Chapter 1:
Introduction to the MM5 Modeling System

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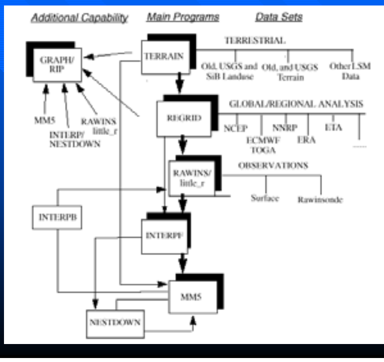
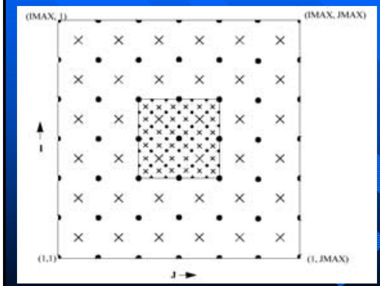
Overview

- MM5 Modeling System
- Horizontal and Vertical Grid
- Nesting
- Lateral Boundary Conditions
- Nonhydrostatic v Hydrostatic Dynamics
- Reference State
- Four-Dimensional Data Assimilation
- Land-Use Categories
- Map Projections and Map-Scale Factors
- Data Required to Run Modeling System

Description of the MM5 System

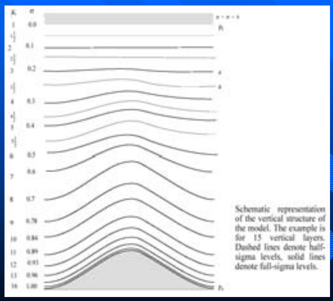


Horizontal Grid



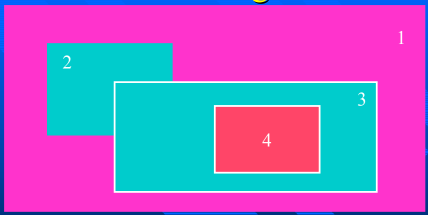
- B-grid staggering
- Horizontal velocities at dots; scalars at crosses
- I increases north
- J increases east
- 3:1 nest ratio

Vertical Grid



- Vertical velocity on full levels
- Other variables on half levels
- Full and half levels
- K increases downwards

Nesting



- Parent/mother domain
- Child/daughter domain
- Domains numbered

One-way nesting

- One-way interaction (boundaries only)
- Any integer ratio
- Run as separate MM5 job

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Two-way nesting

- Two-way interaction (interior feedback)
- All domains run in one MM5 job
- 3:1 ratio in grid length and time step
- Multiple levels (up to four)
- Multiple domains on each level (up to 9 total)
- Overlapping nests allowed
- Moving innermost nest allowed

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Lateral Boundary Conditions

Outermost domain

- Multiple times of analysis needed
- Boundary values time-interpolated from analyses
- Boundary file contains initial value and tendency for each period
- Outer row/column is specified
- Next 4 are nudged/relaxed towards analysis

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Lateral Boundary Conditions

Nested domain

- All boundary values and tendencies come from parent domain
- Updated each parent-domain timestep
- Outer two rows and columns specified
- No relaxation zone required

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Nonhydrostatic versus Hydrostatic Dynamics

- NH has additional equations for
  - prognostic 3D vertical velocity
  - perturbation pressure
- NH has no equations for
  - prognostic surface pressure
  - diagnostic pressure integration
  - diagnostic omega integration
- H dynamics holds for large aspect ratio (horiz scale : vert scale)

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Nonhydrostatic versus Hydrostatic Dynamics (cont'd)

- NH dynamics become important when aspect ratio approaches unity
- NH effects include
  - overturning eddy motion (such as in a density current)
  - parcel theory for thunderstorm updrafts
  - tilting of mountain-wave pattern downstream

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Reference State in Nonhydrostatic Model

- Reference state defines base-state pressure and temperature
- Function of height only
- T0 is linear with log p0
- Three parameters define it (Ts0, A, p00)
- Isothermal layer can be used for stratosphere (A=0, Ts0=Tiso)

$$T_0 = T_{s0} + A\log_e(p_0/(p_{00}))$$

Reference State in Nonhydrostatic Model

- Base-state pressure, p0, defines sigma levels

$$p_0 = p_{s0}\sigma + p_{top}$$

- Ps0(x,y) is a function of surface elevation only

$$p_{s0} = p_0(surface) - p_{top}$$

Reference State in Nonhydrostatic Model

- Height and p0 are related by the reference state parameters

$$Z = -\frac{RA}{2g}\left(\ln\frac{p_0}{p_{00}}\right)^2 - \frac{RT_{s0}}{g}\left(\ln\frac{p_0}{p_{00}}\right)$$

- This also relates ps0 to terrain elevation

Coordinate system

The vertical coordinate, σ, is defined from

$$\sigma = (p_0 - p_t)/(p_0(surface) - p_t)$$

where p_0 is a reference pressure, $p_0(surface)$ is reference surface pressure, and p_t is reference top pressure.

