Met Office

GASS microphysics comparison project and a bit more…

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Talk Overview

- Kinematic driver (KiD) model
  - Introduction to the KiD model
  - Microphysics comparison with 1-D KiD (Shipway & Hill, 2012)
- Aerosol-cloud interactions in KiD model
- WMO/GASS microphysics comparison
  - Aerosol processing
  - Initial results from bin comparison
- Do results from KiD mean anything for large-scale modelling?

Kinematic driver (KiD) model

- Large spread in modelled precipitation in GCSS RICO intercomparison due to microphysics?
  - Using a kinematic flow in participants models suggested and discussed in GCSS Toulouse meeting 2008, but too complicated
- 1D Kinematic driver (KiD) model developed at Met Office and release in early 2010
  - Simple microphysics interface to a common dynamical core
  - Developed to test a range of microphysics schemes in a consistent way
  - Code and documentation available from http://www.convection.info /microphysics
  - Shipway and Hill (2012) describes the KiD model and a comparison of warm bulk rain schemes with a bin resolved scheme. Other publications – Dearden et al, 2011 (aerosol-cloud interactions), Onishi & Takahashi, 2012 (development and testing of new bin-bulk hybrid scheme), Field et al, 2012 (ice nucleation mechanisms)
- May 2012 – new version of KiD release, which is a 1-D or 2-D framework, with new test-cases including the WMO/GASS case, a 2-D Sc, Cu and Squall line case

Comparison of warm bulk microphysics schemes (Shipway & Hill, 2012)

Intercomparison set-up

Prescribed Vertical velocity:

$$w(z,t) = \begin{cases} w_1 \sin(\pi/t_1), \text{ if } t < t_1 \\ 0.0 \quad , \text{ if } t > t_1 \end{cases}$$

t_1 = 600 s and w_1 is max velocity (w_{max}) which is **2 ms^{-1} in W2** and **3 ms^{-1} in W3**

Initial Profiles: based on RICO case

height (m)	warm 1		W2 and W3	
	qv	θ	qv	θ
0	0.016	297.9	0.015	297.9
740	0.0138	297.9	0.0138	297.9
3260	0.0024	312.66	0.0024	312.66

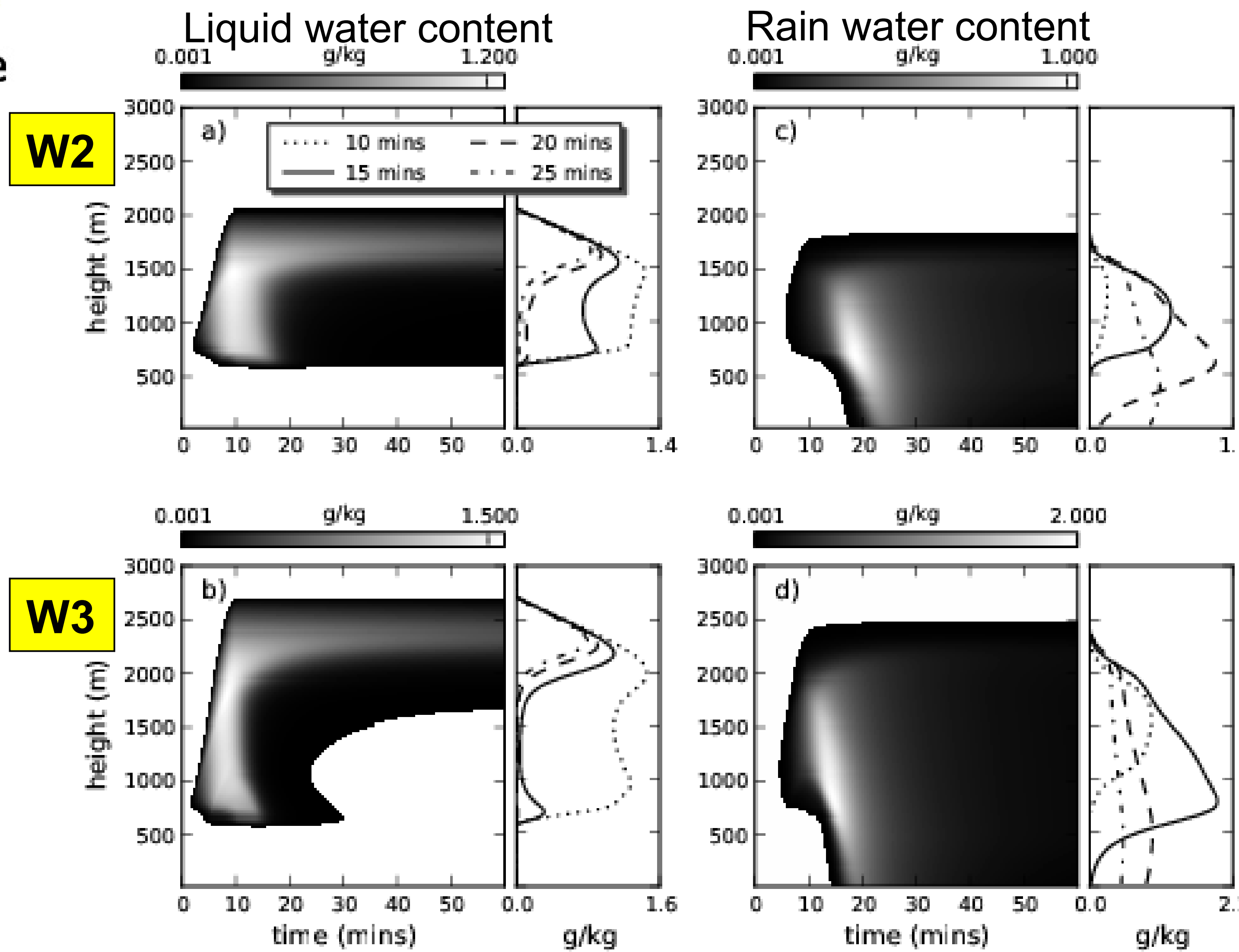
Aim:

Investigate how some bulk microphysics scheme compare to a "best estimate" bin resolved scheme

