Tropical, Convective-Scale NWP for Singapore: The 'SINGV' Project

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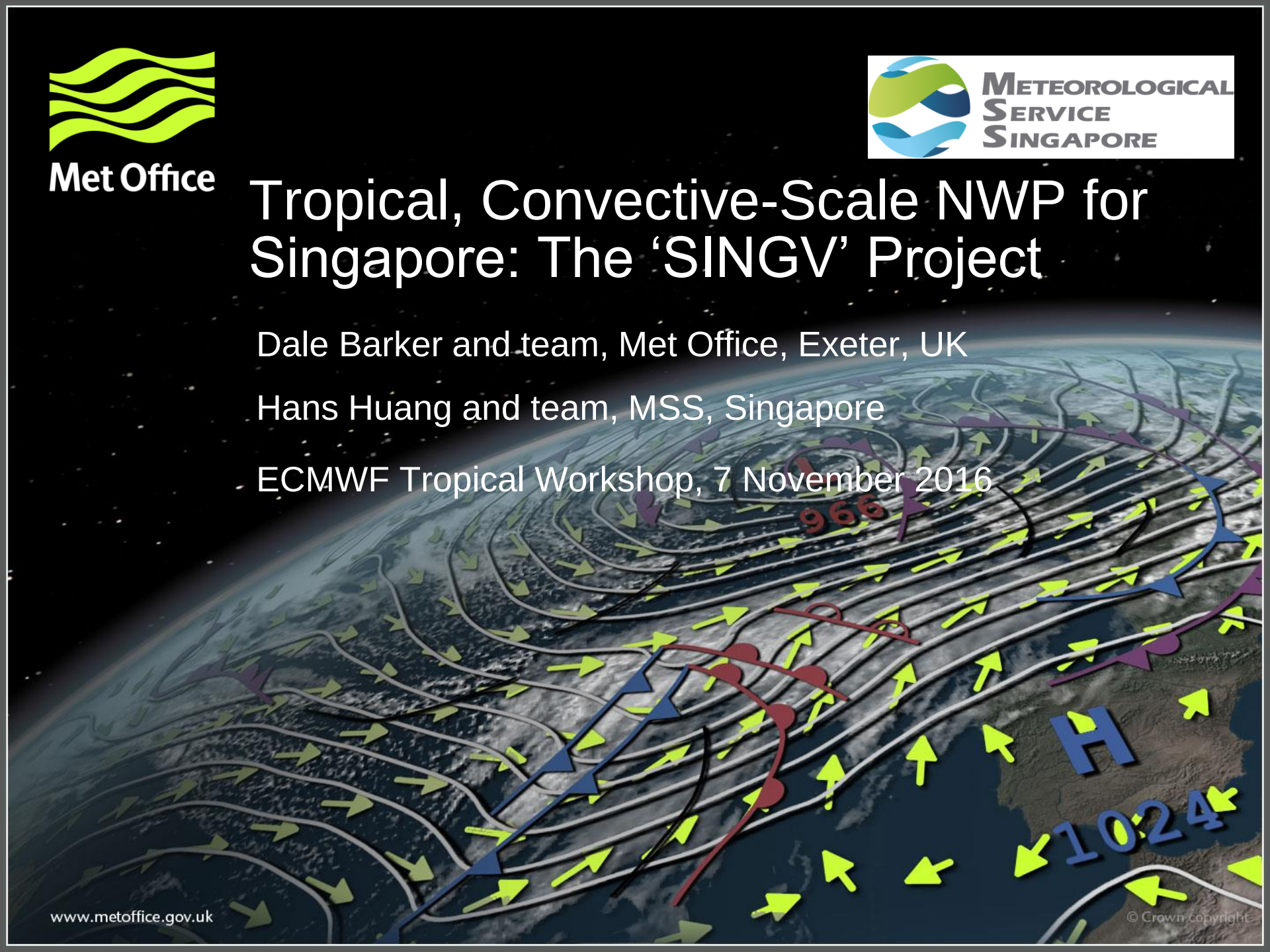
Hans Huang and team, MSS, Singapore

ECMWF Tropical Workshop, 7 November 2016



Outline

1. Singapore Weather

2. Global NWP: Skill In SE Asia

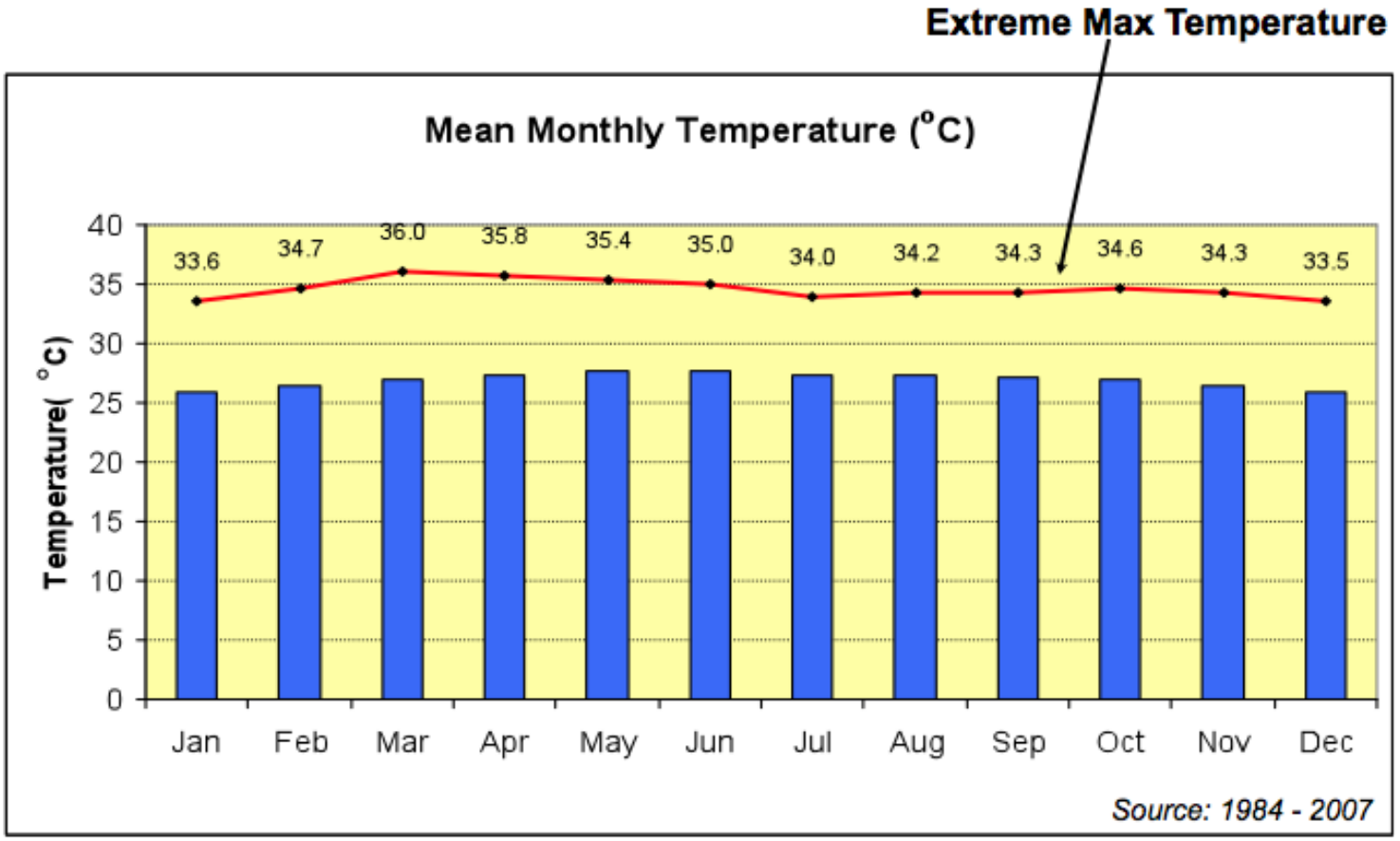
3. High-Resolution NWP: The SINGV Project
   a. UM / WRF Studies
   b. High-resolution UM studies
   c. Impact of UM driving model (UM, ECMWF)
   d. High-resolution data assimilation and observations

4. Future Work

5. Summary

Singapore Weather: Surface Temperature

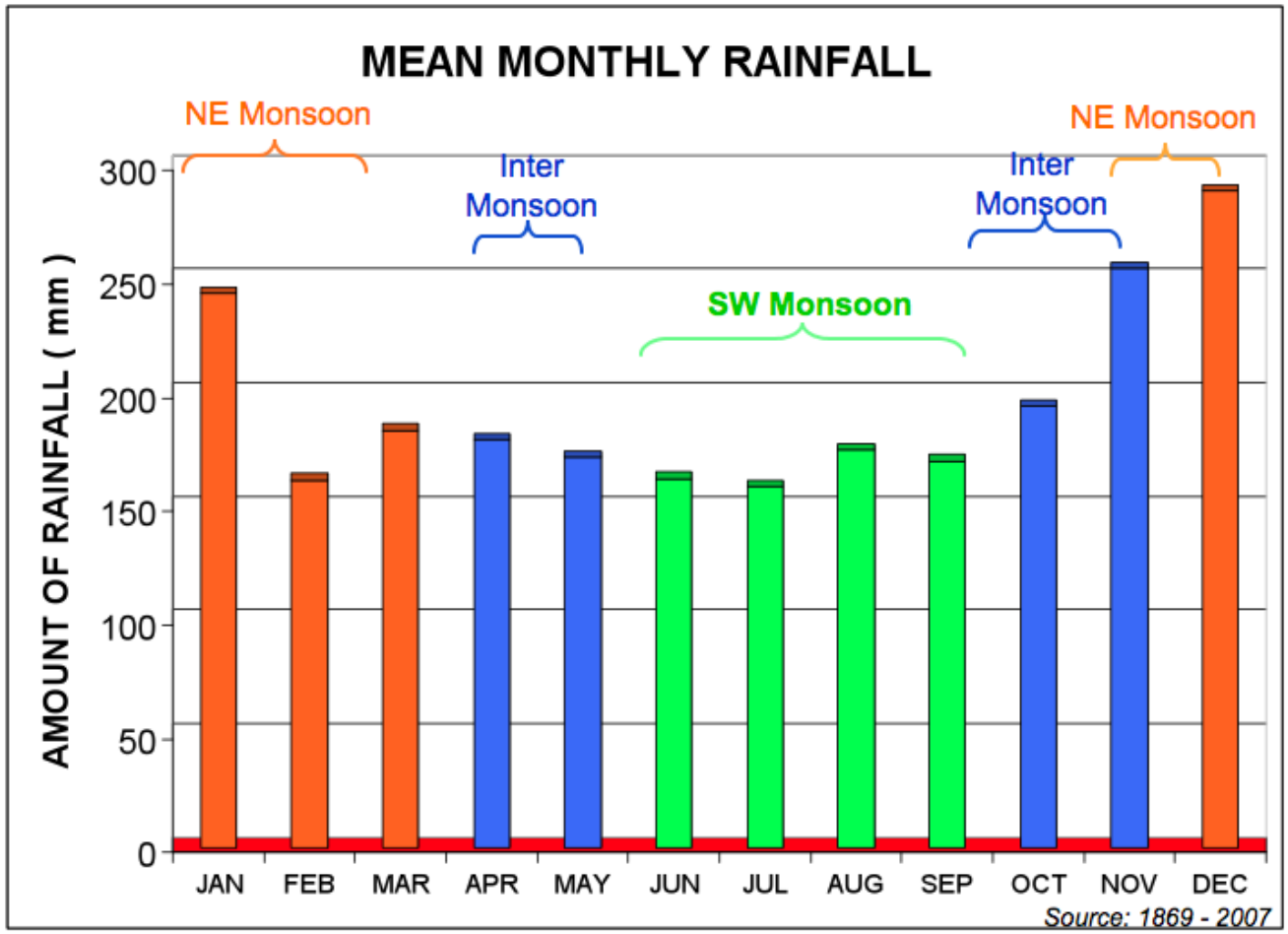
- Little variability through year….



Raizan, MSS

Singapore Weather: Rainfall

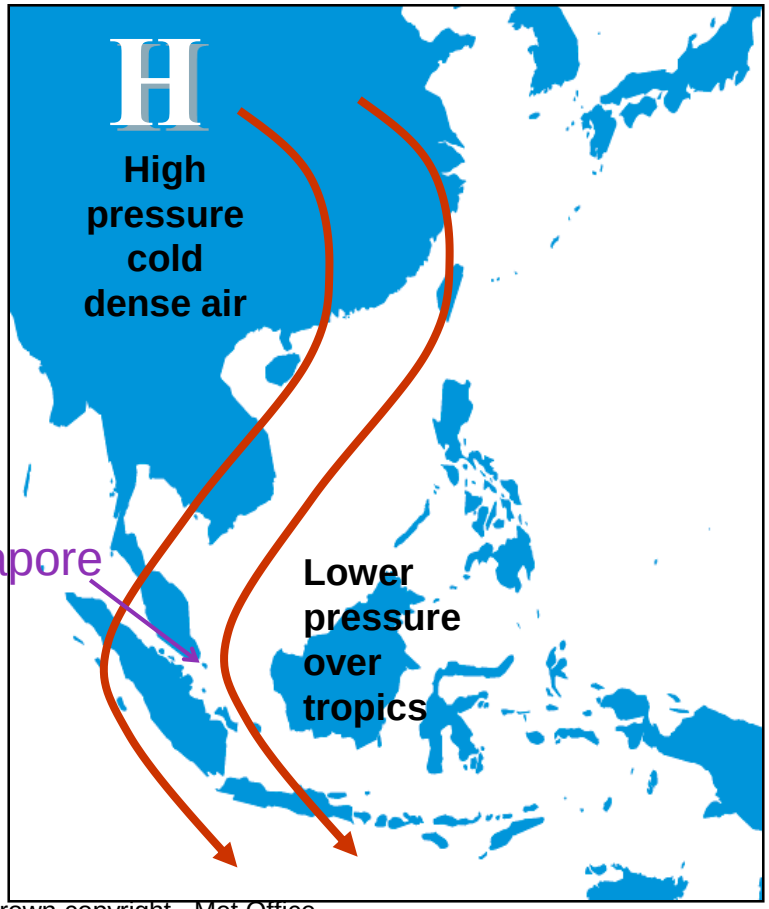
- NE (Dec-Mar) and SW (Jun-Sep) monsoon seasons

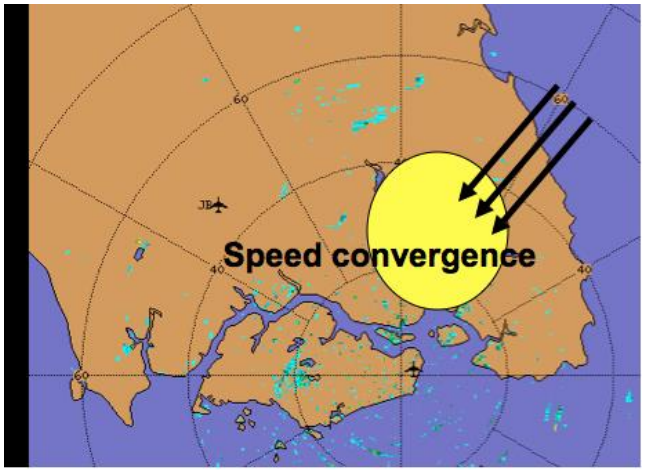


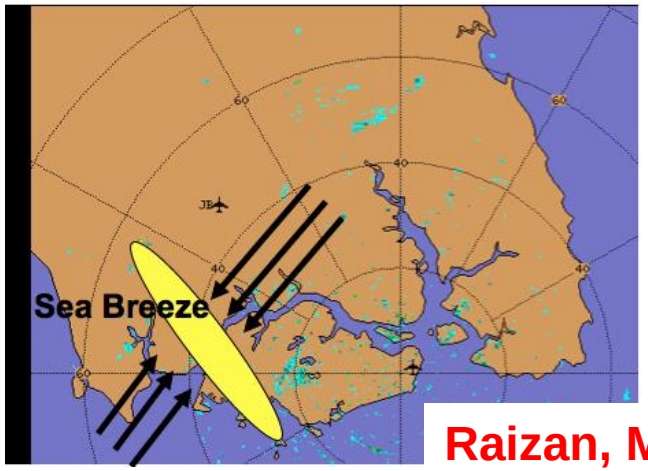
Raizan, MSS

Singapore Weather: NE Monsoon (~Dec-Mar)

- Strong NE winds, wet monsoon surge
- Speed convergence enhanced by convective heating, sea-breeze



