Working Group I
The Physical Science Basis

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

Near-Term Climate Predictability and Prediction

IPCC AR6 Scoping Meeting – WGI Scene Setting

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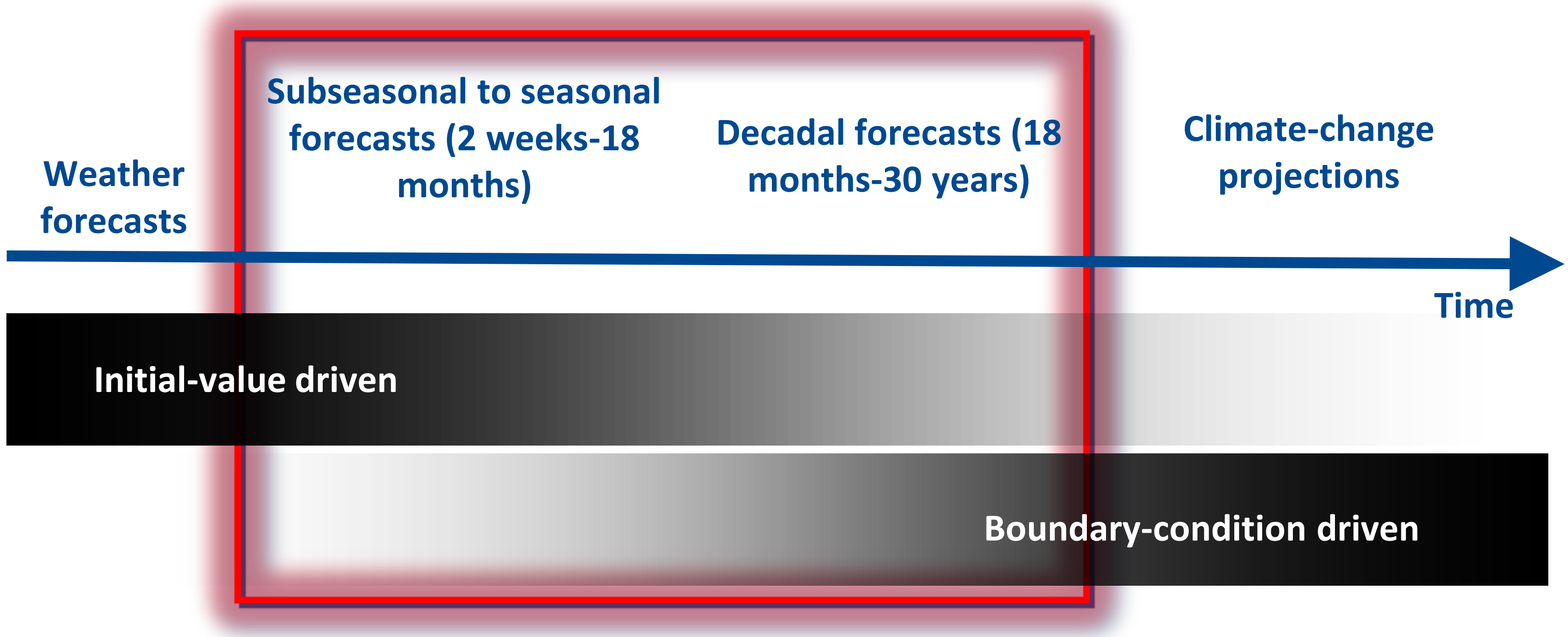
Introduction

- Variability, predictability and prediction are closely linked
  - Systems aim at predicting the relevant variability up to the level that predictability estimates suggest is possible
  - Predictability is non-observable and changes across time scales, variables and regions
- From a policy-relevant perspective predictions count for the formulation of statements about climate variations for the next 30 years; it involves merging predictions and projections
- Climate predictions allow to both phase in the internal variability and correct the forced model response
- Close links exist with climate services (GFCS) as many stakeholders make decisions on interannual to interdecadal time scales -> WGII
- Predictability and prediction rely on scientific coordination from WCRP's CLIVAR, WGSIP, DCPP, GC-NTCP, as well as increasingly from WMO's CBS

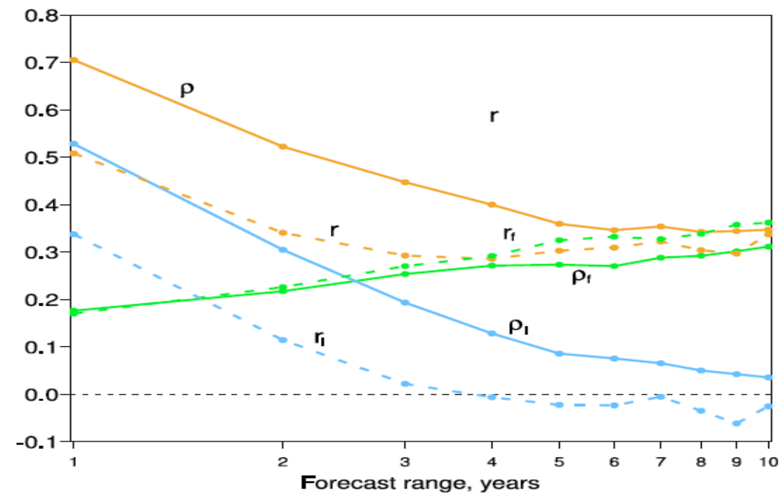


Climate Prediction

- Multi-seasonal, annual, multi-annual, up to decades
- *Initialized* forecasts of *both* forced and internally generated components of variability

Lessons from AR5

- Near-term climate information in Chapter 11
- Skill in near-term climate information, while initialisation increases the skill mainly in the North Atlantic for a range of variables up to 10 years; annual, multi-annual skill for temperature, not so much for precipitation; large regional variations
- The disconnect between predictability estimates (e.g. signal-to noise ratio measured by individual models) and skill was left open
- Pervasive forecast drift presence, of which no use was made

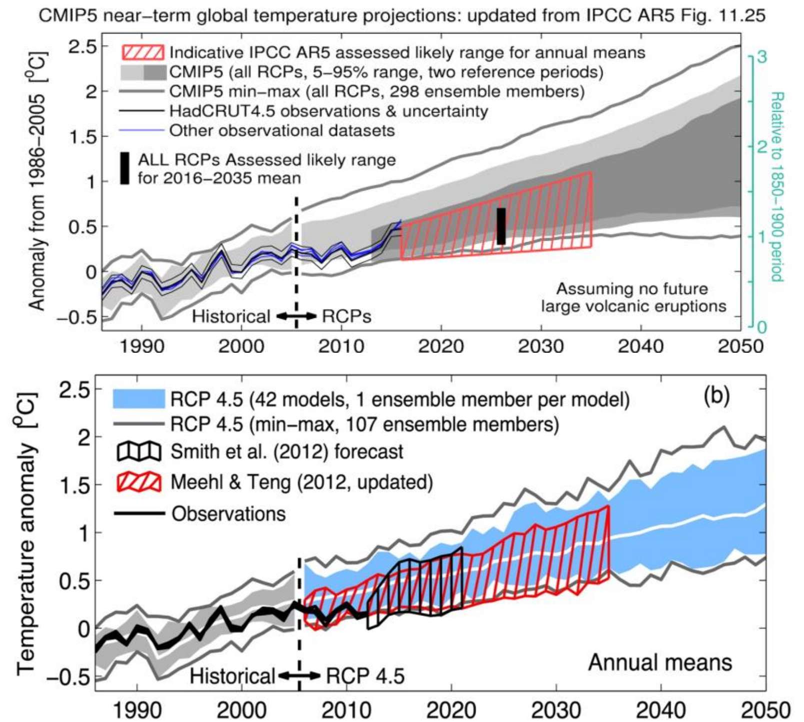


Actual skill (dashed, correlation between model ensemble mean and observations)
Predictability estimate (solid, correlation between ensemble mean and ensemble members)
Orange for total, blue for initial condition and green for forced

Boer et al. (2013)

Lessons from AR5

- Merging prediction/projection information (up to 2035) a challenge
- The hiatus was predicted by the forecast systems and ingested by the consensus assessment
- Need of data assimilation to optimise the use of the scarce data available, particularly for the pre-satellite and pre-ARGO eras
- Predictions need long sequence of historical forecasts with many start dates
  - drift adjustment
  - forecast quality assessment
  - observational uncertainty is key