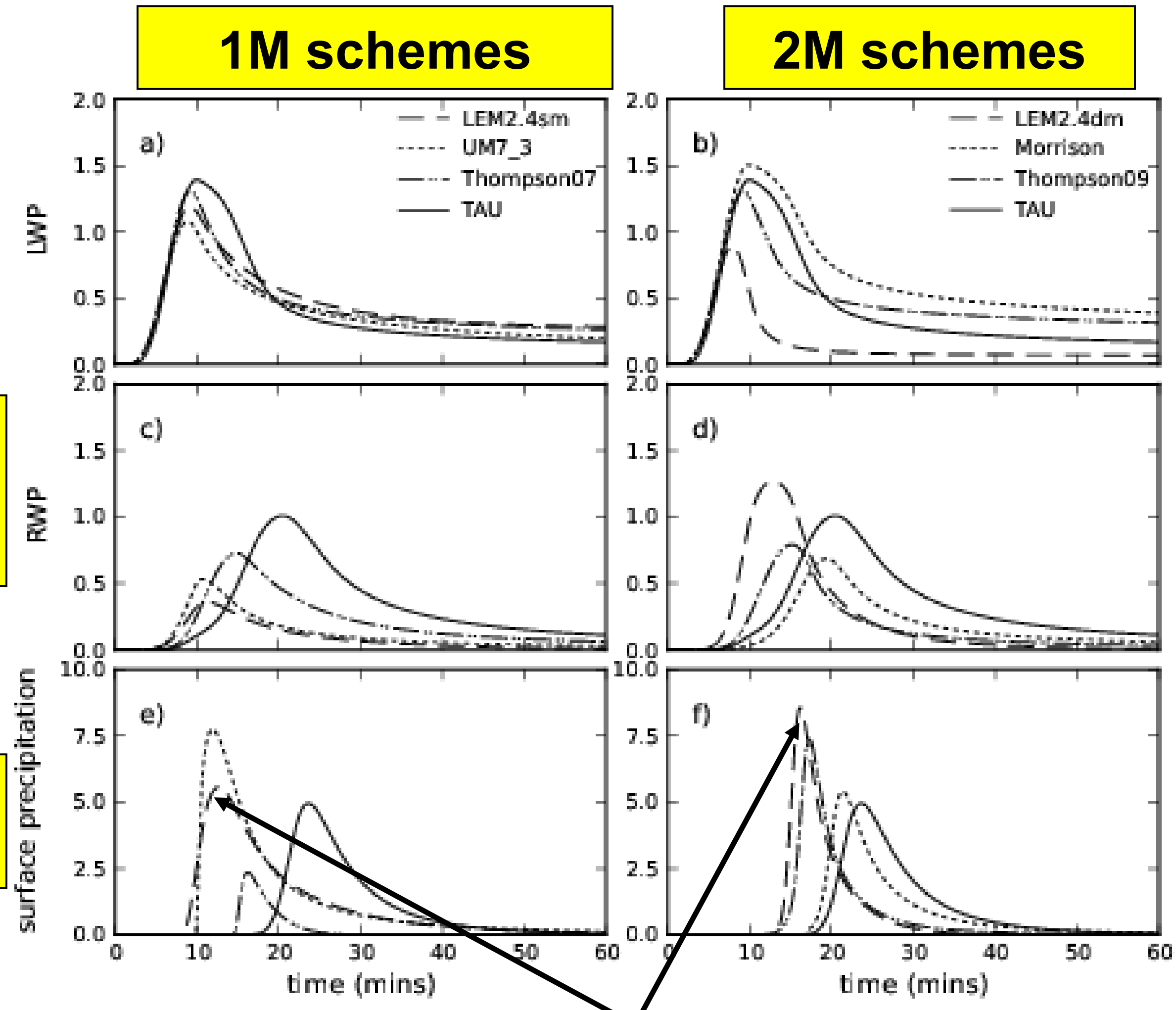
Microphysics schemes:

- The Tel-Aviv University (TAU) multi-moment bin scheme – "best estimate"
- 1-moment (1M) bulk schemes
  - UM, LEM2.4, Thompson08
- 2-moment (2M) bulk schemes (1M cloud, 2M rain)
  - LEM2.4, Morrison, Thompson09
- All schemes initialised with N_d/aerosol = 50 cm^{-3}

TAU scheme – "best estimate"