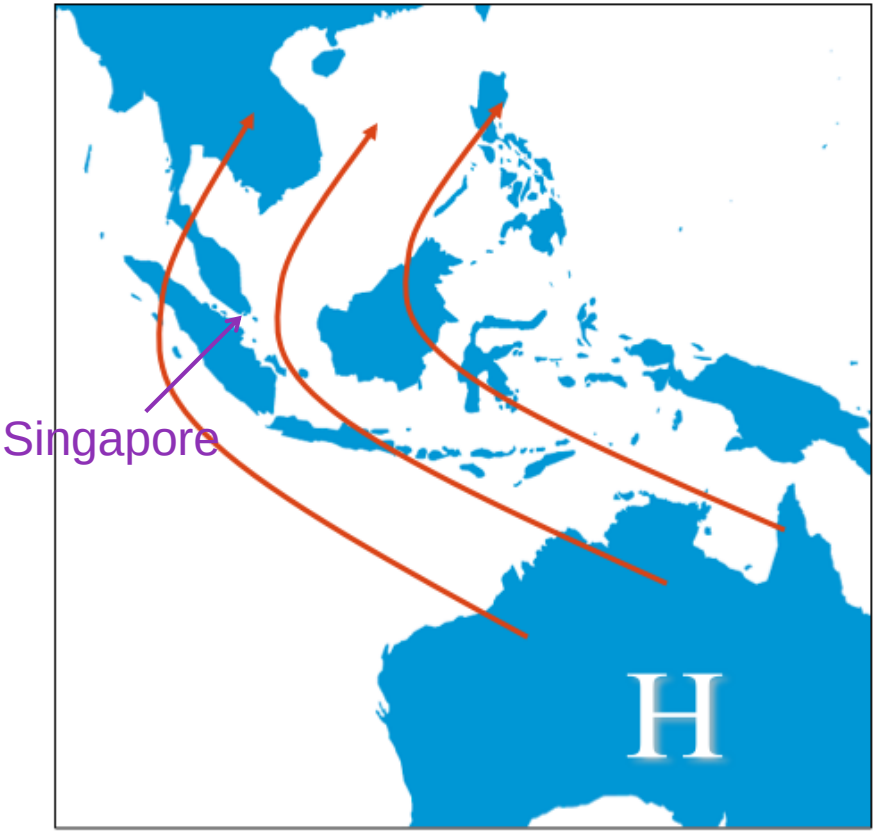


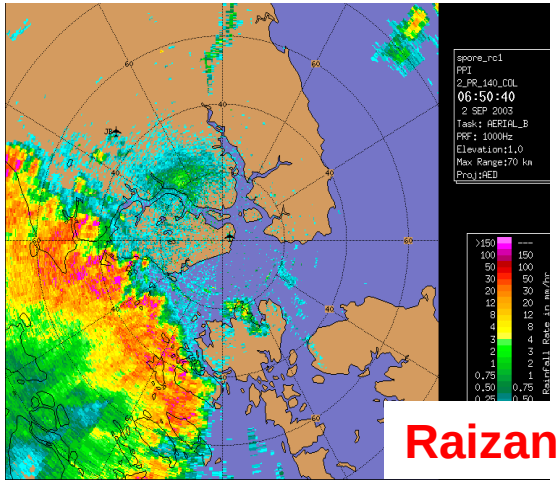


Raizan, MSS

Singapore Weather: SW Monsoon (~Jun-Sep)

- Speed convergence enhanced by local convective heating
- “Sumatra” squalls – pre-dawn/morning line of thunderstorms



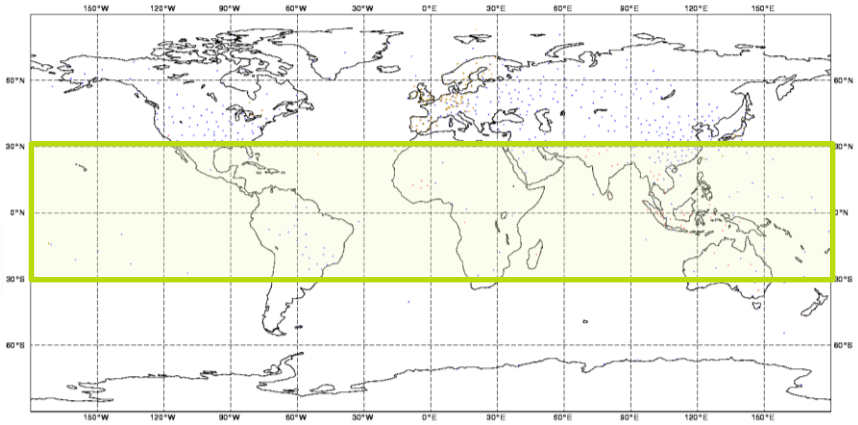


Raizan, MSS

2. Global NWP Skill in SE Asia

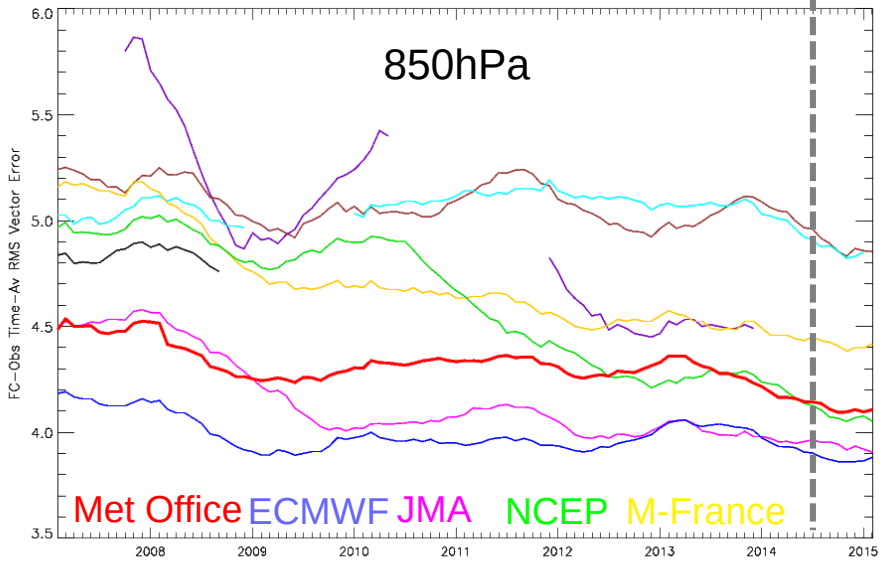
Tropical Winds Performance

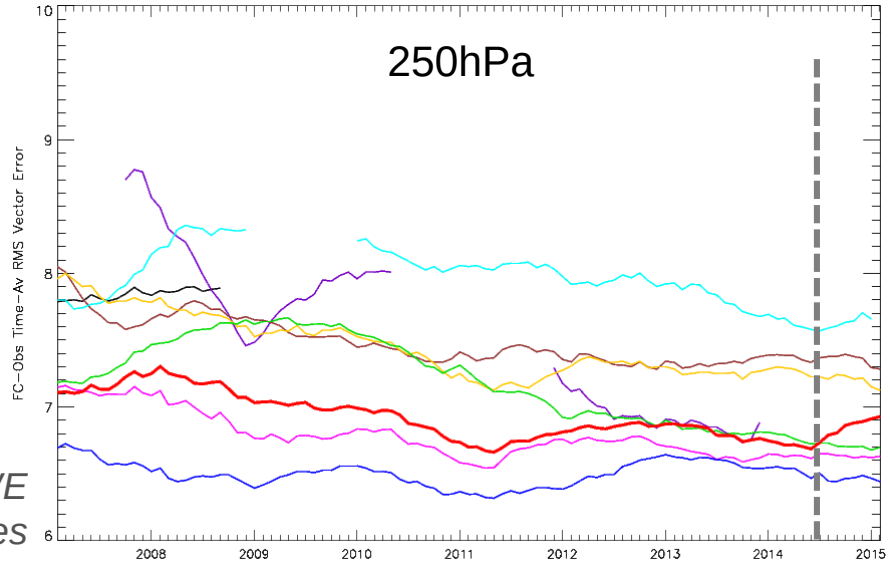
Impact of GA6-GC2 ENDGame/Physics/Resolution



Typical Sonde Coverage

GA6





- Continuing improvements in wind errors (~9% over 8 years for Met Office 850hPa winds).
- Degradation in 250hPa winds - ENDGame/GA6/N768.

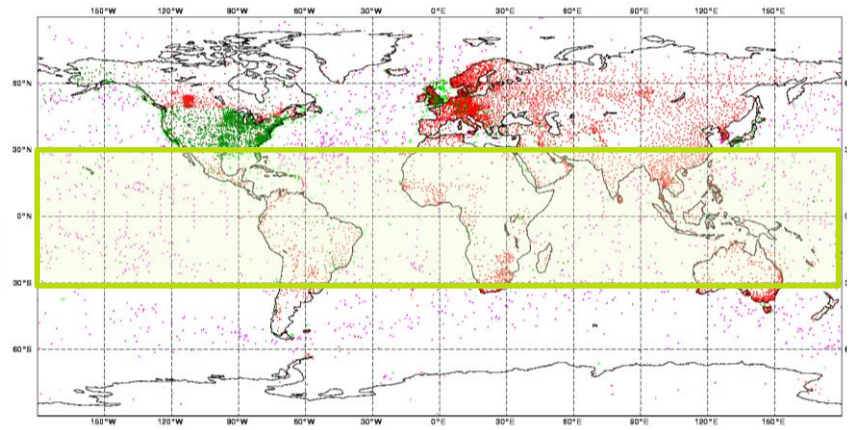
Sean Milton

CBS Day 3 RMS VWE

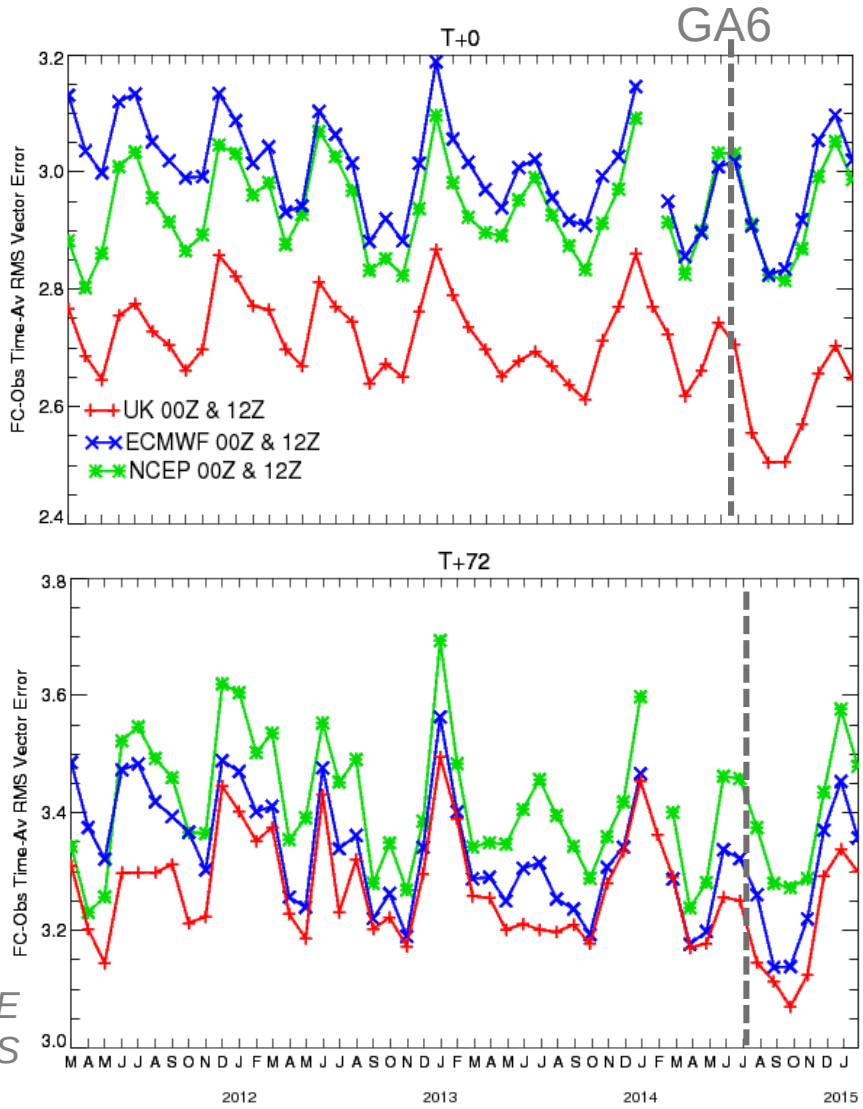
2007-2015 12-month running mean vs. Sondes

Tropical Winds at 10m

Impact of GA6-GC2 ENDGame/Physics/Resolution



Typical SYNOP Coverage



Met Office improved near surface wind RMS vector wind errors with ENDGame/GA6/N768.

Sean Milton

Analysis & Day3 RMS VWE
2011-2015 Monthly Averages vs. SYNOPS

ENDGame dynamics (GA6)

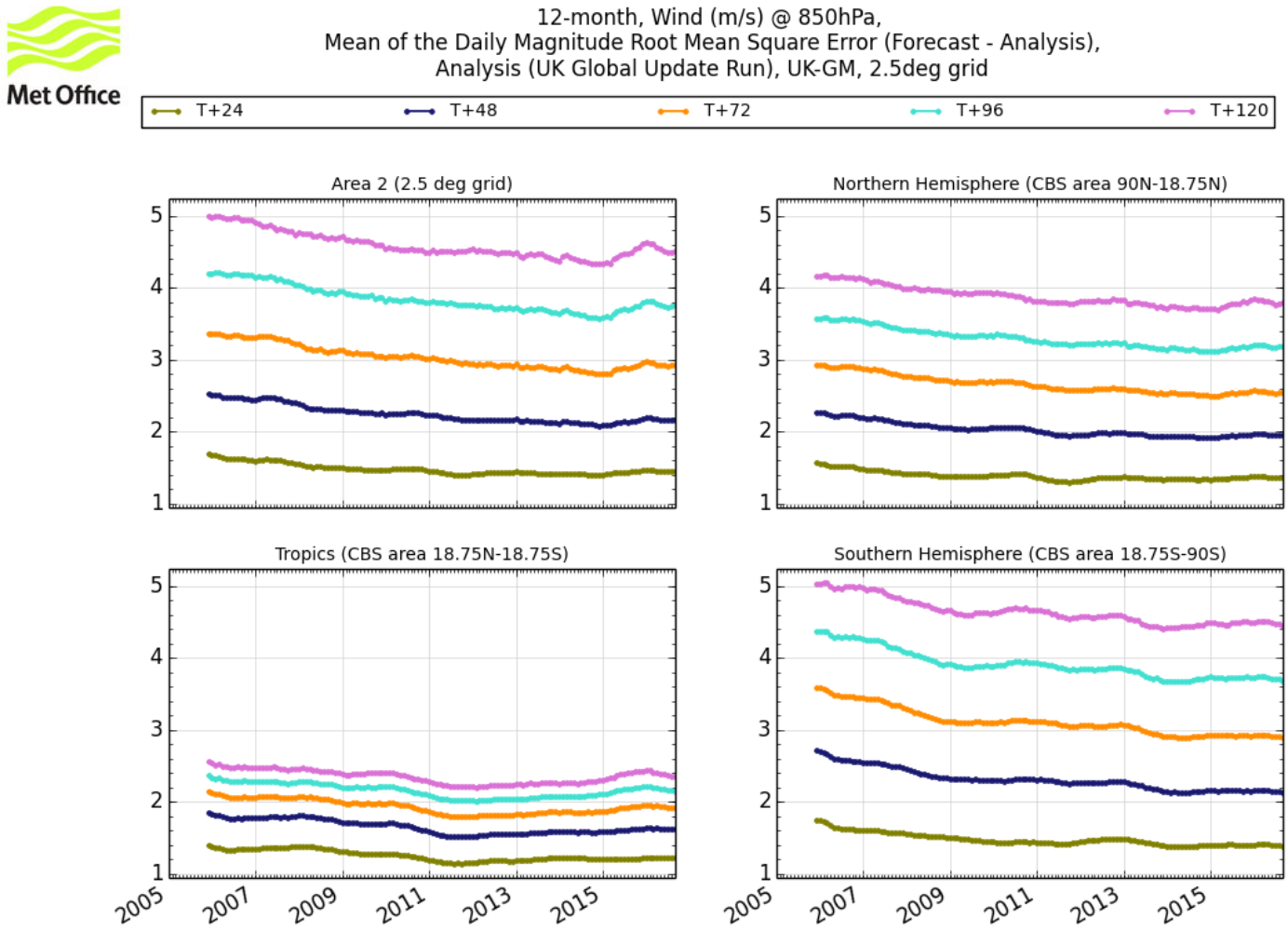
Even Newer Dynamics…operational since 2014

