A Limited Area Model (LAM) Intercomparison Study of the TWP-ICE Case

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Participating models

Weather Research and Forecast (WRF) model
United Kingdom Meteorological Office (UKMO) model
Consortium for Small-scale Modeling (COSMO) model

WRF has three different configurations

Case Specification

*Monsoon trough: 23-25 Jan 2006 (start on 12:00Z 22 Jan)
It includes a monsoon deep convective event (Event C, 23.5 – 24.5) and the following outflow cirrus evolution (24.5 – 25.5).
Suppressed monsoon: 28-30 Jan 2006 (start on 12:00Z 27 Jan)
CRM period, 0Z 18 Jan - 0Z 3 Feb (optional)

Forcing data

ECMWF analyses

Model domain

128.891E - **132.891E,**
13.923 S - 10.925
Center: 130.891E, 12.425S

Resolution

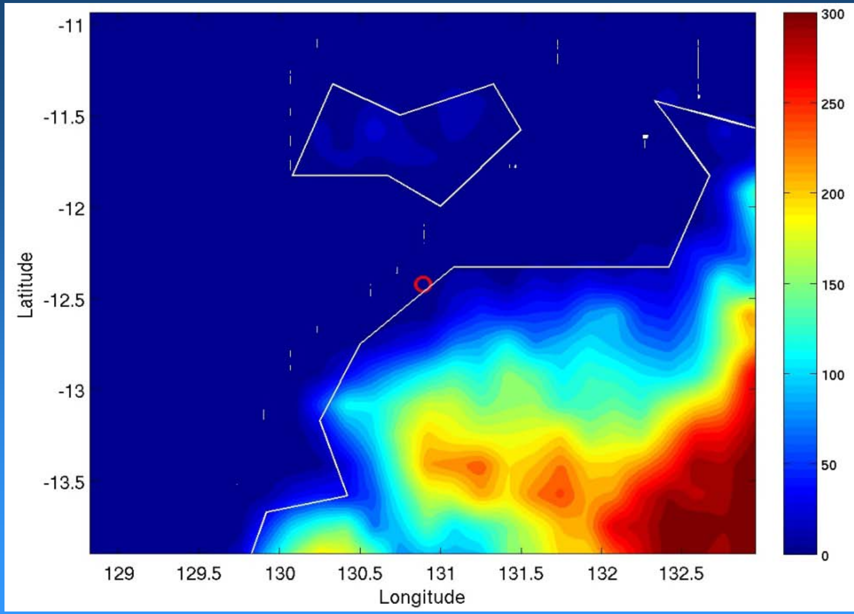
WRF, UKMO: 1km

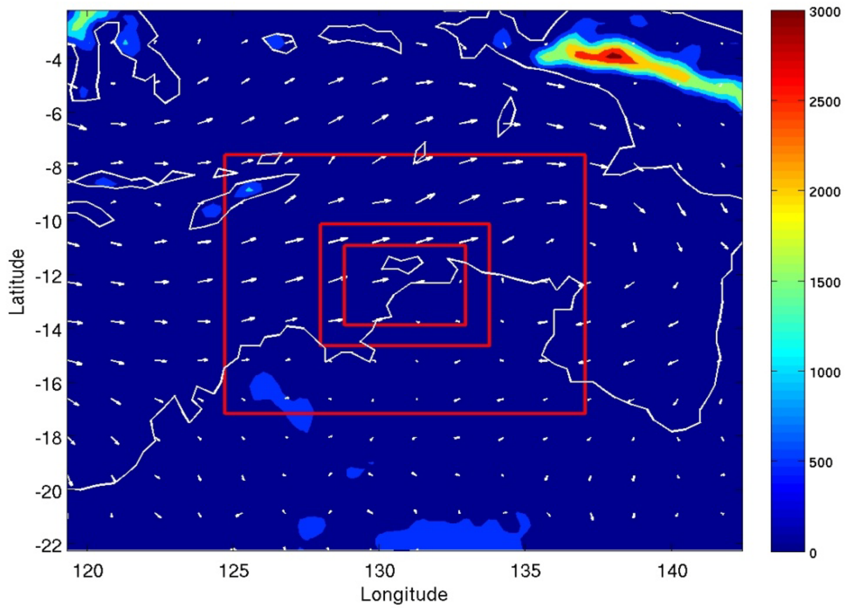
COSMO: 2.8km

Nesting

WRF and UKMO used two-way nesting.

COSMO (2.8 km) was forced by a coarser COSMO (7 km), which was nested in the Global model GME.





Two-way nested WRF-1 configuration

Model setup

	WRF-1	WRF-2	UKMO	COSMO	WRF-3
Levels	92	76	70	50	92
Surface model	5-layer thermal diffusion	4-layer Noah land model	MOESE (Essery et al. 2003)	7-layer Heise and Schrodin model	5-layer thermal diffusion
PBL	YSU	YSU	Lock	Mellor and Yamada	YSU
Microphysics	Thompson	WSM 6-class graupel	Mixed phase (Wilson and Ballard)	Kessler-type class 6	WSM 6-class graupel

1. Can LAM simulations reproduce the observed dynamic and thermodynamic structure during the monsoon event?

2. Can LAMs realistically simulate the observed life cycle of monsoon convective systems ?

3. Do models produce consistent cloud properties and structures? How big is the inter-model spread in cloud fields?

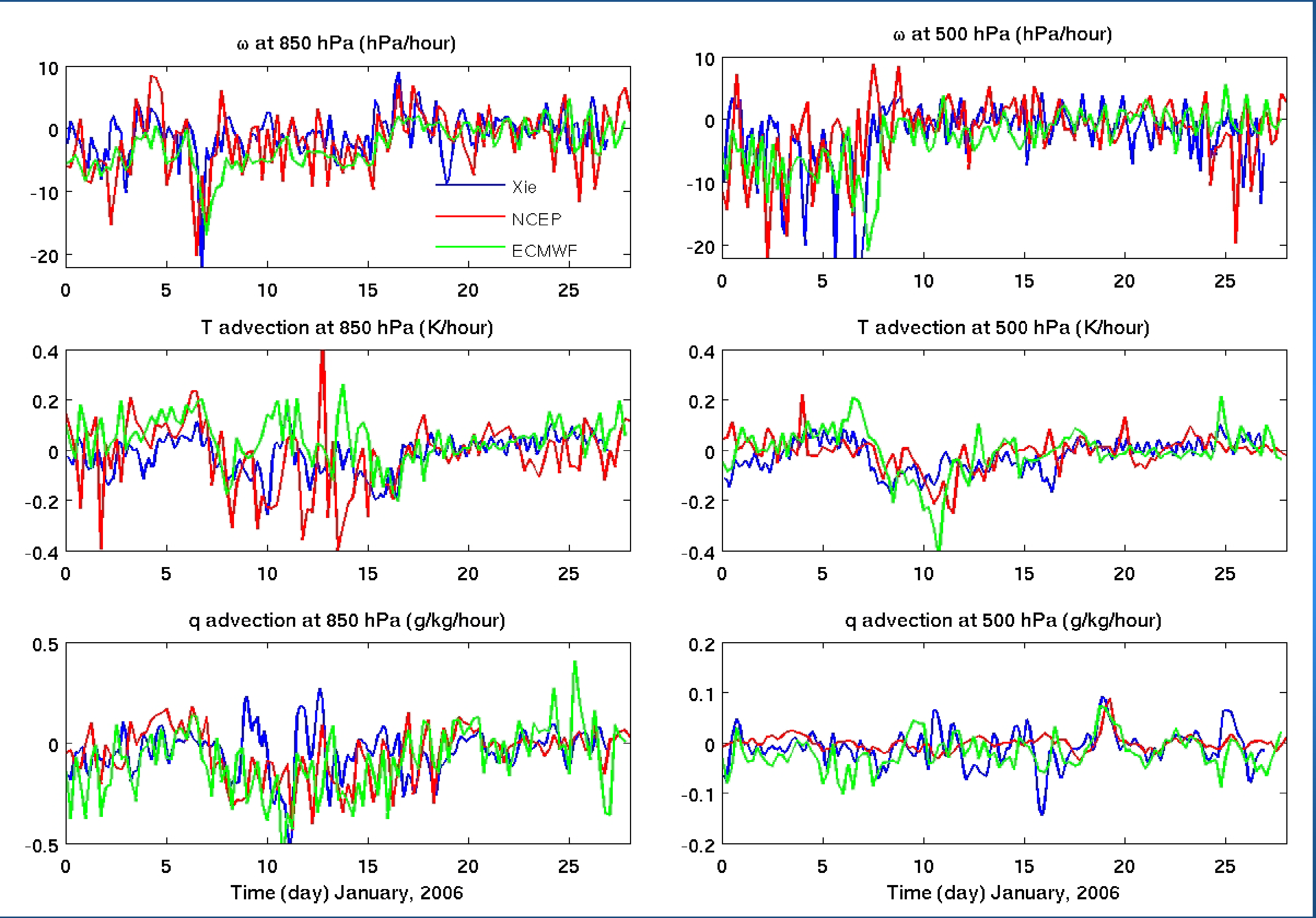
4. Do LAMs produce the vertical velocity fields consistent with those derived from CPOL radars?

5. Can LAMs realistically reproduce the diurnal cycle of the convective clouds initiated by the mainland and islands? How does surface heterogeneity, in particular the land/sea contrast, affect the cloud evolution during the monsoon event?

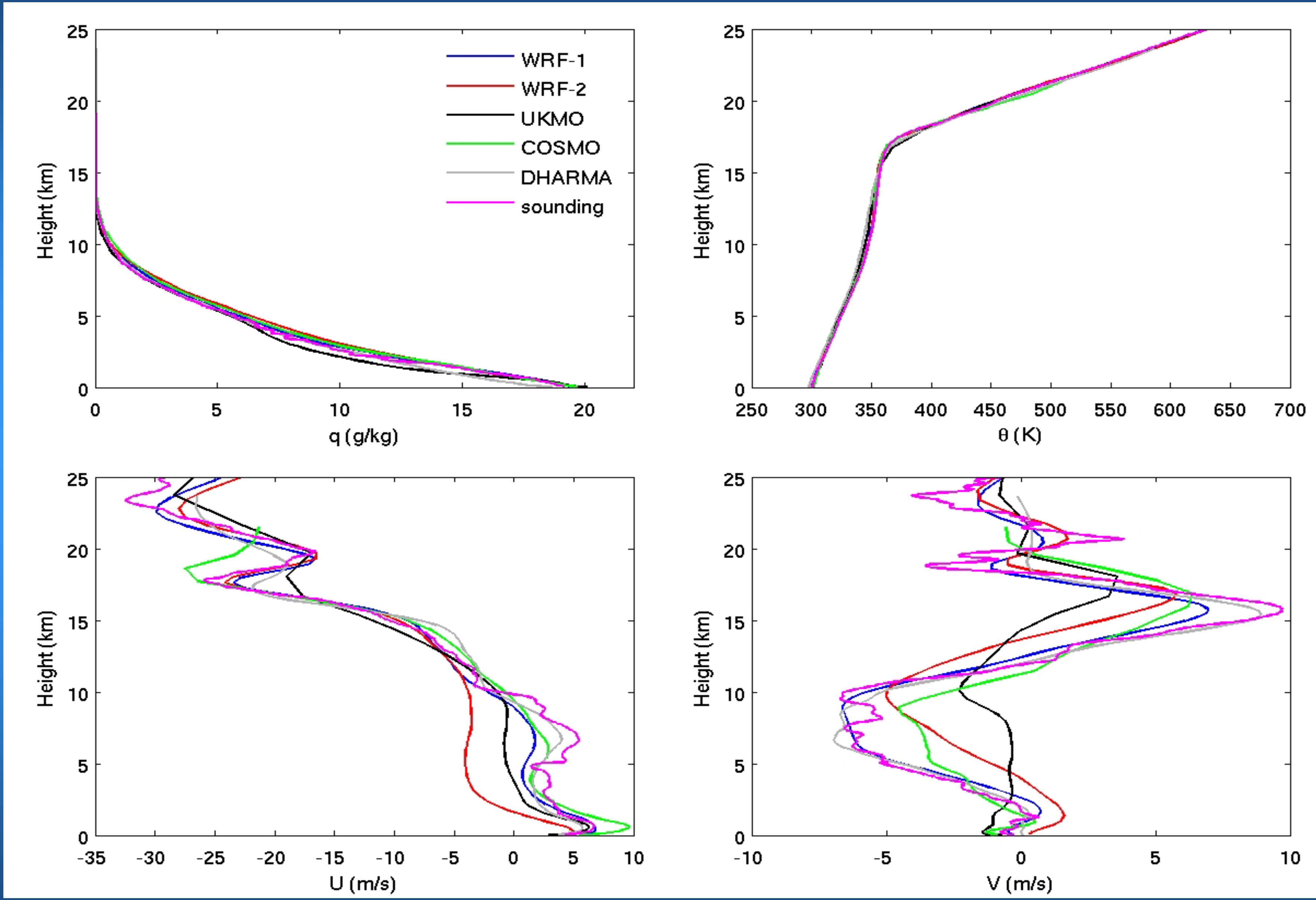
6. How sensitive are the simulated cloud fields to cloud microphysics?

