Ocean *Downscaling* of Climate Projections: case study for the Arabian Gulf (using ROMS)

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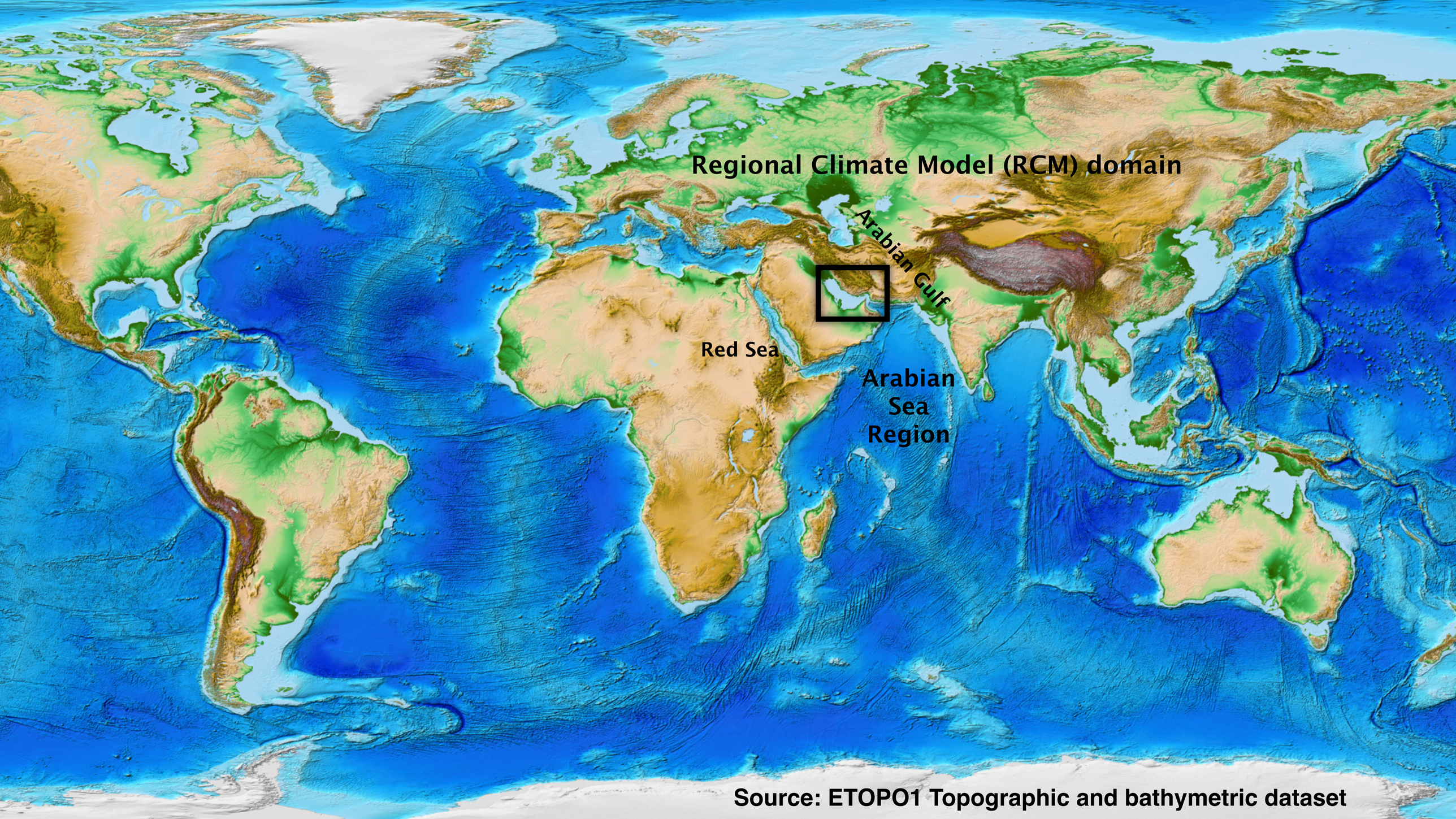
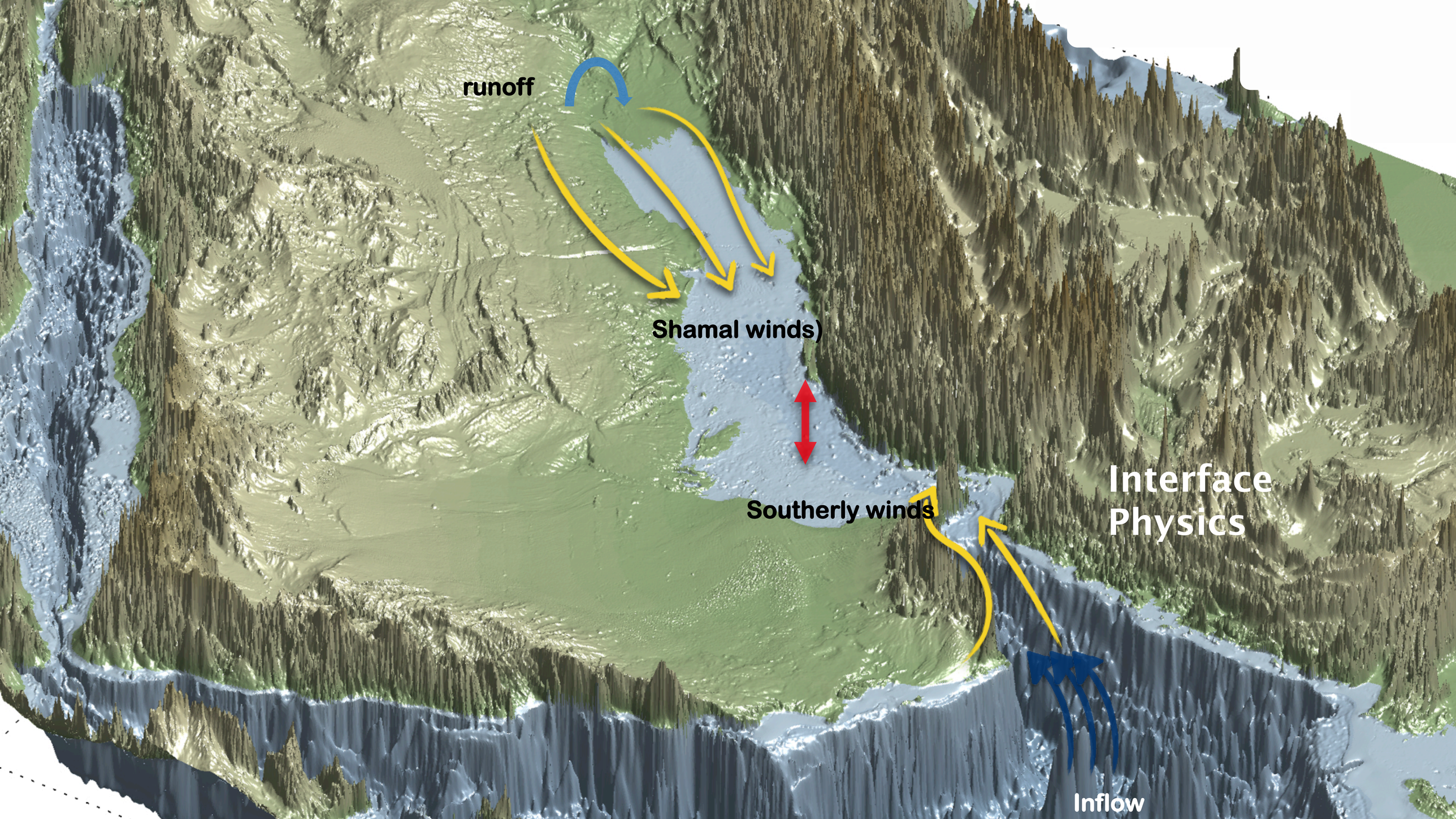
1. Introduction
2. The Arabian Sea
   - Characteristics
   - Model set-up
3. Results of 20thC simulation
4. Time-slice experiments (early 21st C/ late 21st C)

