

區域波譜模式(RSM)的 動力框架與改進— 應用高解析度地形資料及 非疊代分維半拉格朗日法(NDSL)



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2018.11.19 @ CWB



交通部中央氣象局
Central Weather Bureau

RSM: Regional Spectral Model (hydrostatic version)

MSM: Mesoscale Spectral Model (non-hydrostatic version)

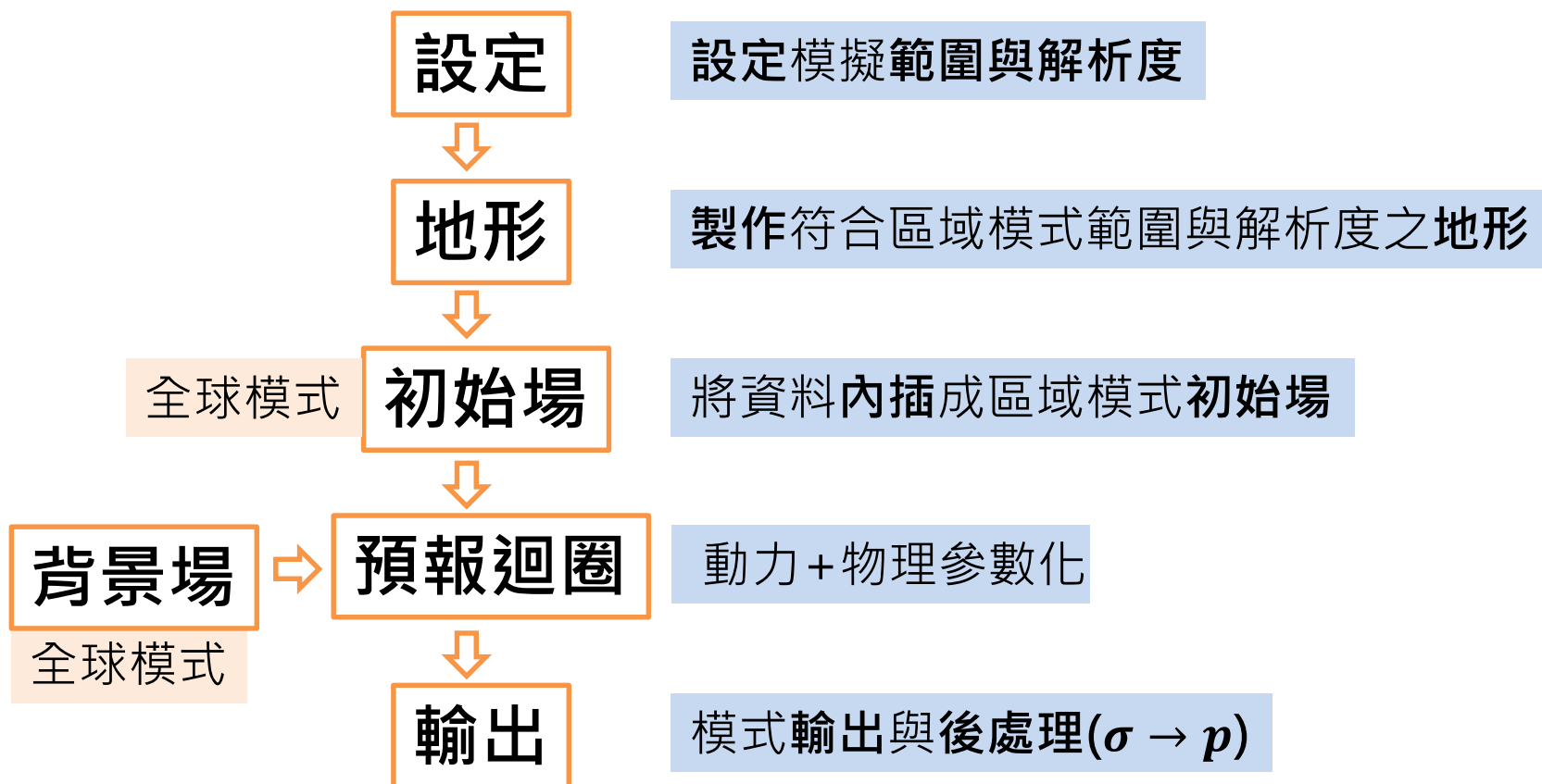
區域波譜模式(RSM/MSM)簡介

RSM/MSM

- Double Fourier Series
- Perturbation Method (perturbation filtering model)
 - satisfy zero boundary condition
 - better B.C. for semi-implicit scheme
 - keep large scale (over domain size) properties from global model
 - 4-th order horizontal diffusion
 - time filter
 - implicit lateral boundary relaxation

(Juang and Kanamitsu, 1994)

RSM/MSM架構



應用

高解析度地形資料

SRTM (SHUTTLE RADAR TOPOGRAPHY MISSION)

SRTM (Shuttle Radar Topography Mission)

- **SRTM 1 Arc-Second Global elevation data** offer worldwide coverage of void filled data at a resolution of **1 arc-second (30 meters)** and provide open distribution of this high-resolution global data set. Some tiles may still contain voids. Users should check the coverage map in EarthExplorer to verify if their area of interest is available. Please note that tiles above 50° north and below 50° south latitude are sampled at a resolution of 2 arc-second by 1 arc-second.
- source: <https://lta.cr.usgs.gov/SRTM1Arc>
- data accessible at: <https://earthexplorer.usgs.gov/>

USGS EarthExplorer

The screenshot shows the USGS EarthExplorer homepage. The browser address bar displays <https://earthexplorer.usgs.gov>. The page features the USGS logo and the tagline "science for a changing world". The main navigation bar includes links for Home, Search, Load Favorites, and Manage Criteria. A "login" button is prominently displayed in red. A "Page Expires In 1:58:11" notification is visible in the top right corner. Three orange callout boxes with numbers 1, 2, and 3 are overlaid on the page: callout 1 points to the "login" button, callout 2 points to the "Search" link, and callout 3 points to the "Load Favorites" link. The main content area is divided into two sections. The left section, titled "1. Enter Search Criteria", provides instructions for narrowing search areas and includes input fields for Address/Place, Coordinates, and Date Range. The right section, titled "Search Criteria Summary (Show)", displays a satellite map of North America with a search area highlighted. The map includes a coordinate display: (56° 59' 42" N, 041° 41' 18" W) and buttons for Options and Overlays.

link: <https://earthexplorer.usgs.gov/>

USGS EarthExplorer

2

Search Criteria Data Sets Additional Criteria Results

1. Enter Search Criteria

To narrow your search area: type in an address or place name, enter coordinates or click the map to define your search area (for advanced map tools, view the [help documentation](#)), and/or choose a date range.

Address/Place Path/Row Feature Circle

Show Clear

Coordinates Predefined Area Shapefile KML

Degree/Minute/Second Decimal

i No coordinates selected.

Use Map Add Coordinate Clear Coordinates

Date Range Result Options

Search from: mm/dd/yyyy to: mm/dd/yyyy

Search months: (all)

Data Sets » Additional Criteria » Results »

4

3

Search Criteria **Data Sets** Additional Criteria Results

2. Select Your Data Set(s)

Check the boxes for the data set(s) you want to search. When done selecting data set(s), click the *Additional Criteria* or *Results* buttons below. Click the plus sign next to the category name to show a list of data sets.

☐ Use Data Set Prefilter [\(What's This?\)](#)

Data Set Search:

Declassified Data

Digital Elevation

- ☐ ASTER GLOBAL DEM
- ☐ CoNED TBDEM
- ☐ EDNA
- ☐ GMTED2010
- ☐ GTOPO30
- ☐ GTOPO30 HYDRO 1K
- ☐ IFSAR Alaska

SRTM

- ☒ SRTM 1 Arc-Second Global
- ☐ SRTM Non-Void Filled
- ☐ SRTM Void Filled
- ☐ SRTM Water Body Data

Digital Line Graphs

Digital Maps

link: <https://earthexplorer.usgs.gov/>

USGS EarthExplorer

The screenshot displays the EarthExplorer - Home interface. On the left, the 'Search Results' section shows a single result for 'SRTM 1 Arc-Second Global'. The main map area shows a satellite view of a region including San Diego and San Bernardino. A 'Download Options' dialog box is open, listing three download choices: 'BIL 1 Arc-second (13.4 MB)', 'DTED 1 Arc-second (24.8 MB)', and 'GeoTIFF 1 Arc-second (24.8 MB)'. The bottom of the page contains links for 'DOI Privacy Policy', 'Legal', 'Accessibility', 'Site Map', and 'Contact USGS', as well as 'U.S. Department of the Interior', 'DOI Inspector General', 'White House', 'E-gov', 'No Fear Act', and 'FOIA'.

EarthExplorer - Home

Home Save Criteria Load Favorite Manage Criteria

Search Criteria Data Sets Additional Criteria Results

4. Search Results

If you selected more than one data set to search, use the dropdown to see the search results for each specific data set

Show Result Controls

Data Set Click here to export your results

SRTM 1 Arc-Second Global

Displaying 1 - 1 of 1

Entry ID: SRTM1N33W11V3
Publication Date: 23-SEP-14
Resolution: 1 Arc-Second
Coordinates: 33, -117

Download Options

- Download BIL 1 Arc-second (13.4 MB)
- Download DTED 1 Arc-second (24.8 MB)
- Download GeoTIFF 1 Arc-second (24.8 MB)

Band interleaved by line (BIL) is a binary raster format with an accompanying header file which describes the layout and formatting of the file.

link: <https://earthexplorer.usgs.gov/>

Data Format and How to Read

n33_w117_1arc_v3_bil.zip

1	BYTEORDER	I	
2	LAYOUT	BIL	
3	NROWS	3601	
4	NCOLS	3601	25,327 KB
5	NBANDS	1	
6	NBITS	16	1 KB
7	BANDROWBYTES	7202	
8	TOTALROWBYTES	7202	1 KB
9	PIXELTYPE	SIGNEDINT	1 KB
10	ULXMAP	-117	
11	ULYMAP	34	
12	XDIM	0.0002777777777777778	
13	YDIM	0.0002777777777777778	
14	NODATA	-32767	

$$1 \text{ arc. second} = 1'' = \left(\frac{1}{60 \times 60}\right)^0 = 0.0002777777777777778$$

Read file by Fortran:

```

1  integer*2, allocatable :: ifile(:, :)
2  allocate (ifile(3601,3601),stat=ierr)
3
4  open(21,file='n33_w117_1arc_v3_bil',form='unformatted' &
5  & ,access='direct',convert='LITTLE_ENDIAN',rec1=25934402)
6  read(21,rec=1) ((ifile(l,m),l=1,3601),m=1,3601)
7  close(21)
8
9  deallocate(ifile)

```

$$3601 \times 3601 \times 2 = 25934402$$

Implement into RSM/MSM

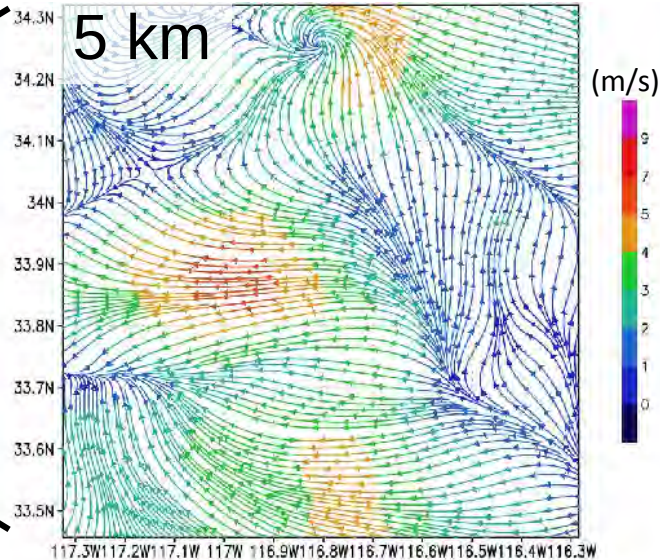
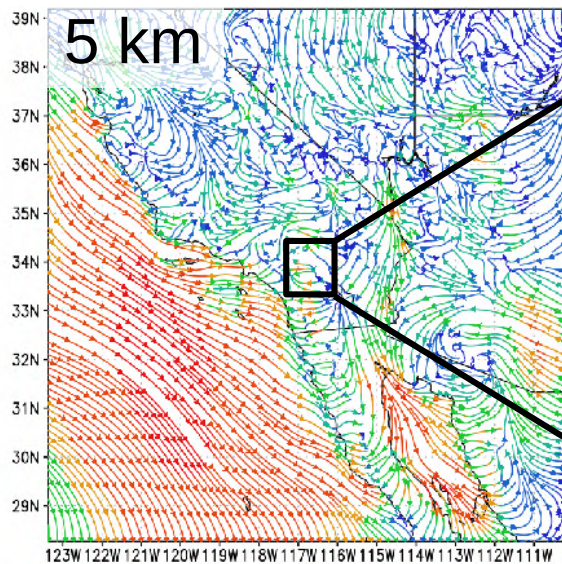
- **Case: Esperanza Fire**
- MSM setting:
 - Initial time:
2006 Oct. 25_12 UTC
 - Simulation time: 96 hours
(2006 Oct. 29_12 UTC)
 - Topo. data:
 - 5 km: 2 arc min.
 - 1 km: GTOPO30
(30 arc second ~ 1 km)
 - 1 km: SRTM1ARC
(1 arc second ~ 30 m)
 - 650 m: SRTM1ARC
(1 arc second ~ 30 m)



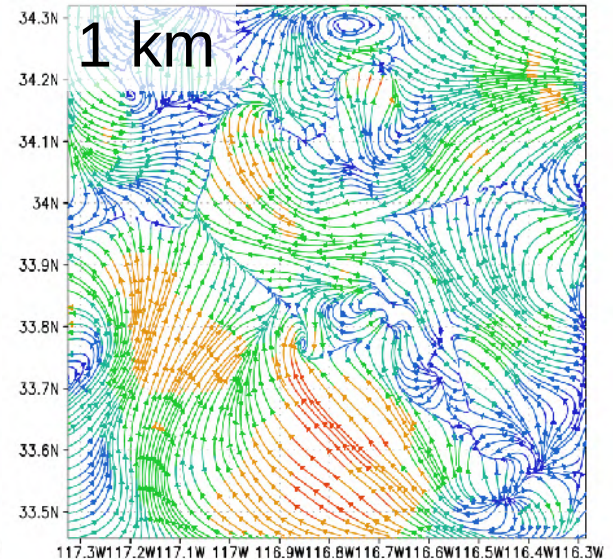
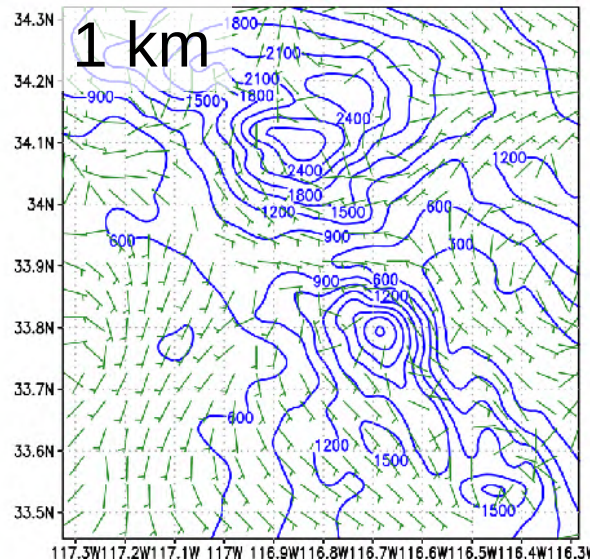
Credit: NASA image by Jeff Schmaltz, [MODIS Rapid Response Team](#), Goddard Space Flight Center.

