DEEPWAVE Workshop
23-24 October 2014, Boulder, CO

ENSEMBLE UNCERTAINTY IN GRAVITY WAVE SIMULATIONS

Background and Motivation

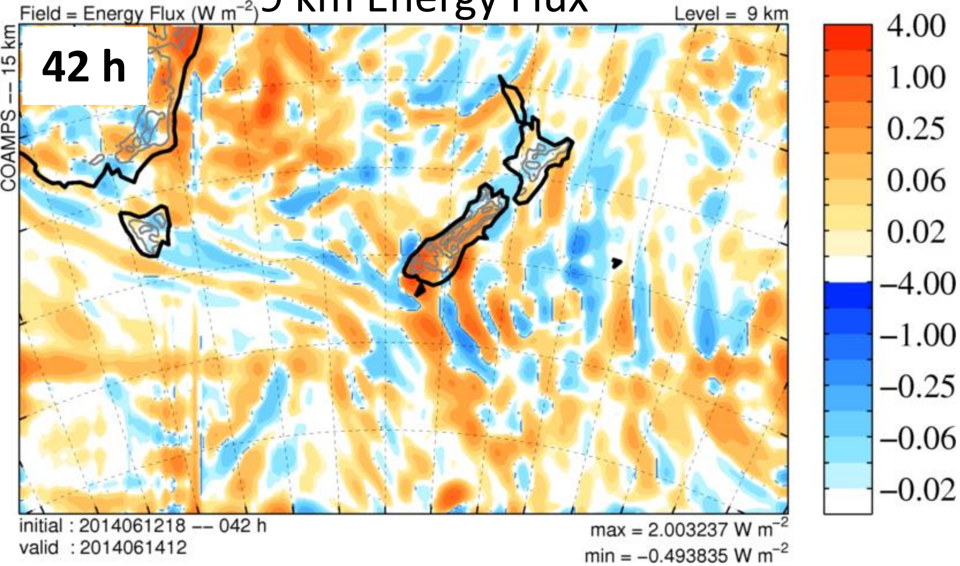
- Non-linear numerical models exhibit a sensitive dependence on initial conditions.
  - Small scale errors initial errors propagate upscale
  - Large scale initial errors rapidly propagate downscale

- Initial conditions for NWP models will always contain errors at all scales

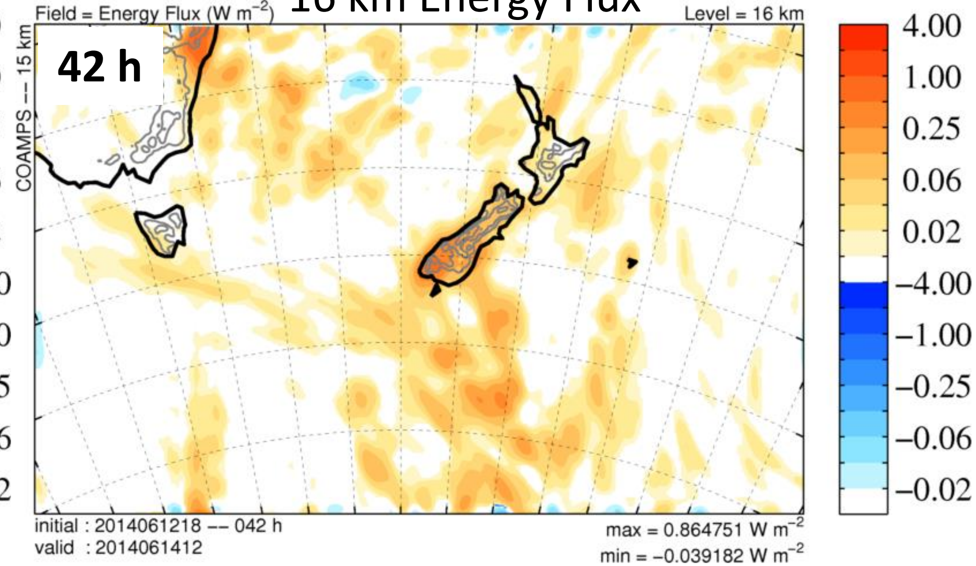
- Need to quantify how the initial error grows in gravity wave predictions:
  - Are observations contained within the expected model uncertainty?
  - Is there a difference between orographic and non-orographic sources?

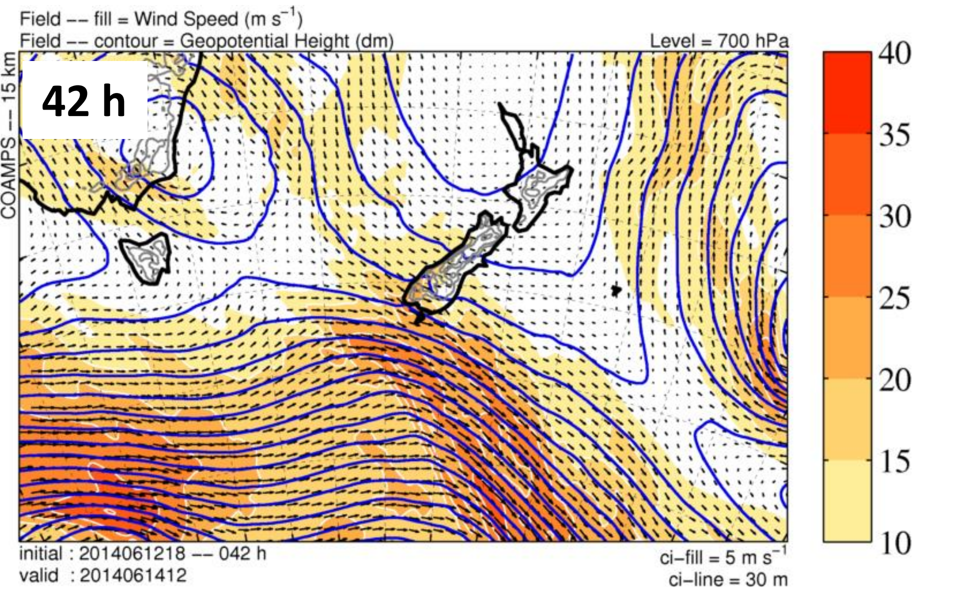
IOP 4: Real Time Wave Forecasts
Valid: 12 UTC 14 June