Evolution of New Dynamics

- Same equation set & variables (θ-π)
- Same horizontal staggering (Arakawa C-grid)
- Same vertical staggering (Charney-Phillips)
- (Iterative) Semi-implicit semi-Lagrangian

- Improved (iterative) solution procedure:
- More implicit, approaching Crank-Nicolson
- ⇒ Improved robustness, accuracy and variability
- Improved scalability (change variable held at poles)
- Option for improved conservation via SLICE (not in GA5)

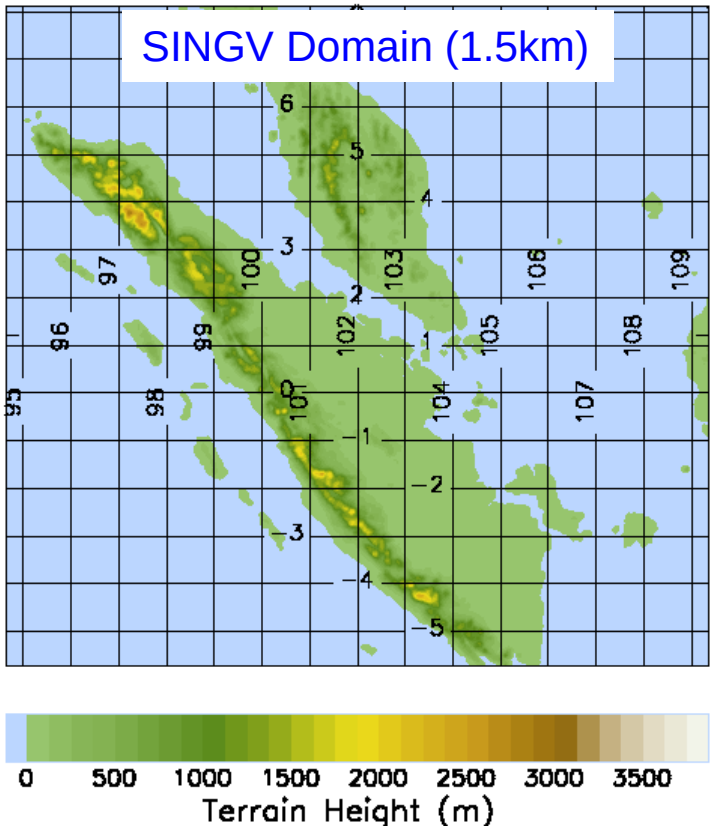
Historical Global NWP Performance: 850hPa winds – latest results

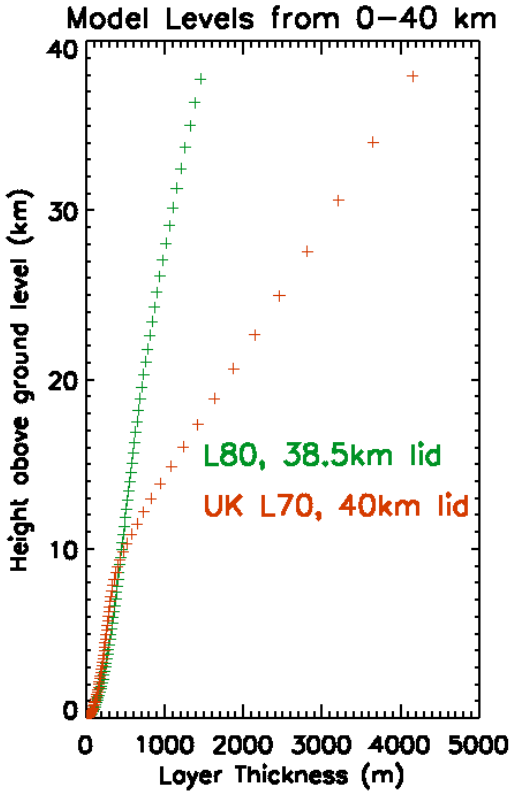


Jul 15 (PS36) 'Minor' Science Changes – Helmholtz solver tolerance, orography, 4DVar

3. SINGV Project Introduction

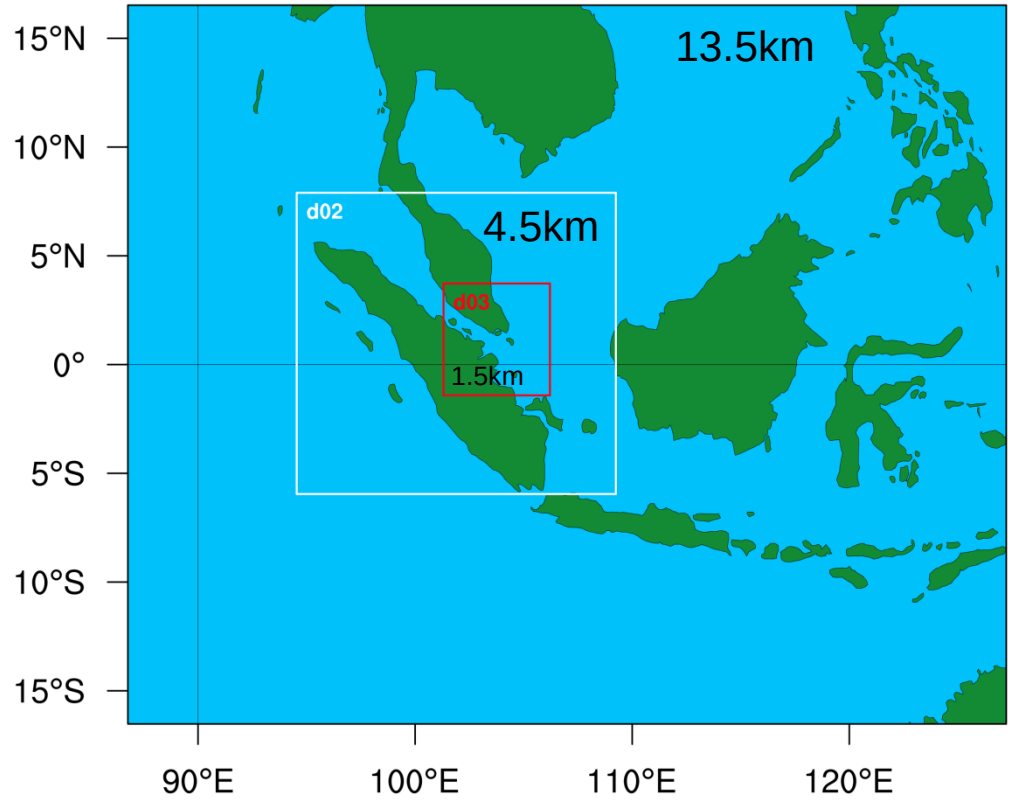
- Collaboration: Met Office and Meteorological Service Singapore (MSS).
- 5 year project (2013 – 2018) involving ~4FTE/yr from each partner.
- Tropical, km-scale NWP R&D plus operational implementation target.
- Core Model R&D -> Evaluation -> DA -> Ensemble + Tech Infrastructure





WRF Research Model Config

• SINGV WRF Research Configuration defined in summer 2013 with assistance from NCAR (Jimy Dudhia, Wei Wang, Dave Gill)



- WRF V3.5
- Model top: 10mb
- Model levels: 74
  - Same as UM, but lower lid
- Resolution: 4.5km / 1.5km
- 364x342/364x382 LAT-LON
- Timestep: 24s / 9s
  - c.f. UM = 100s / 50s
- Explicit convection
- YSU PBL
- WSM6 microphysics
- GFS p-level forecast IC/LBCs
- NoDA

SINGV: UM/WRF Comparison

- ‘Clean’ assessment of impact of driving model (e.g. global UM, ECMWF, GFS) and regional model (UM, WRF).

- 2 1-month test periods: Jun 11, Dec 2012 chosen.

- 00/12UTC ‘downscaler’ (i.e. no DA) T+30 UM/WRF forecasts.

- Verify T+6-30 accumulated precip (bias, fractional skill score (FSS)).

- Experiments performed:
  - GFS->WRF: WRF 13/4.5/1.5km driven by GFS IC/LBCs.
  - UM->WRF: WRF 4.5/1.5km driven by global UM IC/LBCs.
  - UM->UM 4.5/1.5km driven by global UM IC/LBCs.

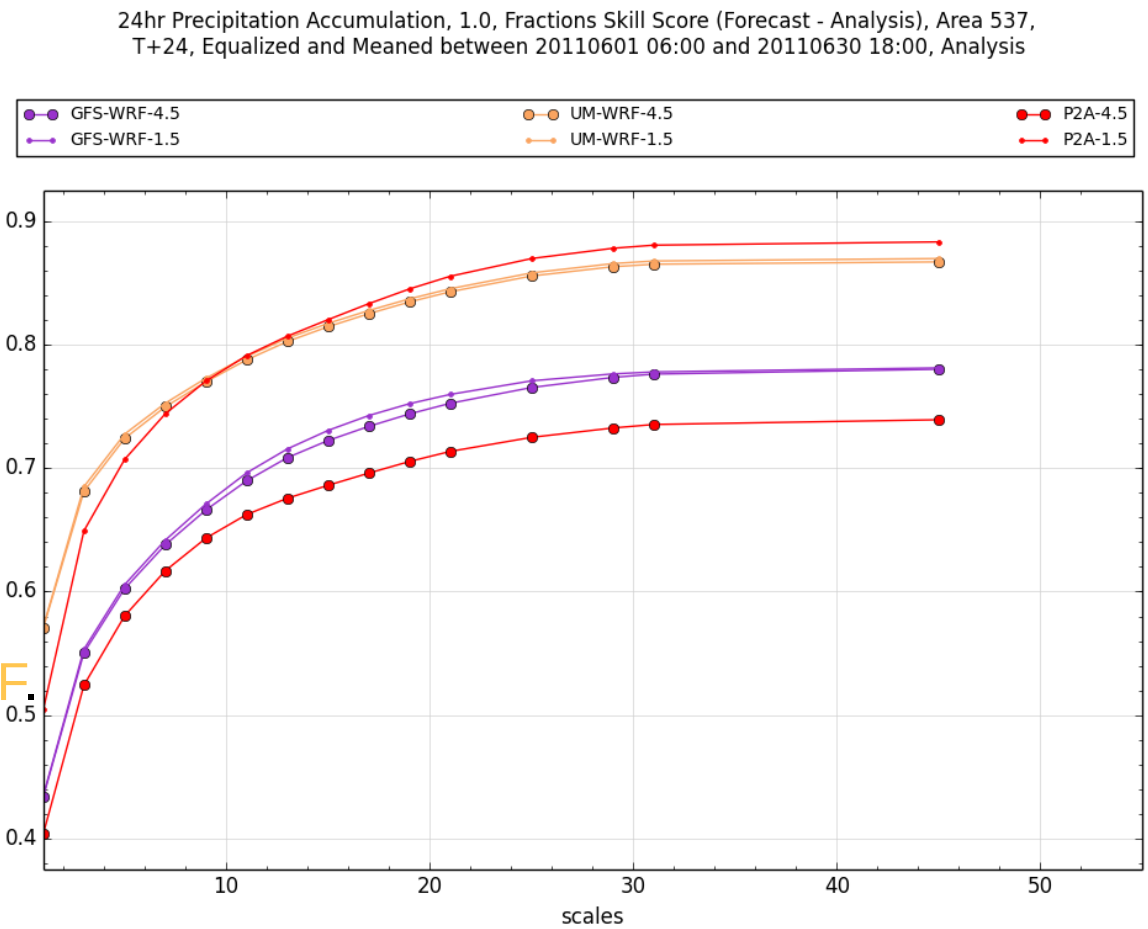
GFS-WRF versus UM-WRF versus UM-UM
Fractional Skill Scores
June 2011

Met Office

Meteorological Service Singapore
Centre for Climate Research Singapore

>1mm/day

- UM-WRF has too many light rainfall events.
- However, UM-WRF is clearly the most skilful.
- Impact of driving global model is very large.
- UM-UM 1.5 km model is almost as skilful as UM-WRF.



No. of TRMM grid-lengths

Stats for 1.5 km domain
Big dots = 4.5 km model
Small dots = 1.5km model

Plots c/o Ric Crocker

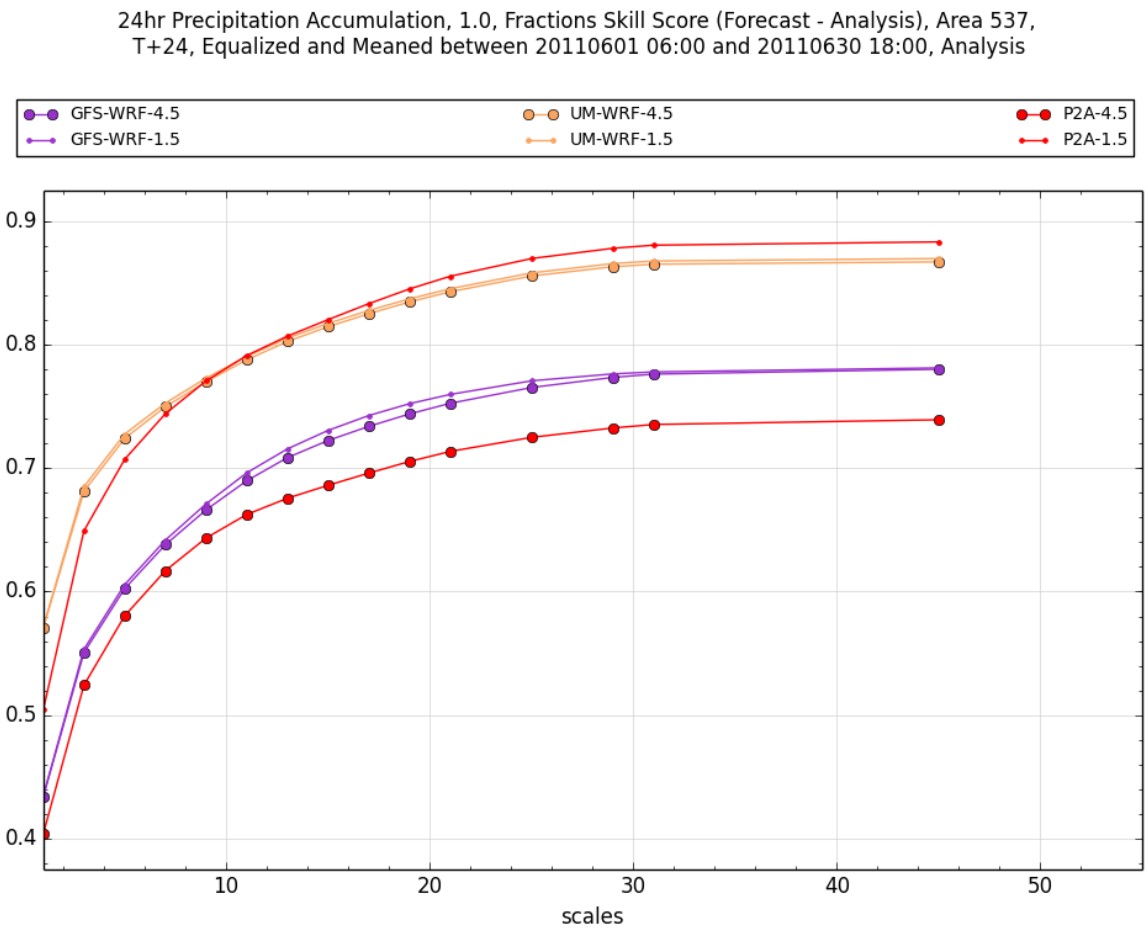
GFS-WRF versus UM-WRF versus UM-UM
Fractional Skill Scores
June 2011

Met Office

Meteorological Service Singapore
Centre for Climate Research Singapore

>1mm/day

- Two UM-UM (4.5km + 1.5km) models much more different to each other than either pair of WRF models.
  - i.e. LAM UM is much more sensitive to horizontal resolution than WRF.