10 m wind of +96 hr MSM simulation

(2006 Oct. 29_12 UTC)



Topo. data:
5km: 2 arc min.
1 km: GTOPO30

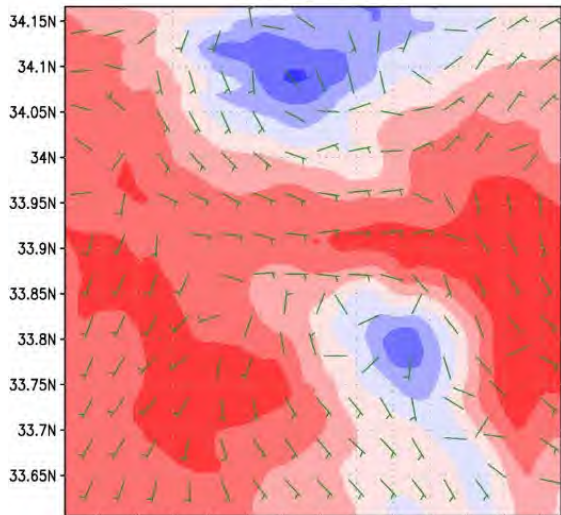


(Google, Maps, 2018)

10 m wind & 2 m T of +96 hr MSM simulation

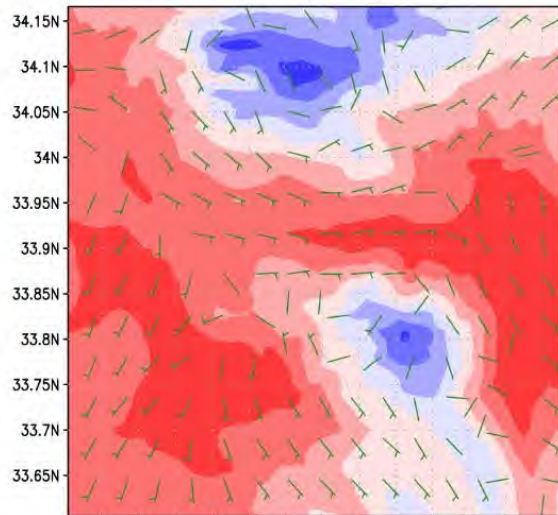
1km GTOPO30

wind10,T2 +96



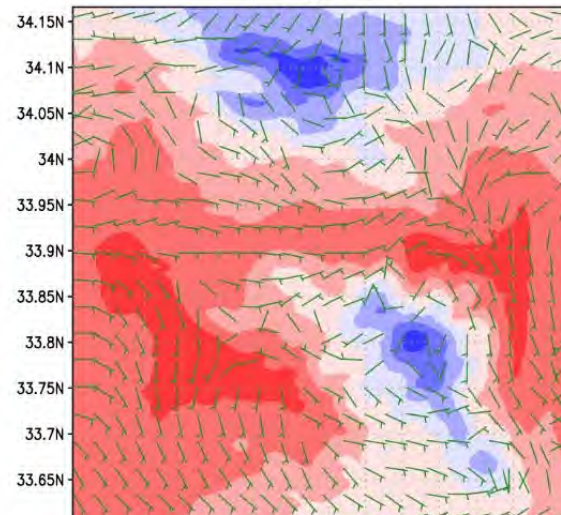
1km SRTM1ARC

wind10,T2 +96

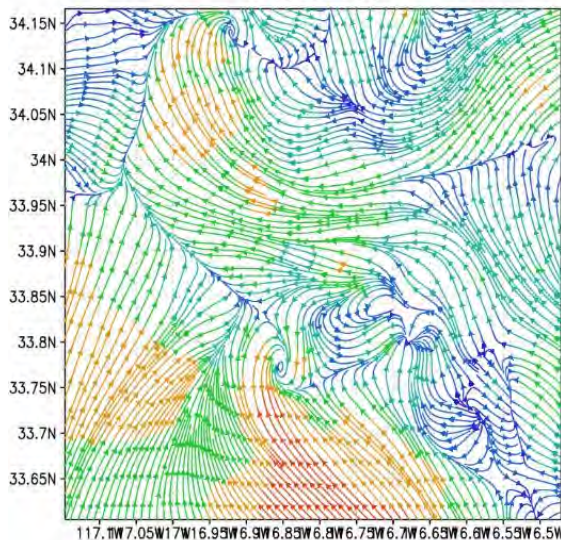


650m SRTM1ARC

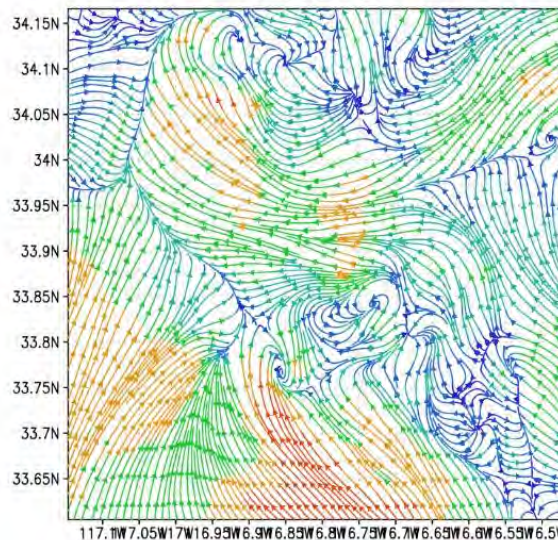
wind10,T2 +96



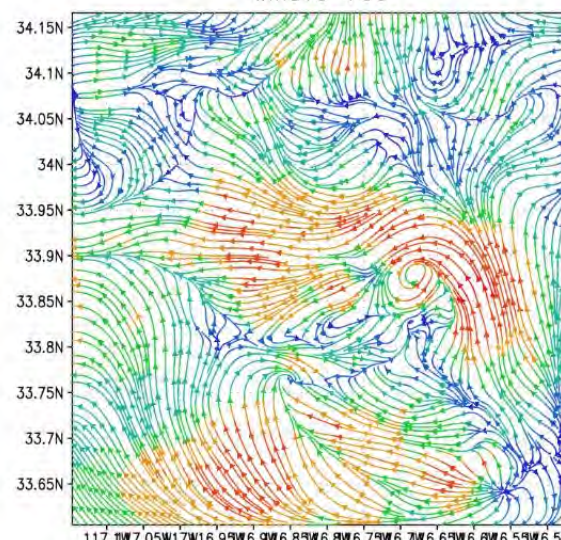
wind10 +96



wind10 +96



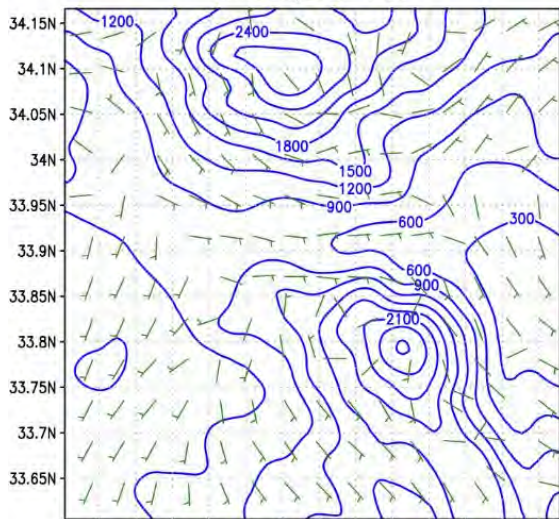
wind10 +96



10 m wind & sfc. height of +96 hr MSM simulation

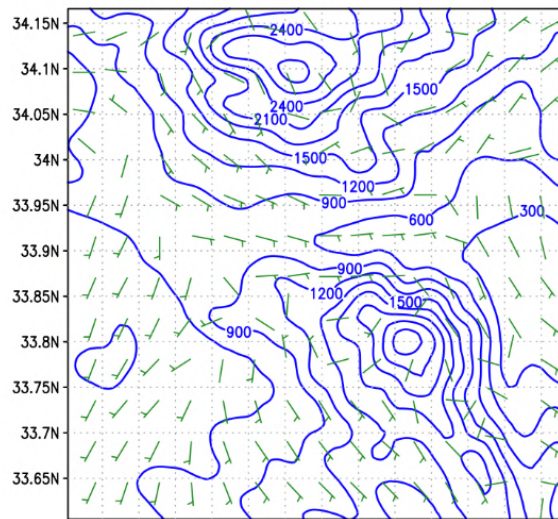
1km GTOPO30

wind10,Zsfc +96



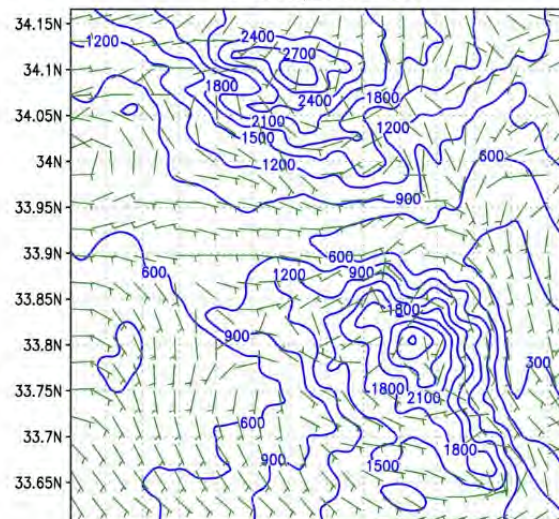
1km SRTM1ARC

wind10,Zsfc +96

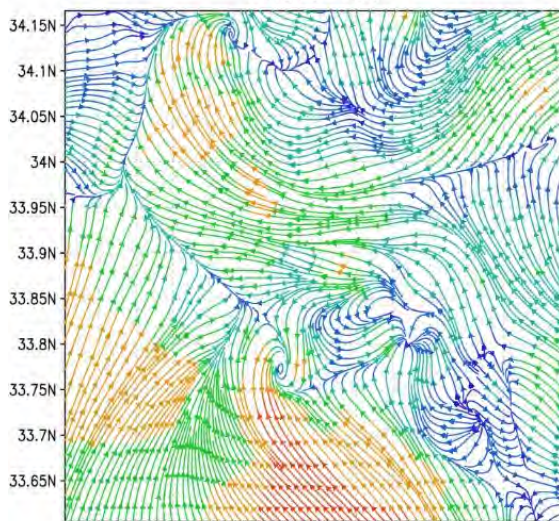


650m SRTM1ARC

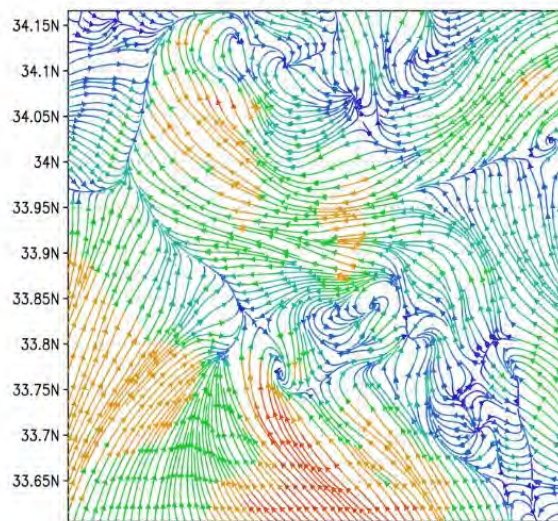
wind10,Zsfc +96



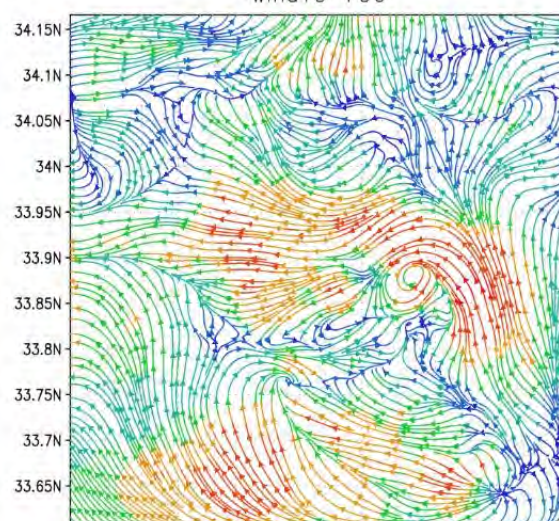
wind10 +96



wind10 +96



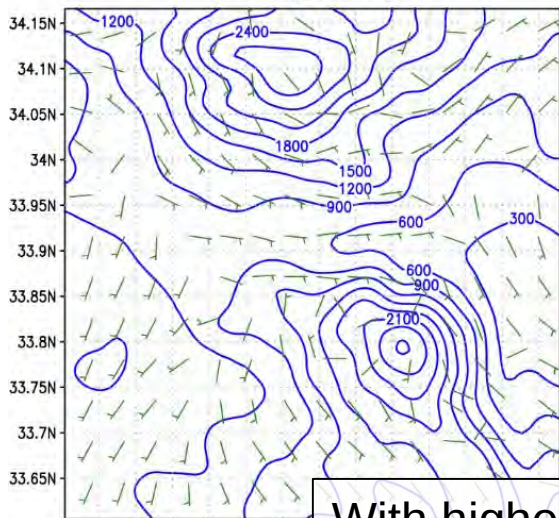
wind10 +96



10 m wind & sfc. height of +96 hr MSM simulation

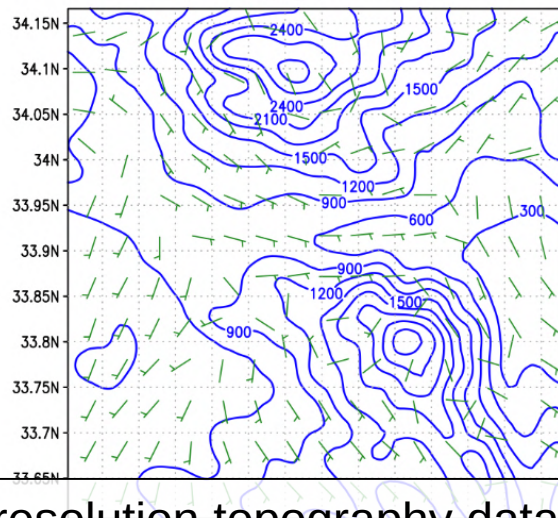
1km GTOPO30

wind10,Zsfc +96



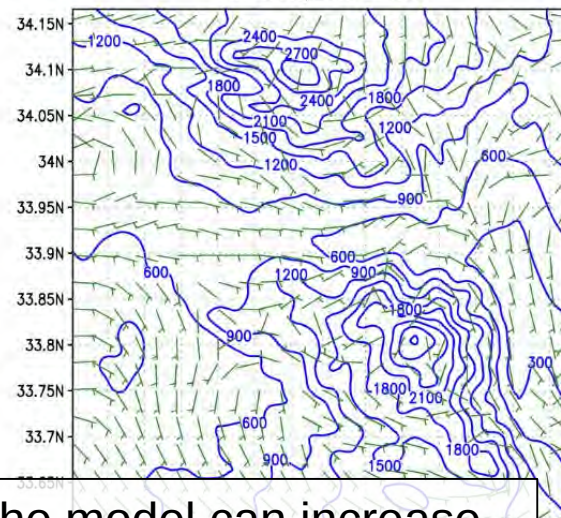
1km SRTM1ARC

wind10,Zsfc +96

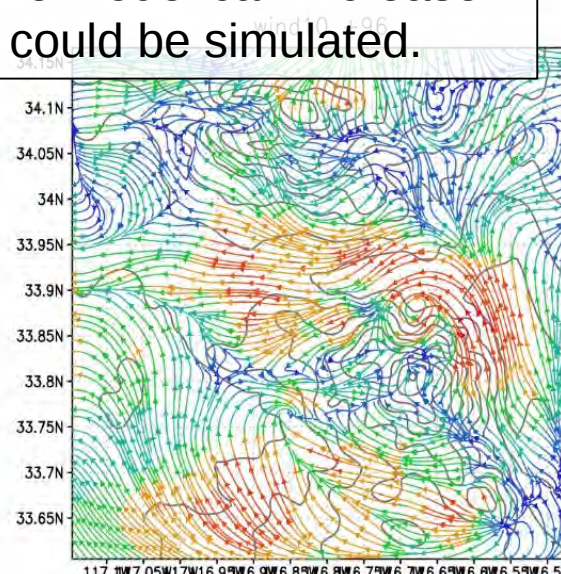
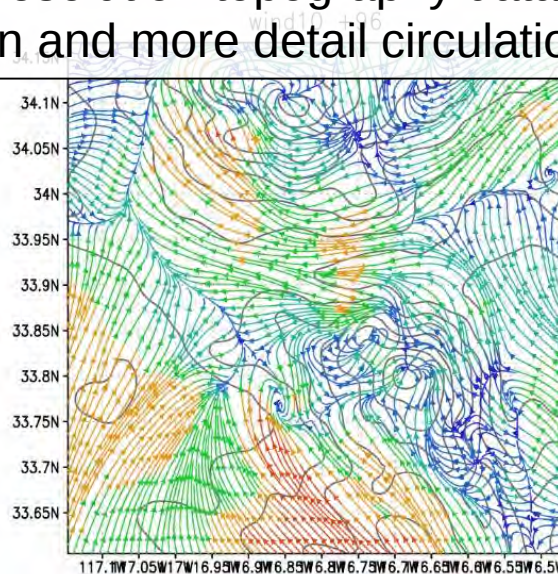
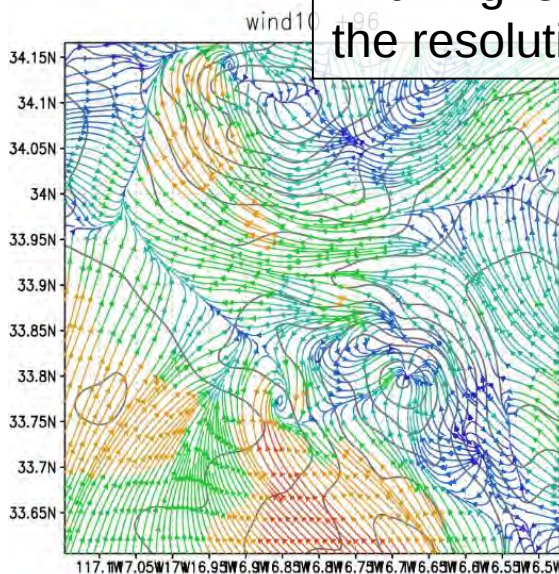


650m SRTM1ARC

wind10,Zsfc +96



With higher resolution topography data, the model can increase the resolution and more detail circulation could be simulated.



