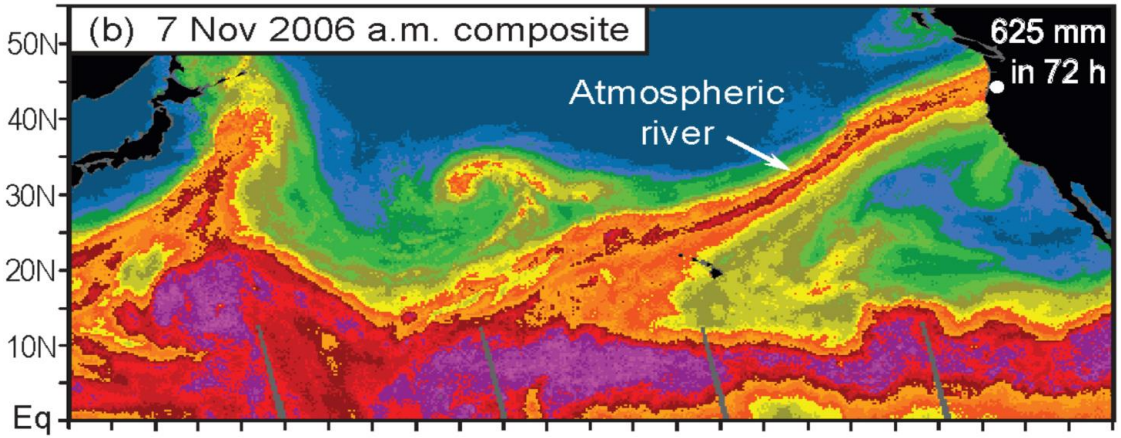
Developing and Testing a High-Resolution Ensemble-Based 6-10 Day Forecast System for Atmospheric Rivers and Heavy Precipitation over the Western U.S.



Nick Weber, Greg Hakim and Cliff Mass
University of Washington

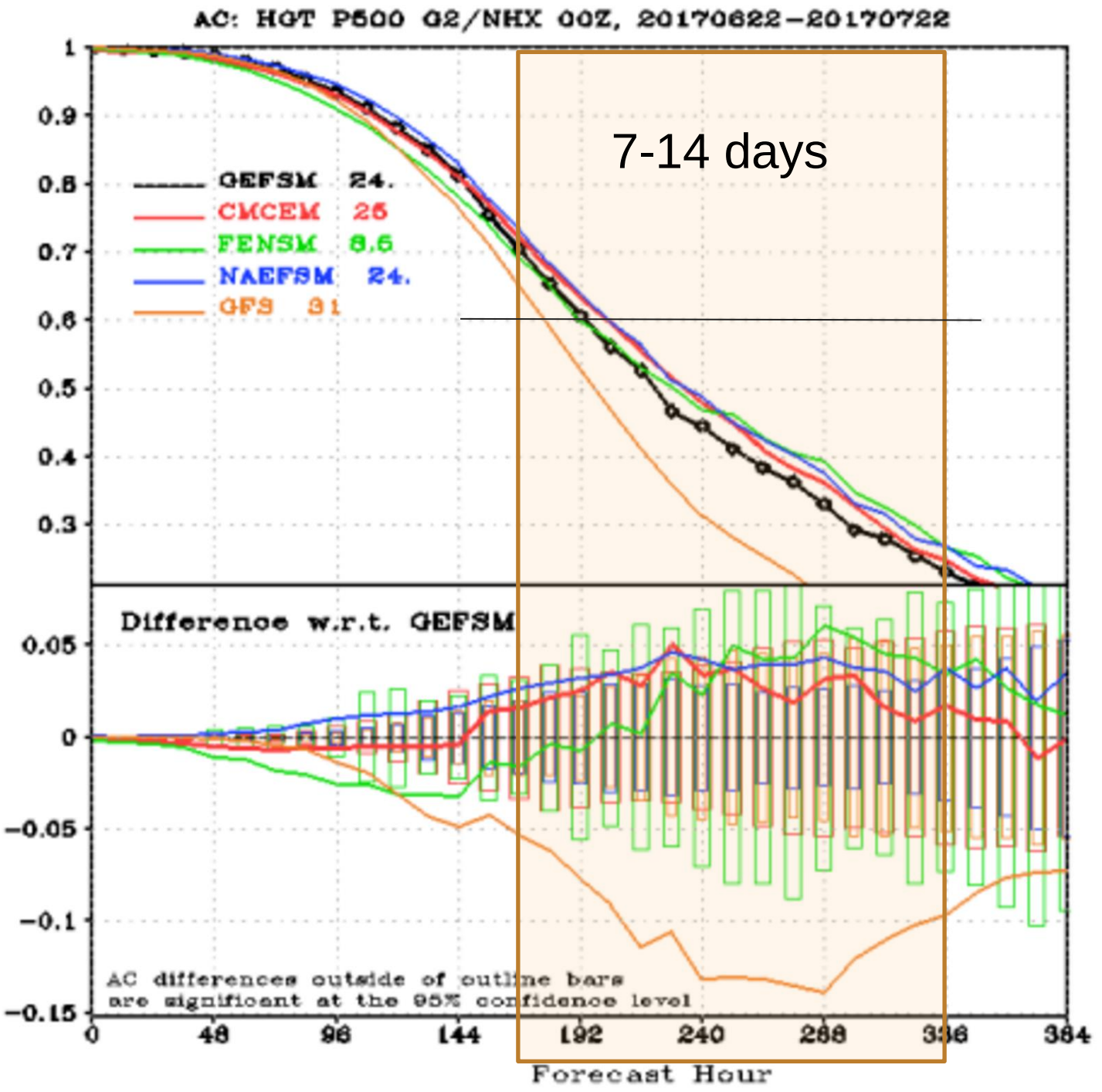
Improving 1-2 Week Forecasts Over the Western U.S. with an Emphasis on Atmospheric Rivers

