Analysis of Balance/Unbalance Parts of Background Error Covariance Option 3(CV3) and Option 5(CV5) in CWB WRFDA

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Outline

- Introduction of Background error covariance
- Comparison of CV3 and CV5
  - PSOT (Pseudo Single Observation test)
    - Balance/Unbalance part analysis

$$J = \frac{1}{2}\left(\mathbf{x} - \mathbf{x}^{\mathbf{b}}\right)^{T} \mathbf{B}^{-1}\left(\mathbf{x} - \mathbf{x}^{\mathbf{b}}\right) + \frac{1}{2}\left(\mathbf{y} - H(\mathbf{x})\right)^{T} \mathbf{R}^{-1}\left(\mathbf{y} - H(\mathbf{x})\right)$$

- Observation **y**
- Observation operator *H*
- Observation error covariance **R**
- Background $\mathbf{x}^{\mathbf{b}}$
- Background error covariance **B**

- What data assimilation does?
  - FG+OBS -> ANALYSIS
- KEY: Background error and Observation error
  - if BE is very large compared to observation error, analysis is closer to observation otherwise it is closer to FG
- What is BE?

What is Background error covariance

- It is the covariance of (forecast-truth) for analysis control variables

$$BE = \langle (x - x^t), (x - x^t) \rangle$$

- Size of BE
  - [(how many variables)*(i*j*k)]^2 ~ $10^7 * 10^7$

Too big to deal with…….

Instead of Covariance…..

- Regression coefficient
  - Only for variances with Balance part
  - Capture the Large scale relation (thermal wind, geostrophic balance, hydrostatic balance…etc)
- Variance, Length scale
  - Use Recursive filter or EOF to spread the information

Analysis control Variables

- stream function (φ);
- unbalanced part of velocity potential (χ_u)
- unbalanced part of temperature (T_u)
- unbalanced part of surface pressure (Ps_u)
- pseudo relative humidity (water vapor mixing ratio^{k}divided by the saturated value from the guess field, p_RH)

$$\chi_b^{'} = c\psi^{'}$$

$$T_b^{'}(k) = \sum G(k,k1)\psi^{'}(k1)$$

$$p_{sb}^{'} = \sum W^{k1}(k)\psi^{'}(k)$$

Role of BE

- BE exchanges information between wind, temperature, pressure, and capture the large scale balance, and contain a near-balanced property.
- BE spreads information, both vertically & horizontally with proper weights to observations and FG.

CV3 and CV5 in CWB WRFDA

- WRFDA V3.3.1 (CWB OP2.4)

- CV3: Provided by NCEP (Global model)
  - Latitude dependent
- CV5: Generated from CWB WRF model (regional)
  - Without Latitude dependent (homogenous)

Pseudo Single OBS test

- at (111,65), sigma level=12
  (in the middle of CWB WRF domain, around 850hPa)
  - T: innovation=1°C, OBS_error=1
  - U: innovation=1m/s, OBS_error=1
- Tuning factors :

CV3			
	Variance	Horizontal scale	Vertical scale
as1 (φ)	0.063	0.75	1.5
as2 (χ_u)	0.063	0.75	1.5
as3 (T_u)	0.220	1.00	1.5
as4 (p-RH)	0.230	2.00	1.5
as5 (Ps_u)	0.27	0.5	1.5

(CWB operational setting but only for 1 outerloop)

CV5	
var_scaling1 (φ)	1.47
var_scaling2 (χ_u)	1.47
var_scaling3 (T_u)	1.70
var_scaling4 (p-RH)	0.85
var_scaling5 (Ps_u)	0.80
len_scaling1 (φ)	1.00
len_scaling2 (χ_u)	1.00
len_scaling3 (T_u)	1.00
len_scaling4 (p-RH)	0.55
len_scaling5 (Ps_u)	0.80

