# Ensemble adjustment Kalman filter study for Argo data

Xunqiang Yin
Fangli Qiao, Yongzeng Yang and Changshui Xia

Key Laboratory of Marine Science and Numerical Modeling, SOA
The first institute of oceanography, SOA, China, Qingdao,266061

2008/10/31

# Outline

1. **EAKF method and its implementation**
   - Introduction of EAKF method
   - Designing of EAKF assim system
   - Parallel designing of EAKF assim system
2. **Assimilation for Argo profiles (NWP)**
   - Distributions of Argo profiles & precondition
   - Ensemble free runs & ensemble spread
   - EAKF assimilation for Argo profiles
   - Comparison against SST & GTSPP
3. **Conclusions and discusses**

# Introduction of EAKF method

- **Model uncertainties**
  - ✓ Incomplete understanding of the ocean (Basic eqs)
  - ✓ Inaccurate numerical implementation (Parameterization, discrete & Computational method)
  - ✓ Initial conditions (IC) & forcing have errors (lack of observation)

**Uncertainties**

$$\frac{dX_t}{dt} = M(X_t, t) + G(X_t, t) w_t$$

Determination part

- **Data assimilation (DA)**
  - ✓ Combine the numerical model & observation
  - ✓ Reconstruct the reliable states of the real ocean
  - ✓ Improve the forecast abilities & help to understand the physical processes
  - ✓ Ensemble Adjustment Kalman Filter (**EAKF**) can maintain physical balance between different variables

# Introduction of EAKF method

- Bayesian theory

Obs info — Prior info — normalization

$$p(Z_{t,k} \mid Y_{t,k}) = p(y^o_{t,k} \mid Z_{t,k})\, p(Z_{t,k} \mid Y_{t,k-1}) / p(y^o_{t,k} \mid Y_{t,k-1})$$

$$\Sigma^u = [(\Sigma^p)^{-1} + H^T R^{-1} H]^{-1}$$

$$\overline{Z}^u = \Sigma^u [(\Sigma^p)^{-1} \overline{Z}^p + H^T R^{-1} y^o]$$

Assuming that the prior PDF and observation PDF are all Gaussian processes. The linear operator **A** can be derived through SVD analysis **(Anderson 2001)**, which satisfy

$$\Sigma^u = A \Sigma^p A^T$$

Then update the model states.

