

Treatment of cloud-related processes in GEM

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- Overview of GEM configurations
- Description of condensation processes in physics package

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GEM model configurations

■ GEM regional Model

- next version: 24 km => 15 km
- improved physics: surface process scheme (ISBA), condensation schemes (Kain-Fritsch, explicit scheme with mixed phases)

■ GEM-HIMAP

- 2 windows (East and West) at 10 km

■ GEM global mesoscale Model

- next version: 100 km => 25-50 km with physics of regional model

■ GEM-LAM

- development of a non-hydrostatic limited-area version for high-resolution local applications

Regional model configuration

Current configuration

Uniform-grid resolution ($\Delta = 24 \text{ km}$)
28 vertical levels
12 min timesteps
Horizontal diffusion for variables with ∇^2

Force-restore surface scheme

Turbulence kinetic energy scheme with shallow convection for PBL clouds

Fritsch-Chappell for deep convection

Sundqvist condensation scheme

Next configuration

Uniform-grid resolution ($\Delta = 15 \text{ km}$)
43 vertical levels
7.5 min timesteps
Horizontal diffusion only for momentum variables with ∇^6

New surface processes package
(**ISBA land scheme/sea ice/glacier**)

Unified **moist turbulence scheme**

Kuo Transient for shallow convection

Kain-Fritsch for deep convection

MixPhas (Tremblay) cloud microphysics scheme

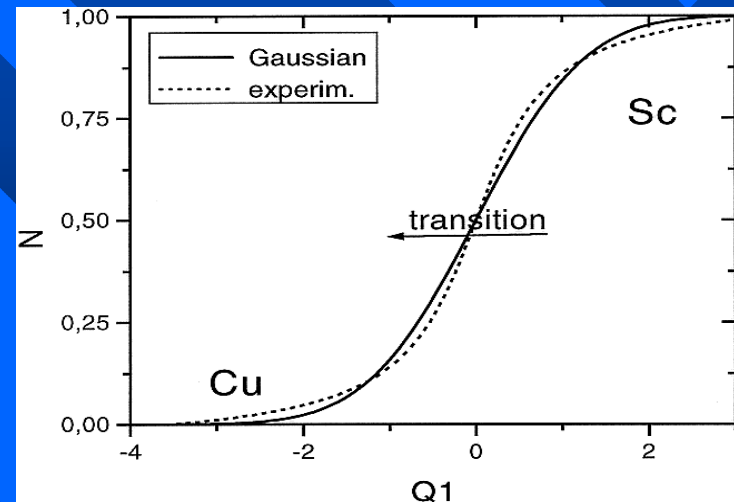
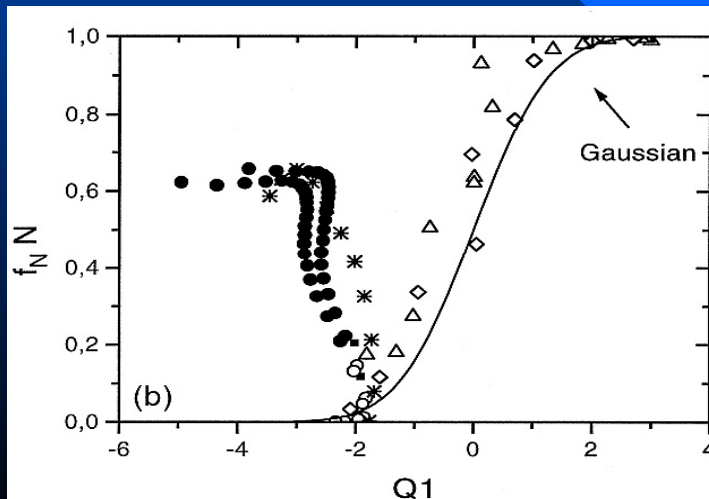
Refinement to cloud optical properties (radiation)

Low-level blocking due to SGS orography (Lott-Miller)

