



106年天氣分析與預報研討會
-氣象資訊在綠色能源之應用服務-

中央氣象局中尺度動力降尺度系統
(MDDS)之發展及測試結果

王建勛、鄧仁星、簡榮佑、湯寶君
中央氣象局

Weather⁺

Service Observation Climate Forecasts Satellite Earthquakes Marine Radar Astronomy



中央氣象局中尺度動力降尺度系統(MDDS)

- MDDS簡介
- MDDS鍾形山測試
- MDDS實際案例測試
 - 東北風
 - 鋒面
- 結論與未來展望





降尺度的方法

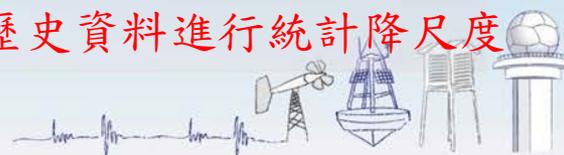


動力降尺度與統計降尺度的綜合比較

(取自 Wilby et al,1997 與 Xue et al.,2007 綜合比較)

	統計降尺度	動力降尺度
優點	<ul style="list-style-type: none"> • 運算成本相對便宜且計算效能高 • 可以由GCM輸出資料得到點-尺度的氣象變數 • 可以不透過RCM即能解析到變數 • 容易轉換到不同區域使用 • 結合觀測資料 	<ul style="list-style-type: none"> • 包含大氣的物理及動力過程為基礎 對於結果能以物理機制做適當的解釋，也能針對極端氣候進行研究 • 不同變數間滿足物理過程 • 可做不同氣候情境下之區域解析
缺點	<ul style="list-style-type: none"> • 需要長期可靠的歷史資料去做驗證 • 依選擇的預報因子會有不一樣的結果 • 預報因子-預報變量的關係並不是絕對定性的 • 不包含氣候預報系統的回饋 • 降尺度技術的表現受到區域的大小、氣候區域、季節之影響 • 不同變數間不保證滿足物理過程 	<ul style="list-style-type: none"> • 計算上耗時耗材 • 降尺度表現對於選定區域大小、水平解析度、地形、地表利用等變數非常敏感 • 須專家學者解釋降尺度氣候的特性

➤ 第三世界無人力物力資源進行動力降尺度，也無好的歷史資料進行統計降尺度



中央氣象局中尺度動力降尺度系統(MDDS)簡介

- Meso Dynamic Downscale System (MDDS)為中央氣象局與NOAA之GSD合作發展的複雜地形區的三維連續變分降尺度系統。
 - 當地形越複雜且天氣系統尺度越小，氣象場受地形的影響越嚴重，MDDS是為了解決因複雜地形下所產生的較小尺度氣象場變化。
 - MDDS相對於統計降尺度及動力降尺度的優點
 - 不需要長期模式及歷史資料
 - 屬於動力降尺度滿足物理過程
 - 相對於動力降尺度耗時少、且技術門檻較低
 - 追隨地勢座標、垂直跳點網格
- MDDS之泛函J可以寫成為：

$$J = \iiint (\alpha_1 P_1^2 + \alpha_2 P_2^2 + \alpha_3 P_3^2 + \alpha_4 P_4^2 + \alpha_5 P_5^2 + \alpha_6 P_6^2 + \alpha_7 P_7^2) d\Omega$$

- $\alpha_{1\sim 7}$ 為各項約束條件的權重
- $P_{1\sim 7}$ 為追隨地勢座標下之水平動量方程、垂直動量方程、熱力方程、水汽方程、平滑項⁺

Weather



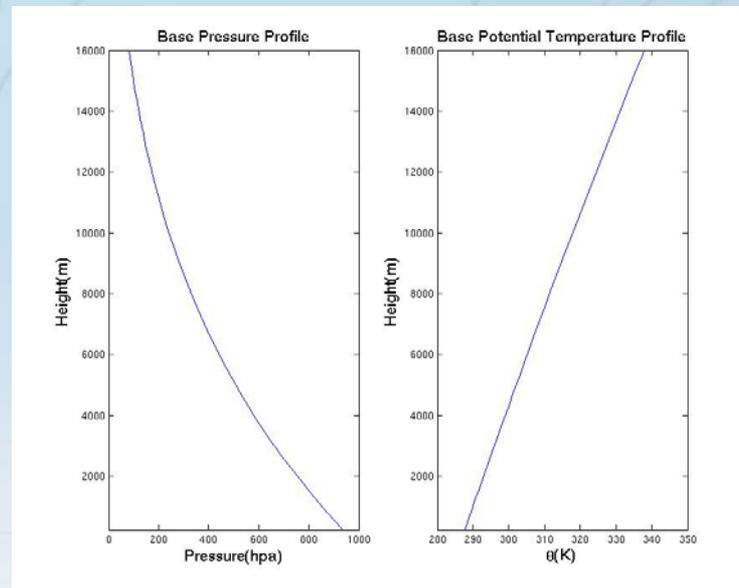


MDDS鍾形山測試

- 利用美國奧克拉荷馬大學所發展的 Advanced Regional Prediction System(ARPS)模式來驗證MDDS。
- 鍾形山：西風5m/s，山高4公里，半山寬50公里。
- 使用ARPS模式模擬鍾形山，跑32、16、8、4四種解析度，及至穩定態(取模擬第15小時)時，將32、16、8公里解析度結果由MDDS降尺度至4公里，並和ARPS模式4公里解析度結果做比較。

右：base場之垂直剖面
下：鍾形山公式

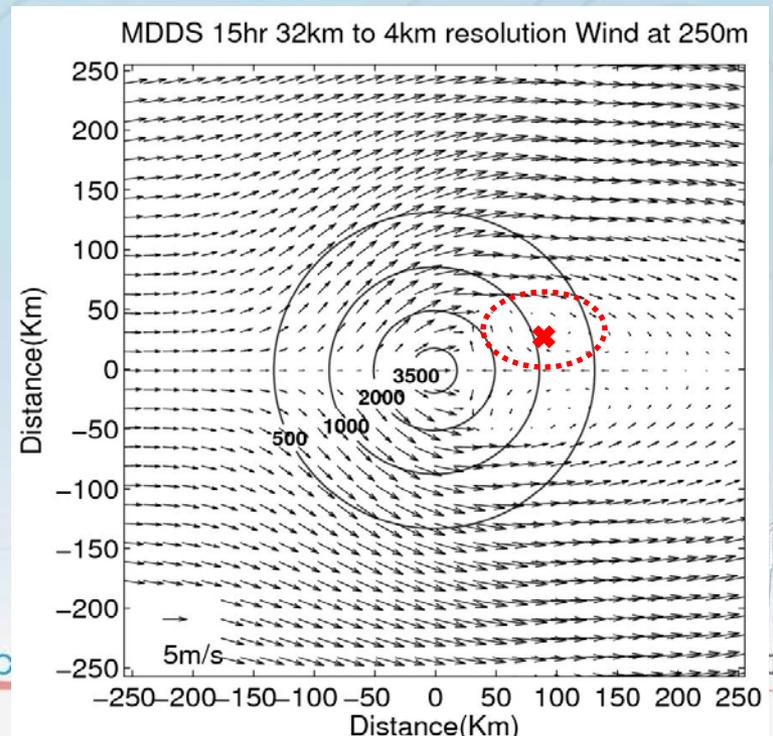
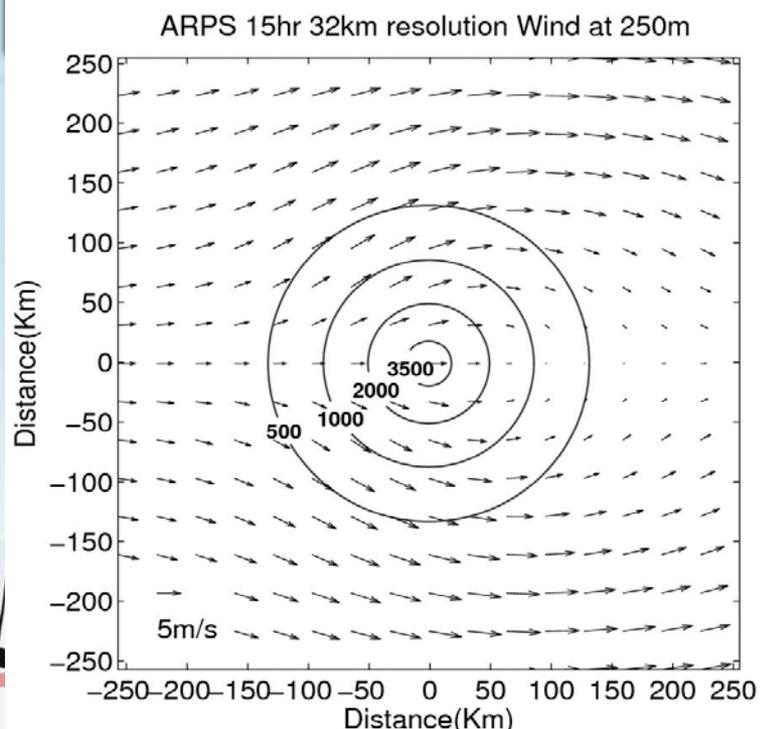
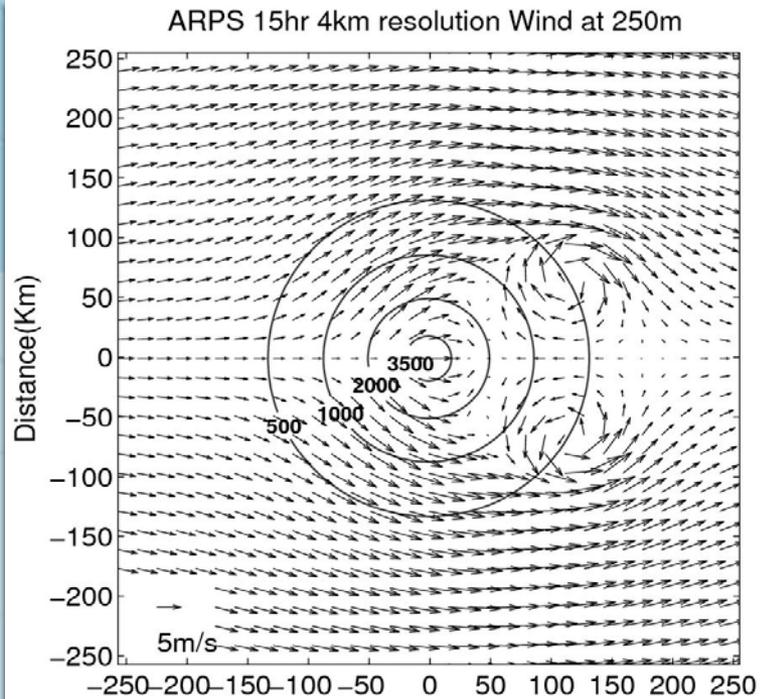
$$h(x, y) = \frac{h_t}{\frac{x^2}{a^2} + \frac{y^2}{a^2} + 1}$$

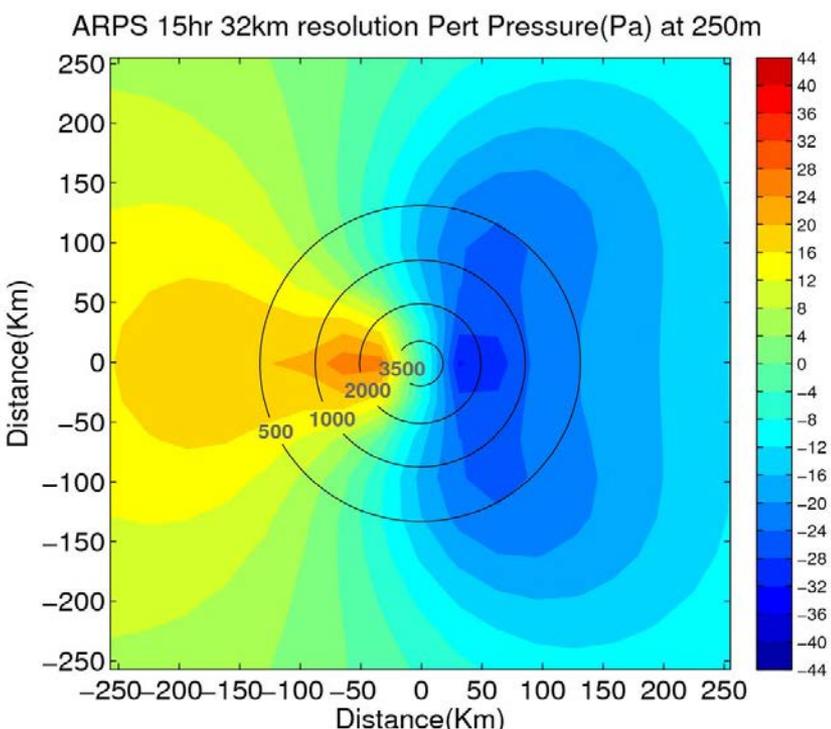
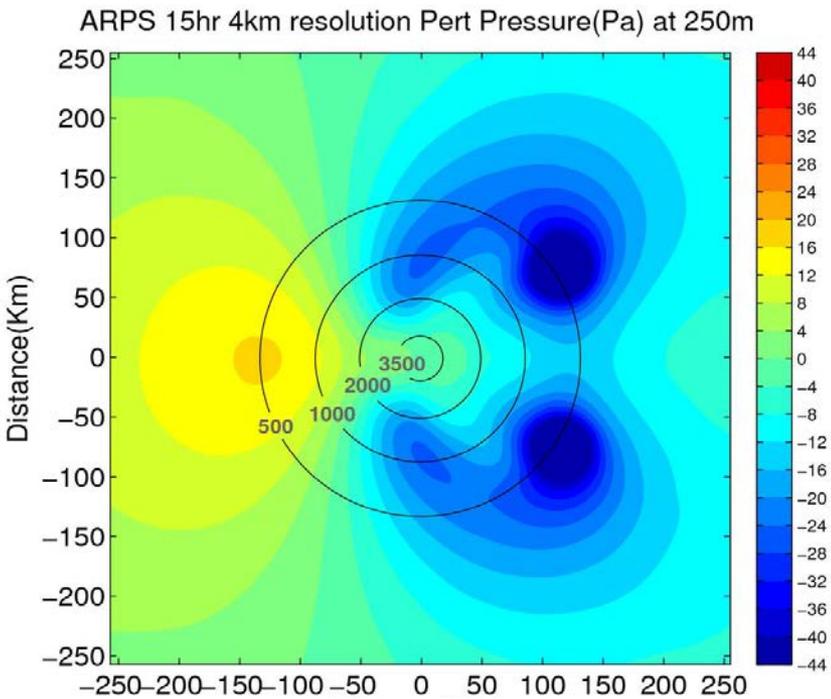




