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*Supplement of*

## **Early-Holocene warming in Beringia and its mediation by sea-level and vegetation changes**

**P. J. Bartlein et al.**

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1 **Supplementary Material**

2

3 This supplement contains figures displaying 10-year long-term means or long-term mean differences (anomalies) from the various simulations.  
4 Each simulation is described by two pages of figures (A & B): Page A displays net radiation ( $\text{Wm}^{-2}$ ), 2-m air temperature ( $^{\circ}\text{C}$ ), 500 mb heights  
5 (gpm) and winds ( $\text{m s}^{-1}$ ), sea-level pressure (hPa) and surface winds ( $\text{m s}^{-1}$ ), total cloud (fraction), precipitation rate ( $\text{mm d}^{-1}$ ), and soil moisture  
6 (%). Page B displays surface energy-balance components including net shortwave radiation, net longwave radiation, net radiation, sensible heat  
7 flux, latent heat flux, and the heat flux into the substrate (or change in heat storage), all in  $\text{Wm}^{-2}$ , and 2-m air temperature ( $^{\circ}\text{C}$ ). (Net radiation and  
8 2-m air temperature appear on both figures for convenience.) The sign convention for the energy-balance components is described below.  
9

10 **Figures:**

11

- 12 1) Present-Day Simulation (with modern continental outlines)
- 13 2) Present-Day Simulation (with 11 ka continental outlines)
- 14 3) Present-Day Simulation (with modern continental outlines) minus Present-Day Simulation (with 11 ka continental outlines)
- 15 4) 11 ka Control Simulation
- 16 5) 11 ka Control Simulation minus Present-Day Simulation
- 17 6) 11 ka Control Simulation minus Present-Day Simulation (with 11 ka continental outlines)
- 18 7) 11 ka Sea-Level Simulation
- 19 8) 11 ka Sea-Level Simulation minus 11 ka Control Simulation
- 20 9) 11 ka Vegetation Simulation
- 21 10) 11 ka Vegetation Simulation minus 11 ka Control Simulation
- 22 11) 11 ka Lakes Simulation
- 23 12) 11 ka Lakes Simulation minus 11 ka Control Simulation
- 24 13) 11 ka All Simulation
- 25 14) 11 ka All Simulation minus 11 ka Control Simulation
- 26 15) 11 ka All Simulation minus Present-Day Simulation (with modern continental outlines)
- 27 16) 6 ka Simulation
- 28 17) 6 ka Simulation minus Present-Day Simulation (with modern continental outlines)
- 29 18) 6 ka Simulation minus 11 ka All Simulation

30

31

32 **Surface energy-balance components**

33

34 The surface energy balance is given by

35

36

$$K\downarrow - K\uparrow + L\downarrow - L\uparrow - Q_H - Q_E - Q_G = 0, \text{ or}$$

$$Q_{net} = K\downarrow - K\uparrow + L\downarrow - L\uparrow, \text{ or}$$

37

$$= K_{net} + L_{net}, \text{ and}$$

$$= Q_H + Q_E + Q_G, \text{ or}$$

$$= Q_H + Q_E + \Delta Q_S$$

38

where

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40

$K\downarrow$  = incoming shortwave radiation (all terms in  $\text{Wm}^{-2}$ ),

41

$K\uparrow$  = outgoing shortwave radiation,

42

$K_{net} = K\downarrow - K\uparrow$ , net shortwave radiation, or  $(1 - \alpha)K\downarrow$  where  $\alpha$  is the albedo of the surface,

43

$L\downarrow$  = incoming longwave radiation,

44

$L\uparrow$  = outgoing longwave radiation ( $\sim T_{sfc}^4$  where  $T_{sfc}$  is the temperature of the surface),

45

$L_{net} = L\downarrow - L\uparrow$ , or net longwave radiation,

46

$Q_H$  = sensible heat flux,

47

$Q_E$  = latent heat flux ( $\sim E$  or  $\sim ET$ , where  $E$  is evaporation and  $ET$  is evapotranspiration), and

48

$Q_G = \Delta Q_S$ , heat flux into or out of the substrate (land or water) or change in heat storage

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50 **Sign conventions for and interpretation of surface energy-balance component**

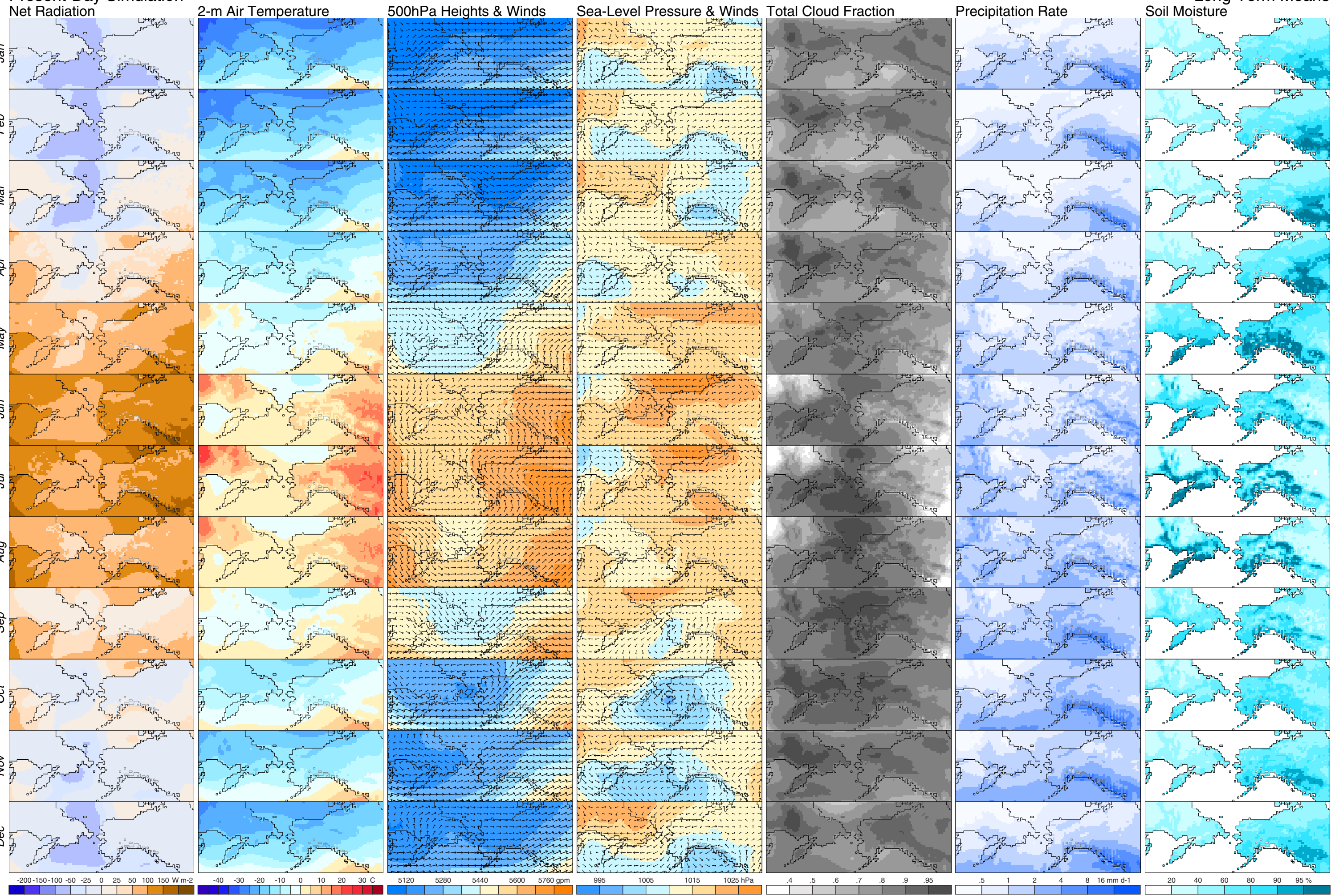
51

	<b>Long-term mean</b>	<b>Long-term mean difference (anomalies)</b>
<b>Radiative components</b>		
Net shortwave radiation, $K_{net}$	positive: toward surface (i.e., surface heating) negative: 0.0	positive: increased $K\downarrow$ or decreased albedo (e.g. sea-ice replaced by land) negative: decreased $K\downarrow$ or increased albedo (e.g. land replaced by sea-ice)
Net longwave radiation, $L_{net}$	positive: toward surface negative: from surface (i.e., surface cooling)	positive: increased $L\downarrow$ or decreased $L\uparrow$ negative: decreased $L\downarrow$ or increased $L\uparrow$
<b>Non-radiative components</b>		
Sensible heat flux, $Q_H$	positive: heat flow from surface to atmosphere negative: heat flow from atmosphere to surface	positive: increased heating of atmosphere by surface or decreased heating of surface by atmosphere negative: decreased heating of atmosphere by surface or increased heating of surface by atmosphere
Latent heat flux, $Q_E$	positive: heat flow (via $E$ or $ET$ ) from surface to atmosphere negative: heat flow (via condensation) from atmosphere to surface	positive: increased $E$ or $ET$ (or decreased condensation) negative: decreased $E$ or $ET$ (or increased condensation)
Substrate heat flux, $Q_G = \Delta Q_S$	positive: heat flow from surface into substrate (land or water), i.e., into storage negative: heat flow from substrate to surface, i.e., from storage	positive: increased heat flow from surface to substrate (or increased flow into storage) negative: decreased heat flow from surface to substrate (or decreased flow into storage)

52

Present-Day Simulation

Long-Term Means



Present-Day Simulation

Long-Term Means

Net Shortwave Radiation

Net Longwave Radiation

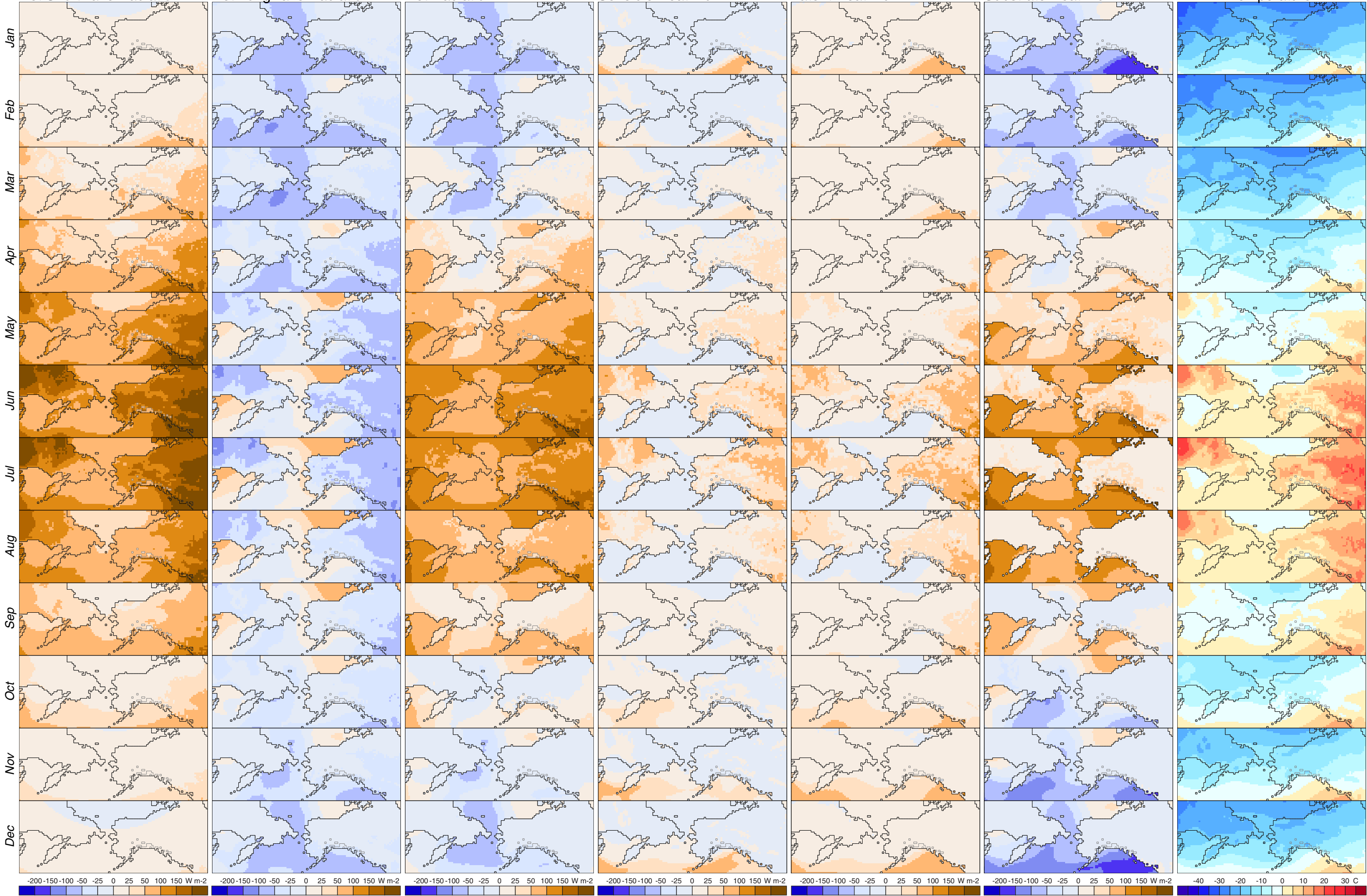
Net Radiation

Sensible Heat Flux

Latent Heat Flux

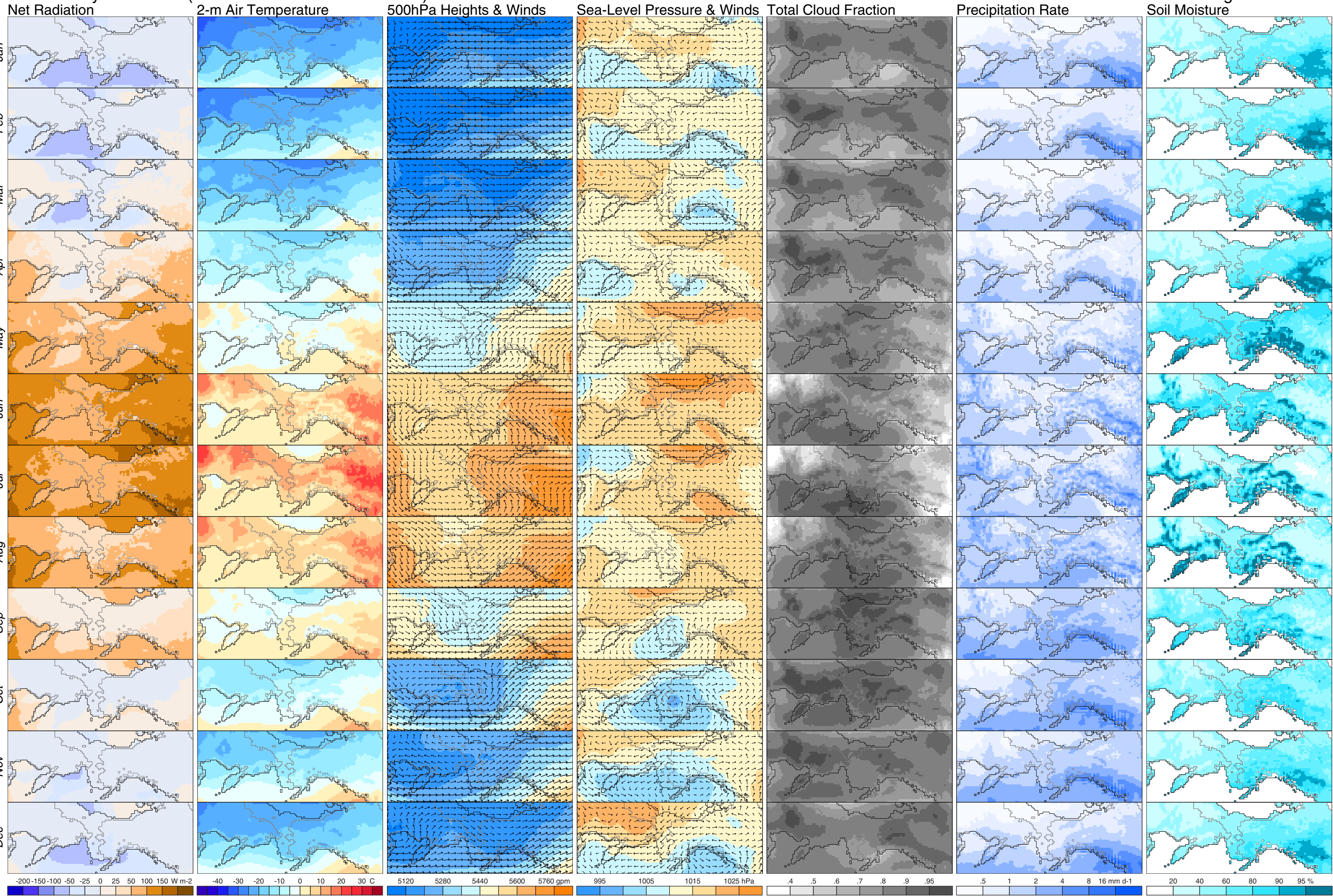
Substrate Heat Flux

2-m Air Temperature



Present-Day Simulation (with 11 ka Continental Outlines)

Long-Term Means



Present-Day Simulation (with 11 ka Continental Outlines)