$$Z_i^u = A^T (Z_i^p - \overline{Z}^p) + \overline{Z}^p$$

✓ **Suit to do assim for large size model**

✖ **Localization for smaller ensemble size**

**•EAKF method**

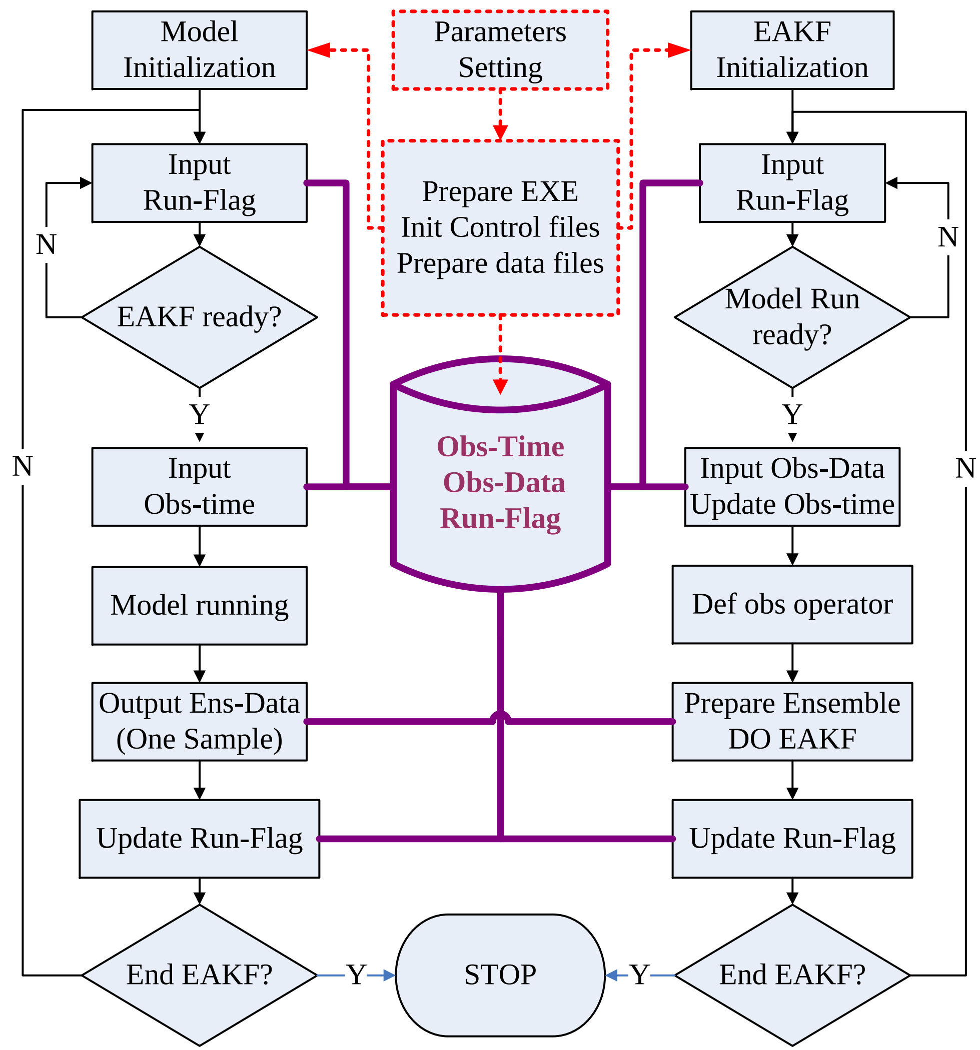
# Designing of EAKF assim system

- ➢Right black part is for EAKF process
- ➢ Left black part is for ensemble models run (one sample)
- ➢Dot lines is for control process (UNIX shell scripts)
- ➢ Thick lines is for data I/O

