Team Meeting Notes

We discussed the goals of the meeting. In particular, we discussed the following ideas:

- Is dust an active or passive tracer? We should calculate the density and temperature perturbations due to dust.
- Can we use mini TES data in our PBL work? Mini TES is an infrared spectrometer. Tero has access to the Mini TES data and will analyze it.
- How good is the Boussinesq approximation on Mars? What is the speed of sound on Mars? Peter says that it is a good approximation in the boundary layer.
- Peter Read would like to look at how the boundary layer affects the larger scale flow, such its impact on large-scale transport. Currently, there are no ways to test boundary layer parameterizations because of the lack of Mars data. What is good about the current approaches to simulate Mars's climate is that based on reasonable physical principles.
- If dust lifting is forced by surface shear stresses, then the proper simulation of the turbulent boundary layer is critical.
- What kind of data do we need to better understand boundary layers? How can we connect boundary layer measurements with larger scale measurements?
- What can we do to influence the selection of instruments to next landed missions to Mars? We need to point out what the key measurements for understanding the boundary layer are. What are the requirements for these measurements?
    - What the hazards caused by the lack of a good understanding of the boundary layer processes? As an example, we should point out the MER Spirit rover experience.
- Peter Rogberg pointed out the need for data assimilation models for Mars.
    - Current data assimilation models are not constrained by boundary layer measurements.
    - The key measurements are surface pressure measurements together with orbital measurements of the large-scale dynamics (wind, temperature profiles, dust opacity, water distribution).
    - There is a little bit of data from Viking, MPF, and MER.
- We don't have proper ways to simulate the Mars boundary layer. There is a lack of Mars wind tunnels data to constrain models of turbulence?
- What triggers global dust storms on Mars? Peter Read pointed out that the 2001 global dust storm was well observed from orbit and that it appears that it was caused by resonant interaction between various weather systems? The large-scale circulation seems to have organized dust lifting on various local or regional storms.
- Comparisons between turbulence models implemented into single column models show large discrepancies between them.
    - Boris has been developing an innovative turbulence models, the QNEC spectral model of turbulence. His model does not require a critical Richardson number.
    - There is a paper in Boundary Layer Meteorology describing the compassion between various LES models.
- Mark Richardson is using the dynamical core of the Planet-WRF model, but the French group is using the terrestrial WRF model with the physics package of the European model. Boundary layer is important for all models of planetary atmospheres and oceans.

- There is a body of knowledge from the turbulence community that must passed to the planetary science community. Experiments must be combined with modeling and numerical simulations.

The following tasks were discussed for our Team:

1. Review the current status of boundary layer physics;
2. Describe the need for coupling between boundary layer processes and the larger-scale flow;
3. Describe the requirements for measurements;
4. Describe possible instruments for studying the martian PBL.

Peter Read's presentation on his group's "Boundary Layer Parameterization Scheme" –The French Implementation

Basic Scheme:

1. Turbulent mixing is represented as eddy diffusion with different coefficients for momentum, temperature, etc.
2. The surface layer is assumed to follow a logarithmic temperature profile. The first layer above the temperature is about 4 m above the surface. Boris asked how the temperature of this layer is determined. Peter answered that different approaches are taken for stable and unstable boundary layers.
3. The boundary length scale is assumed to be constant everywhere (Blackadar, 1962).
4. The Mellor-Yamada level 2.5 closure scheme is used. The scheme has various arbitrary parameters.
5. The PBL parameterization scheme leads to various diffusion coefficients, such as for potential temperature, velocity, TKE…
6. Simulations show collapse of the boundary layer during the night, and the formation of nocturnal jets. However, very short time-scales are necessary when the static stability is high to avoid numerical instability.

Approximate Method of Hourdin & Fournier

1. Decouple prognosis of vertical wind shear.
2. The implementation of their model was not well documented.
3. Simplified scheme also predicts collapse during the night and the formation of nocturnal jets.
4. Boris commented that their approach is just the implementation of a vertical filter.
5. Issues: Parameterizations are suspect in conditions of strong static stability; the critical Ri for decay of turbulence is too low, performance poor with high stability typically found on Mars. Turbulent Prandtl number should become large as Ri increases. Efficient mixing of momentum and weak mixing of heat. Internal waves are not considered.