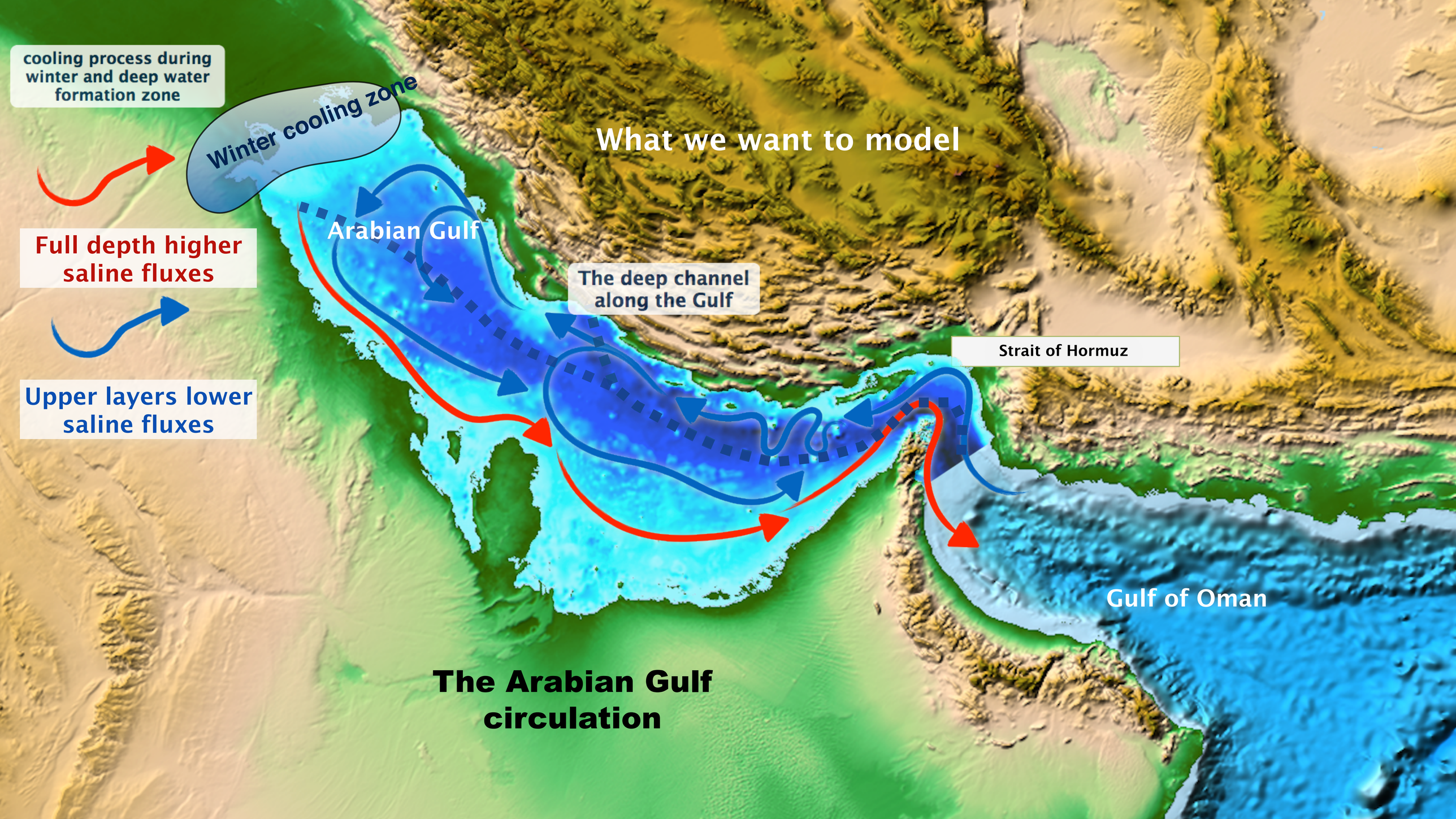

Regional Climate Model (RCM) domain
Arabian Gulf
Red Sea
Arabian
Sea
Region
Source: ETOPO1 Topographic and bathymetric dataset

We use the Regional Ocean Model System (ROMS[1])

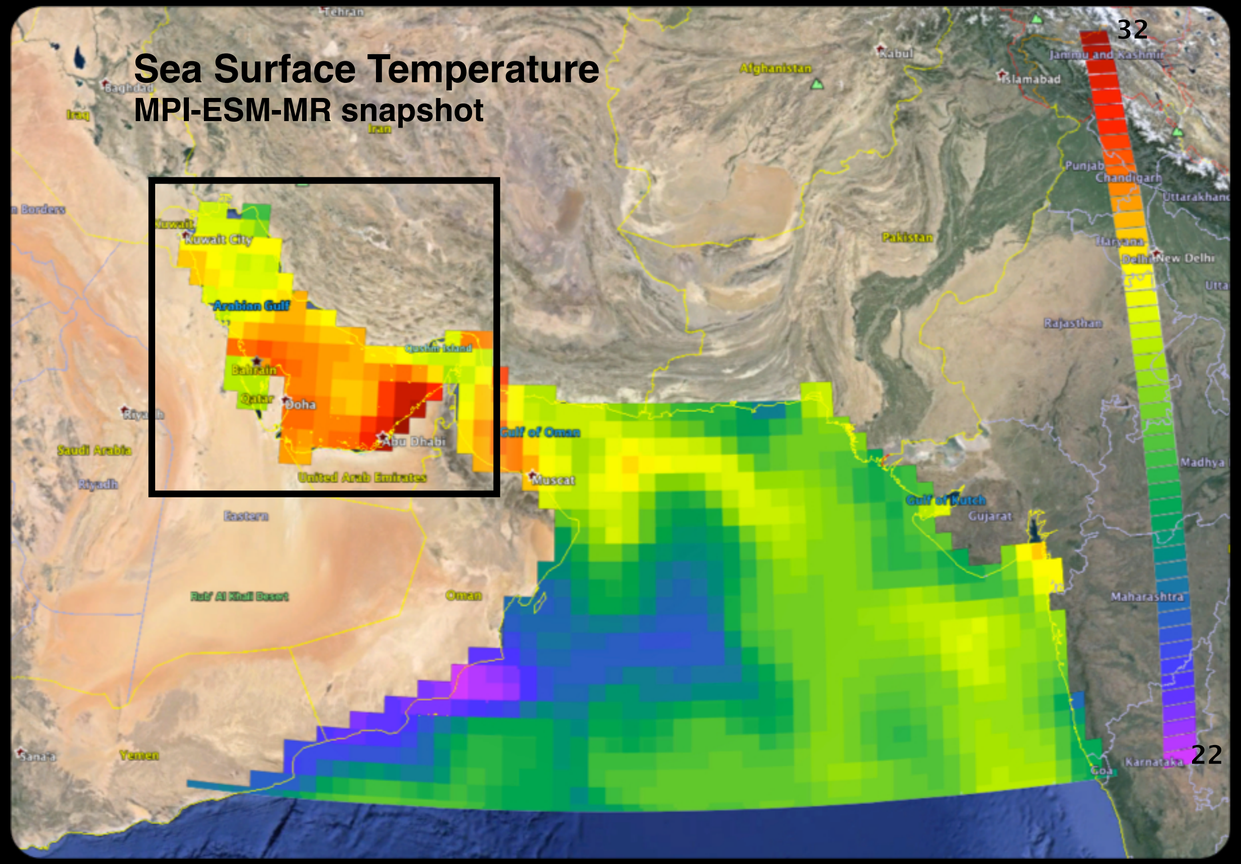
- **Define a domain that is stable enough to run long experiments [model setup]**
- **Adjusting the forcing from the *Earth System Model (ESM)***

[1] *Haidvogel et. al (2008). Ocean forecasting in terrain-following coordinates: Formulation and skill assessment of the Regional Ocean Modelling System. Journal of Computational Physics, 227(7), 3595–3624. doi:10.1016/j.jcp.2007.06.016*

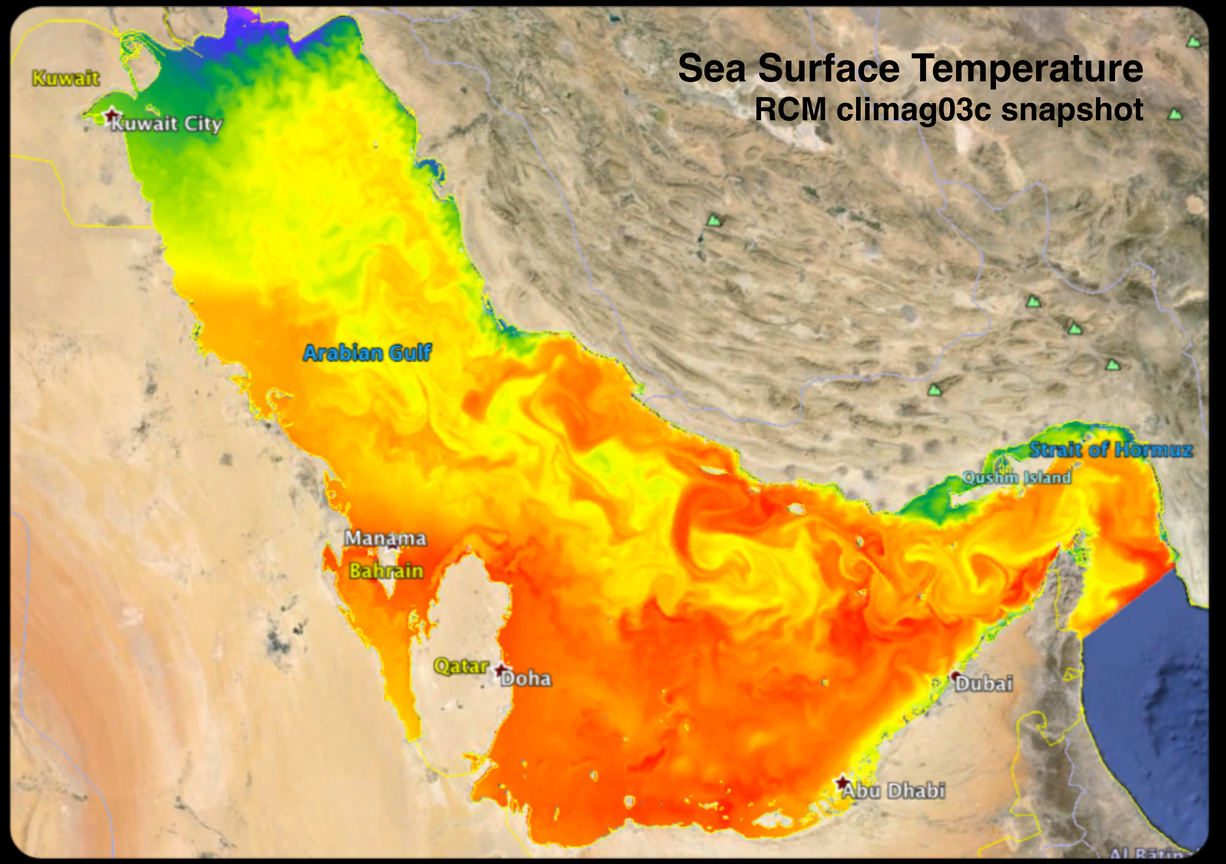

runoff
Shamal winds)
Southerly winds
Interface
Physics
Inflow


cooling process during winter and deep water formation zone
Winter cooling zone
What we want to model
Arabian Gulf
Full depth higher saline fluxes
The deep channel along the Gulf
Strait of Hormuz
Upper layers lower saline fluxes
Gulf of Oman
The Arabian Gulf circulation