Unified cloudiness-turbulence scheme

- Approach of Bechtold et al. appropriate for TKE model
- Use moist conservative thermodynamic variables (θ_{il} and q_w)
- Implicit cloudiness scheme with treatment for mixed-phase clouds
- Unified description of stratiform clouds and shallow non-precipitating convection
- Smooth transition between moist turbulence / explicit condensation schemes

Flux enhancement factor (f_N) and implicit cloud fraction (N) as a function of Q_1 , a normalized measure of



supersaturation, for a series of observational experiments (taken from Bechtold and Siebesma 1998)

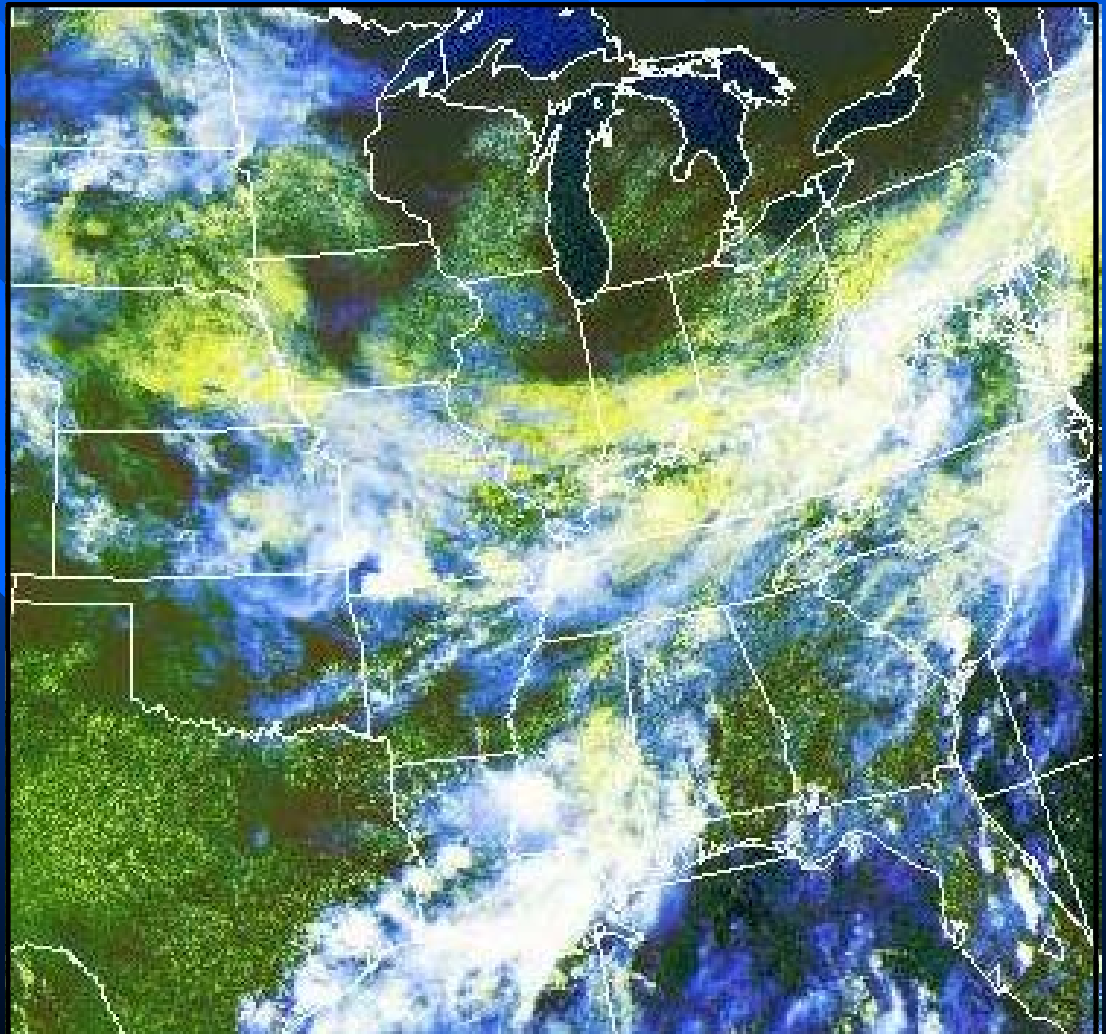
Moist turbulence scheme

- Tested by Bechtold et al. in 1-D on number of marine BLs
 - regimes of stratocumulus (Sc) clouds in mid-latitudes and tropics
 - trade winds BL clouds with shallow and deeper cumulus (Cu) clouds
 - BLs with intermediate cloud fraction
- Extension with 3-D mesoscale model to wider range of conditions:
 - Sc BL clouds over a polynya in the Arctic (FIRE.ACE)
 - cases of summertime scattered Cu clouds over land (MERMOSZ-2) in progress
 - results from next version of Canadian operational mesoscale model

