Development and evaluation of isotopic proxy data assimilation system

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GCM and proxy forward models

Isotope-enabled AGCM
(Okazaki and Yoshimura, in prep)
• MIROC5

Isotope in Ice core
• Monthly $\delta^{18}O_{\text{prcp}}$ is weighted by Prcp

Isotope in coral
(Thompson et al., 2011; Liu et al., 2013)
• $\delta^{18}O_{\text{coral}} = \delta^{18}O_{\text{sea water}} + a \times \text{SST}$
• $\delta^{18}O_{\text{sea water}} = f(P, E, \text{mixing})$

Isotope in Tree-ring cellulose
(Roden et al., 2000)
• Monthly $\delta^{18}O_{\text{cell}}$ is weighted by NPP
Reproducibility of $\delta^{18}$O in precipitation
Reproducibility of $\delta^{18}$O$_{Prp}$; interannual variability

(a) T2m

(b) Prcp

(c) $\delta^{18}$O$_{Prp}$

# of sites for $\delta^{18}$O

<table>
<thead>
<tr>
<th>Region</th>
<th>MIROC5 (20CR)</th>
<th>MIROC5 (JRA25)</th>
<th>GISS (NNR1)</th>
<th>GSM (NNR2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NH (205)</td>
<td>138</td>
<td>159</td>
<td>119</td>
<td>154</td>
</tr>
<tr>
<td>Tropics (95)</td>
<td>44</td>
<td>71</td>
<td>53</td>
<td>57</td>
</tr>
<tr>
<td>SH (31)</td>
<td>12</td>
<td>15</td>
<td>11</td>
<td>14</td>
</tr>
</tbody>
</table>
Reproducibility of $\delta^{18}$O in proxies

Significant ($p<0.05$)
Not significant

△...Tree-ring cellulose
◇...Coral
〇...Ice core

% of proxy ($p < 0.05$)

- precip. 0.58
- ice core 0.16
- coral 0.75
- tree-ring cellulose 0.67
Proxy Assimilation System and Experimental design

- OSSE
- 1871-2007 (137yr)
- Offline-Optimal Interpolation
- 1 yr assimilation cycle

First guess

Simulated climatology

Analysis

State vector: Annual mean T, P, $\delta^{18}$O in coral, tree-ring cellulose, ice core

Sim-to-Obs Conversion

Sim-minus-Obs

CTRL

$\delta^{18}$O in proxies SNR=2.0

N=94/year

Background error covariance is constructed from 137yr model simulation
Correlation between the truth and the analysis in proxy-DA (1970-2000)

\[ \bar{R} = 0.50 \quad \text{RMSE} = 0.46K \]

\[ \bar{R} = 0.30 \quad \text{RMSE} = 0.50\text{mm/h} \]

- Observation site
- Not significant \((p>0.05)\)
### Real proxy data assimilation: Experimental design

<table>
<thead>
<tr>
<th></th>
<th>CTRL</th>
<th>REAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation</td>
<td>Simulated $\delta^{18}$O in ice cores, corals, and tree-ring cellulose in nature run</td>
<td>Observed $\delta^{18}$O in ice cores, corals, and tree-ring cellulose</td>
</tr>
<tr>
<td># of proxy</td>
<td>constant</td>
<td>variable</td>
</tr>
<tr>
<td>First guess/Background error cov.</td>
<td>Constructed from 137yr model simulation which is driven by observed-SST</td>
<td>Constructed from 137yr model simulation which is driven by simulated-SST</td>
</tr>
<tr>
<td>Model bias</td>
<td>No (OSSE)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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![Diagram of # of proxy](image.png)
Correlation between observation and the analysis in (1970-2000)

Observation: HadCRUTv3

Observation site Not significant (p>0.05)
What does degrade the skill?

<table>
<thead>
<tr>
<th>Exp. Name</th>
<th>Observation</th>
<th># of proxy</th>
<th>First guess / Background error cov.</th>
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<tr>
<td>CTRL</td>
<td>Simulated proxy</td>
<td>Constant</td>
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<tr>
<td>CGCM</td>
<td>Simulated proxy</td>
<td>Constant</td>
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<tr>
<td>VOBS</td>
<td>Simulated proxy</td>
<td>Variable</td>
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<td>REAL</td>
<td>Observed proxy</td>
<td>Variable</td>
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</table>
What does degrade the skill?

Imperfect SST

Model error, temporal/spatial mismatch in assimilated variable, and more...
Conclusion and future direction

Unanalyzed areas remained due to the paucity of observation data and short correlation length

➡️ More observation
   • Develop proxy models (observation operator) for unused ones
   • Drill more proxies

➡️ Better first guess
   • Need to constrain model dynamics through online-DA
     • AOGCM

Gaps b/w CTRL and REAL remained unexplained

➡️ bias, R,...
Thank you!

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