The recent improvement of high resolution model T511L60 of CWBGFS

陳建河　陳雯美　汪鳳如

中央氣象局氣象資訊中心

中央氣象局氣象科技研究中心

CWBGFS Team:

資料同化: 陳雯美、陳登舜、趙子瑩、鄧雯心

模式動力: 陳建河、劉邦彥、李長華(Fujitsu)

模式物理: 汪鳳如、張美玉、黃小玲、郭珮萱

系集預報: 張庭槐、曾建翰、賴永鑫、羅昌鴻

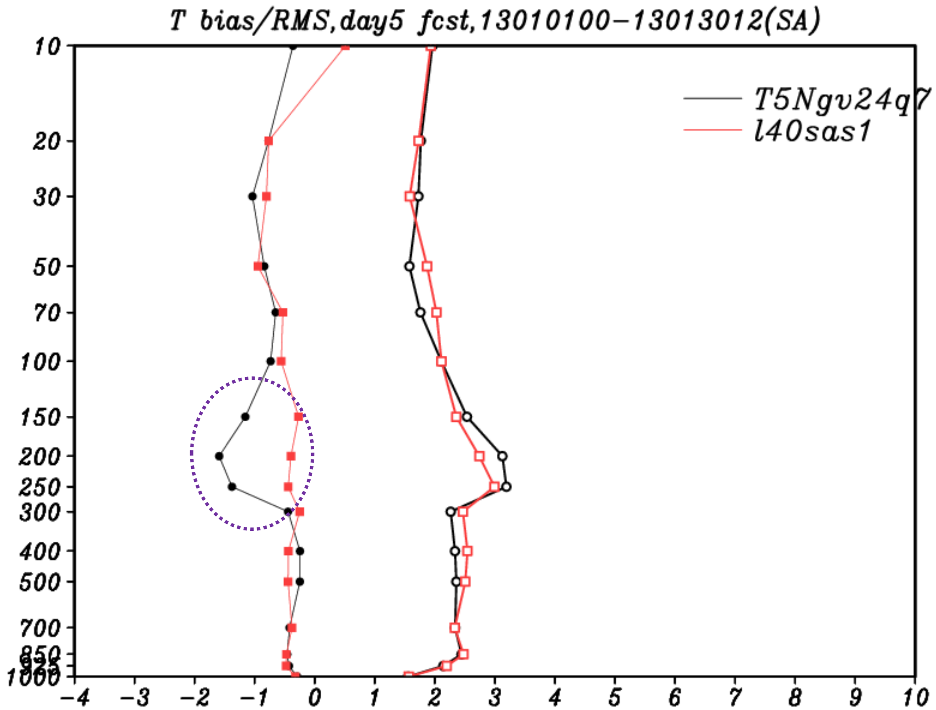
大綱:

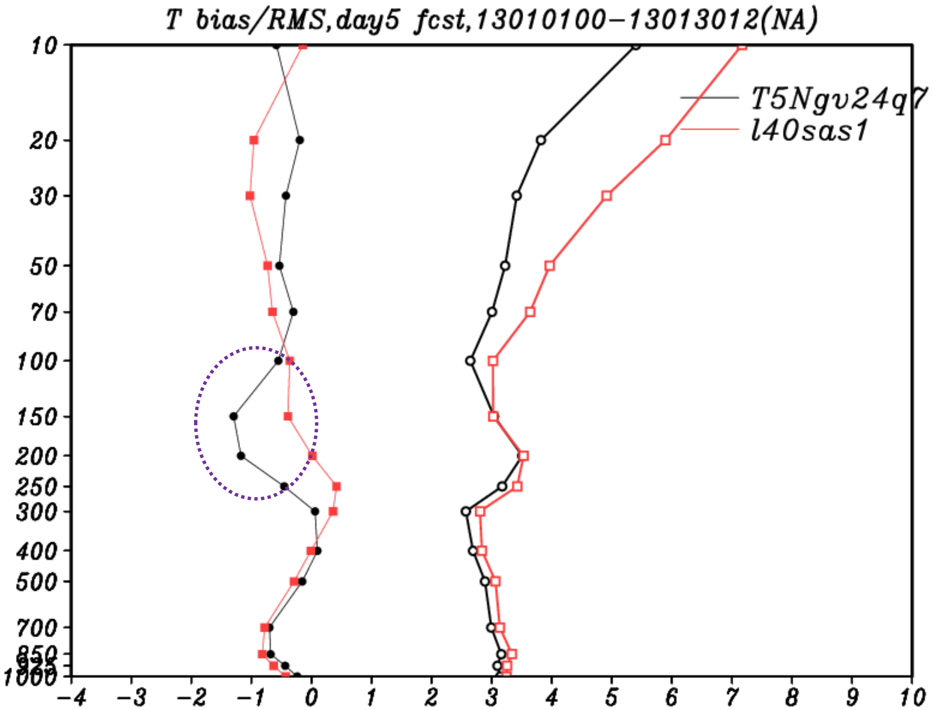
1. T319L40 與 T511L60的比較
2. T511L60的改進
3. CWBGFS 未來的發展

1. T319L40 與 T511L60的比較

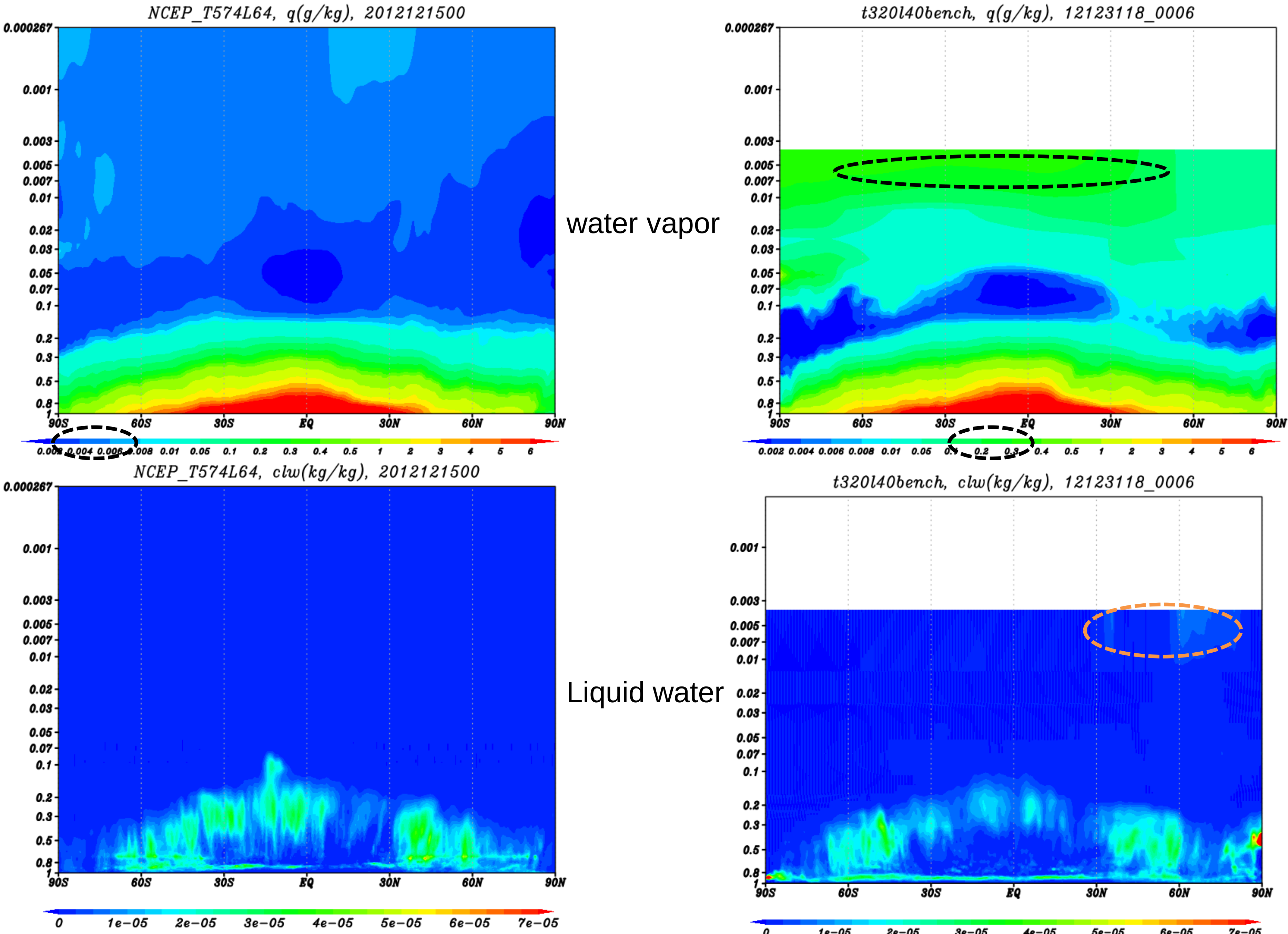
	T511L60	T319L40
資料同化	Hybrid GSI	Hybrid GSI
模式動力 ★	模式層頂: 0.1MB 垂直座標: S-P hybrid 60層 水平座標: reduced gaussian grid (~25KM)	模式層頂: 1MB 垂直座標: Sigma 40層 水平座標: regular gaussian grid (~40KM)
模式物理	**Soil model : Noah Land Surface model** ★**Vertical turbulence : Hong and Pan (2011)** **Cumulus convection : NSAS** Han and Pan(2011) **Grid scale precipitation:** Zhao and Carr (1997) ★**Shallow convection:** Han and Pan(2011) **Topographic gravity wave drag: palmer (1986)** **Radiation :** Fu et.al. (1997) 、 Fu an Liou（1992；1993) ★**nonorographic gravity wave drag: Scinocca (2003)**	**Soil model : Noah Land Surface model** **Vertical turbulence:** Mahrt and Pan (1984) **Cumulus convection : NSAS** Han and Pan(2011) **Grid scale precipitation:** Zhao and Carr (1997) **Shallow convection:** Li and Wang (2000) **Topographic gravity wave drag: palmer (1986)** **Radiation :** Fu et.al. (1997) 、Fu an Liou（1992；1993)