GOES-8 visible satellite imagery

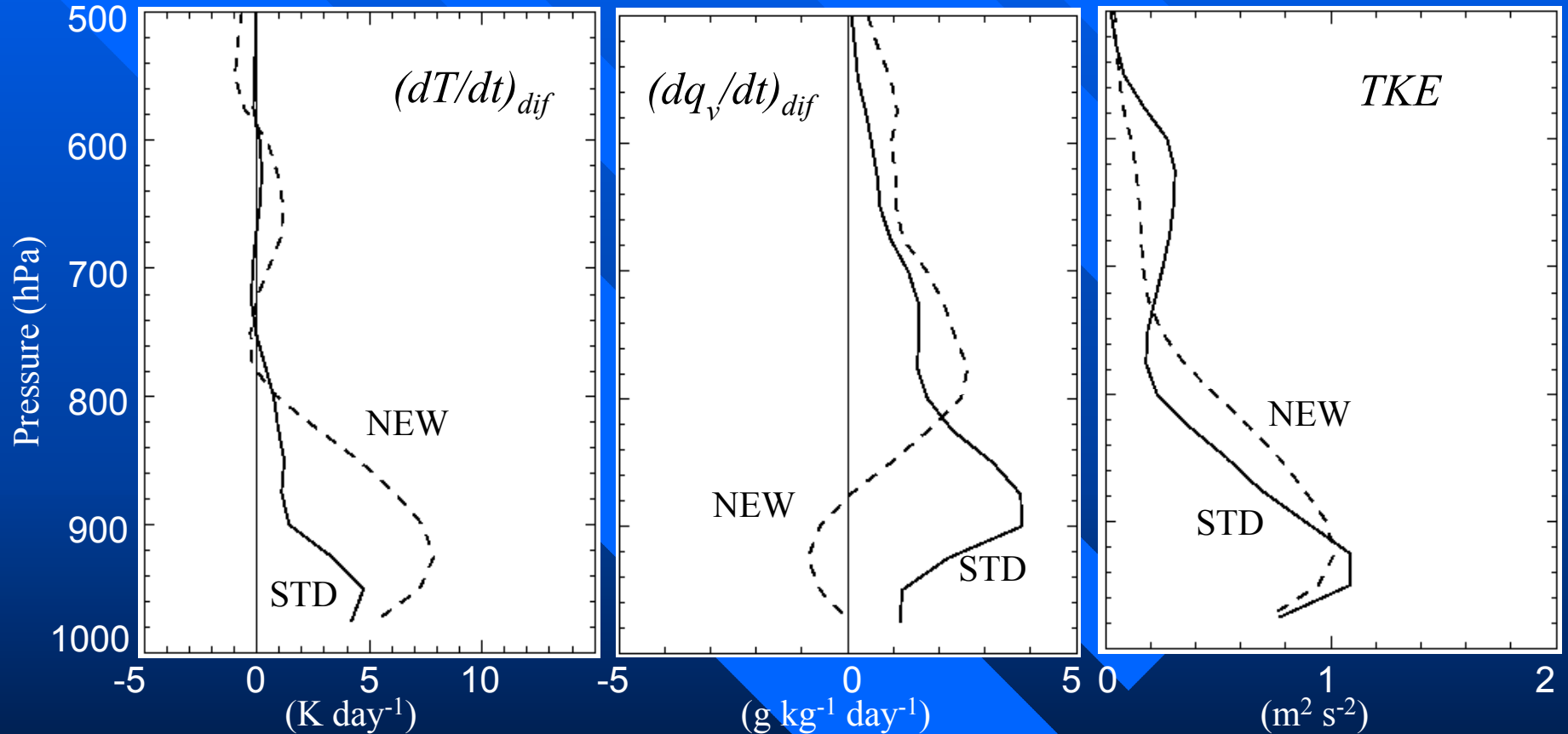
1800 UTC 26 July 2001

- ★ next version of Canadian operational mesoscale (15-km) GEM model in progress
- ★ includes unified cloud-turbulence scheme (NEW)
- ★ tests on series of benchmark cases from summer 2001



Diffusion tendency average profiles

1800 UTC 26 July 2001



- Profiles of diffusion tendencies and TKE averaged over whole horizontal domain
- Systematic errors with STD (PBL too cold/moist) due to incorrect triggering
- Significant reduction of biases of temperature and moisture with NEW scheme

Revisions to cloud-radiation interactions

■ Cloud optical properties

- revised broadband solar and infrared radiative properties
- extinction coefficient β , single-scattering albedo ω , asymmetry factor g
- water and ice clouds

■ Liquid droplets

- current parameters based on Slingo (1989)
- with mean effective size $r_{eff} = 4-17 \mu\text{m}$ (too much solar attenuation)
- new parameters based on Hu and Stamnes (1993)
- new $r_{eff} = 2.5-60 \mu\text{m}$

■ Ice crystals

- current parameters based on Ebert and Curry (1992)
- with constant $r_{eff} = 15 \mu\text{m}$

Revisions to cloud-radiation interactions

■ Ice crystals

- numerous recent parameterizations proposed for cloud optical properties and effective size
- e.g. Fu et al. (1993, 1996, 1998); McFarquhar and Heymsfield (1996, 1998); Platt (1997); Wyser (1998); Ryan (2000); Boudala et al. (2002)
- large scatter among the results, especially for mean effective size

■ Need for a consistent scheme that includes

- parameterization of ice cloud optical properties
- definition of mean effective size in terms of T and IWC
- applicable to wide range of ice clouds (cirrus, frontal clouds, high-latitude stratiform clouds,...)

A Mesoscale Global Model for Medium-Range Weather Forecasting at MSC

Current configuration

Uniform Hor. Resolution ($\Delta = \mathbf{0.9^\circ}$)

28 vertical levels

45 min timesteps

Horizontal diffusion with ∇^2

Complete radiation every **2 hours**

Proposed configuration

Uniform Hor. resolution ($\Delta \sim \mathbf{0.22^\circ}$ to $\mathbf{0.45^\circ}$)

