The Role of the Persian (Arabian) Gulf in Shaping Southwest Asian Surface Climate

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nature climate change

LETTERS

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Future temperature in southwest Asia projected to exceed a threshold for human adaptability

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Wet-Bulb Temperature

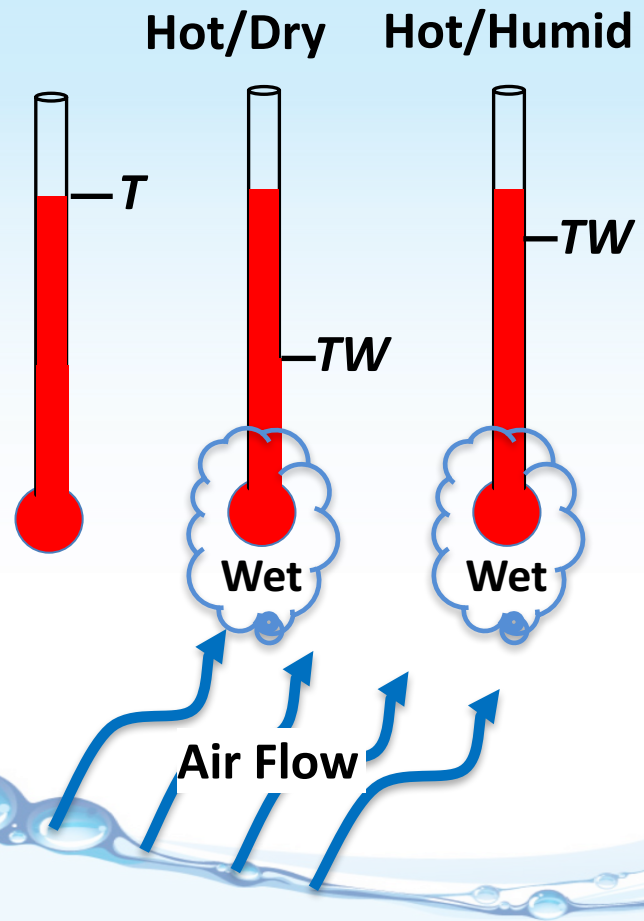
Temperature air would cool to if water were evaporated into it until saturation at constant pressure.

High TWs are associated with low lifting condensation levels (LCLs) and tend to trigger moist convection.

- Hence cooling and a negative feedback.
- TW rarely exceeds 31°C in nature.

Measure of total heat flux.

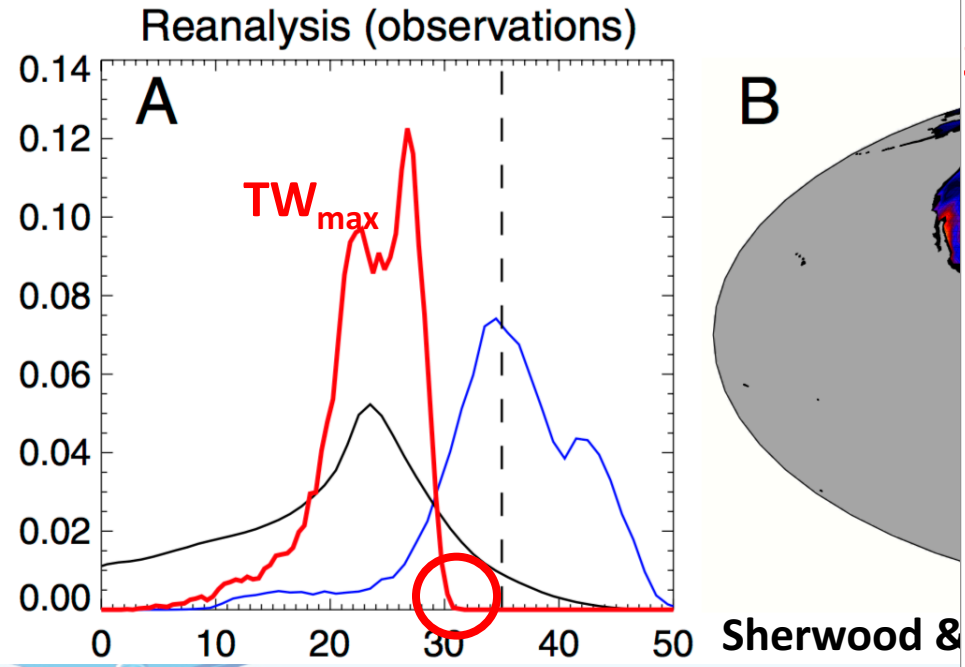
If TW exceeds the 35°C – the skin temperature of a human – metabolic heat cannot be dissipated.



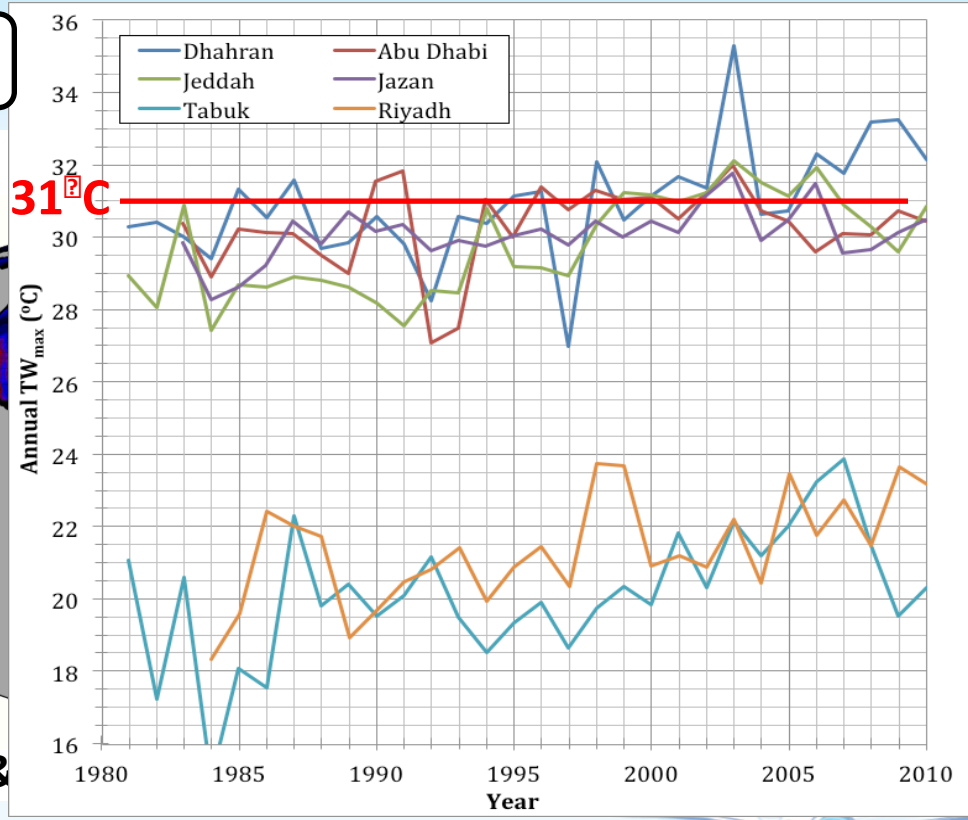
Maximum Wet-Bulb Temperature

TW rarely exceeds 31°C in nature.

