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US Navy plans for seasonal forecasting

Sergey Frolov (UCAR) on Behalf of the NRL ESPC team

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Overview

Predictability in coupled ocean-atmosphere systems:

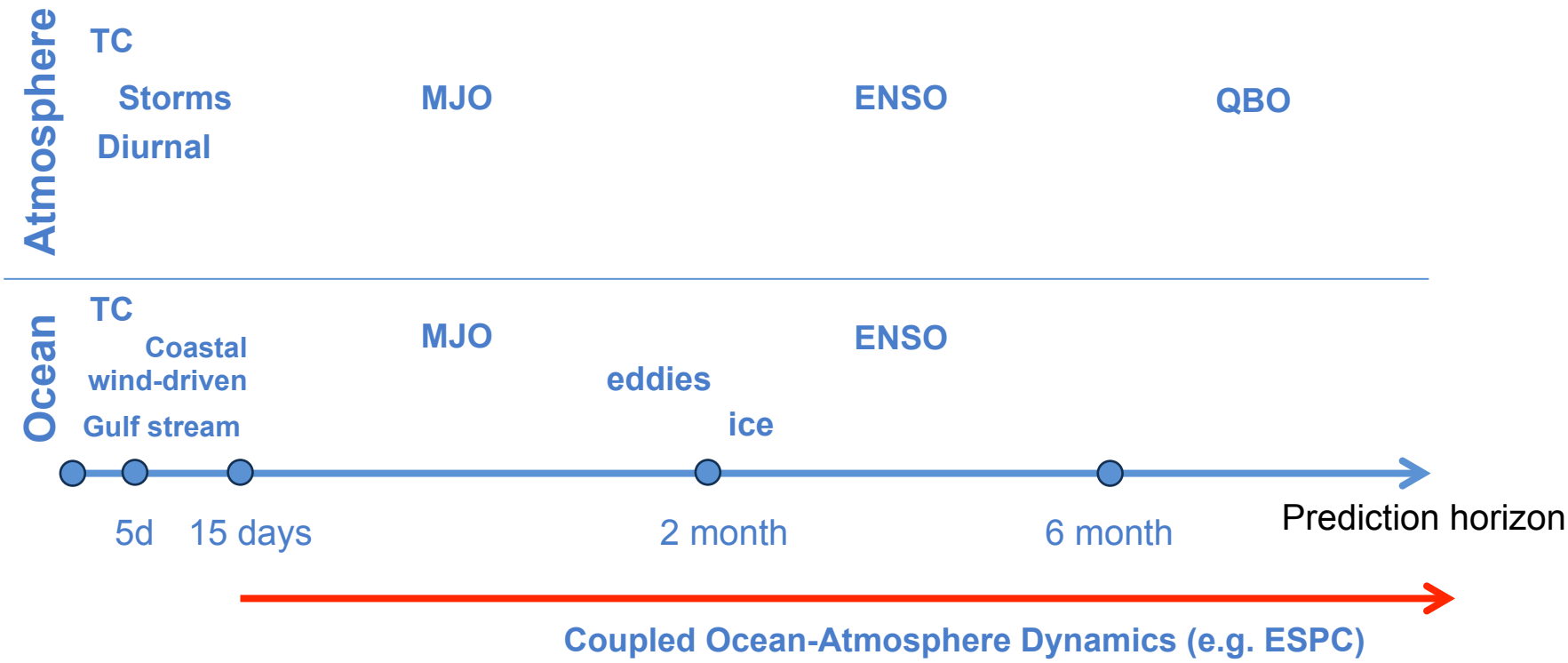
- A primer on the ensemble prediction

Navy Earth System Prediction Capability:

- Towards high-resolution, global ocean-atmosphere-ice-wave seasonal forecast
- Design of the ESPC ensemble system

A couple of thoughts on the design of the seasonal forecast for the West Coast Ecosystem (WCE)