- Atmospheric rivers represent the most impactful weather feature of the western U.S.
- Associated with flooding, loss of life, and dam/reservoir safety. Billion dollar disasters. Water resources.
- Skill in the second week can be important, since it provides guidance for reservoir draw downs during multiple atmospheric river events

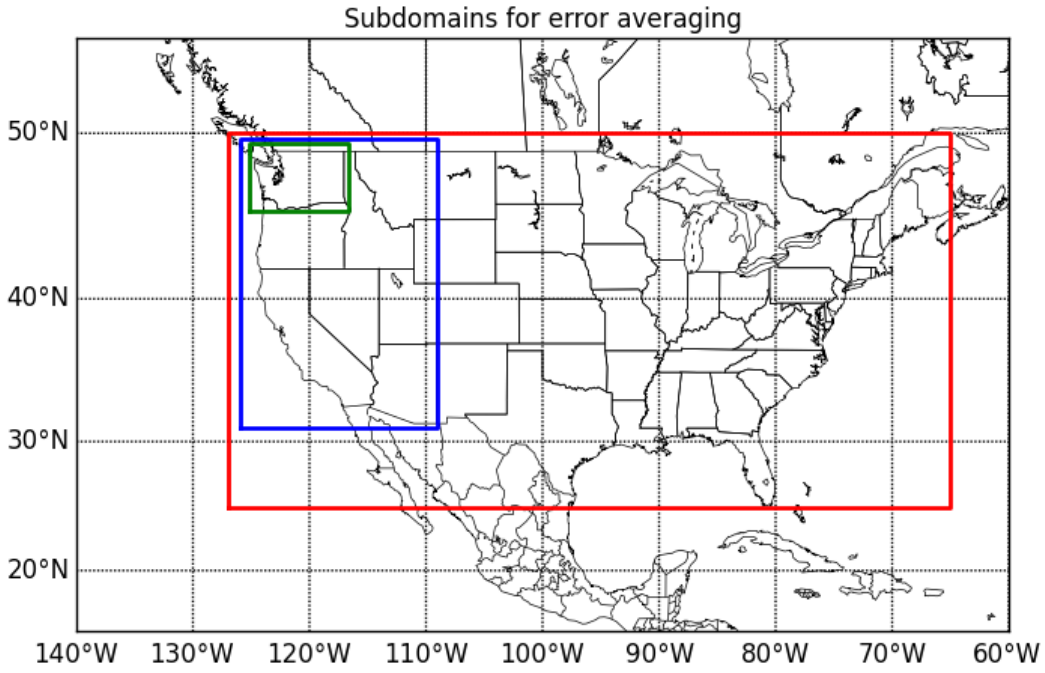
The Problem

There is a rapid decline of forecast skill during the second week

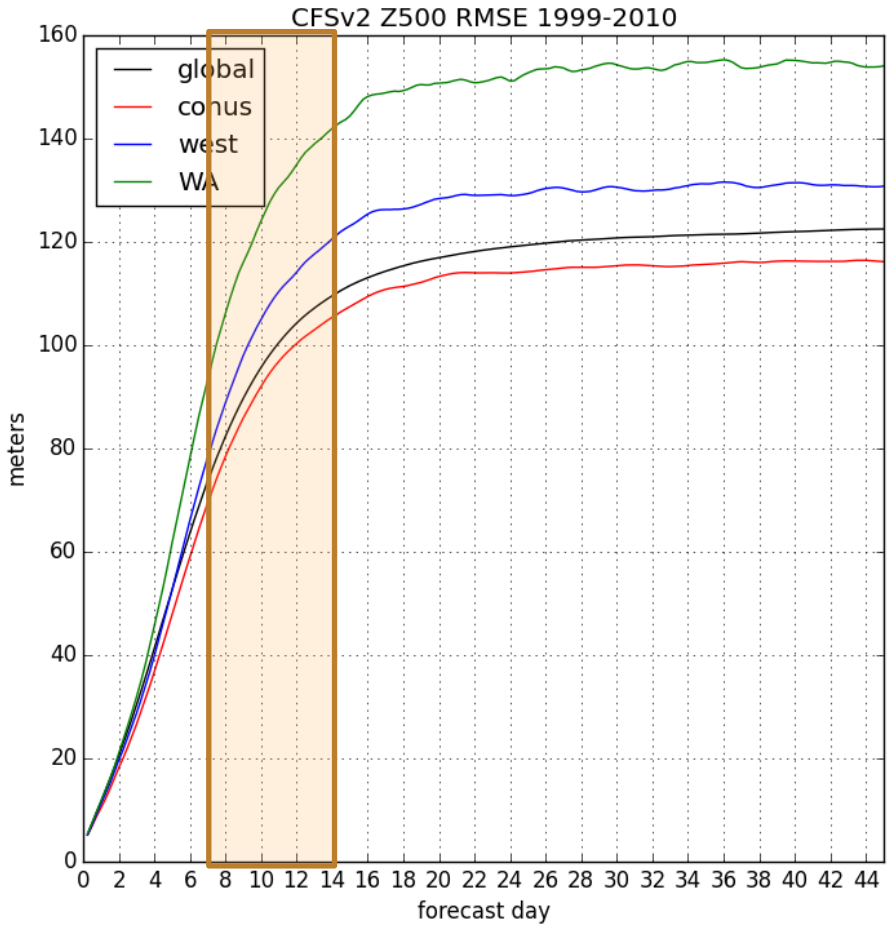
Skill in Second Week Declines Rapidly (GEFS 500 hPa)



Evaluation of CFSv2 skill over the Western U.S.