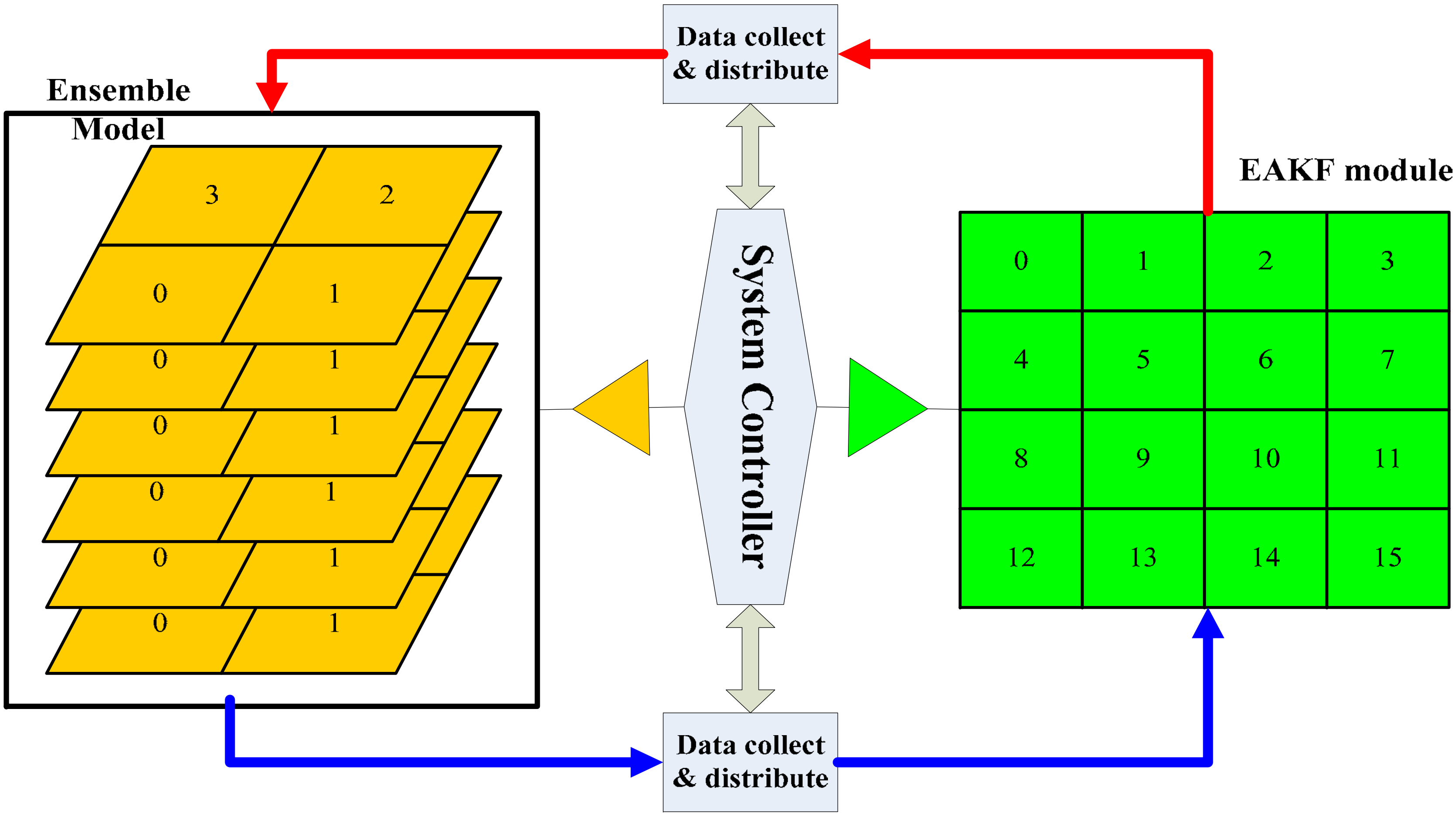
**Scripts Parallel**

**All processes are started at the same time, exchanging by file I/O**

**Parallel designing is based on this flowchart.**



# Parallel designing of EAKF assim system



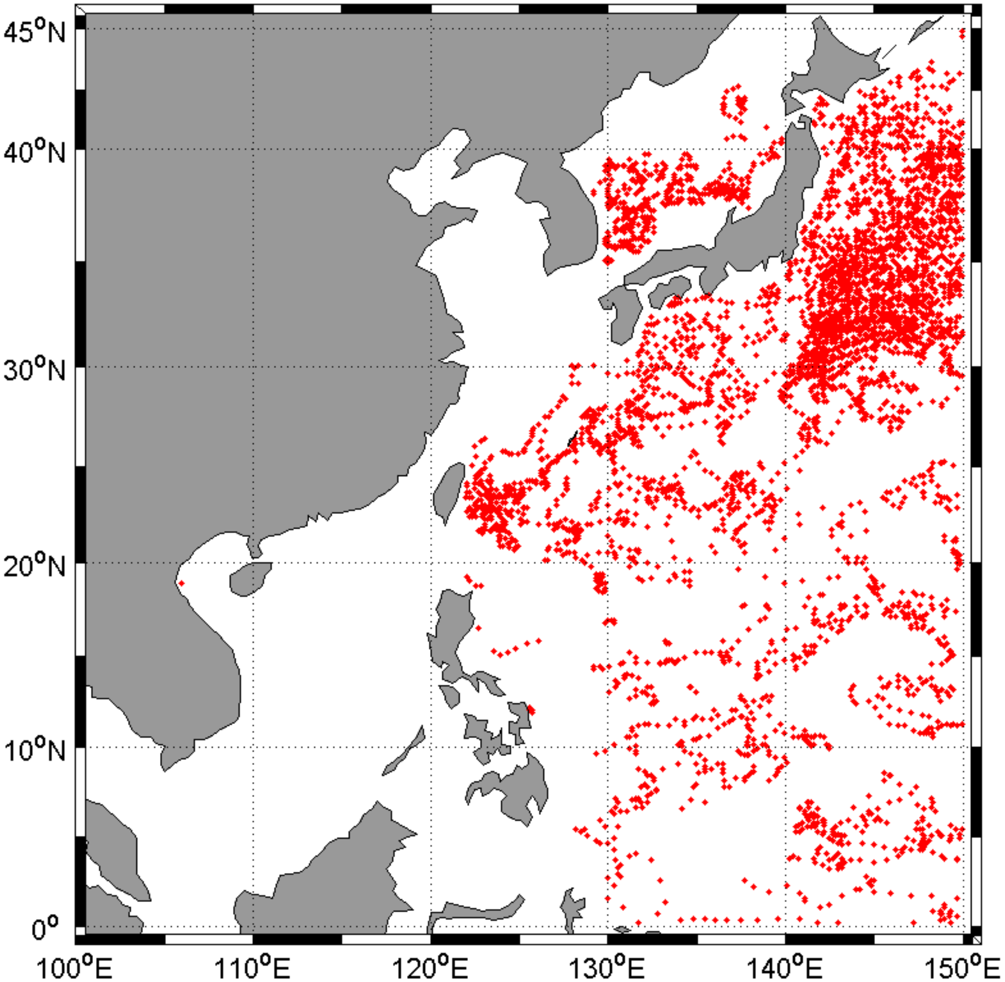

Structure of parallel EAKF assim system

- Ocean Model of North-west pacific ocean (NWP)

## Model Setting & Forcing

- Based on POM, Wave-current coupled， North-West Pacific ocean, $1/8^o \times 1/8^o$ ， 21-layers
- Climatologic BC from Global model, $1/2^o \times 1/2^o$
- QuikSCAT blend wind
- Climatologic heat flux
- Ensemble ICs:

  8 member, from different year's restart
- Ensemble free runs (EnFR)
- EAKF assimilation for Argo temperature & salinity profiles