Comparison of bulk schemes – W2

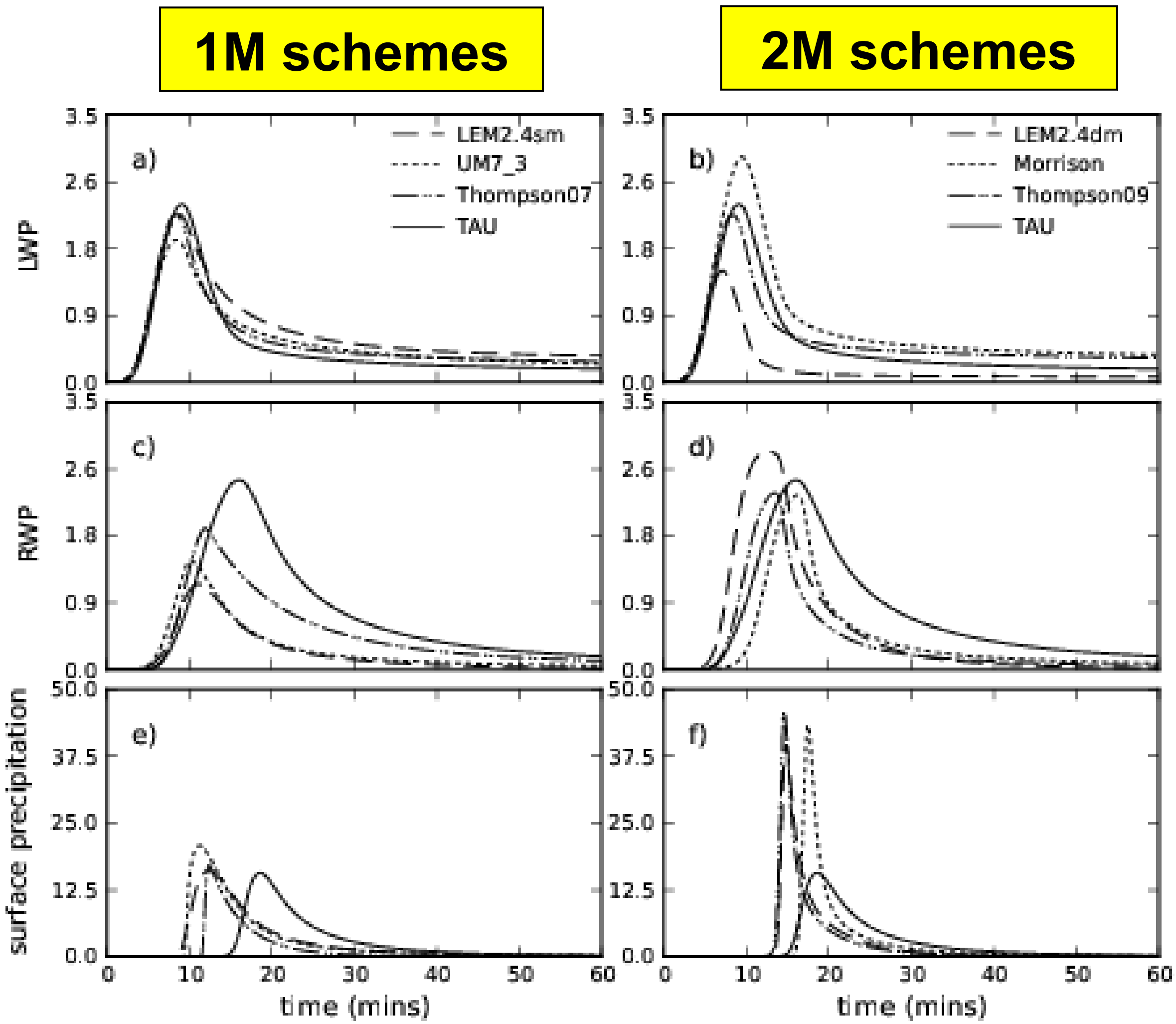


All schemes (except morrison) produce Rain water earlier…

…and start raining earlier than TAU

Increase complexity from 1M to 2M → increase in peak precipitation…

Comparison of bulk schemes – W3



Timing of initial rain water shows better agreement with TAU…

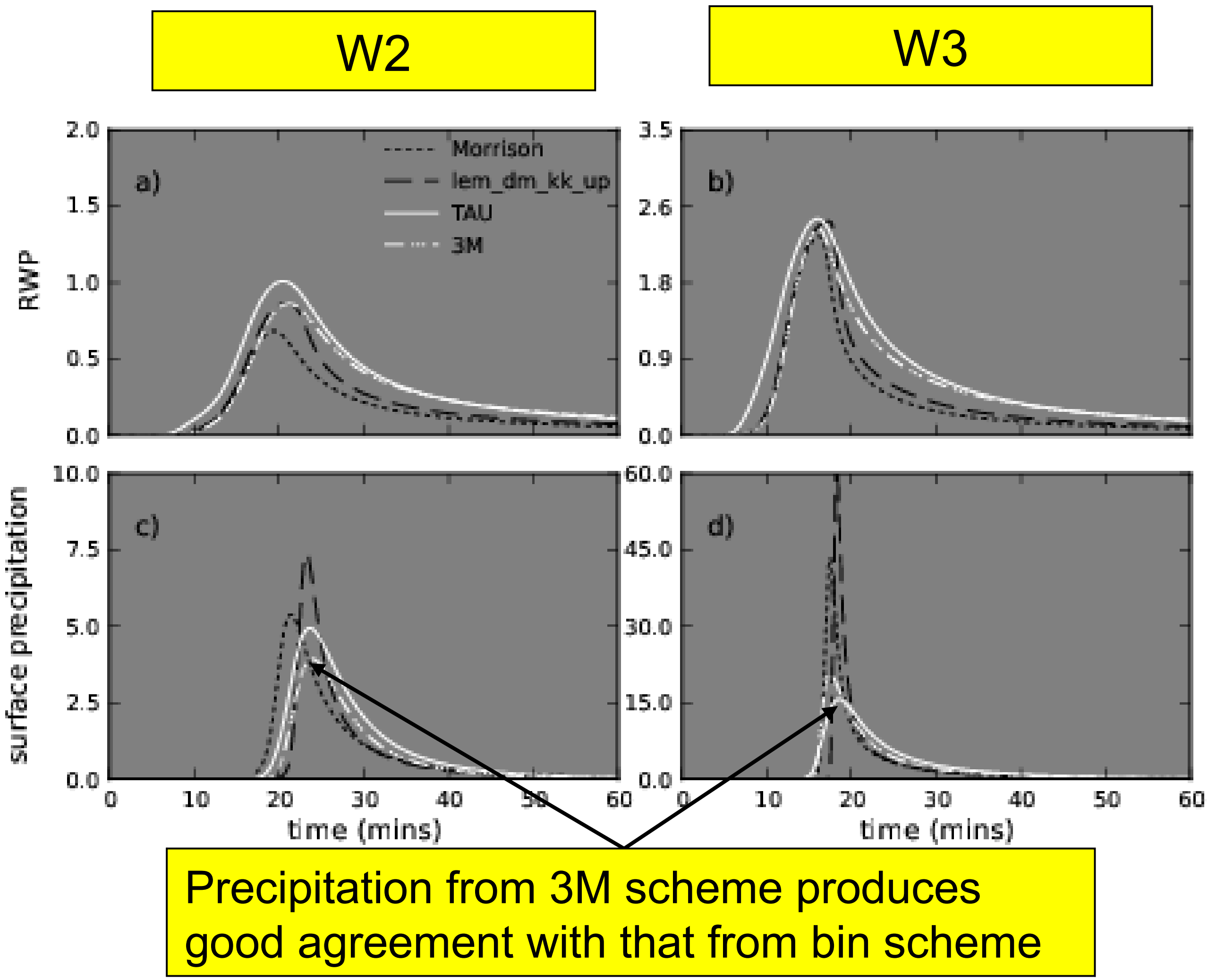
…but bulk schemes still rain too early than TAU

Discrepancy between 1M and 2M peak precip. increased with w

Overview of new multi-moment bulk scheme - "4A"

- Longterm replacement for the UM and LEM microphysics scheme that is coupled to aerosol/UKCA
- User definable number of cloud species (e.g. cloud, rain, ice, snow, graupel)
- Assumes a generalised particle size distribution described by Nd, μ, λ.
- User definable number of moments to describe each species (1,2 or 3)
  - 1-M scheme – λ vary, Nd and μ fixed (mass is prognostic variable)
  - 2-M scheme – λ and Nd vary, μ fixed (mass and number are prognostic variables)
  - 3-M scheme – all 3 parameters adapt due to changes in prognostic variables which potentially improves accuracy in description of particle size distribution

3-moment (3M) rain vs double moment rain



Aerosol-Cloud interactions in KiD model

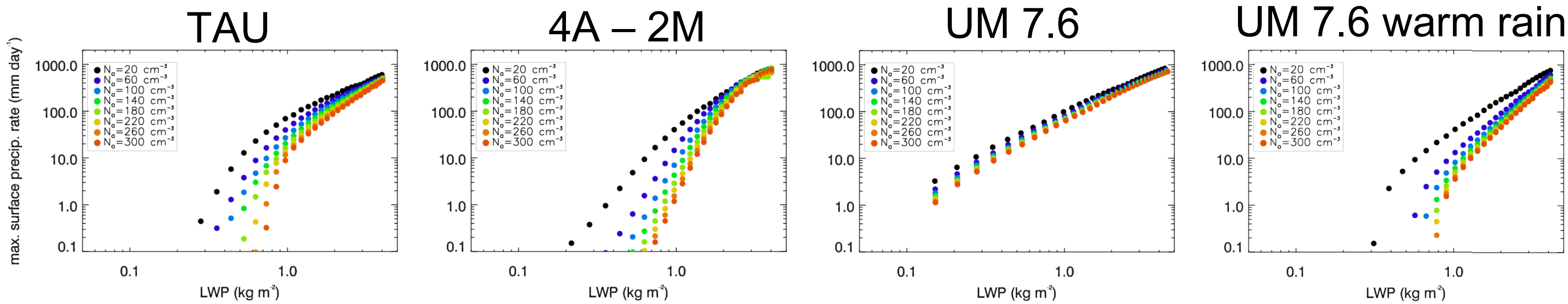
To investigate aerosol-cloud interactions, in particular the response of precipitation processes to changes in N_d we use the same set-up as W2 & W3 but…

• w_{max} range = 0.1 → 4.5 m s^{-1}, increasing by increments of 0.1 m s^{-1}

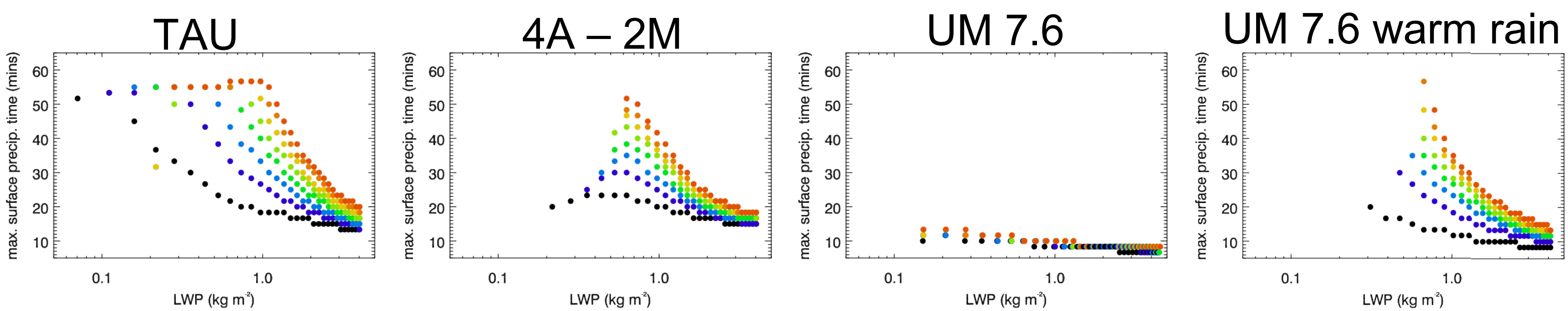
• initial N_a or N_d range = 20 → 300 cm^{-3}, increasing by increments of 10 cm^{-3}

