A New Measure of Ensemble Central Tendency

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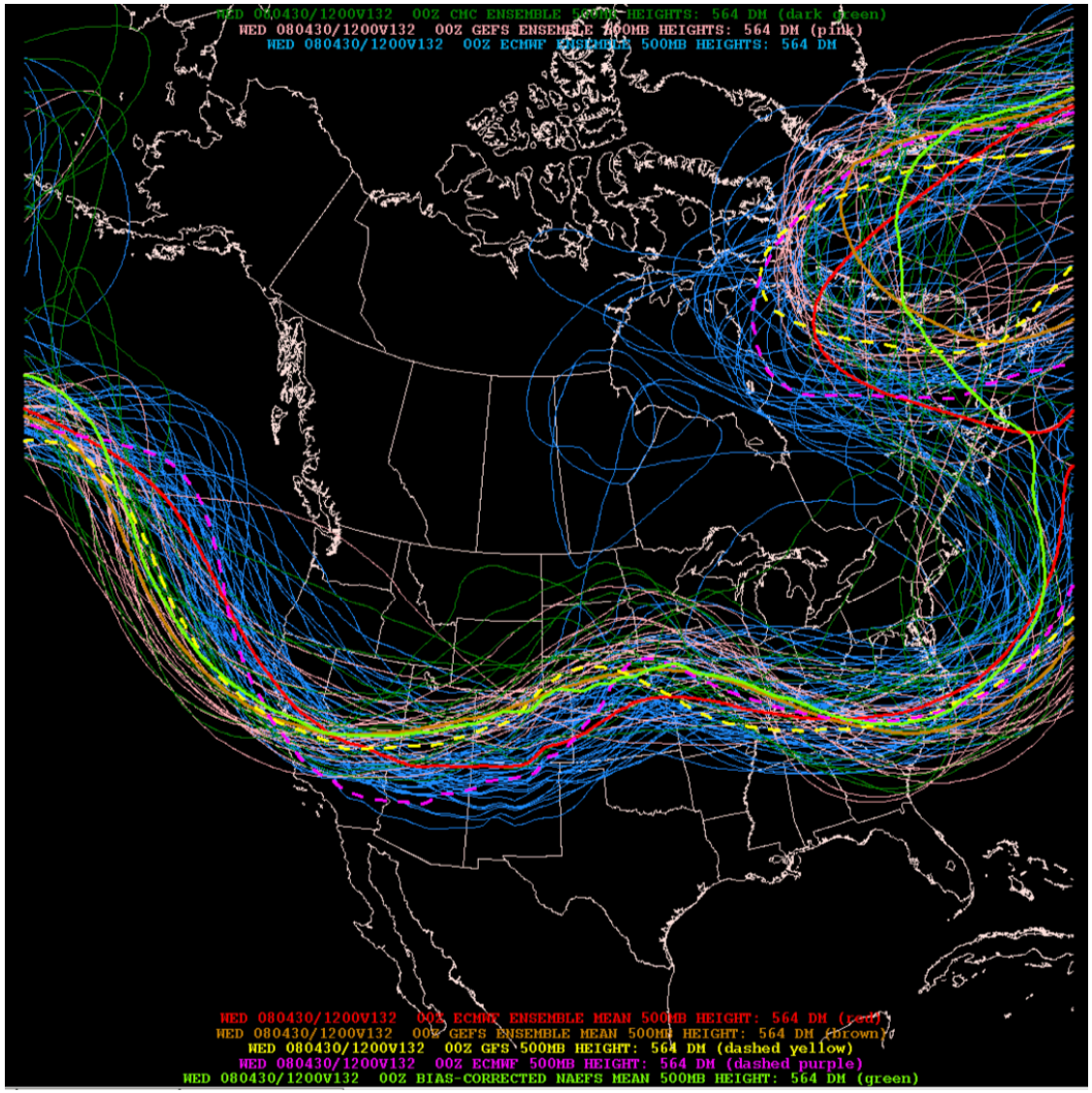
Outline

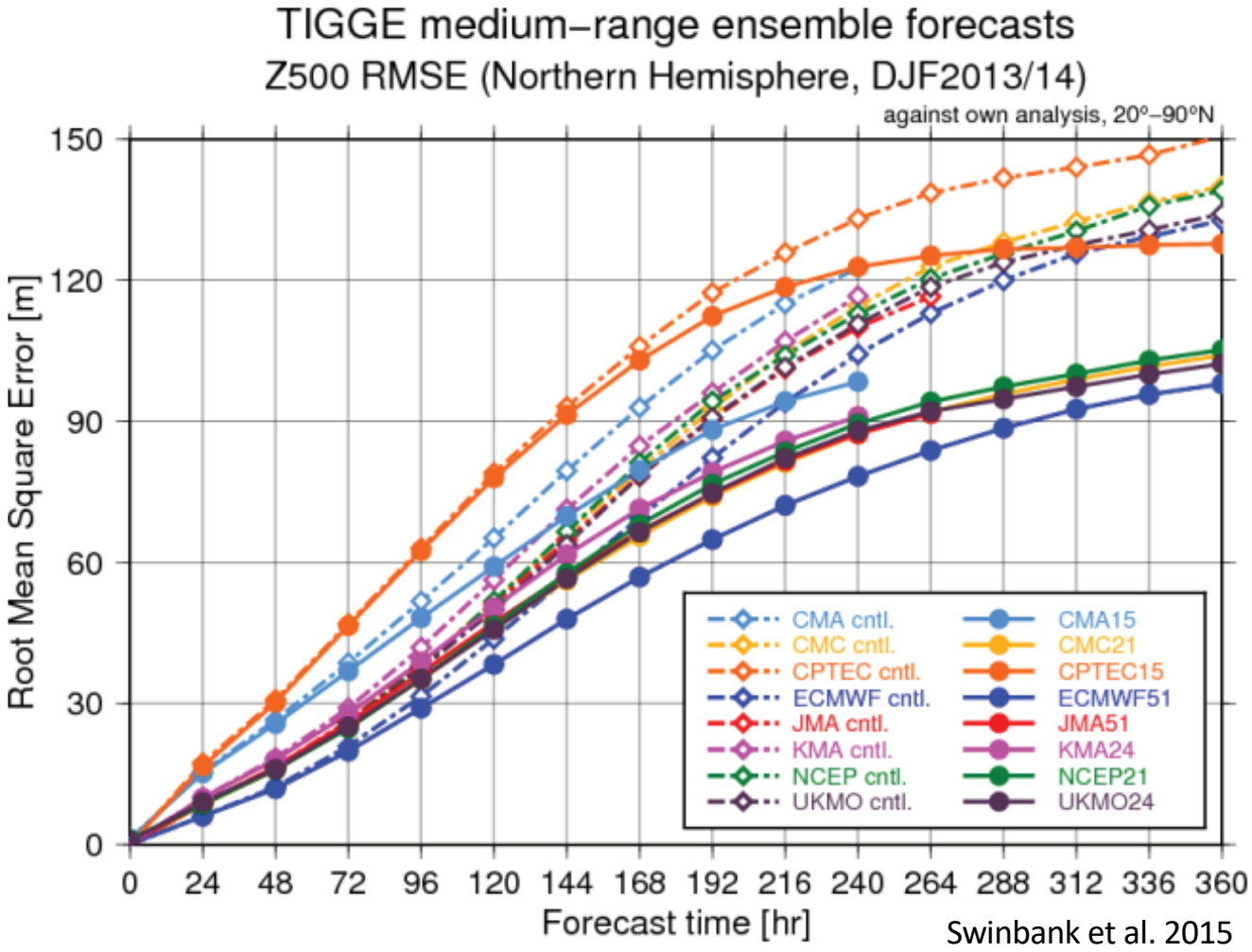
- Background
  - Pros and cons of traditional arithmetic ensemble mean (AM)
- Motivation
  - How to improve AM?
- Feature-based mean (FM)
  - Technique and method
- Compare AM and FM
- Summary and discussion

Arithmetic Ensemble Mean



https://severe.worldweather.wmo.int/TCFW/RAIV_Workshop2016/12_EnsemblePredictionSystems_EricBlake.pdf