2. T511L60的改進

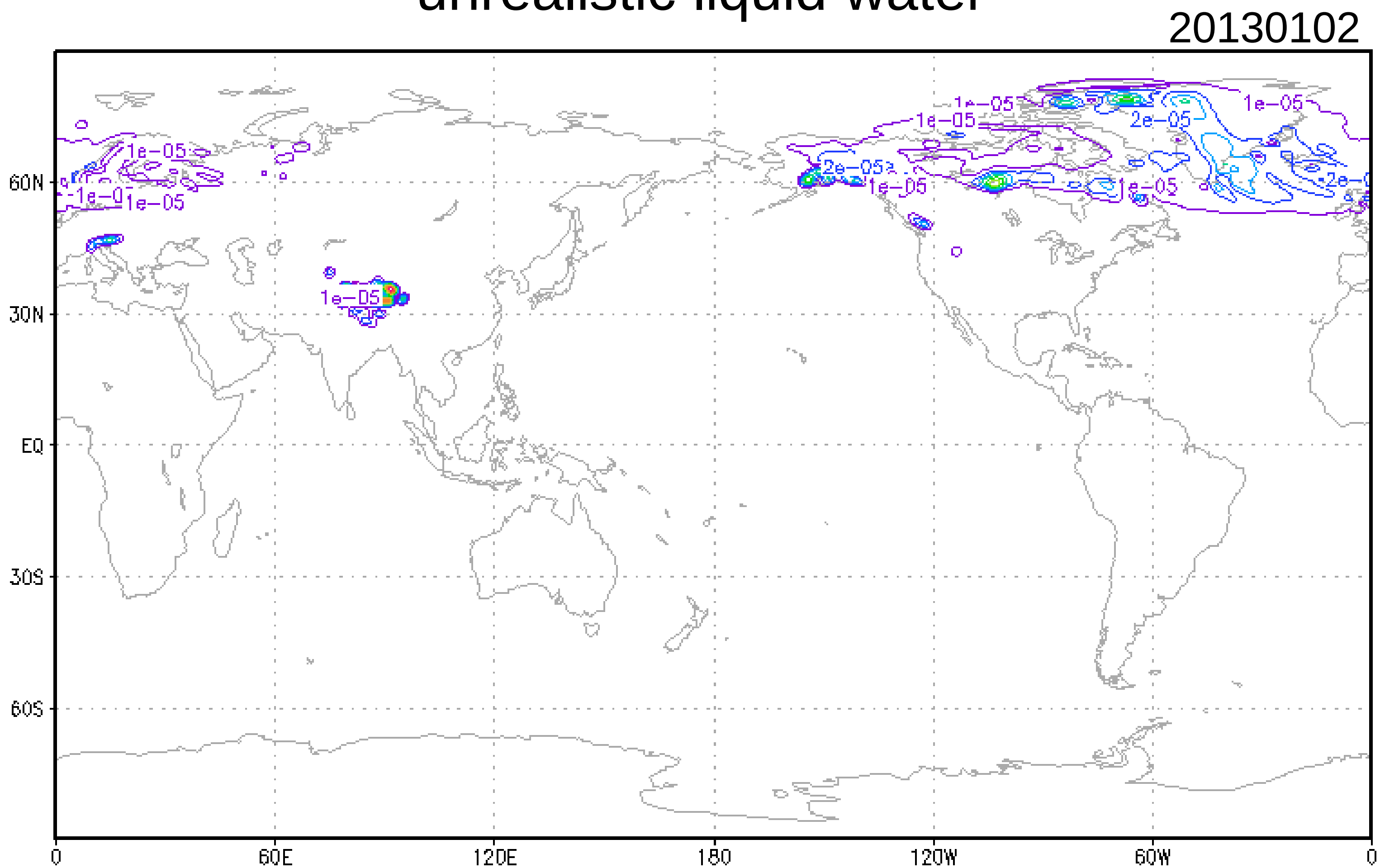




NCEP Zonal mean CWB (T319L40)

