Convective Scale Modelling in the UM

Current Research and Developments

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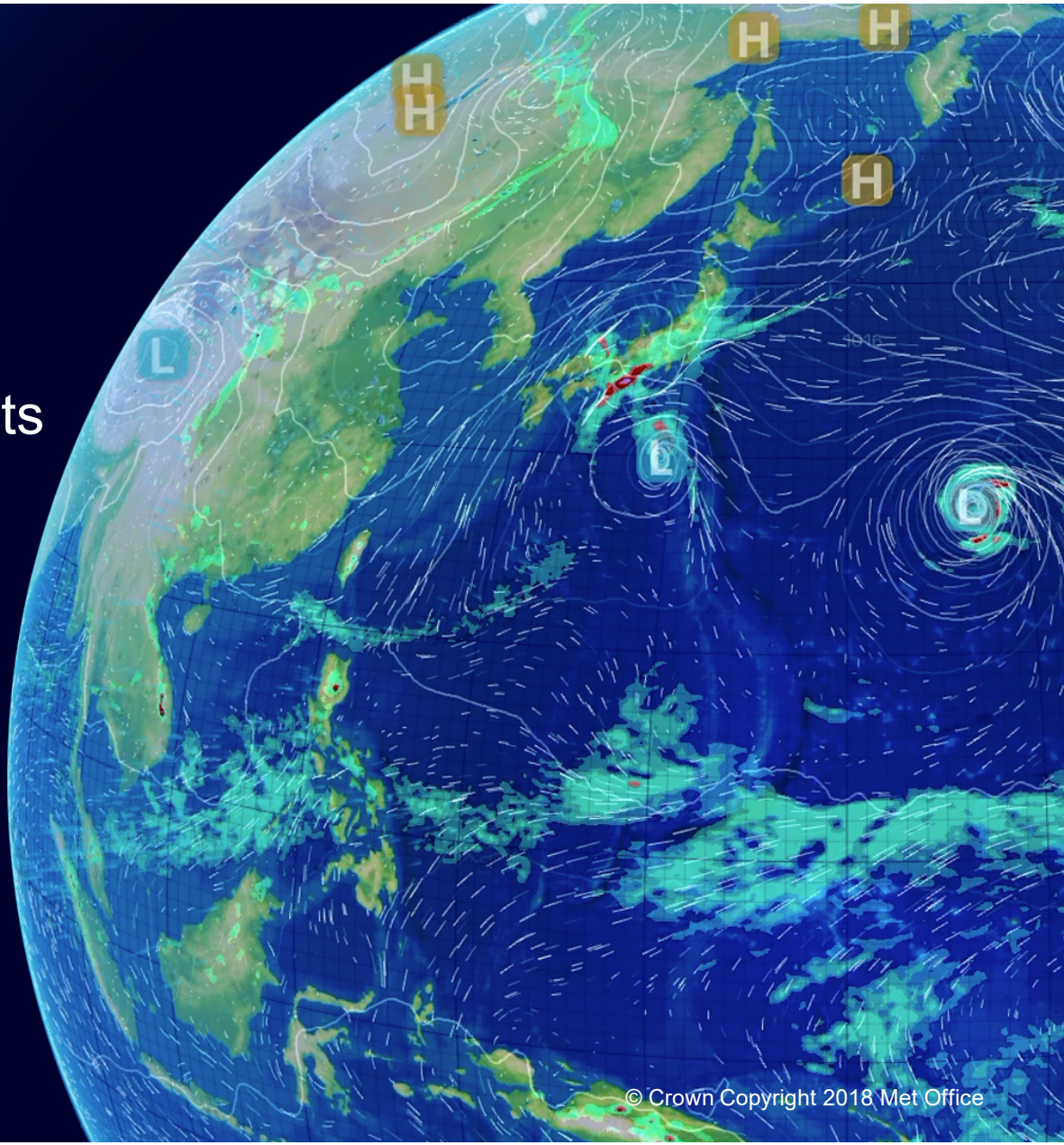
Martin Best

Mike Bush



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RAL - the “Regional Atmosphere and Land” configuration

- Large range of convection permitting models → risk of proliferation of model configurations
- Difficult to design a coherent programme of model development and ensure that research findings are relevant to the most up-to-date model configurations
- The aim: A single configuration for use in NWP operations, climate applications and research projects
- Currently focussing model development on two key model configurations distinguishing between mid-latitude and tropical configurations (RAL-M, RAL-T)

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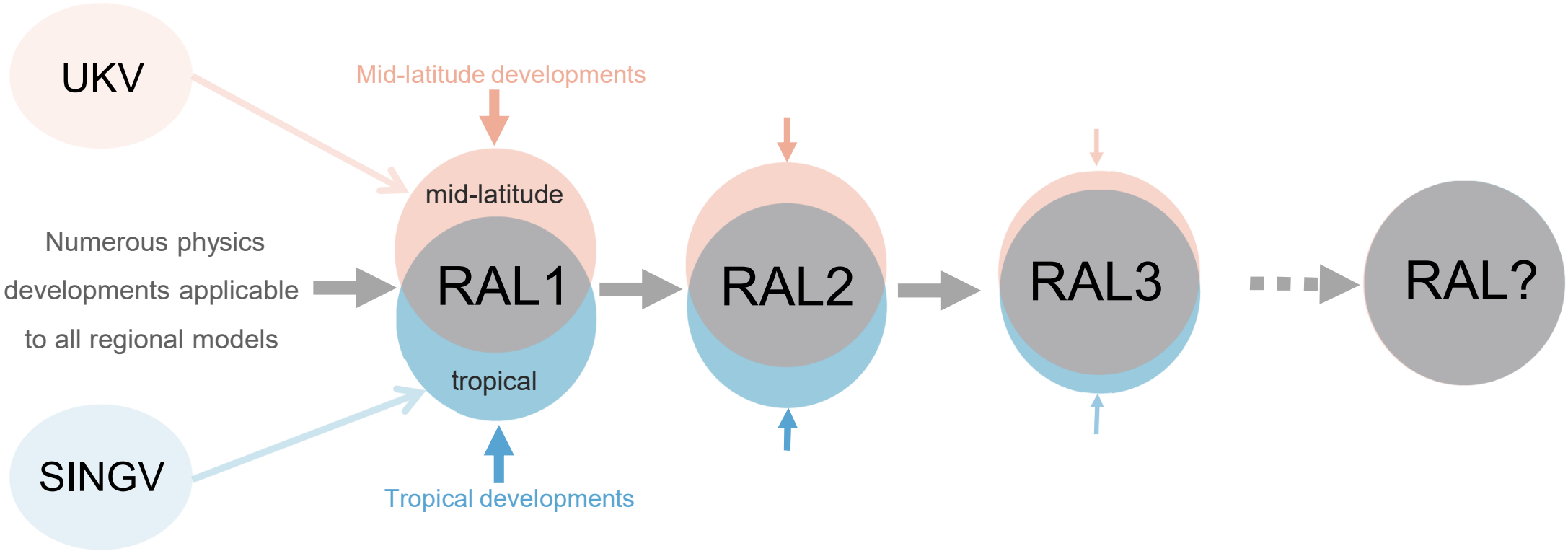
Differences:

RAL-M vs RAL-T

cloud scheme	cloud scheme	~~cloud scheme~~ ?
vertical resolution	~~vertical resolution~~	
boundary-layer settings	BL settings	BL settings



Sep 2018: all RAL1-M changes operational	*operational in Nov 2019 (except vertical resolution)*	*currently in preparation*

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Plans for RAL3 and beyond

- Removing “legacy differences” between model configurations
  - → Mid-latitude vs Tropics
  - → Short-range NWP vs Climate
  - → Global vs Regional
- Improvements to microphysics scheme
- **Improvement and unification of cloud scheme**
- Scale aware convection scheme

Land surface changes (Martin Best)

- Removing “legacy differences” between model configurations
  - → Mid-latitude vs Tropics
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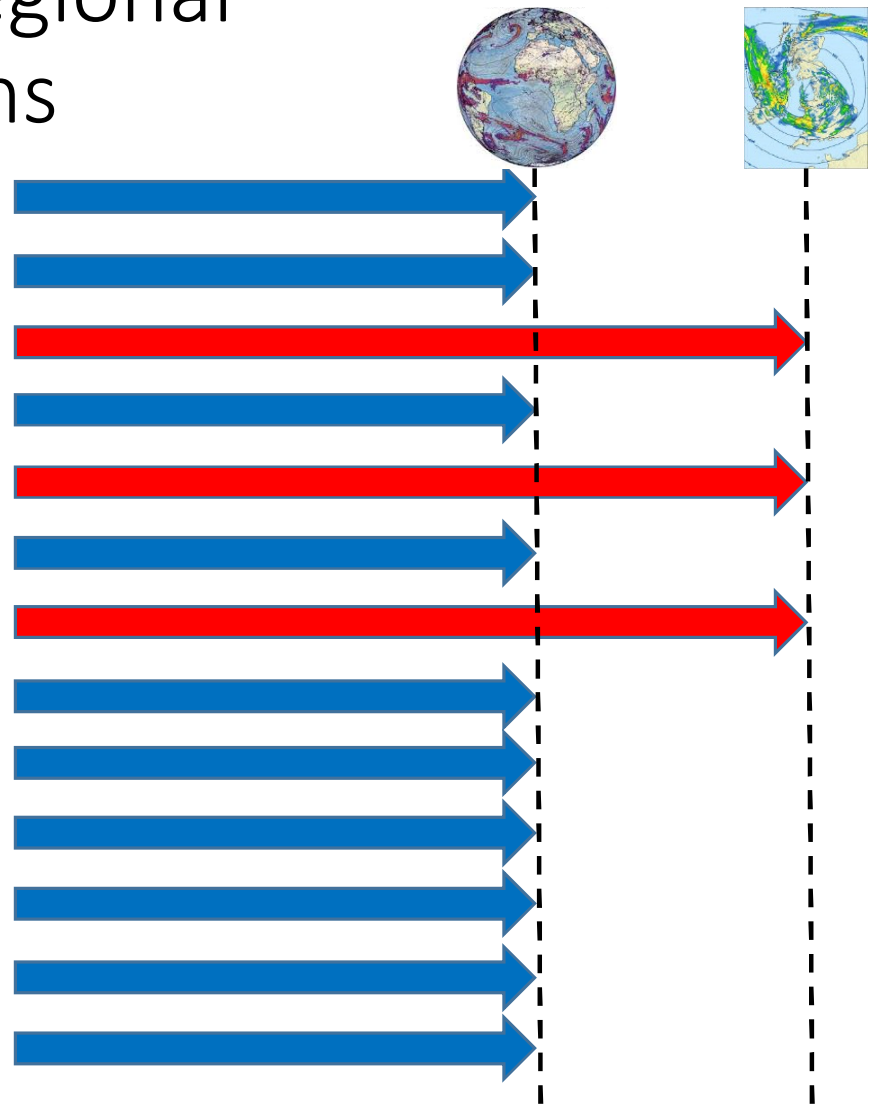
- Scale aware convection scheme

Consolidating global and regional (land) surface configurations

- Vegetation roughness lengths …….
- Bare soil roughness length ……..
- Albedo parameters ……..
- Grid mean albedo set to climatology …….
- Grass canopy light extinction coefficient …..
- Vegetation canopy radiation scheme …….
- Representation of urban areas ……..
- Hydrology heterogeneity ……..
- Soil parameter calculation at boundaries ….
- Saturated soil moisture movement …….
- Surface form drag settings ……..
- Sea-ice albedo properties ……
- Sea surface settings ……..



CASIM (Adrian Hill, Paul Field, Kalli Furtado)

- Removing “legacy differences” between model configurations
  - → Mid-latitude vs Tropics
  - → Short-range NWP vs Climate
  - → Global vs Regional
- Improvements to microphysics scheme
- Improvement and unification of cloud scheme
- Scale aware convection scheme

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Cloud **A**ero**S**ol **I**nteracting **M**icrophysics - CASIM

- Highly flexible design enables research into the role of microphysical complexity in aerosol-cloud interactions for a wide range of cloud types
- Includes in-cloud aerosol processing
- Includes functionality for multi-moment (single moment to triple moment)
- User definable
  - number of cloud species (e.g. cloud, rain, ice, snow, graupel)
  - number of moments to describe each species (1,2 or 3)
- Ongoing work includes code optimisation to reduce runtime
- CASIM is suitable to work with both Smith cloud scheme (RAL-M) and PC2 cloud scheme (RAL-T)

Multi-Modal Cloud Scheme (Kwinten Van Weverberg)