Aerosol-Cloud interactions in KiD model

max. surface precip. rate vs. max. liquid water path (LWP)

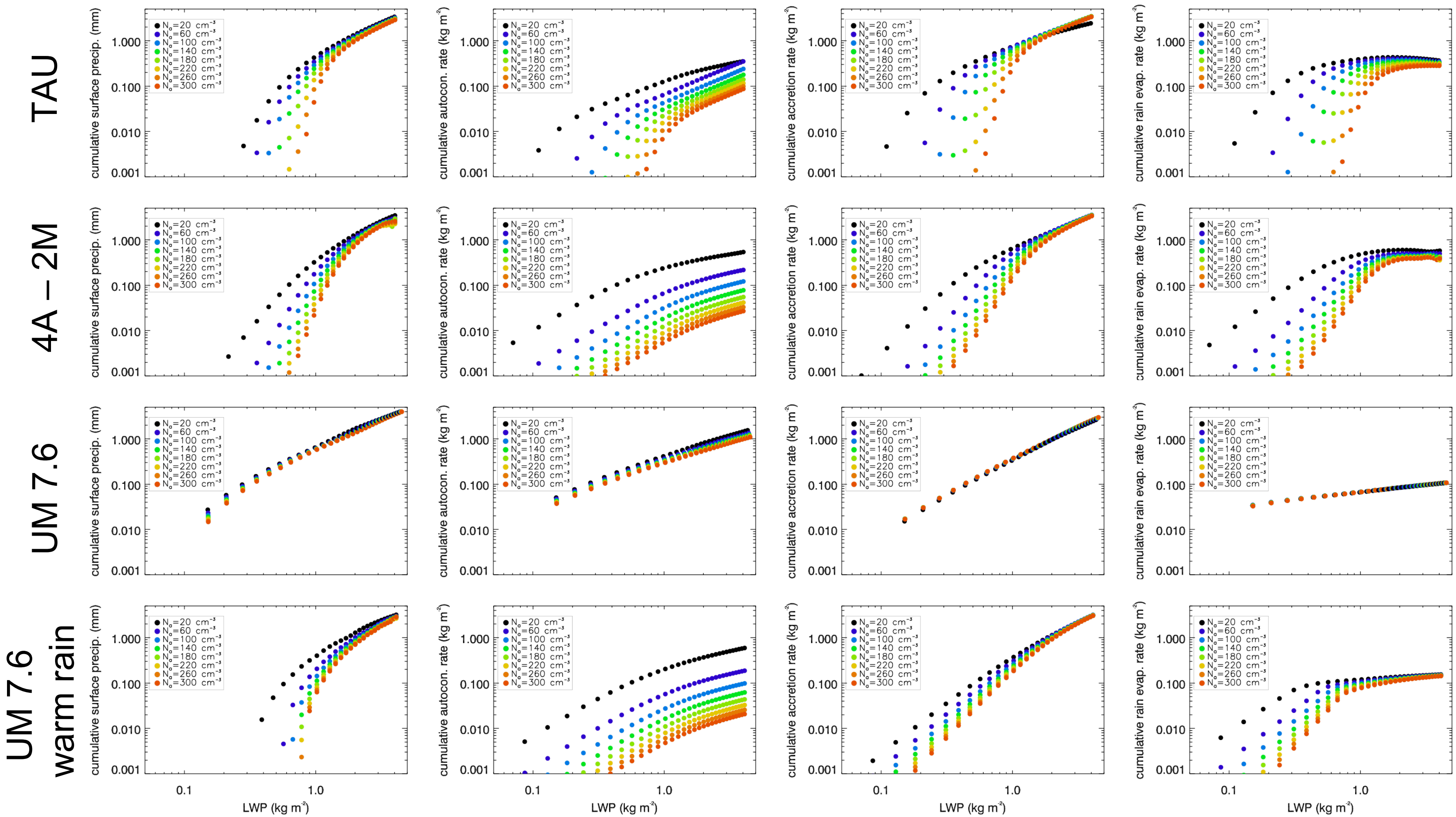


Time of max. precip. rate vs. max. liquid water path (LWP)



Rain water budget response to changes in N_d

Accumulated surface precip. = Integrated autoconversion + Integrated accretion - Integrated rain evaporation - ΔRWP

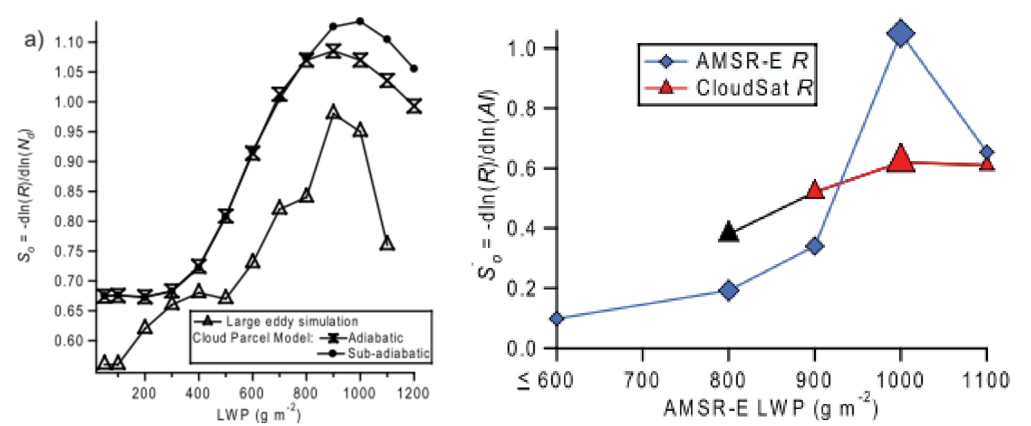


Precipitation susceptibility

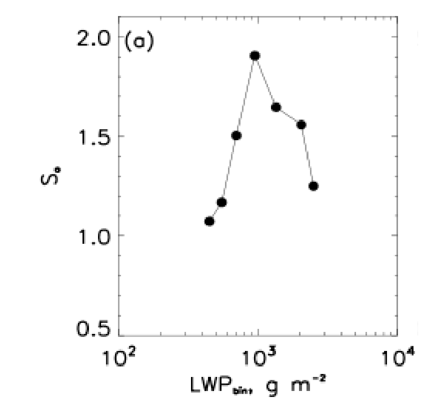
- The concept of precipitation susceptibility (S_0) was introduced as a framework to investigate aerosol effects on precipitation (Feingold and Seibert, 2009; Sorooshian et al, 2010).

