How do S2S subseasonal systems beat seasonal forecasts?

Adrian M Tompkins, ICTP

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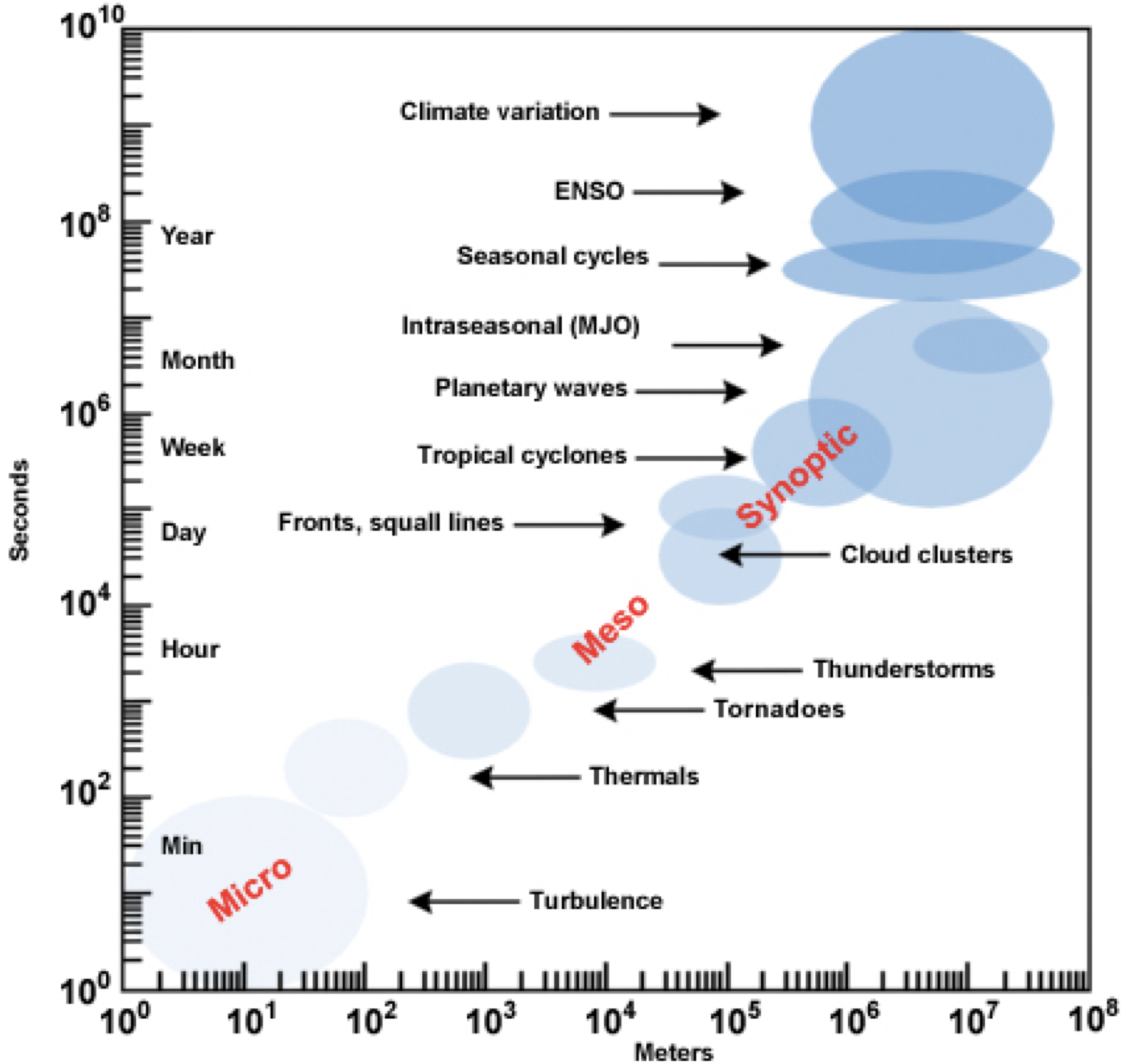
southern Italy yesterday!



Climate variation
ENSO
Seasonal cycles
Intraseasonal (MJO)
Planetary waves
Tropical cyclones
Fronts, squall lines
Cloud clusters
Thunderstorms
Tornadoes
Thermals
Turbulence
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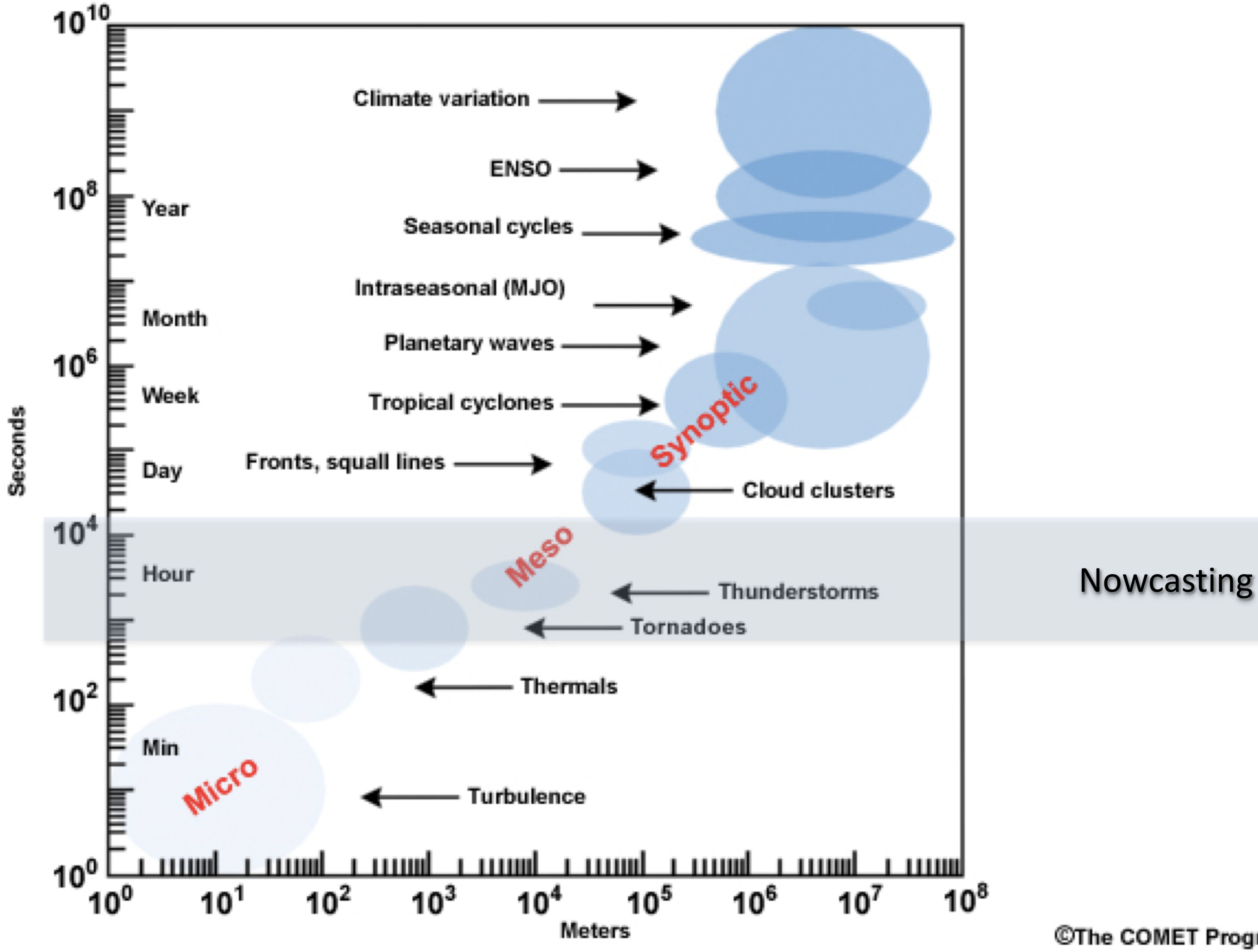
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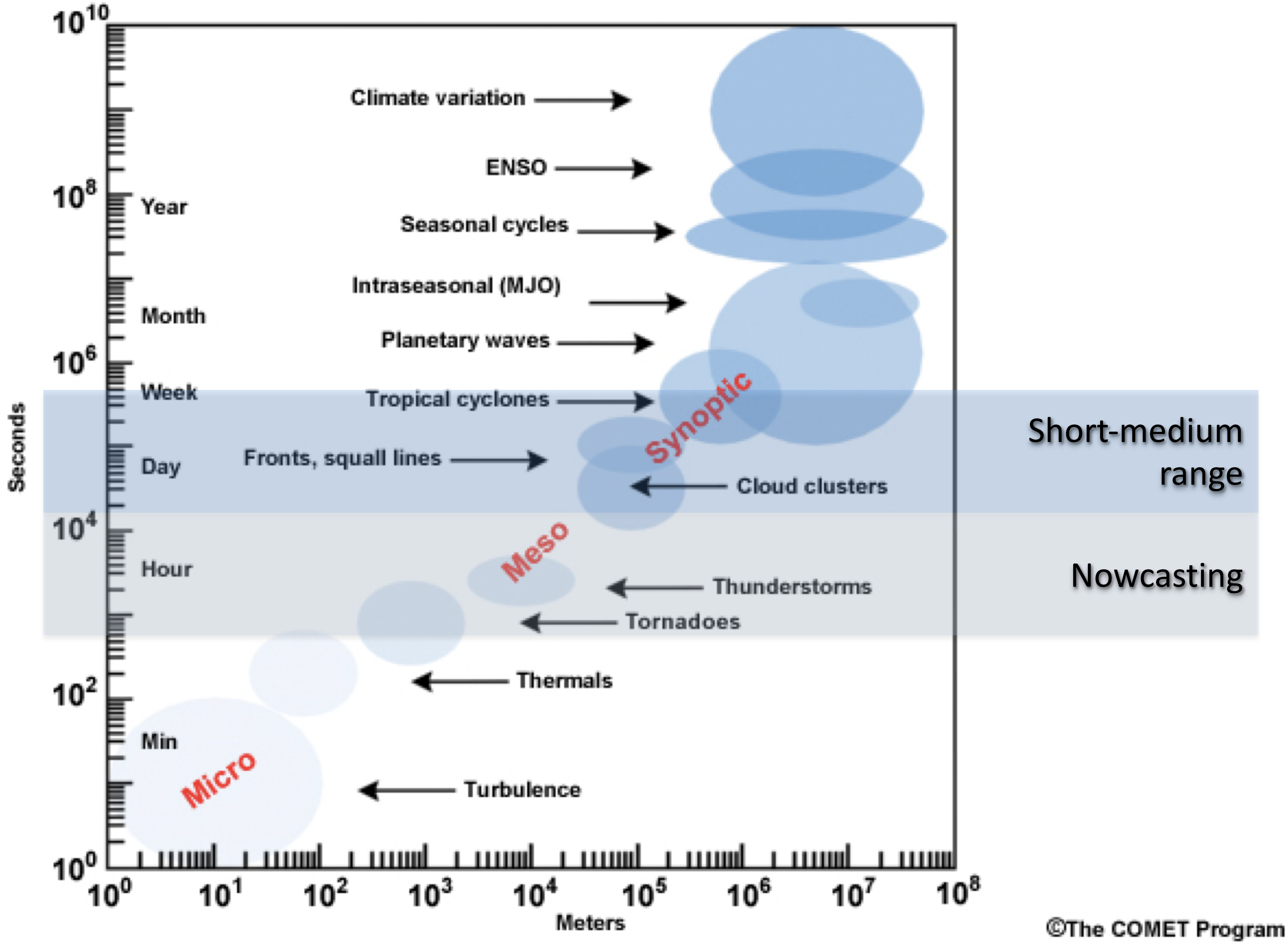
Nowcasting



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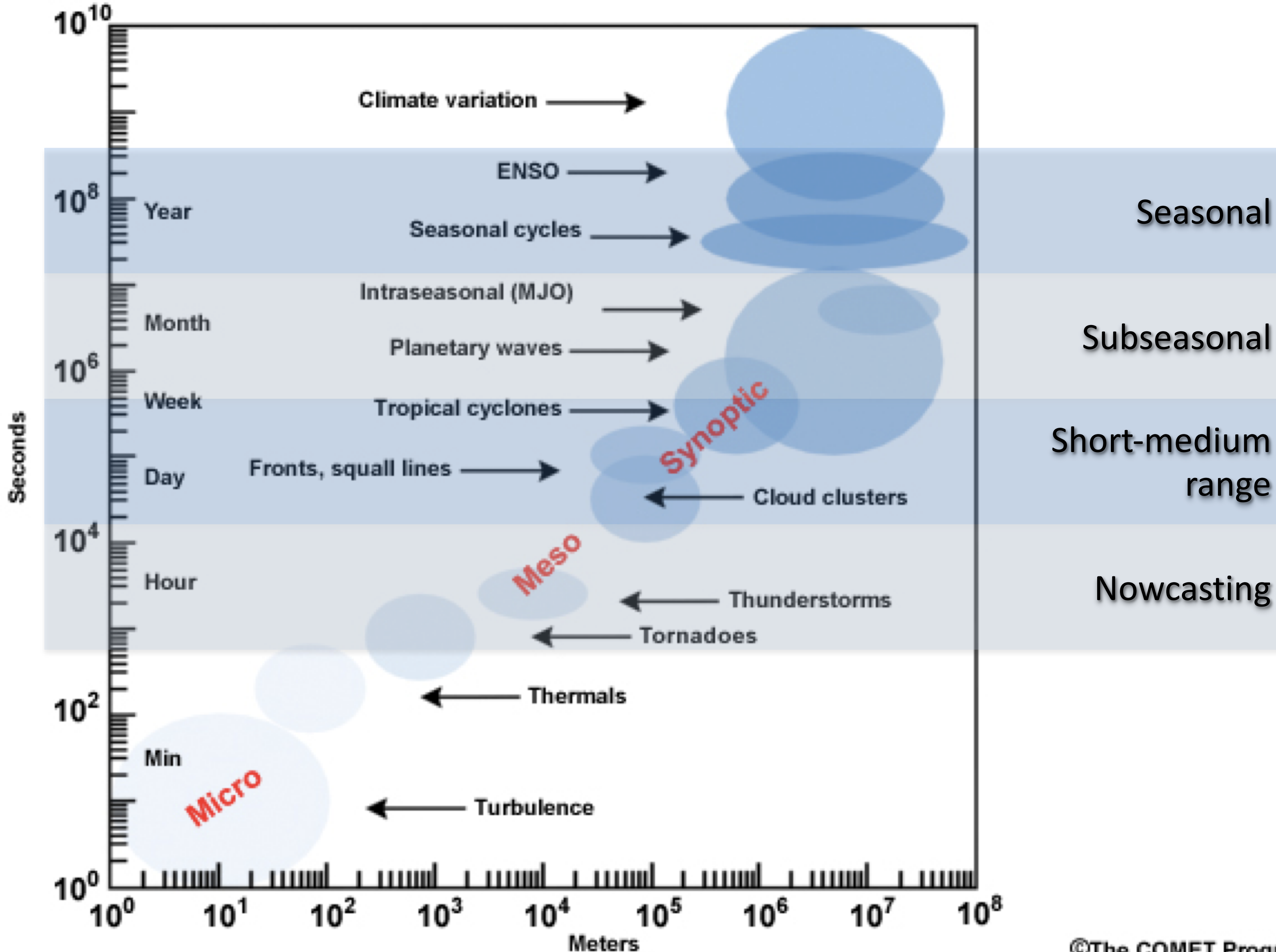