Predictability of the Earth's ocean-atmosphere



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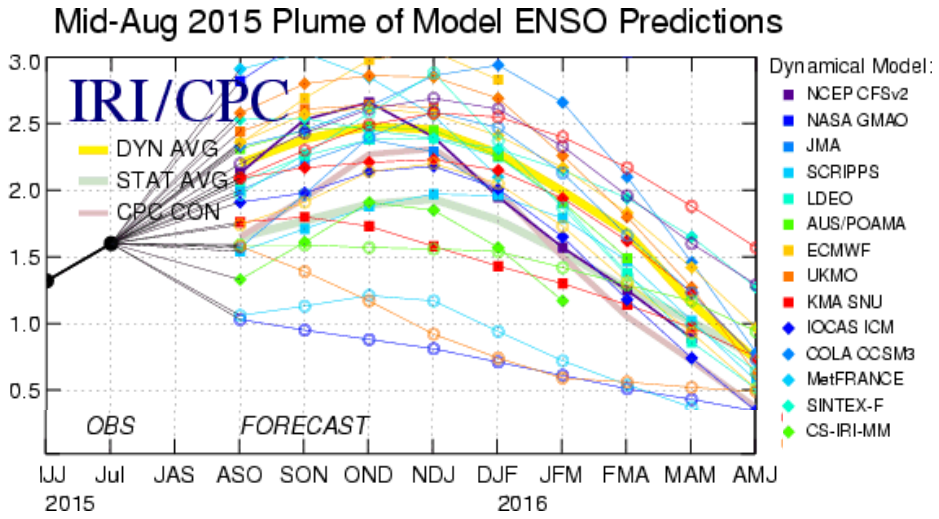
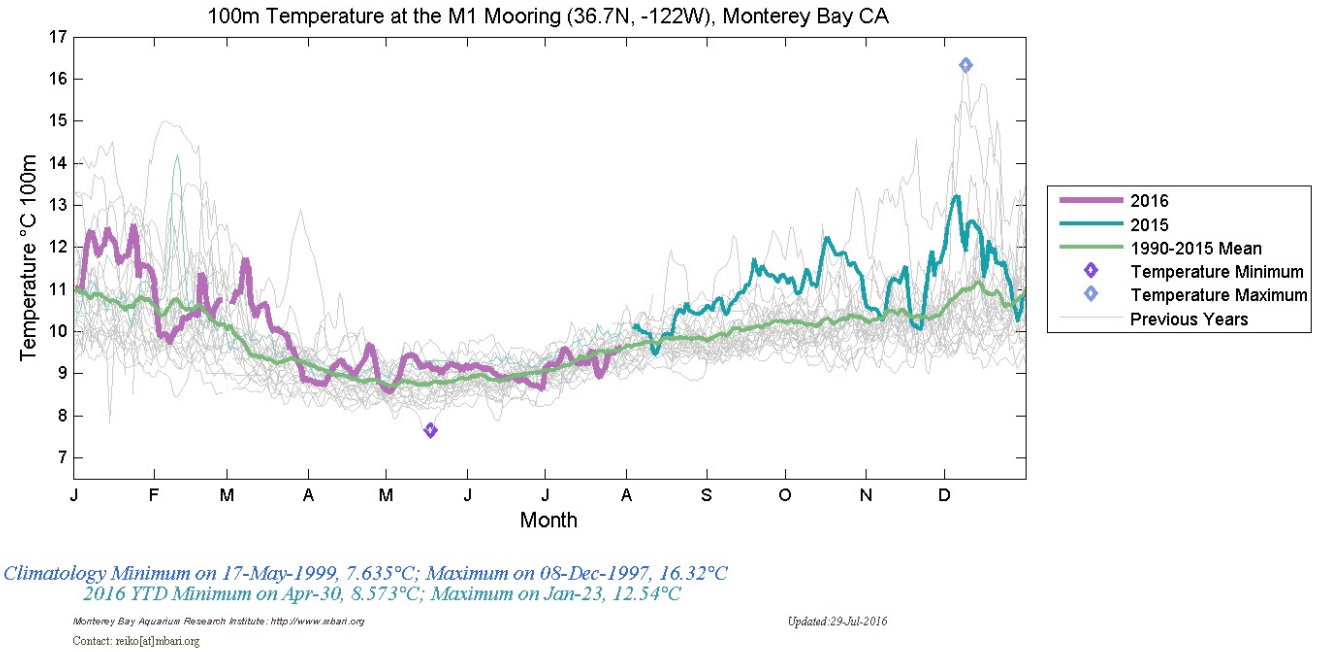
What we know about ENSO forecasts: Need for ensemble predictability