$$S_o = -\frac{d\ln R}{d\ln N_d}$$

Where R = precipitation rate, N_d = cloud droplet number concentration



From Sorooshian et al, 2010, GRL



From Jiang et al 2011, JAS

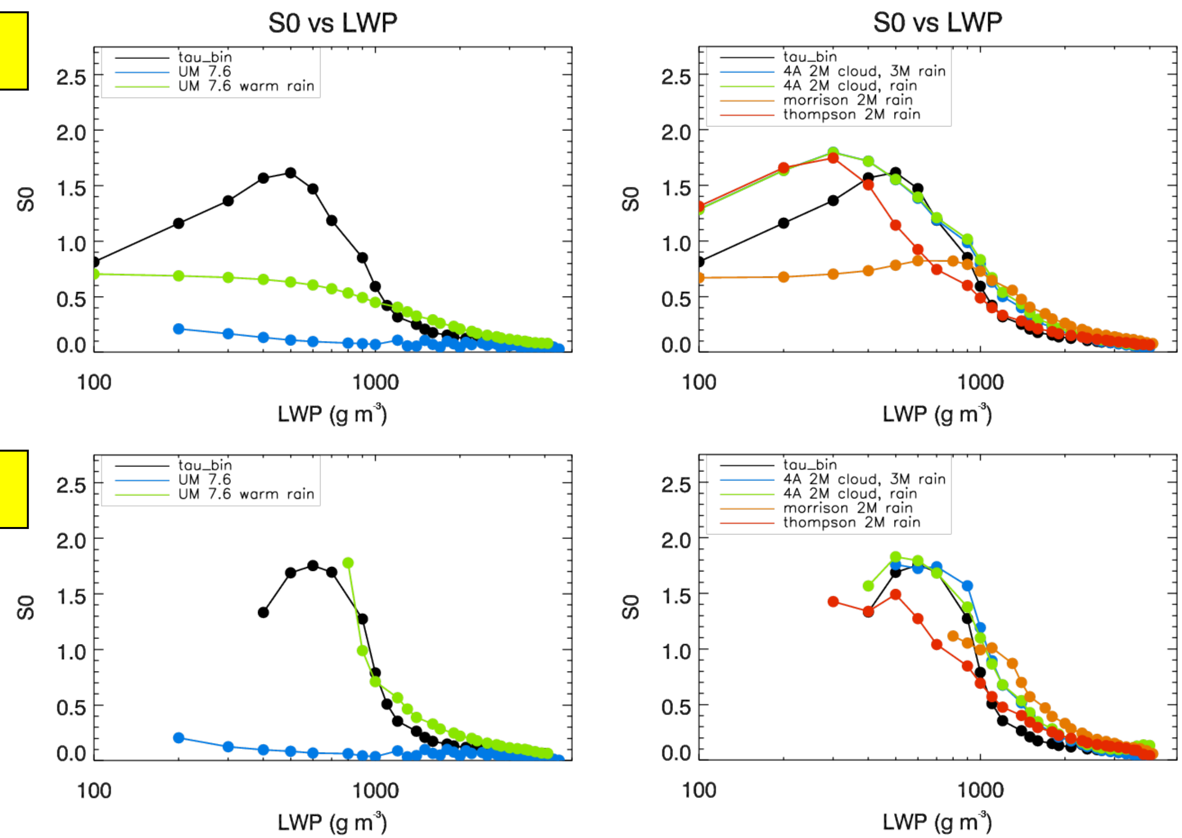
- S_0 is used to compare the relative response of different microphysics schemes to changes in aerosol concentration…

Precipitation susceptibility (cont.)

1. Bin accumulated surface ***R*** and ***N$_d$*** into LWP bins (width of LWP bin =100 g m^{-2})
2. Perform a linear regression in each bin to find a best fit for **ln*R*** against **ln*N$_d$***
3. Calculate **S$_0$** in each bin using the fitted **ln*R*** in the equation above

Cloud base

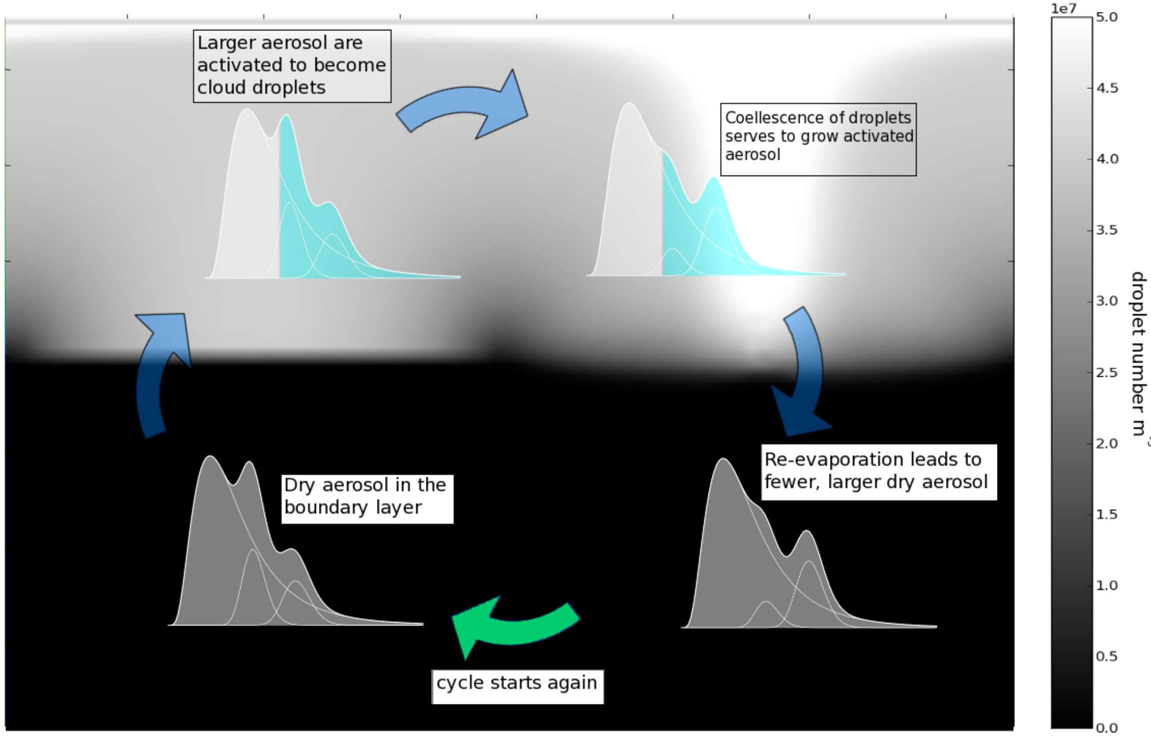
Surface



GASS/WMO microphysics intercomparison

• Increasing complexity therefore shows better agreement with bin scheme but **do we trust the bin scheme**?

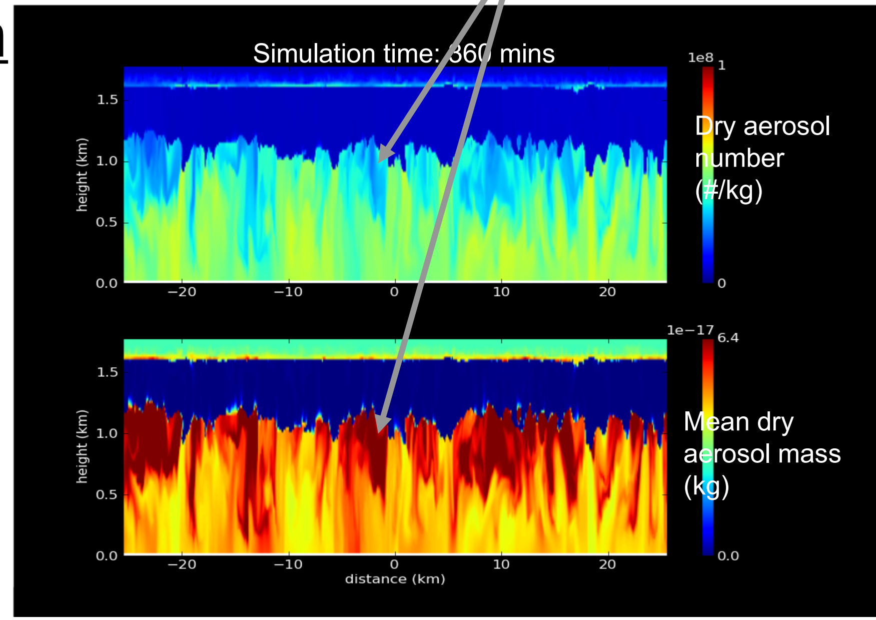
• No aerosol processing in these simulations – **how important is this?** For example…