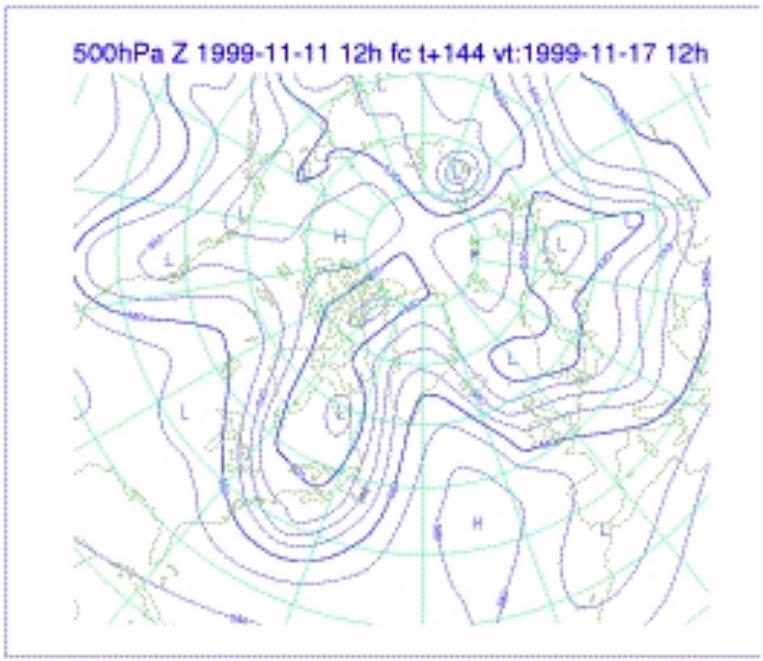
Advantage



Swinbank et al. 2015

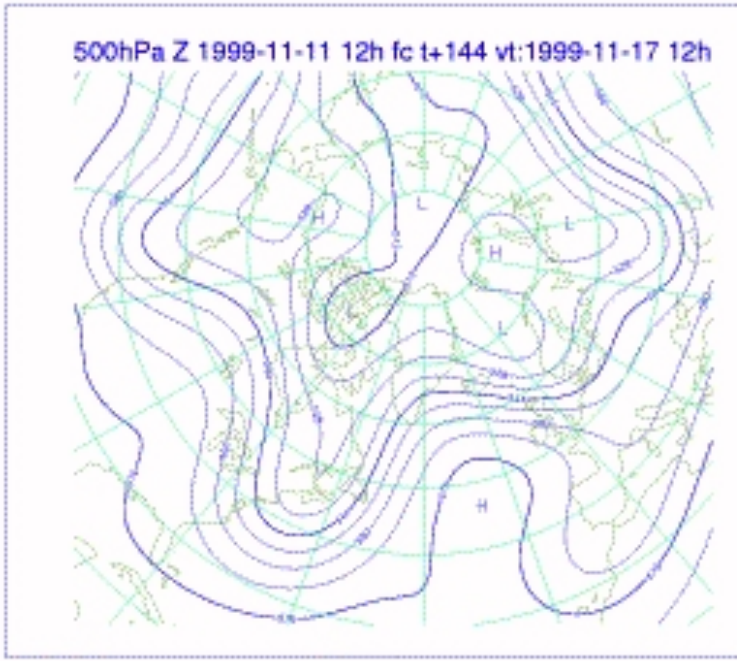
- AM without exception performs better than the control
- In the past two decades, AM gained significant use in weather forecasting

- AM offers a nonlinear filter of unpredictable forecast features across ensemble members
  - RMSE below that of individual forecasts



Day+6 Full resolution

< Smoother

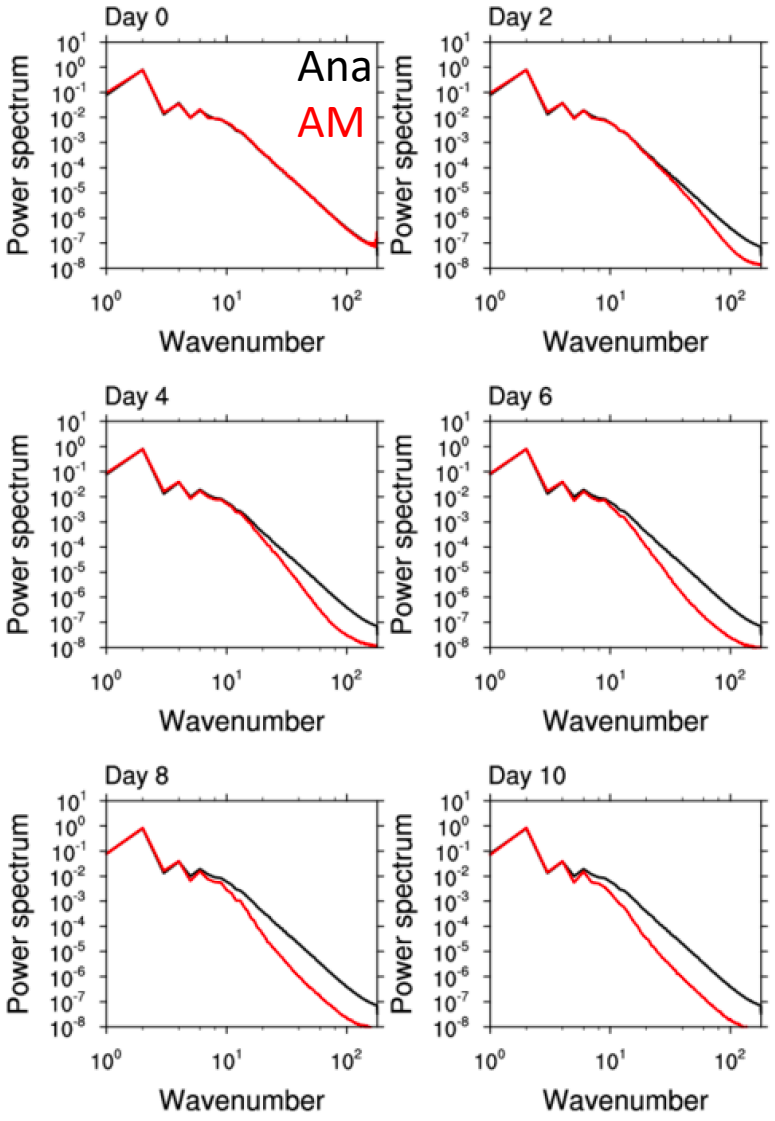


Day+6 Ens. Mean

https://www.wpc.ncep.noaa.gov/ensembletraining/

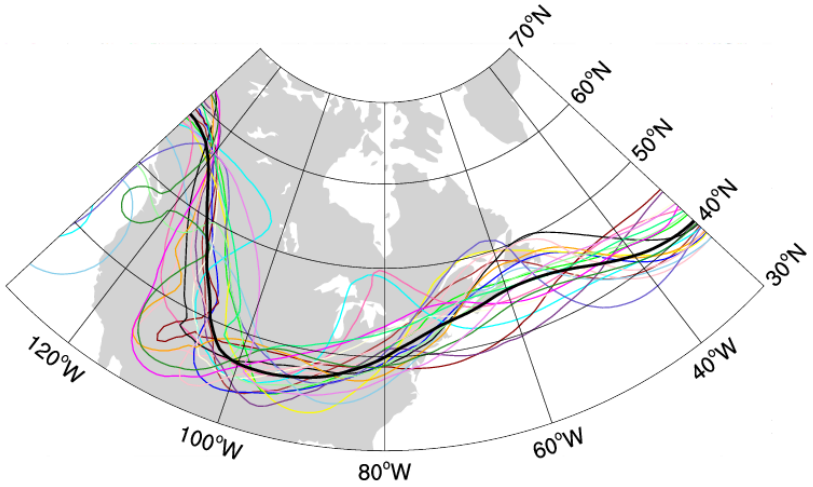
Disadvantage

Normalized power spectrum of fcsts



- Loss of small to medium scales
- Unrealistic smoothing due to the position displacement

