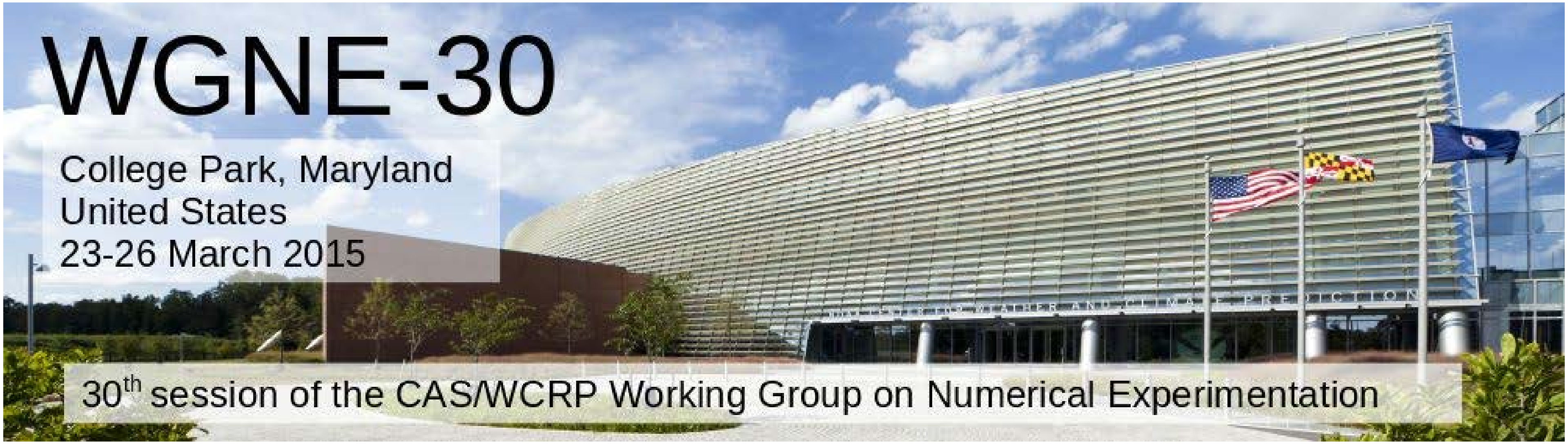
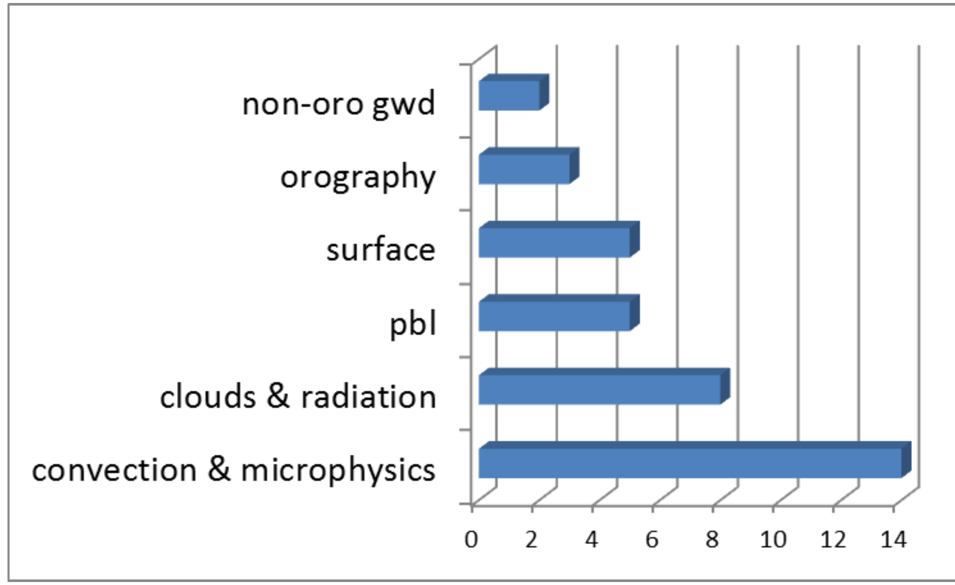