Boris Galperin presentation on "Quasi-normal scale elimination (QNSE) model of stability in stratified fluids"

1. The literature on internal waves is disorganized.

2. The QNSE model has been developed to bring some order to this by systematically accounting for the effects of internal waves.
3. Fully three-dimensional flow field with imposed vertical temperature gradient.
4. The general idea is that the Re number is small for the smallest scales of motion.
    a. Perturbation solution is derived for these small scales.
    b. Assume that these modes have quasi-normal statistics. This makes the viscosity and diffusivity to be flow dependent.
5. The basic aspect of the theory is the partial scale elimination. Turbulence and waves are not separated.
6. A coupled system of four differential equations is obtained for scale-dependent processes. Horizontal and vertical eddy viscosities and eddy diffusivities.
7. Limitations of classical theories:
    a. Anisotropy is not adequately addressed.
    b. Lumley-Shur theory does not account for anisotropy due to the decrease of viscosity in the vertical direction.
    c. The predictions of the QNSE theory are in good agreement with observed spectra in the troposphere, stratosphere, mesosphere, thermosphere… ocean.
    d. It gives an expression of internal waves that includes the effects of turbulence.
    e. It also gives the threshold value to k for which waves are overwhelmed by turbulence.
    f. RANS modeling eliminates all fluctuating scales. Everything in given in terms of bulk numbers.
        i. All atmospheric and oceanic models employ "background mixing" coefficients in strong stable stratification. The results are sensitive of the values of these numbers (e.g., Zhang and Steele, JGR, 2007).
        ii. However, there are problems for z/L above 3, high stability.
        iii. QNSE-derived parameterizations have been implemented in HIRLAN and WRF models. It decreases the warm bias that other models produce near the surface.
        iv. QNSE-based PBL surface layer turbulences scheme solves the Nordic warm bias in very stable conditions.
        v. The value of the Ozmidov scale is very important.
    g. QNSE-based models are viable alternative to Reynolds stress models.
    h. Time series and vertical profiles of various physical quantities can be used to test the model.

Boris Galperin presentation on "Zonostrophic Turbulence"

A regime with large anisotropy.

Motivation: To understand planetary and zonal flows from the point of view of anisotropic turbulence and waves.

The barotropization paradigm (Rhines 1979, Salmon 1998, read 2001)

Arakel presentation on the "Development of a PBL Model"

The main objective is to develop a dust lifting/transport model.

The no-slip boundary condition was removed.

Assumption: the volume concentration of particles is moderately high.

Solves governing hyperbolic equations describing a two-phase flow.

His model might be able to predict the distribution of dust and its transport above the surface.

It seems that his approach is what is known as explicit LES simulation.

It is very simple to implement dust lifting using this model.

Tero's presentation on "Models and Observations of the Martian PBL"

Mesoscale simulations of Mars Limited Area Model (MLAM) with HIRLAM (Unden et al., 2002). The current model is dry and does not include dust.

Mini-TES observations (Smith et al., JGR 2006).

Mini-TES is a Fourier transform IR spectrometer.

Planet WRF was used for LES simulation at the Opportunity landing site for comparison with Mini-TES measurements.

Discussion on the Possible Outcomes of our Team Meetings

Review of current understanding of boundary layer process and dust transport.

- What are the current PBL schemes used on Mars modeling?
- How can them be improved?
- What data is available to constraint current theories for the parameterization of turbulence?
- What kind of data do we need?
    - There is terrestrial data available that can be used to test the Mars PBL parameterizations.
    - Peter Read suggested testing current schemes with terrestrial data as a first step. Boris suggested comparing them with data from GABLES in one-dimensional setting.
    - Peter Read suggests degrading terrestrial data to simulate "Mars data" and use it to test the PBL schemes.
    - Boris et al suggests conducting field experiments on earth, in conditions as similar to Mars as possible (e.g., Antarctica).

