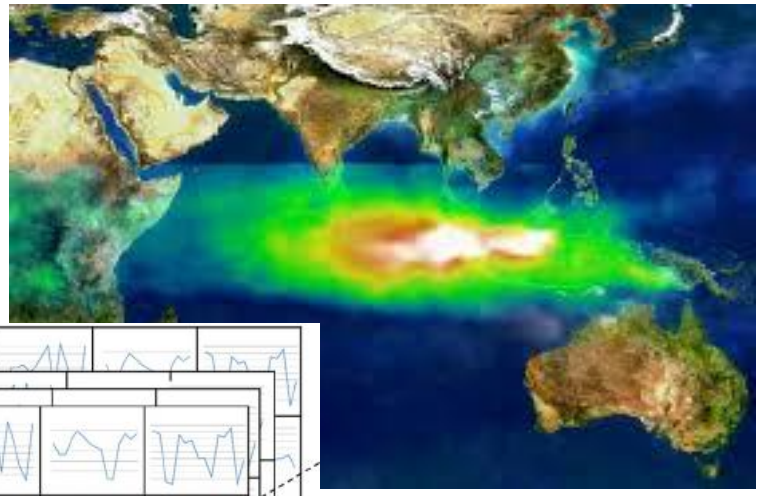
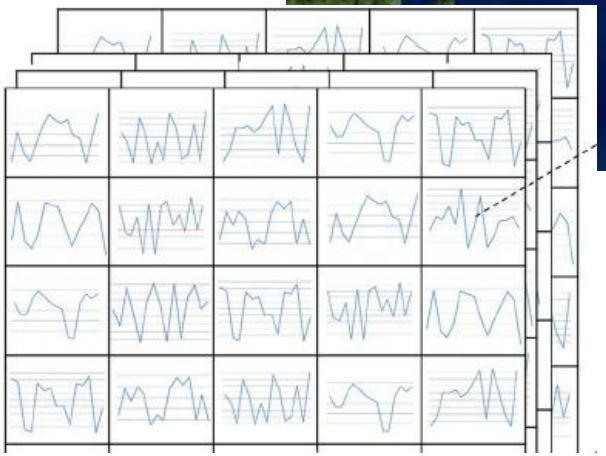
Modeling of smoke transport over Southeast Asia: an ensemble analysis of uncertainties