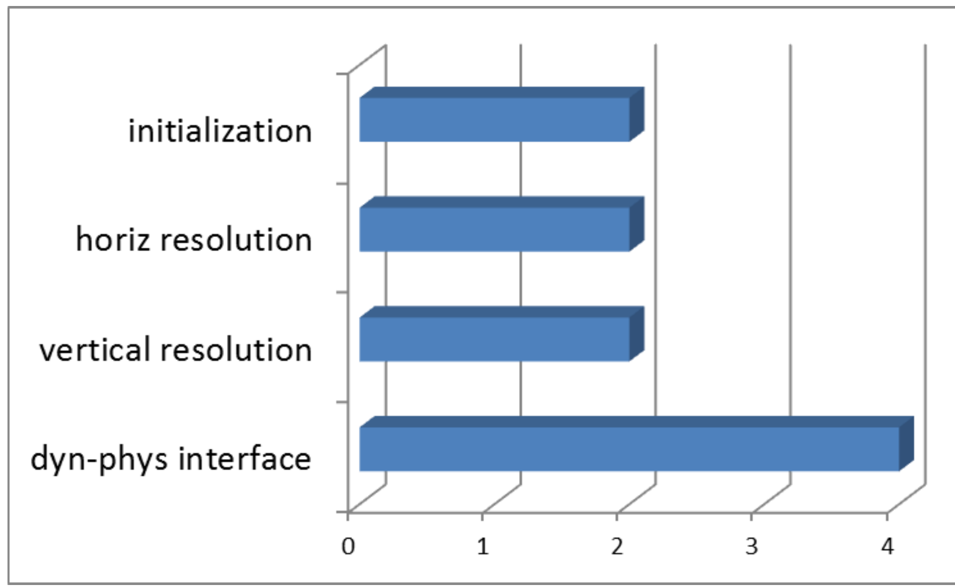
WGNE report: recent developments in physical parametrizations

François Bouyssel & Ayrton Zadra
with contributions from
WGNE members (thanks!)

Reports related to changes or improvements to a given **process** or **parametrization**



Reports related to "**infra-structure**" issues



* Based on contributions from NCAR, CMA, CMC, DWD, ECMWF, JMA, MeteoFrance, NRL, UKMO

Plans for **CAM** physics

- MG2: **Updated microphysics** w/ prognostic rain and snow

  [will go into CMIP6 version of CAM]

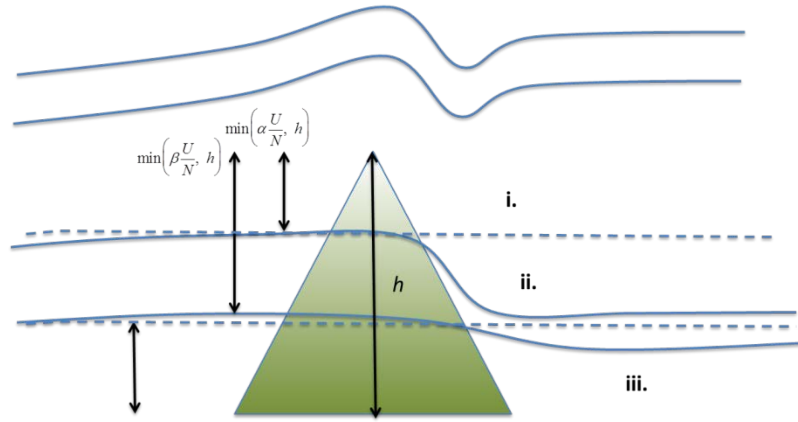
- Anisotropic **Orographic drag** + mesoscale **blocking**

  [may go into model after CMIP6]

