ENDGame

Nigel Wood,
Dynamics Research and an ever increasing cast of players…

Raison d’être

- Build on foundations of New Dynamics

- Aims are:
  - Improved robustness
  - Improved accuracy
  - Maintain/improve conservation

- While maintaining/improving efficiency

$\Rightarrow$ Accuracy/Robustness/Scalability

What has *not* changed?

- Evolution of New Dynamics
  - Same equation set & variables (θ-π)
  - Same horizontal staggering (Arakawa C-grid)
  - Same vertical staggering (Charney-Phillips)
  - Semi-implicit semi-Lagrangian

- Physics and DA unchanged

What *has* changed (I)?

- Improved (iterative) solution procedure
  - More implicit, approaching Crank-Nicolson
  - Reduced off-centring (alpha's)
- Resolves number of New Dynamics issues:
  - Non-interpolating in the vertical for theta advection Removed
  - Explicitly handled vertical Coriolis terms Removed
  - Extrapolated trajectory calculation Removed

$\Rightarrow$ Improved robustness and accuracy

What *has* changed (II)?

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- Iterated approach
  - ➢ Allows much simpler Helmholtz problem (7 point stencil cf. 45 point)
  - ➢ Much simpler (red/black) preconditioner $\Rightarrow$ greatly reduced communications

$\Rightarrow$ Improved scalability

- Same SL advection for all variables
  - Cf Eulerian continuity equation + SL in New Dynamics

$\Rightarrow$ Improved robustness

What *has* changed (III)?

- Coriolis terms based on mass flux variables
  - ➢ improved Rossby mode propagation

⇒Improved accuracy

- No polar filtering or horizontal diffusion
  - ➢ Control near lid and poles achieved by implicit damping of w

⇒Improved scalability and accuracy

What *has* changed (IV)?

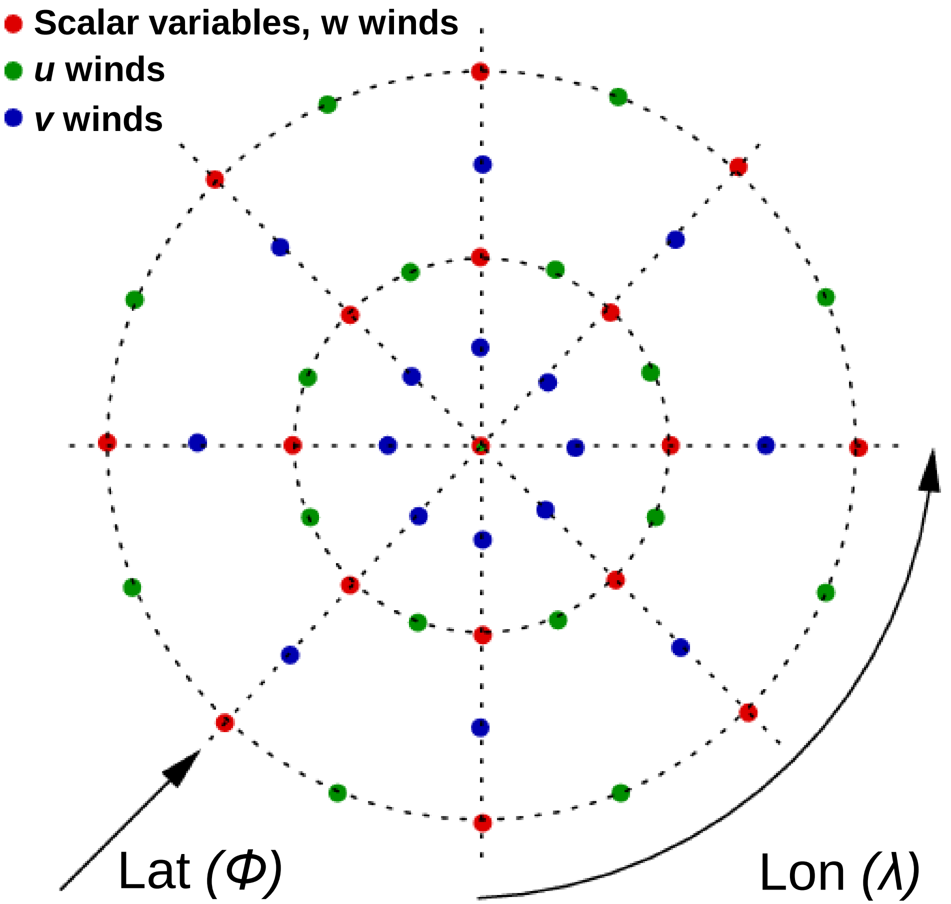
- V-at-poles (cf. u, w and all scalars)
  - Not solving Helmholtz problem at singular point of grid!
  - And improved energy properties