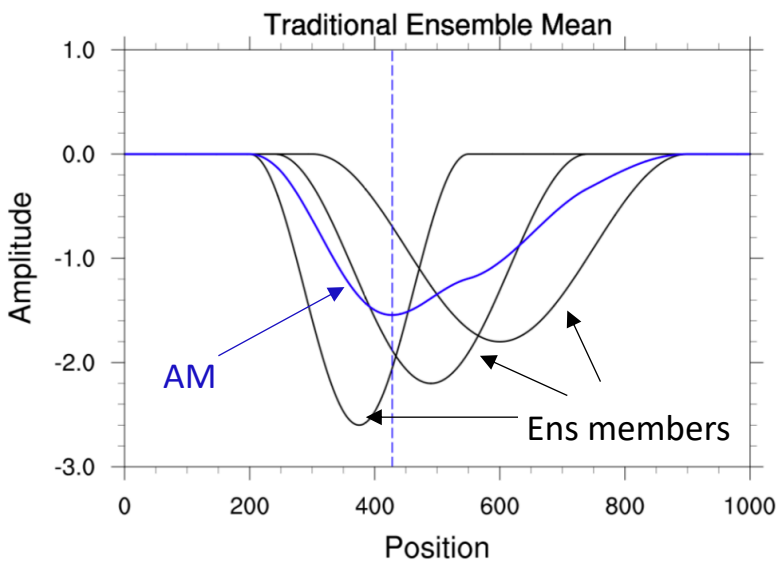
8-day ens fcsts and AM (black)



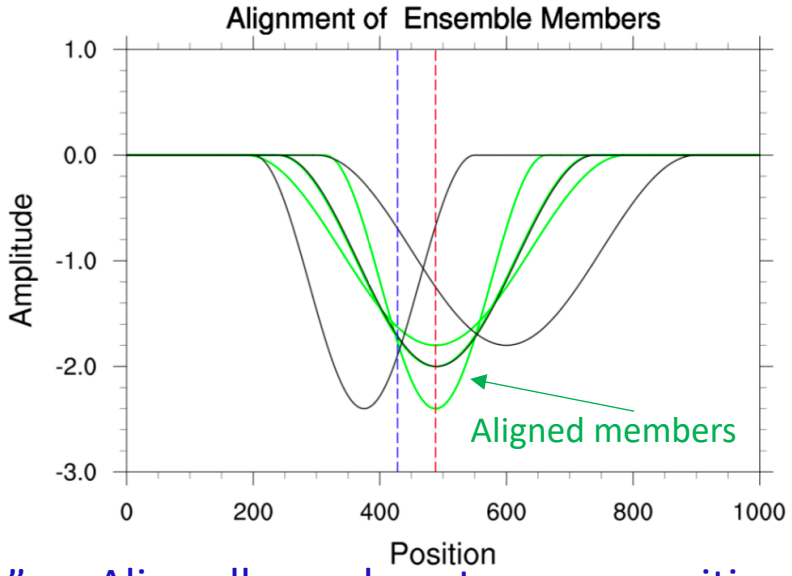
Each member has positional and amplitude errors!

How to improve AM?

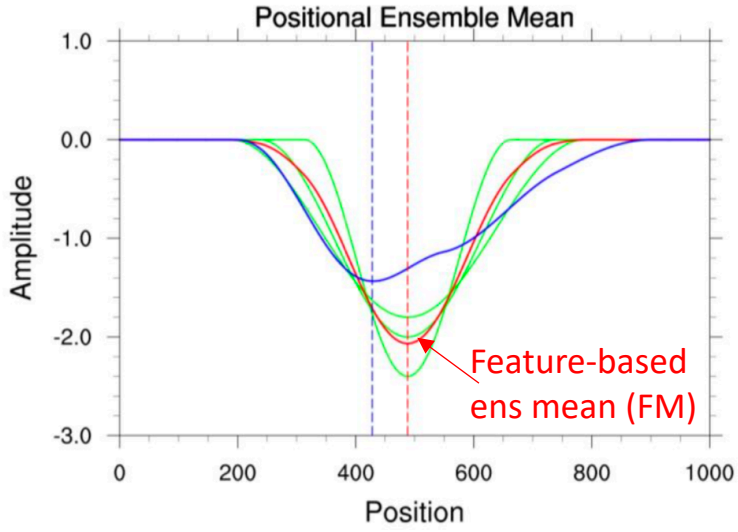
Schematic



AM presents wide and shallow "low pressure"



Align all members to mean position



- FM measures mean position and amplitude more accurately

Calculate ens mean of aligned members

How to estimate and adjust the position displacement?

Fundamental tool : Field alignment (Ravela, S., 2007a, b, 2012)

- DTC Code Repository
- Variationally estimate a smooth 2D displacement vector btw two displaced fields
- Adjust one field by these displacement vector

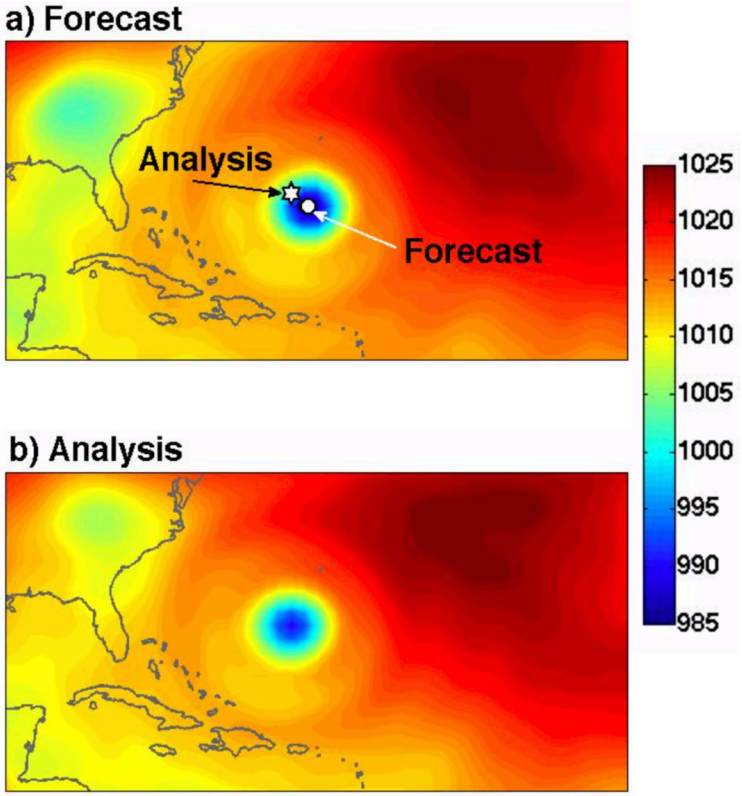
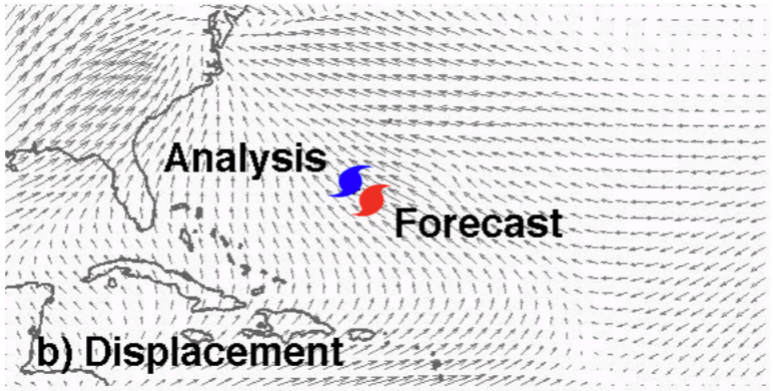
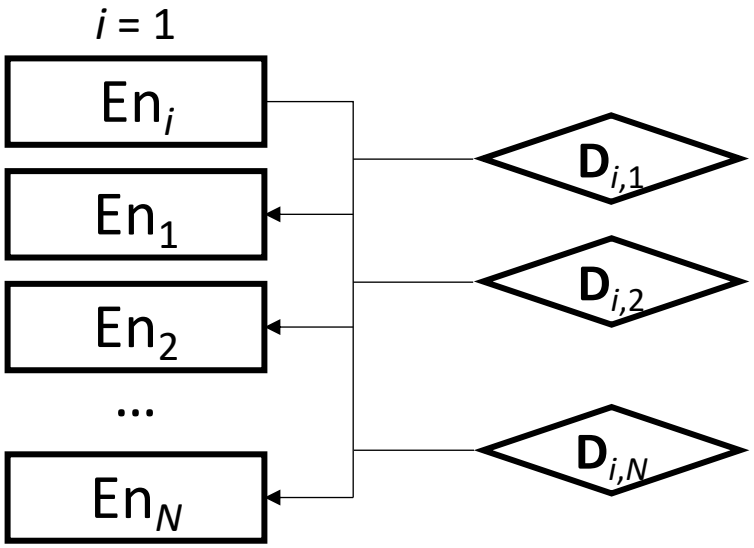


Figure 1. GEFS control member forecast and the GFS analysis valid at September 6, at 12Z. A star and dot in panel (a) indicates the analyzed vs. forecast central position of Hurricane Katia.