58 vertical levels

10-15 min timesteps

Horizontal diffusion with ∇^6

Complete radiation every **1 hour**

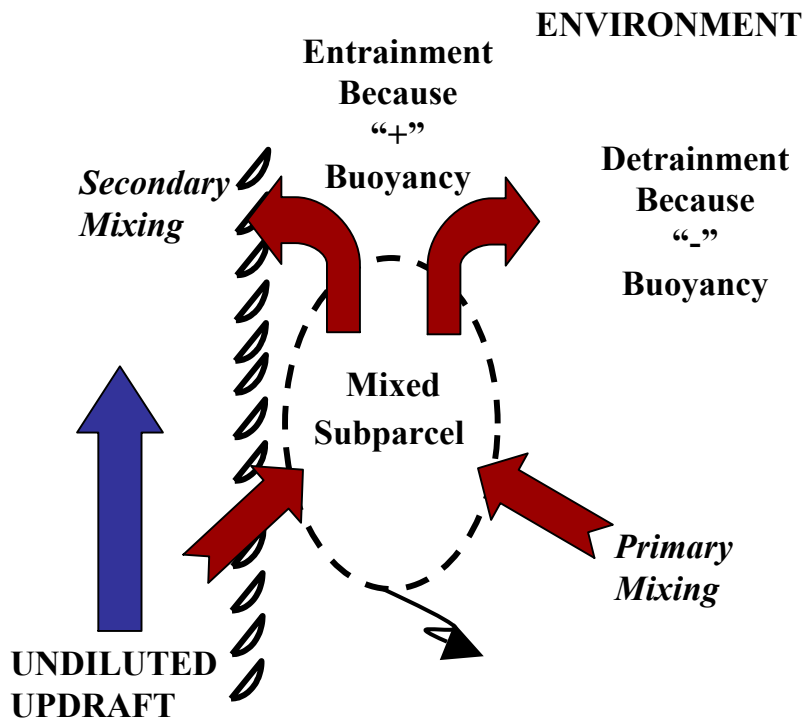
New physics (see next slide)

Sequence of Physical Processes in GEM

MEDIUM-RANGE GLOBAL MODEL

<u>Process</u>	<u>OP (0.9°)</u>	<u>MESO (0.22-0.45°)</u>
Radiation (solar)	Fouquart-Bonnell	Fouquart-Bonnell
Radiation (IR)	Garand	Garand
Surface Processes	Force-Restore	ISBA
Gravity wave drag	McFarlane (1987)	McFarlane (1987)
Low-level blocking	Lott-Miller (1997)	Lott-Miller (1997)
Turbulence	TKE 1.5	TKE 1.5 (with BL)
PBL clouds	Girard	Girard
Shallow convection	none	Kuo Transient
Deep convection	Kuo	Kain-Fritsch
Grid-scale cond.	Sundqvist	MixPhase

The Kain-Fritsch Scheme for Deep Convection



- Younger brother of the Fritsch-Chappell scheme
- Main closure based on removal of CAPE
- 1D entrainment/detrainment cloud model for the updrafts and downdrafts mass fluxes
- More sophisticated microphysics compared to FC (e.g., glaciation effects)
- Detrainment of cloud water to the grid scale (dq_c/dt)
- Precipitation efficiency depending on vertical wind shear and cloud base height (same as in FC)
- Trigger function based on a stability test at the LCL (same as in FC)
- Less dependent on the horizontal scale than FC
- Optimized (i.e., vectorized) version of the code

