The GRIMs shallow convection scheme

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1 Global/Regional Integrated Model system (GRIMs)

General description

- The Global/Regional Integrated Model system (GRIMs, Hong et al. 2013, http://grims-model.org) is an atmospheric model system designed for numerical weather prediction, seasonal simulations, and climate researches.
- The GRIMs not only keeps the advantages of the predictability of the operational model but also includes the advanced dynamics and physics schemes that have been developed in research communities, i.e., Weather and Research Forecast (WRF) model.
- The GRIMs has a great flexibility with multi-platforms from a personal computer to super-computers, with either a thread mode or a message parallel interface(MPI) mode.
- Within Fortran 90 programs with C-pre-processor source codes, a global model program (GMP), regional model program (RMP), and single-column model program (SMP) can be selected.

Dynamical core

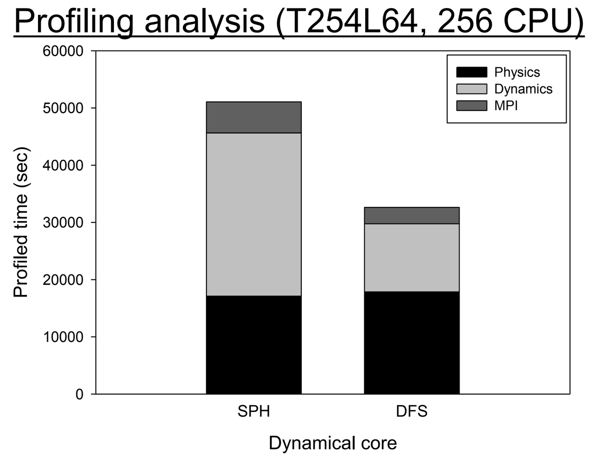
Spherical Harmonic (SPH)

- Widely used in operational center
- Computational efficiency is of concern at high resolutions
- Based on the NCEP CVS MRF (Kanamitsu et al. 2002, Juang 2005)

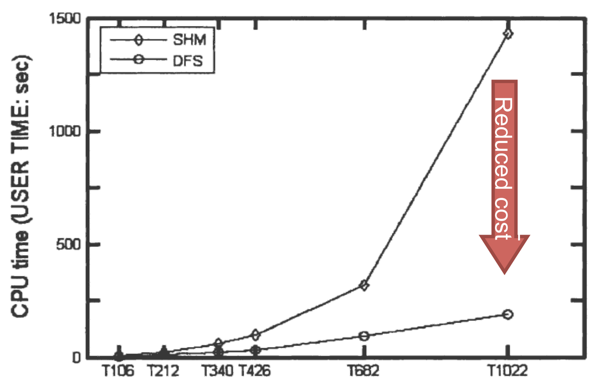
Double Fourier Series (DFS)

- Unique core developed by Cheong (2006)
- Implemented to the GRIMs model with full physics package (Park et al. 2013)
- Reduces the computational cost, but still preserves the advantages of spectral core numerics

Profiling analysis (T254L64, 256 CPU)



Comparison of wall-clock time



- Computational efficiency of the DFS dynamical core is more distinct in computing the dynamics and MPI modules by a factor of about 2.
- Although improvement of the computational cost is inconspicuous at relatively low resolutions, the efficiency remarkably increases as the model resolution increases.

Description of GRIMs-DFS dynamical core

- Latitude-longitude grid, Hydrostatic approximation, 8th-order horizontal diffusion, semi-implicit time integration
- Terrain-following sigma coordinate, Eulerian-based tracer (or moisture) advection

