Global Modeling/Assimilation Theme Presentation

Review Icosahedral Global Models Development /Overview NIM (non-hydrostatic Icos-model)

Jin Lee

Outline of this talk

- ESRL's goal for icosahedral global models
- Icosahedral models development plan
- Status of FIM and NIM
- Conclusion and future outlook

Earth System Research Laboratory

Director, Dr. A.E. (Sandy) MacDonald

GFDL,NSSL,ARL,AOML,GLERL,PMEL

Aeronomy Lab.
Climate Diagnostic center
Climate Monitoring and Diagnostic Lab
Environmental Technology Lab
Forecast Systems Lab

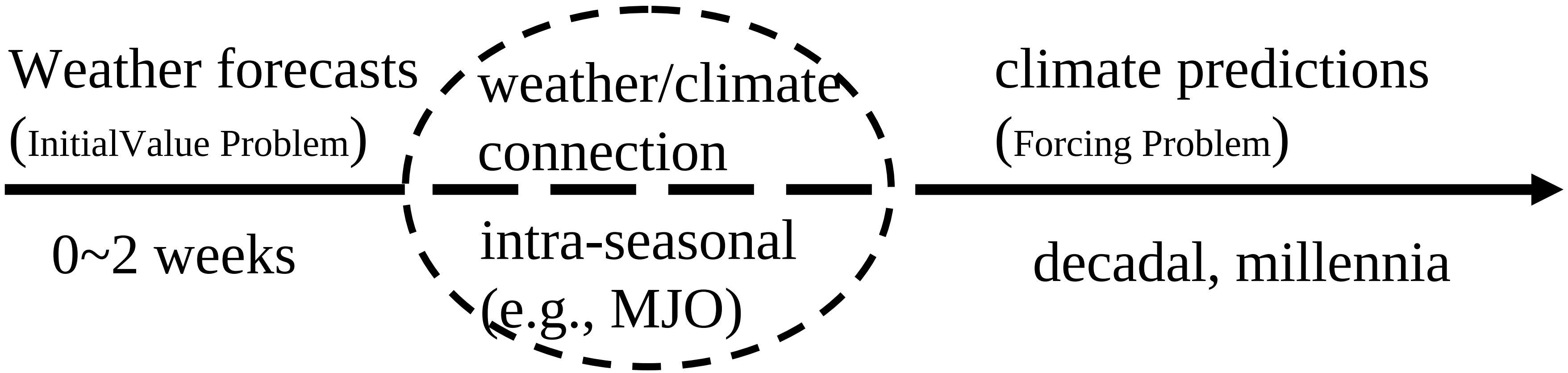
→

→

Chemical Sciences Div
Global Monitoring Div
Physical Sciences Div
Global Systems Div

Modeling goal: to develop a non-hydrostatic global cloud resolving model ***(GCRM)*** for ***weather*** and ***climate*** predictions through collaborations among OAR labs and others.