➤ 風場

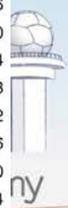
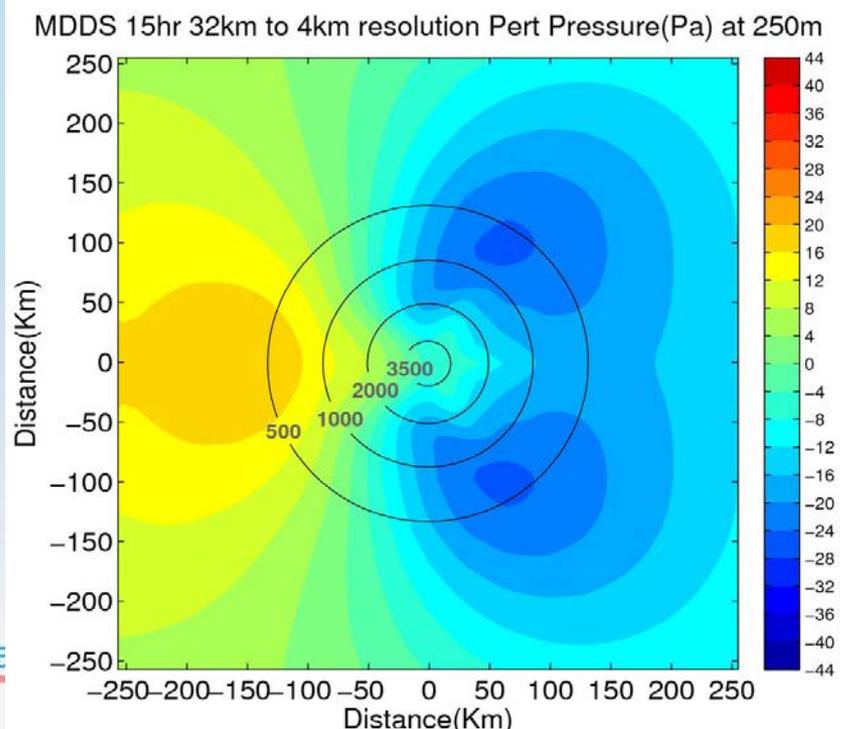
- 左上：ARPS 4公里解析度
- 左下：ARPS 32公里解析度
- 下：MDDS 4公里解析度





➤ 壓力擾動場(p')

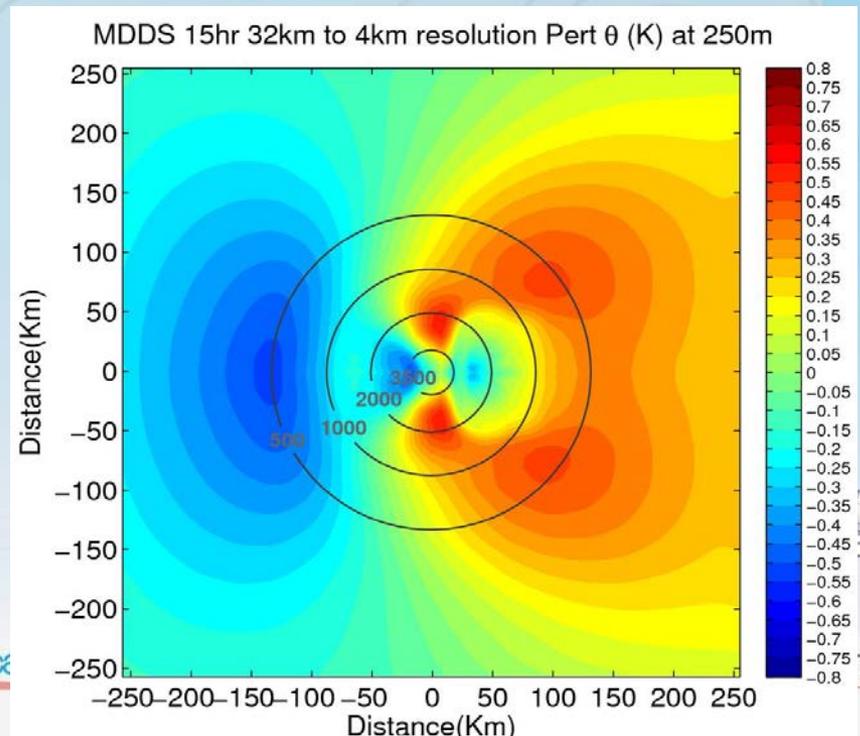
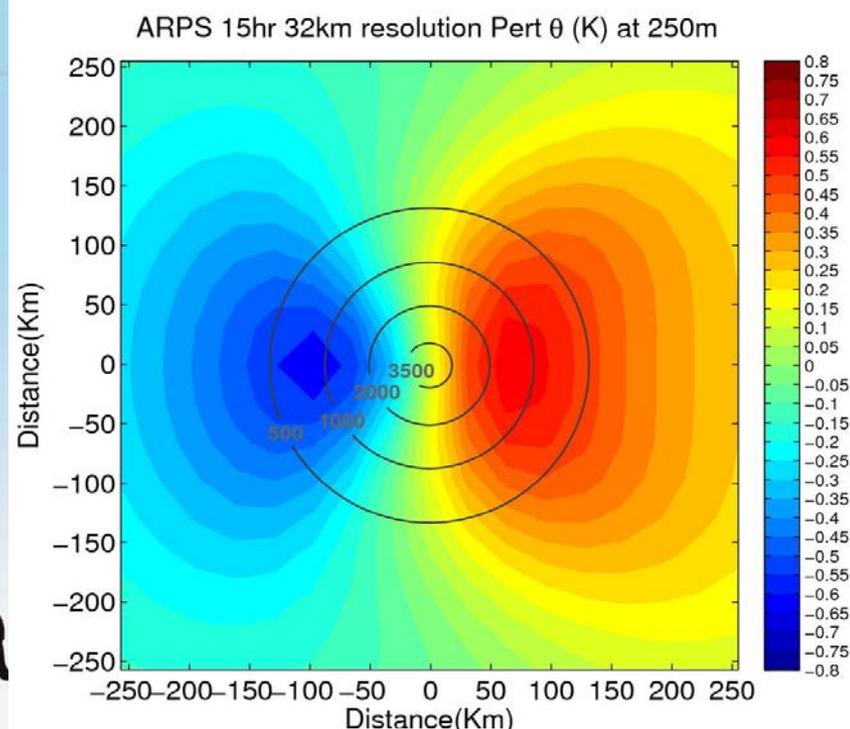
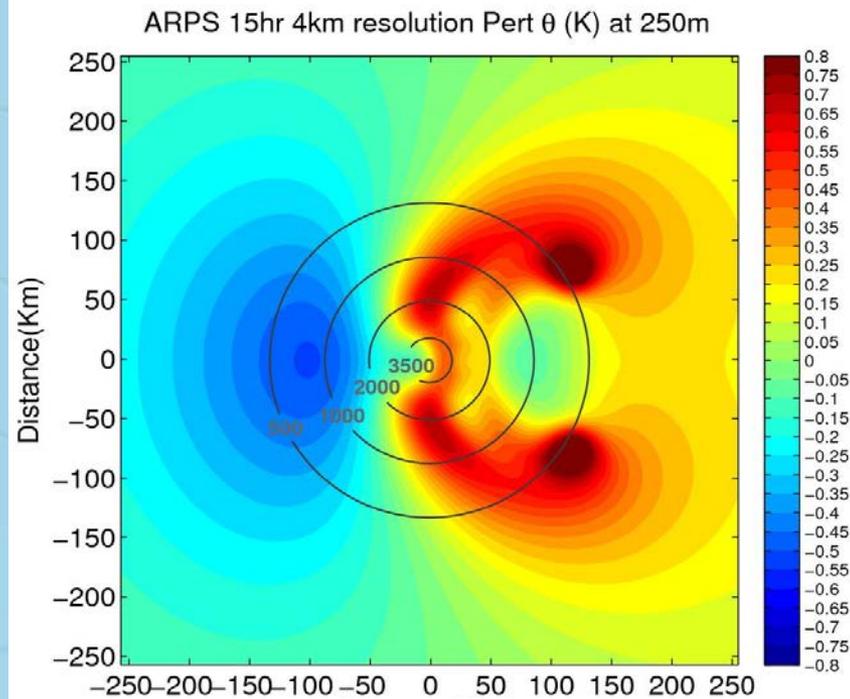
- 左上：ARPS 4公里解析度
- 左下：ARPS 32公里解析度
- 下：MDDS 4公里解析度

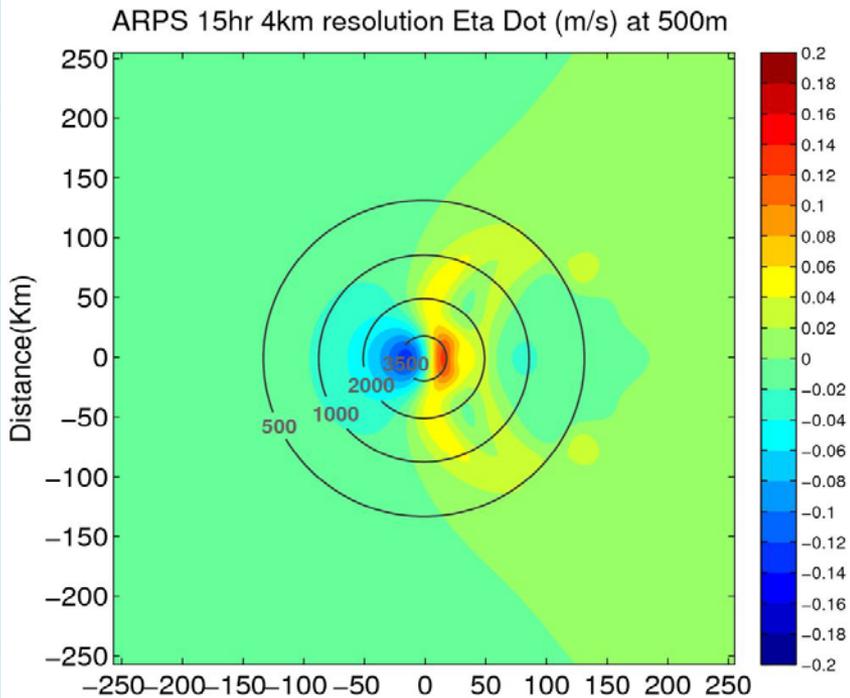




➤ 位溫擾動場(θ')

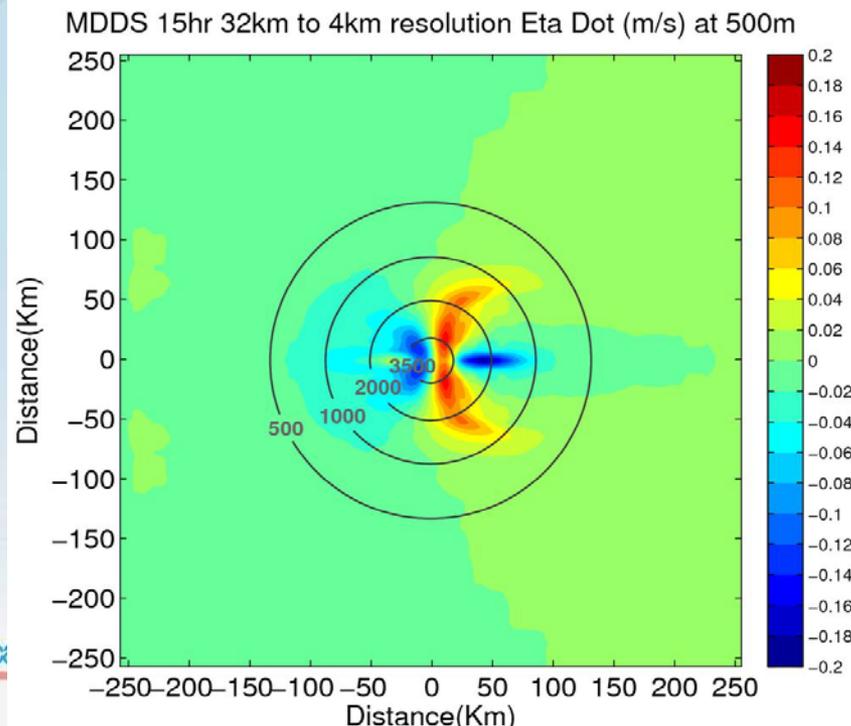
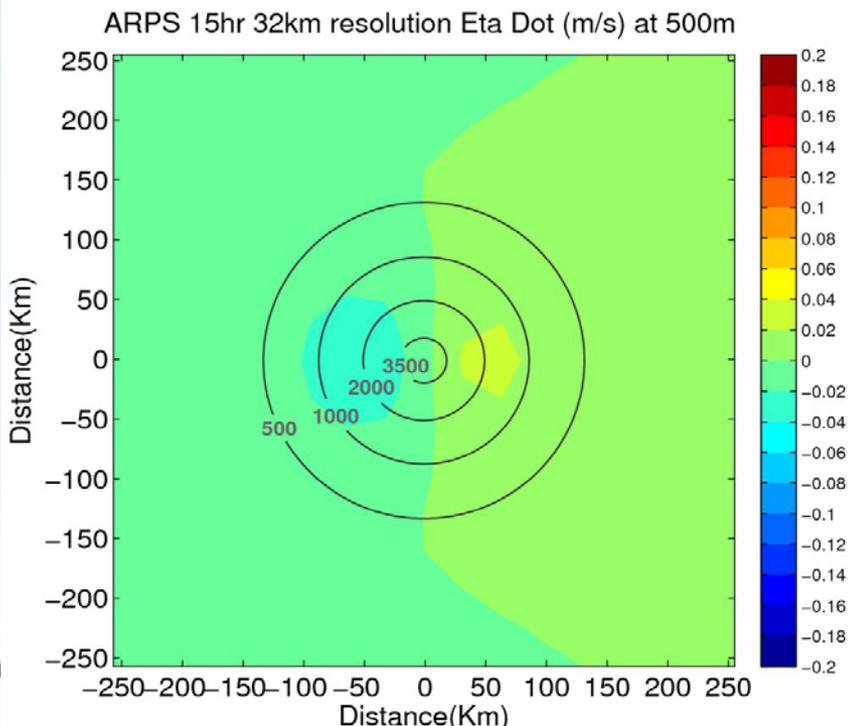
- 左上：ARPS 4公里解析度
- 左下：ARPS 32公里解析度
- 下：MDDS 4公里解析度

