The PRECIS Regional Climate Model

General overview (1)

- The regional climate model (RCM) within PRECIS is a model of the atmosphere and land surface, of limited area and high resolution and locatable over any part of the globe.

- The Hadley Centre's most up to date model: HadRM3P

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General overview (2)

- The advective and thermodynamical evolution of atmospheric pressure, winds, temperature and moisture (*prognostic* variables) are simulated, whilst including the effects of many other physical processes.

- Other useful meteorological quantities (*diagnostic* variables) are derived consistently within the model from the prognostic variables
  - precipitation, cloud coverage, …

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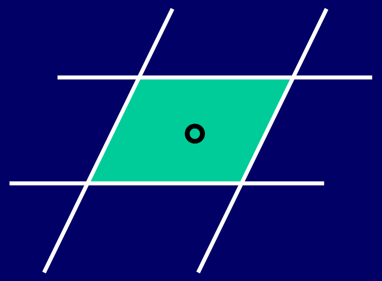
Discretizing the model equations

- All model equations are solved numerically on a discrete 3-dimensional grid spanning the area of the model domain and the depth of the atmosphere

- The model simulates values at discrete, evenly spaced points in time
  - The period between each point in time is called the model's timestep

- Spatially, data is an average over a grid box
- Temporally, data is instantaneous



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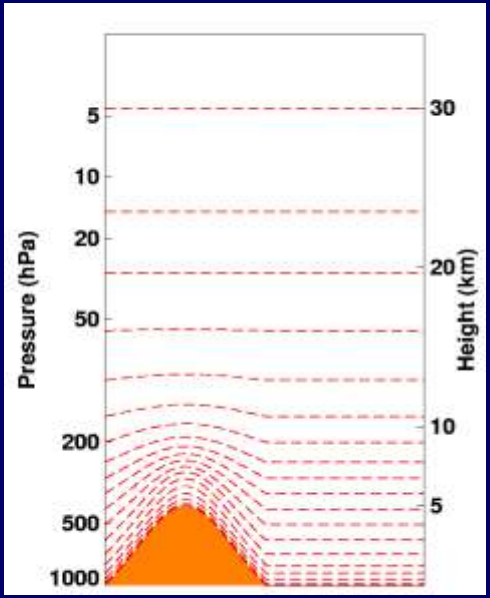
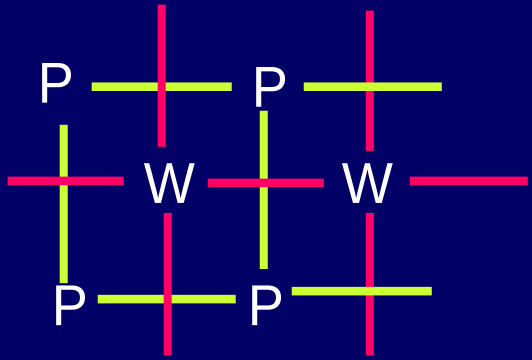
The model grid

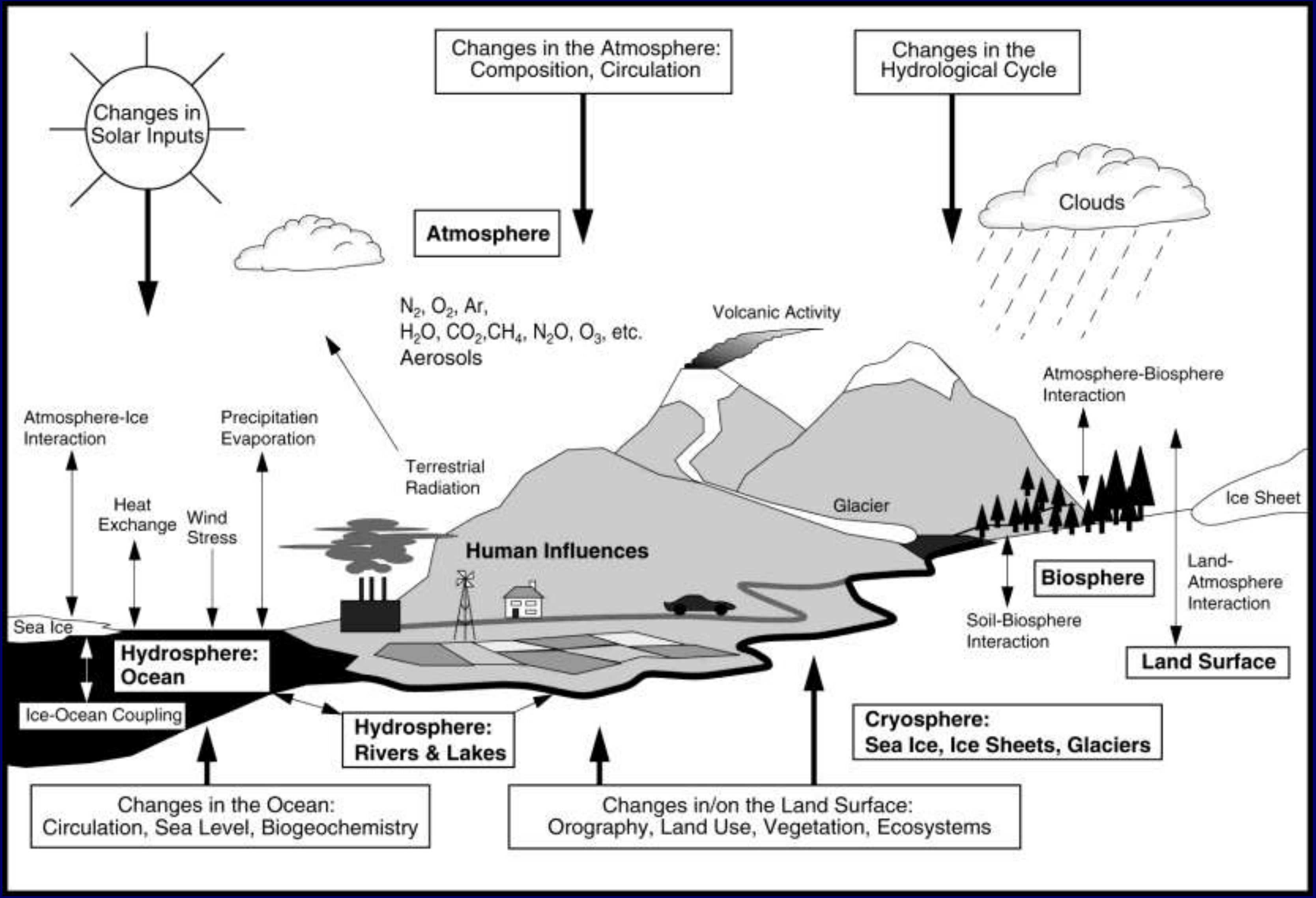
- Hybrid vertical coordinate
  - Combination of terrain following and atmospherics pressure
  - 19 vertical levels (lowest at 50m, highest at 5Pa)



