An Evaluation and Constraint of Thermodynamic Boundary Conditions over the Maritime Continent

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Question: How can the natural variability in vertical temperature, moisture, and wind profiles in the tropics be constrained for numerical modeling?

Conclusion: Vertical patterns can be represented by empirical orthogonal functions and used as boundary conditions in simulations.

Motivations

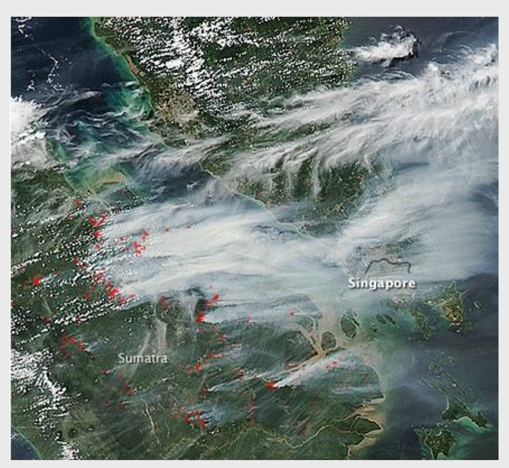

Fig. 1) 6/19/2013 burning event. From Aqua MODIS.

Biomass burning over the Maritime Continent (MC) is a strong aerosol source that can affect precipitation. This impact of aerosols on cloud development and tropical convection cannot be isolated without constraining the larger-scale and more variable regional meteorology. Furthermore, difficult land-ocean topography leads to biases in reanalysis datasets, which must be addressed with comparisons to observations.

Project Overview

Fig. 2) Spatial Domain. From Google Earth.

<u>Case Study</u>: Ranai, Indonesia (2008-2015)

<u>Reanalysis Datasets:</u>

1) ERA-Interim (1.0° x 1.0°)
2) MERRA (1.25° x 1.25°)

<u>Observations</u>: Radiosonde Soundings

Principal Component Analysis (PCA) was employed to transform vertical patterns in temperature, humidity, and wind into typical thermodynamic profiles for the reanalysis datasets and radiosonde observations.

Principal Component Analysis

PCA is a statistical method that decomposes correlated variables into orthogonal, linearly uncorrelated principal components (PCs), or empirical orthogonal functions (EOFs). It is used as a dimensional reduction technique.

PCA Methods

Vertical atmospheric levels covary. PCA will remove these correlations and represent the largest possible variance with the fewest components.

<u>Methods:</u>

- Temperature, relative humidity, and U & V wind components interpolated to 10-mb increments and standardized
- Each 10-mb partition is treated as a dimension (1000-mb to 50-mb)
- PCA performed separately for each variable for the three datasets
- Scree plot analysis used to determine the number of EOFs to retain

Results

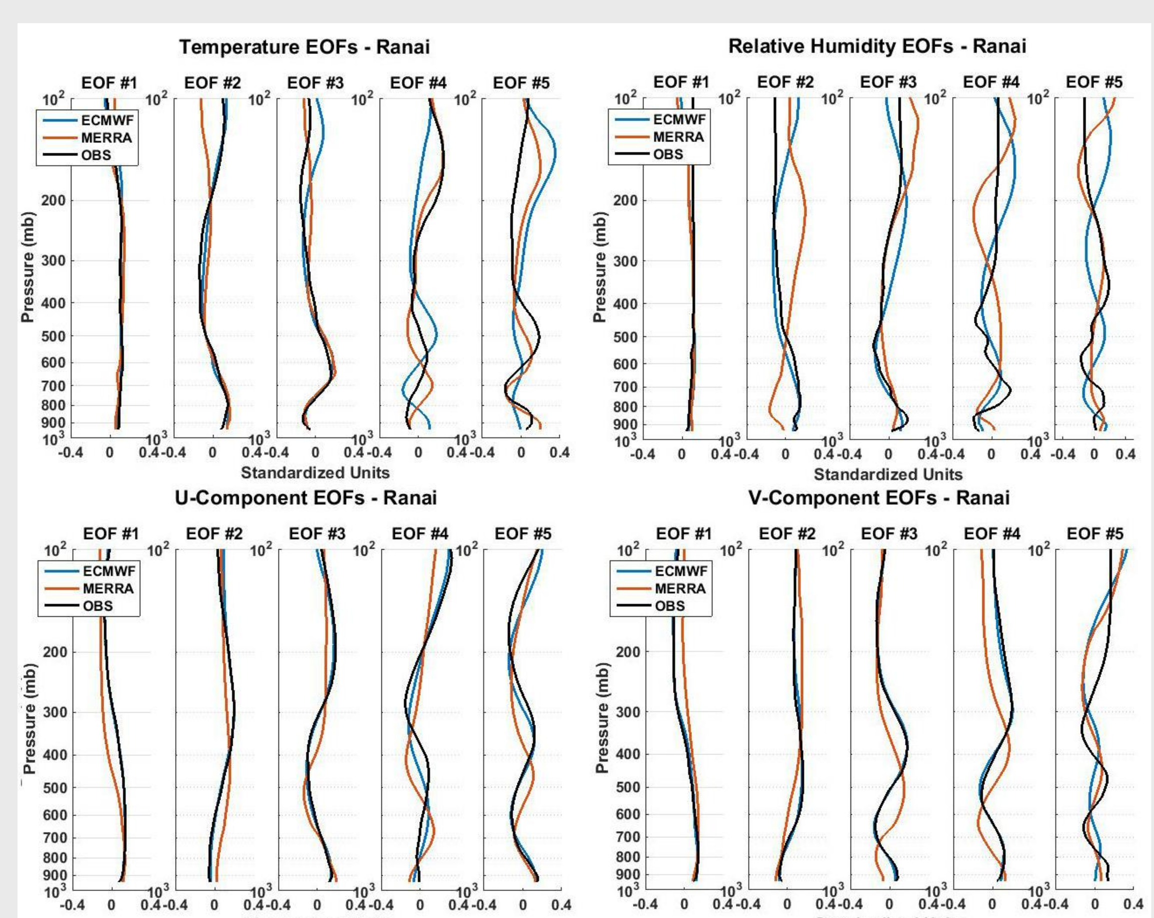

Fig. 3) First 5 EOFs for temperature, relative humidity, and U and V wind.