7. Can LAMs statistically produce the similar cloud fields to those simulated by CRMs if they are configured at the similar resolution?

Comparisons of large-scale forcing between Xie, ECMWF, and NCEP

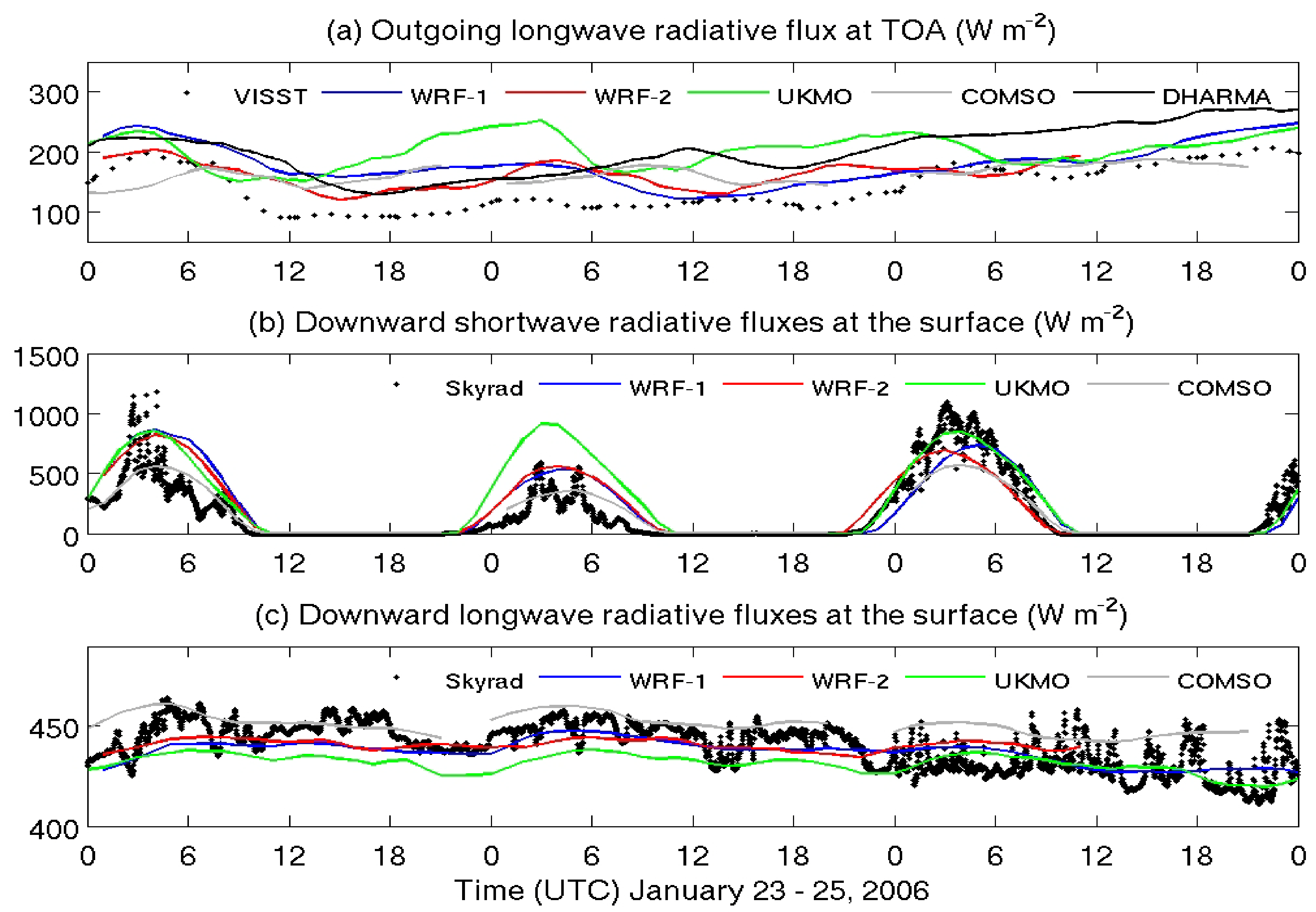


Simulated dynamic and thermodynamic profiles compared with OBS

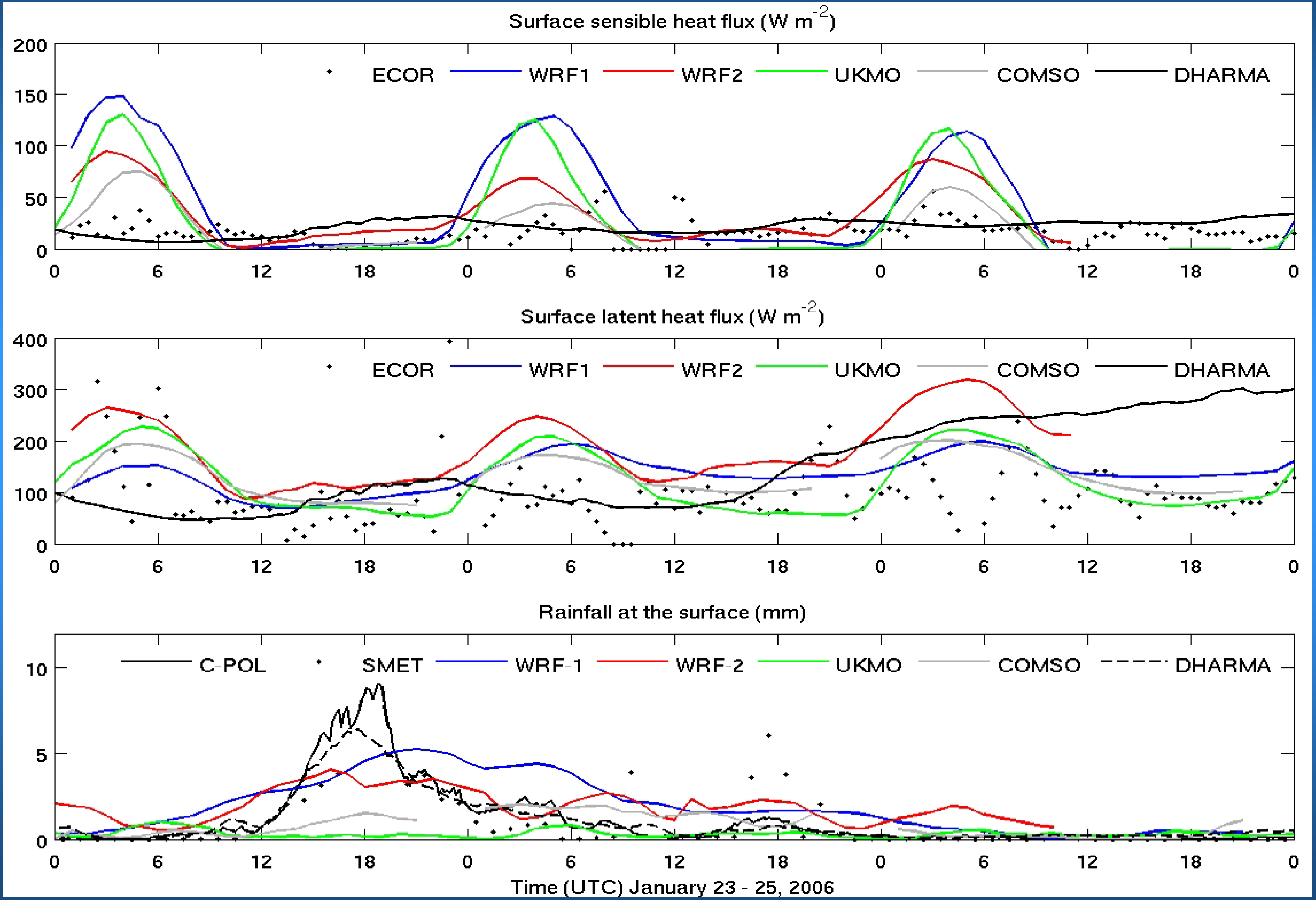


Averaged from 00UTC, 23 to 00 UTC, 26, January, 2006

Simulated radiative fields compared with observations



Simulated surface fluxes and rainfall compared with observations

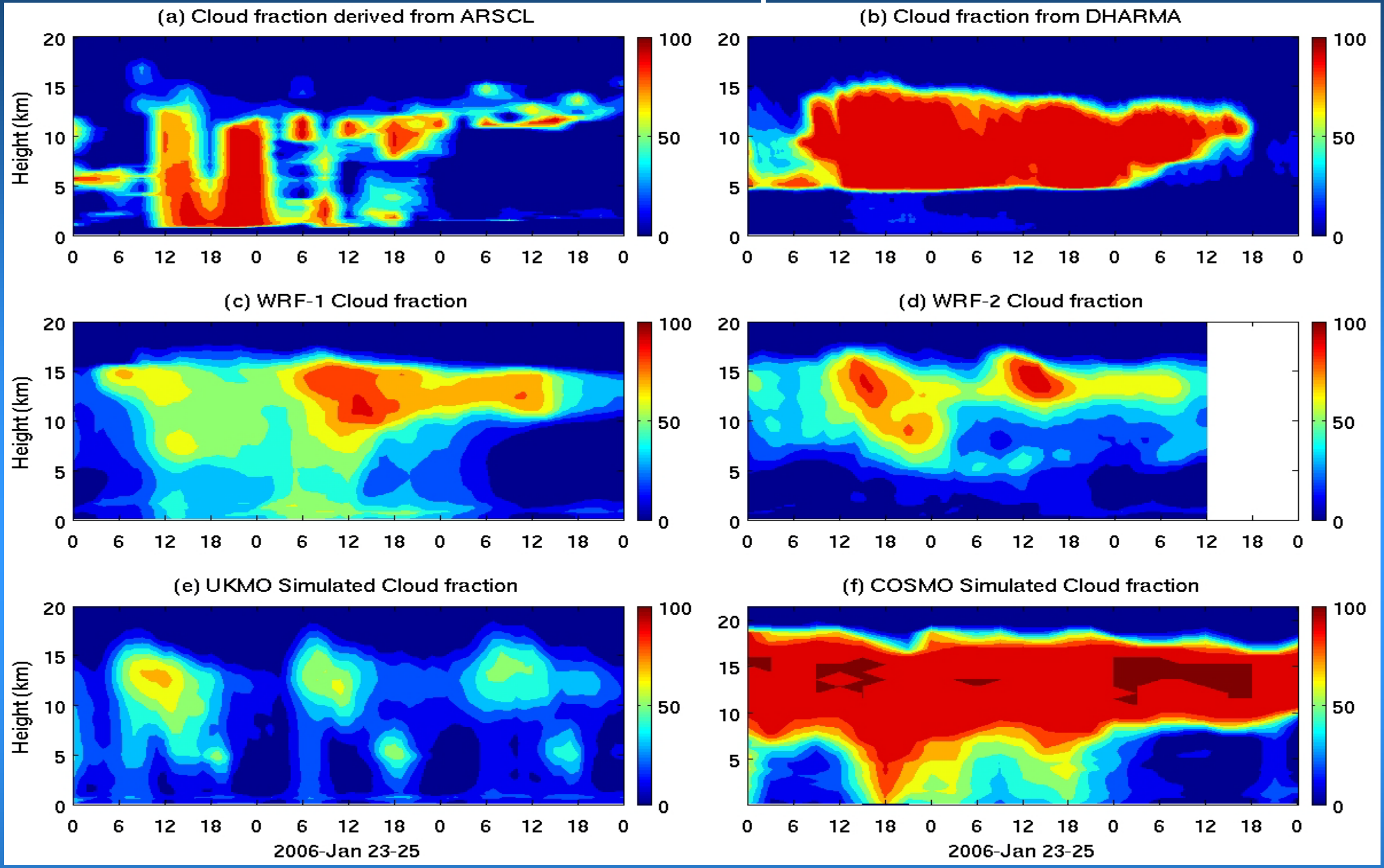


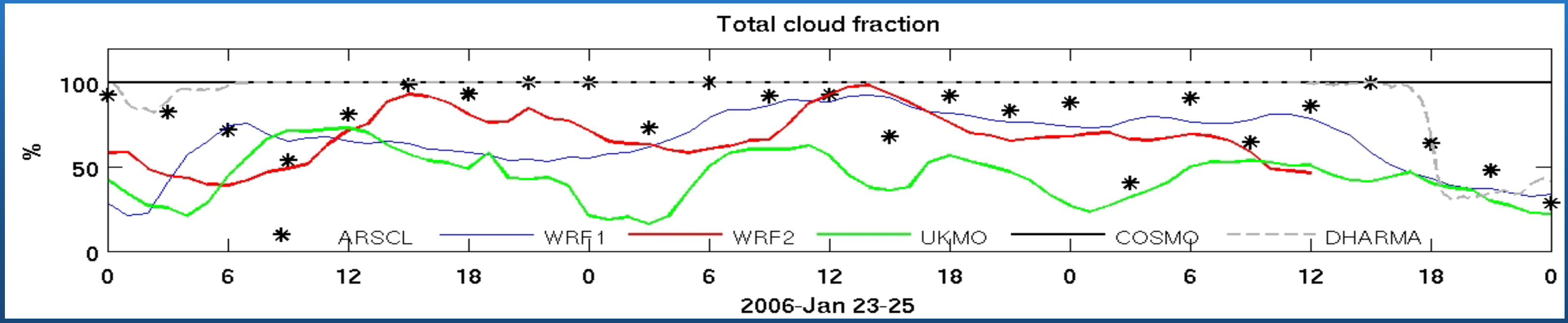
What do we see so far?