$\Rightarrow$ Improved scalability and accuracy

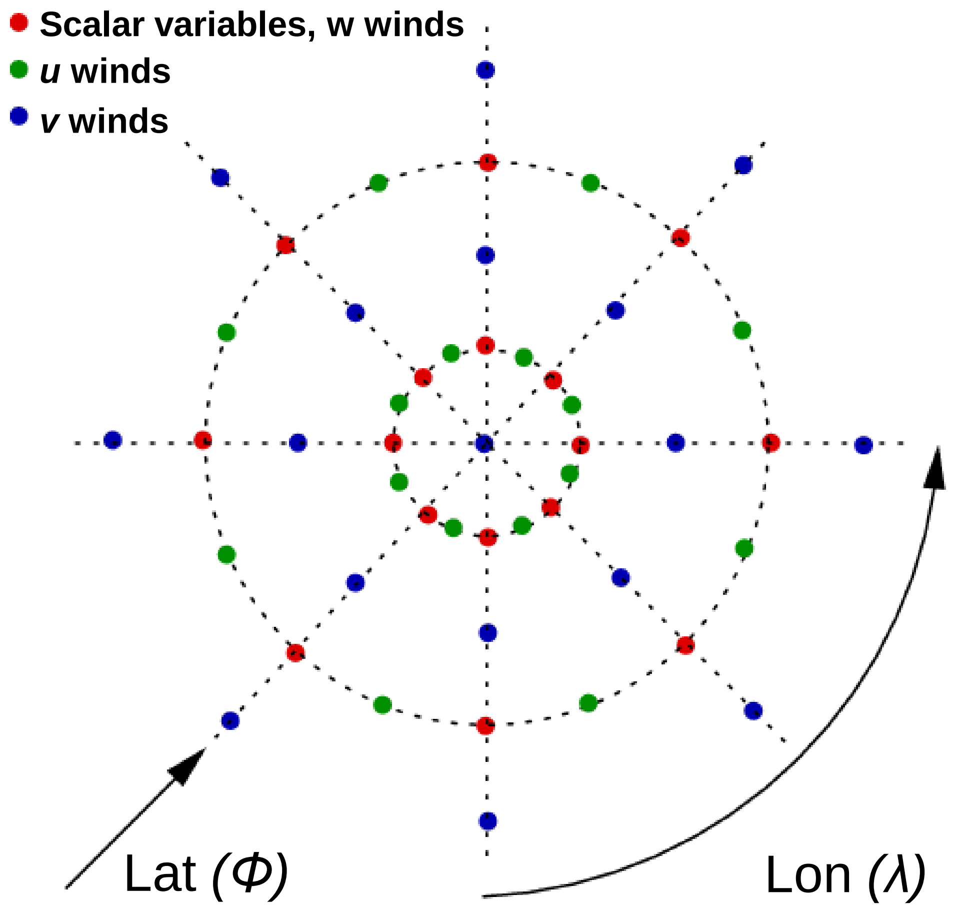
V-at-poles vs. U-at-poles

A “trivial” change to model grid!