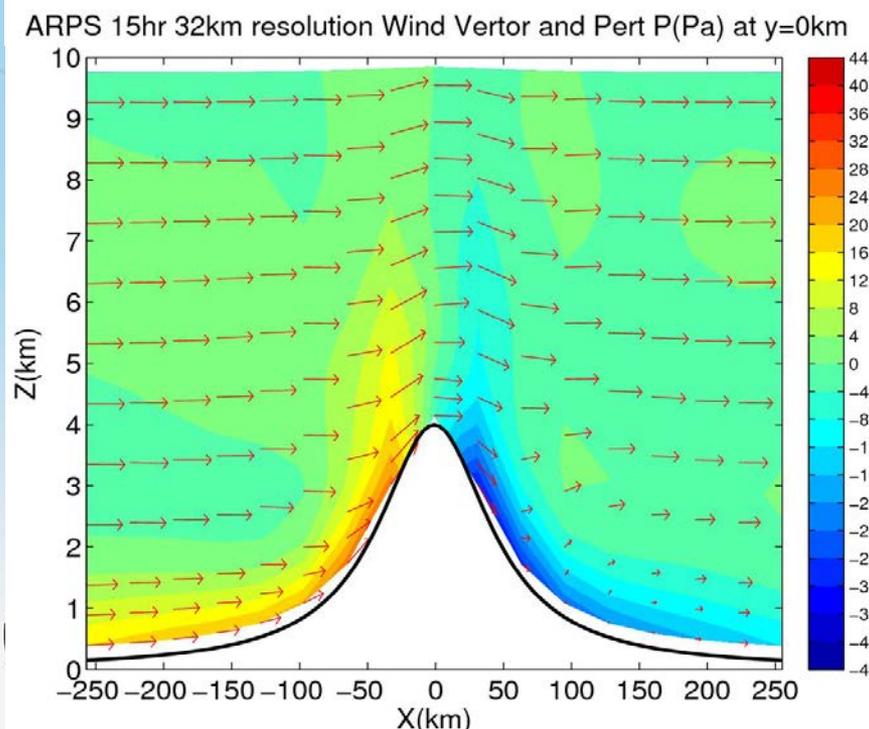
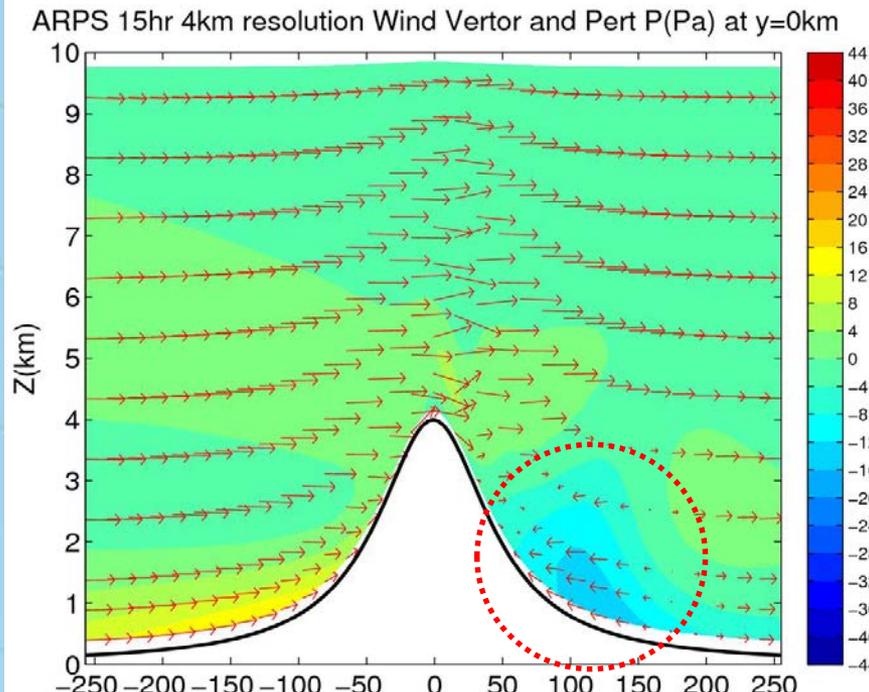




➤ 垂直速度場(η)

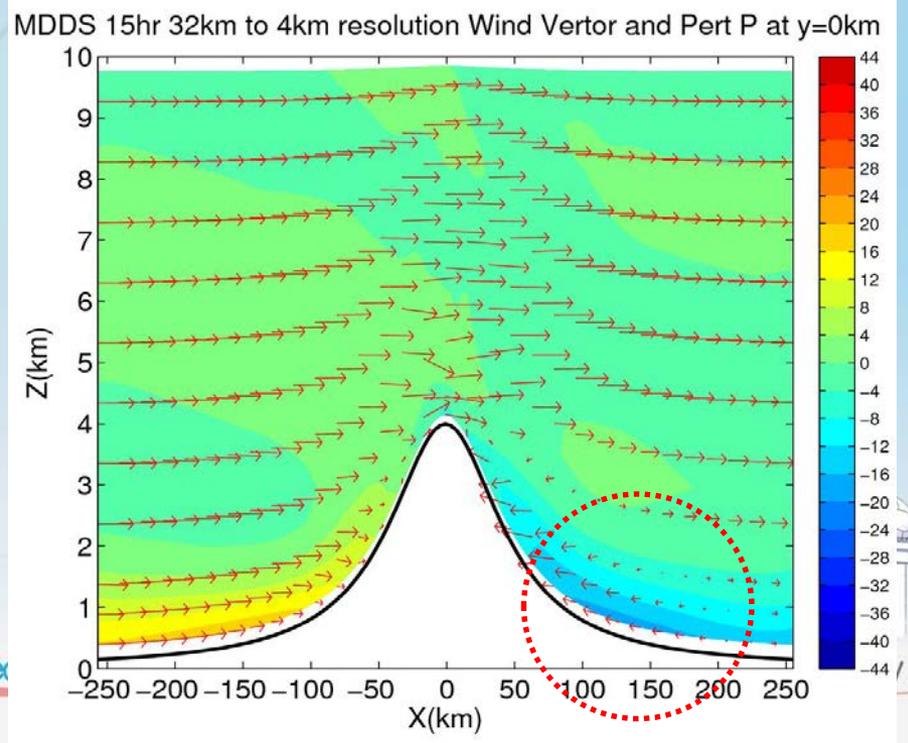
- 左上：ARPS 4公里解析度
- 左下：ARPS 32公里解析度
- 下：MDDS 4公里解析度



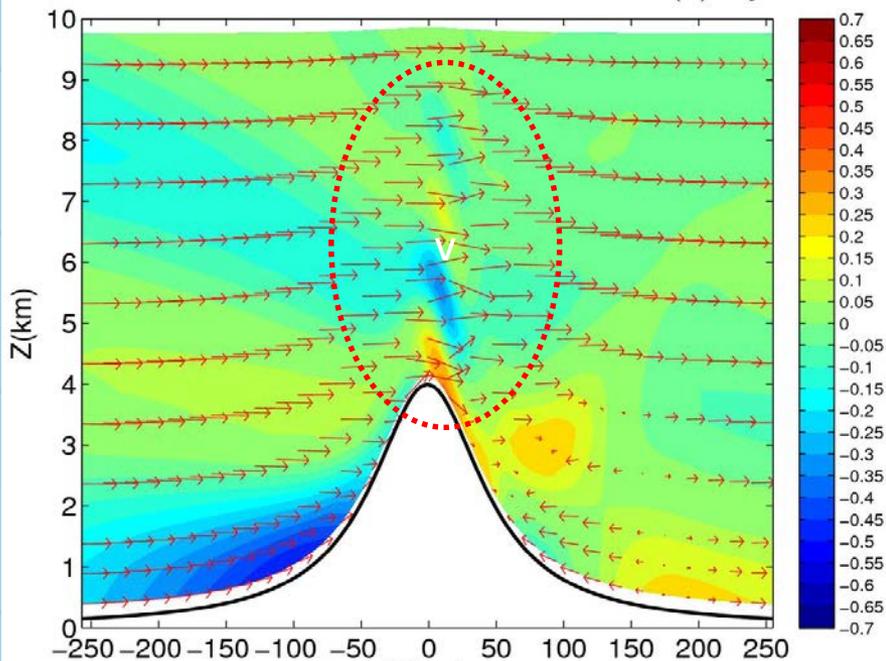


➤ 壓力擾動場(p')

- 左上：ARPS 4公里解析度
- 左下：ARPS 32公里解析度
- 下：MDDS 4公里解析度



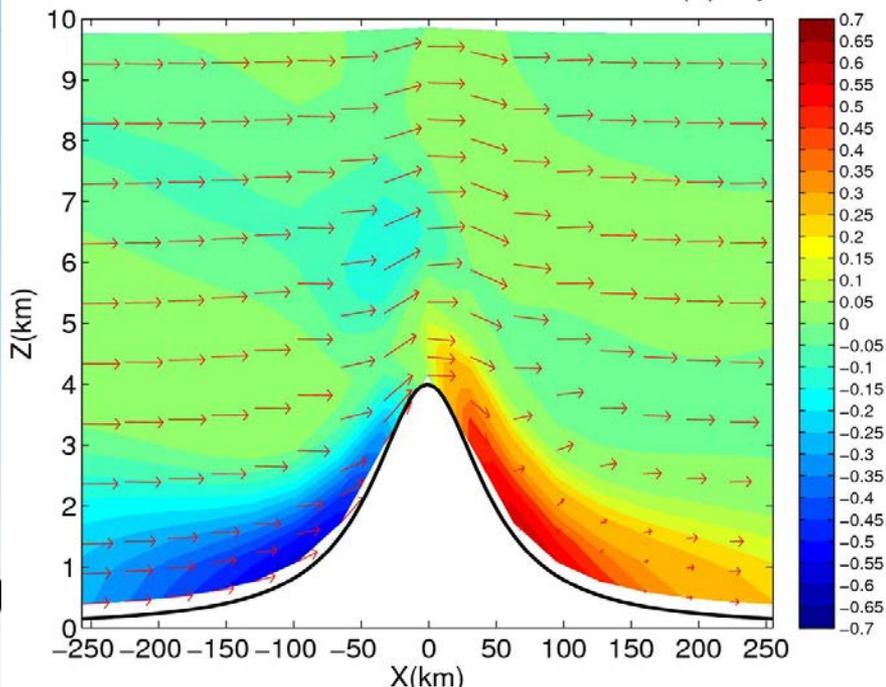
ARPS 15hr 4km resolution Wind Vector and PERT θ (K) at y=0km



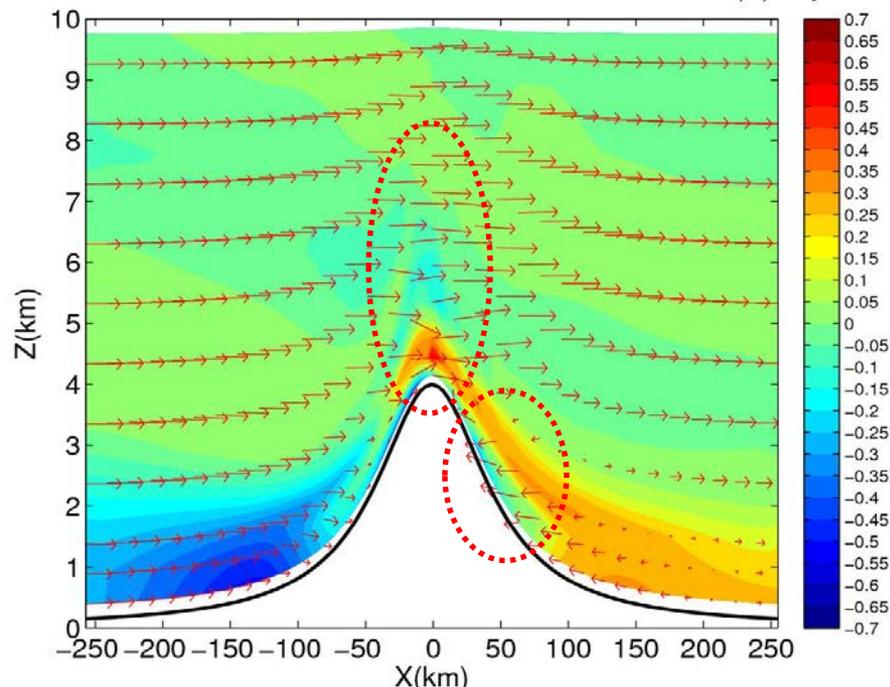
➤ 位溫擾動場(θ')