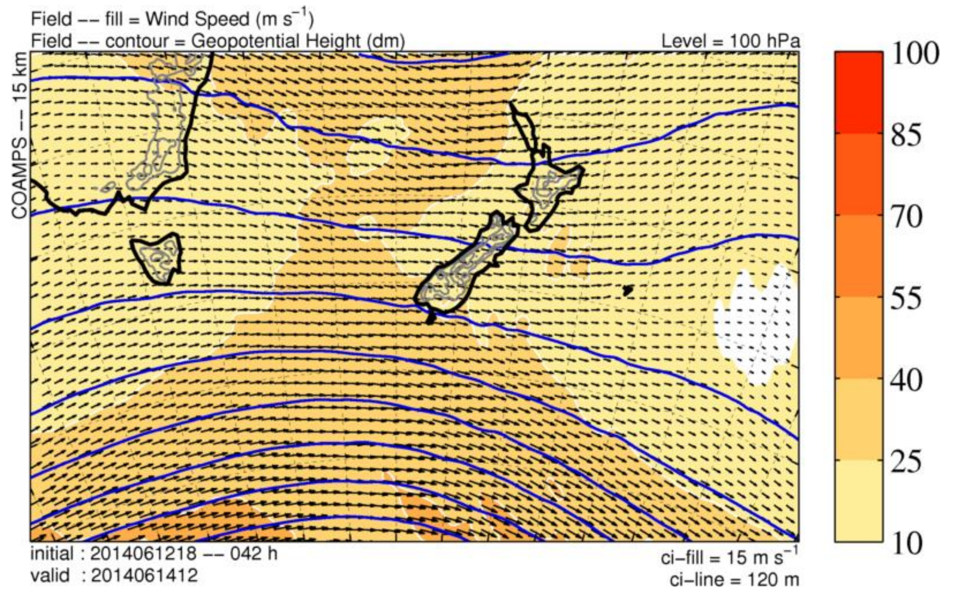
9 km Energy Flux



16 km Energy Flux





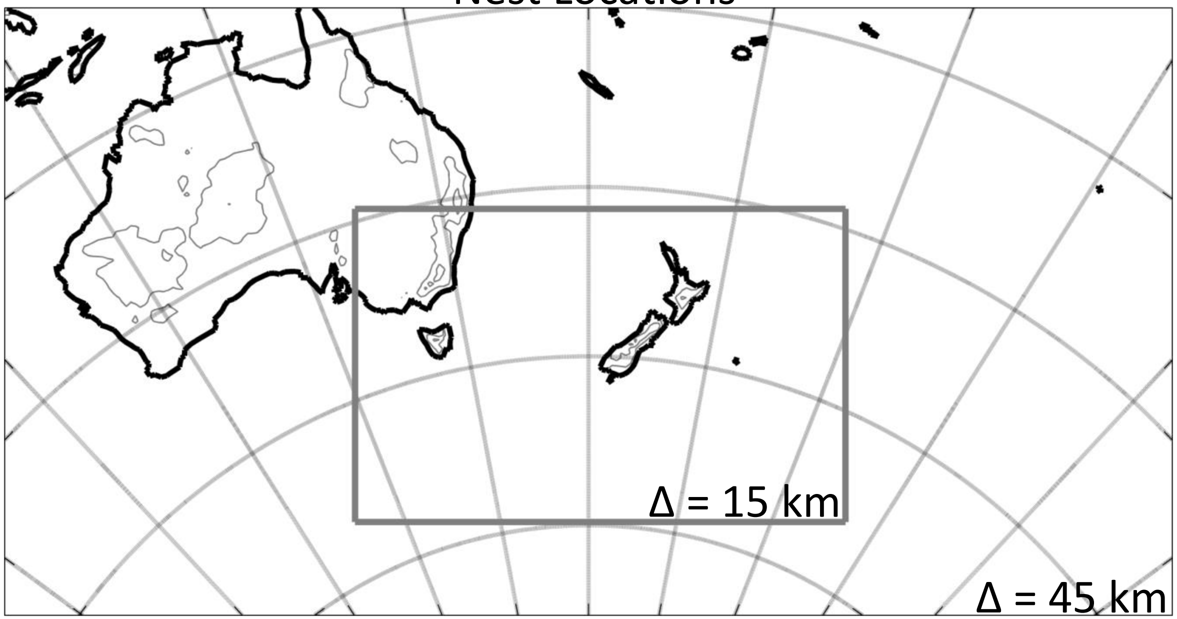


Methodology

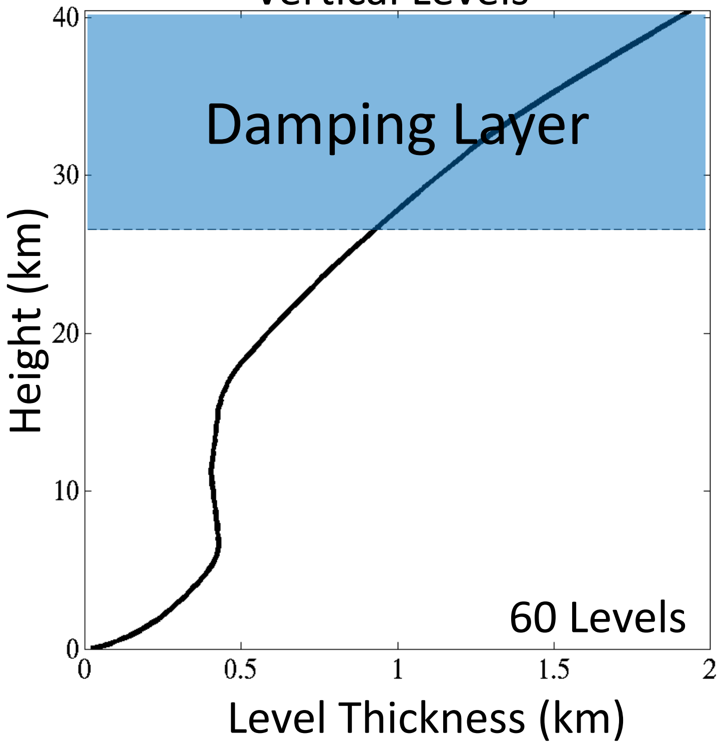
- Use the COAMPS ensemble system to quantify the initial perturbation growth over the SI and SO.
  - Focus on orographic (IOP 3) and non-orographic (IOP 14; not this presentation) gravity waves events
- 20-member ensemble with IC and BC perturbations.
  - Simplistic approach, climatological covariance, no DA
  - Better to cycle the perturbations with either ET or DA (plan to do this in the near future)
- Perform 48- to 72-h forecasts
  - Evaluate spread of diagnostic quantities (MF, EF, …)
  - Do observations fall within the range of the predicted spread?
  - Use the ensemble covariance to inform the dynamics