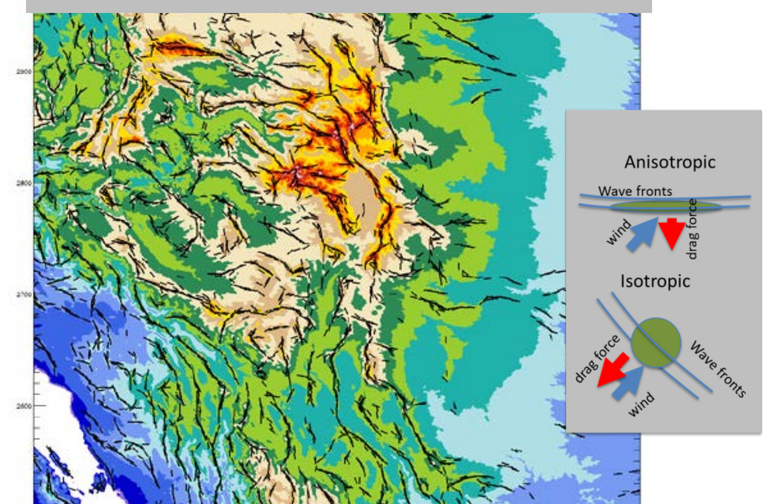
- **Vertical resolution increases** may be considered after CMIP6

Blocking, low-level turning

(follows Scinocca&McFarlane 2000)

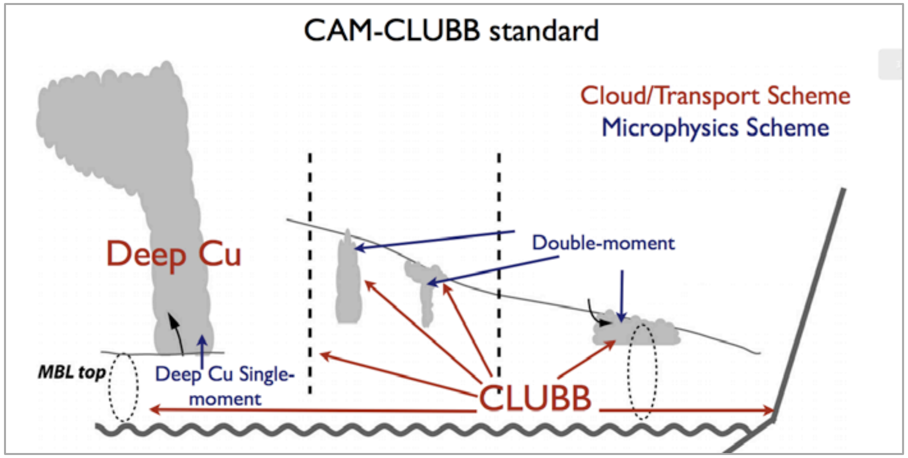


Anisotropic “Ridge-y” topography



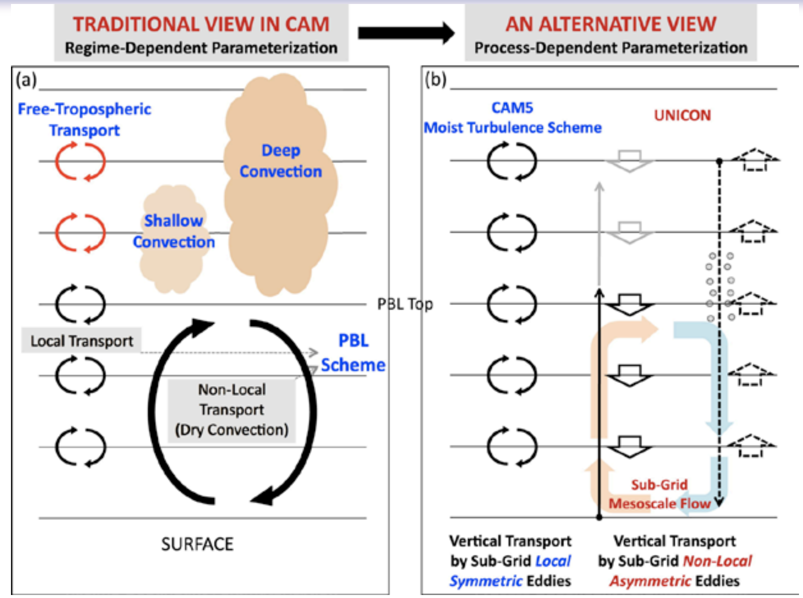
Black lines show ridges identified by analysis algorithm