Long-Term Means

Net Shortwave Radiation

Net Longwave Radiation

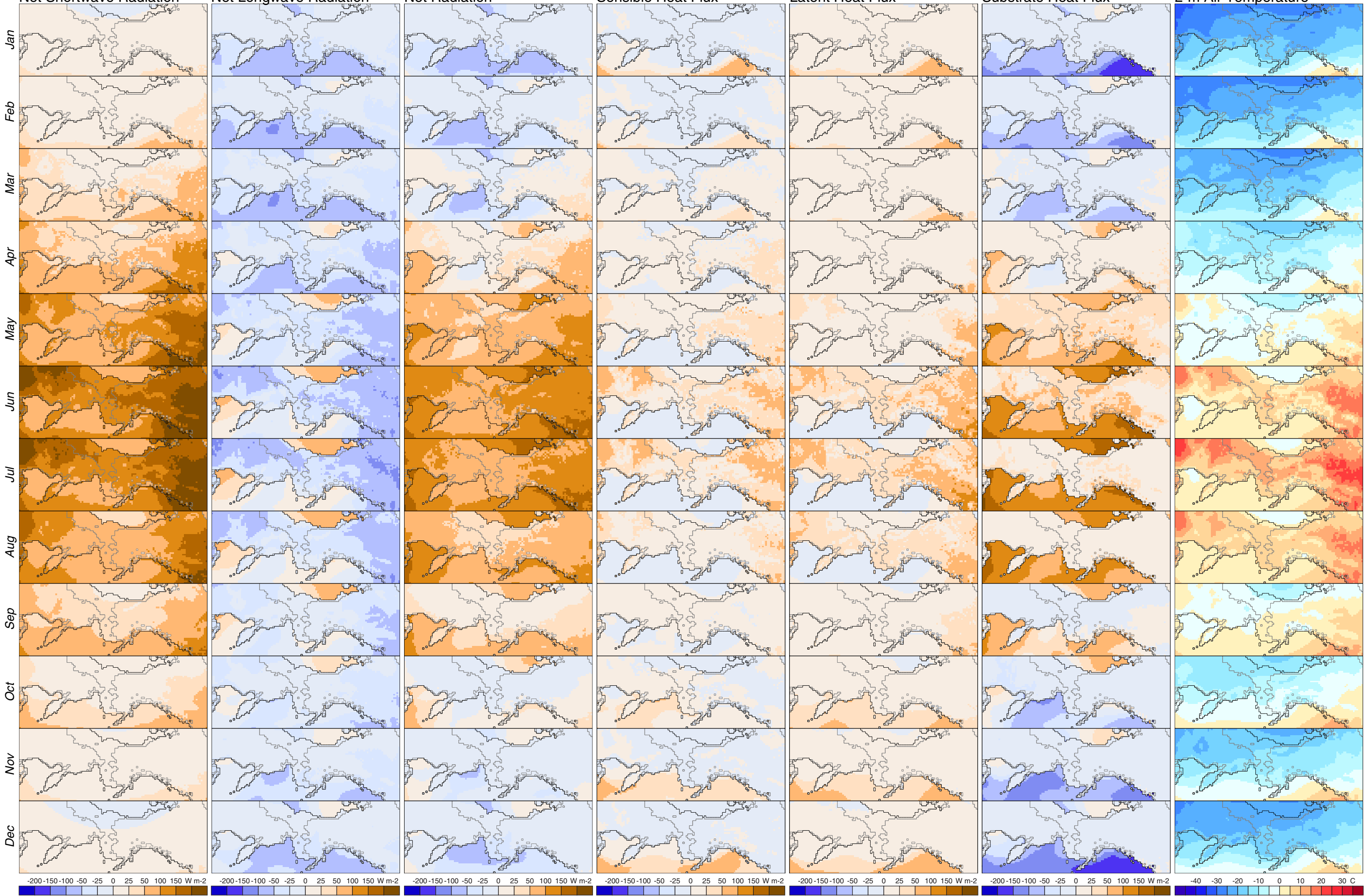
Net Radiation

Sensible Heat Flux

Latent Heat Flux

Substrate Heat Flux

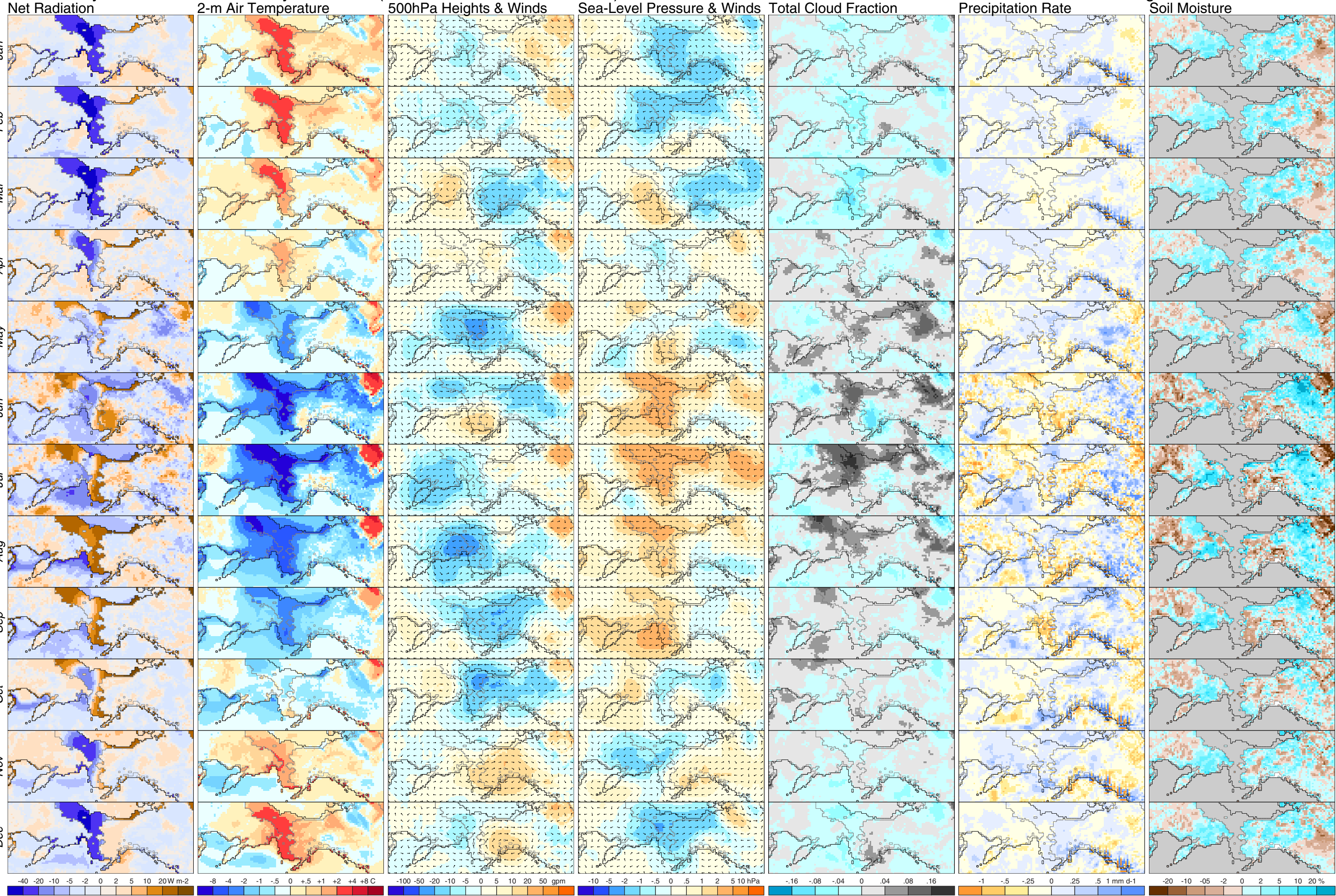
2-m Air Temperature



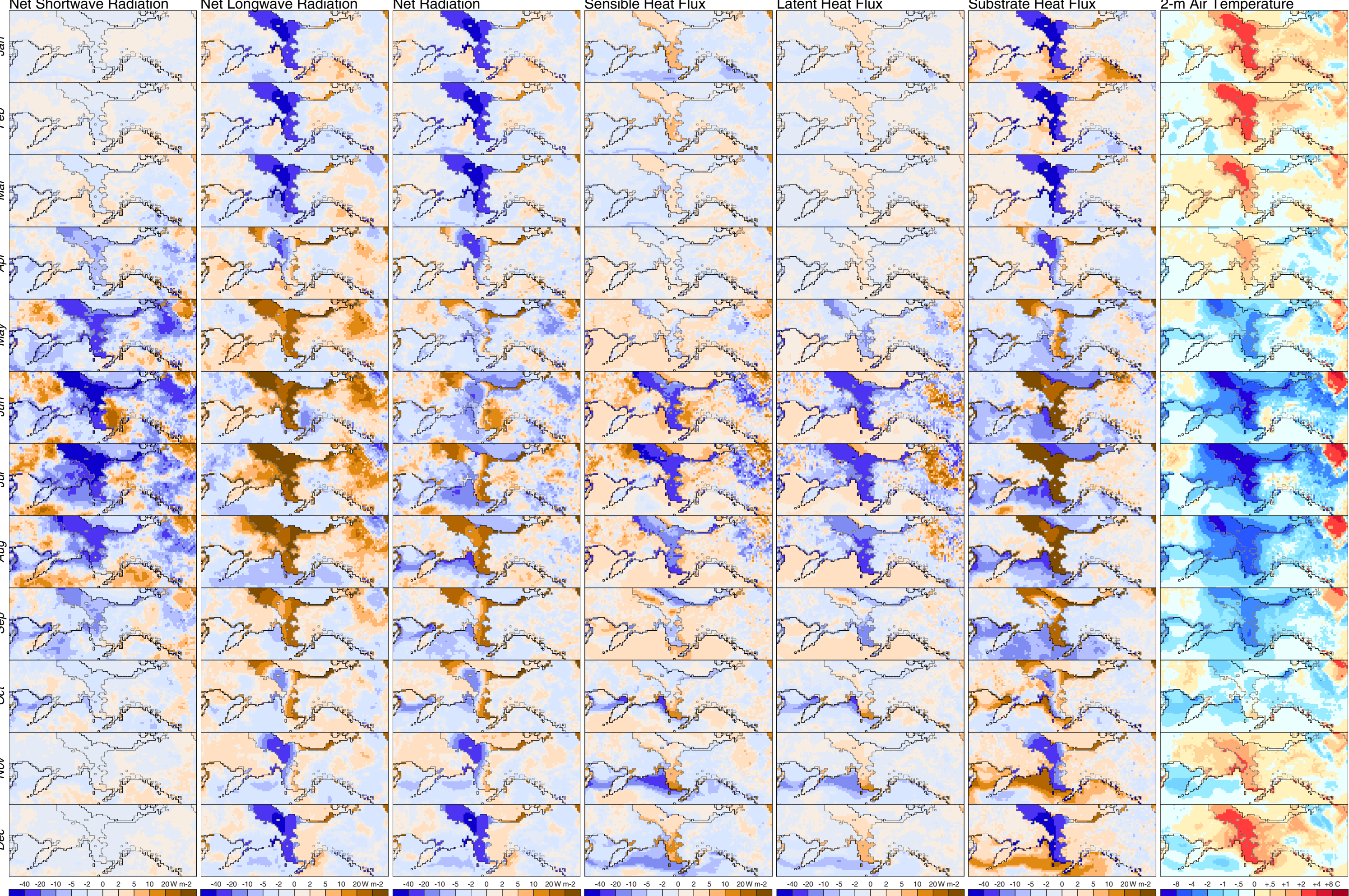


Present-Day Simulation - Present-Day Simulation (with 11 ka Continental Outlines)

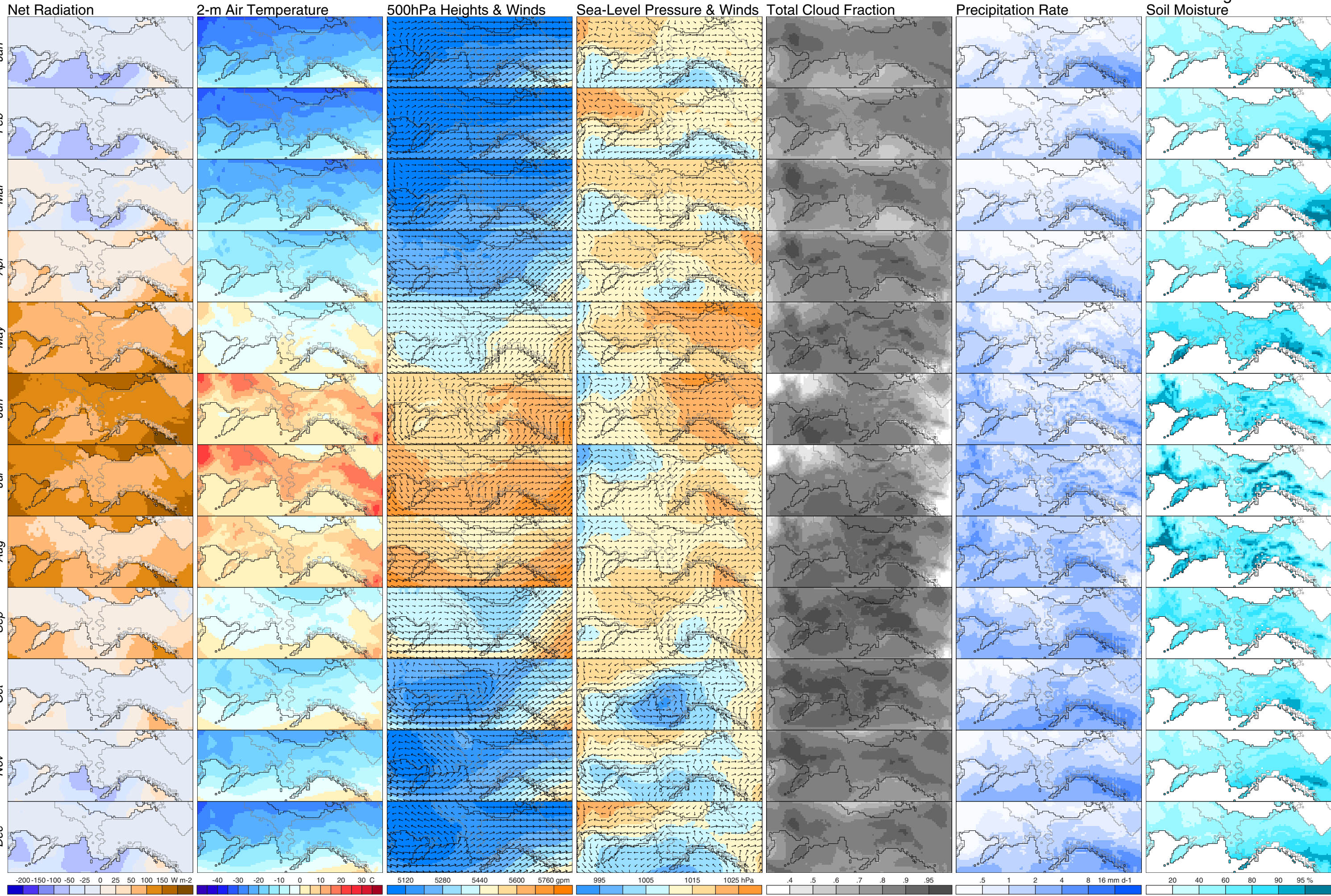
Long-Term Mean Differences



Present-Day Simulation - Present-Day Simulation (with 11 ka Continental Outlines) Long-Term Mean Differences