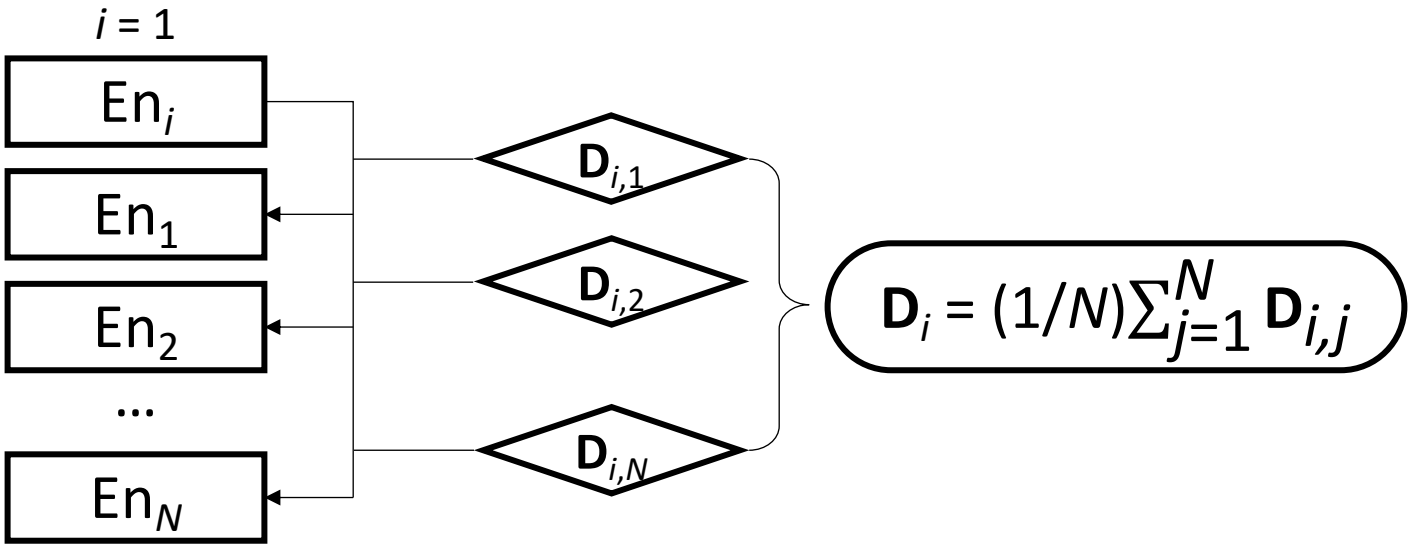
Peña et al. 2017

Methodology



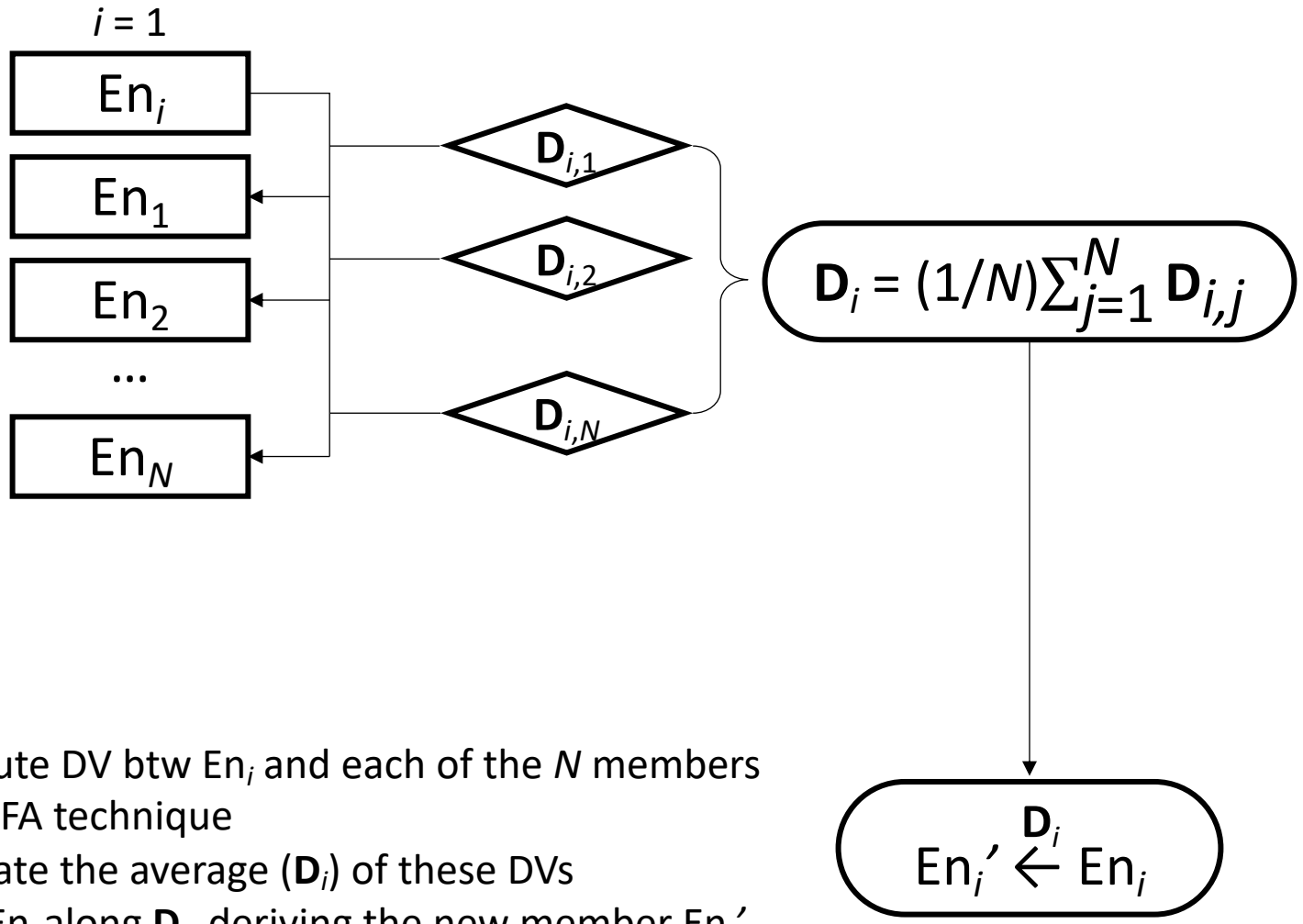
1. Compute DV btw En_i and each of the *N* members by using FA technique

