Mechanisms Driving Seasonal Forecast Skill in the California Current System

Mike Jacox

Symposium on the Effects of Climate Change on the World’s Oceans
June 7, 2018

Mike Alexander, Steven Bograd, Elliott Hazen, Gaelle Hervieux, Nate Mantua, James Scott, Charlie Stock, Desiree Tommasi, Robin Webb, Cisco Werner
AUGUST 1991 FORECAST OF NOVEMBER 1991
AUGUST 1991 FORECAST OF NOVEMBER 1991
AUGUST 1991 FORECAST OF NOVEMBER 1991
AUGUST 1991 FORECAST OF NOVEMBER 1991

PERSISTENCE FORECAST

MODEL FORECAST

OBSERVATIONS
AUGUST 1991 FORECAST OF NOVEMBER 1991

AUGUST 1991 FORECAST OF MAY 1992
AUGUST 1991 FORECAST OF NOVEMBER 1991

PERSISTENCE FORECAST

MODEL FORECAST

OBSERVATIONS

AUGUST 1991 FORECAST OF MAY 1992

PERSISTENCE FORECAST

MODEL FORECAST
Persistence

<table>
<thead>
<tr>
<th>Initialization Month</th>
<th>Lead Time (months)</th>
<th>Anomaly Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>F</td>
<td>1</td>
<td>-0.8</td>
</tr>
<tr>
<td>M</td>
<td>2</td>
<td>-0.6</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
<td>-0.4</td>
</tr>
<tr>
<td>M</td>
<td>4</td>
<td>-0.2</td>
</tr>
<tr>
<td>J</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>A</td>
<td>6</td>
<td>0.2</td>
</tr>
<tr>
<td>S</td>
<td>7</td>
<td>0.4</td>
</tr>
<tr>
<td>O</td>
<td>8</td>
<td>0.6</td>
</tr>
<tr>
<td>N</td>
<td>9</td>
<td>0.8</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>1</td>
</tr>
</tbody>
</table>

Jacox et al., Climate Dynamics (2017)
**NORTH AMERICAN MULTI-MODEL ENSEMBLE FORECASTS**

Jacox et al., Climate Dynamics (2017)
Persistence

<table>
<thead>
<tr>
<th>Lead Time (months)</th>
<th>J F M A M J J A S O N D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12 10 8 6 4 2 0</td>
</tr>
</tbody>
</table>

Model

<table>
<thead>
<tr>
<th>Lead Time (months)</th>
<th>J F M A M J J A S O N D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1</td>
</tr>
</tbody>
</table>

Jacox et al., Climate Dynamics (2017)
M. Jacox | Mechanisms Driving Seasonal Forecast Skill in the California Current System | June 7, 2018

Persisting

<table>
<thead>
<tr>
<th>JFMAMJASOND</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Lead Time (months)

Initialization Month

Skill Above Persistence

<table>
<thead>
<tr>
<th>JFMAMJASOND</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>8</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Lead Time (months)

Initialization Month

Model

Anomaly Correlation Coefficient

Jacox et al., Climate Dynamics (2017)
Persistence

Skill Above Persistence

Model

Jacox et al., Climate Dynamics (2017)
Anomaly Correlation Coefficient

Skill Above Persistence

Jacox et al., Climate Dynamics (2017)
Anomaly Correlation Coefficient


Skill Above Persistence

JFMAMJJASOND

Skill Above Persistence

JFMAMJJASOND

ENSO Events

ENSO Neutral

JFMAMJJASOND

Initialization Month

Initialization Month

Jacox et al., Climate Dynamics (2017)
Possible forcing mechanisms
Surface heat flux
Wind stress
Coastal trapped waves
Possible forcing mechanisms
Surface heat flux
Wind stress
Coastal trapped waves

To generate SST predictability, forcing must:
1. Exert influence over SST in the model
2. Exert similar influence over SST in nature
3. Be predictable
**Heat Flux**

Jacox et al., Climate Dynamics (2017)

Heat Flux Influence (model)

- **ENSO Events**
  - $r = 0.46$

- **ENSO Neutral**
  - $r = -0.06$
HEAT FLUX

Jacox et al., Climate Dynamics (2017)
HEAT FLUX

Jacox et al., Climate Dynamics (2017)
**Wind Stress**

Jacox et al., Climate Dynamics (2017)

![Graph showing the relationship between wind stress and seasonal SST anomalies](image-url)
WIND STRESS

Jacox et al., Climate Dynamics (2017)
WIND STRESS

Jacox et al., Climate Dynamics (2017)
SST Predictability comes primarily from:
1. Persistence
2. Wind driven anomalies during ENSO events

Jacox et al., Climate Dynamics (2017)
2014-16 Mean SST Anomaly

SST Anomaly (°C)