Cui Ge

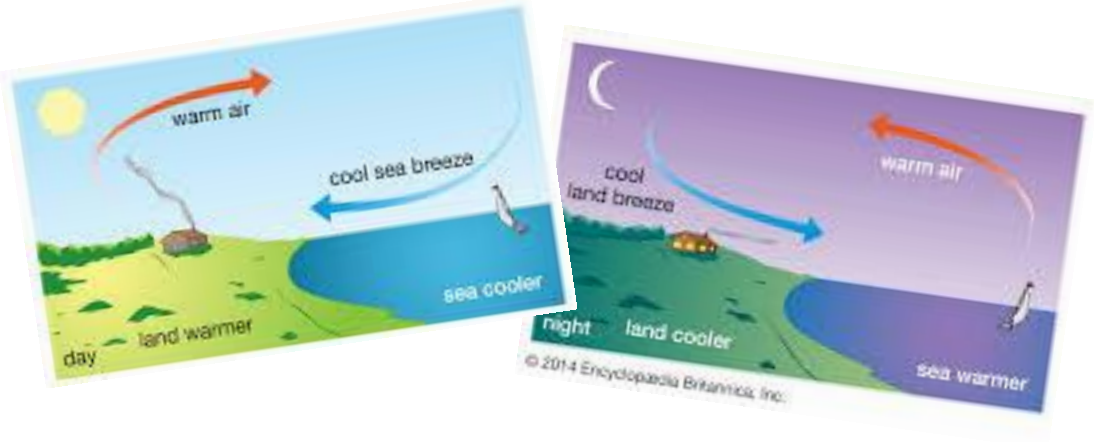
Jun Wang

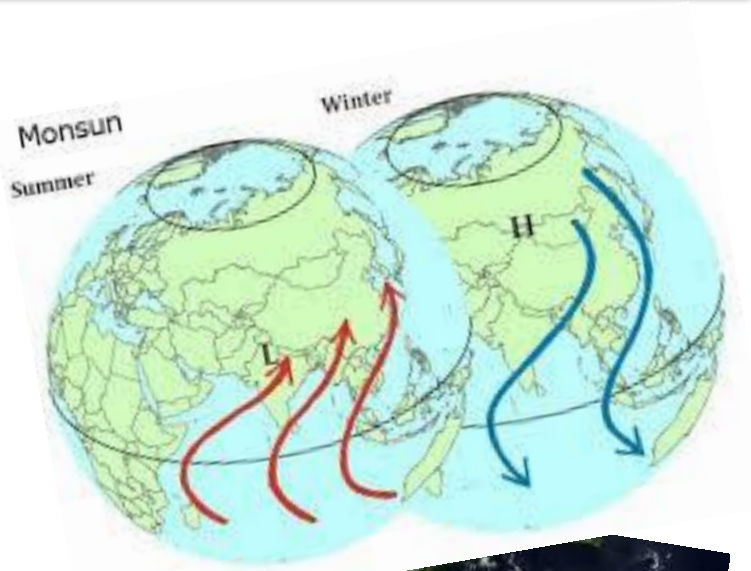
Jeffrey S. Reid

7seas meeting

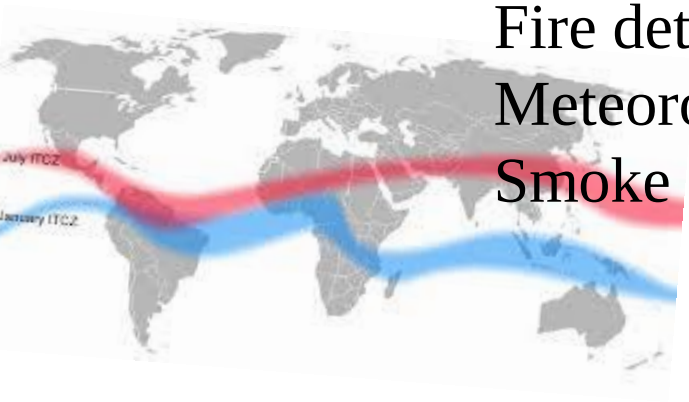
Sep. 20, 2016

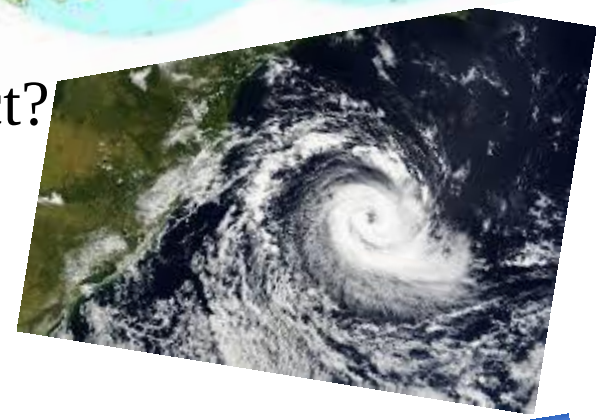
Challenges for mesoscale modeling

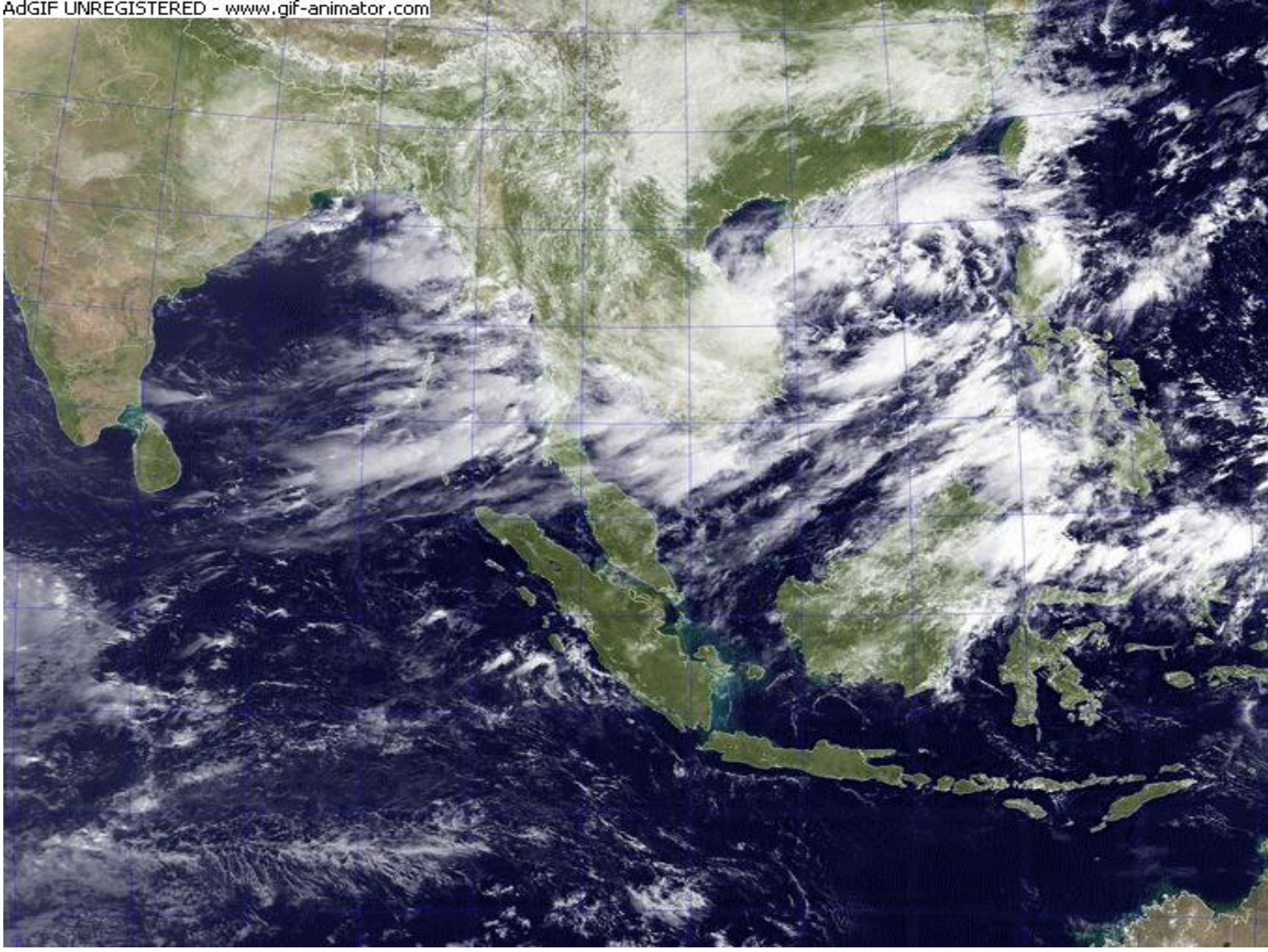




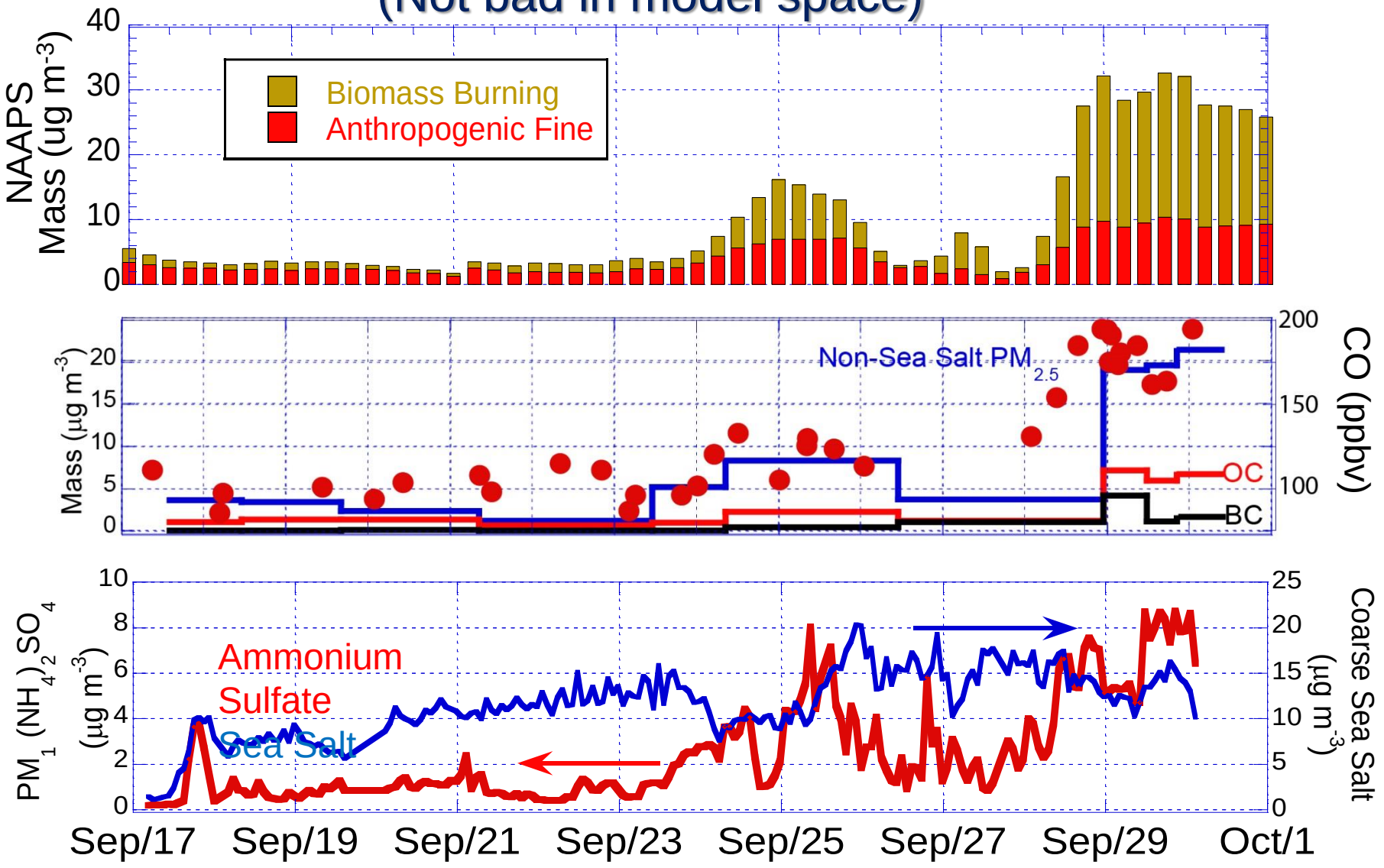
Fire detection ?
Meteorology forecast?
Smoke & cloud radiative impact?







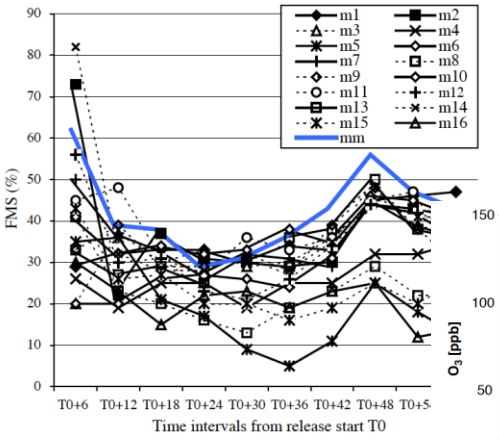
2011 Cruise Time Series
Northern Palawan Archipelago