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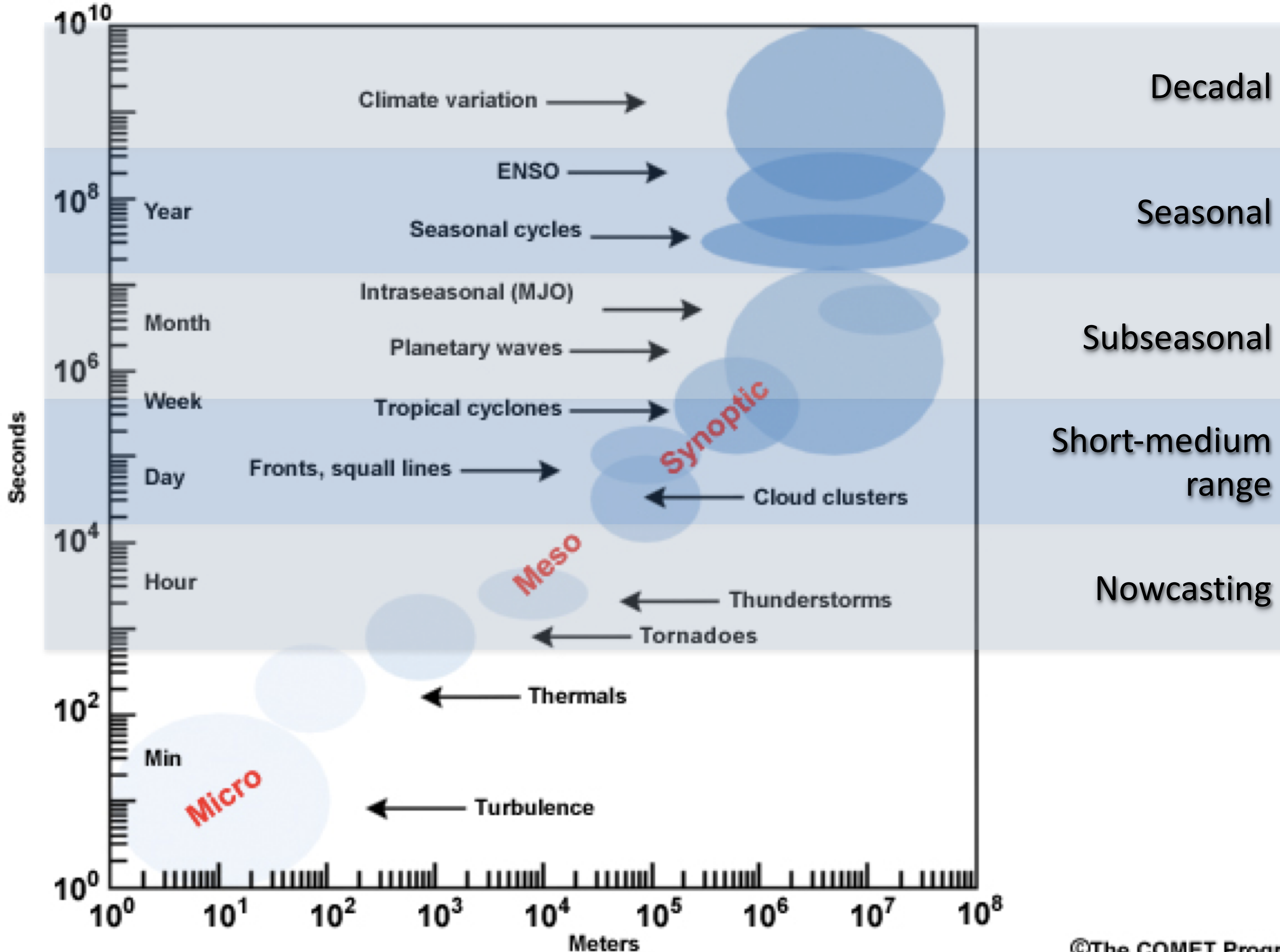

Decadal
Seasonal
Subseasonal
Short-medium range
Nowcasting
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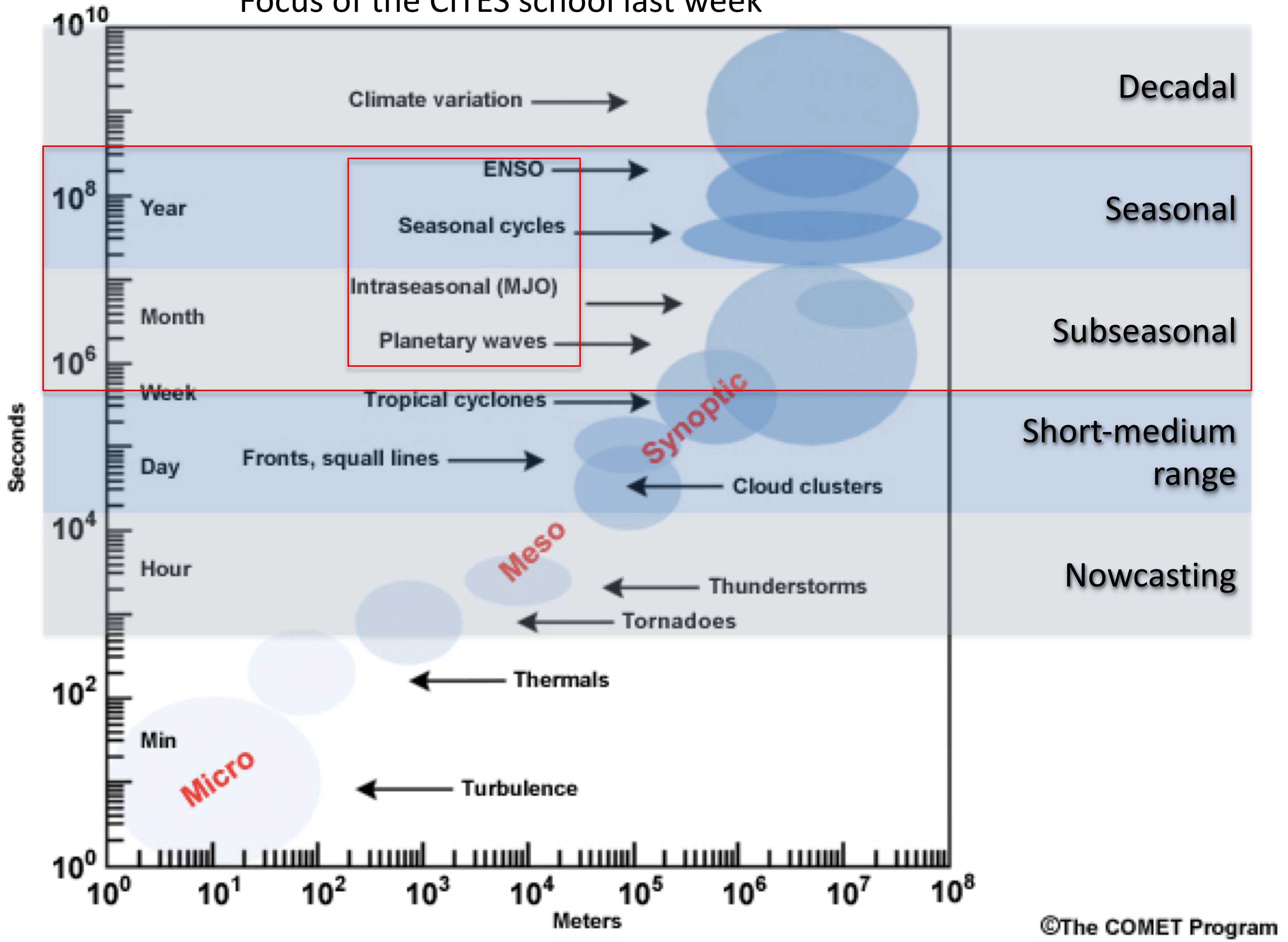
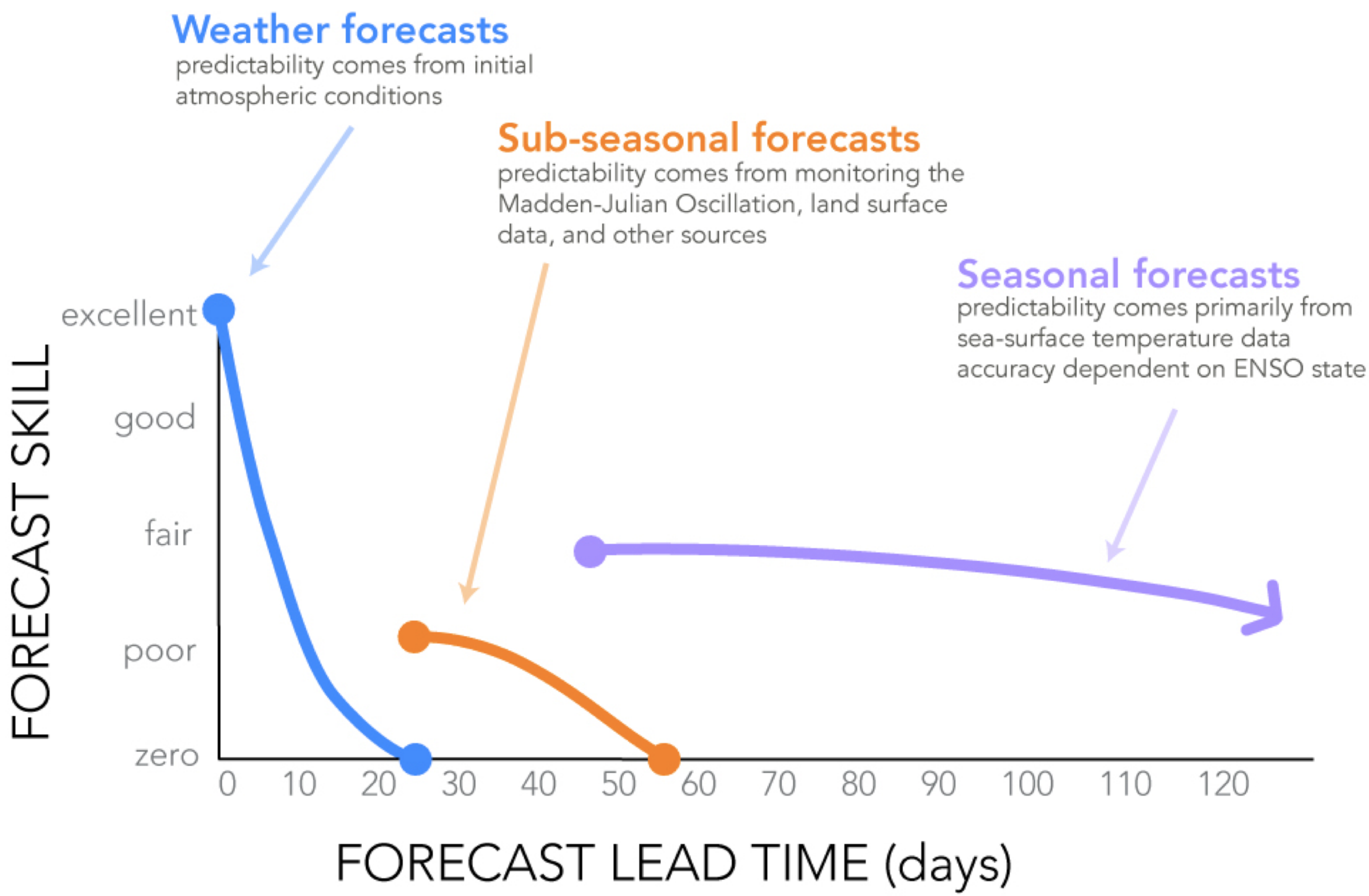
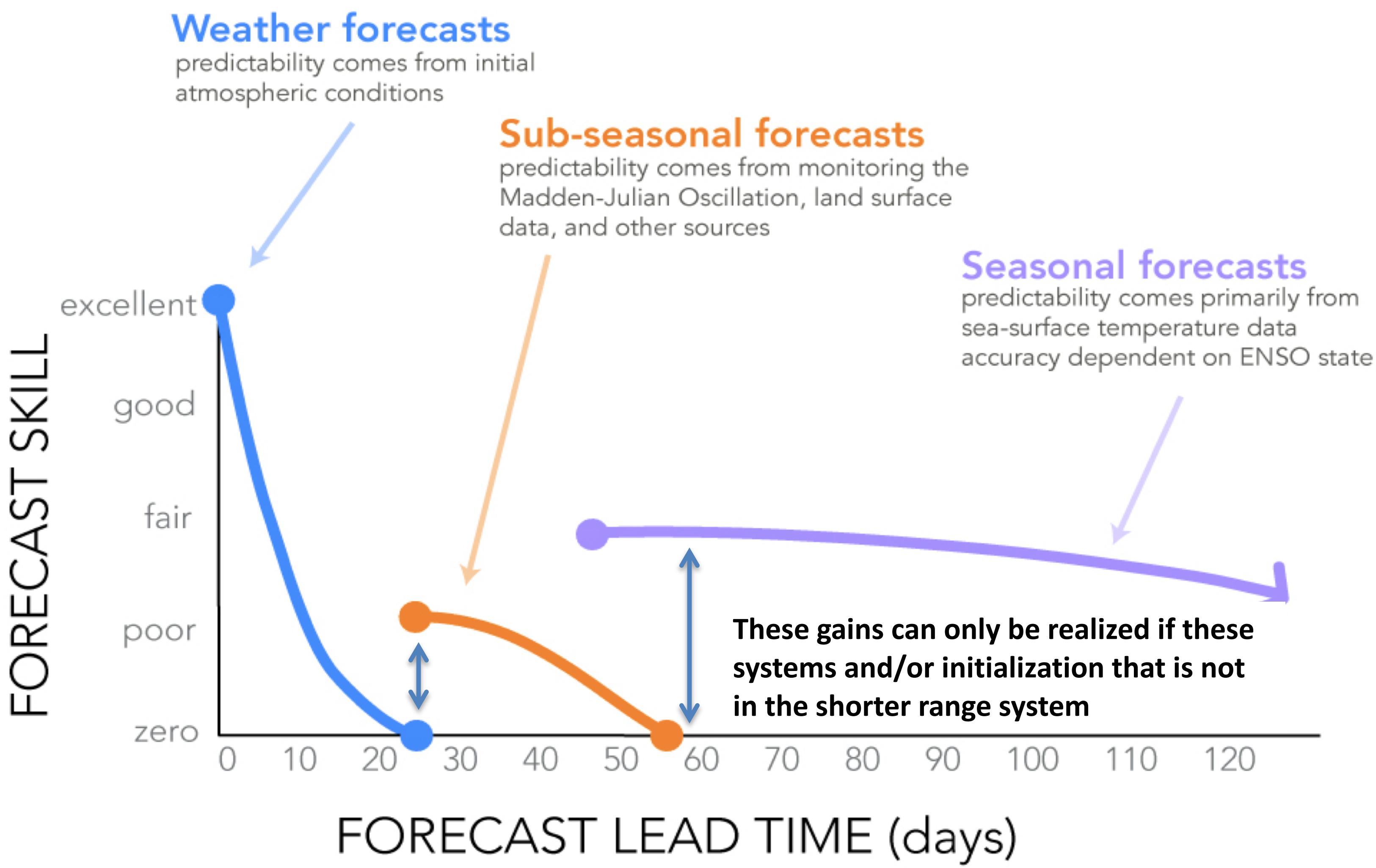
Focus of the CITES school last week