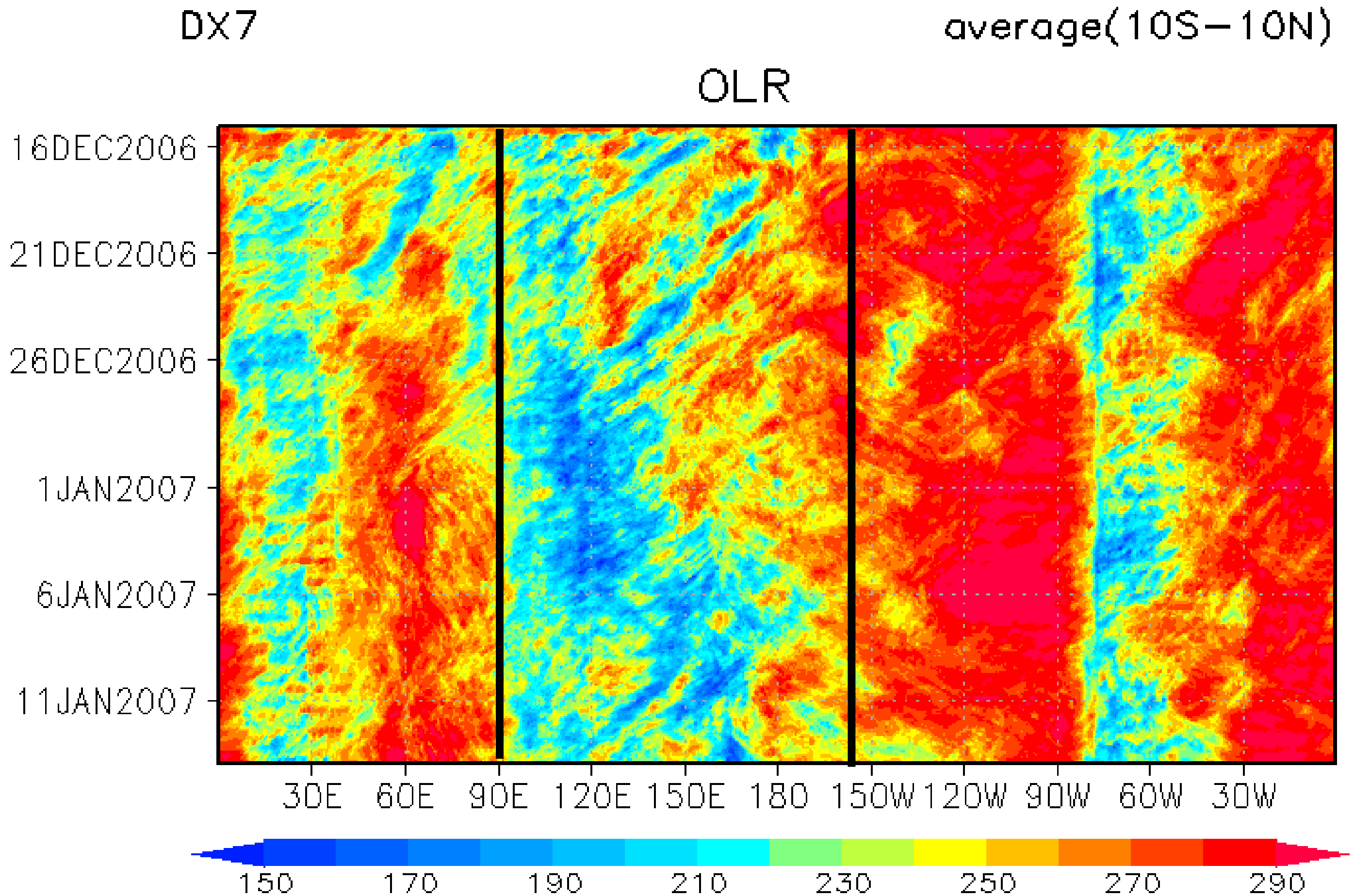
- What’s GCRM ?
  -> A global model with dx~O(km) to “explicitly resolve” convective precip, especially tropical convective clouds.
- Why? -> to avoid uncertainty in cumulus parameterizations.



OLR Hovmoller showing MJO simulation

NICAM dx=3.5/km7km

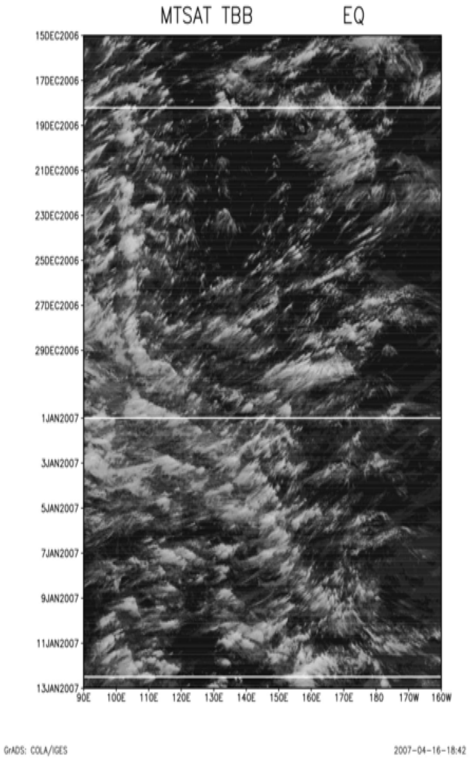
(Non-hydrostatic ICosahedral Atmospheric Model)