Physics package

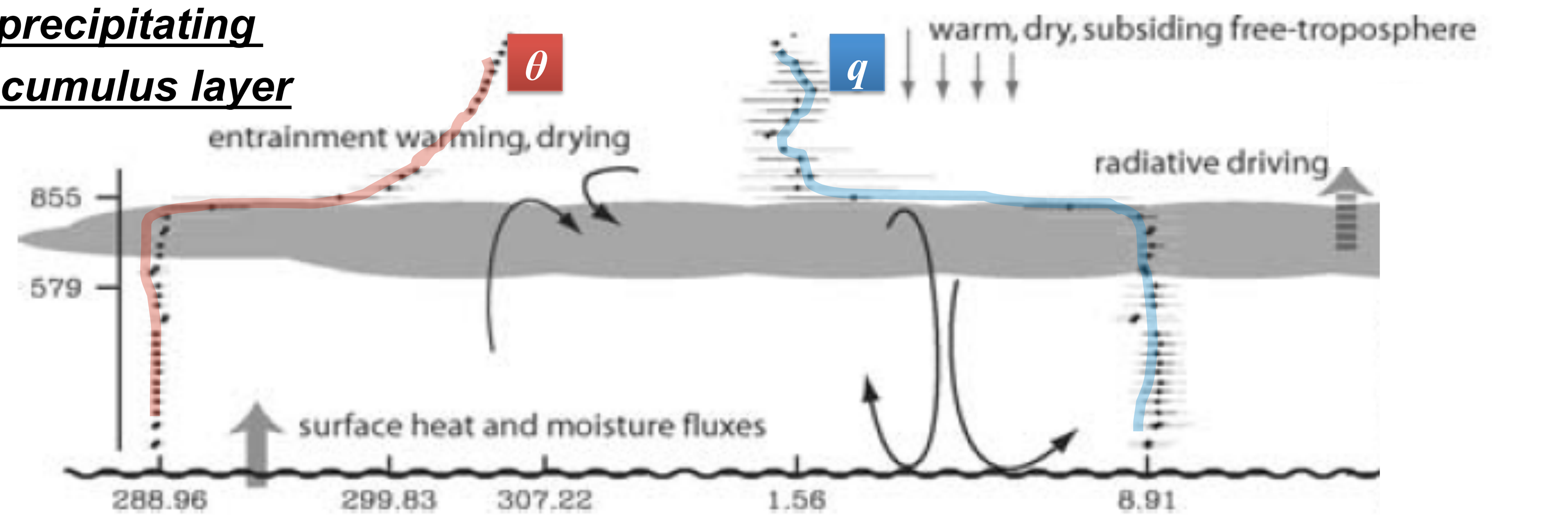
Physical parameterization	Version 1.0	Version 3.2
Deep convection	Hong and Pan (1998) Pan and Wu (1995)	Park and Hong (2007) Byun and Hong (2007)
Shallow convection	Tiedtke (1984)	Hong et al. (2012)
Cloud microphysics	Hong et al. (1998)	Hong et al. (1998)
Longwave radiation	Fels and Schwarztkopf (1975)	Chou et al. (1999)
Shortwave radiation	Chou and Lee (1996) Chou (1992)	Chou and Lee (2005) Chou and Suarez (1999)
Cloudiness	Campana et al. (1994)	Ham et al. (2009) Hong et al. (1998)
Vertical diffusion	Hong and Pan (1996) Troen and Mahrt (1986)	Hong et al. (2006) Noh et al. (2003)
Stable boundary layer	Louis (1979)	Hong (2010)
Gravity wave drag by orography	Alpert et al. (1988)	Hong et al. (2008) Kim and Arakawa (1995)
Gravity wave drag by convection	N/A	Jeon et al. (2010) Chun and Baik (1998)
Land surface layer	Pan and Mahrt (1987)	Yhang and Hong (2008) Ek et al. (2003)
Ocean surface layer	Charnock (1955)	Kim and Hong (2010)
Ozone chemistry	Diagnostic	Prognostic

Default test cases for GMP

	Short-range	Medium-range	Seasonal
Start time	2001. 7. 14. 00UTC	2010. 8. 1~31. 00UTC (for boreal summer) 2010. 1. 1~31. 00UTC (for boreal winter)	1996. 5. 1~5. 00UTC (for boreal summer) 1996. 11. 1~5. 00UTC (for boreal winter)
Forecast	2-day (6-hour spin-up)	10-day (at each day)	4-month (single month spin-up)
Analysis	Heavy rainfall (South Korea)	Deterministic verification (Global)	Seasonal precipitation + Diagnostics (Global)
Resolution	T510L64 (~25 km)	T254L64 (~50 km)	T126L28 (~100 km)
Initial data	NCEP RA2 (T62L28)	NCEP GFS-final (T574L64)	NCEP RA2 (T62L28)
Obs. (or analysis)	AWS, TMPA (~13 km)	ERA Interim, TMPA (1.5°×1.5°)	RA2, CMAP (2.5°×2.5°)
Physics package	GRIMs version 3.2		

- The version 1.0 is the package that was operational at the NCEP in 1998, which has also been used as an atmospheric model in the NCEP/DOE reanalysis 2.
- The version 3.2, which is the default setting as of April 2013, accommodates advanced physics components in the WRF model.
- The GRIMs is evaluated at various time scales (short-range to season) and horizontal resolutions (200 km to 25 km).