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Stats for 1.5 km domain
Big dots = 4.5 km model
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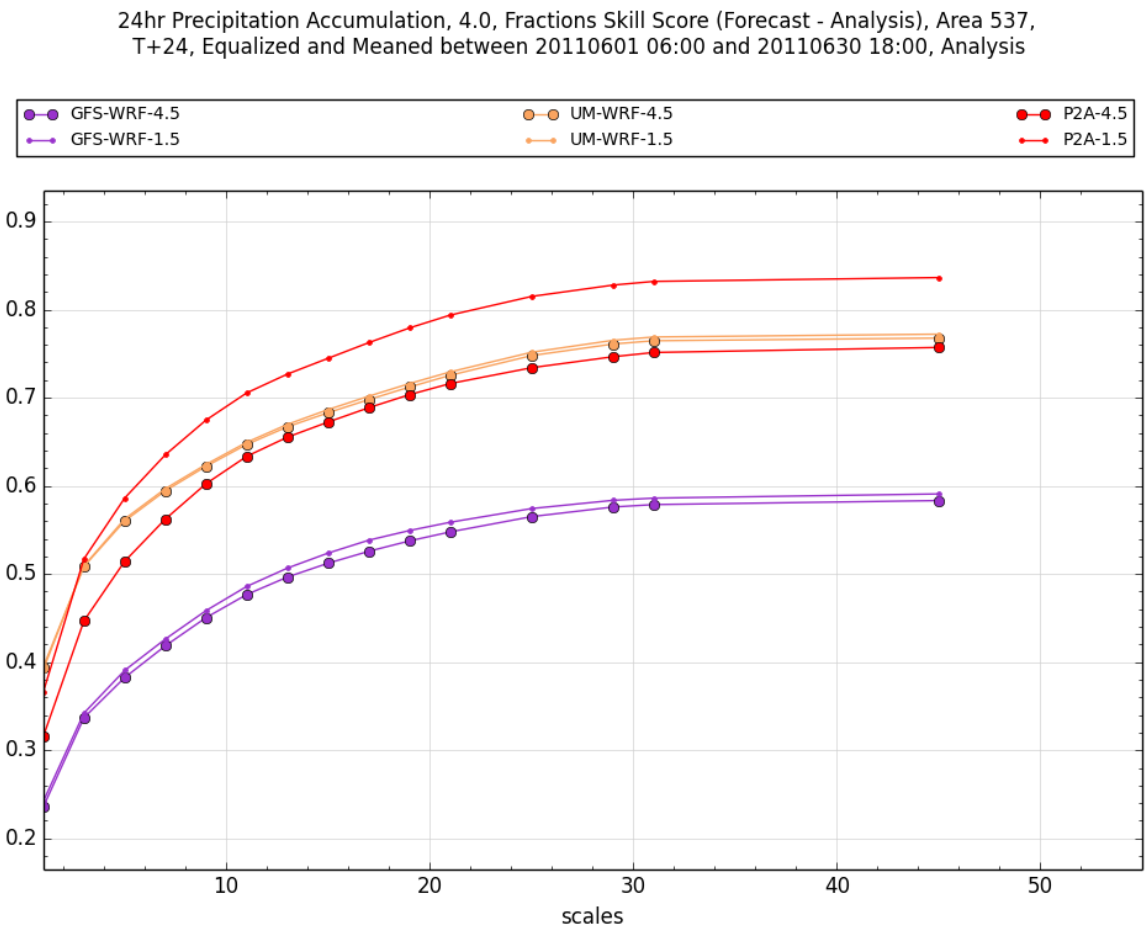
Plots c/o Ric Crocker

GFS-WRF versus UM-WRF versus UM-UM
Fractional Skill Scores
June 2011

Met Office

Meteorological Service Singapore
Centre for Climate Research Singapore

>4mm/day



Stats for 1.5 km domain
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Small dots = 1.5km model

No. of TRMM grid-lengths

Plots c/o Ric Crocker

GFS-WRF versus UM-WRF versus UM-UM
Fractional Skill Scores
June 2011

Met Office

Meteorological Service Singapore
Centre for Climate Research Singapore

>8mm/day

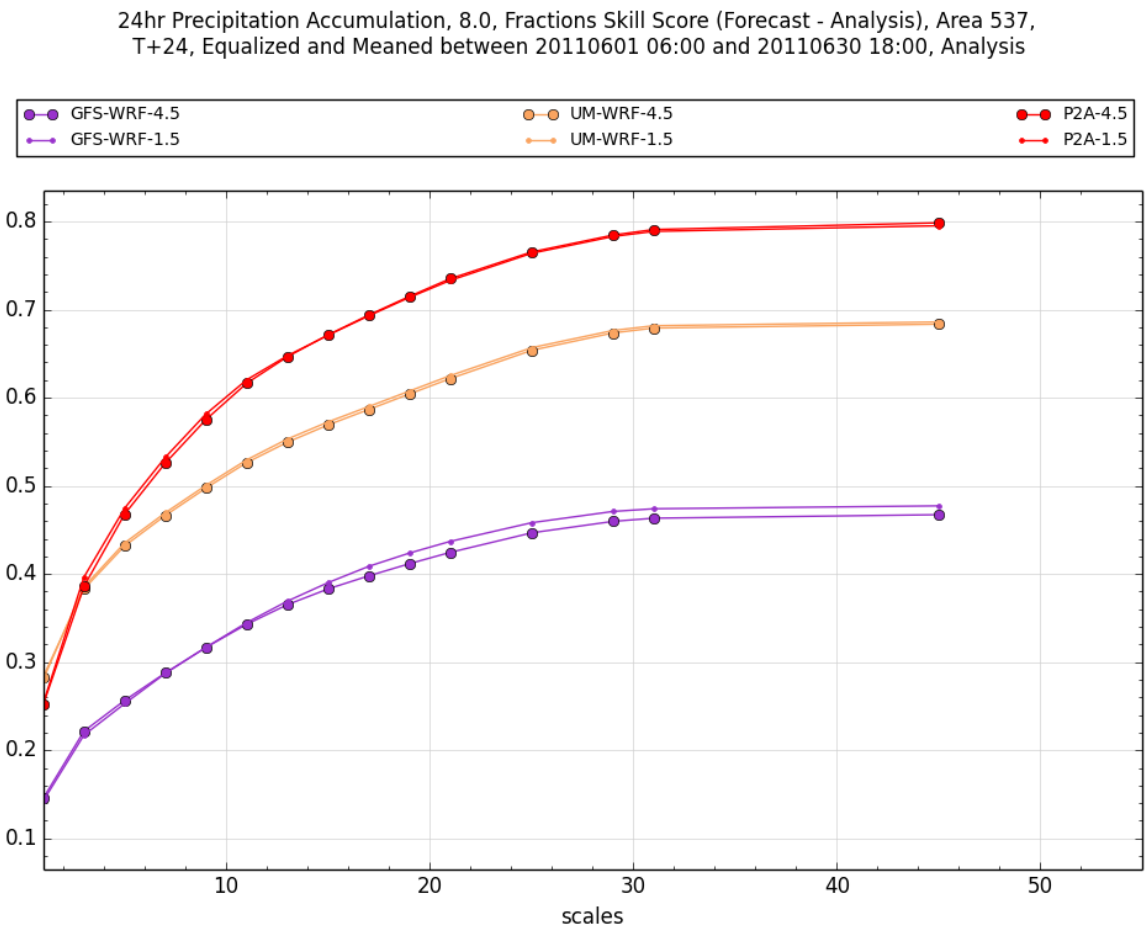
- For moderate rainfall rates:-

1.UM-UM

2.UM-WRF

3.GFS-WRF

- So see benefit of both global UM and LAM UM.



No. of TRMM grid-lengths

Stats for 1.5 km domain
Big dots = 4.5 km model
Small dots = 1.5km model

Plots c/o Ric Crocker

GFS-WRF versus UM-WRF versus UM-UM
Fractional Skill Scores
June 2011

Met Office

Meteorological Service Singapore
Centre for Climate Research Singapore

>16mm/day

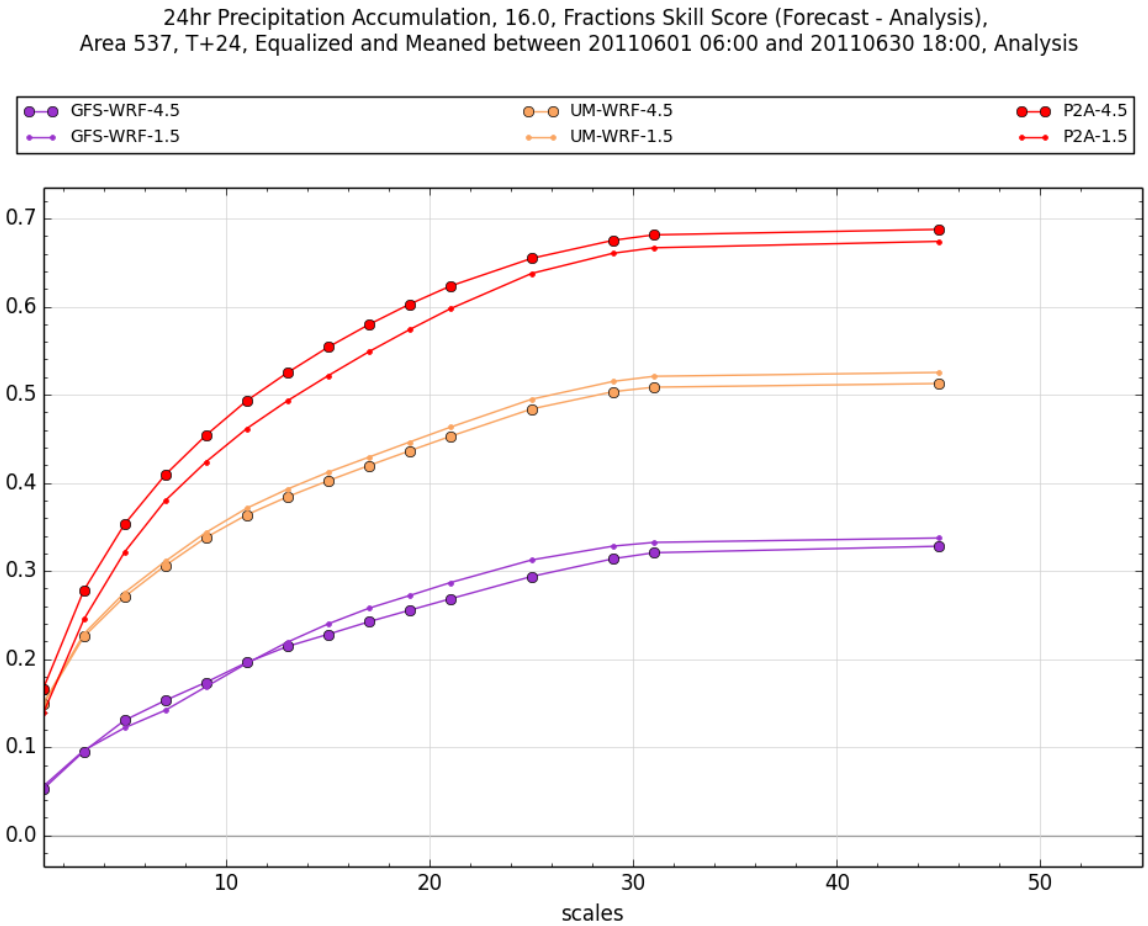
- For moderate rainfall rates:-

1.UM-UM

2.UM-WRF

3.GFS-WRF

- So see benefit of both global UM and LAM UM.



No. of TRMM grid-lengths

Stats for 1.5 km domain
Big dots = 4.5 km model
Small dots = 1.5km model

Plots c/o Ric Crocker

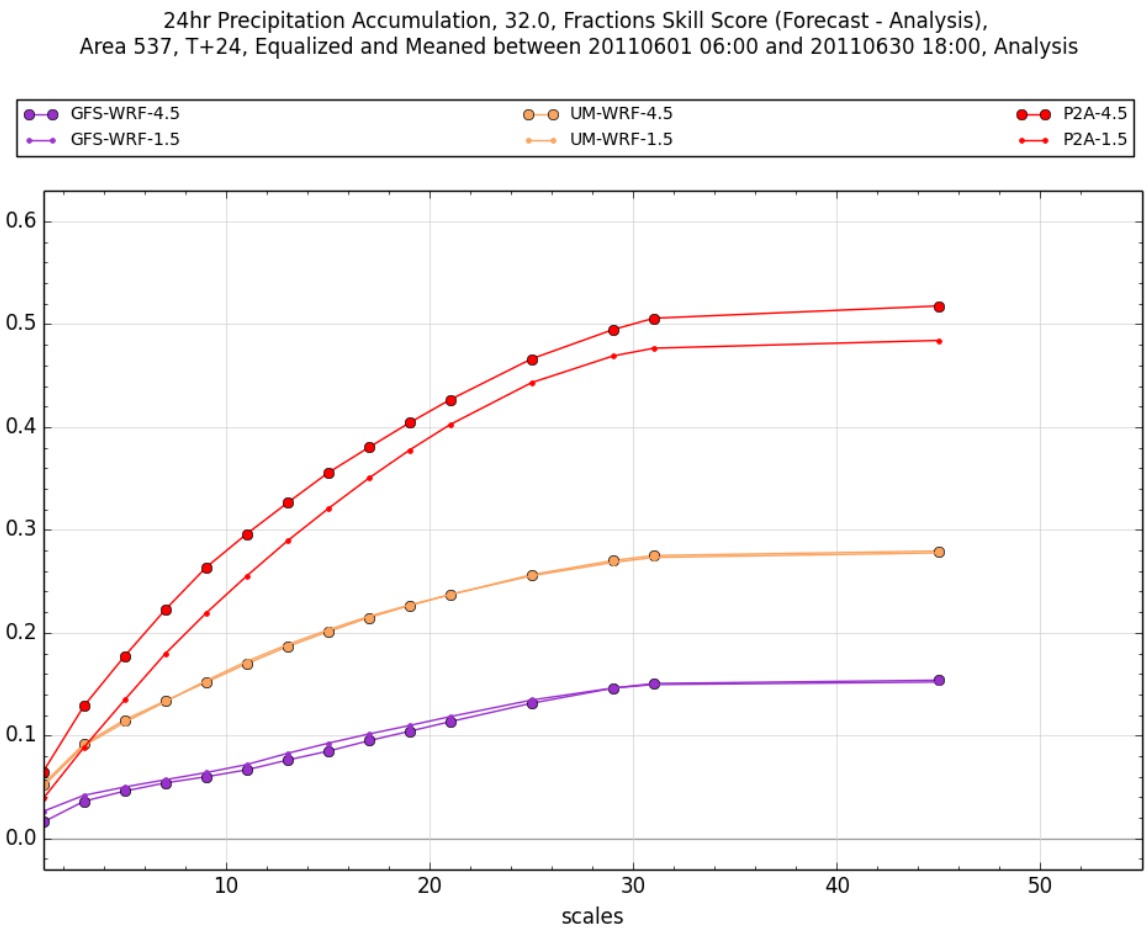
GFS-WRF versus UM-WRF versus UM-UM
Fractional Skill Scores
June 2011

Met Office

Meteorological Service Singapore
Centre for Climate Research Singapore

>32mm/day

- Too few events for robust stats for heavy rainfall.
- With that caveat in mind, results still consistent with moderate rainfall events.