(Not bad in model space)



Ensemble approach

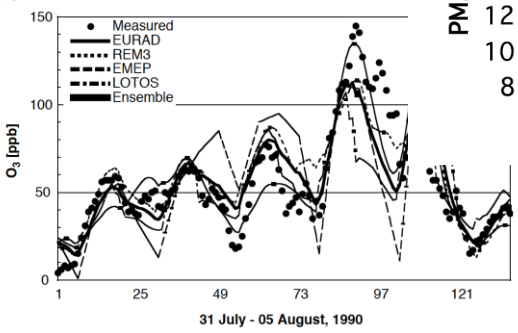
The ensemble forecast has been operational in all major weather prediction agencies for decades [*Kalnay*, 2002], only limited studies have applied it to the air quality forecast modeling.

radionuclides (16 models)



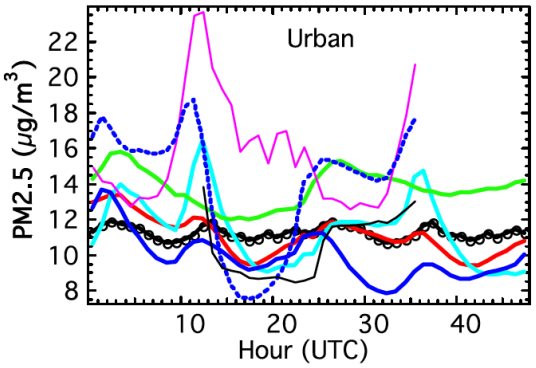
Galmarini et al. 2004

O_3 (4 models)



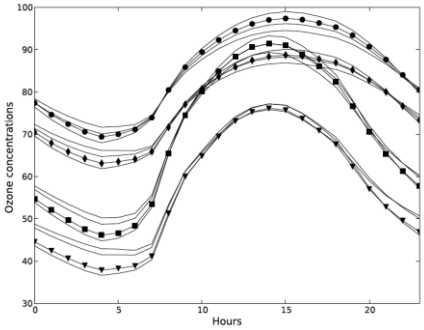
Delle Monache and Stull, 2003

$PM_{2.5}$ (7 models)



McKeen et al. 2007

O_3 (16 simulations)