2 Shallow convection parameterization



Taken from Stevens (2005)

Eddy diffusivity approach K (eddy diffusivity)

$$\frac{\partial \bar{T}}{\partial t} = \frac{1}{\bar{\rho}}\frac{\partial}{\partial z}\left(\bar{\rho}K\left[\frac{\partial \bar{T}}{\partial z}+\Gamma\right]\right) \qquad \frac{\partial \bar{q}}{\partial t} = \frac{1}{\bar{\rho}}\frac{\partial}{\partial z}\left(\bar{\rho}K\frac{\partial \bar{q}}{\partial z}\right)$$

TDK shallow convection scheme

Empirically determined diffusivity

K = 1 m² s⁻¹ at the cloud top,
= 3 m² s⁻¹ at a level below the cloud top,
= 1.5 m² s⁻¹ at the cloud bottom,
= 5 m² s⁻¹ otherwise

Triggering:
1. Column should not have deep convection
2. There must be at least one potentially unstable layer within the conditionally unstable column

Cloud bottom: LCL
Cloud top: Neutral buoyancy (below sigma < 0.7)

GRIMs shallow convection scheme

PBL coupled diffusivity

$$K = RH \times 1.47 w^* \times \delta \times (1 - z/h)^3$$

w^*: convective velocity scale (m s⁻¹) from PBL
δ: the entrainment layer depth

Triggering:
1. Column should not have deep convection (same as TDK scheme)
2. Check the parcel buoyancy (between parcel originating level and PBL (LCL), and between the originating level and LFC)

Cloud bottom: PBL
Cloud top: limited to the minimum moist static energy after checking the buoyancy of parcel as in the TDK scheme (below sigma < 0.6)

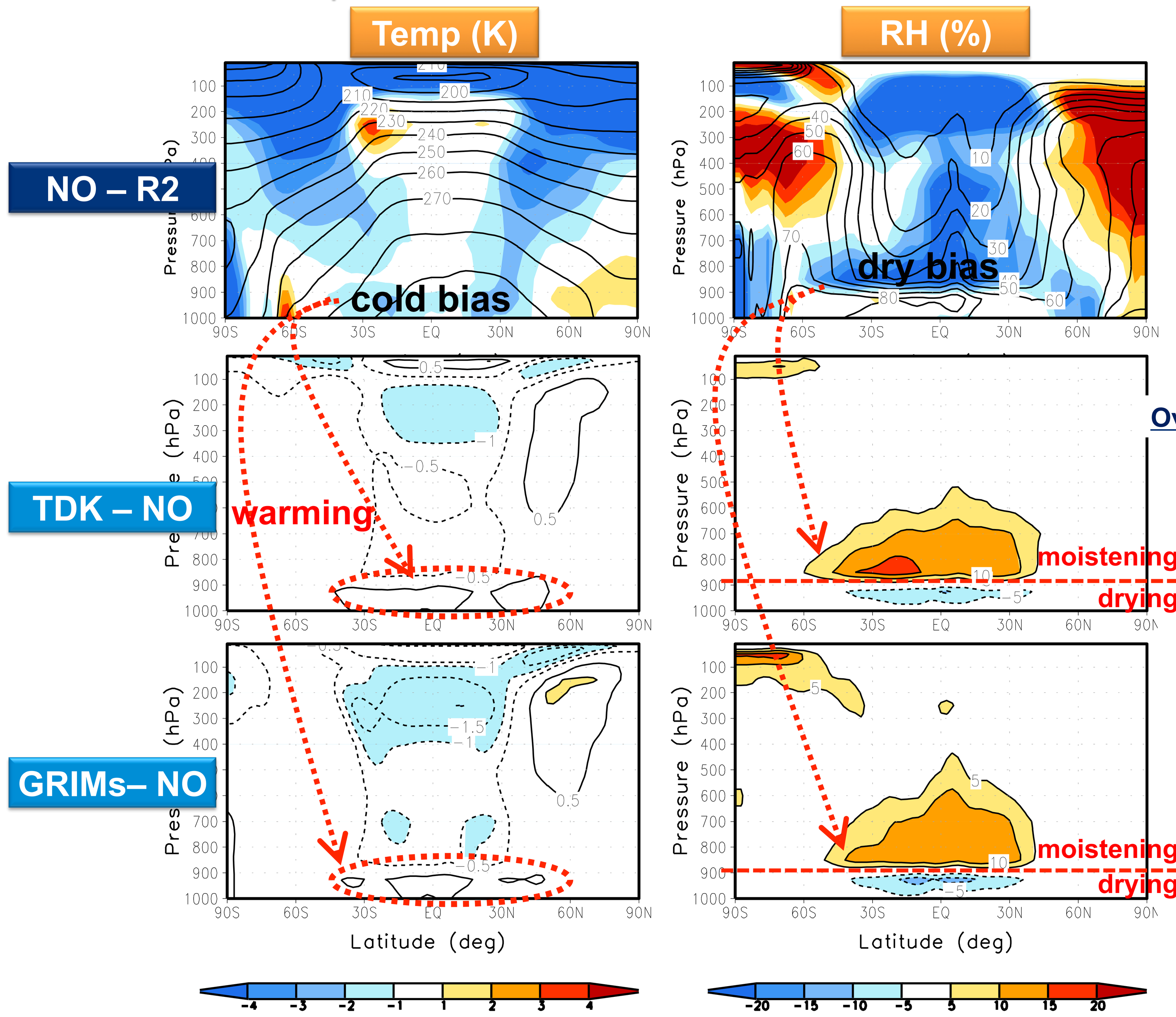
3 Impacts of shallow convection parameterization on seasonal forecasts

