GEMRAMS training
September 23-25, 2008. South Florida Water Management District
Adriana Beltrán-Przekurat and Roger. A. Pielke, Sr.

Training schedule
Tuesday, September 23rd
Morning

RAMS overview. Examples of RAMS applications. Physical and dynamic processes simulated within the model. RAMS-GEMRAMS differences

Identification of the various input files needed for a regional simulation:

1. Topography
2. Land-use/land-cover
3. Soil type
4. Atmospheric lateral boundary conditions.
5. Sea surface temperature
6. Leaf area index, vegetation fraction
7. Other: soil moisture and temperature

Afternoon

RAMS structure of directories. Compilation process: include.mk, compilation flags. Hands on compilation. (Exercise 1)

Procedure for setting up GEMRAMS: MAKESFC, MAKEVFILE, INITIAL, HISTORY. (Exercise 2)

Description of the options in the RAMSIN namelist, physical parameters and parameterization options (microphysics, convection, radiation, land-surface models: LEAF2, GEMTM).

RAMS training schedule

Wednesday, September 24th
Morning
Continuation with the RAMSIN options.
Format of the output files and visualization of the results. Revu options. GEMTM variables. Grads. (Exercise 3)
Continuation with the output and visualization options.
Set-up the run from Marshall et al. (2004) (Exercise 4)

Afternoon
Hands on setting up GEMRAMS for different cases (Exercise 5): changing the surface boundary condition, downscaling global and regional atmospheric datasets and increasing CO_2 concentration levels in the atmosphere

Thursday, September 25th
Continuation of the hands-on exercises (Exercise 5).

➢ Overview of recent and ongoing work that has been conducted using RAMS within Pielke's group.

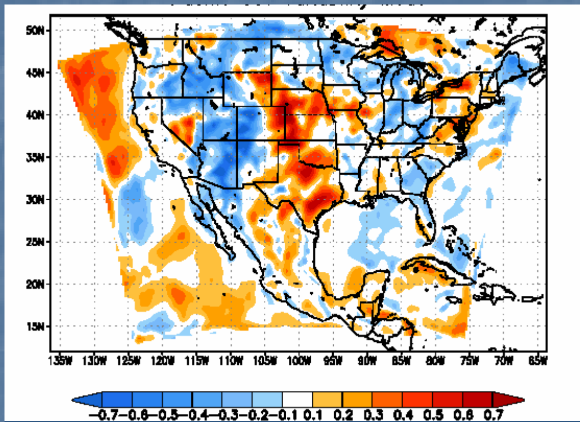
➢Examples of RAMS applications:

- **seasonal climate diagnosis,**
- **effects of land-use and land-cover changes on the near-surface atmosphere,**
- **simulations with an urban boundary-layer scheme,**
- **investigation of infrasound generated by tornadic storms,**
- **mesoscale dynamics**
- **development of a look-up-table (LUT) procedure**

Large-scale

Short-scale

Investigation of the Summer Climate of North America: A Regional Atmospheric Modeling Study



Percentage change in diurnal moisture flux convergence

➢Objective

•Create a long-term summer climatology of North America using RAMS as a regional climate model (RCM) by downscaling the NCEP-NCAR Reanalysis (1950-2002).

➢Additional RAMS-user benefits

❖Kain-Fritsch cumulus parameterization scheme,
❖incorporation of NLDAS soil moisture,
❖evaluation of value retained and added by RAMS as a regional climate model (Castro et al. 2005).

➢Principal Results

❖ RAMS produced a reasonable summer climatology, substantially improving upon the global reanalysis representation of the North American Monsoon.
❖ Improvement largely due to the model representation of the terrain-driven diurnal cycle of convection and low-level moisture transport.
❖Categorizing the simulation years by dominant modes of Pacific SST shows how large-scale climate forcing interacts with terrain to control interannual variability in summer rainfall.

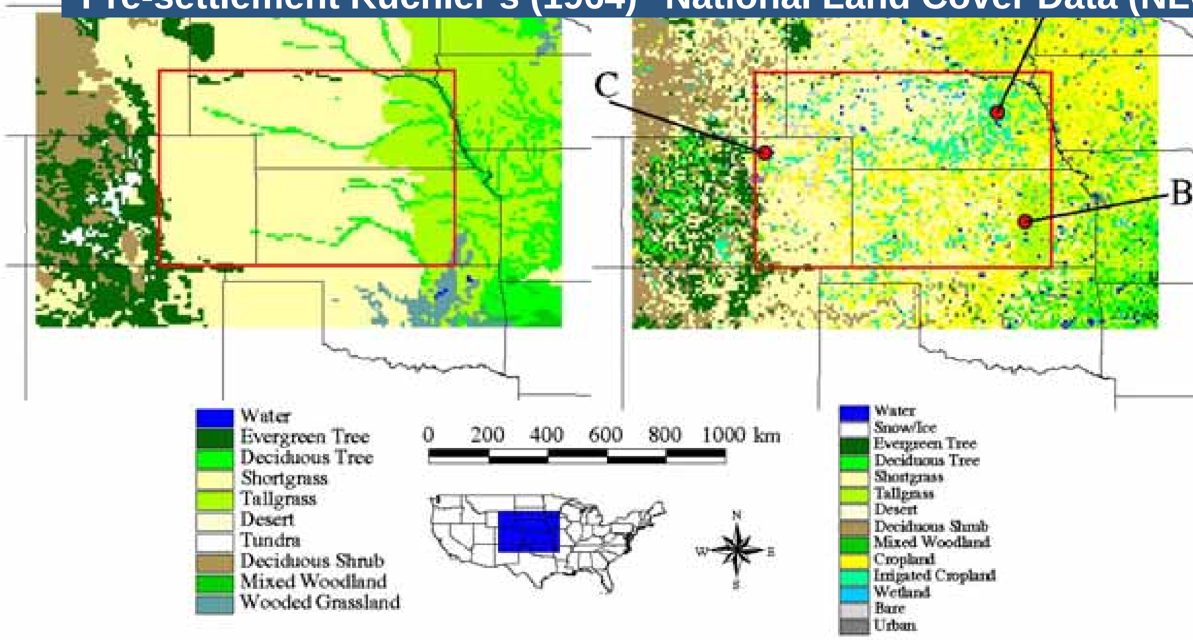
Castro, CL., R.A. Pielke, Sr., and J.O. Adegoke, 2006. A Summer Climatology of the Contiguous U.S. and Mexico using the Regional Atmospheric Modeling System. *J. Climate*, submitted. http://blue.atmos.colostate.edu/publications/pdf/R-306.pdf
Castro, C.L., R.A. Pielke, Sr., J.O. Adegoke, S.D. Schubert, and P.J. Pegion, 2006. Diagnosing the Effect of Pacific SST Associated Teleconnections Using the Regional Atmospheric Modeling System. *J. Climate*, submitted. http://blue.atmos.colostate.edu/publications/pdf/R-307.pdf

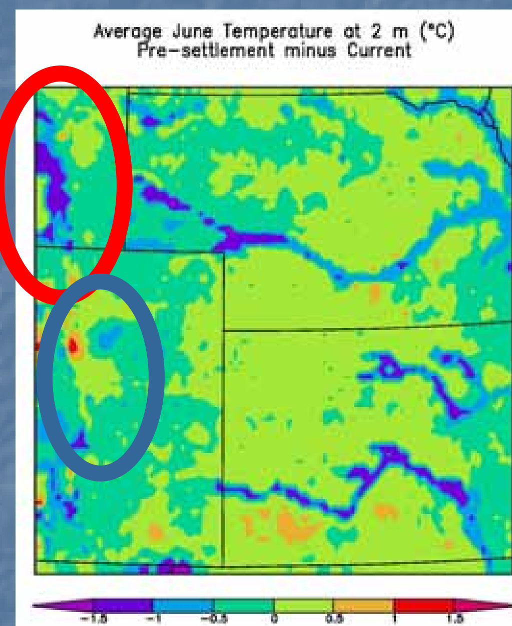
The Influence of Pre-settlement and Current High Plains Land Use and Land Cover on Atmospheric, Soils, and Vegetation Properties

- **Objective**

  Quantify the role of High Plains land-use and land-cover change in modifying near-surface air temperature, precipitation, soil moisture, and plant growth.