Current “New Dynamics” grid



ENDGame grid



ENDGame has additional “zeroth” model level, but not yet being used

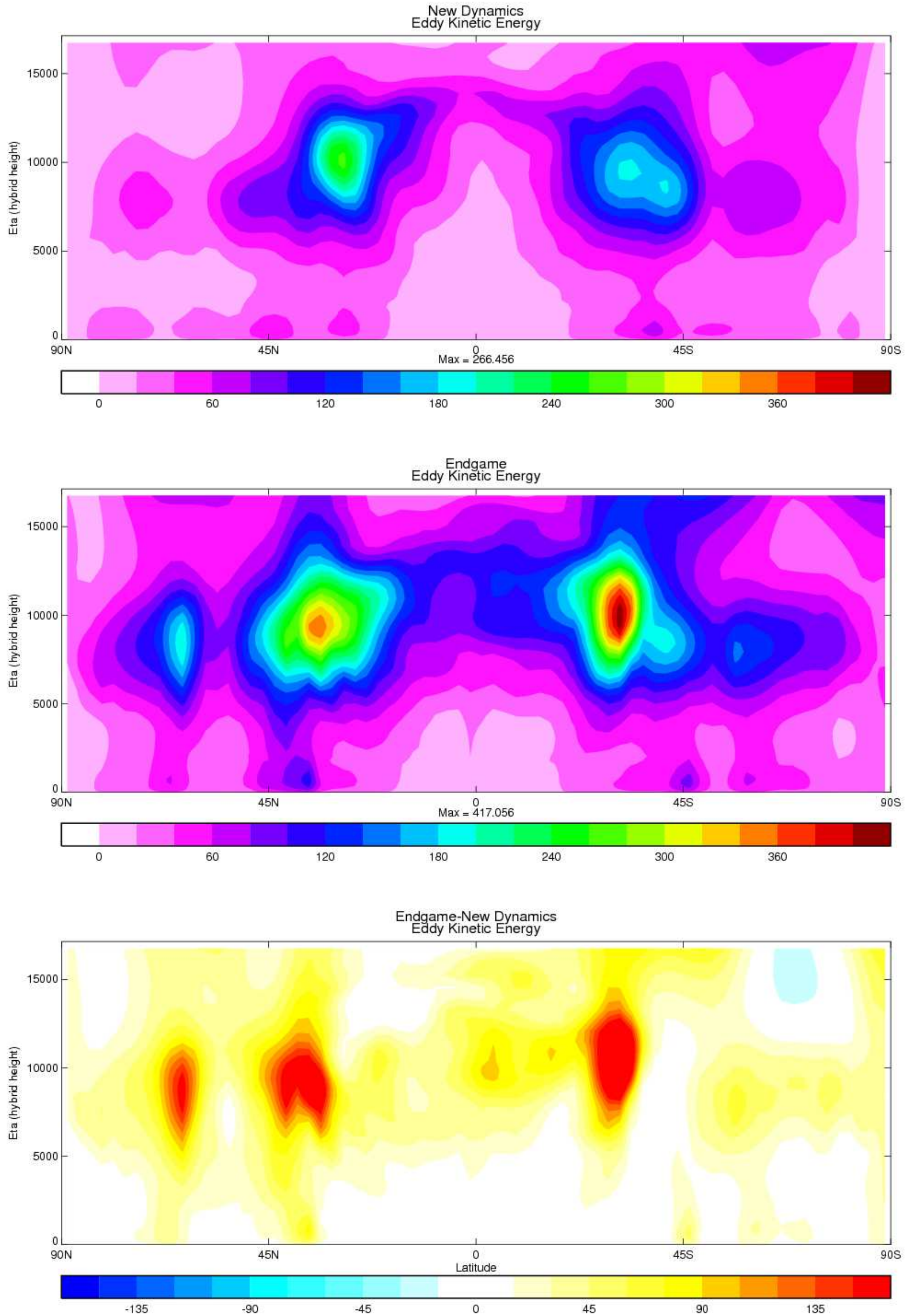
Some results…

ND Max = 266

Accuracy: Aquaplanet EKE

EG Max = 417

Ian Boutle



EG@N48 ≈ ND@N96

Accuracy: Case studies Ts for summer

Better

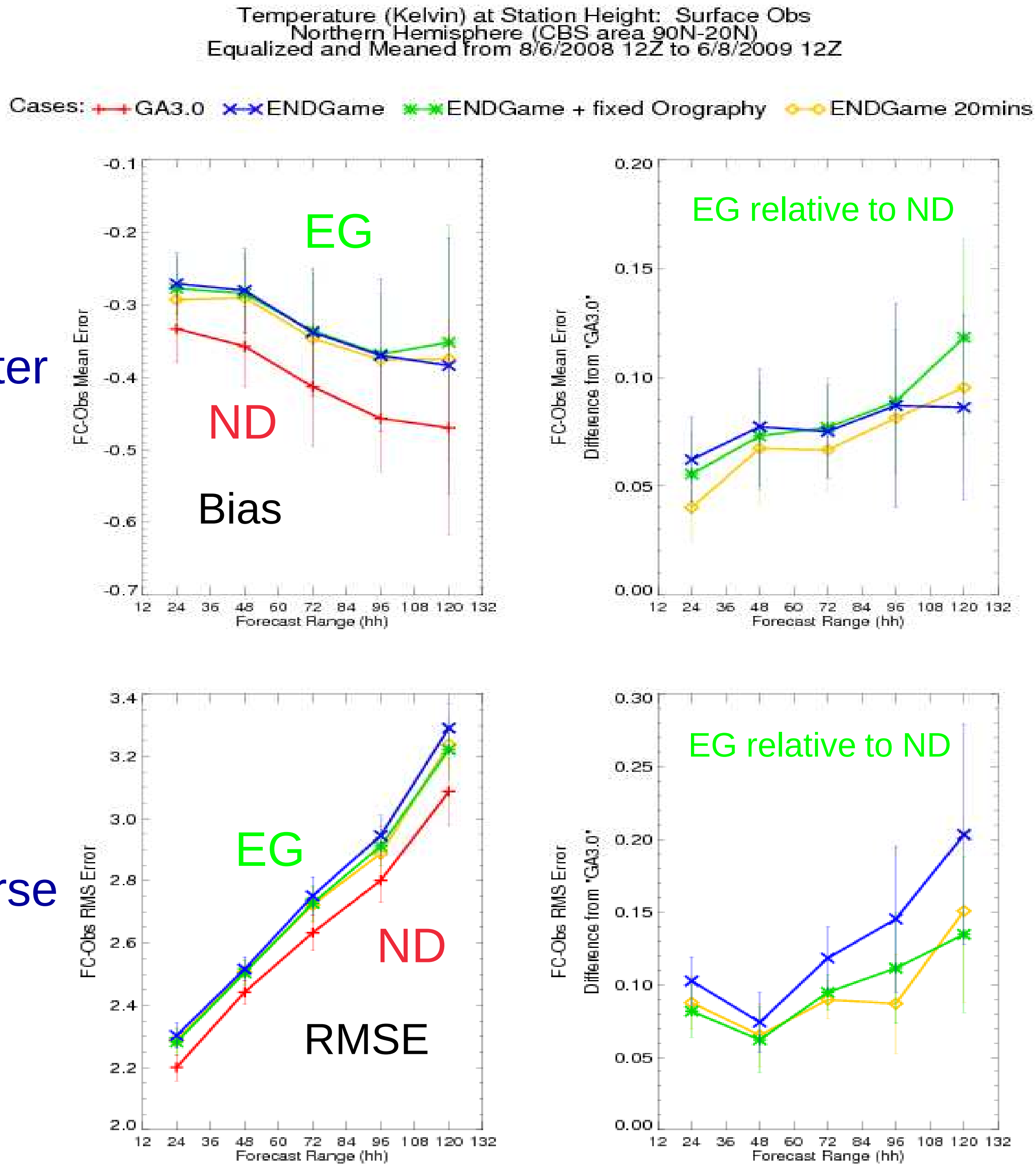
Worse

GA3.0 12 mins

ENDGame 12 mins

ENDGame 20 mins

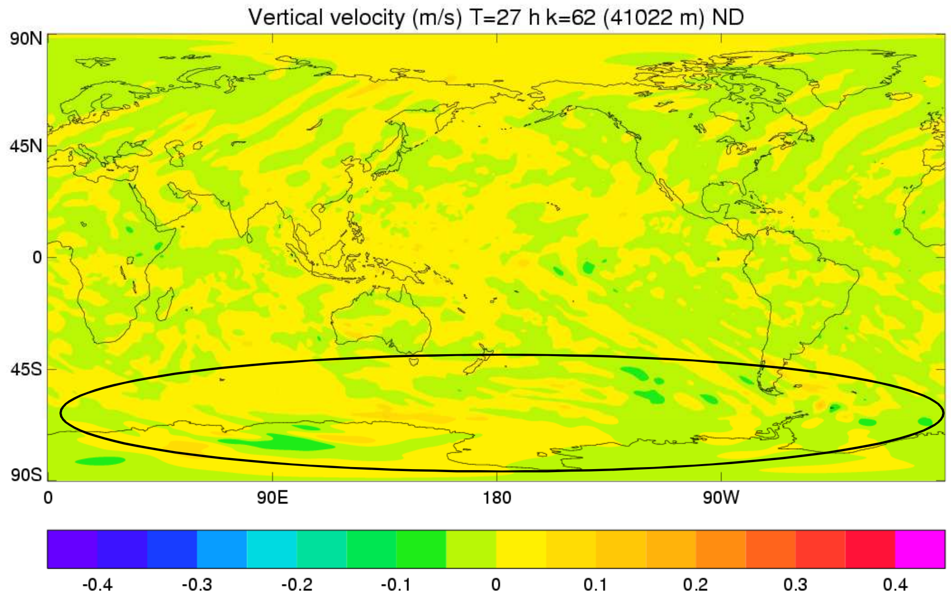
Paul Earnshaw



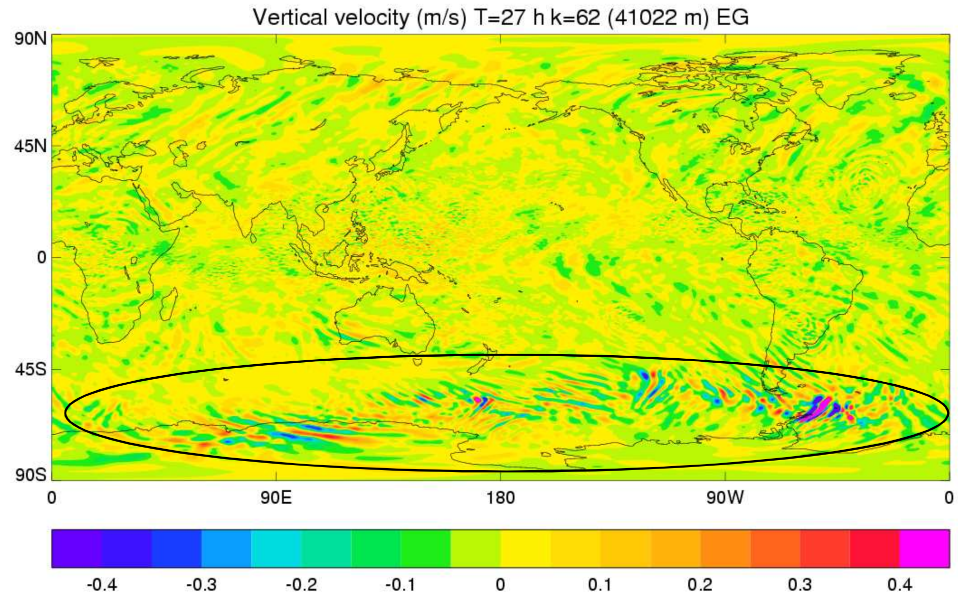
68% error bars calculated using S/(n-1)[1/2]