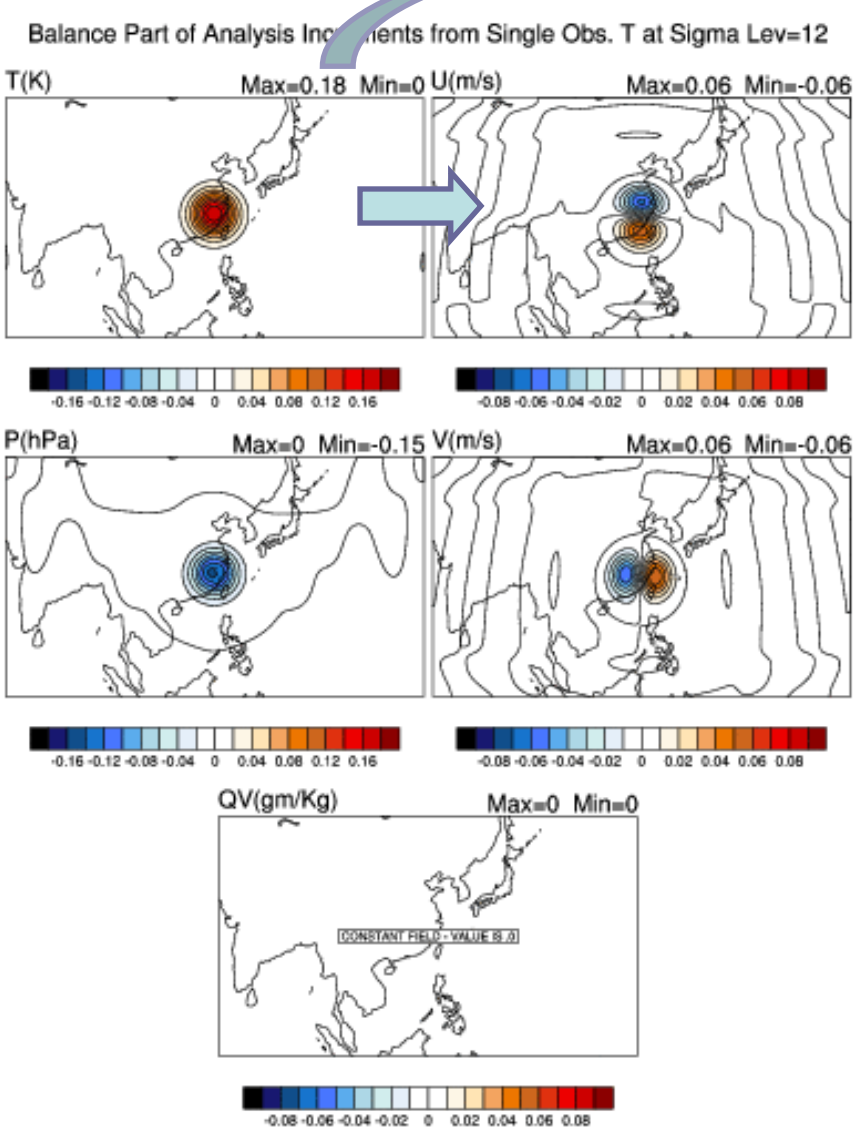
Single OBS Test “**T**”