Processes that provide extended range predictability



But important to recall…



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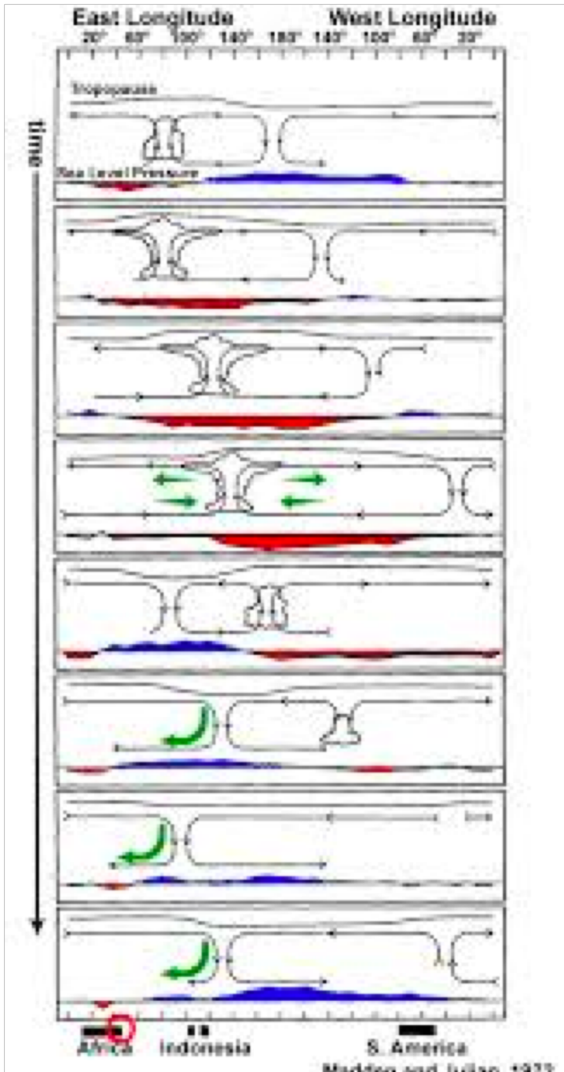
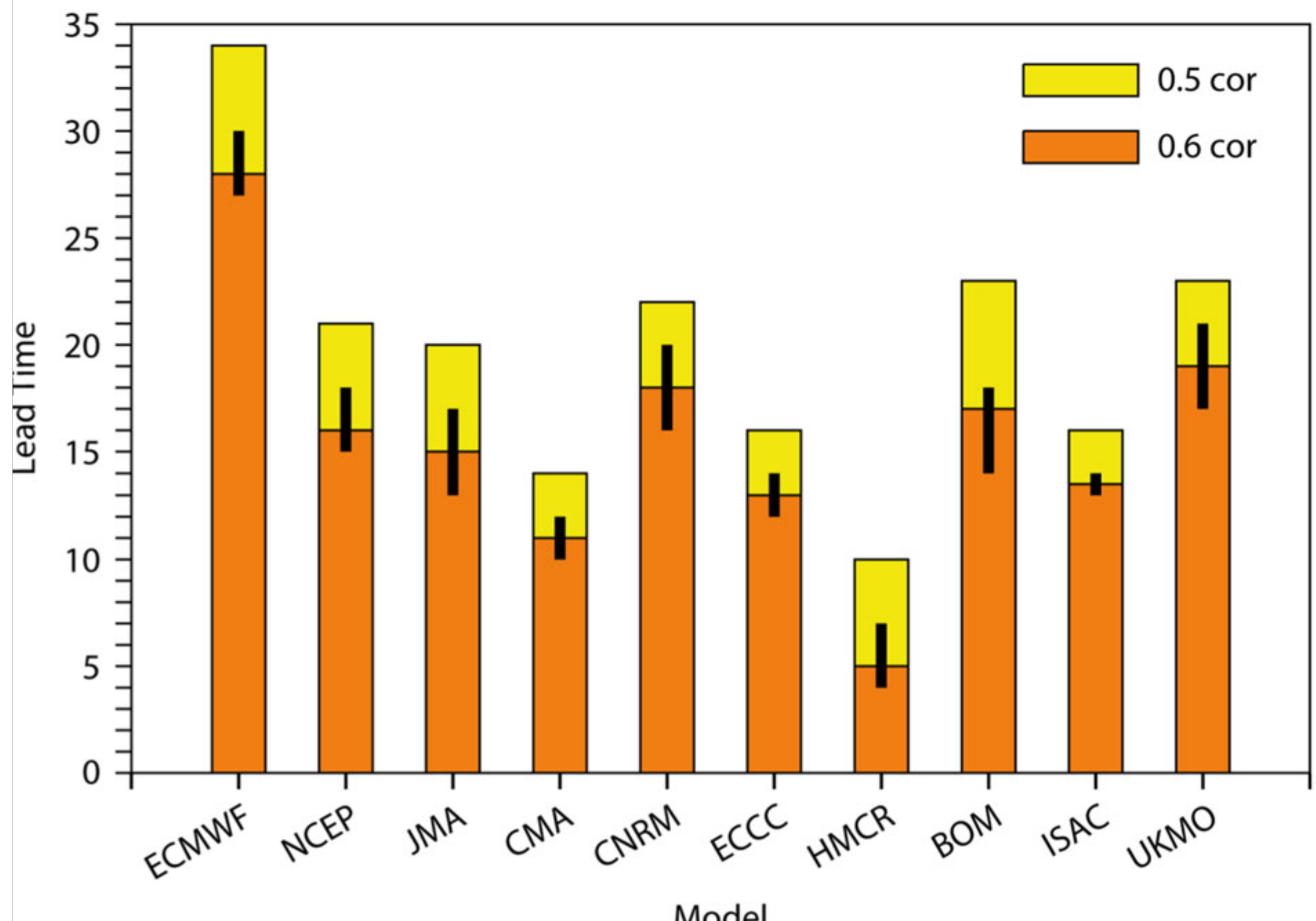
This is important as the MJO skill has been improving in models



From Robertson and Vitart, 2018

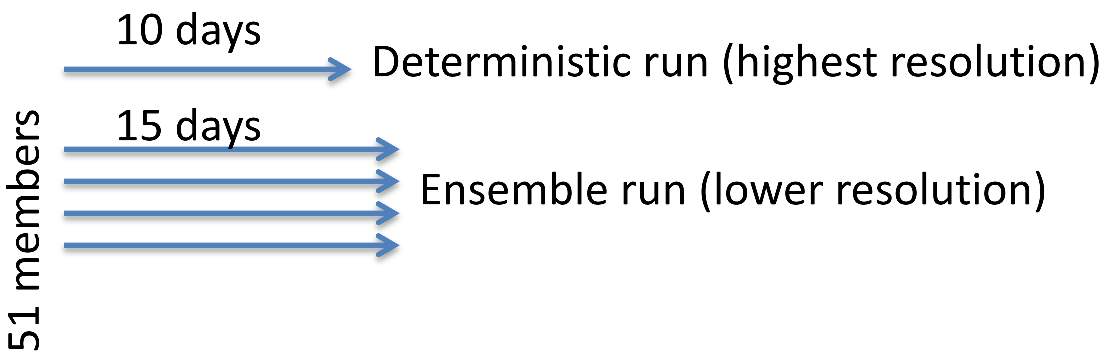


An introduction to forecast timescales
The ECMWF framework

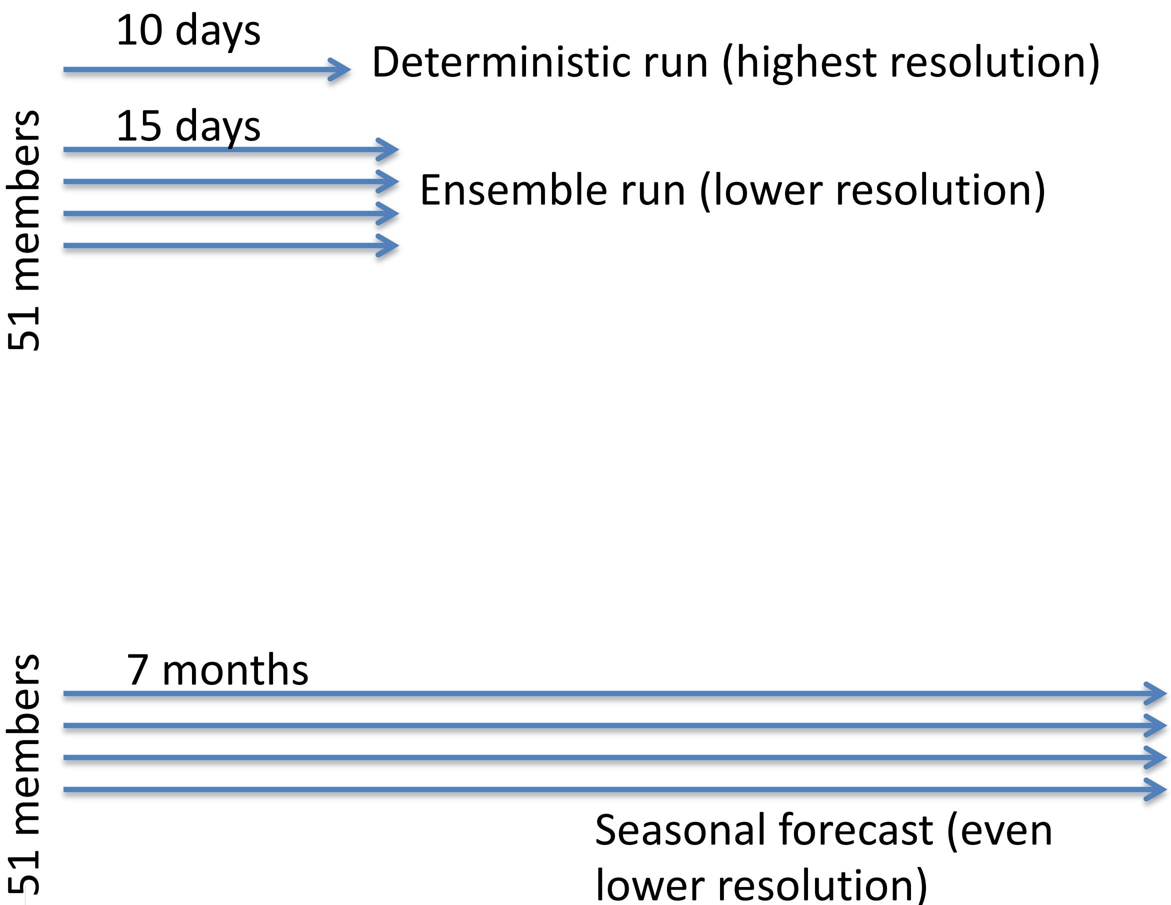
10 days

Deterministic run

An introduction to S2S timescales: The ECMWF framework



An introduction to S2S timescales: The ECMWF framework



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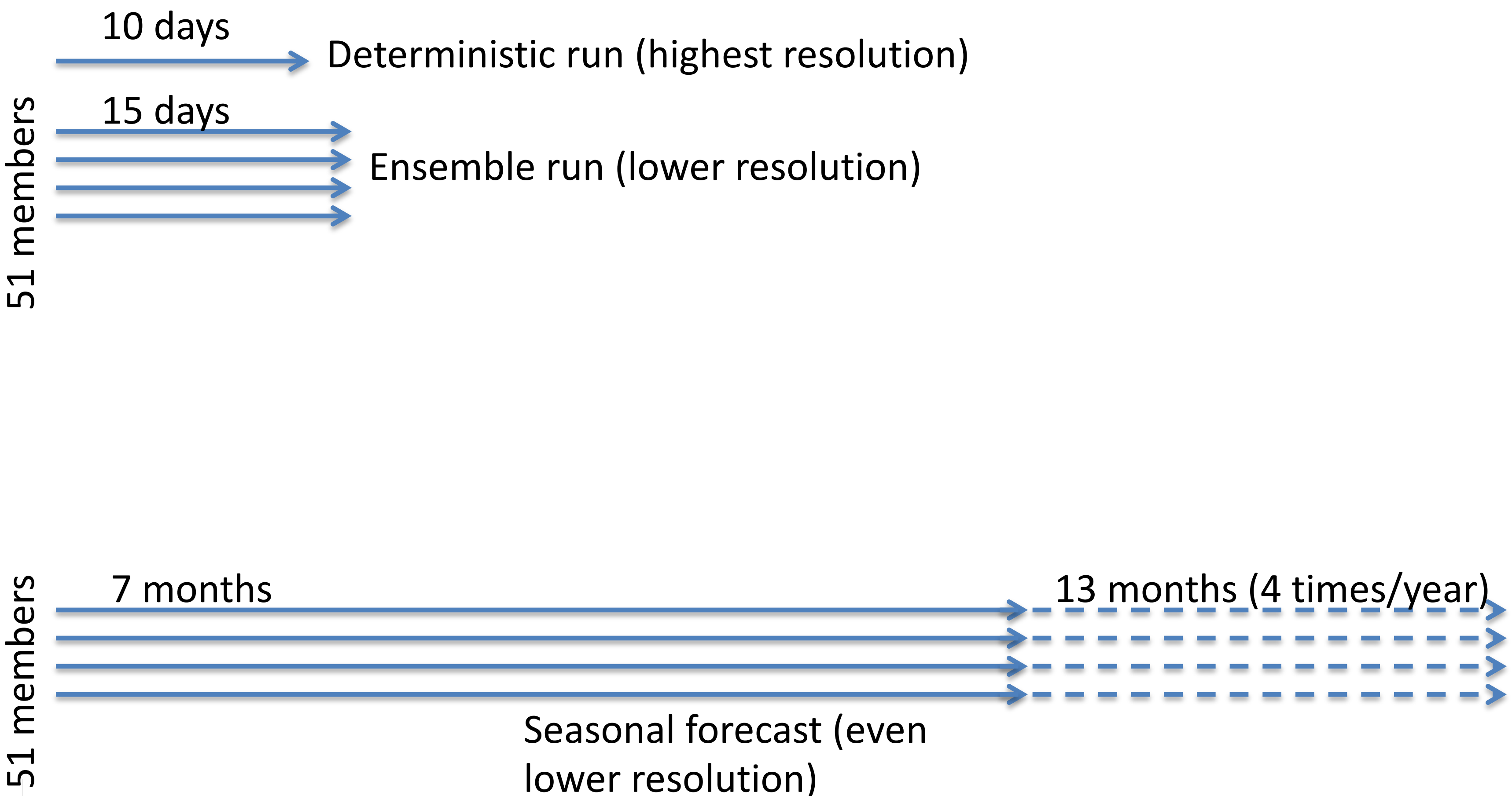

