Sensitivity of WRF-RTFDDA Model Physics in Weather Forecasting Applications: From Synoptic Scale to Meso-γ Scale

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Motivation

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- WRF has been broadly used for mesoscale weather forecasting. For example, the NCAR-ATEC WRF-based RTFDDA system has been deployed in tens of geographic locations to support diverse weather-sensitive applications.
- Mesoscale weather phenomena are highly sensitive to atmospheric physical processes. WRF model physics schemes should be carefully evaluated and chosen in setting up a WRF forecasting system.
- Objective of this study is to evaluate sensitivity of WRF physics and to document challenges for two weather events:

  1. wind energy ramp-up from MCS in N. Colo.
  2. coastal stratus from high pressure-capped inversion in E. Med.

The Model: NCAR/ATEC WRF-Based RTFDDA

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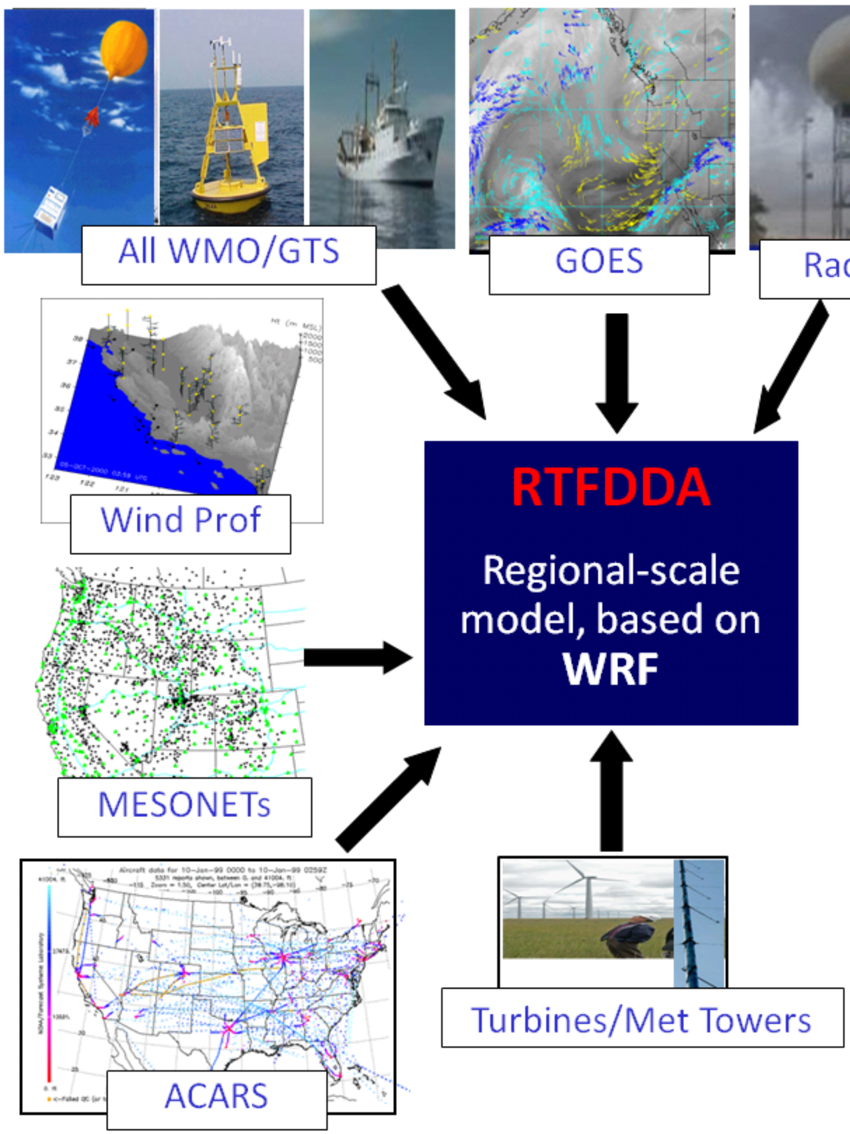
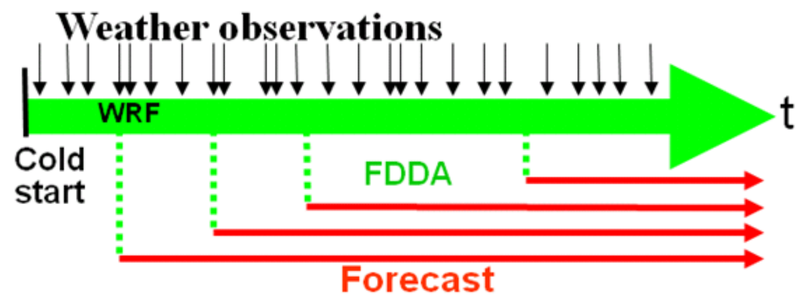
Modified WRF/MM5:

$Dx/Dt = \dots + GW\,(x_{obs} - x_{model})$

where $x = T, U, V, Q, P1, P2 \dots$

W is weight function





Δx = 30, 10, 3.3 km

Case 1 - Wind Energy Ramp-Up from MCS

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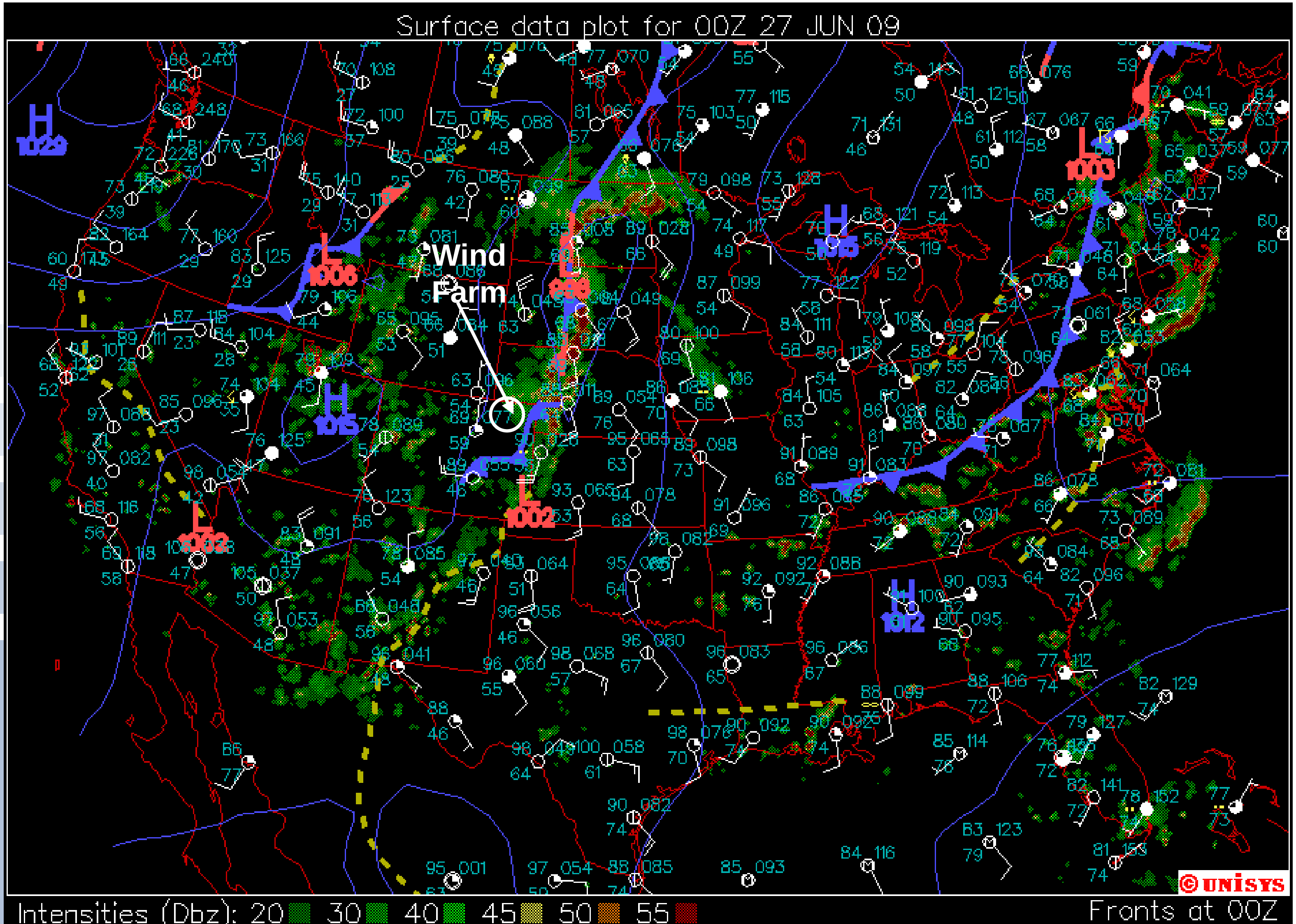
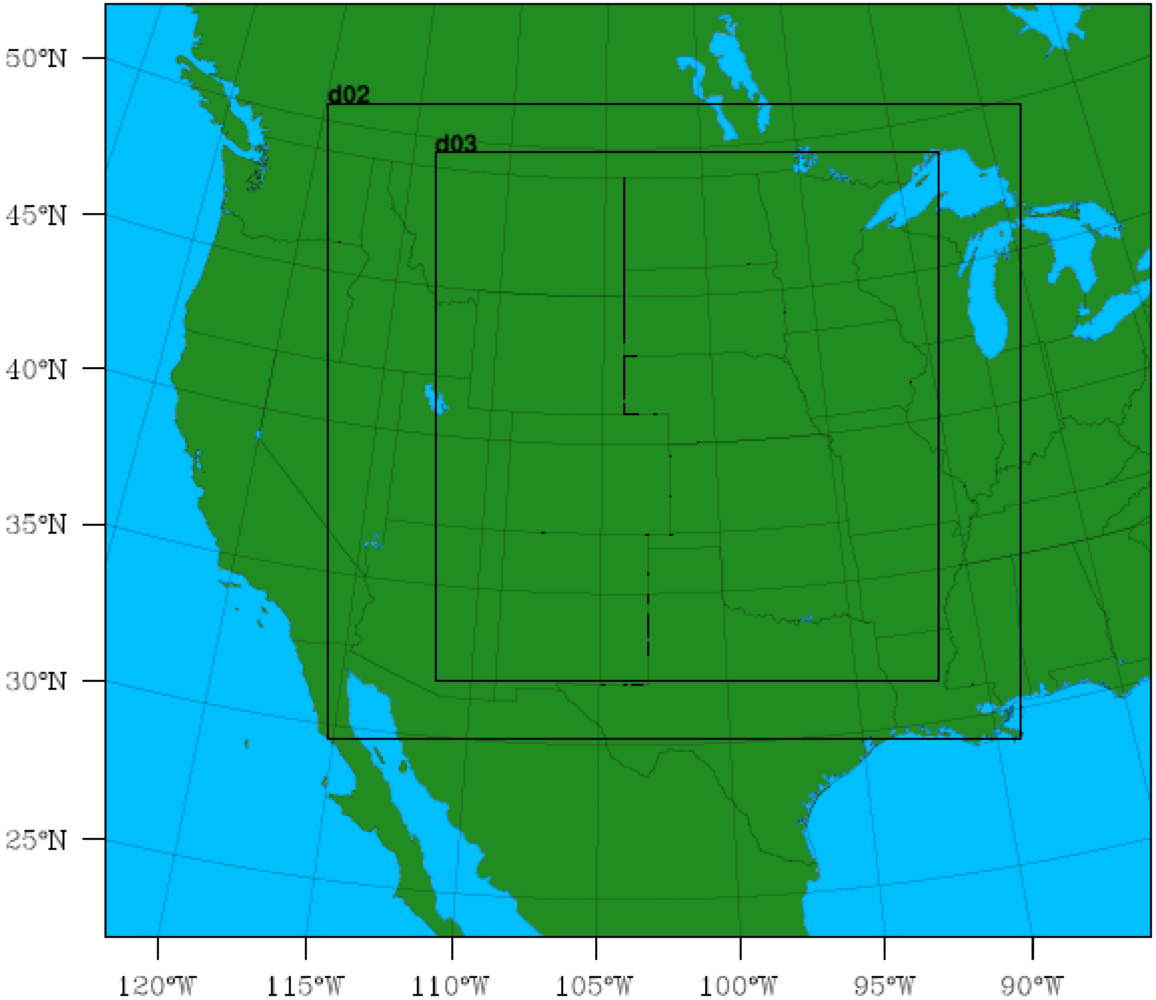