Except in the Persian/Arabian Gulf.



Sherwood &

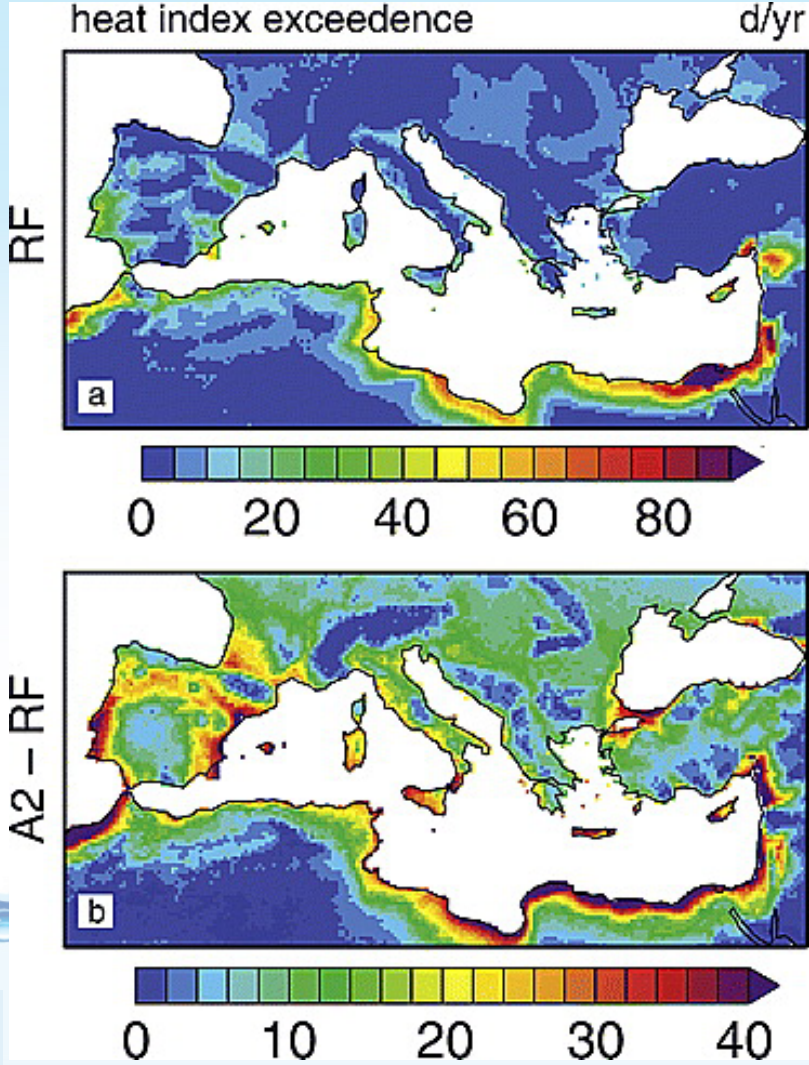


Pal & Eltahir, Nature CC SI, 2015

Dangerous Heat Stress Exceedance

Amplified in coastal regions due to higher humidity.

Therefore high resolution simulations are potentially required to predict combined temperature and humidity variables.



Diffenbaugh, Pal, Giorgi, Gao, GRL 2007

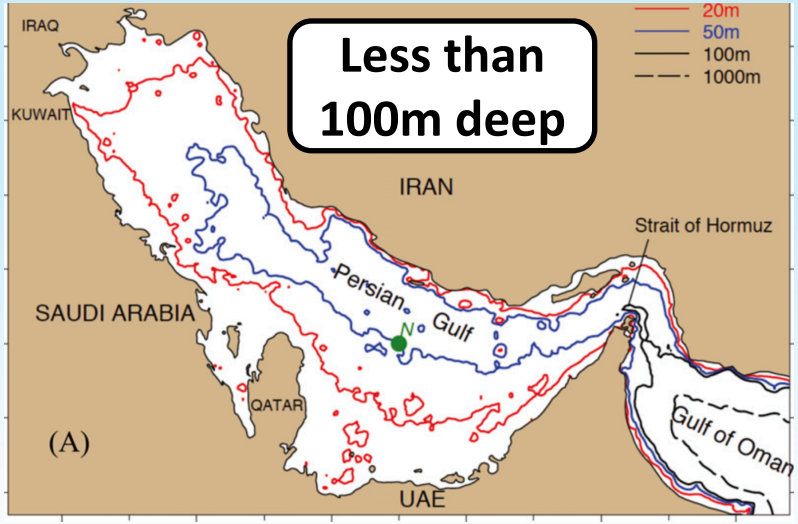
The Persian/Arabian Gulf

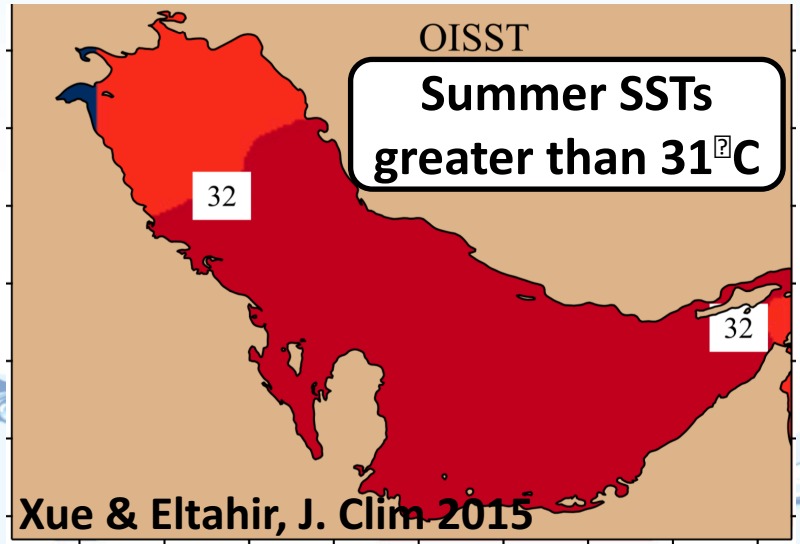
Largely cloud-free
- Subsidence Region

Shallow warm waters.
- Summer SSTs above 31°C
- Evaporation ~2 m/yr
- Little interaction with ocean.

Close to sea level.

Hot and Humid.
- High TW → High Heat Index
- High potential for heat stress.