Rapid Increase in RMSE During Second Week

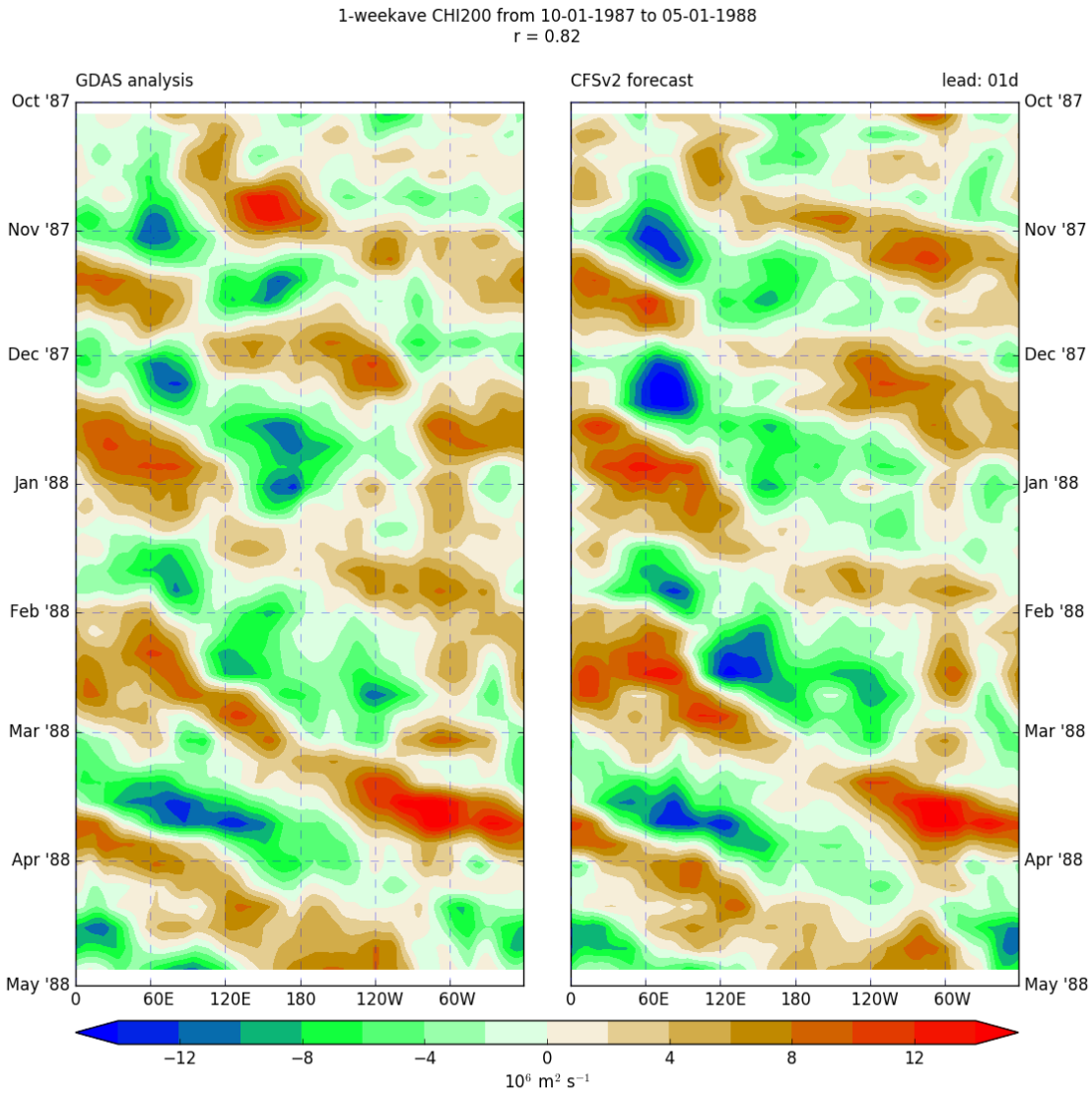


Work Presented Last Year Suggests that GFS/CFS Fails to Properly Simulate Mesoscale Convection in the Tropics

May be a key problem in the loss of skill in weeks 2+.