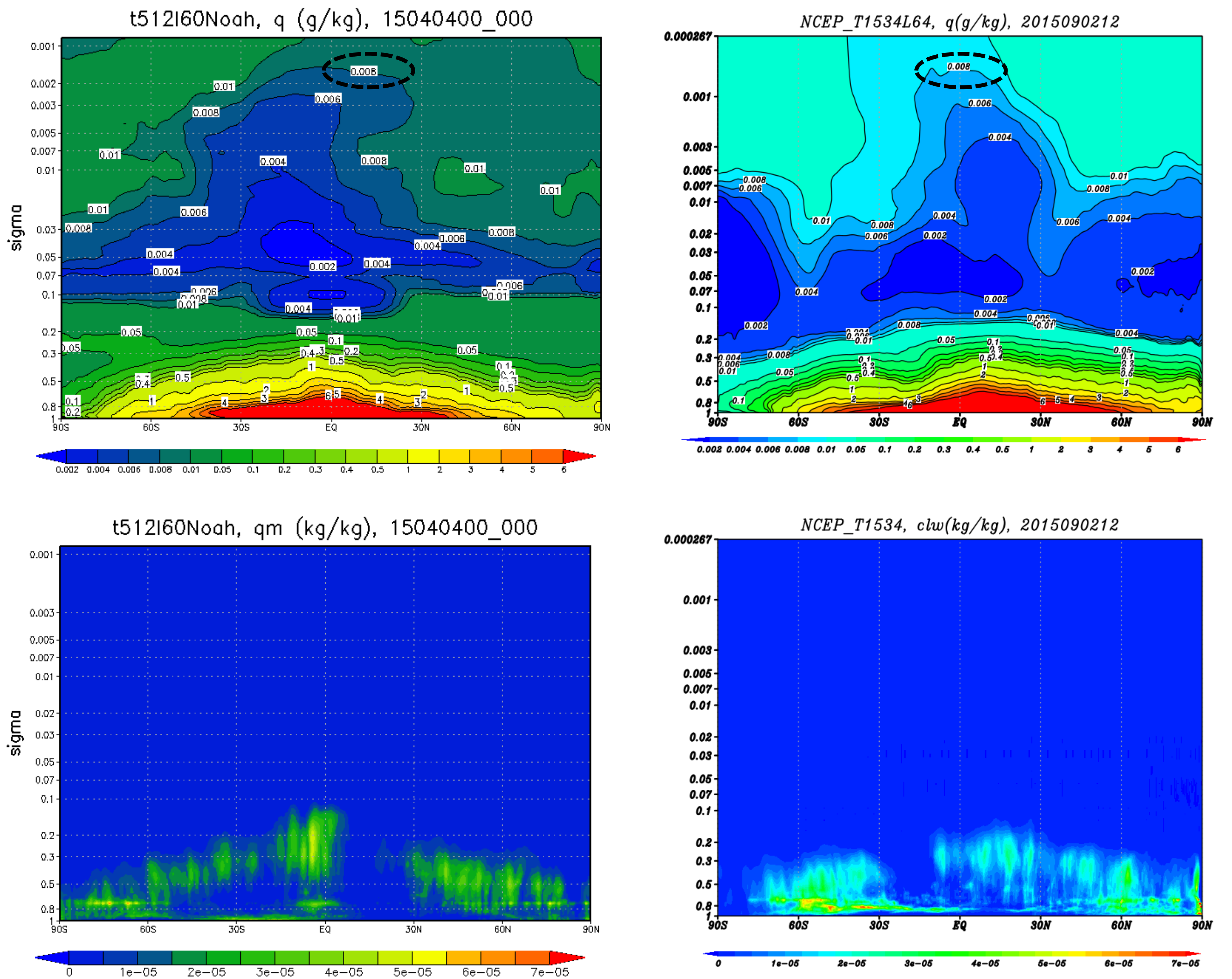


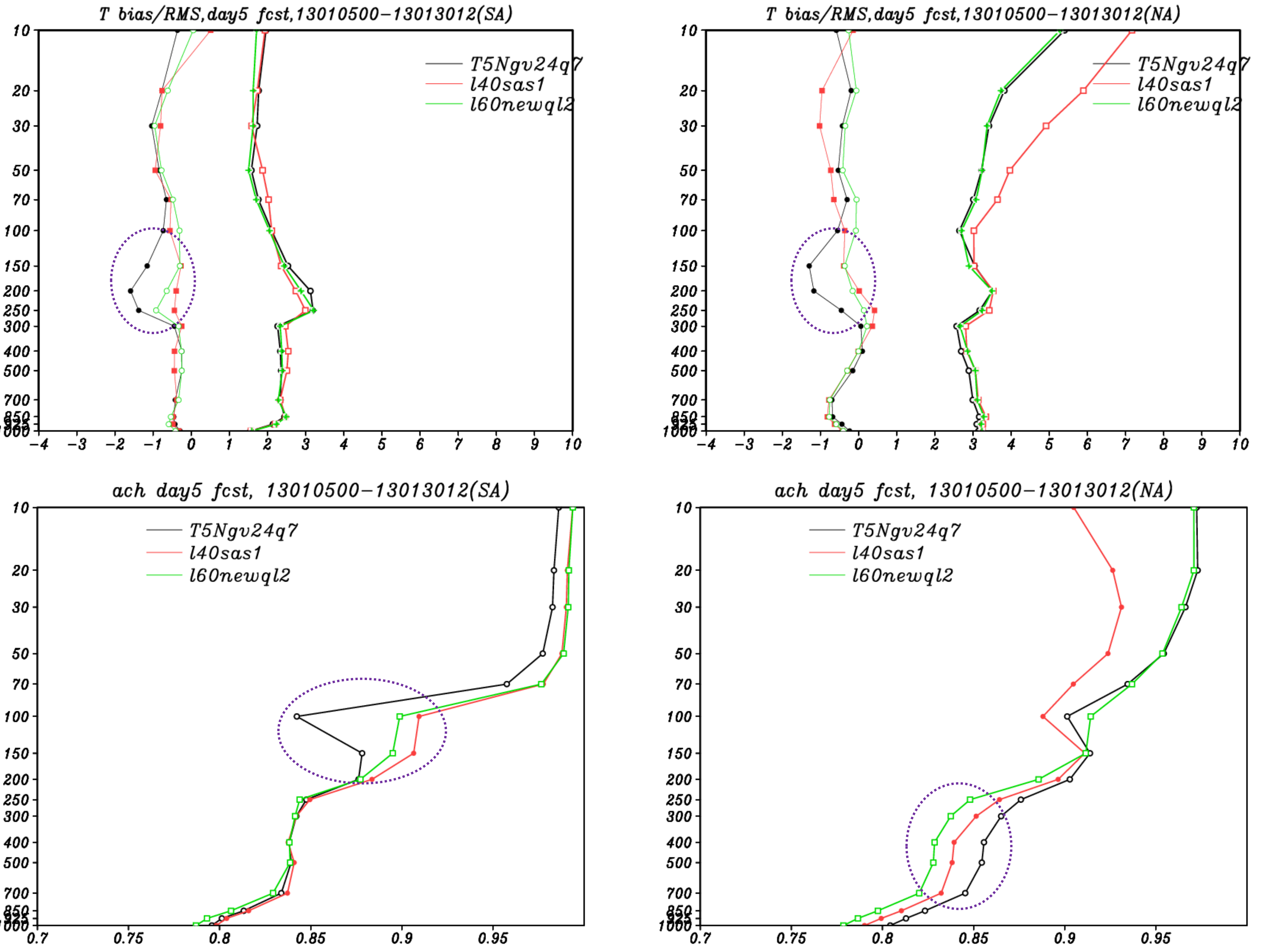
unrealistic liquid water



q_l Sigma level=10

by evaporation process to have too much water vapor


t512l60Noah, q (g/kg), 15040400_000
NCEP_T1534L64, q(g/kg), 2015090212
t512l60Noah, qm (kg/kg), 15040400_000
NCEP_T1534, clw(kg/kg), 2015090212
sigma
90S 60S 30S EQ 30N 60N 90N
0.002 0.004 0.006 0.008 0.01 0.05 0.1 0.2 0.3 0.4 0.5 1 2 3 4 5 6
0 1e−05 2e−05 3e−05 4e−05 5e−05 6e−05 7e−05



T bias/RMS,day5 fcst,13010500-13013012(SA)
T bias/RMS,day5 fcst,13010500-13013012(NA)
ach day5 fcst, 13010500-13013012(SA)
ach day5 fcst, 13010500-13013012(NA)
T5Ngv24q7
l40sas1
l60newql2

TABLE 1. Definition of symbols in Eqs. (1), (2), and (3).