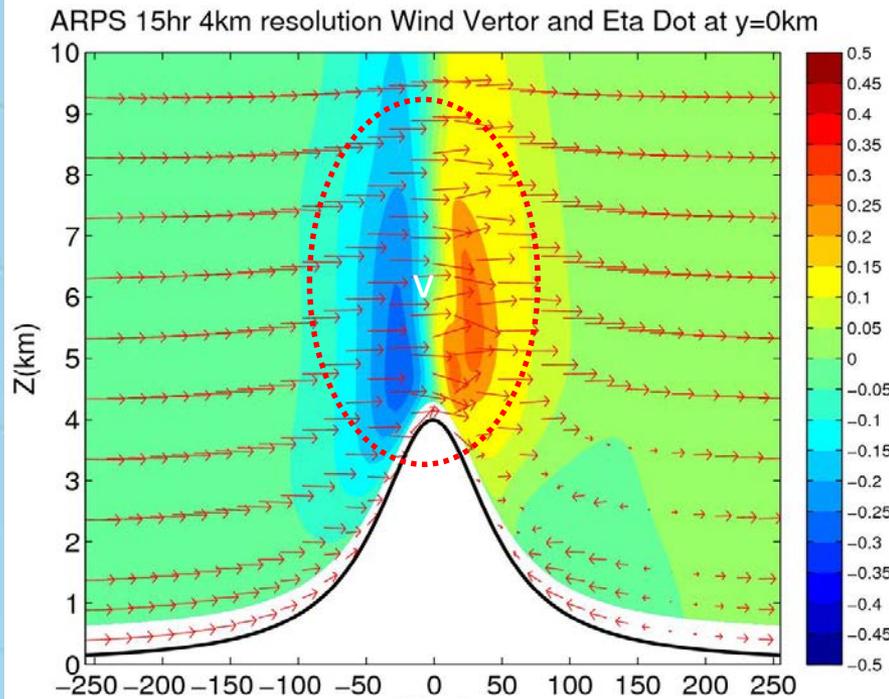
- 左上：ARPS 4公里解析度
- 左下：ARPS 32公里解析度
- 下：MDDS 4公里解析度

ARPS 15hr 32km resolution Wind Vector and PERT θ (K) at y=0km



MDDS 15hr 32km to 4km resolution Wind Vector and PERT θ (K) at y=0km

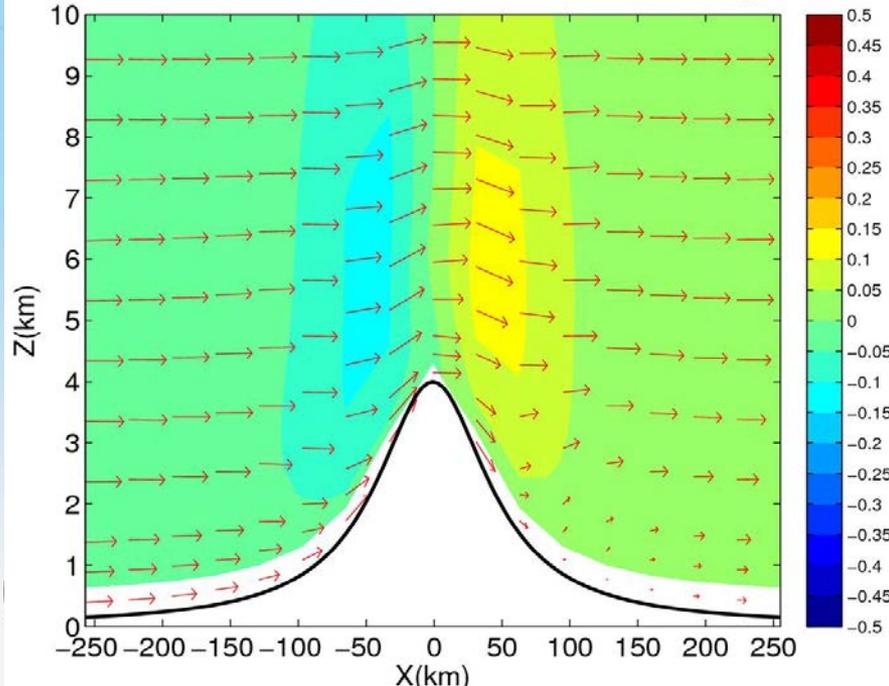




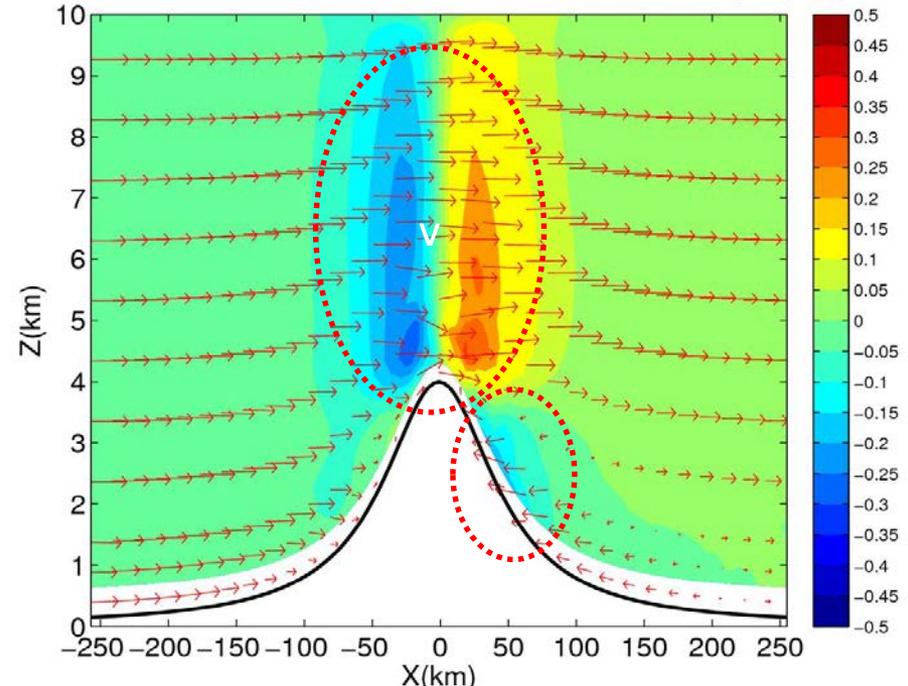
➤ 垂直速度場(η)