CHI200 Hovmoller: analysis vs week-1 CFS forecasts

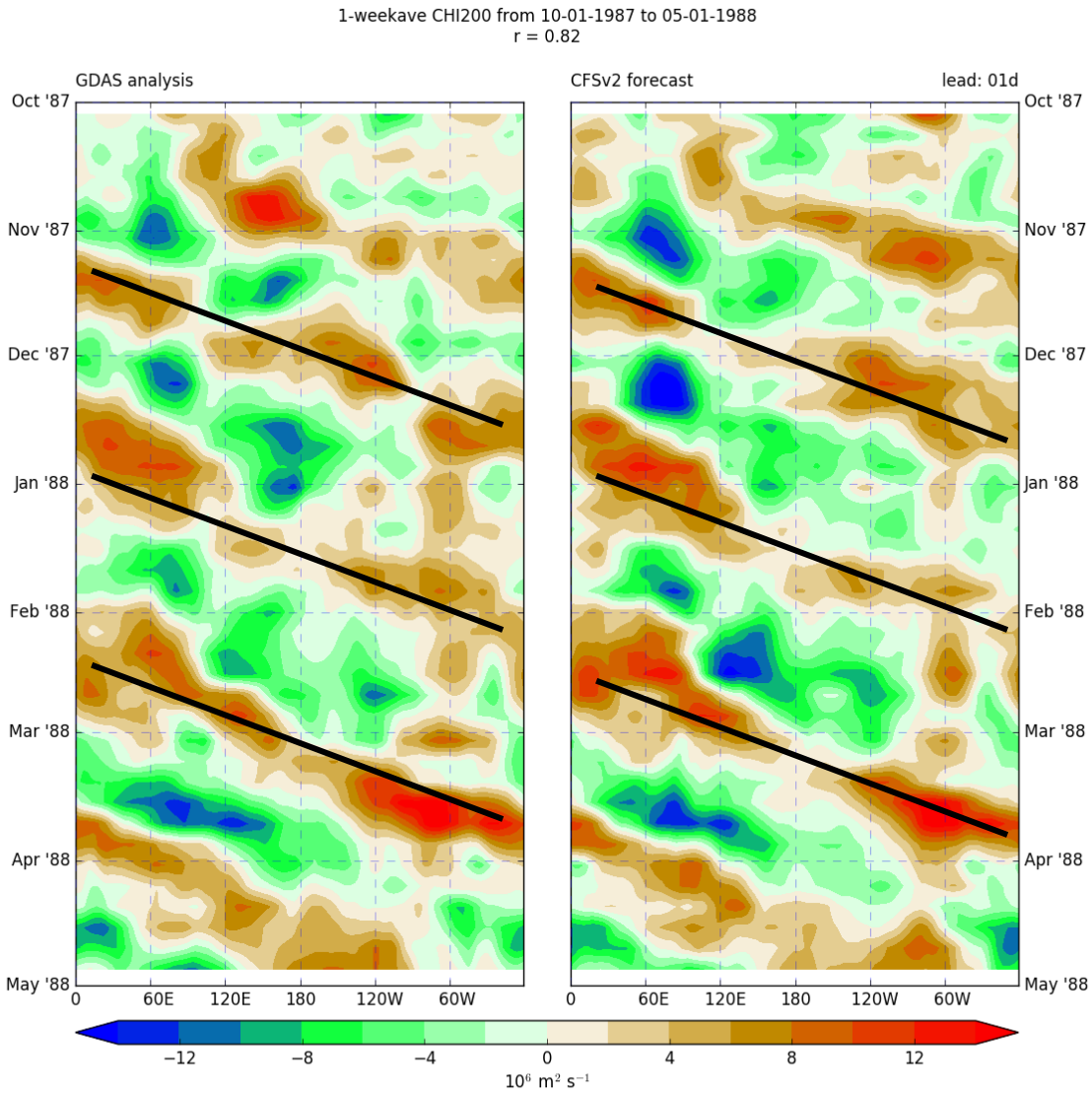
Winter/Spring
‘87-’88



*single-member forecasts

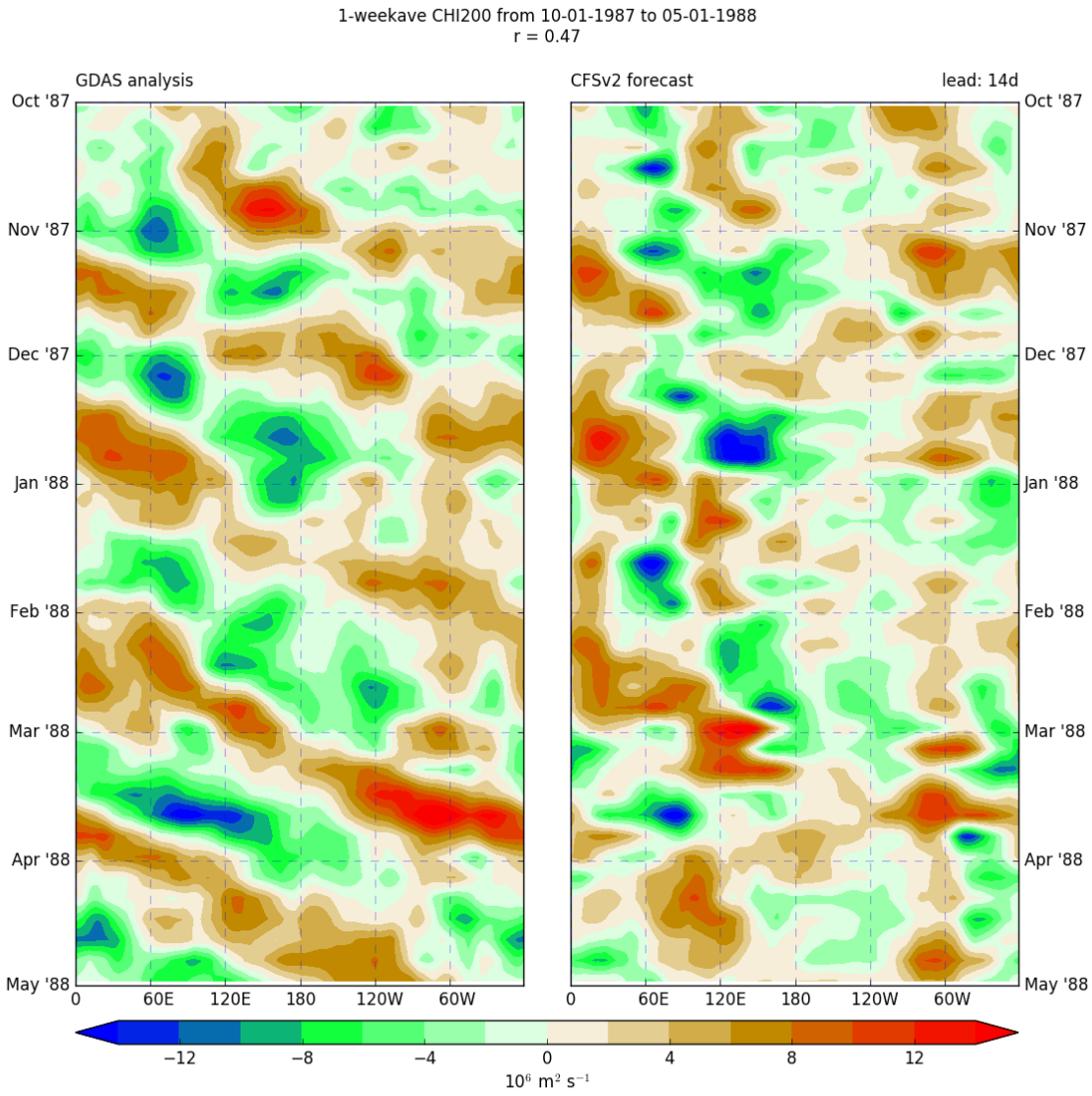
CHI200 Hovmoller: analysis vs week-1 forecasts