- Regular lat-lon grid in the horizontal
  - 'Arakawa B' grid layout
    - » P = pressure, temperature and moisture related variables
    - » W = wind related variables



Physical processes

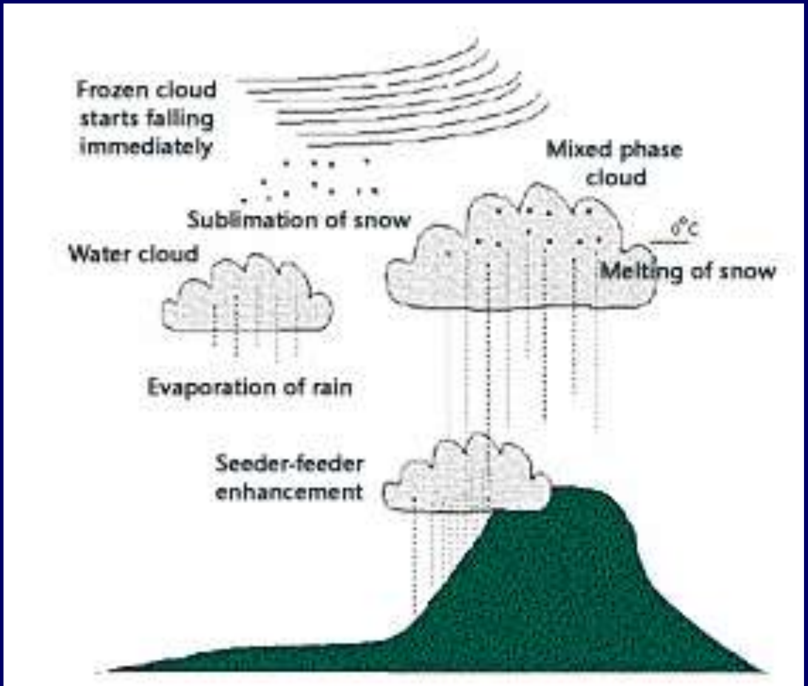


Physical parameterizations

- Clouds and precipitation
- Radiation
- Atmospheric aerosols
- Boundary layer
- Land surface
- Gravity wave drag

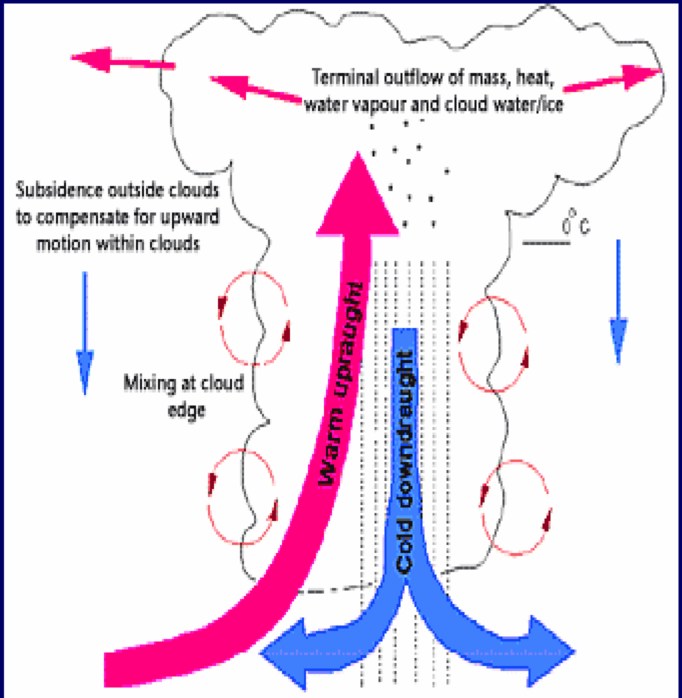
Large scale clouds and precipitation

- Resulting from the large scale movement of air masses affecting grid box mean moisture levels
- Due to dynamical assent (and radiative cooling and turbulent mixing)
- Cloud water and cloud ice are simulated
- Conversion of cloud water to precipitation depends on
  - the amount of cloud water present
  - precipitation falling into the grid box from above (seeder-feeder enhancement)
- Precipitation can evaporate and melt



Convection and convective precipitation

- Cloud formation is calculated from the simulated profiles of
  - temperature
  - pressure
  - humidity
  - aerosol particle concentration