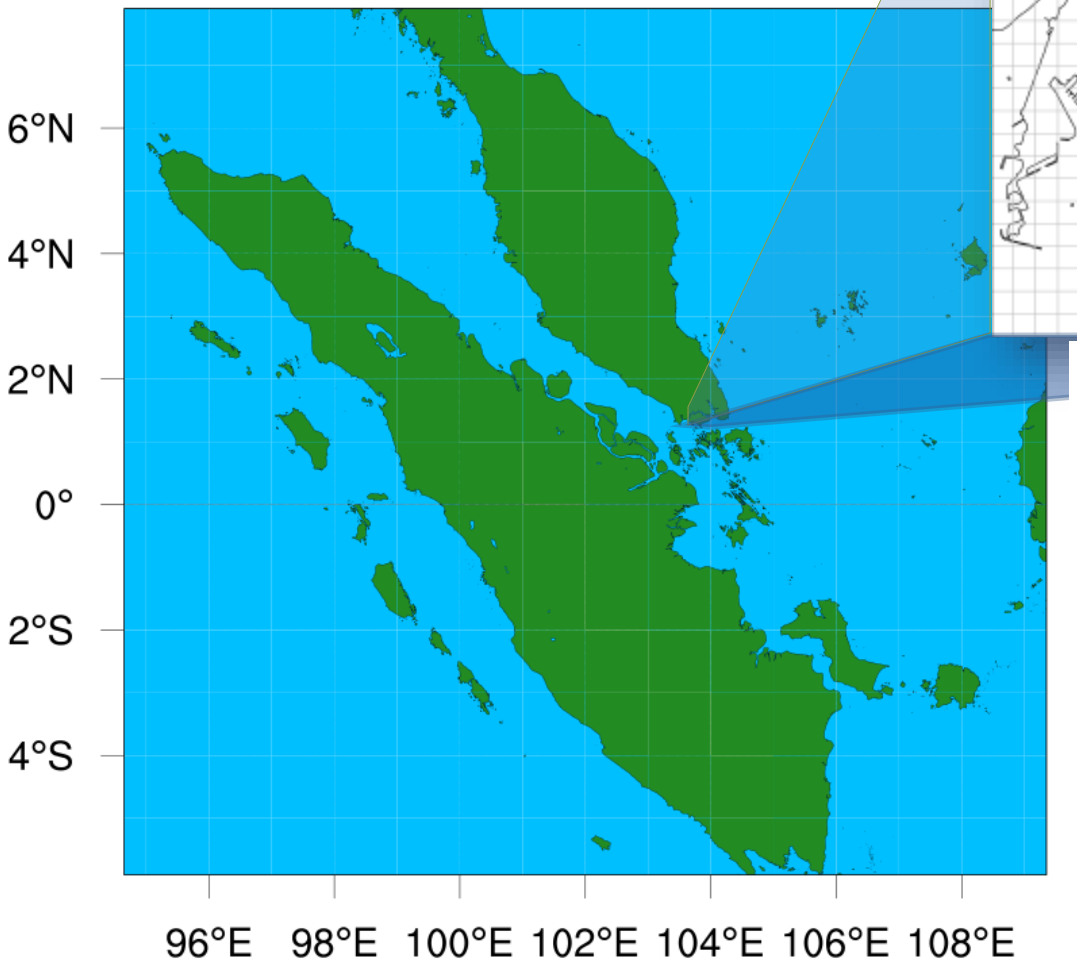


No. of TRMM grid-lengths

Stats for 1.5 km domain
Big dots = 4.5 km model
Small dots = 1.5km model

Plots c/o Ric Crocker

SINGV Version 2 (April 2015)



- Based on PS35 UKV ENDGame
  - No MURK aerosol
  - But L80 rather than L70
- Changes from Version 1
  1. P2A blended BL scheme
  2. Single 1.5 km domain
     - As opposed to version 1 = double nest
     - 1092 x 1026 x L80, dt=50s
     - Fixed not variable resolution
     - ~5 times cost of Version 1 configuration

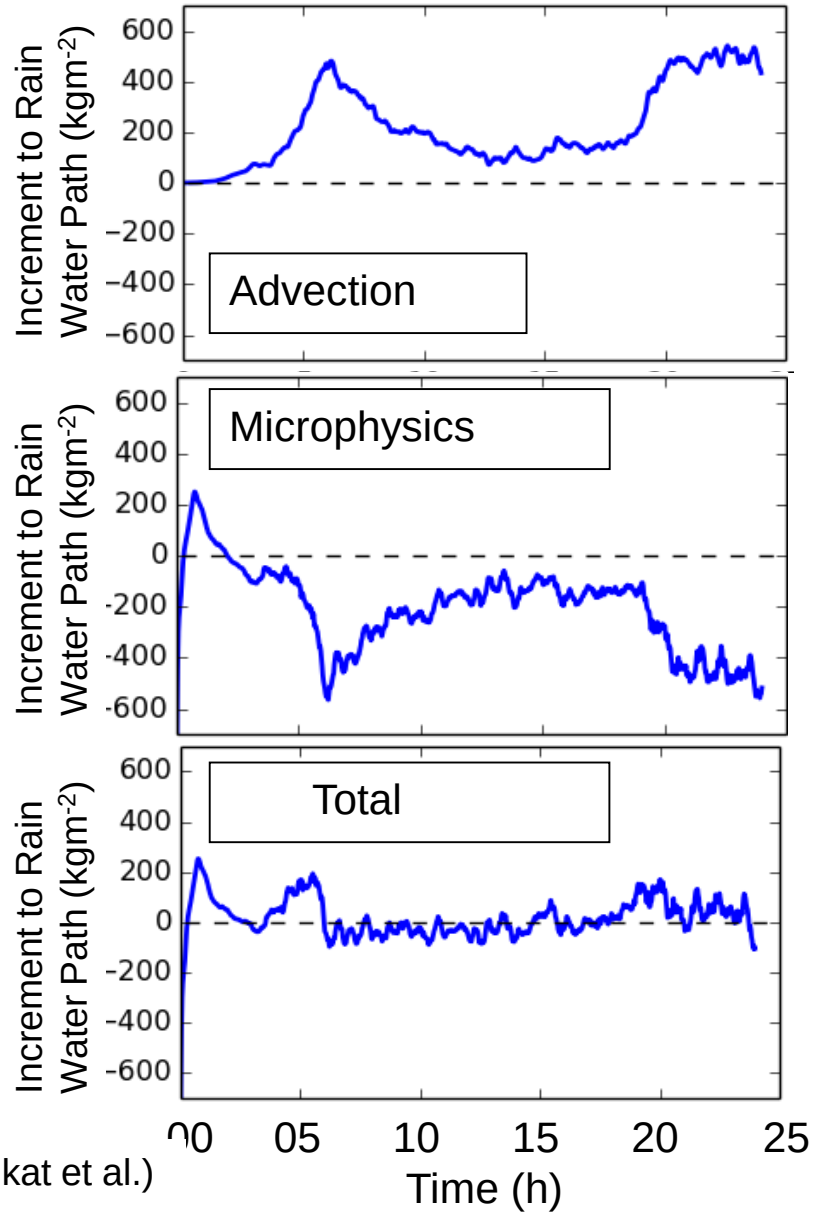
Stu Webster

Conservation of moisture

Simon Vosper

- Excess convective rainfall is partly a result of spurious rain water associated with non-conserving SL advection

- Work underway to understand and address the problem:
  - Conservation errors associated with sharp gradients in moisture fields and strong convergence and updraughts
  - Enforcing mass-conservation (Priestley-like approach) helps and reduces peak rain rates



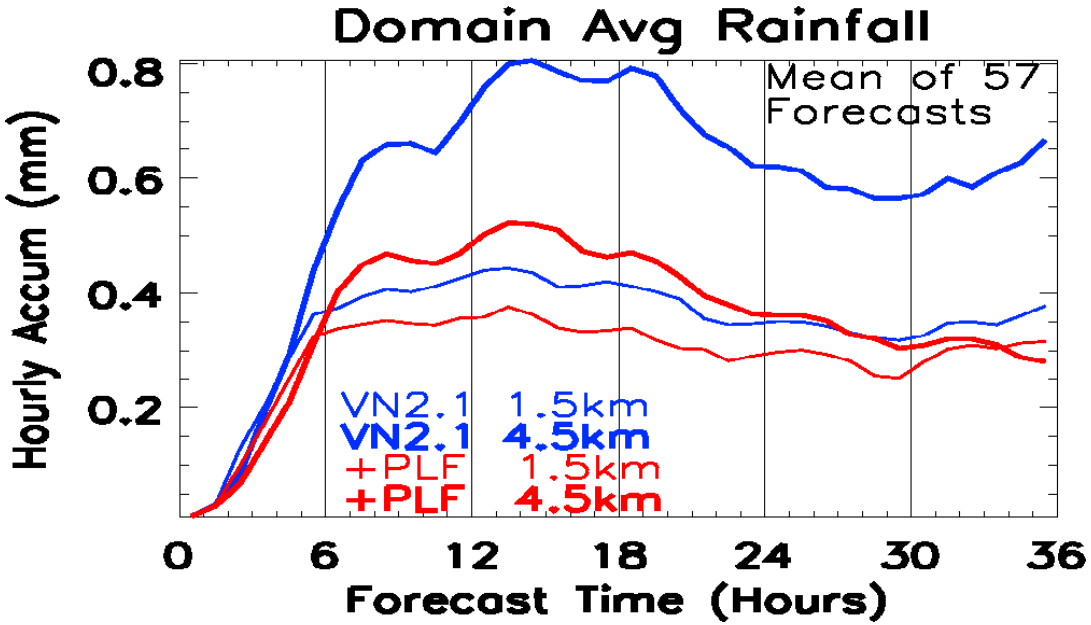
(Nigel Wood, Jonathan Wilkinson, Chris Smith, Mohamed Zerroukat et al.)

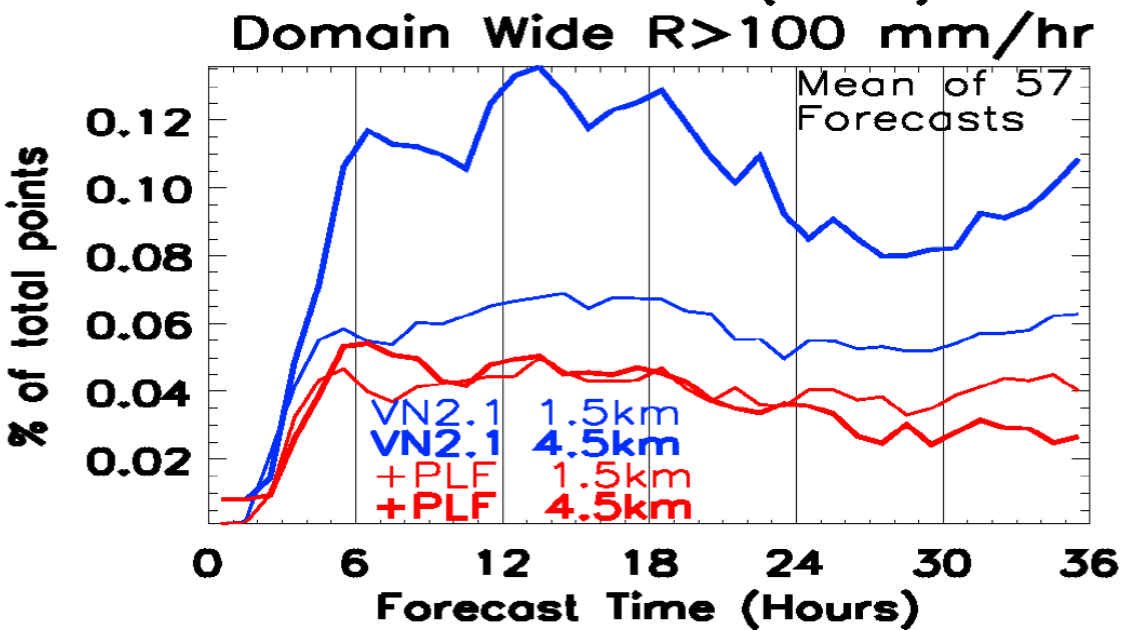
Conservation of moisture

Move to PLF (red) reduces the resolution sensitivity to precipitation rate.

Problem worse at 4.5km.

Stuart Webster

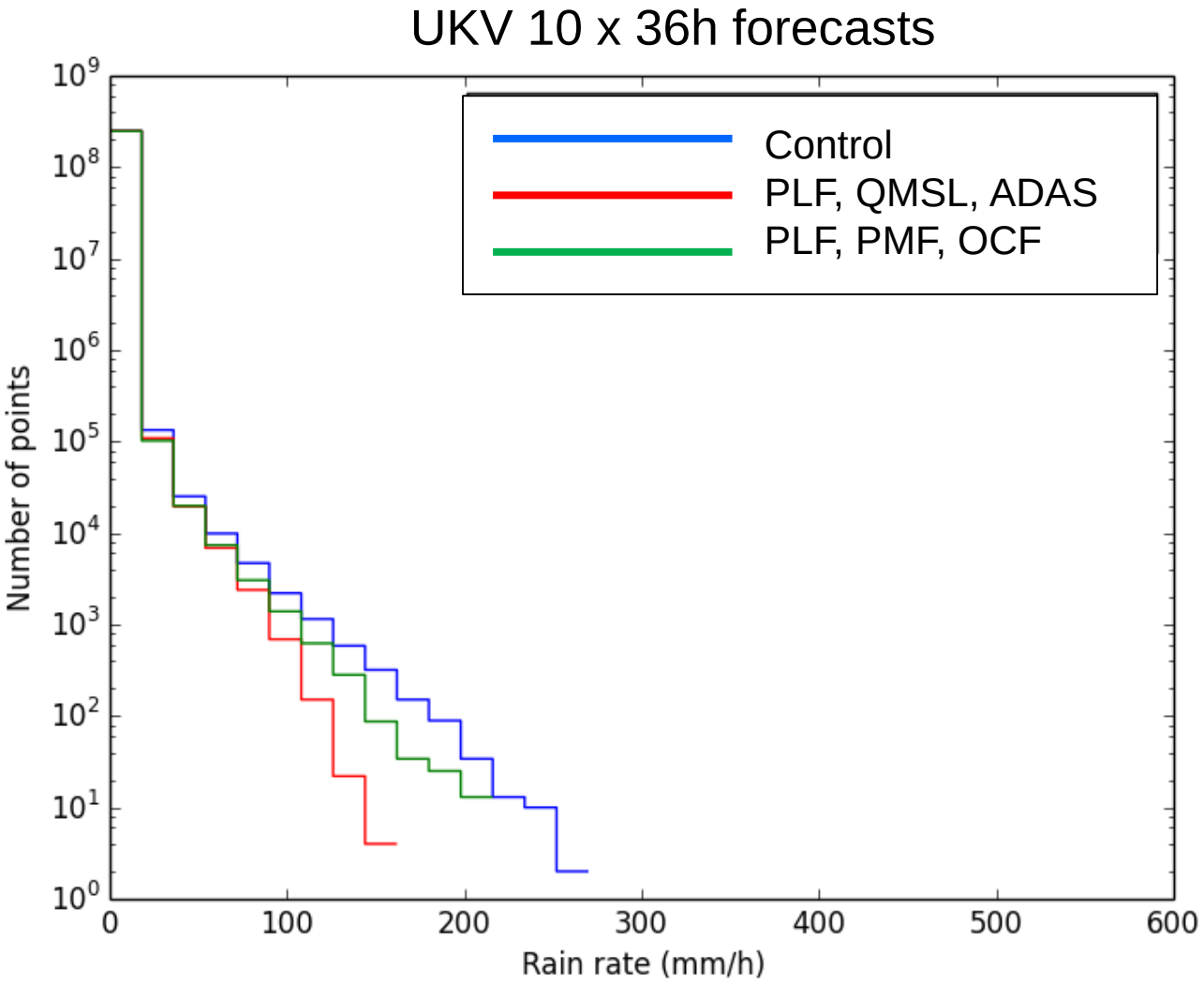




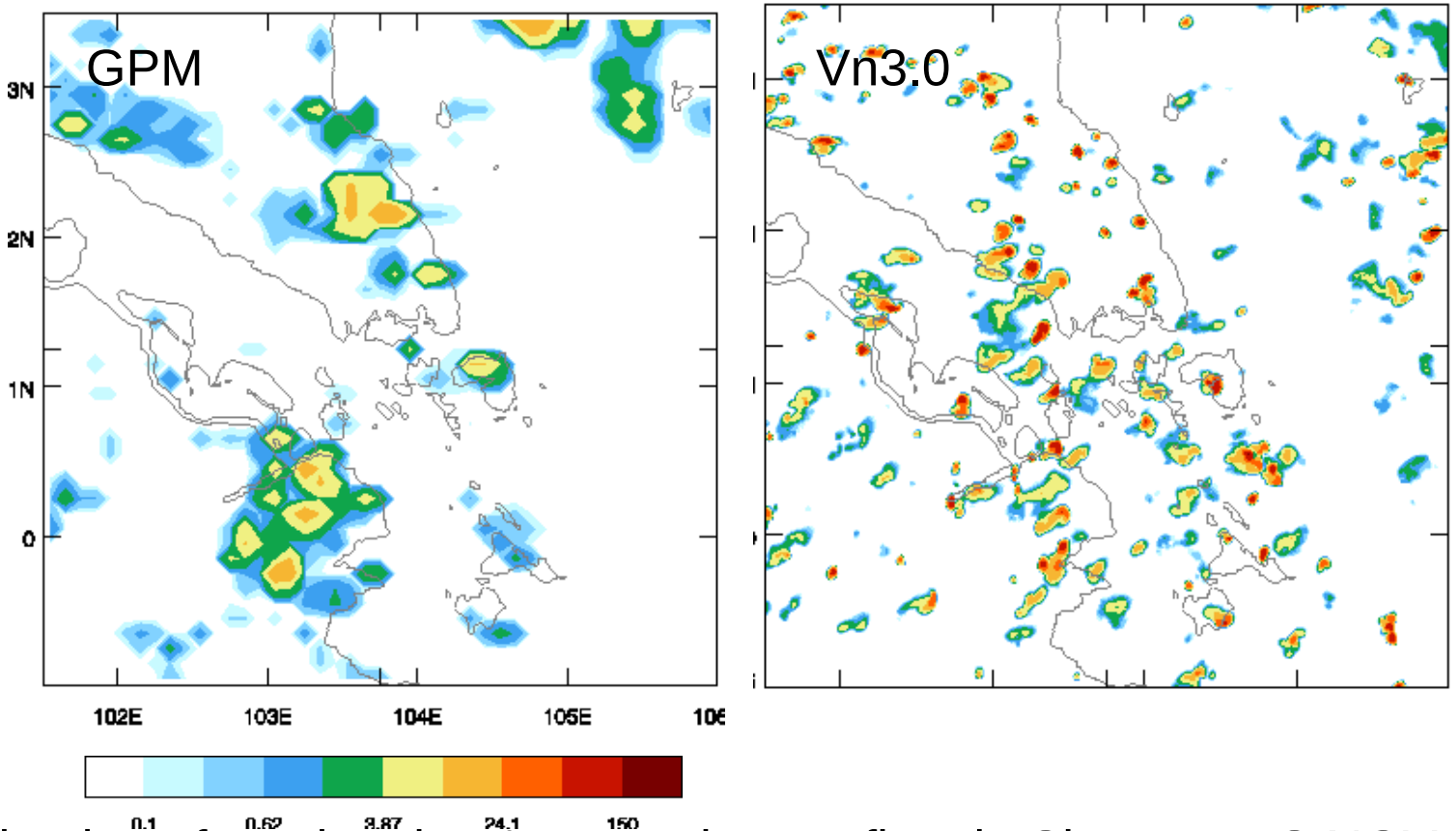
Conservation of moisture

Simon Vosper

- Aranami *et al.* mass fixer applied to moisture variables
- Removes highest rain rates
- ~10% reduction in mean rainfall