All models are able to produce similar dynamic and thermodynamic fields consistent with observations. LAMs also simulate the radiative fluxes reasonably well, but they appear to over-estimate surface heat fluxes compared with the ECOR observation.

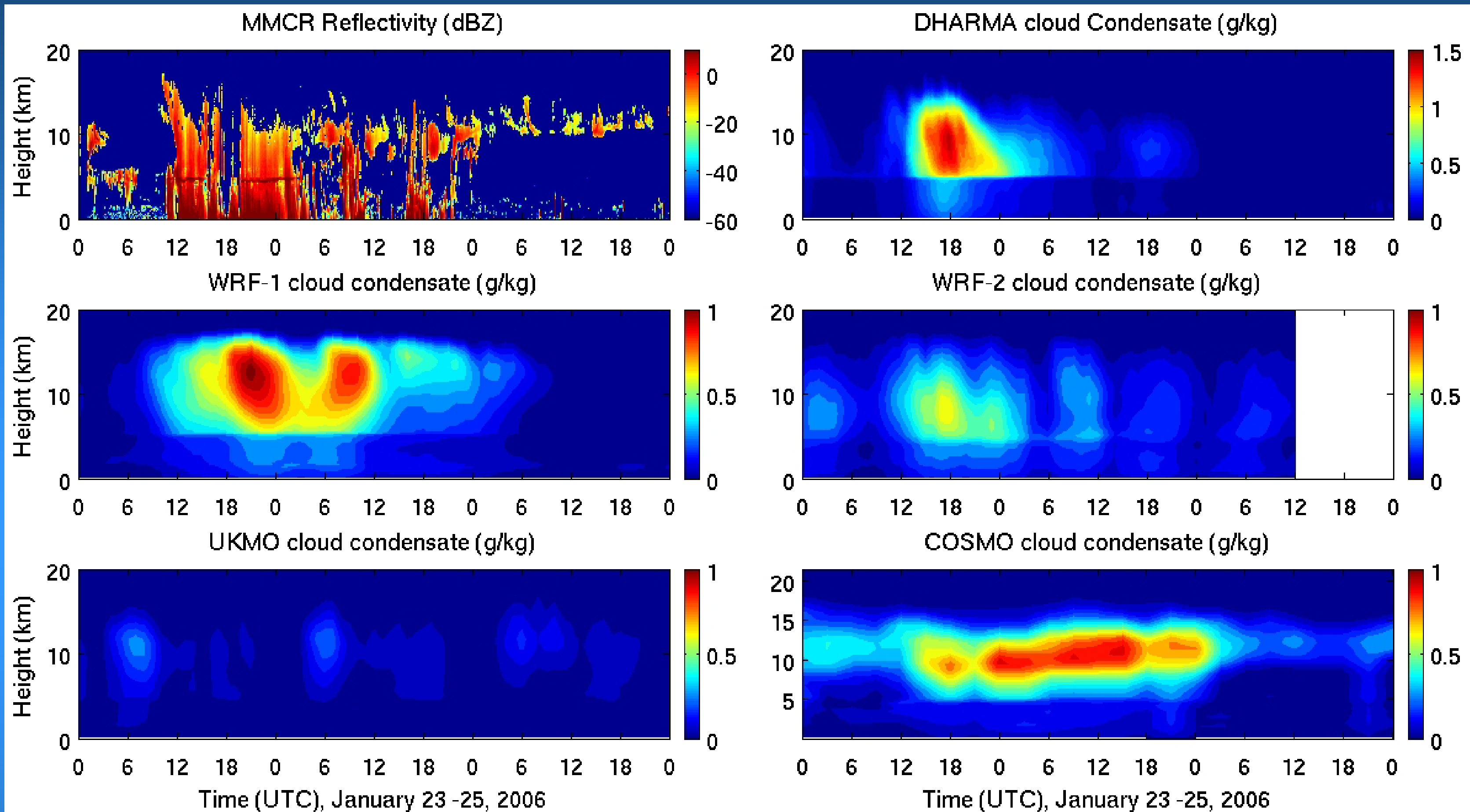
How do LAMs simulate the cloud systems under the realistic large-scale dynamic and thermodynamic environment?

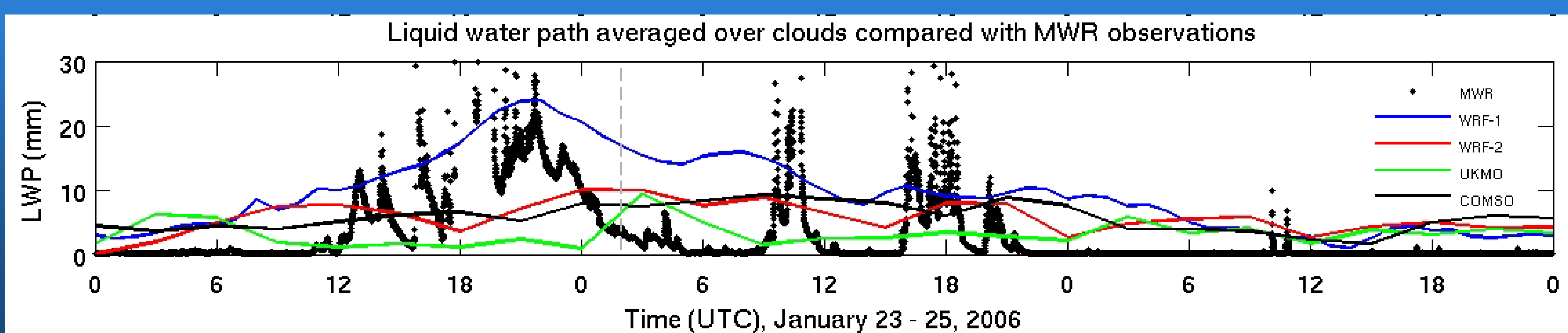
Simulated cloud fraction compared with observations