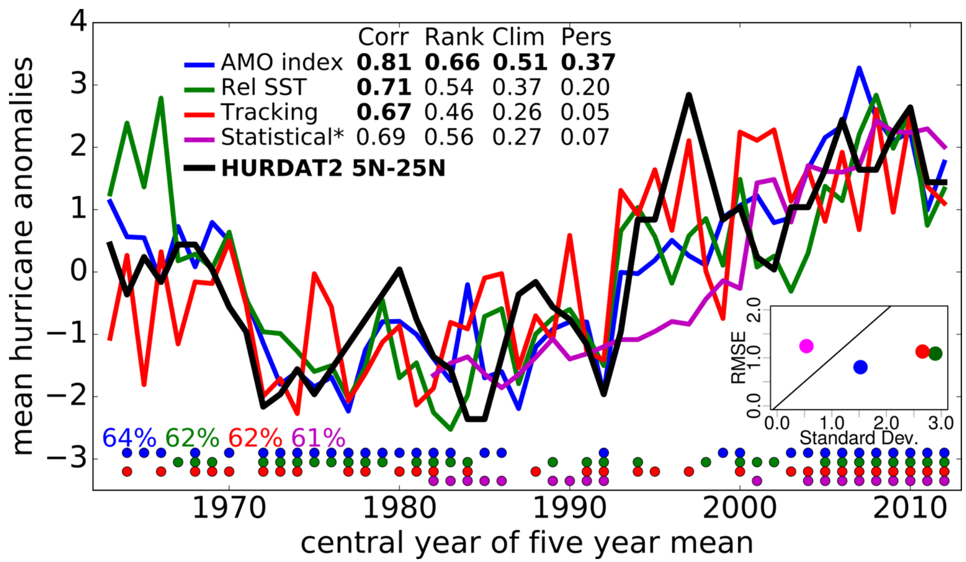


Top: Updated version of IPCC AR5 WGI Figure 11.25b with HadCRUT4.5 global-mean temperature).
Bottom: Figure 11.25a from IPCC AR5 WGI.

E. Hawkins

What's new since AR5

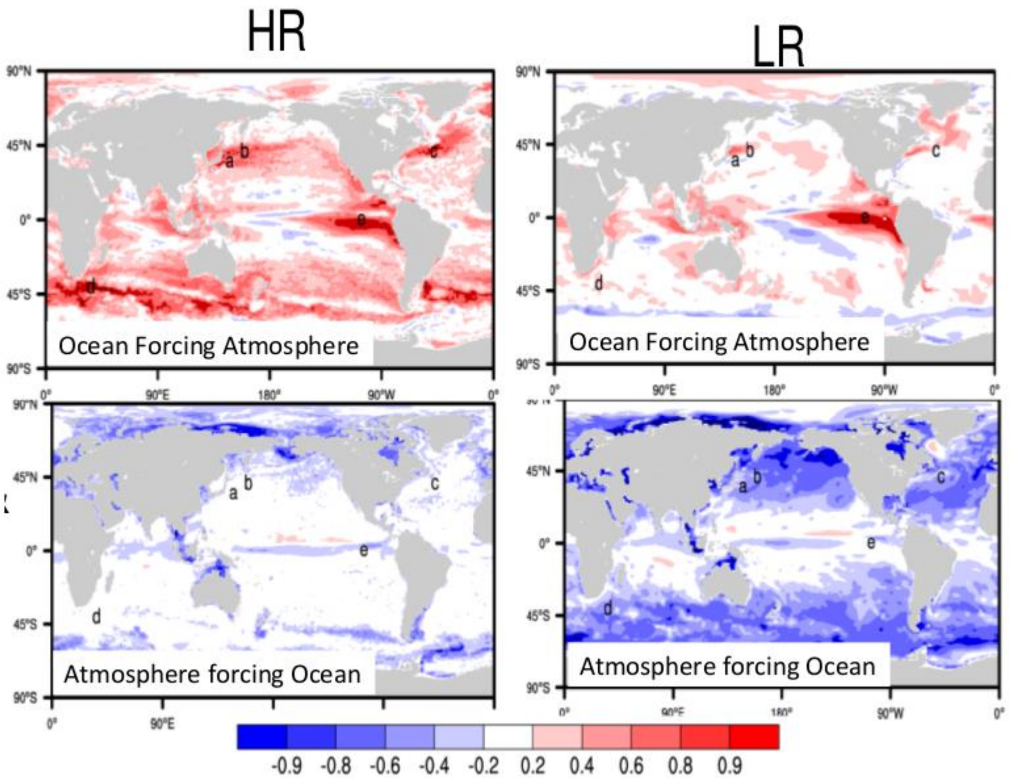
- DCPP provides, among other things, multi-model archive of hindcasts updated annually; "de facto" transpose-CMIP
- Large ensembles and millenium simulations available
- Drift and bias in decadal variability degrades the information
- Forecast extension >10 years, still large ensembles needed
- Use of climate predictions to assess risks of unobserved events in current climate (multi-breadbasket collapse)
- Little attention from CORDEX
- Increasing number of users (North Atlantic tropical cyclones, year 1-5 forecasts)



Caron et al. (2017)

What's new since AR5

- Improved understanding of recent extreme events (during data-rich period) increases confidence in statements
- Very useful empirical forecast systems
- Predictability possibly being larger than current estimates as skill may be larger than predictability suggests; still a controversial idea
- Higher resolution systems (e.g. eddy permitting) and larger HPC resources now available

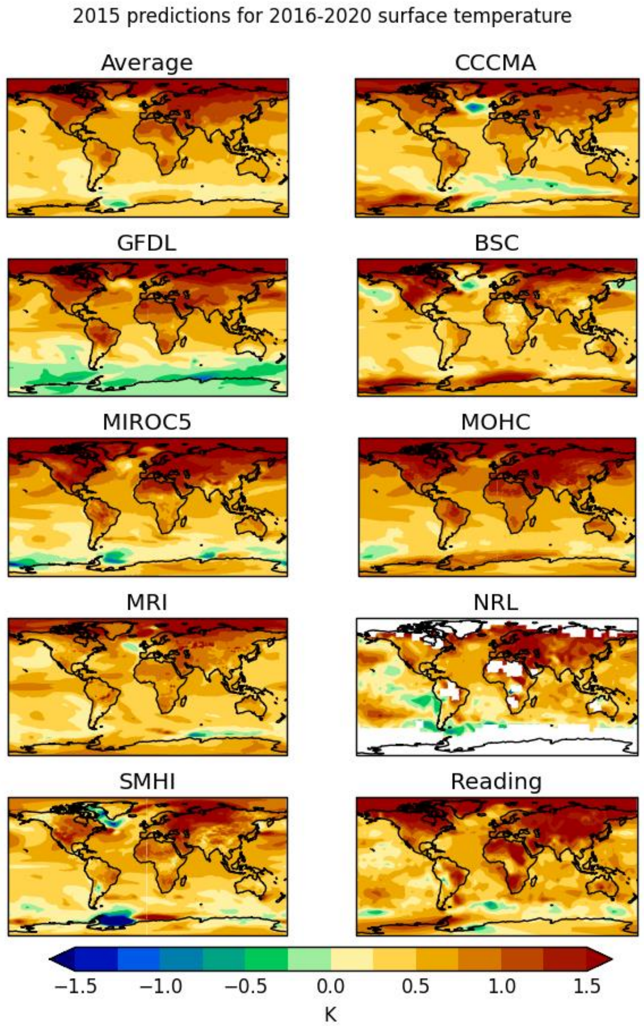


Lagged correlation SST-heat flux in CAMS4, high (0.1º) and standard (1º) ocean resolution

B. Kirtman (2017)

What’s new since AR5

- GC-NTCP and [real-time exchange of decadal predictions]
  - promote and provide new knowledge of climate mechanisms and climate forecasting systems
  - produce standards, verification methods and guidance for near-term predictions
  - promote & support the establishment of operational decadal predictions under WMO
  - initiate & issue real-time “Global Annual to Decadal Climate Update” each year
- GC-NTCP leads way to operationalisation of climate prediction
  - WMO Lead Centre for NTCP
  - setting standards
  - updated forcings required as close to real time as possible