# 11 ka Control Simulation



# 11 ka Control Simulation

Net Shortwave Radiation

Net Longwave Radiation

Net Radiation

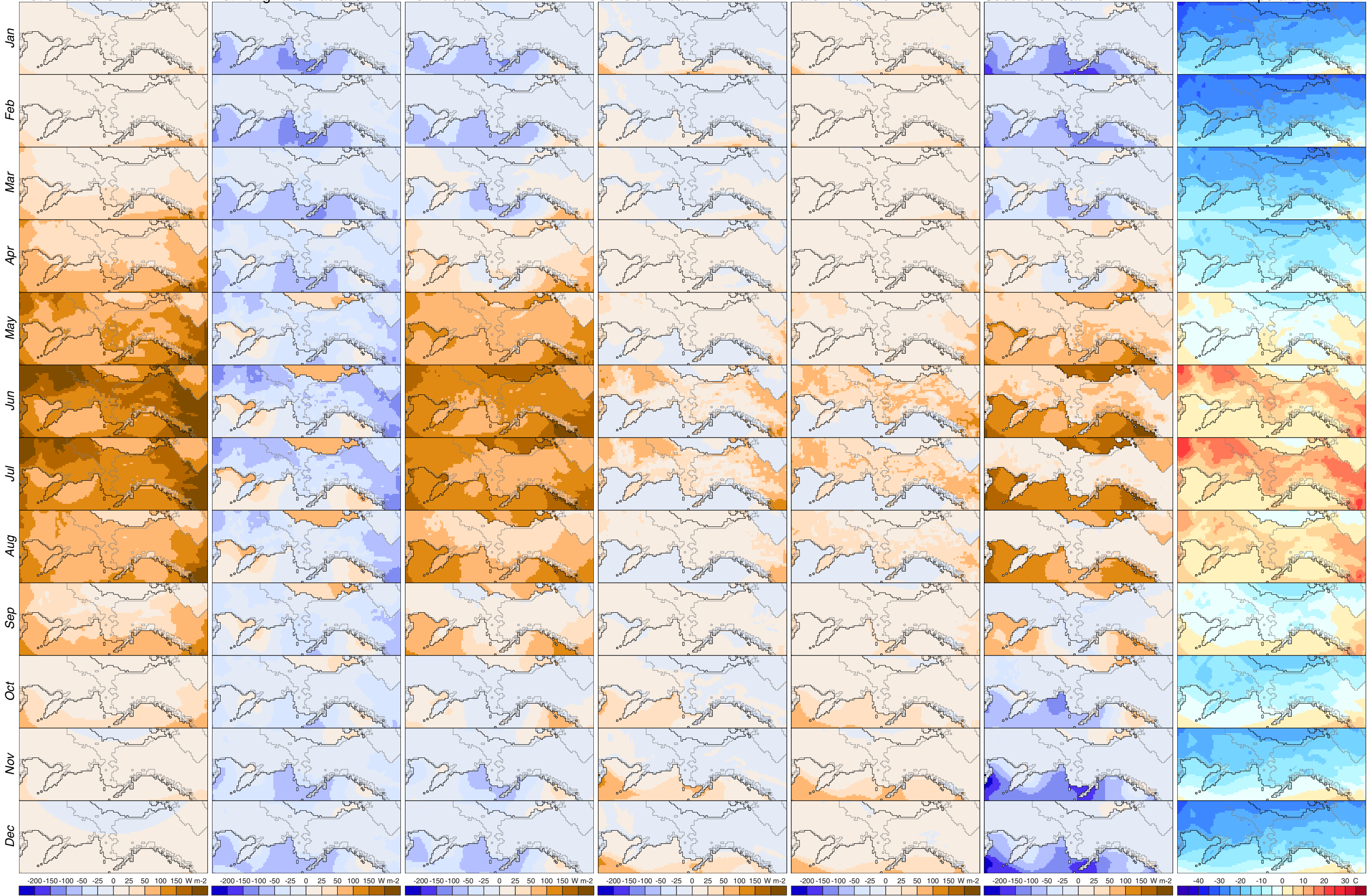
Sensible Heat Flux

Latent Heat Flux

Substrate Heat Flux

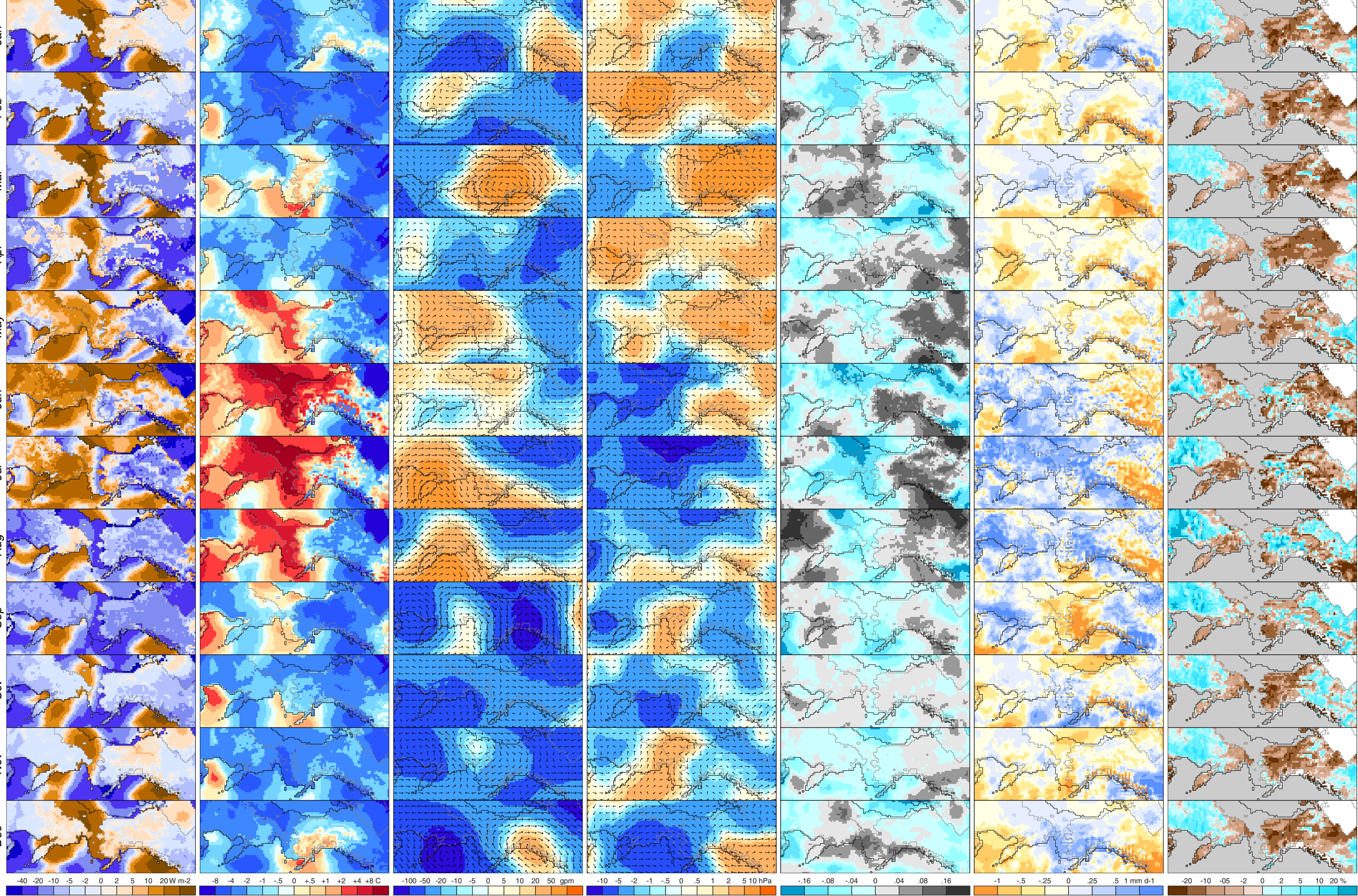
# Long-Term Means

2-m Air Temperature



11 ka Control Simulation - Present-Day Simulation

Long-Term Mean Differences



11 ka Control Simulation - Present-Day Simulation

Long-Term Mean Differences

Net Shortwave Radiation

Net Longwave Radiation

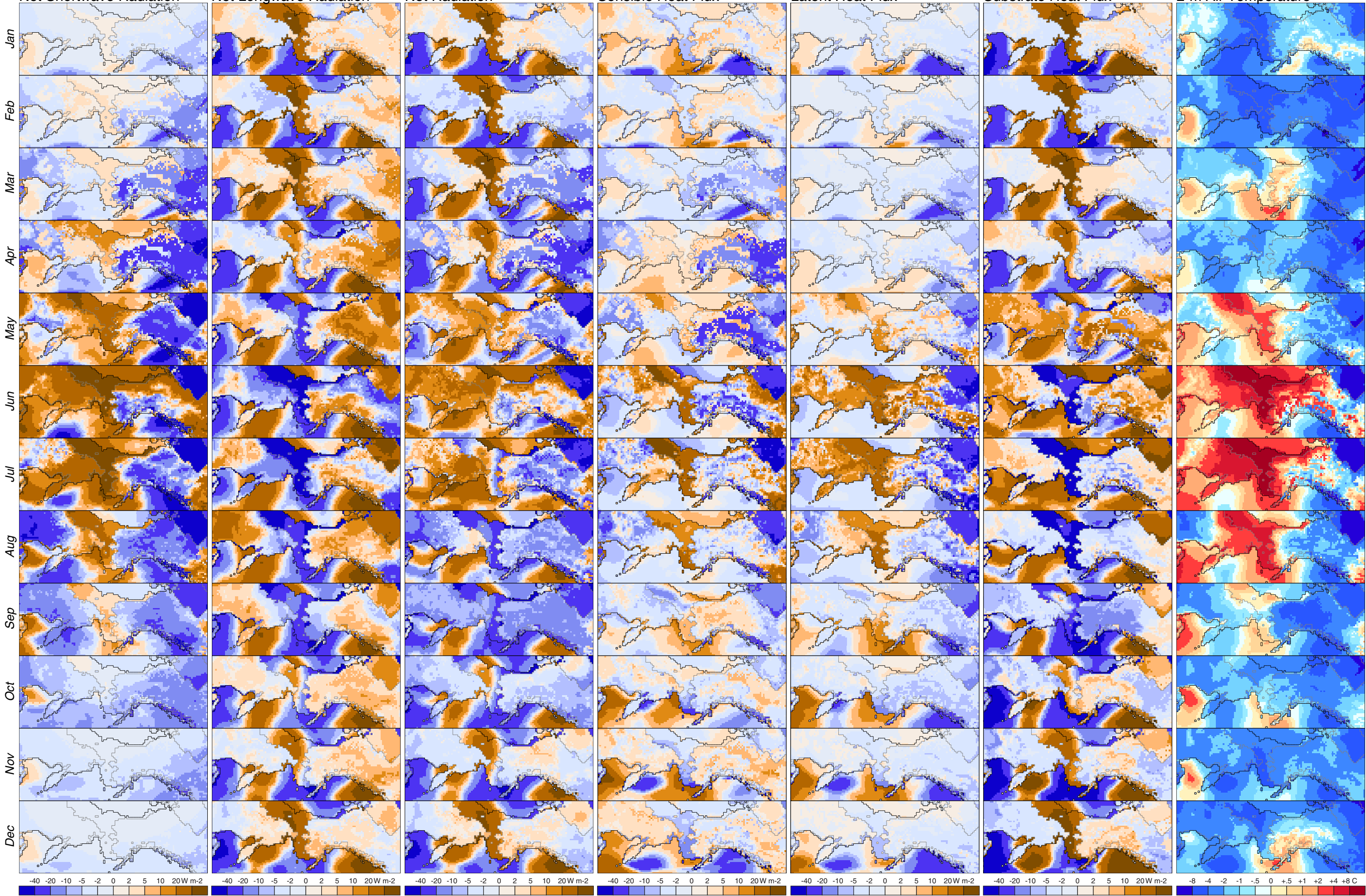
Net Radiation

Sensible Heat Flux

Latent Heat Flux

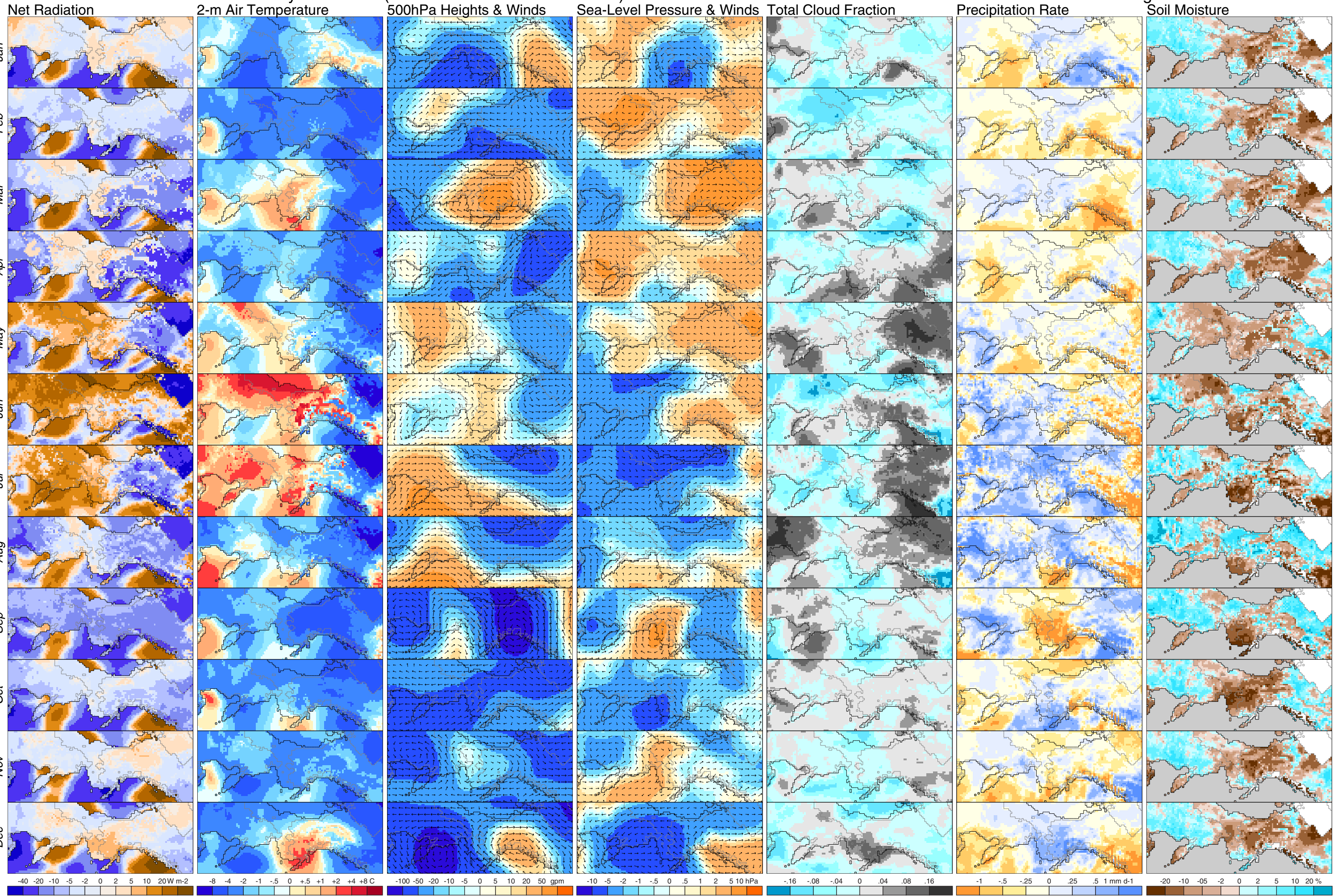
Substrate Heat Flux

2-m Air Temperature



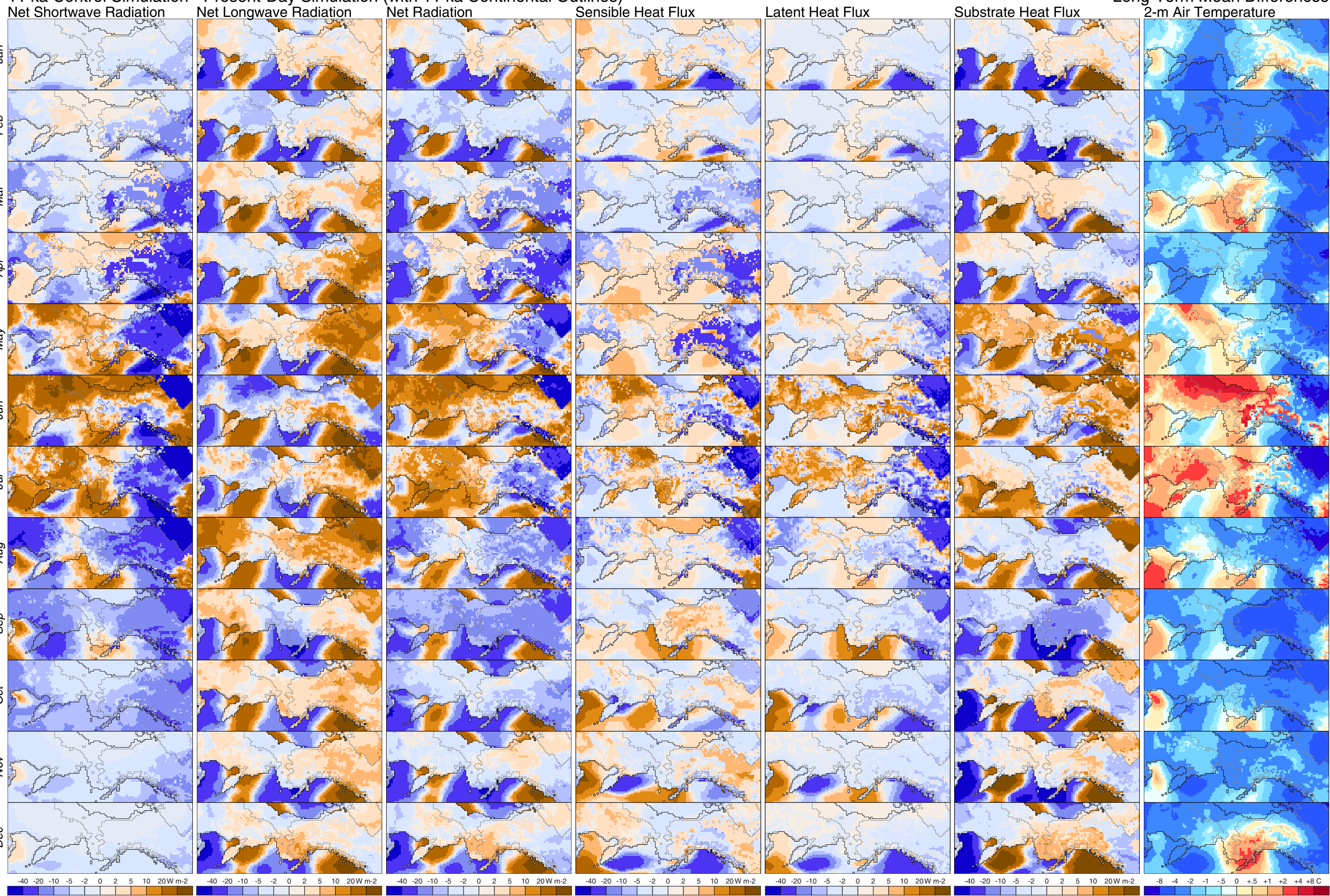
11 ka Control Simulation - Present-Day Simulation (with 11 ka Continental Outlines)