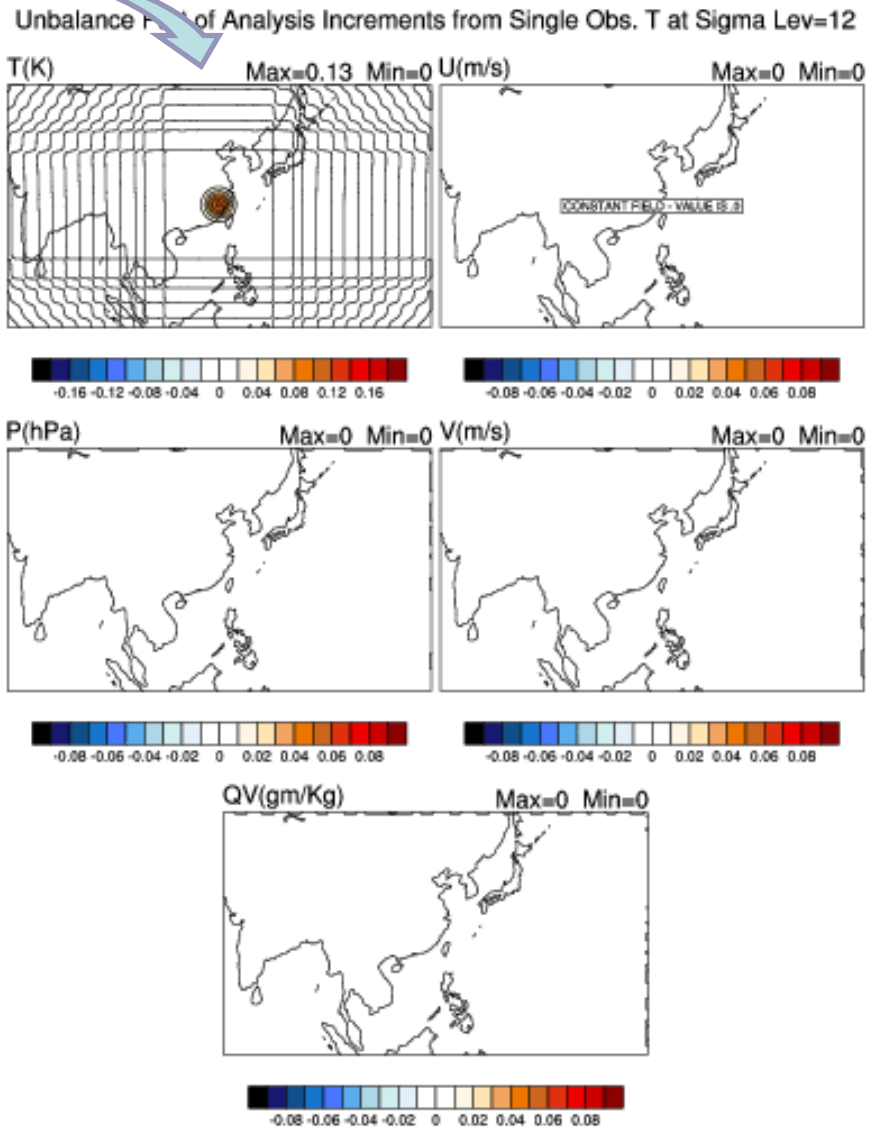
CV3

Balance Part

1:1

Unblance Part