COAMPS Ensemble Configuration

Nest Locations

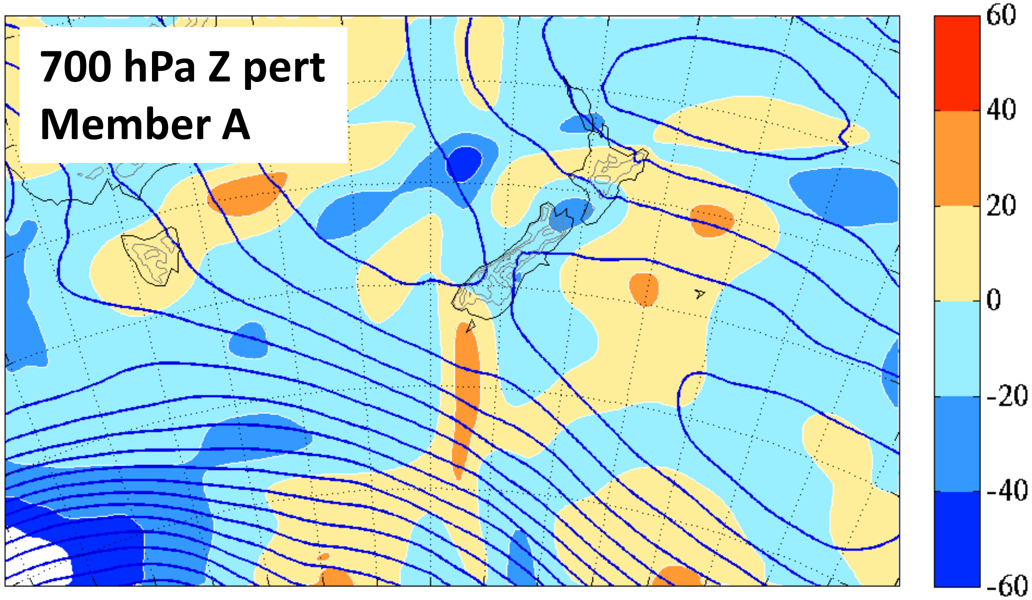


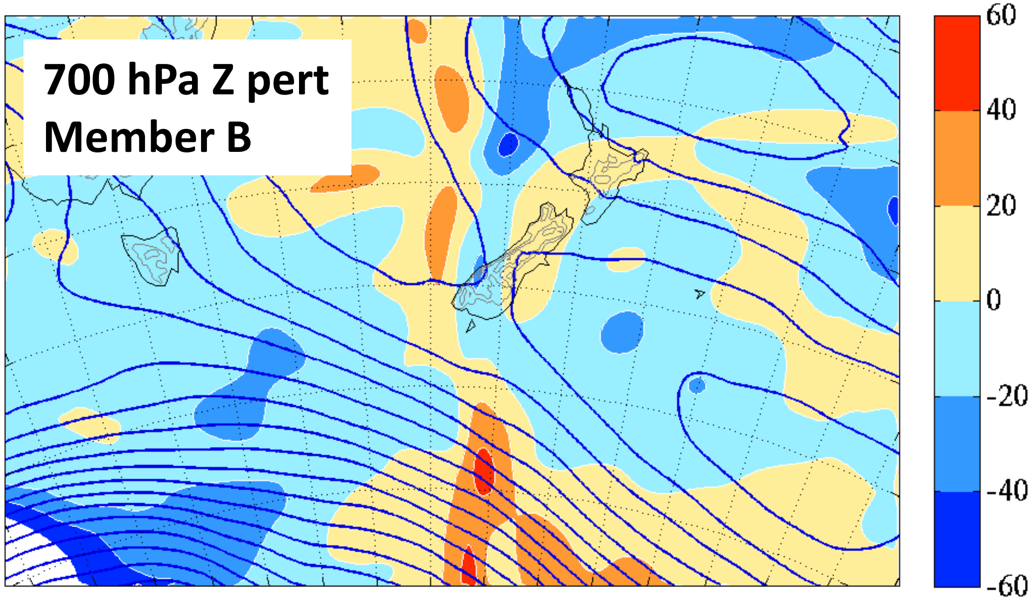
Vertical Levels



- Two-way nested domains of 45- and 15-km horizontal resolution
- 79 vertical levels: 38 levels below 10 km, 61 levels below 20 km
- Lateral boundaries updated every 6-hours from NAVGEM forecast
- 20 members: IC’s and BC’s perturbed from climatological covariance

Initial Condition Perturbations





IC perturbations sampled from climatological covariance

Positives

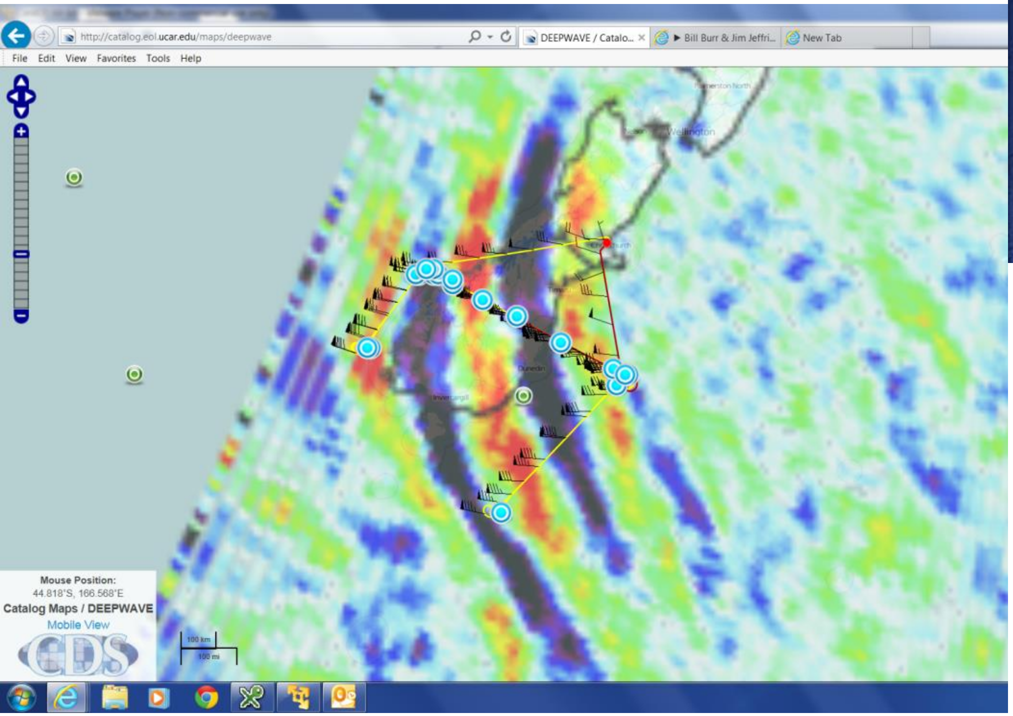
- Extremely simple to generate an ensemble
- Balanced and represent average expected IC errors