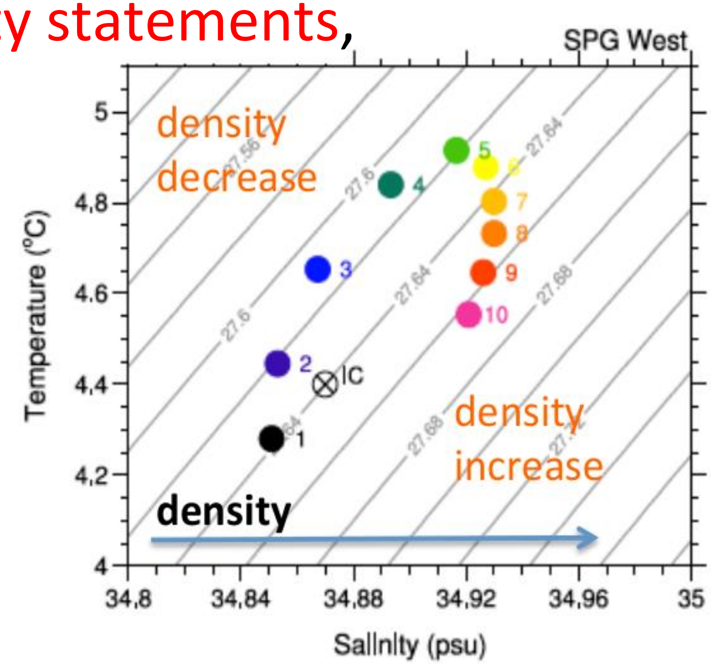


Challenges for AR6

- Forcings: better understanding, increased frequency, seasonal cycle and spatial variability, updated in real time; not just short- but also long-lived and water vapour feedback
- Role of atmosphere, ocean, land, cryosphere on predictability
- Increased focus on near-term climate information to respond to the increased number of users -> WGII
- Communication of near-term statements
- Coherence with model validation (initial shocks, drift and bias in decadal variability), observations, and D&A
- Merging of assessments from predictions and projections for a consistent story line; not necessarily seamless modelling
- Teleconnectivity (tropical-extratropical, inter-basin and land-ocean) at decadal scales
- Link research and operations

Challenges for AR6

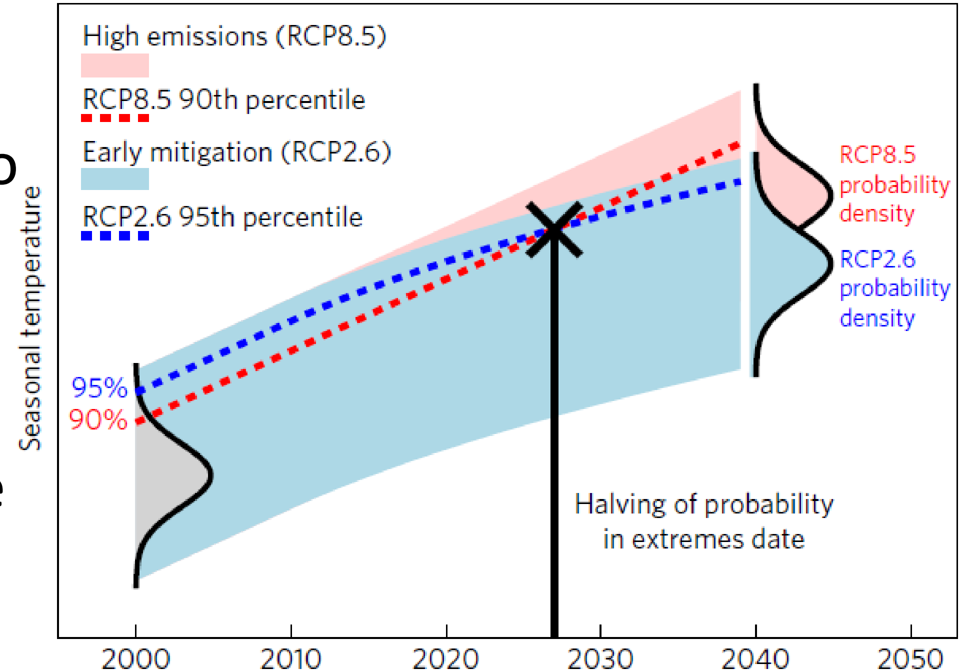
- Improve the use of information from uncertain observations, large ensembles and the millennium simulations (PAGES2K)
- Test emergent constraint methodologies in the near-term
- Need for reliable (or robust) probability statements, particularly for user-defined extremes
- Make a better use of the drift information, including the interaction between the drift and the forced signal
- Role in the global stocktake (near-term mitigation, attribution) especially after operationalisation of decadal prediction -> WGIII



Drift of the top 700 m western North Atlantic subpolar gyre in CERFACS decadal predictions
Sánchez-Gómez (2016)

Challenges for AR6

- Use climate predictions to formulate near-term regional attribution statements subject to recent past conditions
  - need large ensembles
  - impact of mitigation efforts
- Short-term ocean carbon uptake to assess mitigation efficiency
  - consider internal variability
  - attribution of carbon-cycle variations (natural or anthropogenic) versus near-term scenarios with/without mitigation (impact of NDCs)



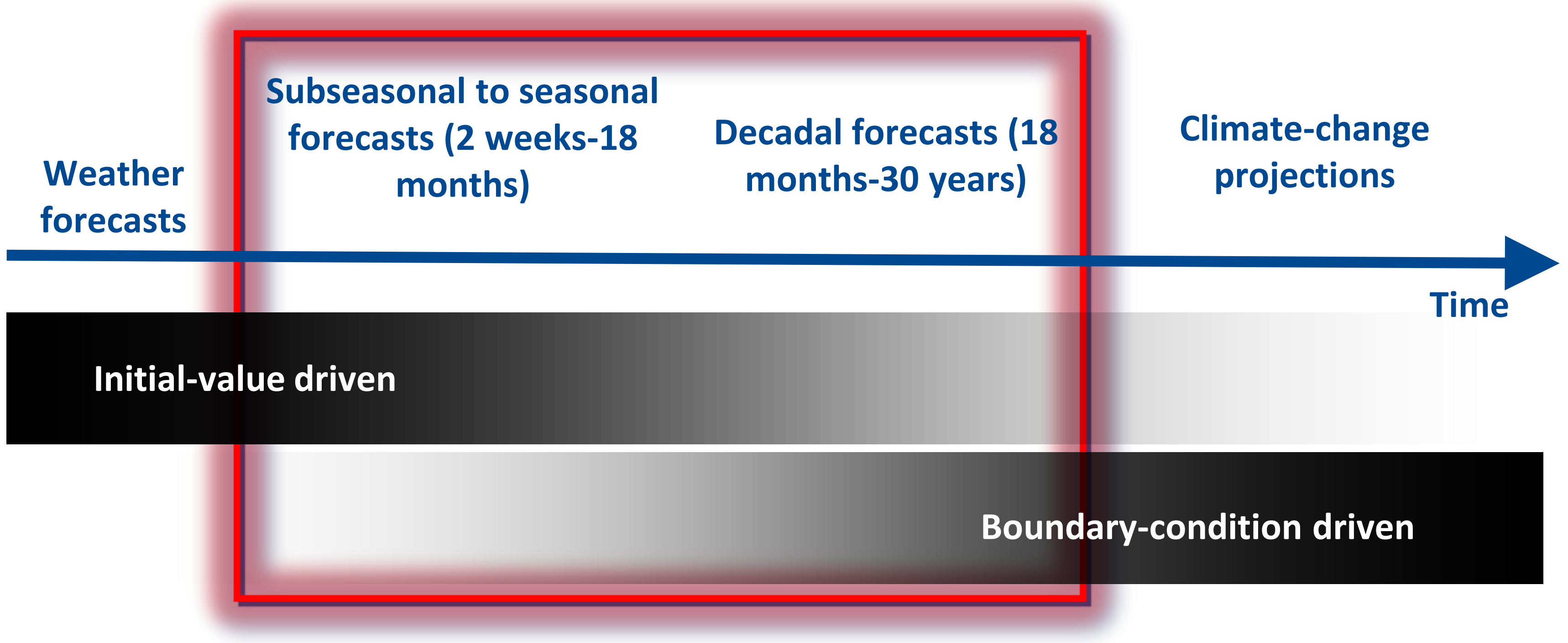
Halving of probability in extremes date: an indication of when the likelihood of extreme seasonal warmth in an emission-mitigated world is half that of the same warmth in the unmitigated world

Ciavarella et al. (2017)

