The development of Semi-Lagrangian Semi-Implicit Global Forecast model of the Taiwan Central Weather Bureau

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CWB have been developed NWP system since 1984. The second generation global forecast model was a spectrum model and operational in 1994. Base on this model, we are developing the third generation operational model which the dynamic core is semi-Lagrangian.

1. **Brief description of the current CWBGFS.**
2. **New HPC in CWB.**
3. **Plan and on going development of CWBGFS.**
4. **The performance of current CWBGFS.**
5. **The equations and numerical scheme used in SLSI model.**
6. **The result of Solid body rotation test: Crosse north and south pole.**
7. **Example of primitive equation model.**
8. **PI chart of spectrum and SLSI model.**

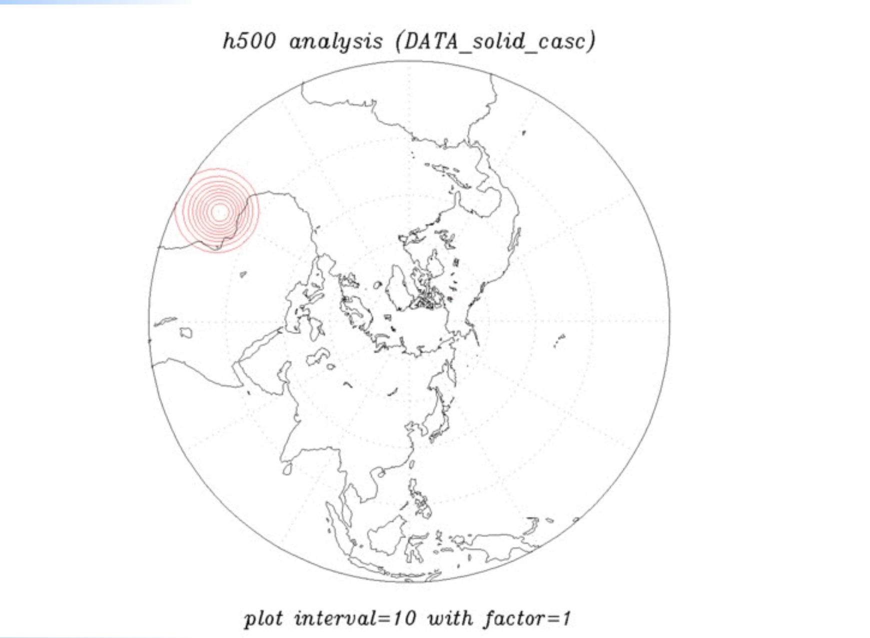
Brief description of numerical scheme in SLSI

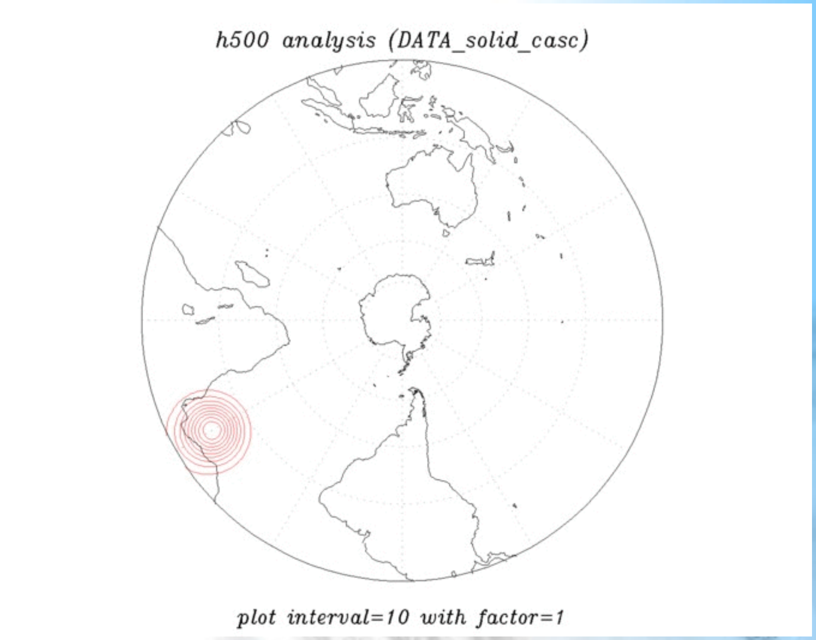
- Departure point(traditional iteration method)