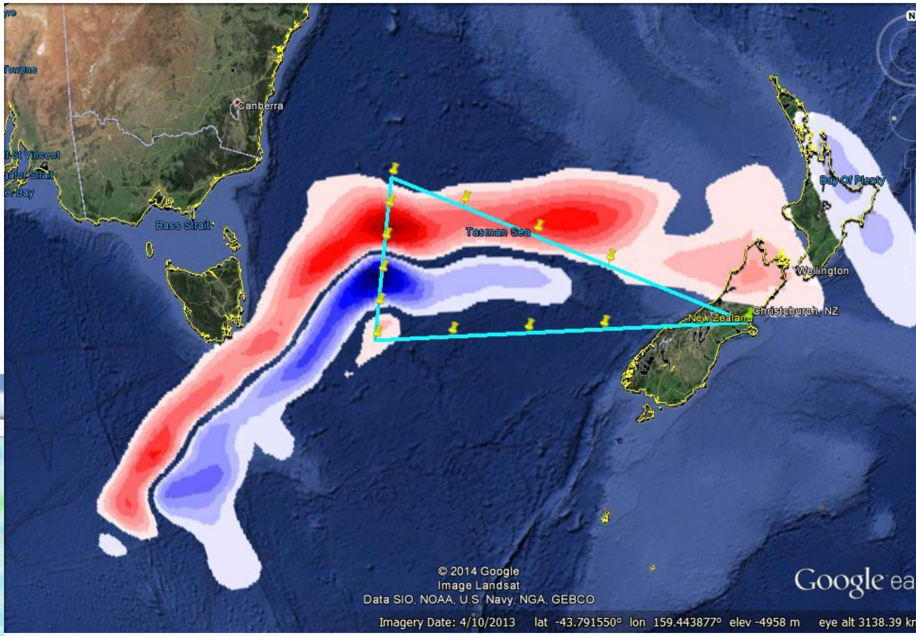
Negatives

- Not informed by current flow
- Not cycled, do not represent growing/decaying modes
- Not informed by data assimilation obs. errors

IOP 03: RF03 and RF04
14 June 2014

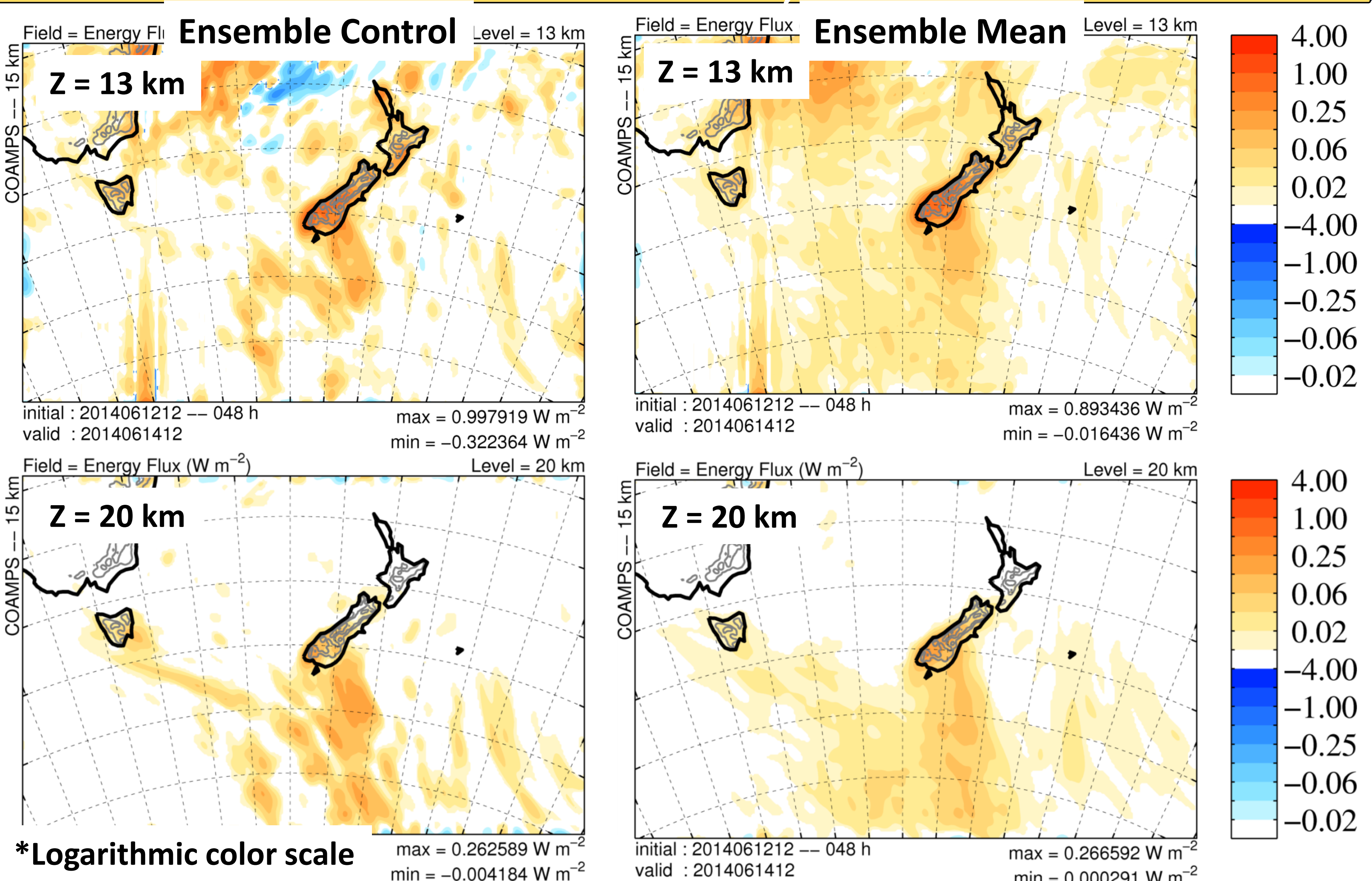
RF03: Sample a region of predicted sensitivity upstream of the Southern Alps.