NDSL: Non-iteration Dimensional-splitting Semi-Lagrangian
應用於追蹤粒子(tracers)場

非疊代分維半拉格朗日法(NDSL)

RSM Governing Equations

perturbation tendency

(full field forcing) – (base field forcing)

$$\begin{aligned} \frac{\partial u^{*'}}{\partial t} = & -m^2 \left(u^* \frac{\partial u^*}{\partial x} + v^* \frac{\partial u^*}{\partial y} \right) - \dot{\sigma} \frac{\partial u^*}{\partial \sigma} \\ & - \frac{1}{2} (u^{*2} + v^{*2}) \frac{\partial m^2}{\partial x} + f v^* \\ & - \left(\frac{\partial \phi}{\partial x} + RT \frac{\partial Q}{\partial x} \right) + F_u - \frac{\partial u_g^*}{\partial t}, \quad (1.1) \end{aligned}$$

$$\begin{aligned} \frac{\partial v^{*'}}{\partial t} = & -m^2 \left(u^* \frac{\partial v^*}{\partial x} + v^* \frac{\partial v^*}{\partial y} \right) - \dot{\sigma} \frac{\partial v^*}{\partial \sigma} \\ & - \frac{1}{2} (u^{*2} + v^{*2}) \frac{\partial m^2}{\partial y} - f u^* \\ & - \left(\frac{\partial \phi}{\partial y} + RT \frac{\partial Q}{\partial y} \right) + F_v - \frac{\partial v_g^*}{\partial t}, \quad (1.2) \end{aligned}$$

$$\begin{aligned} \frac{\partial T'}{\partial t} = & -m^2 \left(u^* \frac{\partial T}{\partial x} + v^* \frac{\partial T}{\partial y} \right) - \sigma^* \dot{\sigma} \frac{\partial T \sigma^{-\kappa}}{\partial \sigma} \\ & + \kappa T \left[\frac{\partial Q}{\partial t} + m^2 \left(u^* \frac{\partial Q}{\partial x} + v^* \frac{\partial Q}{\partial y} \right) \right] \\ & + F_T - \frac{\partial T_g}{\partial t}, \quad (1.3) \end{aligned}$$

$$\begin{aligned} \frac{\partial Q'}{\partial t} = & - \int_0^1 m^2 \left(u^* \frac{\partial Q}{\partial x} + v^* \frac{\partial Q}{\partial y} \right) d\sigma \\ & - \int_0^1 m^2 \left(\frac{\partial u^*}{\partial x} + \frac{\partial v^*}{\partial y} \right) d\sigma - \frac{\partial Q_g}{\partial t}, \quad (1.4) \end{aligned}$$

$$\frac{\partial q'}{\partial t} = -m^2 \left(u^* \frac{\partial q}{\partial x} + v^* \frac{\partial q}{\partial y} \right) - \dot{\sigma} \frac{\partial q}{\partial \sigma} + F_q - \frac{\partial q_g}{\partial t}, \quad (1.5)$$

$$\frac{\partial \phi}{\partial \sigma} = - \frac{RT}{\sigma}, \quad (1.6)$$

$$\phi = g z_s + \mathbf{A} \mathbf{T}_j, \quad (1.7)$$

$$\begin{aligned} \frac{\partial \dot{\sigma}}{\partial \sigma} = & + \int_0^1 m^2 \left(u^* \frac{\partial Q}{\partial x} + v^* \frac{\partial Q}{\partial y} + \frac{\partial u^*}{\partial x} + \frac{\partial v^*}{\partial y} \right) d\sigma \\ & - m^2 \left(u^* \frac{\partial Q}{\partial x} + v^* \frac{\partial Q}{\partial y} + \frac{\partial u^*}{\partial x} + \frac{\partial v^*}{\partial y} \right), \quad (1.8) \end{aligned}$$

m: map factor

$$u^* = u/m$$

$$v^* = v/m$$

$$Q = \ln(p_s)$$

(Juang and Kanamitsu, 1994)

MSM Governing Equations



perturbation tendency



(full field forcing) – (base field forcing)

$$\begin{aligned} \frac{\partial u^{*'}}{\partial t} = & -m^2 u^* \frac{\partial u^*}{\partial x} - m^2 v^* \frac{\partial u^*}{\partial y} - \dot{\sigma} \frac{\partial u^*}{\partial \sigma} - E \frac{\partial m^2}{\partial x} + f v^* - R(\bar{T} + T') \frac{\partial \bar{Q}_s + Q'}{\partial x} \\ & - \left(1 + \frac{T'}{\bar{T}}\right) \left(1 + \frac{\partial Q'}{\partial \ln \sigma}\right) \frac{\partial \bar{\phi}}{\partial x} + F_{u^*} - \frac{\partial u_b^*}{\partial t}, \end{aligned} \quad (3.9)$$

$$\begin{aligned} \frac{\partial v^{*'}}{\partial t} = & -m^2 u^* \frac{\partial v^*}{\partial x} - m^2 v^* \frac{\partial v^*}{\partial y} - \dot{\sigma} \frac{\partial v^*}{\partial \sigma} - E \frac{\partial m^2}{\partial y} - f u^* - R(\bar{T} + T') \frac{\partial \bar{Q}_s + Q'}{\partial y} \\ & - \left(1 + \frac{T'}{\bar{T}}\right) \left(1 + \frac{\partial Q'}{\partial \ln \sigma}\right) \frac{\partial \bar{\phi}}{\partial y} + F_{v^*} - \frac{\partial v_b^*}{\partial t}, \end{aligned} \quad (3.10)$$

$$\frac{\partial w'}{\partial t} = -m^2 u^* \frac{\partial w}{\partial x} - m^2 v^* \frac{\partial w}{\partial y} - \dot{\sigma} \frac{\partial w}{\partial \sigma} - g \left[1 - \left(1 + \frac{T'}{\bar{T}}\right) \left(1 + \frac{\partial Q'}{\partial \ln \sigma}\right) \right] + F_w - \frac{\partial w_b}{\partial t}, \quad (3.11)$$

$$\epsilon_Q \left[\frac{\partial \bar{Q}_s'}{\partial t} \right] = -m^2 \int_0^1 \left[u^* \frac{\partial \bar{Q}_s}{\partial x} + v^* \frac{\partial \bar{Q}_s}{\partial y} + \left(\frac{\partial u^*}{\partial x} + \frac{\partial v^*}{\partial y} \right) \right] d\sigma - \frac{\partial \bar{Q}_{sb}}{\partial t}, \quad (3.12)$$

$$\epsilon_T \left[\frac{\partial \bar{T}'}{\partial t} \right] = -m^2 u^* \frac{\partial \bar{T}}{\partial x} - m^2 v^* \frac{\partial \bar{T}}{\partial y} - \dot{\sigma} \sigma^\kappa \frac{\partial \bar{T} \sigma^{-\kappa}}{\partial \sigma} + \kappa \bar{T} \left(\frac{\partial \bar{Q}_s}{\partial t} + m^2 u^* \frac{\partial \bar{Q}_s}{\partial x} + m^2 v^* \frac{\partial \bar{Q}_s}{\partial y} \right) + F_{\bar{T}} - \frac{\partial \bar{T}_b}{\partial t}, \quad (3.13)$$

$$\frac{\partial Q'}{\partial t} = -m^2 u^* \frac{\partial \bar{Q}_s + Q'}{\partial x} - m^2 v^* \frac{\partial \bar{Q}_s + Q'}{\partial y} - \dot{\sigma} \frac{\partial Q'}{\partial \sigma} - \frac{\dot{\sigma}}{\sigma} - \gamma \nabla_3 \cdot \mathbf{V}^* + \gamma \frac{F_T}{T} - \frac{\partial \bar{Q}_s}{\partial t}, \quad (3.14)$$

$$\begin{aligned} \frac{\partial T'}{\partial t} = & -m^2 u^* \frac{\partial \bar{T} + T'}{\partial x} - m^2 v^* \frac{\partial \bar{T} + T'}{\partial y} - \dot{\sigma} \sigma^\kappa \frac{\partial (\bar{T} + T') \sigma^{-\kappa}}{\partial \sigma} \\ & + \kappa (\bar{T} + T') \left[\frac{\partial (\bar{Q}_s + Q')}{\partial t} + m^2 u^* \frac{\partial \bar{Q}_s + Q'}{\partial x} + m^2 v^* \frac{\partial \bar{Q}_s + Q'}{\partial y} + \dot{\sigma} \frac{\partial Q'}{\partial \sigma} \right] + F_T - \frac{\partial \bar{T}}{\partial t}, \text{ and} \end{aligned} \quad (3.15)$$

$$\frac{\partial q'}{\partial t} = -m^2 u^* \frac{\partial q}{\partial x} - m^2 v^* \frac{\partial q}{\partial y} - \dot{\sigma} \frac{\partial q}{\partial \sigma} + F_q - \frac{\partial q_b}{\partial t}, \quad (3.16) \quad (\text{Juang, 2000})$$

Equation for Tracers

perturbation tendency

full field forcing

– base field forcing

$$\frac{\partial q'}{\partial t} = \underbrace{-m^2 u^* \frac{\partial q}{\partial x} - m^2 v^* \frac{\partial q}{\partial y} - \dot{\sigma} \frac{\partial q}{\partial \sigma}}_{\text{dynamic}} + \underbrace{F_q}_{\text{physics}} - \underbrace{\frac{\partial q_b}{\partial t}}_{\text{known}}$$

spectrum

NDSL

Non-iteration Dimensional-splitting
Semi-Lagrangian

NDSL: Non-iteration Dimensional-splitting Semi-Lagrangian

use 1-D equation for example:
Consider mass conservation,

$$\frac{\partial \rho}{\partial t} + u \frac{\partial \rho}{\partial x} + \rho \frac{\partial u}{\partial x} = 0$$

where ρ is scalar and u is wind. Write the last term $\frac{\partial u}{\partial x}$ as

$$\frac{\partial u}{\partial x} = \frac{1}{\Delta_x} \left(\frac{d\Delta_x}{dt} \right)$$

then the first equation becomes

$$\frac{d\rho\Delta_x}{dt} = 0$$

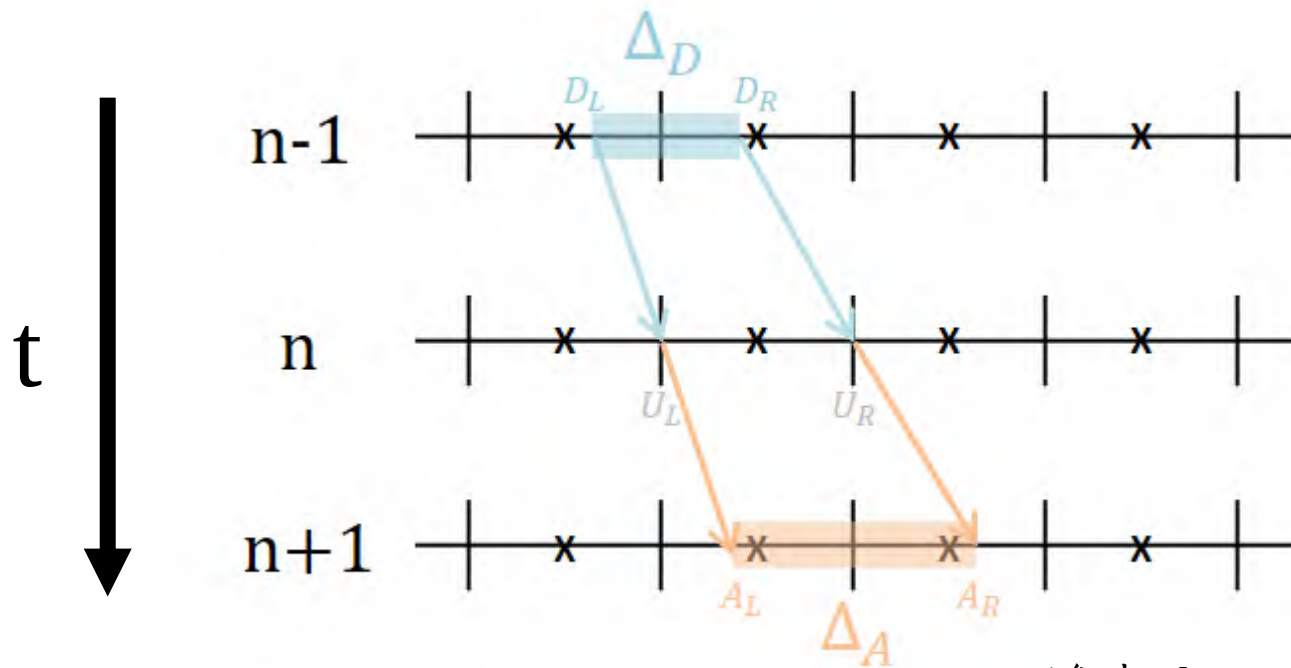
that is

$$(\rho\Delta_x)_D^{n-1} = (\rho\Delta_x)_A^{n+1}$$

(Juang, 2007, 2008)

(Zhang and Juang, 2012)

一維質量保守NDSL示意圖

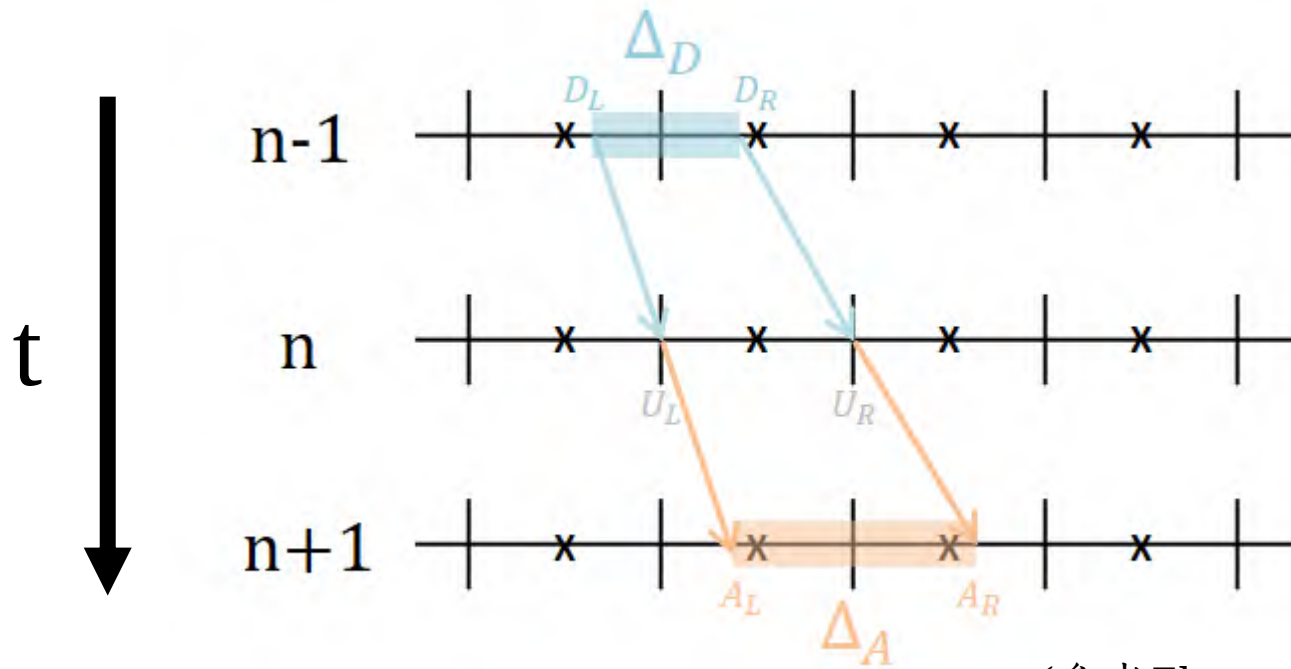


(參考Zhang and Juang, 2012 圖2)

一維NDSL質量保守平流的計算細節為

1. 計算網格邊界的風場。
2. 計算出發點(n-1)與抵達點(n+1)的位置和網格大小。
3. 以PLM將密度由模式網格點內插(interpolation)到n-1時的出發點座標。
4. 透過 $(\rho \Delta_x)_D^{n-1} = (\rho \Delta_x)_A^{n+1}$ ，將質量由出發點(n-1)座標移至抵達點(n+1)座標。
5. 將密度以PLM由抵達點(n+1)座標再映射(remap)回模式網格點上。

一維質量保守NDSL示意圖



(參考Zhang and Juang, 2012 圖2)



格點值內插得 q_D^{n-1}
(interpolation)

q_A^{n+1} 再映射回格點上
(remap)

Dimensional Splitting

- For 2D:

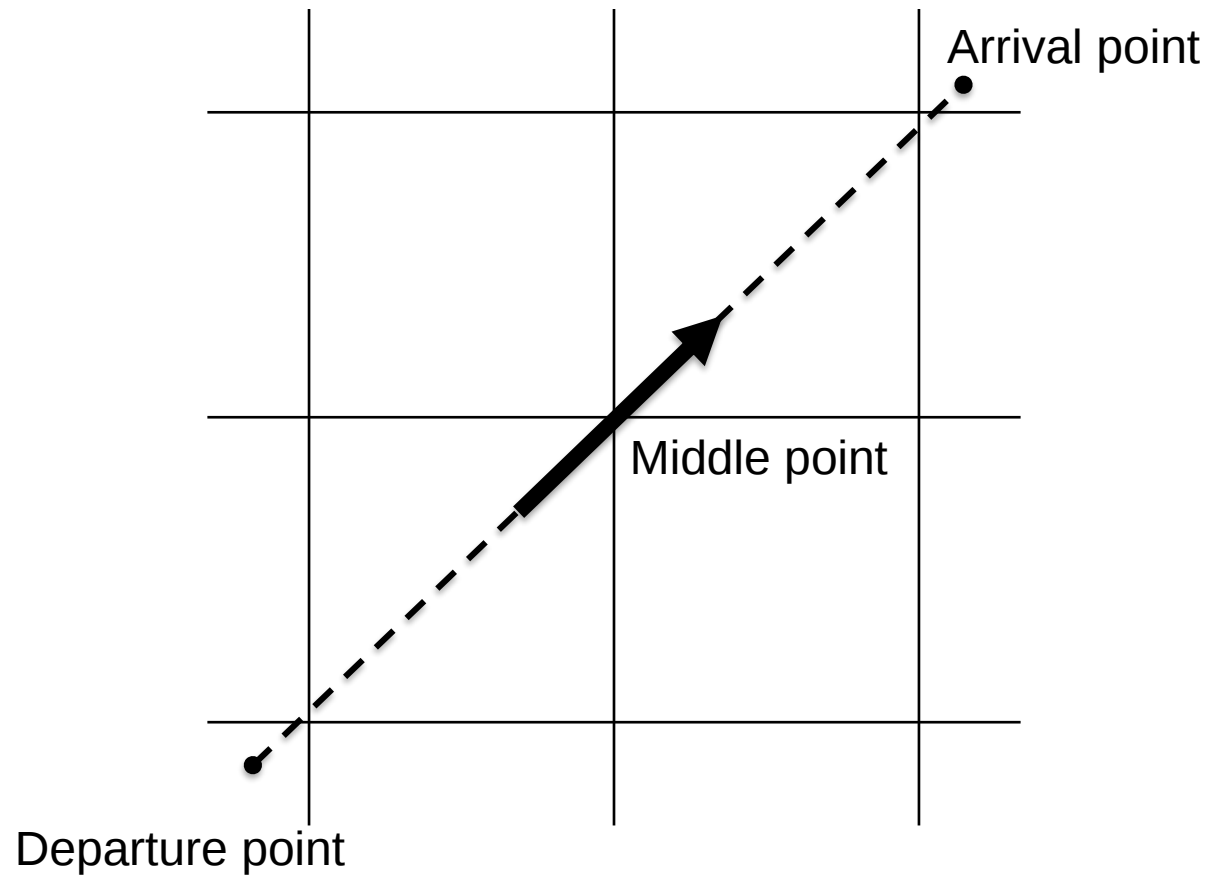
$$\frac{\partial q}{\partial t} + u \frac{\partial q}{\partial x} + v \frac{\partial q}{\partial y} = 0$$


➤ *dimensional splitting into x direction and y direction*

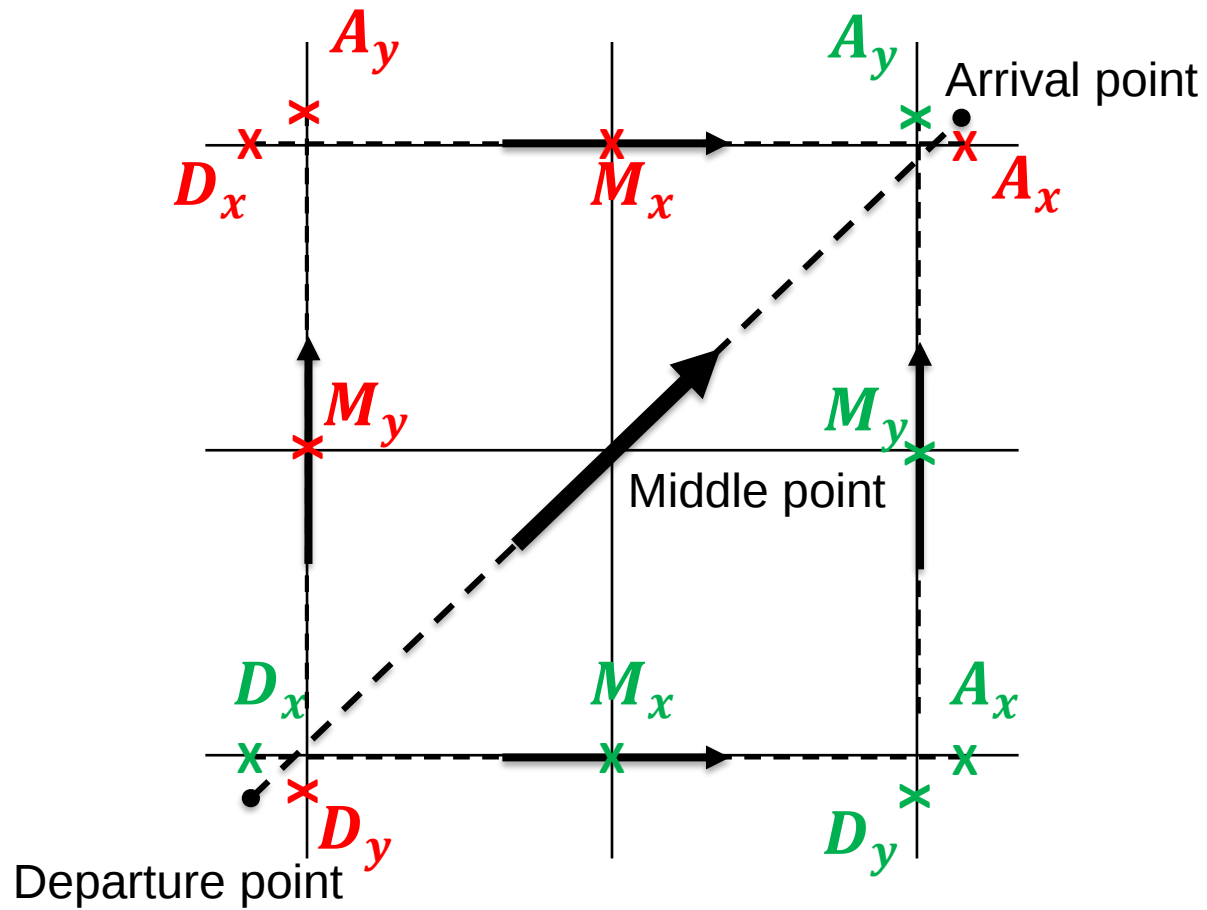
$$\left(\left(\frac{\partial q}{\partial t} \right)_{x\text{direction}} + u \frac{\partial q}{\partial x} \right) + \left(\left(\frac{\partial q}{\partial t} \right)_{y\text{direction}} + v \frac{\partial q}{\partial y} \right) = 0$$

(Zhang and Juang, 2012)

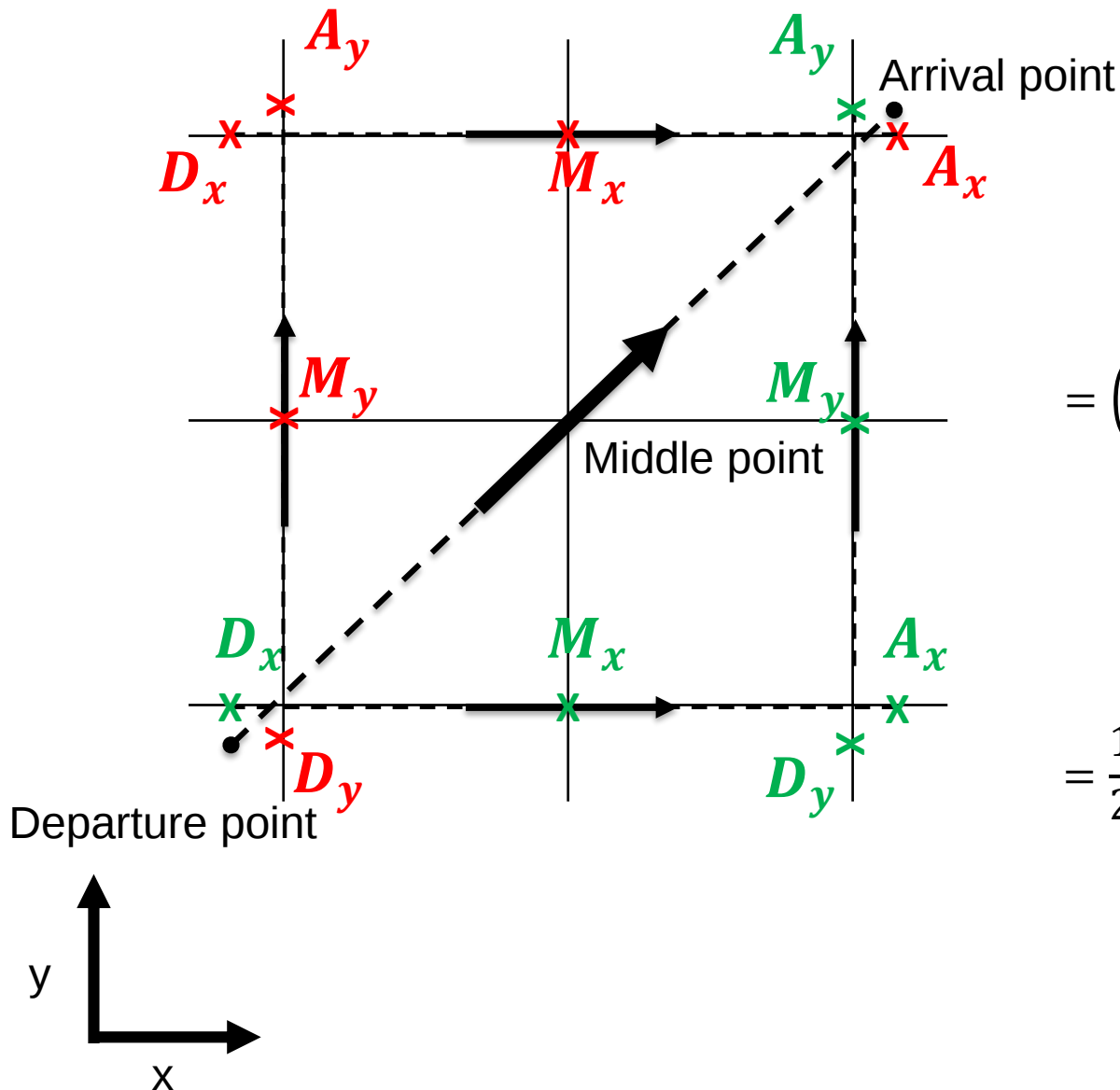
2D NDSL



2D NDSL



2D NDSL



$$\left(\frac{\partial q}{\partial t}\right)_{adv} = \left(\frac{q^{n+1} - q^{n-1}}{2\Delta t}\right)_{adv}$$

$$= \left(\frac{q^{n+1} - q^{n+1*}}{2\Delta t} + \frac{q^{n+1*} - q^{n-1}}{2\Delta t}\right)_{adv}$$

Y X

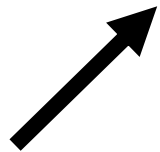
X Y

$$= \frac{1}{2} [X(Y(q)) + Y(X(q))]$$

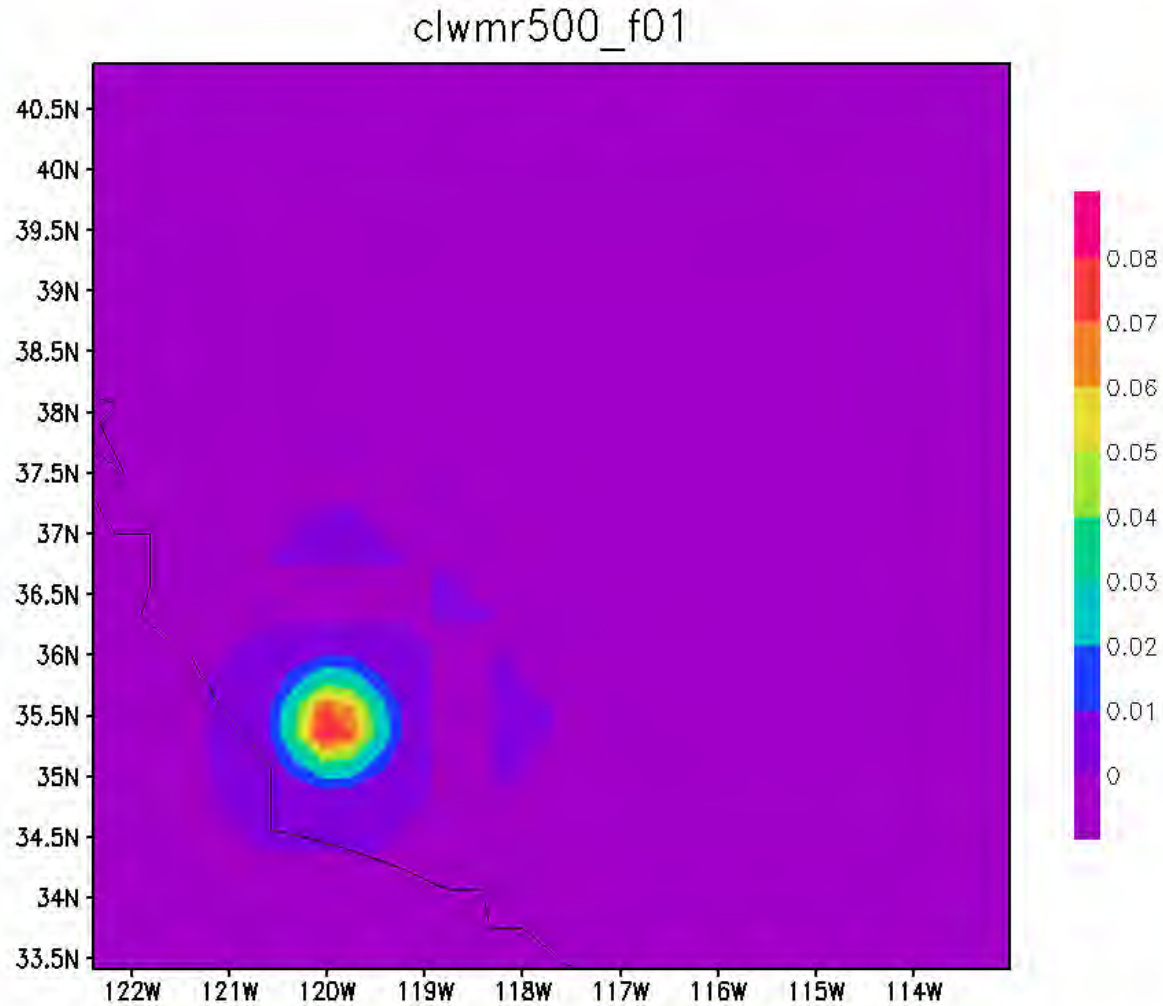
理想個案測試

domain size: 32x32

$\Delta t = 60\text{ s}$



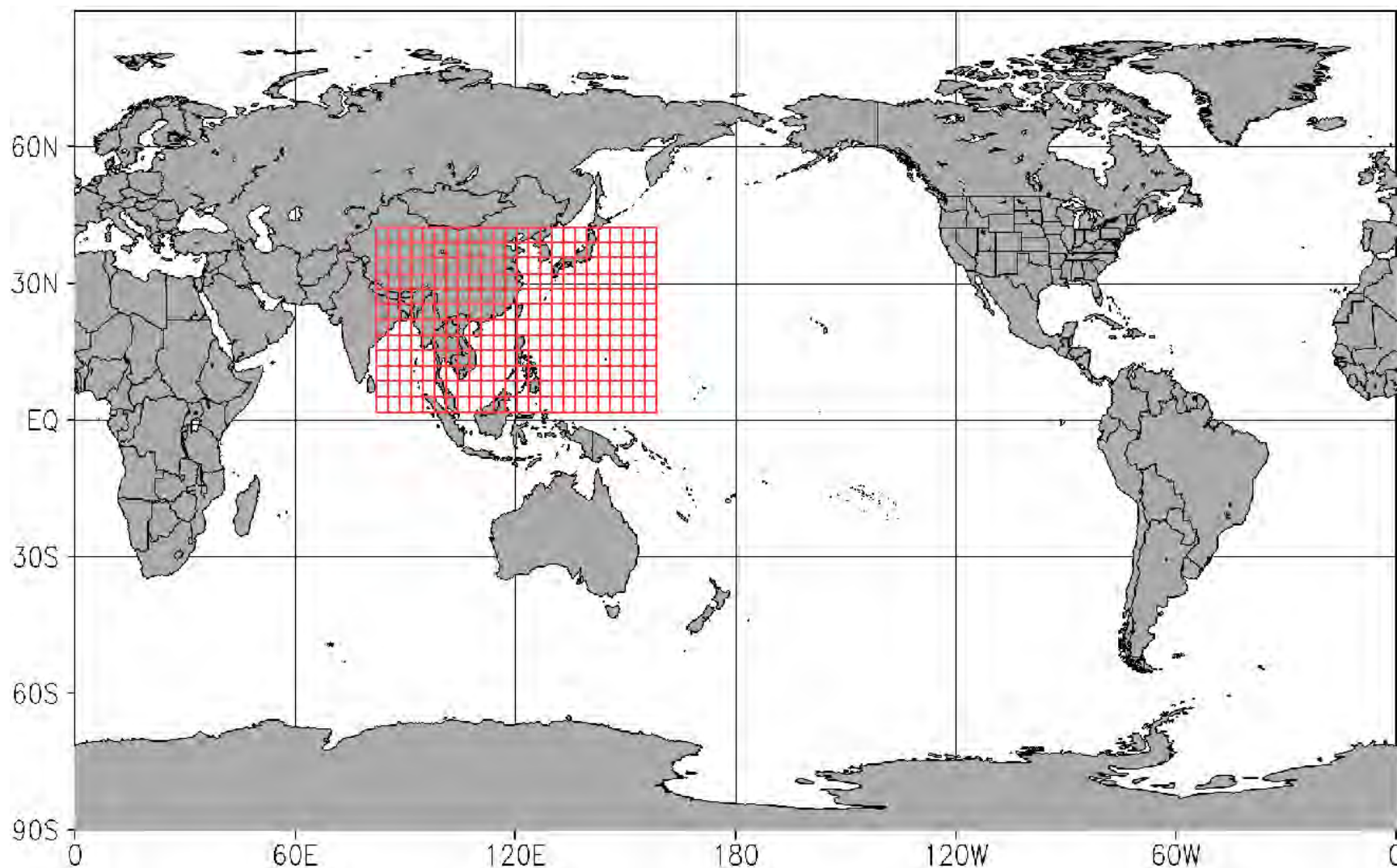
$u = v = 5\text{ m s}^{-1}$



NDSL 實際個案測試

- 個案：泰利颱風(2017年)
- 初始場: 2017/09/11 00 UTC
- 預報時間：5天
- 模式設定：
 - CWBGFS T511 + RSM(靜力) 12 公里

