CWB GFS非靜力動力架構發展現況

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發展目的與方向

目的

- 全球非靜力動力模式已是現今各國作業中心發展重點
- 本局全球模式之水平解析度仍持續提升（T511L60 → T1279L80）

方向

- 穩定且可靠的非靜力動力架構
- 配合未來Unified model發展趨勢
- 利於與原有之靜力架構進行比較

動力架構之發展：淺層大氣非靜力動力系統 I

- 垂直座標：sigma-p
- 參考NCEP MSM所採用之擾動法，將非靜力效應加入模式中
- 方程式滿足角動量守恆、動量守恆、熱力守恆以及位勢能守恆
- 垂直通量由垂直速度方程式逐層求解
- 預報變數：$u, v, \hat{w}, \bar{T}, T', \bar{P}_s, lnp', q$

動力架構之發展：淺層大氣非靜力動力系統II

$$\frac{\partial u^*}{\partial t} = -m^2\frac{u^*}{a}\frac{\partial u^*}{\partial \lambda} - \frac{v^*}{a}\frac{\partial u^*}{\partial \mu} - \dot{\zeta}\frac{\partial u^*}{\partial \zeta} - RT\frac{\partial lnp}{a\partial \lambda} - \bar{p}g\frac{T}{\bar{T}}\frac{\partial r}{a\partial \lambda}\frac{\partial \zeta}{\partial \bar{p}}\frac{\partial lnp}{\partial \zeta} + f_s v^* + F_u$$

$$\frac{\partial v^*}{\partial t} = -m^2\frac{u^*}{a}\frac{\partial v^*}{\partial \lambda} - \frac{v^*}{a}\frac{\partial v^*}{\partial \mu} - \dot{\zeta}\frac{\partial v^*}{\partial \zeta} - cos^2\phi\, RT\frac{\partial lnp}{a\partial \mu} - cos^2\phi\,\bar{p}g\frac{T}{\bar{T}}\frac{\partial r}{a\partial \mu}\frac{\partial \zeta}{\partial \bar{p}}\frac{\partial lnp}{\partial \zeta} - f_s u^* - m^2\frac{u^{*2} + v^{*2}}{a}sin\,\phi + F_v$$

$$\frac{\partial w}{\partial t} = -m^2\frac{u^*}{a}\frac{\partial w}{\partial \lambda} - \frac{v^*}{a}\frac{\partial w}{\partial \mu} - \dot{\zeta}\frac{\partial w}{\partial \zeta} + \bar{p}g\frac{T}{\bar{T}}\frac{\partial \zeta}{\partial \bar{p}}\frac{\partial lnp}{\partial \zeta} - g + F_w$$

$$\frac{\partial}{\partial t}\left(\frac{\partial \bar{p}}{\partial \zeta}\right) + m^2\frac{1}{a}\frac{\partial}{\partial \lambda}\left(u^*\frac{\partial \bar{p}}{\partial \zeta}\right) + \frac{1}{a}\frac{\partial}{\partial \mu}\left(v^*\frac{\partial \bar{p}}{\partial \zeta}\right) + \frac{\partial}{\partial \zeta}\left(\dot{\zeta}\frac{\partial \bar{p}}{\partial \zeta}\right) = 0$$

$$\frac{\partial T}{\partial t} = -m^2 u^*\frac{\partial T}{a\partial \lambda} - v^*\frac{\partial T}{a\partial \mu} - \dot{\zeta}\frac{\partial T}{\partial \zeta} + kT\frac{dlnp}{dt} + \frac{F_T}{C_p}$$

Unknow?

$$\frac{\partial \bar{T}}{\partial t} = -m^2 u^*\frac{\partial \bar{T}}{a\partial \lambda} - v^*\frac{\partial \bar{T}}{a\partial \mu} - \dot{\zeta}\frac{\partial \bar{T}}{\partial \zeta} + \frac{k\bar{T}}{\bar{p}}\frac{d\bar{p}}{dt}$$

$$k = \frac{R}{C_p}$$

$$\frac{p}{RT} = \rho = \frac{\bar{p}}{R\bar{T}}$$

$$\left(\frac{\partial}{\partial r}\right)_{\lambda,\phi,t} = \frac{\partial \zeta}{\partial r}\left(\frac{\partial}{\partial \zeta}\right)_{\lambda,\phi,t} = -\frac{\bar{p}g}{R\bar{T}}\frac{\partial \zeta}{\partial \bar{p}}\left(\frac{\partial}{\partial \zeta}\right)_{\lambda,\phi,t}$$

$$\left(\frac{\partial}{\partial s}\right)_r = \left(\frac{\partial}{\partial s}\right)_s - \left(\frac{\partial r}{\partial s}\right)_s\left(\frac{\partial \zeta}{\partial r}\right)\left(\frac{\partial}{\partial \zeta}\right)_{\lambda,\phi,t} = \left(\frac{\partial}{\partial s}\right)_s + \left(\frac{\partial r}{\partial s}\right)_s\frac{\bar{p}g}{R\bar{T}}\frac{\partial \zeta}{\partial \bar{p}}\left(\frac{\partial}{\partial \zeta}\right)_{\lambda,\phi,t}$$

$$u^* = u\cos\phi$$

$$v^* = v\cos\phi$$

$$f_s = 2\Omega\sin\phi$$

$$\Delta\mu = \cos\phi\,\Delta\phi = \Delta sin\phi = cos^2\phi\,\Delta\varphi$$

$$m^2 = \frac{1}{cos^2\phi}$$

動力架構之發展：垂直離散式 I

將垂直梯度的項次改寫為差分形式，而此差分形式能滿足角動量守恆以及動量守恆，方程式的改寫仍可保有原始方程式的特性並且不會使得能量散失。

地面氣壓趨勢方程：

$$\frac{\partial}{\partial t}\left(\frac{\partial p}{\partial \zeta}\right)+m^2\frac{1}{a}\frac{\partial}{\partial\lambda}\left(u^*\frac{\partial p}{\partial\zeta}\right)+\frac{1}{a}\frac{\partial}{\partial\mu}\left(v^*\frac{\partial p}{\partial\zeta}\right)+\frac{\partial}{\partial\zeta}\left(\dot\zeta\frac{\partial p}{\partial\zeta}\right)=0$$

$$\Rightarrow \frac{\partial \bar p_s}{\partial t} = \sum_{i=1}^{K}\Delta B_i\left[m^2u^*\frac{\partial \bar p_s}{a\partial\lambda}+v^*\frac{\partial\bar p_s}{a\partial\mu}\right]_i+\sum_{i=1}^{K}(\Delta A+\Delta B\bar p_s)_i D_i$$