Long version for BOG

Introduction

- Variability, predictability and prediction are closely linked
  - Systems aim at predicting the relevant variability up to the level that predictability estimates suggest is possible
  - Predictability is non-observable and changes across time scales, variables and regions
- Variability that can be expected to be predicted in the near-term: regional temperature, precipitation, ENSO, AMO, IPO, trans-basin variability, tropical circulation, sea ice, soil moisture, vegetation, ecosystem variability; extremes in all those variables and processes
- The question is the timing of climate variations for the next 30 years
- Model biases in simulating decadal to multi-decadal variability such as IPO and AMO affect skill -> Link to model evaluation
- Decadal climate predictions allow to both phase in the internal variability and correct the forced model response
- Climate prediction and event attribution are increasingly connected
- Close links exist with climate services (GFCS) as many stakeholders make decisions on interannual to interdecadal time scales -> WGII
- Predictability and prediction rely on scientific coordination from WCRP's CLIVAR, WGSIP, DCPP, GC-NTCP, as well as increasingly from WMO's CBS



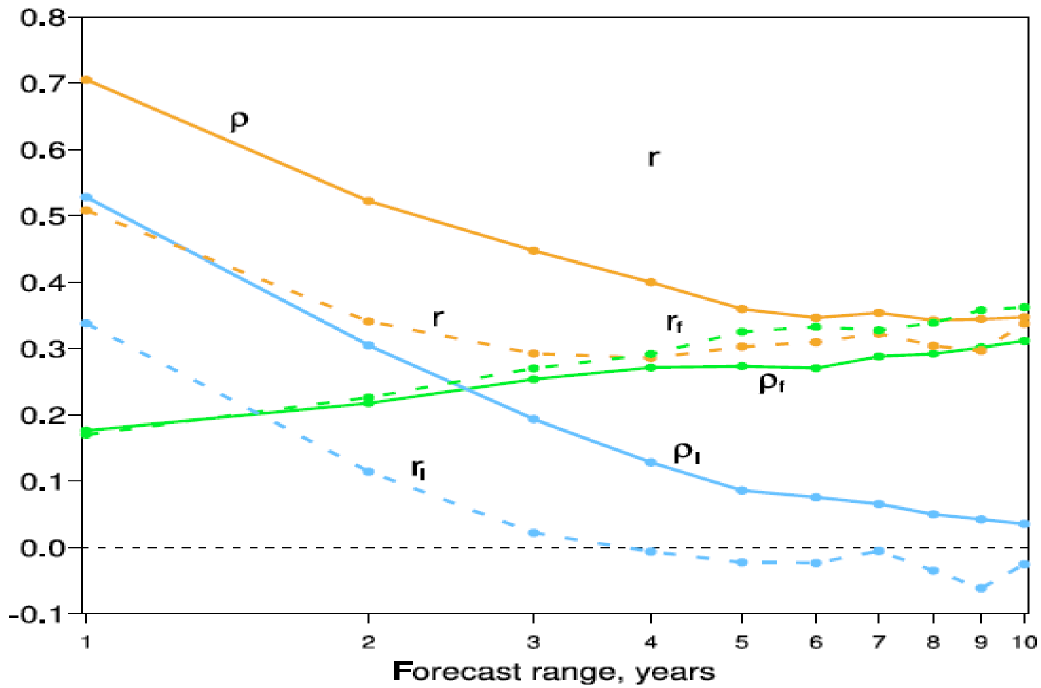
Climate Prediction

- Multi-seasonal, annual, multi-annual, up to decades
- *Initialized* forecasts of *both* forced and internally generated components of variability

Lessons from AR5

- Near-term climate information in Chapter 11
- There is skill in near-term climate information, while initialisation increases the skill for a range of variables up to 10 years. Annual, multi-annual skill for temperature, not so much for precipitation
  - skill varies a great deal geographically, large impact of the "trend" for temperature
  - skill higher over North Atlantic than North Pacific (low skill of the IPO, although potentially for transitions)
  - disconnect between predictability estimates (e.g. signal-to noise ratio measured by individual models) and skill
  - low skill over Southern Ocean
- Merging the prediction/projection information (up to 2035) a challenge
- The value of initialization can be quantified by comparison with skill from uninitialized simulations using the same model and forcings
  - initial condition skill dominates for several years then dies away
  - pervasive drift presence

Lessons from AR5



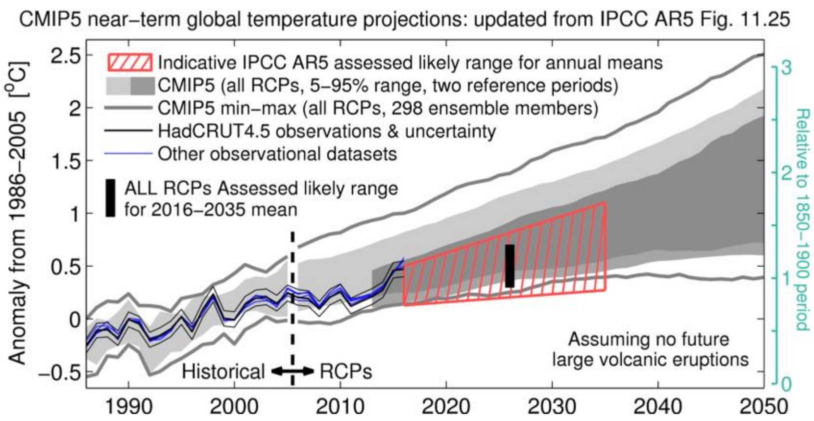
Actual skill (dashed curve, correlation between model ensemble mean and observations)

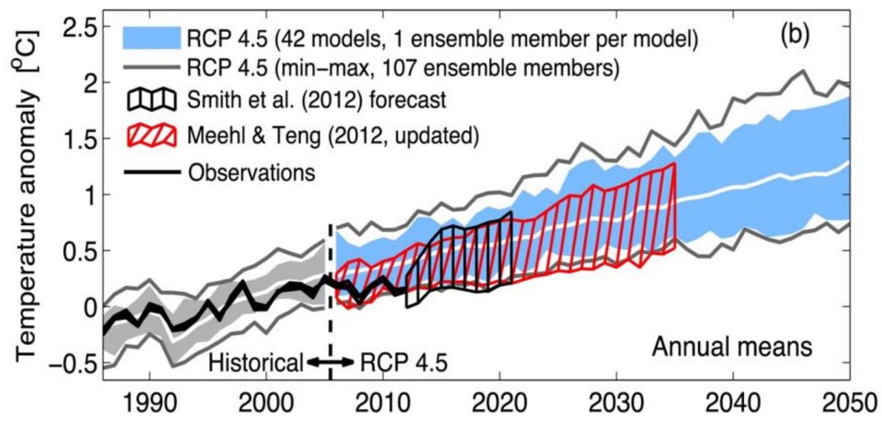
Predictability estimate (solid curve, correlation between model ensemble mean and model ensemble members)

Orange for total, blue for initial condition and green for forced

Boer et al. (2013)

Lessons from AR5





Left: Updated version of IPCC AR5 WGI Figure 11.25b with the HadCRUT4.5 global-mean temperature (uncertainty in black, other observations in blue). CMIP5 model projections relative to 1986-2005 (light grey) and 2006-2012 (dark grey). The red hatching is the IPCC AR5 indicative likely range in 2016-2035 period, with the black bar being the assessed 2016-2035 average.

Right: Figure 11.25a from IPCC AR5 WGI.