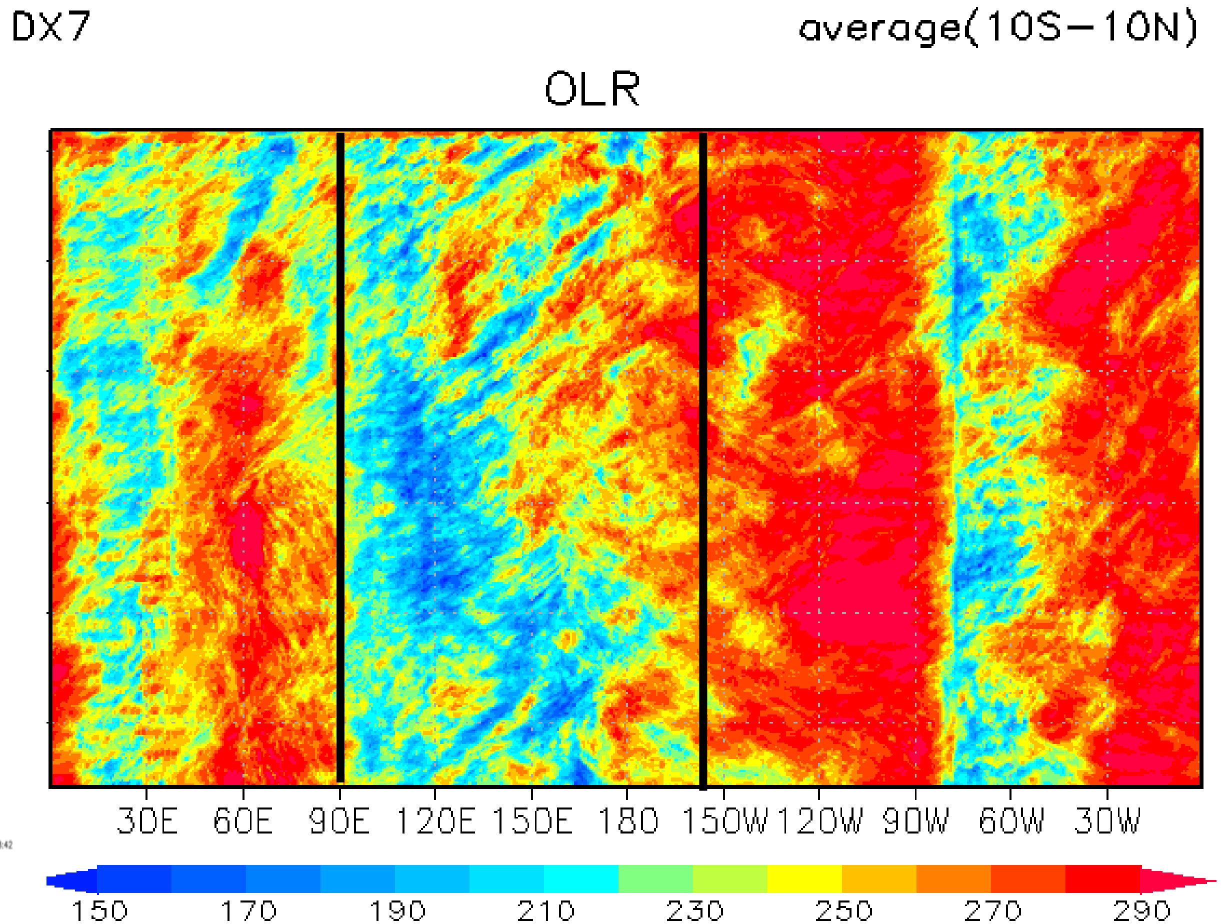
courtesy of Prof. Satoh *(Science, dec. 7, 2007)*

OLR Hovmoller showing MJO simulation

MTSAT-1R TBB
by T.Nakazawa



NICAM dx=3.5/km7km
(<u>N</u>on-hydrostatic <u>IC</u>osahedral <u>A</u>tmospheric <u>M</u>odel)



courtesy of Prof. Satoh *(Science, dec. 7, 2007)*

- What's a GCRM ?
  -> a global model/dx~O(km) to "explicitly resolve" convective precip, especially tropical convective clouds.
- Why? -> to avoid uncertainty in cumulus parameterizations.