- Removing “legacy differences” between model configurations
  - →Mid-latitude vs Tropics
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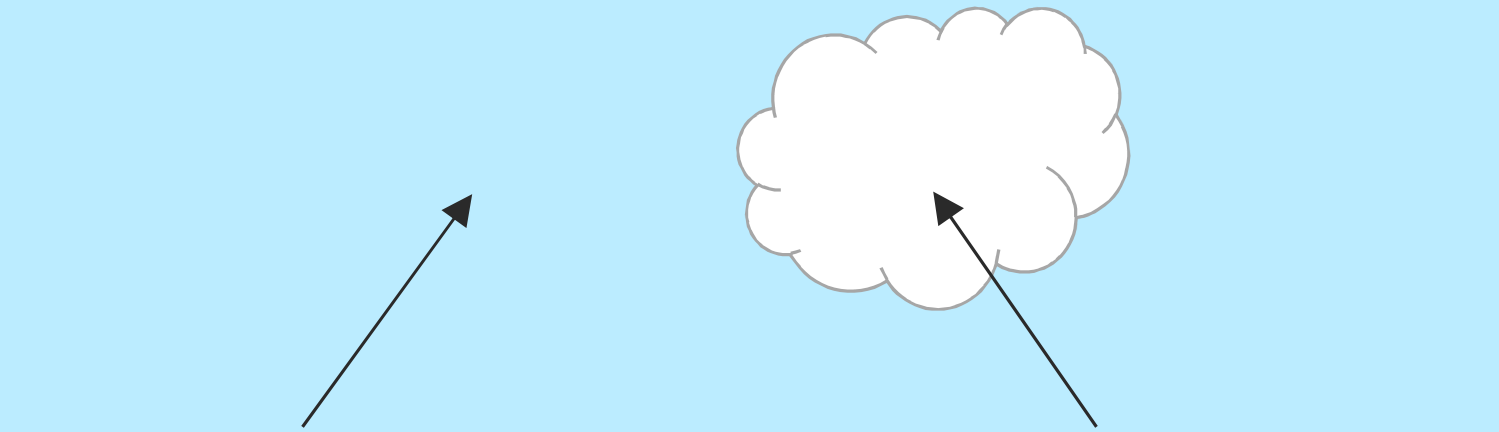
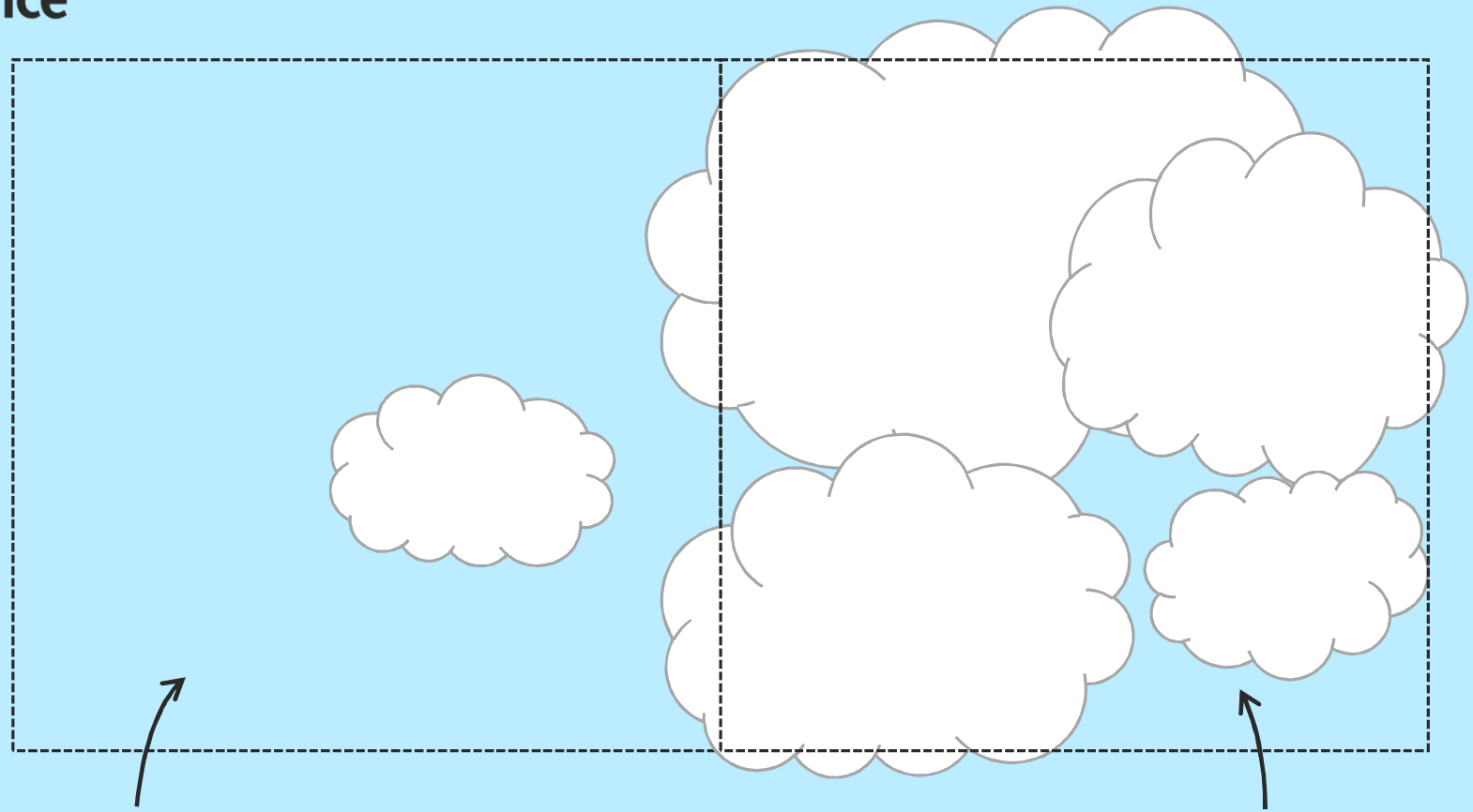
- Scale aware convection scheme