E. Hawkins

Lessons from AR5

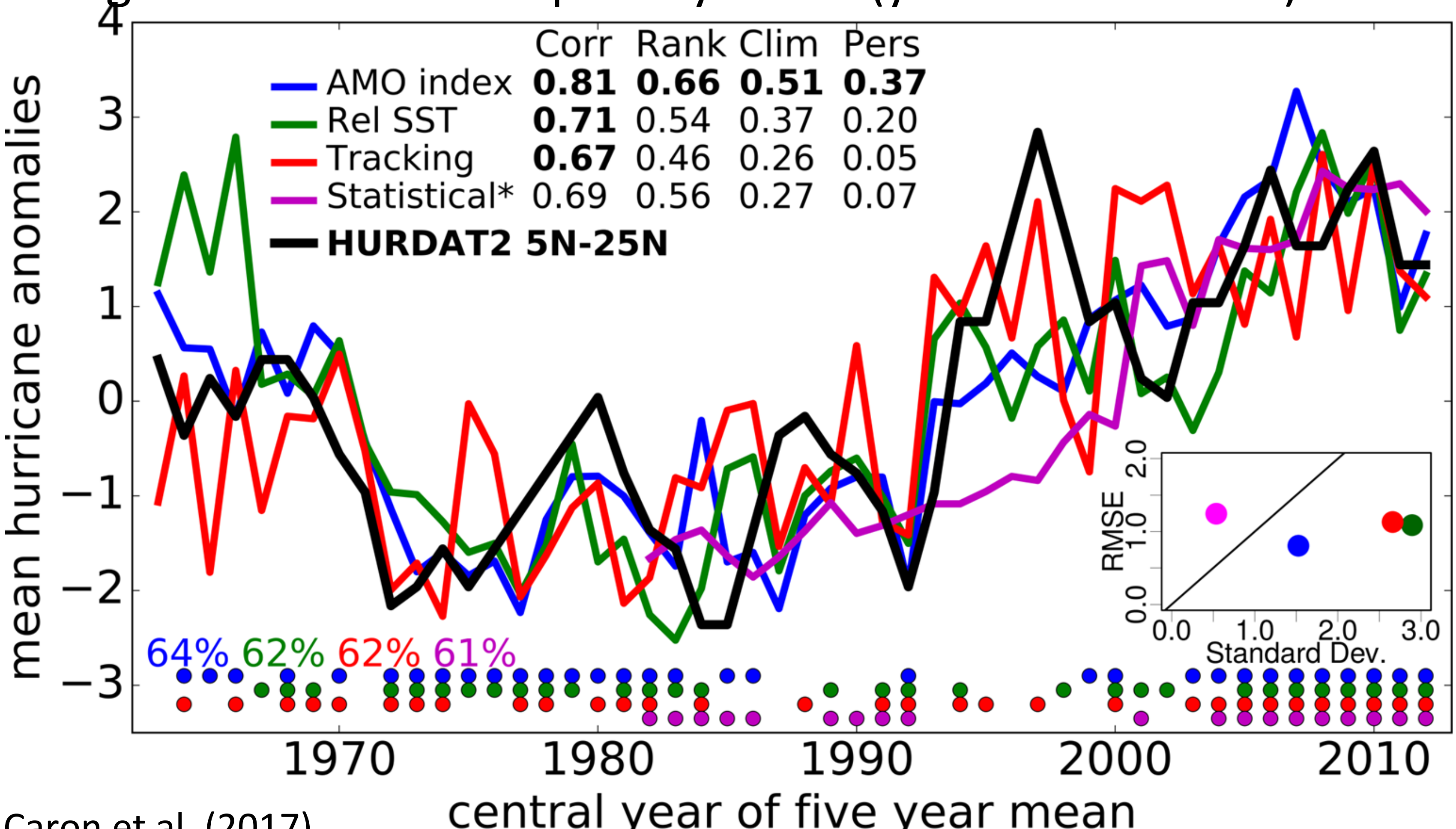
- The hiatus was predicted by the forecast systems
- Predictions need effective data assimilation to optimise the use of the scarce data available, particularly for the pre-satellite and pre-ARGO era
- Predictions need long sequence of historical forecasts with many start dates
  - allow drift adjustment; important lessons about the physical origin of the systematic error were learnt from the drift assessments
  - for statistically robust forecast quality assessment (strong dependency of the observational uncertainty)
  - calibration of forecasts, which has a huge potential to improve the forecast quality and the usability of the forecasts in services and impact assessments
- Single and multi-model assessments of CMIP5 results show
  - importance of general availability of results
  - importance of coordinated multi-model experiments

What's new since AR5

- CMIP6 and DCPP: DCPP provides, among other things, multi-model archive of hindcasts updated annually as basis for
  - systematic error and drift characterisation
  - skill assessment: when and where, parameters (temperature, precipitation, extremes, …), service driven
  - development of objective multi-model probabilistic prediction methods for reliable prediction
  - "de facto" transpose-CMIP
- Importance of internal variability in near-term and long-term predictions/projections (possible underestimation of signal to noise ratio in models, large ensembles needed)
- Model bias and drift in decadal variability degrades near-term climate information
- Possibility of extension beyond 10 years, but compromise required with the need of large ensembles

What's new since AR5

- An increasing number of users focus on near-term time scales e.g. North Atlantic tropical cyclones (year 1-5 forecasts)



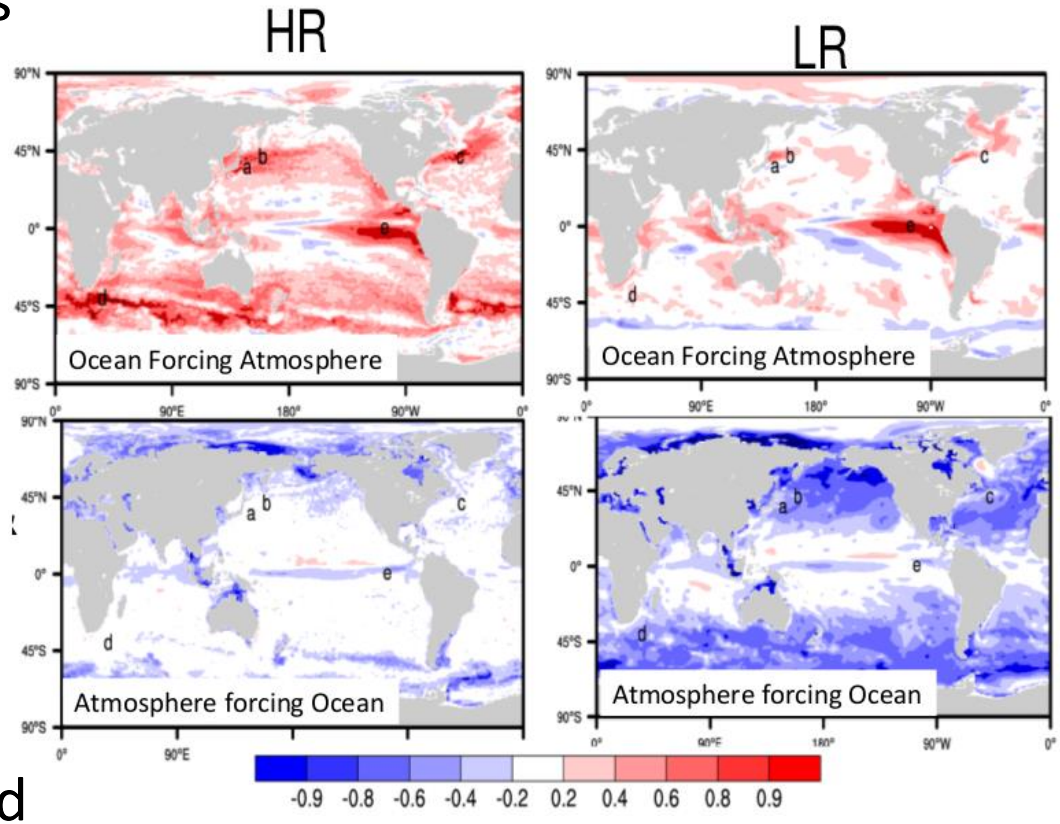
Caron et al. (2017)

What's new since AR5

- Higher resolution of forcings (annual frequency, better estimates of seasonal cycle and spatial variability) needed to get correct balance between simulated forced and internal variability
- Improved understanding of recent extreme events (during data-rich period) increase confidence in future statements
- Very useful empirical/statistical forecast systems
- Use of large sets of climate predictions to assess risks of unobserved events in current climate (multi-breadbasket collapse)
- Little attention from CORDEX (particularly predictions)