Weather forecasts
(InitialValue Problem)

0~2 weeks

weather/climate connection

intra-seasonal
(e.g., MJO)

climate predictions
(Forcing Problem)

decadal, millennia

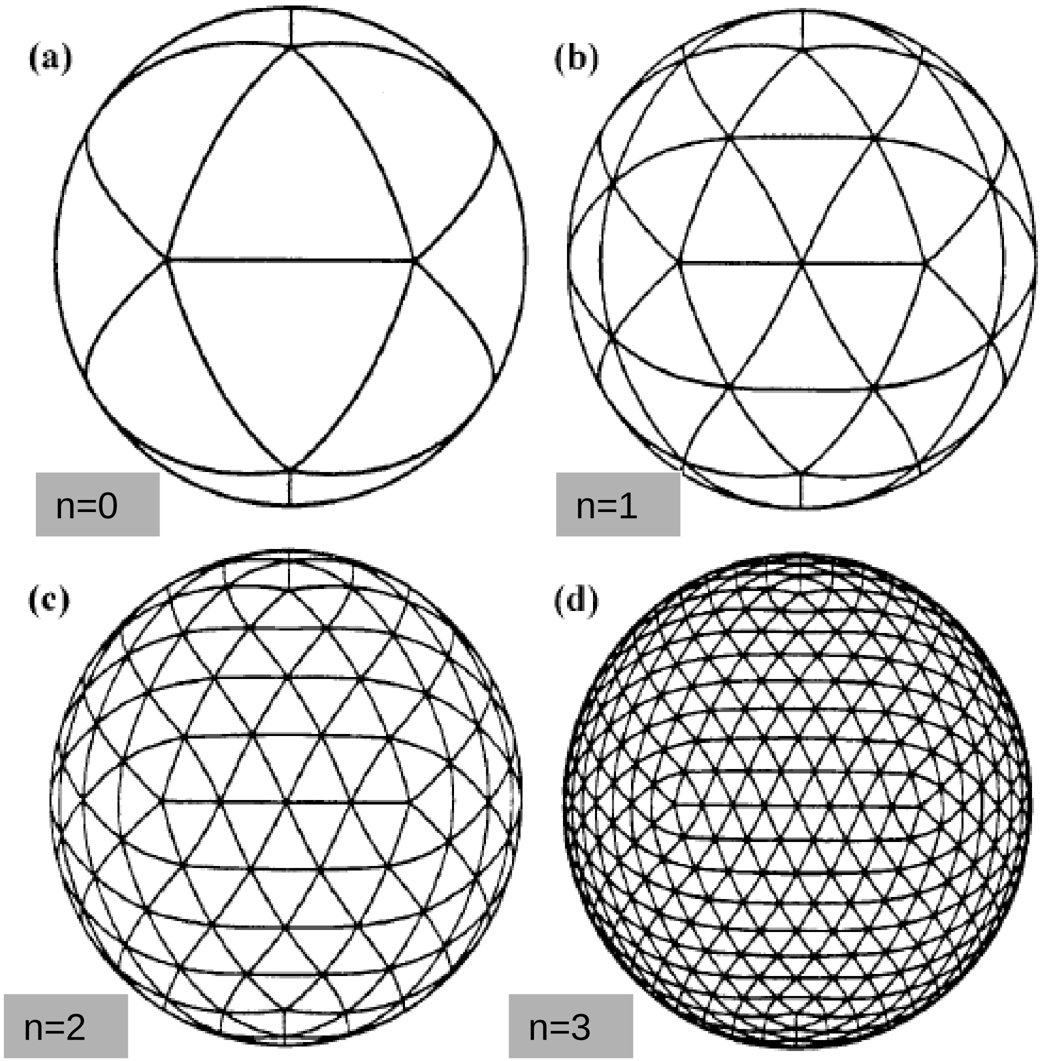
- Who's doing it ?