$$\alpha^{(k+1)} = \Delta t V\left[x - \alpha^{(k)}, t\right]$$

Linear interpolation are used to find the trojectory

- Variables Interpolation : apply Cascade method(Purser and Leslie (1991)) on sphere with cubic interpolation scheme.





Welcome to see my poster

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Abstract

The current Taiwan Central Weather Bureau operational Global Forecast System (CWBGFS) is T319L40 spectral model in which the horizontal resolution is about 37 km and the vertical 40 layers in sigma coordinate. From 2012 to 2014, the Central Weather Bureau installs a new *Peta-Scale high performance computer*, the Fujistu PFX10. Based on this new high performance computer, the CWBGFS is going to increase the horizontal and vertical resolution from current T319L40 to T511L60. Moreover, the vertical coordinate will use sigma-pressure hybrid coordinate instead of sigma coordinate, and the model top layer will be raised from 1 hPa to 0.1 hPa.

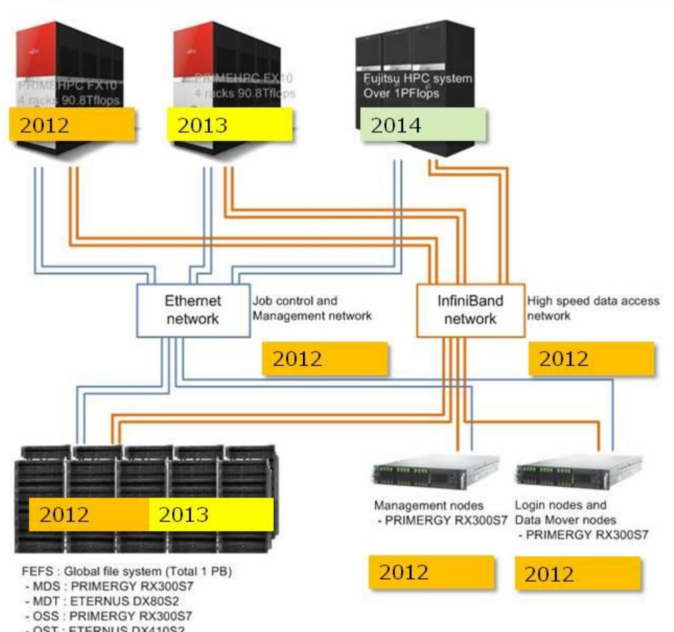
For the accommodation the computation of the increasing resolution, we are developing the *Semi-Lagrangian Semi-Implicit (SLSI) Scheme* in CWBGFS. The characteristics of this SLSI model are: (1) the virtual potential temperature is conserved in thermodynamic equation; (2) using the cascade method (Purser and Leslie, 1992) as the interpolation scheme in variables. The idealized test, the solid body rotation experiment, shows that the shape and amplitude of the mass field passing the North/South pole will be kept well.

Current Global Forecast System (GFS) of CWB

- **Data assimilation module: 3-D Var. GSI (Gridpoint Statistical Interpolation scheme)**
- **Model dynamic:**
  1. **T319L40 (42km，sigma，model top=1mb) (2011)**
  2. **T511L60 (25km，sigma-pressure hybrid，model top=0.1mb)**
- **Bogus typhoon (typhoon relocation)**
- **Physical Parameterization:**
  1. **Soil Param.**：Mahrt and Pan（1984）
  2. **Surface flux Param.**：Miyakoda and Sirutis (1986)
  3. **Mixed PBL Param.:** Troen and Mahrt (1986)
  4. **orographic Gravity wave drag Param.**：Palmer el al.（1986）
  5. **Cumulus Param.**：SAS (Pan and Wu（1995））
  6. **Shallow convection Param.**：Li（1994）、Li and Wang（2000）
  7. **Large scale precipitation Param.**：Zhao and Frederick(1997)
  8. **Radiation Param.**：Fu et al.（1997）and Fu an Liou（1992；1993）
  9. **Raylei-friction** on U,V in stratosphere

