurements.

- Over the Great Basin Desert region, WRF-Chem simulates dust-induced cooling effect (-0.9 W m^{-2}) at the surface, warming effect (0.40 W m^{-2}) in the atmosphere, and top-of-the-atmosphere (TOA) forcing (-0.50 W m^{-2}) on 24-hour average.

- During July and August, the dust-induced heating (~0.3 K/day) of lower atmosphere (<800 hPa) leads to a statistically significant increase of 10~40% of NAM precipitation over the AZNM and TXNM regions, and strengthens the NAM low-level meridional moisture fluxes.

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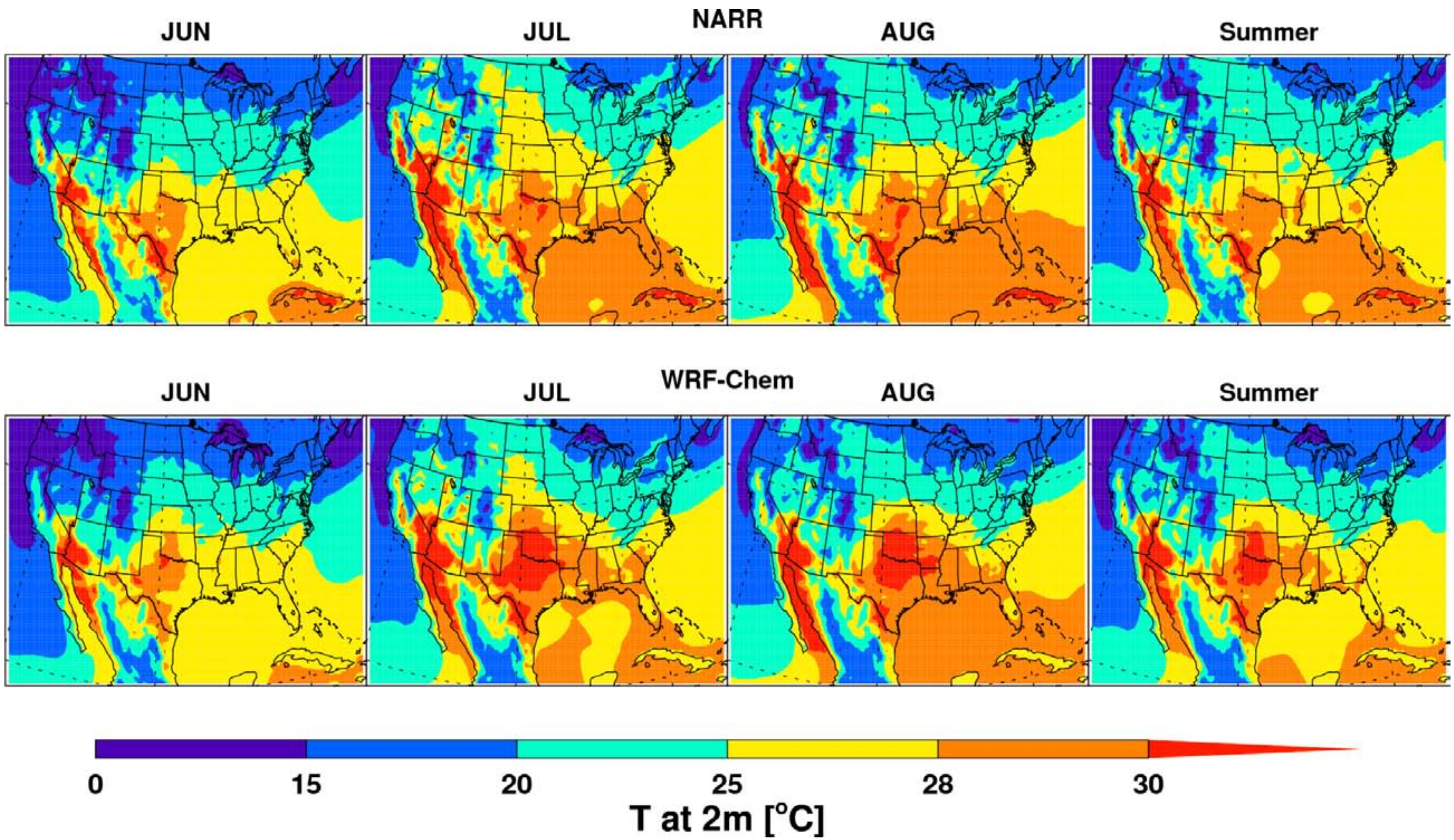
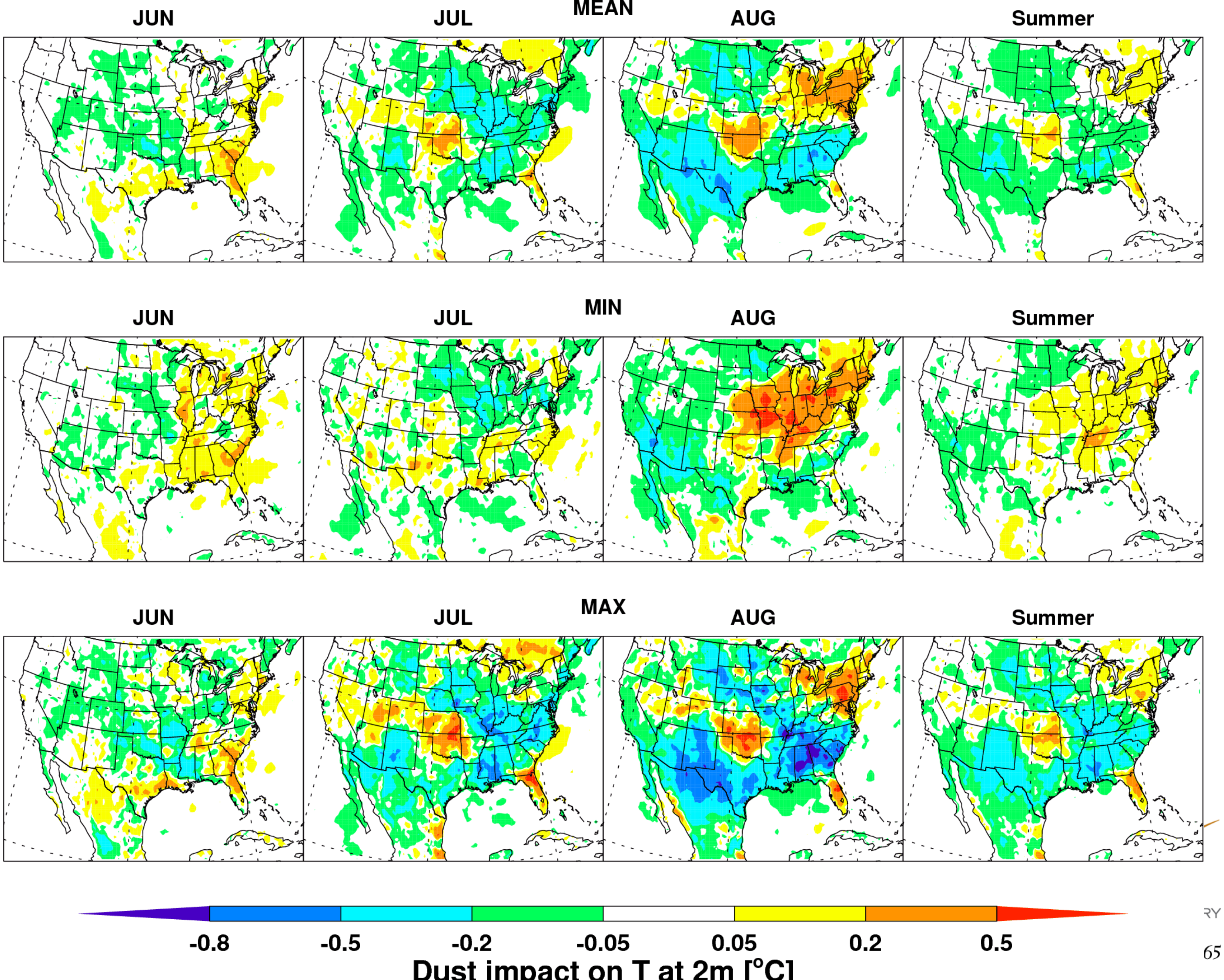
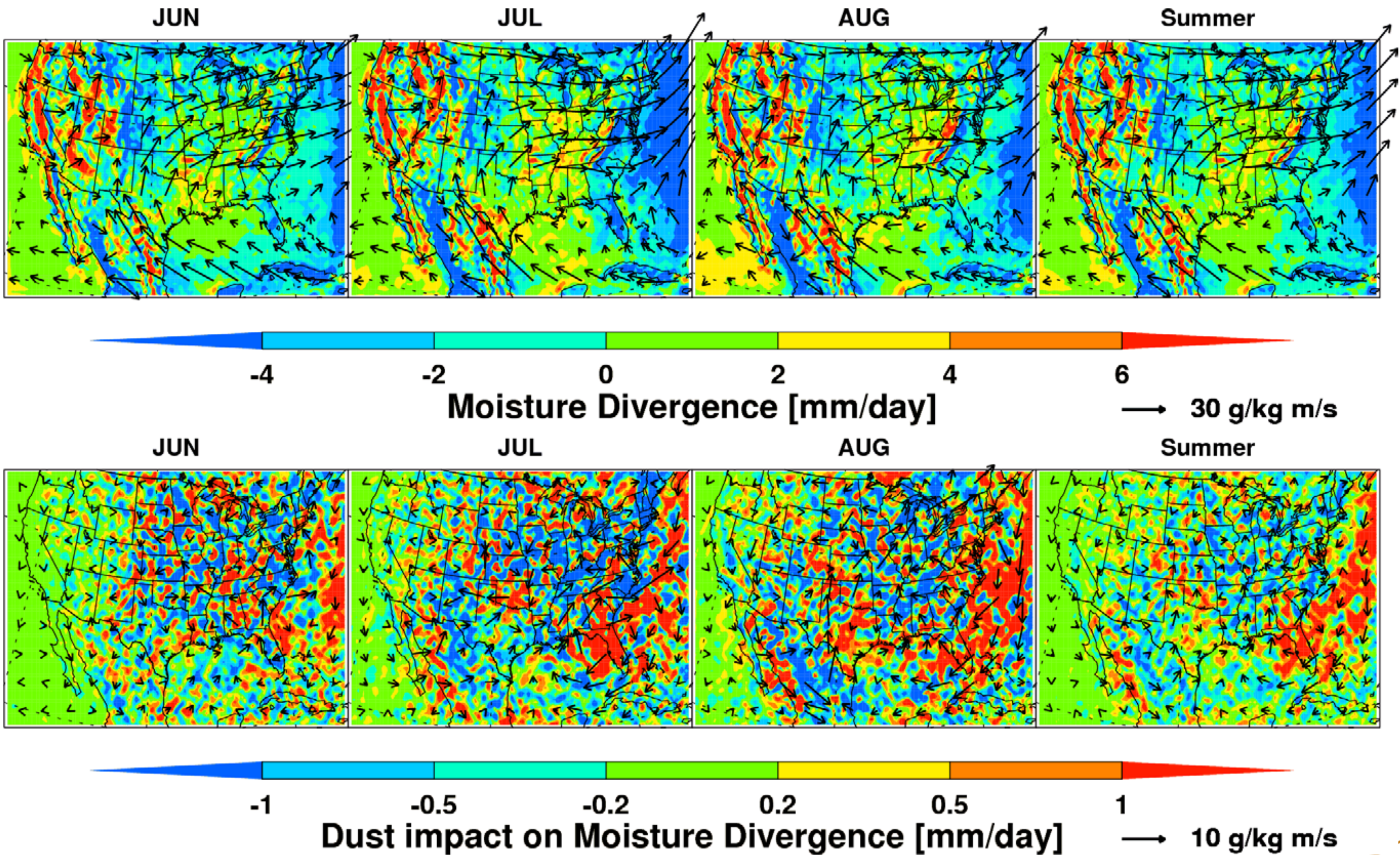
Extra

2002-2009


NARR
JUN
JUL
AUG
Summer
WRF-Chem
JUN
JUL
AUG
Summer
0
15
20
25
28
30
T at 2m [°C]


MEAN
JUN
JUL
AUG
Summer
MIN
JUN
JUL
AUG
Summer
MAX
JUN
JUL
AUG
Summer
-0.8
-0.5
-0.2
-0.05
0.05
0.2
0.5
Dust impact on T at 2m [°C]


JUN
JUL
AUG
Summer
-4
-2
0
2
4
6
Moisture Divergence [mm/day]
30 g/kg m/s
JUN
JUL
AUG
Summer
-1
-0.5
-0.2
0.2
0.5
1
Dust impact on Moisture Divergence [mm/day]
10 g/kg m/s