Radiosonde Observations - Variance Explained (%)				
Eigenvector Number	Temperature	Humidity	U-Component	V-Component
1	40.05	44.60	44.77	33.37
2	16.25	13.72	19.24	17.24
3	10.68	12.42	9.74	12.31
4	5.82	6.62	5.77	9.55
5	5.15	4.38	4.13	4.18
Cumulative %	77.95	81.74	83.66	76.65

ERA-Interim - Variance Explained (%)				
1	78.35	54.61	48.57	40.24
2	14.96	14.48	21.50	20.84
3	2.15	7.97	9.54	12.47
4	1.83	5.22	5.39	8.93
5	1.03	4.06	3.79	4.18
Cumulative %	98.31	86.33	88.78	86.64

MERRA - Variance Explained (%)				
1	70.94	62.86	49.24	38.75
2	15.96	11.28	31.07	23.26
3	4.45	5.70	5.32	7.40
4	3.35	3.89	4.54	6.42
5	1.60	3.07	2.88	4.69
Cumulative %	96.30	86.80	93.06	80.51

Table 1) Percent of variance explained by each EOF.

- Differences between the reanalyses and the radiosonde observations are obvious (Fig. 3).
- The transformed EOFs (Fig. 3) can represent a large fraction of the total variance with few components (Table 1).
- Scree plots recommend the number of EOFs to keep. Eigenvalues above 1.0 (Kaiser) or the Parallel Analysis line (Horn) are significant (Fig. 4).
- Soundings are easily reproduced as a PC-weighted linear sum of EOFs.

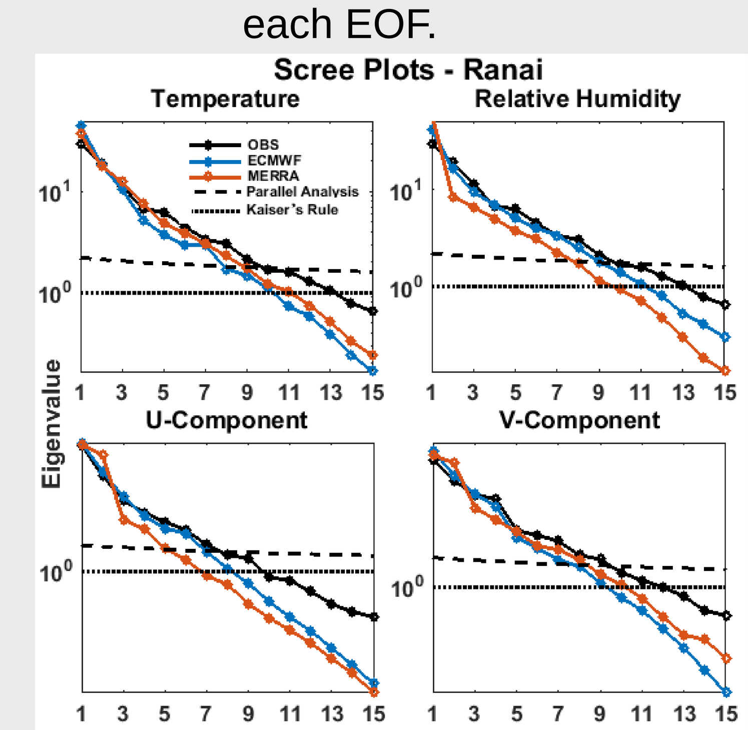

Fig. 4) Scree Plots based on Parallel Analysis (Horn, 1965) & Kaiser's Rule (Kaiser, 1960).

Conclusions

- Principal Component Analysis (PCA) was used to decompose the correlations between thermodynamic variables in vertical atmospheric layers over the Maritime Continent.
- The resulting empirical orthogonal functions (EOFs) represent the vertical variability in temperature, moisture, and winds in a lower-dimensional subspace.
- The EOFs constrain the thermodynamics by resolving patterns and representing variance with less information.
- Differences exist between the MERRA and ERA-Interim data sets and radiosonde observations over the MC, as evident by the structure functions.

Future Work

- EOFs are currently being tested as boundary conditions in a cloud resolving model.
- The sensitivity of cloud development and precipitation to biomass burning aerosols over the MC will be investigated.

Acknowledgements

NASA – Interdisciplinary Research in Earth Science Program (IDS)
NRL - Naval Research Enterprise Internship Program (NREIP)
Pat Pauley (NRL – Monterey)
Tim Whitcomb (NRL - Monterey)
University of Wyoming Sounding Database

References

Horn, J.L, 1965: A rationale and test for the number of factors in factor analysis, *Psychometrika*, **30,** 179–185.

Kaiser, H.F. (1960). The application of electronic computers to factor analysis. *Educational and Psychological Measurement,* **20**, 141-151.

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