Mallet and Sportisse, 2006

Above studies focused on the mid-latitude regions
& no biomass burning emissions

Ensemble simulation members

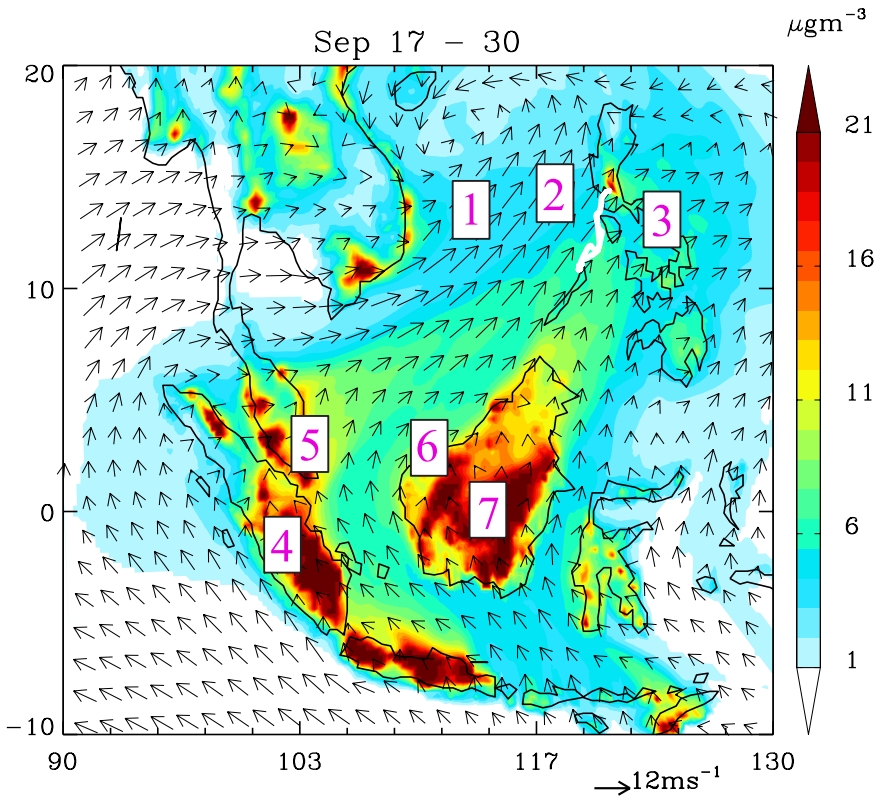
WRF-Chem 24 ensemble members

Meteorological data: FNL & ERA

Emission: e1 & e2 FLAMBE fire

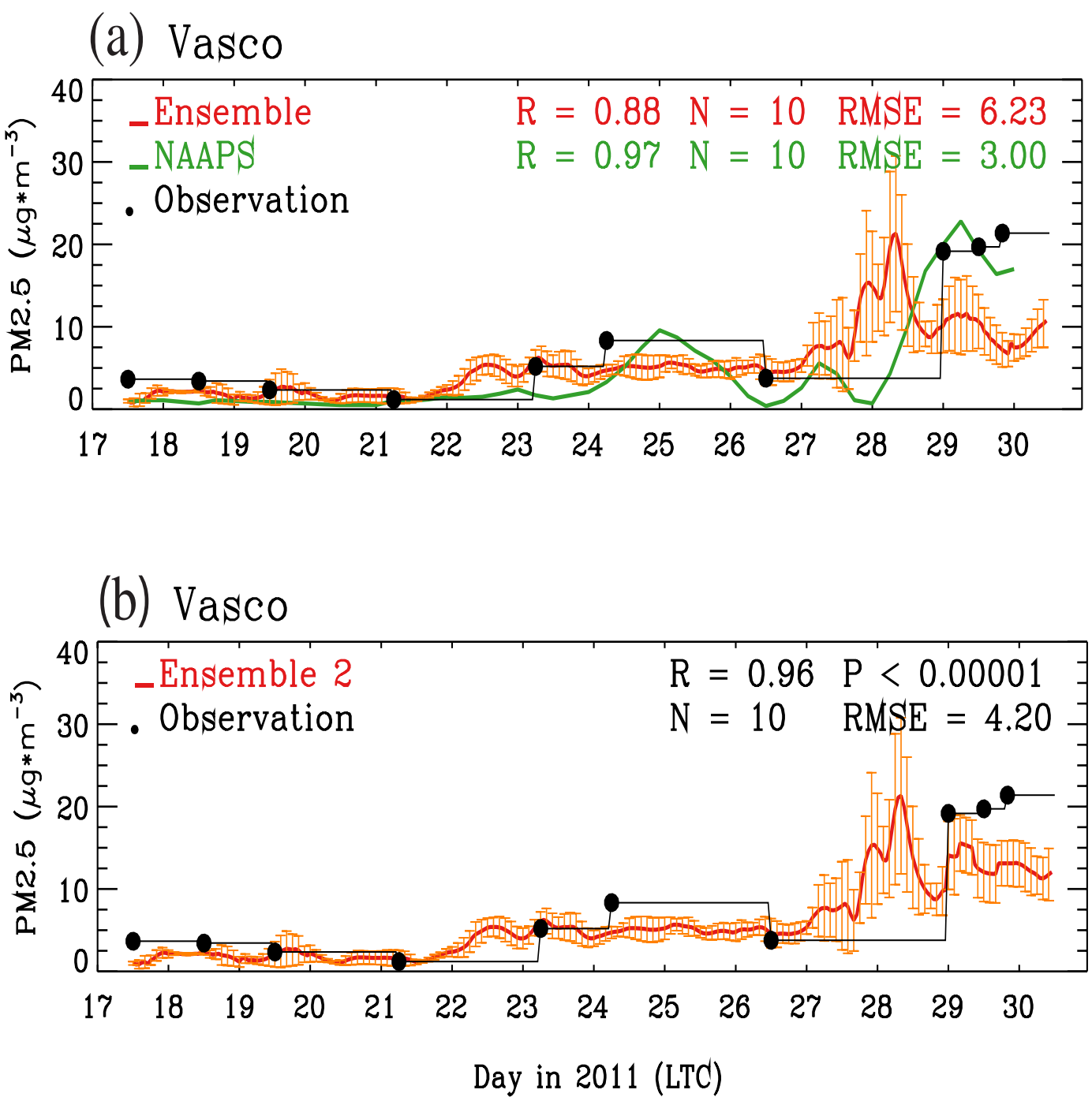
Cumulus scheme: G3 & BMJ

Injection height: 300, 800, 1200 m

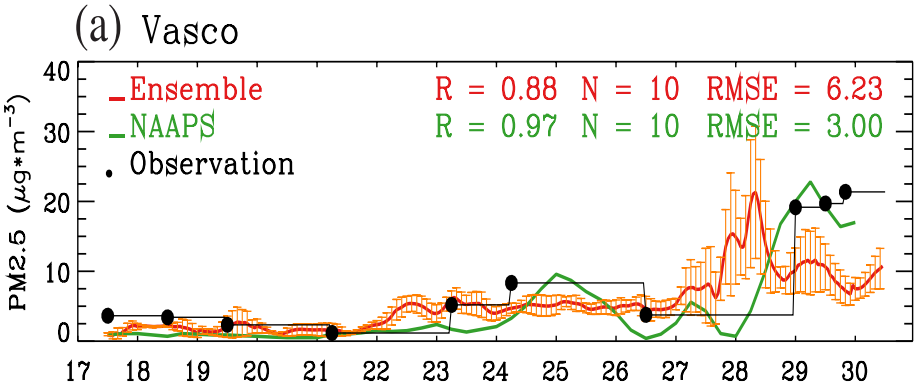


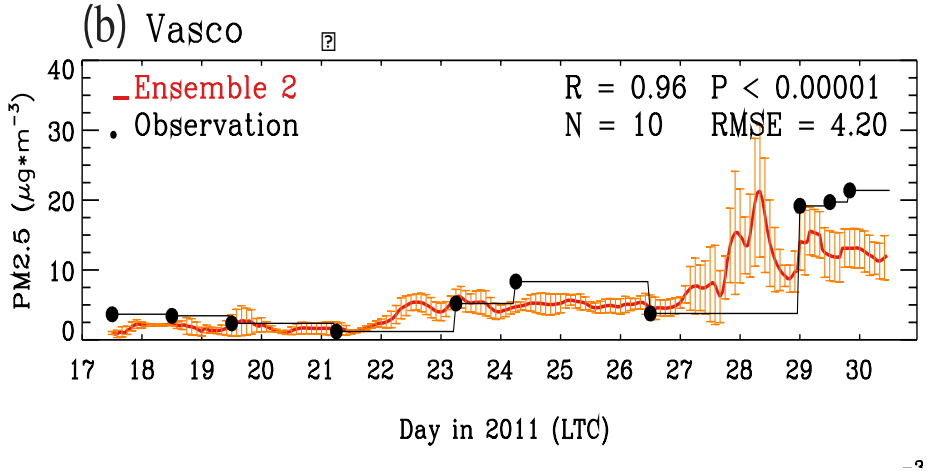
e1: regular FLAMBE
e2: the 2 days maximum FLAMBE emission

1—South China Sea, 2—Vasco,
3—Philippines, 4—Sumatra,
5—Singapore, 6—Kuching, 7—Borneo

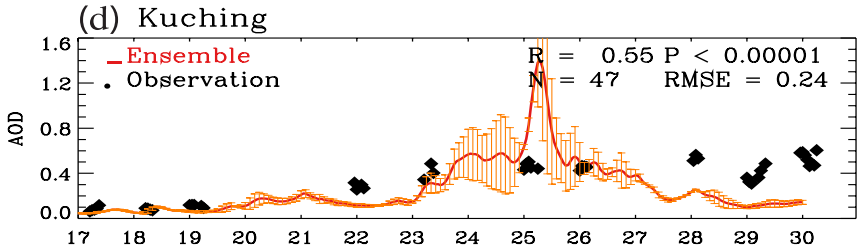

(a) Vasco
Ensemble
NAAPS
Observation
R = 0.88 N = 10 RMSE = 6.23
R = 0.97 N = 10 RMSE = 3.00
PM2.5 (μg*m⁻³)
0
10
20
30
40
17 18 19 20 21 22 23 24 25 26 27 28 29 30
(b) Vasco
Ensemble 2
Observation
R = 0.96 P < 0.00001
N = 10 RMSE = 4.20
PM2.5 (μg*m⁻³)
0
10
20
30
40
17 18 19 20 21 22 23 24 25 26 27 28 29 30
Day in 2011 (LTC)