Wind Farm: WF_A

WRF Domain Setup – Case 1

Xcel Wind Energy Forecast Domain



nx = 128, 253, 540

ny = 114, 232, 571

nz = 37, 37, 37

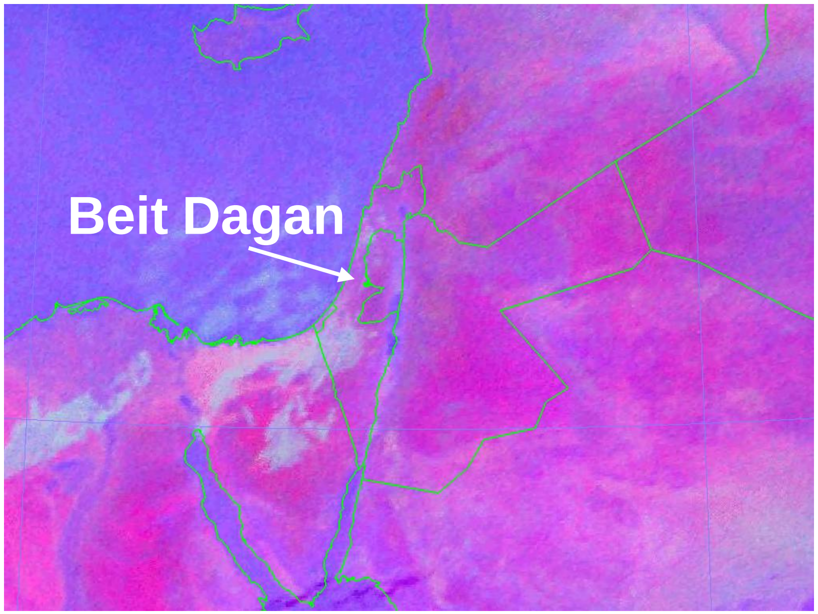
Δx = 30, 10, 3.3 km

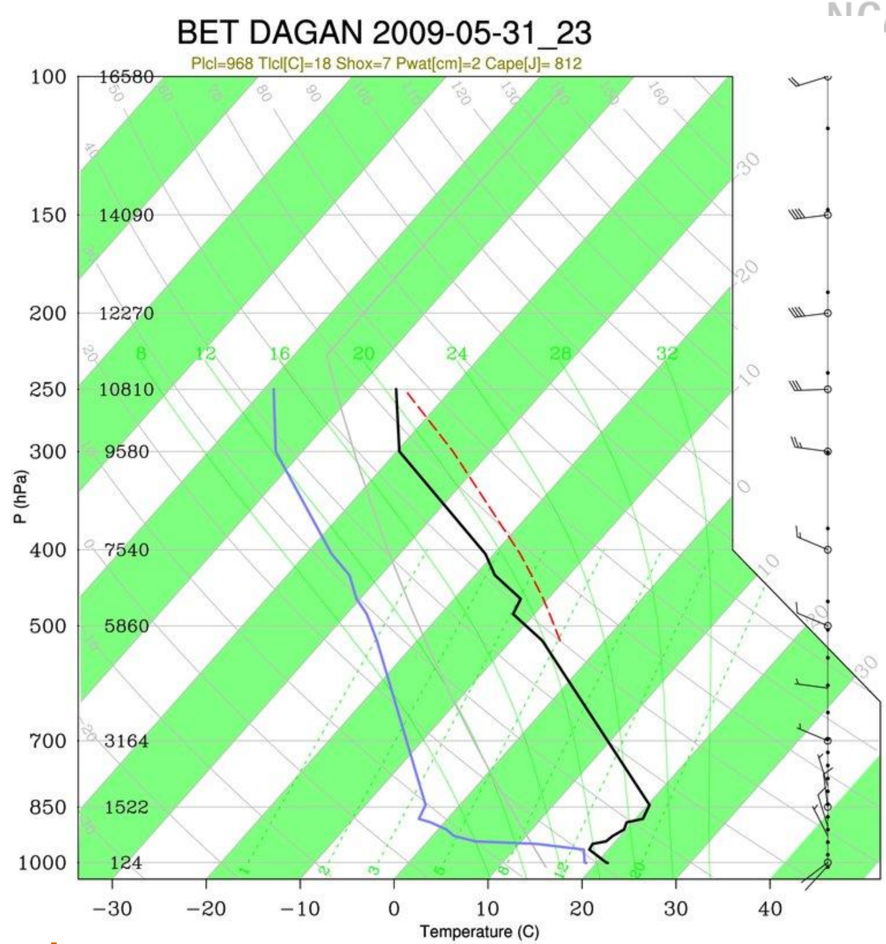
DA: 2009-06-25-12 to 2009-06-26-00

fcst: 2009-06-26-00 to 2009-06-27-00

Methodology: Case 2- Coastal Stratus

2009-06-01-0030

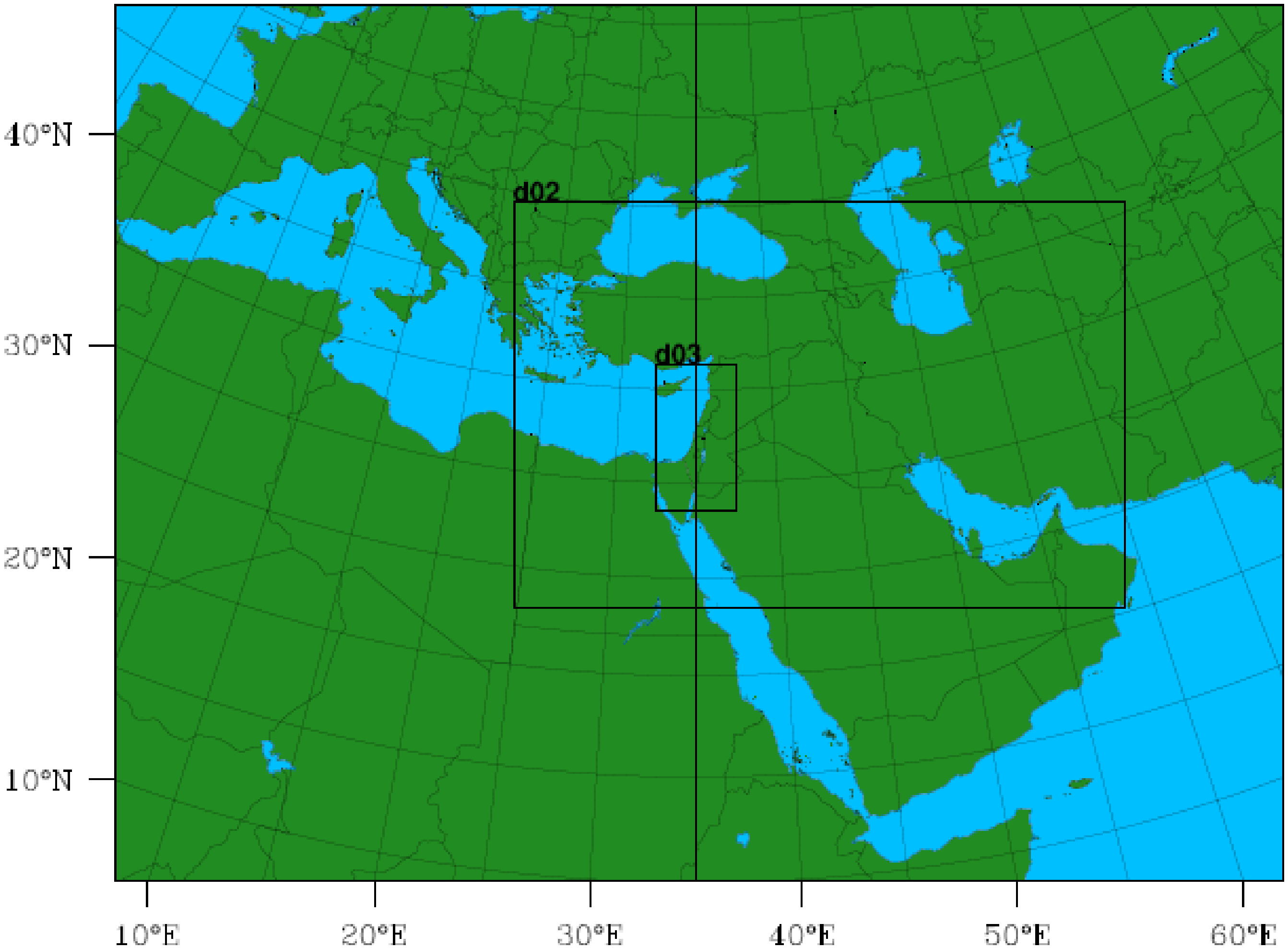




- o High pressure-capped inversion.
- o Clouds formed at night and dissipated during the day (05/31 – 06/03).

Methodology: Setup – Case 2

MAGEN Forecast Domain (Sponsor: Gov't of Israel)



nx = 232, 364, 136

ny = 174, 241, 256

nz = 57, 57, 57

Δx = 30, 10, 3.3 km

DA: 2009-05-30-12- 2009-05-31-12

fcst: 2009-05-31-12 - 2009-06-01-12

Model Physics: Control Experiment

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Physics	Scheme
Nested-grid	One-way
Land-Surface	Noah
Surface Layer	Monin-Obukhov
PBL	YSU (non-local mixing)
Shortwave Radiation	Dudhia (MM5)
Longwave Radiation	RRTM (MM5)
Cloud Microphysics	Lin et al. (3-ice)
Cumulus scheme	Kain-Fritsch