relative humidity < 100%

relative humidity > 100%



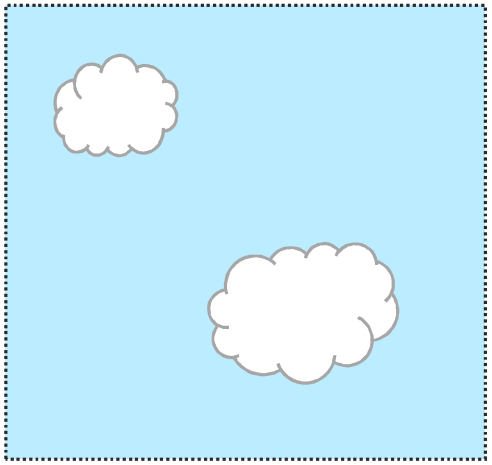
grid box mean relative humidity < 100%

→ not necessarily completely cloud free

grid box mean relative humidity > 100%

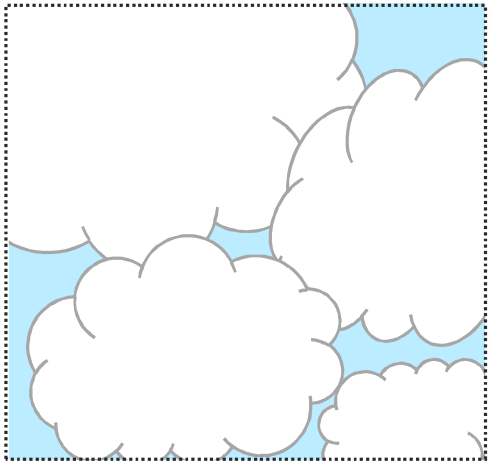
→ not necessarily completely cloudy

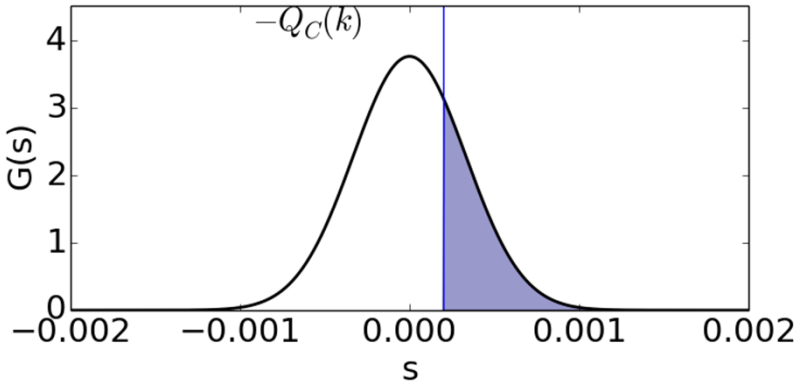
Current uni-modal Smith scheme

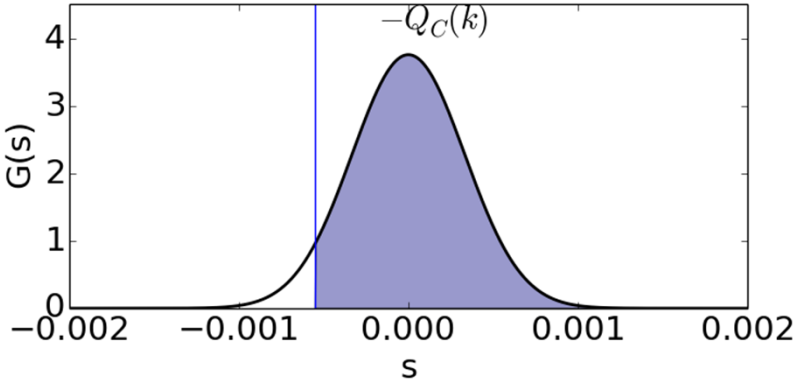


Assume distribution of subgrid variability *s* around mean Q_c

As grid-box mean conditions (Q_c) cool or moisten: integrate over larger portion of *s* distribution.



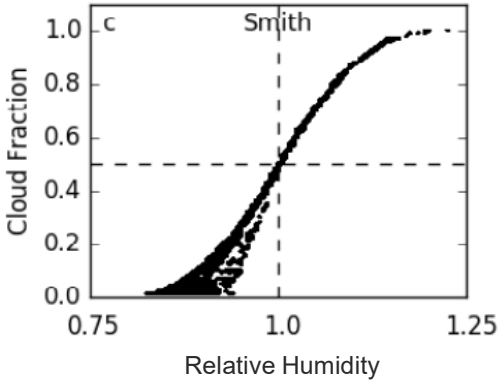




When Q_c increases to 0 (i.e. grid-mean = water saturation), half the grid-box is cloudy

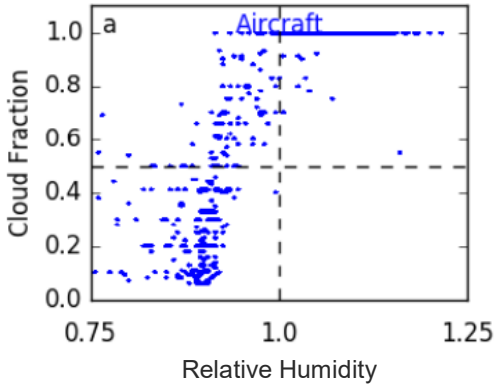
Current uni-modal Smith scheme

UM behaviour



Current uni-modal Smith scheme

Aircraft observations



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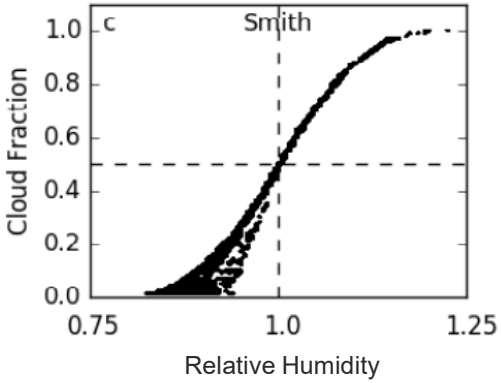

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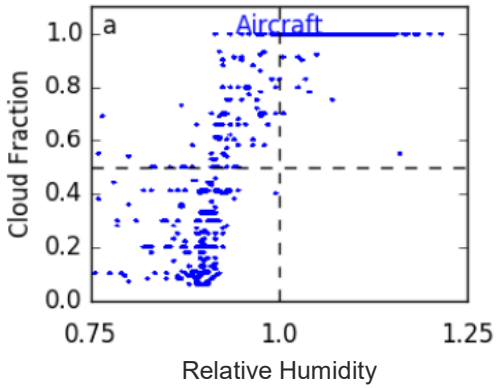