CLUBB
Cloud Layers Unified By Binormals



- High order closures (1 third order, 8 second order)
- Unifies moist and dry turbulence (except deep convection)
- Use two Gaussians to described the sub-grid PDF of each quantity

UNICON
Unified Convection Scheme



- Unifies deep and shallow convection schemes
- Generates forced/free/dry shallow convection + deep convection
- Accounts for sub-grid mesoscale flows

UNICON vs CLUBB is "either – or" decision (*or "neither"*).
External panel is evaluating.

CMA physics - Recent Progress

Orographic scheme

- **GWD** [Kim and Arakawa 1995]
- Low level **blocking** [Lott and Miller 1997]
- Turbulent **form drag** [Beljaars 2003]

Convection

- **Shallow**: **Mass flux** parameterization replaces turbulent diffusion-based approach
- **Deep**: Improve the **entrainment rate** and **moment transfer** convective overshooting

PBL

- Include CTEI **cloud-top entrainment** instability
- Modify **stable boundary layer local closure** scheme

Dynamics-physics coupling

- physics moving to C-P grid (as dynamics)

CMA - Future Plans

- Improve **cloudiness parameterization** and its effect on radiation
- Improve coupling **accuracy of dynamic-physics** and interaction of physics
- Implementation **non-orographic GWD** scheme
- Develop the **trigger functions suitable for East Asia** and Improve the cloud microphysics representation in convective parameterization
- Development of Eddy-Diffusivity Mass-Flux (**EDMF**) to stratocumulus and dry boundary layers as used in ECMWF model
- To a **scale-aware physics**
  - scale-aware convection scheme – under research

Canadian centre: recent developments in physical parametrizations

Ongoing work

1. Sensitivity studies w.r.t. **vertical resolution**
   - *to accommodate the planned increase in vertical resolution (especially in the boundary layer)*
2. Changes to the **PBL scheme** (currently TKE 1.5 closure)
   - *add non-local cumulus term (Lock & Mailhot, BLM 2006)*
   - *introduce turbulent total energy (TTE) approach (Mauritsen et al. 2007)*
   - *explore distributed drag alternative (Beljaars et al. 2004)*
3. Adjustments to the calculation of **surface turbulent fluxes** (mainly over the oceans) to address problem of excessive moisture fluxes
4. Revision of **shallow convection** scheme
5. Explore **stochastic parametrizations**
   - PBL scheme: add stochastic forcing to TKE equation
   - Convection (Plant-Craig scheme)
6. New **microphysics scheme** (see following slides)

New Bulk Microphysics Parameterization:

Predicted Particle Properties (P3) Scheme*

Based on a conceptually different approach to parameterize ice-phase microphysics.

NEW CONCEPT

"free" category – predicted properties, thus freely evolving type

vs.

"fixed" category – traditional; prescribed properties, pre-determined types (e.g. "snow", "graupel", etc.)

Compared to traditional (ice-phase) schemes, P3:

- avoids some intrinsic problems (category conversion, fixed properties)
- has self-consistent physics
- is better linked to observations
- early results are very competitive with detailed, well-tuned schemes
- is more computationally efficient

* Morrison and Milbrandt (2015)
(P3, part 1) *J. Atmos. Sci.*

New Bulk Microphysics Parameterization:

Predicted Particle Properties (P3) Scheme

A given (*free)* category *n* can represent any type of ice-phase hydrometeor

Prognostic Variables:

$\boldsymbol{Q_{dep}}(n)$ – deposition ice mass mixing ratio [kg kg^{-1}]

$\boldsymbol{Q_{rim}}(n)$ – rime ice mass mixing ratio [kg kg^{-1}]

$\boldsymbol{N_{tot}}(n)$ – total ice number mixing ratio [# kg^{-1}]