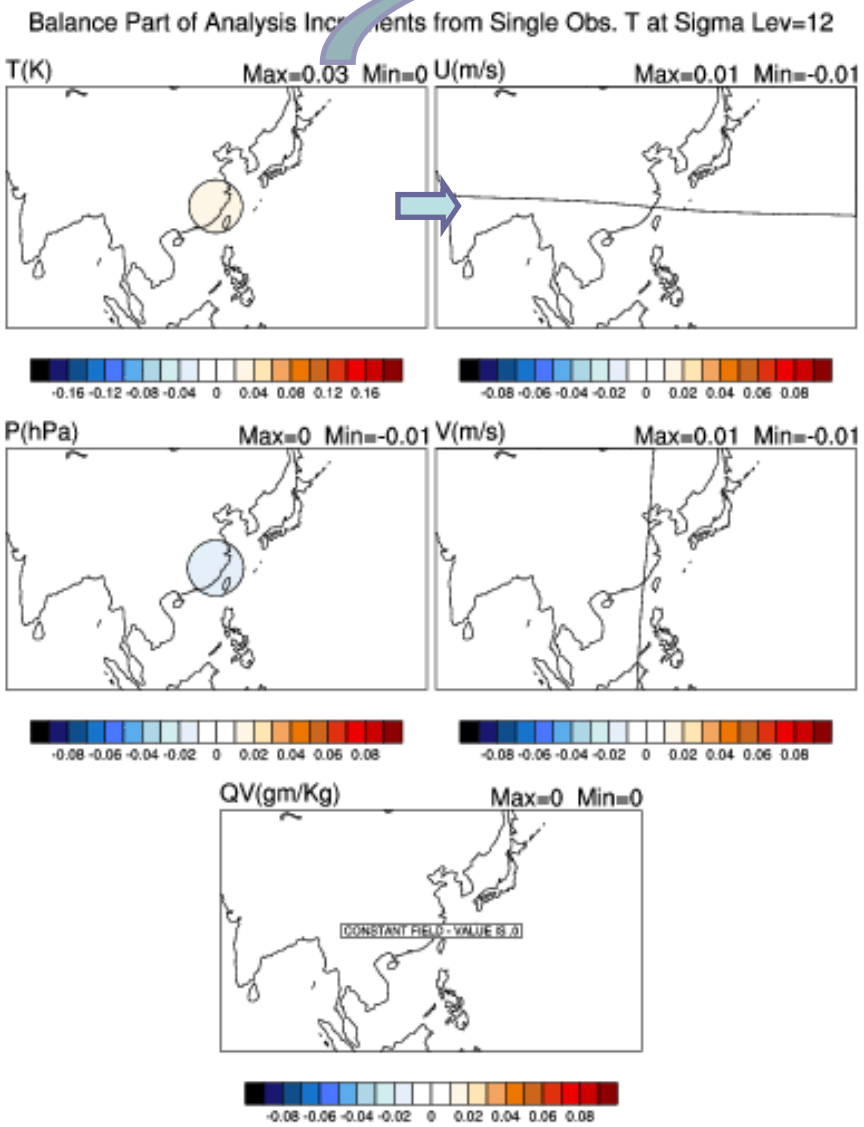
Single OBS Test “**T**”