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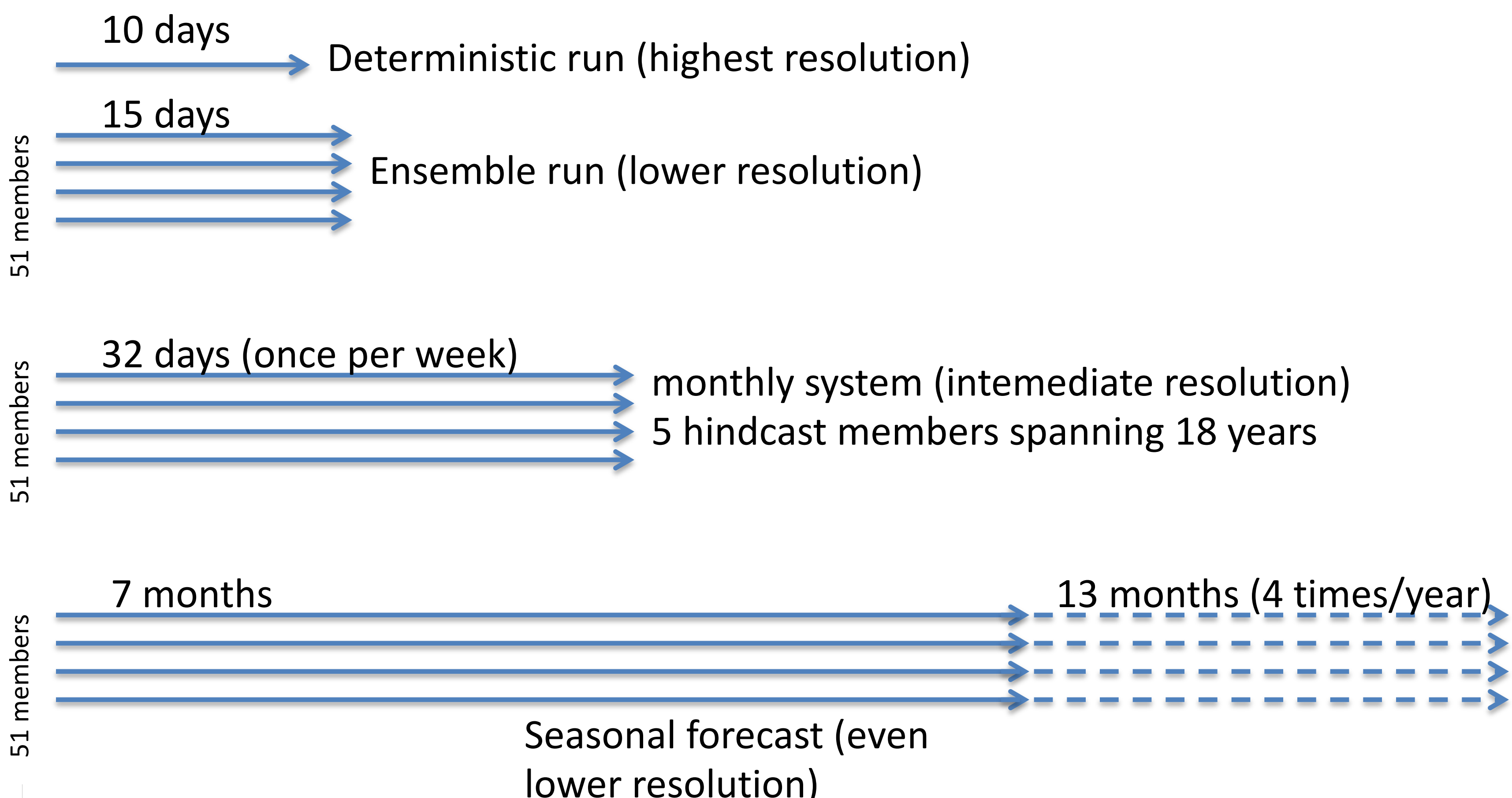

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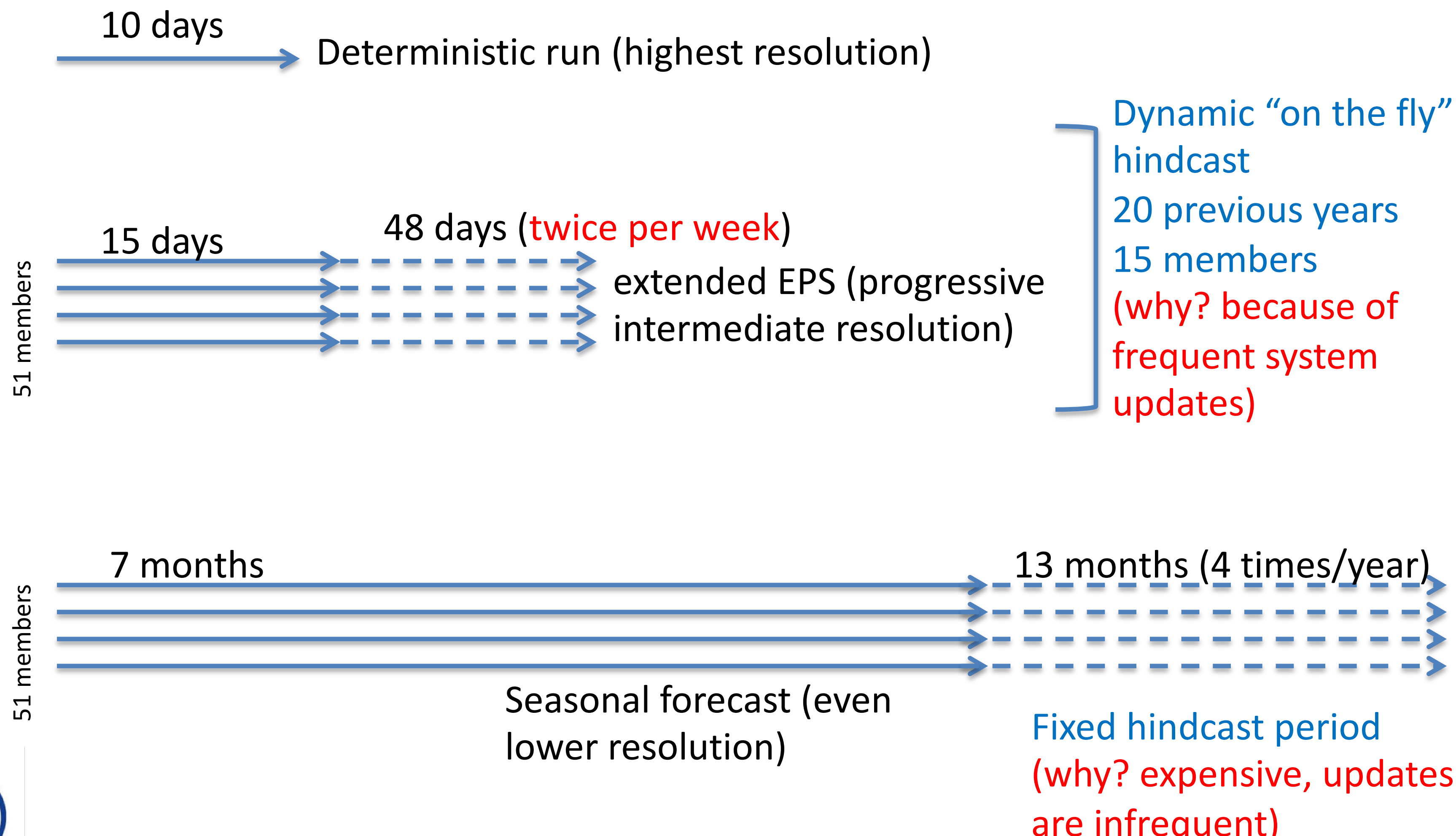


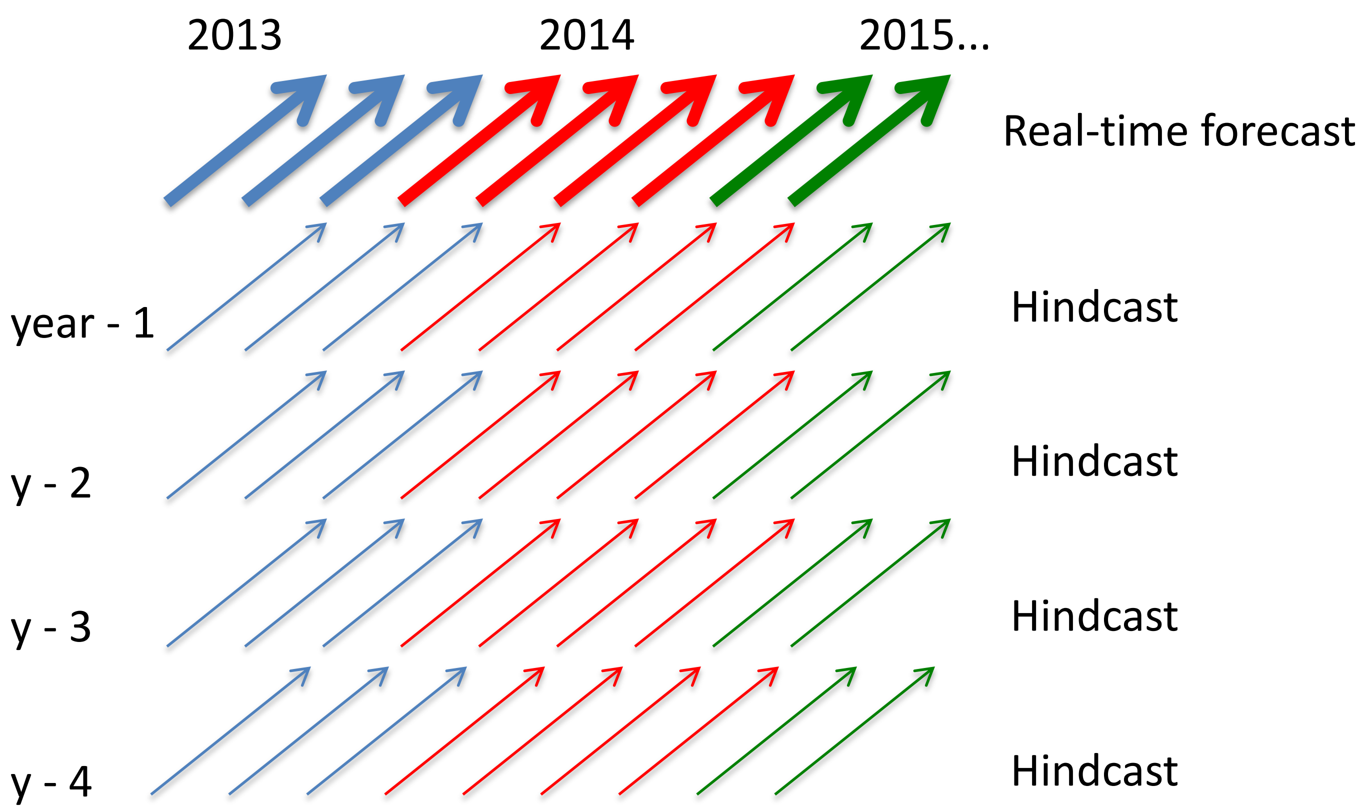
Assessing S2S model skill – the hindcast

- Hindcast primary function is to perform bias correction and output calibration.
- However also useful to assess model skill over interannual timescales since model system is identical
- Disadvantage is that ensemble size is smaller

Colour represents model version

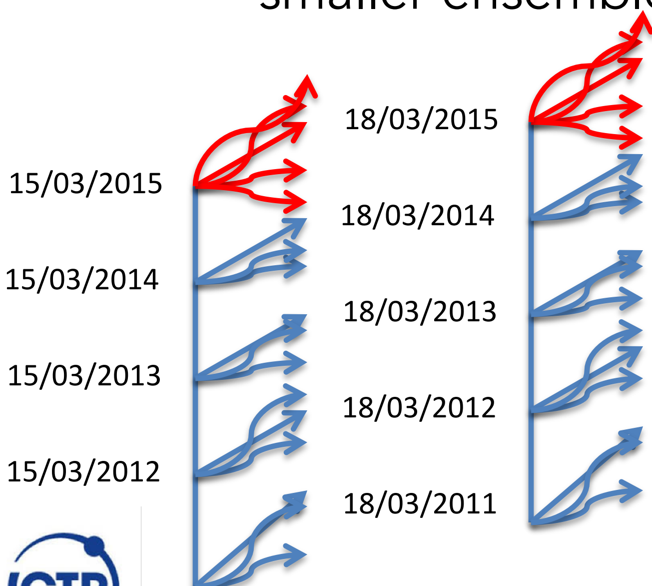
Arrow thickness indicates the ensemble size

(51 versus 5-15)

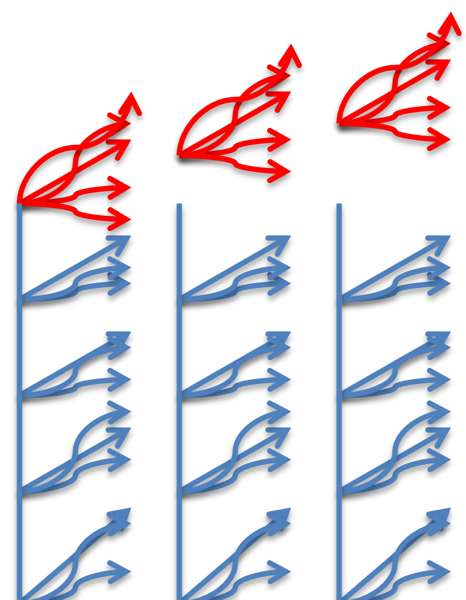


Hindcast Strategies

- "On the fly" – Each forecast is accompanied by a set of hindcasts starting on the same date for the previous N years
  - GOOD: same model version and set up
  - GOOD: Always same start date
  - BAD: Expensive to run, smaller ensemble sizes