Methodology



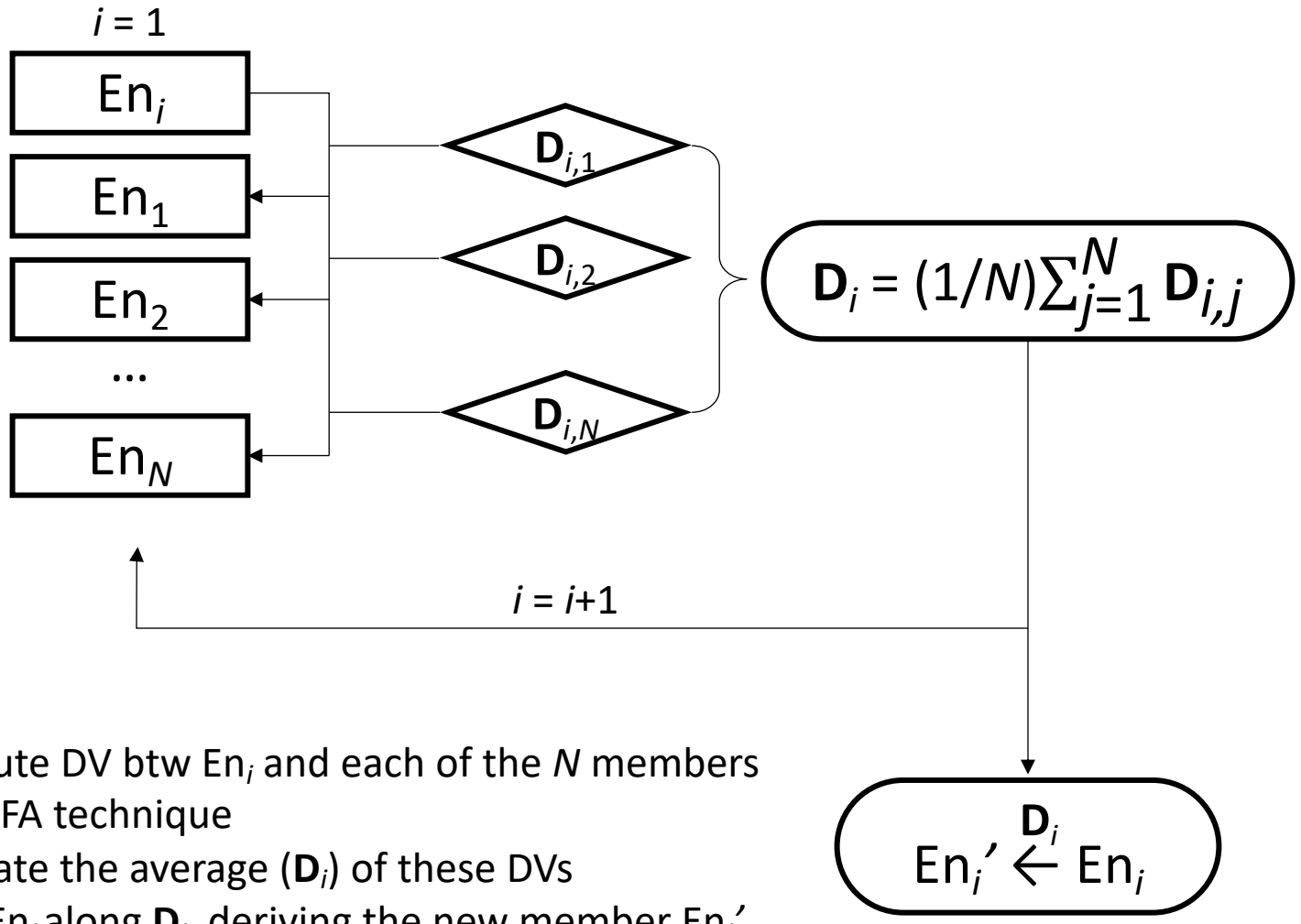
1. Compute DV btw En_i and each of the N members by using FA technique
2. Calculate the average ($\mathbf{D}_i$) of these DVs

Methodology



1. Compute DV btw En_i and each of the *N* members by using FA technique
2. Calculate the average ($\mathbf{D}_i$) of these DVs
3. Align En_i along $\mathbf{D}_i$, deriving the new member En_i'

Methodology



1. Compute DV btw En_i and each of the N members by using FA technique
2. Calculate the average ($\mathbf{D}_i$) of these DVs
3. Align En_i along $\mathbf{D}_i$, deriving the new member En_i'
4. Repeat 1-3 for each member of the ensemble

Data and experimental setup

Data : GEFS operational forecast data with 1°×1° resolution, randomly selected 20 members

Sample: 10/01 – 10/25 2013 with 24-hr interval, totally 25 cases

Lead time: 10-day forecasts with 24-hr interval

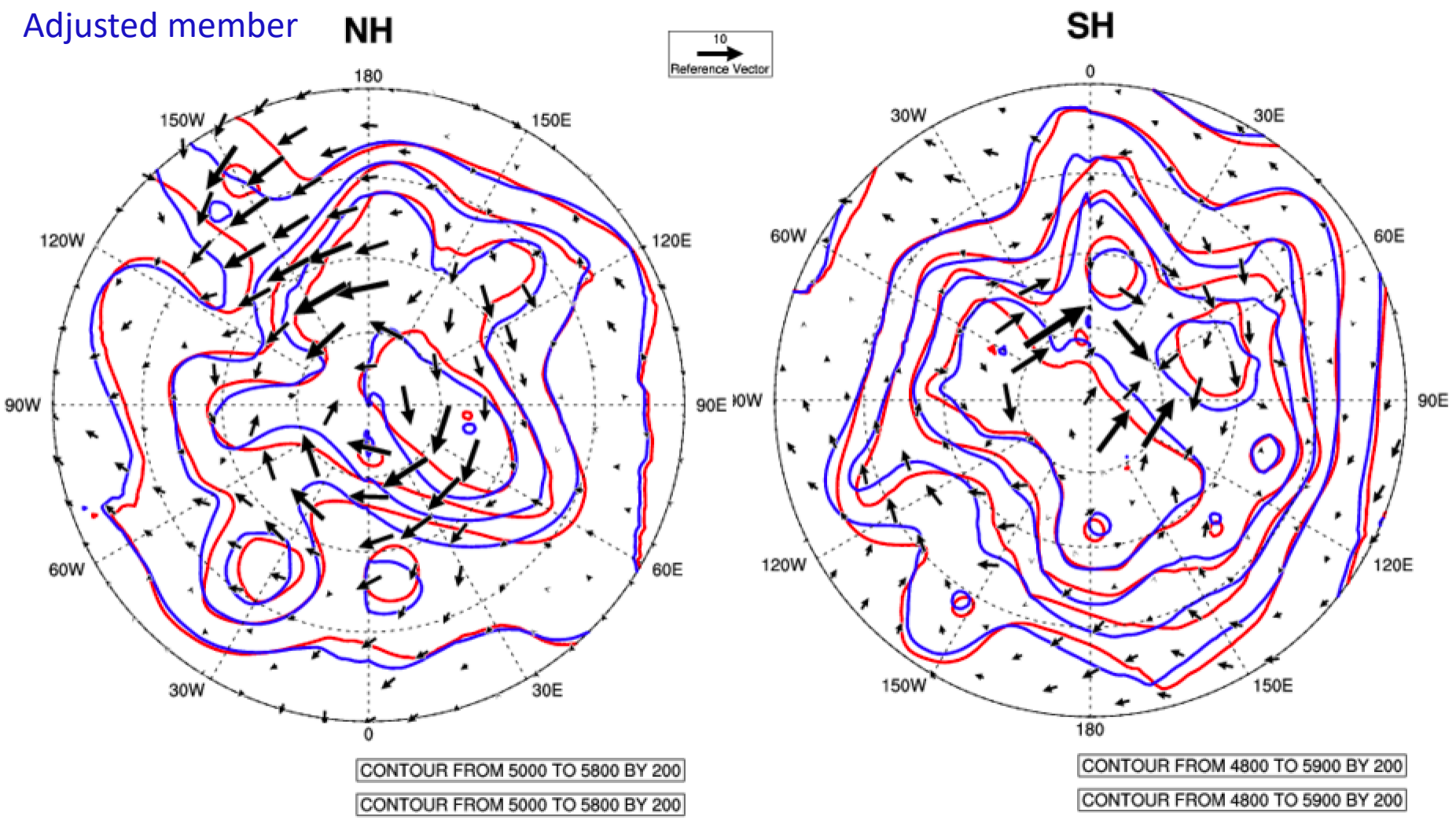
Variable: Geopotential height at 500 hPa