Accuracy: Stratospheric winds

Vertical velocity at 41km N320



New Dynamics



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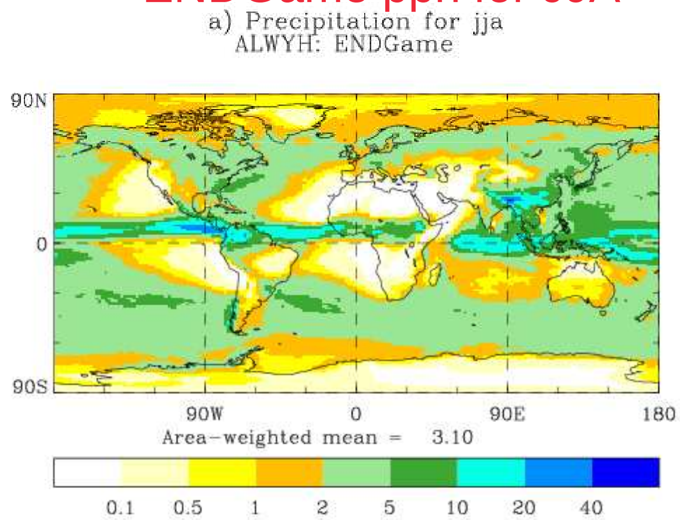
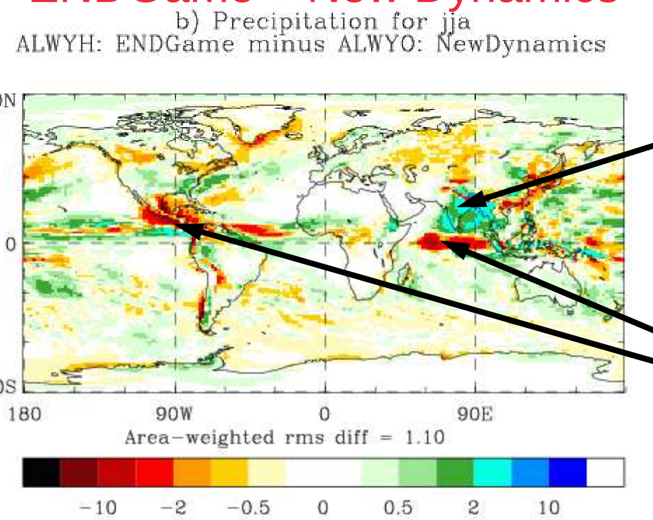
AMIP climate simulations JJA precipitation

ENDGame ppn for JJA

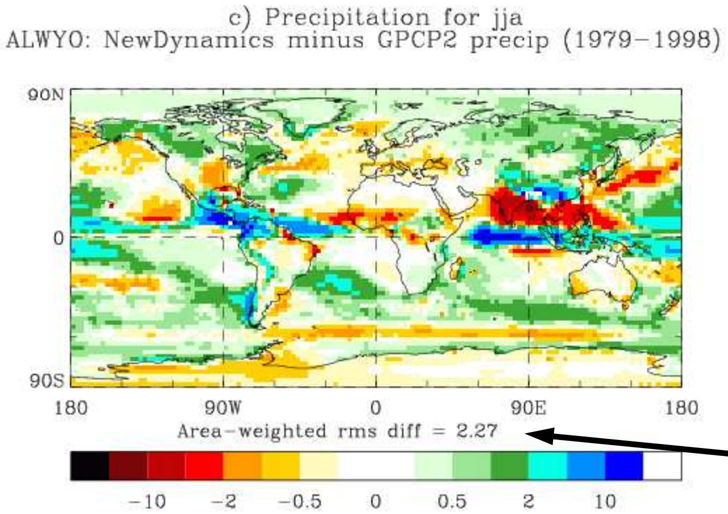


ENDGame – New Dynamics

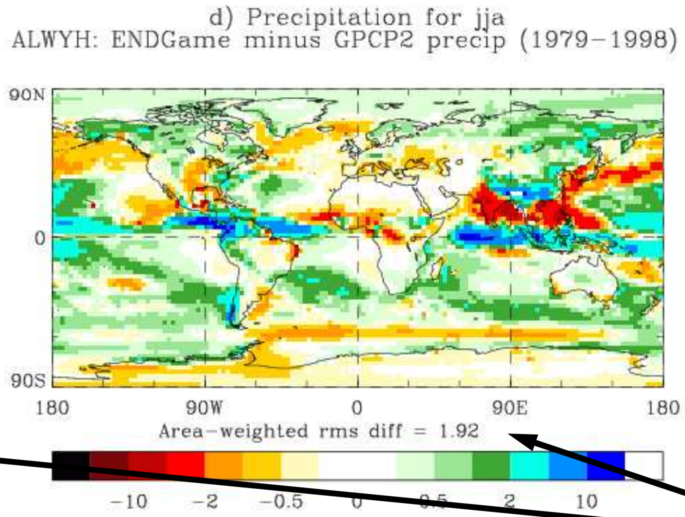


Increased precipitation over India, improving the model

Decreased precipitation over the Indian Ocean and near Central America, improving the model