Xue & Eltahir, J. Clim 2015

Design of Numerical Experiments

Two 31-Year Simulations (1982 – 2012)

1. Control (PG)
2. No Gulf (NoPG)

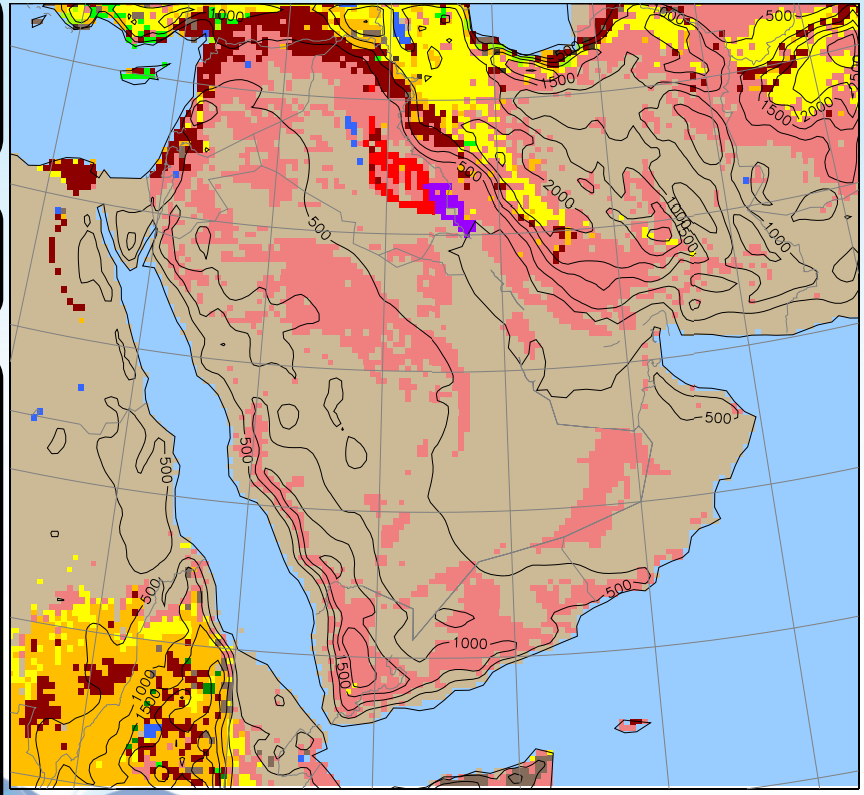
Boundary Conditions

ERA-Interim & NOAA OI Weekly SST

MIT Regional Climate Model (MRCM)

Based on RegCM3 (Pal et al 2007) with:

- Dusts (Marcella & Eltahir 2010)
- Convective cloud water, Emanuel scheme, and PBL (Gianotti & Eltahir 2012)
- IBIS Land Surface (Winter et al 2009)
- New Land Cover Types – Marshland and Irrigated Crop, NASA SRB Soil Albedo, MODIS Desert Emissivity (Pal & Eltahir 2015)



Model Domain:

25-km; nx = 144; ny = 130, nz = 18

Key MRCM Improvements

Climate in Southwest Asia is relatively straightforward to simulate.

- Largely cloud free.
- However, surface properties and dusts must be accurately represented.

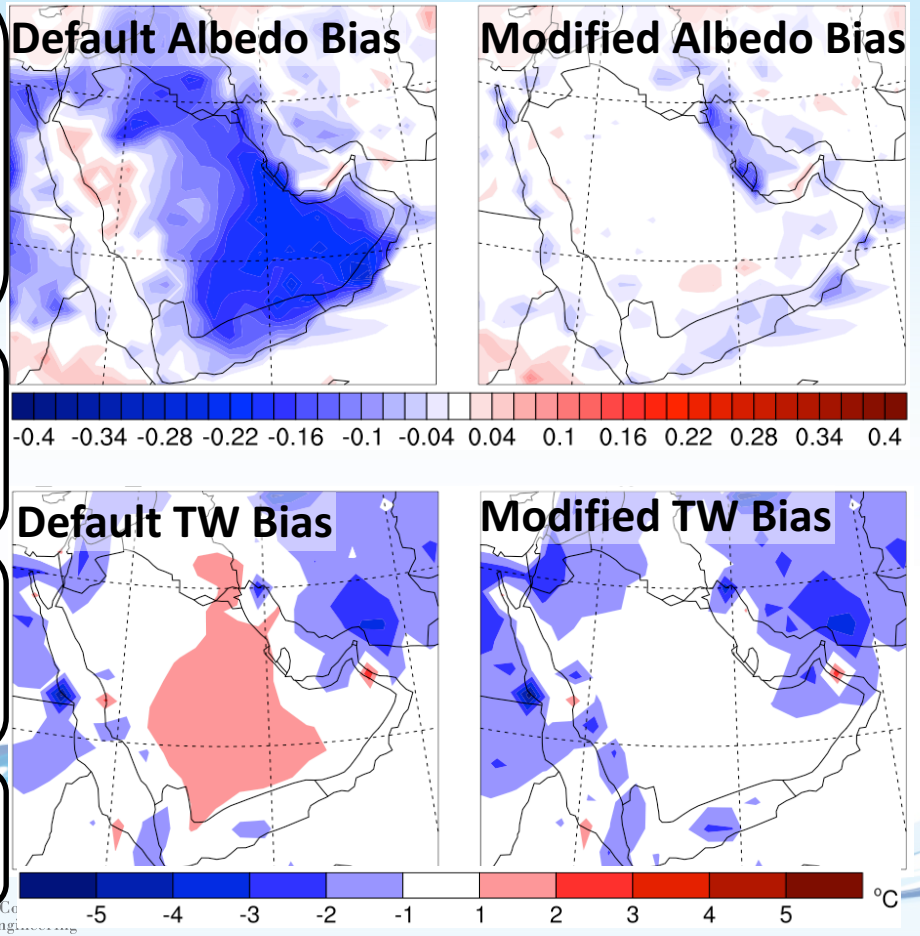
Soil Albedo: NASA SRB

- Reduced albedo bias from 0.06 to 0.01 over the region.

Desert Emissivity: MODIS

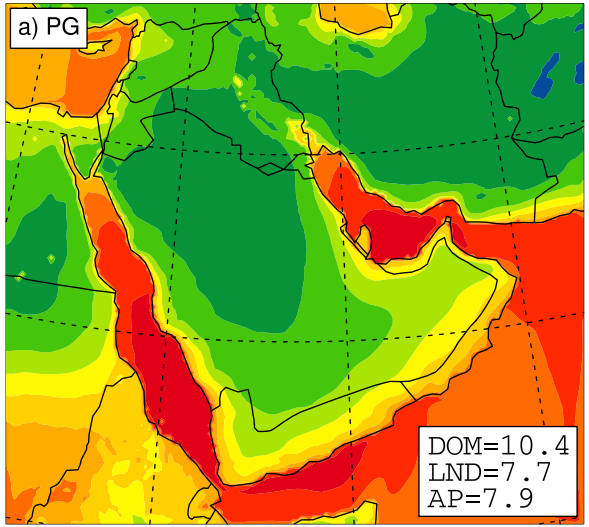
- Changed from 0.95 to 0.91 for desert and 0.93 for semi-desert.

Improvements reduced TW bias to less than 1°C over most of the region.