- **Beyond 5-7 days, inherent deterministic atmospheric predictability is lost and ensemble forecast provides a better skill**
- **ENSO predictions have large spread because of inherent predictability barrier and uncertainty in model formulation**

Role of the high-frequency variability



- **However, recall that ENSO models predict low-frequency anaomalies**
- **High-frequency (storm-specific) variability can exceed the difference between the models**
- **How important is the high-frequency variability for the West Coast?**

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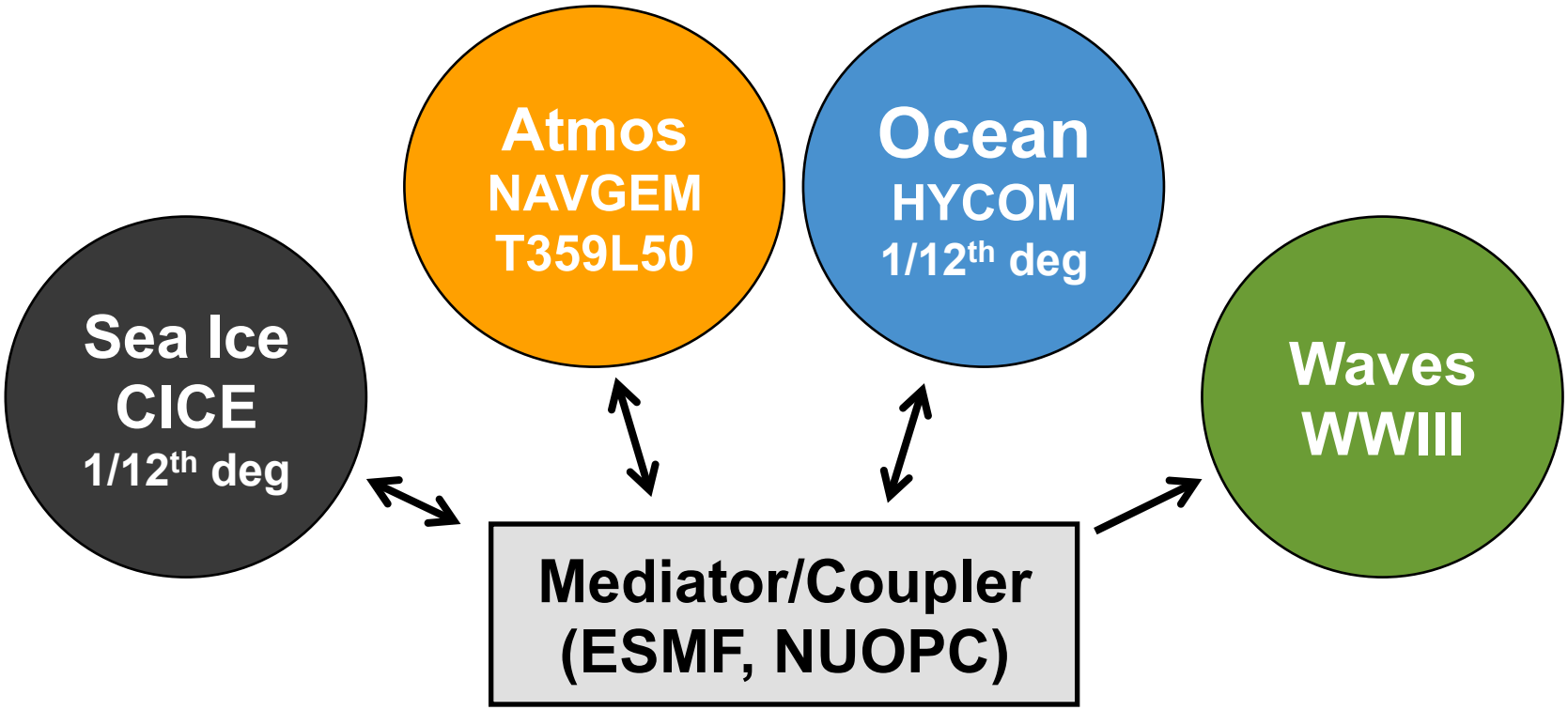
How does one build an ensemble prediction system for a chaotic model?