New Dynamics biases



ENDGame biases

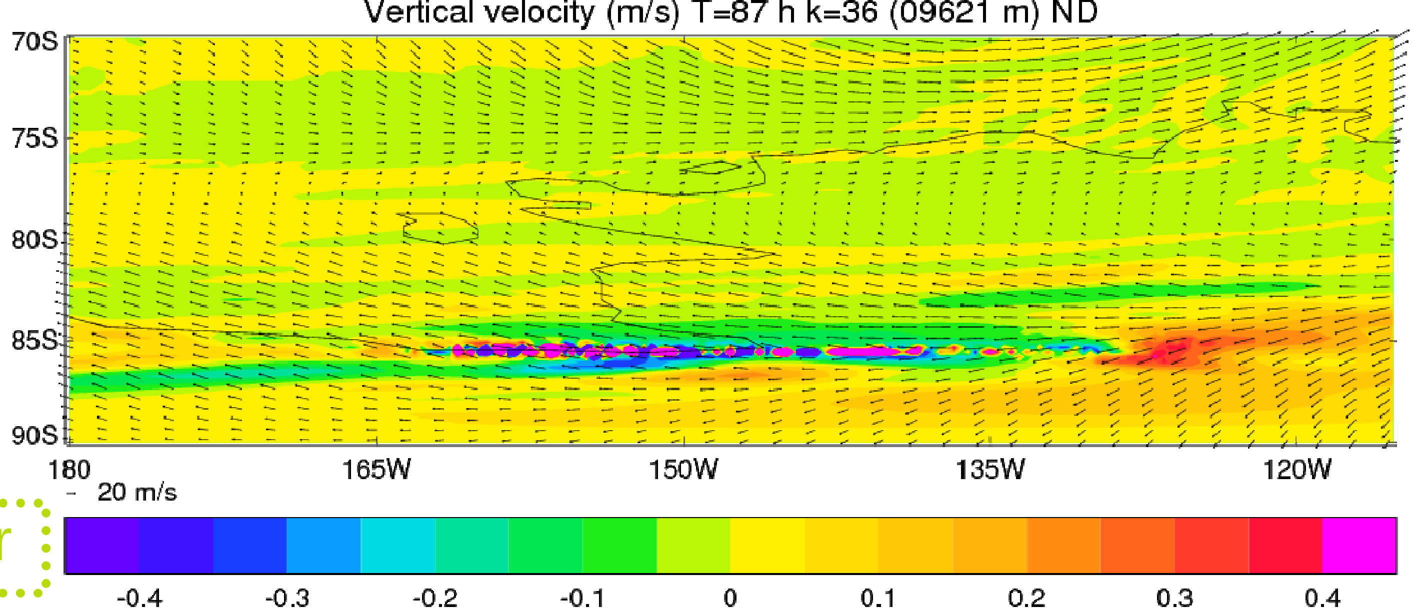
0815

Dan Copsey

ENDGame has reduced RMS error

Stability:
September Antarctic failures

New Dynamics



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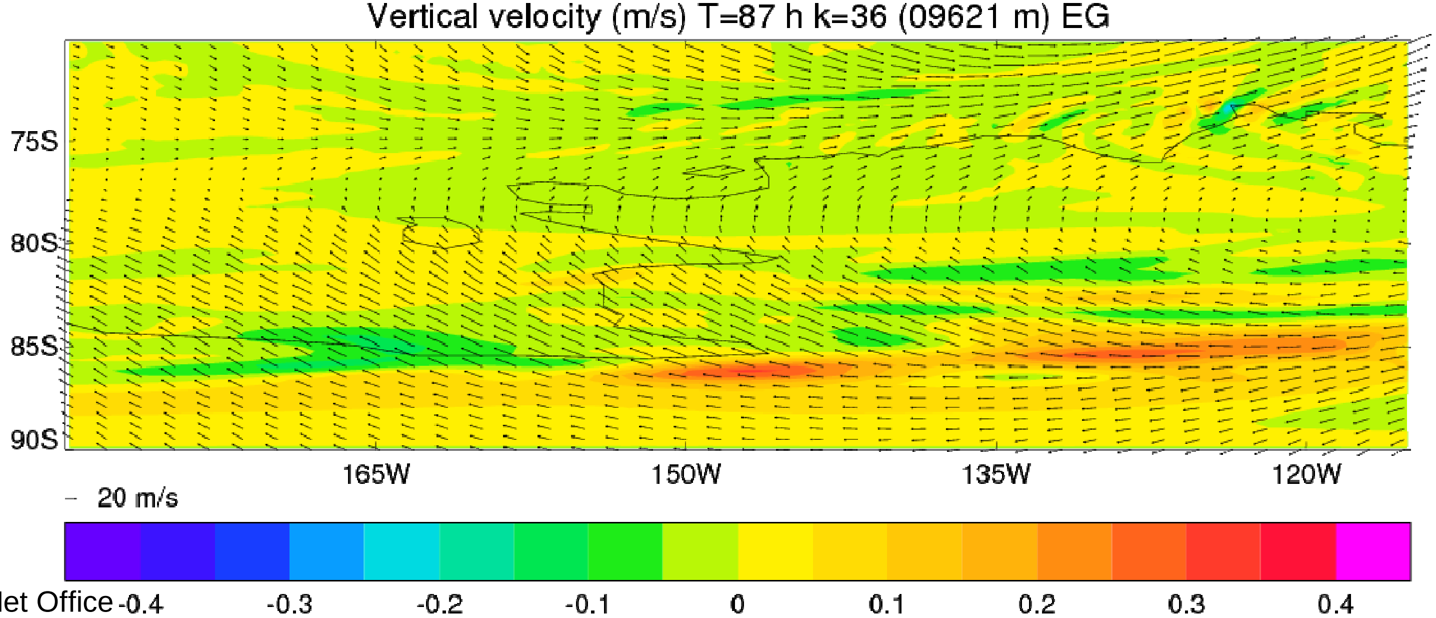