Wave propagation in both analyses and forecasts



*single-member forecasts

CHI200 Hovmoller: analysis vs week-3 forecasts



*single-member forecasts

So what can the NWS do to improve week 2 forecasts in support of atmospheric river and other forecast problems?

- Slow evolution/improvement: better dynamic core (e.g., FV-3), physics, and data assimilation. Use high-resolution downscaling to secure as much useful information as possible.
- Jump to convection-allowing resolution in the tropics. May be the critical advance.

What Should the NWS Do?

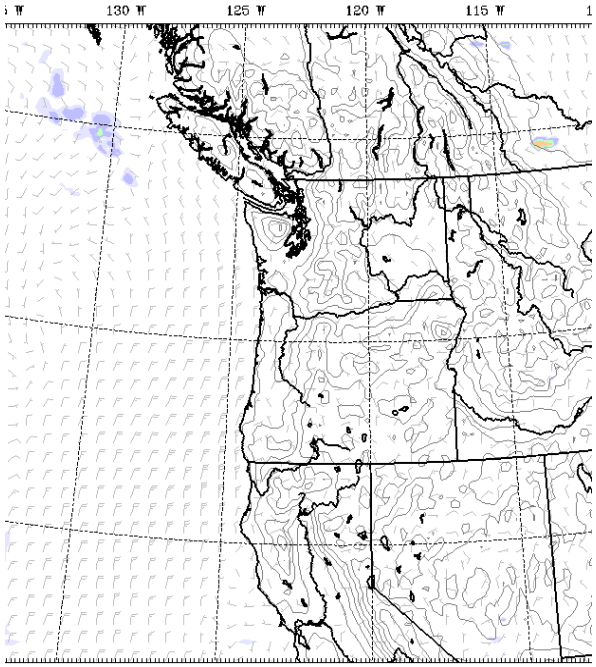
- Try conventional post-processing approaches (e.g., bias correction, Bayesian Model Averaging)
- Try innovative post-processing approaches, such as **Ensemble Forecast Adjustment**

The UW Under NWS Support is Working on Several of These

- **Evaluate convection-allowing resolution in the tropics for subseasonal forecasts**
- Currently working on month-long runs at 3-km grid spacing over the tropics and globe with the MPAS model. Later FV-3.
- **Try innovative post-processing approaches, such as Ensemble Forecast Adjustment**
- **Build an operational, high-resolution (4 km) ensemble for week two using forecast diversity from GEFS, multiple global forecasts, and physics uncertainty**

The Baseline: A High-Resolution Ensemble Downscaling GEFS and other Global Models

- WRF-based, 10-20 members this fall
- Central CA coast to southern BC.
- 4-km grid spacing through 84 h, 12 km for remainder through 10 days.
- Initializations/BC from major international/national centers (UKMET, GFS, GEFS, CMC, Japanese, Australian.
- Stochastic physics diversity.
- Twice a day.