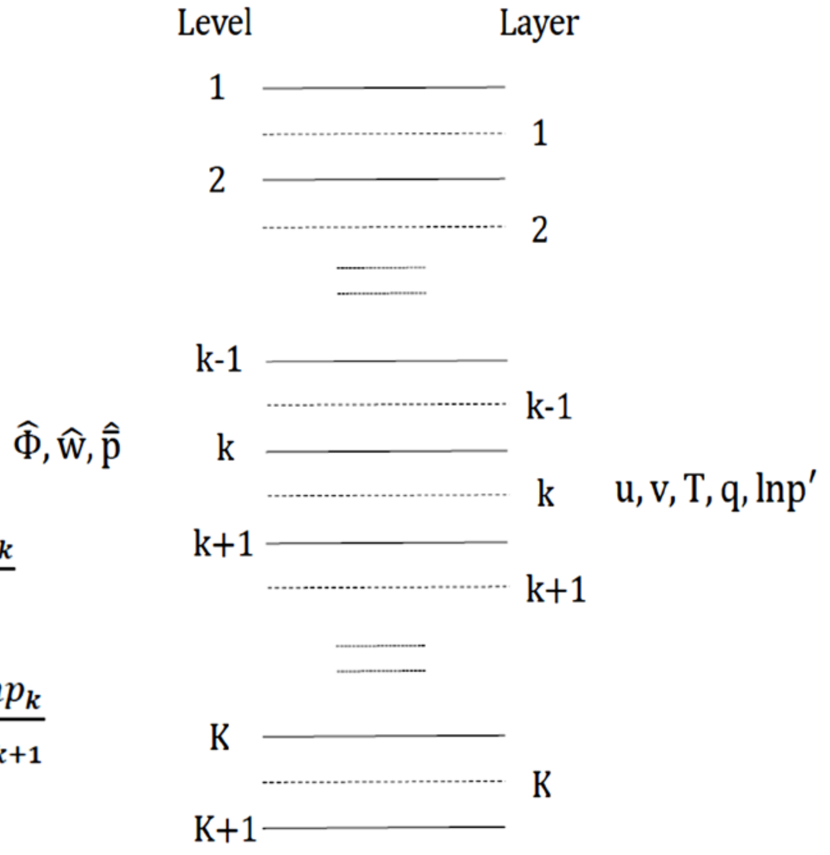
$$D = m^2\frac{\partial u^*}{a\partial\lambda}+\frac{\partial v^*}{a\partial\mu}$$

模式層與介面層之間的靜力關係式：

$$\sum_{i=1}^{K}\left[(\hat{\bar p}_i-\hat{\bar p}_{i+1})\left(RT\frac{\partial \ln p}{\partial\lambda}\right)_i-\Phi_i\left(\frac{\partial\hat p_i}{\partial\lambda}-\frac{\partial\hat p_{i+1}}{\partial\lambda}\right)\right]=-\left(\Phi\frac{\partial p}{\partial\lambda}\right)_T+\left(\Phi\frac{\partial p}{\partial\lambda}\right)_s \Rightarrow$$

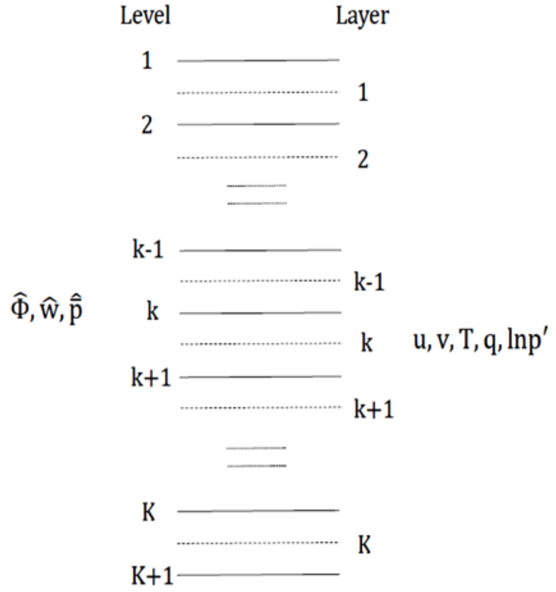
$$\Phi_k-\hat\Phi_k=(RT)_k(\hat{\bar p}_k-\hat{\bar p}_{k+1})\frac{\partial \ln p_k}{\partial \hat p_k}$$

$$\hat\Phi_{k+1}-\Phi_k=(RT)_k(\hat{\bar p}_k-\hat{\bar p}_{k+1})\frac{\partial \ln p_k}{\partial \hat p_{k+1}}$$



動力架構之發展：垂直離散式 II

由水平方向動量守恆過程進一步求得靜力氣壓之趨勢方程式以及重力位高度方程式：



$$\left(\frac{d\bar{p}}{dt}\right)_k = p_k\left[\frac{\partial \ln p_k}{\partial \hat{p}_{k+1}}\frac{\partial \hat{\bar{p}}_{k+1}}{\partial t} + \frac{\partial \ln p_k}{\partial \hat{p}_k}\frac{\partial \hat{\bar{p}}_k}{\partial t}\right] + \left(\mathrm{m}^2 u^* \frac{\partial \bar{p}}{a\partial\lambda} + v^*\frac{\partial \bar{p}}{a\partial\mu}\right)_k + p_k\left[\frac{\partial \ln p_k}{\partial \hat{p}_{k+1}}\left(\widehat{\dot{\zeta}\frac{\partial p}{\partial \zeta}}\right)_{k+1} + \frac{\partial \ln p_k}{\partial \hat{p}_k}\left(\widehat{\dot{\zeta}\frac{\partial p}{\partial \zeta}}\right)_k\right]$$

$$\frac{\partial \bar{p}_k}{\partial t} \qquad\qquad \left(\dot{\zeta}\frac{\partial p}{\partial \zeta}\right)_k$$

$$\Rightarrow \left(\frac{d\bar{p}}{dt}\right)_k = \frac{1}{2}(\hat{B}_k + \hat{B}_{k+1})\left[\sum_{i=1}^{K}\Delta B_i\left(m^2 u^*\frac{\partial \bar{p}_s}{a\partial\lambda} + v^*\frac{\partial \bar{p}_s}{a\partial\mu}\right)_i + \sum_{i=1}^{K}(\hat{\bar{p}}_{0i} - \hat{\bar{p}}_{0i+1})D_i + \left(m^2 u^*\frac{\partial \bar{p}_s}{a\partial\lambda} + v^*\frac{\partial \bar{p}_s}{a\partial\mu}\right)_k\right] + \frac{1}{2}\left[\left(\widehat{\dot{\zeta}\frac{\partial p}{\partial \zeta}}\right)_k + \left(\widehat{\dot{\zeta}\frac{\partial p}{\partial \zeta}}\right)_{k+1}\right]$$

$$\hat{\Phi}_k = \Phi_s + 2\sum_{i=K}^{k}(R\bar{T})_i\frac{\hat{\bar{p}}_{i+1} - \hat{\bar{p}}_i}{\hat{\bar{p}}_{i+1} + \hat{\bar{p}}_i}$$