SINGV V3: Conservation + Stochastic Physics

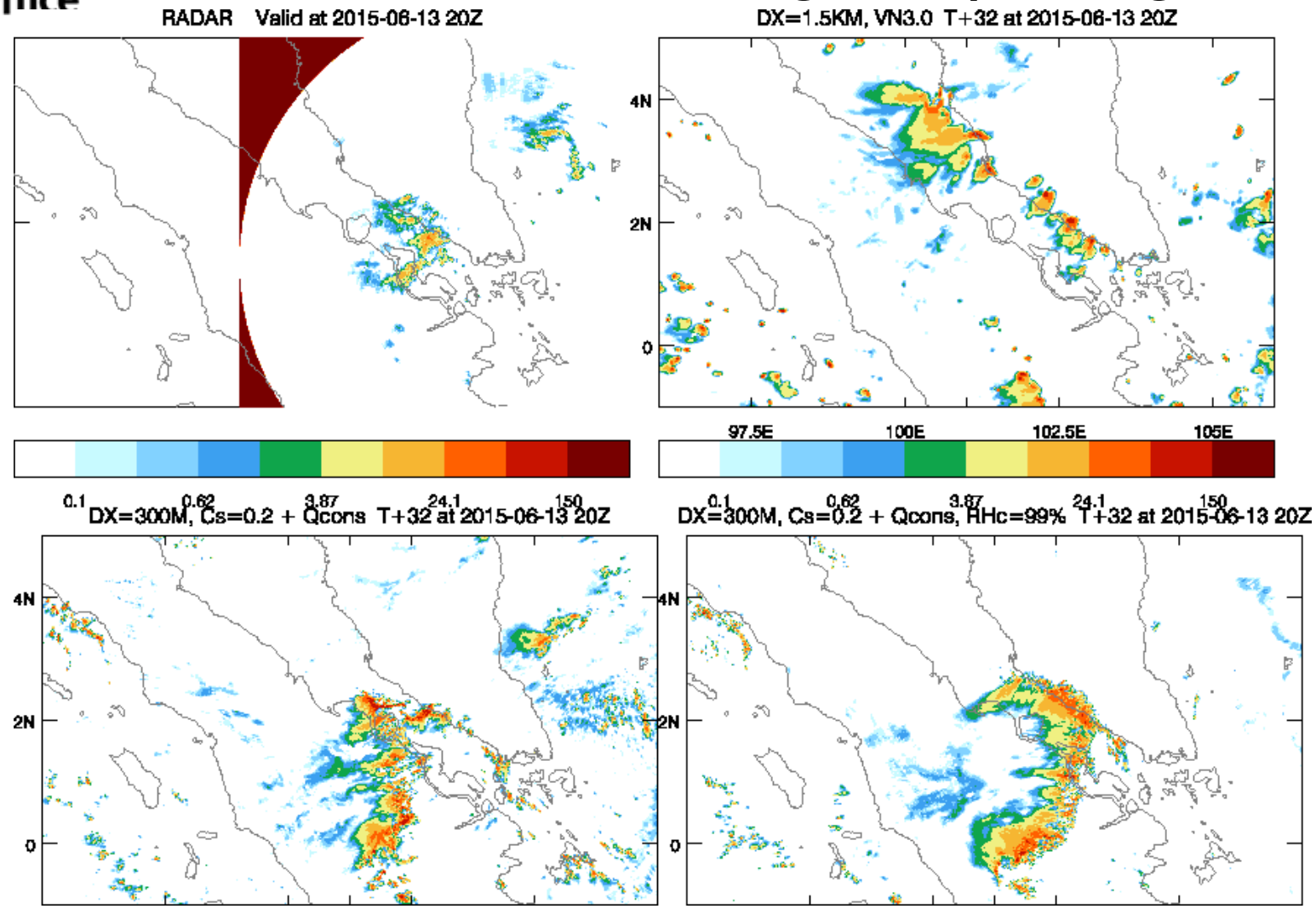


Combination of stochastic $\Delta\theta$, Δq and mass fixer in Singapore SINGV model

- Reduced resolution sensitivity
- Reduction in area of high (excessive) rain rates
- Less blobby look to surface precipitation patterns

(Stu Webster)

Resolution:
Initial tests at 300m grid-spacing

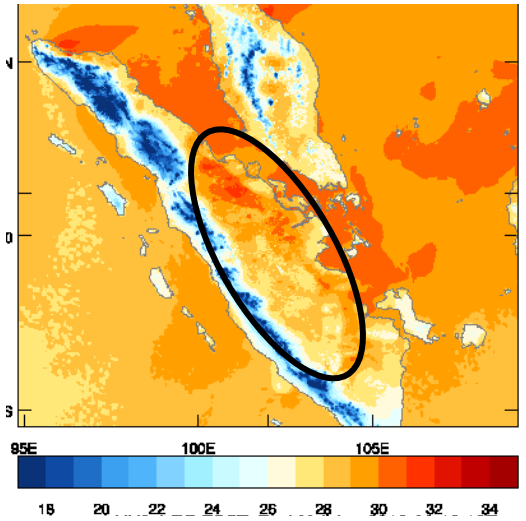


Stu Webster

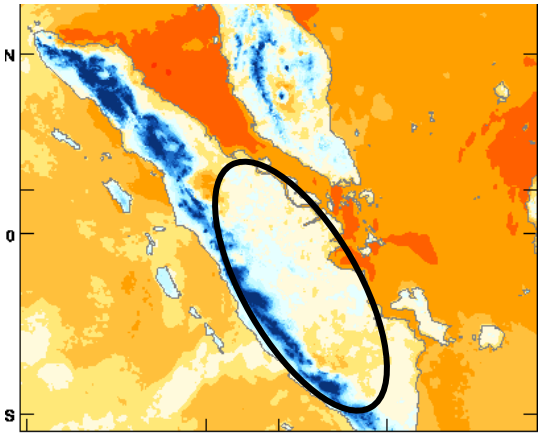
c. Impact Of Driving Model on High-Resolution UM in SINGV

- Previous WRF results illustrate strong dependence on driving model.
- MSS have been running WRF within ECMWF – good results compared to GFS.
- ECMWF model main tool for MSS forecasters.
- Q: What is impact of driving model on SINGV: global UM and ECMWF?
- Technicality: Use 0.1deg cut-out of ECMWF ICs/LBCs on local area, no DA.