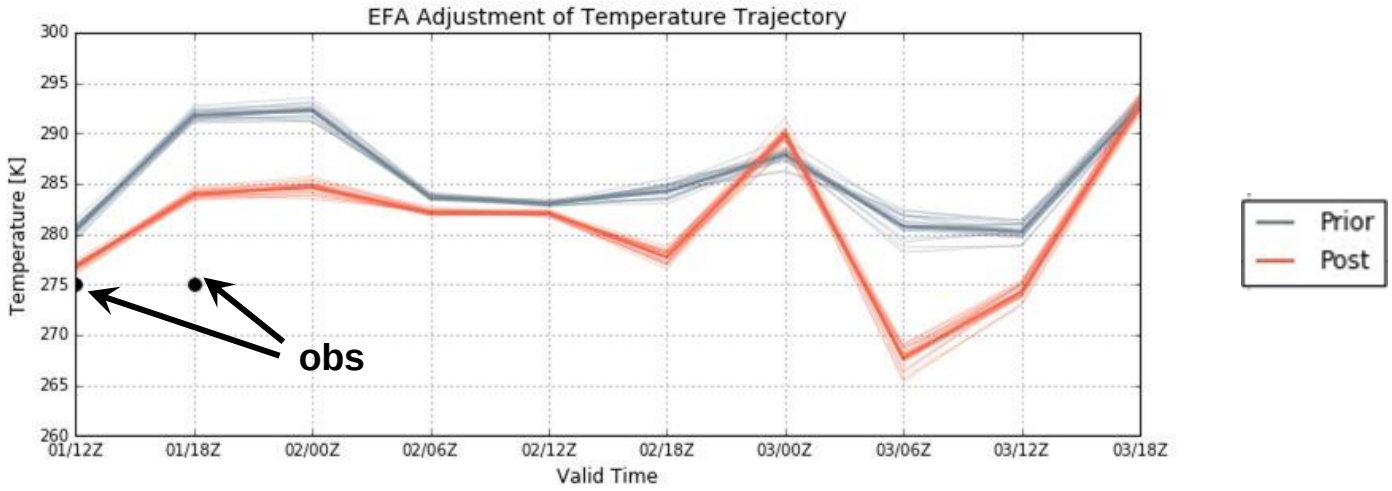


Ensemble Forecast Adjustment EFA

Can we correct for some of GEFS deficiencies in week 2 **statistically** using ensemble-derived spatial and temporal correlations?

What is EFA?

<u>Ensemble forecast adjustment</u>: An offline data assimilation technique that uses *temporal* and spatial covariances to adjust the entire forecast using observations at one time (or several times) AFTER the forecasts are started.



EFA

It is a post-processing technique that requires little computer resources

Can use temporal correlations for either averaged or non-averaged fields.

It uses the difference between forecasts and observations to correct the forecasts

EFA Provided Improvements for Short Term Forecasts (24-30 h)

Rapid, Short-Term Ensemble Forecast Adjustment Through Offline Data Assimilation

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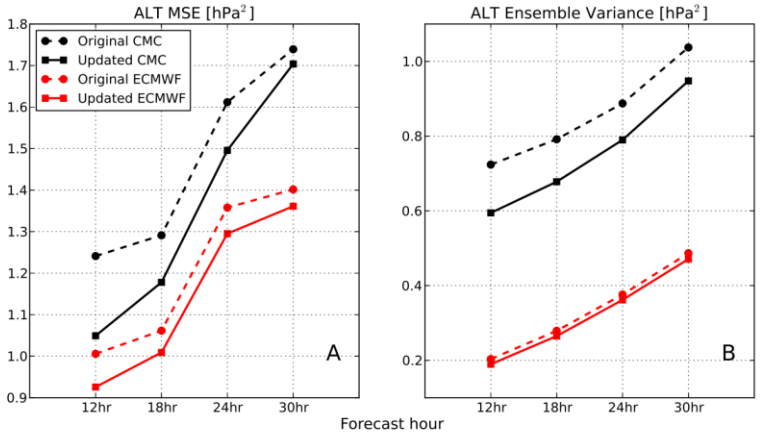
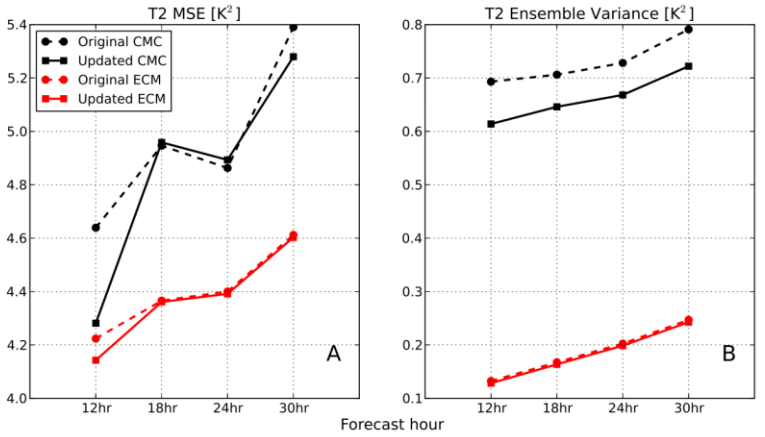


ure 2. Altimeter setting RMSE and ensemble spread in both the original ensemble forecast (dashed) and the updated ensemble forecast (solid) as a function of forecast r for the CMCE ensemble (black) and ECMWF ensemble (red). Only altimeter setting observations were assimilated at forecast hour 6.

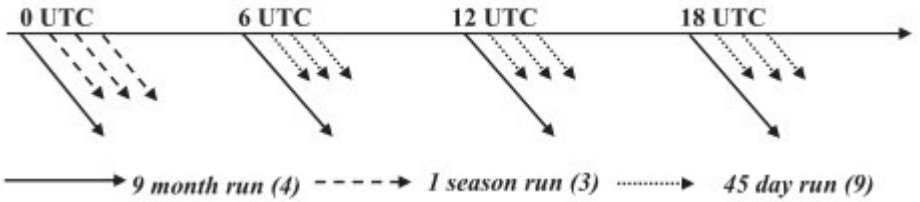


ure 4. 2m temperature RMSE and ensemble spread in both the original ensemble forecast (dashed) and the updated ensemble forecast (solid) as a function of forecast r for the CMCE ensemble (black) and ECMWF ensemble (red). Only 2m temperature observations were assimilated at forecast hour 6.

EFA Test dataset

CFSv2 ***operational*** forecasts from DJF 2015-2016.