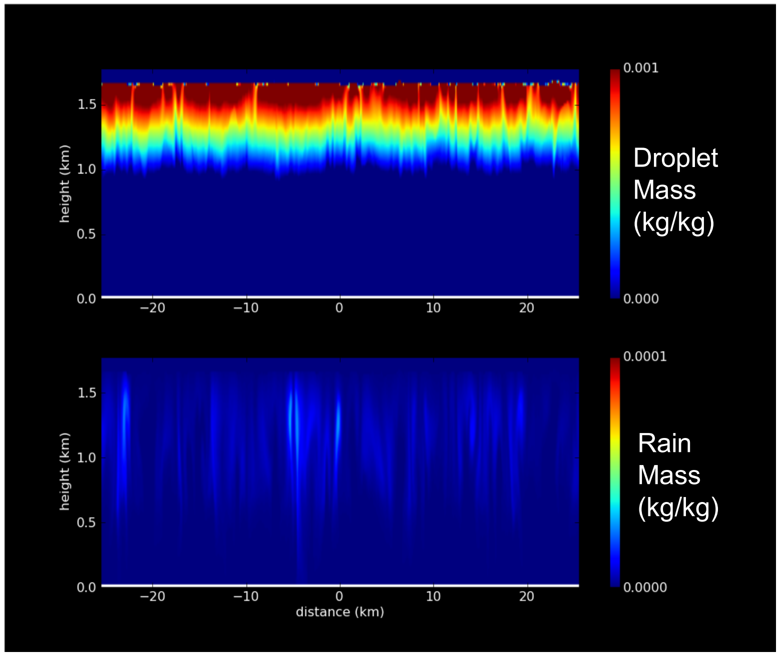


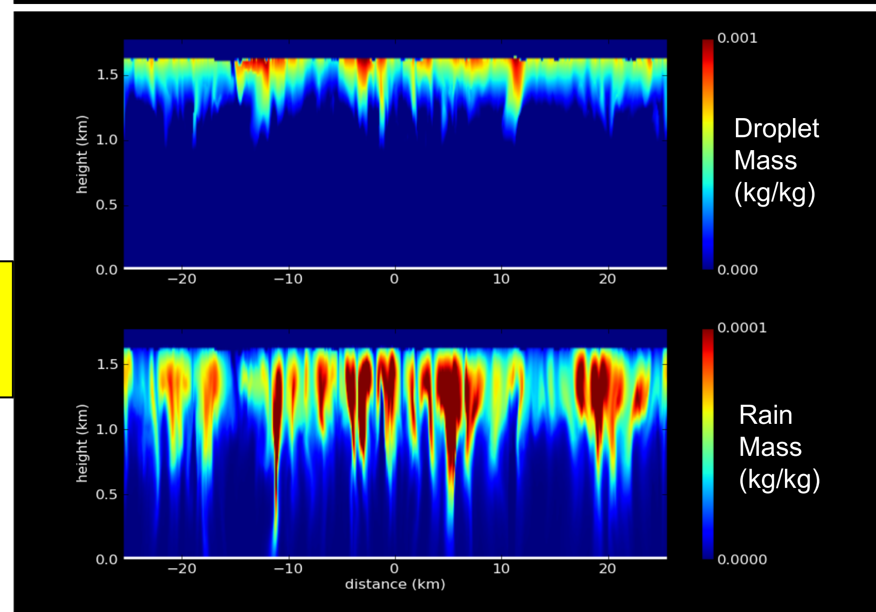
• GASS/WMO intercomparison uses a kinematic (no dynamic feedbacks) and dynamic case (LES with dynamic feedbacks) that is loosely based on VOCALS.

Example of the dynamic case with 4A

Processing decreases number and increases mean size of dry aerosol







As a result, the cloud layer thins and drizzle rate increases significantly.

Expected outcomes

Aerosol-cloud comparison is first of its kind – unknown territory, but a benchmark of where we're at.

A key objective will be to evaluate different microphysical approaches without aerosol processing - can we say something conclusive here?

The microphysics schemes consist of 3 broad types:

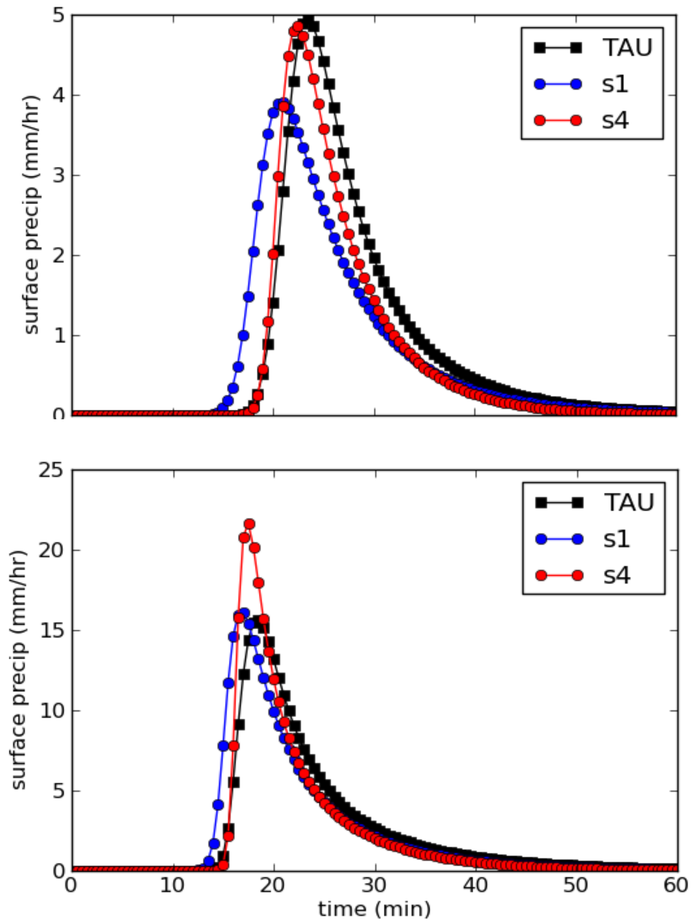
Bulk models: 1-moment, 2-moment, 3-moment

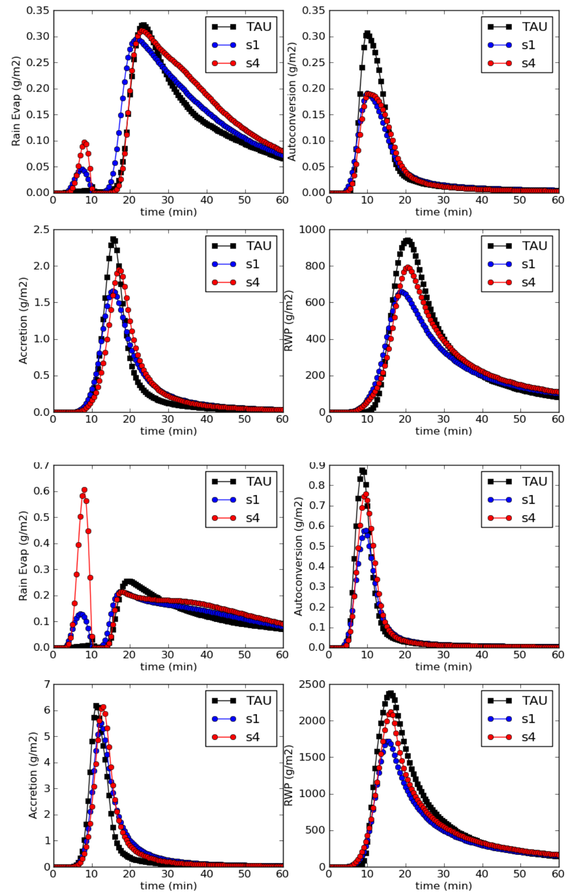
Bin models: 1-moment, 2-moment, various bin resolutions

'Super-droplets': How do these sit among the other methods?