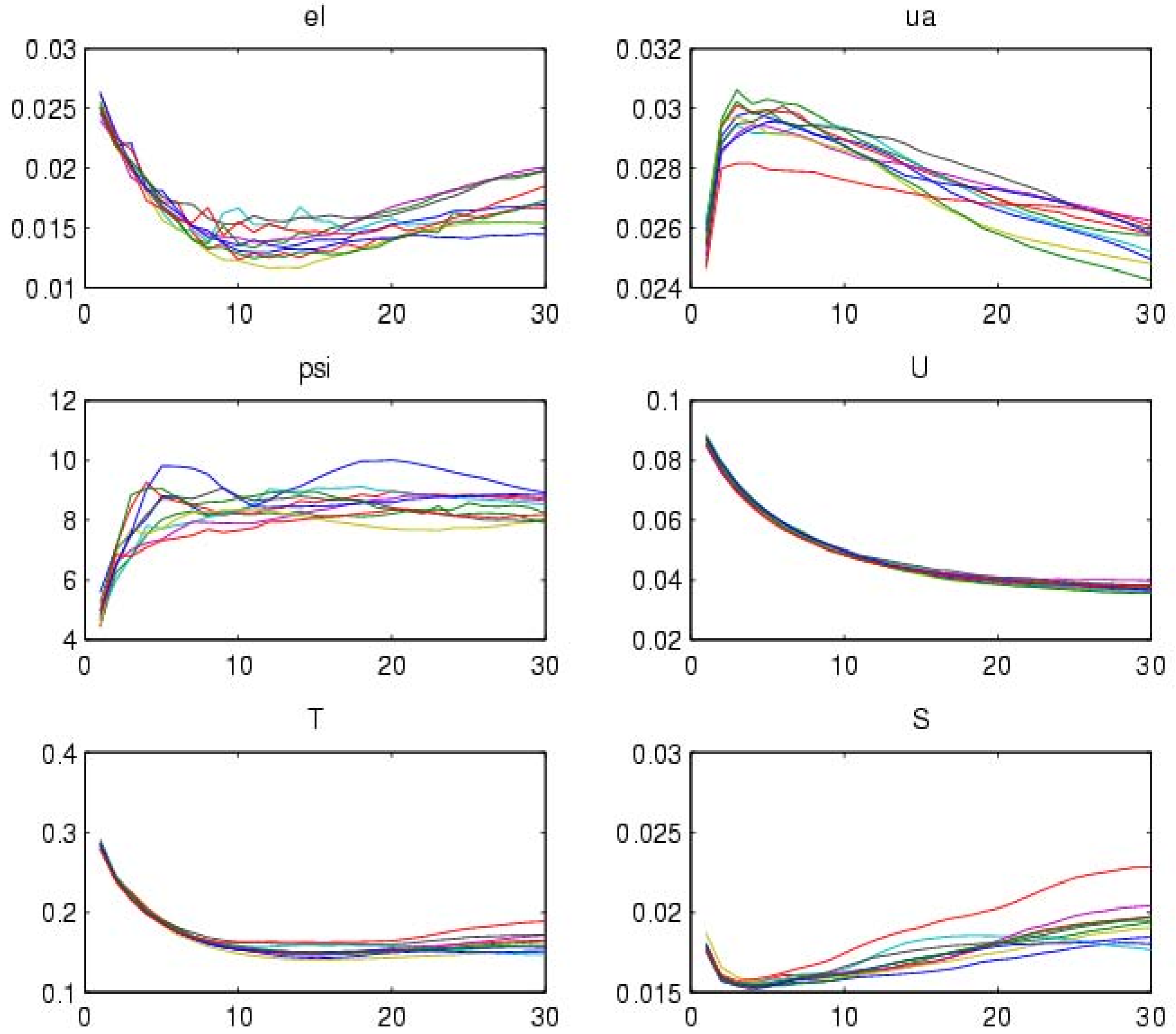



Model domain & Argo profiles locations in 2005

# Ensemble free runs & ensemble spread

**Ensemble Free Runs**

This test shows that the ensemble model runs have enough spread to ensure an accurate EAKF.