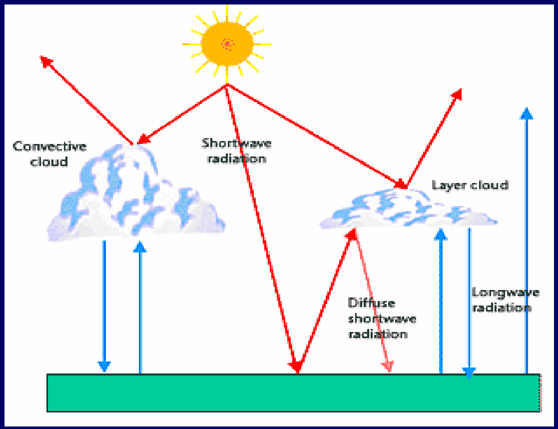


- Entrainment and detrainment

- Anvils of convective plumes are represented

Radiation

- The daily, seasonal and annual cycles of incoming heat from the sun (shortwave insolation) are simulated
- Short-wave and long-wave energy fluxes modelled separately
- SW fluxes depend on
  - the solar zenith angle, absorptivity (the fraction of the incident radiation absorbed or absorbable), albedo (reflected radiation/incident radiation) and scattering (deflection) ability
- LW fluxes depend on
  - the amount an emitting medium that is present, temperature and emissivity (radiation emitted/radiation emitted by a black body of the same temperature)
- Radiative fluxes are modelled in 10 discrete wave bands spanning the SW and LW spectra
  - 4 SW, 6 LW



Atmospheric aerosols

- The spatial distribution and life cycle of atmospheric sulphate aerosol particles are simulated
  - Other aerosols (e.g. soot, mineral dust) are not included

- Sulphate aerosol particles (SO_4) tend to give a surface cooling:
  - The direct effect (scattering of incoming solar radiation $\Rightarrow$ more solar radiation reflected back to space)
  - The first indirect effect (increased cloud albedo due to smaller cloud droplets $\Rightarrow$ more solar radiation reflected back to space)

- Natural and anthropogenic emissions are prescribed source terms (scenario specific)

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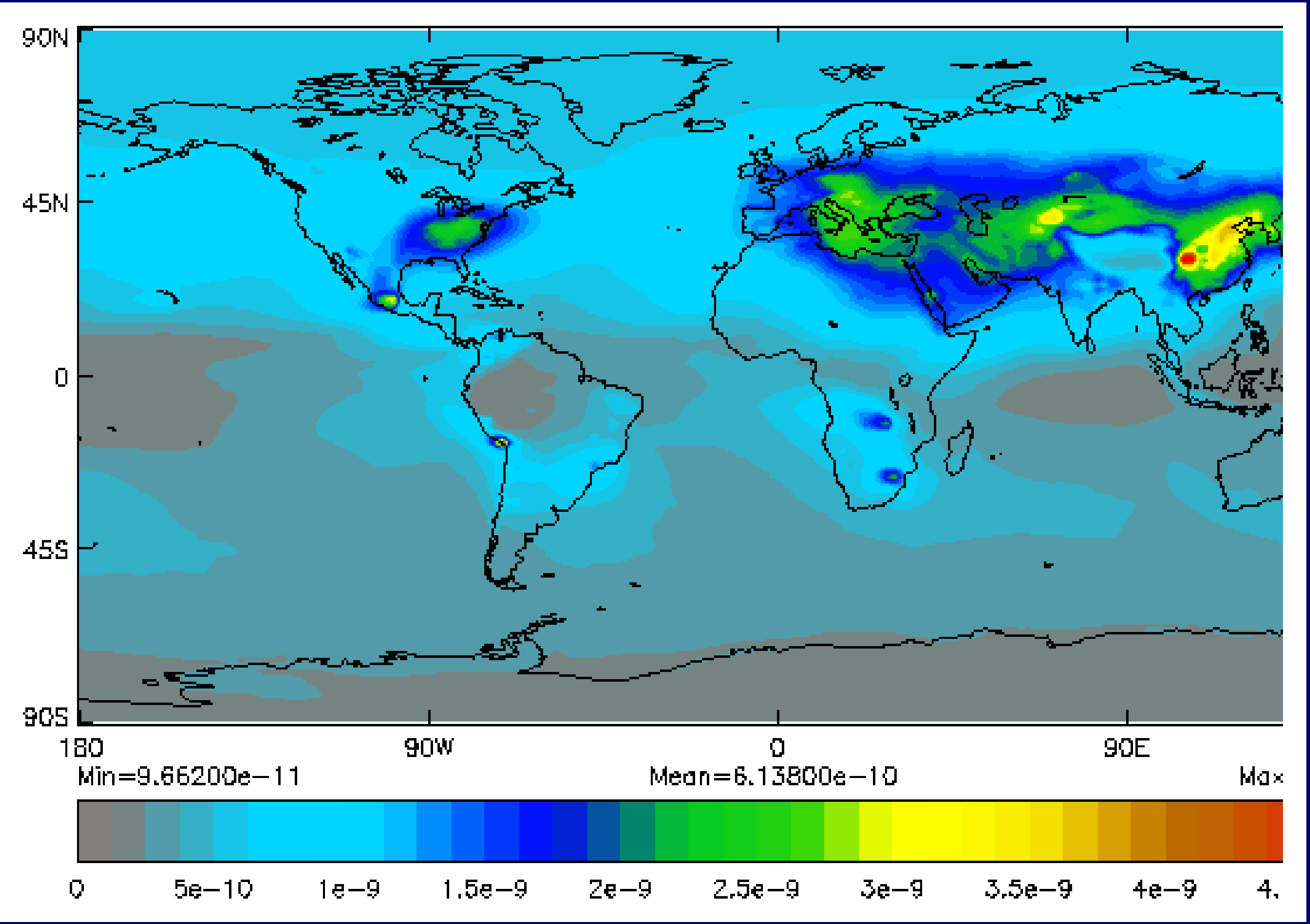
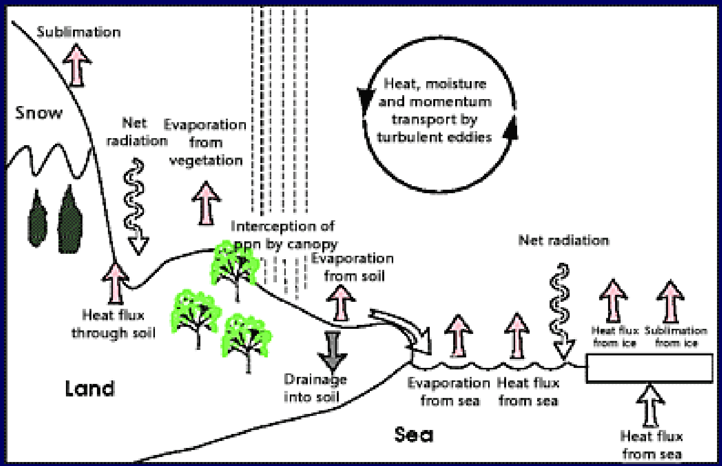
Anthropogenic surface and chimney height SO2 emissions