The Kuo Transient Scheme for Shallow Convection

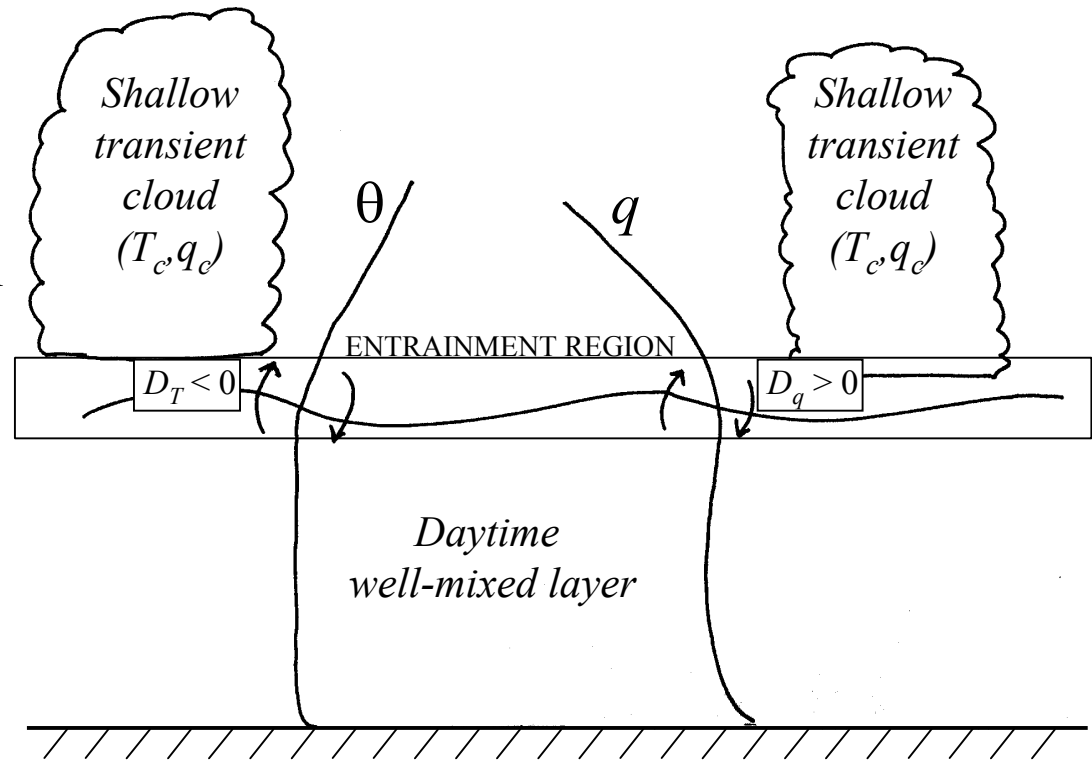
Transient shallow cloud model driven at its base by turbulent boundary layer fluxes developed at RPN by Claude Girard.

This scheme is essentially the same as the Kuo Symmetric scheme (also by C. Girard) in which the temperature and