VTMX Meeting, Sept 14-16, 1999, Salt Lake City

VTMX @ CoRA: The Role of Internal Gravity Waves and Shear Instability in Basin Cold Pool Turbulence and Transport

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Hypothesis: Gravity wave and shear instability processes caused primarily by basin-wide orographic forcing are a major component of the basin turbulence budget, flow variability and scalar/ momentum fluxes, and thus contribute to its complicated scalar dispersion.

Goal: To utilize atmospheric observations in combination with mesoscale modeling and DNS to test the hypothesis and implement improvements to current parameterizations which contain errors under stably stratified conditions.

Atmospheric Phenomena of Interest

1. Mountain waves descending upon or propagating across the basin cold pool.

2. Shear interaction of layered, propagating katabatic flows

3. Kelvin-Helmholtz billows at or below the basin inversion

Resources to be utilized

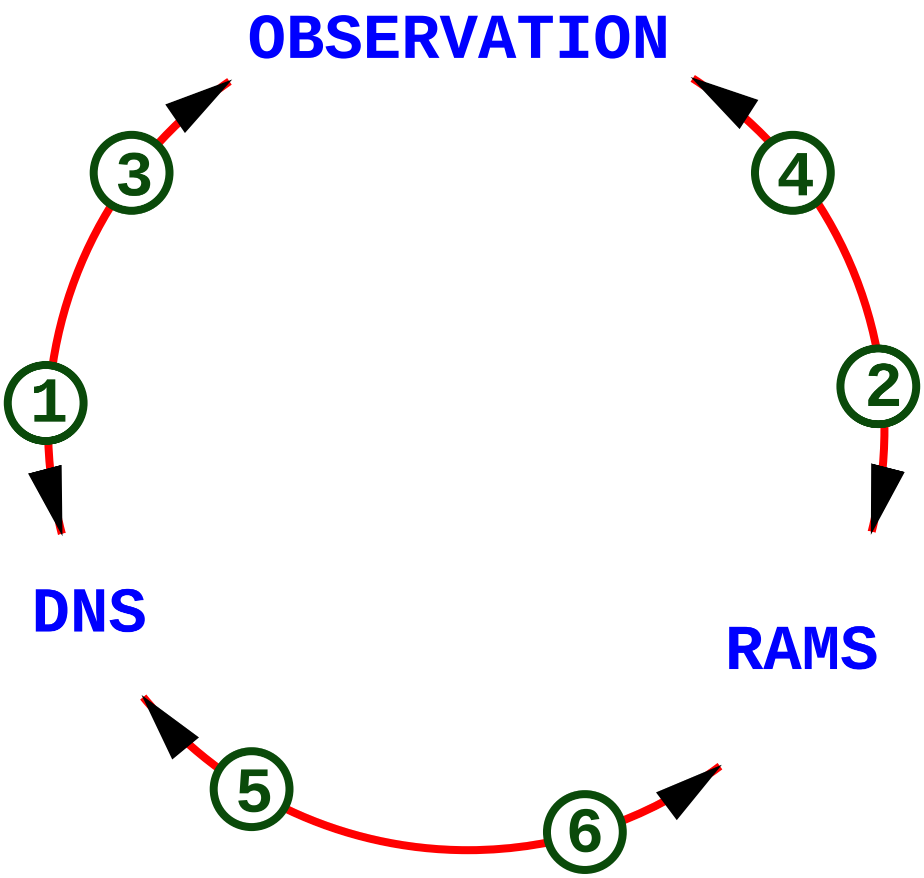
- VTMX observational data

- CASES-99 observational data

- High-resolution, ($\Delta x = \Delta y = O[100]$m, $\Delta z = O[10]$m) mesoscale modeling using RAMS.