**Ensemble Spread for EnFR along time**

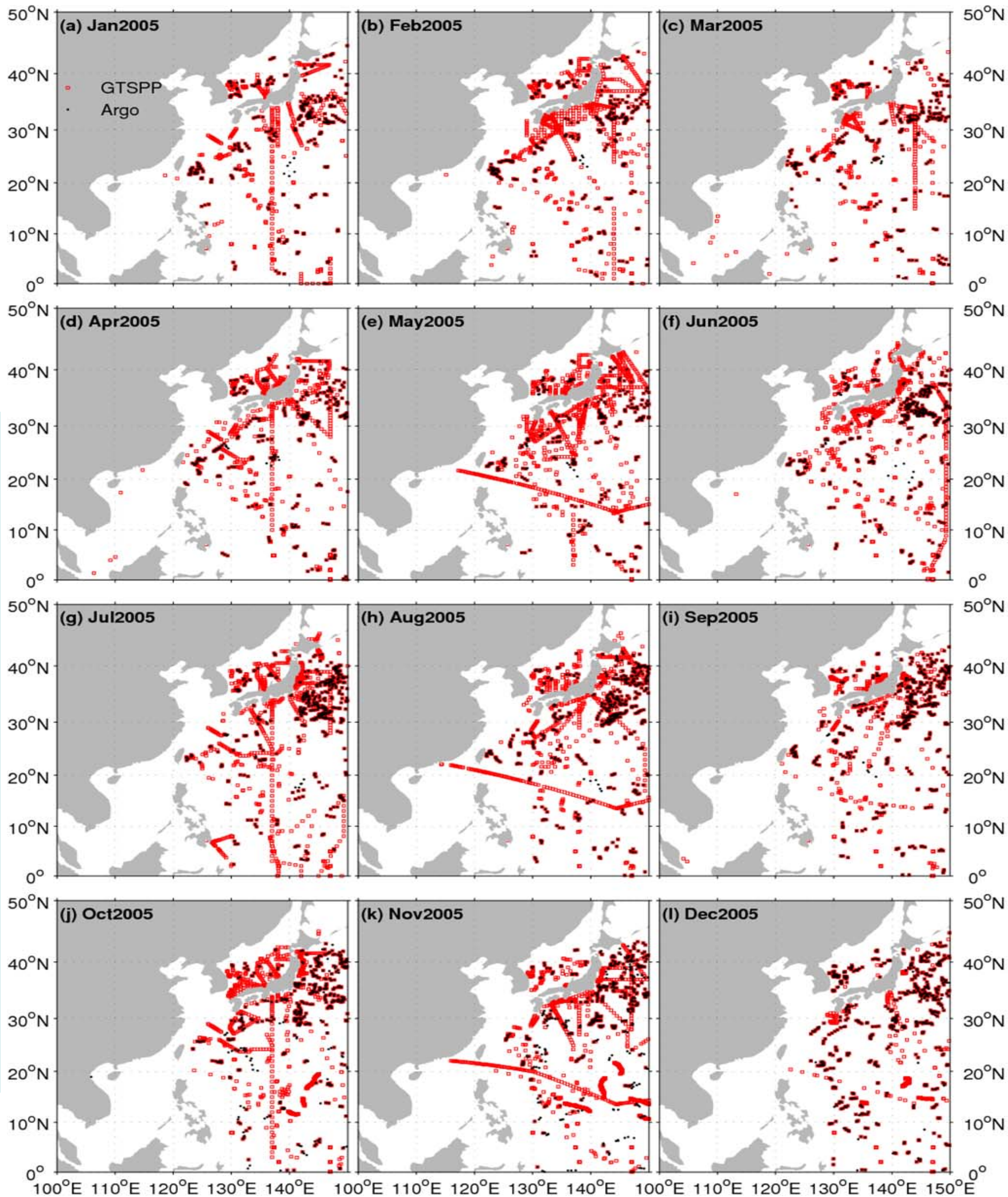
# EAKF assimilation
# for Argo temperature & salinity profiles

# Distributions of Argo profiles & precondition

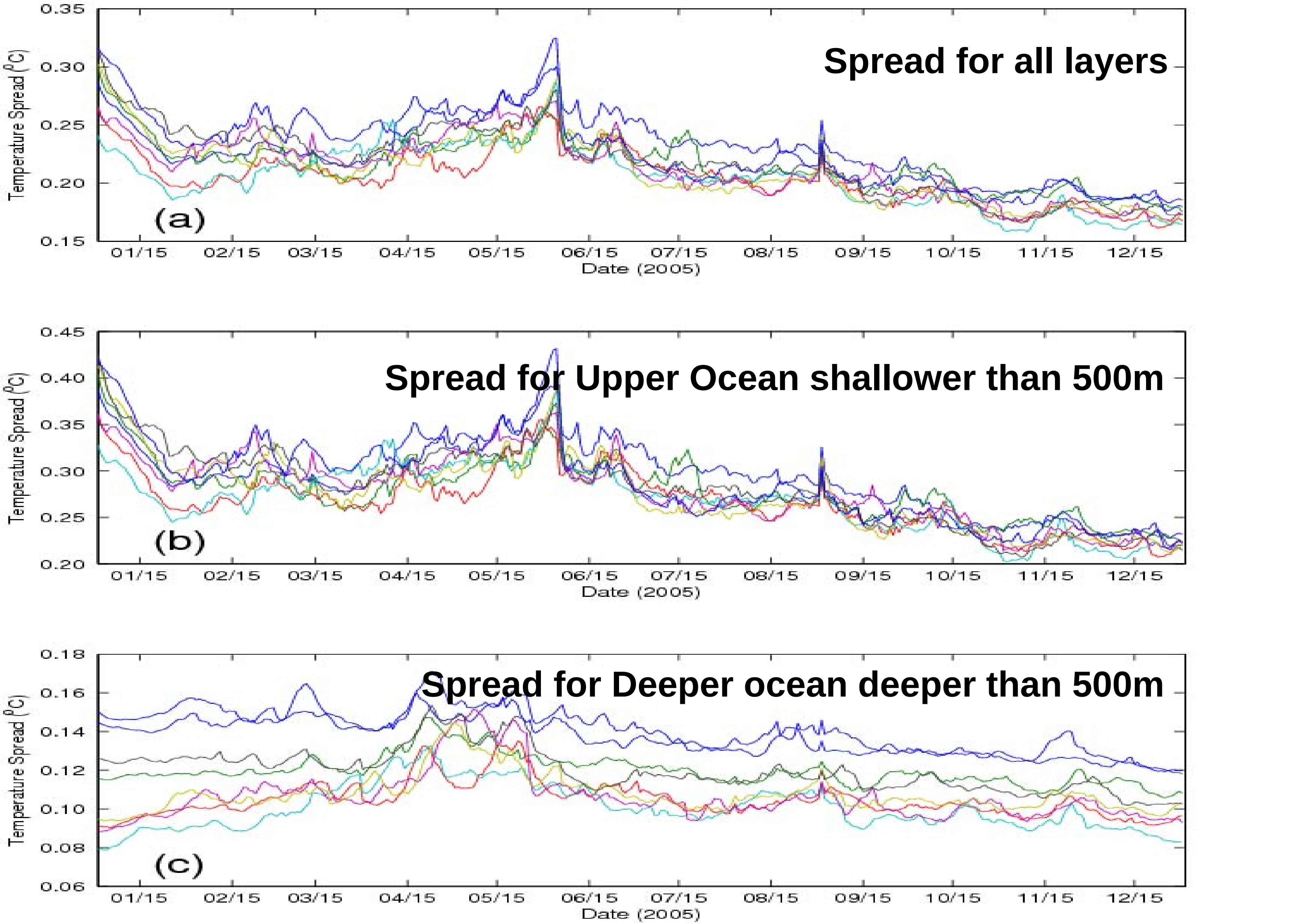
- Vertical profile
- Varying location
- Varying levels