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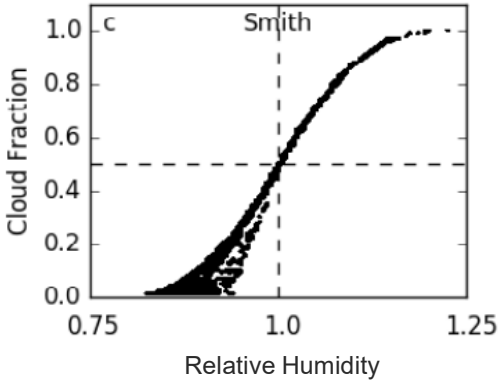
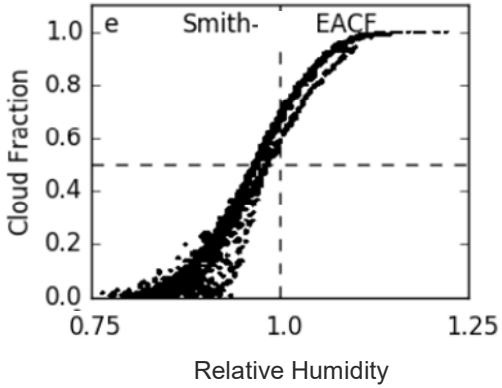


UK model

Empirically Adjusted Cloud Fraction



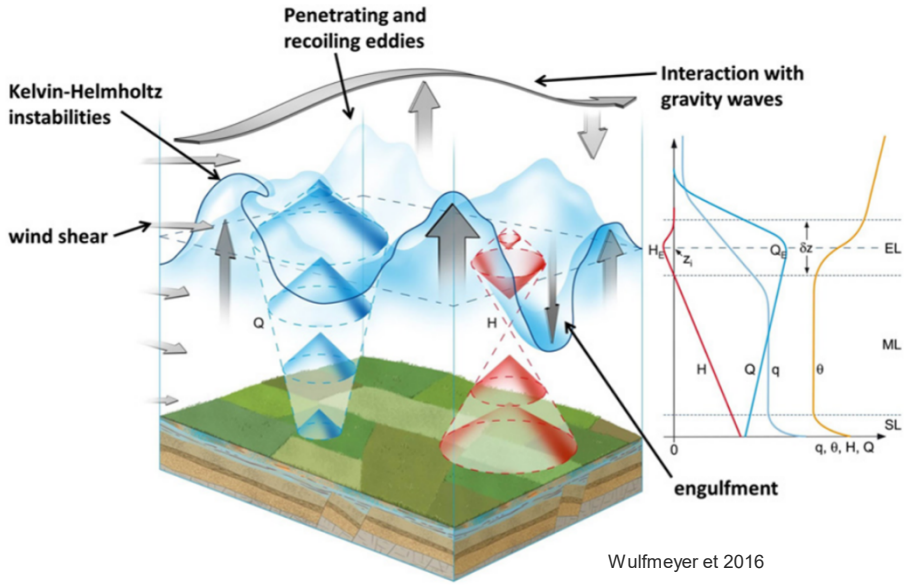
Sledge-hammer approach of increasing cloud cover, regardless of regime

- Beneficial for stratocumulus, i.e. performs well over the UK (RAL-M)
- Does not work well in the tropics (RAL-T)

Multi-modal cloud scheme

→ a more physical approach to improve stratocumulus

Entrainment zone near top of boundary layer with large temperature and moisture variance



Wulfmeyer et 2016

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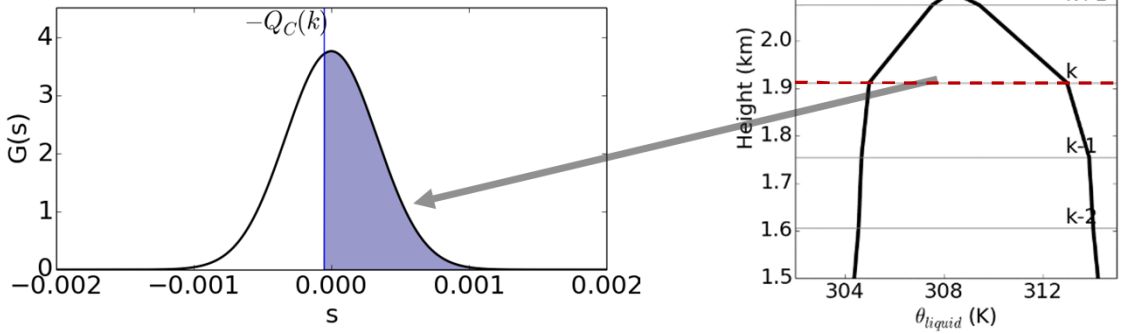
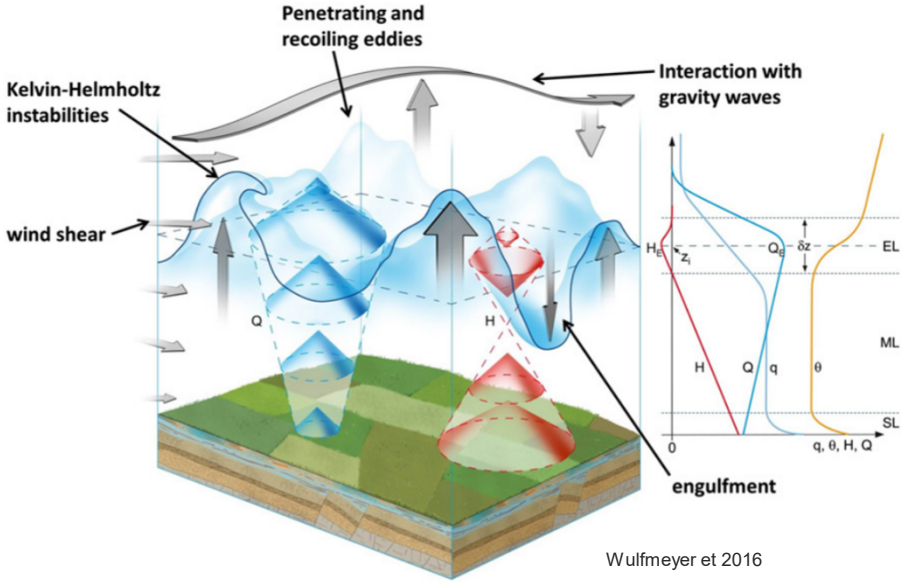
current Smith scheme: uni-modal pdf