Methodology: Experimental Design

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Case 1: Wind Ramp-Up

CPS (d01/d02)
- BMJ
- GD

Microphysics
- MORR
- THOM
- WDM6
- WSM6

Variable of interest: wind speed

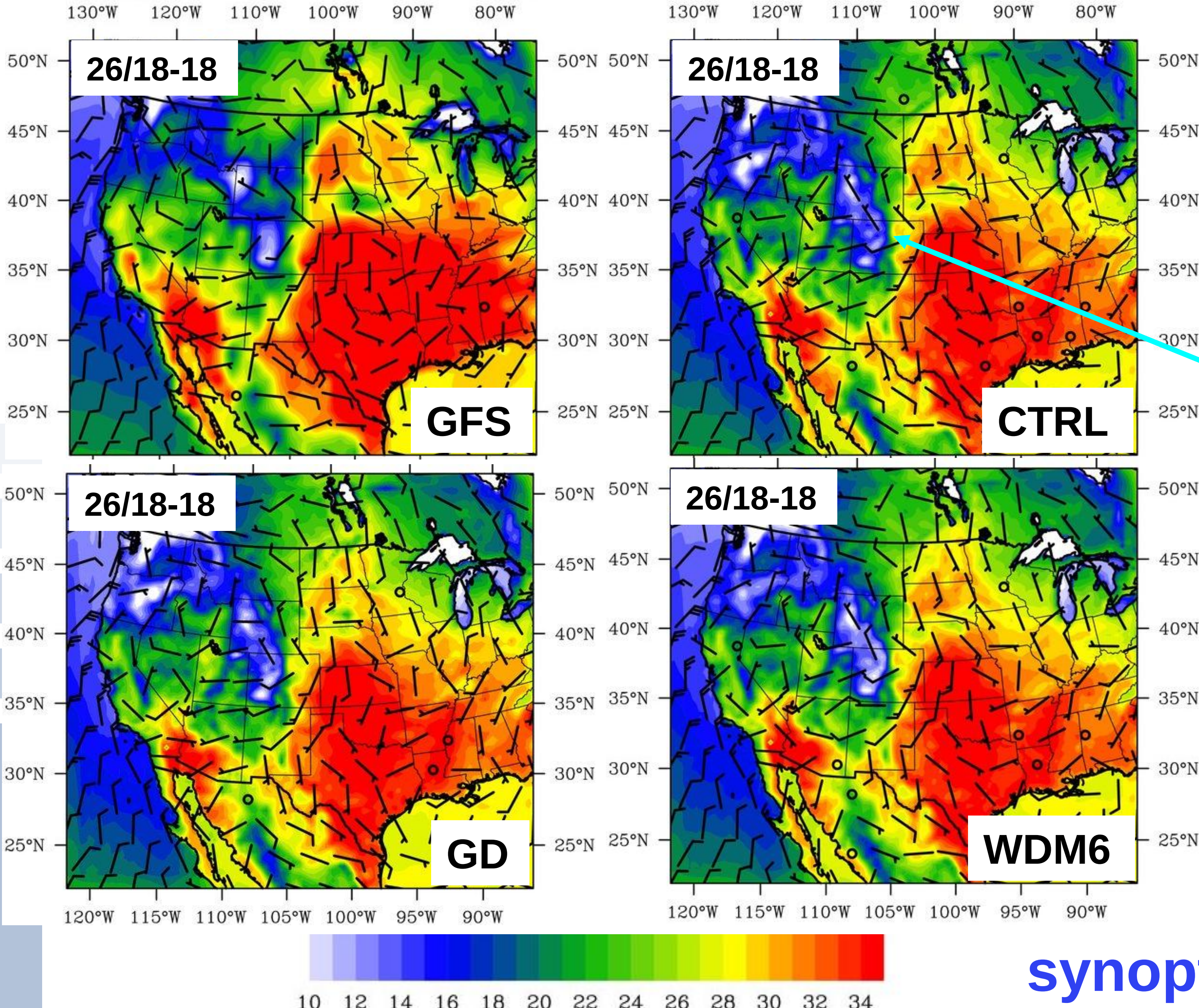
Case 2: Coastal Stratus

PBL
- MYJ
- QNSE
- MYNN2.5

Radiation
- GFDL
- RRTMG
- CAM3

Variables of interest: cloud properties

Results - Case 1: d01 2-m Temperature



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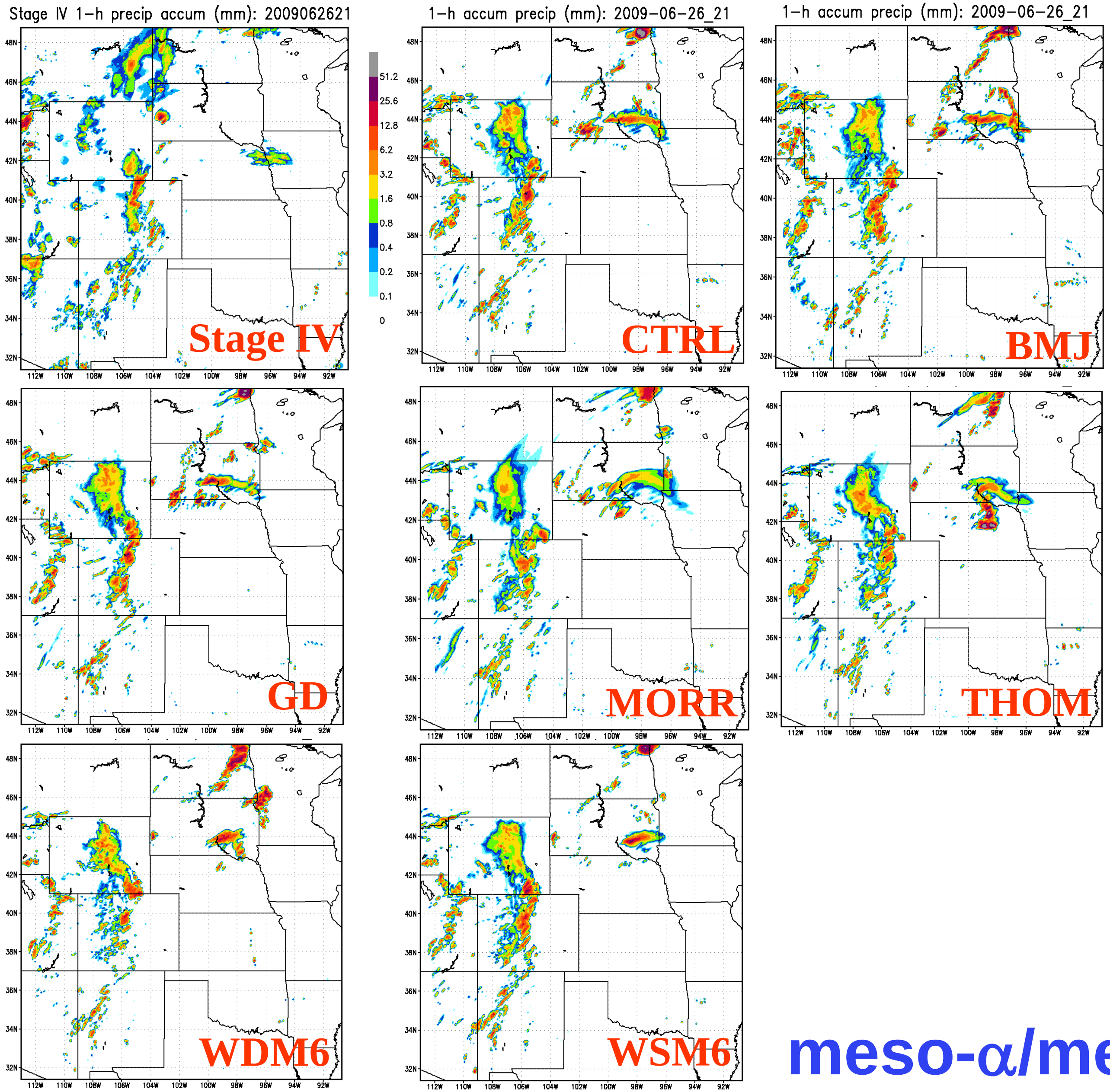
Frontal boundary provided favorable conditons for convection to develop.