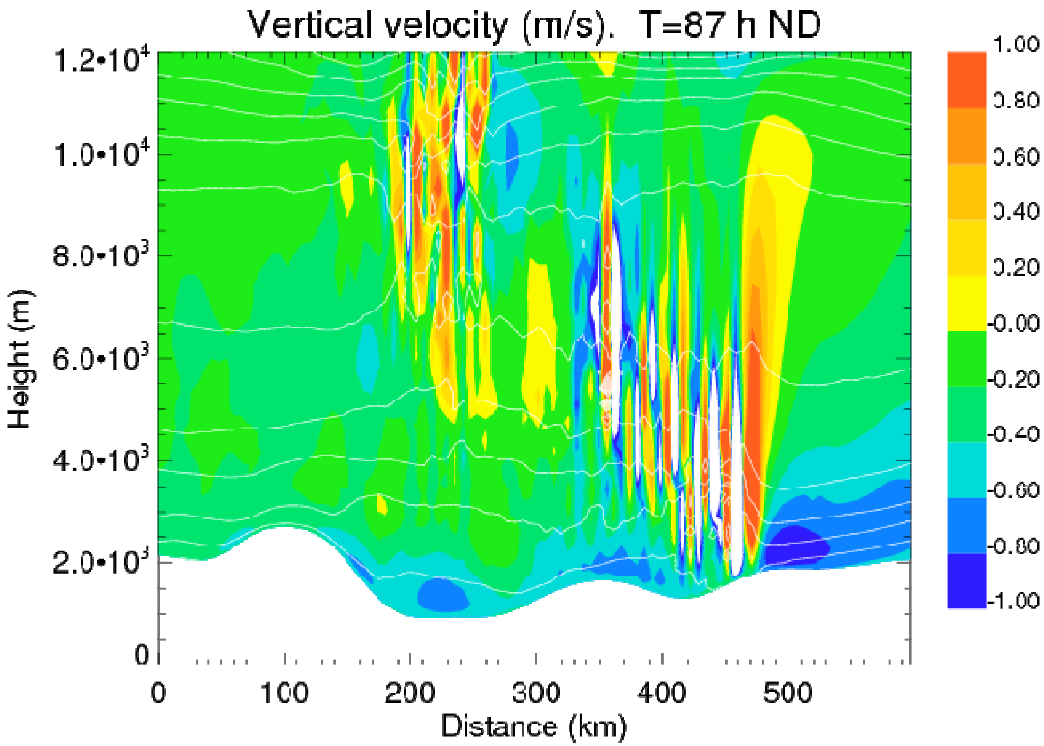
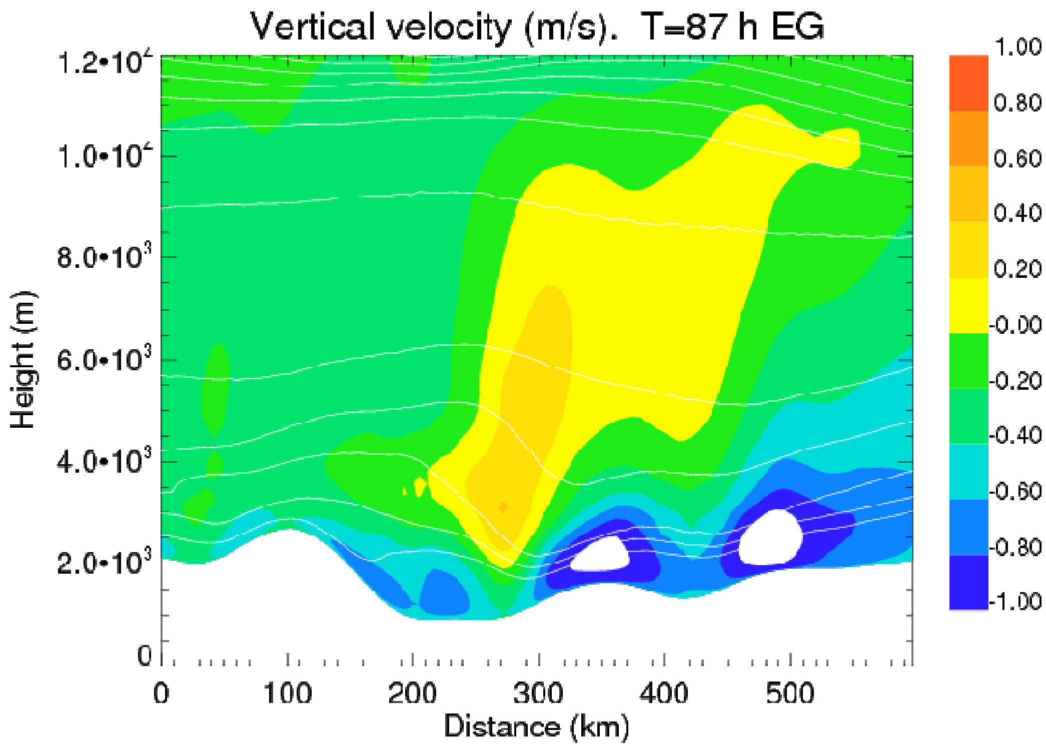


Stability:
September Antarctic failures





New Dynamics

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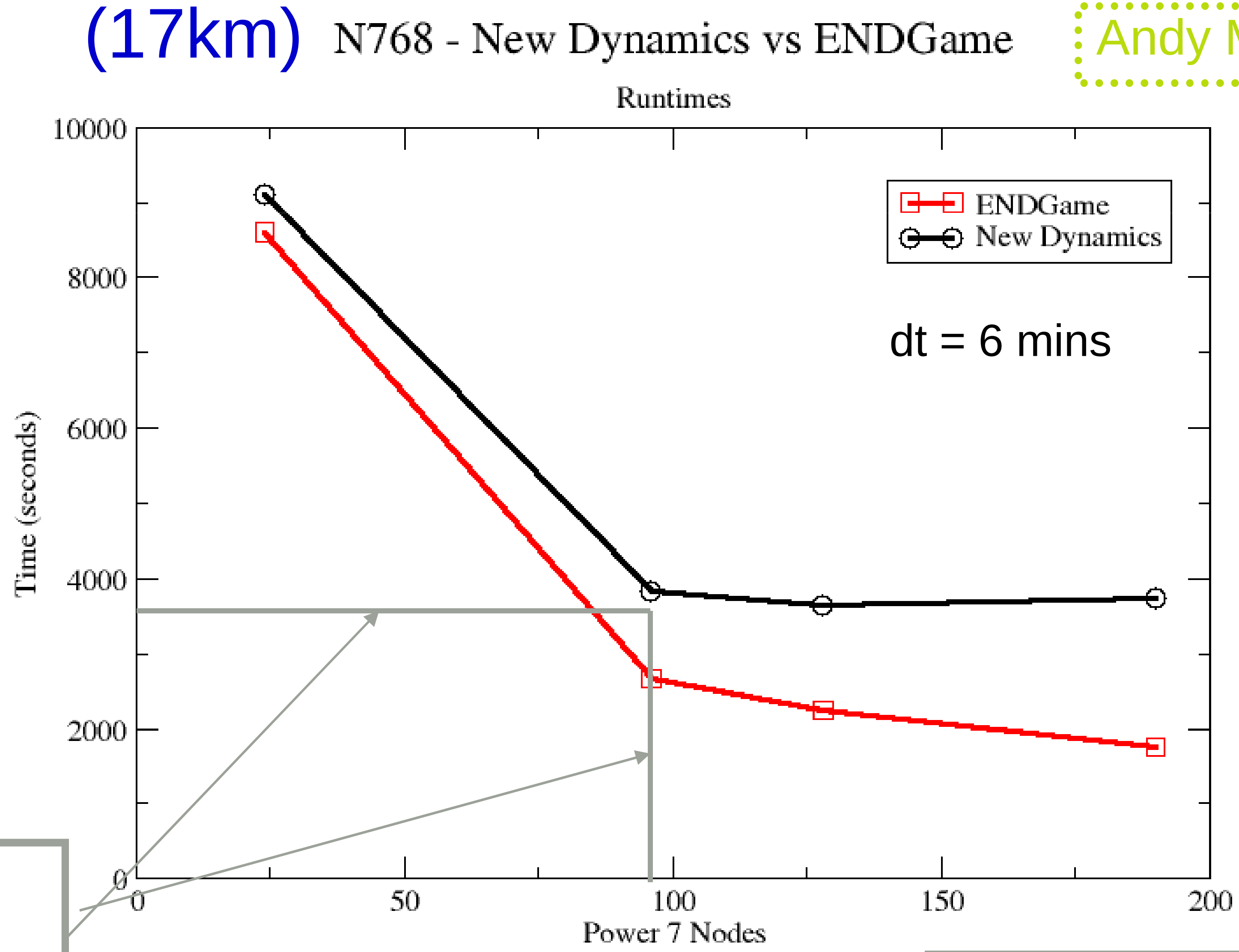
Improved Scalability