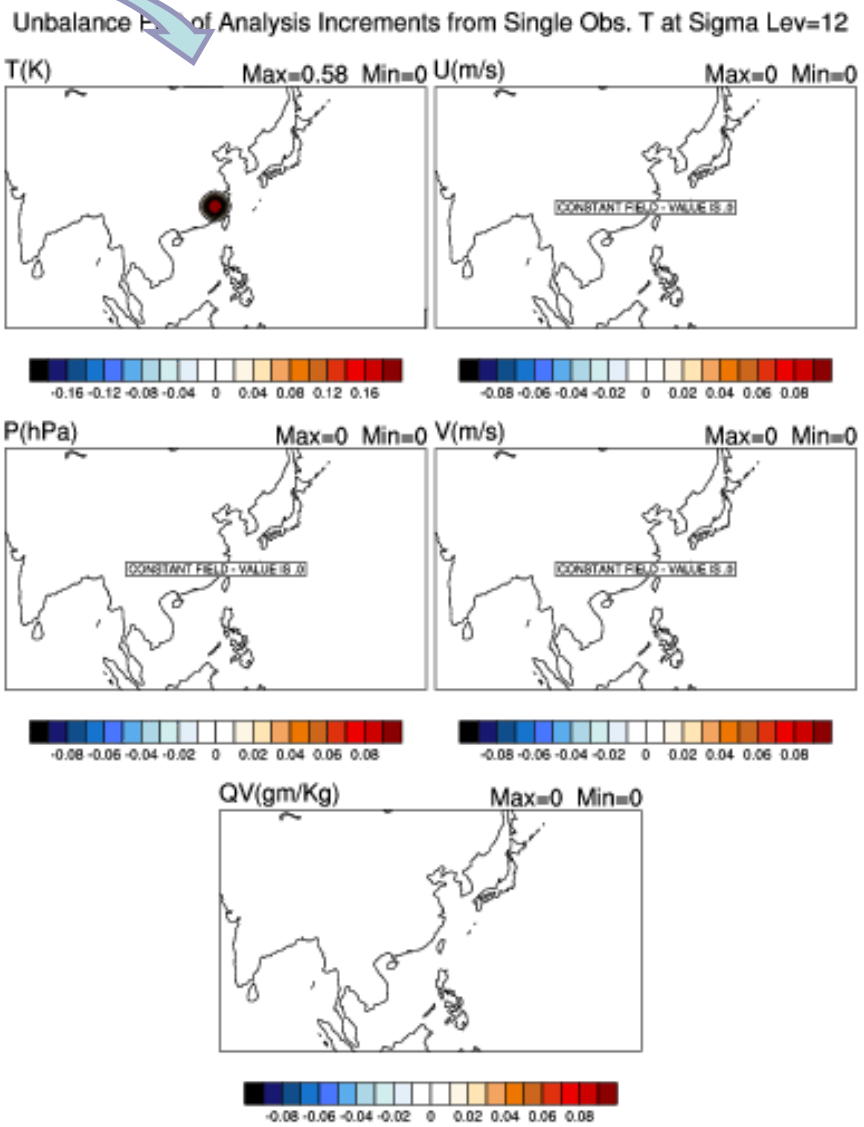
CV5

Balance Part

1:19

Unblance Part