Boundary layer processes

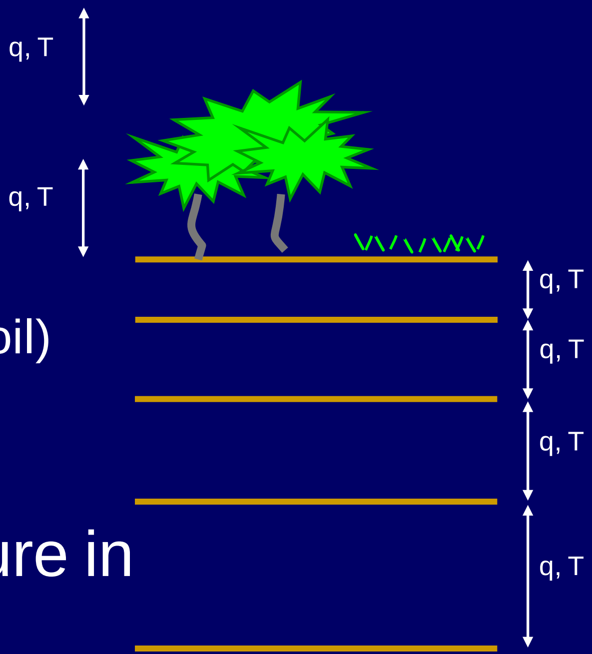
- Turbulent mixing in the lower atmosphere
  - Sub-gridscale turbulence mixes heat, moisture and momentum through the boundary layer
  - The extent of this mixing depends on the large scale stability and nature of the surface

- Vertical fluxes of momentum
  - ground ⇔ atmosphere
  - Fluxes depend on atmospheric stability and roughness length



Surface processes: MOSES I

- Exchange of heat and moisture between the earth's surface, vegetation and atmosphere
- Surface fluxes of heat and moisture
  - Precipitation stored in the vegetation canopy
  - Released to soil or atmosphere
  - Depends on vegetation type
  - Heat and moisture exchanges between the (soil) surface and the atmosphere pass through the canopy
- Sub-surface fluxes of heat and moisture in the soil
  - 4 layer soil model
  - Root action (evapotranspiration)
  - Water phase changes
  - Permeability depending on soil type
  - Run-off of surface and sub-surface water to the oceans

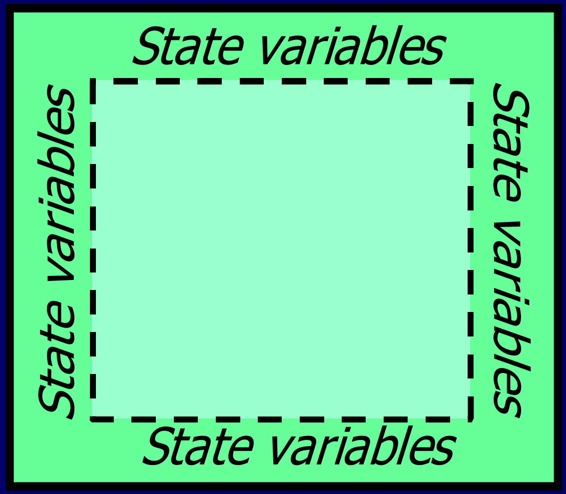


Lateral Boundary Conditions (LBCs)

- LBCs = Meteorological boundary conditions at the lateral (side) boundaries of the RCM domain
  - They constrain the prognostic variables of the RCM throughout the simulation

- 'Driving data' comes from a GCM or analyses

- Lateral Boundary condition variables:
  - Wind
  - Temperature
  - Water vapour
  - Surface pressure
  - Sulphur variables (if using the sulphur cycle)



Other boundary conditions

- Information required by the model for the duration of a simulation
- They are:
  - Constant data applied at the surface
    - Land-sea mask
    - Orographic fields (e.g. surface heights above sea level, 3-D s.d. of altitude)
    - Vegetation and soil characteristics (e.g. surface albedo, height of canopy)
  - Time varying data applied at the surface
    - SST and SICE fractions
    - Anthropogenic SO_2 emissions (sulphur cycle only)
    - Dimethyl sulphide (DMS) emissions (sulphur cycle only)
  - Time varying data applied throughout the atmosphere
    - Atmospheric ozone (O_3)
  - Constant data applied throughout the atmosphere
    - Natural SO_2 emissions volcanos (sulphur cycle only)
  - Annual cycle data applied throughout the atmosphere
    - Chemical oxidants (OH, HO_2, H_2O_2, O_3) (sulphur cycle only)