- 左上：ARPS 4公里解析度
- 左下：ARPS 32公里解析度
- 下：MDDS 4公里解析度

ARPS 15hr 32km resolution Wind Vector and Eta Dot at y=0km

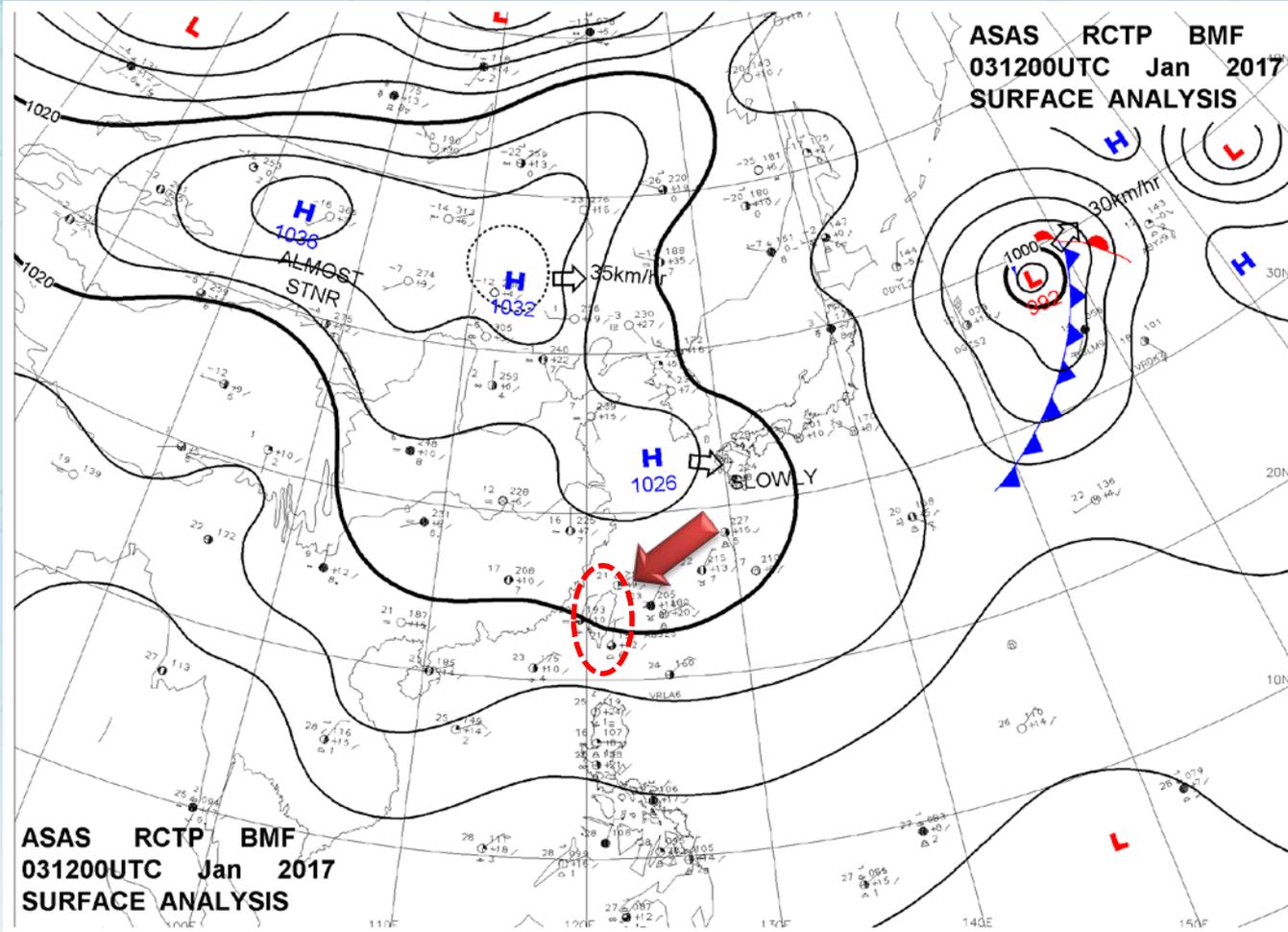


MDDS 15hr 32km to 4km resolution Wind Vector and Eta Dot (m/s) at y=0km



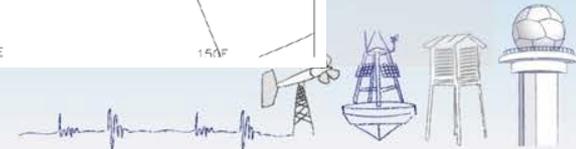
MDDS 實際案例測試-東北風

2017/01/03 12Z UTC



Weather⁺

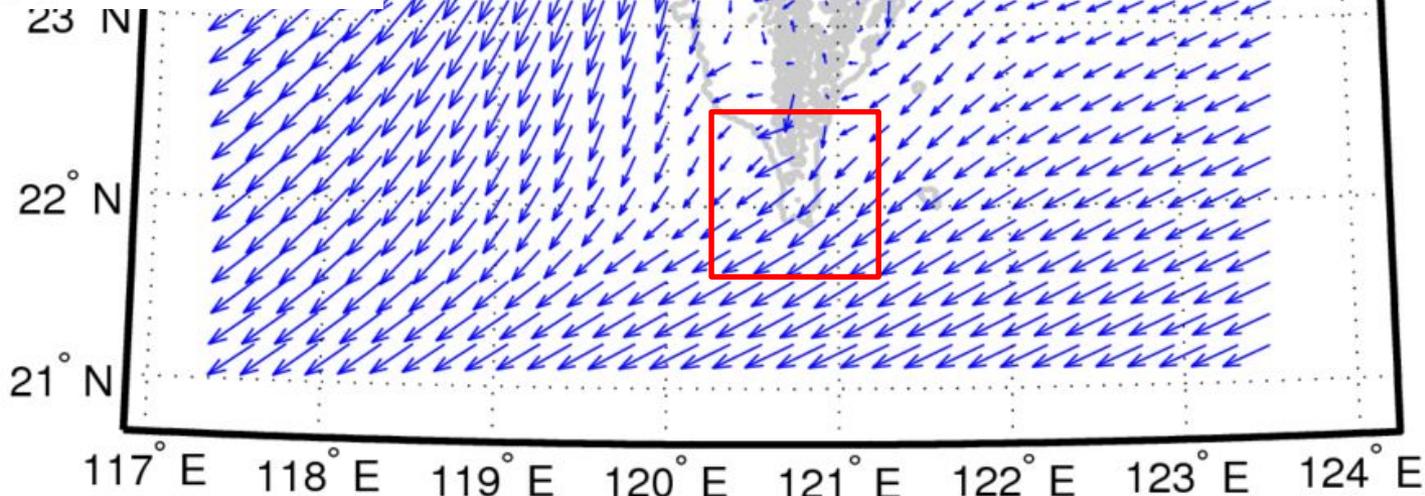
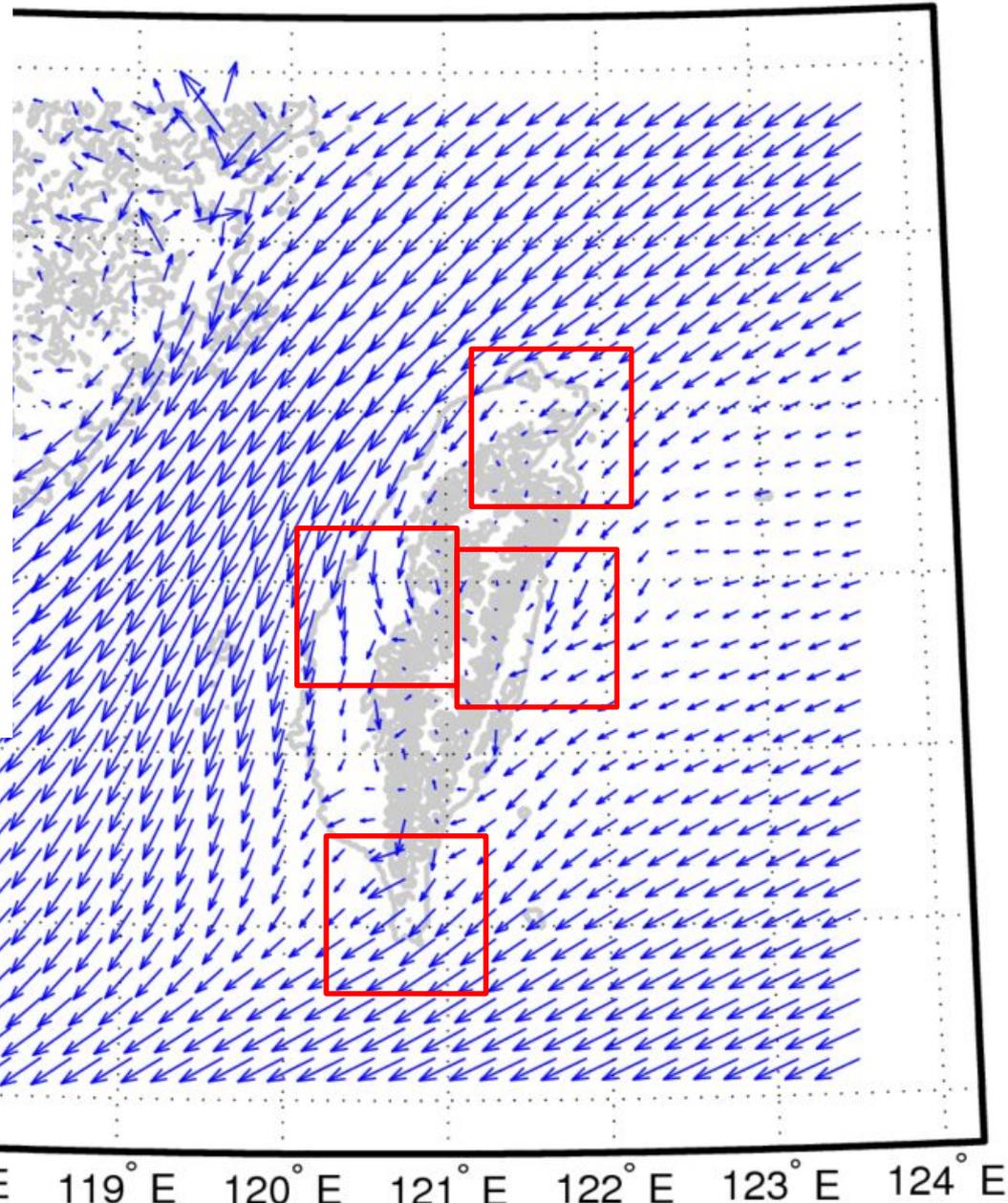
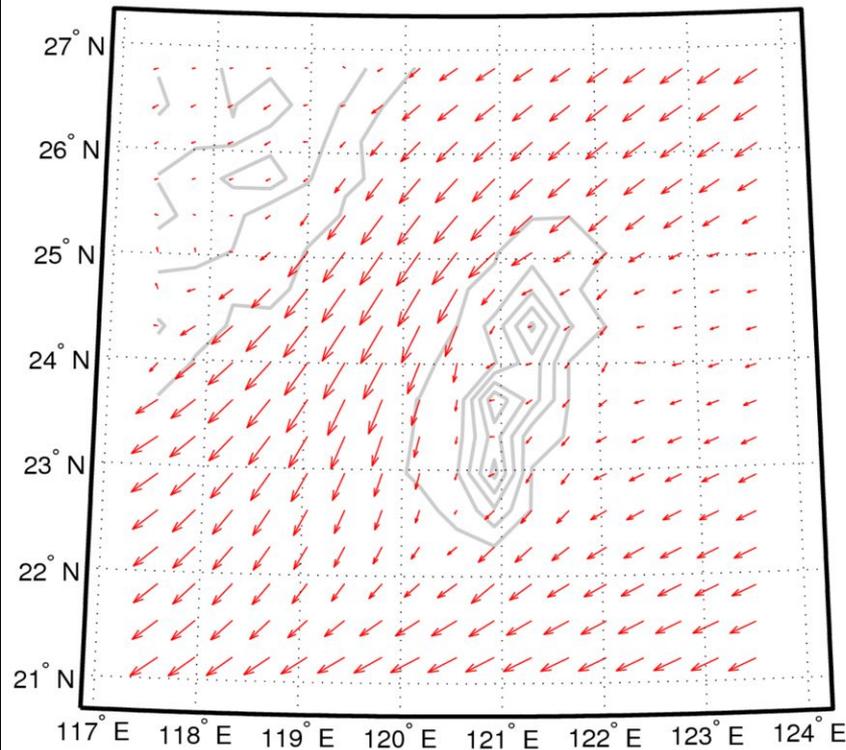
Service Observation Climate Forecasts Satellite Earthquakes Marine Radar Astronomy



After mdds last output 20170103 12Z f000

Wind Speed at 250m

Original NCEP/GFS 20170103 12Z f000
Wind Speed at 250m



→
NCEP Wind

→
MDDS Wind

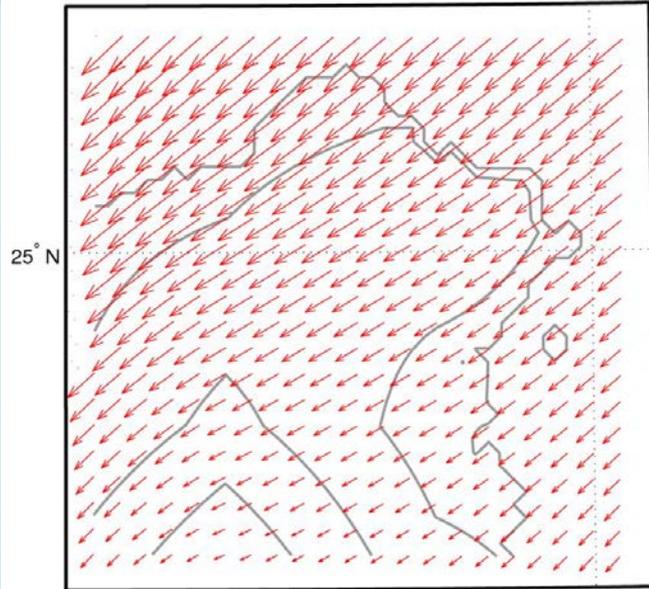
Weather
Ser

MDDS 實際案例測試-東北風



NCEP Wind

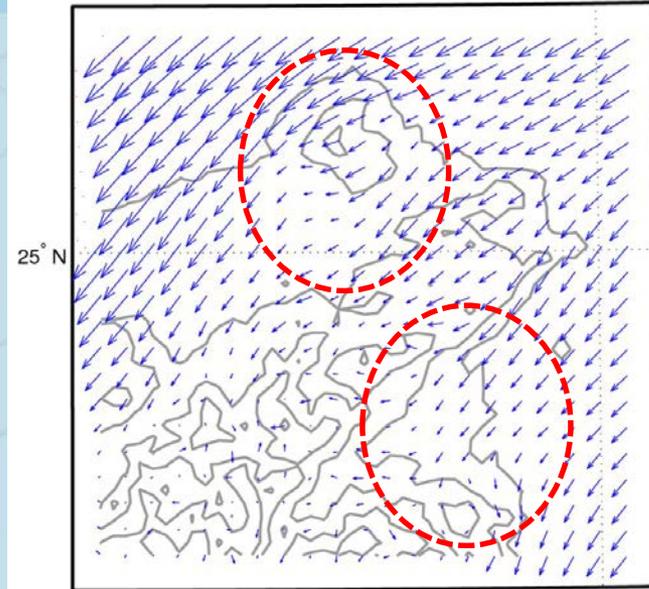
Taipei, Ilan input



Taipei, Ilan ingest_meso

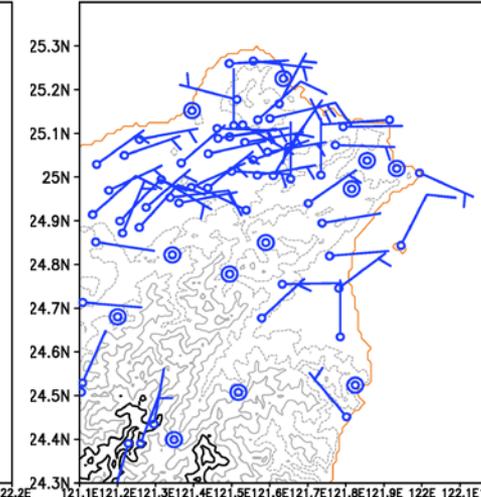
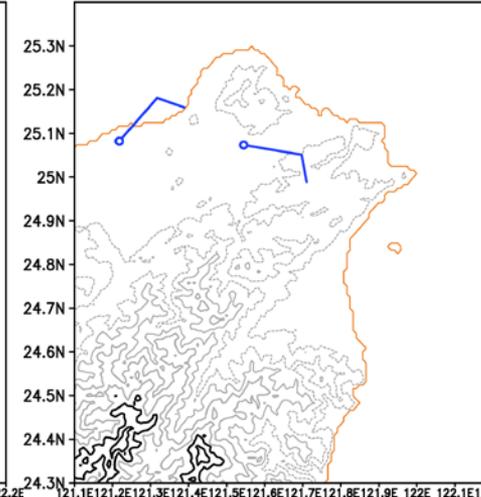
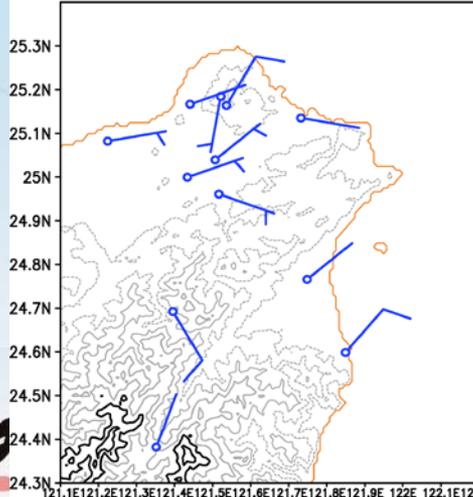
MDDS 5st Wind

Taipei, Ilan output



Taipei, Ilan ingest_metar

Taipei, Ilan ingest_newshp



Weo

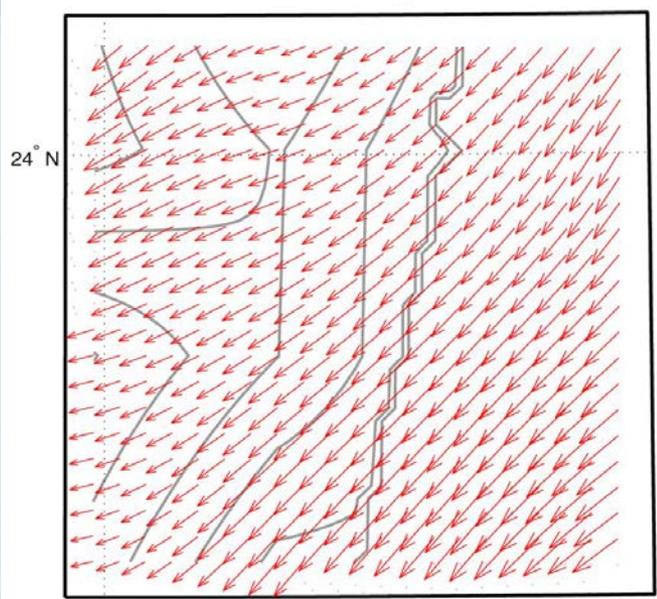


Astronomy

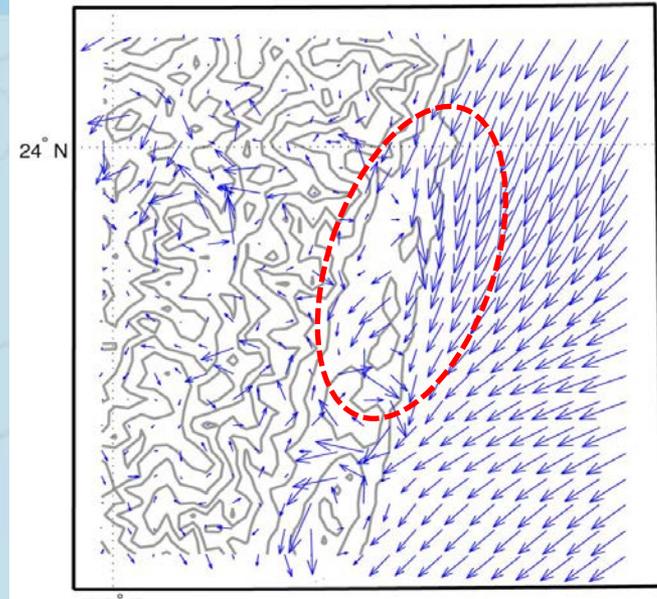
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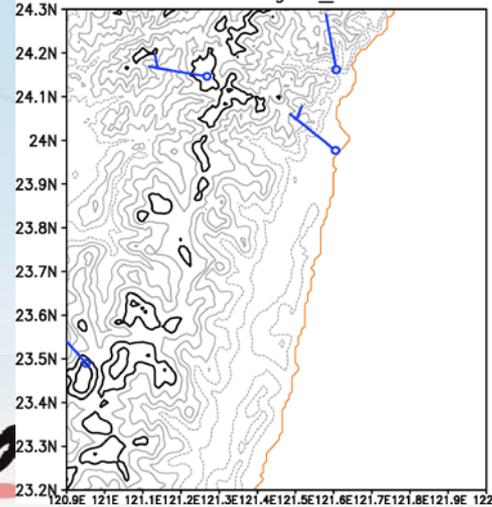
NCEP Wind
Hualien input