humidity "accessions" are given by the tendencies from the vertical diffusion scheme:

$$\left(\frac{\partial q}{\partial t}\right)_{shallow} = K(q_c - q) - D_q$$

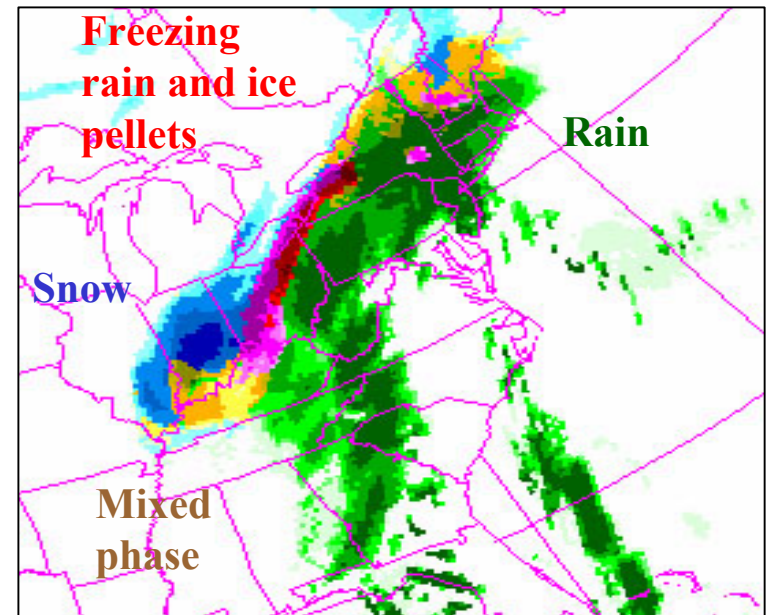
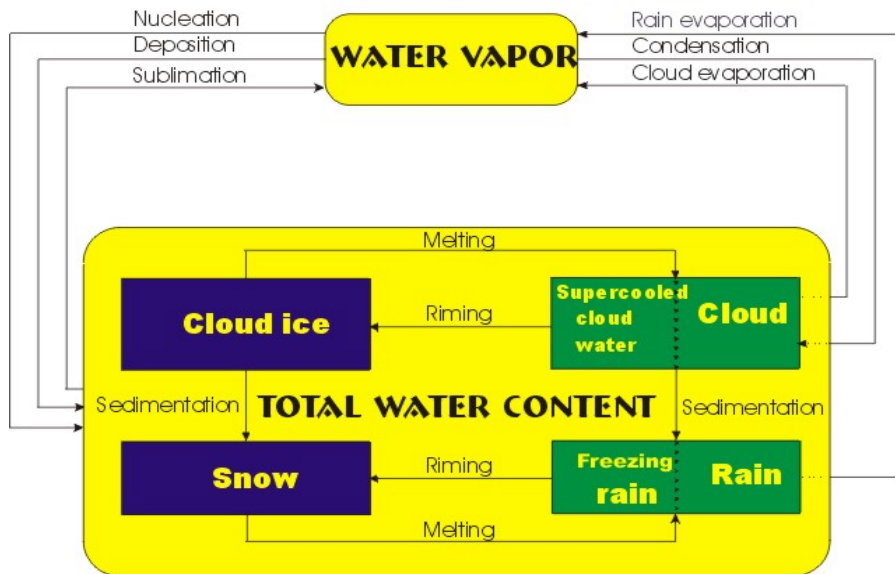
$$\left(\frac{\partial T}{\partial t}\right)_{shallow} = K(T_c - T) - D_T$$