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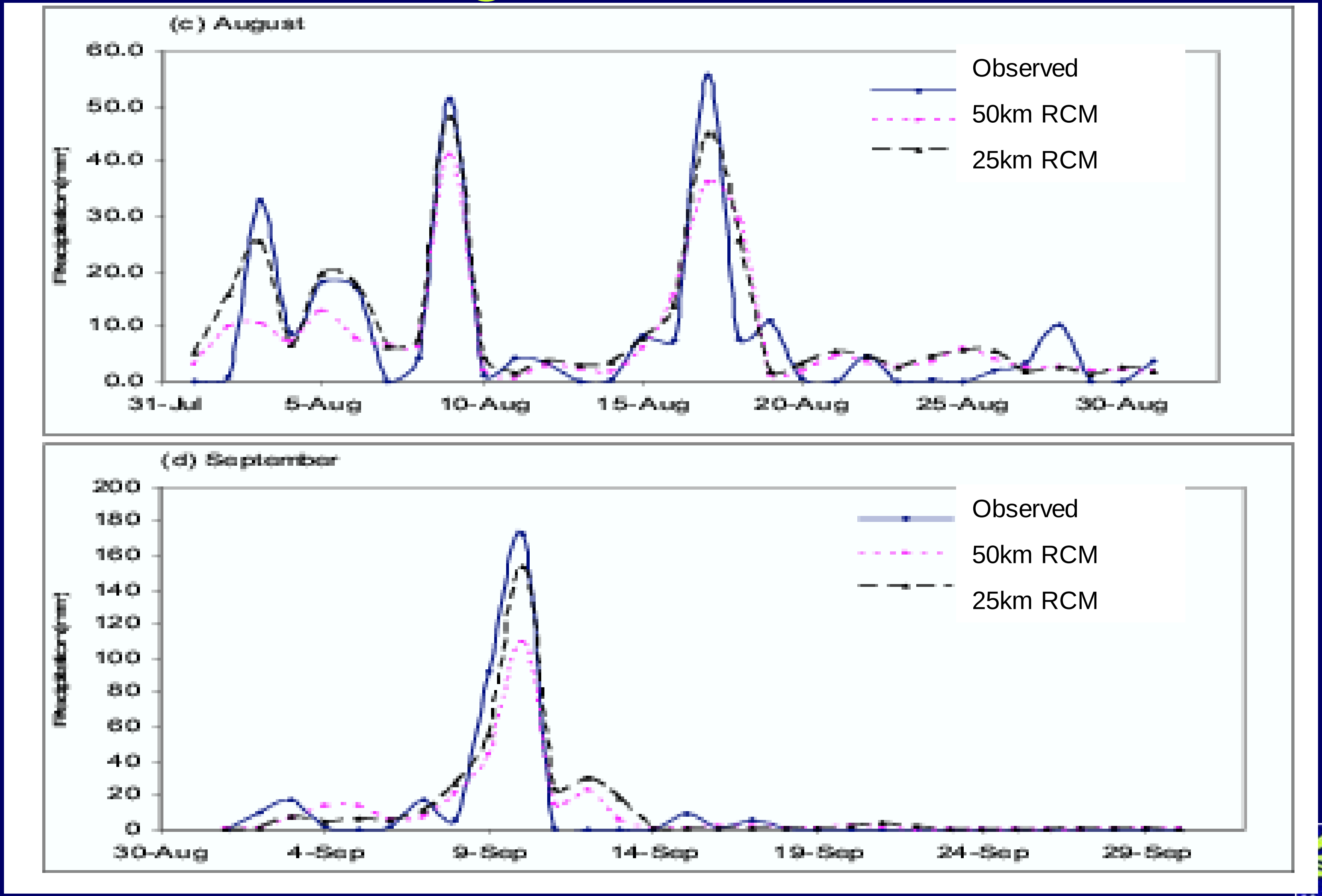
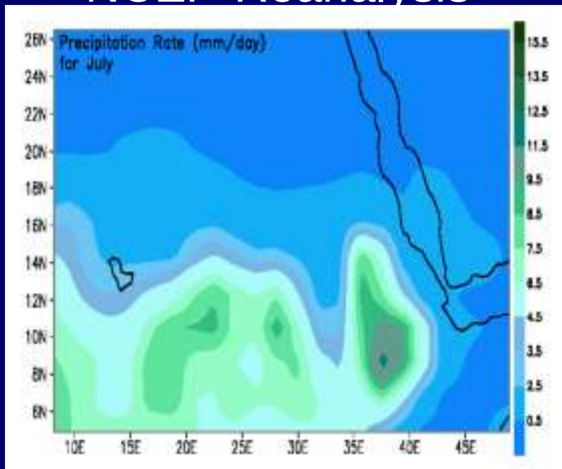
Some examples using PRECIS

Understanding Jhelum river Pakistan rainfall during the 1992 flood

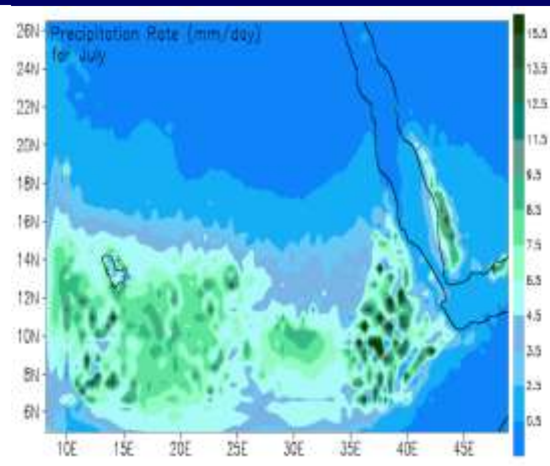


Precipitation estimates over Eastern Africa

NCEP-Reanalysis



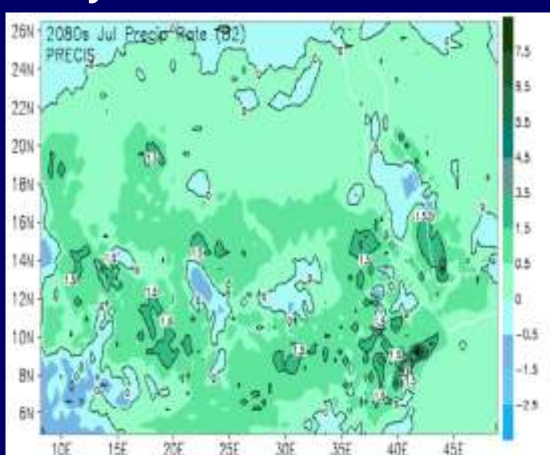
PRECIS



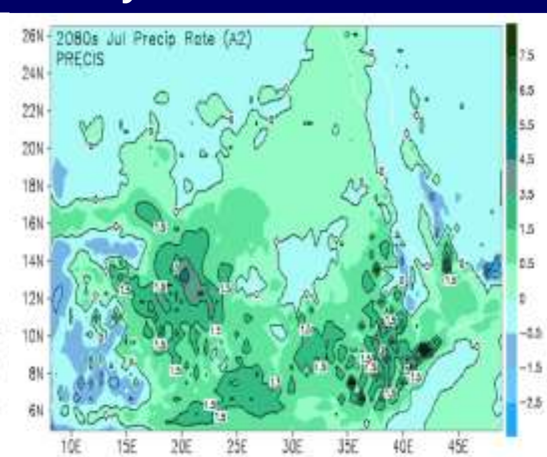
Current climate (1961-1990)