由三維動量守恆過程求得完全氣壓之趨勢方程式：

$$\left(\frac{d\ln p}{dt}\right)_k = -\frac{C_p}{C_v}\left[\left(m^2\frac{\partial u^*}{a\partial\lambda} + \frac{\partial v^*}{a\partial\mu}\right)_k - \frac{\hat{\bar{p}}_k + \hat{\bar{p}}_{k+1}}{2(R\bar{T})_k(\hat{\bar{p}}_k - \hat{\bar{p}}_{k+1})}\left[m^2\frac{u_k^* - u_{k-1}^*}{2}\frac{\partial \hat{\Phi}_k}{a\partial\lambda} + \frac{v_k^* - v_{k-1}^*}{2}\frac{\partial \hat{\Phi}_k}{a\partial\mu} - m^2\frac{u_k^* - u_{k+1}^*}{2}\frac{\partial \hat{\Phi}_{k+1}}{a\partial\lambda} - \frac{v_k^* - v_{k+1}^*}{2}\frac{\partial \hat{\Phi}_{k+1}}{a\partial\mu} + g(\hat{w}_k - \hat{w}_{k+1})\right]\right]$$

動力架構之發展：垂直通量

$$\hat{w} = \frac{1}{g}\left(\frac{\partial\hat{\Phi}}{\partial t} + \widehat{V_H \cdot \nabla_H}\Phi - \frac{\widehat{R\overline{T}}}{\overline{p}}\dot{\zeta}\frac{\partial\overline{p}}{\partial\zeta}\right) \Longleftarrow \hat{\Phi}_k = \Phi_s + 2\sum_{i=K}^{k}(R\overline{T})_i\frac{\hat{\overline{p}}_{i+1} - \hat{\overline{p}}_i}{\hat{\overline{p}}_{i+1} + \hat{\overline{p}}_i}$$

$$\frac{R}{g}\left(\frac{\overline{T}_{k-1} + \overline{T}_k}{2\hat{\overline{p}}_k} - \frac{\overline{T}_{k-1} - \overline{T}_k}{\hat{\overline{p}}_{k+1} + \hat{\overline{p}}_k} - \frac{2(k\overline{T})_k(\hat{\overline{p}}_{k+1} - \hat{\overline{p}}_k)}{(\hat{\overline{p}}_{k+1} + \hat{\overline{p}}_k)^2}\right)\left(\widehat{\dot{\zeta}\frac{\partial\overline{p}}{\partial\zeta}}\right)_k$$

$$= H_k - \hat{w}_k + \frac{R}{g}\sum_{i=K}^{k+1}\left(\frac{\overline{T}_{i-1} - \overline{T}_i}{\hat{\overline{p}}_{i+1} + \hat{\overline{p}}_i} + \frac{2(k\overline{T})_i(\hat{\overline{p}}_{i+1} - \hat{\overline{p}}_i)}{(\hat{\overline{p}}_{i+1} + \hat{\overline{p}}_i)^2}\right)\left(\widehat{\dot{\zeta}\frac{\partial\overline{p}}{\partial\zeta}}\right)_i + \frac{R}{g}\sum_{i=K}^{k}\left(\frac{\overline{T}_i - \overline{T}_{i+1}}{\hat{\overline{p}}_{i+1} + \hat{\overline{p}}_i} + \frac{2(k\overline{T})_i(\hat{\overline{p}}_{i+1} - \hat{\overline{p}}_i)}{(\hat{\overline{p}}_{i+1} + \hat{\overline{p}}_i)^2}\right)\left(\widehat{\dot{\zeta}\frac{\partial\overline{p}}{\partial\zeta}}\right)_{i+1}$$

$$H_k = \frac{2}{g}\sum_{i=K}^{k}\left[R\frac{\hat{\overline{p}}_{i+1} - \hat{\overline{p}}_i}{\hat{\overline{p}}_{i+1} + \hat{\overline{p}}_i}\left(\frac{\partial\overline{T}}{\partial t}\right)_i^h + 2\frac{(R\overline{T})_i}{(\hat{\overline{p}}_{i+1} + \hat{\overline{p}}_i)^2}\left[\hat{\overline{p}}_i\frac{\partial\hat{\overline{p}}_{i+1}}{\partial t} - \hat{\overline{p}}_{i+1}\frac{\partial\hat{\overline{p}}_i}{\partial t}\right]\right] + \frac{1}{g}\left(V_H \cdot \widehat{\nabla_H}\Phi\right)_k$$

$$\left(\widehat{\dot{\zeta}\frac{\partial\overline{p}}{\partial\zeta}}\right)_1 = \left(\widehat{\dot{\zeta}\frac{\partial\overline{p}}{\partial\zeta}}\right)_{K+1} = 0$$