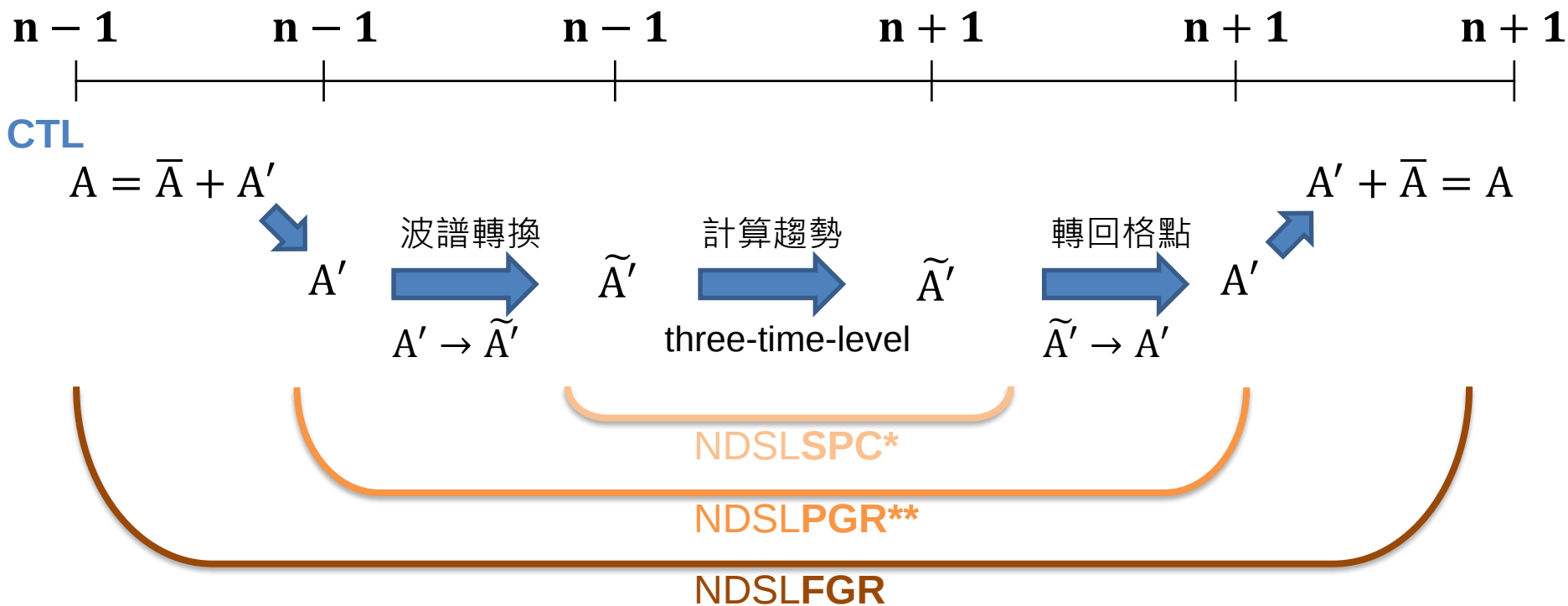
RSM模擬範圍



NDSL 實際個案測試

- 測試四組模擬:
 - CTL: original RSM
 - NDSL**SPC**: NDSL with spectrum transform
 - NDSL**PGR**: NDSL with perturbation relaxation and time filter
 - NDSL**FGR**: NDSL with full grid relaxation and time filter

RSM計算流程(CTL)與三組NDSL改法示意圖



*NDSLSPC: 由波譜轉回格點，加上背景場後，執行NDSL。

**NDSLPGR: 由擾動場加上背景場後進行NDSL。

RSM/MSM

- Double Fourier Series
- Perturbation Method (perturbation filtering model)
 - satisfy zero boundary condition
 - better B.C. for semi-implicit scheme
 - keep large scale (over domain size) properties from global model
 - 4-th order **horizontal diffusion**
 - **time filter**
 - implicit lateral boundary **relaxation**

控制組CTL與三組NDSL改法的計算細節

	spectrum truncation	advection term	relaxation	horizontal diffusion	time filter
CTL	O	spectrum	perturbation	O	perturbation
NDSL SPC	O	NDSL	perturbation	O	perturbation
NDSL PGR	X	NDSL	perturbation	X	perturbation
NDSL FGR	X	NDSL	full field	X	full field

O表示有執行，X表示沒執行。

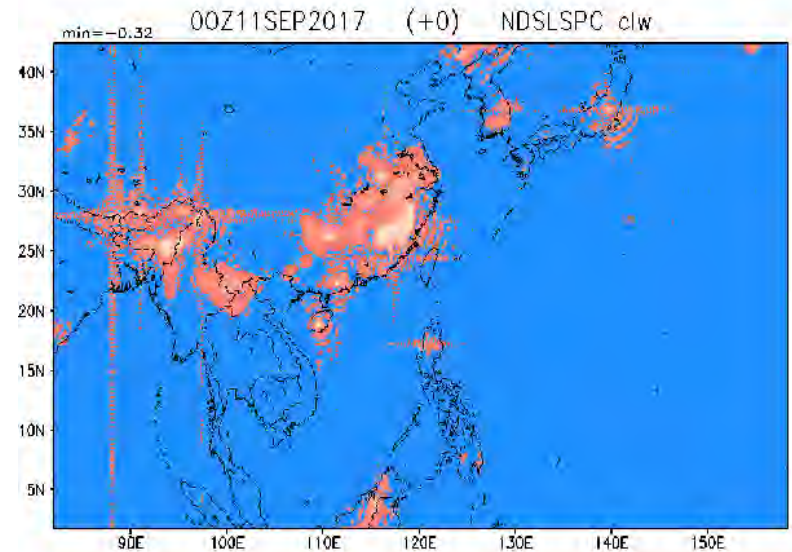
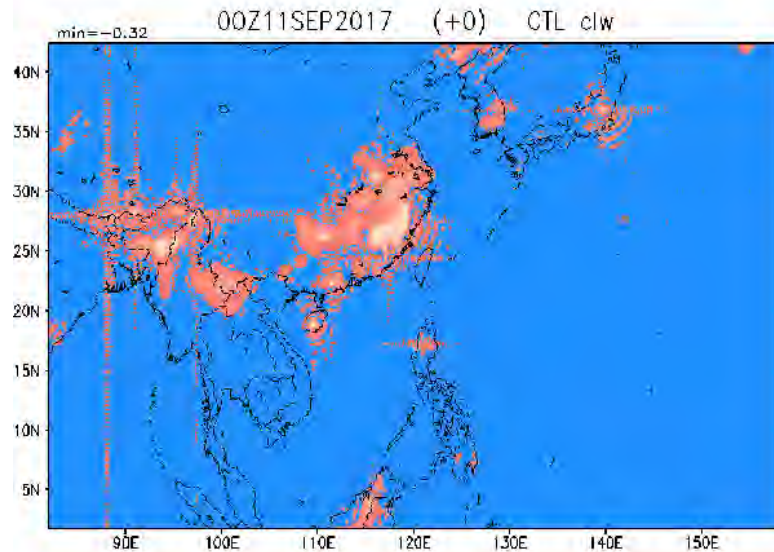
CTL

NDSLSPC

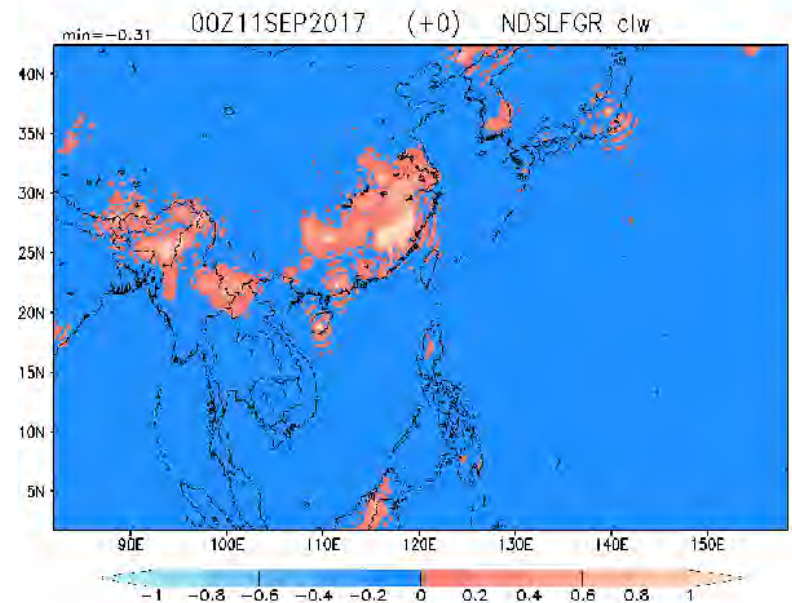
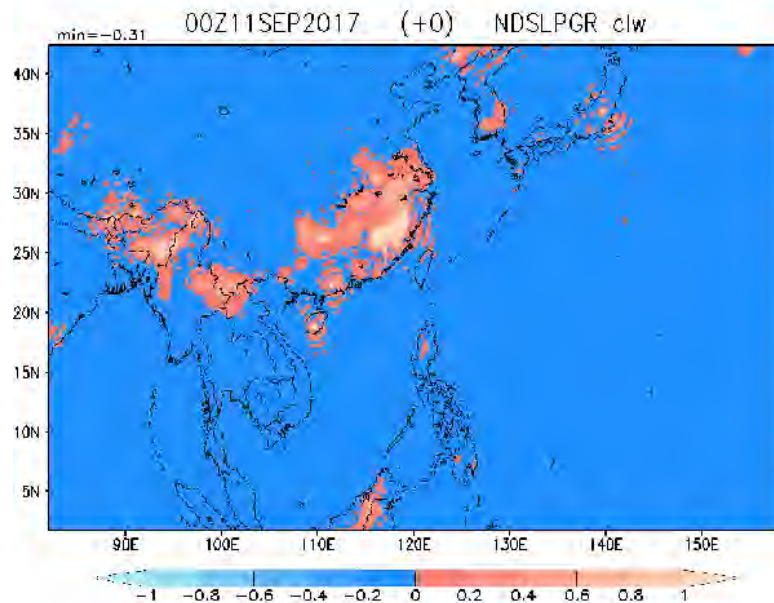
NDSLPGR

NDSLFGR

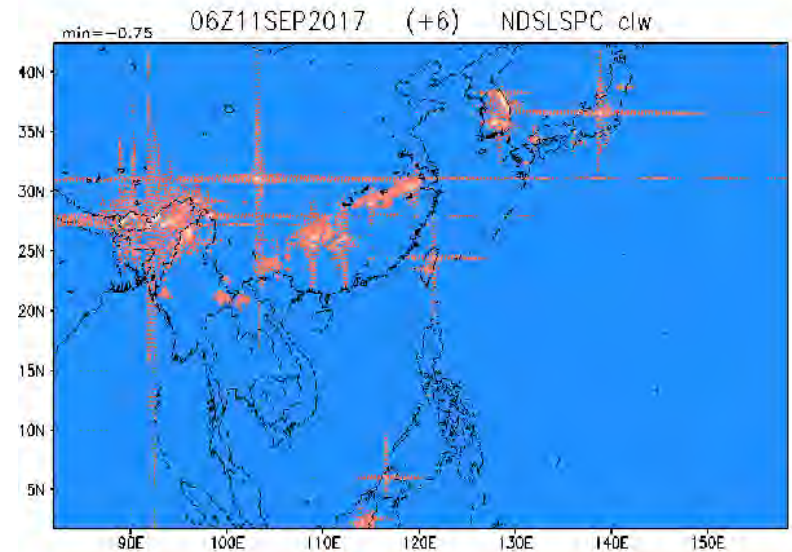
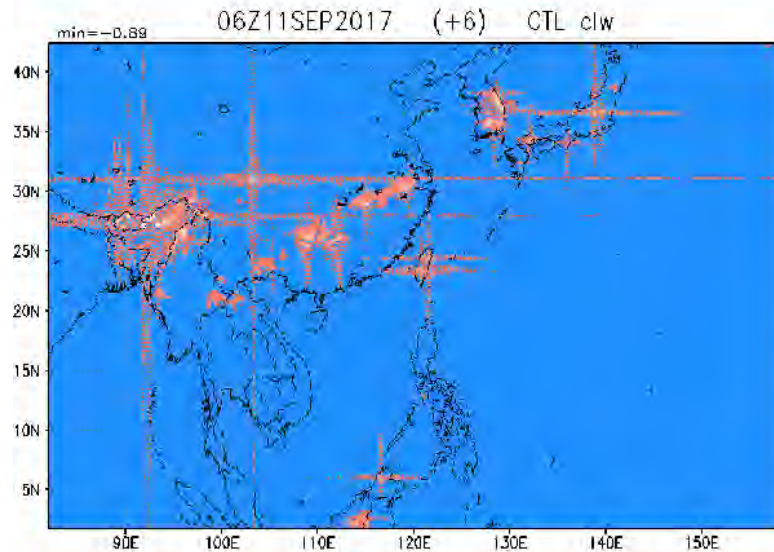
雲水(cloud water)第0小時預報的1000百帕等壓面分布圖



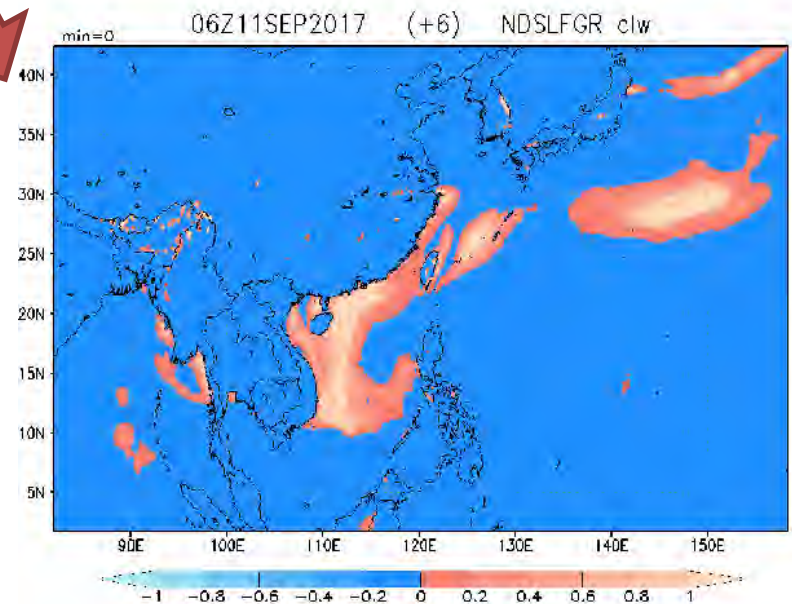
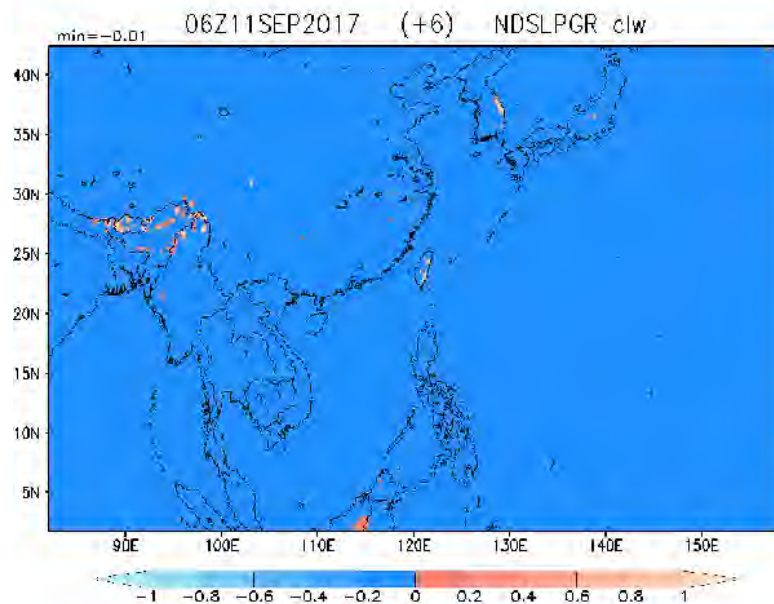
Without spectral transform, the noise caused by Gibbs phenomenon is eliminated.