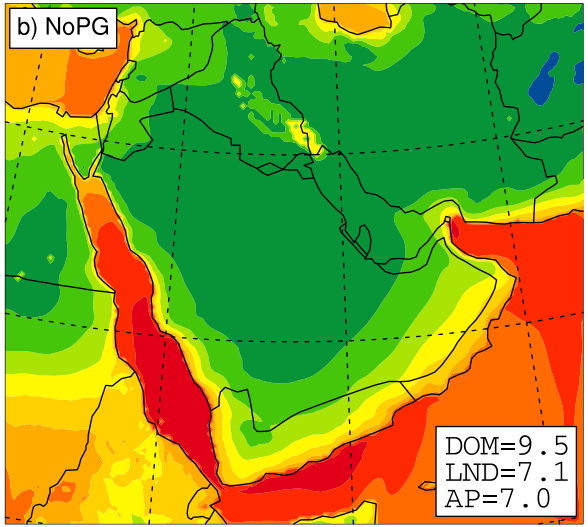


JAS 2-m Surface Specific Humidity

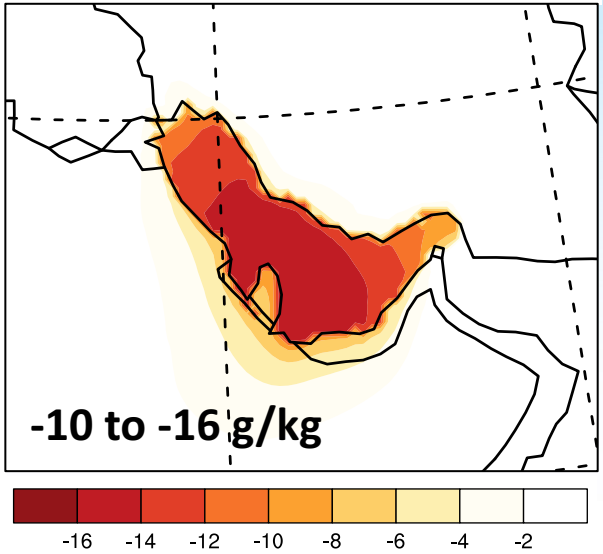
Gulf

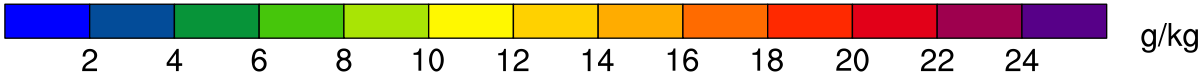


No Gulf



No Gulf – Gulf

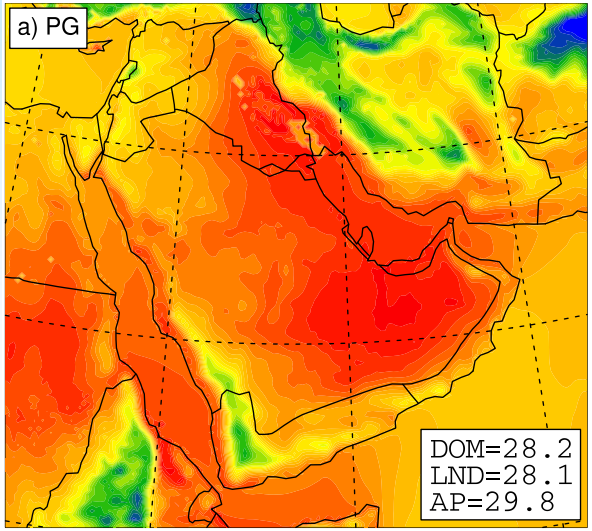




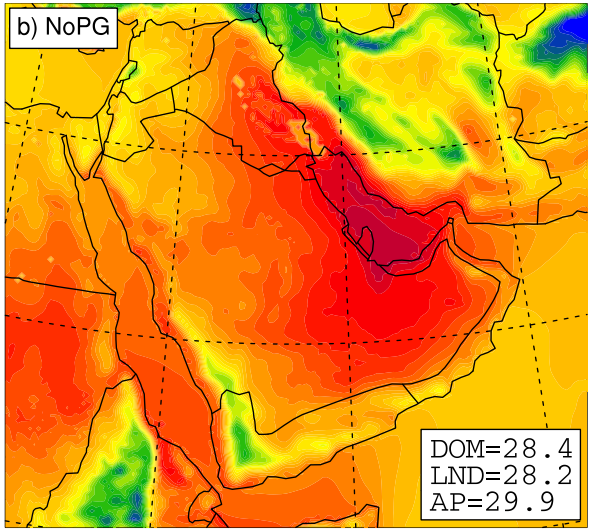
The presence of the Gulf results in an increase in surface specific humidity of 10 to 16 g/kg.