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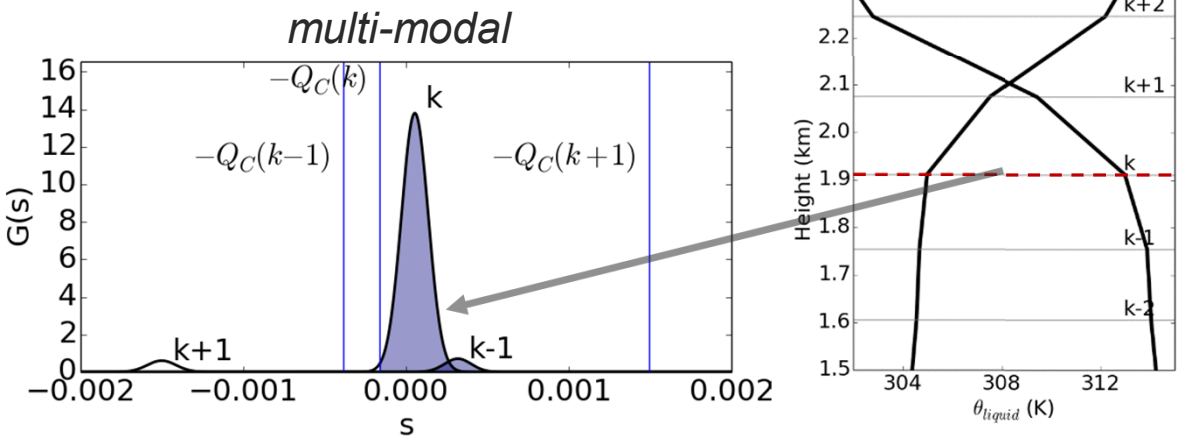
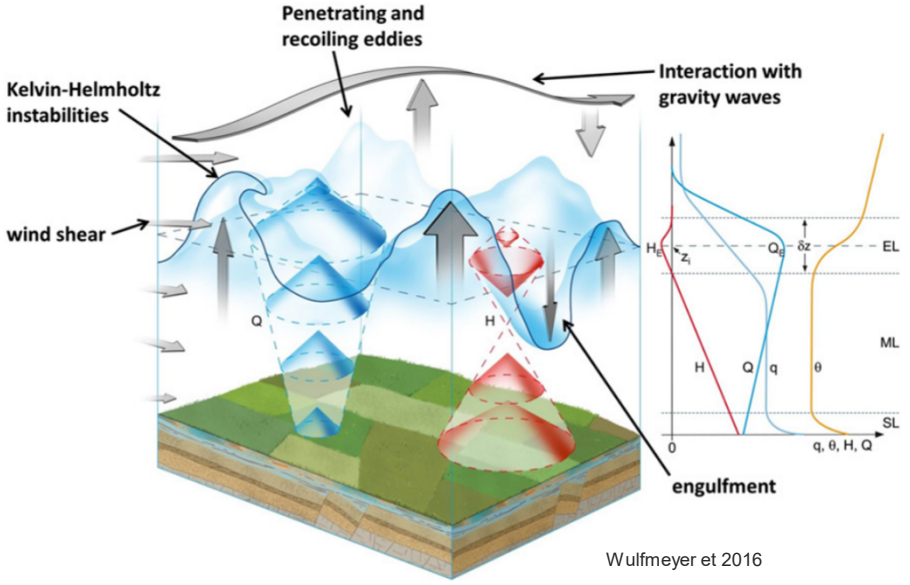
Entrainment zone near top of boundary layer with large temperature and moisture variance

Some variance caused by fluctuations in BL-top:

→ Air from below and above BL-top present at the same time





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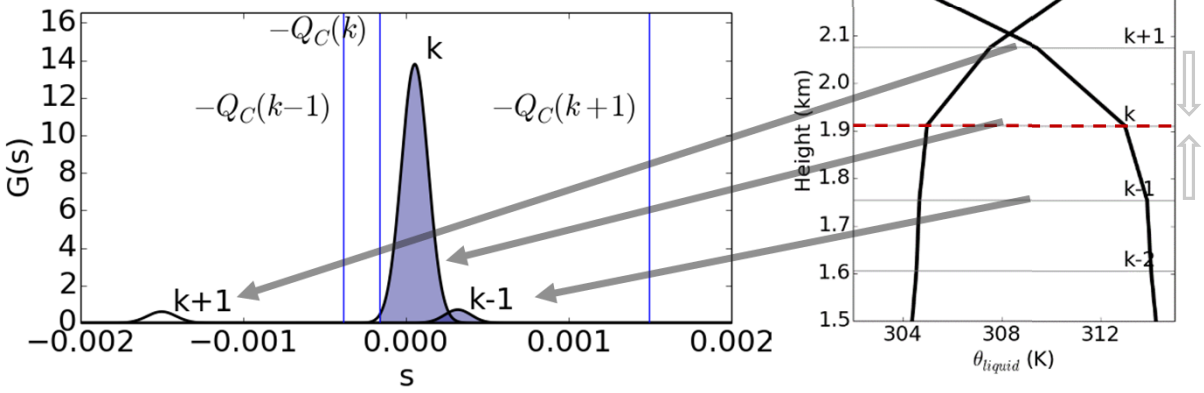
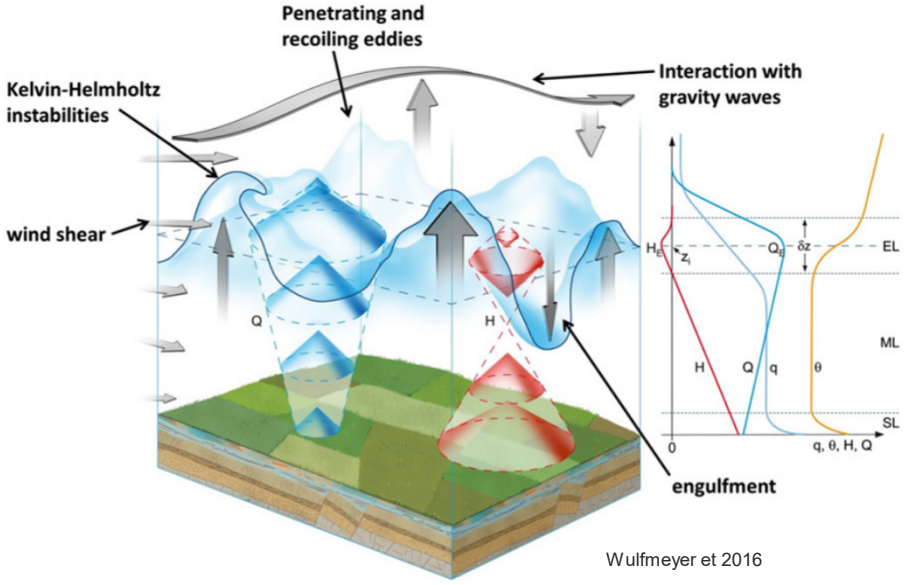