The reference state temperature profile is

$$T_0 = T_{s0} + A\log_e(p_0/(p_{00}))$$

where T_{s0}, p_{00} and A are constants, and

$$p_0 = p^*\sigma + p_t$$

$$p^* = p_0(surface) - p_t$$

Four-Dimensional Data Assimilation

- Method of nudging model towards observations or analysis
- May be used for
  - Dynamical initialization (pre-forecast period)
  - Creating 4D meteorological datasets (e.g. for air quality model)
  - Boundary conditions (outer domain nudged towards analysis)

Four-Dimensional Data Assimilation (cont'd)

- Methods
  - Grid or analysis nudging (suitable for coarse resolution)
  - Observation or station nudging (suitable for fine-scale or asynoptic obs)
- Nudging can be applied to winds, temp, and water vapor

Note: nudging terms are fake sources, so avoid FDDA use in dynamics or budget studies

Land-use Categories

- Used to specify physical properties of land and water in the model (see Table 4.2, page 4-12)
  - Old 13 categories (mostly 1 degree global, locally 5’ in East USA)
  - USGS 24 categories (30” global)
  - SiB 16 categories (30” North America only, used by NCEP Eta model)

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Table 4.2c: 24-category USGS vegetation and physical properties for summer

ID	Description	Albedo (%)	Moisture Avail. (0-1)	Emissivity (% at 9 um)	Roughness length (cm)	Thermal inertial
1	urban	18	10	88	50	.03
2	drylnd crop	17	30	92	15	.04
3	Irrg. crop	18	50	92	15	.04
4	mixdry/irrg	18	25	92	15	.04
5	crop/grass	18	25	92	14	.04
6	crop/wood	16	35	93	20	.04
7	grassland	19	15	92	.12	.03
8	shrubland	22	10	88	10	.03
9	mix shrb/gr	20	15	90	11	.03
10	savanna	20	15	92	15	.03
11	dec broadlf	16	30	93	50	.04
12	dec needle	14	30	94	50	.04
13	everg br-lf	12	50	95	50	.05

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Table 4.2c: 24-category USGS vegetation and physical properties for summer (cont)

ID	Description	Albedo (%)	Moisture Avail. (0-1)	Emissivity (% at 9 um)	Roughness length (cm)	Thermal inertial
14	everg nd-lf	12	30	95	50	.04
15	mix forest	13	30	94	50	.04
16	water	8	100	98	.01	.06
17	herb wetlnd	14	60	95	20	.06
18	wd wetland	14	35	95	40	.05
19	sparse veg	25	2	85	10	.02
20	herb tundra	15	50	92	10	.05
21	wd tundra	15	50	93	30	.05
22	mix tundra	15	50	92	15	.05
23	bare grnd tundra	25	2	85	.10	.02
24	snow or ice	55	95	95	5	.05
25	no data					.

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Land-Surface Properties

- Albedo (%): solar radiation reflection
- Moisture Availability (0-1): determines water available for evaporation
- Emissivity (%): long-wave emission factor from ground
- Roughness length (cm): determines surface momentum flux (friction)
- Thermal inertia: determines response of ground temperature to net forcing

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Map Projections and Map-Scale Factors

- Projections (all conformal : dx = dy)
  - Polar Stereographic (suitable for high lats)
  - Lambert Conformal (suitable for mid lats)
  - Mercator (suitable for low lats)
- Map-scale factor
  - distance on grid (const) ÷ actual distance on earth
  - Only varies with latitude
  - Usually stays close to 1.0

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Data Required to Run Modeling System

- Topography and land-use
- Gridded analyses (global or regional)
  - Need several times for boundaries
  - A minimum number of levels (10 mandatory levels
  - 3D winds, heights, temperature, RH
  - 2D SLP, SST, and snow cover (optional) for surface

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Data Required to Run Modeling System (cont'd)

- Observation data
  - Radiosonde and surface data
  - Needed if doing a reanalysis (e.g. with coarse gridded data)
  - At least at initial time (optionally at later times for boundaries)
- Land-surface model requires more data (see Appendix C)