Can bulk schemes handle aerosol processing effectively?

How do our size bin resolved microphysics ("best estimates") schemes compare?



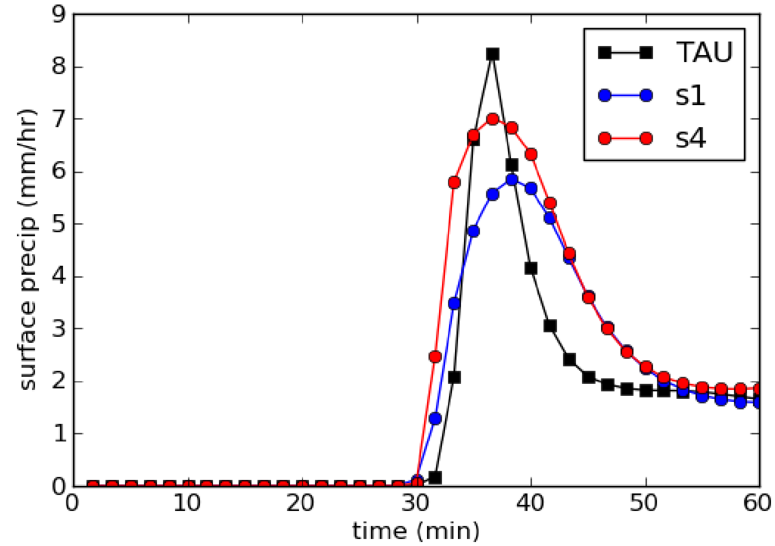


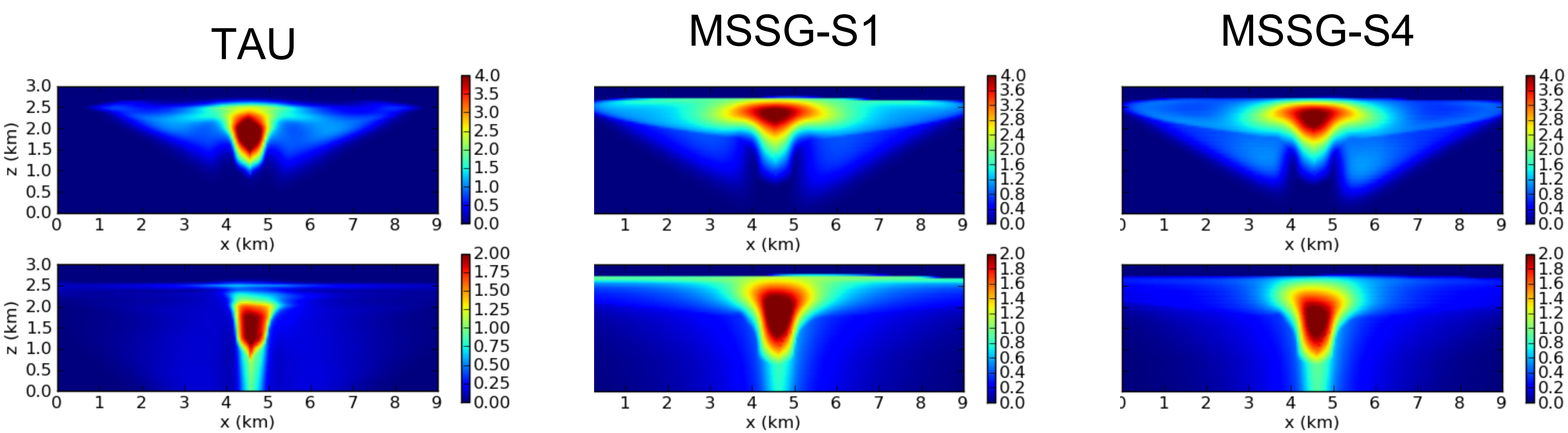
1. The Tel-Aviv University (TAU) multi-moment scheme (used in Shipway & Hill (2012)
2. MSSG-Bin – single moment bin scheme described Onishi & Takahashi (2012)
   - S1 = 33 bins
   - S4 = 128 bins

Both schemes initialised with aerosol = 50 cm^{-3}

How do our size bin resolved microphysics ("best estimates") schemes compare?

- Simulate the 2-D Cu case detailed in Morrison & Grabowski (2006)
- Bin schemes show reasonable agreement with each other…

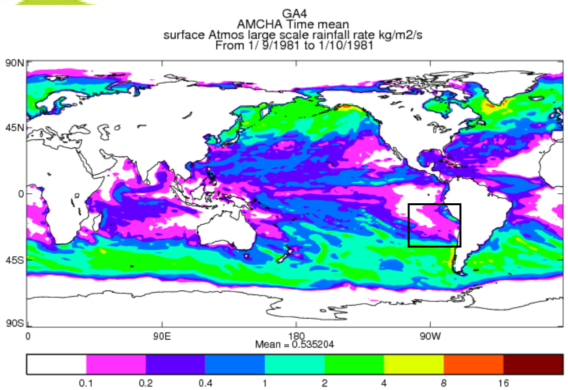


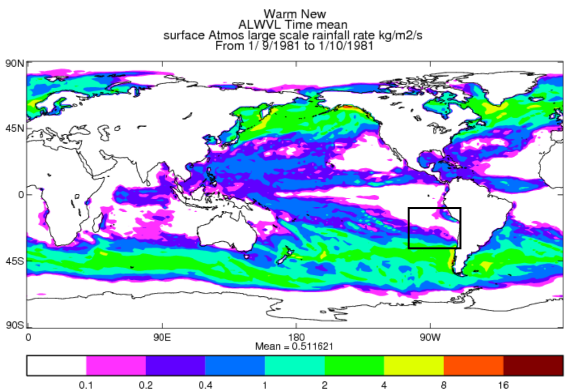


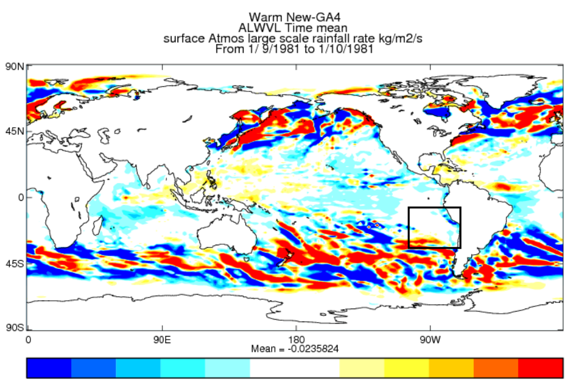
Do the results from kinematic schemes mean anything?