CSU (Prof. Randall),
NICAM/Earth Simulator: Prof. Satoh
NOAA/OAR (ESRL/GSD, GFDL, AOML)
NCAR/ESM (Drs. Klemp, Skamarock)

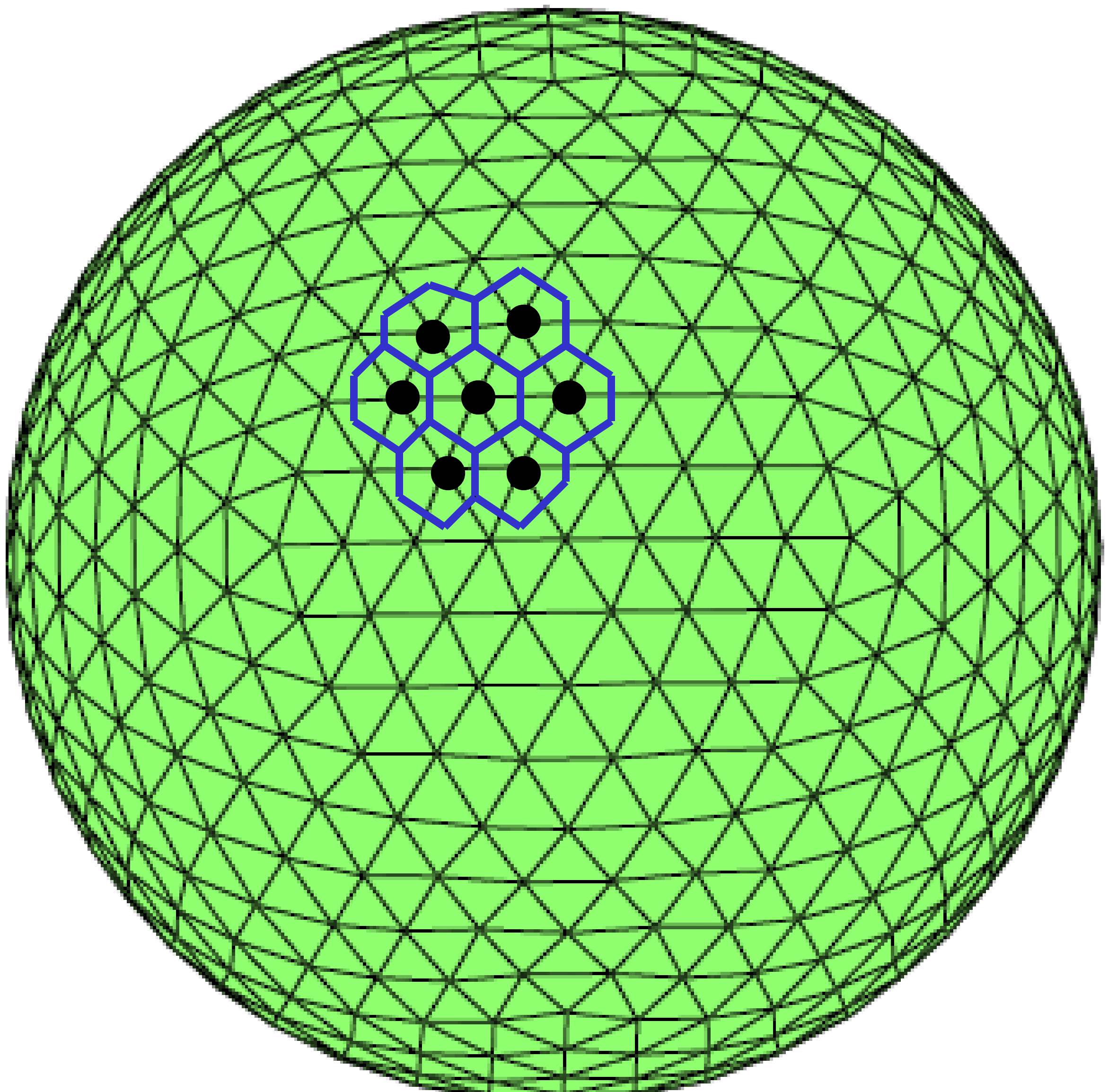
<u>Icosahedral grid</u>

<u>(coincidence ?)</u>

Icosahedral Grid Generation



N=((2**n)**2)*10 + 2 ; 5th level – n=5 → N=10242 ~ 240km; max(d)/min(d)~1.2
6th level – n=6 →N= N=40962 ~ 120km; 7th level – n=7→N=163842   ~60km
8th level – n=8→N=655,362   ~30km;   9th level – n=9→N=2,621,442 ~15km
10th level ~7.km;   11th level ~3.5km , 12th level ~1.7km



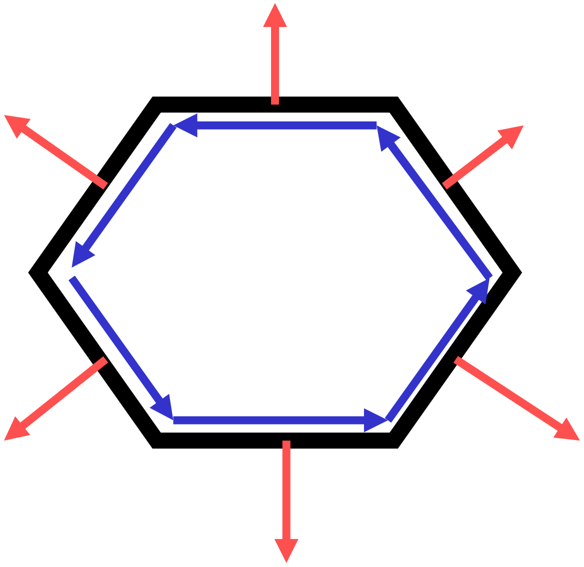
suitable for finite - volume numerics, e.g.,

Stokes' theorem :

$$\int_A \left(\nabla_h \times \vec{V}_h\right) dA = \oint_s \left(\vec{V}_h \cdot \vec{l}\right) ds$$

Divergence theorem :

$$\int_A \left(\nabla_h \cdot \vec{V}_h \phi\right) dA = \oint_s \left(\vec{V}_h \phi \cdot \vec{n}\right) ds$$



ESRL global models development plan

- A finite-volume Icosahedral Shallow Water Model (SWM)

- Convert SWM to Single-Layer Model (SLM);
  Implement FCT for monotonicity and positive definite

- A 3-D model composed of Stacked SLMs using
  Lagrangian-type of vertical coordinate.

- Implement physics packages for weather and climate forecasts

- Implement Earth System Modeling Framework (ESMF)