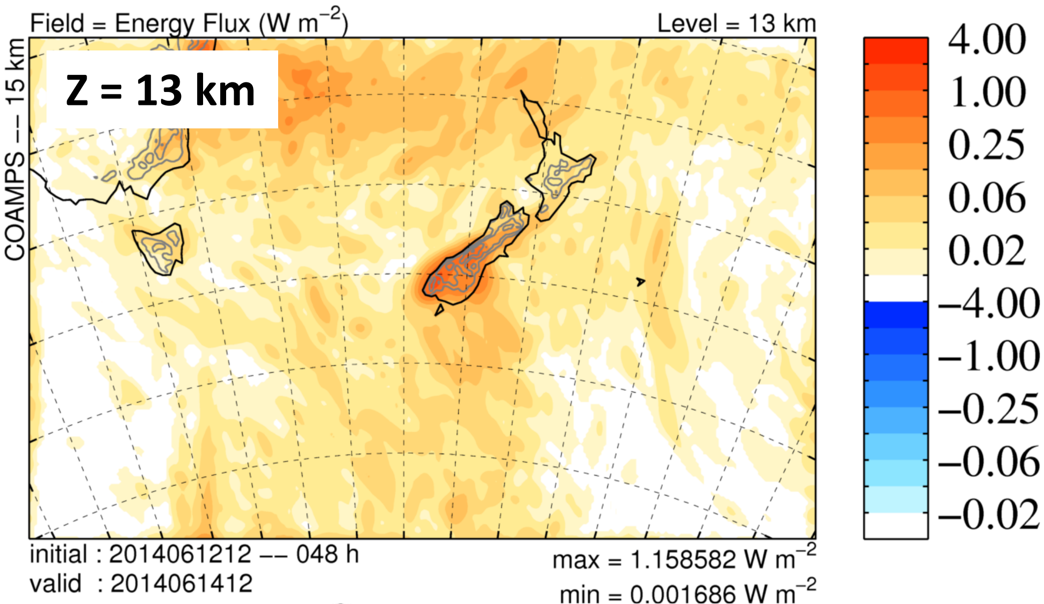


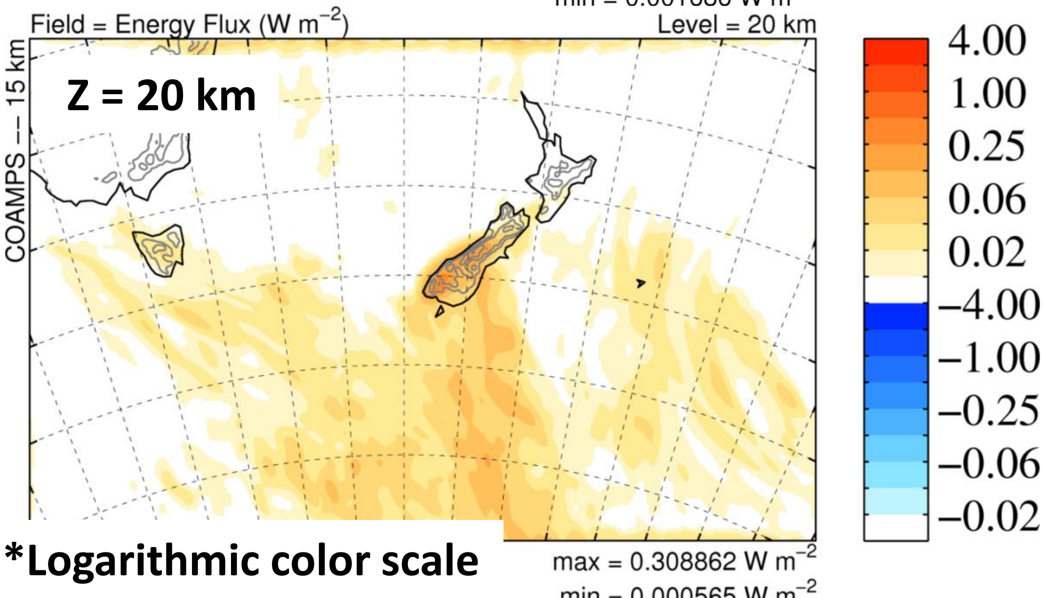
RF04: Observe mountain waves and trailing waves over the South Island.

Energy Flux: Control vs. Mean Valid: 12 UTC, 14 June



Ensemble Std. Dev. Energy Flux Valid: 12 UTC, 14 June

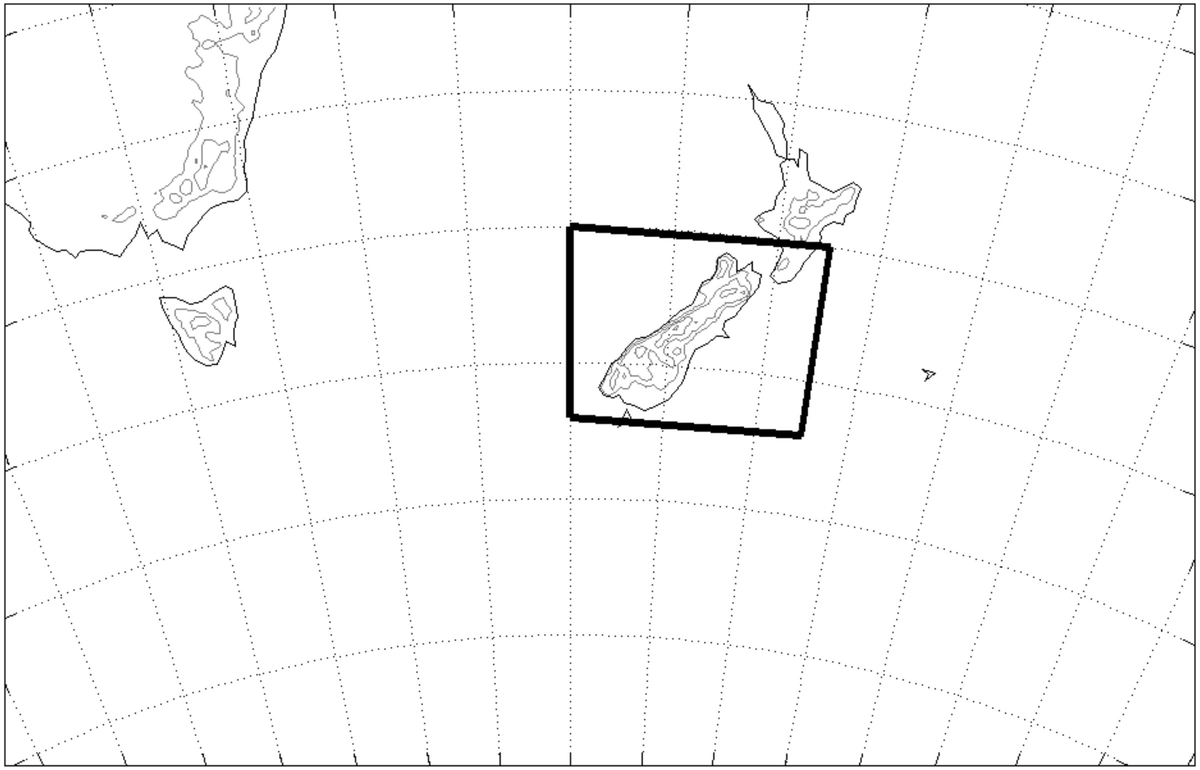




***Logarithmic color scale**

- Ensemble spread is coincident with energy flux
- Standard deviation is the same order magnitude as ensemble mean flux values
- Need to consider IC uncertainty to compare observations to simulations.
- Ensemble spread decays with height.