動力架構之發展：擾動法

$$lnp = ln\bar{p} + lnp' \quad \Rightarrow \ln p' = lnp - ln\bar{p}$$

$$\left(\frac{\partial lnp'}{\partial t}\right)_k = -m^2 u^*{}_k \left(\frac{\partial lnp'}{a\partial\lambda}\right)_k - v^*{}_k \left(\frac{\partial lnp'}{a\partial\mu}\right)_k - \left(\dot{\zeta}\frac{\partial lnp'}{\partial\zeta}\right)_k$$

$$-\frac{C_p}{C_v}\left[\left(m^2\frac{\partial u^*}{a\partial\lambda} + \frac{\partial v^*}{a\partial\mu}\right)_k\right.$$

$$\left.-\frac{(\hat{A}_{k+1}+\hat{A}_k)+(\hat{B}_{k+1}+\hat{B}_k)\bar{p}_s}{2(R\bar{T})_k[(\hat{A}_k-\hat{A}_{k+1})+(\hat{B}_k-\hat{B}_{k+1})\bar{p}_s]}\left[m^2\frac{u_k^*-u_{k-1}^*}{2}\frac{\partial\hat{\Phi}_k}{a\partial\lambda} + m^2\frac{u_{k+1}^*-u_k^*}{2}\frac{\partial\hat{\Phi}_{k+1}}{a\partial\lambda} + \frac{v_k^*-v_{k-1}^*}{2}\frac{\partial\hat{\Phi}_k}{a\partial\mu} + \frac{v_{k+1}^*-v_k^*}{2}\frac{\partial\hat{\Phi}_{k+1}}{a\partial\mu} + g(\hat{w}_k-\hat{w}_{k+1})\right]\right]$$

$$-\frac{2}{\hat{\bar{p}}_k+\hat{\bar{p}}_{k+1}}\left(\frac{d\bar{p}}{dt}\right)_{k,}$$

$$T = \bar{T} + T' \Rightarrow T' = T - \bar{T}$$

$$\left(\frac{\partial T'}{\partial t}\right)_k = \left[-m^2u^*\frac{\partial(\bar{T}+T')}{a\partial\lambda} - v^*\frac{\partial(\bar{T}+T')}{a\partial\mu} - \dot{\zeta}\frac{\partial(\bar{T}+T')}{\partial\zeta}\right]_k + k(\bar{T}+T')_k\left(\frac{dlnp}{dt}\right)_k + \frac{F_T}{C_p} - \left(\frac{\partial\bar{T}}{\partial t}\right)_k$$

動力架構之發展：最終方程式 I

$$\left(\frac{\partial u^*}{\partial t}\right)_k = -m^2 u^*_k \left(\frac{\partial u^*}{a\partial\lambda}\right)_k - v^*_k \left(\frac{\partial u^*}{a\partial\mu}\right)_k - \frac{1}{2(\hat{\bar{p}}_k - \hat{\bar{p}}_{k+1})}\left[\overline{\overline{\begin{matrix}(u^*_{k-1} - u^*_k)\left(\dot{\zeta}\frac{\partial \bar{p}}{\partial \zeta}\right)_k \\ +(u^*_k - u^*_{k+1})\left(\dot{\zeta}\frac{\partial \bar{p}}{\partial \zeta}\right)_{k+1}\end{matrix}}}\right] - R(\bar{T} + T')_k \left[\frac{\hat{B}_k + \hat{B}_{k+1}}{\hat{\bar{p}}_k + \hat{\bar{p}}_{k+1}}\frac{\partial \bar{p}_s}{a\partial\lambda} + \left(\frac{\partial \ln p'}{a\partial\lambda}\right)_k\right]$$

$$-\frac{1}{2}\left(1 + \frac{T'}{\bar{T}}\right)_k \left(\frac{\partial\hat{\Phi}_k}{a\partial\lambda} + \frac{\partial\hat{\Phi}_{k+1}}{a\partial\lambda}\right)\left[1 + \frac{1}{2(\hat{\bar{p}}_k - \hat{\bar{p}}_{k+1})}\left(\overline{\overline{\begin{matrix}(\ln p'_{k-1} - \ln p'_k)\hat{\bar{p}}_k \\ +(\ln p'_k - \ln p'_{k+1})\hat{\bar{p}}_{k+1}\end{matrix}}}\right)\right] + f_s v^*_k + F_u$$

$$\left(\frac{\partial v^*}{\partial t}\right)_k = -m^2 u^*_k \left(\frac{\partial v^*}{a\partial\lambda}\right)_k - v^*_k \left(\frac{\partial v^*}{a\partial\mu}\right)_k - \frac{1}{2(\hat{\bar{p}}_k - \hat{\bar{p}}_{k+1})}\left[\overline{\overline{\begin{matrix}(v^*_{k-1} - v^*_k)\left(\dot{\zeta}\frac{\partial \bar{p}}{\partial \zeta}\right)_k \\ +(v^*_k - v^*_{k+1})\left(\dot{\zeta}\frac{\partial \bar{p}}{\partial \zeta}\right)_{k+1}\end{matrix}}}\right] - \cos^2\phi\, R(\bar{T} + T')_k \left[\frac{\hat{B}_k + \hat{B}_{k+1}}{\hat{\bar{p}}_k + \hat{\bar{p}}_{k+1}}\frac{\partial \bar{p}_s}{a\partial\mu} + \left(\frac{\partial \ln p'}{a\partial\mu}\right)_k\right]$$

$$-\cos^2\phi\left(1 + \frac{T'}{\bar{T}}\right)_k \frac{1}{2}\left(\frac{\partial\hat{\Phi}_k}{a\partial\mu} + \frac{\partial\hat{\Phi}_{k+1}}{a\partial\mu}\right)\left[1 + \frac{1}{2(\hat{\bar{p}}_k - \hat{\bar{p}}_{k+1})}\left(\overline{\overline{\begin{matrix}(\ln p'_{k-1} - \ln p'_k)\hat{\bar{p}}_k \\ +(\ln p'_k - \ln p'_{k+1})\hat{\bar{p}}_{k+1}\end{matrix}}}\right)\right] - f_s u^*_k - m^2\frac{u^{*2}_k + v^{*2}_k}{a}\sin\phi + F_v$$

$$\left(\frac{\partial\hat{w}}{\partial t}\right)_k = -m^2\frac{u^*_k + u^*_{k-1}}{2}\left(\frac{\partial\hat{w}}{a\partial\lambda}\right)_k - \frac{v^*_k + v^*_{k-1}}{2}\left(\frac{\partial\hat{w}}{a\partial\mu}\right)_k - \overline{\overline{\frac{1}{2}\left(\dot{\zeta}\frac{\partial\bar{p}}{\partial\zeta}\right)_k\left(\frac{\hat{w}_{k-1} - \hat{w}_k}{\hat{\bar{p}}_{k-1} - \hat{\bar{p}}_k} + \frac{\hat{w}_k - \hat{w}_{k+1}}{\hat{\bar{p}}_k - \hat{\bar{p}}_{k+1}}\right)}} + g\left(1 + \overline{\overline{\frac{T'_{k-1} + T'_k}{\bar{T}_{k-1} + \bar{T}_k}}}\right)\left(1 + 2\hat{\bar{p}}_k\overline{\overline{\left(\frac{\ln p'_{k-1} - \ln p'_k}{\hat{\bar{p}}_{k-1} - \hat{\bar{p}}_{k+1}}\right)}}\right) - g + F_w$$

$$\frac{\partial\bar{p}_s}{\partial t} = \sum_{i=1}^{K}\Delta B_i\left[m^2 u^*\frac{\partial\bar{p}_s}{a\partial\lambda} + v^*\frac{\partial\bar{p}_s}{a\partial\mu}\right]_i + \sum_{i=1}^{K}(\Delta A + \Delta B\bar{p}_s)_i D_i$$