JAS 2-m Surface Dry-Bulb Temperature

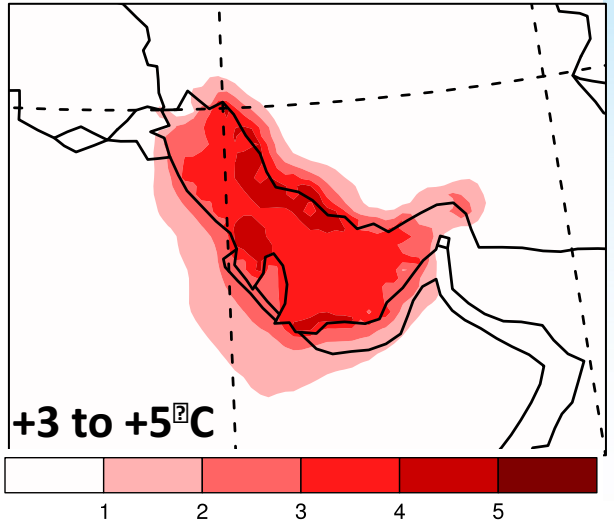
Gulf

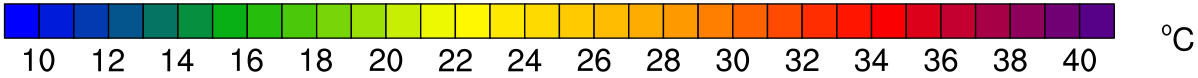


No Gulf



No Gulf – Gulf

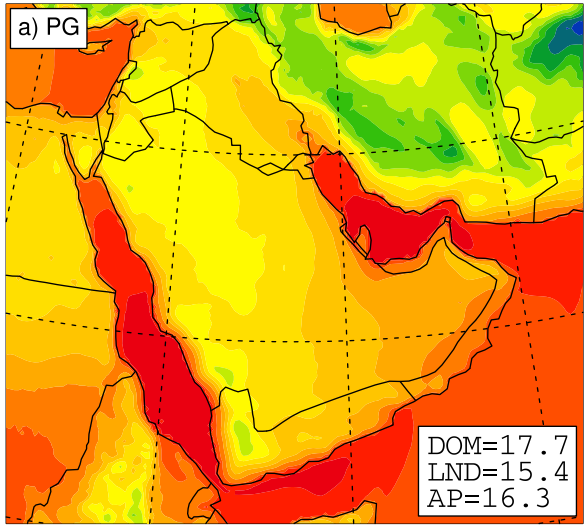




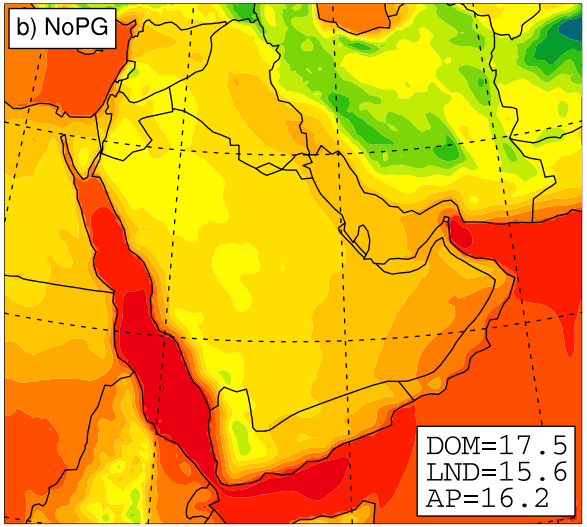
The presence of the Gulf results in a decrease in surface air temperature of 3 to 5°C.

JAS 2-m Surface Wet-Bulb Temperature

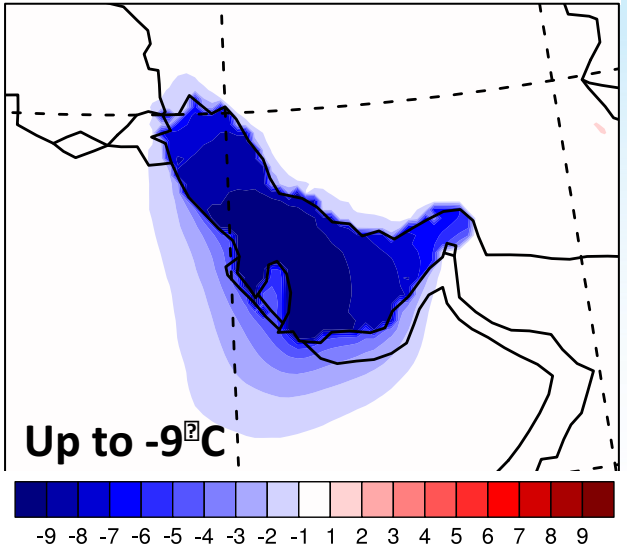
Gulf

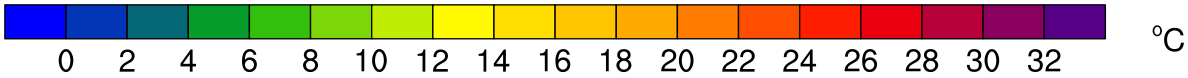


No Gulf



No Gulf – Gulf



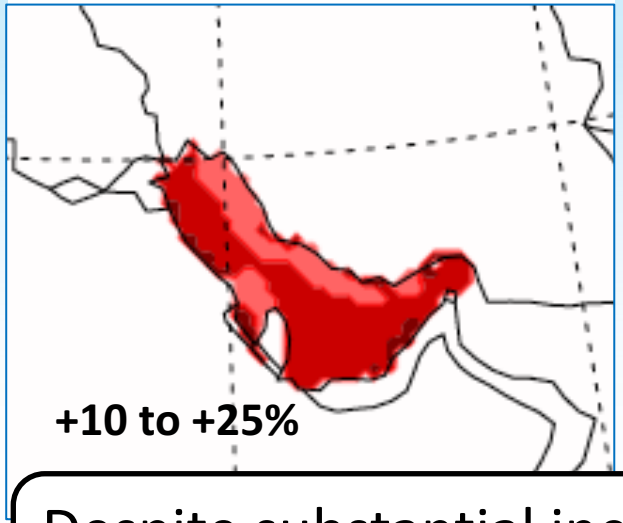


The increase in humidity greatly outweighs the decrease in dry-bulb temperature resulting in a net increase in wet-bulb temperature of 5 to 9°C when the Gulf is present.

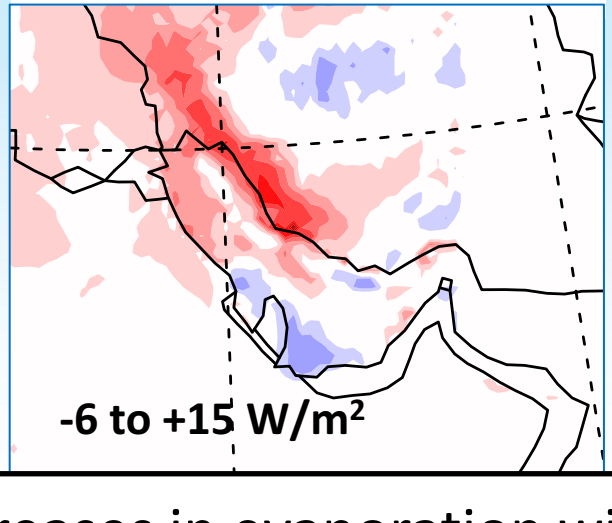
MECHANISM

JAS Surface Solar Radiation Difference (No Gulf – Gulf)

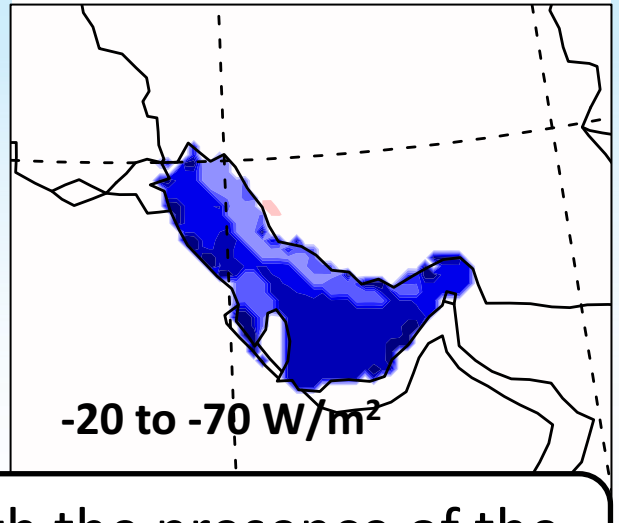
Albedo



Incident Surface Solar



Absorbed Surface Solar

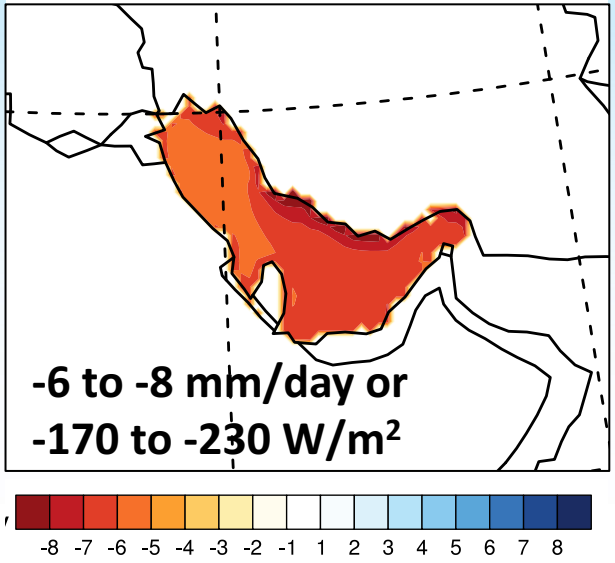


Despite substantial increases in evaporation with the presence of the Gulf, there is little change in cloud cover and incident solar radiation.