(17km)

Andy Malcolm

Run time (s)



Target configuration

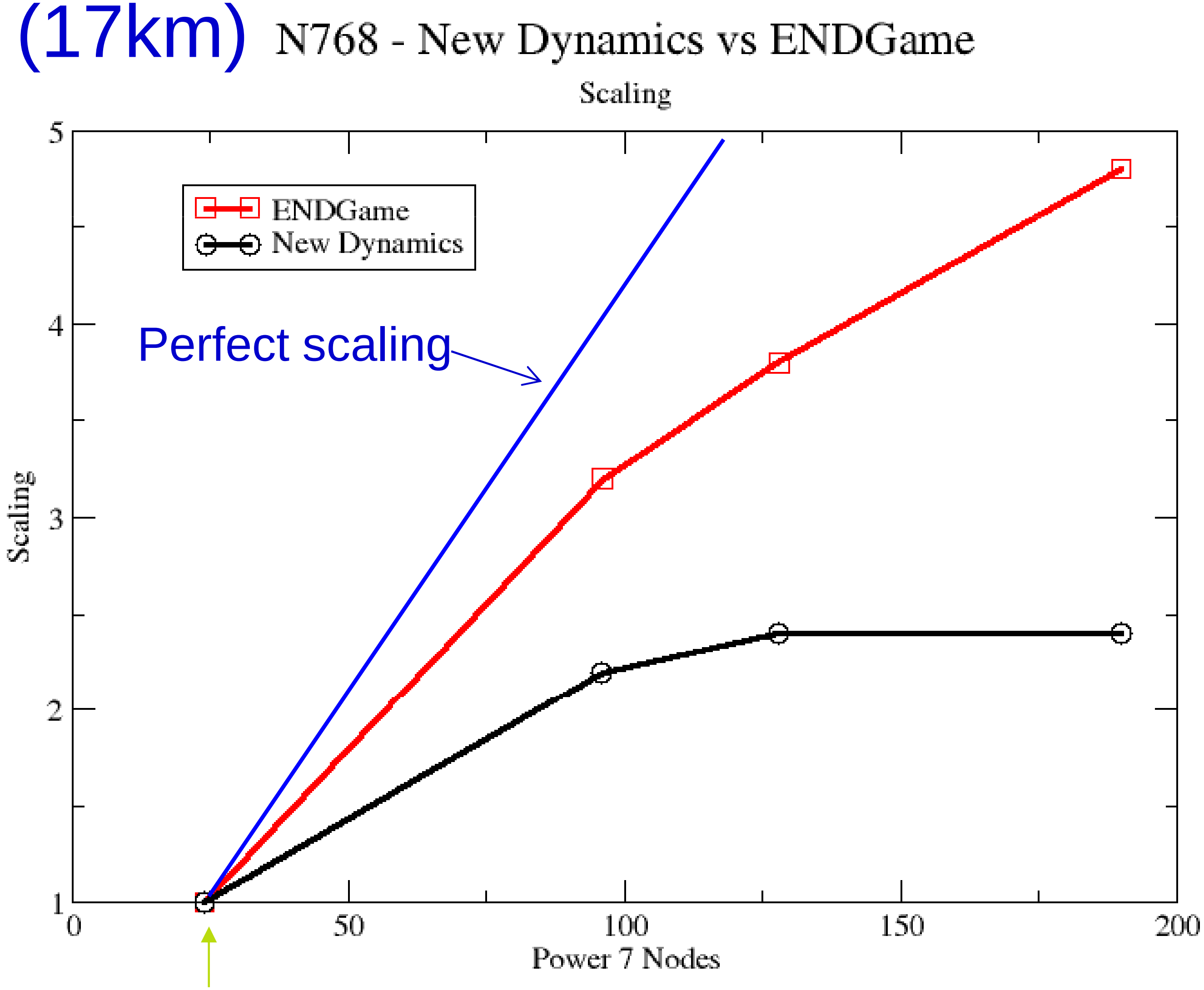
Nodes

(1 node=32 processors)

ENDGame within the target for 7 day f/cast

Improved Scalability

(17km)



T_{24}/T_N

24 nodes

Nodes

(1 node=32 processors)

Conservation

- Simplified and improved a posteriori conservation (Zerroukat 2010)
- SLICE:
  - Semi-Lagrangian Inherently Conserving and Efficient advection scheme (Zerroukat et al QJ 2002/04) =
    - SL finite-volume scheme
    - Made efficient by applying a cascade approach
    - Ie a flow dependent dimensional splitting
  - Still evaluating/improving…

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A challenging timetable…

- Currently:
  - ➢ Development of an ENDGame package (GA5)
  - ➢ ENDGame being trialled and tested in various systems
- Spring 2013:
  - ➢ Freeze GA5 with ENDGame in it
- Early 2013 start full EPS and hybrid trialling
- Aim to implement Autumn 2013…?