ESRL f.-v. Icos- models (FIM and NIM)

ESMF

1. Collab. with NCEP/EMC
   (Icos- for NCEP model ensemble)

- **FIM** (flow-following finite-volume Icosahedral model): for weather fcsts.

  model components:
  Icosahedral grid,
  finite-volume,
  theta-sig hybrid coord,
  hydrostatic,
  GFS physics

2. Collab. among OAR Labs.
   (ESRL/GSD, GFDL, AOML)

- **NIM** (Non-hydrostatic Icosahedral model) is a global cloud resolving model (GCRM) for Wx/Clmt fcsts.

  model components:
  Icosah-grid, cubed sphere,..
  high-order finite-volume,
  largrangian vertical coord,
  non-hydrostatic,deep-atm,
  full coriolis terms,
  physics(GFDL, GFS, …)

NOAA/ESRL

Flow-following-
finite-volume

Icosahedral

Model

FIM

Jin Lee
Sandy MacDonald
Rainer Bleck
Stan Benjamin
Jian-Wen Bao
John M. Brown
Jacques Middlecoff
Ning Wang

Earth System Research Laboratory

Status of FIM

- **Complete FIM model numerics and GFS physics**

Complete Icosahedral grid meta system

Complete parallel version of FIM

Model verification:

FIM is run twice daily for real time verification

confg: GFS initial data, dx~30km/50 layers, without explicit dissipation

*Same initial condition, terrain & sfc parameters, physics package run at similar model resolutions