Jacox et al., BAMS (2017)
2014-16 Mean SST Anomaly

Jacox et al., BAMS (2017)
Meridional Wind Stress

Jacox et al., BAMS (2017)
SST(t) = a*SST(t-1) + b*\tau(t)

Meridional Wind Stress

Jacox et al., BAMS (2017)
SST(t) = a*SST(t-1) + b*\(\tau(t)\)

Jacox et al., BAMS (2017)
\[ \text{SST}(t) = a \times \text{SST}(t-1) + b \times \tau(t) + c \times \text{SST}_{\text{GOA}}(t - 0.5) \]

\[ + c \times \text{SST}_{\text{GOA}}(t - 0.5) \]

Jacox et al., BAMS (2017)
\[ \text{Meridional Wind Stress} \quad \text{GOA SST (6-month lead)} \quad \text{ENSO Variability} \]

\[ \text{SST}(t) = a \times \text{SST}(t-1) + b \times \tau_y(t) + c \times \text{SST}_{GOA}(t - 0.5) \]

Jacox et al., BAMS (2017)
\[ \begin{align*}
\text{SST}(t) &= a \cdot \text{SST}(t-1) + b \cdot \tau(t) + c \cdot \text{SST}_{GOA}(t-0.5) + d \cdot \text{EqSOI}(t) \\
\end{align*} \]

M. Jacox, Mechanisms Driving Seasonal Forecast Skill in the California Current System, June 7, 2018

Jacox et al., BAMS (2017)
Jacox et al., BAMS (2017)
Meridional Wind Stress

GOA SST (6-month lead)

ENSO Variability

Jacox et al., BAMS (2017)
Mid-Apr 2014 Plume of Model ENSO Predictions

**IRI/CPC**
- NCEP CFSv2
- Model Mean
- CMC CANSIP

**Dynamical Model:**
- NCEP CFSv2
- NASA GMAO
- JMA
- SCRIPPS
- LDEO
- AUS/POAMA
- ECMWF
- UKMO
- KMA/SNU
- MetFRANCE
- CS-IRI-MIM
- GFDL CM2.1
- CMC CANSIP

**Statistical Model:**
- CPC MPRKOV
- CDC LIM
- CPC CA
- CPC CCA
- CSU CLIPPR
- UBC NN2
- FSU REGR
- UCLA-TCD

**Observations**

---

M. Jacox              |              Mechanisms Driving Seasonal Forecast Skill in the California Current System              |              June 7, 2018
Standardized SST Anomaly

Lead 1

-2
-1
0
1
2
OBSERVATIONS
DYNAMICAL FORECAST

r = 0.81

Lead 10

-2
-1
0
1
2


r = 0.56
Standardized SST Anomaly

Lead 10

-2
-1
0
1
2
2012 2013 2014 2015 2016 2017

Observations
Dynamical Forecast

r = 0.71

Lead 10

-2
-1
0
1
2

r = 0.56
Standardized SST Anomaly

Lead 10

-2
0
2
2012 2013 2014 2015 2016 2017

Observations
Dynamical Forecast

r = 0.71
The diagram illustrates the standardized SST anomaly over the years 2012 to 2017. It shows two lines: one representing observations (black) and the other representing dynamical forecast (blue). The correlation coefficient, $r = 0.71$, indicates a strong positive relationship between the observed and forecasted values, particularly noticeable in the Lead 10 period highlighted by the pink box.
Standardized SST Anomaly

Lead 10

-2 -1 0 1 2

2012 2013 2014 2015 2016 2017

Observations
Dynamical Forecast

r = 0.71
M. Jacox

Mechanisms Driving Seasonal Forecast Skill in the California Current System

June 7, 2018

Forecast

Observations

Standardized SST Anomaly

r = 0.71
Forecast Observations

Standardized SST Anomaly

-2 -1 0 1 2

2012 2013 2014 2015 2016 2017

Lead 10

Observations
Dynamical Forecast

r = 0.71
Lead 10

Standardized SST Anomaly

Observations
Dynamical Forecast

\[ r = 0.71 \]
M. Jacox              |              Mechanisms Driving Seasonal Forecast Skill in the California Current System              |              June 7, 2018

Forecast

Observations

Standardized SST Anomaly

r = 0.71
Standardized SST Anomaly

Lead 10

Observations
Dynamical Forecast

r = 0.71
Standardized SST Anomaly

Lead 10

- Lead 10 shows a significant correlation between observations and dynamical forecast, with a correlation coefficient of $r = 0.71$.
Forecast Observations

Standardized SST Anomaly

r = 0.71
Global Forecast (CanCM4)

Regional Model (ROMS)

Wind Stress (N m⁻²)  Vertical Velocity (m day⁻¹)  SST (°C)  Pycnocline Depth (m)