ESM resolution

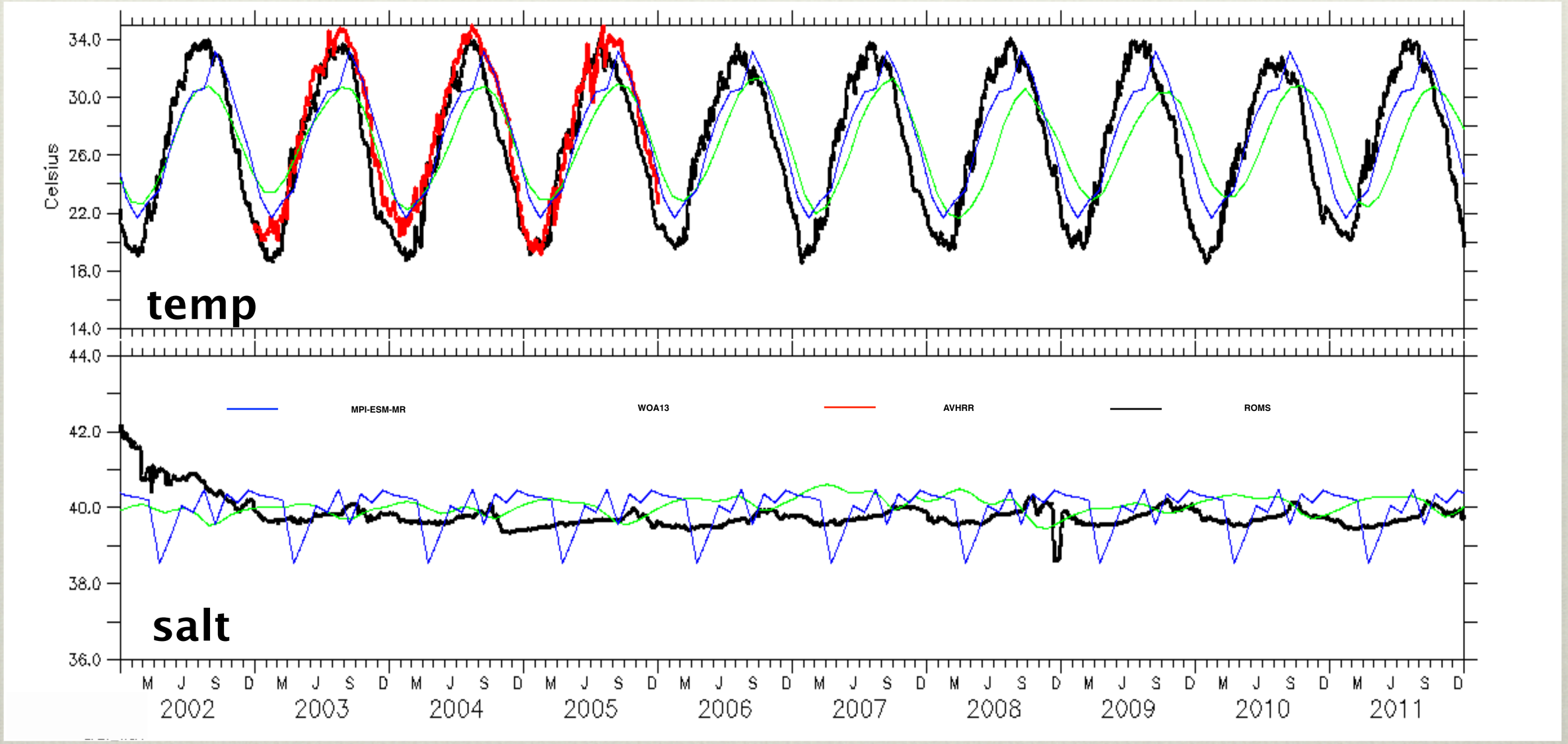


downscaled results

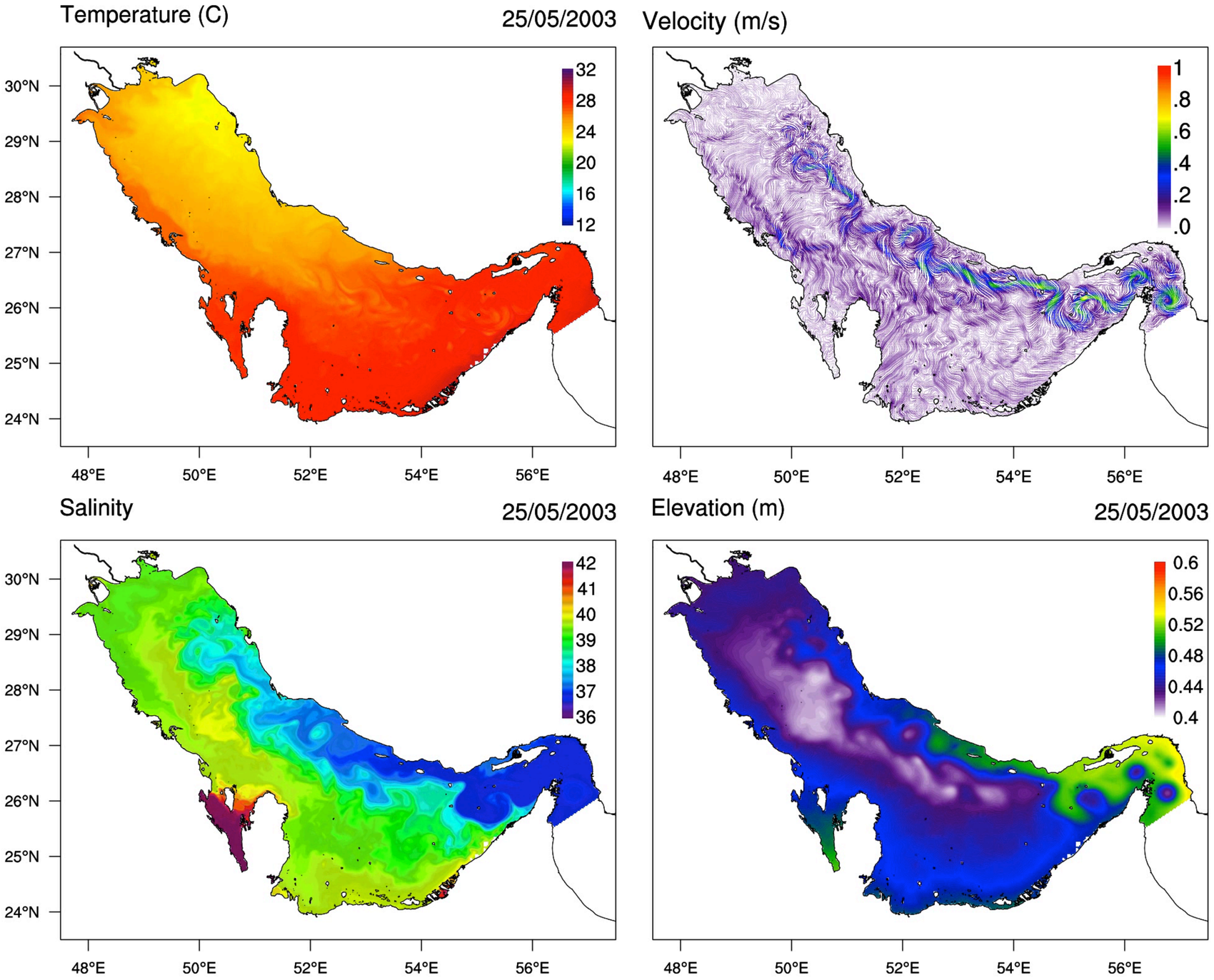


From Ocean (ESM) to Regional Climate Model (RCM)