Symbol	Meaning
$\mathbf{V}_3 \cdot \mathbf{\nabla}_3$	Three-dimensional advection
$\mathbf{V}_h \cdot \mathbf{\nabla}_h$	Horizontal advection
p	Pressure
R_d	Gas constant for dry air
C_p	Specific heat of air at constant pressure
ω	Vertical velocity in pressure coordiante (Pa s^{-1})
Q_r	Heating rate by radiation (K s^{-1})
E_c, E_r	Evaporation rate of cloud and precipitation (s^{-1})
C_b, C_g	Convective and grid-scale condensation rate (s^{-1})
C_b'	Net convective condensation rate (s^{-1})
P	Precipitation production rate from clouds (s^{-1})
P_{sm}	Melting rate of snow (s^{-1})
L	Latent heat of condensation/deposition
L_f	Latent heat of freezing

Zhao and Car(1997)

$$\frac{\partial q}{\partial t} = A_q + E_c - C_g$$

$$\frac{\partial T}{\partial t} = A_t - \frac{L}{C_p} E_c + \frac{L}{C_p} C_g$$

$$\frac{\partial m}{\partial t} = m_{non} + C_b' + C_g - P - E_c$$

where

$$A_q = q_{non} + E_r - C_b$$

$$A_t = T_{non} + \frac{L}{C_p} C_b - \frac{L}{C_p} E_r - \frac{L_f}{C_p} P_{sm}$$

$$q_{non} = -V_3 \nabla_3 q + \text{turbulent term}$$

$$T_{non} = -V_3 \nabla_3 T + \frac{\kappa \omega T}{p} + Q_r + \text{turbulent term}$$

$$m_{non} = -V_h \nabla_h m$$

$$C_g = \frac{M - q_s f_t}{1 + (f \varepsilon L^2 q_s / R C_p T^2)} + E_c$$

where

$$M = A_q - \frac{f \varepsilon L^2 q_s}{R T^2} A_t + \frac{f q_s \partial p}{p \partial t}$$

$$f = \frac{2(1-b)(f_s - f_0)\left[(1-b)M + E_c\right]}{2 q_s (1-b)(f_s - f_0) + m / b}$$

$$b = 1 - \left(\frac{f_s - f}{f_s - f_0}\right)^{1/2}$$

$$f_s = 1$$

$$C_b' = RB$$

$$C_b = \frac{q - q_s}{\tau}$$

τ : timescale of convective adjustment

$$R = \frac{\int_{\eta_t}^{\eta_b} C_b d\eta}{\int_{\eta_t}^{\eta_b} B d\eta} \quad (R \le 1)$$

$$B = C_b \quad \text{if } C_b \ge 0$$

$$B = 0 \quad \text{if } C_b < 0$$

the constran for C_b' is $\int_{\eta_t}^{\eta_b} C_b' d\eta = \int_{\eta_t}^{\eta_b} C_b d\eta$

if $\int_{\eta_t}^{\eta_b} C_b d\eta < 0$ no adjustment is allowed

$$E_c = \frac{q_0 - q}{\Delta t}$$

$$q_0 = f_0 q_s$$

$$E_c = \frac{q_s}{\Delta t}(f_0 - f)$$

f_0: crtical value of relative humidity for condensation and evaporation

$$P = P_{raut} + P_{saut} + P_{racw} + P_{sacw} + P_{saci}$$

$$P_{sm} = P_{sm1} + P_{sm2}$$

$$E_r = E_{rr} + E_{rs}$$

$$P_{raut} = C_0 m \left\{ 1 - \exp\left[-\left(\frac{m}{m_r b}\right)^2 \right] \right\}$$

$$C_0 = 1.0e^{-4} s, \quad m_r = 3.0e^{-4}$$

$$P_{saut} = a_1 (m - m_{i0})$$

$$m_{i0} = 1.0e^{-4} (kgkg^{-1})$$

$$a_1 = 10^{-3} \exp[0.025(T - 273.15)]$$

$$P_{racw} = C_r m P_r$$

$$C_r = 5.0e^{-4} m^2 kg^{-1} s^{-1}$$

$$P_{saci} = C_s m P_s$$

$$C_s = c_1 \exp[c_2 (T - 273.15)]$$

$$c_1 = 1.25e^{-3} m^2 kg^{-1} s^{-1}, \quad c_2 = 0.025 K^{-1}$$

$$P_{sacw} = C_r m P_s$$

$$P_{sm1} = C_{sm} (T - 273.15)^{\alpha} P_s$$

$$C_{sm} = 5.0e^{-8} m^2 kg^{-1} s^{-1}, \quad \alpha = 2$$

$$P_{sm2} = C_{ws} P_{sacw}$$

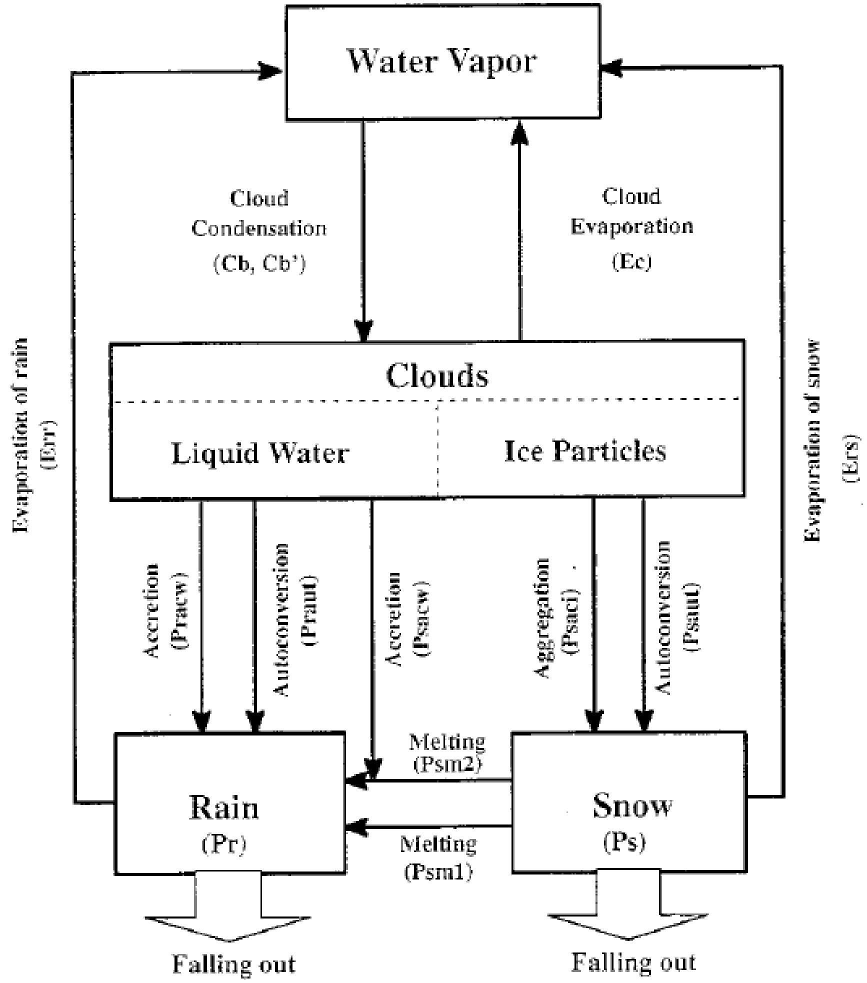
$$C_{ws} \approx 0.025$$

$$E_{rr} = k_e (f_0 - f)(P_r)^{\beta}$$

$$k_e = 2.0e^{-5} m^1 kg^{-0.5} s^{-1}, \quad \beta = 0.5$$

$$E_{rs} = [(C_{rs1} + C_{rs2}(T - 273.15)]\left(\frac{f_0 - f}{f_0}\right)$$

$$C_{rs1} = 5.0e^{-6} m^2 kg^{-1} s^{-1}, \quad C_{rs2} = 6.67e^{-10} m^2 kg^{-1} K^{-1} s^{-1}$$



$$P_r(\eta) = \frac{p_s - p_t}{g\eta_s} \int_{\eta}^{\eta_t} (P_{raut} + P_{racw} + P_{sacw} + P_{sm1} + P_{sm2} - E_{rr}) d\eta$$

$$P_s(\eta) = \frac{p_s - p_t}{g\eta_s} \int_{\eta}^{\eta_t} (P_{saut} + P_{saci} - P_{sm1} - P_{sm2} - E_{rs}) d\eta$$

$$\eta_s = \frac{p_{ref}(z_{sfc}) - p_t}{p_{ref}(0) - p_t}$$

$$P_{sfc} = \frac{P_r(\eta_{sfc}) + P_s(\eta_{sfc})}{\rho_w}$$

TABLE 2. The IW values in different temperature regions.