Mass Conservation and Positive Definiteness

Total mass	=	5.022915528916858E+018	at time step=	1
Total mass	=	5.022915528916743E+018	at time step=	60
Total mass	=	5.022915528916771E+018	at time step=	120
Total mass	=	5.022915528916695E+018	at time step=	180
Total mass	=	5.022915528917074E+018	at time step=	240
Total mass	=	5.022915528917066E+018	at time step=	300
Total mass	=	5.022915528916768E+018	at time step=	360
Total mass	=	5.022915528916948E+018	at time step=	420
Total mass	=	5.022915528916820E+018	at time step=	480
Total mass	=	5.022915528916910E+018	at time step=	540
Total mass	=	5.022915528916967E+018	at time step=	600
Total mass	=	5.022915528916953E+018	at time step=	660
Total mass	=	5.022915528916784E+018	at time step=	720
Total mass	=	5.022915528916850E+018	at time step=	780
Total mass	=	5.022915528916886E+018	at time step=	840
Total mass	=	5.022915528916961E+018	at time step=	900
Total mass	=	5.022915528916819E+018	at time step=	960
Total mass	=	5.022915528916939E+018	at time step=	1020
Total mass	=	5.022915528916824E+018	at time step=	1080
Total mass	=	5.022915528916941E+018	at time step=	1140
Total mass	=	5.022915528916814E+018	at time step=	1200

Final Remarks

1. Developed a hydrostatic hybrid ($\sigma - \theta$) f.-v. icosahedral global model, FIM, which shows excellent conservation properties.
2. **NIM development in progress**

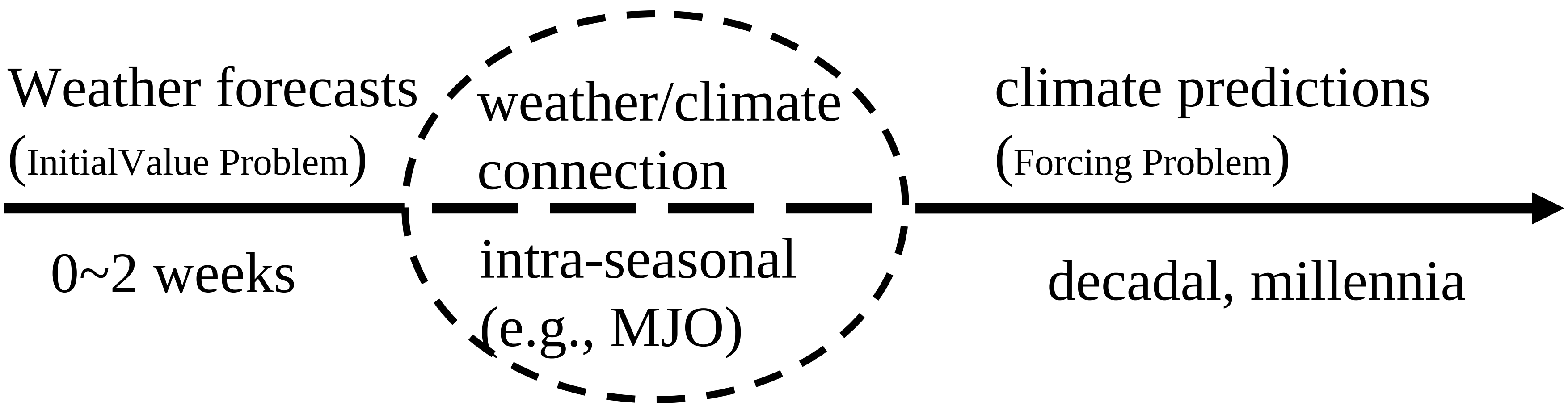
Couple Icos-SWM with Lagrangian vertical coordinate developed by S.-J. Lin at GFDL.

Implement GFDL physics into NIM dycore.