Verification: Control analysis as a reference

Example of the adjustment of ensemble fields

Original member

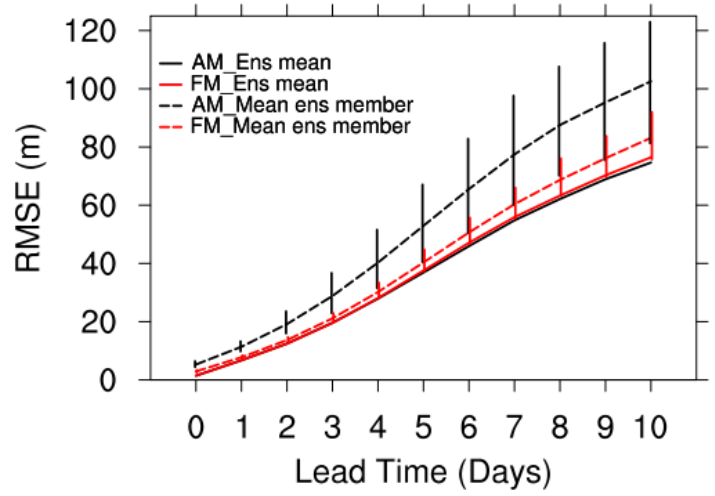
Adjusted member



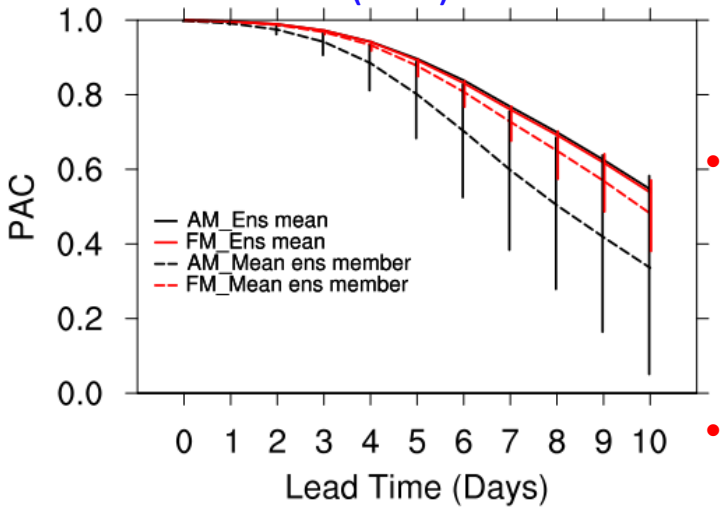
Sample Mean RMSE and PAC of AM and FM

Solid: ens mean
Dash: mean of each member
Bar: range of member error

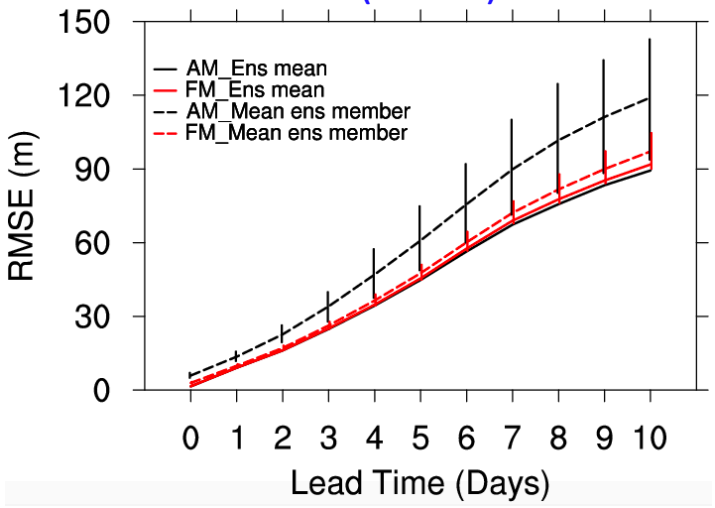
NH (RMSE)



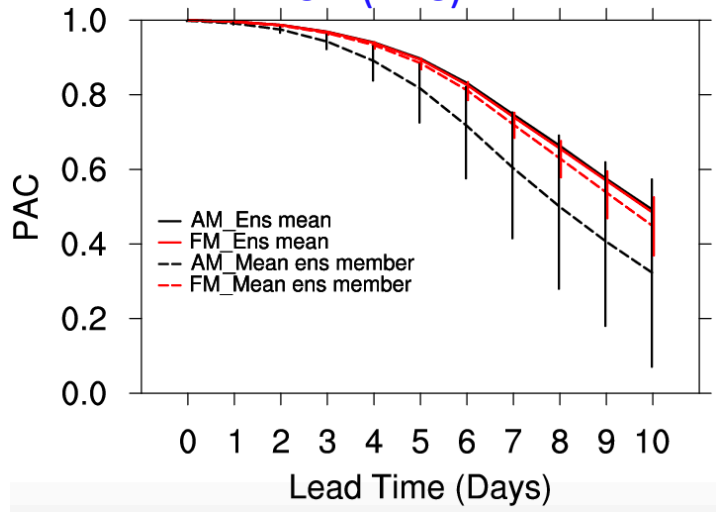
NH (PAC)



SH (RMSE)

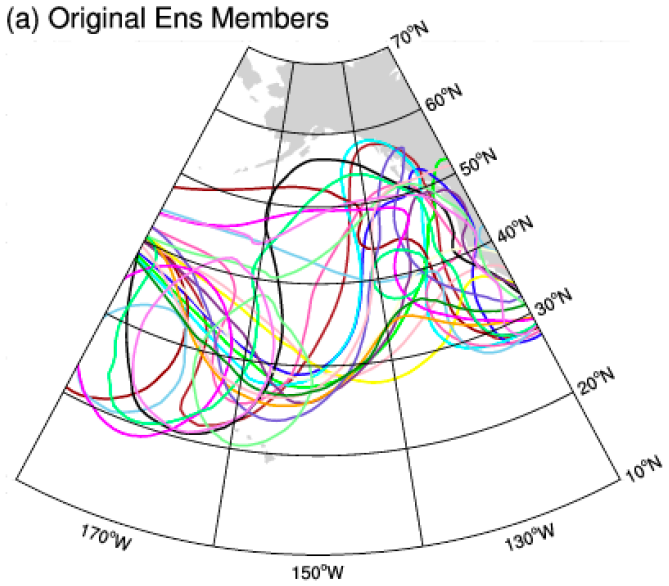


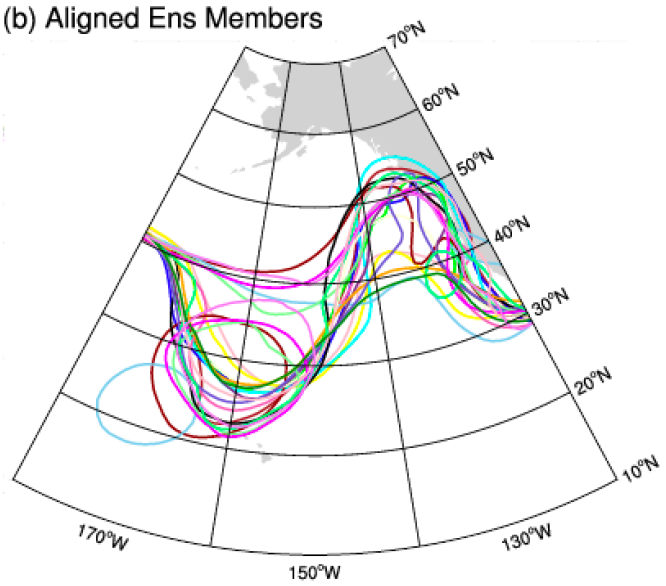
SH (PAC)



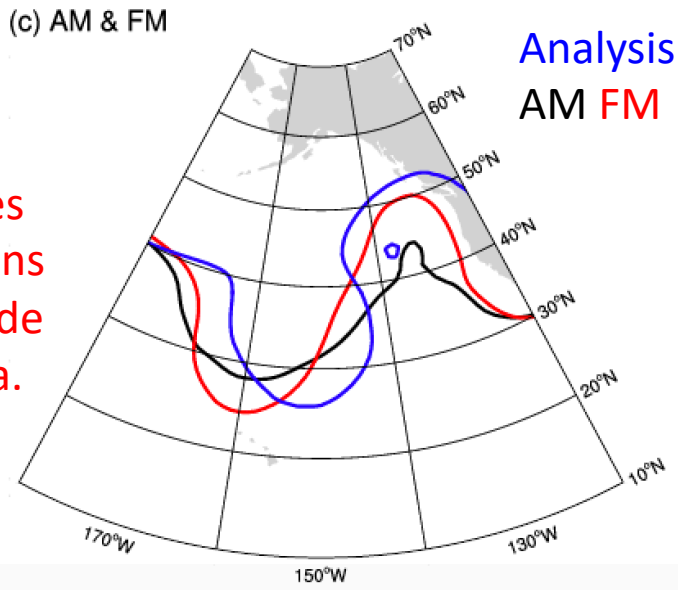
- AM and FM are very similar (bad news!)
  - AM seems to be "effective" to reduce errors
- Mean member error of FM is significantly better than that of AM
  - Probably lower positional errors
  - But much smaller spread