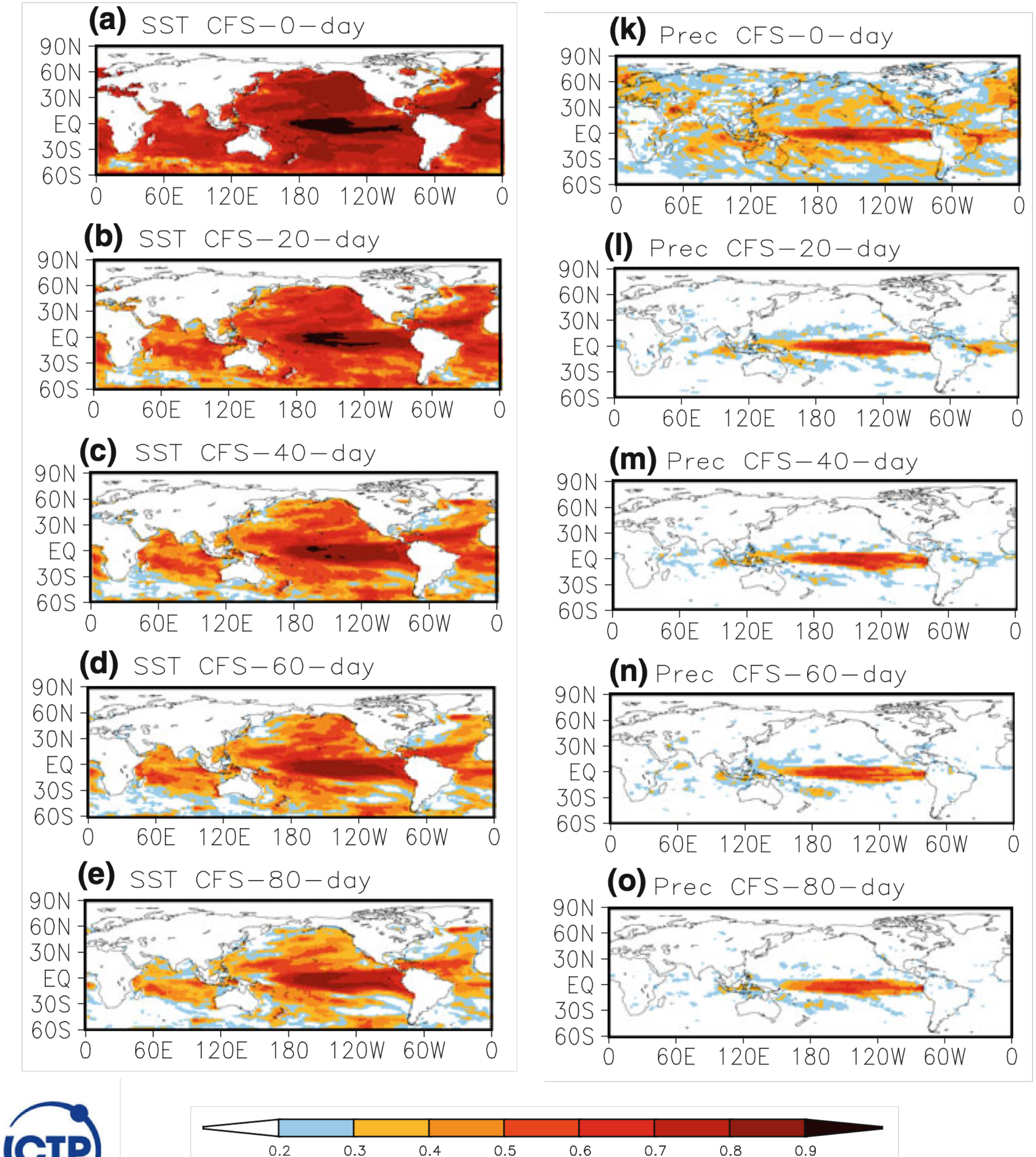


- "Fixed" – Hindcast data set run once for a particular model cycle
  - GOOD: Cheaper (if system not updated too frequently), larger ensemble sizes possible
  - BAD: Not always matching dates



CFS lead time skill

From Kumar et al 2011, clim dyn

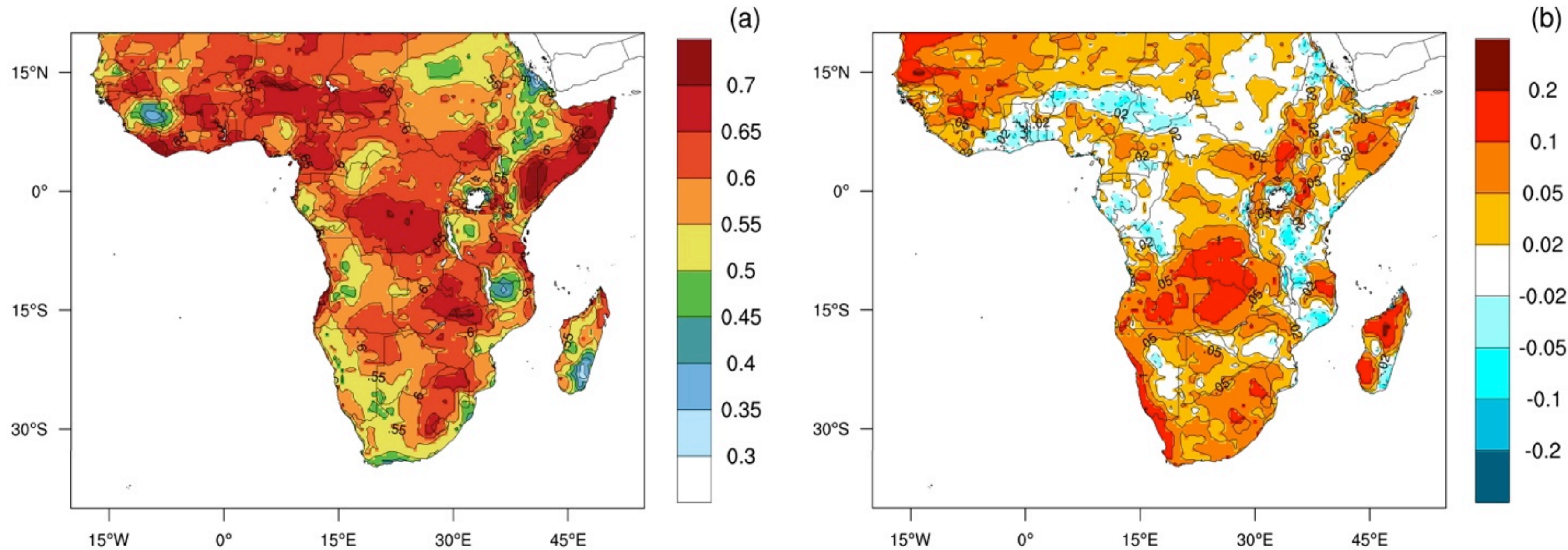


Longer range predictability in the tropics in surface temperatures

Skill defined as temporal correlation

Should S2S systems improve season systems?

from Tompkins and Digiuseppe, JAMC, 2015



Correlation of day 1-32 T2m anomaly against ERA-Interim for 1994-2012 of Extended range EPS over Africa
12 start dates in 2012 (First Thursday of each month)

Increase in correlation relative to the exact same days predicted by the most recent seasonal forecast system

QUESTION: Where does this skill gain come from?

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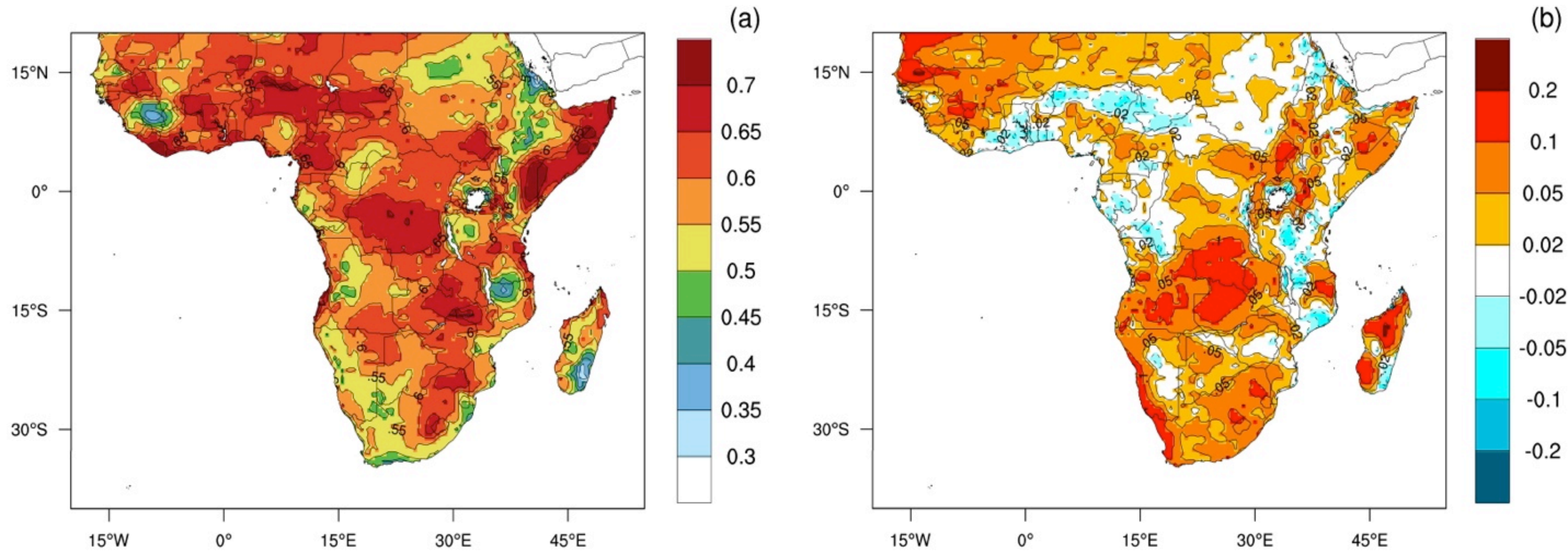
Should S2S systems improve season systems?

from Tompkins and Digiuseppe, JAMC, 2015



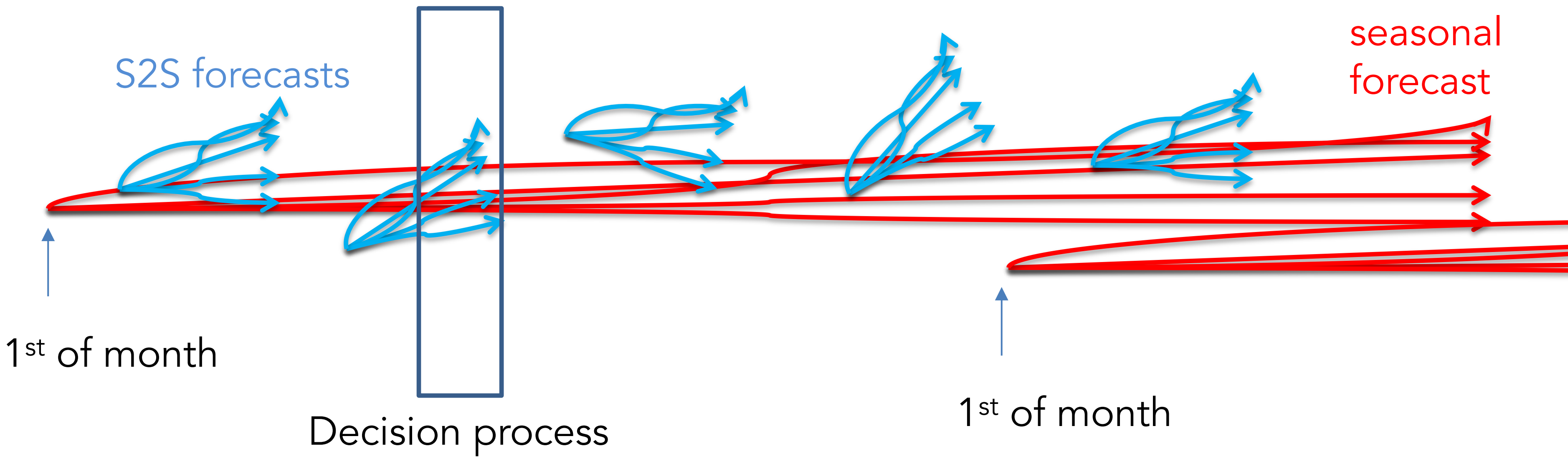
Correlation of day 1-32 T2m anomaly against ERA-Interim for 1994-2012 of Extended range EPS over Africa
12 start dates in 2012 (First Thursday of each month)

Increase in correlation relative to the exact same days predicted by the most recent seasonal forecast system

1. Lead time advantage (more frequent updates)
2. Model physics (more frequent updates)
3. "Setup" (higher resolution, different ocean initialization…)

Schematic of lead time gain

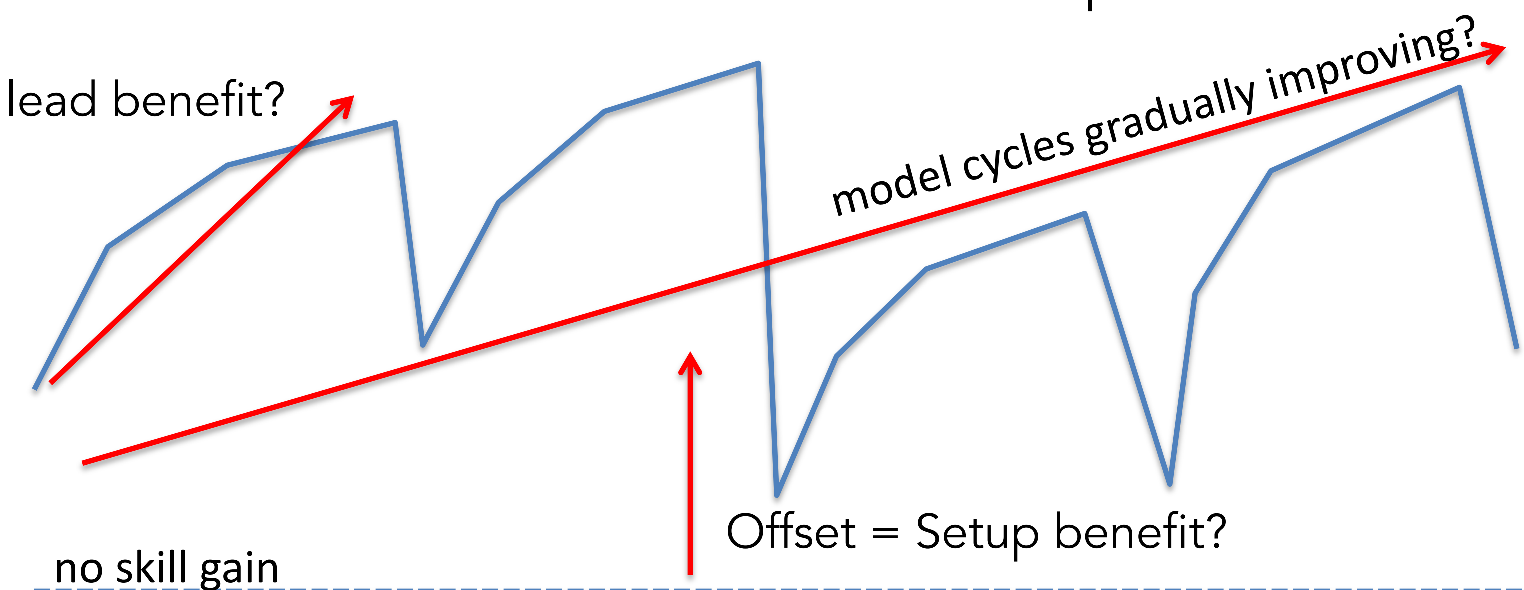
Usually there is always a newer S2S forecast available for a week 2 to 6 decision window



Note: in this talk we will treat the lead gain as if all forecasts are immediately available (i.e. forecast on the 1st available on the 1st), whereas the seasonal system in fact has a lag, for example in C3S, release is on the 13th of the month.