Long-Term Mean Differences



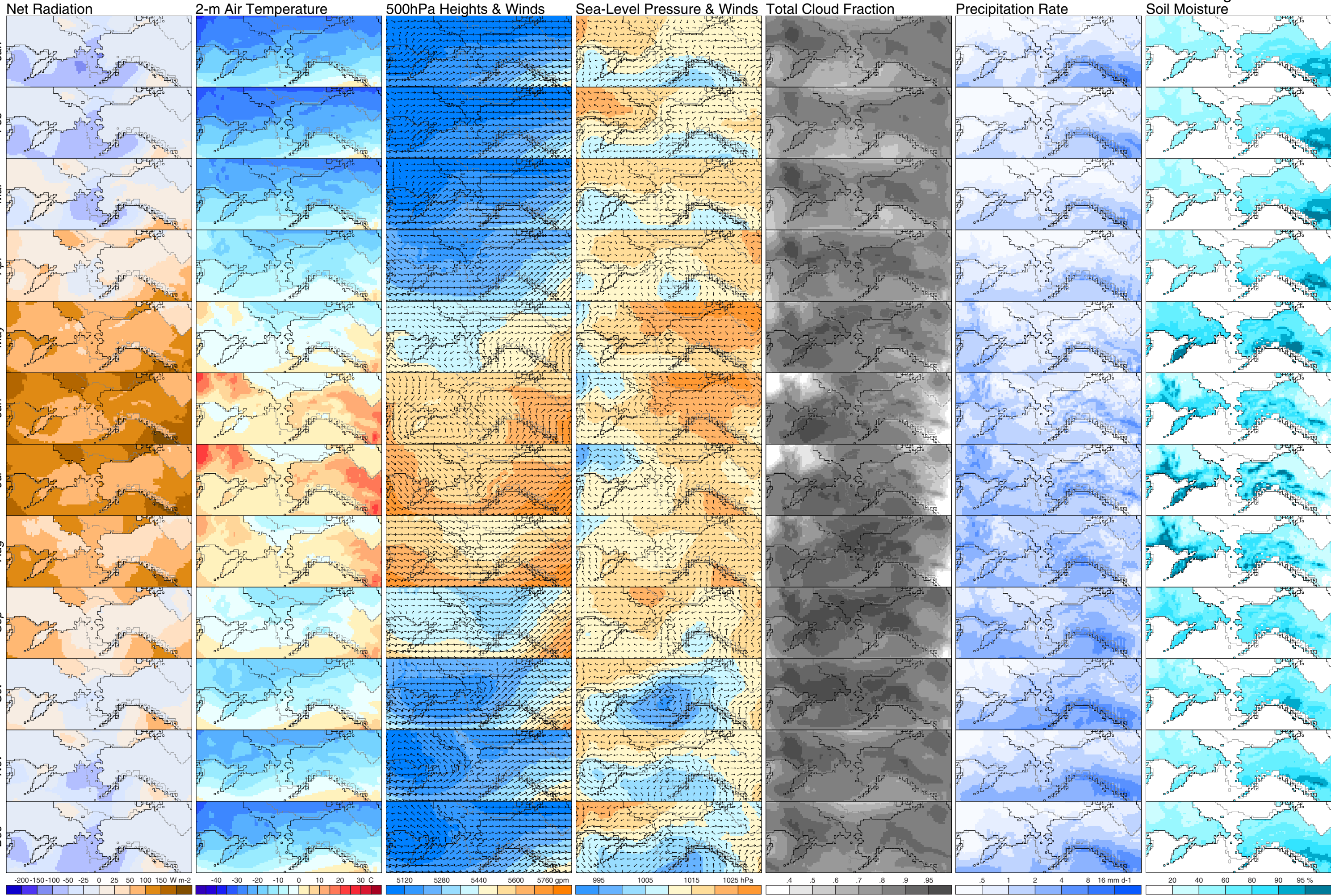
11 ka Control Simulation - Present-Day Simulation (with 11 ka Continental Outlines)