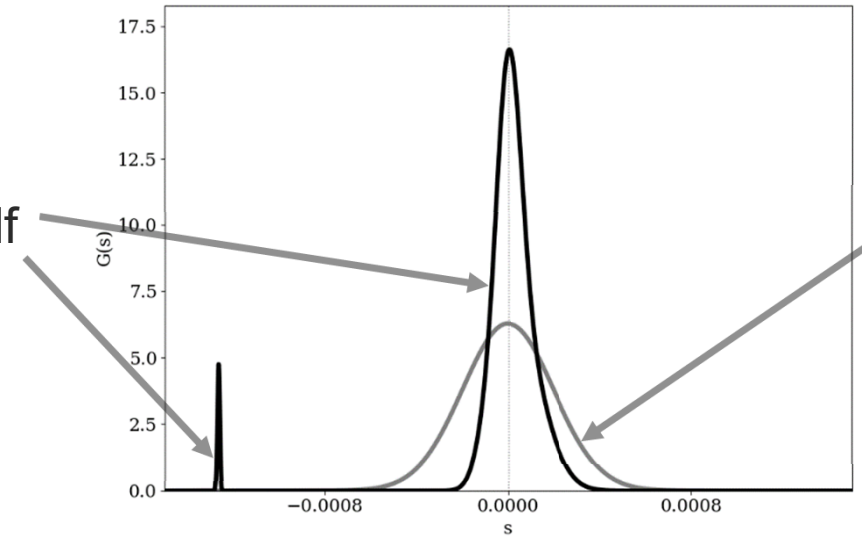
Wulfmeyer et 2016

Multi-modal cloud scheme

→ a more physical approach to improve stratocumulus

NEW

multi-modal skewed pdf



CURRENT

uni-modal symmetric pdf

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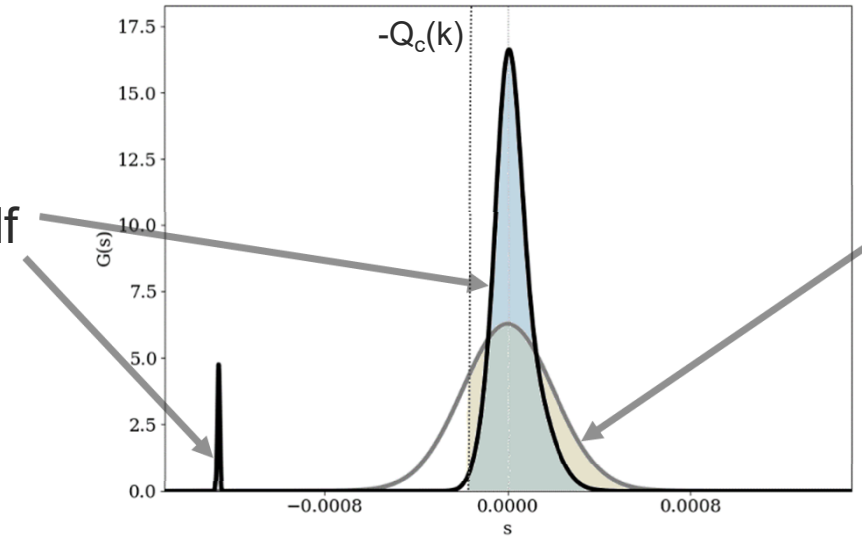
Multi-modal cloud scheme

→ a more physical approach to improve stratocumulus

NEW

multi-modal skewed pdf



CURRENT

uni-modal symmetric pdf

→ **Increased cloud fraction for given grid box mean conditions $Q_c(k)$**

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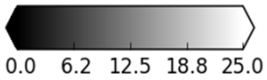
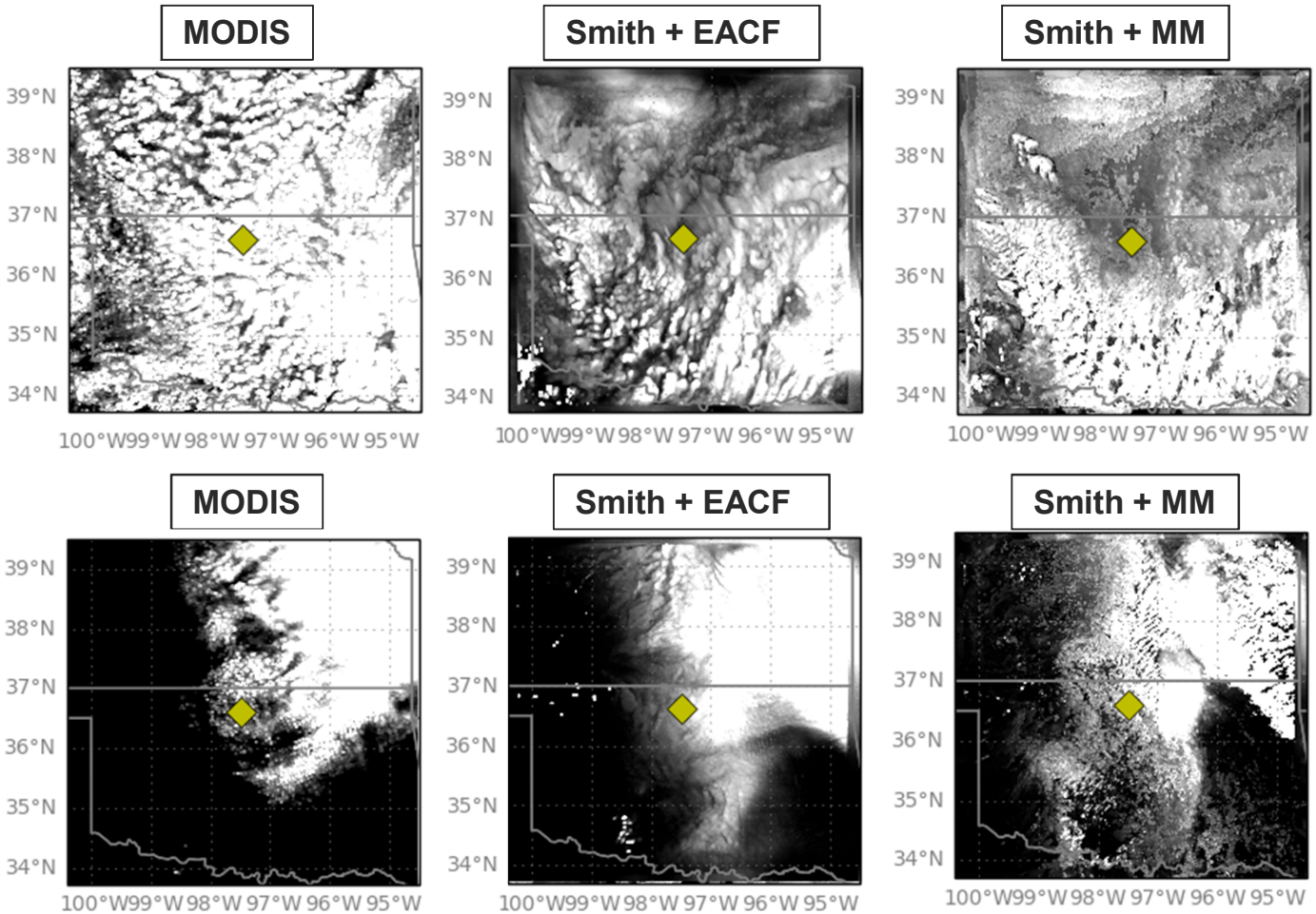
Cloud optical thickness