Pre-settlement Küchler's (1964) National Land Cover Data (NLCD)



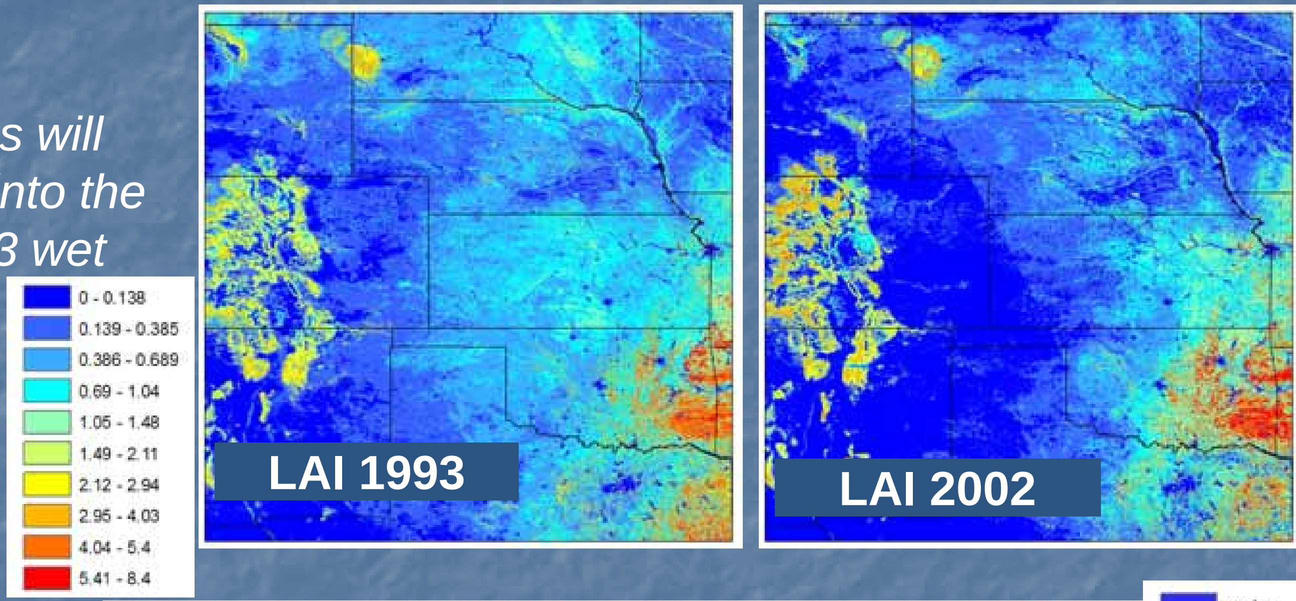


C.A. Hiemstra, R.A. Pielke Sr., T.L. Sohl[1], K.L. Sayler[1], T.R. Loveland[1], and L.T. Steyaert[1,2]. [1]Center for Earth Resources Observation and Science (EROS), U.S. Geological Survey, Sioux Falls, SD. [2]Biospheric Sciences Branch, NASA Goddard Space Flight Center, Greenbelt, MD

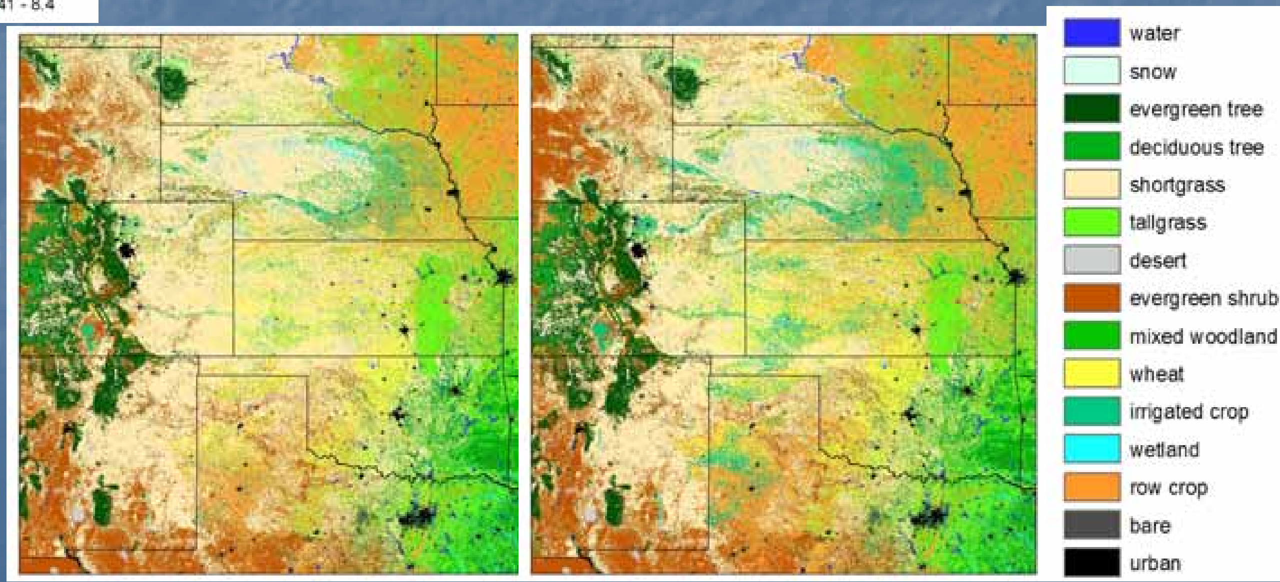
http://blue.atmos.colostate.edu/presentations/PPT-47.pdf

- ✓ **GEMRAMS**’ capabilities include simulation of plant growth (carbon accumulation, C_3 and C_4 photosynthetic pathways).
- ✓ Use **detailed** and high resolution vegetation initial conditions

Satellite derived parameterizations will be incorporated into the simulations (1993 wet vs. 2002 dry



Different agriculture scenarios (i.e loss and expansion) due to different federal policy

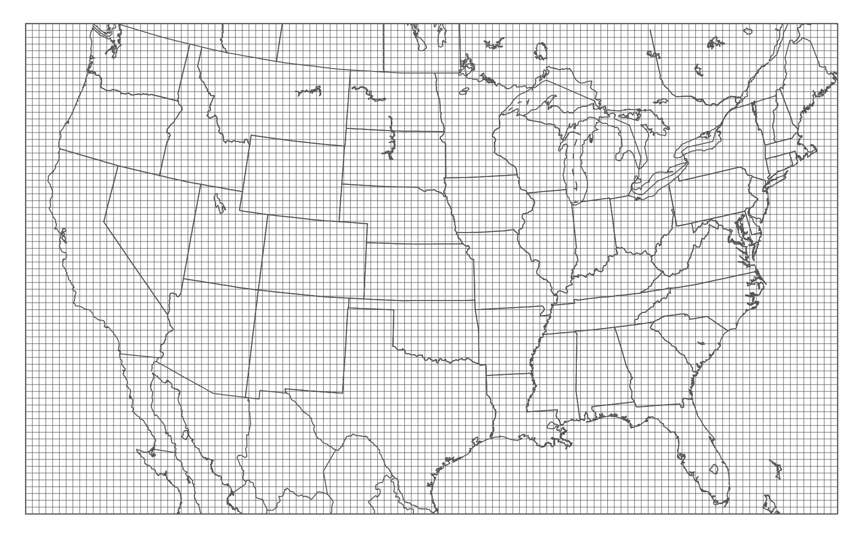


Impact of a Dynamic Vegetation Parameterization in the Numerical Simulation of Recent Warm-Season Weather

Objective

Investigate the utility of applying a dynamic vegetation parameterization in an explicitly predictive framework.