Long-Term Mean Differences





# 11 ka Sea-Level Simulation



# Long-Term Means

# 11 ka Sea-Level Simulation

Net Shortwave Radiation

Net Longwave Radiation

Net Radiation

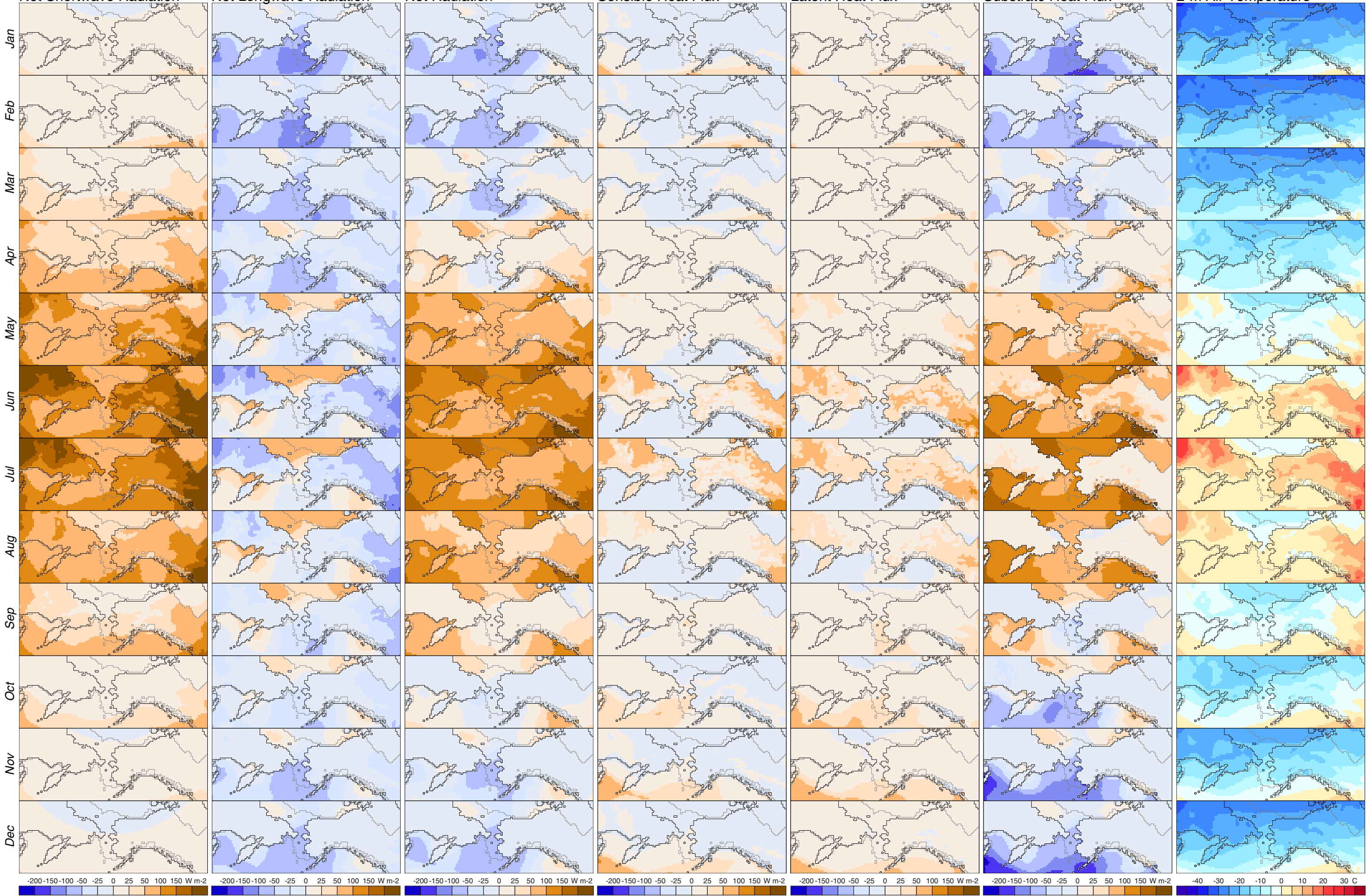
Sensible Heat Flux

Latent Heat Flux

Substrate Heat Flux

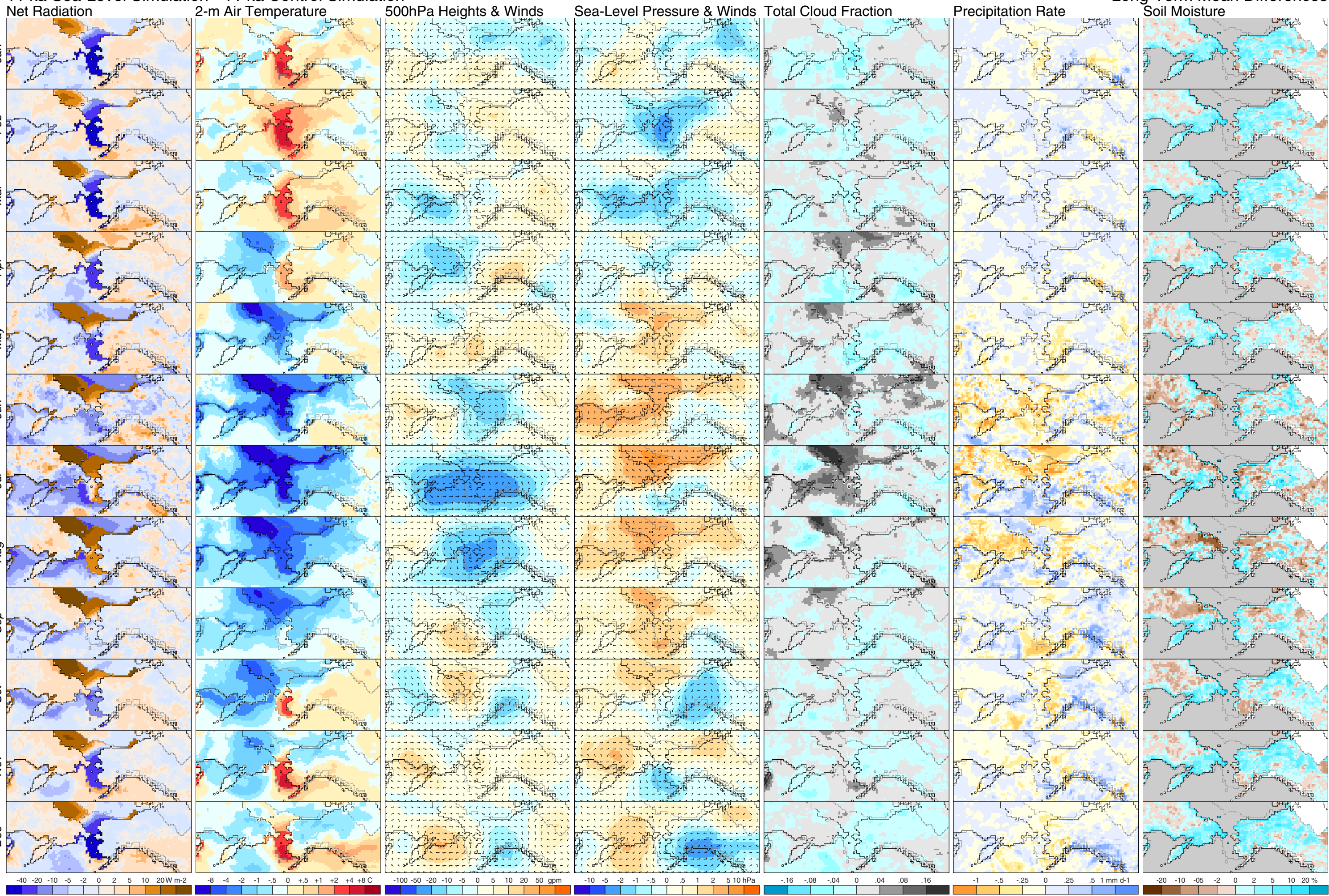
2-m Air Temperature

# Long-Term Means



11 ka Sea-Level Simulation - 11 ka Control Simulation

Long-Term Mean Differences



# 11 ka Sea-Level Simulation - 11 ka Control Simulation

# Long-Term Mean Differences

Net Shortwave Radiation

Net Longwave Radiation

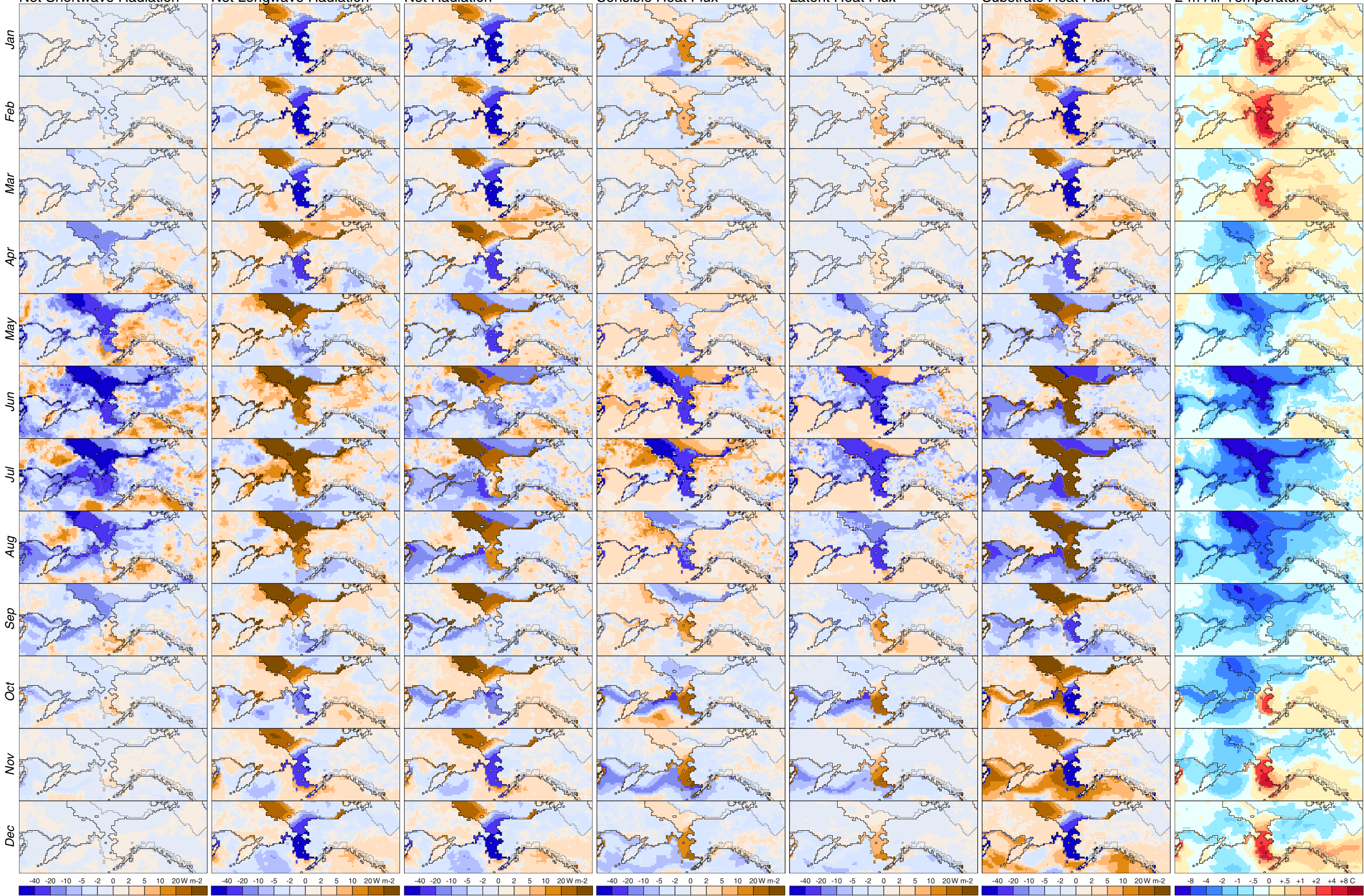
Net Radiation

Sensible Heat Flux

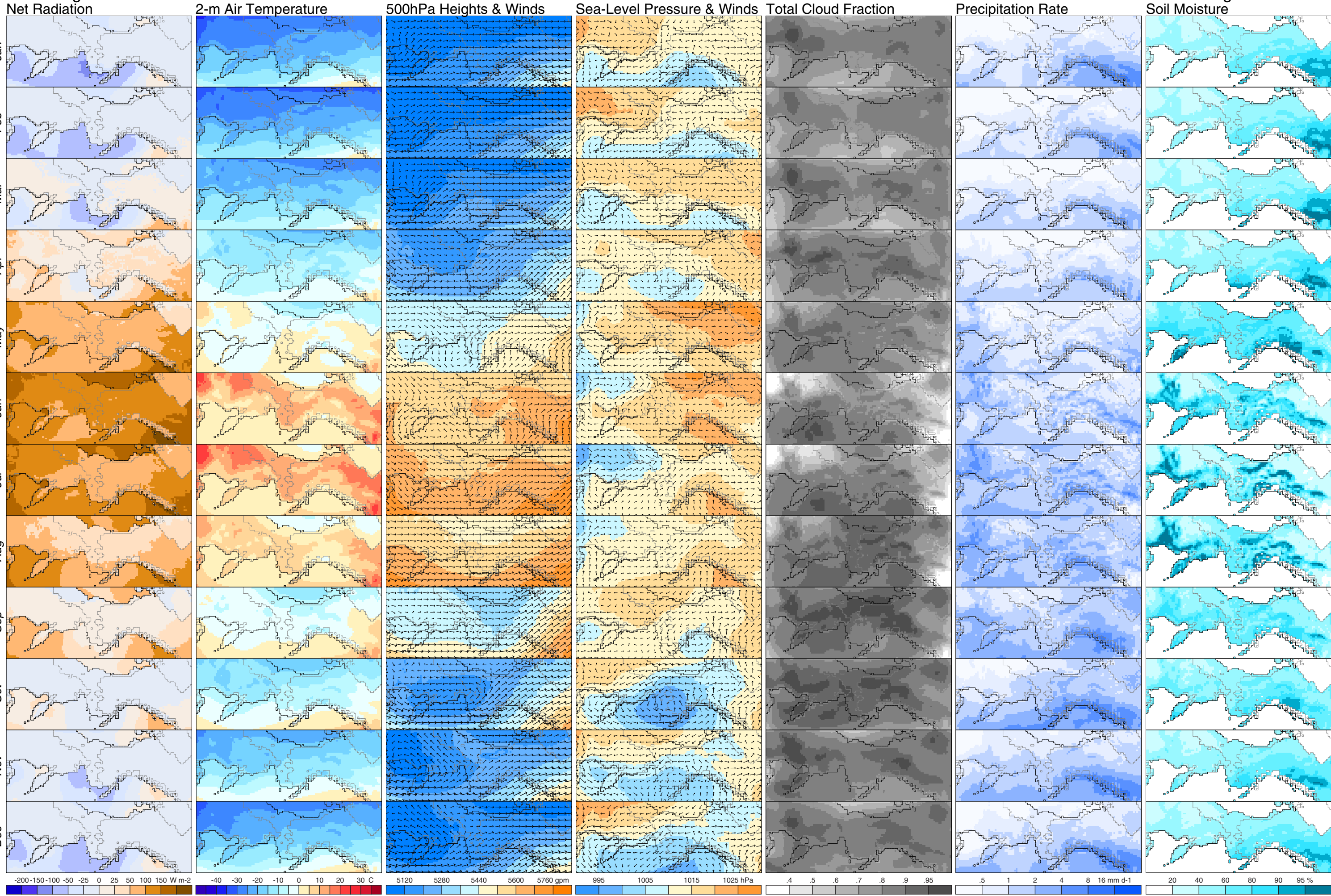
Latent Heat Flux

Substrate Heat Flux

2-m Air Temperature



# 11 ka Vegetation Simulation



# Long-Term Means

# 11 ka Vegetation Simulation

Net Shortwave Radiation

Net Longwave Radiation

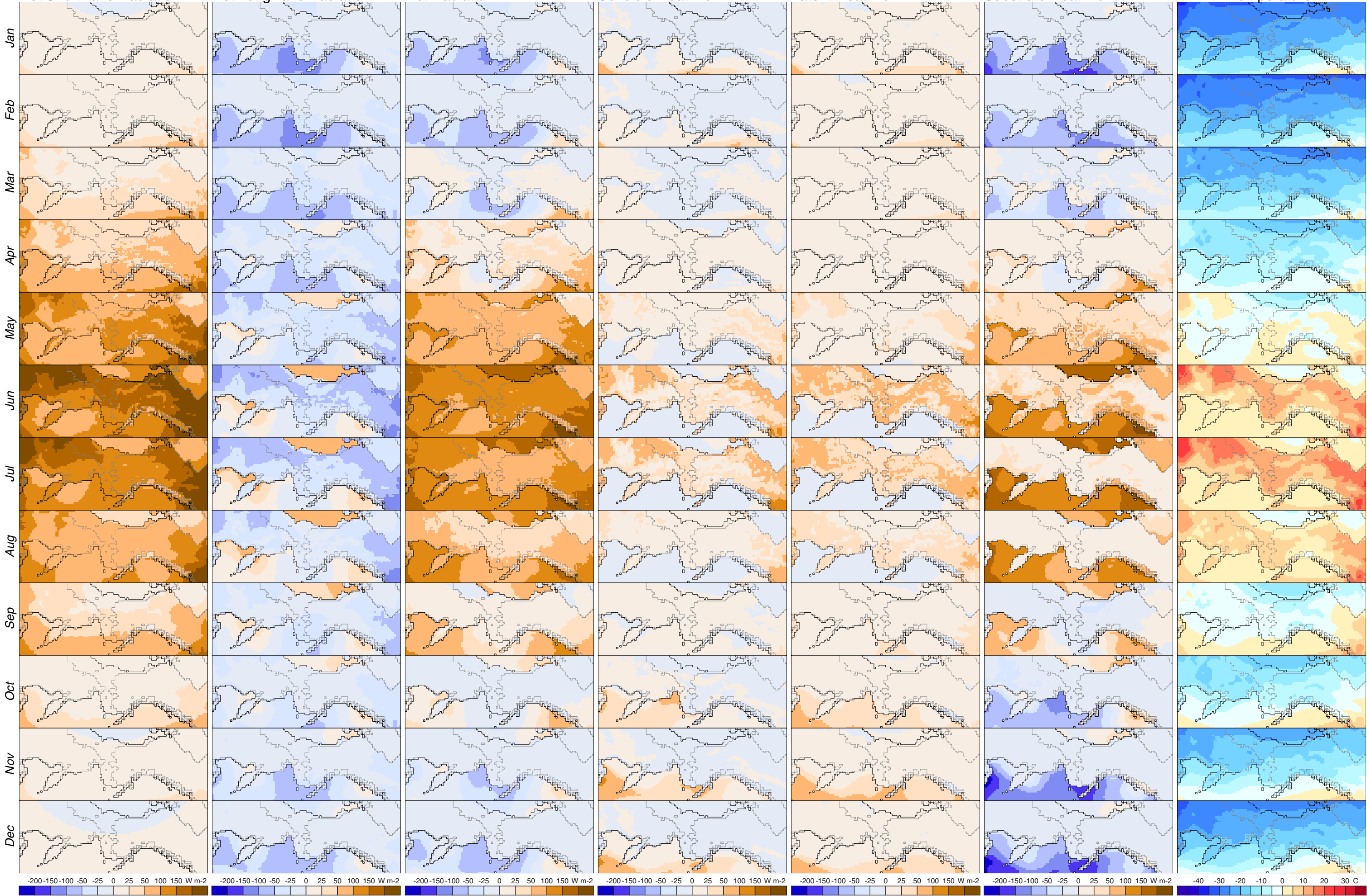
Net Radiation

Sensible Heat Flux

Latent Heat Flux

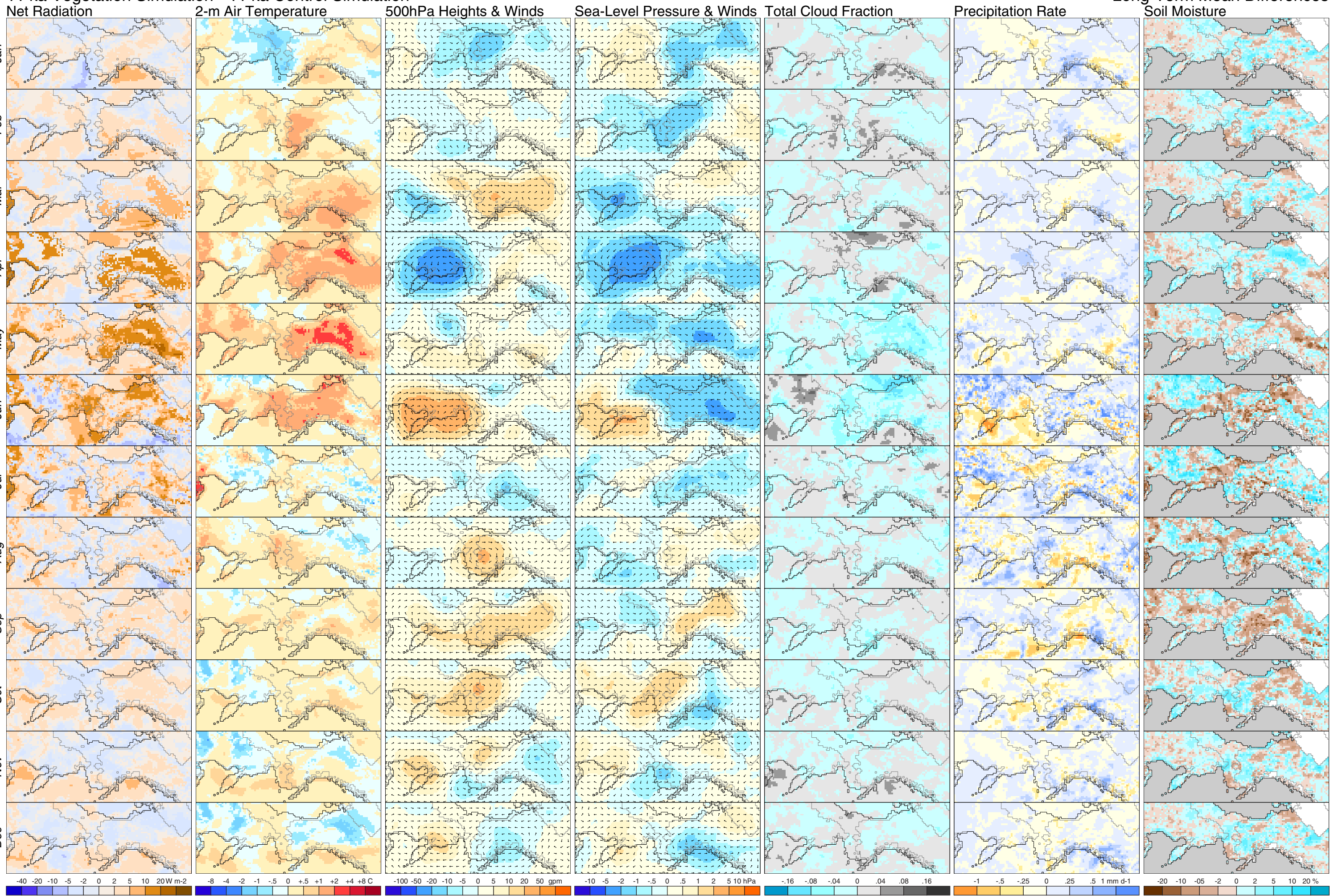