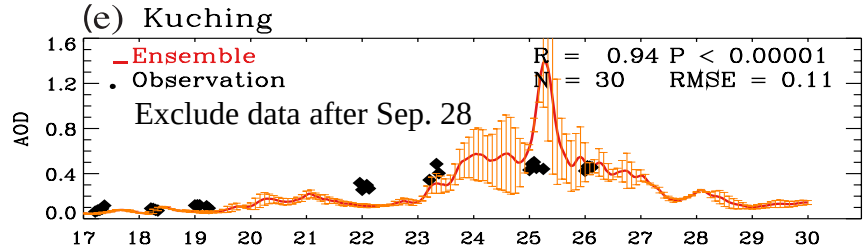
Ensemble Simulation

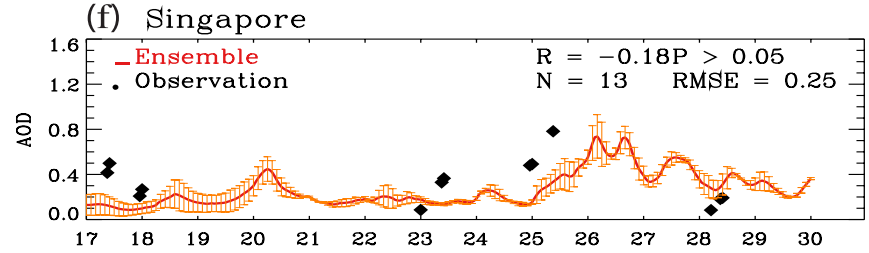


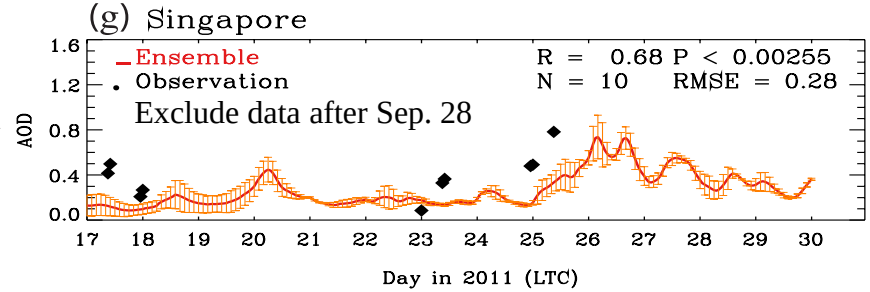


Ensemble 2: scale up from 27x27 km to 50x50 km

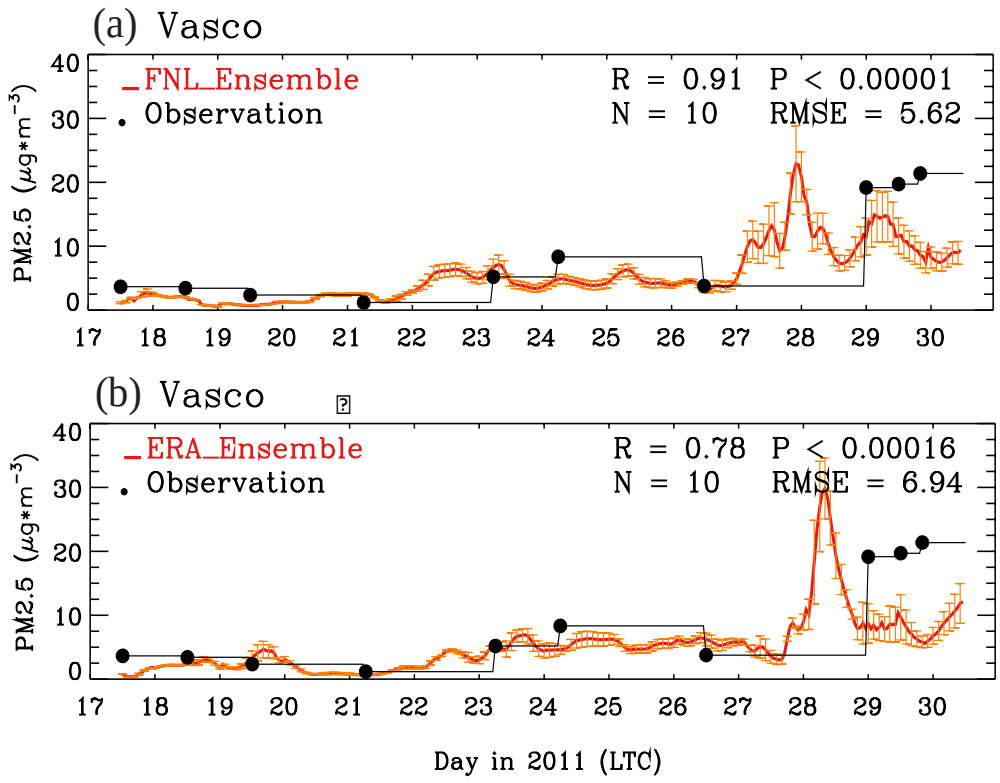


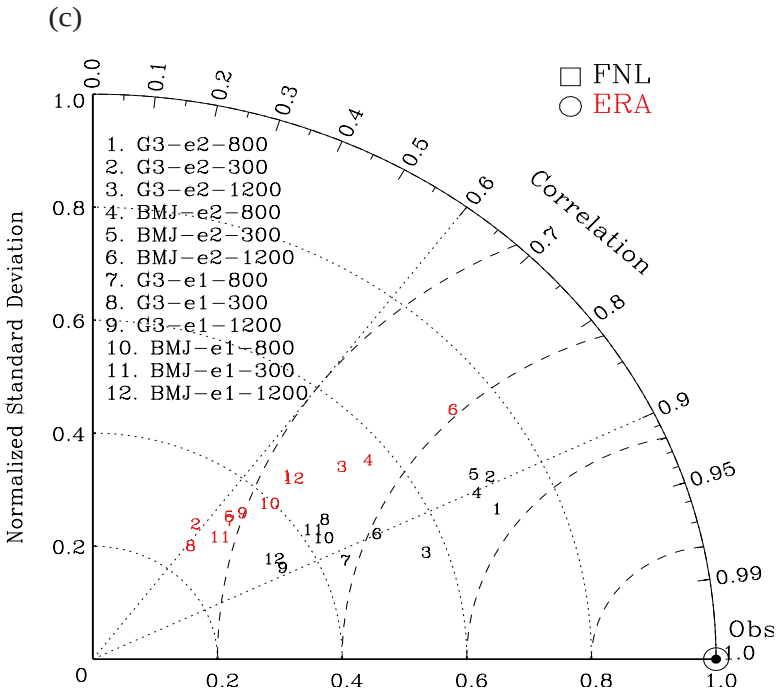




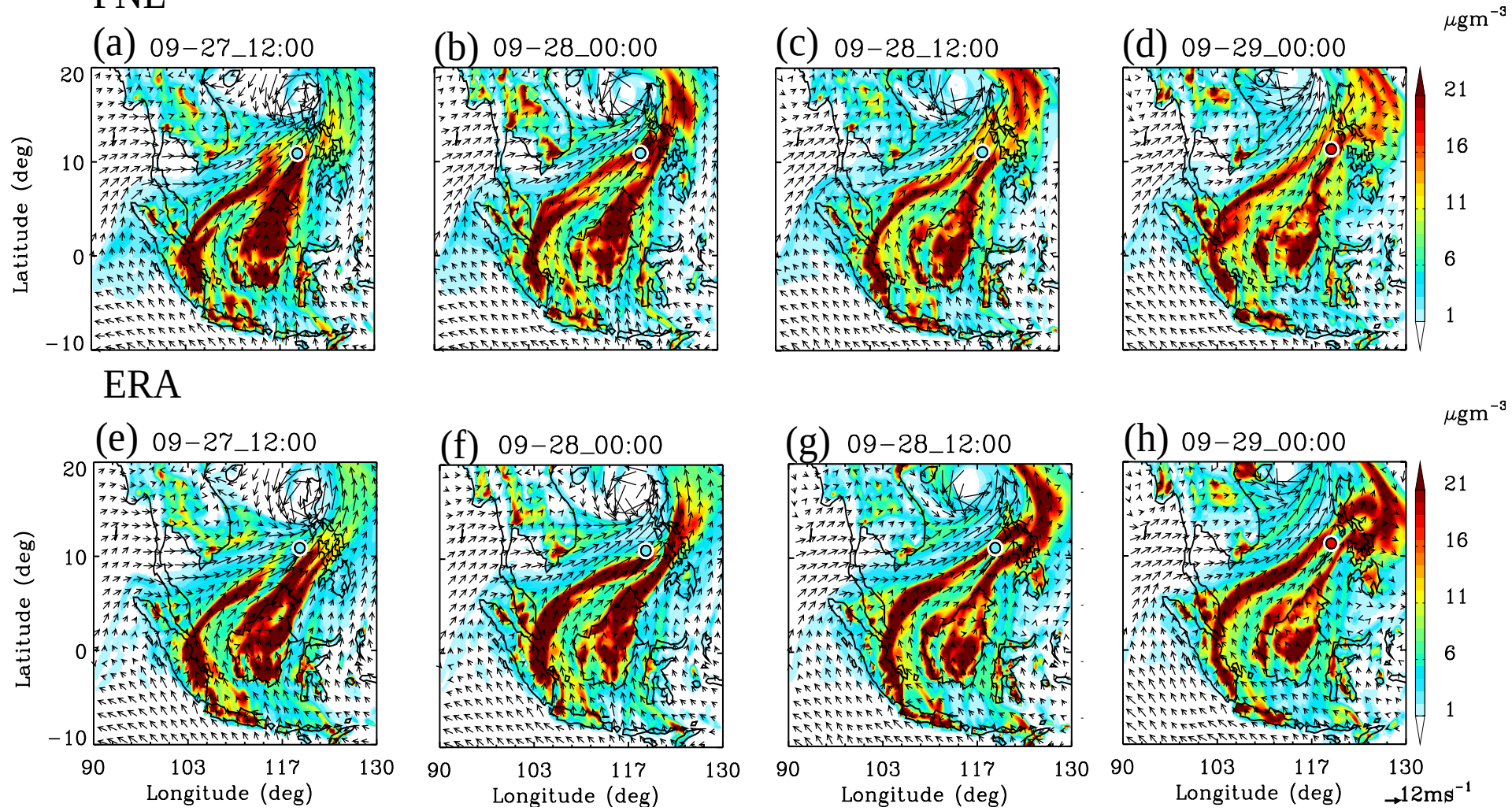