Does the added freedom (i.e. in the coupled modelling framework) for vegetation to respond to weather result in more skilful seasonal weather predictions than when vegetation phenology is prescribed (i.e. RAMS, default LAI).?



- **RAMS**
- **GEMRAMS (coupled RAMS+GEMTM)**

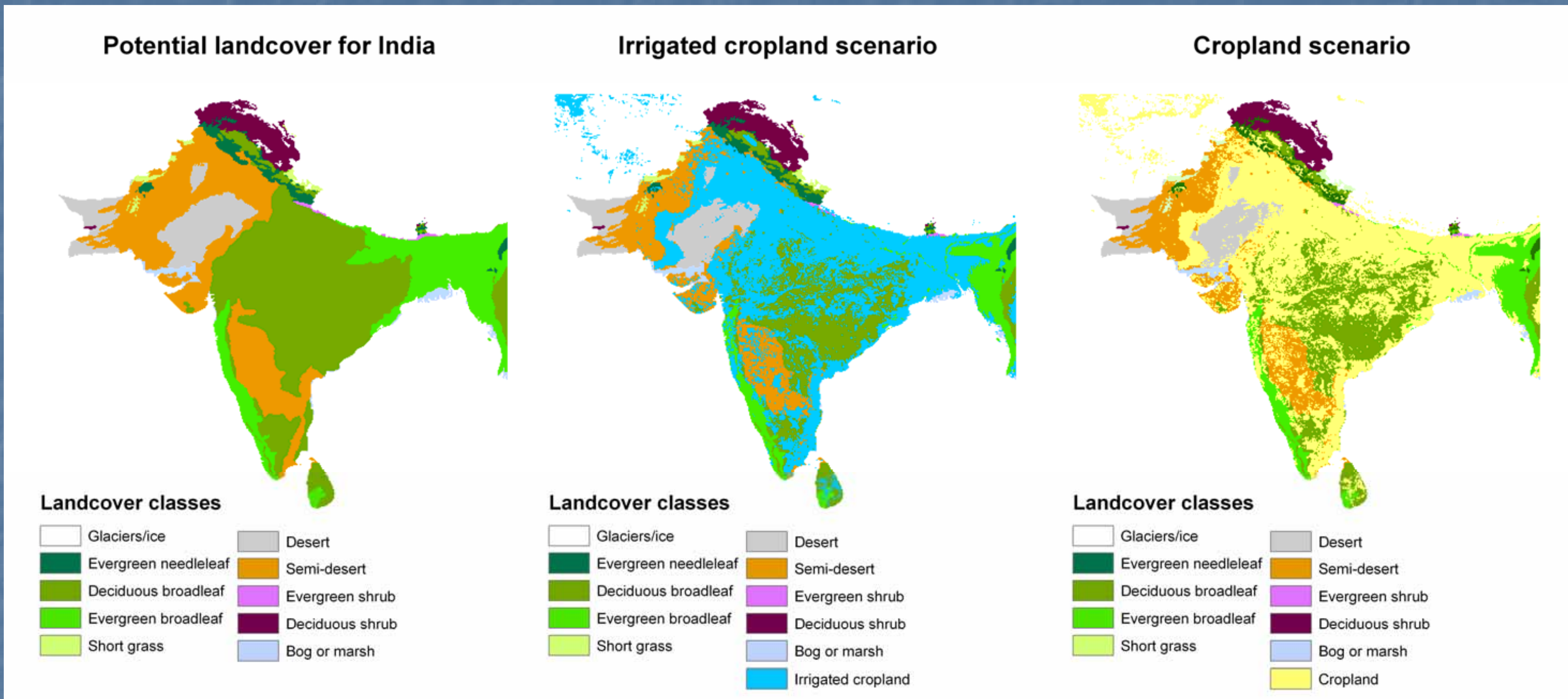
- **Initial and lateral boundary conditions**
  - **NCEP/NCAR Reanalysis**
  - **10 member ensemble of the NCEP Seasonal Forecast Model (SFM).**

- **Simulation period**

15 May to 1 September 2000 and 2001.

Beltrán-Przekurat, A., C. Marshall, and R.A. Pielke, Sr. Accepted in JGR

Simulating changes in land-atmosphere interactions from expanding agriculture and irrigation in India and the potential impacts on the Indian Monsoon.