What's new since AR5

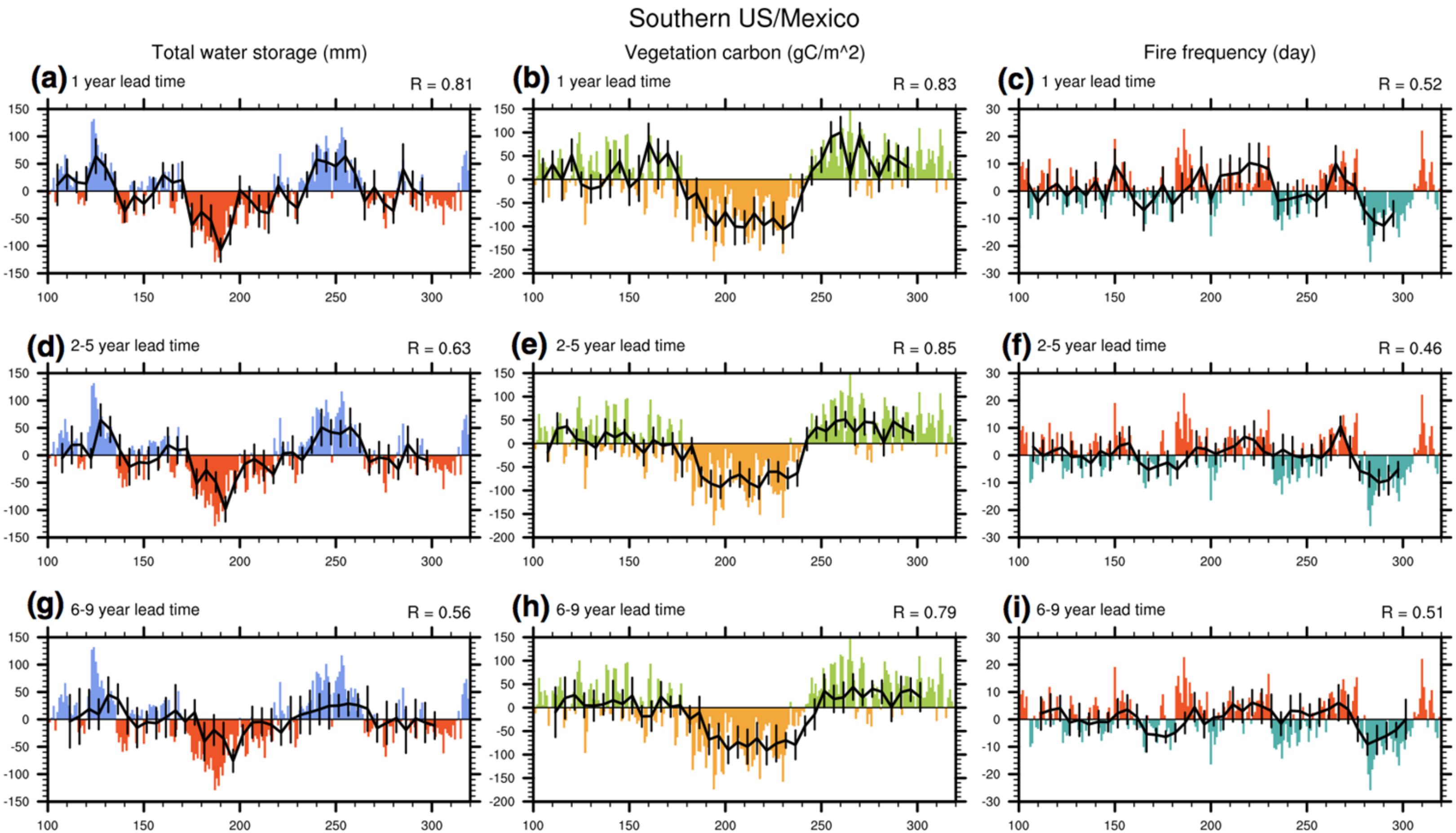
- Predictability possibly being larger than current estimates as skill may be greater than "perfect model" studies suggest, although still controversial idea
- Higher resolution systems (e.g. eddy permitting) and larger HPC resources now available
- Lagged correlation SST-heat flux in CAMS4, high (0.1º) and standard (1º) ocean resolution

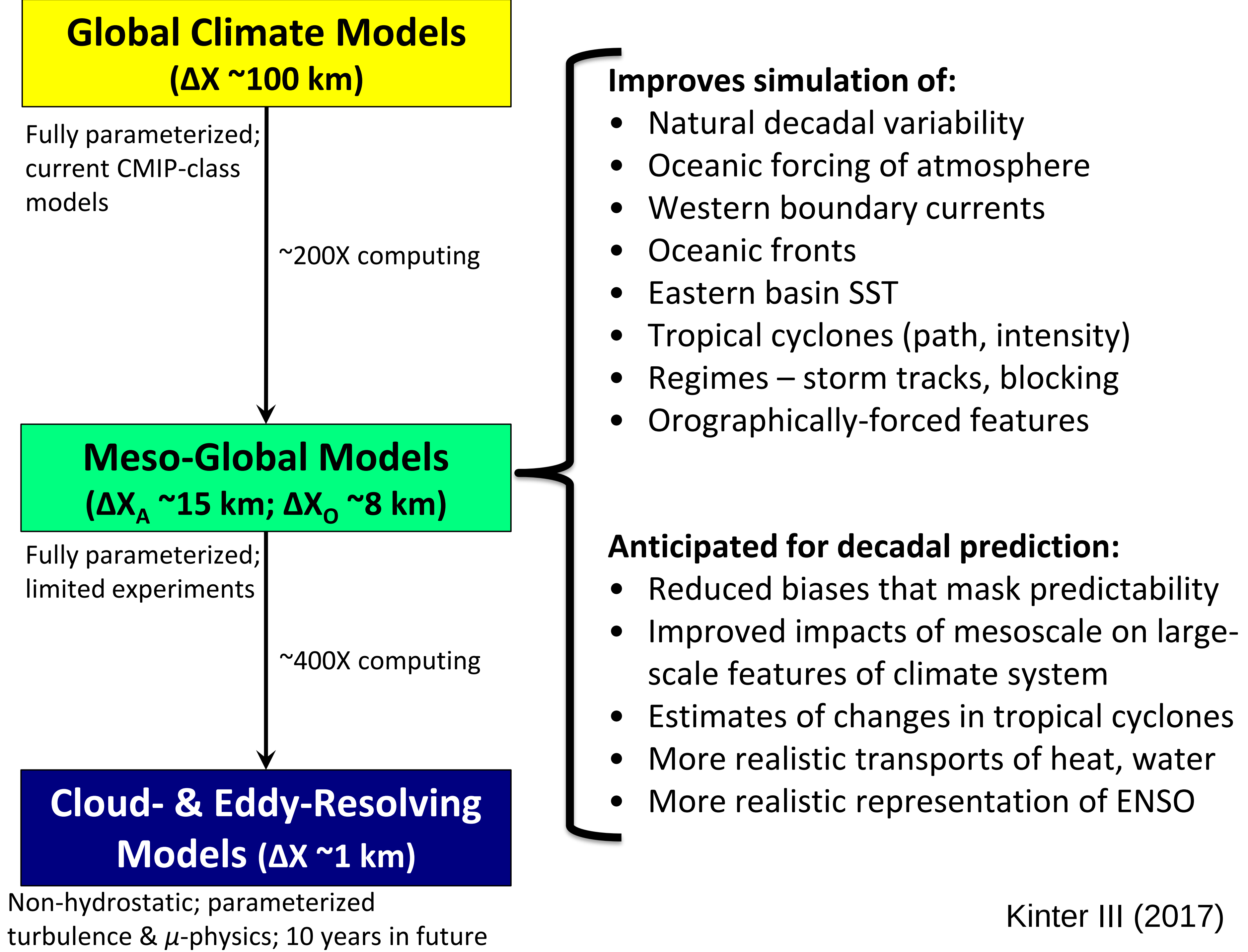


Kirtman (2017)