Experimental setup

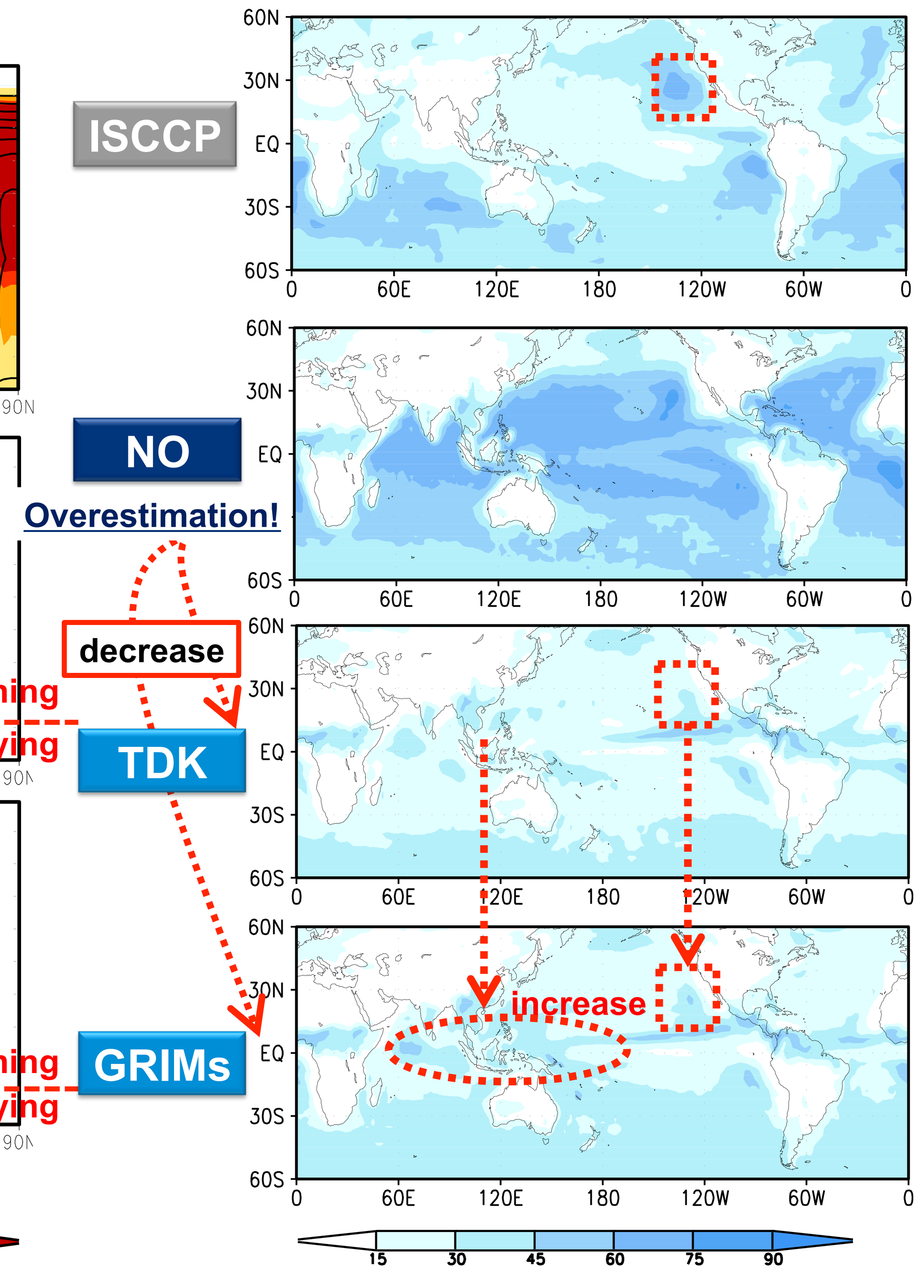
Model GRIMs **Resolution** ▪ T62 (~ 200 km) ▪ 28-layer hybrid sigma-pressure coordinate **Forecast time** JJA 1996