UM Driver, UM 1.5mT T+0



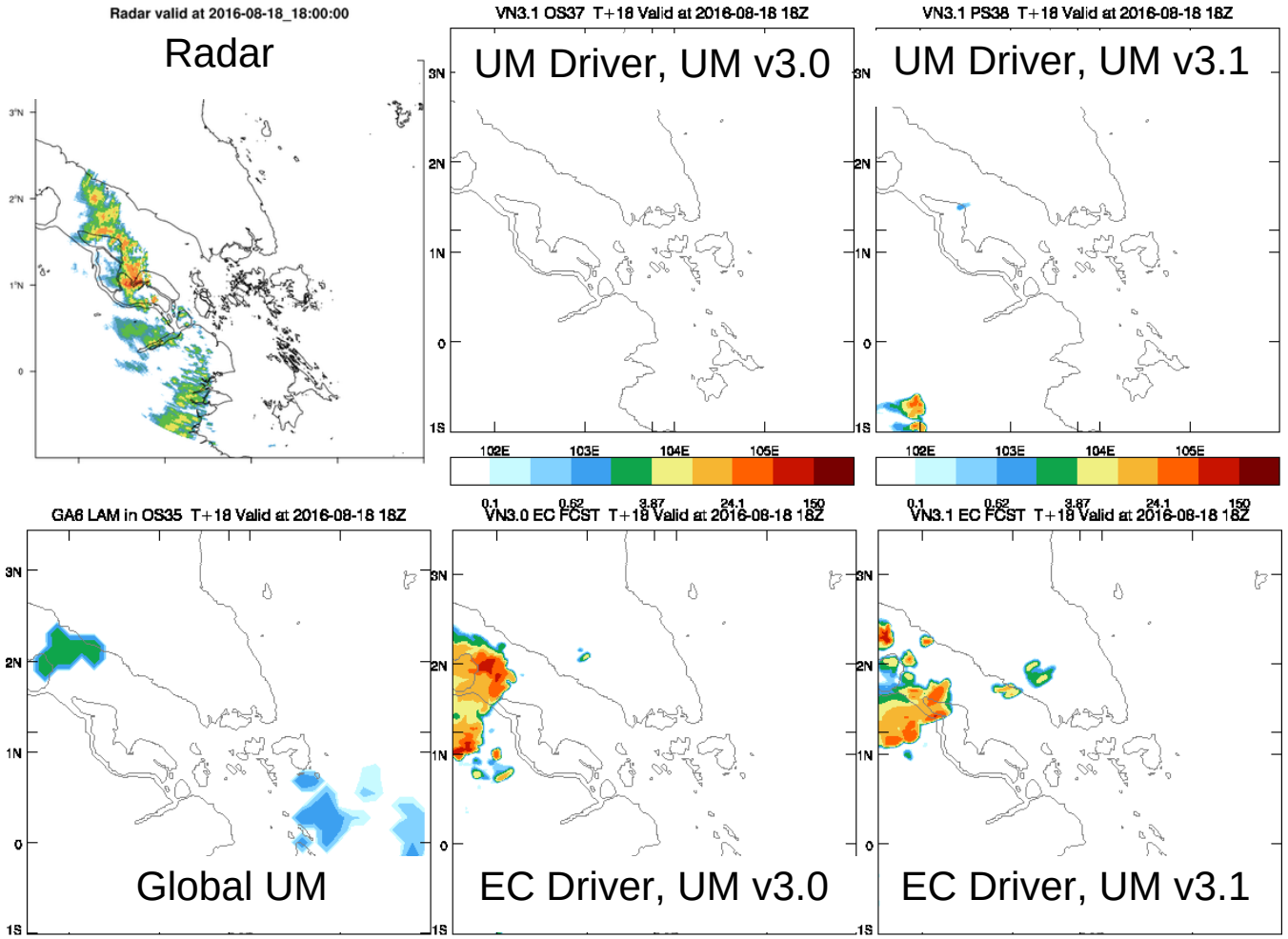
EC Driver, UM 1.5mT T+0



Impact Of Driving Model on High-Resolution UM in SINGV

Initialised 18th August 00z

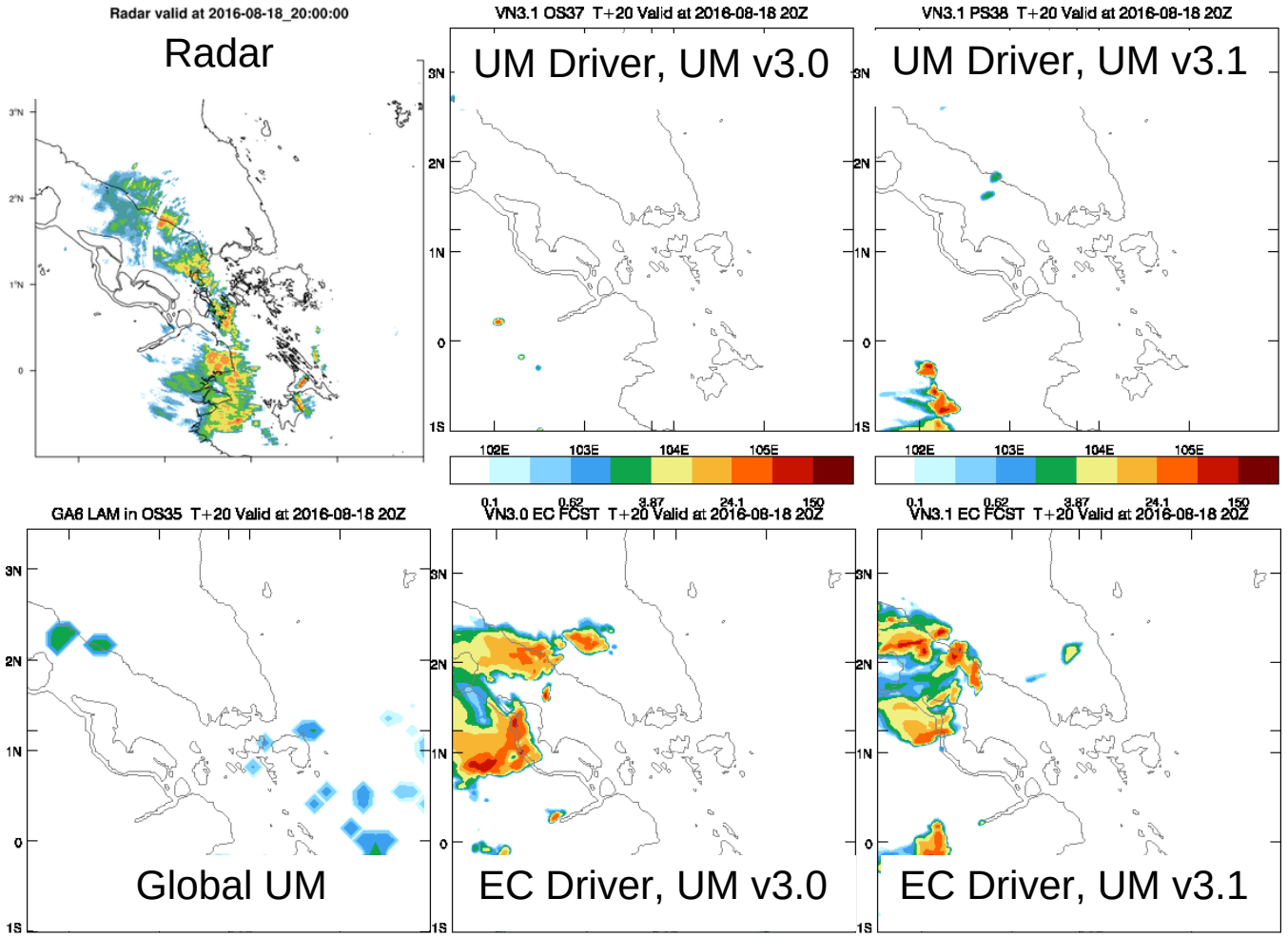
T+18



Impact Of Driving Model on High-Resolution UM in SINGV

Initialised 18th August 00z

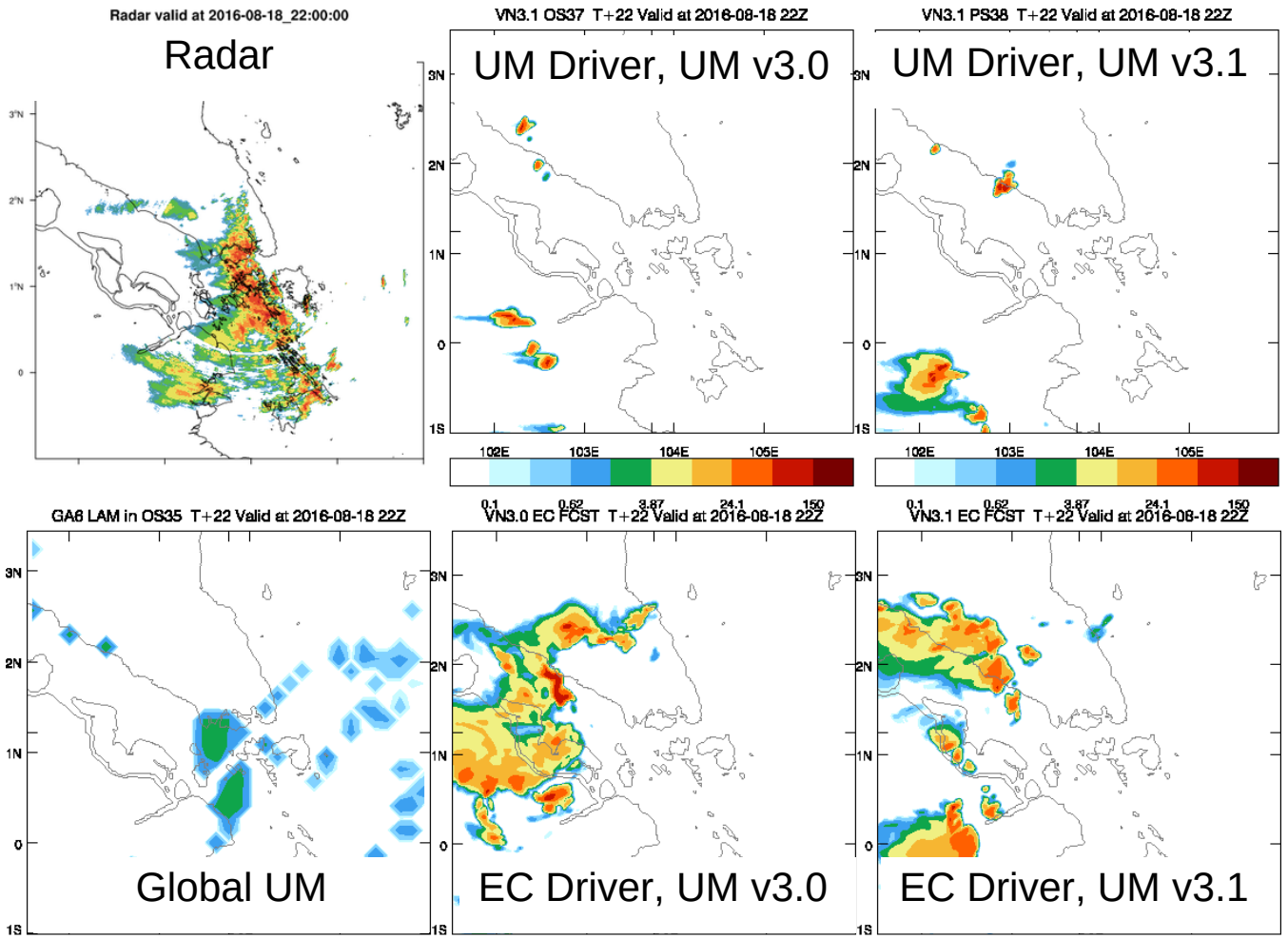
T+20



Impact Of Driving Model on High-Resolution UM in SINGV

Initialised 18th August 00z

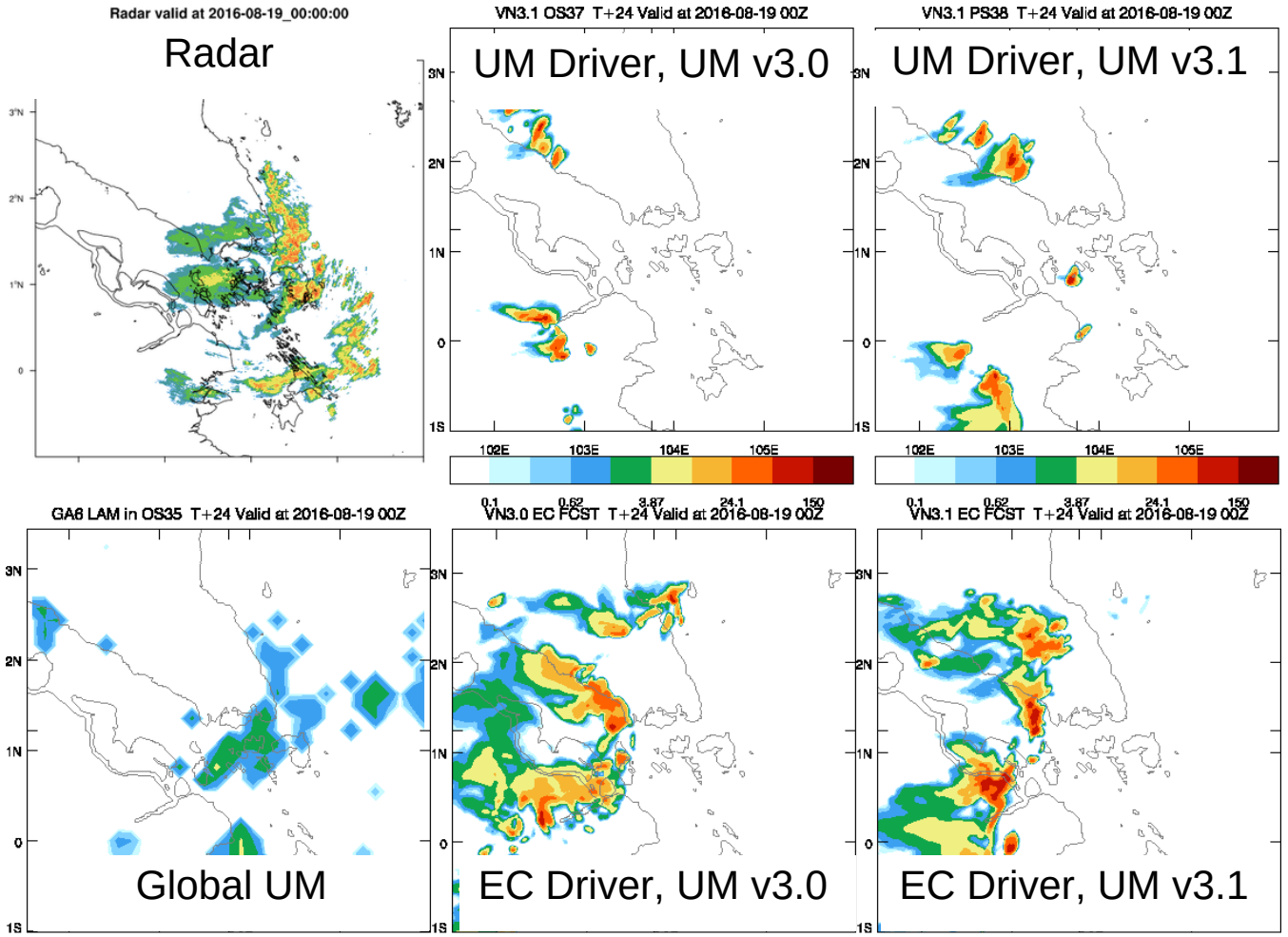
T+22



Impact Of Driving Model on High-Resolution UM in SINGV

Initialised 18th August 00z

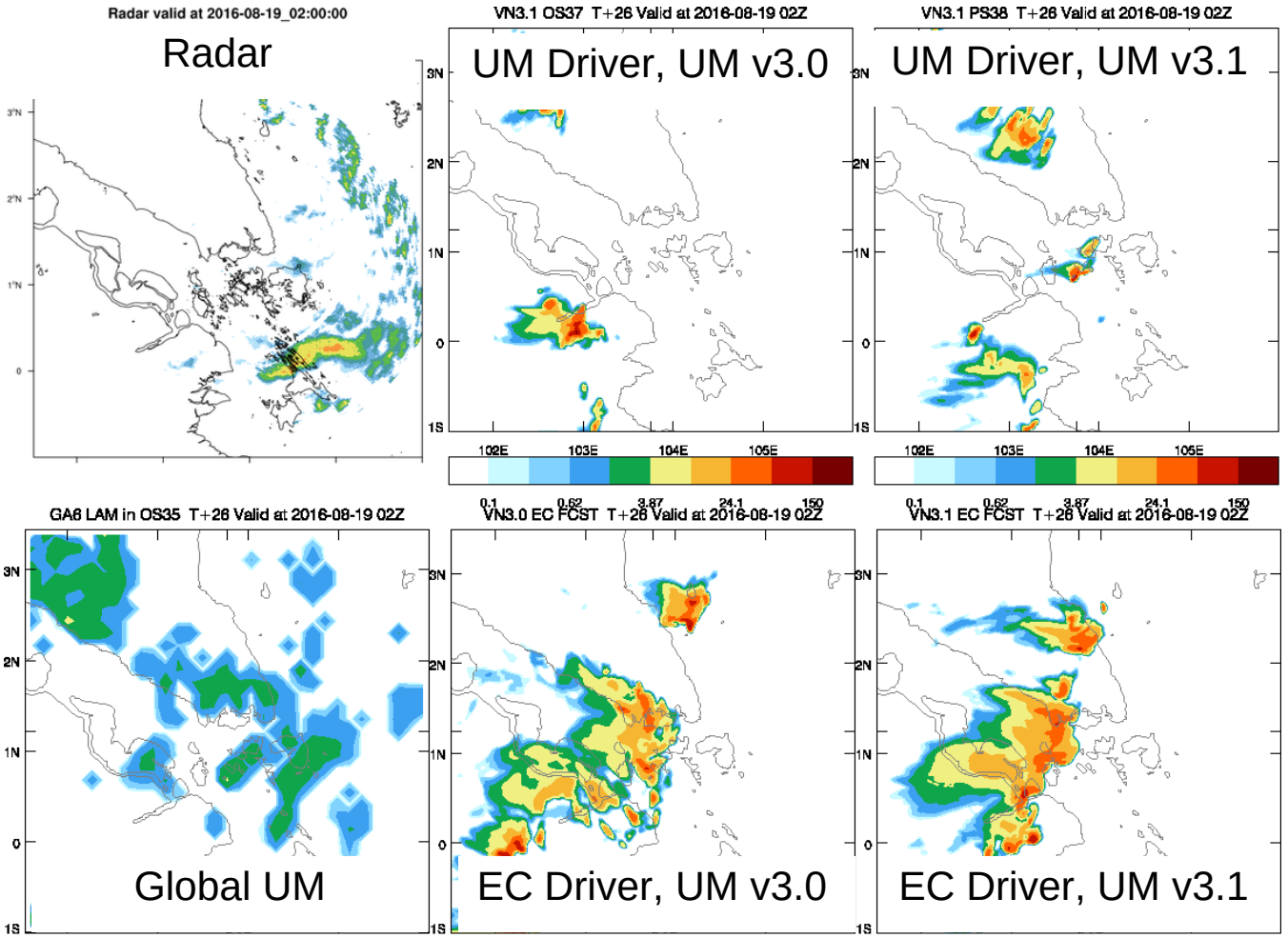
T+24



Impact Of Driving Model on High-Resolution UM in SINGV

Initialised 18th August 00z

T+26



Impact Of Driving Model on High-Resolution UM in SINGV

- T+36 forecasts run from 00Z/12Z analyses for period 17th August 12Z to 23rd August 12Z.

- 3 Sumatran squall events during this period, which could all potentially be captured by 3 successive forecasts (so up to 9 forecasts could capture a squall).

- Illustrate performance using forecasts initialised 18th 00Z: EC driven runs better capture the squall (if a little late).

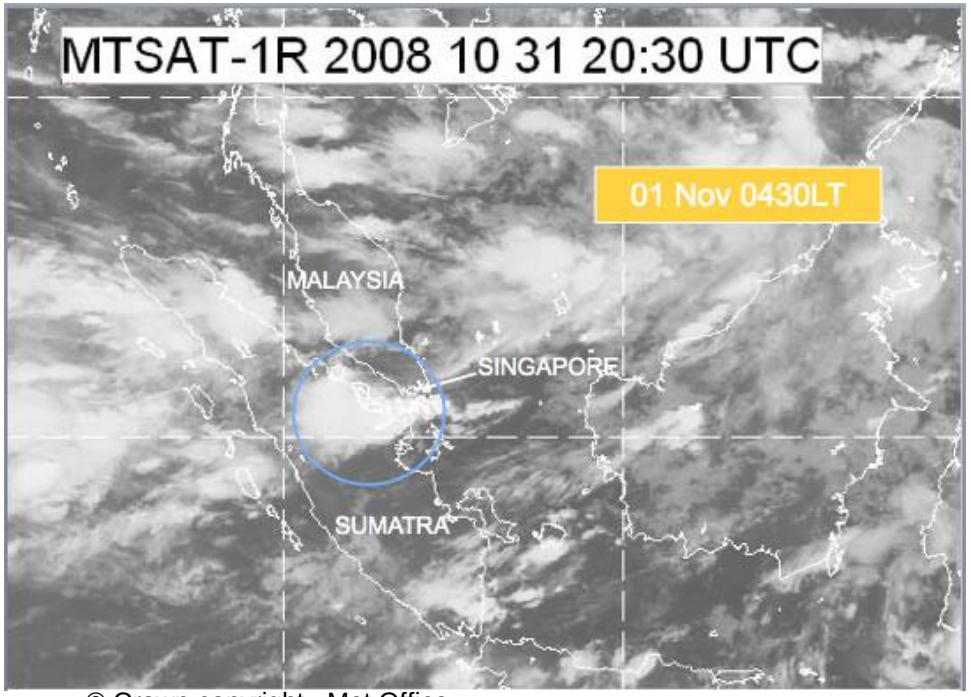
- Over the 9 forecasts:-
  - squall missed by all models in 1 forecast.
  - All models captured the squall – and none clearly better – in 3 forecasts.
  - EC driven runs better captured the squall in 4 forecasts.
  - UM driven runs produced spurious squall in 1 forecast, EC better in this case too.

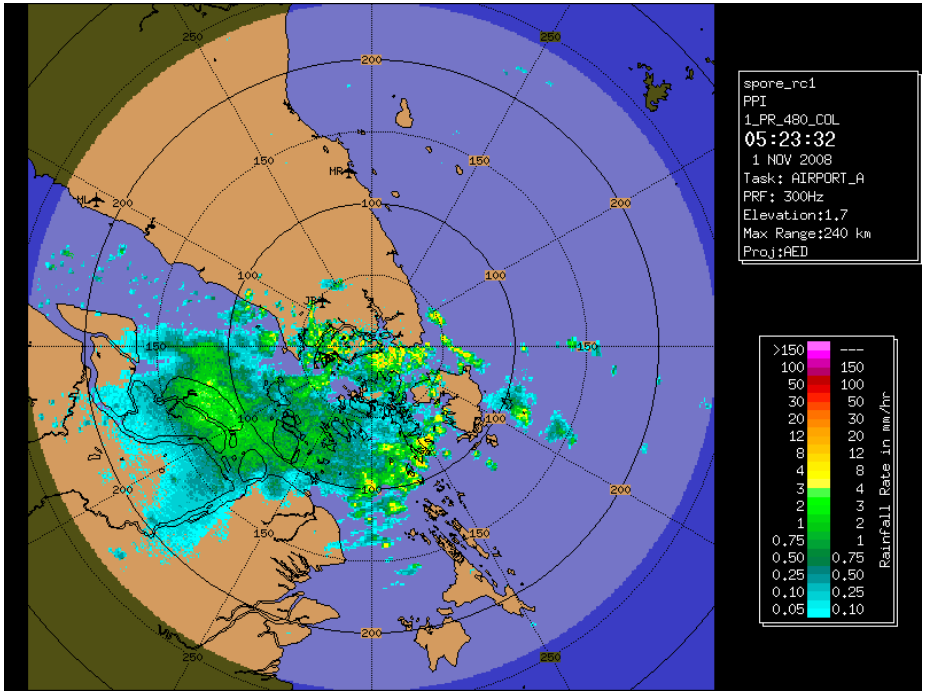
- Overall EC driven SINGV forecasts better capture squall events.