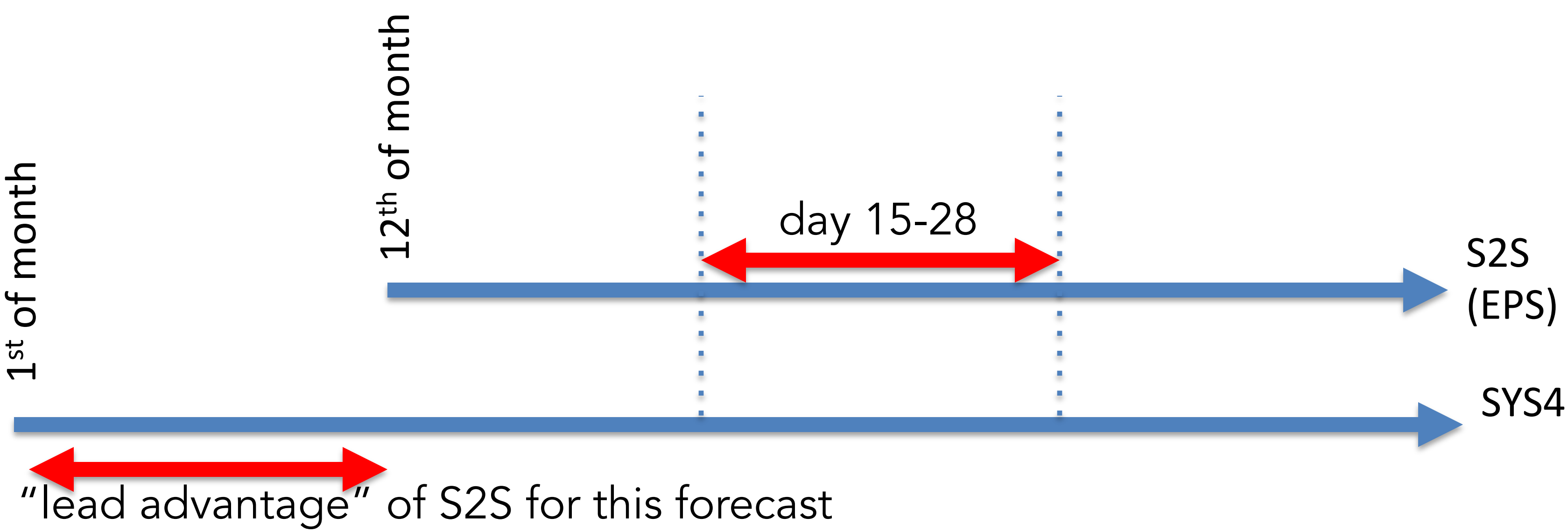
How can we calculate the contributions of these factors to changes in skill?

- Controlled experiments?
  - ensembles of cycles/lead advantage?
  - too expensive!
- What using the operational cycles?
  - O(10^5) forecasts
  - but lead time/model version/setup mixed

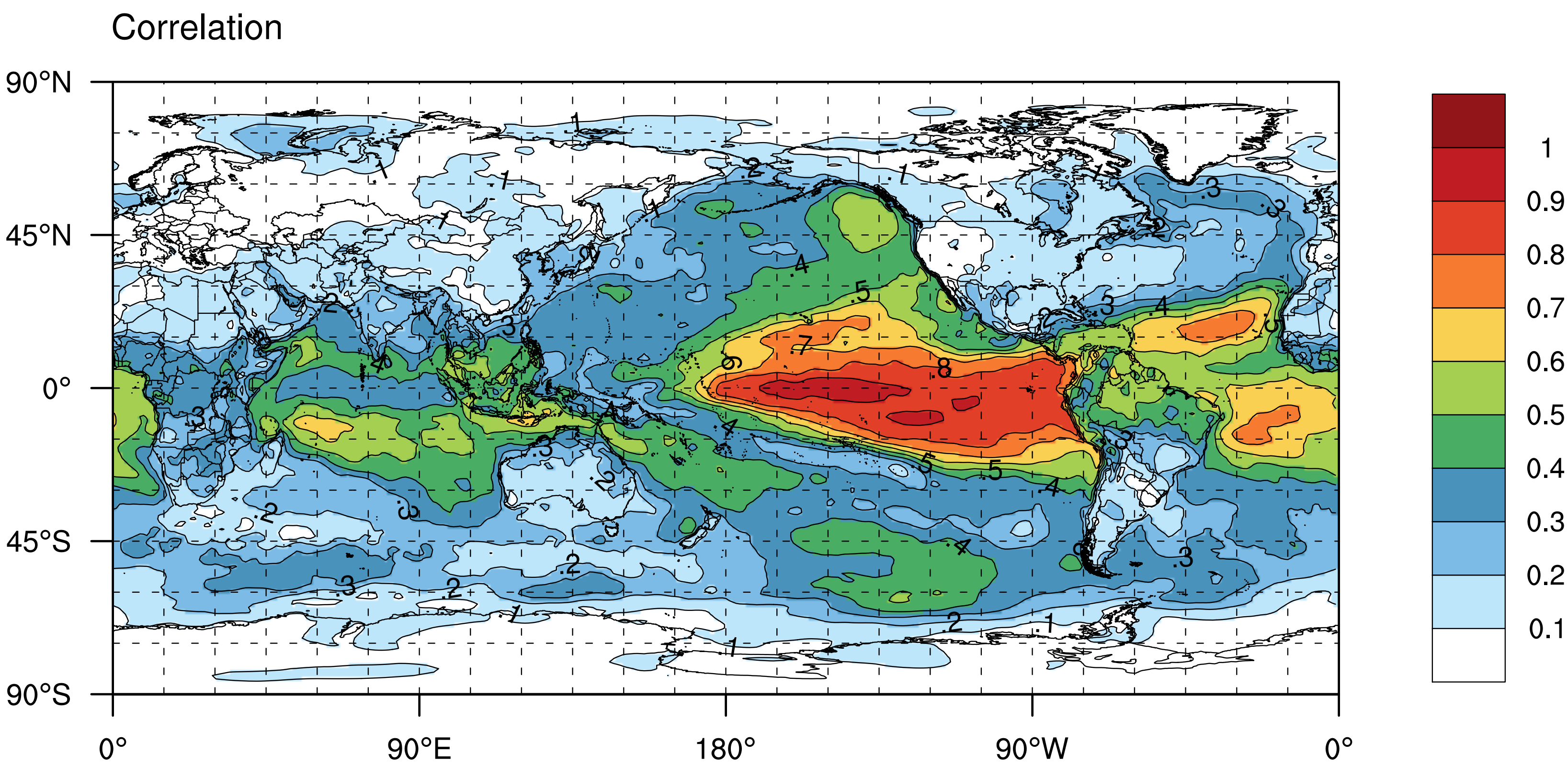


System 4 versus S2S – analysis of T2m

- Sept 2008 to January 2014 (no resolution or major "setup" changes)
- Use 5 members and 19 years (1+18 hc) throughout period = O(30,000) forecasts.
- Hindcasts are initialized using ERA Interim
- Examine the correlation of the ensemble mean
- Assume that differing hindcast period does not impact statistics (1990-2008 versus 1996-2014) – "ENSO count" similar...
- "Like-for-like" comparison for leads