Captures the regional rainfall pattern along the East African steep topography and Red Sea area

July rainfall 2080 -B2



July rainfall 2080 -A2

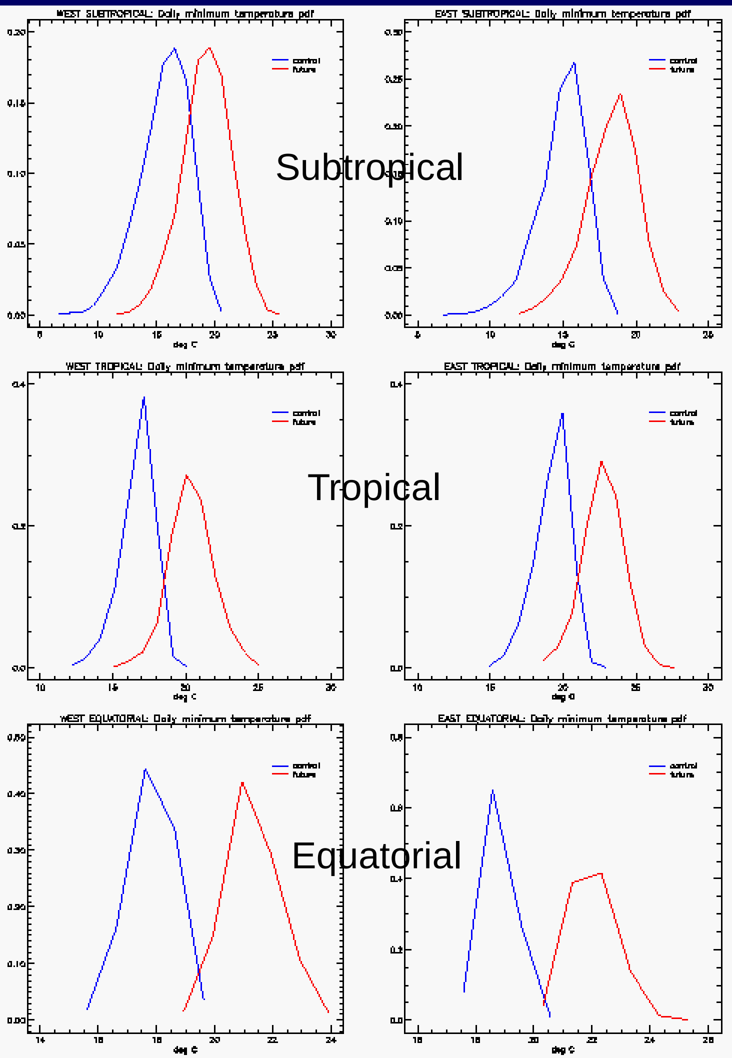


Future projections: 2080s

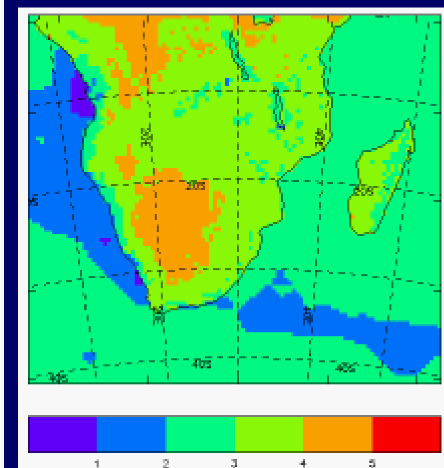
- Increased rainfall (1.5mm/day) over the domain for both A2 & B2
- More areas in A2 would experience higher rainfall increases