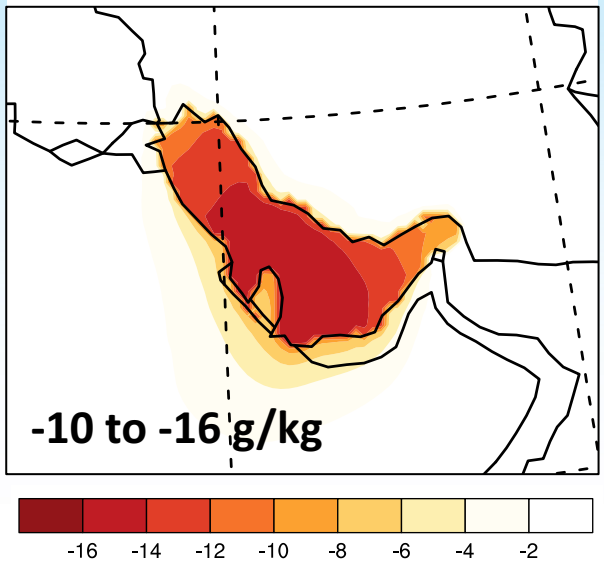
Decreased surface albedo and little change in incident solar radiation result in increased absorbed solar radiation by 30 to 70 W/m^2.

JAS Surface Terrestrial Radiation (No Gulf – Gulf)

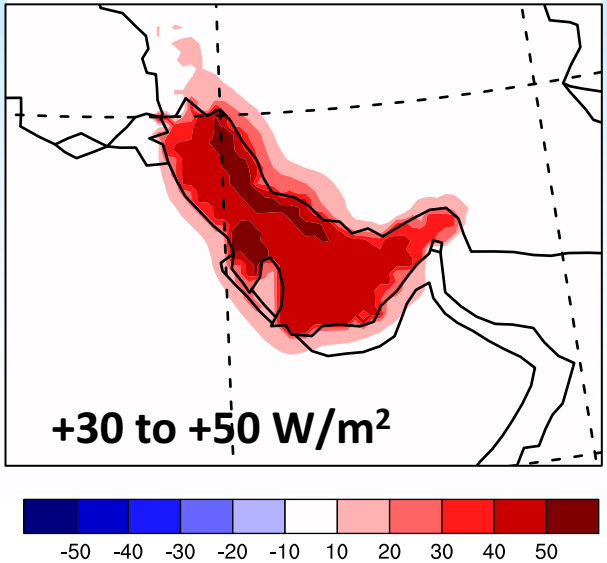
Evaporation



Specific Humidity



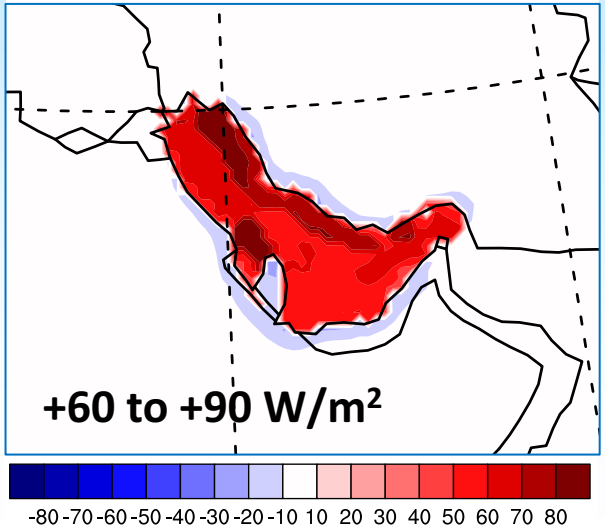
Net Terrestrial



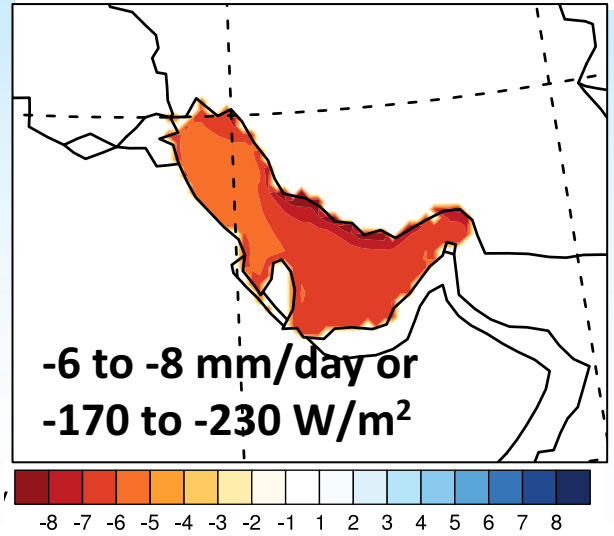
The presence of Gulf results in an increase of 30 to 50 W/m² in net terrestrial radiation due to greenhouse effect for water vapor.

JAS Surface Energy Flux Difference (No Gulf – Gulf)