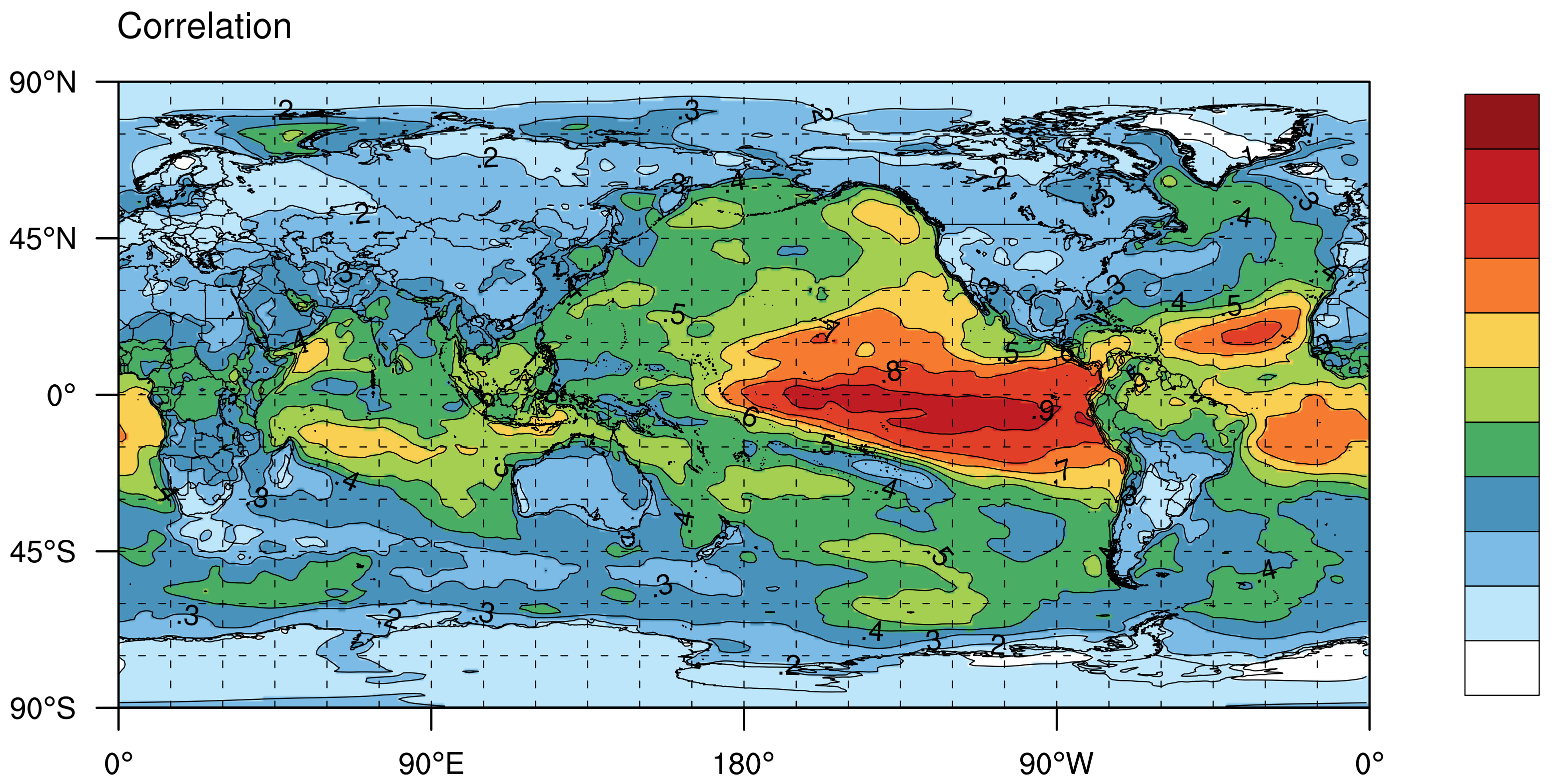


System 4 week 3-4 correlation

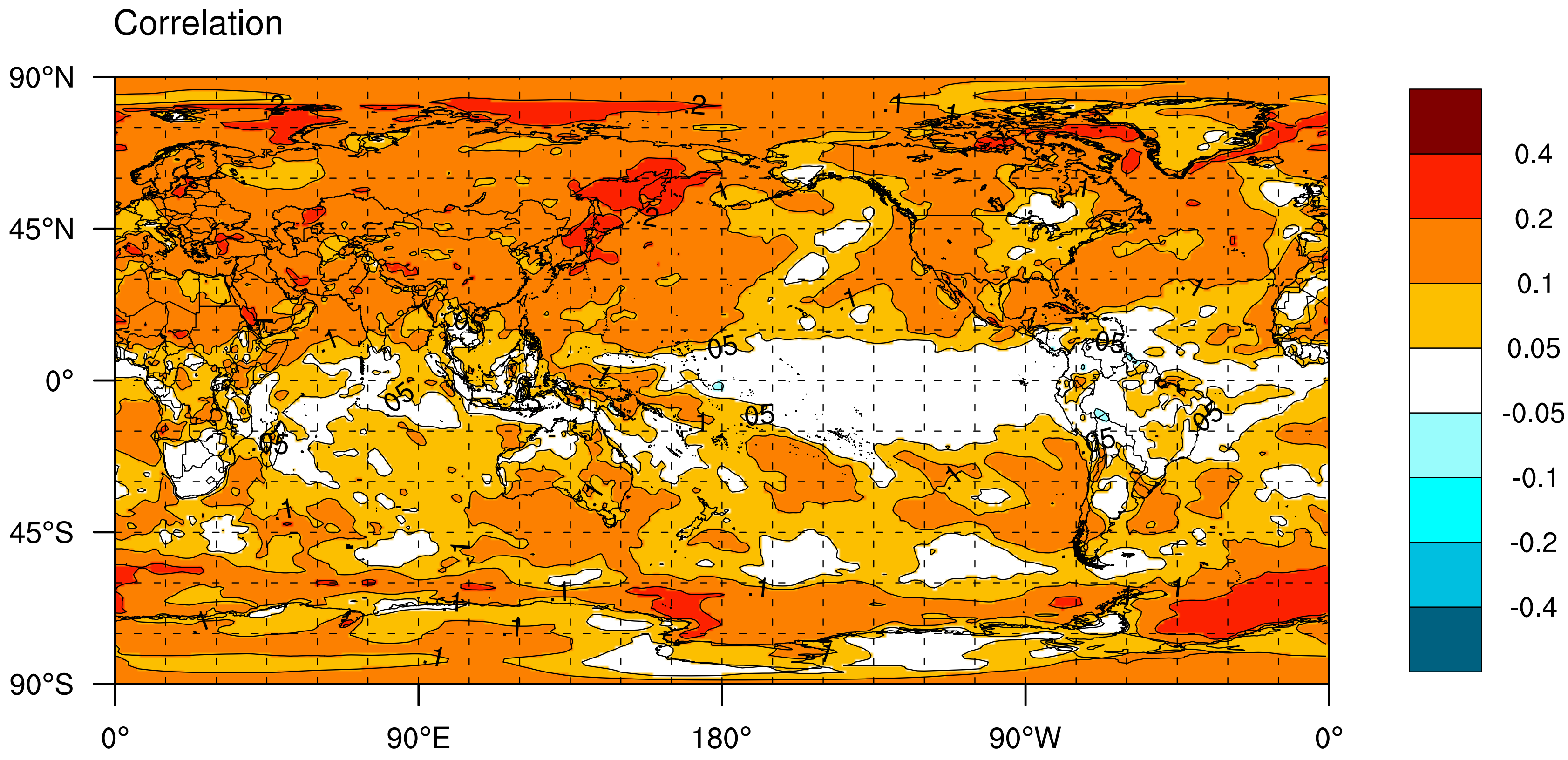


As expected correlation highest over oceans and ENSO region

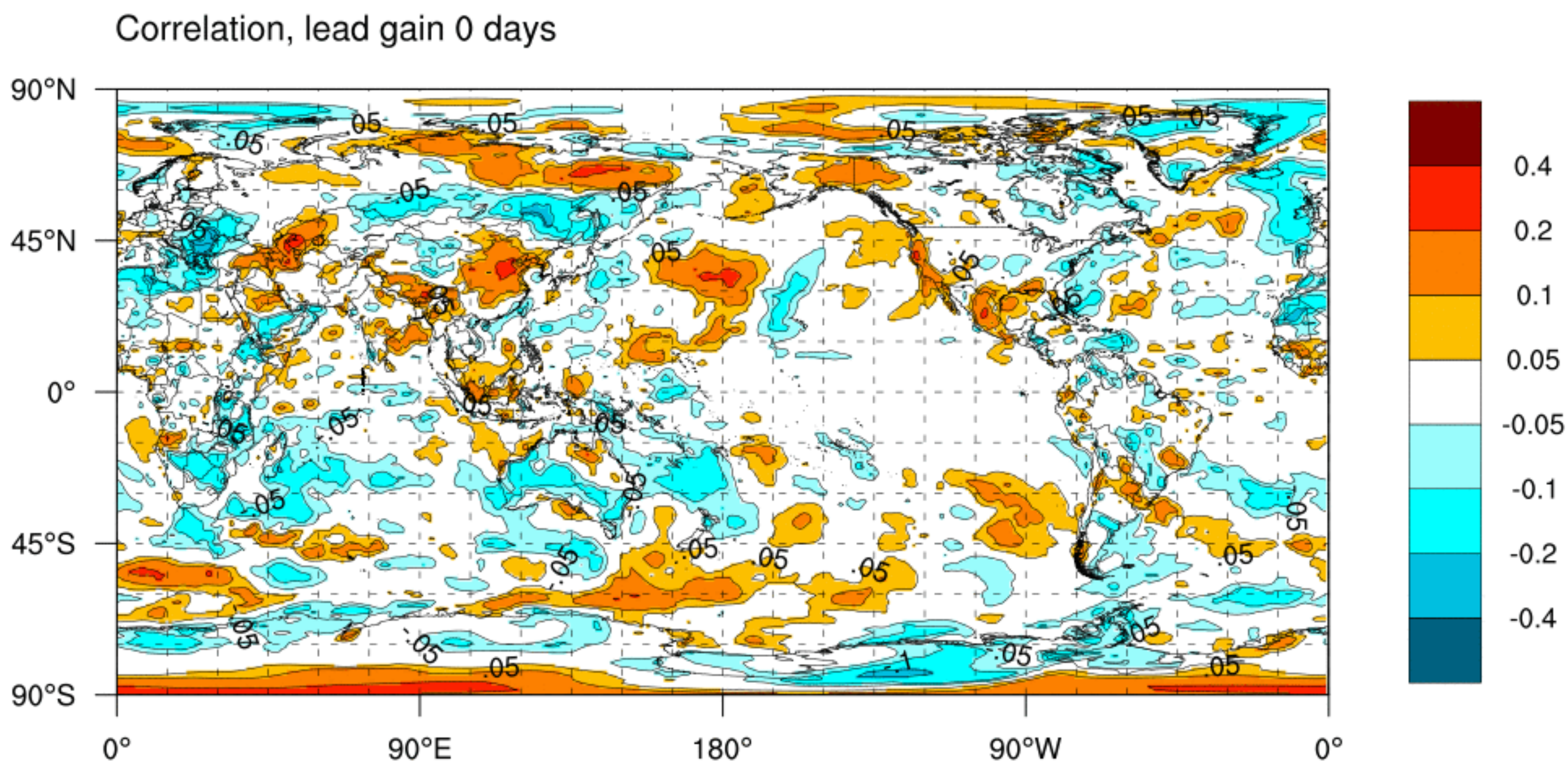
S2S week 3-4 correlation



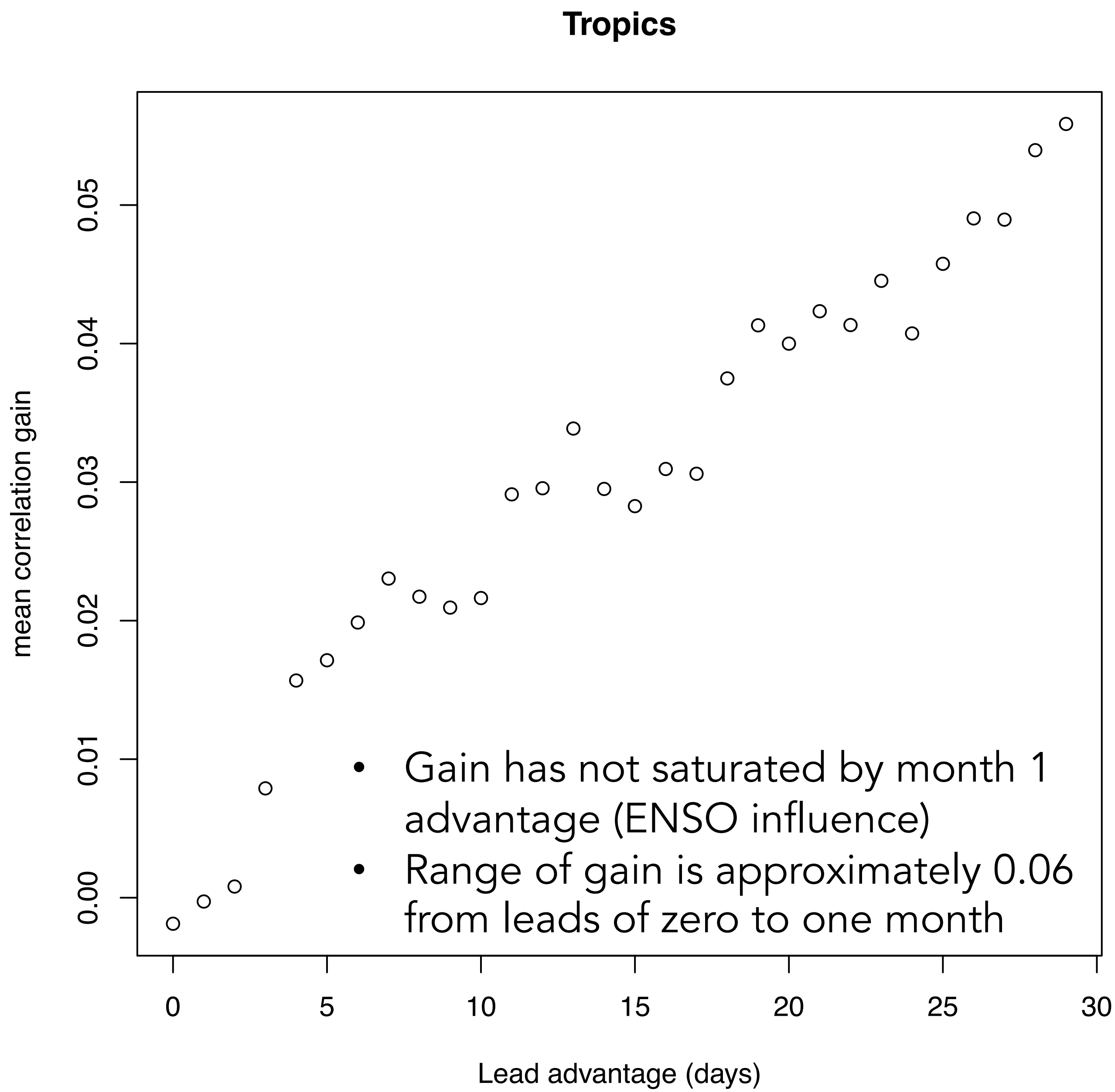
S2S advantage week 3-4 correlation



Lead advantage gain, looping 0 to 29 (days)

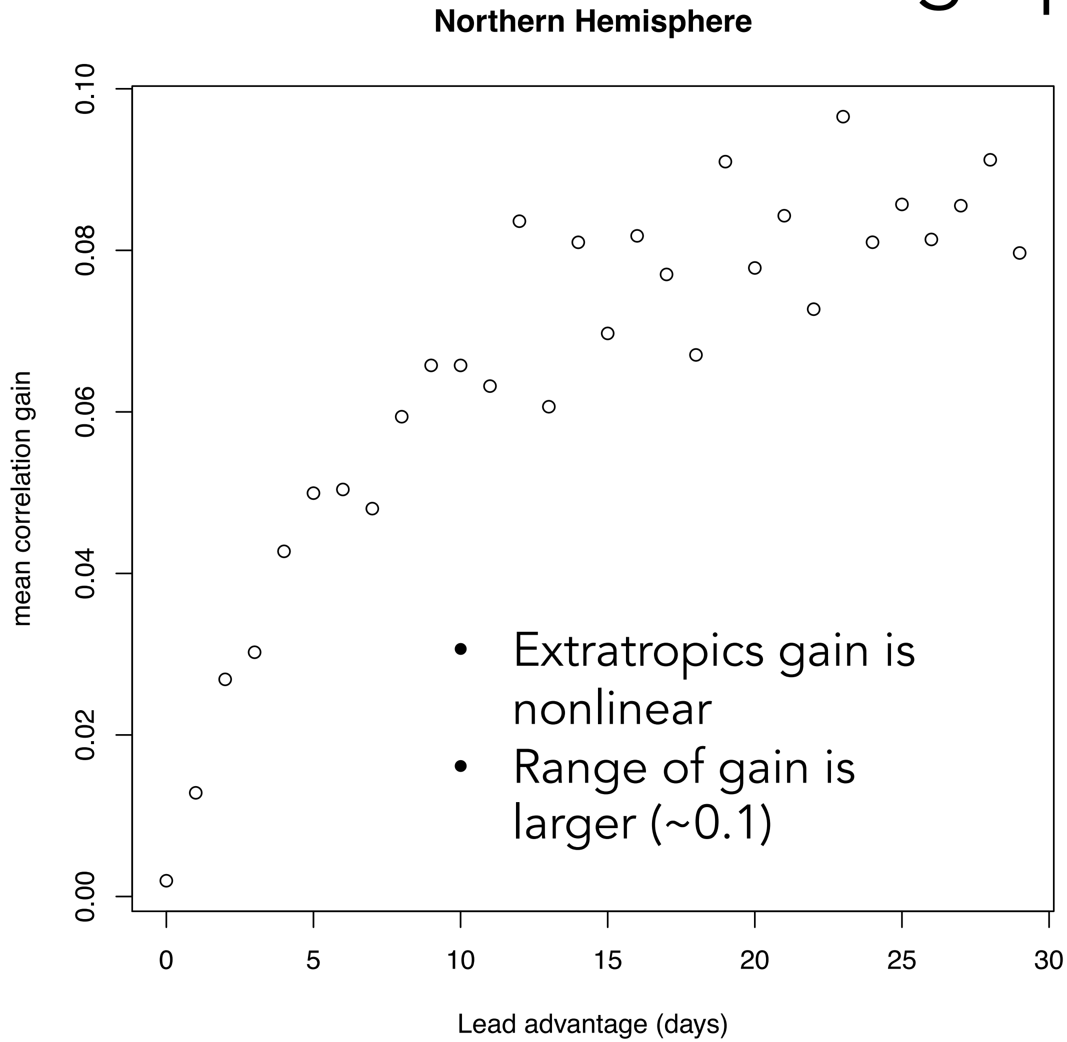


lead time relative skill advantage plot



- Gain has not saturated by month 1 advantage (ENSO influence)
- Range of gain is approximately 0.06 from leads of zero to one month

lead time relative advantage plot

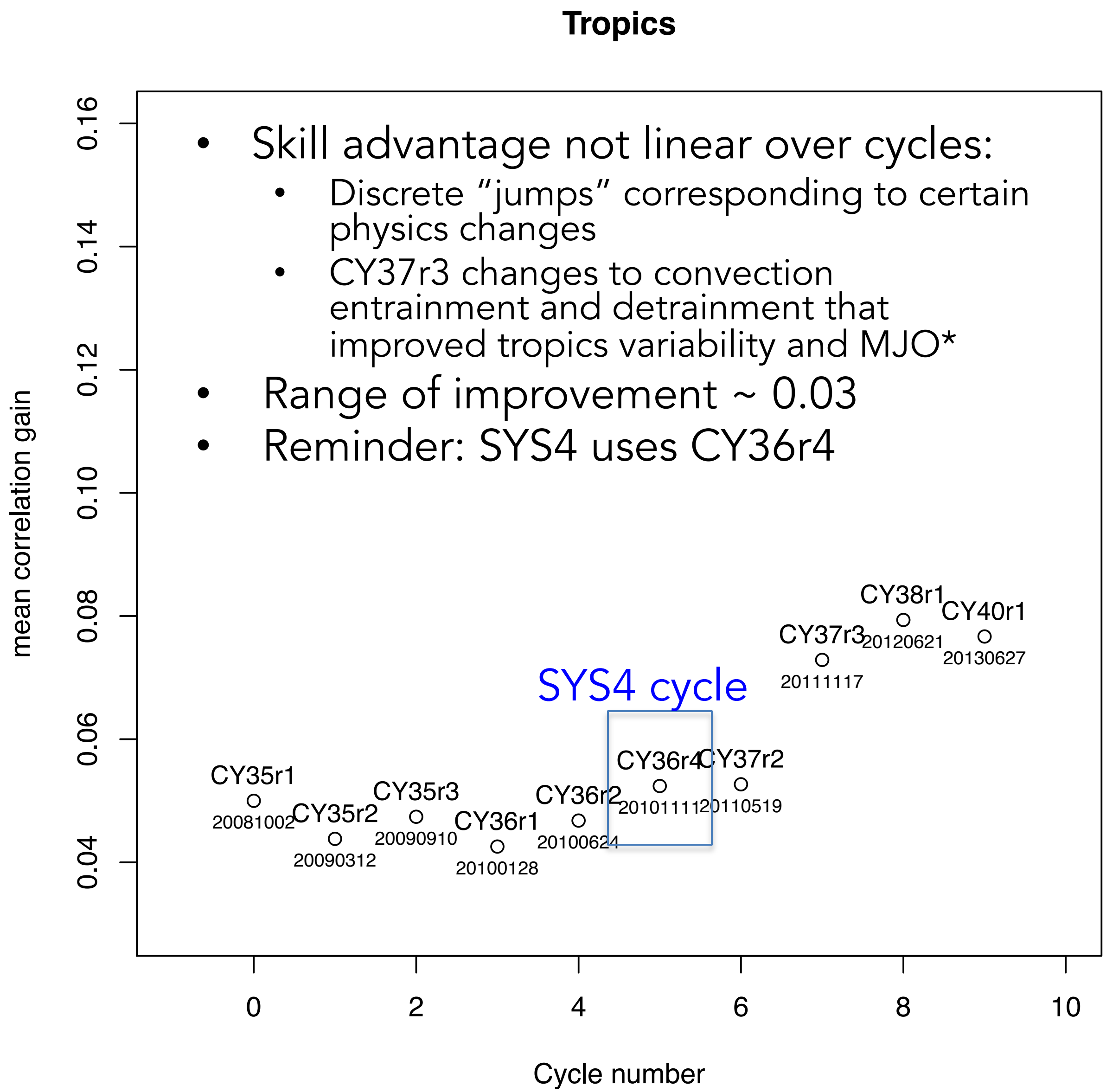


- Extratropics gain is nonlinear
- Range of gain is larger (~0.1)

Assumption: We will assume that the lead time gain is independent of physics contributions (setup changes minimal across period) i.e. we assume that we can add contributions linearly.