$\boldsymbol{B_{rim}}(n)$ – rime ice volume mixing ratio [m^3 kg^{-1}]

Predicted Properties:

$\boldsymbol{F_{rim}}(n)$ – rime mass fraction, $F_{rim} = Q_{rim} / (Q_{dep} + Q_{rim})$ [--]

$\boldsymbol{\rho_{rim}}(n)$ – rime density, $\rho_{rim} = Q_{rim} / B_{rim}$ [kg m^{-3}]

$\boldsymbol{D_m}(n)$ – mean-mass diameter, $D_m \propto (Q_{dep} + Q_{rim}) / N_{tot}$ [m]

$\boldsymbol{V_m}(n)$ – mass-weighted fall speed, $V_m = f(D_m, \rho_{rim}, F_{rim})$ [m s^{-1}]

etc.

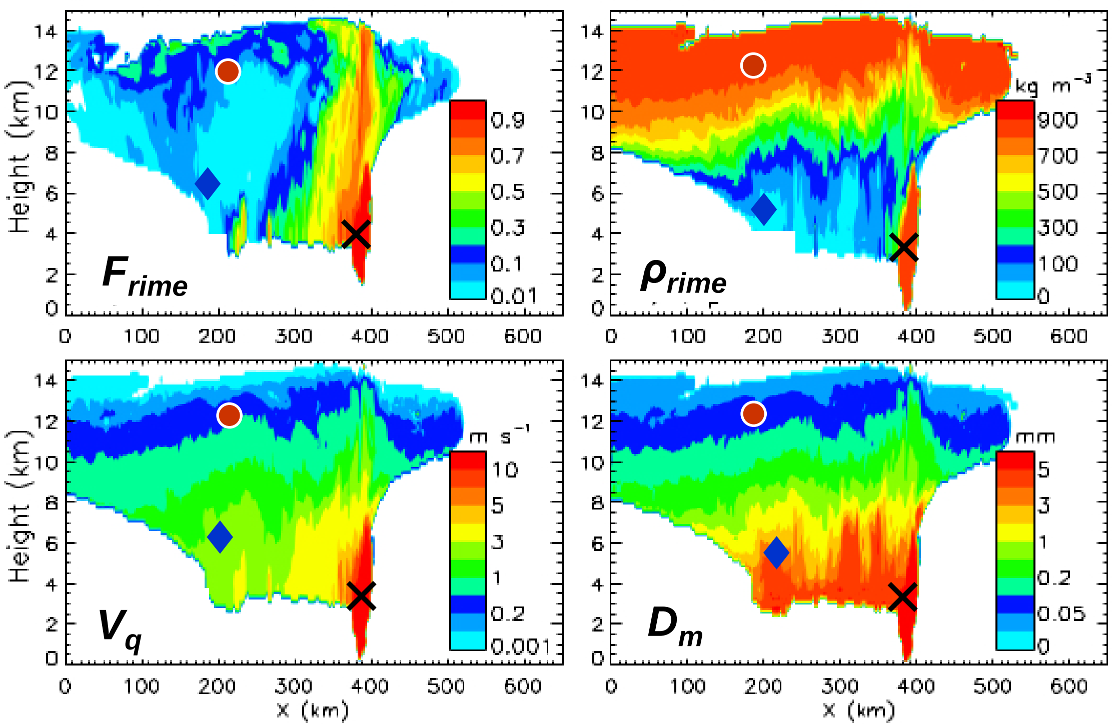
Diagnostic Particle Types:

Based on the <u>predicted properties</u> (rather than pre-defined)

1-km WRF Simulations with P3 (1 category configuration)**:**

Quasi-real case 3D simulation of a severe squall line

Ice Particle Properties:



Vertical cross section of model fields (t = 6 h)

Diagnostic Types:

F_r ~ 0-0.1
ρ ~ 900 kg m-3
V ~ 0.3 m s^{-1}
D_m ~ 100 μm
→ ***small crystals***

F_r ~ 0
ρ ~ 50 kg m-3
V ~ 1 m s^{-1}
D_m ~ 3 mm
→ ***aggregates***

F_r ~ 1
ρ ~ 900 kg m^{-3}
V > 10 m s^{-1}
D_m > 5 mm
→ ***hail***

This realistic range of particle types is simulated using only *one (free) ice-phase category*

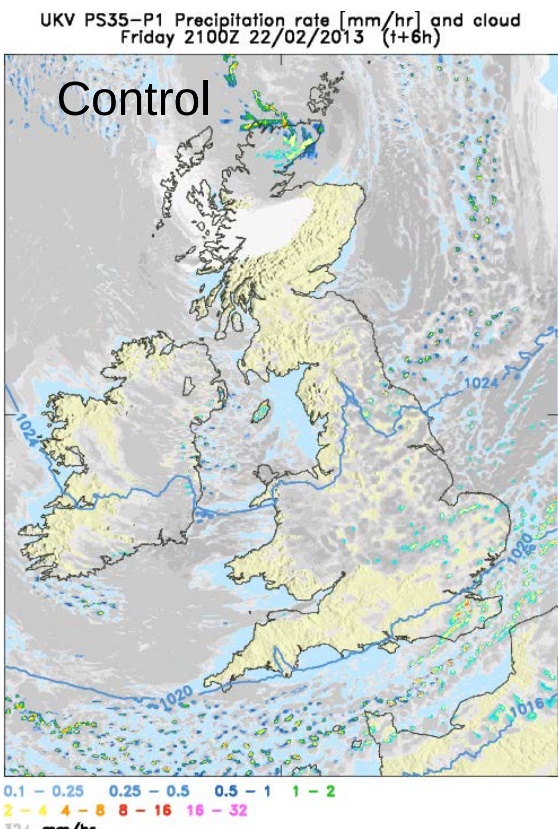
Recent model upgrades

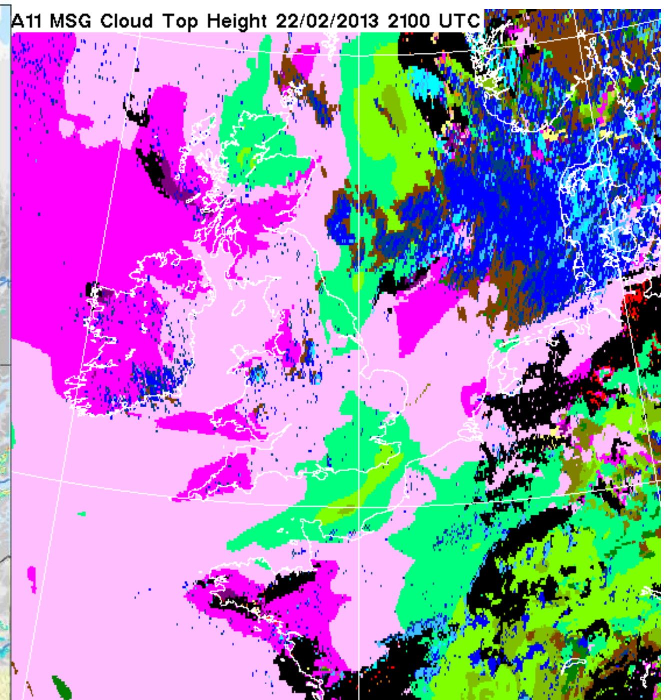
- Major upgrades to seamless global modelling system (GA6)
- Operational in Jul 2014
  - ENDGame dynamical core
  - Major package of physics changes