**Self-define type:**

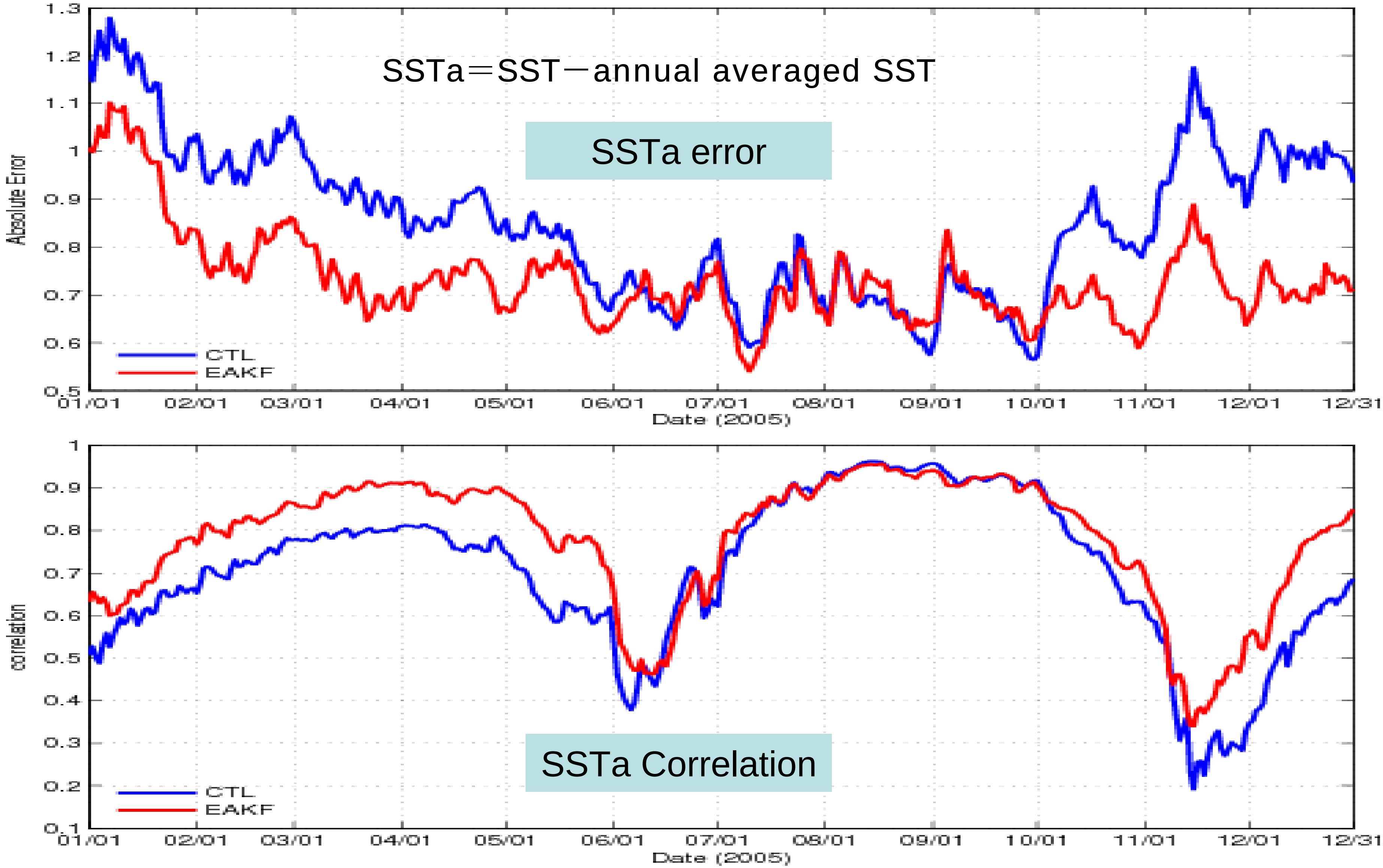
1. prof_data_type
2. prof_def_type
3. obs_dep_type
4. prof_dep_type