Temperature	Large-scale condensation		Convective condensation
$T > 0°C$	IW = 0		IW = 0
$-15°C < T < 0°C$	IW = 1,	if there is cloud ice at or above this point at current or the previous time step;	
	IW = 0,	otherwise.	IW = 1
$T < -15°C$	IW = 1		IW = 1

Exp1:T5D1q7 test 1: reduce: $P_{saci}, P_{sm1}, P_{sm2}, E_{rs}$

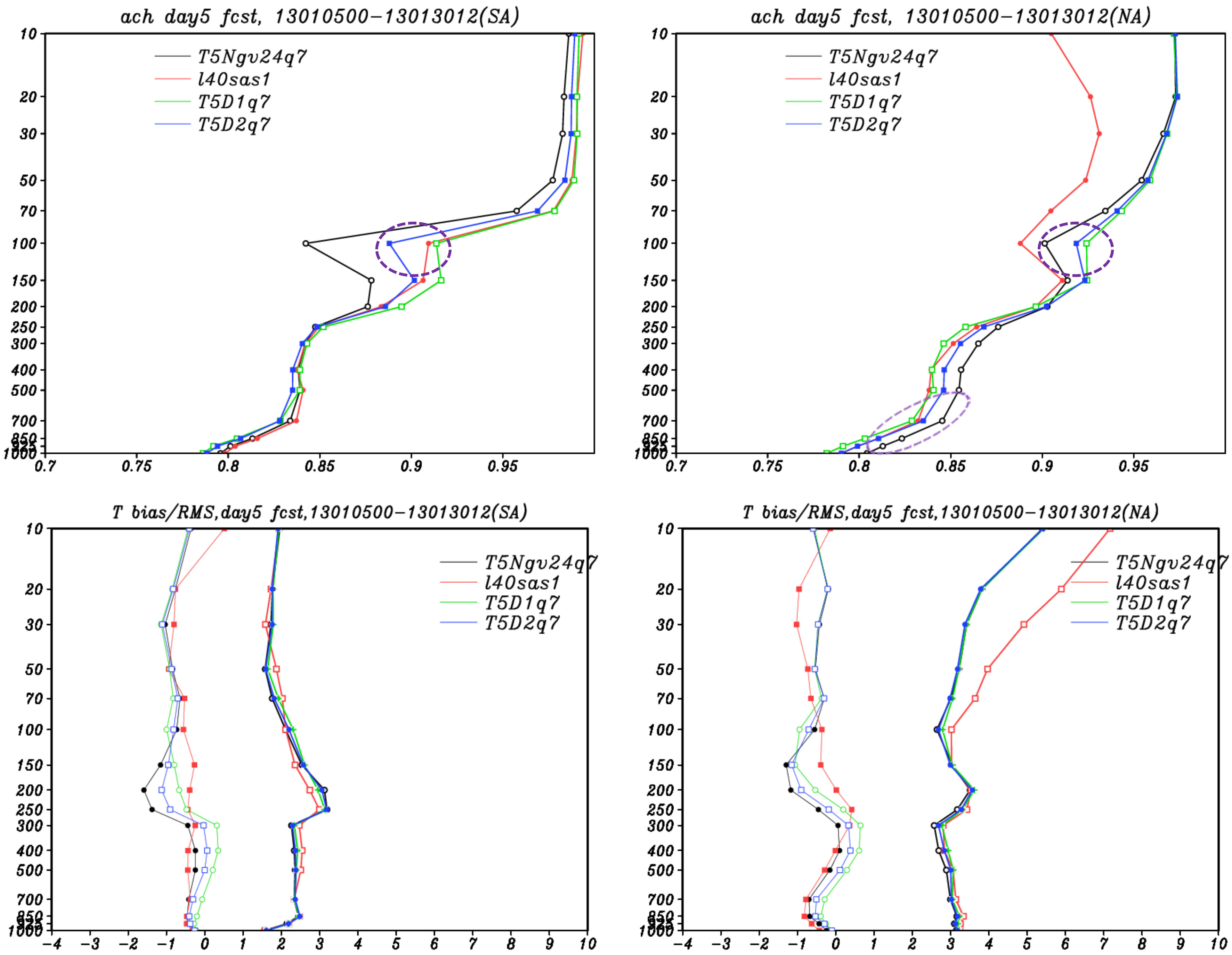
Exp2:T5D2q7 test 2: reduce evaporation process

$$if\,(\mathrm{IW}=1 \quad .and. \quad t \le 248.16)\, f_0 = f_0 \bullet c1 \bullet \exp(c2(t-248.16))$$