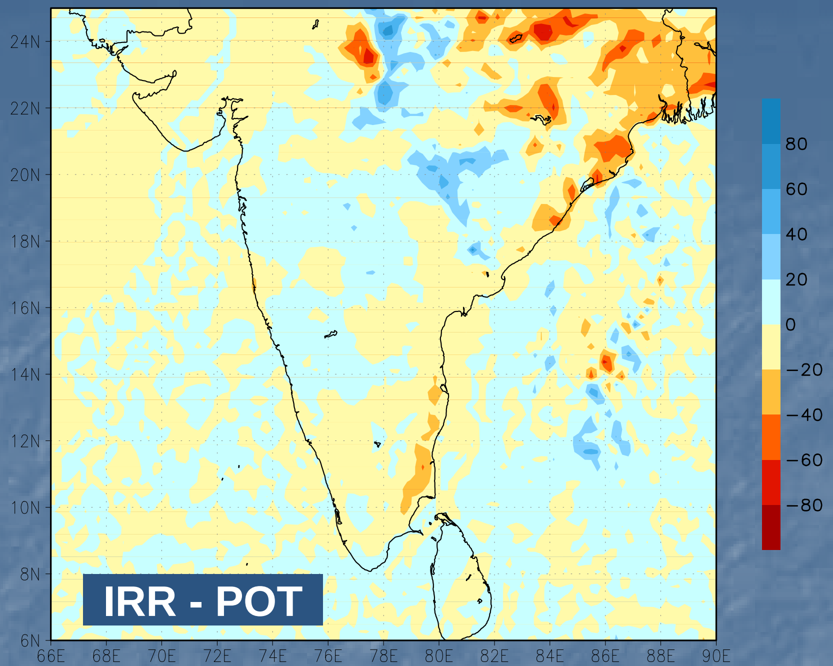


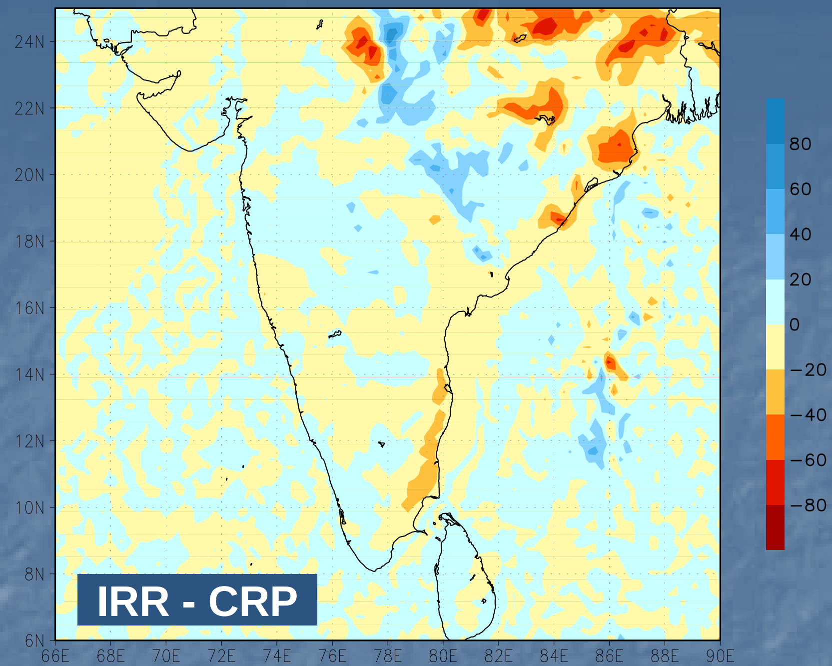
WWF Terrestrial Ecoregions of the World.

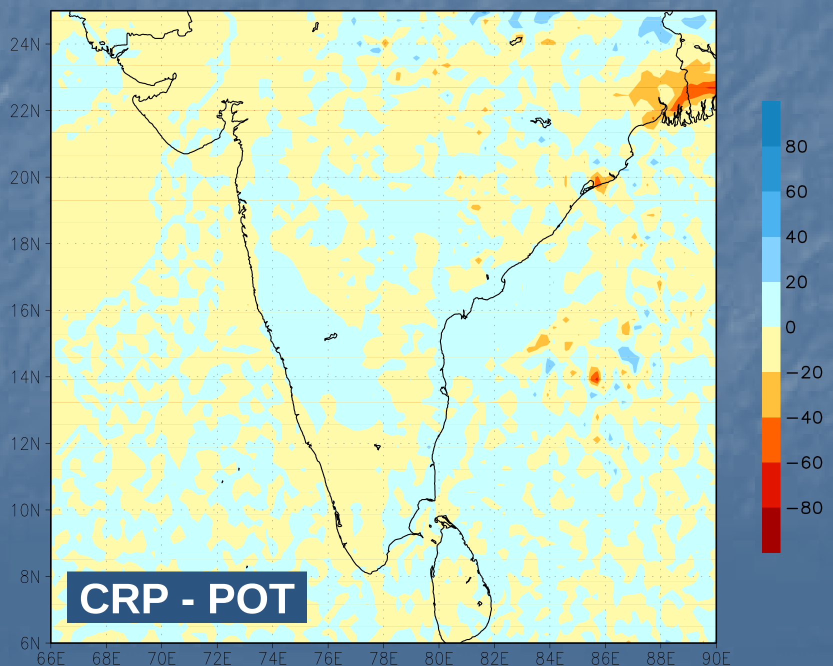
Irrigated cropland extent from GLC2000 landcover map overlain onto the potential landcover.

Rainfed + irrigated cropland extent from GLC2000 landcover map overlain onto the potential landcover.

E. M. Douglas[1], A. Beltrán-Przekurat, D. S. Niyogi, R.A. Pielke, Sr.. 1 Water Systems Analysis Group, University of New Hampshire







- Most noticeable differences occur between the irrigated crop and potential scenario, and are mainly due to irrigation.

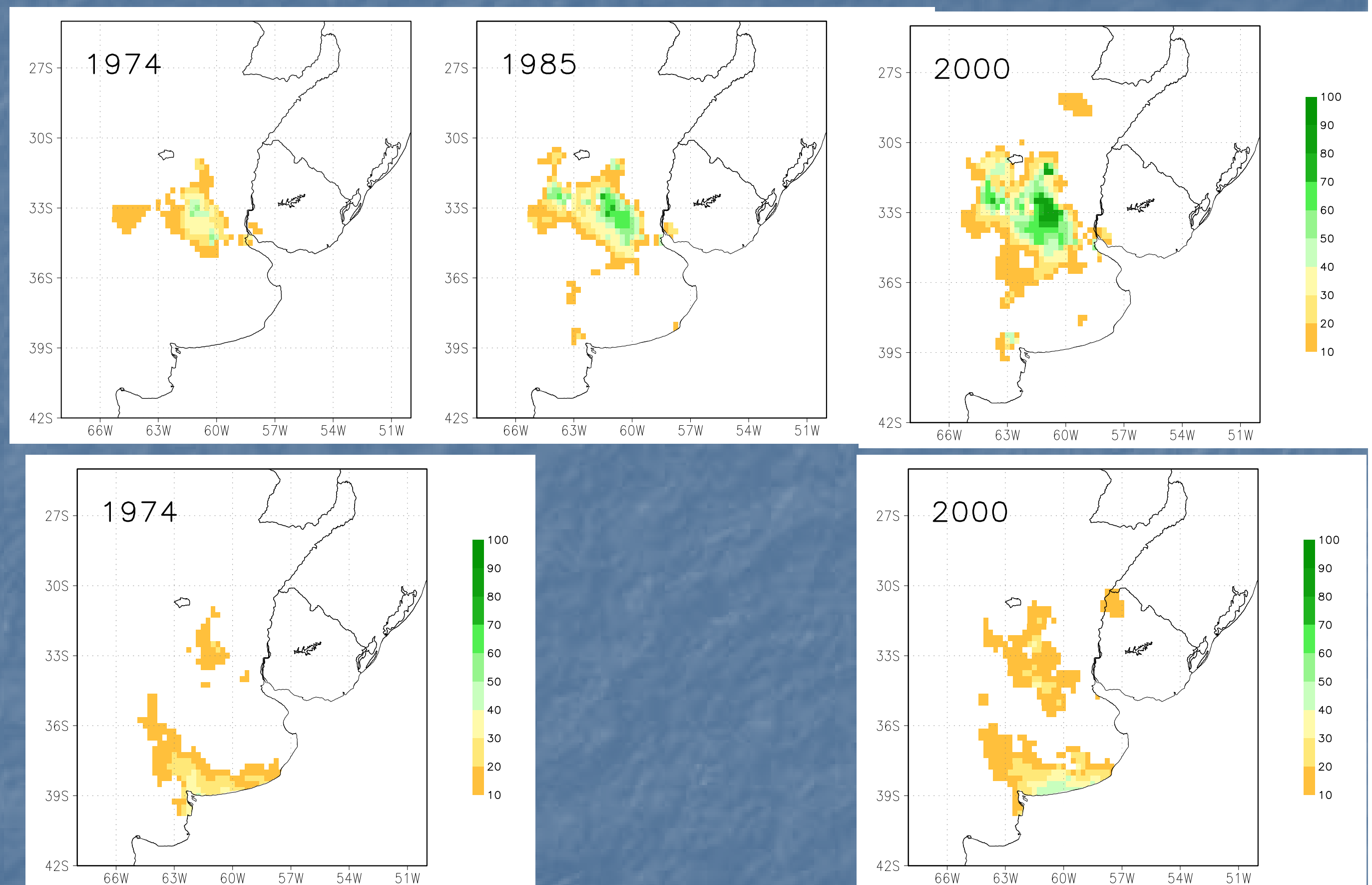
- Decrease in precipitation appears to be associated with areas of decrease in SH and lower temperatures. Although near-surface water vapor increases in those areas, lower SH might possible affected the initiation of convection and precipitation.