紅色方框所標示之項次為非靜力之貢獻項

動力架構之發展：最終方程式Ⅱ

$$\left(\frac{\partial \ln p'}{\partial t}\right)_k = -m^2 u^*_k \left(\frac{\partial \ln p'}{a\partial\lambda}\right)_k - v^*_k\left(\frac{\partial \ln p'}{a\partial\mu}\right)_k - \frac{1}{2(\hat{\bar p}_k - \hat{\bar p}_{k+1})}\left[\overline{\overline{(\ln p'_{k-1} - \ln p'_k)\left(\dot\zeta \frac{\partial \hat{\bar p}}{\partial\zeta}\right)_k}} + \underline{\underline{(\ln p'_k - \ln p'_{k+1})\left(\dot\zeta\frac{\partial\hat{\bar p}}{\partial\zeta}\right)_{k+1}}}\right]$$

$$- \frac{C_p}{C_v}\left[\left(m^2\frac{\partial u^*}{a\partial\lambda} + \frac{\partial v^*}{a\partial\mu}\right)_k - \frac{\hat{\bar p}_k + \hat{\bar p}_{k+1}}{2(R\bar T)_k(\hat{\bar p}_k - \hat{\bar p}_{k+1})}\left[m^2 \overline{\overline{\frac{u^*_k - u^*_{k-1}}{2}\frac{\partial\hat\Phi_k}{a\partial\lambda}}} + m^2\underline{\underline{\frac{u^*_{k+1}-u^*_k}{2}\frac{\partial\hat\Phi_{k+1}}{a\partial\lambda}}} + \overline{\overline{\frac{v^*_k - v^*_{k-1}}{2}\frac{\partial\hat\Phi_k}{a\partial\mu}}} + \underline{\underline{\frac{v^*_{k+1}-v^*_k}{2}\frac{\partial\hat\Phi_{k+1}}{a\partial\mu}}} + g(\hat w_k - \hat w_{k+1})\right]\right]$$

$$-\frac{2}{\hat{\bar p}_k + \hat{\bar p}_{k+1}}\left(\frac{d\bar p}{dt}\right)_{k,}$$

$$\left(\frac{\partial T'}{\partial t}\right)_k = \left[-m^2 u^*\frac{\partial (T')}{a\partial\lambda} - v^*\frac{\partial (T')}{a\partial\mu}\right]_k - \frac{1}{2(\hat{\bar p}_k - \hat{\bar p}_{k+1})}\left[\overline{\overline{(T'_{k-1} - T'_k)\left(\dot\zeta \frac{\partial \hat{\bar p}}{\partial\zeta}\right)_k}} + \underline{\underline{(T'_k - T'_{k+1})\left(\dot\zeta\frac{\partial\hat{\bar p}}{\partial\zeta}\right)_{k+1}}}\right]$$

$$-\frac{R}{C_v}(\bar T + T')_k\left[\left(m^2\frac{\partial u^*}{a\partial\lambda} + \frac{\partial v^*}{a\partial\mu}\right)_k - \frac{\hat{\bar p}_k + \hat{\bar p}_{k+1}}{2(R\bar T)_k(\hat{\bar p}_k - \hat{\bar p}_{k+1})}\left[m^2 \overline{\overline{\frac{u^*_k - u^*_{k-1}}{2}\frac{\partial\hat\Phi_k}{a\partial\lambda}}} + \overline{\overline{\frac{v^*_k - v^*_{k-1}}{2}\frac{\partial\hat\Phi_k}{a\partial\mu}}} + m^2\underline{\underline{\frac{u^*_{k+1}-u^*_k}{2}\frac{\partial\hat\Phi_{k+1}}{a\partial\lambda}}} + \underline{\underline{\frac{v^*_{k+1}-v^*_k}{2}\frac{\partial\hat\Phi_{k+1}}{a\partial\mu}}} + g(\hat w_k - \hat w_{k+1})\right]\right] + \frac{F_T}{C_p}$$

$$-\frac{2(k\bar T)_k}{\hat{\bar p}_k + \hat{\bar p}_{k+1}}\left(\frac{d\bar p}{dt}\right)_k$$

$$\left(\frac{\partial \bar T}{\partial t}\right)_k = \left[-m^2 u^*\frac{\partial \bar T}{a\partial\lambda} - v^*\frac{\partial \bar T}{a\partial\mu}\right]_k - \frac{1}{2(\hat{\bar p}_k - \hat{\bar p}_{k+1})}\left[\overline{\overline{(\bar T_{k-1} - \bar T_k)\left(\dot\zeta \frac{\partial \hat{\bar p}}{\partial\zeta}\right)_k}} + \underline{\underline{(\bar T_k - \bar T_{k+1})\left(\dot\zeta\frac{\partial\hat{\bar p}}{\partial\zeta}\right)_{k+1}}}\right] + \frac{2(k\bar T)_k}{\hat{\bar p}_k + \hat{\bar p}_{k+1}}\left(\frac{d\bar p}{dt}\right)_k$$