- Direct Numerical Simulation (DNS) with ~ 1000^3 spectral modes

INTERDEPENDENCY



①	Observations establish relevance of physical processes for DNS
②	Observations identify input conditions for RAMS
③ ④	DNS and RAMS aid interpretation of Observations
⑤	RAMS identifies for DNS the environment of instability processes leading to turbulent mixing
⑥	DNS evaluates RAMS SGS paramterization and suggests improvements

Regional Atmospheric Modeling System (RAMS)

- Primitive equation, mesoscale model, σ-coordinate system
- Parallelized
- Idealized and realistic simulations

Grid structure

- 3 dimensions, nested as needed to achieve desired resolution
- Vertically stretched for enhanced boundary layer/cold pool resolution

Parameterizations

- turbulent diffusion, soil/vegetation, radiation, surface layer

Physiographic information

- 30 s USGS terrain, vegetation data
- 5 minute (~ 8 km) land percentage data

Initialization/Nudging

- NCEP 32 km Eta model analyses and forecasts
- Local Analysis and Prediction System (LAPS) to integrate VTMX observations and improve initialization and nudging

Direct Numerical Simulation (DNS)

$$\partial_t u + u \cdot \nabla u = \nu \nabla^2 u - \nabla P + g\alpha T \hat{z}$$

$$\partial_t T + u \cdot \nabla T = \kappa \nabla^2 T$$

$$\nabla \cdot u = 0$$

$\nu \longrightarrow Re^{-1}$ $\kappa \longrightarrow Pe^{-1}$ $g\alpha \longrightarrow Ri$

Strengths/Weaknesses

− Exact representation of Navier−Stokes equations

− Idealized simulation

− Limited Reynolds number $\sim 10^4 - 10^5$

Algorithm

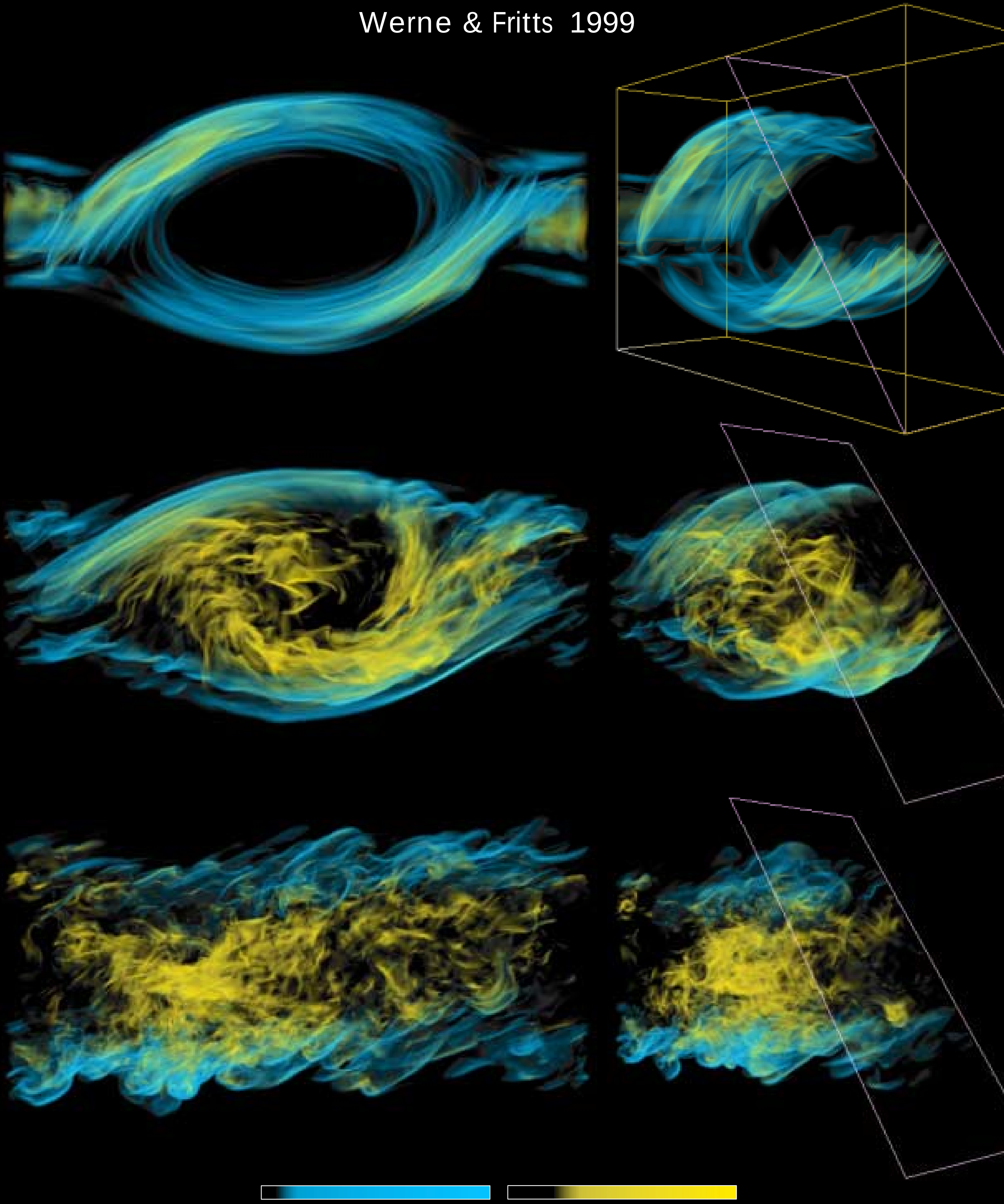
− Divergence−free streamfunction/vorticity formulation