What's new since AR5

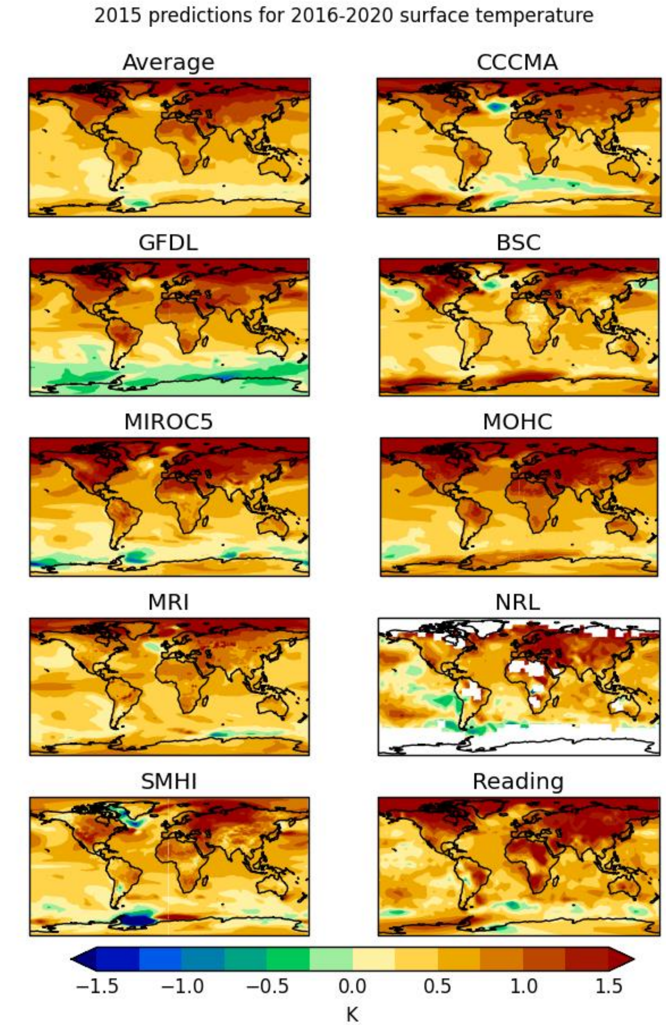
- Potential for decadal prediction of Earth System variability (Chikamoto et al , 2015)




Global Climate Models
(ΔX ~100 km)
Fully parameterized; current CMIP-class models
~200X computing
Meso-Global Models
(ΔX_A ~15 km; ΔX_O ~8 km)
Fully parameterized; limited experiments
~400X computing
Cloud- & Eddy-Resolving Models (ΔX ~1 km)
Non-hydrostatic; parameterized turbulence & μ-physics; 10 years in future
Improves simulation of:
• Natural decadal variability
• Oceanic forcing of atmosphere
• Western boundary currents
• Oceanic fronts
• Eastern basin SST
• Tropical cyclones (path, intensity)
• Regimes – storm tracks, blocking
• Orographically-forced features
Anticipated for decadal prediction:
• Reduced biases that mask predictability
• Improved impacts of mesoscale on large-scale features of climate system
• Estimates of changes in tropical cyclones
• More realistic transports of heat, water
• More realistic representation of ENSO
Kinter III (2017)

What’s new since AR5

- GC-NTCP and real-time exchange of decadal predictions
  - Promote and provide new knowledge of climate mechanisms and climate forecasting systems
  - Produce standards, verification methods and guidance for near-term predictions
  - Promote & support the establishment of operational decadal predictions under WMO
  - Initiate & issue real-time “Global Annual to Decadal Climate Update” each year
- GC-NTCP leads way to operationalisation of climate prediction
  - WMO Lead Centre for NTCP
  - Setting standards
  - Updated forcings required as close to real time as possible

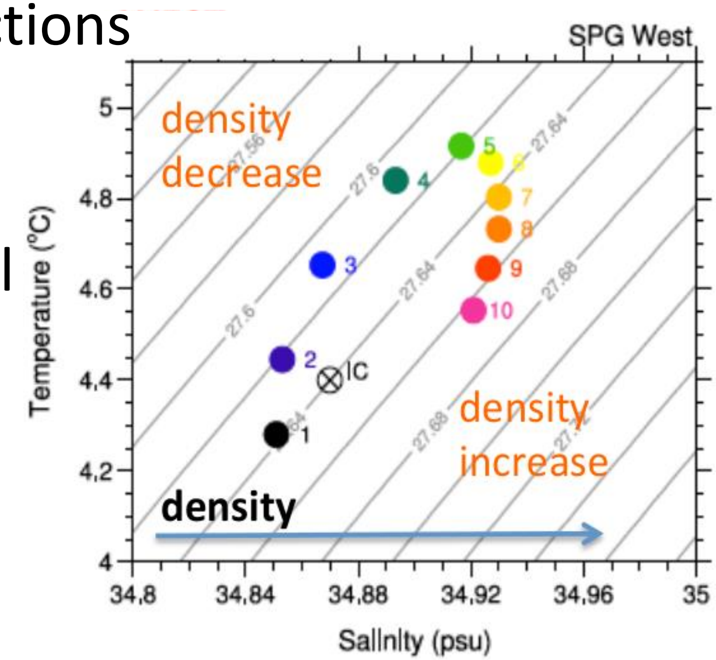


Challenges for AR6

- Formulate reliable statements (and evaluate that they are reliable)
- Predictability analyses on the relative role of atmosphere, ocean, land, cryosphere
- Deeper understanding of the role of the forcings, not just short -lived (aerosols, ozone, solar taking account spectrum, stratospheric water), but also the spatial distribution of long lived; also consider water vapour feedback
- Better understanding of the teleconnectivity (tropical-extratropical, inter-basin and land-ocean) at decadal scales

Challenges for AR6

- Communication is key as near-term statements are validated almost in real time
- Find the best way to link research and operational
- Improve the use of information from both observations and the millennium simulations (PAGES2K) on decadal variability
- Test the emergent constraint methodologies in the near-term, both with projections and predictions
- Make a better use of the drift information, including the interaction between the drift and the forced signal

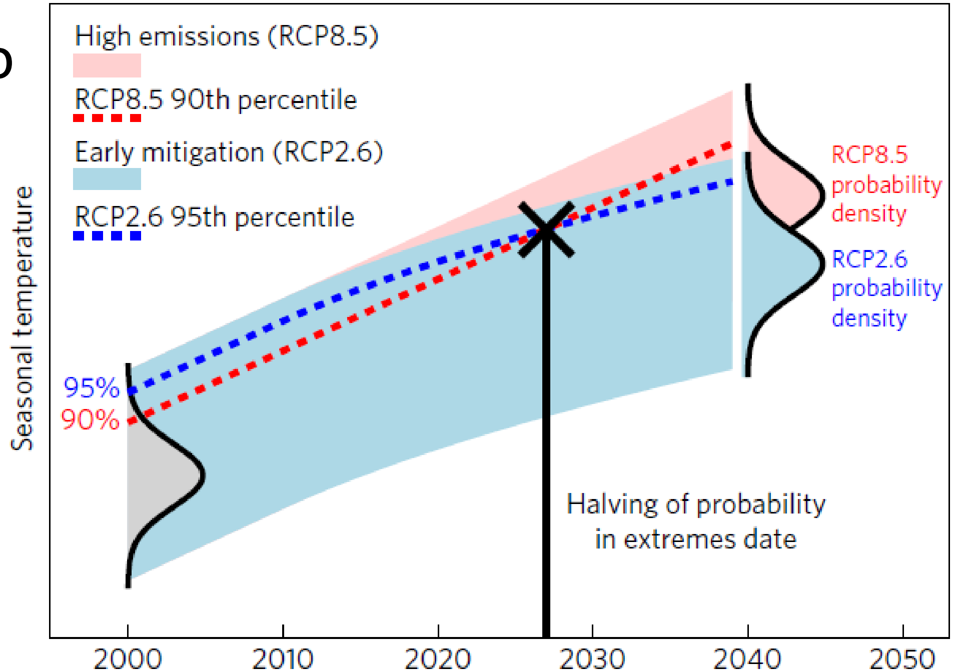


Drift of the top 700 m in the western North Atlantic subpolar gyre in the CNRM-CM5 decadal predictions

Sánchez-Gómez (2016)

Challenges for AR6

- Use climate predictions to formulate near-term regional attribution statements subject to recent past conditions
  - Need large ensemble sizes
  - Impact of mitigation efforts
- Simulate short-term ocean carbon uptake to assess mitigation efficiency
  - Consider internal variability
  - Consider attribution of carbon-cycle variations (natural or anthropogenic) versus near-term scenarios with/without mitigation (impact of commitments)