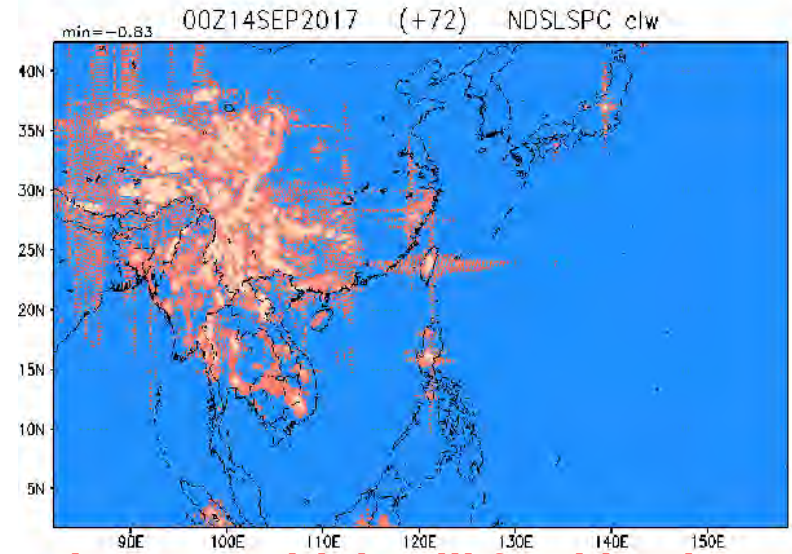
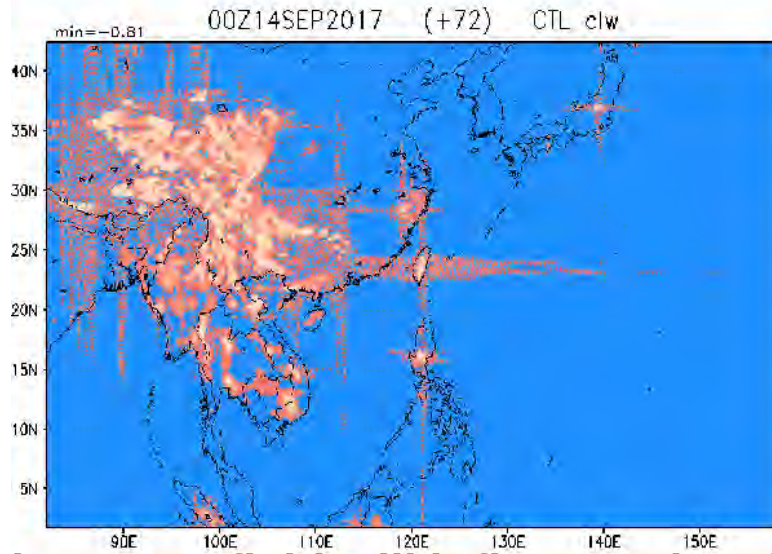
雲水(cloud water)第6小時預報的1000百帕等壓面分布圖



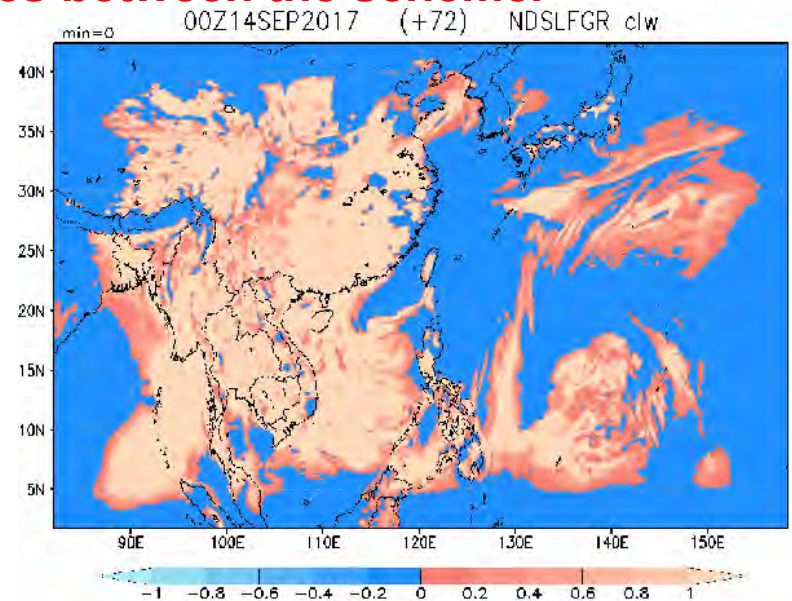
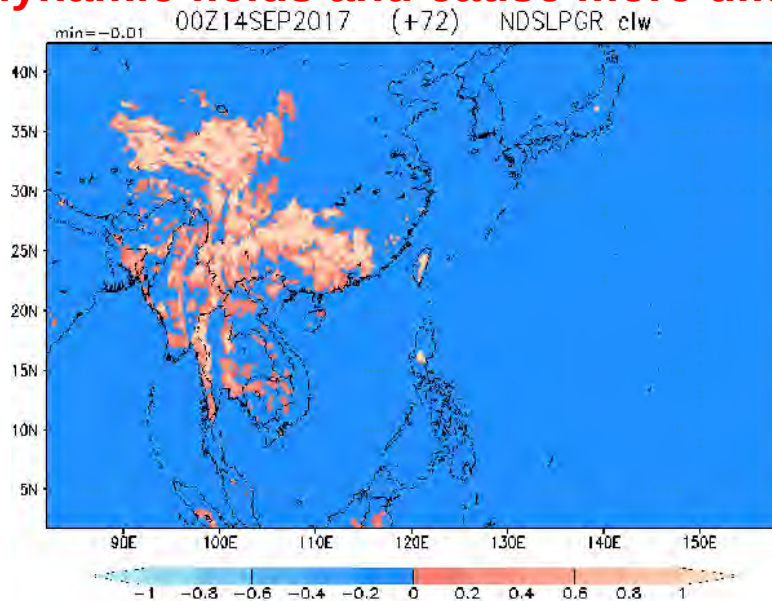
Time filter over full grid value may cause problems.



雲水(cloud water)第72小時預報的1000百帕等壓面分布圖

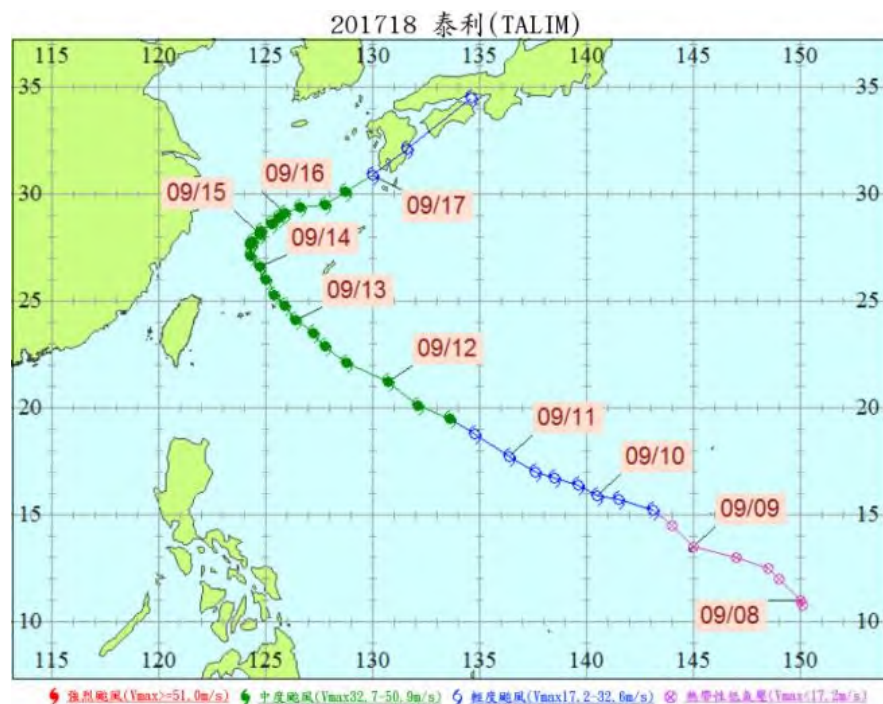


The tracer field will influence the physics schemes, which will feed back to dynamic fields and cause more differences between the scheme.



2017年第18號颱風泰利颱風(Talim)

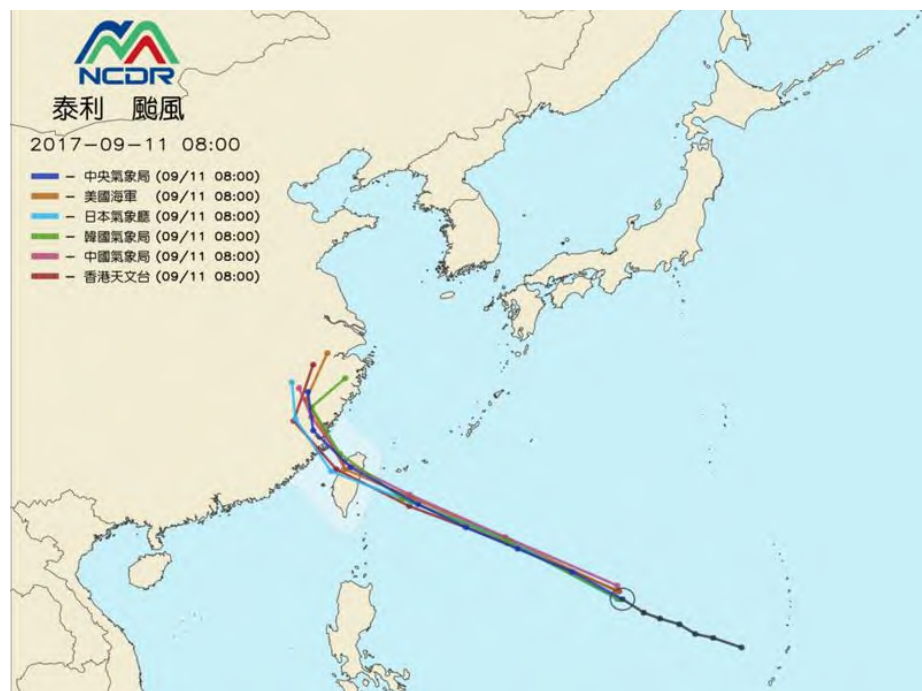
泰利 (Talim) 路徑圖



資料來源：

中央氣象局颱風資料庫

泰利颱風路徑預測圖



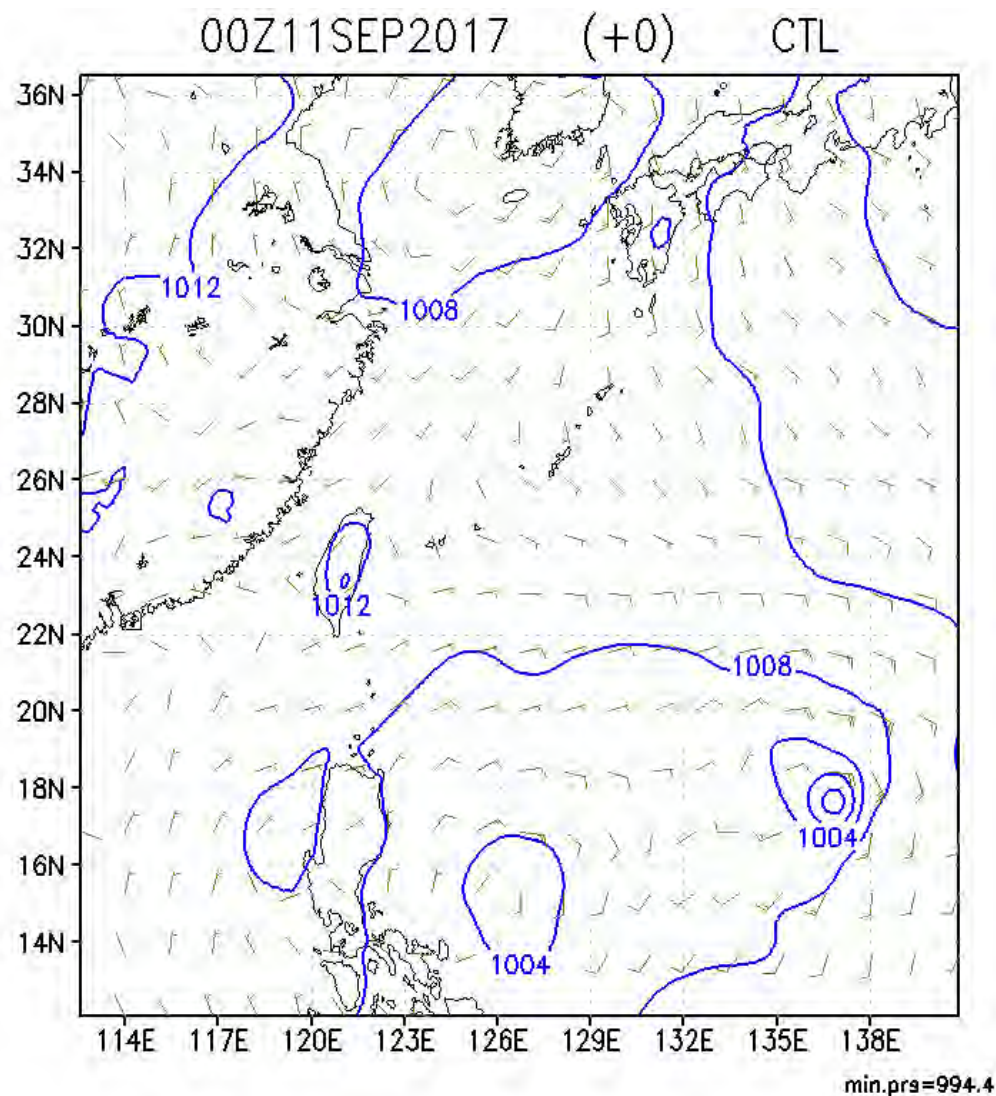
預報初始場為2017年9月11日00 UTC。

資料來源：

國家災害防救中心天氣與氣候監測網

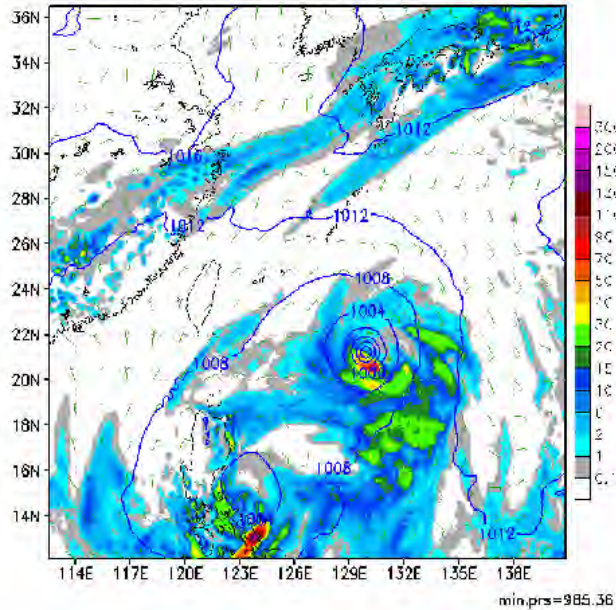
NDSL 實際個案測試-泰利颱風(2017年)