New HPC in CWB

2014 5th Generation of HPC system



PEAK: >1.3 PFlops Storage: 1.2 PByte	
Machine Name	PRIMEHPC FX10 / P-FX10
Cores	46,848
Peak Performance	>1.3 PF
Rmax	>1.1 PF
Storage size	1.221 PB
Power consumption	747.2 kW

Year/Month	2012/12	2013/9	2014/12
HPC System	FX-10	FX-10	FX-10/P-FX10
Tflops Rmax	81.2	162.4	
Storage Capacity (TB)	305.4	1,221.6	

Plan & On-Going Development of CWBGFS

1. **Data assimilation**
   1. Use more satellite data: AIRS, IASI (2014)
   2. Developing Global hybrid data assimilation system (2013~2015)
2. **Forecast model**
   1. Upgrade to T511L60 (25km, 2014)
   2. Improve Physical parameterization
      - Noah Land Surface model : (Ek et al. 2003)
      - NSAS: (Han and Pan, 2011)
      - RRTMG
      - Ozone Physics
      - Aerosol Physics
      - non-orographic gravity wave drag: (Scinocca, 2002)
   3. Developing Semi-Lagragian model TL1151L80 (16km, 2013~2016)
   4. Developing typhoon ensemble track prediction system (2013~2016)
   5. Develop global ensemble forecast system(2015~2020)
   6. Couple ocean with CWBGFS(2015~2020)
   7. Develop Non-hydrostatic model base on CWBGFS(2015~2020)

Performance of current operational CWBGFS

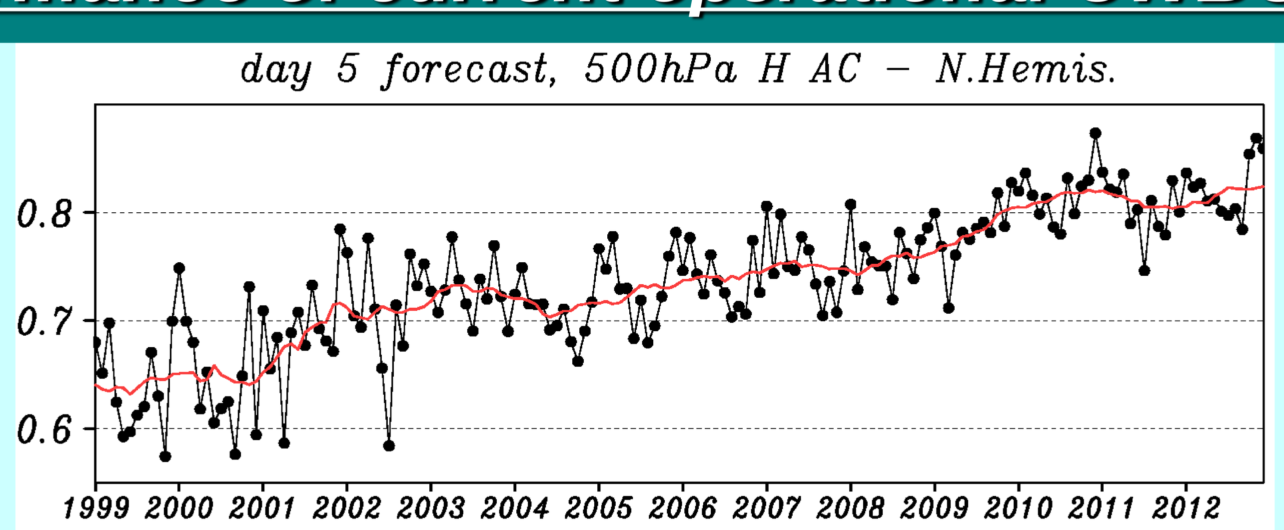


FIG 1. Anomaly Correction of 500hPa on day 5 forecast of operational CWBGFS in North Hemisphere from 1999 to 2013.