in which the K coefficients are calculated using the energy conservation principle.



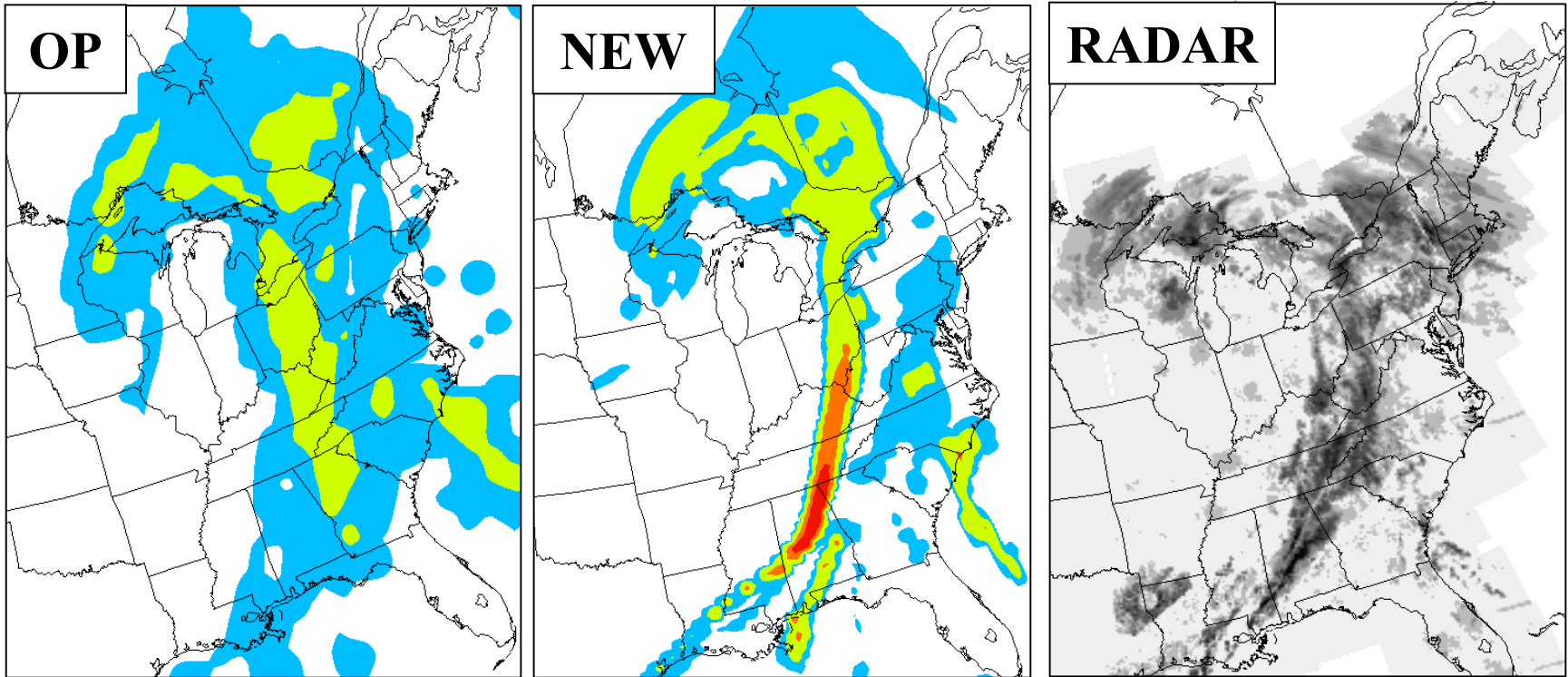
MixPhas condensation scheme

MIXPHAS CLOUD SCHEME



- Single prognostic equation for total water content
- Includes key cloud microphysical processes
- 3D forecast of solid particles, liquid, and supercooled cloud droplets
- Forecast of different types of precipitation based on vertical profiles and local statistics
- Inclusion of physical processes for the formation of supercooled liquid water
- Reference: Tremblay and Glazer (2000)