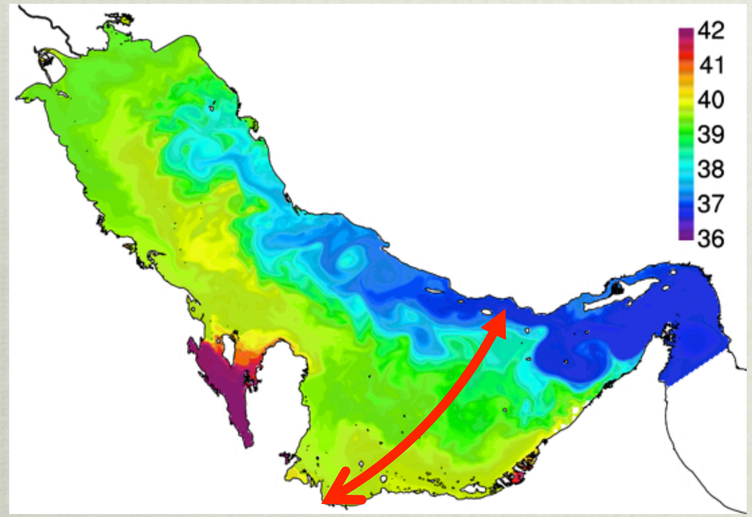
validation

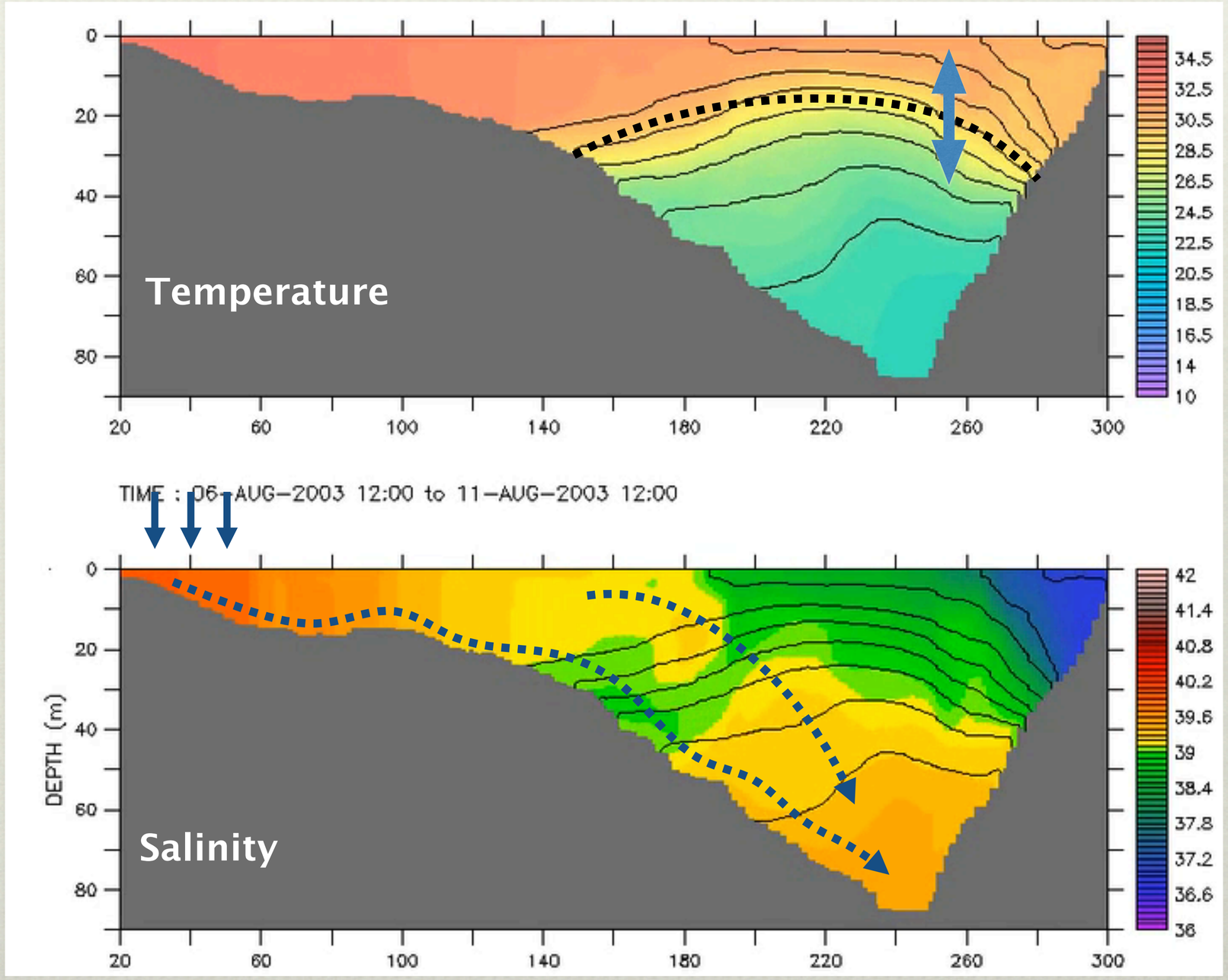

Celsius
34.0
30.0
26.0
22.0
18.0
14.0
temp
44.0
42.0
40.0
38.0
36.0
salt
MPI-ESM-MR
WOA13
AVHRR
ROMS
M J S D M J S D M J S D M J S D M J S D M J S D M J S D M J S D M J S D
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

Results


Temperature (C)
25/05/2003
32
28
24
20
16
12
Velocity (m/s)
1
.8
.6
.4
.2
.0
Salinity
25/05/2003
42
41
40
39
38
37
36
Elevation (m)
25/05/2003
0.6
0.56
0.52
0.48
0.44
0.4
30°N
29°N
28°N
27°N
26°N
25°N
24°N
48°E
50°E
52°E
54°E
56°E

Vertical profile: Temperature and Salinity





✓ We are confident Regional Model captures Arabian Gulf circulation characteristics

✓ We can now run the climate change experiments

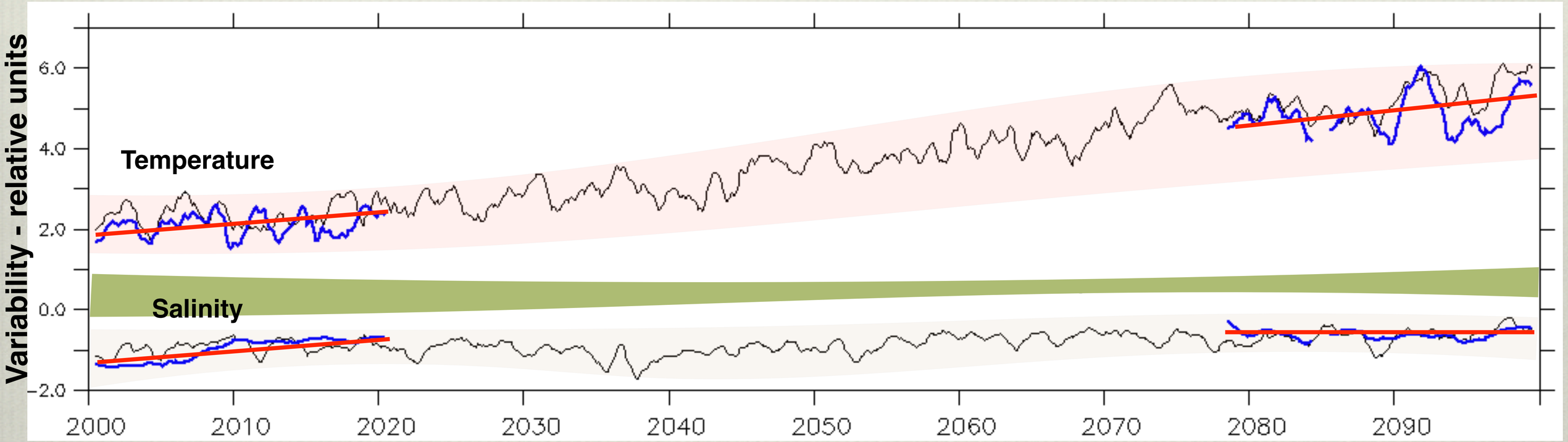
✦ Examine 2 experiments for specific time-slices

Area averaged time series for the Arabian Gulf (low pass filter)

MPI-ESM normalised results

RCM time-slice normalised results

Temp & Salt



Time-slices

Early 21st Century

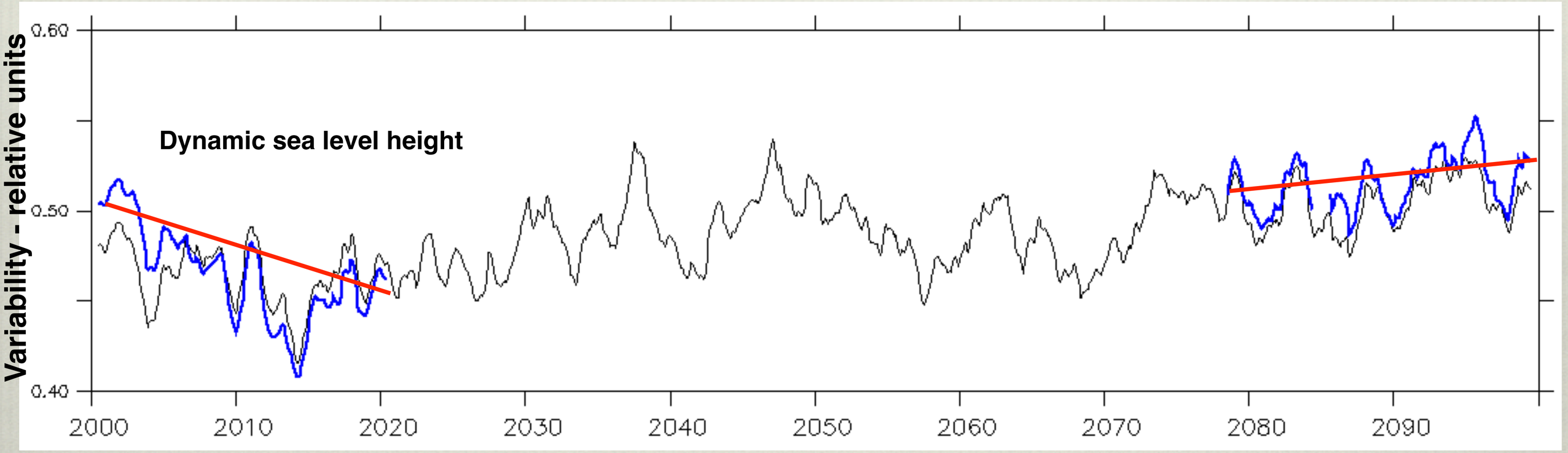
Late 21st Century

Area averaged time series for the Arabian Gulf (low pass filter)