Summer daily temperature changes: 2080

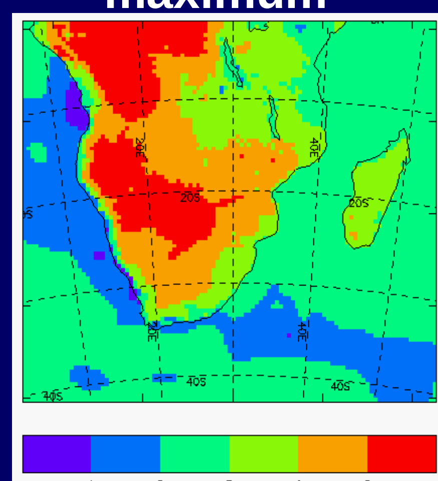
Minimum



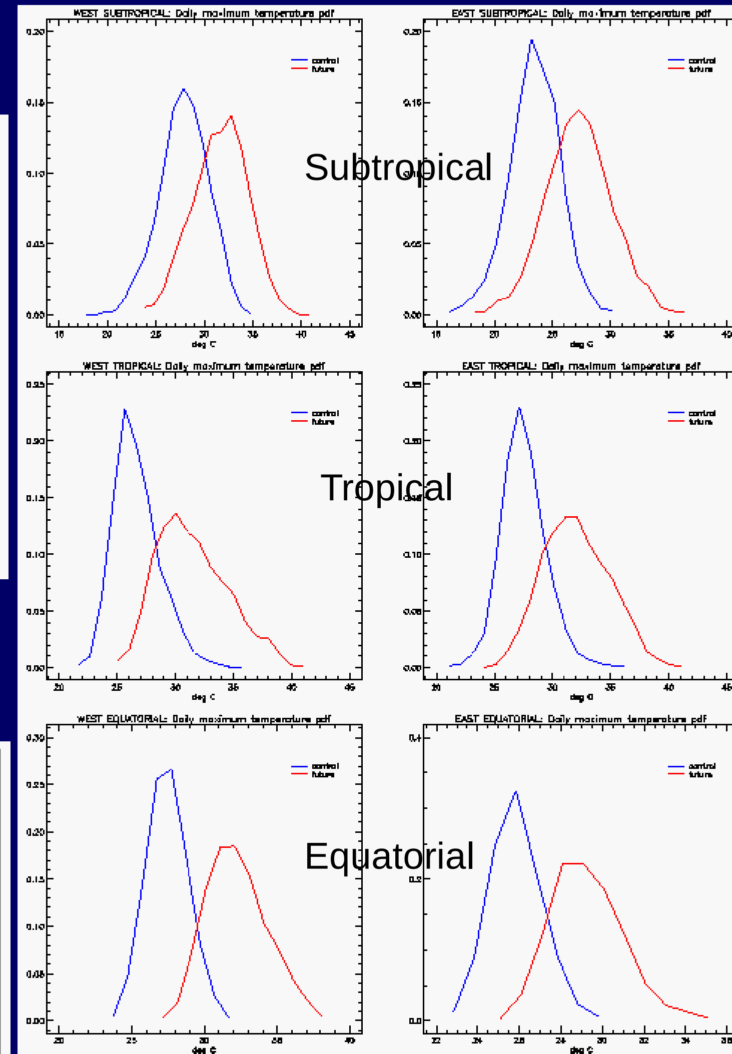
Change in mean minimum



Change in mean maximum



Maximum



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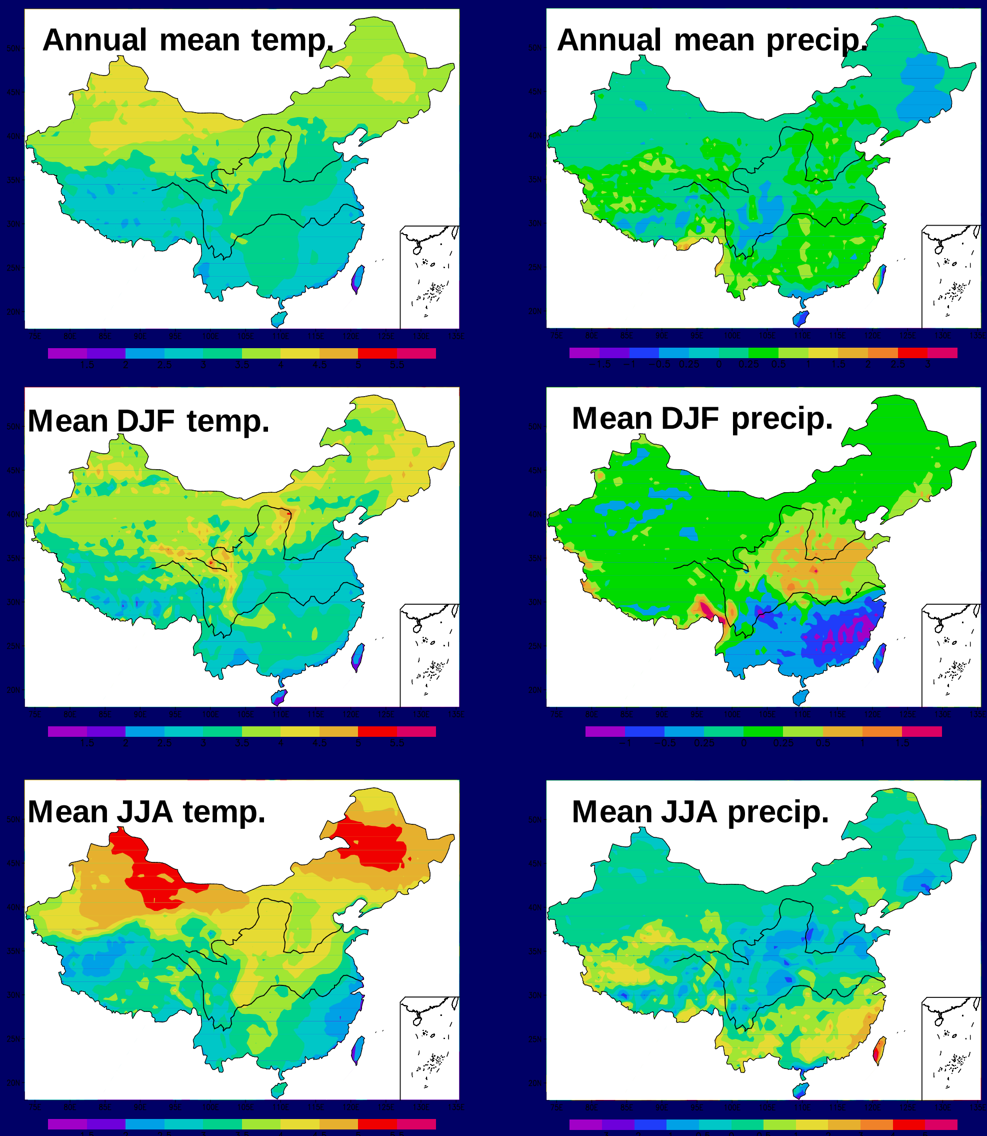
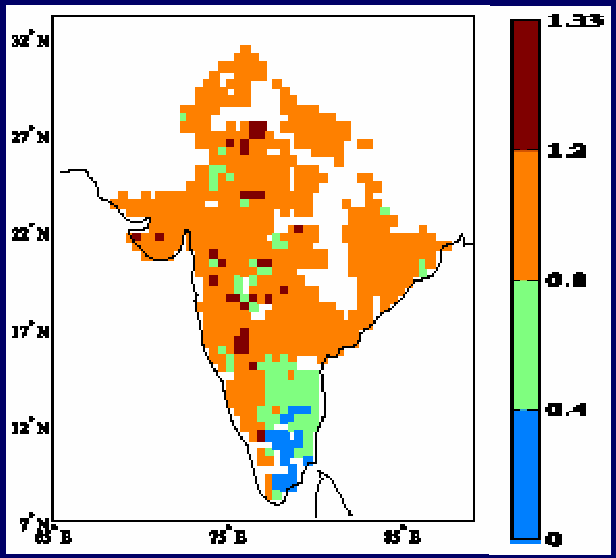
Projected changes in future climates for 2080 under B2 scenario over China