Synoptic conditions similar amongst diff. exps.

synoptic scale

Results - Case 1: d03 1-h accum precip



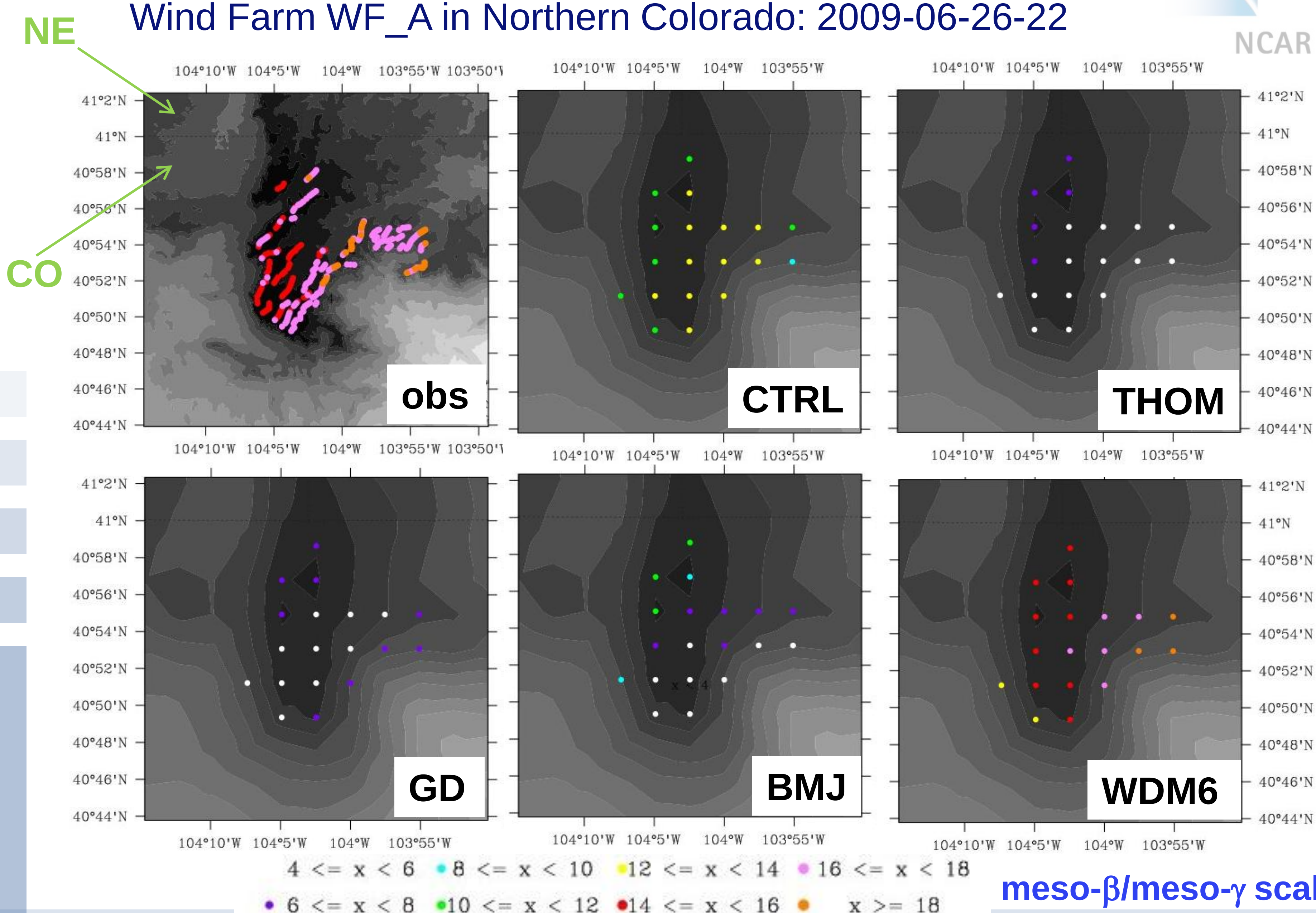
All exps. produced similar squall line over CO as in Stage IV.

However, meso-β features differ amongst diff. exps.

meso-α/meso-β scale

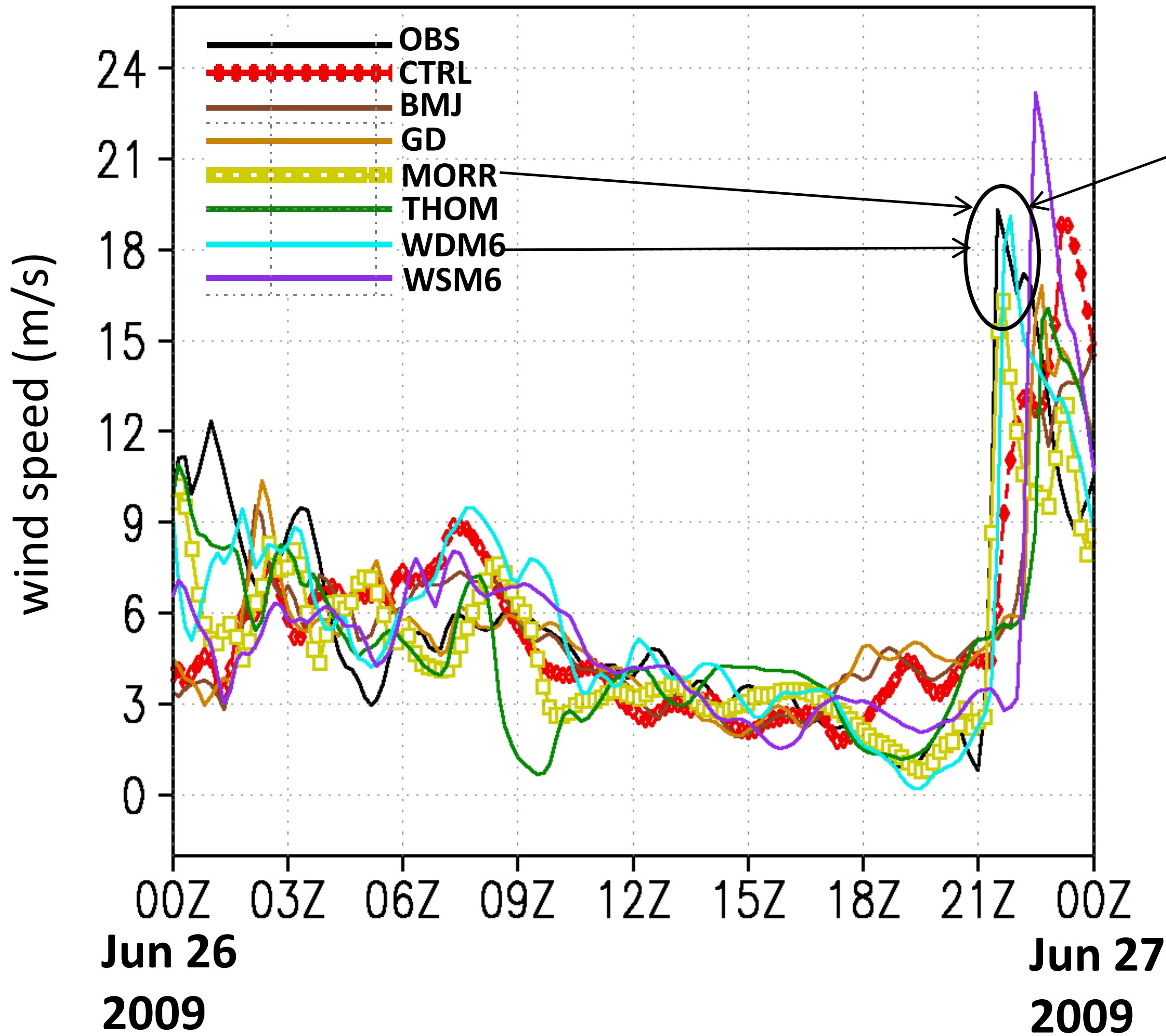
Results - Case 1: d03 wind speed (22-h forecast)