初始場

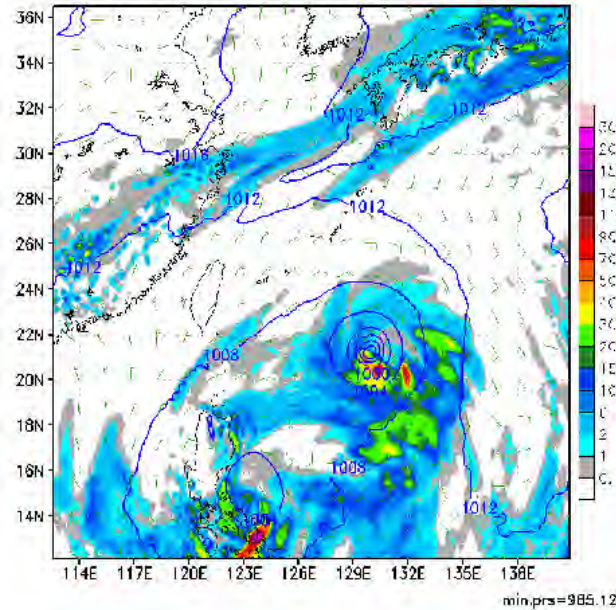


泰利颱風(2017)-第24小時預報結果

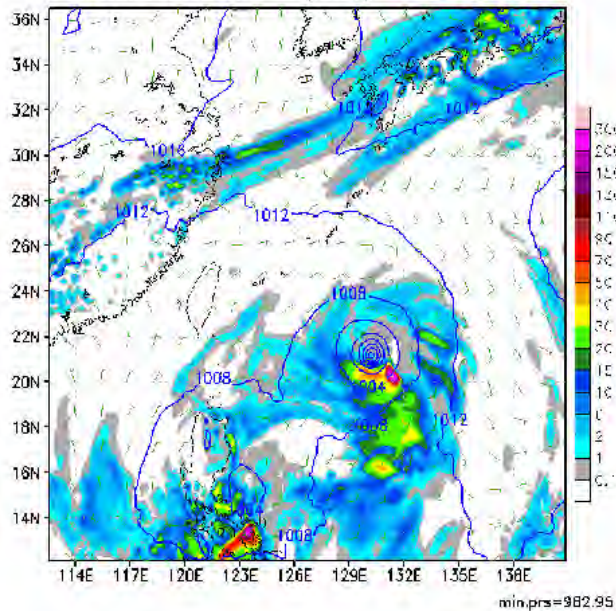
00Z12SEP2017 (+24) CTL



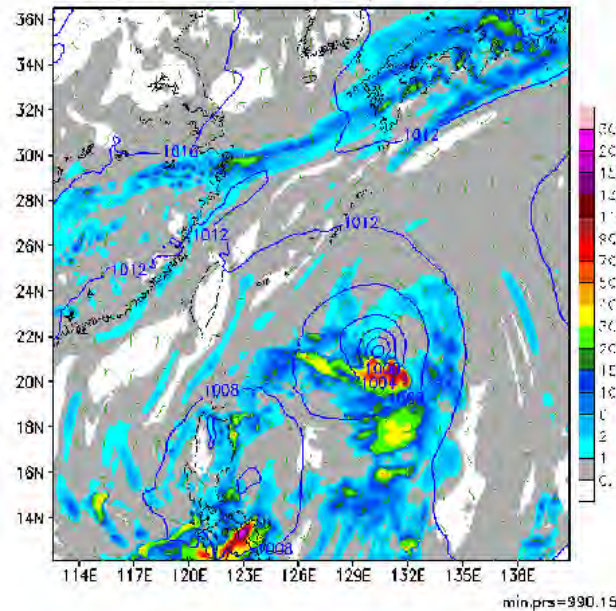
00Z12SEP2017 (+24) NDSLSPC



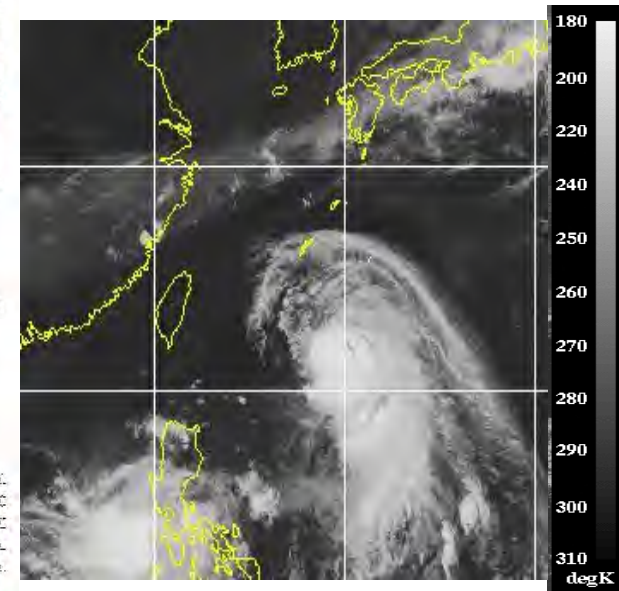
00Z12SEP2017 (+24) NDSLPGR



00Z12SEP2017 (+24) NDSLFGP



HIMAWARI INFRARED

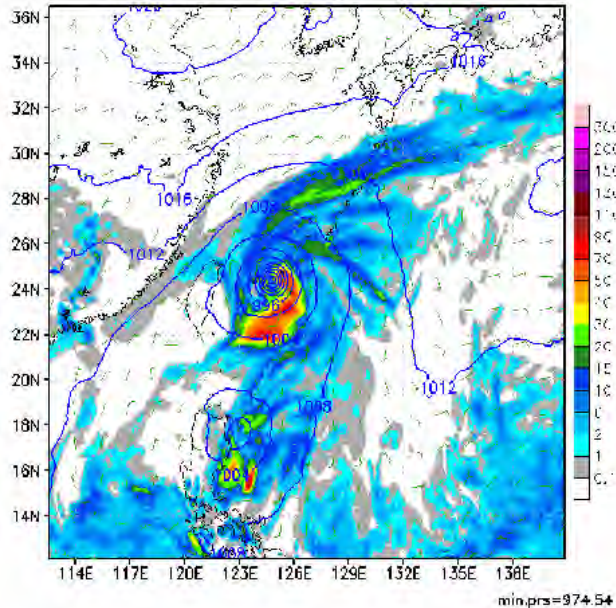


01:30 UTC

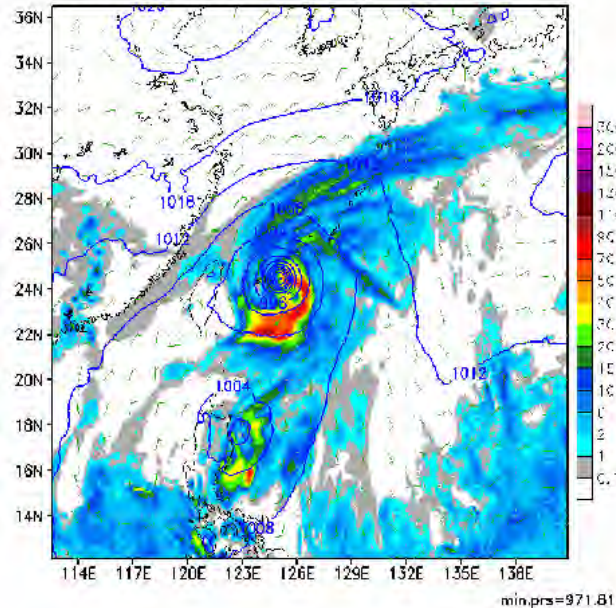
資料來源: CIMSS

泰利颱風(2017)-第48小時預報結果

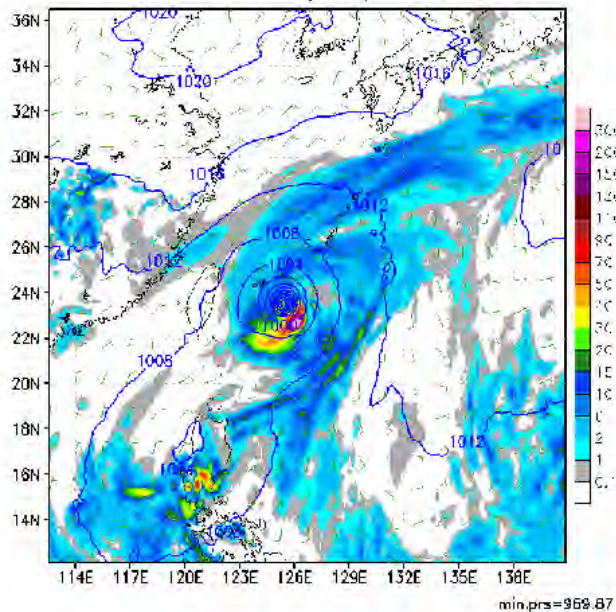
00Z13SEP2017 (+48) CTL



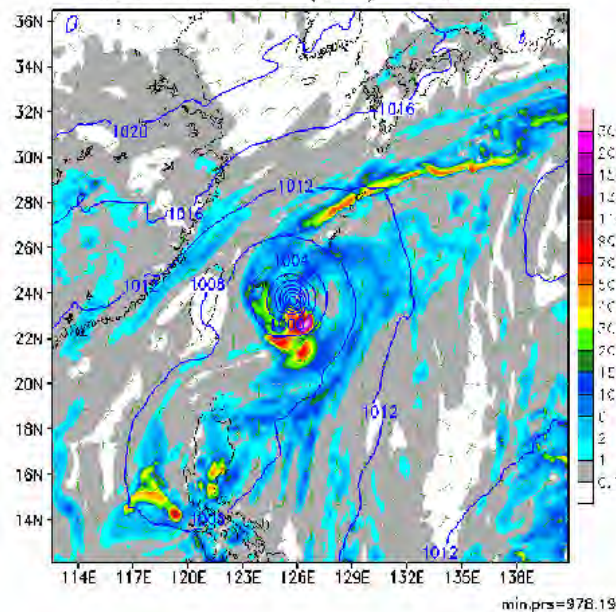
00Z13SEP2017 (+48) NDSLSPC



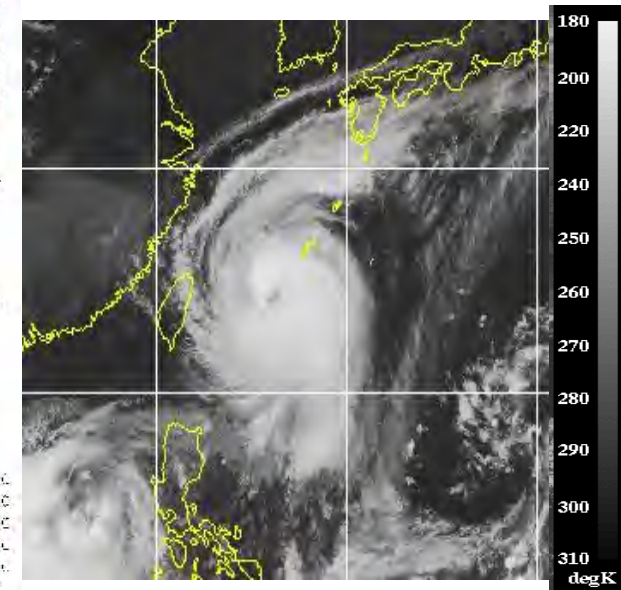
00Z13SEP2017 (+48) NDSLPCR



00Z13SEP2017 (+48) NDSLFR



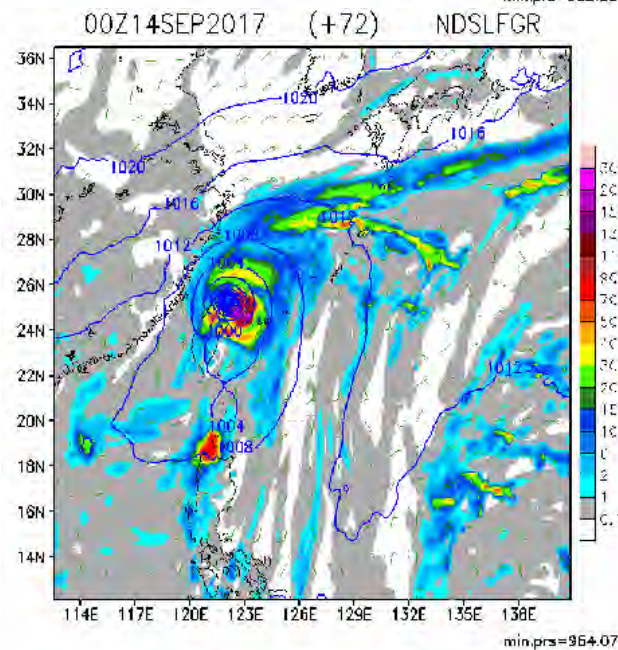
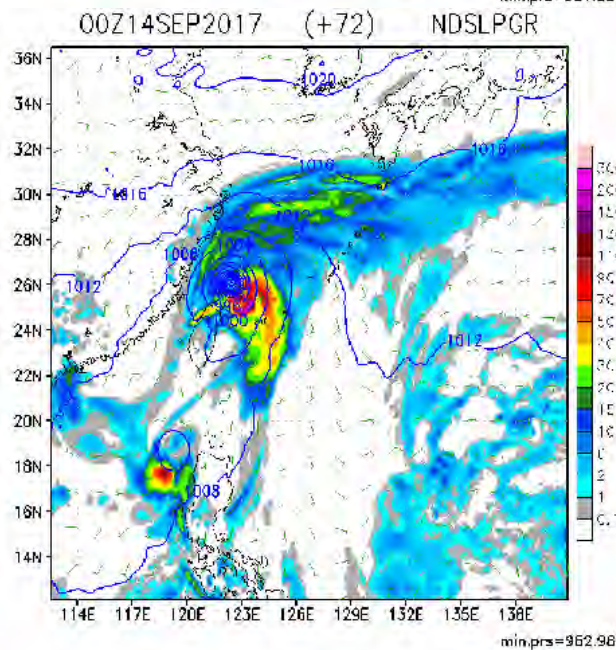
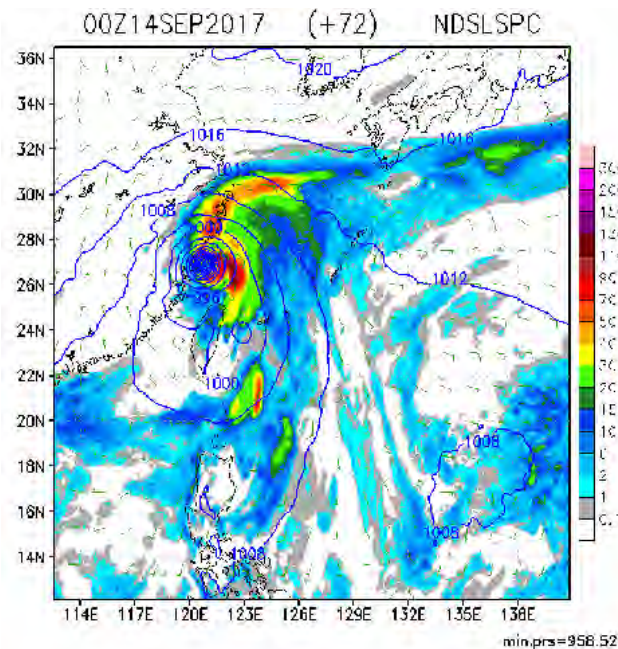
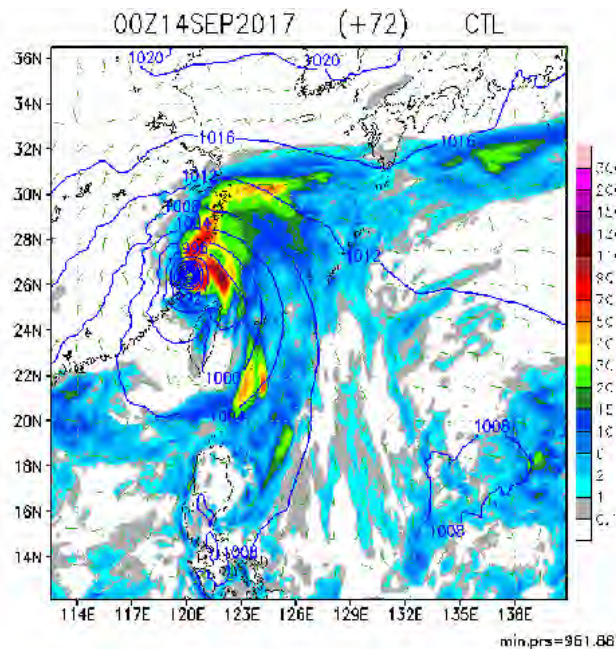
HIMAWARI INFRARED