FNL & ERA simulation

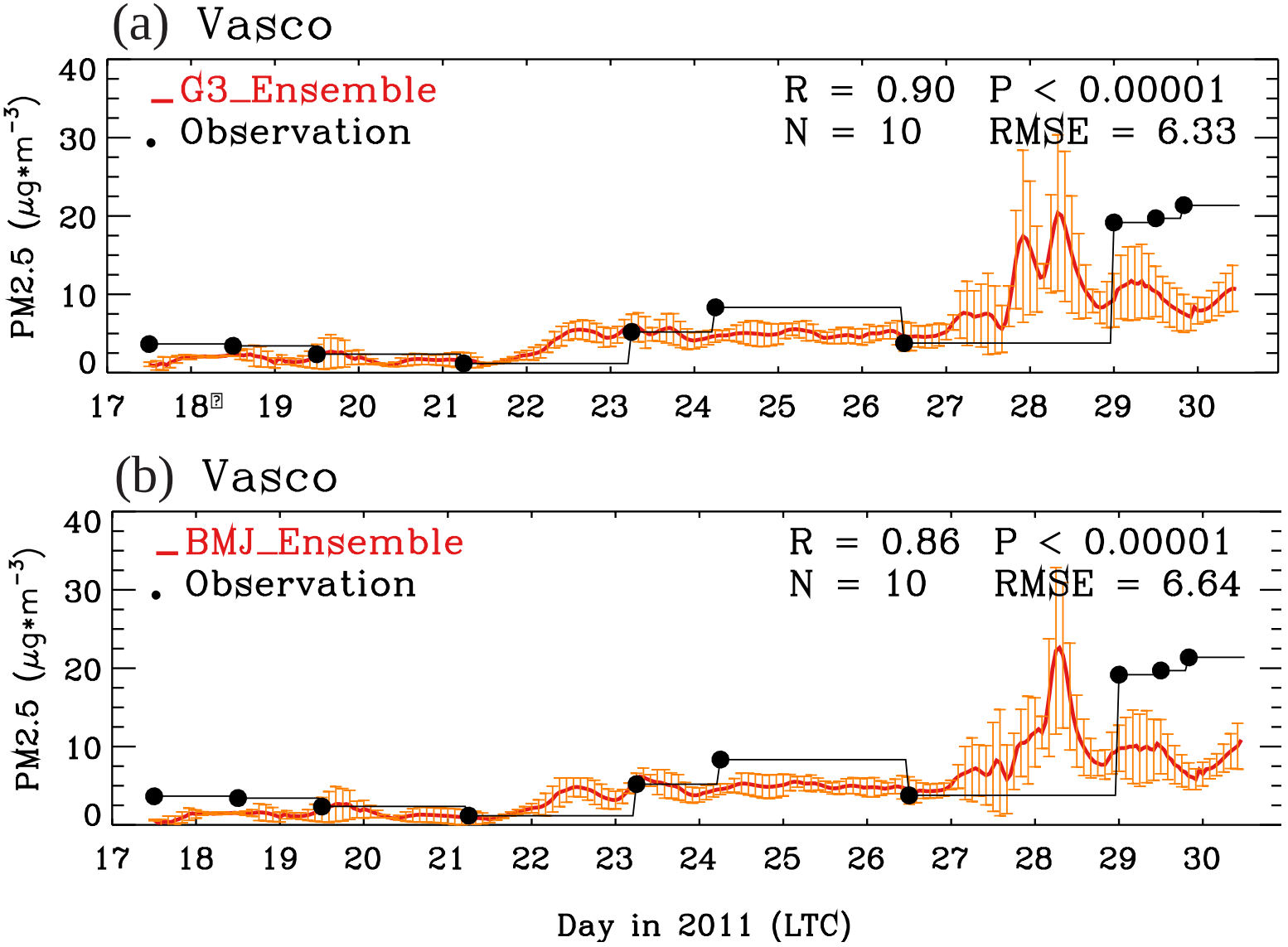




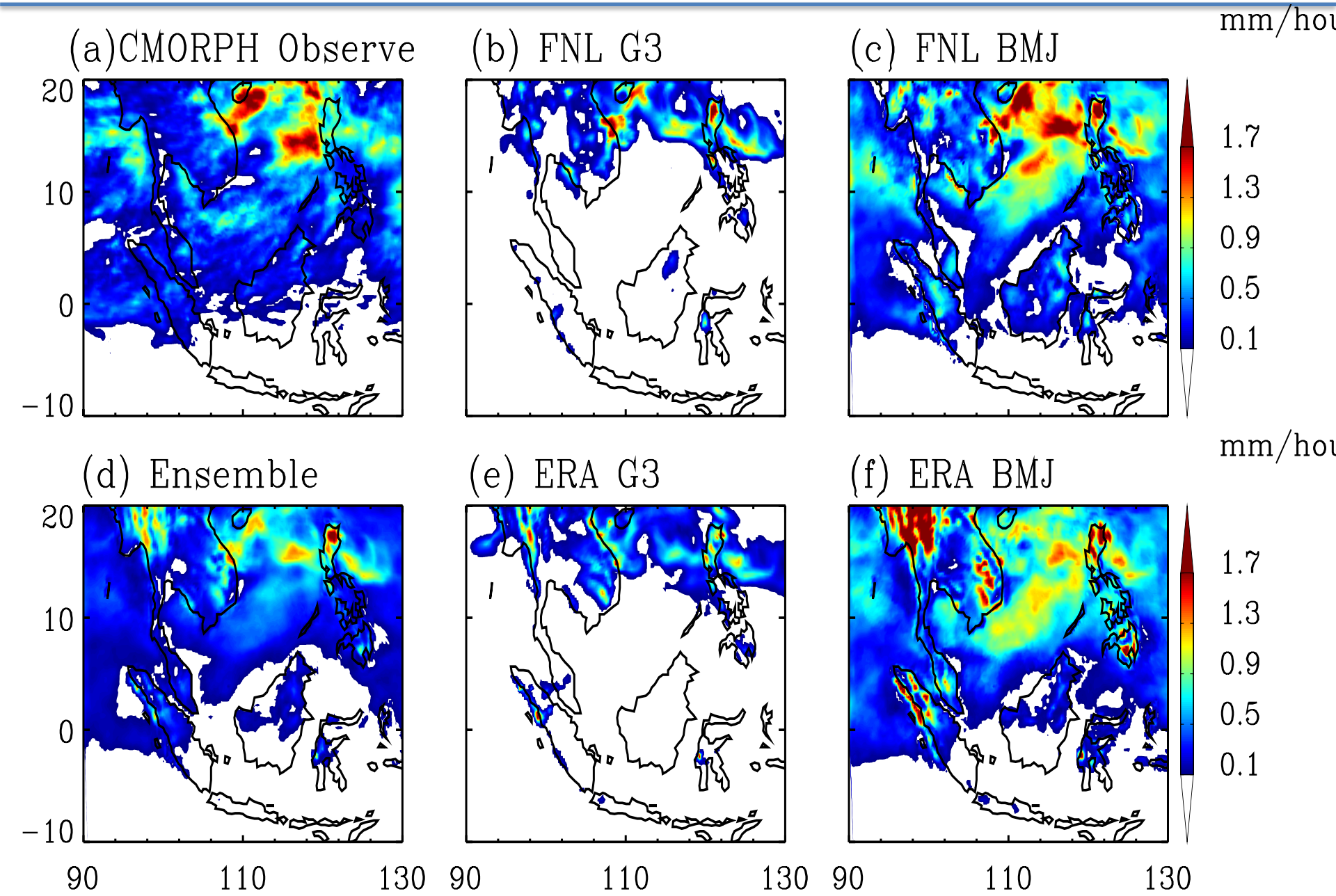
FNL & ERA simulation



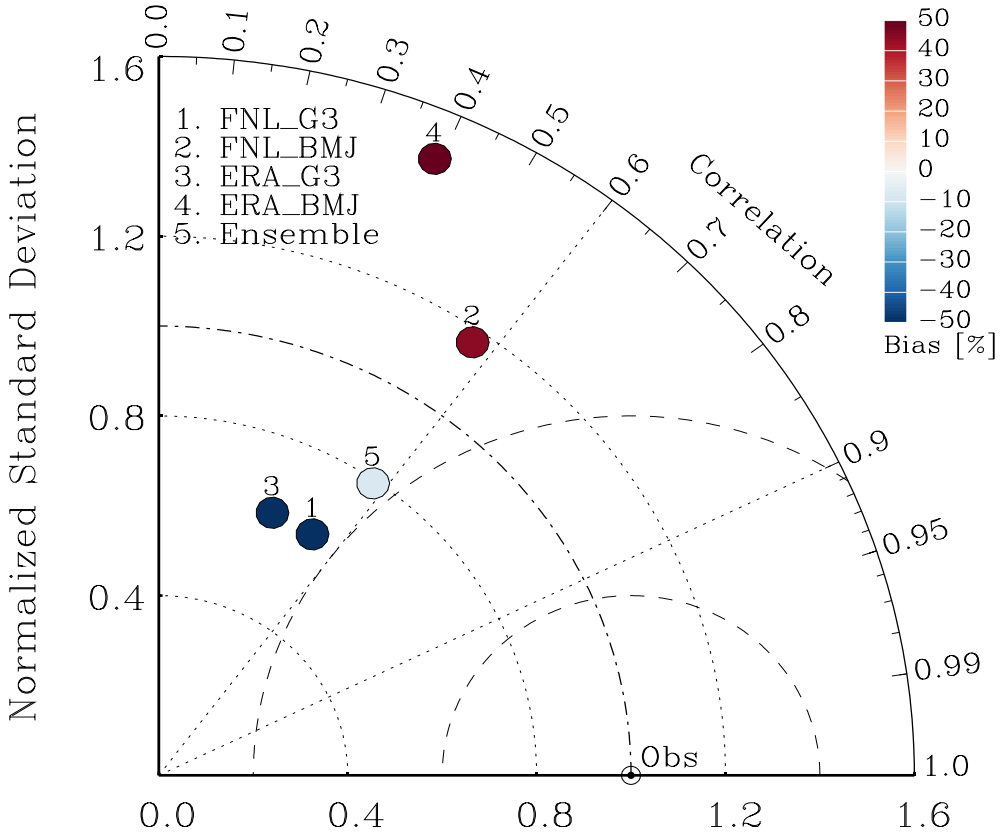
G3 & BMJ cumulus parameterization



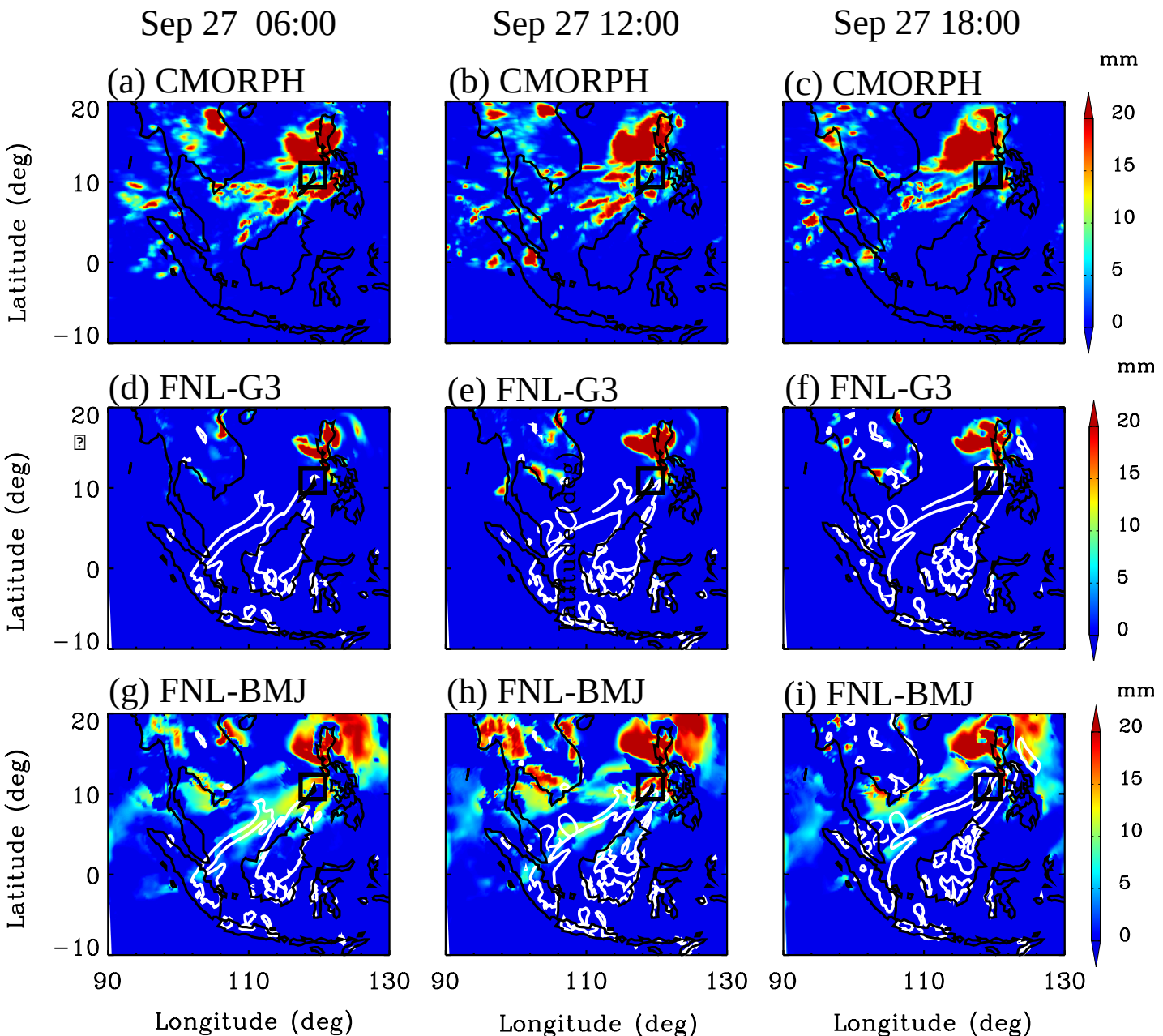
2-weeks (Sep. 17 - 30) averaged precipitation