Navy Earth System Prediction Capability



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Navy ESPC
Initial Operational Capability (IOC): FY18

Forecast	Time Range, Frequency	Atmosphere NAVGEM	Ocean HYCOM	Ice CICE	Waves WW3[3]	Land-Surface NAVGEM-LSM	Aerosols
Deterministic short term	0-16 days, Daily	T681L80 (19 km) 80 levels	1/25° (4.5 km) 41+ layers[1]	1/25° (4.5 km)	1/8° (14 km)	Module within NAVGEM	Module within NAVGEM
Probabilistic long term	0-30 days, Daily 15 members[2]	T359L60 (37 km) 60 levels	1/12° (9 km) 41 layers	1/12° (9 km)	1/4° (28 km)	Module within NAVGEM	Module within NAVGEM

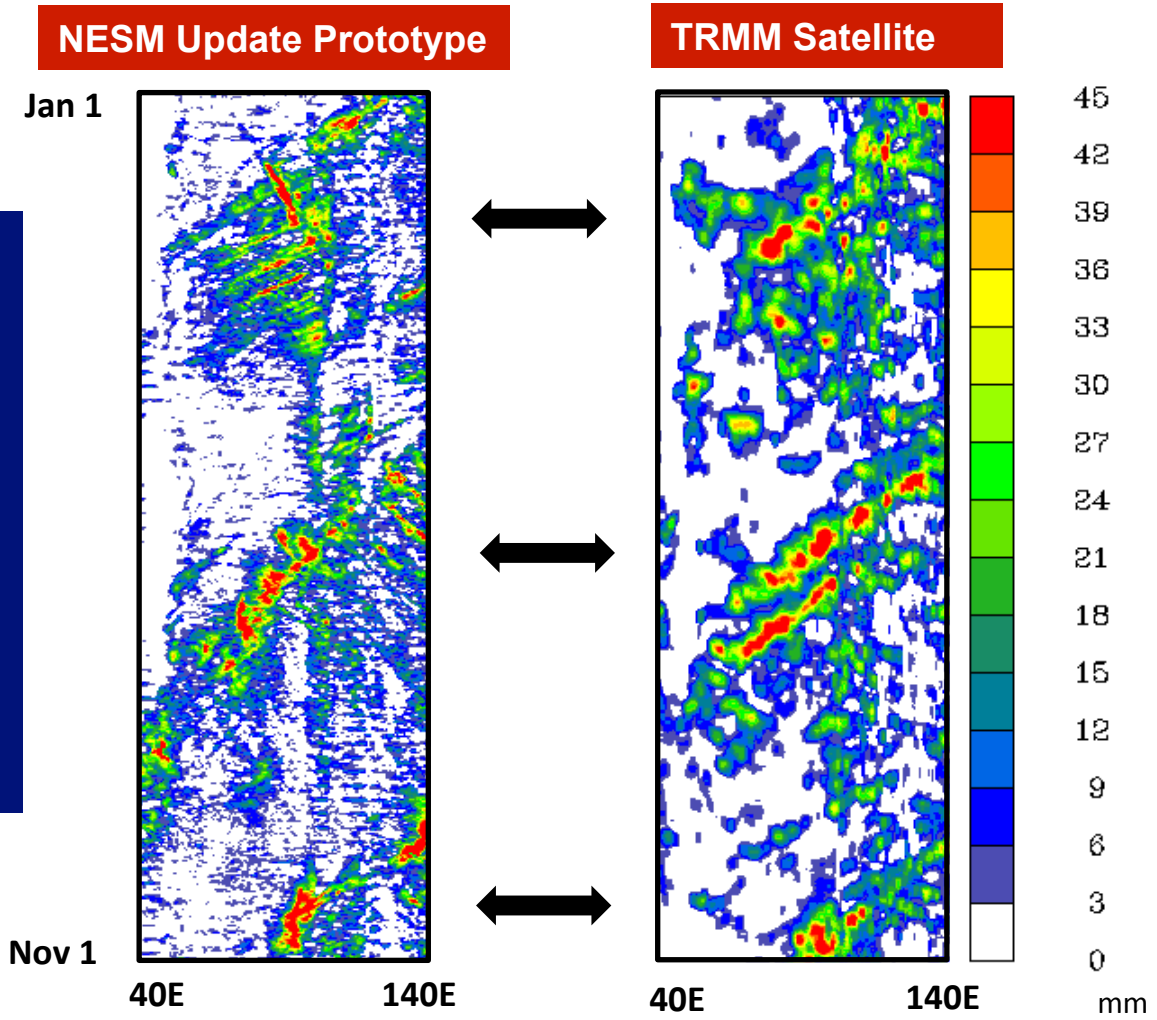
- **IOC Data Assimilation will be weakly coupled (independent DA systems but coupled forecast for first guess)**
- **Final Operational Capability: FY22**
  - **Seasonal (90-day) ensemble forecasts**
  - **Coupled data assimilation**