Using A Coupled Atmospheric-Biospheric Modeling System (GEMRAMS) to Model the Effects of Land-Use/Land-Cover Changes on the Near-Surface Atmosphere

Soybean

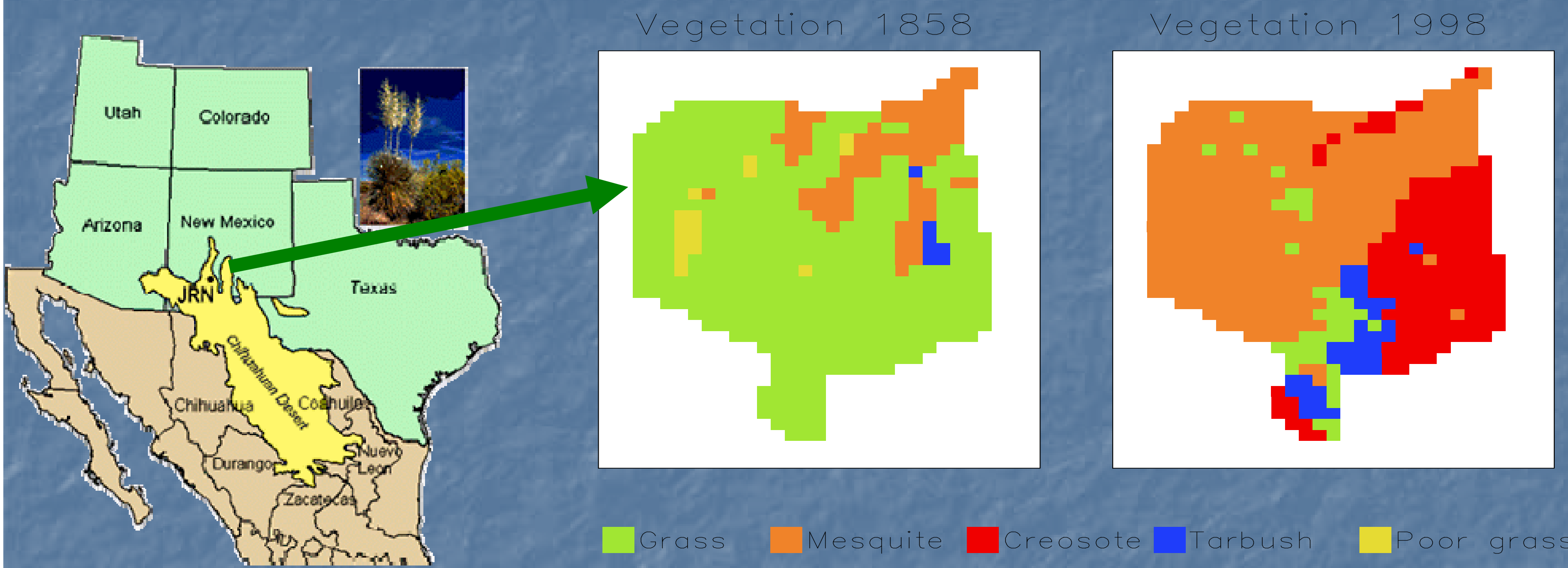
Increase in cropping area and changes in crop type distribution in a southern South American area

Wheat



A. Beltrán-Przekurat. Ph.D. Dissertation. Department of Atmospheric Science. 2005

Land-atmosphere interactions in semiarid areas. Jornada Experimental Range.



GEMRAMS used to assess interactions between plants, soils & atmosphere due to vegetation changes in the Jornada between 1858 (grasses) & 1998 (shrubs).

Beltran-Przekurat, A., Pielke Sr., R.A., Peters, D.C., Snyder, K.A., Rango, A. 2008. Modeling the effects of historical vegetation change on near-surface atmosphere in the northern Chihuahuan Desert. Journal of Arid Environments. 72:1897-1910.

Physical and dynamical processes in RAMS are described by the basic equations

Advection terms

Equations of motion:

$$\frac{\partial u}{\partial t} = -u\frac{\partial u}{\partial x} - v\frac{\partial u}{\partial y} - w\frac{\partial u}{\partial z} - \theta\frac{\partial \pi'}{\partial x} + fv + \frac{\partial}{\partial x}\left(K_m\frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_m\frac{\partial u}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_m\frac{\partial u}{\partial z}\right)$$

$$\frac{\partial v}{\partial t} = -u\frac{\partial v}{\partial x} - v\frac{\partial v}{\partial y} - w\frac{\partial v}{\partial z} - \theta\frac{\partial \pi'}{\partial y} - fu + \frac{\partial}{\partial x}\left(K_m\frac{\partial v}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_m\frac{\partial v}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_m\frac{\partial v}{\partial z}\right)$$

$$\frac{\partial w}{\partial t} = -u\frac{\partial w}{\partial x} - v\frac{\partial w}{\partial y} - w\frac{\partial w}{\partial z} - \theta\frac{\partial \pi'}{\partial z} - \frac{g\theta_v'}{\theta_0} + \frac{\partial}{\partial x}\left(K_m\frac{\partial w}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_m\frac{\partial w}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_m\frac{\partial w}{\partial z}\right)$$

Thermodynamic equation:

$$\frac{\partial \theta_{il}}{\partial t} = -u\frac{\partial \theta_{il}}{\partial x} - v\frac{\partial \theta_{il}}{\partial y} - w\frac{\partial \theta_{il}}{\partial z} + \frac{\partial}{\partial x}\left(K_h\frac{\partial \theta_{il}}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_h\frac{\partial \theta_{il}}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_h\frac{\partial \theta_{il}}{\partial z}\right) + \left(\frac{\partial \theta_{il}}{\partial t}\right)_{rad}$$

Water species mixing ratio continuity equation:

$$\frac{\partial r_n}{\partial t} = -u\frac{\partial r_n}{\partial x} - v\frac{\partial r_n}{\partial y} - w\frac{\partial r_n}{\partial z} + \frac{\partial}{\partial x}\left(K_h\frac{\partial r_n}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_h\frac{\partial r_n}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_h\frac{\partial r_n}{\partial z}\right)$$