Substrate Heat Flux

Long-Term Means  
2-m Air Temperature



# 11 ka Vegetation Simulation - 11 ka Control Simulation

# Long-Term Mean Differences



# 11 ka Vegetation Simulation - 11 ka Control Simulation

# Long-Term Mean Differences

Net Shortwave Radiation

Net Longwave Radiation

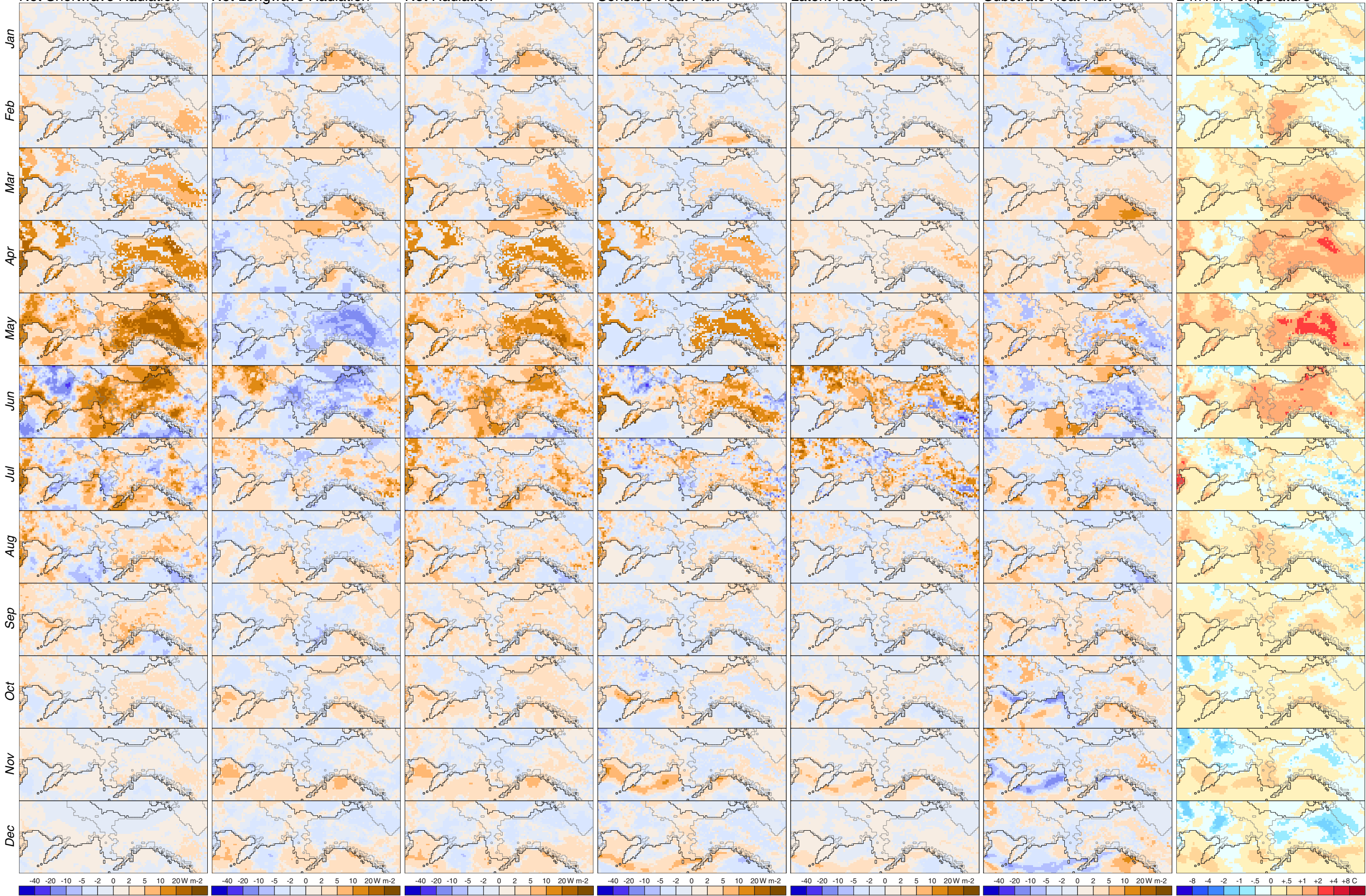
Net Radiation

Sensible Heat Flux

Latent Heat Flux

Substrate Heat Flux

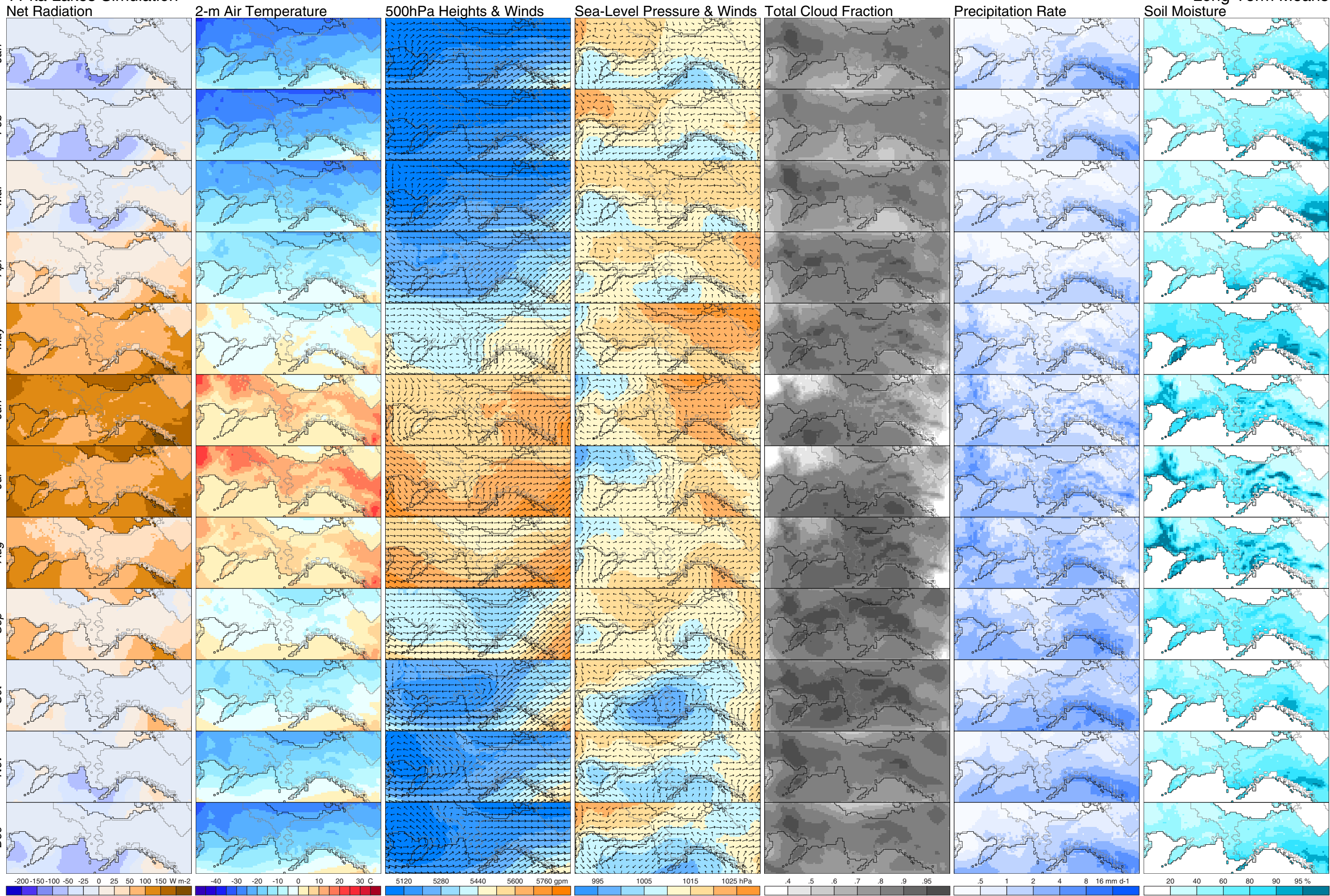
2-m Air Temperature





# 11 ka Lakes Simulation

# Long-Term Means



11 ka Lakes Simulation

Long-Term Means

Net Shortwave Radiation

Net Longwave Radiation

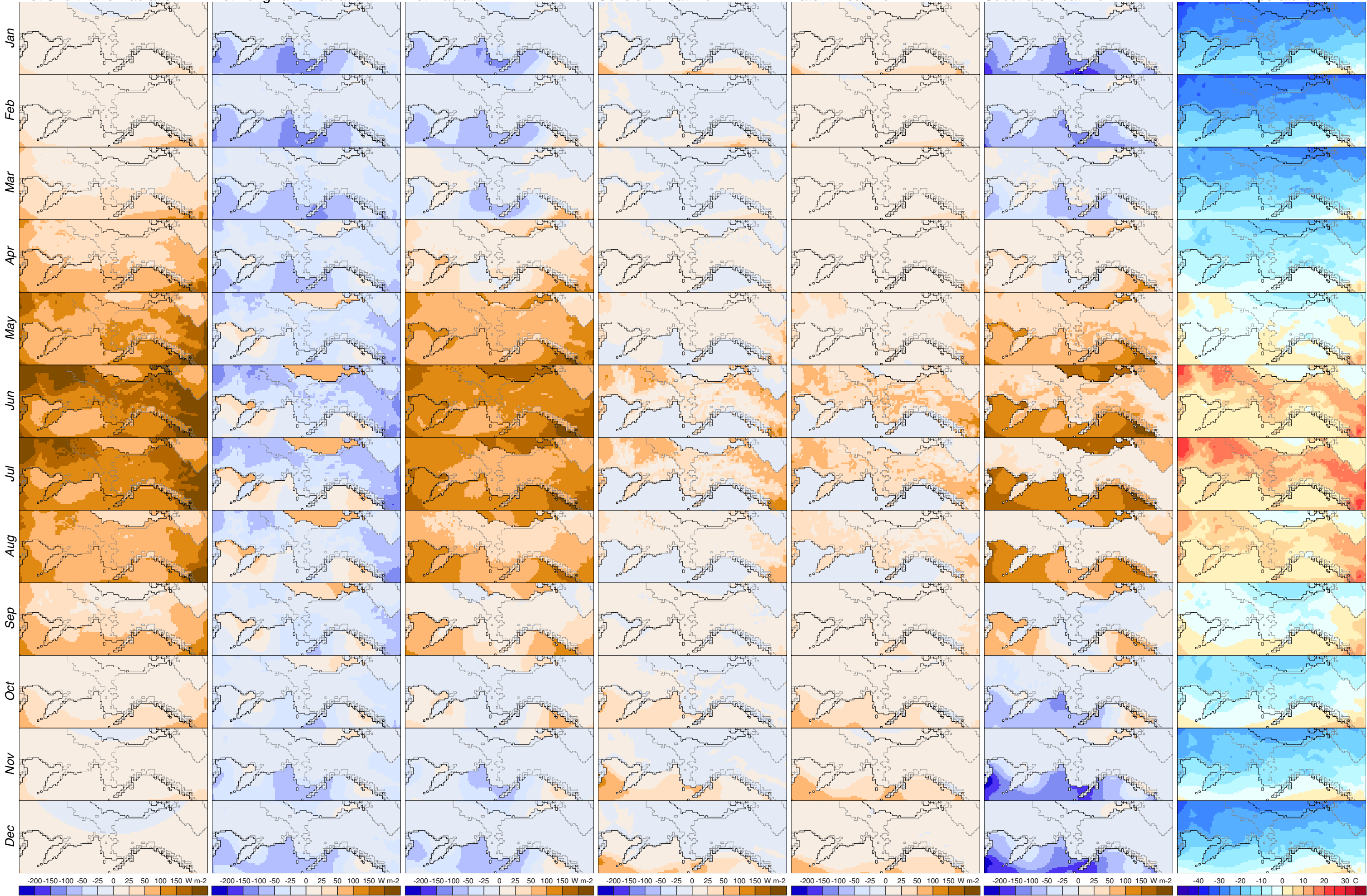
Net Radiation

Sensible Heat Flux

Latent Heat Flux

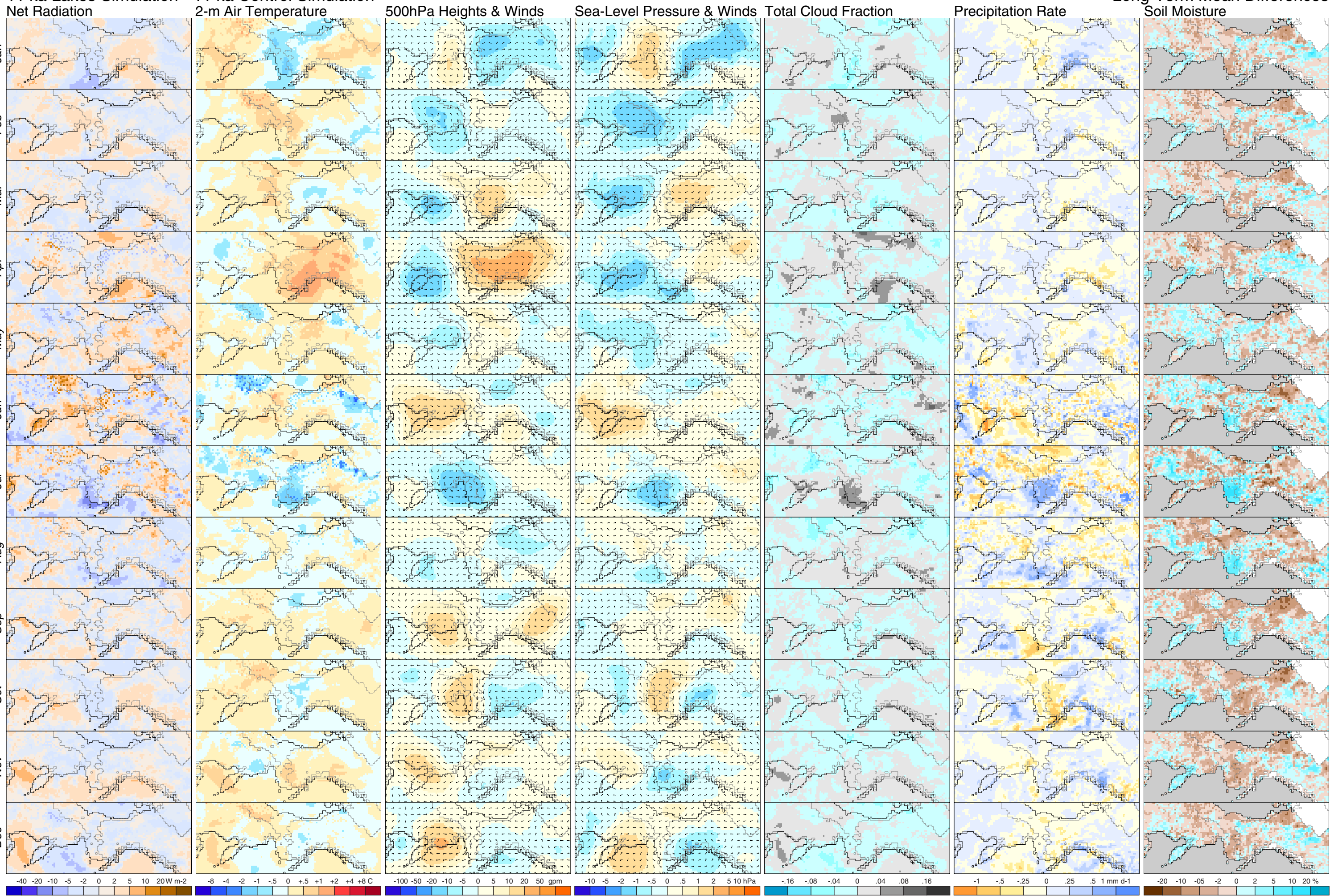
Substrate Heat Flux

2-m Air Temperature



11 ka Lakes Simulation - 11 ka Control Simulation

Long-Term Mean Differences



# 11 ka Lakes Simulation - 11 ka Control Simulation

Net Shortwave Radiation

Net Longwave Radiation

Net Radiation

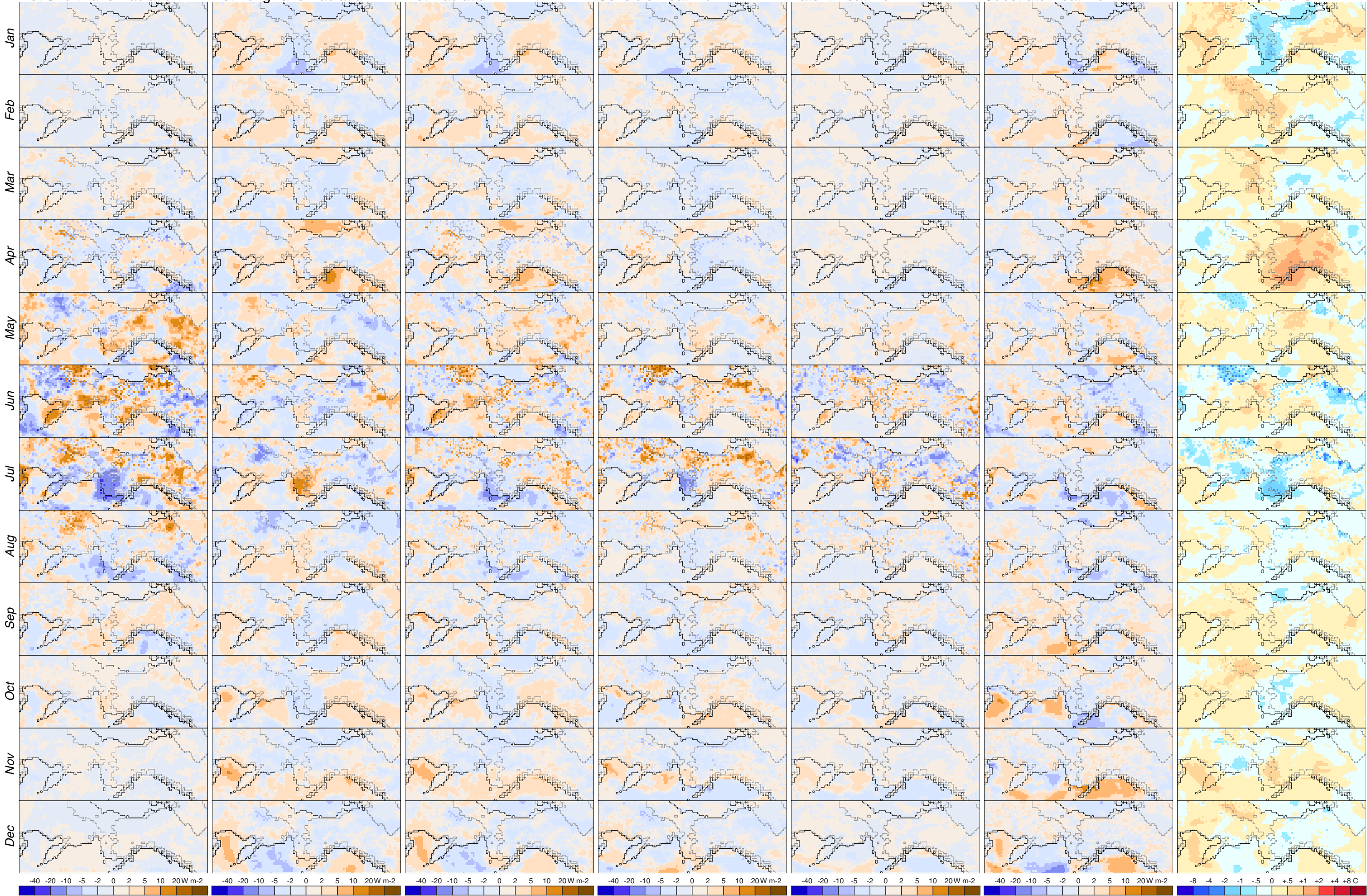