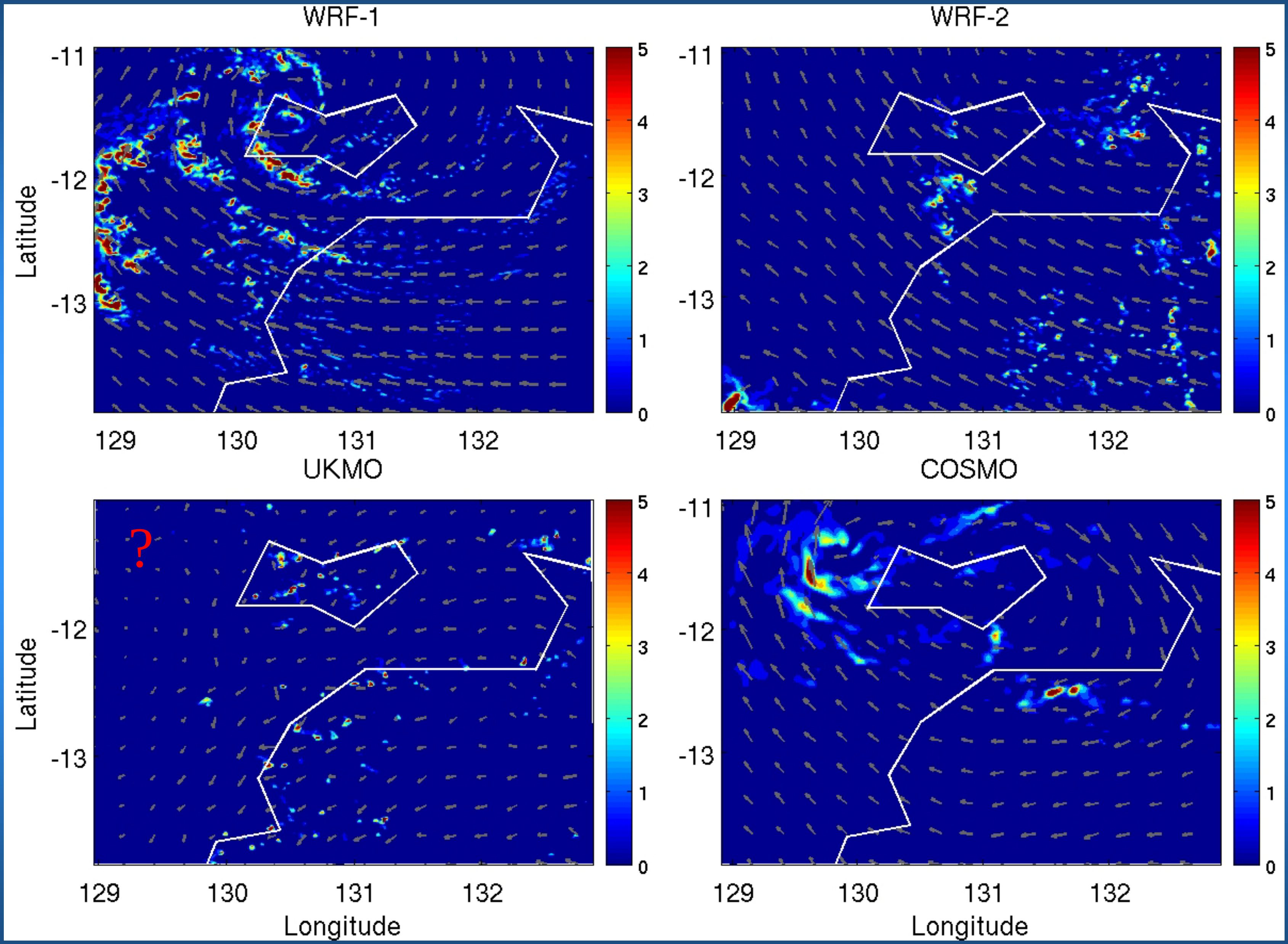


Simulated cloud condensate and LWP compared with observations



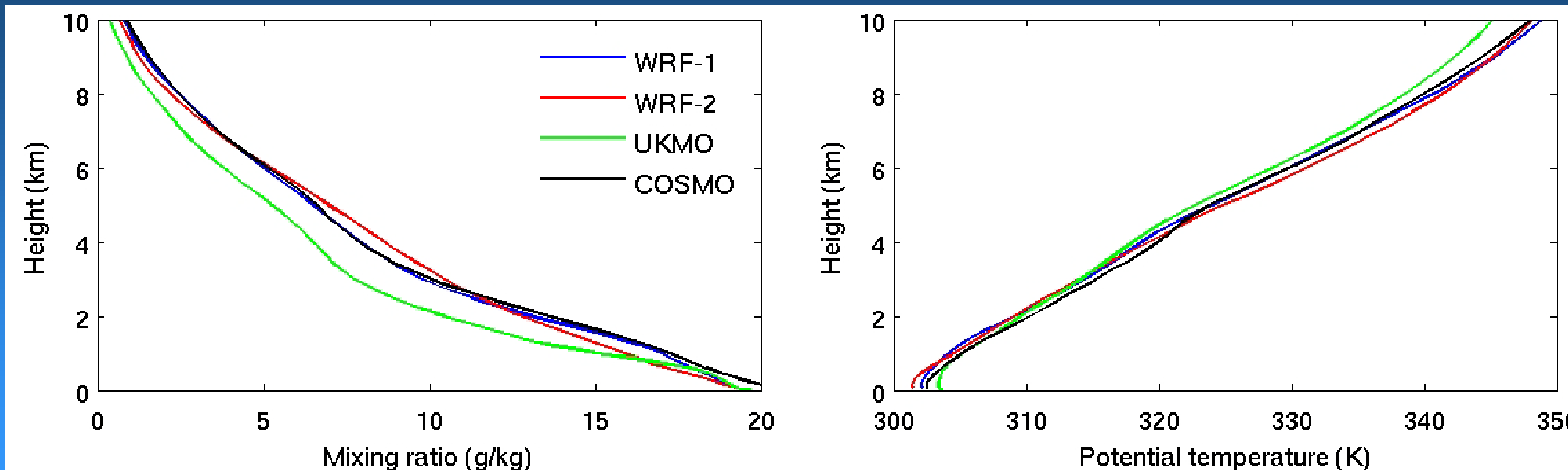


LAM simulated cyclone during the event C

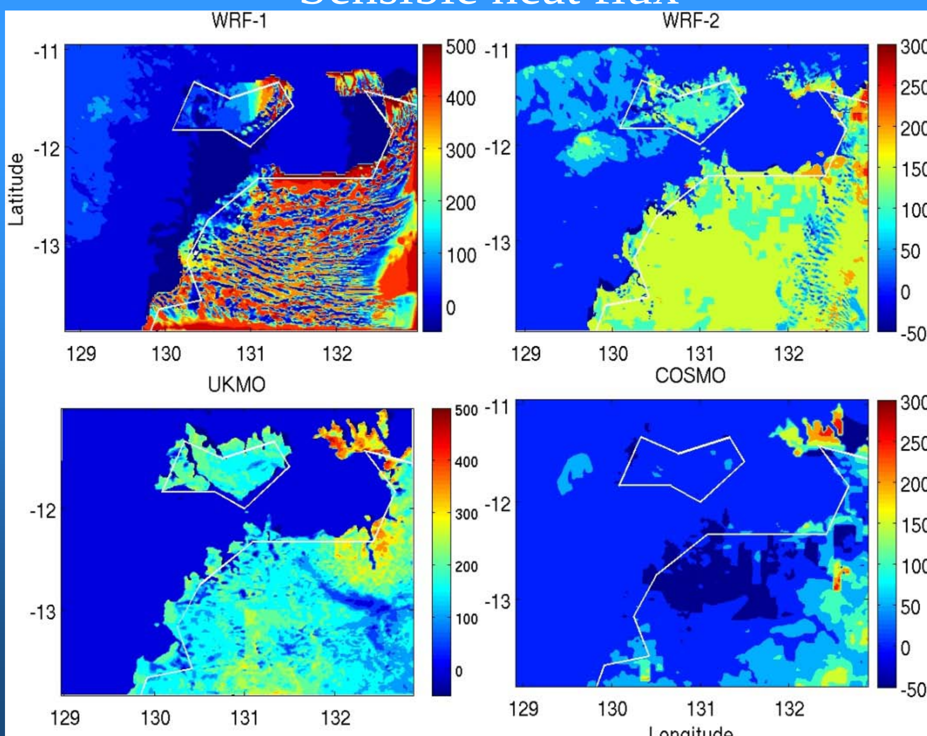


2 km cloud condensate (g/kg) and wind vector at 02:00 UTC, January 24, 2006

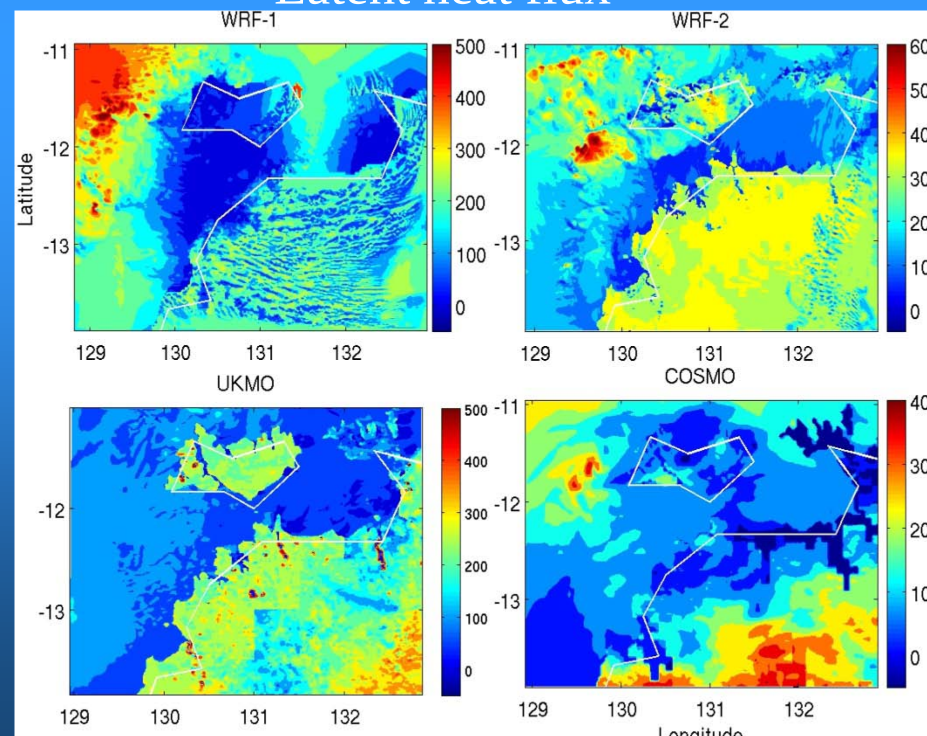
Vertical profiles and surface heat fluxes at 02 UTC, 24th