Summary of PBL Team tasks

- Compile observational data for model validation
  - Mars
    - Existing/available data
    - New/proposed measurements
  - Earth
    - GABLES
    - Deserts
    - Arctic/Antarctic
- Compare Mars PBL schemes in a 1D setting
  - Existing schemes
  - New schemes (e.g., QNSE)
  - Turbulence model hierarchy
    - Bulk
    - K-l model
    - K-E model
  - Radiation model
  - Convection scheme. Nilton will look at current Mars models to find out what kind of parameterizations of dry convection they use. Do we need more sophisticated models for Mars in order to transport dust 10s of kms above the surface?
  - Existing Mars Models accessible by our team. These models will be compared with each other in idealized cases. How do their predictions compare with terrestrial data? We need to know what the heritage of each scheme is.
    - UK/French Model
    - MLAM
    - Helsinki 1-D Model
    - Caltech Model, Planet WRF
  - Other models
    - John Wilson/GFDL Model
    - NASA Ames Model
    - Mars RAMS
    - Oregon/Tyler Model
    - Etc…
  - The PBL schemes for Mars models should be as simple as possible. Ideas should be justified based on physical principles and tests should include those with terrestrial data because we will never be able to make detailed measurements on Mars within the timeframe of this team. Thus, we should use detailed earth measurements to test the Mars models as well as available Mars data. But some relevant comparisons may already exist in the literature.
- Comparison parameters
  - T(z, t) from z = 0 to a few km
  - PBL height
  - Wind (Z, t)
  - Variances & co-variances? [T, wind]
  - Transported scalars (e.g., dust, H_2O, CO_2, …)

- Computational tools
  - Turbulence schemes
  - Convection schemes
  - Radiative transfer
  - Dust lifting and transport
  - Water cycle
- Test cases
  - What kind of data is available and useful?
    - Viking data (p, T, wind strength & direction)
    - MPF data (temperature at 3-levels, pressure)
    - Mini-TES data (time series of T profiles)
    - Phoenix data (MET & Lidar)?
  - Tero will organize the data sets for model comparison. In particular, Mini-TES data showing the growth of the PBL during the morning and its collapse in the evening.
  - Stable vs. unstable conditions

Goals to be achieved before the next meeting

Nilton set up a project website using UM ctools.

Document existing data sets available for testing PBL schemes

1. Mars data sets
   a. Viking (What is the range of sampling rates of the Viking data set? What portion of the diurnal and seasonal cycle does it include? Peter Read will contact Jim Tillman and/or Soeren Larsen.)
   b. MPF (Nilton will organize it).
   c. Mini-TES (Tero will organize it).
2. Earth data sets
   a. GABLES (BLM, 2006), etc.
   b. Steve will review the available radio occultation data to test the ability of the various PBL models to calculate the BL height.
3. Model comparison
   a. We need a 1-D version of each PBL model easily accessible to our group.
      i. Separate models or single 1D code with different subroutines?
   b. We should identify the test cases that we will use to compare the various models.
   c. Each modeler will provide a two-page description of his model that includes descriptions of the turbulence scheme, convection, and radiation (four models: Mark Richardson –Planet WRF, Peter & Peter –LMD/UK Mars GCM, Tero/Hannu will document the MLAM model, Tero/Hannu will document the UH1DModel).
   d. Boris will compare the Mars schemes with terrestrial PBL state of the art schemes.
   e. Boris will ask Mark to implement his QNSE scheme on Planet WRF.
4. One of our goals is to give a brief report on our goals and progress at the Mars Modeling Workshop in Virginia.

a. Arakel will be the lead author of an article reporting the task of our Team. A draft of the article/abstract must be completed by the middle of August.
b. Individual members might also submit articles to the Virginia workshop – coordinate via Arakel.
c. Boris will write a one-page description of atmospheric and oceanic PBL models by the middle of July.

Date of Next Meetings

Mars Modeling Workshop and Observation, November 10-14
Williamsbug, Virginia.

It was suggested to meet again in the Spring and Fall of 2009.