Initialized 4x daily with 4 ensemble members. **16 members per day.**



Lagged ensembles are assembled with members from the previous days' forecasts

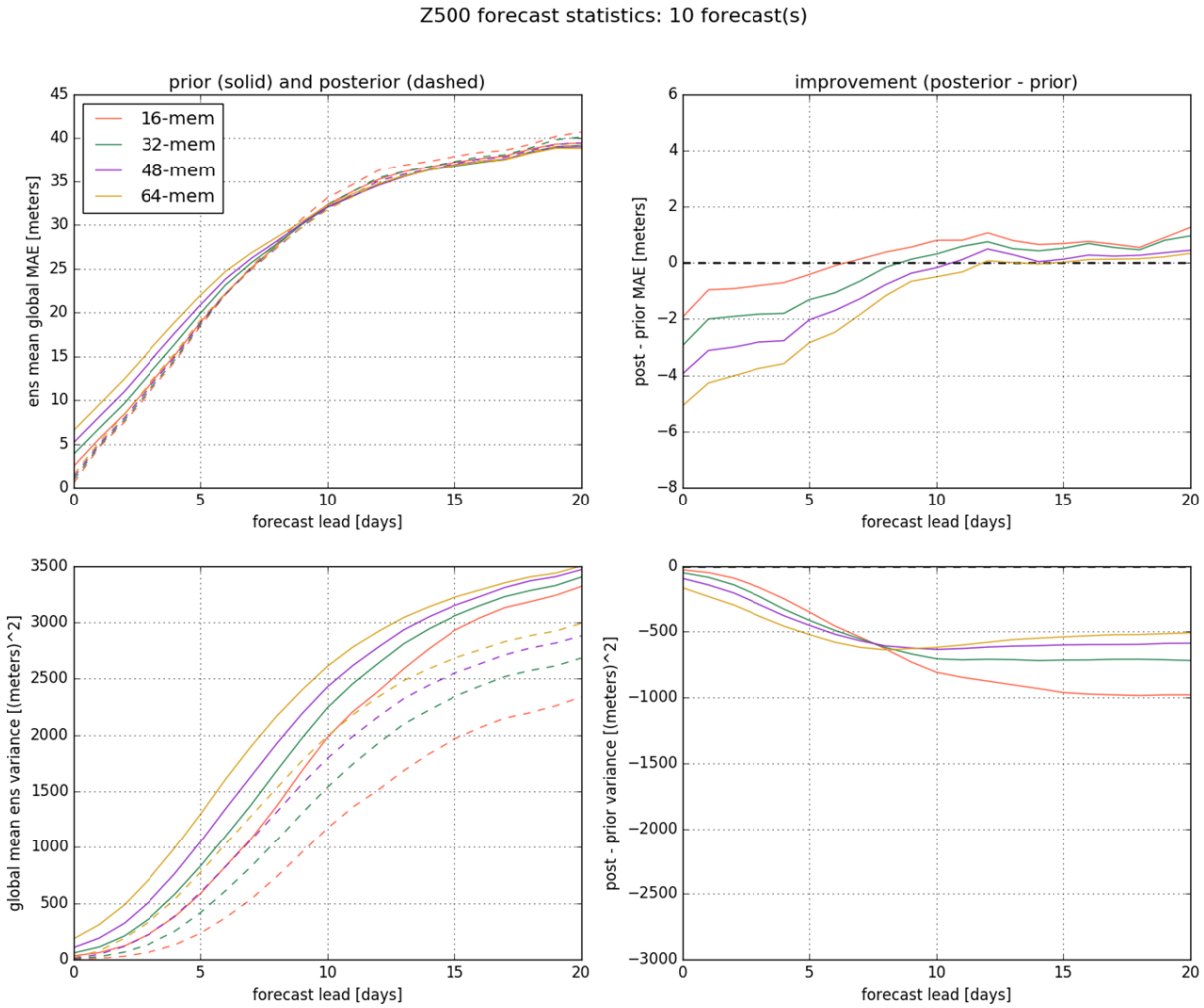
- **e.g., a 48-member ensemble contains members from the past 3 days**

Data and Methods

- Verification: CFS Reanalysis (CFSF)
- Our “obs” for assimilation are a spatial sampling of GDAS analyses
- Used on day difference from forecast from observation.
- Many “knobs” can be turned in the assimilation process
  - Ensemble size, localization, ob error variance, ob assimilation order…