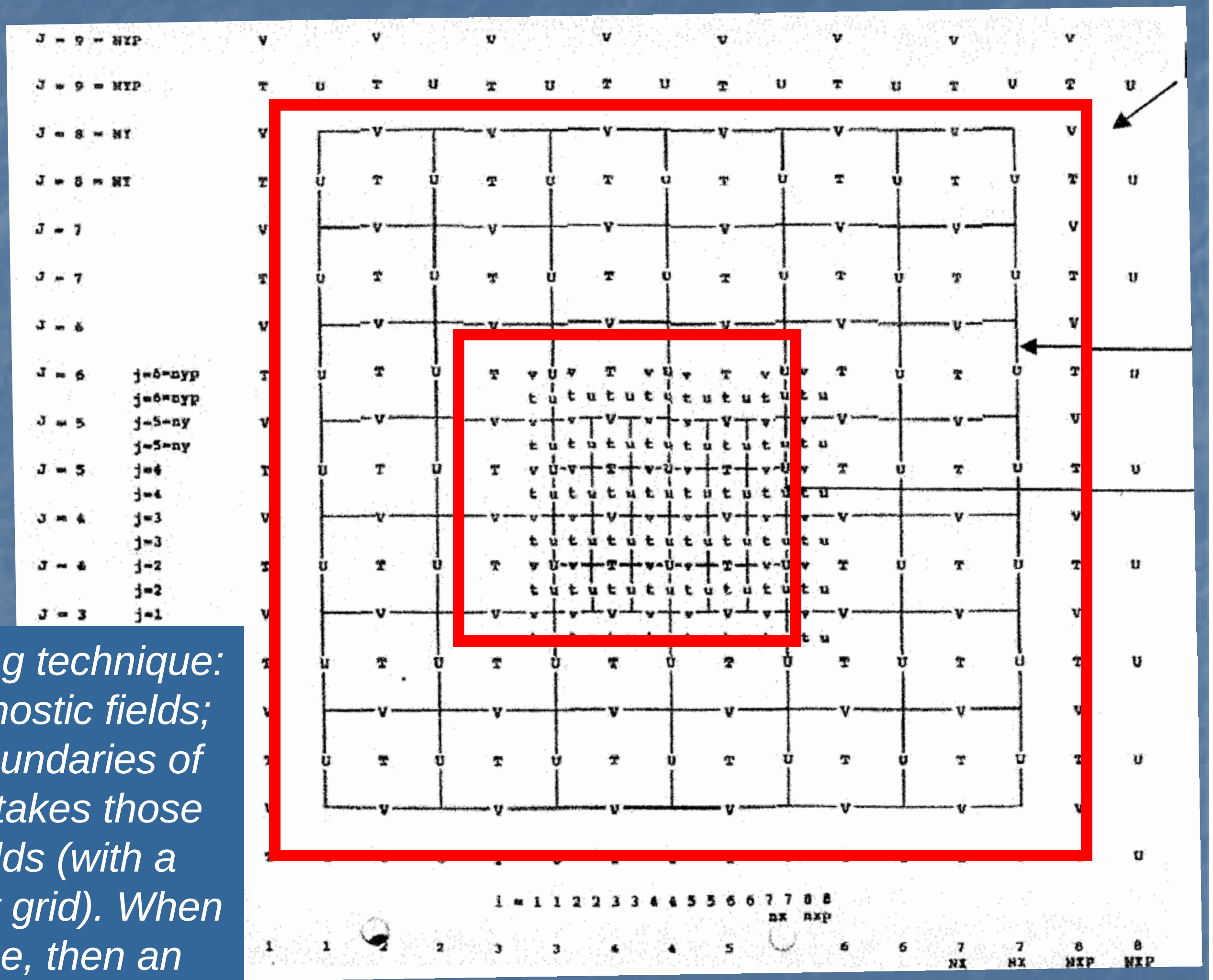
Mass continuity equation:

$$\frac{\partial \pi'}{\partial t} = -\frac{R\pi_0}{c_v\rho_0\theta_0}\left(\frac{\partial \rho_0\theta_0 u}{\partial x} + \frac{\partial \rho_0\theta_0 v}{\partial y} + \frac{\partial \rho_0\theta_0 w}{\partial z}\right)$$

Sources-sinks and subgrid-scale processes

Grid structure in RAMS

*# **Staggered**: thermodynamic and moisture variables at the same point, but velocity components staggered*



*# **Nested grid:** allows a higher spatial resolution in selected areas of interest.*

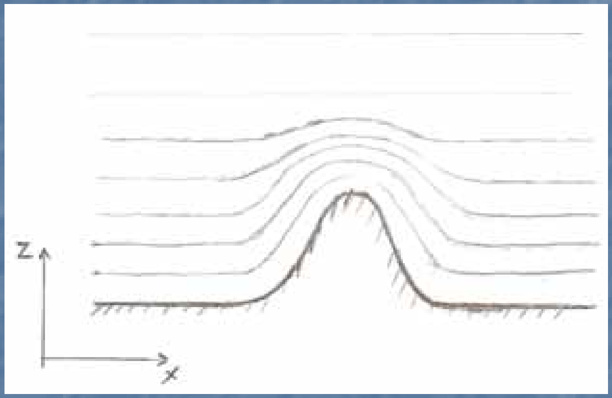
RAMS employs a two-way nesting technique: the parent grid updates the prognostic fields; values are interpolated on the boundaries of the nested grid. The nested grid takes those values an produce prognostic fields (with a smaller time step than the parent grid). When it gets to the same simulation time, then an average of the prognostic value is performed over all the grid-cells that occupy a single parent grid-cell.

Grid structure in RAMS

 # Variable vertical grid spacing: stretched grid.

Resolution is higher closer to the ground; a expansion ratio is specified. An upper bound is imposed on the depth, above which the ratio is 1 (constant depth).

 # Terrain-following coordinate: *the bottom follows the terrain and the top of the model is flat*



Parameterization of turbulent diffusion

 # Grid spacing determine the spatial scales of the prognostic variables that can be explicitly resolved and those which cannot.

 # After averaging the terms in the prognostic equations, covariances/correlations terms between momentum (u,v) and scalars (temperature, water mixing ratios) appear.

 # Those terms have to be represented en terms of quantities that can be resolved with the grid cell.

 # RAMS parameterized the subgrid-scale fluxes using K-theory: the covariances are evaluated as the product of an eddy mixing coefficient and the gradient of the transported quantity:

$$\overline{u_i' \phi'} = -K_{hi} \frac{\partial \phi}{\partial x_i}$$

Where K_{hi} is the eddy mixing coefficient for scalars in the i-direction.

Parameterization of turbulent diffusion

 # For velocity components, there are two different forms for the representation of the turbulence, depending on the scales of motion resolved by the model grid (horizontal vs. vertical grid spacing).

 # There are currently four options for computing the mixing coefficients:

- *Two local schemes: the coefficients only depend on the local and current flow properties*
- *Two non-local schemes: based on the local current value of turbulent kinetic energy but are regarded as non-local because kinetic energy can be generated anywhere in the simulation domain and transported.*