AM and FM in one case (7-day lead time)



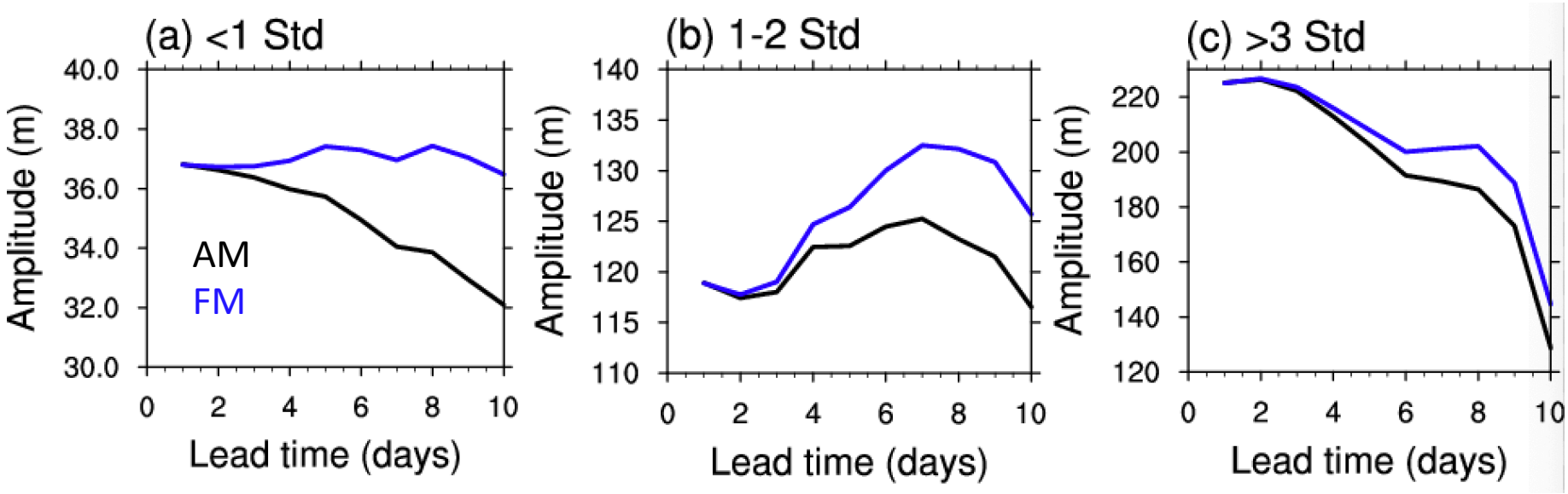


- Old members have large positional and amplitude deviations
- Trough and ridge in new ones are aligned to similar positions
- FM has much larger amplitude than AM, much closer to ana.



Mean Amplitudes (climatology removed)

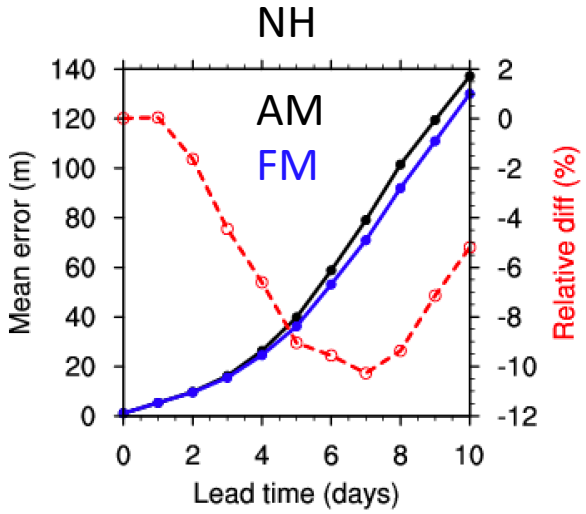
Sample mean of grid amplitude for three categories of events (selected by AM)

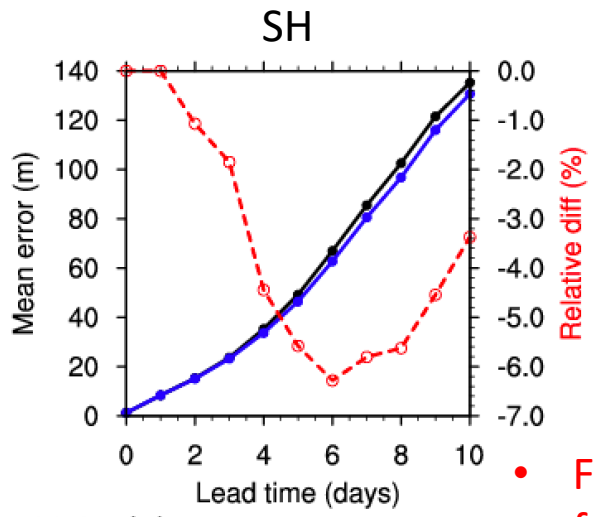


- FM fcst has larger amplitude (or variance) than AM for all three categories
  - 6-10% increase beyond 6 days.

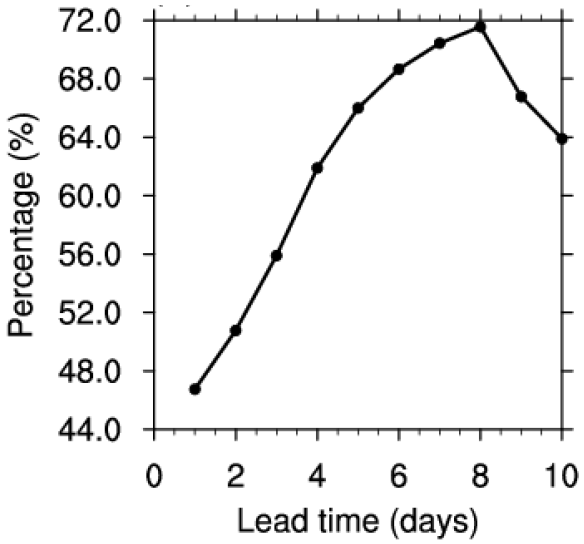
Forecast Skill for Extreme Events (>1.5 StD)