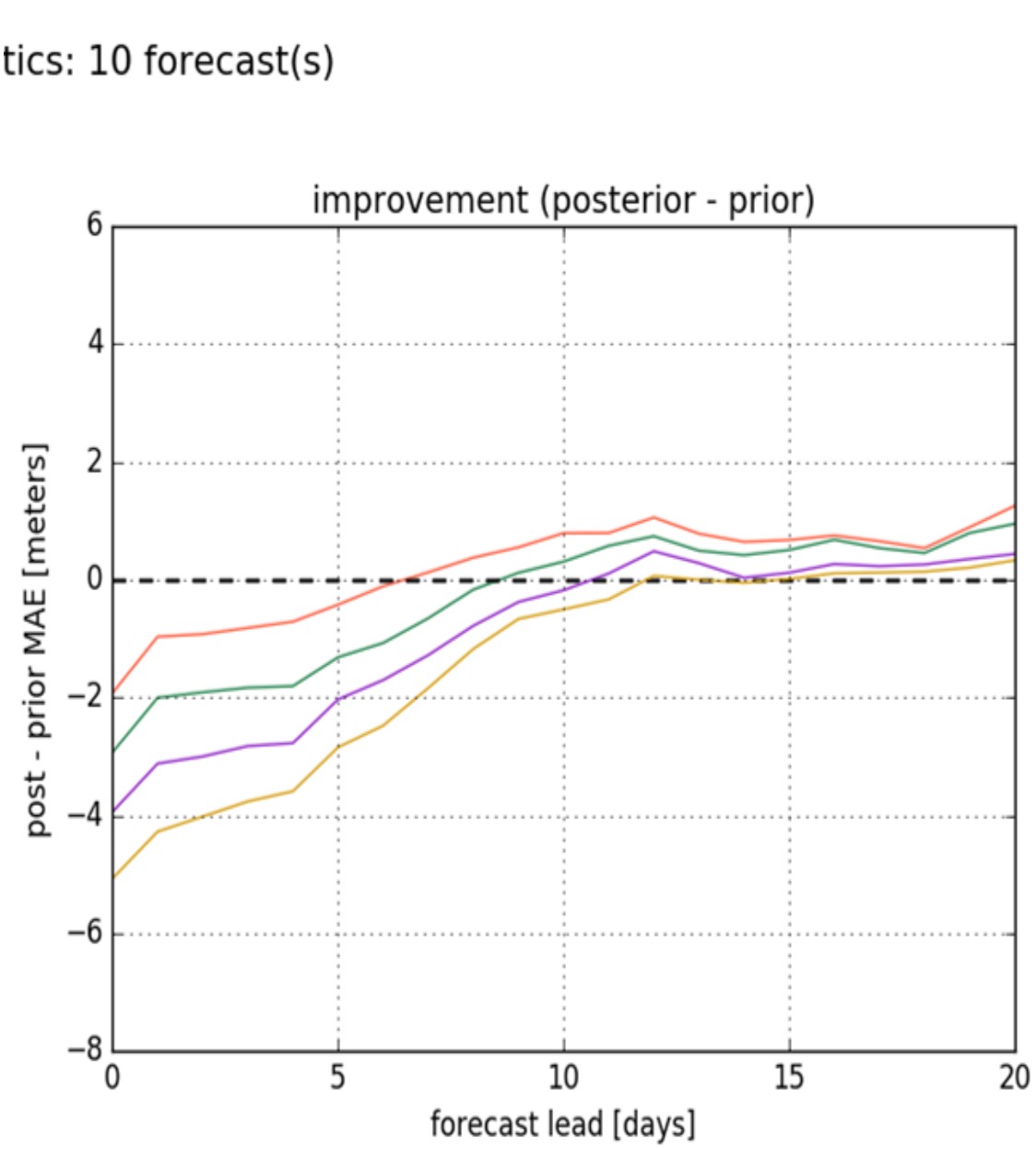
Initial Results Starting With Synoptic Fields for Extended Periods

Improving global daily Z500 forecasts with EFA



- EFA improves the daily-avg forecasts through day 6-12
- Larger ensembles produce greater benefit
- This is because EFA serves largely to erase the errors of the initial state, which are larger for lagged ensembles

Not Much Help



Current Work

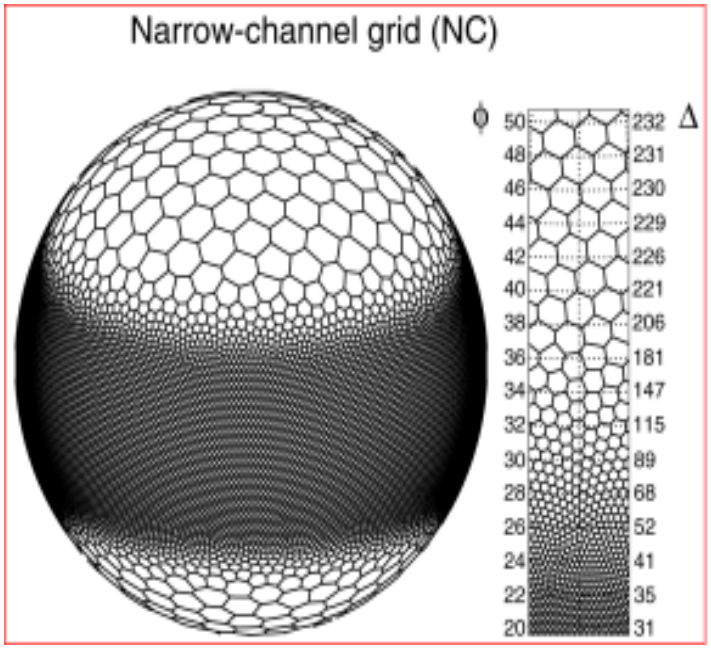
- Moving to GEFS
- Use various correction times (e.g., 3hr, 6 hr)
- Experimenting with localization: how far away from observations should we change the forecasts?
- Averaging periods? Might averaging over several days or a week improve the forecasts?
- Might the approach be more useful for certain synoptic situations. Evaluate atmospheric river periods

Testing the Grand Hypothesis

- **The only way to make dramatic progress with subseasonal prediction is to move towards convection-allowing resolution (1-3 km) over the tropics and particularly in the tropical Pacific.**
- There is a deep literature showing the superiority of explicit convective simulation versus parameterizaed convection over the U.S. and for MJO.
- The computer power to do this is now becoming viable

Testing the Convection/Subseasonal Hypothesis

- Have started experiments using MPAS
- 3 km globally and 3 km over the tropics
- Month-long simulations
- Have secured substantial computer resources at NCAR
- Will try with FV-3 if the MPAS results are favorable and when FV-3 becomes available.



The End