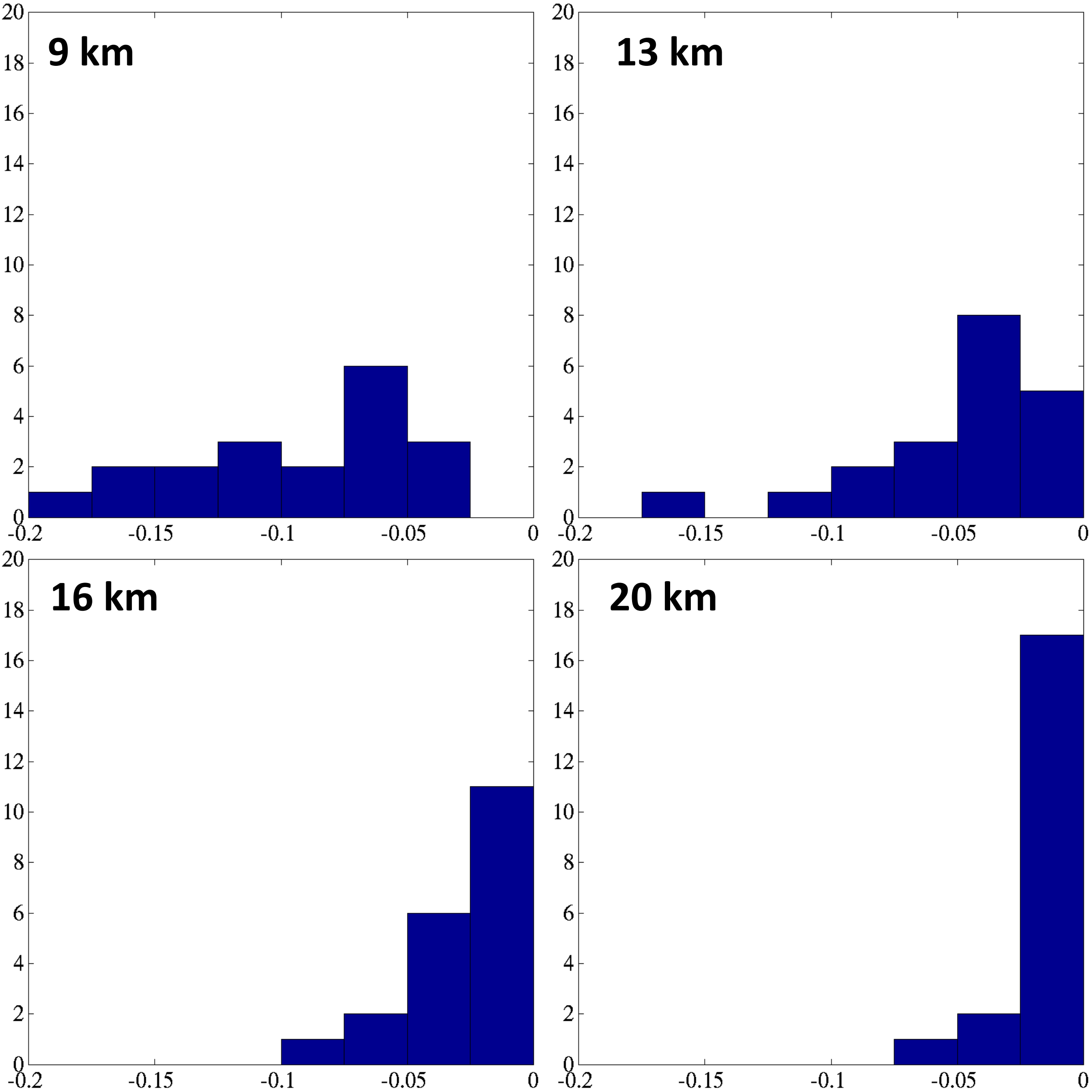
Metric Box



Compute mean and extremes of diagnostic quantities in a box centered over the South Island (e.g. momentum flux, energy flux, wind speed…)

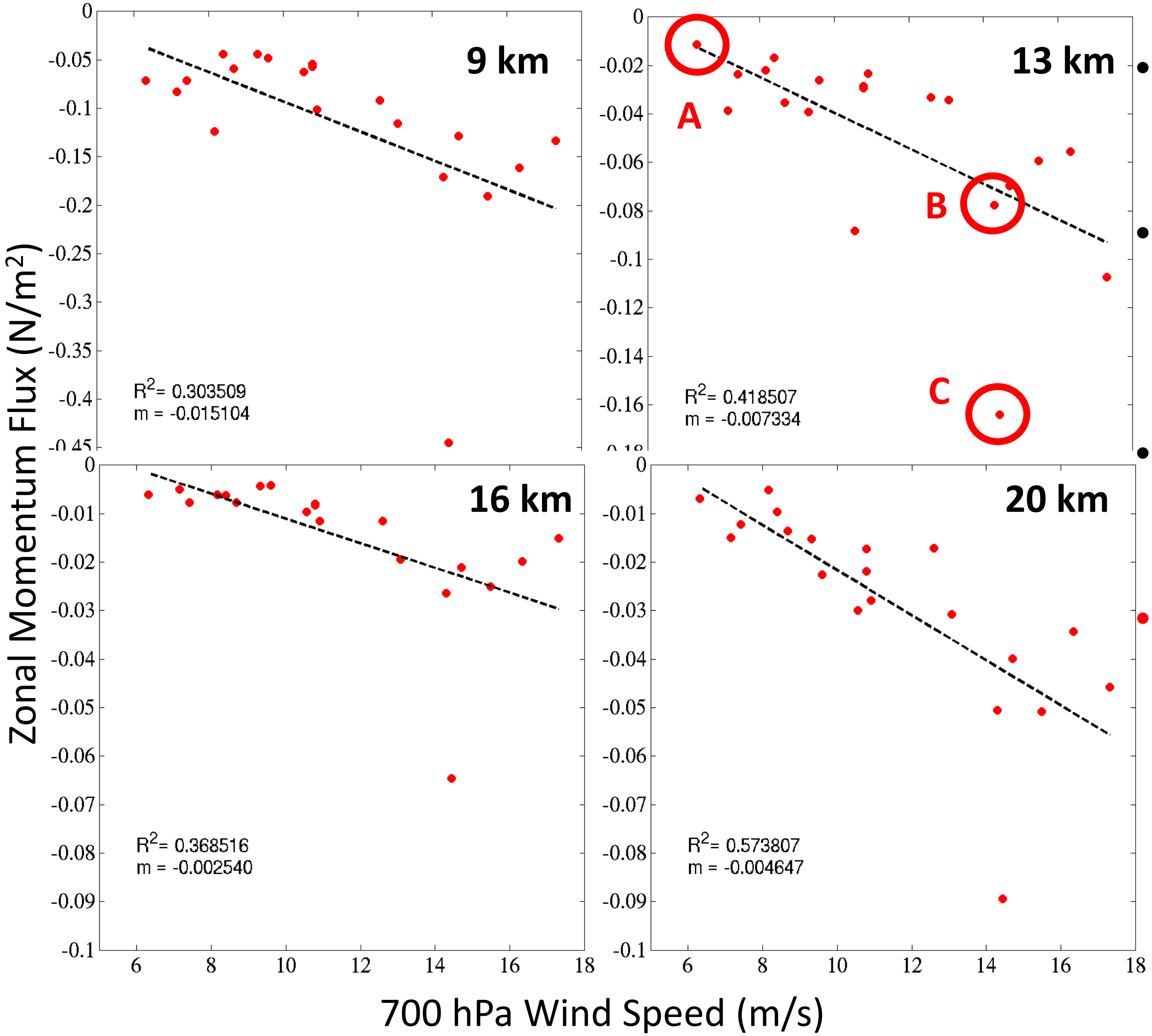
Computation is done for each ensemble member and variance and covariance of metric is determined