Wind Farm WF_A in Northern Colorado: 2009-06-26-22



meso-β/meso-γ scale

Results – Turbine-Averaged Wind Speed: Wind Farm WP_A



DM micro best, most likely due to better simulated gust fronts.

Case 2 Results – PBL Sensitivity

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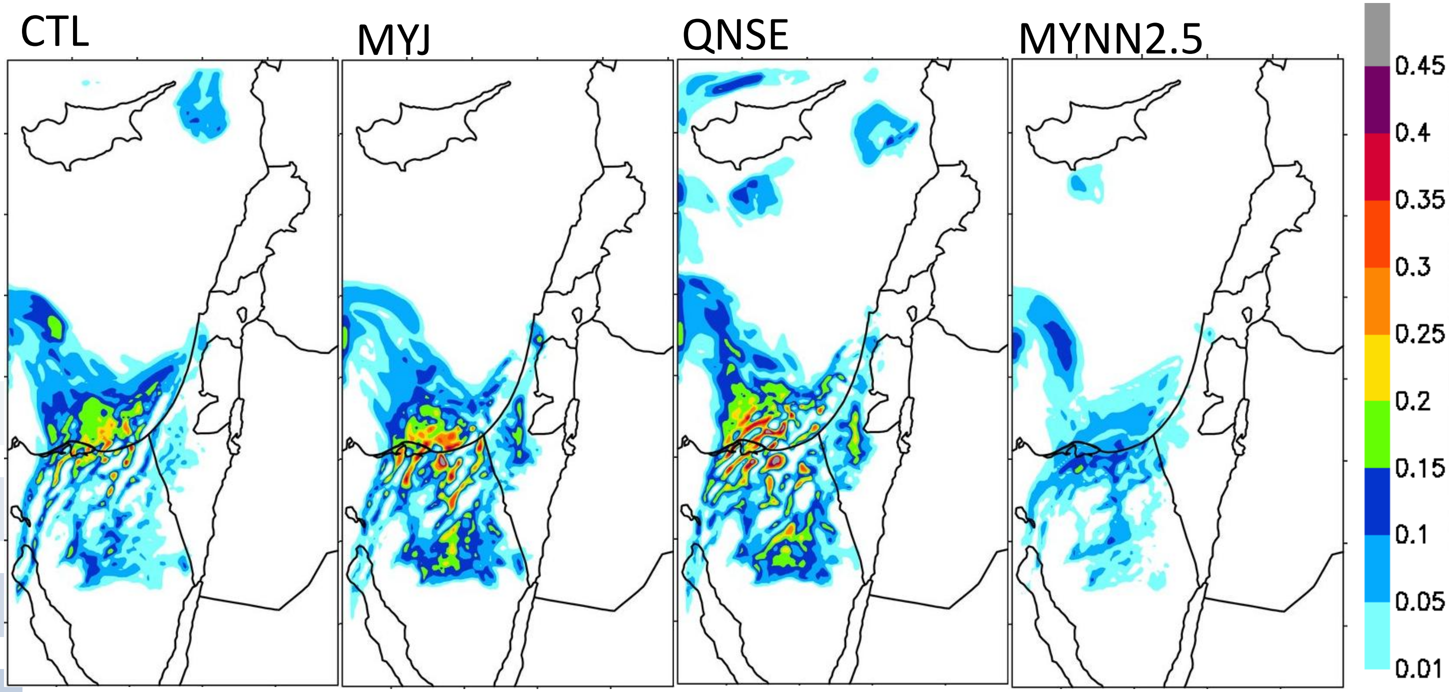
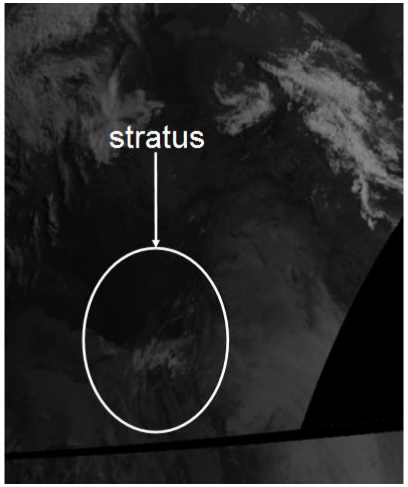
01/05-17: liquid water path (mm)