- Studies continuing……..

d. SINGV DA: Foci for research

- Obs focus: Radar, satellite (e.g. HIMAWARI 8), GPS RO, etc
- Technique: 3DVar initially, LHN, tropical covariances.
- Consider advanced DA (4DVar/4DEnVar) later…





SINGV DA (version 2): Observations

Adam Maycock

Aircraft
MetDB Subtypes
- AMDARS
- AIREPS

AIRS
MetDB Subtypes
- AIRSWF

AMSUB
MetDB Subtypes
- AMSUB

Sonde
MetDB Subtypes
- TEMP
- PILOT
- DROPSOND
- WINPRO

CrIS
MetDB Subtypes
- CRIMMS

IASI
MetDB Subtypes
- IASIG

Satwind
MetDB Subtypes
- ESAHRVW
- ESAHRWVW
- ESACSWVW
- JMAWINDS

Scatwind
MetDB Subtypes
- ASCATHR
- ASCATCO

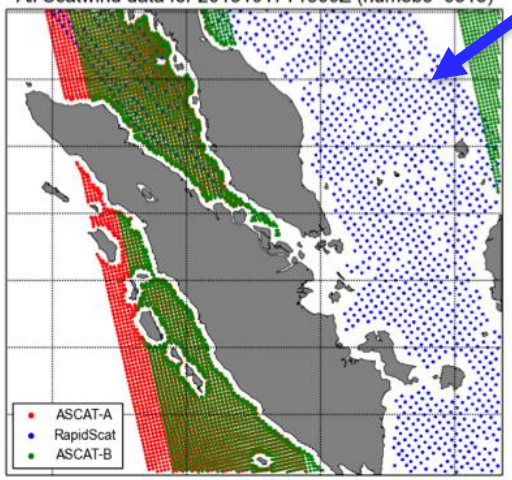
Surface
MetDB Subtypes
- LNDSYN
- SHPSYN
- BUOY
- BOGUS
- MOBSYN
- METARS

MT SAPHIR
MetDB Subtypes
- SAPHIR

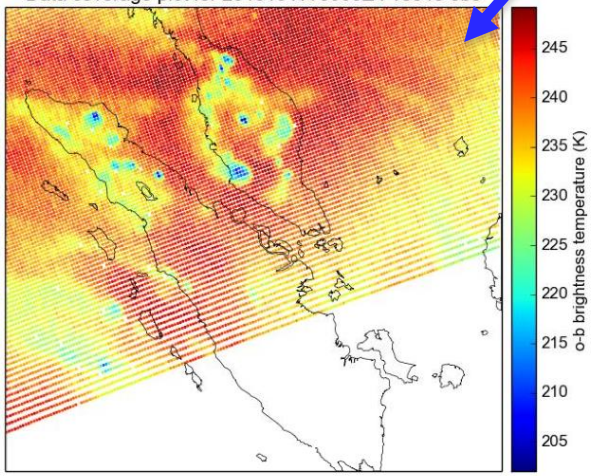
ATMS
MetDB Subtypes
- ATMS

RapidScat

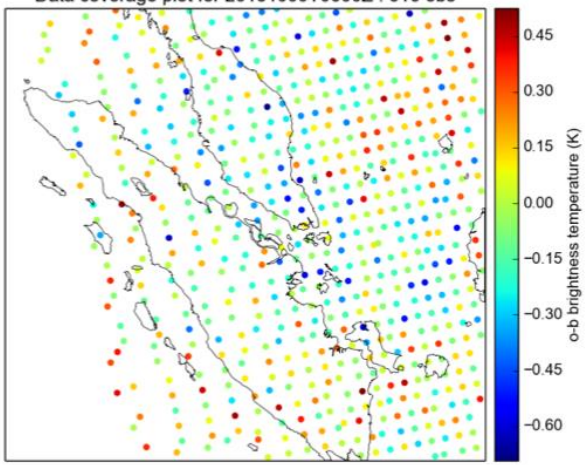
All Scatwind data for 20151017T1500Z (numobs=6315)



Data coverage plot for 20151011T0900Z : 13845 obs

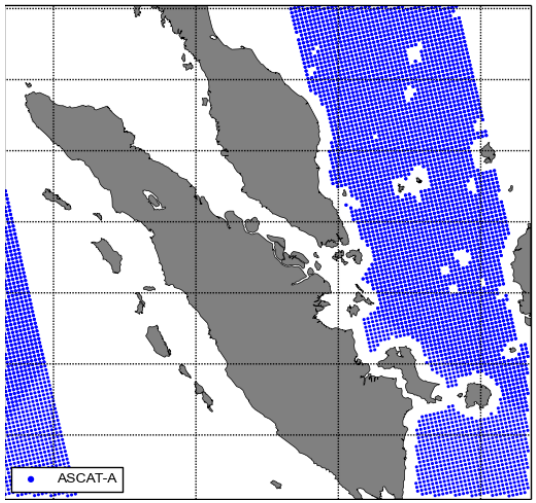


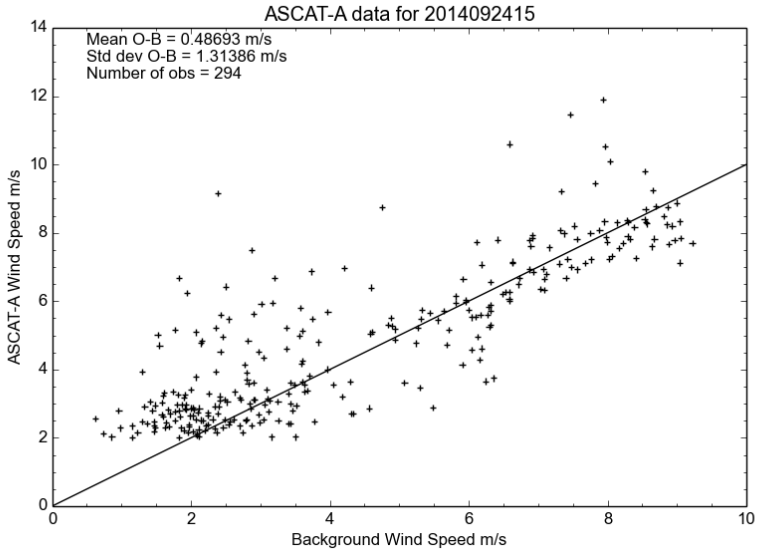
Data coverage plot for 20151009T0600Z : 616 obs

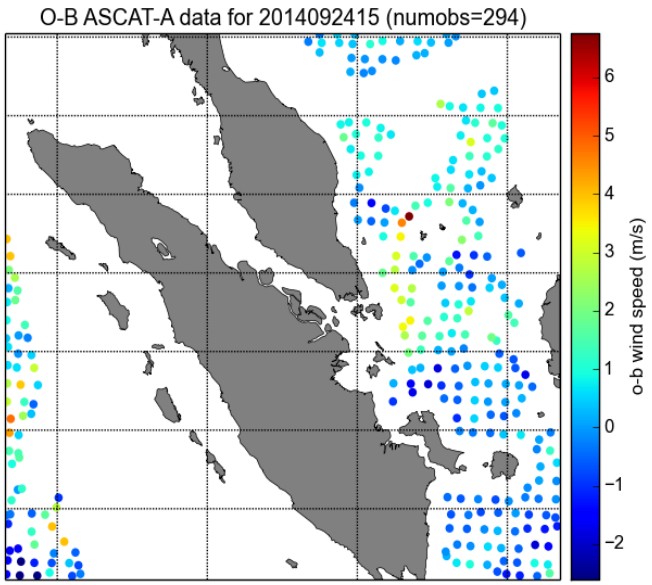


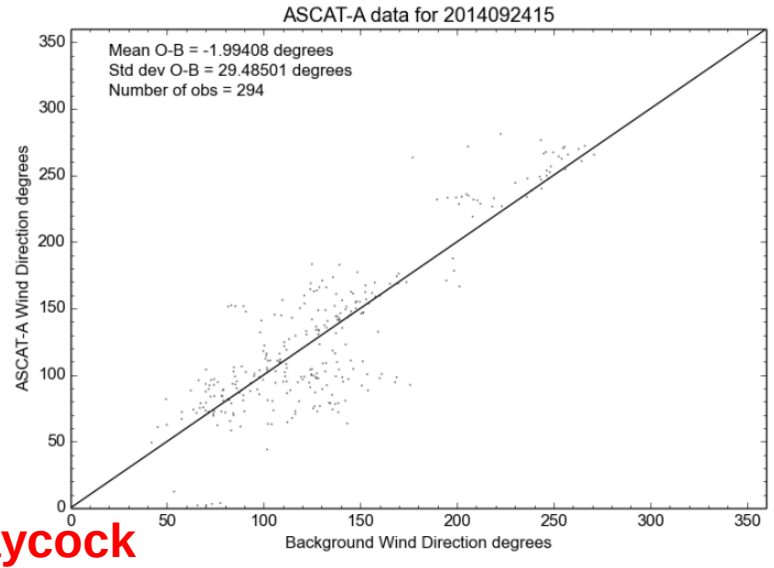
Example Ob Monitoring (ASCAT Winds)

Met Office



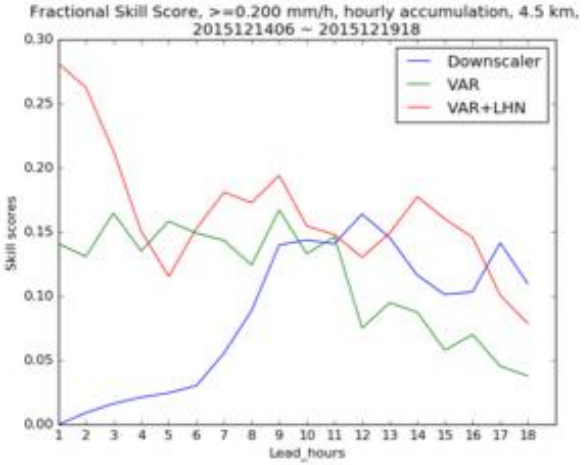




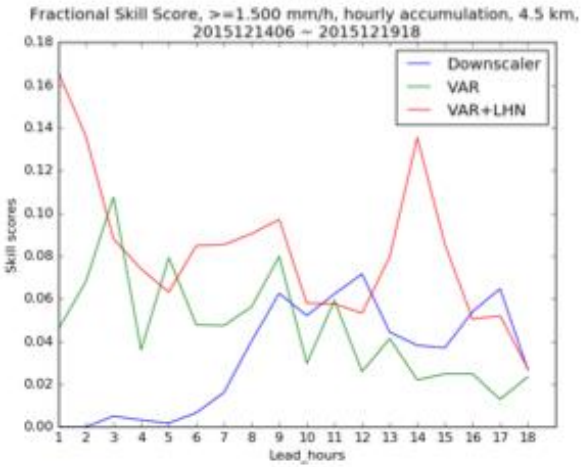


Met Office

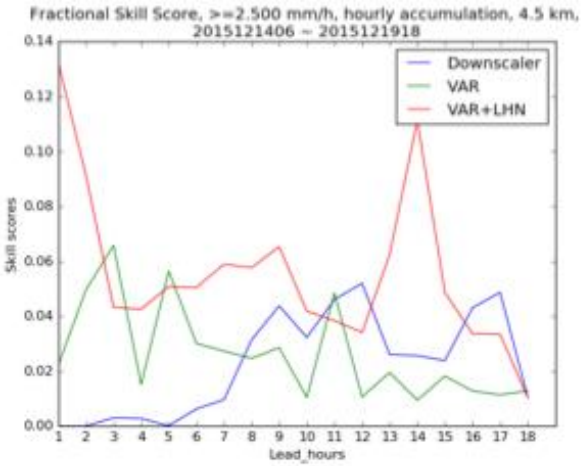
Sl ults



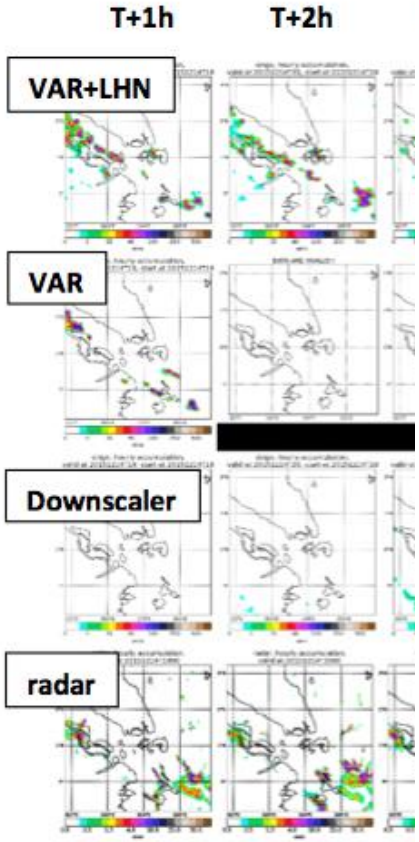
Thres: 0.2 mm/h

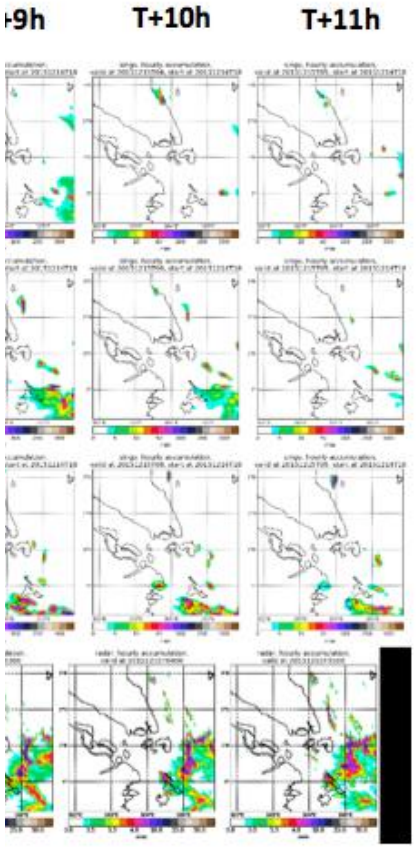


Thres: 1.5 mm/h



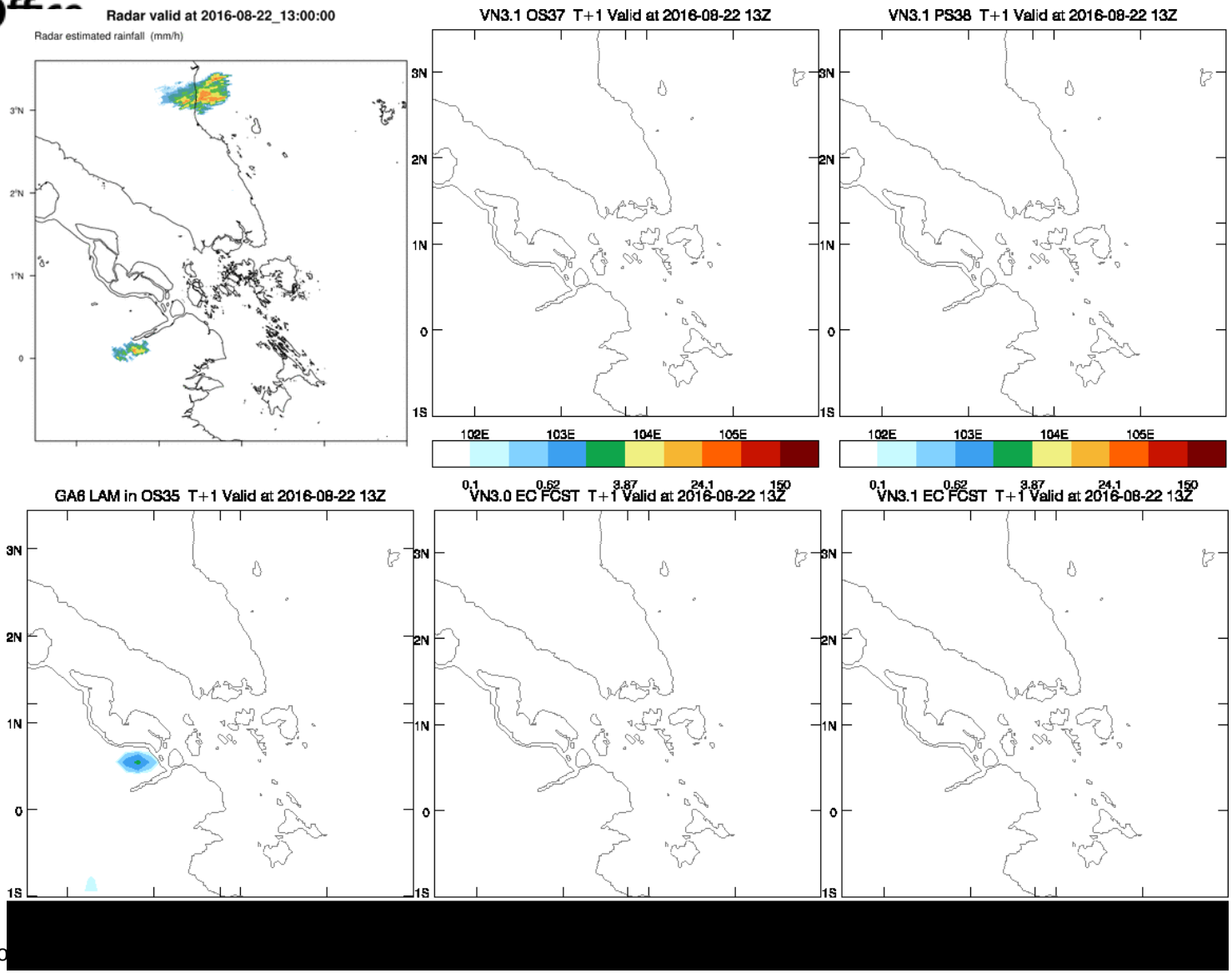
Thres: 2.5 mm/h





Example: mber 2015

August 22-23 2016



Summary

- Deep-tropics provides a challenging environment for model, obs and DA.
- Global model tropical performance improving, but significant biases remain. Strongly influences performance of high-resolution NWP e.g. SINGV.
- SINGV project focussed on km-scale NWP – initial focus on basic model performance e.g. resolution, physics sensitivity. Beginning DA, EPS work…
- SINGV current work:
  - Model improvements (V-grid, conservation, ‘blobbiness’).
  - Data assimilation – cycling 3DVar with full range of obs, LHN.
  - Appropriate evaluation (metrics, observations, forecaster input).
  - Need for uncertainty estimation through ensemble.
  - Operational implementation (MSS forecaster’s view critical!).

Thank You For Listening!