Zonal Momentum Flux
48 h Forecast : Valid 12 UTC, 14 June



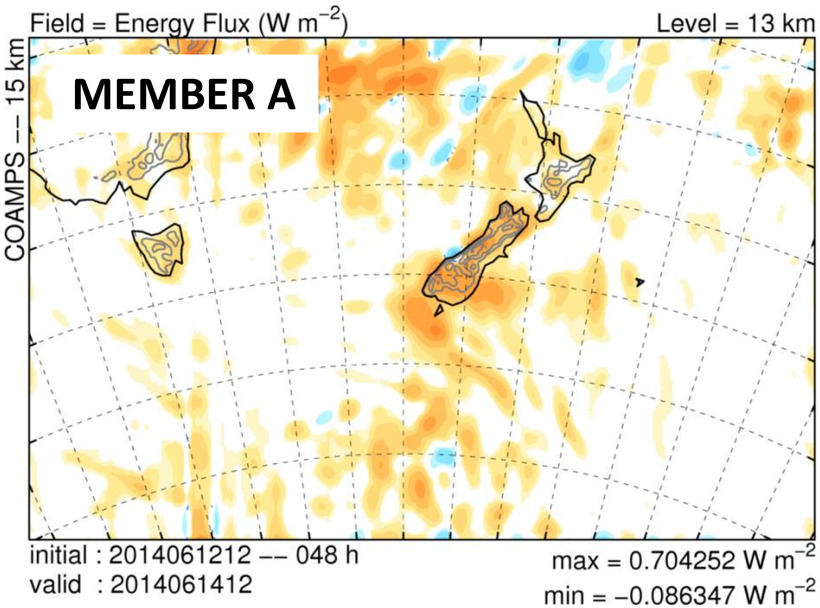
- Ensemble spread decays with height
- Similar behavior at other lead times
- Mechanism of decreasing spread in the stratosphere?

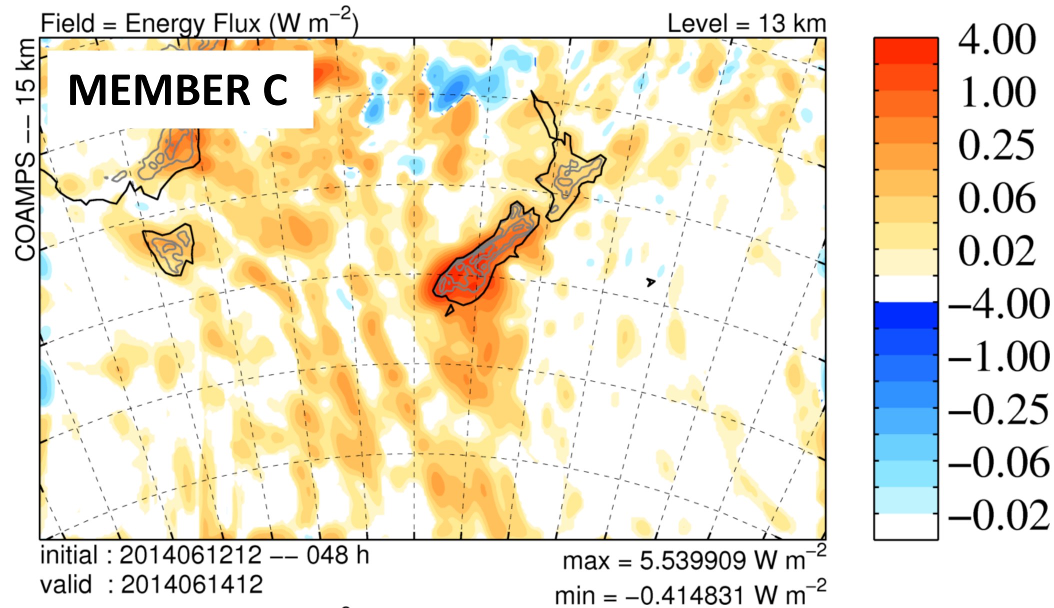
Momentum Flux vs. 700 hPa Wind

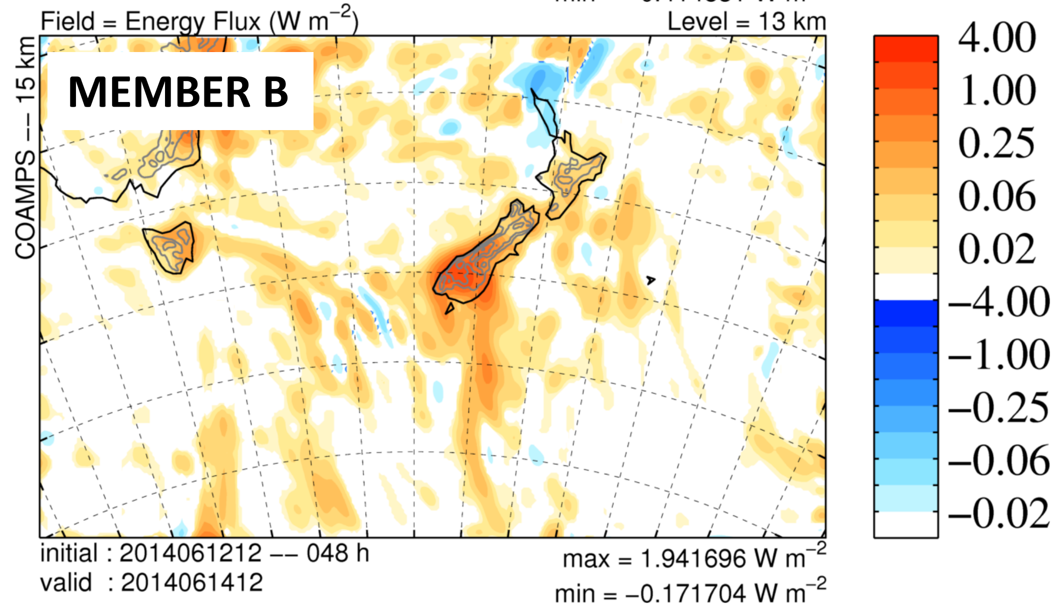


- **Stronger forcing -> larger momentum flux**
- **700 hPa wind speed explains large fraction of variance**
- **However, large outlier present**
- **Examine members A, B, and C individually.**

Flight Level Energy Flux (Outliers)