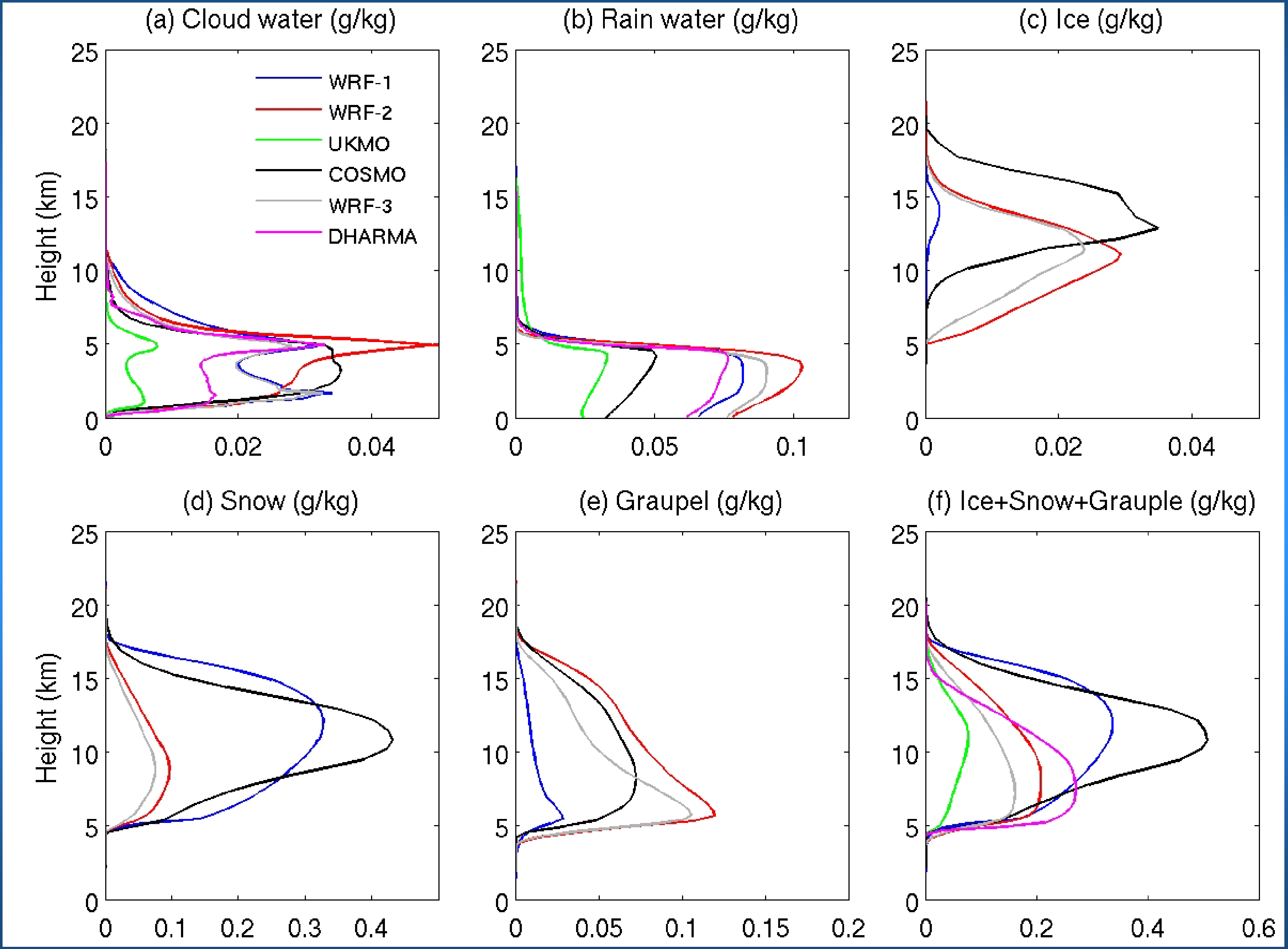
Sensible heat flux



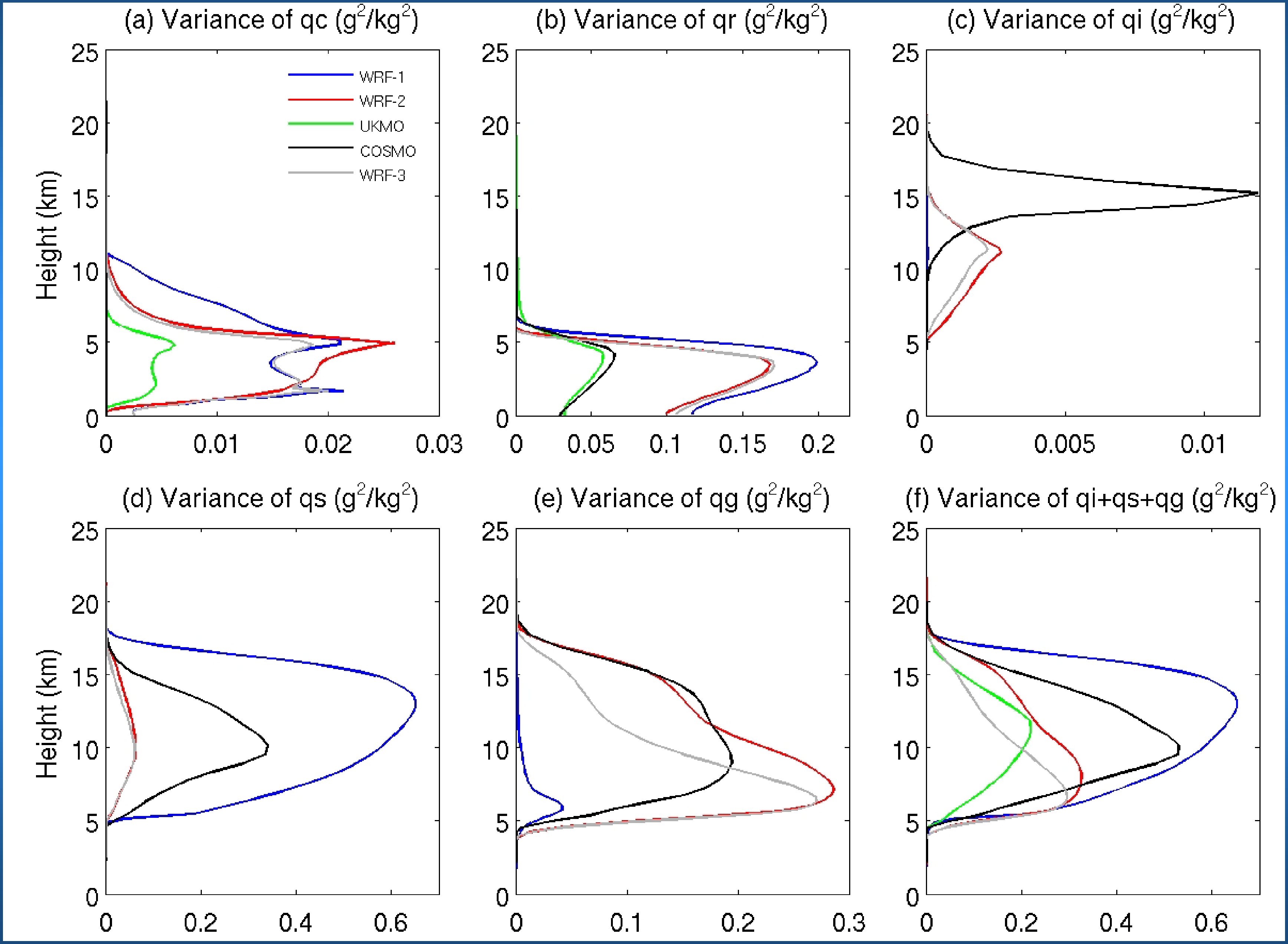
Latent heat flux



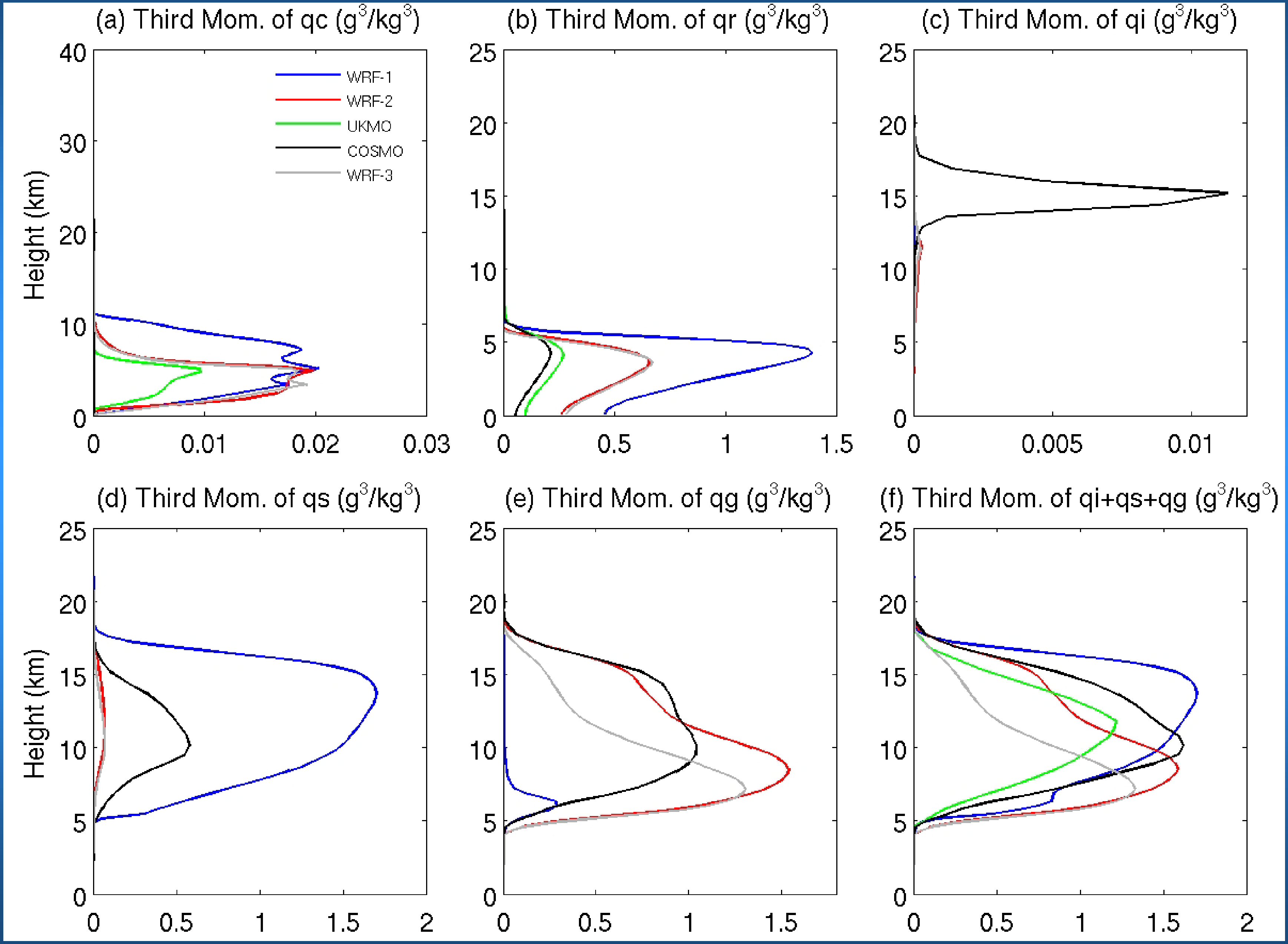
Domain mean cloud condensate



Variance of cloud condensate



Third order moments of cloud condensate



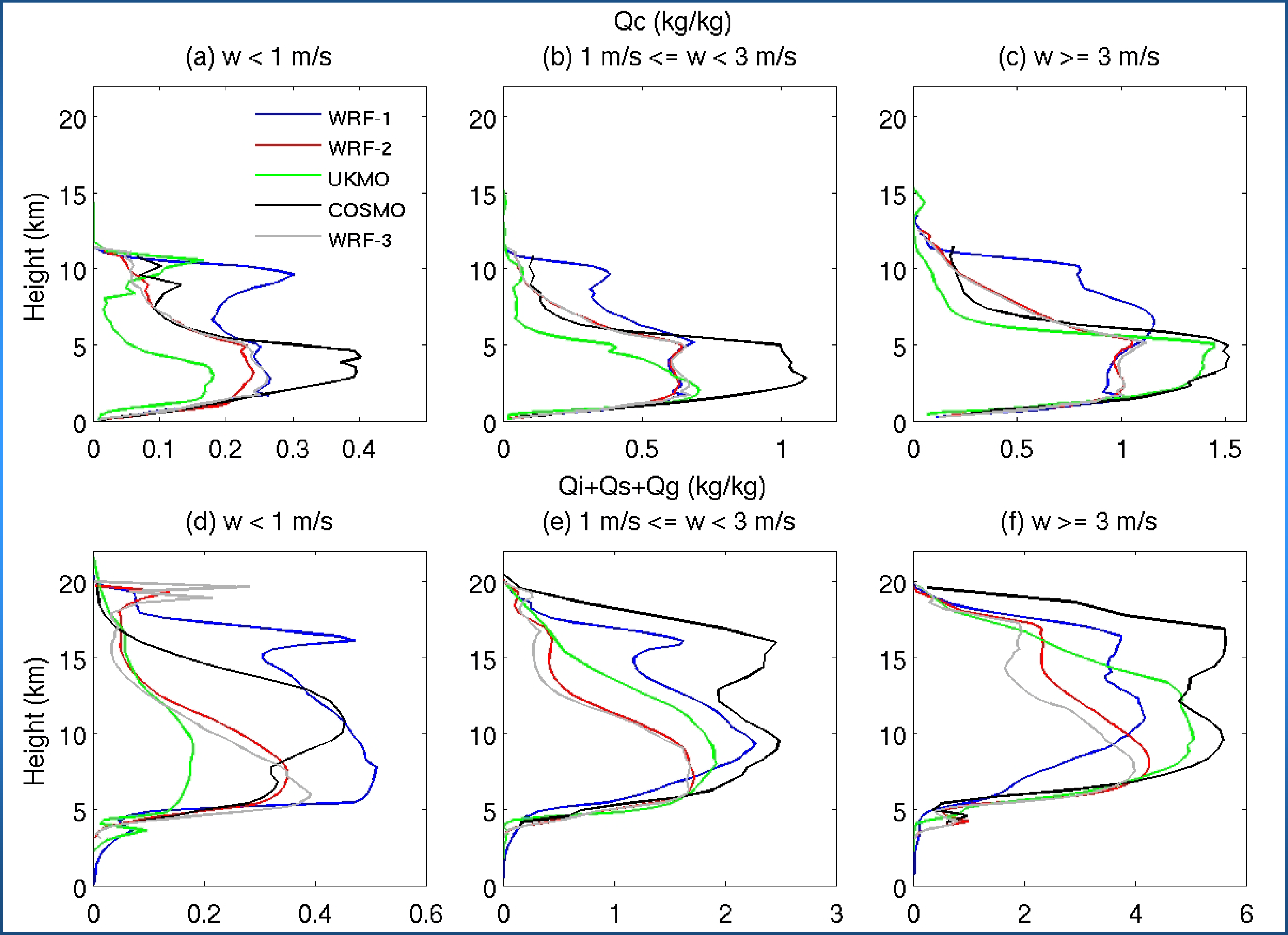
What do we see so far?

1. WRF and COSMO are able to produce the strong deep convective clouds in the monsoon event consistent with observations. The model simulations indicate that these strong deep convective clouds are associated with a cyclone although its strength can vary substantially from model to model. UKMO fails to produce the cyclone, and thus, the deep convective cloud system.

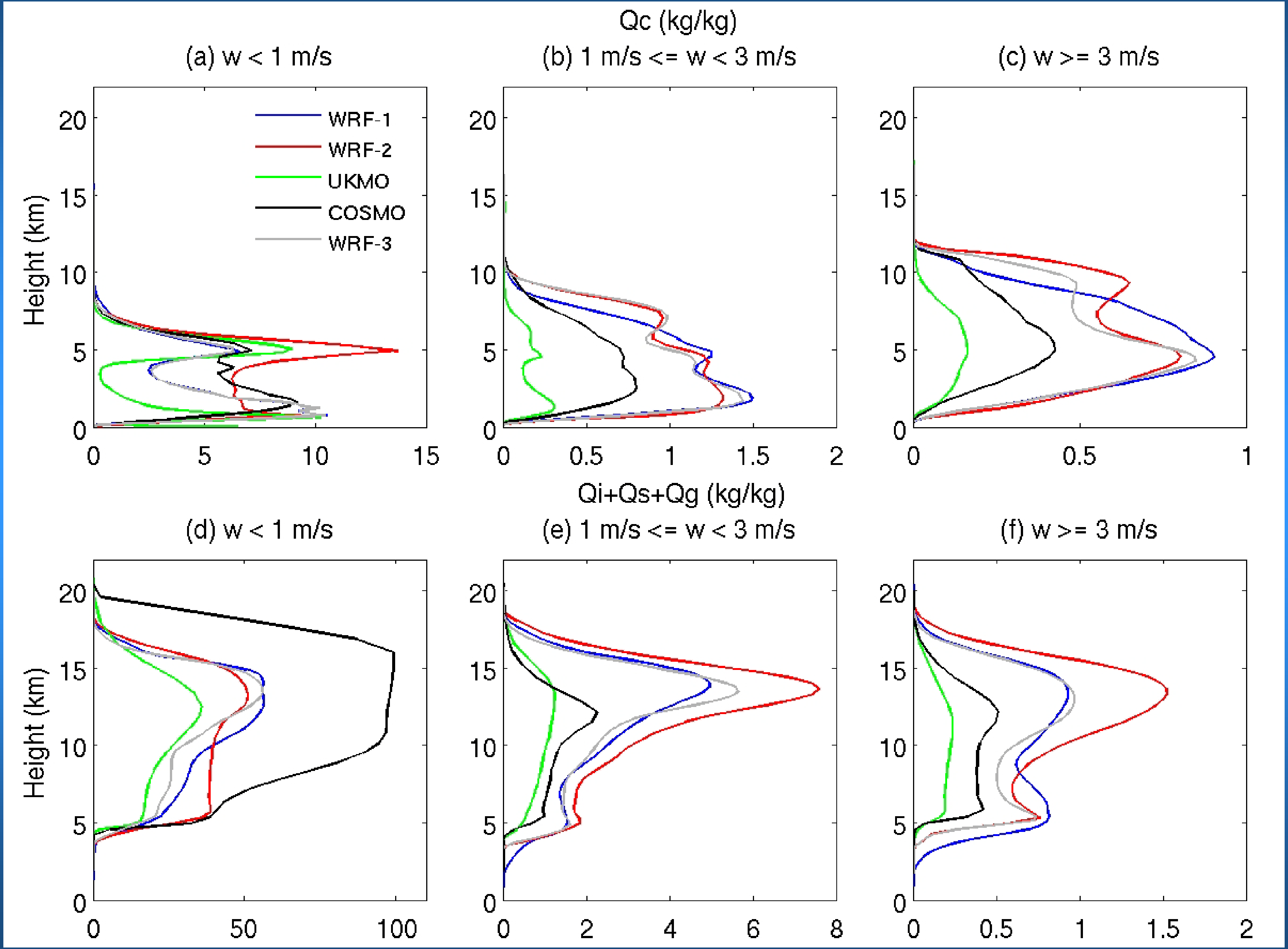
2. Models produced a large discrepancy in cloud fraction and cloud condensate. The inter-model difference in cloud water, ice, snow, and graupel can be as large as a factor of 10.