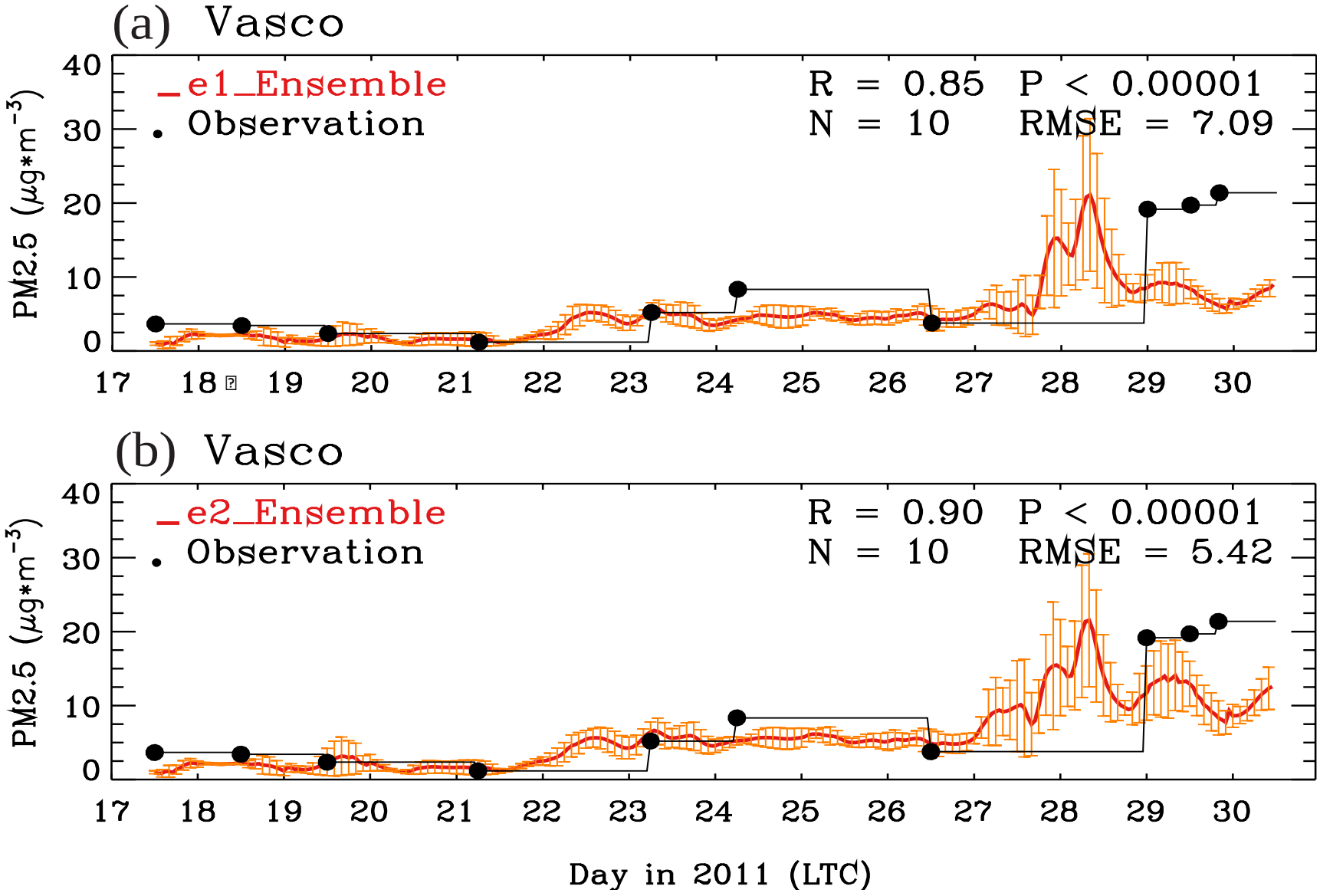
2-weeks averaged precipitation



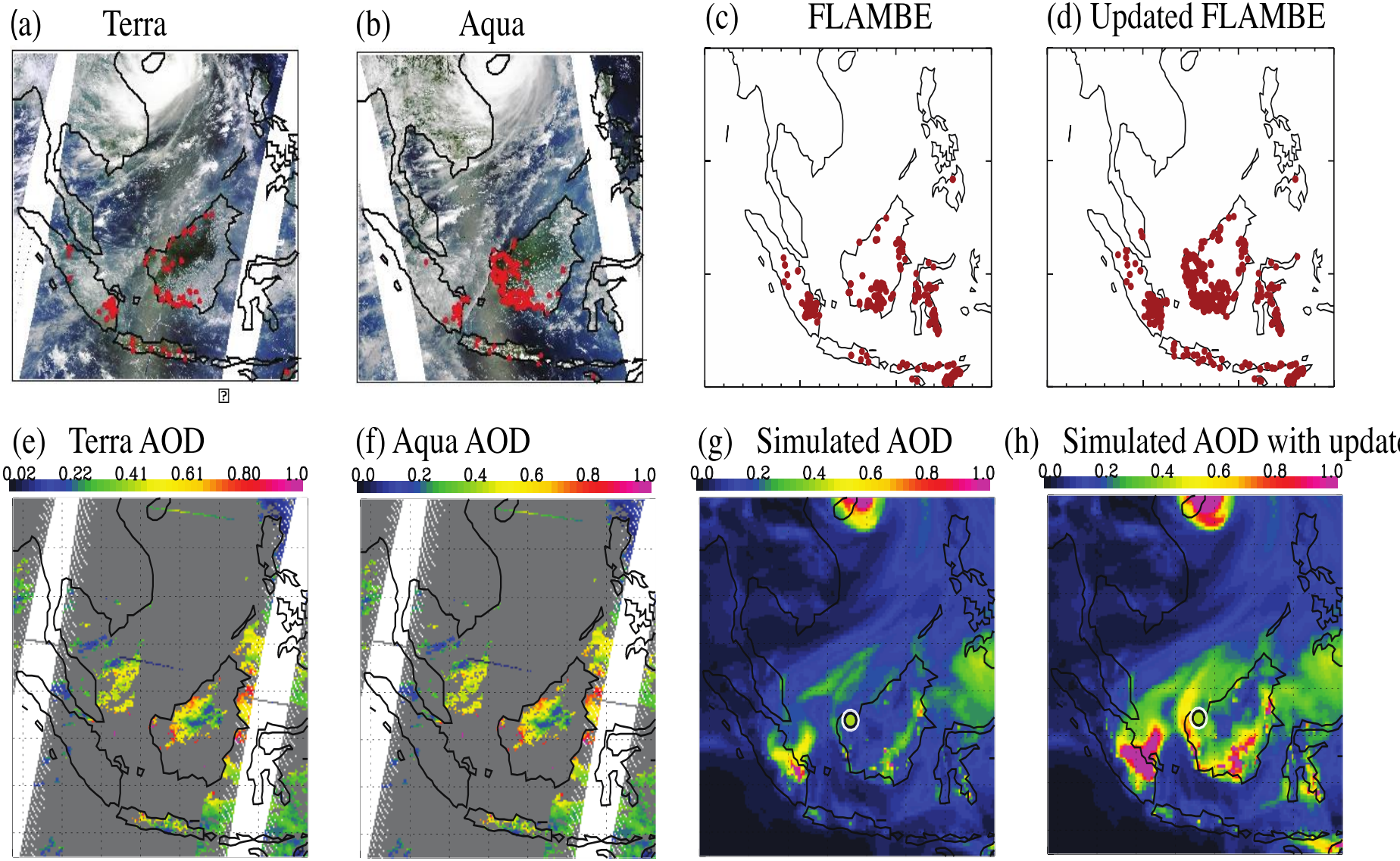
$PM_{2.5}$ and precipitation



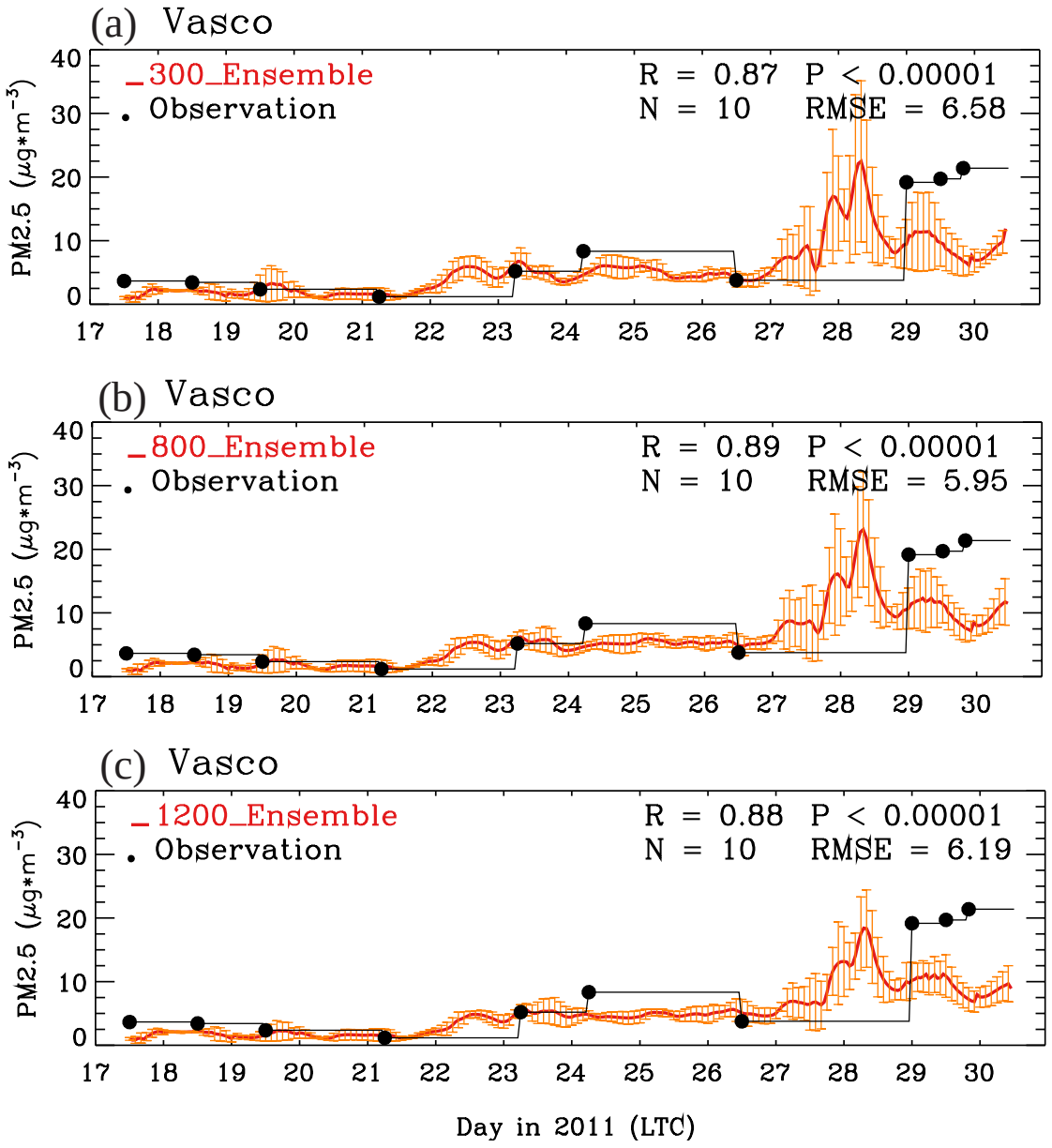
Regular (e1) & 2-days maximum (e2) FLAMBE