Sensible Heat Flux

Latent Heat Flux

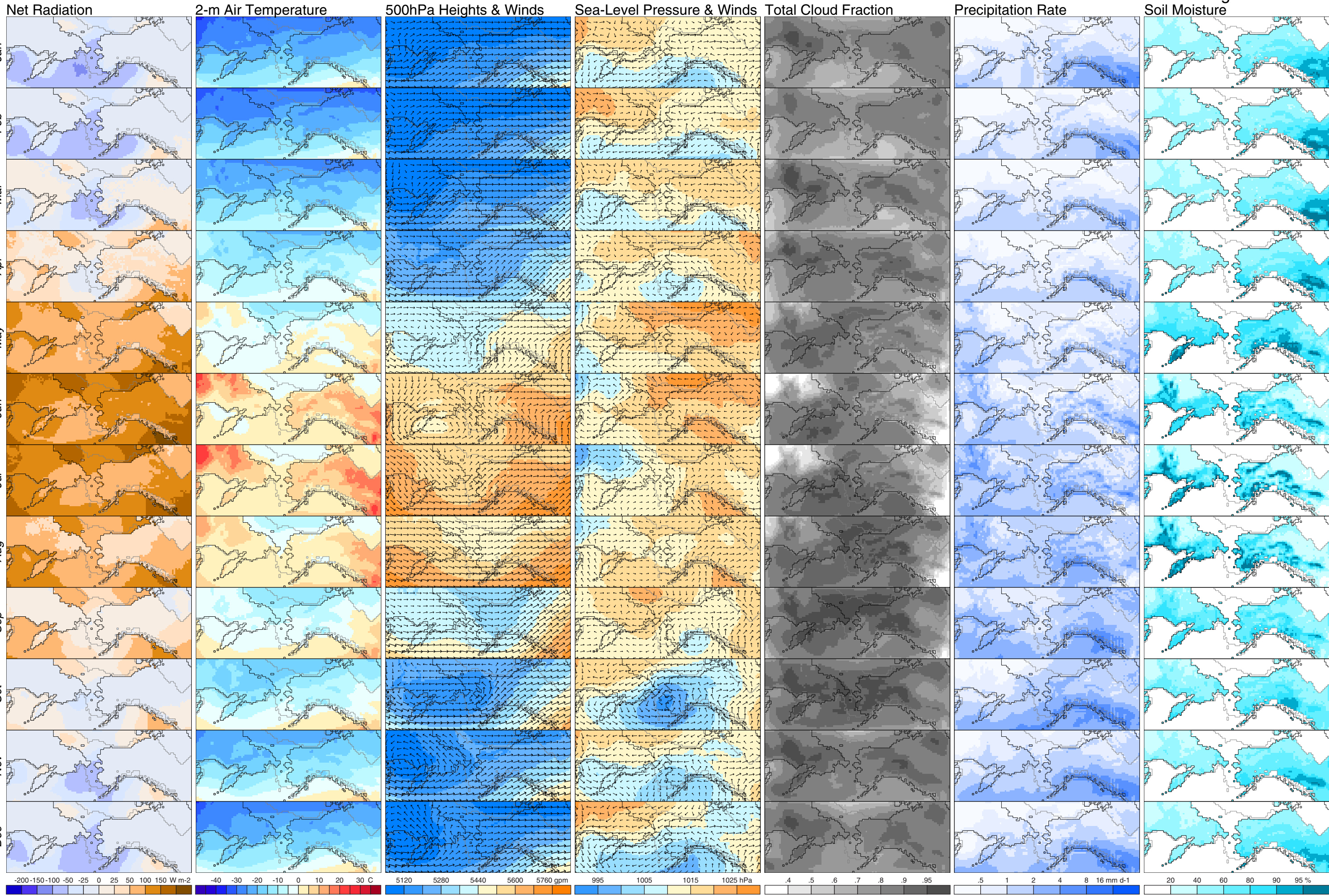
Substrate Heat Flux

# Long-Term Mean Differences

2-m Air Temperature



# 11 ka All Simulation



11 ka All Simulation

Net Shortwave Radiation

Net Longwave Radiation

Net Radiation

Sensible Heat Flux

Latent Heat Flux

Substrate Heat Flux

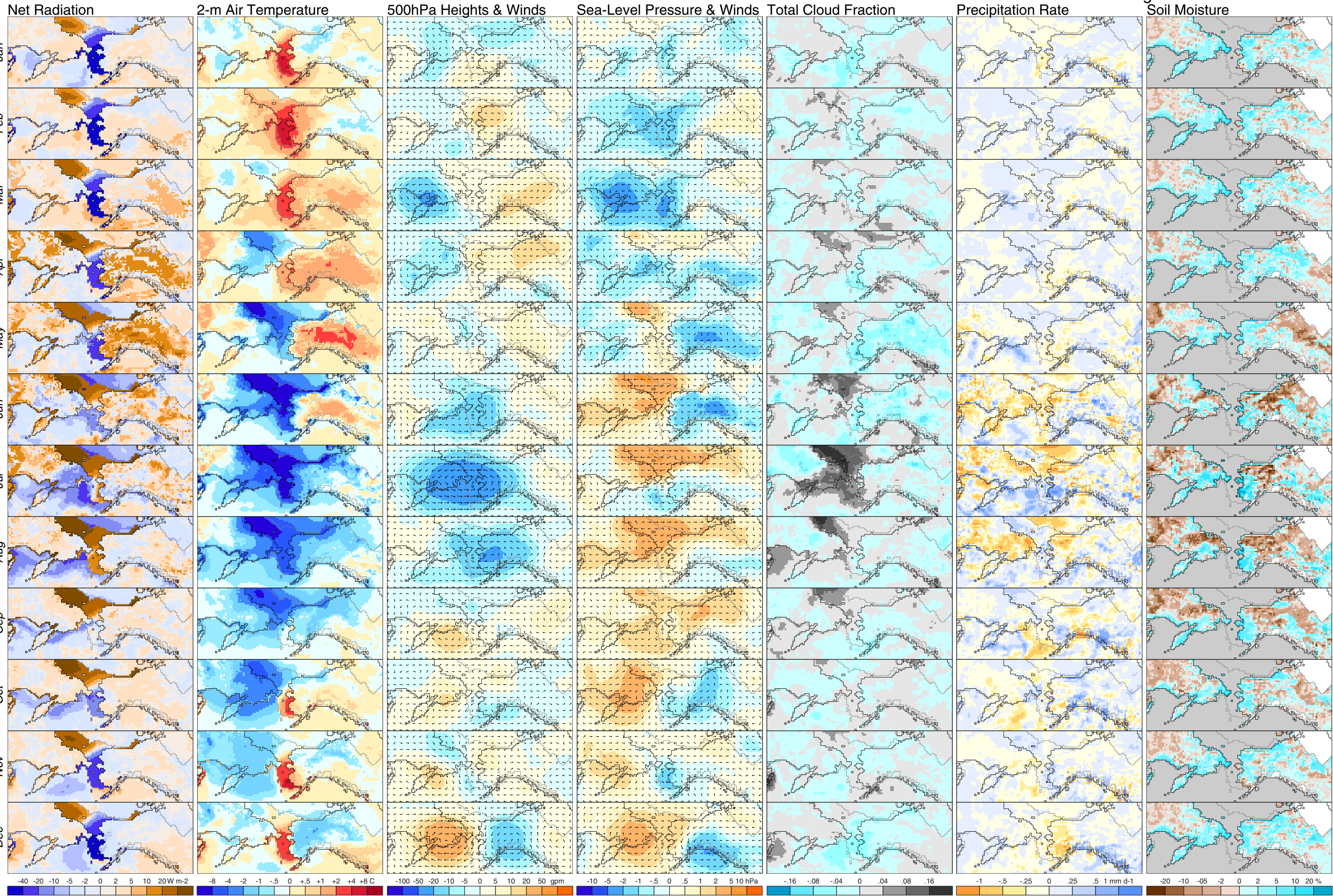
Long-Term Means

2-m Air Temperature



11 ka All Simulation - 11 ka Control Simulation

Long-Term Mean Differences



11 ka All Simulation - 11 ka Control Simulation

Long-Term Mean Differences

Net Shortwave Radiation

Net Longwave Radiation

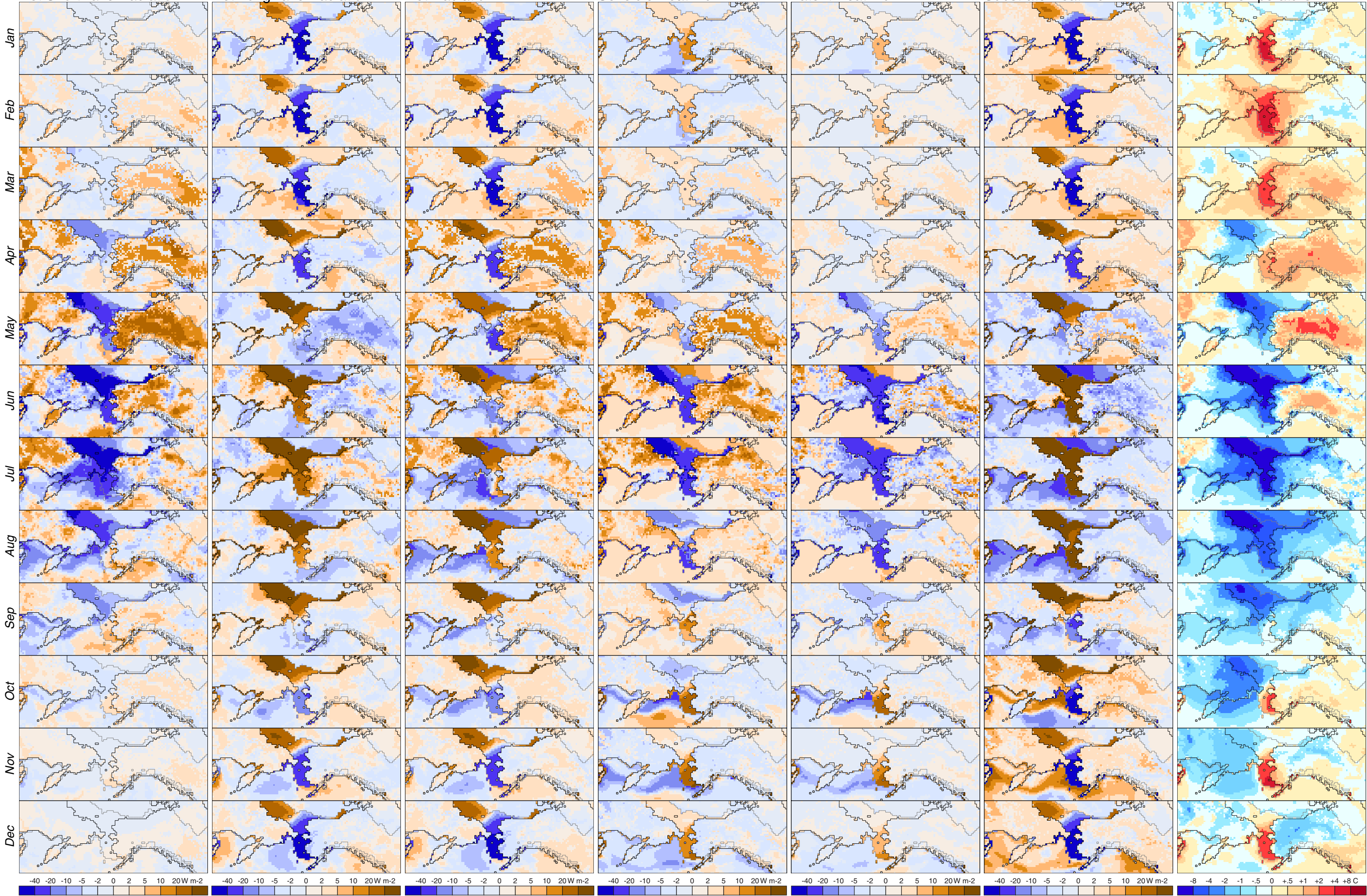
Net Radiation

Sensible Heat Flux

Latent Heat Flux

Substrate Heat Flux

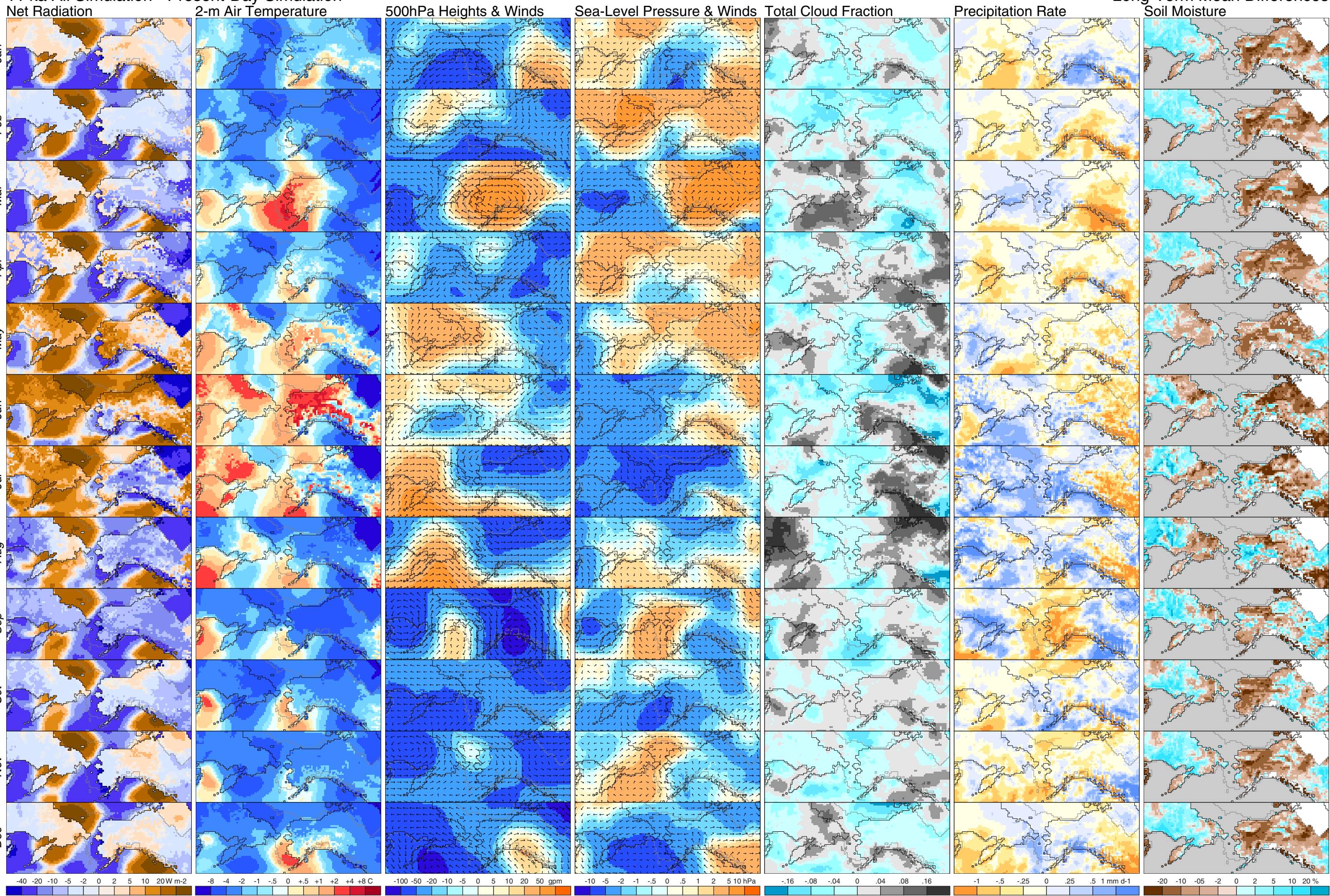
2-m Air Temperature





# 11 ka All Simulation - Present-Day Simulation

# Long-Term Mean Differences



# 11 ka All Simulation - Present-Day Simulation

# Long-Term Mean Differences

Net Shortwave Radiation

Net Longwave Radiation

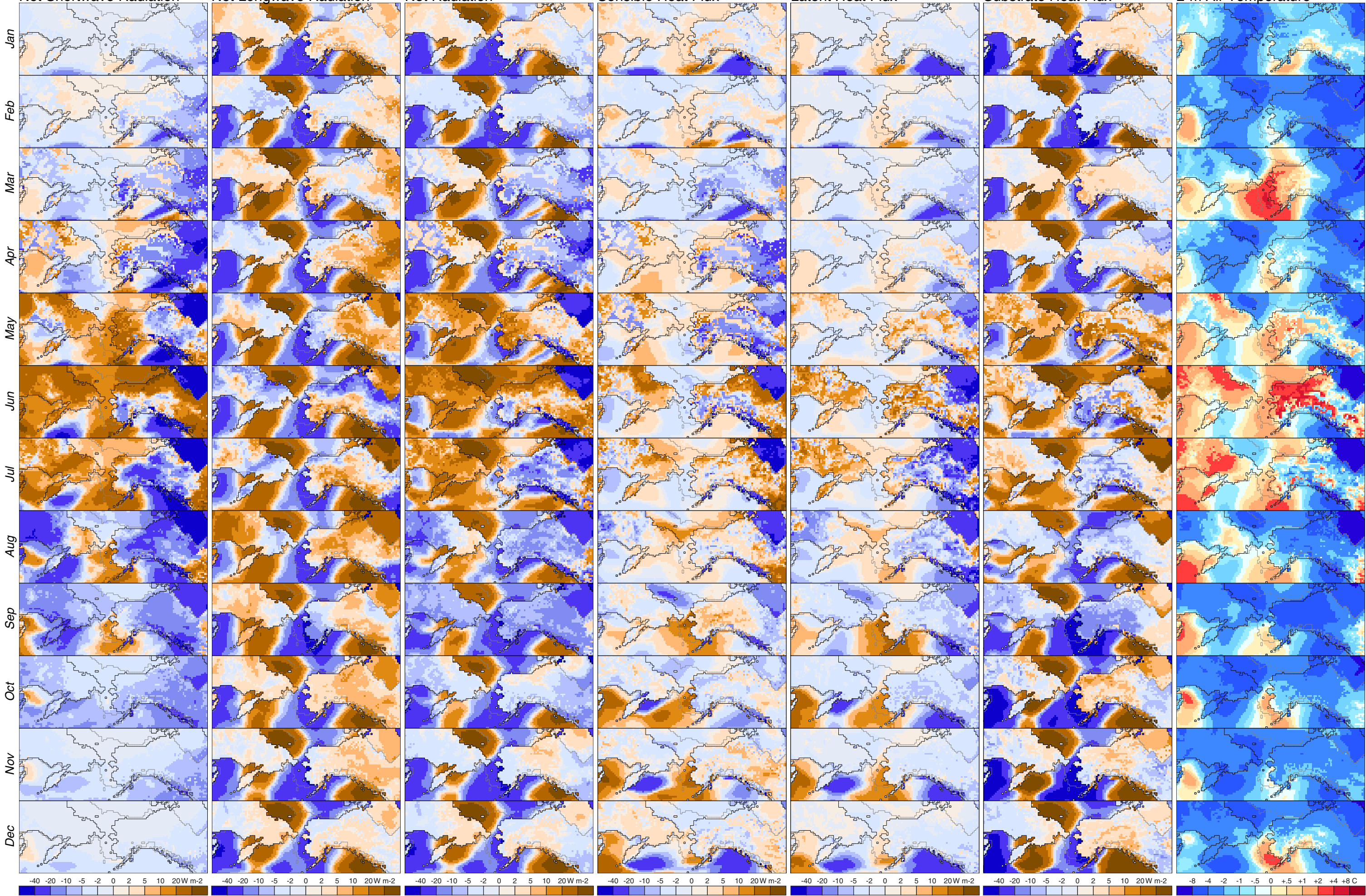