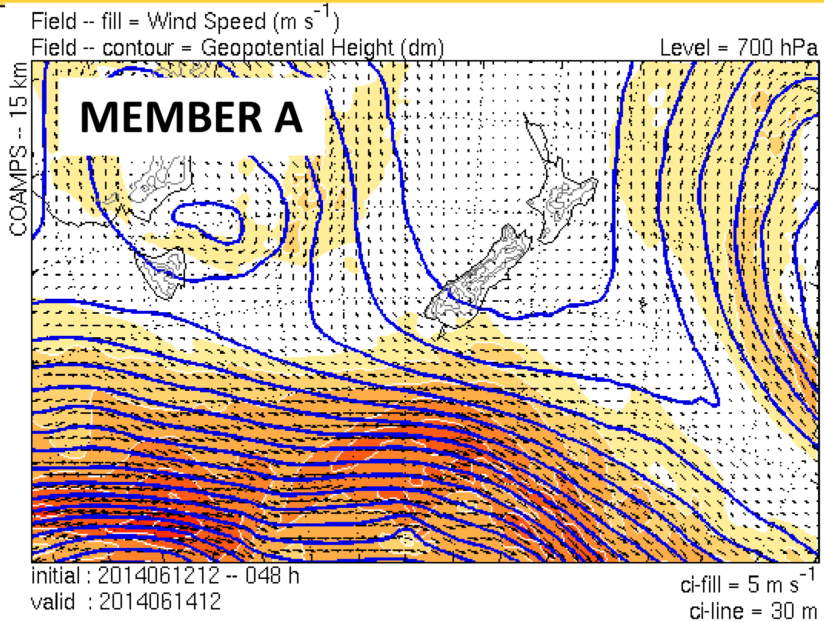


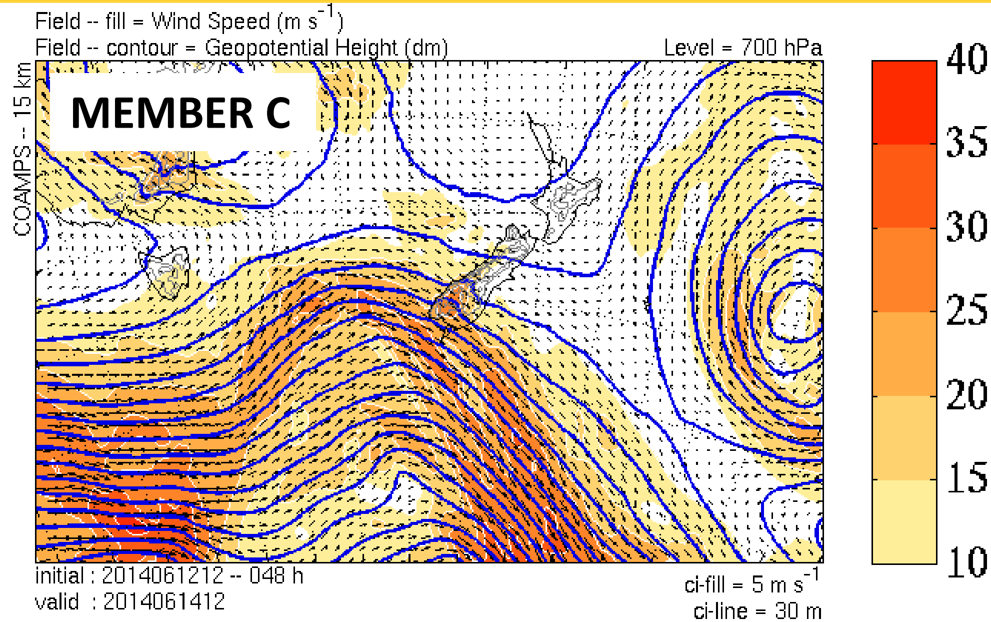


- **Similar spatial coverage of EF over and downstream of SI**
- **Order of magnitude difference in EF at distribution tails:**
  - **5.5 W/m^2 for member C**
  - **1.9 W/m^2 for member B**
  - **0.3 W/m^2 for member A**

***Logarithmic color scale**

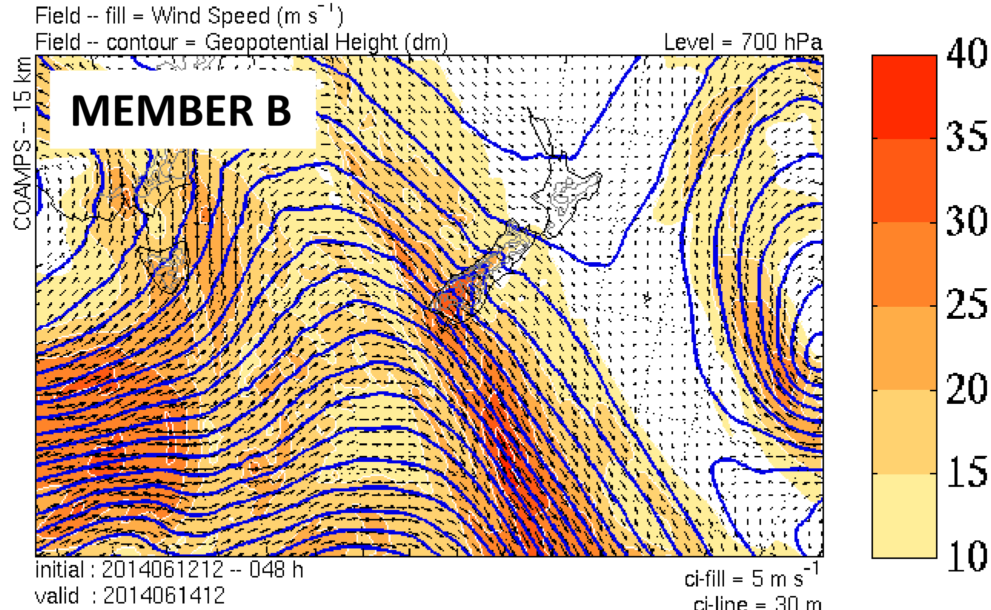
700 hPa Wind (Outliers)





Is perturbation growth too large?

Could growth be associated with IC perts projecting onto adjoint sensitivity region?



Summary and Q's

- Decay of ensemble spread with height:
  - Is this real and repeatable? If real, what is the underlying mechanism?
  - Characteristic of spread for GW entering the stratosphere?
  - Is spread same for orographic and non-orographic waves?
- Spread of zonal momentum flux increases with wind speed.
  - Large, strong outlier is present.
  - How does the forcing and environment differ from the other members?
- Large spread in synoptic scale flow field after 48 hours:
  - Is this realistic or are IC perturbations too large?
  - Do initial perturbations project onto adjoint sensitivities?

Future Work

- Examine additional cases to include both orographic and non-orographic events:
  - Continue to diagnose differences at tails of ensemble distribution
  - Characterize the differences in GW perturbation growth.
- Evaluate different IC perturbation methods and quantify spread-skill:
  - Cycling COAMPS ET with/without DA
  - Cold Start from NAVGEM ET
  - Cycling EnKF
- Compare ensemble spread predictions to observations:
  - What is the frequency that observations fall outside the expected uncertainty?

Questions?

END

IOP 14 : RF24
15 July 2014