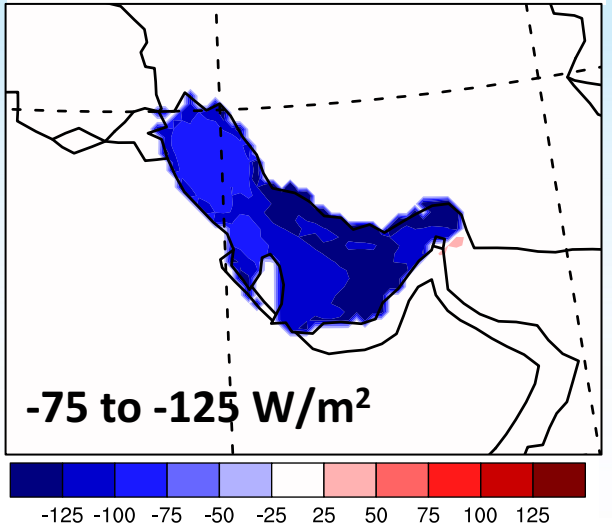
Sensible Heat



Evaporation



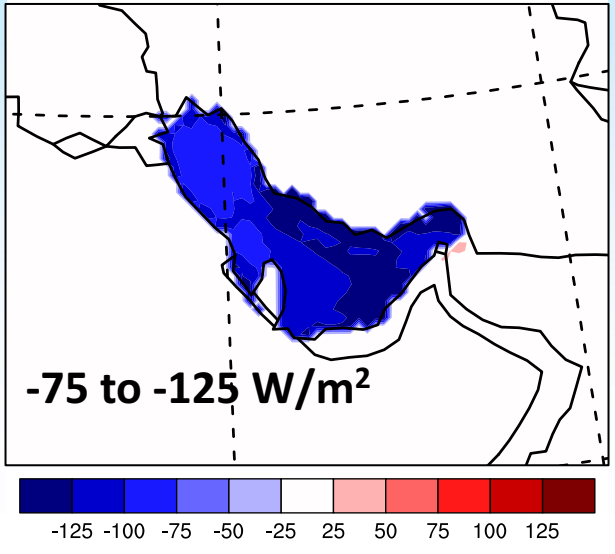
Sensible + Latent Heat



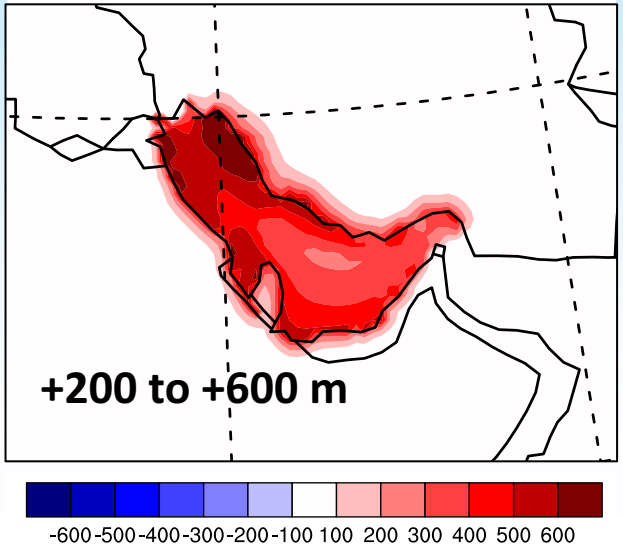
The increase in latent heat flux outweighs the decrease in sensible heat flux resulting in a net increase in total flux of 75 to 125 W/m² when the Gulf is present.

JAS Energy Flux into PBL Difference (No Gulf – Gulf)

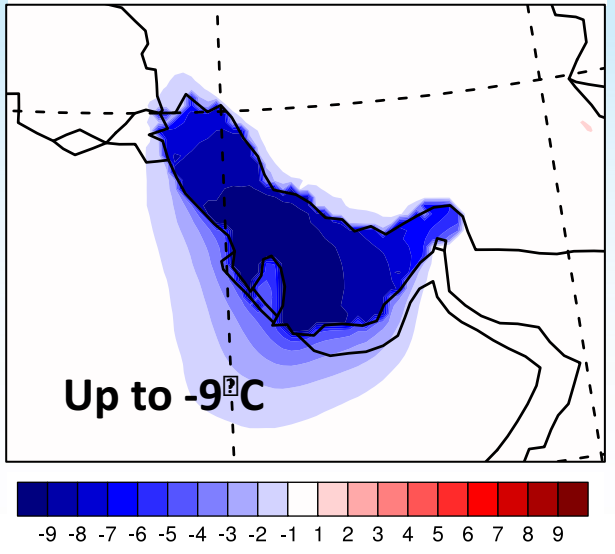
Sensible + Latent Heat



PBL Height

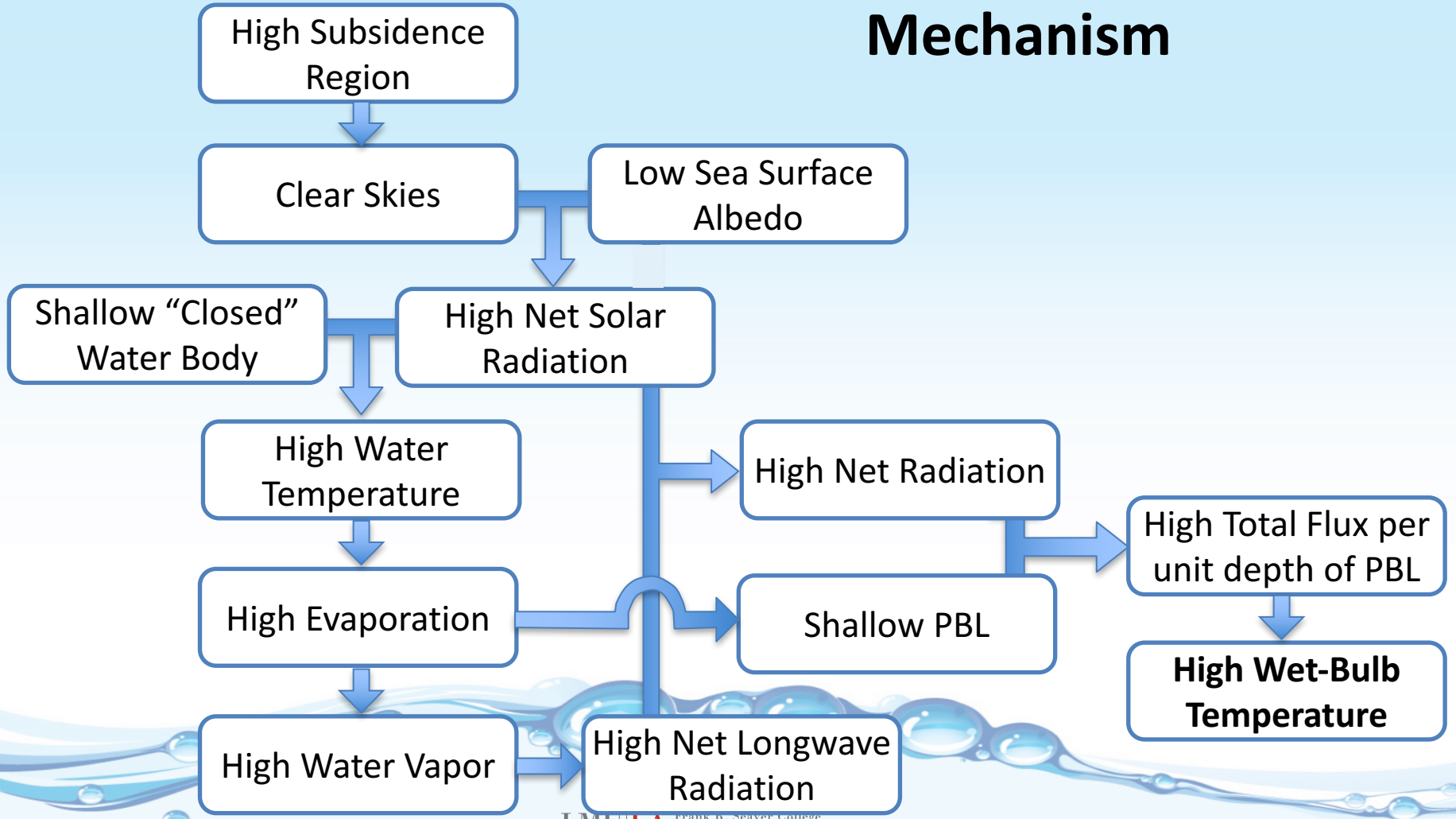


Wet Bulb Temperature



The presence of the Gulf results in an increased total heat flux (sensible + latent) into a relatively shallow PBL.