− Spectral representation (Nth−order accurate)

− 3rd−order semi−implicit timestepping

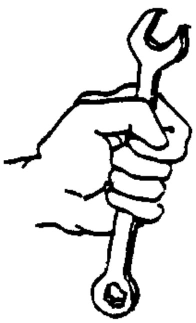
− Massively Parallel (~500 Processors)

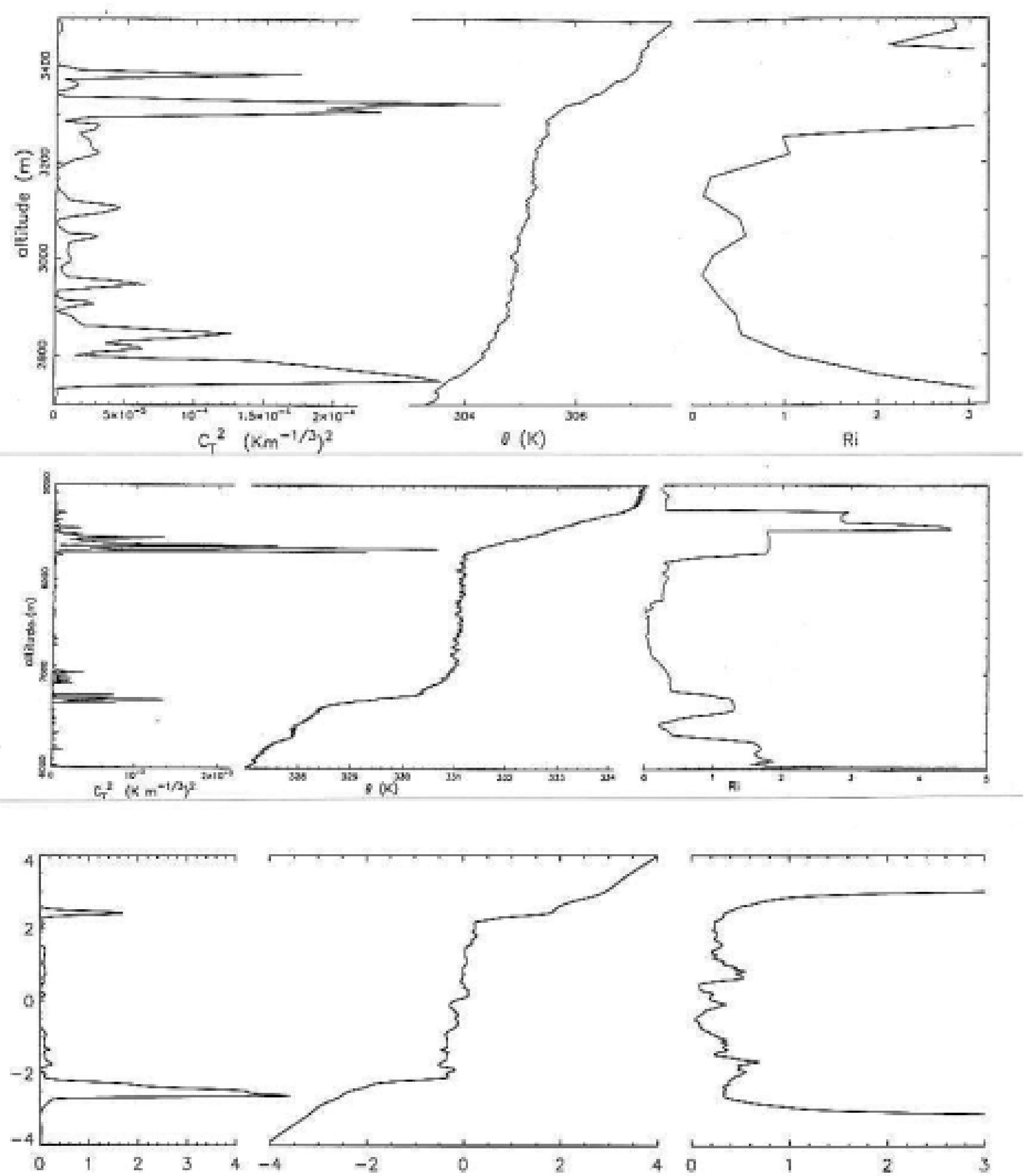
Werne & Fritts 1999



Comparison with Balloon Soundings

Coulman, Vernin & Fuchs, Applied Optics, vol 34, p 5461 (1995)