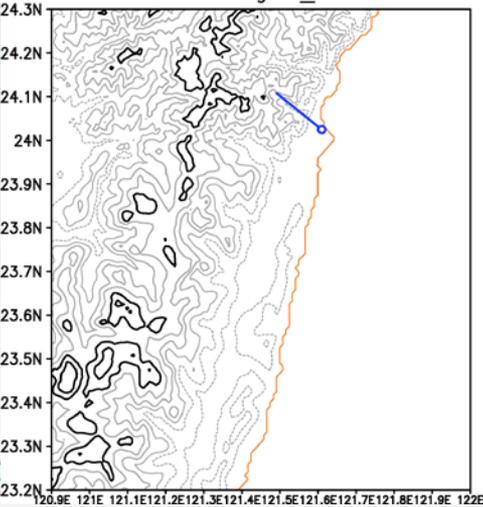
MDDS 5st Wind
Hualien output



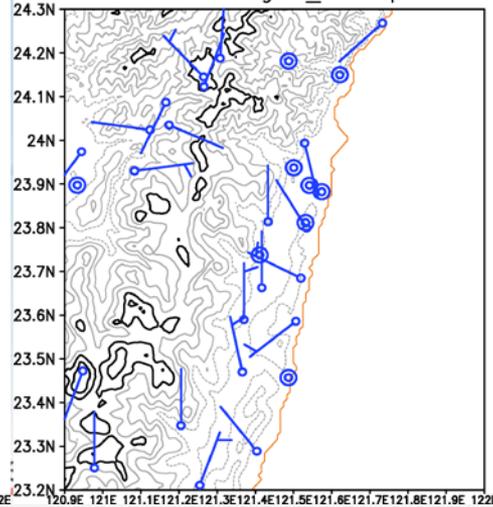
Hualien ingest_meso



Hualien ingest_metar



Hualien ingest_newshp



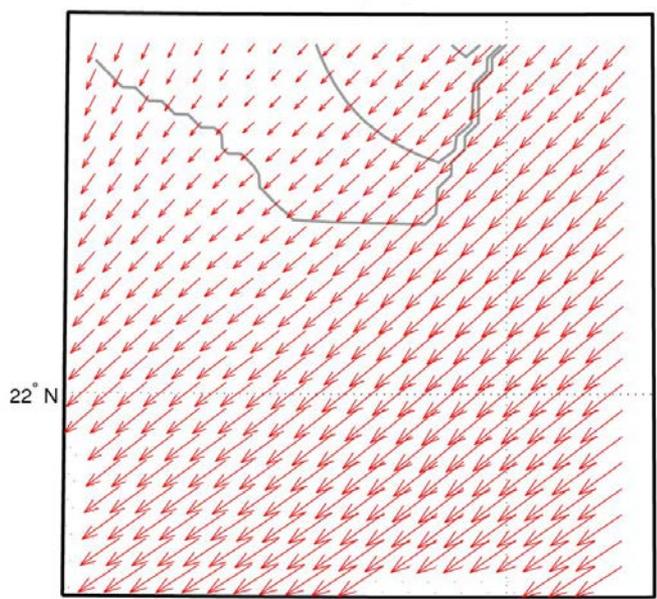
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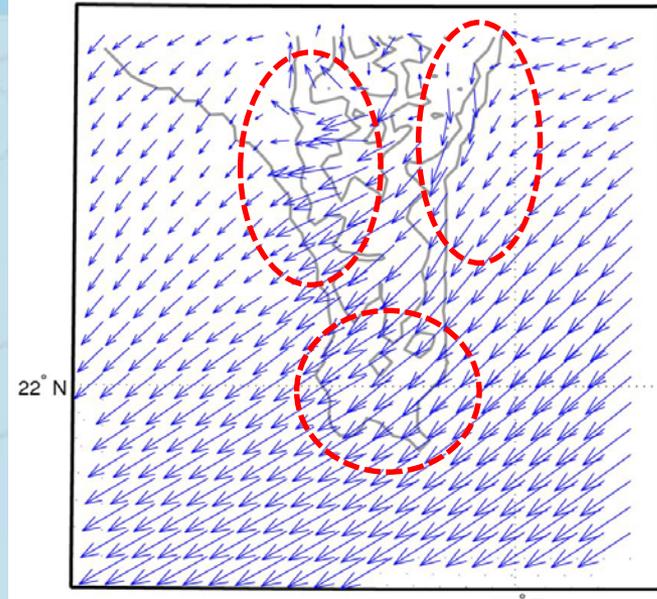
MDDS 實際案例測試-東北風



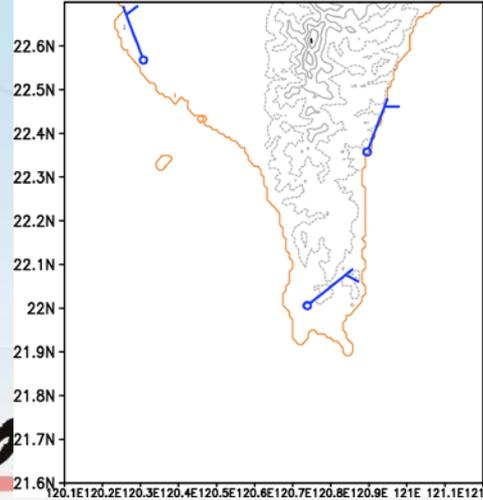
NCEP Wind
Kenting input



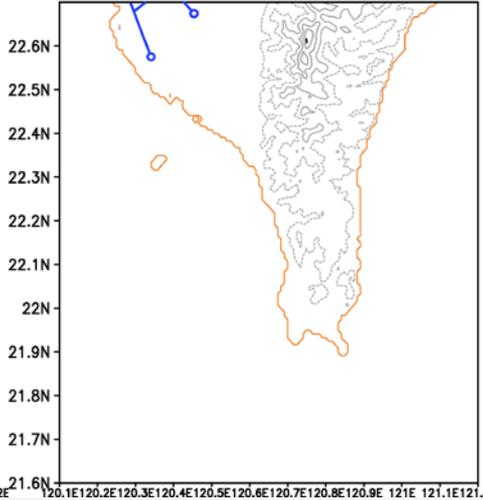
MDDS 5st Wind
Kenting output



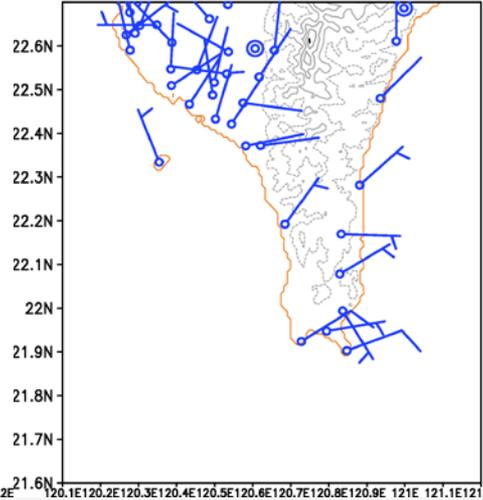
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Kenting ingest_metar



Kenting ingest_newshp



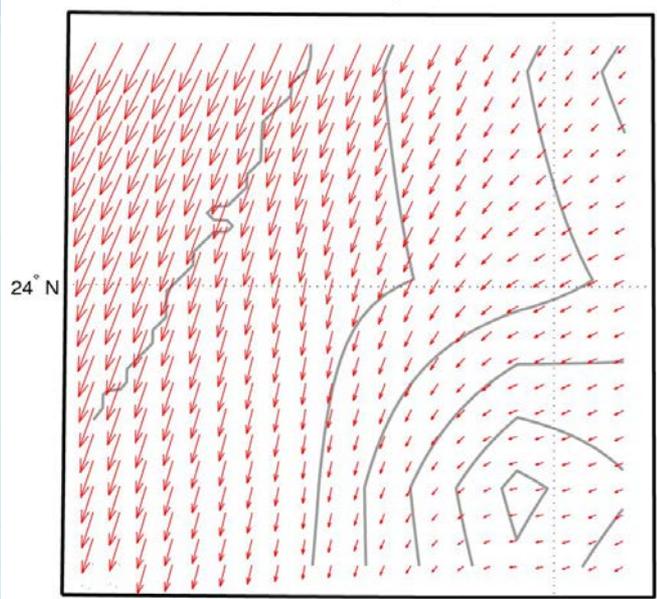
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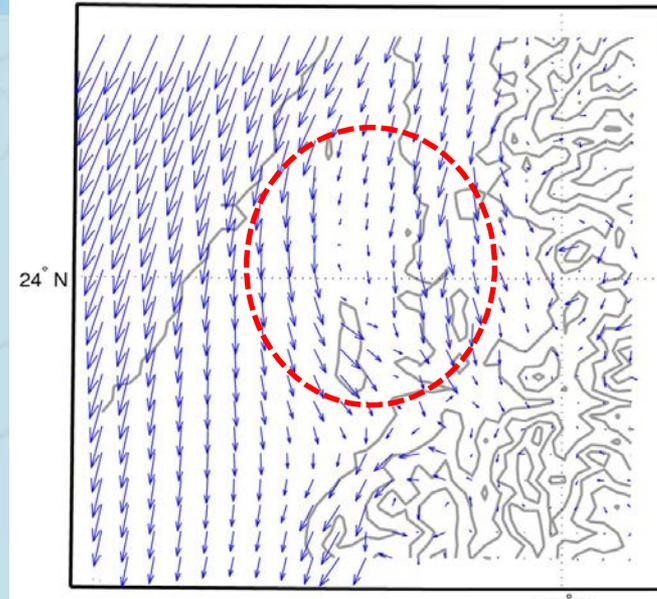
MDDS 實際案例測試-東北風



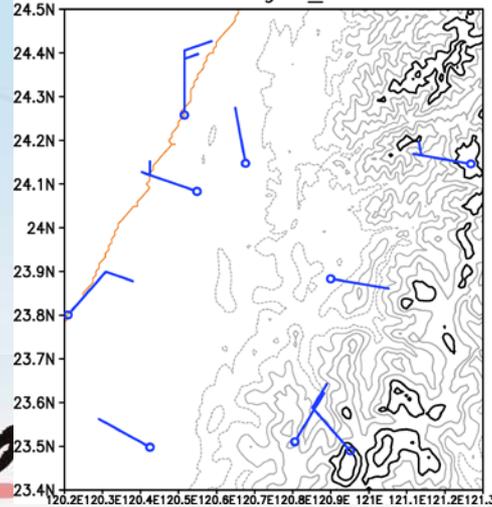
NCEP Wind
Nantou input



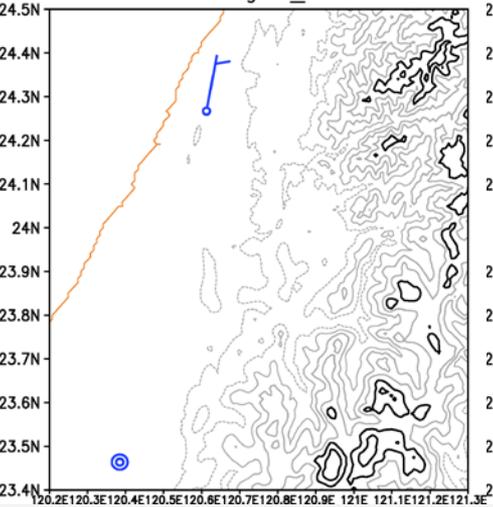
MDDS 5st Wind
Nantou output



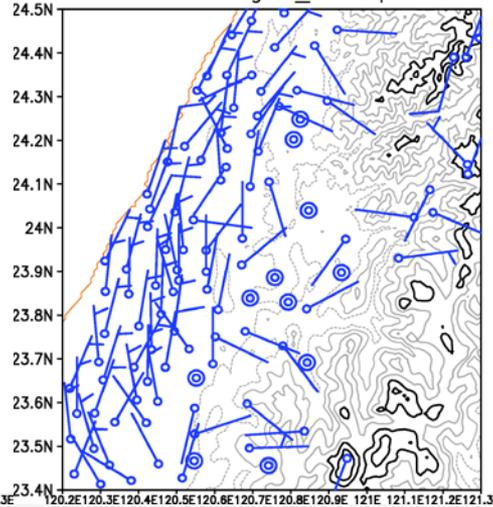
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Nanto ingest_metar