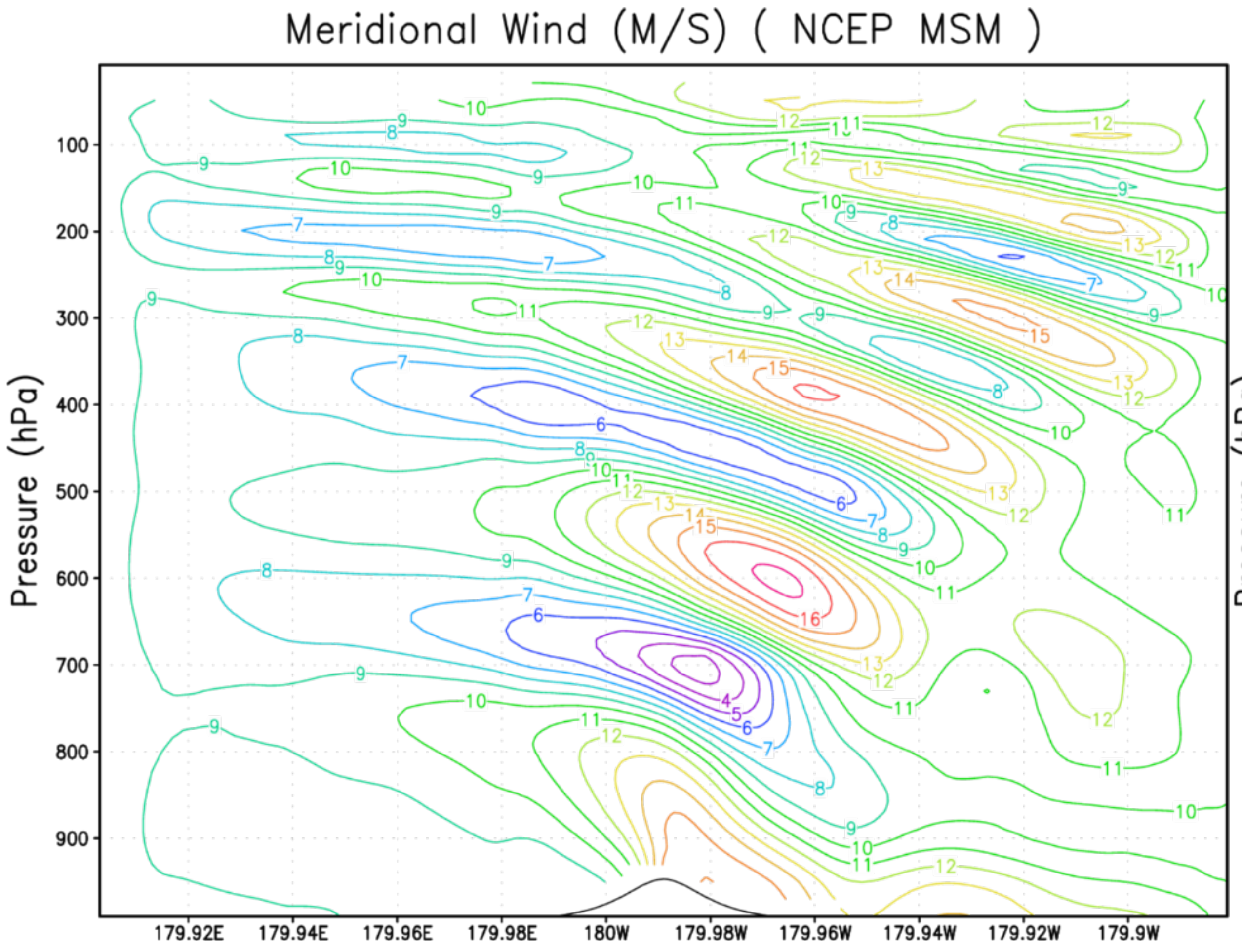
紅色方框所標示之項次為非靜力之貢獻項

動力架構之驗證 I

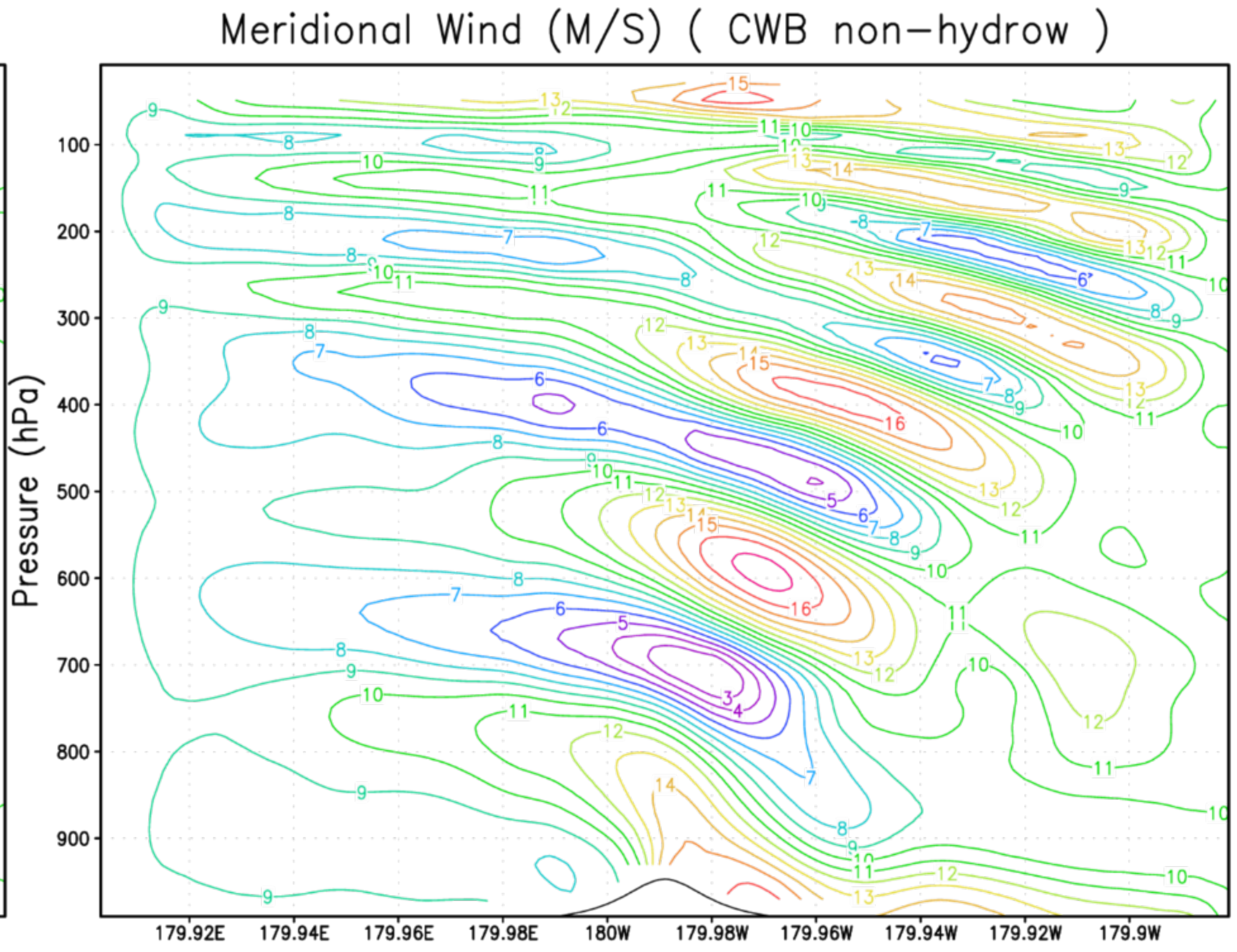
Mountain wave

- Total Dimensions = 109 x 10 x 50
- Model Resolution = 200m
- Terrain = Central peak is 400m
- U = 10 m/s
- Surface Pressure = 1000 hPa
- Temperture = 250 K
- Time Step = 0.01 sec
- Forecast Hour = 1 hour
- Horizontal Diffusion = 6 secs
- Upper Layer Relaxation ≦ 200hPa