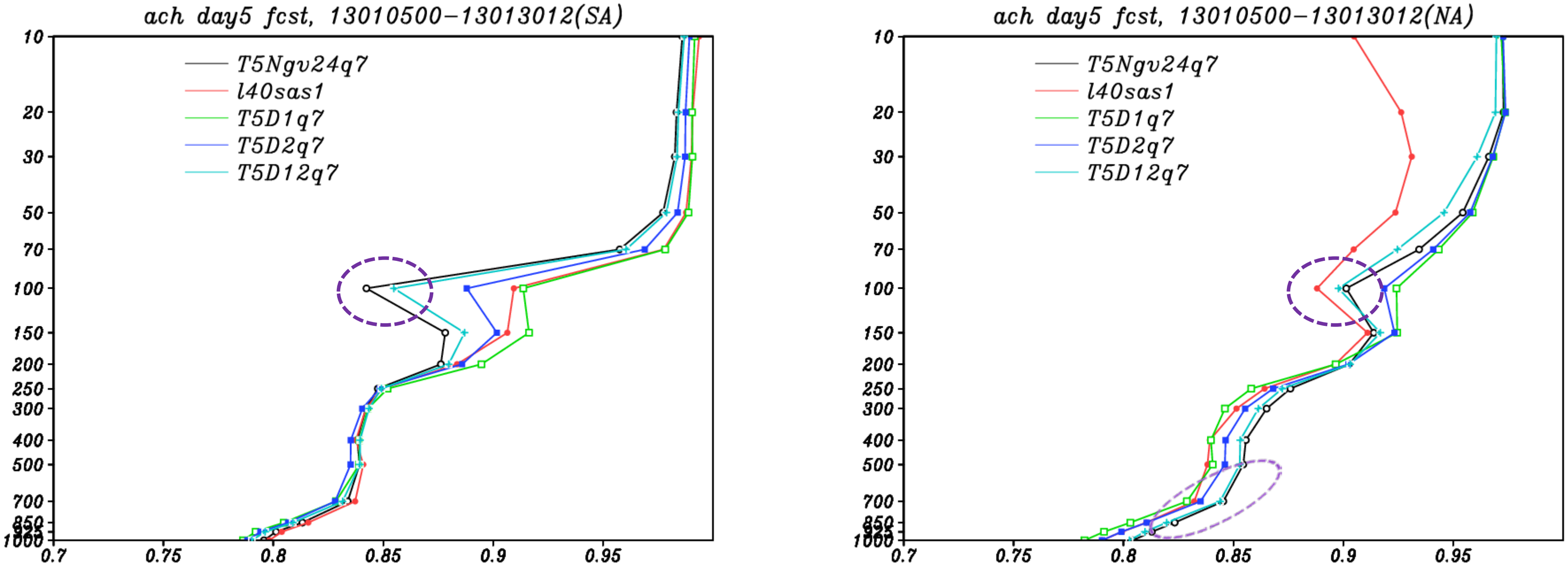
where

$$c1 = 1. \quad c2 = 0.0015$$

Exp3:T5D12q7 test 3: $f_0 = 0.999 - a1 * \cos(\phi_j - \phi_{sun})^{a2}$



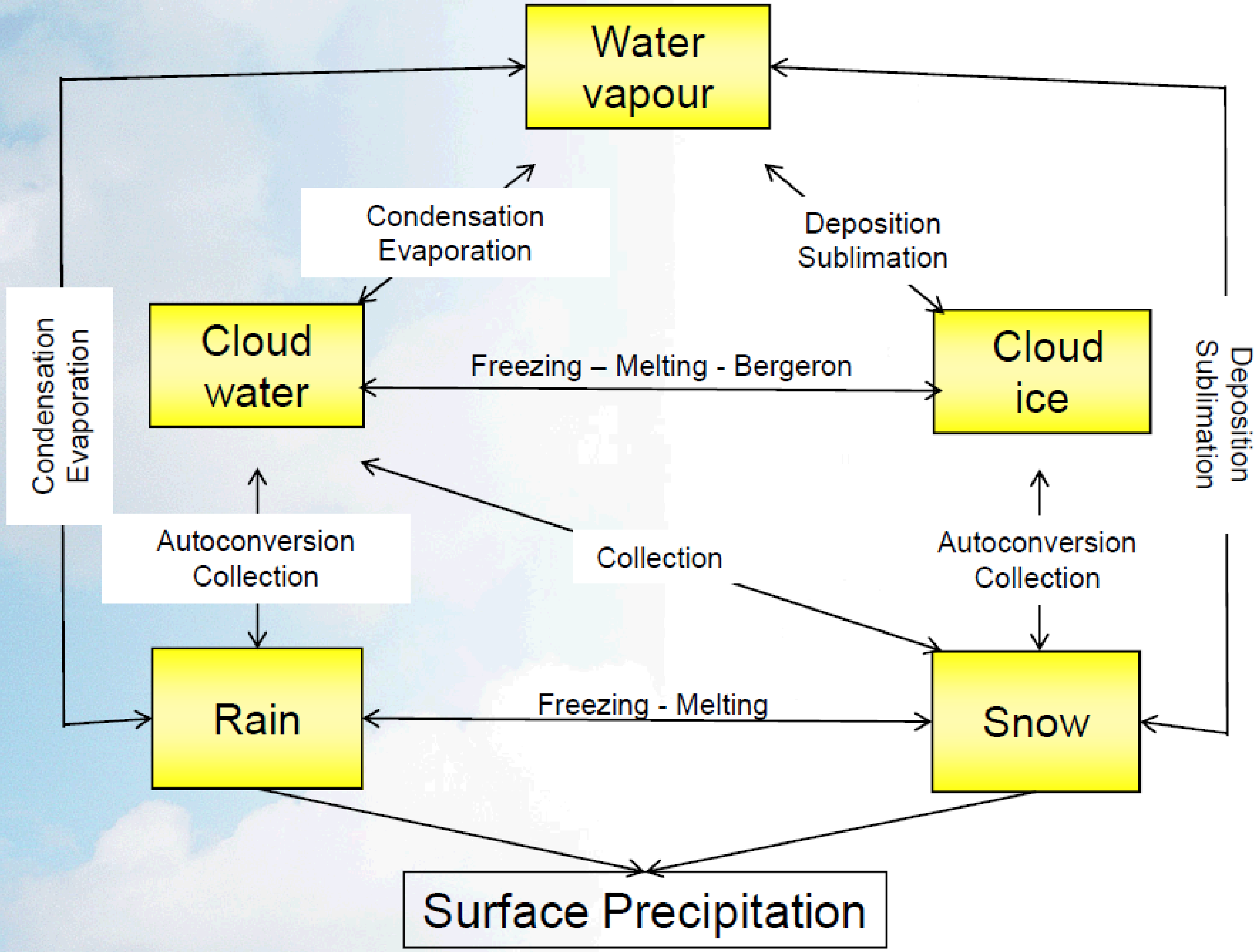
ach day5 fcst, 13010500-13013012(SA)
ach day5 fcst, 13010500-13013012(NA)
T bias/RMS,day5 fcst,13010500-13013012(SA)
T bias/RMS,day5 fcst,13010500-13013012(NA)
T5Ngv24q7
l40sas1
T5D1q7
T5D2q7
10
20
30
50
70
100
150
200
250
300
400
500
700
850
925
1000
0.7
0.75
0.8
0.85
0.9
0.95
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10



Exp3:T5D12q7 test 3 : $f_0 = 0.999 - a1 * \cos(\phi_j - \phi_{sun})^{a2}$

Microphysics Parametrization:
The "category" view

Cloud (radiation) + hydrology + diabatic interaction



T5D31q7

Xu and Randall (1996)

$$C_s = RH^p \left\{1 - \exp(-\alpha_0 \overline{q}_l / [(1 - RH) q^*]^\gamma)\right\}$$