Nanto ingest_newshp

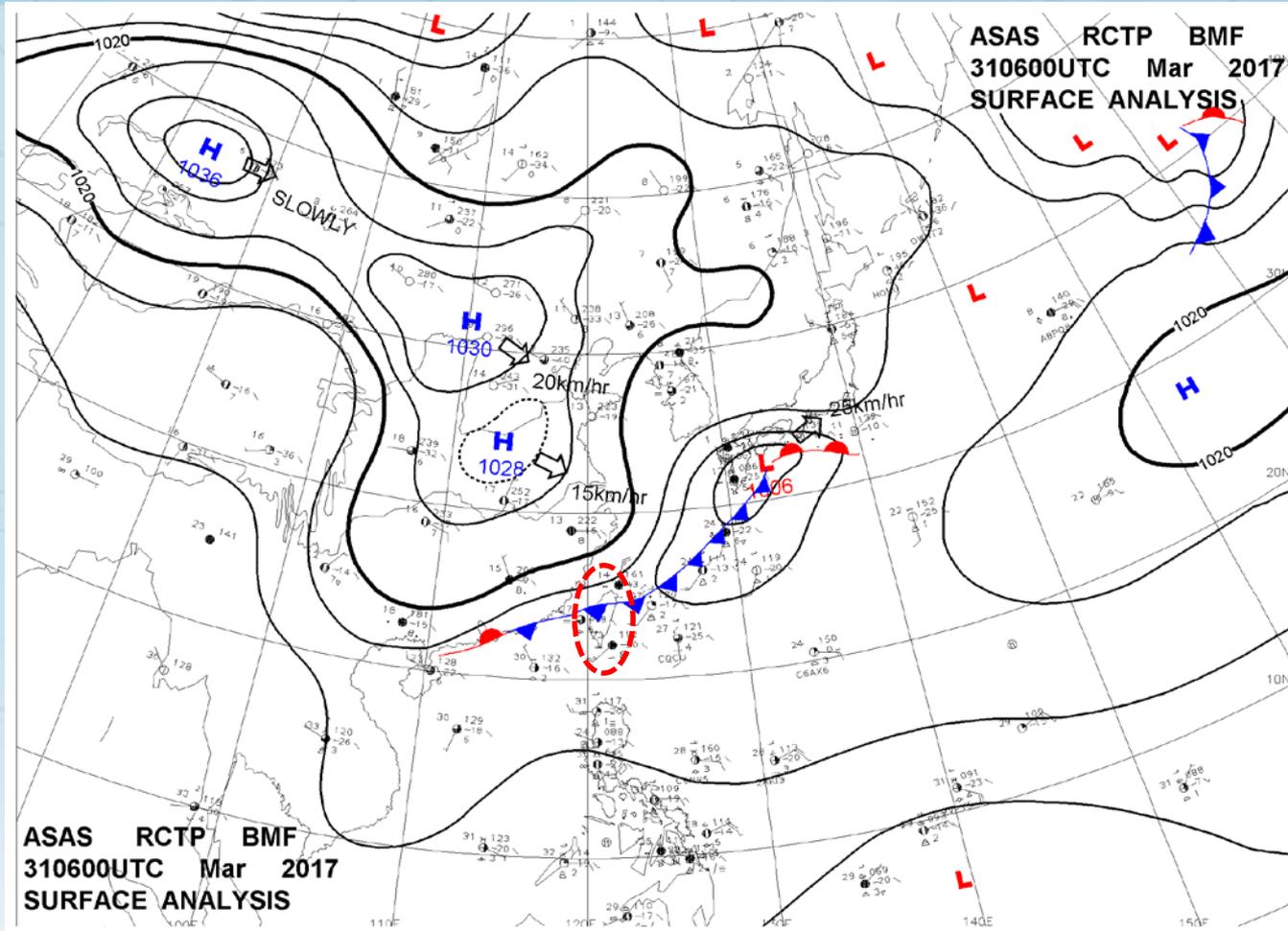


Weo



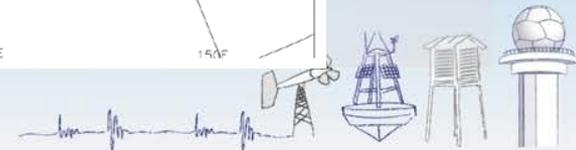
MDDS 實際案例測試-鋒面

2017/03/31 06Z UTC



Weather⁺

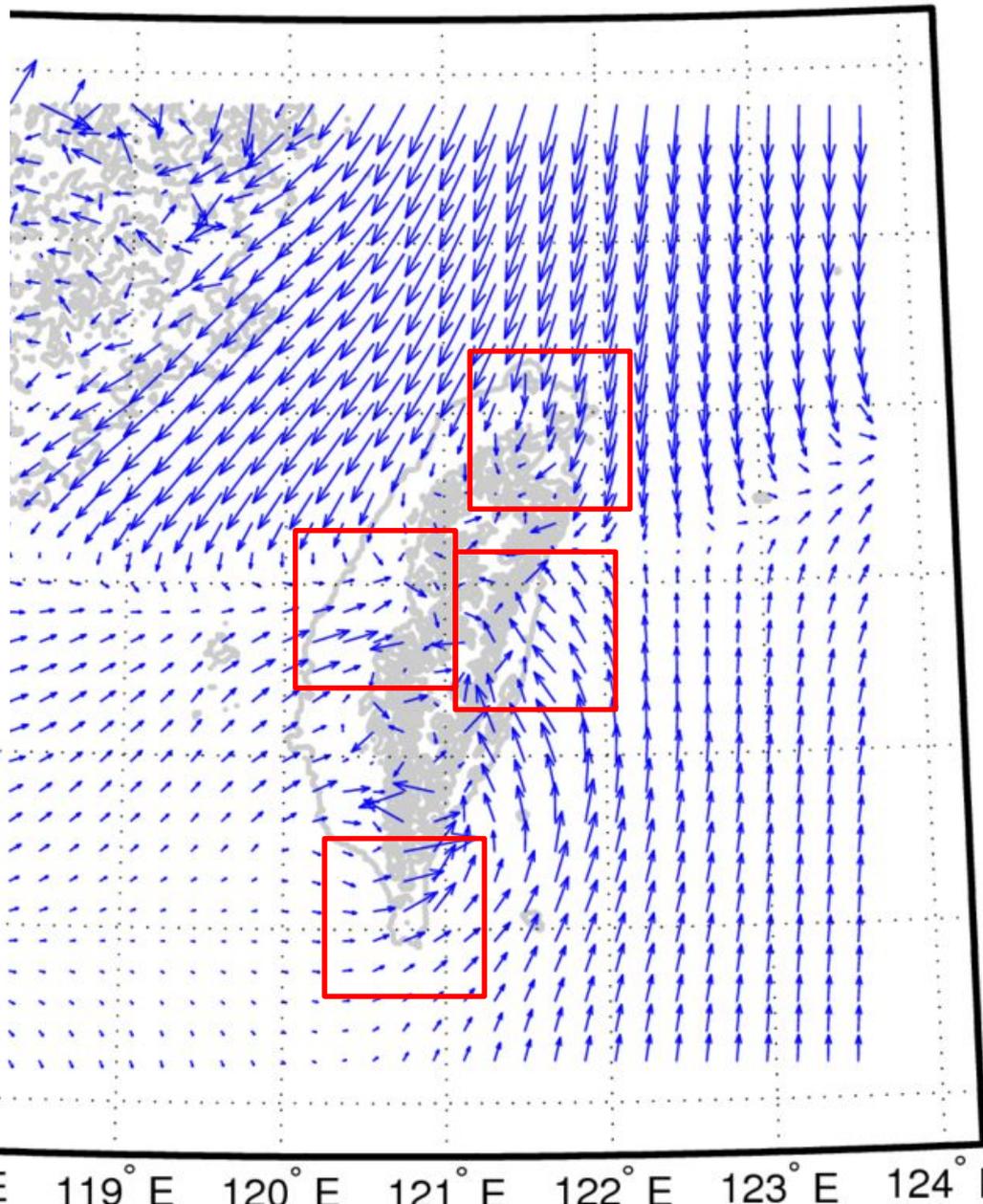
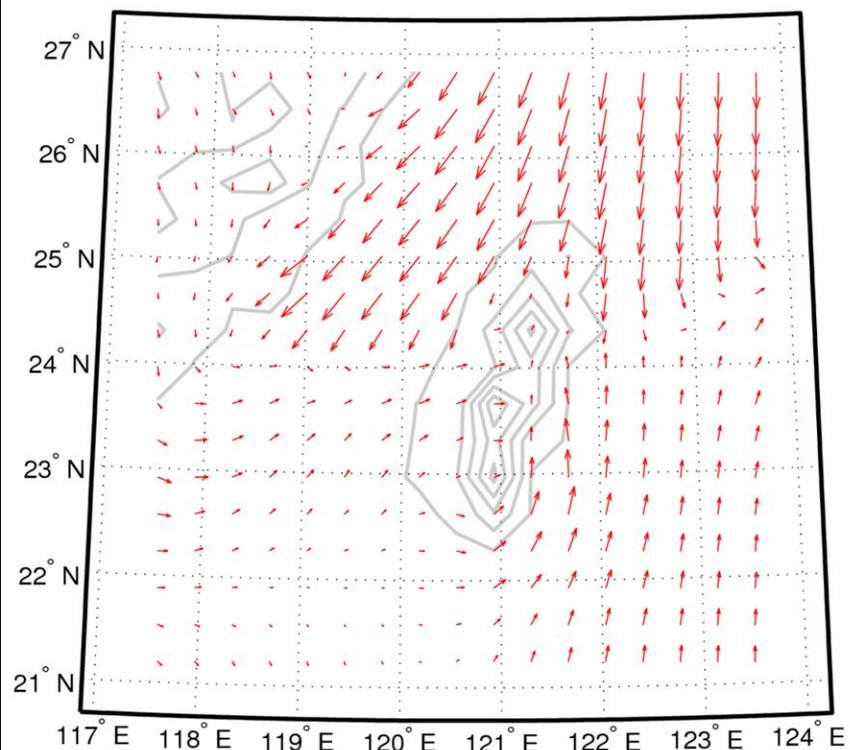
Service Observation Climate Forecasts Satellite Earthquakes Marine Radar Astronomy



After mdds last output 20170331 06Z f000

Wind Speed at 250m

Original NCEP/GFS 20170331 06Z f000
Wind Speed at 250m



→
NCEP Wind

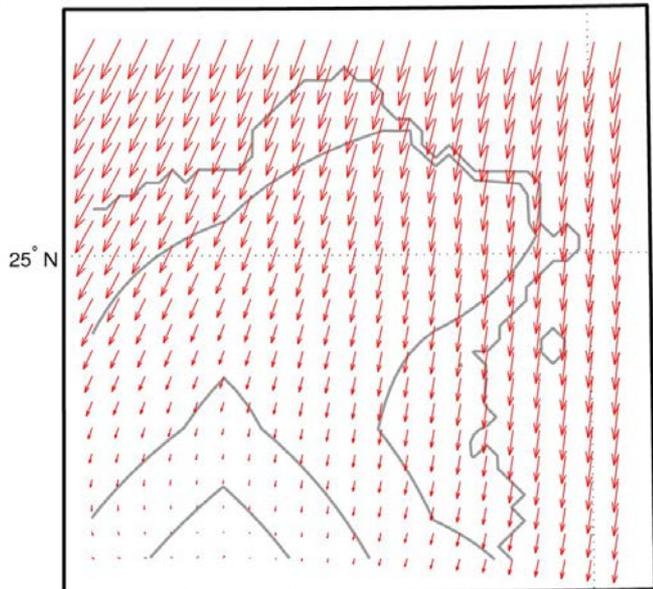
→
MDDS Wind

Weather
Ser

MDDS 實際案例測試-鋒面

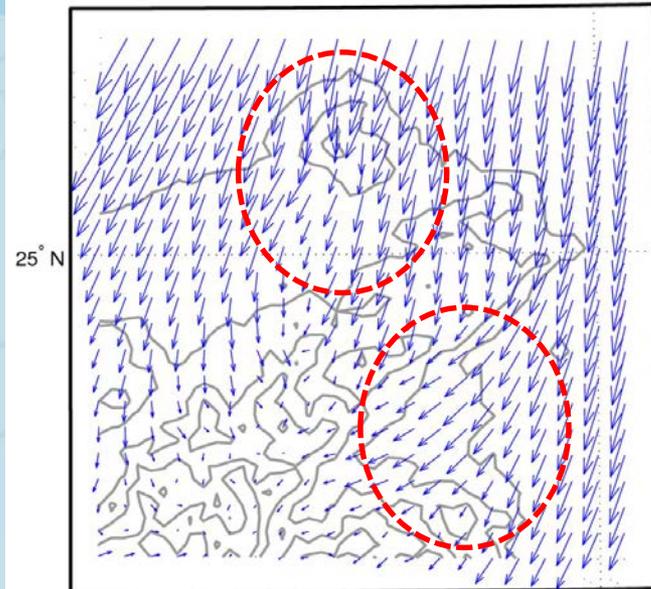


NCEP Wind
Taipei, Ilan input



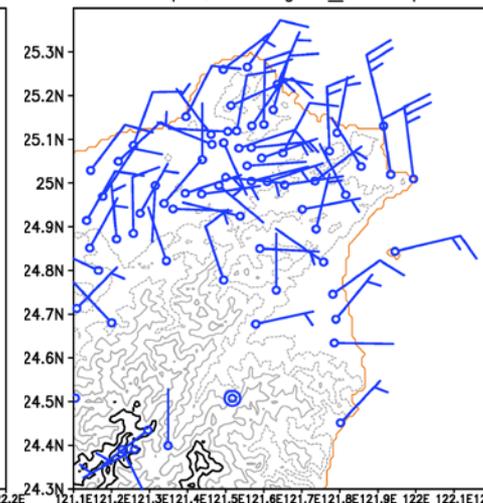
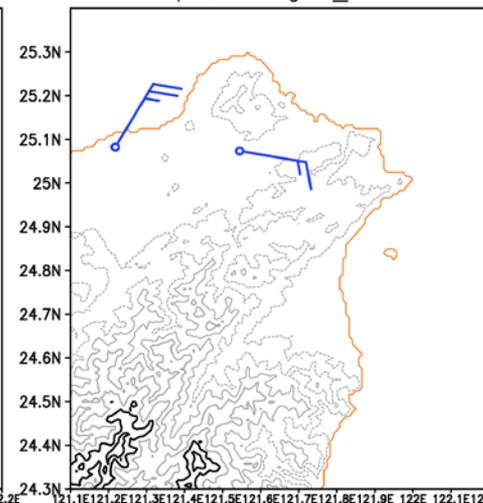
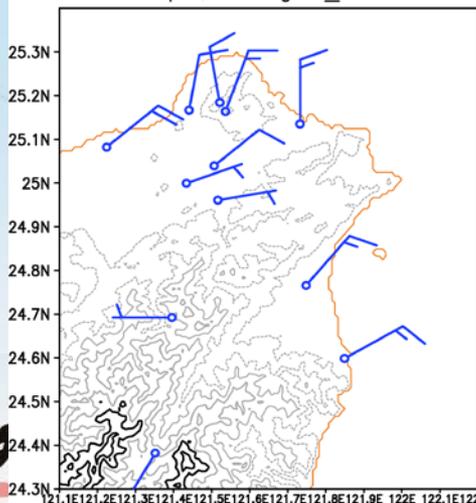
Taipei, Ilan ingest_meso