Stratocumulus Case

Multi modal scheme can reproduce benefits of the EACF for widespread stratocumulus

Cumulus Case

Multi modal scheme does not alter the characteristics of cumulus in the way the EACF does

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Multi-modal cloud scheme

- Paper in review with Monthly Weather Review
- Effort underway to implement multi-modal framework in the PC2-initiation (currently used in RAL-T)
- Longer trials with multi-modal Smith and multi-modal PC2 will be needed to explore the behaviour of the schemes in different conditions and on longer (climate) time scales
- Ultimate aim is to use same cloud-setup for mid-latitudes and tropics

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Met Office Unified Model™ Regional Atmosphere

The next steps for RAL3 …

- Component trials
  Testing proposed changes individually against baseline RA2 configuration
- Package trials
  Testing combined change packages

… and beyond

- Addressing remaining “legacy differences” between model configurations
- Scale aware convection scheme
  → “CoMorph” (Mike Whitall), planned for RA4+
- …

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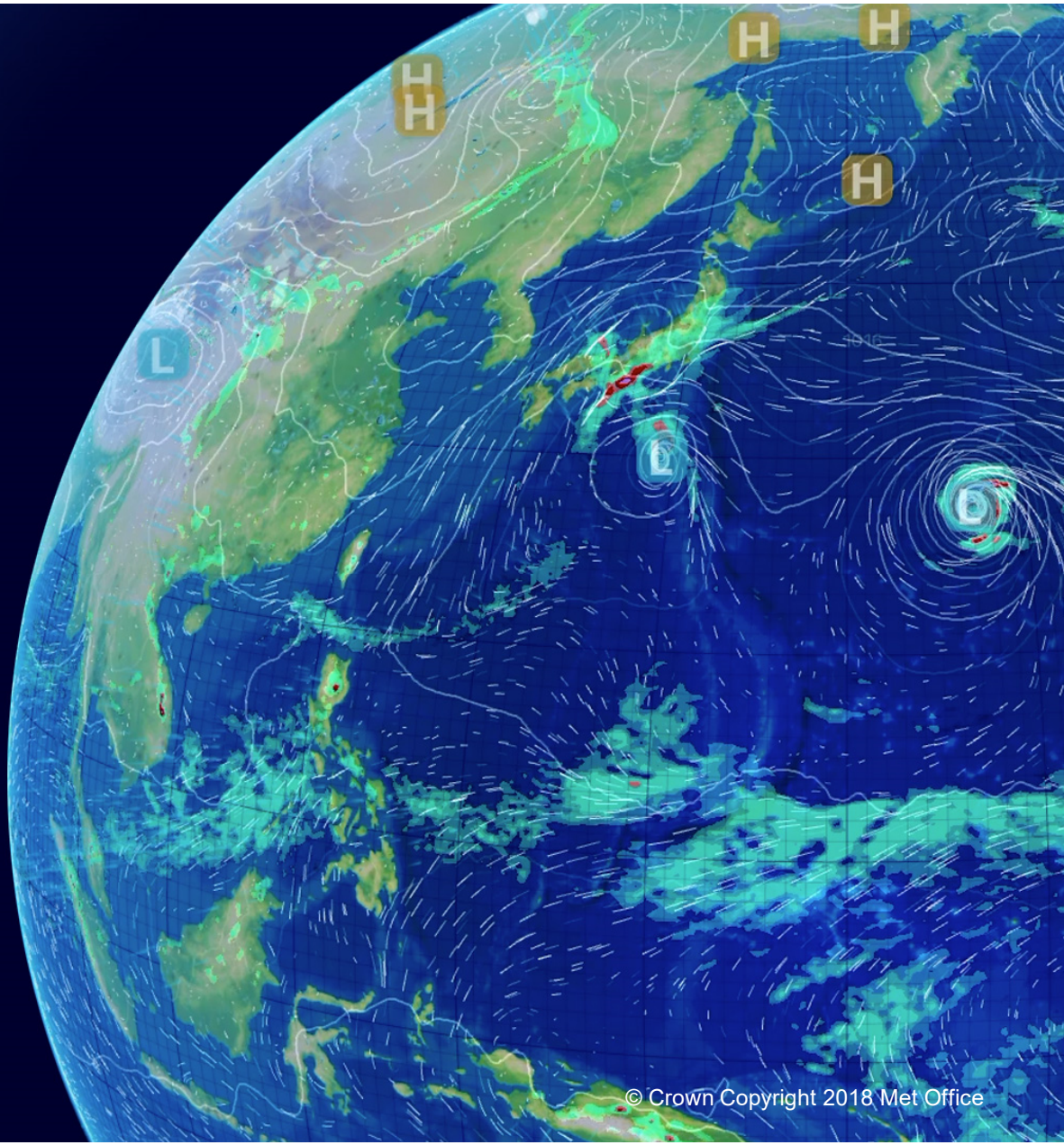

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