RH : relative humidity

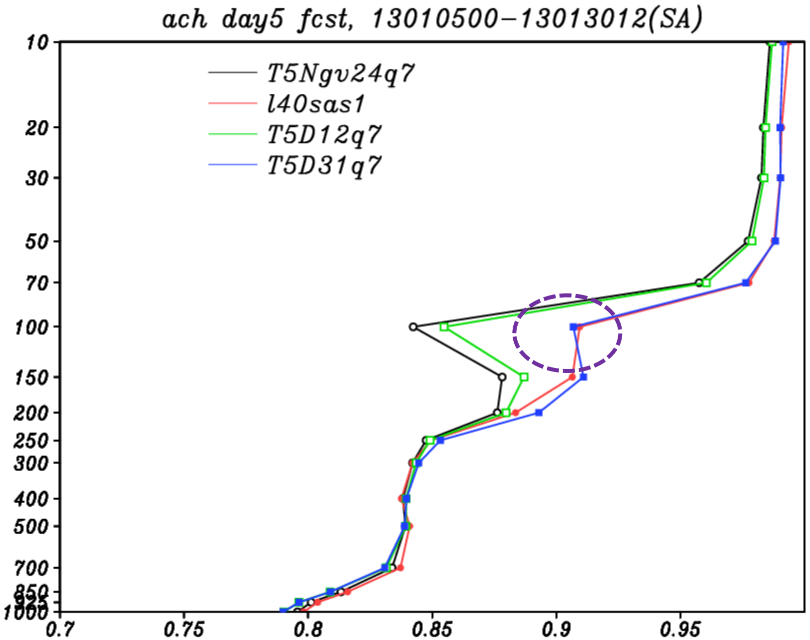
$\overline{q}_l$: liquid water content

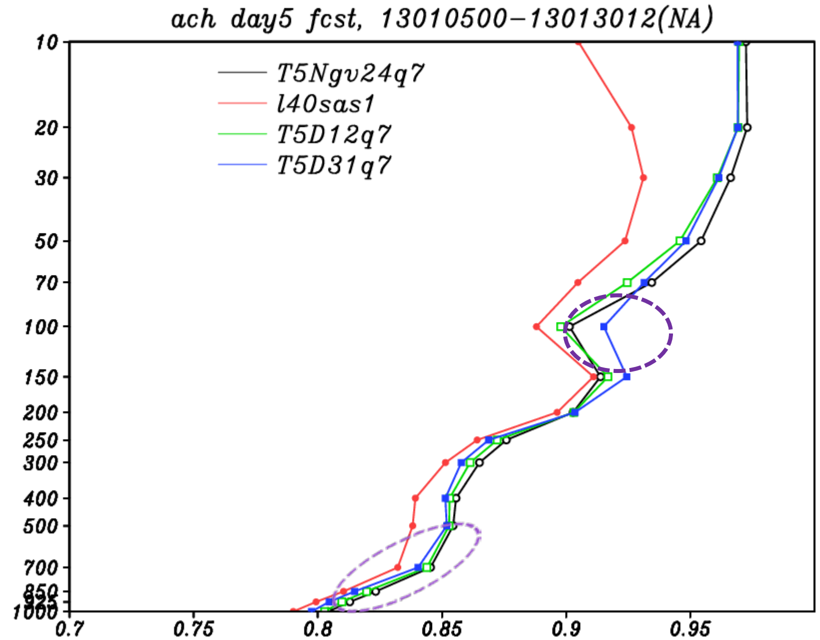
q^* : saturation water vapor mixing ratio

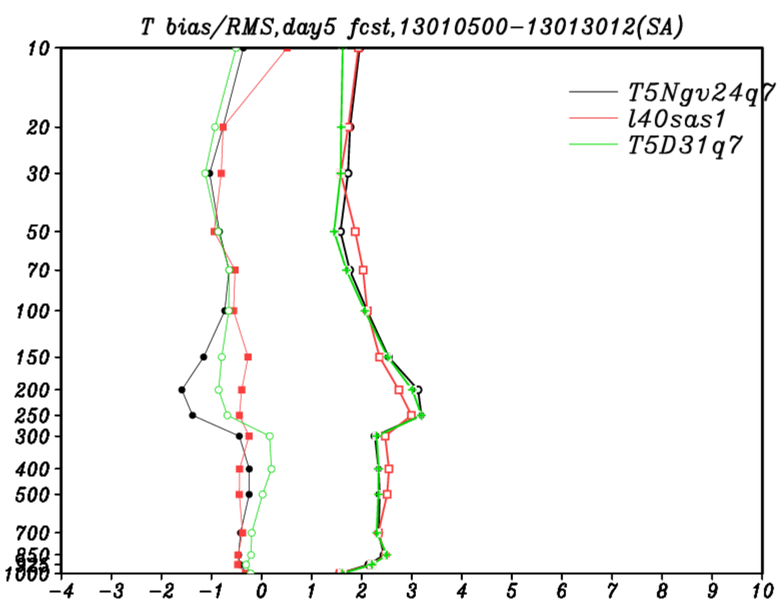
where $p = 0.25, \quad \gamma = 0.49, \quad \alpha_0 = 100$

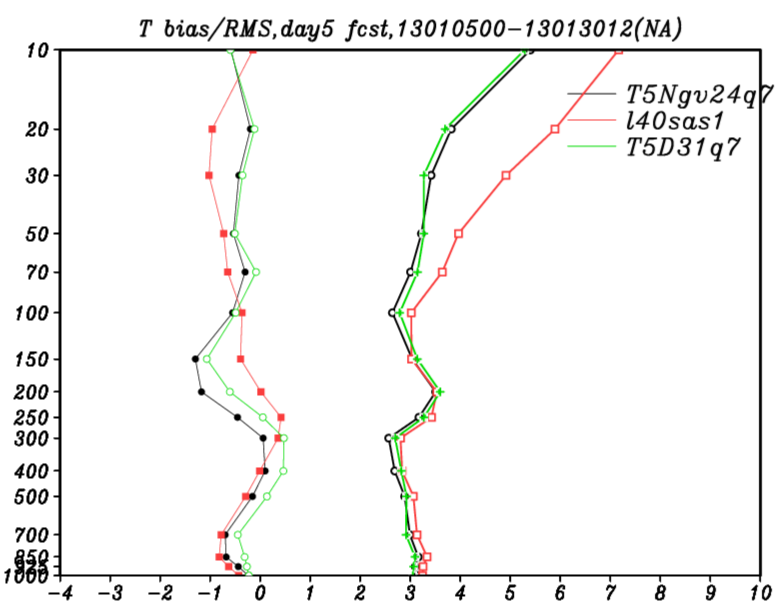
$$cldmaxv = 0.9 - 0.2(1. - \cos^2(\phi - \phi_s))$$

ϕ_s = latitude of sun

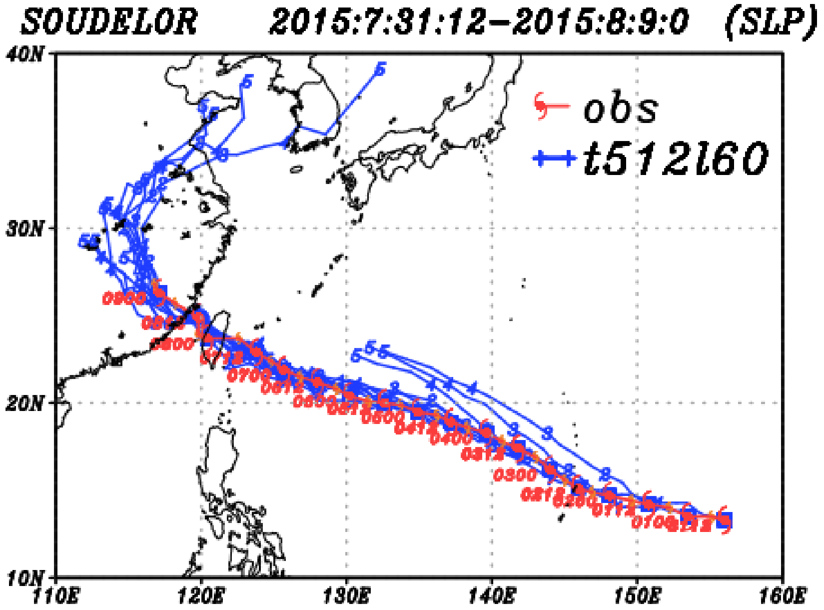

ach day5 fcst, 13010500-13013012(SA)
T5Ngv24q7
l40sas1
T5D12q7
T5D31q7
10
20
30
50
70
100
150
200
250
300
400
500
700
850
925
1000
0.7
0.75
0.8
0.85
0.9
0.95


ach day5 fcst, 13010500-13013012(NA)
T5Ngv24q7
l40sas1
T5D12q7
T5D31q7
10
20
30
50
70
100
150
200
250
300
400
500
700
850
925
1000
0.7
0.75
0.8
0.85
0.9
0.95

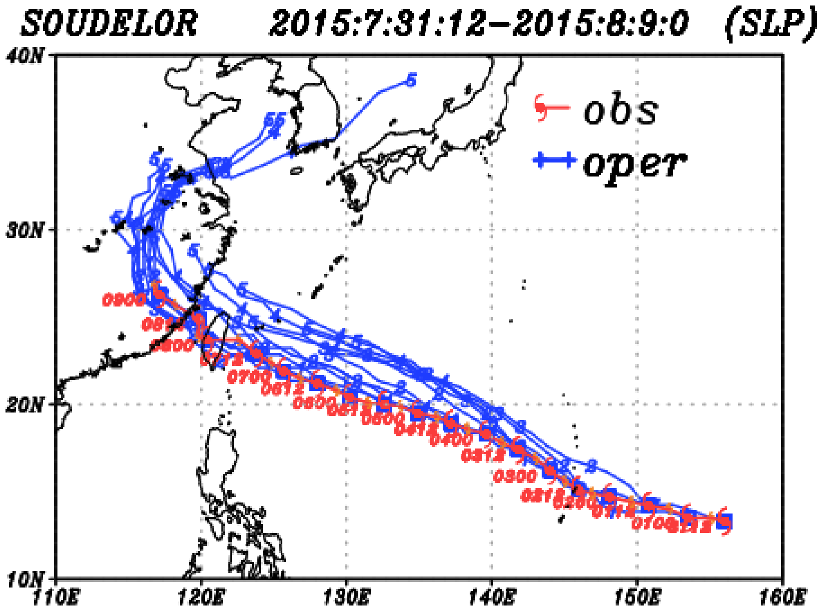

T bias/RMS,day5 fcst,13010500-13013012(SA)
T5Ngv24q7
l40sas1
T5D31q7
10
20
30
50
70
100
150
200
250
300
400
500
700
850
925
1000
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10