- KiD model, and kinematic frameworks in general, are invaluable development & debugging tools
- But, comparing microphysics schemes within such frameworks seems to identify underlying behaviours and interactions that may be relevant to CRM, high resolution NWP and GCM
- For example a comparison of GCM simulations seem to have similar behaviour to that identified in the KiD. The configurations compared in the are
  - UM GCM sims with GA 4.0 microphysics, which is (roughly) equivalent to UM7.6 in KiD and…
  - UM GCM sims with warm rain package (plus some extras)

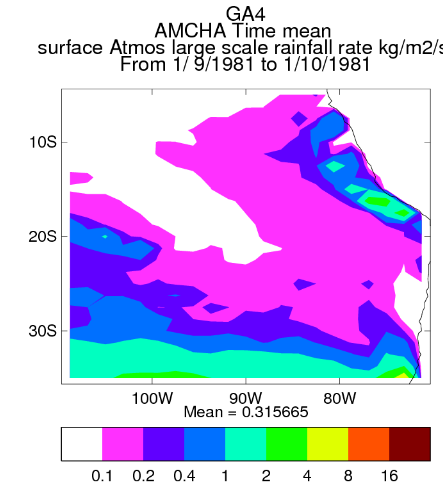
Large-scale (non-convective) precipitation

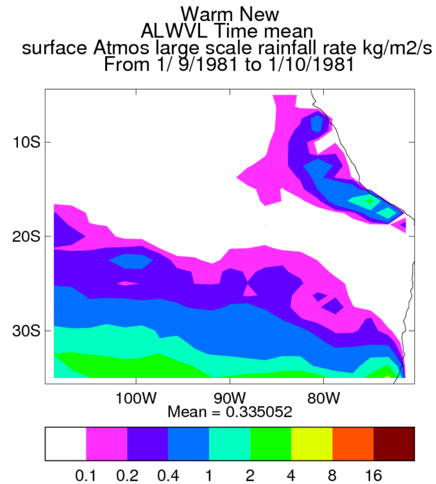


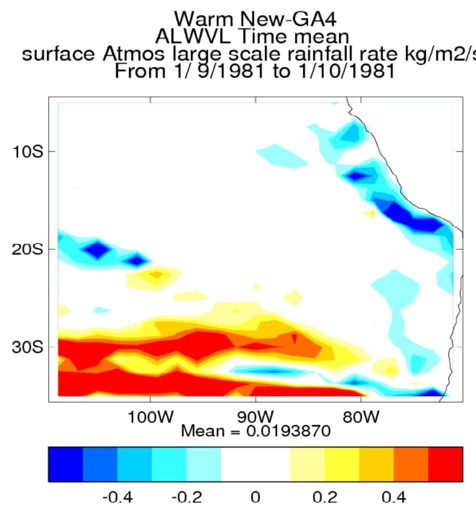




VOCALS Region

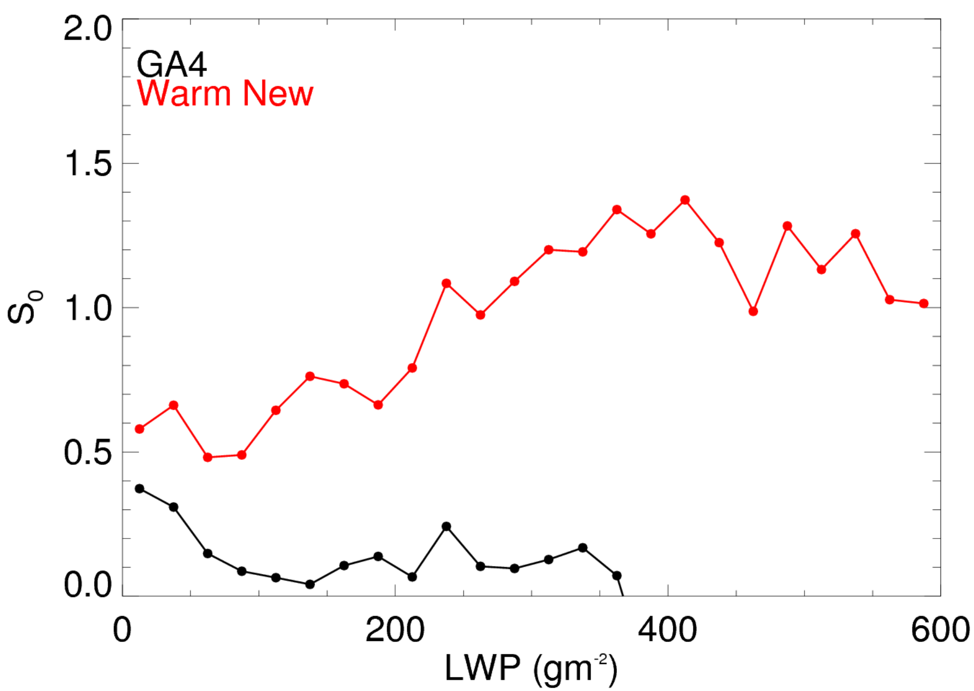


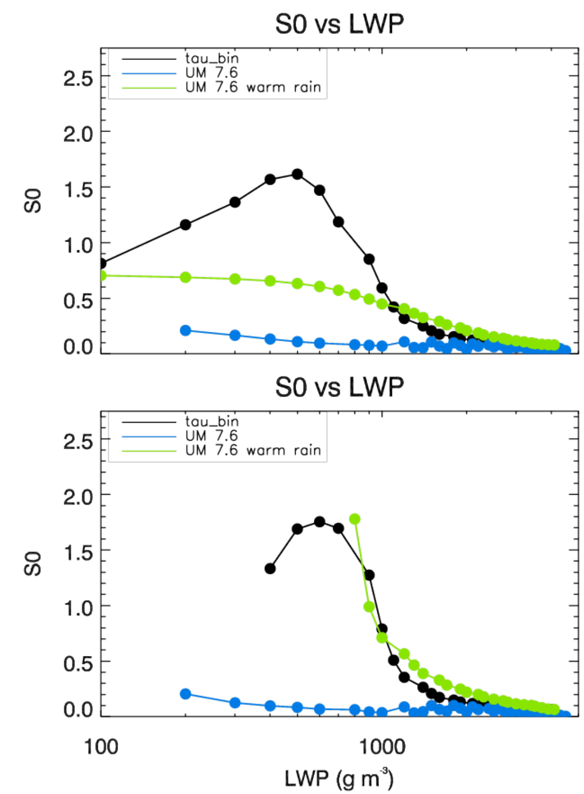




Warm-rain package produces less rain in “high” aerosol regions & more rain in “low” aerosol regions…

Precipitation susceptibility in the GCM?





Summary

- KiD model used to analyse response of precipitation to changes in aerosol (or N_d), i.e. precipitation susceptibility
- S_0 is very dependent on microphysics complexity and parametrizations
    - S_0 of 2M bulk schemes, particularly 2M cloud & rain, exhibit good agreement with the bin scheme **but** 2M schemes rain earlier
    - 1M schemes show poor agreement with the bin scheme with substantial variation in S_0 & timing of precipitation
- S_0 from UM 1M scheme clearly improved (relative to TAU) by modifying autoconversion and accretion representations
- Initial results from GCM sims with UM suggest that such a modifications to microphysics result in qualitatively similar changes in S_0 as that demonstrated with the KiD model (very early result, lots of caveats, more work required…)
- S_0 does not give information about timing of precip. so needs to be used with care, particularly if applied to high resolution NWP

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