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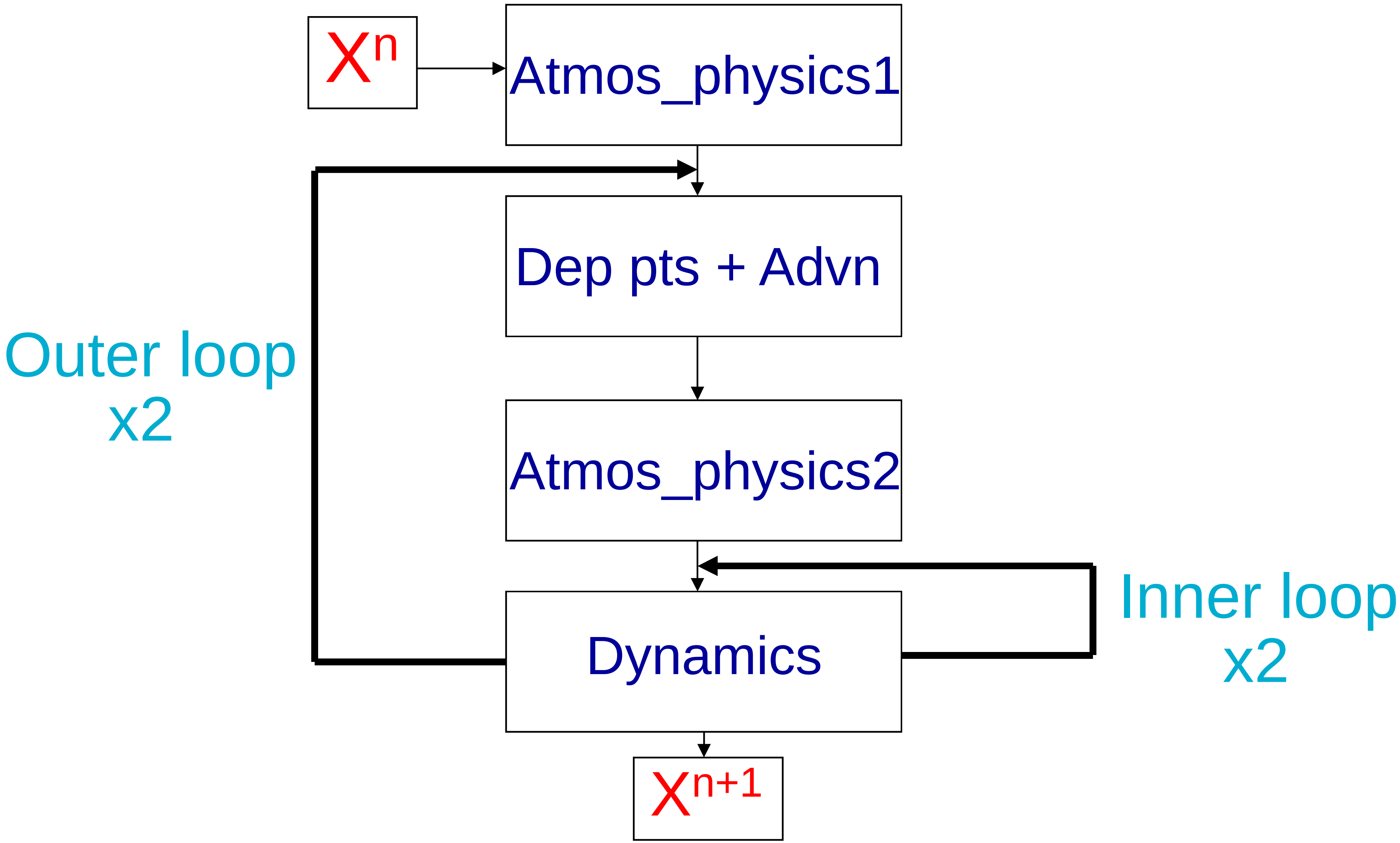
Thank You!

Questions?

Iterative solution



Reduced off-centring

- Wave equation:

$$dF/dt = i\omega F \Rightarrow F(t+\Delta t) = F(t)*\exp(i\omega\Delta t)$$

$$|F(t+\Delta t)/F(t)|^2 = 1$$

- Semi-implicit:

$$F^{n+1}-F^n = i\omega\Delta t\ [\alpha F^{n+1} + (1-\alpha)F^n]$$

- $\alpha=1 \Rightarrow$

$$|F(t+\Delta t)/F(t)|^2 = 1/[1+(\omega\Delta t)^2] << 1$$

- $\alpha=1/2 \Rightarrow$

$$|F(t+\Delta t)/F(t)|^2 = 1$$

Target scheme

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$$Dx/Dt = U$$

$$DF/Dt = N(F) + P_S + P_F$$

- Target SISL scheme:

$$X_A - X_D = (\Delta t/2)[U^{n+1} + U^n(X_D)]$$

$$F^{n+1} - F_D = (\Delta t/2)[N(F^{n+1}) + N(F^n)_D] + \Delta t\{P_F(F^{n+1}) + [P_S(F^n)]_D\}$$

- Rewrite exactly as:

$$[I - (\Delta t/2)L(F^{Ref})]F^{n+1} = \{F^n + \Delta t[N(F^n)/2 + P_S(F^n)]\}_D$$
$$+ (\Delta t/2)[N(F^{n+1}) - L(F^{Ref})F^{n+1}] + \Delta t P_F(F^{n+1})$$

Solve as:

$$F^{(n+1)} \longleftarrow F^{n}$$

$$X_D = X_A - (\Delta t/2)[U^{n+1} + U^{n}(X_D)]$$

$$F^{*} = \{F^{n} + \Delta t[N(F^{n})/2 + PS(F^{n})]\}_D + (\Delta t/2)N(F^{(n+1)})$$

$$F^{k} = F^{(n+1)}$$

$$[I - (\Delta t/2)L(F^{n})]\, F^{k+1} = \{F^{n} + \Delta t[N(F^{n})/2 + P_S(F^{n})]\}_D + (\Delta t/2)[N(F^{k}) - L(F^{n})F^{k}] + \Delta t P_F(F^{*})$$

$$F^{k} \leftarrow F^{k+1}$$

$$F^{(n+1)} \longleftarrow F^{k+1}$$

Outer loop x2

Inner loop x2