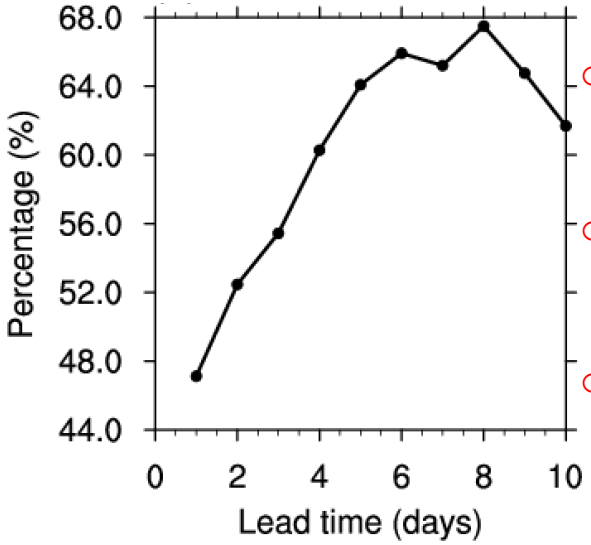
RMSE &
Relative diff %





#Grid percentage of better FM

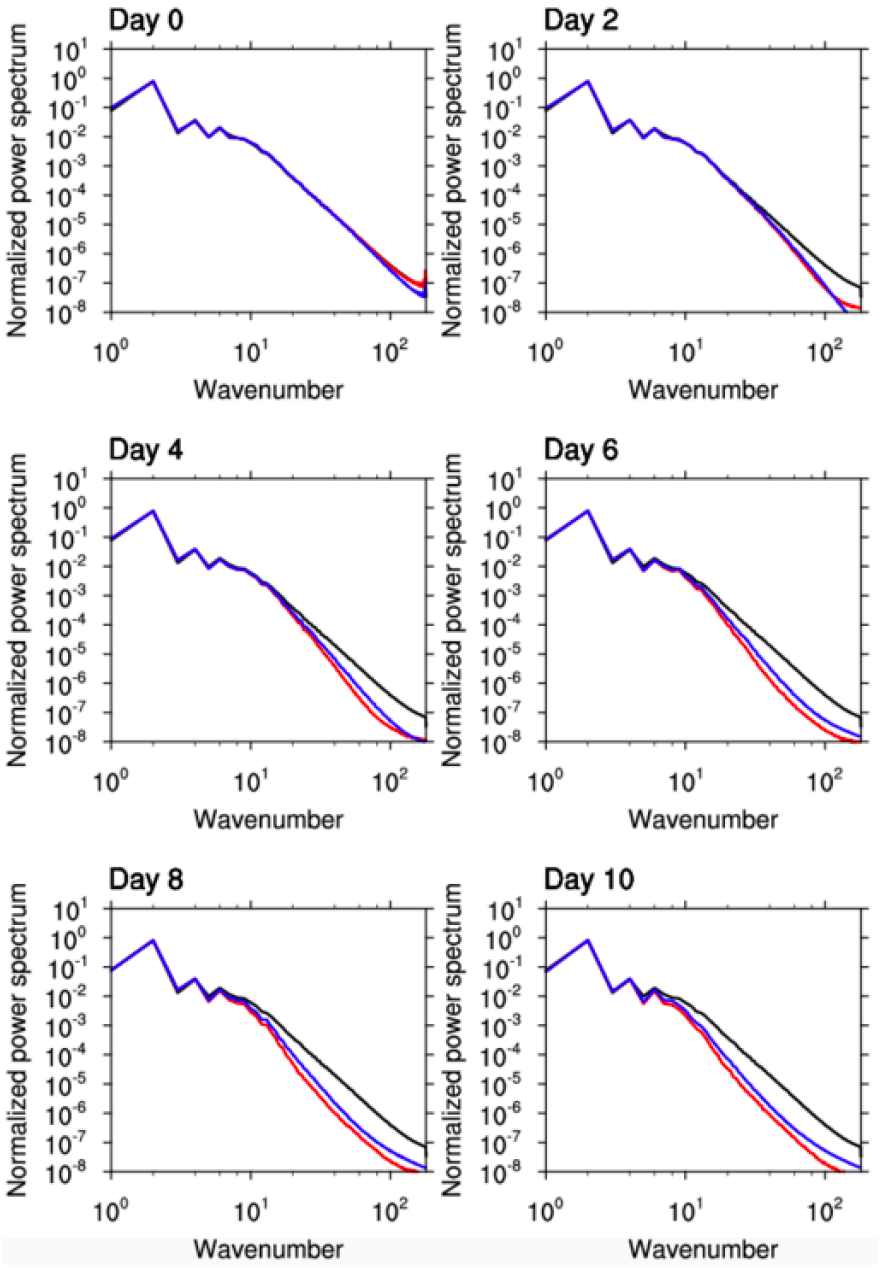




- FM better than AM for extreme events
  - Max 10% for NH, 6% for SH at 6-7 days
  - Improvements mainly for medium-range fcsts (>3 d)
  - Maximum reaches ~70% grids

Normalized Power Spectrum of Ens Mean

Analysis
AM FM



- AM smooths out small to medium scale features with increasing lead time
- FM fcsts present more medium and small scale features than AM
  - Especially for medium-range fcsts

Summary

- FM aligns features of individual members to their mean position, then computes the mean amplitude
- FM performs better than AM in predicting extreme events
  - Maximum 6-10% RMSE reduction at 6-8 day lead time
  - Continuous improvements beyond 3 days
- FM shows larger amplitude in forecasts
  - 6-10% beyond 6 days
- FM forecasts recognize more medium to small scale features than AM

Discussion

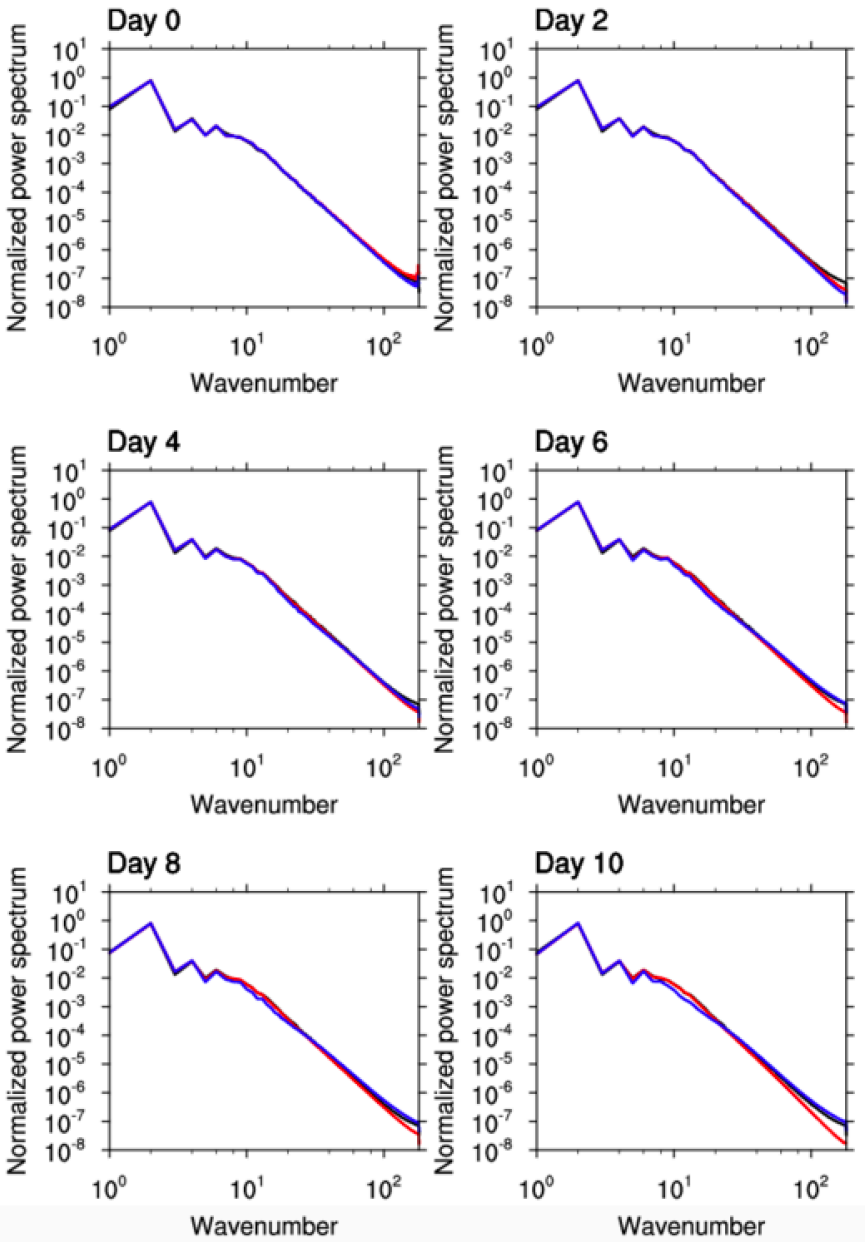
- Computational efficiency
  - Easy parallel computing
    - Each member is processed in a single core
    - ~ 1 min to calculate the DV btw two fields, e.g. 20 mems = 20 mins & 20 cores for one field and lead time
  - Effective for medium-range forecasts, peak at ~7 day
    - Used for only 4-9 days?
  - Use the DV as a first guess for next lead time
  - Matlab code -> Fortran code?

- Future work
  - Other variables, precipitation, hurricane intensity and track forecasts?
  - Field alignment more or less affects the amplitude, how to make a ”clean” position adjustment?

Thank you!

Normalized Power Spectrum of Each Member

Analysis Members for AM FM



- FM members do not loss any scale
  - Not aligned to AM
  - Probably smaller positional errors