SLSI equations and interpolation scheme

Level	Variable
1/2	$p_{top}, \dot{\eta}_{1/2}$
1	
3/2	
2	
5/2	
k-1/2	$p_{k-1/2}, P_{k-1/2}, \dot{\eta}_{k-1/2}$
K	$U_k, V_k, D_k, \zeta_k, \theta_k, q_k, \phi_k$
k+1/2	$p_{k+1/2}, P_{k+1/2}, \dot{\eta}_{k+1/2}$
L-1/2	
L	
L+1/2	$p_s, P_s, \dot{\eta}_{L+1/2}$

- Finding the Departure point:
  $\alpha^{(k+1)} = \Delta t V\left[x - \alpha^{(k)}, t\right]$
  Linear interpolation are used to find the trojectory
- Variables Interpolation: apply Cascade method(Purser and Leslie (1991)) on sphere with cubic interpolation scheme.

Equations set of SLSI model

$$\frac{d\pi}{dt} = \sum_{k=1}^{L} \Delta B_k \left\{ \left(\frac{\partial \pi}{\partial t} + \vec{V}_k \nabla \pi \right) \right\} - \beta \sum_{k=1}^{L} \Delta \bar{p}_k \widehat{D_k}$$

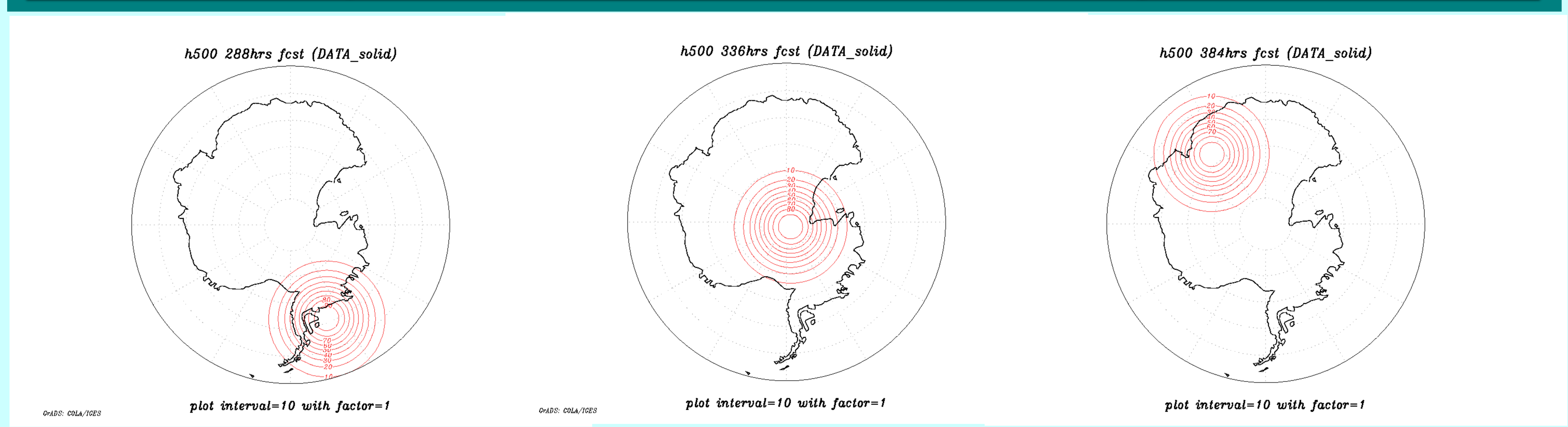
$$\frac{d\theta}{dt} = -\beta \sum_{l=1}^{L} g_{kl} \widehat{D_l}$$