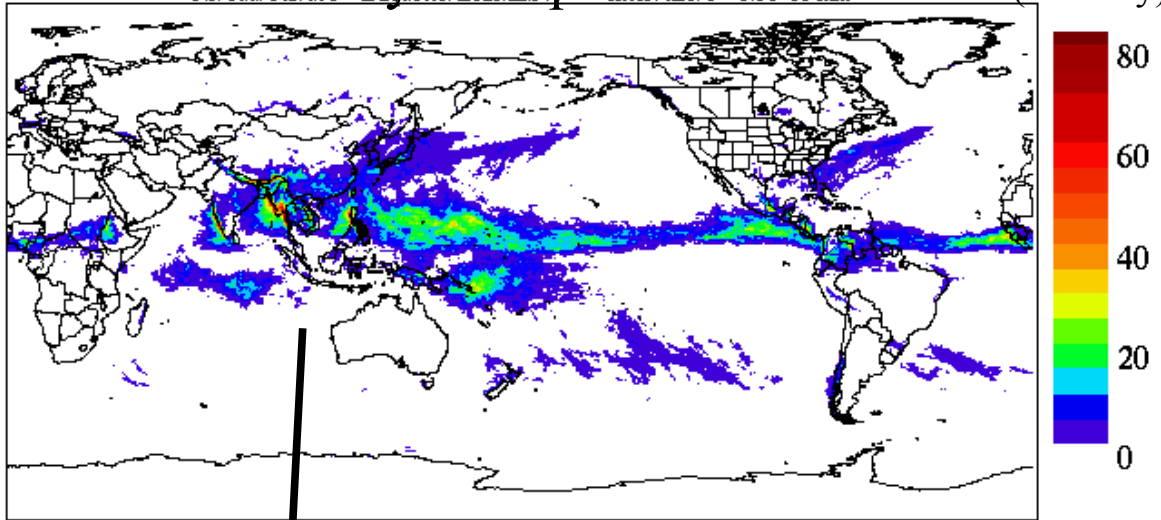
Improved Forecast of Weather Systems



60-h forecasts of instantaneous precipitation rates valid at 1200 UTC 25 Feb. 2001 using the current operational model and the proposed configuration. The black and white image shows the radar reflectivities valid at the same time

Improved Representation of Global-Scale Precipitation and Clouds

Daily Precipitation (mm/day)



*Averages from 16
five-day forecasts in
June, July, and
August 2002
(i.e., 80 days)*

Shallow Convection Activity (%)