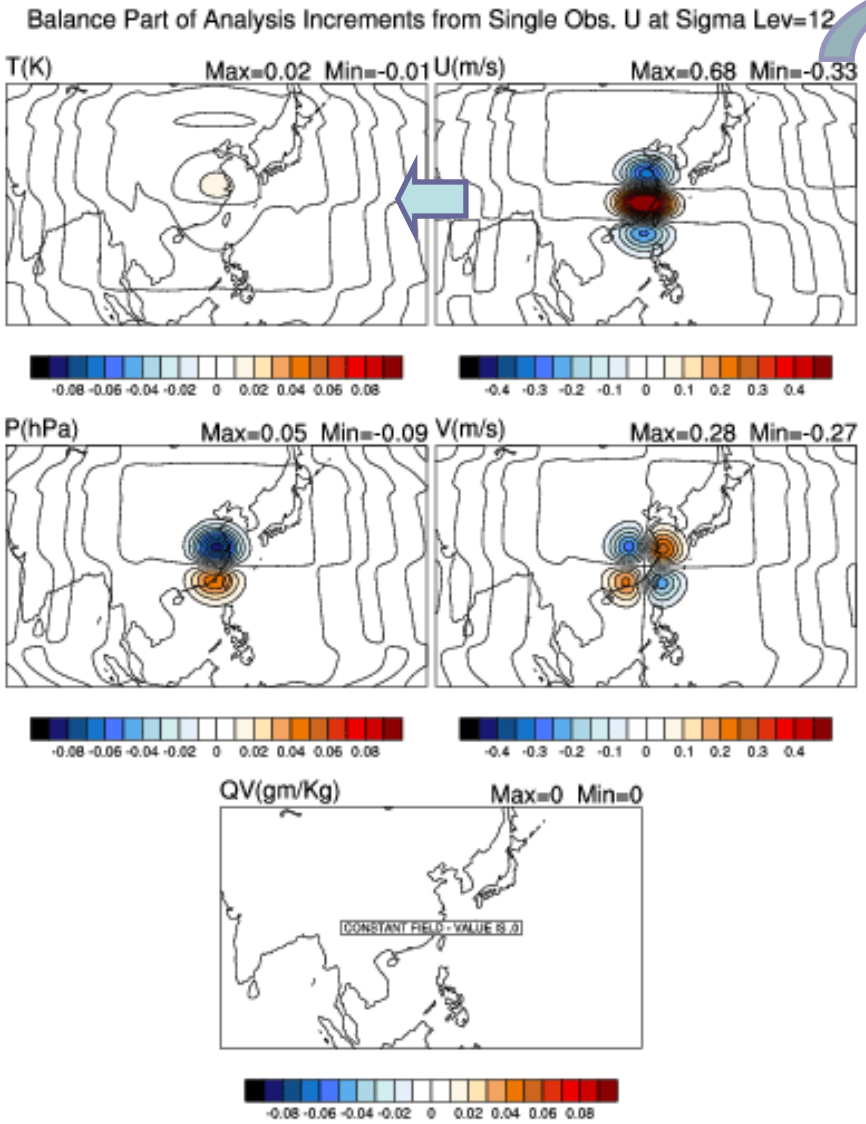


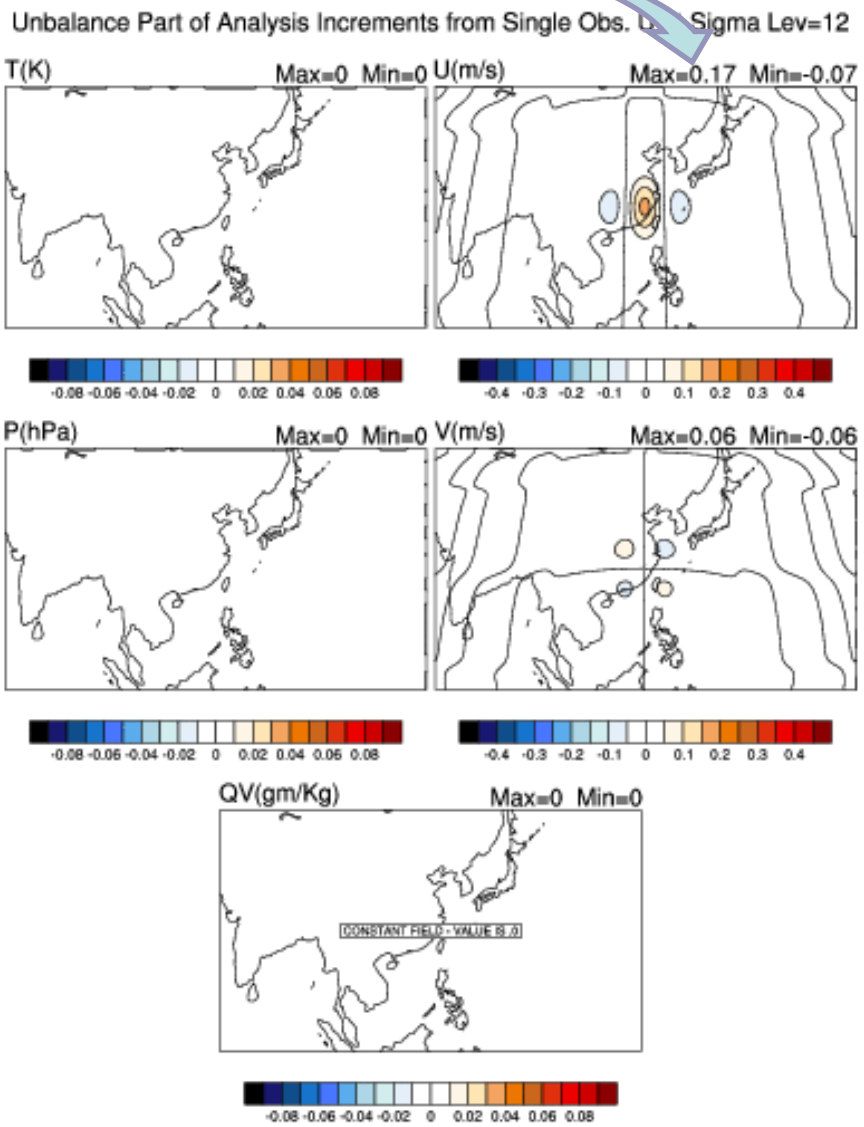
Single OBS Test “**U**”