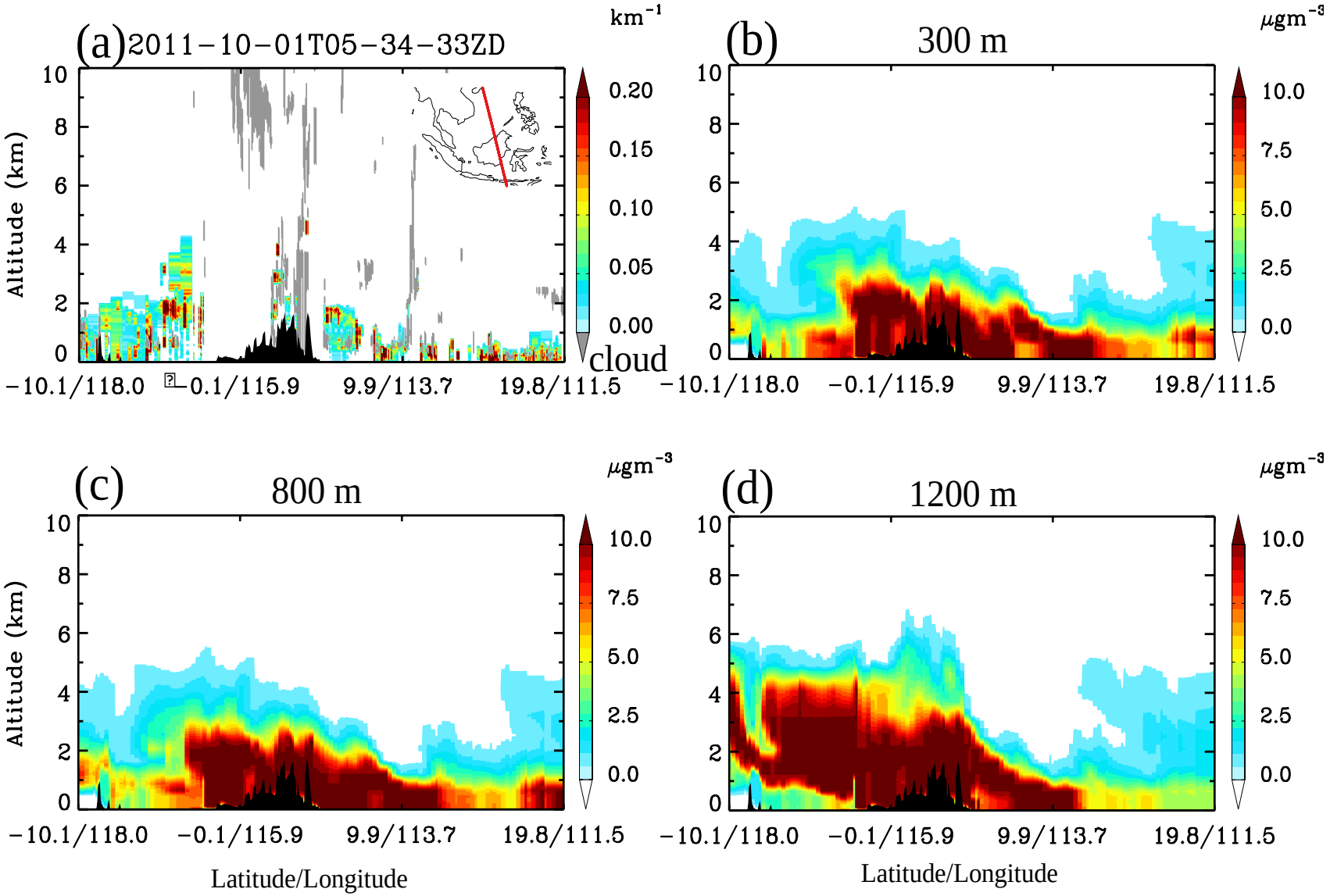
Updated emission testing based on Terra & Aqua



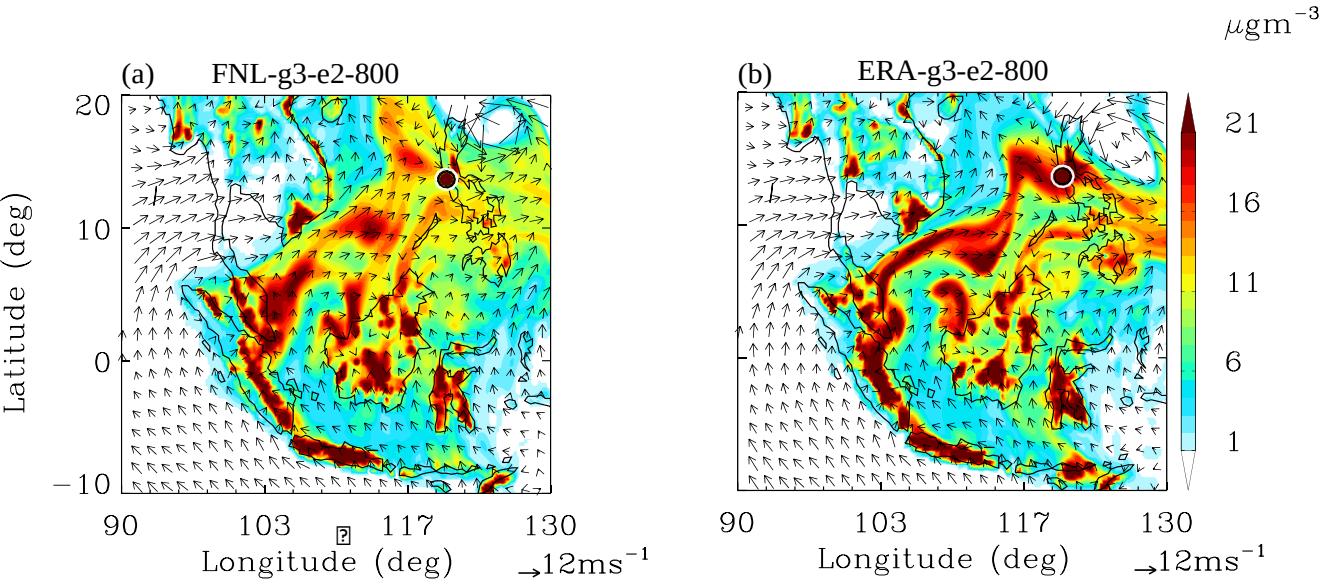
Smoke injection height – 300m, 800m, 1200m



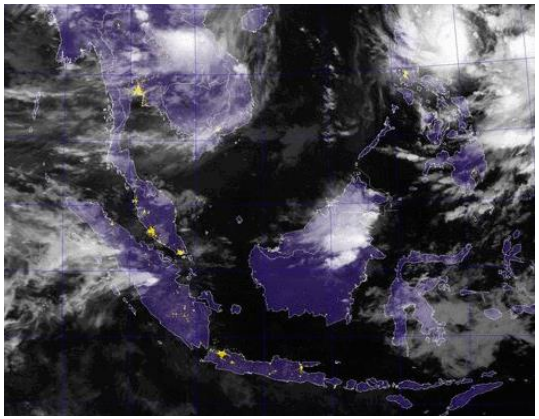
Smoke injection height – 300m, 800m, 1200m



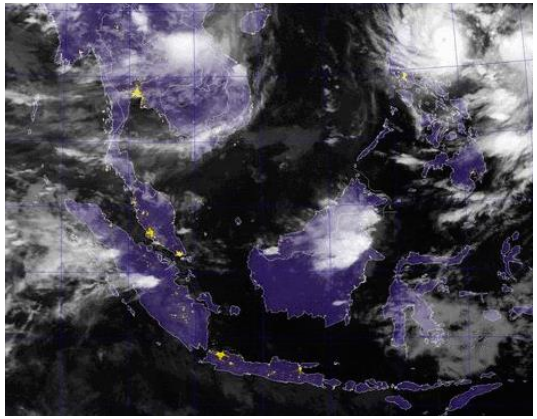
Wind differences in 2011-09-30 18:00 UTC



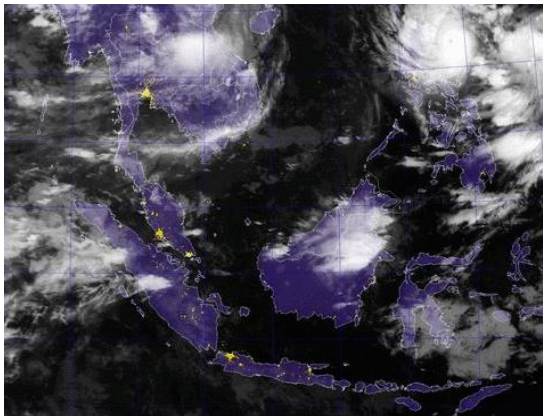
(d) 2011-09-30 17:32



(e) 201 1-09-30 18:32



(f) 2011-09-30 19:32



Discussion and conclusions

1, Simulation uncertainty: meteorology initial and boundary condition, and FNL-driven simulations outperformance ERA-driven simulations.

2, The second big uncertainty is due to different fire emission, the 2 days maximum FLAMBE emission gives superior results than the regular FLAMBE emission.

3, From the two weeks' average, the cumulus scheme G3 underestimates the precipitation over most MC ocean area. The cumulus scheme BMJ has slightly underestimate Borneo coast area convection hence the precipitation. And the ensemble mean of precipitation gives a best agreement with the observation.

Thank you

Background

(1) The interplay of topography, sea breeze, and typhoon that regulates the smoke transport (*Wang et al.* AR, 2013)

Smoke source area & adjacent oceans

(2) Coupling of smoke direct radiative effect below and above the low-level clouds (*Ge et al.* ACP, 2014)

Smoke transport to Philippians

(3) Ensemble simulation using WRF-Chem (Weather Research and Forecasting model with Chemistry), and ship-based (Vasco) observation of aerosol composition data is used for the model validation

Ensemble simulation