3. Sensitivity test indicates that the simulated cloud condensates are very sensitive to cloud microphysics, but seem to be less sensitive to vertical resolution as long as it gets sufficiently high.

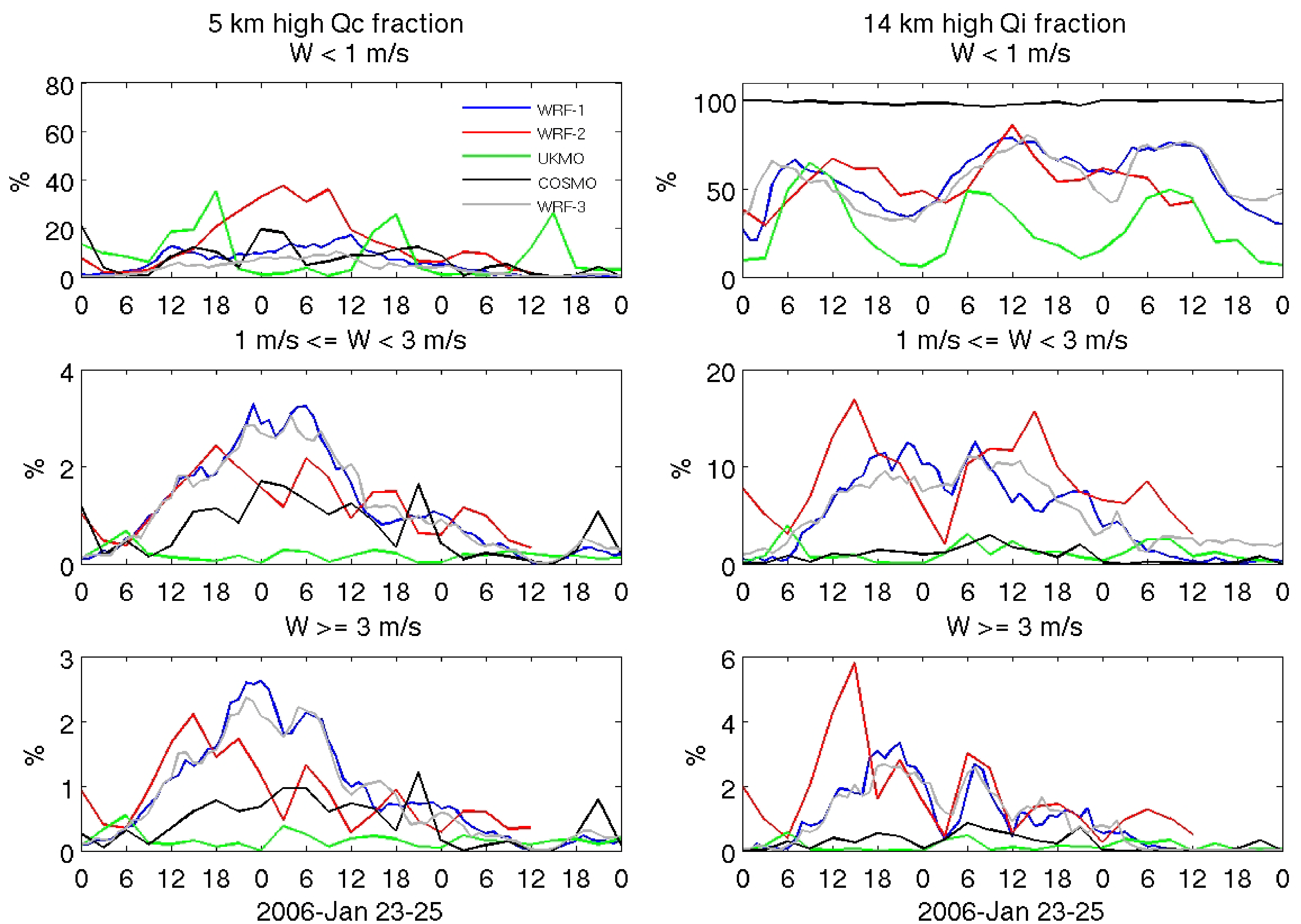
Convective and stratiform cloud condensate

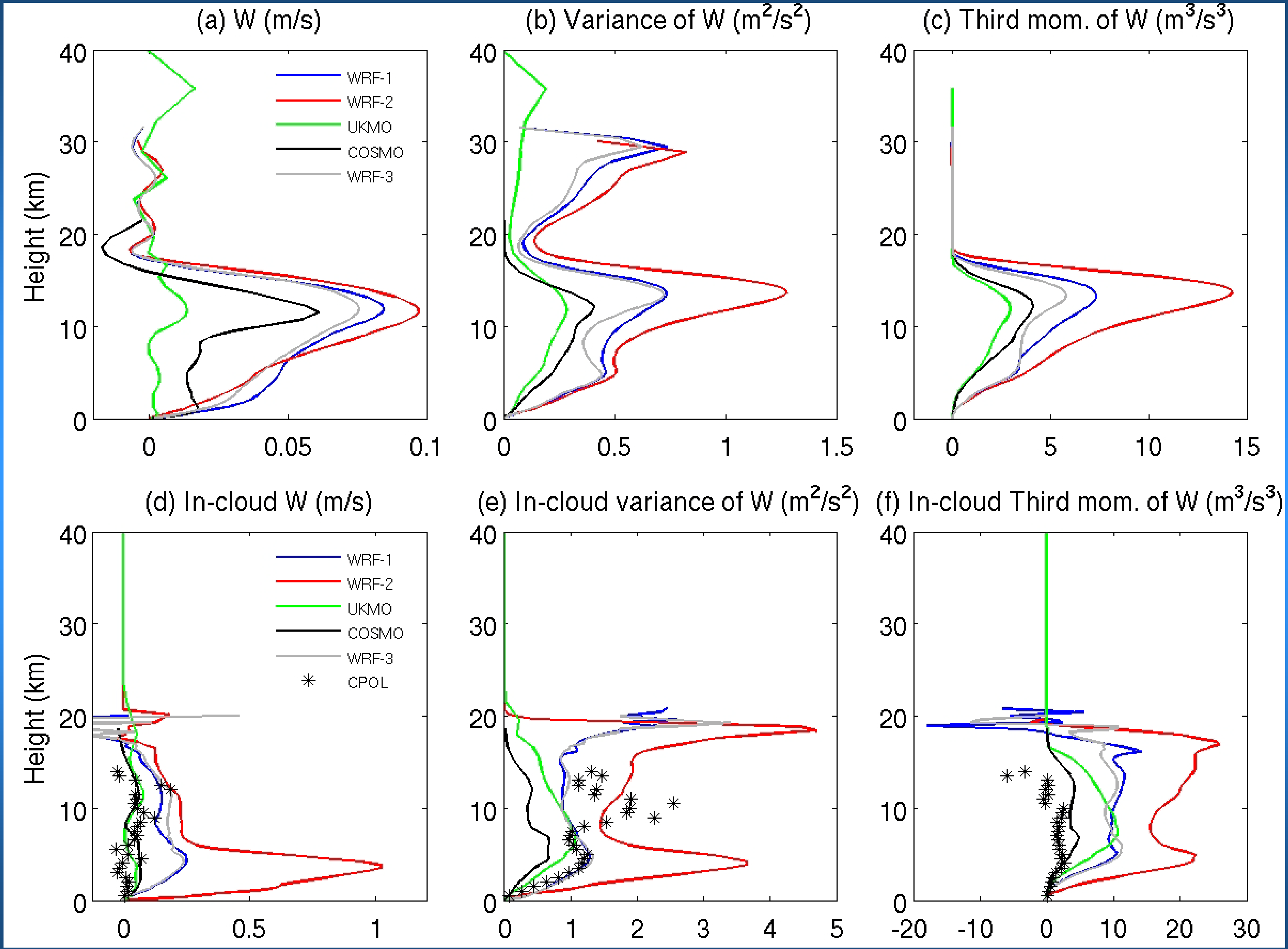


Convective and stratiform cloud fraction (%)



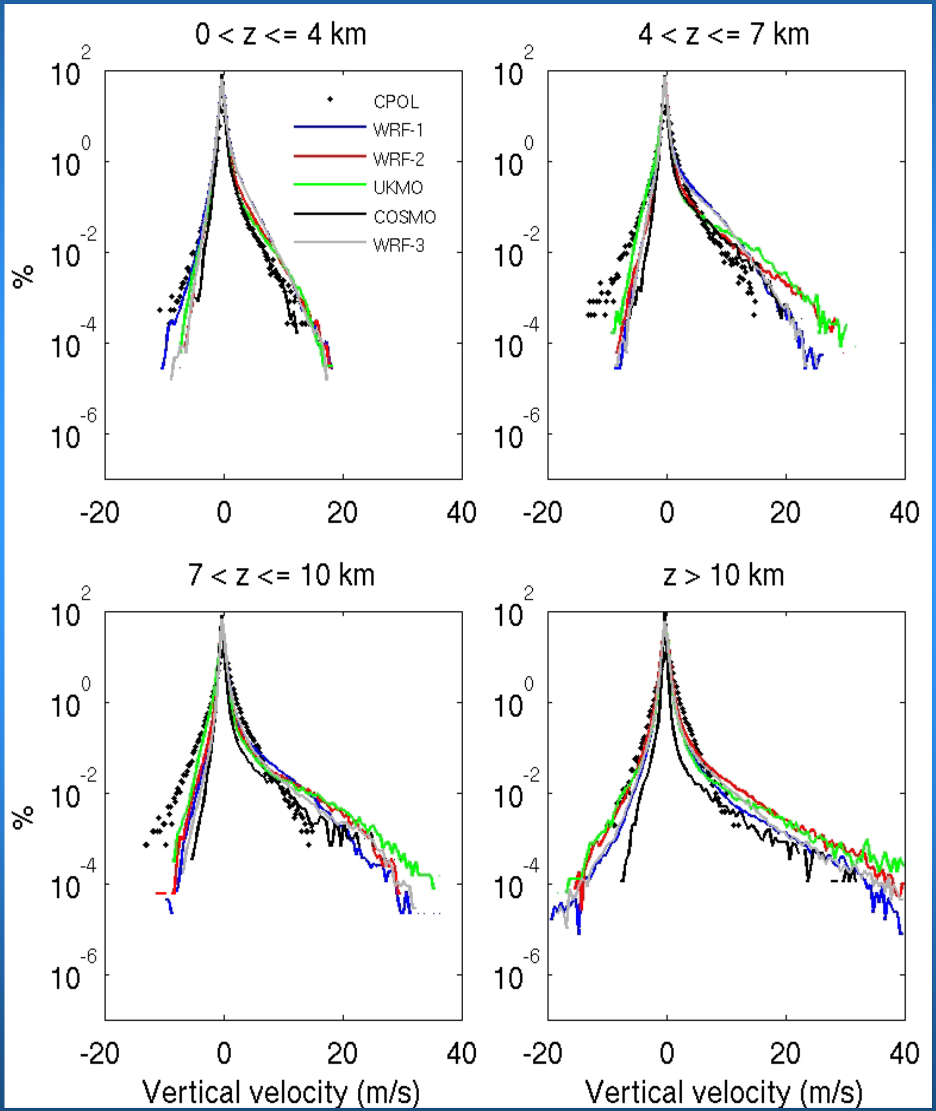
Convective and stratiform cloud fraction (%) at 5km and 14km