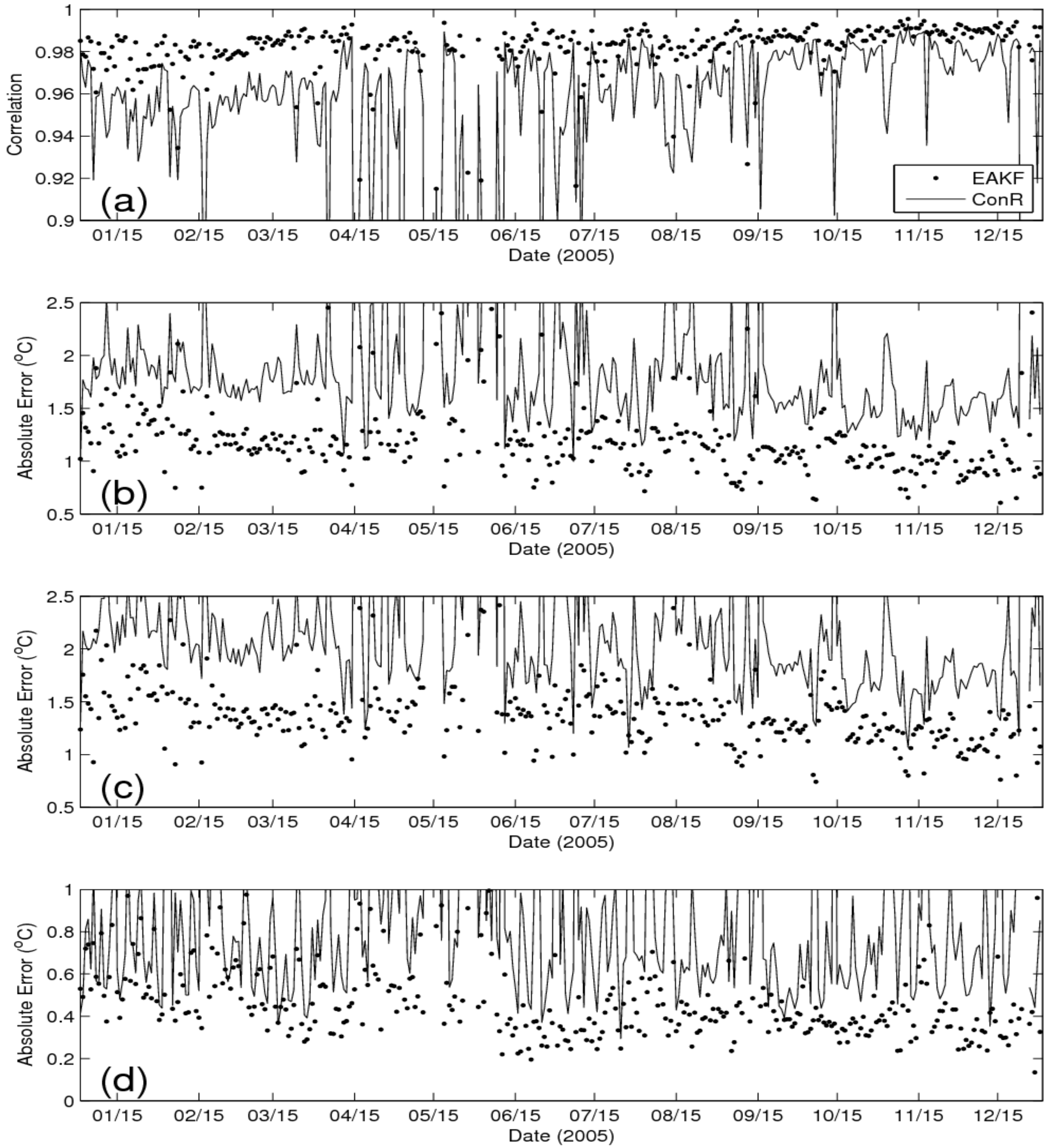
# EAKF assimilation for Argo profiles



# Comparison against SST



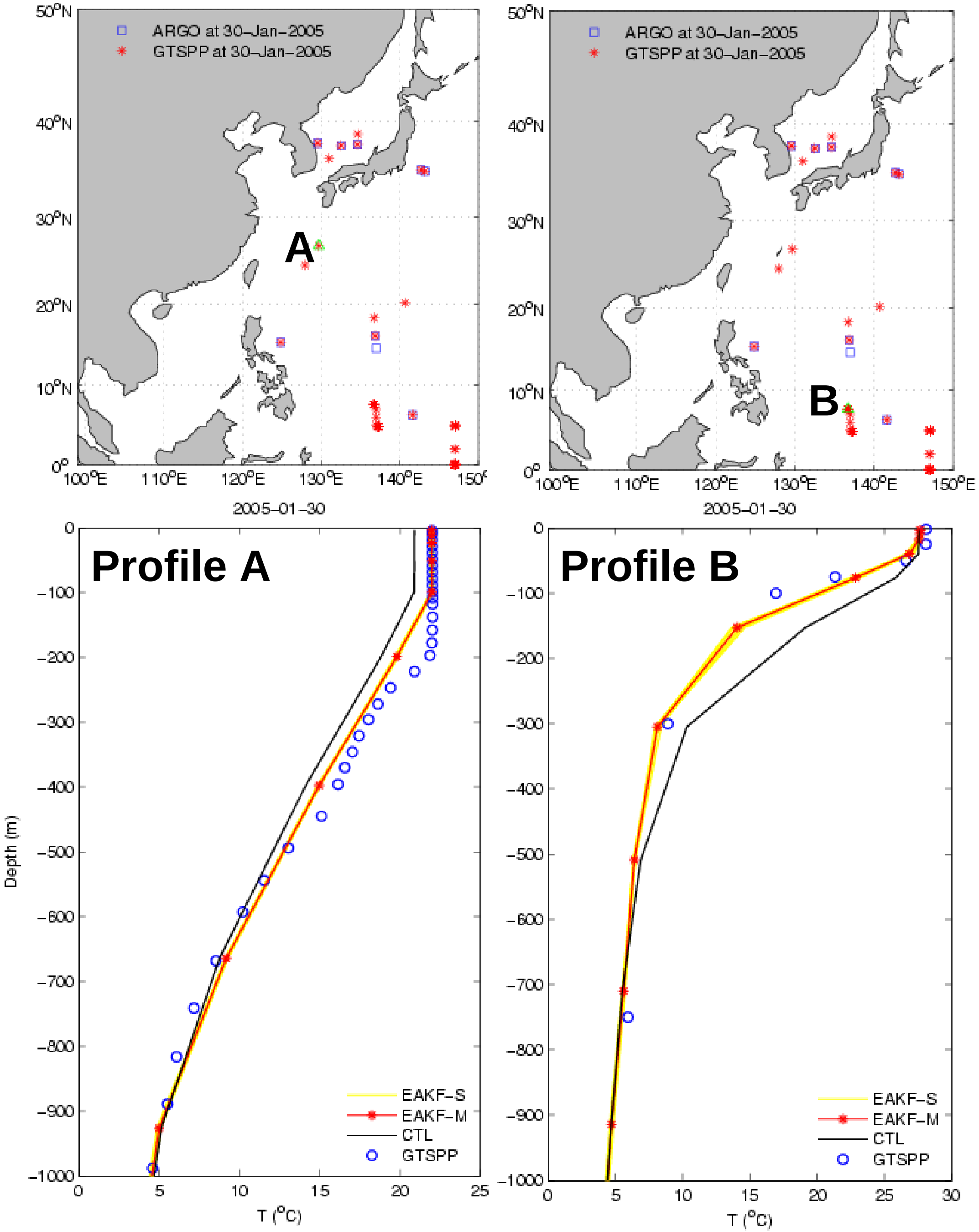
# Comparison with GTSPP




**The absolute error at all levels**

**The absolute error at depth shallower than 500m**

**The absolute errors at depth deeper than 500m**




Comparison with GTSPP temperature profiles

Top: Distribution of GTSPP & ARGO data

Green triangle with A / B represent the location of GTSPP data

Bottom: Temperature Profiles

Black: w/o assimilation
Yellow: w/ assimilation for all ensemble members
Red: w/ assimilation for ensemble mean

# Conclusions and discusses

- **The EAKF assim system performs well**
  - ✓ Tested the ensemble spread for all experiments
  - ✓ Tested the assim for Argo T & S profiles
  - ✓ This system can efficiently combine the observations and model to improve the simulated results
- **The vertical temperature structures & SSTa evolution trend are improved**
  - ✓ The temperature errors reduced not only in Upper Ocean but also in the Deeper Ocean
  - ✓ The assimilated results reduced SST errors & improved the correlation.
  - ✓ The temporal evolution/trend of SST becomes much better than those results w/o DA
- **This system is potentially capable of reconstructing oceanic data sets which are of high quality, and temporally and spatially continuous.**


yinxq@fio.org.cn

# Thank you


yinxq@fio.org.cn