MPI-ESM normalised results

RCM time-slices normalised results

SSH



Time-slices

Early 21st Century

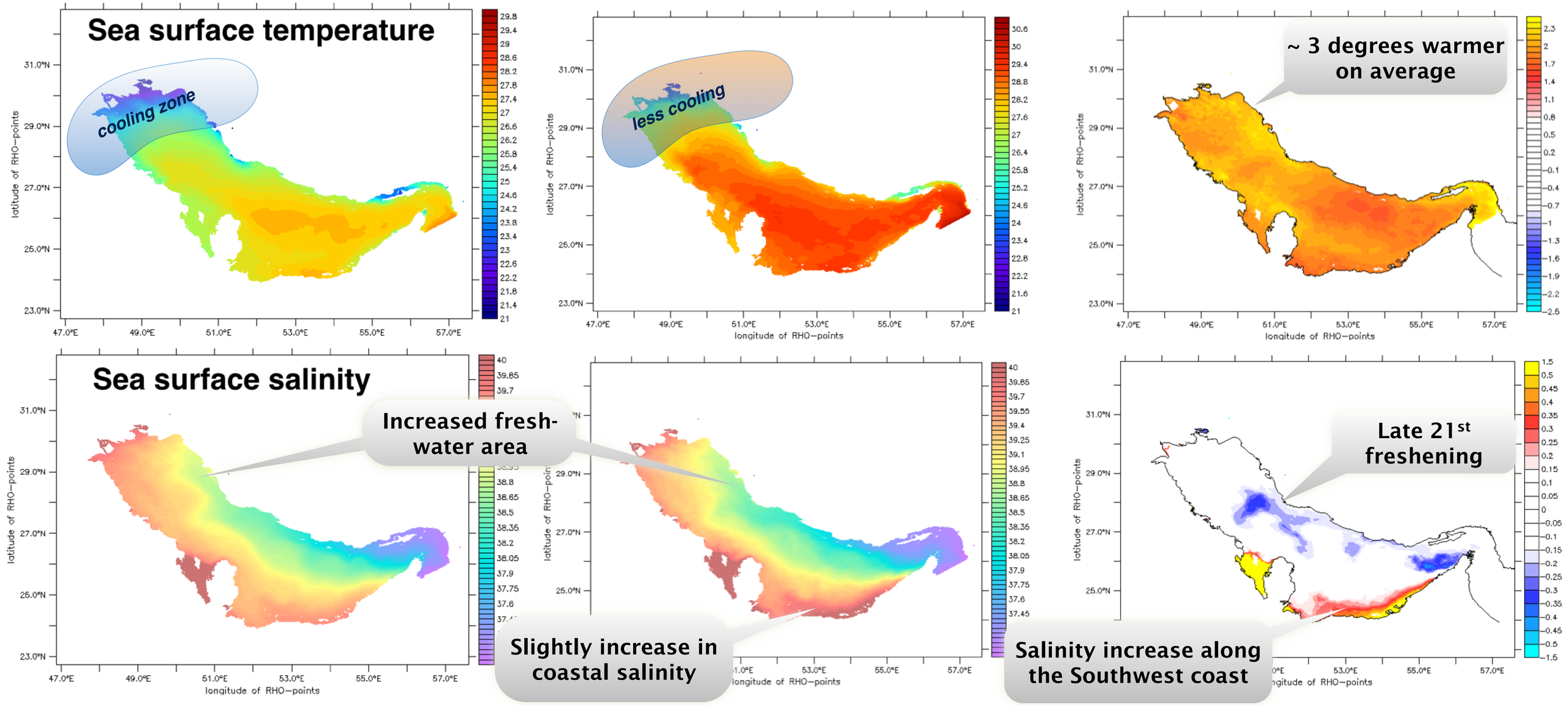
Late 21st Century

Temperature and Salinity differences between the experiments

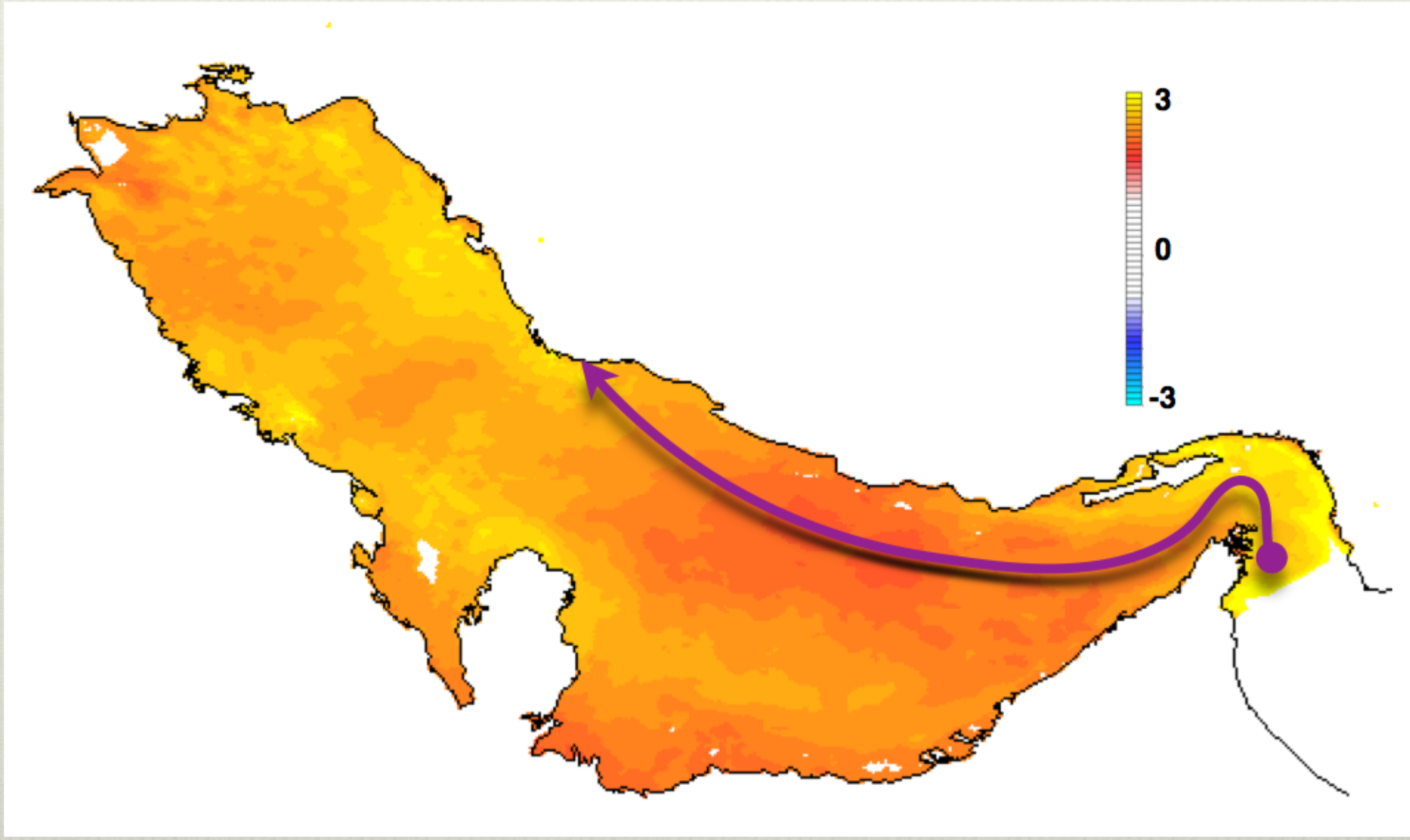
Early *21st: 5 years climatology*

Late *21st: 5 years climatology*

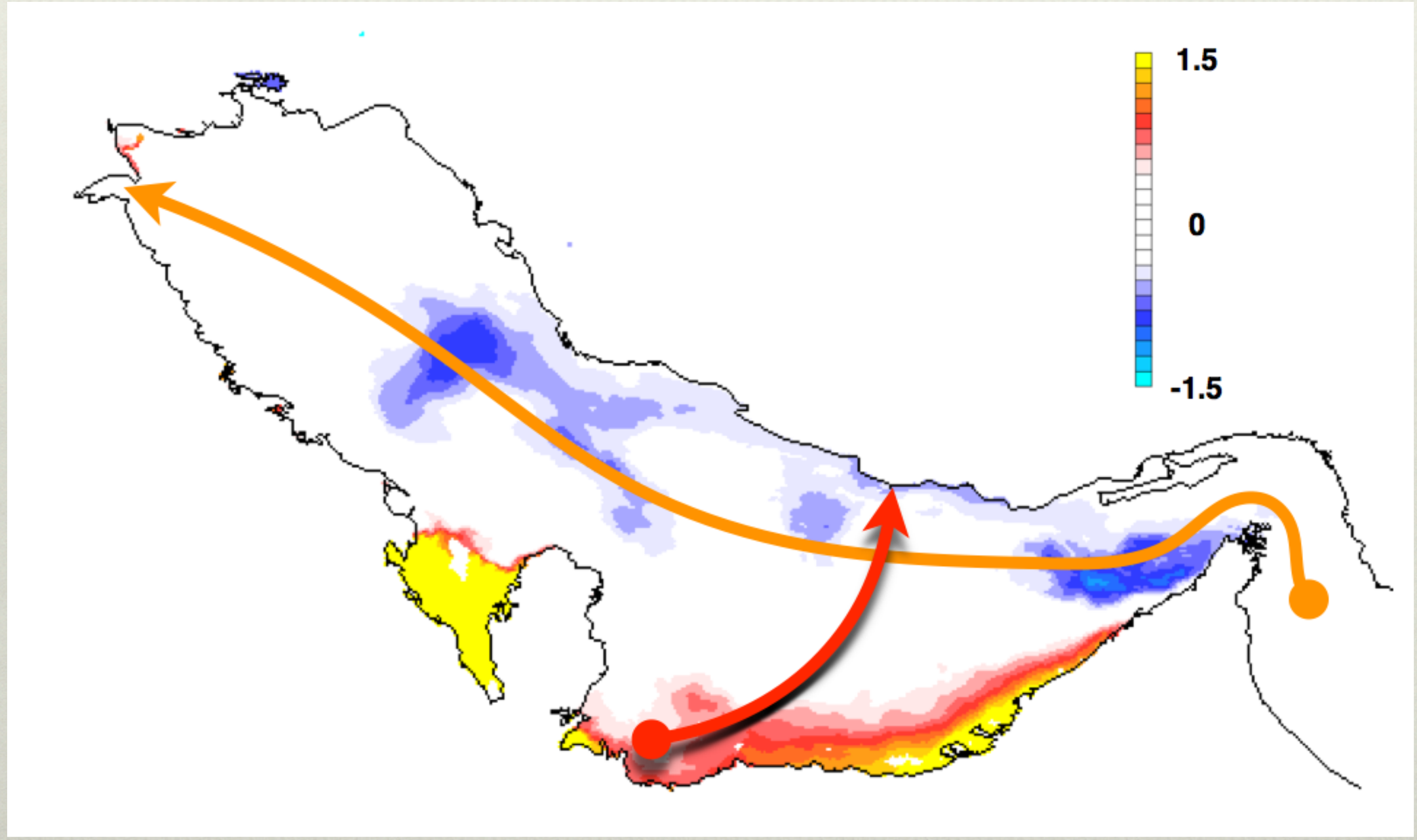
Difference



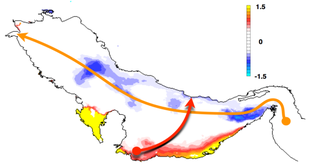
Temperature differences (Late-Early 21st)