T bias/RMS,day5 fcst,13010500-13013012(NA)
T5Ngv24q7
l40sas1
T5D31q7
10
20
30
50
70
100
150
200
250
300
400
500
700
850
925
1000
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
9
10

SOUDELOR



T511L60



T319L40

3. CWBGFS 未來的發展

1. **Data assimilation**
   - Use more satellite data： AIRS、AMSUA_N19(2015) 、HIRS、ATMS(2016) 、MHS and others(2017-2019)
   - improve data analysis module: 4-D ensemble-Var (2015~)
2. **Forecast model**
   1. Improve Physical parameterization
      - RRTMG (2014~2016)
      - Ozone (2014~2016)
      - Aerosol (2017~2020)
      - topographic gravity wave drag (Kim and Arakawa,1995) (2016~2017)
      - SIT (Snow/Ice/Thermocline) (Tsuang et al., 2001)(2014~2016)
      - Micro physics (rain, snow) (J.-L. F. Li et. al. 2014) (2015~2018)
   2. Developing Semi-Lagragian model TL1279L80 (15km,2013~2017)
   3. Developing next generation non-hydrostatic model of CWBGFS (CWB National Earth Weather-climate System (CWB NEWS) (10km,2015~2020)
3. Developing global ensemble forecast system: typhoon , week2 to one month forecast (2014~2020)

What we need and the priority in 2016-2019

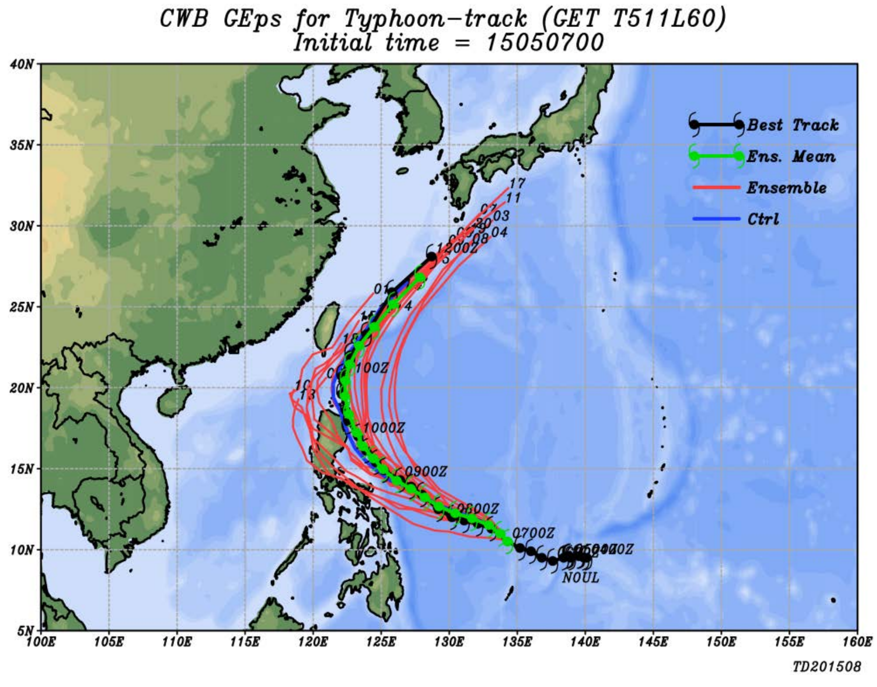
1. **consult from, cooperate with the NCEP and academic**
2. **Update and diagnose of physical parameterization package:**
   - RRTMG, Ozone , topographic gravity wave drag, SIT
   - Micro physics (rain, snow), Aerosol
   - diagnose of all physical parameterization package
3. **Data assimilation**
   - How to use the satellite data: AIRS、AMSUA_N19 、HIRS、ATMS、MHS and others
   - 4-D ensemble-Var
4. **Week 2 to 1 month ensemble forecast:**
   - stochastic physics
   - post process of forecast data
5. **Next generation non-hydrostatic global model :**
   - New Dynamic and Physics

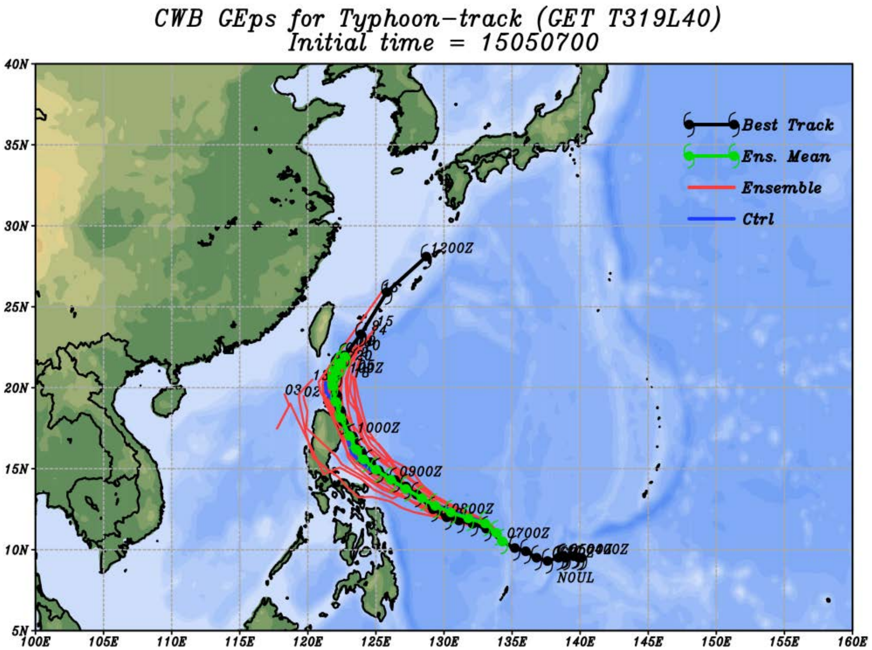
Typhoon Track Ensemble System

<table>
<tr><th colspan="4">CWB GFS EPS for Typhoon track (GET)</th></tr>
<tr><td rowspan="2">resolution</td><td colspan="2">deterministic model</td><td>T511L60</td></tr>
<tr><td colspan="2">ensemble</td><td>T511L60</td></tr>
<tr><td rowspan="3">initial perturbation, singular vector</td><td colspan="2">global</td><td>T319L60</td></tr>
<tr><td rowspan="2">nested typhoon domain</td><td>east Asia</td><td>20^0N-60^0N, 100^0E-180^0E</td></tr>
<tr><td>typhoon</td><td>$15^0 \times 10^0$</td></tr>
<tr><td>optimization time</td><td colspan="3">48 hrs</td></tr>
<tr><td>ensemble size</td><td colspan="3">20</td></tr>
<tr><td>forecast length</td><td colspan="3">5-day</td></tr>
</table>

CWB GET

T511L60 NOUL T319L40





Thank You for your attention