 # Values for different parameters associated with those cases have to be provided by the user and the specific case.

Other parameterizations

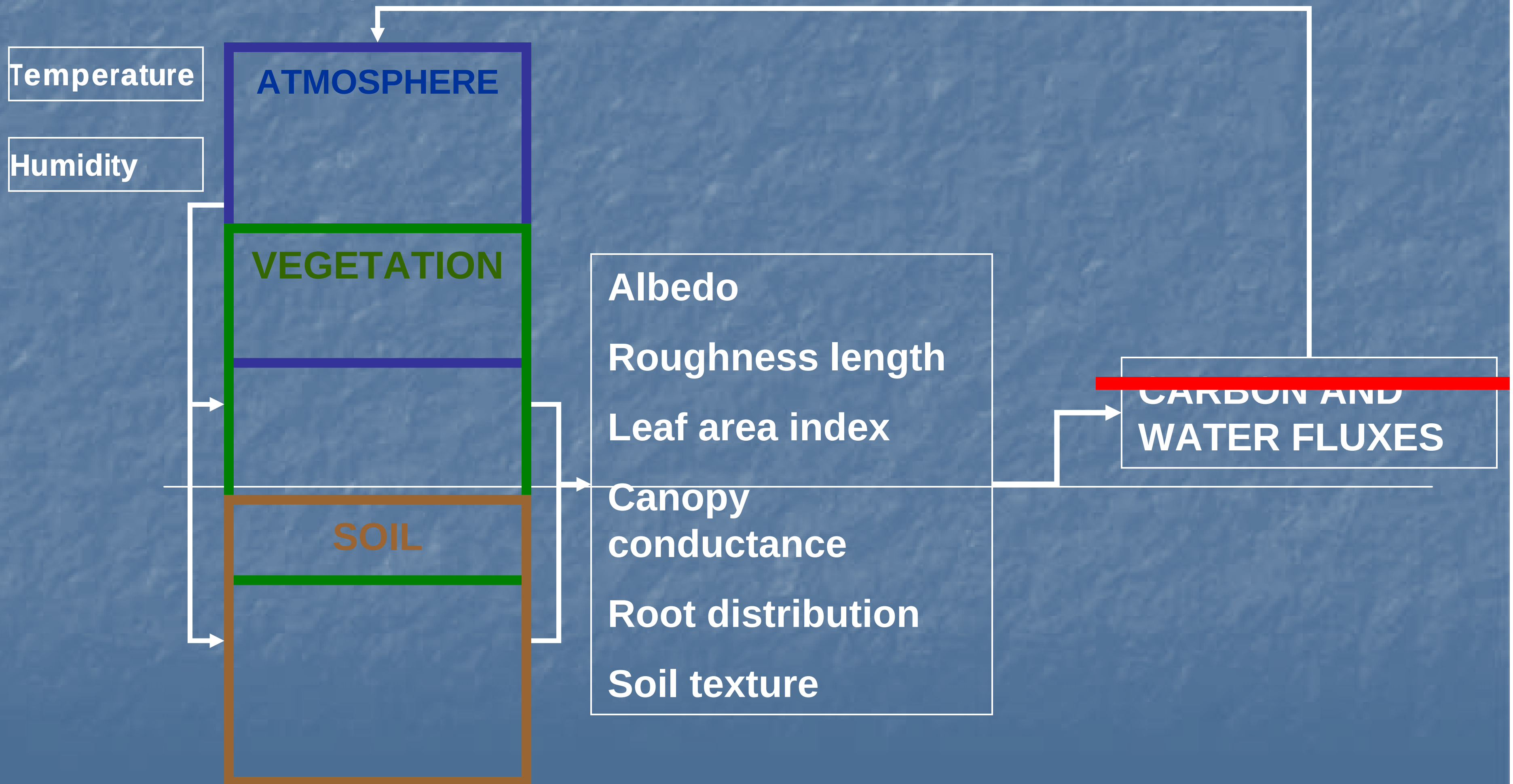
Precipitation processes: convection and large scale precipitation

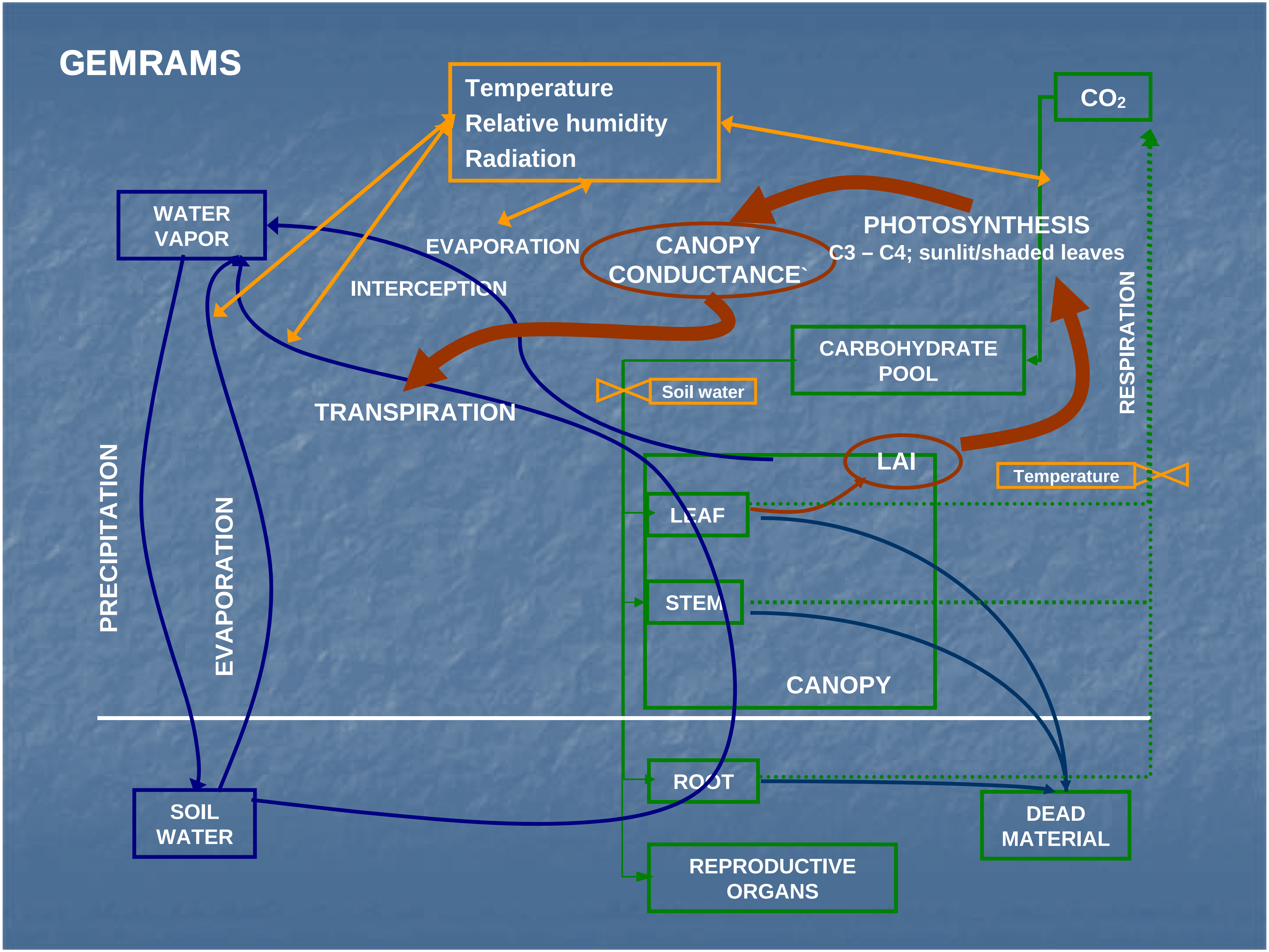
- *Kuo, Kain-Fritsch schemes for convection*
- *Single-moment scheme for cloud microphysics*
- *Dump-bucket type of large scale parameterization*

Shortwave and longwave radiation processes

Soil and vegetation parameterizations

- *The Land-Ecosystem Atmosphere Feedback model (LEAF-2) is the scheme to represent land-surface processes within RAMS.*
- *Temperature and water content of soil, snow cover, vegetation and canopy air are prognosed based on air temperature and humidity, and precipitation (among other variables).*




GEMRAMS
Temperature
Relative humidity
Radiation
CO2
WATER VAPOR
EVAPORATION
CANOPY CONDUCTANCE`
PHOTOSYNTHESIS
C3 – C4; sunlit/shaded leaves
INTERCEPTION
CARBOHYDRATE POOL
Soil water
RESPIRATION
TRANSPIRATION
LAI
Temperature
PRECIPITATION
EVAPORATION
LEAF
STEM
CANOPY
ROOT
SOIL WATER
DEAD MATERIAL
REPRODUCTIVE ORGANS

Input data for GEMRAMS

Bottom boundary conditions

Topography

Land-use / land-cover

Soil type

Leaf area index, vegetation fraction

Soil moisture and temperature

Initial and lateral conditions

Atmospheric conditions

Sea surface temperature

Most of the datasets needed come with the default RAMS43 installation.