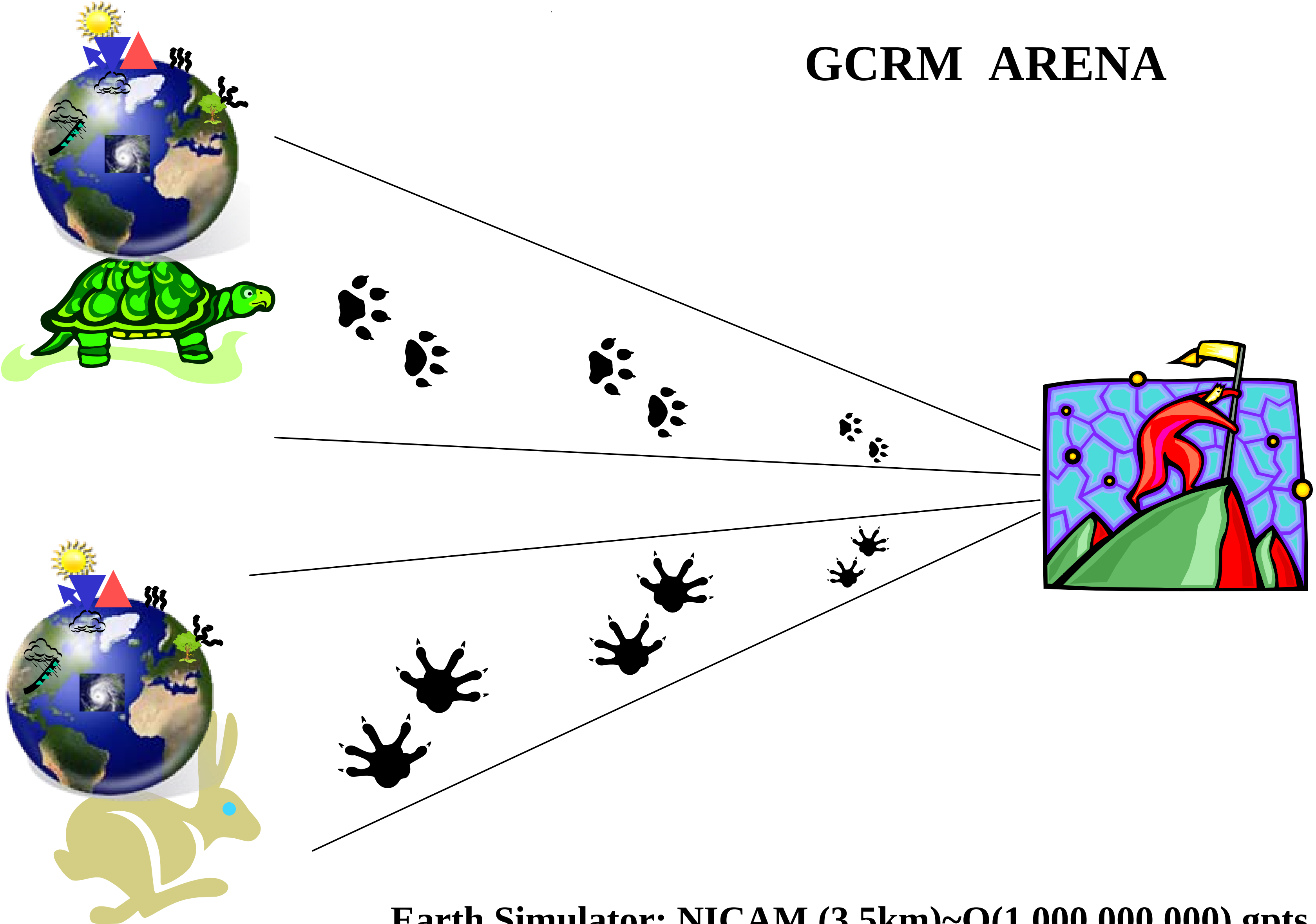
Local stencil allows scaling up to O(***100,000*** **) cpus.**

Focus on model accuracy of long-term integrations.

Research! Rsch! Rsch! to extend/improve weather/climate predictions.



GCRM ARENA



Earth Simulator: NICAM (3.5km)~O(1,000,000,000) gpts

NEC: 10 PF/2012 =>dx~3-400 meters ~O(100,000,000,000) gpts