Experiments	NO	TDK	GRIMs
Shallow conv.	Without shallow conv. scheme	TDK scheme	GRIMs scheme

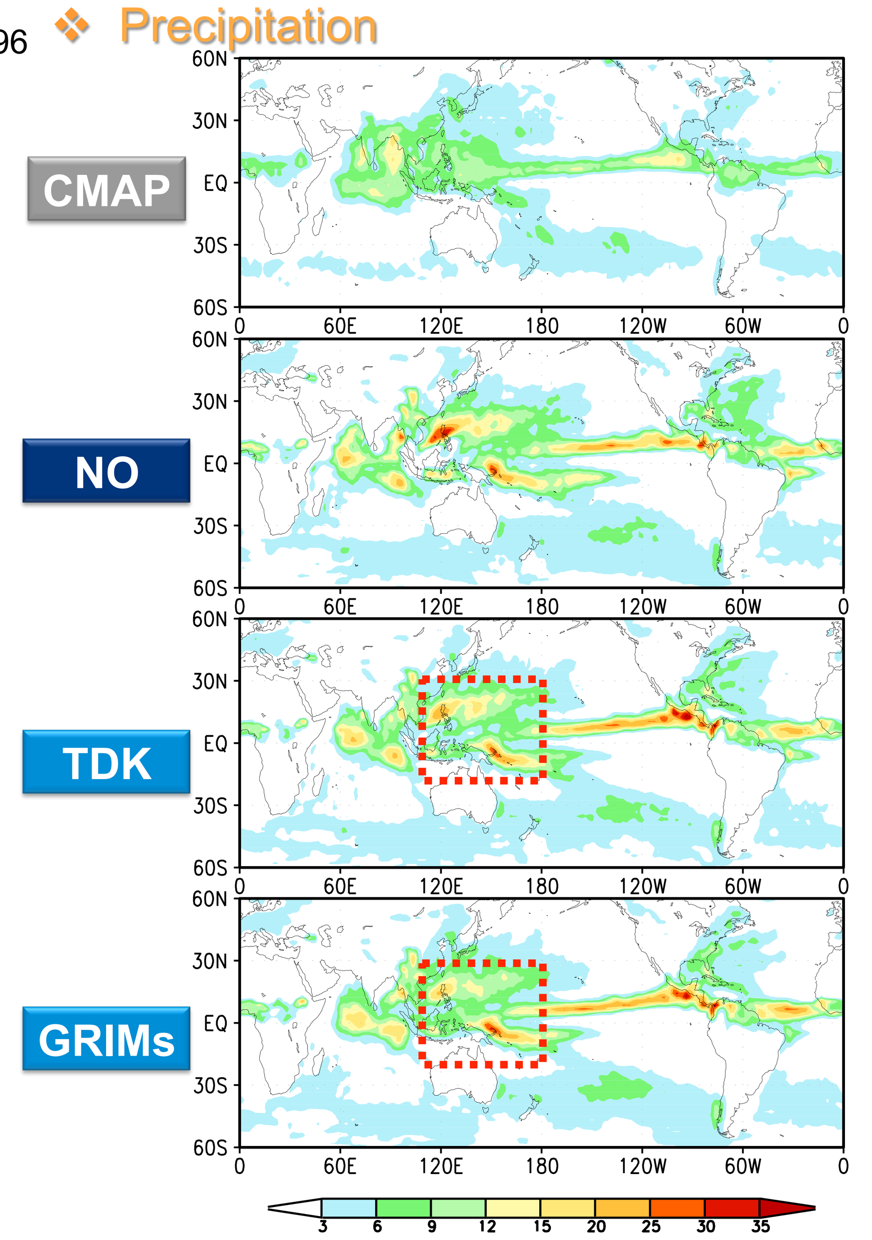
Zonal mean temperature and moisture



Low-level cloudiness



Precipitation



▪ Daily precip. and skill scores over the globe.
( ) : over the Western Pacific (110°E-180°E, 20°S-30°N)

Experiment	Amount (mm d⁻¹)	RMSE	PC
CMAP	2.71 (5.37)		
NO	3.47 (7.89)	2.94 (5.78)	0.69 (0.45)
TDK	3.40 (7.63)	2.71 (4.71)	0.74 (0.55)
GRIM	3.40 (7.57)	2.60 (4.40)	0.77 (0.61)