Already downloaded in GEMRAMS/ramsgeog

Boundary conditions datasets : default from www.atmet.com

Topography : DEM30s

> ***Contains the global USGS topography dataset at 10m, or about 20km resolution. Each file contains 20x20 degree blocks, with the filename denoting the southwest corner.***

Vegetation classes :

> ***This is the Olson Ecosystem dataset. This USGS dataset is based on 1-km Advanced Very High Resolution Radiometer (AVHRR) data spanning April 1992 through March 1993.***

Sea surface temperature:

> ***Monthly climatological conditions from Reynolds, 1°x1°***

Soil texture :

> ***From the Food and Agriculture Organization. Contains the global soil texture data for RAMS at 2 min, or about 4km resolution. Each file contains 5x5 degree blocks***

- *All of them are global*
- *The data is in blocks, with an additional HEADER file*
- *This data is processed "online" by RAMS through the Makesfc step*

Initial and lateral boundary conditions

It can be any output of an atmospheric model that:

- Has a size larger than the parent grid (2x2 deg larger)
- With the variables: u and v, geopotential height, temperature and relative humidity
- Defined for several pressure levels (at least 12)
- With a temporal frequency of 3 – 12hs

For example: reanalysis, global forecast model

Public domain websites for large scale reanalysis

NCEP/NCAR reanalysis

ftp.cdc.noaa.gov/Datasets/ncep.reanalysis/pressure

ECMWF reanalysis (ERA40)

http://www.ecmwf.int

NCAR: dss.ucar.edu/pub/era40

NCEP Regional Reanalysis

http://nomads.ncdc.noaa.gov/#narr_datasets

http://dss.ucar.edu/pub/narr

Forecast models

GFS: http://fttpprd.ncep.noaa.gov/pub/data/nccf/com/pfs/prod/gfs.yyyymmddhhh/

GDAS: http://dss.ucar.edu/datasets/ds082.0/

Public domain websites for upper air and surface observations

University of Wyoming

Global, 1973 to present

Upper air

http://weather.uwyo.edu/upperair/sounding.html

Surface observations

http://weather.uwyo.edu/surface/meteogram/

NOAA/ESRL

Upper air: global, 1994 to present, online; North American archive, 1946-1997, CD-ROM

http://raob.fsl.noaa.gov/

NCAR DSS

Upper air: global, 1973 to present

http://dss.ucar.edu/datasets/ds353.4/

Surface: global, 1975 to present

http://dss.ucar.edu/datasets/ds464.0/

Other initial boundary conditions, like LAI, vegetation fraction and temperature and soil moistures are optional, but can have a great impact in the modeling results

In a fully-coupled mode, GEMRAMS uses only initial conditions in LAI and veg fraction. An option exists to run the model ingesting daily LAI and veg fraction datasets; this option did not exist in the original RAMS4.3.

For all those cases, the files with the datasets need to be generated "offline", before start the model, i.e. converted to a RAMS_grid. In addition some options in RAMSIN need to be modified.

For LAI and veg fraction, they can be estimated from satellite measurements of Normalized Difference Vegetation Index (NDVI). Several dataset exist. The one we use is from GIMMS-NASA NDVI:

http://gimms.gsfc.nasa.gov/

The 8x8km dataset for North and South America is downloaded in GEMRAMS/

Soil moisture and temperature datasets are harder to obtain to initialize the model simulations.

There are some soil moisture content data out there:

- *CPC http://www.cpc.ncep.noaa.gov/soilmst/sm_glb.html*
  global soil moisture datset from 1979-present at 1 degree resolution.

- *University of Washington, one of which is a 1/8 degree dataset over North America for 1950-2000. www.hydro.washington.edu*

  This dataset is processes offline, and ingested in RAMS during a make init run

Other input data (non-default)

Other Databases that can be of interest

- **Soil texture**
- STASTGO database:

  http://soils.usda.gov/survey/geography/statsgo/

  State Soil Geographic (STATSGO) Database. The STATSGO spatial and tabular data were revised and updated in 2006. STATSGO has been renamed to the U.S. General Soil Map (STATSGO2).

- **Land cover**

  http://landcover.usgs.gov/

  From the USGS Land Cover Institute, NLCD dataset
- Other sites:
  - http://landcover.usgs.gov/landcoverdata.php

GEMRAMS model source code and tests

code:/

- **bin/:** make and include files, and model binaries
- **src/:** source code (several subdirectories)
- **ramsgeog/:** several subdirectories with topography, vegetation, sea surface temperature, soil texture datasets

gemtest/:

- ssa/: Southern South America test
- sfl/: South Florida set-up and test

code:/

bin/: make and include files, and model binaries

include.mk : compiler settings and MPI variables

Makefile : calls other Makefiles for building rams, utils, lib, ncargd, revu

dep_rams-4.3.0.mk : include the dependencies for each fortran file

src/: source code (several subdirectories)

post/: REVU 2.3.1, RAMS outputs post-processing

rams/:

- model/: main model source code
- isan/: main code to create the atmospheric initial and lateral boundary conditions (Variable initialization step)
- lib/: library for /rams directory
- include/: include files

utils/: utilities library

RAMS compilation steps

To build new binaries, execute within bin/ (specially if compilation flags changed or .h files were modified):

make clean_all
make ncargd
make utils
make lib
make rams
make revu

Or make all

The steps:

Makesfc

Makevfile and

Initial

Are the sequence to start a new modeling simulation. Parameters in RAMSIN have to be change accordingly.

dp- files format

```
999999   2
1979   4   9  1200 1800  12 145  73
1    2.50    2.50   .00  -90.00   90.0    0.0   45.0   -45.0   45.0
1  1000   850   700   500   400   300   250   200   150   100   70   50
     -.117     -.071     -.024      .023      .070      .116      .162      .208
      .254      .299      .343      .387      .430      .473      .514      .555
      .594      .632      .669      .705      .740      .773      .804      .834
      .863      .890      .914      .938      .959      .980      .997     1.013
     1.028     1.039     1.050     1.058     1.064     1.068     1.071     1.071
```

Leaf-2 & GEMTM arrays structure

SCHAR array for each (i,j) location

ipatch=1	ipatch=2	ipatch=3 ...	k
			18
		soil temp	17
datq 0 ocean 1 inland H_2O	datq	datq	22 k=11
	ksnow	ksnow	k=10
	patch wet index	patch wet index	k=9
	veg disp ht.	veg disp ht.	k=8
	veg roughness	veg roughness	k=7
sea roughness	net roughness	net roughness	k=6
	leaf area index	leaf area index	k=5
	veg frac area	veg frac area	k=4
	inland ocean 6 veg type	veg type	k=3
	soil roughness	soil roughness	k=2
frac area (water)	frac area (land)	frac area	k=1

WGP array for each (i,j) location

ipatch=1	ipatch=2	ipatch=3 ...	k
"can" mix rat	canopy mix rat	canopy mix rat	k=mg+ms+3=n4
	veg moisture	veg moisture	k=mg+ms+2=n4-1
	grnd mix ratio	grnd mix ratio	k=mg+ms+1=n4-2
	snow (kg/m2)	snow (kg/m2)	k=mg+ms=n4-3
	snow (kg/m2)	snow (kg/m2)	.
	snow (kg/m2)	snow (kg/m2)	.
	snow (kg/m2)	snow (kg/m2)	k=mg+2
	snow (kg/m2)	snow (kg/m2)	k=mg+1
	soil moisture	soil moisture	k=mg 16
	soil moisture	soil moisture	k=mg-1
	soil moisture	soil moisture	.
	soil moisture	soil moisture	.
	soil moisture	soil moisture	k=3
	soil moisture	soil moisture	k=2
	soil moisture	soil moisture	k=1

mg = number of soil levels → 8. x2 patches

ms = number of snowcover levels 1