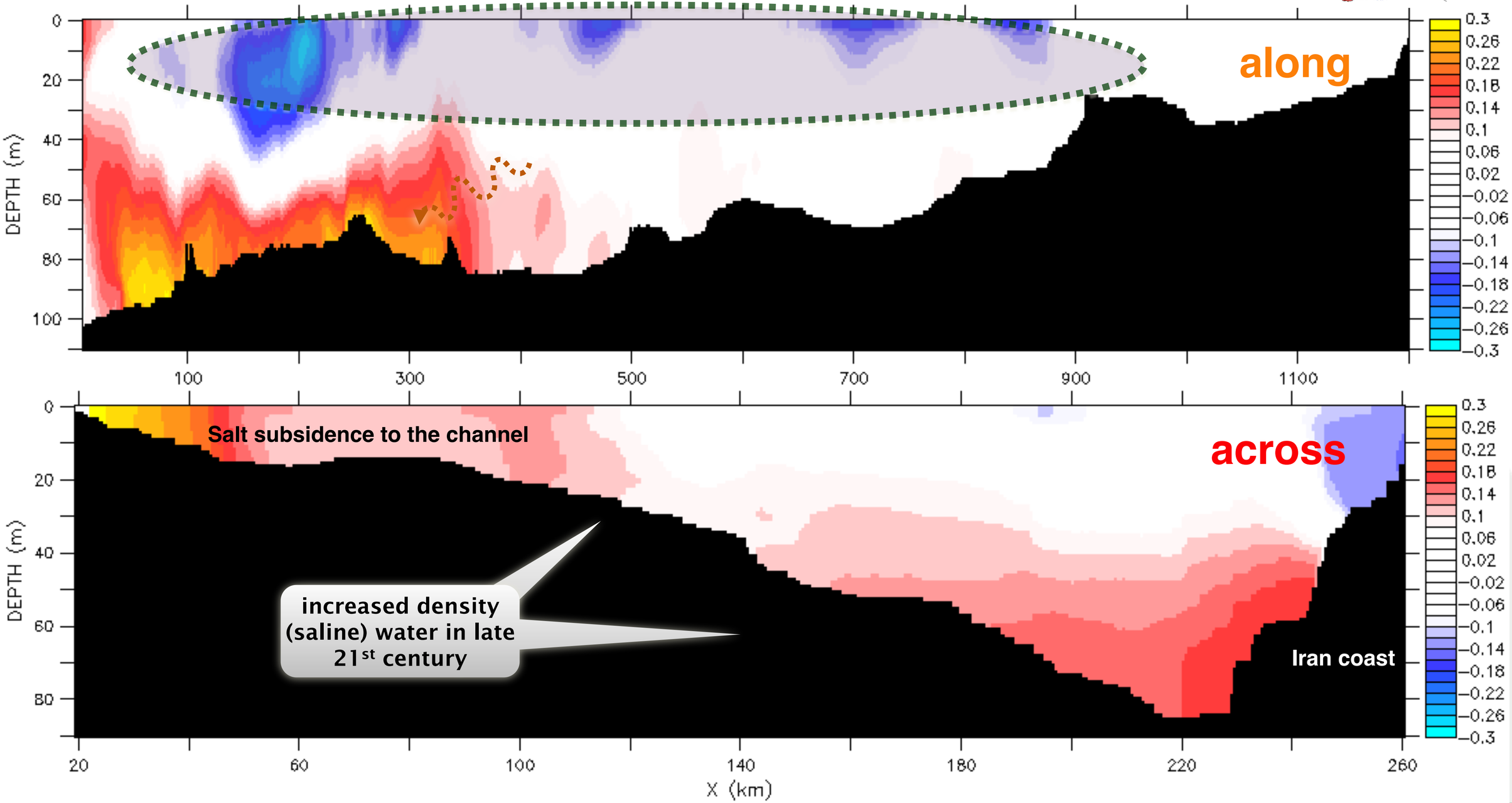


Salinity differences (Late-Early 21st)