MDDS 5st Wind
Taipei, Ilan output



Taipei, Ilan ingest_metar

Taipei, Ilan ingest_newshp



Woo



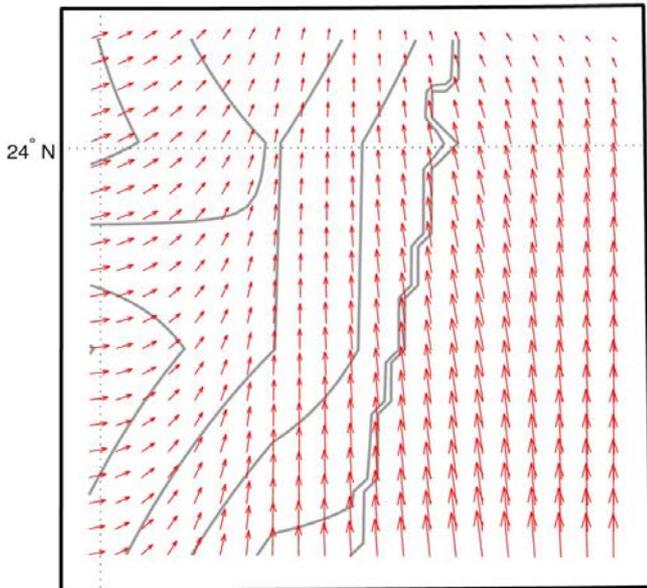
Astronomy

MDDS 實際案例測試-鋒面



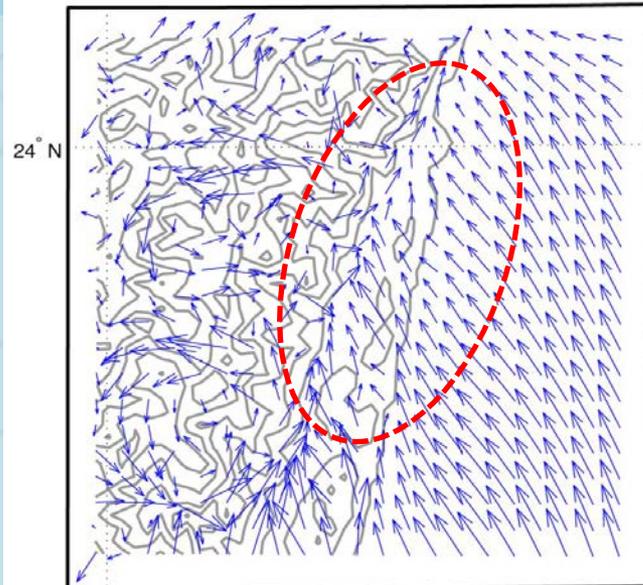
NCEP Wind

Hualien input

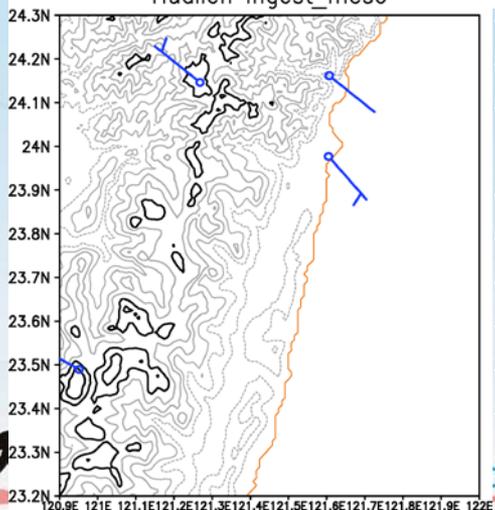


MDDS 5st Wind

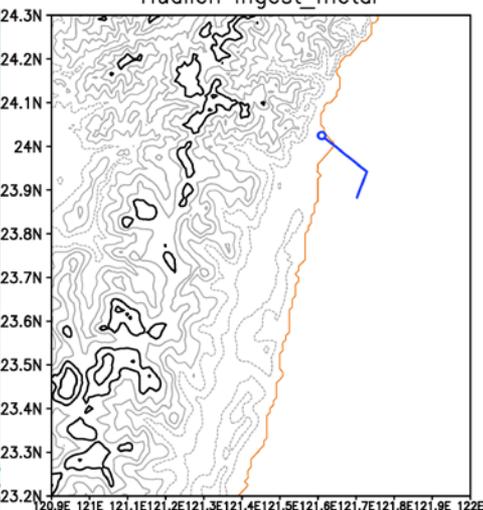
Hualien output



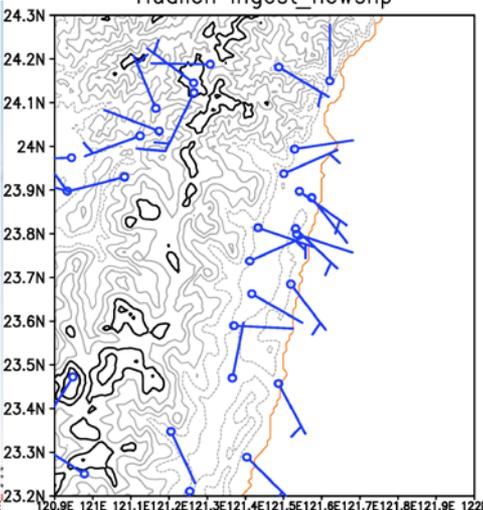
Hualien ingest_meso



Hualien ingest_metar



Hualien ingest_newshp



Wes

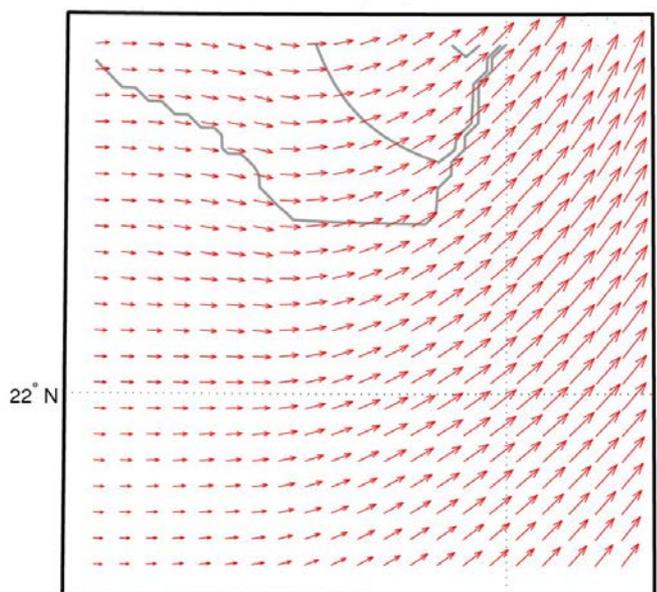


Astronomy

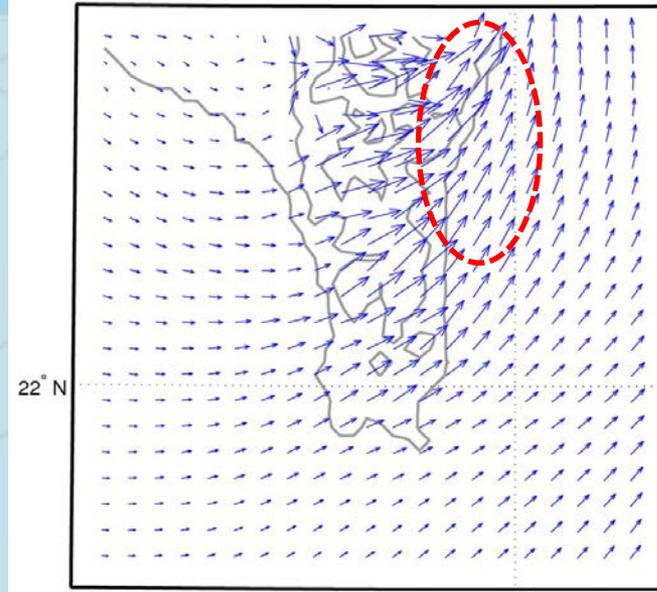
MDDS 實際案例測試-鋒面



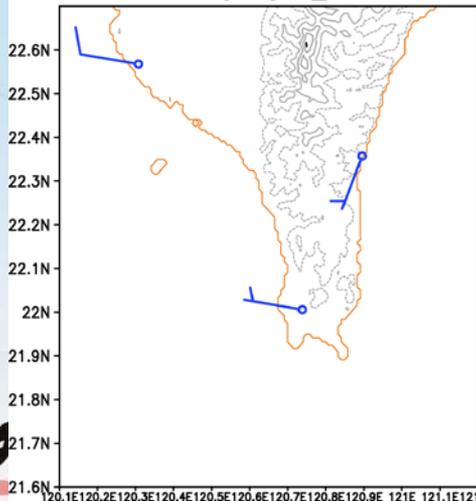
NCEP Wind
Kenting input



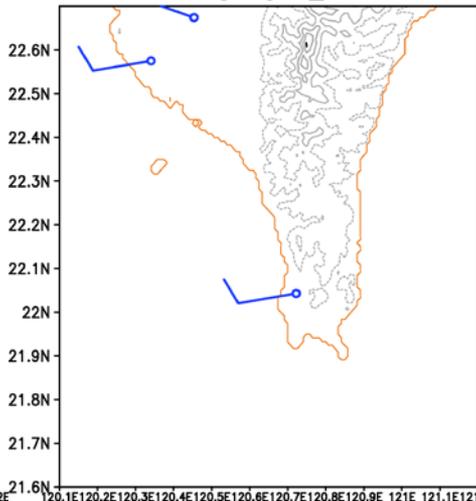
MDDS 5st Wind
Kenting output



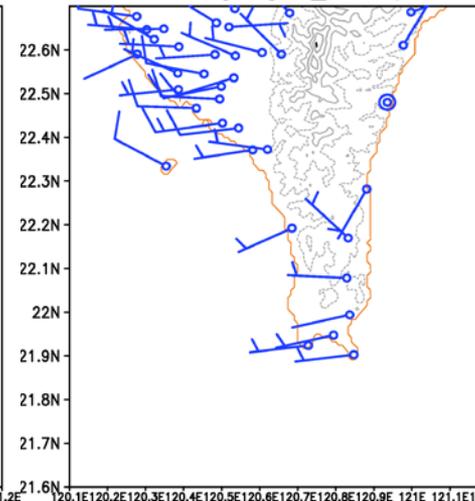
Kenting ingest_meso



Kenting ingest_metar



Kenting ingest_newshp



Wea



Astronomy



結論與未來展望

結論：

- 鍾形山及實際案例中，粗網格資料無法看到的地形效應經MDDS降尺度後，可以解析出應有的效應。
- MDDS結合統計降尺度和動力降尺度的優點，可以快速解析出因複雜地形下產生的較高解析度三維氣象場。

未來展望：

- 從多個實際的觀測中發現，MDDS仍然有一定的調整空間。例如解析出的風場繞山較強、過山較弱，需要對權重再調整。
- MDDS可以提供即時作業系統高解析度的三維氣象場。
- MDDS可以結合氣象局的實際觀測資料，以應用於分析研究。

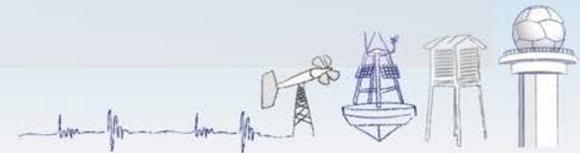




Thank you!

Weather⁺

Service Observation Climate Forecasts Satellite Earthquakes Marine Radar Astronomy





MDDS變分法之約束條件



三維
動量
方程

$$P_1 = R_d p_{00}^{-\kappa} (\bar{\theta}_v + \theta'_v) (\bar{p} + p')^{\kappa-1} \left(\frac{\partial p'}{\partial x} + \frac{J_1}{J_3} \frac{\partial p'}{\partial \eta} \right) + \left(u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + \mathcal{R} \frac{\partial u}{\partial \eta} \right) - fv$$

$$P_2 = R_d p_{00}^{-\kappa} (\bar{\theta}_v + \theta'_v) (\bar{p} + p')^{\kappa-1} \left(\frac{\partial p'}{\partial y} + \frac{J_2}{J_3} \frac{\partial p'}{\partial \eta} \right) + \left(u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + \mathcal{R} \frac{\partial v}{\partial \eta} \right) + fu$$

$$P_3 = \frac{R_d p_{00}^{-\kappa} \theta'_v p'^{\kappa-1}}{J_3} \frac{\partial p'}{\partial \eta} + \left(u \frac{\partial J_3 \mathcal{R}}{\partial x} + v \frac{\partial J_3 \mathcal{R}}{\partial y} + \mathcal{R} \frac{\partial J_3 \mathcal{R}}{\partial \eta} \right) - \left(u \frac{\partial J_1 u}{\partial x} + v \frac{\partial J_1 u}{\partial y} + \mathcal{R} \frac{\partial J_1 u}{\partial \eta} \right) - \left(u \frac{\partial J_2 v}{\partial x} + v \frac{\partial J_2 v}{\partial y} + \mathcal{R} \frac{\partial J_2 v}{\partial \eta} \right) - \frac{(\kappa-1)g}{\bar{p}} p' - \frac{g}{\theta'_v} \theta'$$

連續
方程

$$P_4 = (1-\kappa)p^{-1} \left(u \frac{\partial p'}{\partial x} + v \frac{\partial p'}{\partial y} + \mathcal{R} \frac{\partial p'}{\partial \eta} \right) - \frac{(1-\kappa)p^{-1}g}{R_d \bar{\theta}_v p_{00}^{-\kappa} \bar{p}^{\kappa-1}} (J_3 \mathcal{R} - J_1 u - J_2 v) + \left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial \mathcal{R}}{\partial \eta} - \frac{u}{J_3} \frac{\partial J_1}{\partial \eta} - \frac{v}{J_3} \frac{\partial J_2}{\partial \eta} + \frac{\mathcal{R}}{J_3} \frac{\partial J_3}{\partial \eta} \right)$$

熱力方程

$$P_5 = u \frac{\partial \theta'_v}{\partial x} + v \frac{\partial \theta'_v}{\partial y} + \mathcal{R} \frac{\partial \theta'_v}{\partial \eta} + \frac{1}{J_3} (J_3 \mathcal{R} - J_1 u - J_2 v) \frac{\partial \bar{\theta}_v}{\partial \eta}$$

水氣方程

$$P_6 = u \frac{\partial q'_v}{\partial x} + v \frac{\partial q'_v}{\partial y} + \mathcal{R} \frac{\partial q'_v}{\partial \eta} + \frac{1}{J_3} (J_3 \mathcal{R} - J_1 u - J_2 v) \frac{\partial \bar{q}_v}{\partial \eta}$$

Weather