Mechanism


High Subsidence Region
Clear Skies
Low Sea Surface Albedo
Shallow "Closed" Water Body
High Net Solar Radiation
High Water Temperature
High Net Radiation
High Total Flux per unit depth of PBL
High Evaporation
Shallow PBL
High Wet-Bulb Temperature
High Water Vapor
High Net Longwave Radiation

Conclusions

Clear sky subsidence conditions unique to the region in the presence of a warm water water body result in conditions conducive to extreme wet-bulb temperatures.

This poses risks to human health in the region, particularly under the threat of climate change.

See companion talk today at 16:15 - 16:30 in Moscone West 3003.

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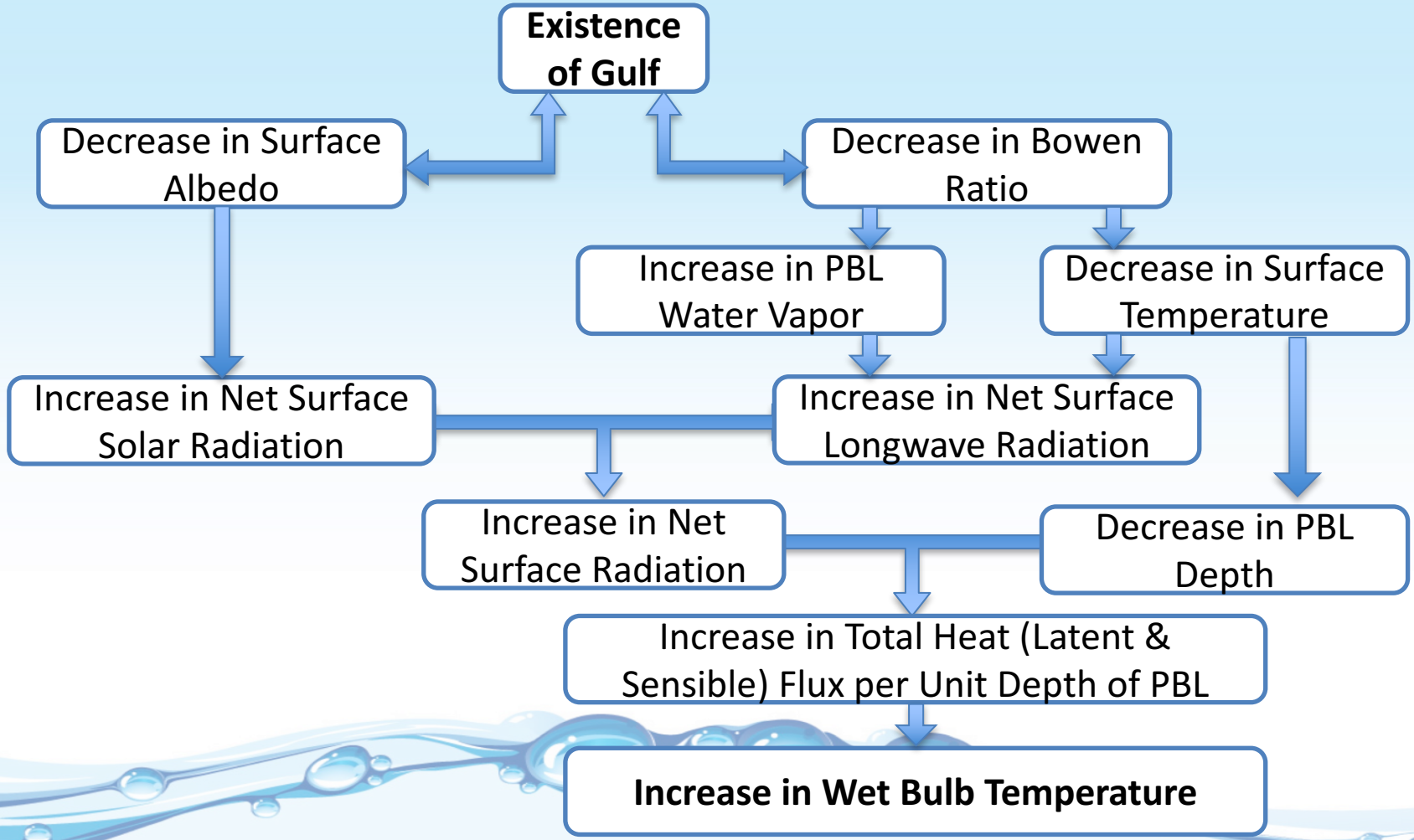
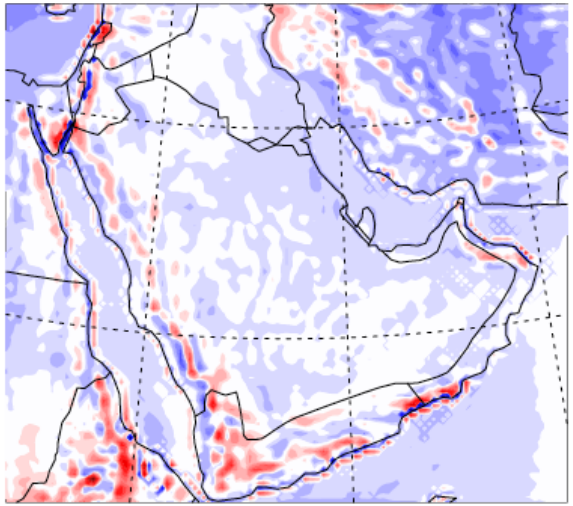
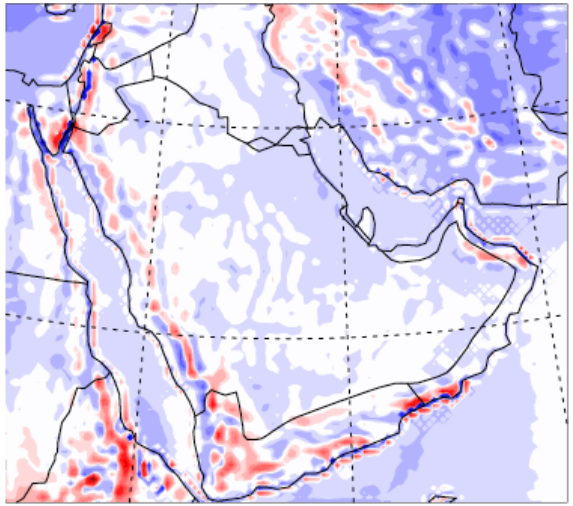

Existence of Gulf
Decrease in Surface Albedo
Decrease in Bowen Ratio
Increase in PBL Water Vapor
Decrease in Surface Temperature
Increase in Net Surface Solar Radiation
Increase in Net Surface Longwave Radiation
Increase in Net Surface Radiation
Decrease in PBL Depth
Increase in Total Heat (Latent & Sensible) Flux per Unit Depth of PBL
Increase in Wet Bulb Temperature

JJAS Sigma 0.35 Vertical Pressure Velocity

Gulf



No Gulf



Difference