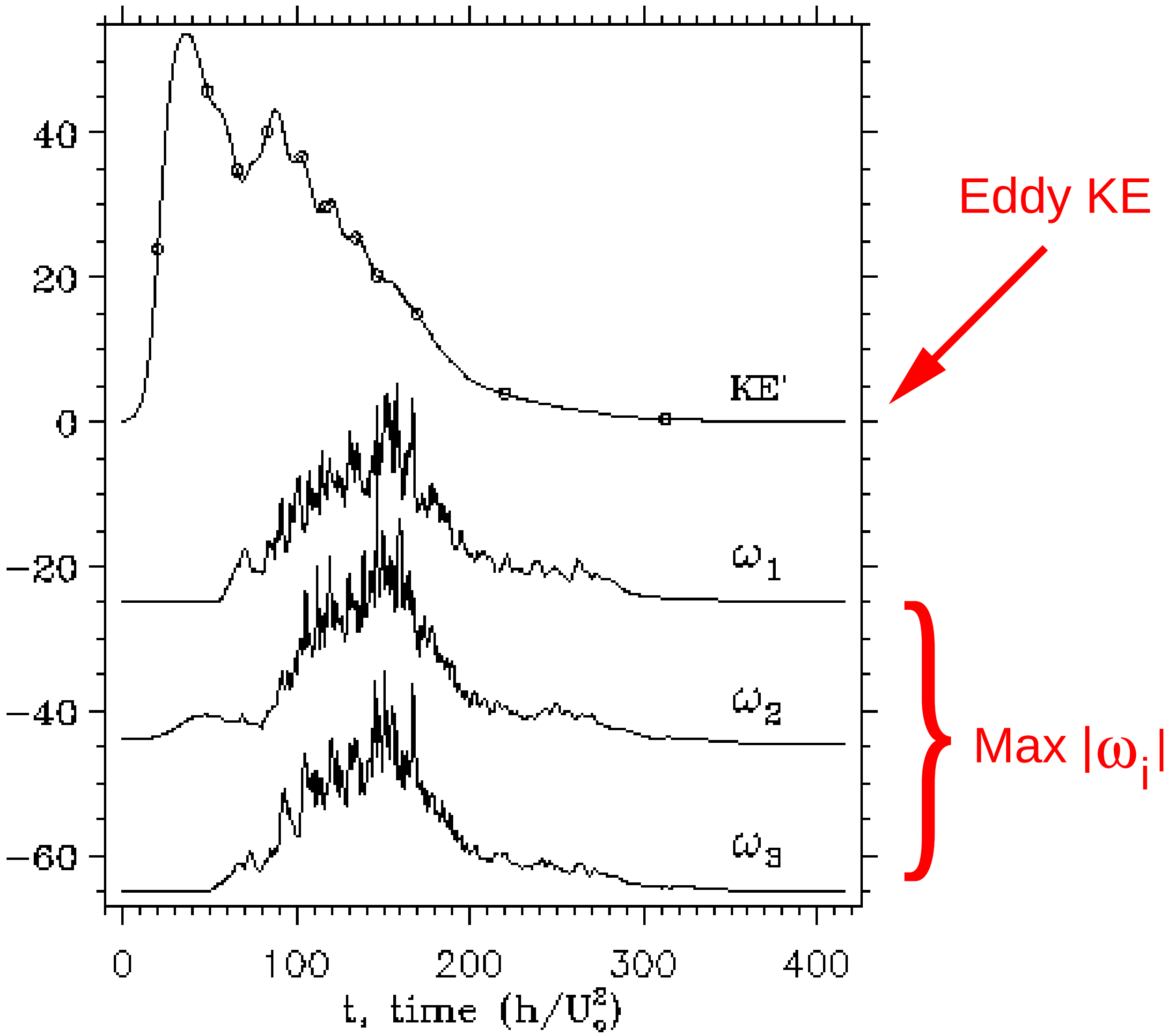




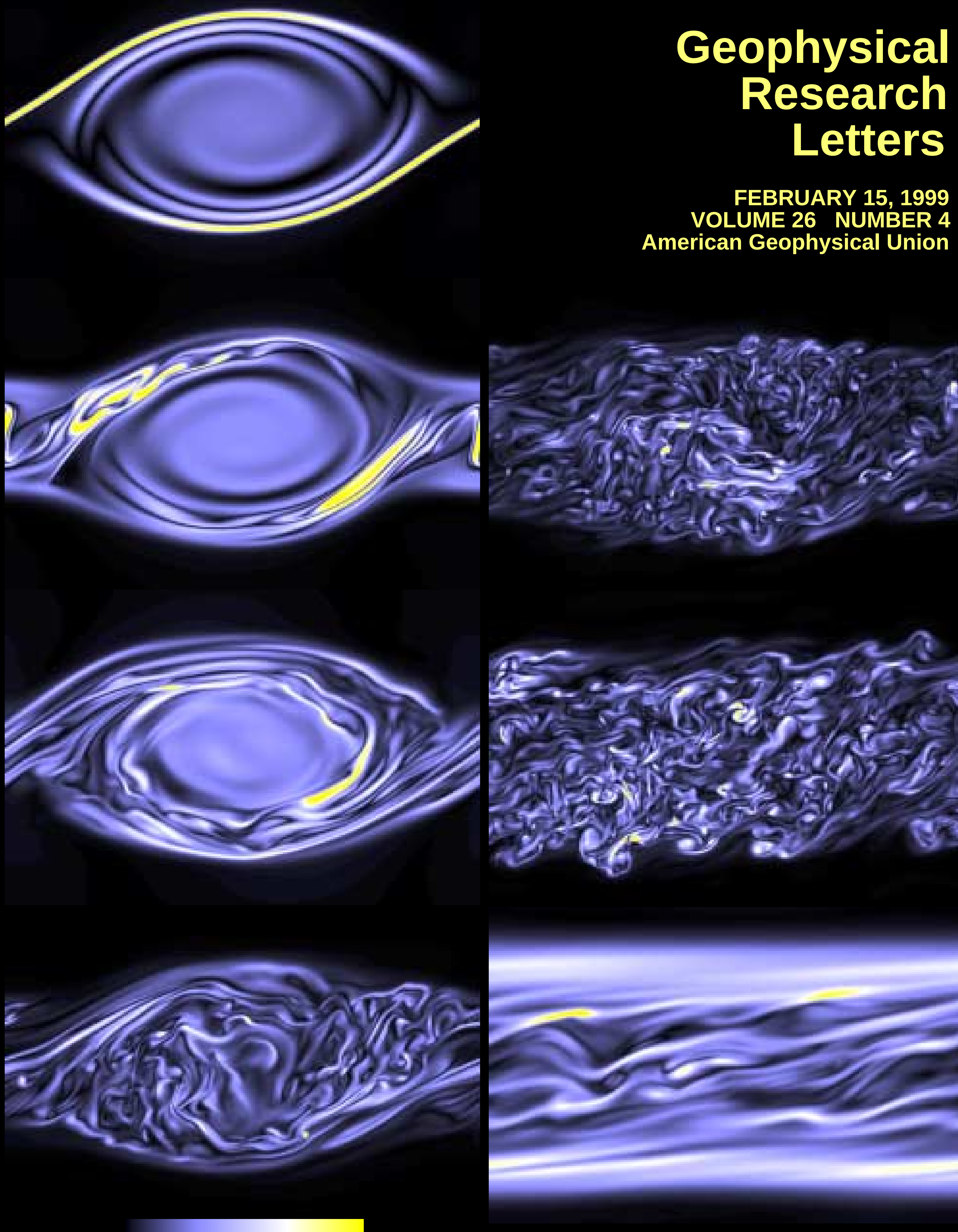
C_T^2 T Ri

Shear−Layer Evolution

Werne & Fritts, GRL vol 26, p 439 (1999)



Werne & Fritts 1999



Geophysical Research Letters

FEBRUARY 15, 1999
VOLUME 26 NUMBER 4
American Geophysical Union

Nile flood record shows recent El Niño trend • Climate variability affects long-range transport to Greenland • Ionospheric vortices induced by magnetopause deformation

Research Plan

Year 1 (2000)

1. Analysis of CASES-99 stable boundary layer data as related to VTMX goals

- Field experiment Oct 1-31, 1999 (very soon!)

- Many similar instruments as VTMX field experiment, but in considerably less complex environment

- Non-urban, average slopes ~0.5^o, no lake, only minor katabatic flows and pooling

- See www.co-ra.com/cases/CASES-99.html

2. Detailed analysis of mesoscale model parameterizations in preparation for more intensive modeling

- Evaluation of surface layer parameterization algorithm

- Evaluation of turbulence parameterization algorithm

- Idealized DNS/RAMS studies of very stable conditions to evaluate individual terms within parameterizations

3. Planning for the VTMX field program

- Utilize experience from CASES-99 planning to help optimize deployment of VTMX resources

- Identify which data will be of most use in reaching our goals