$$\frac{dq}{dt} = 0$$

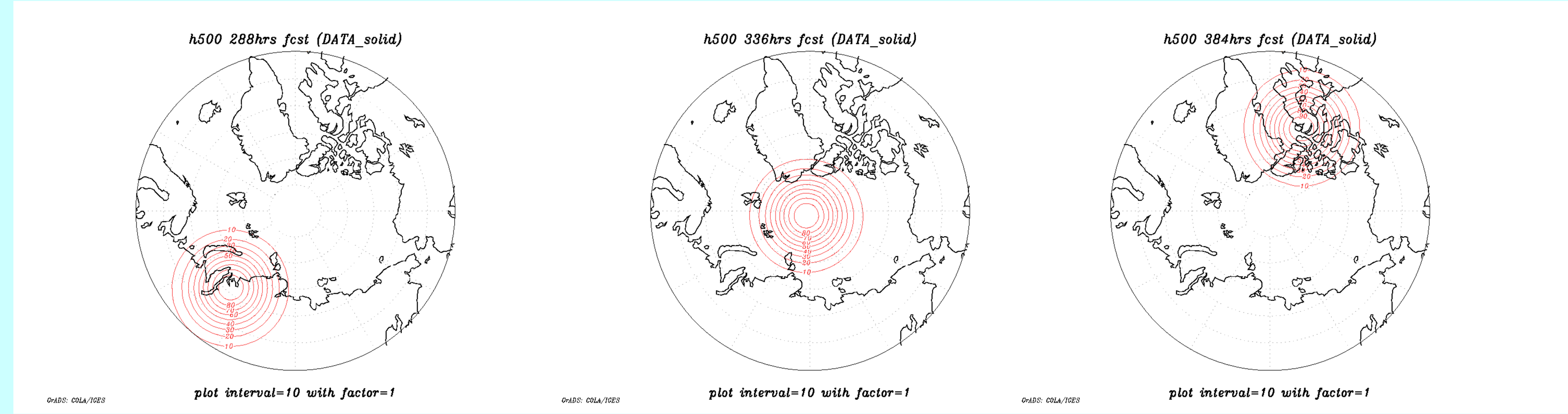
$$\frac{dU_k}{dt} = fV_k - \left(\frac{1}{a^2} \frac{\partial \phi_k}{\partial \lambda} + \frac{c_p}{a^2} \theta_k \frac{\partial P_k}{\partial \pi} \frac{\partial \pi}{\partial \lambda} \right) - \beta \frac{1}{a^2} \sum_{l=1}^{L} \sum_{j=1}^{L} a_{kl}^{-1} b_{lj} \frac{\partial \widehat{\theta_j}}{\partial \lambda} - \beta \frac{1}{a^2} \left(\sum_{l=1}^{L} a_{kl}^{-1} c_l + c_p \bar{\theta}_k \overline{\frac{\partial P_k}{\partial \pi}} \right) \frac{\partial \widehat{\pi}}{\partial \lambda}$$

$$\frac{dV_k}{dt} = -fU_k - \frac{\sin \varphi}{\cos^2 \varphi} (U_k^2 + V_k^2) - \frac{\cos^2 \varphi}{a^2} \left(\frac{\partial \phi_k}{\partial \mu} + c_p \theta_k \frac{\partial P_k}{\partial \pi} \frac{\partial \pi}{\partial \mu} \right) - \beta \frac{\cos^2 \varphi}{a^2} \sum_{l=1}^{L} \sum_{j=1}^{L} a_{kl}^{-1} b_{lj} \frac{\partial \widehat{\theta_j}}{\partial \mu} - \beta \frac{\cos^2 \varphi}{a^2} \left(\sum_{l=1}^{L} a_{kl}^{-1} c_l + c_p \bar{\theta}_k \overline{\frac{\partial P_k}{\partial \pi}} \right) \frac{\partial \widehat{\pi}}{\partial \mu}$$