Skill of the pre-operational forecast system: MJO

61-Day MJO Reforecasts from 1 Nov, 2011 (DYNAMO* period)

Equatorial Zonal Propagation of Rainfall (5°N - 5°S)

Recent runs with improved convective physics suggest MJO prediction skill at the frontiers of current global models.



* DYNAMO (Dynamics of the Madden-Julian Oscillation)

J. Ridout

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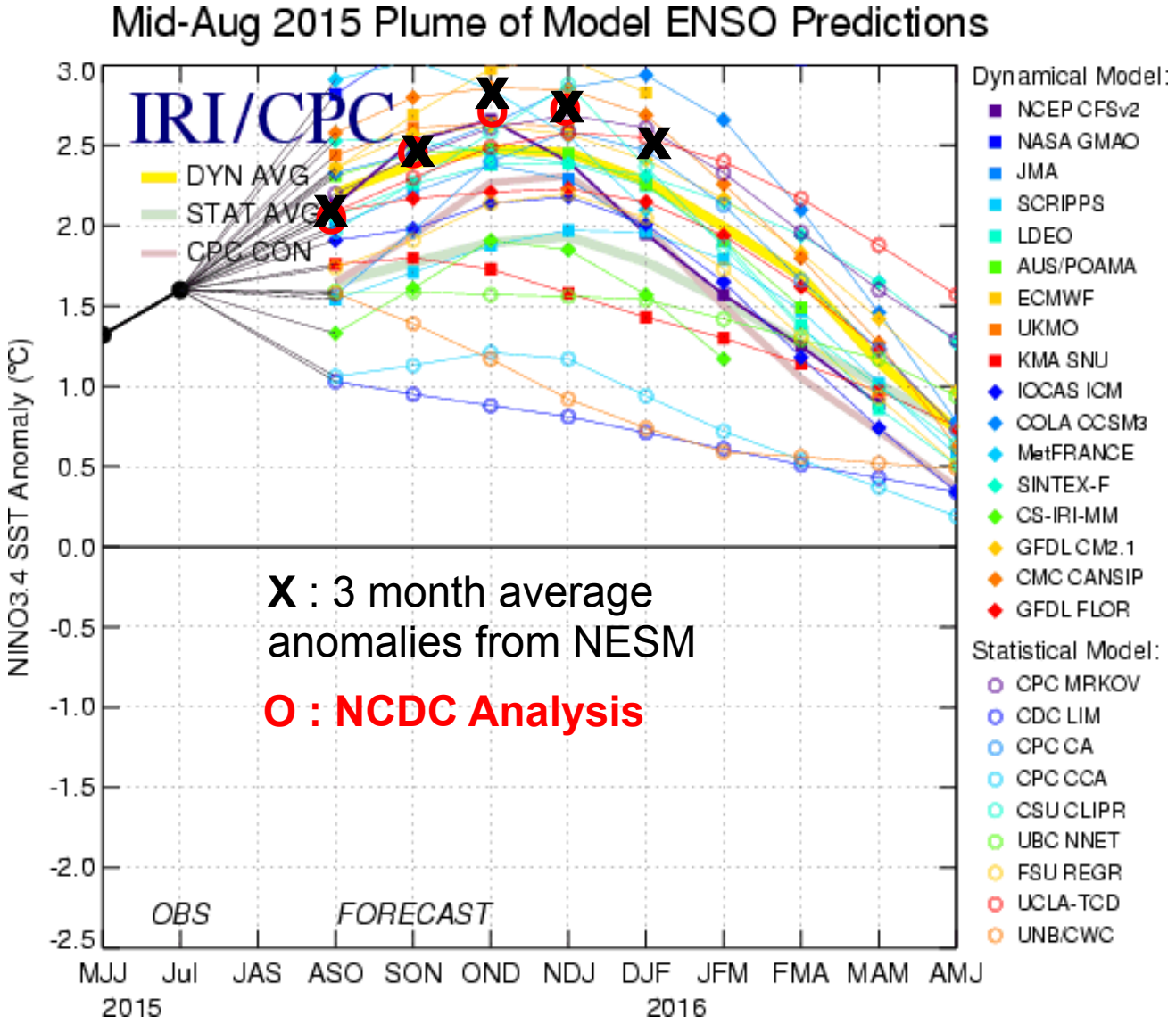
Skill of the pre-operational forecast system: ENSO (2016 event)



ENSO forecasts are within the prediction range of other systems, and very close to the observed NINO3.4 anomaly (N. Barton, M. Flatau).