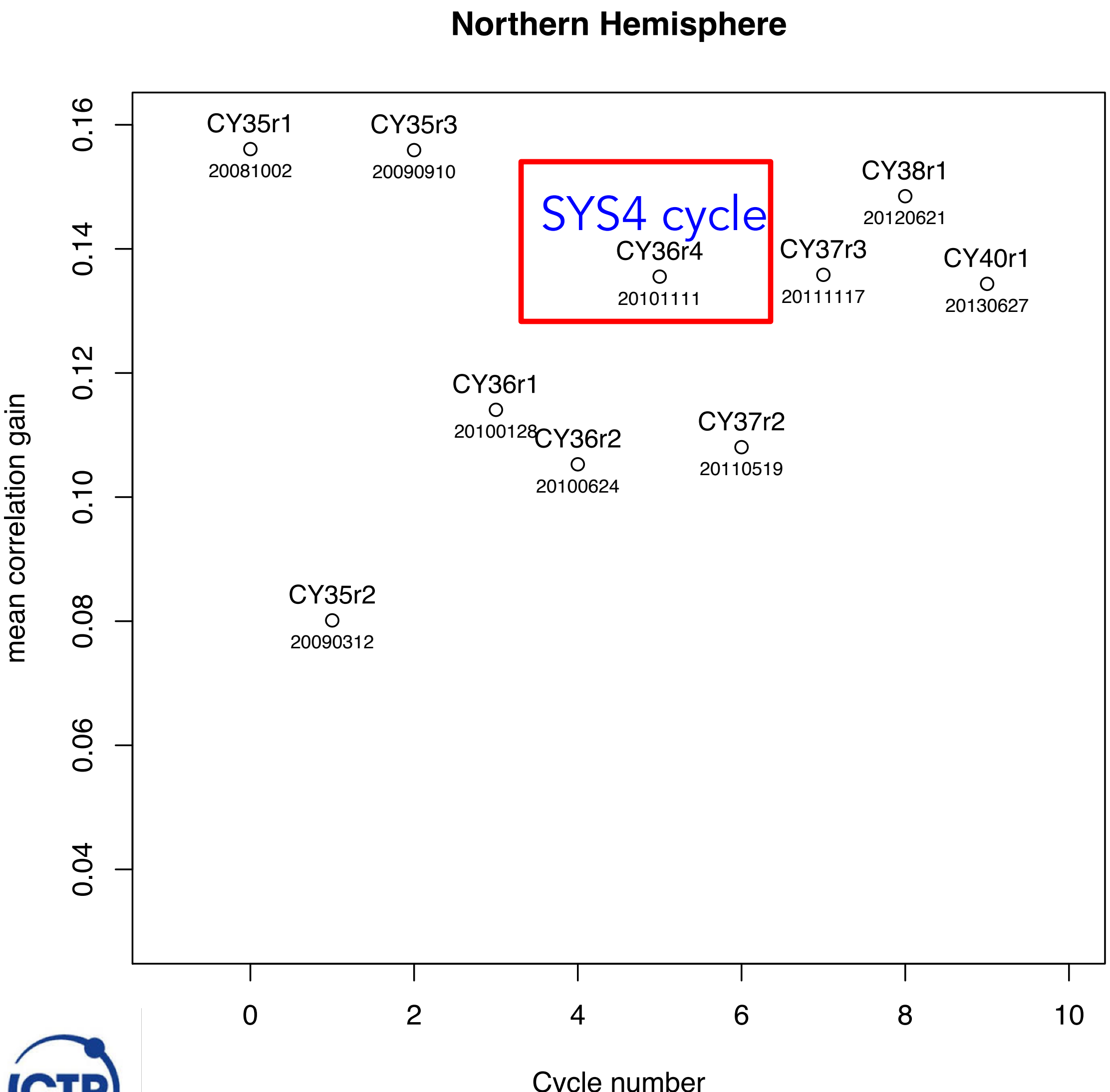
Model physics advantage

- Skill advantage not linear over cycles:
  - Discrete “jumps” corresponding to certain physics changes
  - CY37r3 changes to convection entrainment and detrainment that improved tropics variability and MJO*
- Range of improvement ~ 0.03
- Reminder: SYS4 uses CY36r4



* See Bechtold et al. QJRMS 2008

Model physics advantage in extra tropics



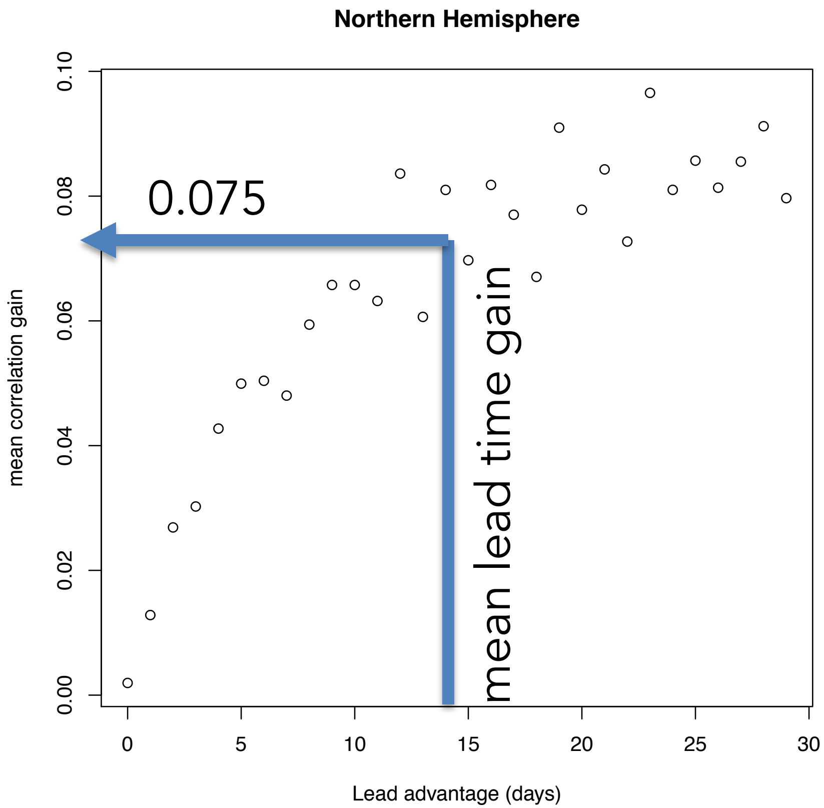
No clear systematic improvement (in T2m) in extratropics

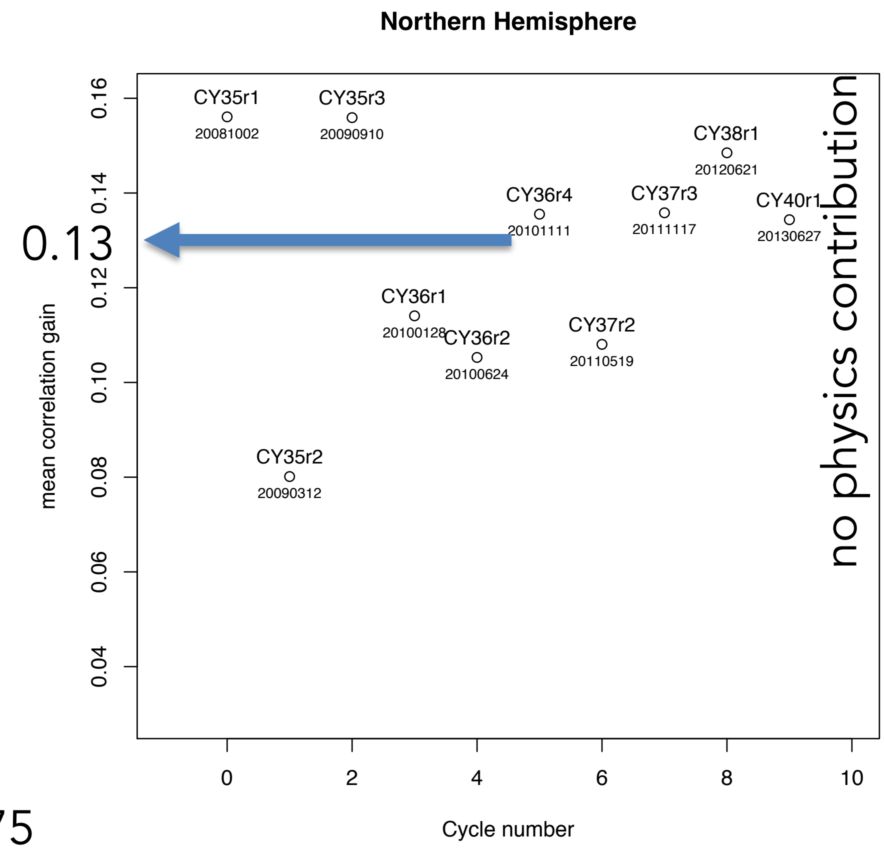
Unsurprising, as skill very limited at this range.

Most model physics gains are reflected in day 1-10 gains

Extra tropics gains likely only through gains via tropics (MJO)

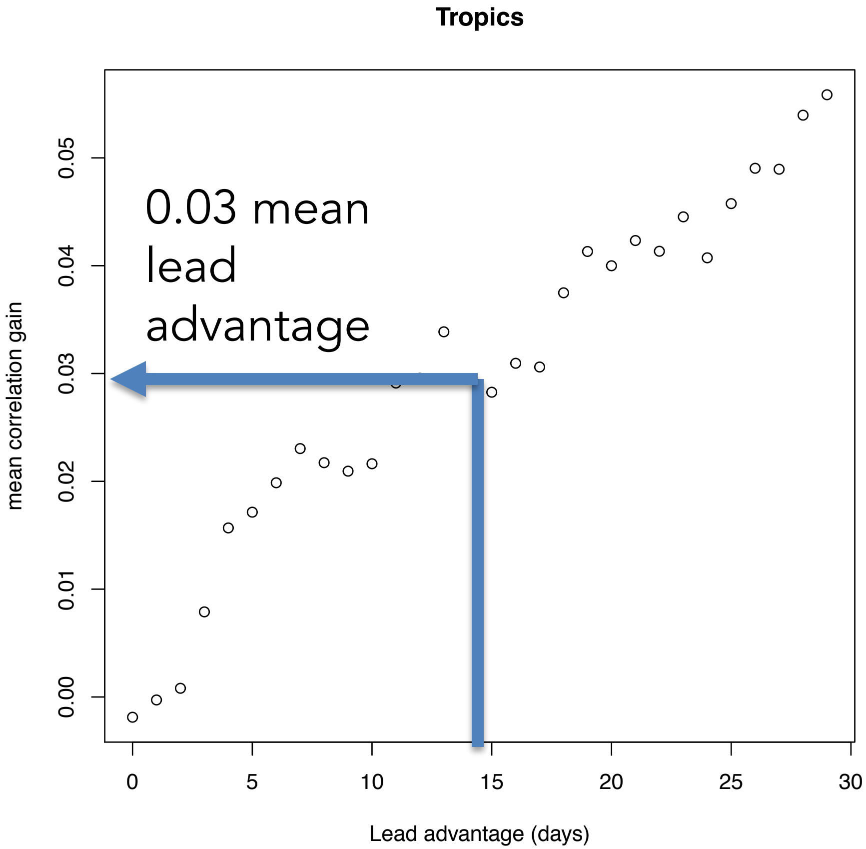
How do the contributions compare? NH

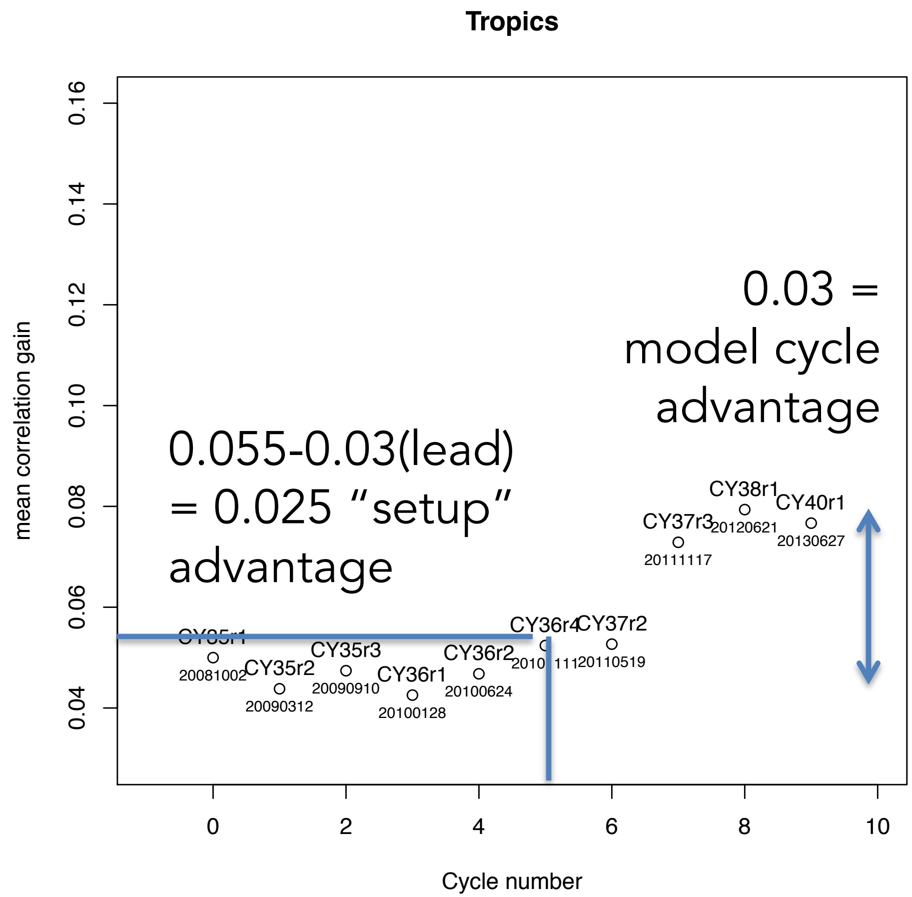




- Lead gain is approximately 0.075
- Total gain is 0.13 (=setup + lead + physics) [right panel]
- Model physics contribution is minimal (no trend across cycles)
- Setup gain is approximately 0.06 (all forecasts minus lead contribution)

How do the contributions compare? Tropics





- In Tropics contribution similar from lead gain, model physics, and setup

Conclusions

- Subsampled 30,000 forecasts/hindcasts to try to "pull apart" contributions to S2S (EPS) gain in skill for T2m
  - Lead advantage
  - Model cycle
  - System set up (resolution…)
- In the tropics, all three contribute fairly equally over a 6 year period, while in the NH extratropics, lead and setup contribute equally.
- Extend the analysis to precipitation and winds, (also for remainder of SYS4 period).