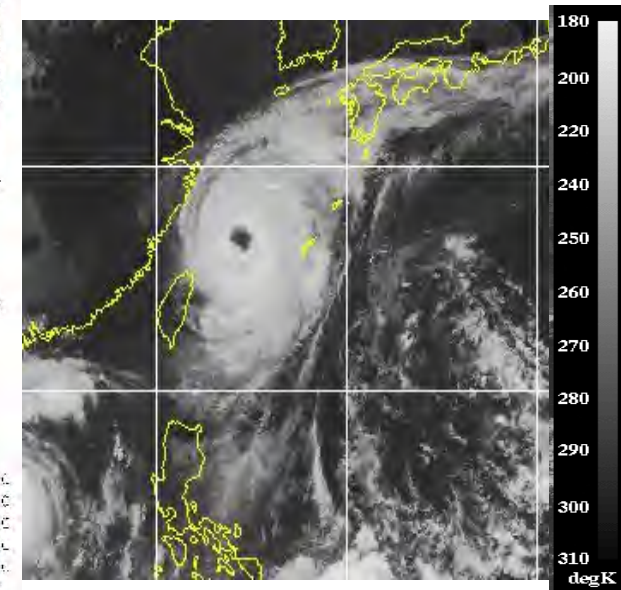
01:30 UTC

資料來源: CIMSS

泰利颱風(2017)-第72小時預報結果



HIMAWARI INFRARED

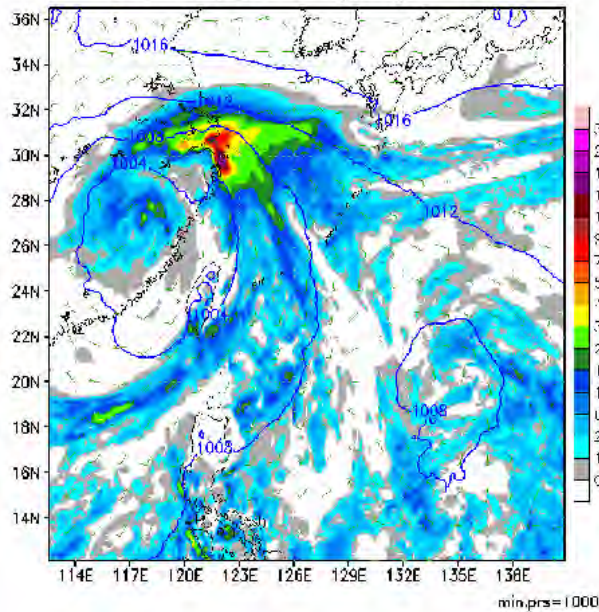


01:30 UTC

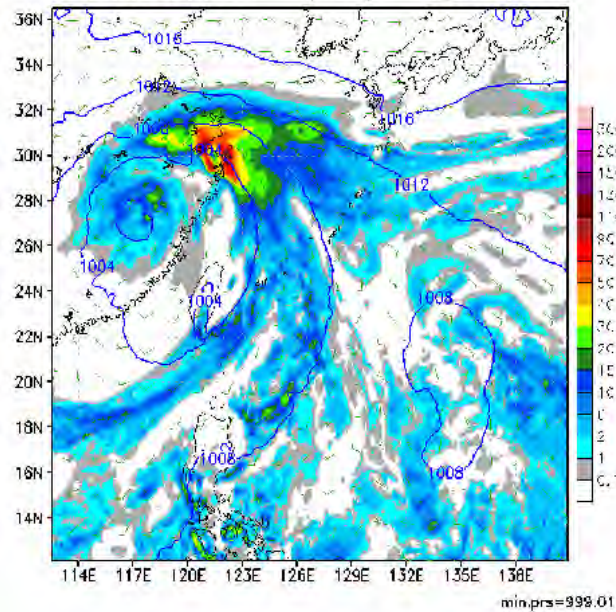
資料來源: CIMSS

泰利颱風(2017)-第96小時預報結果

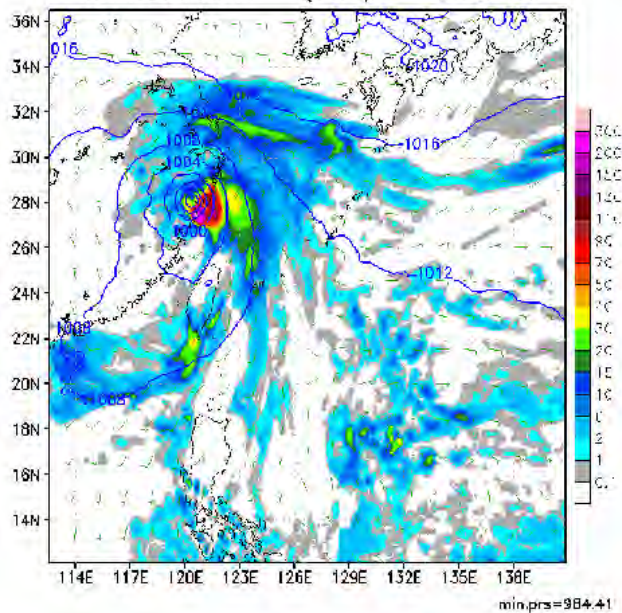
00Z15SEP2017 (+96) CTL



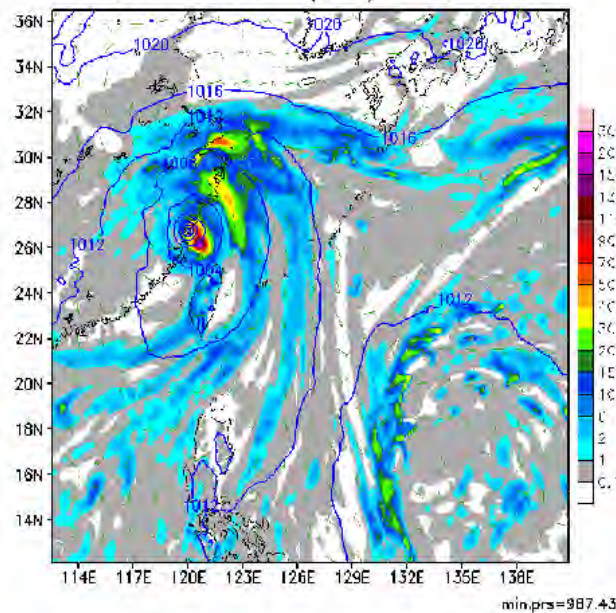
00Z15SEP2017 (+96) NDSLSPC



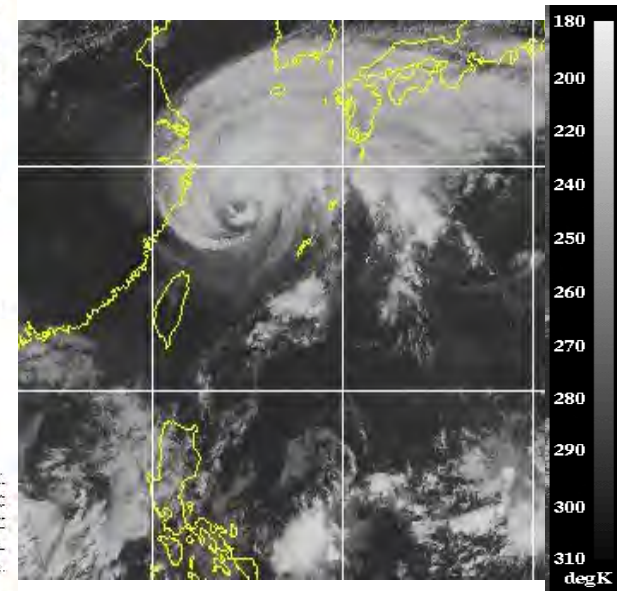
00Z15SEP2017 (+96) NDSLPCR



00Z15SEP2017 (+96) NDSLFGP



HIMAWARI INFRARED

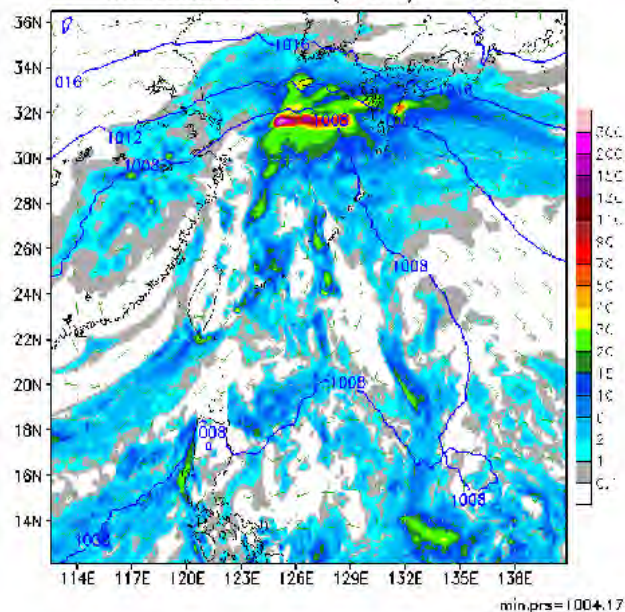


01:30 UTC

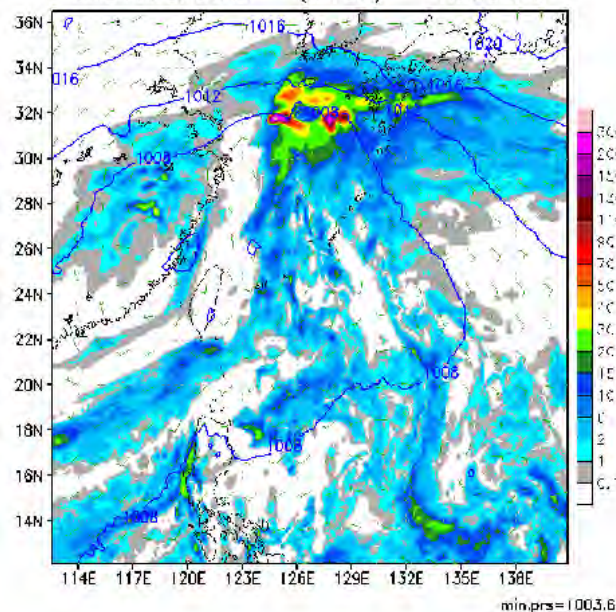
資料來源: CIMSS

泰利颱風(2017)-第120小時預報結果

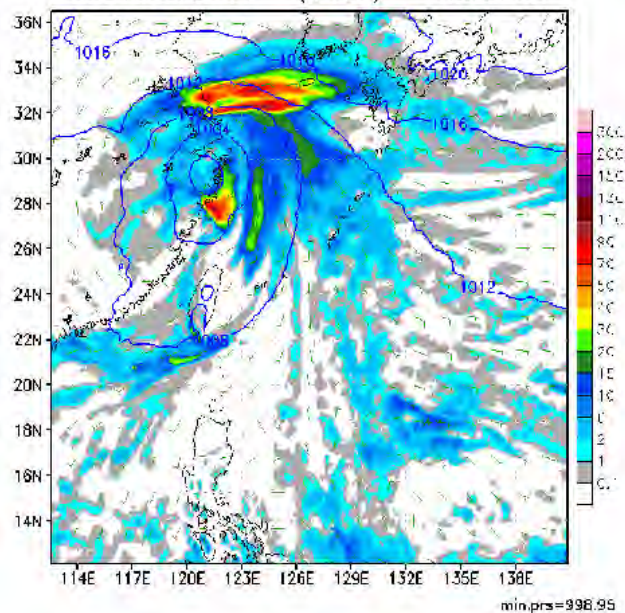
00Z16SEP2017 (+120) CTL



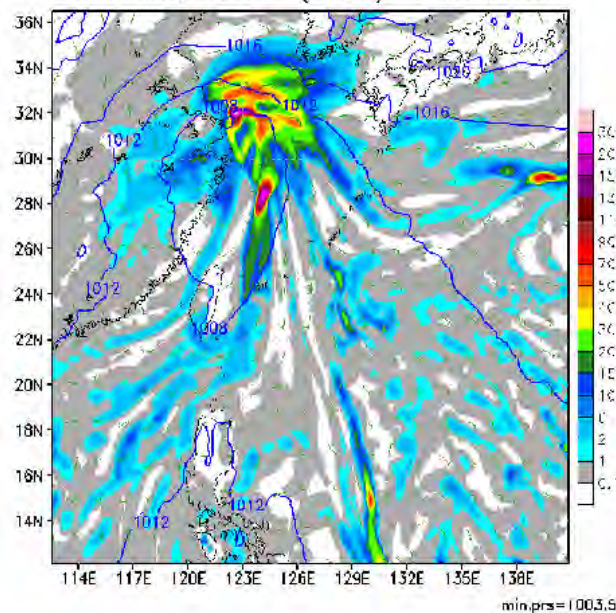
00Z16SEP2017 (+120) NDSLSPC



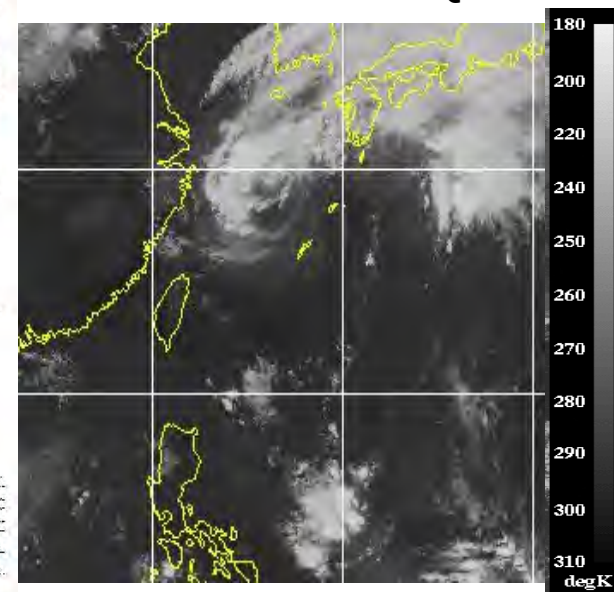
00Z16SEP2017 (+120) NDSLPCR



00Z16SEP2017 (+120) NDSLFR



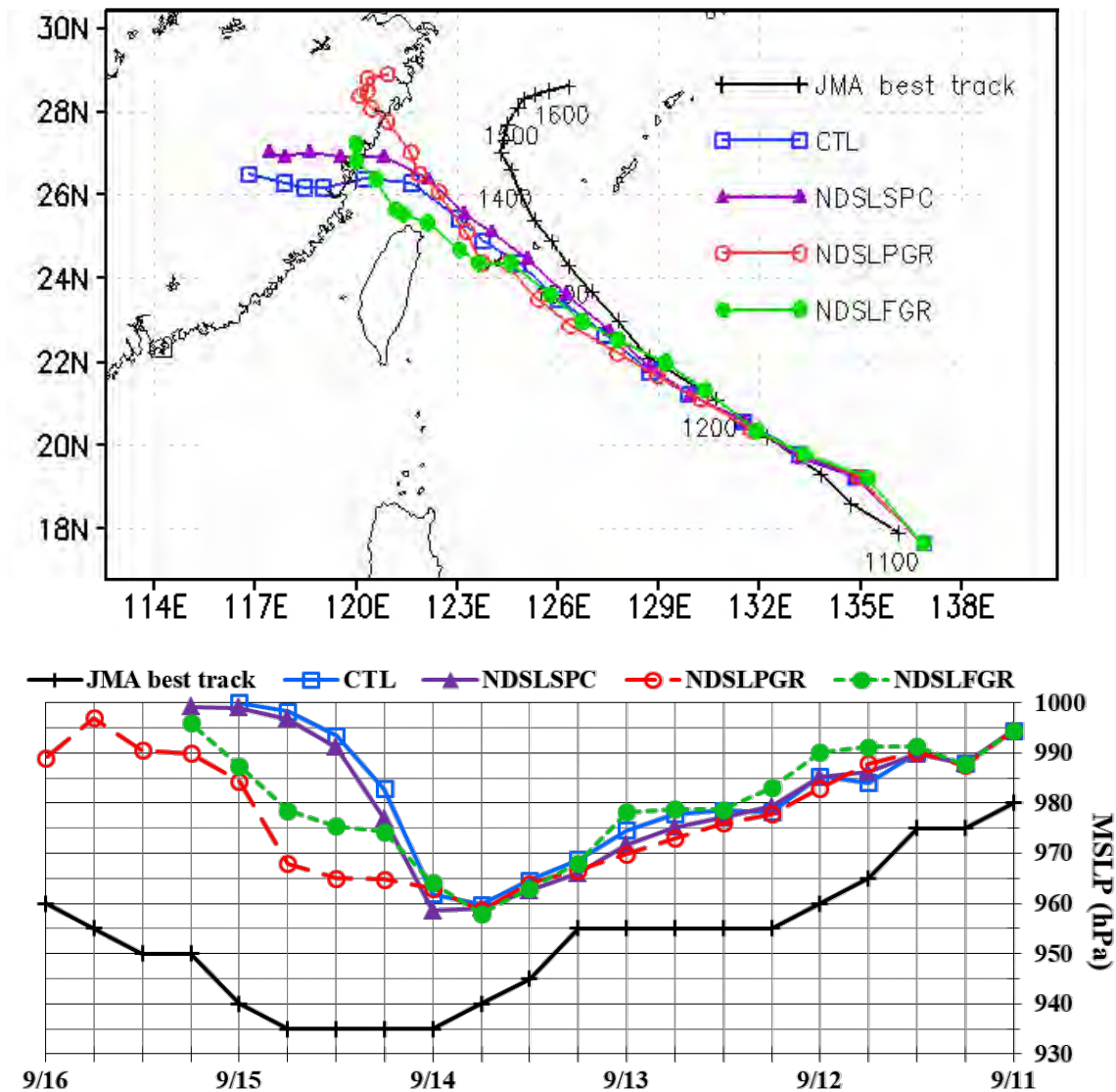
HIMAWARI INFRARED



01:30 UTC

資料來源: CIMSS

泰利颱風(2017)路徑與MSLP趨勢圖。 (minimum sea level pressure)



Conclusions

1. By using higher resolution topography data -**SRTM 1 ARC Global**, the model can increase the resolution and more detail circulation could be simulated.
2. NDSL with perturbation lateral boundary relaxation and time filter (NDSL**PGR**) gives the most reasonable result in TY Talim (2017) simulation.
 - 1) without noises
 - 2) better track and typhoon intensity

Ongoing Works

1. Increasing model resolution with SRTM 1 Arc Global data
 - problem sizes may increase
 - speeding up the model will be very important
2. implementing NDSL into other dynamic variables (such as u , v , T , ...) to increase the timestep

References

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- Juang, H.-M. H., S.-Y. Hong, and M. Kanamitsu, 1997: The NCEP regional spectral model: An update, *Bull. Amer. Meteor. Soc.* **78**, 2125-2143.
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- 國家災害防救中心天氣與氣候監測網
https://watch.ncdr.nat.gov.tw/watch_tracks.aspx
- CIMSS <http://tropic.ssec.wisc.edu/>
- Japan Meteorological Agency <http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/besttrack.html>
- Google Maps. (2018). *Esperanza Accident*. Retrieved from
<https://www.google.com/maps/place/33%C2%B052'49.4%22N+116%C2%B048'58.1%22W/@33.8013313,-116.8757035,163410m/data=!3m1!1e3!4m5!3m4!1s0x0:0x0!8m2!3d33.88038!4d-116.81615>
- USGS EarthExplorer: <https://earthexplorer.usgs.gov/>

Thanks for your attention!

- Comments and questions are welcome!
- Thank you!