Research Plan cont'd

Year 2 (2001)

1. VTMX field project participation
2. VTMX data analysis

   - evaluation of gravity wave and shear instability conditions: General Analysis

   - correlate varied instrumentation's measurements of phenomena of interest: Event Specific Analysis

   - quantify distribution of turbulent fluxes in stable basin cold pool from tower array (compare to similar CASES-99 analysis)
3. Primary Modeling underway

   - Case study mesoscale modeling of VTMX IOP(s): flux distributions versus observations (attempt to capture shear layers and crudely represent K-H billows)

   - Utilize DNS for specific observed wave breaking or shear instability events (full resolution of KH)

Research Plan cont'd

Year 3 (2002)

1. **Intensified numerical modeling for detailed analysis of mesoscale model failures in stable basin cold pool and possible examination of gravity wave influence on SBL flows**

   - evaluation of parameterization performance (perhaps test some changes) for IOP(s) of interest

   - quantify representation of individual events/vertical fluxes in mesoscale model compared with observations

2. **Evaluation of mixing processes in DNS**

   - comparison with mesoscale model results

   - comparison with observed values

   - continue evaluation of modeled processes for use in parameterization

Year 4 (2003)

1. **VTMX-II field program participation**
2. **Implementation of improvements to subgrid-scale parameterization(s)**
3. **Iteration with modeling and new parameterization testing**

Collaborations

1. With Los Alamos National Lab

- Bossert group: phenomenological intercomparisons (with other mechanisms related to vertical mixing in the basin) and model interpretation (Hi-Grad)

2. With Pacific Northwest National Lab

- Whiteman and Zhong: Measurements and analysis in the SLC Basin; primarily investigation of fluxes and wave generation/ shear instability mechanisms at the top of the basin inversion
- Fast and Zhong: Parameterization improvements, share ideas on how to interpret CASES-99 and VTMX data relative to mesoscale model performance

WISH LIST

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1. Data suitable for RAMS initiation/nudging

2. Co−location of high−resolution temperature and wind field measurements (sufficient for differentiation → Ri) where shear instability is likely.

3. Identification of gravity−wave signatures (at cold−pool top?) to identify possible forcing below.

4. Observation of anisotropic scattering from edges of turbulence layers.

5. FDI augmentation of TEP to resolve fine 3D features of shear and wave−breaking secondary instability processes.

6. Get those U. Mass. guys to use VIZ!

3D volume−rendering software