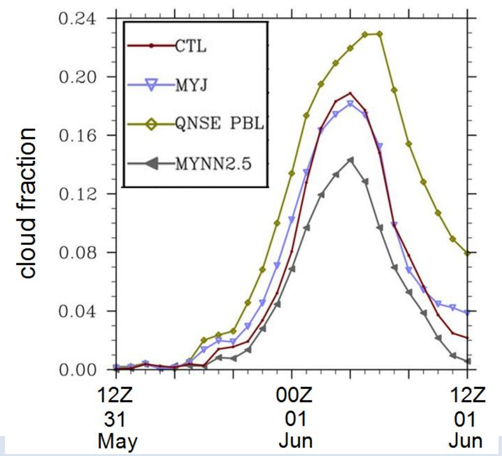
$$LWP = \int_{z=0}^{\infty} \rho_{air} r_L dz'$$



VIS Sat: 04:30



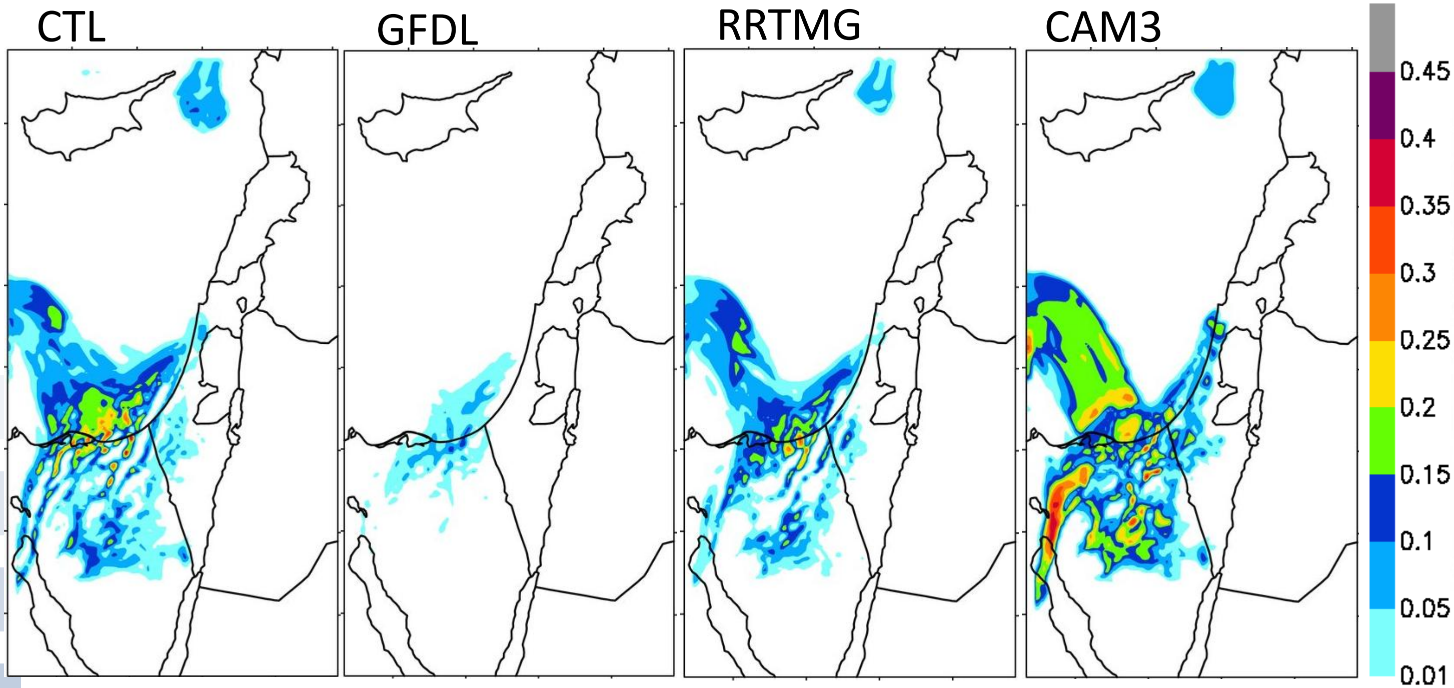
- PBL too active in MYNN2.5; lowest LWP and cloud fraction.
- QNSE maintained higher cloud fraction a bit too long.



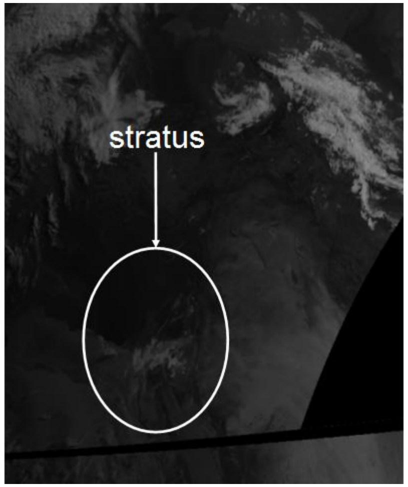
meso-β/meso-γ scale

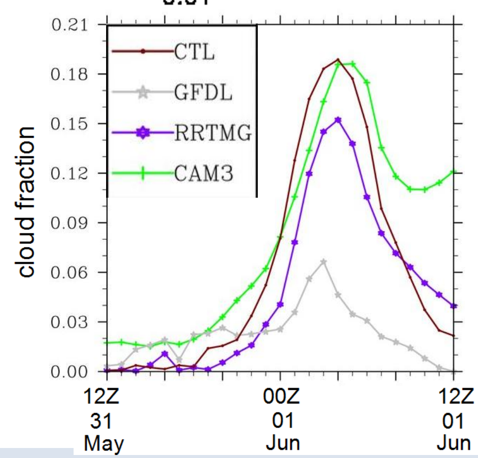
Sensitivity to Radiation Schemes

01/05-17: liquid water path (mm)



VIS Sat: 04:30





- GFDL radiation is the worst; not much cloud.
- CAM3 maintained cloud far too long.

meso-β/meso-γ scale

Summary Remarks

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- Need to have synoptic environment well simulated in order to get the mesoscale right.
  - Model physics is important but plays a 2nd role compared to synoptic and mesoscale environment; DA is important.
- DM micro: better wind prediction most likely due to better simulation of gust fronts from more sophisticated microphysics.
- Effects of outer grid CPS can propagate into inner grids.
- Large sensitivity in BL clouds to PBL and radiation schemes. Best results: MM5 or RRTMG rad; YSU or MYJ PBL.
- Future plans: test parameters within model physics.