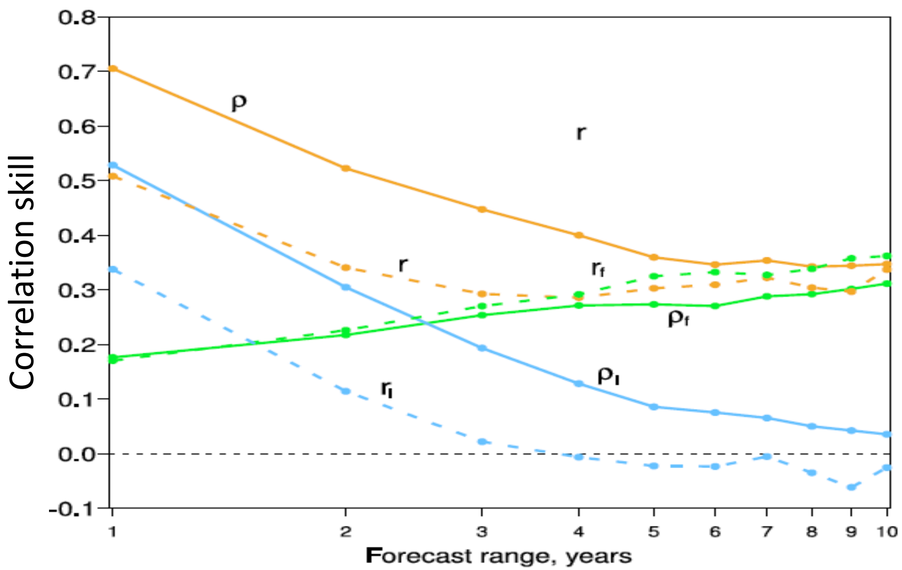
Ciavarella et al. (2017)

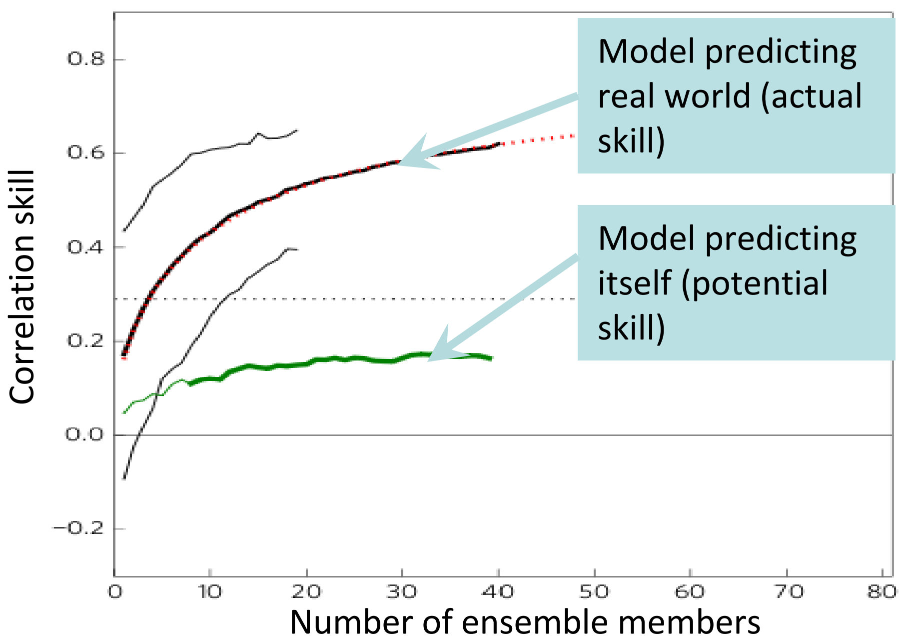
Challenges for AR6

- Increased focus on information for the near term to respond to the increased number of users interested in that time scale; links to WGII
- Coherence with chapters on model validation (forecasts suffer from forecast initial shocks, drift and bias in decadal variability), observations, and D&A
- Merging of assessments from predictions and projections for a consistent story line; not necessarily a seamless modelling approach but a seamless probabilistic information across time scales
- Need for reliable (also known as robust) probability statements, particularly for extreme (which should be defined by the range of users) events
- Role in the global stocktake (near-term mitigation, attribution) especially after operationalisation of decadal prediction

Extra

Estimating predictability





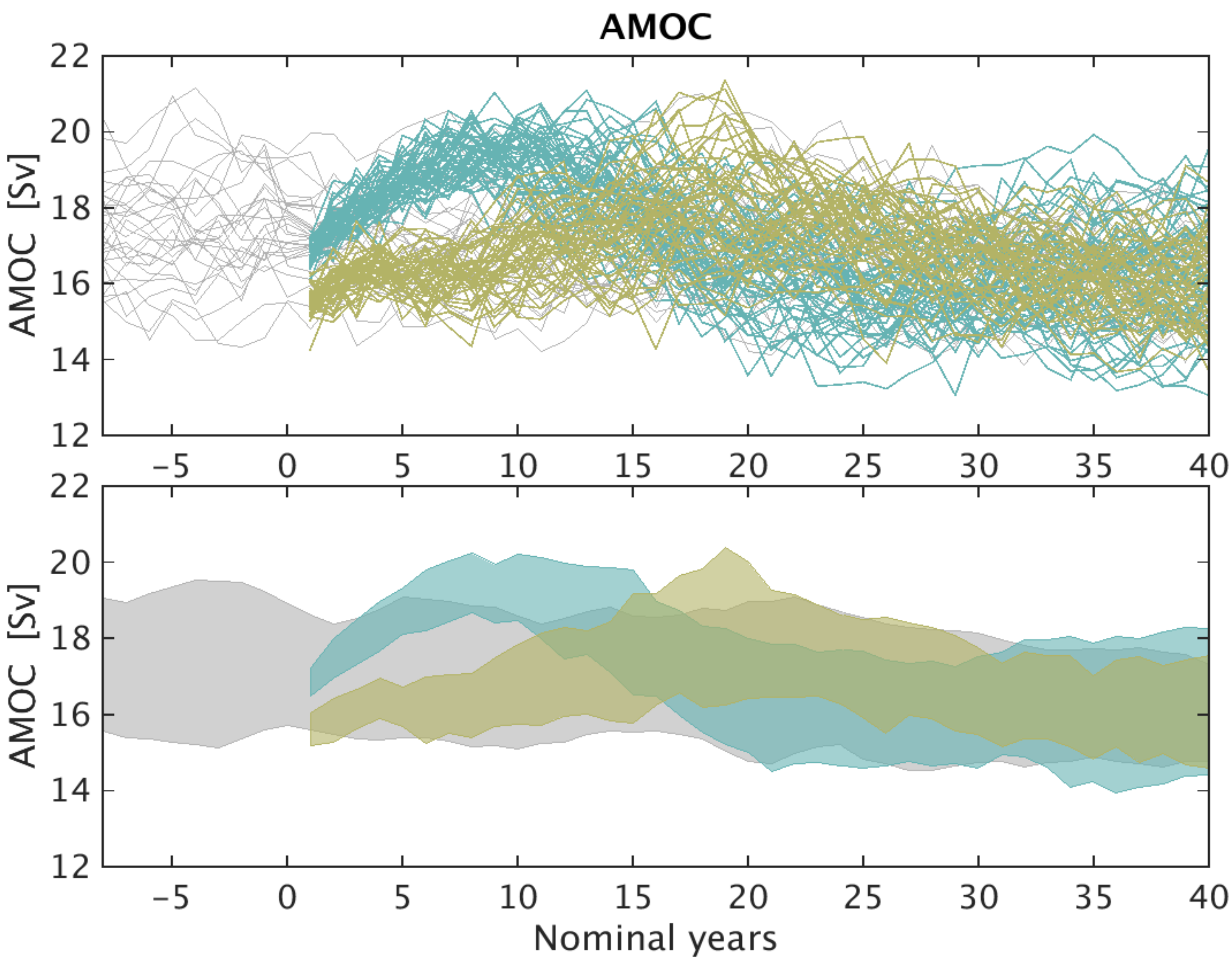
- **Actual skill** (dashed orange curve, correlation between model ensemble mean and observations)
- **Potential skill** (solid orange curve, correlation between model ensemble mean and model ensemble members)

- Predictions of global mean temperature: potential skill > actual skill
  - ➢ more skill possible with improved observations / initialisation

- Seasonal forecasts of North Atlantic Oscillation: actual skill > potential skill
  - ➢ unexpected
  - ➢ signal to noise ratio is too small in models
  - ➢ predictability of real world is unknown

Boer et al 2013; Dunstone et al 2016; also Eade et al 2014; Scaife et al 2014; Shi et al 2915; Stockdale et al 2015

Estimating predictability



Additional

- Interesting dichotomy emerging in literature about the relative role of external forcing vs internal variability in driving North Atlantic SST variability and hence Atlantic impacts such as multi-decadal tropical storm frequency
- (external forcings (e.g. aerosols) may driver AMV by either directly changing downward SW radiation, or (more likely?) via modulating ocean circulation (e.g. AMOC) by driving multi-annual to decadal trends in atmospheric circulation/windstress (e.g. the NAO))