Issues include prediction of an El Nino in 2014, and evidence of an eastern Pacific warm bias.

Design of the ESPC ensemble prediction system

Ensemble members capture uncertainty in initial conditions

deterministic forecast= =ensemble mean

Cycling data assimilation system

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Ensemble members capture uncertainty in initial conditions

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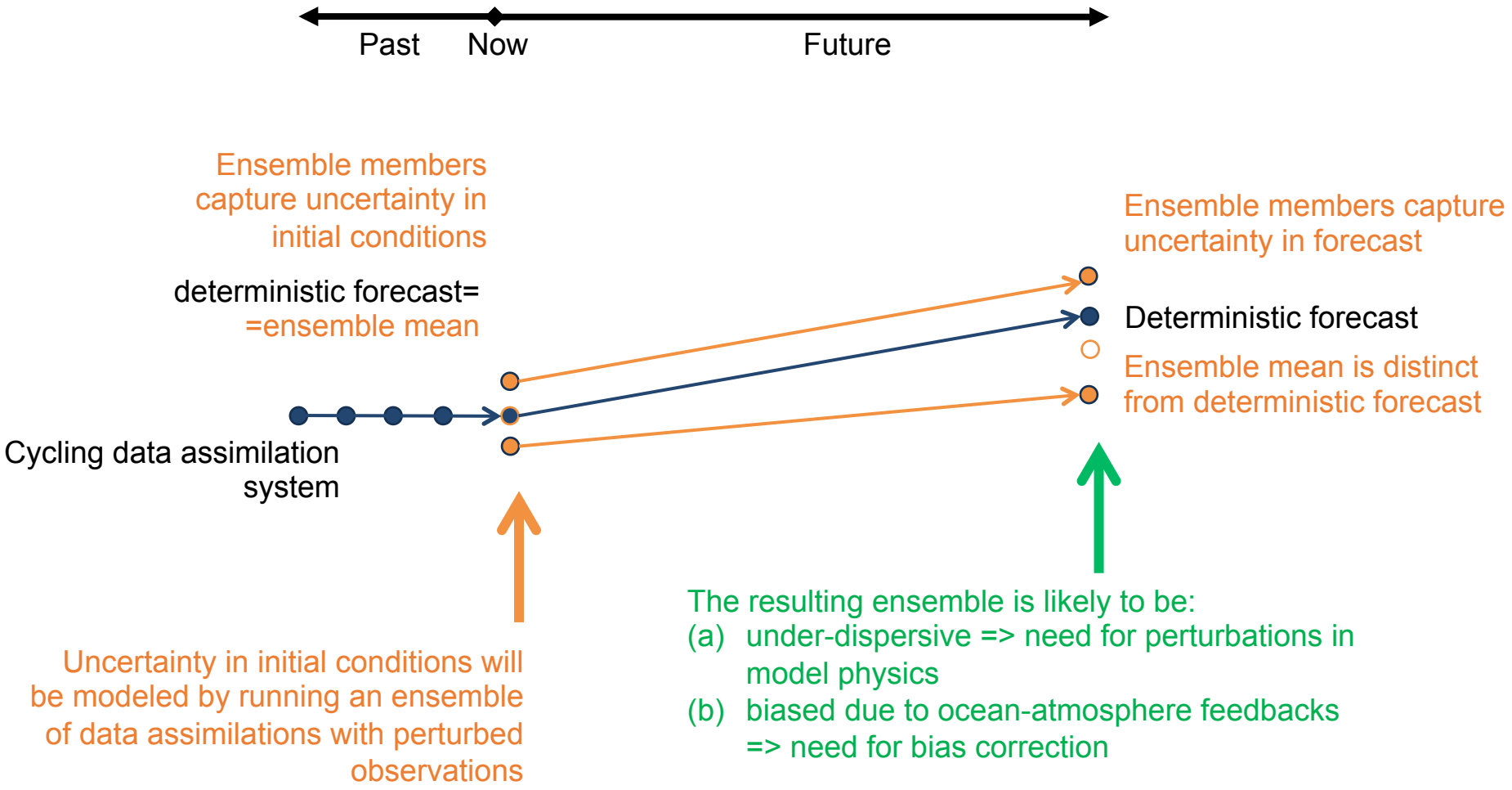
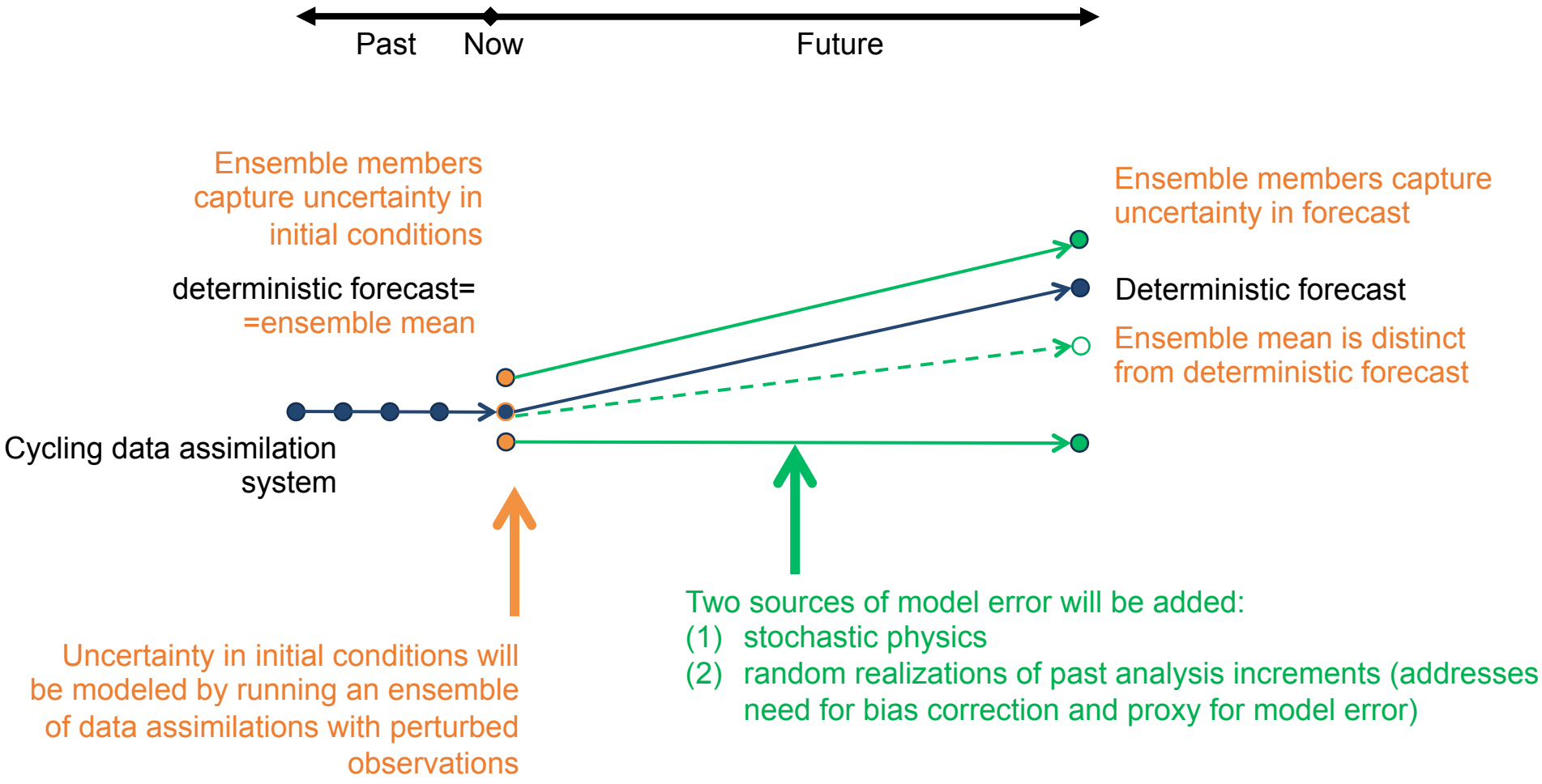
Cycling data assimilation system