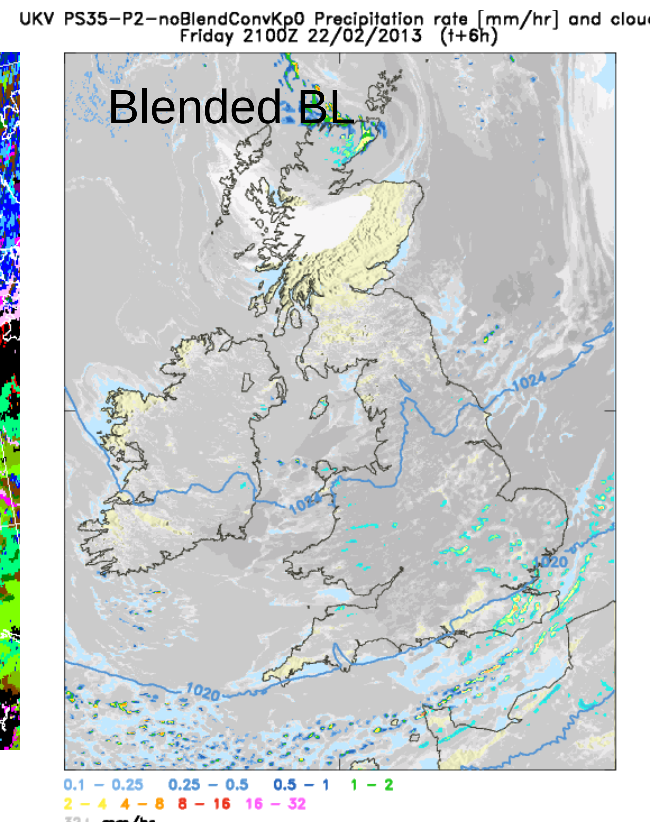
- Following global models, upgrades to regional convective-scale models
- Operational Feb 2015
  - ENDGame dynamical core
  - Improvements to physics – greyzone “blended” turbulence, warm rain microphysics, cloud assimilation,…

Winter case study
Blended BL scheme vs control
(22 Feb 2013, T+6 from global analysis)

- Blended BL scheme much better than control, giving improved stratocumulus and screen temperatures
- Sc still breaks into broken cloud too much







Global model plans

Met Office

Short term plans (Global Atmosphere 7.0, spring 2016)

- Convection: Improvements to accuracy and conservation properties of current scheme; CAPE closure timescale dependent on large scale vertical velocity
- Clouds and Radiation: Improved treatment of gaseous absorption; convective cores seen by radiation; link between critical relative humidity for cloud initiation and sub-grid variability of T and q; forced convective clouds; McICA upgrades; New ice optical properties
- Microphysics: more realistic ice PSD; new warm rain microphysics, turbulent production of liquid water
- Boundary layer: Revised cloud top entrainment
- Gravity-wave drag: Implement heating due to gravity-wave dissipation
- Land surface: New multi-layer snow scheme; revised tile types, improvements to surface albedo; including over ocean surface

NCEP Physical Parameterizations Update: GFS

14 January 2015 Implementation:

- Radiation modifications.
- Reduced drag coefficient at high wind speeds.
- Stationary convective gravity wave drag.
- Soil moisture climatology from CFSv2.
- Changes to roughness length calculations.

2016:

- Convective upgrade.
- Land and surface layer upgrades.

2017:

- Aerosol prediction – initially lower resolution used as forcing in high resolution.
- WAM – Whole Atmosphere Model – initially lower resolution up to 600km.
- Wave-atmosphere interaction: Ocean surface stress/wave-state (*WAVEWATCH III*).

NCEP Physical Parameterizations Update: NAM, other

NAM Oct 2014:
- RRTM radiation scheme.
- Ferrier-Aligo microphysics; tuned to improve severe storm structure; Convection: Modified BMJ (moister profiles) to improve 12km parent bias; explicit in nests.

NAM Late 2015:
- CONUS/Alaska nest to 3km, explict convection in AK nest.
- New shallow convection scheme in 12km parent NAM; improves cold season QPF bias; more frequent calls to radiation/physics.

HWRF (Hurricane):
- *"Advanced physics tailored for hurricane conditions"*, Noah LSM.

Land/LDAS (Noah land-surface model):
- Dynamic vegetation/CO2/explicit canopy, 3-layer snow, ground-water/hydrology/streamflow to oceans.

Waves/WAVEWATCH III, Ocean:
- Air-Sea-Wave flux interaction, 2-way wave-ocean coupling.