CV3

Balance Part

Unblance Part 4:1



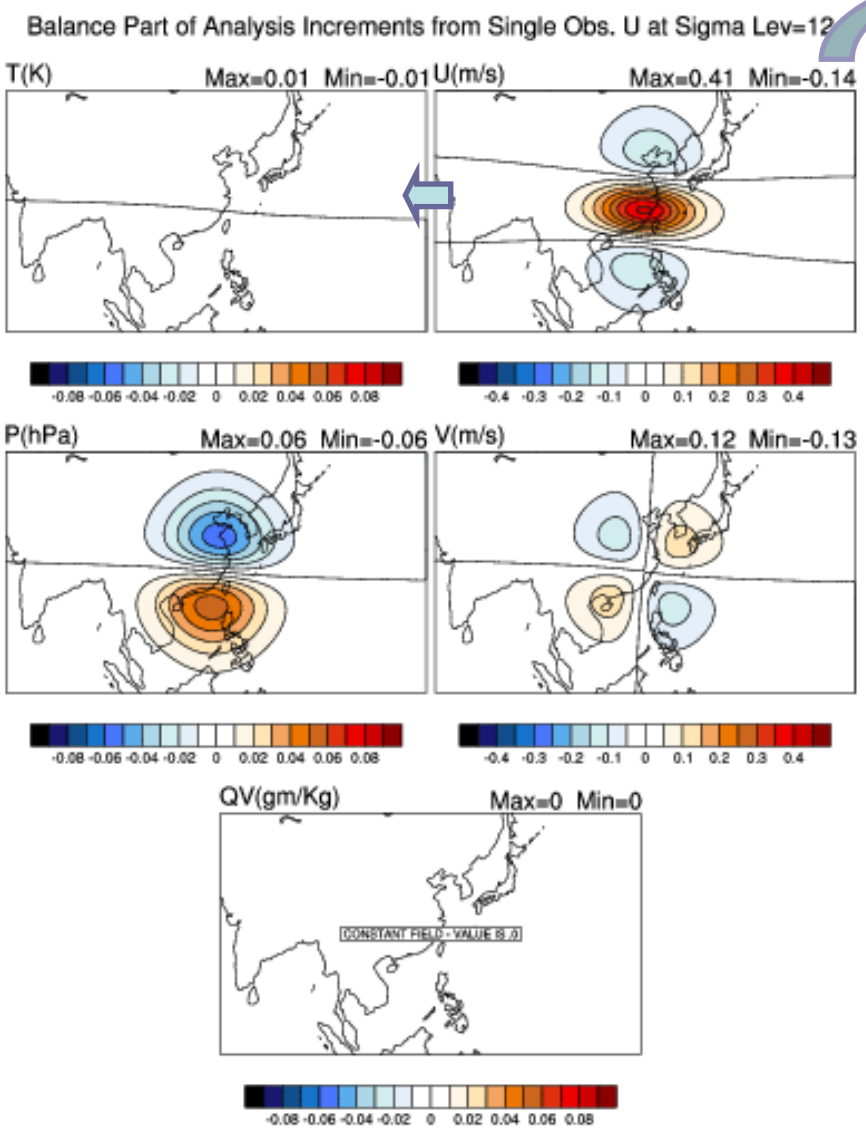


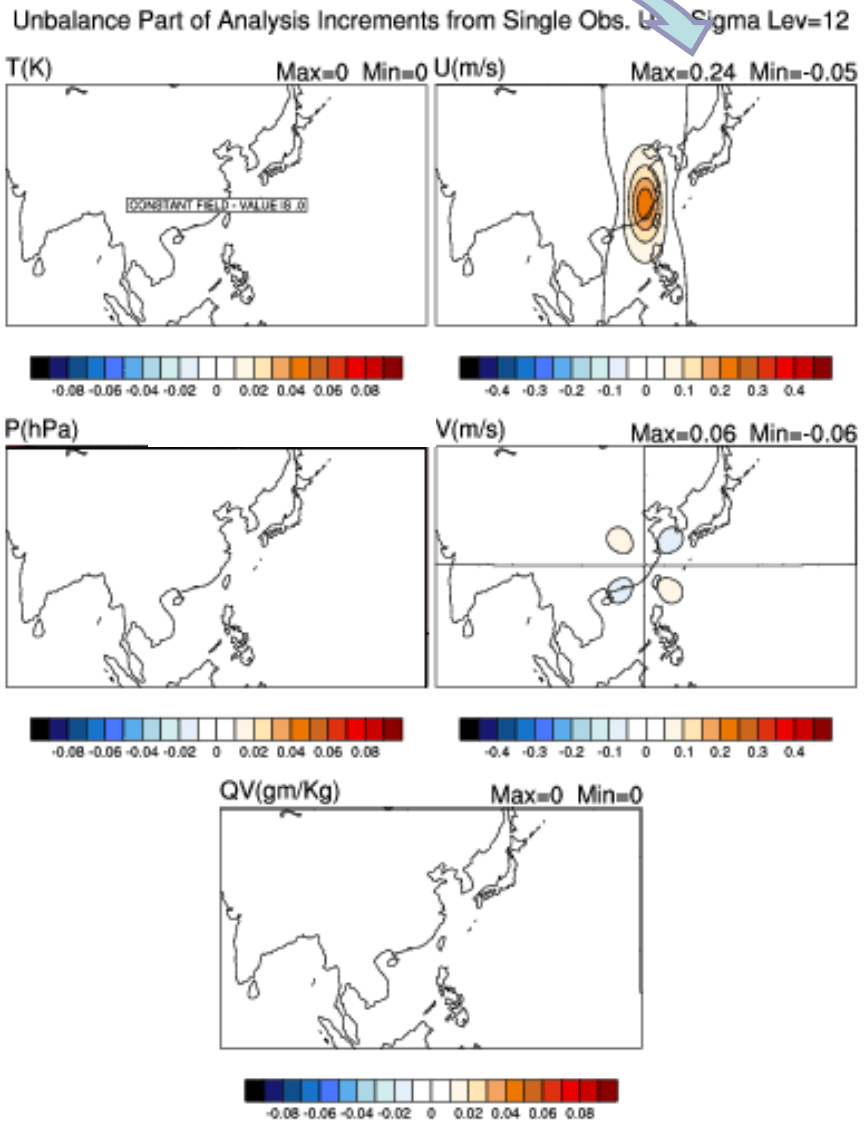
Single OBS Test “**U**”

CV5

Balance Part

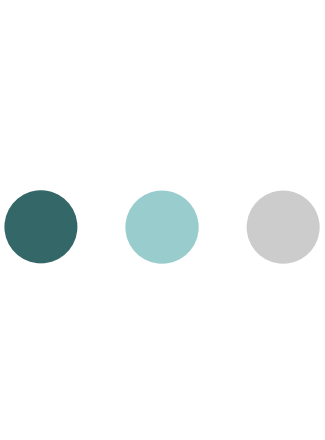
Unblance Part 2:1





Discussion & Summary

- In CW WRFDA, CV3 is for general forecast, and CV5 is especially for typhoon forecast.
- For CV3, balance part dominate, there is interaction between variables in balance part, good for synoptic forecast.
- For CV5,
  - For temperature observation, unbalance part dominate, so temperature observation only induce temperature increments, won't affect wind or other fields.
  - For wind observation, balance part dominate, but the interaction between variables is not efficient.
- CV5, due to the unbalance part domination and inefficient interaction between variables, is good for systems which is unlike thermal wind balance, for example : typhoon.
- Experience in CWB shows that when bogus typhoon with CV5, the effect of bogus will be kept in. If CV3 is applied in typhoon bogus, balance part will quickly spread the information between variables, then become much more like thermal balance, then the effect of bogus is decreased. So CV5 is a better choice for typhoon bogus.
- But due to the inefficient interaction between variables, using CV5 to bogus typhoon may also get a noisy analysis field. In this situation, digital filter initialization will be needed. This is the strategy used in CWB for typhoon cases.
- It's important to know how balance and unbalance each background error may induce in analysis field, to know the behavior of each background error, then the related measures could be done.



THE END

THANK YOU