Solid Body Rotation Test- Crossing South Pole



Solid Body Rotation Test- Crossing North Pole



Example of Semi-Lagrangian model TL768L60

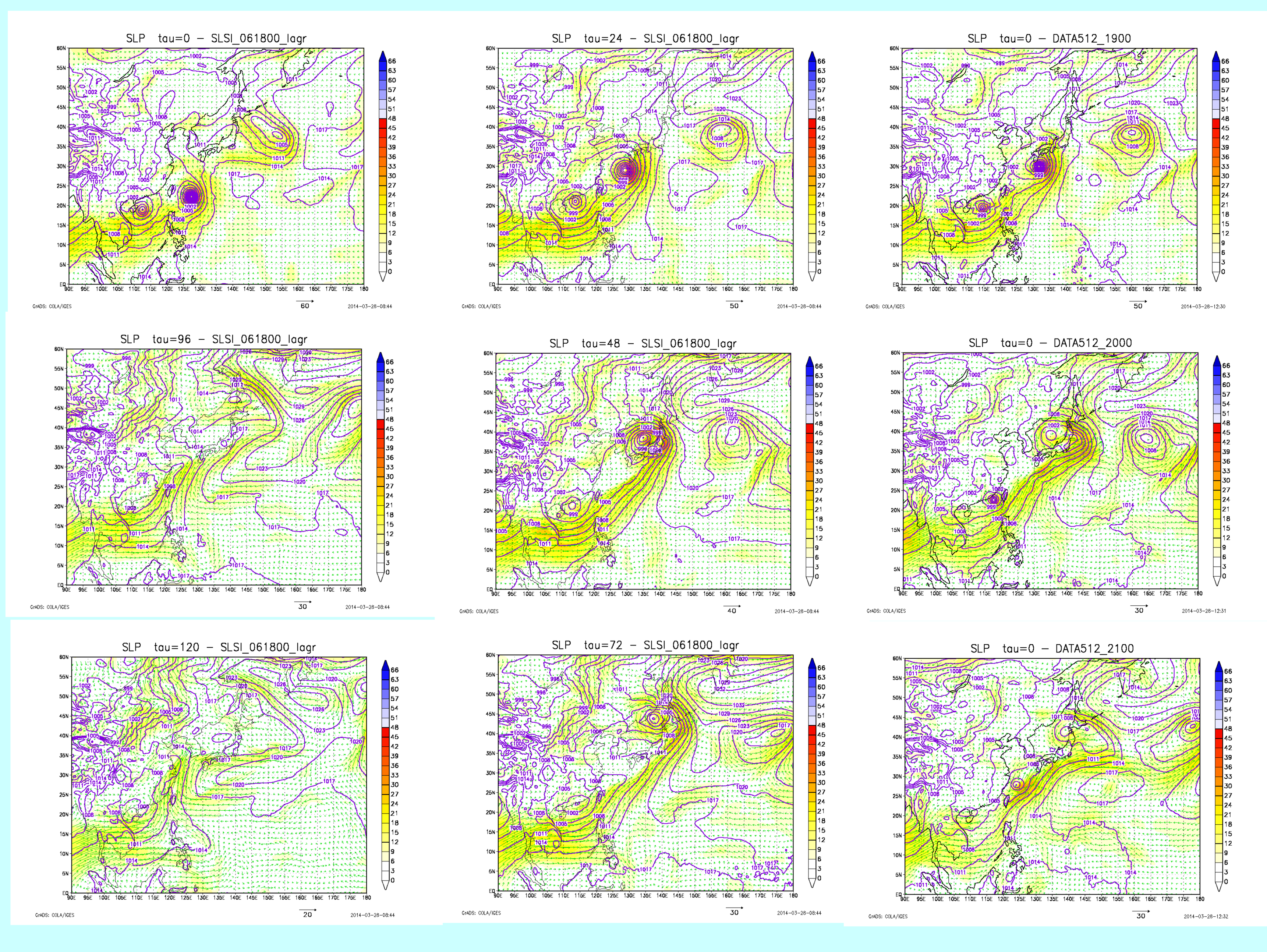


FIG 2. The example 5 day forecast of the sea level pressure with Semi-Langrangian Semi-Implicit model TL768L60. The initial time is 2012-06-18 00Z with 24 hour interval forecast output (left and middle penal). The right penal is the verification of 24, 48 and 72 hours forecast.

Pi Chart of spectrum & semi-Lagrangian model