Net Radiation

Sensible Heat Flux

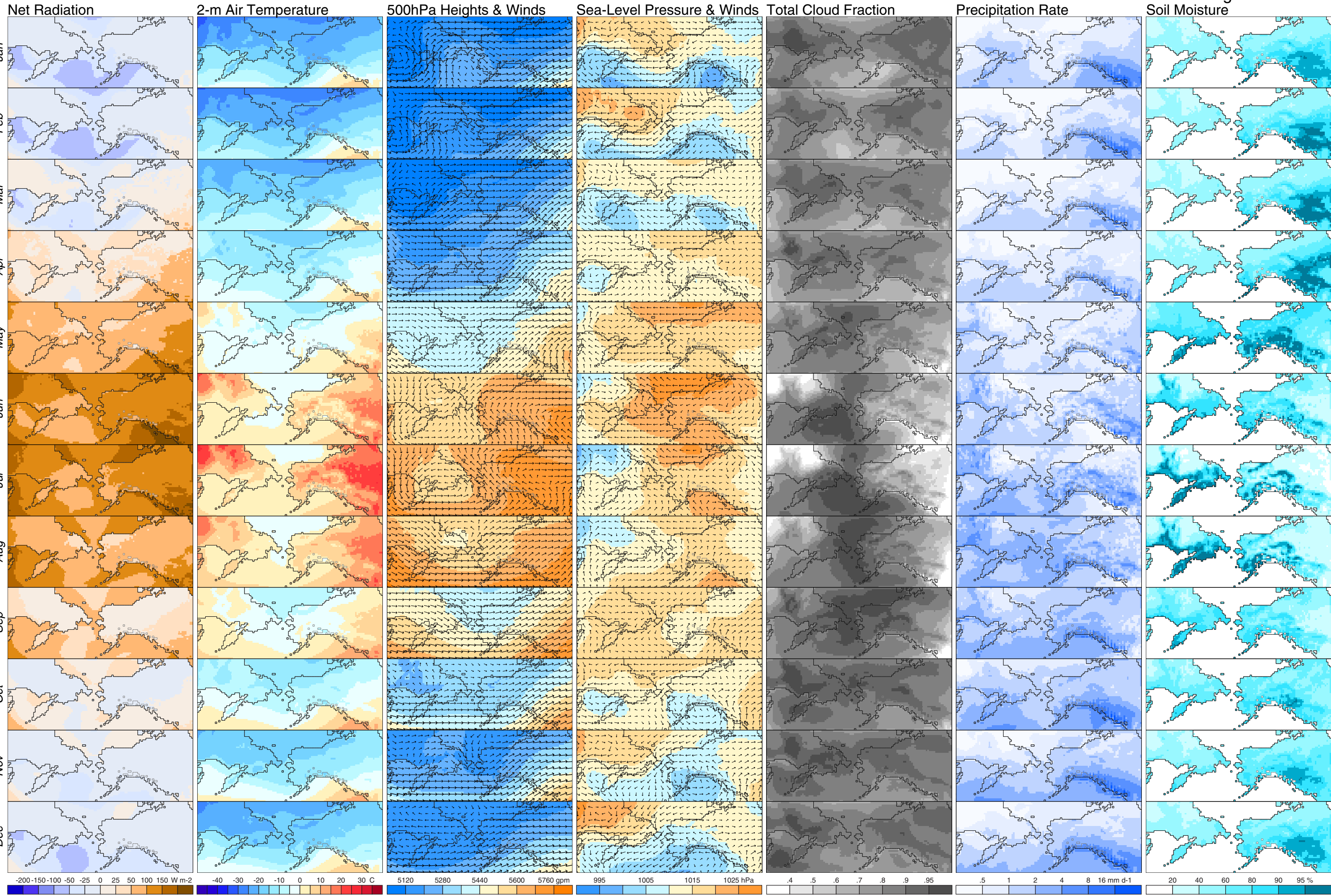
Latent Heat Flux

Substrate Heat Flux

2-m Air Temperature



# 6 ka Simulation



# 6 ka Simulation

Net Shortwave Radiation

Net Longwave Radiation

Net Radiation

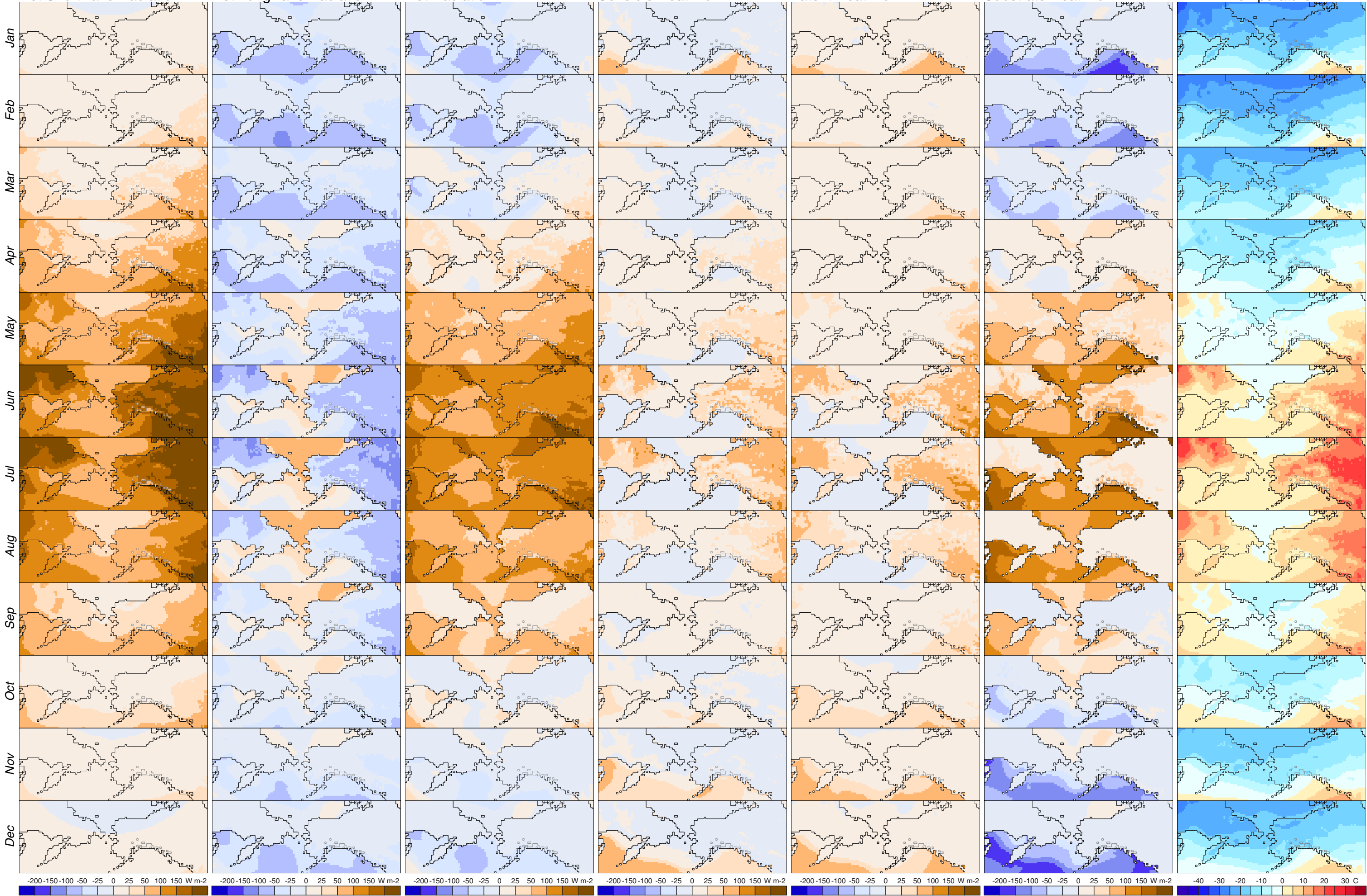
Sensible Heat Flux

Latent Heat Flux

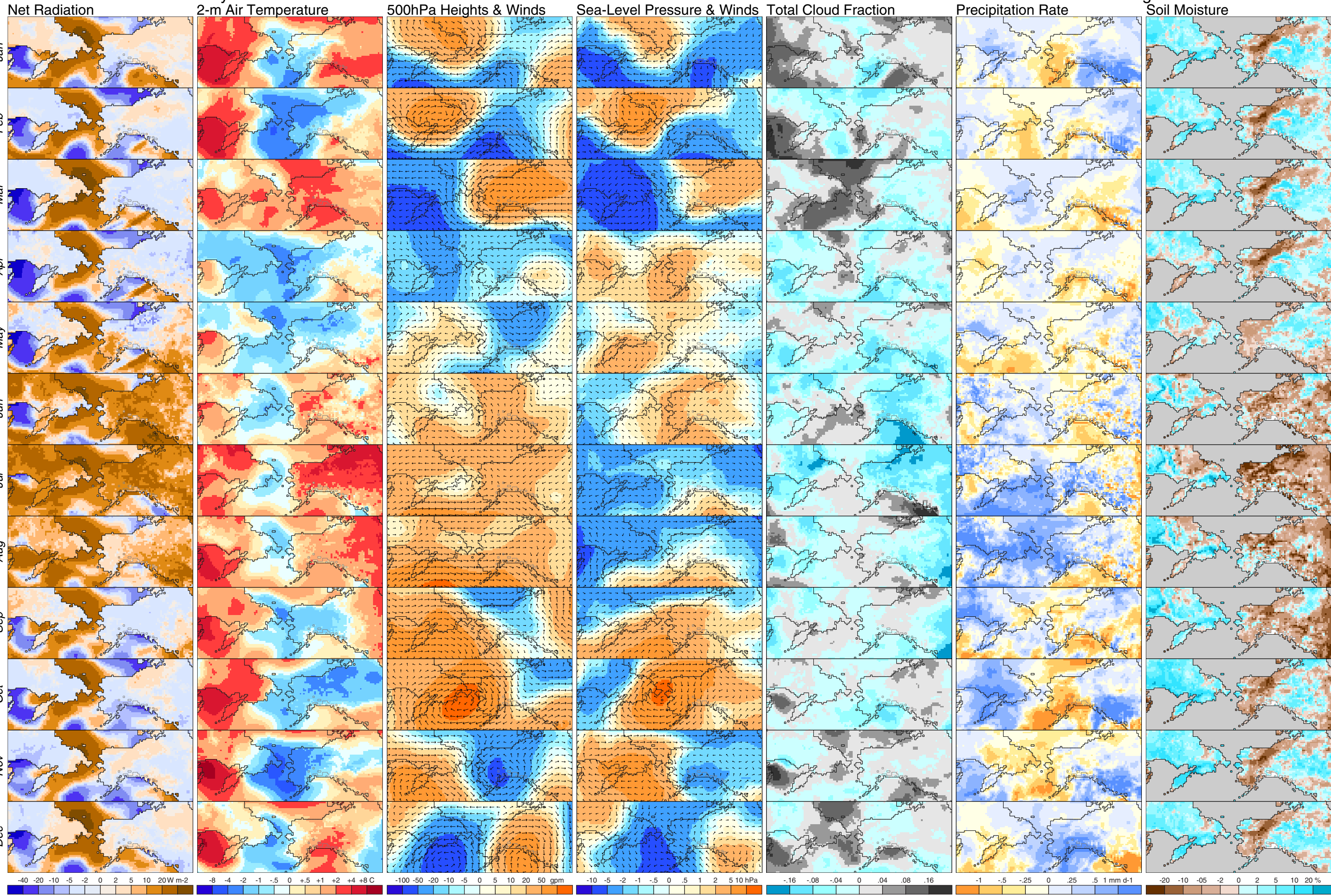
Substrate Heat Flux

# Long-Term Means

2-m Air Temperature



# 6 ka Simulation - Present-Day Simulation



# 6 ka Simulation - Present-Day Simulation

Net Shortwave Radiation

Net Longwave Radiation

Net Radiation

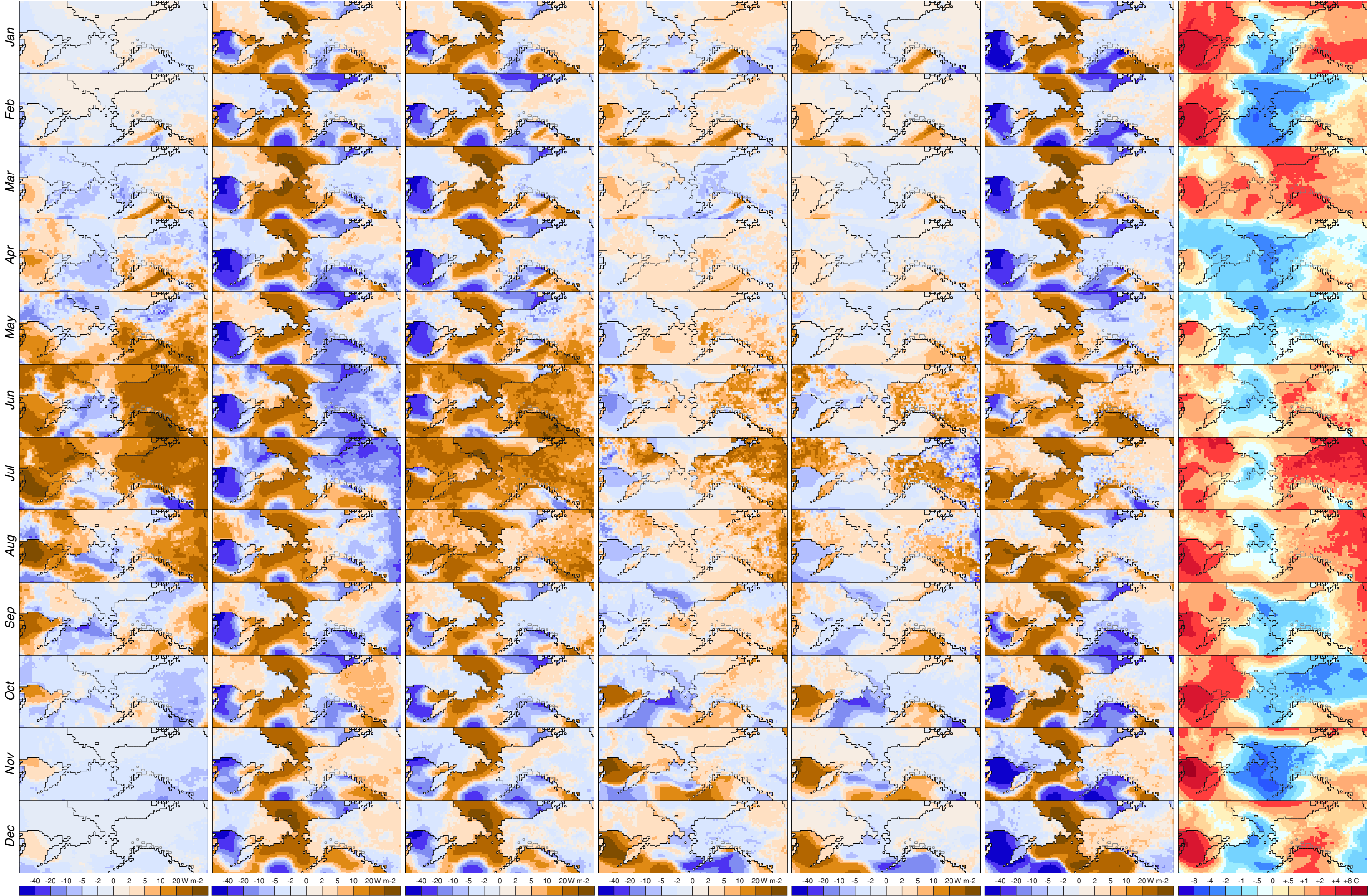
Sensible Heat Flux

Latent Heat Flux

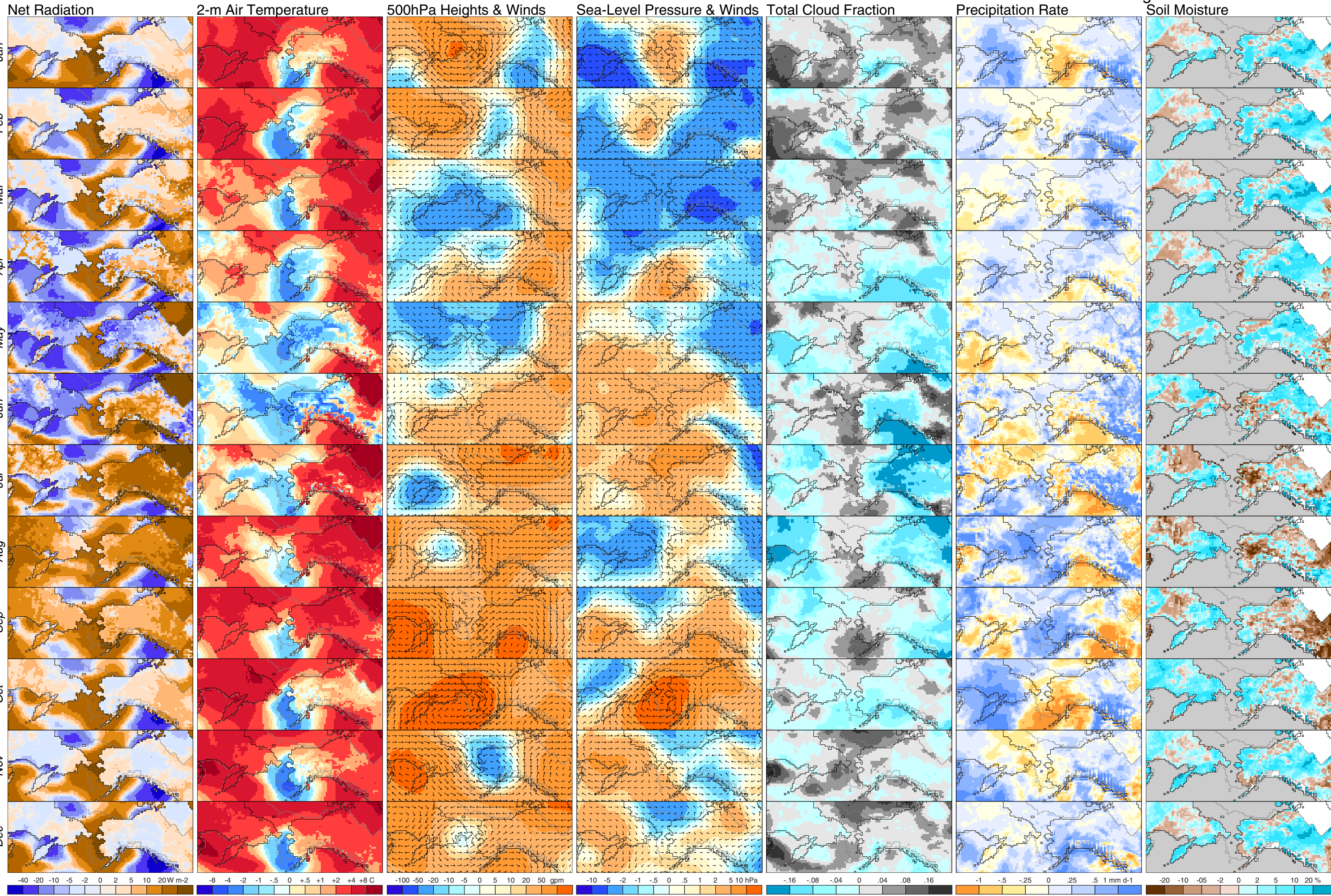
Substrate Heat Flux

# Long-Term Mean Differences

2-m Air Temperature



# 6 ka Simulation - 11 ka All Simulation



6 ka Simulation - 11 ka All Simulation

Long-Term Mean Differences

Net Shortwave Radiation

Net Longwave Radiation

Net Radiation

Sensible Heat Flux

Latent Heat Flux

Substrate Heat Flux

2-m Air Temperature