動力架構之驗證 II

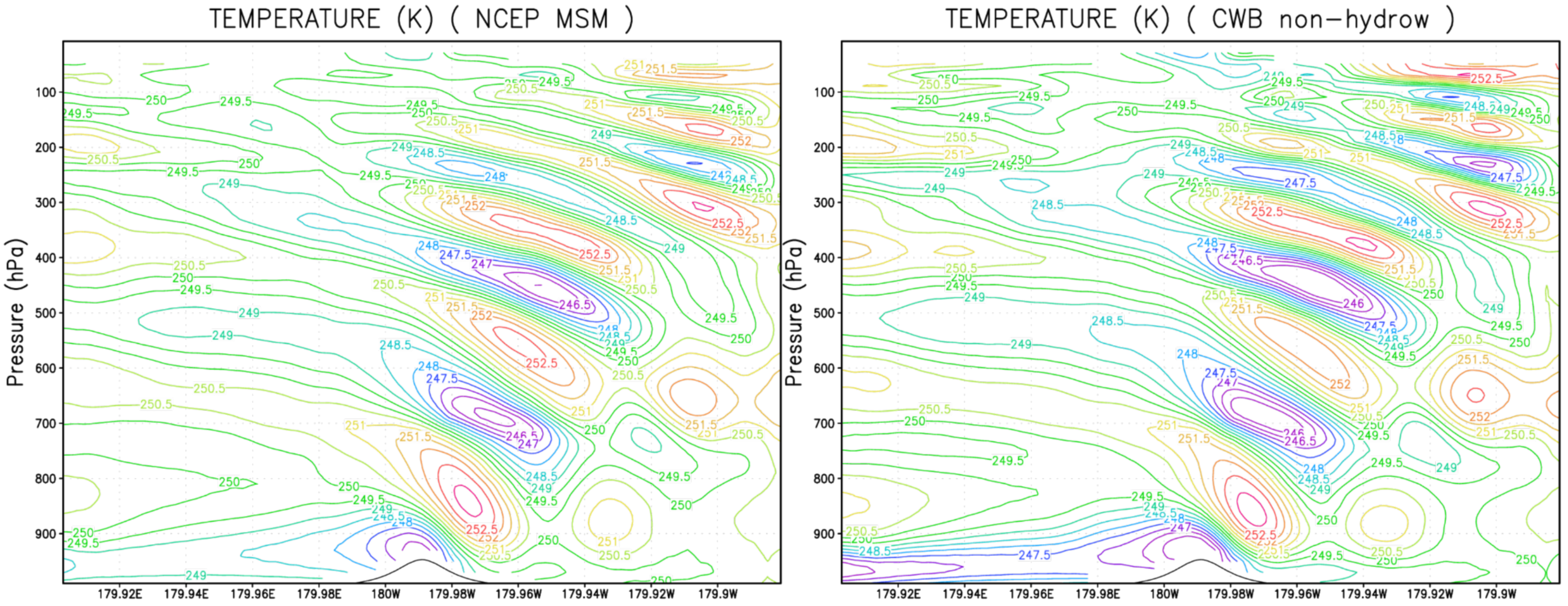


Meridional Wind (M/S) (NCEP MSM)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
179.92E
179.94E
179.96E
179.98E
180W
179.98W
179.96W
179.94W
179.92W
179.9W



Meridional Wind (M/S) (CWB non-hydrow)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
179.92E
179.94E
179.96E
179.98E
180W
179.98W
179.96W
179.94W
179.92W
179.9W