Uncertainty in initial conditions will be modeled by running an ensemble of data assimilations with perturbed observations

Design of the ESPC ensemble prediction system



Design of the ESPC ensemble prediction system



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Re-cap: Ingredients of the ensemble forecasting system

An ensemble of initial conditions (important for the first 10-20 days):

- An ensemble of initial conditions from S2S archive
- Or an ensemble of data assimilations

Simulated sources of model error:

- Multi-model ensembles
- Perturbations to model parameters
- Stochastics physics (e.g. random noise added to the physics tendency terms)
- Samples of model error drawn from the archive of analysis increments

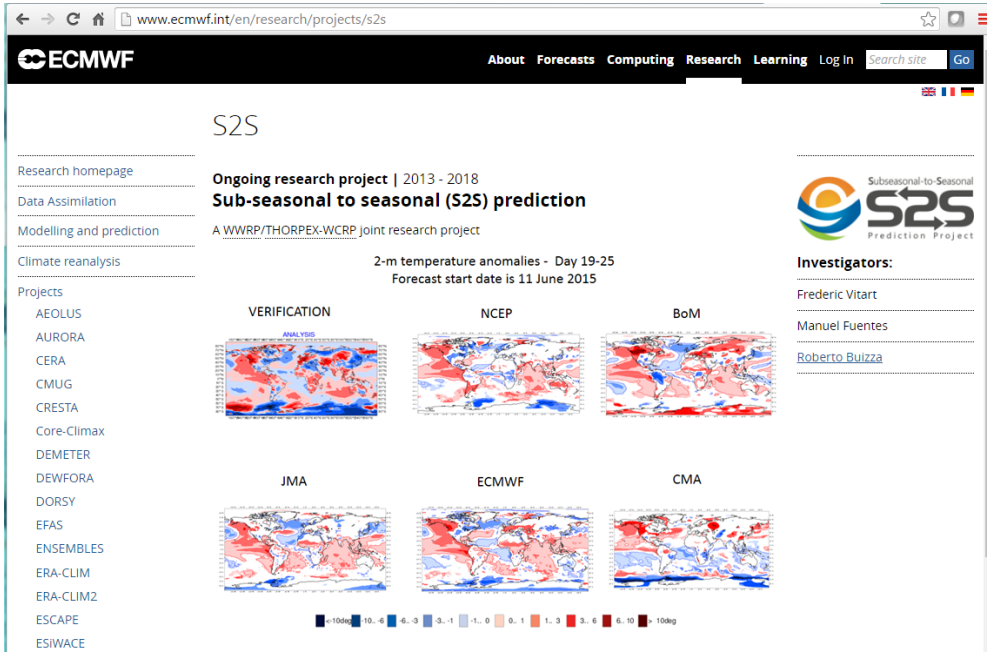
Bias correction:

- Off-line bias correction base on match-ups between hindcast simulations and historic observations
- Samples of model error drawn from the archive of analysis increments

Ensemble verification system

- E.g. ensemble spread and mean diagnostics
- Diagnostics over sufficient number of historic events.

Some thoughts on building the seasonal forecast for the West Coast



How does one capture the uncertainty inherent to the West Coast Ecosystem (WCE) downscaled forecast?

- Should the WCE forecasts be driven by multi-model ensembles (e.g. the 5 members of the S2S archive)?
- Is there a need for a larger ensemble with a single model that shows different storm realizations (Navy ESPC, ECMWF ensembles, etc.)
- How large of an ensemble does one need (~10 member)?

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Some thoughts for building the seasonal forecast for the West Coast

Is it sufficient to only have external drivers of the ENSO anomaly (S2S ensembles) or does the internal chaos of the WCE matter?

- Are variations in boundary conditions dominate the uncertainty in the WCE models?
- Are variations in model parameters dominate the uncertainty in the WCE models?
- Is it important to capture possible distribution of exact storms or will the inter-annual anomaly dominate?
- Is it important to have coupled ocean-atmosphere model (coupled models tend to have higher biases)?
- Is it important to characterize errors in unresolved physics (e.g. need for stochastic physics)?

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