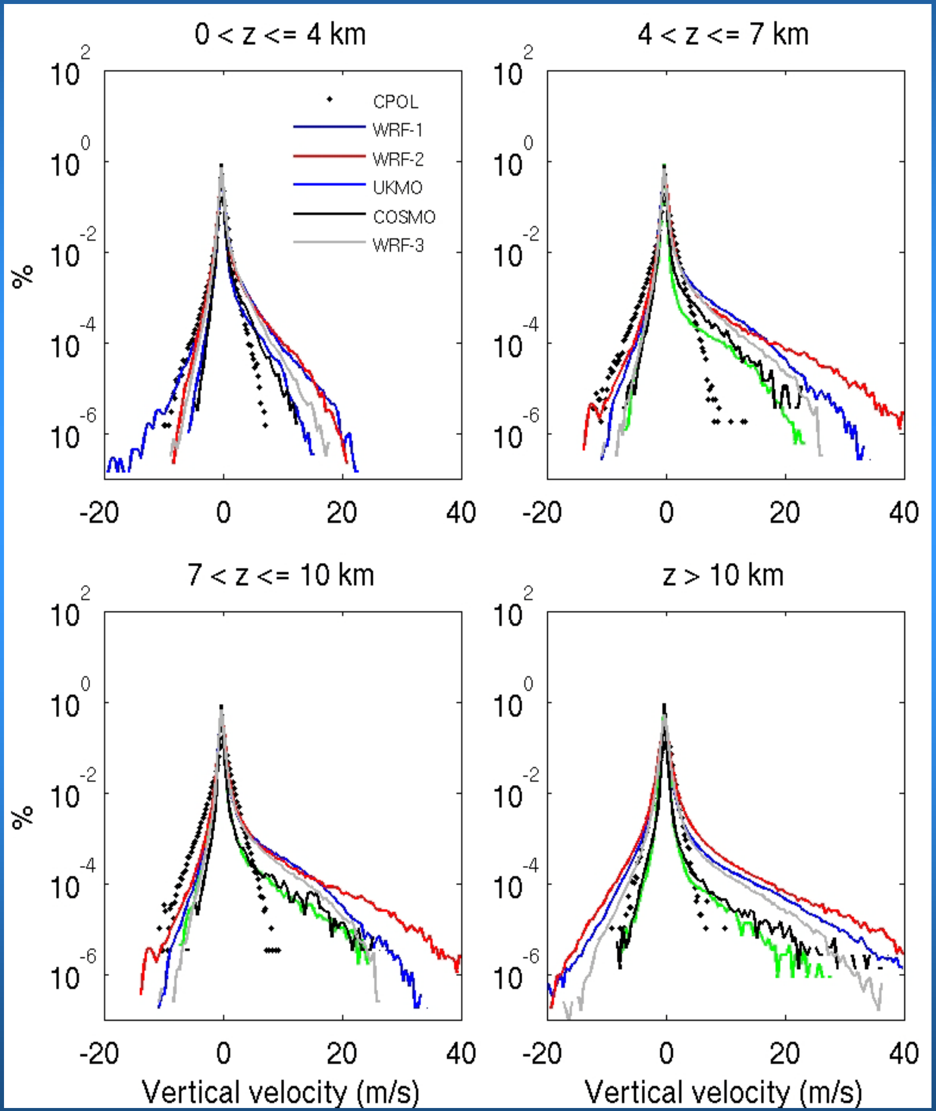

(a) W (m/s)
(b) Variance of W (m²/s²)
(c) Third mom. of W (m³/s³)
(d) In-cloud W (m/s)
(e) In-cloud variance of W (m²/s²)
(f) In-cloud Third mom. of W (m³/s³)
Height (km)
WRF-1
WRF-2
UKMO
COSMO
WRF-3
CPOL

In-cloud vertical velocity distribution

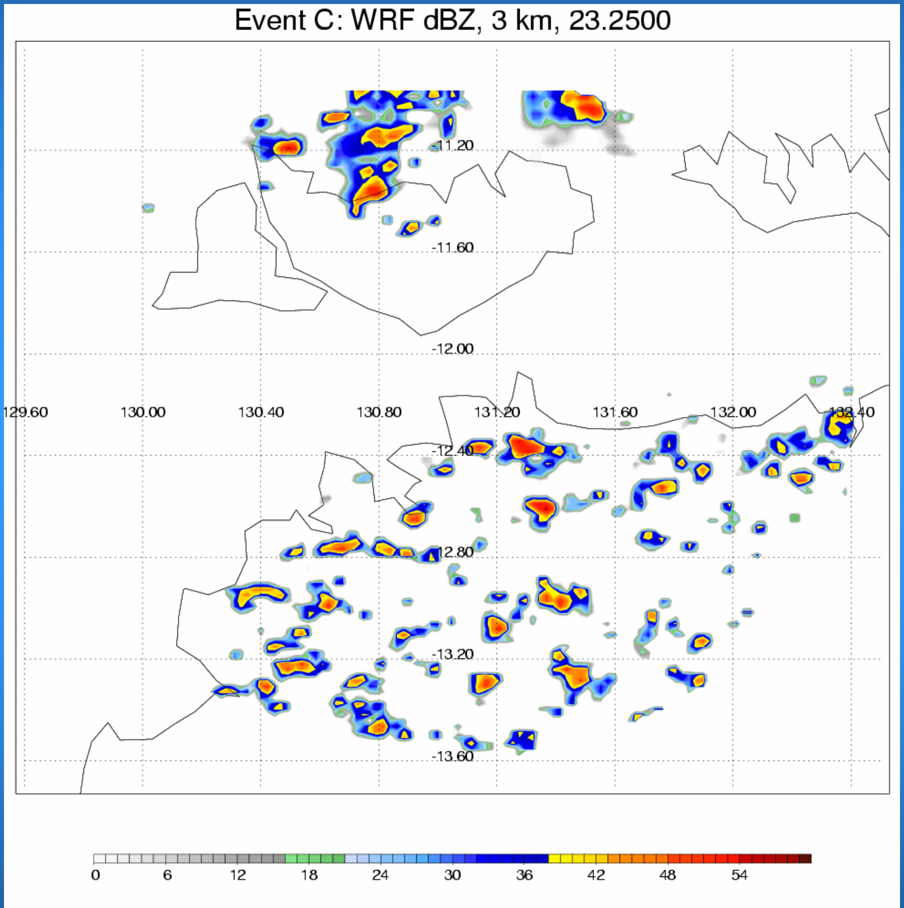
0 – 6 UTC (9:30 -15:30 LST)

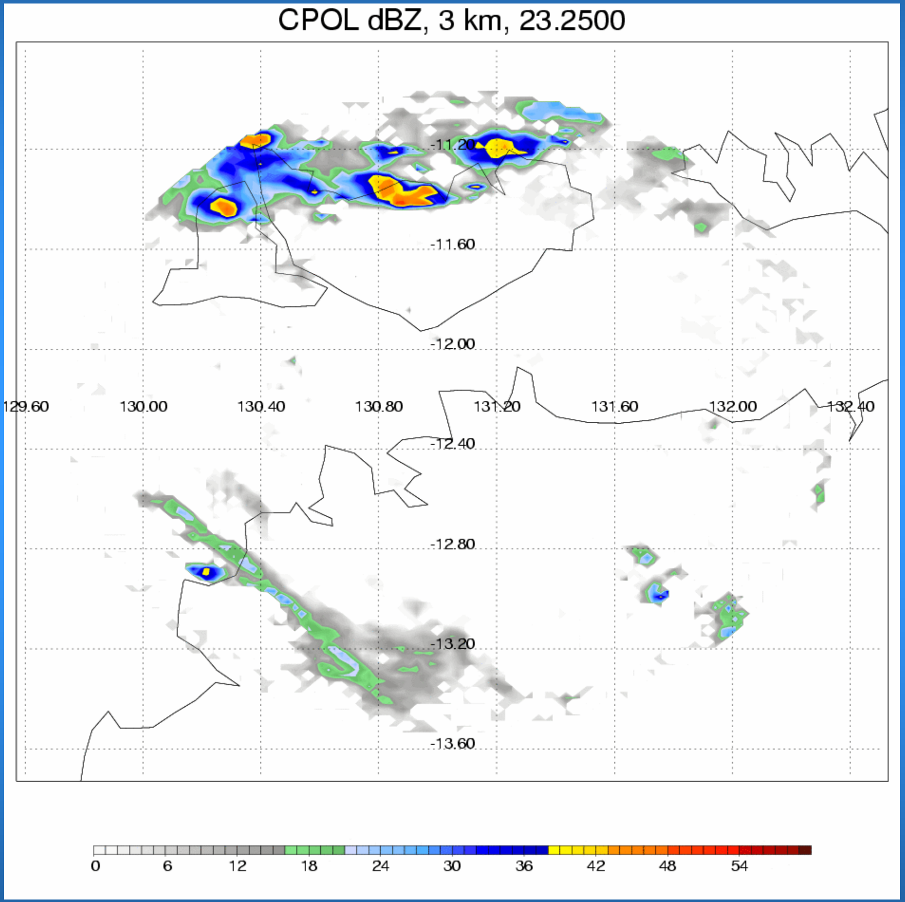


12 – 18 UTC (21:30 -03:30 LST)



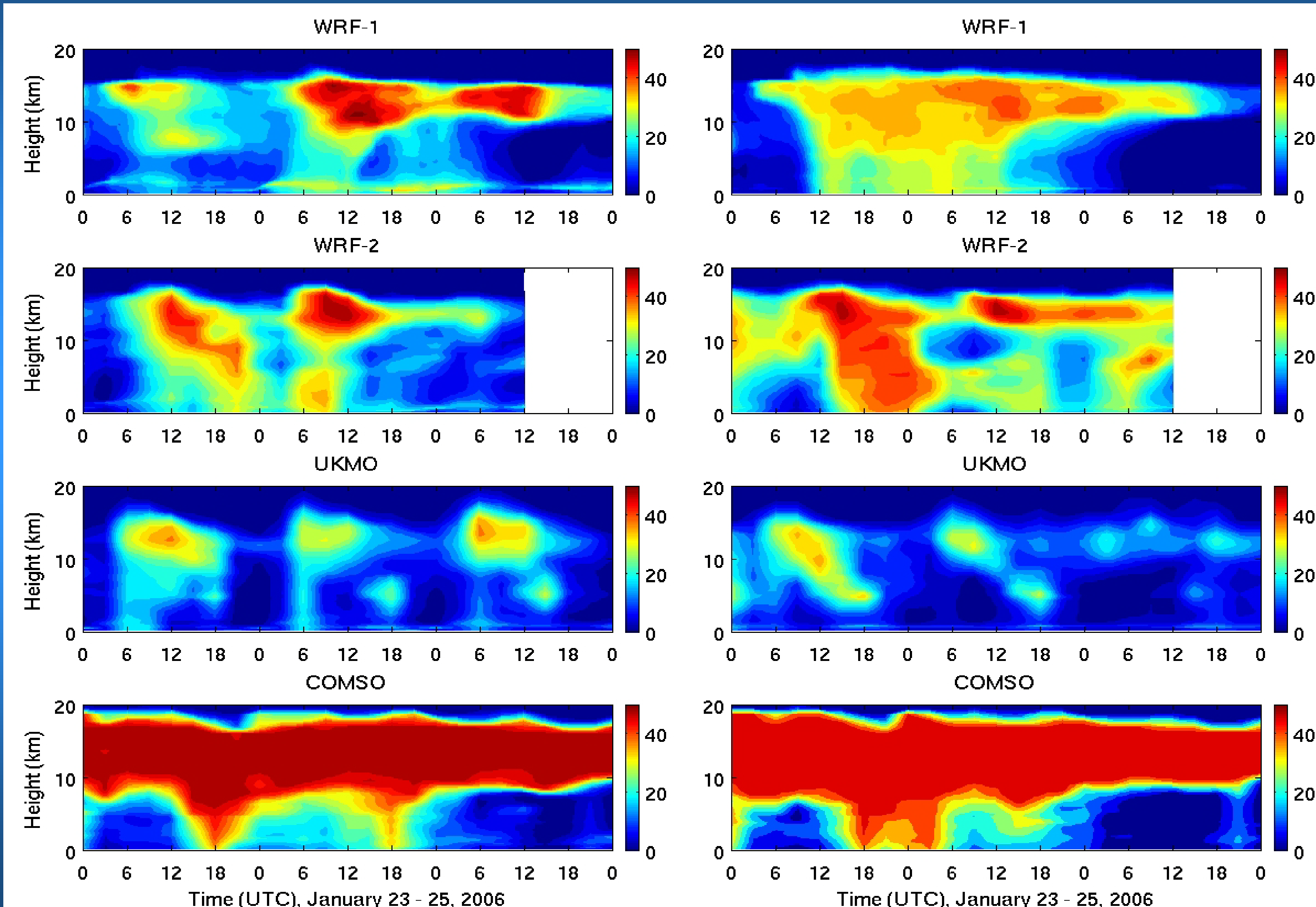
Excessive Low Level (3km) Convective dBZ and Lack of Stratiform Area