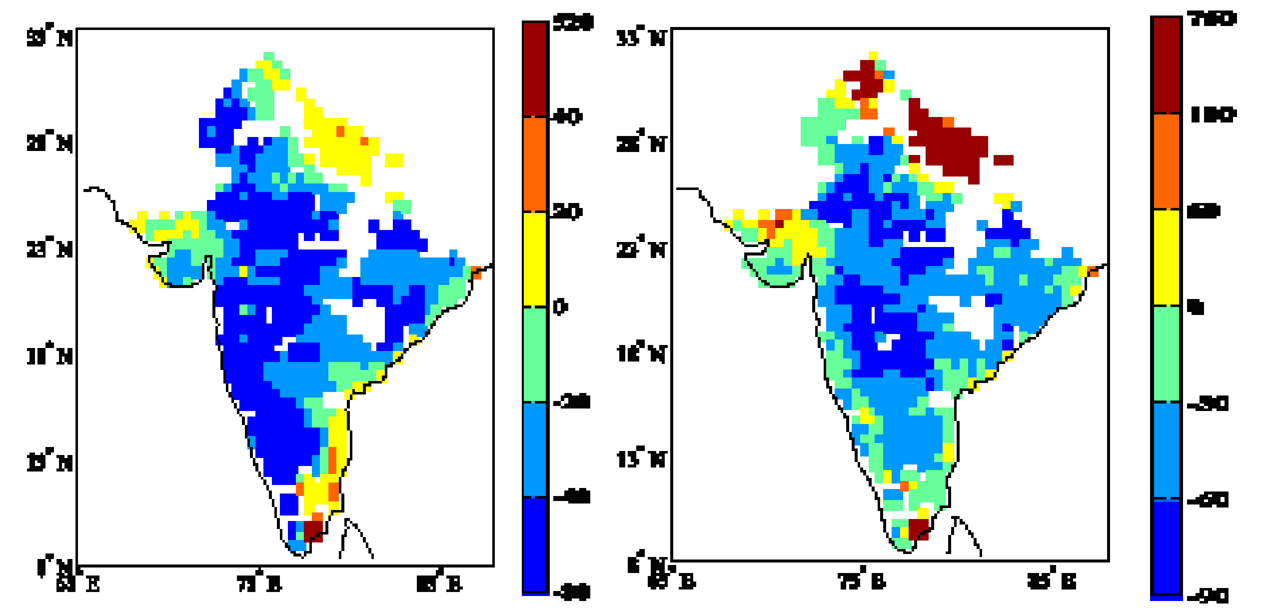
- Precipitation would increase over most areas of China (mid. of south, north and Tibetan plateau) and decrease over the northeast.
- Over all temperature increase with a south-north gradient (up to 5°C).
- Increasing JJA precip. Amounts within Yangtze Basin would increase frequency of flooding.
- Decreasing precip. in Yellow Basin and the north, coupled with increasing temp. would enhance drought in these areas.

Change in ground-nut yields over India



Ratio of simulated to observed mean (left) of yield for the baseline simulation with T_{opt}=28ºC.

Percentage change in mean yield for 2071-2100 relative to baseline:TOL-28 (bottom left) & TOL-36 (bottom right).



Over 70% reduction in some areas.

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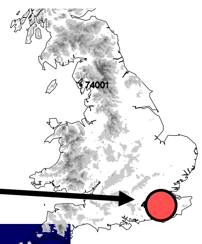
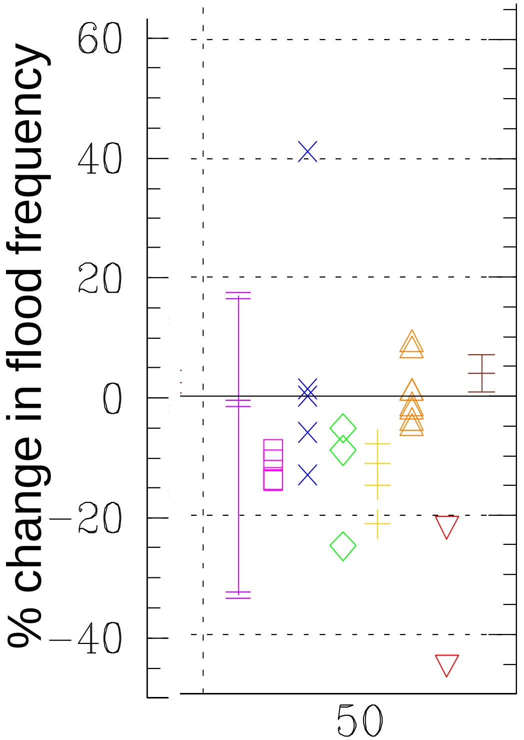
Climate Impacts Uncertainty

Changes in 50-year flood (%) from different drivers: River Beult in Kent



Natural variability – resampling:	-34	to	+17
Emissions – B1 to A1FI:	-14	to	- 9
GCM structure – 5 GCMs:	-13	to	+41
Natural variability – 3xGCM ICs:	-25	to	- 5
Downscaling – RCM v statistical:	-22	to	- 8
RCM structure – 8 RCMs:	-5	to	+8
Hydro' model structure – 2 models:	-45	to	- 22
Hydro' model parameters:	+1	to	+ 7



Q1: Are ranges additive?

Q2: Should model or observed climates be used as the baseline?

Q3: Are flow changes reliable enough to apply to observed flows?

Q4: Do reliable changes require full spectrum variability changes?