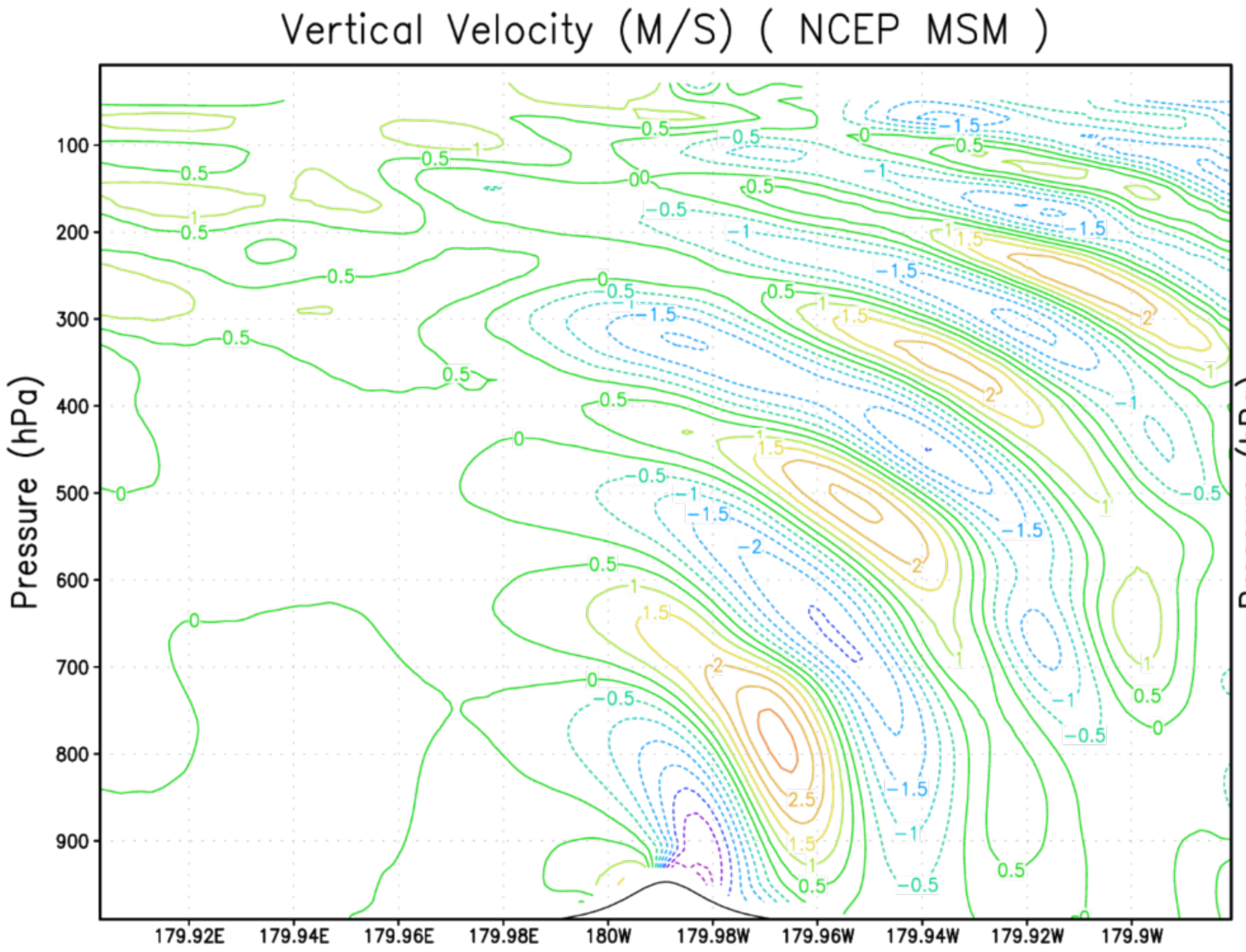
動力架構之驗證Ⅲ

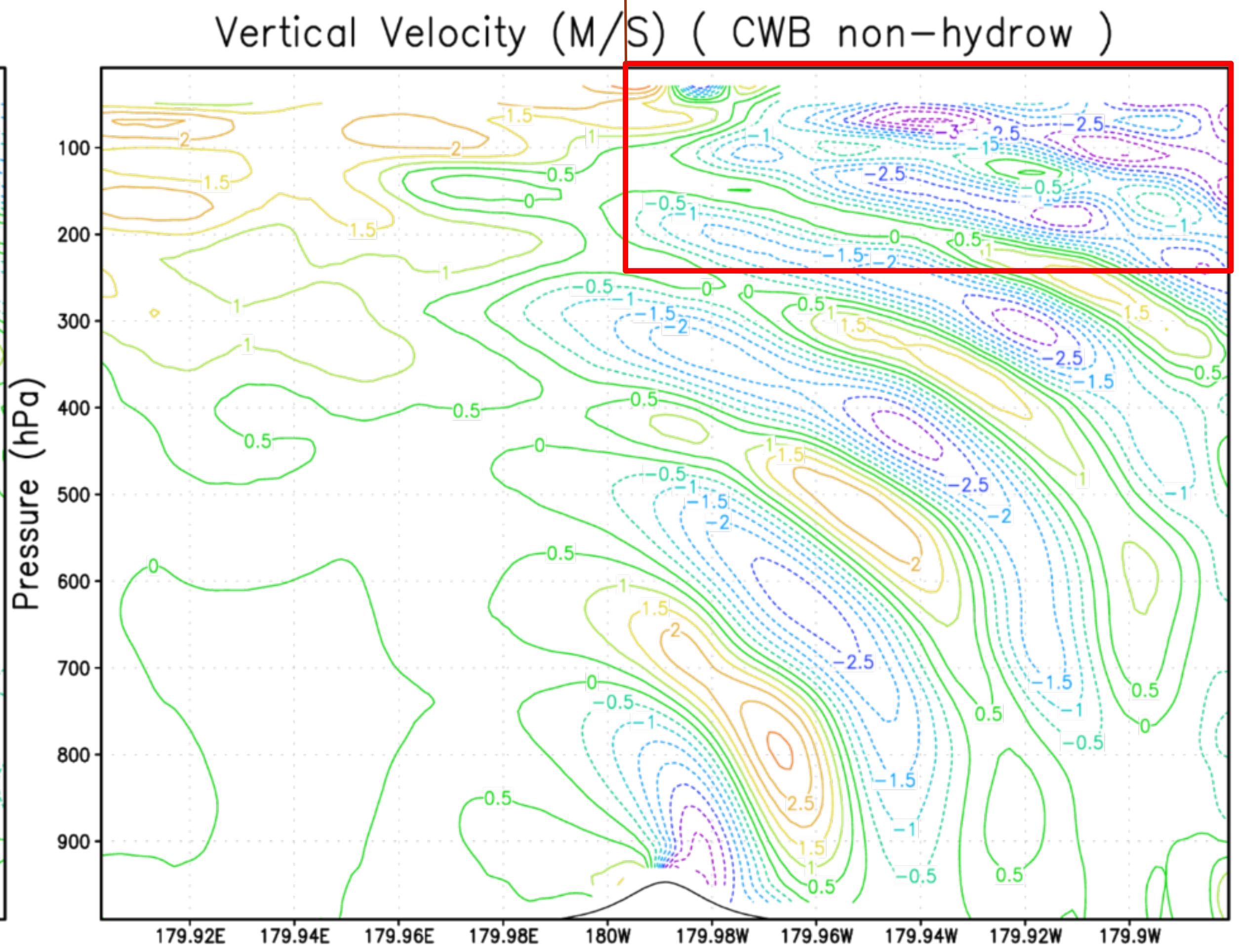


TEMPERATURE (K) (NCEP MSM)
TEMPERATURE (K) (CWB non-hydrow)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
179.92E
179.94E
179.96E
179.98E
180W
179.98W
179.96W
179.94W
179.92W
179.9W

動力架構之驗證Ⅳ

較多小擾動存在





結論與未來工作

- 採用擾動法，將靜力與非靜力效應分離，利於與現行CWB GFS比較時，運用靜力架構進行積分。
- CWB non-hydrow 之動力架構積分測試，可得到與NCEP MSM相近之結果，但在高層垂直速度之模擬上CWB non-hydrow存在較多擾動。
- 造成擾動之問題仍需進一步釐清是否為垂直通量計算方式所造成？
- 未來將再加入semi-implicit，持續針對此非靜力動力架構進行評估。

~THE END~