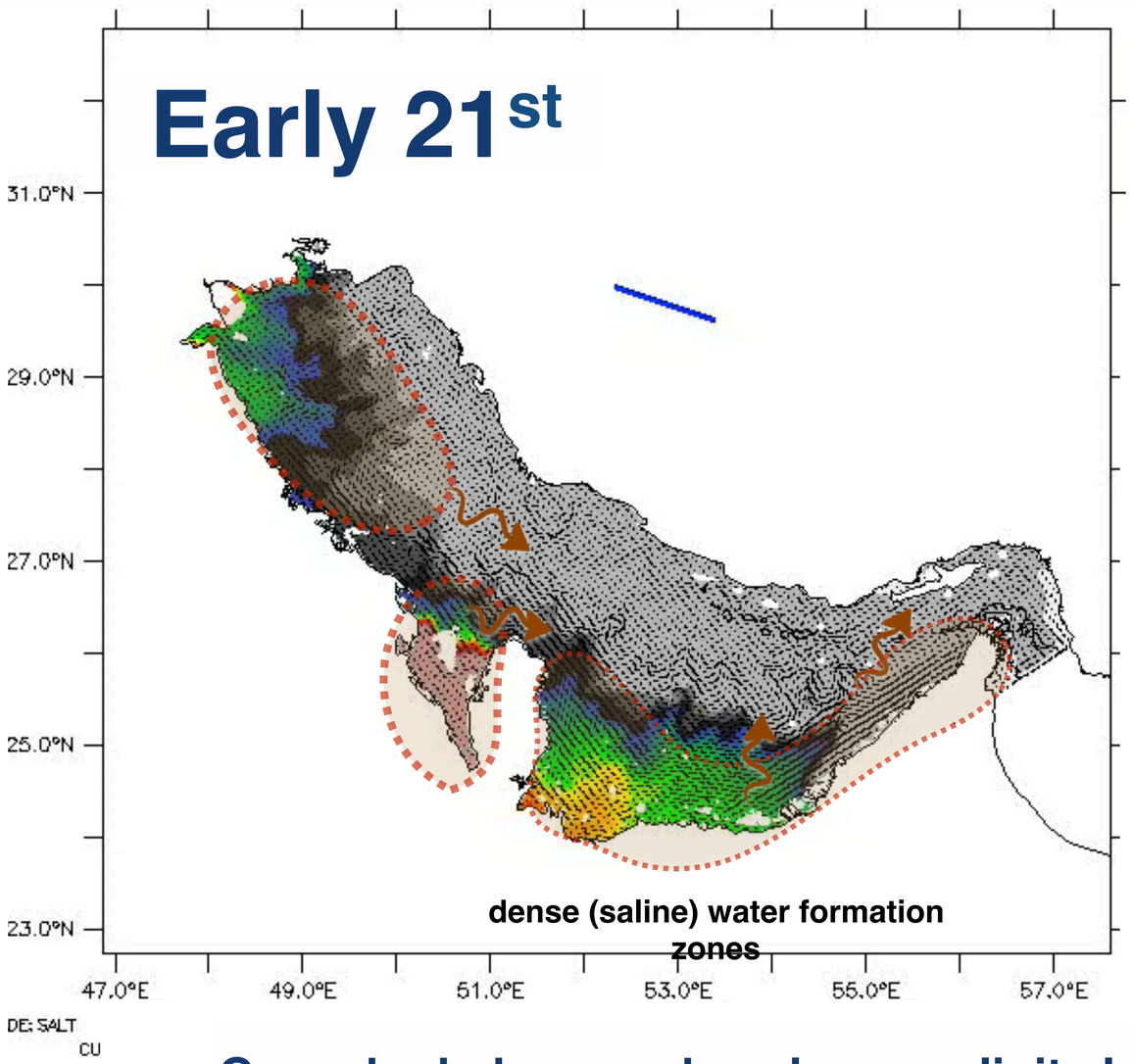


Salinity differences (late-early 21st) section along and across

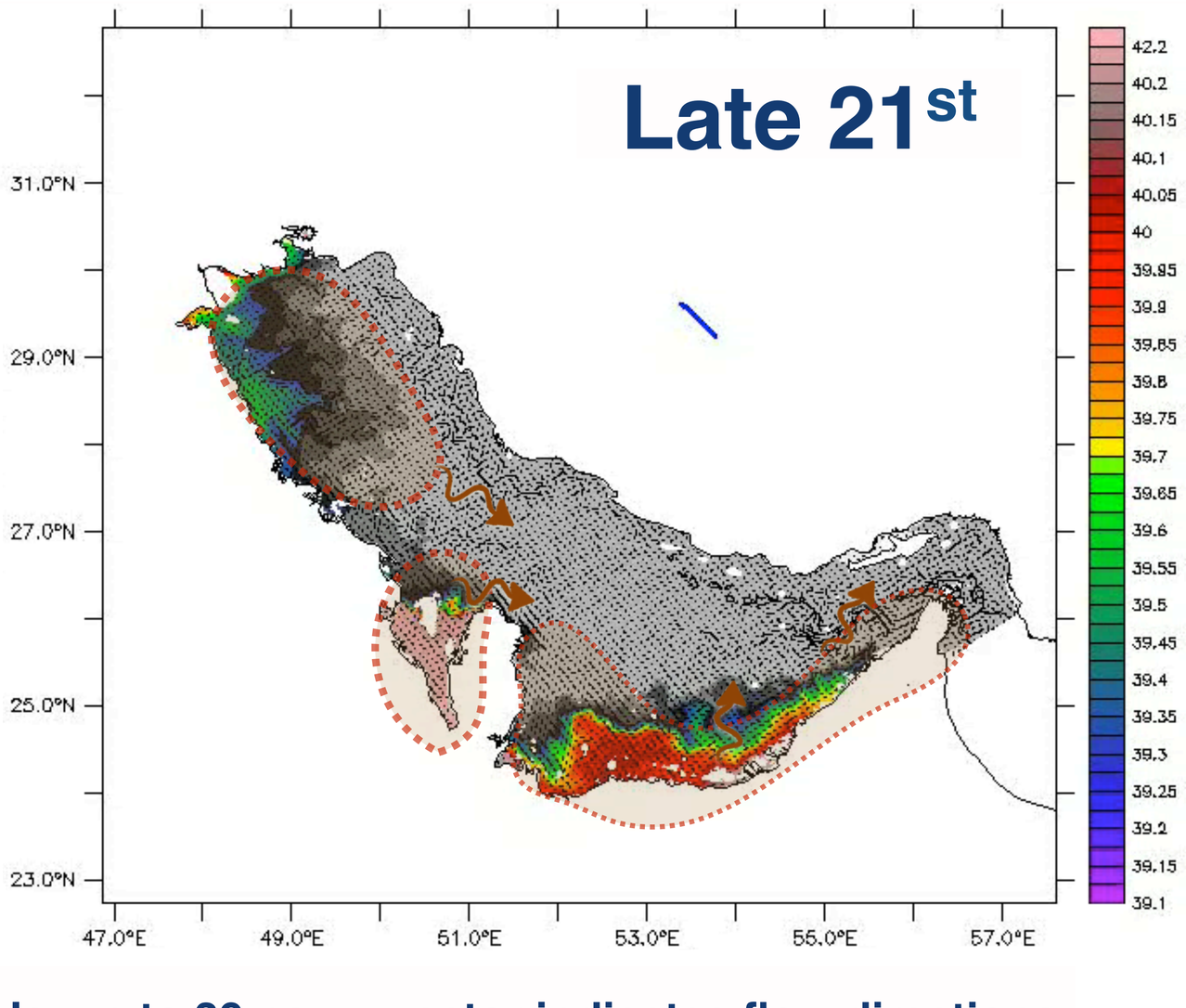




Salinity formation zones and its advection processes

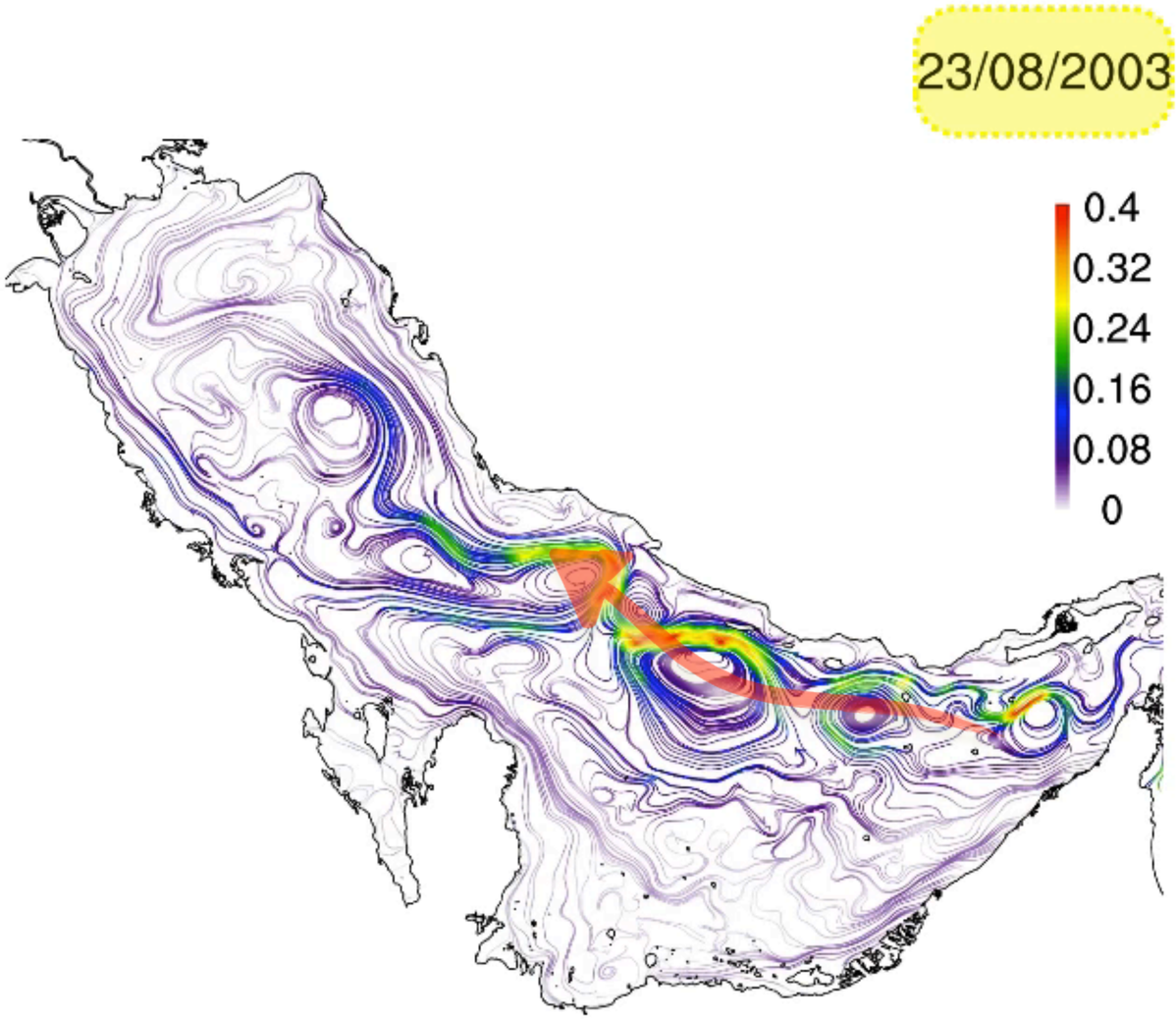


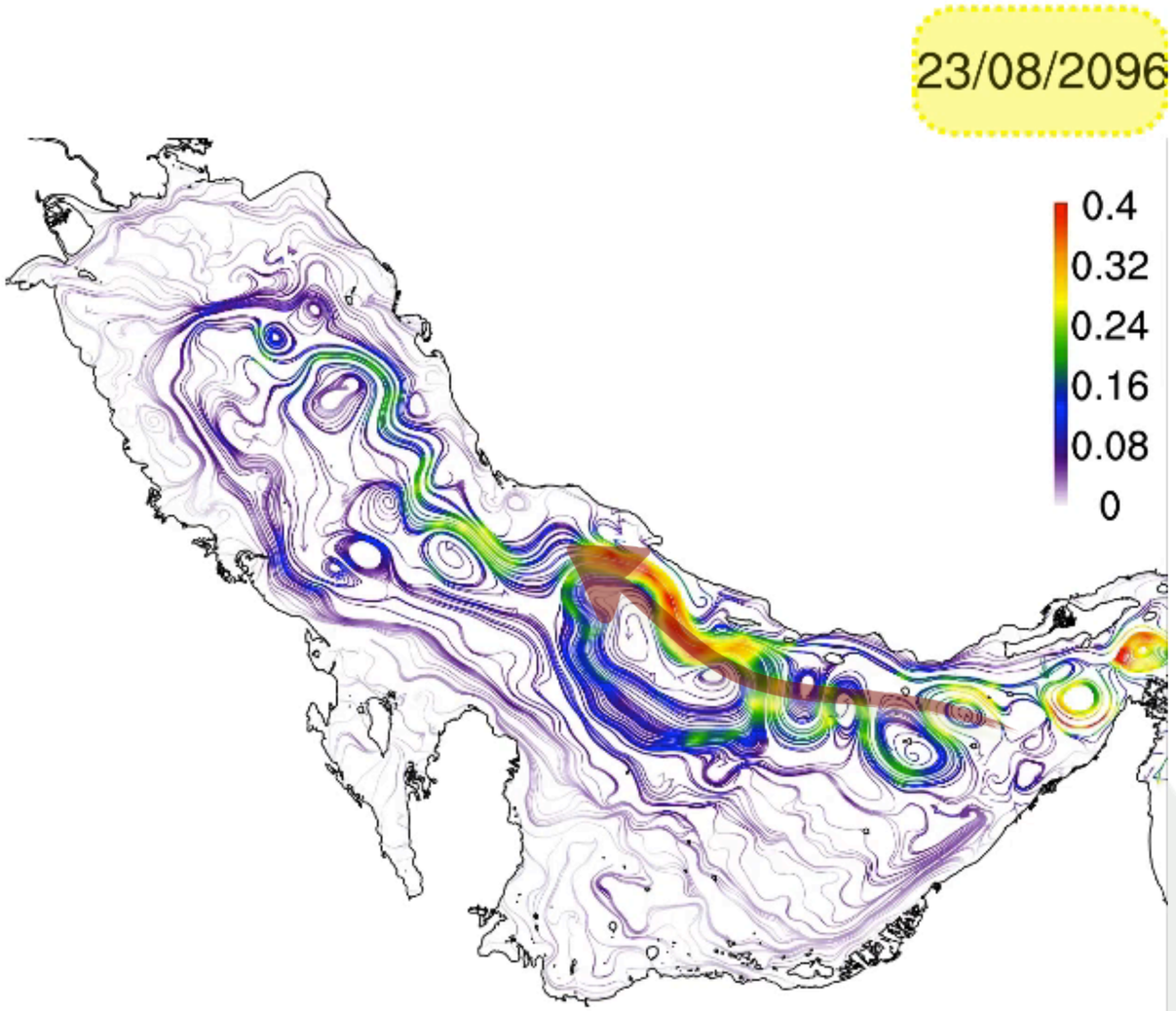
dense (saline) water formation zones

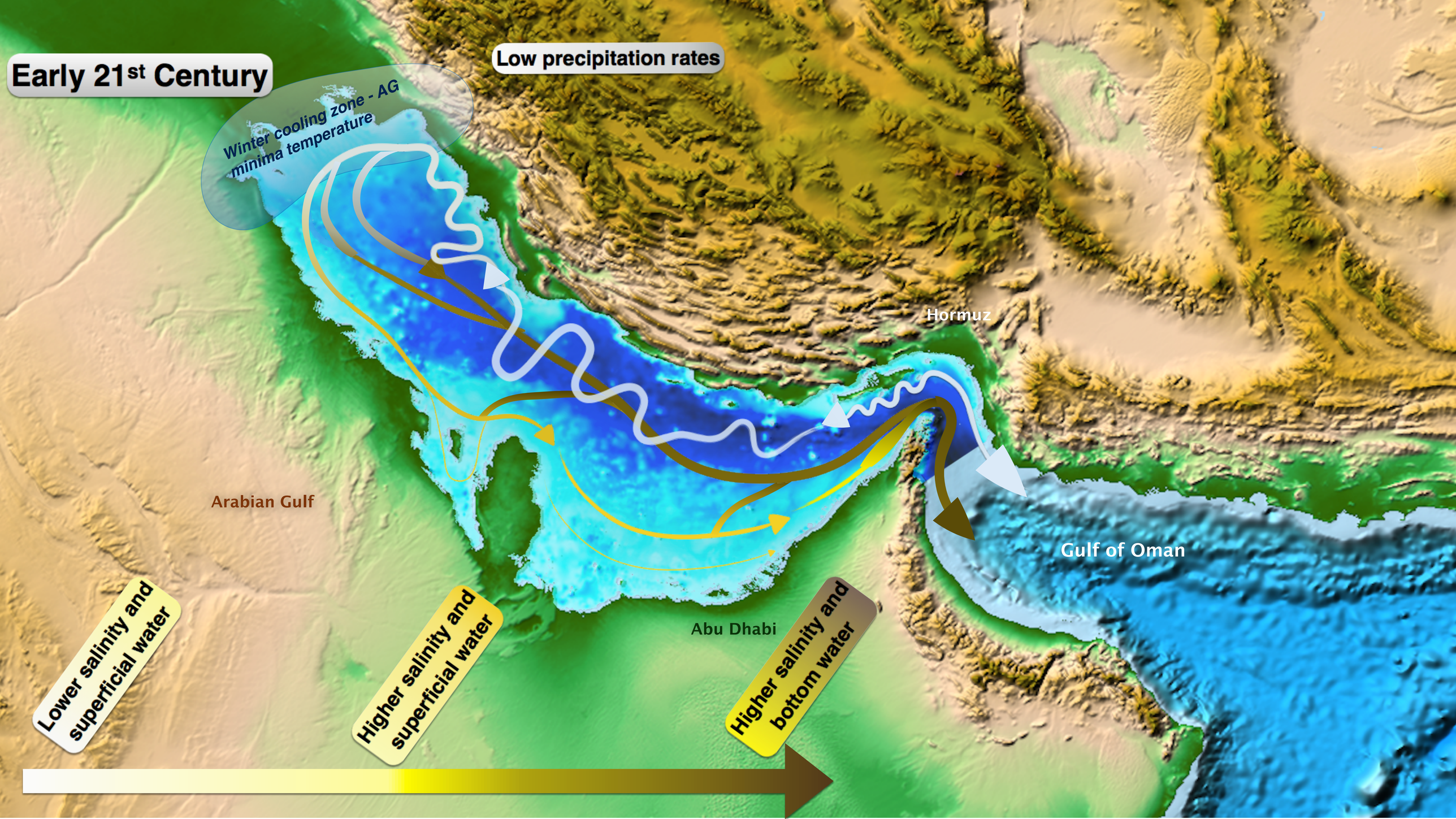


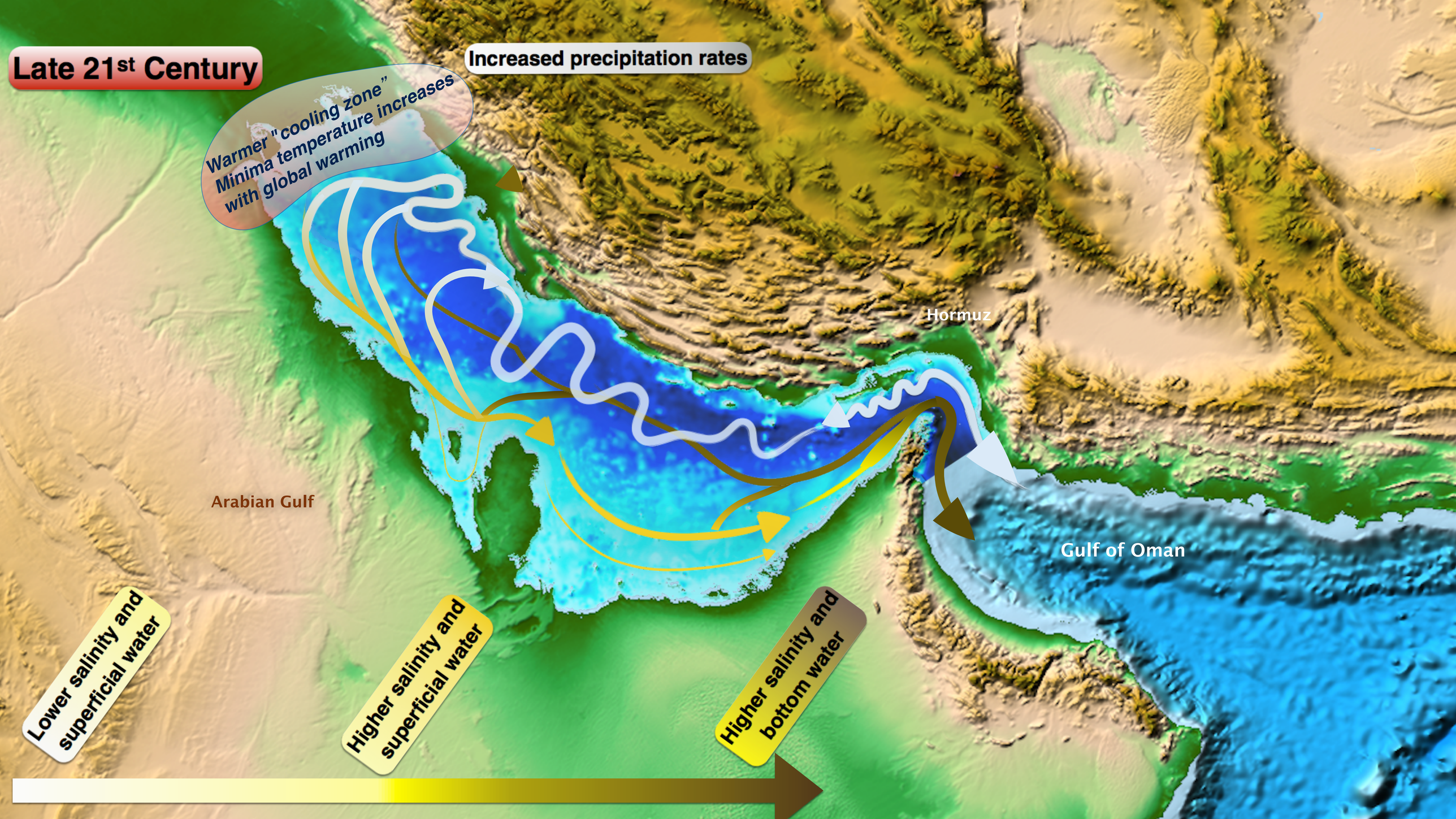
Grey shaded areas show lower salinity levels, up to 39 psu - vector indicates flow directions.

surface currents streamlines: Early and Late time slices






Early 21st Century
Low precipitation rates
Winter cooling zone - AG
minima temperature
Hormuz
Arabian Gulf
Gulf of Oman
Abu Dhabi
Lower salinity and superficial water
Higher salinity and superficial water
Higher salinity and bottom water


Late 21st Century
Increased precipitation rates
Warmer "cooling zone"
Minima temperature increases
with global warming
Hormuz
Arabian Gulf
Gulf of Oman
Lower salinity and
superficial water
Higher salinity and
superficial water
Higher salinity and
bottom water

By the end of the 21st C

- **The Arabian Gulf is ~3°C warmer**
- **Dense saline waters are advected southwards**
- **Stronger recirculations speeds**
- **Increased mixing processes**