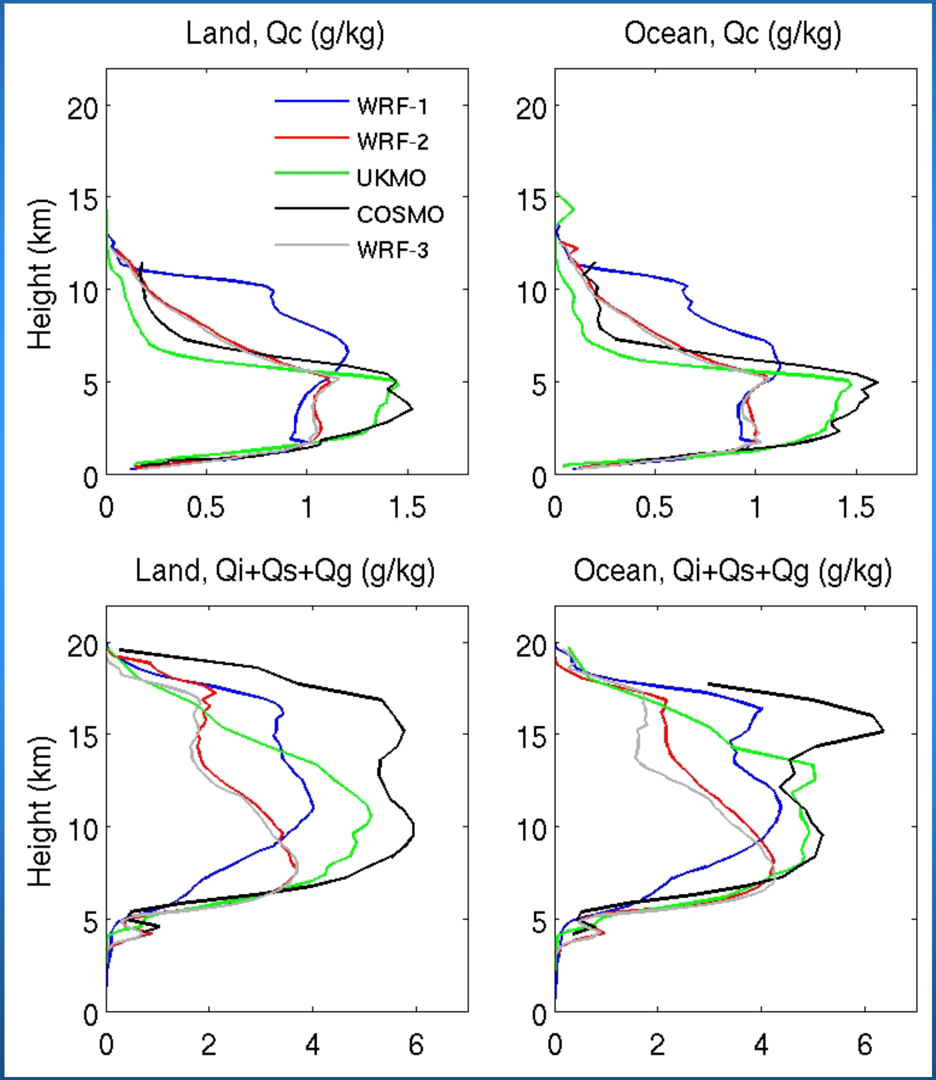
Cloud fraction over land and ocean

Land | Ocean

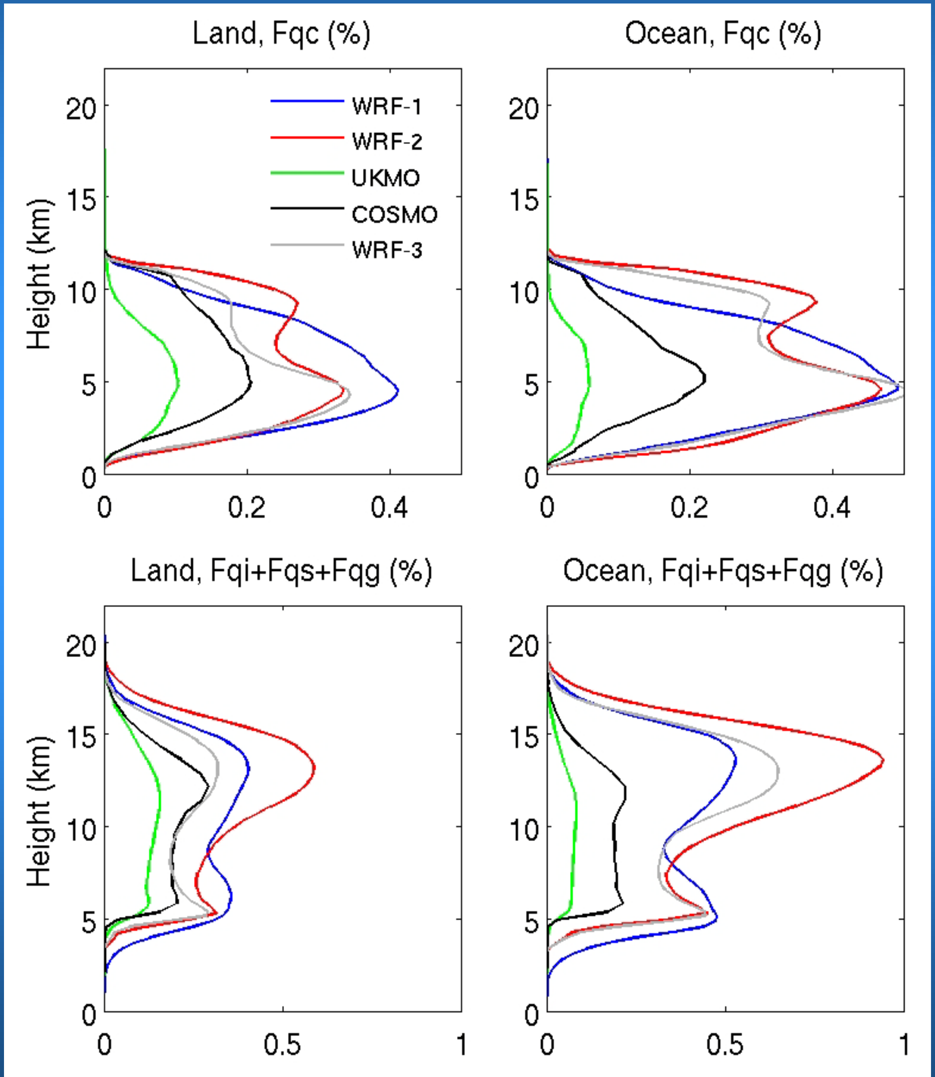


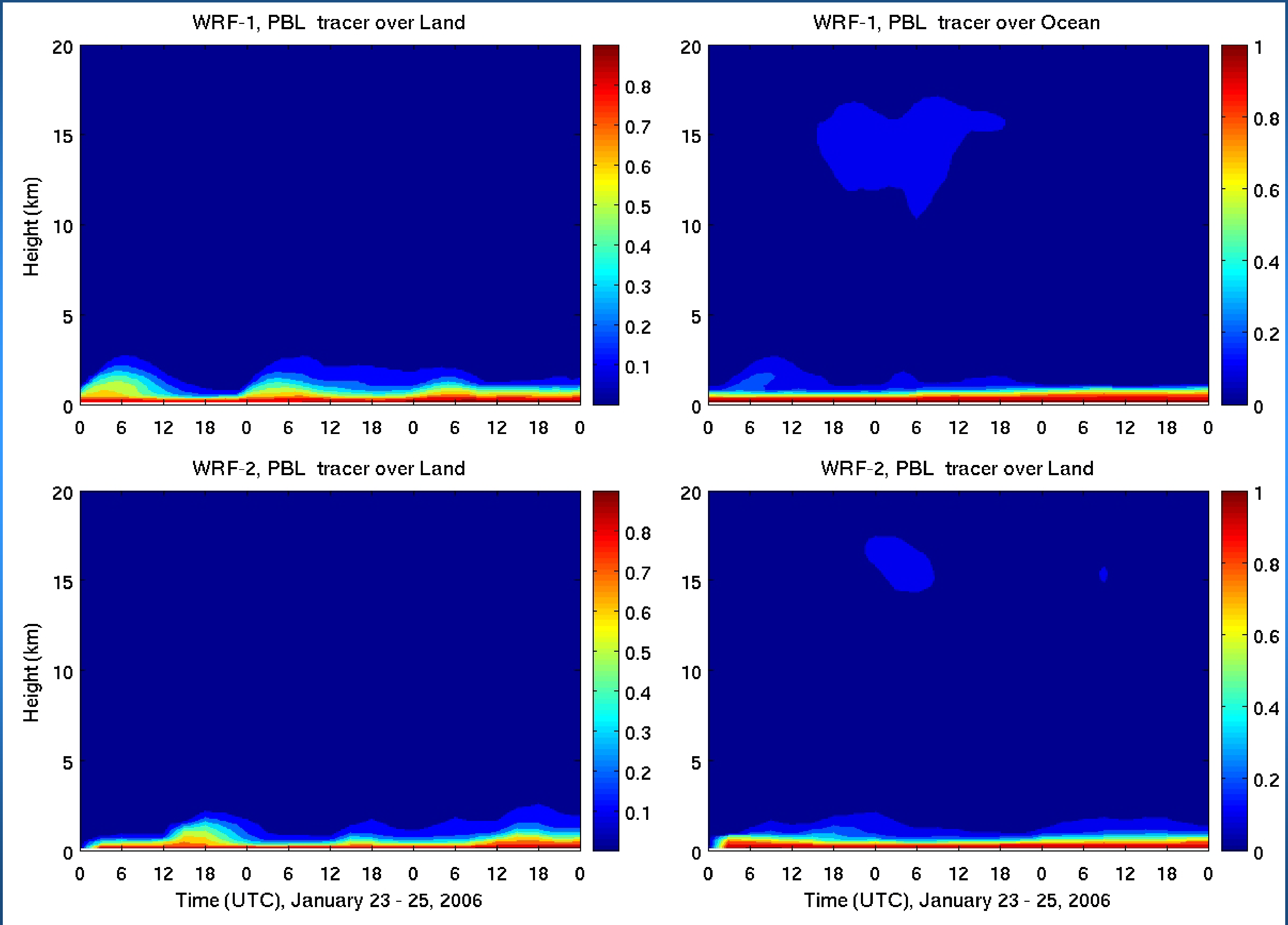
Convective clouds (W>3 m/s) over land and ocean

Cloud condensate



Cloud fraction




WRF-1, PBL tracer over Land
WRF-1, PBL tracer over Ocean
WRF-2, PBL tracer over Land
WRF-2, PBL tracer over Land
Height (km)
Time (UTC), January 23 - 25, 2006
0 6 12 18 0 6 12 18 0 6 12 18 0
0 5 10 15 20
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
0 0.2 0.4 0.6 0.8 1

What do we see so far?

1. The inter-model spread is smaller for convective condensate than stratiform condensate. Although cloud condensate shows a great sensitivity to microphysics, microphysics is not a key factor to determine cloud amount.

2. All models are able to produce similar shape of profiles of mean vertical velocity, vertical velocity variance, and the third moment, although there is a large inter-model spread in the magnitude.

3. All LAMs produced compatible continental clouds to their maritime counterparts. The tracer analyses show that the land initiated convection is shallow, generally below 4 km, suggesting that the continental convection is of secondary importance to monsoon deep convective cloud system.

Summary

1. Can LAM simulations reproduce the observed dynamic and thermodynamic structure during the monsoon event?

Yes, all LAMs are able to produce the dynamic and thermodynamic fields consistent with observations.

2. Can LAMs realistically simulate the observed life cycle of monsoon convective systems ?

Not all models are able to produce the monsoon deep convective clouds associated with cyclones and the following outflow cirrus clouds. The reason is complex. Further investigation is needed.

3. Do models produce consistent cloud properties and structure? How big is the inter-model spread in cloud fields?

Models show a great discrepancy in the simulated cloud fields. The difference of cloud water, ice, snow, and graupel between models can be as large as a factor of 10.

4. Do LAMs produce the vertical velocity fields consistent with those derived from CPOL radar?

Only partially consistent. Modeled vertical velocity appears to be too strong. The inter-model spread of velocity statistics is pretty large.

5. Can LAMs realistically reproduce the diurnal cycle of the convective clouds initiated by the mainland and islands? How does surface heterogeneity, in particular the land/sea contrast, affect the cloud evolution during the monsoon event?

LAMs do produce the diurnal variation of convection initiated by the land, but some of them are not consistent with radar observation. The tracer analyses show that the convection initiated by land is shallow and is of secondary importance to the monsoon deep convective cloud system.

6. How sensitive are the simulated cloud fields to cloud microphysics?

Cloud condensate shows a great sensitivity to cloud microphysics, but not cloud cover.

7. Can LAMs statistically produce the similar cloud fields to those simulated by CRMs if they are configured at the similar resolution?

Quite promising.